Seasonal Forecasting in a changing climate: where are we heading?

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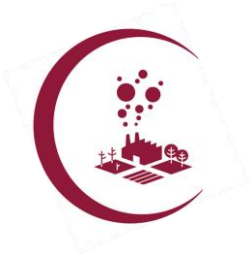
Tim Stockdale, Michael Mayer, Steffen Tietsche, Antje Weisheimer, Retish Senan, Stephanie Johnson, Christopher Roberts, Frederic Vitart, Souhail Boussetta, Gianpaolo Balsamo, Daniel Befort , Jonathan Day, Matthias Aengenheyster, Charles Pelletier, Sarah Keeley



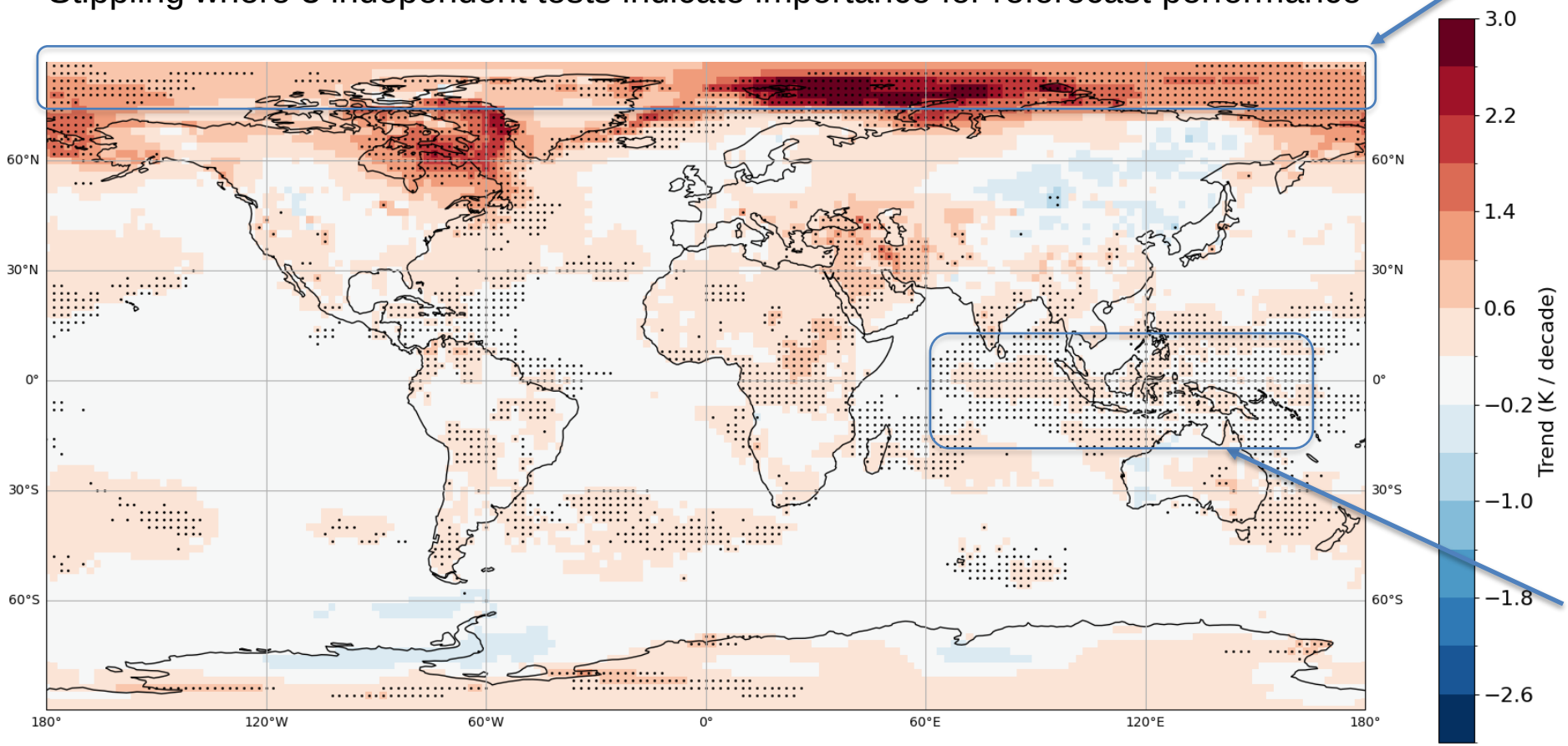
With the support of the EU Horizon CONFESS project

ECMWF

Climate change is affecting our climate now

35-year trends of DJF 2m temperature in ERA5 (1987 - 2001)

Stippling where 3 independent tests indicate importance for reforecast performance



robust and important trends:

1. tropics

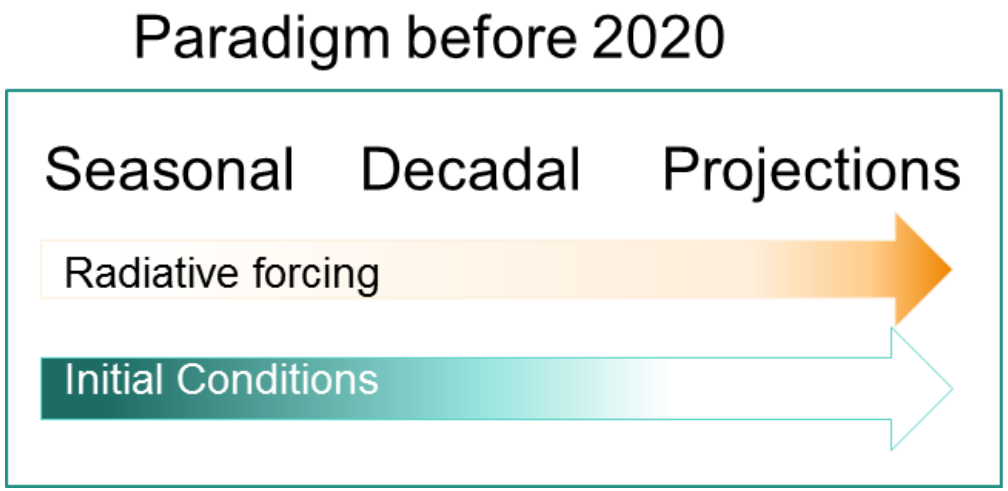
2. NH high latitudes

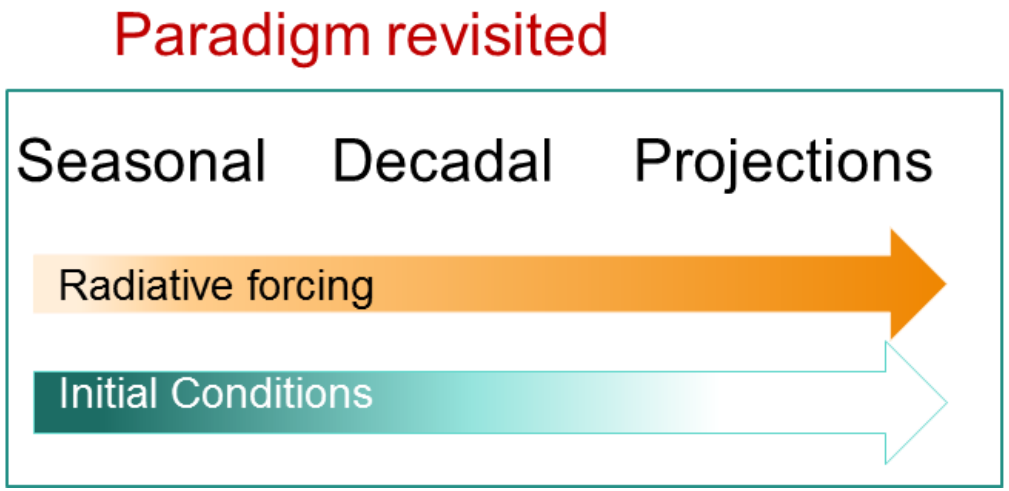
Cp. Simmons, A. J.: Trends in the tropospheric general circulation from 1979 to 2022, Weather Clim. Dynam., 3, 777–809

Courtesy of Steffen Tietsche

The need for seasonal forecasts is more pressing than ever

- The climate is changing. Increased demand of information for adaptation (e.g. water management, agriculture)
- A changing climate does not only make climatology less informative, but can be an additional source of predictability



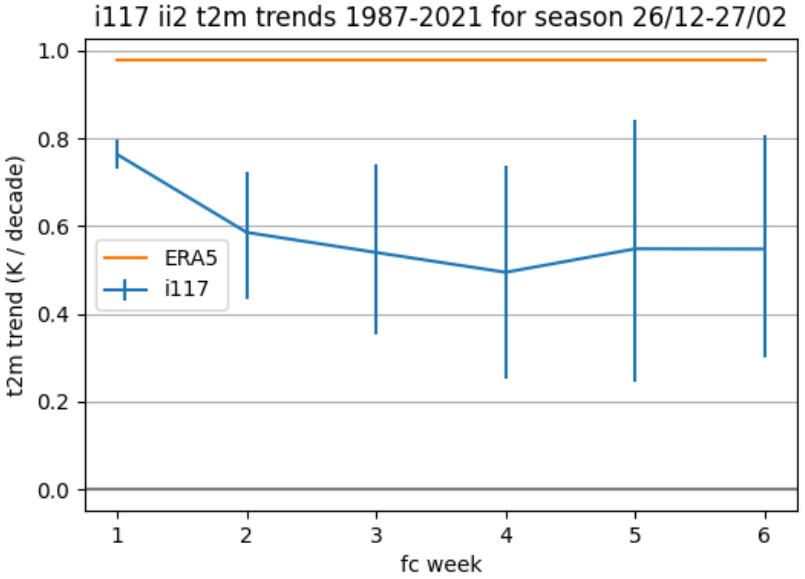


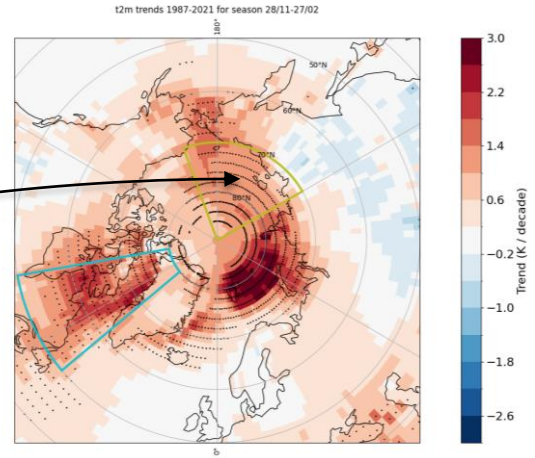
This has implications for different aspects of the seasonal forecasting systems:

evaluation (importance of trends) – modelling – initialization – forecast range - products

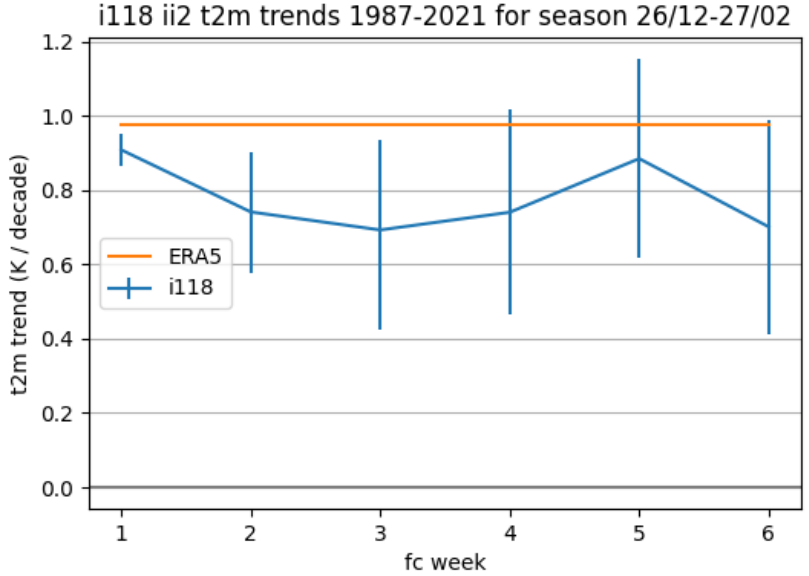
Importance of trends in S2S forecasts: effect of sea ice temperature coupling

Control





Experiment



- ERA5 trend in t2m is underestimated by 50% in first weeks of reforecasts, indication is fast processes responsible

- Experiment: use actual ice and snow thickness to compute Tsurf, instead of constant 1.5m
- Experiment has improved consistency in t2m trends (cp. Zampieri et al (2023)

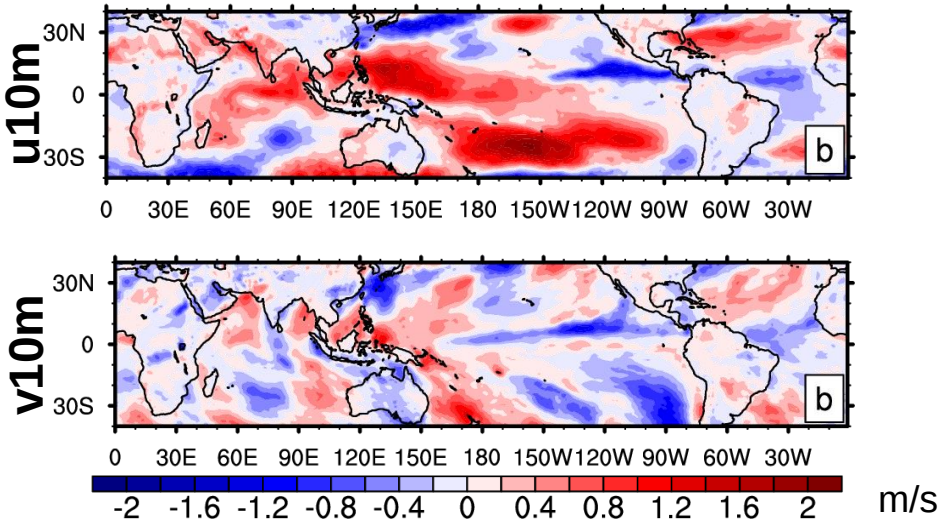
Tietsche et al, in preparation

SF Trend errors in the tropics related to errors in SF o Triple La Niña 2020-2023

- Composite of five warmest (=worst) forecast members started in May 2020-2022 (totalling 15 members) exhibit similar circulation and SST errors as 1993-2019 trend errors

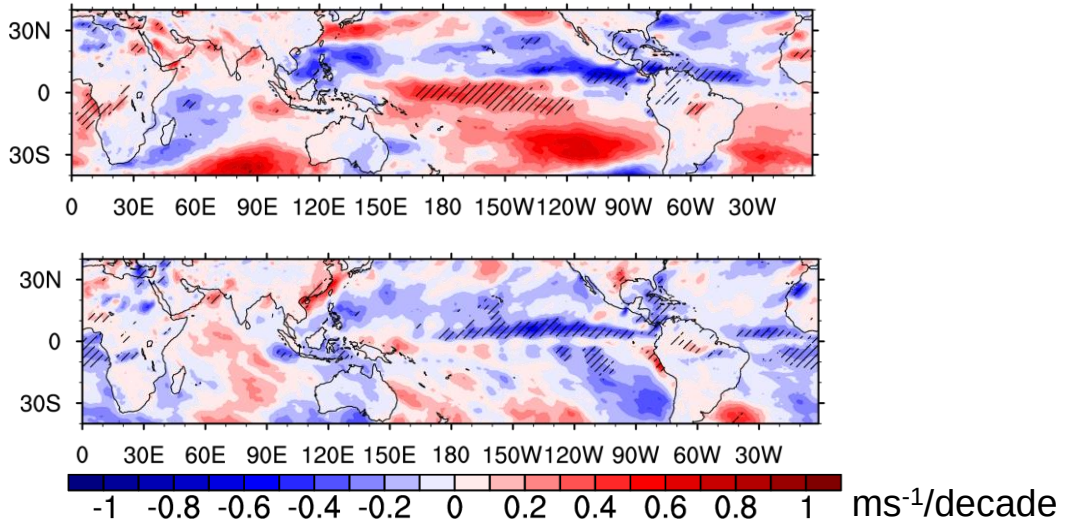
SEAS5: 3x5 warmest members

JJA 2020-2022 forecast errors

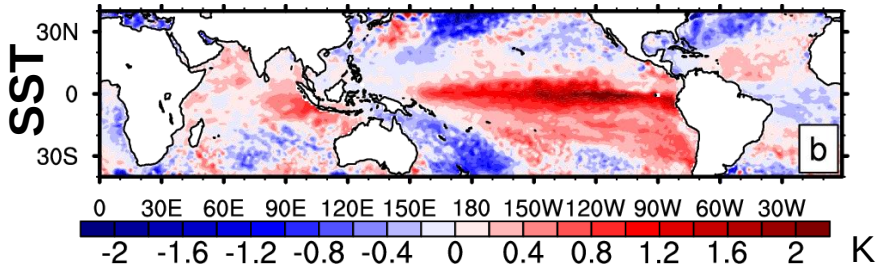


SEAS5 (May starts)

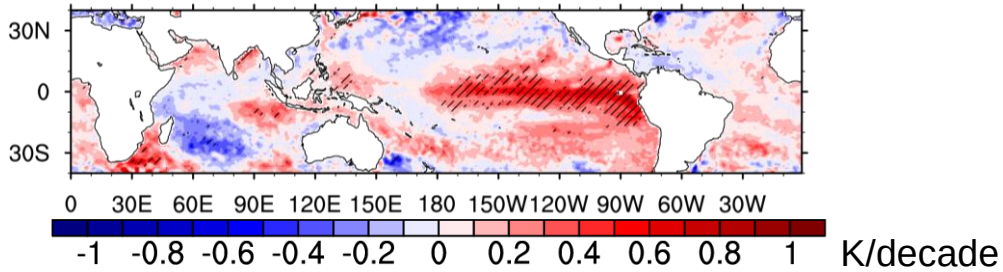
JJA 1993-2019 trend errors



November 2020-2022 forecast errors



November 1993-2019 trend errors



Mayer et al, in preparation

Consistent Representation of Boundary Forcings in Reanalyses and Seasonal Forecasts

- Radiative forcing, land cover-use and vegetation are prescribed as boundary conditions in reanalyses and subseasonal-seasonal –decadal integrations. Their temporal variability impacts the solution.

The EU CONFESS project aims at **improving the representation of global trends and regional extremes in next generation of C3S earth system reanalyses and Subseasonal-Seasonal forecasts,** by taking stock of observational data sets and model developments across different Copernicus Services on vegetation, land cover, atmospheric composition and biomass burning.

CONFESS Strategic Objectives

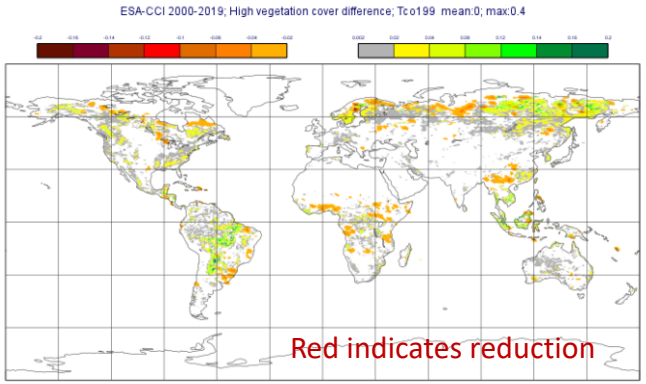
- Representation, **for the first time**, of **temporal variations of land cover and vegetation** in C3S systems by exploiting state of the art Copernicus observational datasets
- **Improved** temporal representation of **tropospheric aerosols by harmonization of CMIP6 and CAMS datasets.**
- **Increased prognostic capabilities** by inclusion of prognostic vegetation and new capabilities for response to volcanic and biomass burning emissions.

Ultimate aims:

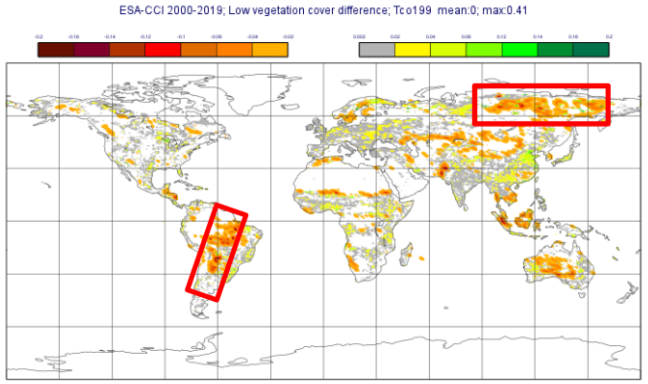
- To avoid discontinuities between reforecasts and real-time forecasts
- To improve the representation of trends and extremes
- To find converging best practices for reanalyses, initialized predictions and climate simulations

Time variations of LULC 2000-2019

Low vegetation

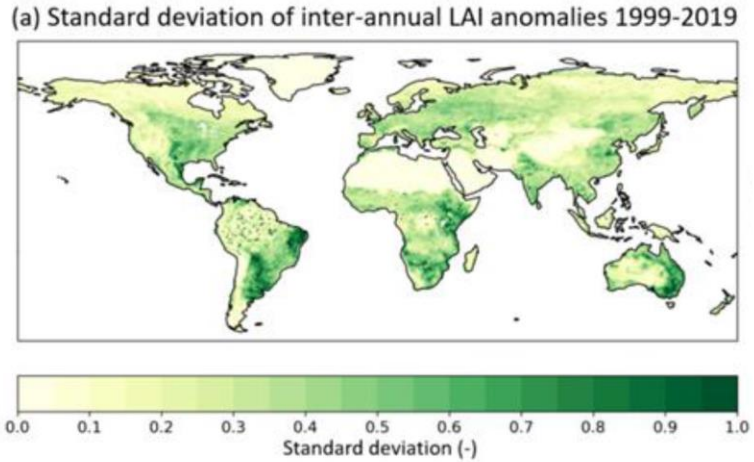


High vegetation



In the last 20 years there has been a decrease of high vegetation over tropical rainforest and Siberia boreal forest, and an increase in low vegetation Courtesy of Souhail Boussetta

Time variations of vegetation

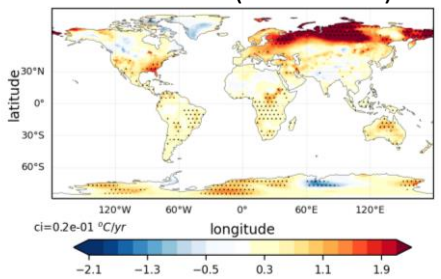


Courtesy of A. Alessandri

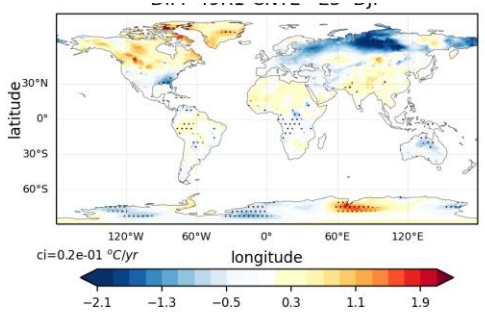
Impact of time varying land properties Seasonal reforecasts

Impact on T2m trend errors DJF (2000-2019)

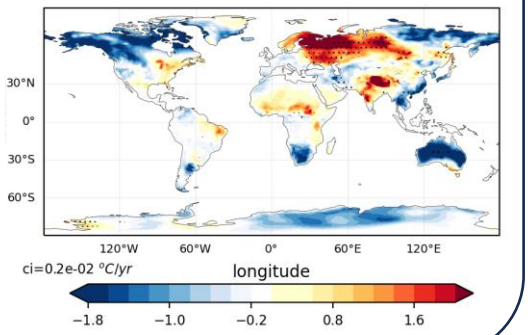
Era5 T2m trends (2000-2019)



Trend errors in CNTL

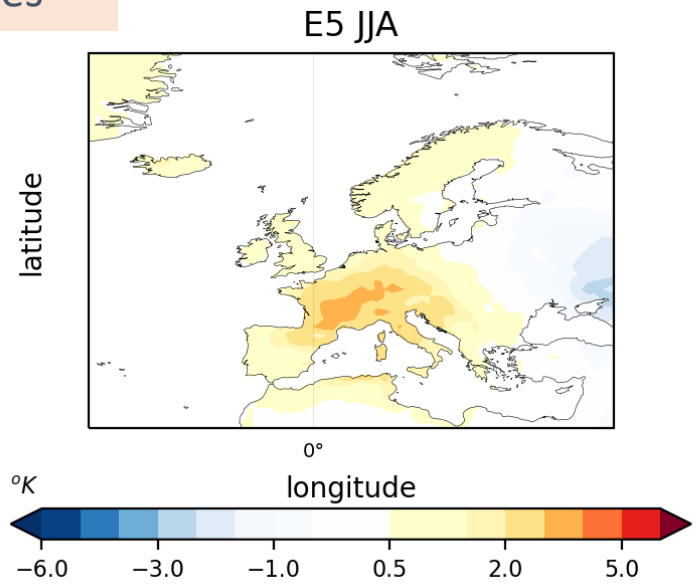


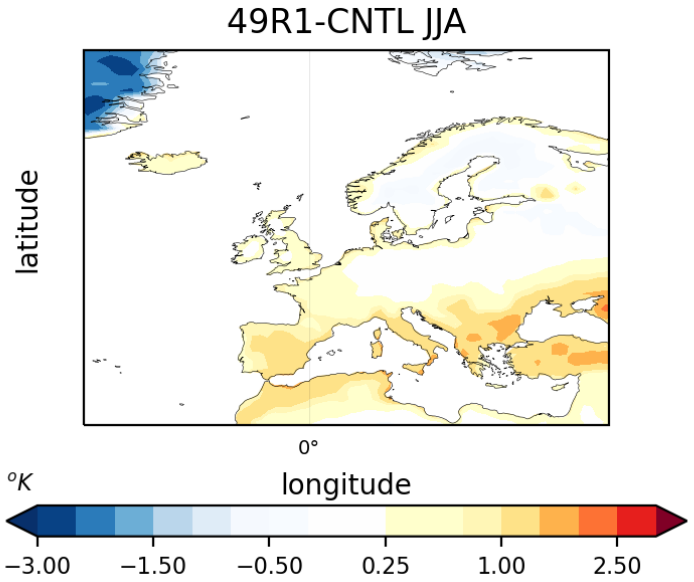
Impact of LAI variations

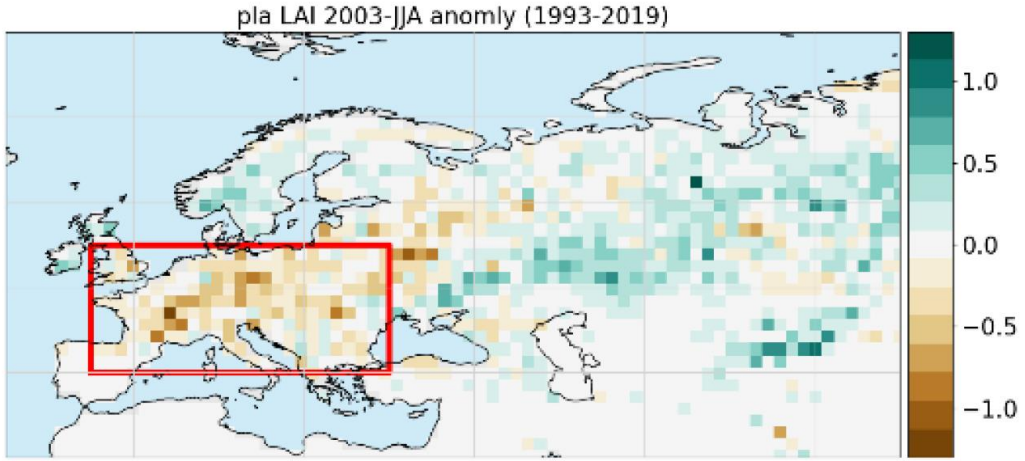


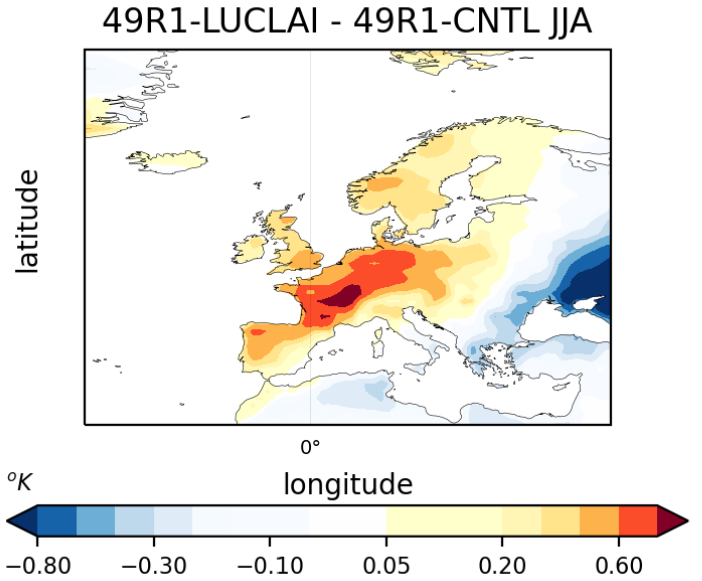
Time-varying vegetation improves the seasonal forecasts of T2m extremes

ECMWF Seasonal forecasts of T2m anomalies for JJA 2003.
Forecast initialized May 2003





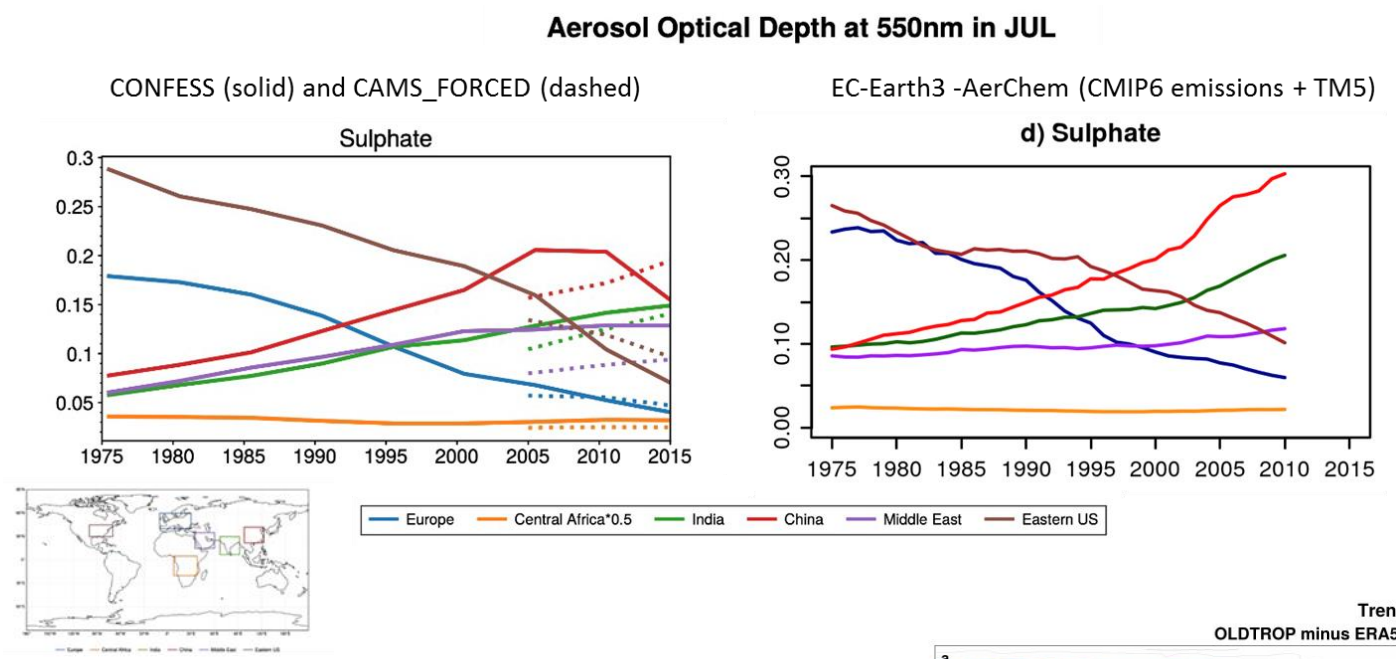




This result is consistent with the impact on surface fluxes in offline simulations (CONFESS deliverable D2.1)

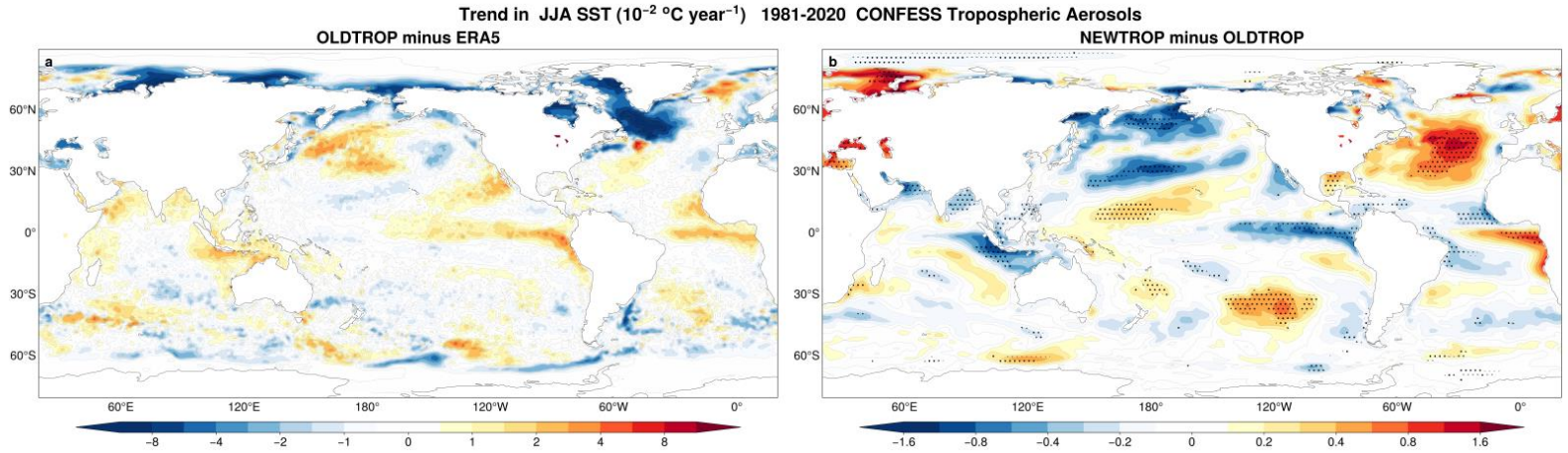
Harmonized tropospheric aerosols datasets

Run CAMS model (IFS-COMPO) with updated CMIP6 emissions (CEDS, GFED/GFAS) constrained by ERA5 meteorology



- Downward trends in sulphate aerosols over Europe and Eastern US.
- After peaking ~2006, downward trend on sulphates over China in later period, not captured by CAMS-FORCED.
- Overall consistency with time variations in EC-EARTH that uses CMIP6, but the latter shorter records do not show decrease of sulphates over China

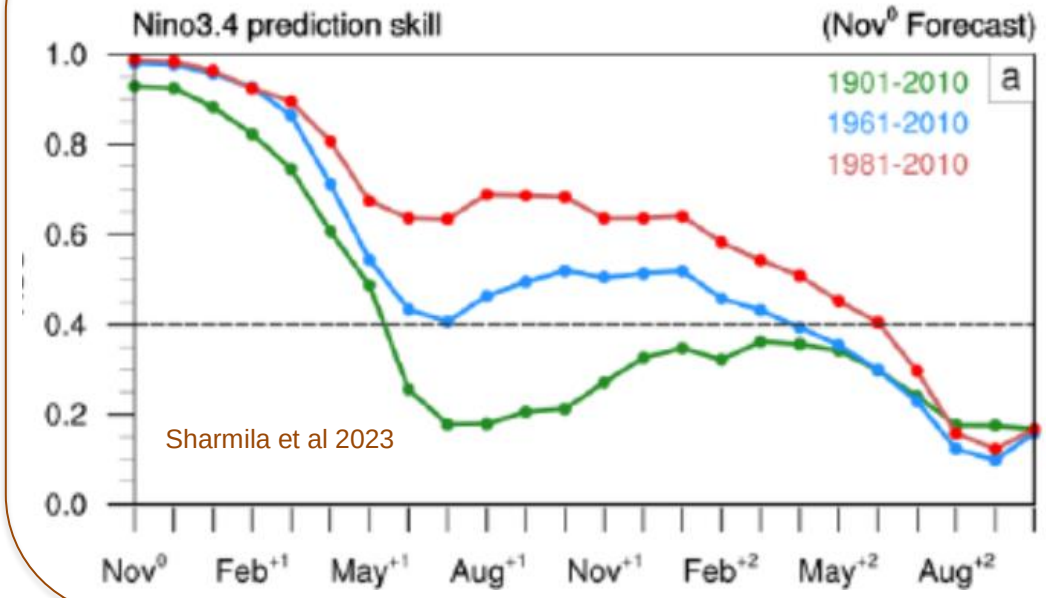
Impact of tropospheric aerosols projects into the pattern of forecast errors in trends
Forecast initialized in November, verifying in JJA



Towards 2-year ENSO forecasts

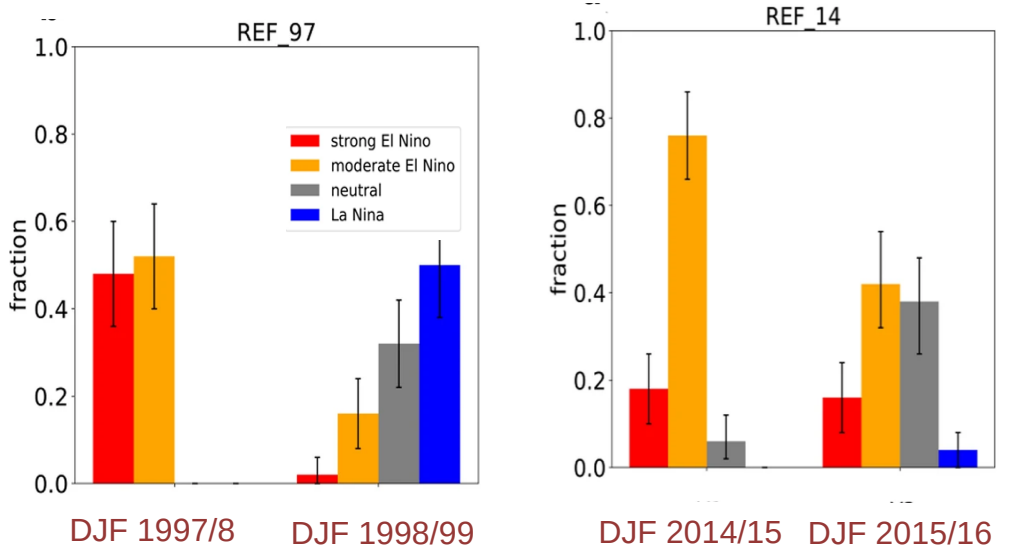
- Several systems show skill beyond 18 months for ENSO prediction.(Sharmila et al 2023, Mayer and Balmaseda, 2021, Yeager et al 2022, Dunstone et al 2022)
- In certain occasions –windows of opportunity- that skill can go beyond (eg from El Nino to La Nina). (Sharmila et al 2023).
- The information on 2nd year forecast helps to characterize different types of ENSO and interpretation of 1st year forecast (Mayer and Balmaseda 2021)

Skill beyond 1-years on ENSO forecasts



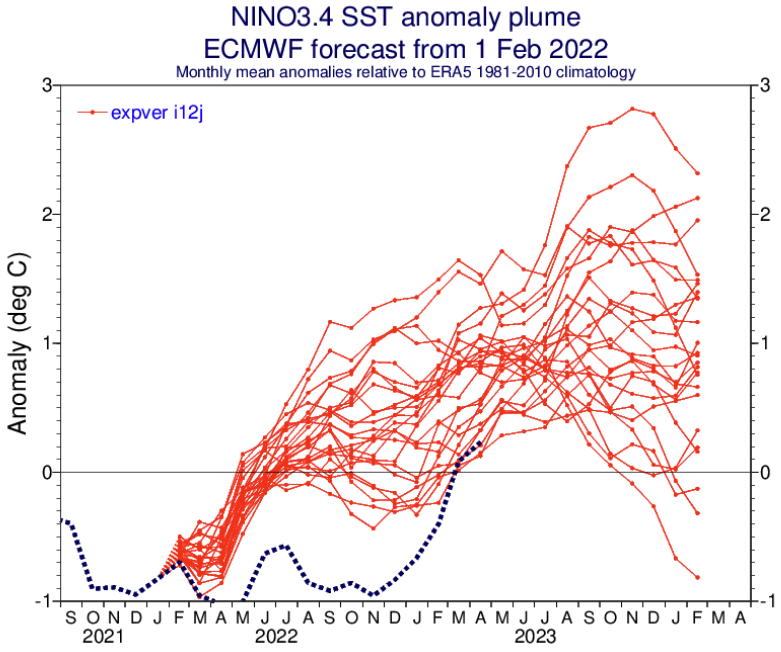
FC Starting Feb 1997

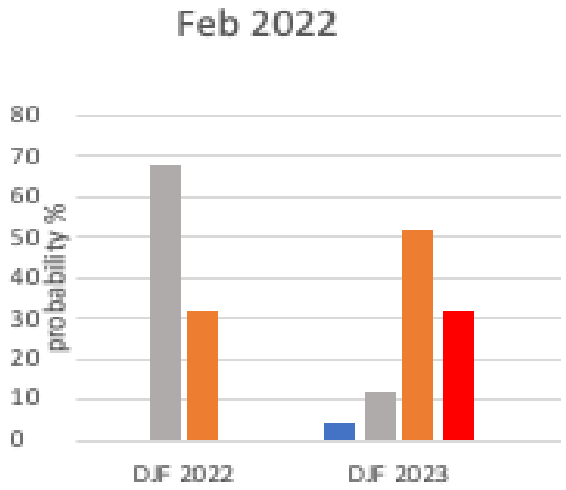
FC Starting Feb 2014



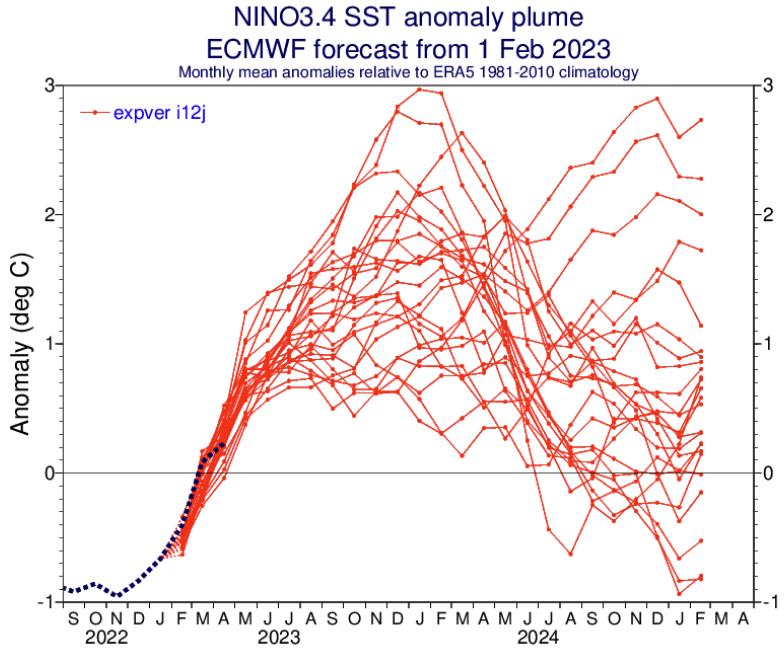
From Mayer and Balmaseda 2021

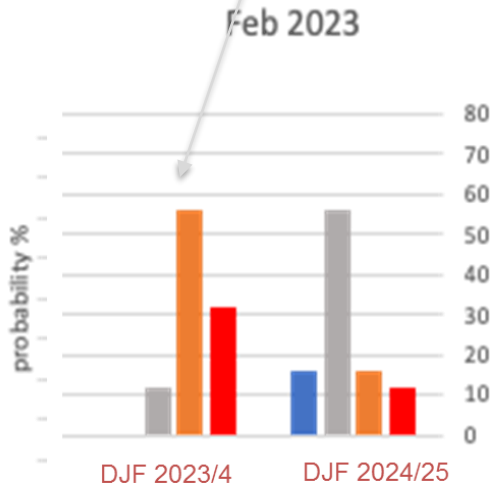
Two-year forecasts: SEAS5-based example for 2023 El Nino





Feb 2022 forecast suggests weak warming in 2022 (which was wrong), followed by likelihood of stronger warming in 2023, with the possibility of a strong El Nino





Feb 2023 forecast is for a moderate to strong El Nino in 2023, with a strong event followed by a return to neutral or La Nina conditions; but the possibility of a moderate warming strengthening to give a strong 2-year event.

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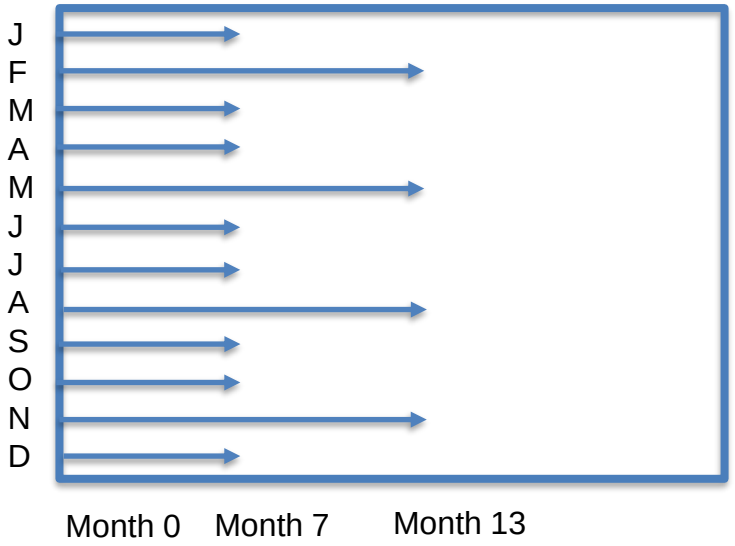
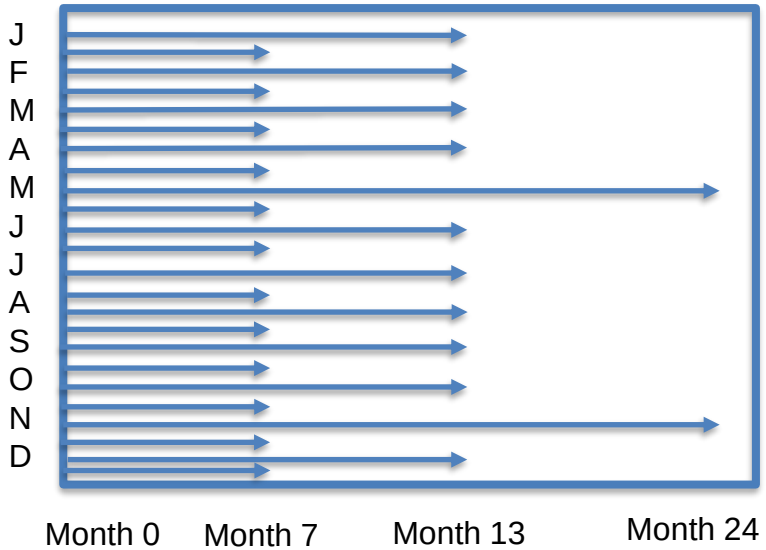
SEAS6 Real-time forecast enhancements at a glance:

- 7m twice a month (101 members)
- 13m every month (33 members)
- 24m twice a year (33 members)

SEAS5



SEAS6



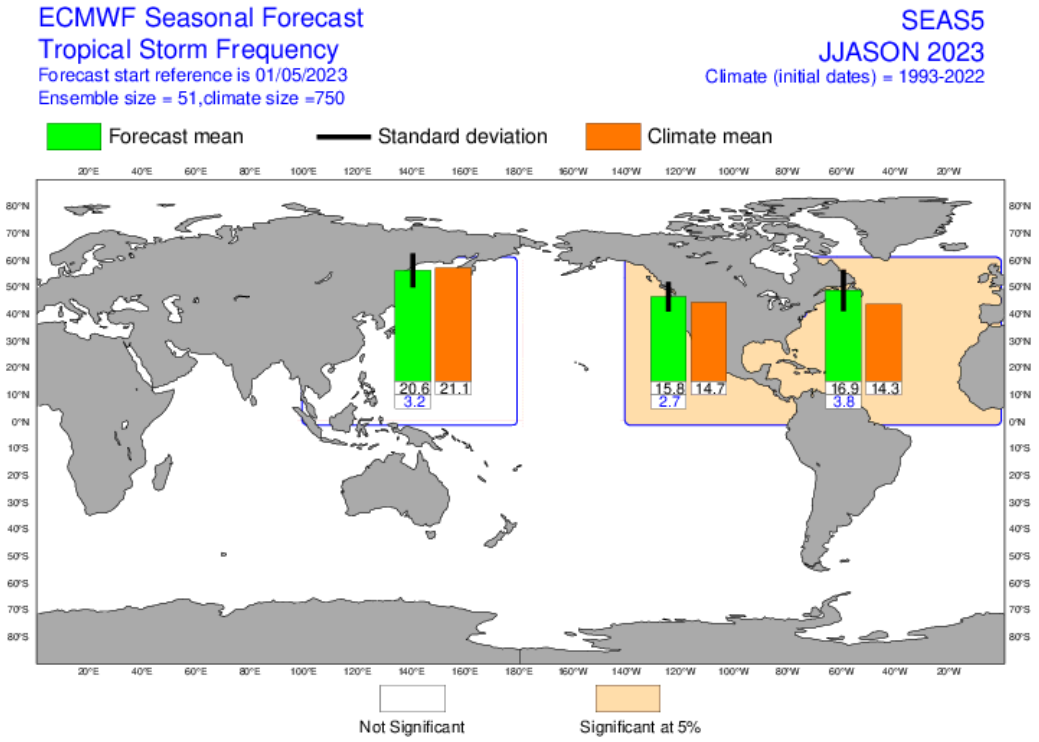
SEAS6 Reforecasts

Main set 1993-2022
7m fc: 33 members twice a month
13m fc: 22 members monthly
24m fc: 22 members twice a year

Supplementary set :
Back extension to 1961 for all
Enhanced ensemble (up-to 55 ens) for 7m fcs quarterly

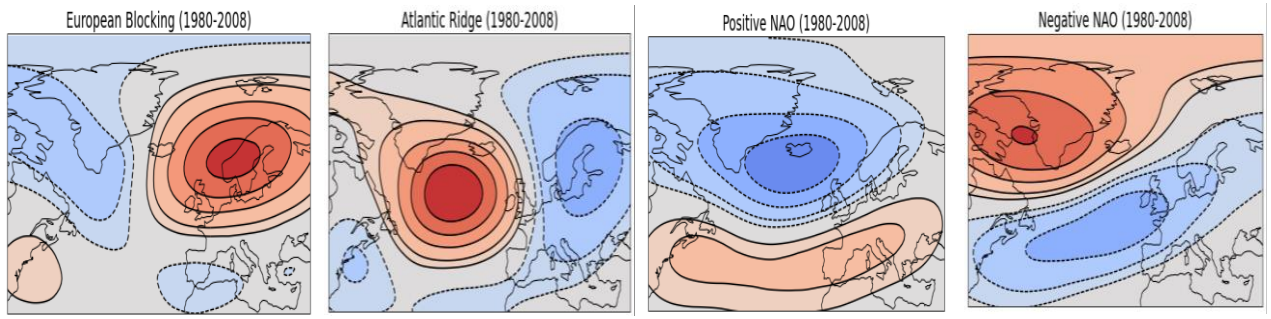
New products and skill assessment: beyond seasonal means

- Currently most seasonal forecasting products are provided as seasonal/monthly means. A notable exception is the probability of TC
- Need to move towards probability of weather events (heat waves, cold spells, regimes, MHW)

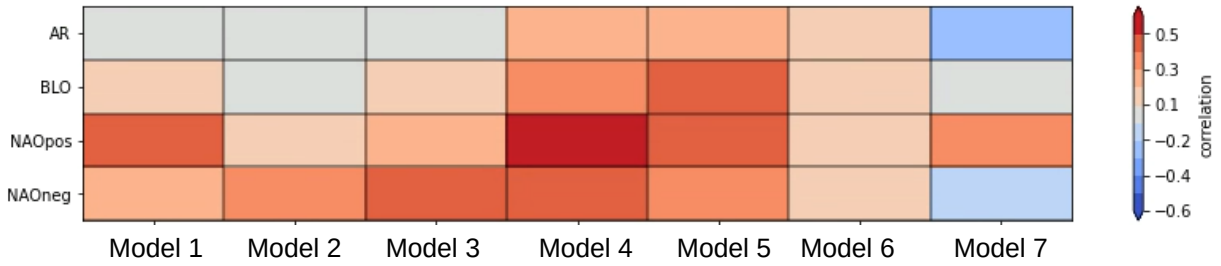


Weather regimes (4 patterns for N. Atlantic).

Same regimes as S2S



C3S SF: Skill on predicting frequency of regimes in a season



Summary

The impact of climate change is visible in observational records. It has several implications for seasonal forecasts:

- **Representing and evaluating climate trends** becomes increasingly important for seasonal forecasts: it affects the skill and the skill assessment and modelling. Important to capture Arctic amplification, ENSO prediction and tropical cyclones, among others.
- **Importance to improve the temporal variability of Land, Vegetation, Aerosol, via observational constrains, and whenever possible via prognostic modelling and initialization**. This will improve trends, skill and extremes. Need to harmonized practices within the climate community – Reanalysis, S2S, CMIP.
- **Promising prospects for 2-year ENSO forecasts**. The next ECMWF forecasting system will issue operational 2-year forecasts twice a year.
- SF should be complemented with model-based attribution case studies and process evaluation.
- Need to develop seamless probabilistic S2D forecast products beyond seasonal-yearly means.

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