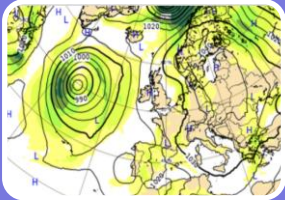


Sub-seasonal Forecasting at ECMWF

Frédéric Vitart

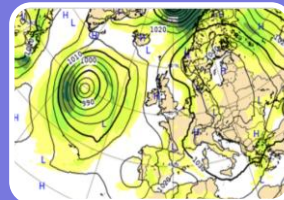
European Centre for Medium-Range Weather Forecasts

Forecast systems at ECMWF



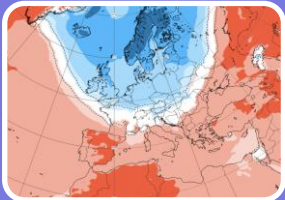
Medium range

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



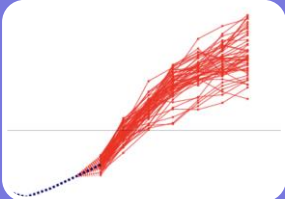
AIFS: Medium range

- 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

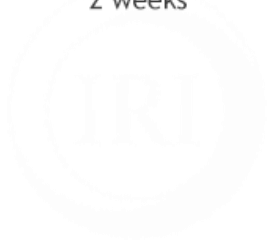


Long range: SEAS5

- 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

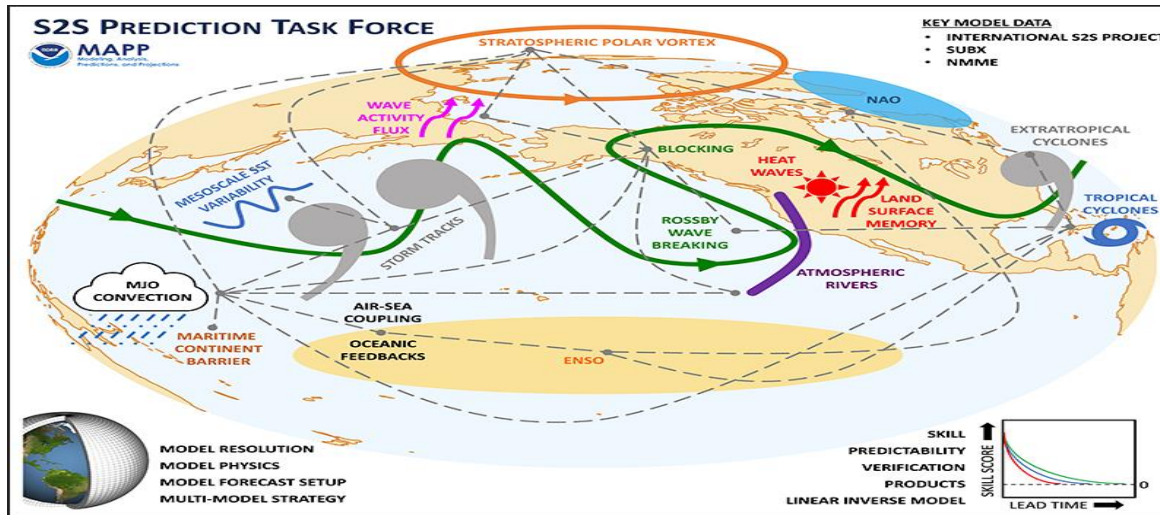
Sub-seasonal to Seasonal prediction



International Research Institute

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

Sources of sub-seasonal predictability

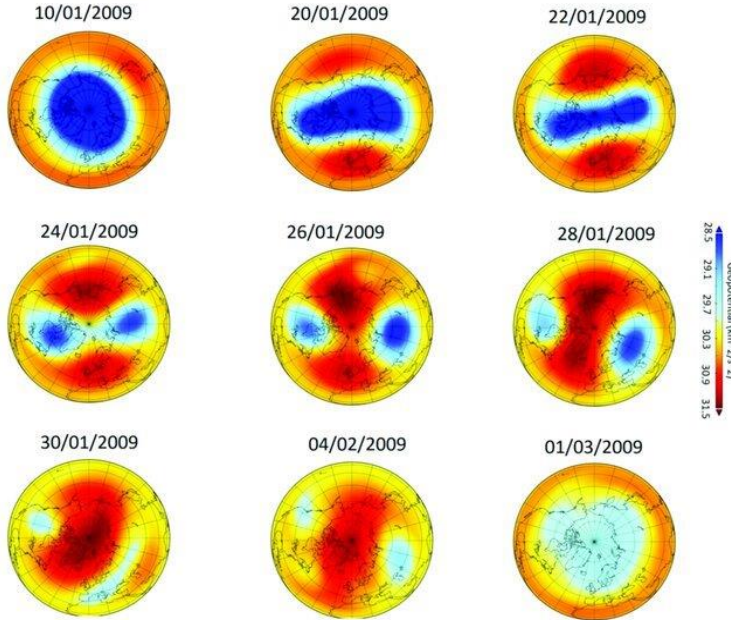


Main sources of predictability include:

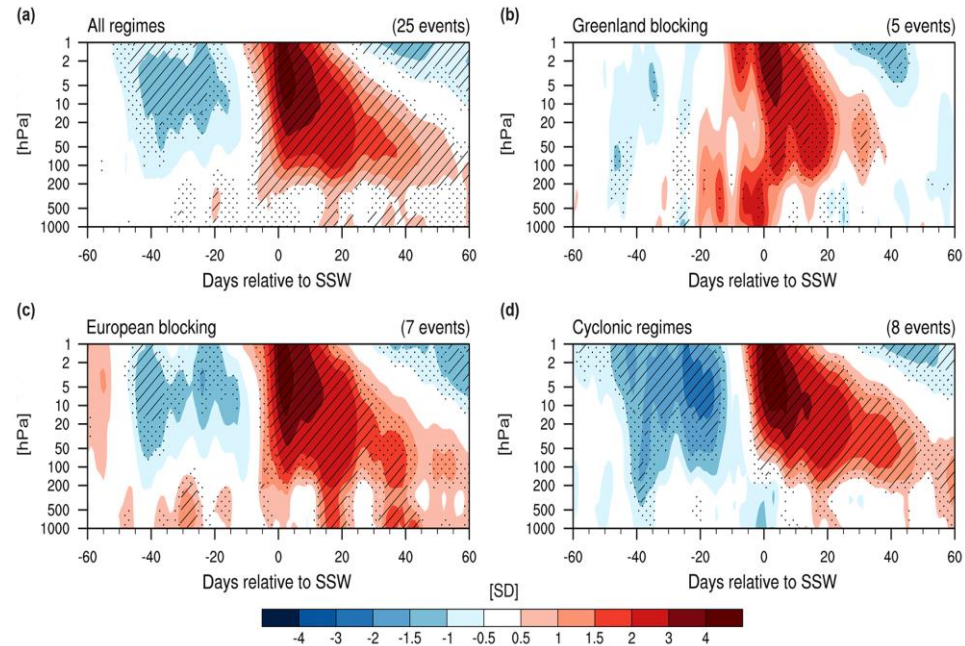
- MJO
- ENSO/IOD
- Land Surface
- Stratospheric variability (e.g. SSW)
- Rossby waves
- SSTs/Sea-ice
- Others?

Sudden Stratospheric warming

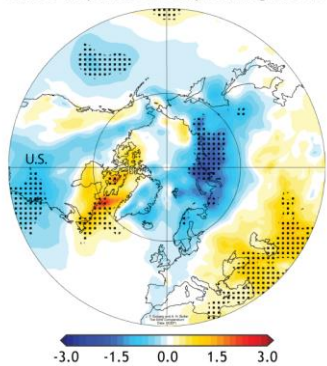
2009 SSW event



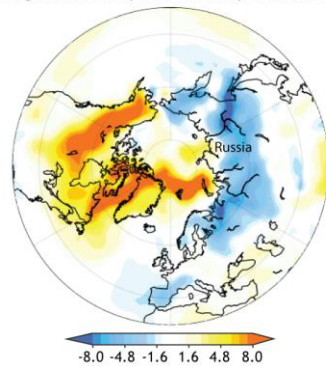
Kozubeck et al, 2020.
Available via license: [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/)



Surface temperature anomaly following all SSWs



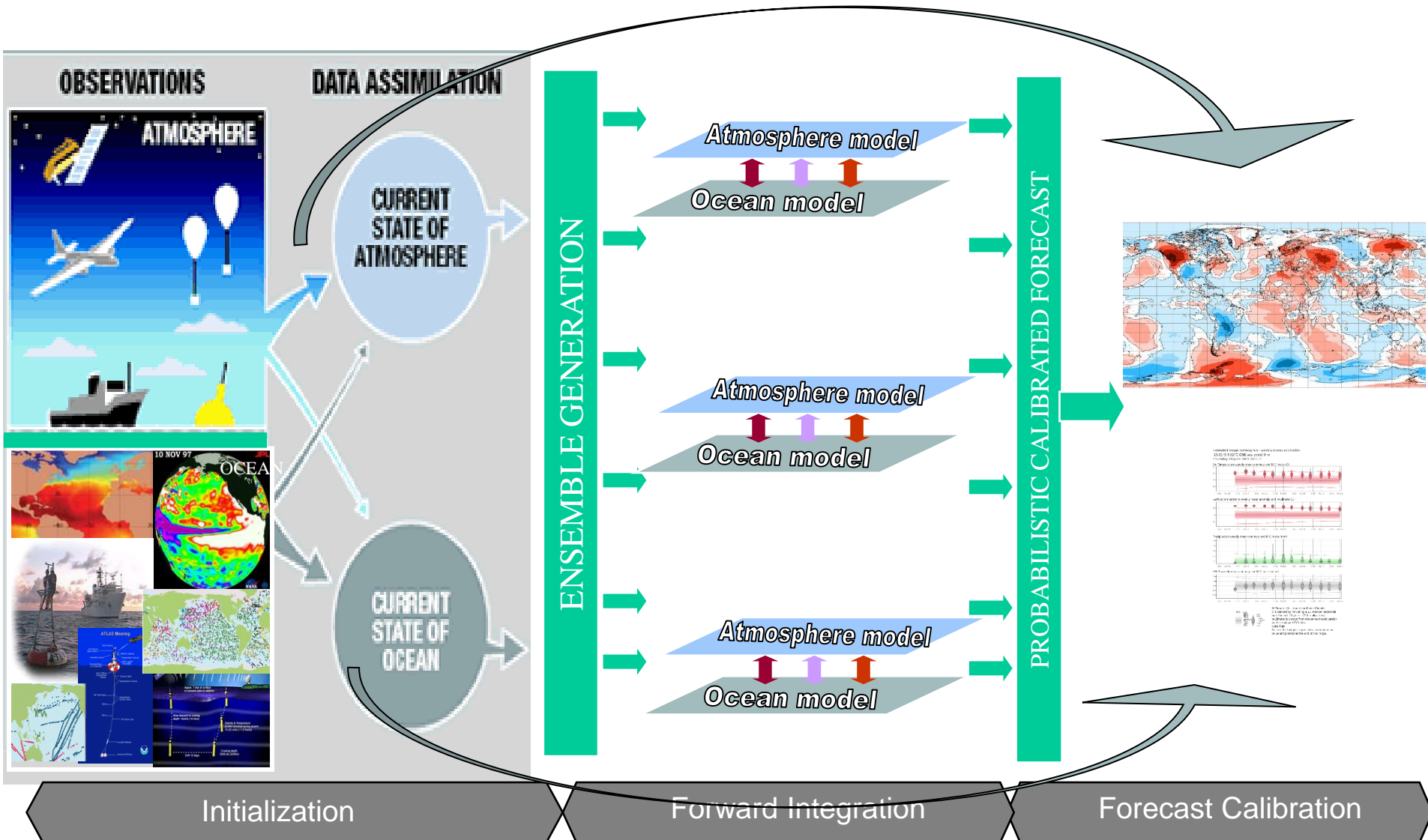
Averaged surface temperature anomaly, Jan 5-23, 2021



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.

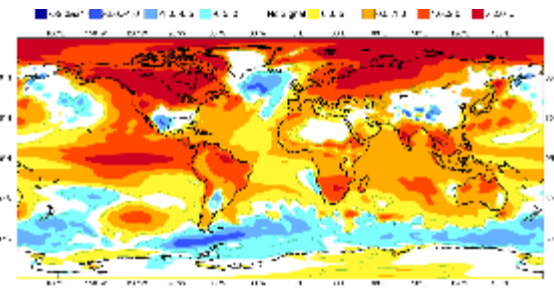
Initial conditions:

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

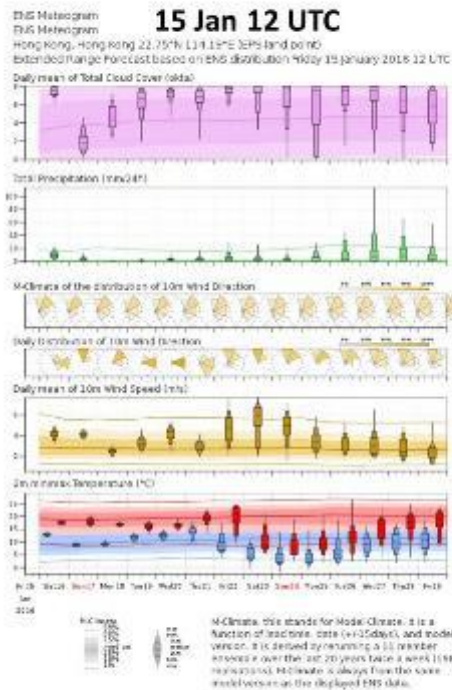
ECMWF products

From medium-range to seasonal to extended range

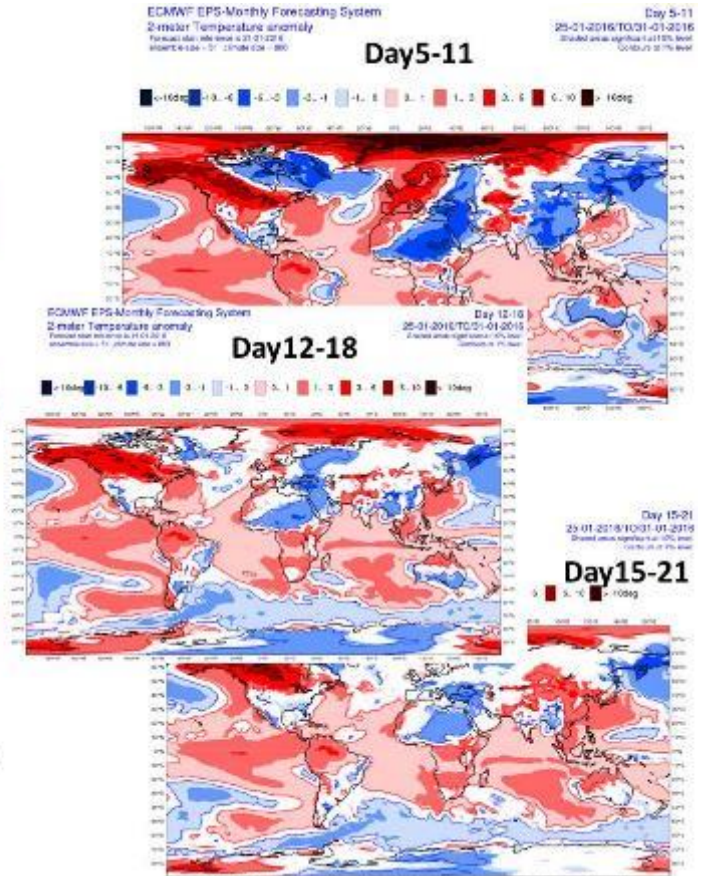
Seasonal Forecast



Medium-range



Extended-range



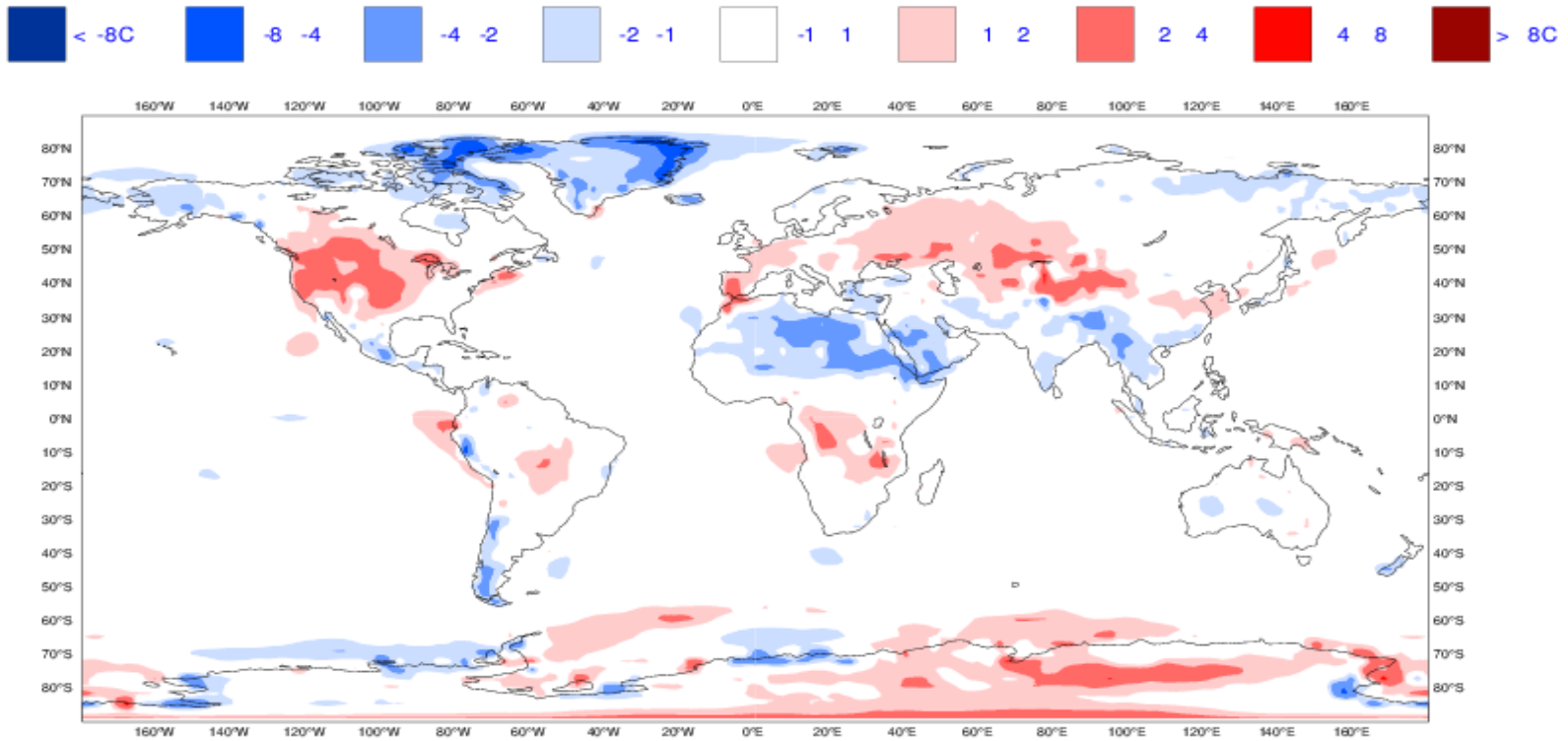
European Centre for Medium-Range Weather Forecasts

Extended-range forecast biases

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

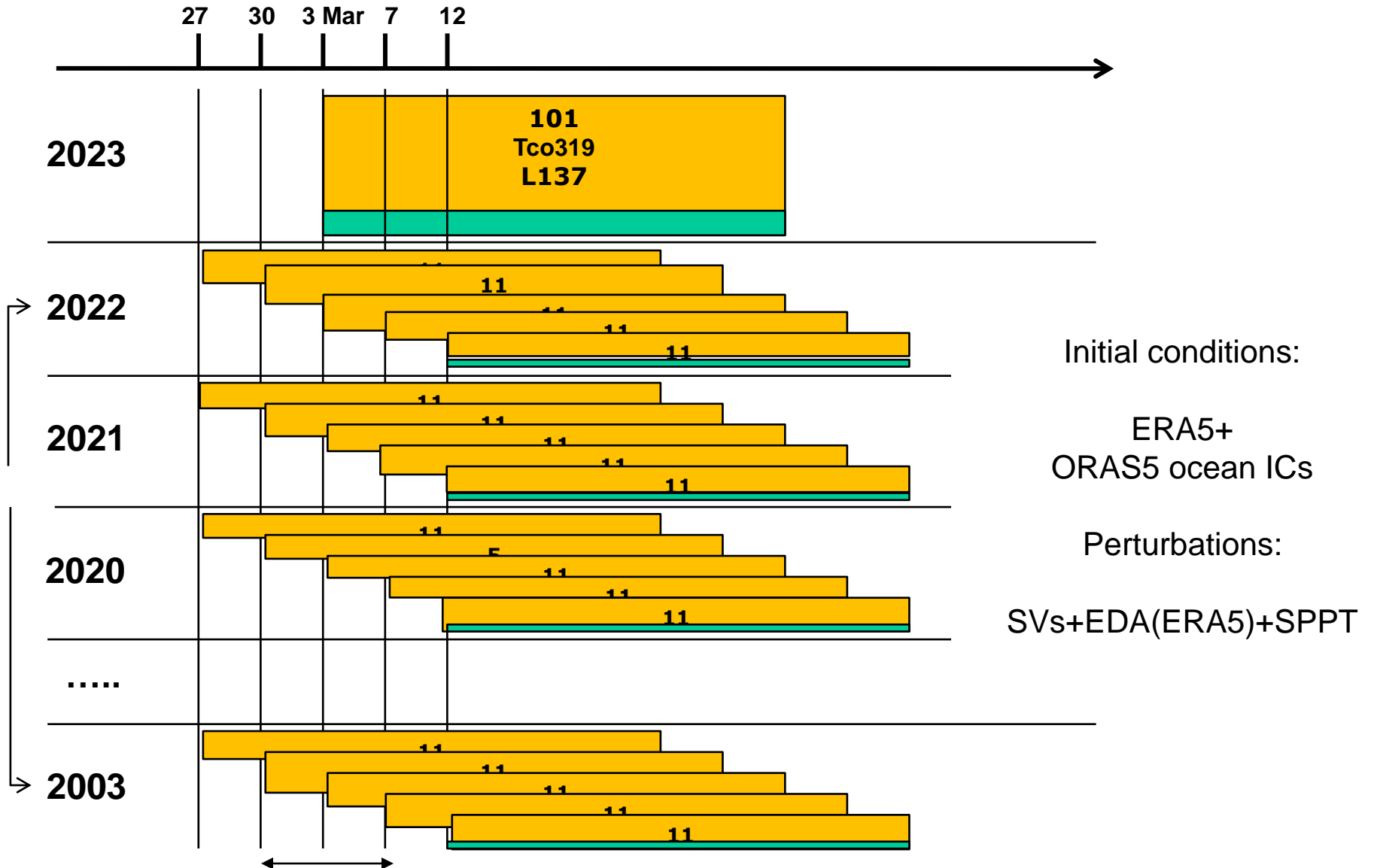
gff1
2-metre temperature Bias
19890801-20140801

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 odd days**, over past 20 year

Medium-range:

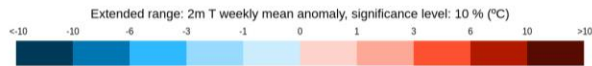
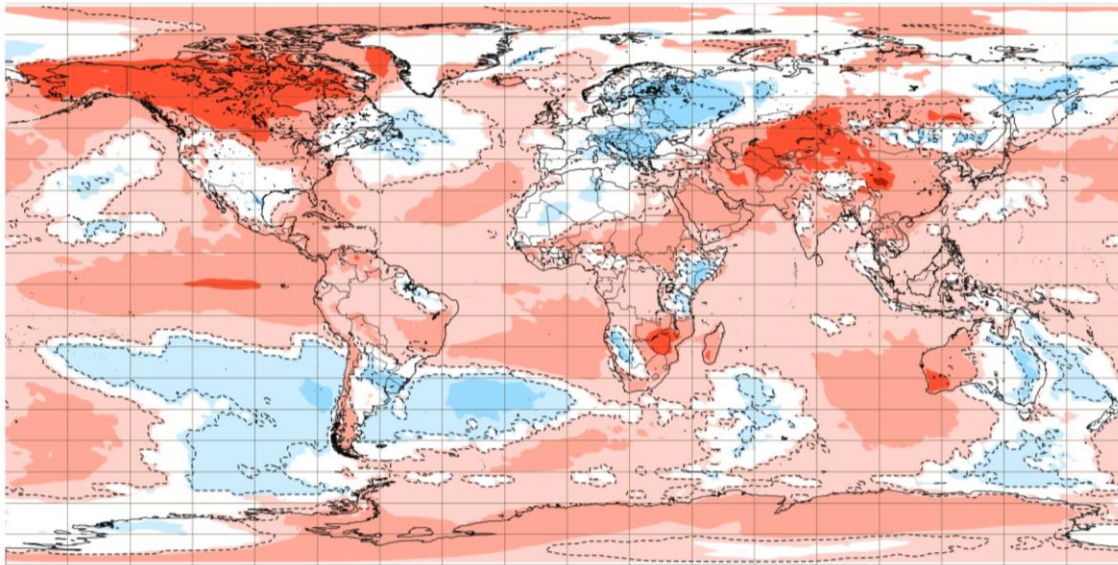
10 perturbed + 1 control fc on fixed days of the month, **every 4 days**, over past 20 years 1/5/9/13/17//21/25/29 (excluding 29 Feb)

Extended-range Real-time Forecasts

Week 3 Forecasts – 20/11/2023

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

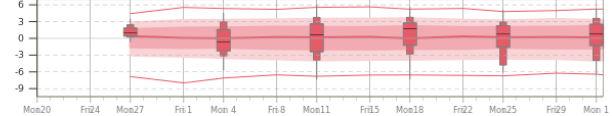
Reading, England, United Kingdom|

Use current location

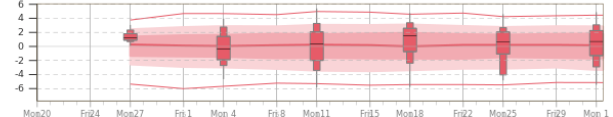
The returned point is at 24 km in the north-west direction from your selection

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

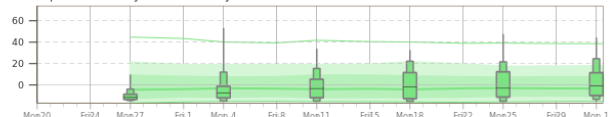
2m Temperature weekly mean anomaly and M-Climat (C)



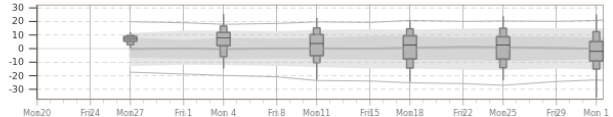
Surface temperature weekly mean anomaly and M-Climat (C)



Precipitation weekly mean anomaly and M-Climat (mm)



MSLP weekly mean anomaly and M-Climat (dam)



M-Climat
max
95%
75%
median
25%
10%
min

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.

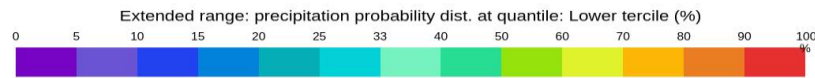
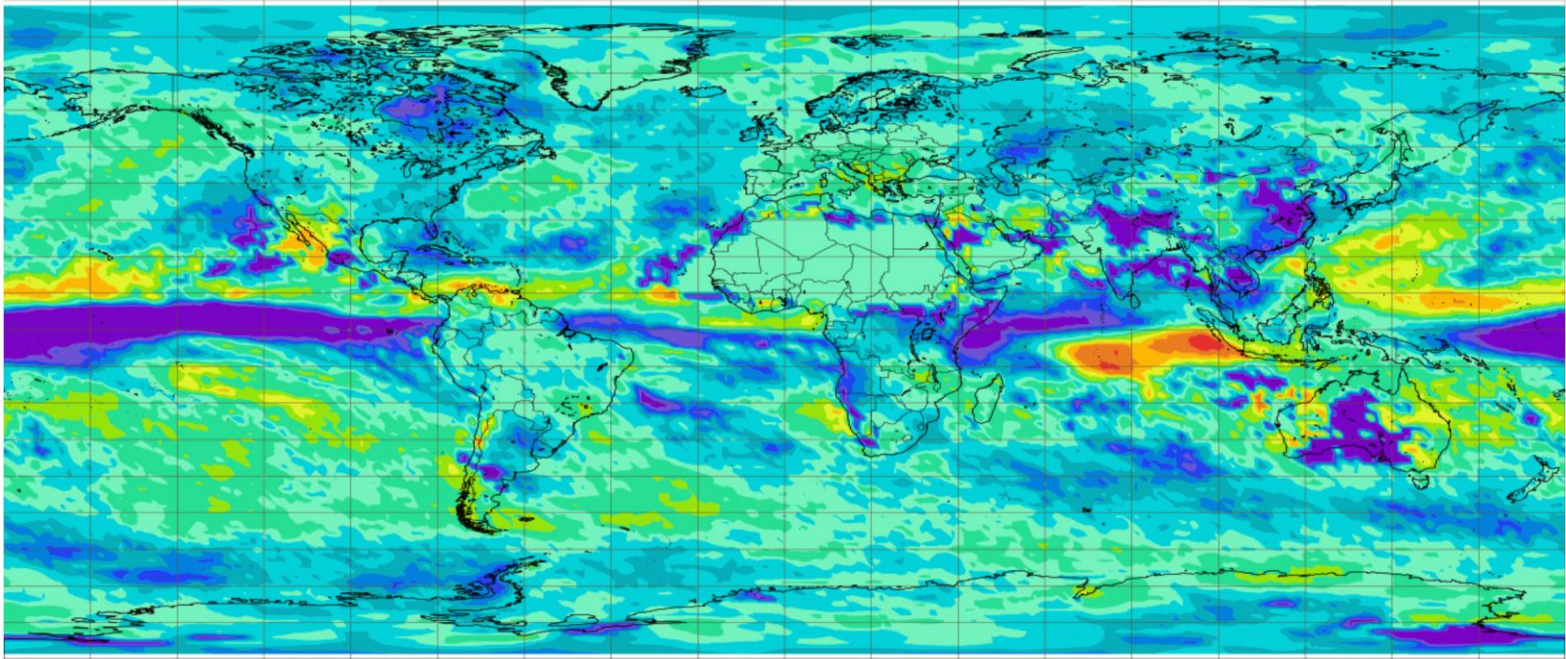
Anomalies (temperature, precipitation..)

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

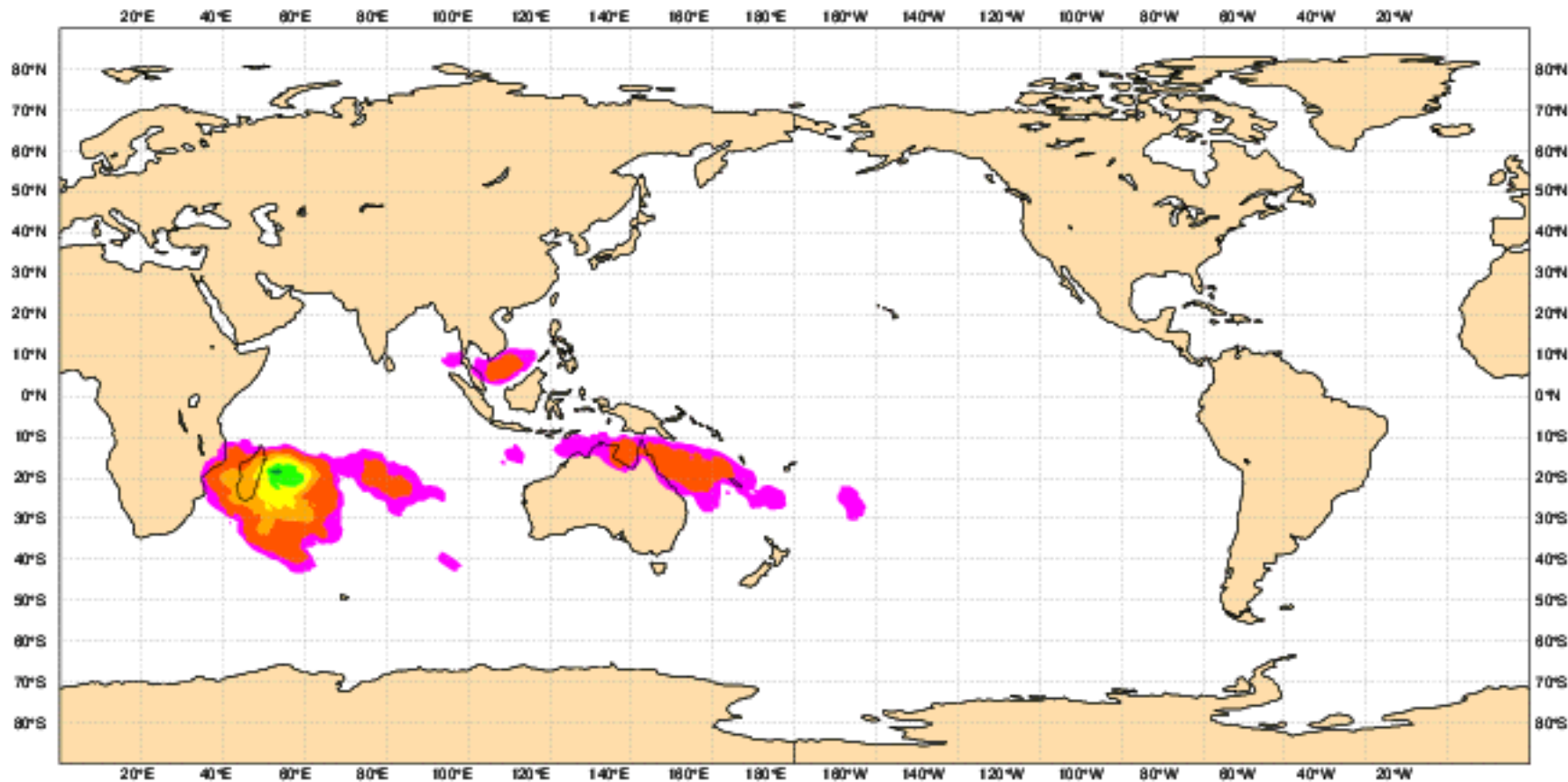


Probabilities (temperature, precipitation..)

Tropical cyclone activity

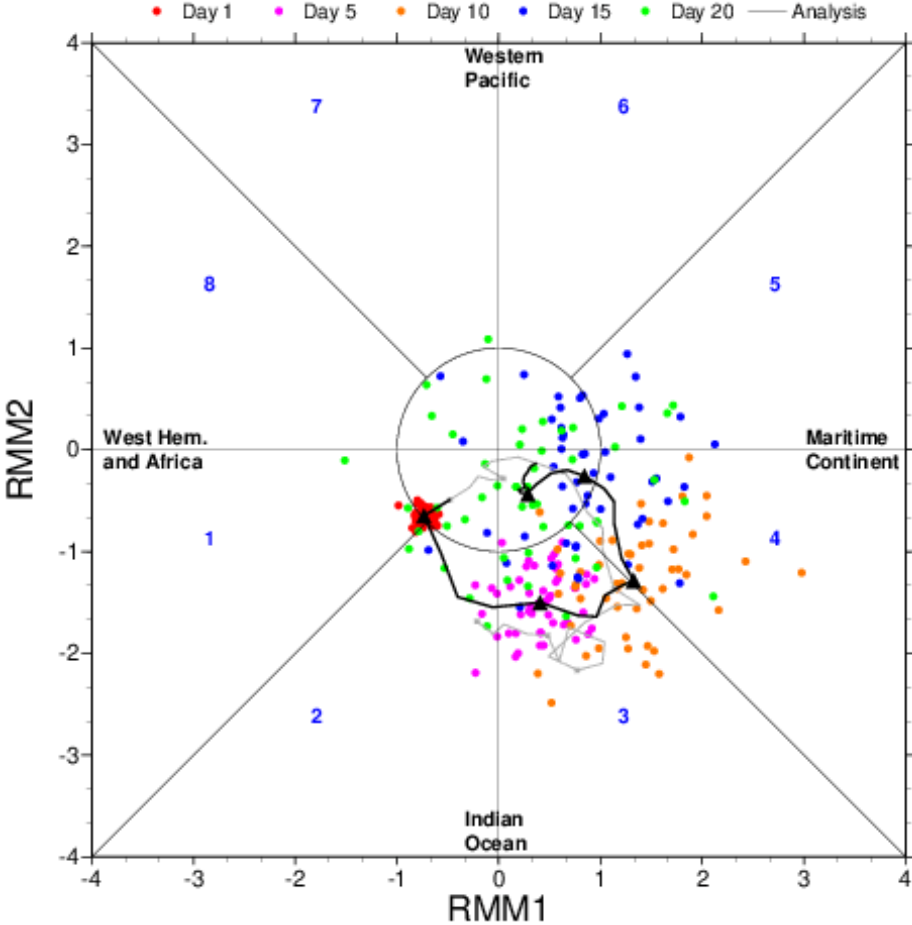
Weekly mean Tropical Storm Strike Probability. Date: 20220214 0 UTC t+(168-336)
Probability of a TS passing within 300km radius

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

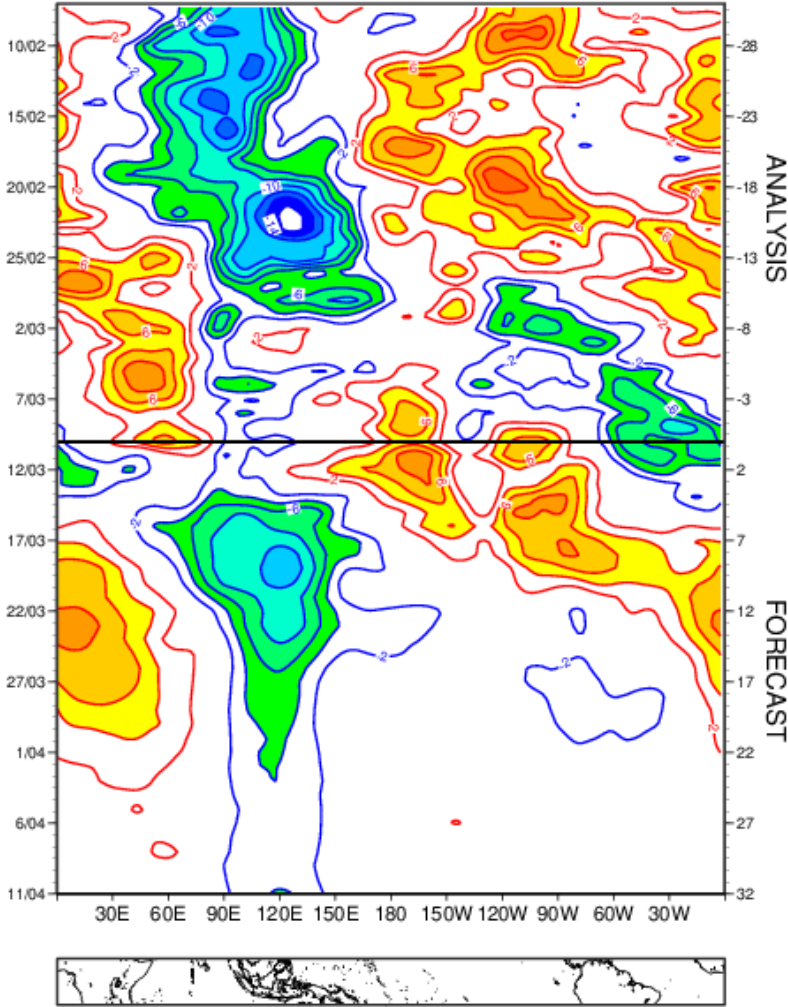


MJO Forecasts

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

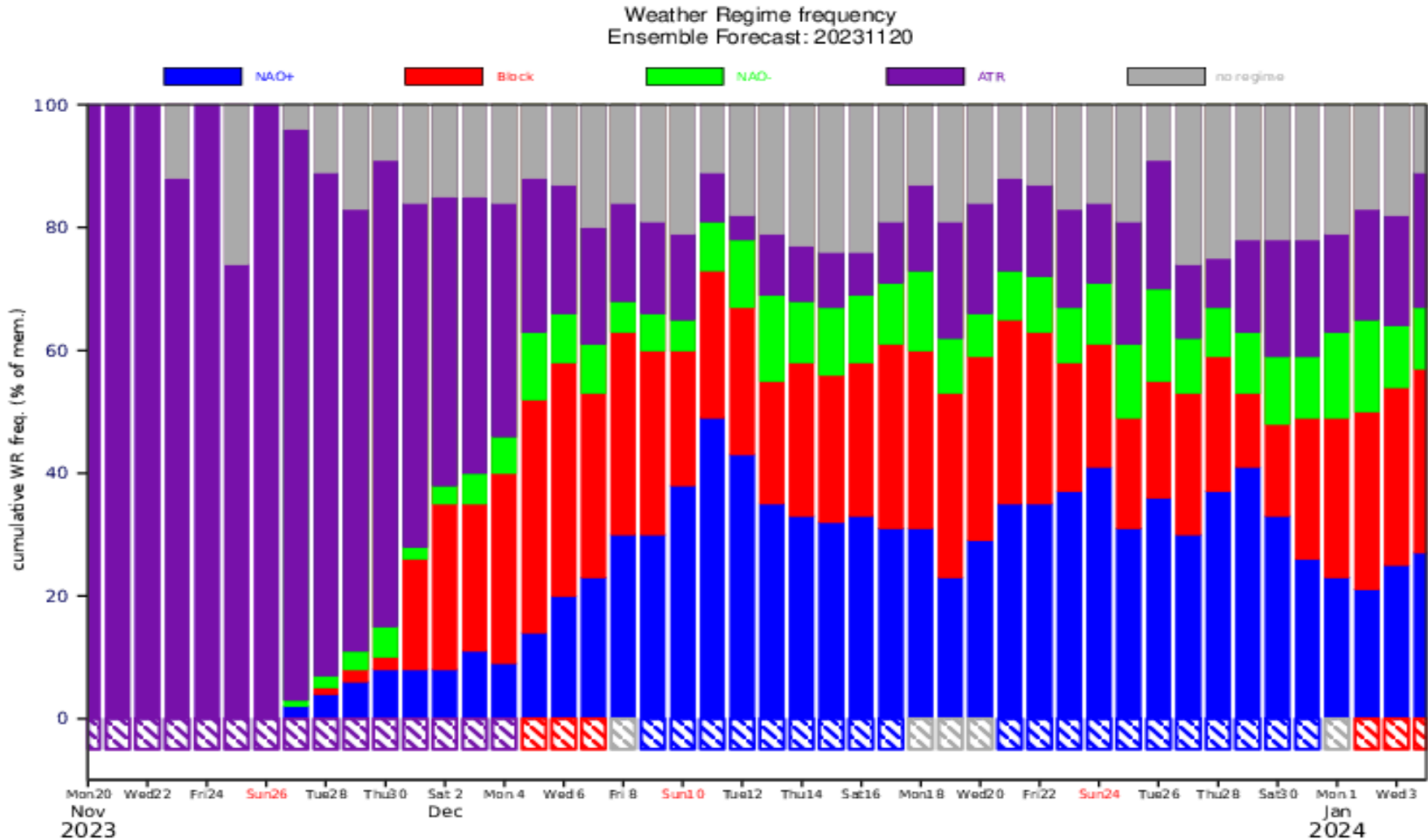


VELOCITY POTENTIAL AT 200 HPA
Ensemble mean between Lat 15S and 15N
FORECAST BASED 10/03/2022 00UTC



Euro-Atlantic Weather regimes

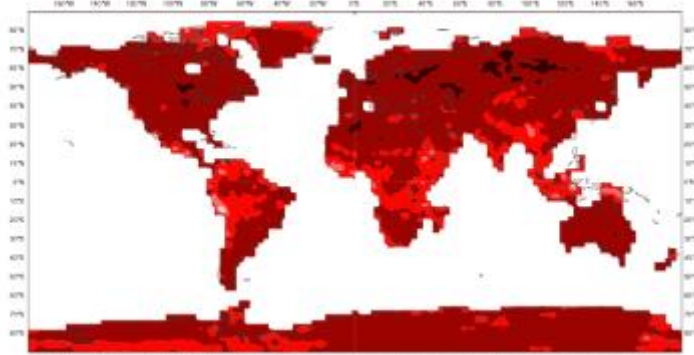
Weather regimes probabilities - Extended range forecast



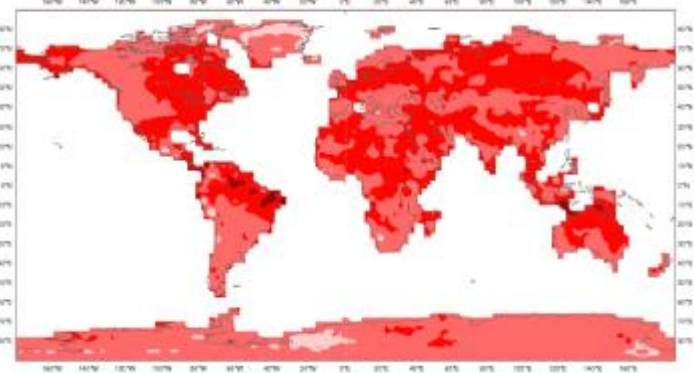
Skill of the ECMWF Monthly Forecasting System

ROC score: 2-meter temperature in the upper tercile

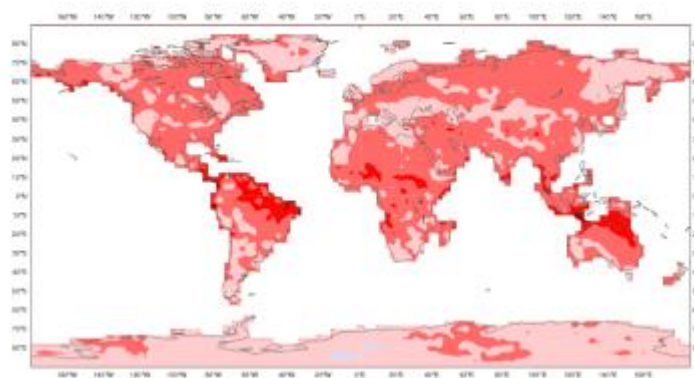
Day 5-11



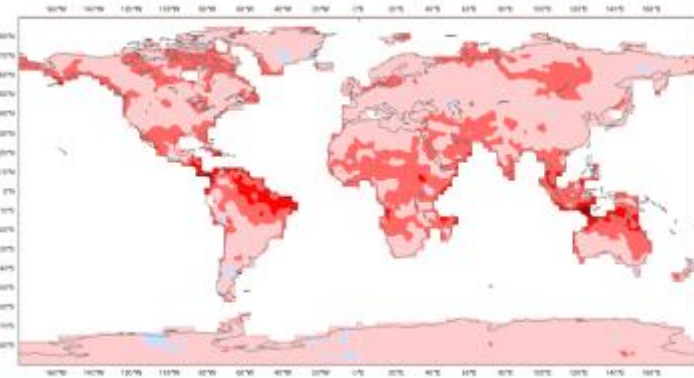
Day 12-18



Day 19-25

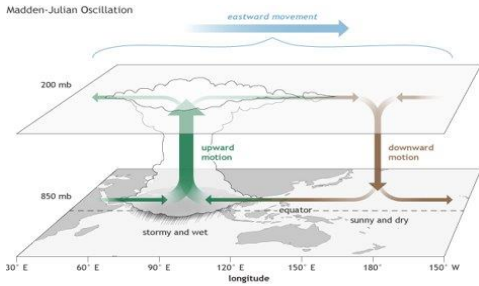


Day 26-32



S2S Forecast skill: “Are we progressing?”

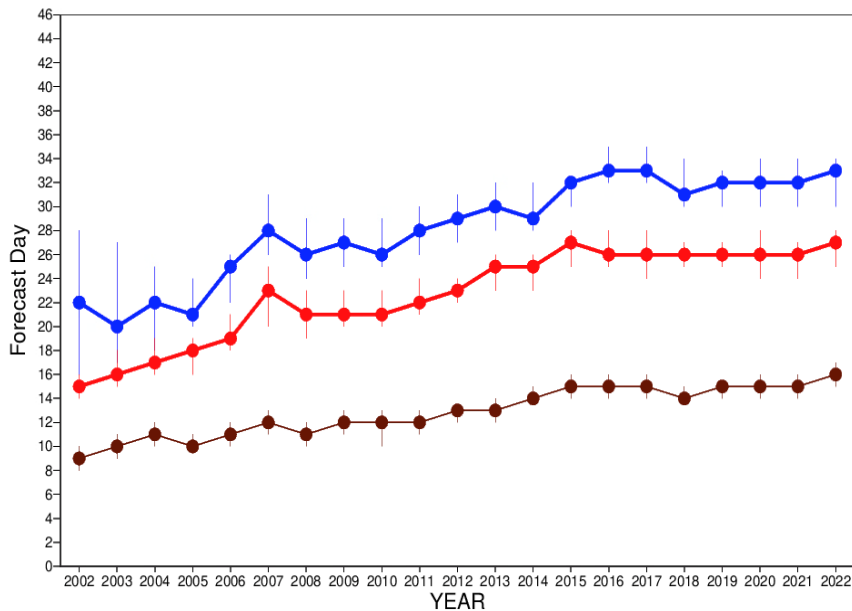
ECMWF Forecast Skill



Madden Julian Oscillation (MJO)

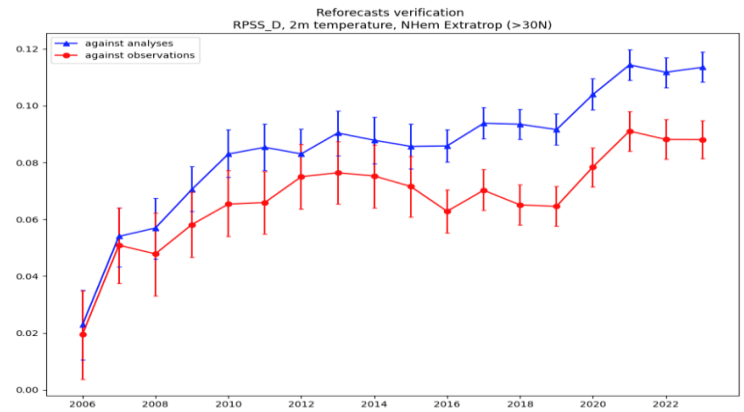
MJO Bivariate Correlation

● 0.5 ● 0.6 ● 0.8

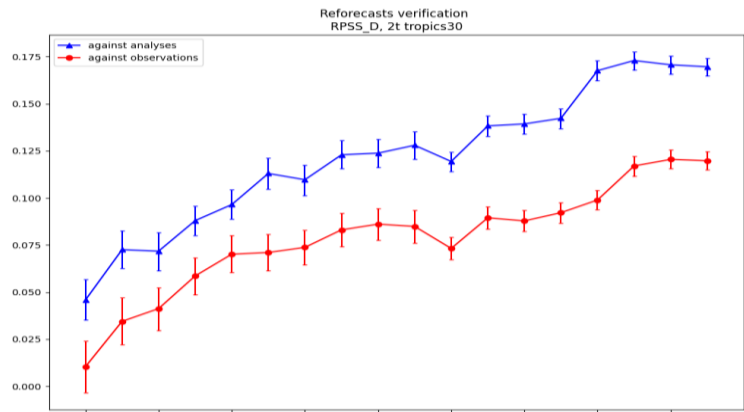


Week 3 2-metre temperature

Ranked probabilistic skill Score



Tropics



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

Using AI/ML to improve sub-seasonal Forecasts

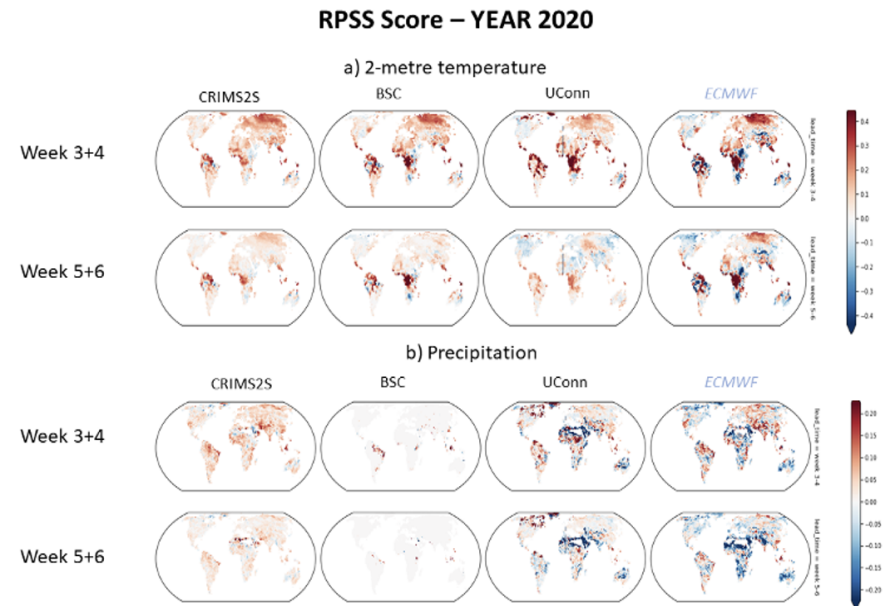
The WMO S2S AI/ML Challenge

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.



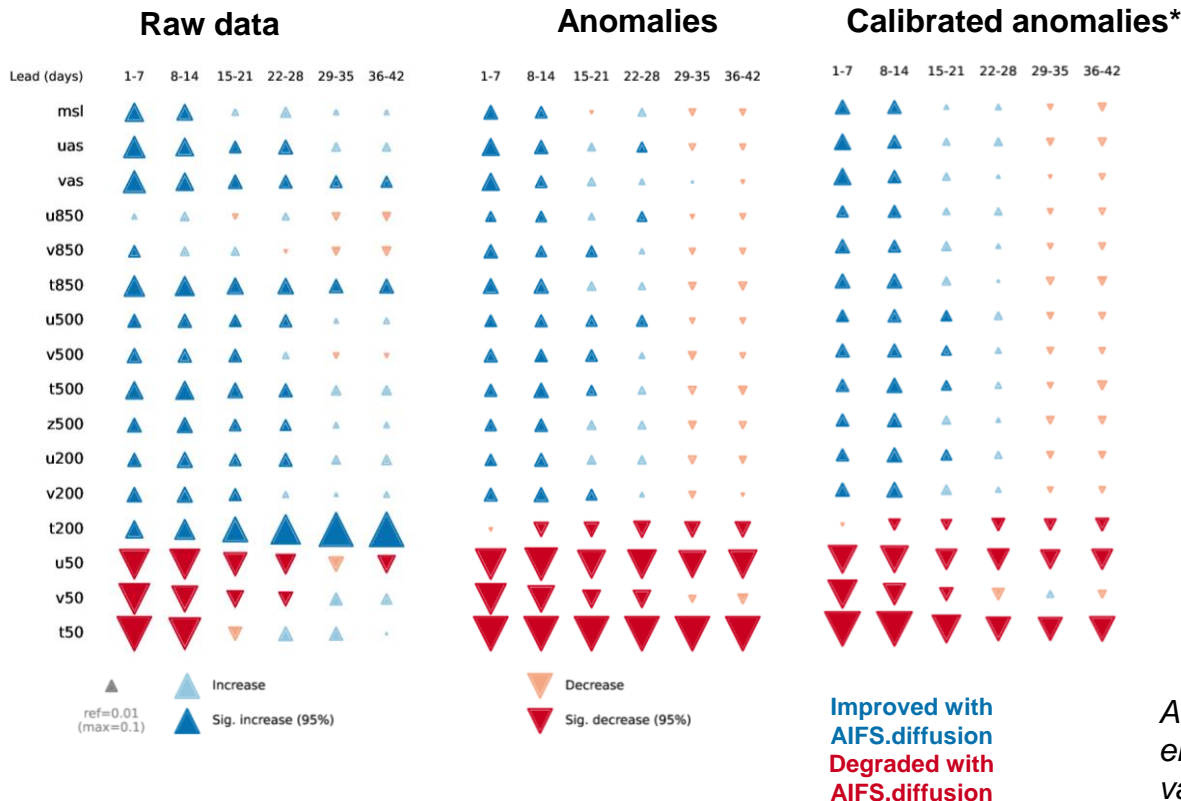
Preliminary evaluation of AIFS.diffusion for S2S timescales

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.

Δ fCRPSS: 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.

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