Stratospheric Prediction in NWP Models

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- **Are there periods when stratospheric prediction is more difficult? (Waugh et al. 1998; Lahoz 1999)**
- **How do NWP models compare during these periods? (BAM,ECMWF,NCEP,NOGAPS,UKMO)**
- **How can these predictions be improved?**

(WGNE deterministic predictions of stratospheric activity study)

DATA

Model	Country	Contact	Top level	Forecasts?
BAM	Australia	Greg Roff	7hPa	8 day
ECMWF	EU	Agatha Untch	1hPa	10 day
NCEP	USA	Mark Iredell	7hPa	10 day
NOGAPS	USA,NRL	John McCormack	10hPa	5 day
UKMO	UK	Adam Scaife	0.3hPa	No (soon ?)

Participants provided daily (12UTC) analyses on pressure levels (inclusive of 1000, 850, 500, 200,100,70,50,30,10,1 hPa) of the fields U, V, T, Z, RH (for p>500hPa), SLP and PV (at 375 425 475 525K). Most participants also have/will provide 5-10 day forecasts.

What period to test in?

We expect better skill in the stratosphere because its flow is dominated by a quasi-stationary polar vortex rather than in the troposphere where the flow is influenced by transient, synoptic scale waves.

The best test would be when the polar vortex is undergoing strong changes - sudden warmings

Sudden warmings

- relatively common in NH - major/2yrs
- polar vortex breakdown/reversal
- rapid rise in polar temperature
- planetary TS wave-mean-flow interaction
- 1st recorded SH sudden warming was in Sep. 2002 perhaps due to pre-conditioning by earlier wave events (Baldwin et al. 2003; Simmons et al. 2003)

These dramatic changes to the polar vortex occur over short time scales and provide an excellent test for short-term forecasting systems operating in the stratosphere

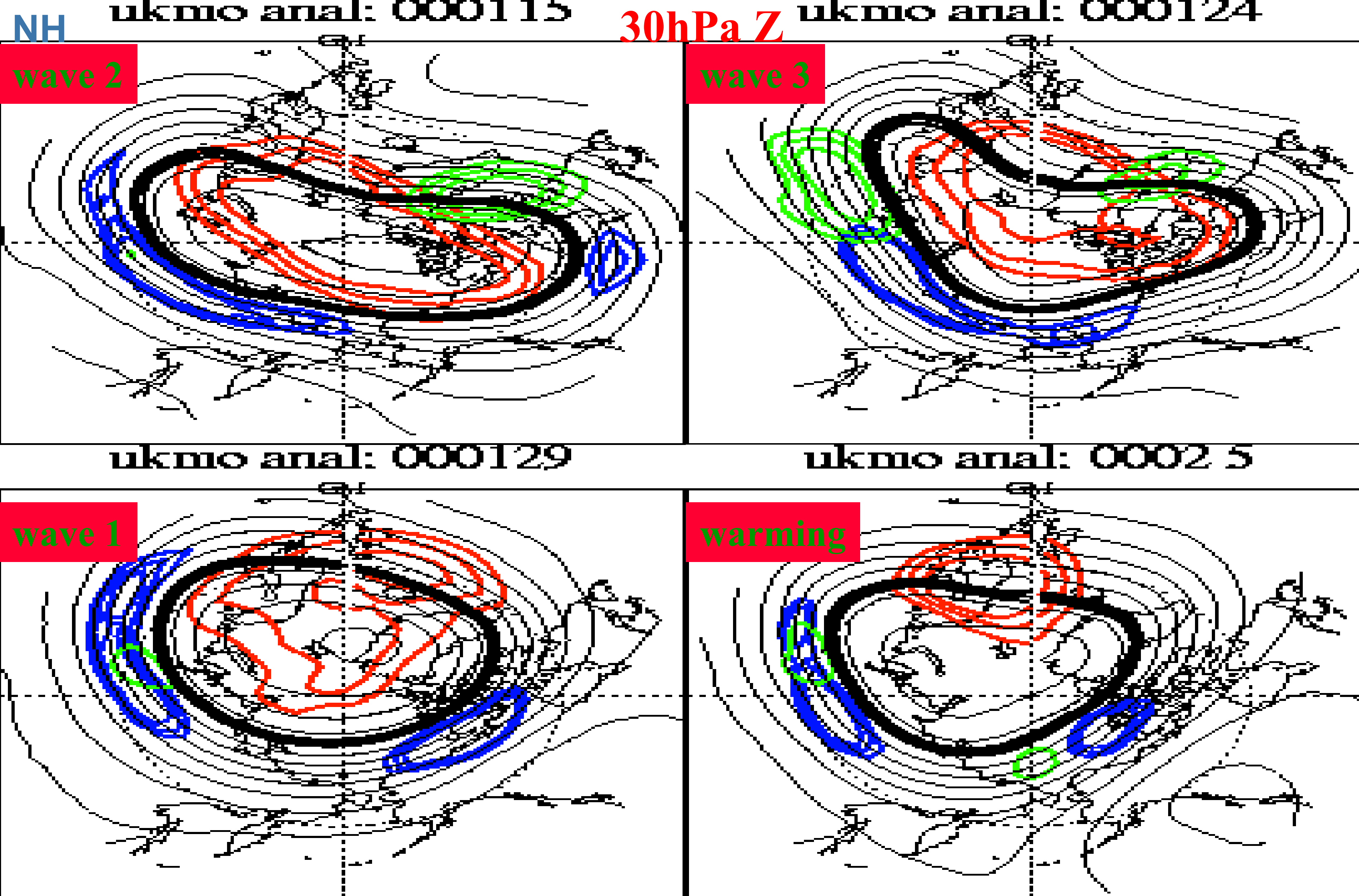
SH / NH Target Periods

Anal / F'casts NH 15/01-15/02 29/01 -14/02 2000

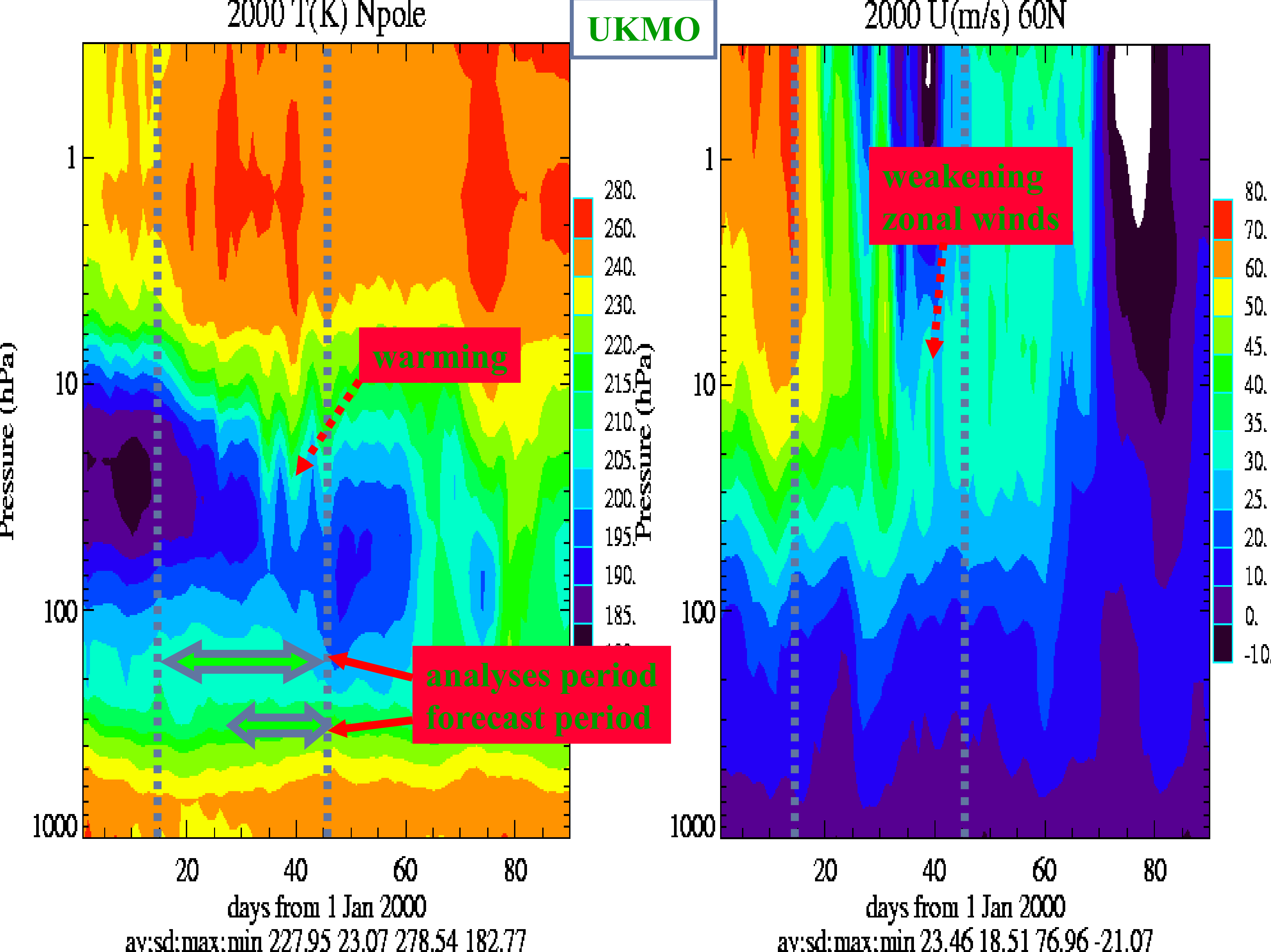
Anal / F'casts SH 15/09-15/10 20/09 - 3/10 2001

Why these periods?

Selected because of the occurrence a wave 3 blocking event in the NH and of the 1st sudden warming event in the SH



Z (thick=21900,22000,50); U(blue=56,60,2);T(red=190,194,2);|V|(green=30,40,5)

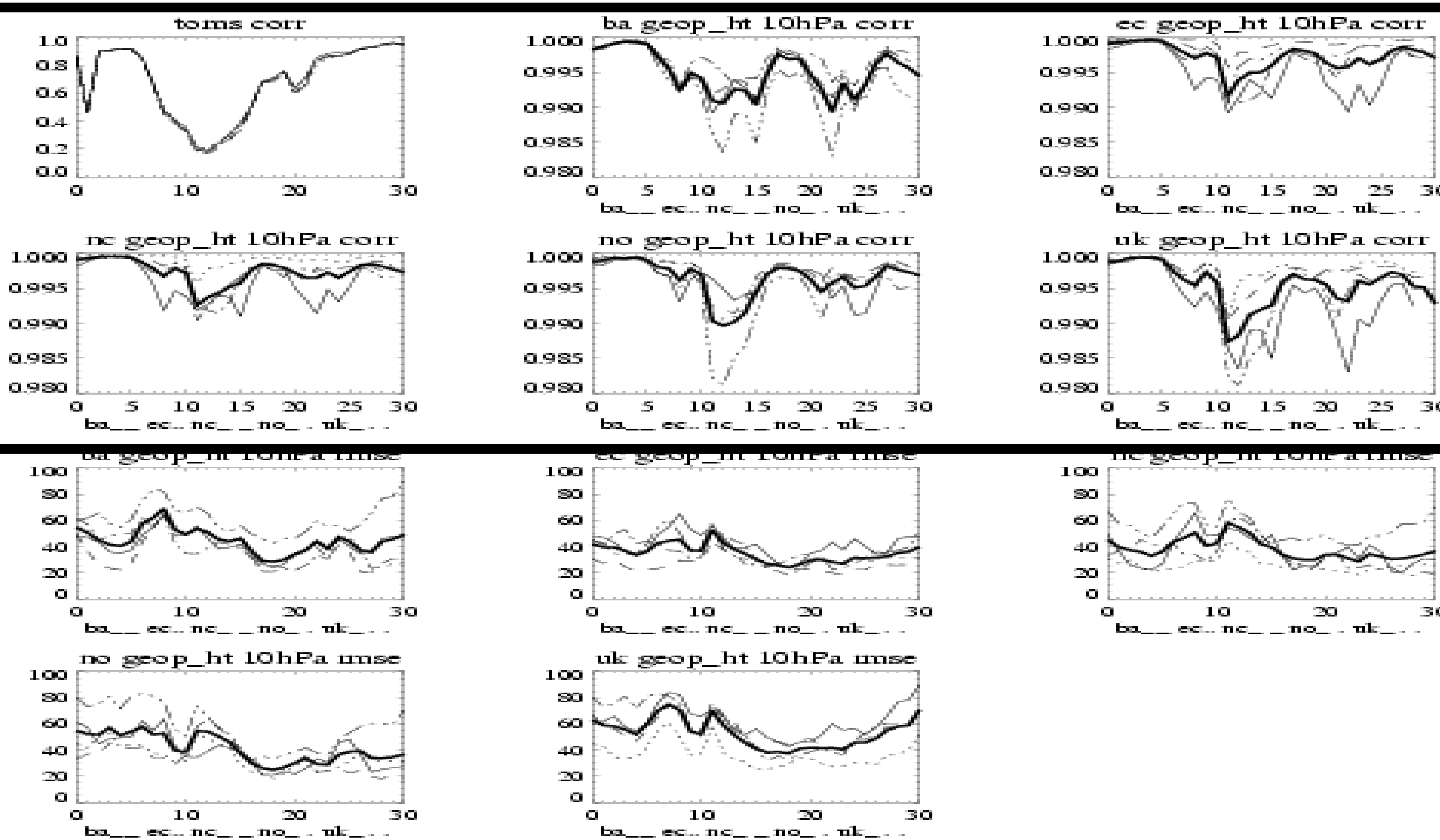


2000 T(K) Npole
UKMO
2000 U(m/s) 60N
Pressure (hPa)
1
10
100
1000
280.
260.
240.
230.
220.
215.
210.
205.
200.
195.
190.
185.
warming
weakening
zonal winds
analyses period
forecast period
80.
70.
60.
50.
45.
40.
35.
30.
25.
20.
10.
0.
20
40
60
80
days from 1 Jan 2000
av:sd:max:min 227.95 23.07 278.54 182.77
av:sd:max:min 23.46 18.51 76.96 -21.07

Southern Hemisphere Analyses

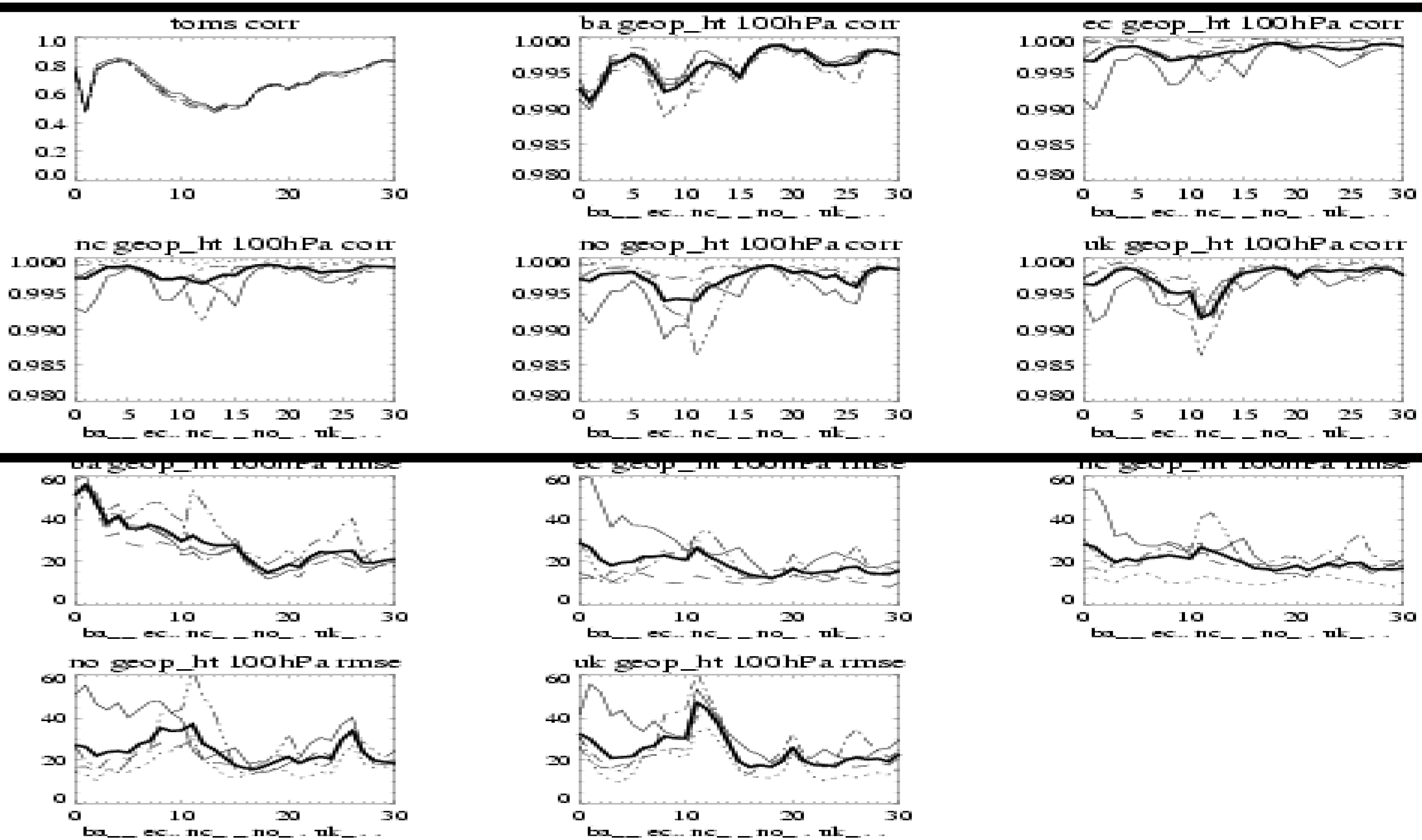
In order to verify the analyses, we compare model fields with TOMS Total Column Ozone (DU) amounts. Total Column Ozone (TCO) has been shown to be well correlated with stratospheric geopotential height and temperature (Petzoldt et al., 1994; Vaughan and Price, 1991; Teitelbaum et al., 1998; Newman and Lait, 1988; Ohring and Muench, 1960).

10hPa Day 0-30 Z CORR / RMSE



TOMS Days 0,5,8,10,19 drops; 1,12,20 min; good 0-5+22-30; bad 6-21

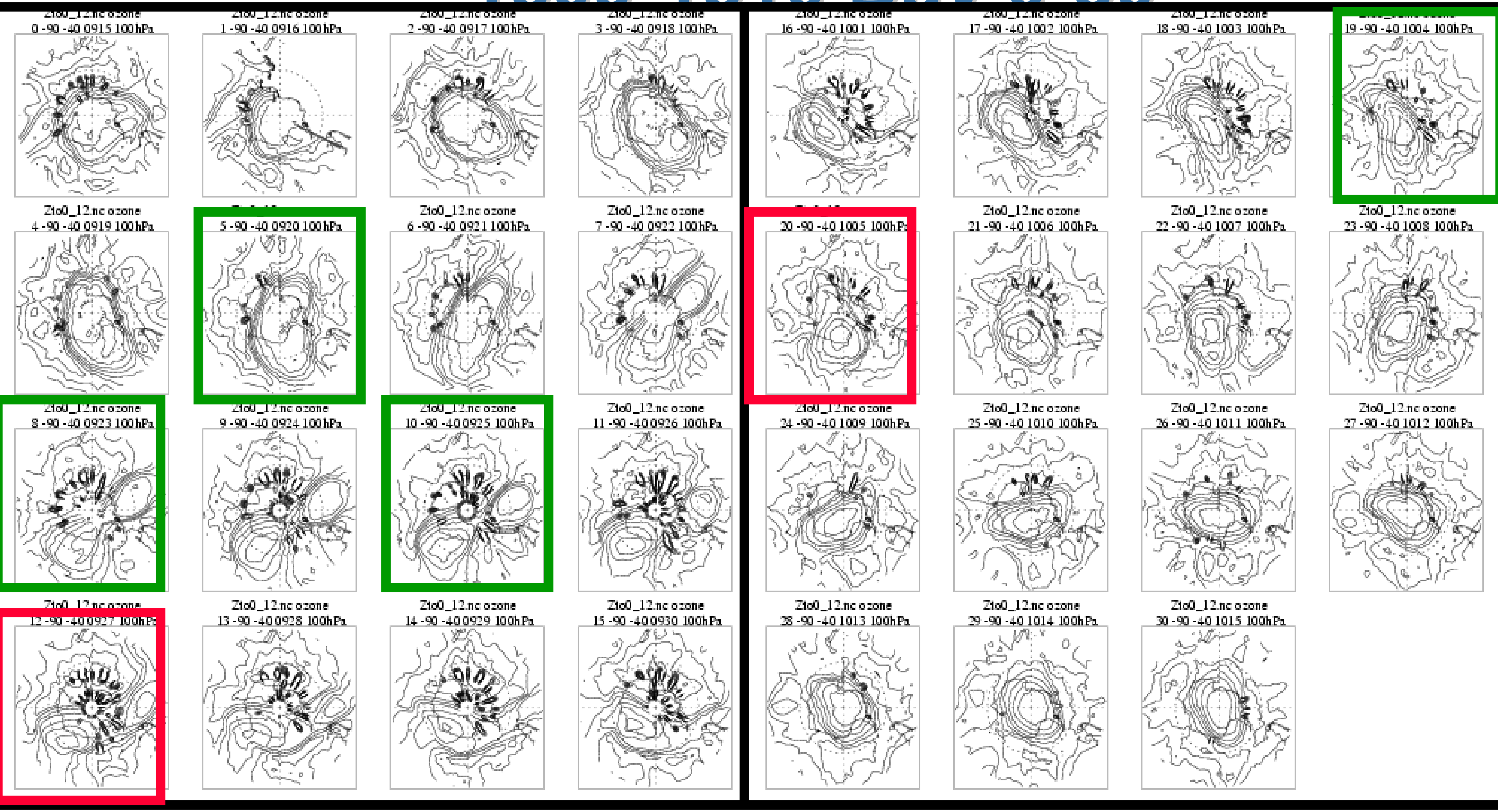
Day 0-30 Z CORR / RMSE 100hPa



TOMS Days 0,5,8,10,19 drops; 1,12,20 min; good 0-5+22-30; bad 6-21

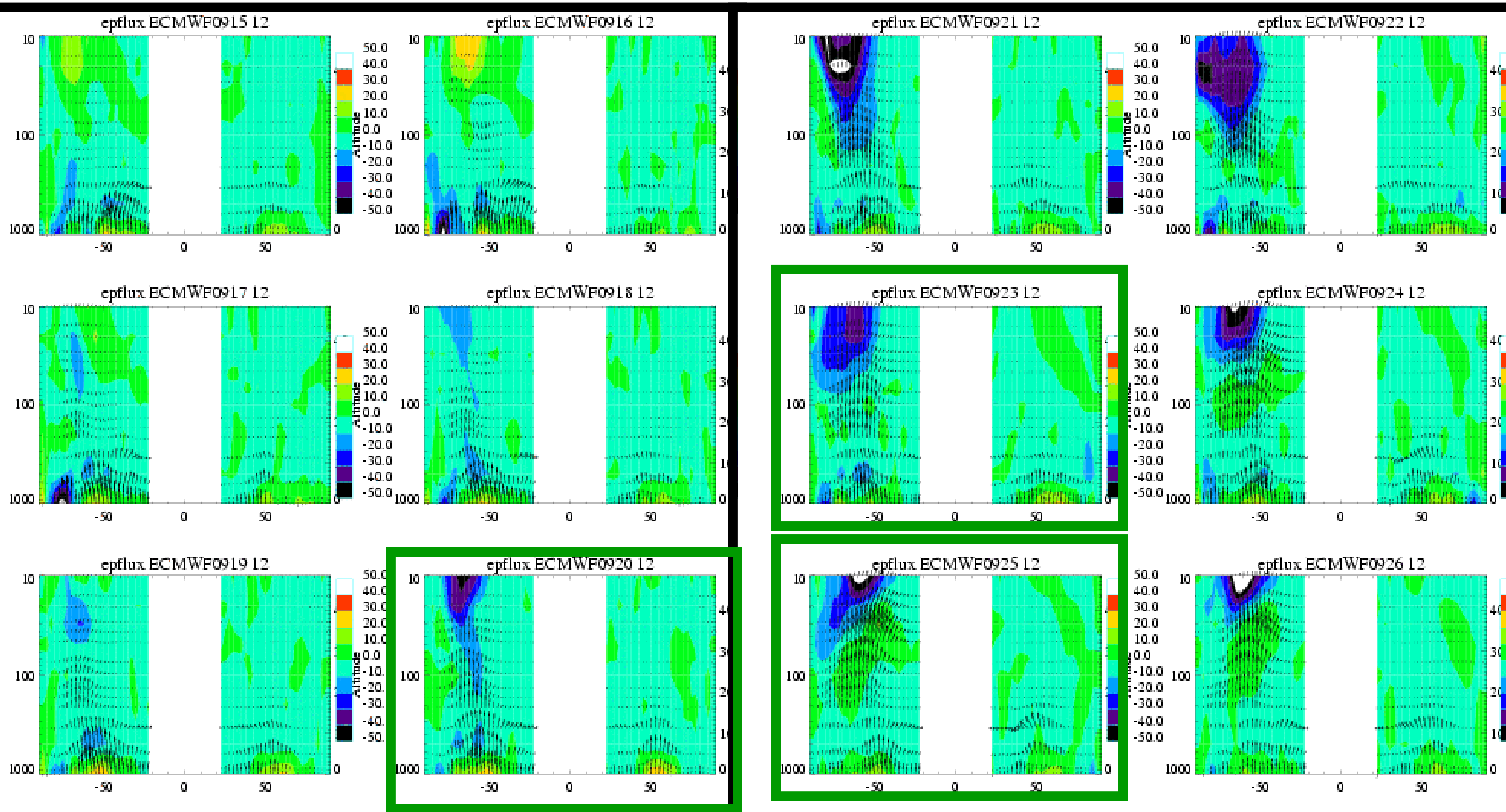
TOMS SH Sudden Warming Day 0-30

1509-1510 Day 0-30



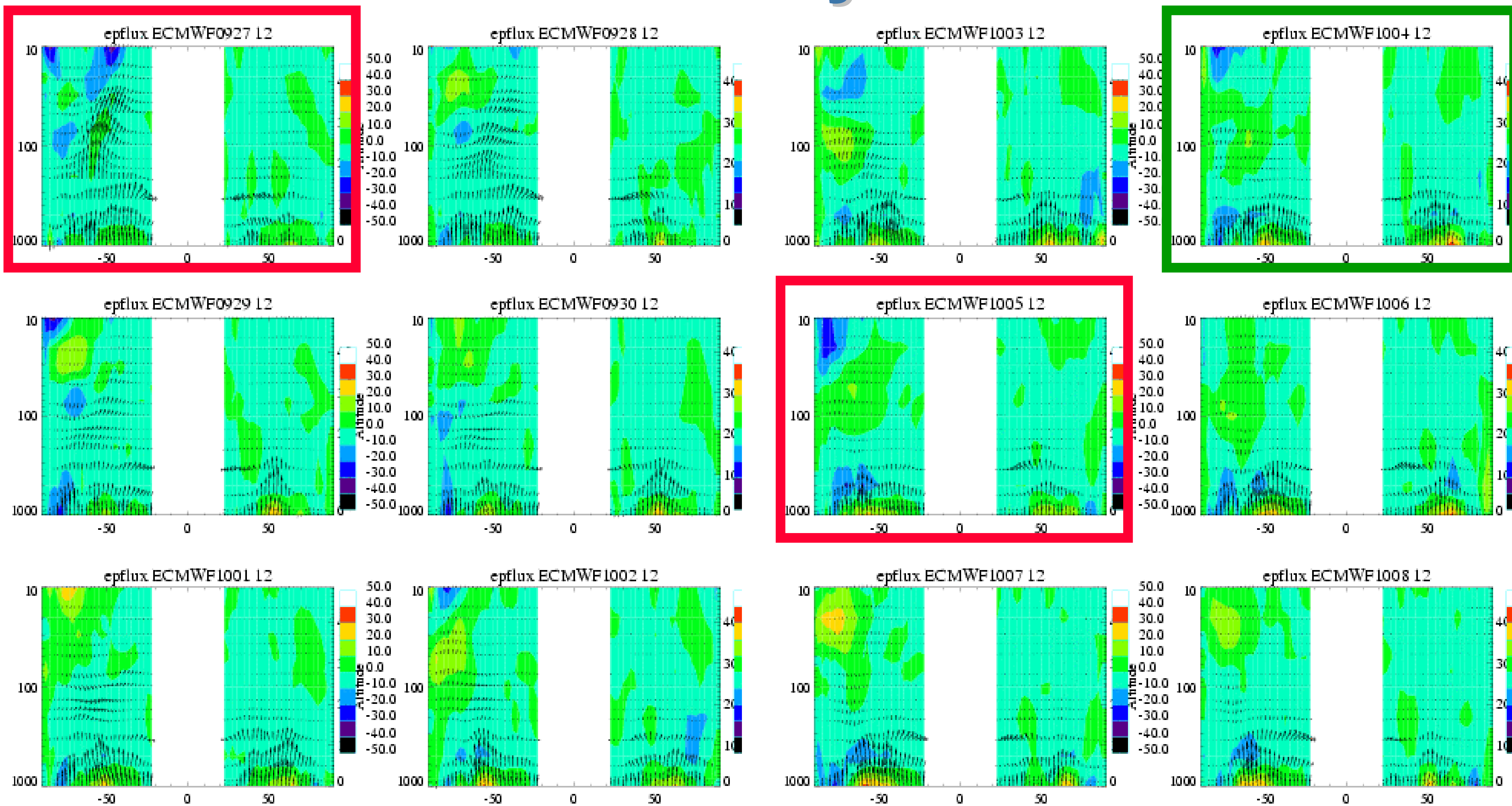
TOMS Days 0,5,8,10,19 drops; 1,12,20 min; good 0-5+22-30; bad 6-21

ECMWF An EPFlux Day 0-11 1509-2609



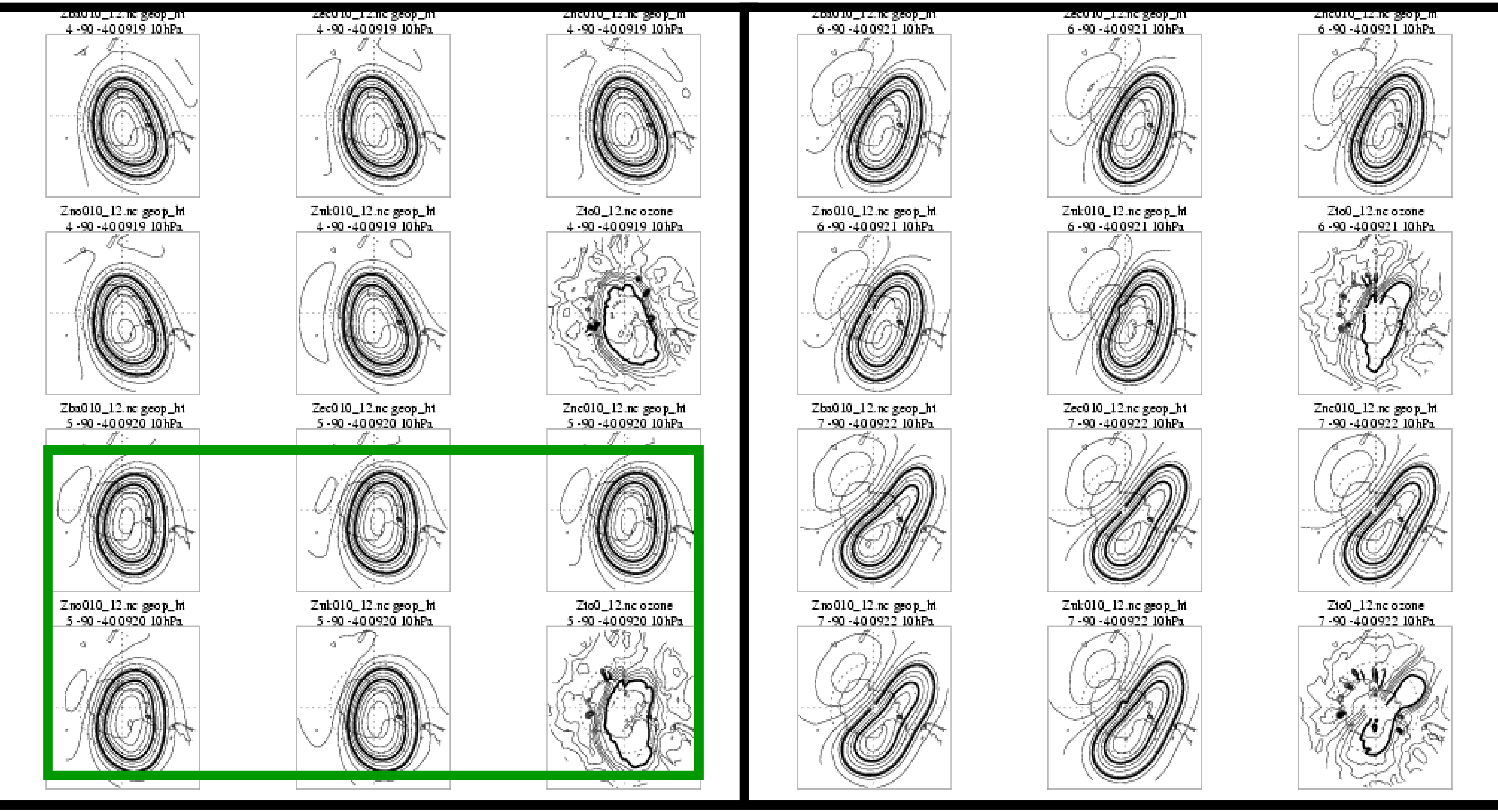
TOMS Days 0,5,8,10,19 drops; 1,12,20 min; good 0-5+22-30; bad 6-21

ECMWF An EPFlux Day 12-23 2709-0810



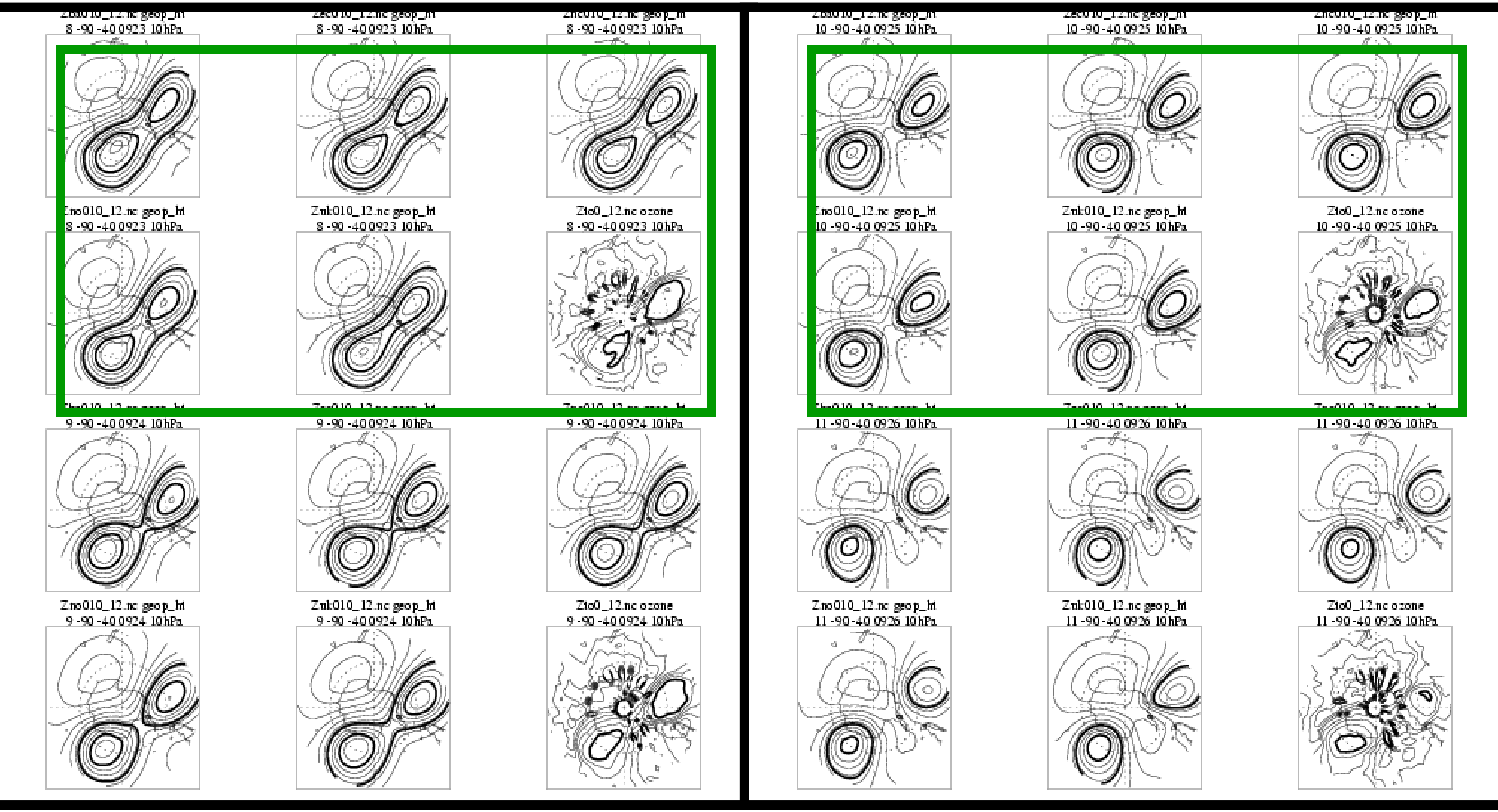
TOMS Days 0,5,8,10,19 drops; 1,12,20 min; good 0-5+22-30; bad 6-21

Analyses 10 hPa Day 4-7 1909-2209



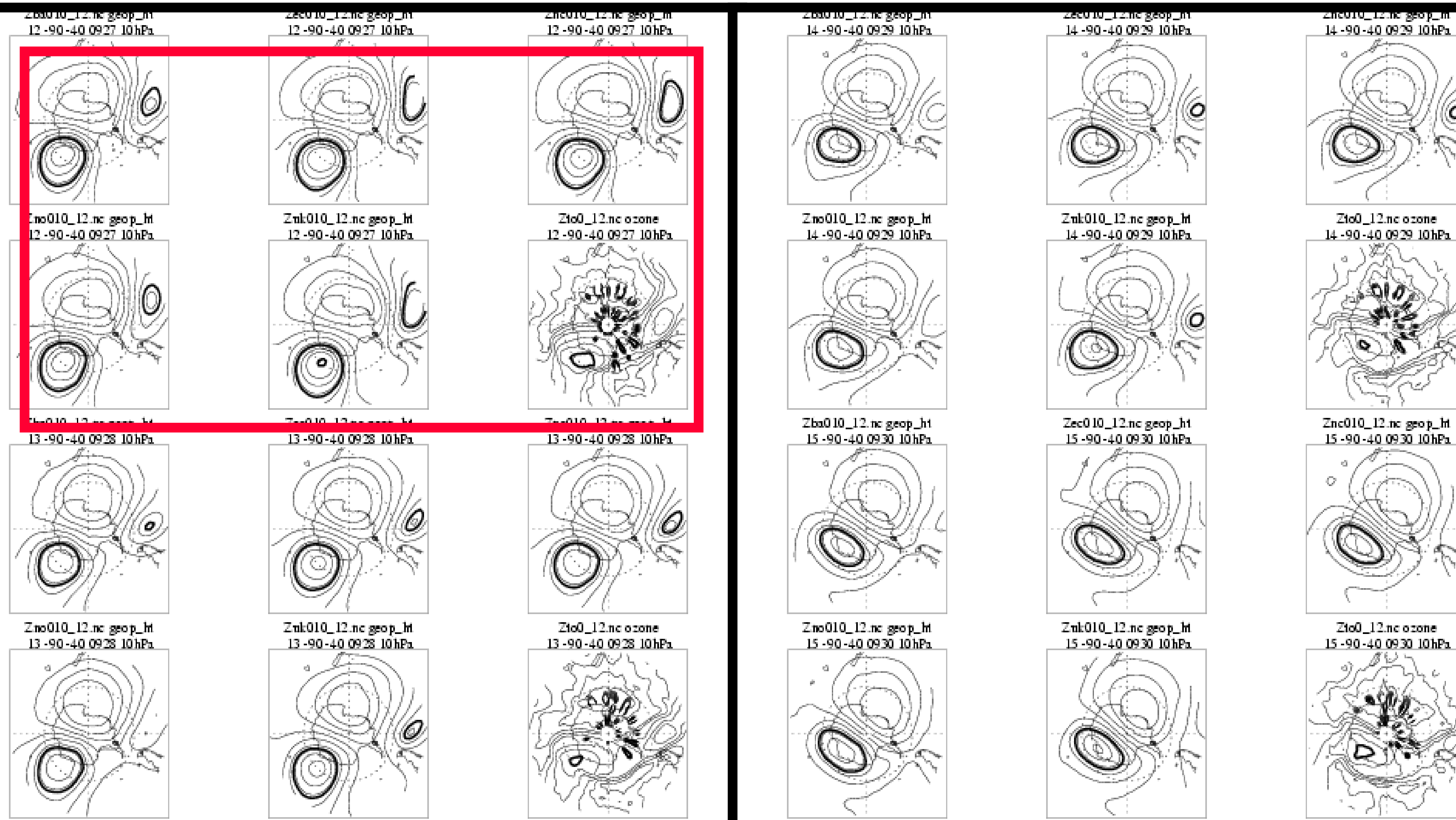
TOMS Days 0,5,8,10,19 drops; 1,12,20 min; good 0-5+22-30; bad 6-21

Analyses 10 hPa Day 8-11 2309-2609



TOMS Days 0,5,8,10,19 drops; 1,12,20 min; good 0-5+22-30; bad 6-21

Analyses 10 hPa Day 12-15 2709-3009



TOMS Days 0,5,8,10,19 drops; 1,12,20 min; good 0-5+22-30; bad 6-21

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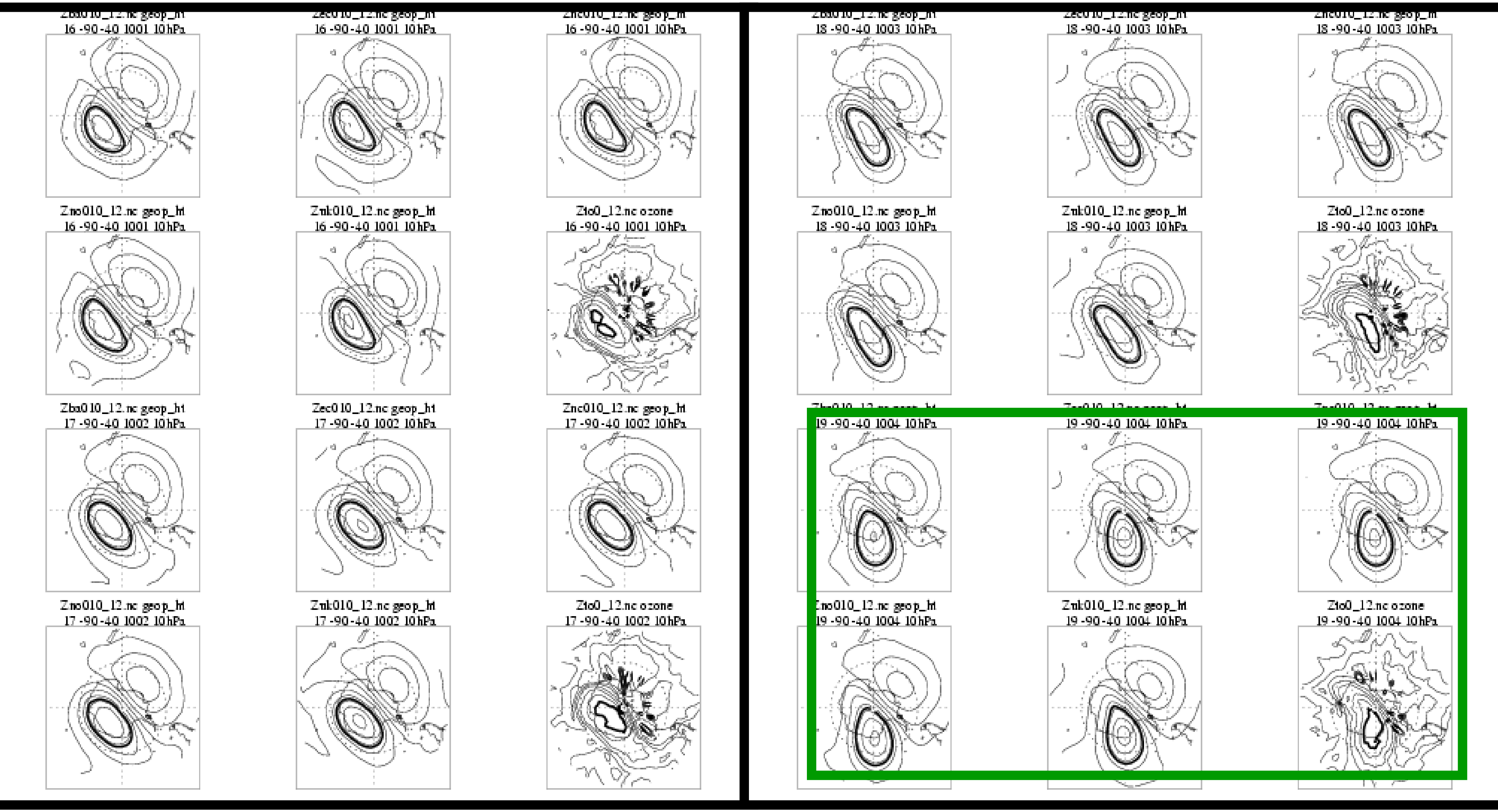
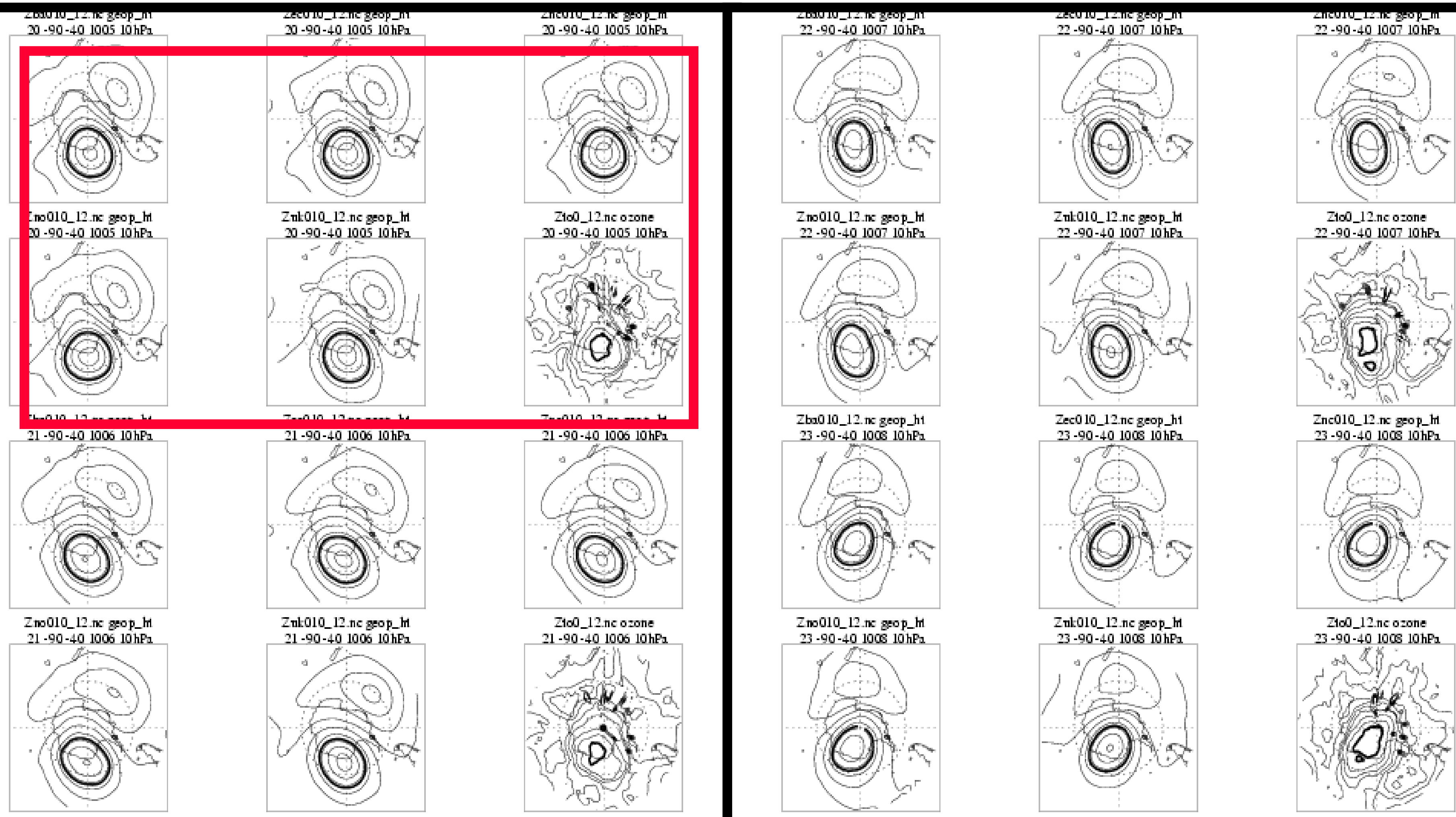
Analyses 10 hPa Day 16-19 0110-0410



TOMS Days 0,5,8,10,19 drops; 1,12,20 min; good 0-5+22-30; bad 6-21

Analyses 10 hPa Day 20-23 0510-0810



TOMS Days 0,5,8,10,19 drops; 1,12,20 min; good 0-5+22-30; bad 6-21

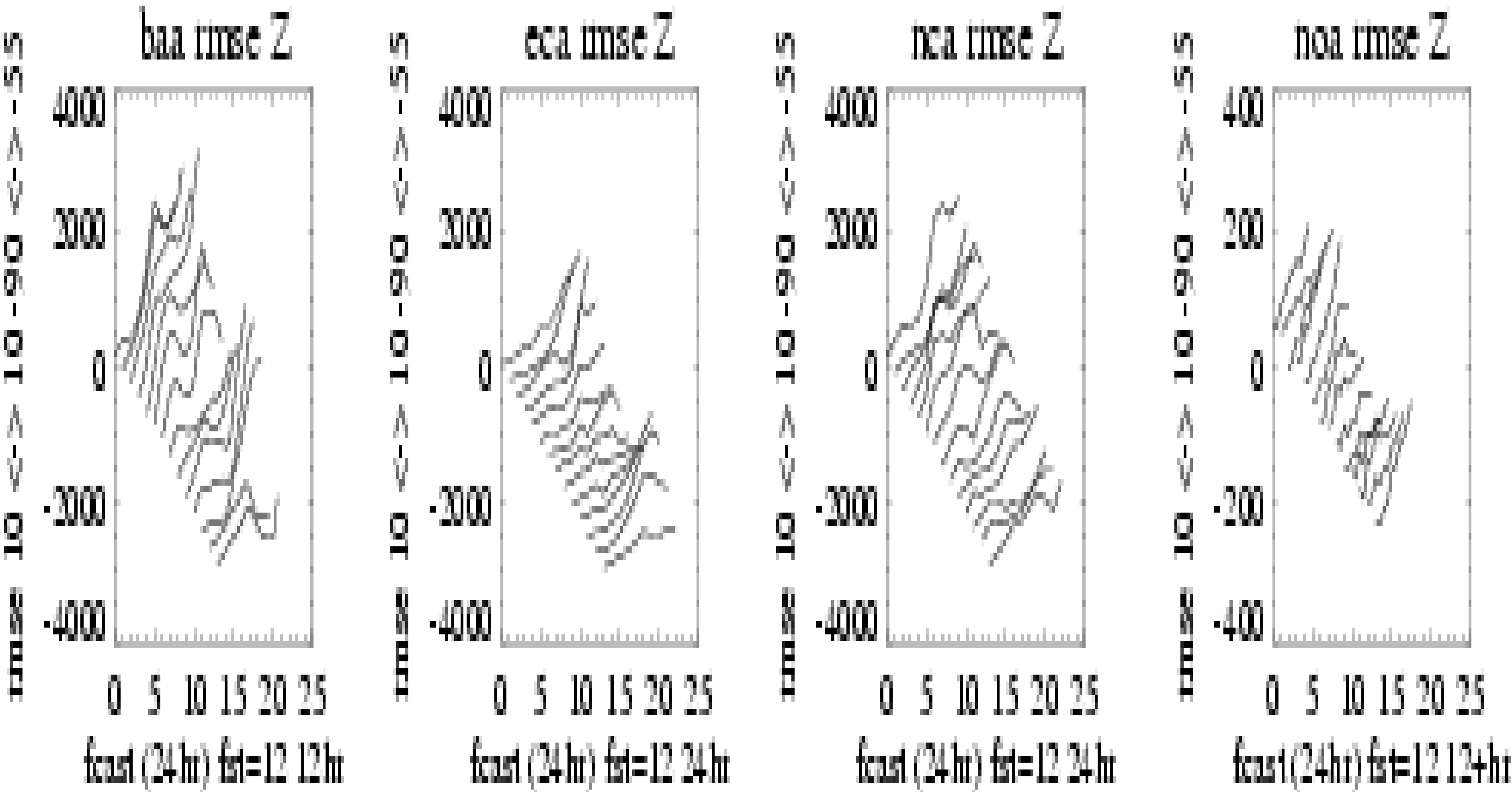
Southern Hemisphere Forecasts

If a NWP model has problems with forecasting a particular day this could be due to a variety of errors with the two main ones being **initialization problems** or difficulties with a particular **dynamic situation** in the atmosphere. If the problem is the former, then we may expect the error to occur on the given initialization day but not necessarily on future days whereas if the problem is the latter then we may expect the error to propagate with the difficult forecast day as we progress through future forecasts, eventually being forecastable

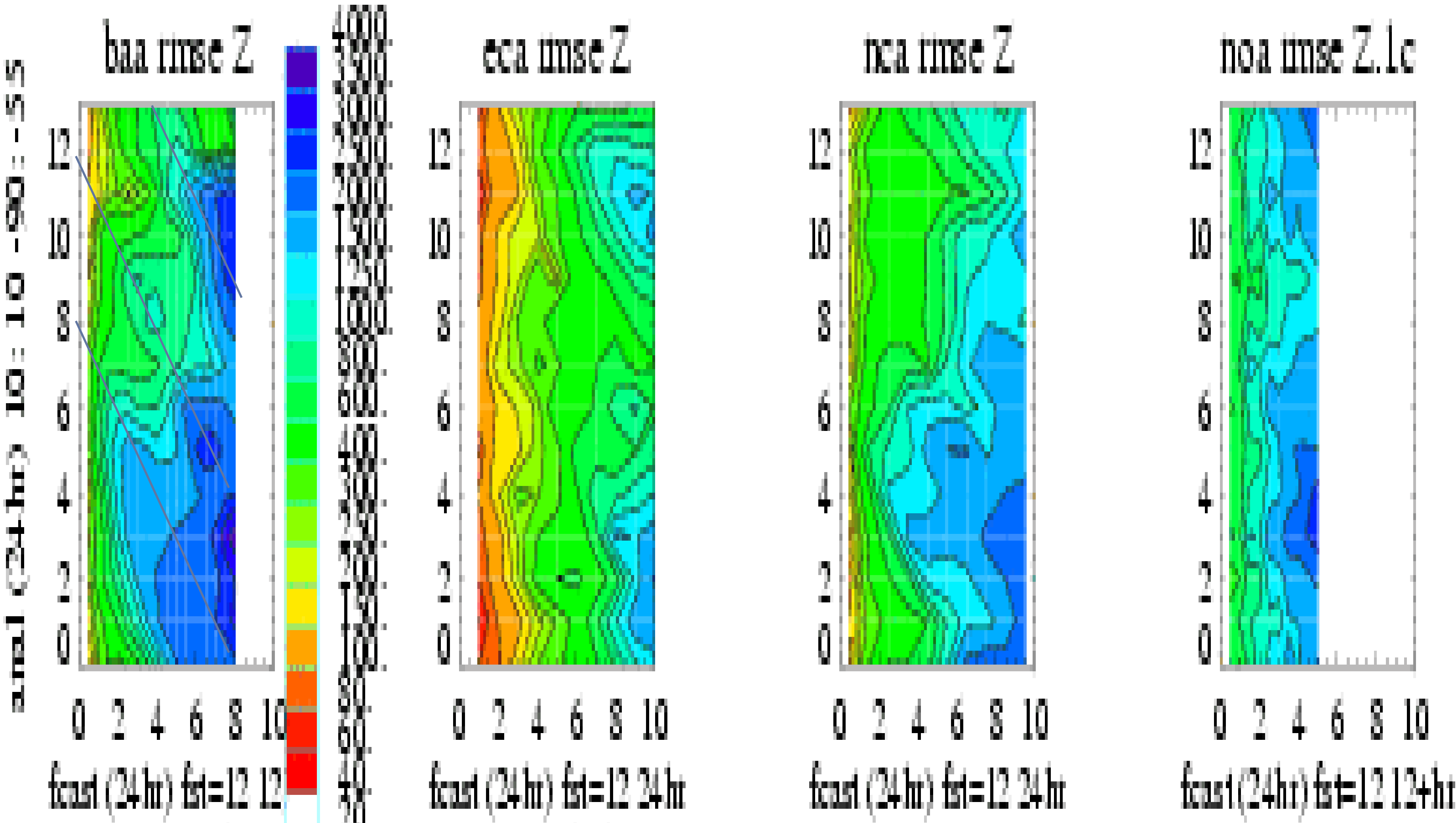
RMSE initialization day / f'cast day plots

In order to examine this proposition, we plot the 10 hPa Z (m), U (m), T (K) and V (m) RMSE between the model forecasts and their respective analyses for the 14 days we have forecasts from, 20 September to 3 October 2002 (Days 5-18), inclusive, averaged over latitudes 55S to 90S for the four available forecast models BAM, ECMWF, NCEP and NOGAPS.

Ba,Ec,Nc,No RMSE Z 10 hPa



Ba,Ec,Nc,No RMSE Z 10 hPa



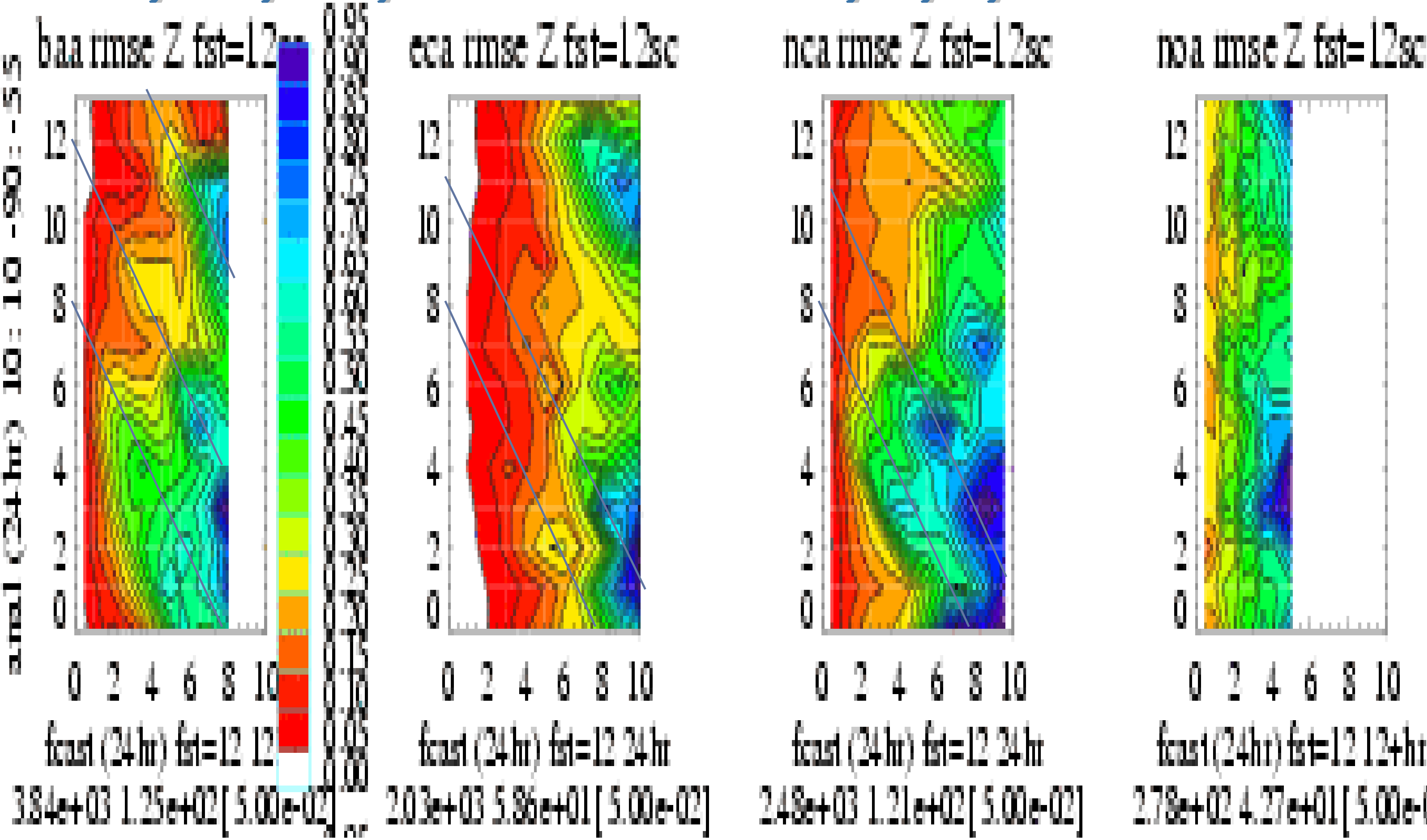
Initiation days 8,12,17 = dates 28/09,02/10,07/10

RMSE 10 hPa

One problem with this plotting method is that, in general, RMSE increases with forecast length and these models have different forecast periods => as we are interested in how each model deals with the changing polar vortex, plot normalized RMSE.

Initiation days 8,12,17 = dates 28/09,02/10,07/10

Ba,Ec,Nc,No nRMSE Z,U,T,V 10 hPa

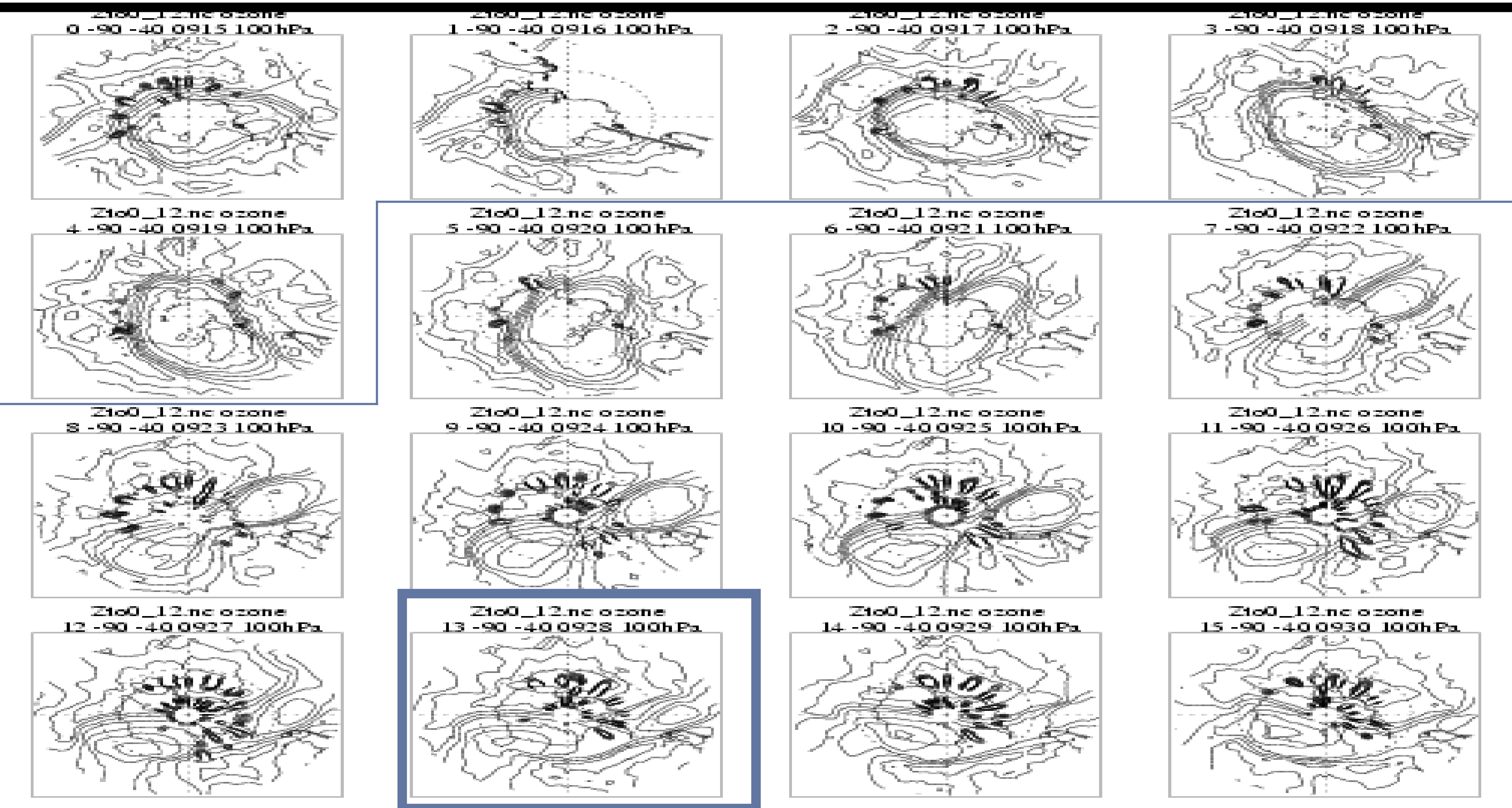


RMSE and nRMSE 10 hPa

The Z plots show: ECMWF is best; largest / smallest errors occur at the end / start of the forecast period; strong day-to-day error variation; strong diagonal dependencies; each model has its own difficult days, but initialization day number 8 (28/09) is a common problematic dynamical situation; the day before gives best forecast for all models; .35 nRMSE line appears after forecast day 6, 2-6, 2-6, 1-2 for ECMWF, BAM, NCEP, NOGAPS.

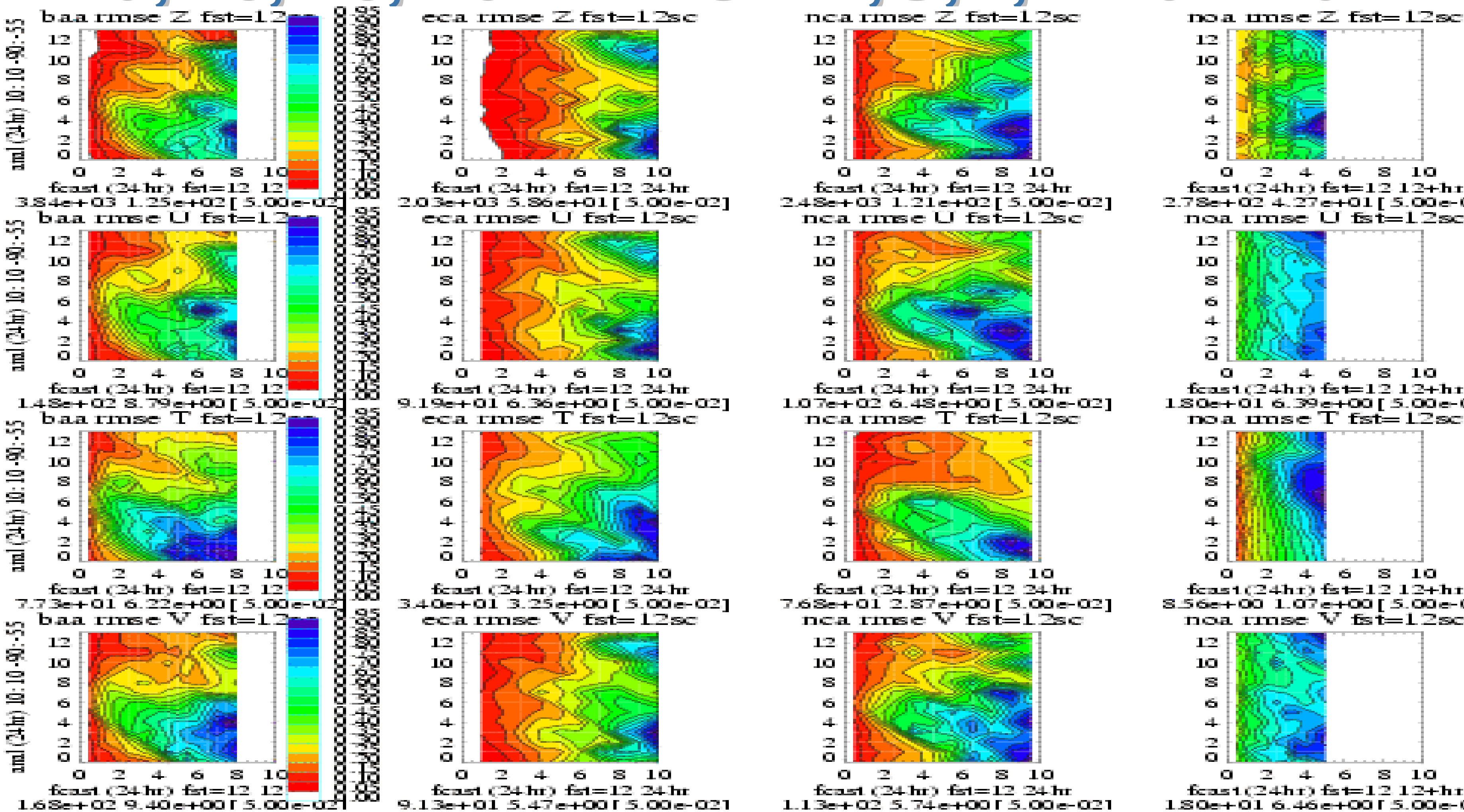
- Are these characteristics also seen in U,T and V?
- What does 28/09 look like? What of lower levels?

TOMS Day 0-15 1509-30/09

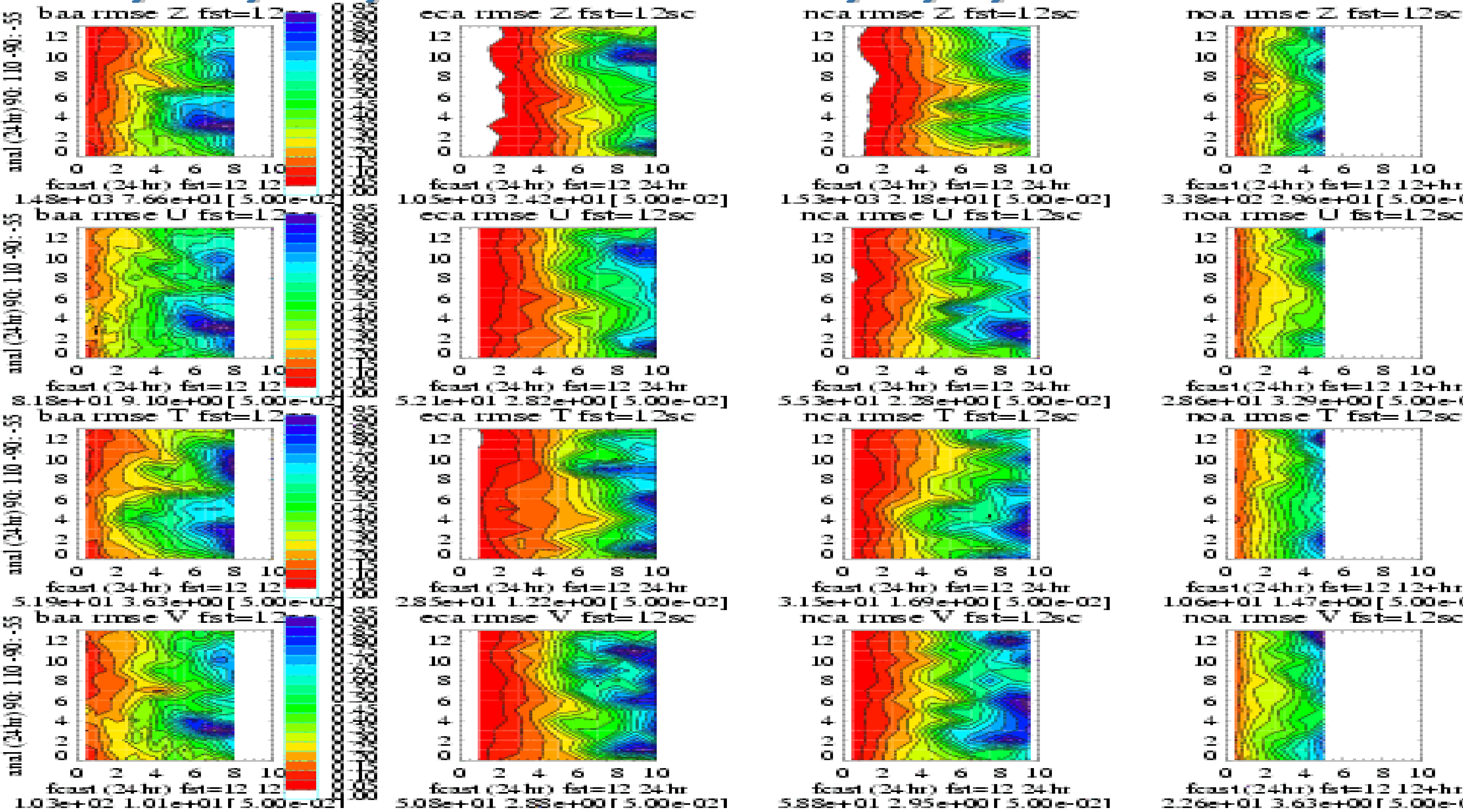


Initiation days 8,12,17 = dates 28/09,02/10,07/10

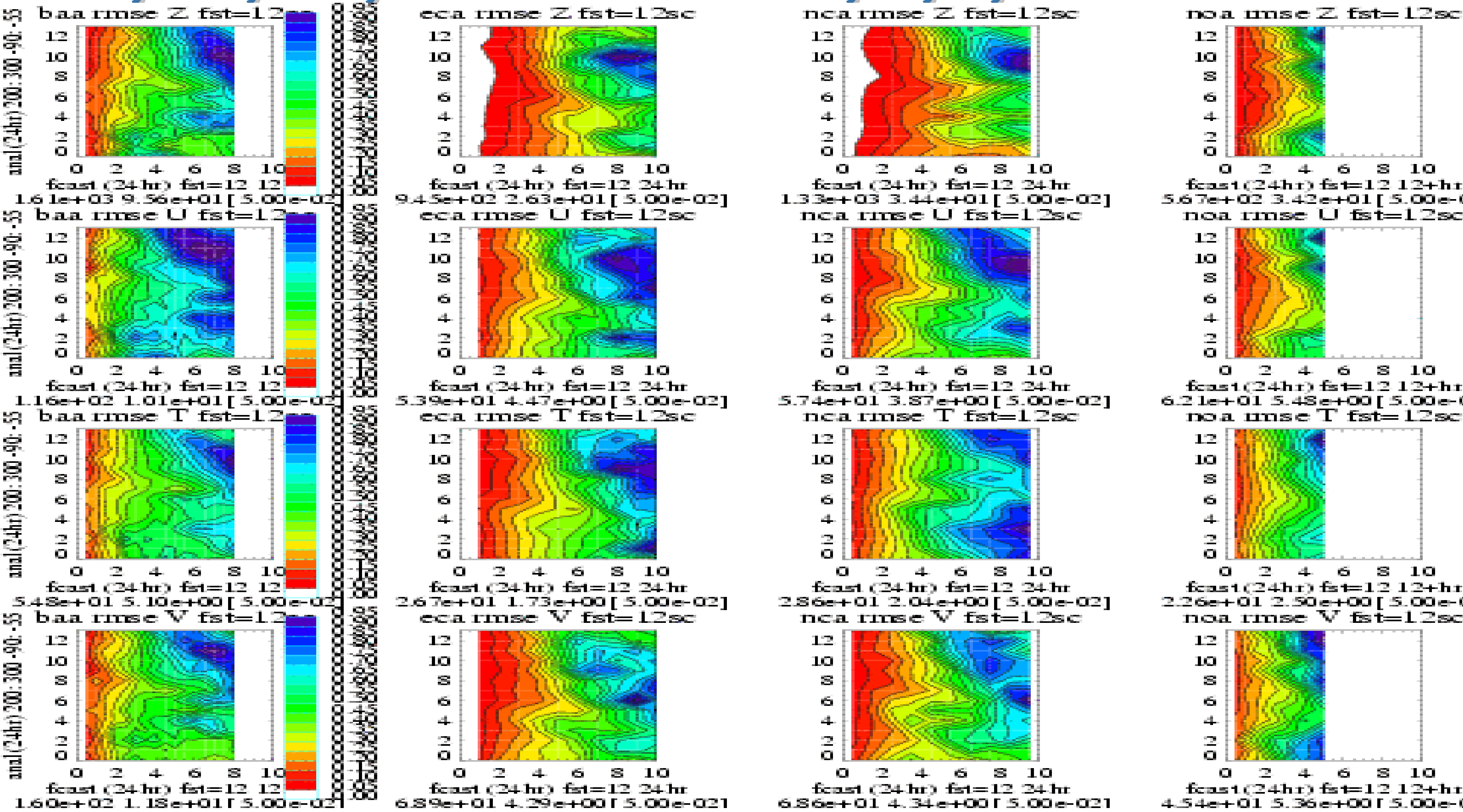
Ba,Ec,Nc,No nRMSE Z,U,T,V 10 hPa



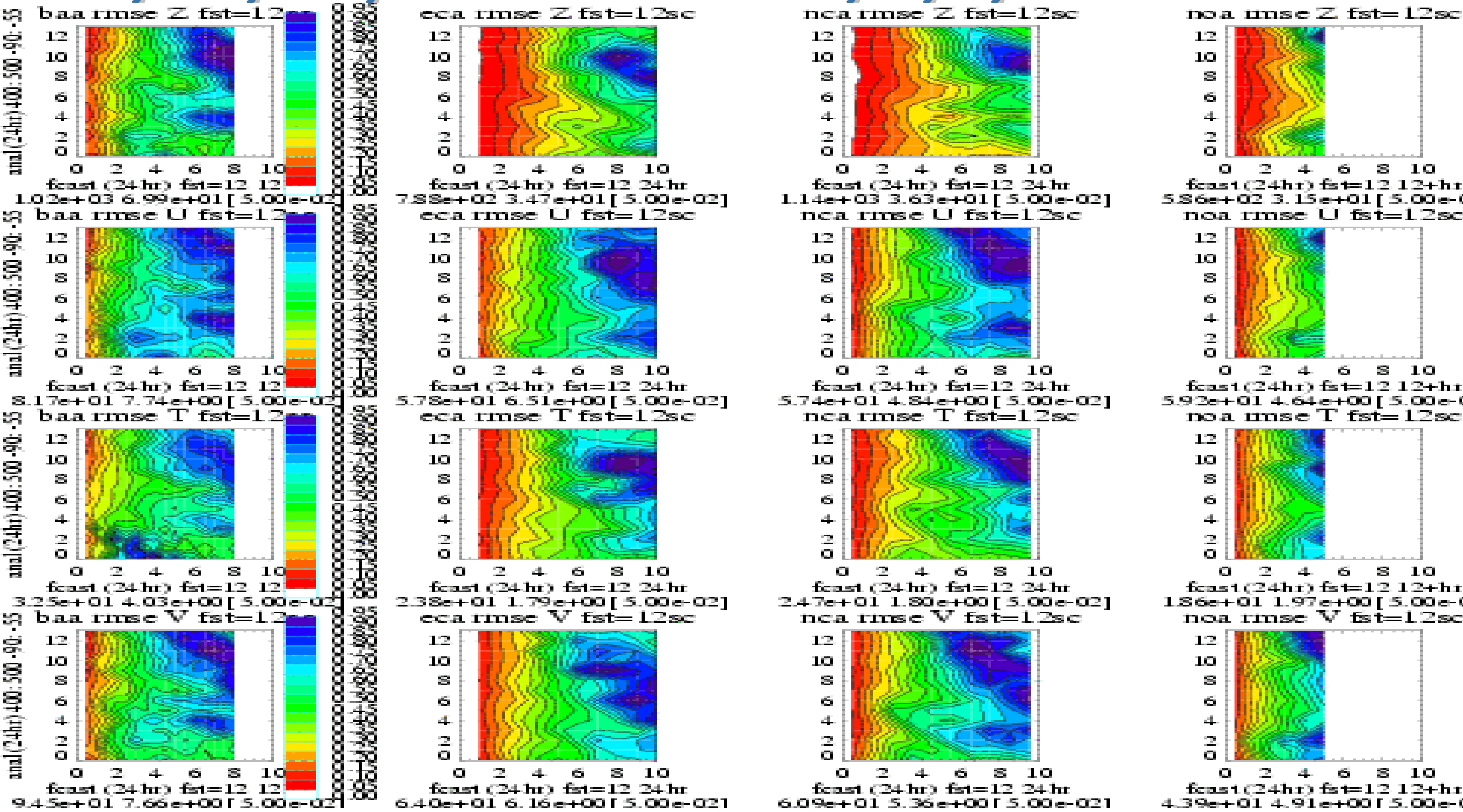
Ba,Ec,Nc,No nRMSE Z,U,T,V 100 hPa



Ba,Ec,Nc,No nRMSE Z,U,T,V 200 hPa



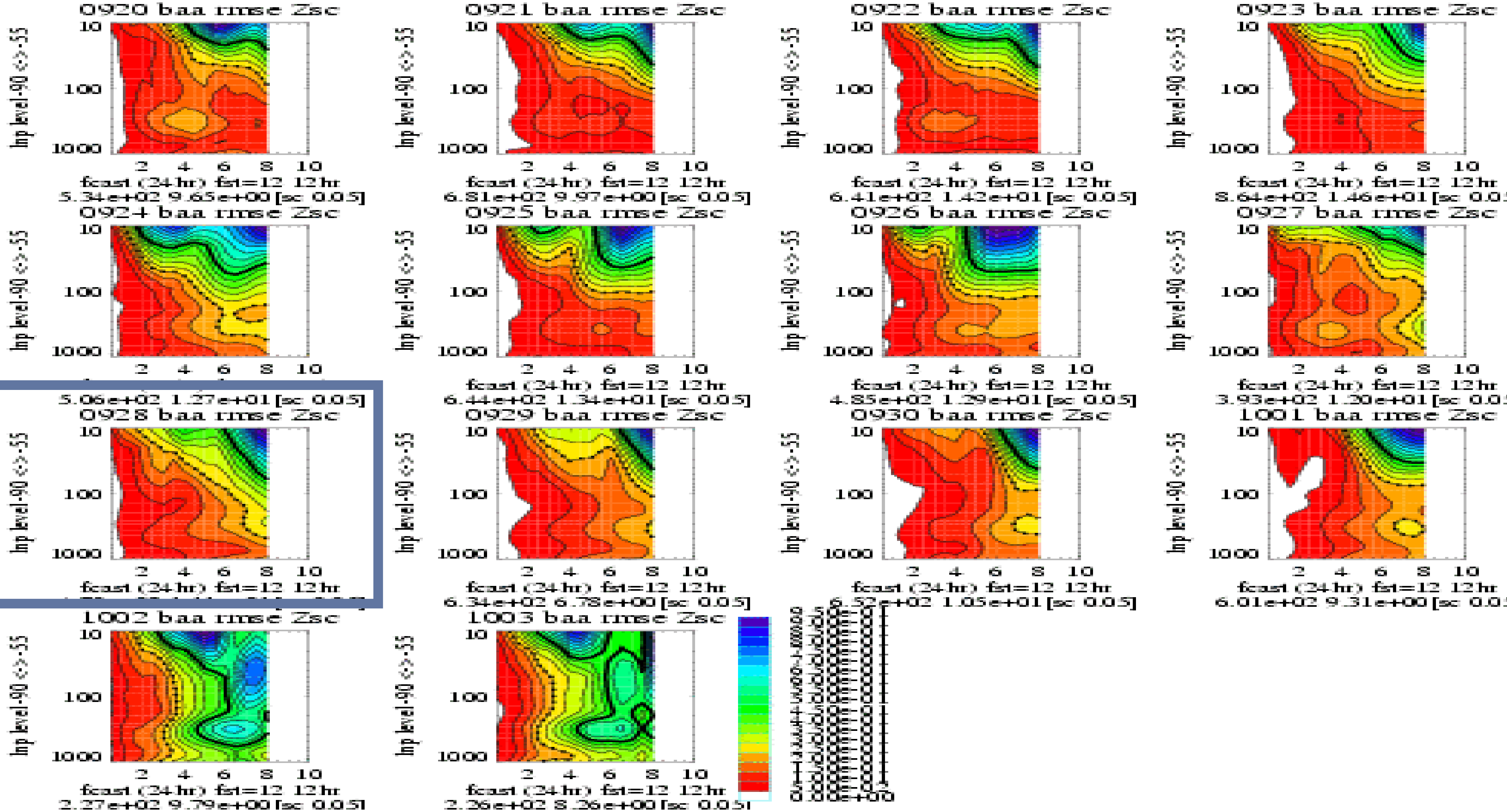
Ba,Ec,Nc,No nRMSE Z,U,T,V 400 hPa



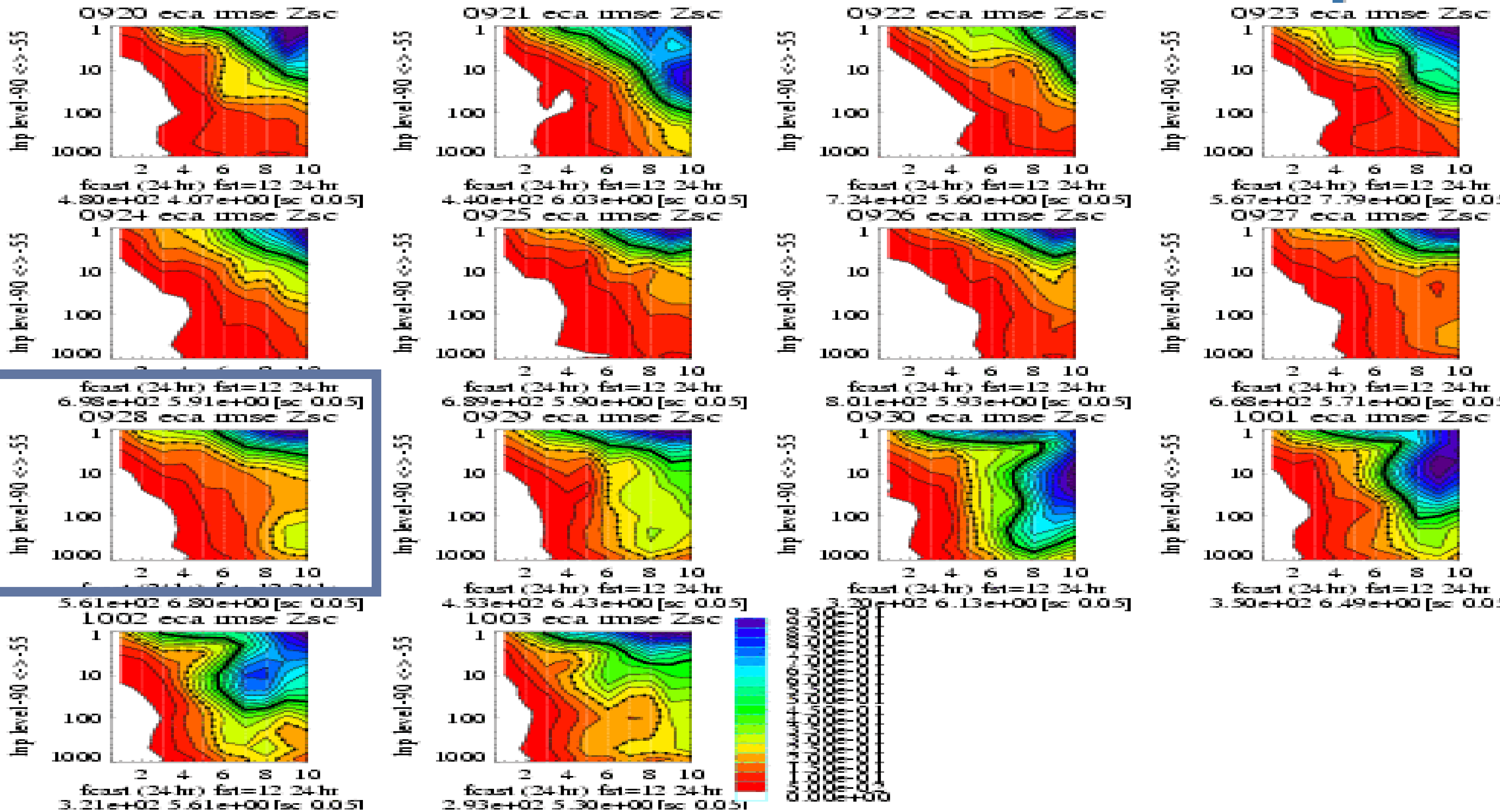
nRMSE 100,200,400 hPa

- Similar characteristics are seen in Z,U,V,T
- nRMSE at 100 hPa shows: there is less variability in the errors; forecasts have less accurracy eg the ECMWF Z .35 contour is now located after day 5; there is less diagonal dependence and more horizontal spiking.
- These trends continue as you move further down into the atmosphere eg ECMWF Z .35 contour is after / before day 4 in the 200 / 400 hPa plots
- Indicating that there is more skill in nRMSE the stratosphere. What of vertical cross-sections?

0920-1003 BAM FCSTs nRMSE Z p/t



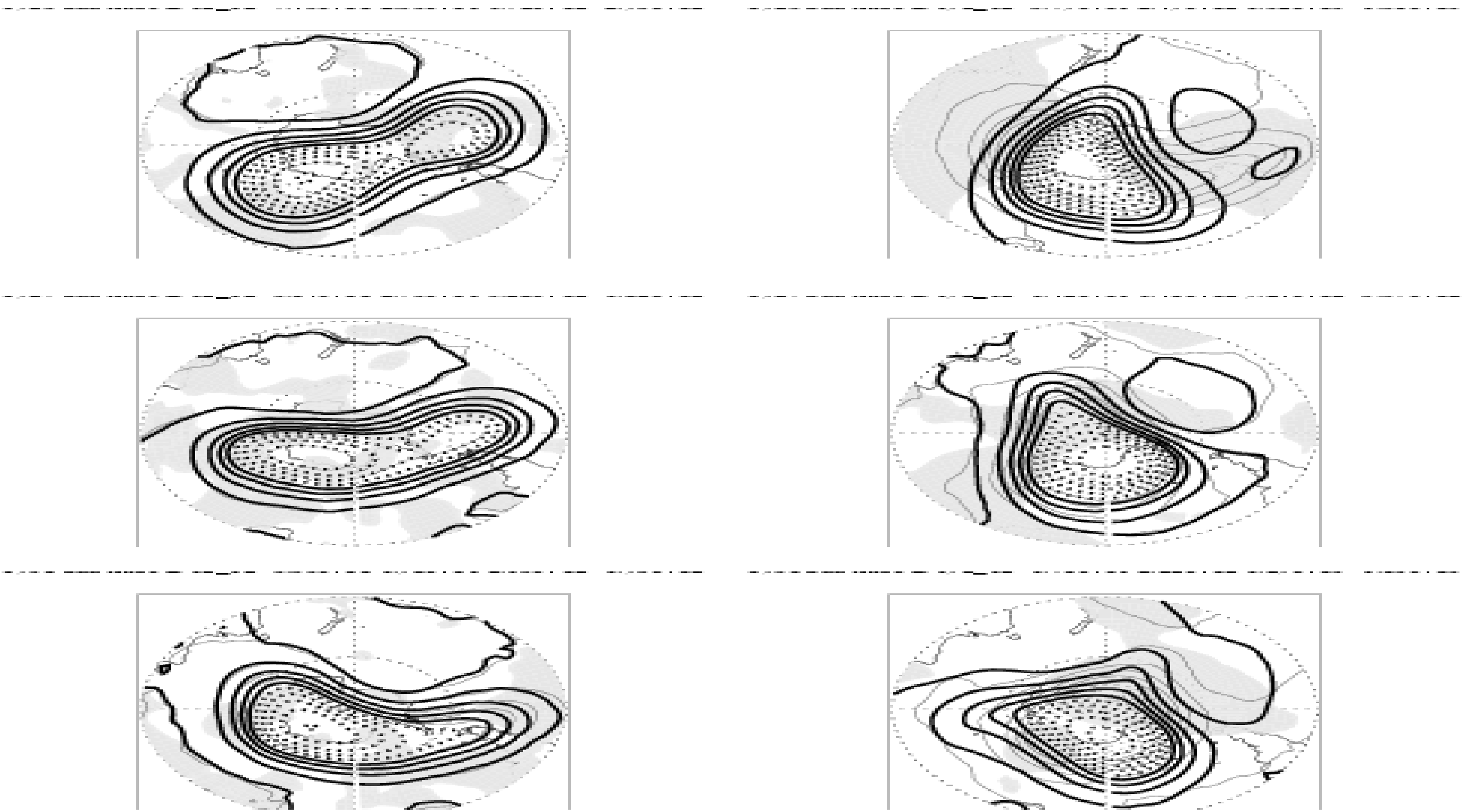
0920-1003 ECMWF FCST nRMSE Z p/t



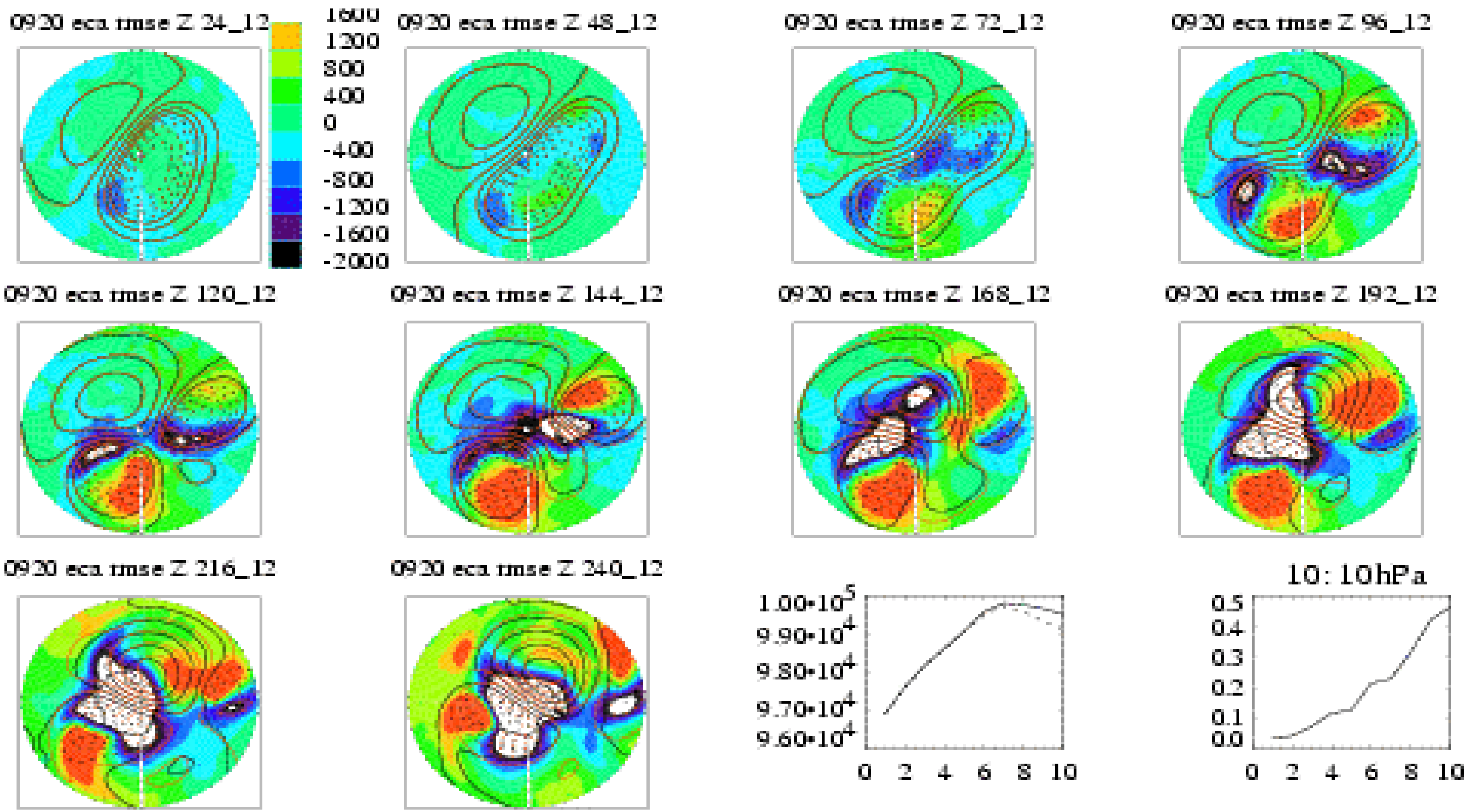
0920-1003 BAM / EC FCST nRMSE Z p/t

- BAM 28/09 = errors grow with this day until 27/09, as do ECMWF, but less obvious
- errors are descending from aloft
- min error growth occurs at: 100-200, 700-800 hPa
- max error growth at: top, 300-400 hPa, surface
- Are all errors the same?

50 hPa Z 0923/27/30 final fcst BAM

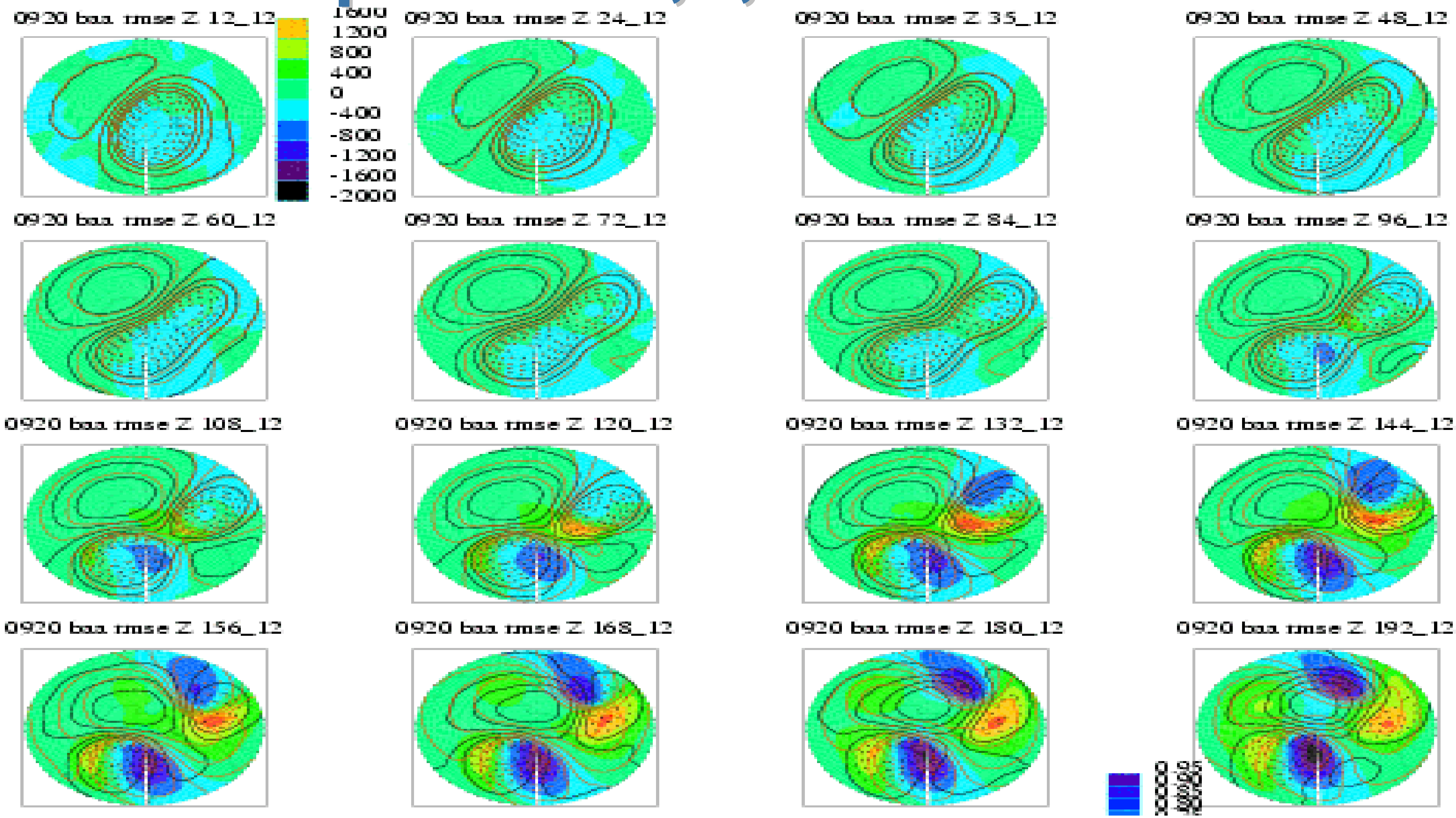


ECMWF pol-ste A,F,RMSE Z 10 hPa



heavy/light=f/a, dashed=lower Z: f-a RMSE - leading + => f rotates faster

BAM pol-ste A,F,RMSE Z 10 hPa



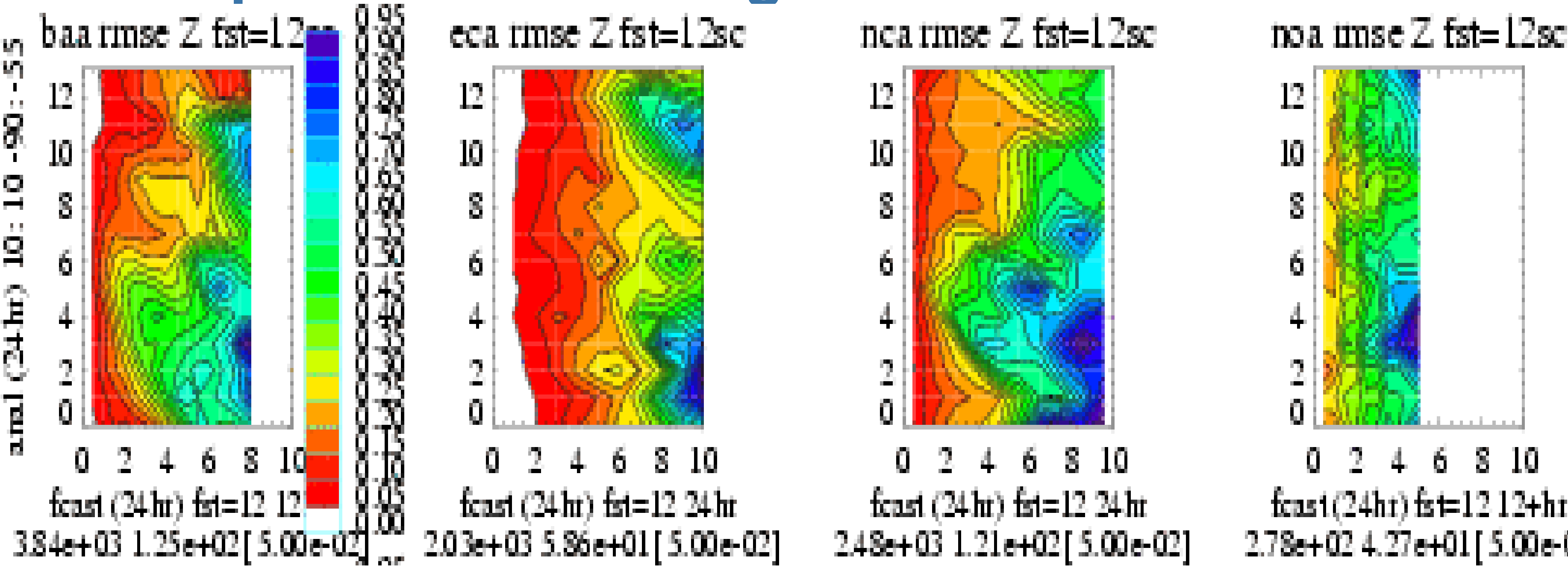
heavy/light=f/a, dashed=lower Z: f-a RMSE + leading - => f rotates slower

Conclusions

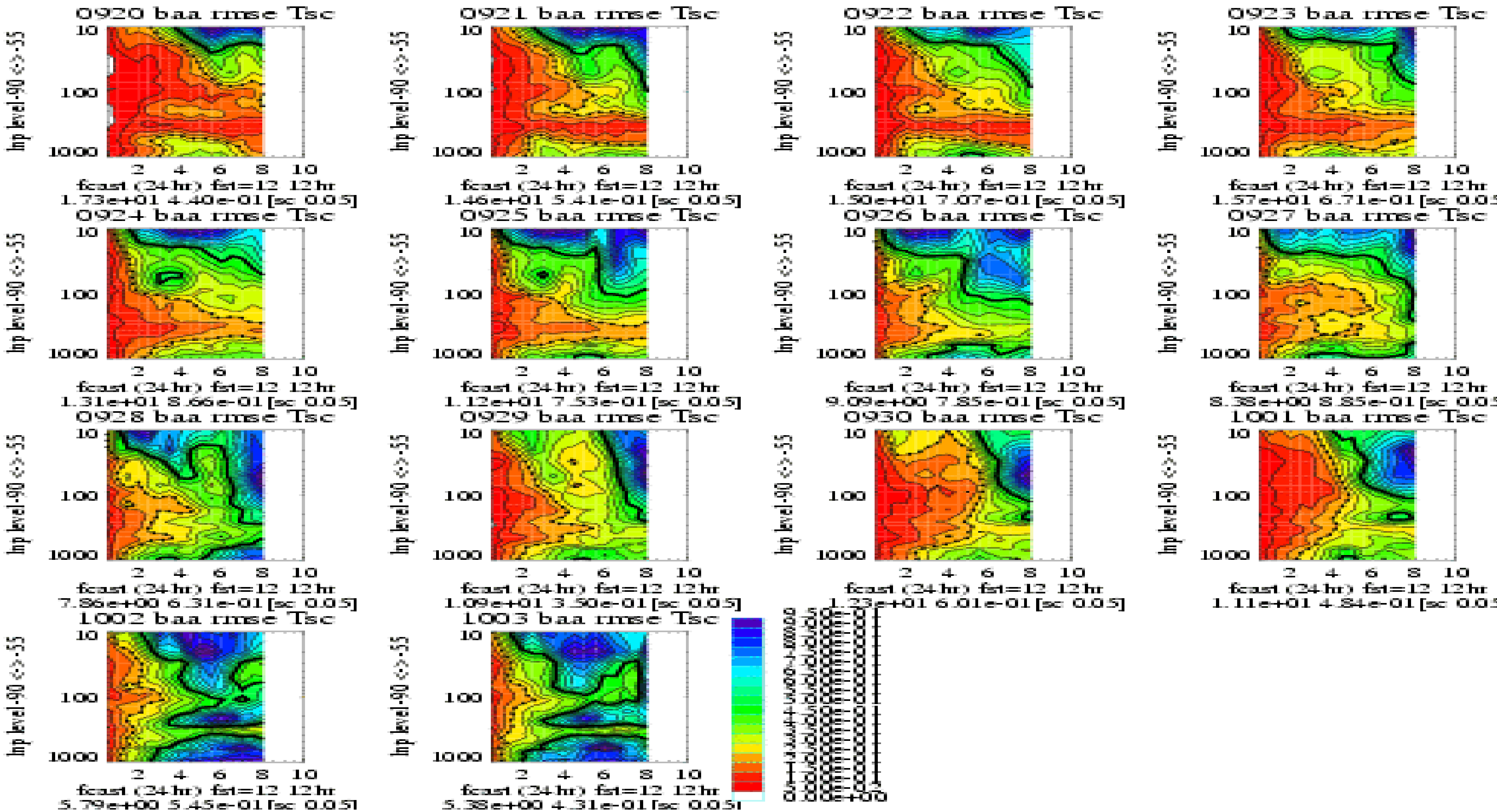
- Stratospheric forecasting performance at 6 days is comparable to 3 days in the troposphere
- Large variability in skill at 6 days
- Poorer scores occurring when the vortex flow is rapidly changing
- The forecast vortex: rotates faster, weaker, closer to the pole
- The min polar T and max U are underestimated
- 28 Sept = difficult day for all models to forecast
- errors propagate from the top and slow the forecast vortex => not all errors are equal!!

Conclusions continued

- Increase stratospheric forecast skill by increasing stratospheric vertical resolution + raise the lid
- There are common dynamic situations difficult for stratospheric forecasting



0920-1003 BAM FCST nRMSE T p/t



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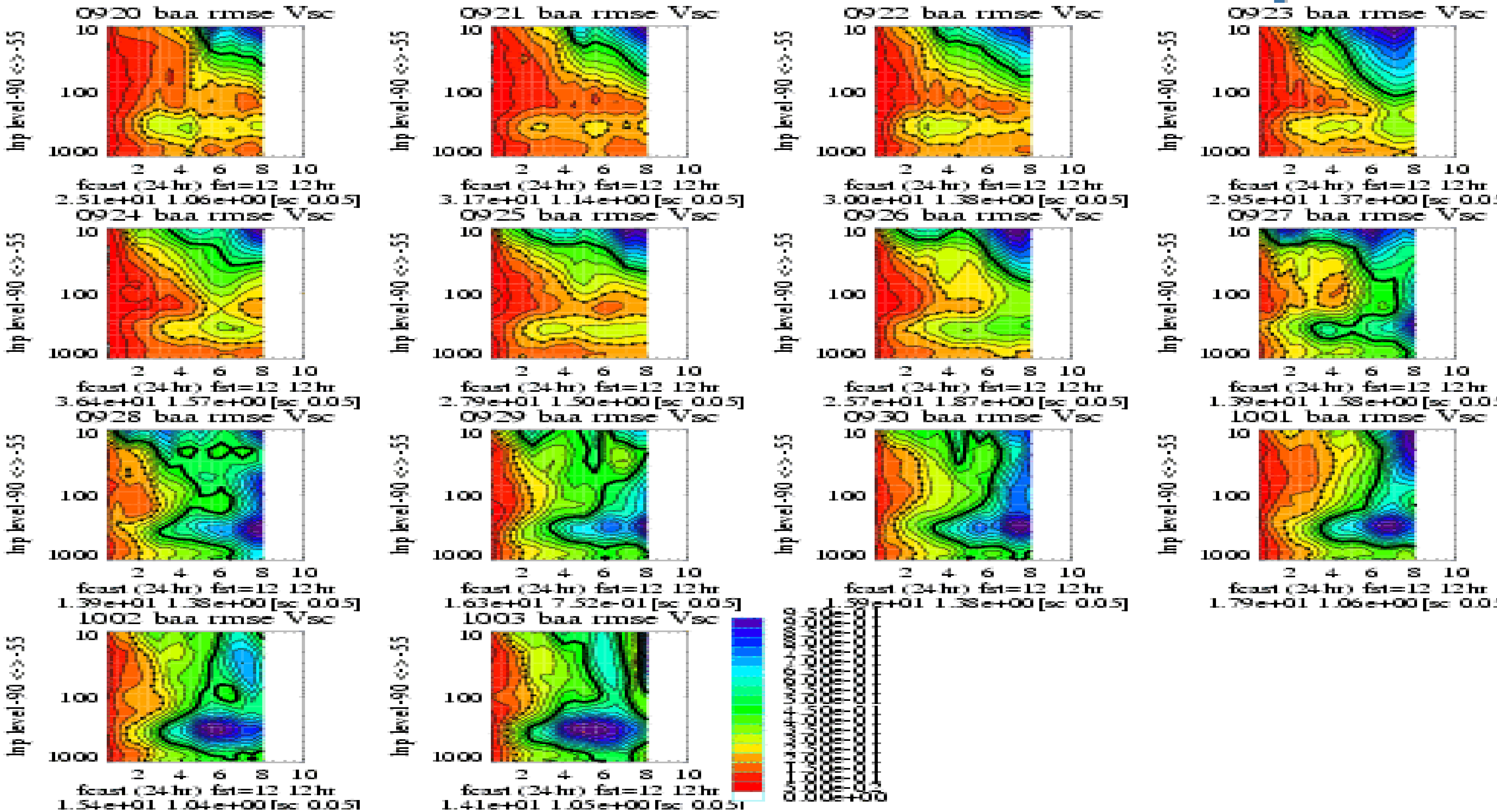
0920-1003 BAM FCST nRMSE V p/t



0920-1003 BAM FCST nRMSE U p/t