2004/11/04
JMA CPD

Report of the Japan Meteorological Agency to the APCN Working Group

Yasuhiro MATSUSHITA
Climate Prediction Division,
Climate and Marine Department
Japan Meteorological Agency (JMA)

Recent Study on Dynamical Seasonal Prediction in Climate Prediction Division /JMA

1, Status of the Japanese Reanalysis Project

JRA-25 working group

2, Development of Cloud Schemes in JMA Global Spectral Model (GSM)

Hideaki Kawai

Japan Meteorological Agency

Status of the

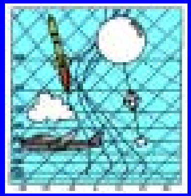
Japanese Reanalysis Project

- JRA-25 and the Status
- System & Source Data
- Preliminary Result
- Product & Distribution

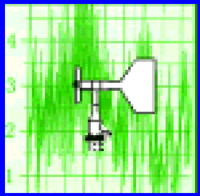
Japanese Reanalysis Project (JRA Project)

Data from Past Observation

Satellite

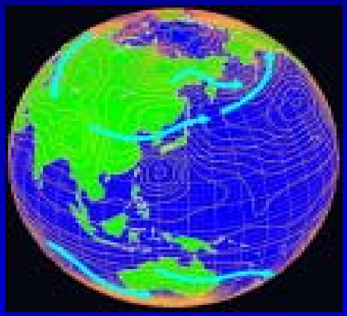


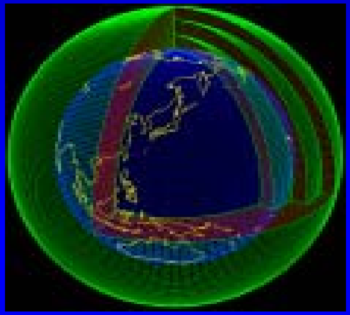
Upper Air



Surface

Ship



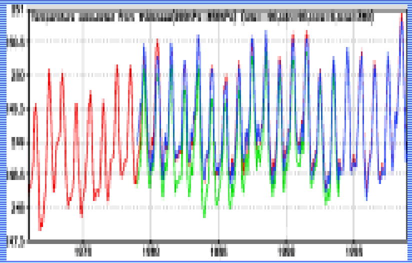


JRA-25 Project

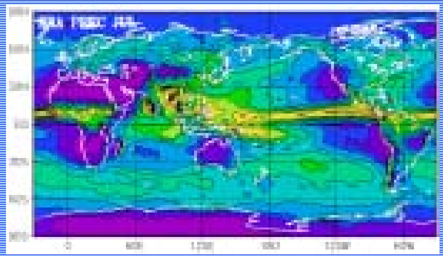
(2001-2005)

6-hourly Climate System Datasets from 1979 to 2004 are computed based on Past Observation and the Numerical Weather Prediction Technology by JMA and CRIEPI

The Best Estimate of the State and Evolution of the Climate System



Physically Consistent Time- Series Data (No Artificial Gap)



Physically Consistent Gridded Data on the Globe (No Empty Area)

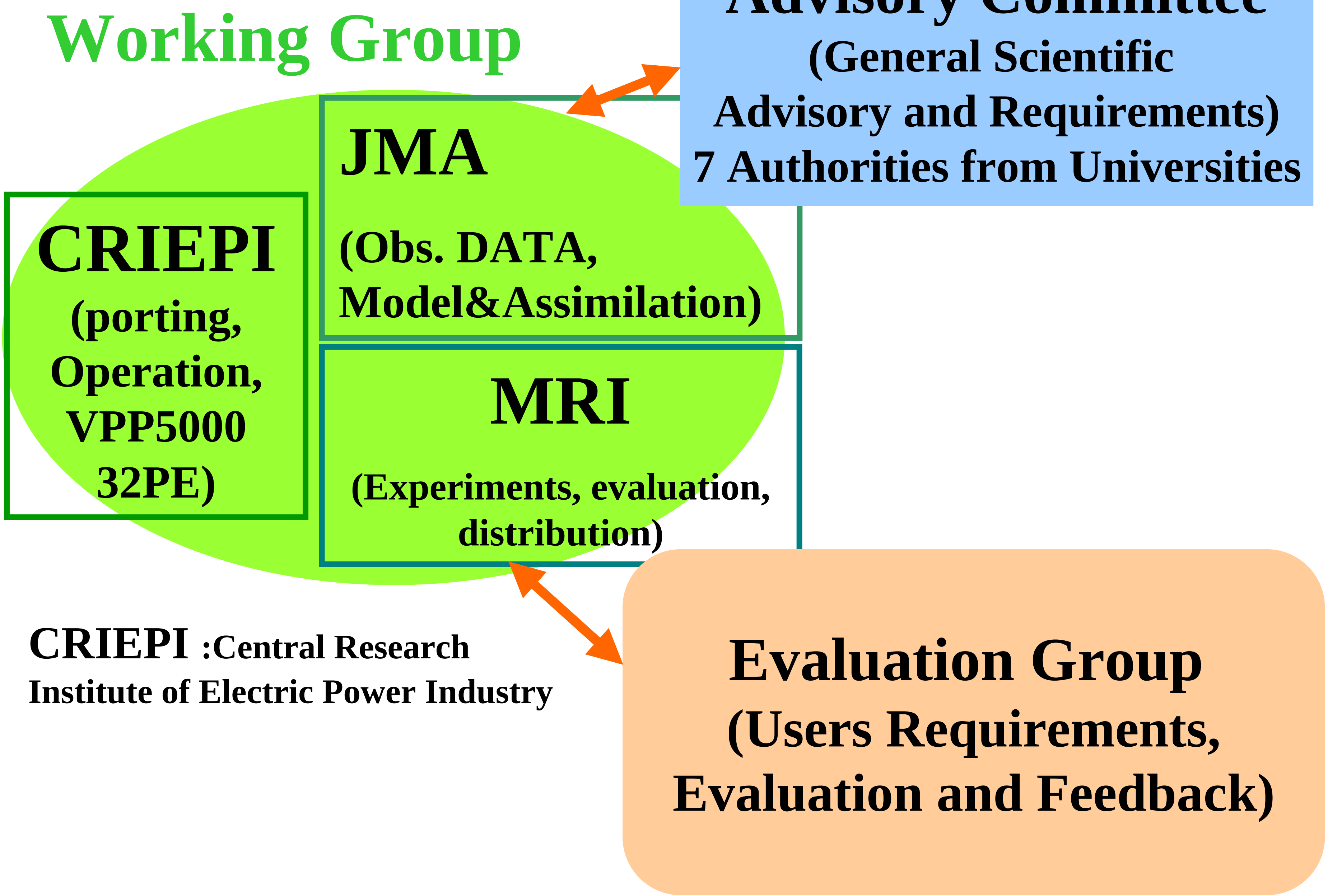
Wind, Air Temperature, Moisture, Precipitation, Evaporation, Soil Moisture, Snow Depth, Surface Fluxes, Radiation, Ground Temperature, etc.

JMA Tokyo Climate Center

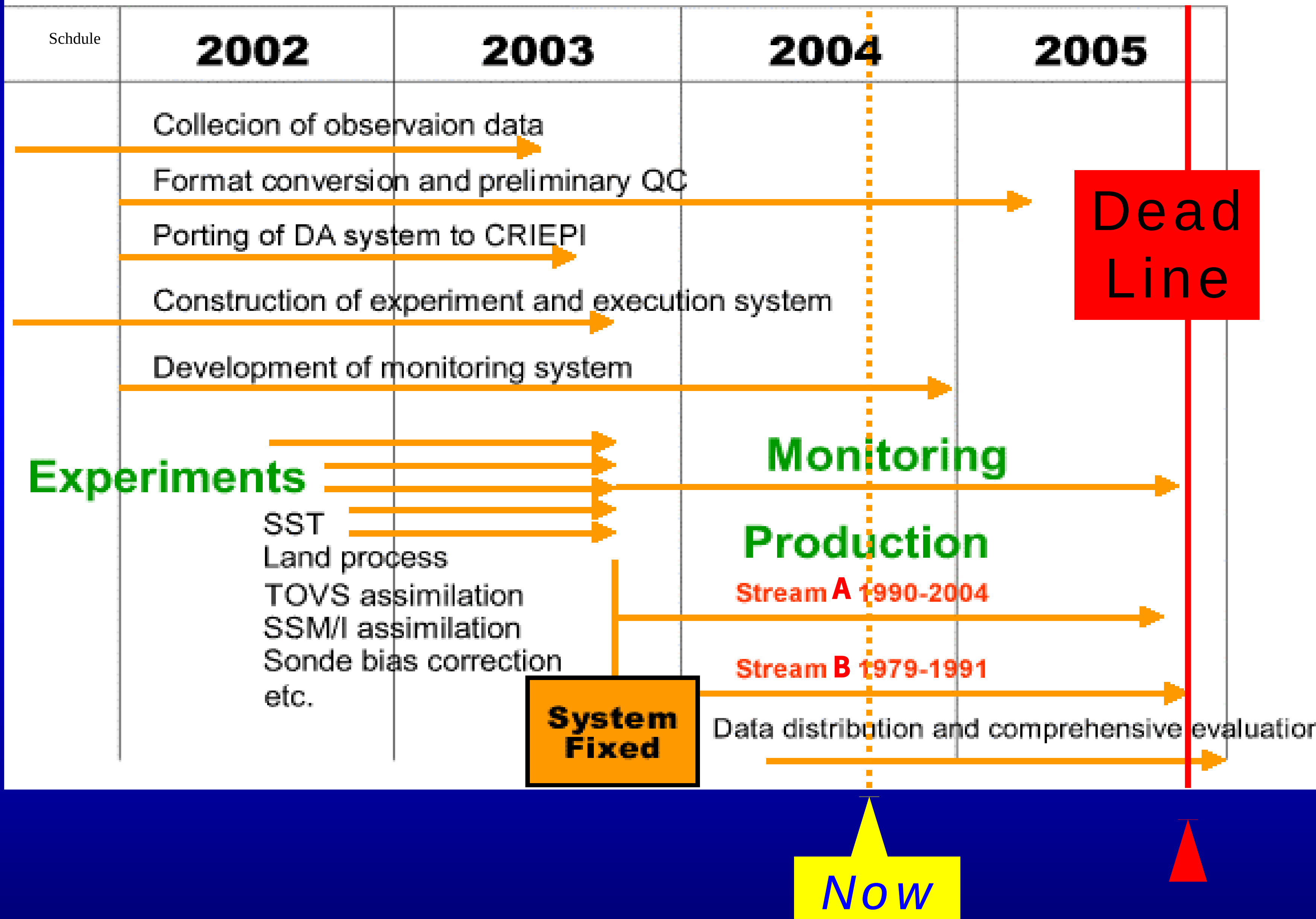
Dissemination of JRA Datasets to the World

Data for Climate System Monitoring and Dynamical Seasonal Prediction

Schematic Framework



Schedule of JRA-25 (Fiscal year)



Specifications *of Japanese Reanalysis*

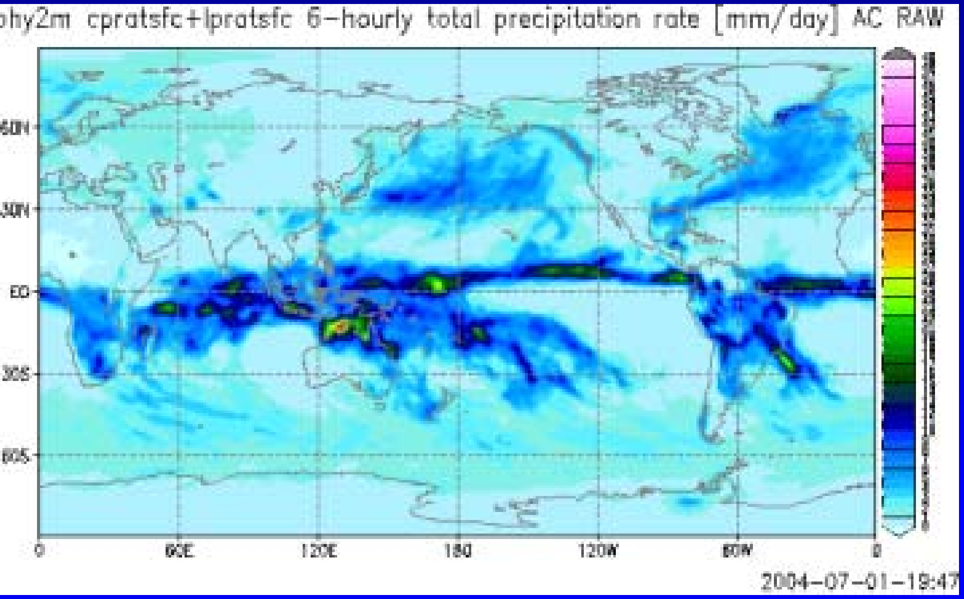
- **Assimilation & Model:JMA Operational**
  3-Dimensional Variational Scheme
  JMA GSM T106, 40 layers with top at 0.4hPa
  Land model : JMA SiB and Snow Analysis
- **Target Period : 1979-2004 (26 years)**
  The analysis cycle will be continued in J-CDAS after JRA-25 completion.

Sources Data

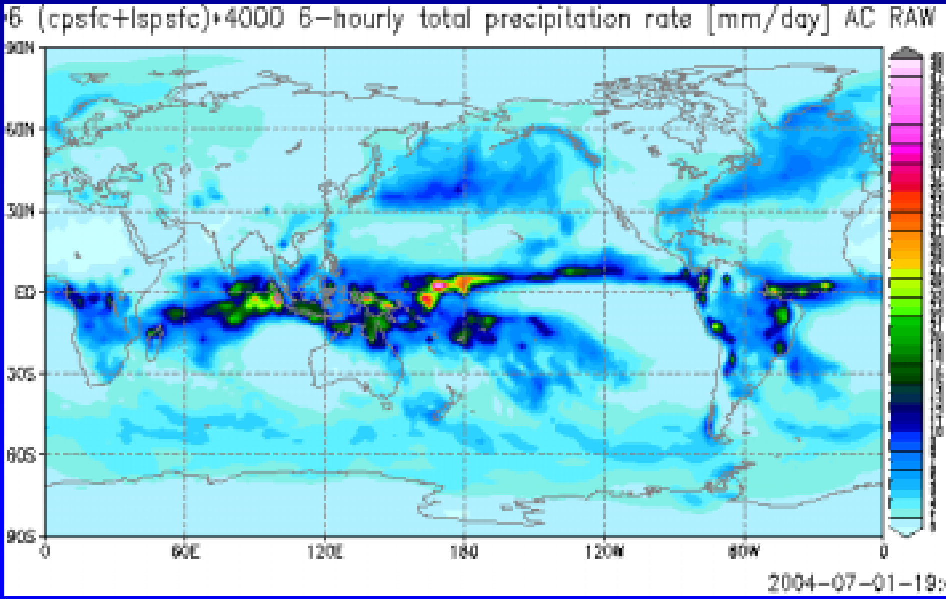
- JMA historical conventional dataset
- NCEP conventional observation database
- ECMWF & NCEP merged data (ERA-40 observation)
- TOVS/ATOVS brightness temperature (level 1c)
- SSM/I (SMMR) retrieved precipitable-water and sea-ice data
- GMS/METEOSAT re-processed cloud motion wind
- COBE JMA-SST and sea ice analyzed by JMA (1901 ~)
- Tropical cyclone wind retrieval from best tracks by Dr M. Fiorino
- Chinese snow depth digitalized from printed matter

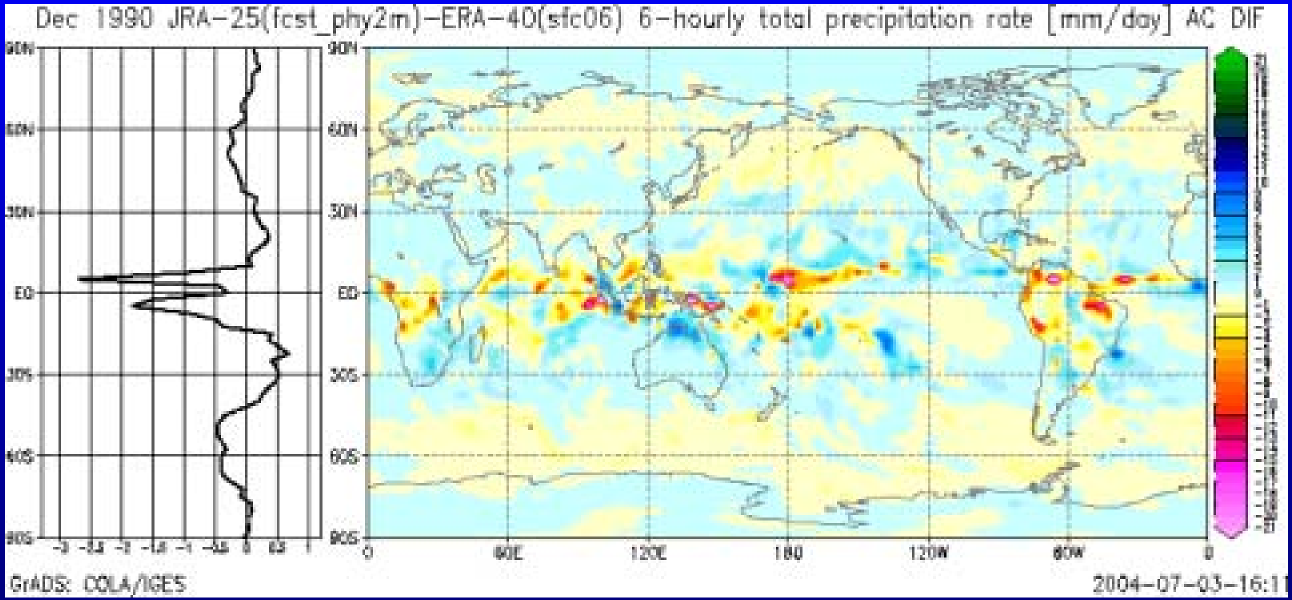
Dec.1990 Total Precipitation *(JRA-25, ERA-40)*

JRA-25



ERA-40

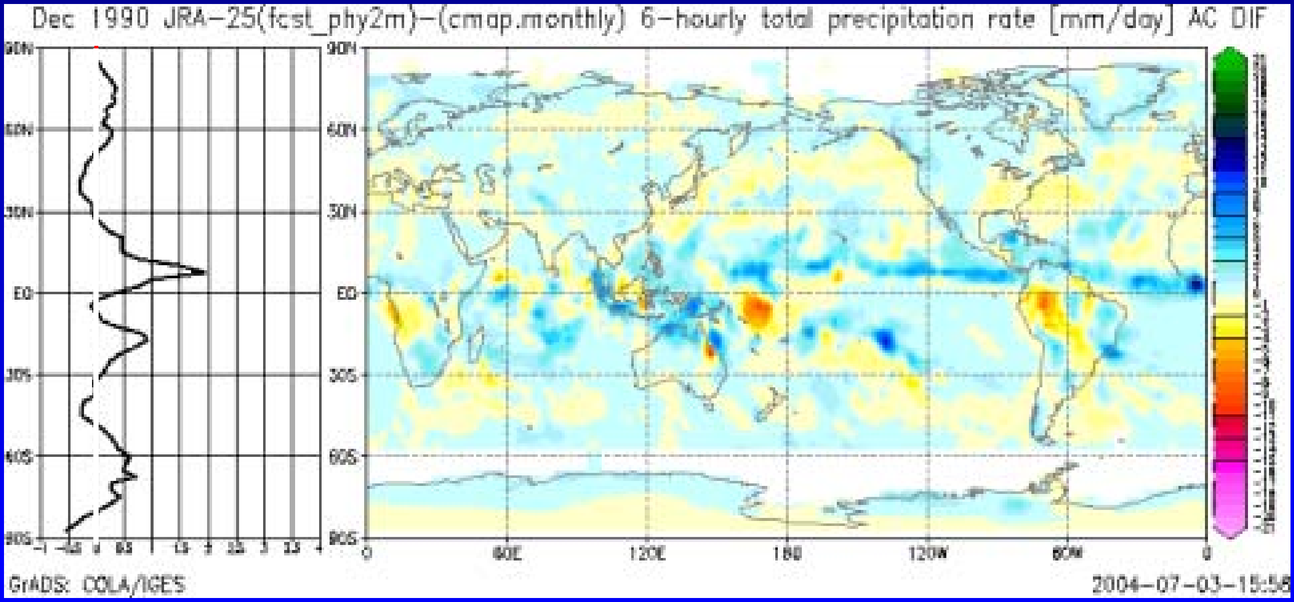




JRA-25 - ERA-40

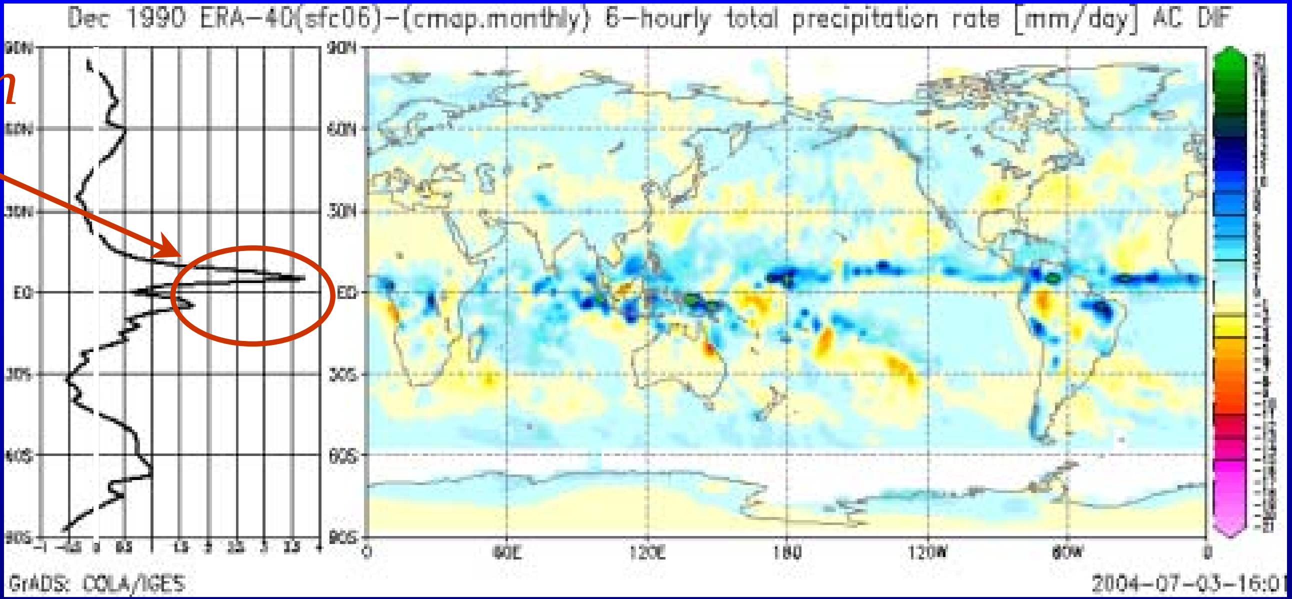
Dec.1990 Total Precipitation (diff. from CMAP)

JRA-25 - CMAP

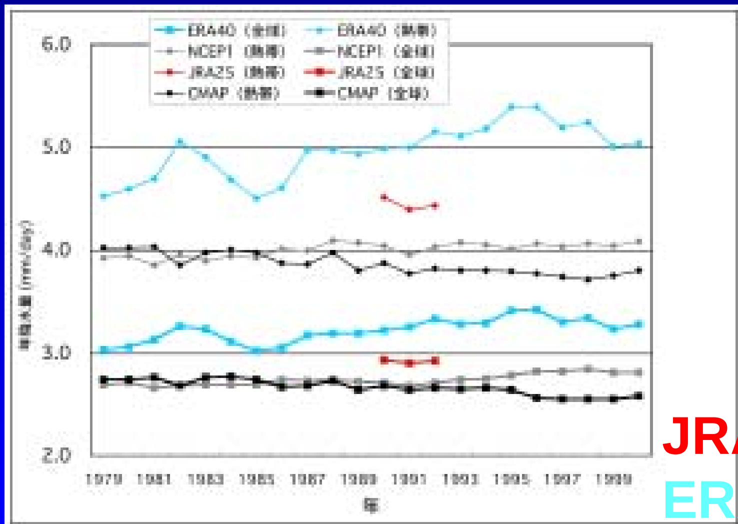


ERA-40 - CMAP

too much precipitation



Annual variability of precipitation of reanalyses compared against CMAP

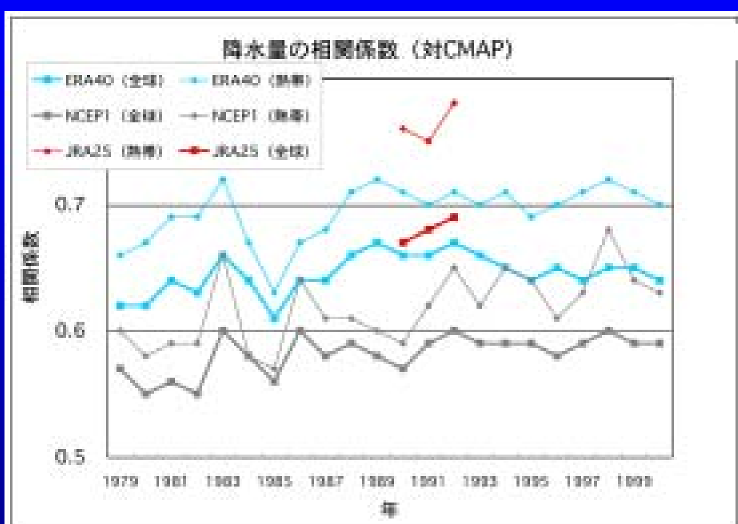


JRA-25

ERA-40

NCEP-R1

AP



[Mean precipitation]

- Much more precipitation in ERA40 than CMAP either in tropics and global.
- More precipitation in JRA25

[Correlation against CMAP]

- JRA-25 has the best correlation.
- NCEP-R1 has the lowest correlation and large variability.

Thin lines : Tropics

Thick lines : Global

(by Kamahori MRI/JMA)

JRA-25 Reanalysis Evaluation Group

http://www.jreap.org/organization/eval-guideline-e.html

Researchers from overseas are welcomed as a member of *Evaluation Group*.

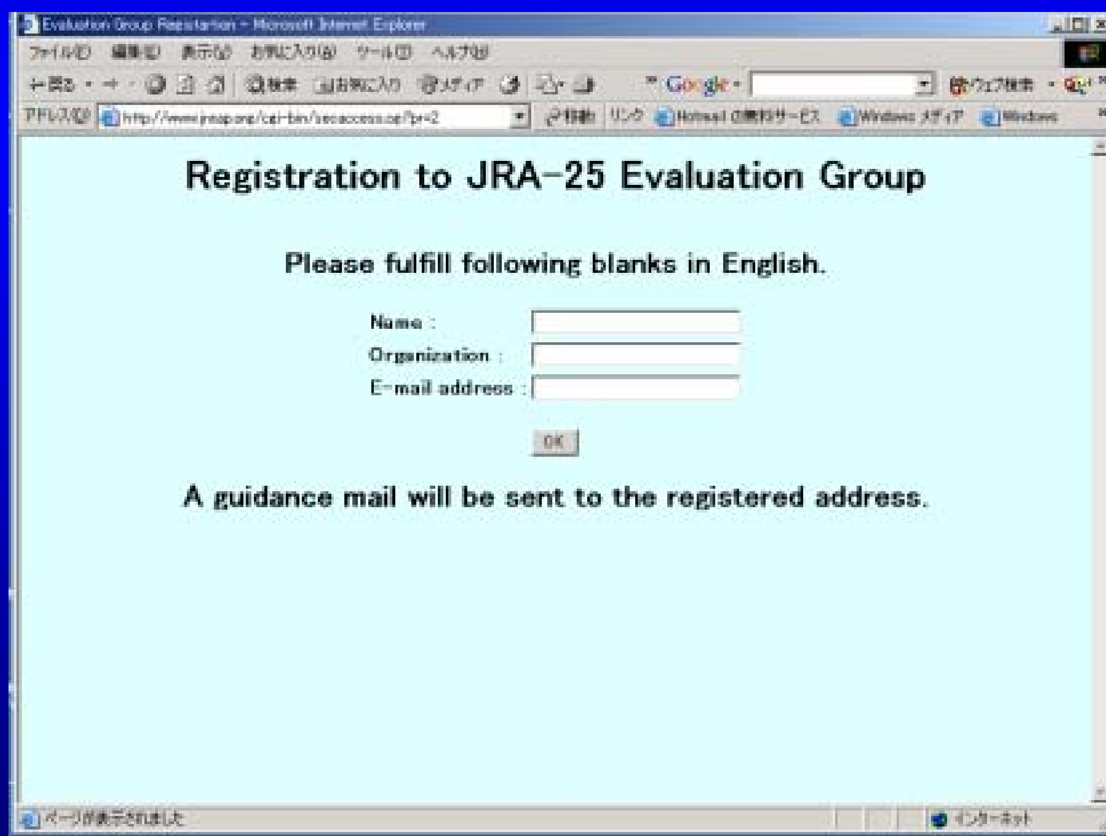
Members

-Access to the basic dataset of experimental and final products of JRA-25 through the Internet, and use them to their research activities.

-Members are expected to contribute the evaluation work.

Data distribution from http://www.jreap.org

Basic Dataset : up to 500GB in our web server.
Full Dataset : 7 TB and more. Not Available at present



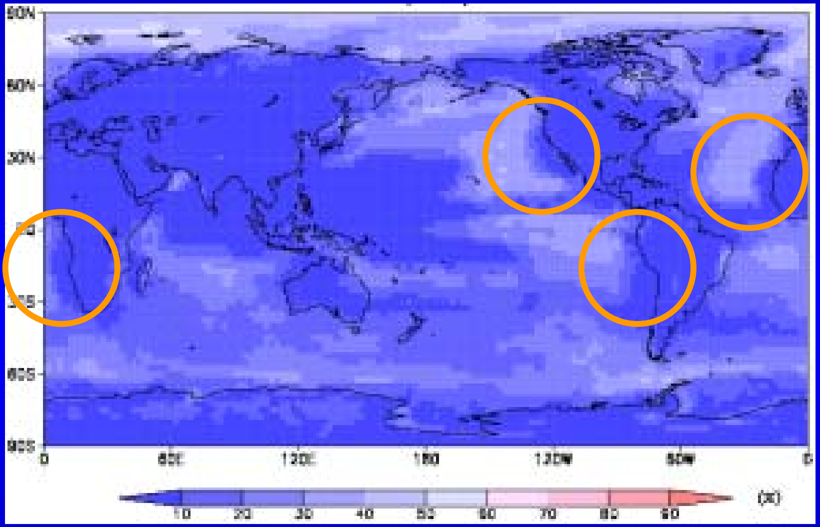
Development of Cloud Schemes in JMA Global Spectral Model (GSM)

1. Parameterization of Subtropical Marine Stratocumulus

1-1. Problem on Representation of Stratocumulus

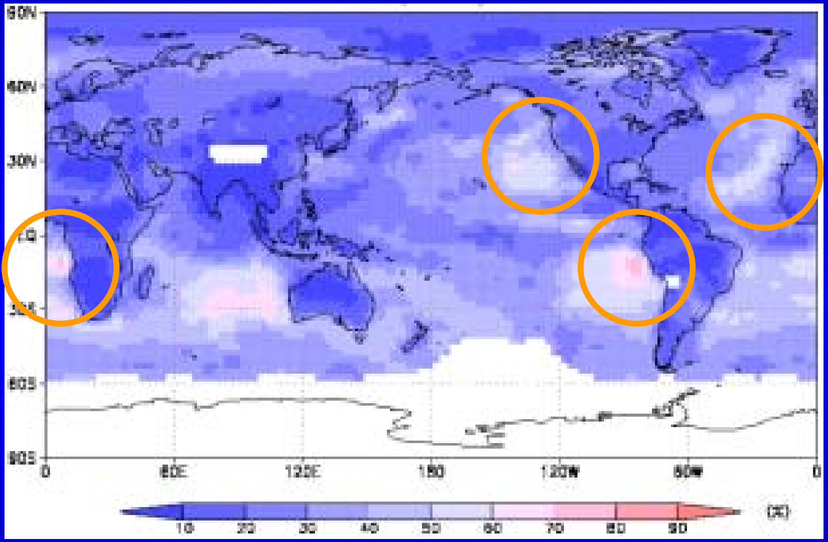
Low Cloud Amount

Model



Model : T106, average of FT=00-720

ISCCP Observation



Jul 1988

Harmful Influence

- Huge bias of a radiation flux in Coupled GCMs

Bias of ~5K on SST (Duynkerke & Teixeira 2001)

Why is Sc difficult to be represented?

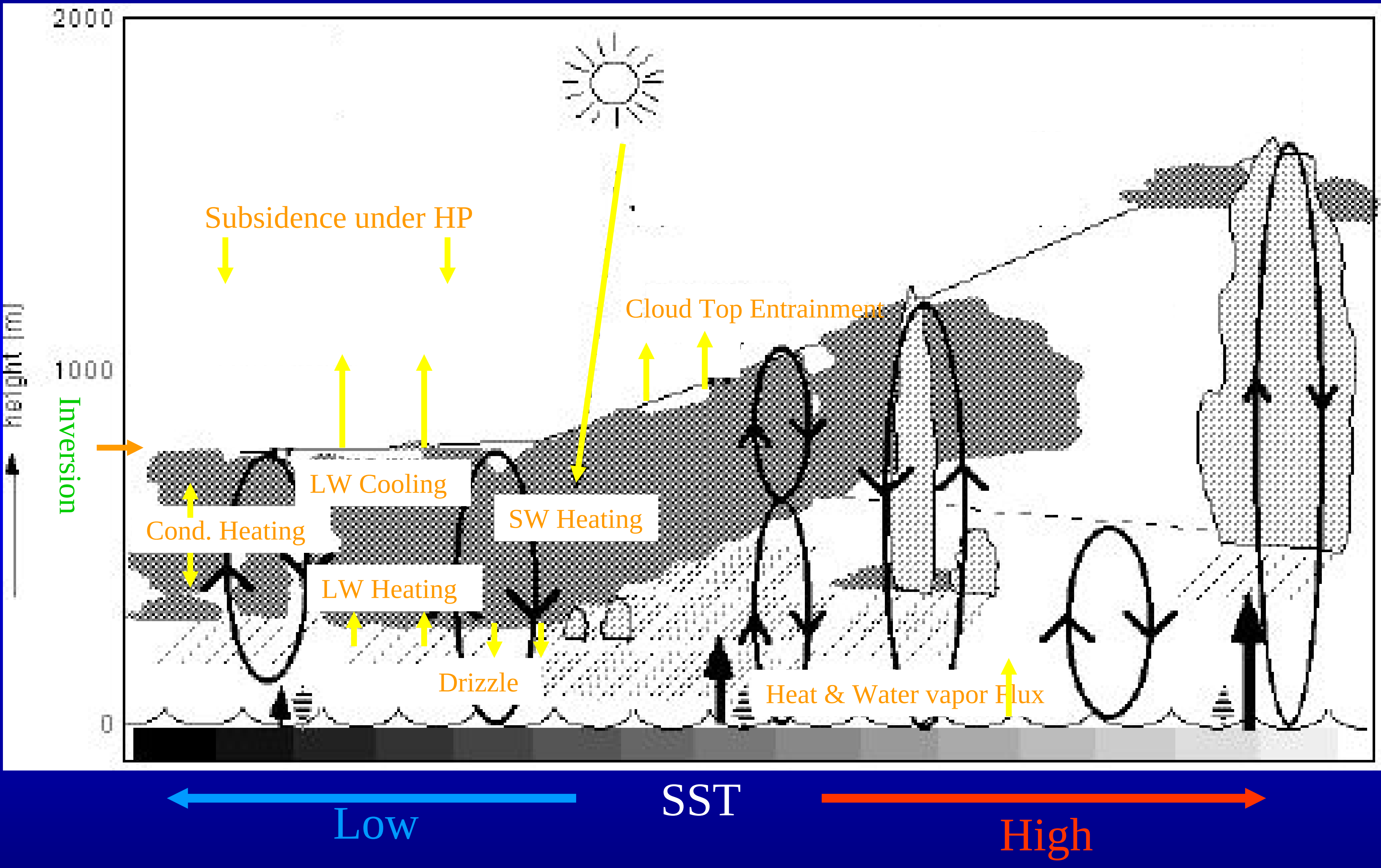
Reason of Difficulty

Complicated interaction of various physical processes is important for Sc

↕

Low Vertical Resolution of the Model

Structure of Marine Stratocumulus



From a HP of Stephan de Roode, Institute for Marine and Atmospheric Research Utrecht, Universiteit van Utrecht

1-2. Parameterization of Stratocumulus

A. Conditions to produce stratocumulus

(1). Strong Inversion just above the Layer

Between the layer and a layer just above the one

$$\left|\frac{\partial \theta}{\partial P}\right| > 0.07 \quad [\mathrm{K/hPa}]$$

Basic concept for production of Sc

(2). Not Stable near the Surface

Between the lowest layer and the 2nd lowest one

$$\frac{\partial \theta}{\partial P} > -0.01 \quad [\mathrm{K/hPa}]$$

Prevent the pseudo formation of Sc, e.g., above land or sea ice during night

(3). Limited Lower than 940hPa

Intercept the fictious development of Sc in shallow convection area

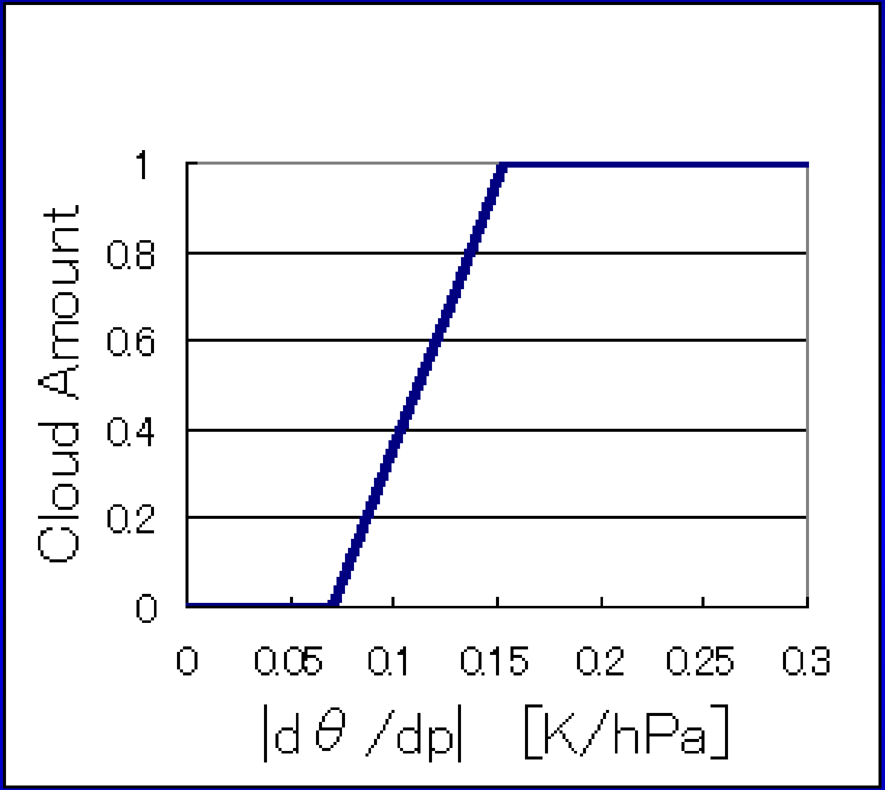
B1. Cloud Amount

Method by Slingo (1980, 1987)

$$C_L = a\left(\left|\frac{\partial\theta}{\partial P}\right| - b\right) \quad [\mathrm{K/hPa}]$$

$$a = 12.0 \quad [\mathrm{hPa/K}],$$

$$b = 0.07 \quad [\mathrm{K/hPa}]$$



Parameterization based on observation

*Exception of PDF cloud scheme by Smith (1990).

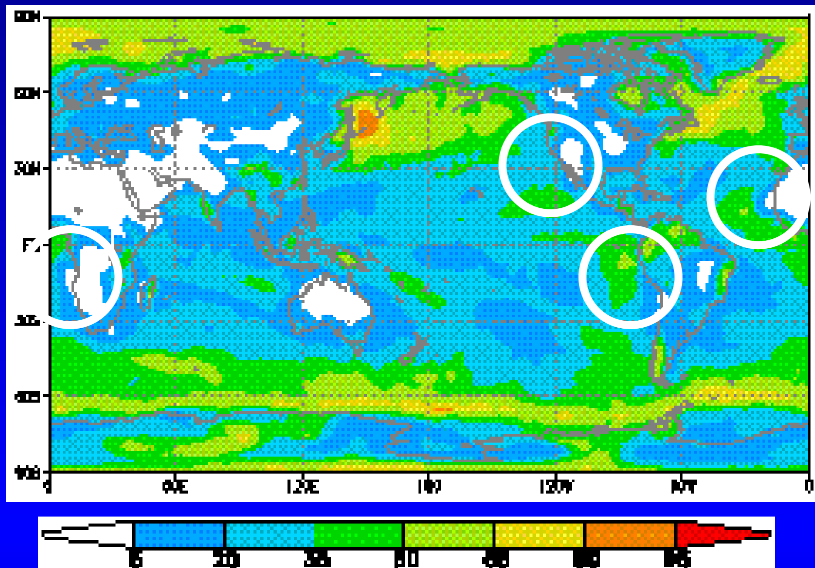
B2. Cloud Water Content

$$q_{c\,cld} = 0.03 q_{sat}$$

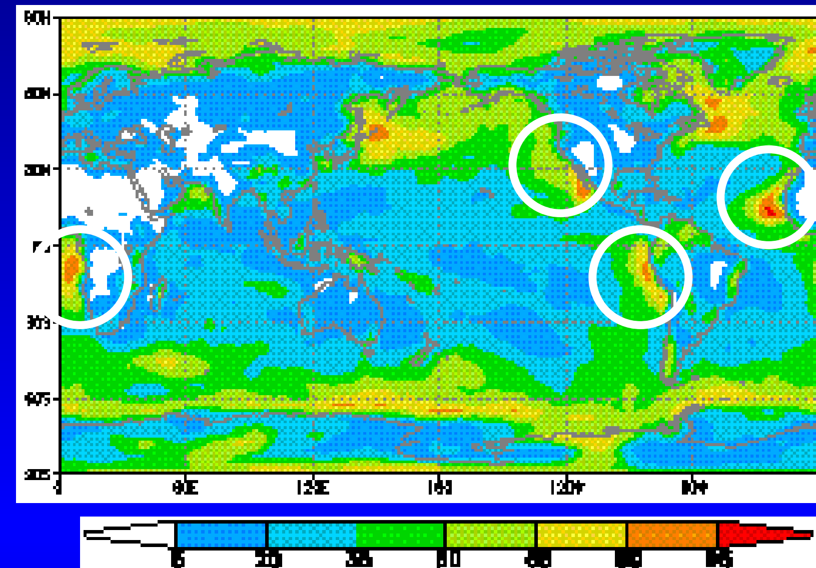
C. Cloud Top Entrainment

1-3. Result A. Low Cloud Amount

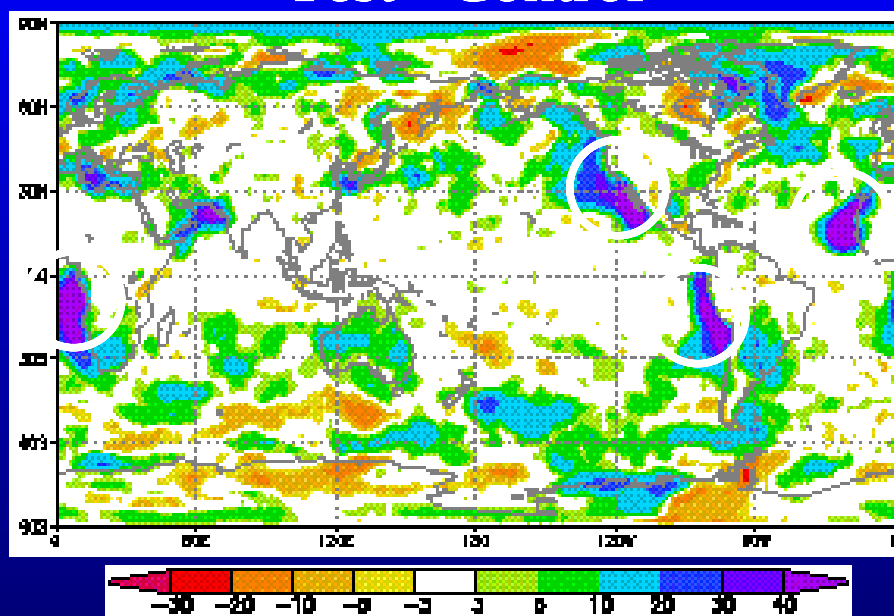
Control



Test



Test - Control



JUN 1992

cf.

Obs. (Off California)

: 83% (JUL 1987)

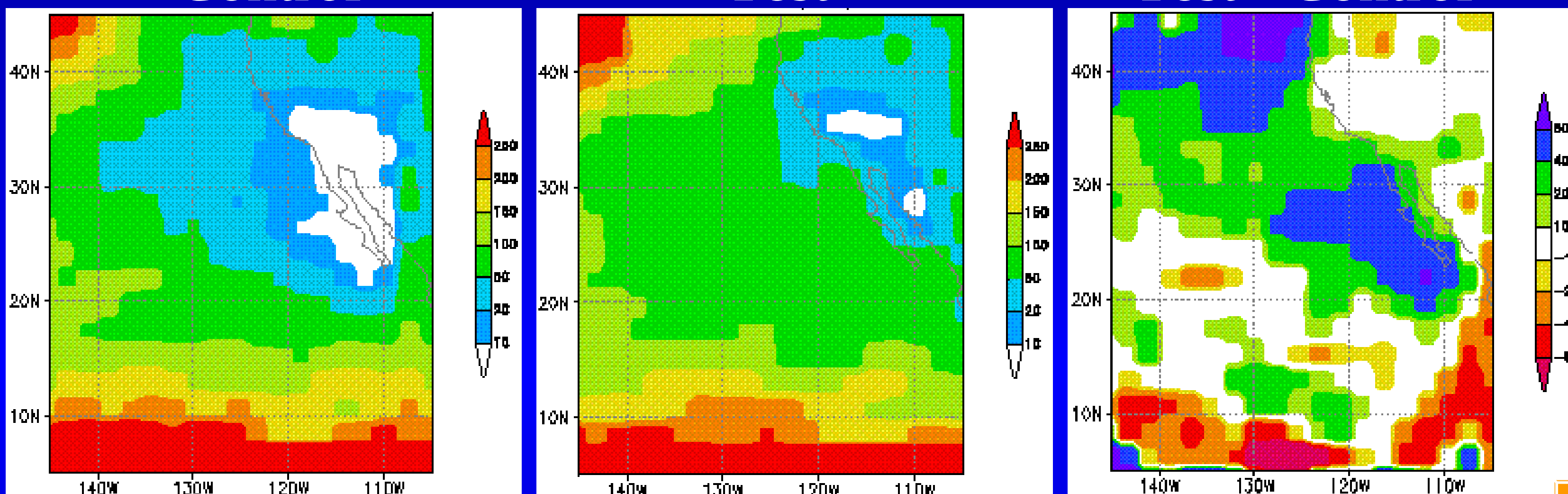
T106

average of FT=00-720

B. Total Cloud Water Content

Off California

Control | Test | Test - Control



JUN 1992

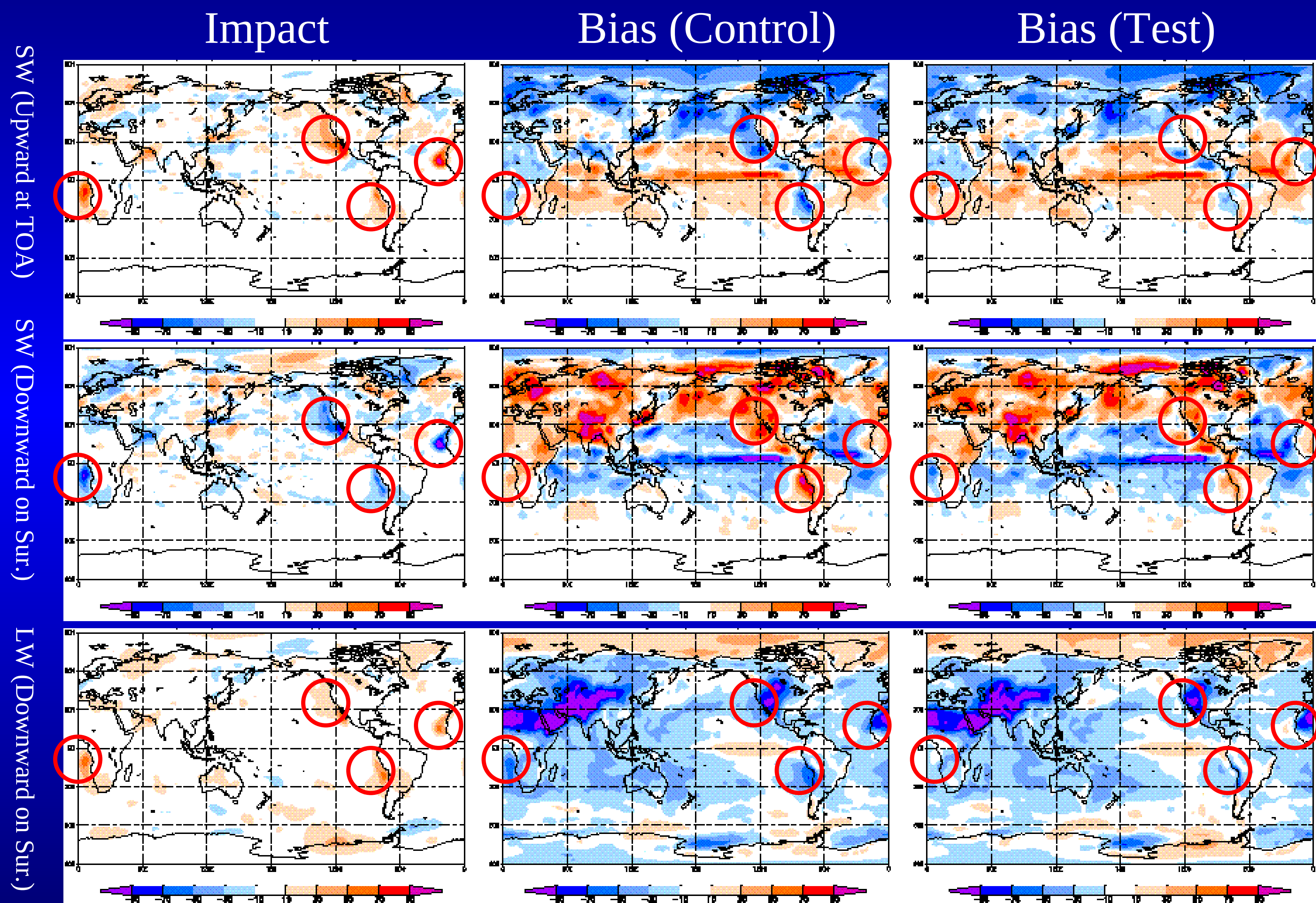
T106, average of FT=00-720

cf. Obs. (TCWC off California) : ~70 [g/m^2] (JUL 1987)

C. Radiation Budget (JUN)

TOA Obs. : ERBE

Surface Obs. : SRB



1-4. Summary and Future Plan

Summary

- Sc have been represented
- Improved Radiation Budget
- TCWC became to be the same extent as observation value
- Diurnal Variation is represented (not shown)
- Seasonal Variation is close to observational one (not shown)

Future

- Diurnal Variation of Cloud Layer thickness, Cloud Water Content
- Transition from Sc to Shallow Convection

→Higher vertical resolution, Shallow Convection Param., CTE Param.

Thank you !

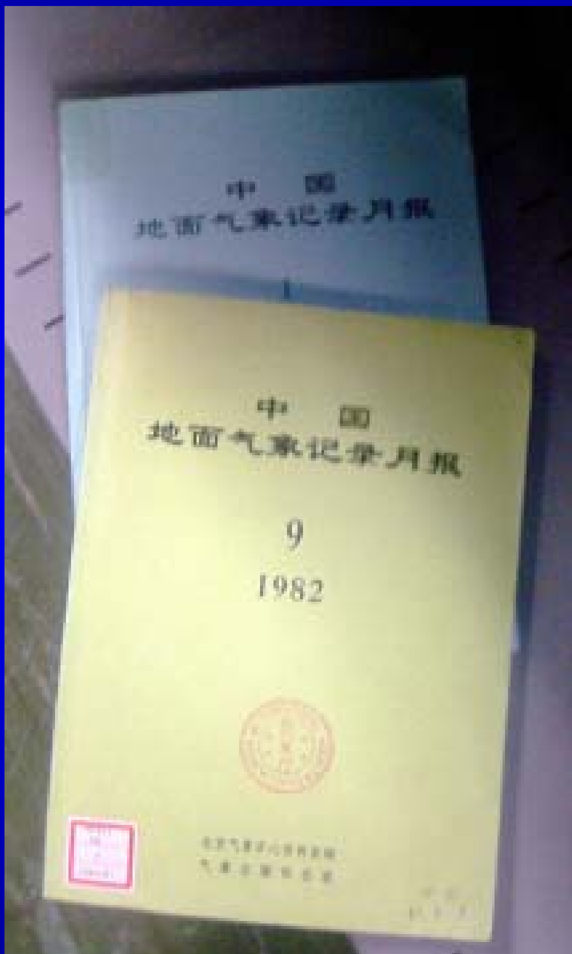
JMA’s new mascot character “Harerun”

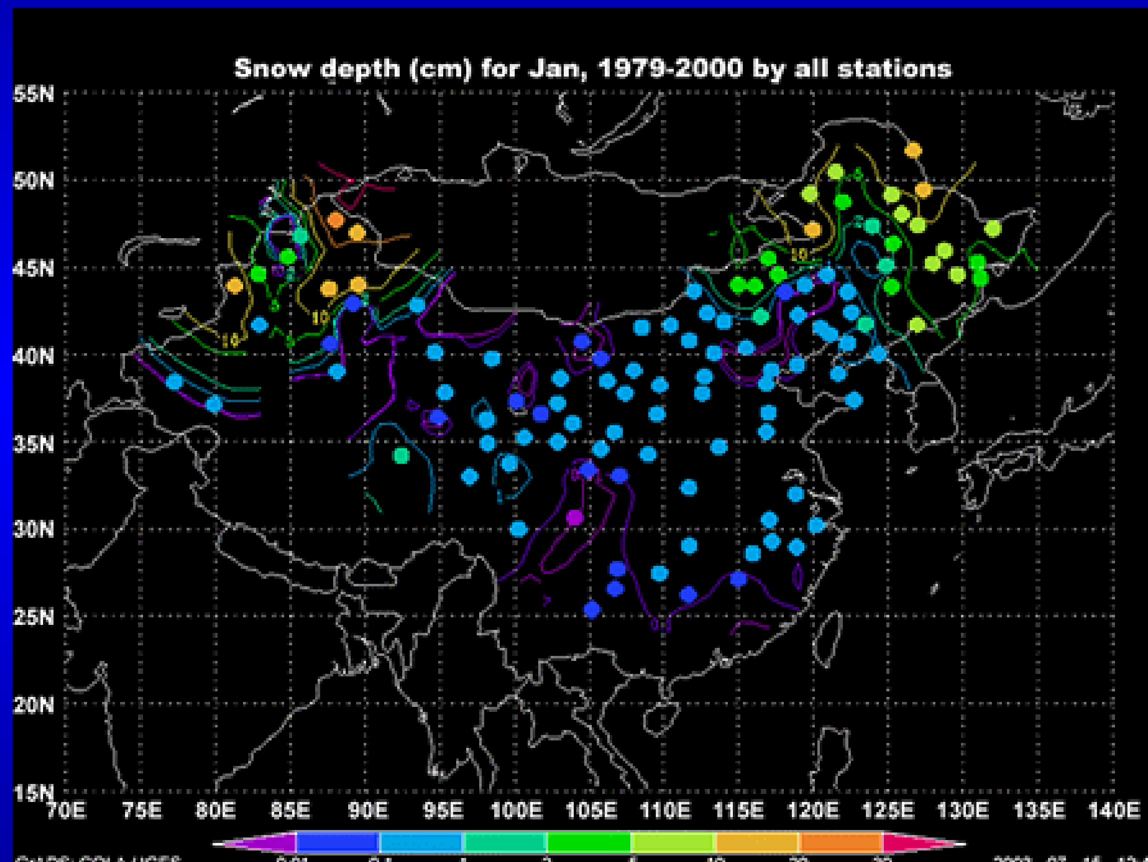
Appendix 1

Source Data used in JRA25

Sources Data

Newly Digitalized Chinese Snow Depth in MRI



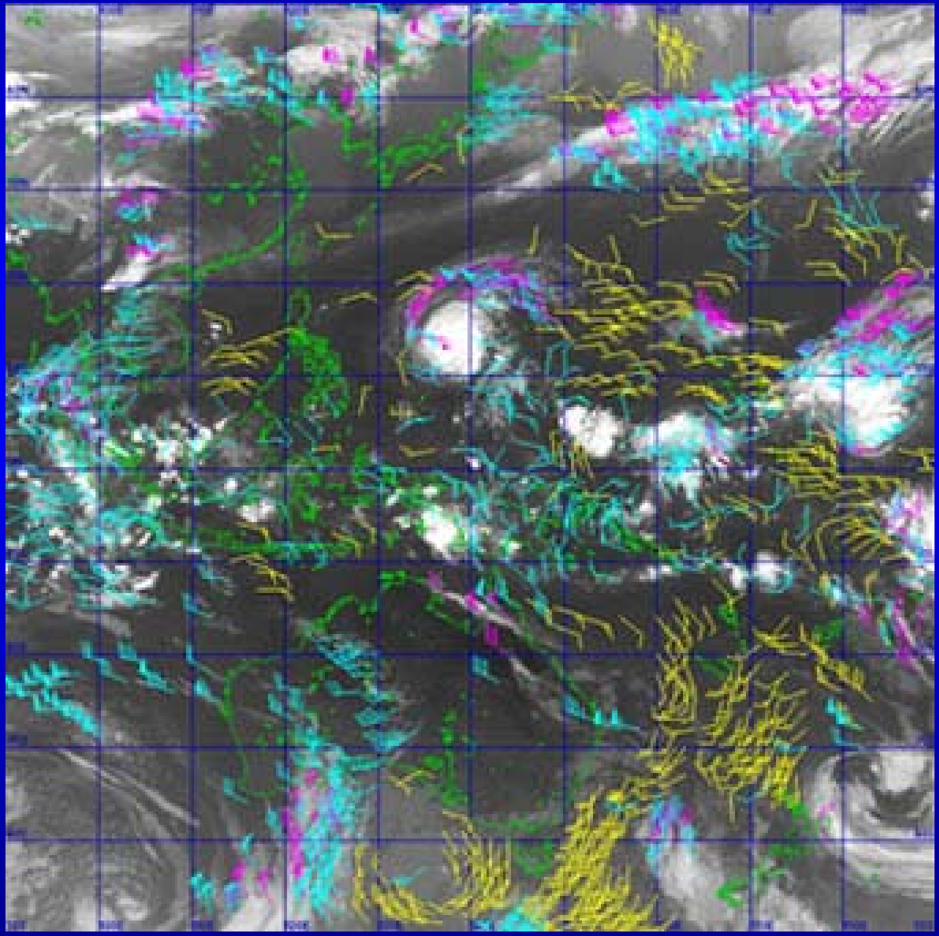


Monthly Report on Chinese Ground Meteorology

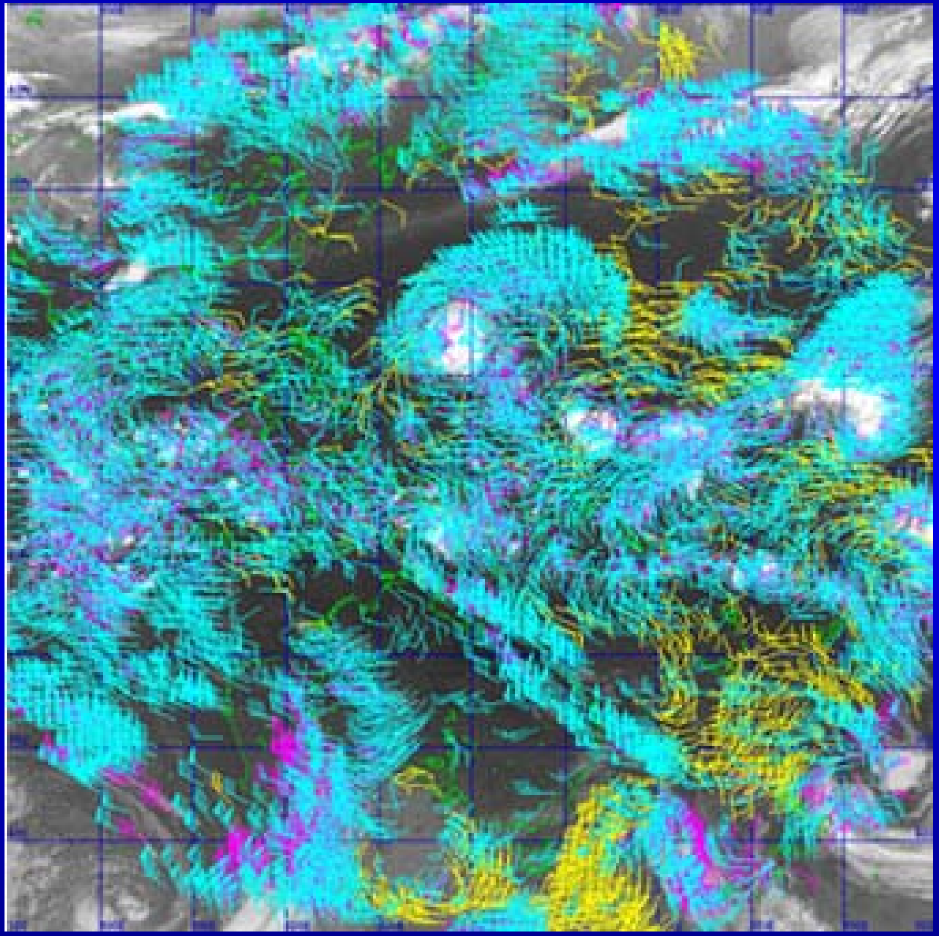
Sources Data GMS
re-processed cloud motion wind

High level
Middle Level
Low Level

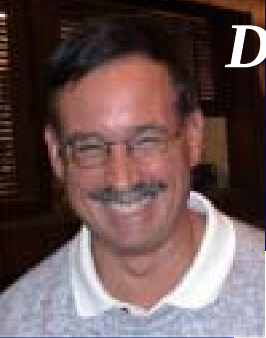
Before reprocessing



After reprocessing



QI : Quality Index attached to each vector

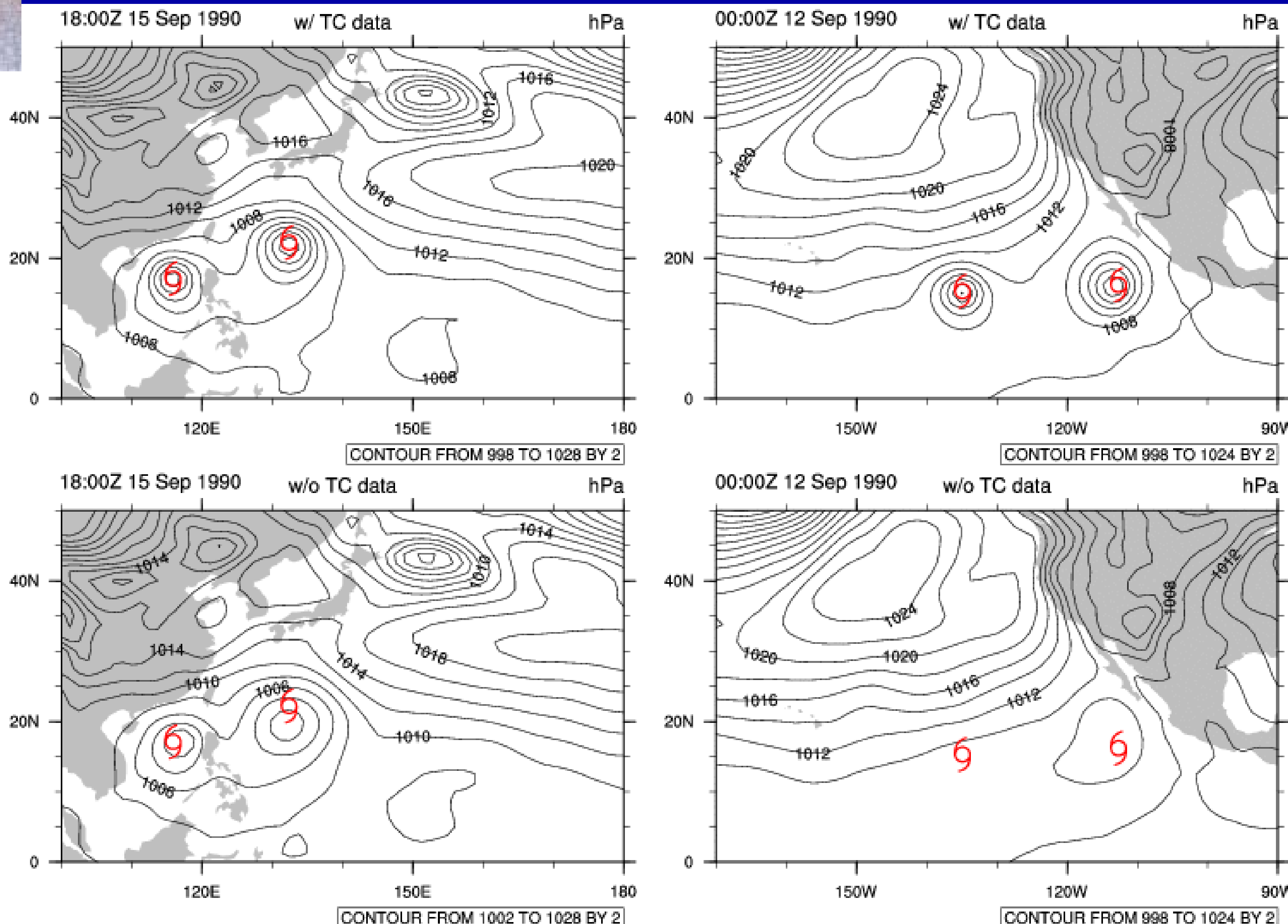


Dr. Mike Fiorino in PCMDI

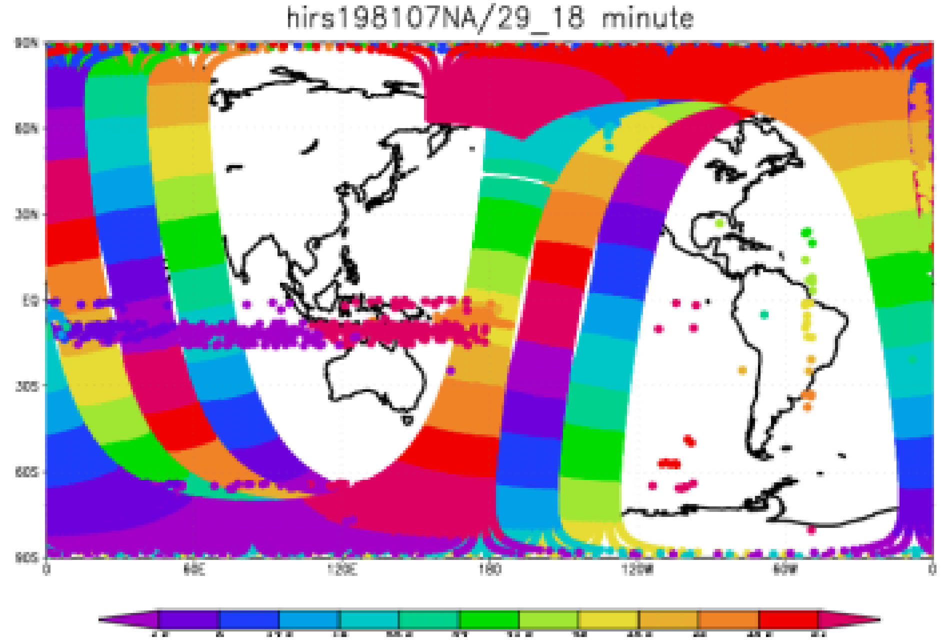
Sources Data
Tropical Cyclone Wind Retrieval

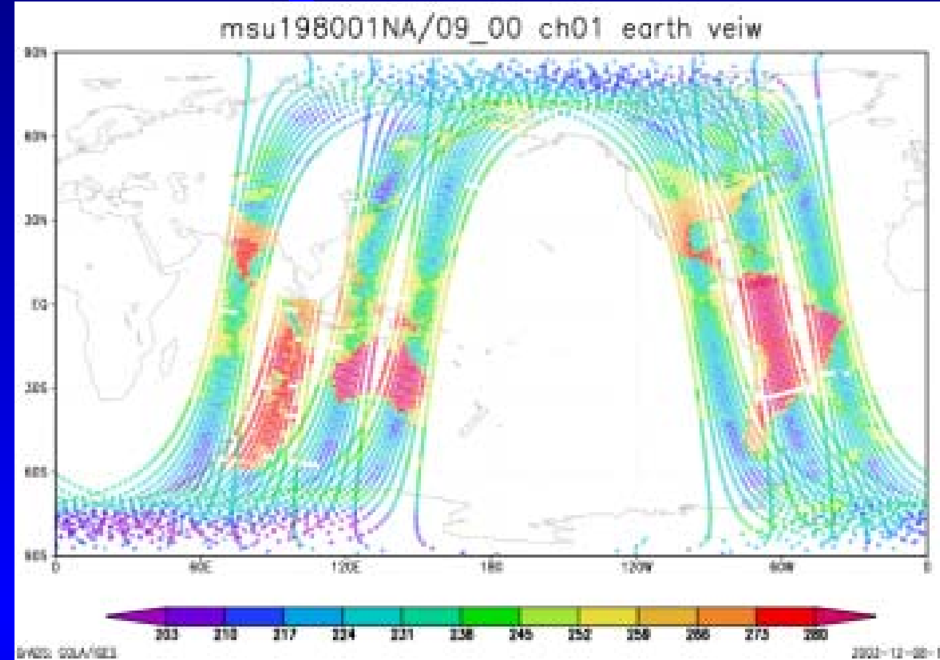
with TCWR (Fiorino on)

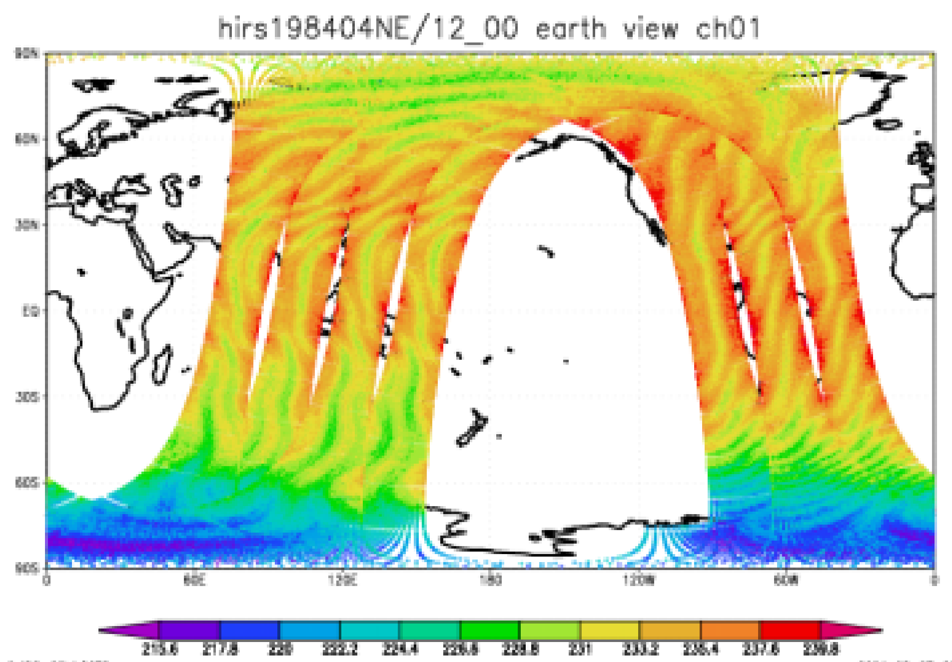
without TCWR (Fiorino off)

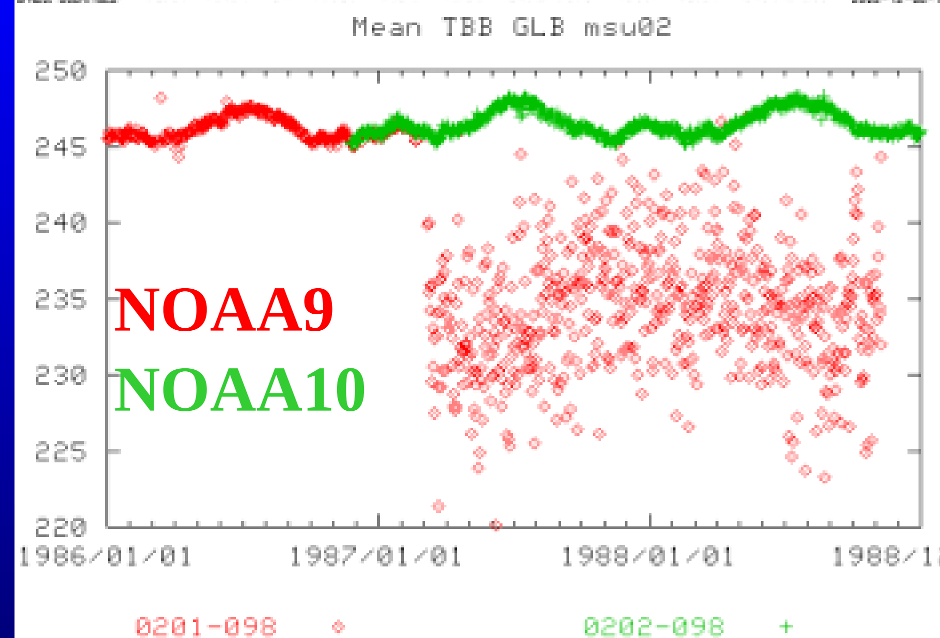


TOVS Data QC


hirs198107NA/29_18 minute

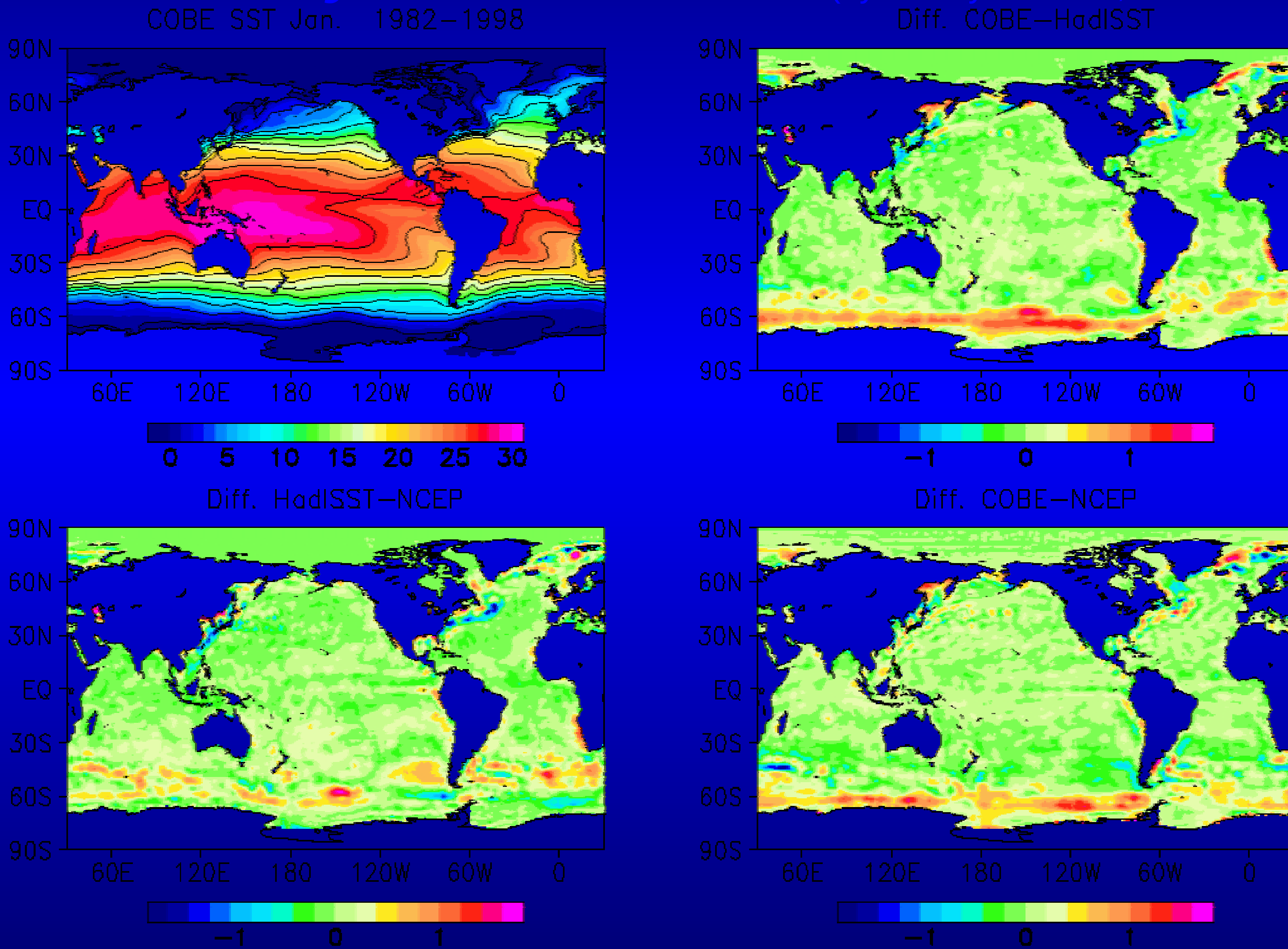

msu198001NA/09_00 ch01 earth veiw
203 210 217 224 231 238 245 252 259 266 273 280


hirs198404NE/12_00 earth view ch01
215.6 217.8 220 222.2 224.4 226.6 228.8 231 233.2 235.4 237.6 239.8


Mean TBB GLB msu02
250
245
240
235
230
225
220
1986/01/01
1987/01/01
1988/01/01
NOAA9
NOAA10
0201-098
0202-098

Prescribed Data
COBE daily SST/Sea Ice

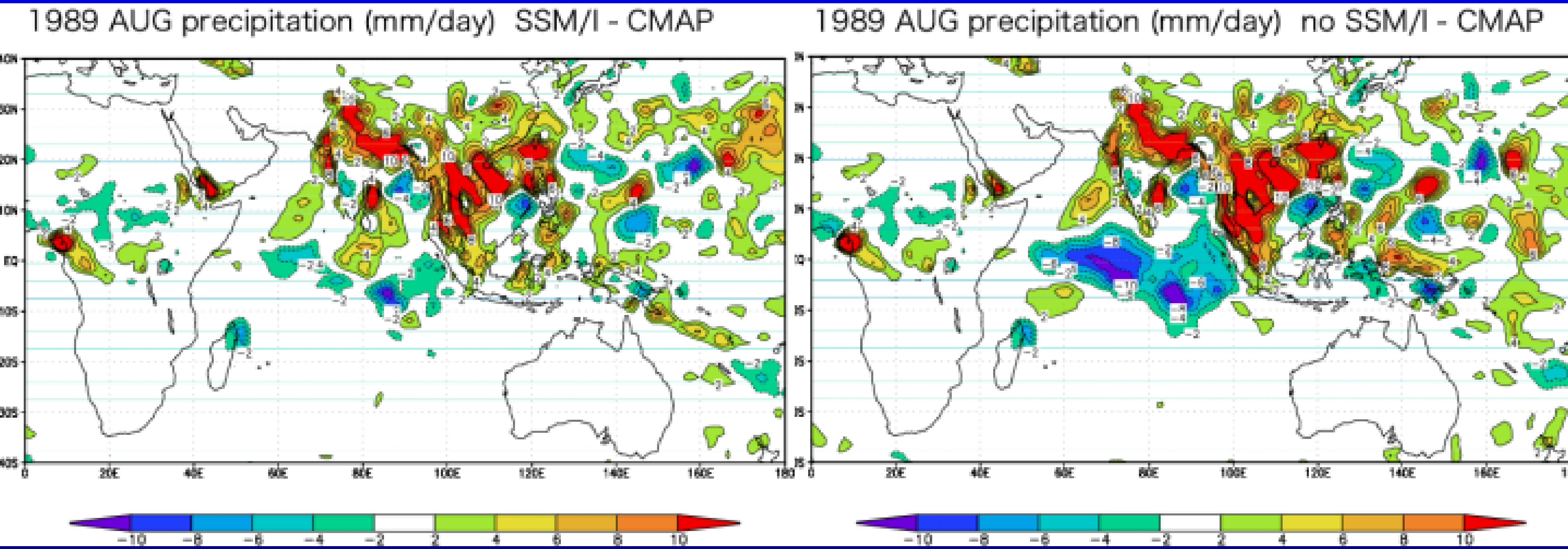
(by Masayoshi Ishii, former CPD/JMA)



SSM/I Precipitable Water Assimilation Experiment

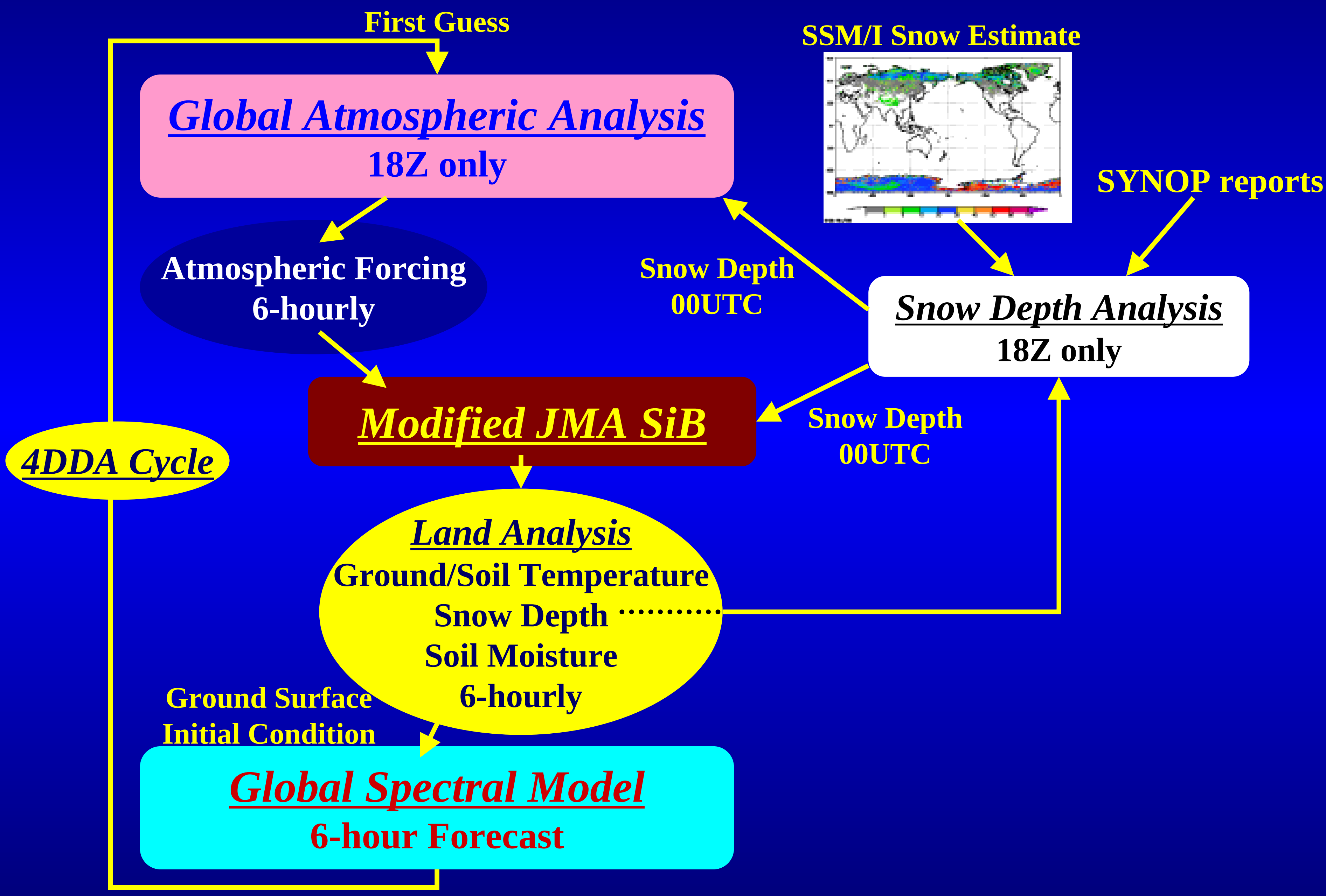
Precipitation difference from CMAP

with SSM/I | **without SSM/I**



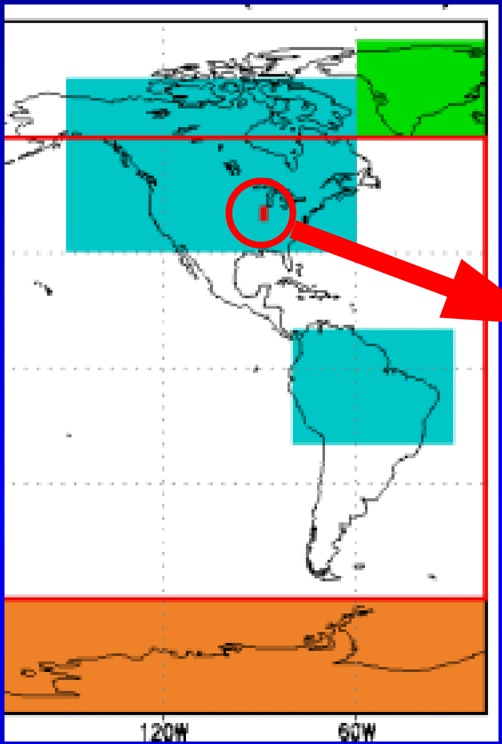
CMAP:
CPC Merged Analysis of Precipitation

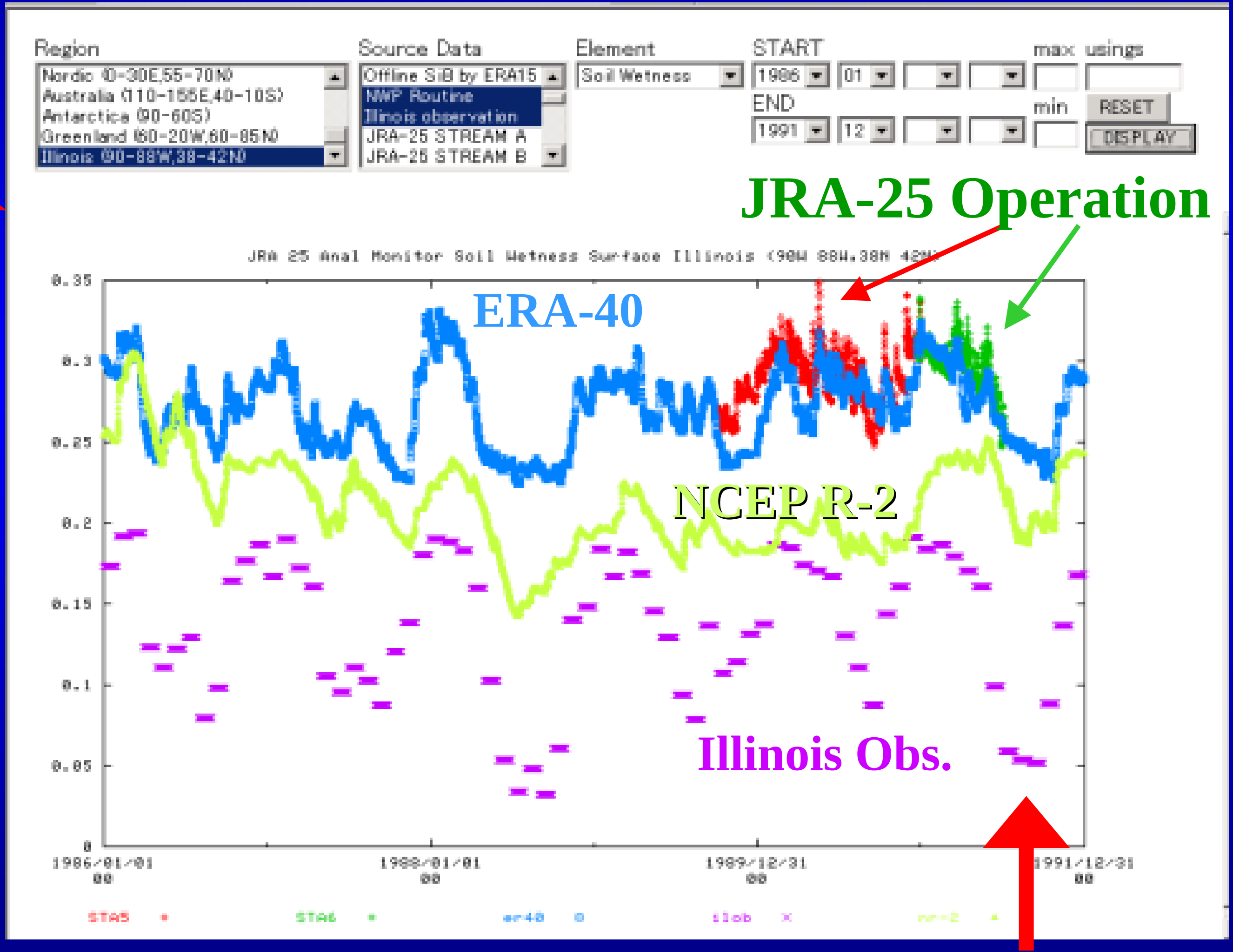
JMA SiB for JRA-25



Product Detail

Soil Wetness in Illinois (Root Depth)





Appendix 2

- Development of Cloud Ice Fall Scheme
- Improvement of Low-level Cloud

2. Cloud Ice Fall Scheme based on Analytical Solution

2-1. Difficulty on Treatment of Cloud Ice Fall

Equation of continuity

$$\left(\frac{\partial q_{ice}}{\partial t}\right)_{icefall} = \frac{1}{\rho}\frac{\partial}{\partial z}(v_{ice}\rho q_{ice})$$

$$\left(\frac{\partial q_{ice}}{\partial t}\right)_{icefall} = \frac{R_f}{\rho \Delta z} - q_{ice}\frac{v_{ice}}{\Delta z}$$

q_{ice}

ρ

R_f

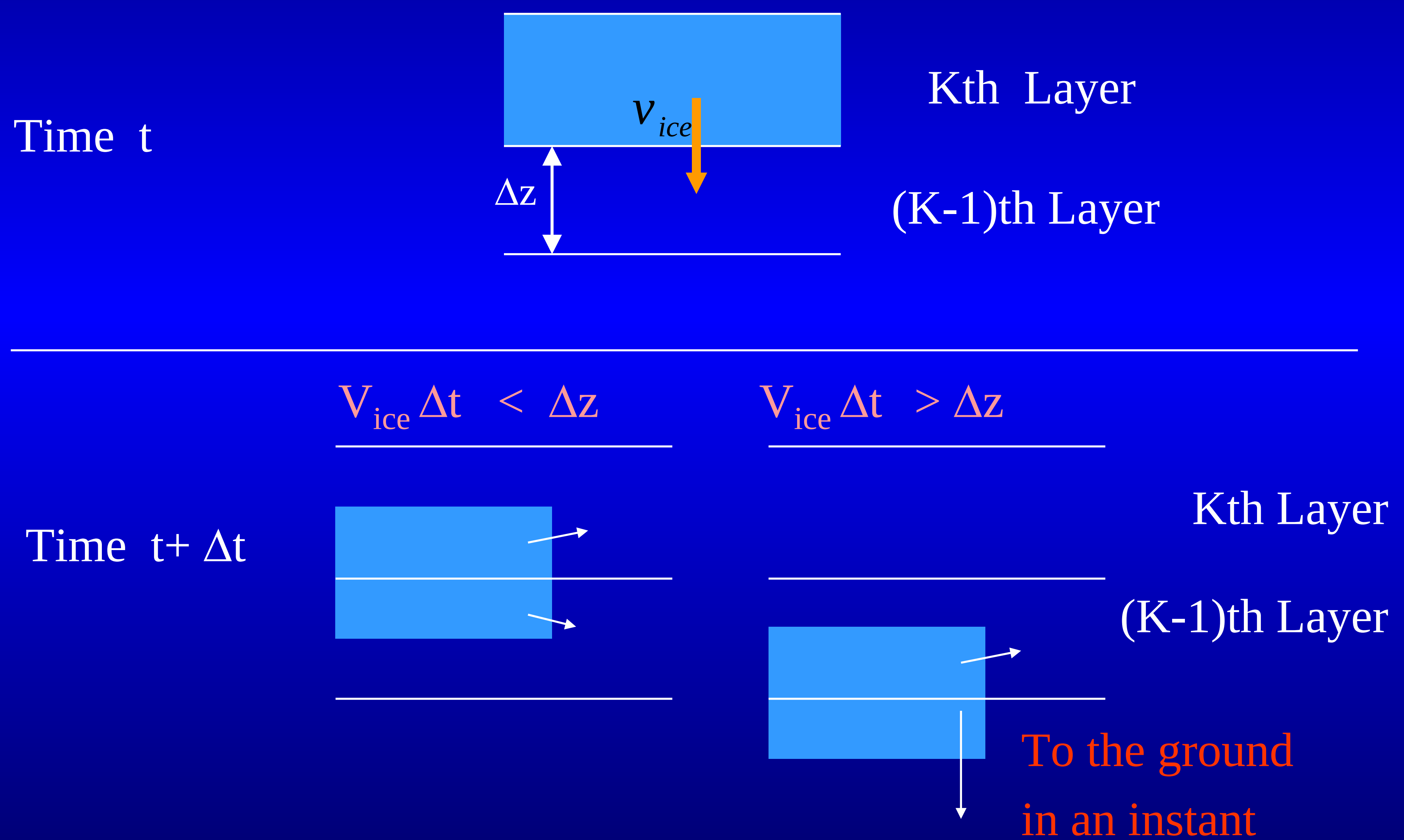
$v_{ice}\Delta t > \Delta z$ ⟶ Difficulty!

Classical measures in GCMs

Ignore R_f : inadequate CI & excessive Rain ×

Upper limit on v_{ice} : excessive CI & inadequate Rain ×

2-2. Current Cloud Ice Fall Scheme

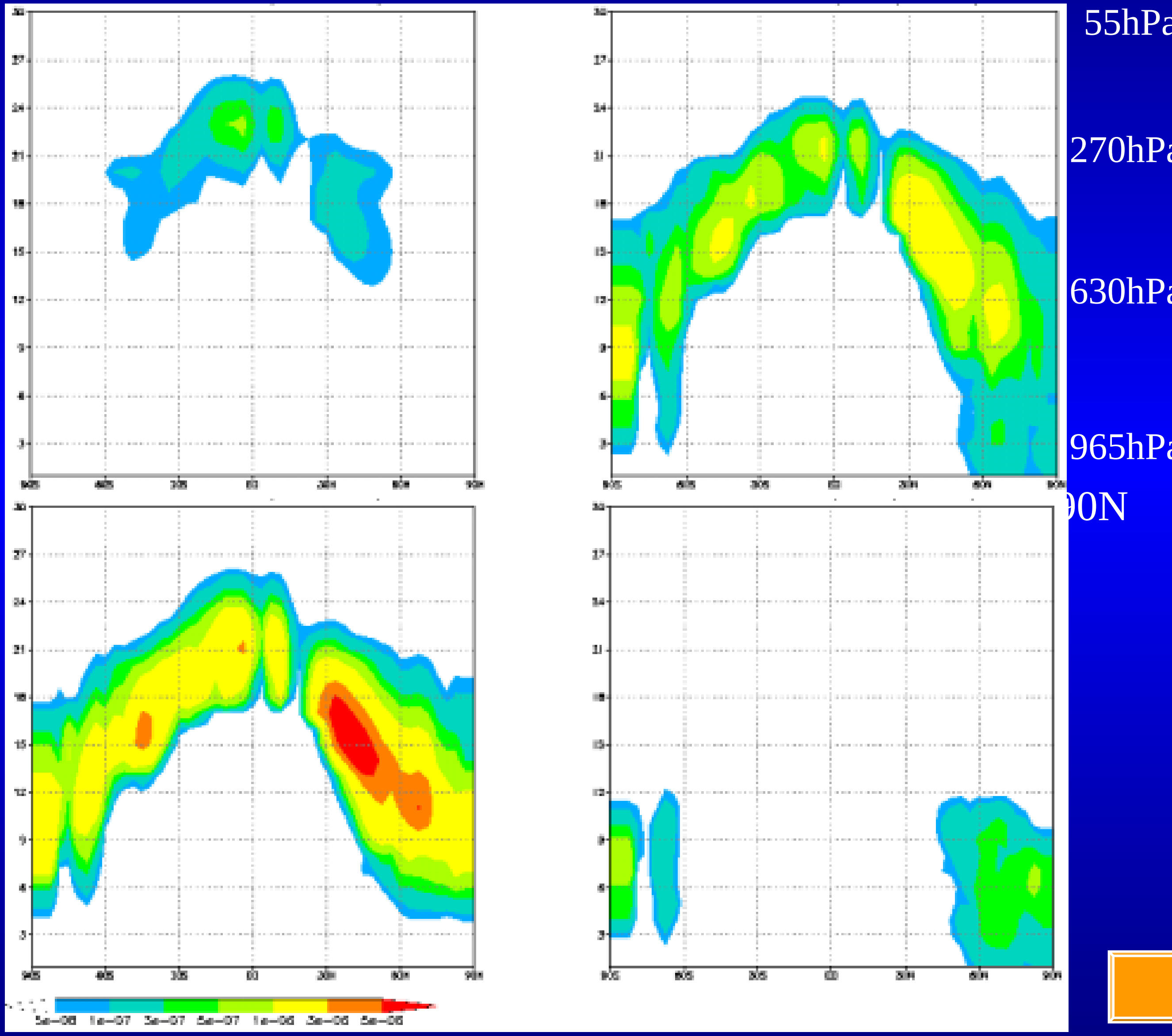


2-3. Problem

Cloud Ice Flux

To (K-1)th layer

To the ground in an instance



Time step ≅ 1500 [s]

Time step = 400 [s]

T63

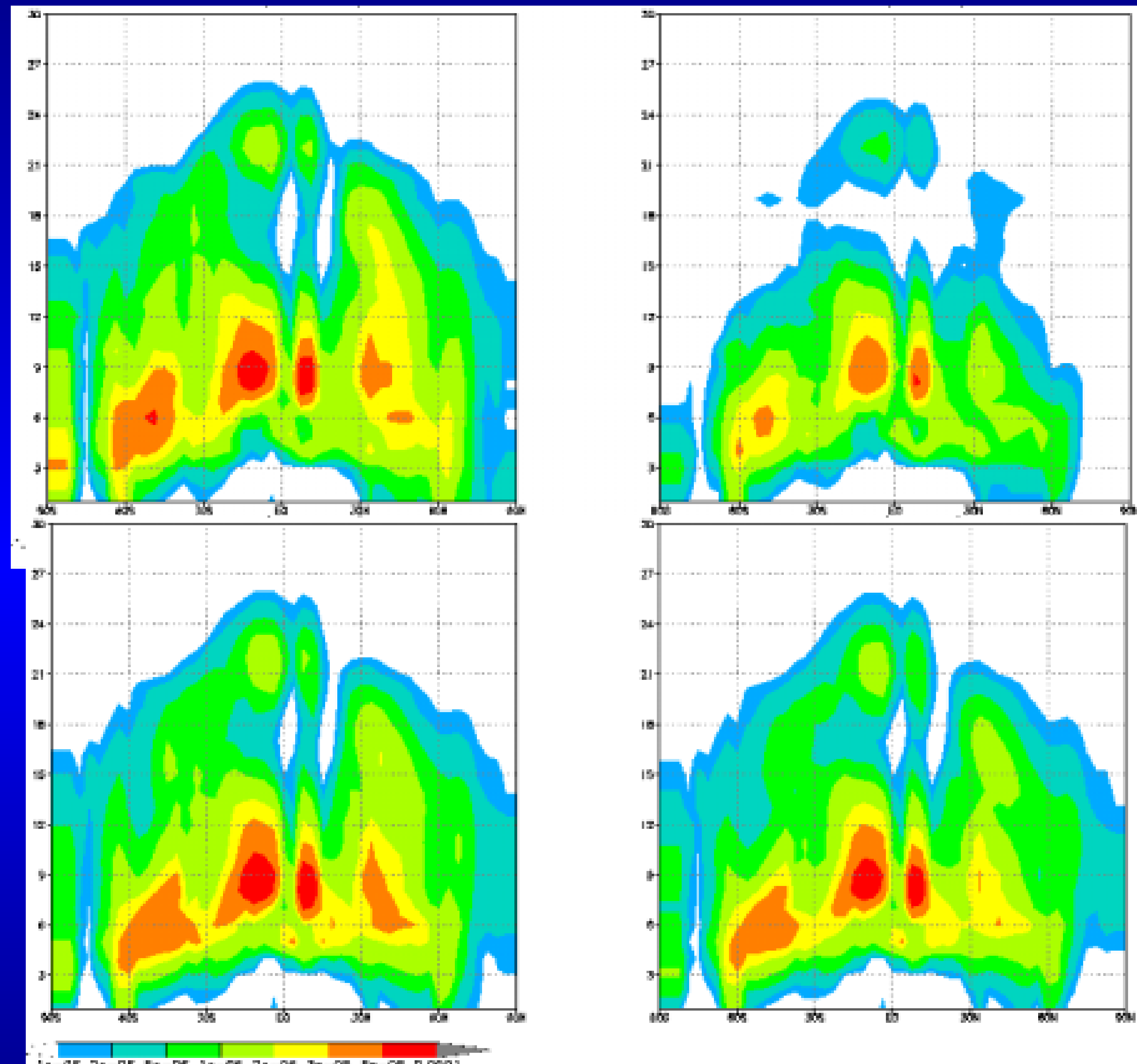
Zonal Mean (120E - 120W), 31Dec1992 Init, Time mean (FT96-216)

CWC

Before fall and conversion | After fall and conversion

Time step ≅ 1500 [s]

Time step =400[s]



T63

Zonal Mean (120E - 120W), 31Dec1992 Init, Time mean (FT96-216)

2-4. Analytical Solution Scheme (Basic Scheme)

Equation of continuity of cloud ice is

By Rotstayn (1997)

$$\left(\frac{\partial q_{ice}}{\partial t}\right)_{icefall} = C - Dq_{ice}$$

Where

$$C = \frac{R_f}{\rho \Delta z}, \quad D = \frac{v_{ice}}{\Delta z}$$

An Analytical solution of above equation is

$$q(t) = q(0)e^{-Dt} + \frac{C}{D}(1 - e^{-Dt})$$

(Assumed R_f, ρ, v_{ice} are constant)

That is,

$$q(t+\Delta t) = q(t)e^{-D\Delta t} + \frac{C}{D}(1 - e^{-D\Delta t})$$

$$q(t+\Delta t) - q(t) = C - Dq(t)$$

Analytical Solution Scheme (distribution of particle diameter)

CIC is divided into 2 parts

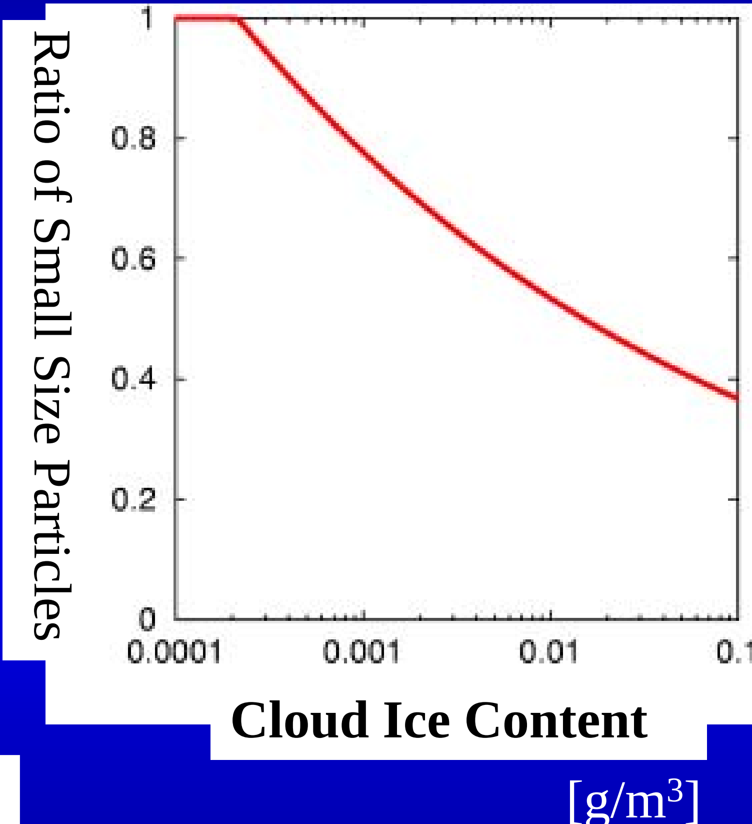
(McFarquhar and Heymsfield 1997)

CI size < 100μm :

fall at a speed of v_{ice}

CI size > 100μm:

to the ground in an instance



$$\left(\frac{\partial q_{ice}}{\partial t}\right)_{icefall} = \frac{1}{\rho}\frac{\partial}{\partial z}\left(v_{ice}\rho\alpha_{<100}q_{ice}\right) - \frac{\alpha_{>100}q_{ice}}{\Delta t}$$

$$\alpha_{<100}, \alpha_{>100}$$

Analytical Solution Scheme (introduction of cloud ice generation term)

Current Scheme

1st step : Distribute H_2O into q_v and q_{ice} (Sommeria and Deardorff 1977)

2nd step : Calculate cloud ice fall process → Inappropriate!

A. S. scheme (with cloud ice generation term)

Generation rate can be obtained, assuming that constant rate of generation in one Δt gives CWC to be distributed by current scheme at the end of the Δt.

Incorporate it into A. S., and Calculate generation and falling simultaneously

$$\left(\frac{\partial q_{ice}}{\partial t}\right)_{icefall} = C_{gnrt} + \frac{1}{\rho}\frac{\partial}{\partial z}(v_{ice}\rho\alpha_{<100}q_{ice}) - \frac{\alpha_{>100}q_{ice}}{\Delta t}$$

$$C_{gnrt} = \frac{q_c^{*}(t+\Delta t) - q_c(t)}{\Delta t}$$

: Cloud Water Generation Rate [kg/kg.s]

Analytical Solution Scheme (Final Form)

$$q(t+\Delta t) = q(t)e^{-D\Delta t} + \frac{C}{D}(1 - e^{-D\Delta t})$$

$$C = \frac{R_f}{\rho \Delta z} + C_{gnrt}$$

$$D = \frac{\alpha_{<100} v_{ice}}{\Delta z} + \frac{\alpha_{>100}}{\Delta t}$$

Others

- $$v_{ice} = 3.29(\rho \frac{\alpha_{<100} q_{ice}}{C_L})^{0.16}$$ (Heymsfield and Donner 1990)

  C_L : Cloudiness

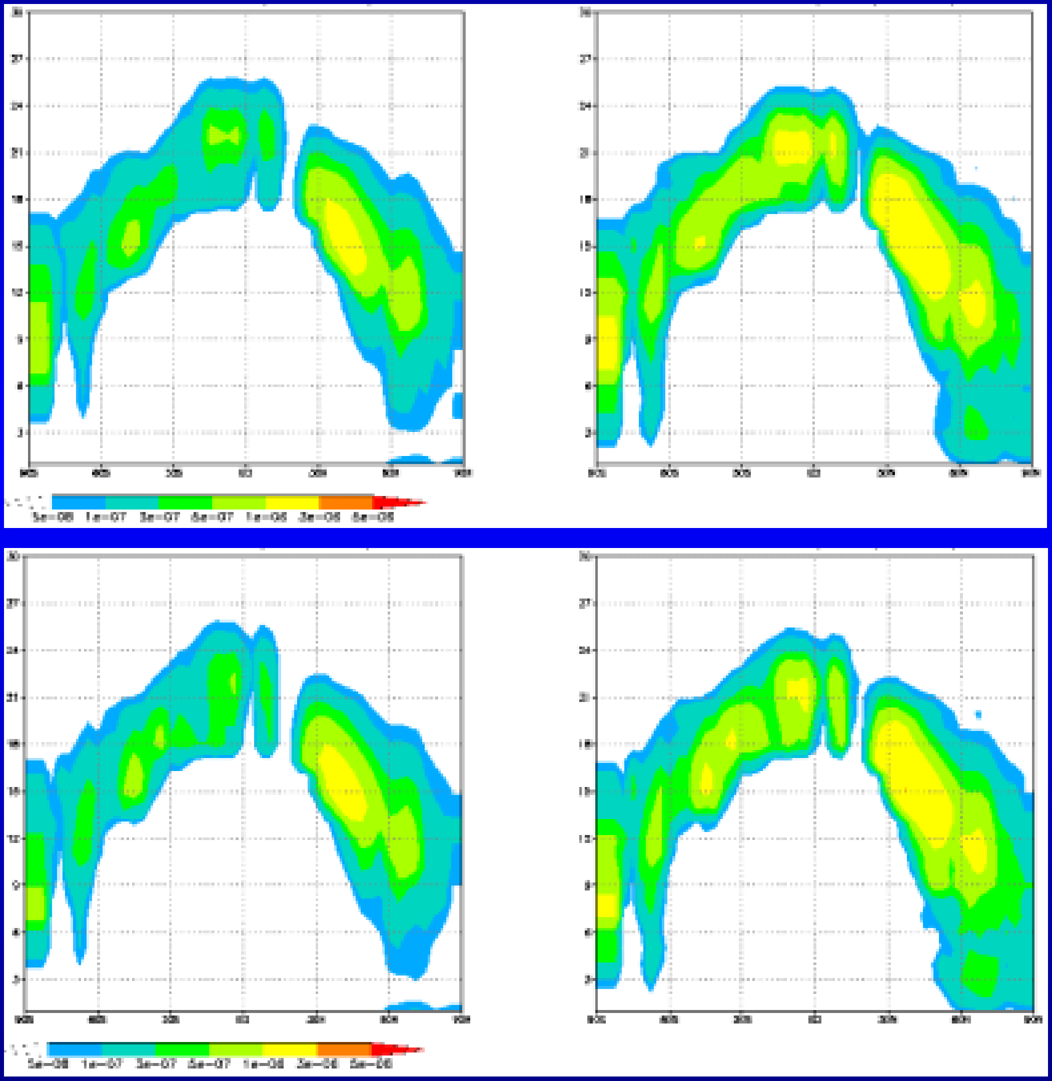
- This scheme is adapted to liquid cloud water too.

2-5. Result (Cloud Ice Flux)

To (K-1)th layer To the ground in an instance

Δt ≅ 1500 [s]

Δt = 400 [s]



T63

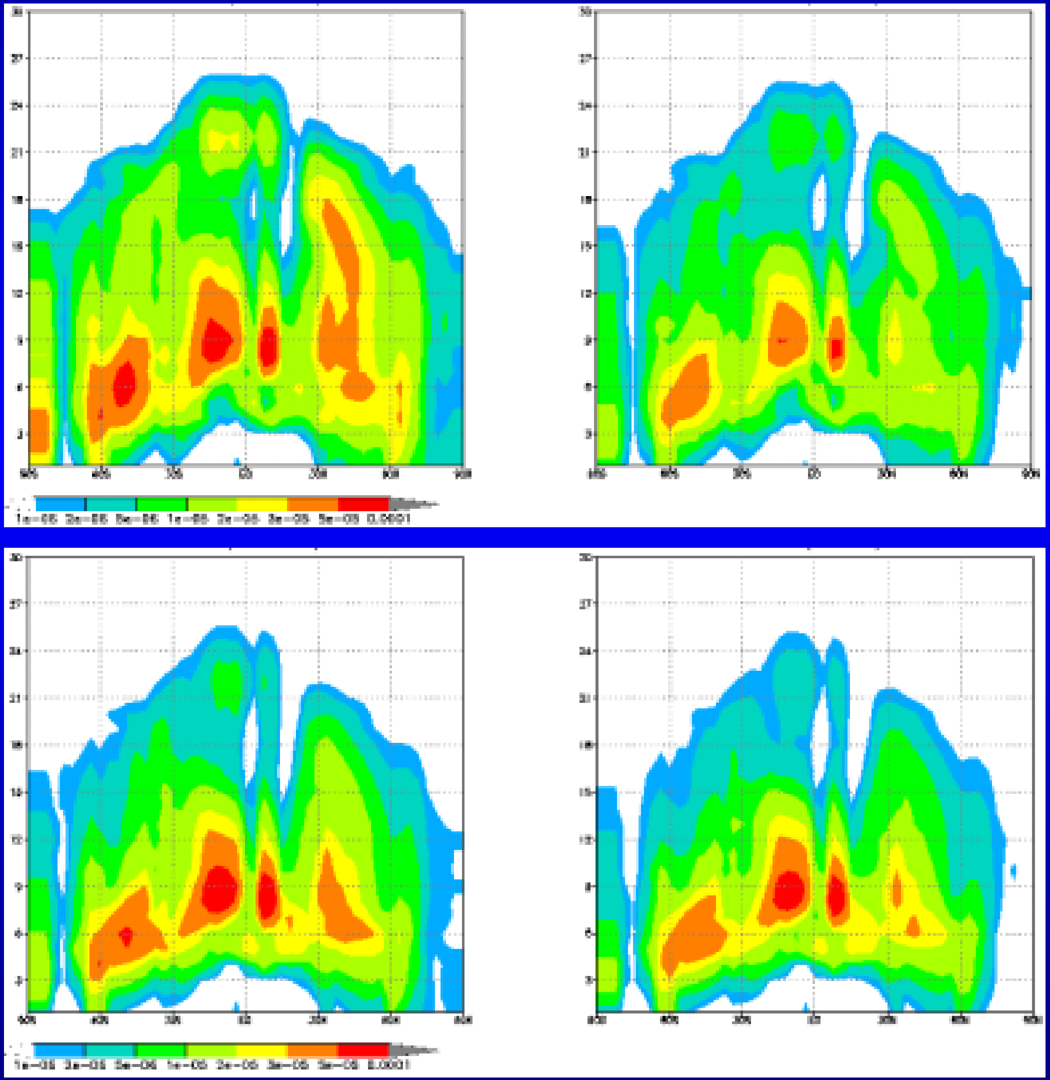
Zonal Mean (120E - 120W), 31Dec1992 Init, Time mean (FT96-216)

Result (CWC)

Before fall and conversion | After fall and conversion

Δt ≅ 1500 [s]

Δt = 400 [s]



T63

Zonal Mean (120E - 120W), 31Dec1992 Init, Time mean (FT96-216)

2-6. Summary

- Mitigate time step dependency on cloud ice fall flux
- Logically appropriate formulation
- Reduce a bias on Radiation a little

3. Improvement of Low-level Cloud

$$C_L' = \frac{z}{10 l_0} C_L \qquad (z \le 10 l_0)$$

$$= C_L \qquad (z > 10 l_0)$$

C_L : Cloud Amount

z : height [m]

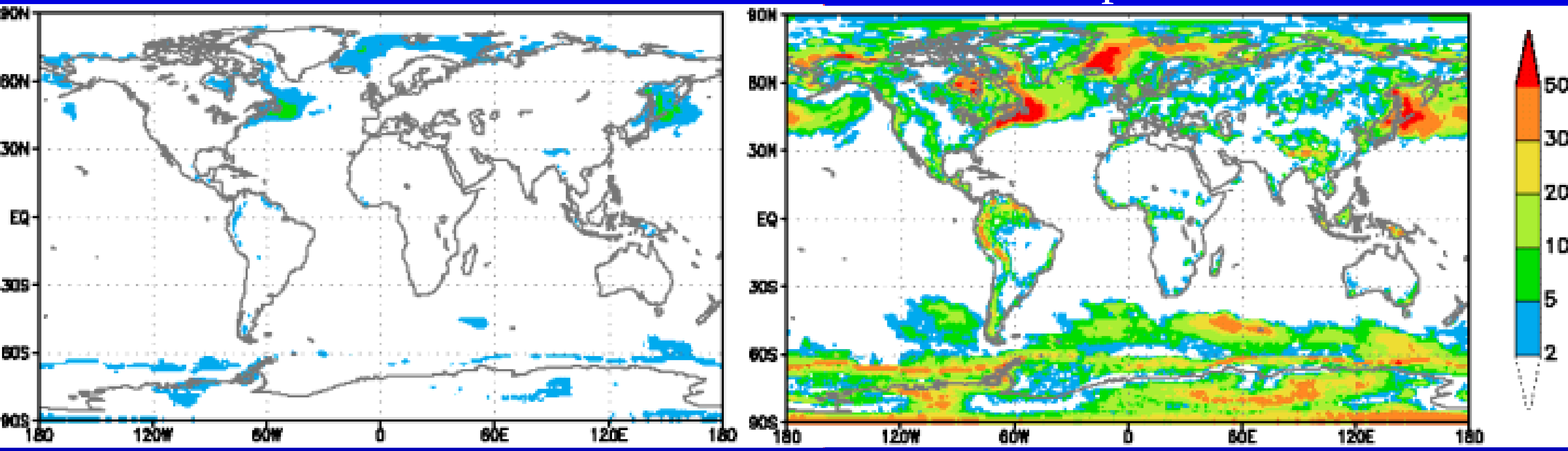
l_0 : maximum mixing length [m]

→ Removed

3.1 Cloudiness of the lowest cloud of the GSM

July

Present After Improvement



Monthly mean of the simulation from the initial condition on 30 June 1992 with T106

3.2 Investigation on Fog Occurrence

Experimental relationship between visibility and cloud water

(Kunkel 1984)

$$VIS = -\frac{\ln(0.02)}{\beta}$$

VIS : model derived visibility [km]

$$\beta = 144.7(\rho l)^{0.88}$$

λ : cloud water (lowest model level) [g/kg]

ρ : atmospheric density [kg/m^3]

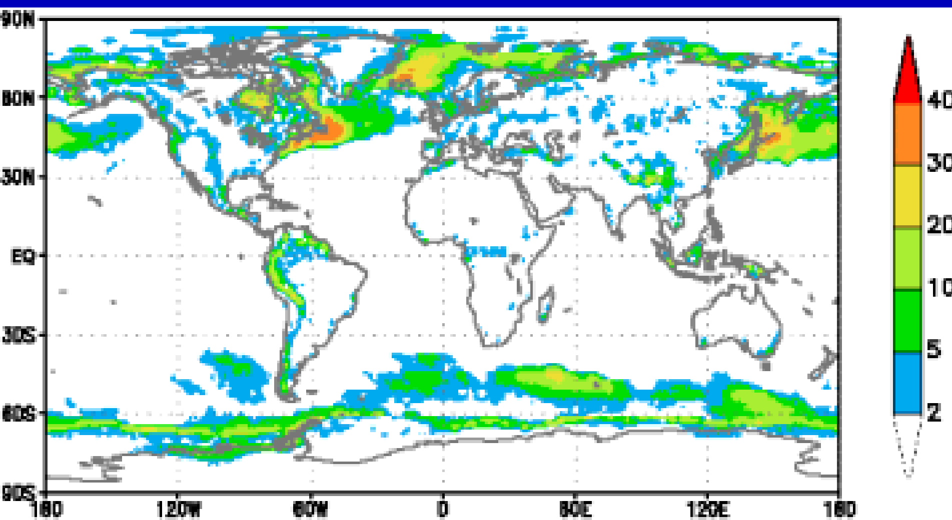
→ Cloud water more than 0.016[g/kg] almost corresponds to the visibility less than 1[km]

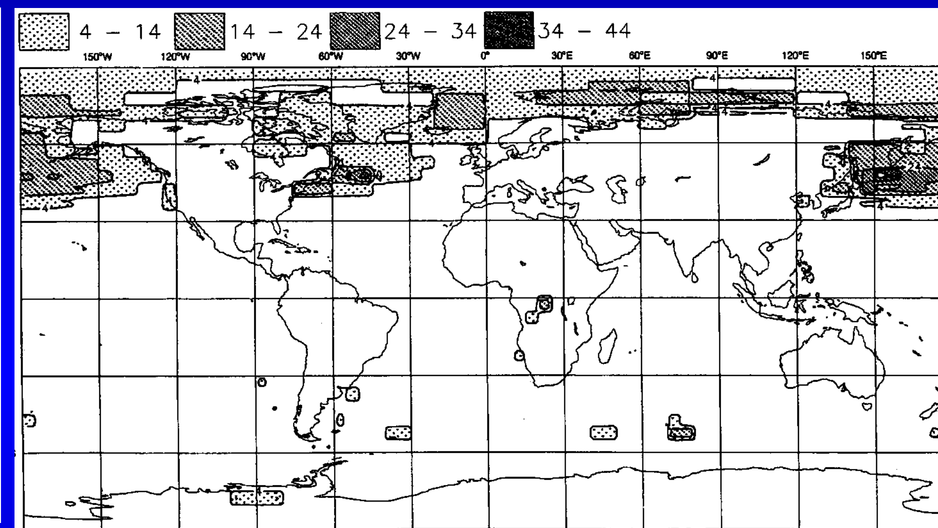
For the comparison with OBS, frequency of fog occurrence in the model is multiplied by a factor of 1/2 (Teixeira 1999)

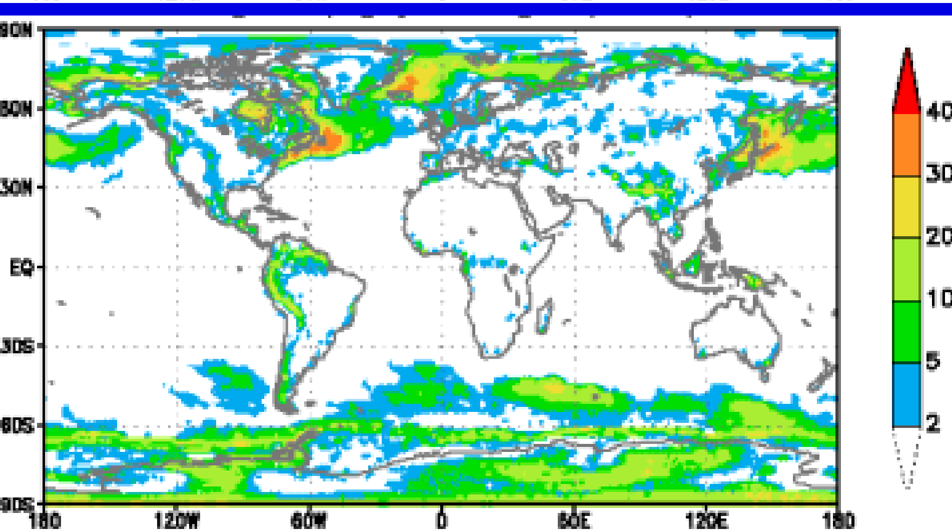
Fog Occurrence (NH-Summer)

GSM (June)

Climatological OBS (June-August)
(Teixeira 1999, Warren et al. 1986,1988)





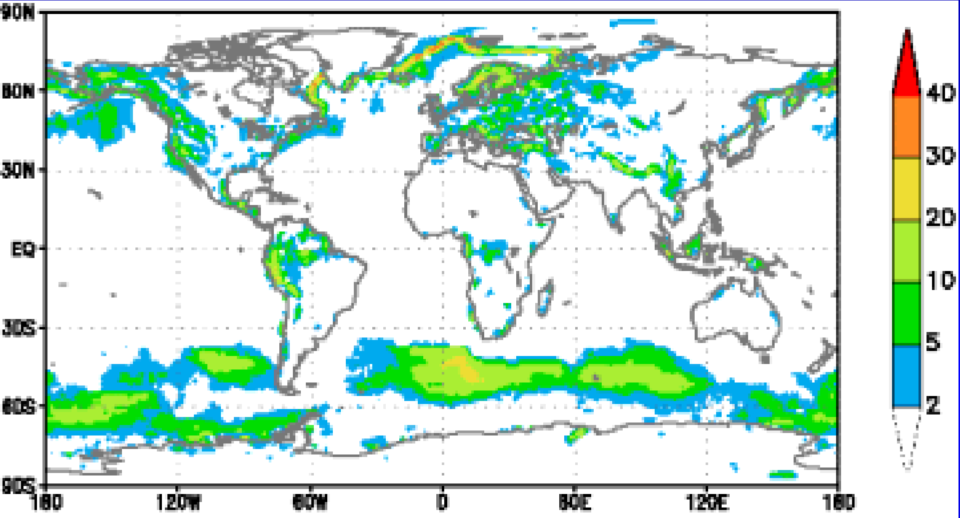


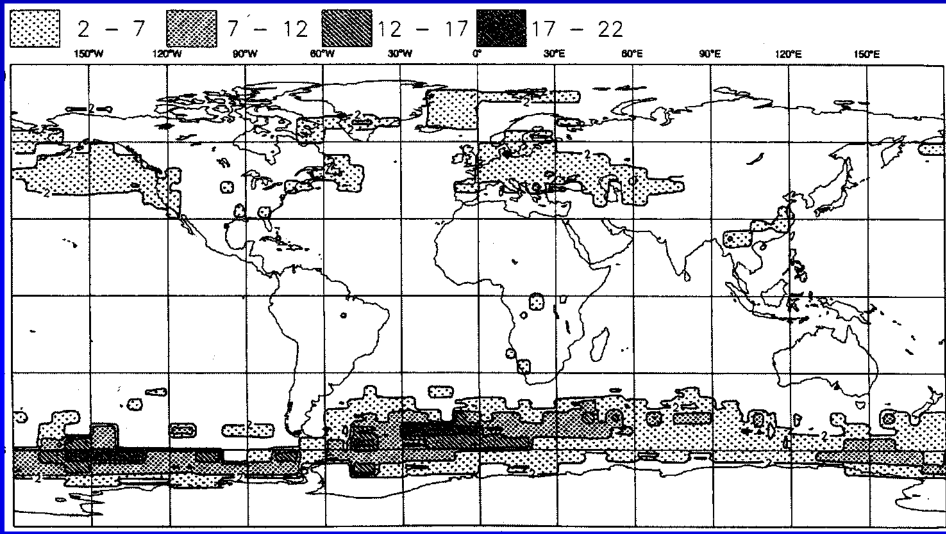
- 千島列島付近
- ニューファンドランド島付近
- アイスランド北部
- 北極海ユーラシア沿岸
- ロッキー、アンデス
- 南半球中高緯度
- 南極海海氷上

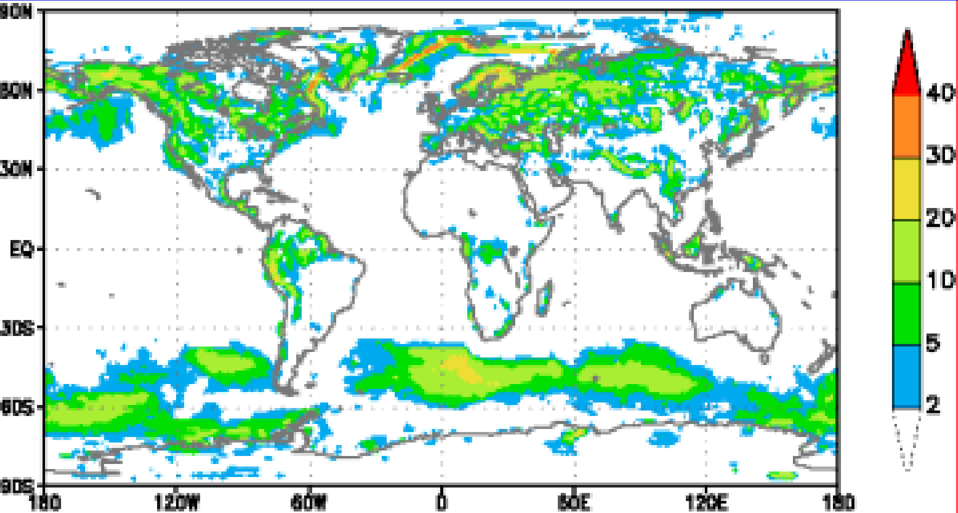
Fog Occurrence (NH-Winter)

GSM (Jan)

Climatological OBS (Dec-Feb)
(Teixeira 1999, Warren et al. 1986,1988)



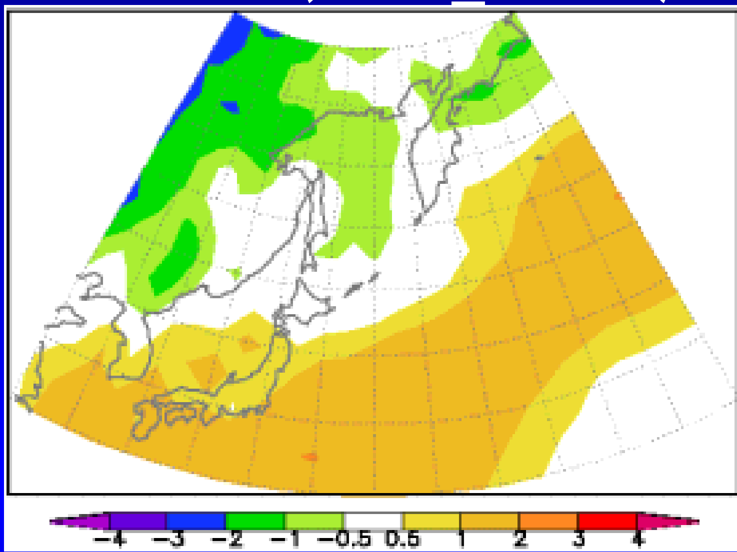




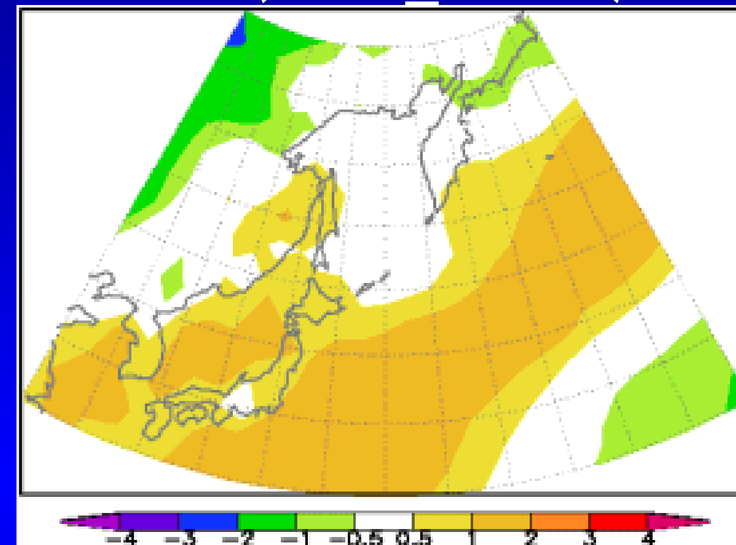
- 南半球中高緯度
- ニューファンドランド島付近
- グリーンランド東岸沖
- 北東太平洋
- ヨーロッパ大陸上
- ロッキー、アンデス

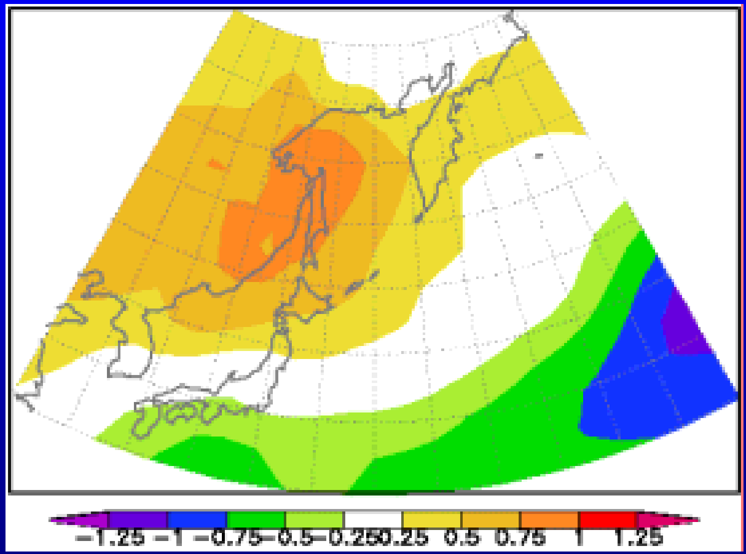
Effect on Okhotskoe High　　Psea

Bias (GSM_V0305)



Bias (GSM_V0407)





V0407ーV0305

データ　：　ハインドキャスト

10年、各年5メンバー

（佐藤さん、伊藤さん）

基準　：　ERA15

3-3. Summary for Improvement of Fog

- Improved low-cloud scheme makes the simulated fog occurrence comparable to the observed one.
- Improved low-cloud scheme results in better simulation of Okhotskoe High.