Plans for verification of ocean fields at ECMWF

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A bit of a disclaimer:

- ECMWF = European Centre for Medium-Range Weather Forecasts
- That means ECMWF's primary mission is not to provide forecasts of the ocean state
- Our primary mission is the provide the best medium-range (15 days) weather forecasts possible
  - As well as sub-seasonal (6 weeks) and seasonal (7 to 12/24 months)
  - In all cases the ocean acts as the lower boundary conditions of the atmosphere for ~70% of the earth
- We and other institutions has shown that the ocean impacts the weather and sub-seasonal to seasonal predictions
  - For longer time-scales the ocean is a strong driver of predictability for *e.g.* ENSO, MJO
  - For medium range the ocean impacts
    - Large scale circulation is impacted by tropical instability waves
    - Strong wind events introduce Ekman pumping
      - Especially important in tropical cyclones, but also present in mid-latitude weather systems
    - Sea-ice freezing and melting happens on a time scales of days and changes lower boundary of the atmosphere
- In the Earth System Modelling (and data assimilation approach) we want to evaluate all components
  - In our upgrade decision making process the atmosphere performance is the main driver, but we believe that in the long-term optimizing each component against observable variables will lead to better forecasts of the atmosphere

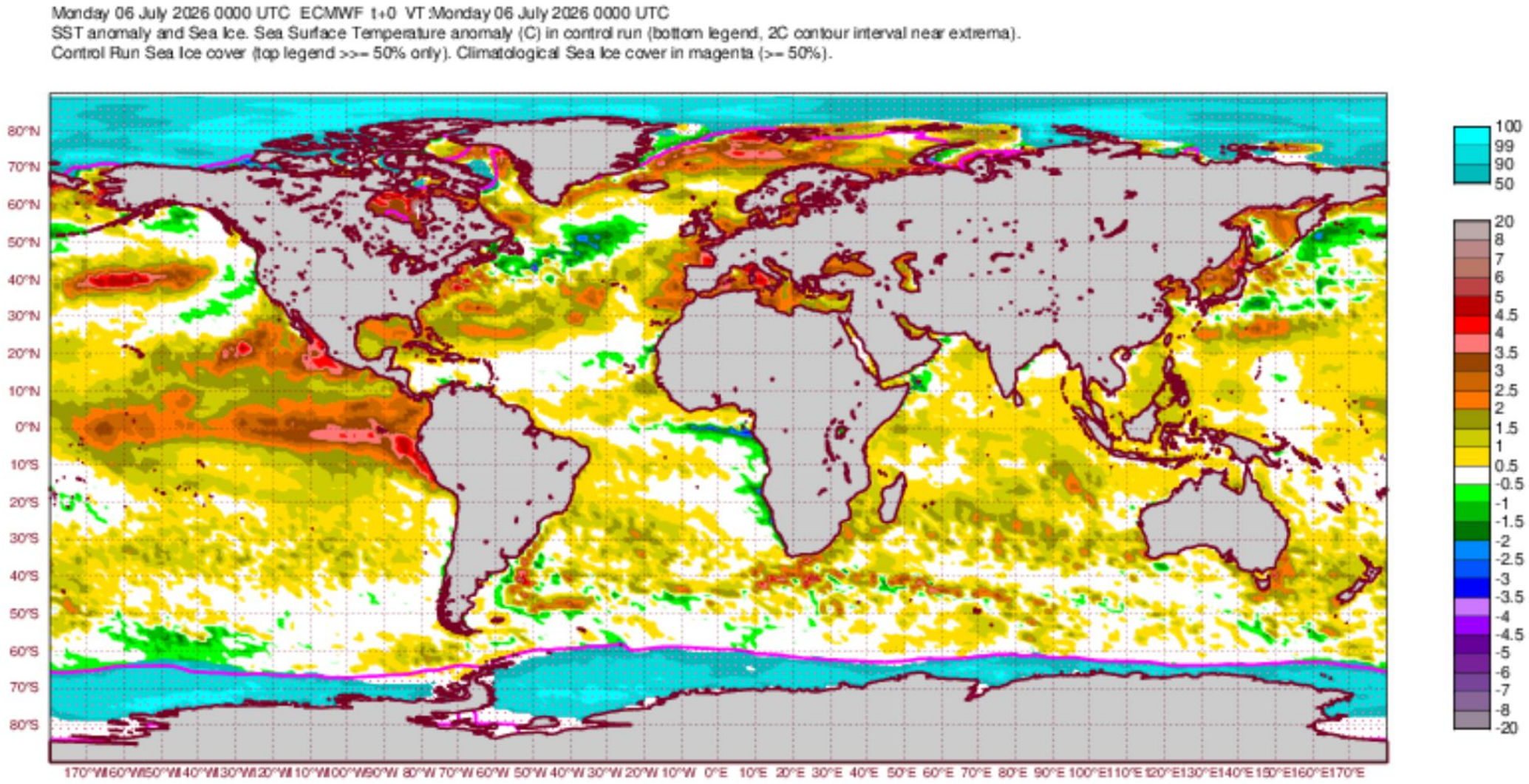
Outline of the rest of the talk

- Making plots of fields available to internal analysts and external users
  - We have a series of charts which are both available to the world and member/corporating states users only
- Operational routine monitoring of the ocean data assimilation system
  - Are the observations available as they should be?
- Outline on how we verify the atmospheric model:
  - Routine operational validation against own analysis and observations
  - Research evaluation of future contributions to new model versions
    - It is important to assess contributions to make decisions on which contributions to include in the next model upgrade
    - Ideally researchers should have access to the same tools as operations to ensure comparable evaluations
- Where we are with ocean operational monitoring and verification
- Verification of reanalysis (focused on the ocean in this talk)
- Working together with the people providing observations
  - Performing OSE's or OSSE's
  - Use of campaign data for process evaluation

Operational ocean plots (so far)

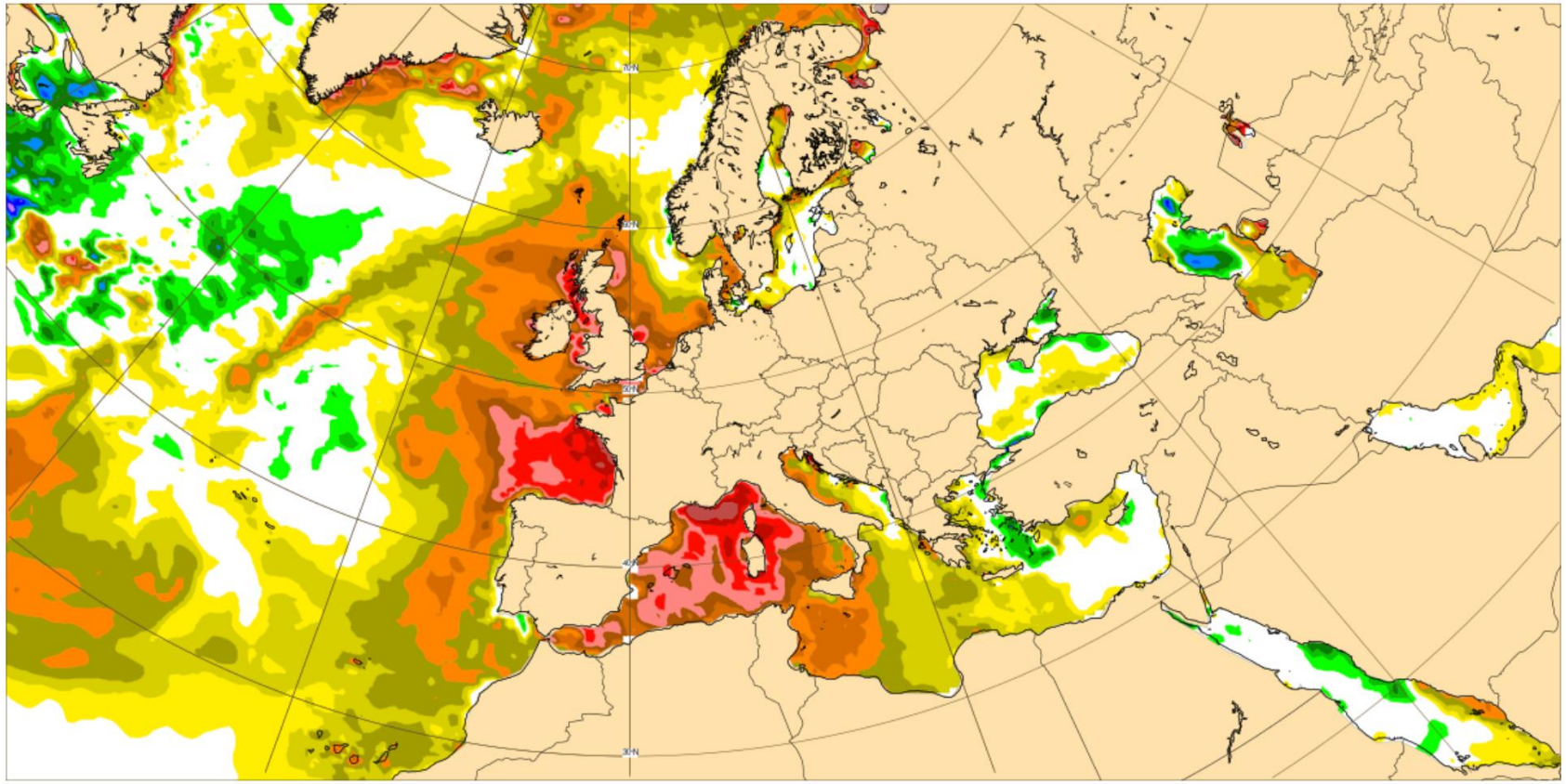
https://charts.ecmwf.int

OpenCharts example (https://charts.ecmwf.int/permalinks/sea-surface-temperature-14235)



MHW around Europe: (https://charts.ecmwf.int/permalinks/sea-surface-temperature-91720)

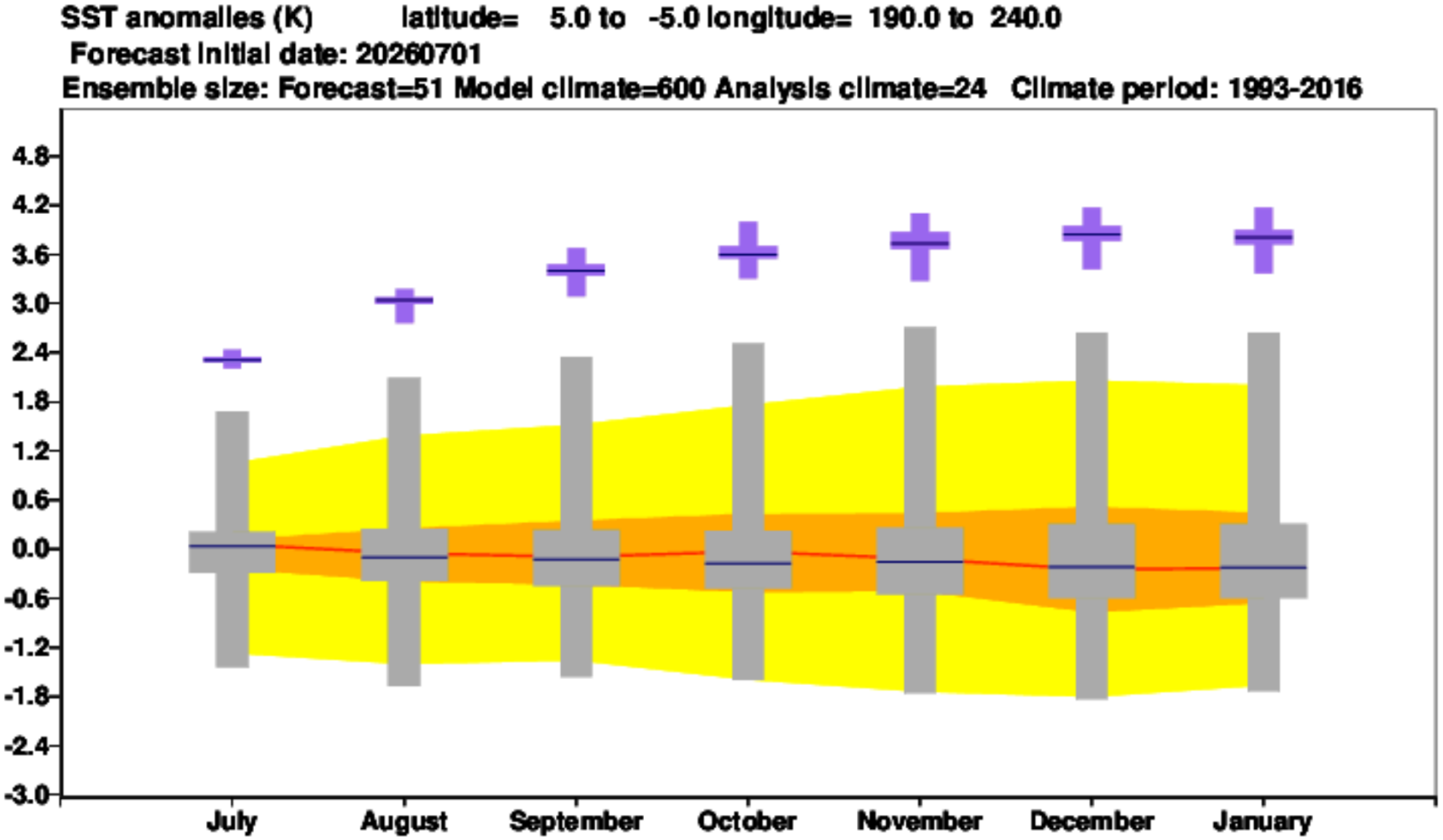
Base time: Mon 06 Jul 2026 00 UTC Valid time: Thu 16 Jul 2026 00 UTC (+240h) Parameter : sst_anomaly Area : Europe



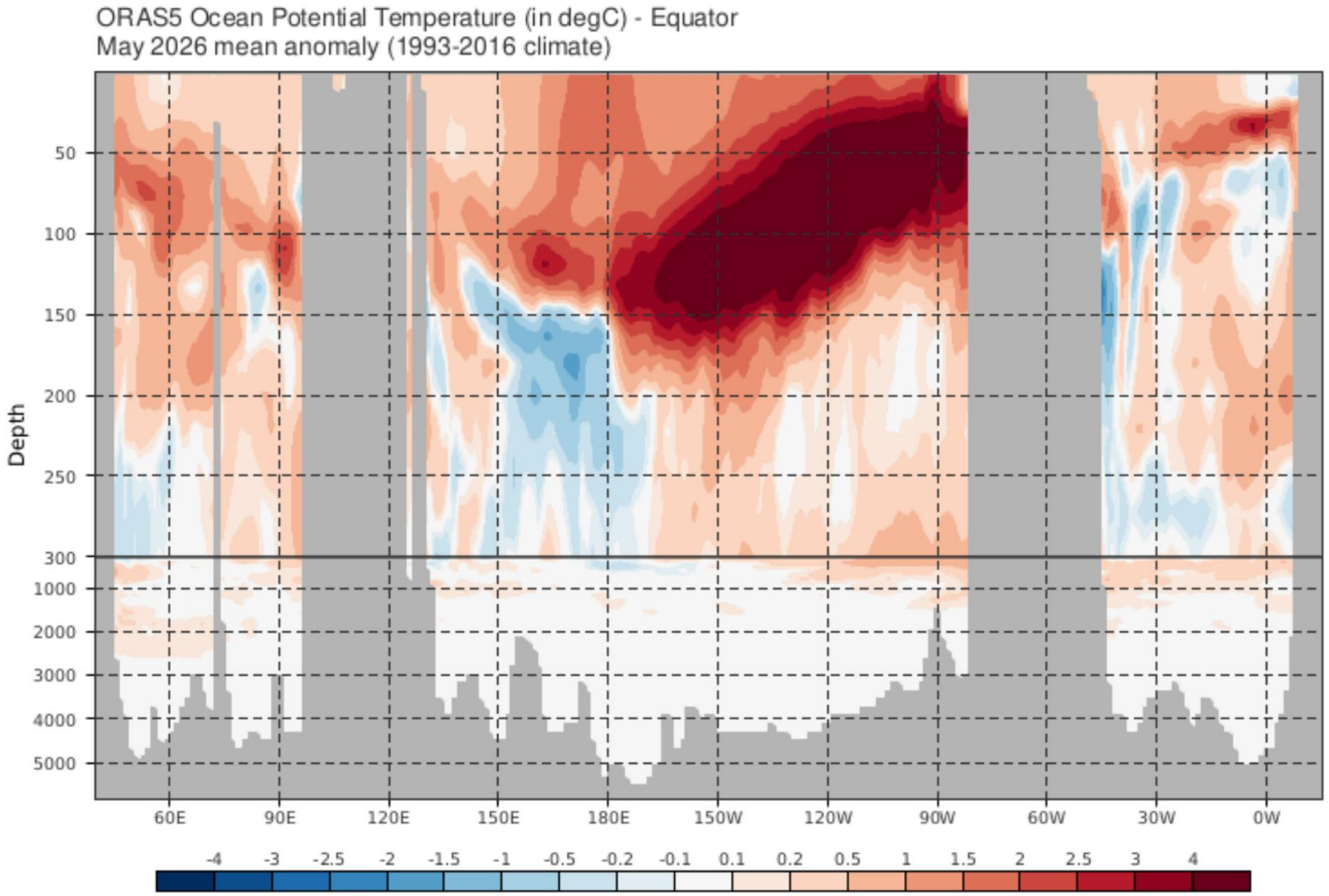
Sea surface temperature anomaly (SST) (C)

-20 -8 -7 -6 -5 -4.5 -4 -3.5 -3 -2.5 -2 -1.5 -1 -0.5 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 6 7 8 20

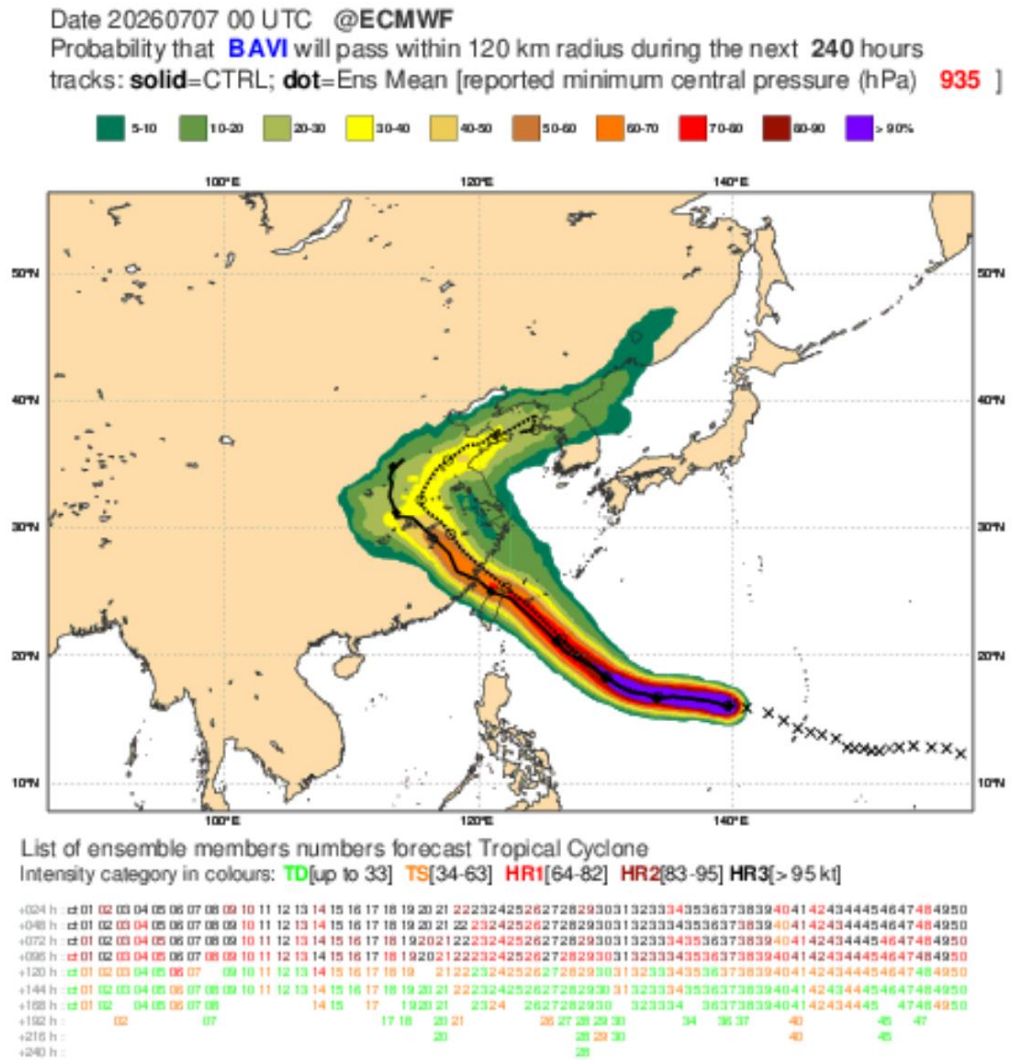
El Nino forecasts: https://charts.ecmwf.int/permalinks/sea-surface-temperature-area-averages-seasonal-forecast-seas5-47240

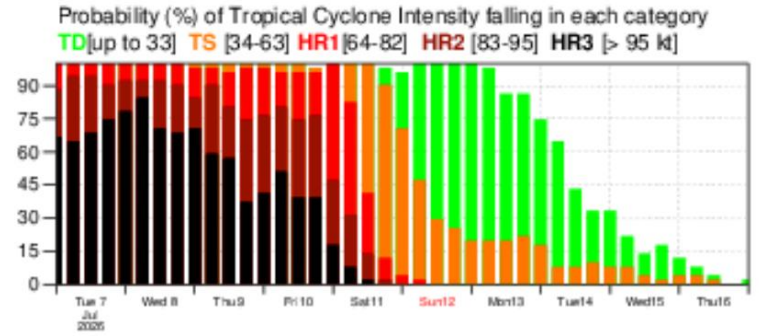


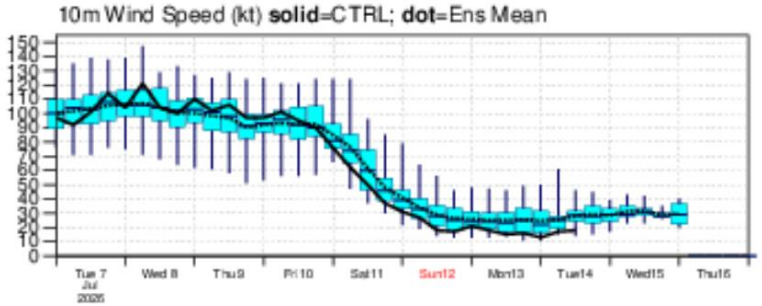
Ocean heat content along equator from ORAS5: https://charts.ecmwf.int/catalogue/packages/oras5/

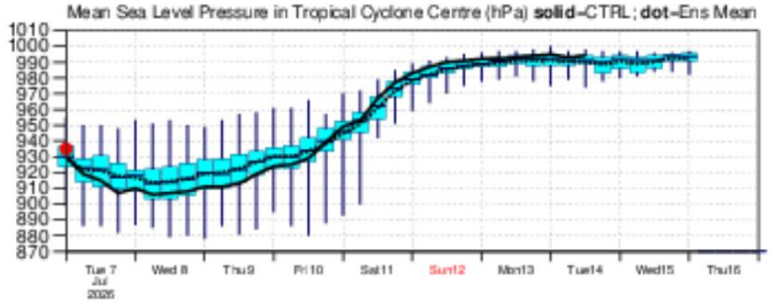


TC Bavi atmospheric prediction:

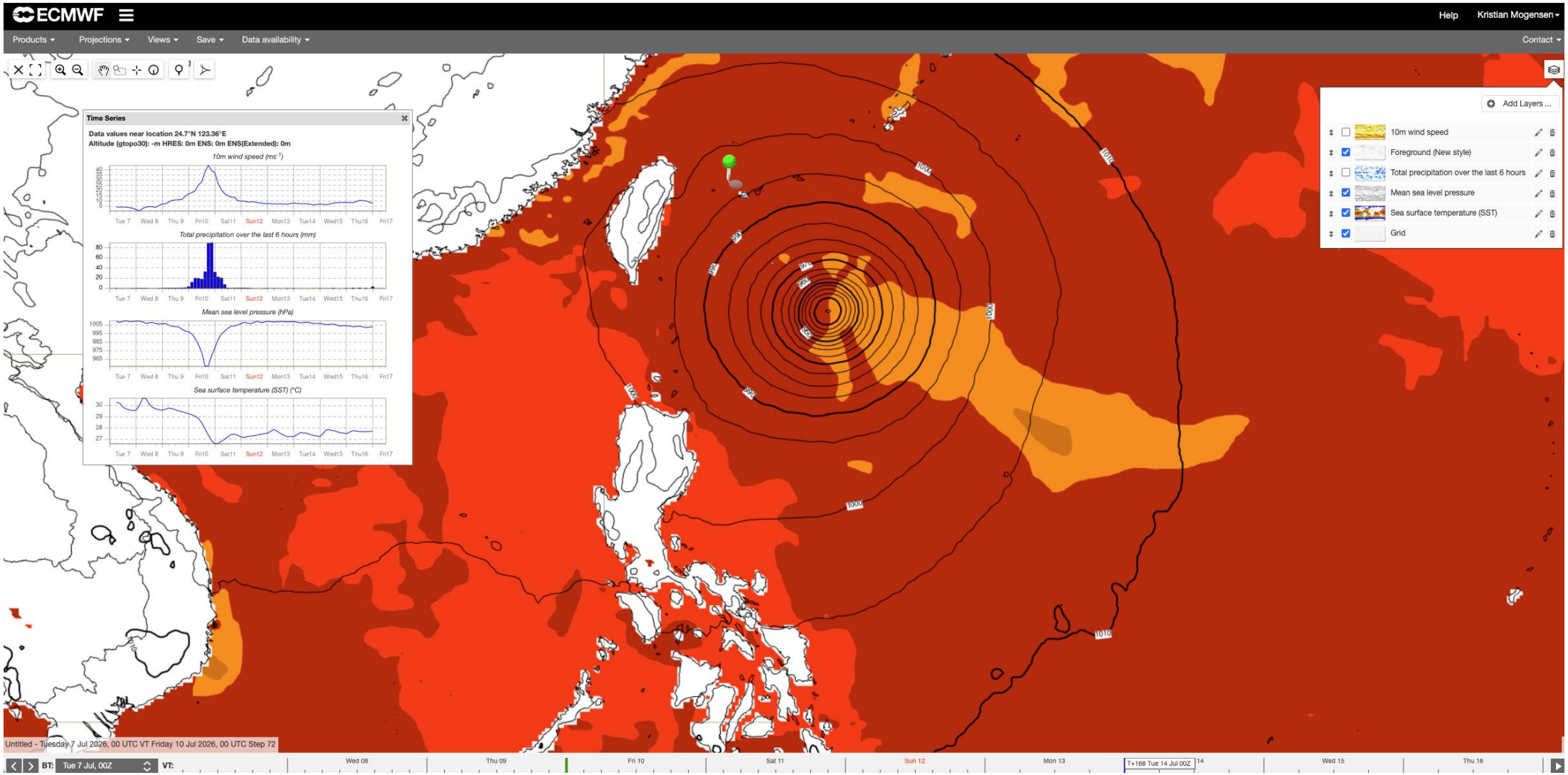








On demand eccharts for ECMWF member and corporation states



Ocean output plots outlook

- We will plan to add more ocean plots to both the opencharts and eccharts systems
- Should help weather forecasters in situations where the ocean matter for the atmospheric predictions
- For TC Bavi having upper ocean heat content or tropical cyclone heat potential could have been useful for forecasters

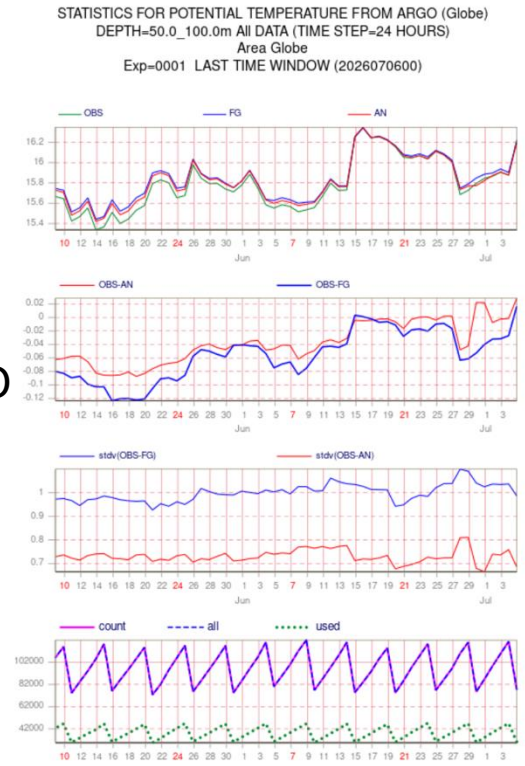
Monitoring of the ocean data assimilation system

https://www.ecmwf.int/en/forecasts/quality-our-forecasts/monitoring-observing-system#Ocean

Ocean observation monitoring

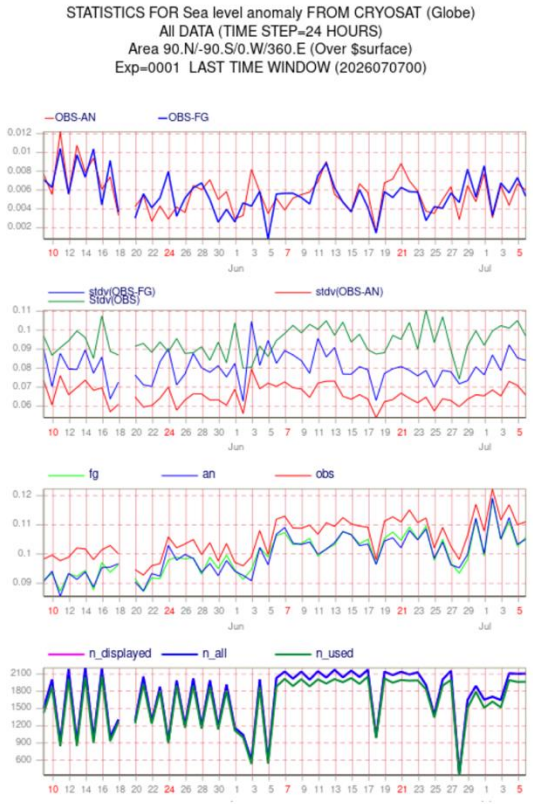
Potential Temperature

ARGO



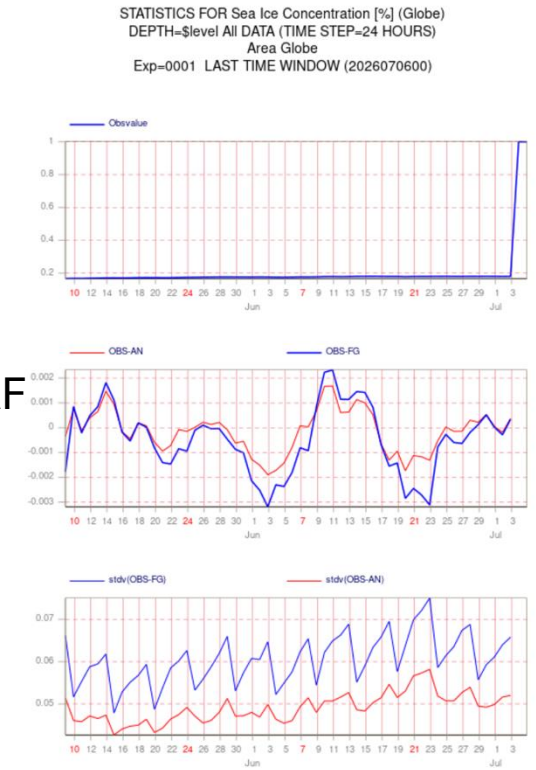
ıeseries of statistics for Sea level anom

Cryosat

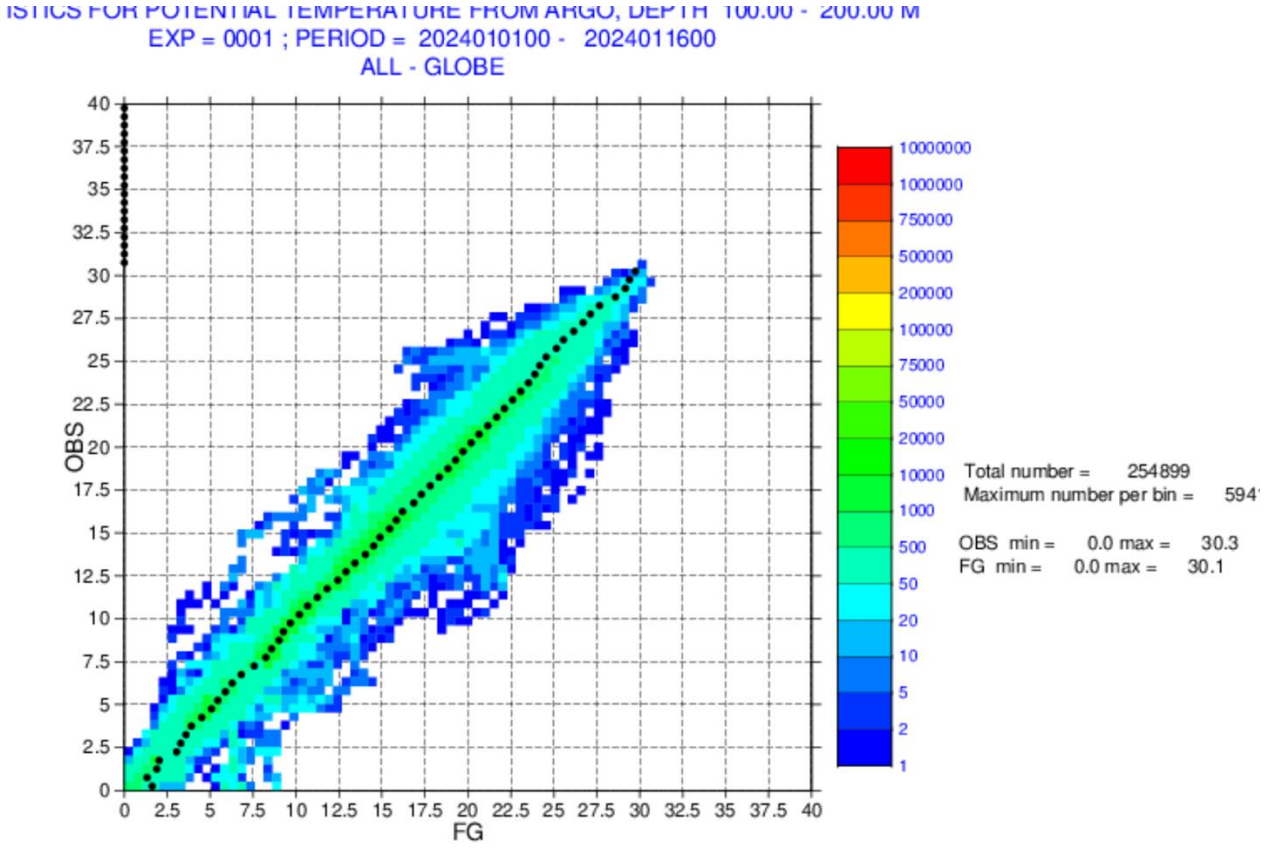


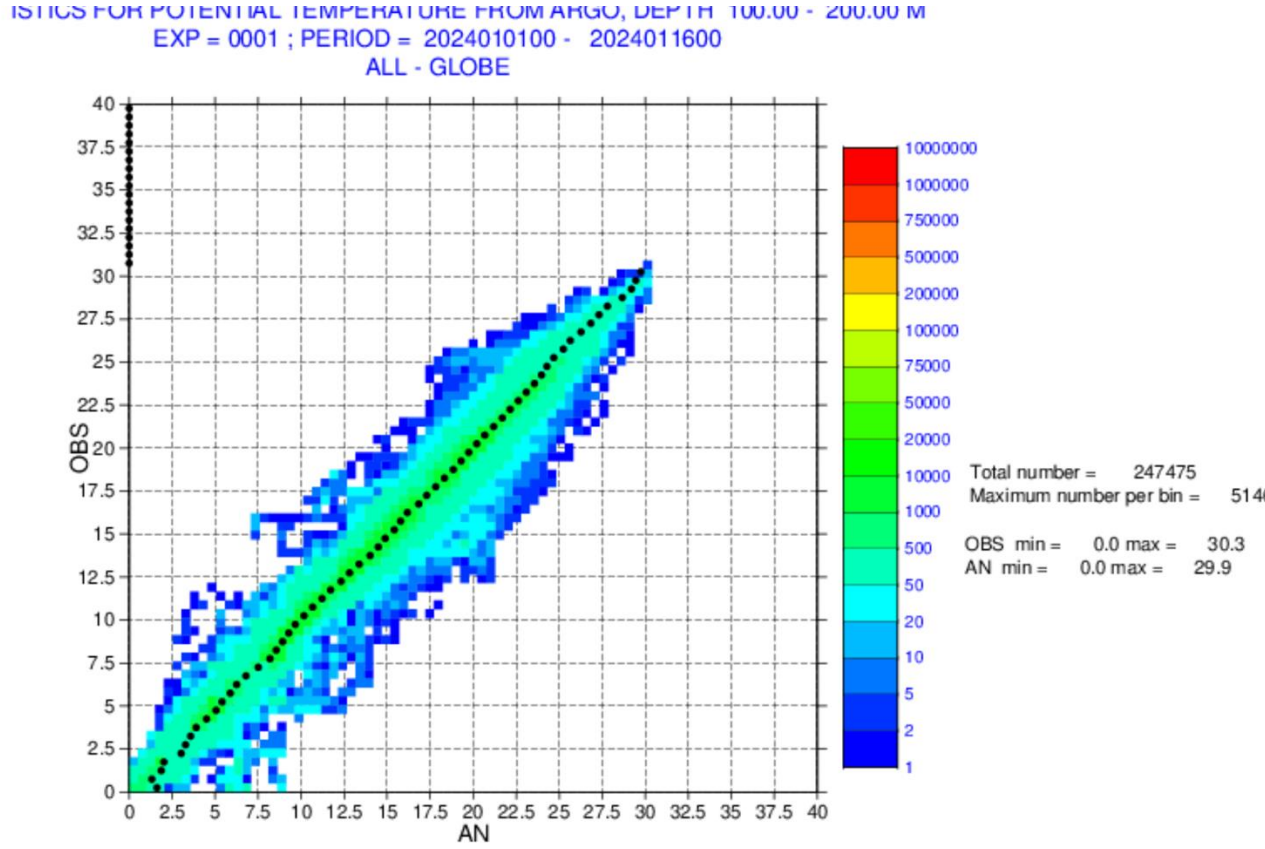
Sea Ice Concentration

OSI-SAF



Observation monitoring: DA performance of ARGO



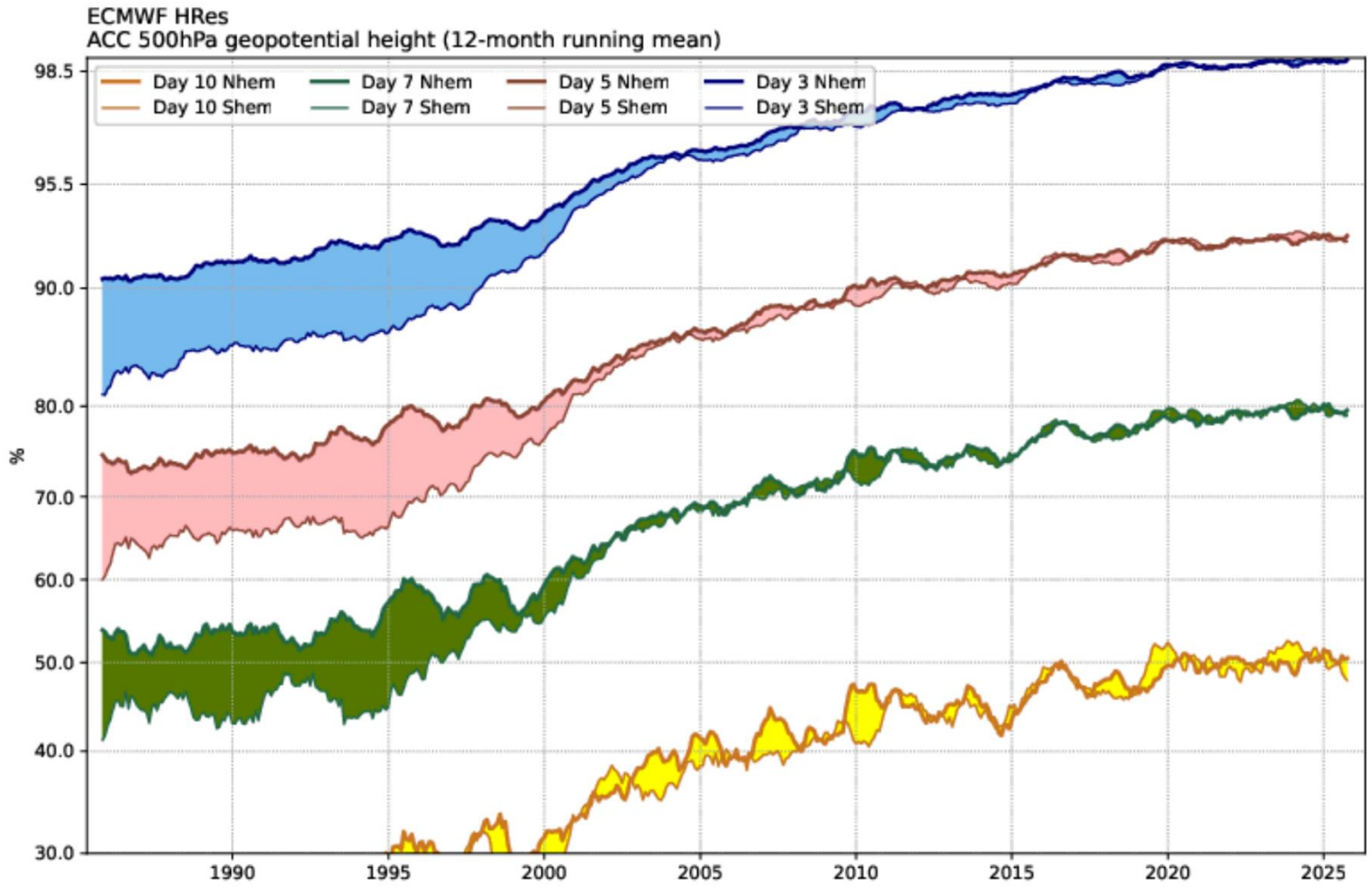


The analysis (AN) versus observation is narrower than the first guest (FG) versus observations

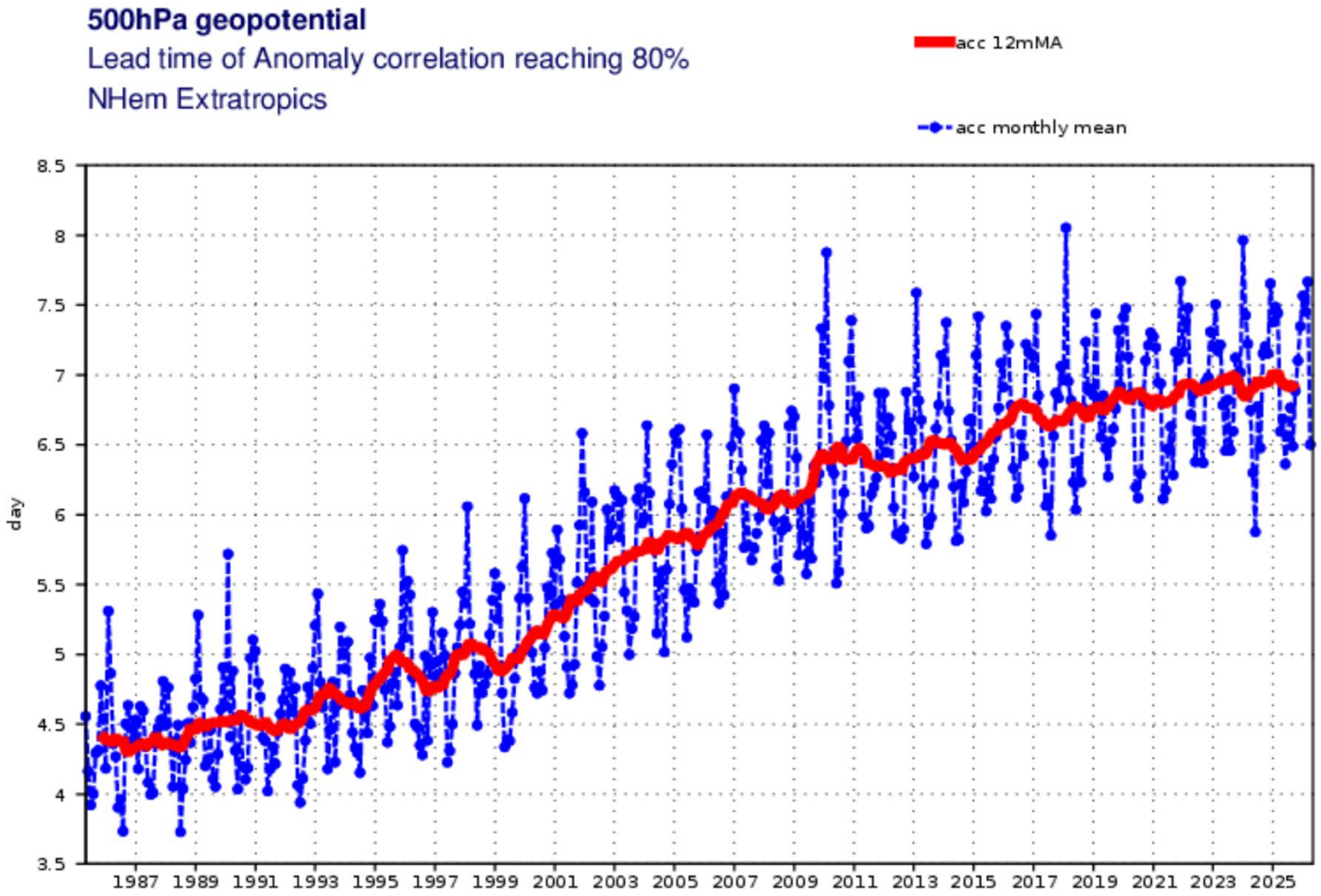
Operational validation of atmospheric forecasts

https://charts.ecmwf.int/?facets=%7B%22Type%22%3A%5B%22Verification%22%5D%7D

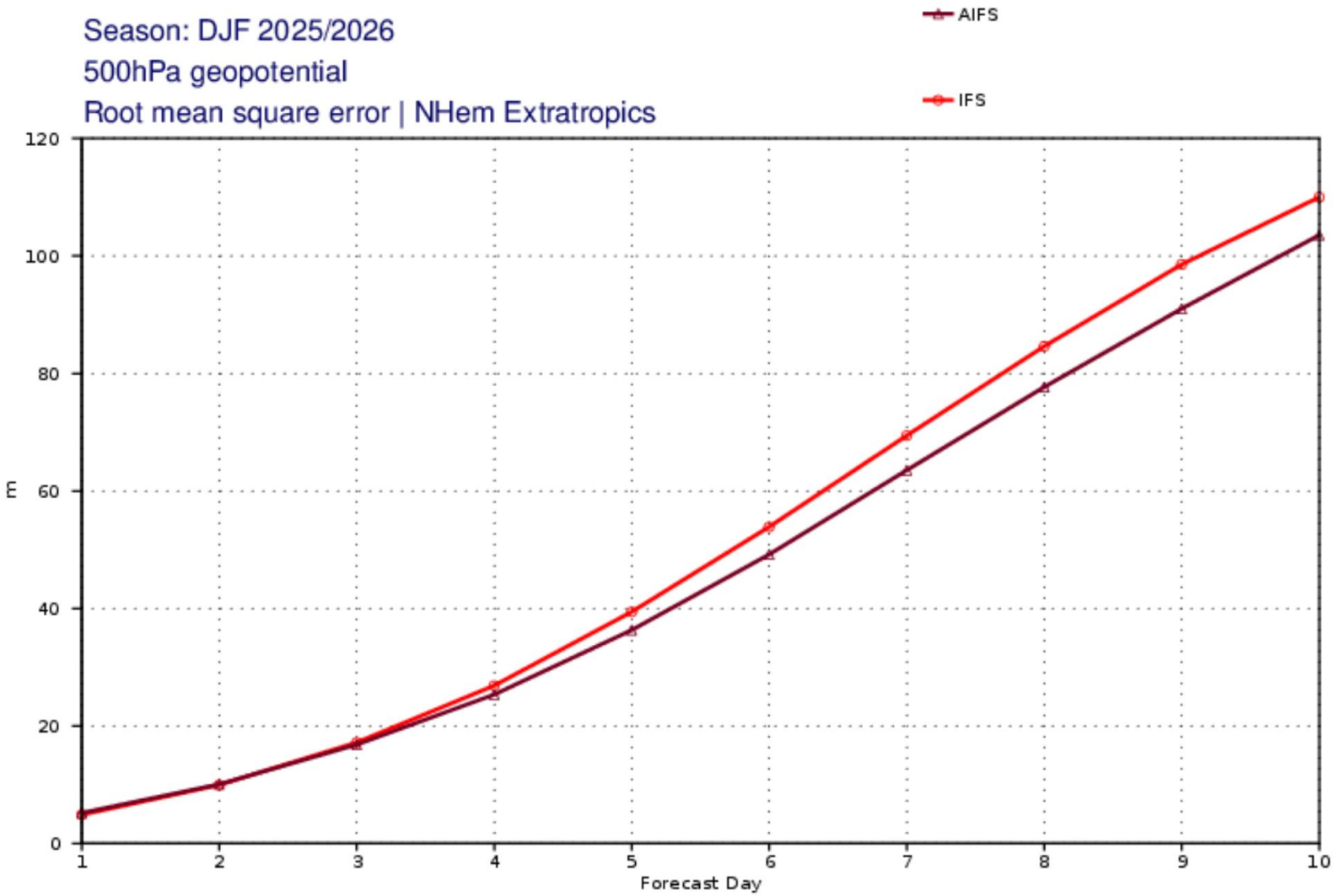
Headline scores: z500 anomaly correlation coefficient



Headline scores: z500 anomaly correlation coefficient



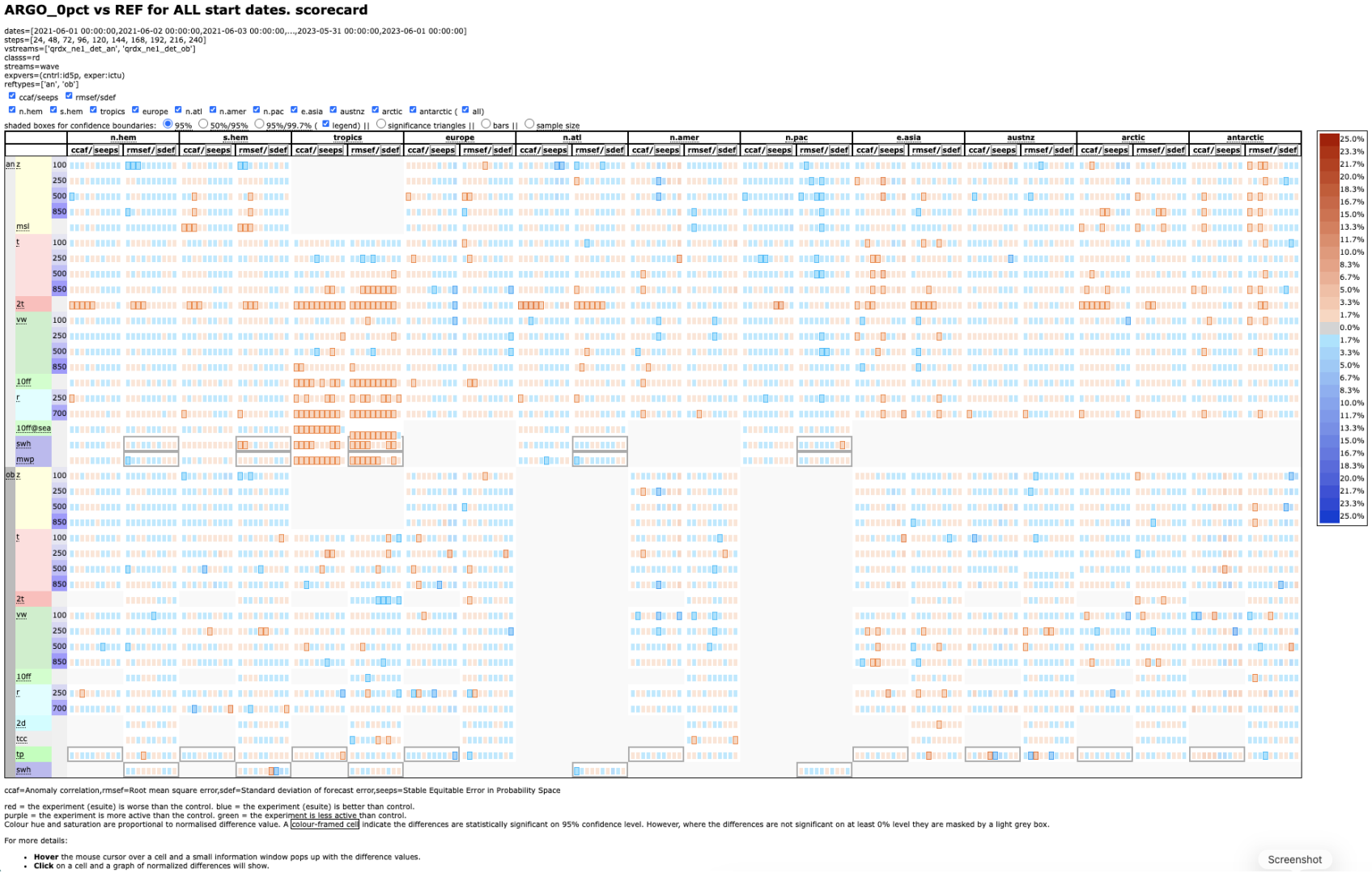
Validation of AIFS against IFS:



Tools used for developments

Scorecards for medium-range and sub-seasonal forecasts

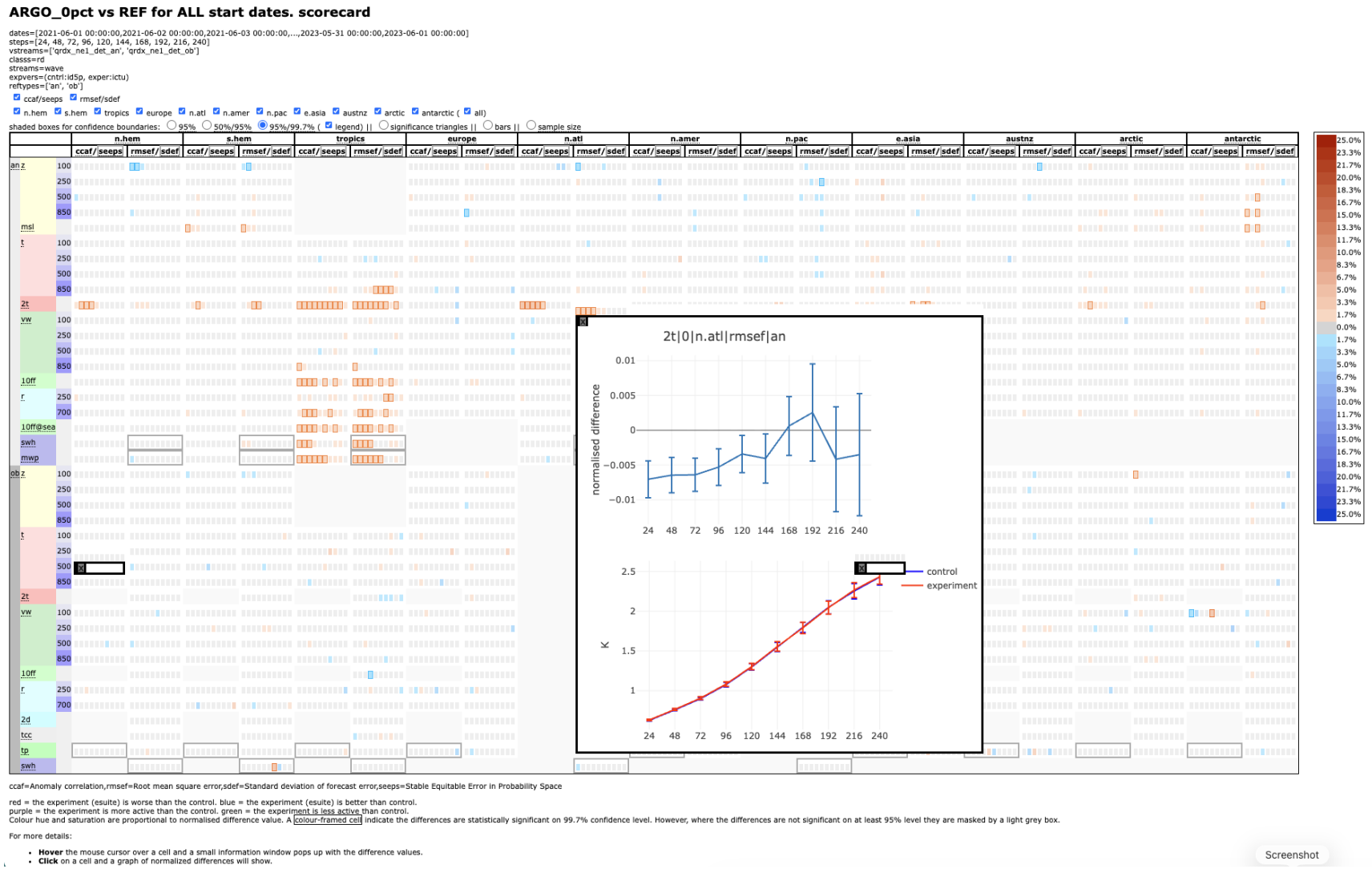
Impact of removing ARGO in ocean DA on NWP 1



Top half: verification against operational atmospheric analysis;

Bottom half: Against observations

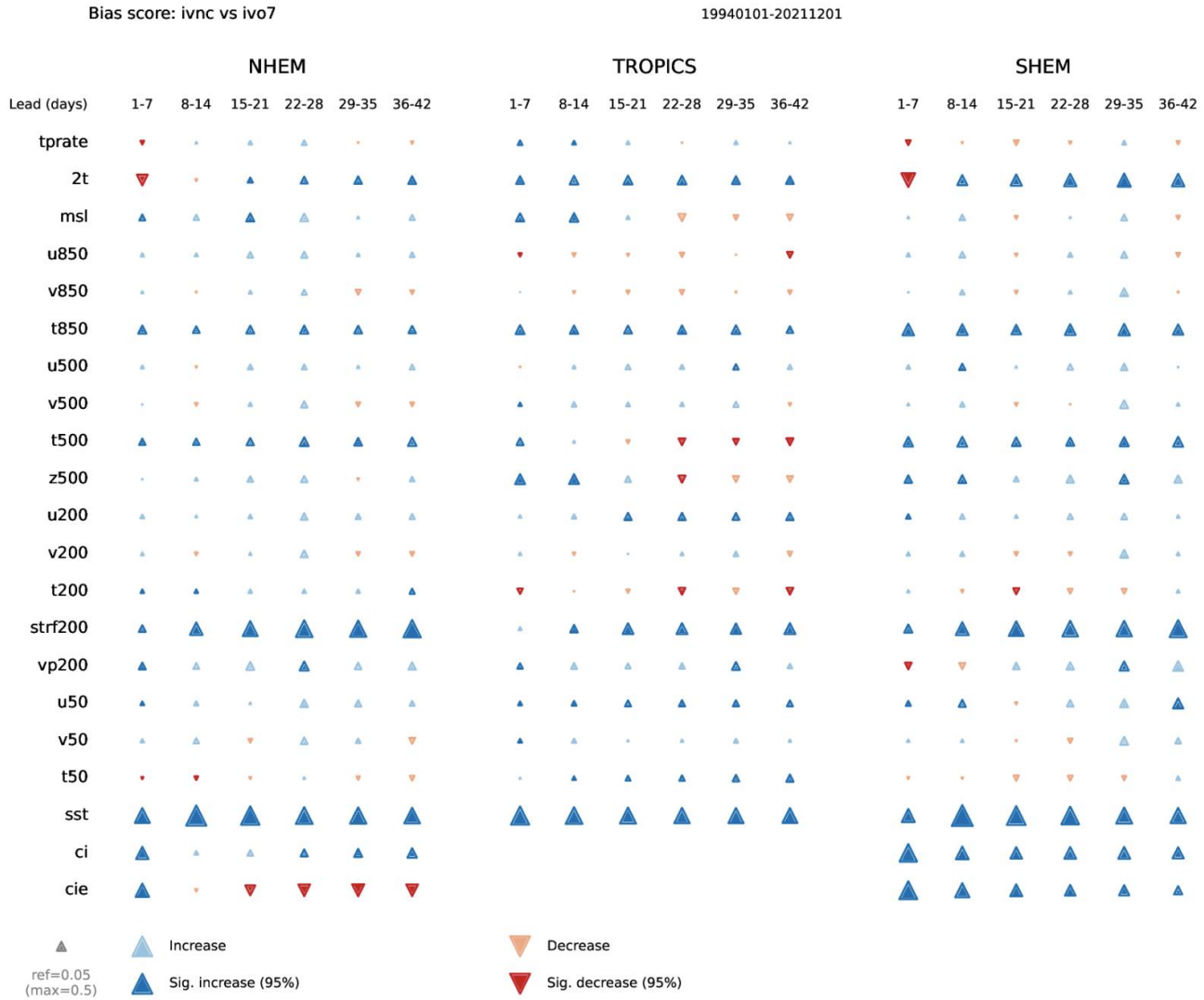
Impact of removing ARGO in ocean DA on NWP 2



Top half: verification against operational atmospheric analysis;

Bottom half: Against observations

Scorecards for S2S model evaluation has some ocean fields



Remarks on our tools

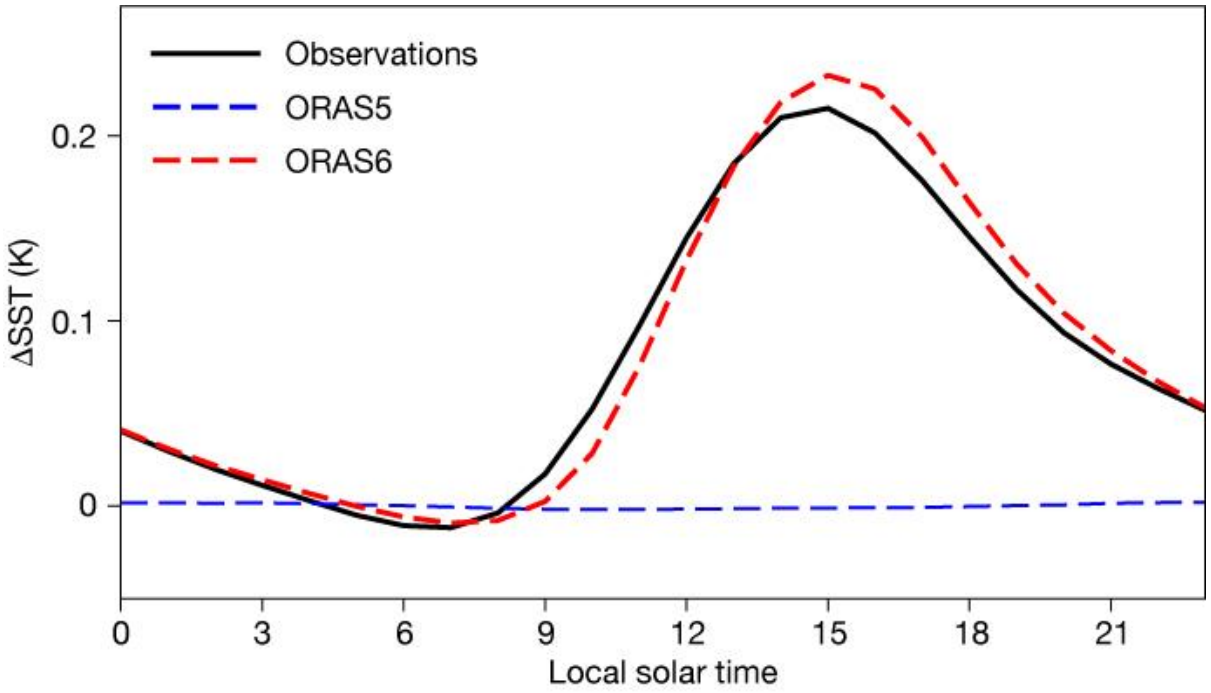
- The score card for medium-range forecasts uses both an atmospheric analysis and observations for evaluation of forecasts
  - Quality control of observations is a key thing to get right
  - Our first attempt to use SST observations from ships and buoys based on our operational archive failed due to errors in the observations
    - Using data from the global drifter programme (https://www.aoml.noaa.gov/global-drifter-program/) is being investigated and seems more successful

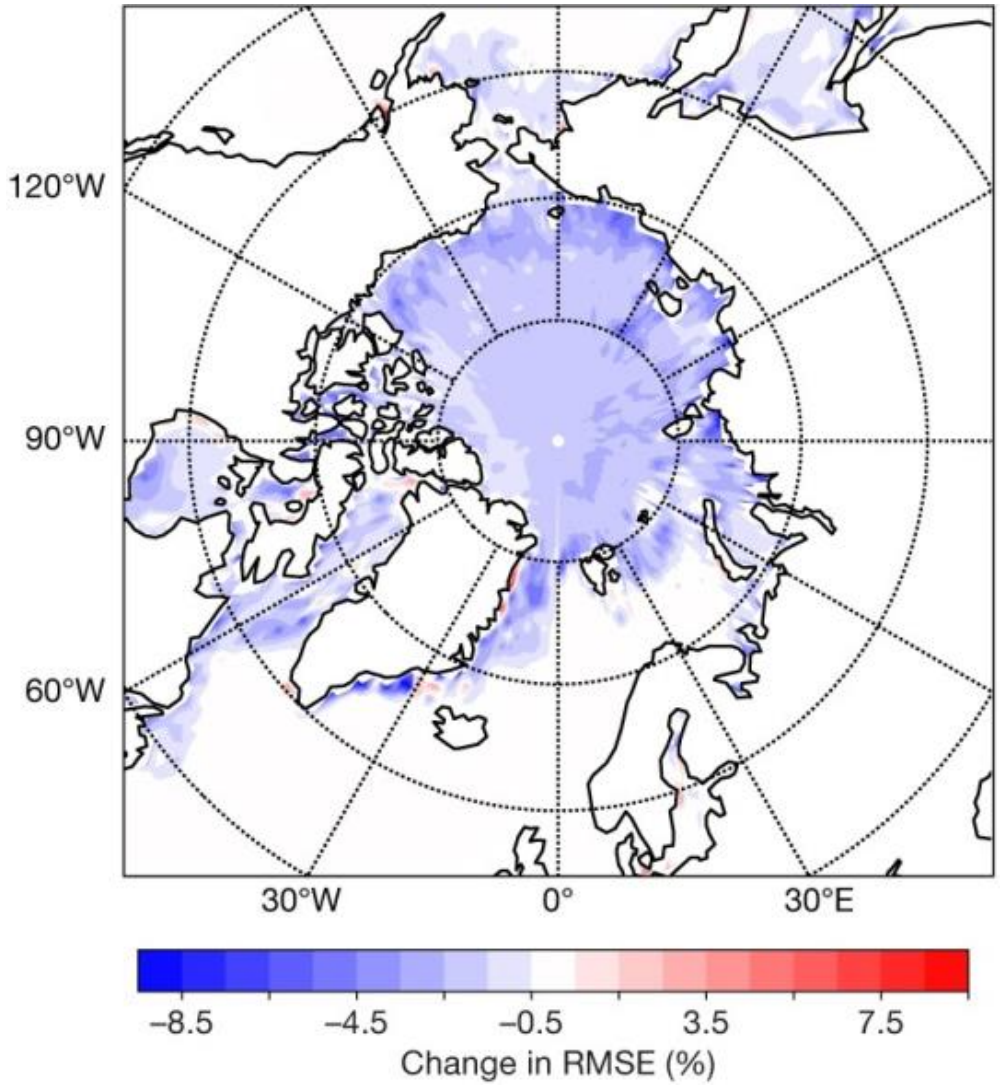
- We will investigate using the IV-TT collected ocean observations with these tools

Evaluation of ocean reanalyses

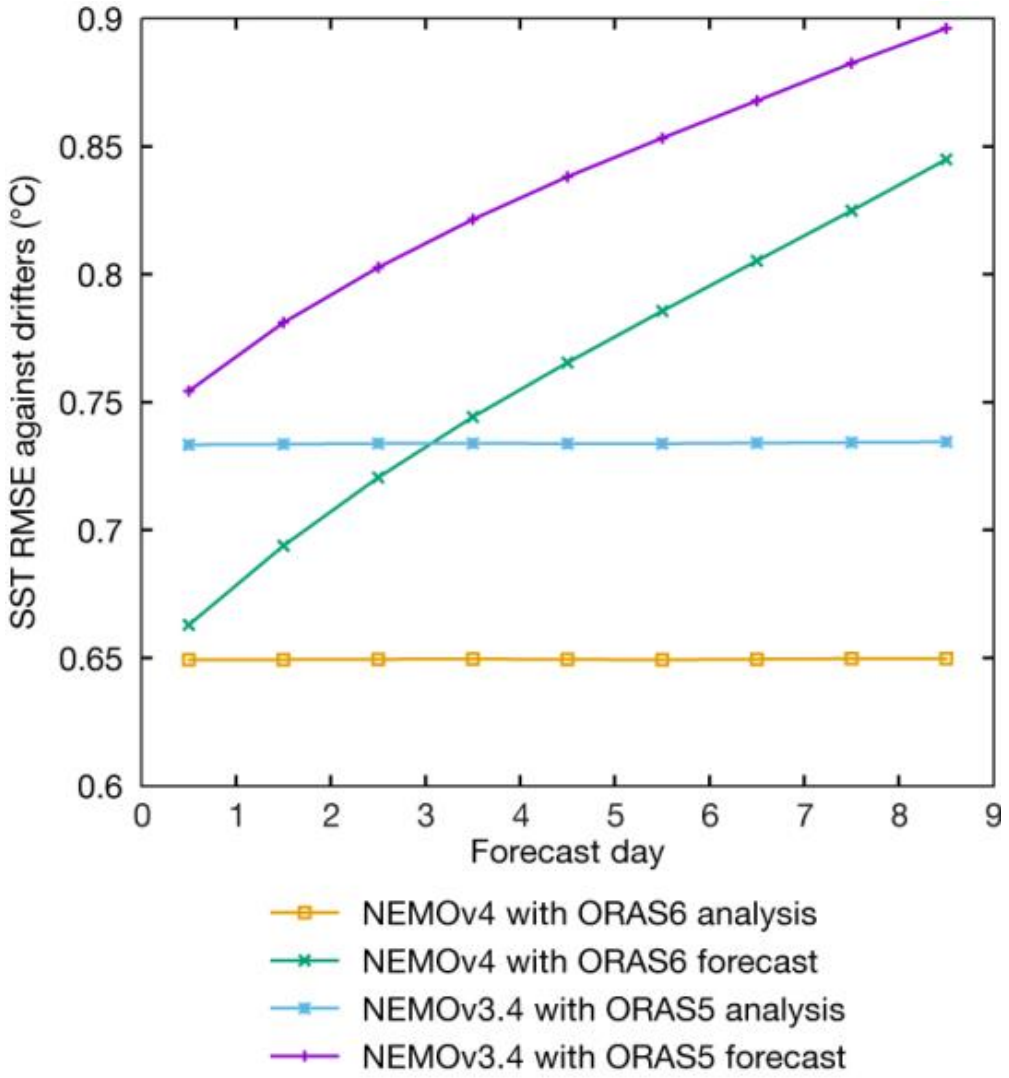
https://www.ecmwf.int/en/newsletter/180/earth-system-science/ecmwfs-next-ensemble-reanalysis-system-ocean-and-sea-ice

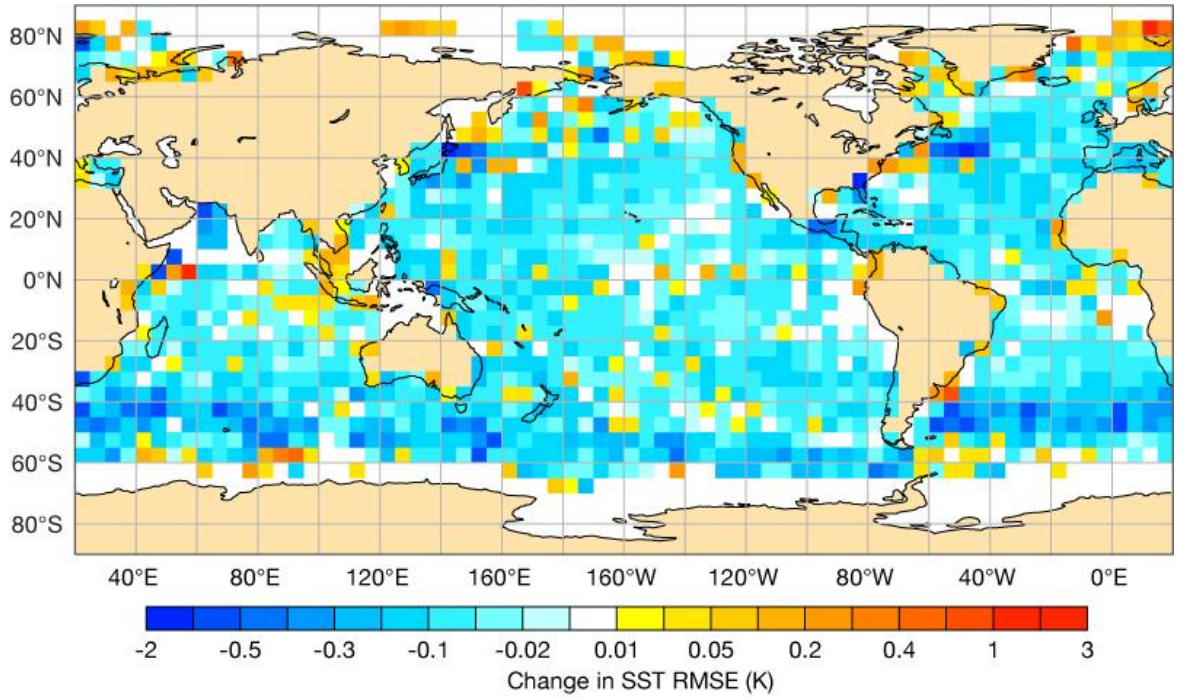
New features in ORAS6: diurnal cycle and better sea-ice model/DA





Validation of ORAS6 compared to ORAS5 against drifters

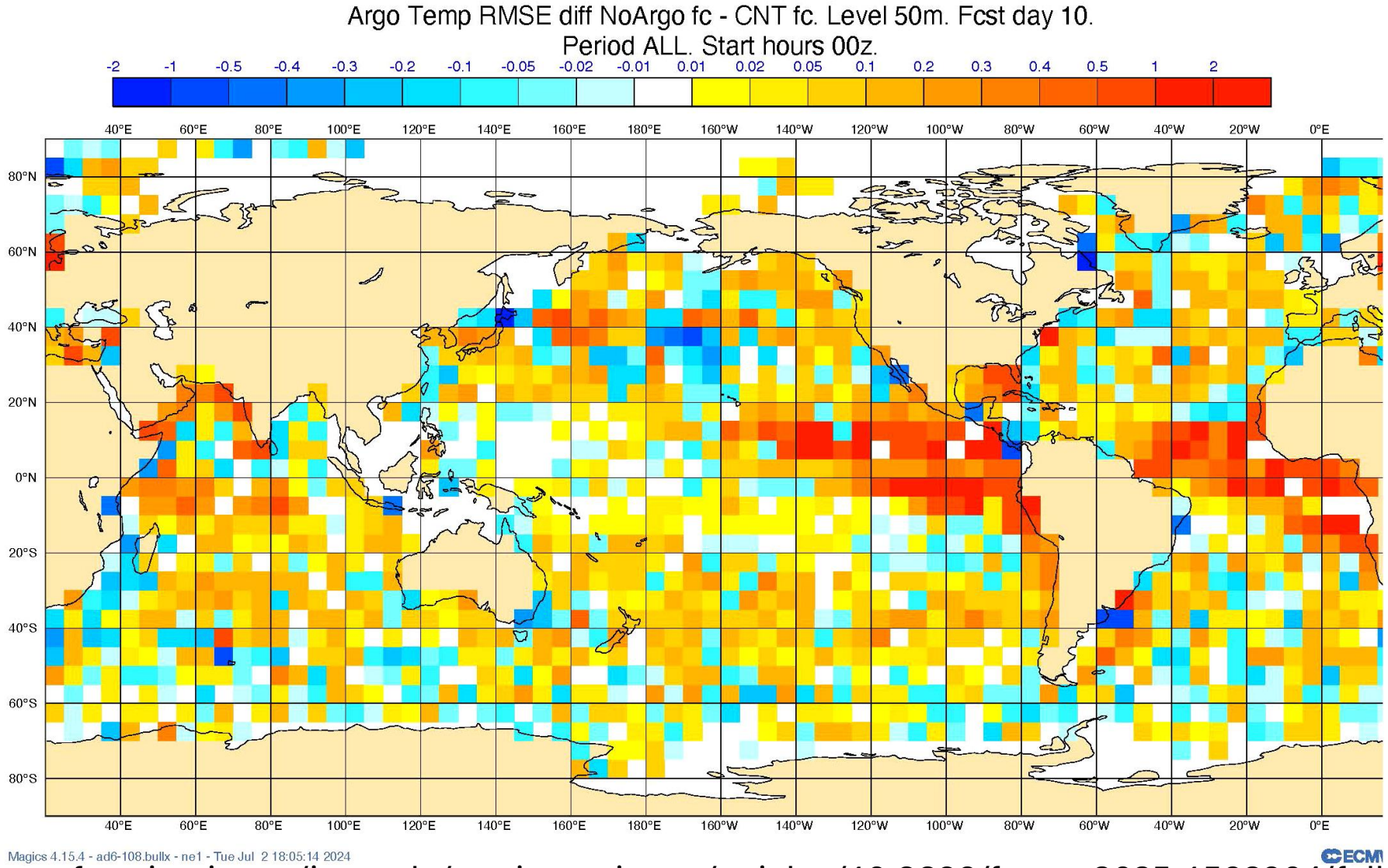




- Blue means ORAS6 is better than ORAS5
- The observations were not directly assimilated, but were still used as calibration for the SST products used

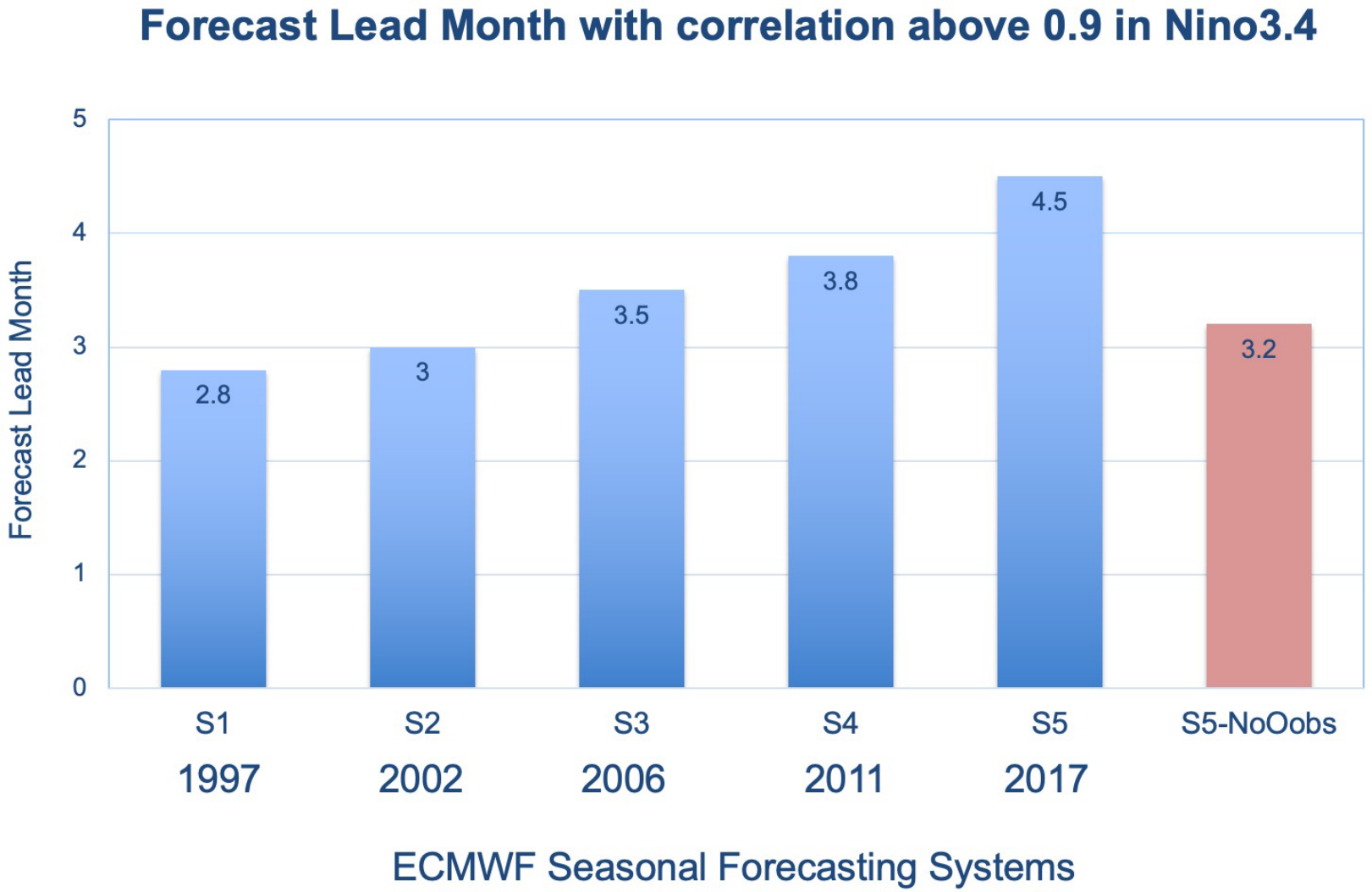
Working with the observational communities

Working with the observational community: ARGO for NWP



https://www.frontiersin.org/journals/marine-science/articles/10.3389/fmars.2025.1593904/full

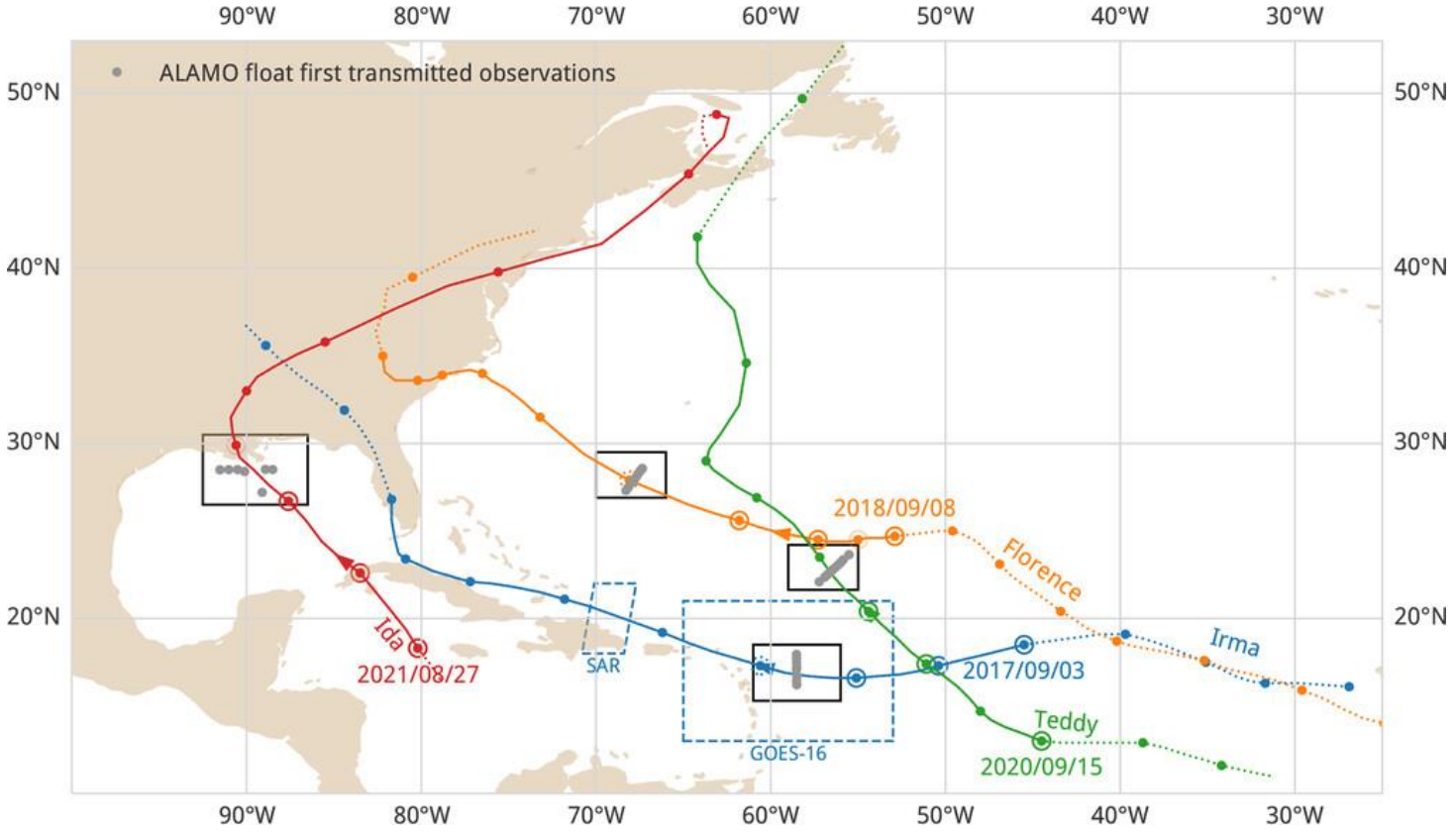
Working with the observational community: ARGO for seasonal forecasting



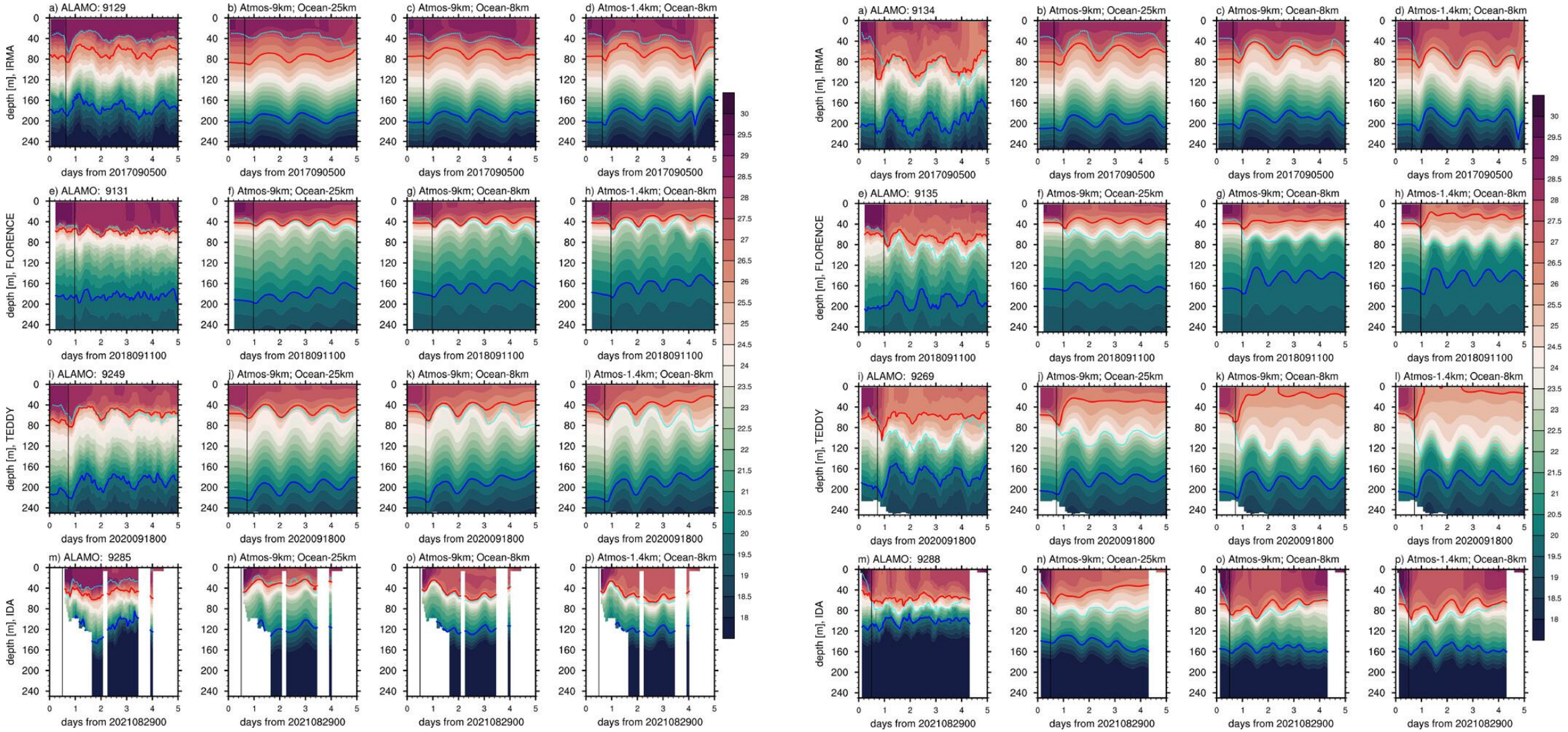
https://www.frontiersin.org/journals/marine-science/articles/10.3389/fmars.2025.1593904/full

Using ALAMO floats for validation of ocean TC response 1

- ALAMO floats are micro profilers which measures temperature and salinity
- High repetition frequency (~2 hours) down to a few hundreds' meters
- Air dropped for observational campaigns
- https://journals.ametsoc.org/view/journals/mwre/153/11/MWR-D-24-0104.1.xml



Using ALAMO floats for validation of ocean response 2



Conclusions and output

- A very limited set of ocean fields are available for users to look at, but we are working on it
  - Scores are great, but having eyes on fields are useful as well
- Monitoring of ocean data assimilation is in place and works well
  - Coupled to an automatic alarm system so missing data can be detected
- Standardizing tools across our different modelling activities to also include ocean variable will be nice
  - Use of IV-TT observations could be a good option
  - Our new ocean model upgrade will have output in GRIB2 which will also help us here
- The plan is to contribute to the IV-TT's activities and provide input to the class-4 diagnostics

Kristian Mogensen (who takes all the blame)

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