Quality monitoring and bias correction for satellite data in JRA-25

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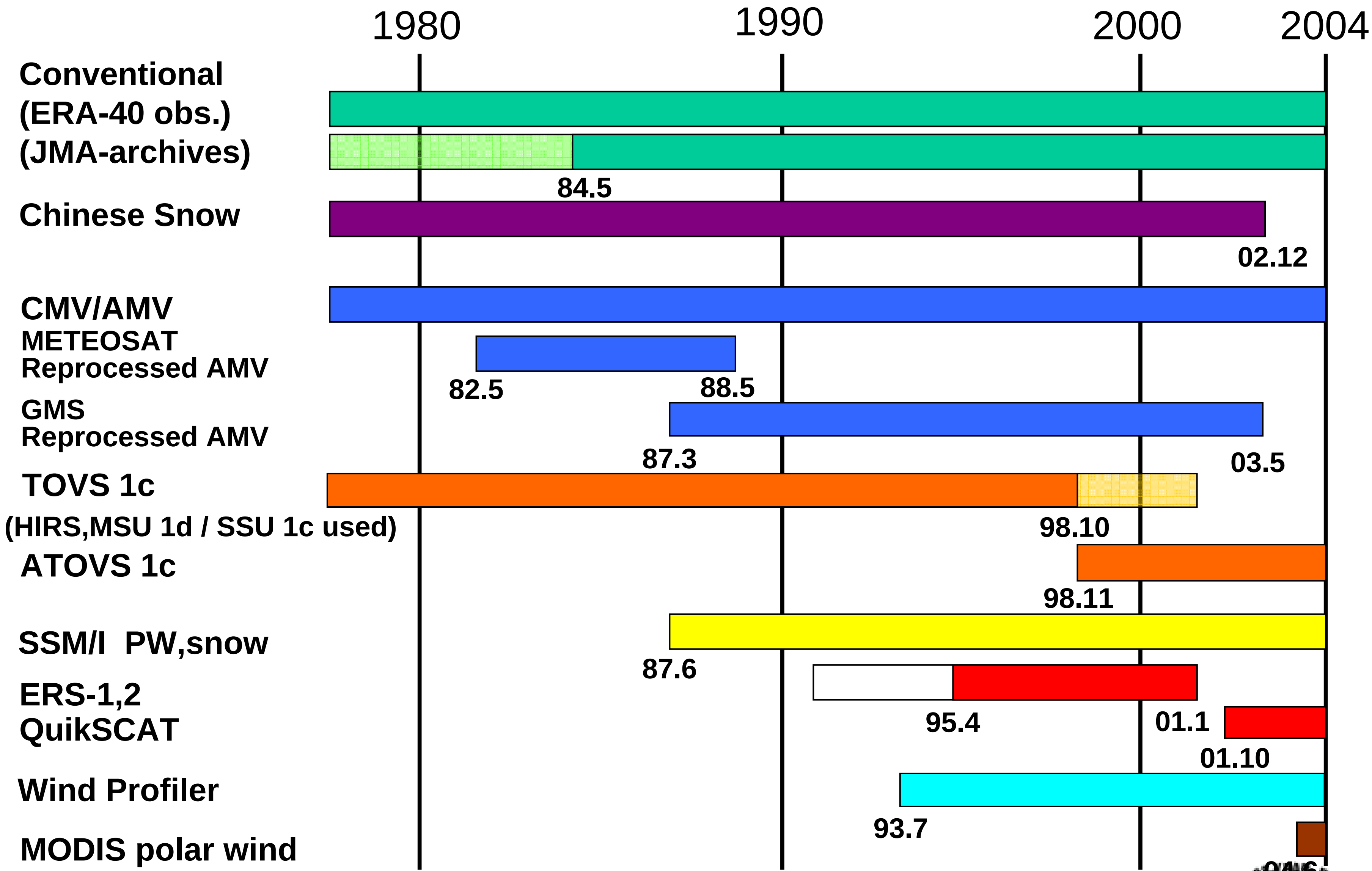
Outlines of JRA-25

- Japan Meteorological Agency (JMA) and the Central Research Institute of Electric Power Industry (CRIEPI) are conducting Japanese 25-year Reanalysis.
- The reanalysis period of JRA-25 is 26 years from 1979 to 2004.
- Most of the observational data were supplied by ECMWF as used in their ERA-40 project. (We appreciate it.)
- Some new historical observational data are used:
  - Wind profile retrievals surrounding tropical cyclones supplied by Dr. M. Fiorino (PCMDI/LLNL).
  - AMV wind data with a quality indicator reprocessed by MSC/JMA.
  - Chinese daily snow depth data digitised from “Monthly Surface Meteorological Data in China” by MRI/JMA.

Observation availability in JRA-25



Translucent : available but not used
White : not in JMA

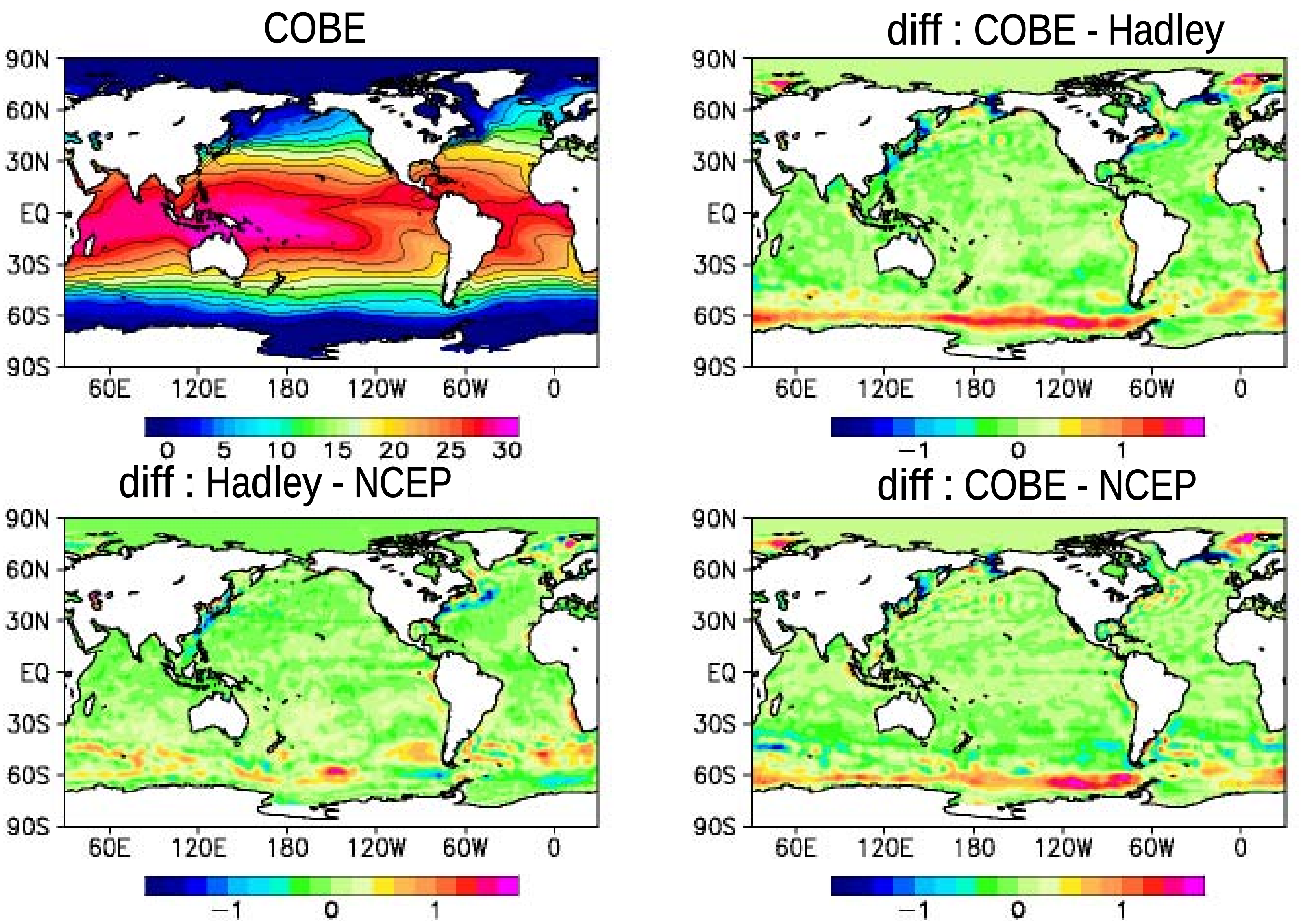
Difference between JRA-25 and JMA operational GSM

	JRA-25	Operational (deterministic)
resolution	T106L40 (top 0.4hPa) 3DVAR Inner T106 Eularian	TL319L40 (top 0.4hPa) 4DVAR Inner T63 semi-Lagrangian
SSM/I PW	assimilated	Not yet
TOVS ATOVS	TOVS 1d with using RTTOV6 ATOVS 1c with using RTTOV7	ATOVS 1d with using RTTOV6 (2003.5-04.12) ATOVS 1c with using RTTOV7 (2004.12-)
Data used in snow anl.	SYNOP + SSM/I snow coverage, (-1986) CPC weekly snow cov. alternatively	SYNOP (SYNOP + SSM/I snow coverage for EPS)
SST	COBE (daily)	2D-OI using climate FG
sea ice	COBE (daily) with using SSM/I	Monthly climate (55% concentration)
ozone	3-D daily	2-D climate (zonal mean)
radiation	Previous scheme (large bias of temperature in the stratosphere)	Improved scheme (reduced the bias of temperature)
background error	New BG error statistics 2003 are used.	Old BG error statistics 2000 were used in the previous 3DVAR.

JMA/CRIEPI

COBE SST

Comparison of SST long-term averages (January)



No satellite data were used in COBE. , Period: 1982-1998.

Ishii et al. (2005)
Int. J. Climatol.

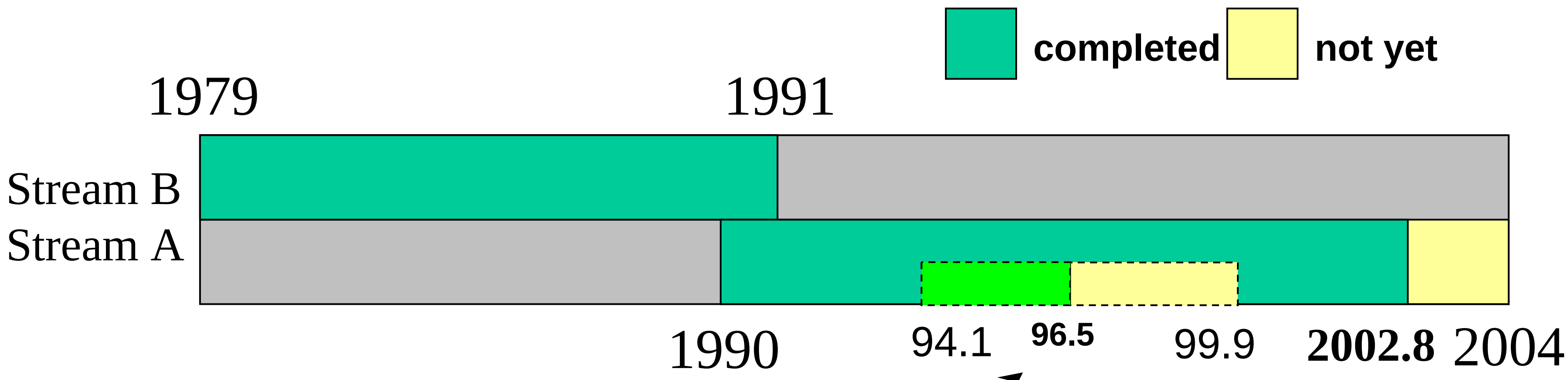
Current status of JRA-25

JRA-25 is executed with 2 streams.

Stream B: 1979-1990(completed)

Stream A: 1990-2004

1990 was overlapped at the end of Stream B.



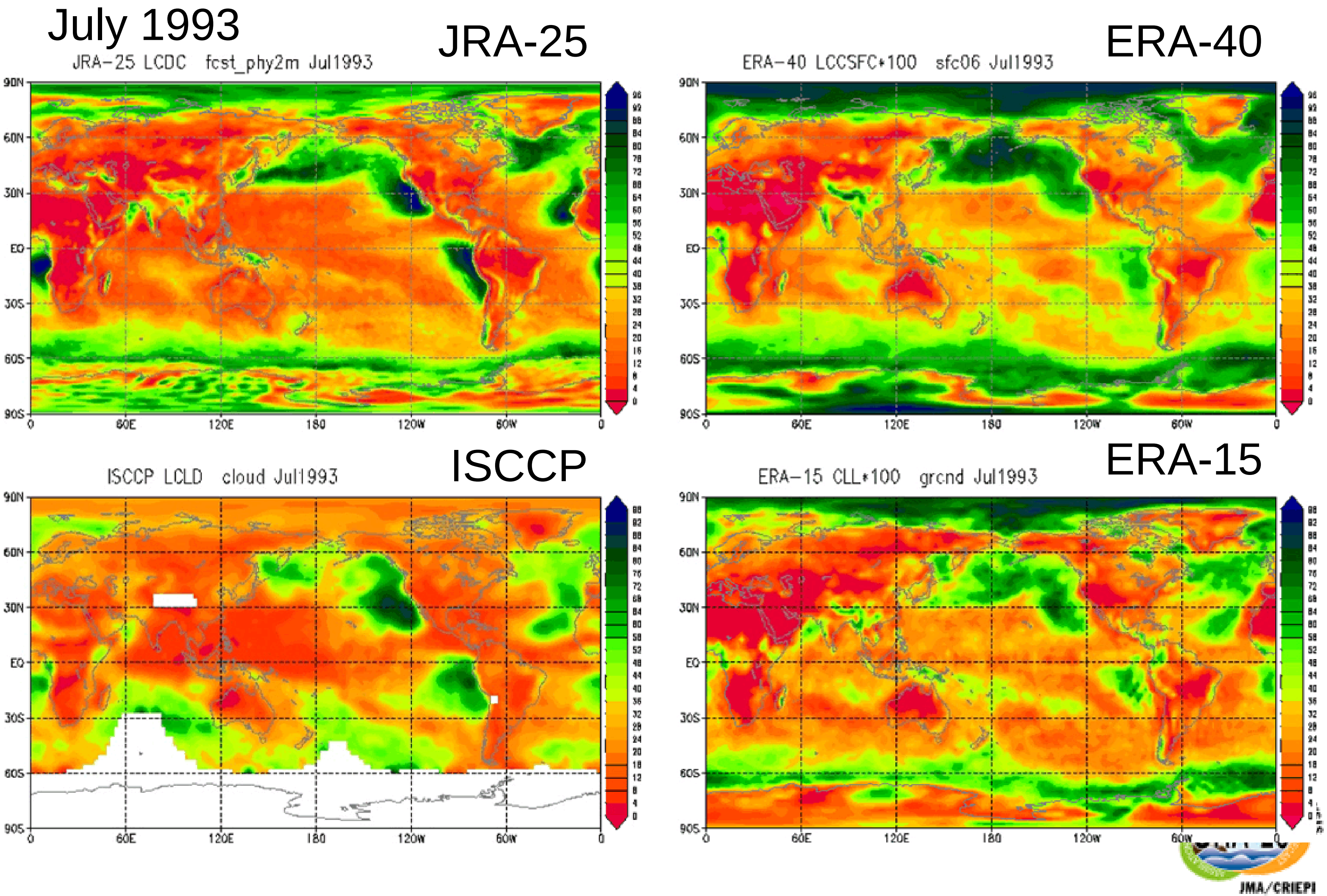
91% completed

83% completed (exclude recalc. part)

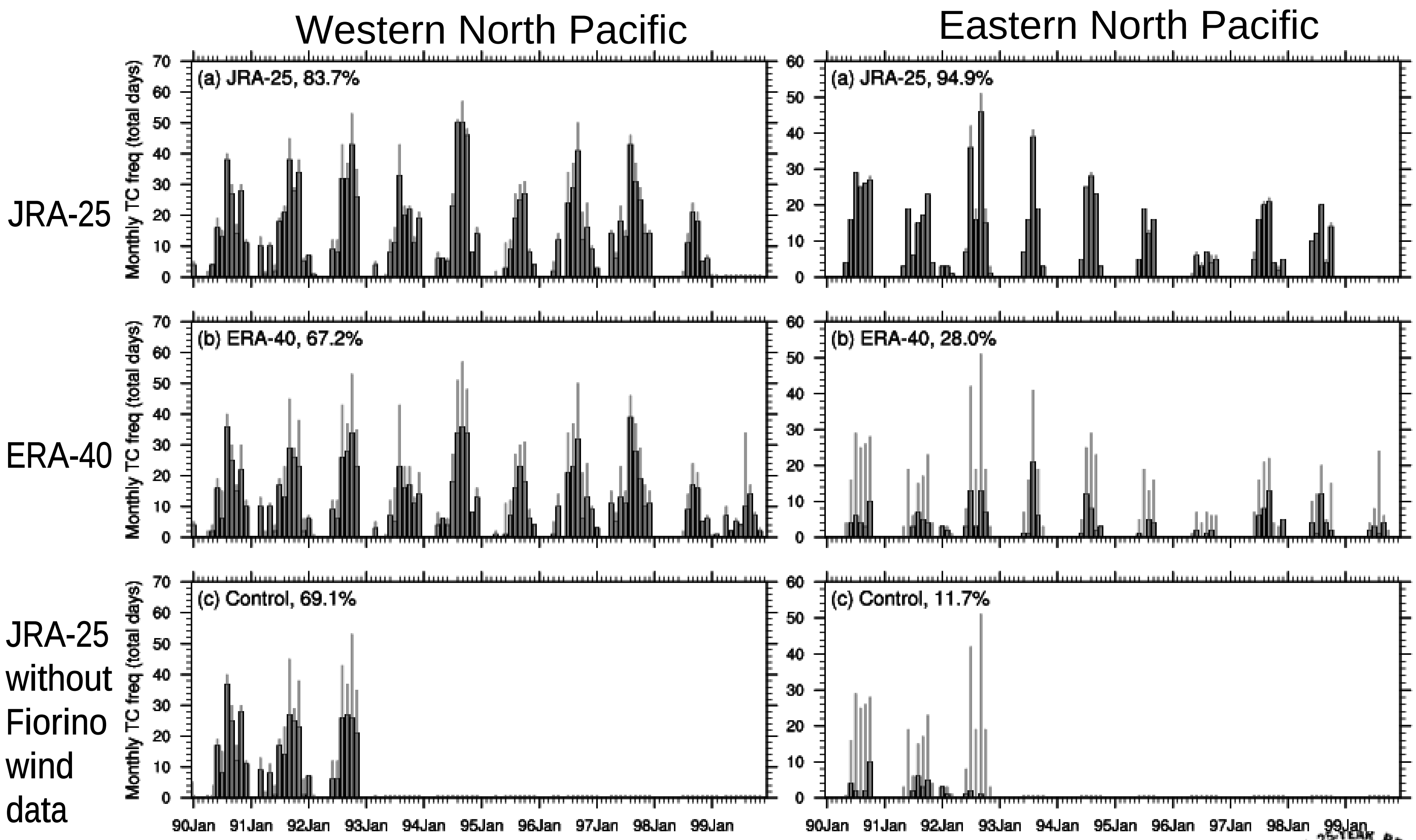
(status as of 2005.11.4)

Calculation with Fujitsu VPP5000 and Hitachi SR8000

Low level cloud along western coasts



TC detection (1991-1999)



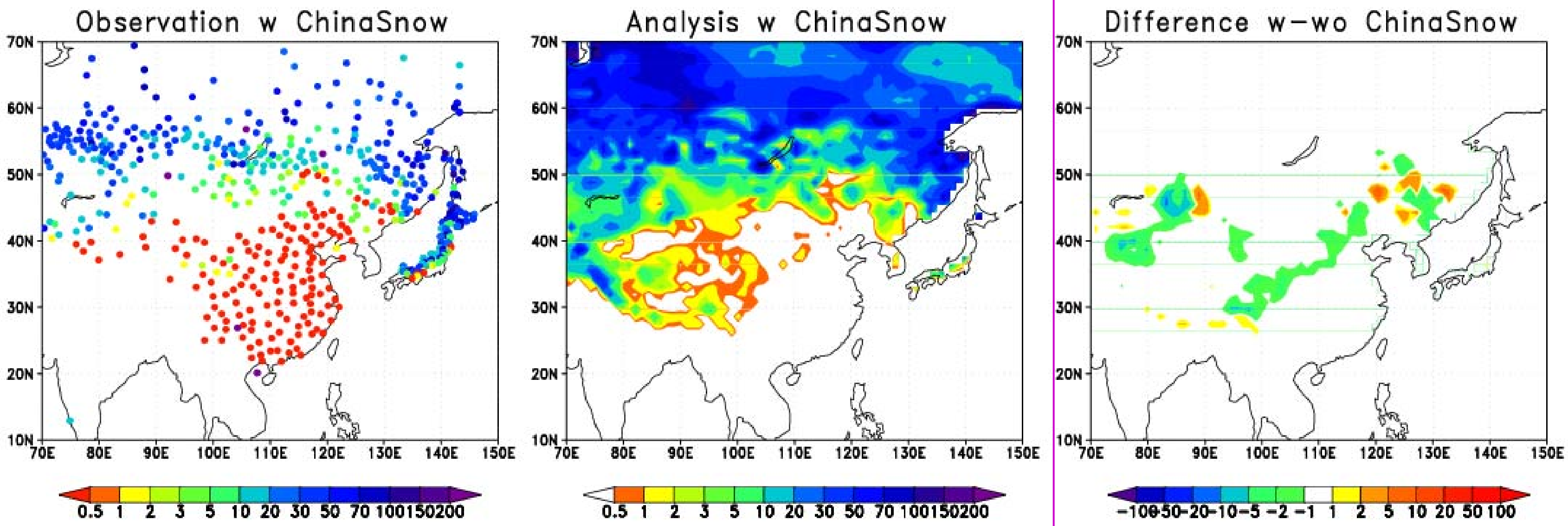
These figures are provided by CRIEPI

black: reanalyses gray: best track

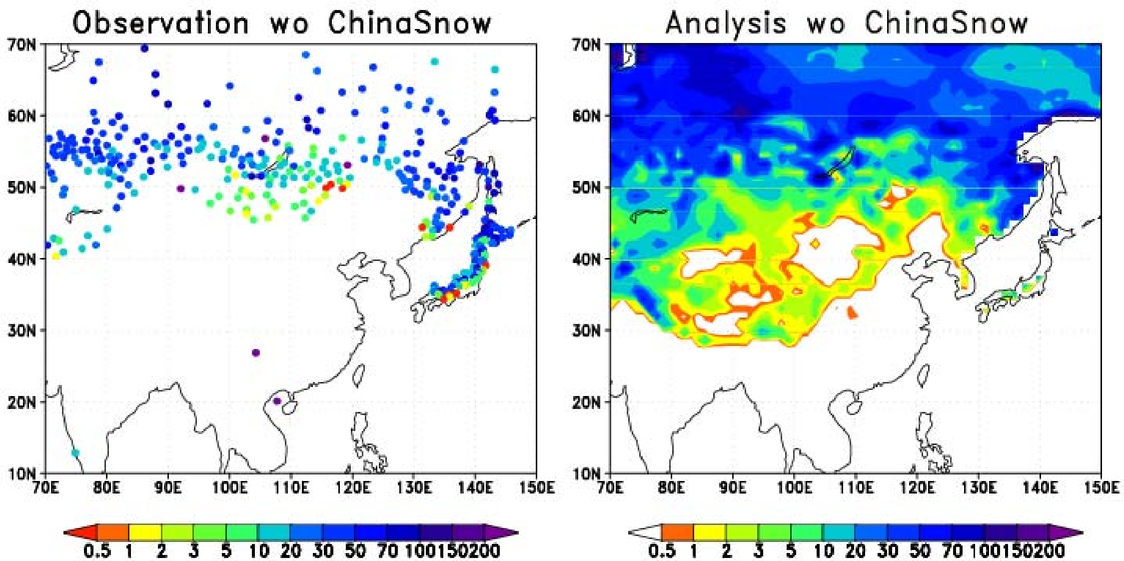
2.5deg. Lat-Lon grid

JRA-25

SnowDepth(cm) 19950131



Control

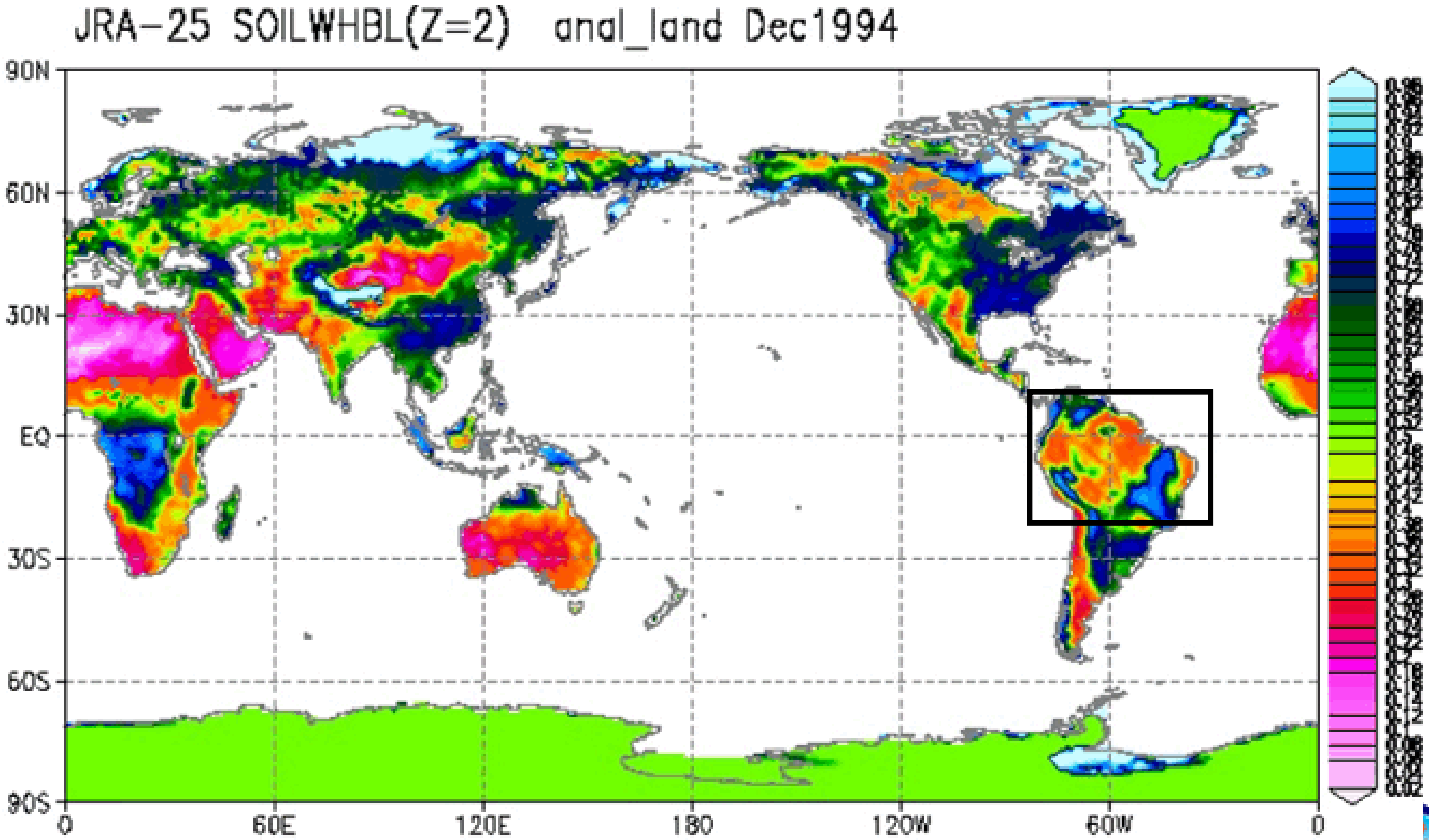


Impact of assimilating Chinese SYNOP snow depth data

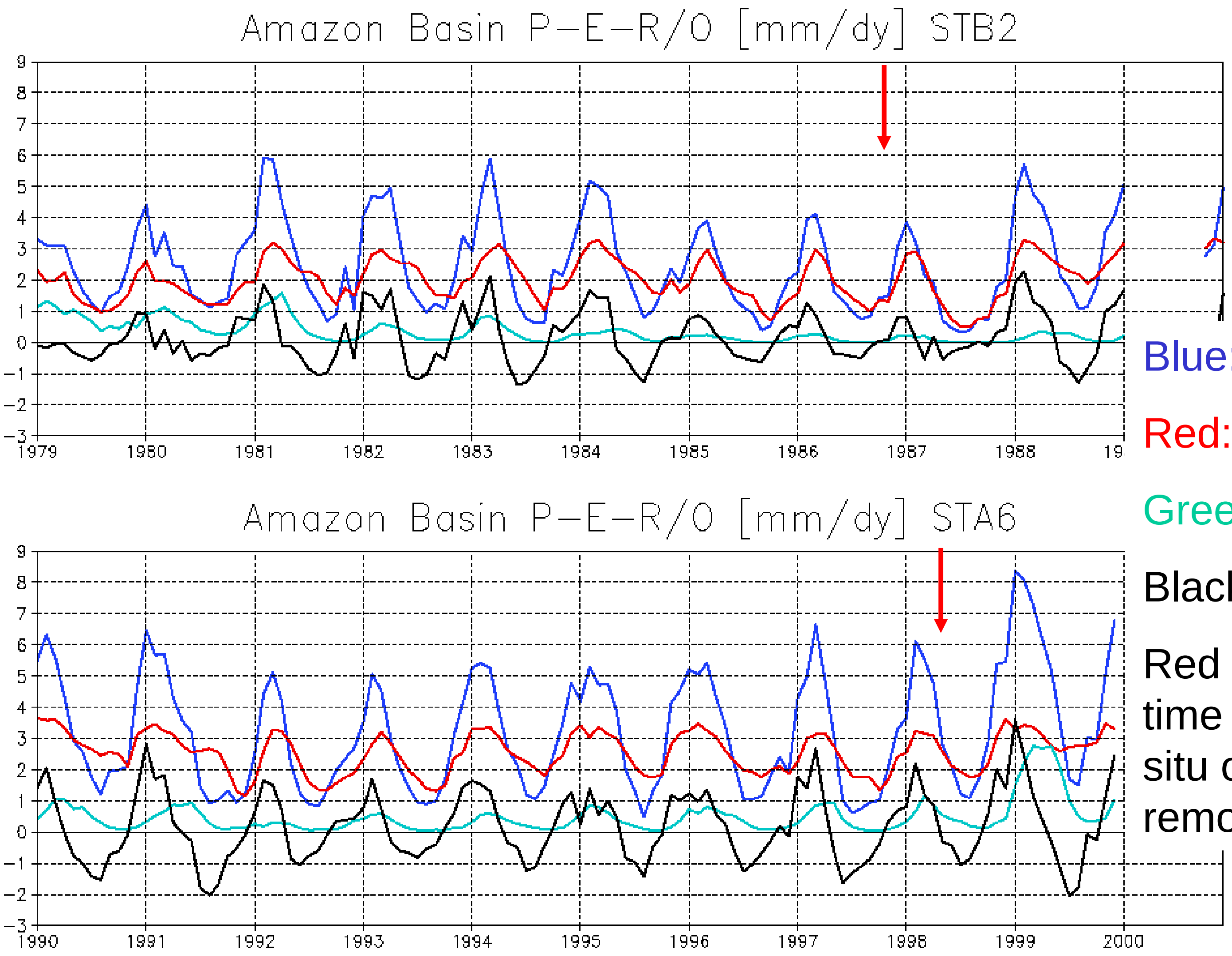
Control : without Chinese data

Drying soil in Amazon

Soil wetness at root level (2nd of 3 levels)



Water budget over the Amazonian area



Blue: precipitation (P)

Red: evaporation (E)

Green: runoff (R/O)

Black: budget (P-E-R/O)

Red arrows indicate the time at which biased in-situ observations were removed.

The quality of the JRA-25 products

- Advantages
  - Precipitation of JRA-25 has the highest correlation both with CMAP and with GPCP version 2 observational precipitation data sets among the reanalyses.
  - The low-level clouds are in good consistency with the ISCCP observational cloud.
  - Tropical cyclones are well captured both in the Western Pacific and in the Eastern North Pacific.
  - Snow depth analysis is of good quality.
- Deficiencies
  - There are some problems in hydrological cycle in the Amazonian area.
  - There are some discontinuities in temperature time series for the stratosphere, which are coincident with satellite switching.

JMA/CRIEPI

Access to the JRA-25 products

- Basic products are available via the Internet.
  - http://www.jreap.org/download/download-e.html
  - Surface analysis, pressure level analysis, 2-dimentional physical monitor ….
  - 2.5 x 2.5 grid.
  - For research use only. Feedbacks from research are expected.
- Time series monitors for observational data and inter-comparison of reanalyses are also available.
  - http://cpd1.kishou.go.jp/monitor/STA6/NpxMon_e.shtml
  - http://cpd1.kishou.go.jp/monitor/STA6/NpxMon_e.shtml
- JRA-25 will be transitioned to the JMA Climate Data Analysis System (JCDAS) after 2005.

Precise quality monitoring for TOVS data

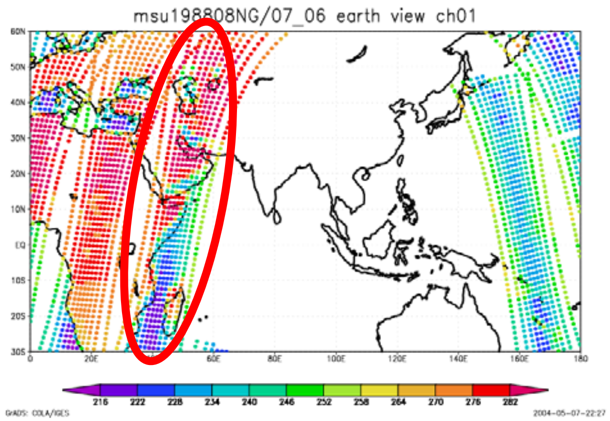
- The assimilation of poor quality data has a negative impact on the analysis. In order to prevent poor quality data being used, it is necessary to specify the channels, the instruments, the satellites and the periods, of poor quality.

- Fortunately, information about the quality of the TOVS data can be obtained from some sources (e.g. Kidwell, 1998; Hernandez et al., 2004).

- However, close examination into the TOVS data revealed that there are many poor quality data, which were not recorded in the sources.

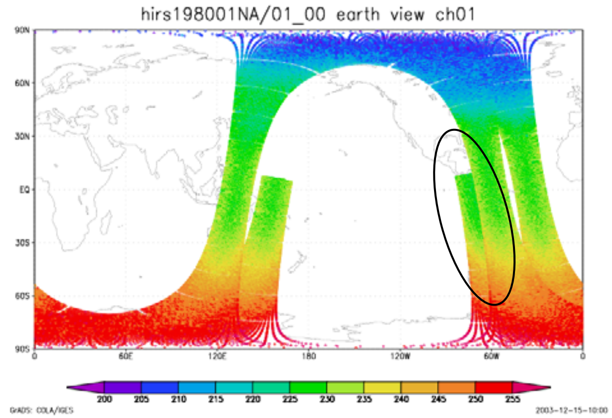
- So, precise quality monitoring for the TOVS data was performed in advance to the JRA-25 production.

Classification of poor quality data



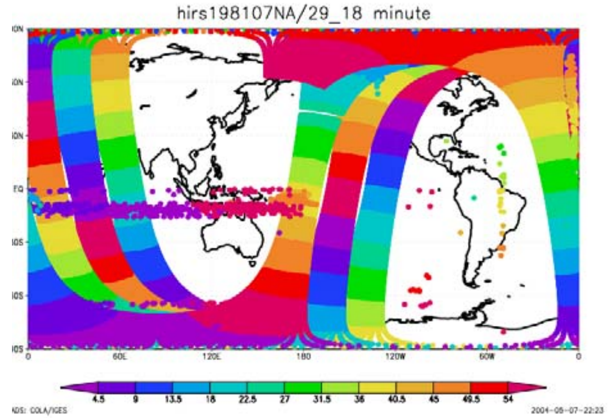
Bad earth-location (a)

Shift along the satellite track



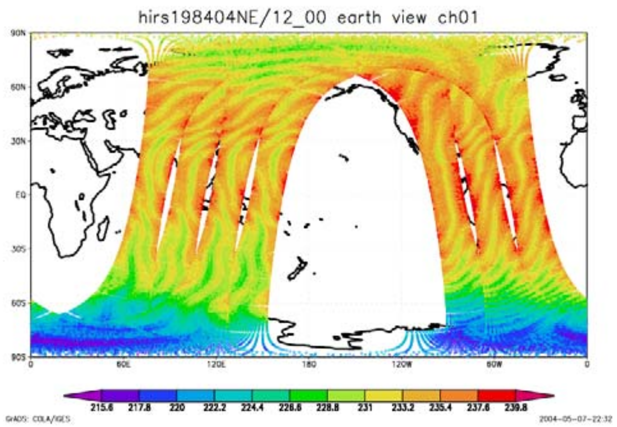
Bad earth-location (b)

Incorrect time information

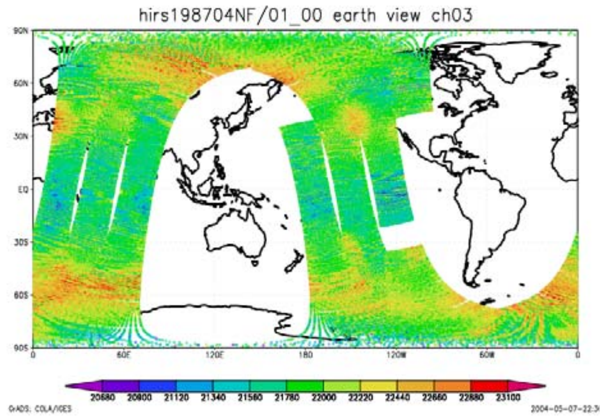


Bad earth-location (c)

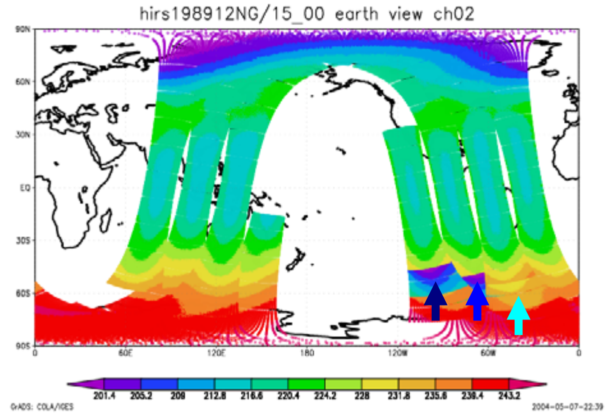
Scattered out



Periodic noise



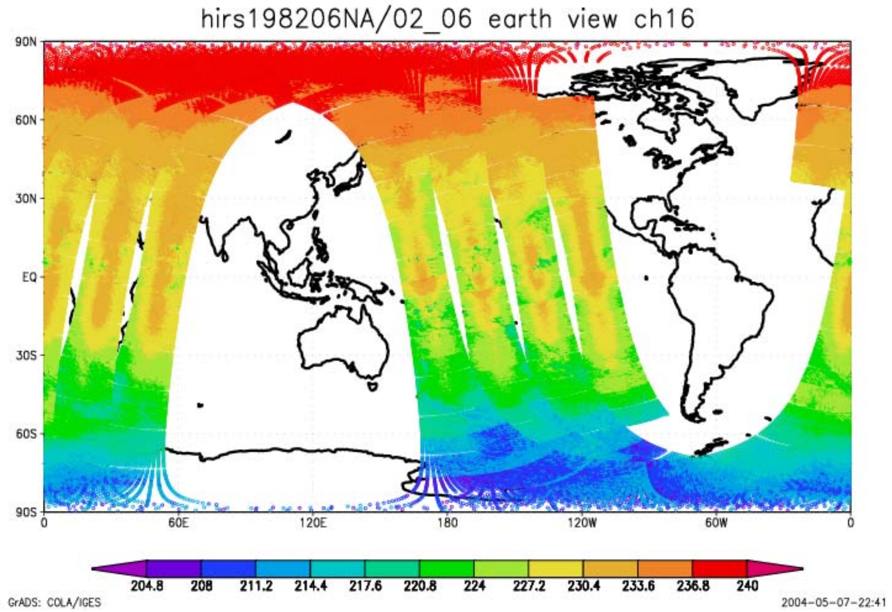
Random noise



Calibration error

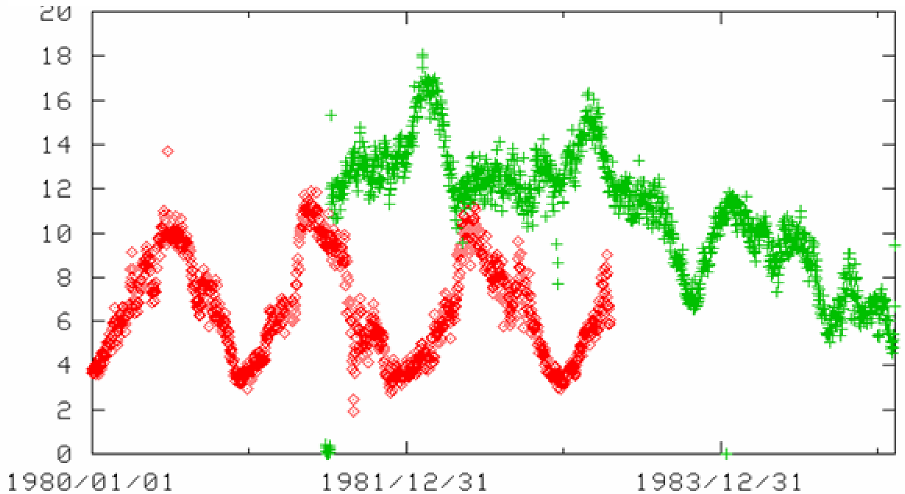
Classification of poor quality data

Discontinuities of BT at the boundaries of a super swath of HIRS



This phenomenon is significant in CO_2 4.3-micron channels (13-17).

The variation of PM satellites is larger than that of AM satellites, and gradually decreases with long-time drift in the local time of measurements.



Red line: NOAA 6 Green line: NOAA

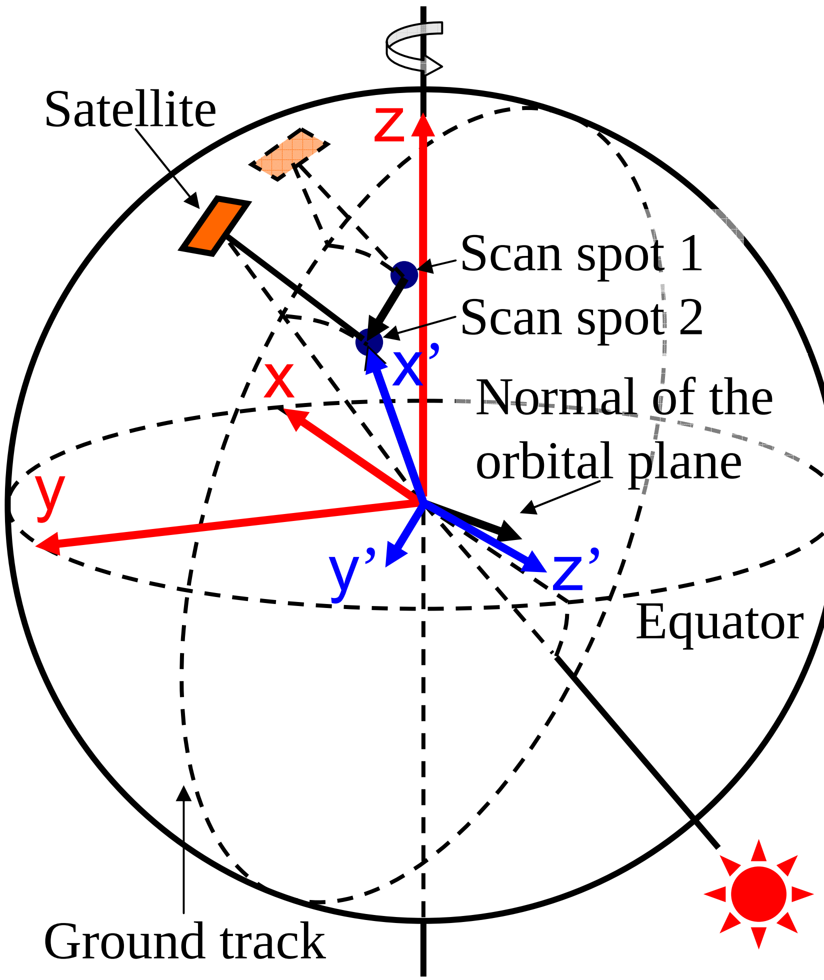
The ratio of the BT variation at the boundaries of a super swath to that of interior

$$ratio \equiv \frac{Quartile(\mu(1) - \mu(40))}{Quartile(\mu(i+1) - \mu(i))}$$

i : scanline number

$\mu(i)$: scanline mean of brightness temperatures

Estimation of orbital elements



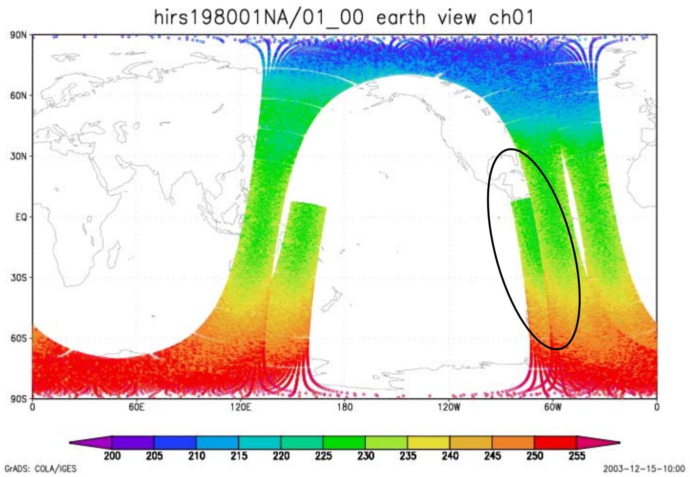
$$\begin{pmatrix} n_x \\ n_y \\ n_z \end{pmatrix} = \begin{pmatrix} k_x & l_x & m_x \\ k_y & l_y & m_y \\ k_z & l_z & m_z \end{pmatrix} \begin{pmatrix} n_{x'} \\ n_{y'} \\ n_{z'} \end{pmatrix}$$

$(n_x\, n_y\, n_z)$, $(n_{x'}\, n_{y'}\, n_{z'})$:
Normal of the orbital plane in (x y z) and (x' y' z')

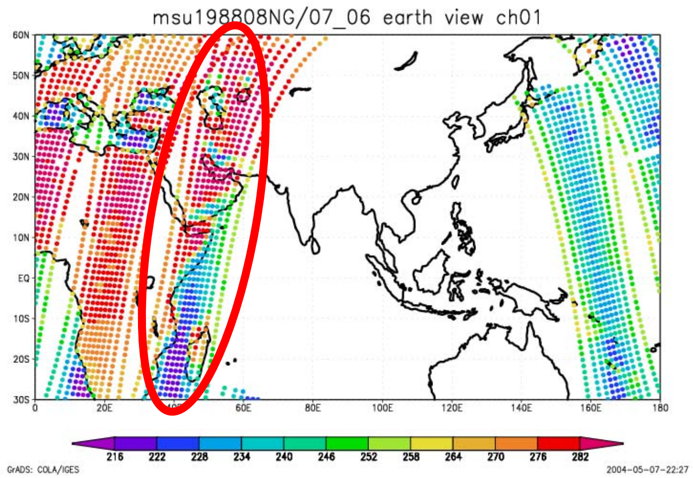
$(k_x\, k_y\, k_z)$, $(l_x\, l_y\, l_z)$, $(m_x\, m_y\, m_z)$:
Direction cosines of x'-, y'- and z'-axes in terms of (x y z)

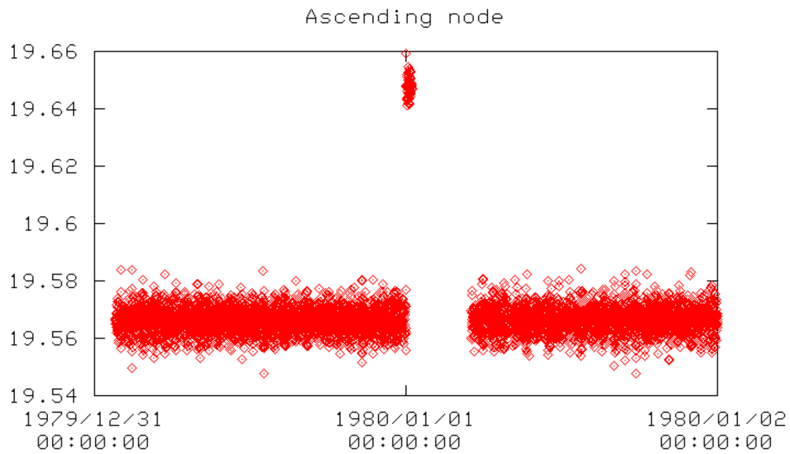
Detecting method for bad earth-location

Incorrect time information

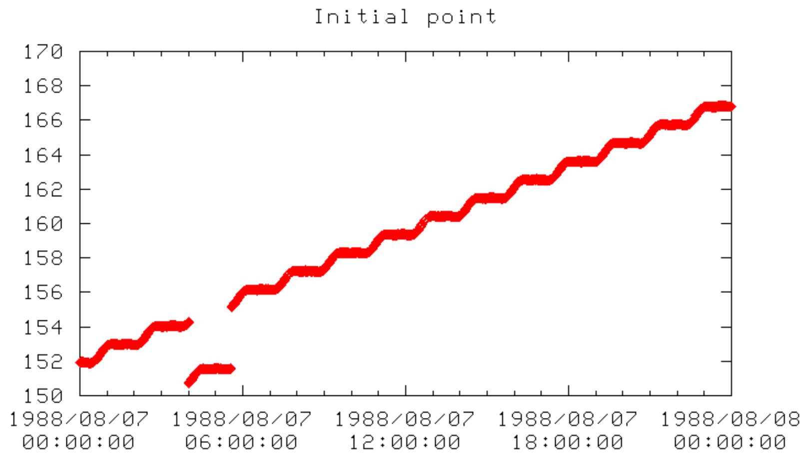


Shift along the satellite track



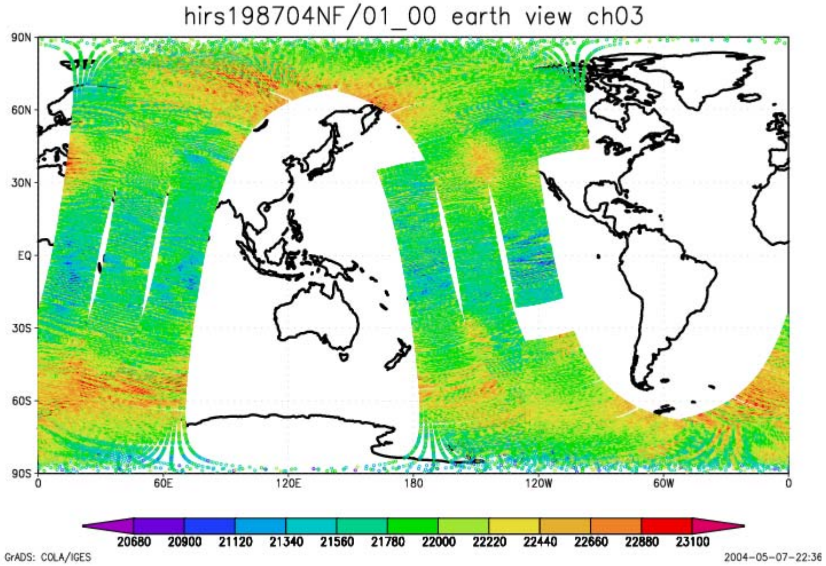


Local time of ascending node

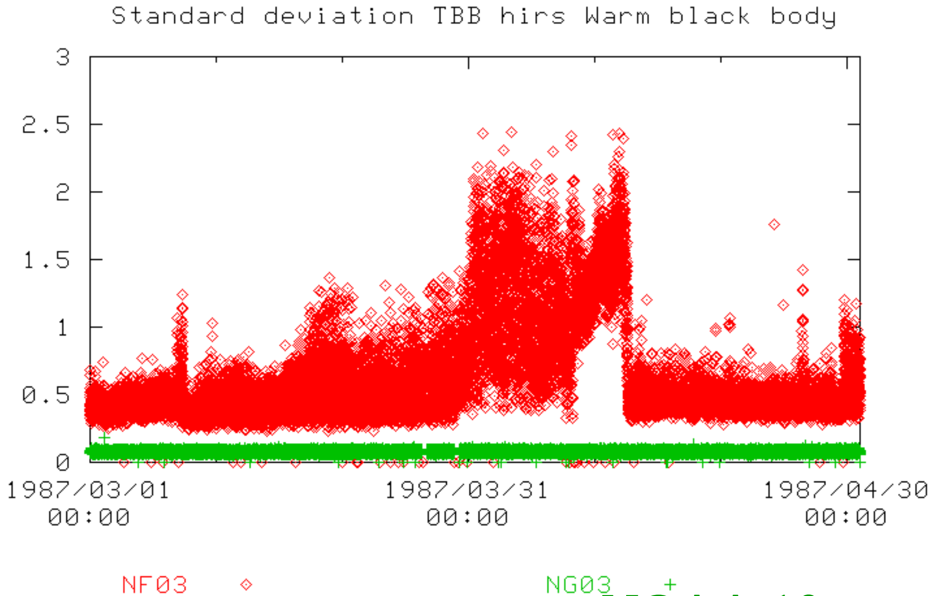


Direction angle of NOAA spacecraft from ascending node

Detecting method for random noise



Random noise

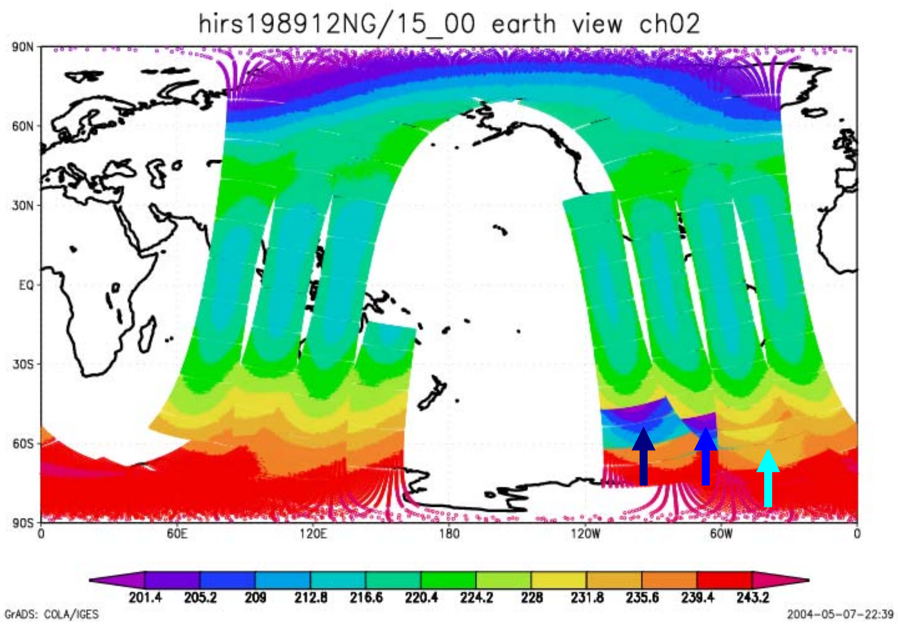


NOAA 9
HIRS channel 3

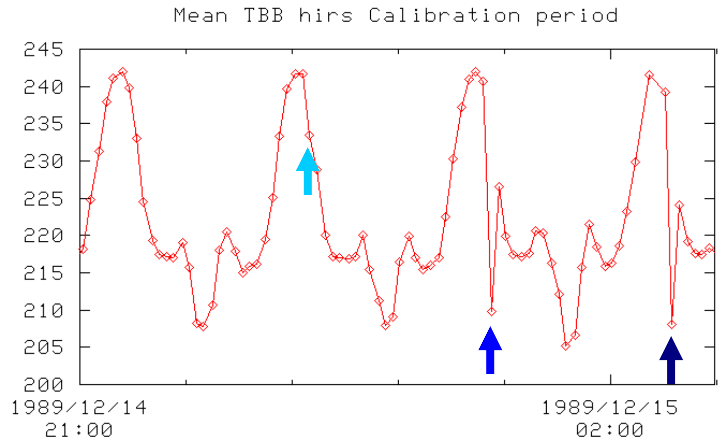
NOAA 10
HIRS channel 3

Time series for standard deviation of brightness temperature of the internal warm target

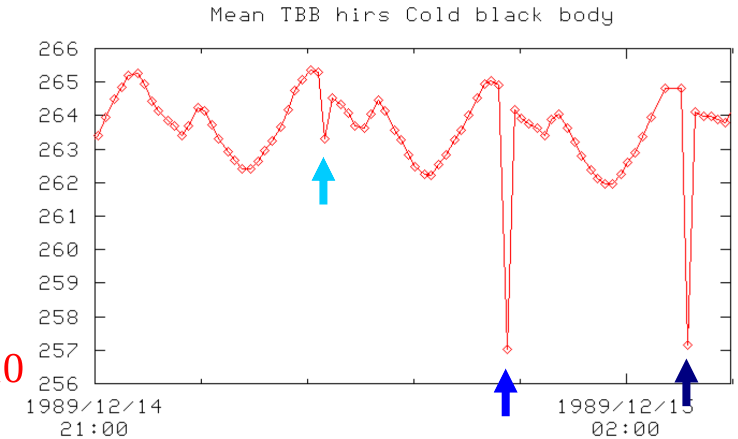
Detecting method for calibration error



Calibration error



Time series for super swath mean BT of earth-view



HIRS ch2 on NOAA 10

Time series for scan line mean BT of the internal cold target

Summary for
precise quality monitoring for TOVS data

- Orbital elements of NOAA satellites can be estimated from earth-location of TOVS data with reasonable accuracy, and they are effective in monitoring bad earth-location.
- Calibration data are effective in quality monitoring, but available for the HIRS of TOVS only.
- It is desirable that further examination for level-1b data is performed, because:
  - Level-1b data include all the information required for calibration.
  - Comparison with the latest calibration algorithm would provide information about radiometric biases.

JMA/CRIEPI

Assimilating scheme for TOVS data

- RTTOV-6 is used for radiative transfer calculation.
- 1DVAR is performed as part of QC processes.
- In order to process HIRS and MSU data together in the 1DVAR, level-1d data were produced from level-1c data.
- An adoptive bias correction scheme is used.
  - Reference values are optimum solution of the 1DVAR.
  - No predictors. The coefficients are calculated for each 5K of observed BT.
  - The coefficients are calculated from the latest 4-day sample and revised every cycle.

Sensor	CH No.	Peak of weighting function	Absorption gas
HIRS	2	60hPa	CO_2
	3	100hPa	CO_2
	4	400hPa	CO_2
	5	600hPa	CO_2
	6	800hPa	CO_2
	7	950hPa	CO_2
	10	900hPa	H_2O
	11	700hPa	H_2O
	12	500hPa	H_2O
	15	700hPa	CO_2/N_2O
MSU	2	700hPa	O_2
	3	300hPa	O_2
	4	90hPa	O_2
SSU	1	15hPa	CO_2
	2	4hPa	CO_2
	3	1.5hPa	CO_2

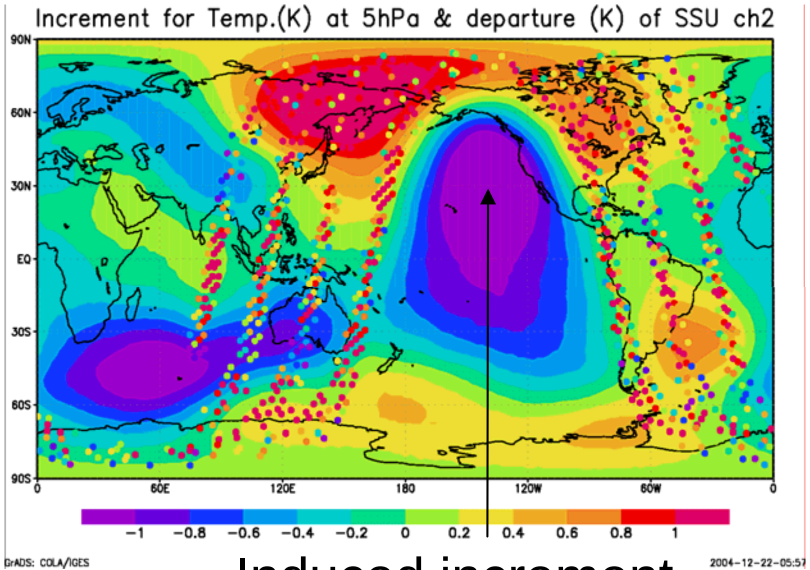
The channels in yellow shade are used only in clear-sky, over sea spots.

Problem with bias correction of TOVS data

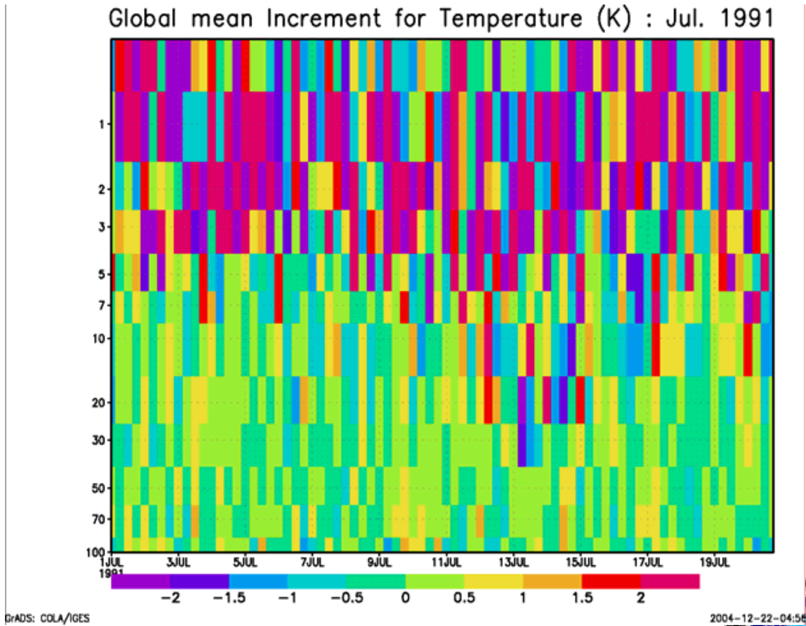
This bias correction scheme is intended to correct inconsistency among channels.

Difference between observations and background is not taken into account.

Consequently, large-scale analysis increments occurred in stratospheric temperatures in a preliminary experiment.



Induced increment
18UTC JUL. 15 1991 with NOAA-11

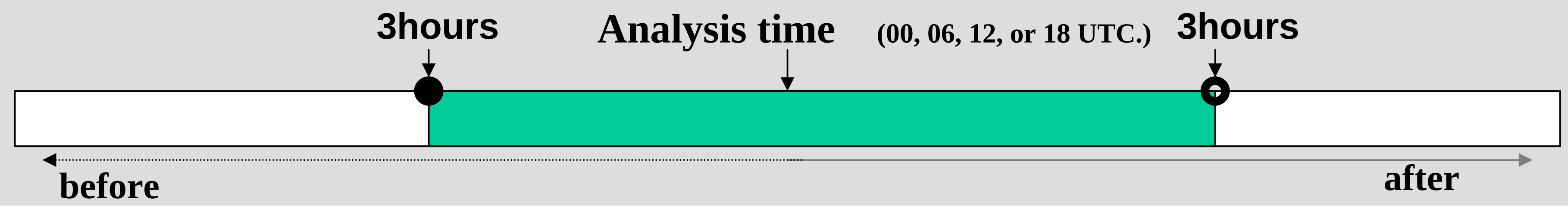


Extended time window for stratospheric observing channels

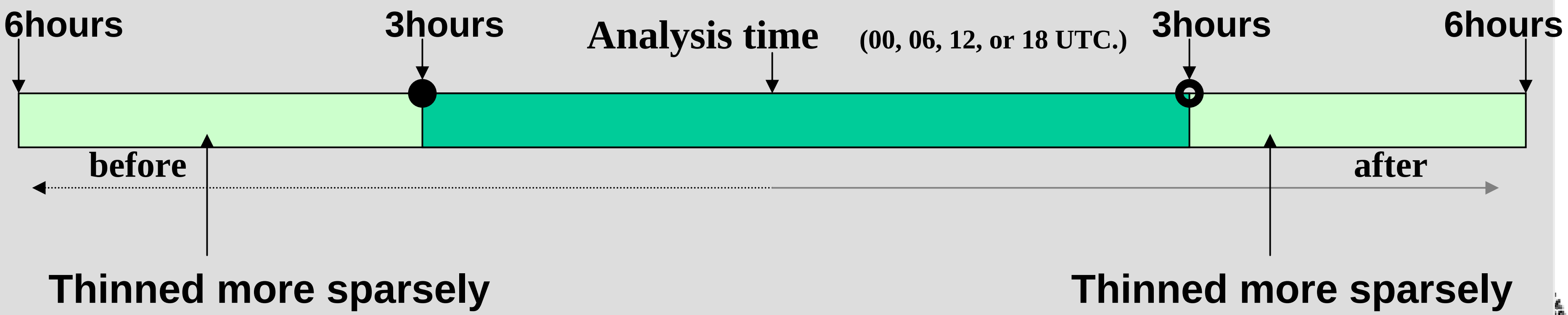
Solution

We extend time window up to 12 hours for stratospheric observing channels, and thin strongly outside the original 6 hour time window.

Tropospheric observing channels (HIRS ch3, 4, 5, 6, 7, 10, 11, 12, 15, MSU ch2, 3)

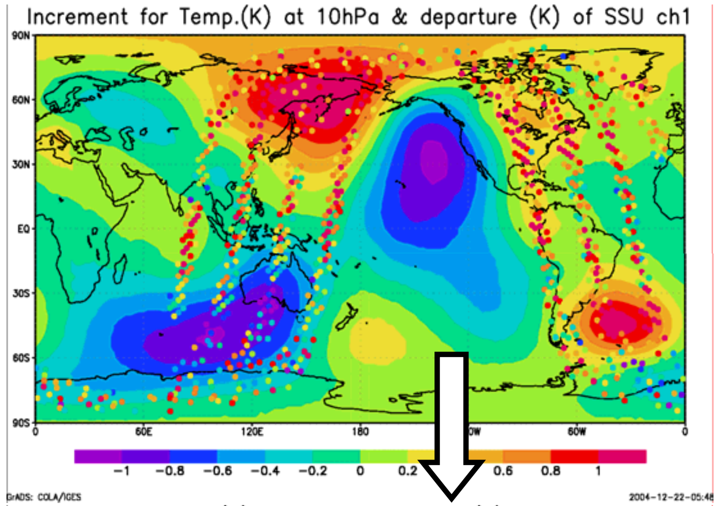


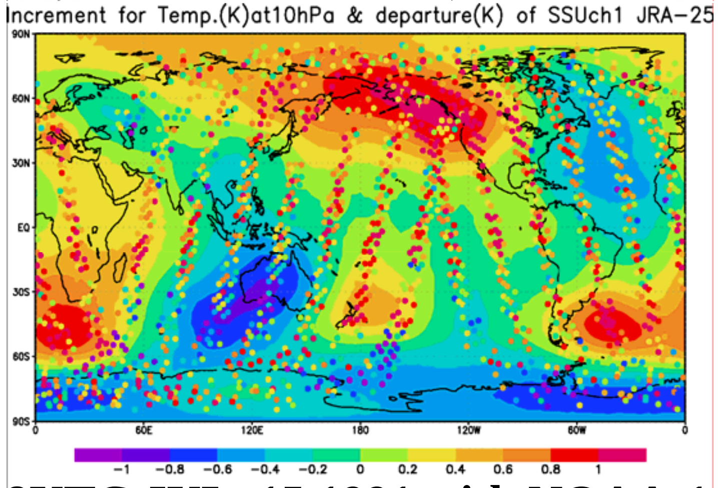
Stratospheric observing channels (HIRS ch2, SSU ch1, 2, 3)

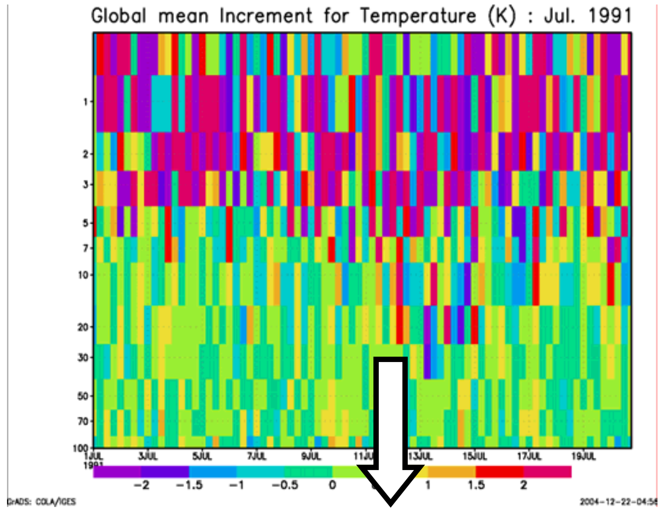


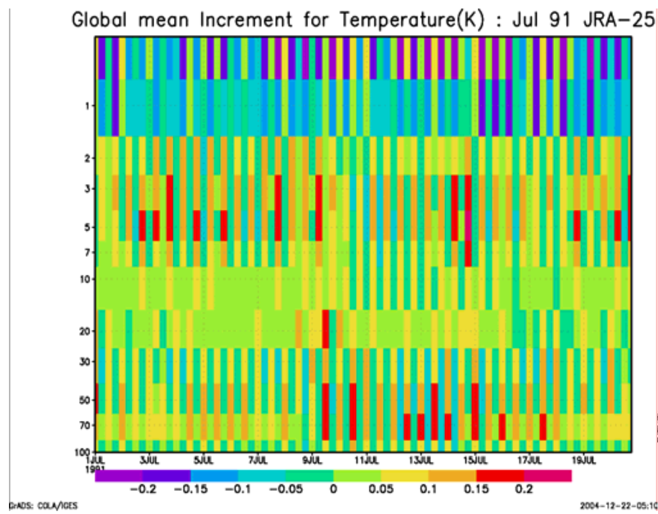
Extended time window for stratospheric observing channels

Extended time window prevents large scale induced increment.









18UTC JUL. 15 1991 with NOAA-11

Assimilating scheme for ATOVS data

- RTTOV-7 is used for radiative transfer calculation.
- A static bias correction scheme is used.
  - Scan-bias correction
    - Both for AMSU-A and for AMSU-B
  - Air-mass bias correction
    - For AMSU-A only
    - Reference data are radiosonde observations.

$$BC = a_0 + a_{surf} \times T_{surf} + \sum_{ch}^{5,7,10} a(ch) \times T_{BB}^{cal}(ch)$$

Sensor	CH No.	Center frequency (GHz)	Absorption gas
AMSU-A	4	52.80	O_2
	5	53.596 ±0.115	O_2
	6	54.40	O_2
	7	54.94	O_2
	8	55.50	O_2
	9	57.2940344=Flo	O_2
	10	Flo±0.217	O_2
	11	Flo±0.3222, (±0.048)	O_2
	12	Flo±0.3222, (±0.022)	O_2
	13	Flo±0.3222, (±0.010)	O_2
AMSU-B	3	183.31±1.0	H_2O
	4	183.31±3.0	H_2O
	5	183.31±7.0	H_2O

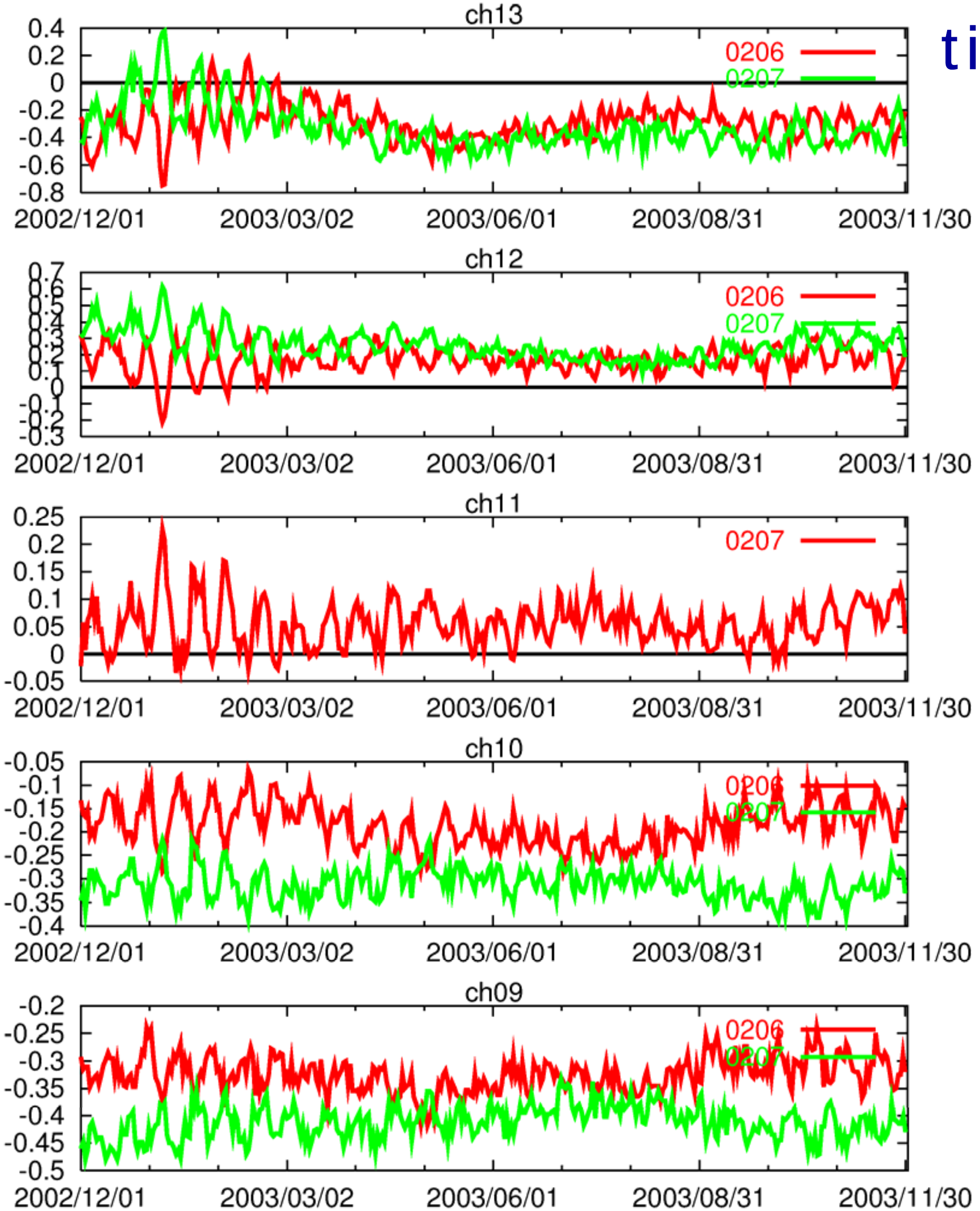
The channels in yellow shade are used only in clear for MW, over sea spots.

The channels in blue shade are used only in rain-free, over sea spots.

JMA/CRIEPI

The lunar semi-diurnal tide observed by AMSU-A

departure value time series of AMSU-A



These time series are all oscillating at about 14.6-day period.

The phase difference is constant.

The amplitudes are large in January and February, and small around June solstice.

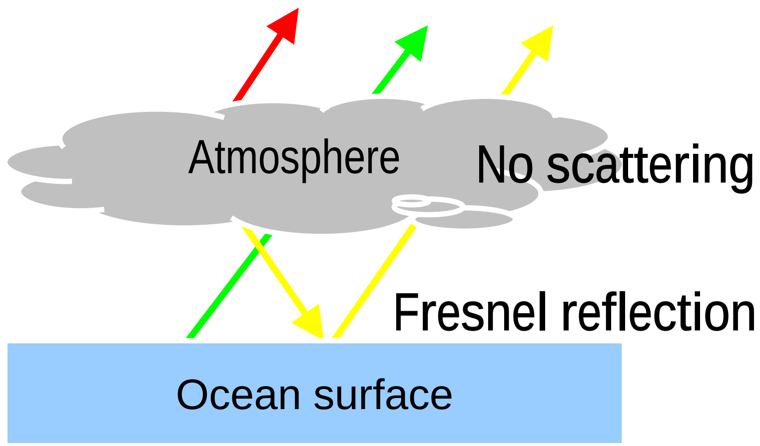
Red: NOAA-15 (AM satellite)

Green: NOAA-16 (PM satellite)

JAPANESE 25-YEAR REANALYSIS DATA JRA-25 JMA/CRIEPI

Assimilating scheme for SSM/I data
MSC algorithm

$$TBB = (1-T_r)T_a + T_r\varepsilon_s T_s + T_r(1-\varepsilon_s)(1-T_r)T_a$$



TBB: brightness temperature

Ts: SST

Ta: atmospheric temperature

εs: emissivity of sea surface

Tr: atmospheric transmittance

Vs: sea surface wind speed

T85: temperature at 850hPa

Deviation from the theoretical relation is considered by look-up tables (LUTs) based on TBB - sonde match-up data set

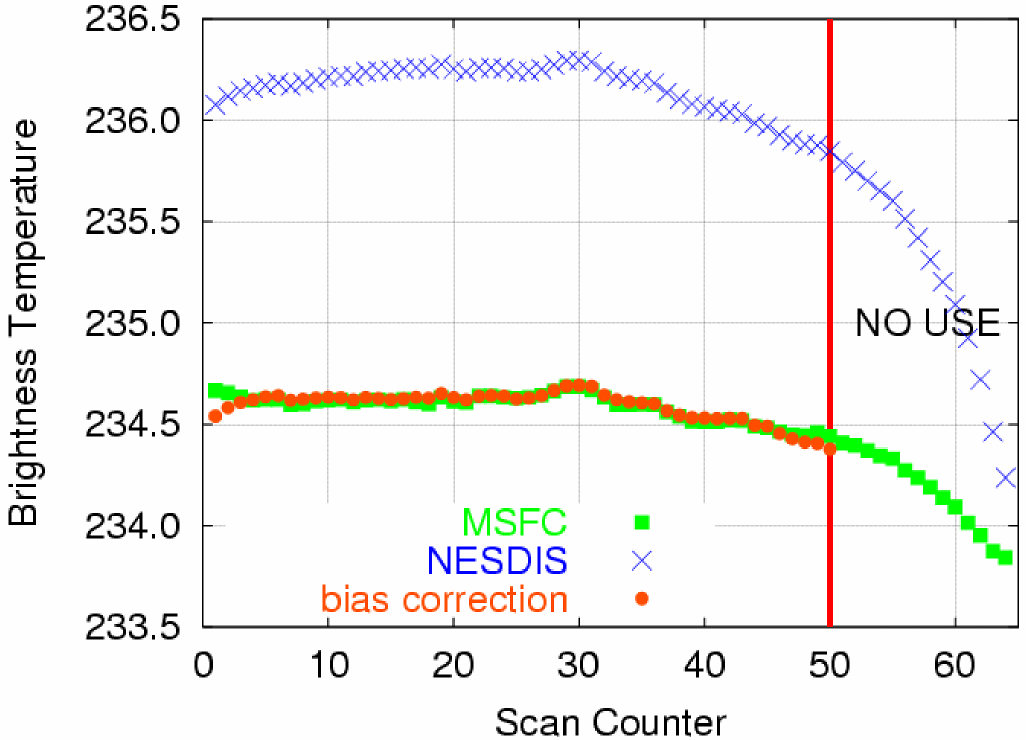
Ts, Vs

↓

εs , TBB, Ta(= f(T85,Tr)), Ts ⇒ Tr ⇒ WV

JRA-25 JMA/CRIEPI

Bias correction for SSM/I data



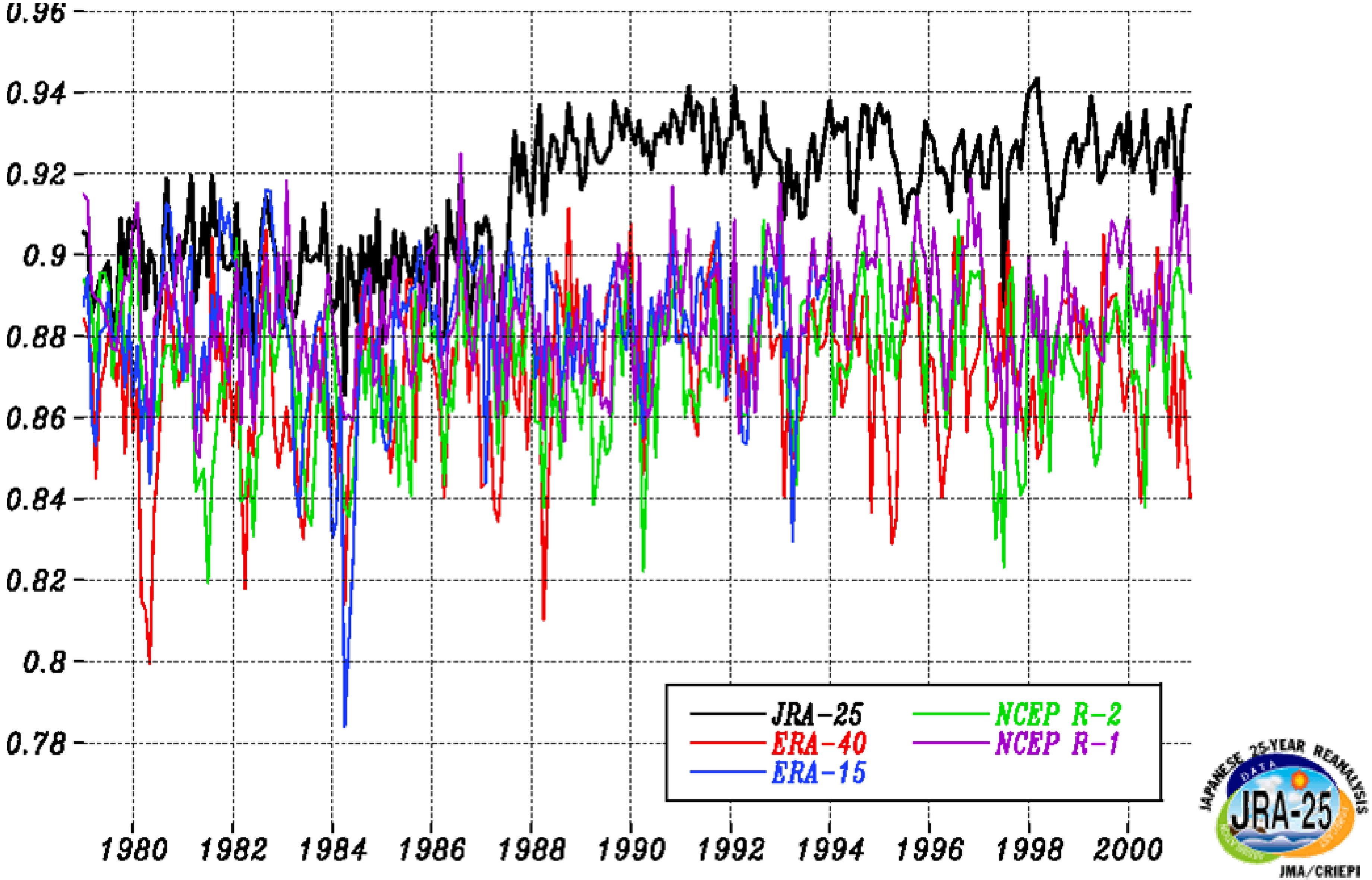
Mean brightness temperature of 22GHz vertical polarization averaged from 45N to 45S over sea for Jul 2007

MSFC :
Brightness temperature data processed with Decord 4 algorithm by NASA/Marshall Space Flight Center

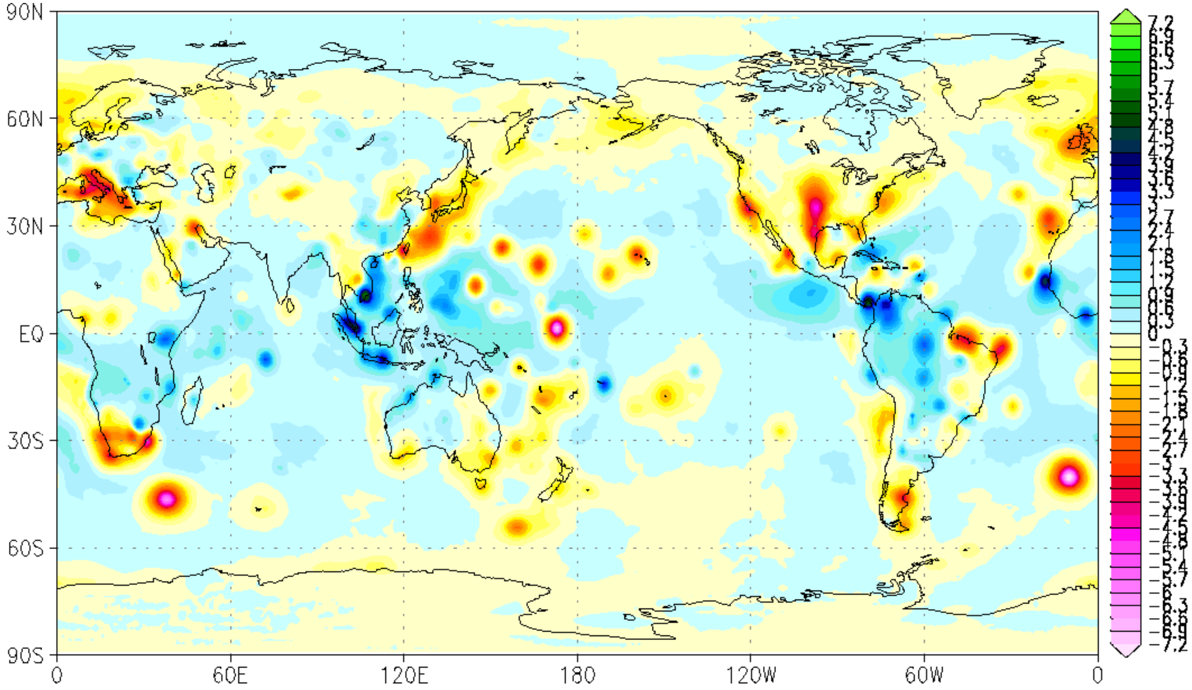
NESDIS :
Brightness temperature data (SDR format) processed by NESDIS

bias correction :
Bias corrected data

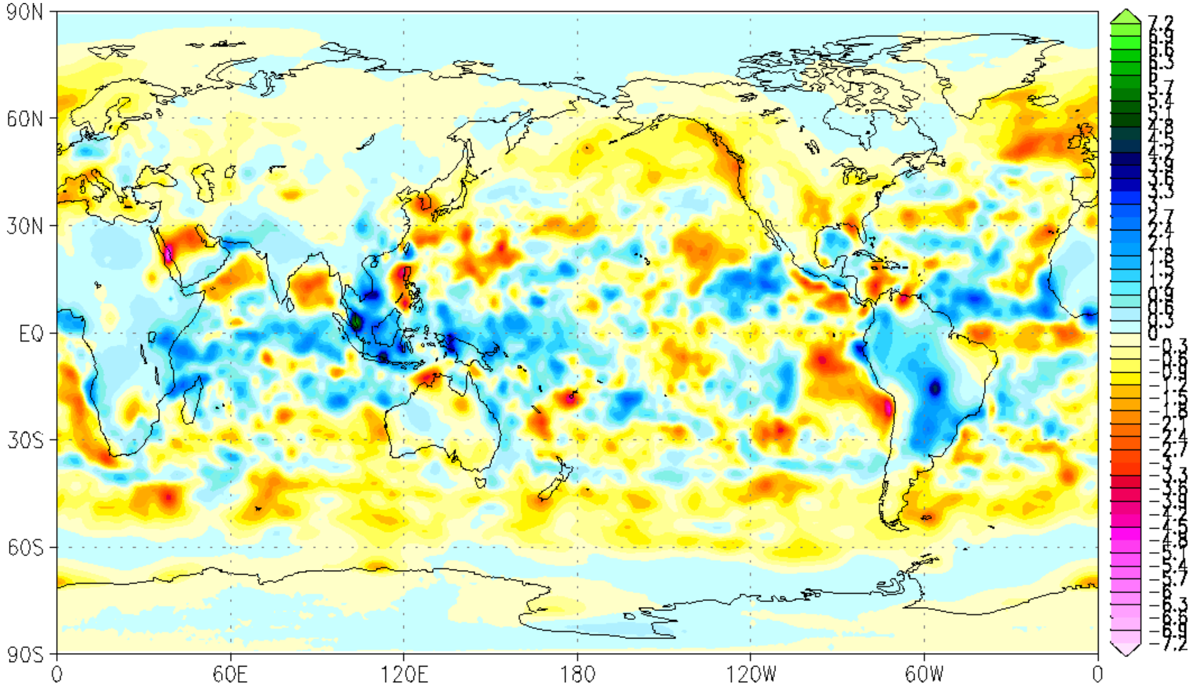
Correlation between monthly precipitation of reanalyses and CMAP



Monthly mean increment of TPW



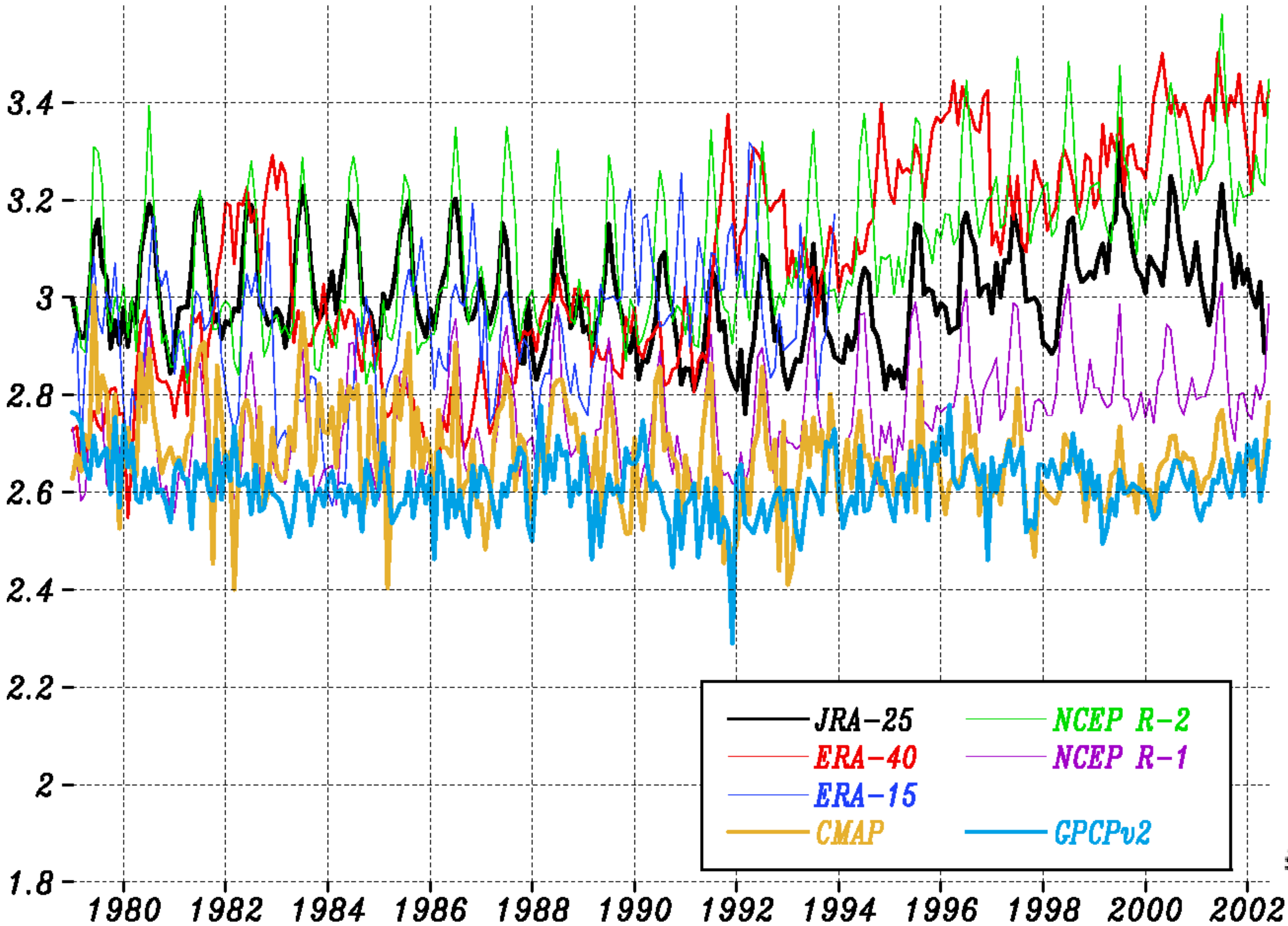
Dec. 1983
(without SSM/I)



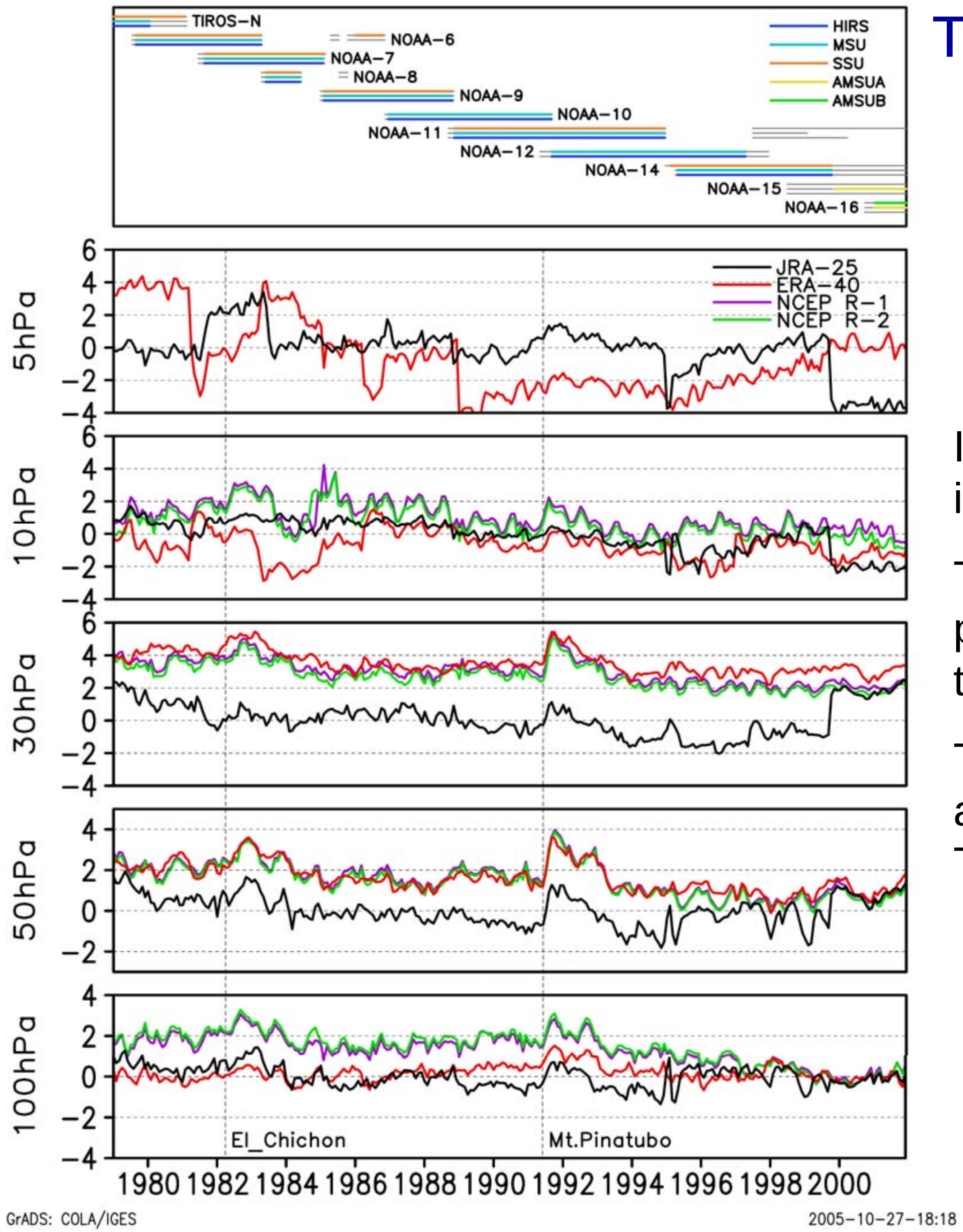
Blue colors indicate moistening by the assimilation.

Dec. 1991
(with SSM/I)

Global mean monthly precipitation



Temperature time series for the stratosphere



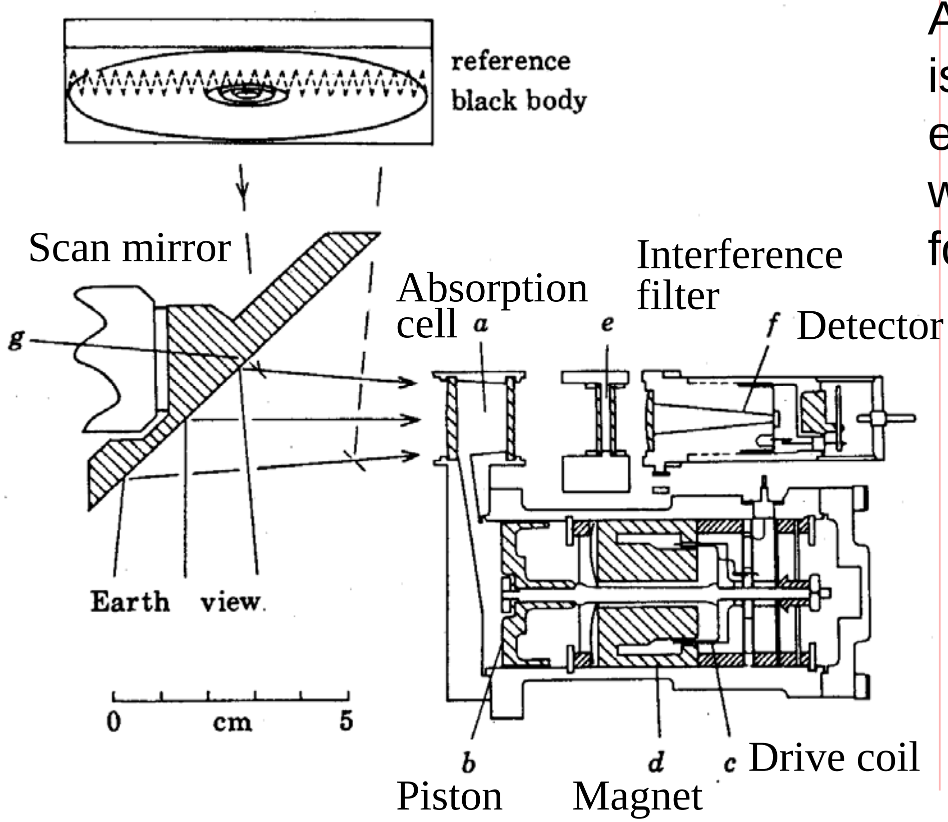
In JRA-25, big jumps occurred early in 1995 and in October 1999.

The former is coincident with the period for which observations from the SSU were absent.

The latter is coincident with the time at which the ATOVS replaced the TOVS.

JMA/CRIEPI

Stratospheric Sounding Unit (SSU)



The optical system and pressure modulator of SSU

quoted from Miller et al., 1980, *Phil. Trans. R. Soc. Lond.*

Assuming that absorption lines are strong, isolated and Lorentz shaped, an analytical expression for the peak pressure of the weighting function would be expected as follows (Taylor et al. 1972, *Appl. Opt.*):

$$p_{peak} = \left[\frac{4(1+b)l}{a}\right]^{\frac{1}{2}} p_0$$

p_0: the mean pressure of the CO_2 cell

a: the total amount of CO_2 in the atmosphere (atm cm/atm)

b: the self-broadening coefficient for CO_2

l: the length of the CO_2 cell.

It depends on P_0 and a, but they are assumed to be constant in JRA-25.

Summary for the quality of the JRA-25 products relevant to satellite data

- Precipitation of JRA-25 has the highest correlation with CMAP among the reanalyses.
  - The bias correction for SSM/I data was performed to adjust to background TPW.
  - Strict QC was performed for water vapor channels of HIRS.
- There are some discontinuities in temperature time series for the stratosphere, which are coincident with satellite switching.
  - Inappropriate bias correction for the stratospheric observing channels of TOVS and ATOVS.
  - The bias is partly because of inappropriate spectroscopic parameters assumed in the radiative transfer calculation.