

Verification of the NCEP Operational GFS Predictions for the Stratosphere Circulation Anomalies in an Isentropic Potential Vorticity Coordinate

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Sources of Prediction Skill

- NWP: initial value problem. Rossby waves and baroclinic system => chaotic nature => inherent predictability (1-2 weeks).
- NWP+lower boundary forcing: **“forced” problems**
Internal variability is often as large as the forced anomalies, particularly in the absence of large SST anomalies (e.g. non ENSO years) and over the regions where prominent atmospheric internal modes are present at all time scale =>**the forecasts of the “forced” anomalies are indecisive.**
- New Source: Global mass circulation => The extratropics is connected to the tropics via stratosphere: => Much a longer time scale.

Observational Evidence derived from NCEP/NCAR reanalysis (1979-2003)

Cai (2003, GRL)

Cai and Ren (2006, GRL)

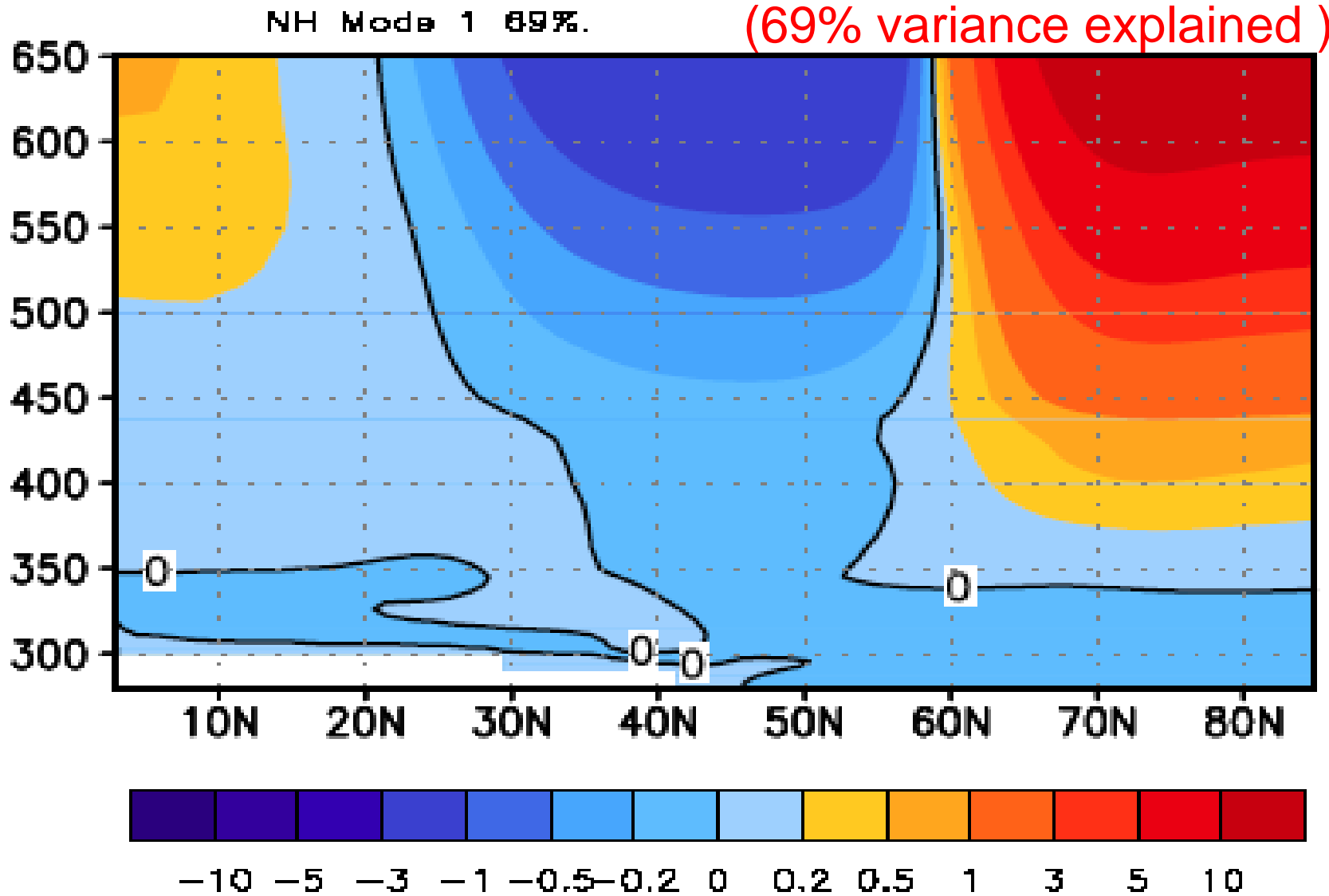
Ren and Cai (2006, AAS)

Cai and Ren (2007, JAS)

Ren and Cai (2007, GRL)

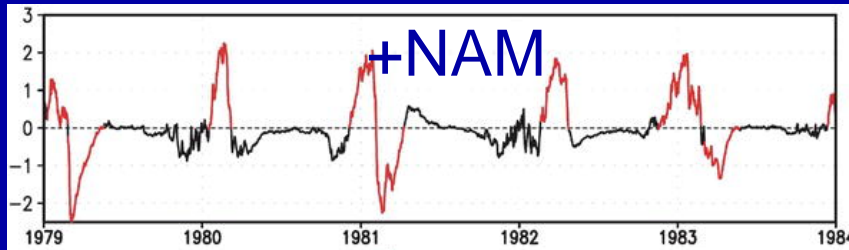
Shin and Cai (ongoing research)

1st EOF of NH daily PV anomalies in Θ -PVLAT coordinate

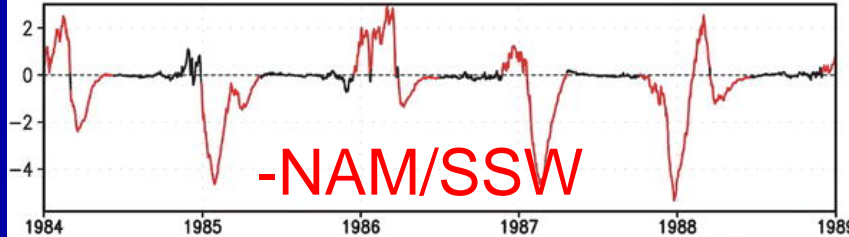


Daily time series of NH Polar vortex oscillation

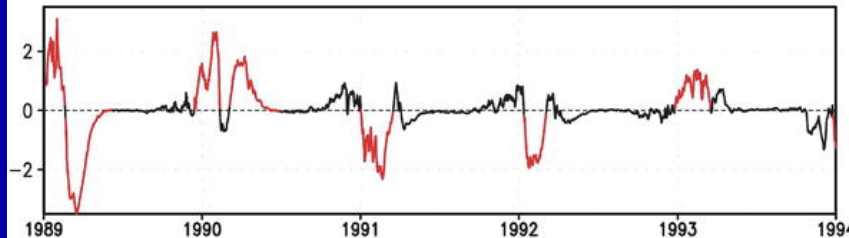
1979-83



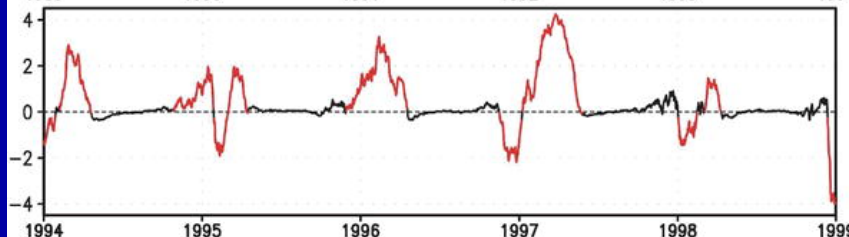
1984-88



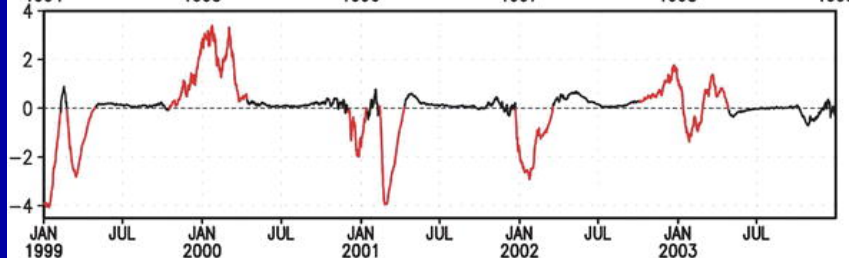
1989-93



1994-98



1998-03



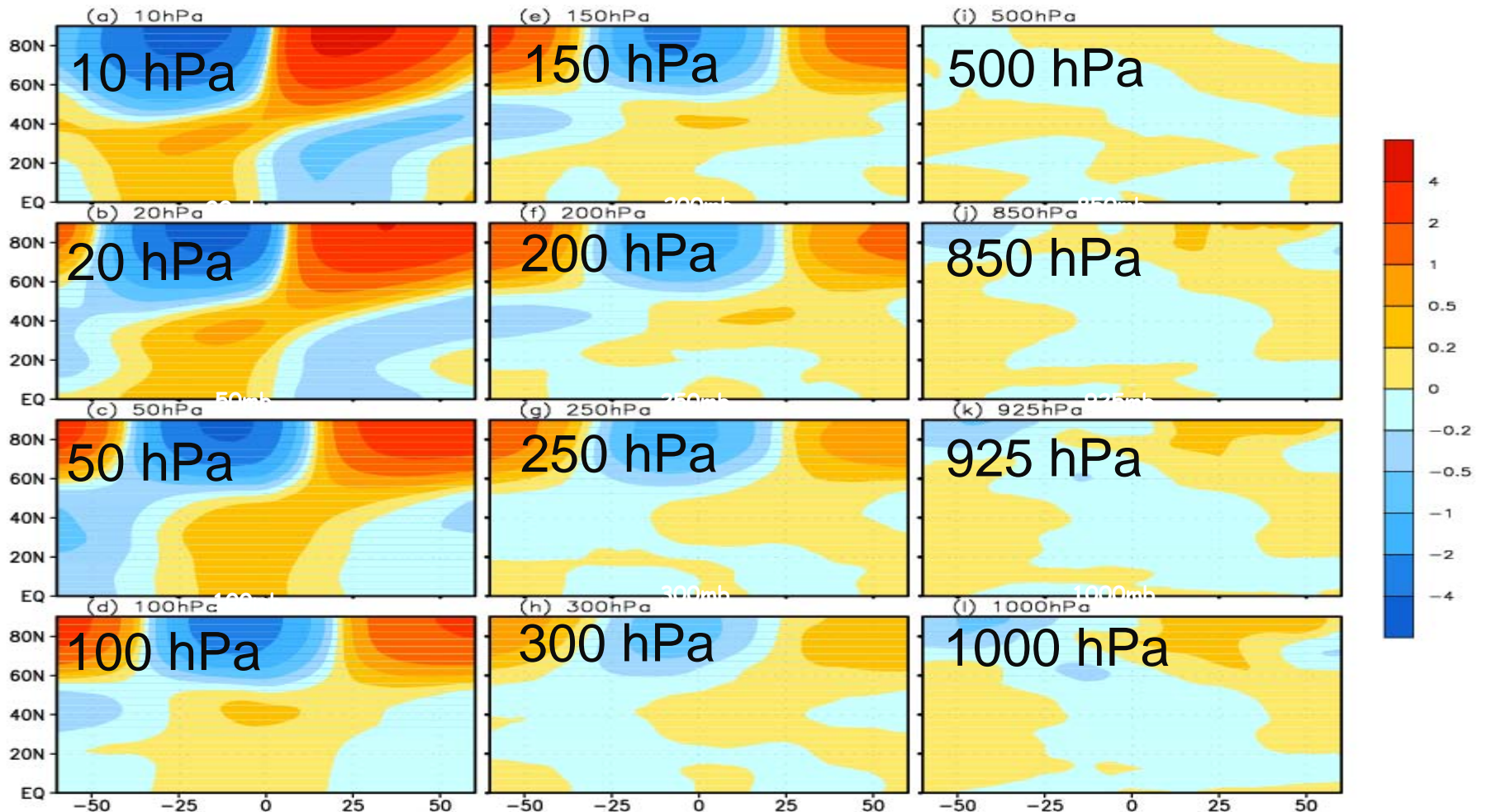
Time

Meridional propagation of thermal anomalies

Upper layers
totally in the ST

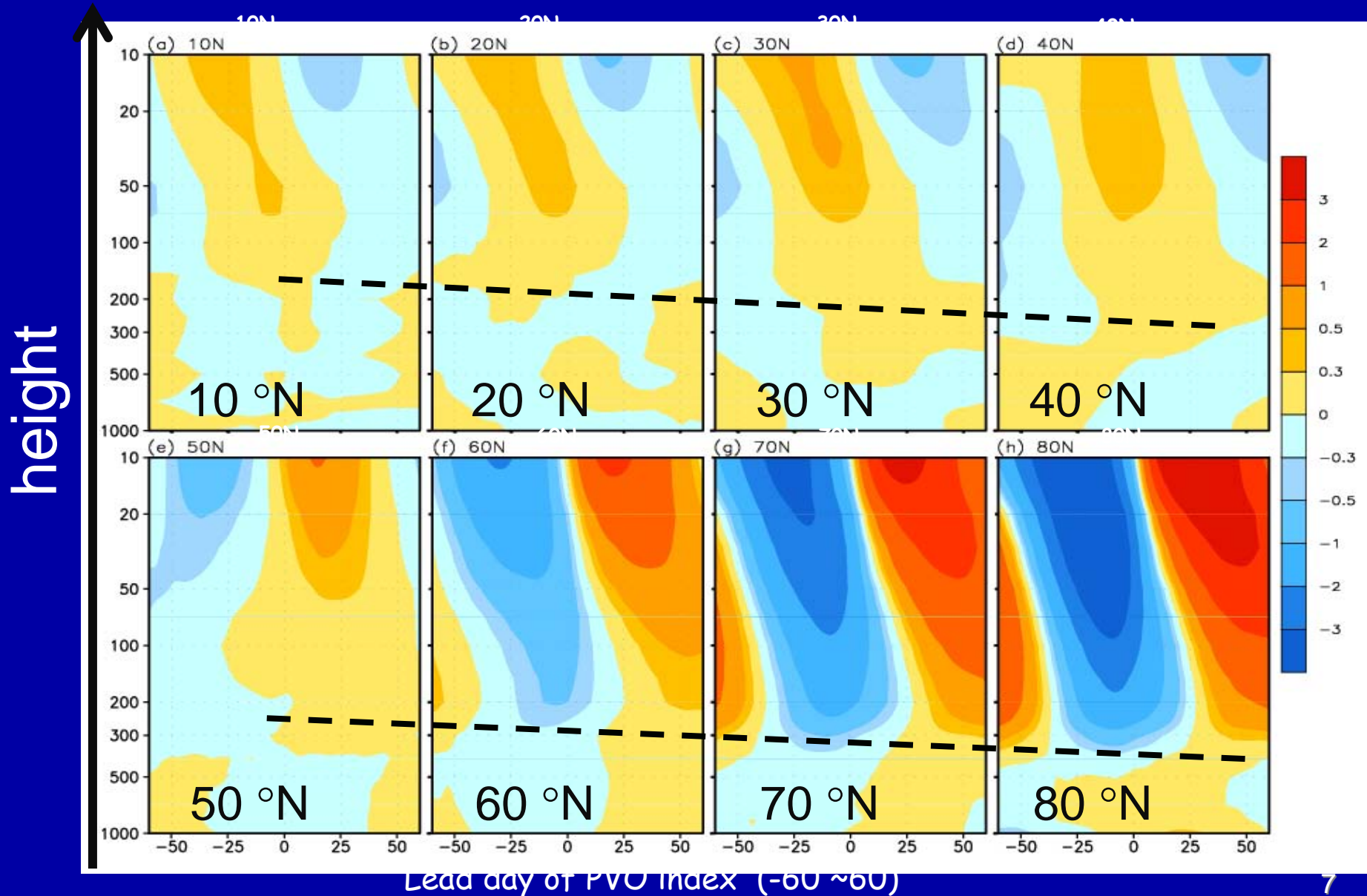
Middle layers across
the Tropopause

Troposphere



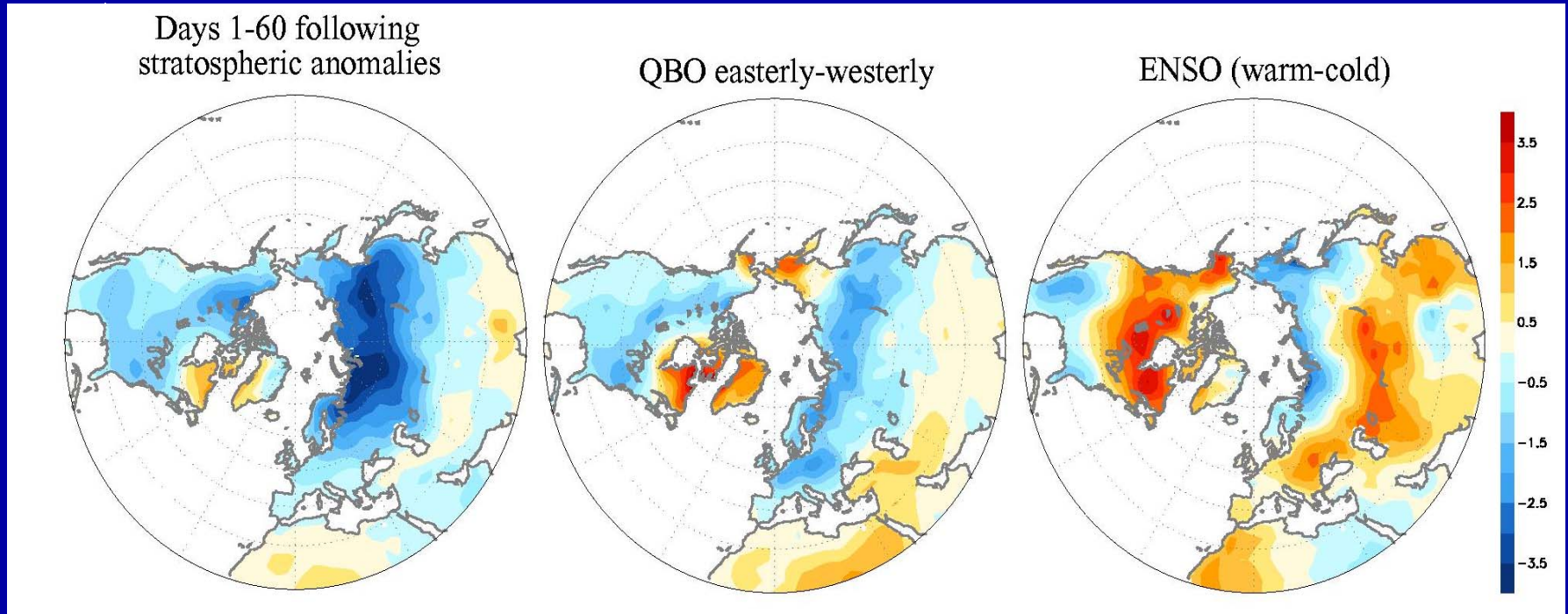
Lead day of PVO index (-60 ~60)

Downward Propagation of thermal anomalies



weaker_vortex minus stronger_vortex

(28 versus 31 cases)



Jan. only

17 Easterly versus 17 Westerly

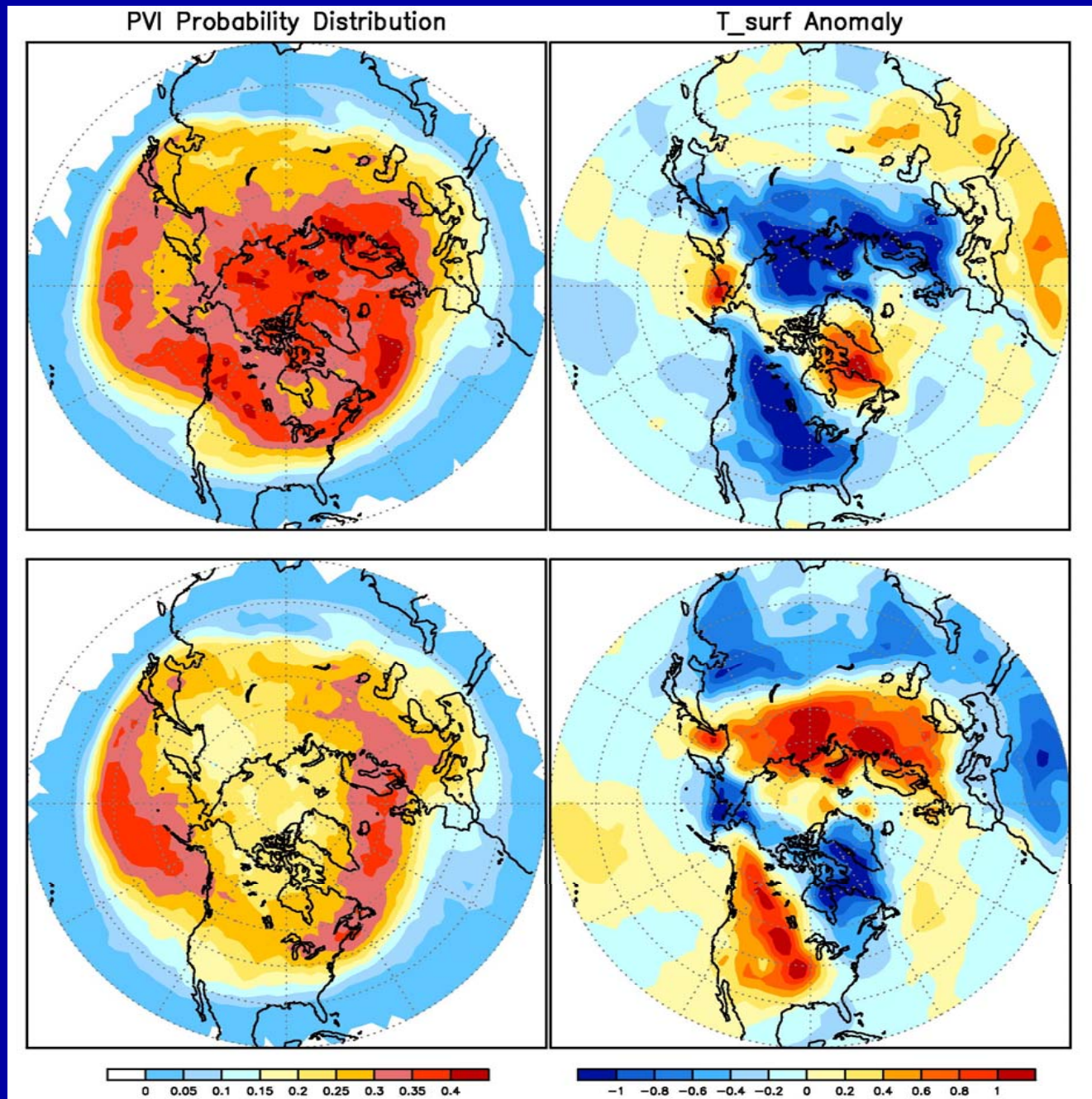
Thompson, Baldwin, and Wallace (JC, 2002)

Neg. NAM
Or High PVI
Index

Winter (DJF)

Pos. NAM,
Low PVI
Index

Cai (2003)



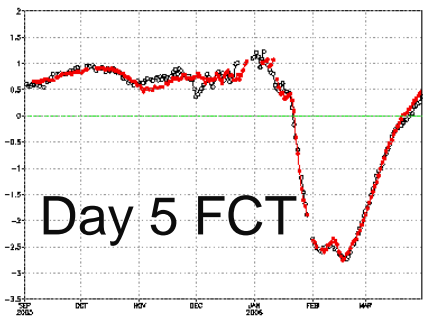
NCEP Operational GFS Prediction Skill for Stratospheric Variability (T382L64)

Day 1 through Day 16 FCT
from 09/01/2005 to 04/30/2007

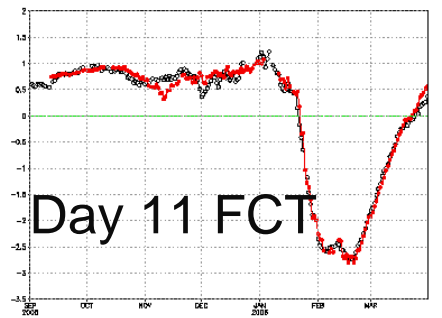
Forecasting PVO index (2005~2006 winter)



Analysis



Day 5 FCT

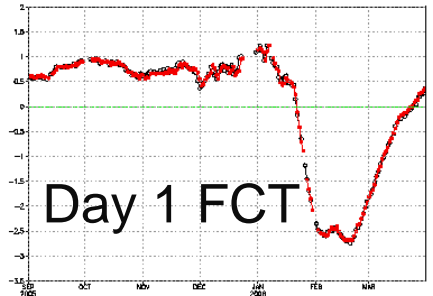


Day 11 FCT

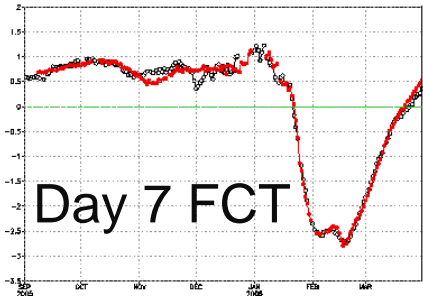
Fct01(red) & Analysis(black)

Fct07(red) & Analysis(black)

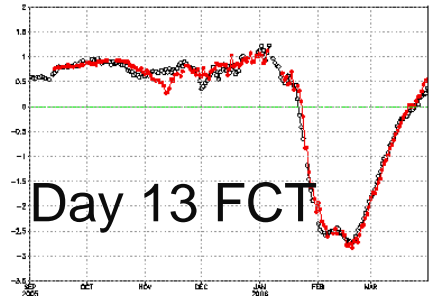
Fct13(red) & Analysis(black)



Day 1 FCT



Day 7 FCT

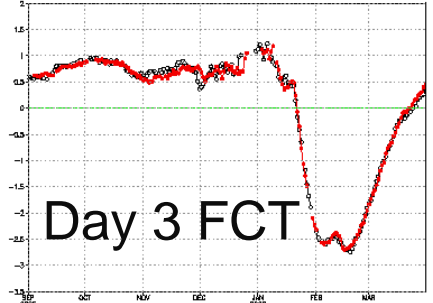


Day 13 FCT

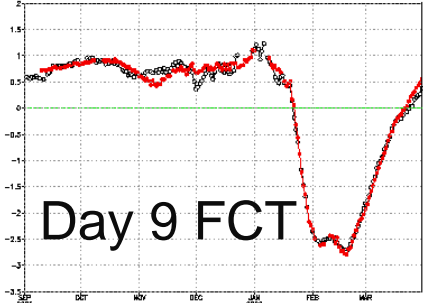
Fct03(red) & Analysis(black)

Fct09(red) & Analysis(black)

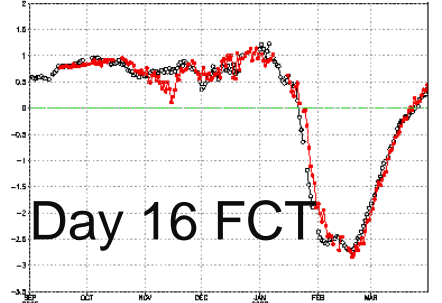
Fct16(red) & Analysis(black)



Day 3 FCT



Day 9 FCT



Day 16 FCT

S O N D J F M

S O N D J F M

S O N D J F M

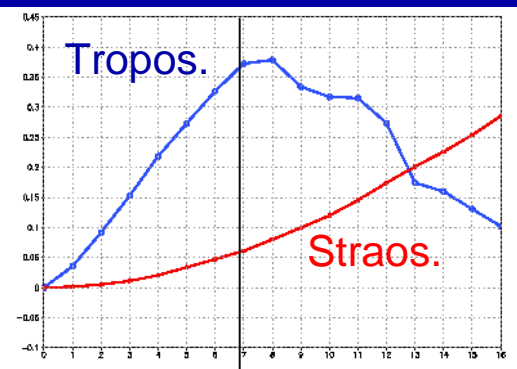
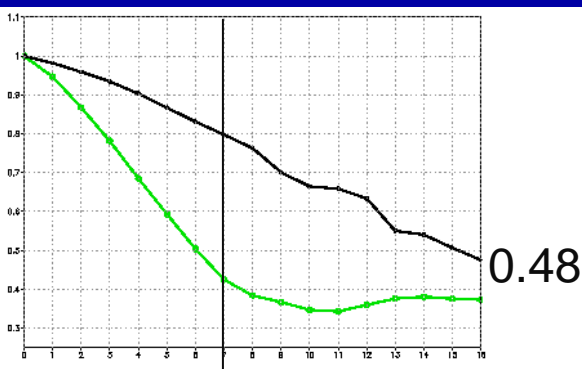
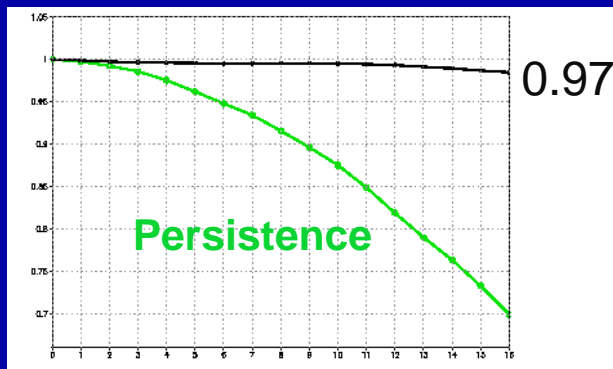
Prediction Skill of the PVO index

AC

Stratosphere

Troposphere

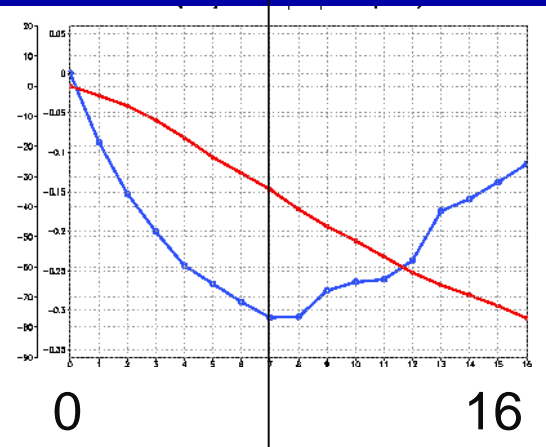
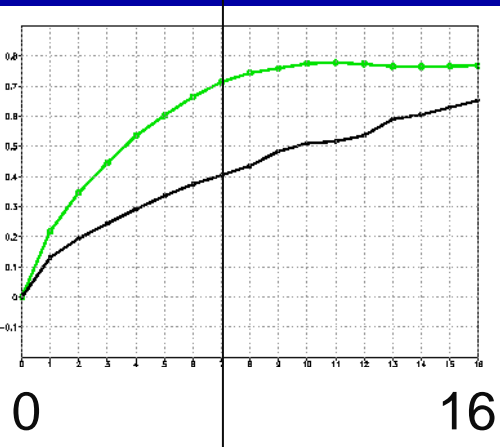
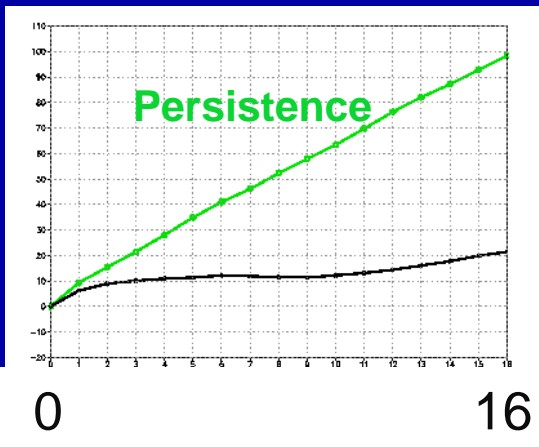
Relative to persistence



RMSE



FCT lead time (days)



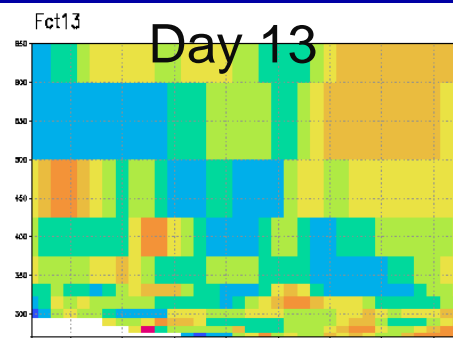
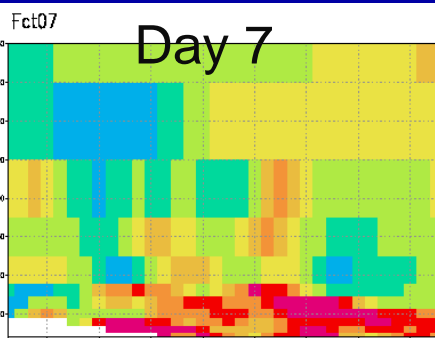
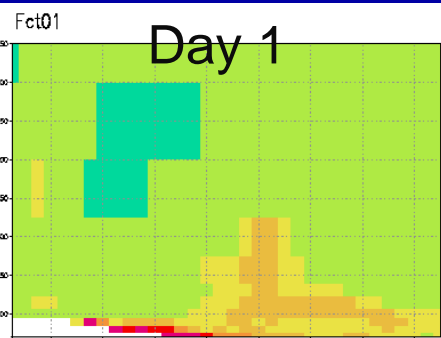
Day 7

Day 7

AC skill relative to the persistent forecasts

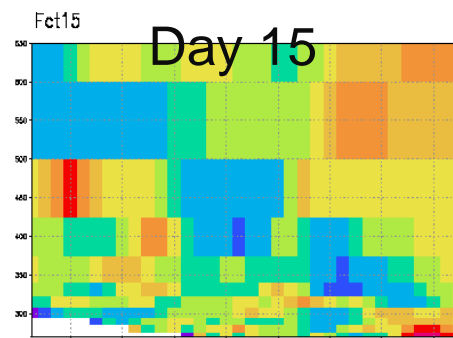
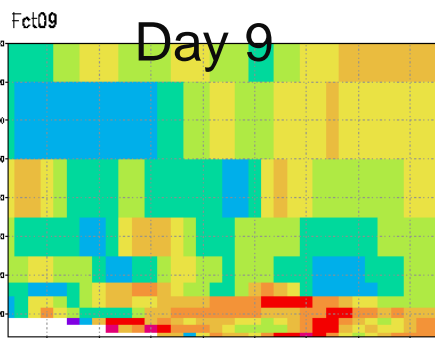
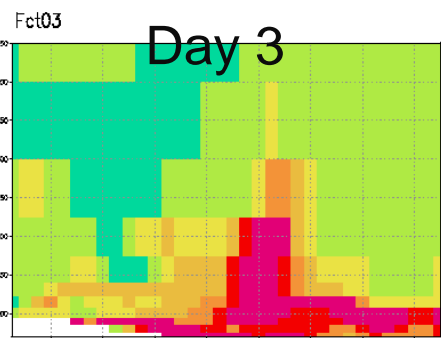
2005~2006 winter

650 K



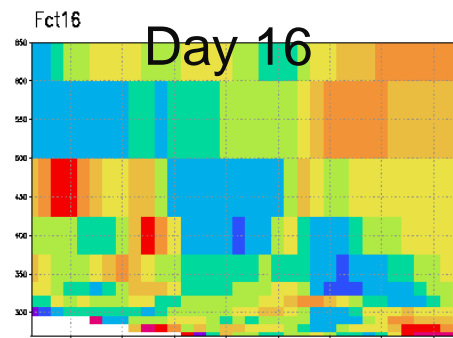
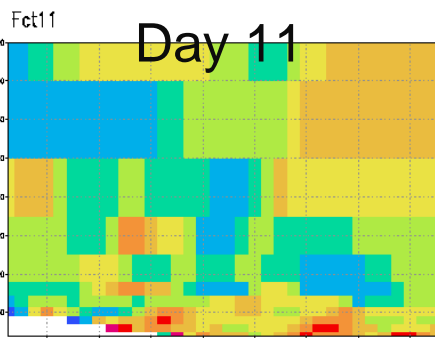
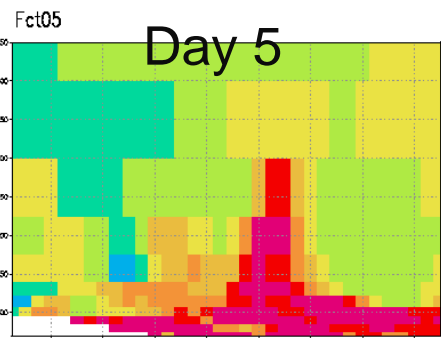
270 K

650 K



270 K

650 K



270 K

EQ

NP

EQ

NP

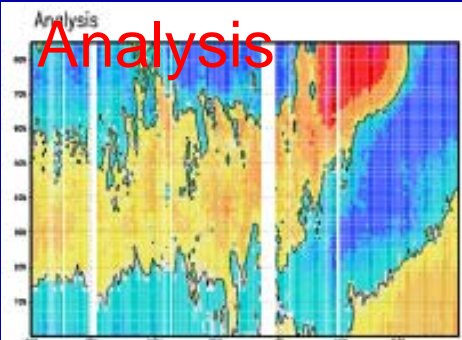
EQ

NP 13

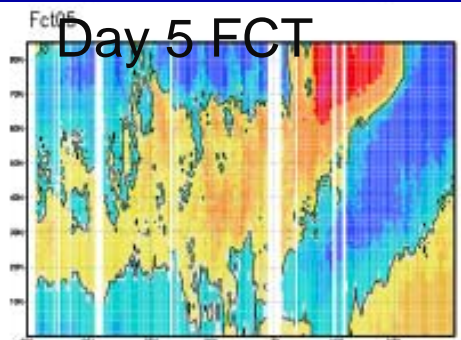
Temporal evolution of observed and forecasted temperature anomaly (2005~2006 winter)

NP

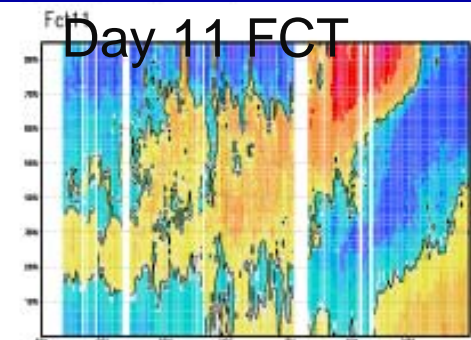
Analysis



Day 5 FCT

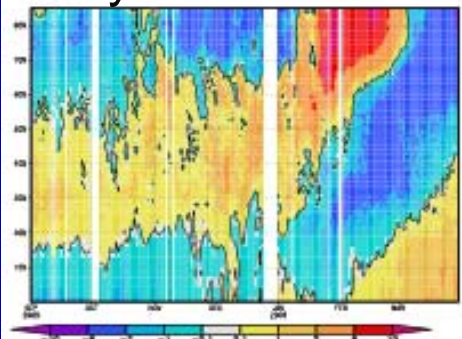


Day 11 FCT

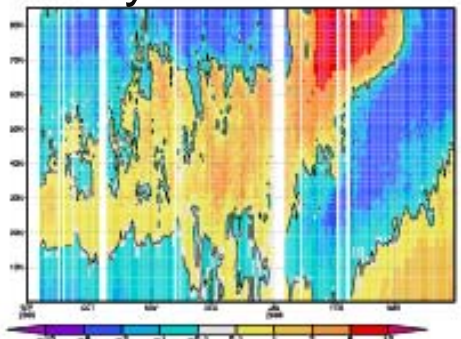


EQ

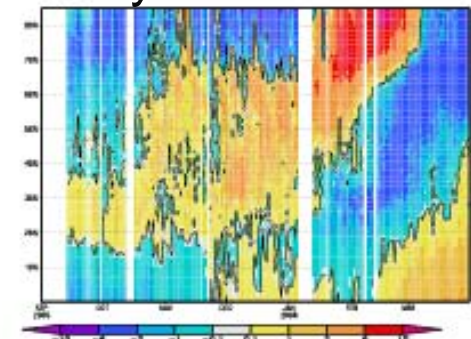
Day 1 FCT



Day 7 FCT



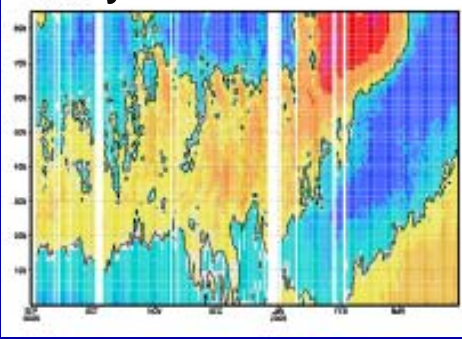
Day 13 FCT



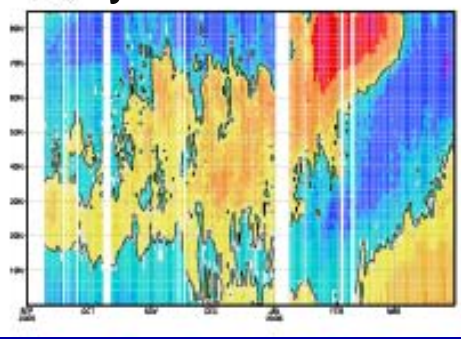
NP

EQ

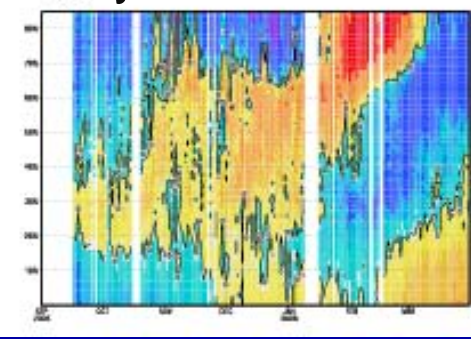
Day 3 FCT



Day 9 FCT



Day 16 FCT



NP

EQ

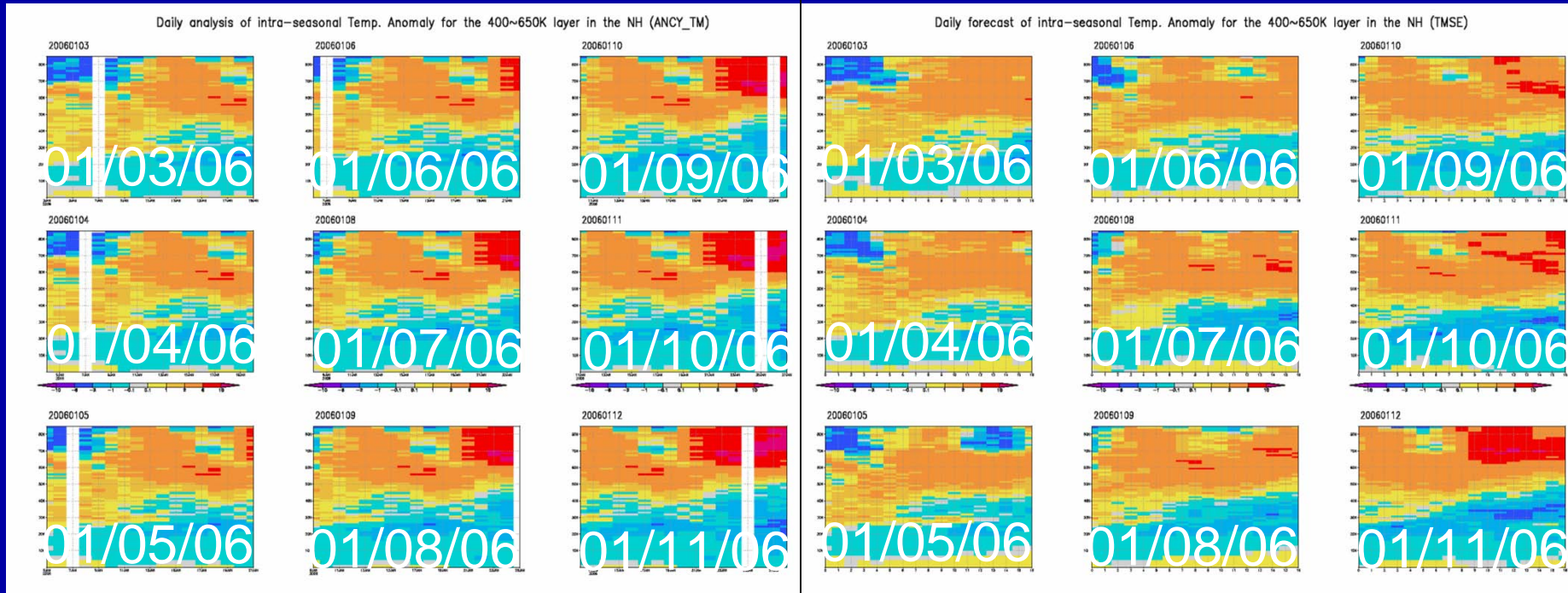
S O N D J F M

S O N D J F M

S O N D J F M

The cases of arrival of warm anomalies (01/03/2006 - 01/11/2006)

Latitude



Time (day 0 - day 16)

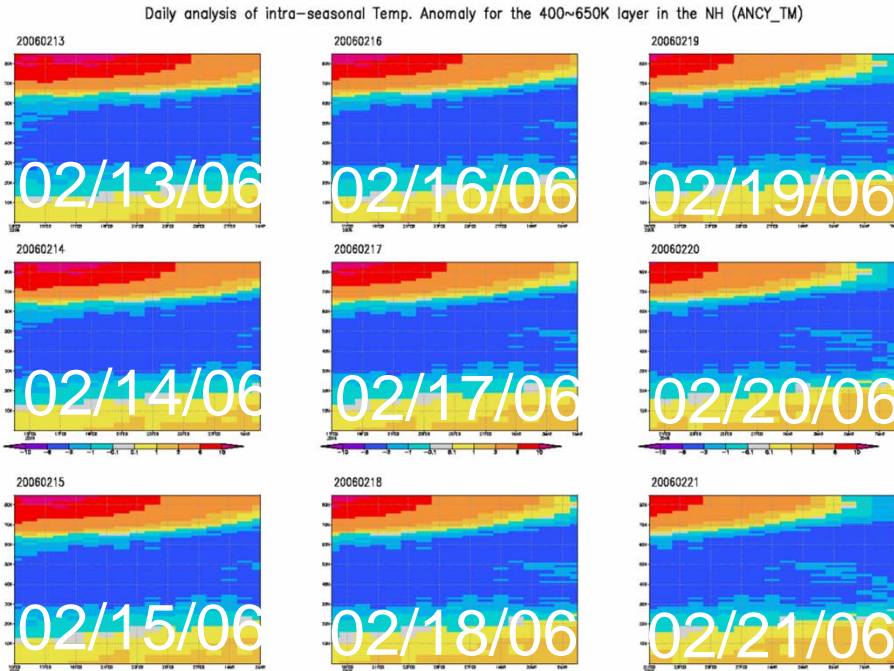
Observation

Time (day 0 - day 16)

Forecast

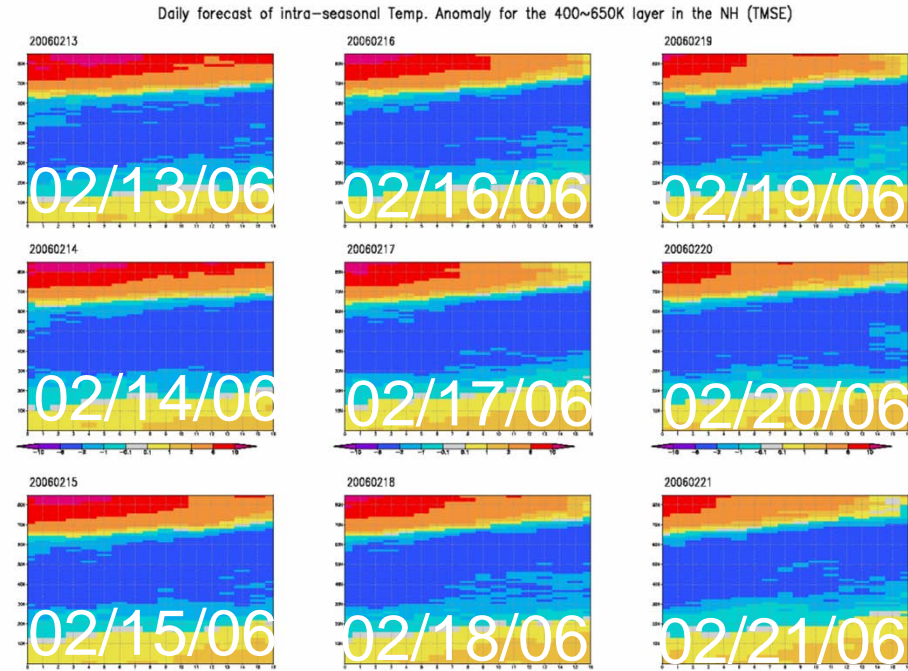
The cases of arrival of cold anomalies (02/12/2006 - 02/21/2006)

Latitude



Time (day 0 - day 16)

Observation



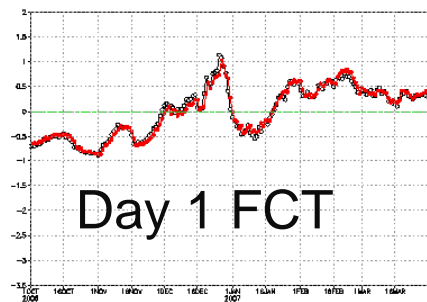
Time (day 0 - day 16)

Forecast

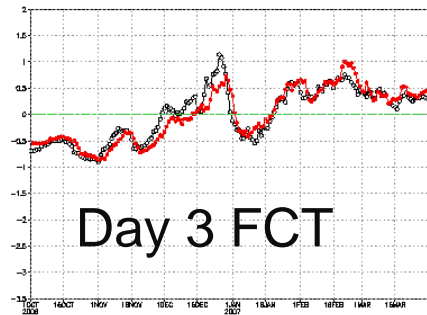
Forecasting PVO index (2006~2007 winter)



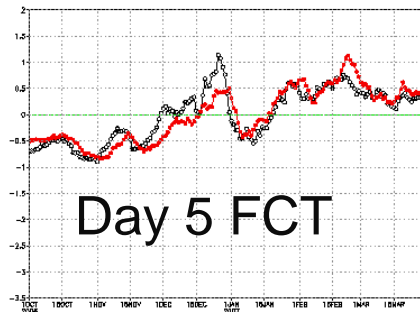
Fct01(red) & Analysis(black)



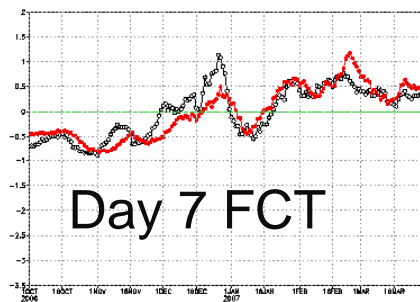
Fct03(red) & Analysis(black)



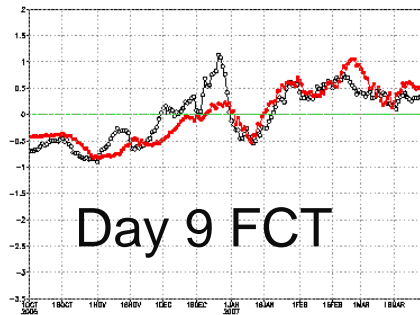
O N D J F M



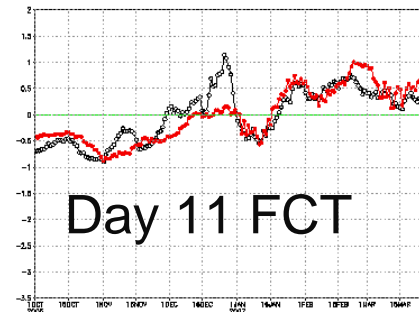
Fct07(red) & Analysis(black)



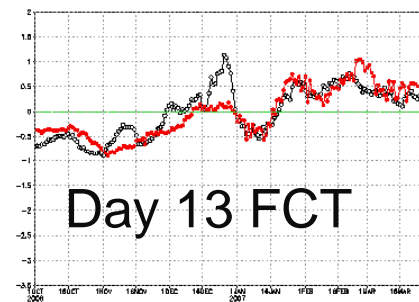
Fct09(red) & Analysis(black)



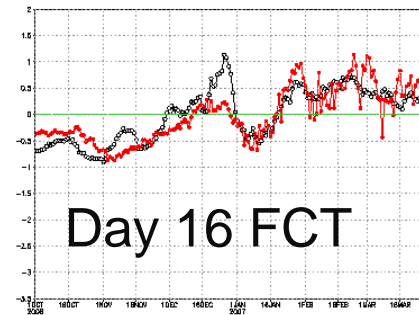
O N D J F M



Fct13(red) & Analysis(black)



Fct16(red) & Analysis(black)



O N D J F M

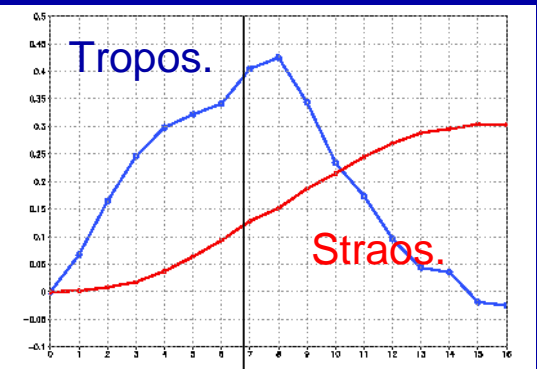
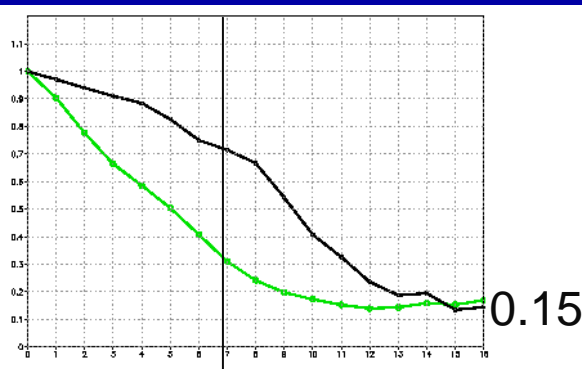
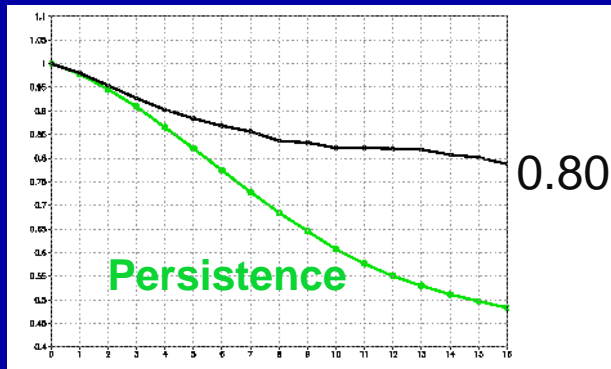
Prediction Skill of the PVO index

AC

Stratosphere

Troposphere

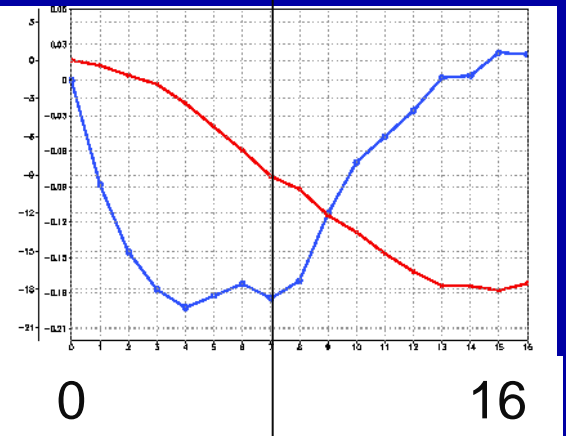
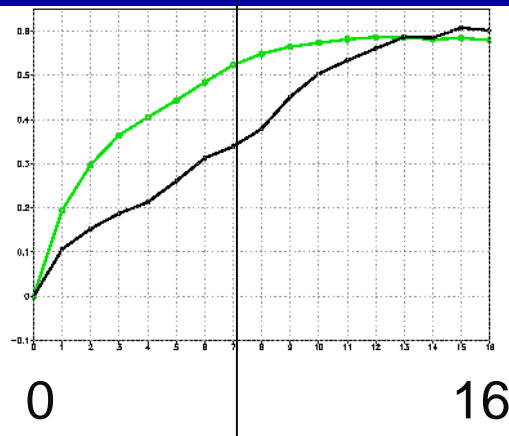
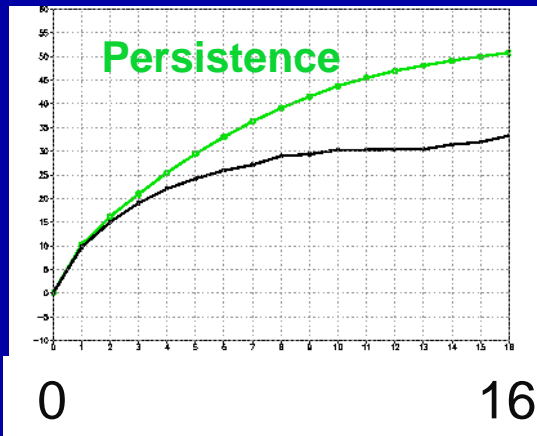
Relative to persistence



RMSE



FCT lead time (days)



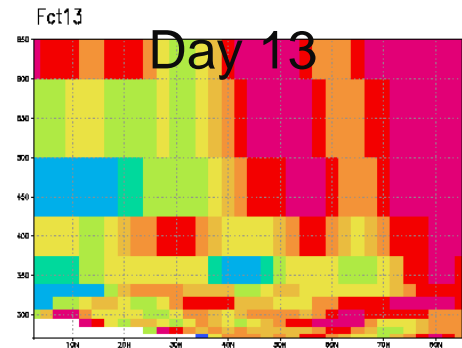
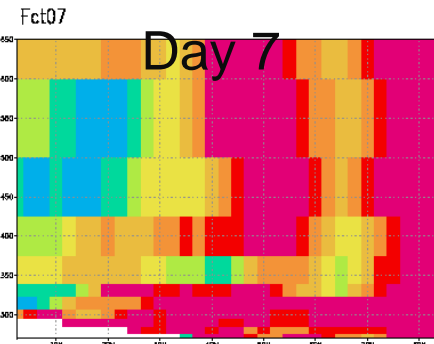
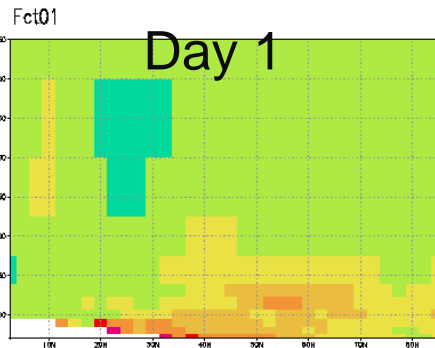
Day 7

Day 7

AC skill relative to the persistent forecasts

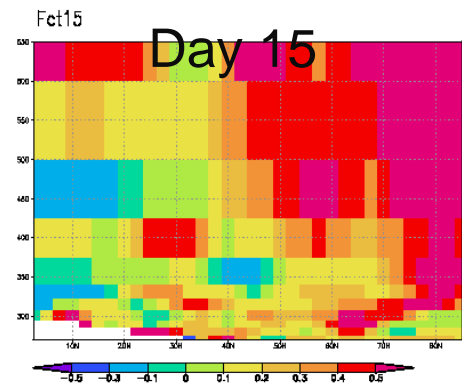
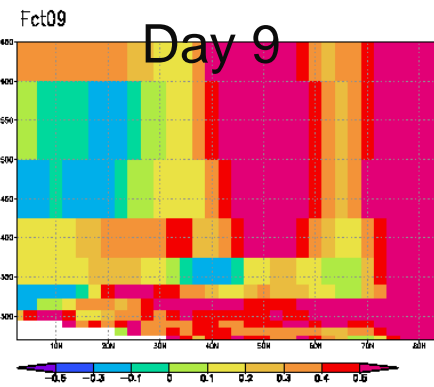
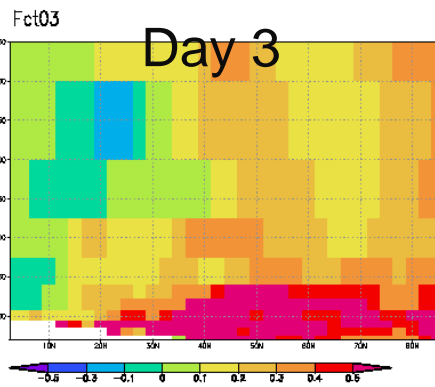
2006~2007 winter

650 K



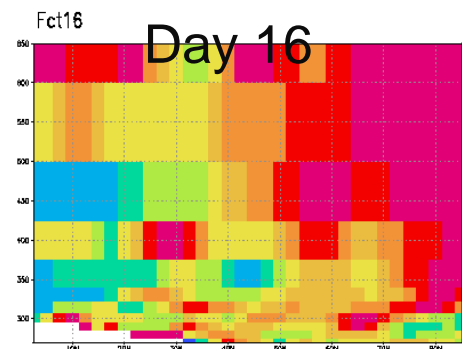
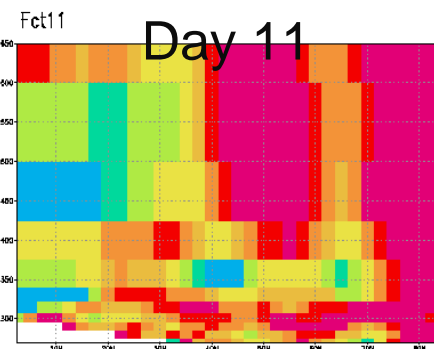
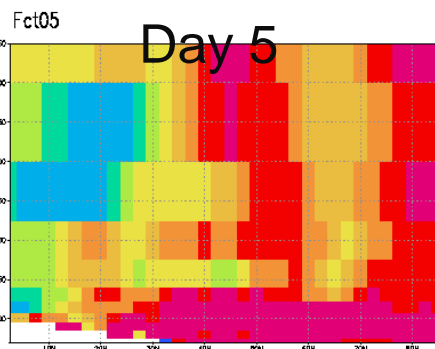
270 K

650 K



270 K

650 K



270 K

EQ

NP

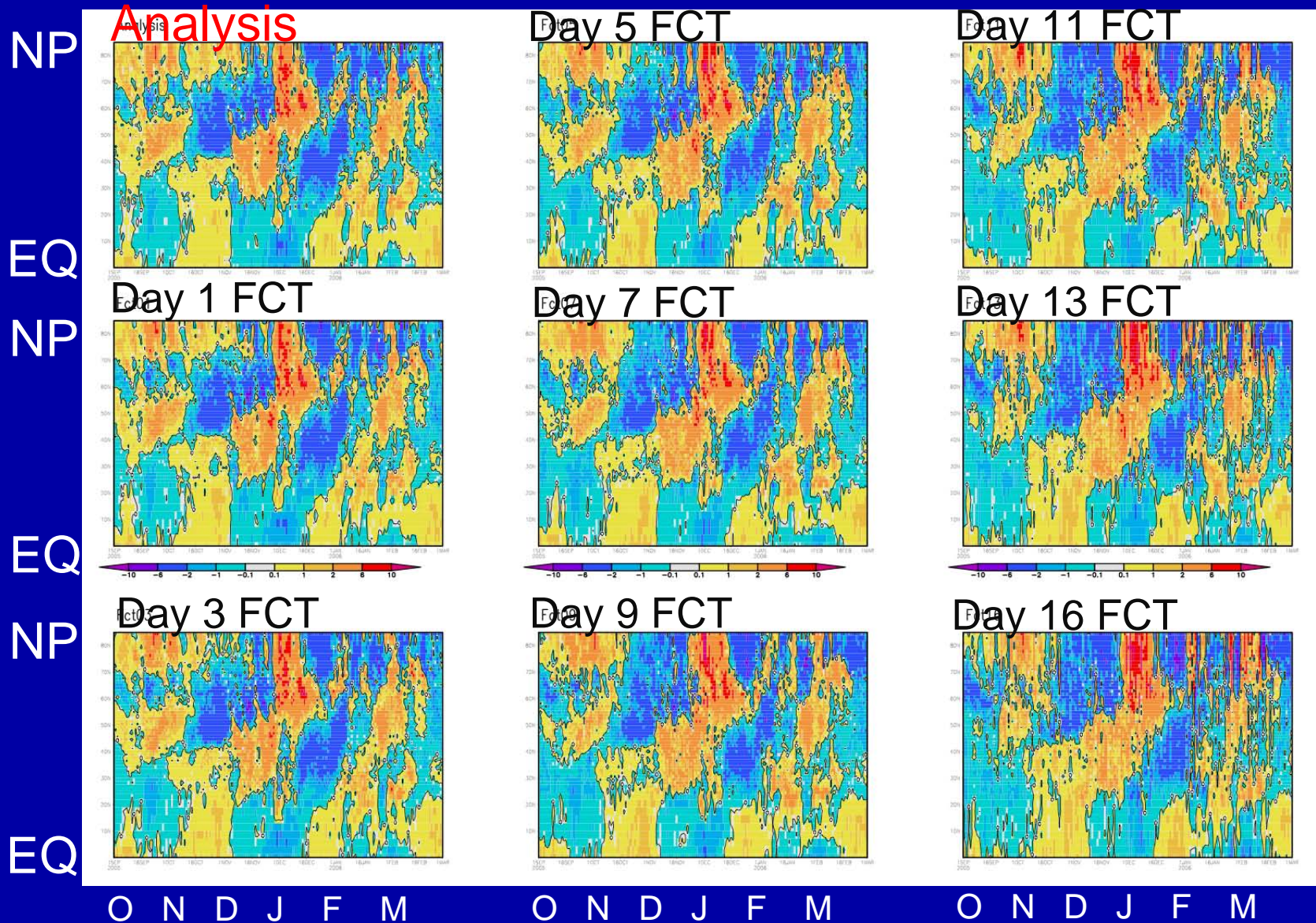
EQ

NP

EQ

NP 19

Temporal evolution of observed and forecasted temperature anomaly (2006~2007 winter)



Summary

- The NCEP operational GFS still has a remarkable prediction skill of (stratospheric) polar vortex oscillation (PVO) index at the lead time of day 16, despite a very poor skill in forecasting tropospheric circulation anomalies beyond day 7.
- The largest gain of prediction skill w.r.t. the persistence is over the stratospheric polar region.
- The remarkable skill comes from the signal of systematic poleward propagation of thermal anomalies from the equator to the pole in the stratosphere associated with the global mass circulation variability (intensity/time scale)