Data assimilation of atmospheric observations of the Earth using ensemble Kalman filter

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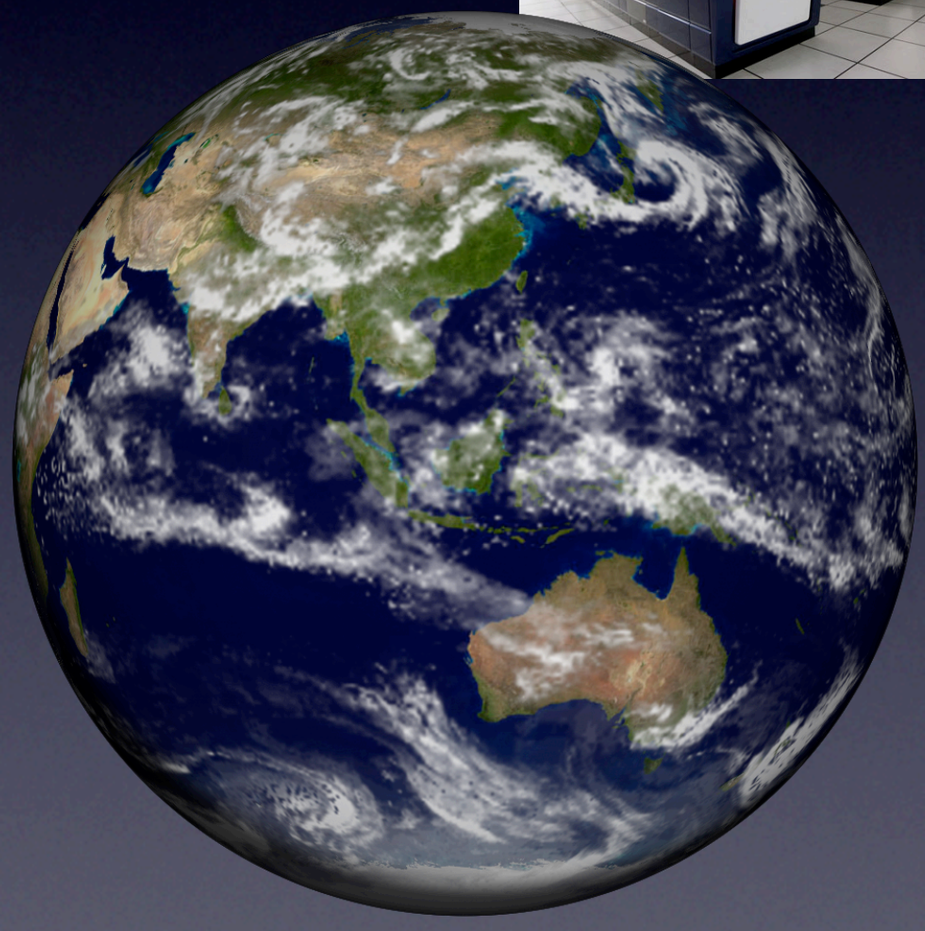
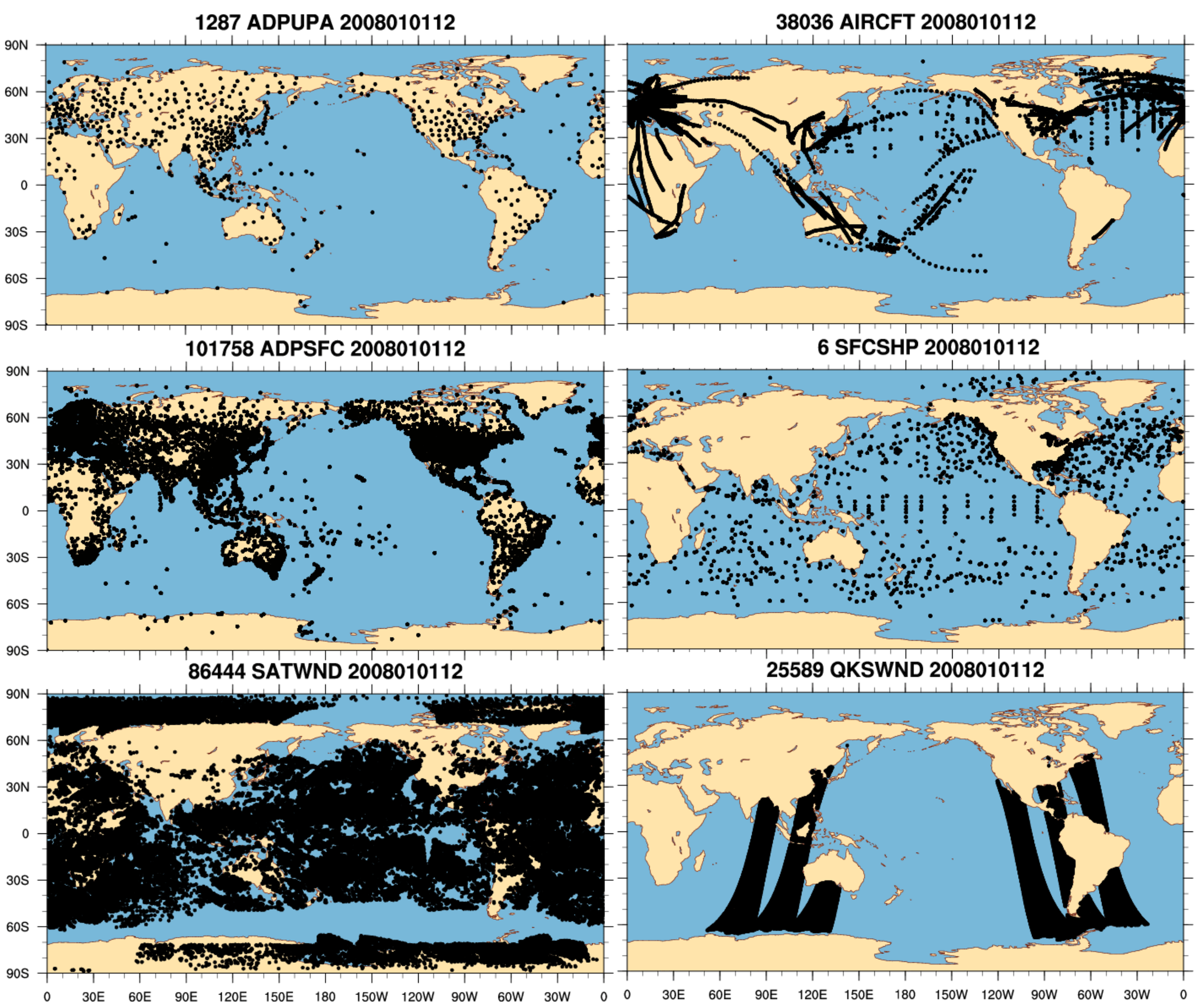
9 April 2012
CPS seminar

Plan of the talk

- Data assimilation
- Mechanisms and predictability
- Evaluation of observations

Observation and forecast




1287 ADPUPA 2008010112
38036 AIRCFT 2008010112
101758 ADPSFC 2008010112
6 SFCSHP 2008010112
86444 SATWND 2008010112
25589 QKSWND 2008010112
90N
60N
30N
0
30S
60S
90S
0
30E
60E
90E
120E
150E
180
150W
120W
90W
60W
30W

Observation and Simulation

	observation	simulation
distribution	inhomogeneous	homogeneous
consistency	individual	model
error	small	large

Data assimilation

- Minimum variance, sequential
  - Optimal interpolation, Ensemble Kalman filter
- Maximum likelyhood, iterative
  - 3DVar, 4DVar

3DVar, 4DVar, EnKF compared

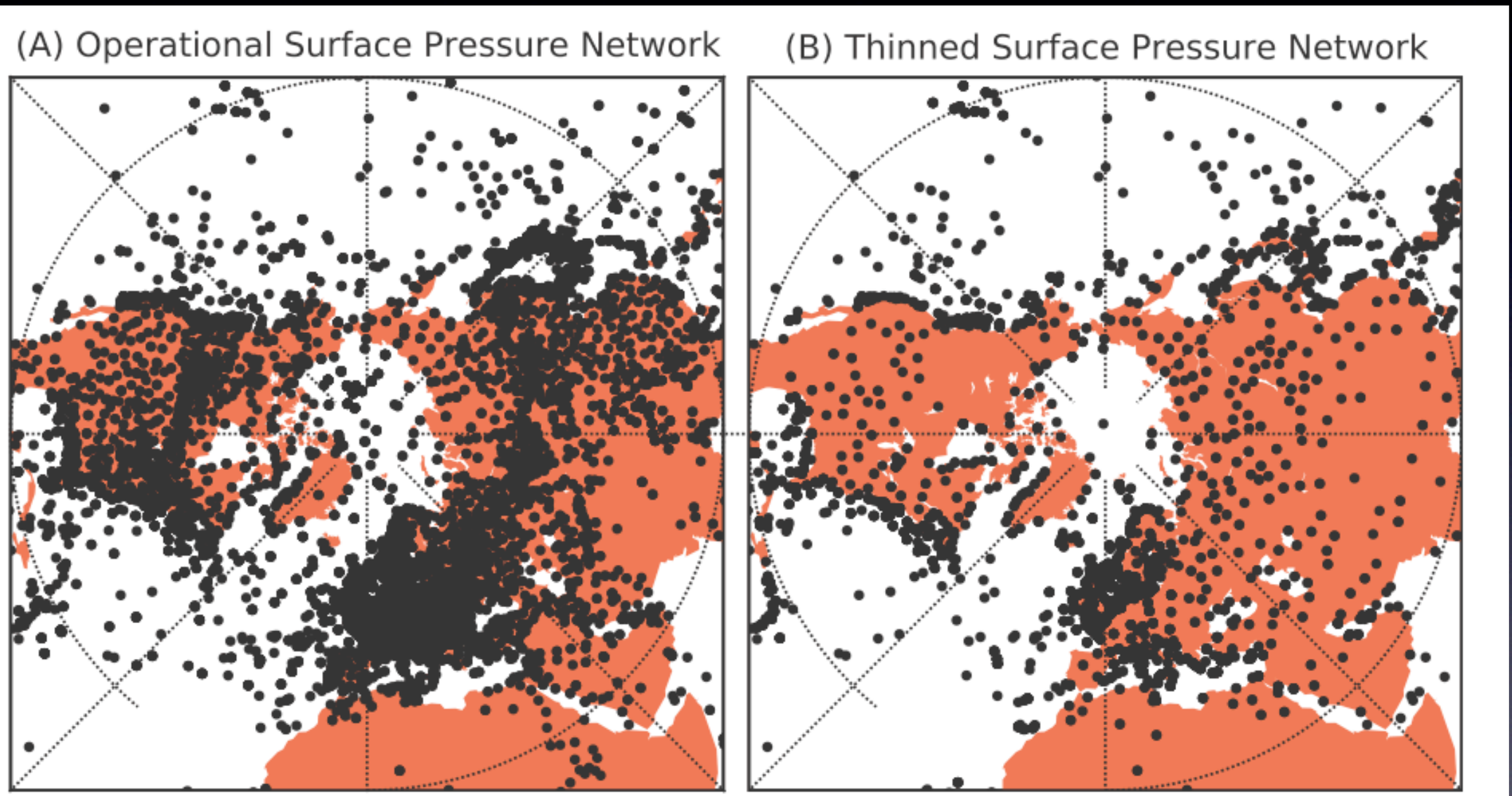


FIG. 1. (a) Operational and (b) thinned surface pressure networks for 0000 UTC 1 Jan 2005.

Whitaker, Compo, Thépaut (2009)

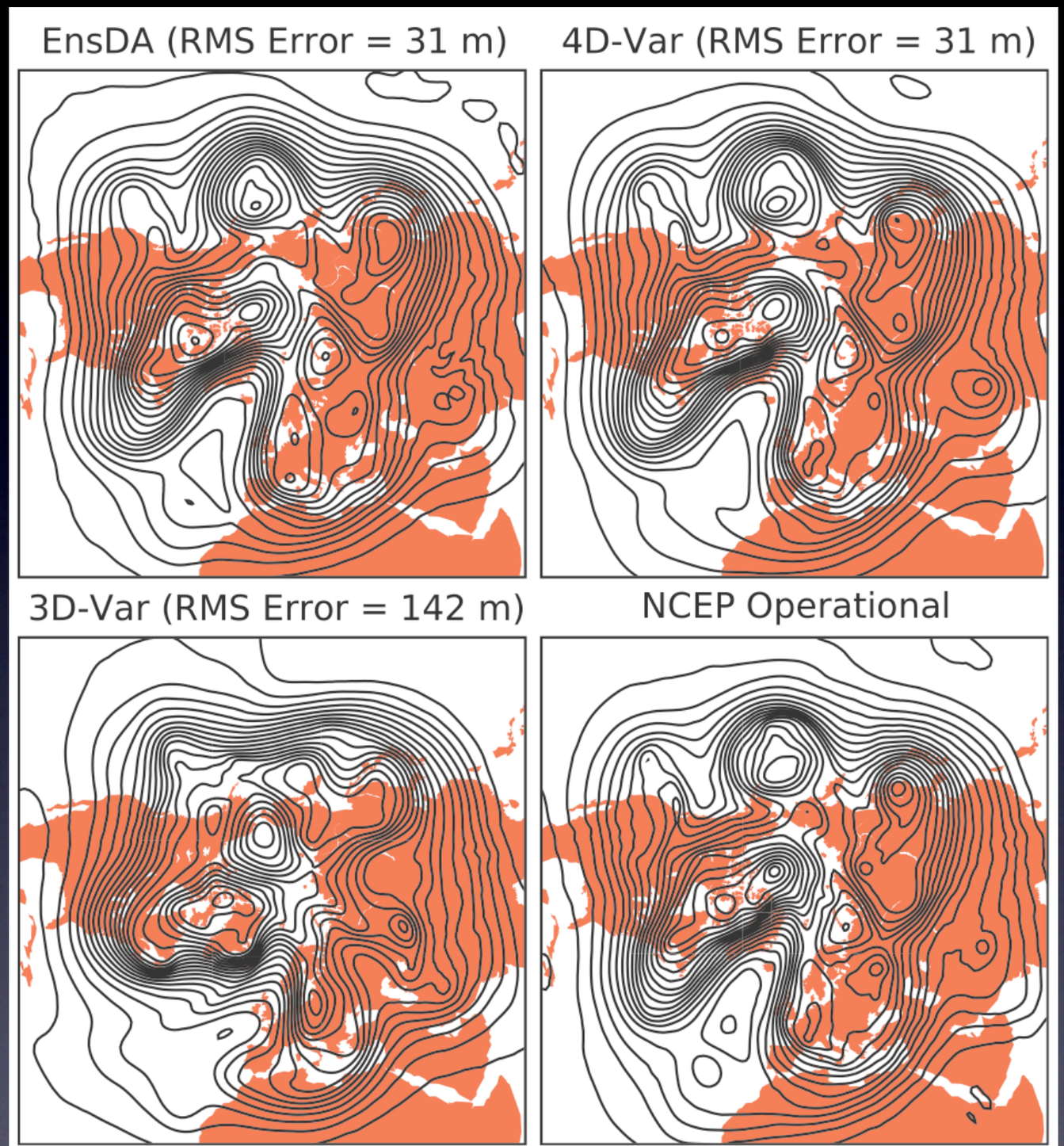
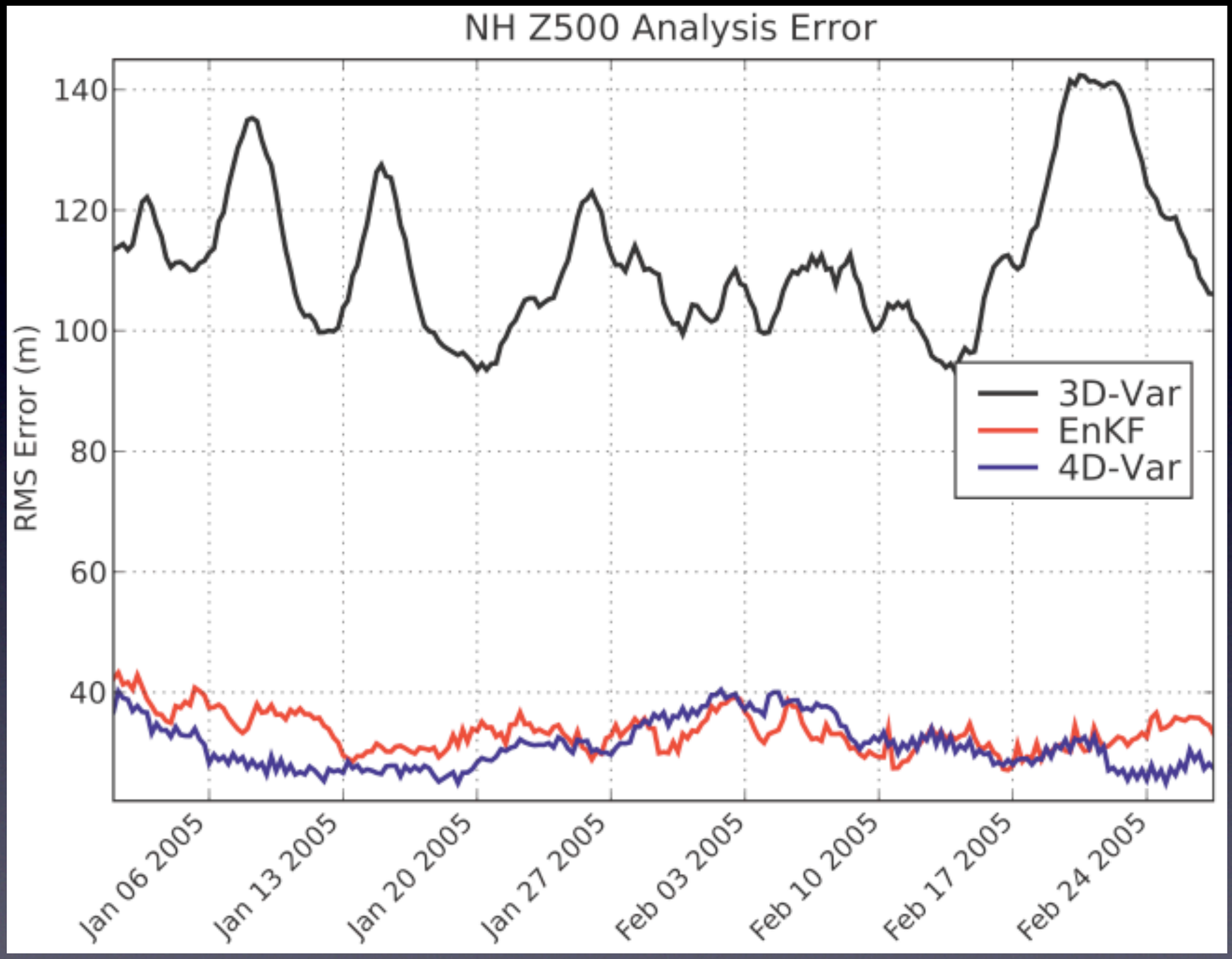


FIG. 3. Example of 500-hPa geopotential height analyses for 1200 UTC 20 Feb 2005. The contour interval is 50 m. The lower-right panel shows the NCEP operational analyses, which used all available observations, and is used as a reference to estimate analysis error. The root-mean-square analysis error in the Northern Hemisphere poleward of 20°N is noted in each panel.

Whitaker, Compo, Thépaut (2009)

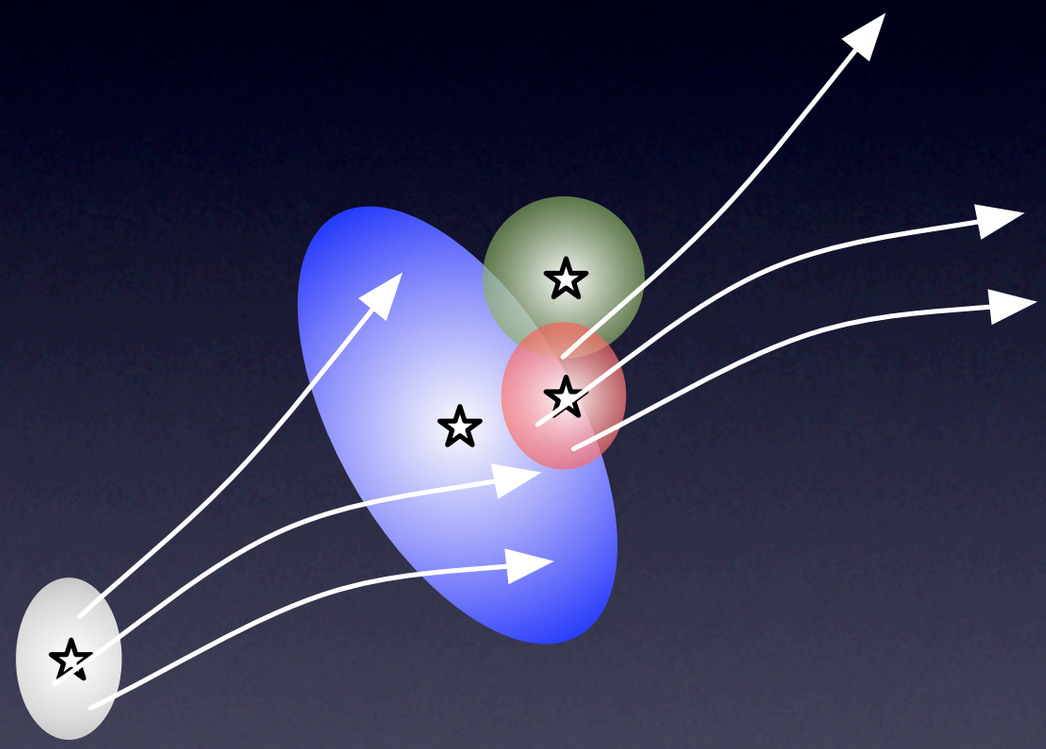


Whitaker, Compo, Thépaut (2009)

LETKF

Local Ensemble Transform Kalman Filter

- Weighted average
- Assimilate observations into the mean
- The analysis error covariance is the linear combination of the forecast error covariance
- Local analysis



LETKF: Hunt et al. 2007; Miyoshi and Yamane 2007; Miyoshi et al. 2007

ALERA

ALERA

AFES-LETKF experimental reanalysis

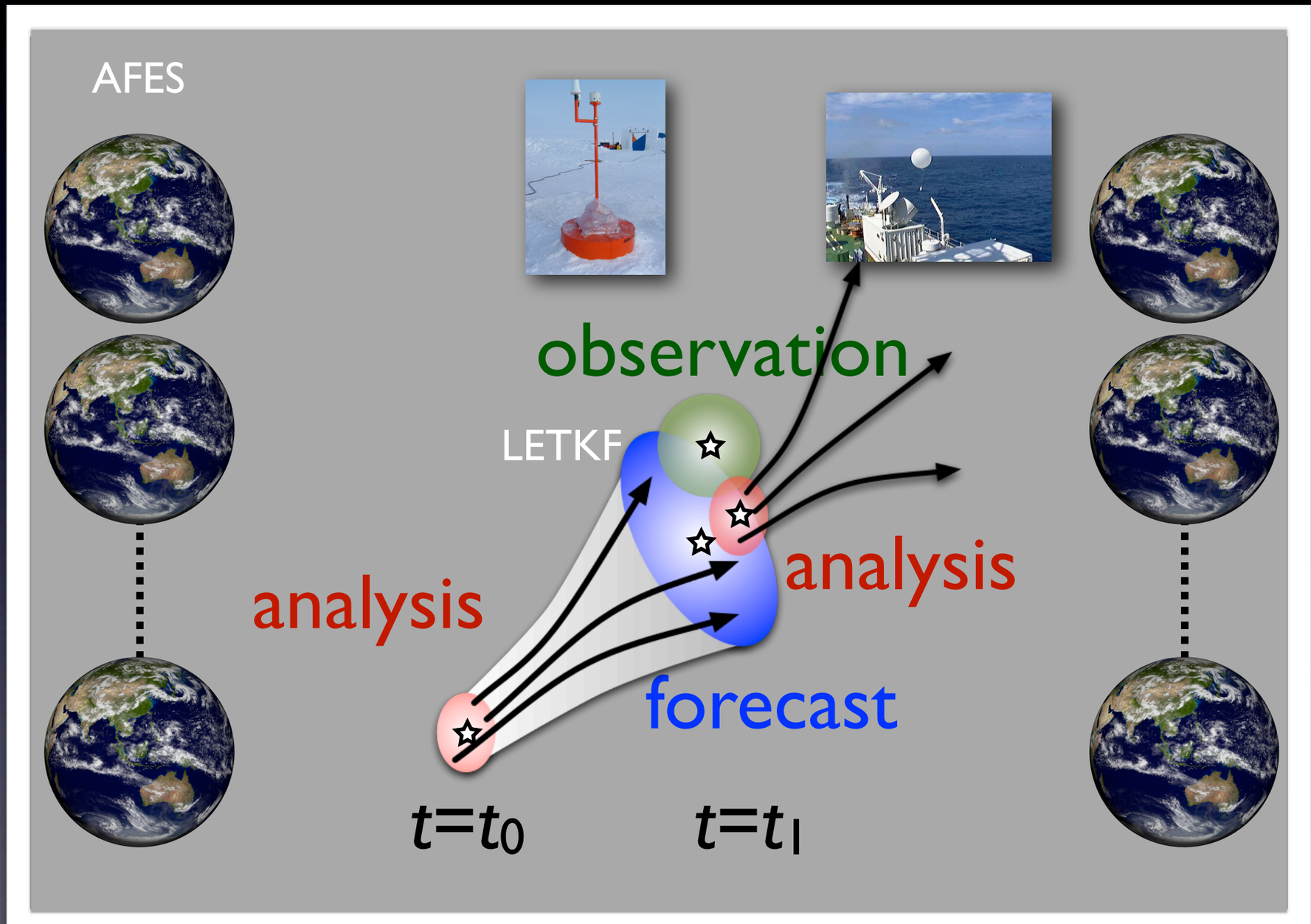
- first application of LETKF to full AGCM
- provides analysis ensemble spread as error estimates
- a product of collaboration among JMA, JAMSTEC and CIS

ALERA: specifications

- Observations used in NWP at JMA
- AFES T159L48M40
- from 18UTC 1 May 2005 to 12UTC 11 Jan 2007
- *u, v, T, T–Td, z*, slp
- available from the Earth Simulator Center
  http://www.jamstec.go.jp/esc/afes/alera/

Hunt et al. 2007; Miyoshi and Yamane 2007; Miyoshi et al. 2007a

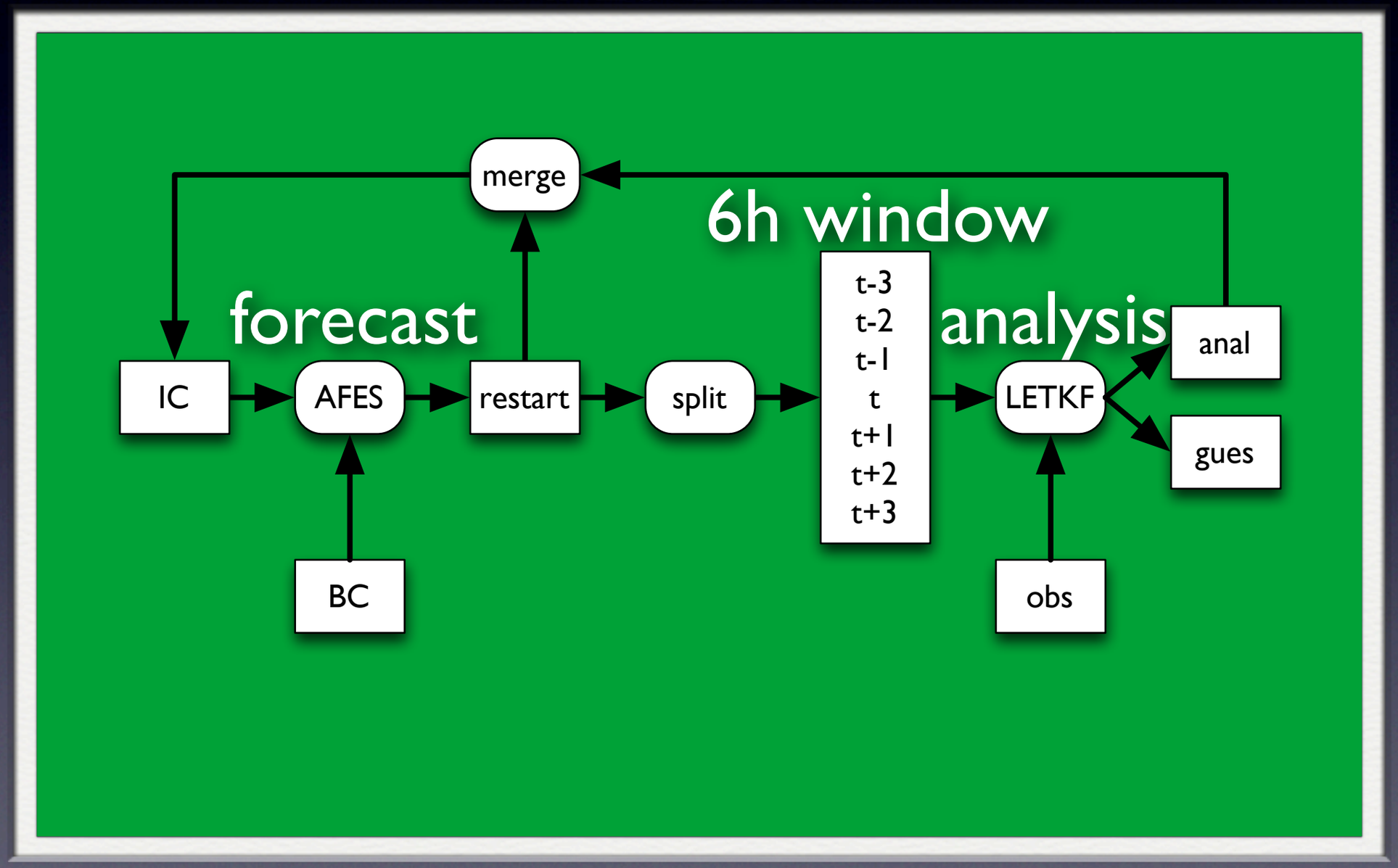
ALEDAS: AFES-LETKF Ensemble Data Assimilation System

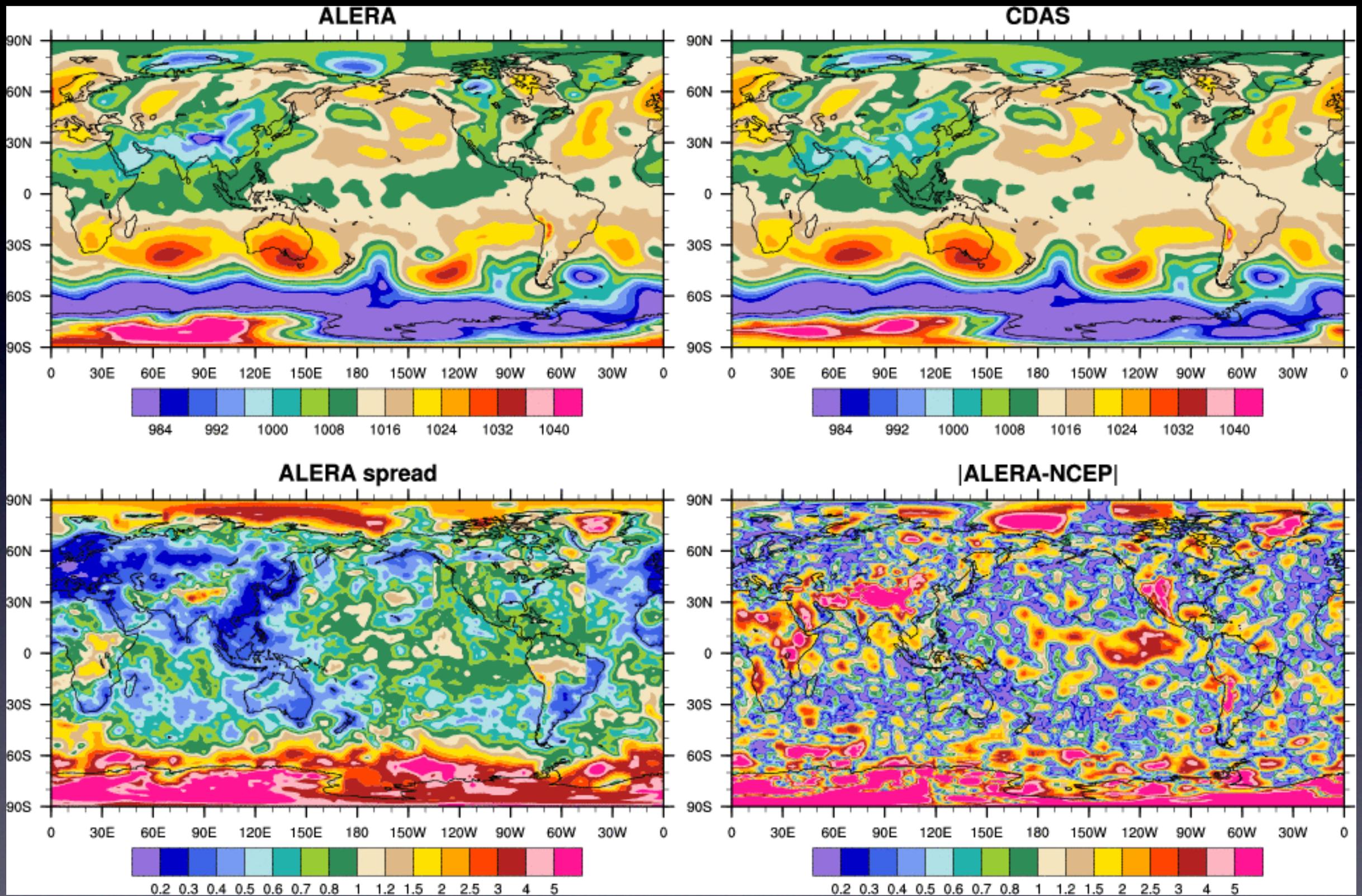


LETKF: Hunt et al. 2007; Miyoshi and Yamane 2007; Miyoshi et al. 2007

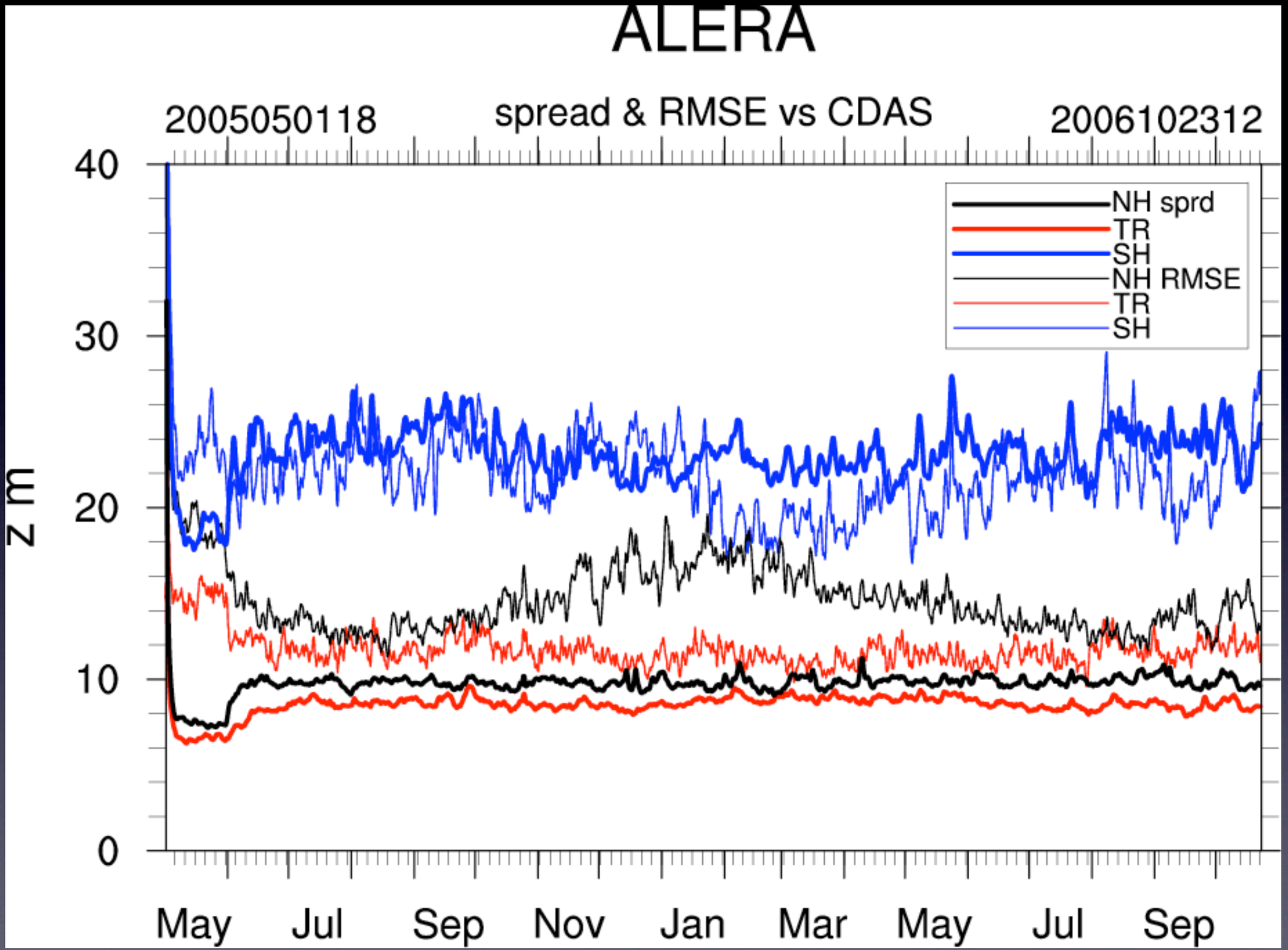
AFES: Numaguti et al. 1997; Ohfuchi et al. 2004; Enomoto et al. 2008

Forecast–Analysis Cycle





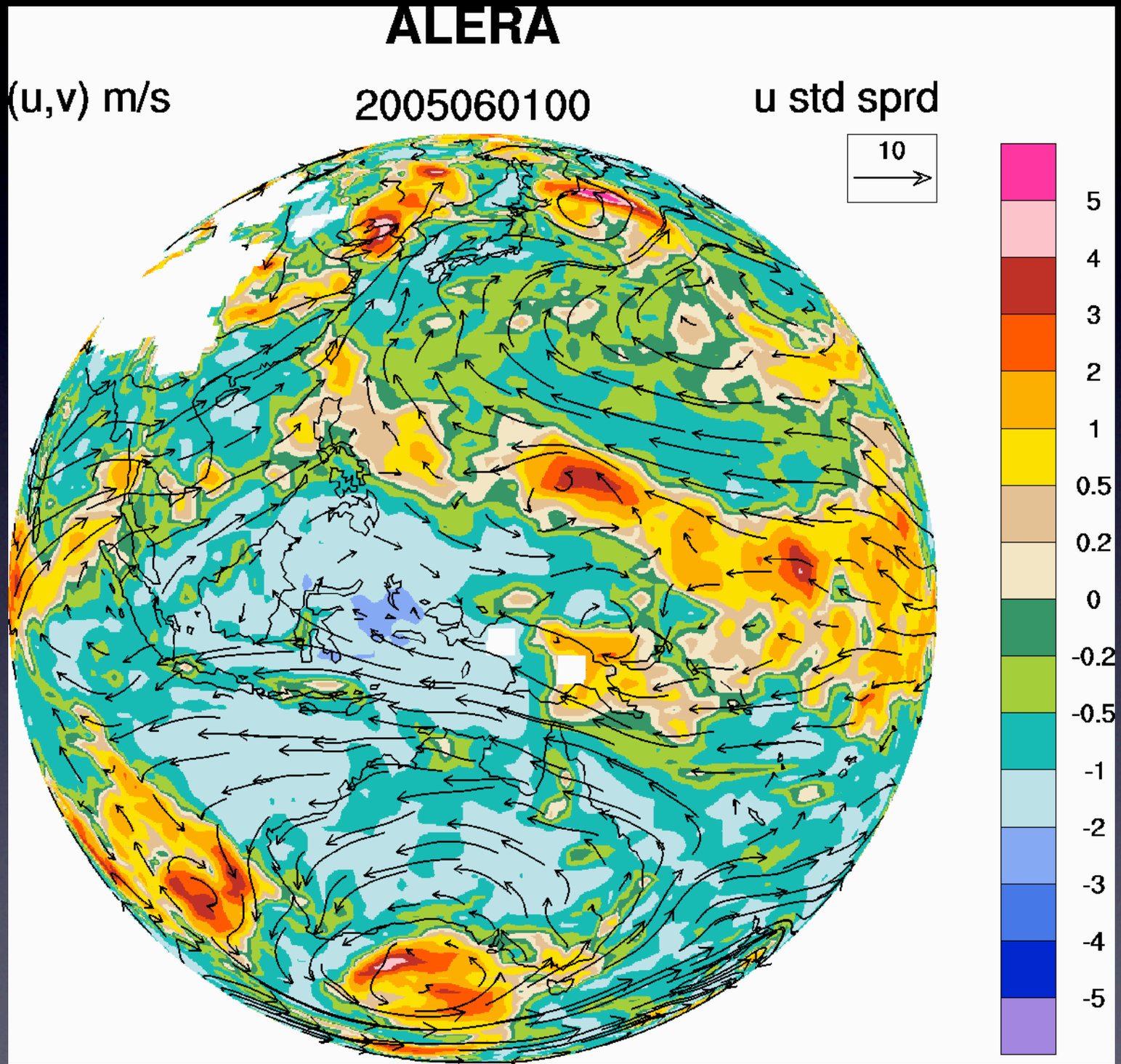
Miyoshi et al. 2007a



Miyoshi et al. 2007a

Typhoons

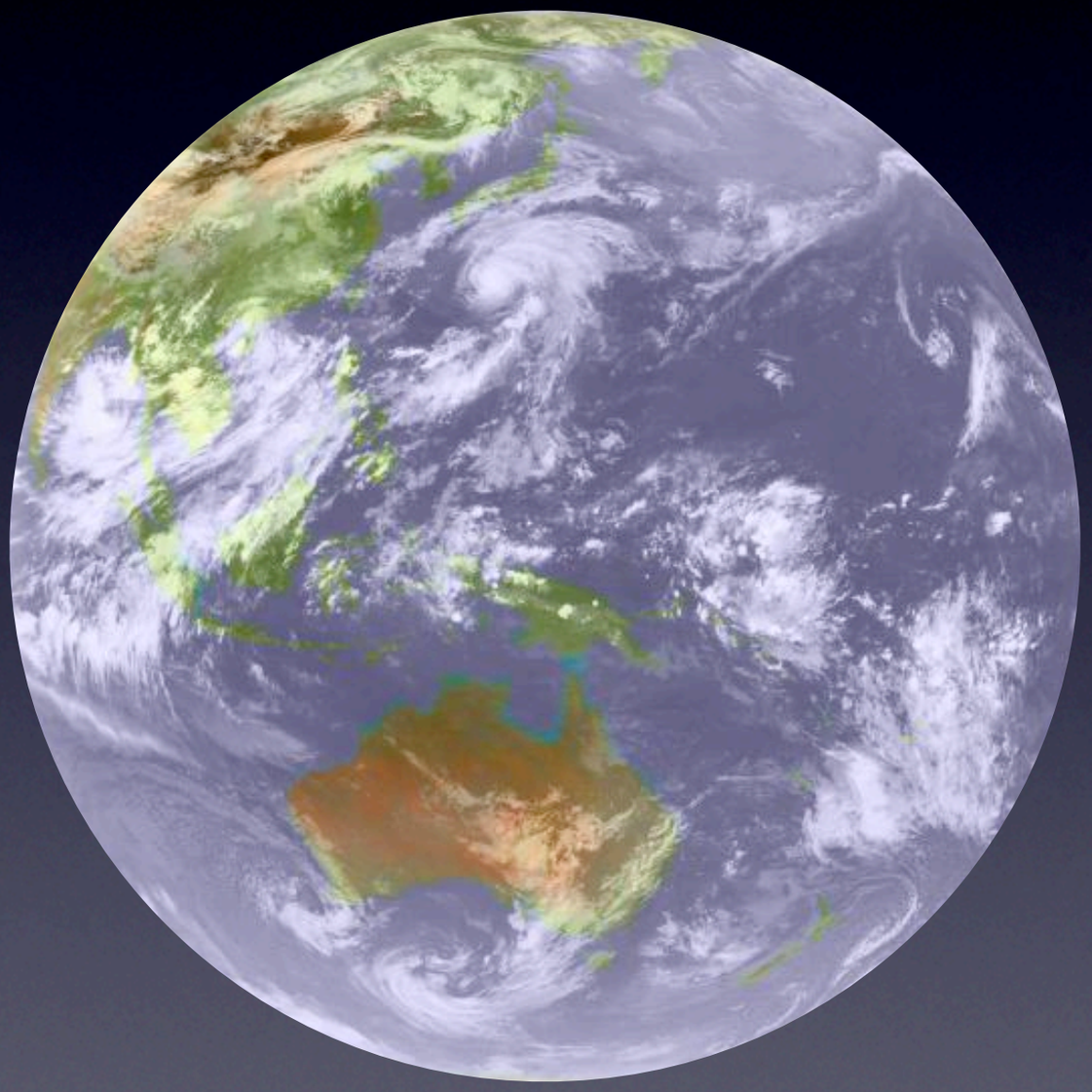
850 (u,v) and standardized U850 spread



ET of Typhoon 0504

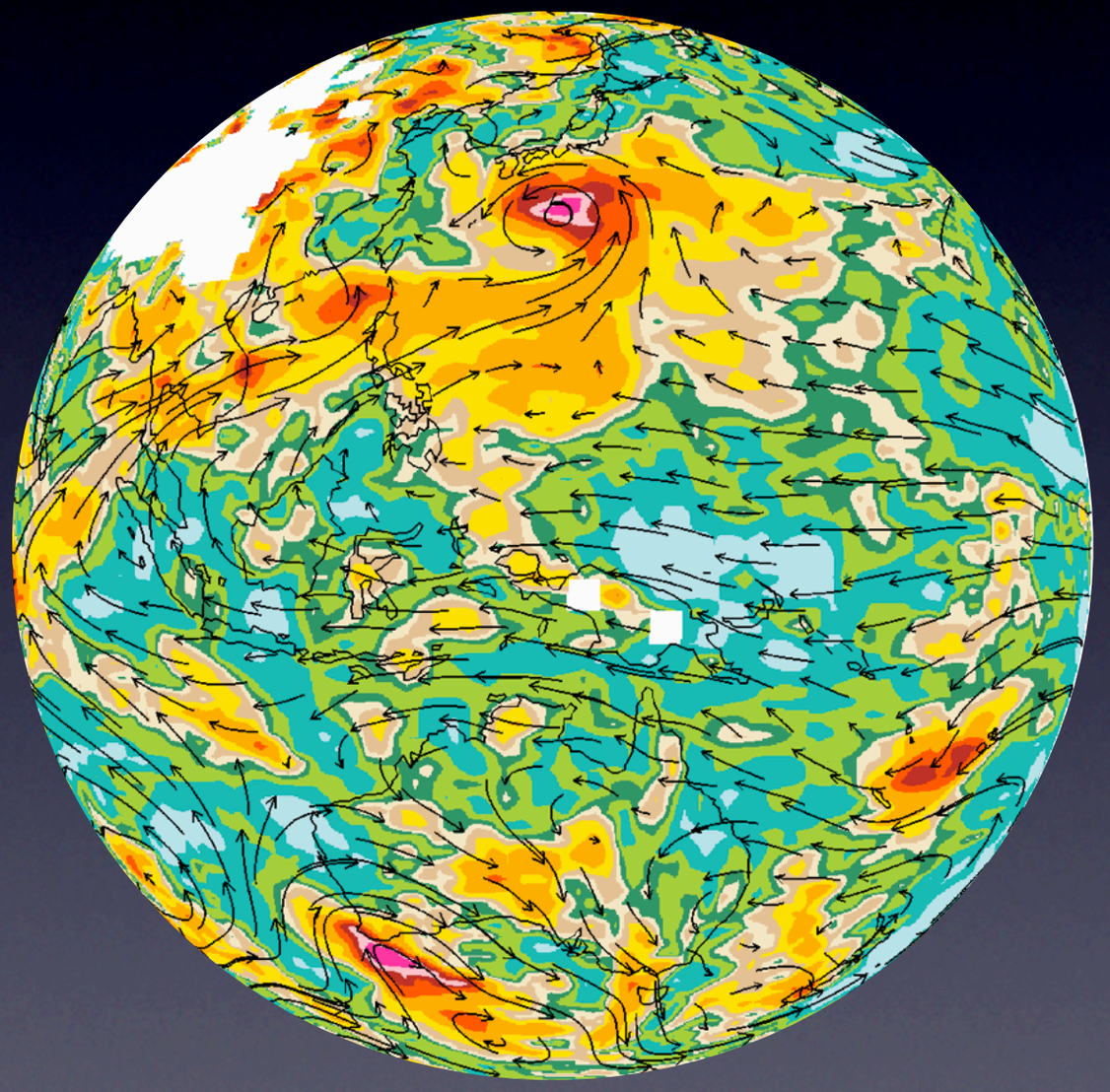
GOES 9 IR

JMA/Kochi Univ

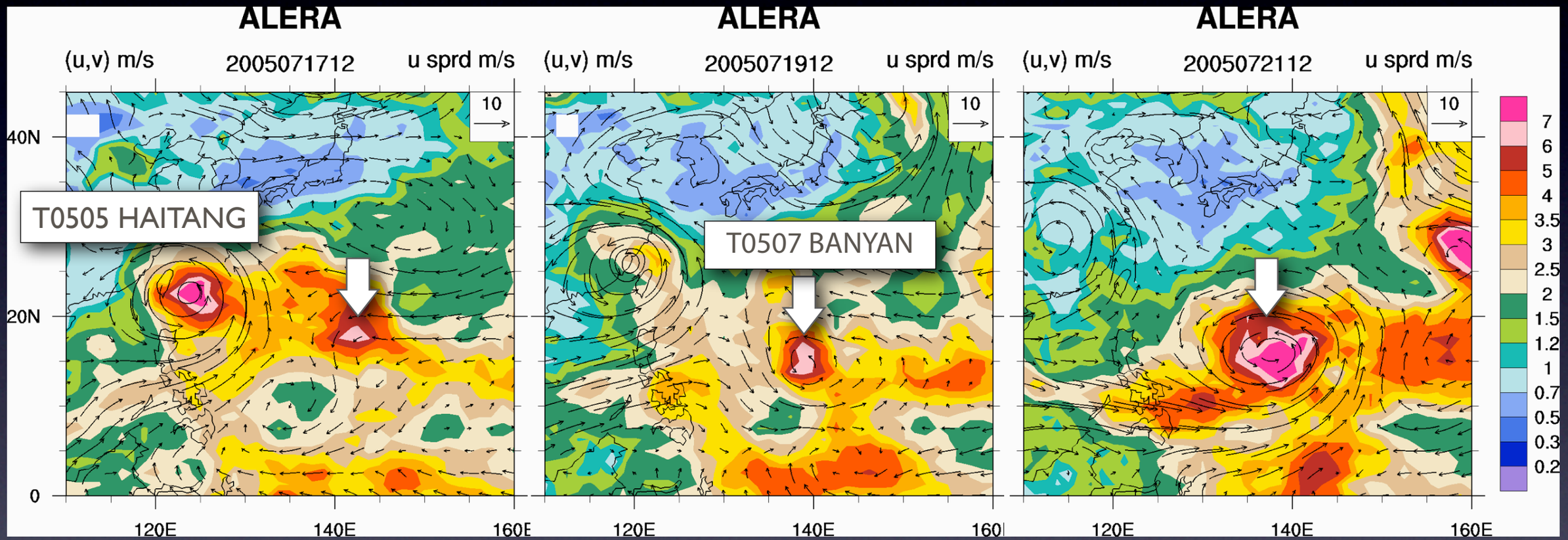


ALERA

(u,v) 850 hPa & u850 sprd

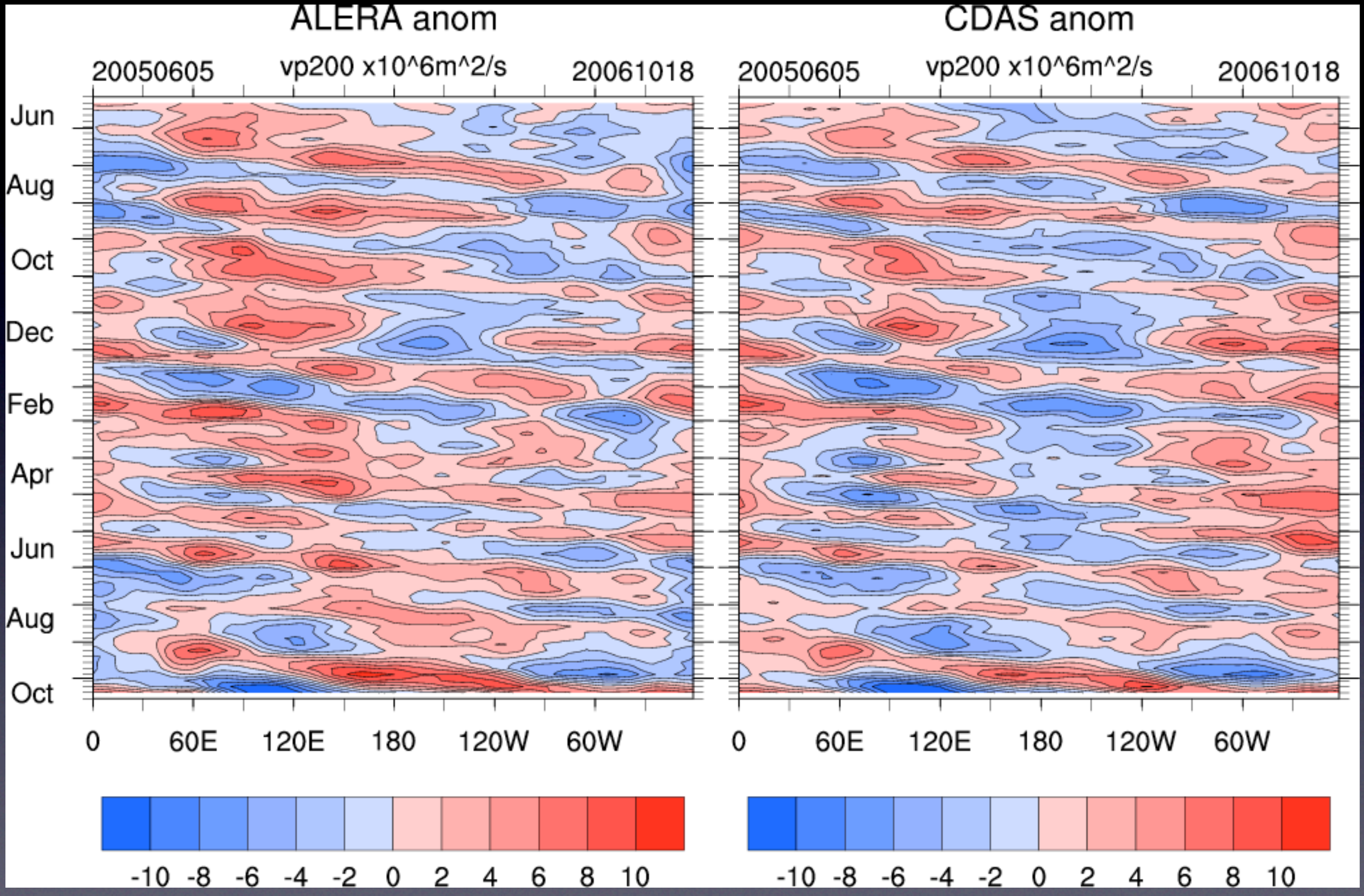


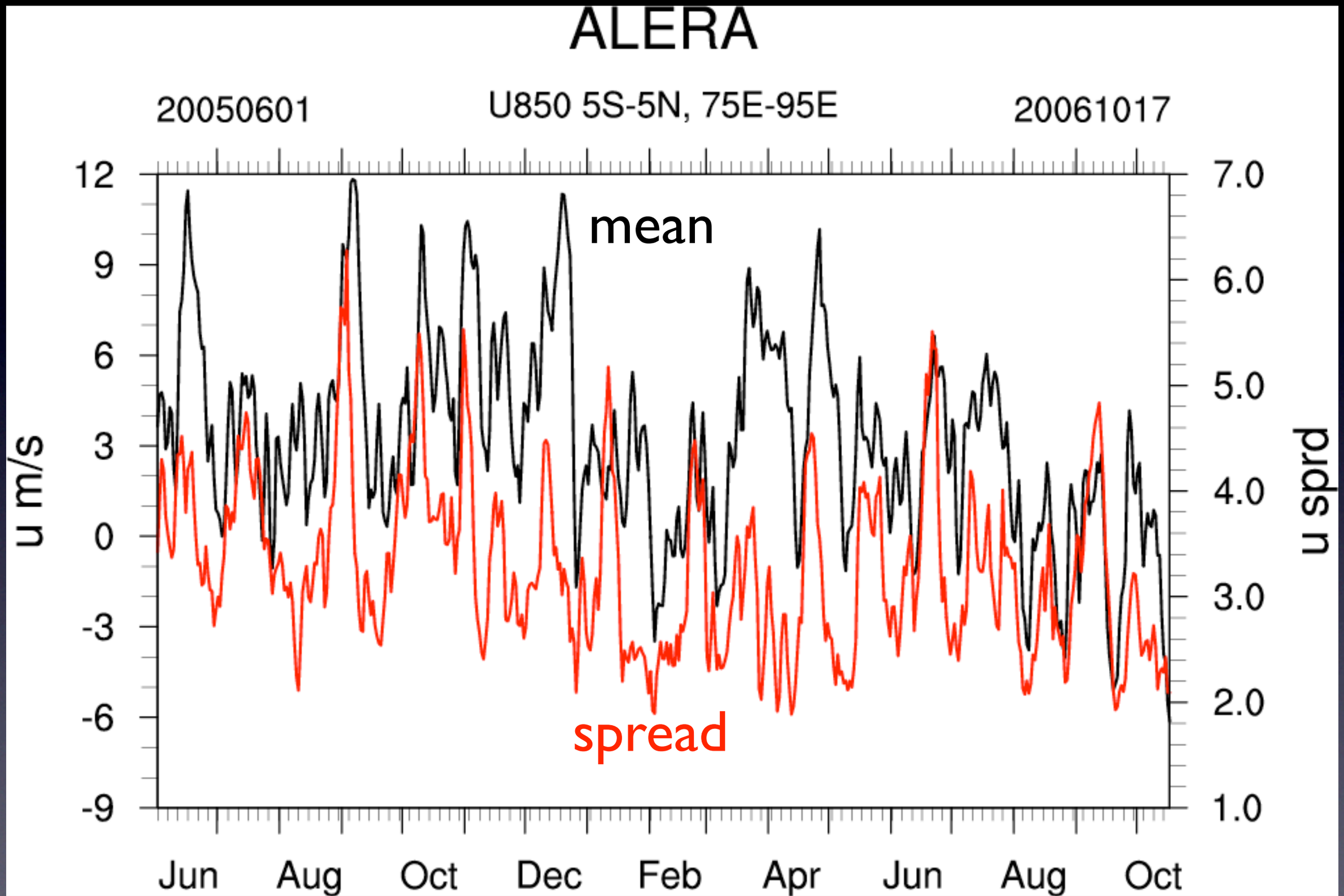
2005-06-09 0UTC


ALERA
(u,v) m/s
2005071712
u sprd m/s
10
T0505 HAITANG
ALERA
(u,v) m/s
2005071912
u sprd m/s
10
T0507 BANYAN
ALERA
(u,v) m/s
2005072112
u sprd m/s
10
40N
20N
0
120E
140E
160E
7
6
5
4
3.5
3
2.5
2
1.5
1.2
1
0.7
0.5
0.3
0.2

Tropics

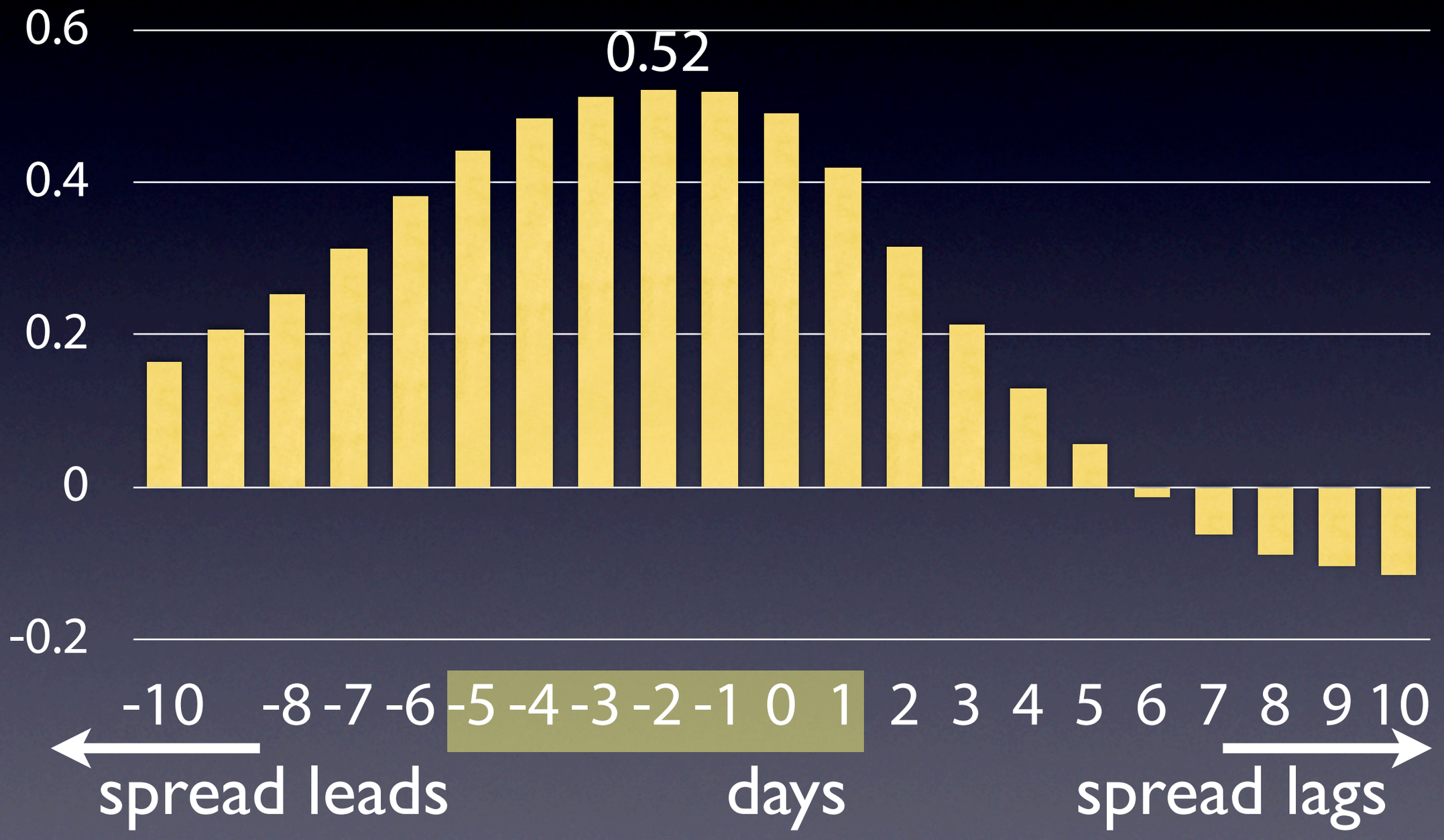
VP200


ALERA anom
20050605
vp200 x10^6m^2/s
20061018
Jun
Aug
Oct
Dec
Feb
Apr
Jun
Aug
Oct
0
60E
120E
180
120W
60W
-10 -8 -6 -4 -2 0 2 4 6 8 10
CDAS anom
20050605
vp200 x10^6m^2/s
20061018
0
60E
120E
180
120W
60W
-10 -8 -6 -4 -2 0 2 4 6 8 10



Enomoto et al., 2010 GRL

Lag correlation between mean and spread



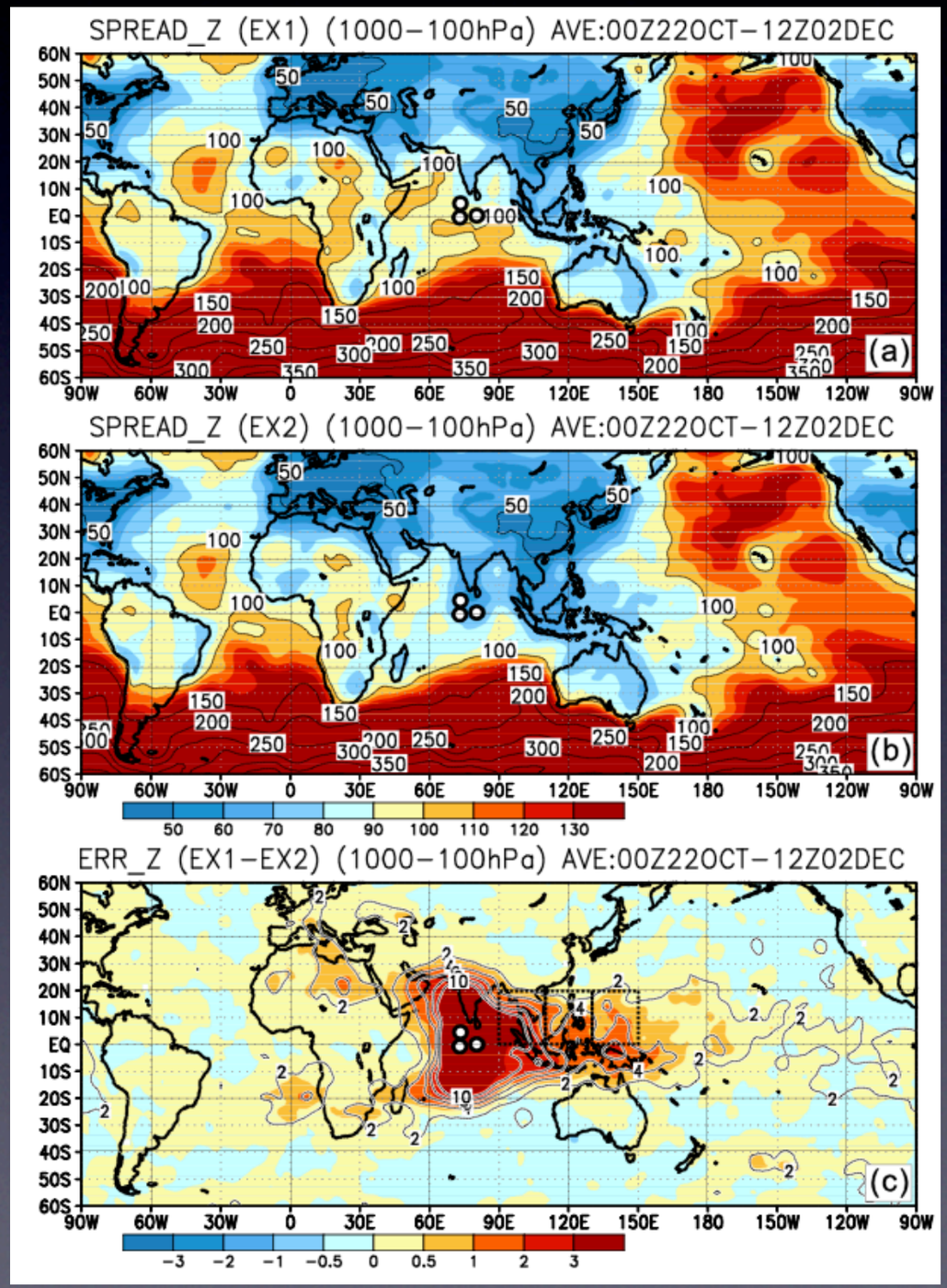
Enomoto et al., 2010 GRL

Influence of sondes in Matsuno-Gill pattern

ALERA (w/o MISMO sondes)

with MISMO sondes

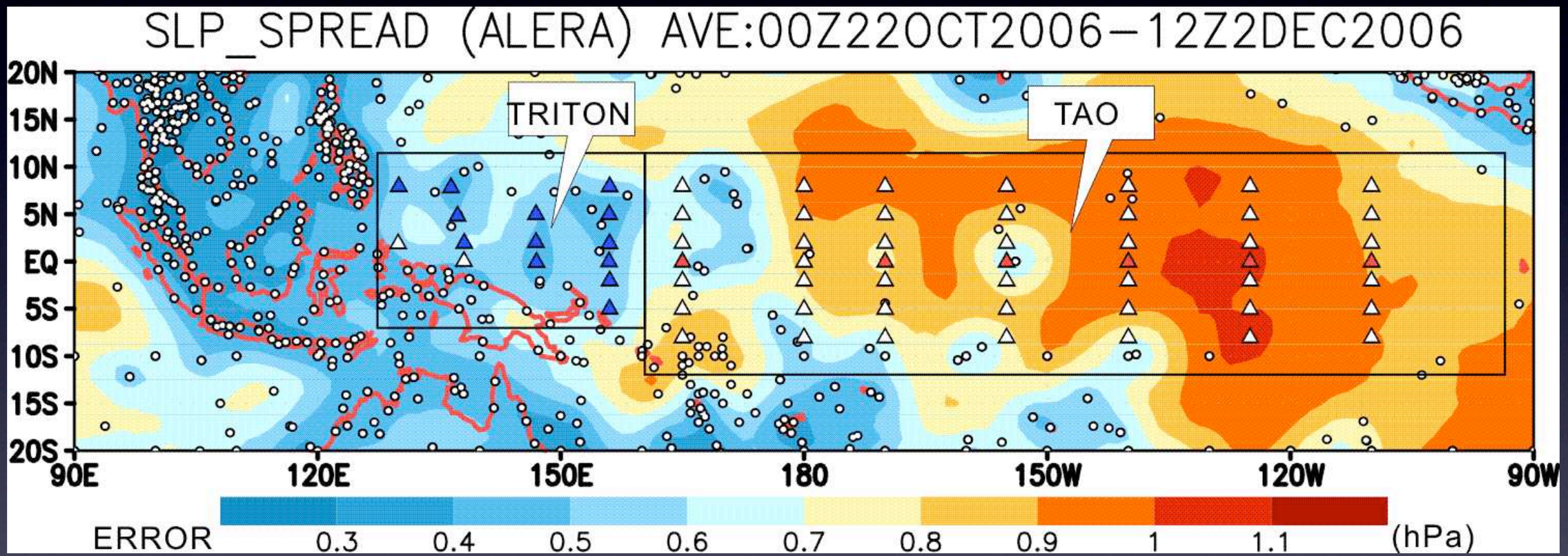
ALERA – with MISMO



MISMO Oct–Dec 2006
in the Indian Ocean

Influence on typhoon genesis

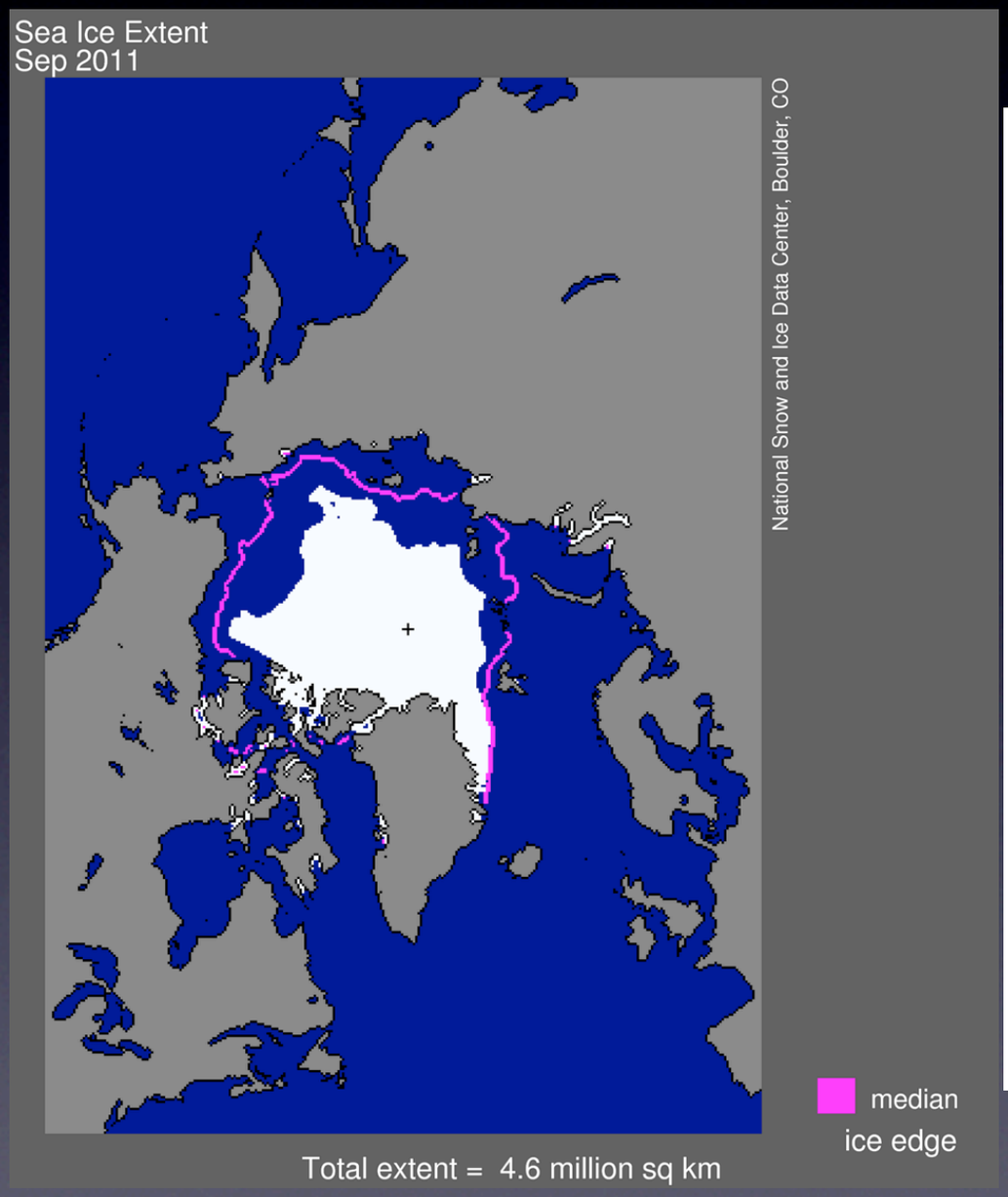
Moteki et al. 2011, *QJRMS*

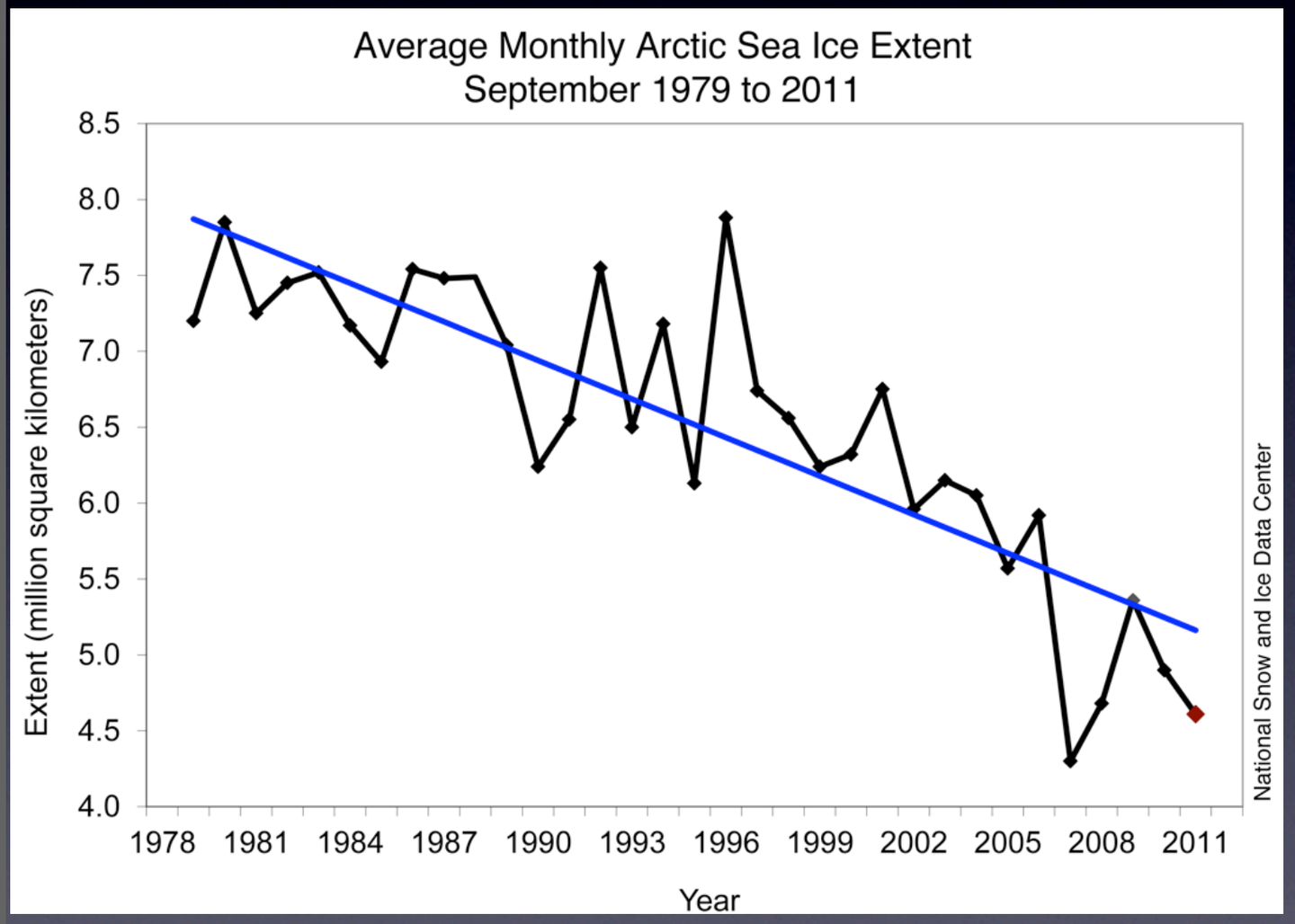


Moteki, *pers. comm.*

Arctic

Arctic ice in September 2011



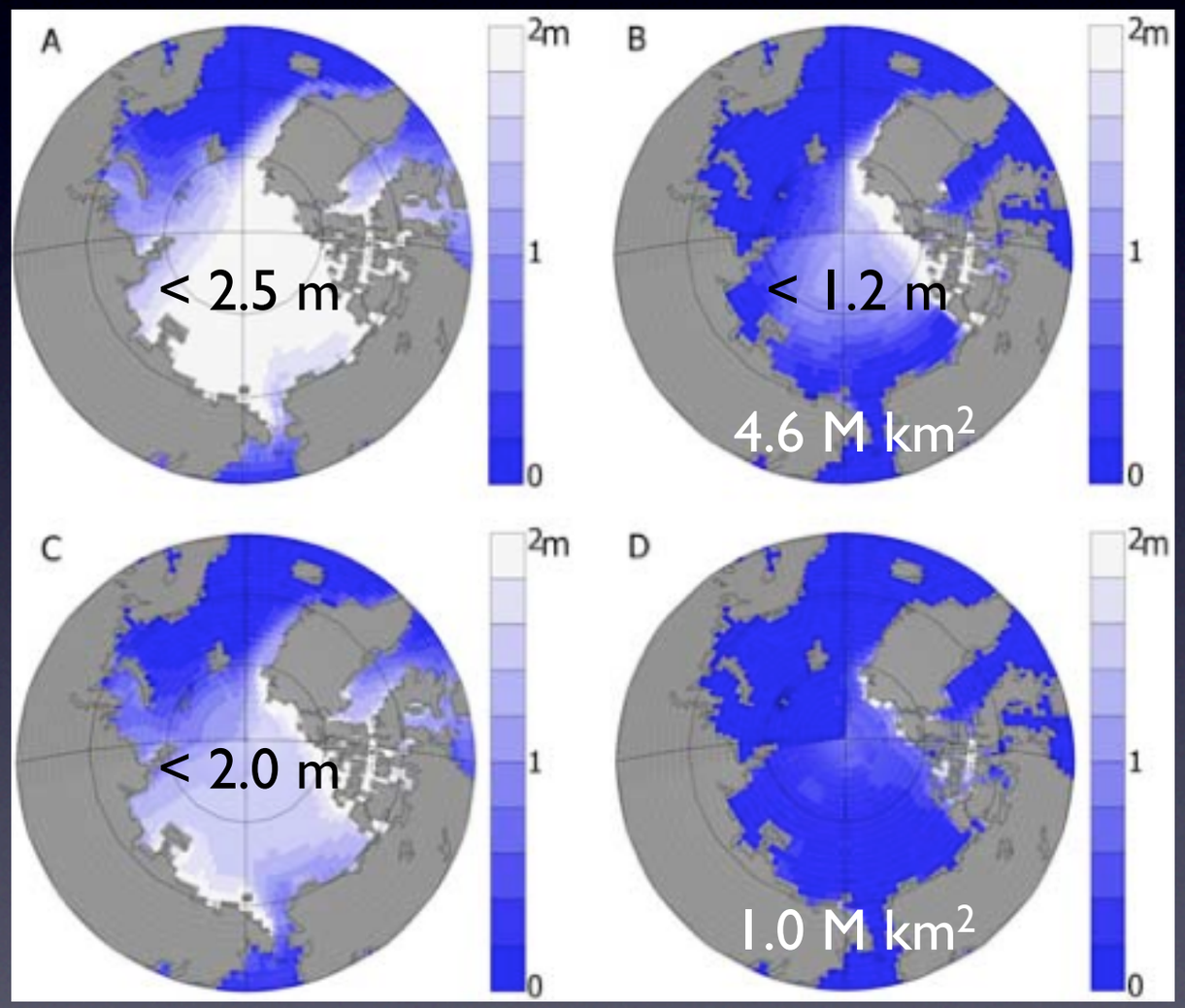


NSIDC

Blue Arctic in 30 years?

Ensemble mean sea ice thickness

March | September



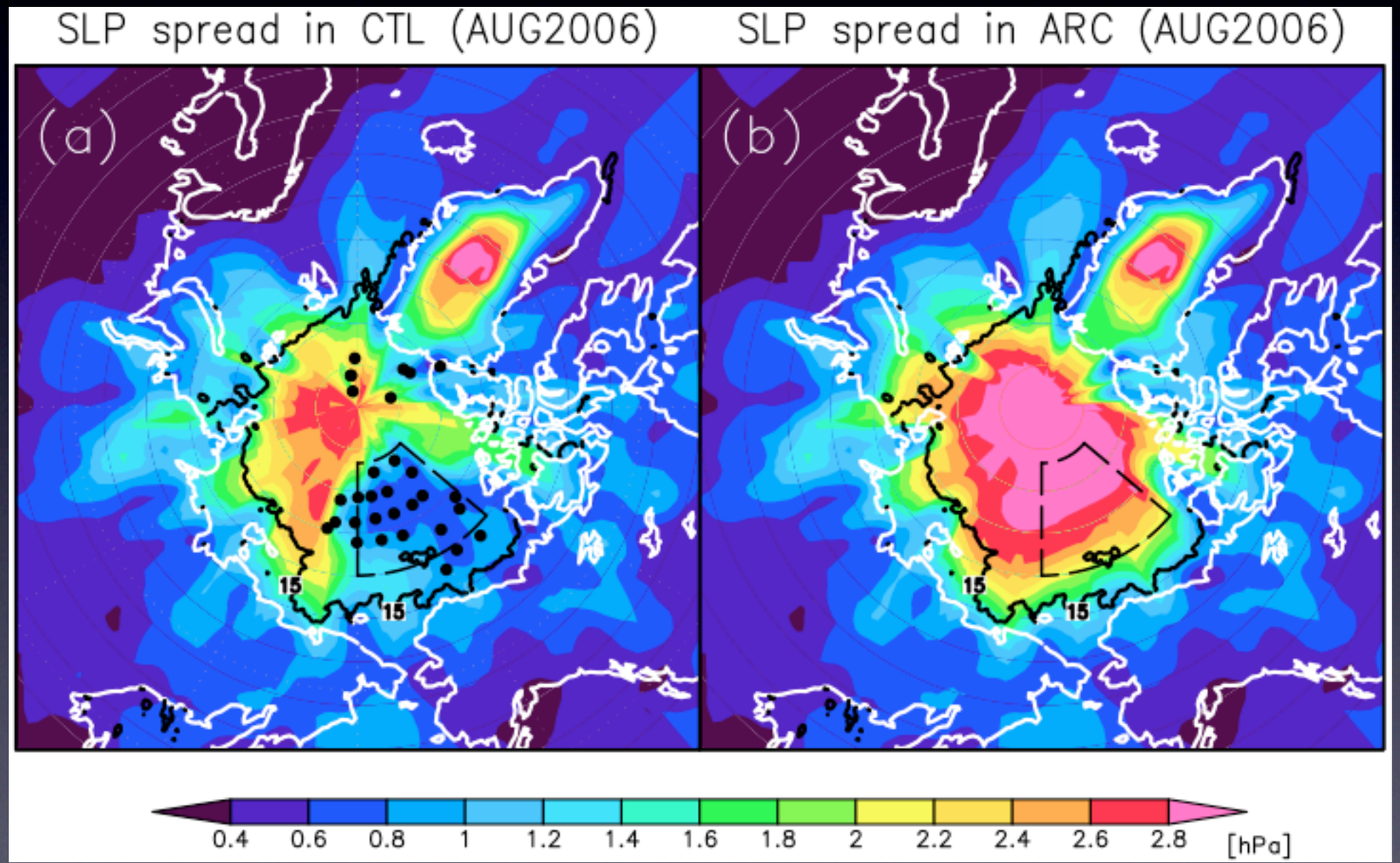
6 selected IPCC models

Wang and Overland 2009

Experimental settings

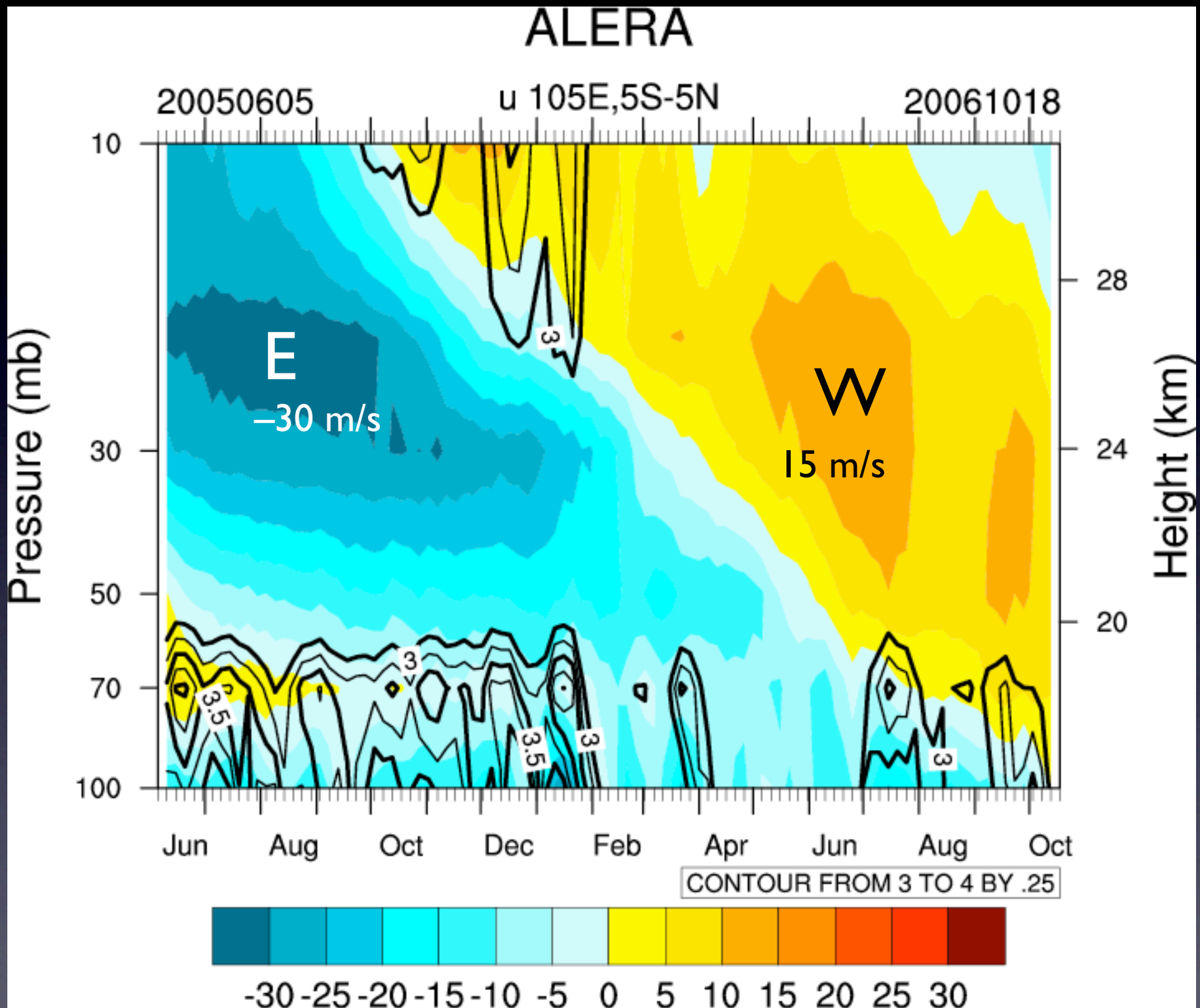
- Reference: ALERA
- Test: pressure observations north of 70N removed
- About half a year from June 2006

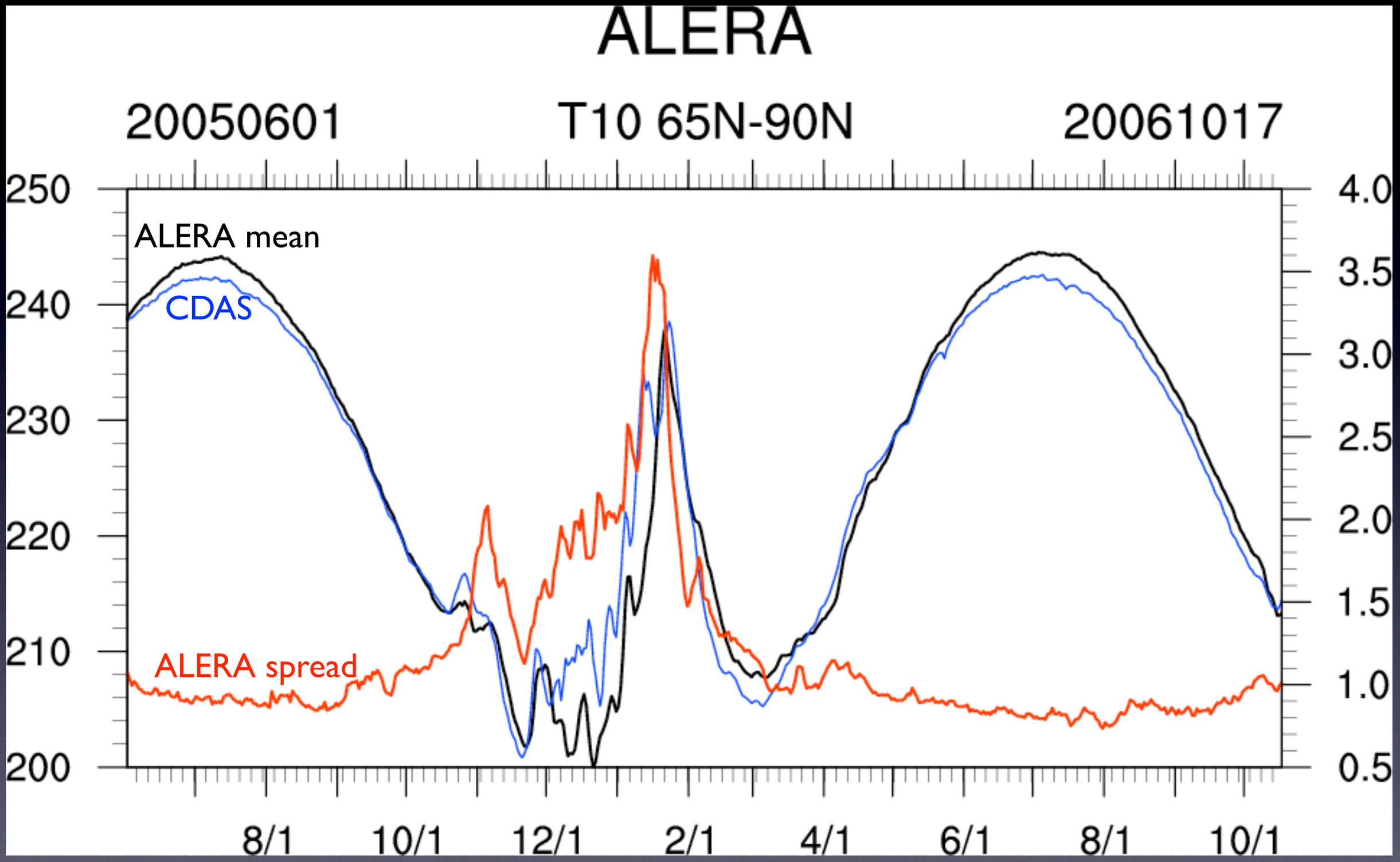
Impact on sea-level pressure



Inoue et al 2009

Stratosphere


ALERA
20050605
u 105E,5S-5N
20061018
10
30
50
70
100
Pressure (mb)
28
24
20
Height (km)
E
–30 m/s
W
15 m/s
3
3.5
3
3.5
3
3
Jun
Aug
Oct
Dec
Feb
Apr
Jun
Aug
Oct
CONTOUR FROM 3 TO 4 BY .25
-30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30

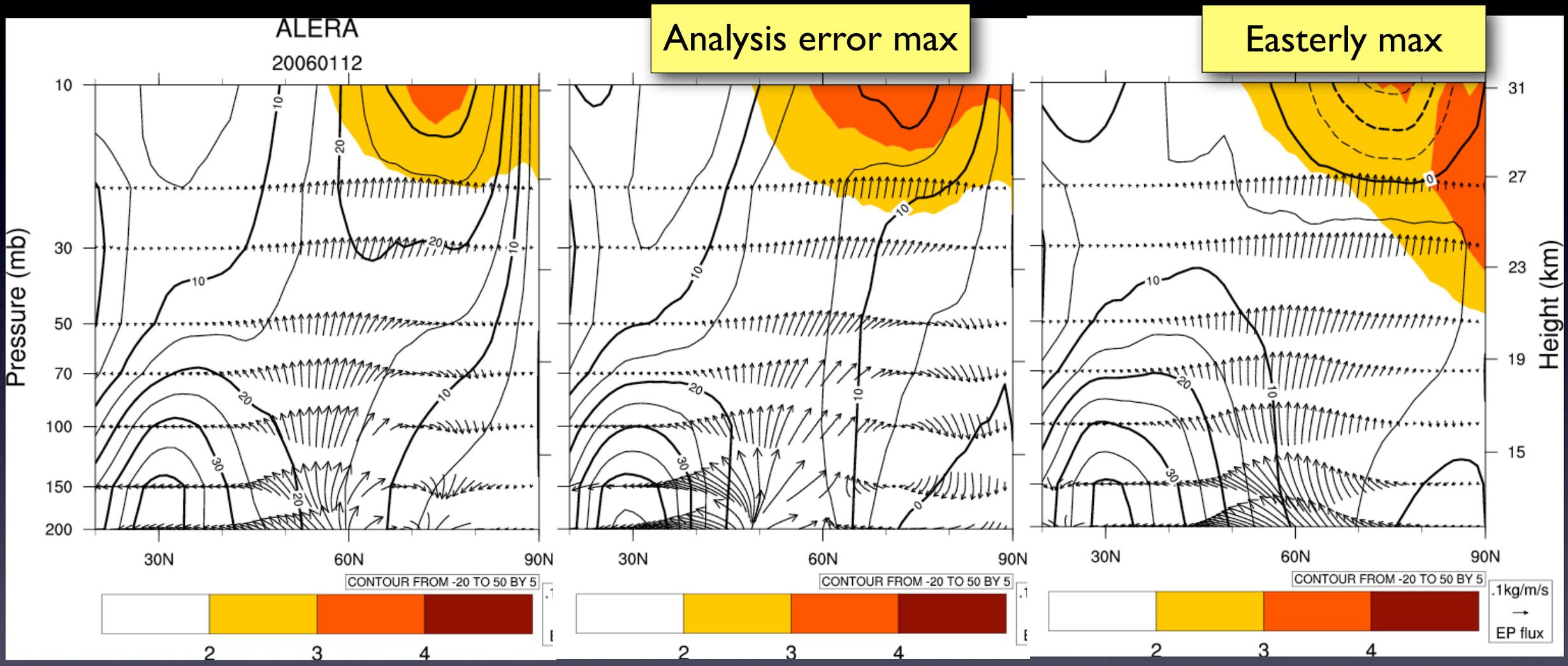


Enomoto et al., GRL, 2010

12 Jan 2006

16 Jan 2006

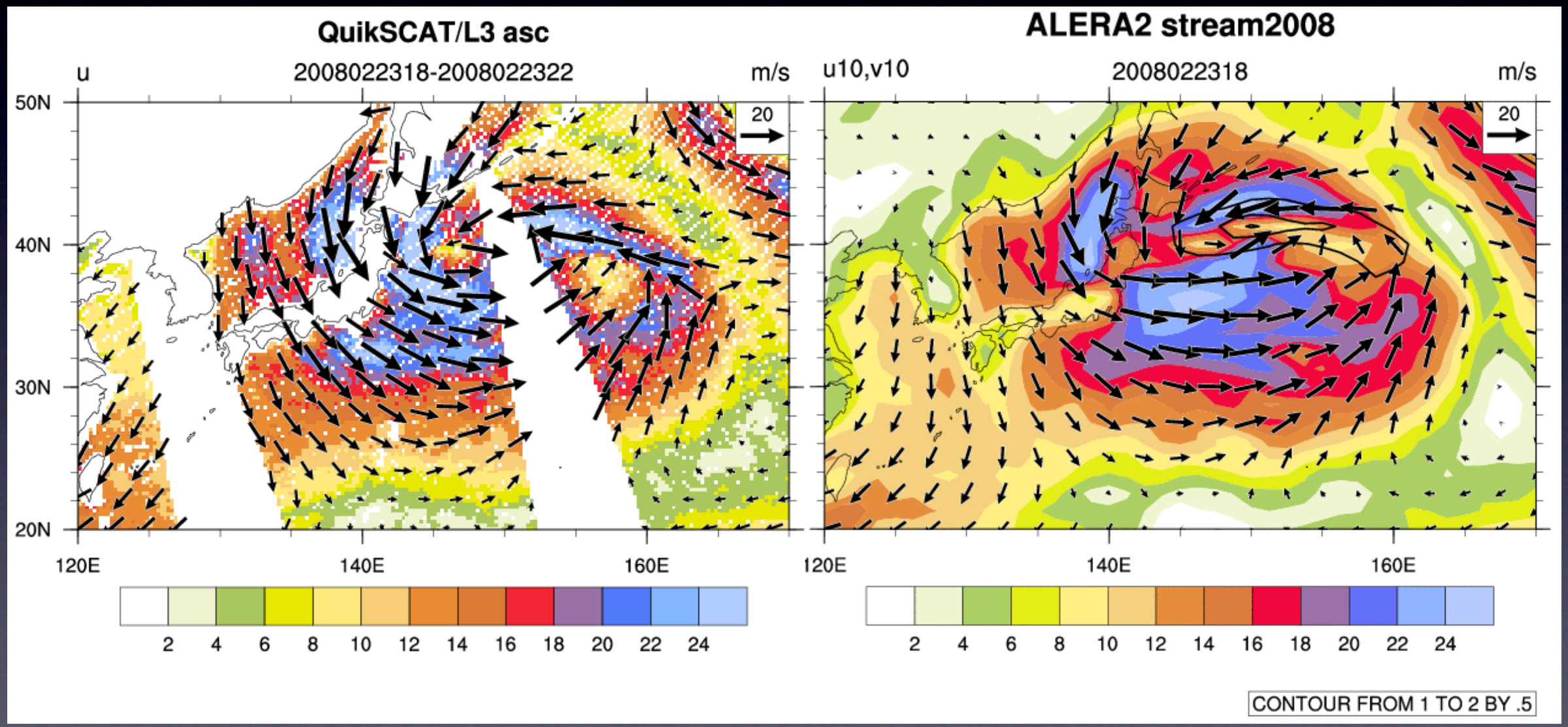
22 Jan 2006



→ EP flux, *u* (contours), *u* ensemble spread (shades)

Bomb cyclones

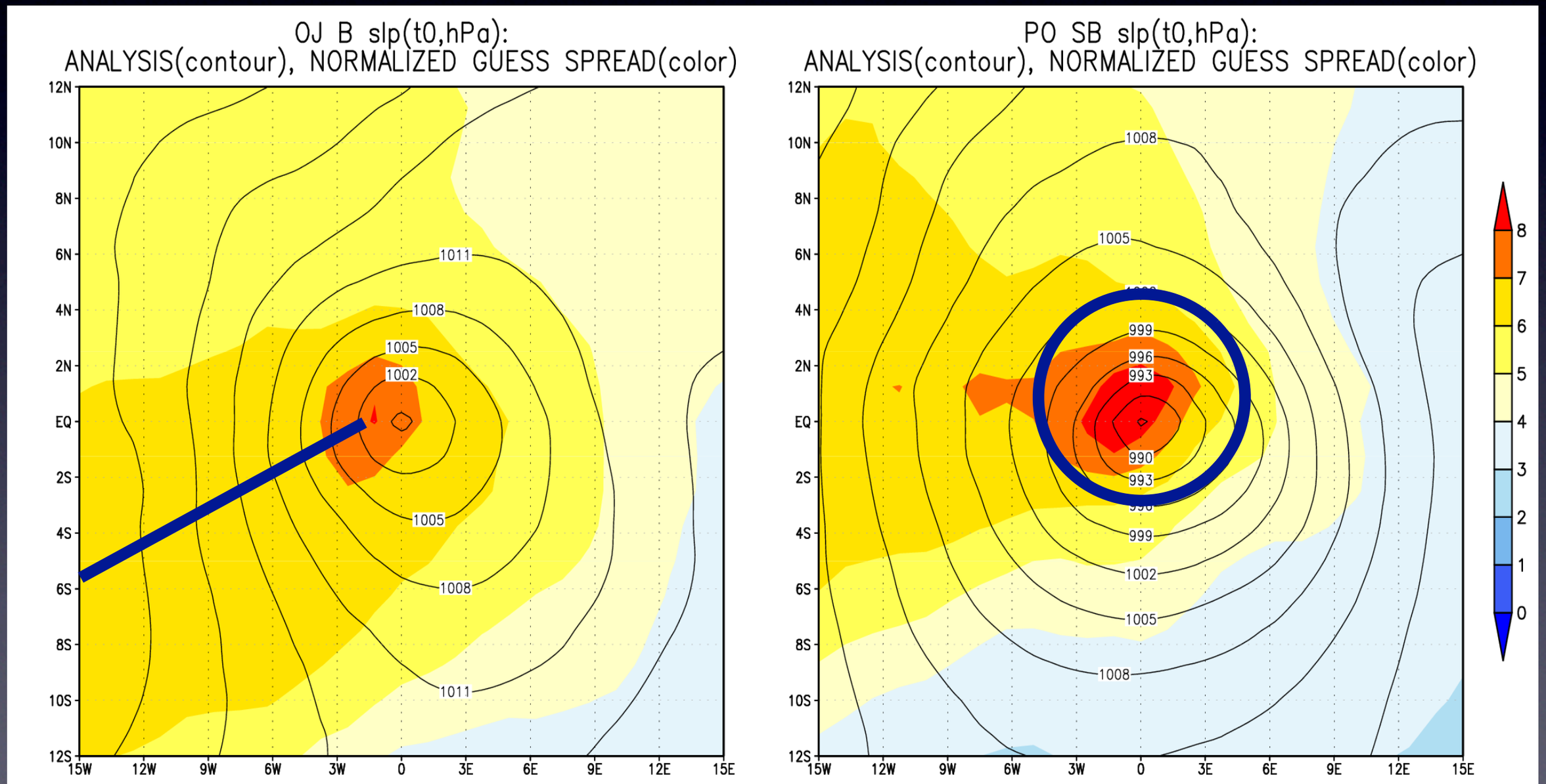
Bomb cyclone



Development locations

Sea of Japan

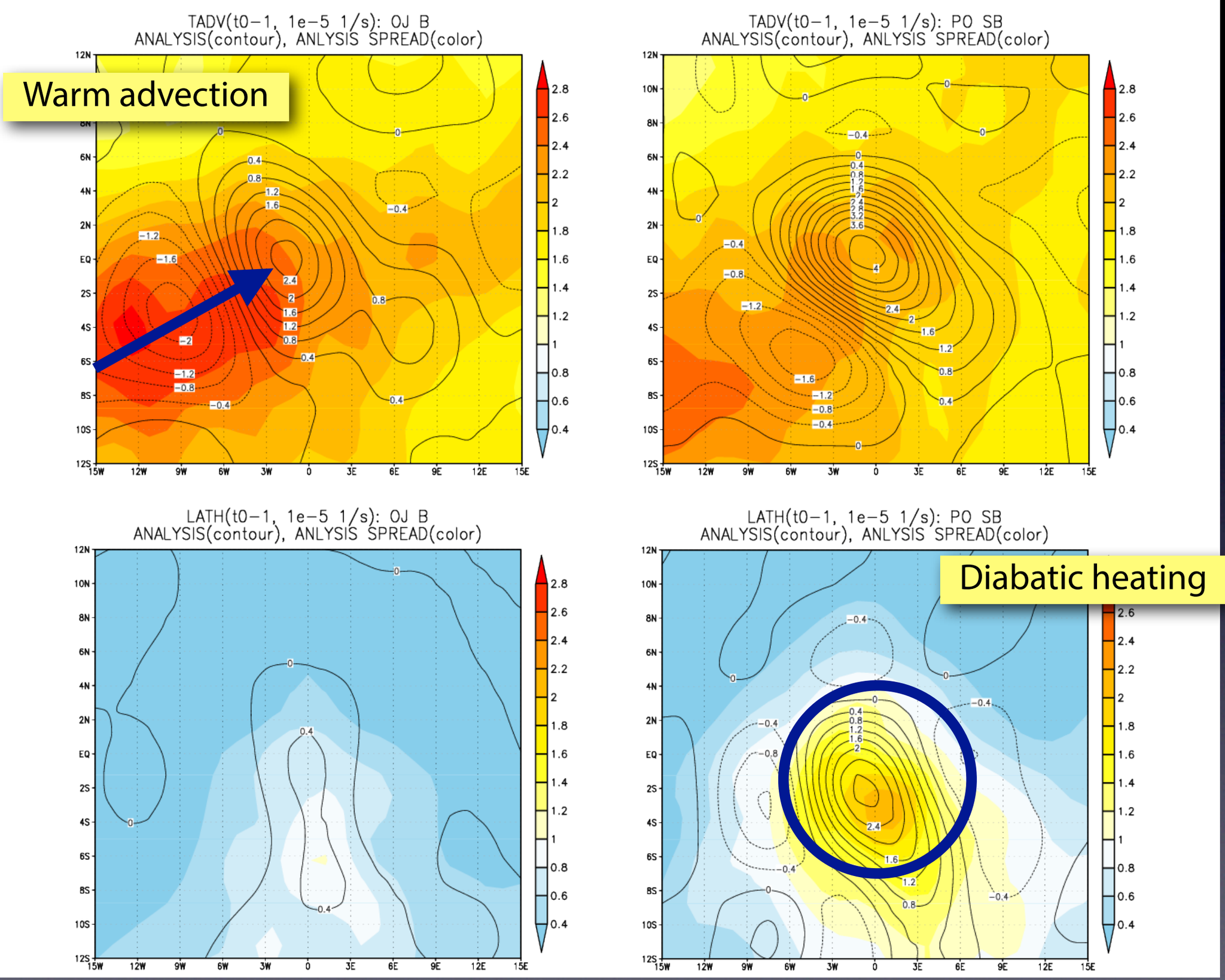
Pacific



Kuwano-Yoshida

Sea of Japan

Pacific



Kuwano-Yoshida

Summary

- Analysis = Observation + Forecast
- Ensemble-based analysis provides analysis error estimation
- Mechanisms, predictability and evaluation of observations