Sub-seasonal Forecasting at ECMWF

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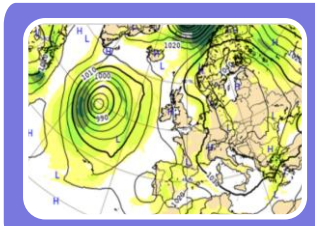
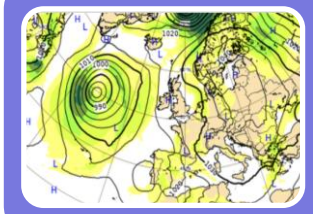
European Centre for Medium-Range Weather Forecasts

Forecast systems at ECMWF



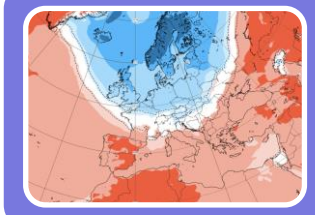
Medium range

- 0-15 days
- 9 km resolution, 137 levels
- 51 ensemble members, run twice daily
- Upgraded approximately once a year



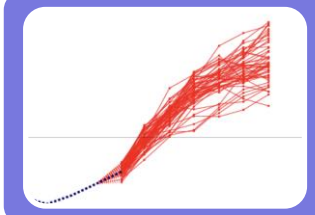
AIFS: Medium range

- Experimental real-time system
- 0-15 days
  - ~0.25 degree resolution
- Currently deterministic
- Upgraded as developments are ready



Sub-seasonal

- 0-46 days
- 36 km, 137 levels
- 101 ensemble members, run once daily
- Upgraded approximately once a year, with medium range

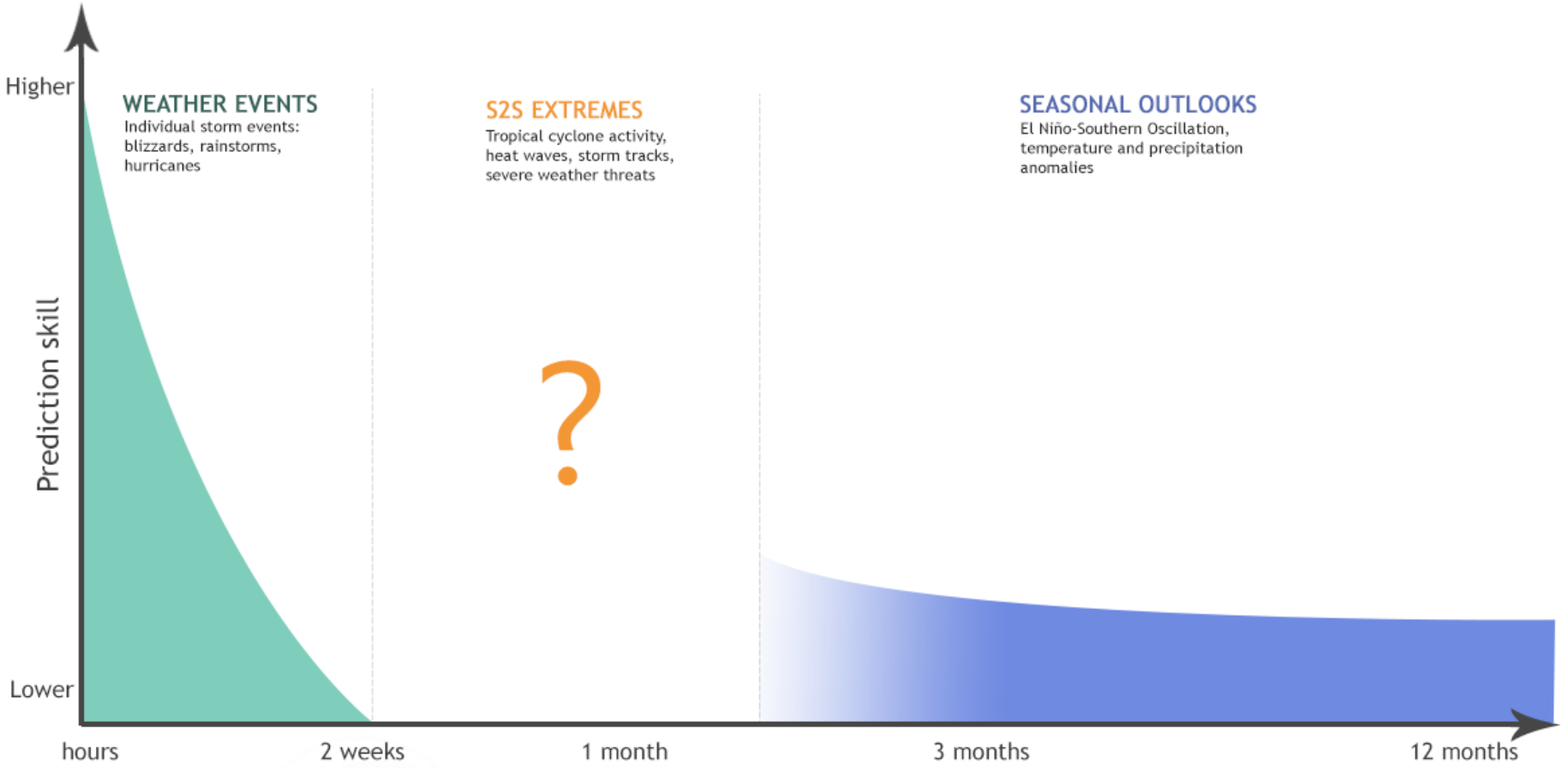


Long range: SEAS5

- 0-7 months
- 36 km, 137 levels
- 51 ensemble members, run once a month
- Four times a year, the forecast is run out to 13 months
- Last upgraded in 2017 (Cy43r1), next upgrade in 2025

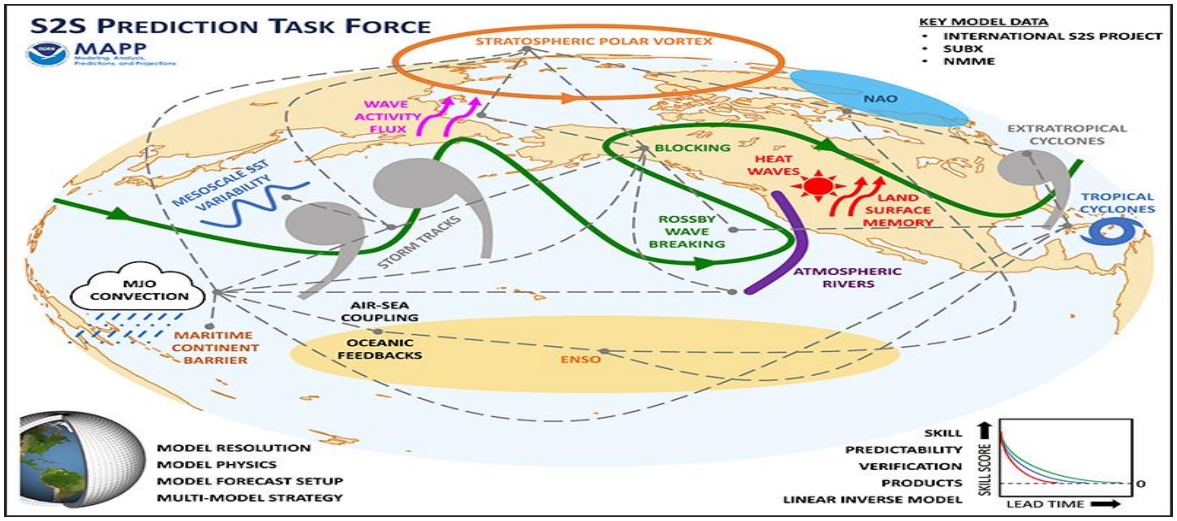
From S.Johnson

Sub-seasonal to Seasonal prediction



Adapted from: iri.columbia.edu/news/qa-subseasonal-prediction-project

Sources of sub-seasonal predictability



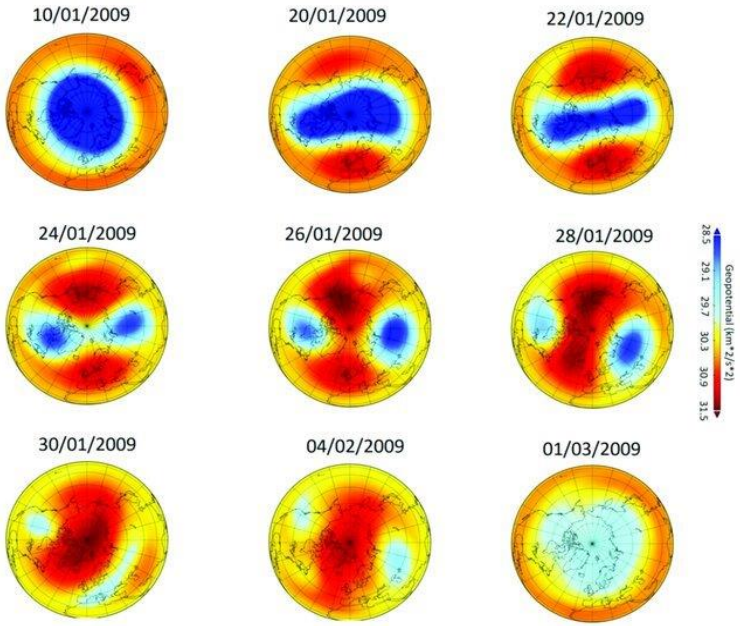
Main sources of predictability include:

- MJO
- ENSO/IOD
- Land Surface
- Stratospheric variability (e.g. SSW)
- Rossby waves
- SSTs/Sea-ice
- Others?

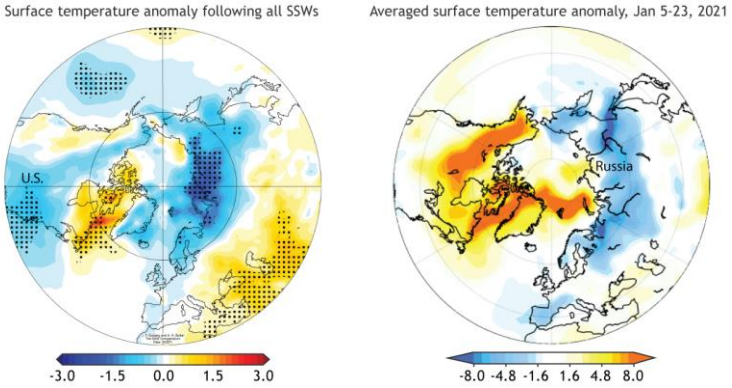
ECMWF

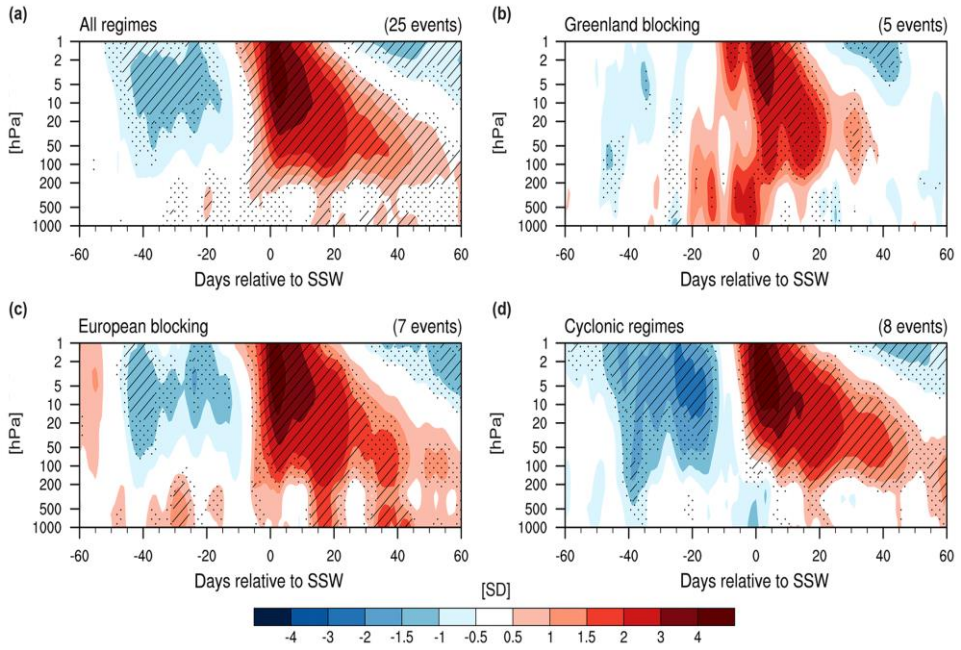
Sudden Stratospheric warming

2009 SSW event



Kozubeck et al, 2020.

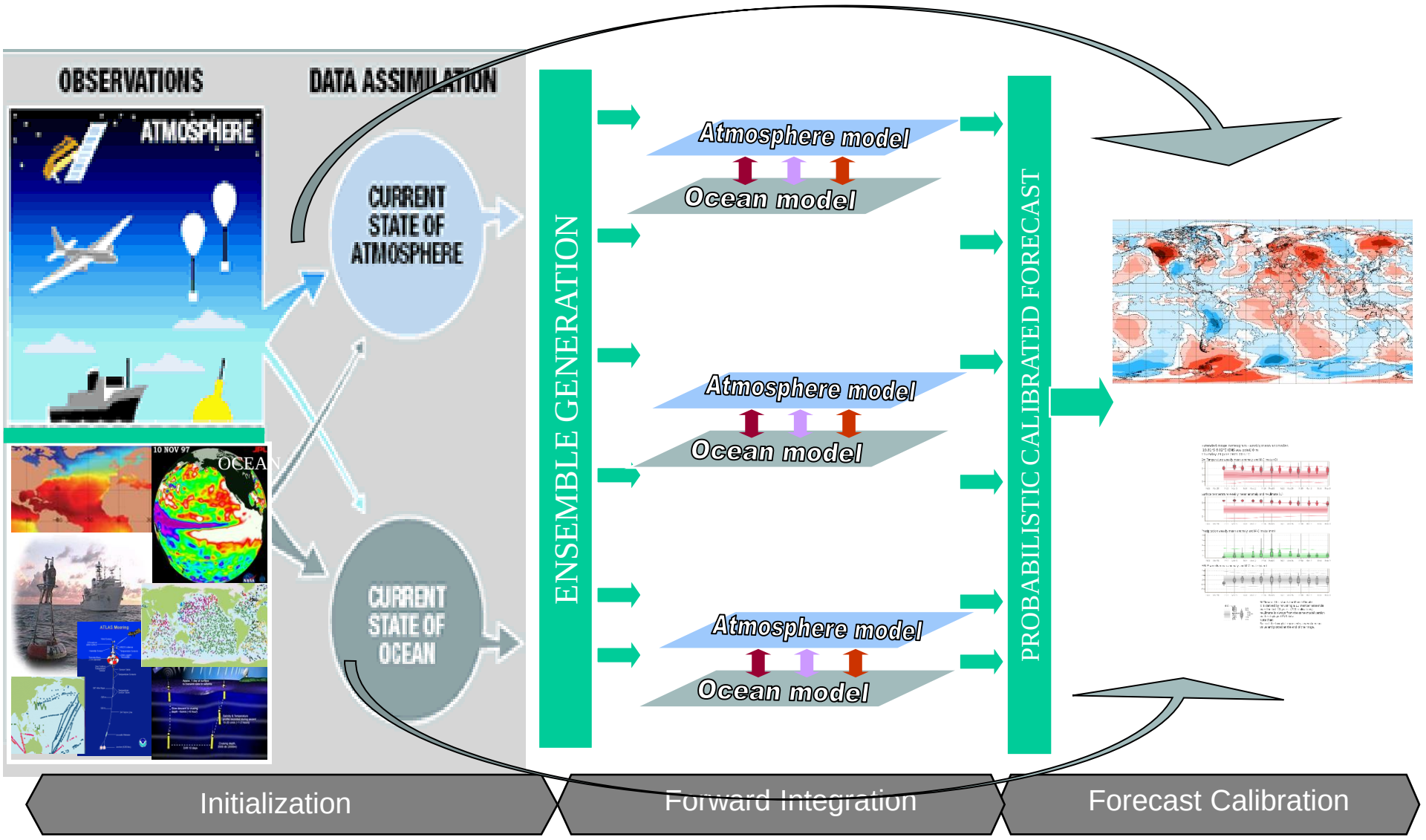




Domeisen et al. et al. 2020

How are S2S forecasts produced?

End-To-End forecasting System



ECMWF sub-seasonal forecasts

- A 101-member ensemble is integrated for 46 days every day at 00Z
- Atmospheric component: IFS with the latest operational cycle and with a resolution TCo319L137
- Ocean-atmosphere coupling from day 0 to NEMO (about 1/4 degree) every hour.

Initial conditions:

- Atmosphere: Operational 4-D var analysis + SVs+ EDA perturbations
- Ocean: 3D-Var analysis (NEMOVAR) + wind stress perturbations

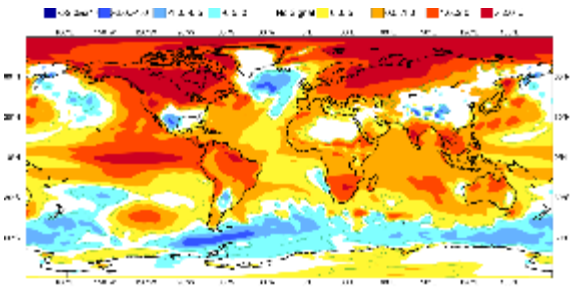
ECMWF products

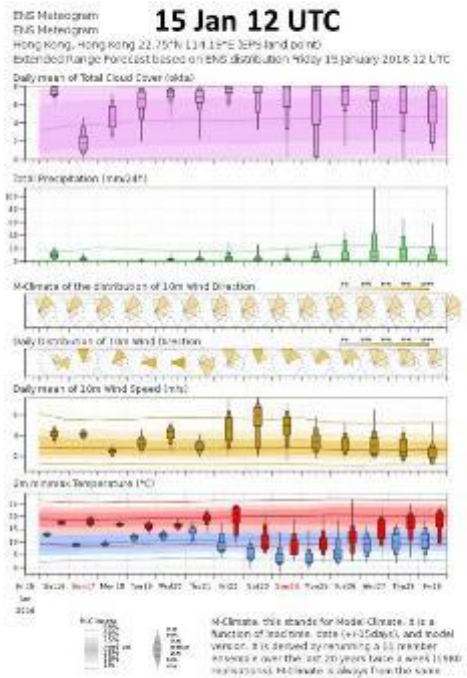
From medium-range to seasonal to extended range

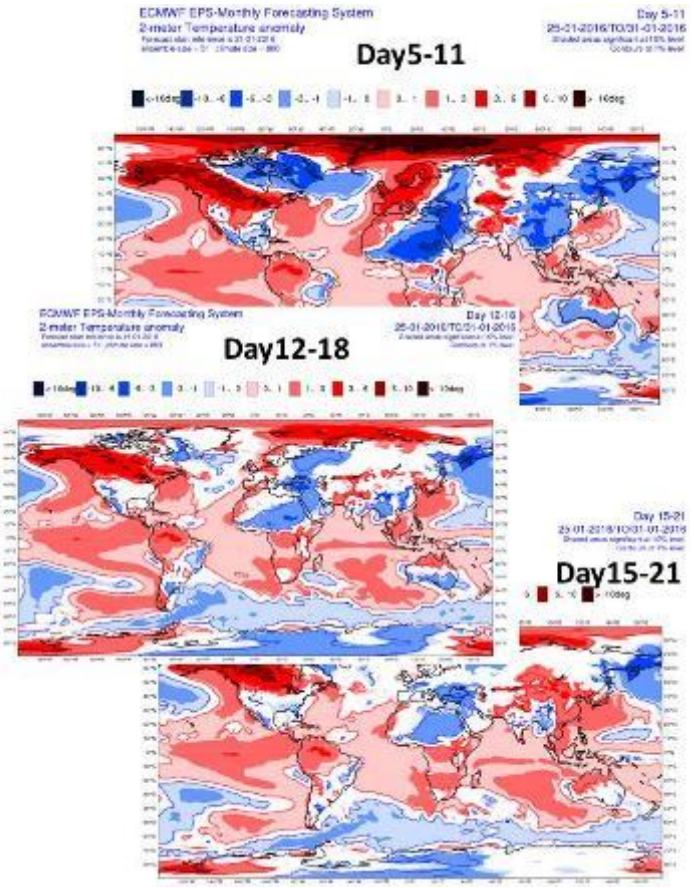
Extended-range

Medium-range

Seasonal Forecast



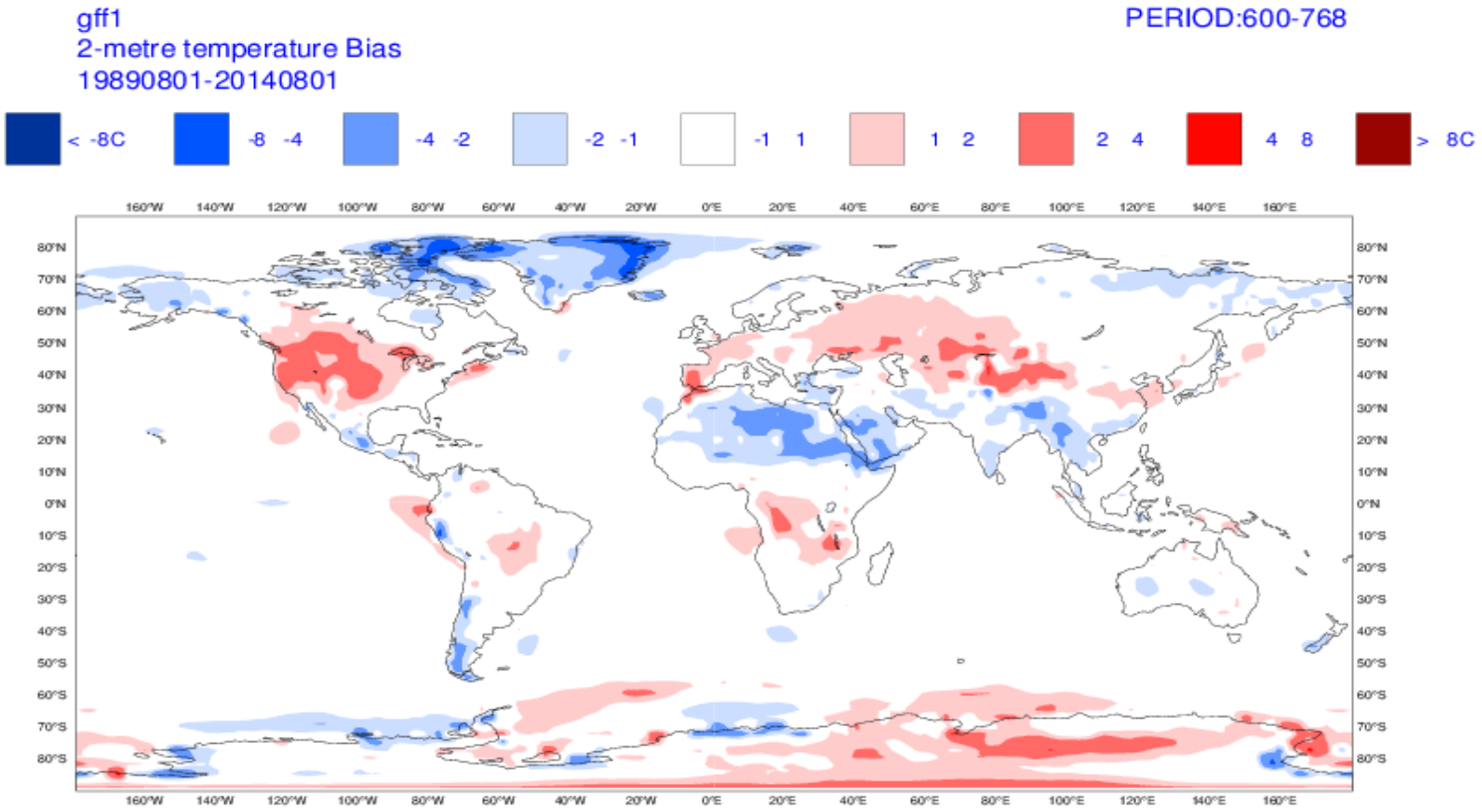




European Centre for Medium-Range Weather Forecasts

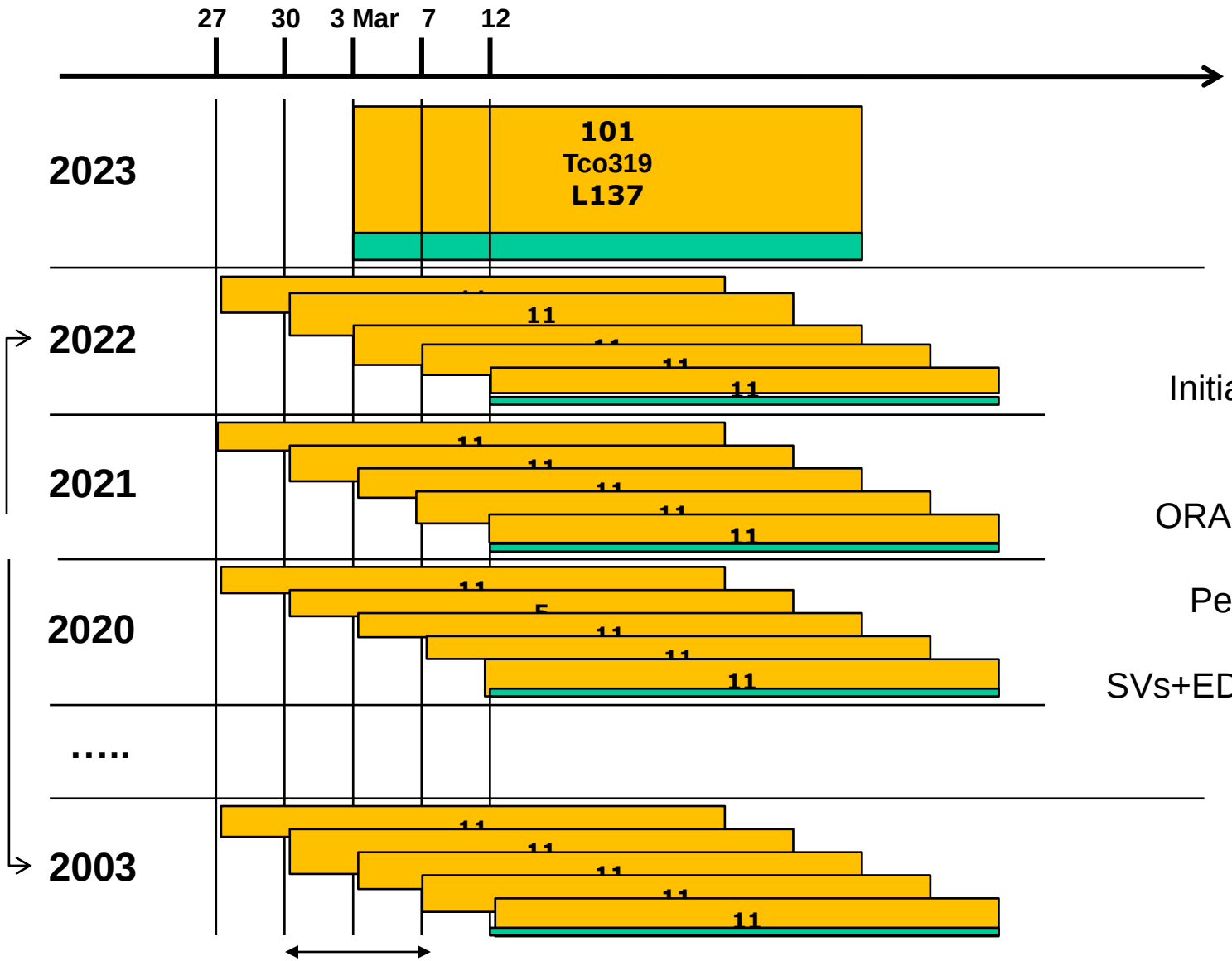
Extended-range forecast biases

Biases (eg 2mT as shown here) are often comparable in magnitude to the anomalies which we seek to predict



Extended-range Re-forecasts

The ENS re-forecast suite to estimate the M-climate



Initial conditions:

ERA5+
ORAS5 ocean ICs

Perturbations:

SVs+EDA(ERA5)+SPPT

1-week window = 3 consecutives sets of re-forecasts= 3*11 members * 20 years=660-member model climate

Current re-forecast configuration

10 perturbed + 1 control fc twice a week over past 20 years

Future reforecast Configuration (49R1)

Extended-range:

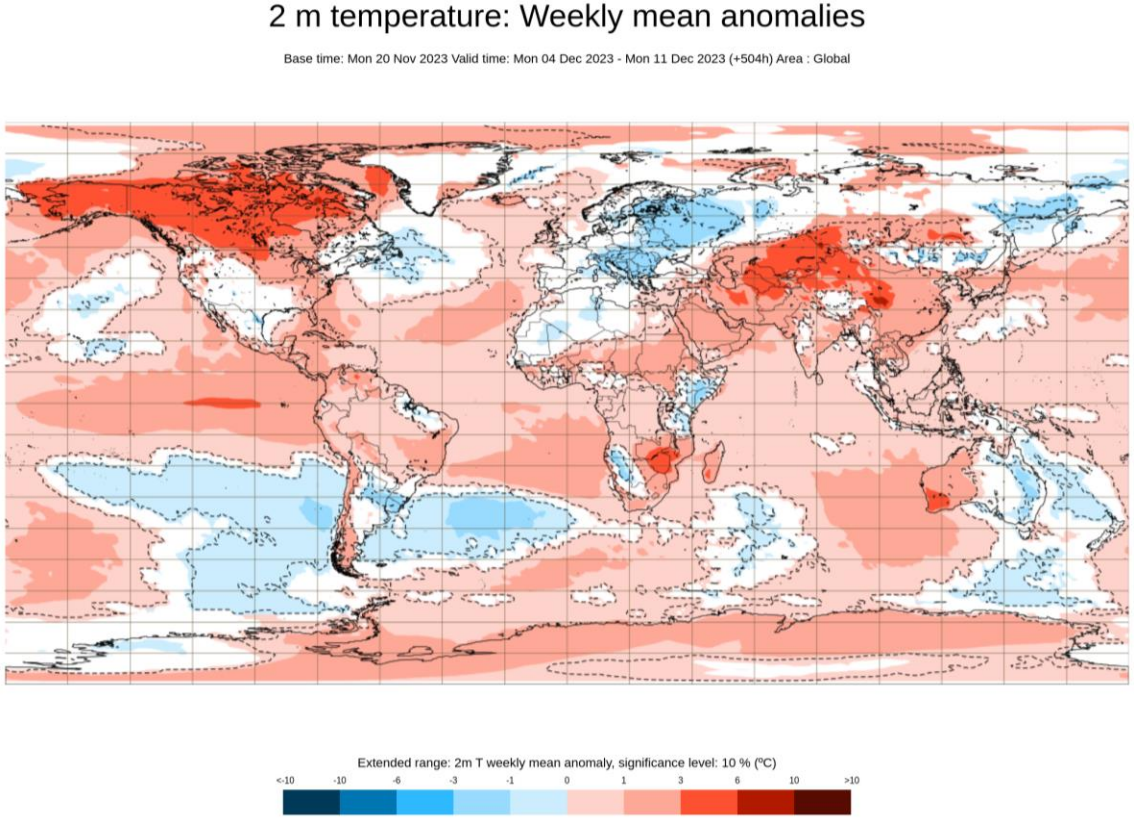
10 perturbed + 1 control fc on fixed days of the month, **every odd days,** over past 20 year

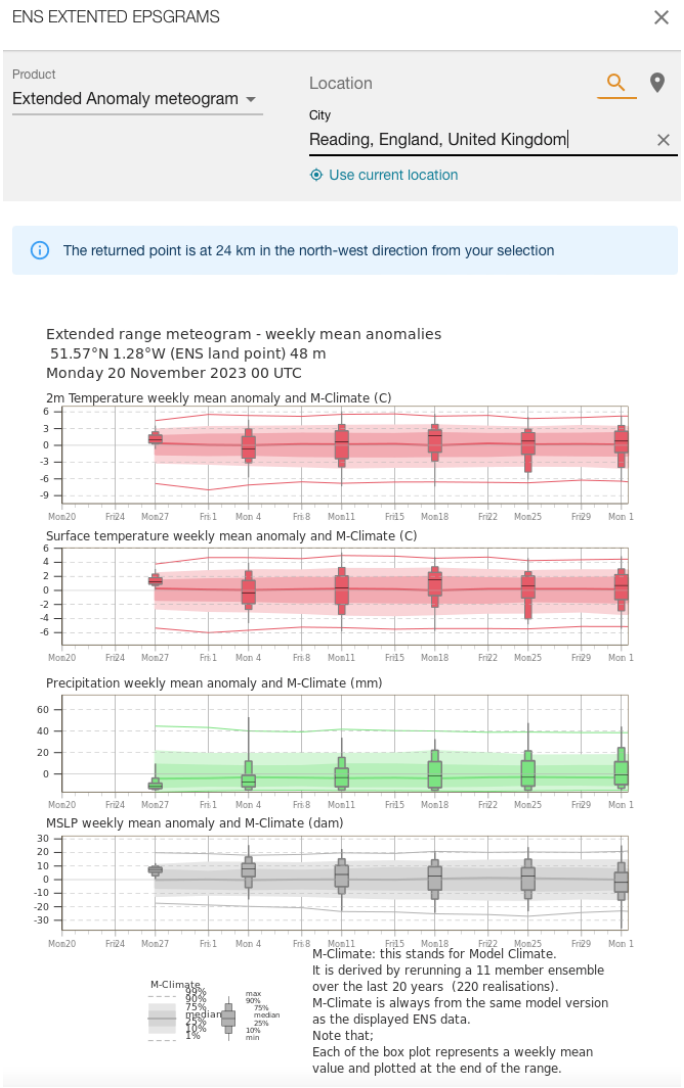
Medium-range:

10 perturbed + 1 control fc on fixed days of the month, **every 4 days,** over past 20 years 1/5/9/13/17//21/25/29 (excluding 29 Feb)

Extended-range Real-time Forecasts

Week 3 Forecasts – 20/11/2023

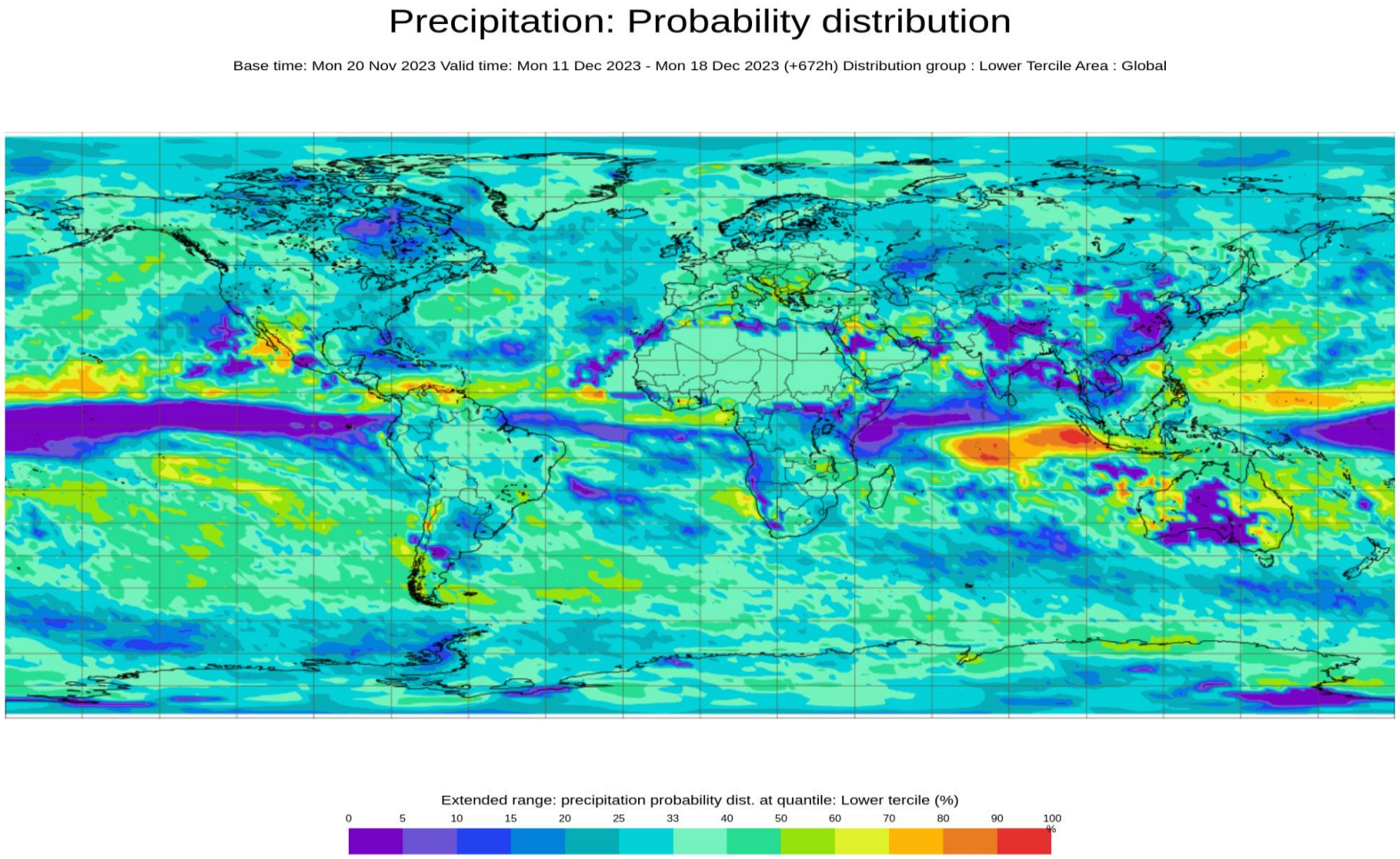




Anomalies (temperature, precipitation..)

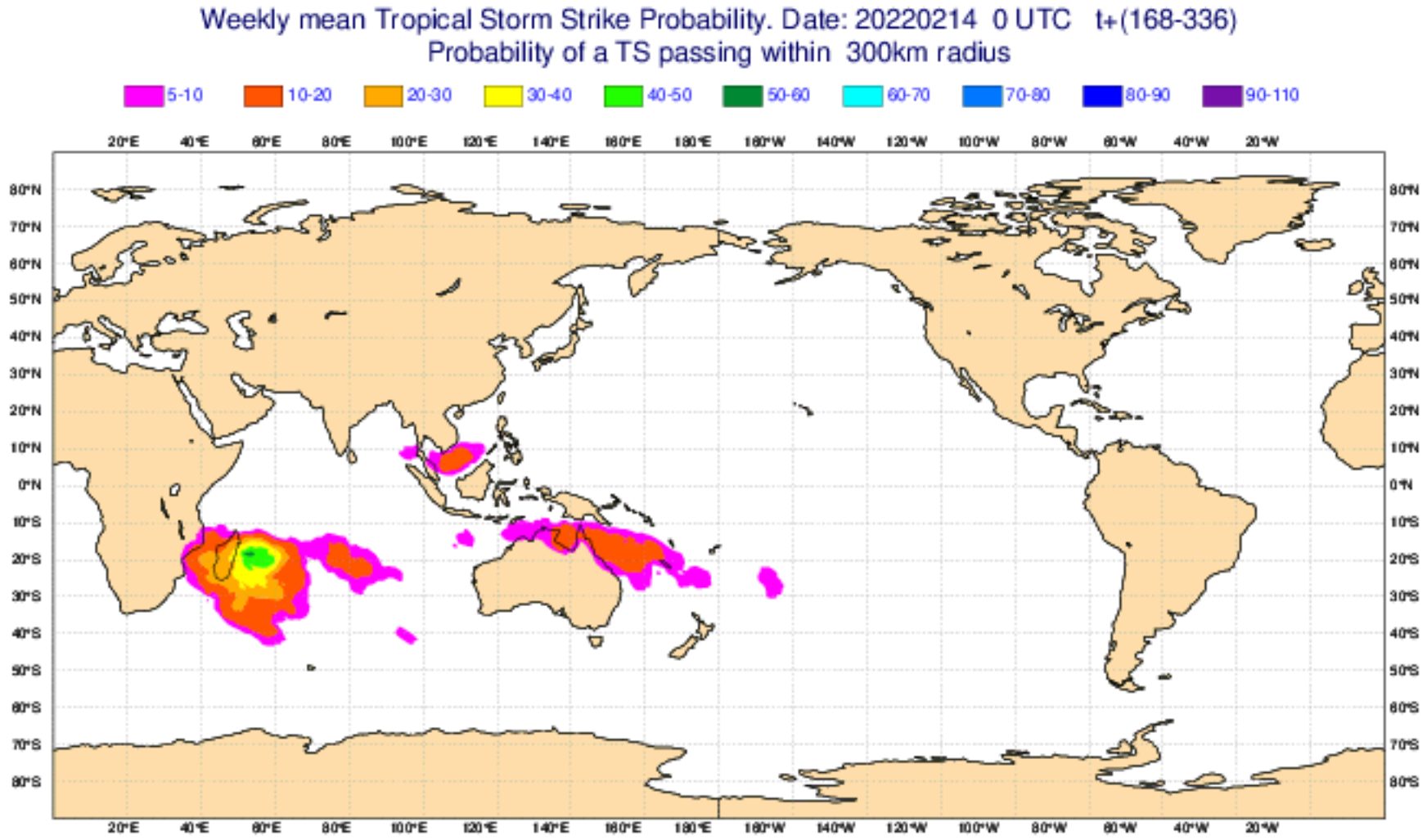
Extended-range Real-time Forecasts

Probability of total precipitation in upper tercile
20 Nov 2023 - Week 4

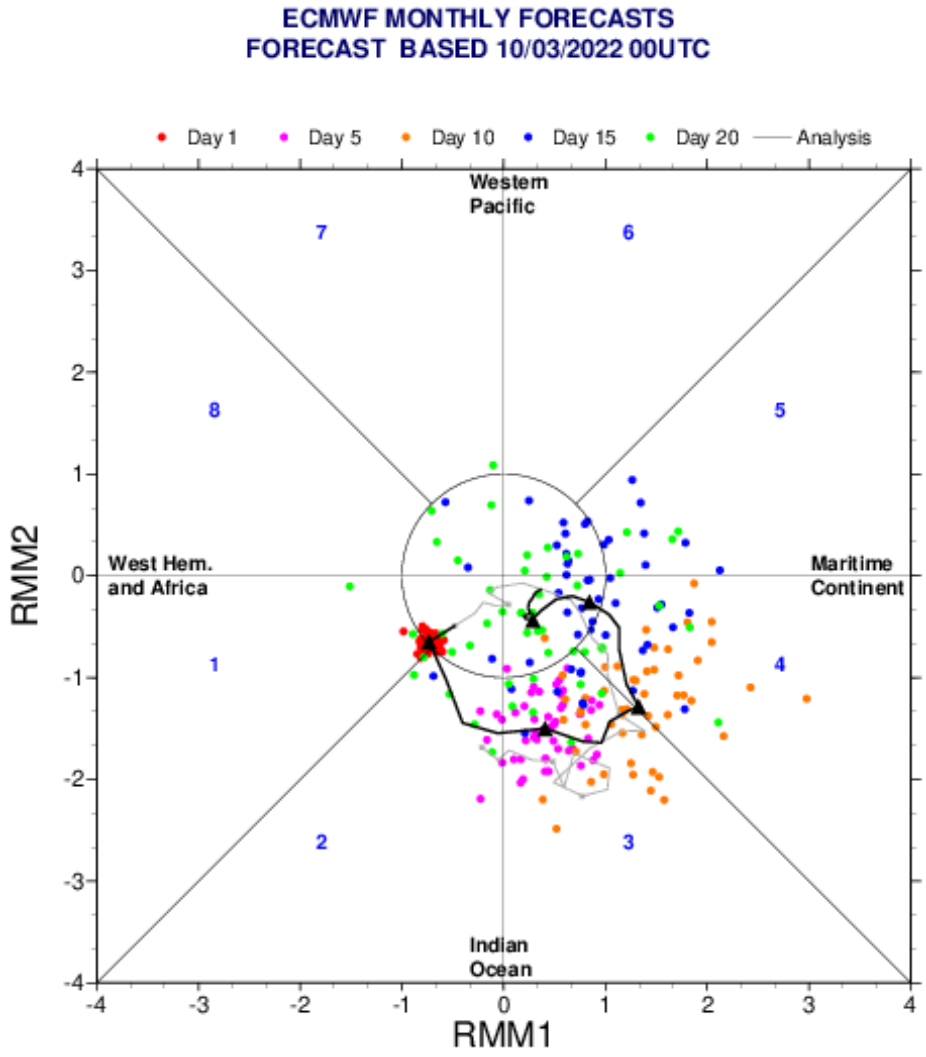


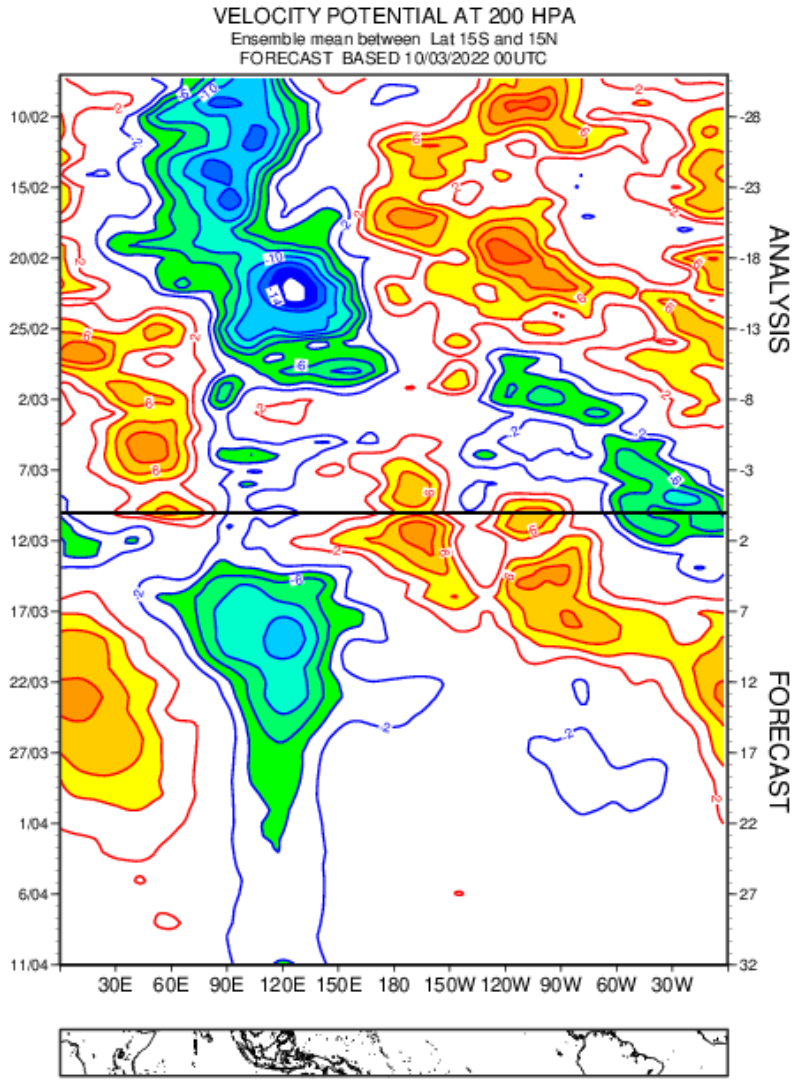
Probabilities (temperature, precipitation..)

Tropical cyclone activity



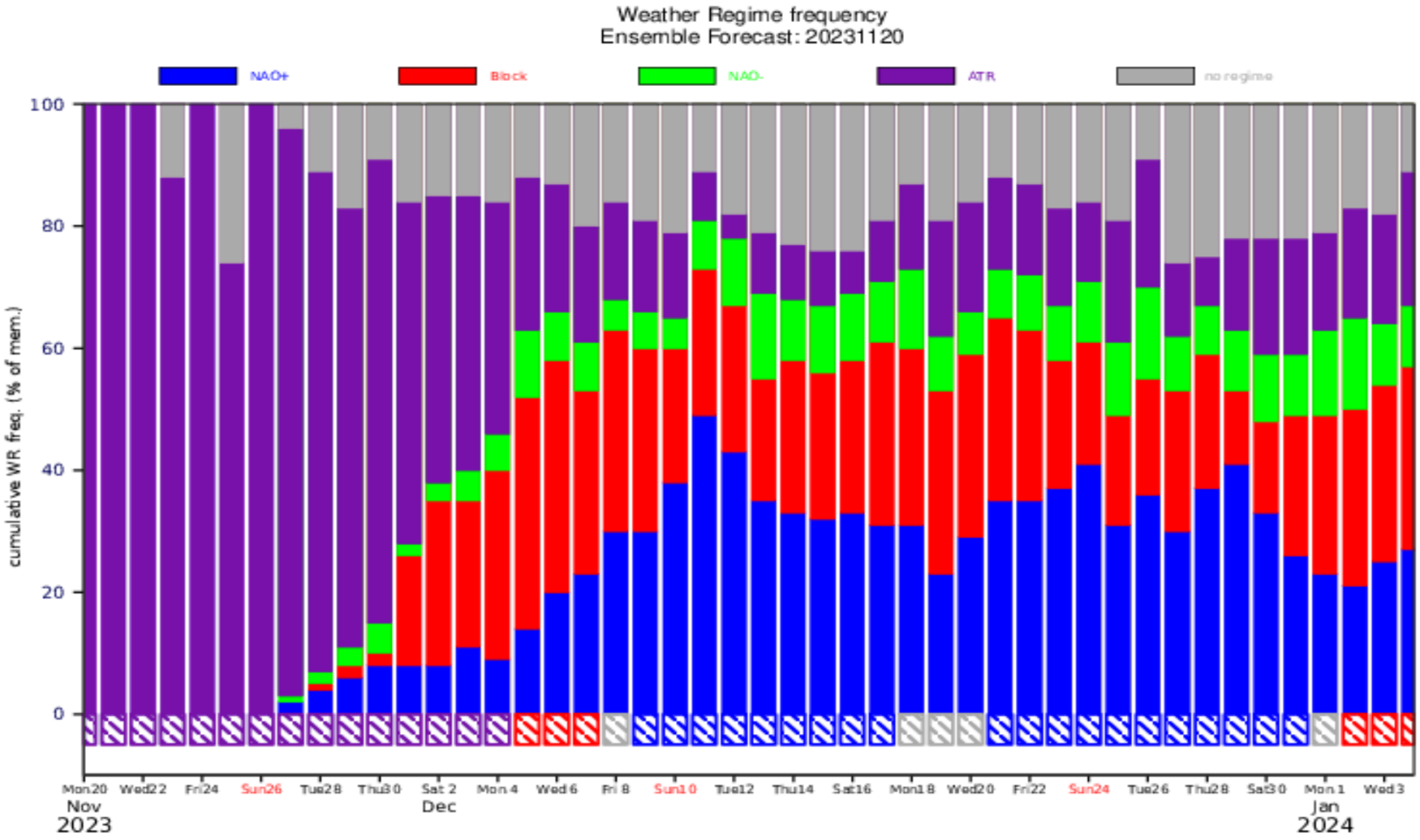
MJO Forecasts





Euro-Atlantic Weather regimes

Weather regimes probabilities - Extended range forecast

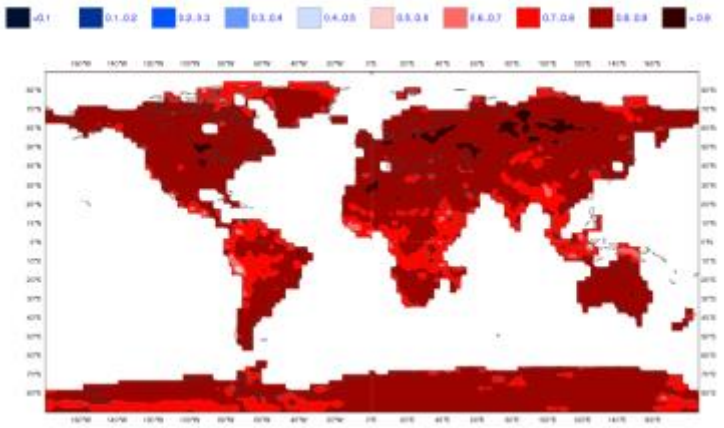


ECMWF

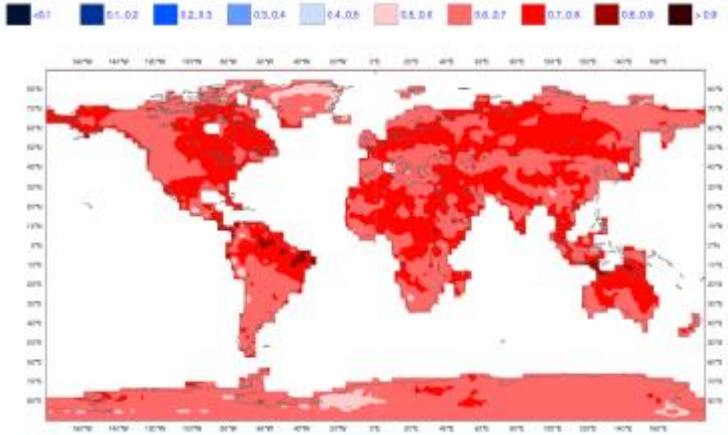
Skill of the ECMWF Monthly Forecasting System

ROC score: 2-meter temperature in the upper tercile

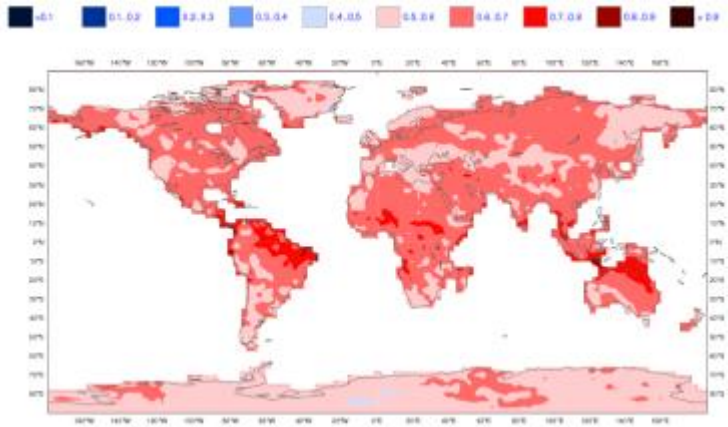
Day 5-11



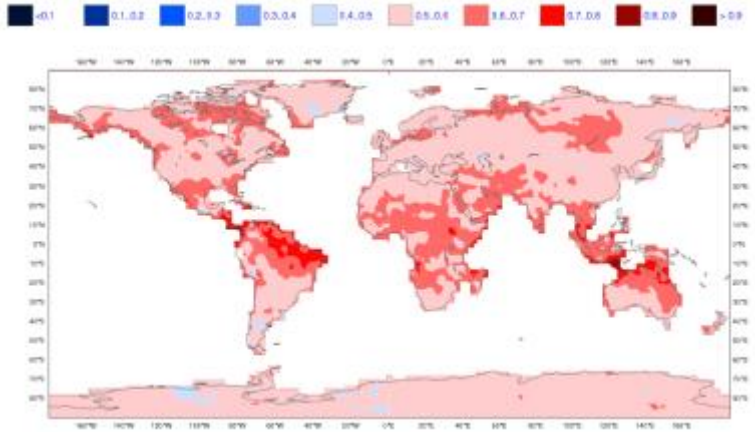
Day 12-18



Day 19-25

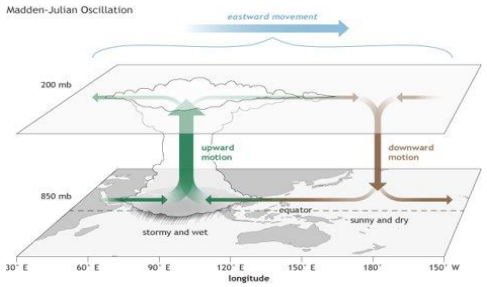


Day 26-32

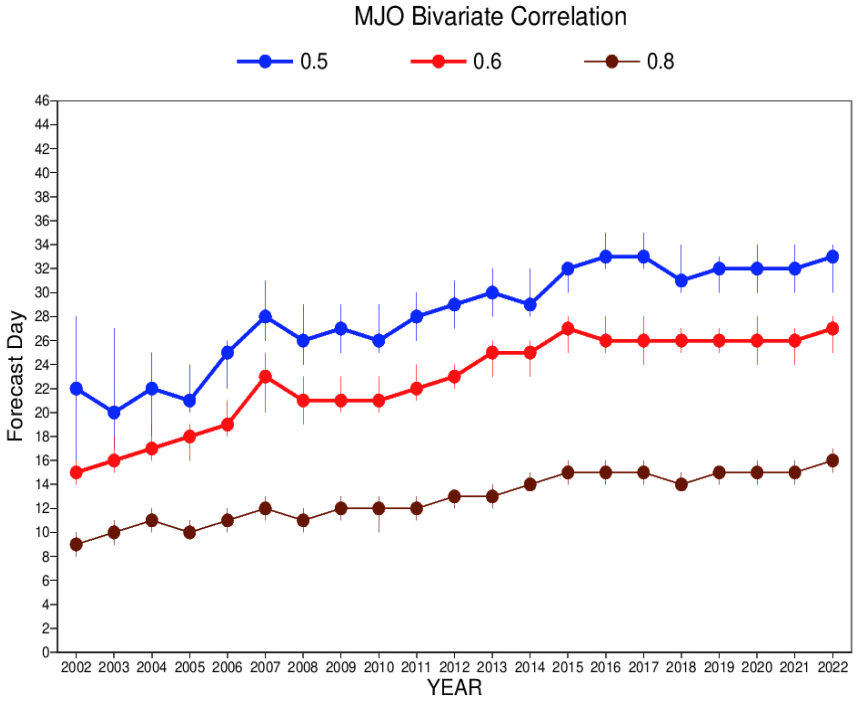


S2S Forecast skill: “Are we progressing?”

ECMWF Forecast Skill

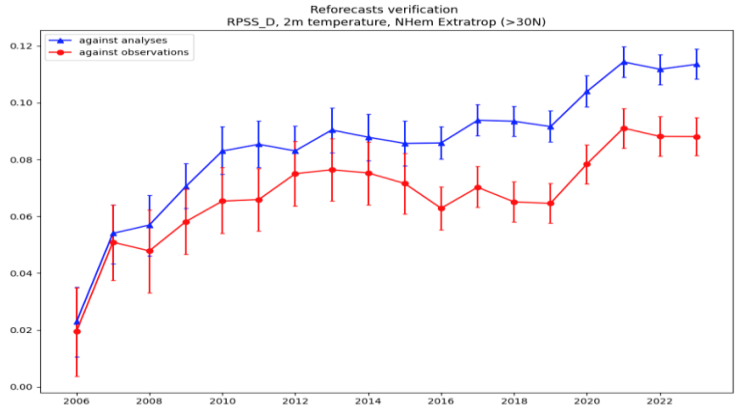


Madden Julian Oscillation (MJO)

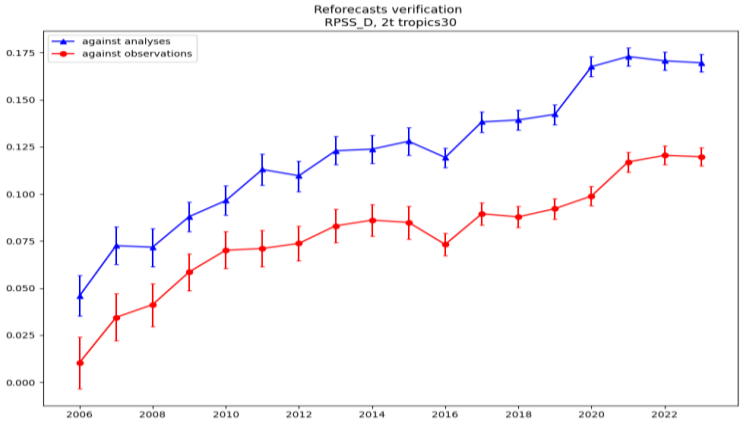


Week 3 2-metre temperature

Ranked probabilistic skill Score



Tropics



Significant Improvements in recent years. Gain of 2-weeks of MJO predictive skill over the past 20 years!

Using AI/ML to improve sub-seasonal Forecasts

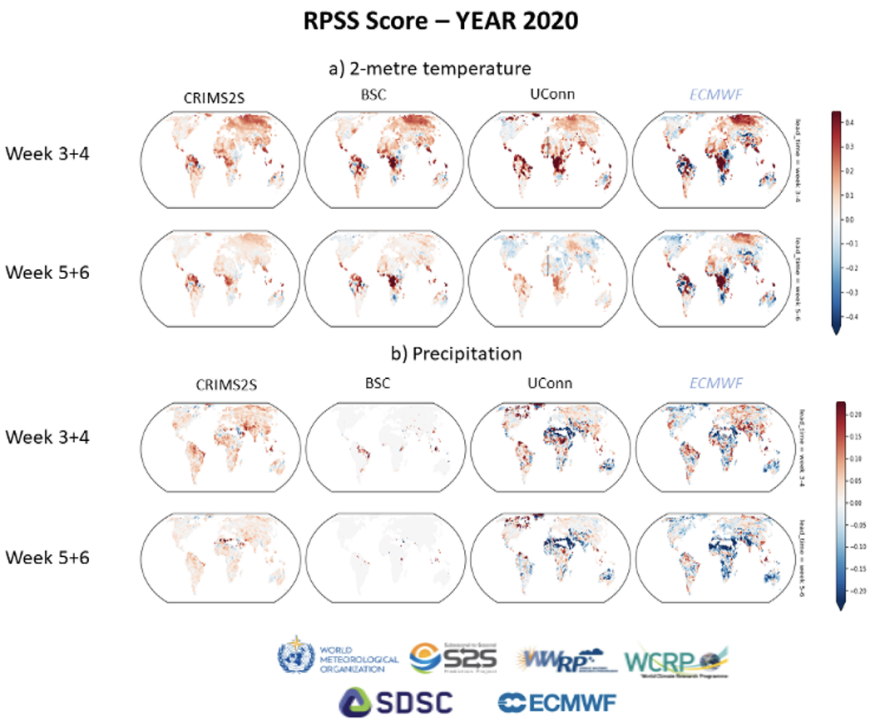
The WMO S2S AI/ML Challenge

Challenge: Provide forecasts of near surface temperature and precipitation for weeks 3+4 and 5+6 more skilful than ECMWF operational forecasts for the year 2020.

- Hosted by Swiss Data Science Center at ETH Zürich, **with ECMWF support through the new European Weather Cloud for data access to S2S forecasts, the use the CliMetLab software and the provision of virtual machines to some participants from developing countries**.
- Timeline: June-November 2021
- **All codes and forecasts are open source** to foster community learning on AI/ML methods for S2S
- 30k Swiss Francs prize from WMO

Outcome of the competition:

- 49 registered teams
- 5 teams succeeded in providing better forecasts than the Benchmark (ECMWF S2S operational forecasts)
- Top 3 teams got rewarded a prize.



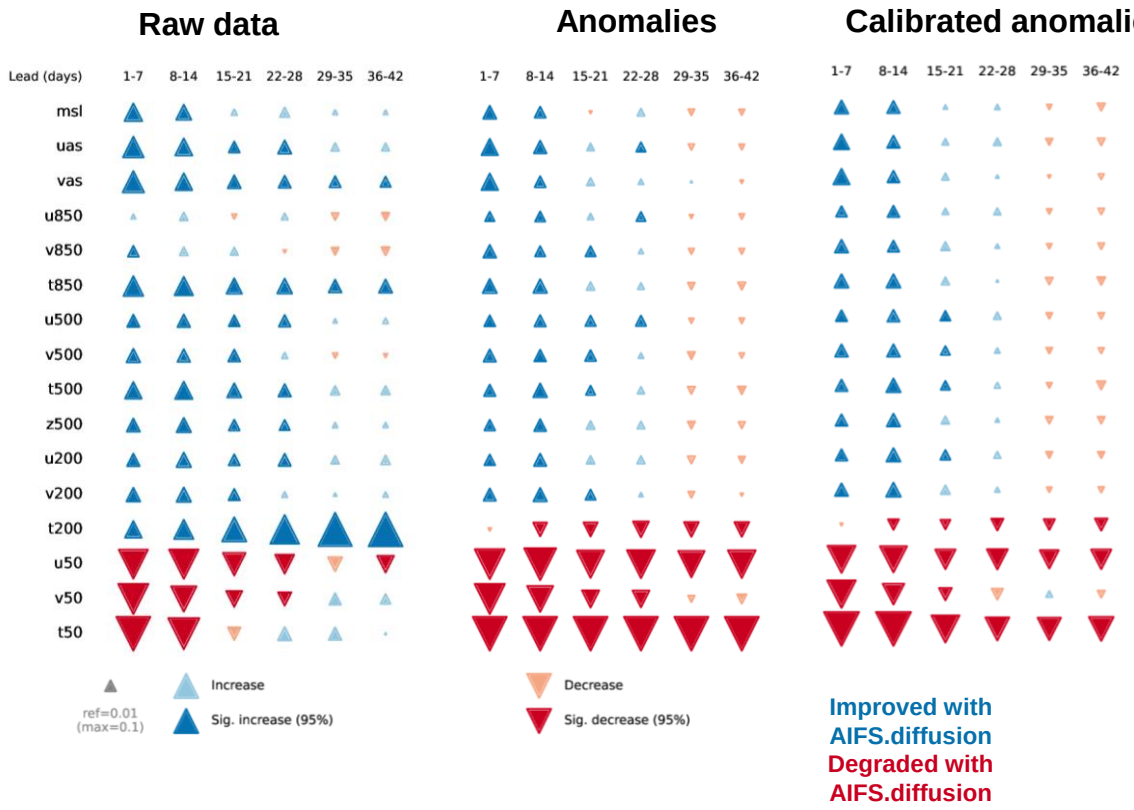
New AI/ML Sub-seasonal forecast competition in 2025!

Preliminary evaluation of AIFS.diffusion for S2S timescales

Reforecasts from Simon Lang using initial version of AIFS.diffusion (no IniPert) trained on ERA5 for medium-range and applied to S2S timescales without modification

Reforecast configuration
- AIFS.diffusion vs IFS (2023 47r2/48r1)
- 8 perturbed members.
- 46-days, twice per week.
- 2018-2022.

ΔfCRPSS: NHEM



AIFS.diffusion mean state is very good, sufficient to improve fCRPSS of raw forecasts relative to IFS (2023).

Skill of anomalies (or calibrated anomalies) is very similar at S2S lead times.

Stratosphere
AIFS.diffusion mean state is good but anomaly forecasts are significantly worse than IFS.

MJO (not shown)
AIFS.diffusion MJO correlation skill slightly better than IFS.2023 during days 1-15 and similar afterwards.

After in-sample statistical calibration that enforces perfect reliability in terms of total variance and spread-error ratio.

ECMWF

Chris Roberts

Conclusions

- SSTs, sea ice , Soil moisture, stratospheric initial conditions and MJO are sources of predictability at the intra-seasonal time scale.

- The monthly forecasting system produces forecasts for days 12-18 that are generally better than climatology and persistence of day 5-11. Beyond day 20, the monthly forecast is marginally skilful. For some applications and some regions, these forecasts could however be of some interest.

- Extended-range forecasts are improving!

- AI/ML likely to improve extended-range even further