Holger Pohlmann, Wolfgang Müller, Panos Athanasiadis

Workshop for National Meteorological Services, 23rd October 2024

ASPECT

FACILITATING SEAMLESS CLIMATE ADAPTATION

Opportunities and Challenges of Seasonal-to-Decadal Climate Predictions of European Mean Climate and Extremes

Funded by the European Union

Motivation

ASPECT (Adaptation-oriented Seamless Predictions of European Climate)

WP2: Improve knowledge of climate prediction for preparedness and adaptation

- increase the level of confidence in climate predictions by improving understanding of mechanisms and by accounting for model deficiencies
- provide an assessment of the predictive skill in operational climate prediction systems for impactful variables, indices and extremes in Europe and beyond

Outline

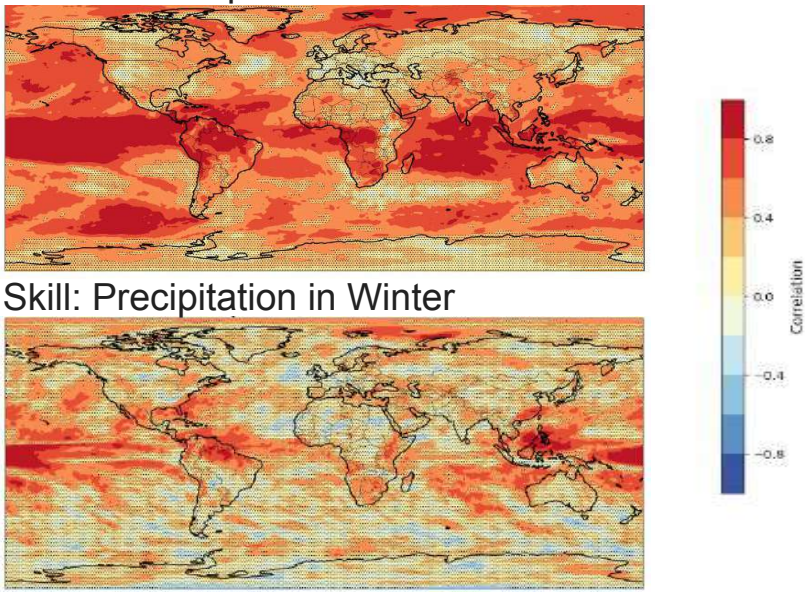
- Current Skill Assessment
- Skill of Mean Climate
- Skill of Extremes
- Challenges

Current Skill Assessment

Seasonal Prediction Skill

- more skillful for 2m temperature than for precipitation
- strongest in the tropical ocean regions, especially over the ENSO-impacted regions
- mainly arising from the oceans

Skill: 2m Temperature in Winter



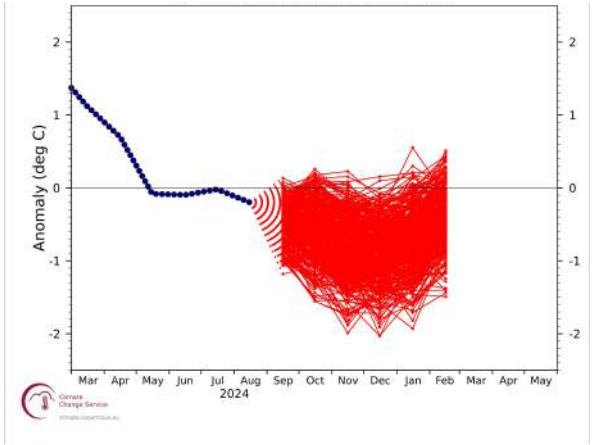
Skill: Precipitation in Winter

Correlation skill of winter near-surface temperature and precipitation forecasts (DJF, foreacsts started in Nov) from C3S multi-model ensemble of seasonal forecasts for 1993-2016.

Current Skill Assessment

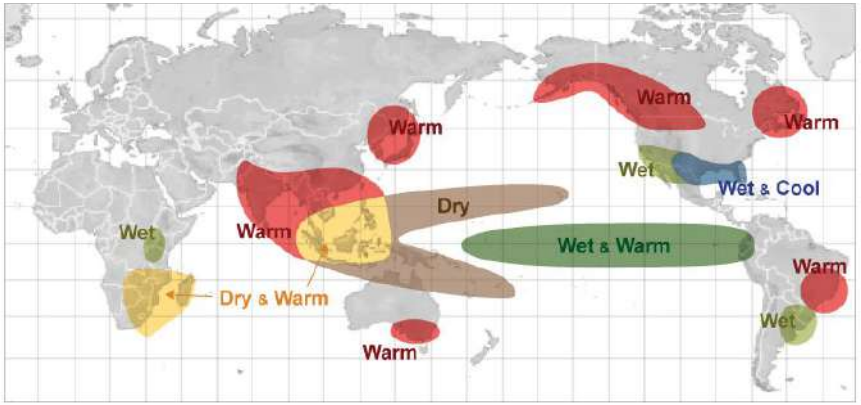
Seasonal Predictions

ENSO Prediction



Seasonal prediction of sea surface temperature (SST) anomalies in the NINO3 region (150°W - 90°W, 5°S - 5°N) from the C3S multi-model system started on 1st of September 2024. (Copernicus Climate Change Service (C3S)-Climate Data Store seasonal)

ENSO teleconnection (winter)

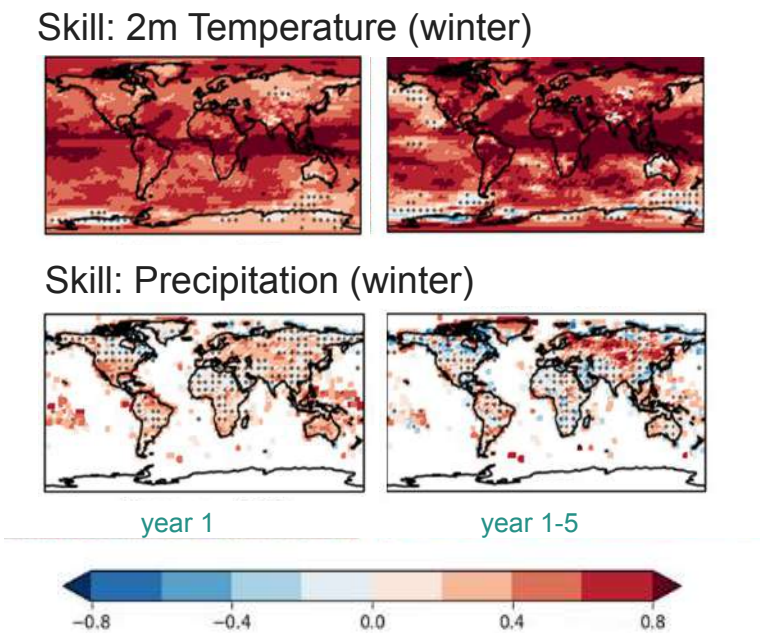


Teleconnections of ENSO in winter with warm (red) and cold (blue) temperatures, together with dry (yellow) and wet (green) climate conditions. (www.noaa.gov)

Current Skill Assessment

Decadal prediction skill

- strongest in the tropical ocean regions
- more skillful for 2m temperature than for precipitation
- precipitation shows, in general, reduced and more localized skill
- for longer forecast periods, the trend imposed by external boundary conditions gives rise to prediction skill

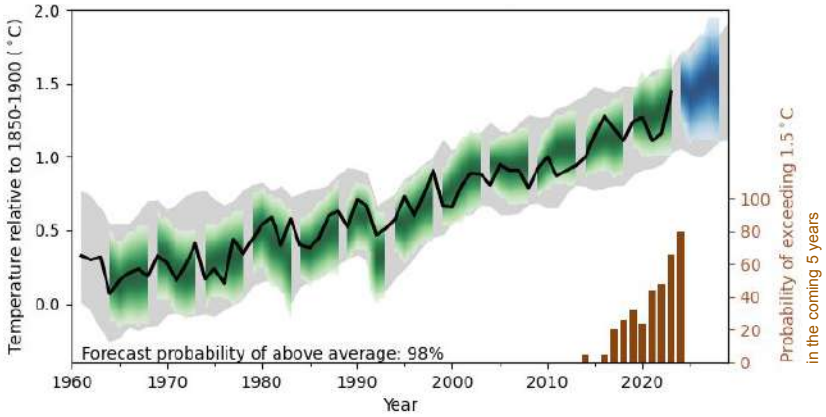


Anomaly correlation of surface temperature and precipitation of multi-model mean of winter months (November–March) for the first year (left) and years 1–5 (right). (Hermanson et al., 2022, doi:10.1175/BAMS-D-20-0311.1)

Current Skill Assessment

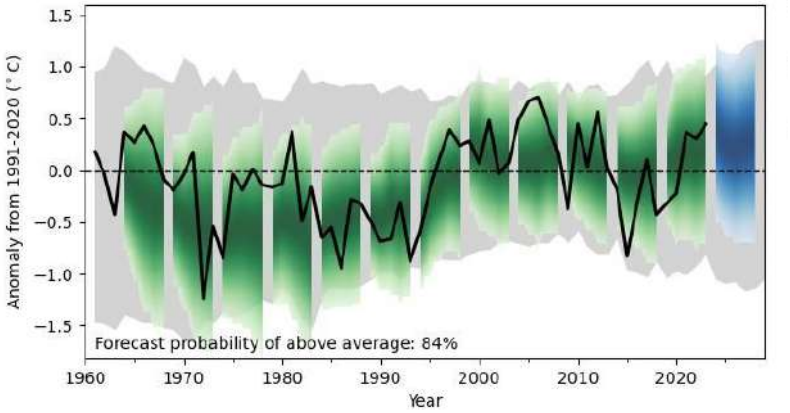
Decadal Predictions

Global 2m Temperature



Global temperature anomalies relative to climatology (observations in black, forecast in blue, hindcasts in green). In brown: probability of global temperature exceeding 1.5°C above 1850-1900 levels for at least one of the five following years, starting from the year indicated. (WMO Global Annual to Decadal Climate Update for 2024–2028)

Atlantic Multidecadal Variability



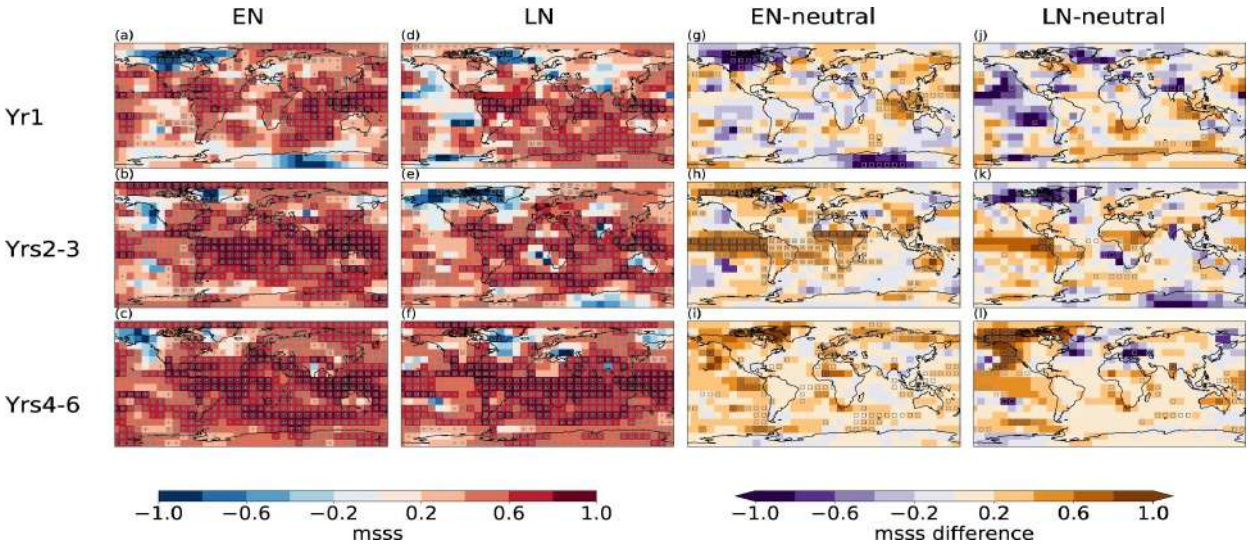
Atlantic Multidecadal Variability ((45-60ºN,0-60ºW) minus (0-45ºS,10ºE-30ºW)) (right) anomalies relative to climatology. Observations in black, forecast in blue, hindcasts in green. (WMO Global Annual to Decadal Climate Update for 2024–2028)

- Current Skill Assessment
- Skill of Mean Climate
- Skill of Extremes
- Challenges

Skill of Mean Climate

ENSO

- enhanced skill when predictions are initialized under El Niño or La Niña conditions compared to predictions initialized under neutral ENSO conditions

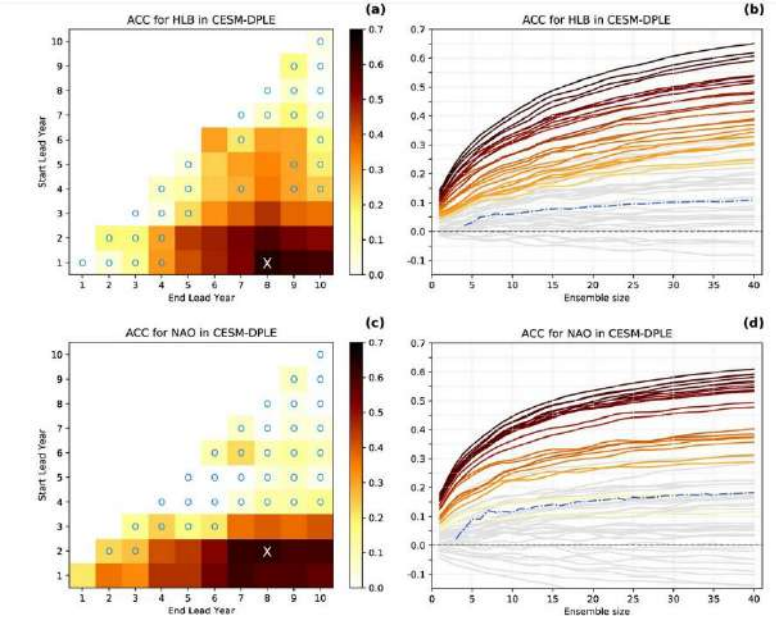


Skill for prediction initialized in El Niño (EN) and La Niña (LN) years for different prediction horizons (year 1, years 2-3 and years 4-6) and their differences to neutral years. (Liu et al., 2023, doi:10.1038/s41467-023-42113-9)

Skill of Mean Climate

Blocking and NAO in Winter

- decadal prediction experiments with CESM exhibit remarkable skill in high-latitude blocking (HLB) frequency over the North Atlantic and the North Atlantic Oscillation (NAO)
- skill due to the large ensemble and in response to Atlantic Multidecadal Variability (AMV)
- this may be used in statistical climate predictions

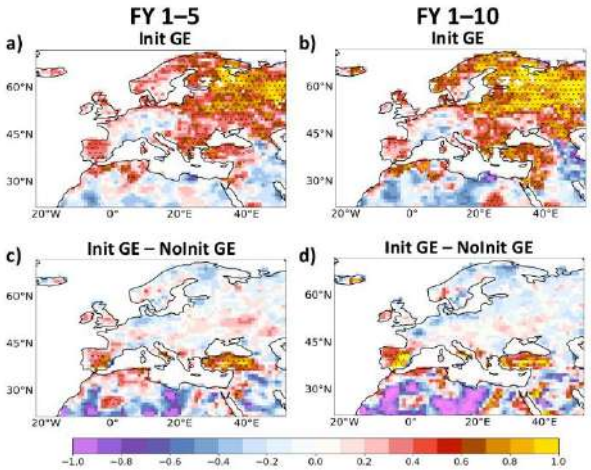


Skill for the CESM-DPLE ensemble-mean for high-latitude blocking (HLB) and the North Atlantic Oscillation (NAO). Each cell below the diagonal corresponds to a different lead-year range defined by the start lead-year (ordinate) and the end lead-year (abscissa). The cyan markers (o) indicate not statistically significant correlations. In b and d, the respective skill is computed as a function of the ensemble size (averaged for all possible member combinations). Each line corresponds to a different lead-year range. (Athanasiadis, et al., 2020, doi:10.1038/s41612-020-0120-6)

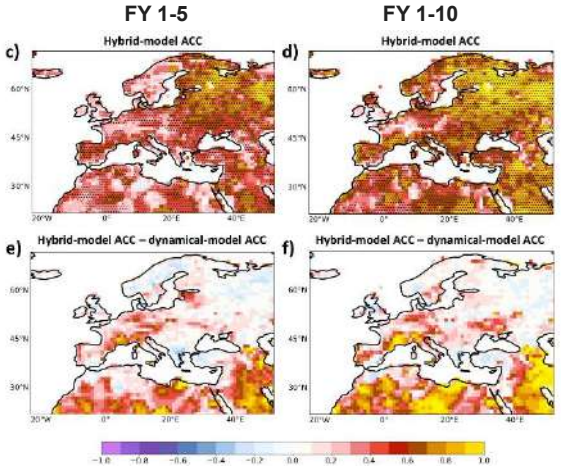
Skill of Mean Climate

Precipitation in Winter

- initialized predictions outperform un-initialized predictions
- skill is improved with a hybrid dynamical-statistical model



Skill maps for precipitation in winter (DJFM) predicted with the multi-model grand ensemble and their differences to the uninitialized ensemble. (Nicolì et al., 2024, in review)



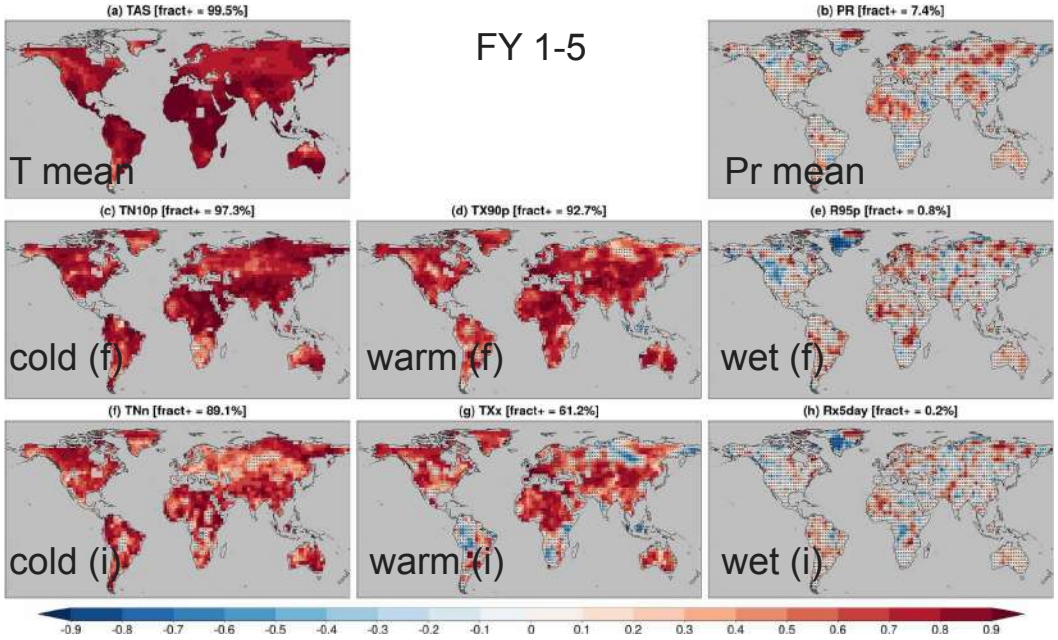
Skill maps for precipitation in winter (DJFM) predicted with a hybrid model using regression onto the NAO-index and North Atlantic SST index. The lower figures show their differences to the dynamical model. (Nicolì et al., 2024, in review)

- Current Skill Assessment
- Skill of Mean Climate
- Skill of Extremes
- Challenges

Skill of Extremes

Temperature and Precipitation

- high skill for temperature
- lower and more localized skill for precipitation
- higher skill for mean variables than for extreme indices
- higher skill for indices of extremes related to the frequency (f) than for those related to the intensity (i)

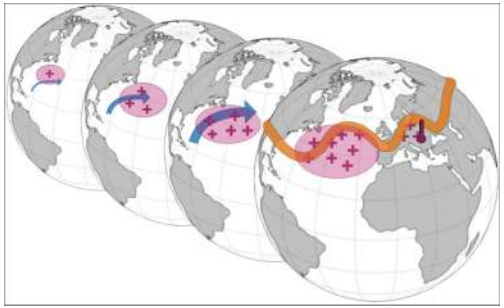


Skill maps obtained from a multi-model ensemble for the forecast years 1-5 (annual means) for the mean variables (upper), frequency (middle) and intensity (bottom) indices. The percentage of the global area with statistically significant positive or negative values is shown in the titles. (Delgado-Torres, et al., 2023, doi:10.1088/1748-9326/acbbe1)

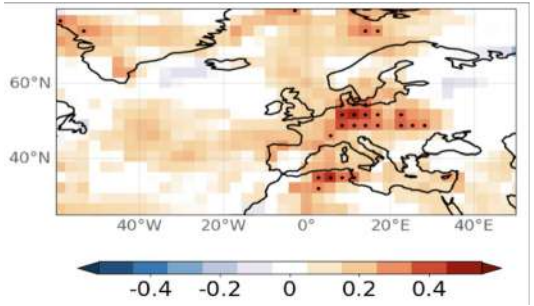
Skill of Extremes

Summer Heat Waves

- physical link from the heat accumulation in the North Atlantic to European heat waves in summer
- the heat accumulation leads the heat waves in Europe by several years
- sub-selection of ensemble members with realistic heat accumulation as a precursor can enhance prediction skill



Schematic illustrating the heat accumulation in the North Atlantic and its teleconnection with heat waves in Europe (Wallberg et al. 2024, doi.org/10.5194/esd-15-1-2024)

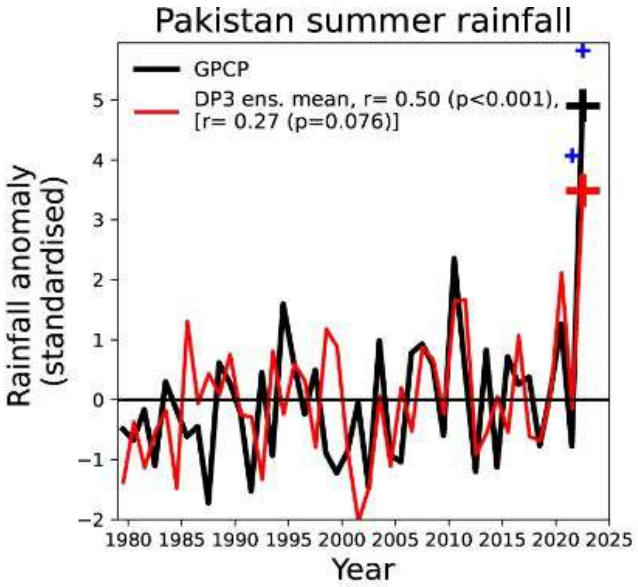


Difference of prediction skill of 3-year mean near surface temperature between the selected and the full ensemble mean, using ocean heat accumulation as a precursor. (Wallberg et al. 2024, in review)

Skill of Extremes

Pakistan Flood

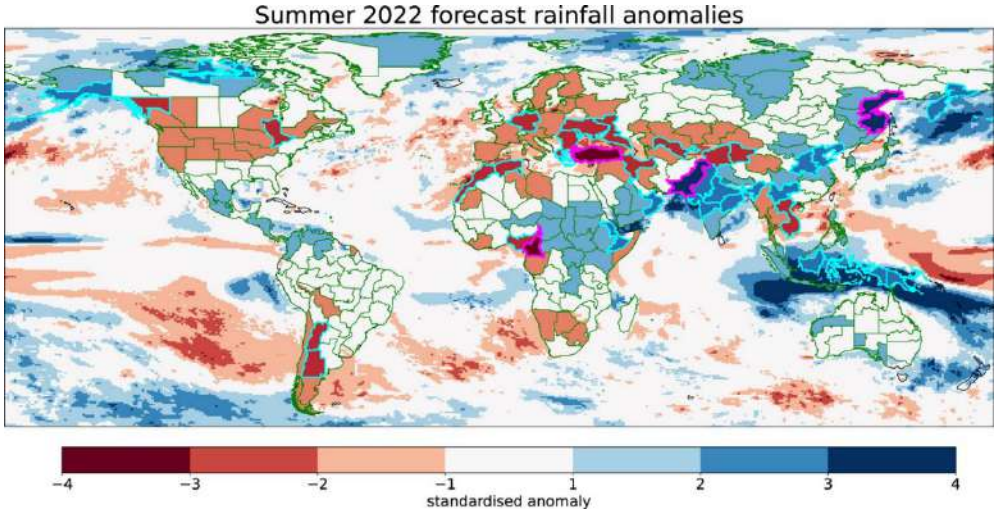
- the Pakistan flood of summer 2022 was well forecasted
- however, average skill before the event was low (r=0.27) and confidence was not high enough for action to be taken
- but further confidence could have been gained by examining the physical processes (unusual summer La Niña)



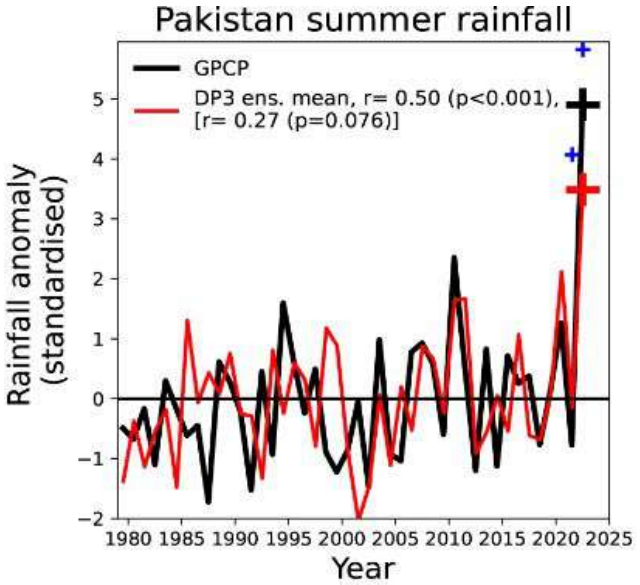
Timeseries of observed and predicted standardized Pakistan summer rainfall anomalies with correlation coefficients shown both including and excluding summer 2022. Large crosses show 2022 values, and the small blue crosses in 2021 and 2022 show estimates of the impact due to La Niña from perturbation experiments (Dunstone et al., 2023, doi:10.1038/s41467-023-42377-1)

Skill of Extremes

Extreme Season Alert Tool (under development)



DP3 ensemble mean standardised predicted rainfall anomalies for summer 2022 from 1st May initialised predictions are shown. Global land is split into 237 regions28 of approximately equal area (0.5 Mm2) with regional averages shown and green lines dividing regions. The 31 regions with a >±2σ anomaly are highlighted by a thicker cyan border and the four regions with a >±3σ are highlighted with a magenta border. (Dunstone et al., 2023, doi:10.1038/s41467-023-42377-1)



Timeseries of observed and predicted standardized Pakistan summer rainfall anomalies with correlation coefficients shown both including and excluding summer 2022. Large crosses show 2022 values, and the small blue crosses in 2021 and 2022 show estimates of the impact due to La Niña from perturbation experiments (Dunstone et al., 2023, doi:10.1038/s41467-023-42377-1)

- Current Skill Assessment
- Skill of Mean Climate
- Skill of Extremes
- Challenges

Challenges

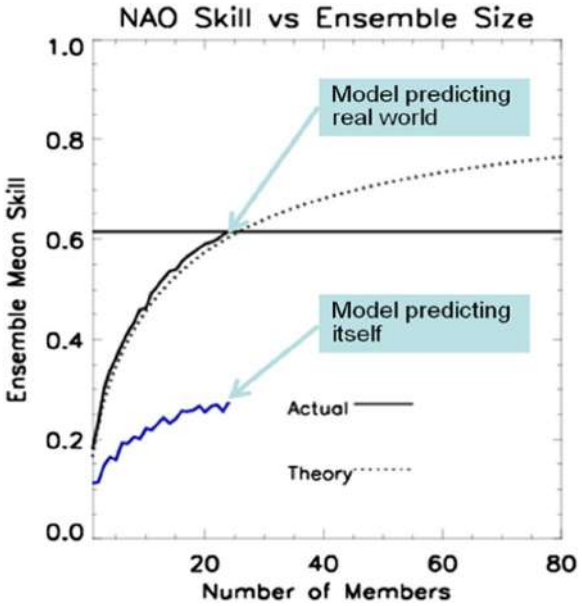
- downscaling of climate predictions to the user needs
- operational seasonal and decadal predictions **of extreme events**, e.g. like the flood in Central Europe in September 2024

https://pixabay.com

Challenges

Signal-to-Noise Paradox

- predictability of the North Atlantic Oscillation is more predictable in the real world (black) than in the model (blue)
- in principle the curves should be the same, but in practice the model is better able to predict the real world than itself



The black line shows the average correlation score when different size ensemble averages are correlated with the observed NAO. The blue line shows the same quantity when ensemble means are correlated with a single forecast member. The black dotted line is a theoretical fit to the solid black line. Data are from the GloSea5 forecast system (Scaife & Smith, 2018, doi:10.1038/s41612-018-0038-4)

Summary

- Skill scores provide an integrated forecast assessment, but the origin of skill is sometimes difficult to interpret. To understand the predictability, the underlying mechanism is key for correcting forecast errors and reduction of uncertainties in regional climate information.

- The likelihood of occurrence of weather and climate extremes has increased in the past decades. In addition, unprecedented and record-shattering extreme events will become more likely in the next decades, and pose a threat for various regions and sectors. The prediction of extreme events and their likelihood of occurrence for the next decade is therefore of fundamental importance for population protection and damage limitation.

- Some challenges remain, such as the underestimation of the predictable climate variations compared to the total variability in current forecast systems.

- I have presented here only **a few highlights**, ASPECT has already produced many more results! Please visit **www.aspect-project.eu** for a complete list of publications.

ASPECT

FACILITATING SEAMLESS CLIMATE ADAPTATION

CONTACT

Holger Pohlmann
holger.pohlmann@mpimet.mpg.de

CONNECT

hello.aspect@bsc.es

@ASPECT_project

/company/aspect-project

Funded by the European Union

This project has received funding from the European Union's Horizon Europe research and innovation programme under Grant Agreement No 101081460. The sole responsibility for the content of this document lies with the ASPECT project and does not necessarily reflect the opinion of the European Union.