Effects of an interactive ocean component on NWP: Lessons learned so far and some thoughts on future directions

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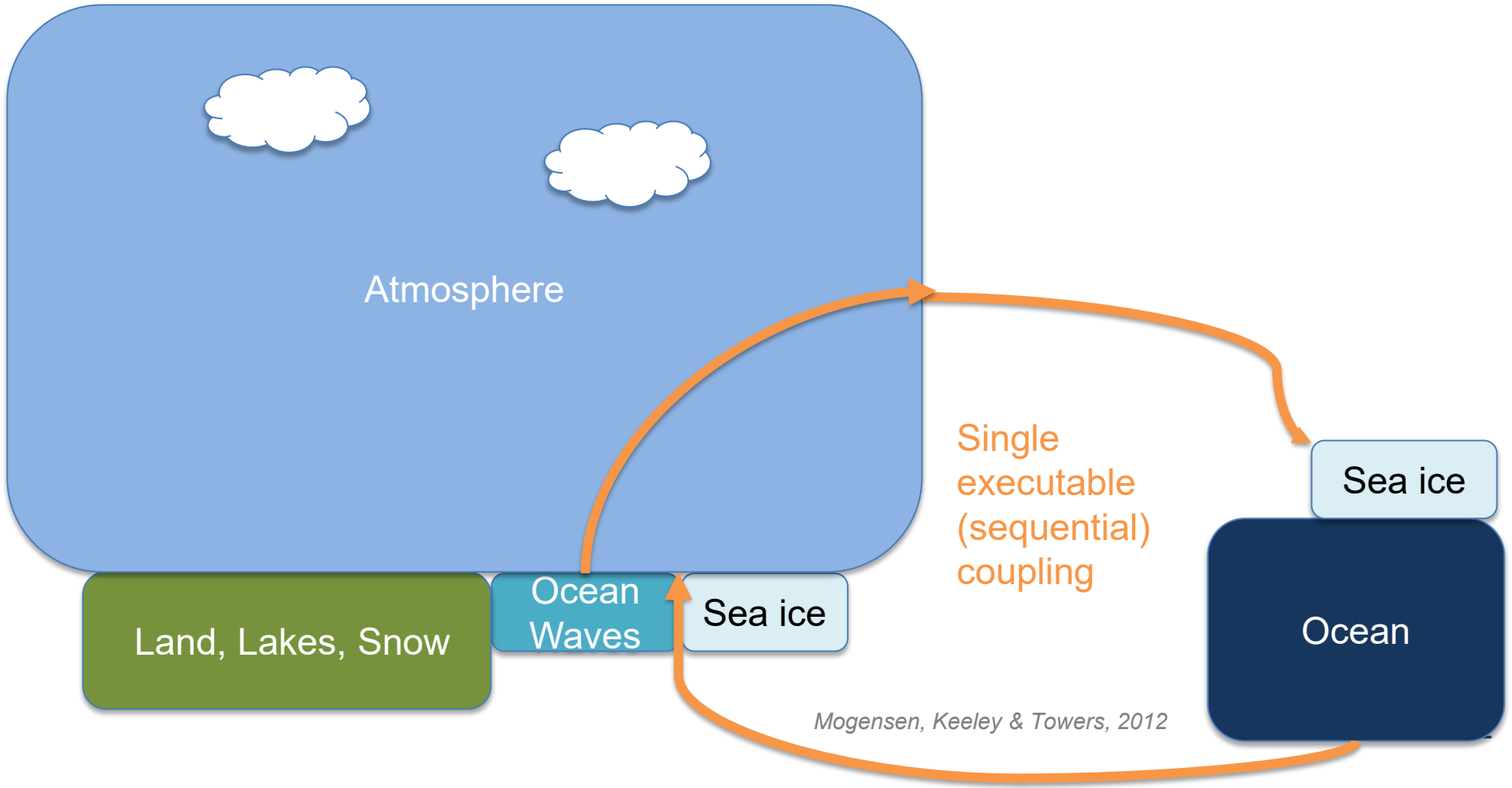
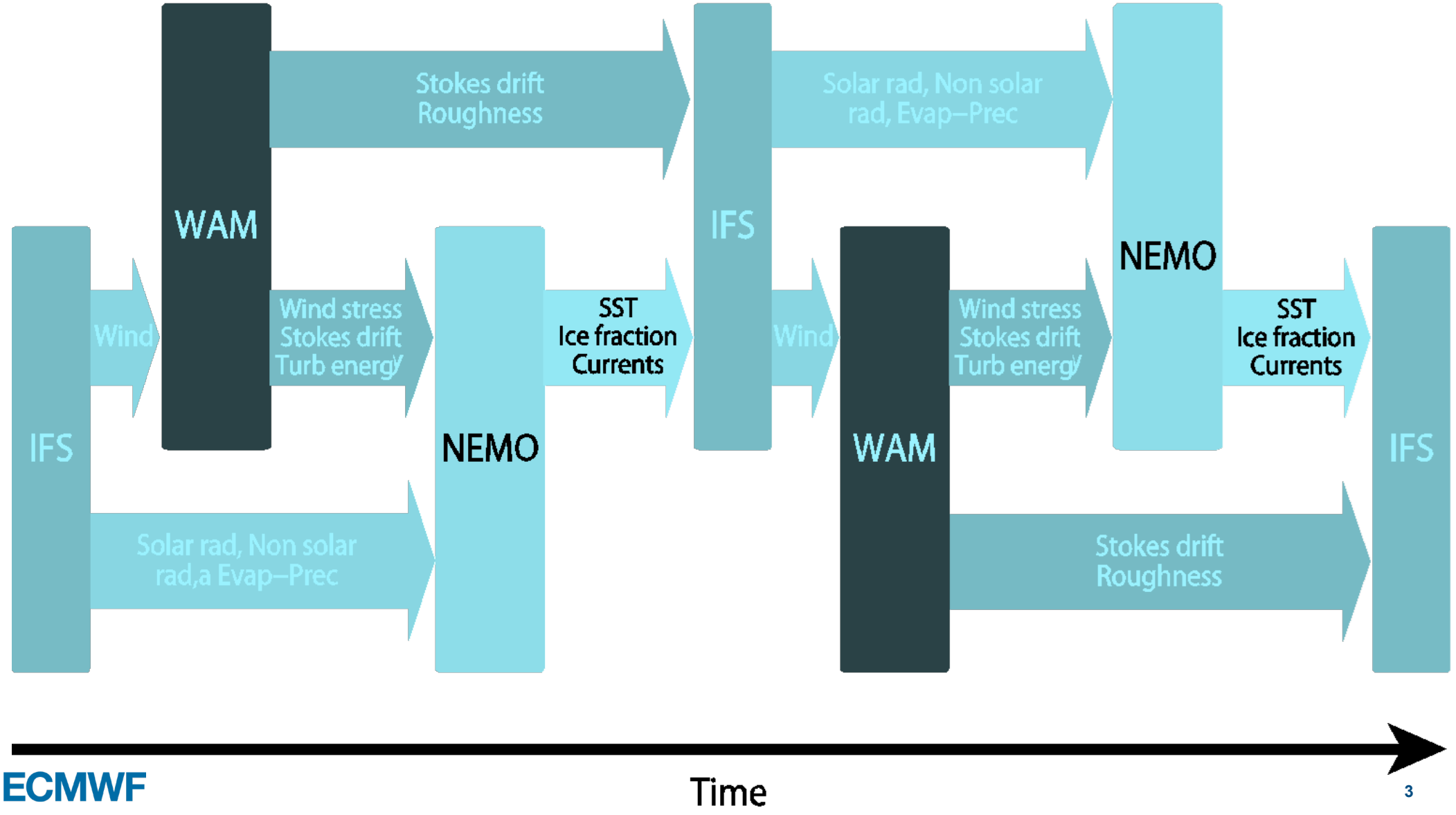
ECMWF

Model Components at ECMWF

- Coupled model in all our forecast systems

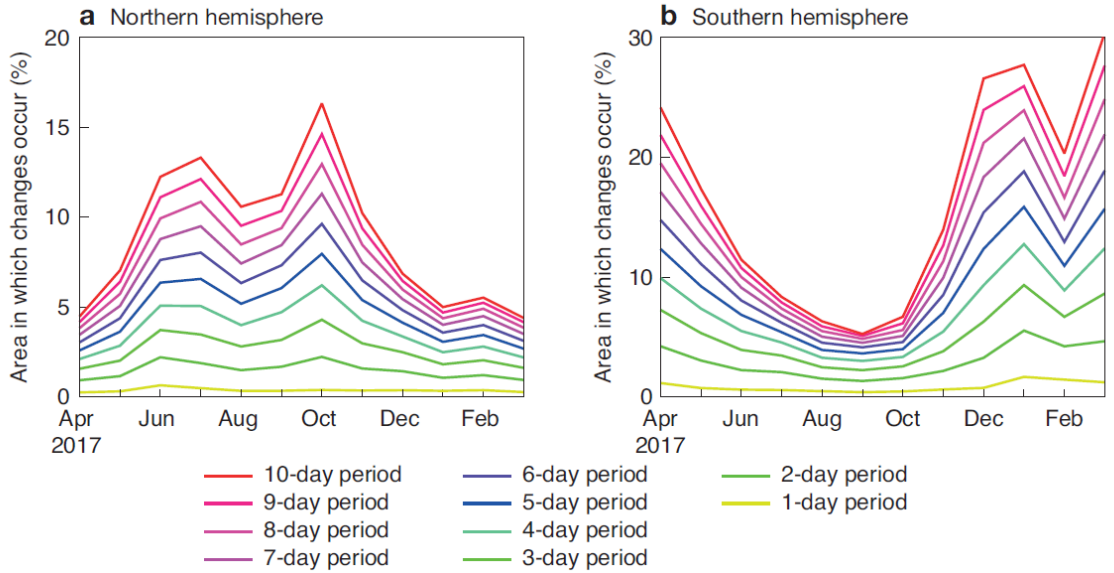


Schematic overview of coupled system:

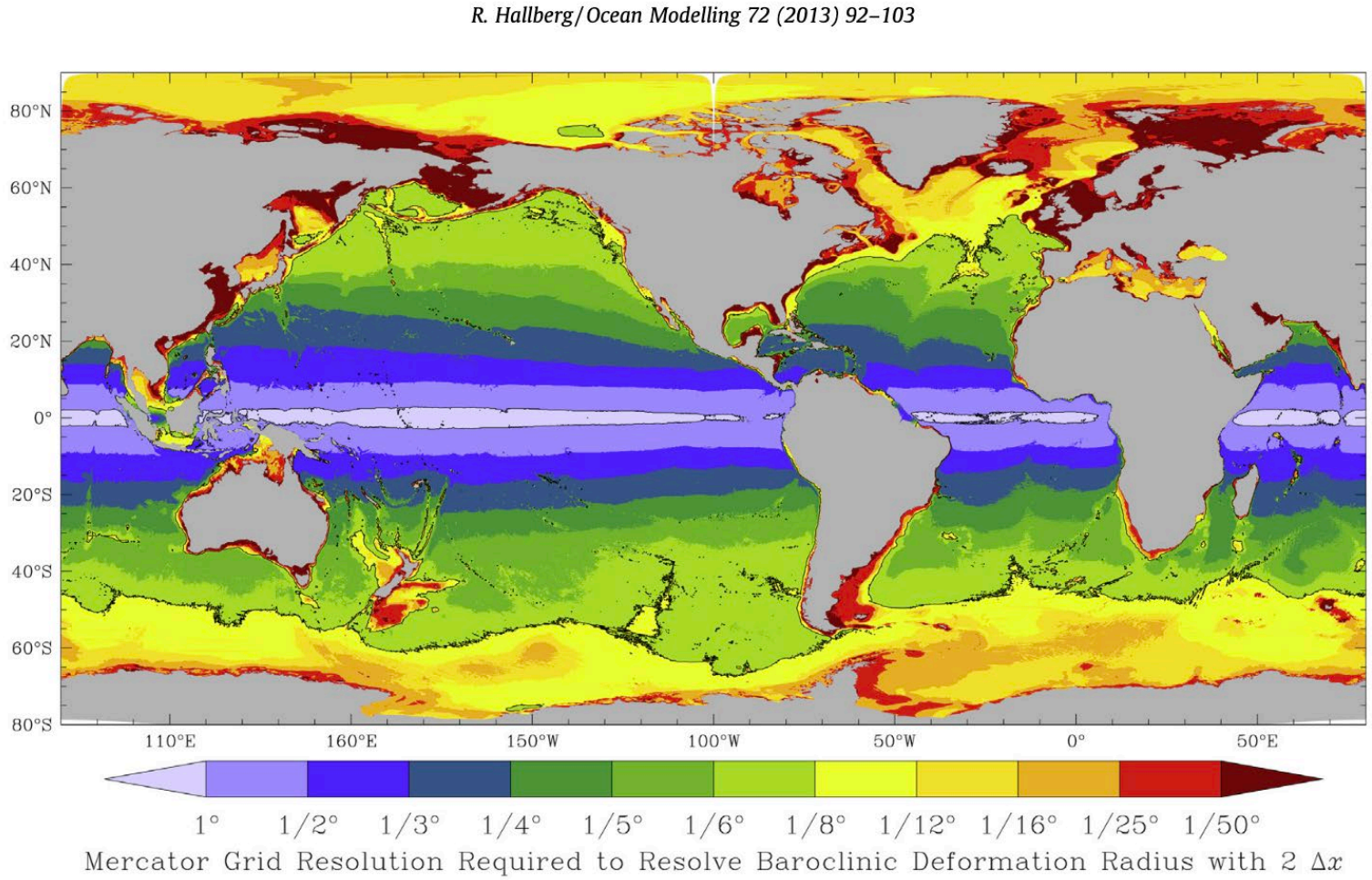


Moving to dynamic boundary conditions - heat, momentum and moisture

- Waves
  - source of momentum, heat & moisture exchange for the atmosphere
  - source of momentum and mixing in the upper ocean
- Sea Ice
  - limits heat, moisture and momentum exchange between atmosphere and ocean
  - persistence is not a good assumption – especially in summer and winter
  - using recent climatology is proxy is difficult in a period of rapid change
- Ocean
  - source of heat and moisture for storms
  - SST gradients and evolution matter for interaction with overlying atmosphere



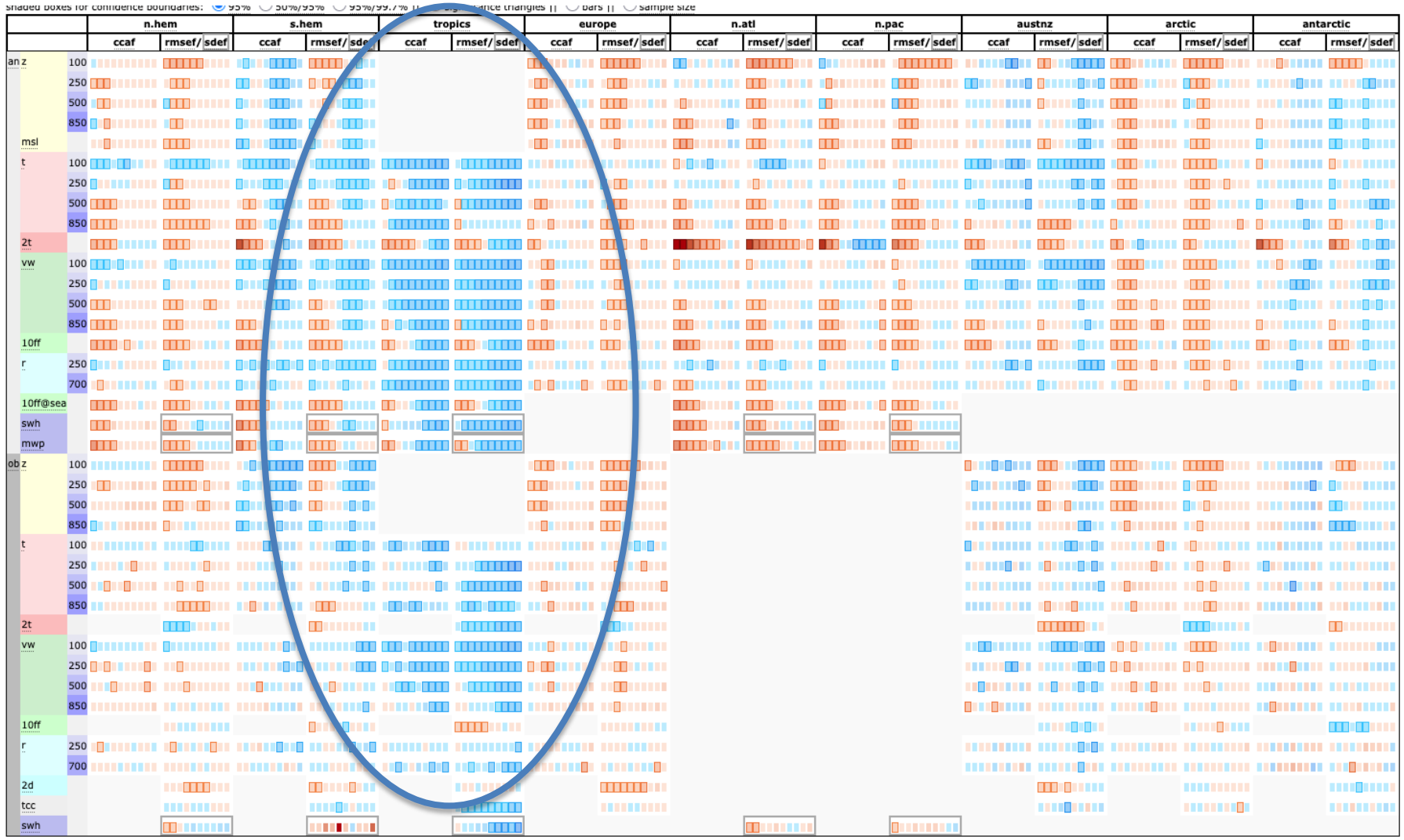
A brief diversion – to ocean modelling



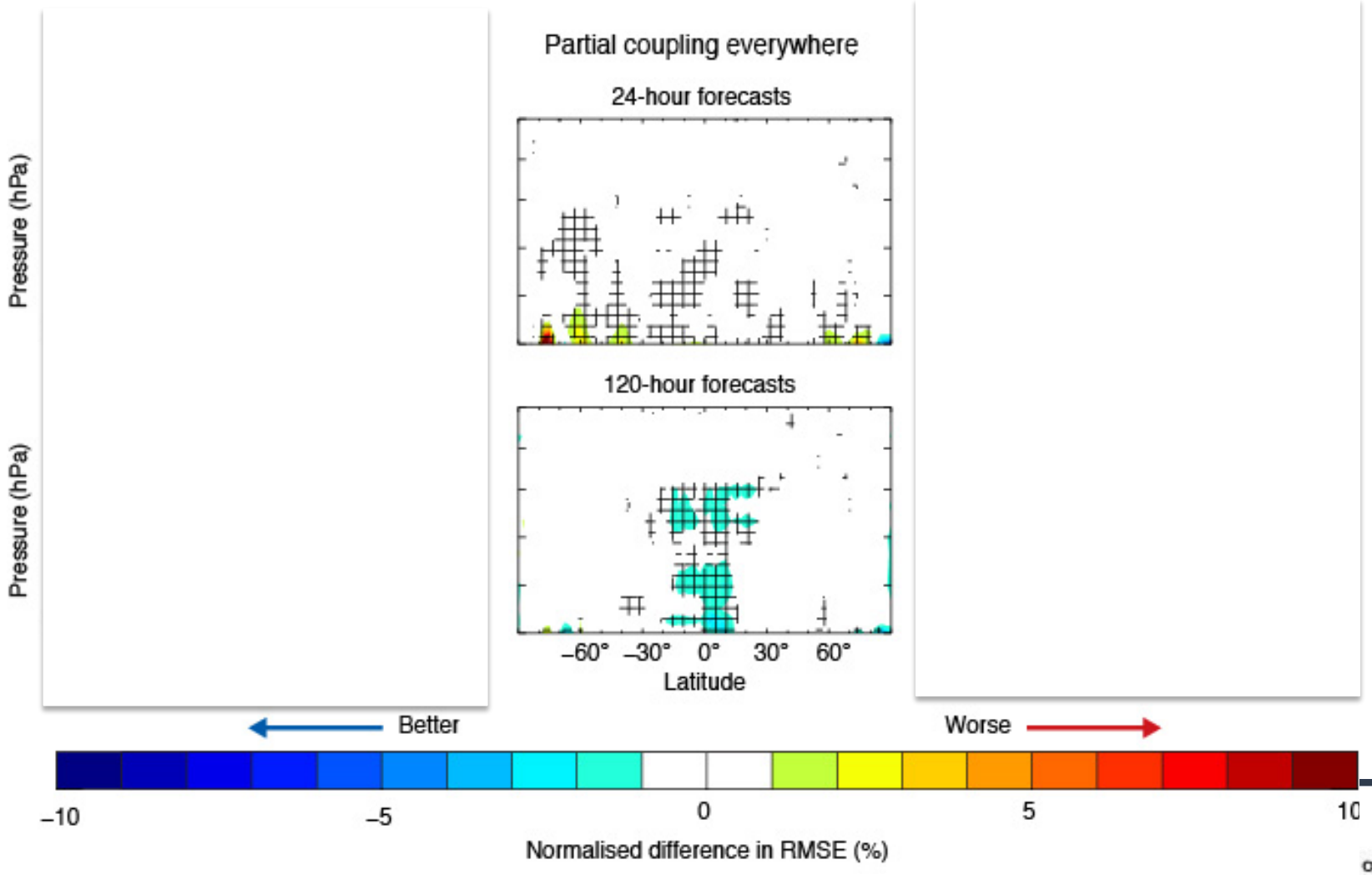
At different model resolutions we can resolve features in different geographical locations.

Impact of coupling an ocean – first implementation

- Biggest improvement seen in the Tropics
- Near surface temperatures compared to observations have reduced error

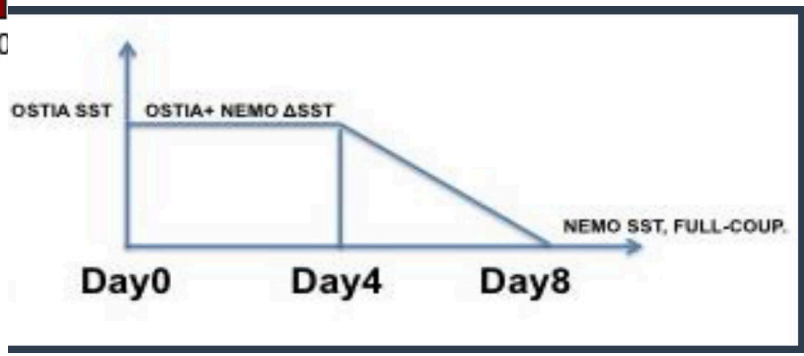


Partial coupling at ECMWF – Couple the tendency & keep high res features



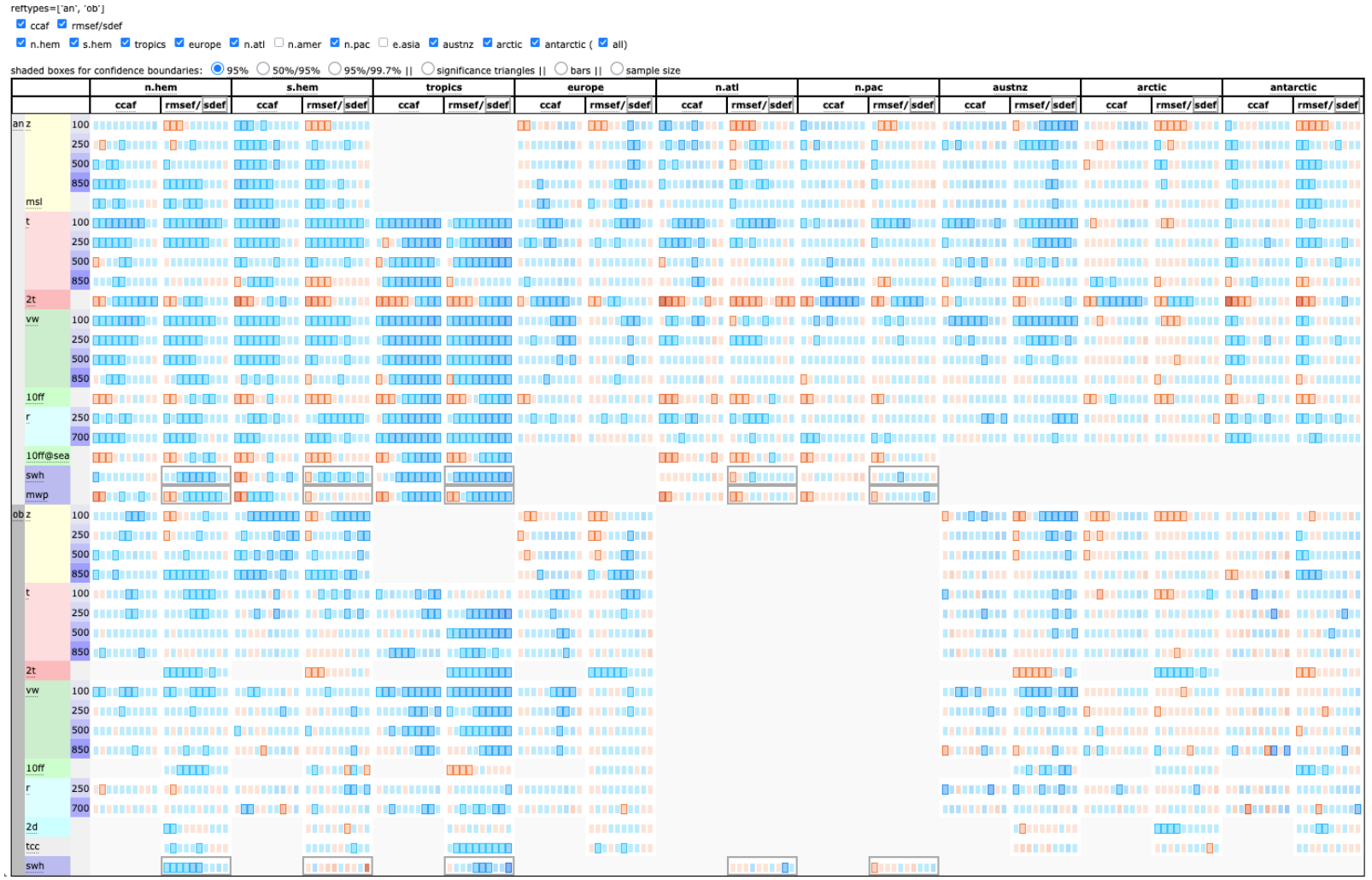
With partial coupling we add the change of SST from the ocean model to the SST of the initial conditions (OSTIA) rather than use the SST of the ocean model

- In practice we only do this for the first 4 days and gradually change to use the ocean SST directly (below figure)



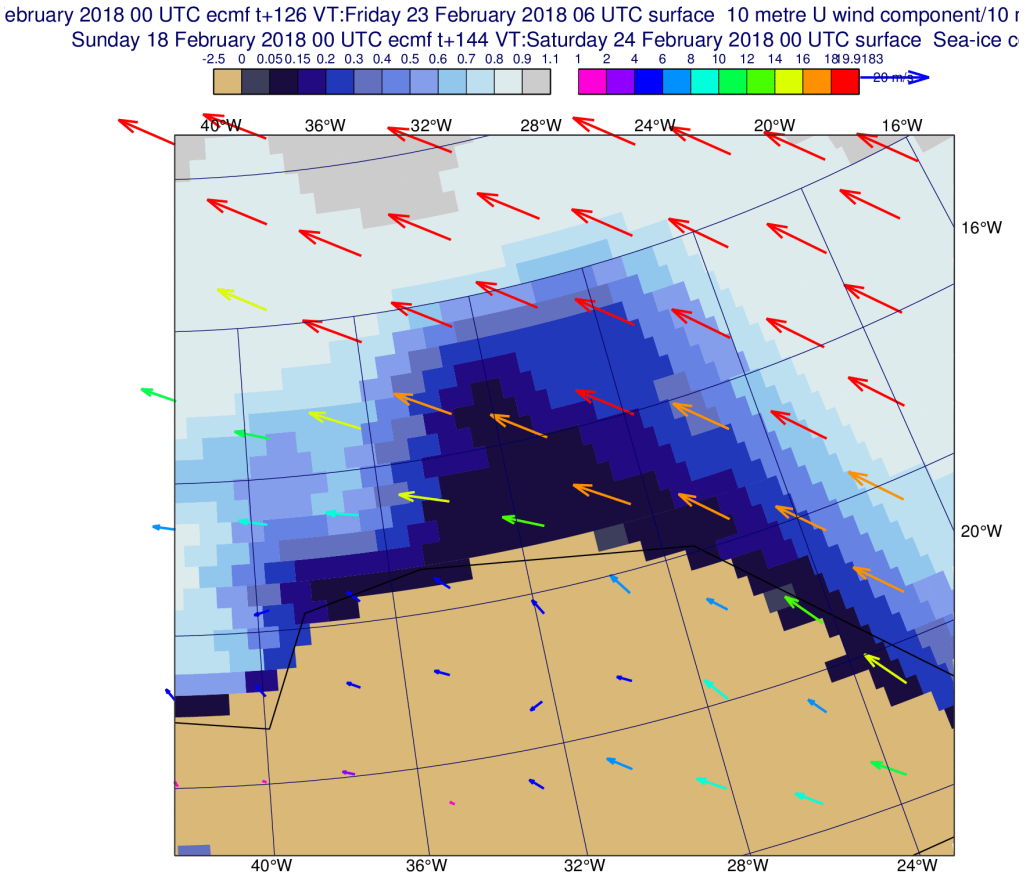
Impact with partial coupling

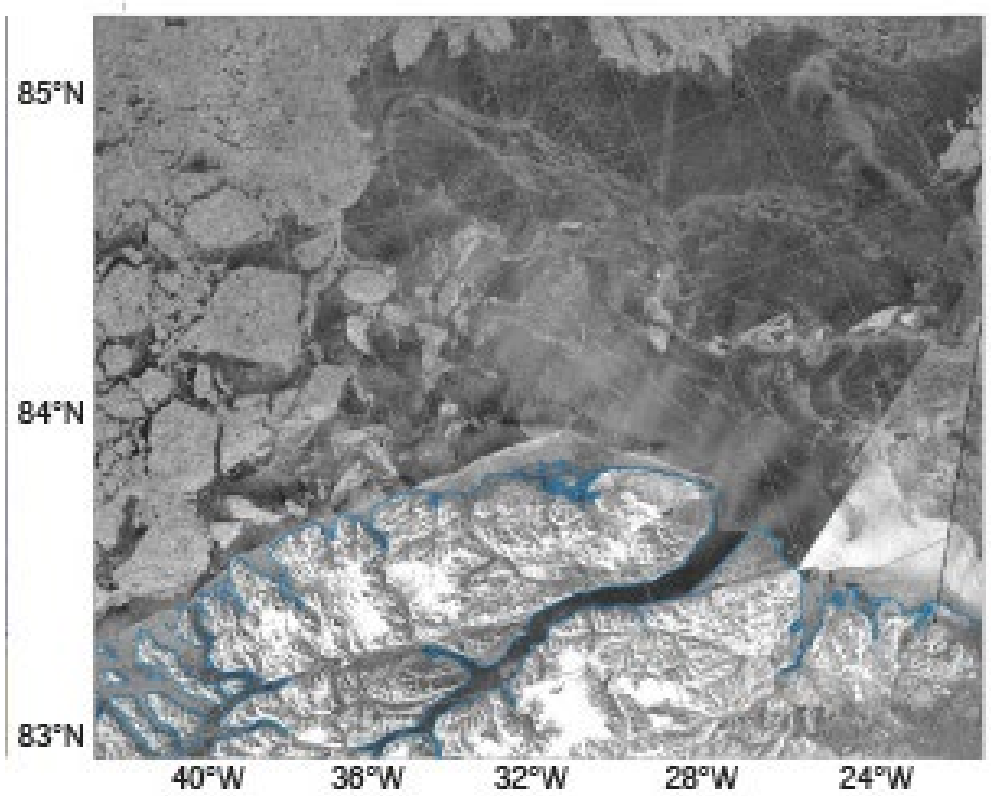
- Capturing the SST features that are important for the extra-tropics



Example: Cape Morris Jesup February 2018

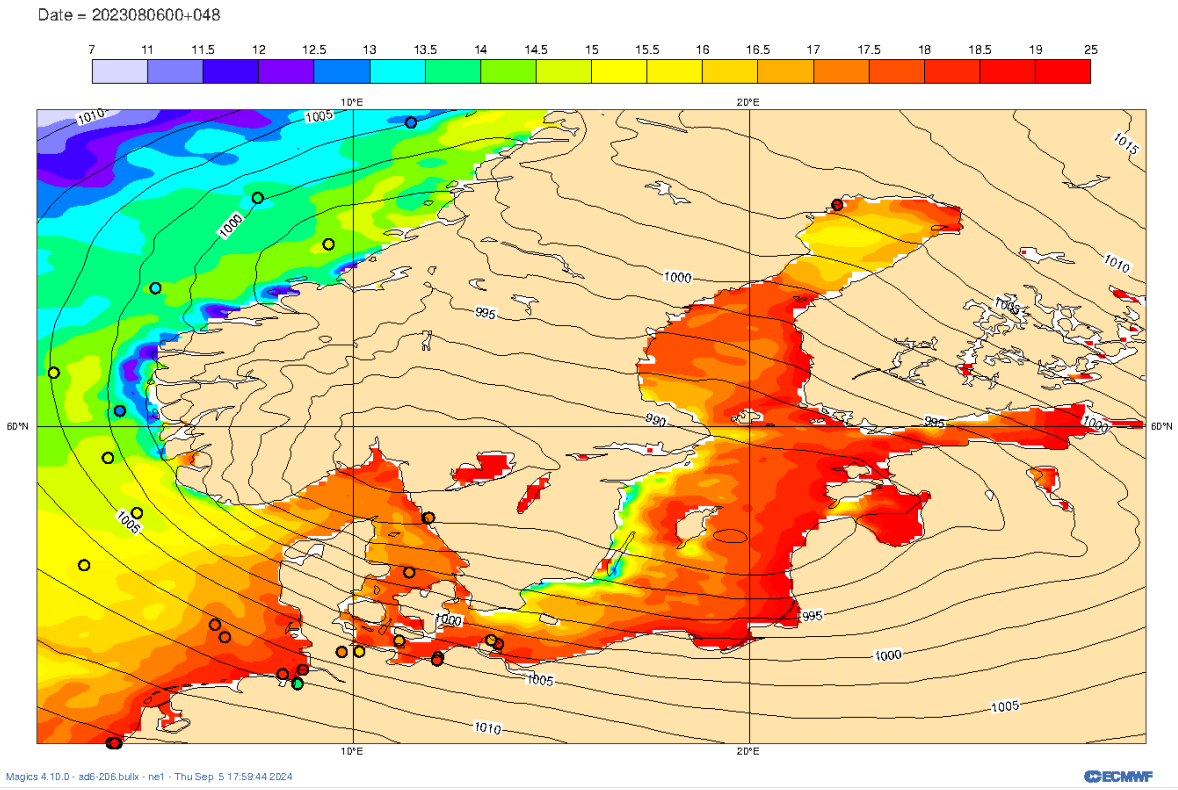
- Wind driven event that was well captured by the 10 day forecast. Sea ice advected off the coast

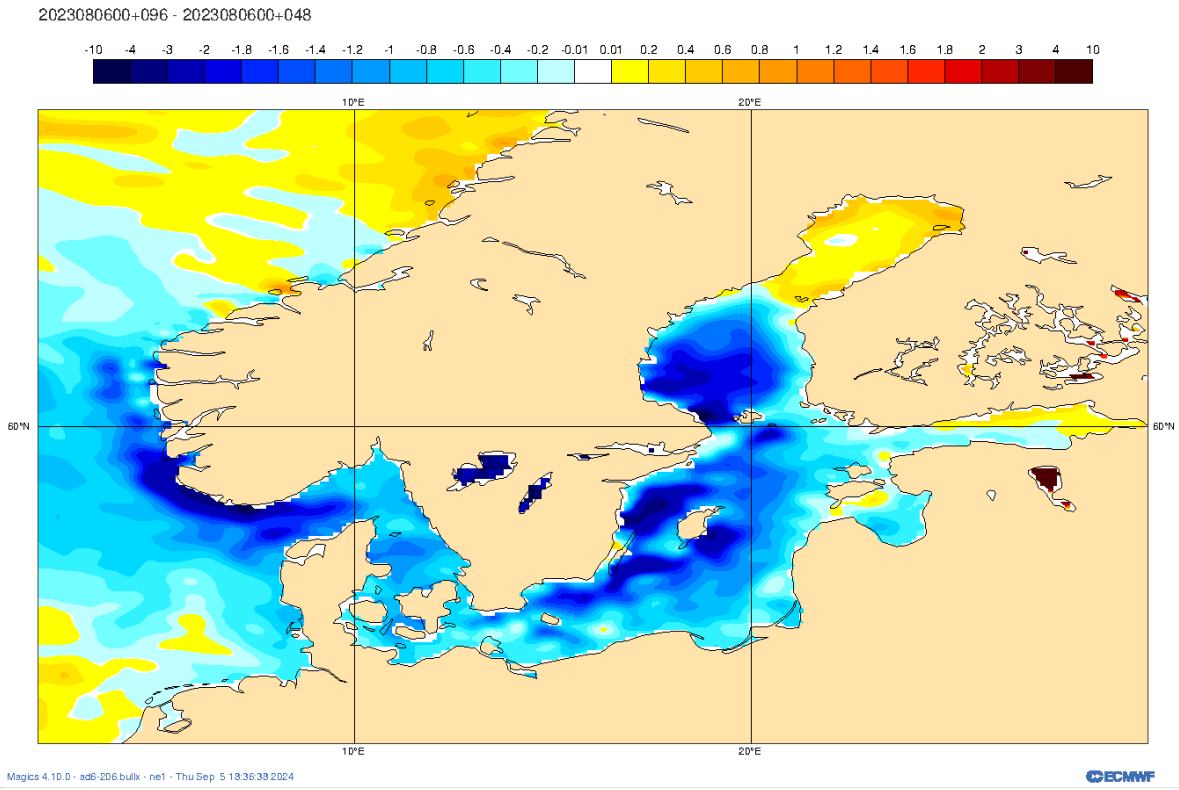




(Satellite image: European Space Agency via Danish Meteorological Institute)

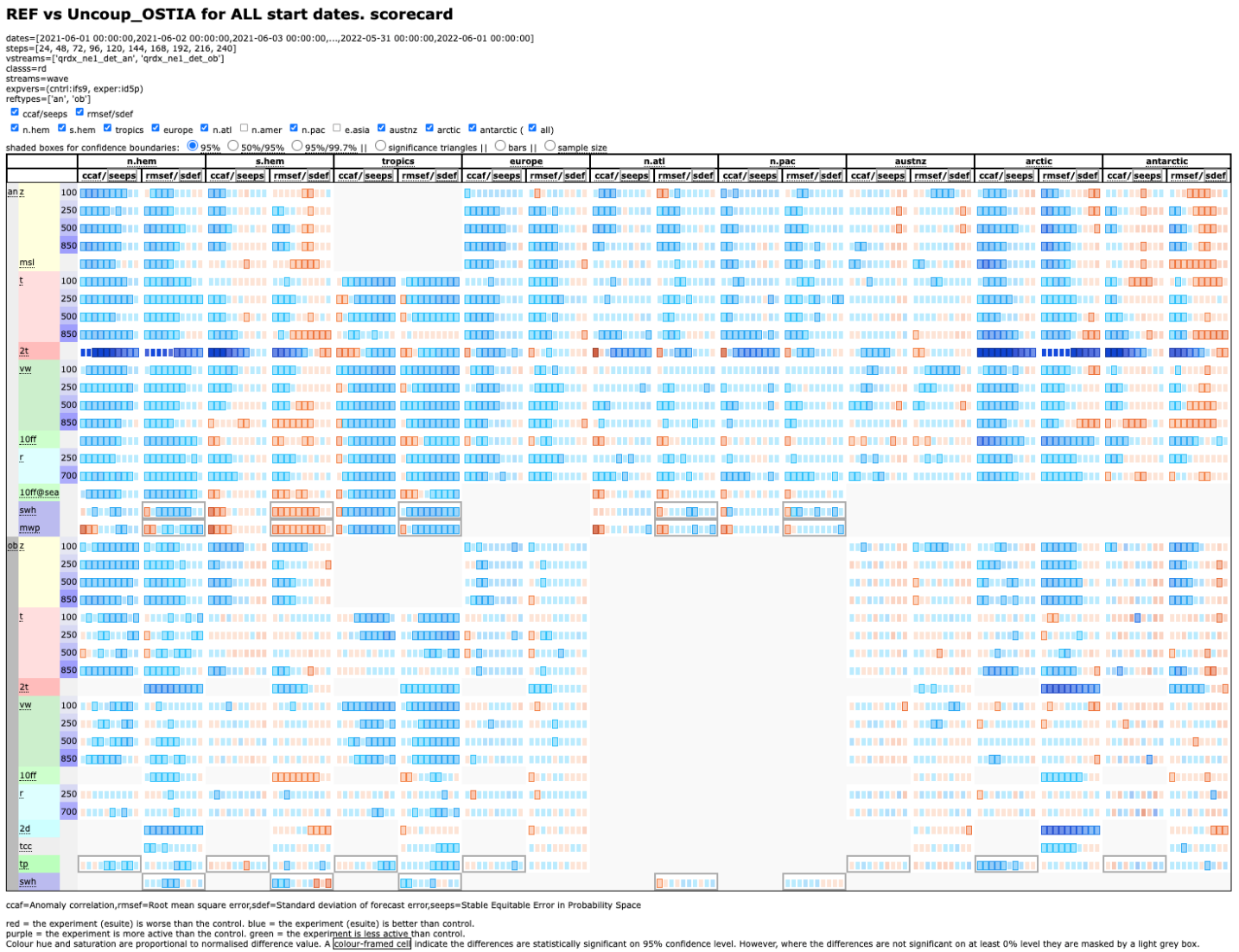
Storm Hans August 2023 predictions





SST from ECMWF HRES on the 2023080600+048 (left) and the difference in SST prediction 2 days later showing a strong cooling in the seas around Southern Scandinavia

Does the ocean coupling matter for NWP? (revisited from the 45r1 HRES coup)



Large positive impact of running coupling for NWP time scales

Both ocean initial conditions and model matter

Degradation in SHEM wave scores believed to be due to difference in sea-ice cover

Figure from Kristian Mogensen

Looking forward – heat, momentum and moisture

- Revisit the energy and water cycles to improve the conservation properties
- capture processes that are important for physical modelling and data driven training
- how to improve while not losing skill

Sea ice coupling and snow on sea ice for ERA6/SEAS6 + 50r1

- ERA5 has known deficiencies in representing polar surface temperatures.
  - too warm in clear sky snow covered situations
- ERA6 bringing snow on sea ice
  - using of ORAS6, snow depths and ice thickness
  - compare MOSAiC data with ERA6 Tco799 v7 prototype
  - ongoing testing with field campaign data

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A Machine Learning Correction Model of the Winter Clear-Sky Temperature Bias over the Arctic Sea Ice in Atmospheric Reanalyses

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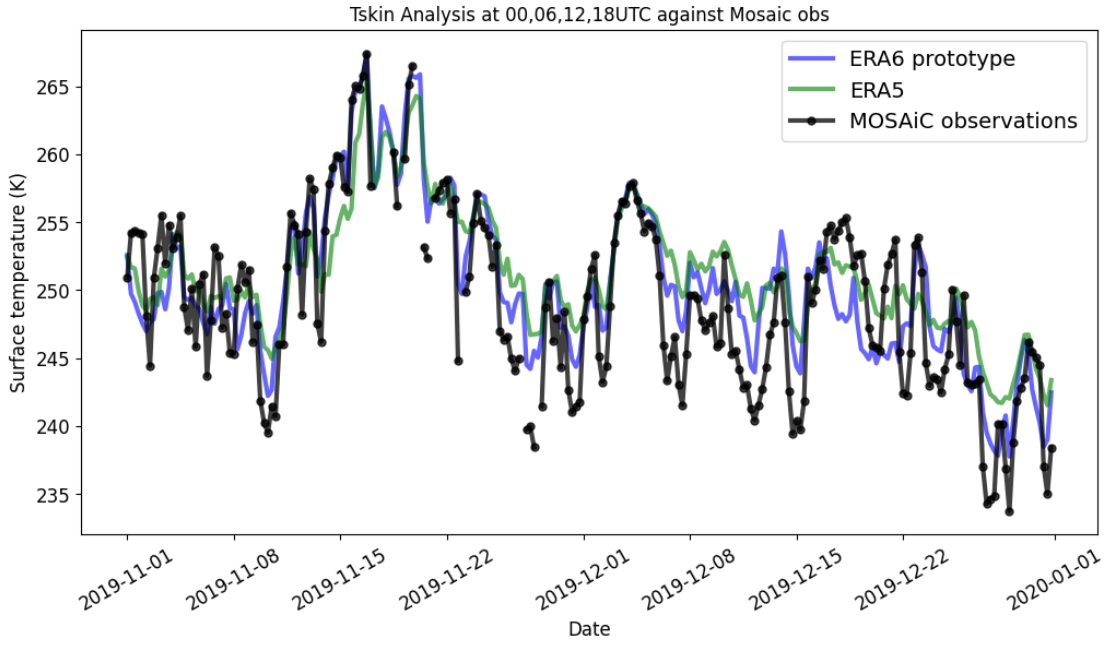
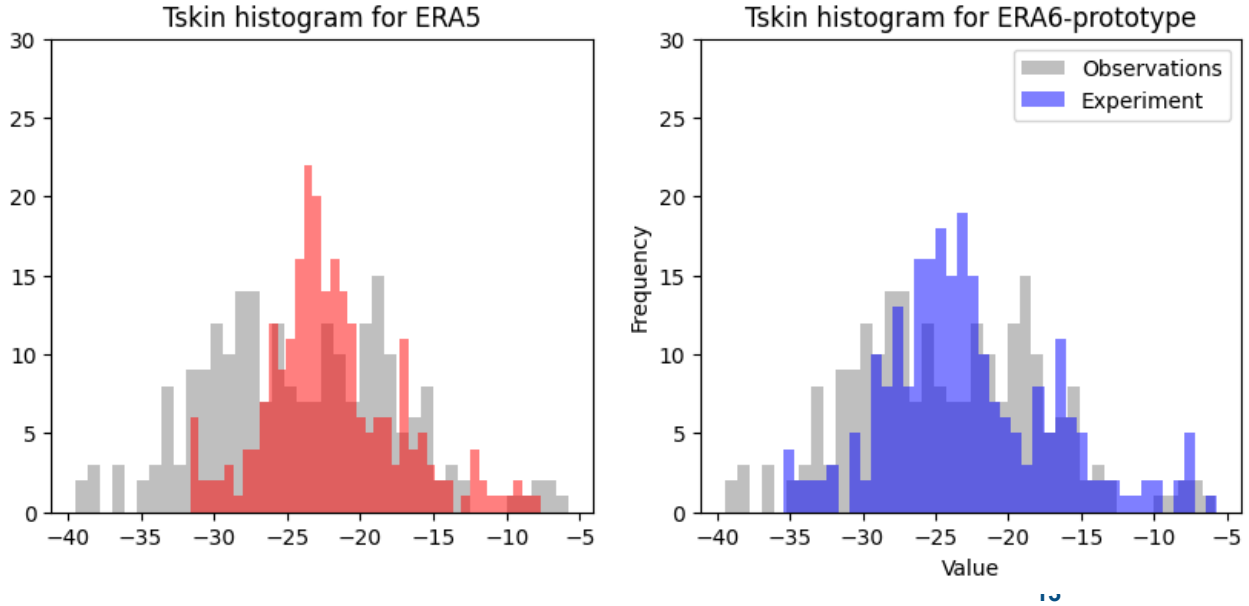




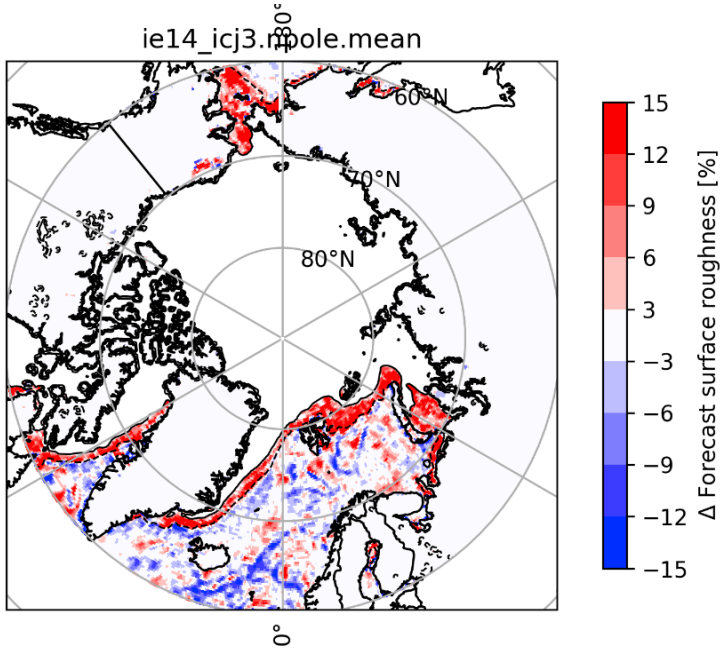
Figures from Gabriele Arduini

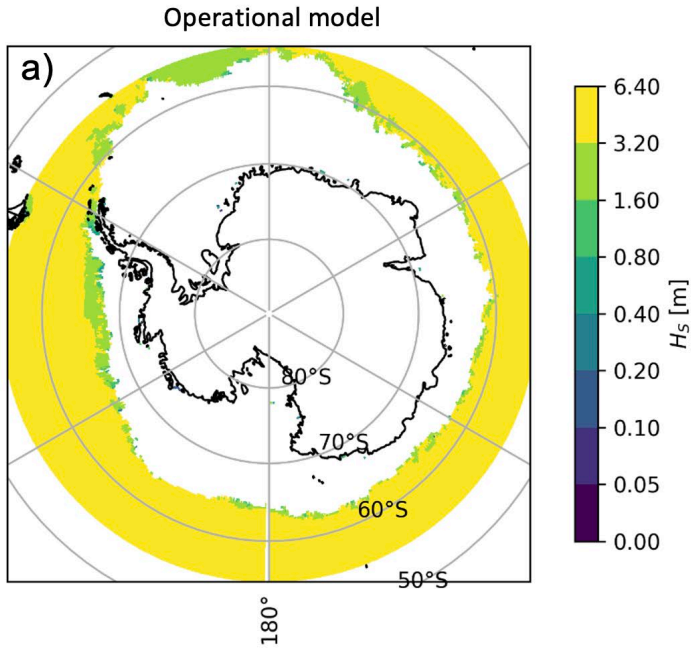
Wave ice interactions

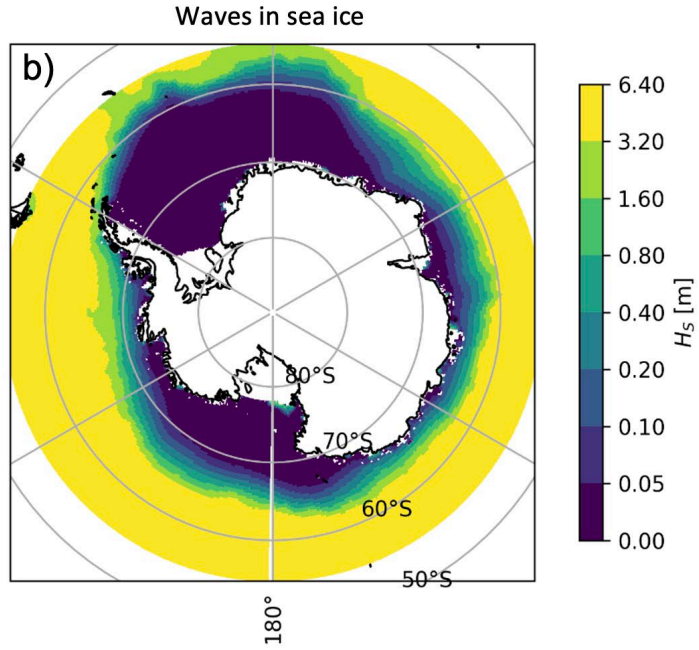
Operations
SIC<30%: No attenuation of waves
SIC>30%: Wave model turned off; full blocking

Development: waves in ice + attenuation

Impact seen through changes in surface roughness > changes in local fluxes in MIZ

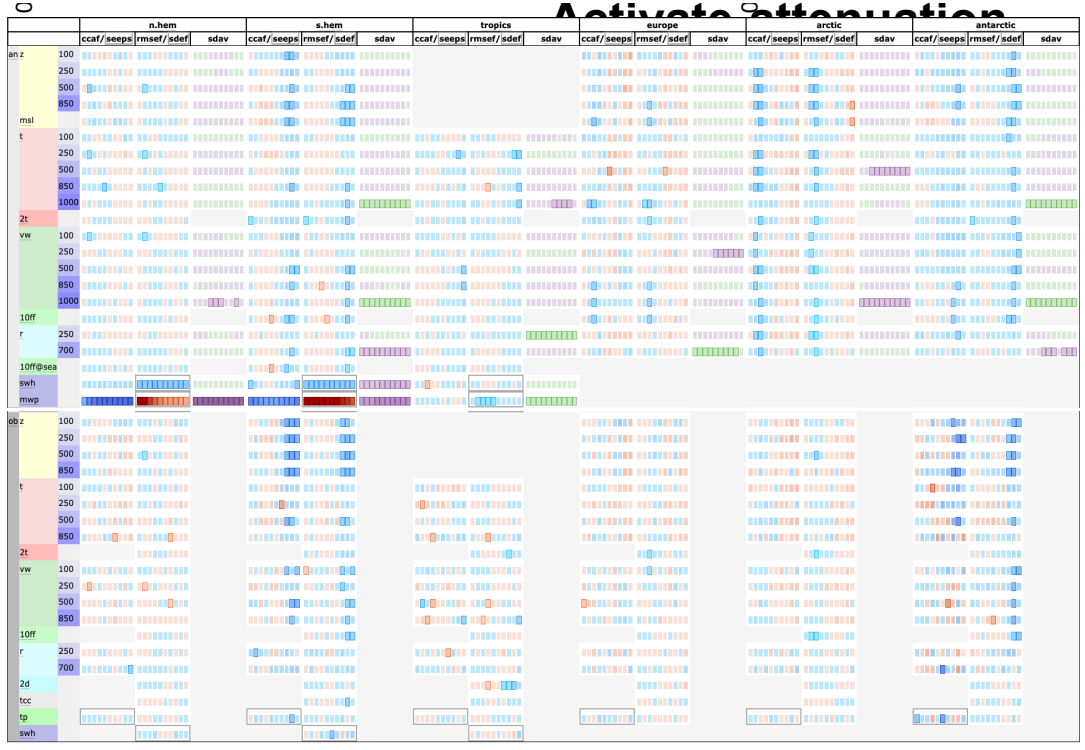






Comparison with own analysis

Comparison with observations

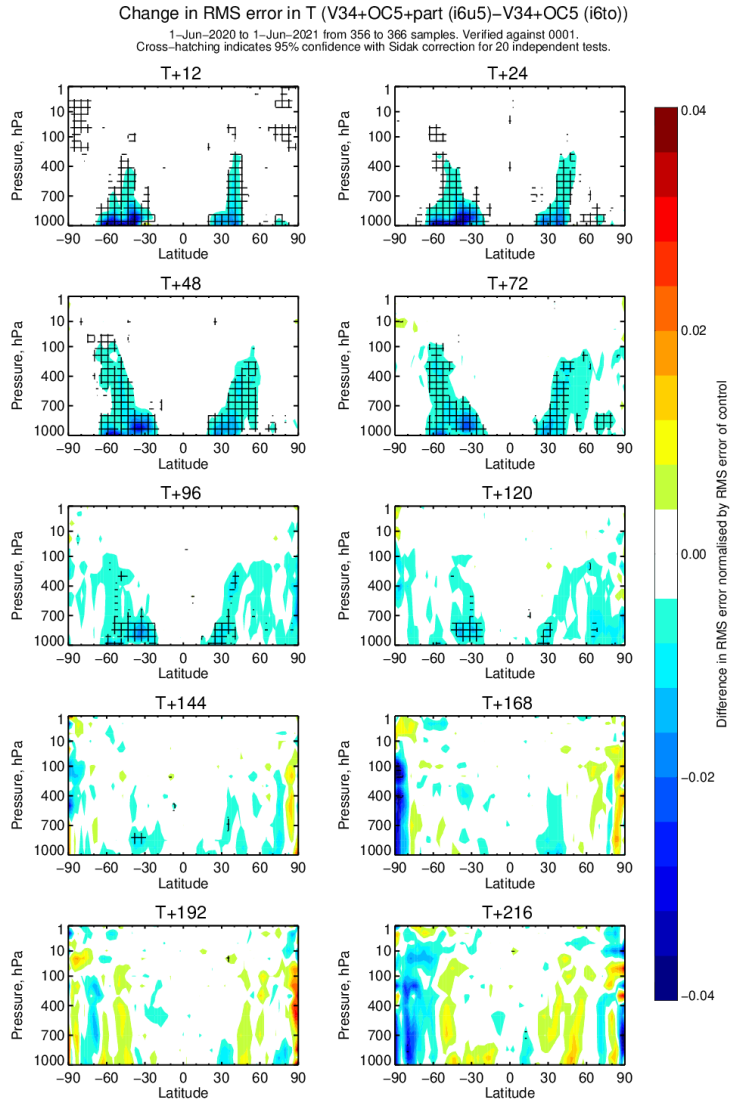


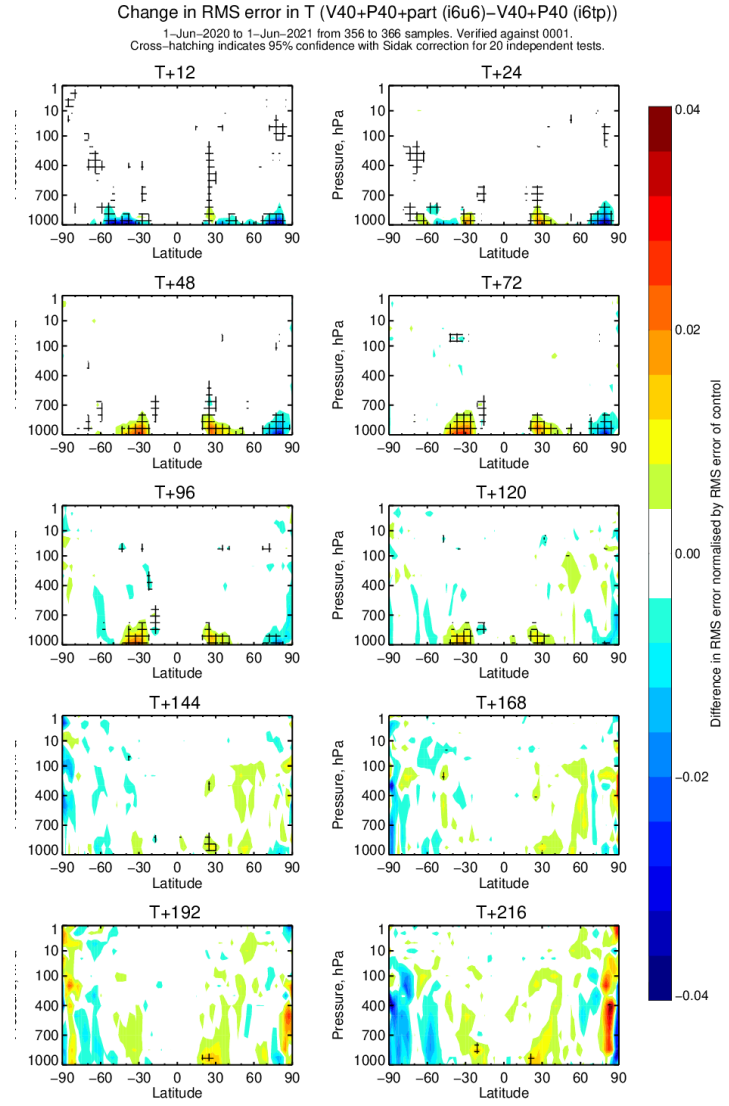
Conclusions

- The marine component of the Earth System is valuable for enhancing NWP on timescales from days to months.
- The value of the ocean model is demonstrated more clearly in the tropics
  - is this currently limited by the ocean resolution?
- Adding complexity and realism is hard where there are compensating errors – value in tuning and assessing a coupled system

Effect of partial coupling in V40 compared to V34

V34





V40

The positive impact of partial coupling we have in the old system is gone and replaced with negative impact (at least after 24 hours)