Workshop on Climate Prediction and Services over the Atlantic-Arctic region

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Book of Abstracts

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Thematic Area 1: Progress in understanding the mechanisms for predictability

Keynote: Understanding low-frequency AMOC variability and associated predictability over the Atlantic-Arctic region

Rong Zhang[1]

[1]Ocean and Cryosphere Division, GFDL, NOAA, New Jersey, USA

Abstract

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Keynote: Extending Climate Predictions to Earth System Perspectives on the Carbon Cycle

Hongmei Li[1,2], Tatiana Ilyina[3,1,2], István Dunkl[2], Aaron Spring[2], Sebastian Brune[3], Wolfgang A. Müller[2], Raffaele Bernardello[4], Laurent Bopp[5], Pierre Friedlingstein[6], William J. Merryfield[7], Juliette Mignot[8], Michael O'Sullivan[6], Reinel Sospedra-Alfonso[7], Etienne Tourigny[4], Michio Watanabe[9]

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Abstract

TO BE UPDATED. The global carbon cycle plays a crucial role in regulating climate changes, while natural climate variability can cause fluctuations in the carbon cycle. To better predict climate changes, as well as evaluate the effectiveness of climate adaptation and mitigation strategies, we need to understand the carbon-climate interactions over time. Studies have shown that initializing climate models with observations improves predictions of temperature and circulation changes over seasons and decades. We have extended this approach to predict the evolution of the Earth System, incorporating

biogeochemical processes and developing a new framework of Earth system modeling forced by CO_2 emissions. This allows us to reconstruct and predict the global carbon cycle, including a prognostic atmospheric CO_2 with an interactive carbon cycle.

By assimilating physical data products of the atmosphere and oceans, we can reconstruct the historical changes in air-sea and air-land CO_2 fluxes and atmospheric CO_2 growth in line with the available observations. This helps in assessing regional carbon cycle variations and the global carbon budget (GCB). Since there are limited carbon cycle measurements, these reconstructions offer a comprehensive perspective on the global carbon cycle variations in recent decades. The predictions initialized from these assimilation reconstructions are significantly extended up to 5 years for air-sea CO_2 fluxes and 2 years for air-land CO_2 fluxes and atmospheric carbon growth rate. Predictions from Earth system models (ESMs) on CO_2 variations for the next year together with the assimilation reconstructions in the past decades for the first time were added to the Global Carbon Budget 2023 annual assessment (GCB2023, Friedlingstein et al. 2023). We will update reconstructions and predictions from ESMs regularly and contribute to the annual assessment of the GCB in the future. More ESMs are expected to be involved in the activity of assessing the GCB. In the meantime, we are also trying to implement the predictions on the seasonal scale to improve the skill. Furthermore, the atmospheric CO_2 concentrations exhibit spatial and vertical gradients, the novel predictions can be further broken down to investigate regional features and predictability.

Standard Oral: Extreme cold events in Europe under a reduced AMOC

Virna Meccia[1], Claudia Simolo[1], Katinka Bellomo[2,3], Susanna Corti[1]

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Abstract

There is a consensus that a weakened Atlantic Meridional Overturning Circulation (AMOC) decreases mean surface temperature in the Northern Hemisphere, both over the ocean and the continents. However, the impacts of a reduced AMOC on cold extreme events have not yet been examined. We analyse the impacts of a reduced AMOC strength on extreme cold events over Europe using targeted sensitivity experiments with the EC-Earth3 climate model. Starting from a fully coupled ocean-atmosphere simulation in which the AMOC was artificially reduced, a set of atmosphere-only integrations with prescribed sea surface temperature and sea-ice cover was conducted to evaluate the effects of weakly and strongly reduced AMOC strength. Despite overall cooling, reduced AMOC leads to fewer winter cold spells in Europe. We find that the weakened AMOC intensifies near-surface meridional gradient temperature in the North Atlantic and Europe, thus providing the energy to boost the jet stream. A stronger jet stream leads to less atmospheric blocking, reducing the frequency of cold spells over Europe. Although limited to the output of one model, our results indicate that a reduced AMOC strength may play a role in shaping future climate change cold spells by modulating the strength of the jet stream and the frequency of atmospheric blocking.

Standard Oral: The North Atlantic Oscillation gets more extreme under global warming

Quan Liu, Juergen Bader, Johann Jungclaus, Matei Daniela

Max Planck Institute for Meterology, Germany

Abstract

Extreme surface weather is strongly associated with specific atmospheric circulation. Recent studies have debated the role of global warming and internal variability in generating the unusual atmospheric circulation. Such discussions assume that internal variability in the atmospheric circulation is independent of global warming. Here, we present evidence for the anthropogenic influence on the leading natural variability in the atmospheric circulation over the North Atlantic sector, the North Atlantic Oscillation (NAO). In particular, our findings show the anthropogenic influence on the extreme states of the NAO. Both an increase in their occurrence and an amplification of their impacts over northwestern Europe in response to background warming are presented. These findings underscore the importance of incorporating intensifying atmospheric extreme conditions into regional climate change adaptation strategies.

Standard Oral: Identifying causes of Arctic sea-ice extent reduction in CMIP6 large ensembles using information transfer

David Docquier[1], François Massonnet[2], Francesco Ragone[1,2], Annelies Sticker[2], Stéphane Vannitsem[1]

[1]Royal Meteorological Institute of Belgium, Belgium. [2]Université catholique de Louvain, Belgium

Abstract

Large reductions in Arctic sea-ice extent have occurred since the beginning of satellite observations in the late 1970s, and model projections show that a summer ice-free Arctic by the middle of this century is possible. These changes have been attributed both to anthropogenic global warming and internal variability. However, the exact drivers influencing sea-ice loss and their respective contributions are not fully understood. In our study, we make use of five different large ensembles from the Coupled Model Intercomparison Project Phase 6 (CMIP6) over the 1970-2100 period, combining both historical and scenario model simulations. We investigate the impact of Arctic air temperature, ocean heat transport and winter sea-ice extent and volume on summer Arctic sea-ice extent by using the Liang-Kleeman information flow method. This allows us to go beyond classical correlation analyses and identify causal links between variables. Results show that air temperature is the most important controlling factor, and that ocean heat transport at the Barents Sea Opening and winter sea-ice extent and volume also play an important role. We also separate periods including a large amount of rapid sea-ice declines and/or sea-ice lows from more stable periods, and apply our causal method to these different periods, making use of the large number of ensemble members. Our study demonstrates the usefulness of the Liang-Kleeman information flow method in climate problems, which can be potentially applied to both climate predictions and projections.

Standard Oral: Non-stationary NAO—Gulf Stream SST front interaction

Luca Famooss Paolini[1,2,3], Noureddine Omrani[4], Alessio Bellucci[5], Panos J. Athanasiadis[1], Paolo Ruggieri[3], Casey R. Patrizio[1], Noel Keenlyside[4]

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Abstract

The interaction between the North Atlantic Oscillation (NAO) and the latitudinal shifts of Gulf Stream sea surface temperature front (GSF) has been the subject of extensive investigations. There are indications of non-stationarity in this interaction, but differences in the methodologies used in previous studies make it difficult to draw consistent conclusions. Furthermore, there is a lack of consensus on the key mechanisms underlying the response of the GSF to the NAO forcing. This study assesses the possible non-stationarity in the NAO—GSF interaction and the mechanisms underlying this interaction over the last few decades, using reanalysis data.

Results show that the NAO and GSF indices covary on the decadal timescales but only during 1972—2018. A secondary peak in the NAO-GSF covariability emerges on multiannual timescales but only during 2005—2015. The non-stationarity in the decadal NAO-GSF covariability is also manifested through the dependency of their lead—lag relationship on the analyzed time period. Indeed, the NAO leads the GSF shifts by 3 years during 1972—1990 and by 2 years during 1990—2018.

The lag between GSF shifts and NAO on decadal timescales can be interpreted as the joint effect of the fast response of wind-driven oceanic circulation, the response of deep oceanic circulation, and the propagation of Rossby waves. However, there is evidence of Rossby wave propagation only before 1990. Here it is suggested that the non-stationarity of Rossby wave propagation causes the time lag between the NAO and the GSF latitudinal position on decadal timescales to differ before and after 1990.

Considering the impact that the GSF variability has on the North Atlantic variability, the non-stationarity in the NAO—GSF covariability has important implications for the predictability of the North Atlantic sector.

Standard Oral: Signal-to-noise problems in winter Euro-Atlantic predictions linked to pervasive North Atlantic jet biases

Christopher O'Reilly

University of Reading, United Kingdom

Abstract

Signal-to-noise problems in seasonal predictions have been reported in several previous studies, yet they remain poorly understood. In this study, we examine the predictability of circulation over the Euro-Atlantic region. It is found that the signal-to-noise errors in the C3S forecasting systems are linked to the strength of teleconnections, which are weaker than those seen in observations. A scaling relationship from a simple theoretical model can explain the changes in signal-to-noise across the models. Further analysis reveals that the model errors are linked to systematic biases in the North Atlantic jet stream.

Standard Oral: Why do recent decadal predictions show large errors in the North Atlantic?

Leon Hermanson, Rosie Eade, Doug Smith

Met Office, United Kingdom

Abstract

Historically the North Atlantic has been one of the most predictable regions on decadal timescales. Both near surface temperature and atmospheric circulation including the Arctic Oscillation (AO), North Atlantic Oscillation (NAO), North Atlantic jet speed and latitude show high correlation skill, though a very large ensemble is required to overcome signal to noise errors in atmospheric circulation. Due to the many teleconnections from this region to the rest of the world, the scope for climate prediction is very promising and new decadal climate services have begun to be developed. However, recent decadal predictions initialised from the beginning of the 2010s predicted a warm sub-polar gyre and a negative NAO in contrast to observed sub-polar gyre cooling and positive NAO. These recent errors may be due to time-varying skill in the North Atlantic, errors in the initial conditions, incorrect boundary conditions (climate forcings) or errors in the models. We investigate the cause of recent errors in the North Atlantic and highlight a potential role for errors in aerosol climate forcings.

Standard Oral: Marine heatwaves: Can we predict them in the Barents Sea?

Helene R. Langehaug[1], Anne Britt Sandø[2], Robinson Hordoir[2], Francois Counillon[1], Ping-Gin Chiu[3], Roshin Raj[1]

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Abstract

Marine heatwaves (MHW) can have large negative impacts on life in the ocean, such as kelp forest and corals. These environments are vital for protecting a range of different species in the ocean. With global warming, the occurrence and intensity of MHW are expected to increase, also in the polar regions. Being able to predict the likelihood of MHW to occur in the Barents Sea could be highly beneficial to fisheries, aquaculture, and other relevant stakeholders. Such information could be useful in long-term risk assessment. In this study, we assess for the first time the skill of the Norwegian Climate Prediction Model (NorCPM) in predicting the likelihood of MHW. For this analysis, we focus on intense MHW in July 2016 taking place in the Barents Sea, and previously documented by satellite data. We find promising results in the seasonal predictions from NorCPM, where the predictions show increased probability for MHW to occur in July 2016 compared to July 2015 (when the MHW activity was lower than in 2016). The increased probability was already seen six months prior to the event. Furthermore, we downscale the results from the global NorCPM to a more refined grid with a horizontal resolution of 10km. This test case shows that downscaling can provide valuable information on the subsurface signature of MHW. We found the event in July 2016 to be shallow (down to about 50m) compared to another MHW event in July 2013, where warm anomalies occupied the whole water column. These results suggest that the event in July 2016 was atmospheric-driven, consistent with a previous study, whereas the event in 2013 is more likely to be ocean-driven. More in-depth studies are needed to quantify the predictive skill for different cases and different regions.

Standard Oral: Delayed and transient impacts of the NAO on subdecadal variability of Norwegian Sea temperature

Hongdou Fan[1,2], Sebastian Brune[1], Leonard Borchert[1], Johanna Baehr[1]

[1]Universität Hamburg, Germany. [2]Max Planck Institute for Meteorology, Hamburg, Germany

Abstract

It has been demonstrated that poleward ocean propagation plays a role in connecting salinity variability in the Nordic Seas with upstream variations in the North Atlantic subpolar gyre (SPG). It remains unclear why the impact of SPG variations on downstream temperature is limited. In this study, we disentangle the roles of the SPG and the North Atlantic Oscillation (NAO) in the sub decadal variability of Norwegian Sea temperature. With emphasis on the sub decadal time scale, we illustrate the delayed and transient impact of the NAO on Norwegian Sea temperature. By inducing SPG variations via buoyancy forcing, the delayed impact of the NAO manifests itself through the oceanic pathway. The resulting temperature anomalies in the SPG region show clear poleward propagation to the Norwegian Sea in the following 4 years. Besides, the NAO exerts a transient impact on the Norwegian Sea temperature by modulating wind-driven transport into the Norwegian Sea. The positive NAO phase elevates sea surface height along-shelf, enhancing temperature transport into the Norwegian Sea simultaneously and vice versa. With the direct influence and oceanic pathway, the twofold impact of the NAO reveals insights into the low predictability of Norwegian Sea temperature. Although that lagged impact stores sub decadal memory of the subsurface ocean, the transient impact via wind-driven transport and heat flux may counteract the lagged oceanic signal thus degrade prediction. We further show that Norwegian Sea temperature is better predicted at forecast lead year 1 when the NAO is initialized in the positive phase, highlighting the limited predictability provided by NAO and challenges in predicting Norwegian Sea temperature.

Standard Oral: Improved Prediction Skill of Extremely Warm European Summers

Lara Wallberg[1], Laura Suarez-Gutierrez[2], Daniela Matei[1], Wolfgang A. Müller[1]

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Abstract

The frequency of occurrence of extremely warm European summers has increased dramatically in recent years and is expected to further increase with rising global temperatures. Reliable and skillful predictions of these high-impact events years in advance are crucial to reduce potential societal, political, and economic impacts. In the context of climate variability, mechanisms with long-term memory play a crucial role. On sub-decadal timescales, one such mechanism involves the heat inertia in the North Atlantic Ocean, which includes the ocean's ability to store heat and delay its eventual transfer and release. Previous work has already highlighted that the accumulation of heat in the North Atlantic Ocean can precede extremely warm European summers on sub-decadal time scales. The accumulated heat is thus acting as a precursor for the occurrence of such extreme events. Building upon this understanding, we examine how the accumulation of heat in the North Atlantic Ocean can be used to increase the prediction skill of extremely warm summers. By introducing an ensemble selection based on this accumulation of heat, we find an improvement in prediction skill of Central European summer temperatures several years in advance.

Standard Oral: Heat extremes in scenario projections: the role of variability

Claudia Simolo, Susanna Corti

ISAC - CNR, Italy

Abstract

Heat extremes have grown disproportionately since preindustrial times and are expected to intensify further under unabated greenhouse warming, spreading unevenly across the globe. However, their future trajectories are highly uncertain because of the complex interplay between the regional physical responses to human forcing and the statistical properties of atmospheric temperatures. By uncovering the key amplification factors, here we provide a comprehensive, quantitative understanding of how these rare, yet impactful, events will evolve in the future. Temperature variability is found to be pivotal for tracking the trajectories of heat extremes and their nonuniform intensification across the globe. Changes in variability can greatly affect the severity of the extremes and account for major temperature increases, including the prominent warming of cold extremes expected at middle and high latitudes. Intrinsic variability governs the future frequencies of extremely hot events, reshaping the effects of the background warming. For instance, it underpins the rapid increase in tropical regions, where hot extremes may become commonplace before the end of the century. These findings offer valuable new insights into the roots of the differential regional vulnerabilities and responses to increased greenhouse gas forcing and lay the foundations for improving model projections of future climate.

Standard Oral: Forced and internal components of observed Arctic sea ice changes

Jakob Dörr[1], David Bonan[2], Marius Årthun[1], Robert Wills[3], Lea Svendsen[1]

[1]University of Bergen, Norway. [2]California Institute of Technology, USA. [3]ETH Zürich, Switzerland

Abstract

The Arctic sea-ice cover is strongly influenced by internal variability on decadal timescales, which affects both short-term trends and the timing of the first ice-free summer but offers prospects of decadal predictions of sea ice. Several mechanisms of variability have been proposed, but how these mechanisms manifest both spatially and temporally remains unclear. The relative contribution of internal variability to observed Arctic sea-ice changes also remains poorly quantified. Here, we use low-frequency component analysis to identify the dominant patterns of winter and summer decadal Arctic sea-ice variability in the satellite record. The identified patterns account for most of the observed regional sea-ice variability and trends, and they thus help to disentangle the role of externally forced and internal sea-ice changes over the satellite record. In particular, we identify a mode of decadal ocean–atmosphere–sea-ice variability, characterized by an anomalous atmospheric circulation over the central Arctic, that accounts for approximately 30 % of the accelerated decline in pan-Arctic summer sea-ice area between 2000 and 2012 but accounts for at most 10 % of the decline since 1979. For winter sea ice, we find that internal variability has dominated decadal trends in the Bering Sea but has contributed less to trends in the Barents and Kara seas. These results, which detail the first purely observation-based estimate of the contribution of internal variability to recent Arctic sea-ice changes, suggest a lower estimate of the contribution from internal variability than most model-based assessments.

Standard Oral: Ocean circulation constrains multi-year predictability of marine biogeochemical system

Yong-Yub Kim[1], Axel Timmermann[1], Eun Young Kwon[1], Ingo Bethke[2], Filippa Fransner[2], June-Yi Lee[1], Yoshimitsu Chikamoto[3], Sun-Seon Lee[1]

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Abstract

Beyond efforts to predict the physical condition of the earth, there are challenging to predict ecosystem on a multi-year timescale. Although understanding the predictability sources is essential for the prediction, the predictability sources in marine biogeochemical systems remain poorly identified. Here, using a seasonal-to-multiyear earth system prediction system based on the Community Earth System Model version 2 (CESM2) to quantify the extent to which marine biogeochemical variables are constrained by physical conditions. To differentiate the effects of external forcing and natural climate variability on longer-term predictability, we analyse anomalies calculated relative to the 50-member ensemble mean of the CESM2 large ensemble. We find that nitrate, net primary production, phytoplankton and zooplankton biomass are predictable for several years ahead in subtropical nutrient-limited area. The variability of limiting nutrient is constrained by subsurface oceanic circulation, and this damped variability allows the prediction of marine ecosystem on a multi-year time scale. This study provides crucial insights into error growth of phytoplankton and the resulting limitations for multiyear predictability constrained by ocean circulation. Our findings may help us better understand the multi-year predictable process in marine ecosystems and guide the development of prediction systems.

Standard Oral: Impact of volcanic eruptions on CMIP6 decadal predictions in the North Atlantic.

Roberto Bilbao

Barcelona Supercomputing Center, Spain

Abstract

In recent decades three major volcanic eruptions of different intensity have occurred (Mount Agung in 1963, El Chichón in 1982 and Mount Pinatubo in 1991), with reported climate impacts on seasonal-to-decadal timescales that could have been potentially predicted with accurate and timely estimates of the associated stratospheric aerosol loads. The Decadal Climate Prediction Project component C (DCPP-C) includes a protocol to investigate the impact of such volcanic eruptions on decadal prediction. It consists in repeating the retrospective predictions that are initialised just before the three aforementioned eruptions but without the inclusion of the volcanic forcing. These idealised predictions are then compared with the baseline predictions to disentangle the climatic effect of the eruptions. We present the results from six CMIP6 decadal prediction systems. These systems show a strong agreement in predicting the radiative response to the volcanic eruptions, however some differences across models and eruptions arise due to the varying magnitude and spatiotemporal structure of the volcanic forcing. Taking advantage of the large multi-model ensemble we analyse the dynamical responses in the Northern Hemisphere atmospheric circulation and the North Atlantic Ocean. The atmospheric response is characterised by a strong tropical warming in the lower stratosphere accompanied with a strengthening of the Northern Hemisphere polar vortex in the first winter, which resembles a positive NAO-like pattern. In the North Atlantic Ocean we show that there is a significant enhancement of the mixed layer depth in the Labrador Sea during the three boreal winters following the eruptions, and a weak but significant strengthening of the AMOC during years 2-9 after the eruptions. Comparing the predicted surface temperature anomalies in the two sets of hindcasts with observations we show that including the volcanic forcing is particularly relevant for reproducing the observed SST variability in the North Atlantic Ocean following the eruption of Pinatubo.

Thematic Area 2: Development of climate prediction systems

Keynote: Use of AI deep learning for climate forecasts

Jing-Jia Luo

Institute of Climate and Application Research (ICAR), Nanjing University of Information Science and Technology, China

Abstract

AI machine learning has attracted more and more attentions for climate science in recent years with expanding applications to many areas. In this talk, I will briefly present our recent progresses on using various deep learning methods for seasonal-to-multi-seasonal predictions of ENSO, the Indian Ocean Dipole (IOD), summer precipitation in China and East Africa, Arctic sea ice cover, ocean waves, as well as the bias correction and downscaling of dynamical model's forecasts. The results suggest that many popular deep learning methods, such as convolutional neural networks, residual neural network, long-short term memory, ConvLSTM, multi-task learning, cycle-consistent generative adversarial networks and vision transformer, can be well applied to improve our understanding and prediction of weather-climate phenomena. A brief discussion and perspective on the fusion of machine learning and physics will also be presented.

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Keynote: Recent Developments in Climate Prediction using High-Resolution Models

Stephen Yeager[1], Jon Robson[2], Who Kim[1], Nan Rosenbloom[1]

[1]National Center for Atmospheric Research, USA. [2]University of Reading, United Kingdom

Abstract

TO BE UPDATED. North Atlantic decadal climate predictability is widely believed to be related to decadal variability of the Atlantic meridional overturning circulation (AMOC) and associated changes in upper ocean heat content (UOHC). Decadal AMOC variability has been linked to North Atlantic Oscillation (NAO) forcing—specifically, to persistent NAO buoyancy forcing that modifies deep ocean density. We present the results from coupled ensemble experiments in which observation-derived winter NAO heat

flux is applied as a perturbation forcing during the first decade of multidecadal simulations. The experiment has been conducted in two configurations of the CESM2 model: a low-resolution (LR) configuration in which all components use a nominal 1° horizontal resolution grid; and a high-resolution (HR) configuration in which the ocean and atmosphere components use nominal 0.1° and 0.25° grids, respectively. In both configurations, NAO forcing drives an AMOC and UOHC response that, in general terms, corroborates previous work on North Atlantic decadal variability/predictability mechanisms. The HR configuration, however, reveals a much stronger atmospheric response to the evolving sea surface temperature field, with higher signal-to-noise than in LR. The results suggest that HR could ameliorate the overly weak signal variance that is prevalent in current decadal prediction systems.

Standard Oral: Weakly coupled data assimilation for climate predictions with ICON-Seamless

Christine Sgoff[1], Holger Pohlmann[2], Sebastian Brune[3], Trang Van Pham[1], Andrea Schneidereit[1], Thorsten Steinert[1], Kristina Fröhlich[1]

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Abstract

We present the development of the initialization strategy for seasonal to decadal climate predictions based on the ICON-seamless model, within DWD's Innovation in the Applied Research and Development (IAFE) program. The used prototype of ICON-seamless is based on the ICON-NWP as atmospheric model, ICON-O as ocean model, JSBACH as land model and uses a hydrological discharge model. To develop a coupled data assimilation system for ICON-seamless, we use the experience build on a former ICON-ESM version (Pohlmann et al 2023). We initialize the ocean component of the climate system by assimilating salinity and temperature profiles from EN4. For this we use a localized singular evolutive interpolated Kalman filter implemented by the Parallel Data Assimilation Framework. The atmosphere is initialized by nudging temperature, pressure, and horizontal wind fields of the ERA5 reanalysis. ICON-seamless is run as R2B5 (~80km resolution) in the atmosphere and R2B6 (~40km resolution) in the ocean. Our assimilation starts from a historical run, which was started from a pi-control run. We show the first results of our experiments with the coupled data assimilation system and discuss its challenges.

Standard Oral: Initialization shock in the ocean circulation reduces skill in decadal predictions of the North Atlantic subpolar gyre

Iuliia Polkova[1], Didier Swingedouw[2], Leon Hermanson[3], Armin Köhl[4], Detlef Stammer[4], Doug Smith[3], Jürgen Kröger[5], Ingo Bethke[6], Xiaosong Yang[7], Liping Zhang[7], Dario Nicolì[8], Panos Athanasiadis[8], Pasha Karami[9], Klaus Pankatz[10], Holger Pohlmann[5], Bo Wu[11], Roberto Bilbao[12], Pablo Ortega[12], Shuting Yang[13], Reinel Sospedra-Alfonso[14], William Merryfield[14], Takahito Kataoka[15], Hiroaki Tatebe[15], Yukiko Imada[16], Masayohi Ishii[17], Richard Matear[18]

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Abstract

Due to large northward heat transports, the Atlantic Ocean circulation is strongly affecting the climate of various regions. Its internal variability has been shown to be predictable decades ahead within climate models, providing the hope that synchronizing ocean circulation with observations can improve decadal predictions, notably of the North Atlantic subpolar gyre (SPG). There is no unique data assimilation method to derive the initial conditions for climate predictions. Moreover, this can be done using full-field observations or their anomalies superimposed on the model's climatology to avoid strong drifts in predictions. How critical ocean circulation drifts, following the initialization step, are for prediction skill has not been assessed yet.

We analyse this possible connection using the dataset of twelve decadal prediction systems from the WMO Lead Centre for Annual-to-Decadal Climate Prediction. We find a variety of initial errors for the Atlantic meridional overturning circulation (AMOC) within the predictions related to a dynamically imbalanced AMOC cell leading to strongly displaced or multiple maxima in the overturning structures. This likely results in a blend of what is known as model drift and initial shock. We identify that the AMOC initialization influences the quality of predictions of the SPG. When predictions show a large initial error in their AMOC, they usually have low skill for predicting internal variability of the SPG for a time horizon of 6-10 years. Full-field initialized predictions with low AMOC drift show better prediction skill of the SPG than those with a large AMOC drift. Nevertheless, while the anomaly-initialized predictions do not experience large drifts, they show low SPG skill when skill also present in historical runs is removed using

a residual correlation metric. Thus, reducing initial shock and model biases for the ocean circulation in prediction systems might help to improve their prediction for the SPG beyond 5 years.

Standard Oral: Supermodeling: an ensemble of interacting models

Francine Schevenhoven[1], Noel Keenlyside[1,2], William E. Chapman[3], Judith Berner[3], Mao-Lin Shen[1], Gregory S. Duane[4]

[1]Geophysical Institute, University of Bergen and Bjerknes Centre for Climate Research, Norway. [2]Nansen Environmental and Remote Sensing Center, Bergen, Norway. [3]National Center for Atmospheric Research, Boulder, Colorado, USA. [4]Department of Atmospheric and Oceanic Sciences, University of Colorado Boulder, Boulder, Colorado, USA

Abstract

Instead of combining data from an ensemble of different models only after the simulations are performed, as in a standard multi-model ensemble, we let the models interact with each other during their simulation. This ensemble of interacting models is called a `supermodel’. Because of the interaction between the models, they can compensate for each other's errors before the errors spread to other regions or variables. The exchange between the models is frequent enough such that the models synchronize, in order to prevent loss of variance when the models are combined. In previous work, we experimented successfully with combining atmospheric models of intermediate complexity in the context of parametric error. Here we go beyond and show results of combining two different versions of the Community Atmosphere Model (CAM). When the models have a different resolution, we convert the individual model states to a common state space with interpolation techniques. We train the connection coefficients between the models, determining the extent and type of information exchange between the models, resulting in a supermodel that outperforms the individual models.

Standard Oral: CoRea-20CR: coupled reanalysis of the climate from 1860 to the present

Yiguo Wang[1,2], Francois Counillon[1,2]

[1]Nansen Environmental and Remote Sensing Center, Norway. [2]Bjerknes Centre for Climate Research, Norway

Abstract

Climate reanalyses refer to dynamically consistent reconstruction of past climate conditions using a combination of observational data and numerical models. It is of high importance to study climate variability, understand climate processes, and initialise climate predictions. We recently produced a long and coupled reanalysis from 1860 to the present with the Norwegian Climate Prediction Model (NorCPM) that assimilates sea surface temperature (SST) observations. NorCPM combines the Norwegian Earth System Model and the ensemble Kalman filter data assimilation method. SST is available for the whole period and is the primary source of instrumental oceanic measurements prior to the 1950s. Our reanalysis belongs to the category of sparse input reanalysis that minimizes artefacts due to changes in the observation network. The time extent of the reanalysis allows us to assess robustly the mechanisms driving the decadal variability and predictability. Furthermore, as we only used the oceanic data during assimilation, the reanalysis helps to understand the contribution of the ocean in driving variability of the climate system (e.g., the atmosphere and sea ice). We present a comprehensive analysis of the reanalysis in surface air temperature, sea level pressure, Arctic sea ice extent, ocean heat/salt content, and Atlantic Meridional Overturning Circulation (AMOC).

Standard Oral: Climate reconstruction and climate predictions in the North Atlantic with MPI-ESM

Sebastian Brune[1], Leonard F. Borchert[1], André Düsterhus[2], Hongdou Fan[1,3], Lara Heyl[1], Vimal Koul[4,5], Daniel Krieger[3,6], Simon Lentz[1], Adama Sylla[1], Johanna Baehr[1]

[1]CEN, Universität Hamburg, Germany. [2]Danmarks Meteorologiske Institut (DMI), Copenhagen, Denmark. [3]International Max Planck Research School on Earth System Modelling, Hamburg, Germany. [4]NOAA/Geophysical Fluid Dynamics Laboratory, Princeton, USA. [5]Princeton University, USA. [6]Helmholtz-Zentrum Hereon, Geesthacht, Germany

Abstract

We highlight recent findings with the MPI-ESM in terms of sub-seasonal to decadal climate predictions as well as climate reconstructions in the North Atlantic and sub-Arctic region. To this end we use MPI-ESM in three different resolutions (low, medium, high), in particular we extended the low resolution MPI-ESM into an 80 member decadal prediction ensemble, and we initialize our predictions by assimilating atmosphere, ocean, and sea ice observations. In terms of decadal climate predictions with MPI-ESM-LR in the North Atlantic, we demonstrate why ocean salinity outperforms ocean temperature prediction skill in the Nordic Seas, how AMOC and SST interact to form time-dependent prediction skill, and that for AMOC and surface air temperature, initialization effects may remain visible in predictions beyond 10 years. In terms of sub-seasonal to seasonal climate predictions with MPI-ESM-MR and MPI-ESM-HR, we found that extreme events over Europe, e.g. severe storms and summer heatwaves could be predicted a few weeks ahead, and we show how lagged teleconnections can help to improve wintertime NAO predictions as well as predictions of European surface temperatures. Beyond the well trodden path of initialized predictions, we also highlight how machine learning can assist in ocean climate reconstructions of the sparsely observed pre-Argo era, and how and when uninitialized large ensemble simulations can be used in terms of the prediction of inter-annual trends in North Atlantic sea surface temperature.

Standard Oral: Data-driven seasonal forecast of heat waves in Western Europe

Stefano Materia[1], Markus G. Donat[1], Lluís Palma[1], Amanda Duarte[1], Martin Jung[2]

[1]Barcelona Supercomputing Center, Spain. [2]Max Planck Institute for Biogeochemistry, Germany

Abstract

In Western Europe, extremely hot events have highly exacerbated since the beginning of the century, and heat waves have recently become common even beyond the classic summer season. Seasonal Forecasts of such weather extremes may be critical for early-warning decision support systems, and help reduce their related risk, which strongly affects a multitude of socio-economic sectors. Recent advances in both statistical approaches and numerical modelling have improved the skill of Seasonal Forecasts. However, especially in mid-latitudes, they are still affected by large uncertainties that can limit their usefulness.

This study aims at improving our knowledge of climate predictability at the seasonal timescale, focusing on the role of unexplored drivers, to finally enhance the performance of current prediction systems in forecasting heat waves in Western Europe. Here we present a first attempt to predict heat wave accumulated activity across different target seasons. An empirical seasonal forecast is designed based on Machine Learning techniques. A feature selection approach is used to detect the best subset of predictors among a variety of candidates, while an explainable AI algorithm allows an assessment of the relative importance of each predictor.

Results show forecast skill at times comparable to that of dynamical predictions, and many observed teleconnections are caught by the data-driven approach. On the other hand, a few features that show to be linked to the heat wave propensity of a season deserve a deeper understanding of the underpinning physical process. Future developments foresee the hybridization of the data-driven approach with numerical models, to further reduce uncertainties and make forecasts efficiently usable by regional meteorological services and private bodies.

Standard Oral: Improving subseasonal forecast skill in the Norwegian Climate Prediction Model using soil moisture data assimilation

Akhilesh Nair[1], François Counillon[2,1], Noel Keenlyside[1,2]

[1]UiB, Norway. [2]NERSC, Norway

Abstract

This study emphasises the importance of soil moisture (SM) in subseasonal-to-seasonal (S2S) predictions at midlatitudes. To address this we introduce the Norwegian Climate Prediction Model Land (NorCPM-Land), a land reanalysis framework tailored for integration with the Norwegian Climate Prediction Model (NorCPM). NorCPM-Land assimilates blended SM data from the European Space Agency's Climate Change Initiative into a 30-member offline simulation of the Community Land Model with fluxes from the coupled model. The assimilation of SM data reduces error in SM by 10.5 % when validated against independent SM observations. It also improves latent heat flux estimates, illustrating that the adjustment of underlying SM significantly augments the capacity to model land surface dynamics. We evaluate the added value of land initialisation for subseasonal predictions, by comparing the performance of hindcasts (retrospective prediction) using the standard NorCPM with a version where the land initial condition is taken from NorCPM-Land reanalysis. The hindcast covers the period 2000 to 2019 with four start dates per year. Land initialisation improves predictions up to a 3.5-month lead time for SM and a 1.5-month lead time for temperature and precipitation. The largest improvements are observed in regions with significant land-atmospheric coupling, such as the Central United States, the Sahel, and Central India. It also better captures extreme (high and low) temperature events in parts of Europe, the United States, and Asia, at mid and high latitudes. Overall, our study provides further evidence for the significant role of SM content in enhancing the accuracy of subseasonal predictions. This study provides a technique for improved land initialisation, utilising the same model employed in climate predictions.

Standard Oral: Advancing Arctic Climate Prediction Capability at Subseasonal to Decadal Timescales

Wieslaw Maslowski[1], Younjoo Lee[1], Anthony Craig[2], Mark Seefeldt[3], Robert Osinski[4], John Cassano[3], Jaclyn Clement Kinney[1], Bart Nijssen[5]

[1]Naval Postgraduate School, USA. [2]Contractor, USA. [3]University of Colorado Boulder, USA. [4]Institute of Oceanology PAS, Poland. [5]University of Washington, USA

Abstract

This talk will review the utility of the Regional Arctic System Model (RASM) for modeling and prediction of Arctic climate change at time scales from weeks to decades. RASM is a fully coupled limited-domain Earth system model (ESM) configured over the pan-Arctic domain extending south to ~30^{o}N in the North Pacific and to ~40^{o}N in the North Atlantic oceans. The default atmosphere and land components are configured on a 50-km grid. The ocean and sea ice components are configured on rotated sphere meshes with the default configuration of 1/12^{o} (~9.3km) in the horizontal space and with 45 vertical layers. High-resolution model configurations include the atmosphere/land at 25-km and ice-ocean at 2.4-km grids. As a regional climate model, RASM requires boundary conditions along its lateral boundaries and in the upper atmosphere, which are derived either from global atmospheric reanalyses for simulations of the past to present or from ESMs for climate projections. The hindcasts allow evaluation and synthesis of RASM results with observations in place and time, which is a unique capability not available in ESMs.

Within this framework, RASM has been used to downscale output from three global models: the National Center for Environmental Predictions Coupled Forecast System version 2 (CFSv2), the National Center for Atmospheric Research Community Earth System Model initialized Decadal Predictability Large Ensemble (CESM-DPLE), and the Department of Energy Energy Exascale Earth System Model (E3SM). Forced with CFSv2, RASM has produced probabilistic intra-annual (i.e., 6-month) sea ice forecasts each month since January 2019. The CESM-DPLE and E3SM output was used for downscaling and evaluation of multi decadal simulations. Here, we review some of these results, including evaluation of RASM sea ice predictive skill in comparison with observations and relative to the original global output using the common metrics to quantify model skill.

Standard Oral: Improving the forecast quality of near-term climate projections by constraining internal variability based on decadal predictions and observations

Markus Donat[1,2], Rashed Mahmood[1,3], Josep Cos[1], Pablo Ortega[1], Francisco Doblas-Reyes[1,2]

[1]Barcelona Supercomputing Center, Spain. [2]ICREA, Spain. [3]now at Danish Meteorological Institute, Denmark

Abstract

Projections of near-term climate change in the next few decades are subject to substantial uncertainty from internal climate variability. Approaches to reduce this uncertainty by constraining the phasing of climate variability in large ensembles of climate simulations have recently been developed. These approaches select those ensemble members that are in closer agreement with sea surface temperature patterns from either observations or initialised decadal predictions. Previous studies demonstrated the benefits of these constraints for projections up to 20 years into the future, but these studies applied the constraints to different ensembles of climate simulations, which prevents a consistent comparison of methods or identification of specific advantages of one method over another.

Here we apply both constraining methods to an identical multi-model ensemble consisting of 311 simulations from 37 models from the Coupled Model Intercomparison Project phase 6 (CMIP6) and compare their forecast qualities. We show that constraining based on both observations and decadal predictions significantly enhances the skill of 10 and 20-year projections in some regions, and that constraining based on decadal predictions leads to the largest added value in terms of probabilistic skill. We further explore the sensitivity to different implementations of the constraint that focus on the patterns of either internal variability alone or a combination of internal variability and long-term changes in response to forcing. Looking into the near-term future, all variations of the constraints suggest an accelerated warming of large parts of the Northern Hemisphere for the period 2020-2039, in comparison to the unconstrained CMIP6 ensemble.

Standard Oral: Constraining near to mid-term climate projections by combining observations with decadal predictions

Rémy Bonnet[1], Julien Boé[1], Emilia Sanchez[2]

[1]CNRS / Cerfacs, France. [2]Cerfacs, France

Abstract

The implementation of adaptation policies requires seamless and relevant information on the evolution of the climate over the next decades. Decadal climate predictions are subject to drift because of intrinsic model errors and their skill may be limited after a few years or even months depending on the region. Non-initialized ensembles of climate projections have large uncertainties over the next decades, encompassing the full range of uncertainty attributed to internal climate variability. Providing the best climate information over the next decades is therefore challenging. Recent studies have started to address this challenge by constraining uninitialized projections of sea surface temperature using decadal predictions or using a storyline approach to constrain uninitialized projections of the Atlantic Meridional Overturning Circulation using observations. Here, using a hierarchical clustering method, we select a sub-ensemble of non-initialized climate simulations based on their similarity to observations. Then, we try to further refine this sub-ensemble of trajectories by selecting a subset based on its consistency with decadal predictions. This study presents a comparison of these different methods for constraining surface temperatures in the North-Atlantic / Europe region over the next decades, focusing on CMIP6 non-initialized simulations.

Thematic Area 3: Emerging opportunities in and application of climate prediction services

Keynote: A case for transcending disciplines and sectors, based on experiences from Climate Futures and Africa

Erik W. Kolstad

NORCE, Norway. Bjerknes Centre for Climate Research, Norway

Abstract

TO BE UPDATED. I have dedicated several years to collaborating with stakeholders across the so-called "value chain" of climate services on two continents. The striking contrast between the extremes of co-production has been a focal point of my observations. People mean different things when they talk about co-production, but a common denominator is that the people who will end up using a climate service are involved in the conception and development of the service from early on.

At one extreme, the top-down model involves scientists creating services without user consultation, often resulting in well-developed but underutilized services. The other extreme embraces a holistic co-development approach, integrating developers into the user organization to ensure accurate needs assessment. While resource-intensive and not universally applicable, this approach increases the chance of service utilization.

Drawing on experiences in Norway, Europe and Africa, I will present examples of failed, successful, and adequate co-production processes. These experiences were instrumental in shaping Climate Futures, a Norwegian research-based innovation center with 30 partners and a budget of about 200 million NOK over eight years. As the former leader and current scientific lead of the center, my emphasis on engaging user partners has yielded mixed results, but successful engagements have fostered deep collaboration, combining climate prediction expertise with user partners in diverse sectors including renewable energy, insurance, shipping, and agriculture.

Observing a concern among the new generation of climate professionals for issues such as ethics, policy, transdisciplinarity, and equity/equality, I am hopeful that our new and future colleagues are motivated for an inclusive approach to climate services co-development. This reflection prompts my interest in discussing these issues with fellow workshop participants.

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Keynote: The Next Step for Climate Services

Asun Lera St.Clair[1,2], Marina Baldissera Paccheti[3,2]

[1]DNV, Norway. [2]Barcelona SuperComputing Center, Spain. [3]University College London (UCL), United Kingdom

Abstract

TO BE UPDATED: Timely, salient and accessible climate services (the provision of climate information and knowledge for use in decision-making), are a necessary for progress towards evidence-based adaptation, net-zero strategies and robust Environmental, Social and Governance reporting (ESG). However, there is evidence of unequal quality of many climate services which may be related to financing, capacity, or ignorance of climate risks. Nevertheless, standards and quality assurance mechanisms have the potential to mitigate some of the issues related to quality management and control and will key to benchmark climate services. This paper presents the first Framework for the equitable standardisation of climate services, which provides a path for developing standards and quality management and assurance. The framework emerges from Climateurope2, a consortium of 32 partners including WMO, Copernicus, and standard setting and assurance experts in addition to an interdisciplinary group of scholars. This Framework is based on a broad understanding of standards and standardisation processes across different fields – standardisation being quite new to climate services – and an understanding of climate services as complex and intersecting combinations of data, products, processes, knowledge systems and stakeholders, including their social and human dimensions. The framework also takes equity as an instrumental and intrinsic value to be protected and promoted throughout processes and outcomes related to standardisation, standards, and quality. To do so, the framework consists of a decision tree, which provides a guide of key steps to address for standardisation, a distinction between different components of climate services to guide standardisation across more or less mature components of the complexity of climate services, and a glossary of a key terms necessary to navigate the decision tree.

Standard Oral: Tools for facilitating co-production with urban stakeholders: Communicating via a catalogue of (urban climate) services

Sam Pickard[1], Dragana Bojovic[1], Eren Duzenli[1], Paloma Trascasa Castro[1], Pablo Martínez[2], Mar Santamaria[2]

[1]Barcelona Supercomputing Centre, Spain. [2]300000 km/s, Spain

Abstract

The Barcelona demonstrator in the Impetus4Change (I4C) project is co-producing climate services related to extreme summer temperatures. Much of the project's first year has involved co-exploring with local stakeholders the potential decision contexts that these services could support (different hazards, different timescales, different informational requirements). Discussions with stakeholders covered a variety of geographies, climates and layers of governance within the broader Barcelona region and yielded a huge range of possible contexts that could benefit from (improved) climate information. However, stakeholder familiarity with other data sources – particularly weather and air quality services – risked creating unrealistic demands.

It became clear that our conversations were operating as a two-way knowledge exchange between contexts in which climate information could be useful and the scientific limitations of climate models. To better facilitate communication, a key stakeholder suggested we create a catalogue of services given that the format is familiar to municipal decision makers. Analogous to a two-dimensional translation tool, we link stakeholders action timelines with climate information's temporal scale on one hand, and climate data with stakeholder decision criteria on the other.

Driven by stakeholder suggestions, the catalogue currently provides six example themes that concretise the areas where I4C can provide climate information. Each theme includes multiple types of climate information (e.g., 'A deeper understanding of heat' includes extreme temperatures, heatwave trends, and thermal comfort indices rather than just "temperature") and the availability of this climate information at different timescales. Alongside this, there are example decisions that could be supported, potential links to non-climate data and concrete inputs required from stakeholders, which aims to motivate and guide stakeholders to actively participate in tailoring the services. As we continue iterating our efforts, we share our progress in the hope of supporting a shift from service provision to a more genuine co-production of climate services.

Standard Oral: Reimaging the scale in climate service

Dragana Bojovic, Samuel Pickard, Eren Duzenli, Paloma Trascasa Castro, Sara Octenjak, Carlos Delgado Torres, Eulalia Baulenas

Barcelona Supercomputing Center, Spain

Abstract

The scale of the issue, e.g., the expected climate change impact, and the scale at which this is governed need to be aligned. Scales are neither apolitical nor static, rather scales are socially and politically constructed dimensions.

Scale framing varies across scientific disciplines. Climate science often equates spatial and temporal scale with a model resolution. In contrast, the term scale within the social or ecological sciences, or for stakeholders, can refer to the conceptual hierarchy of physical and imagined spaces, and their interplay, i.e., to the organisation in the real world, like governance levels or administrative boundaries. Climate science is increasingly concerned with finer scales - approaching it with downscaling techniques and high-resolution modelling - but rarely considers other elements of the complex socio-ecological system that this information is supposed to inform.

We present results from a transdisciplinary endeavour to coproduce climate services across scales for two different climate risks and socio-economic contexts: (1) urban heatwaves in Barcelona (from the HE Impetus4Change project) and food security in Malawi (from the H2020 FOCUS-Africa project). Urban stakeholders like local governments and citizens experience and perceive heatwaves at many spatial and temporal scales. Preliminary results from co-designing harmonised climate services aim to show how we will provide climate information at the temporal, spatial and governance scales of urban resilience initiatives, such as managing public spaces and services during heatwaves or planning urban redevelopment. Likewise, while being directly impacted by prolonged droughts and shifted onset of the rainy season, food security also depends on the complex interplay between actors from different governance levels and international, national, and local stakeholders and their adaptation knowledge and experiences. Managing this urgent challenge in Malawi further requires seamlessly bridging climate modelling timescales and spatial boundaries.

Standard Oral: Co-producing streamflow forecasts useful for decision-making

Ole Wulff[1], Thea Roksvåg[2], Kamilla Wergeland[3], Silius M. Vandeskog[2], Øyvind Paasche[1]

[1]NORCE Norwegian Research Centre, Norway. [2]Norwegian Computing Center, Norway. [3]Småkraft, Norway

Abstract

Predictions of catchment streamflow are crucial for hydropower producers to estimate production, plan downtime and prepare for hazardous events. Often, producers operating in ungauged river catchments face challenges in predicting streamflow due to a lack of historical observations. This project is a collaboration within the Climate Futures SFI between the Norwegian Computing Center, NORCE and Småkraft, a hydropower producer operating small-scale power plants in Norway. With the expertise from all partners, we have co-developed an operational system that integrates freely available data with existing techniques from hydrology and weather prediction to provide probabilistic predictions of streamflow and production up to three weeks ahead. These are based on extended-range weather forecasts from Met Norway’s novel seamless 21-day forecast. Despite a lack of data necessary for proper verification, the forecasts facilitate estimating production at Småkraft's plants. The real-time system is updated daily, delivering forecasts through an online dashboard which provides a user-friendly interface with a traffic light system indicating favourable, adverse, or hazardous conditions. Continuous refinement of the dashboard design, guided by feedback from Småkraft's power plant operators, enhances its practical usefulness.

We have co-developed a climate service that provides a basis for operational decision-making in the hydropower sector. The potential of our forecasting system extends beyond hydropower production as it can offer early warnings for flood-prone areas by adapting the system to other catchments if certain key characteristics are known. Rigorous evaluation of forecast performance, especially during extreme events, remains crucial for utilizing the system’s full potential in flood risk management.

Standard Oral: What is the role of seasonal and sub-seasonal forecasts in farmers’ decision processes? A serious game approach

Ingrid Vigna, Anders Sivle, Jelmer Jeuring

Norwegian Meteorological Institute, Norway

Abstract

The development of forecasts on seasonal and sub-seasonal timescales has enriched the range of available information on future weather and climate conditions. This information can be crucial in sectors such as agriculture, where the adaptation to weather conditions plays an extremely important role in daily activities and production outcomes. However, more work is still needed to make it available and meaningful to farmers. In particular, a gap exists in the understanding of 1) how farmers use the available forecast products in their everyday decision-making processes and 2) how the introduction of medium and long-term forecasts changes these decision processes, especially in a changing climate. The present work addresses these questions through a serious game targeted at farmers, developed together with agricultural consultants from the Norwegian advisory organisation Norsk Landbruksrådgivning. The serious game approach aims to observe farmers’ decision-making processes by simulating the planning of production activities. In the game, the sources of information that they can base their decision on (10-day and 21-day forecasts, seasonal outlooks, traditional knowledge, newspapers…) are represented by consultable cards. This artefact makes it possible to collect data on players’ choices and preferences during the gameplay and to discuss them collectively during the following debriefing. The game sessions provide insights into the value farmers place on weather and climate information sources and how those sources interact with each other in their decision-making processes. The results will be instrumental in developing new tailored long-term forecast products by the Norwegian Meteorological Institute.

Standard Oral: Preparing for extremes: downscaling subseasonal climate predictions for understanding heat wave risks at Paris Olympics

Eren Duzenli, Jaume Ramon Gamon, Verónica Torralba, Sam Pickard, Dragana Bojovic

Barcelona Supercomputing Center, Spain

Abstract

Global warming is already exacerbating various harmful weather extremes. Among these, heat waves stand out as critical climate-driven events, which typically last from several days to a few weeks. Predicting and assessing heat waves in advance and at a reasonably high spatiotemporal resolution is crucial for the provision of early warning to the organization of summertime outdoor events and for informing actionable adaptive measures. Accordingly, we investigate the ability to provide this information for the 2024 Paris Olympics. As part of the Horizon Europe Impetus4Change project, this study tests 9 different statistical methods to downscale subseasonal climate predictions from CFSv2 climate prediction system for the retrospective period (i.e., l1999-2020) over Paris to specify the best approach. We evaluate each method's accuracy in forecasting temperature during the weeks of the 2024 Paris Olympics using three different skill metrics: i) RPSS (assessing the methods' ability to predict terciles), ii) Brier score - 10 (assessing the methods' ability to predict lower extremes), iii) Brier score - 90 (assessing the methods' ability to predict higher extremes). The downscaling process is repeated for 4 different lead times, i.e., on the outputs of the models that are initiated 1, 2, 3 and 4 weeks before the target weeks. The analogues and 4NN regression methods show the highest skill and overall downscaled subseasonal predictions of temperature are skilful for the lead times of 1 and 2 weeks. However, beyond a lead time of 2 weeks, the added value of the downscaled climate predictions compared to a climatological forecast depends on the metric considered; for example, they provide predictive capabilities for temperature extremes (but not terciles) up to three weeks in advance. Taken together, these findings demonstrate that downscaled predictions can be a valuable tool for providing timely climate information for summer events like the 2024 Paris Olympics.

Standard Oral: Statistical downscaling of extremes in seasonal predictions - a case study on spring frosts for the viticultural sector

Sebastiano Roncoroni, Panos Athanasiadis, Silvio Gualdi

Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC), Bologna, Italy

Abstract

Spring frost events occurring after budburst of grapevines can hinder plant growth and cause large economic losses to the viticultural sector. Frost protection practices encompass a range of vineyard management actions across multiple timescales, from comparatively short-term (seasonal) to medium- and long-term (decadal and beyond). The cost-effectiveness of such measures rests on the availability of accurate predictions of the relevant climate hazards at the appropriate timescales.

In this study, we present a statistical downscaling method which predicts variations in the frequency of occurrence of spring frost events in the important winemaking region of Catalunya at the seasonal timescale. The downscaling method leverages the seasonal predictability associated with predictable components of the atmospheric variability over the Euro-Atlantic region and produces local predictions of frost occurrence at a spatial scale relevant to vineyard management.

The method is designed to meet the specific needs highlighted by a representative stakeholder in the local viticultural sector and is expected to deliver an actionable prototype climate service. The statistical procedure is developed in perfect prognosis mode: the method is trained with large-scale reanalysis data against a high-resolution gridded observational reference and tested on the multi-model seasonal hindcast predictions retrieved from the Copernicus Data Store system.

Our work spotlights the potential benefits of transferring climate predictability across spatial scales for the design and provision of usable climate information, particularly regarding extremes.

Standard Oral: OceansforFuture: Communicating with society the changes in ocean impacts on climate

Sofía Fernández Álvarez[1], Irene Polo Sánchez[1], María Belén Rodríguez de Fonseca[1,2]

[1]Departamento de Física de la Tierra y Astrofísica, Universidad Complutense de Madrid, Spain. [2]Instituto de Geociencias (IGEO), Centro Superior de Investigaciones Científicas-Universidad Complutense de Madrid (CSIC-UCM), Spain

Abstract

The OFF project aims to build a decision making tool to identify the regions with potential predictability from ocean conditions, based on an assessment of teleconnections driven by anomalous SSTs with impact on Mediterranean and North African climate, using observations and models under historical and future conditions.

OFF is centred in analysing changes in ocean-forced teleconnections and impacts on marine ecosystems, energy and health. For marine ecosystems, the predictands include biomass of various consumers, nutrient concentrations, species abundance, and chlorophyll-a concentration. In the context of health, we examine minimum and maximum temperature, mortality rates, and the incidence of various diseases. For energy, we analyse wind speed and direction at different levels, precipitation, and surface shortwave radiation.

The impacts of these changes have enormous interest in policy makers and decision making.

Here we will present a methodology of how in OFF we communicate with society, with a gender perspective and encouraging STEM, the consequences of ocean-driven climate variability on ecosystems, energy, and health in present and future conditions. We will present the most outstanding results at the date of the meeting in order to increase discussion with the community. Results relating the impact of teleconnections on one health-related variables will be presented in more detail.

Discussion sessions (preliminary distribution of oral pitches by tentative topics)

State of the Art: Local atmospheric -and oceanic processes – Ocean/Atmosphere

Oral Pitch: Decadal predictability of seasonal temperature distributions

André Düsterhus[1], Sebastian Brune[2]

[1]Danish Meteorological Institute, Denmark. [2]Universität Hamburg, Germany

Abstract

Climate predictions focus regularly on the predictability of single values, like means or extremes. While this information offer important insight into the quality of a prediction system, some stakeholders might be interested in the predictability of the full underlying distribution. These allow beside evaluating the amplitude of an extreme also to estimate their frequency. Especially on decadal time scales, where we verify multiple lead years at a time, the prediction quality of full distributions may offer in some applications important additional value.

In this study we investigate the predictability of the seasonal daily 2m-temperature on time scales of up to ten lead years within the MPI-ESM decadal prediction system. We compare yearly initialised hindcast simulations from 1960 onwards against estimates for climatology and uninitialised historical simulations. To verify the predictions, we demonstrate a novel approach based on the non-parametric comparison of distributions with the integrated quadratic distance (IQD).

We show that the initialised prediction system has advantages in particular in the North Atlantic area and allow so to make reliable predictions for the whole temperature distribution for two to ten years ahead. It also demonstrates that the capability of initialised climate predictions to predict the temperature distribution depends on the season. Finally, we will also discuss potential opportunities and pitfalls of such approaches.

Oral Pitch: The relationship between SST gradients and ocean heat content along the Gulf Stream and the 250mb Jet Stream

Samantha Hallam, Gerard McCarthy

ICARUS, Maynooth University, Ireland

Abstract

The 250mb jet stream latitude follows a well-defined path in winter which is tightly confined, particularly on the western boundary of the North Atlantic (41°N) aligning with the Gulf Stream/North Atlantic Current, for the period since 1940. The jet stream troughs are also located in these areas in winter, the main areas for cyclogenesis.

The relationship between the SST gradient and mean jet latitude position was explored and highlights a close alignment in winter and spring on the western boundary of the North Atlantic where the SST gradient is strongest. The relationship is not as strong in the other seasons when there is a weaker SST gradient.

For the period since 1940 we find a weaker SST gradient in the North Atlantic region between 55-65W, 35-40N leads to a northward shift in the winter (DJF) jet stream and vice versa. The ocean leads by up to 6 months. The ocean heat content in the upper 100m in the gulf stream region between 40-50N and 50-70W also plays an important role. Negative ocean heat content anomalies in the region are associated with a northward shift in the jet position, with the ocean leading by up to 9 months. The results are verified using causality networks.

Oral Pitch: Causal Oceanic Feedbacks onto the Winter NAO

Erik W. Kolstad[1,2], Christopher H. O'Reilly[3]

[1]NORCE, Norway. [2]Bjerknes Centre for Climate Research, Norway. [3]Department of Meteorology, University of Reading, United Kingdom

Abstract

Of the climate variability patterns that influence the weather in the North Atlantic region in winter, the North Atlantic Oscillation (NAO) is the most dominant. The effects of the NAO span from cold air outbreaks to unseasonably warm conditions and unusual precipitation, with significant impacts on human activities and ecosystems. While a connection between the NAO and antecedent sea surface temperature (SST) conditions has been recognised for decades, the precise causal interaction between the ocean and the atmosphere remains enigmatic. In the study presented here we uncover a robust statistical relationship between North Atlantic SSTs in November and the NAO throughout the subsequent winter in the extended ERA5 reanalysis back to 1940. We apply a well-established causal inference technique called mediation analysis, commonly used in social science and now adopted in climate research. This analysis highlights the roles of low-level baroclinicity, latent heat fluxes, and latent heat release in mediating the effect of November SSTs on the NAO in January and February. It is important to recognise that these mediators are interrelated. Moreover, our analysis reveals bidirectional relationships, where the NAO reciprocally mediates the effects of the November SSTs on these variables. This is evidence of a complex web of feedback mechanisms which collectively contribute to the response of the winter NAO to late autumn/early winter SSTs.

Oral Pitch: Comparing Northern Hemisphere Polar Vortex Dynamics in Climate Change and Weak Vortex Events: Implications for Tropospheric Climate and Seasonal Prediction

Nour-Eddine Omrani[1], Noel Kennlyside[1], Sandro Lubis[2], Fumiaki Ogawa[3]

[1]Geophysical Institute, University of Bergen and Bjerknes Centre for Climate Research, Norway. [2]Pacific Northwest National Laboratory,, USA. [3]Graduate School of Science, Hokkaido University, Japan

Abstract

The stratosphere plays a crucial role in enhancing the atmospheric temporal memory, thereby influencing the persistence of large-scale tropospheric patterns such as the Northern Annular Mode (NAM) or North Atlantic Oscillation (NAO). Consequently, it plays a significant role in endowing the troposphere with predictive skill on seasonal time scales. Understanding the processes contributing to the persistence of large-scale stratospheric anomalies is thus essential for comprehending the sources of seasonal predictability of the NAO or NAM.

In this study, we employed the Finite Amplitude Local Wave Activity (FAWA) theory to understand the role of wave activity and non-conservative dissipative processes, such as irreversible diffusive mixing, in influencing the life cycle and persistence of stratosphere/troposphere coupled circulation anomalies during weak polar stratospheric events and in response to future climate change. Our findings reveal that while wave activity is responsible for the initiation and development of the weakening of the polar stratospheric vortex in both climate change experiments and weak vortex events, non-conservative dissipative processes play a crucial role in the seasonal persistence of stratospheric anomalies in both scenarios. Moreover, our analysis indicates that the impact of

non-conservative processes in the stratosphere is more pronounced in climate change experiments compared to weak vortex events. The implication of this result for the adjustments of the tropospheric circulation and therefore also for seasonal climate prediction will be discussed.

The FAWA theory offers therefore a new perspective for understanding the mechanisms, persistence and therefore also the source of the seasonal predictive skill in large-scale atmospheric circulation.

Oral Pitch: The subpolar gyre induces predictability to the NE Atlantic

Hjálmar Hátún

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Abstract

The subpolar North Atlantic oceans are important for the global climate system, and for the global production of marine food. Poleward upper-ocean flows of warm and saline Atlantic waters, and southward returning cold and dense near-bottom waters (the *Atlantic Meridional Overturning Circulation*, AMOC) are highly important for the living conditions around the subpolar oceans, the rapidly changing Arctic Ocean, as well as for the circulation in the World Oceans. The strong, but variable, atmospheric jet stream controls the number, intensity and pathways of storm systems across the subpolar Atlantic, which cool the surface ocean, lead to deep winter convection (1-2 km) and nutrient upwelling, in addition to adding vorticity to the ocean. This induces marked horizontal circulation cells like the *subpolar gyre* and the Norwegian Sea gyre, whose variable size and strength modulate the physical characteristics of the main AMOC flow branches, and their biogeochemical and biological content. Together with the northward flowing warm water, ideal conditions for primary production are established, which in turn enables the subpolar North Atlantic to accommodate its very rich ecosystems. The involvement of a deep water column and the considerable lateral oceanic connectivity and associated advective delays, both make these water more predictable than the rest of the World Oceans. Key convective processes, and the upper ocean Arctic-to-Atlantic oceanic connectivity take place on Greenlandic waters, while Faroese waters represent the main gateway between the North Atlantic and the high Arctic. Furthermore, there is trans-Atlantic connectivity. Waters from Greenland flow eastwards across the North Atlantic and influence properties of the Atlantic inflow in Faroese waters, and this signal returns westwards, and can be observed far north along the east Greenland slope - after a time lag.

Oral Pitch: Atmospheric patterns over the North Atlantic and their links to European precipitation in CMIP6 climate models

Stephen Outten[1,2], Richard Davy[1,2]

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Abstract

The North Atlantic Oscillation explains a large fraction of the climate variability across the North Atlantic from the eastern seaboard of North America across the whole of Europe. Many studies have linked the North Atlantic Oscillation to climate conditions in this region, especially in winter, which has motivated considerable study of this pattern of variability. Large-scale patterns like the NAO also influence precipitation downstream over Europe through the modulation of weather features such as low-pressure systems, atmospheric rivers, frontal zones, etc. Understanding how large-scale patterns like the NAO change over time and how they influence downstream weather conditions is valuable for regional climate prediction.

This study identifies the three primary modes of variability over the North Atlantic-European sector using Empirical Orthogonal Function and Common Basis Function approaches. We investigate how the variability explained by these patterns has changed over the course of the 20th Century in reanalyses and compare these changes to those found in the historical simulations of 50 models from CMIP6. This includes two runs from the Norwegian Earth System Model and one from the Norwegian Climate Prediction Model. Furthermore, we examine the relationship between these large-scale patterns and the precipitation across the region and assess how well the 50 CMIP6 models reproduce this relationship. This approach has highlighted a stark contrast between approximately two thirds of the models which show a relationship between large-scale flow and precipitation that is similar to that found in the reanalysis and approximately one-third of the climate models which do not.

Oral Pitch: Decadal predictions outperform projections in forecasting winter precipitation over the Mediterranean region

Dario Nicolì, Silvio Gualdi, Panos Athanasiadis

CMCC Foundation, Italy

Abstract

The Mediterranean region is highly sensitive to climate change, having experienced an intense warming and drying trend in recent decades, primarily due to the increased concentrations of anthropogenic greenhouse gases. In the context of decision-making processes, there is a growing interest in understanding the near-term climate evolution of this region.

In this study, we explore the climatic fluctuations of the Mediterranean region in the near-term range (up to 10 years ahead) using two different products: projections and decadal predictions. The former are century-scale climate change simulations initialized from arbitrary model states to which were applied anthropogenic and natural forcings. A major limitation of climate projections is their limited information regarding the current state of the Earth's climate system. Decadal climate predictions, obtained by constraining the initial conditions of an ensemble of model simulations through a best estimate of the observed climate state, provide a better understanding of the next-decade climate and thus represent an invaluable tool in assisting climate adaptation.

Using retrospective forecasts from eight decadal prediction systems contributing to the CMIP6 Decadal Climate Prediction Project (CMIP6 DCPP) and the corresponding ensemble of non-initialized projections, we compare the capabilities of the state-of-the-art climate models in predicting future climate changes of the Mediterranean region for some key quantities so as to assess the added value of initialization. Beyond the contribution of external forcings, the role of internal variability is also investigated since part of the detected predictability arises from internal climate variability patterns affecting the Mediterranean. The observed North Atlantic Oscillation, the dominant climate variability pattern in the Euro-Atlantic domain, as well as its impact on wintertime precipitation over Europe are well reproduced by decadal predictions, especially over the Mediterranean, outperforming projections.

State of the Art: Local atmospheric -and oceanic processes – Biogeochemistry

Oral Pitch: Predicting chlorophyll-a in the tropical Atlantic from SST information

Elena Calvo Miguélez[1,2], Belén Rodríguez de Fonseca[1,2], Iñigo Gómara[3]

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Abstract

Chlorophyll-a surface concentration and its variability are partially determined by environmental conditions, as the highest concentrations are generally found in wind-driven oceanic upwelling regions. These wind regimes that affect upwelling strength can be forced by local and remote drivers, such as sea surface temperature (SST) anomaly patterns.

By performing a Maximum Covariance Analysis (MCA) between chlorophyll-a concentration from Copernicus Satellite data and SST anomalies from OISST (January 1998-December 2023), we here identify the individual SST patterns and the associated atmospheric responses that lead to a change in chlorophyll concentration in the Mauritanian-Senegalese coast and the equatorial Atlantic during their seasonal maxima (February to May). A cross-validated hindcast based on Maximum Covariance Analysis (MCA) is used to assess chlorophyll predictability through the individual SST variability modes. In parallel, to validate the results found, reanalysis and historical global marine ecosystem simulation from the FishMIP initiative (EcoOcean) are used.

Oral Pitch: Phytoplankton predictability in the Tropical Atlantic - triggered by nutrient pulses from the South?

Filippa Fransner[1], Marie-Lou Bachèlery[2], Shunya Koseki[1], David Rivas[1], Noel Keenlyside[1], Nicolas Barrier[3], Matthieu Lengaigne[3], Olivier Maury[3]

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Abstract

The variability and predictability of the Tropical Atlantic primary productivity remains little explored on interannual-to-decadal time scales. Here, we present the results of two studies, in which find a decadal scale variability in phytoplankton abundance that can be predicted three years ahead. The predictions are made with NorCPM, which is a fully coupled climate prediction model with ocean biogeochemistry that assimilates temperature and salinity to reconstruct past variability. From these reconstructions, predictions are initialized that are run freely ten years ahead. We find that the predictability is a result of nutrient pulses that are advected with the southern branch of the South Equatorial Current from the most southern part of the Atlantic, and that then get caught in the Equatorial undercurrent before they reach the surface in the Tropical Atlantic Ocean. A more detailed analysis is being done in order to pinpoint the underlying mechanisms in a forced ocean model, where we find a link to the Pan-Atlantic decadal oscillation.

Oral Pitch: On predictability of surface phytoplankton and its physical/biogeochemical drivers in the Tropical and South Atlantic

David Rivas[1,2], Noel Keenlyside[1]

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Abstract

In a previous study, the physical drivers responsible for the satellite-derived chlorophyll-a (CHL) variability in key areas of the Tropical and South Atlantic were identified; these findings were used to generate empirical models to reconstruct CHL series in the analysed regions with a relatively high level of success. As follow-up research, the predictability of the regional CHL and its physical drivers is assessed at a seasonal-scale using hindcast experiments from the Norwegian Climate Prediction Model (NorCPM). The NorCPM-modeled surface phytoplankton (assumed to be qualitatively consistent with the CHL) shows to be predicted 3-6 months in advance in most of the analysed regions. However, this modelled phytoplankton concentration shows no significant correlation with the observational (satellite derived) CHL, hence the predictability is then focused on its physical drivers which also explain the variability of this observational CHL. This analysis will allow the assessment of the physical/biogeochemical processes diagnosed by the NorCPM even if the final output (phytoplankton, in this case) is not consistent with the observations, which will provide hints about potential issues in the model's biogeochemical component.

Oral Pitch: Harmful algae bloom frequency response to climate change along the Norwegian coast

Edson Silva, Francois Counillon, Julien Brajard, Richard Davy

NERSC, Norway

Abstract

Harmful Algae Bloom (HAB) produces toxins that contaminate or kill fishery resources, posing a significant challenge for the fishing and aquaculture industry. We evaluate how the frequency of HAB will evolve along the Norwegian coastline as a response to climate change. We use probabilistic models to estimate the HAB frequency of key toxic species -- *A. tamarense* and *D. acuta* -- under different climate warming levels (1 to 3°C). The probabilistic models are fed with projections of sea surface temperature (SST), sea surface salinity, and mixed layer depth (MLD) from three CMIP6 models (AWI-CM1-1-MR, MPI-ESM1-2-HR, and NorESM2-MM) under the SSP585 scenario. The HAB frequency is estimated for 30 points along the Norwegian coast spread from 59°N to 71°N. Under these warming levels, the Norwegian coastal waters are warmer and fresher, with MLD stratifying earlier and deepening later in the year. In a 3-degree warmer world, the expected number of HABs of *A. tamarense* reduces from 53 to 44 per year, while HABs of *D. acuta* increase from 18 to 26 per year. The SST rise yields an increase in the HAB frequency during spring for *A. tamarense* and summer and autumn for *D. acuta*. The earlier shallowing and delayed deepening of MLD yields a slight increase in the frequency of HABs of *A. tamarense* and *D. acuta* during spring and autumn. However, the lower salinity in the summer and autumn strongly yields a frequency reduction for both taxa. Our results indicate that the future scenario of HABs might become more evenly spread throughout the year, with more HABs during spring and autumn and less during summer compared to the present. Furthermore, the freshening of the coastal waters can counteract the impact of SST warming and MLD shallowing for *D. acuta* and even reduce the frequency of *A. tamarense* HABs.

State of the Art: Remote links and impacts on the North-Atlantic-Arctic region – to the Atlantic

Oral Pitch: Important changes in the ENSO teleconnection to the North Atlantic-European sector in the last decades and its implications on temperature predictability

Pablo Fernández-Castillo[1,2], Diego García-Maroto[1,2], Teresa Losada[2], Belén Rodríguez-Fonseca[2,1], Elsa Mohino[2], Luis Durán[2], Esteban Rodríguez-Guisado[3]

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Abstract

El Niño-Southern Oscillation (ENSO) is the main mode of climate variability at interannual timescales. Sea-surface temperature anomalies in the equatorial Pacific basin modify the energy balance in the tropics, leading to important modifications in the atmospheric circulation that propagate to the extratropics. A number of studies have characterised the impacts of ENSO on the North Atlantic-European sector (NAES) climate. However, most of them consider a stationary signal, which may attenuate strong signals present during certain periods of time. Additionally, most of these studies have focused on the impacts on precipitation, leaving impacts on temperature less characterised. In this study, we analyse how ENSO impacts in the atmospheric circulation over the NAES have changed over the last decades and how these changes may have modulated its subsequent impacts on surface air temperature. This has been done taking advantage of the latest updates in the observational and reanalysis datasets, spanning until 2023, thus covering the most recent period, which has not been fully characterised by previous studies in the field. Results reveal that the way ENSO impacts the atmospheric circulation over the NAES has significantly changed at interdecadal timescales, leading to changes in impacts on temperature in Europe. The study has been completed by analysing the SEAS5 seasonal weather forecasting model, from the European Centre for Medium-Range Weather Forecasts. The period analysed with the model forecasts spans from 1981 to 2022, which allows to address whether this numerical weather prediction model is able to capture the non-stationarity of the teleconnection.

Oral Pitch: Characterizing Atlantic interhemispheric teleconnection established by South American monsoon in austral summer

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Abstract

This study aims to characterize the interhemispheric teleconnection pattern, which is established by the South America (SA) summer monsoon over the Atlantic Ocean during January and February and referred it as the Atlantic symmetric pattern (ASP). The ASP is characterized using the leading mode of interannual sea surface temperature (SST) variability of the Southwest Atlantic Ocean, where strong convection-SST coupling occurs. The pattern is manifested as two anomalous cyclonic-anticyclonic-cyclonic circulation trains aligned meridionally over the Atlantic Ocean, with a distinct SST dipole of the Southwest Atlantic Ocean and a tripole of the North Atlantic Ocean. The interhemispheric wave trains of the ASP are excited as a Gill-type response to convective activity in the SA summer monsoon, as confirmed in linear baroclinic model. Complementing previous studies on observed interhemispheric connection in the Atlantic, our findings highlight the importance of characterizing the ASP and its role in linking the South Atlantic SST, the SA summer monsoon, and North Atlantic climate. Further research is warranted to explore the impacts of the ASP on the Northern Hemisphere and its interactions with other climatic modes.

Oral Pitch: Origins of Barents-Kara sea-ice interannual variability modulated by the Atlantic pathway of El Niño–Southern Oscillation

Binhe Luo[1], Dehai Luo[2], Yao Ge[2], Aiguo Dai[3], Lin Wang[4], Ian Simmonds[5], Cunde Xiao[1], Lixin Wu[6], Yao Yao[2]

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Abstract

Winter Arctic sea-ice concentration (SIC) decline plays an important role in Arctic amplification which, in turn, influences Arctic ecosystems, midlatitude weather and climate. SIC over the Barents-Kara Seas (BKS) shows large inter- annual variations, whose origin is still unclear. Here we find that interannual variations in winter BKS SIC have significantly strengthened in recent decades likely due to increased amplitudes of the El Niño-Southern Oscillation (ENSO) in a warming climate. La Niña leads to enhanced Atlantic Hadley cell and a positive phase North Atlantic Oscillation-like anomaly pattern, together with concurring Ural blocking, that transports Atlantic ocean heat and atmospheric moisture toward the BKS and promotes sea-ice melting via intensified surface warming. The reverse is seen during El Niño which leads to weakened Atlantic poleward transport and an increase in the BKS SIC. Thus, interannual variability of the BKS SIC partly originates from ENSO via the Atlantic pathway.

Oral Pitch: Impact of AMV on rainfall intensity distribution and timing of the West African Monsoon in DCPP-C-like simulations

Elsa Mohino[1], Paul-Arthur Monerie[2], Juliette Mignot[3], Moussa Diakhaté[4], Markus Donat[5,6], Christopher David Roberts[7], Francisco Doblas-Reyes[5,6]

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Abstract

Previous studies agree on an impact of the Atlantic Multidecadal Variability (AMV) on total seasonal rainfall amounts over the Sahel. However, whether and how AMV affects the distribution of rainfall, or the timing of the West African Monsoon is not well known. Here we explore these impacts by analysing daily rainfall outputs from climate model simulations with an idealized AMV forcing imposed in the North Atlantic, consistently with the DCPP-C protocol. In response to a persistent positive AMV pattern, models show an enhancement in total summer rainfall over continental West Africa, including the Sahel, where the number of wet days and the intensity of daily rainfall events are both enhanced. The frequency of both moderate and heavy events increases over the Sahel's northern fringe. Conversely, over the southern limit, it is mostly the frequency of heavy events which is enhanced, affecting the mean rainfall intensity there. Extreme rainfall events are also enhanced over the whole Sahel in response to a positive phase of the AMV. Over the Sahel, models with stronger negative biases in rainfall amounts compared to observations show weaker changes in response to AMV, suggesting systematic biases could affect the simulated responses. The length of the monsoon season is enhanced between 2 and 5 days with the positive AMV pattern due to a delay in the monsoon cessation date. The effect of AMV on the seasonality of the monsoon is more consistent to the west of 10ºW, with all models showing a statistically significant earlier onset, later demise, and enhanced monsoon season with the positive phase of the AMV. Our results suggest a potential for the decadal prediction of changes in the intraseasonal characteristics of rainfall over the Sahel, including the occurrence of extreme events.

Oral Pitch: Variability and seasonal predictability of precipitation in the Iberian Peninsula with special focus on mountain areas.

Diego García-Maroto[1,2], Pablo Fernández-Castillo[1,2], Luis Durán[1], Elsa Mohino[1], Álvaro González-Cervera[1,3], Teresa Losada[1], Belén Rodríguez-Fonseca[1,2]

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Abstract

Mountain areas are of particular interest due to their critical role in the hydrological resources, especially in the Iberian Peninsula, a region subject to strong climate variability and change. This work aims to evaluate the seasonal prediction of precipitation over these areas. We begin by revisiting the variability and teleconnections of precipitation in the Iberian Peninsula using observational gridded datasets and reanalysis, with a particular emphasis on El Niño-Southern Oscillation (ENSO). We show how the impact on precipitation of the ENSO teleconnection is greater during early fall (September and October) and how it is subject to strong decadal changes that may have implications for predictability. Additionally, we evaluate the skill of ECMWF's fifth generation seasonal forecast system (SEAS5) in predicting precipitation. As the horizontal resolution of most seasonal forecast systems remains too coarse to simulate some mountain-specific processes, we propose and evaluate an approach based on the use of large-scale atmospheric and oceanic patterns with specific regional impacts to achieve a better predictability at high elevations. The findings of this research have significant implications for seasonal prediction and Climate Services, contributing to our understanding of precipitation variability and predictability in the Iberian Peninsula and in high elevation areas within.

State of the Art: Remote links and impacts on the North-Atlantic-Arctic region – from the Atlantic

Oral Pitch: Conditional impacts of the North Atlantic SST anomaly on the Asian winter climate

Shui Yu, Jianqi Sun

Institute of Atmospheric Physics, Chinese Academy of Sciences, China

Abstract

North Atlantic SST is a principal driver of the Eurasian seasonal-to-decadal climate variability and provides valuable information for Eurasian climate prediction. We have conducted the conditional impacts of the North Atlantic SST anomaly on the Asian winter climate on different time scales. First, on the interannual time scale, we investigate the relationship between the North Atlantic sea surface temperature (NASST) in autumn (September–October–November, SON) and the tropospheric Asian polar vortex (APV) in the following winter (December–January–February, DJF). The results show that the SON SST anomaly over the mid-latitude North Atlantic conditionally provides a valuable source for predicting the DJF APV's interannual variability. Only when the SON NASST anomaly can persist into DJF can the NASST anomaly excite a wave train pattern to influence the APV, and there is a practical prediction of the DJF APV. Physical diagnosis indicates that the presence/absence of an active air-sea interaction determines whether the SON SST anomaly signals could be maintained to DJF. Second, on the inter-monthly time scale, a dipole pattern of SST anomalies over the Eastern North Atlantic-Eastern Mediterranean Sea is responsible for the persistent East Asian trough (EAT) anomaly in DJF. Their connection depends on the SST's persistence. When positive feedback exists between the local atmosphere and the sea, the dipole SST pattern is well-sustained in the three winter months. Further, it leads to a persistent EAT anomaly by exciting the Rossby wave train over mid-latitude Eurasia. Numerical simulations by the linear baroclinic model further validate the role of dipole SST pattern-related diabatic and vorticity forcing in air-sea interactions. In contrast, in the SST poorly sustained years, the dipole SST pattern has a weak connection with the persistent EAT anomaly.

Oral Pitch: Impact of northern tropical Atlantic SST on Northeast China spring precipitation and the prediction biases of such impact in the dynamic model

mengqi Zhang, jianqi Sun

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Abstract

The North Atlantic sea surface temperature (SST) is an important influencing and prediction factor of climate variations over downstream Eurasia. A significant lead-lag interannual relationship between February northern tropical Atlantic (NTA) SST and Northeast China spring precipitation (NECSP) is revealed after the late 1970s, while the relationship is weak before the late 1970s. The NTA SST anomalies can persist well from February to following spring. Under the warmer SST background after the late 1970s, the spring NTA SST warming can induce stronger tropical diabatic heating, and further induce stronger transient eddy feedback over mid-latitude North Atlantic, finally leading to a significant negative phase NAO-like pattern. The NAO-like atmospheric anomalies further excite a Rossby wave train that propagates eastward to East Asia, inducing cyclonic anomalies over Northeast Asia and further increase the NECSP. The interdecadal enhanced influence of NTA SST on NECSP is further confirmed by atmospheric general circulation model (AGCM) experiments forced with idealized NTA warming. The 1-month lead information of the NTA SST provides a prediction source for NECSP. Additionally, the dynamic prediction skill of the observed NTA SST–NECSP connection is evaluated based on the operational climate prediction model, and the causes of prediction biases are investigated.

Oral Pitch: Atlantic Niño as predictor for California Upwelling Ecosystem

Belen Rodriguez-Fonseca[1,2], Mercedes Pozo Buil[3,4], Jerome Fiechter[5], Steve Bodard[5,4]

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Abstract

The Atlantic Niño is the dominant mode of sea surface temperature variability in the tropical Atlantic at interannual time scales. In the last decades this mode of variability has been identified as a driver of Pacific Niño, increasing its predictability. The mechanism involved in the relation between the Atlantic Niño and ENSO is through the modification of the Walker Cell, altering surface winds in the western Pacific and triggering oceanic Kelvin waves. These Kelvin waves propagate to the east in the equatorial Pacific and along the north and south American coasts, altering the structure of the water column. The impact of this teleconnection on coastal upwelling has not been analysed so far. This work demonstrates, for the first time, the impact of the Atlantic Niño on the California Current ecosystem, by the alteration of coastal upwelling and the modification of the biogeochemistry. The mechanism relates an Atlantic Niño with enhanced production due to the lifting of the isopycnals that put more nutrients in the surface and enhance the remineralization. In addition, statistical prediction is performed, indicating strong predictability of California Current biogeochemistry from the equatorial Atlantic anomalous SSTs more than one year ahead. The relation with other Atlantic marine ecosystems is also addressed.

Oral Pitch: Going beyond the traditional pacemaker experiment approach to evaluate the role of the Atlantic in the global climate variability during the historical era.

Yohan Ruprich-Robert, Veronica Martin Gomez

Barecelona Supercomputing Centre, Barcelona, Spain

Abstract

Pacemaker experiments are an interesting tool in order to isolate the potential climate impacts driven by observed SST anomalies from a given sub-region of the world. Within this framework, large ensemble members differing from initial conditions are performed in which model SSTs are constrained over a sub-region to follow the past evolution of the observed SST variability. However, by construction, this protocol can provide results matching the past evolution of the observed climate system only if the SST over the constrained region was in fact forcing the atmosphere. In the other case, the model simulation would fail to reproduce the past atmospheric conditions.

Here we assess how this protocol limitation alter our ability to attribute past climate fluctuations to the Atlantic variability at interannual to multi-decadal timescales. In particular, performing pacemaker simulations using a perfect model approach with the EC-Earth3-CC model, we quantify the maximum of attributability one can reach with a classical pacemaker approach. We discuss potential improvement to implement to this protocol in order to better attribute past climate variability, and therefore to improve our knowledge about the sources of climate predictability.

State of the Art: The role of forced vs internal variability in driving climate variations

Oral Pitch: The impact of sea ice thickness biases on the projected sea ice declining speed: insights from CMIP6 ensemble experiments

Tian Tian, Shuting Yang

Danish Meteorological Institute, Denmark

Abstract

The IPCC's 2021 assessment suggested that substantial emissions reduction and limiting global temperature rise to well below 2.0°C could prevent the complete loss of Arctic sea ice. However, these assessments come with large uncertainties. Recent research projects a summer ice-free Arctic by the 2050s even under a low emissions scenario, by constraining future sea ice area with satellite-derived sea ice concentration (SIC) since 1979. Notably, the climate models in these assessments commonly underestimate accelerated Arctic warming and the pace of sea ice melting, particularly over the last two decades. Moreover, some recent studies reveal that in a warming climate, the thinning of sea ice and snow over sea ice may intensify surface warming, thereby accelerating the melting.

In this study, we take advantage of the recent increasing availability of Arctic-wide sea ice thickness (SIT) data to investigate the link between changes in SIT, SIC, and Arctic warming. We apply the most readily available observational and reanalysis products of SIC and SIT to evaluate the biases and uncertainties in the CMIP6 multi-model ensemble in historical periods and future scenarios. We further investigate the relationship between the thinning of sea ice and the snow layer on sea ice, and surface temperature changes on a basin/regional scale. The findings are then used to constrain projected Arctic changes. Our study aims to gain some insights into the impact of model biases in the Arctic on climate predictions and projections, crucial for decision-making in a changing climate.

Oral Pitch: Sea ice loss drove rapid Arctic warming in the early 20th century

Fei Li[1], Vladimir Semenov[2], Noel Keenlyside[1], Tatiana Aldonina[2]

[1]GFI, UiB, Norway. [2]Institute of Geography, RAS, Russian Federation

Abstract

Arctic warming and melting sea ice are iconic features of global warming. Yet, the actual contribution of anthropogenic greenhouse gas emissions to the recent rapid warming remains unclear. The early 20th century Arctic warming—similar in magnitude to the recent one—provides a baseline for variability arising from natural climate variability, but is poorly understood because of lack of data (ref _AMIP_reanalysis). Here using a new sea-ice reconstruction and atmospheric model experiments, we show for the first time that a strong reduction in sea ice was crucial to the early 20th century Arctic warming. The reconstruction is more physically consistent than other available sea-ice datasets for this period, being based on well understood dynamics and reliable meteorological and oceanographic observations. Atmospheric model simulations forced with the new reconstruction replicate well the observed early 20th century warming pattern in summer and winter, in contrast to ones using a standard sea-ice dataset. The reduced sea-ice warms the lower atmosphere through increased oceanic heat release that is further amplified by the positive lapse-rate feedback. These findings indicate that natural variability could explain as much as 75% of the present Arctic warming, given the remarkably similarities to the early 20th century event.

Climate predictions for society: Climate information production to climate information use

Oral Pitch: Seasonal Forecasts for Resilient Food Systems - The Co-production of Climate Services for Norwegian Agriculture

Manuel Hempel

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Abstract

The Nordics are among the regions in which climate change trends and extended growing seasons could benefit agricultural production. Potential advantages are however threatened by a simultaneous increase of climate variability and extreme weather events.

Norwegian agriculture has e.g. recently experienced several crisis years caused by extended wet periods and dry spells, such as the 2018 summer drought, which caused heavy losses and economic damages to both farmers and society.

These experiences indicate that the sector is currently not well enough prepared for a future climate in which such weather events are projected to occur more and more frequently. There is therefore a need to strengthen climate resilience in Nordic food systems. A possible pathway lies in the development and provision of advanced long-term weather information.

Sub-seasonal to seasonal forecasts (S2S) provide climate information from 10 days to 3 months ahead in time and serve as a promising tool to reduce climate risk by introducing reliable weather data into the seasonal decision-making processes.

Within my research I work on the co-production of climate services for the Norwegian agriculture sector.

- How should S2S-forecasts be designed in terms content and form to encourage their uptake and application in agriculture?
- To which degree can S2S- forecasts inform agricultural decision making?
- And could their availability have made a difference in the handling of previous crisis, such as the 2018 drought in Norway?

These are some of the questions I investigate by applying hind-casts and real time S2S- forecasts in a triangulation of qualitative methods in human geography, such as interviews, focus groups, participatory mapping sessions and system dynamics modelling.

I intend to present the results from the Norwegian case study with a focus on the co-production of climate services and their potential for reducing climate risk in agricultural decision making.

Oral Pitch: OceansforFuture: Innovating climate services using ocean information and communication with society (OFF)

Irene Polo, Belen Rodriguez-Fonseca, Pablo Duran-Rodríguez, Javier Vegas

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Abstract

Modes of sea surface temperature variability and their teleconnections are known to change according to the mean state of the oceans. Given the effect of anthropogenic climate change on ocean heat content, the characteristics of these modes of variability together with their impacts could also change in future scenarios. OFF project aims to build a decision-making tool to identify the regions with potential predictability from ocean conditions, based on an assessment of teleconnections driven by anomalous SSTs with impact on Mediterranean and North African climate, using observations and models under historical conditions. In terms of methodology, we have engineered an SST-based prediction tool, Spy4CAST. based on the diagonalization of the covariance matrix between a predictor field, which in our case is Sea Surface Temperature, and a variable to be predicted, which is related to climate, health, energy, or marine ecosystems. Spy4CAST uploaded to ESMValTool produces predictions for different IPCC models and scenarios. Also, multiple machine learning techniques are used both to determine the most influential factors in a given phenomenon under study and to find behavioural patterns to analyse the relationships between different events and make predictions.

Oral Pitch: From Super Users to a Community of Practice: bringing seamless climate information into mainstream decision making

Marta Terrado[1], Albert Soret[1], Verónica Torralba[1], Freya Garry[2], Dan Bernie[2], Jaroslav Mysiak[3], Julieta Rosenbluth[1], Sheetal Saklani[1], Andria Nicodemou[1], Carmen González[1], Sam Grainger[4], Suraje Dessai[4], Aleksandra Krzic[5], Rose Willoughby[2], Jason Lowe[2]

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Abstract

Research communities providing weather forecasts, climate predictions and climate change projections have traditionally worked in silos, using different methods and approaches, and often different models. This academic divide makes no sense to most users, whose decision making and planning often needs to simultaneously consider different time horizons, otherwise decisions may lead to maladaptation. The EU-funded project ASPECT (Adaptation-oriented Seamless Predictions of European ClimaTe, www.aspect-project.eu) aims to improve climate information and produce seamless climate advice covering from a season to the next 30 years to support societally relevant climate change adaptation decisions over a range of sectors, time scales, geographies, and decision-making levels.

Through a transdisciplinary co-production approach ASPECT is developing novel climate services with five 'Super Users' from climate-sensitive sectors that need to make decisions cutting across different time horizons. These organisations span the agriculture sector (grapes), the finance sector (pensions), governance (EU Mission on Climate Adaptation), disaster response, and the humanitarian sector (children's health and migration). Working with Super Users and encouraging them to guide the scientific development of the project, ASPECT identifies relevant decisions and co-evaluates the benefits of the new prediction products provided in each decision context.

To facilitate upscaling of the climate services co-produced with the five Super Users, ASPECT is building a transdisciplinary community of practice, bringing together a network of organisations interested in learning how to use seamless climate information. Capacity building activities and multi-sector user forums provide a space for interaction involving project scientists and a diverse range of potential users. Through a suitable delivery information system, ASPECT ultimately promotes the mainstream uptake of climate information into decision making for societal adaptation.

Oral Pitch: Co-production of multi-annual climate services to support food and wine production resilience

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Abstract

Nature and society are experiencing unprecedented challenges due to impacts of climate change. These impacts compromise the security of several sectors such as agriculture, biodiversity, water management, food production and economy. Changes in temperature trends, precipitation regimes and increased frequency of extreme climate events due to climate change affect crop production. Besides, natural climate variability at annual to decadal time scales also affects crop yields and alters the optimal crop seasons and varieties. Examples of climate events that affect agricultural productivity are shifts in the rainy season, more intense and frequent heatwaves, prolonged droughts, and floods.

Decision-makers could use information on climate change and variability years in advance to develop adaptation policies to reduce risk and losses. Potential adaptation strategies are investment in new irrigation technologies, sustainable water management, selection of crop varieties, sustainable agricultural practices, purchase of pesticides, agroforestry, and livelihood diversification. To support their decisions, climate information can be extracted from decadal climate prediction models, which have been recently shown to be skilful in predicting mean and extreme temperature and precipitation and drought conditions over several land regions.

To illustrate the climate services co-production based on multi-annual predictions, we present the implementation of two services. The services aim to support food security in Tanzania and Malawi, and wine sector activities in Catalonia, as part of the FOCUS-Africa and ASPECT projects. The climate information on multi-annual time scales has been provided through an interactive online website where the climate predictions and their quality can be accessed. In addition, co-designed multi-annual bulletins summarise the predictions in an accessible language and show maps of the most relevant variables and periods. Using these documents during in-person meetings helped involve participants, facilitate discussion, and concretise feedback. Co-production is an ongoing process of improving and tailoring climate information for its usability in decision-making processes.

Oral Pitch: Can we make nature-based solutions more climate resilient? Co-producing climate services for tree planting in two Catalonian municipalities.

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Abstract

As part of Impetus4Change, the Barcelona demonstrator collaborates with local stakeholders to co-produce climate services related to extreme summer temperatures. Initially, climate adaptation concepts were derived from general climate risks in the broader Barcelona region. The first stage of our co-production efforts involved reassessing these assumptions and co-explore with stakeholders to identify current climate-related challenges and their specific needs for climate information and decision support.

Two municipalities mentioned the potential for developing services related to tree planting. Planting trees in urban areas is a popular adaptation measure to mitigate the urban heat island effect and create more liveable cities by providing shade, decreasing surface temperatures, and enhancing overall environmental quality.

Tree planting initiatives can benefit from tailored climate information. Factors such as accumulated precipitation and anomalous temperature influence planting dates and irrigation requirements. The latter aspect is particularly relevant as Catalonia faced its worst ever drought in 2023, forcing many local authorities to reduce irrigation of parks and street trees. Many trees died as a result, while others were felled on public safety grounds. Local authorities thus are currently planning how to both replace prior trees and create new resilient nature-based adaptation solutions and have asked us to provide climate information to help decide when to begin planting.

The co-developed service aims to unite pre-existing drought concerns with the planting and growth conditions of different tree species, spanning seasonal and subseasonal timescales. This approach addresses the need for advance information for nursery tree acquisition and approval, as well flexibility in determining planting times.

Here we outline co-production progress to date, the interaction of climate and non-climate information with stakeholder decision contexts and our requests of stakeholders. We conclude by drawing general lessons and the potential of our approach to be applicable to broader contexts.

Climate predictions for society: Prediction of extremes

Oral Pitch: Modelling sub-daily precipitation extremes with the blended generalised extreme value distribution

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Abstract

Extreme precipitation can cause floods, large economic losses and immense destruction of infrastructure. To better mitigate the dangers of future precipitation extremes, we create spatial maps of return level estimates for sub-daily precipitation amounts in Norway, by modelling the spatial distribution of yearly precipitation maxima.

Yearly maxima of climate variables are commonly modelled with the generalised extreme value (GEV) distribution. However, inference with the GEV distribution is known to be difficult, partly because its support depends on its parameters. We therefore model the yearly precipitation maxima with a modified version of the GEV distribution, known as the blended GEV (bGEV) distribution. This distribution has the right tail of a Fréchet distribution and the left tail of a Gumbel distribution, which results in a constant support that allows for more robust inference.

The bGEV distribution is compared against the GEV distribution in a simulation study and found to perform better in more complex scenarios. Then, we apply a latent Gaussian model with a bGEV likelihood for modelling yearly precipitation maxima and creating spatial maps of precipitation return level estimates in Norway. Fast approximate Bayesian inference is achieved using integrated nested Laplace approximations (INLA). The model seems to perform well and delivers promising return level maps.

Oral Pitch: Predicting Intense Marine Heatwaves in Northern Seas (PRIMA)

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Abstract

Marine heatwaves (MHWs) are characterised as periods of extreme high sea temperatures relative to the long-term mean seasonal cycle. MHWs have become more frequent due to climate change, and this trend is likely to increase in the future. MHWs have become a major concern in climate change research largely due to their impact on marine biodiversity with studies noting an effect on biogeochemistry. There are promising results in terms of predicting such extreme events on seasonal time scales, especially in low latitudes; however, research and predictive skill is limited for higher latitudes, including the Arctic Ocean. The annual intensity, frequency, duration, and areal coverage of MHWs have increased significantly in recent decades in the Arctic Ocean. Thus, further research focused on MHWs in higher latitudes is fundamental not only to aid climate prediction services but also to mitigate impacts on marine life. Based on this, a new PhD project has started this year. The main purpose of this PhD project is to assess the predictability of MHWs in the Arctic Mediterranean (AM). This project forms part of the PRIMA (PRedicting Intense MArine heatwaves in Northern seas) project at the Nansen Center. The first steps are to apply regional analysis from TOPAZ and global analysis from the Norwegian Climate Prediction Model (NorCPM). We will thus show the first results from mapping the characteristics of MHWs in the AM during the last decades. Furthermore, we will present the following plans for the project; understand the triggers of MHWs in selected regions, assess predictive skill related to MHW events, and lastly, investigate the impact of specific MHW events on biogeochemistry in the AM.

Oral Pitch: Extreme Arctic sea ice lows investigated with a rare event algorithm

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Abstract

Various studies identified possible drivers of extreme Arctic sea ice lows, such as observed in the summers of 2007 and 2012, including preconditioning, local feedback mechanisms, oceanic heat transport and the synoptic- and large-scale atmospheric circulations. However, a robust quantitative statistical analysis of extreme Arctic sea ice lows is hindered by the small number of events that can be sampled in observations and numerical simulations with computationally expensive climate models. Recent studies tackled the problem of sampling climate extremes by using rare event algorithms, i.e., computational techniques developed in statistical physics to reduce the computational cost required to sample rare events in numerical simulations. Here we apply a rare event algorithm to ensemble simulations with the intermediate complexity coupled climate model PlaSim-LSG to investigate extreme negative summer pan-Arctic sea ice area anomalies under pre-industrial greenhouse gas conditions. Owing to the algorithm, we estimate return times of extremes orders of magnitude larger than feasible with direct sampling, and we compute statistically significant composite maps of dynamical quantities conditional on the occurrence of these extremes. We exploit the improved statistics of extreme sea ice lows to study their precursors, including a surface energy budget analysis to disentangle the oceanic and atmospheric forcing on the sea ice. Likewise, we investigate the linkage between extreme negative sea ice area anomalies and the dominant modes of atmospheric circulation variability, as well as between the extremes and preconditioning through the winter-spring sea ice state.

Oral Pitch: Future climate change impacts of an AMOC weakening on extreme precipitation in East of Northeast Brazil by inter-model differences

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Abstract

Climate model indicates the future weakening of the Atlantic Meridional Overturning Circulation (AMOC) and changes in precipitation. However, the impacts of the AMOC decline over extreme precipitation in Eastern Northeast Brazil (ENEB), one of the most vulnerable regions to the climate change, are not well known. This study investigates the long-term changes of the AMOC and its impacts on extreme precipitation and sea surface temperature in the tropical Atlantic under the CMIP6 SSP5-8.5 scenario. Most of our 29 models show AMOC decline, resulting in a change in meridional heat transport from the southern to the northern hemisphere, increasing sea surface temperature and heat content in the Tropical Atlantic (TA). It affects the AMOC's upper branch in the TA, which is an east-to-west path characterized by the southern branch of the South Equatorial Current transporting heat to the Southwestern Atlantic Warm Pool (SAWP). The SAWP is responsible for the supply of water vapor carried by the southeasterly trade winds into ENEB, a coastal and densely populated area, causing flash floods and landslides. We looked at changes in four extreme precipitation indices: the 99th and 95th percentiles of wet-day precipitation (R99p and R95p), as well as the annual maximum 1-day and 5-day precipitation amounts (Rx1day and Rx5day). These showed that heavy precipitation tends to increase over the ENEB as the AMOC decreased. Our findings have implications, for better understanding how the AMOC's future changes will impact the world's most vulnerable areas to climate change.

Oral Pitch: Hybrid statistical-dynamical seasonal prediction of summer extreme temperatures over Europe

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Abstract

Several studies show that the occurrence of summer extreme temperatures over Europe is increased since the middle of the twentieth century and is expected to further increase in the future due to global warming. Thus, predicting heat extremes several months ahead is crucial given their impacts on socio-economic and environmental systems.

In this context, state-of-the-art dynamical seasonal prediction systems (SPSs) show low skills in predicting European heat extremes on seasonal timescale. However, recent studies have shown that our skills in predicting extratropical climate can be largely improved by subsampling the dynamical SPS ensemble with statistical post-processing techniques.

This study assesses if the seasonal prediction skill of summer extreme temperatures in Europe in the state-of-the-art SPSs can be improved through subsampling. Specifically, we use a multi-model ensemble (MME) of SPSs contributing to the Copernicus Climate Change Service (C3S), analysing di hindcast period 1993—2016. The MME is subsampled by retaining a subset of members that predict the phase of the North Atlantic Oscillation (NAO) and the Eastern Atlantic (EA), typically linked to summer extreme temperatures in Europe. The subsampling relies on spring predictors of the weather regimes and thus allows us to retain only those ensemble members with a reasonable representation of summer heat extreme teleconnections.

Results show that by retaining only those ensemble members that accurately represent the NAO phase, it not only enhances the seasonal prediction skills for the summer European climate but also leads to improved predictions of summer extreme temperatures, especially in the northern and central Europe. Differently, selecting only those ensemble members that accurately represent the EA phase does not improve either the predictions of summer European climate or the predictions of summer extreme temperatures. This can be explained by the fact that the C3S SPSs exhibits deficiencies in accurately representing the summer low-frequency atmospheric variability.

Climate predictions for society: How to communicate accuracy of resolution?

Oral Pitch: Unlocking micro-climate services with a urban integrated modeling system

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Abstract

Micro-climates of complex mountainous coastal areas are extremely diverse. The warm non-freezing ocean penetrates deep inland where it meets cold continental air messes. Environmental conditions along the coast are distinctively different from those over mountain slopes and passes. Sharp temperature gradients support a unique system of atmospheric circulations as well as cause local weather extremes. Coarse resolution of numerical weather prediction models, not to say about climate models, do not allow capturing such coastal conditions. Turbulence-resolving large-eddy simulation models address this challenge, but they must be coupled with meso-scale meteorological models within an integrated modelling system (IMS). This study presents and generalizes our experience with integration of turbulence-resolving and meso-scale models. We investigate several practical meteorological applications of IMS such as urban air quality in Bergen and wind regimes in Tromsø. We look at the UIS sensitivity to coupling configurations and parameters, study numerical inaccuracies, and sensitivity to input data. We also discuss the practical experience with developing the IMS based on WRF-to-PALM and ENVIROHIRLAM-to-PALM as well as on using PALM in a stand-alone mode. We summarize the results in a set of practical recommendations and best practices. The main conclusion of this study is that the IMS centred on the turbulence-resolving PALM modelling system is a robust platform to buildup climate services in the complex coastal areas.

Oral Pitch: Accuracy versus Precision: Refining Weather Forecasts for Climate Adaptation

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Abstract

Accurate and precise weather forecasts are becoming increasingly vital for climate adaptation, such as in early warning systems and impact forecasts. Yet, their practical use is often limited by a mismatch in spatial scale, since these forecasts often provide coarser-scale predictions than what users require. To bridge this gap, we propose a novel application of the fractional skill score, a metric conventionally used to quantify spatial forecast accuracy by the meteorological community, to help users identify their preferred balance between forecast accuracy and precision. Our study examines this trade-off for daily European precipitation, focusing on deterministic predictions of anomalies and probabilistic predictions of extremes, derived from three years of sub-seasonal forecasts from the European Centre from Medium-Range Weather Forecasts (ECMWF). We find that forecast accuracy is limited to two weeks irrespective of spatial scale or time averaging. Within this time horizon, however, increasing spatial scale can extend predictable lead times by a few days, and enhance the maximum possible forecast accuracy achievable at the grid scale. Notably, weekly time averaging diminishes the benefits of increasing spatial scale, yielding similar accuracy across spatial scales. These results suggest a different approach for communicating weather forecasts and incorporating them into impact models: focusing on spatial scales where forecasts are most accurate, rather than the default precision grid scale, thus offering users more actionable information.

Oral Pitch: Predicting avalanche risk from meteorological data in Northern Norway

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Abstract

Snow avalanches are one of the most impactful natural hazards in mountainous areas. Thus, the assessment of avalanche risk is of great importance for the protection of life and property. A changing climate may lead to changes in avalanche risk. However, it is unclear how this change will manifest, and as climate change is regionally different, an assessment of potential avalanche risk changes should be conducted on a regional basis. Here the focus is on avalanche risk in the Arctic.

The Norwegian Water Resources and Energy Directorate (NVE) publishes a daily snow avalanche danger risk assessment on a five-point scale. Here we utilise these data as well as the 3 km Norwegian reanalysis (NORA3) to relate avalanche risk in the Troms and Finnmark county of Norway to the prevailing weather conditions, represented by temperature, wind speed, and precipitation from NORA3. We find that using ordinal regression the avalanche risk from the NORA3 data is predictable with some skill, although with little confidence due to the short time period of available risk assessment data.

Having established our statistical model for predicting avalanche risk from meteorological data, we plan to extend the analysis to climate change scenarios. For this purpose, we apply the statistical model to downscaled global climate model data from the RCP and SSP scenarios, to gauge potential changes in avalanche risk in the Troms and Finnmark county due to future climate change.

Future Developments: Model improvements

Oral Pitch: Adaptive covariance hybridization for coupled climate reanalysis

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Abstract

Because of their very heavy computational burden, climate prediction systems that use ensemble data assimilation methods can afford only a few tens of members. Sampling error in the covariance matrix can introduce biases in the unobserved regions (e.g. in the deep ocean). Here, we assess the potential of hybrid covariance approach (EnKF-OI, Hamill and Snyder 2000) to counteract sampling error. The EnKF-OI combines the dynamical covariance to that of a large static/historical covariance (EnOI). We use the Norwegian Climate Prediction Model (NorCPM), which combines the Norwegian Earth System Model (NorESM) and the Ensemble Kalman Filter (EnKF) in an idealized twin experiment. We test the performance of reanalyses that assimilate synthetic SST observations monthly for the period 1980-2010. We use a dynamical ensemble of 30 members and a static ensemble size of 315 members sampled from a long stable pre-industrial run. We compare the performance of the EnKF to 1) an EnKF-OI with a global hybrid coefficient tuned empirically and 2) an EnKF-OI adaptive, with hybrid coefficient explicitly estimated in space and time (Ménétrier and Auligné, 2015). In the adaptive EnKF-OI, the hybrid coefficient remains stable through the course of the reanalysis with only a weak seasonal variability. Both EnKF-OI versions show comparable performance and cure the emergence of a bias in the deep ocean in the EnKF. The assimilation updates with the EnKF-OI adaptative are smaller, suggesting that it sustains a lower error level in between the assimilation cycle.

Oral Pitch: Initializing hindcasts with ensemble optimal interpolation: challenges and opportunities

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Abstract

IPSL-EPOC decadal hindcast system has long relied on surface nudging initialization procedure using observed anomaly (to limit initial drift). This approach was initially selected because of its simplicity to implement, allowing the group to rapidly produce its first hindcasts. Original nudging strategy towards surface temperature and salinity anomalies has proven to be effective to initialize important features of the climate system, including AMOC, Sahel rainfall, and air-sea carbon fluxes. Yet, nudging does not take into account observation errors and uncertainty, nor horizontal and vertical correlations among various regions. Furthermore, surface information has been shown to hardly penetrate into the deep ocean. For all these reasons, we recently implemented a new approach based on ensemble optimal interpolation applied to both surface temperature and surface salinity, still using anomalies. In this approach, the surface information has an impact on depth based on covariances between surface and subsurface variables calculated in a control simulation. Moreover, with this methodology, observation uncertainties are explicitly take into account. We present here preliminary results of this procedure, including improvements and deterioration as compared to the simpler nudging approach. We also show that this approach implies challenges difficult choices for what concerns the reference period used to compute the anomalies. We conclude this presentation by presenting perspectives from our group on initialization procedure, notably discussing the potential improvements from ensemble Kalman filter.

Oral Pitch: Ensemble based parameter estimation for improving Ocean Biogeochemistry in an Earth System Model

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Abstract

Ocean biogeochemistry (BGC) is crucial for the global carbon cycle, but its representation in Earth System Models (ESMs) is imperfect due to numerous poorly constrained BGC parameters. We demonstrate the potential of parameter estimation/optimization (PE) with an ensemble data assimilation method to enhance BGC representation in an ESM. We optimize five key BGC parameters within the Norwegian Climate Prediction Model (NorCPM), which combines the Norwegian Earth System Model (NorESM) and ensemble data assimilation methods. The parameters are perturbed within reasonable range for each ensemble member, and we produce a 10 years coupled reanalysis with monthly assimilation of observed temperature and salinity climatology with the dual one step ahead smoother to sustain error in ocean physics to a low level. The optimal BGC parameter values are estimated with an iterative ensemble smoother technique from the monthly climatological performance of the BGC state (nitrate, phosphate, and oxygen) in the coupled reanalysis. We compare the performance of the following systems: (i) default parameters without ocean state constraint, (ii) default parameters with ocean state constraint, (iii) globally constant estimated parameters with ocean state constraint, and (iv) spatially varying parameters with ocean state constraint. The ocean state constraint in (ii) yields a strong reduction of the error in the intermediate to deep BGC state, but the error slowly deteriorates as the default parameters were tuned to compensate for the physical biases. Both global and spatial PE (iii and iv) reduce error, including quantities not used in the parameter estimation (dissolved inorganic carbon, alkalinity, CO_2 fluxes and primary production). While the spatial PE (iv) performs best in some regions, the global PE (iii) performs best overall. We also evaluate the benefit of refining the global PE with a second iteration, which further improves performance, specifically for the near-surface profiles of BGC variables, emphasizing the benefits of a multi-iteration PE approach. Second, we compare the performance of the system with the 2-iterations global parameter estimates for a reanalysis from 1993 to 2022. Error is reduced by about 10%, 20% and 25% for oxygen, phosphate and nitrate, respectively. The proposed approach is promising as a cost-effective new tool to calibrate ESM in the future.

Oral Pitch: Enhancing sea ice prediction in NorCPM using assimilation of sea ice thickness from ENVISAT and C2SMOS

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Abstract

We will present the new development of the Norwegian Climate Prediction Model (NorCPM) to improve prediction of Arctic sea ice extent. NorCPM is developed at the Bjerknes Centre for Climate Research in Norway and a combination of the Norwegian Earth System Model (NorESM) and the Ensemble Kalman Filter (EnKF) for the purposes of reanalysis and prediction. The system we use features strongly coupled assimilation of sea surface temperature, temperature and salinity profiles, sea ice concentration and sea ice thickness. The sea ice concentration assimilation scheme has been recently revised to reduce the impact of the degradation of ocean heat content, with the influence of SST near ice covered regions reduced. The assimilation of sea ice thickness is implemented using observations from ESA CCI (ENVISAT) and C2SMOS and we compare full field and anomaly assimilation for thickness. In the reanalysis we find that the assimilation can constrain the error in ice thickness substantially to under 1 m over the ESA CCI period and under 0.4 m over the C2SMOS period. We find that pan-Arctic prediction of sea ice extent is improved particularly well in summer and there is strong regional improvement within the Alaskan and Siberian sectors.

Oral Pitch: Intercomparison of initialization methods for Seasonal-to-Decadal Climate Predictions with the NorCPM

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Abstract

Initialization is essential for accurate seasonal-to-decadal (S2D) climate predictions. The initialization schemes used differ on the component initialized, the Data Assimilation (DA) method, or the technique.

We compare five popular schemes within NorCPM following the same experimental protocol: reanalysis from 1980--2010 and seasonal and decadal predictions initialized from the reanalysis.

We compare atmospheric initialization---Newtonian relaxation (nudging)---against ocean initialization---Ensemble Kalman Filter---(ODA). On the atmosphere, we explore the benefit of full-field (NudF-UVT) or anomaly (NudA-UVT) nudging of horizontal winds and temperature (U, V, and T) observations. The scheme NudA-UV nudges horizontal winds to disentangle the role of wind-driven variability. The ODA+NudA-UV scheme is a first attempt at joint initialization of ocean and atmospheric components in NorCPM.

During the reanalysis, atmospheric nudging improves the synchronization of the atmosphere and land components with the observed data. Conversely, ODA is more effective at synchronizing the ocean component with observations. The atmospheric nudging schemes are better at reproducing specific events, such as the rapid North Atlantic subpolar gyre (SPG) shift. An abrupt climatological change using the NudA-UV scheme demonstrates that energy conservation is crucial when only assimilating winds.

ODA outperforms atmospheric-initialized versions for S2D global predictions, while atmospheric nudging is preferable for accurately initializing phenomena in specific regions, with the technique's benefit depending on the prediction's temporal scale.

Combining atmosphere and ocean initialization yields sub-optimal results, as sustaining the ensemble's reliability---required for ODA's performance---is challenging with atmospheric nudging.

We explore the possibility of using a stochastic atmospheric reanalysis to address this issue.

Oral Pitch: Enhanced atmospheric variability from constraining the ocean in NorCPM1

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Abstract

Prediction of climate variations over Europe on multi-annual to decadal timescales is challenging. However, recent studies using dynamical prediction systems show promising results. This study uses the Norwegian Climate Prediction Model (NorCPM1) and its underlying model, the Norwegian Earth System Model (NorESM1). To investigate the impact of constrained ocean variability on the atmosphere, with a specific focus on Europe. To better understand the impact of constrained ocean variability, we apply constructed circulation analogues to analyse the dynamic (atmosphere-driven) and thermodynamic (ocean-driven) contributions to surface air temperature (SAT) variability. Comparing NorCPM1 (constrained ocean) and NorESM1 (non-constrained) results with CERA20C, we found a higher correlation between the thermodynamic component of NorCPM1 and CERA20C than for NorESM1. This result suggests a significant impact of the constrained ocean variability on NorCPM1's atmospheric behaviour. This study advances our understanding of the effects of constrained ocean variability in a prediction system and has the potential to improve multi-annual to decadal predictions over Europe.

Oral Pitch: Recent development of NorCPM software structure

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Abstract

To assimilate data in climate model, modifying model code is a usual method. However, the modifications maybe obsoleted when model version update. For CESM2 based climate model, there is a component called "External System Process" (ESP). Which is a mechanism design for DART data assimilation, but also can be used to develop our own data assimilation process. Another mechanism is 'multiple instances', which gives the ability to run ensemble members in a single run. We are improving NorCPM software structure with these two functions. Which will be able to assimilate weekly or daily SST data.

Oral Pitch: A perfect-model perspective on the signal to noise paradox in initialized climate predictions

Rashed Mahmood[1,2], Markus G. Donat[2,3], Francisco Doblas-Reyes[2,3], Yohan Ruprich-Robert[2]

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Abstract

Initialised decadal climate predictions are aimed at phasing in variability between numerical simulations and observations, and to correct forced model responses, by starting the simulations from observational climatic states. These predictions have shown some success in terms of predicting interannual to decadal climate variations in some regions, however, a widespread added value from these simulations remains limited due to different issues arising from imperfect initialisations and limitations with resolving physical processes. The higher correlation of initialised prediction ensemble mean with observations than with its own individual members result in a counterintuitive suggestion that the model can predict observations better than itself, also referred to as “the signal to noise paradox”

Here we present results of a ‘perfect model’ decadal prediction experiment, where the predictions have been initialised using climate states from the model's own transient simulation. This experiment avoids issues related to model inconsistencies, initial shock and the climate drift that affect real-world climate predictions. We find that the perfect model decadal predictions are highly skillful in simulating surface temperature and sea level pressure on decadal timescales. Also, the added value from initialisation extends to many global regions. Interestingly, we also find the signal-to-noise issues diagnosed from the ratio of predictable components, indicating that the perfect-model reference run is predicted with higher skill than each of the initialised prediction members. We find that this signal-to-noise problem is related to analysis practices that concatenate ensemble members from different initialisations, as this practice introduces inconsistencies compared to transient climate realisations. In particular, the collation of predictions initialised independently in a single time series breaks the auto-correlation structure and changes the variance of the time series.

Oral Pitch: High resolution global climate simulations with locally refined ocean mesh

Tido Semmler, Enda O'Dea

Met Eireann, Ireland

Abstract

Coarse-resolution state-of-the-art CMIP models correctly simulate the distribution of warming with strong warming over the Arctic region and weak warming over the tropical oceans as well as a slow-down of the Atlantic Meridional Overturning Circulation (AMOC) with increasing greenhouse gas concentrations. However, it was shown in the IPCC-AR6 report that models struggle to simulate the North Atlantic Warming Hole, a slight cooling observed over the North Atlantic subpolar gyre that has been associated with a slow-down of the AMOC. Here we introduce novel climate simulations with the Alfred Wegener Institute Climate Model (AWI-CM 3.0) with an atmospheric resolution of 32 km globally and a locally varying ocean resolution between 5 km in the Arctic and North Atlantic regions and 25 km over subtropical regions. With this setup we can simulate the North Atlantic Warming Hole. Alternative methods to refine both the horizontal and the vertical coordinates within the framework of the EC-Earth global climate model are under investigation.

To further refine these climate projections to be used by stakeholders and policymakers, we are developing a regional coupled ocean-atmosphere model with tides and river routing scheme that should be run in 1-2 km resolution around Ireland to resolve the shores of Ireland well. With this model, future frequency and intensity of compound events (heavy precipitation and storm leading to both high river levels and high coastal water levels) around Ireland under a changing climate can be investigated. Furthermore, this regional coupled ocean-atmosphere model is planned to be used for the day-to-day flood forecasting at Met Eireann.

Oral Pitch: Skilful prediction of the 2015 record summer "Cold Blob" in the subpolar North Atlantic with the MPI-ESM "eddy-resolving" climate prediction system

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Abstract

The subpolar North Atlantic is a hotspot with respect to predictability of longer-term sea surface temperature (SST) variability. In contrast, high-frequency, impact-relevant extreme events are still challenging topredict by state-of-art decadal prediction systems. One such event in the eastern subpolar North Atlantic is the record-cold anomaly in the summer of 2015, often referred to as "cold blob", for which predictive skill could not be demonstrated in the literature yet. We analyse ensemble prediction experiments with the Max Planck Institute for Meteorology ocean-eddy-resolving climate prediction system initialized in November 2013 and 2014 to demonstrate that individual ensemble members reforecast both strength and extent of the 2015 summer "cold blob". The predictive skill is largely driven by the ability of these ensemble members to reproduce a strongly positive phase of the atmospheric circulation and associated large surface heat loss in the two preceding winters, which are the main drivers of the observed "coldblob". In contrast to the real world, strong heat loss due to an oceanic heat transport divergence across the subpolar North Atlantic amplifies the simulated cold anomalies in the coldest ensemble members. Individual ensemble members also reforecast strength and extent of the 2015 European summer heat wave. While cold conditions in the subpolar North Atlantic seem necessary, key to reforecast the location of the heat wave is the ability to reproduce the rather warm surface conditions in the Mediterranean Sea.

Oral Pitch: Arctic Ocean Heat Transport in Met Office Models – is it all about resolution?

Luke Roberts[1,2], Len Shaffrey[2,3], Jon Robson[2,3], Ed Blockley[1], Alex Megann[4]

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Abstract

Arctic Ocean heat transport (OHT) is correlated with Arctic sea ice extent, however the ability for low-resolution climate models to simulate observed OHT, along with other key Arctic processes is poor. Since the release of HadGEM3-GC3.1 (low resolution) in 2017, low Arctic OHT has been compensated by the reduction of sea ice albedo during model tuning to simulate a representative sea ice loss. With decreasing Arctic sea ice and the possibility of new feedback loops such as a halocline instability, improving our understanding and ability to simulate Arctic OHT in global climate models in of increasing importance.

This research aims to trace biases through the main Arctic gateways in the Met Office's global coupled models with three ocean resolutions: eddy parametrising (1°), eddy-present (1/4°) and eddy-rich (1/12°). To evaluate biases, we will use data from the historical and control runs of HadGEM3-GC3.1 HighResMIP experiments along with new high resolution large ensembles from the NERC (National Environmental Research Council) funded CANARI project (Climate Change in the Arctic-North-Atlantic region and impact on the UK). Early results shows that there is a large dependence on horizontal model resolution for volume and heat transport through the Fram Strait and Barents Sea Opening, with warm biases most significant in the surface 100 meters. We aim to trace these biases to their origin to the south and see the impact they have on the structure of the Arctic halocline and deep waters considering the importance on resolution hierarchy.

This talk will summarize our findings in the context of the wider CANARI project and will aim to address the need to better resolve Arctic gateway transports to capture present and future halocline structure. These processes are likely to impact our ability to predict future climate scenarios that will ultimately impact future policy.

Oral Pitch: ICON-Seamless: Towards an integrated model configuration for numerical weather prediction, climate predictions and projections

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Abstract

A wide range of important societal and economic applications on a national and international level strive to an integrated understanding and forecasting of weather and climate on all temporal and spatial scales. The global model ICON (Icosahedral Nonhydrostatic) has been applied to weather as well as to climate timescales with joint developments of the model infrastructure. However, ICON's model configurations differ substantially depending on whether they were designed for numerical weather prediction (NWP) or climate applications. ICON-Seamless is a modelling initiative that integrates the model configurations of NWP, climate predictions, climate projections and atmospheric composition modelling based on the ICON framework and targets a unified treatment of the respective subgrid scale parametrizations. ICON-Seamless aims at the development of well-resolved coupled configurations with suitable resolution to conduct operational weather and ocean forecasts for several days, climate predictions with timescales up to 10 years ahead as well as climate projections, but also provides the model baseline for joint research for NWP and climate. Here, we illustrate the strategic direction of the modelling initiative, show first results of the coupled climate configuration and set prospects for the next generation of climate predictions.

Oral Pitch: Assessing observational constraints on future European climate in an out-of-sample framework

Christopher O'Reilly

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Abstract

Observations are increasingly used to constrain multi-model projections for future climate assessments. This study assesses the performance of five constraining methods, which have previously been applied to attempt to improve regional climate projections from CMIP5-era models. We employ an out-of-sample testing approach to assess the efficacy of these constraining methods when applied to "pseudo-observational'' datasets to constrain future changes in European climate. These pseudo-observations are taken from CMIP6 simulations, for which future changes were withheld and used for verification. The constrained projections are substantially more accurate and broadly more reliable for regional temperature projections, especially in the summer season, which was not clear prior to this study. However, the constraining methods do not improve regional precipitation projections. We also analysed the performance of multi-method projections, by combining the methods. The multi-method projections are generally at least as accurate, and in many cases more accurate, than the best performing individual methods. The performance of the multi-method projection indicates that it captures more information than any current individual methodology, highlighting the potential of combined approaches for the development of constraining methods.

Future Developments: Machine learning

Oral Pitch: Hybrid covariance super-resolution data assimilation

Sébastien Barthélémy[1], Julien Brajard[2], Laurent Bertino[2], François Counillon[2]

[1]University of Bergen, Norway. [2]NERSC, Norway

Abstract

This work extends the concept of "Super-resolution data assimilation" (SRDA, Barthélémy et al. 2022)) to the case of mixed-resolution ensembles pursuing two goals: (1) emulate the Ensemble Kalman Filter while (2) benefit from high-resolution observations. The forecast step is performed by two ensembles at two different resolutions, high and low-resolution. Before the assimilation step the low-resolution ensemble is downscaled to the high-resolution space, then both ensembles are updated with high-resolution observations. After the assimilation step, the low-resolution ensemble is upscaled back to its low-resolution grid for the next forecast. The downscaling step before the data assimilation step is performed either with a neural network, or with a simple cubic spline interpolation operator. The background error covariance matrix used for the update of both ensembles is a hybrid matrix between the high and low resolution background error covariance matrices. This flavor of the SRDA is called "Hybrid covariance super-resolution data assimilation" (Hybrid SRDA). We test the method with a quasi-geostrophic model in the context of twin-experiments with the low-resolution model being twice and four times coarser than the high-resolution one. The Hybrid SRDA with neural network performs equally or better than its counterpart with cubic spline interpolation, and drastically reduces the errors of the low-resolution ensemble. At equivalent computational cost, the Hybrid SRDA outperforms both the SRDA (8.4%) and the standard EnKF (14%). Conversely, for a given value of the error, the Hybrid SRDA requires as little as 50% of the computational resources of the EnKF. Finally, the Hybrid SRDA can be formulated as a low-resolution scheme, in the sense that the assimilation is performed in the low-resolution space, encouraging the application of the scheme with realistic ocean models.

Oral Pitch: Deep Learning methods for increased wintertime Sea Level Pressure predictability

Víctor Galván Fraile[1,2], Marta Martín del Rey[1], Irene Polo Sánchez[1], María Belén Rodríguez de Fonseca[1,2], Magdalena Alonso Balmaseda[3]

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Abstract

Winter seasonal atmospheric variability over the Euro-Atlantic region (EAR) significantly influences key variables like air temperature and precipitation, crucial for water management, including drought and flood mitigation. An important source for its predictability at seasonal time scales come from the ocean. In particular, the current seasonal prediction systems rely on the interannual phenomenon, El Niño-Southern Oscillation (ENSO), that occurs in the Pacific Ocean, exhibiting maximum sea surface temperature (SST) anomalies during boreal winter. Notably, ENSO exhibits a robust and more stationary teleconnection in January-February with EAR atmospheric variability. Accurate assessment of these teleconnections is vital. The seasonal predictions are made by means of dynamic or statistical models, although mostly linear for the latter. It is in this field where the application of deep learning approaches that model non-linear relationships between the seasonal anomalies of different physical variables are of interest. Therefore, this study analyses the predictive ability of wintertime (November-December) SST anomalies to forecast wintertime (November-December and January-February) sea level pressure (SLP) anomalies in the EAR. Various deep neural network models were developed to address teleconnections associated with SST anomalies in different ocean basins and the EAR, with a special focus on the Pacific due to current knowledge about ENSO-EAR teleconnections. Skill assessment was conducted over the study region (EAR), highlighting those areas with more accurate predictions, and sources of skill over the Pacific basin were identified.

Oral Pitch: Predicting Atlantic and Benguela Niño events with deep learning

Marie-lou Bachelery[1], Julien Brajard[2], Massimiliano Patacchiola[3], Noel Keenlyside[4]

[1]Cmcc, Italy. [2]Nansen Environmental and Remote Sensing Center, Norway. [3]University of Cambridge, United Kingdom. [4]Geophysical Institute, University of Bergen and Bjerknes Centre for Climate Research, Norway

Abstract

Extreme Atlantic and Benguela Niño events significantly impact the tropical Atlantic region and have far-reaching effects on African climate and ecosystems. Predicting these events is crucial for effective local ecosystem management and sustainable marine resource utilization. Despite increasing demand for forecasting capabilities, current approaches have shown limited skill in predicting these events. To address this, we present a novel deep learning-based statistical prediction model for Atlantic (Benguela) events with lead times of up to four (three) months. Our convolutional neural network (CNN) model is trained on 90 years of reanalysis data spanning 1900 to 1991, consisting of surface and 100m-averaged temperature. Remarkably, the CNN model outperforms state-of-the-art dynamical forecasting systems during the 1995 to 2016 validation period, demonstrating higher correlation skill for Atlantic and Benguela indices. The CNN model excels in predicting peak-season Atlantic and Benguela events, providing accurate forecasts up to 5 months in advance. Our heat map analysis reveals that the CNN model leverages known physical precursors, particularly their connection to equatorial dynamics, to accurately predict Benguela Niño events. This study showcases the potential of deep learning for predicting Atlantic and Benguela Niño events, shedding light on the contributing forcings that enhance predictability.

Oral Pitch: Improving dynamical seasonal sea ice prediction in the Arctic with machine learning

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Abstract

Dynamical sea ice predictions have significant biases or systematic errors that are difficult to effectively remove. In this work, we introduce machine learning into the Norwegian Climate Prediction Model (NorCPM, a state-of-the-art dynamical prediction system) to improve Arctic sea ice predictions.

We build a statistics bias-correction methodology employing machine learning techniques. An artificial neural network is trained with NorCPM data. It is then used to predict sea ice concentration biases or systematic errors and correct them either in post-processing of the predictions (offline manner) or during the production of the prediction (online manner). We evaluate the outcomes by assessing sea ice extent (SIE) and comparing them against observational data. Our findings reveal that offline correction markedly reduces the prediction biases in summer (more than 30%), while online correction enhances the variability in sea ice predictions up to four months. These results underscore the potential of machine learning as a potent tool for refining the accuracy of Arctic sea ice seasonal predictions.

Oral Pitch: Supermodelling Towards Improved Climate Prediction

Noel Keenlyside[1], Francine Schevenhoven[1], Ping-Gin Chiu[1], Tarkeshwah Singh[2], Francois Counillon[2], Gregory Duane[3]

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Abstract

Climate models are plagued by long-standing biases that degrade predictions. While increasing resolution of global climate models to km scales promises to reduce biases, there is little evidence so far of improvements with currently available computing power. Supermodelling is an alternative approach that has demonstrated reductions in long-standing biases, such as the double ITCZ and tropical SST biases, at a fraction of the computational cost of km scale models. A supermodel is a combination of models that interact during their simulations to mitigate errors before they develop into large-scale biases. Here I will present recent results from a supermodel based on three Earth System Models (NorESM, CESM, MPIESM). The models were combined using ocean data assimilation and trained on observed SST data. The simulation of tropical climate is markedly improved compared to that of the respective standalone models. Seasonal predictions performed with this model are underway and first results will be shown. In addition, I will summarize work on combining atmospheric models that promises to lead to even greater improvements in simulating global climate.

Oral Pitch: A data-driven approach for seasonal prediction of precipitation in Norway

Roberto Suarez-Moreno, Lea Svendsen

University of Bergen and Bjerknes Centre for Climate Research, Norway

Abstract

Accurate seasonal forecasts of precipitation are of pivotal importance for multi-sector informed decision making. In this context, numerous research institutions have done, and continue to do, exhaustive work to develop their own forecast system based on coupled atmosphere-ocean general circulation models (GCMs) to achieve skilful seasonal predictions of climate in general, and precipitation in particular. Nevertheless, despite remarkable performance of these models, seasonal predictability in specific regions for certain seasons is stuck. In particular for the North Atlantic region, the models show persistent biases in the spatial variability of winter atmospheric circulation that prevent seasonal forecast systems from achieving accurate predictions.

With the aim of enhancing predictability, the application of data-driven machine learning-based techniques is an emerging, but already proven field that is showing good performance. In this framework, we use a regression-based multivariate discriminant analysis method to explore the predictability of winter seasonal precipitation in Norway. Accordingly, we generate seasonal hindcasts of average winter precipitation anomalies that are compared with the numerical model-based multi-system ensemble mean from the Copernicus Climate Change Service (C3S) and the Norwegian Climate Prediction Model (NorCPM) for the 1993-2016 standard C3S hindcast period and validated against observations. The results show similar skill-scores that demonstrate the promising applicability of data-driven approaches with high prediction accuracy and reduced computational resources versus prohibitive computational costs of GCMs. Furthermore, regression-based machine learning methodologies allow the physical interpretation of the processes underlying predictability, as in the case of this study, compared to more complex methodologies that operate as a black box.

Oral Pitch: Evaluating AI's role in addressing biases in IPSL climate predictions

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Abstract

While decadal climate predictions have shown potential additional skill as compared to historical simulations, this improvement is now quite strongly hampered by limitations in the climate model predictable signal as compared to its unpredictable noise. To try to circumvent this issue and improve the skill of decadal predictions, the idea of mixing the climate model information with statistical approaches and observations is a promising avenue to investigate.

This research focuses on leveraging artificial intelligence (AI) techniques to improve the skill of the IPSL-EPOC decadal prediction system. In a first step, we assess the skill of this CMIP6 system as compared to former versions and other systems, and we estimate the improvement in skill from initialization. We then focus on the European region, where climate services related to decadal prediction are now developing, in line with this type of activity now emerging at University of Bordeaux (e.g. for viticulture, water management…). The use of AI approach is then considered to improve the skill of the hindcasts, as well as for debiasing some climate variables in view of their use for climate services. We depict the main advances and limitations associated with this AI approach in the last part of the talk and draw a few perspectives for future work.

Oral Pitch: Decadal inflow projections for catchments in Brazil

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Abstract

Our project partner Statkraft owns and operates several hydropower plants in Brazil and requires information about the future potential for hydropower production in this region. To provide inflow projections for the next several decades, we use climate model output in combination with a regression model that links meteorological variables such as precipitation and temperature to inflow over various catchments in the region. The relatively short time period for which observation data are available raises concerns about overfitting. We therefore explore an alternative model fitting approach that retains the original, easily interpretable regression model but estimates the regression coefficients within an artificial neural network (ANN) framework which permits spatial and temporal regularization and thus prevents overfitting. We show some examples of the inflow projections obtained with that methodology and discuss some caveats and limitations.

Oral Pitch: Understanding the predictability of the winter North Atlantic Oscillation using dynamical seasonal forecast models and machine learning techniques

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Abstract

Current generation dynamical seasonal forecast models have been shown to be capable of forecasting the winter North Atlantic Oscillation (NAO) with significant skill. However, there is some uncertainty in the skill of these forecasts. This is seen both by intermittency of skill in individual years within hindcast periods, and also in the decadal variability of skill over long hindcasts.

The Nonlinear AutoRegressive Moving Average with eXogenous inputs (NARMAX) systems identification approach is an interpretable machine learning method which can be used to identify and model linear and non-linear dynamic relationships between meteorological and related variables, including identifying non-stationary associations that can occur over time. NARMAX has been shown to produce skilful forecasts of the NAO when trained on historical observation data. A key element of NARMAX is that information about the predictors used in its predictions and their relative importance is retained and can therefore be used as a tool to understand more about the key processes driving NAO variability.

Here we use NARMAX in conjunction with dynamical seasonal forecast models to understand more about the predictability of the NAO and the temporal intermittency of this predictability. We analyse the key predictors identified by NARMAX in periods where the NAO is well forecast and poorly forecast by the dynamical seasonal forecast models. In addition, we apply NARMAX to the dynamical model NAO hindcasts. We compare the predictors identified by NARMAX in this case with those identified when NARMAX is applied to observations. These results will help to understand how NAO predictability differs between the “real world” and the “model world” and identify potential deficiencies in the dynamical seasonal forecast models.

Oral Pitch: Separation of internal and forced variability using a U-Net

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Abstract

A method is designed to separate the internal variability from the forced variability in the surface temperature between 1901 and 2020. The Noise to Noise approach is applied to train a neural network using an analogy between the internal variability and the noise of an image. A large training dataset is built with the evolution of two-dimensional air surface temperature field from 1901 to 2020 in an ensemble of Atmosphere-Ocean General Circulation Model (AOGCM) simulations. The neural network trained is a U-net, a widely used convolutional network originally designed for image segmentation. The performance is evaluated using the outputs from two single model initial-condition large ensemble (SMILE) and comparing the ensemble mean and the output of the U-net. The U-Net reduces the internal variability by a factor of five with important discrepancy at the regional scale. The U-Net is highly effective at filtering out certain modes of internal variability, such as ENSO, but has more difficulty in regions where forced variability is less well sampled in climate models, such as grid points north of 60°. This method can be extended to other variables to gain understanding in the long-term changes induced by the external forcings.