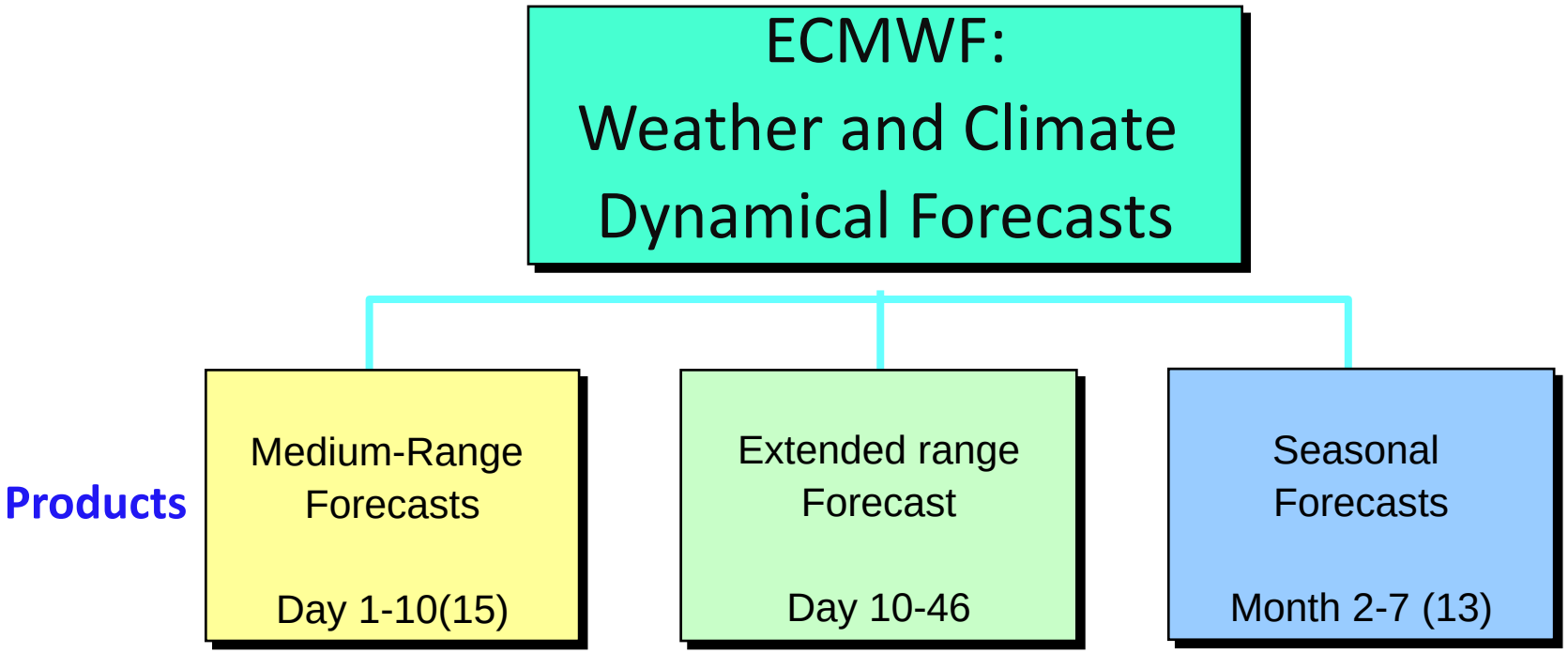
Extended-range Forecasting at ECMWF

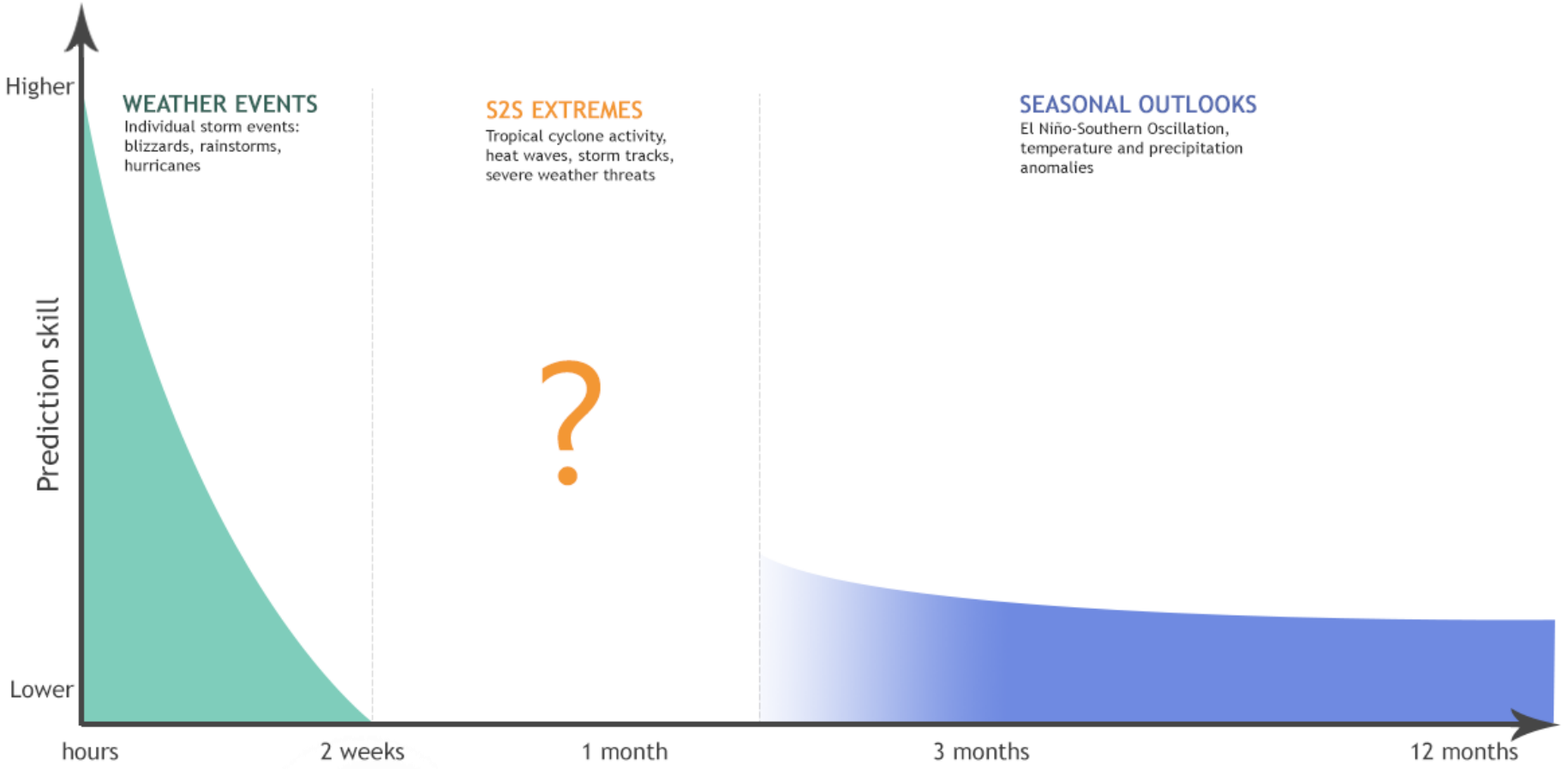
Frédéric Vitart

European Centre for Medium-Range Weather Forecasts

Forecasting systems at ECMWF



Sub-seasonal to Seasonal prediction



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

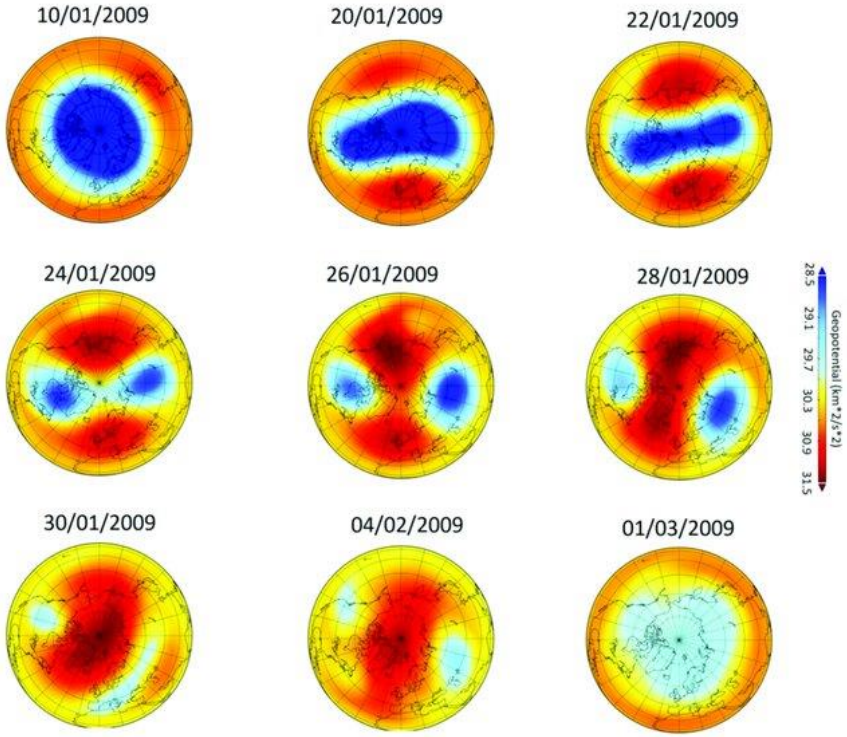
Sources of sub-seasonal predictability

- Madden-Julian Oscillation
- Extra-tropical modes (weather regimes: blockings, NAO, PNA, SAM..)
- Stratospheric Sudden Warming
- Quasi-Biennal Oscillation
- ENSO
- Slowing varying processes: Soil moisture/vegetation, snow, sea ice, ocean SSTs/heat content
- Chemistry: Ozone, aerorols…
- Others?

Sub-seasonal skill is strongly flow-dependent

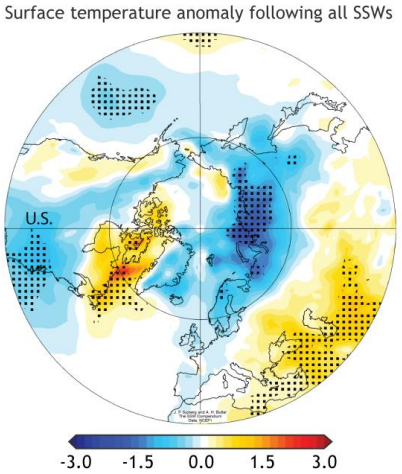
Sudden Stratospheric warming

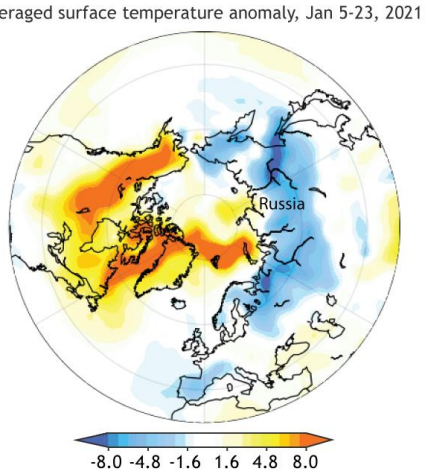
2009 SSW event



Kozubeck et al, 2020.

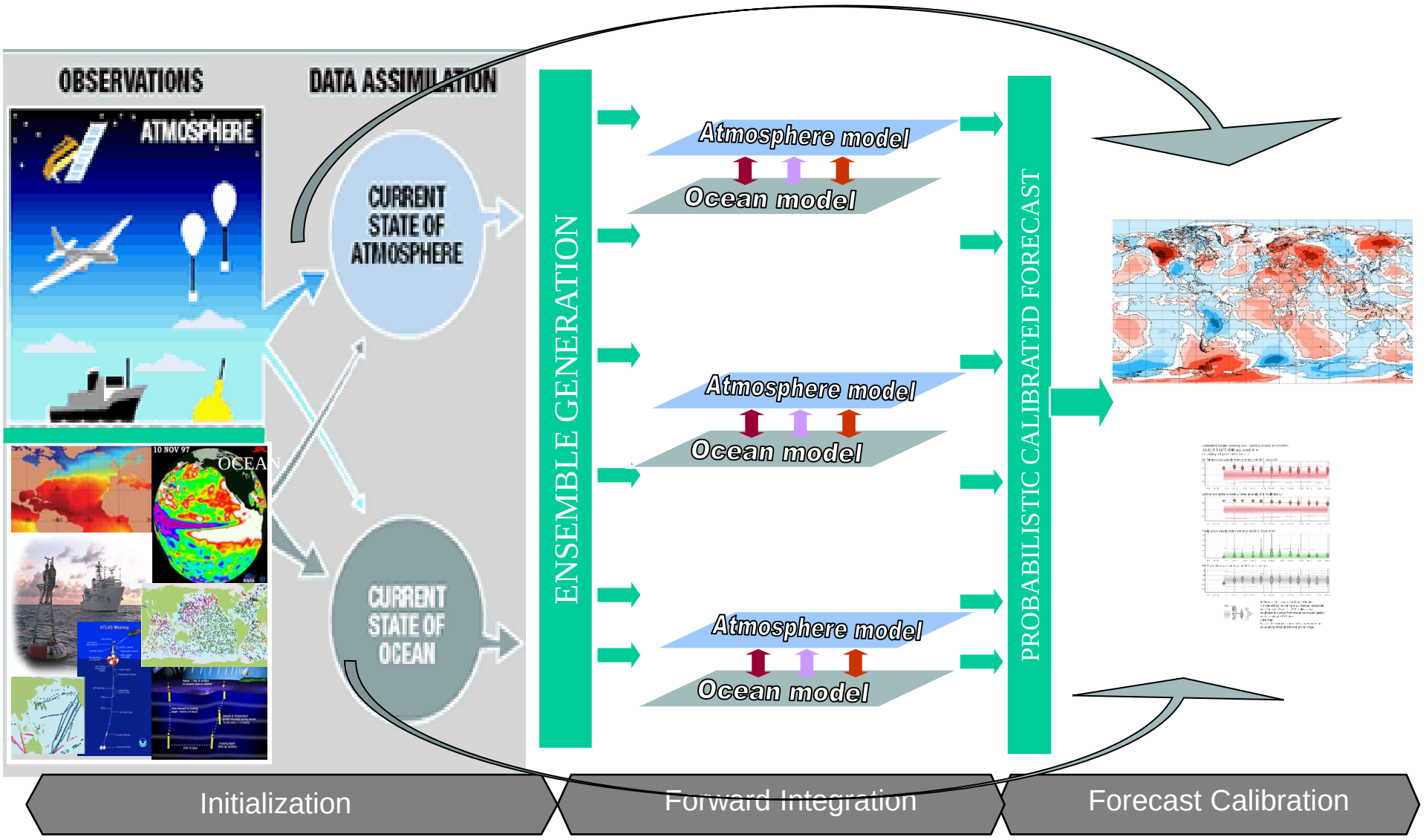
Impact on surface temperature over europe





How are S2S forecasts produced?

End-To-End forecasting System



ECMWF extended-range forecasts

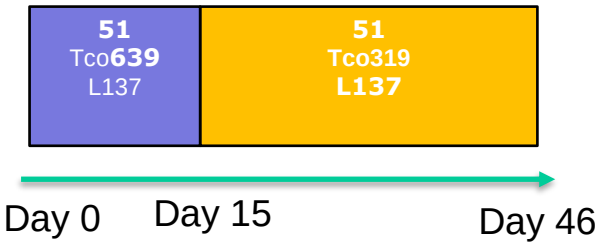
- A 101-member ensemble is integrated for 46 days every day at 00Z
- Atmospheric component: IFS with the latest operational cycle and with a resolution TCo319L137
- Ocean-atmosphere coupling from day 0 to NEMO (about 1/4 degree) every hour.

Initial conditions:

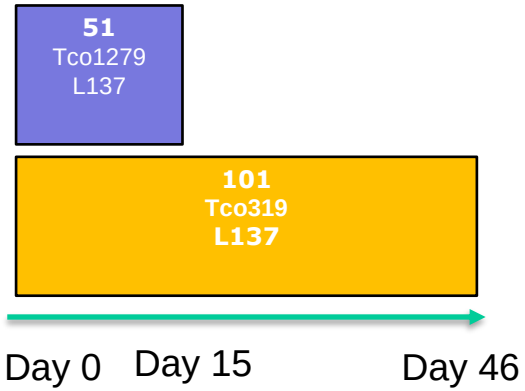
- Atmosphere: Operational 4-D var analysis + SVs+ EDA perturbations
- Ocean: 3D-Var analysis (NEMOVAR) + wind stress perturbations

ECMWF extended-range forecasts

Previous configuration



Current configuration (48R1)

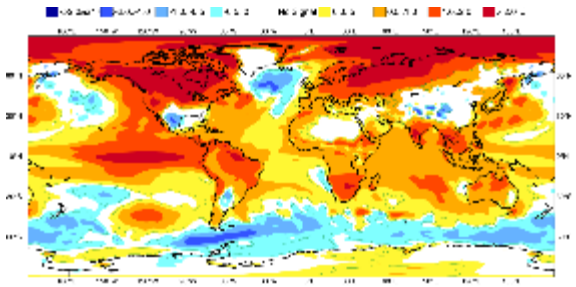


Hres	Vres	Time Step	RT Ens per week	RFC Ens per week	Fct length	Precision
Tco319	137	1200s	102	440	Day 14-46	Single
Tco319	137	1200s	707	440	Day 0-46	Single

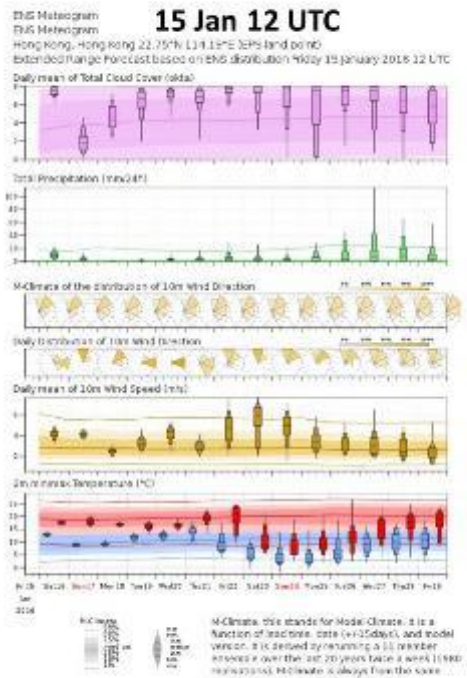
ECMWF products

From medium-range to seasonal to extended range

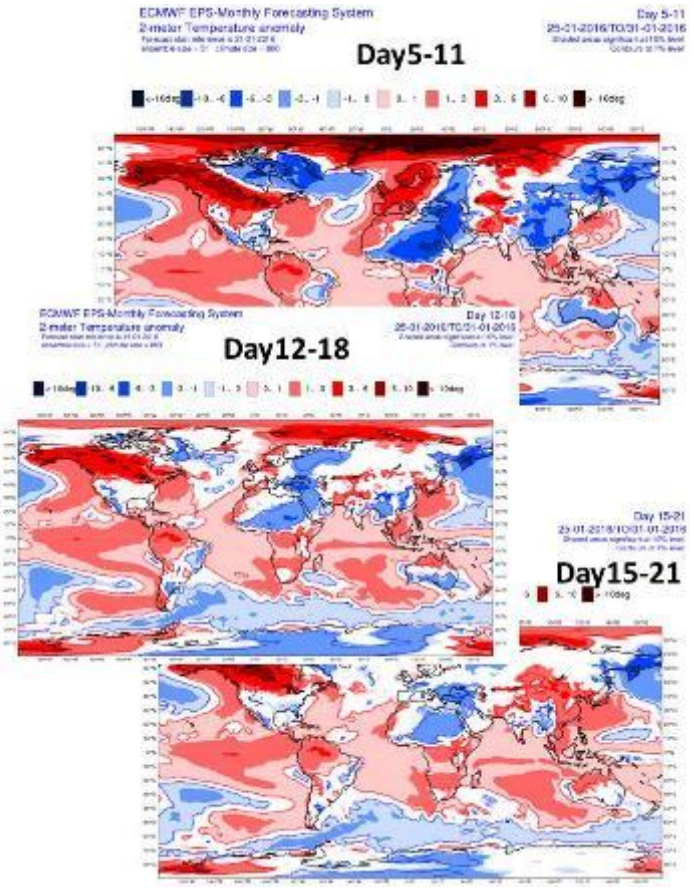
Seasonal Forecast



Medium-range



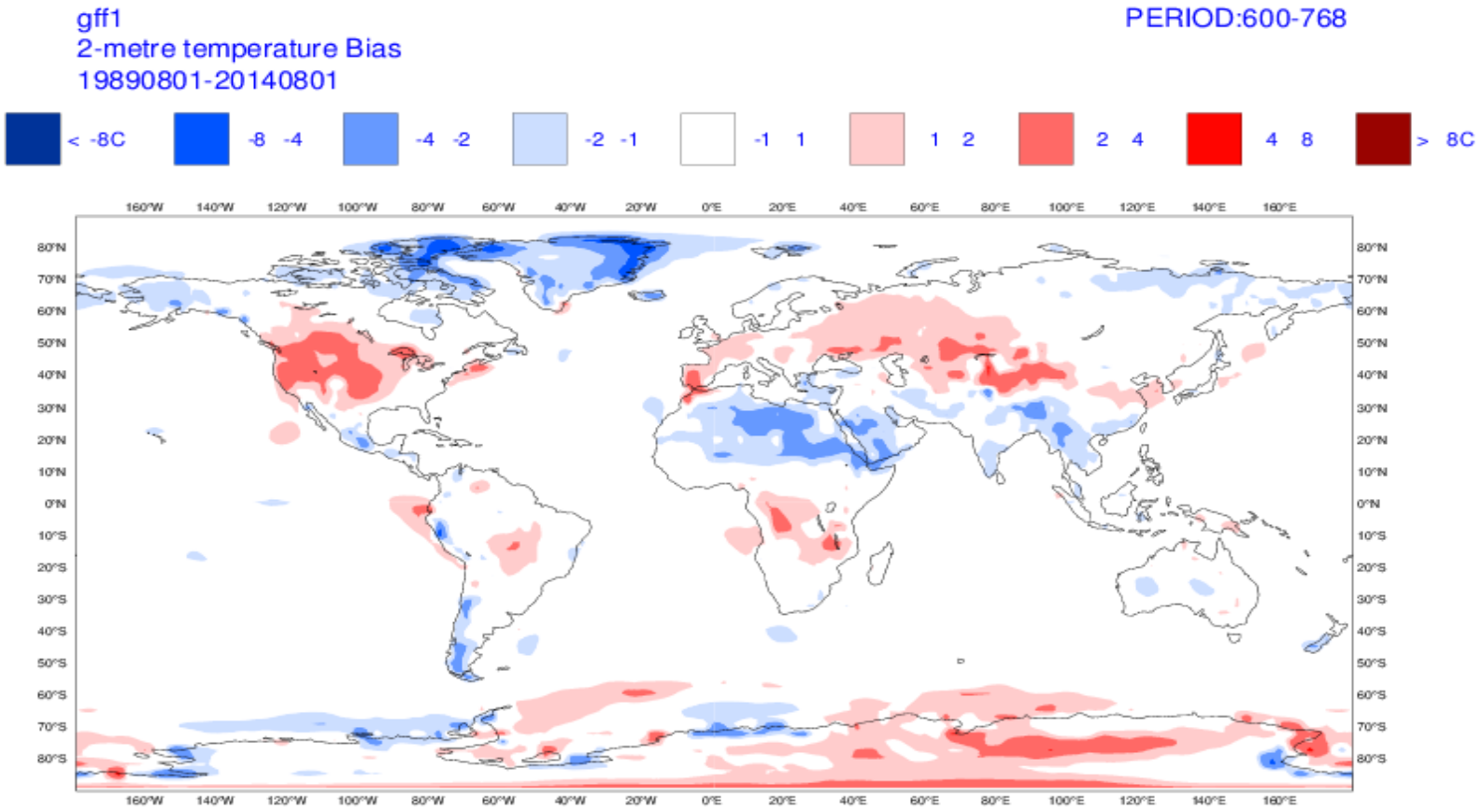
Extended-range



European Centre for Medium-Range Weather Forecasts

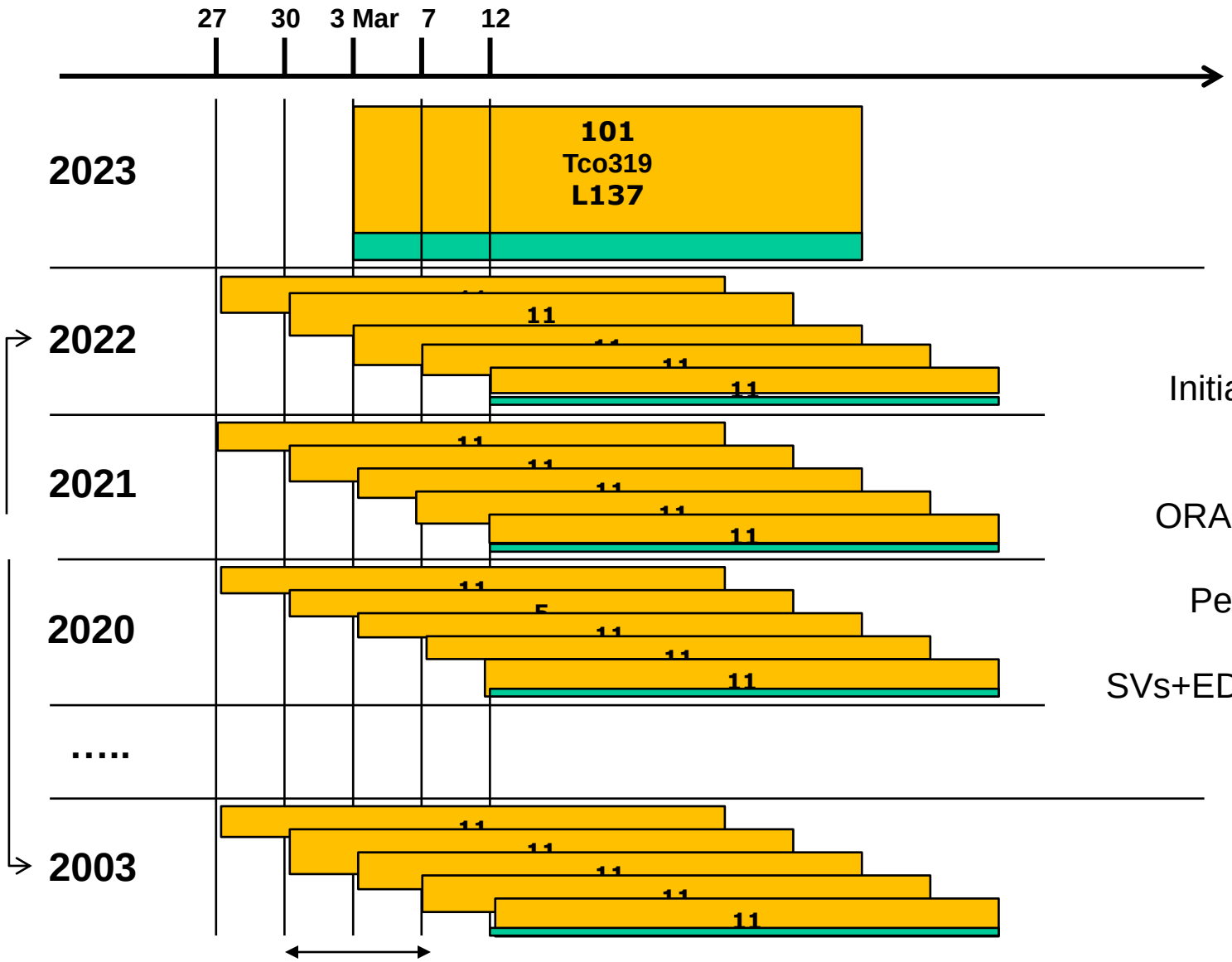
Extended-range forecast biases

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:

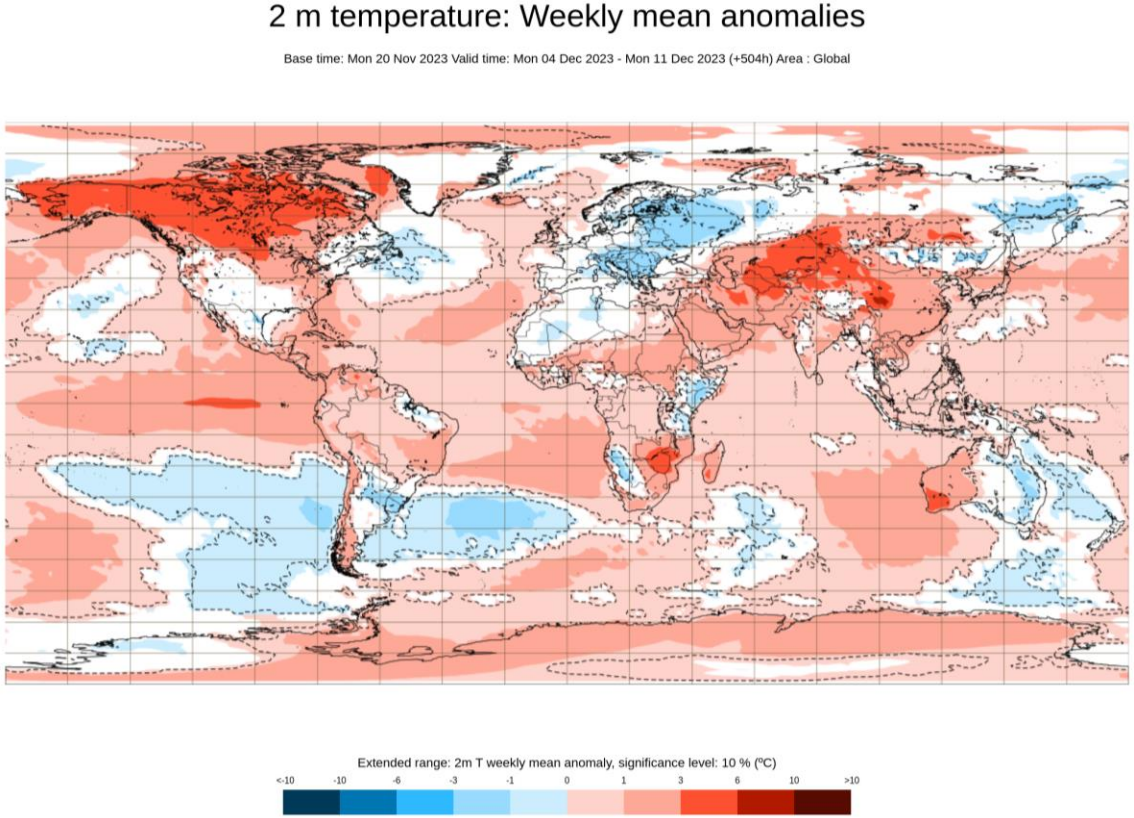
10 perturbed + 1 control fc on fixed days of the month, **every 2 days,** over past 20 years 1/3/5/7/9/11/13/15/17/19/21/23/25/27/29 (excluding 29 Feb)

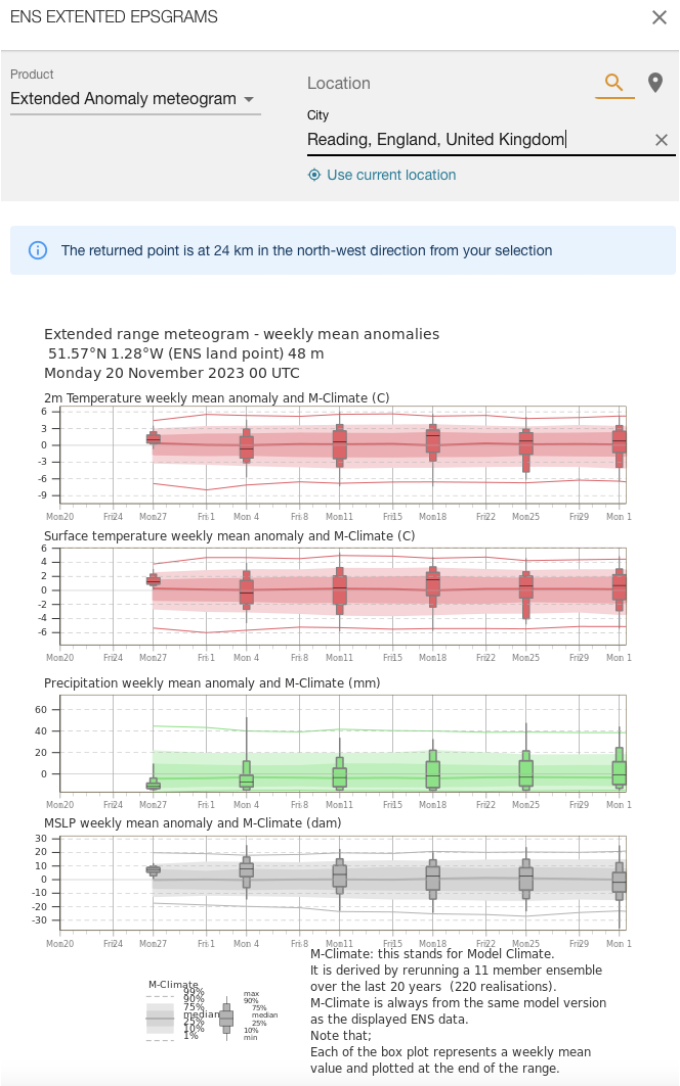
Medium-range:

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

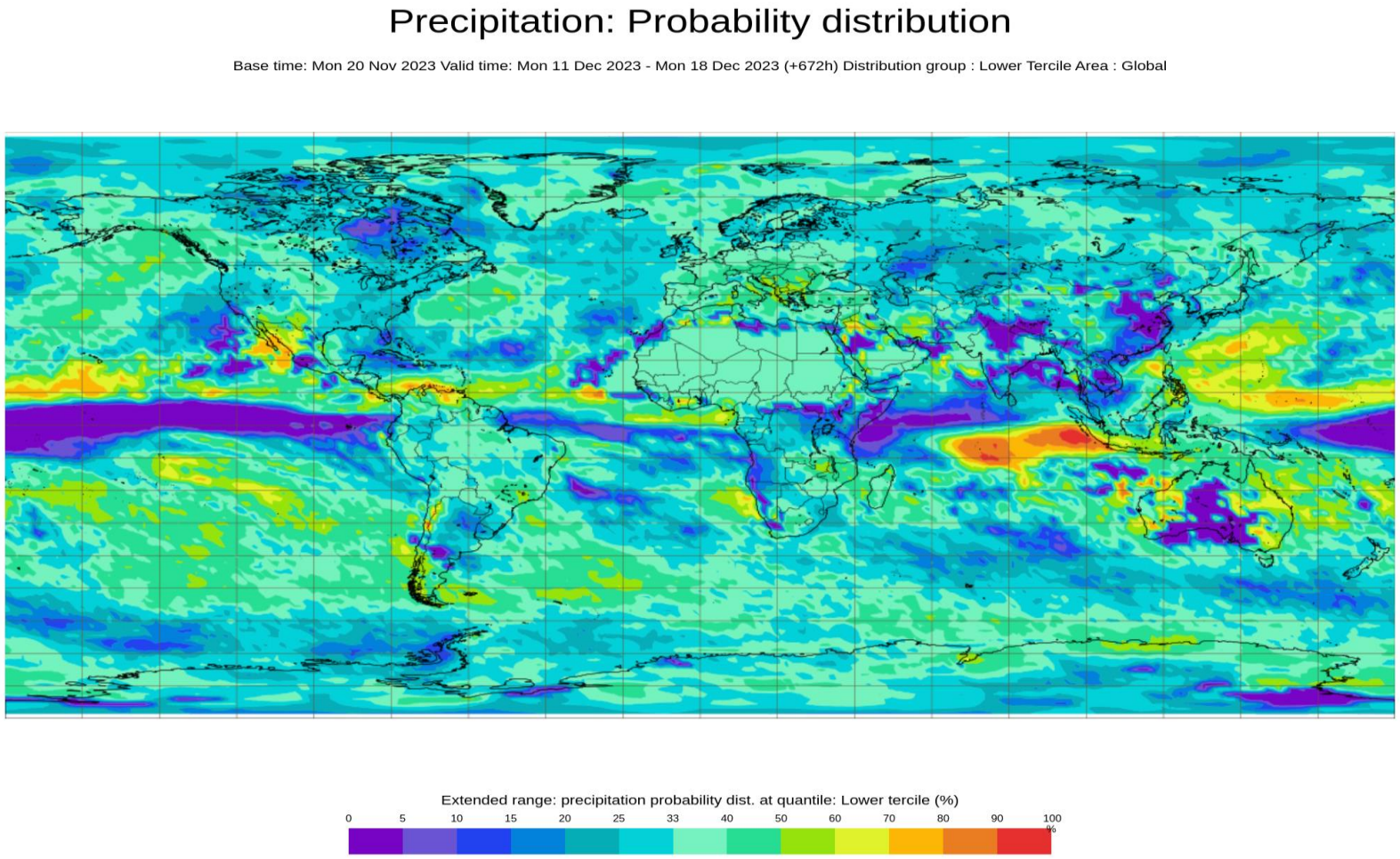




Anomalies (temperature, precipitation..)

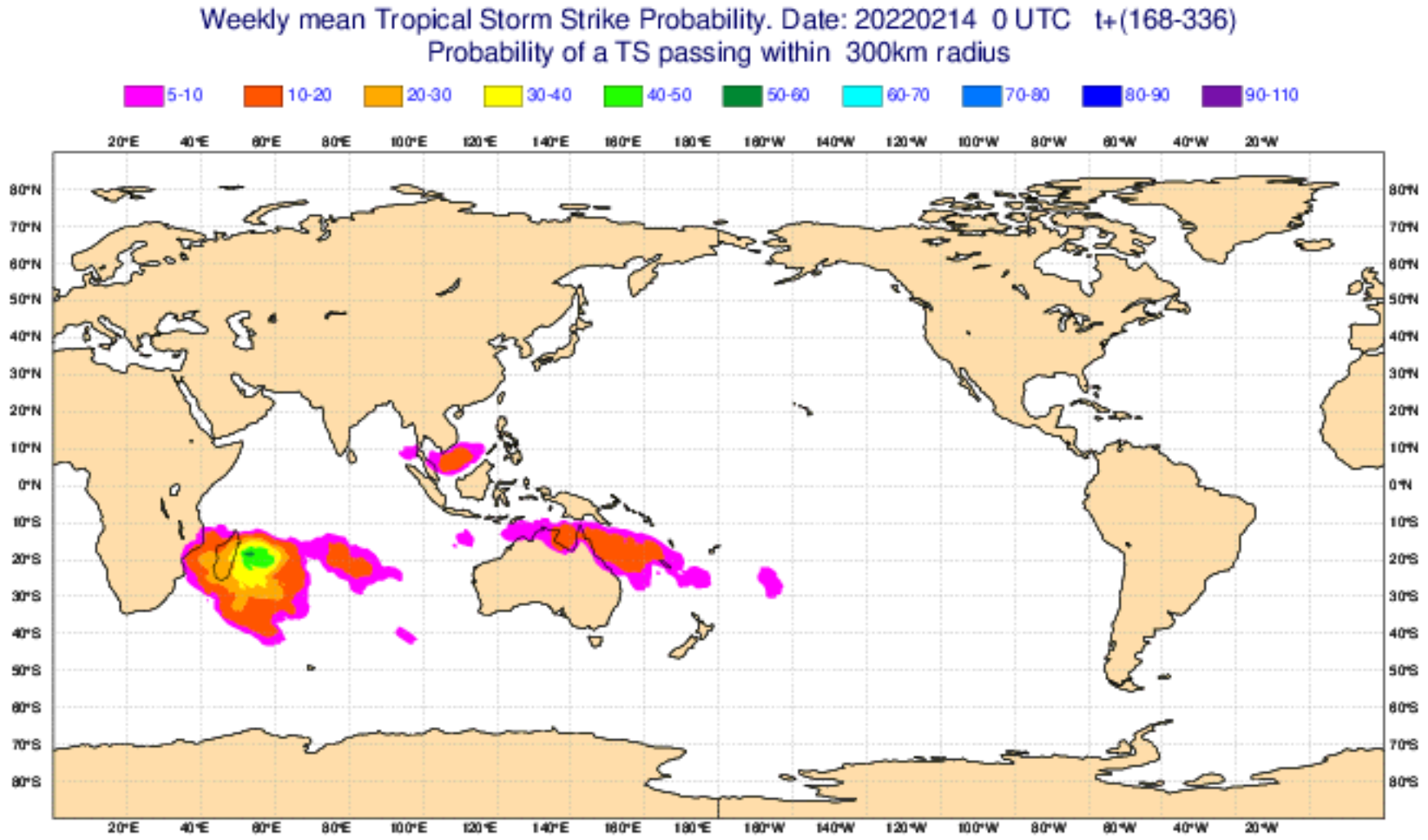
Extended-range Real-time Forecasts

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

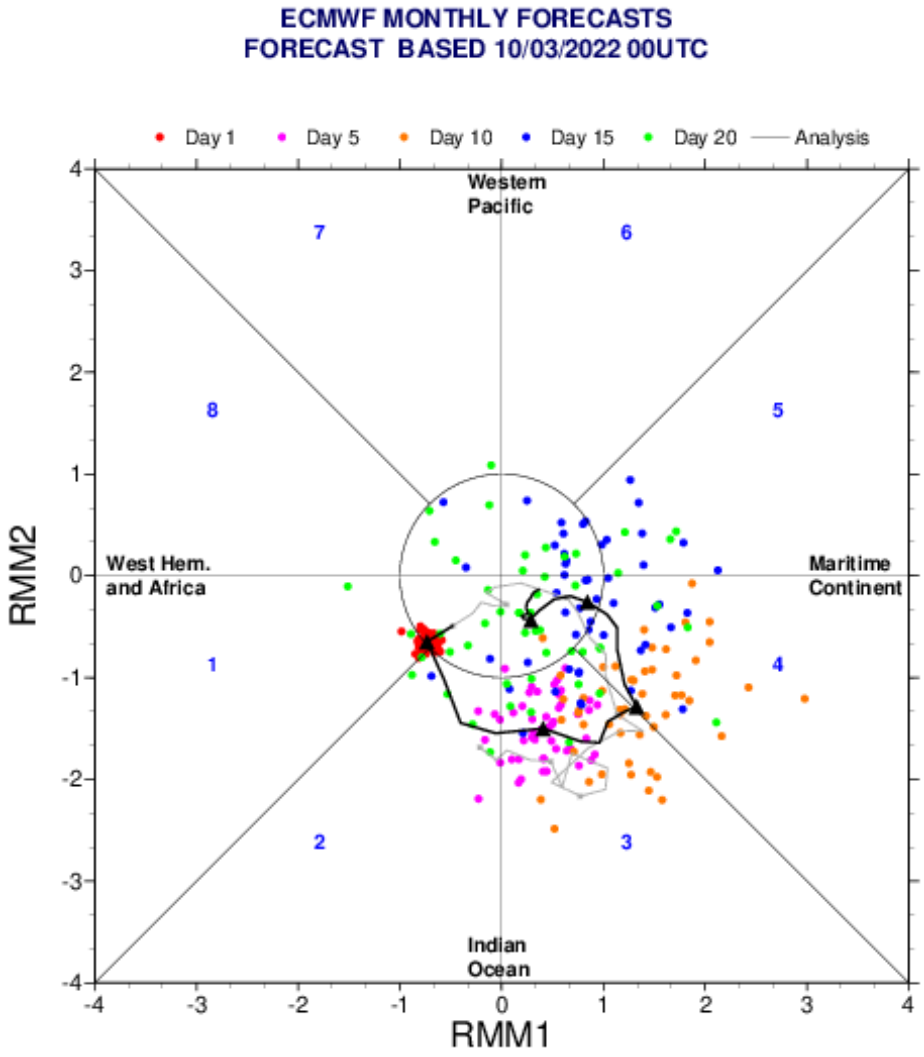


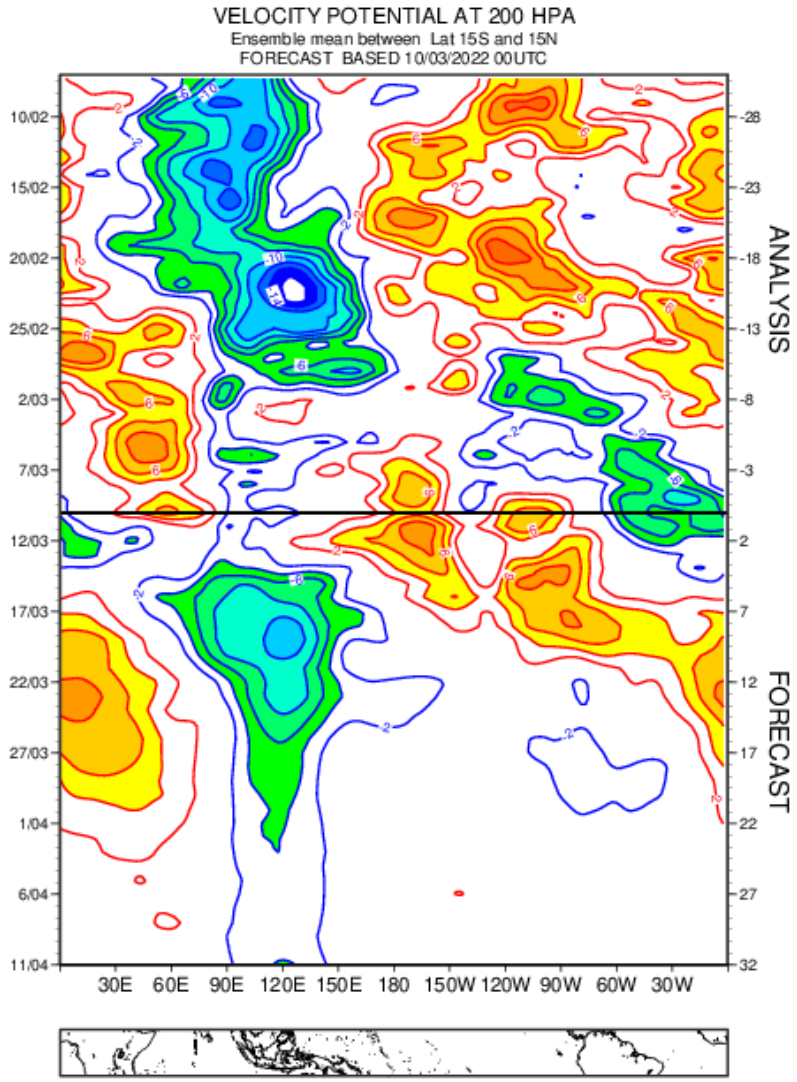
Probabilities (temperature, precipitation..)

Tropical cyclone activity



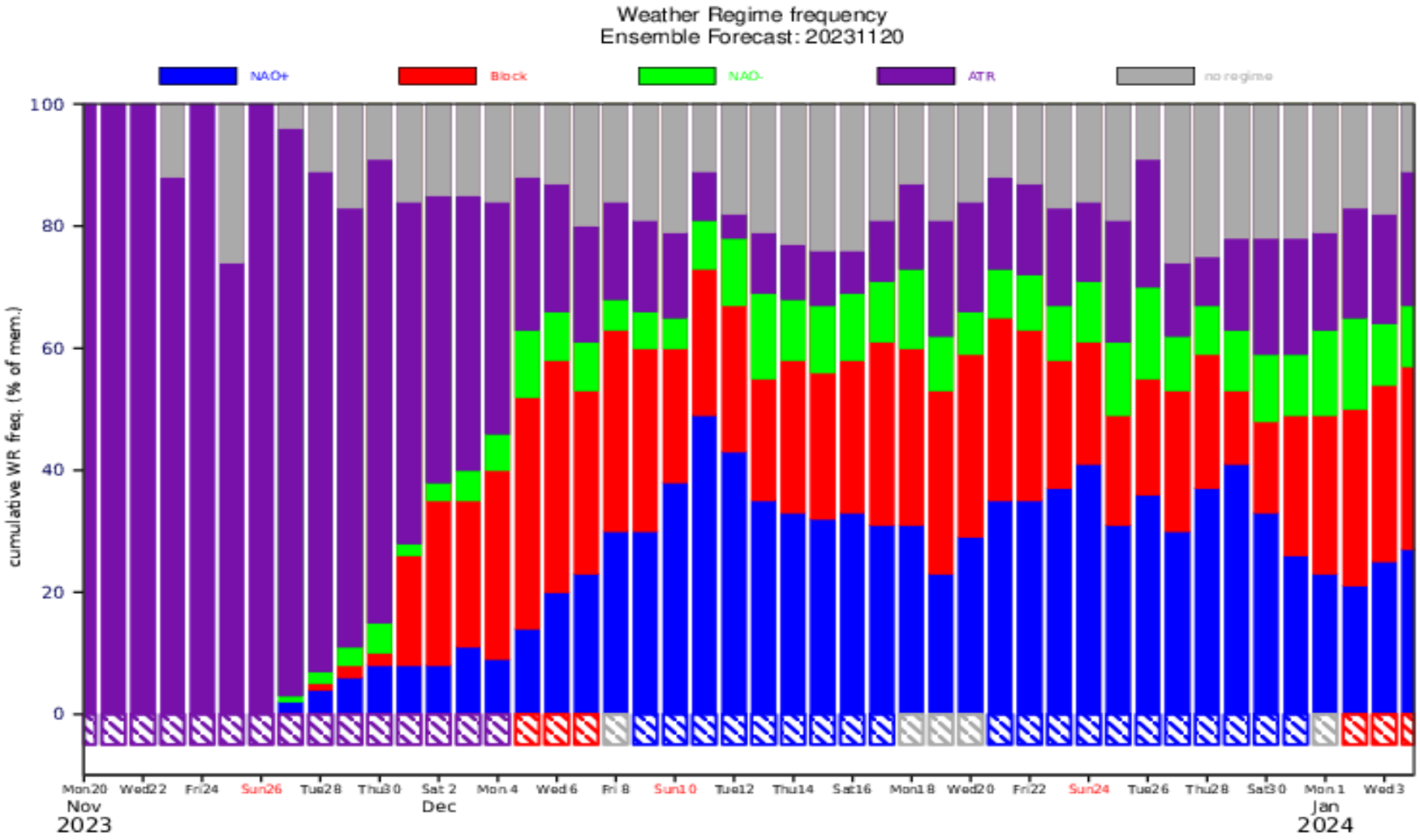
MJO Forecasts





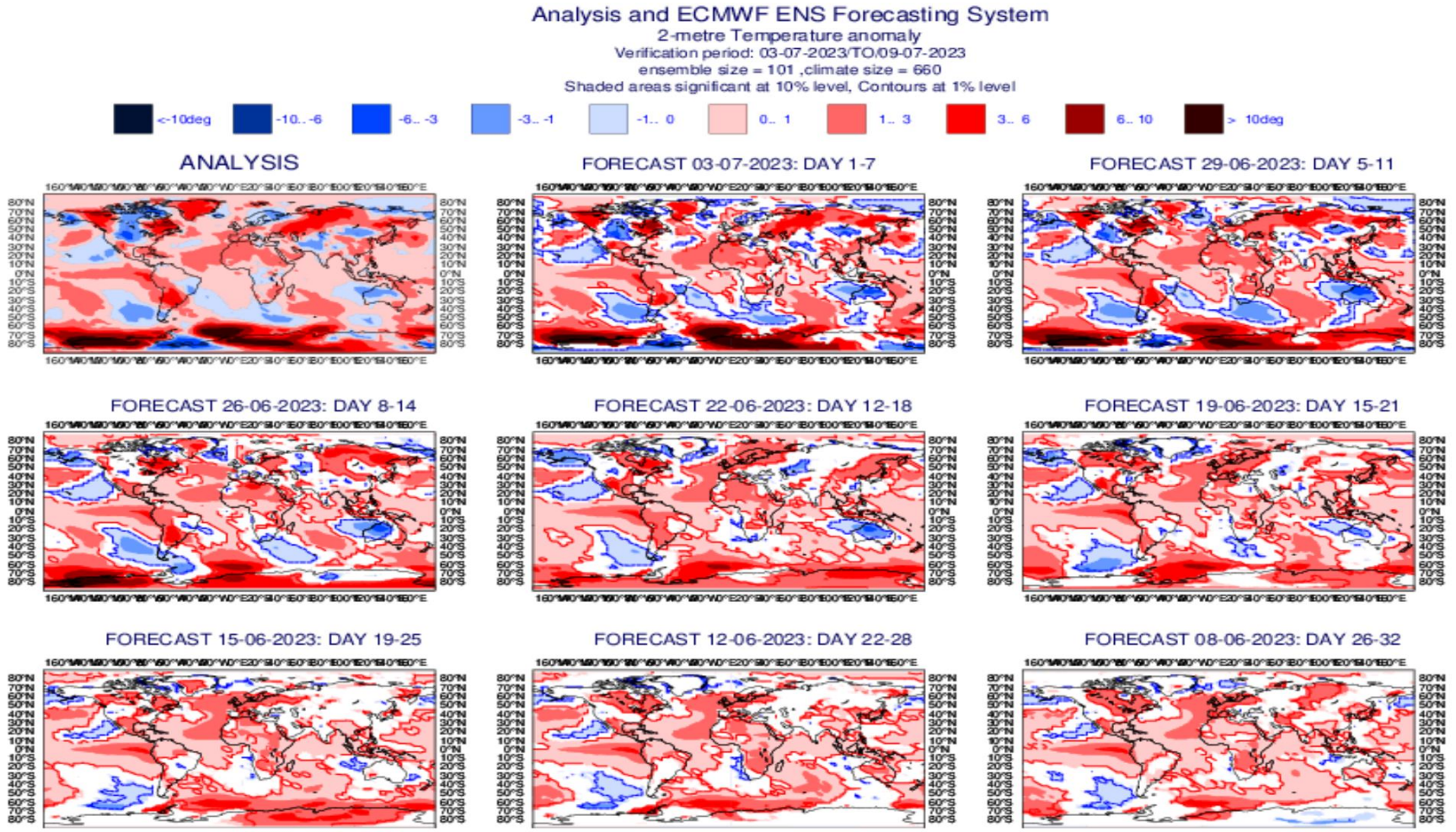
Euro-Atlantic Weather regimes

Weather regimes probabilities - Extended range forecast



ECMWF

Verification

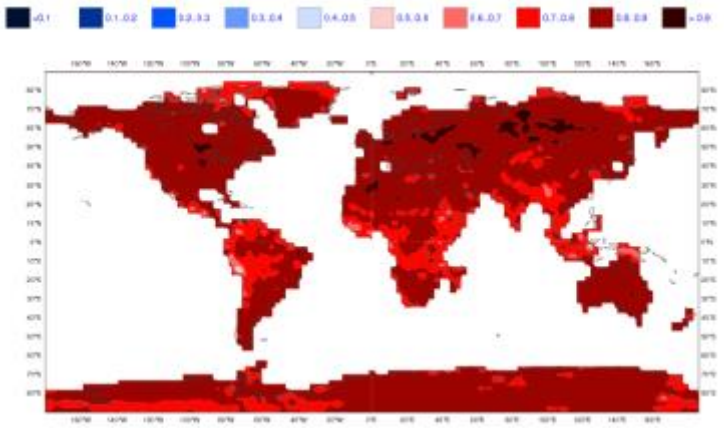


ECMWF

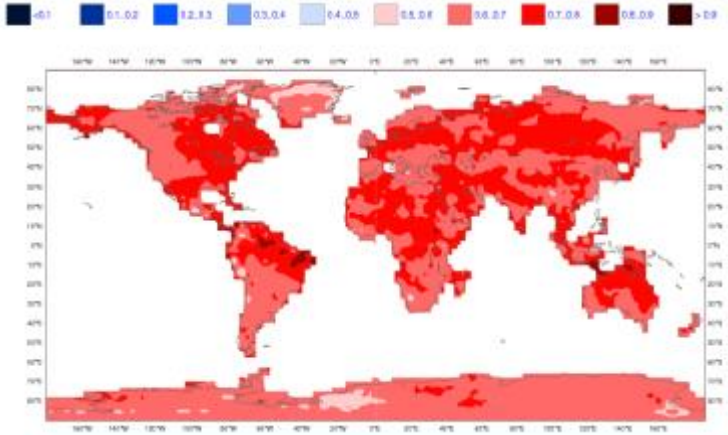
Skill of the ECMWF Monthly Forecasting System

ROC score: 2-meter temperature in the upper tercile

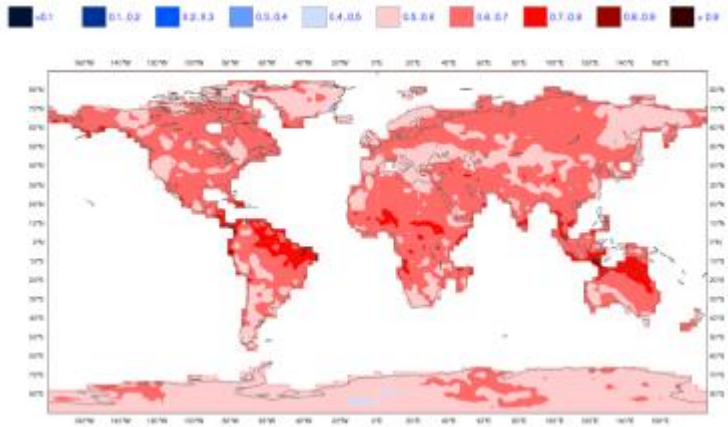
Day 5-11



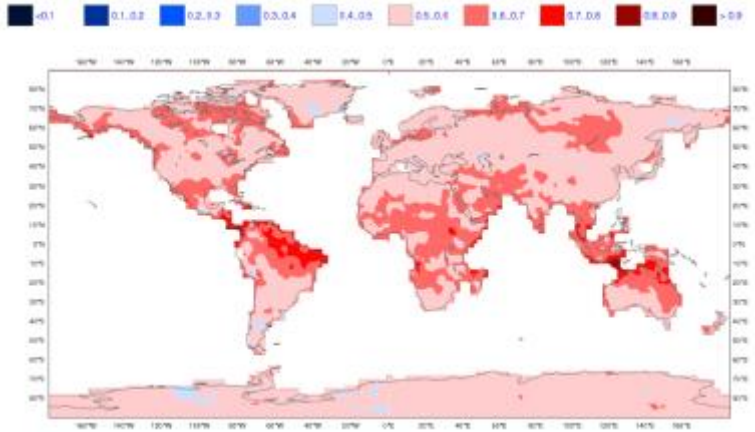
Day 12-18



Day 19-25

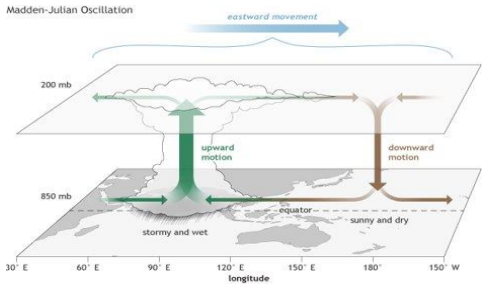


Day 26-32

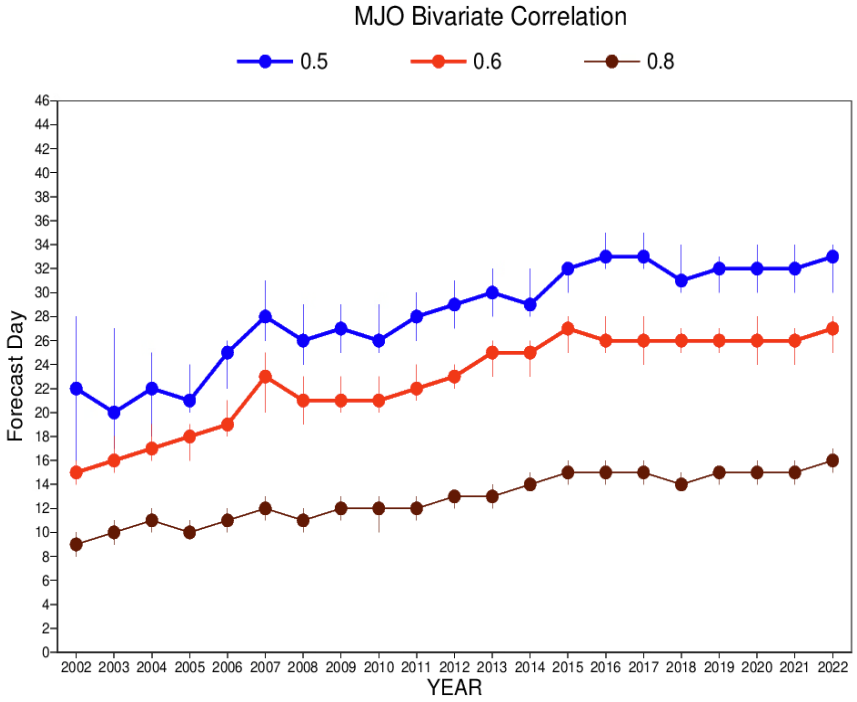


S2S Forecast skill: “Are we progressing?”

ECMWF Forecast Skill

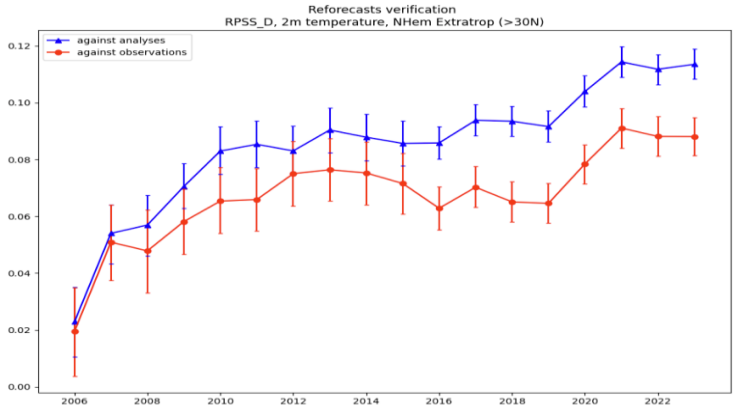


Madden Julian Oscillation (MJO)

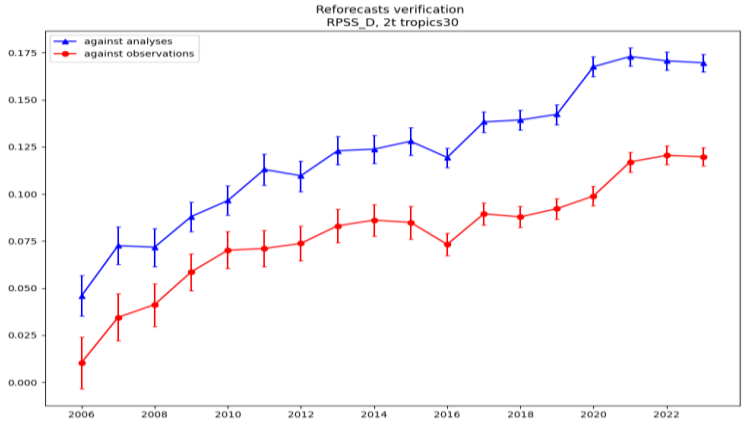


Week 3 2-metre temperature

Ranked probabilistic skill Score



Tropics



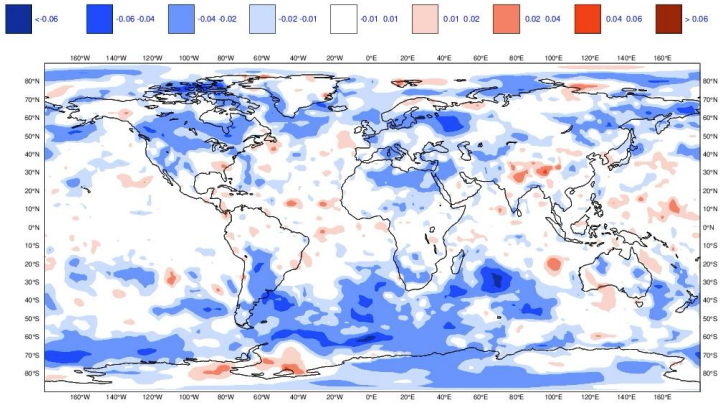
Significant Improvements in recent years. Gain of 2-weeks of MJO predictive skill over the past 20 years!

Creating lagged ensembles?

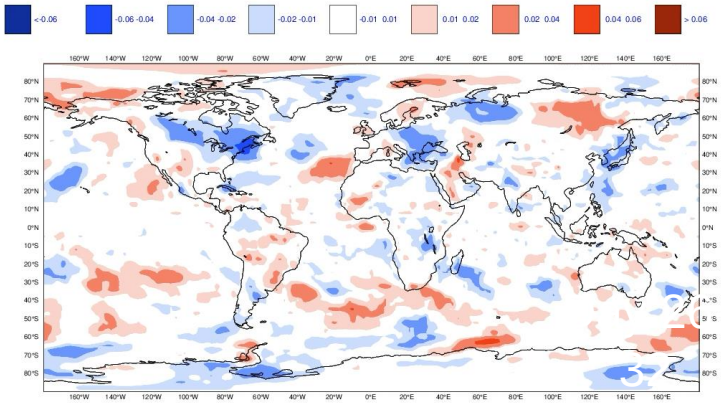
Impact of combining 101 ensemble member at day 0 with 101 member at day -1 to create a 202-member ensemble.

2m-temperature CRPSS difference (lagged-burst)

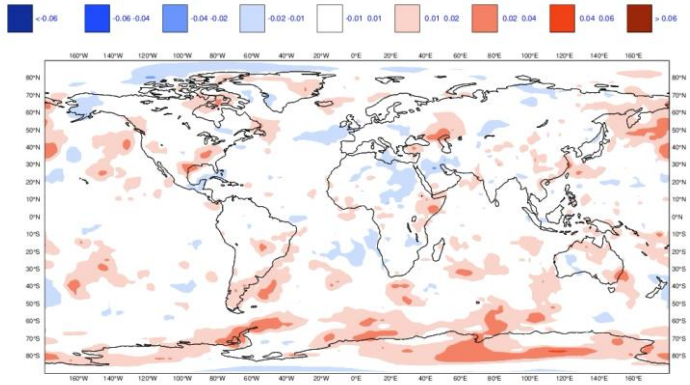
Week 1



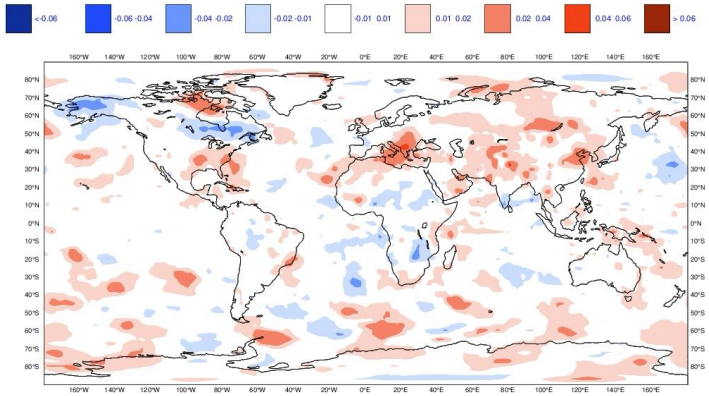
Week 2



Week 3



Week 4



Blue: lagged ensemble is worse

Red: lagged ensemble improves skill

Using AI/ML to improve extended-range Forecasts

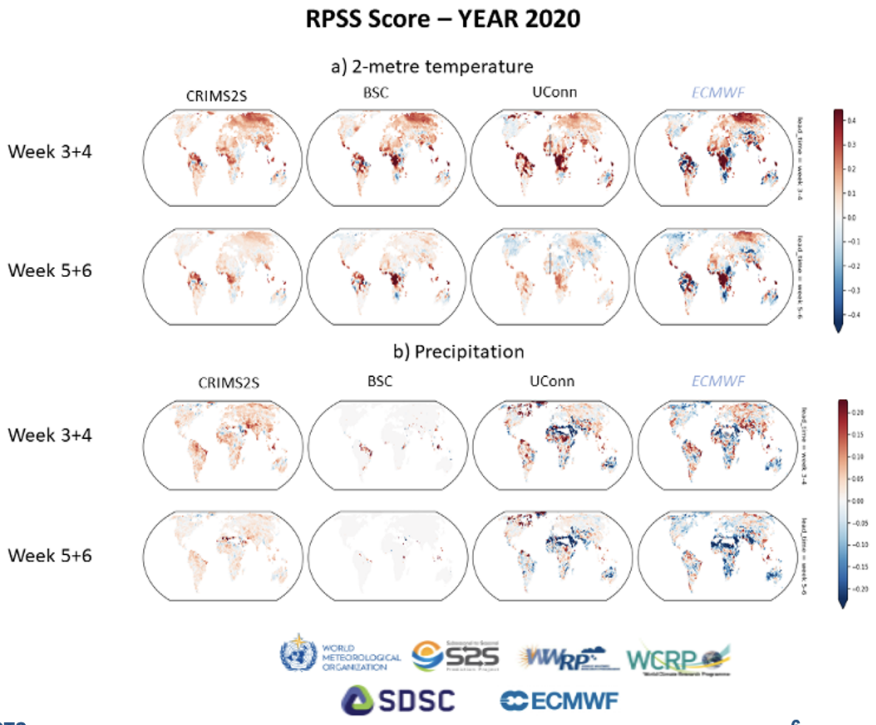
The WMO S2S AI/ML Challenge

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.



ECMWF EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS

6

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 might help improve extended-range even further through improved postprocessing/calibration.