Development of 3D Variational Assimilation System for ATOVS Data in China

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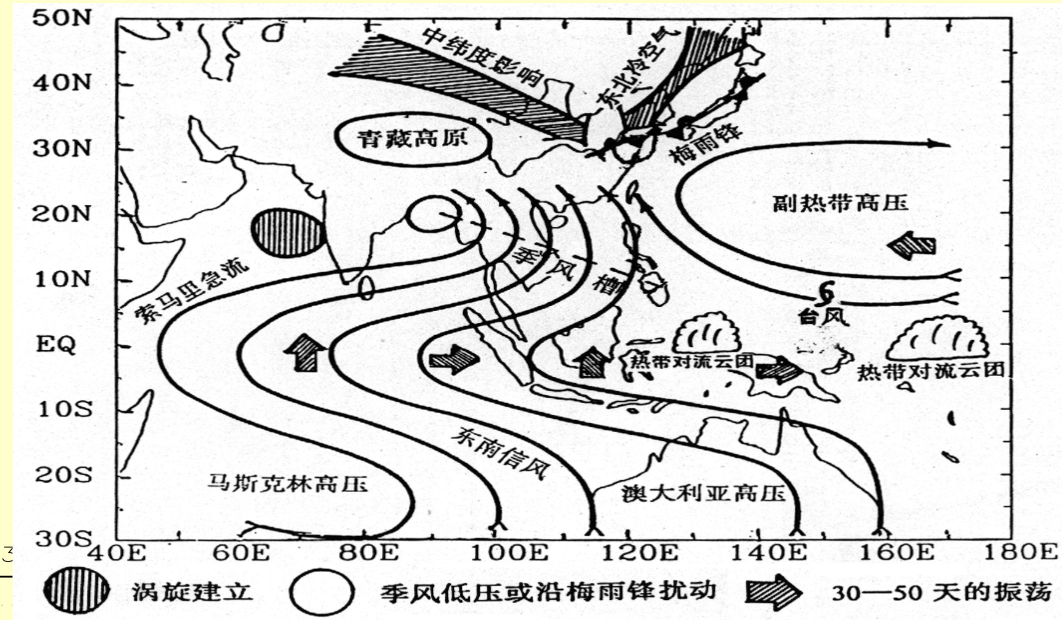
- 5. Towards operational implemantation

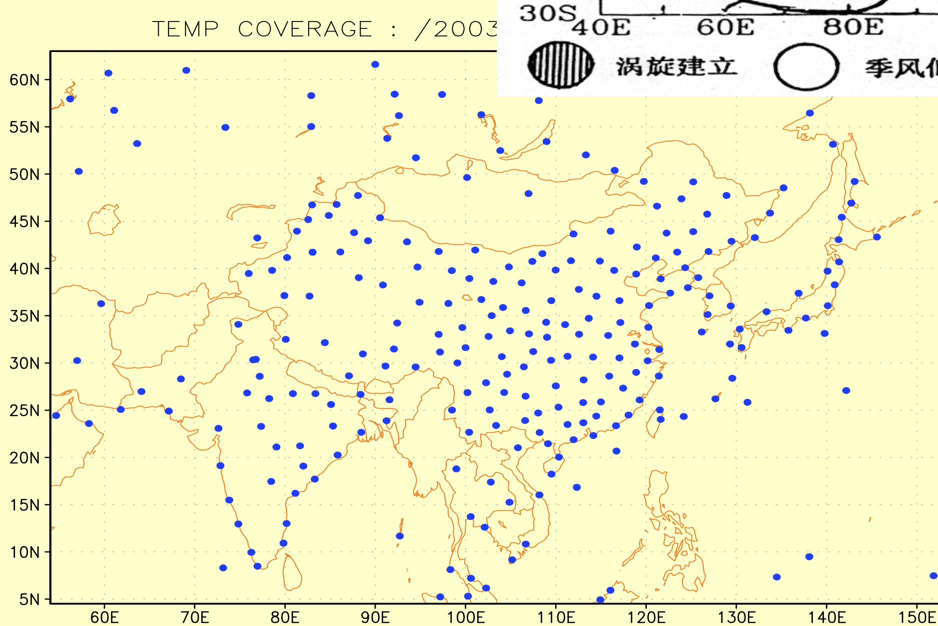
GRAPES

Development of 3D Variational Assimilation System for ATOVS Data in China

1. Introduction

Sparseness of observational data – the biggest challenge in improvement of weather forecasts





The assimilation of satellite observations is in the first priority in the development of next generation NWP system

1.Introduction (cont.)

Two parallel projects for the application of TOVS data:

Direct Assimilation within 3DVar frame work for NWP in National Centers

Application of Retrieved Atmospheric Profiles to Local NWP and Nowcasting

Direct Assimilation of ATOVS Radiance

A R&D project with joint efforts of scientists in the National Satellite Meteorological Center CMA and the Chinese Academy of Meteorological Sciences

Goal of the Project

Alleviate the problem of data sparseness in some crucial areas to which the prediction of disastrous weather are sensitive

Priorities :

Tropical Storms over Northwest Pacific

Regional Torrential Rains (usually caused by vortexes originating near the eastern wing of the Tibetan Plateau)

Studies focus at the application of ATOVS data to improve NWP of Typhoons (both track and intensity), especially those landing on Chinese coast

Direct Assimilation of ATOVS Radiance

as a sub-project of GRAPES: a 5-year project launched in 2001 aiming at the development of next generation numerical weather prediction in China

2. 3DVar in GRAPES

GRAPES : a NWP system newly developed for upgrading the operational medium range and mesoscale NWPs

Global / Regional Assimilation and Prediction System

Main Components of GRAPES :

Variational data assimilation

Unified nonhydrostatic model (grid mesh, SI/SL)

Model physics package

Parallel computing software

2. 3DVar in GRAPES (cont.)

Long / Lat Grid mesh

Control variables different from state variables

Preconditioning :

With square root of back ground error covariance matrix

Recursive filter for limited area domain ;

Spectral filter for the globe

LBGFS for optimization

GRAPeS 3DVar

$$J = (X - X_b)^T B^{-1} (X - X_b) + (H(X) - Y_o)^T O^{-1} (H(X) - Y_o)$$

Analysis variables: Ψ, χ, T,q

Preconditioning with square root of background error covariance matrix

Flexibility for different observational operators

3. Direct Assimilation of Satellite Radiances in GRAPeS 3DVar

$$J = J_b + J_o$$

$$J_o = (Y - H(X))^T O^{-1} (Y - H(X))$$

$$H(X) : R * H * V(X)$$

R **Fast radiation transfer model (RTTOV is used)**

H **Horizontal interpolation**

V **Vertical Interpolation**

Direct Assimilation of Satellite Radiances in *GRAPeS-3DVar*

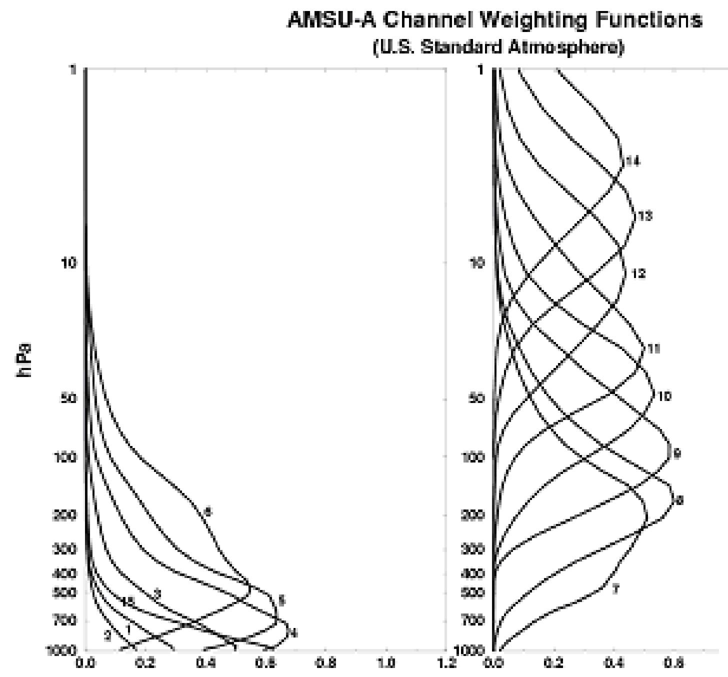
Channel selection *General consideration* :

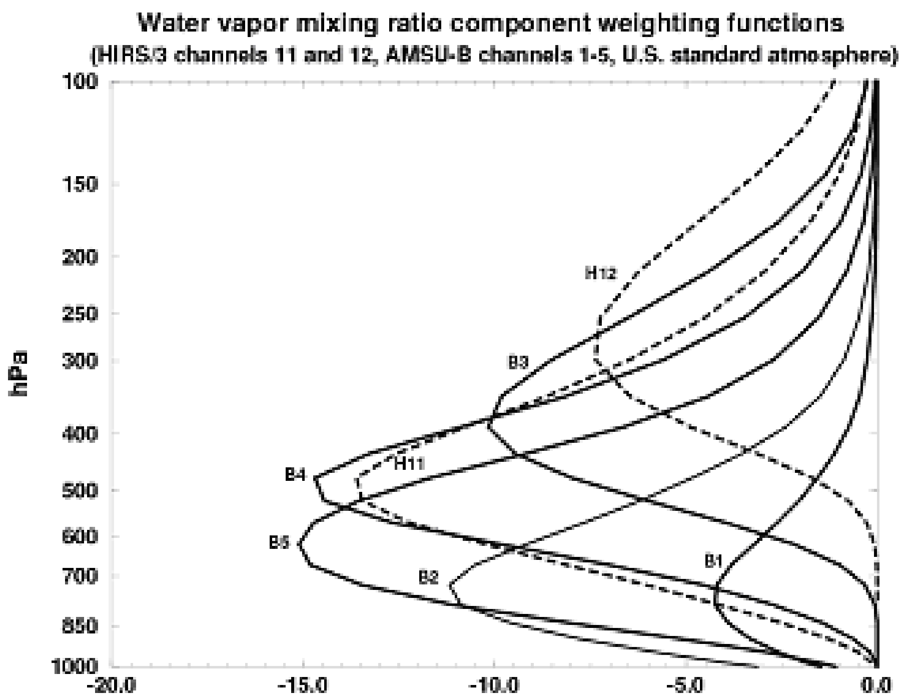
Channels sensitive to the surface characteristics, deep clouds and upper air (above 10 hpa) temperatures are avoided.

Noaa16/17 : AMSU-A CH 5-11

AMSU-B CH 18-20

Weighting functions (AMSU-A and B)





3. Assimilation of ATOVS data (cont.)

Acquisition and preprocessing of data (will be mentioned in 4)

Quality control before 3DVar :

Cloud identification

Bias correction

1DVar quality control

Two kinds of bias under consideration

- Correction depending on scan angles： $s = \langle d_j(\theta) - d_j(\theta=0) \rangle$
- Correction depending on air mass: $b = y - H(x_b) - s$
  - Least square linear fitting
  - Predictors p: air mass dependent

$$\mathbf{b} = \mathbf{A}\mathbf{p} + \mathbf{c}$$

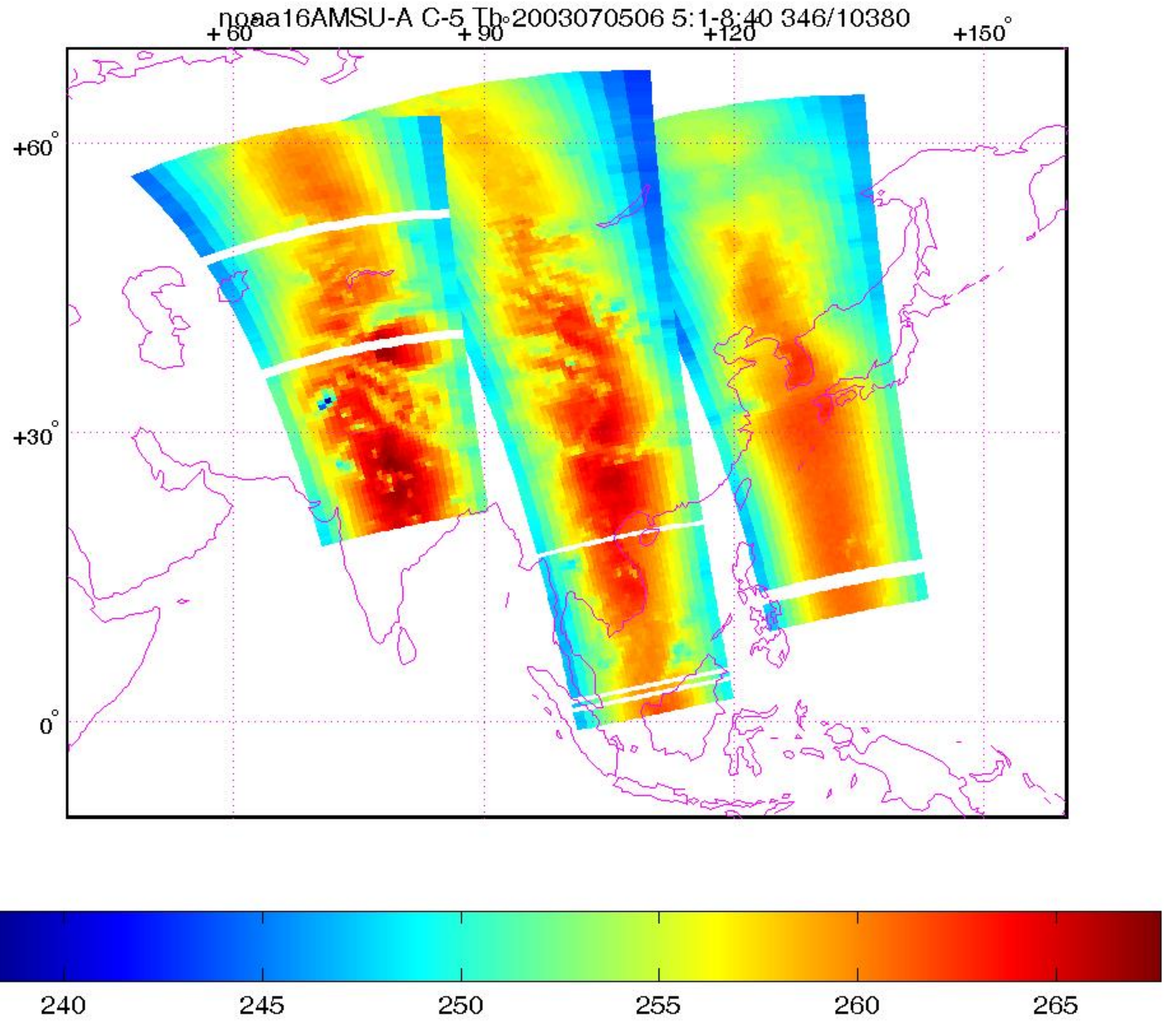
$$\mathbf{A} = \mathbf{b}\mathbf{p}^T(\mathbf{p}\mathbf{p}^T)^{-1}$$

$$\mathbf{c} = \mathbf{b} - \mathbf{A}\mathbf{p}$$

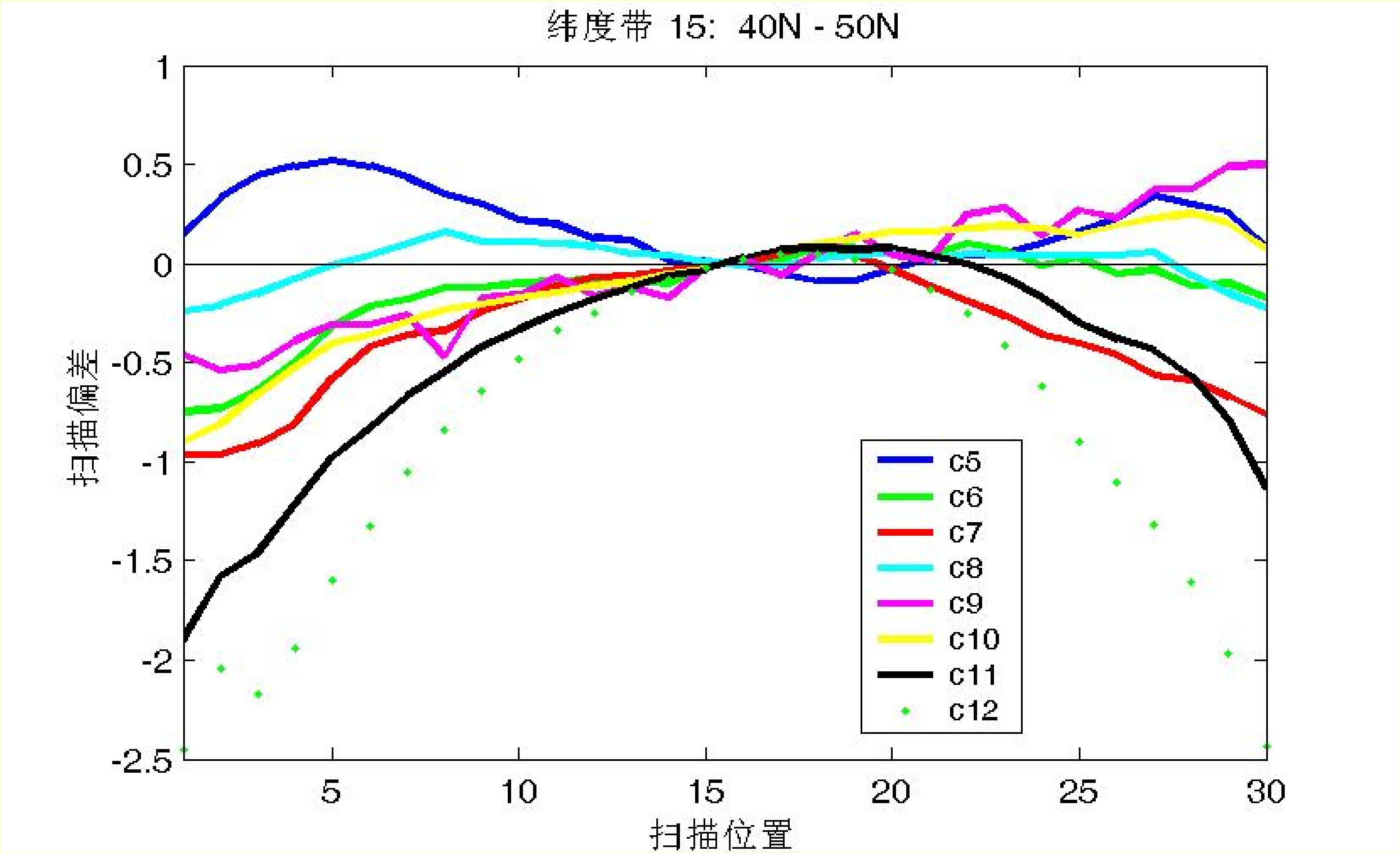
Algorithms of bias correction

Following *Harris， Kelly(2001)*

- Scan angle correction- dependent on latitudes
- Predictors from the background:
  - Thickness between 1000-300hPa
  - Thickness between 200-50hPa
  - Surface temperatures
  - Integrated water vapor


noaa16AMSU-A C-5 Tb 2003070506 5:1-8:40 346/10380
+60°
+90°
+120°
+150°
+60°
+30°
0°
240
245
250
255
260
265

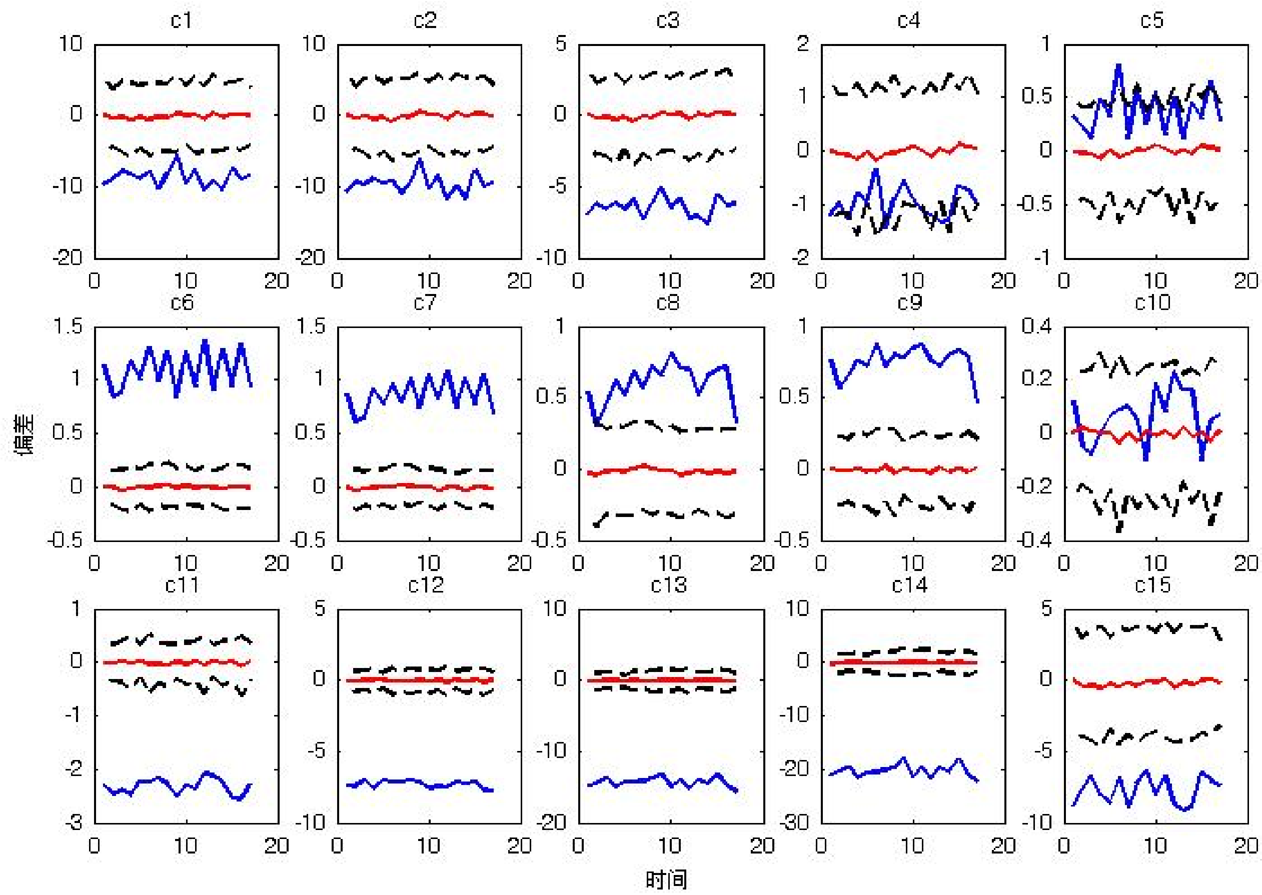
Scan Bias



Scan Bias of NOAA16 AMSU-A CH 5-12 in the Zone 40N-50N

Samples for Statistics: Jul.1-10 2003 06/18 UTC (6 hours time window)

Comparison of NOAA16 AMSU-A before and after bias correction

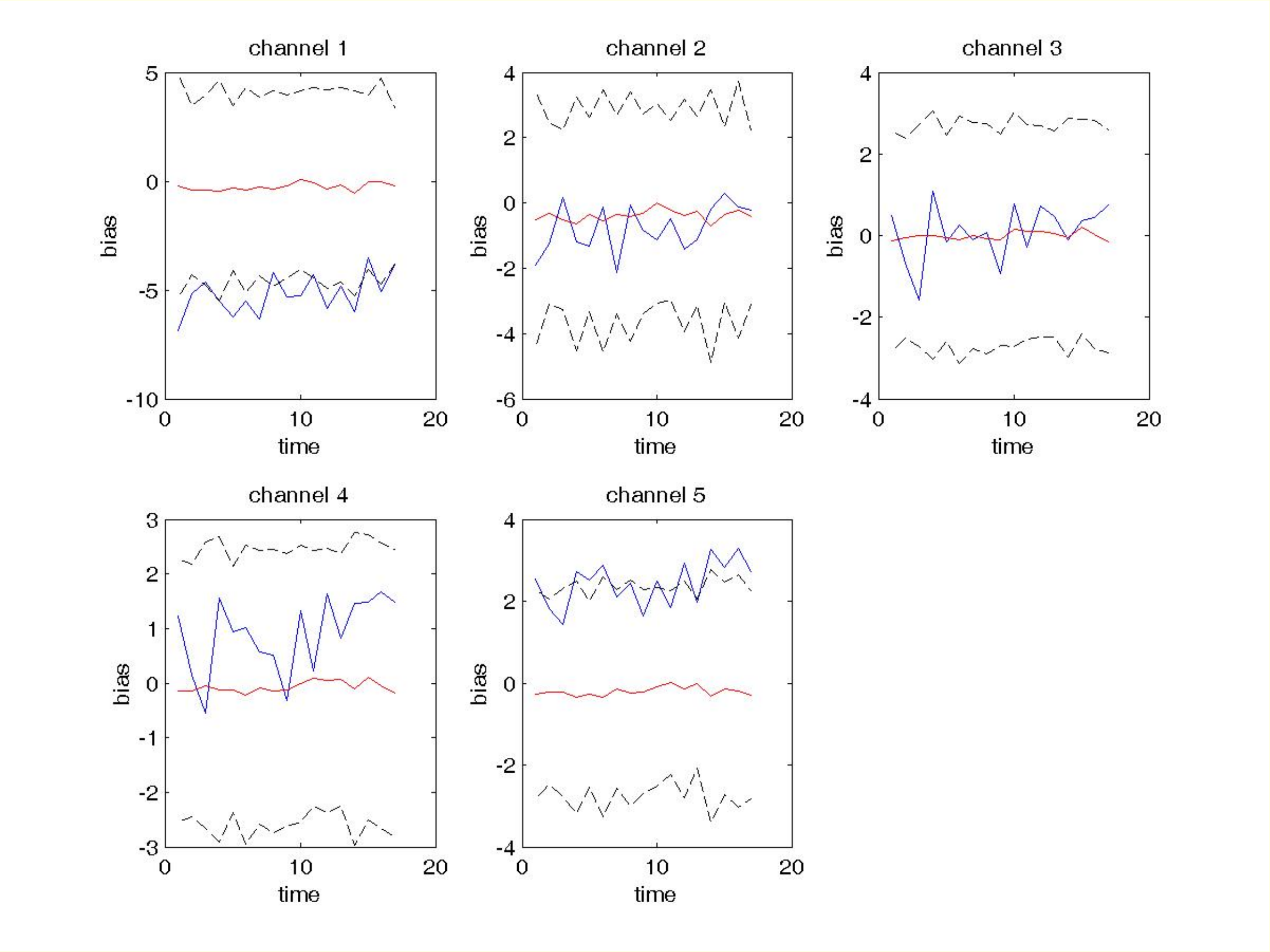


Jul.1-10 2003 06/18 UTC (6 hours time window)

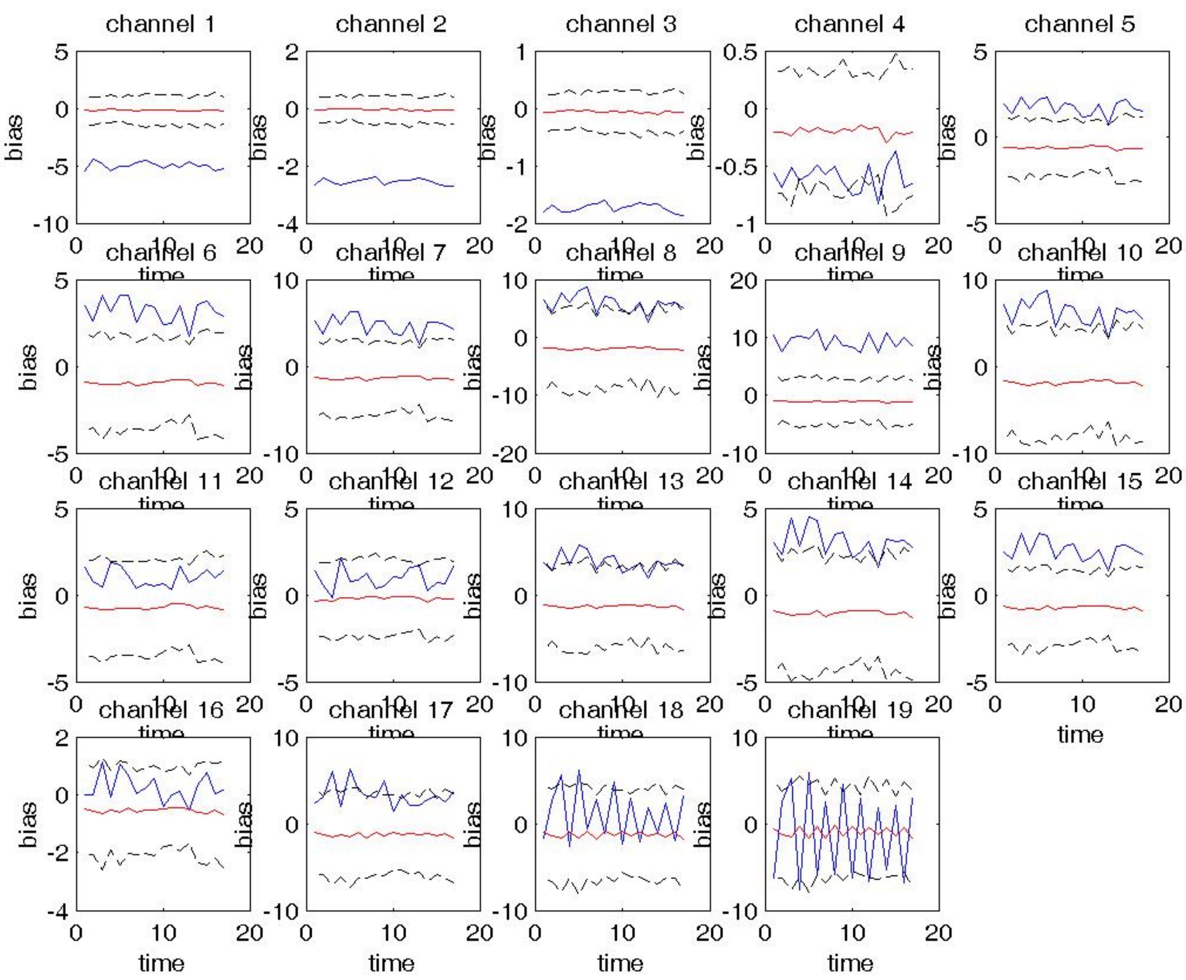
Blue： before correction（background-obs.）； Red： after correction；

Black:with standard deviation added and substacted

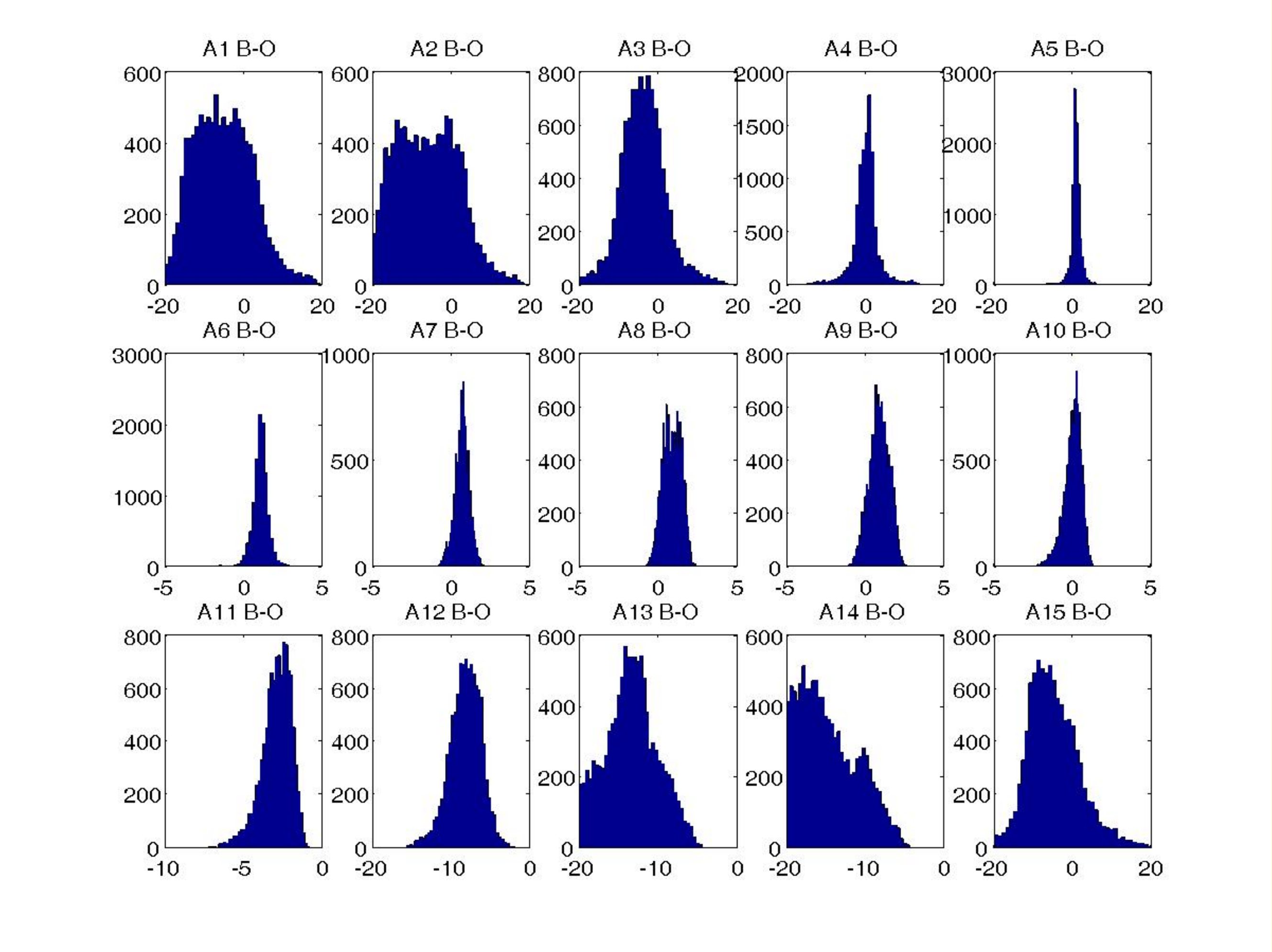
NOAA16 AMSU-B



NOAA16 HIRS


channel 1
channel 2
channel 3
channel 4
channel 5
channel 6
channel 7
channel 8
channel 9
channel 10
channel 11
channel 12
channel 13
channel 14
channel 15
channel 16
channel 17
channel 18
channel 19
bias
time

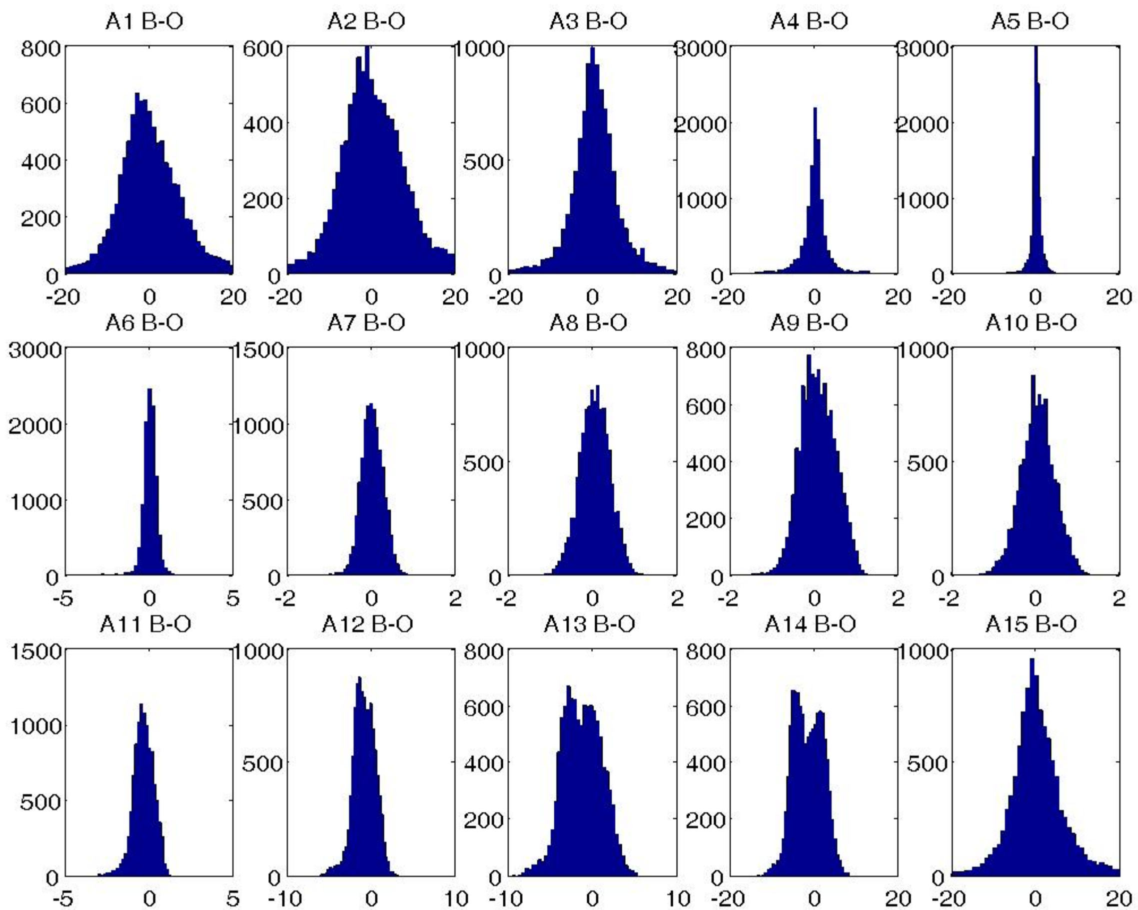
AMSU-A Bias correction



Histogram of background-obs before bias correction July 15 2003 06UTC

Abscissa：TB（ bin width 0.5deg ）； ordinate：number of obs within each bin

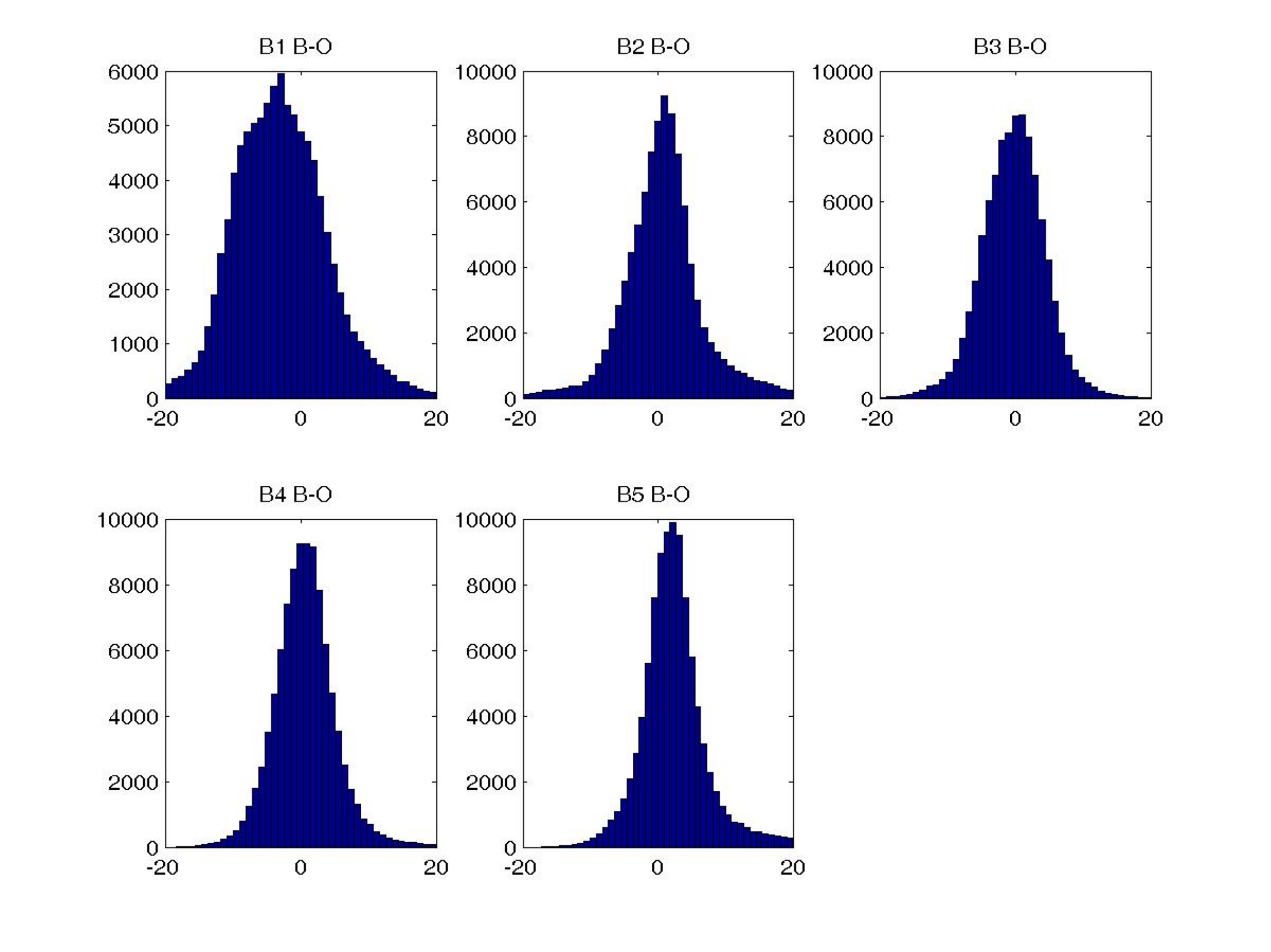
AMSU-A Bias correction



Histogram of background-obs after bias correction July 15 2003 06UTC

Abscissa：TB（ bin width 0.5deg ）；ordinate：number of obs within each bin

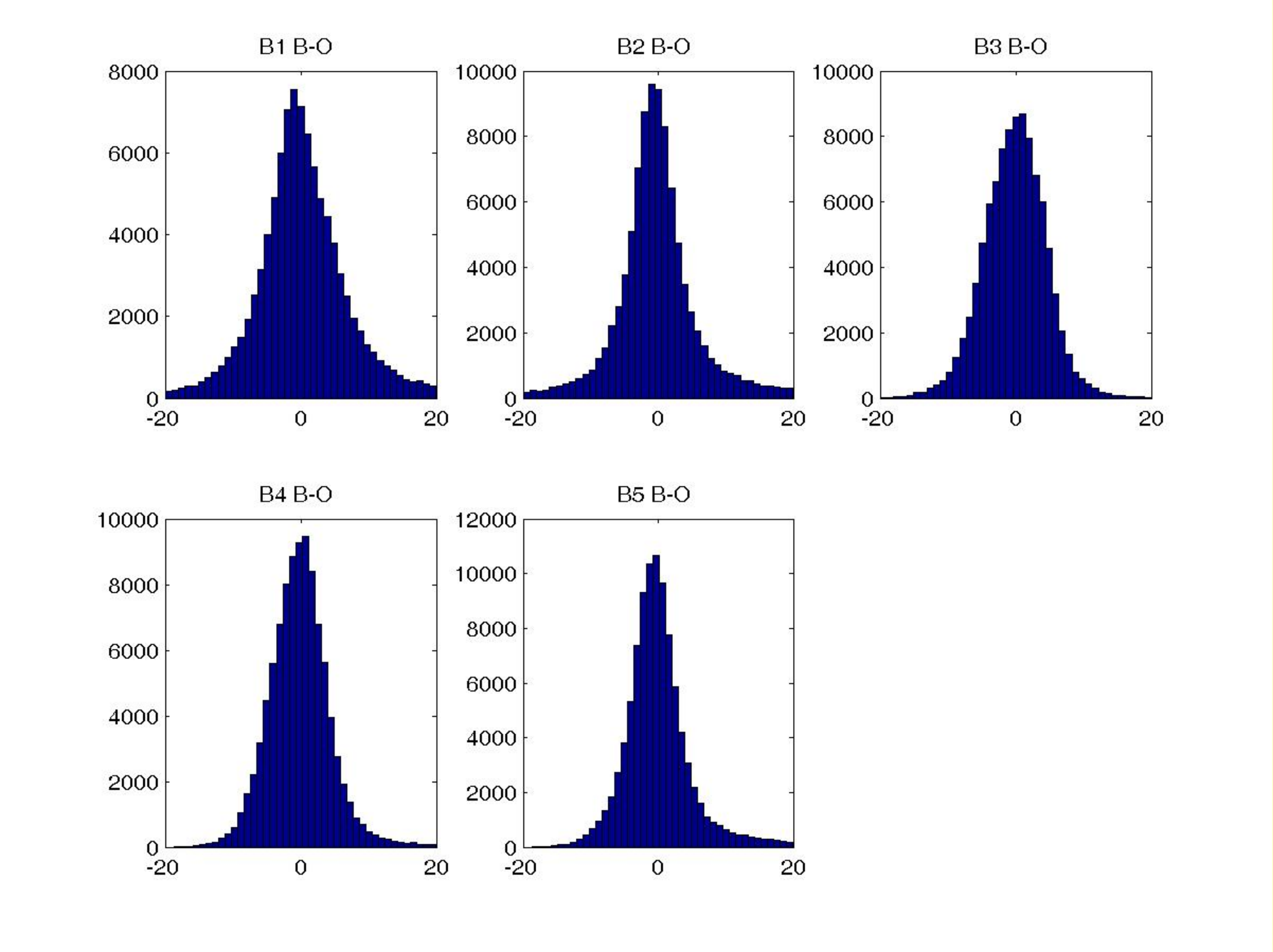
AMSU-B before Bias correction



Histogram of background-obs before bias correction July 15 2003 06UTC

Abscissa：TB（ bin width 0.5deg ）；ordinate：number of obs within each bin

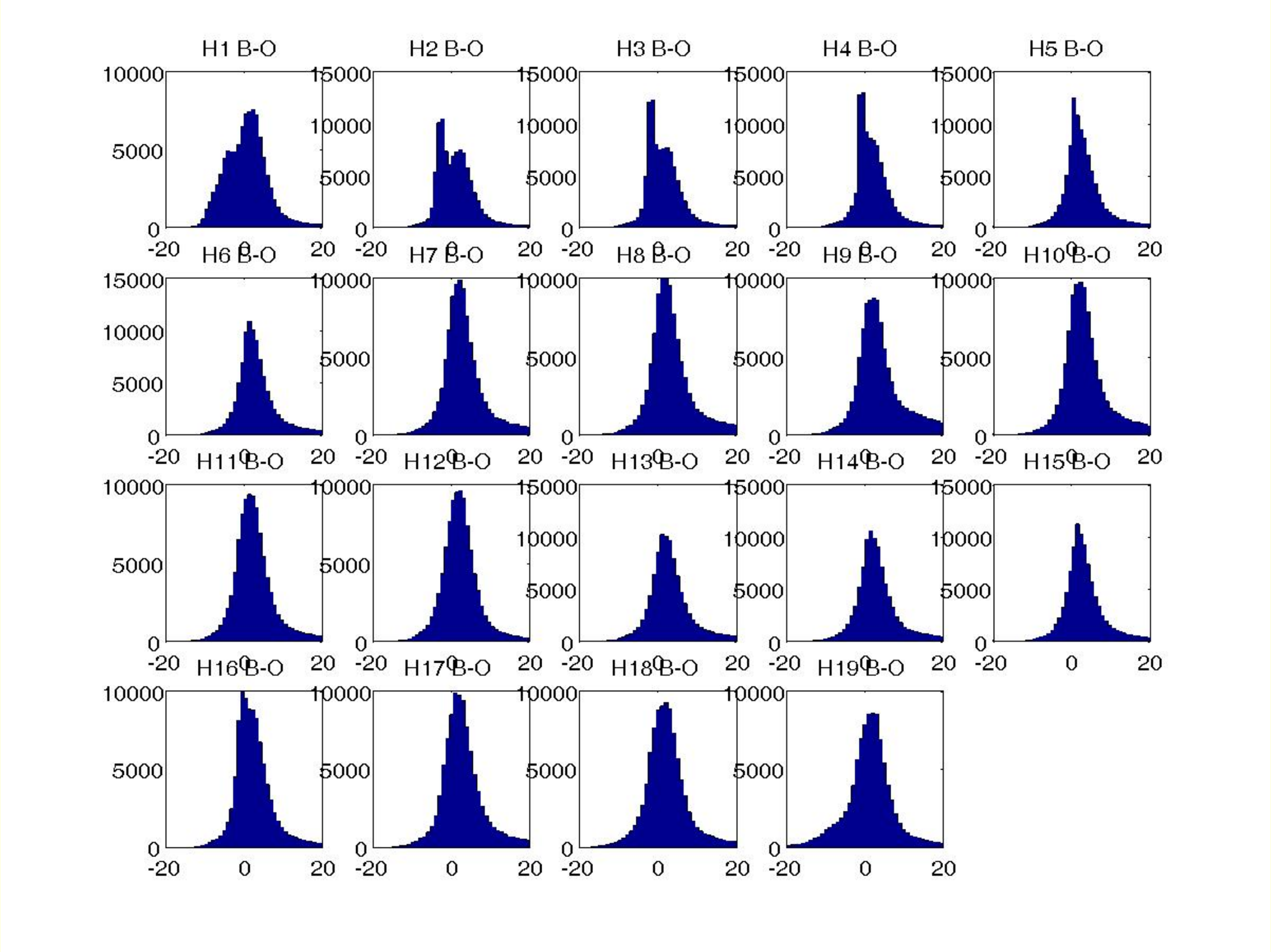
AMSU-B after Bias correction



Histogram of background-obs after bias correction July 15 2003 06UTC

Abscissa：TB（ bin width 0.5deg ）；ordinate：number of obs within each bin

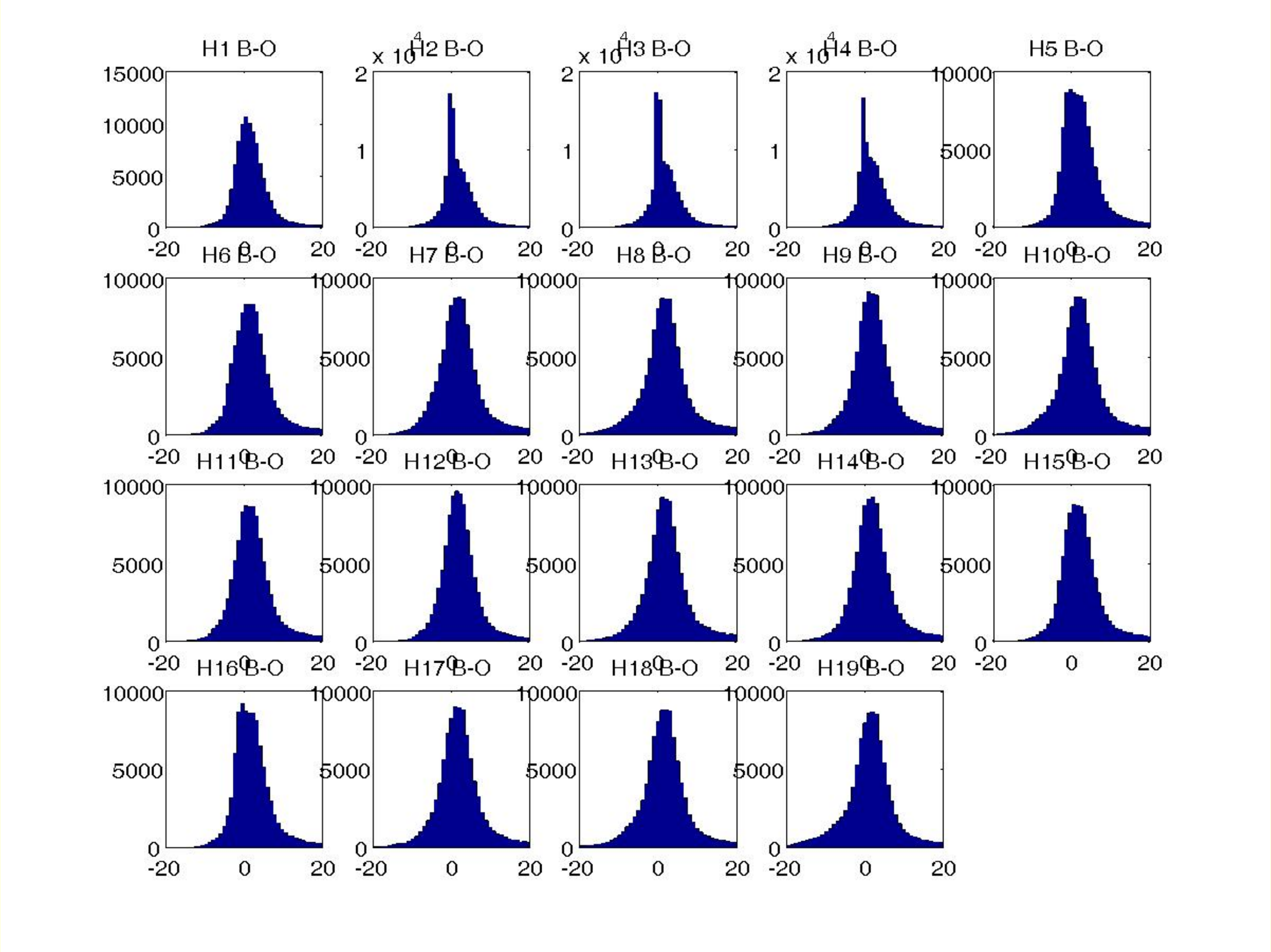
HIRS before Bias correction



Histogram of background-obs before bias correction July 15 2003 06UTC

Abscissa：TB（ bin width 0.5deg ）；ordinate：number of obs within each bin

HIRS after Bias correction



Histogram of background-obs after bias correction July 15 2003 06UTC

Abscissa：TB（ bin width 0.5deg ）；ordinate：number of obs within each bin

4. Impact of ATOVS data on typhoon prediction

A case study :typhoon Rammasun, June30-July6 2002

Data : radiosonde

ATOVS radiation (microwave)

background from T213 prediction

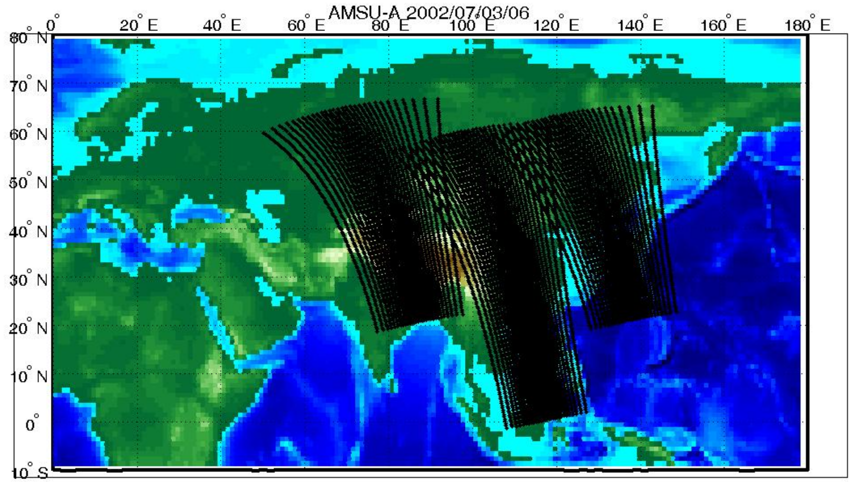
Prediction model : WRF

Control run: with only radiasondes

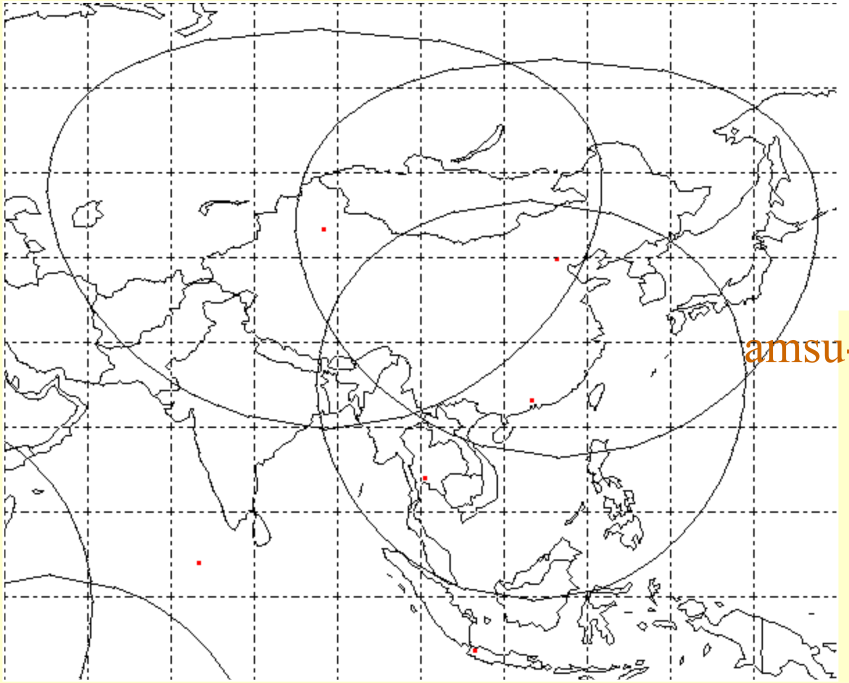
Exp1: with only ATOVS

Exp2: with ATOVS+ radiosondes

Coverage of ATOVS received by 3 ground stations

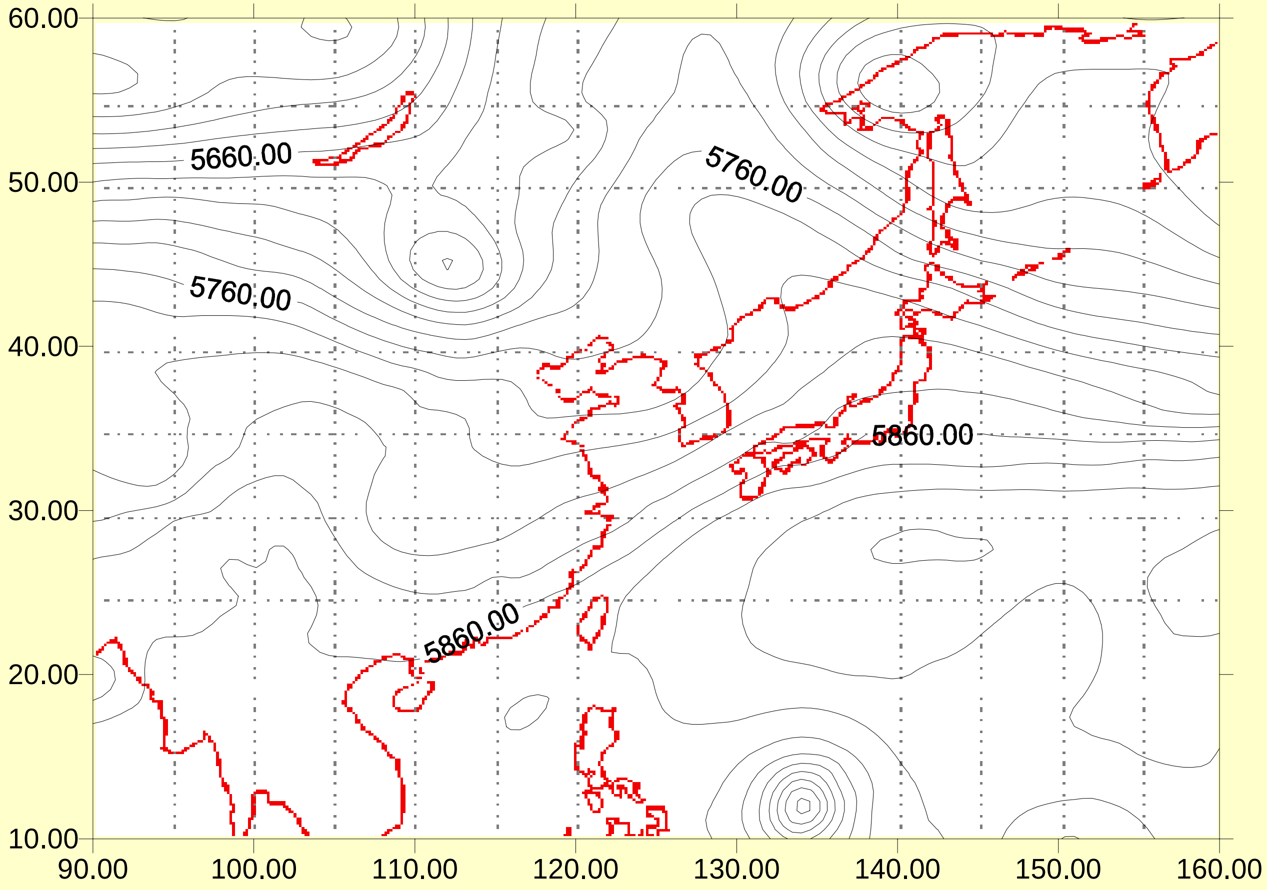


amsu-a（9600），amsu-b（86670），hirs（22400）



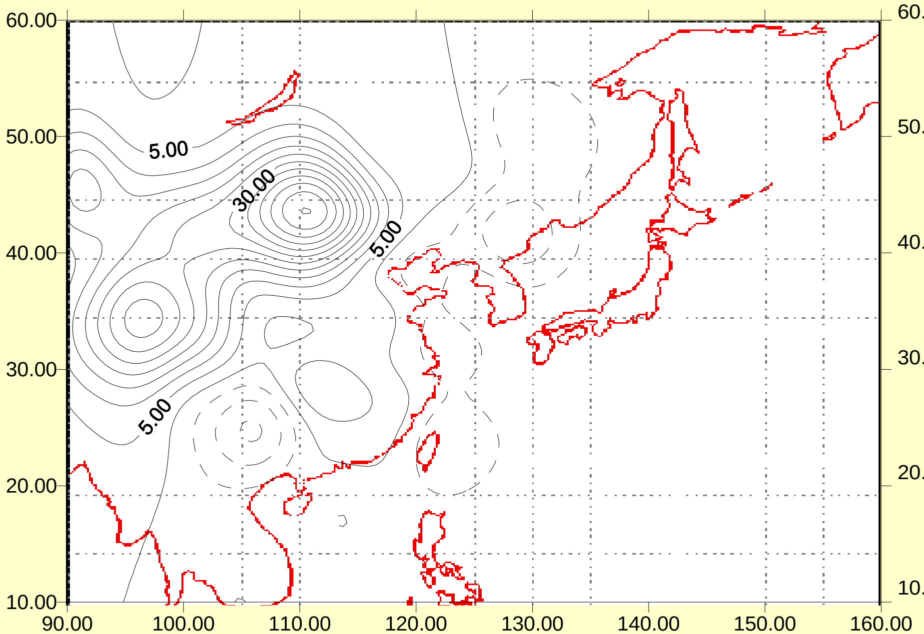
Impacts on forecast

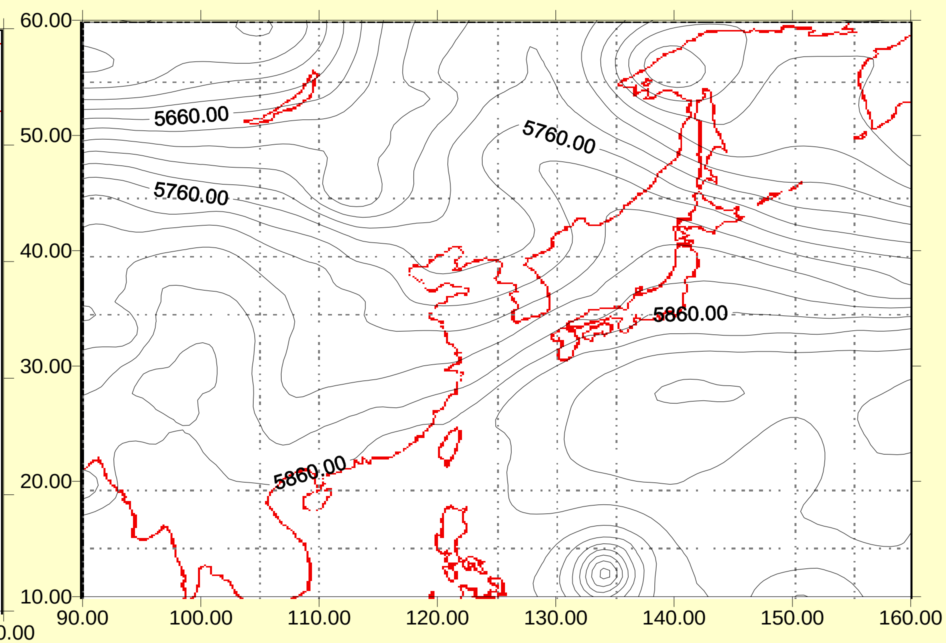
First Guess: 27 hours forecast by NMC's T213 500hPa H



Analysis of 500hPa H

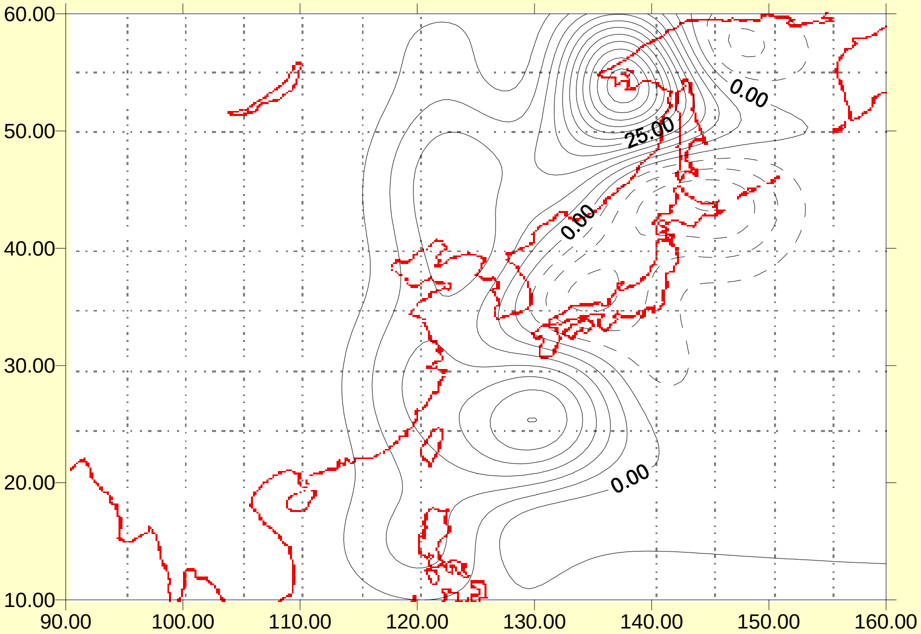
Observations：Radiosondes 12UTC July 30 2002

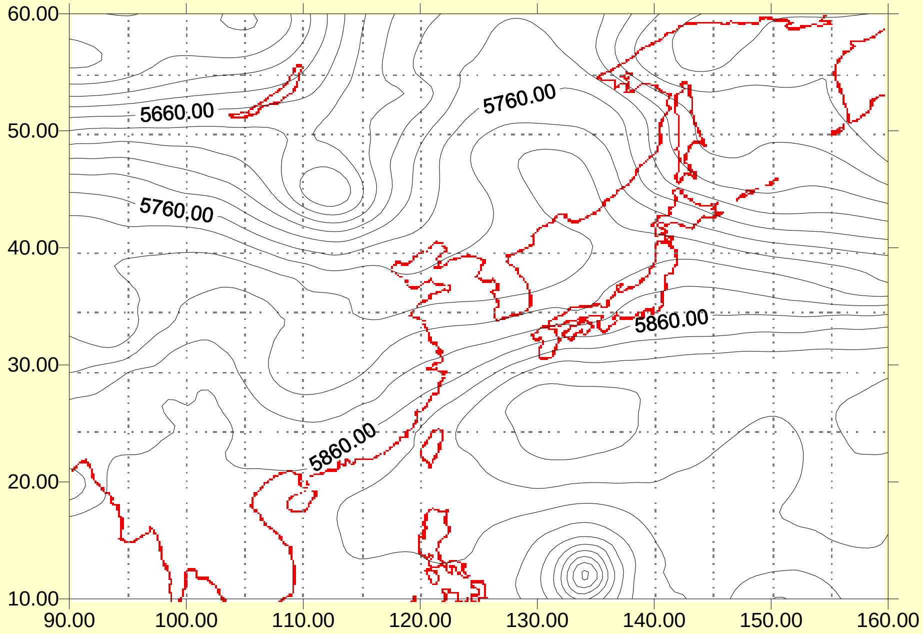




Analysis of 500hPa H

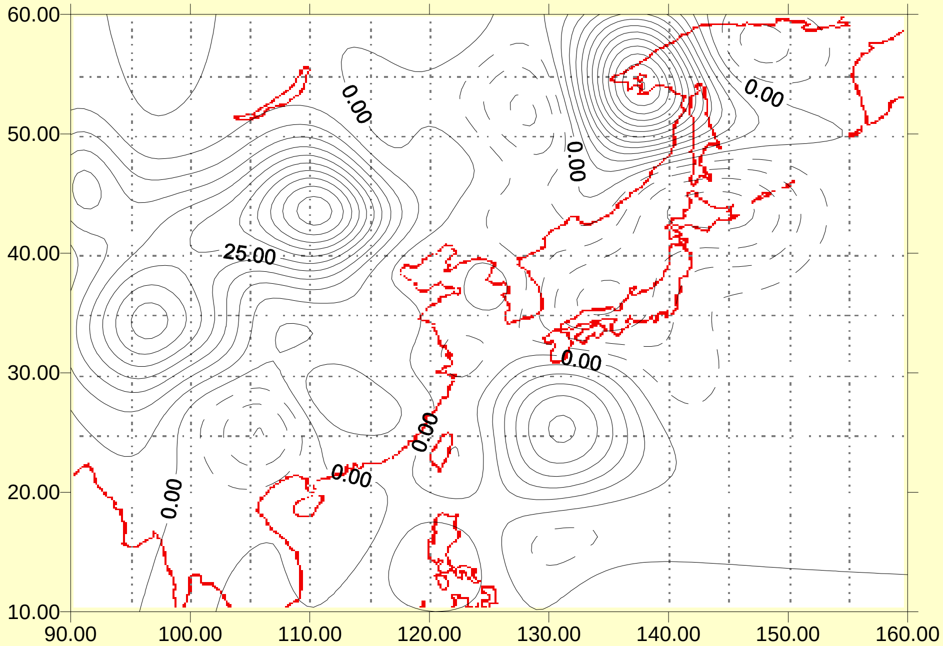
Observations：ATOVS 17UTC July 30 2002

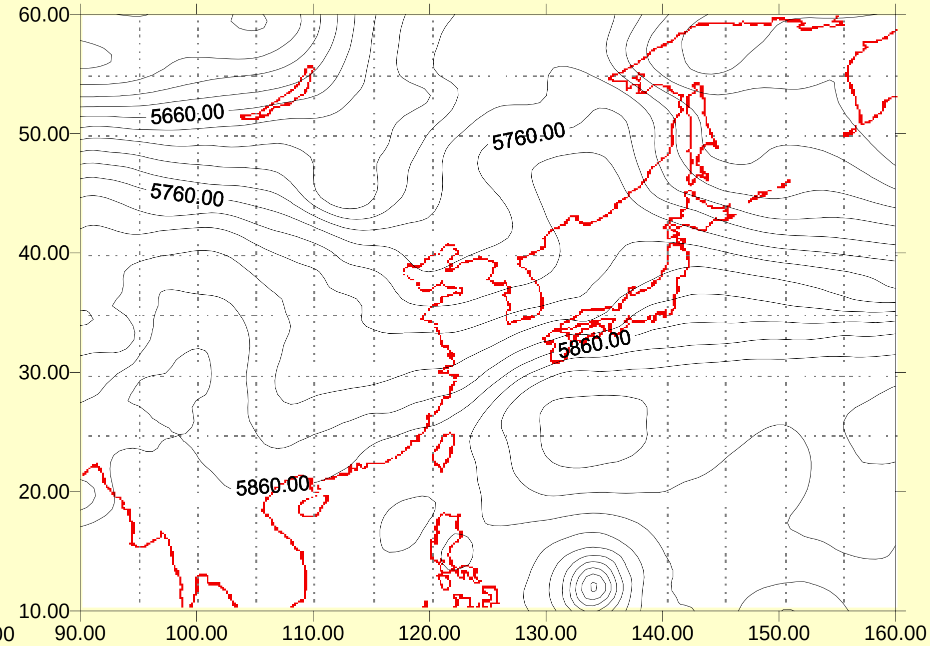




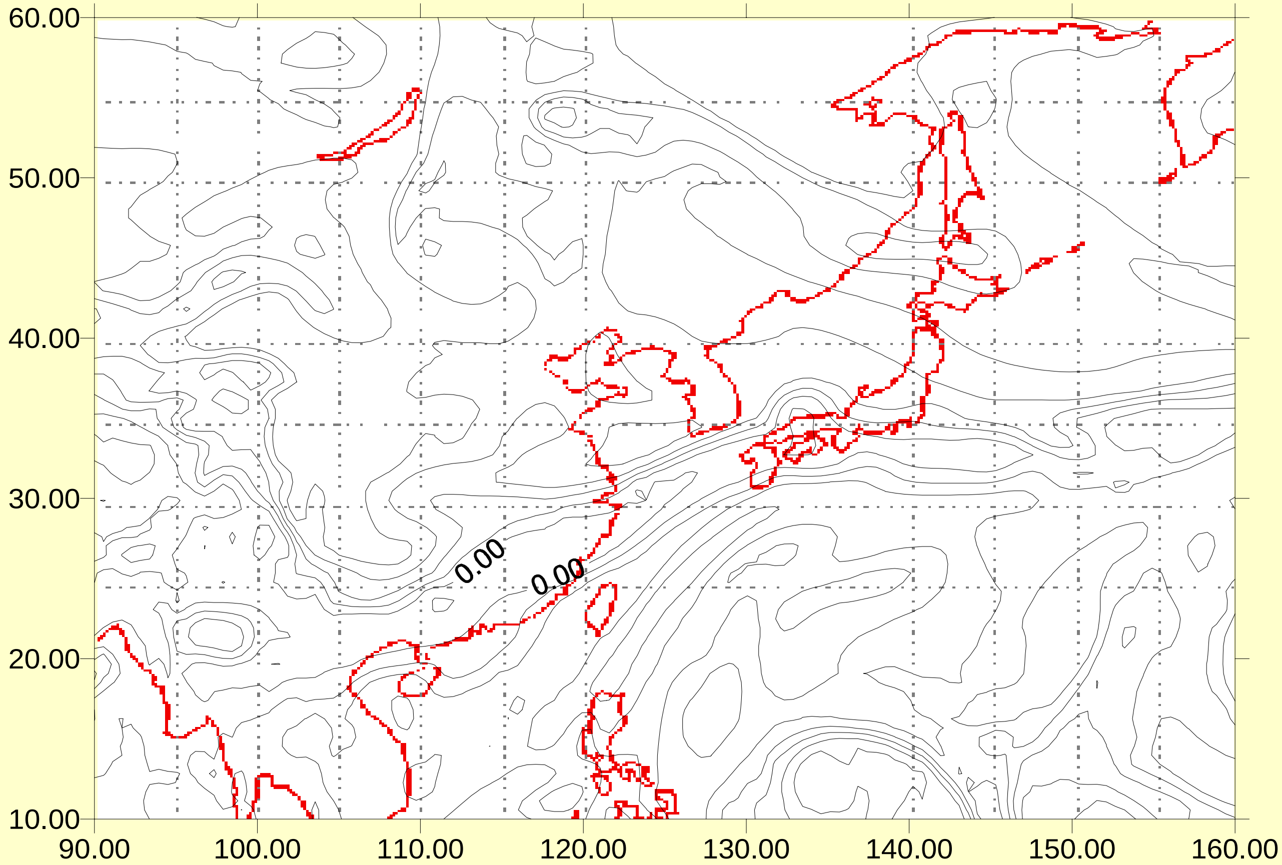
Analysis of 500hPa H

Observations：ATOVS 17UTC July 30 2002+
Radiosondes 12UTC July 30 2002



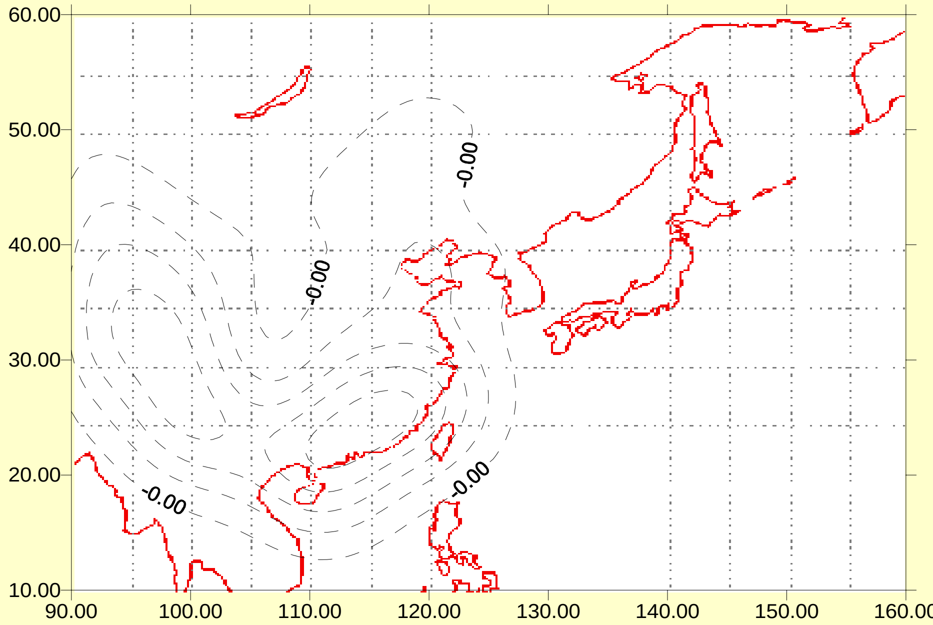


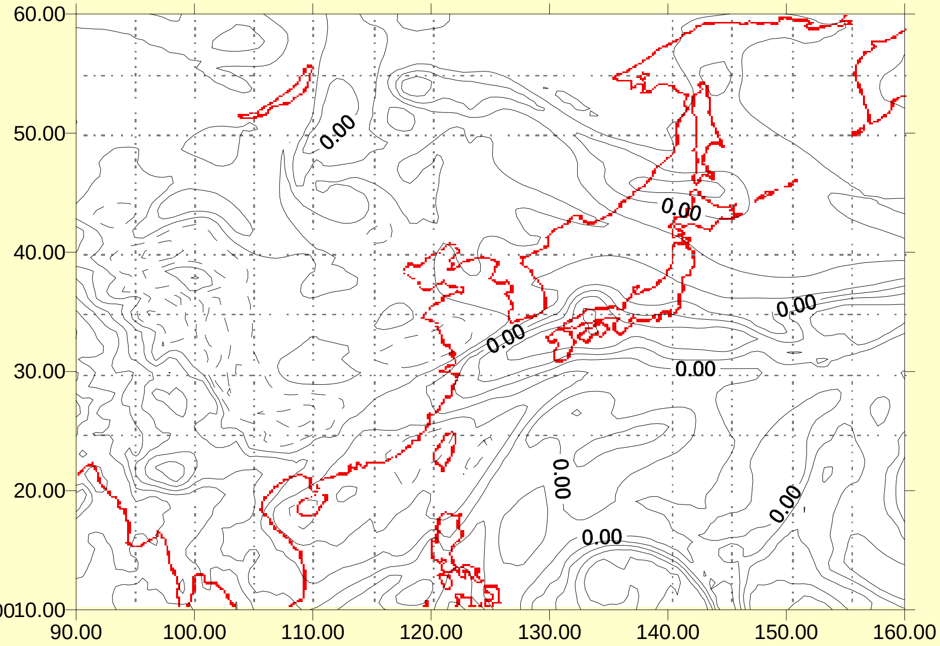
First Guess: 27 hours forecast by NMC's T213 500hPa q



Analysis of 500hPa q

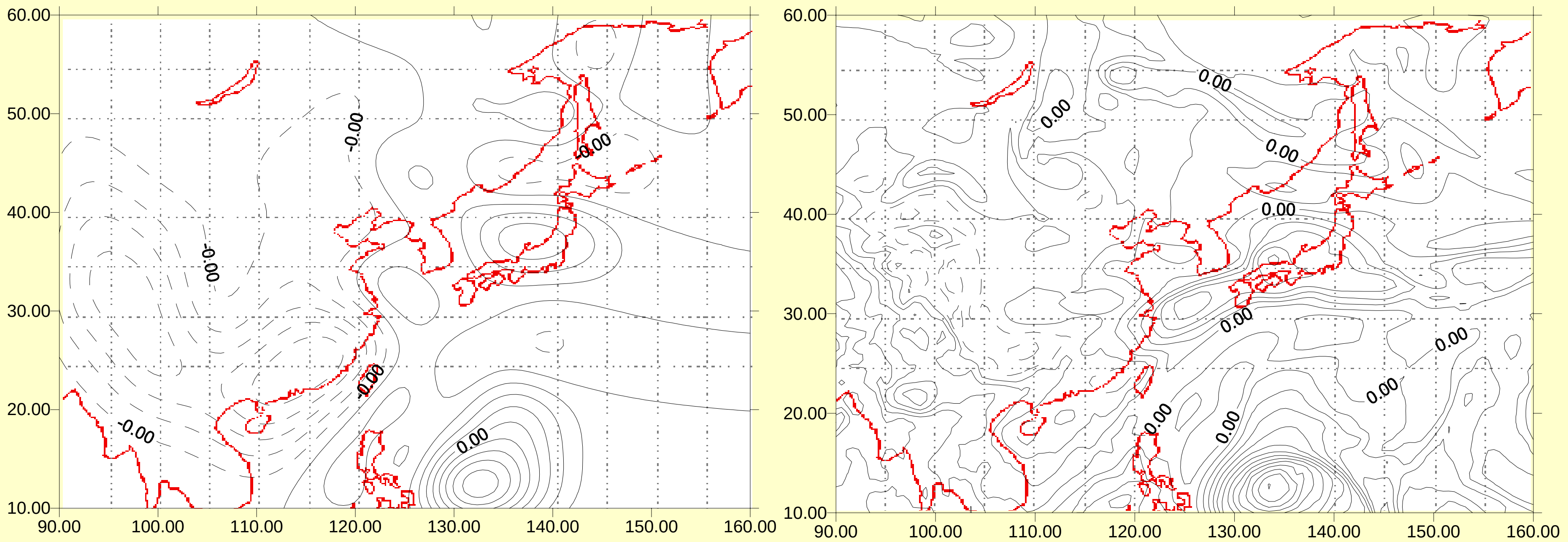
Observations：Radiosondes 12UTC July 30



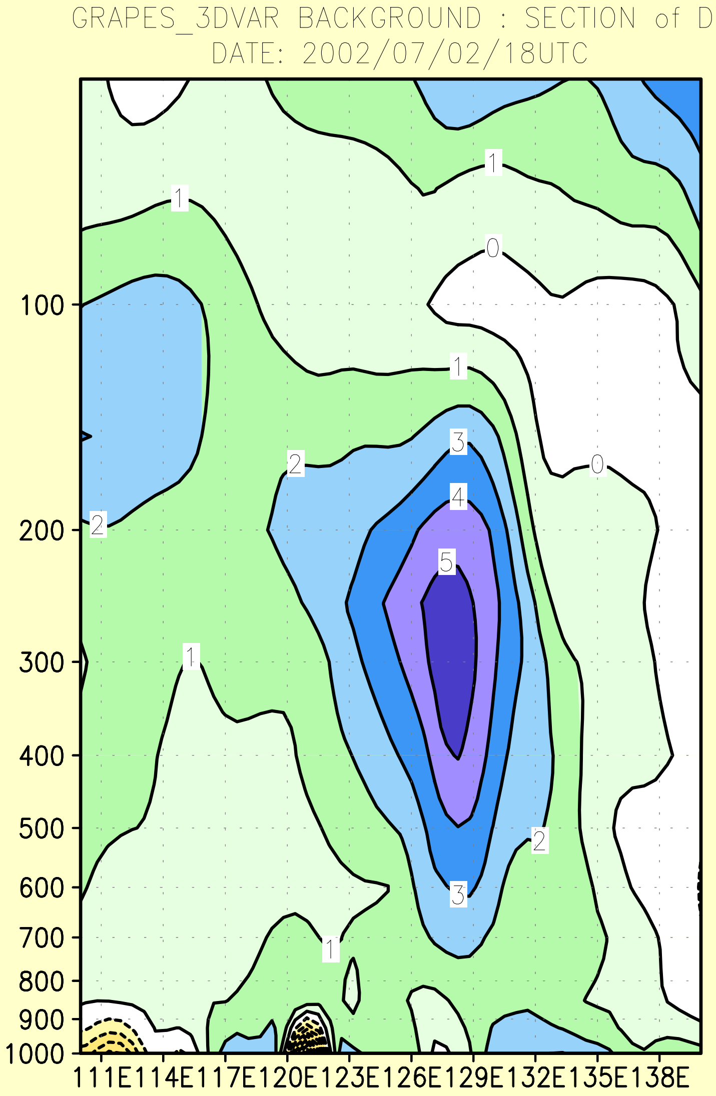


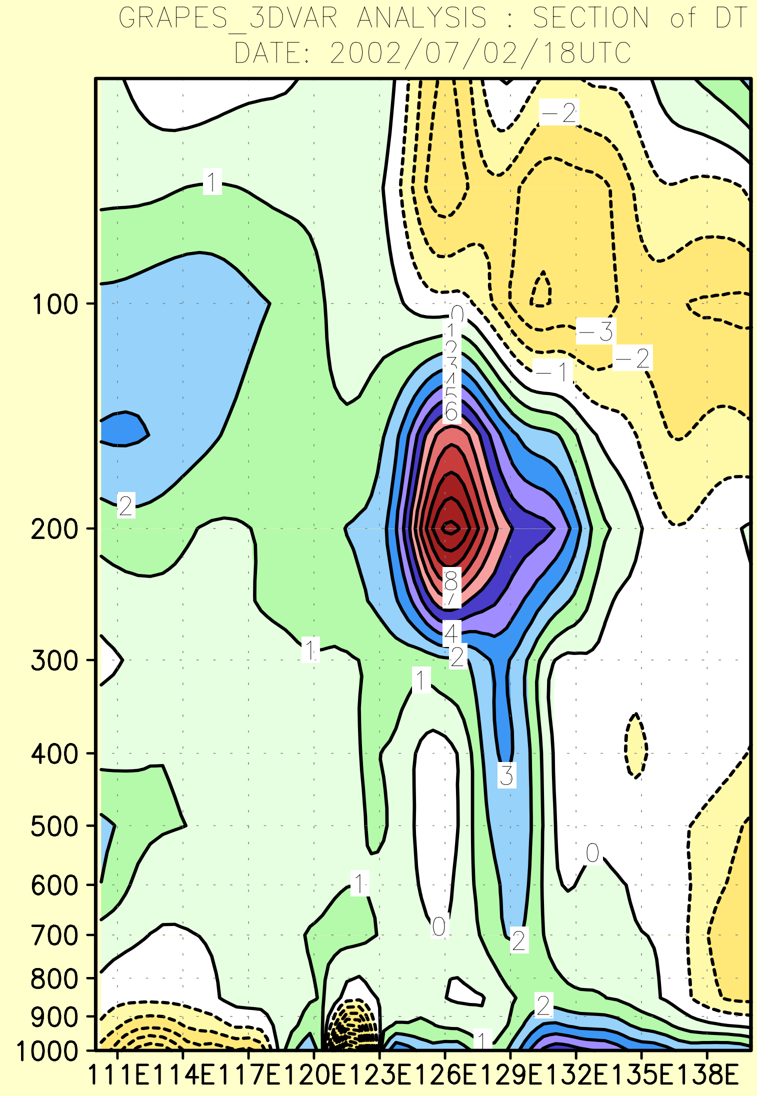
Analysis of 500hPa q

Observations：ATOVS 17UTC June 30 2002
+radiosondes 12 UTC June30



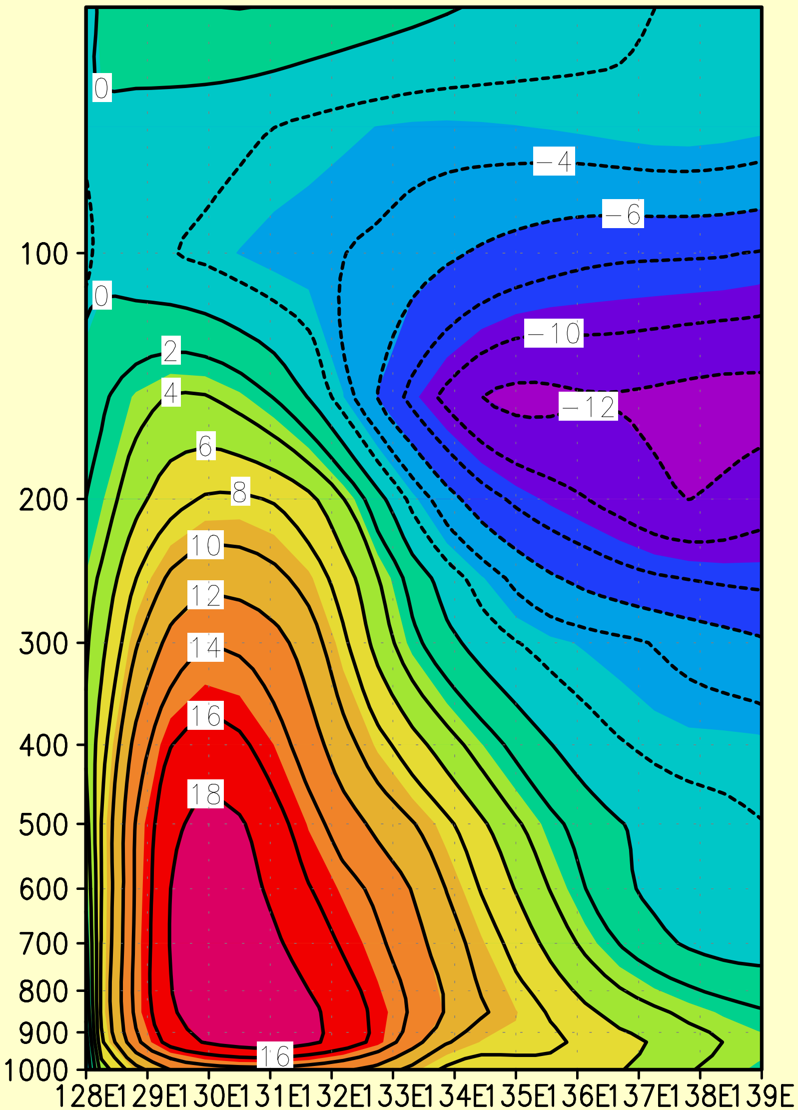
Temperature deviation from zonal mean (along 23 N)



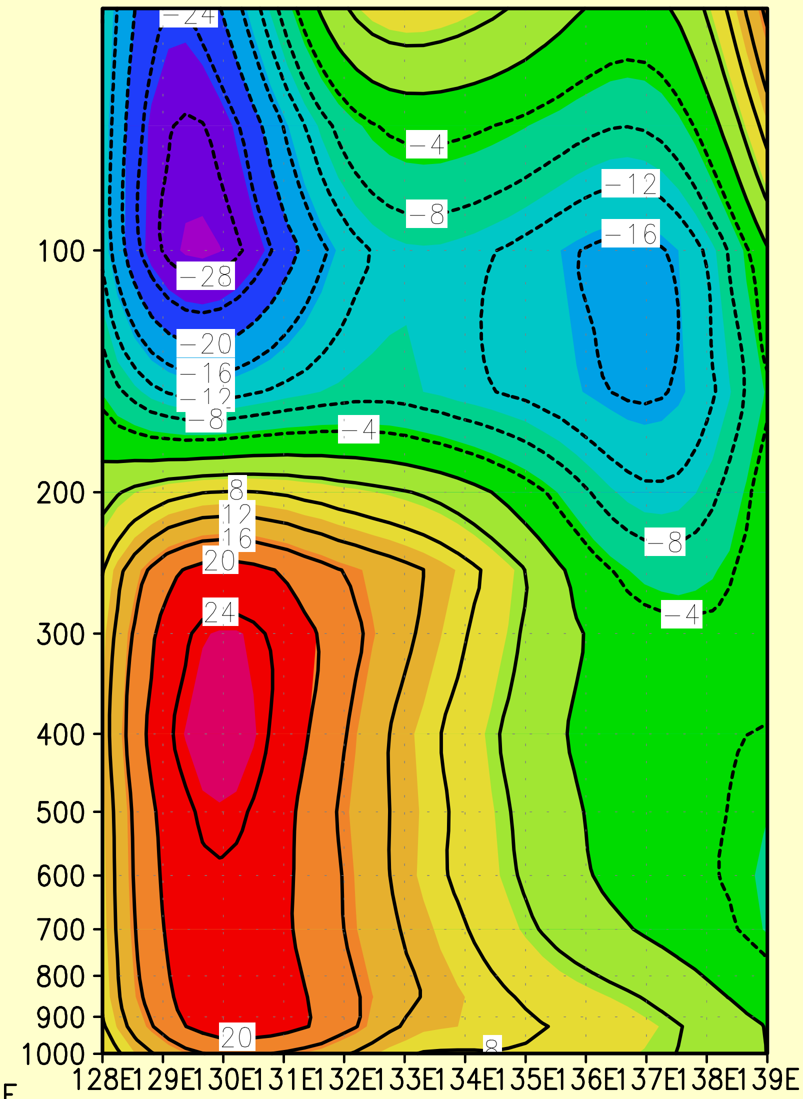


Zonal cross section of tangential winds (23N)

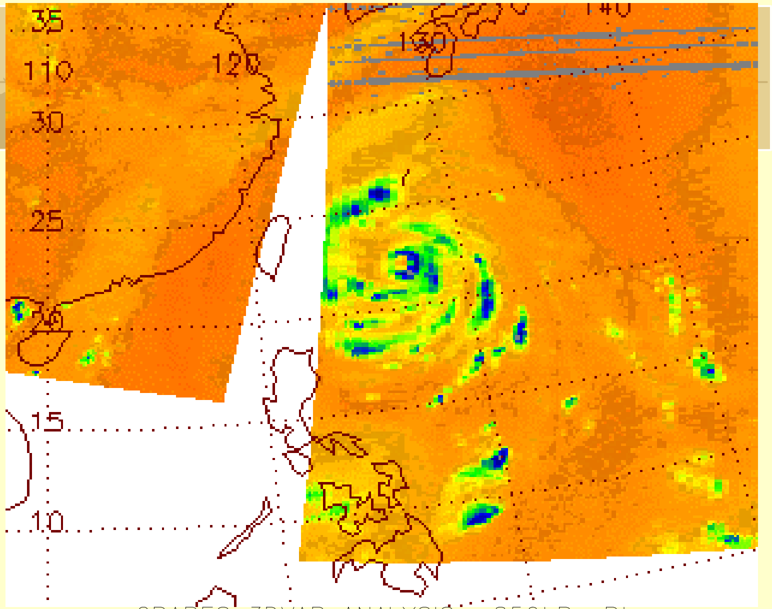
GRAPES_3DVAR BACKGROUND : SECTION of Vn
DATE: 2002/07/02/18UTC

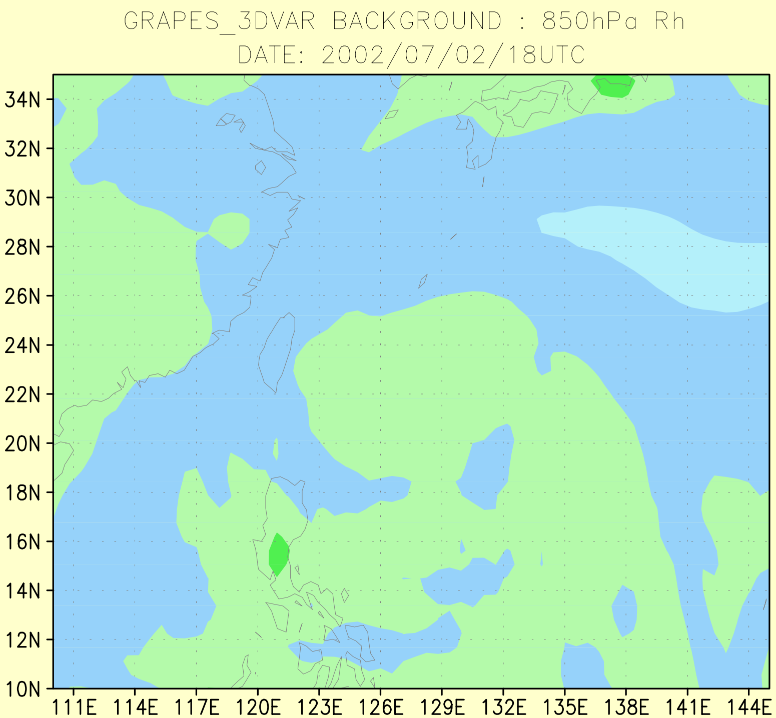


GRAPES_3DVAR ANALYSIS : SECTION of Vn
DATE: 2002/07/02/18UTC

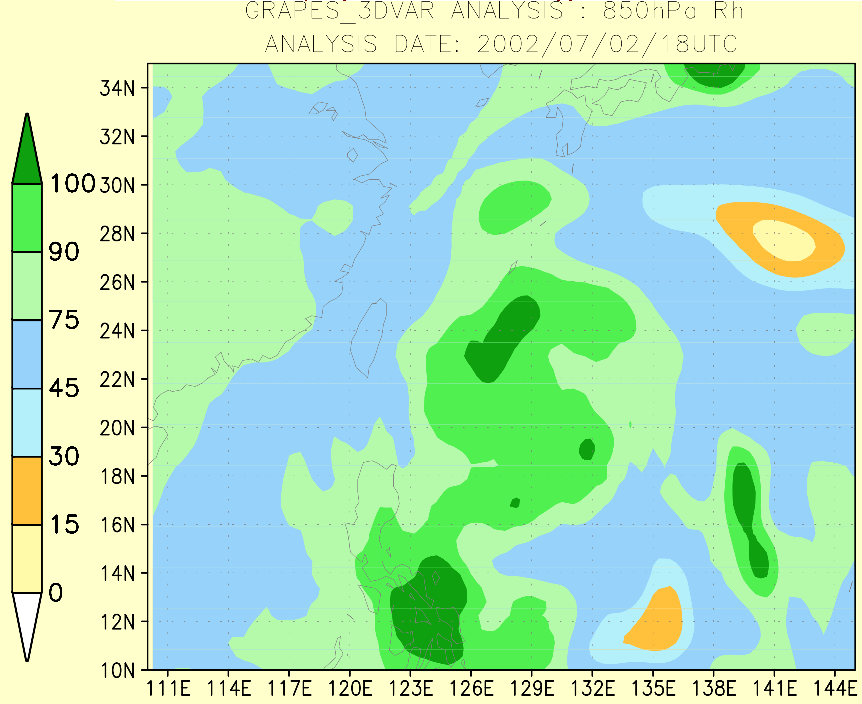


Analyses of moisture fields



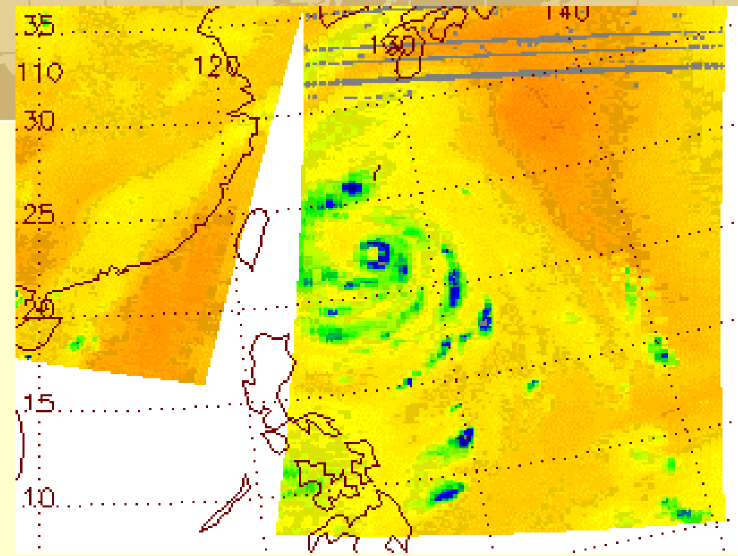


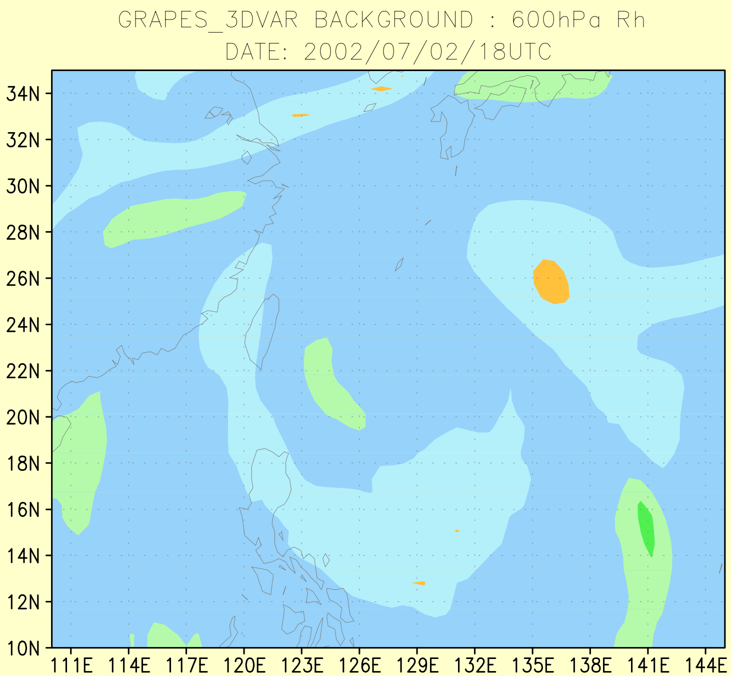
Background



With ATOVS

Analyses of moisture fields





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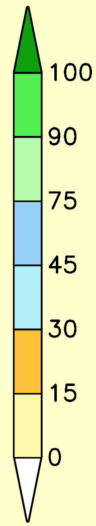
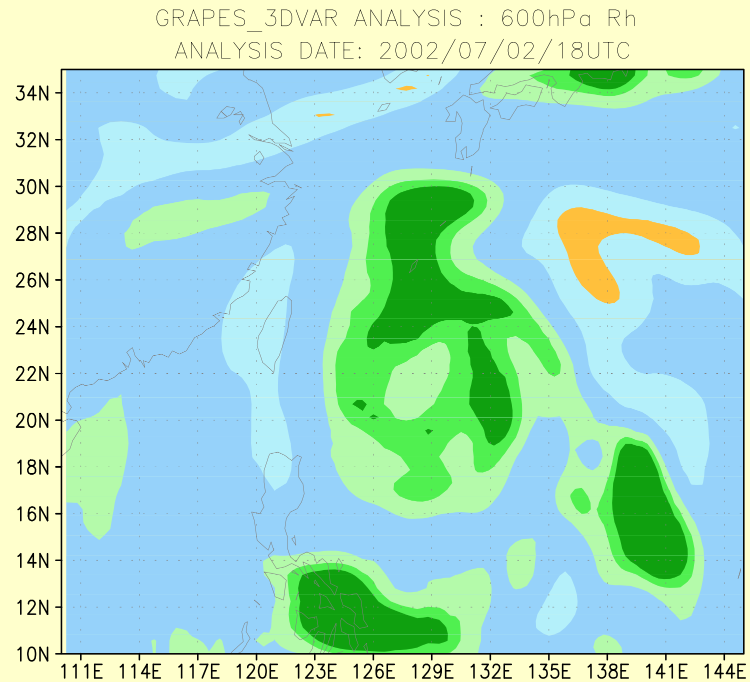
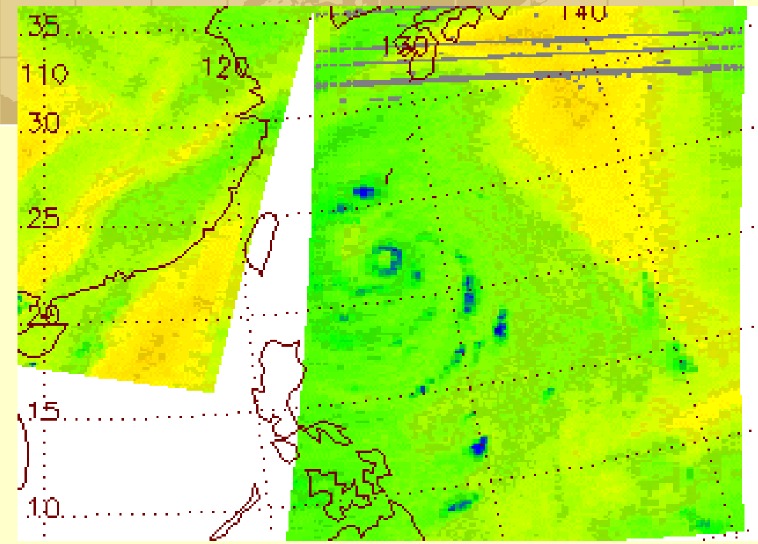
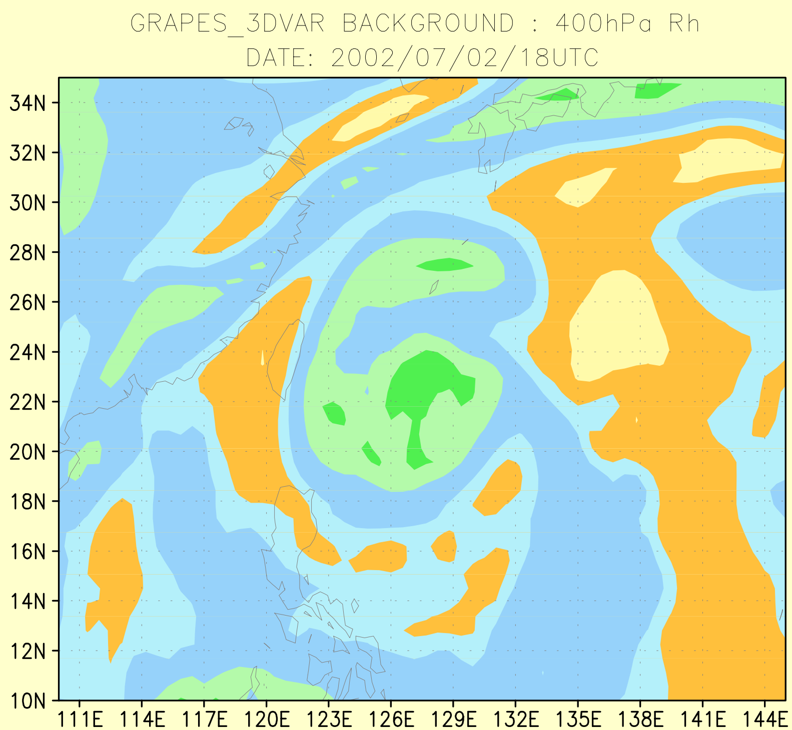




With ATOVS

Analyses of moisture fields





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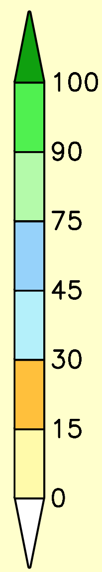
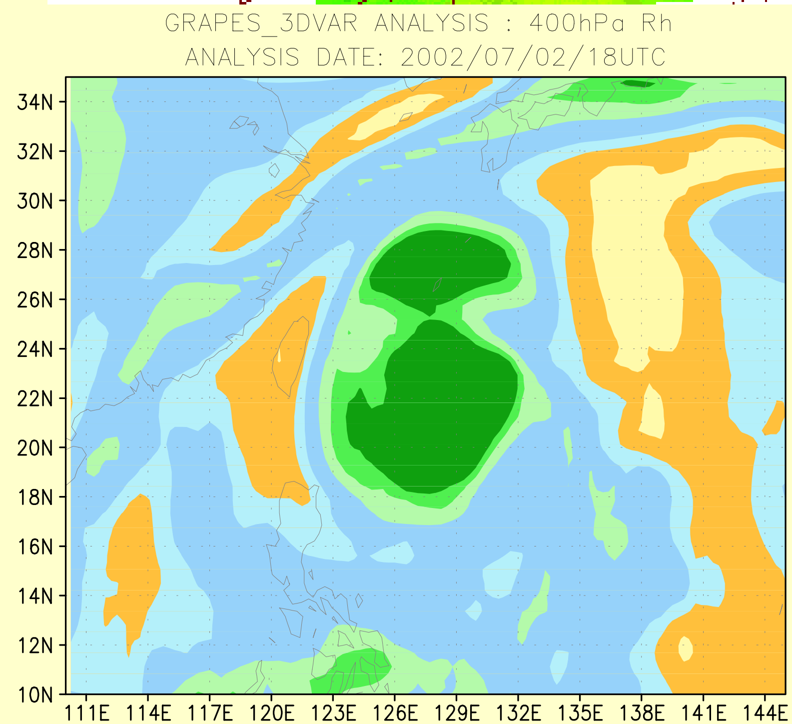
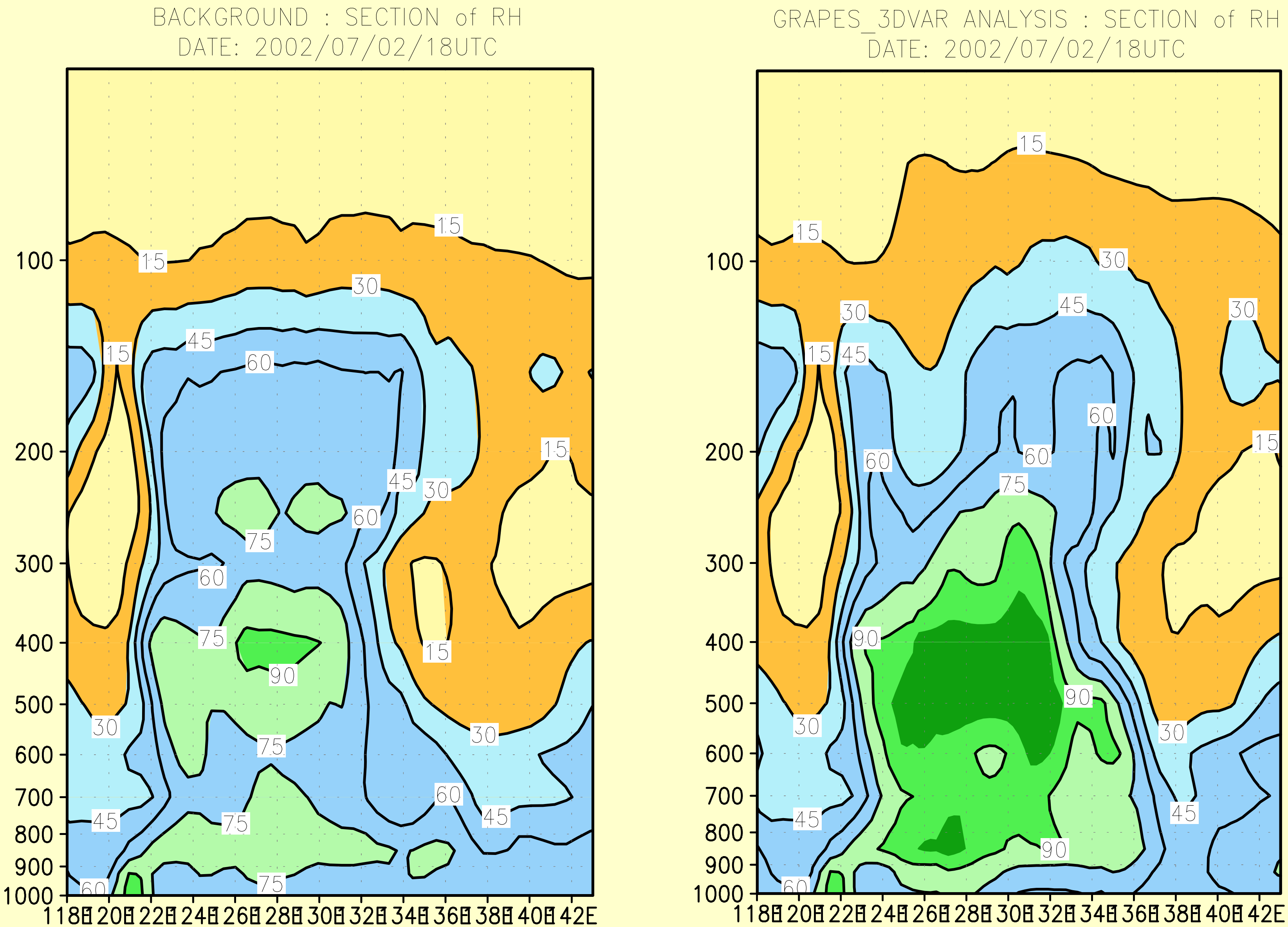


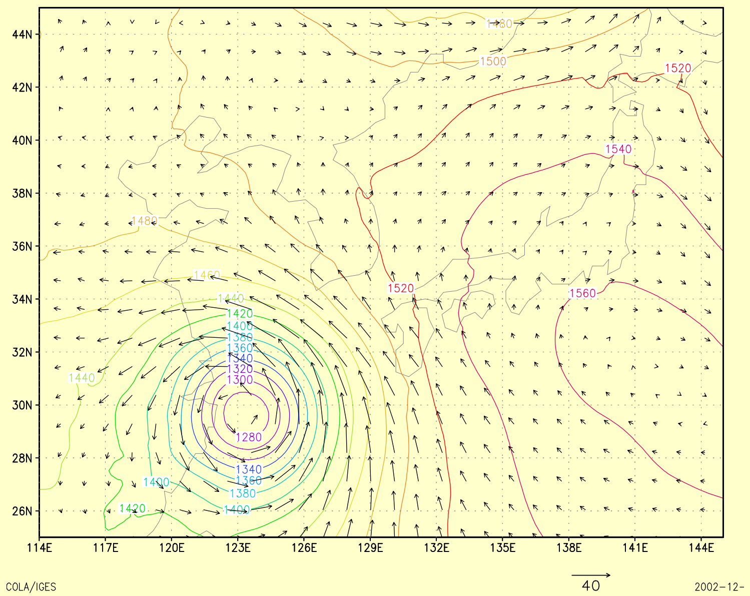


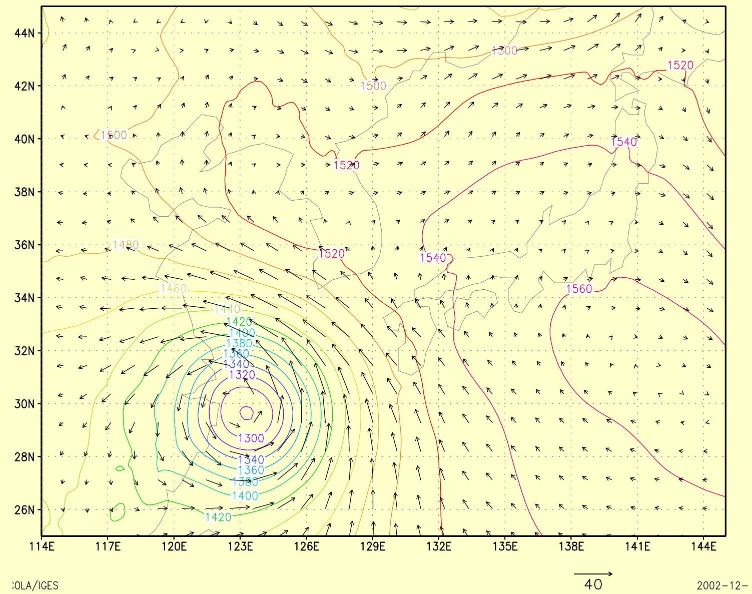
With ATOVS

Vertical-zonal cross section of moisture



Initial field: 850hpa H July 4 15UTC





Left：radiosondes

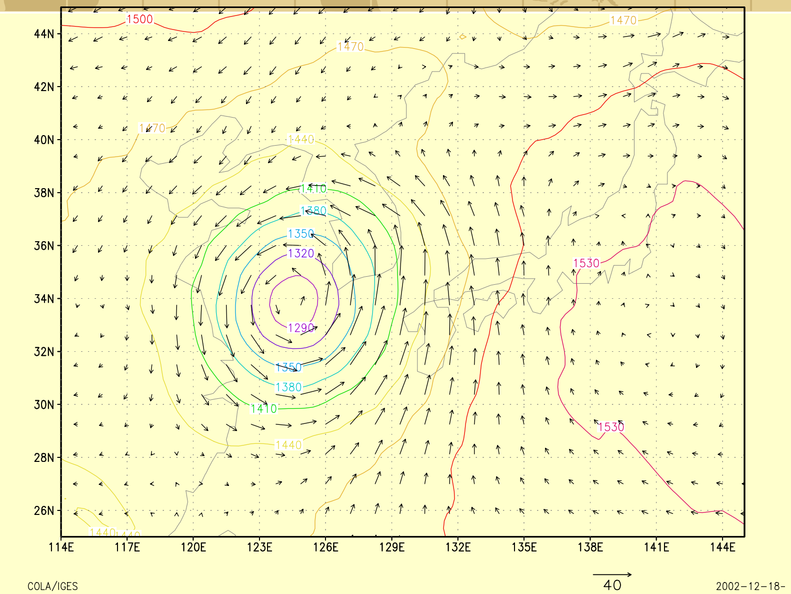
Right：radiosondes+ATOVS

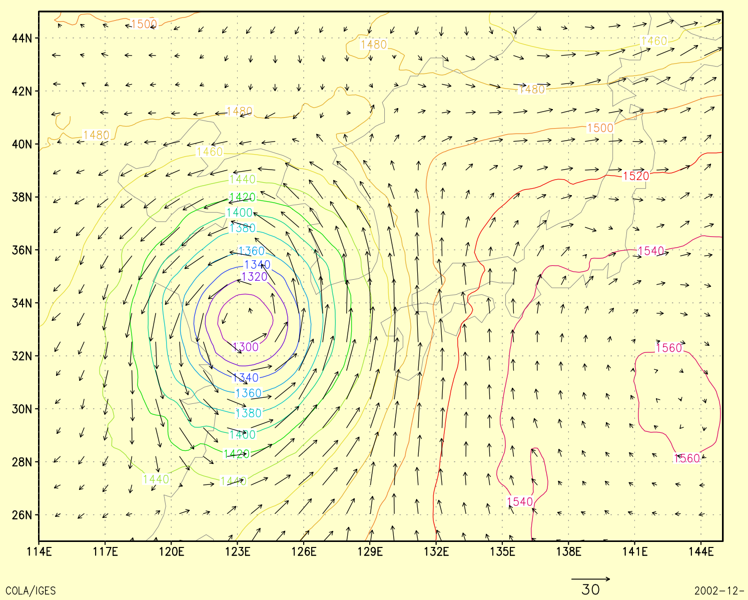
Comparison between Predictions

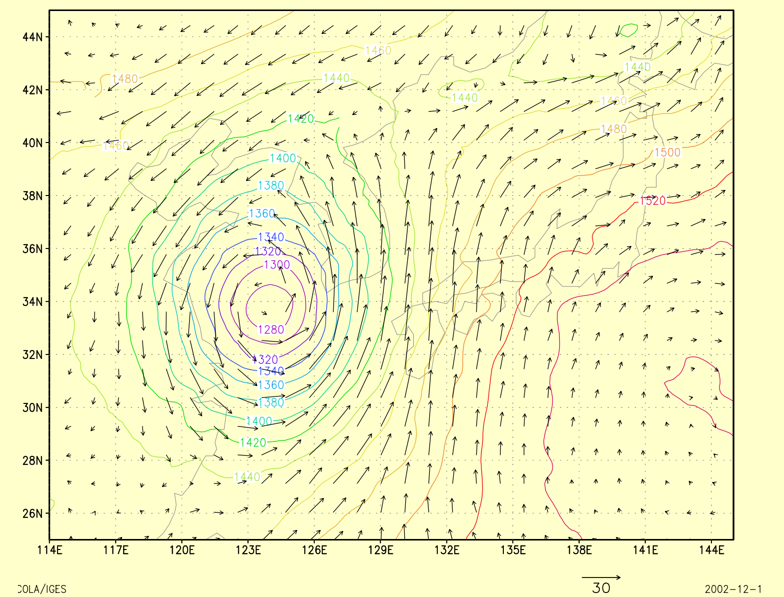
Right： July 5 2002 12UTC 850 hPa H

Below： 21h prediction (radiosondes only)

Right below： 21h prediction (radiosondes+ATOVS)





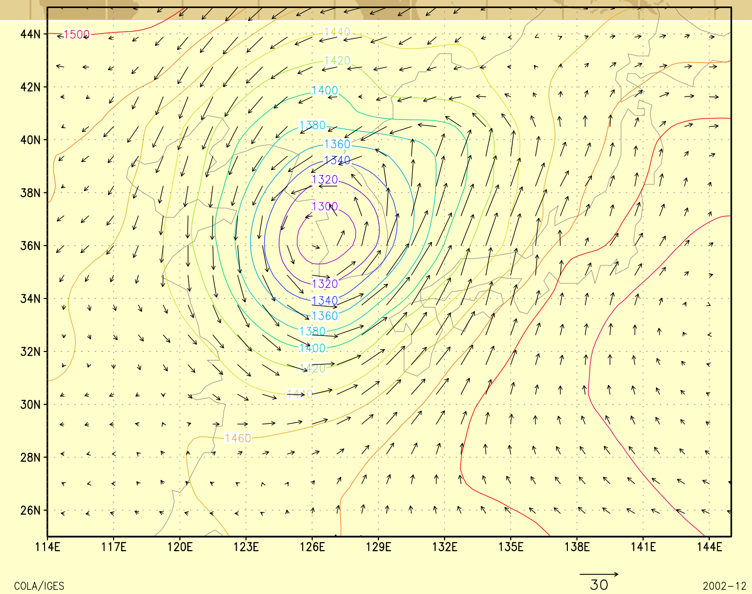


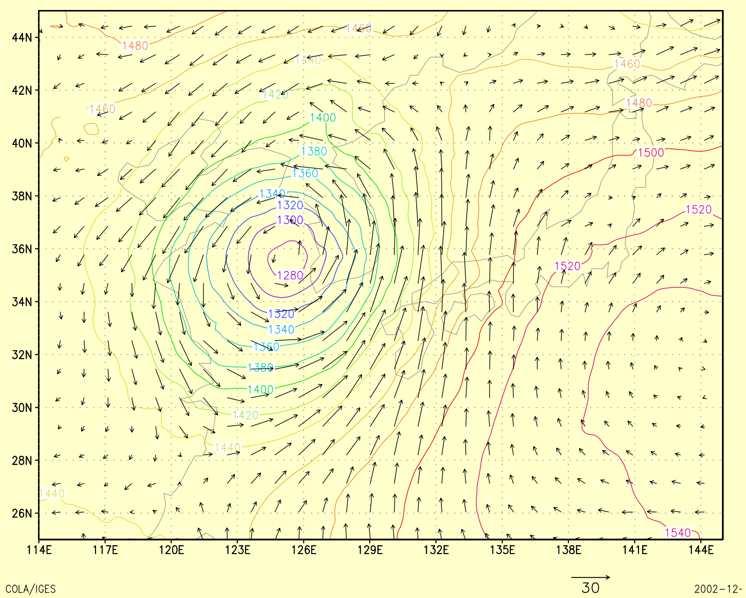
Comparison between Predictions

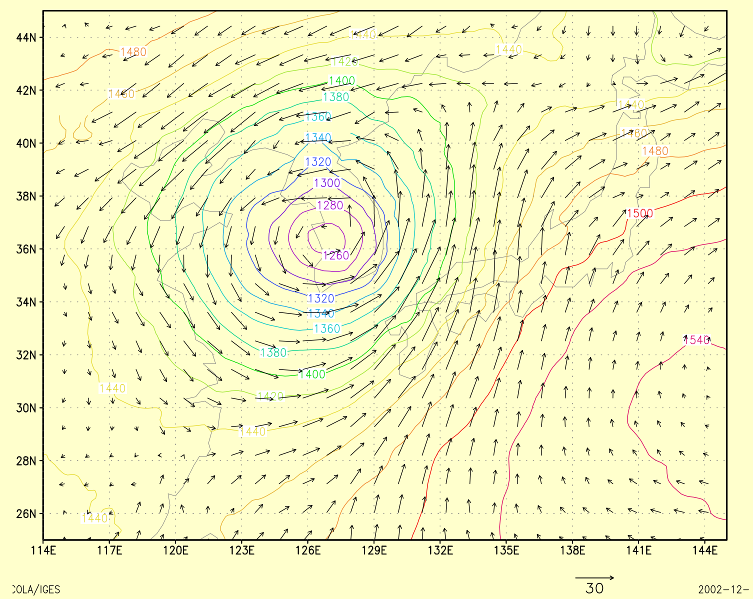
Right：July 6 00UTC 850 hPa H (analysis)

Below：33h prediction (radiosondes only)探空资料, (35.5N,125.3E)

Right below：33h prediction (radiosondes+ATOVS)





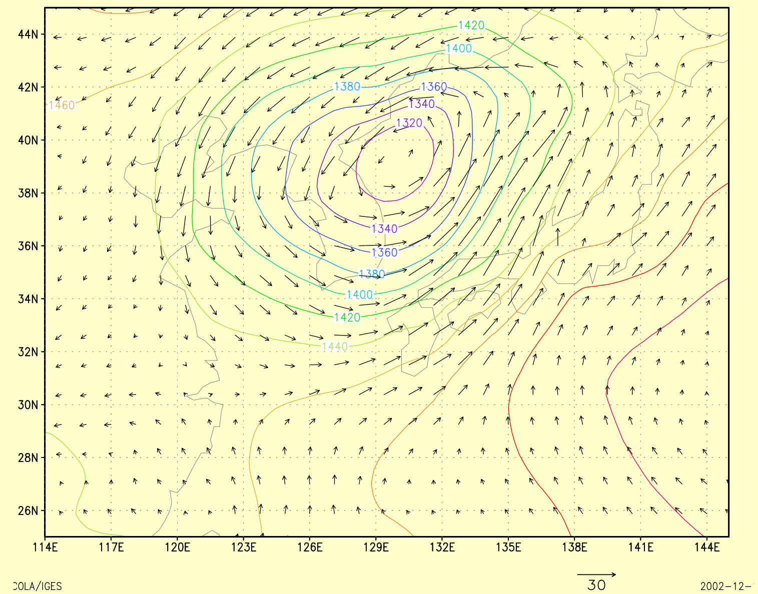


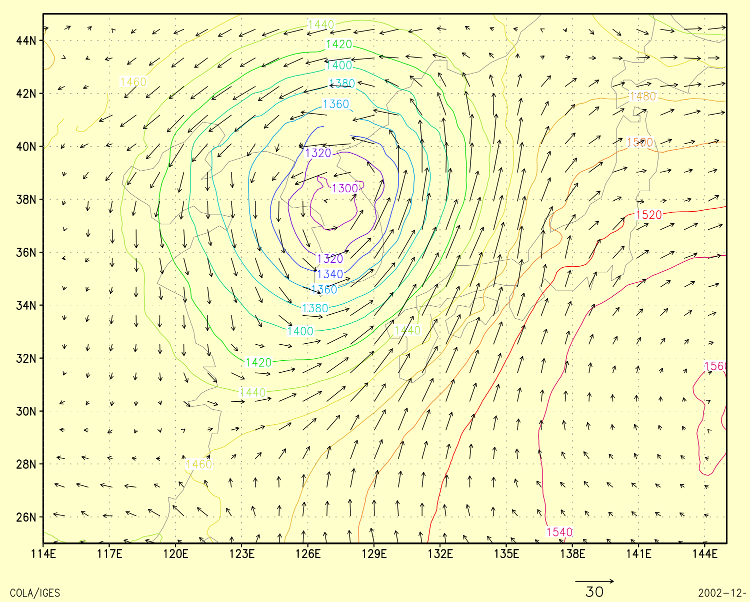
Comparison between Predictions

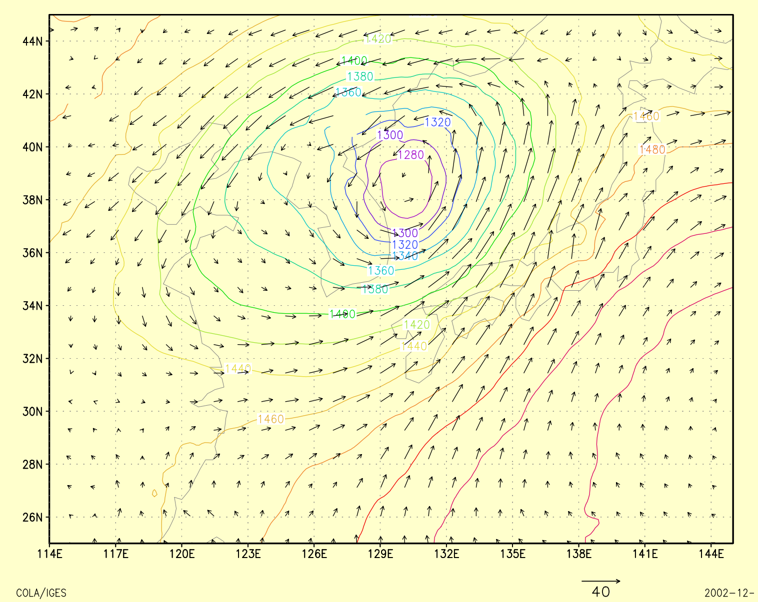
Right：July 6 12UTC 850 hPa H (analysis)

Below：45h prediction (radiosondes only)

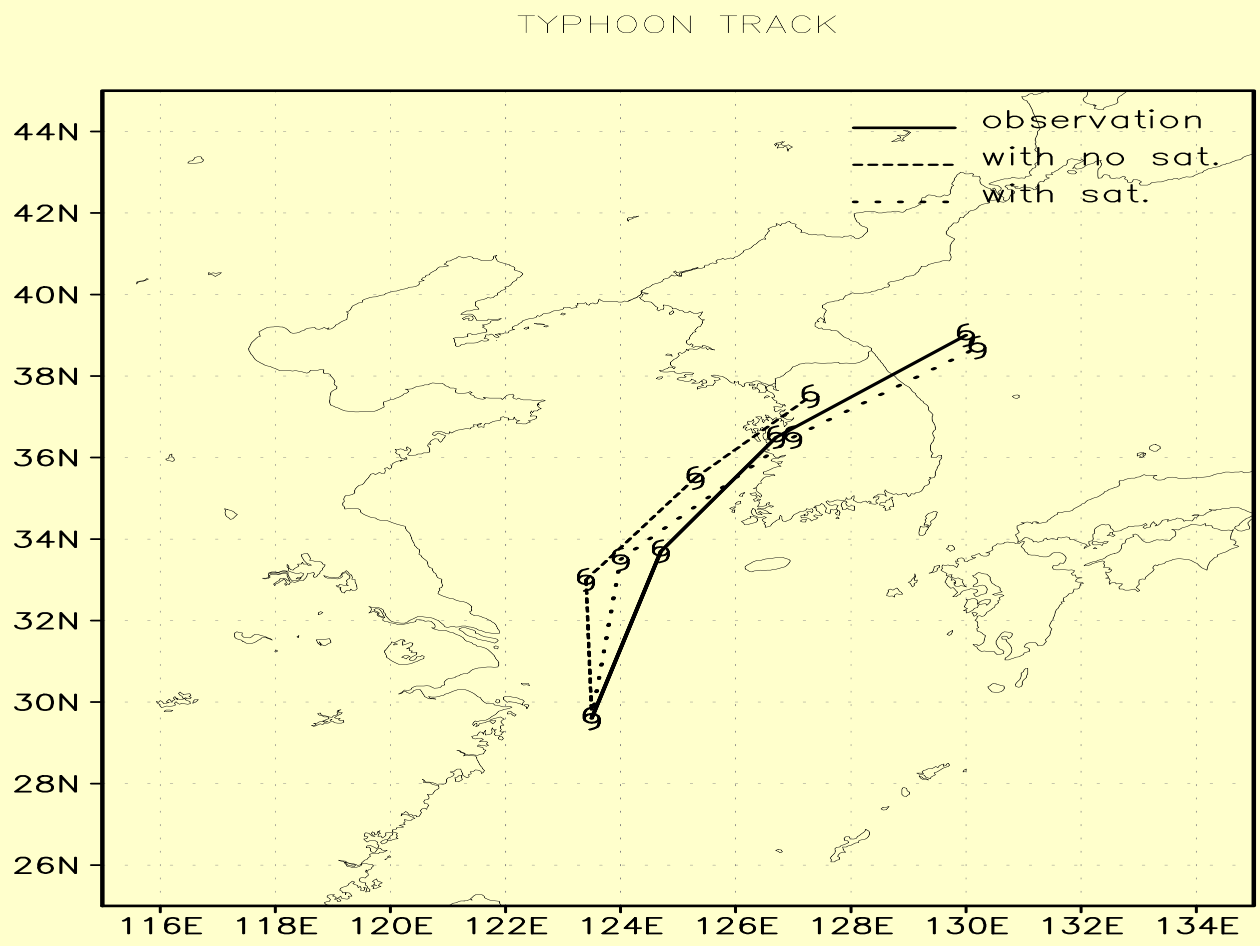
Right below：45h prediction (radiosondes +ATOVS)







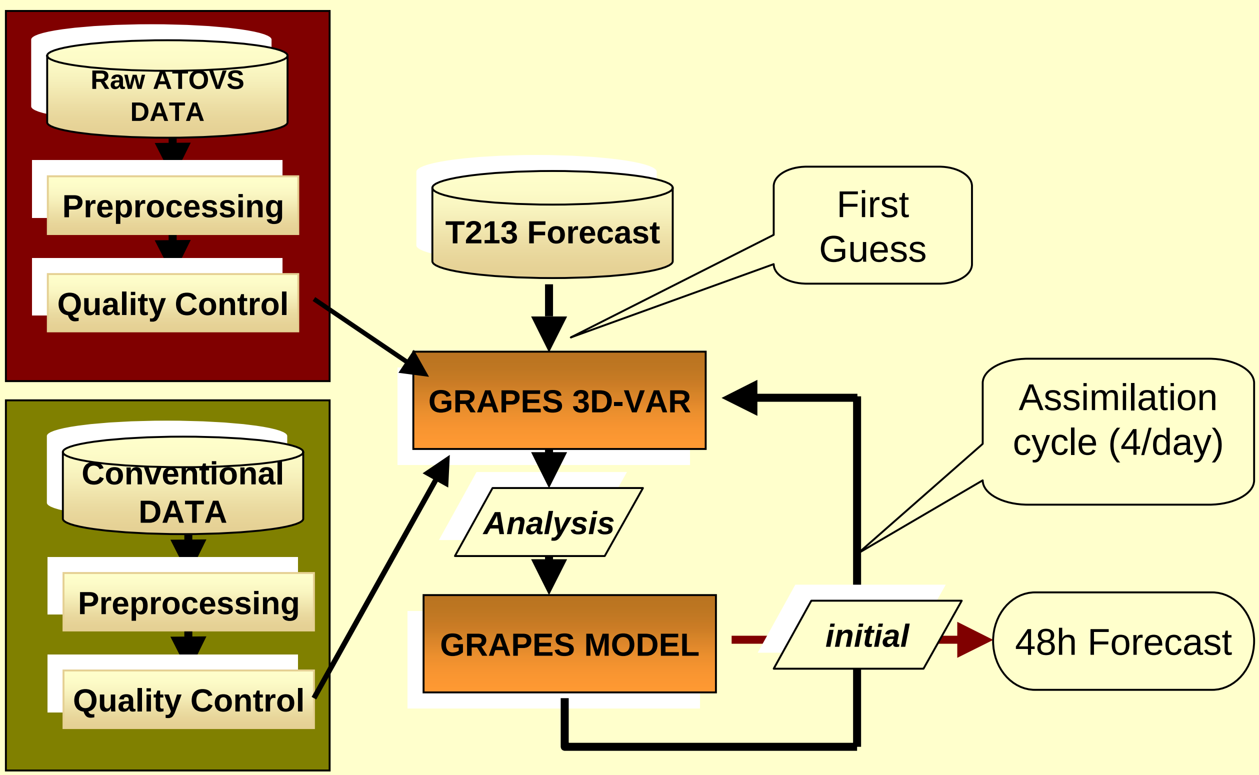
Impact on the track prediction



Starting from 15UTC July 4. 21,33,45 hours forecasts of the center's position are shown

5. Towards operational implementation

Flow Chart of Assimilation System on Pre-operational Trial



5. Towards operational implementation

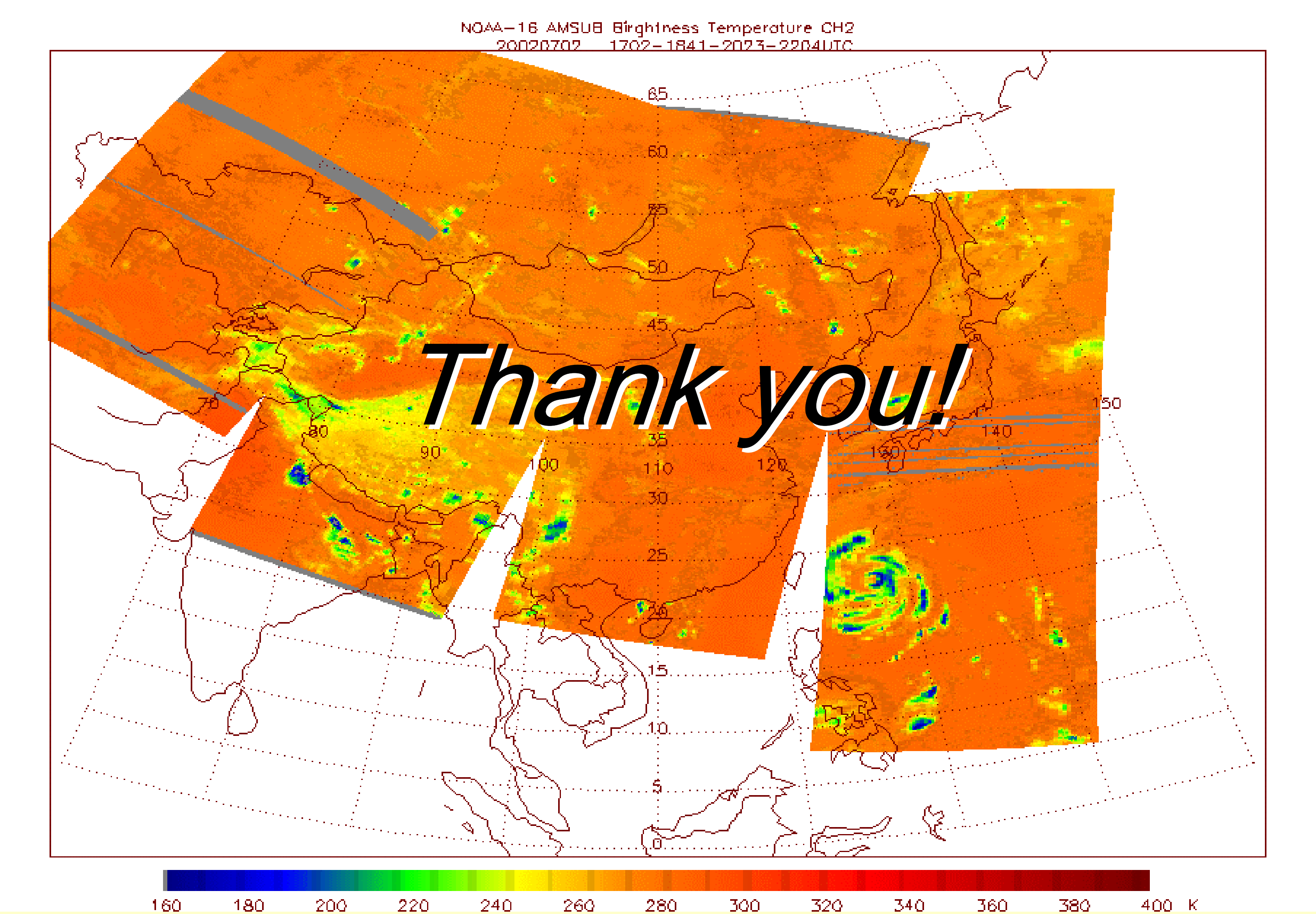
Works in the near future :

Quality control

Usage of HIRS

AMSU over land

GRAPES


NOAA-16 AMSUB Birghtness Temperature CH2
20020707 1702-1841-2023-2204UTC
Thank you!
160 180 200 220 240 260 280 300 320 340 360 380 400 K

International TOVS Study Conference, 13th, TOVS-13, Sainte Adele, Quebec, Canada, 29 October-4 November 2003. Madison, WI, University of Wisconsin-Madison, Space Science and Engineering Center, Cooperative Institute for Meteorological Satellite Studies, 2003.