ECMWF's ensemble forecasts

Medium and extended-range

Simon Lang and ECMWF colleagues

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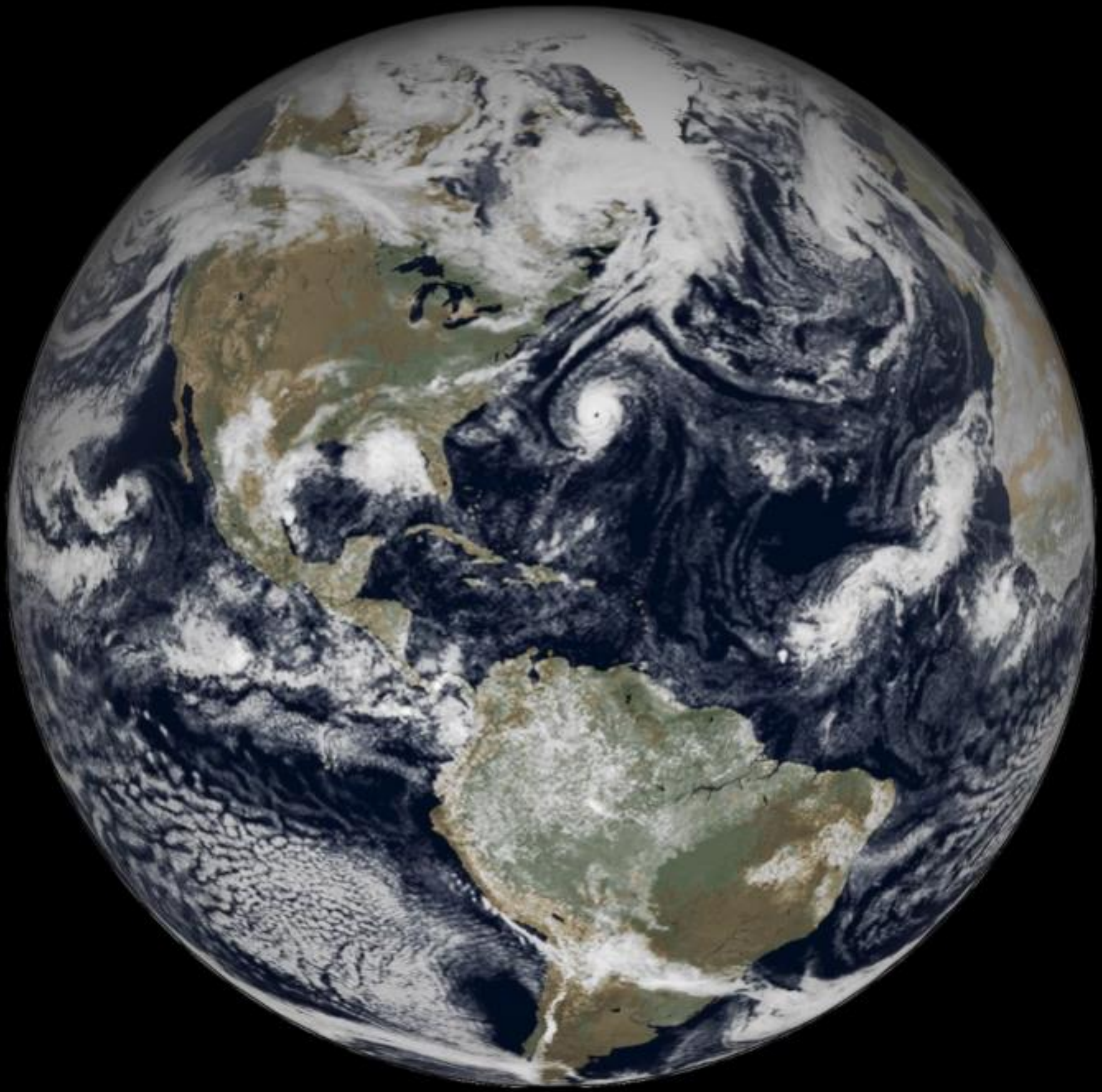
9 km ENS, 51 Members, 20200913 00 UTC + 41 h Simulated Satellite Images



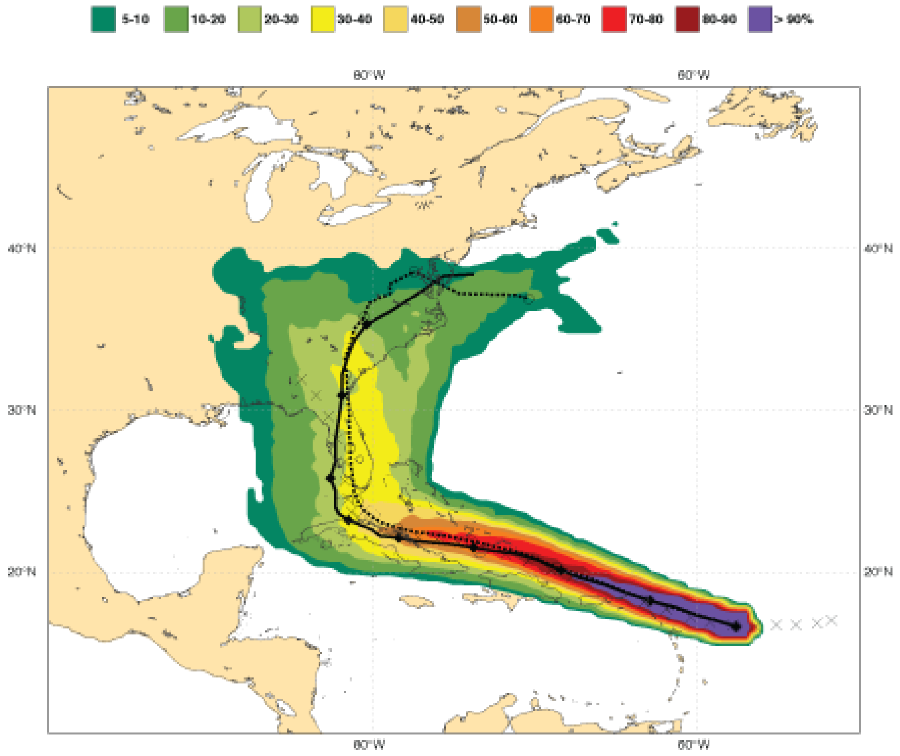
- 51 Members (50 perturbed + control member), TCo639 (~ 18 km) to day 15, then twice weekly, TCo319 (~ 36 km) -> **will change in 48r1**:

51 TCo1279 members to day 15 (medium-range)

101 TCo319 members from day 0 (extended-range), daily

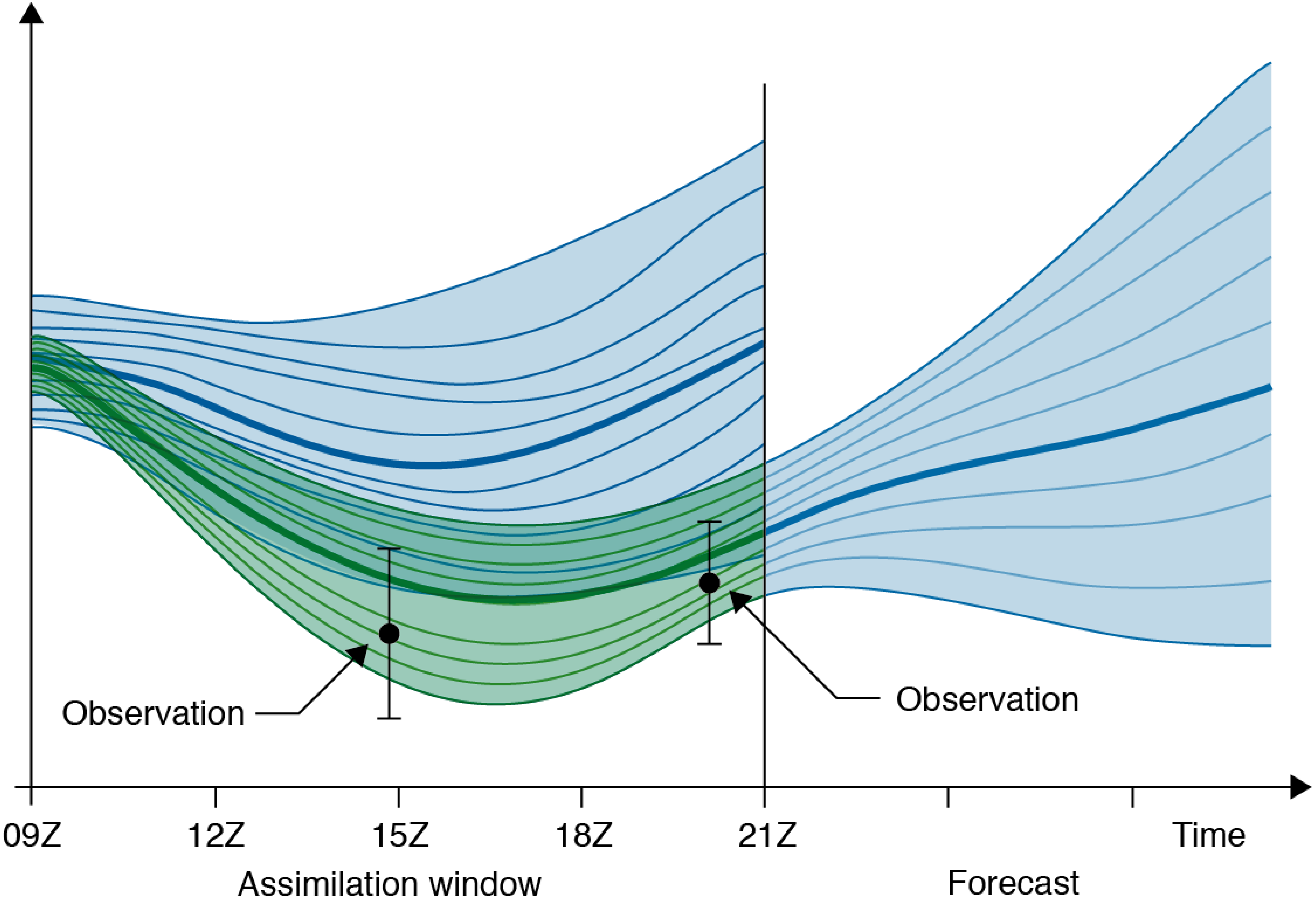
- 137 vertical levels
- Coupled to NEMO ocean model (1/4 degree), ecWAM wave model and LIM2 ice model
- Initial perturbation via an ensemble of data assimilations and singular vectors, 5 member ocean data assimilation, ORAS5
- Model error representation – SPPT

-> plan to change in 49r1 to SPP



Ensemble Data Assimilation

Ensemble Forecast



ECMWF

Perturbed ensemble initial conditions from 50 EDA Members

z500hPa

Member 1
Pert. 1

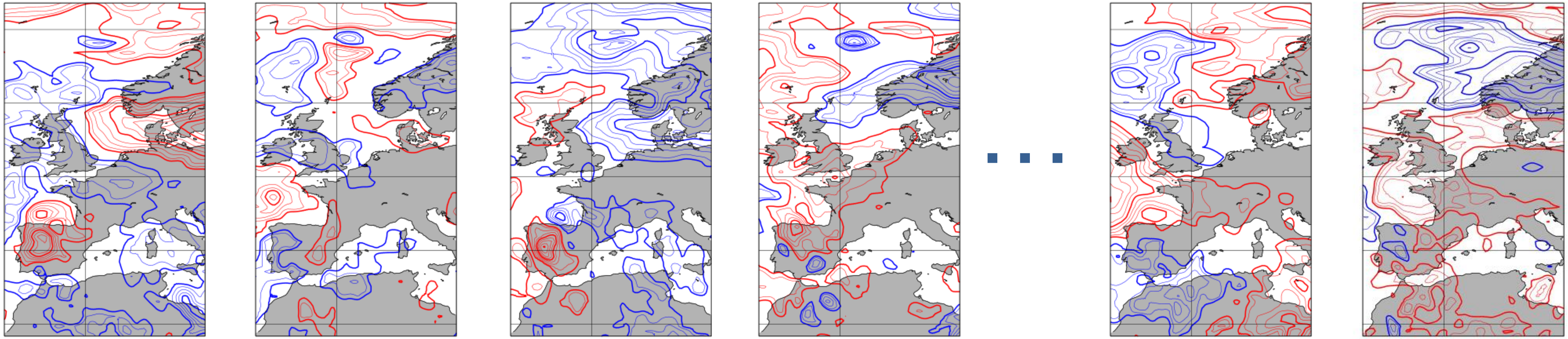
Member 2
Pert. 2

Member 3
Pert. 3

Member 4
Pert. 4

Member 49
Pert. 49

Member 50
Pert. 50

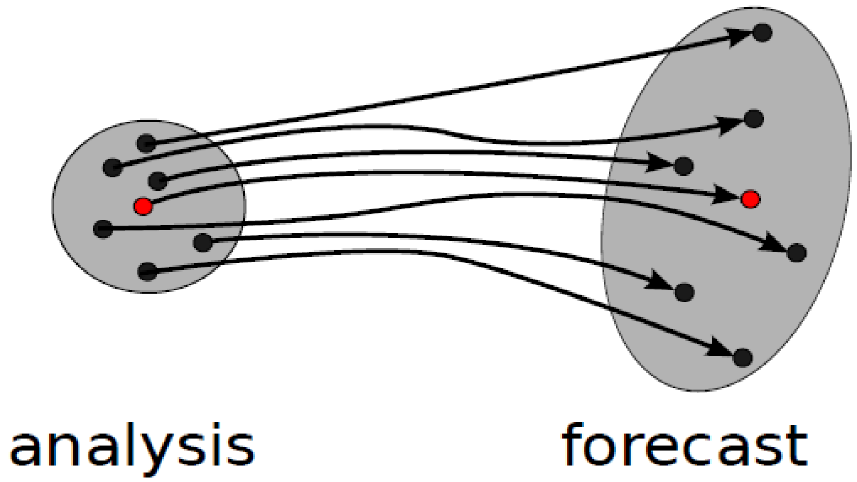


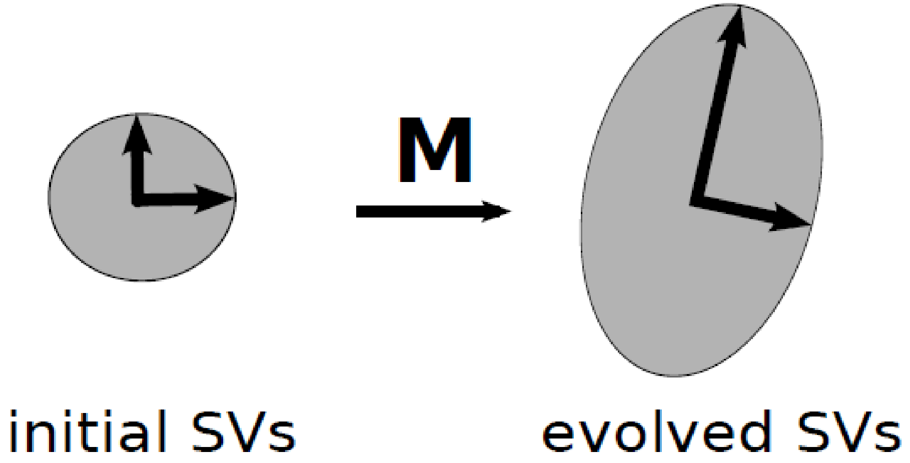
See Lang et al. 2019, ECMWF Newsletter No. 158

Singular Vector Perturbations

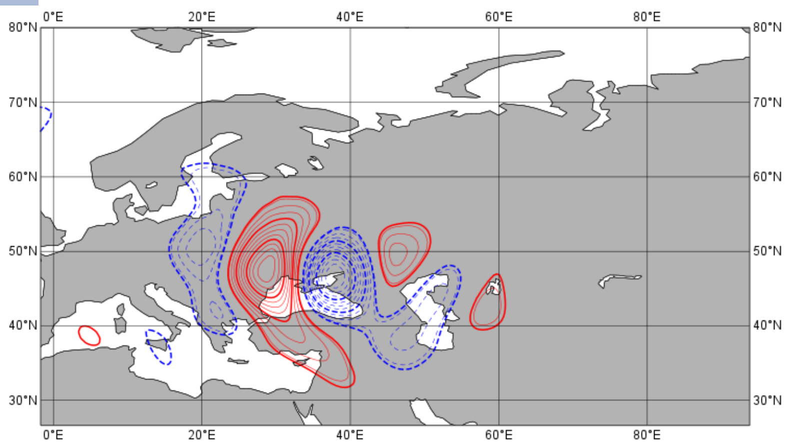
Directions of fastest growth over a finite time interval (optimisation interval)

Justification: EDA + Model Uncertainty representation produce substantial spread in the directions of the leading SVs but ensemble still under dispersive (Leutbecher and Lang, 2014, QJRM)

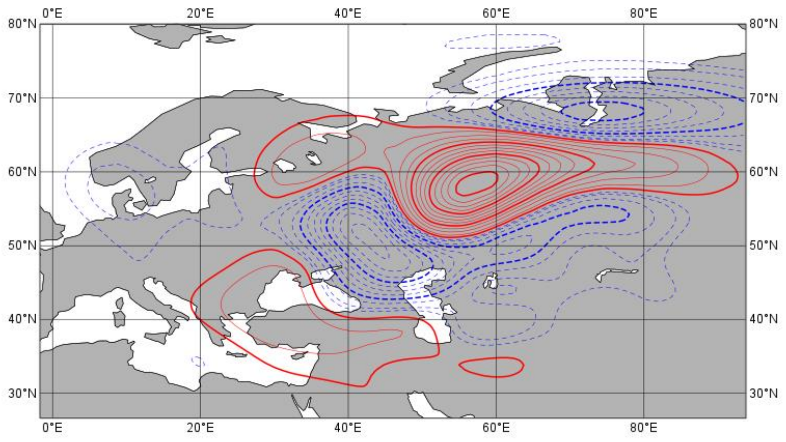




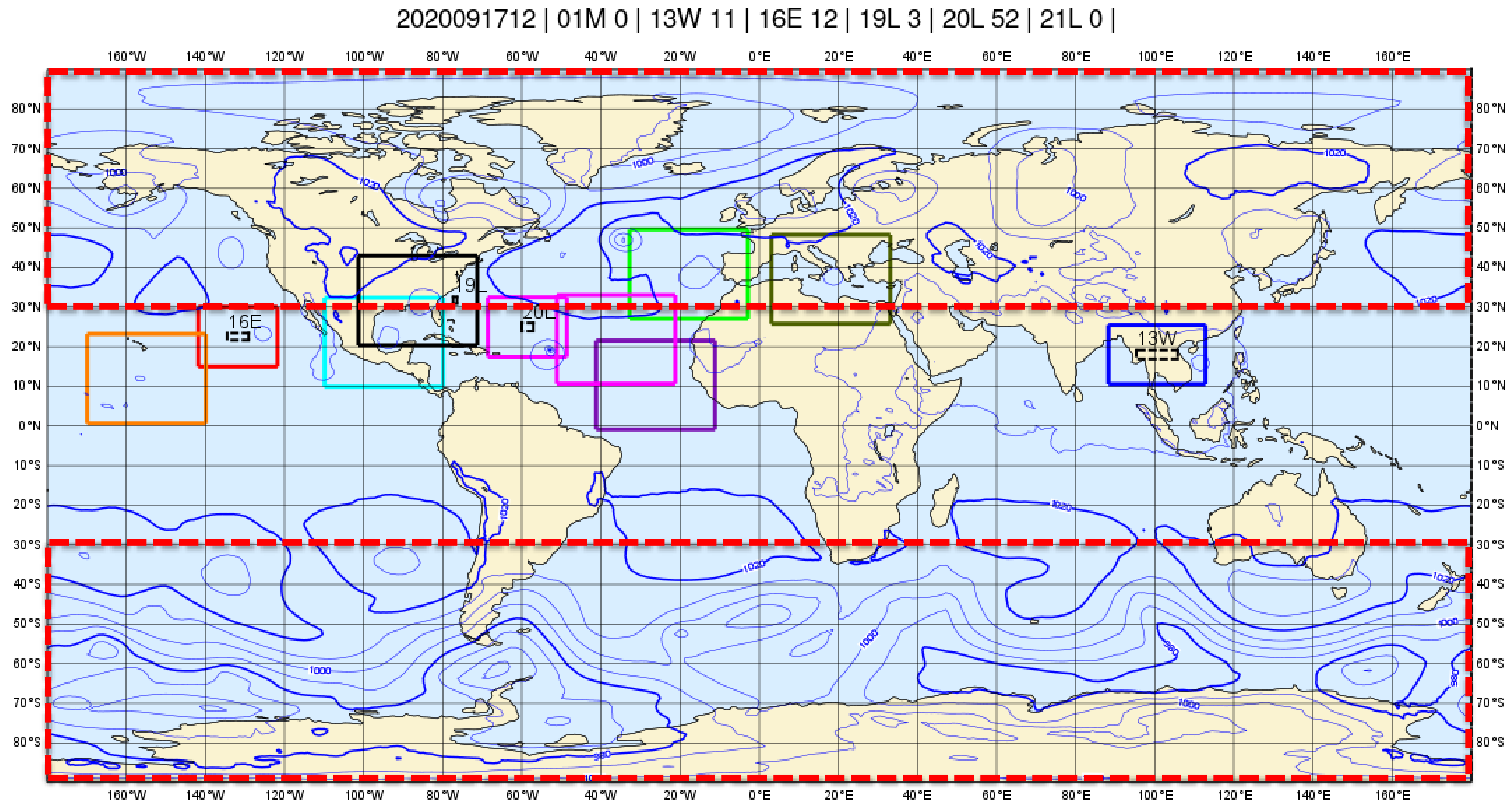
Initial SV, T mlevel 68



evolved SV, T mlevel 49



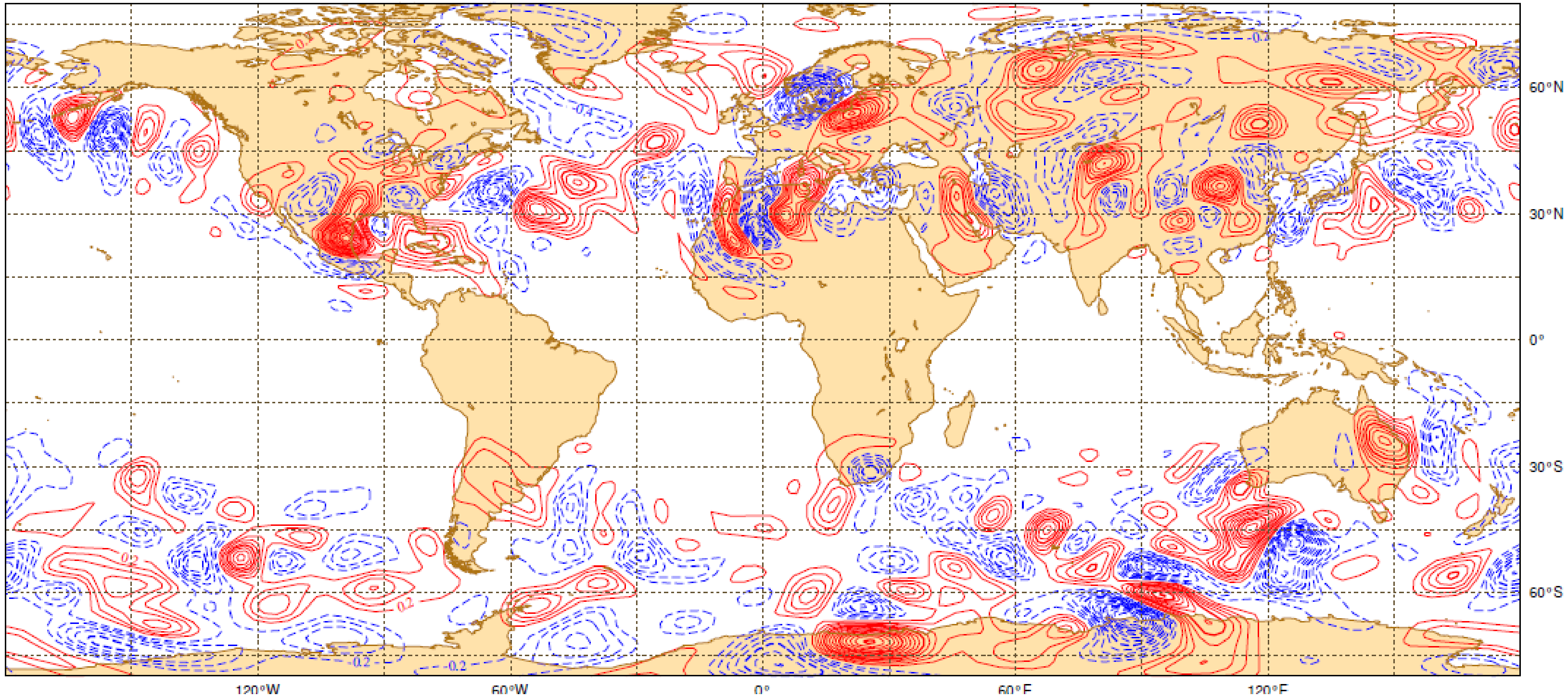
SV Target Areas



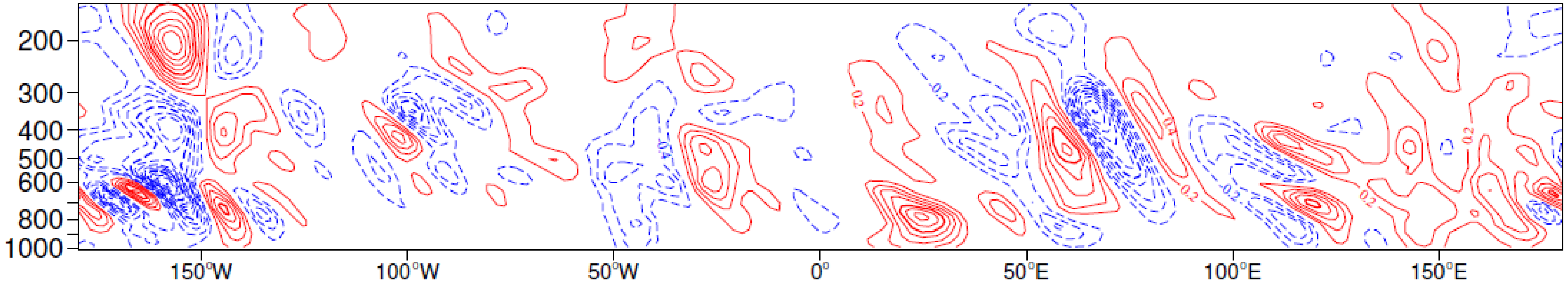
Initial condition perturbation for member 5

Temperature (every 0.2 K);   21 March 2006, 00 UTC

at ≈ 700 hPa



at 50°N



Currently, Model Error Representation via SPPT

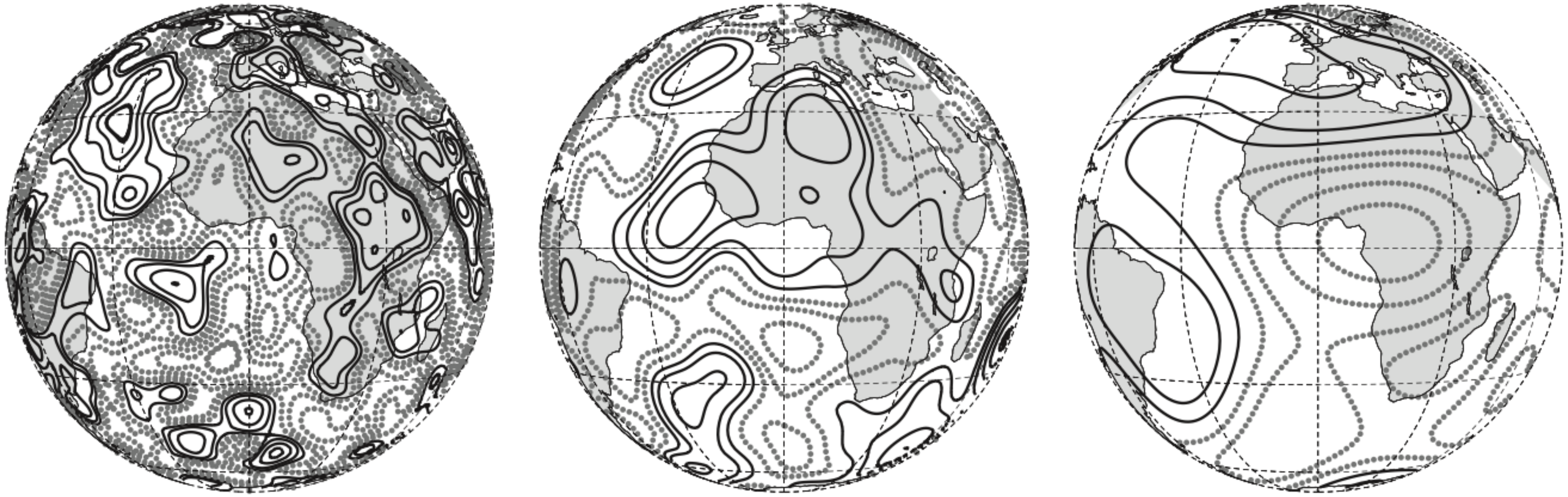
Perturb model tendencies during the forecast:

$$\boldsymbol{x_p} = \boldsymbol{x} + \boldsymbol{\alpha x}$$

$\boldsymbol{x}$ sum of tendencies from parametrization schemes (convection, radiation, cloud etc.)

$\boldsymbol{\alpha}$ includes random time and space correlations, provided by a pattern generator

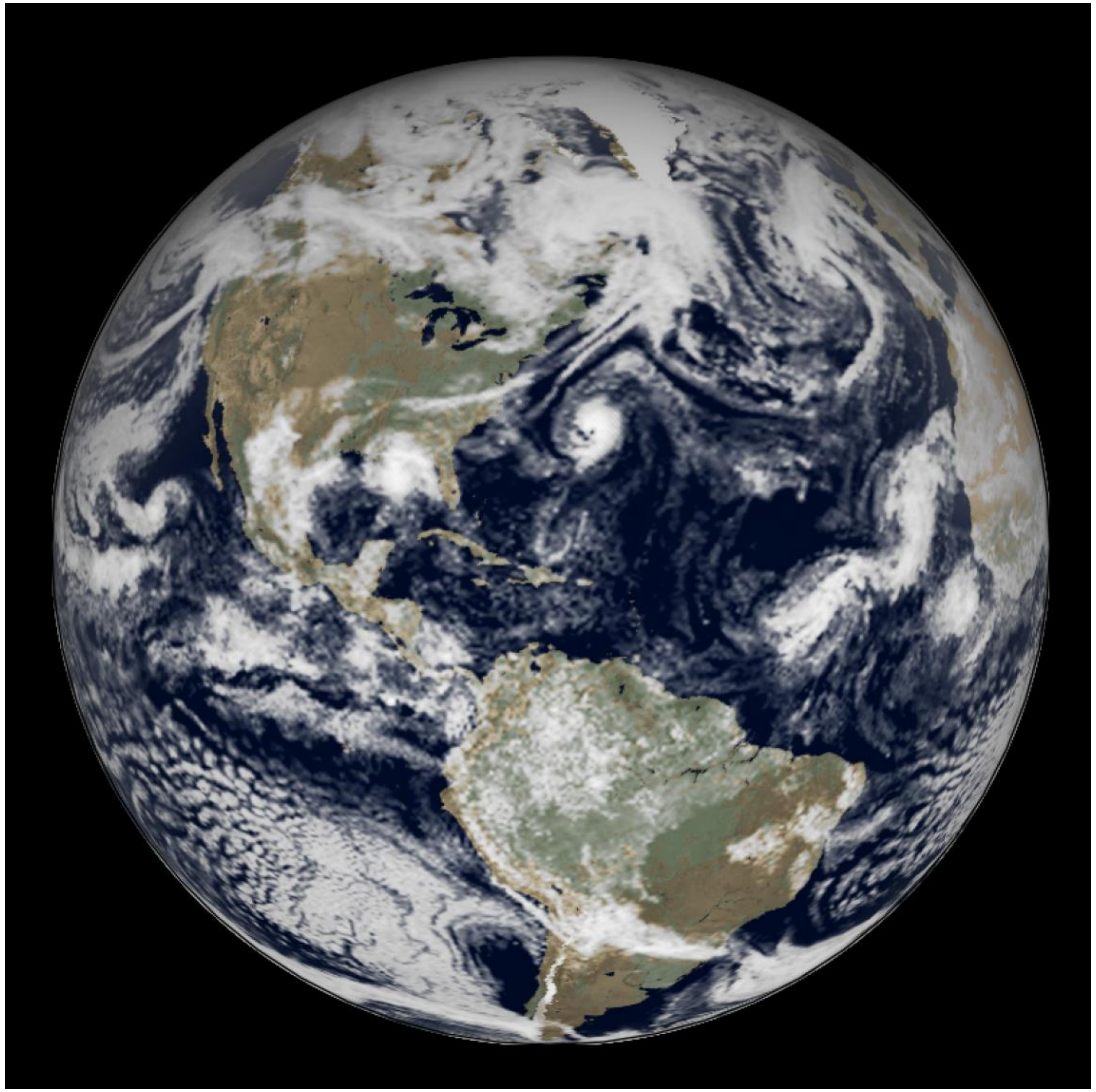
Scale 1 Scale 2 Scale 3



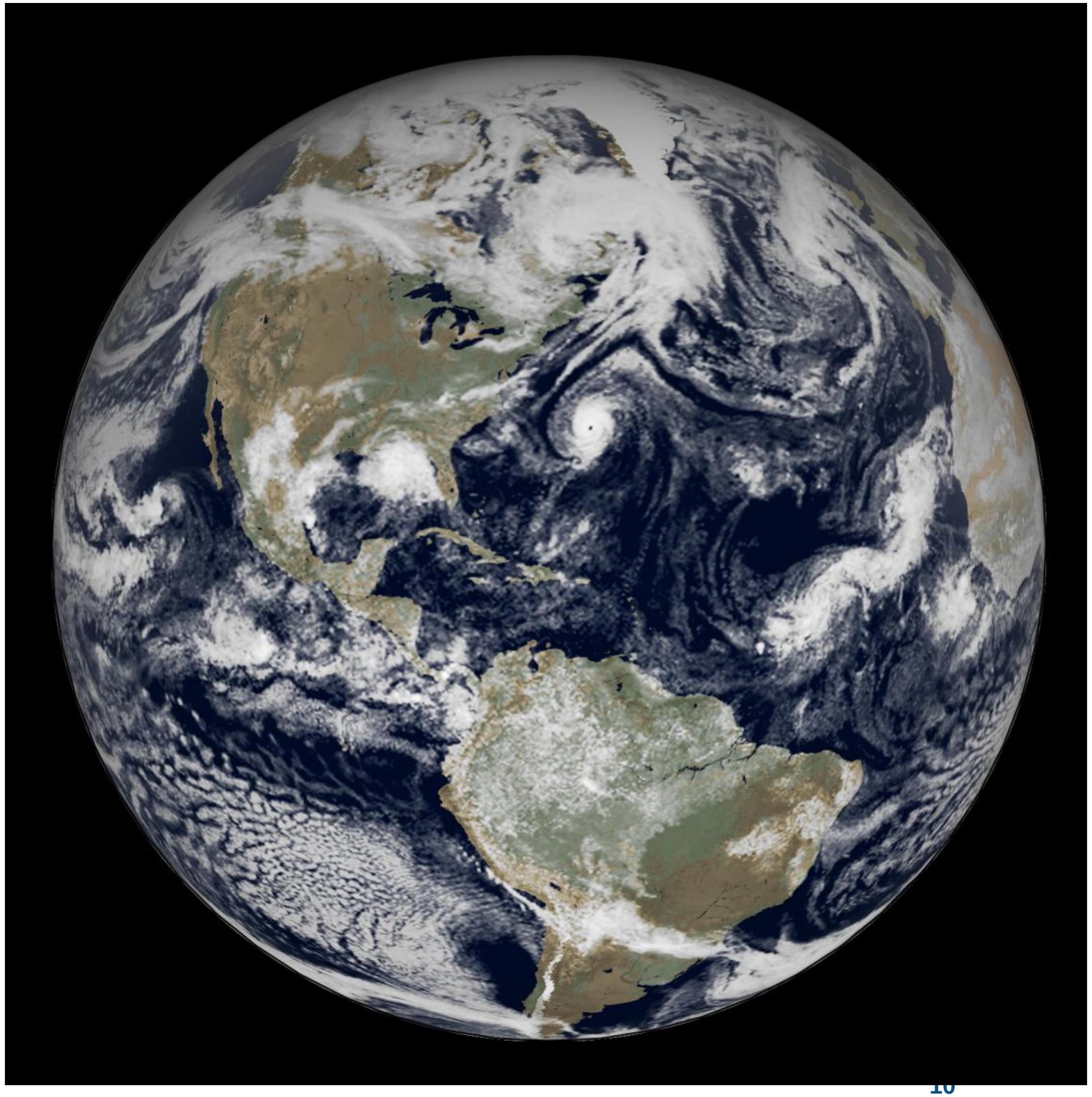
Same model uncertainty representation in ensemble forecasts and ensemble data assimilation

CY48R1

For detailed information pls see Summer Newsletter article Lang et. al, 2023 that will appear on 21 July in ; includes many relevant literature references https://www.ecmwf.int/en/publications/newsletters



TCo639

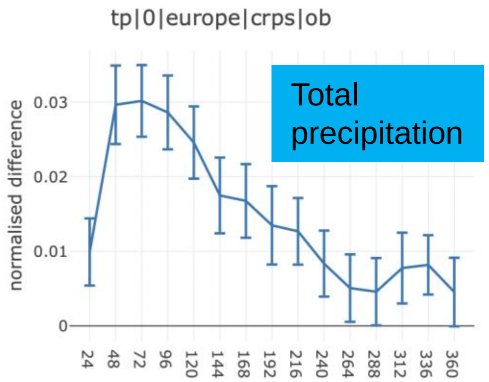


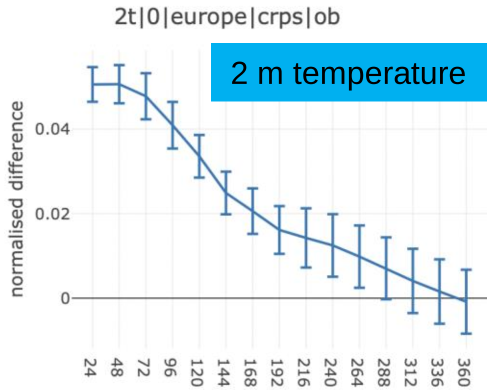
TCo1279

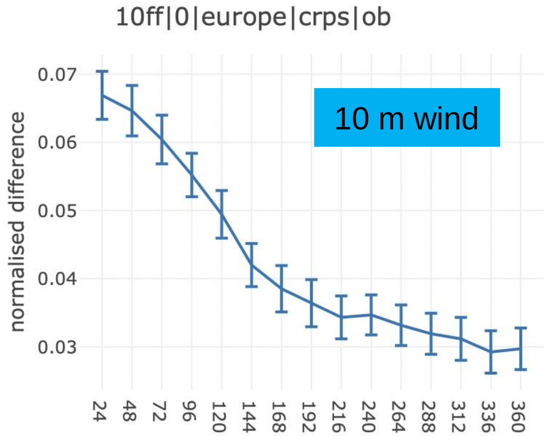
Scorecard of 48R1 compared to 47R3

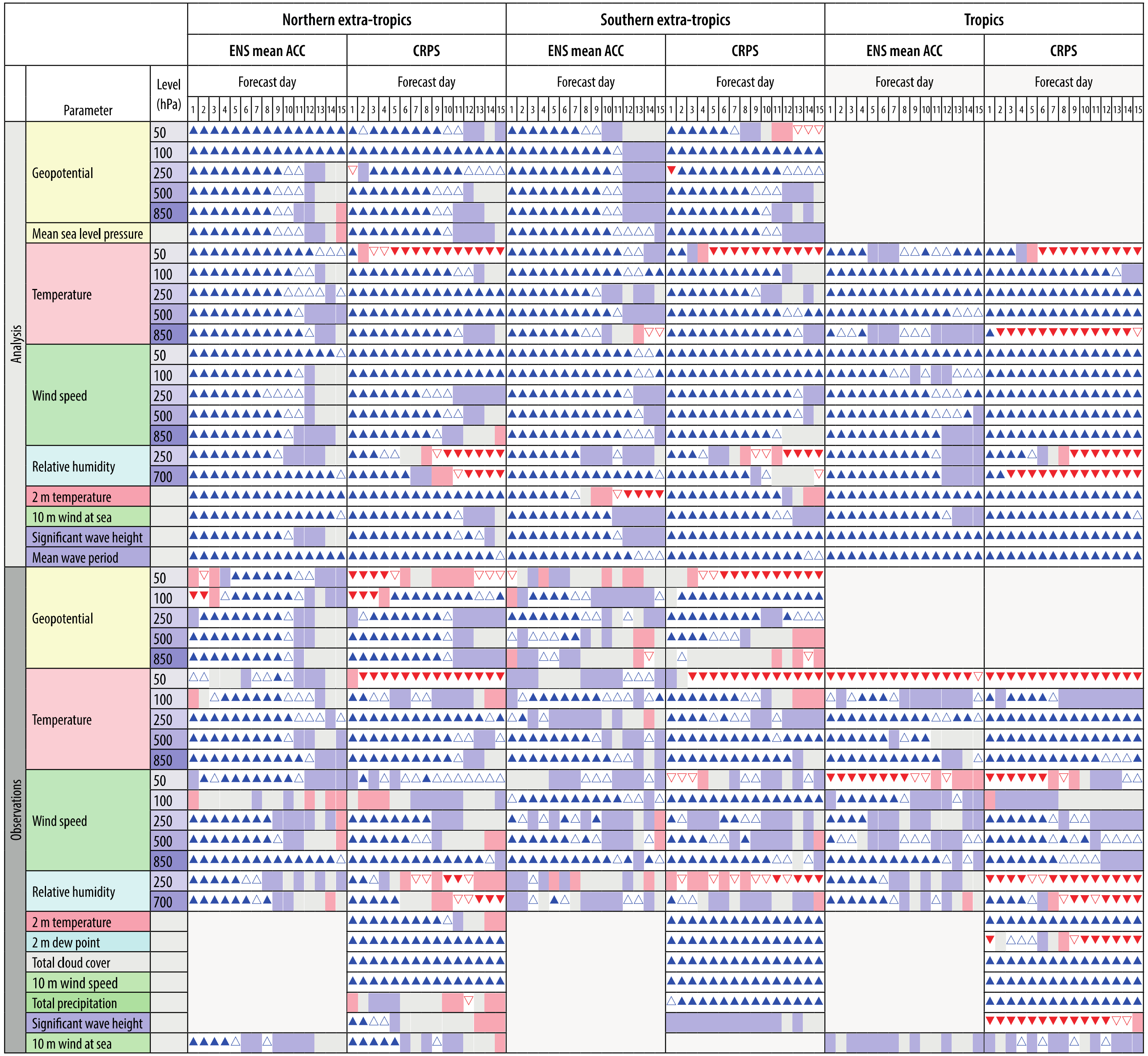
Blue : improvements

~ 1200 initial dates







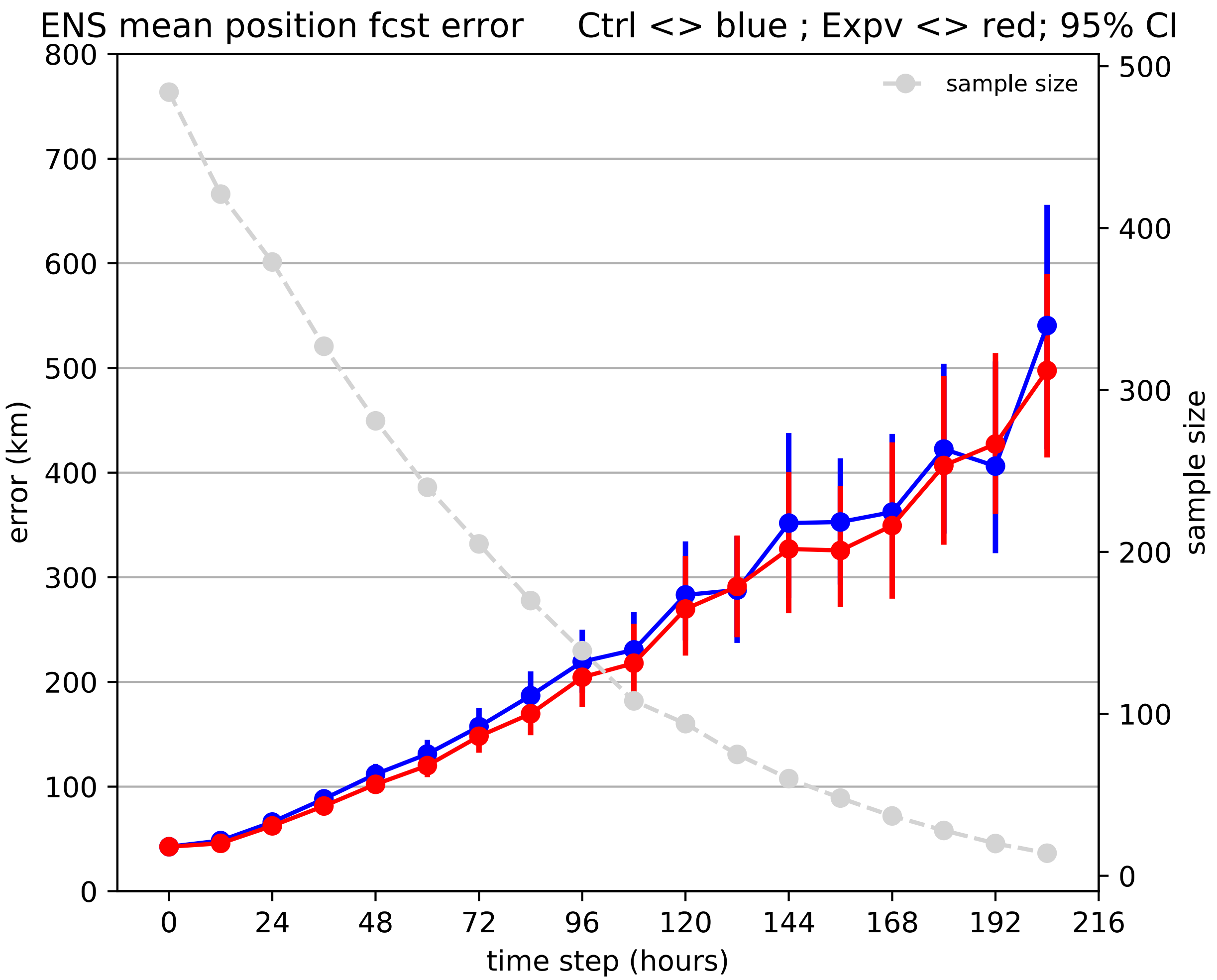


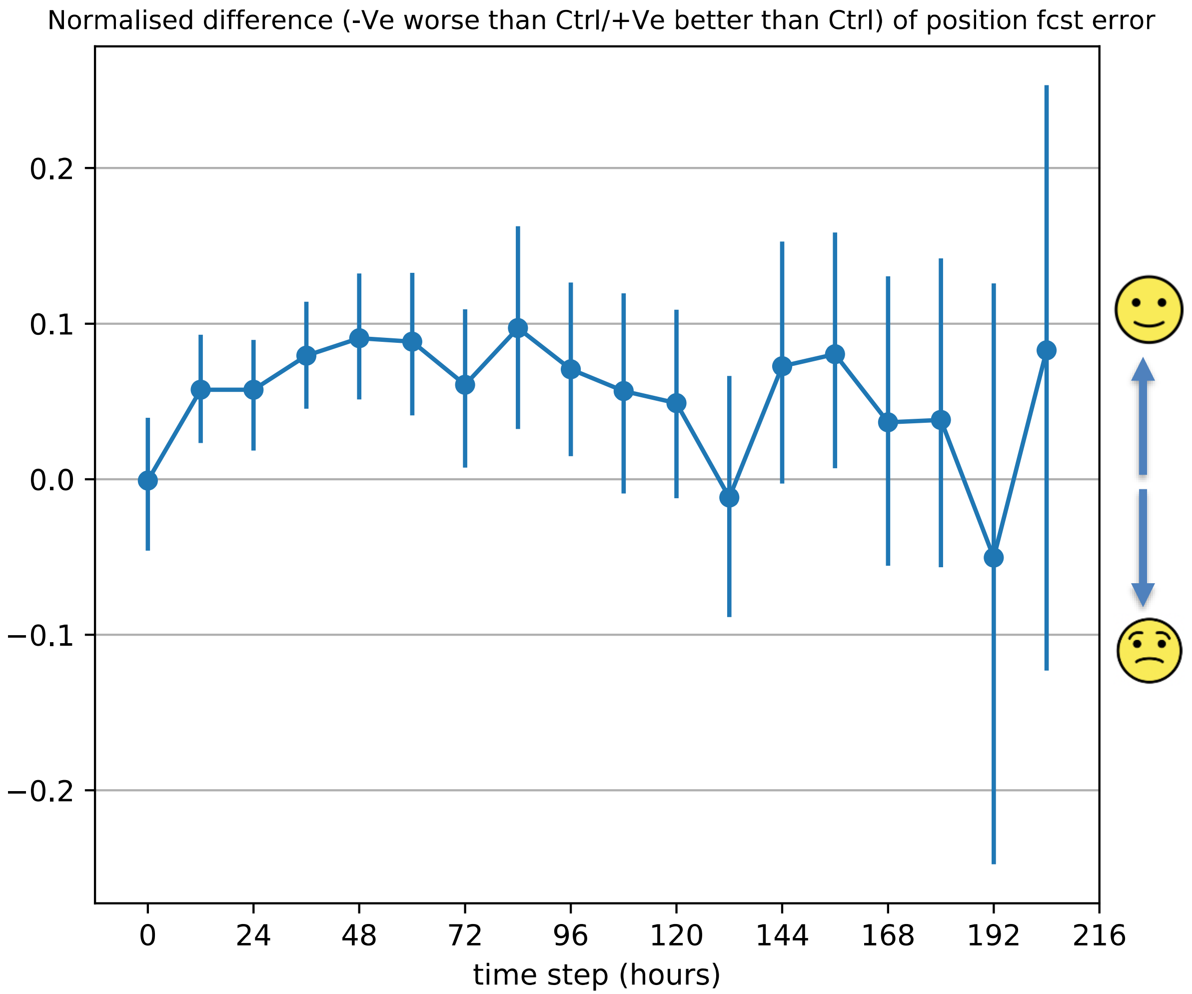
Symbol legend: for a given forecast step...

- ▲ 48r1 better than 47r3 statistically significant with 99.7% confidence
- △ 48r1 better than 47r3 statistically significant with 95% confidence
- 48r1 better than 47r3 statistically significant with 68% confidence
- no significant difference between 47r3 and 48r1
- 48r1 worse than 47r3 statistically significant with 68% confidence
- ▽ 48r1 worse than 47r3 statistically significant with 95% confidence
- ▼ 48r1 worse than 47r3 statistically significant with 99.7% confidence

48r1, ENS TC forecasts: Position

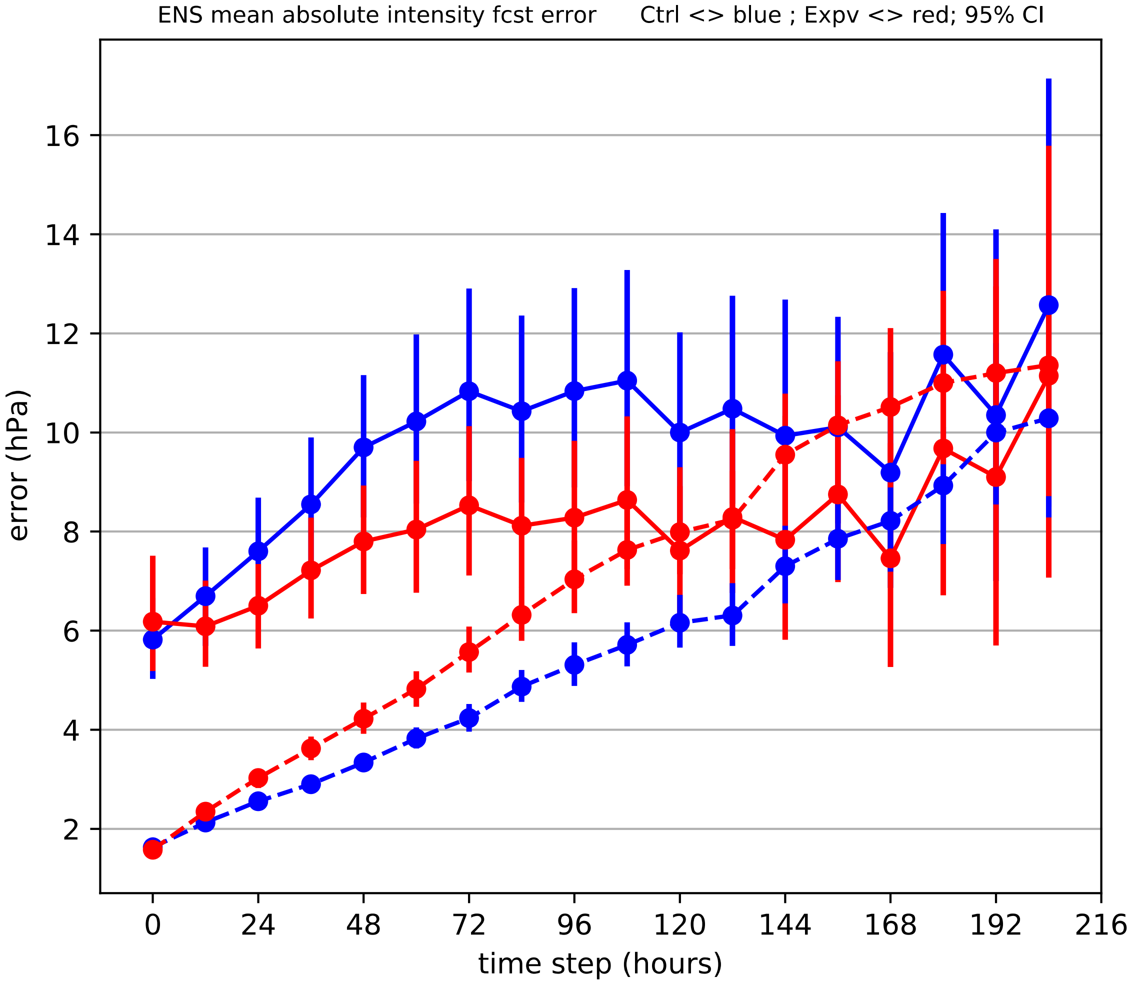
48r1, 47r3

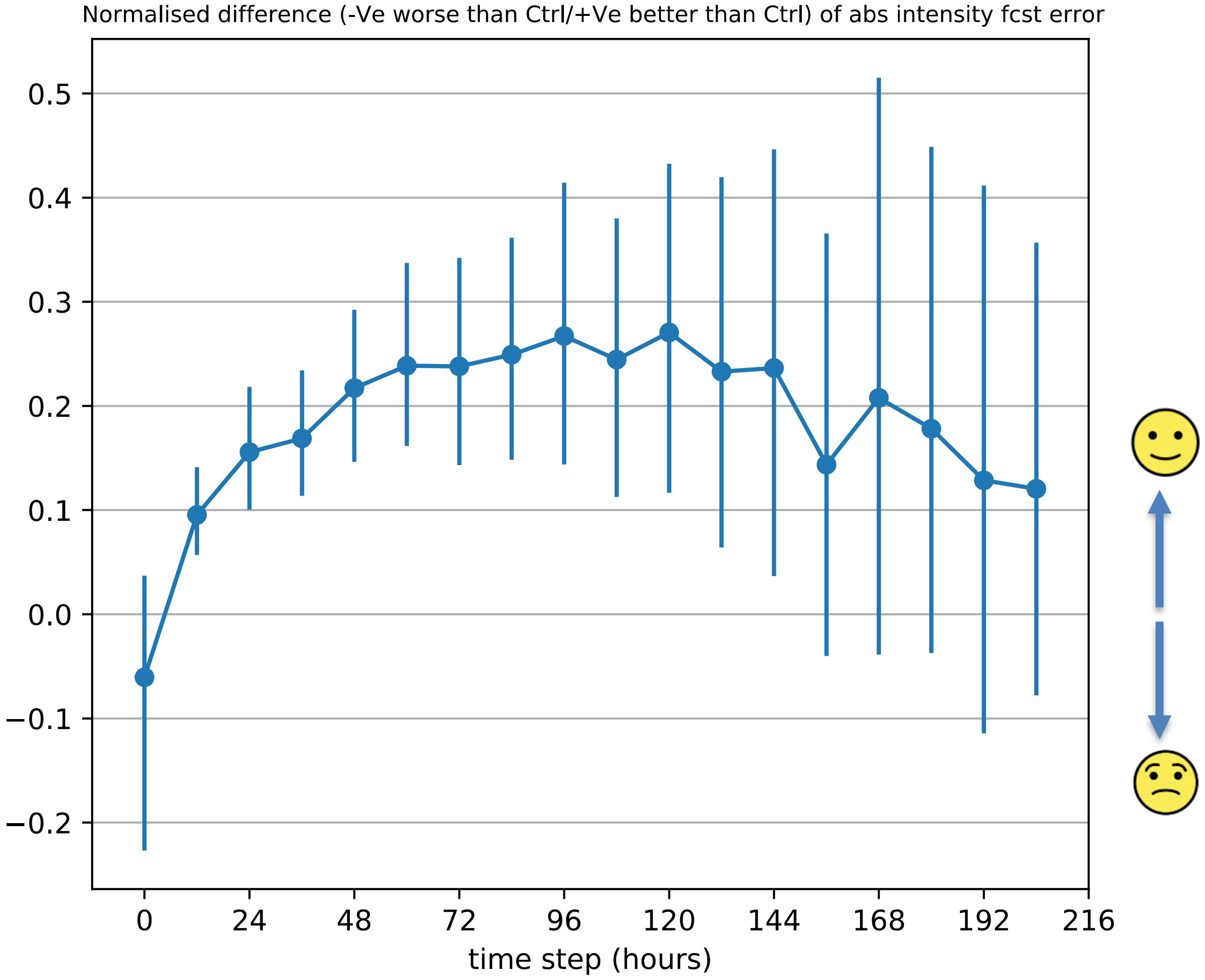


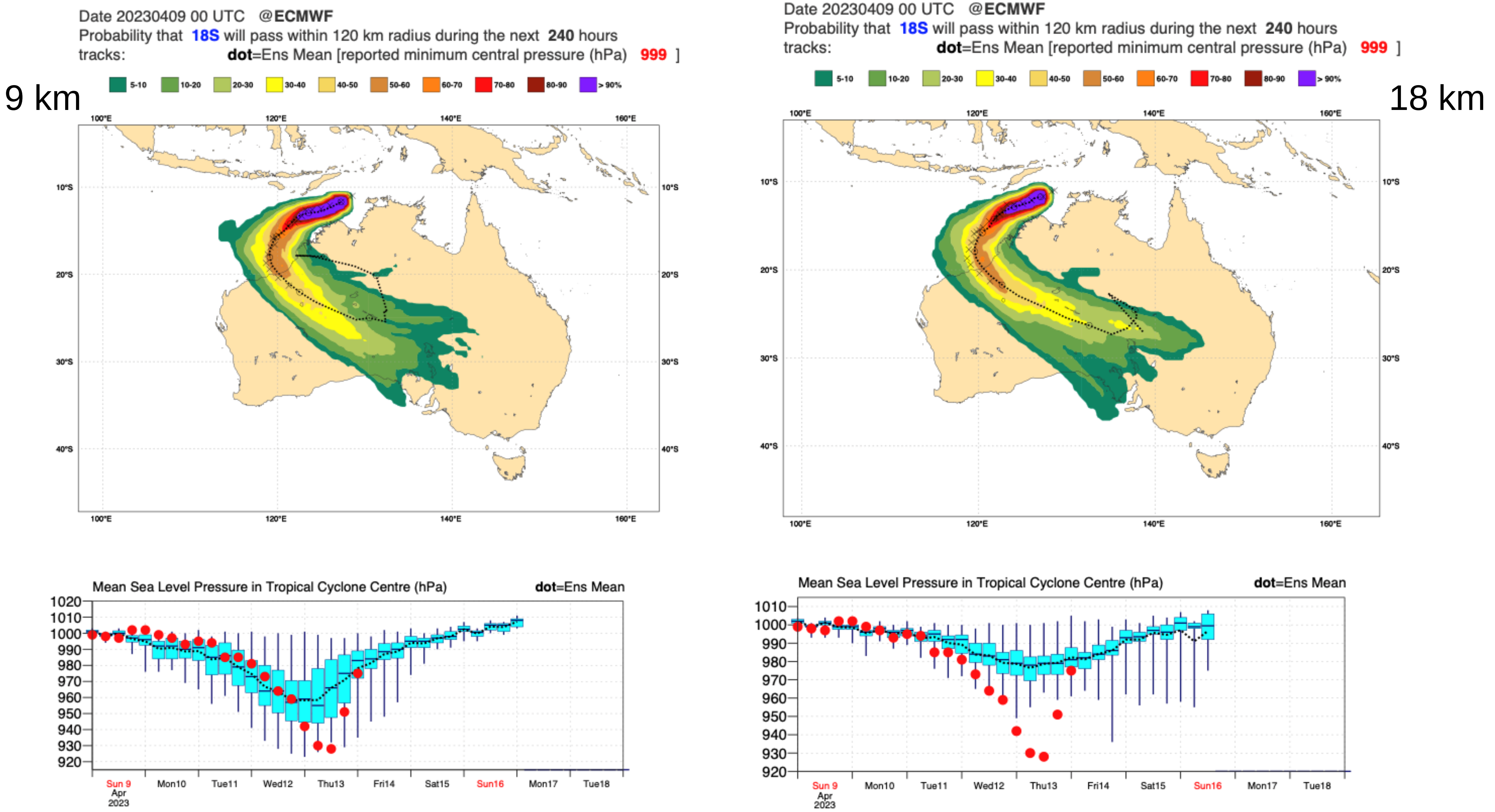


48r1, ENS TC forecasts: Intensity

48r1, 47r3

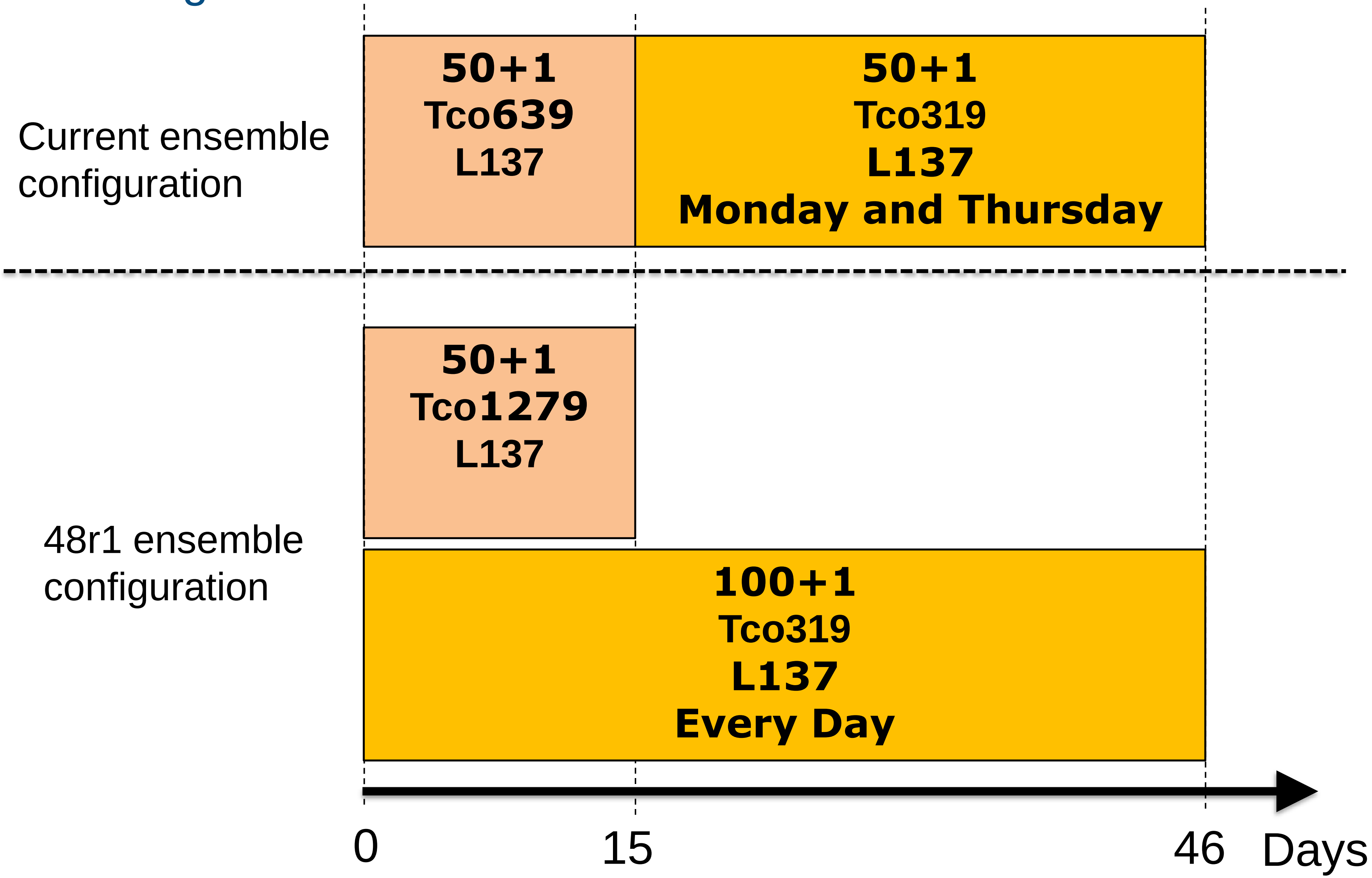






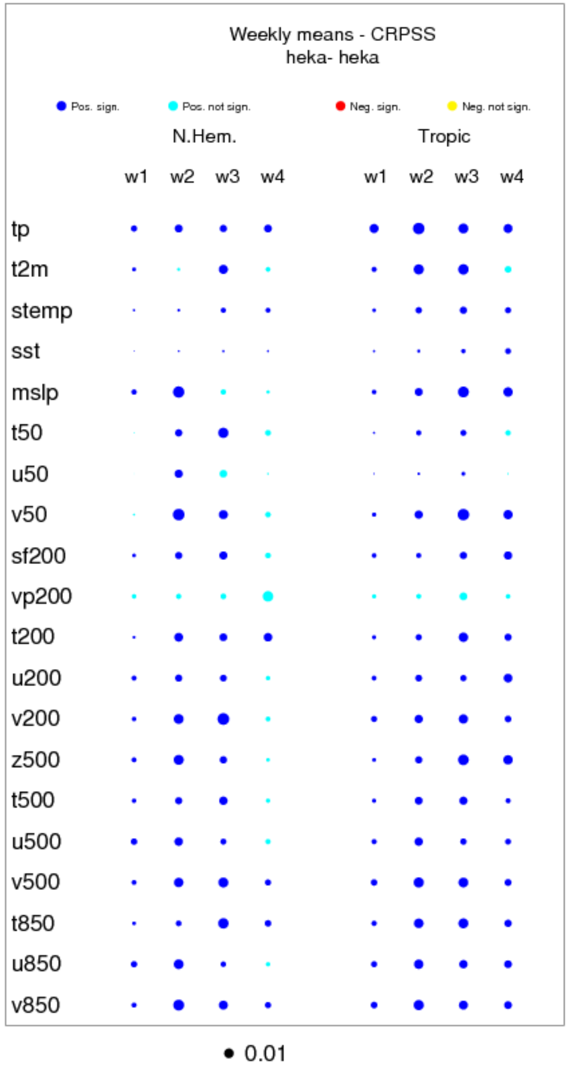
Tropical cyclone Ilsa, forecast from 9 April 2023, 00 UTC, in (a) the IFS Cycle 48r1 ensemble forecast with a resolution of 9 km, and (b) the IFS Cycle 47r3 ensemble forecast with a resolution of 18 km. Shown are the strike probability (top) and mean sea level pressure (MSLP) in the centre of Ilsa (bottom).

48r1: Extended range



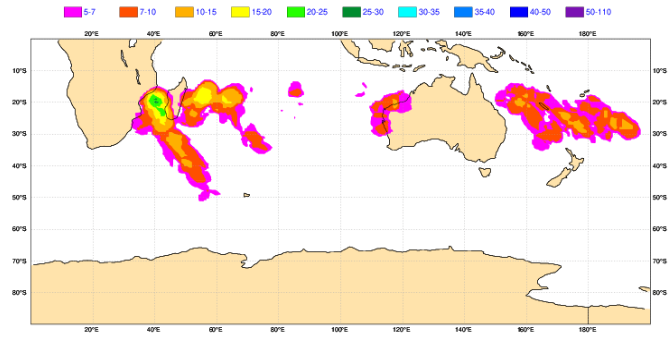
Change to extended-range forecast configuration in 48r1

Impact of increase of ensemble size

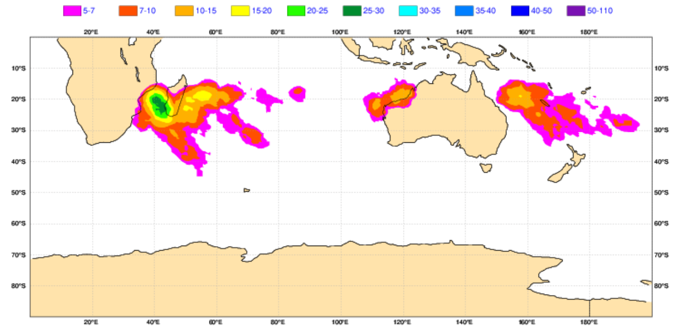


Tropical storm strike probability week 4 forecast
Start date:7/1/2021 – verification 1-7 Feb. 2021

50+1 members



100+1 members

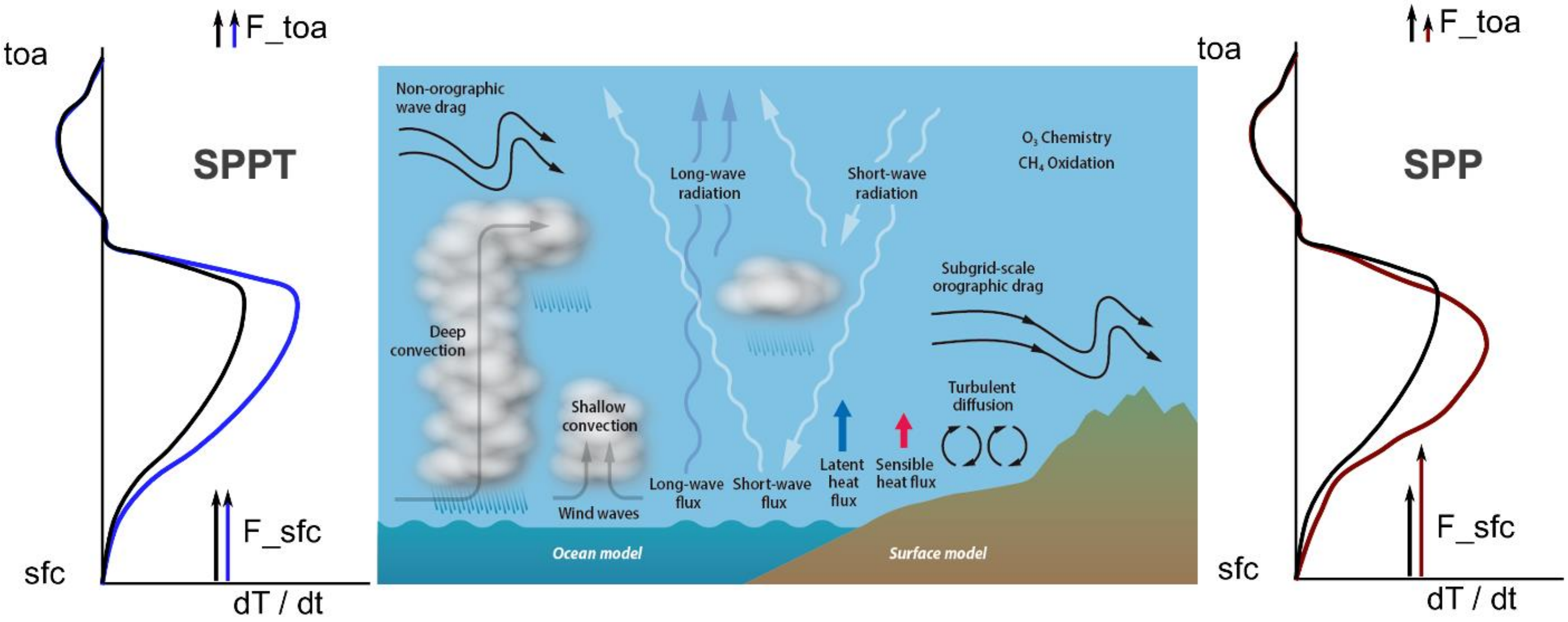


Plans for Model Uncertainty

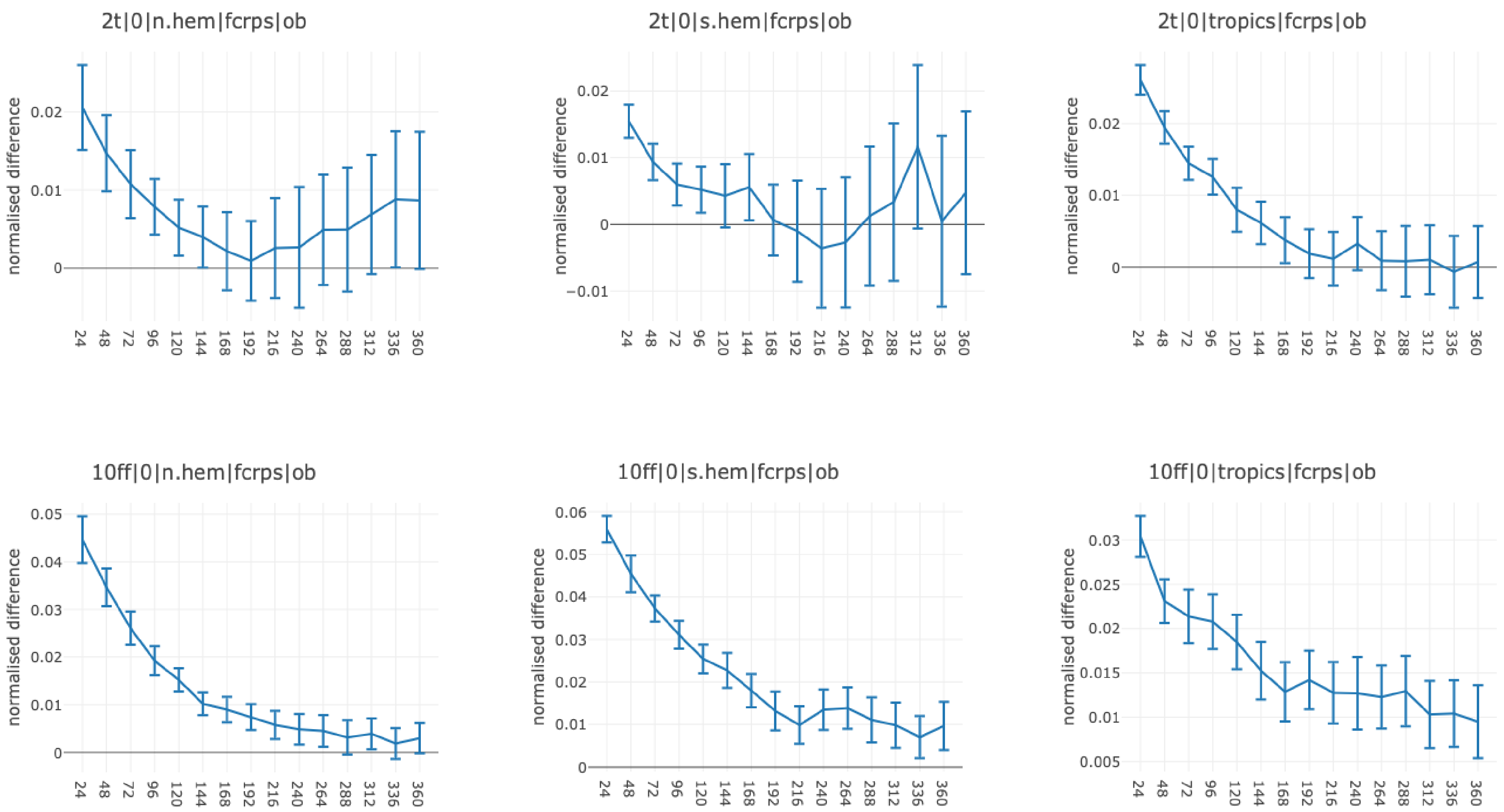
Key differences between SPPT and SPP

Ollinaho et al (2017), https://doi.org/10.1002/qj.2931
Leutbecher et al (2017), https://doi.org/10.1002/qj.3094
Lang et al (2021), https://doi.org/10.1002/qj.3978

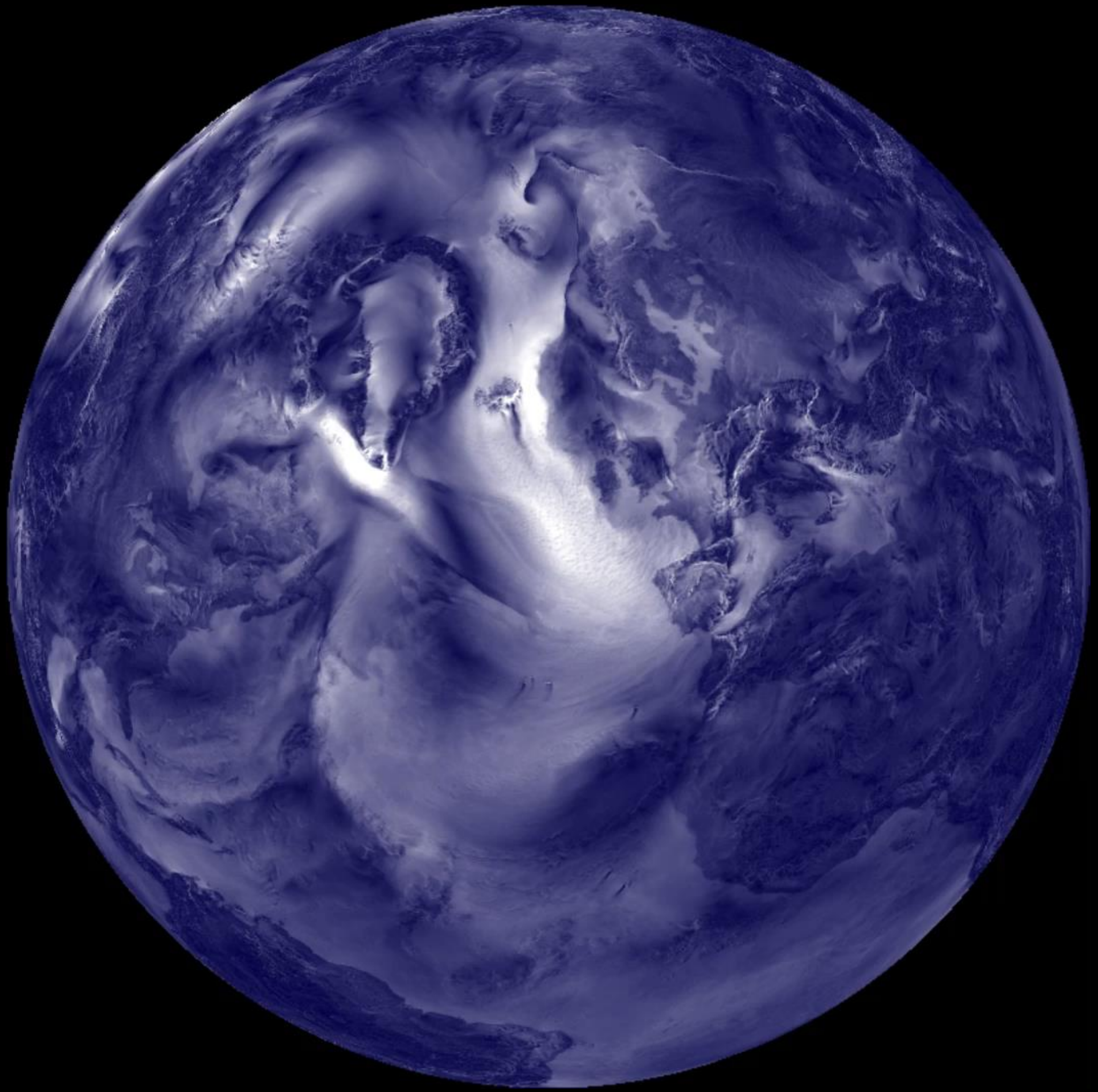
- SPP represents model uncertainties closer to the assumed sources of the errors
- SPP better maintains physical consistency: e.g. local budgets and flux perturbations
- SPPT only represents amplitude errors while SPP can also represent errors in the shape of a heating profile



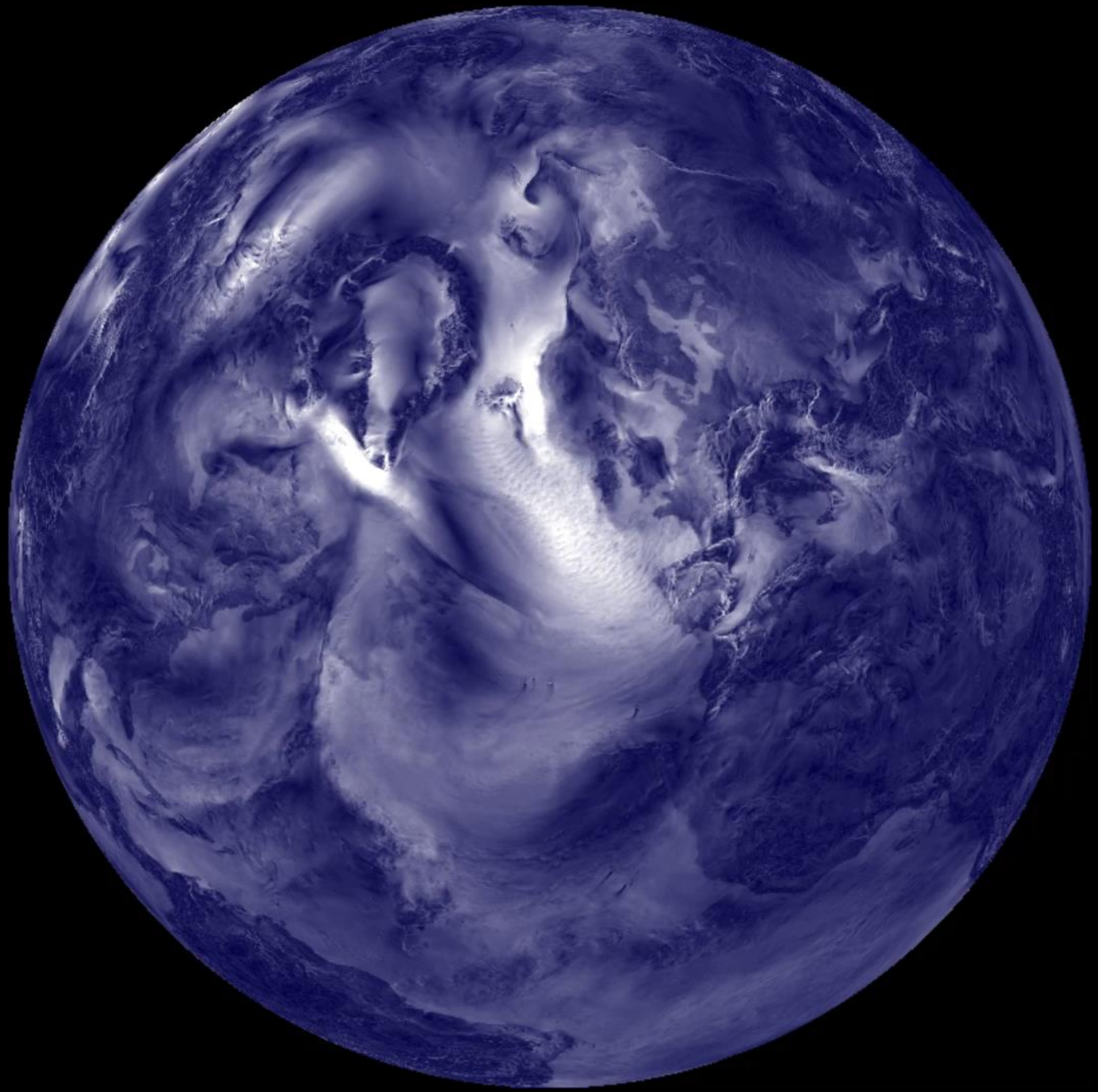
SPP, impact on surface scores (from testing):



10m wind gusts, 2020-12-04 00 UTC 720h forecasts, Next resolution - 9 km spatial resolution



Control Member



Perturbed member 1