Accuracy of the jet stream position forecast as a dynamical core test: Cut-cell Eta vs. ECMWF 32-day ensemble results

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Accuracy ?

of a model, ran using real data IC

Issues:

Atmosphere is chaotic

Results depend on data assimilation system

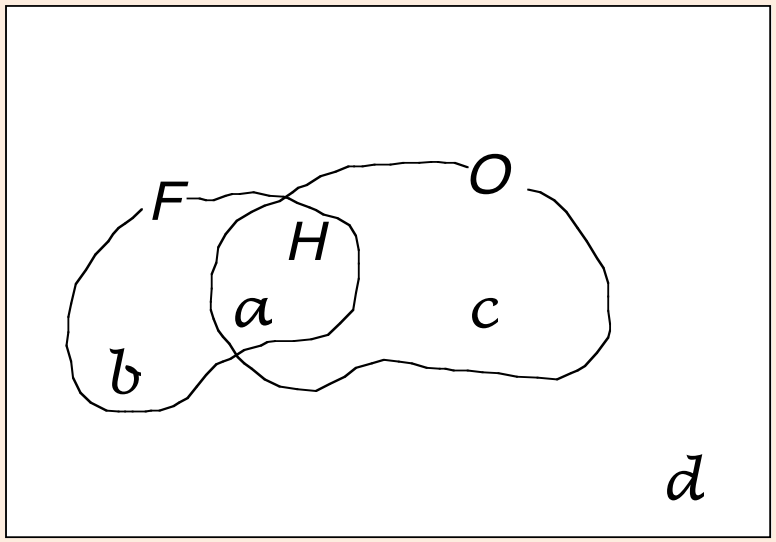
Impacts of both are avoided if we drive our limited area "test model" by ICs and LBCs of an ensemble of a global model

"Although spectral transform methods are being predicted to be phased out, the current spectral model at the European Centre for Medium-Range Weather Forecasts … is the benchmark to beat, and it is not clear that any of the new developments are ready to replace it."

Côté J, Jablonowski C, Bauer P, Wedi N (2015) Numerical methods of the atmosphere and ocean. Seamless prediction of the Earth system: From minutes to months, 101–124. World Meteorological Organization, WMO-No. 1156.

Accuracy of the jet stream position . . . .

Forecast, Hits, and Observed (*F*, *H*, *O*) area,
or number of model grid boxes:



Many verification scores.

One:

$$ETS = \frac{H - E(H)}{F + O - H - E(H)}$$

"Equitable Threat Score"

or, Gilbert (1884 !) Skill Score

Bias = *F* / *O*

ECMWF once a week runs a 51 member ensemble forecast 32 days ahead

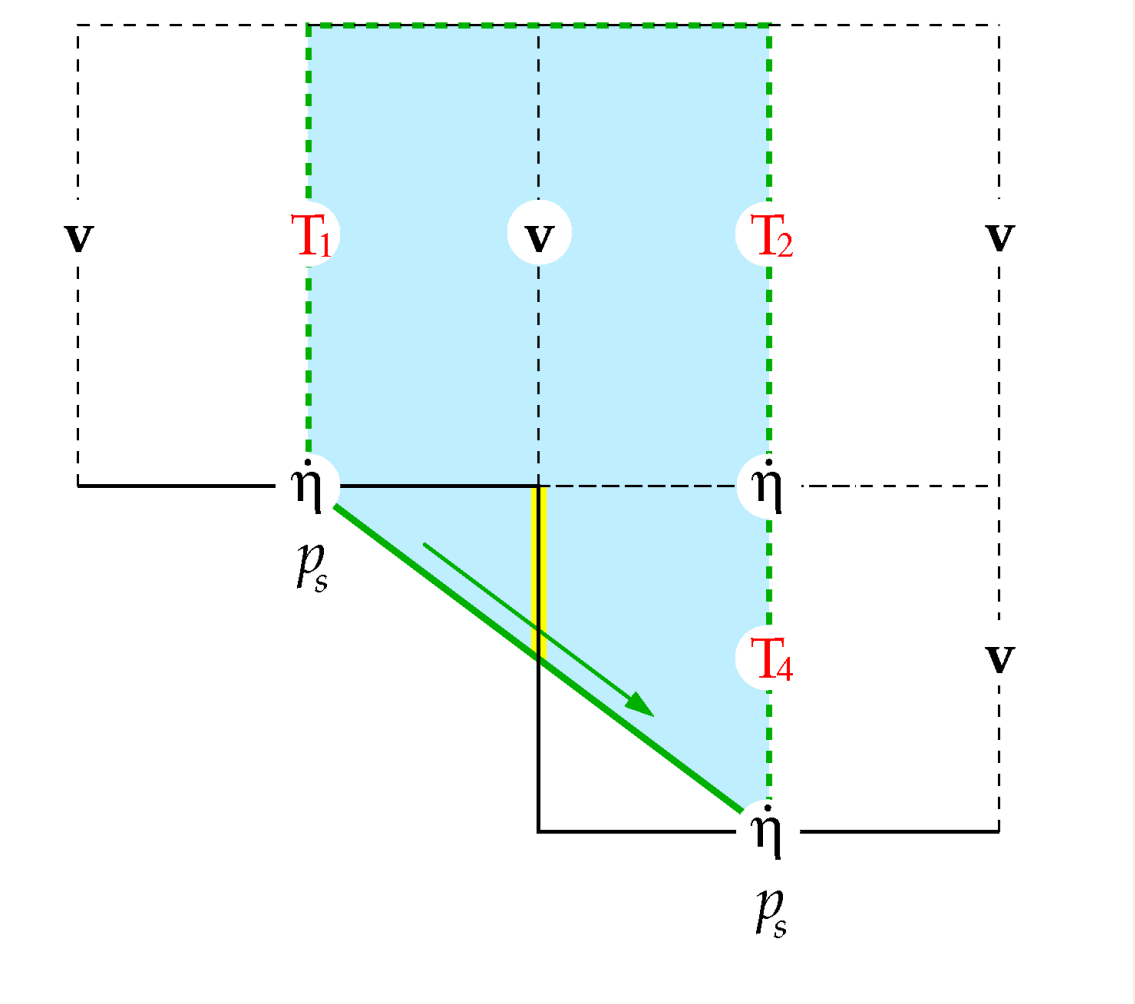
Veljovic K, Rajkovic B, Fennessy MJ, Altshuler EL, Mesinger F (2010) Regional climate modeling: Should one attempt improving on the large scales? Lateral boundary condition scheme: Any impact? Meteorol Zeitschrift, **19**, 237-246, doi:10.1127/0941-2948/2010/0460

Mesinger F, Chou SC, Gomes J, Jovic D, Bastos P, Bustamante JF, Lazic L, Lyra AA, Morelli S, Ristic I, Veljovic K (2012) An upgraded version of the Eta model. Meteorol Atmos Phys **116**, 63–79. doi:10.1007/s00703-012-0182-z

Mesinger, F, Veljovic K (2017) Eta vs. sigma: Review of past results, Gallus-Klemp test, and large-scale wind skill in ensemble experiments. Meteorol Atmos Phys, **129**, 573-593, doi:10.1007/s00703-016-0496-3

To address the Gallus-Klemp (2000) problem: The sloping steps (a simple cut-cell scheme), vertical grid:

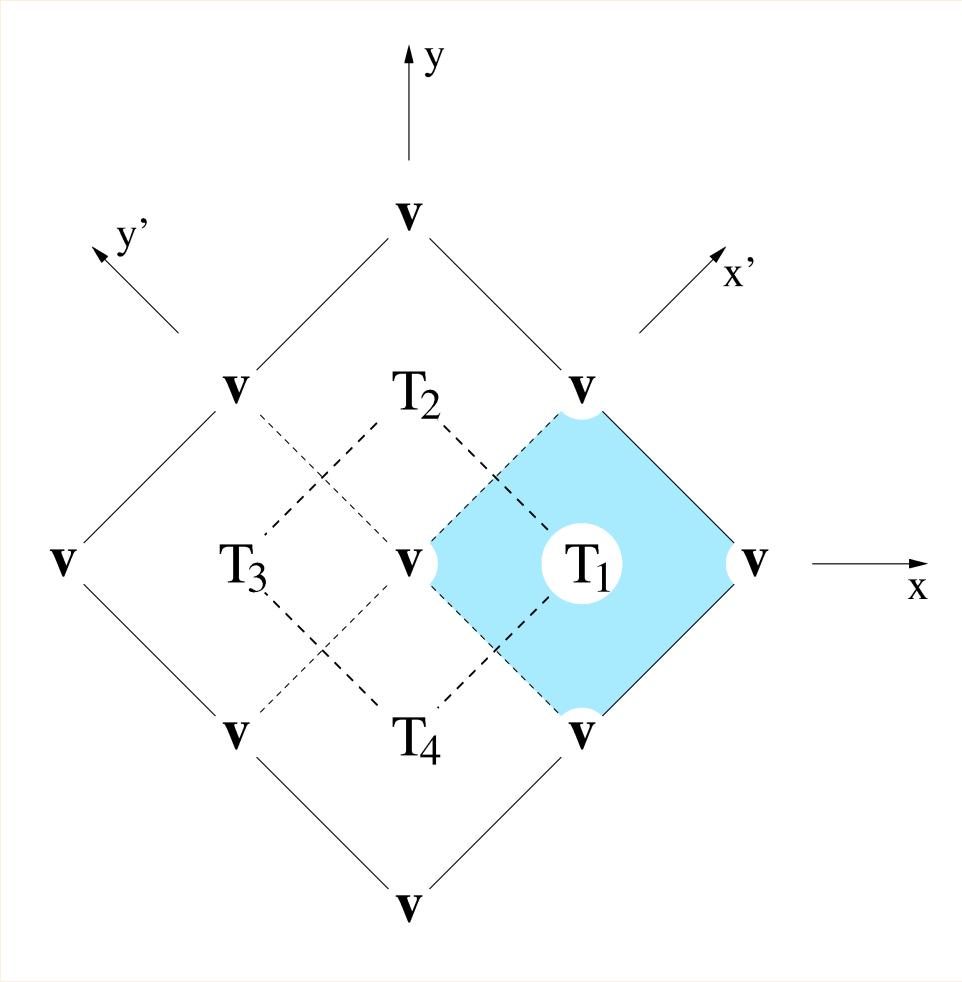
The central **v** box exchanges momentum, on its right side, with **v** boxes of two layers:



Horizontal treatment, 3D

Case #1: topography of box 1 is higher than those of 2, 3, and 4; "Slope 1"

Inside the central **v** box, topography descends from the center of T1 box down by one layer thickness, linearly, to the centers of T2, T3 and T4



Acknowledgements: Dušan Jović, Jorge Gomes

How are grid cell values of topography obtained ?

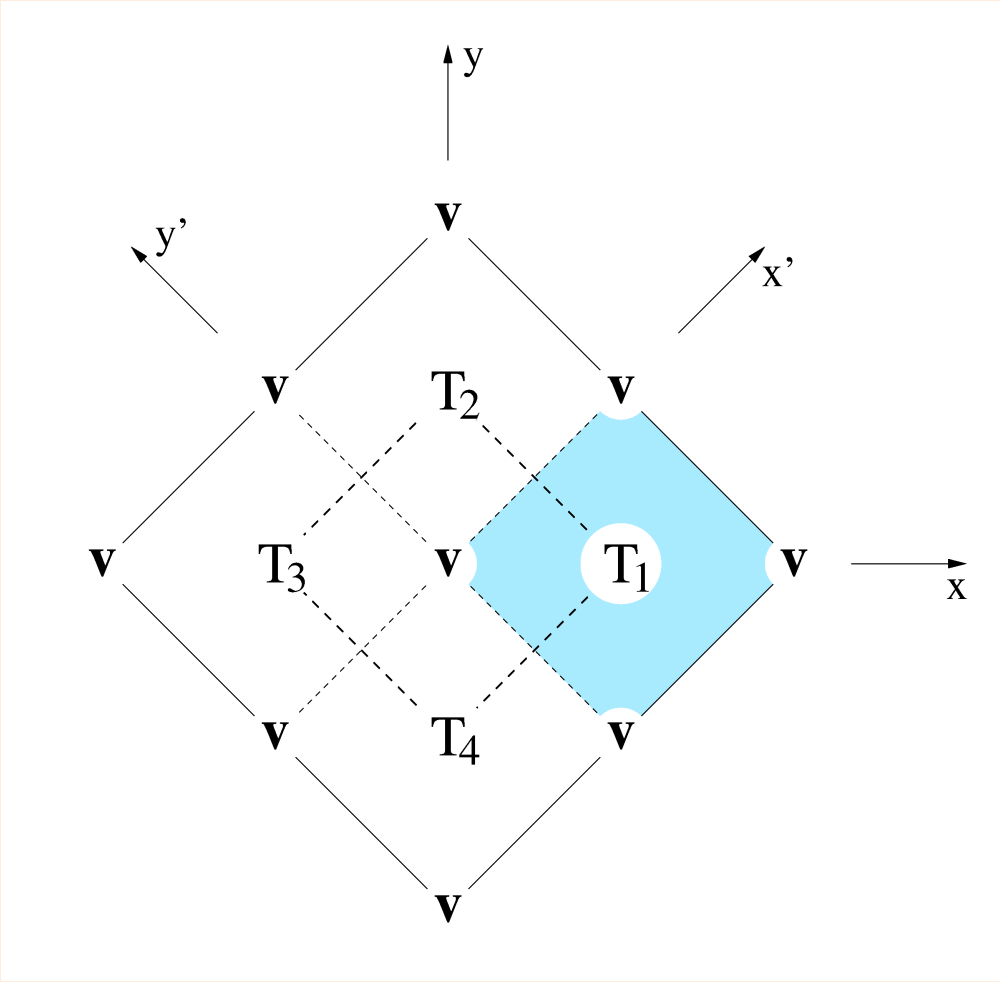
Chop up each cell into n x n sub-cells;

Obtain each sub-cell mean value;

Obtain mean h_m and silhouette cell value, round off to discrete interface value;

Choose one depending on Laplacian h_m

Remove basins with all corner winds blocked;



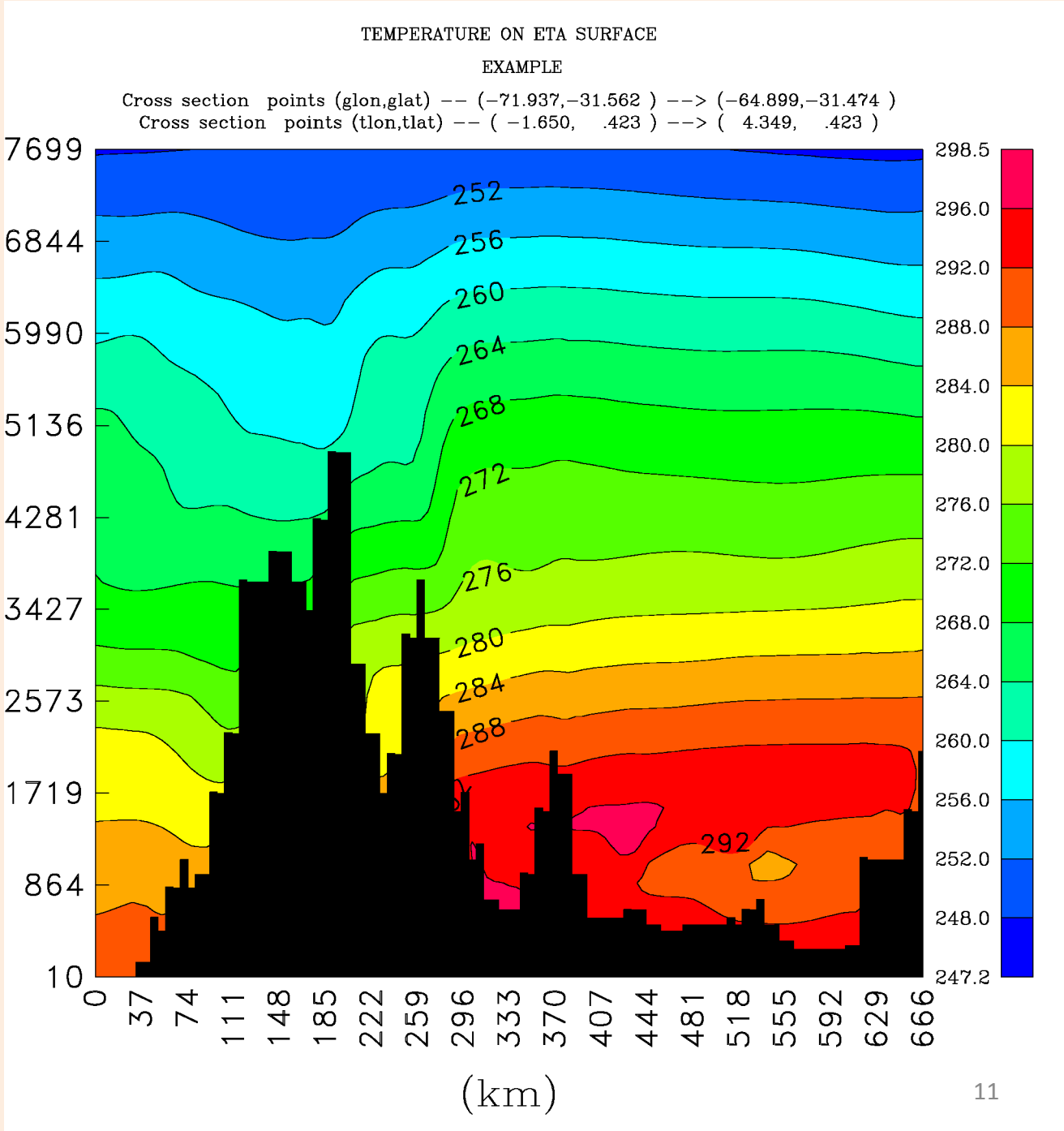
Some more common sense rules (no waterfalls, do not close major ridges by silhouetting), but no smoothing

8 km horizontal resolution,

W/E profile at the latitude of about the highest elevation of the Andes

30 hr forecast:

NCAR graphics, no cell values smoothing

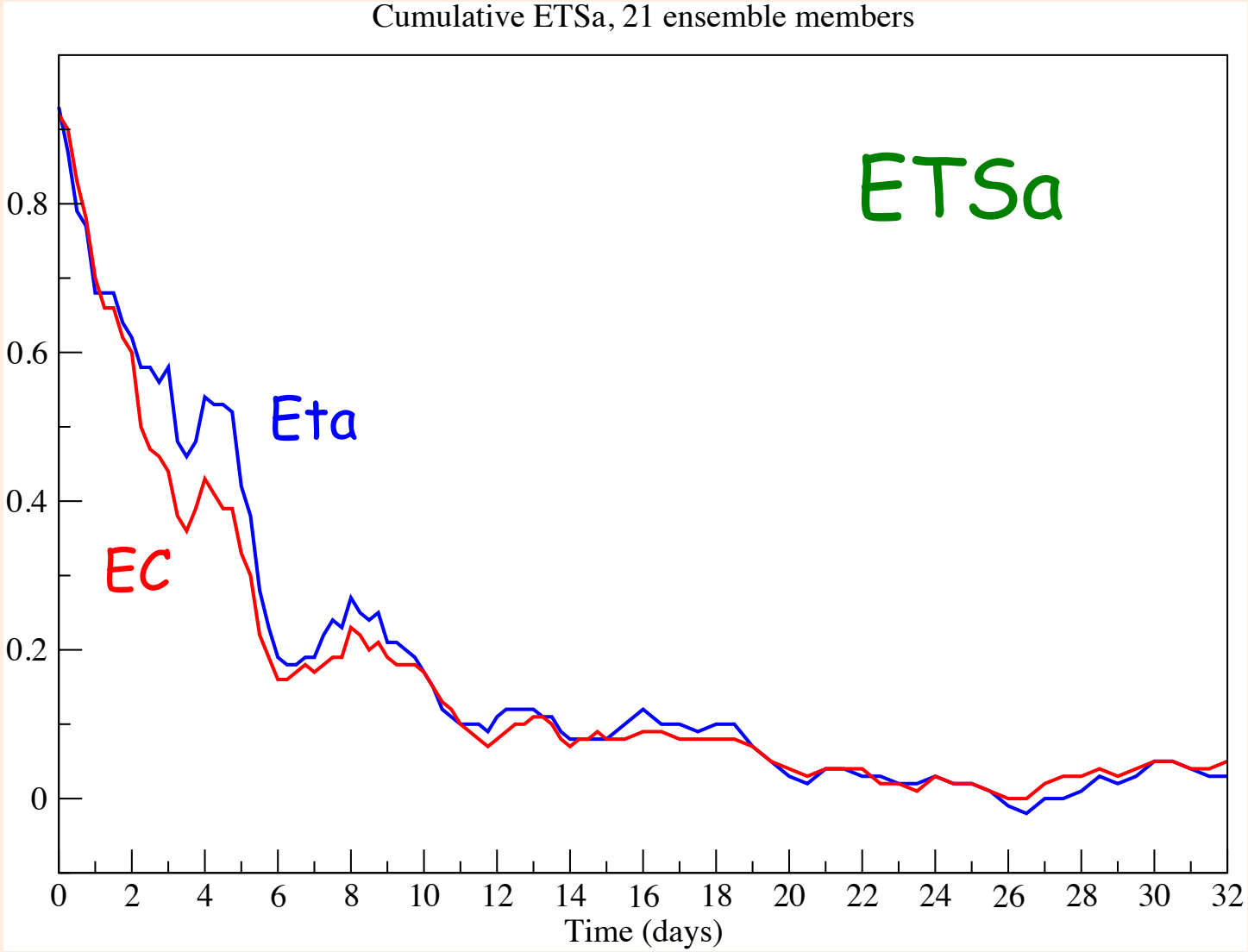


Another cut-cell scheme: Steppeler et al. (2008, 2013):

Steppeler J, Park S-H, Dobler A (2013) Forecasts covering one month using a cut-cell model. Geosci. Model Dev., **6**, 875-882. doi:10.5194/gmd-6-875-2013

Verification results

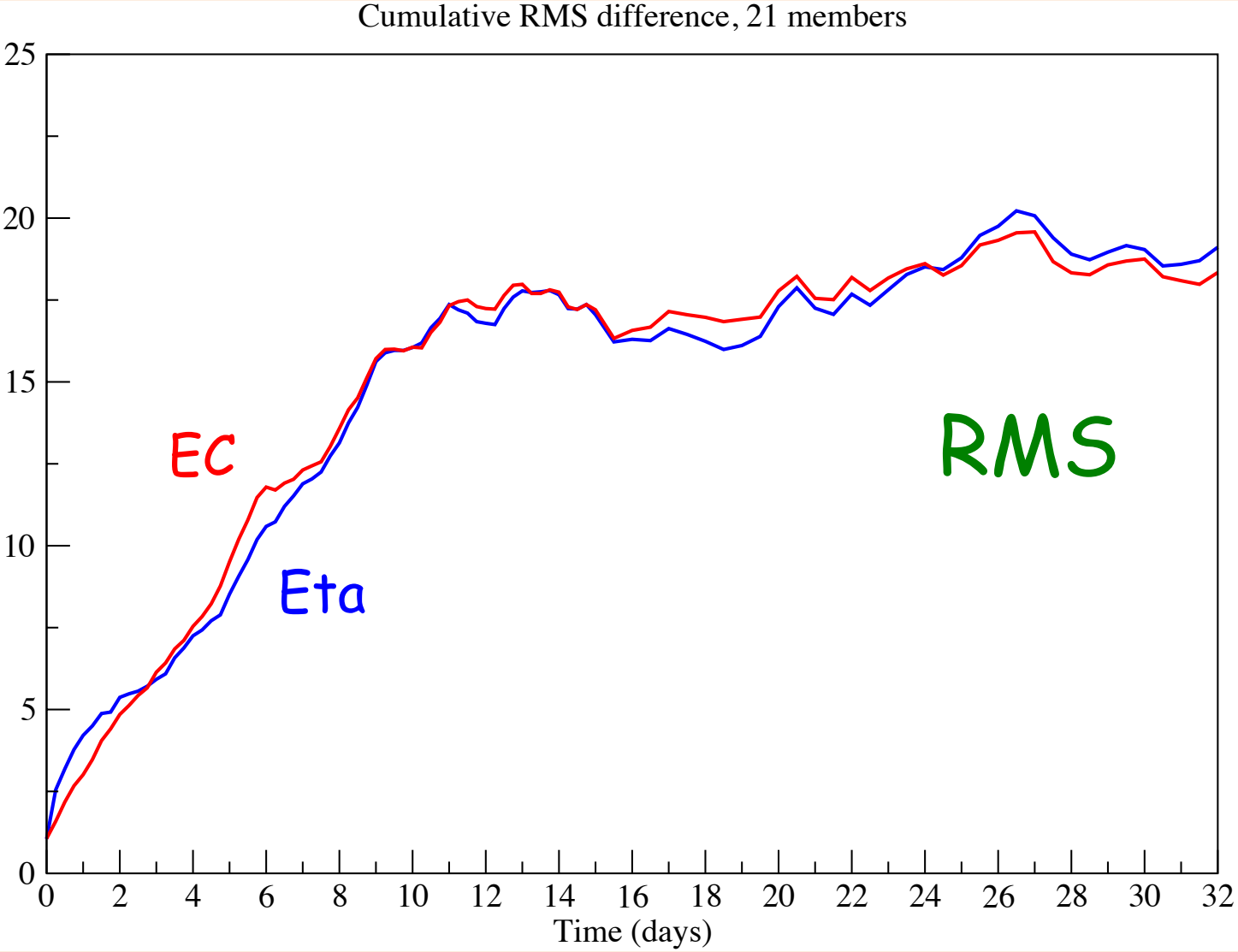
21 ensemble members



Bias adjusted ETS scores of wind speeds > 45 m s^{-1}, at 250 hPa, with respect to ECMWF analyses

ETSa:

More is better !



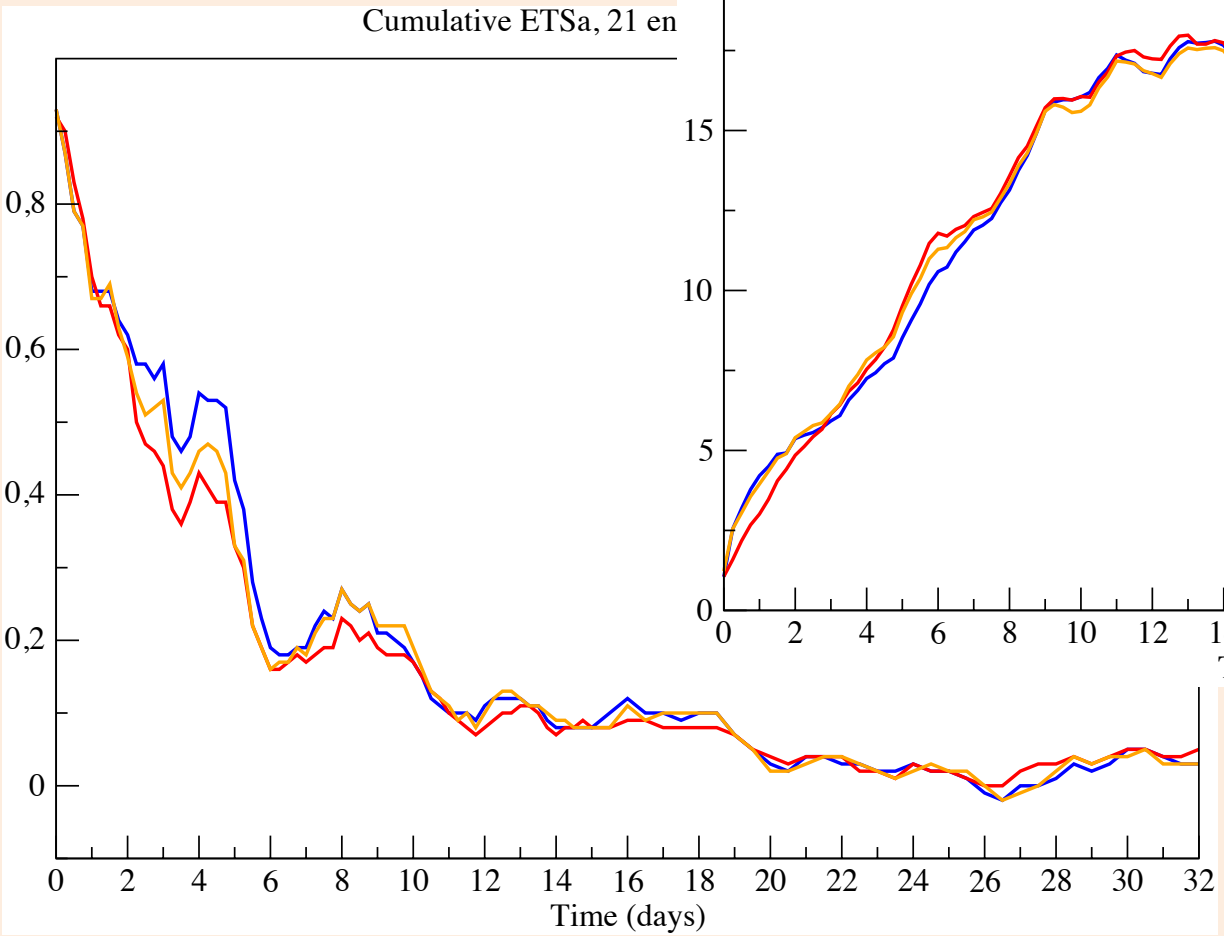
RMS wind difference of 250 hPa winds, with respect to ECMWF analyses

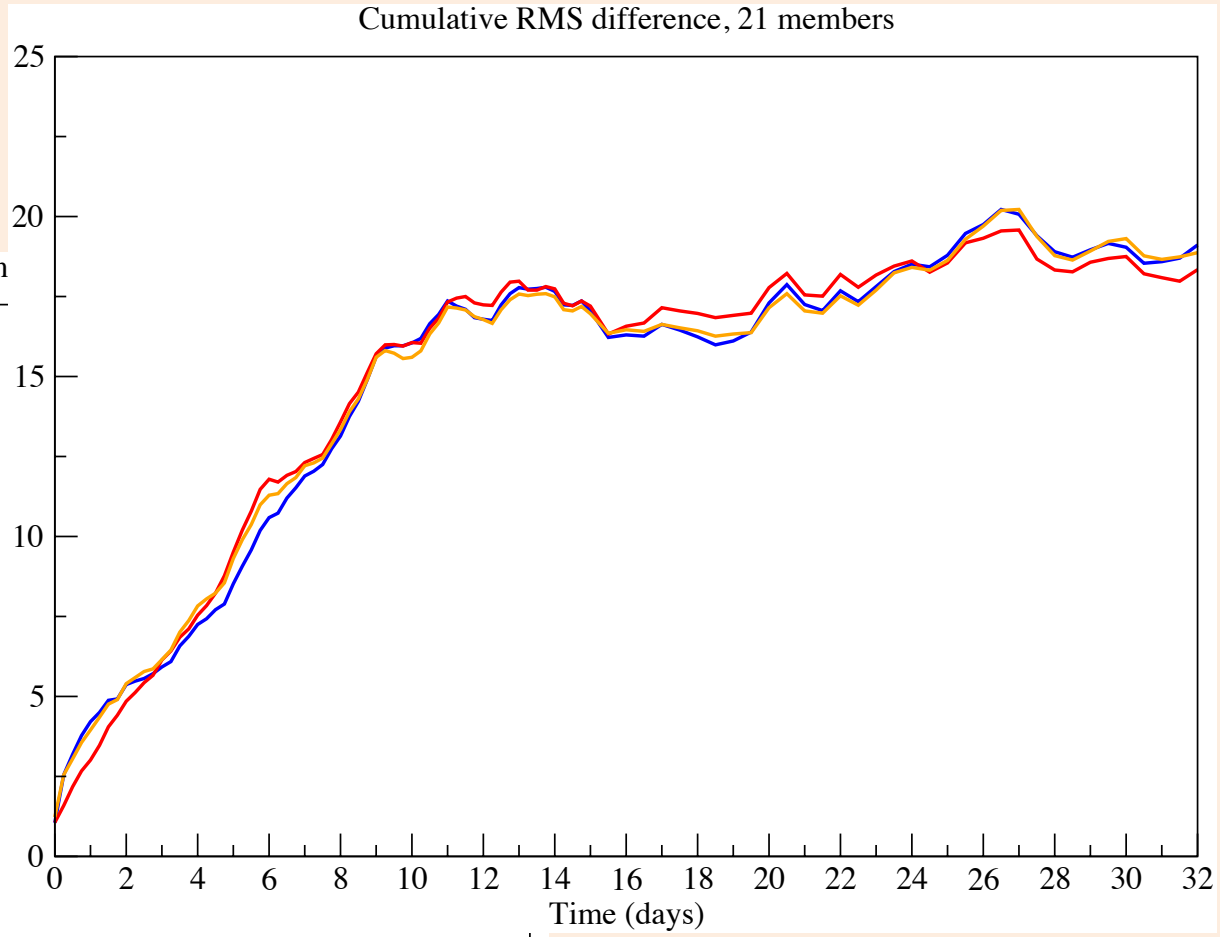
RMS:
Less is better !

What ingredient of the Eta is responsible for the advantage in scores ?

(It is not resolution, the first 10 days resolution of two models was about the same)

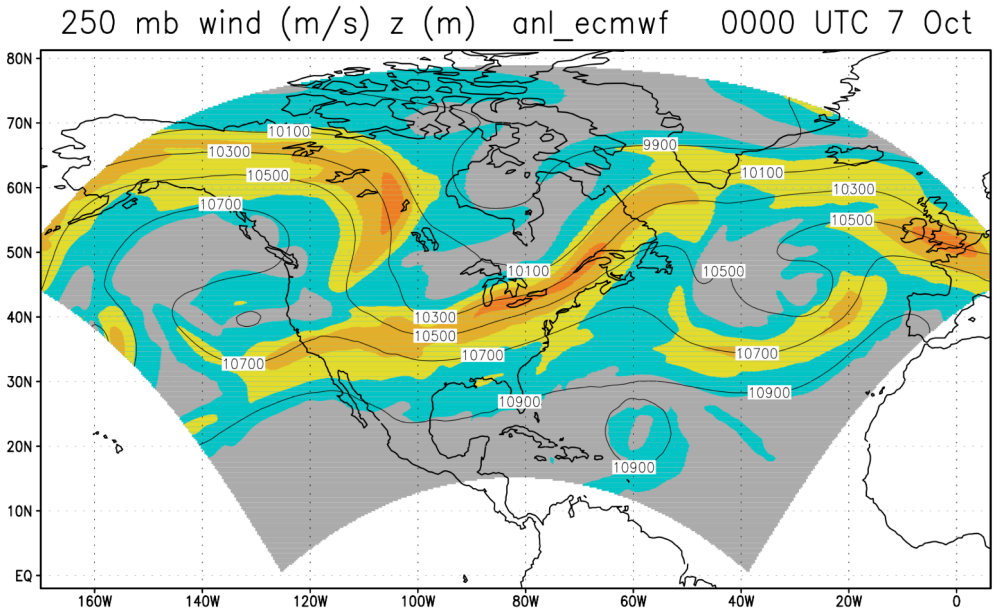
21 members ran using Eta/sigma:

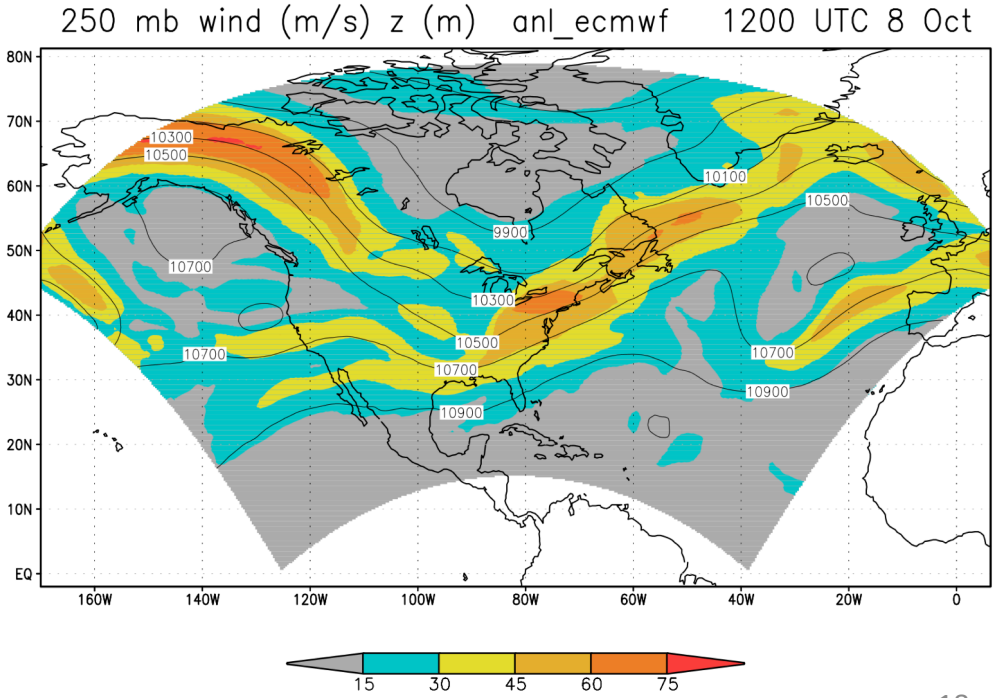




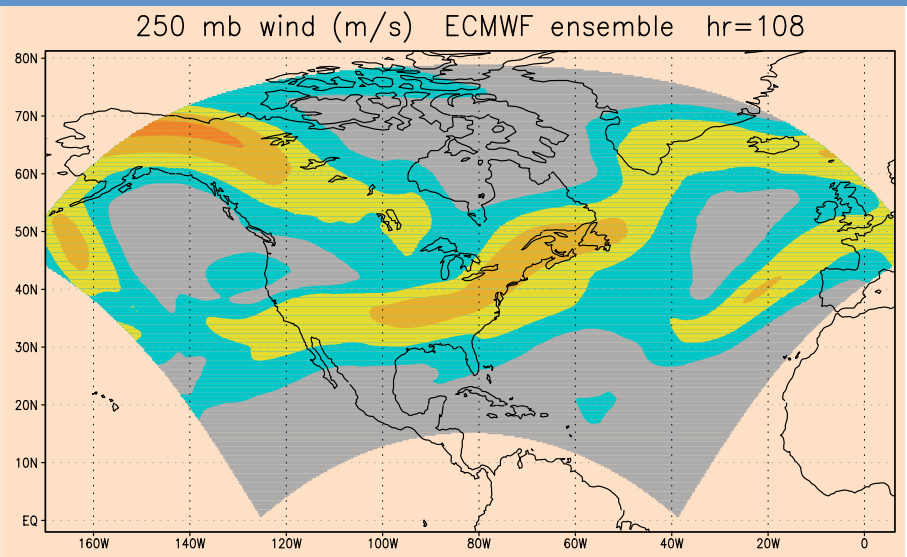
What was going on at about day 2-6 time ?

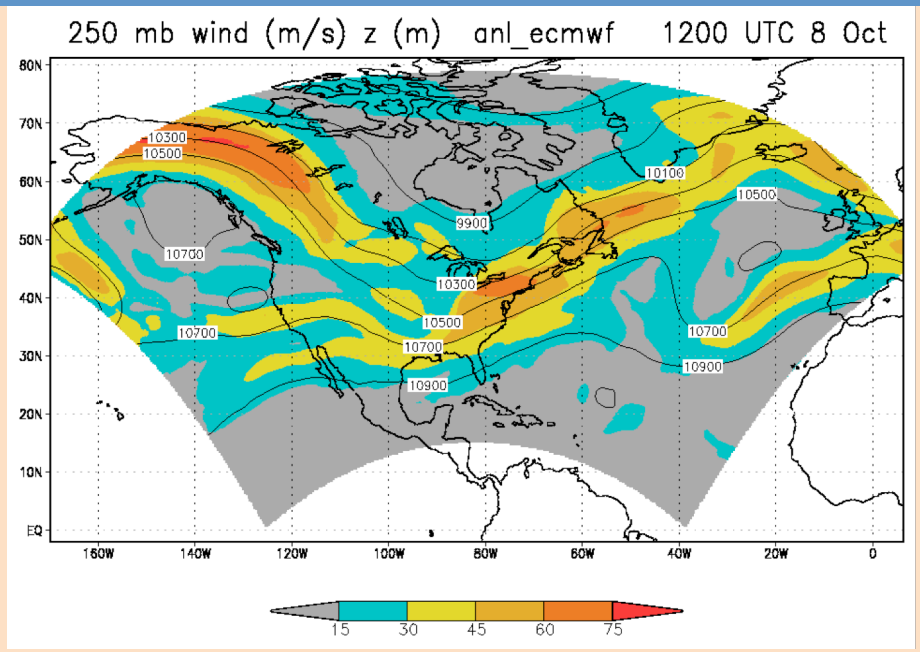
The plot times correspond to day 3.0, and 4.5, respectively, of the plots of the two preceding slides



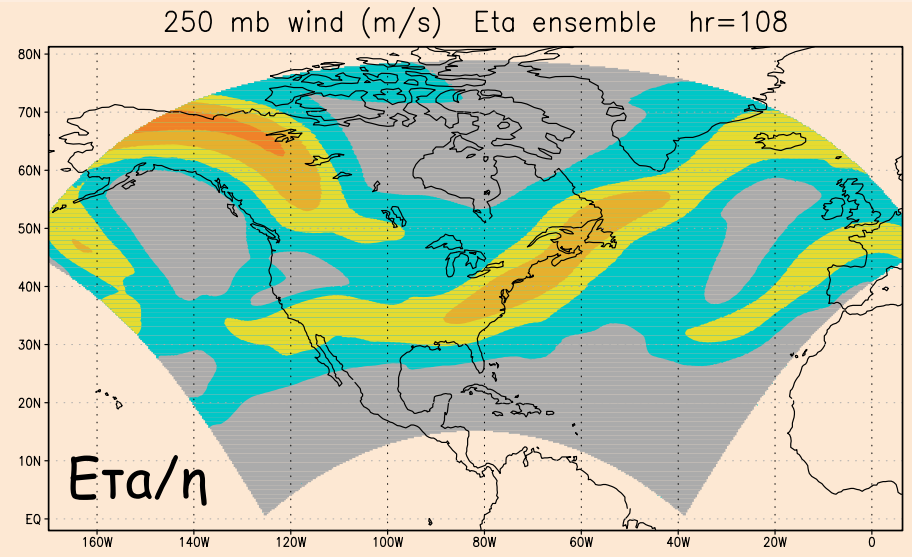


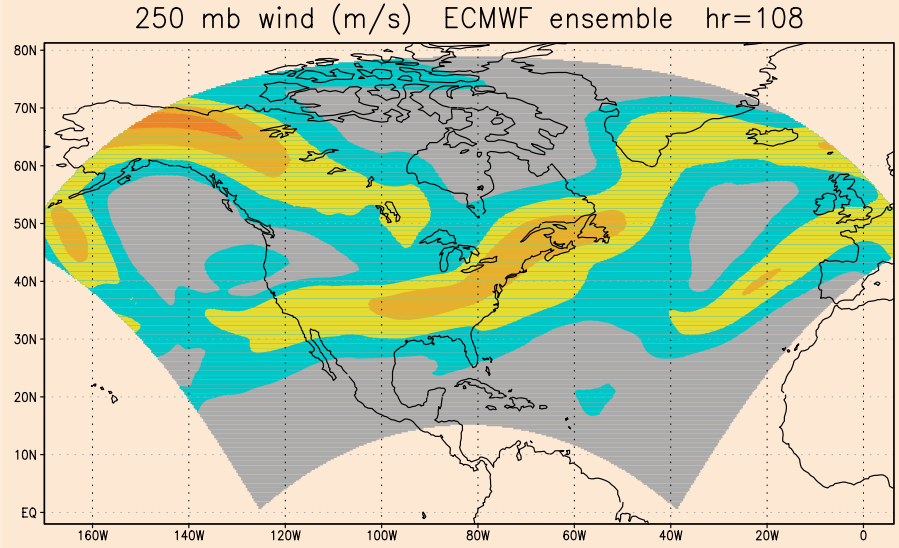
Why was the Eta so much more accurate at this time ?

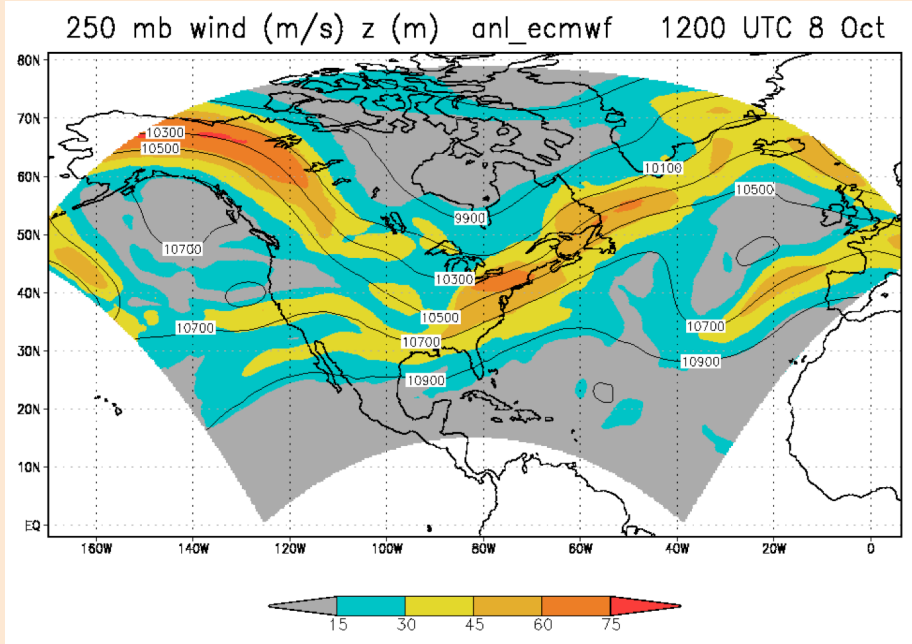




Ensemble average, 21 members, at 4.5 day time: Eta/sigma top left, Eta top right, EC driver bottom left, EC verification analysis bottom right.







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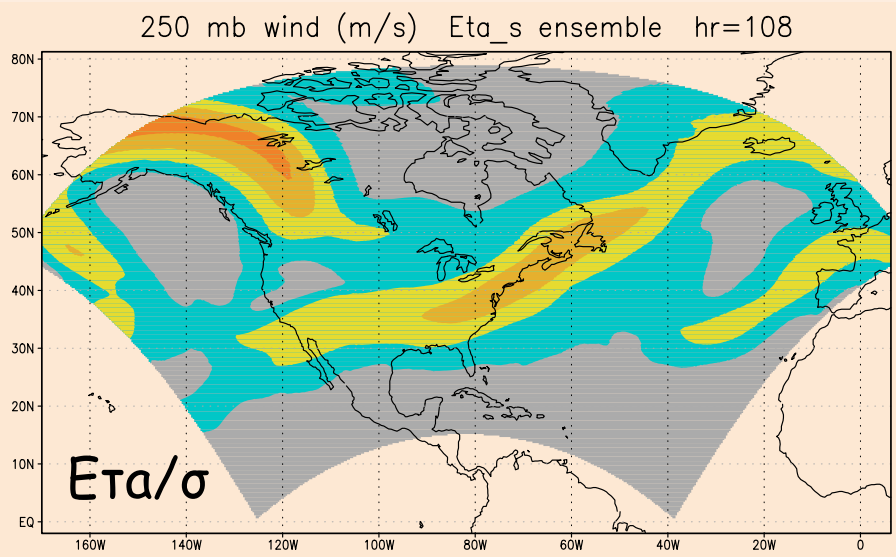

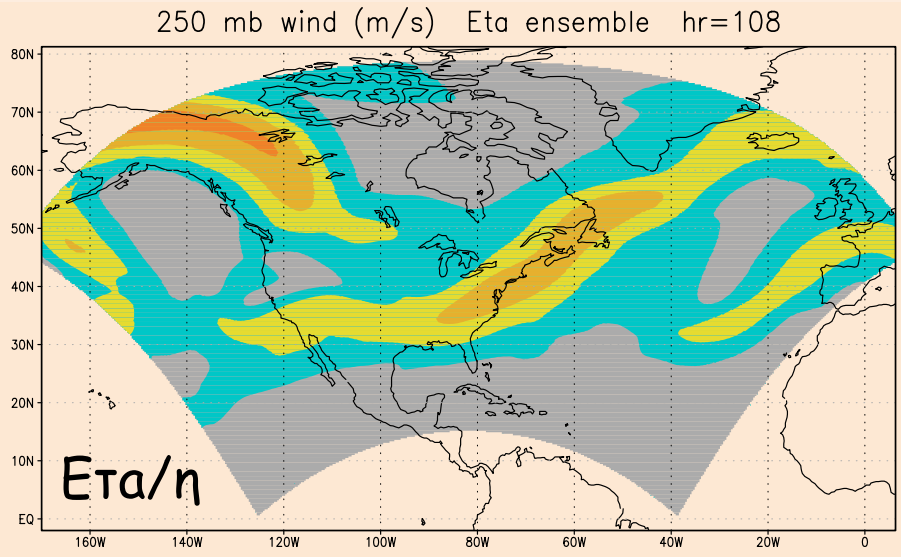

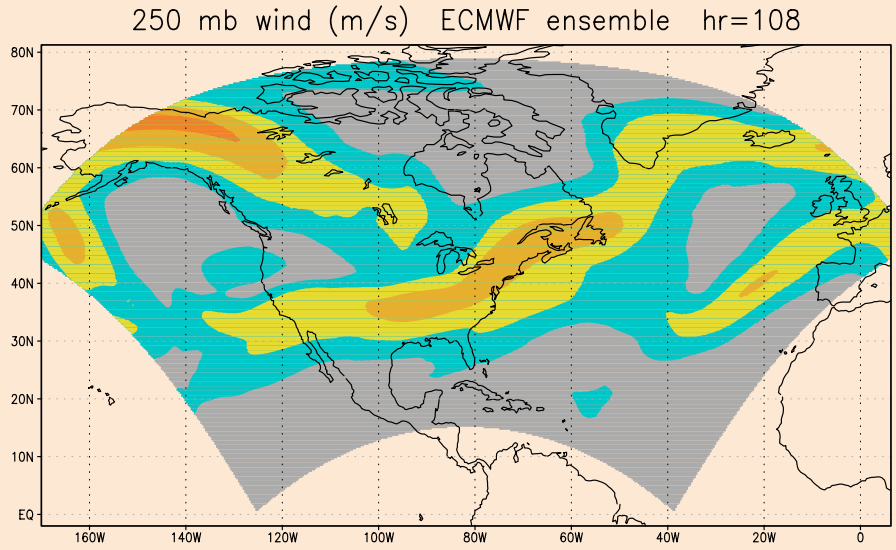

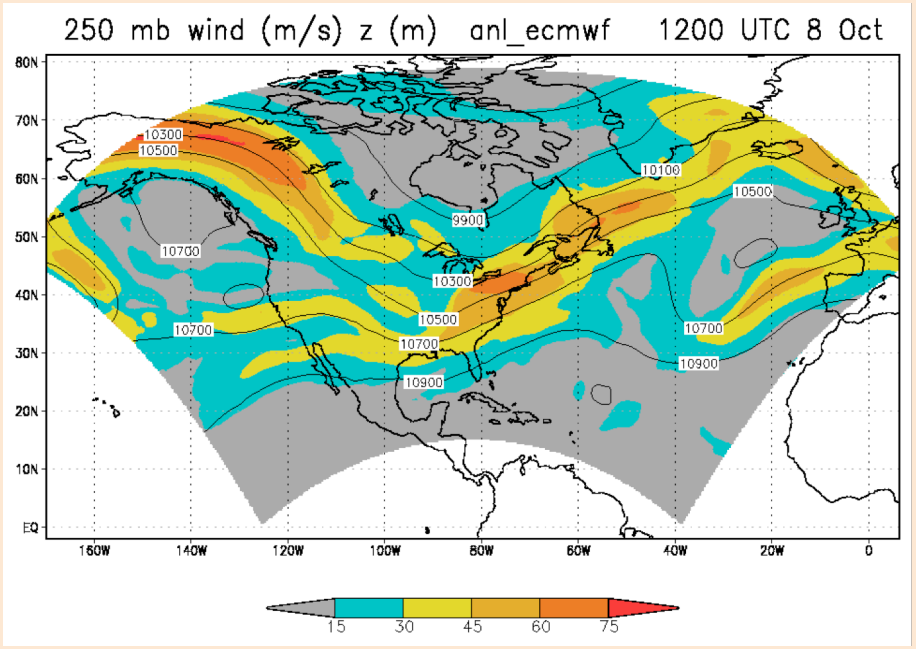

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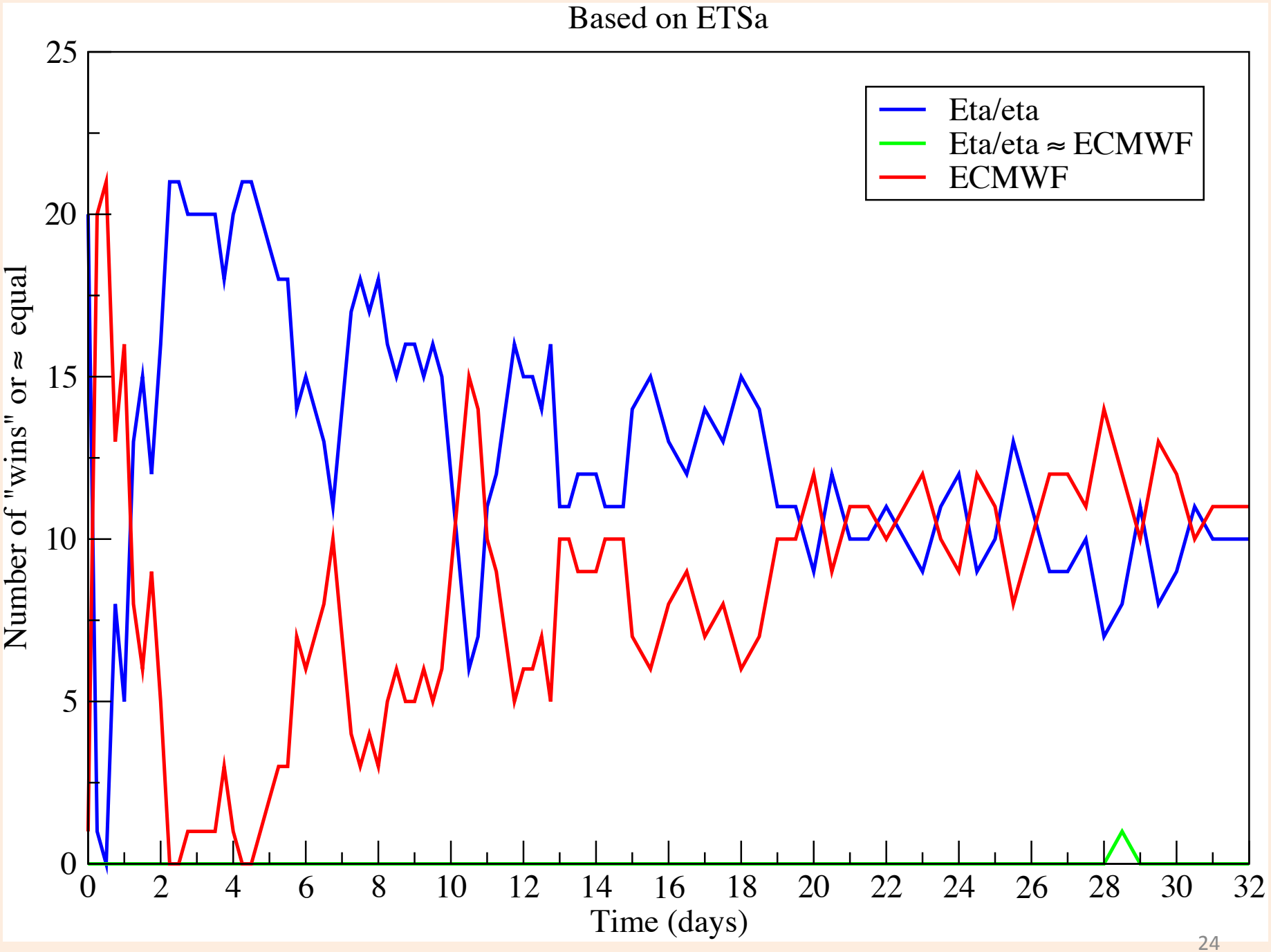
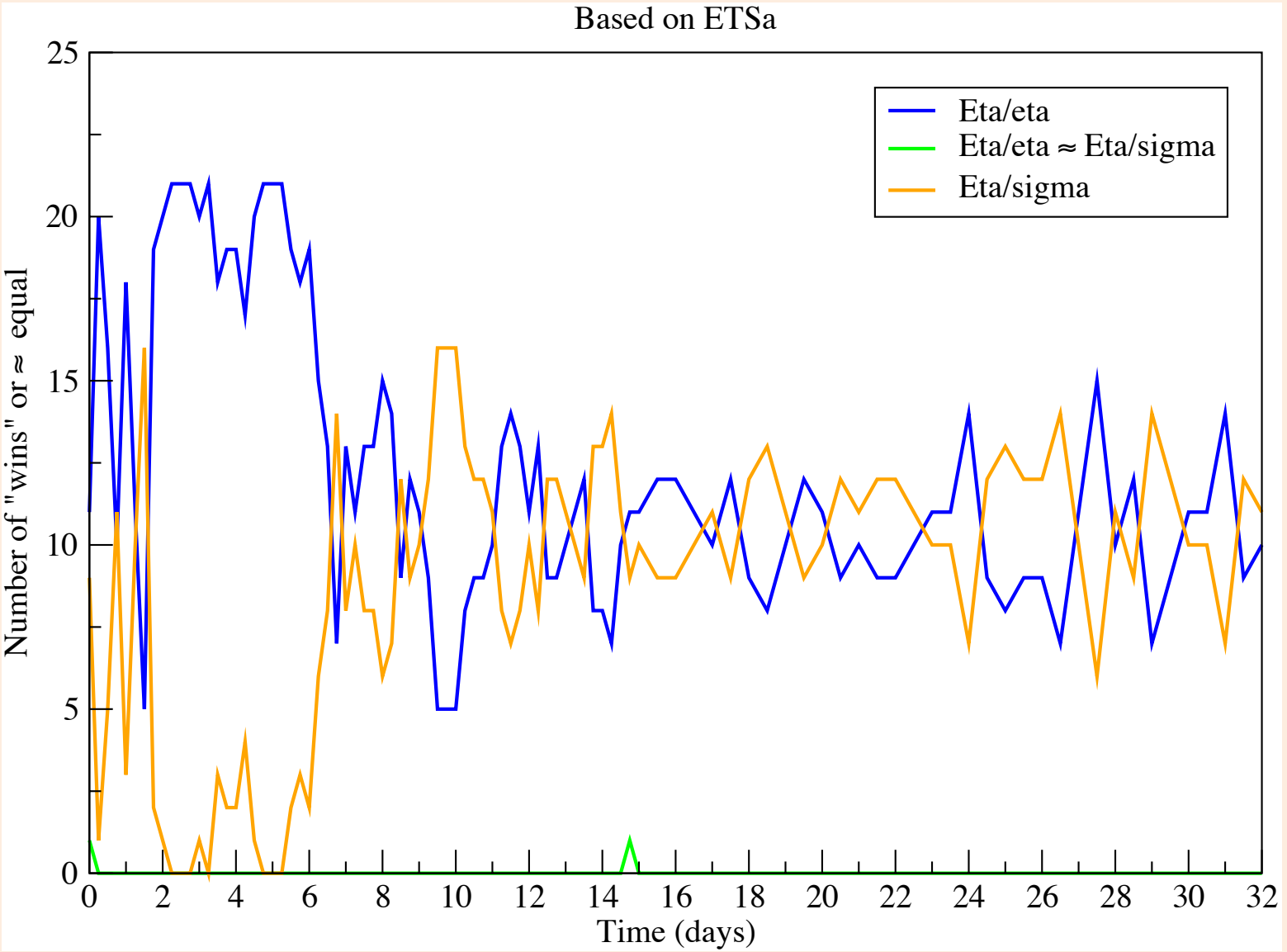
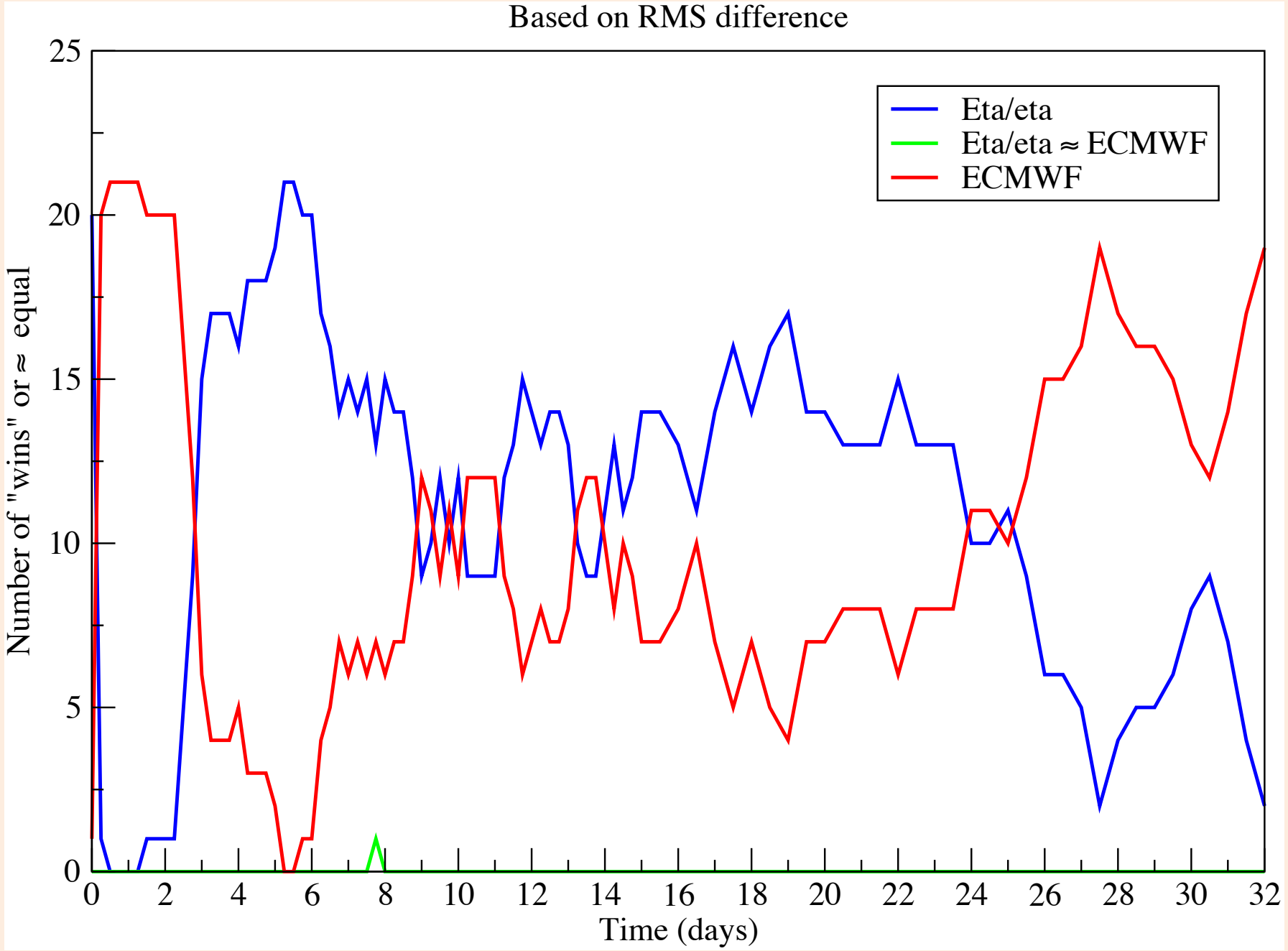
Another way of comparing model skill as a function of time: number of "wins"


Based on ETSa
Eta/eta
Eta/eta ≈ ECMWF
ECMWF
Number of "wins" or ≈ equal
Time (days)
0
5
10
15
20
25
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32

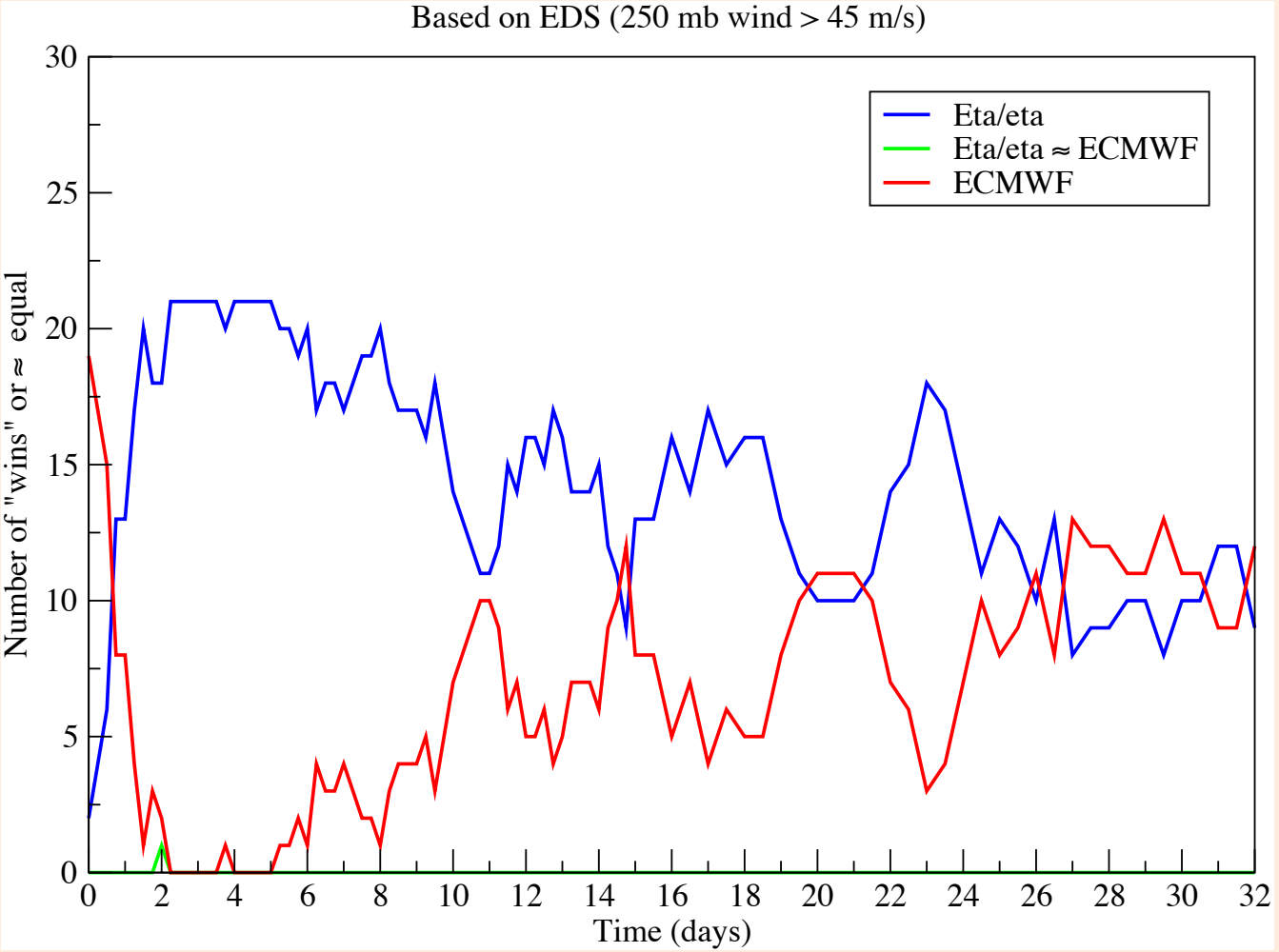
Four times from day 2.25 to day 4.5 every single Eta ensemble member, all 21 of them, had "jet stream" placed more accurately than their ECMWF driver members !

Eta vs. Eta/ sigma:




Based on RMS difference
Eta/eta
Eta/eta ≈ ECMWF
ECMWF
Number of "wins" or ≈ equal
Time (days)
0
5
10
15
20
25
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32

Based on the Extreme Dependency Score (EDS), designed for forecasts of rare binary-events (Stephenson et al., Meteor. Appl. 2008)



So far we looked at score numbers, and average maps of 21 members

Now:

Contours of all 21 members of areas of wind speeds > 45 m/s

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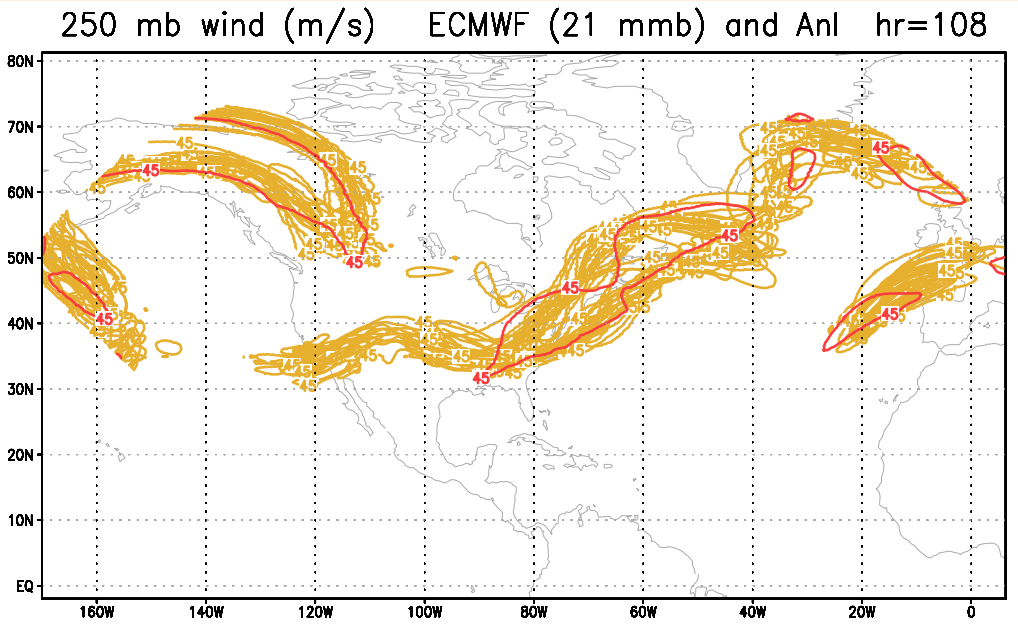

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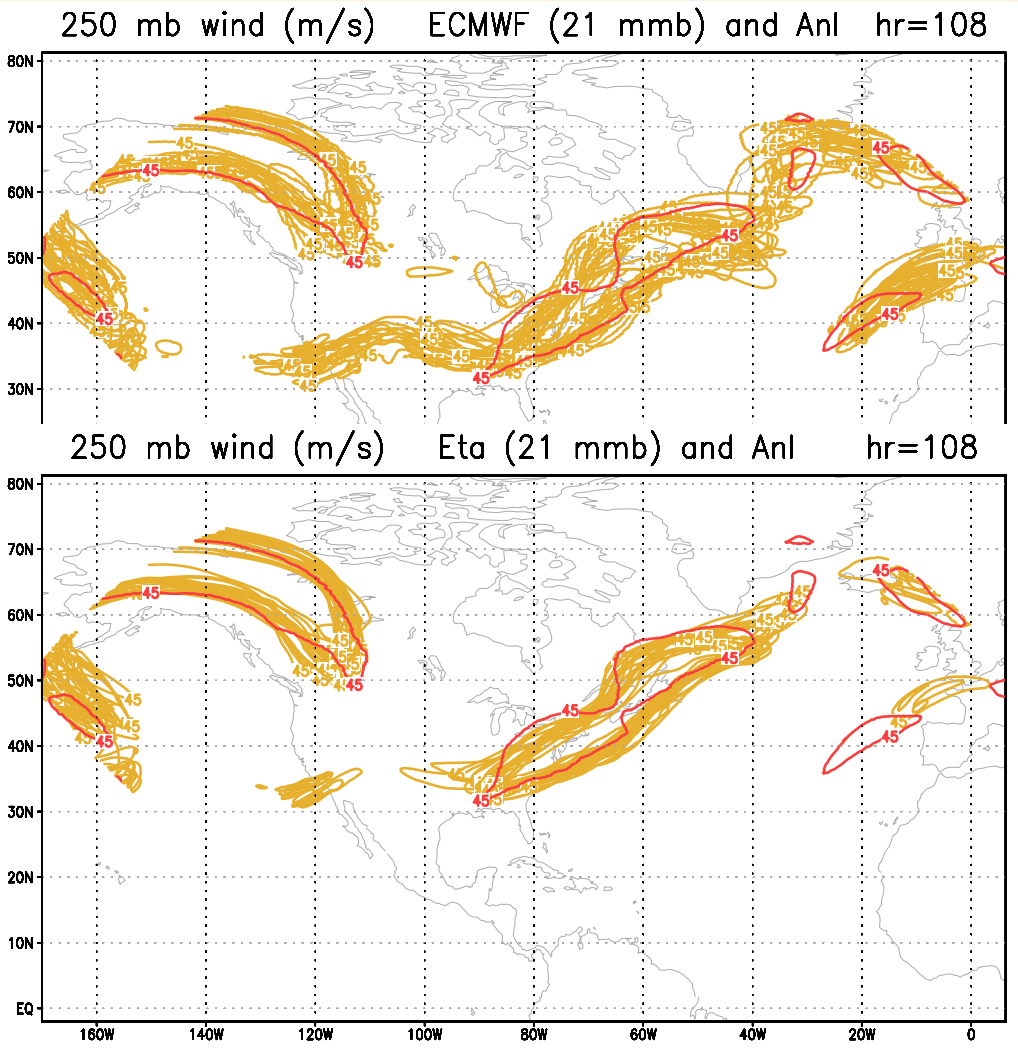

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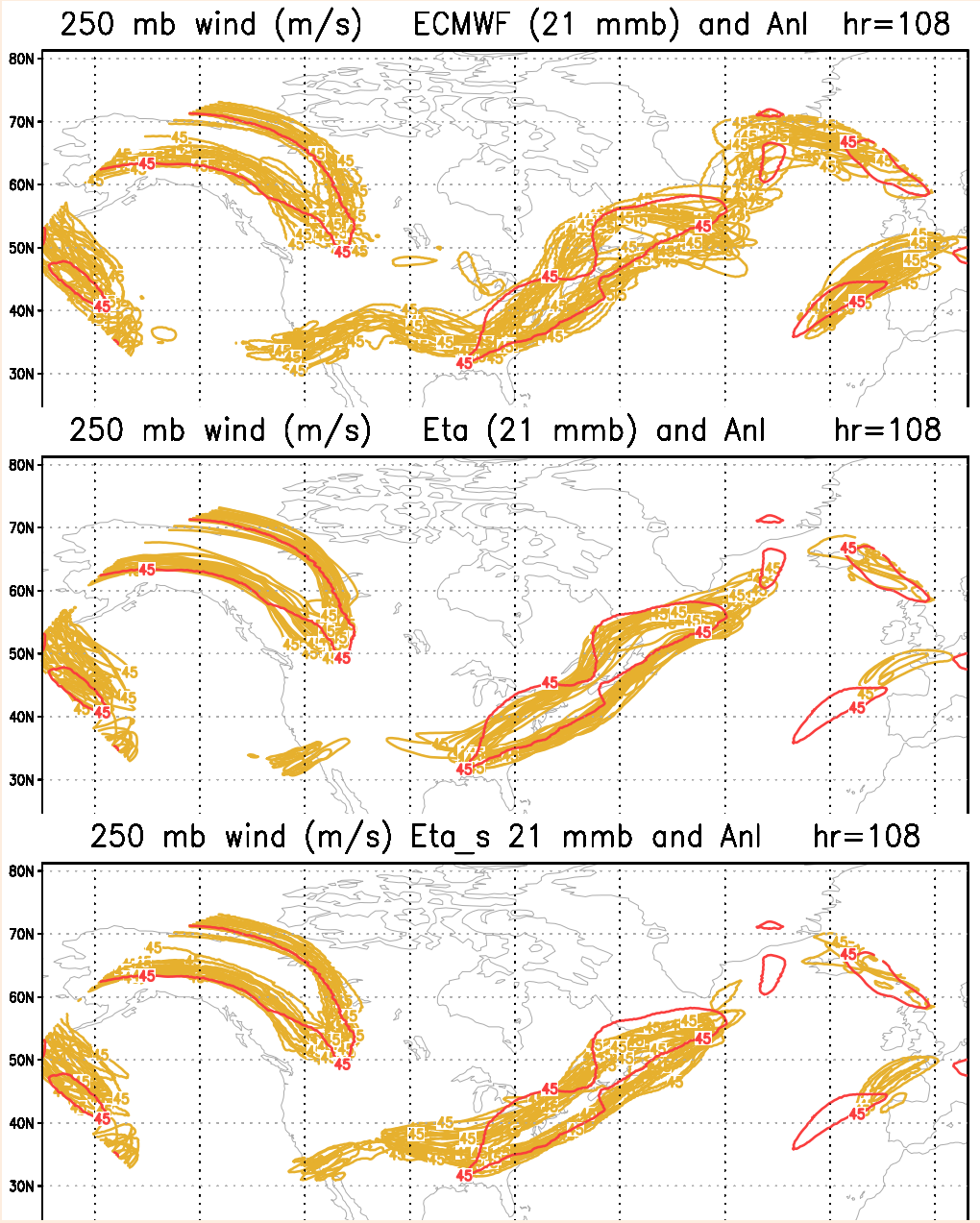

Conclusions

- Strong evidence that coordinate systems intersecting topography are able to perform significantly better than terrain-following systems;

(in agreement with Steppeler et al. 2013)

PGF repair effort does exist (Zängl MWR 2012)

does it remove the problems shown ?

Conclusions

- The Eta must have additional components responsible for its increased accuracy against ECMWF

Candidate reasons:

- Arakawa horizontal advection scheme (Janjić 1984);
- Finite-volume van Leer type vertical advection of all variables (Mesinger and Jovic 2002);
- Very careful construction of model topography (MY2017), with grid cell values selected between their mean and silhouette values, depending on surrounding values, and no smoothing;
- Exact conservation of energy in space differencing in transformation between the kinetic and potential energy;
- . . . . . .