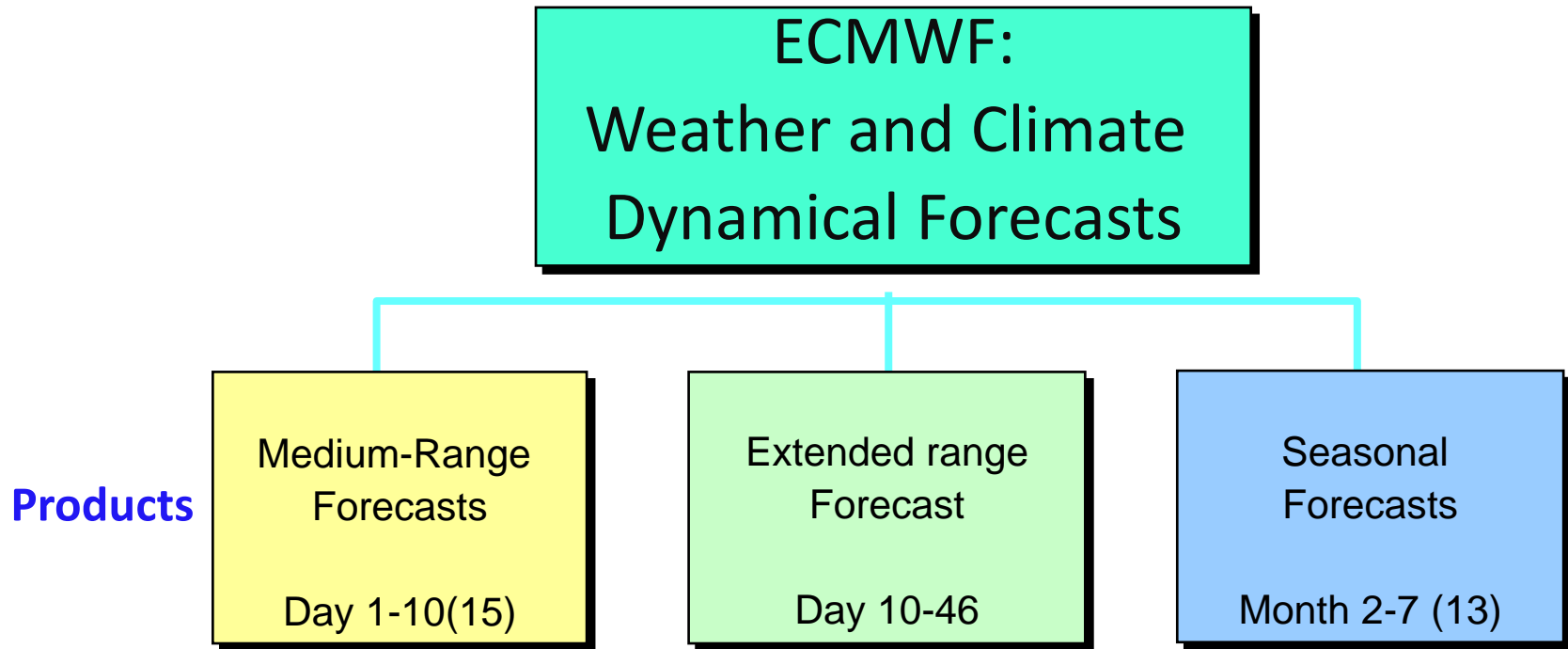


Extended-range Forecasting at ECMWF

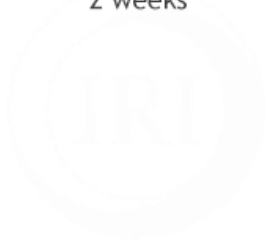
Frédéric Vitart

European Centre for Medium-Range Weather Forecasts

Forecasting systems at ECMWF



Sub-seasonal to Seasonal prediction



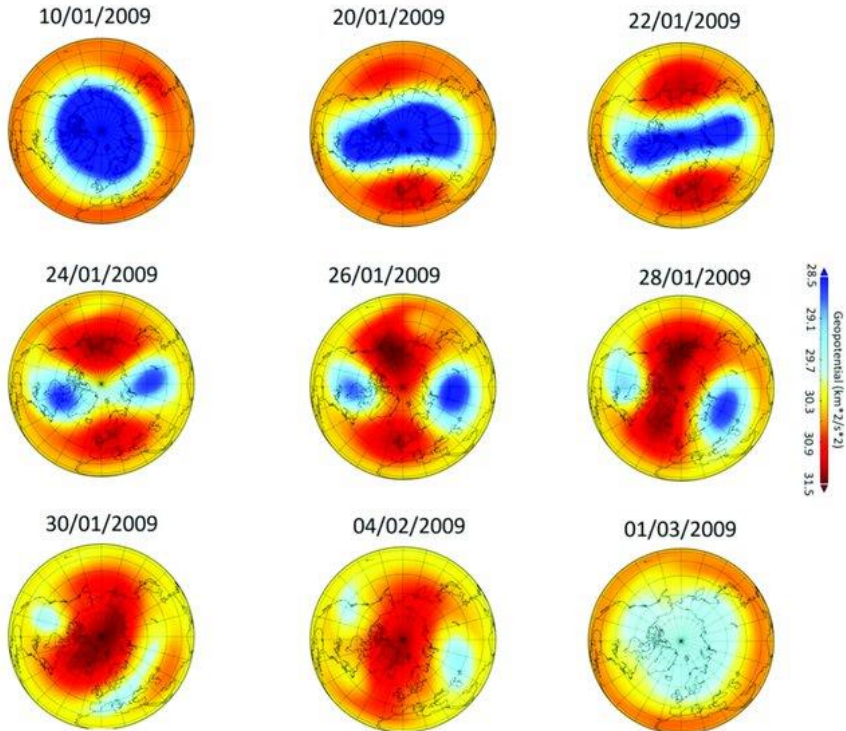
Sources of sub-seasonal predictability

- Madden-Julian Oscillation
- Extra-tropical modes (weather regimes: blockings, NAO, PNA, SAM..)
- Stratospheric Sudden Warming
- Quasi-Biennial 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

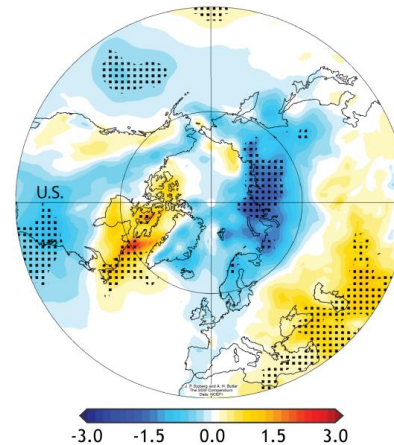
Sudden Stratospheric warming

2009 SSW event

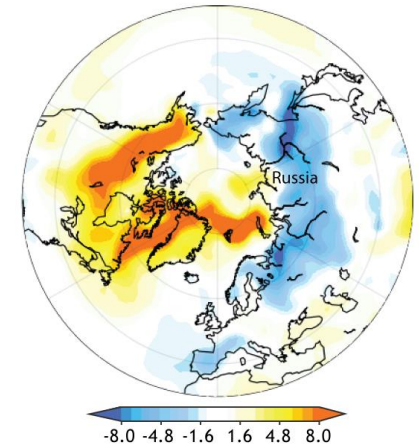


Impact on surface temperature over europe

Surface temperature anomaly following all SSWs



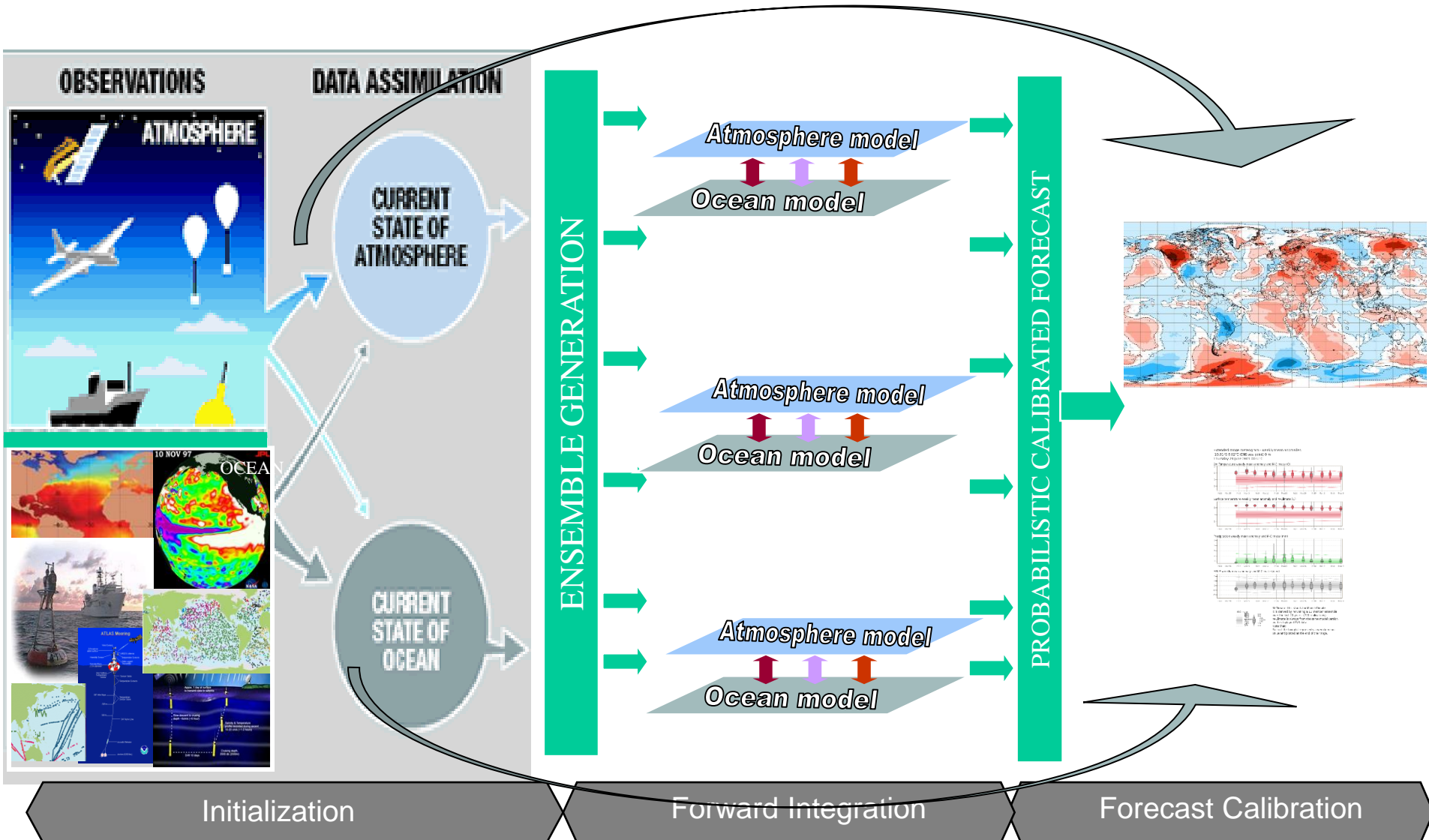
Averaged surface temperature anomaly, Jan 5-23, 2021



Kozubeck et al, 2020.
Available via license: [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/)

How are S2S forecasts produced?

End-To-End forecasting System



ECMWF extended-range forecasts

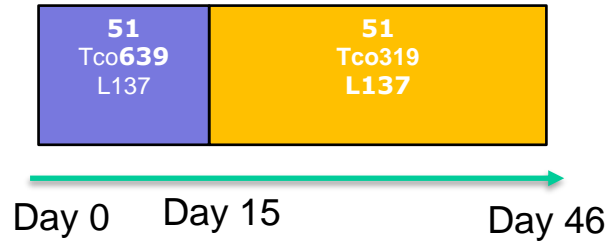
- A 101-member ensemble is integrated for 46 days every day at 00Z
- Atmospheric component: IFS with the latest operational cycle and with a resolution TCo319L137
- Ocean-atmosphere coupling from day 0 to NEMO (about 1/4 degree) every hour.

Initial conditions:

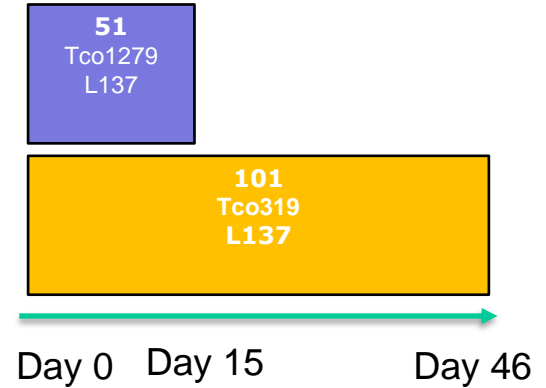
- Atmosphere: Operational 4-D var analysis + SVs+ EDA perturbations
- Ocean: 3D-Var analysis (NEMOVAR) + wind stress perturbations

ECMWF extended-range forecasts

Previous configuration



Current configuration (48R1)

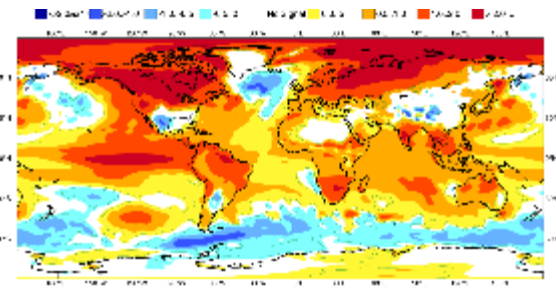


Hres	Vres	Time Step	RT Ens per week	RFC Ens per week	Fct length	Precision
Tco319	137	1200s	102	440	Day 14-46	Single
Tco319	137	1200s	707	440	Day 0-46	Single

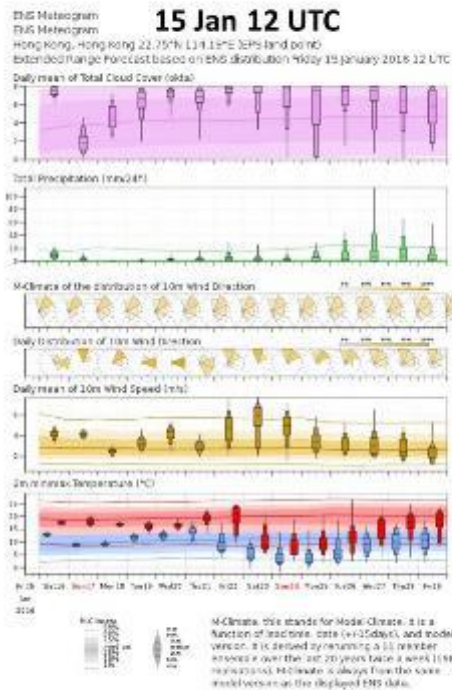
ECMWF products

From medium-range to seasonal to extended range

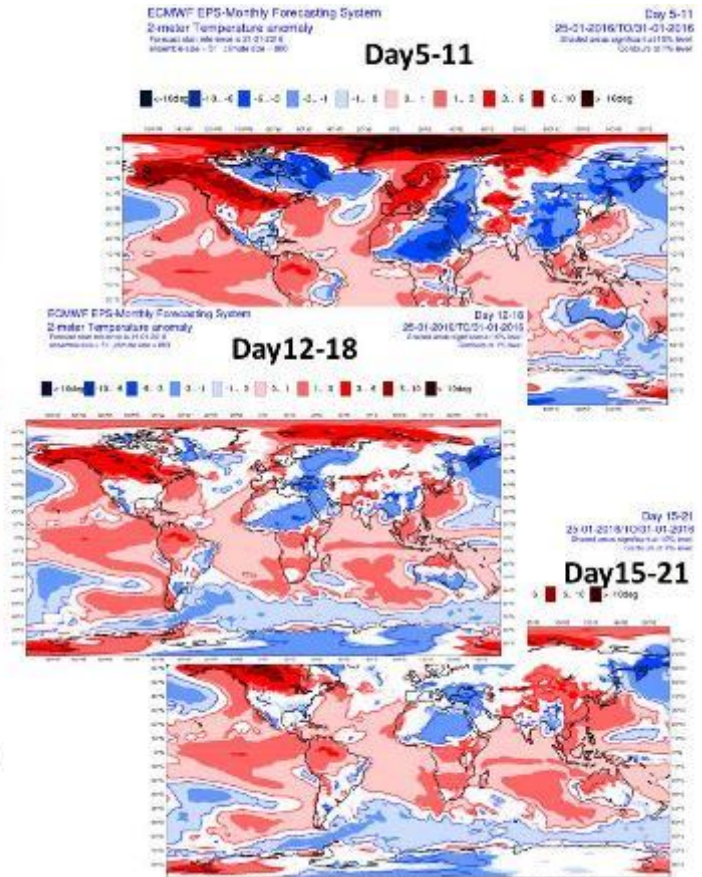
Seasonal Forecast



Medium-range



Extended-range



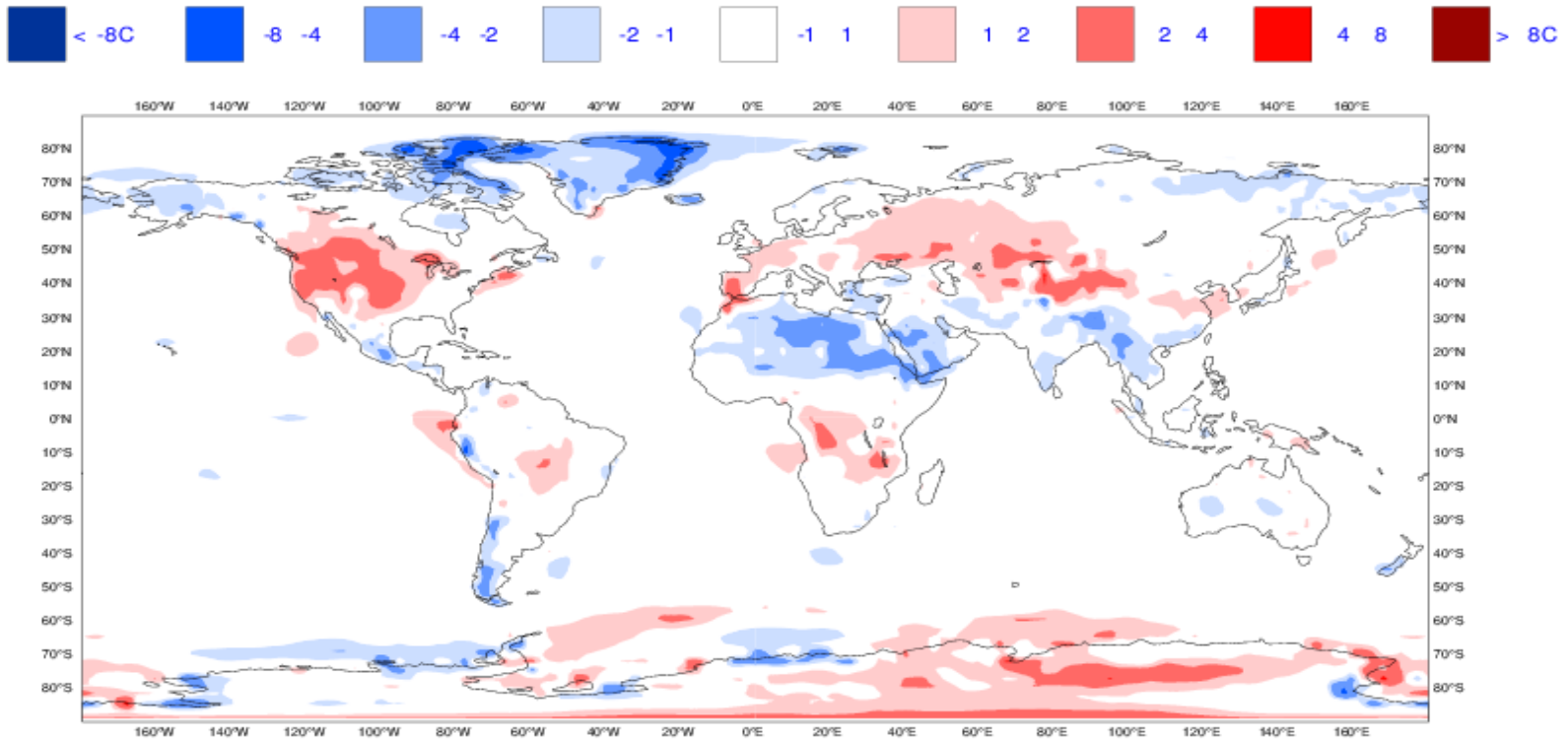
European Centre for Medium-Range Weather Forecasts

Extended-range forecast biases

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

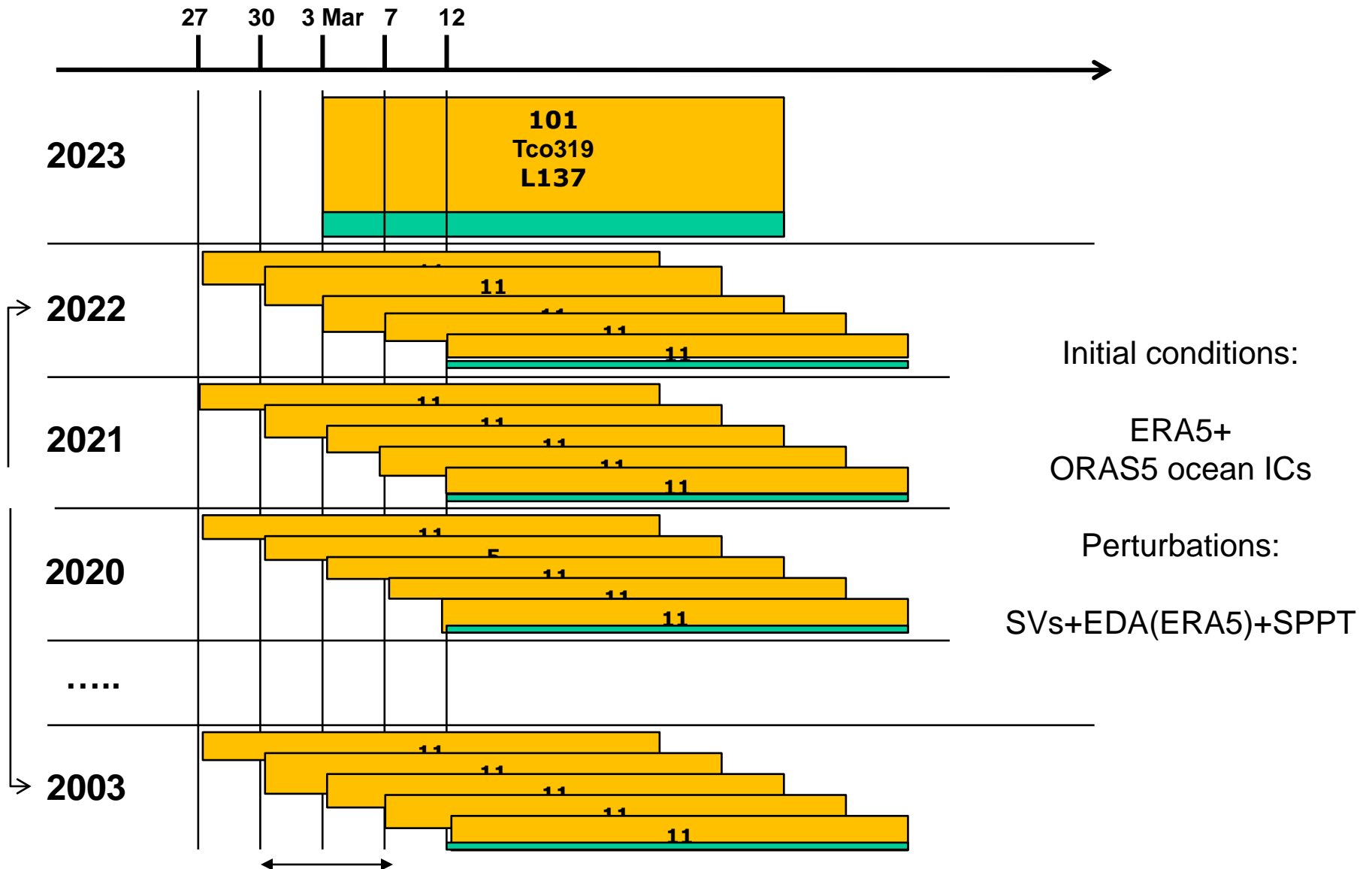
gff1
2-metre temperature Bias
19890801-20140801

PERIOD:600-768



Extended-range Re-forecasts

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



1-week window = 3 consecutive 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:

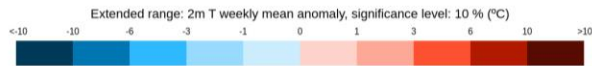
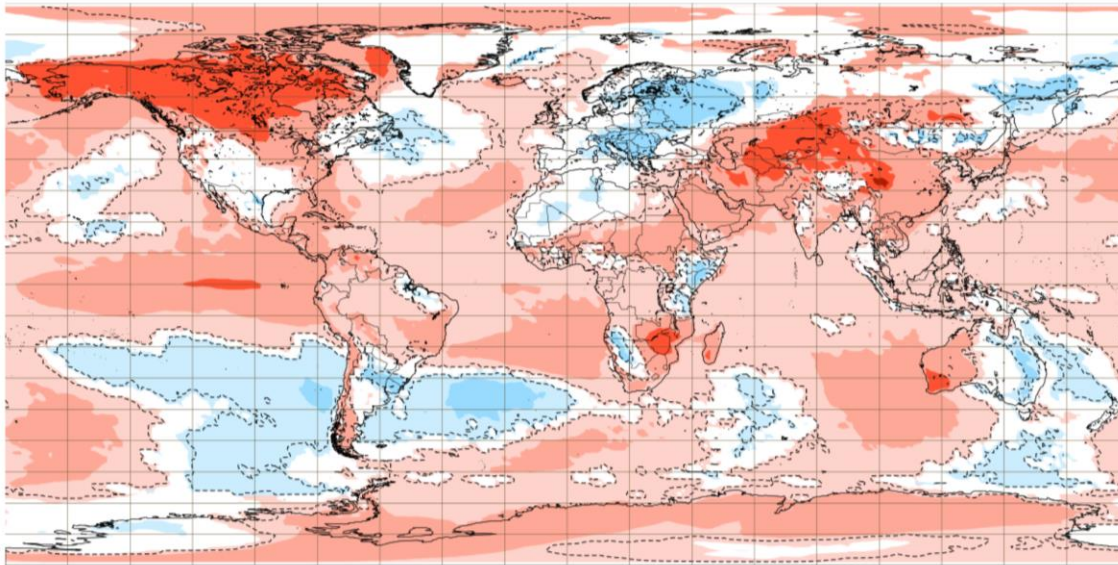
10 perturbed + 1 control fc on fixed days of the month, **every 4 days**, over past 20 years 1/5/9/13/17/21/25/29 (excluding 29 Feb)

Extended-range Real-time Forecasts

Week 3 Forecasts – 20/11/2023

2 m temperature: Weekly mean anomalies

Base time: Mon 20 Nov 2023 Valid time: Mon 04 Dec 2023 - Mon 11 Dec 2023 (+504h) Area : Global



ENS EXTENDED EPSGRAMS

Product

Extended Anomaly meteogram

Location

City

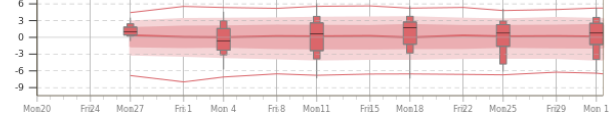
Reading, England, United Kingdom

Use current location

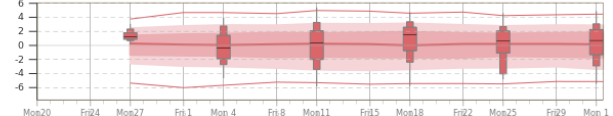
The returned point is at 24 km in the north-west direction from your selection

Extended range meteogram - weekly mean anomalies
51.57°N 1.28°W (ENS land point) 48 m
Monday 20 November 2023 00 UTC

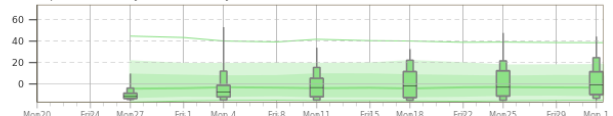
2m Temperature weekly mean anomaly and M-Climat (C)



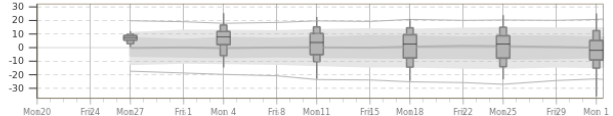
Surface temperature weekly mean anomaly and M-Climat (C)



Precipitation weekly mean anomaly and M-Climat (mm)



MSLP weekly mean anomaly and M-Climat (dam)



M-Climat: this stands for Model Climate. It is derived by rerunning a 11 member ensemble over the last 20 years (220 realisations). M-Climat is always from the same model version as the displayed ENS data. Note that: Each of the box plot represents a weekly mean value and plotted at the end of the range.

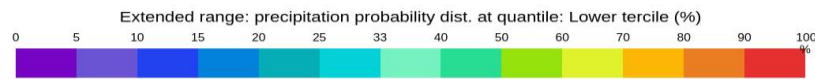
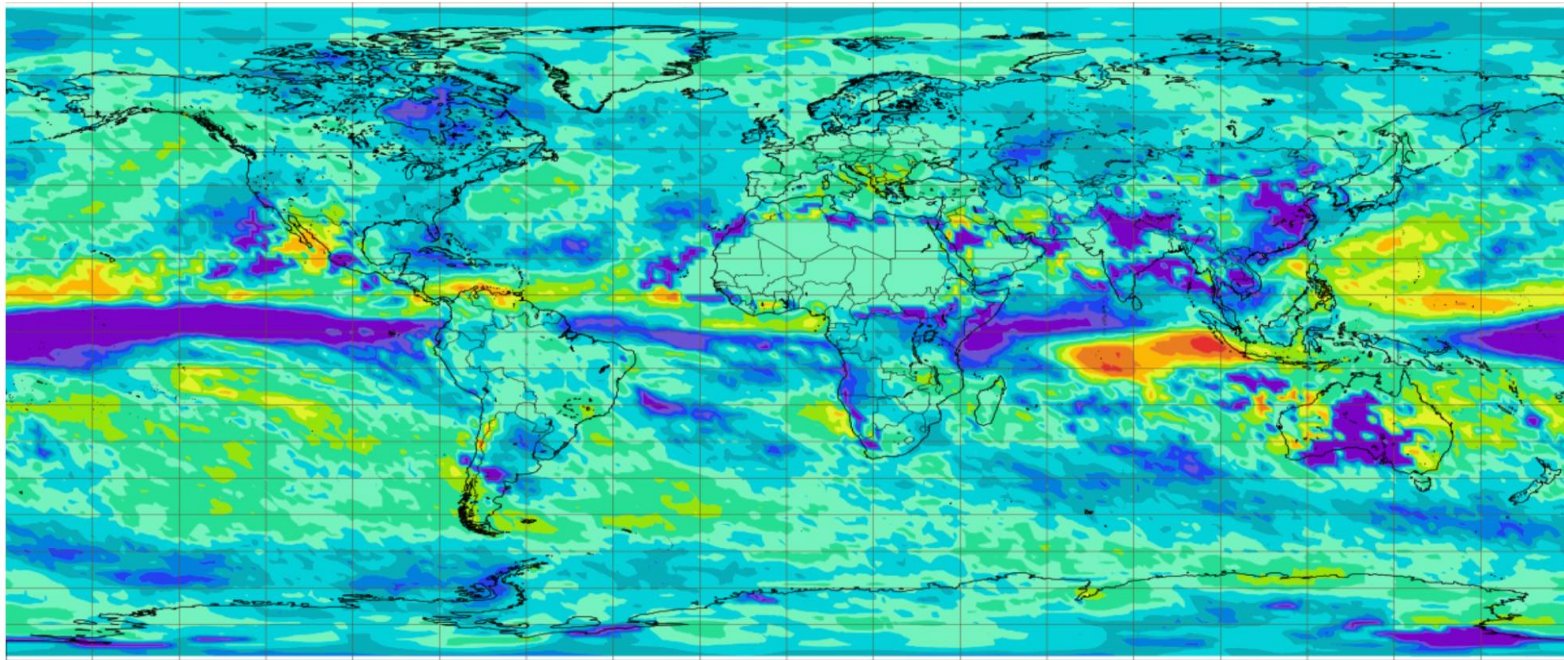
Anomalies (temperature, precipitation..)

Extended-range Real-time Forecasts

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

Precipitation: Probability distribution

Base time: Mon 20 Nov 2023 Valid time: Mon 11 Dec 2023 - Mon 18 Dec 2023 (+672h) Distribution group : Lower Tercile Area : Global

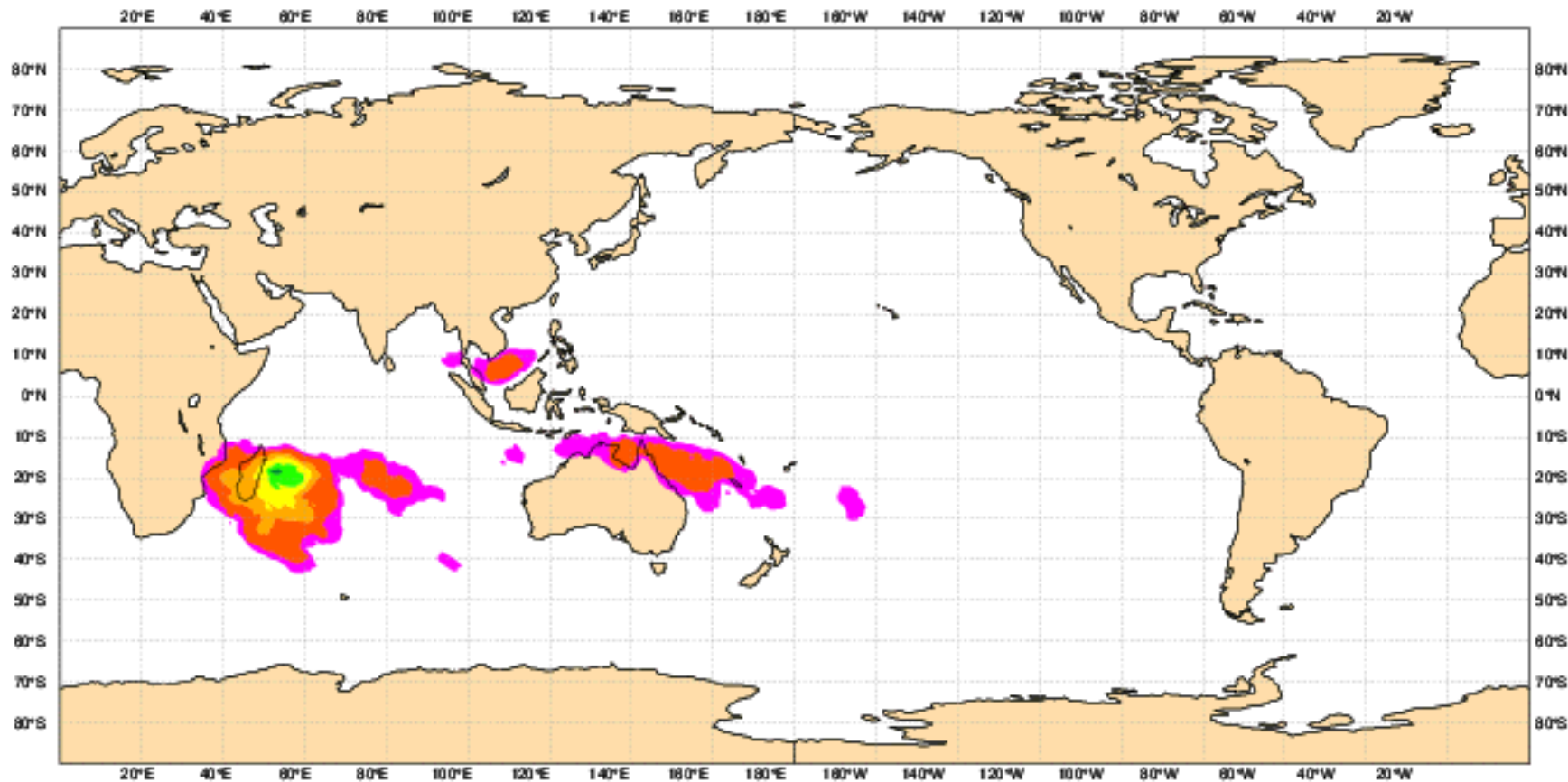


Probabilities (temperature, precipitation..)

Tropical cyclone activity

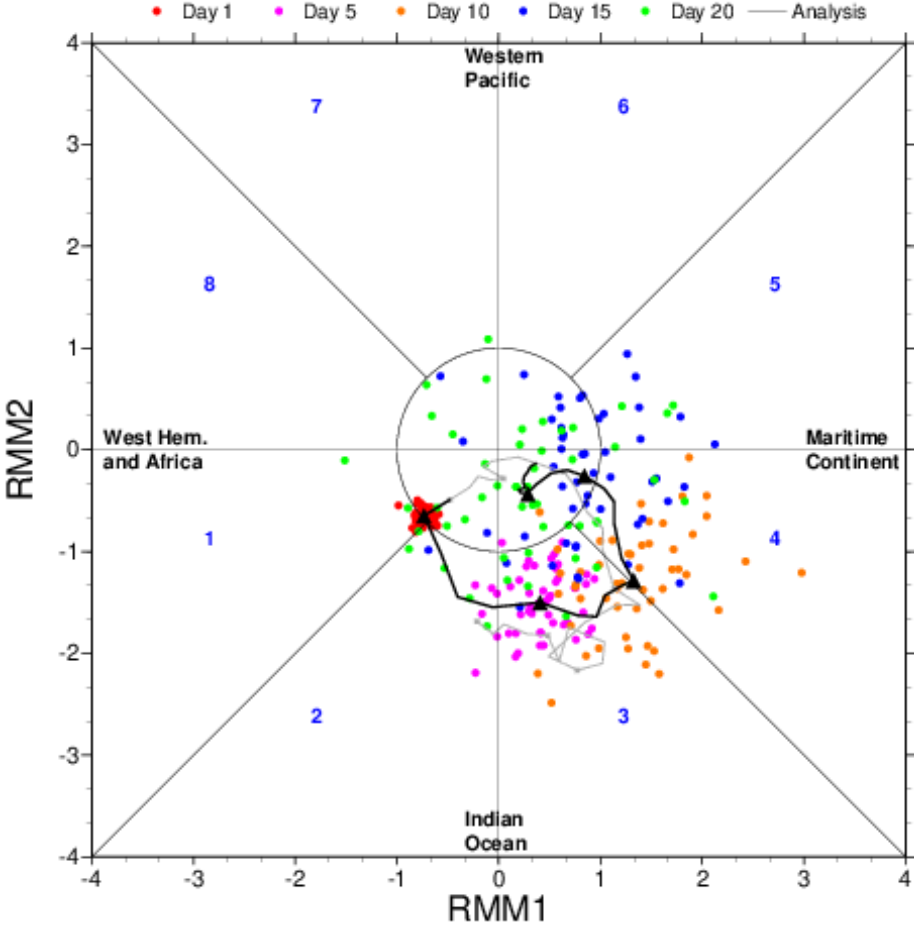
Weekly mean Tropical Storm Strike Probability. Date: 20220214 0 UTC t+(168-336)
Probability of a TS passing within 300km radius

5-10 10-20 20-30 30-40 40-50 50-60 60-70 70-80 80-90 90-110

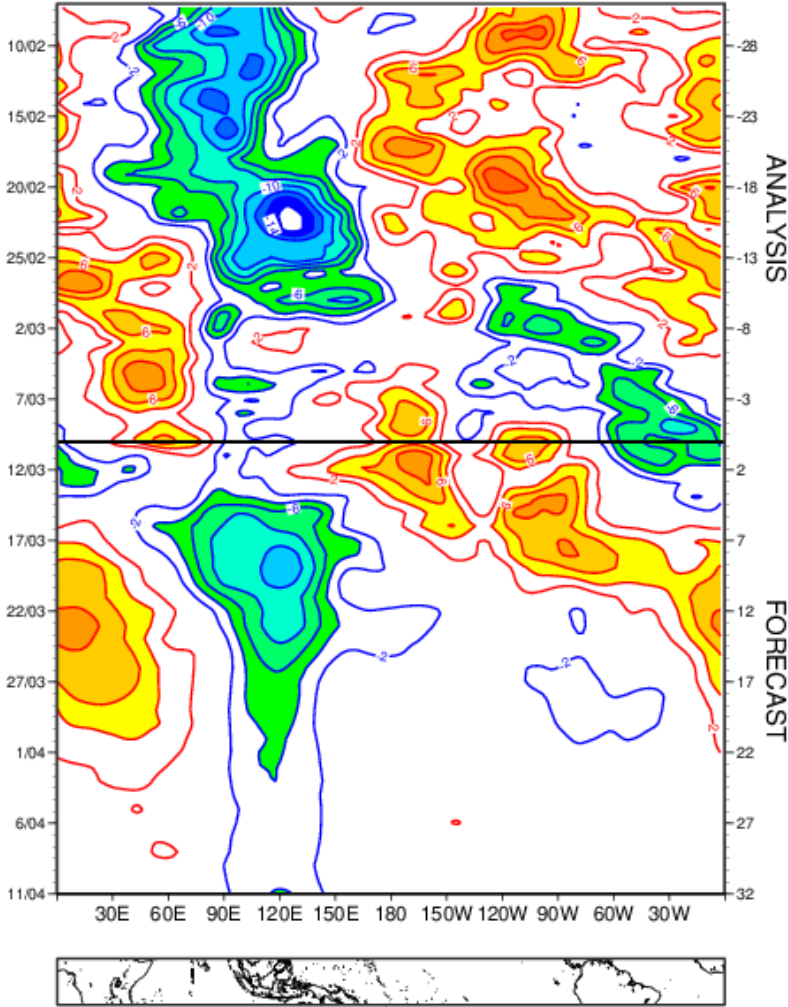


MJO Forecasts

ECMWF MONTHLY FORECASTS
FORECAST BASED 10/03/2022 00UTC

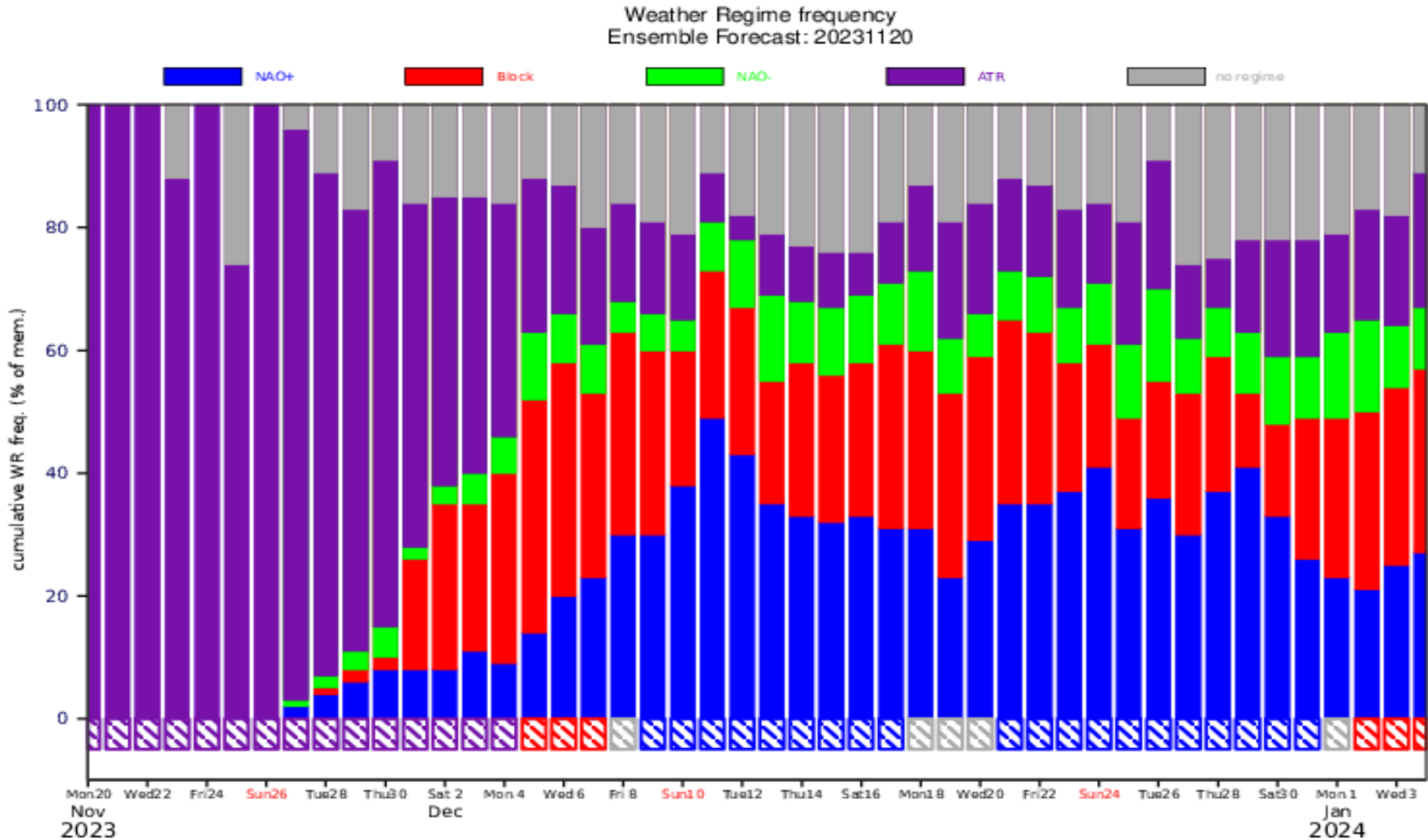


VELOCITY POTENTIAL AT 200 HPA
Ensemble mean between Lat 15S and 15N
FORECAST BASED 10/03/2022 00UTC



Euro-Atlantic Weather regimes

Weather regimes probabilities - Extended range forecast



Verification

Analysis and ECMWF ENS Forecasting System 2-metre Temperature anomaly

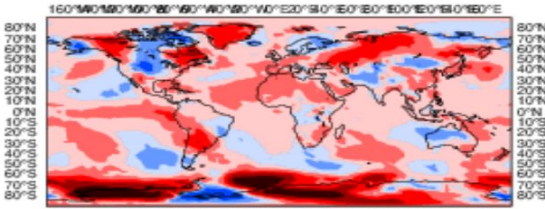
Verification period: 03-07-2023/TO,09-07-2023

ensemble size = 101 ,climate size = 660

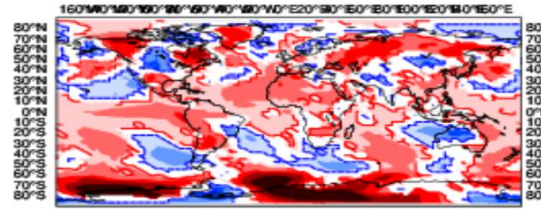
Shaded areas significant at 10% level, Contours at 1% level



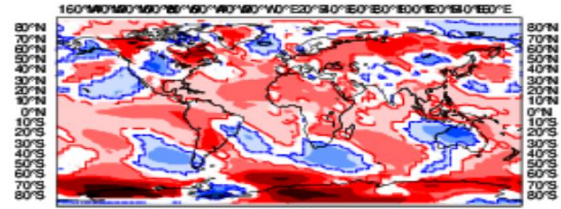
ANALYSIS



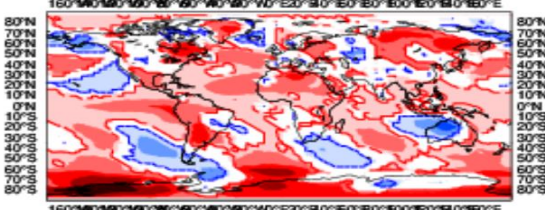
FORECAST 03-07-2023: DAY 1-7



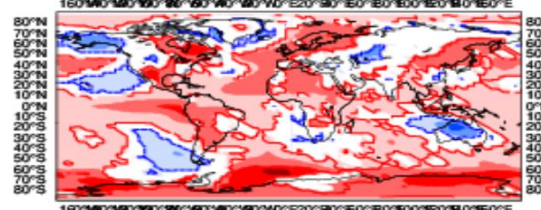
FORECAST 29-06-2023: DAY 5-11



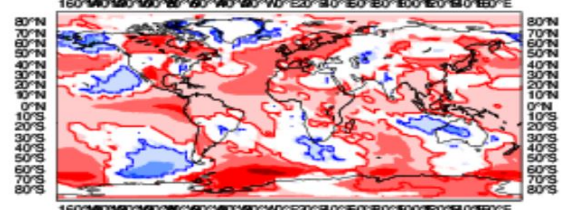
FORECAST 26-06-2023: DAY 8-14



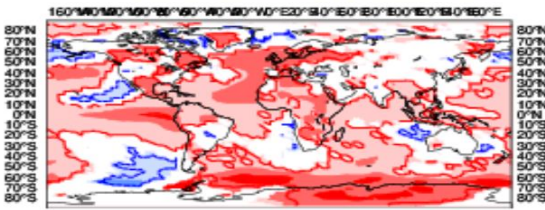
FORECAST 22-06-2023: DAY 12-18



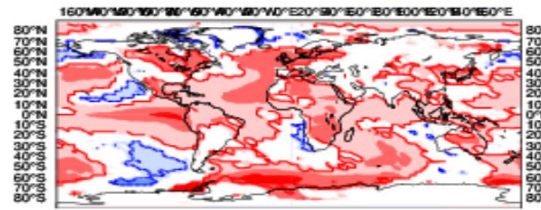
FORECAST 19-06-2023: DAY 15-21



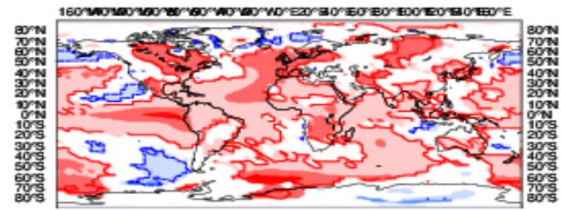
FORECAST 15-06-2023: DAY 19-25



FORECAST 12-06-2023: DAY 22-28



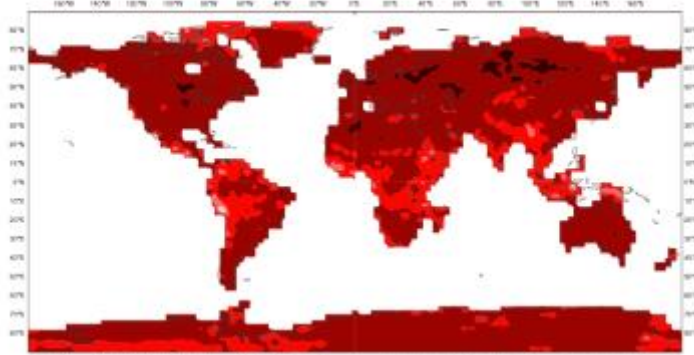
FORECAST 08-06-2023: DAY 26-32



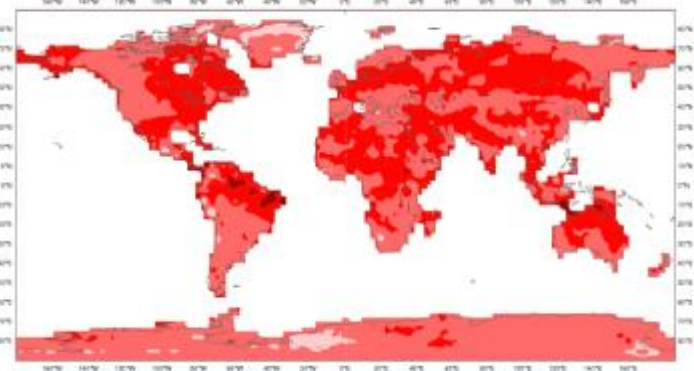
Skill of the ECMWF Monthly Forecasting System

ROC score: 2-meter temperature in the upper tercile

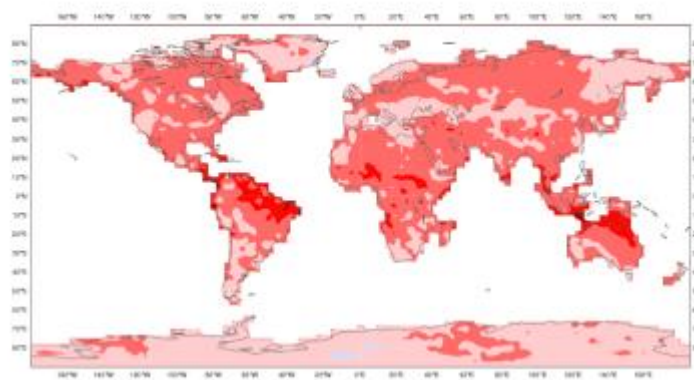
Day 5-11



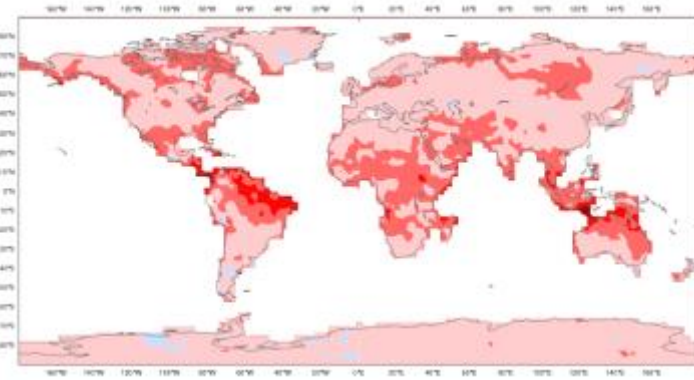
Day 12-18



Day 19-25

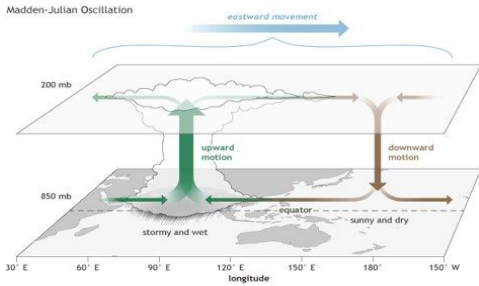


Day 26-32



S2S Forecast skill: “Are we progressing?”

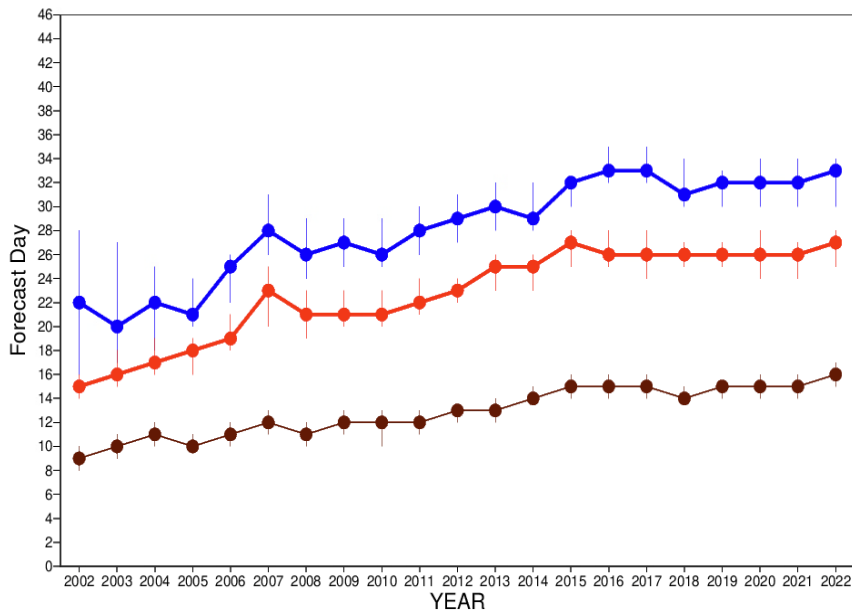
ECMWF Forecast Skill



Madden Julian Oscillation (MJO)

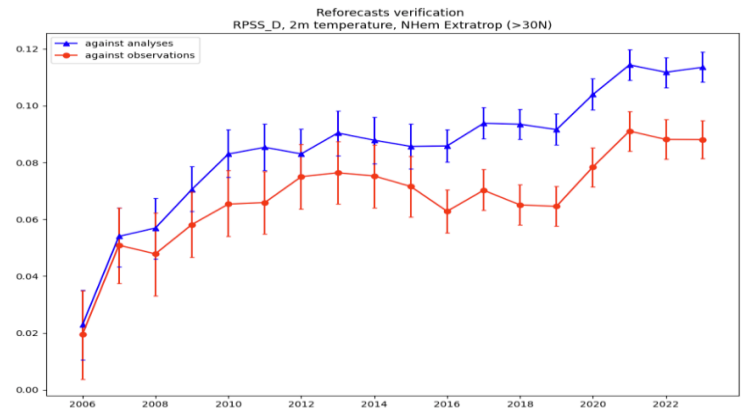
MJO Bivariate Correlation

● 0.5 ● 0.6 ● 0.8

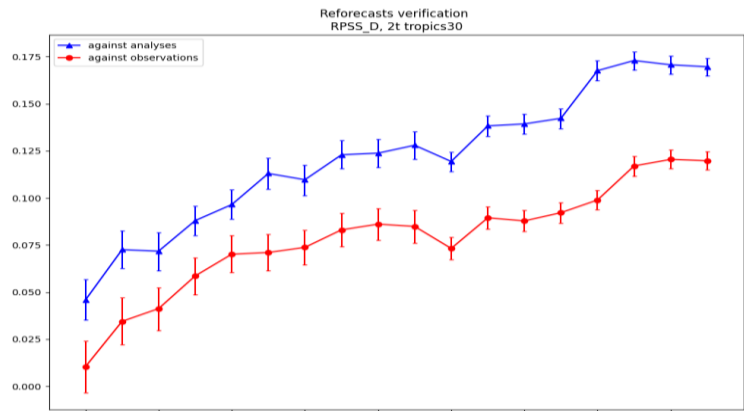


Week 3 2-metre temperature

Ranked probabilistic skill Score



Tropics



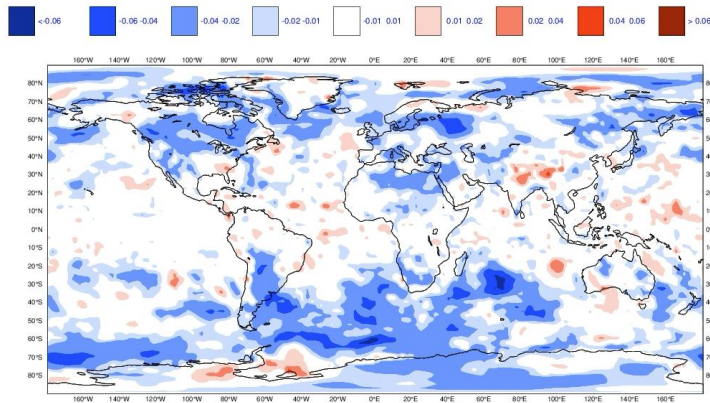
Significant Improvements in recent years. Gain of 2-weeks of MJO predictive skill over the past 20 years!

Creating lagged ensembles?

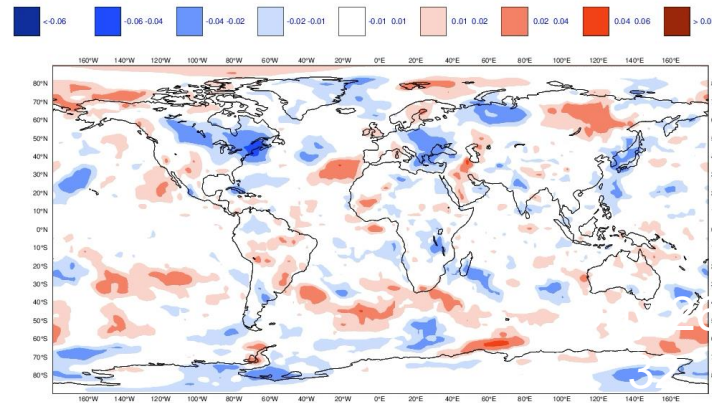
Impact of combining 101 ensemble member at day 0 with 101 member at day -1 to create a 202-member ensemble.

2m-temperature CRPSS difference (lagged-burst)

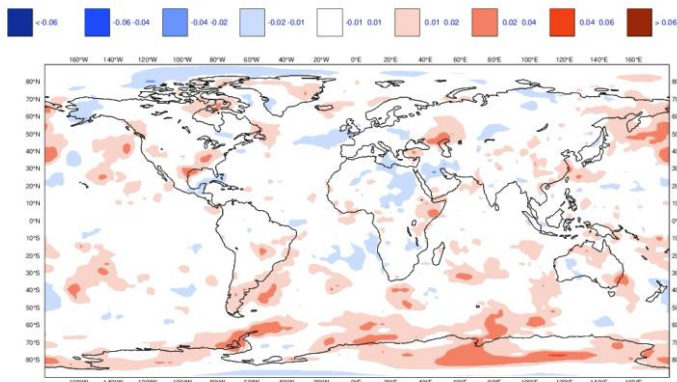
Week 1



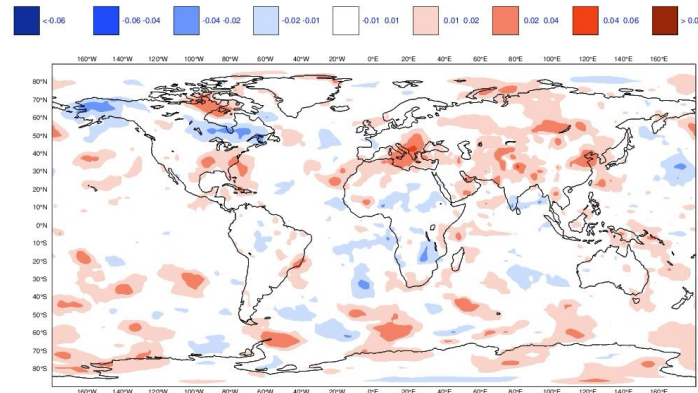
Week 2



Week 3



Week 4



Blue: lagged ensemble is worse

Red: lagged ensemble improves skill

Using AI/ML to improve extended-range Forecasts

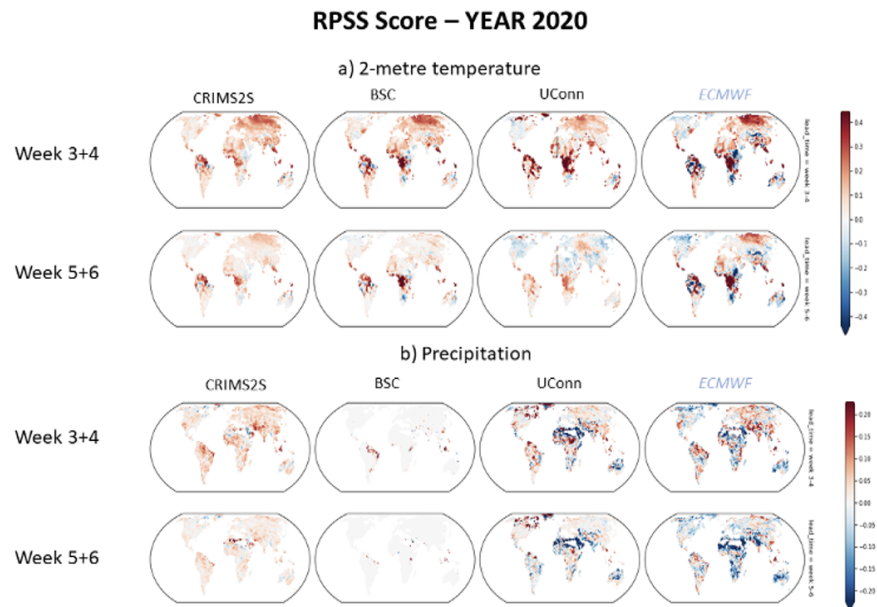
The WMO S2S AI/ML Challenge

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 of 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.



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.