Limited area NWP and regional climate modeling: A test of the relaxation vs Eta lateral boundary condition schemes

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By-product of a study, now published:

Can a nested regional model have large-scale skill comparable to / better than that of the driver global forecasts ?

(RCM: should one attempt improving on the large scales ?)

Why ?

Many contributors (and papers) advocate nudging of large scales ("spectral nudging"): to minimize RCM impact on large scales

The test done using:

"Upgraded Eta"

driven by 26 ECMWF 32-day ensemble members

(Katarina Veljovic, …., Met. Zeitschrift, 2010)

Upgrades compared to NCEP "Workstation Eta" (contains the Janjic (2003) nonhydrostatic option as used in NCEP's NMM):

- "Sloping steps";
- Piecewise linear vertical advection of **v**, T;
- Code refinements involving near surface winds and calculation of surface exchange coefficients;
- Conservation in the vertical diffusion;
- Water vapor sources and sinks and hydrometeor loading;
- Betts-Miller-Janjic convection adjustments;
- Momentum transport with the Kain-Fritsch scheme;
- Molecular sublayer thickness using the suggestion of Brutsaert (1982) and his summary of experimental data

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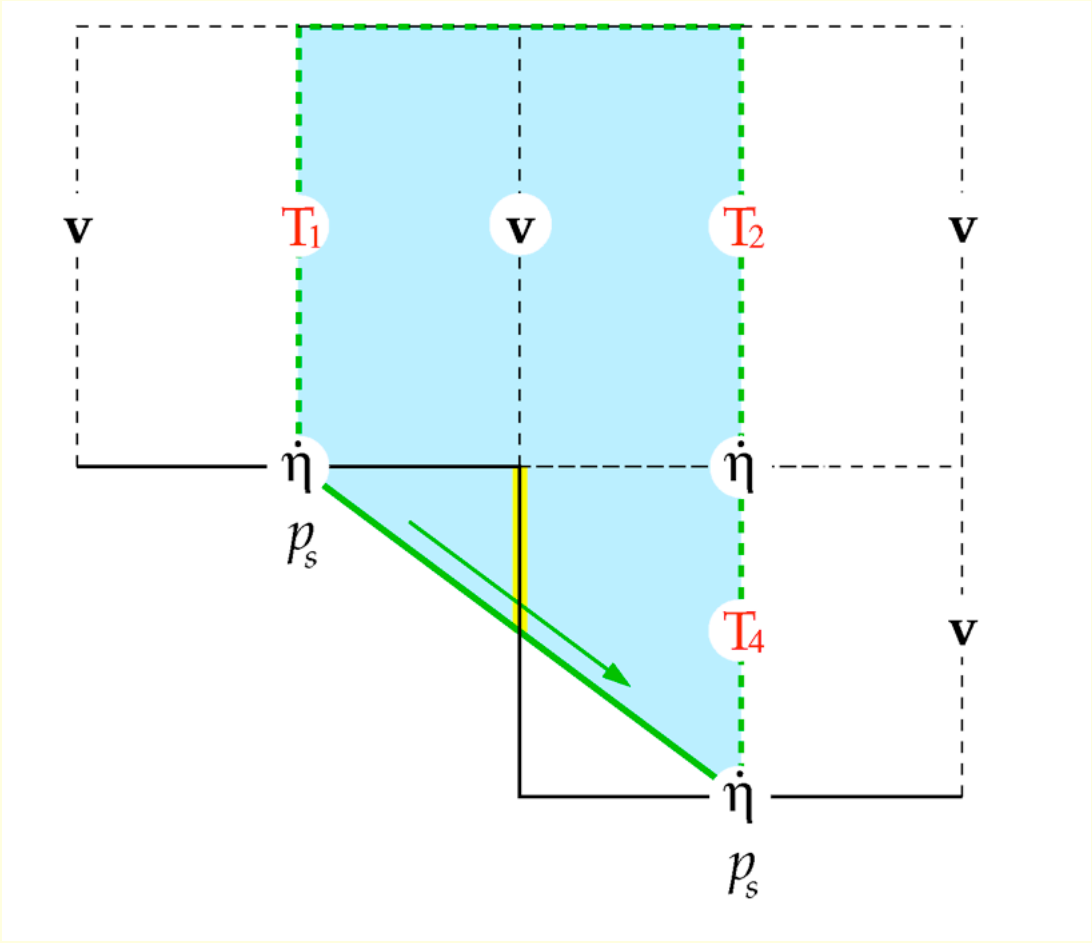
"An upgraded version of the Eta model",
Meteor. Atmosph. Physics, online first / open access;
code downloadable from its CPTEC site

"Sloping steps":



ECMWF ensemble: In. cond. 0000 UTC 1 January 2009;
T399 (~50 km); T255 > 10 days

Eta: 31 km / 45 layer

A. McDonald, MWR 2003:

For multilevel models, no well-posed model has been documented to my knowledge. [Elvius (1977) and Mesinger (1977) have described primitive equation models that do not specify *every field on the boundaries. Their* boundaries are ‘‘fairly well-posed.’’] Flow relaxation schemes (mainly for operational models) and radiation schemes (mainly for research models) totally dominate the literature; see McDonald (1997) for further discussion.

Eta LBCs (Mesinger, Contrib. Atmos. Phys., 1977; but put together in 1973, using knowledge of the time, Charney, Sundström):

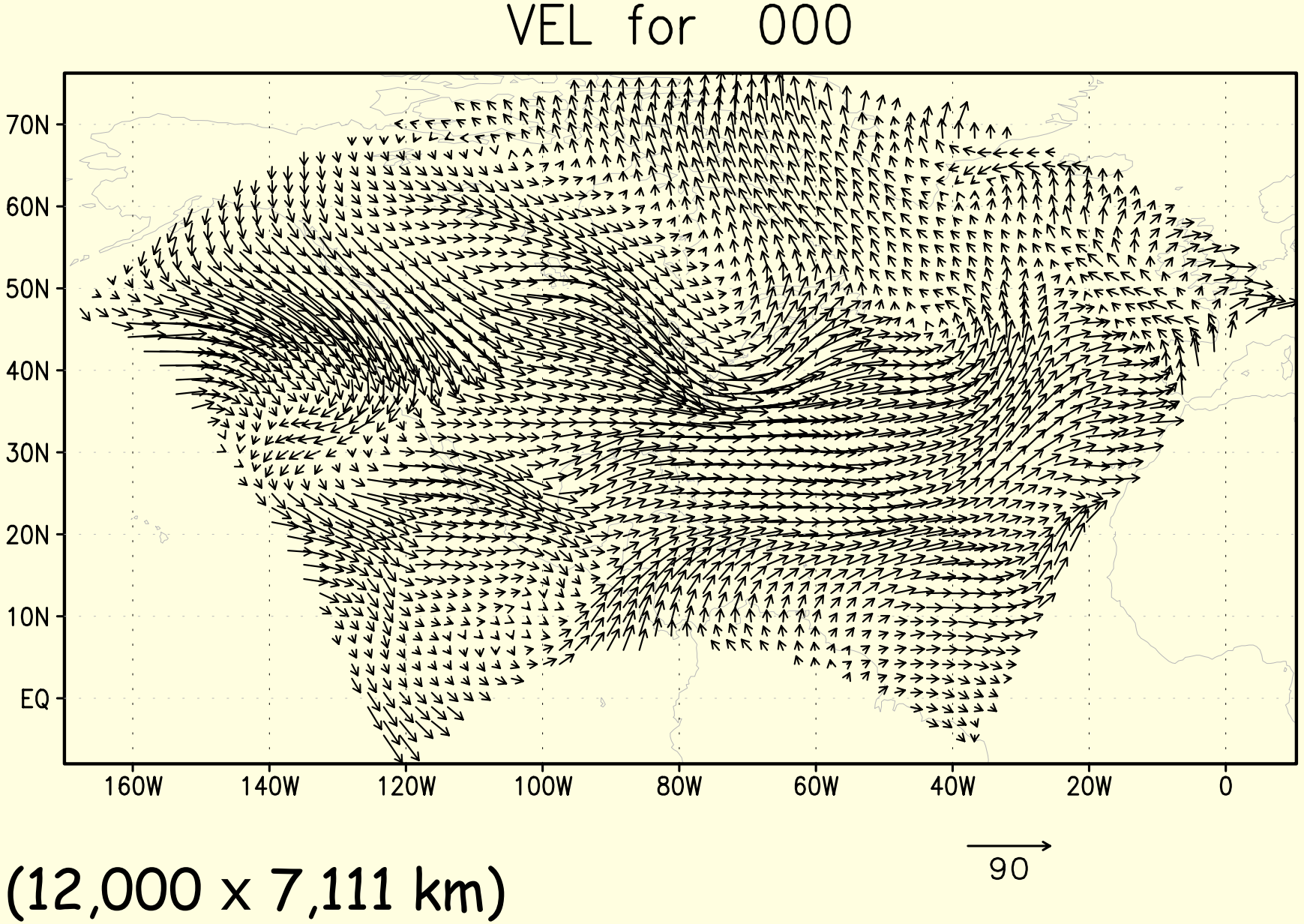
- Driver model information used only along the outermost row of points;
- One variable less is prescribed at the outflow boundary points (tangential velocity extrapolated from inside);
  - 2nd row: 4-point averaging to couple the two C-grid gravity waves of the B/E grid;
  - 3 first outside rows of the integration domain: semi-Lagrangian advection (seems to successfully eliminate reflection problems)
    - Scheme to couple the two gravity waves inside the integration domain (Mesinger 1973, 1974)

Of the 26 ensemble members,

6 members run using both

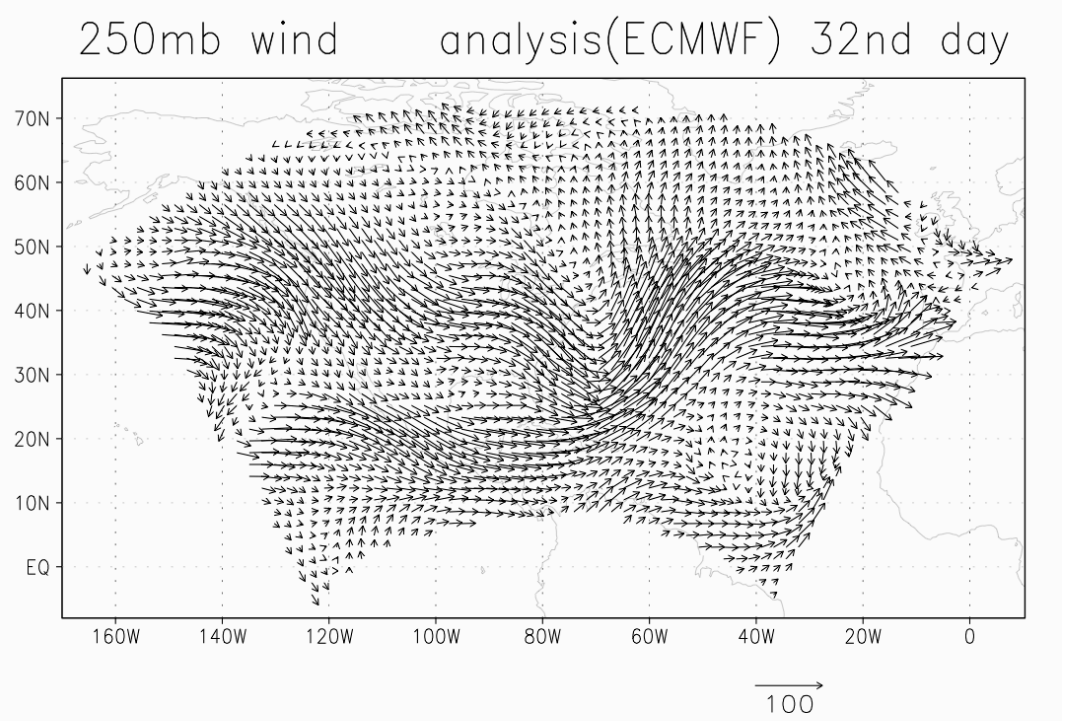
Davies' relaxation and the Eta LBC scheme

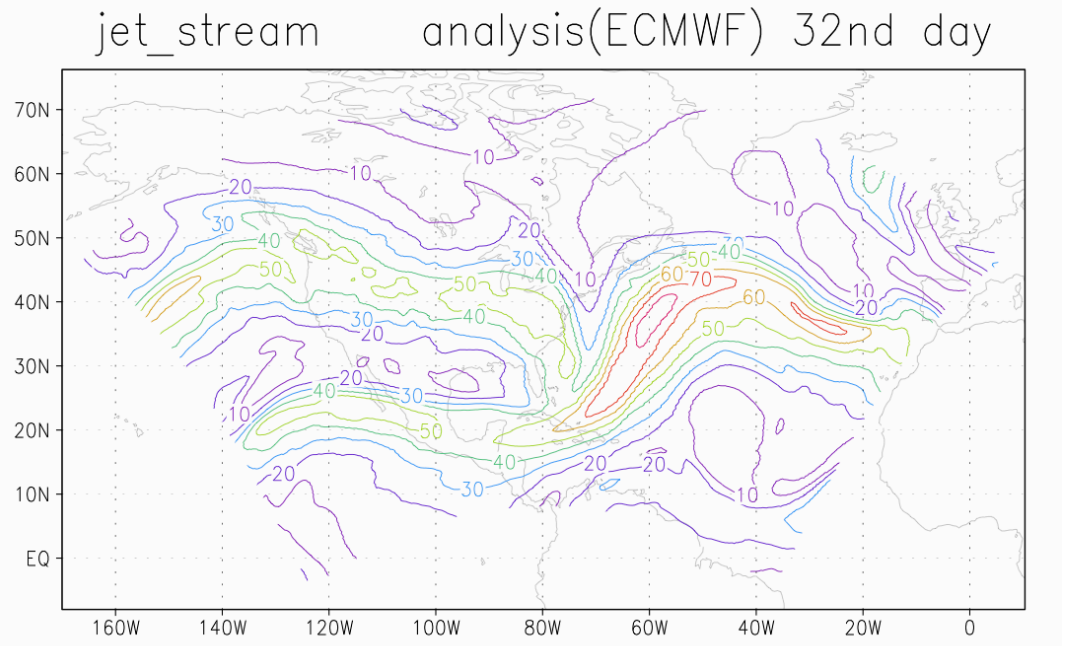
The Eta domain:

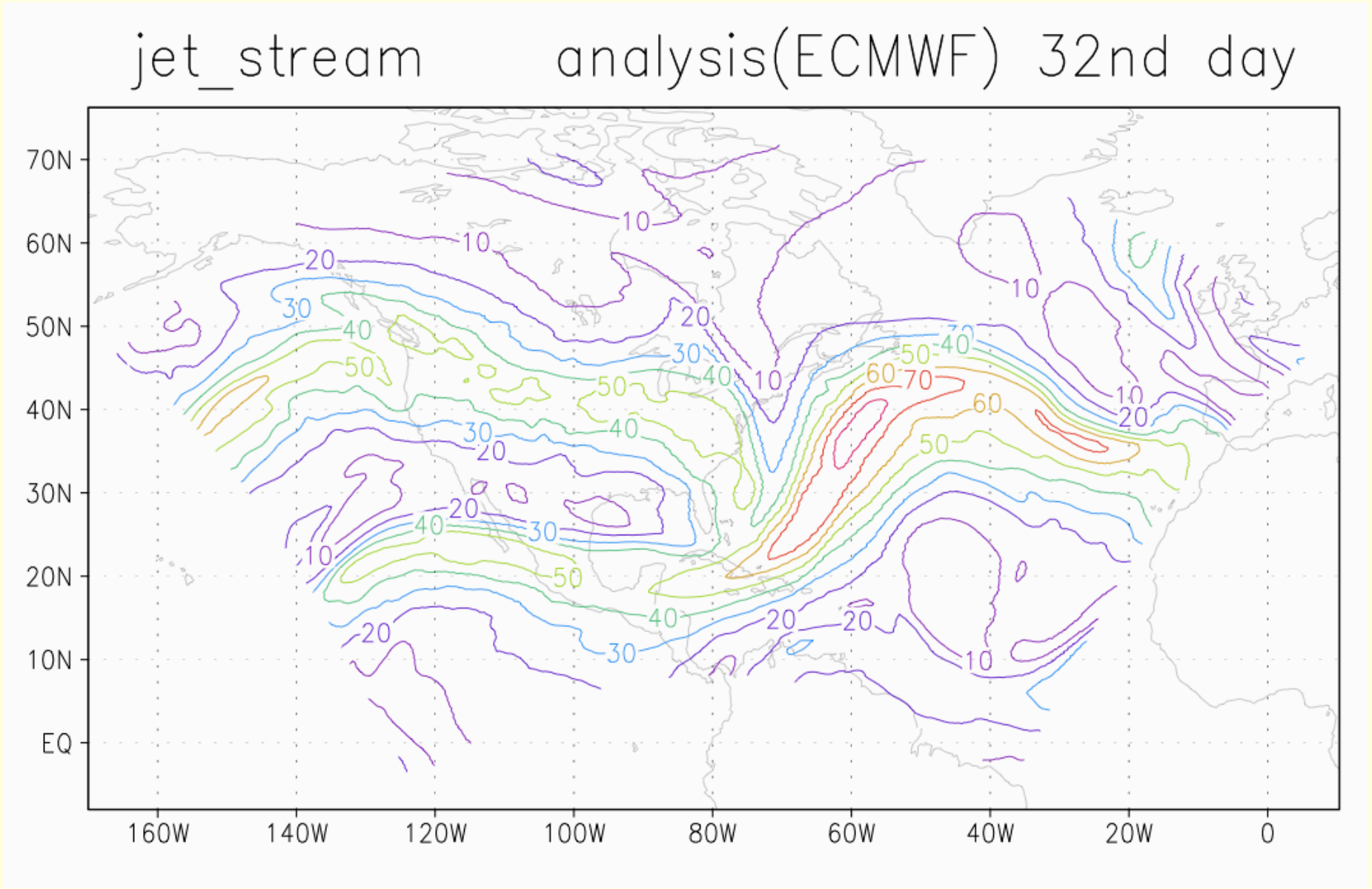


(12,000 x 7,111 km)

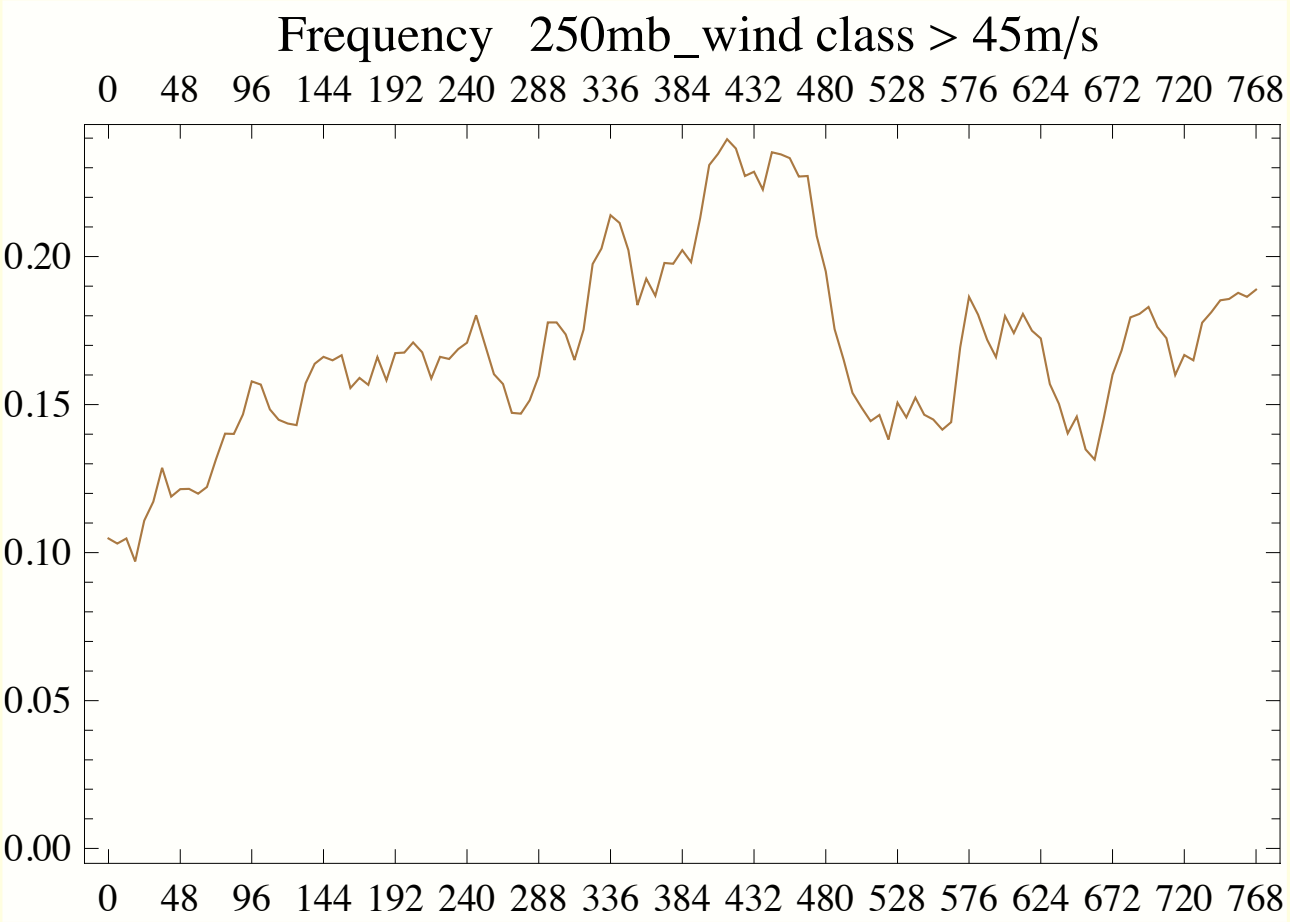
To identify "large scales", we look at the placement of jet stream level winds, (taken as 250 hPa) with speeds > chosen threshold






jet_stream analysis(ECMWF) 32nd day
70N
60N
50N
40N
30N
20N
10N
EQ
160W
140W
120W
100W
80W
60W
40W
20W
0

What speeds should we look at ?



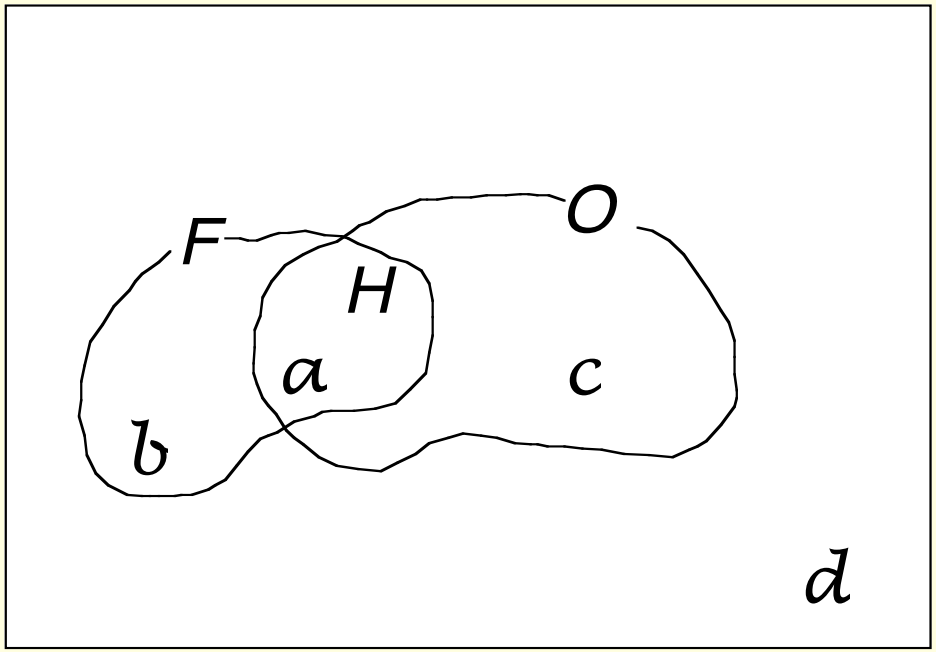
> 45 m/s

What should one do to assess the skill of an *ensemble* of forecasts ?

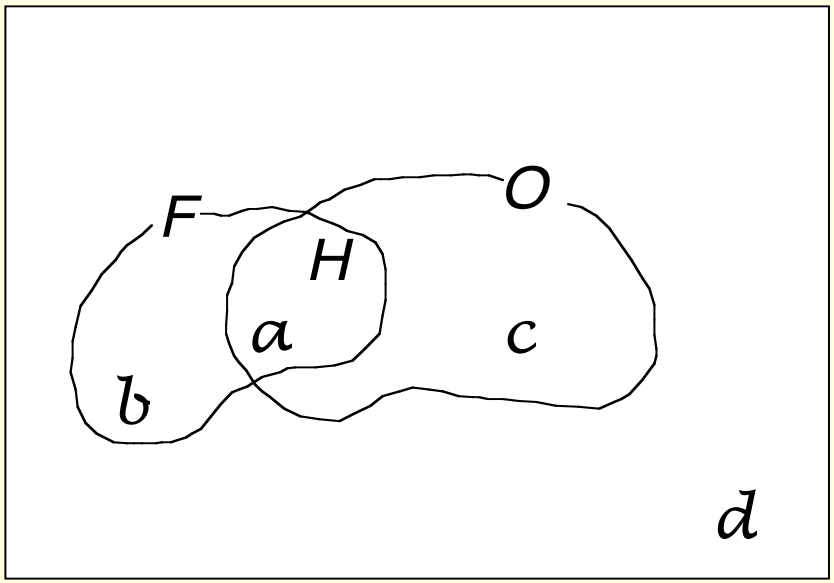
Same as what is done with precipitation:

add all of the values of *F*, *H*, and *O*

F : forecast,
H : correctly forecast: "hits"
O : observed



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



Most popular (?)
"traditional statistics":
ETS (Equitable Threat
Score), Bias:

$$ETS = \frac{H - FO/N}{F + O - H - FO/N}$$

$$Bias = F/O$$

Problem: what does the ETS tell us ?

"The higher the value, the better the model skill is for the particular threshold"

(a relatively recent MWR paper)

? ?

An apparently popular view, but in fact wrong, since ETS can be increased by increasing the bias beyond unity

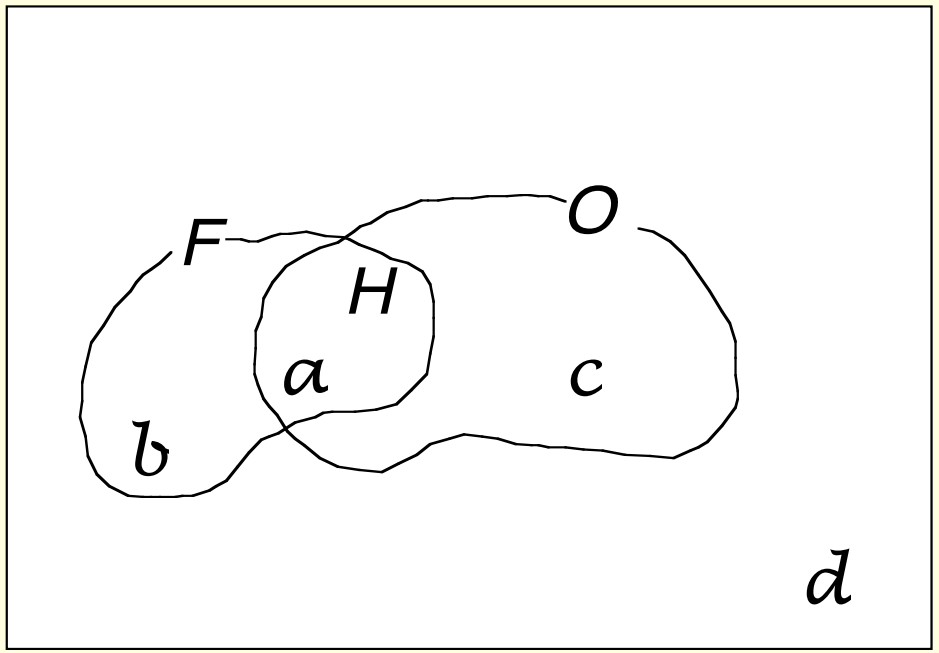
Methods to correct for bias:

Hamill, T. M.: 1999: Hypothesis tests for evaluating numerical precipitation forecasts. Wea. Forecasting, 14, 155–167;

Mesinger, F., 2008: Bias adjusted precipitation threat scores. *Adv. Geosciences*, **16**, 137-143. [Available online at http://www.adv-geosci.net/16/137/2008/adgeo-16-137-2008.pdf.]

"dHdA" method:

F : forecast,
H : correctly
forecast: "hits"
O : observed

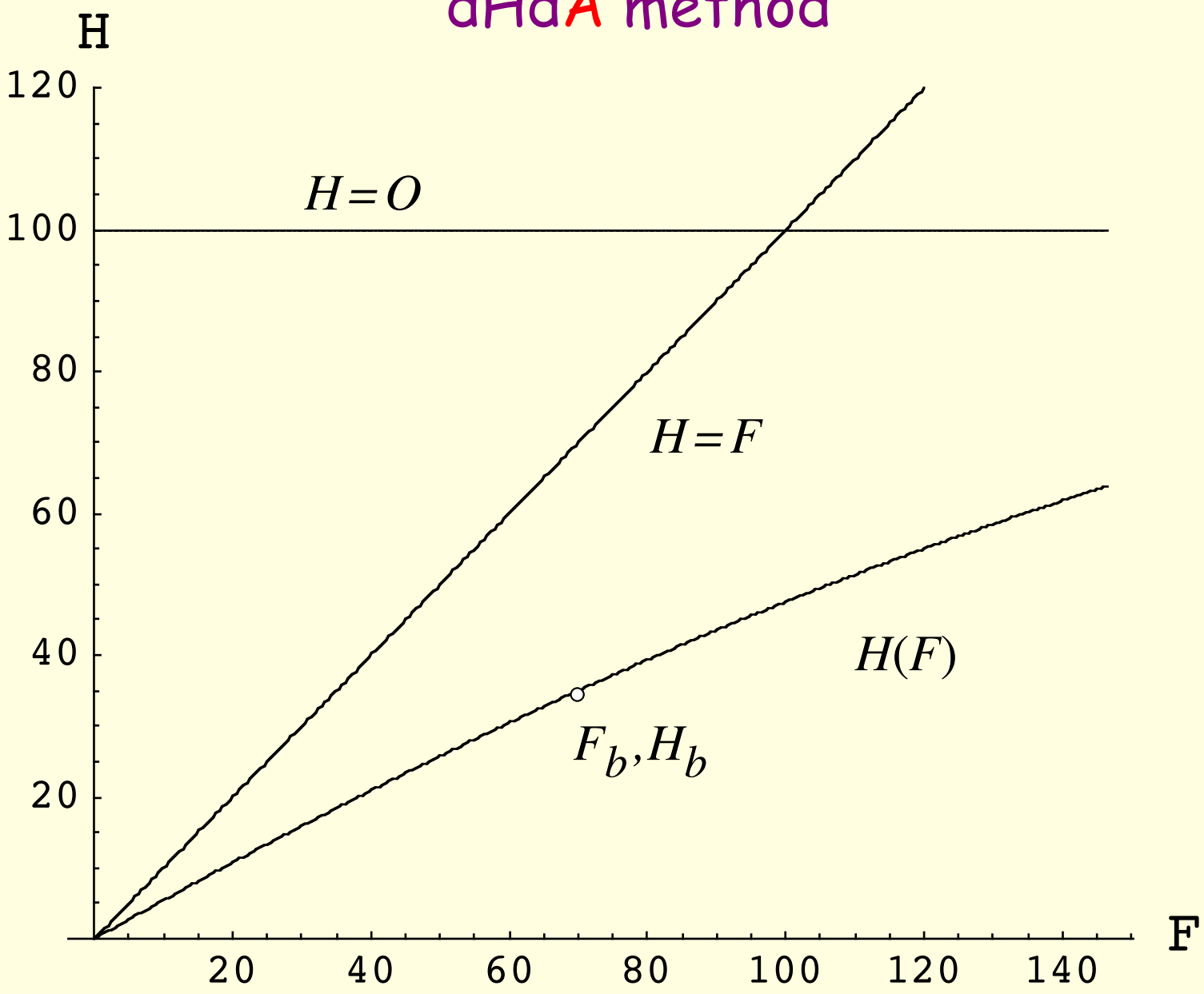


$$\frac{dH}{dA} = b(O - H) \qquad b = const$$

Differential equation, can be solved

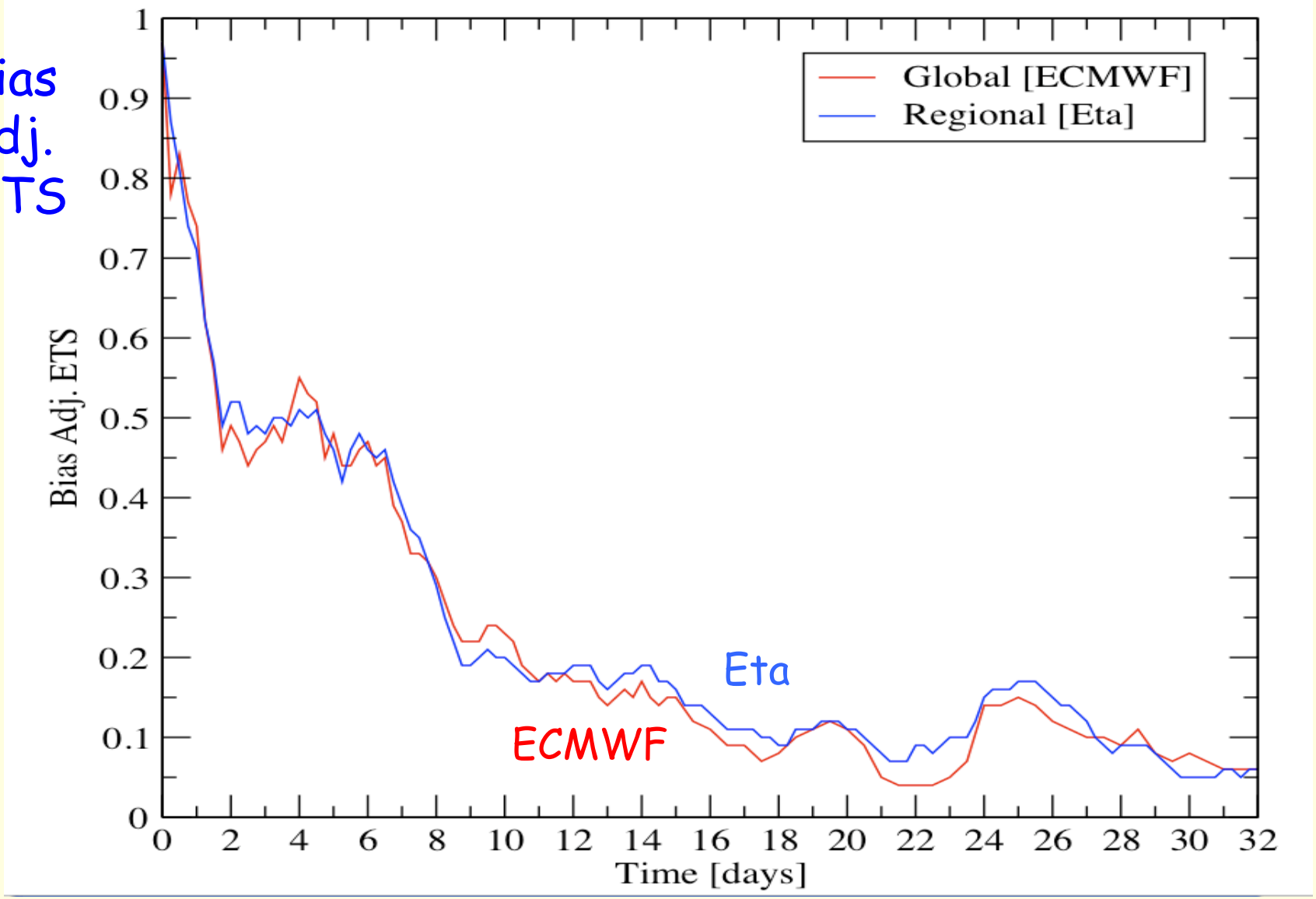
(Mathematica, or MATLAB)

dHdA method

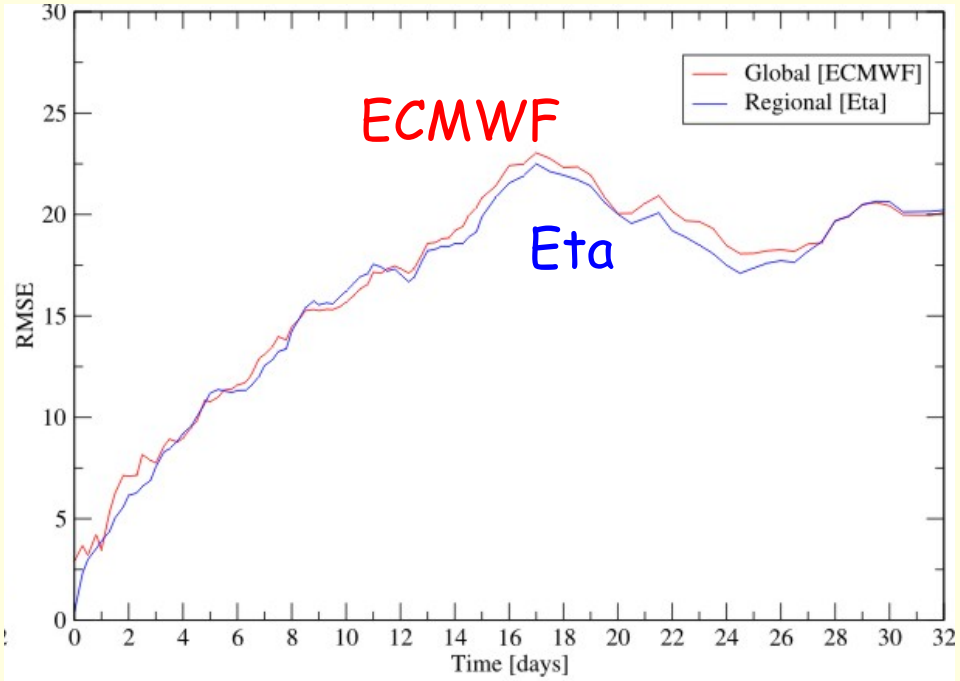


Met. Z.: 26 (25 members + control) 32-day forecasts:

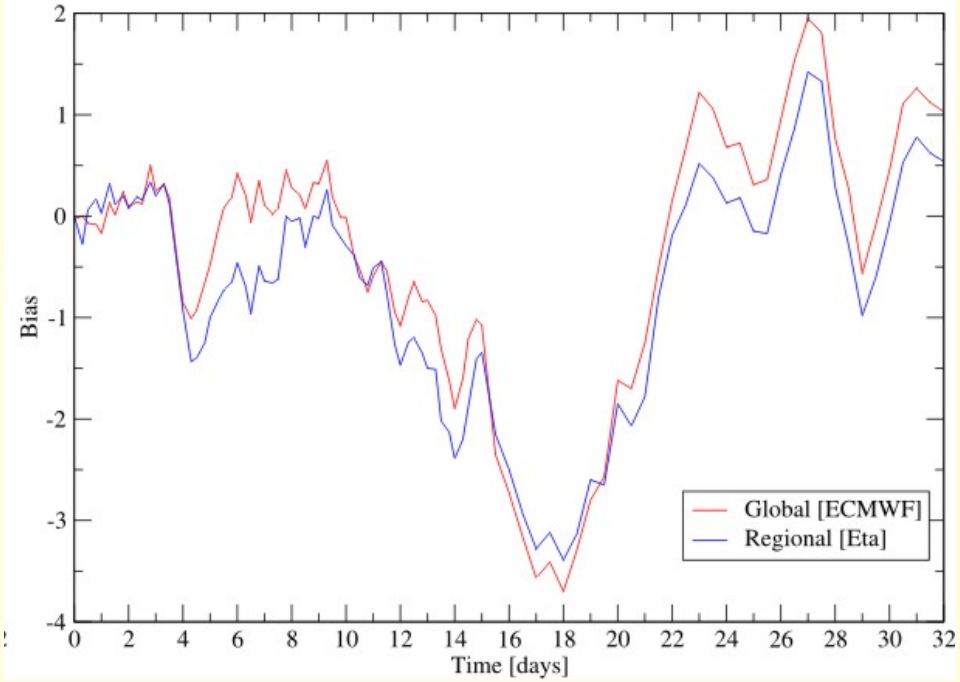
Bias adj. ETS



RMS difference forecast – analysis



Bias



Back to LBCs, 6 members:

Did Eta LBCs different from standard relaxation LBCs hurt the Eta result some; how much – more or less compared to relaxation, had relaxation been used ?
They certainly cannot help – any LBCs result in errors)

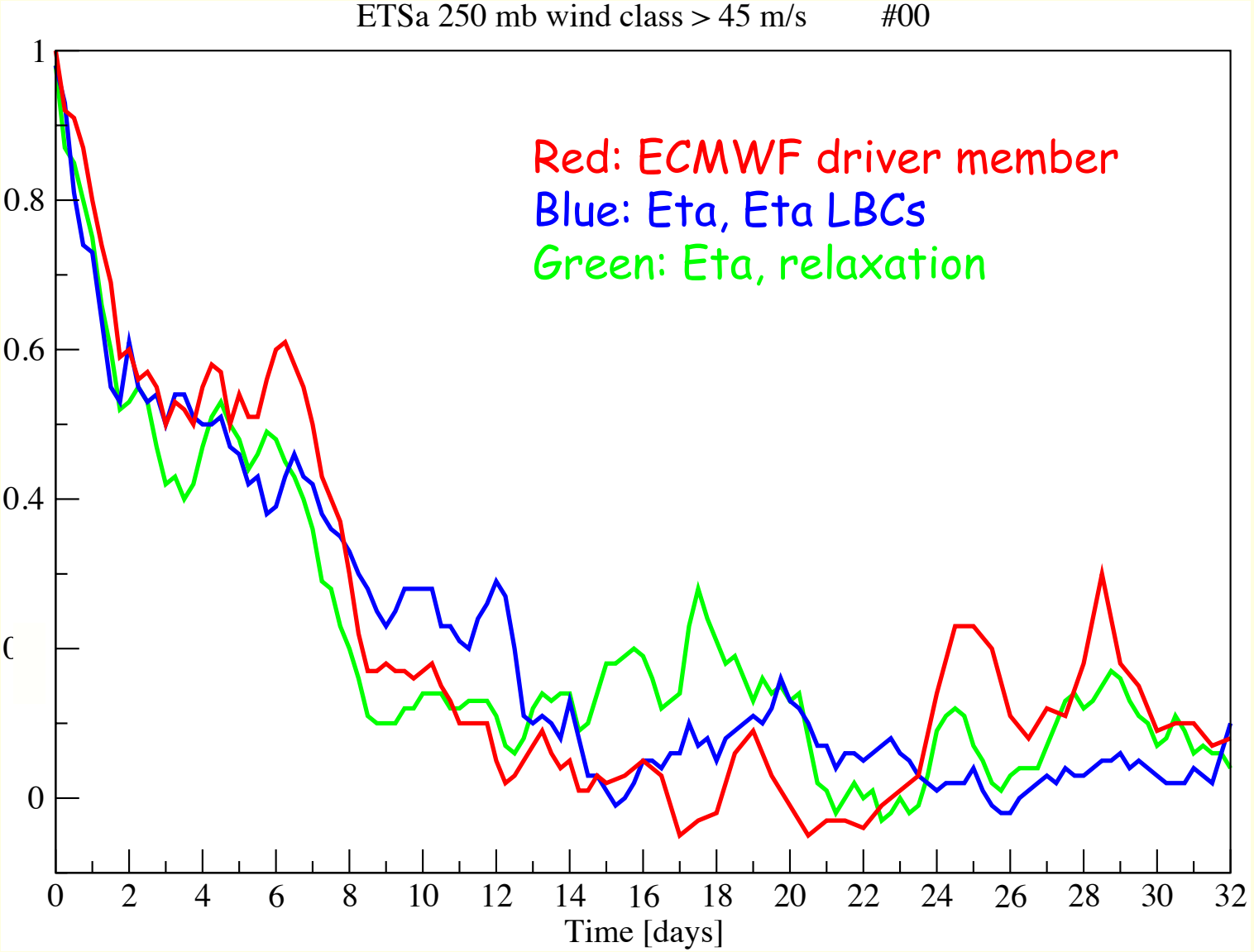
Irrespective of the "large scales" issue:

Eta LBCs vs relaxation: which ones do a better job with verifications in place ?

6 members done with both LBC schemes

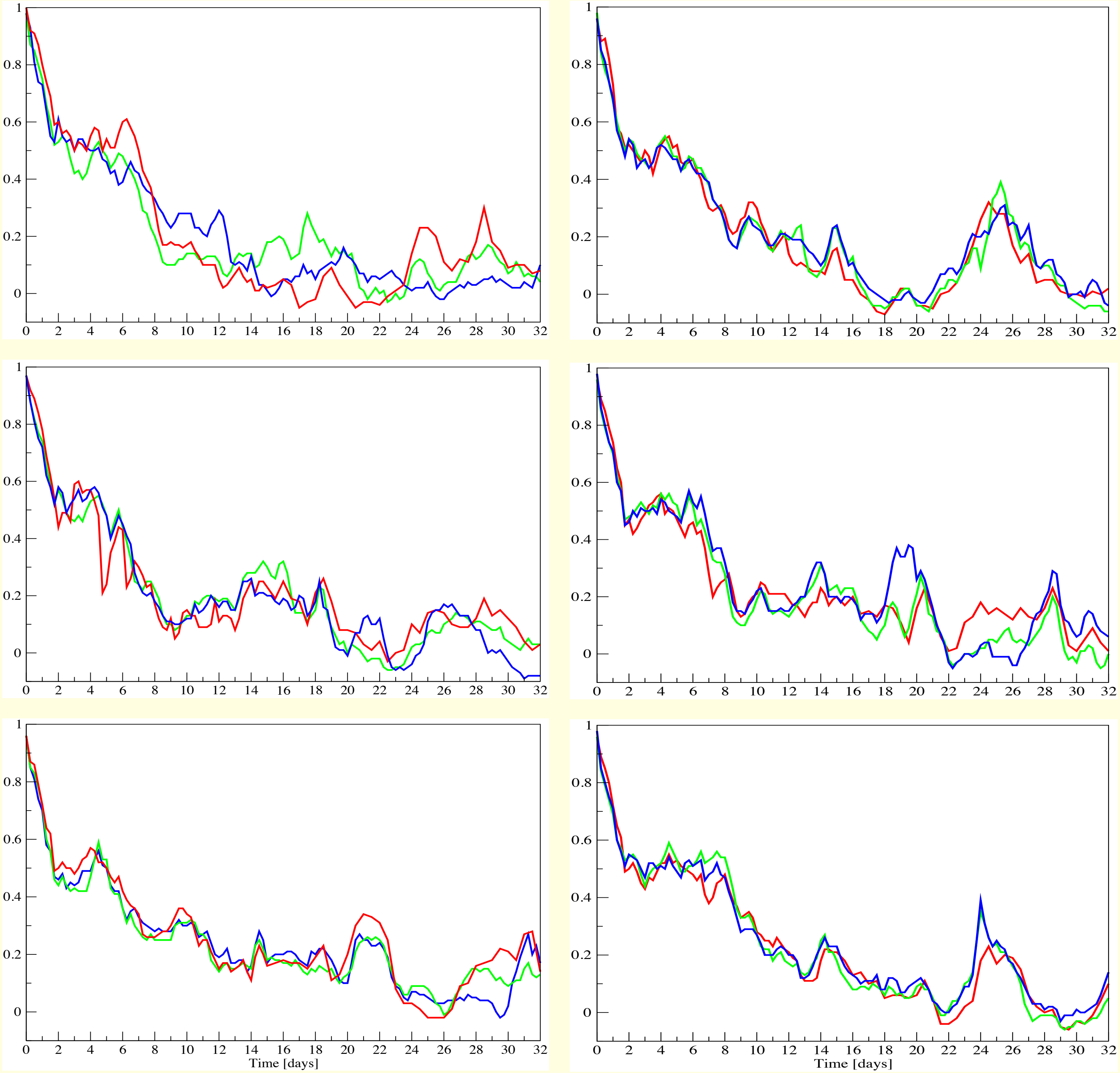
The 1st member (control, #00):

Bias adjusted equitable threat scores:

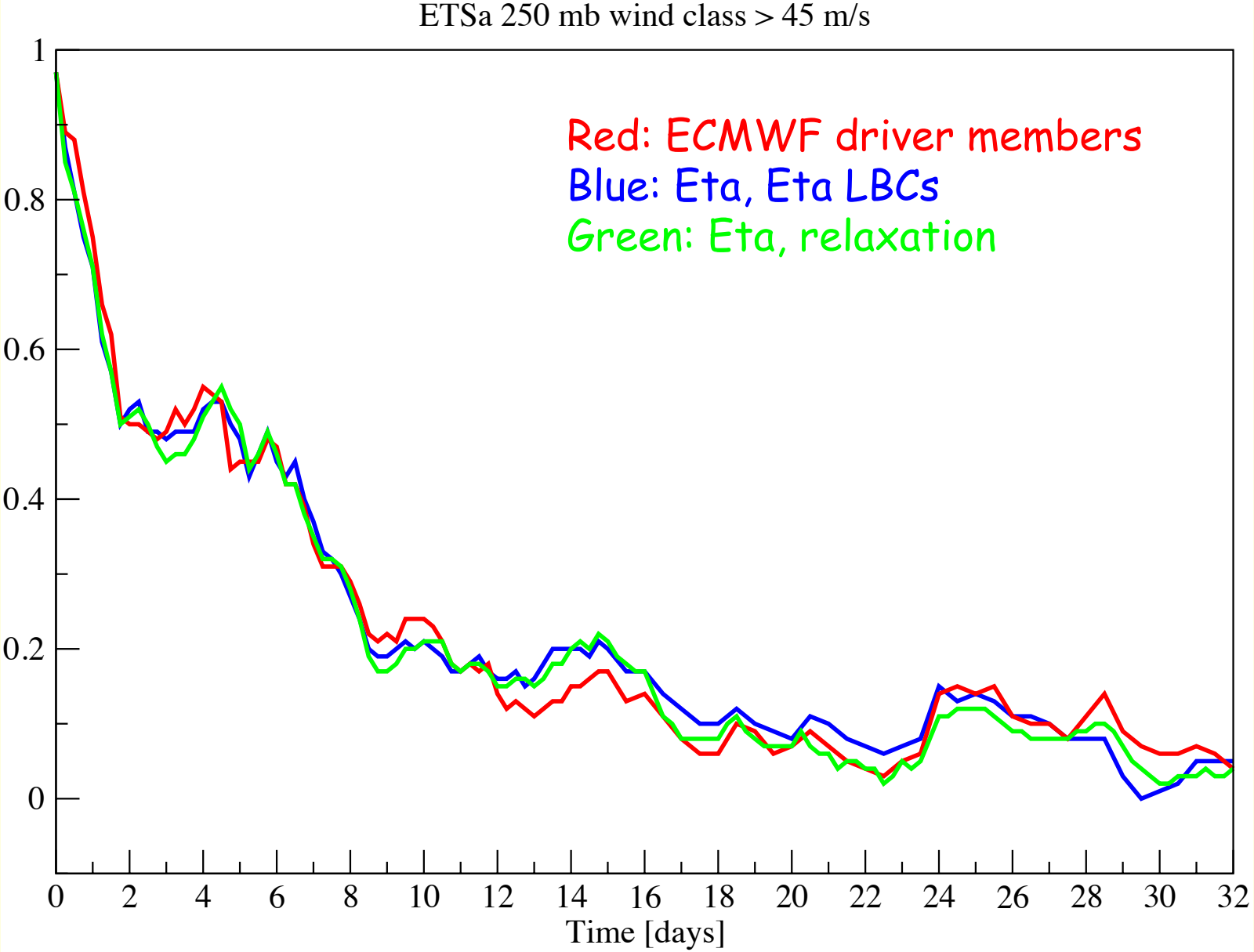


ETSa scores, individual members:

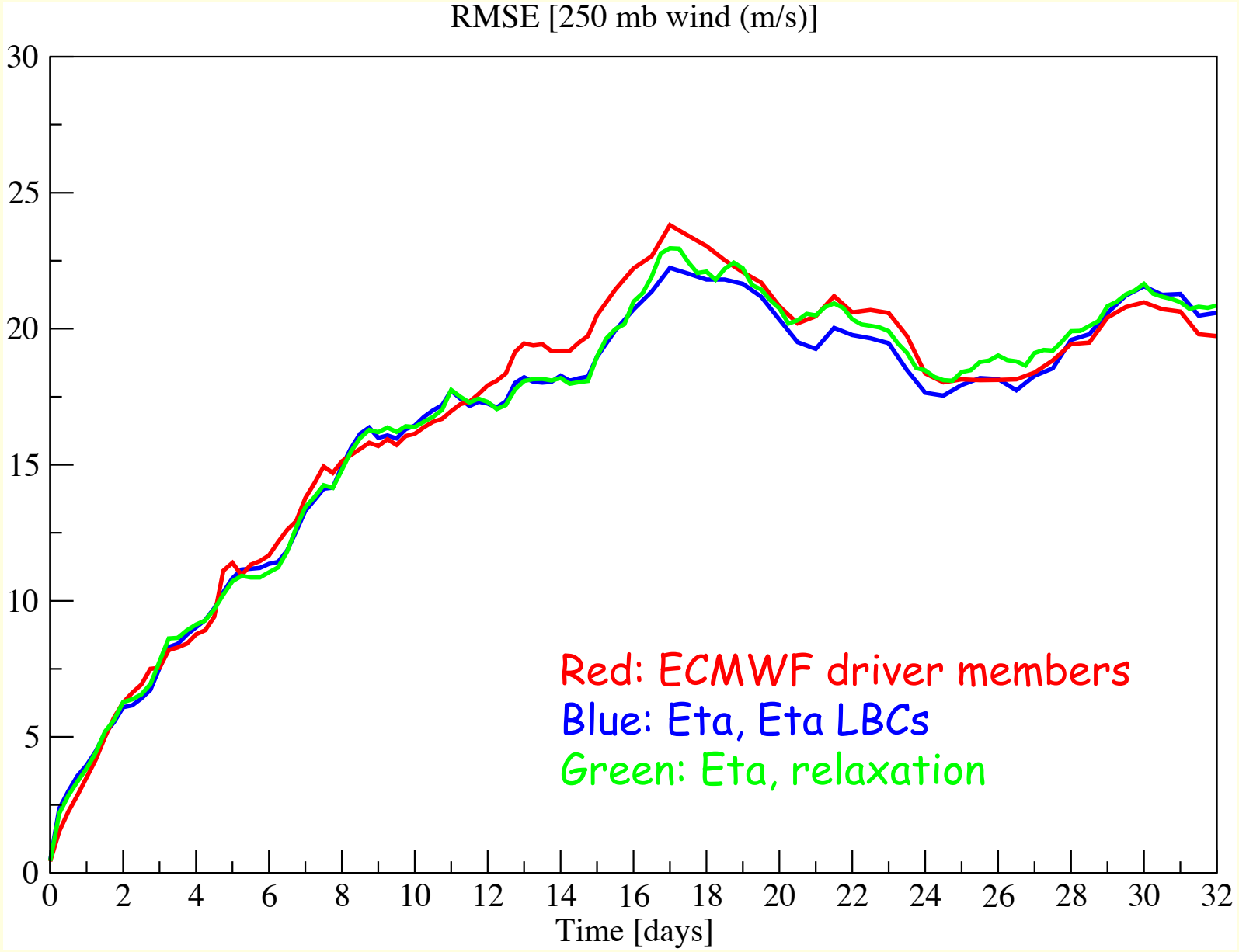
00 03
01 04
02 05



All 6 members:



RMS difference: forecast – ECMWF analysis

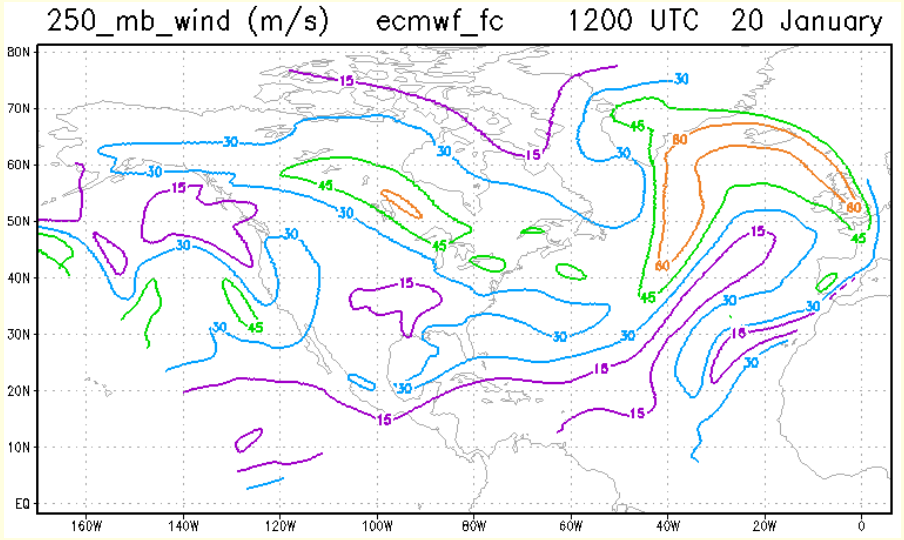


What kind of an advantage over the relaxation can one accomplish? (Example?)

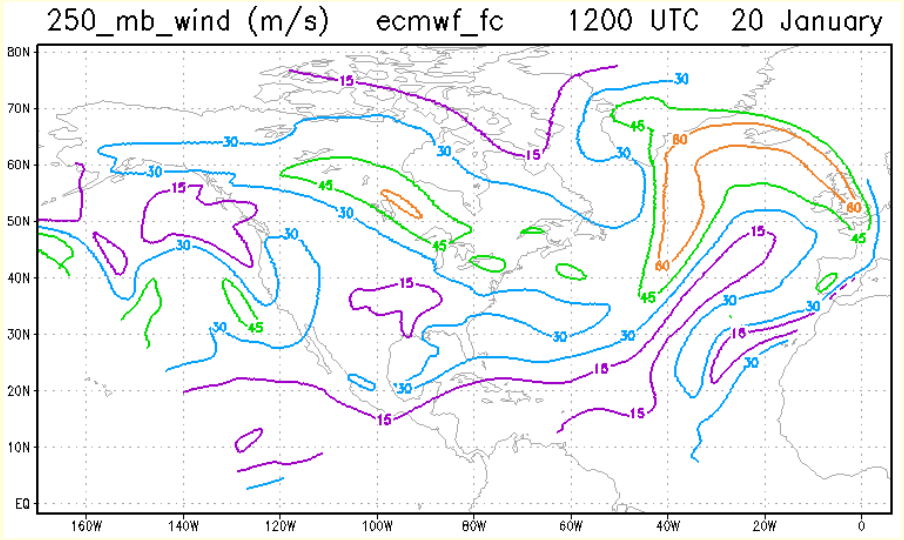
Greatest ETSa advantage of Eta LBC > Eta relaxation:
Member 04, time 19.5 days: ~0.29

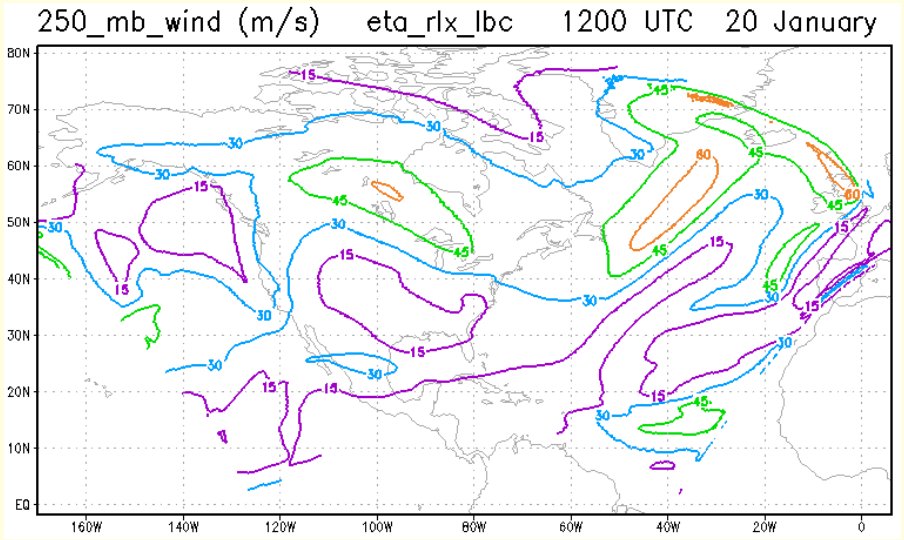
(Greatest ETSa advantage of Eta relaxation > Eta LBC:
Member 00, time 17.5 days: ~0.22)

Member 04, 19.5 days:



Member 04, 19.5 days:





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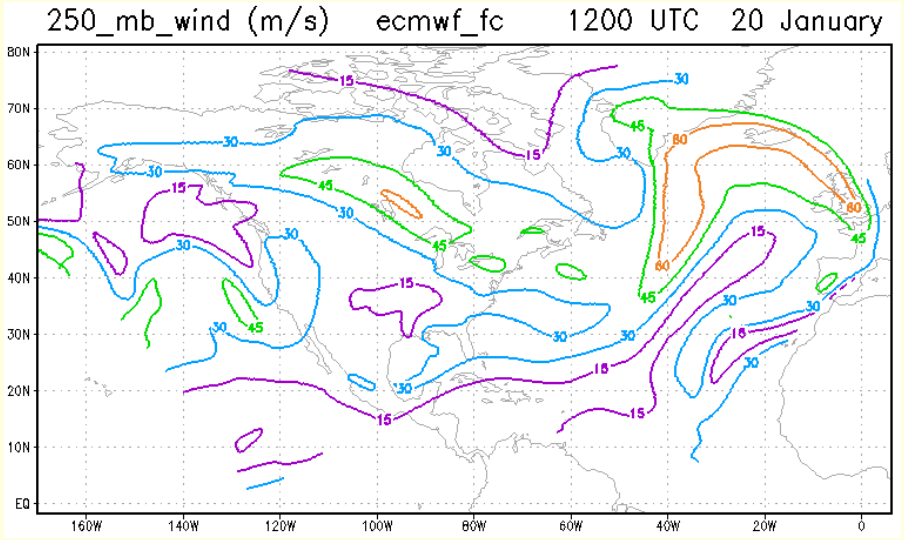
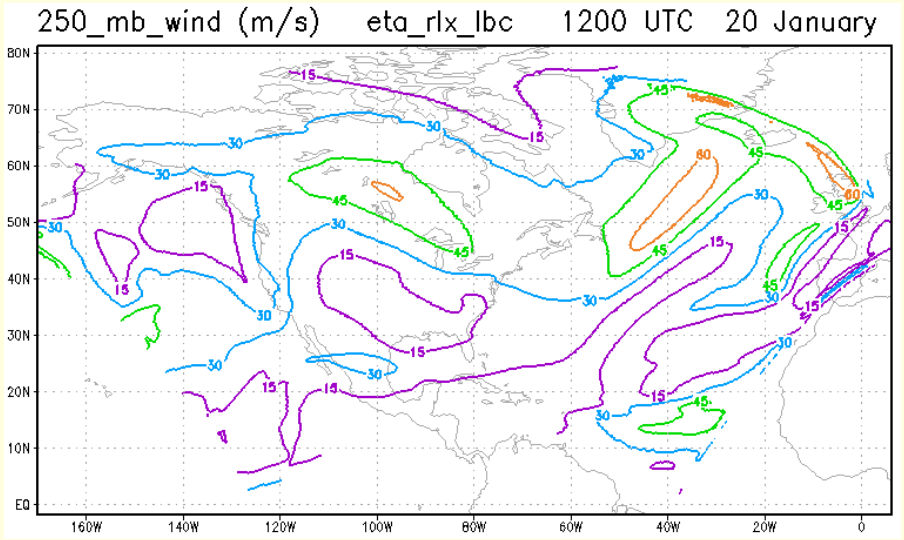
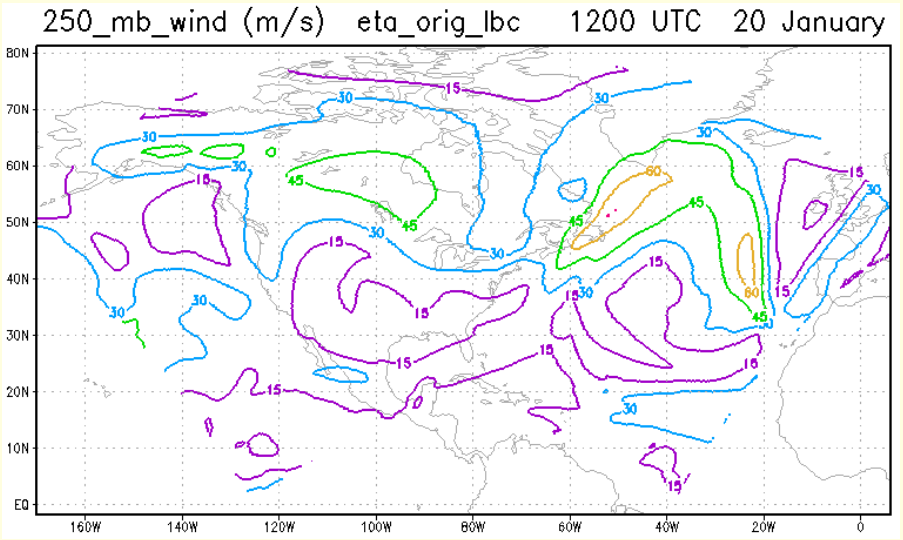
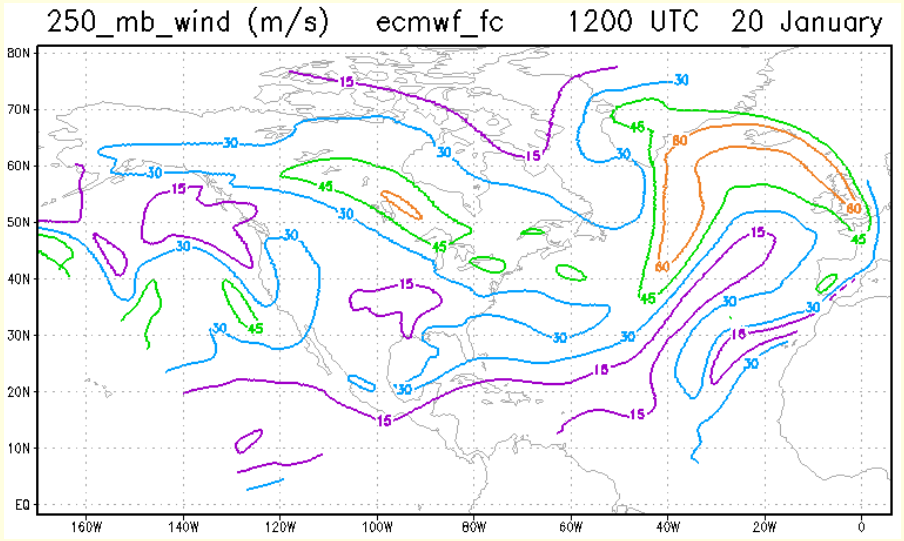
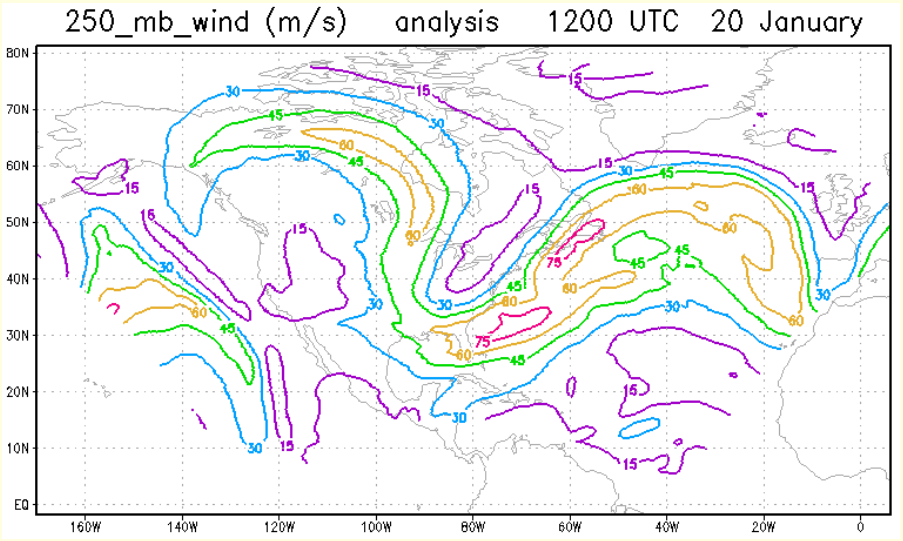


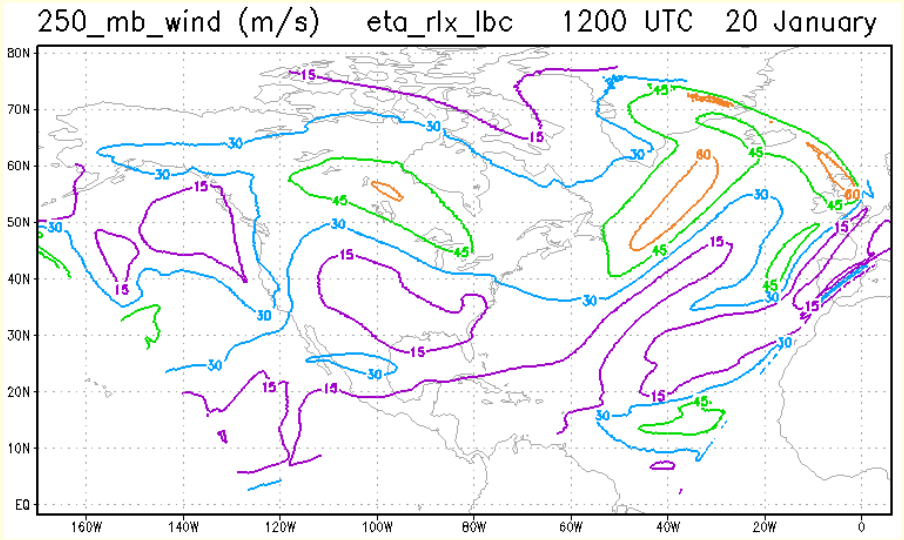


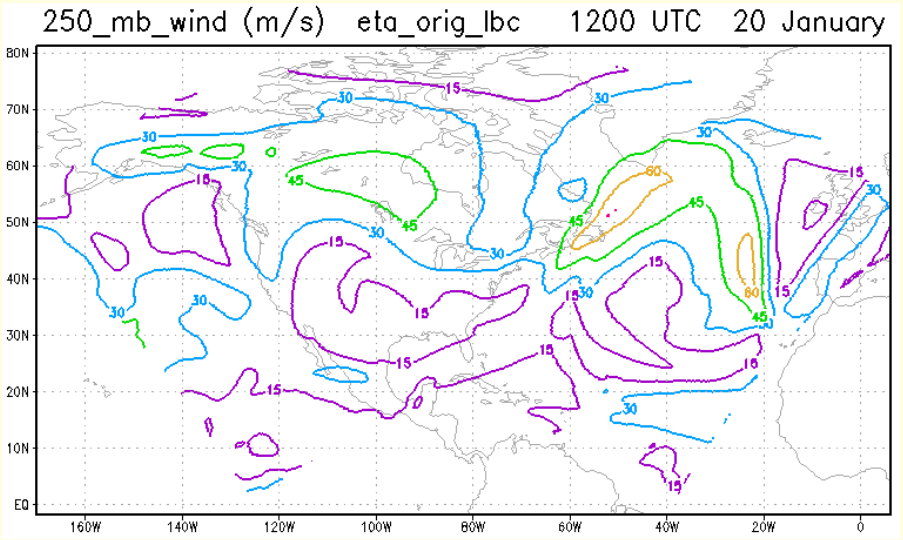


Member 04, 19.5 days:









Thus: the Eta LBCs, less resource demanding, and more in line with the mathematical nature of our problem, have done better than relaxation, more frequently than not

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Thanks

(Manuscript submitted
to Meteorology and Atmospheric Physics)