Role of Equatorial Kelvin Waves, Organized Convections, and Cumulonimbus Clouds in the Tropical Tropopause Layer

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Introduction

- **Equatorial Kelvin waves affect TTL (Obs.)**

  Cold-point-temperature modulation (Tsuda et al., JGR, 1994)
  Ozone transport (Fujiwara et al., JGR, 1998)
  Cirrus clouds modulation (Boehm and Verlinde, GRL, 2000)
  Water vapor control ("dehydration pump") (Fujiwara et al., GRL, 2001)
  Turbulence generation (Fujiwara et al., GRL, 2003)

- **Kelvin waves are dominant around the tropical tropopause**

  (Madden and Julian, JAS, 1972; Parker, QJRMS, 1973)

- There is a strong connection between
  Organized Cumulus Clouds and the
  Large-scale Tropopause-level Disturbances

- **→ Two Global Model Experiments**

Experiments

(1) CCSR/NIES AGCM (Fujiwara and Takahashi, JGR, 2001)

T42 (~2.8 x 2.8 deg.), 60 vertical layers (550 m spacing in UT-LS)

Realistic Topography and Annual Cycle of SST

Arakawa-Schubert Cumulus Parameterization

Simplified Ozone Photochemistry

Analyzed data: Daily averages, 4 years

(2) NICAM (Nonhydrostatic ICosahedral Atmospheric Model) for the Earth Simulator

(Tomita and Satoh, Fluid Dyn. Res., 2004; Tomita et al., GRL, 2005)

Global cloud-resolving calculations

3.5-km horizontal spacing (in this study), 54 layers

Aqua planet (in this study); SST (Neale and Hoskins, 2000)

Microphysics Parameterization (Grabowski, 1998; Lin et al., 1983)

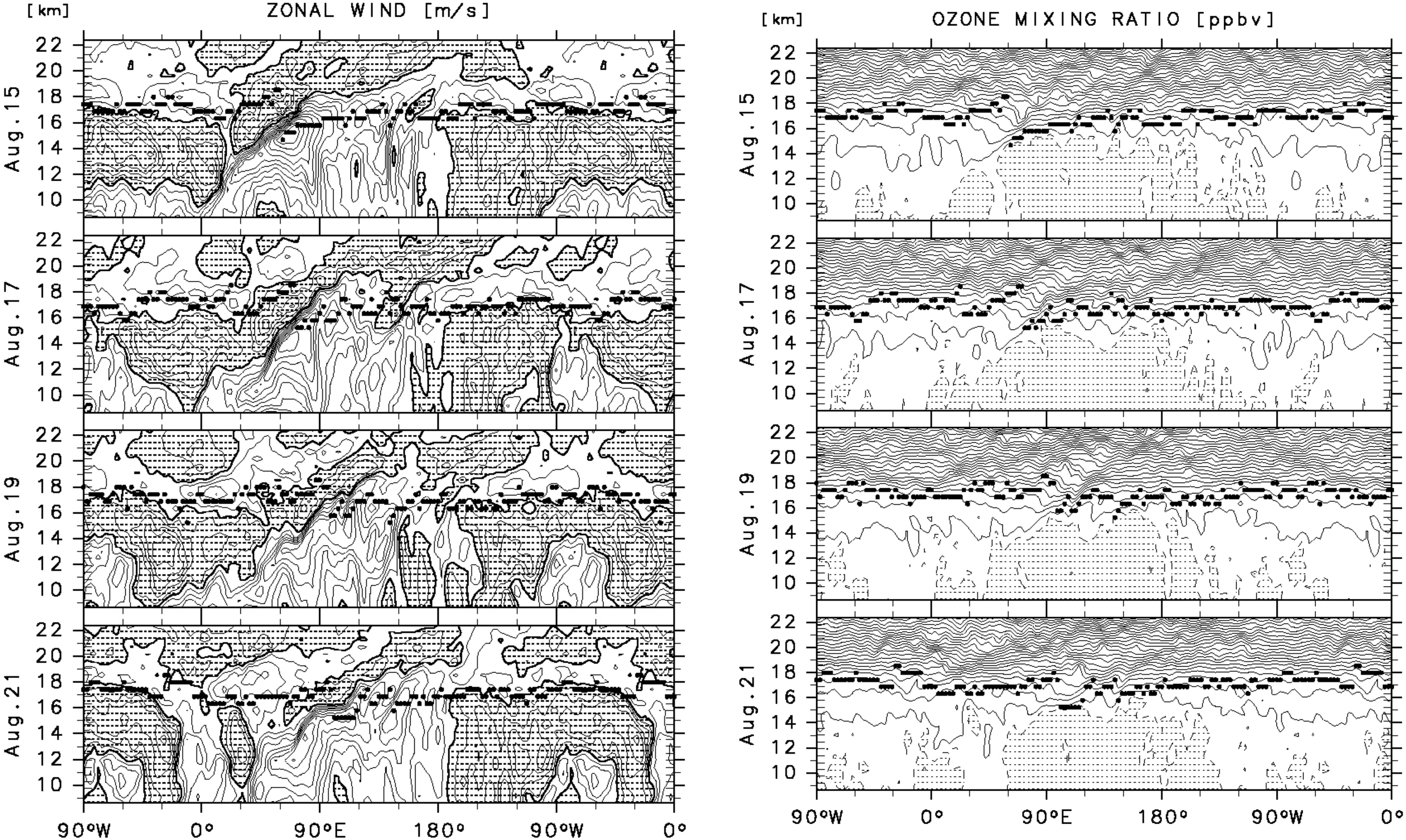
Analyzed data: Snap shot

CCSR/NIES AGCM 1/2

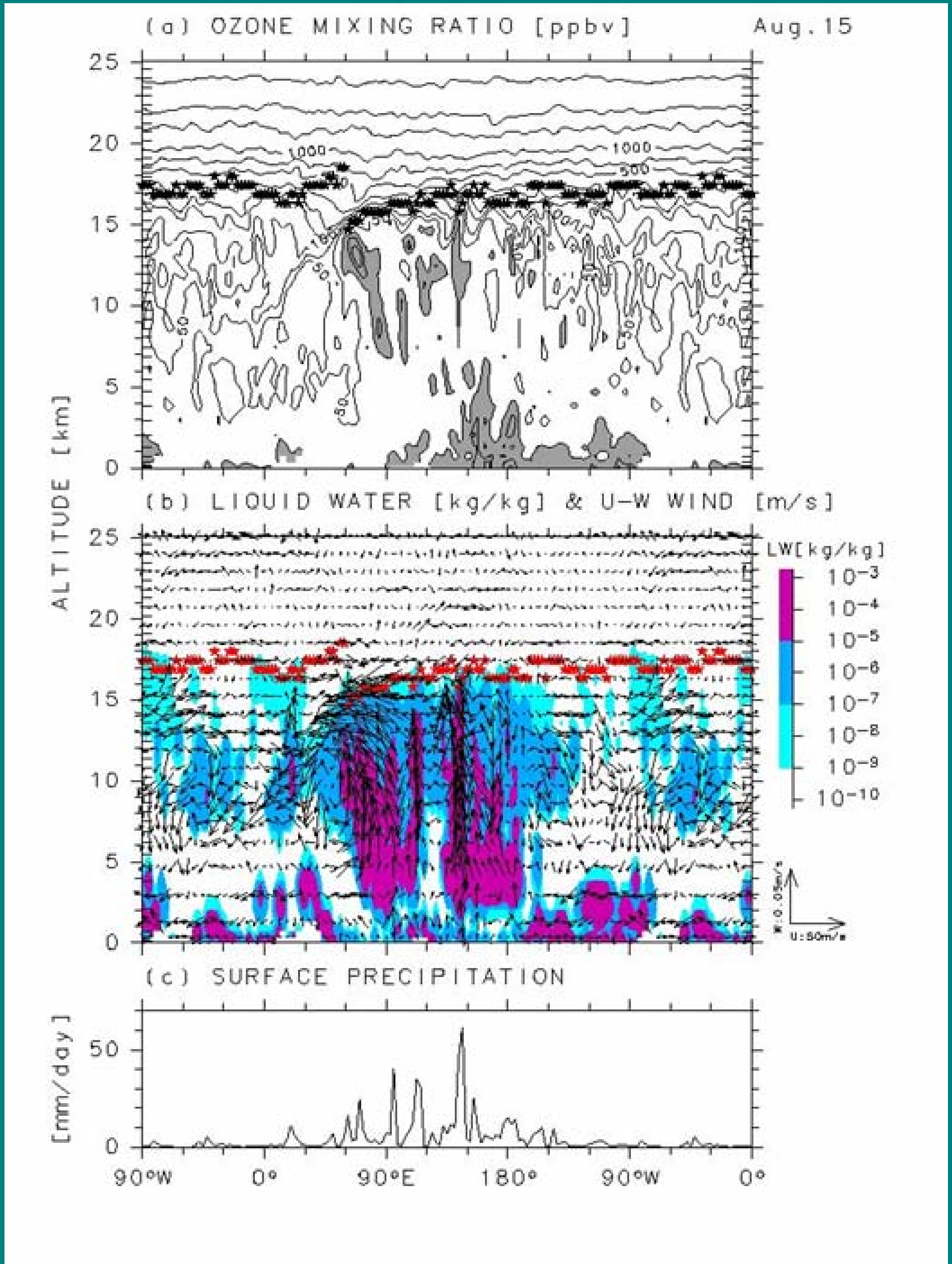
- A case over the Indian Ocean in northern summer :

  Kelvin wave around the tropopause

  coupled with organized convection



Latitude: 1.3953N (equator) [Fujiwara and Takahashi, JGR, 2001]

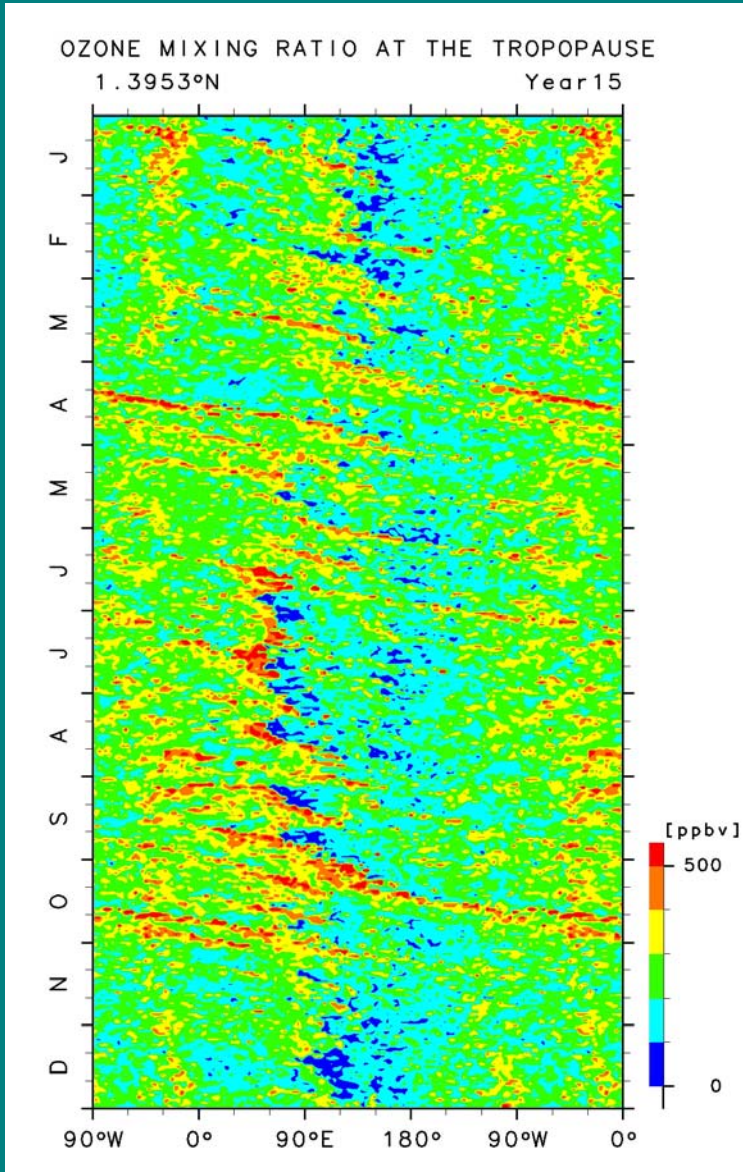


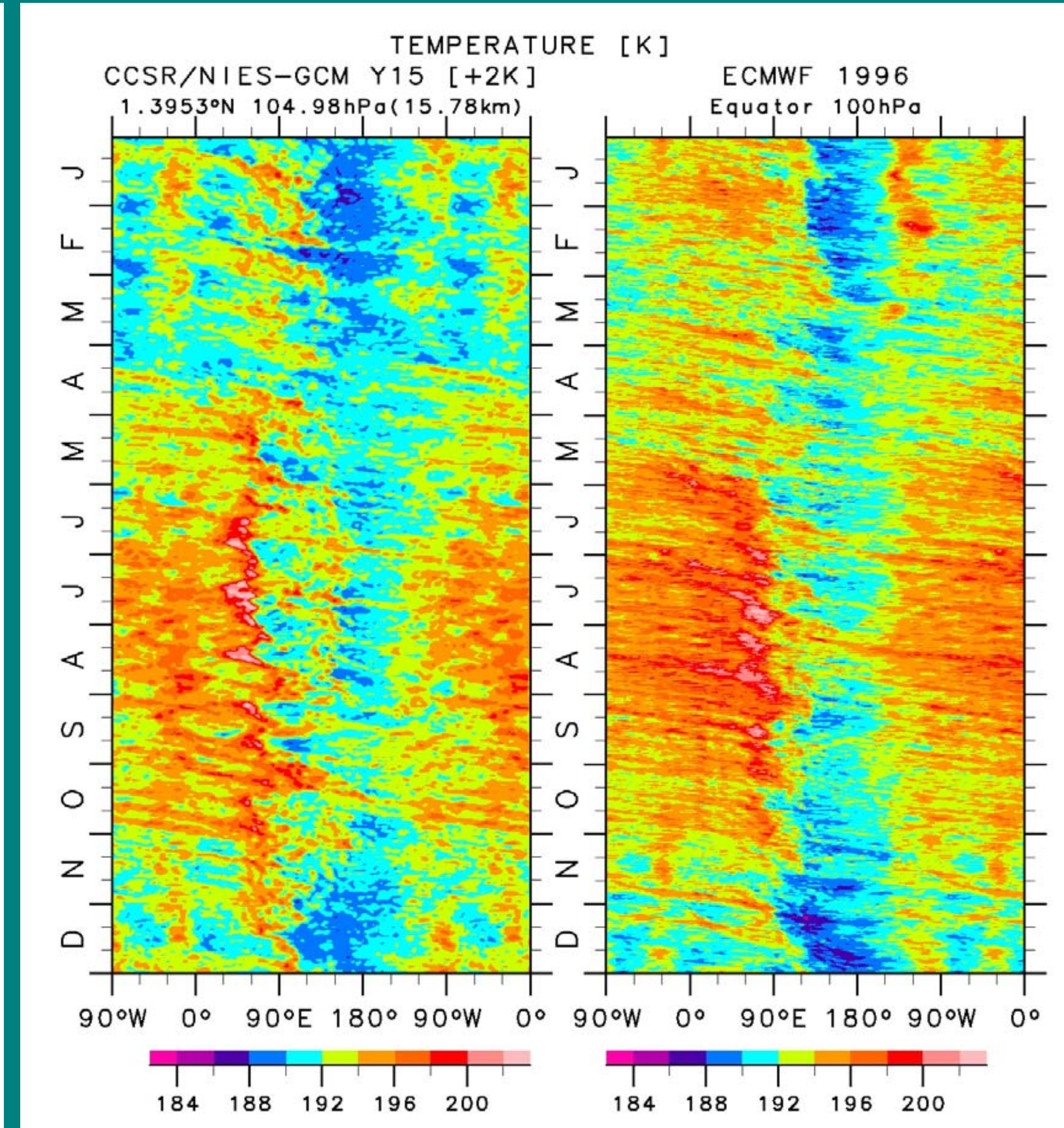
Latitude: 1.3953N

[Fujiwara and Takahashi, 2001]

CCSR/NIES AGCM 2/2

- Seasonal and longitudinal characteristics :
  Large-scale, eastward-moving disturbances are dominant around the tropical tropopause



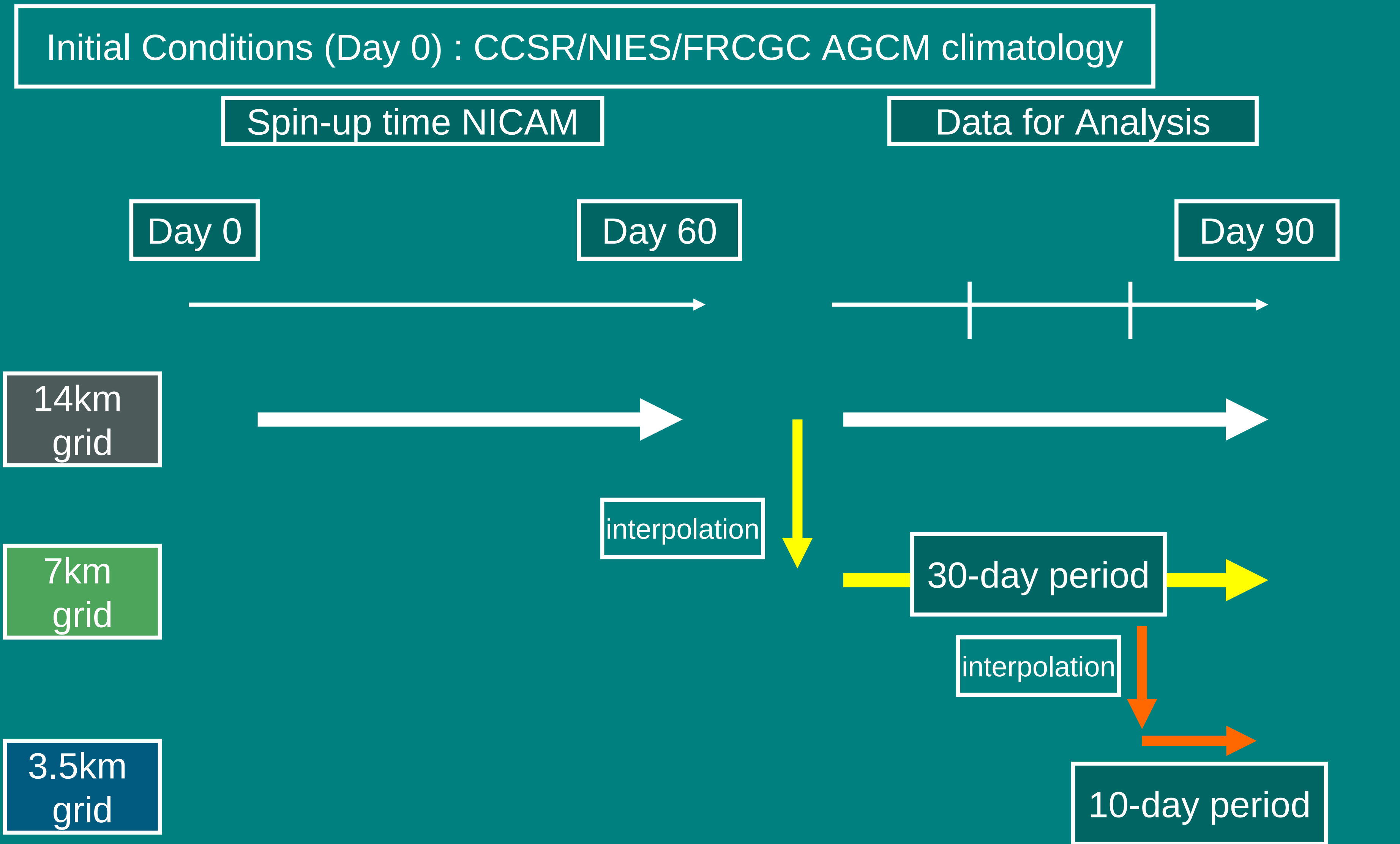


[Fujiwara and Takahashi, 2001]

NICAM 3.5-km Aqua Planet 1/3

- NICAM: Global, non-hydrostatic, cloud-resolving calculations
  (Tomita and Satoh, Fluid Dyn. Res., 2004; Tomita et al., GRL, 2005)
- 3.5-km horizontal spacing; 700-m vertical spacing in TTL
- Aqua planet; SST (Neale and Hoskins, 2000)
- Microphysics Parameterization (Grabowski, 1998; Lin et al., 1983)
- Analyzed data: Snap shot

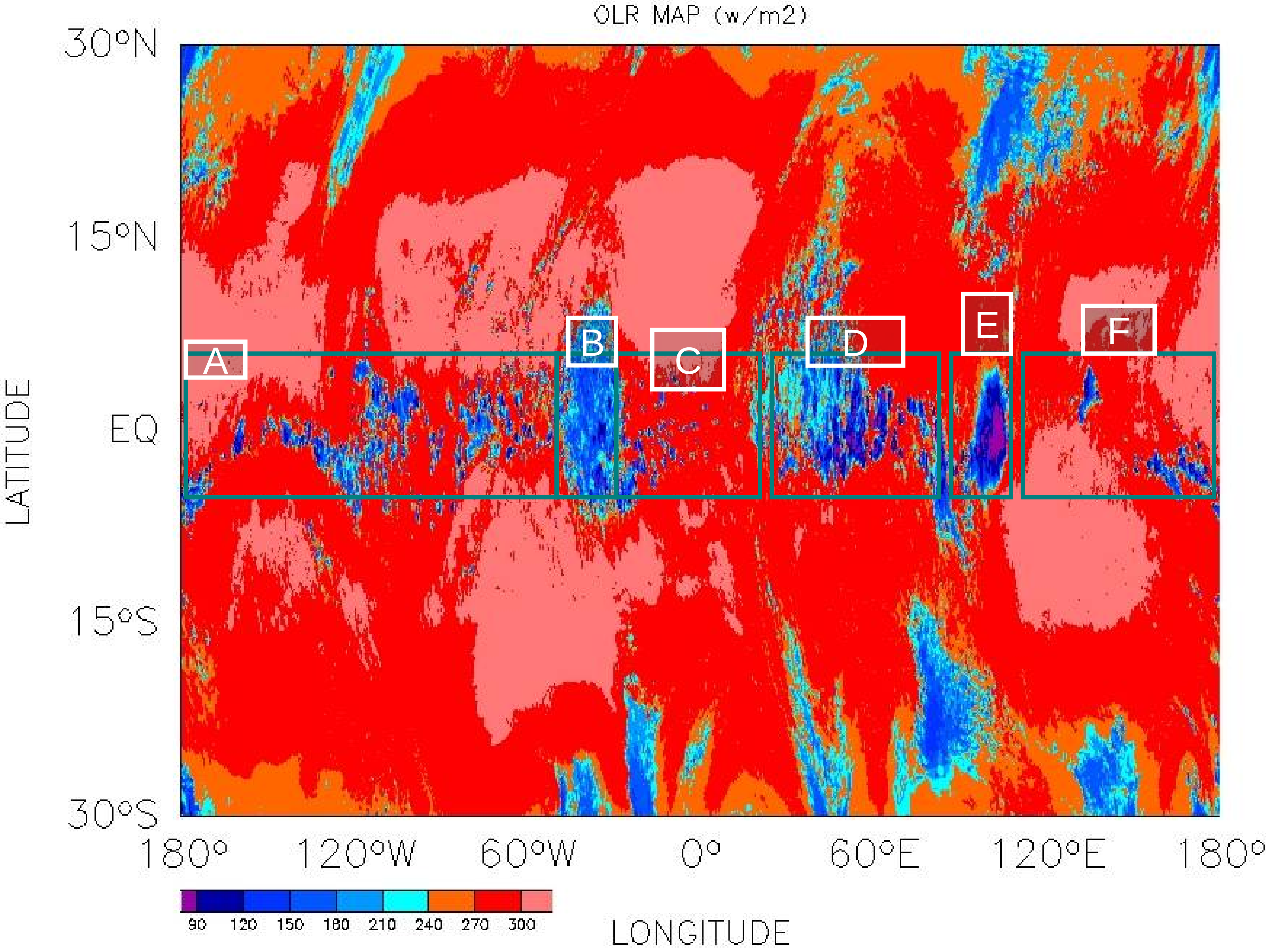
NICAM Aqua-Planet Experiment



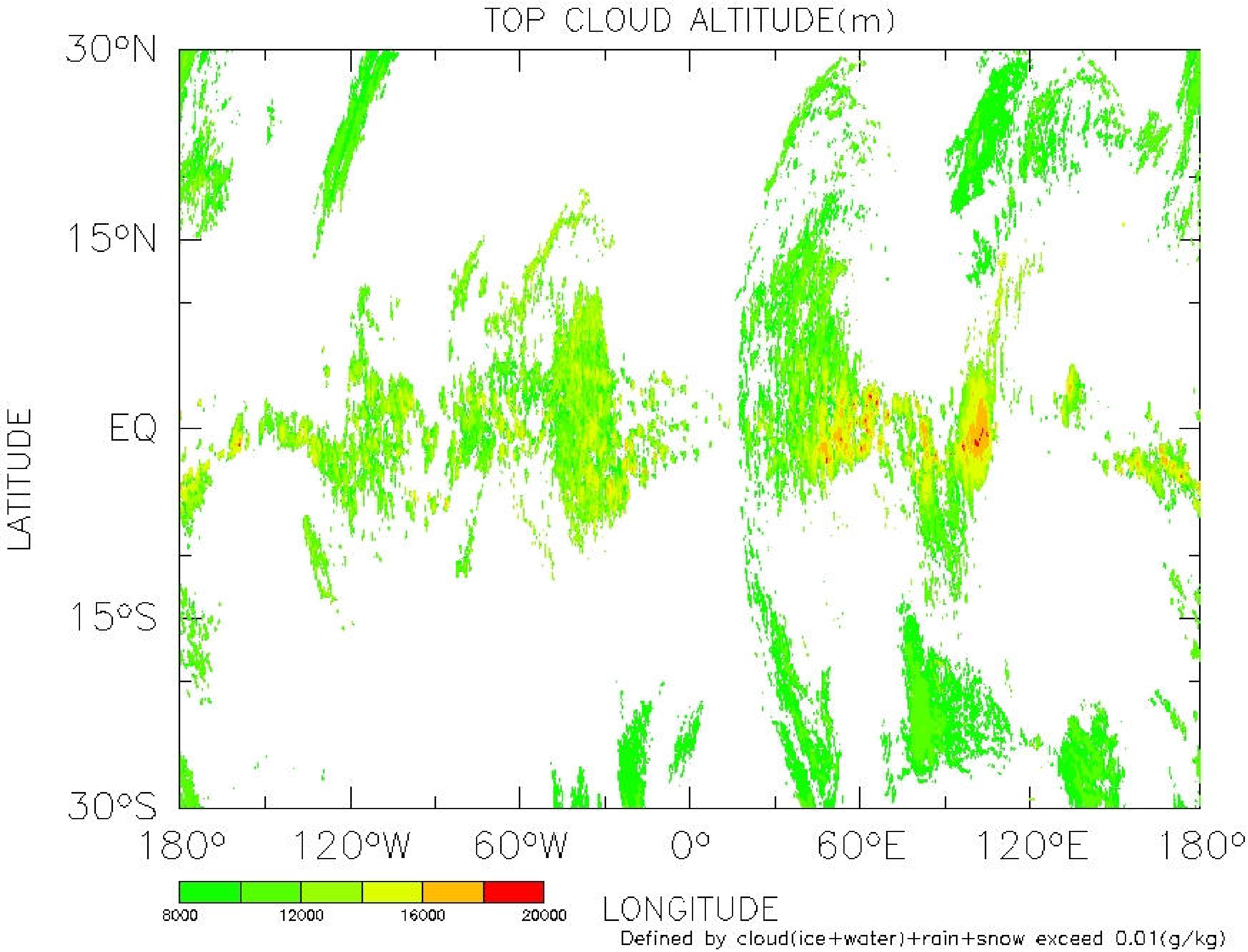
3.5-km data on DAY 85 (snap shot) is analyzed in this presentation

NICAM 3.5-km Aqua Planet 2/3

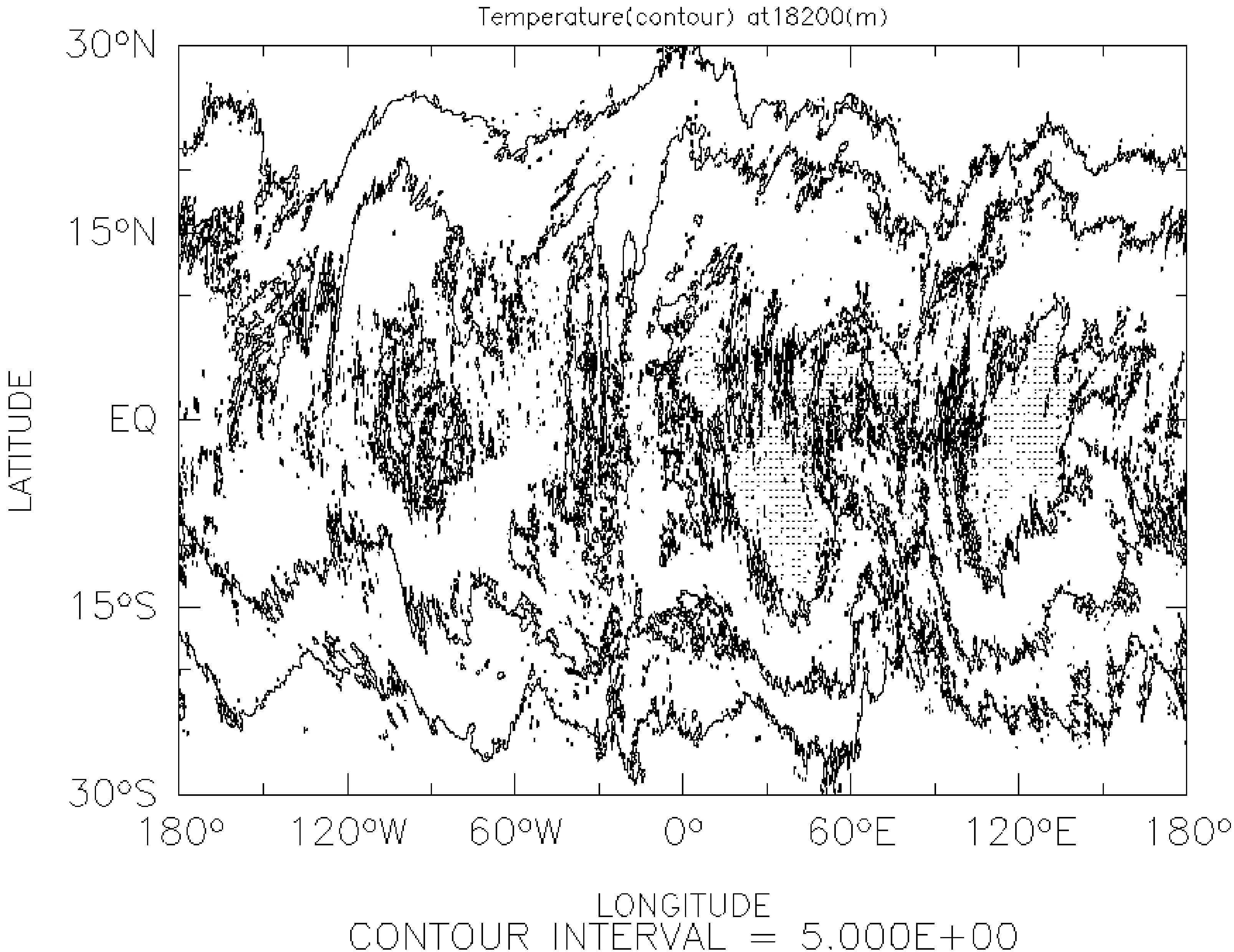
- **Cloud Maps (OLR, total condensate) and Cold-point Tropopause Distribution**

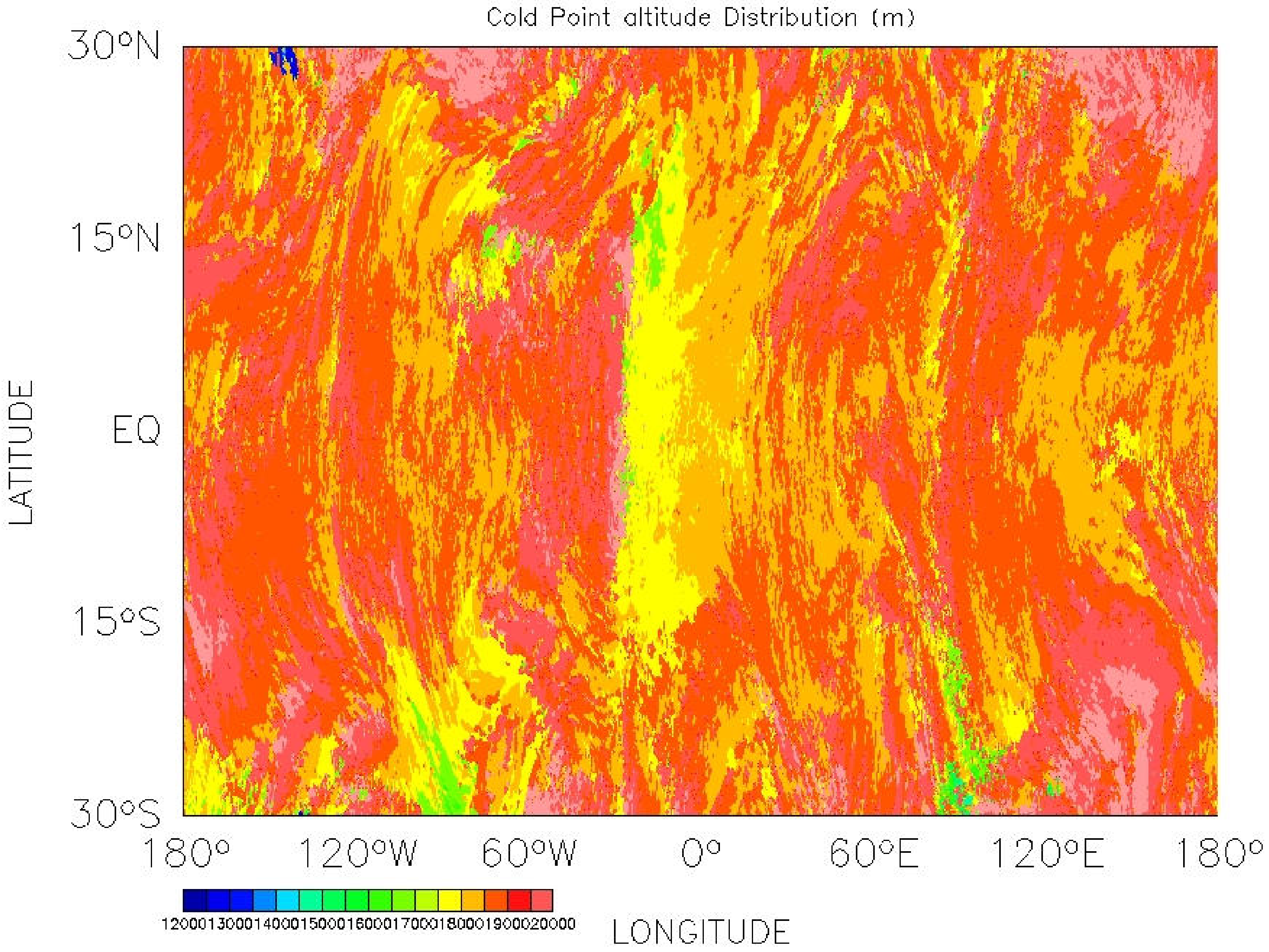


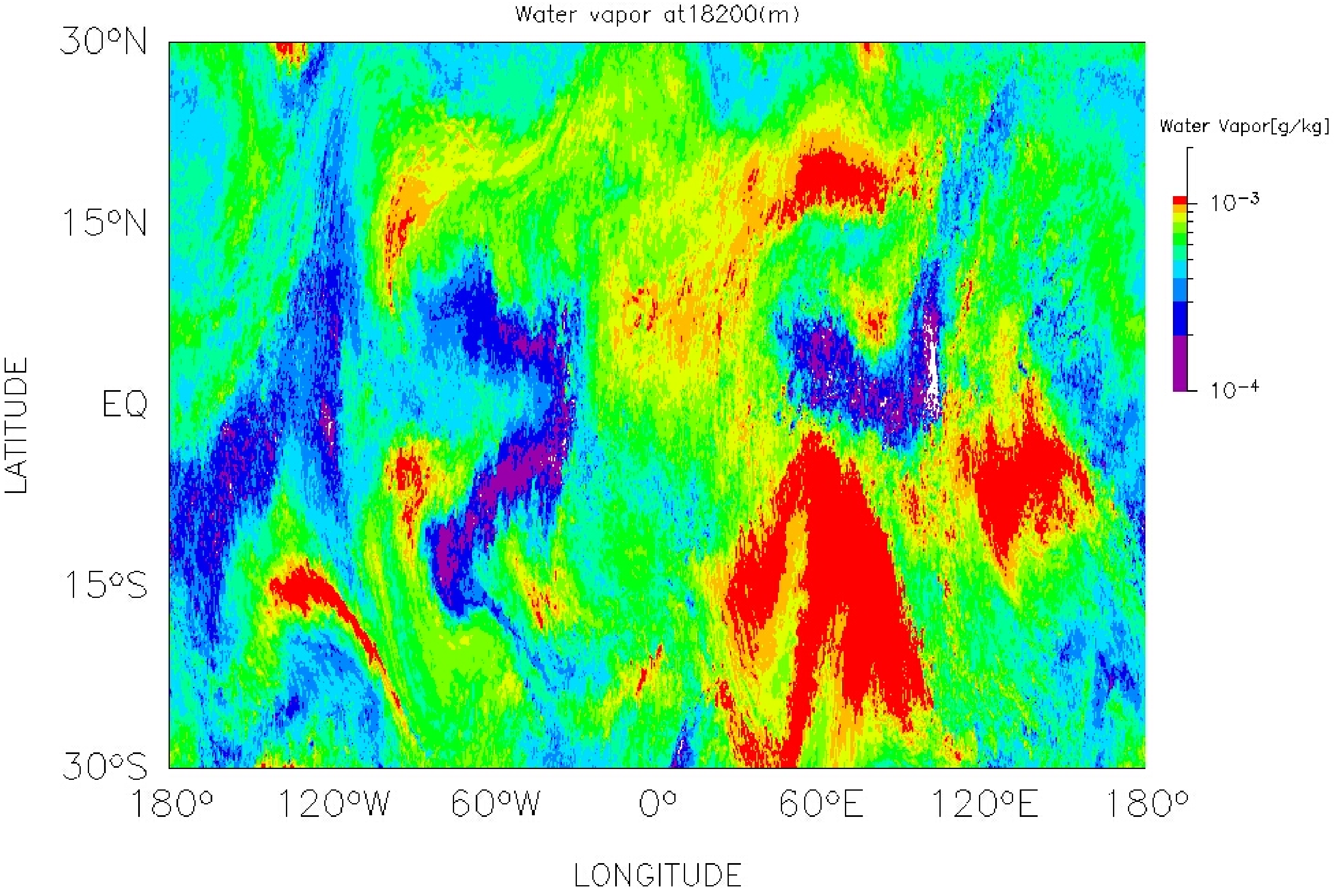
OLR MAP (w/m2)
30°N
15°N
EQ
15°S
30°S
LATITUDE
180°
120°W
60°W
0°
60°E
120°E
180°
LONGITUDE
A
B
C
D
E
F
90
120
150
180
210
240
270
300



TOP CLOUD ALTITUDE(m)
30°N
15°N
EQ
15°S
30°S
LATITUDE
180°
120°W
60°W
0°
60°E
120°E
180°
8000
12000
16000
20000
LONGITUDE
Defined by cloud(ice+water)+rain+snow exceed 0.01(g/kg)


Temperature(contour) at18200(m)
30°N
15°N
EQ
15°S
30°S
LATITUDE
180°
120°W
60°W
0°
60°E
120°E
180°
LONGITUDE
CONTOUR INTERVAL = 5.000E+00


Cold Point altitude Distribution (m)
30°N
15°N
EQ
15°S
30°S
LATITUDE
180°
120°W
60°W
0°
60°E
120°E
180°
12000130001400015000160001700018000190002000
LONGITUDE

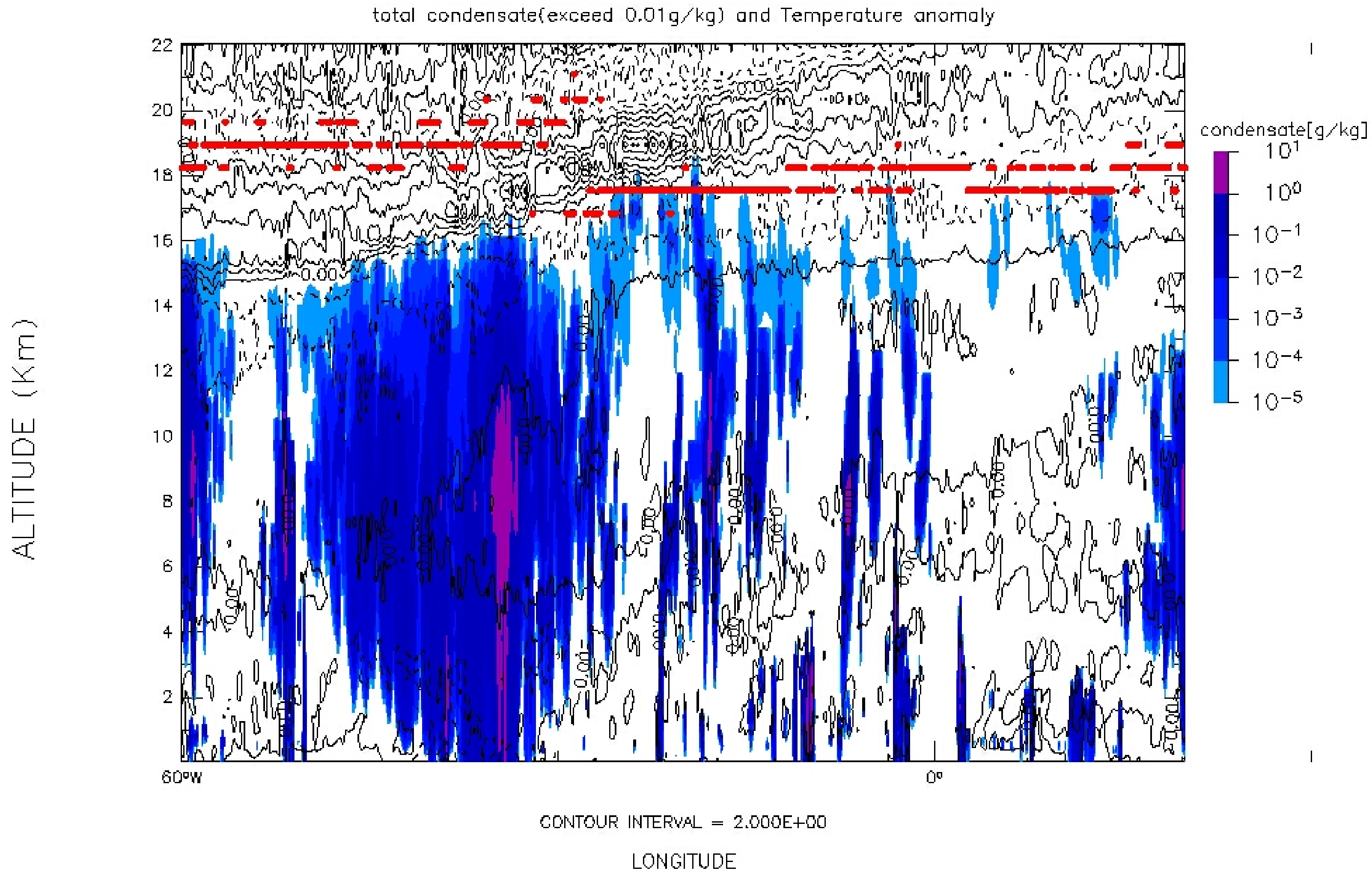


Water vapor at18200(m)
30°N
15°N
EQ
15°S
30°S
LATITUDE
180°
120°W
60°W
0°
60°E
120°E
180°
LONGITUDE
Water Vapor[g/kg]
10^{-3}
10^{-4}

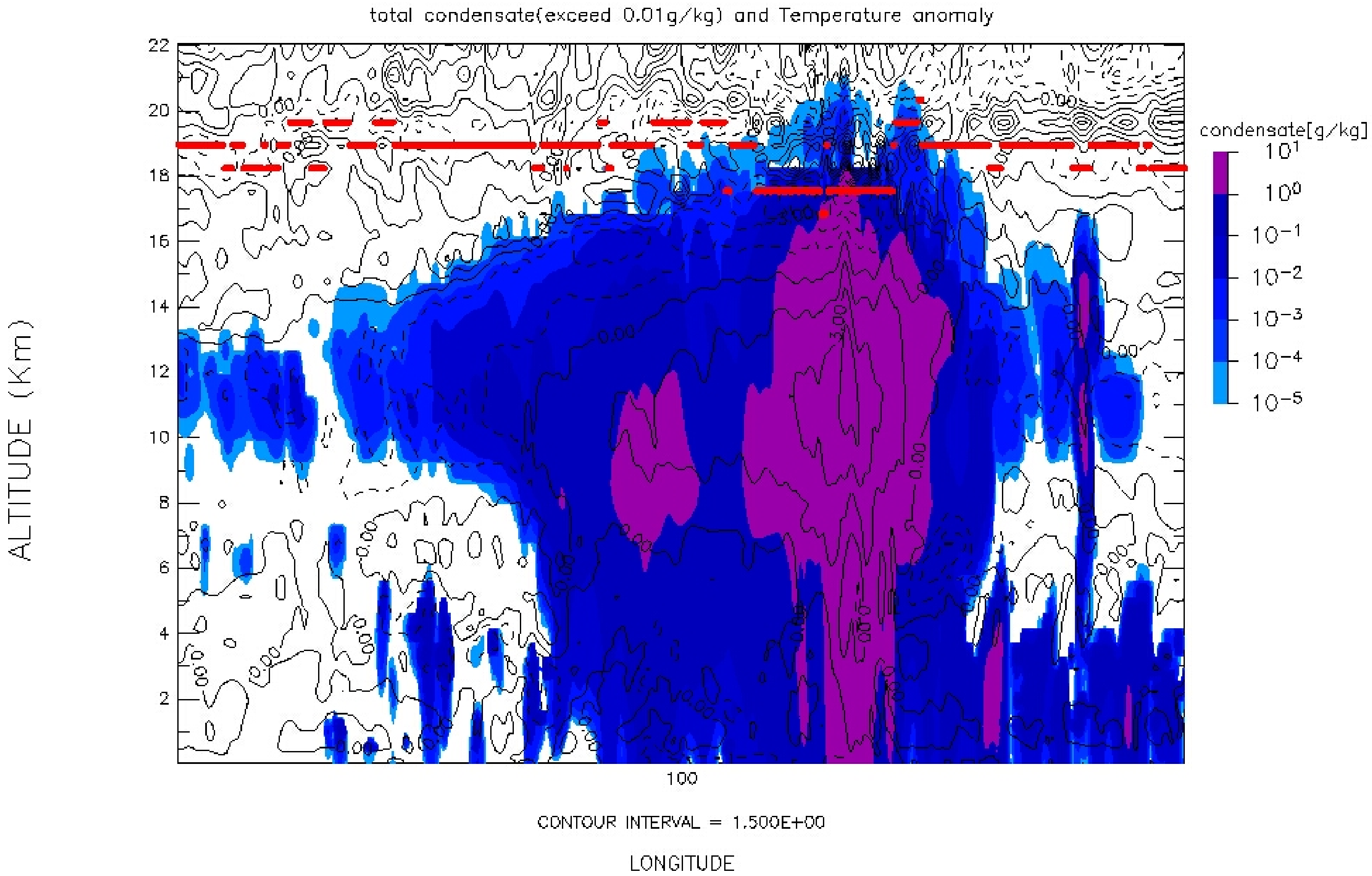
NICAM 3.5-km Aqua Planet 3/3

- Impact on TTL : Kelvin-wave Generating Clouds vs. Penetrating Clouds

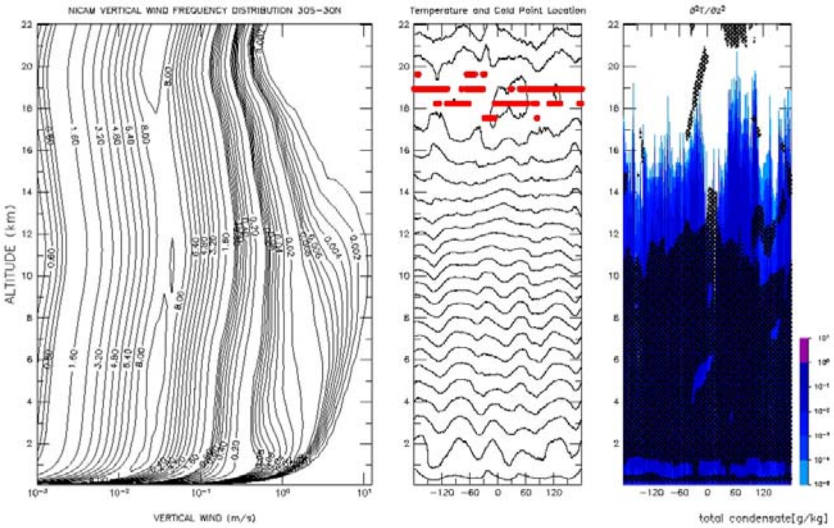
- Definition of the TTL Lower Boundary : Temperature Profile vs. Vertical Wind vs. Total Condensate

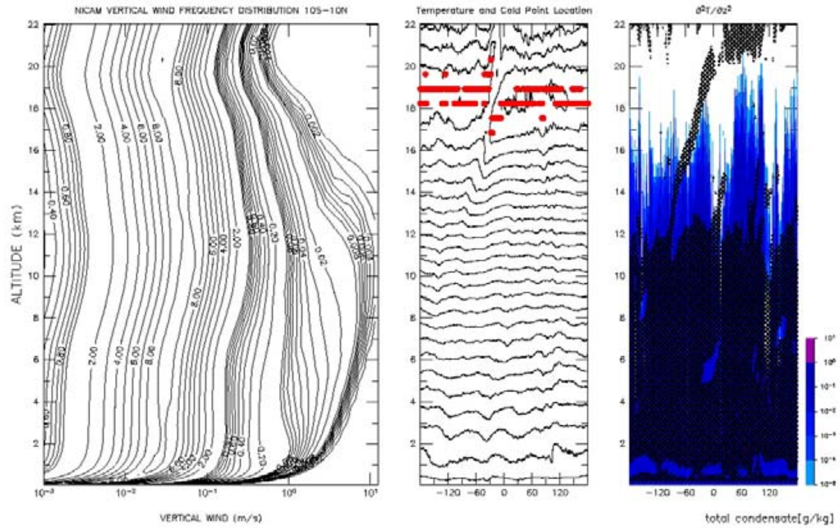


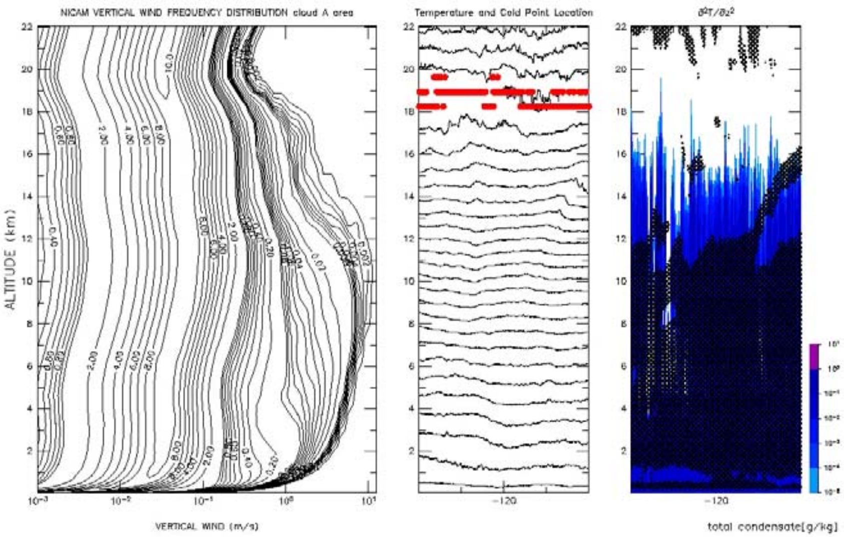
total condensate(exceed 0.01g/kg) and Temperature anomaly
ALTITUDE (Km)
22
20
18
16
14
12
10
8
6
4
2
60°W
0°
condensate[g/kg]
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
CONTOUR INTERVAL = 2.000E+00
LONGITUDE

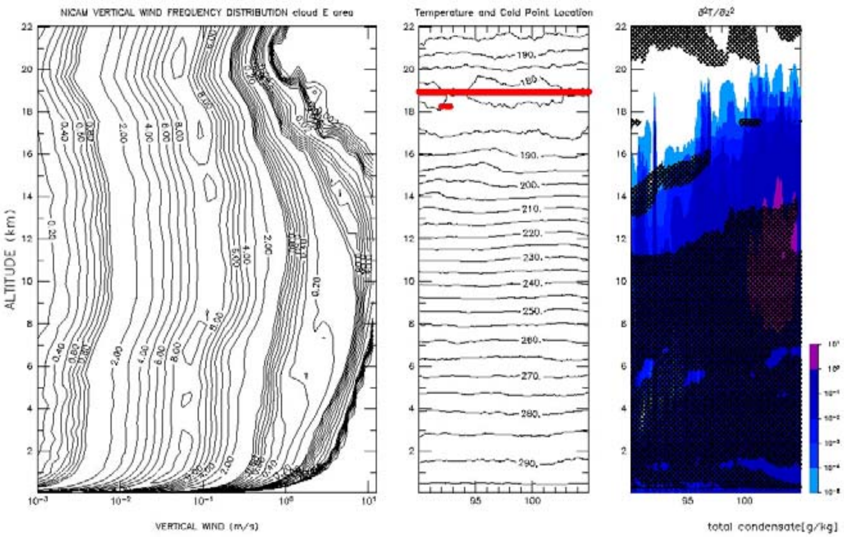


total condensate(exceed 0.01g/kg) and Temperature anomaly
ALTITUDE (Km)
22
20
18
16
14
12
10
8
6
4
2
0.00
-3.00
3.00
condensate[g/kg]
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
100
CONTOUR INTERVAL = 1.500E+00
LONGITUDE


NICAM VERTICAL WIND FREQUENCY DISTRIBUTION 30S-30N
Temperature and Cold Point Location
ALTITUDE (km)
VERTICAL WIND (m/s)
total condensate[g/kg]


NICAM VERTICAL WIND FREQUENCY DISTRIBUTION 10S-10N
Temperature and Cold Point Location
ALTITUDE (km)
VERTICAL WIND (m/s)
total condensate[g/kg]


NICAM VERTICAL WIND FREQUENCY DISTRIBUTION cloud A area
Temperature and Cold Point Location
ALTITUDE (km)
VERTICAL WIND (m/s)
total condensate[g/kg]


NICAM VERTICAL WIND FREQUENCY DISTRIBUTION cloud E area
Temperature and Cold Point Location
ALTITUDE (km)
VERTICAL WIND (m/s)
total condensate[g/kg]

Summary

- Various tropical cloud organizations → different impact on TTL
- Large-scale Kelvin wave signals vs. Locally penetrating clouds

- Definition of the TTL lower boundary : Temperature profile vs. vertical wind vs. total condensate
- Vertical wind data is a good indicator for the TTL lower boundary