Study and Comparison of Simulation of Satellite Microwave Observations in Cloudy and Rainy Areas using RTTOV and CRTM

HAN Wei[*] and DONG Peiming[**]

hanwei@cma.gov.cn

[*] **Numerical Prediction Center, CMA**

[**] **Chinese Academy of Meteorological Sciences,CMA**

Outline

- **Background**
  - **Clear Radiance assimilation in GRAPES**
  - **Cloudy Radiance assimilation: onging Research**
- **Comparisons of RTTOV and CRTM for Cloudy Radiance**
  - **Input from 24h forecast**
    - RTTOV: cloud frac.,water,ice,rain,snow
    - CRTM:effective radius,water,ice,rain,snow,graupel,hail
  - **Jacobians**
- **Discussion**
  - **Training of the fast RT model for cloudy radiance**
    - L2 norm or H1 norm
  - **Control variables choices**

Background: Road map of GRAPES

1999–2000 ⇒ **Framework Design**

2001.–2005 ⇒ **Finish development**
- GRAPES dynamical core
- Implement WRF physics ➔ GRAPES_Meso
- GRAPES_VAR

2006.7 ⇒
- **GRAPES_Meso operation**
- **Regional 4-DVAR development**

2007.7–present ⇒
- **Setup of GRAPES_GFS & pre-operation**
- **Global 4-DVAR development**

Other Apps.:

GRAPES_TCM
typhoon track
GRAPES_SDM
sand storm
GRAPES_RUC

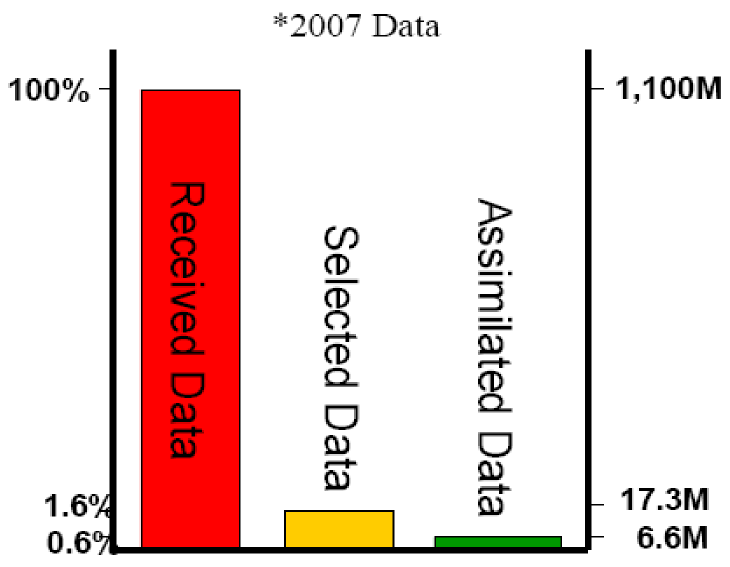
Satellite data assimilation in GRAPES

- **Observation Operator for Radiance Assimilation**
  - **RTTOV: RTTOV6->RTTOV7->RTTOV9**
  - **CRTM: CRTM1.2->*CRTM2.1***
- **Satellite Observations in GRAPES**
  - **ATOVS(NOAA,METOP,FY3)**
  - **GPS Reflectivity (COSMIC)**
  - ***IASI and AIRS***
- **Bias correction**
  - **Harris and Kelly(2001)**
  - **VarBC**
  - ***Constrained VarBC :considering of mobel bias***
- **Observation Error tuning**

Background

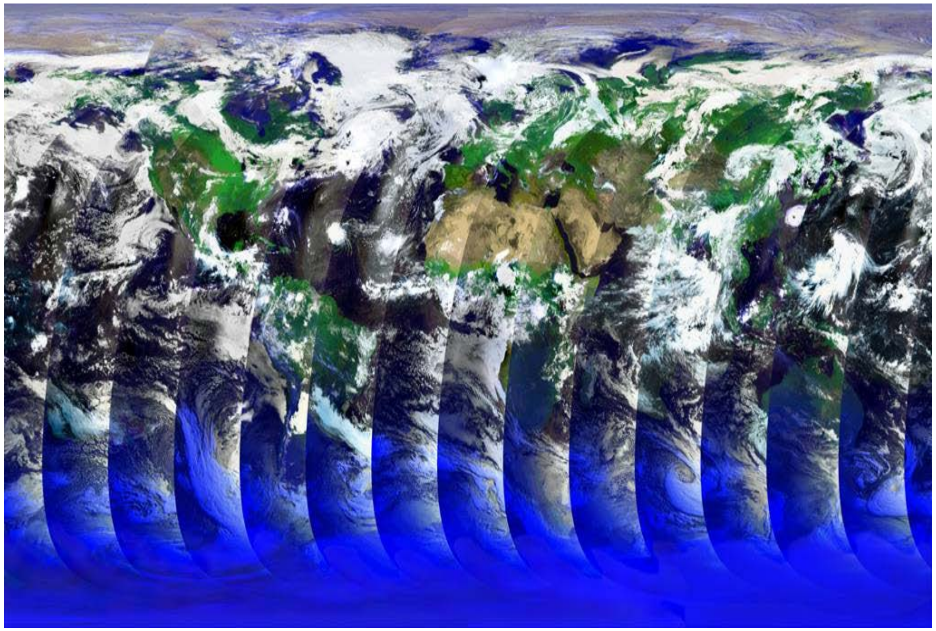
- **GRAPES_VAR**
  - **RT model: RTTOV(9.3) and CRTM(1.2)**
  - **Clear radiance assimilation in preoperational mode**
  - **Cloudy and rain affected radiance: ongoing research**

Daily Percentage of Data Ingested into Models



Received = All observations received operationally from providers
Selected = Observations selected as suitable for use
Assimilated = Observations actually used by models

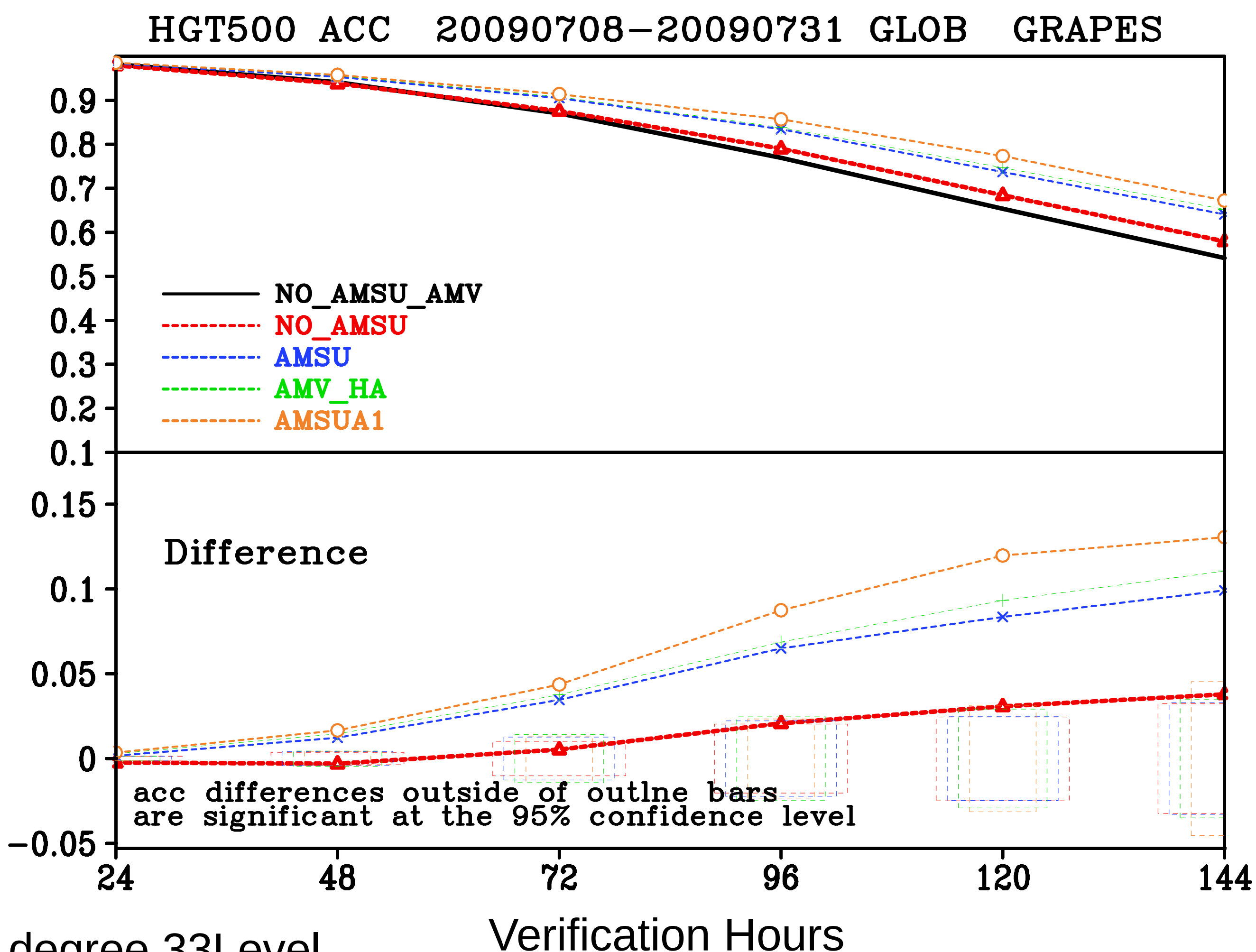
More than 70% of data are rejected due to cloud and rain



Impact of AMSUs and AMVs in GRAPES

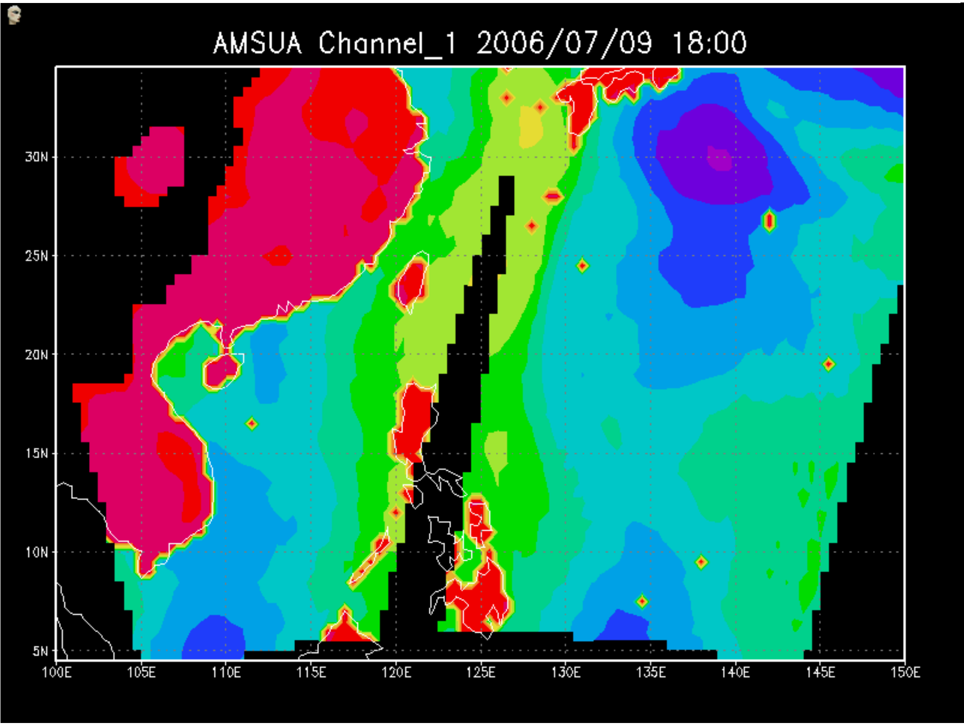
- Baseline+AMVs: positive
- Control+AMV_HA: positive
- Control+AMSU_ch4: positive

Baseline:Sonde+Airep+Synop+ships+COSMIC
Control: Baseline+AMVs+AMSUs

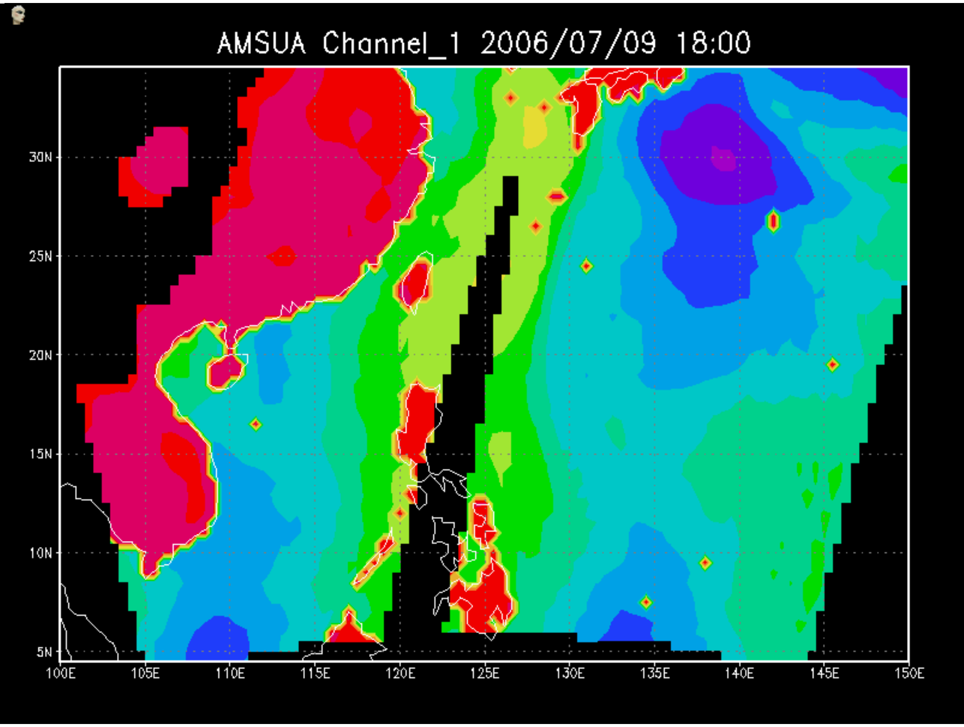


Resolution:1 degree,33Level

The impact of water content: CRTM



Water contents



No water contents

Cloud Scattering and Emission in CRTM vs. RTTOV

	CRTM	RTTOV (RTTOV-SCATT)
Radiative Transfer Solver	**Advanced Adding and Doubling (ADA) scheme**	**Delta-Eddington Approximation**
Scattering Properties (look-up table approach)	**Precalculated using Mie theory and tabulated as a function of frequency, temperature,** radii**, and hydrometeor type anddensity**	**Precalculated using Mie theory and tabulated as a function of frequency, temperature, and hydrometeor type and density.**
Cloud types	**Water, ice, rain, snow, graupel and hail**	**Water, ice, rain, and snow**
Cloud cover	**Not handle yet**	**Cloud fraction profile**

From Yong Chen et al,2011

Comparison of Input for hydrometeors

- **RTTOV**
  - **cloud liquid water, cloud ice water, rain flux and solid precip. flux**
  - **effective cloud fraction**

$$N = \left(\frac{RH - RH_0}{1.0 - RH_0}\right)^b$$

RTTOV-SCATT

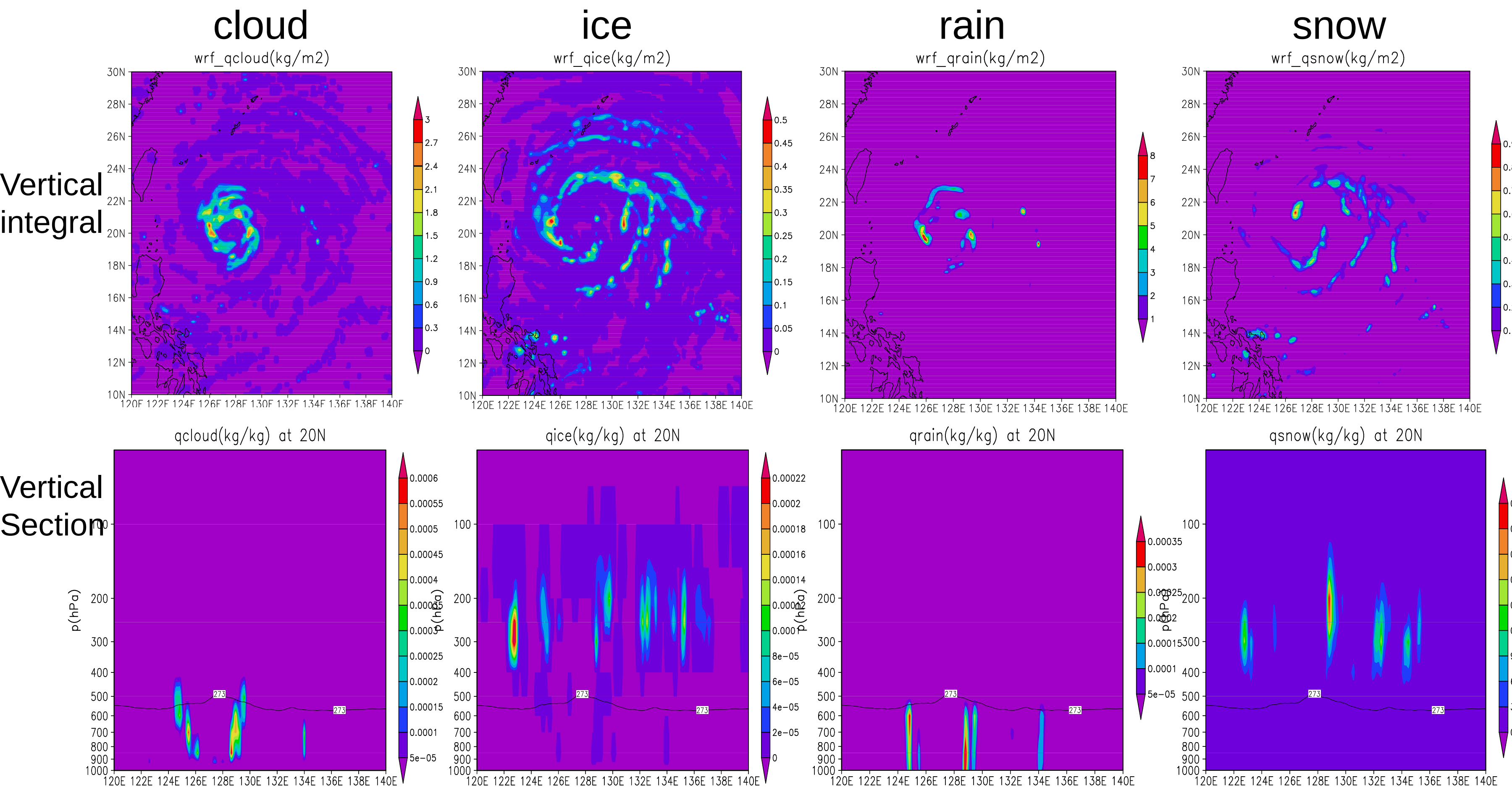
$$T_B^{Total} = (1 - C)T_B^{Clear} + CT_B^{Rainy}$$

- **CRTM**
  - **water, ice, rain, snow, graupel and hail**
  - **effective radius: const.**

$$r_e = \frac{\int_0^\infty n(r) r^3 dr}{\int_0^\infty n(r) r^2 dr}$$

24h Forecast (Initial:18Z 2nd Oct. 2007)

Area(10°-30° N, 120°-140° E) water content vertical integrate, Unit: kg m^{-2}

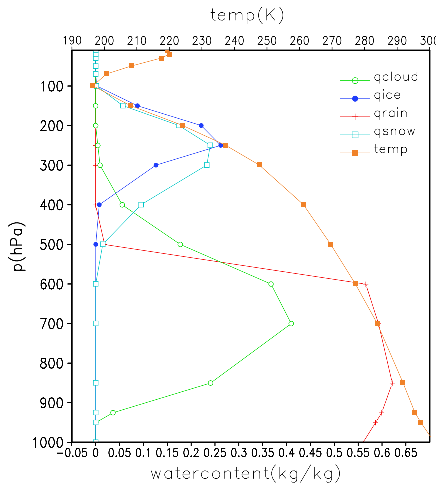


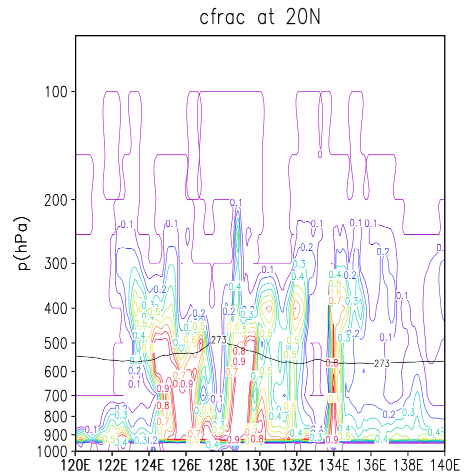
Along 20N, Vertical Section, Unit: **kg/kg**

18km,Lin scheme

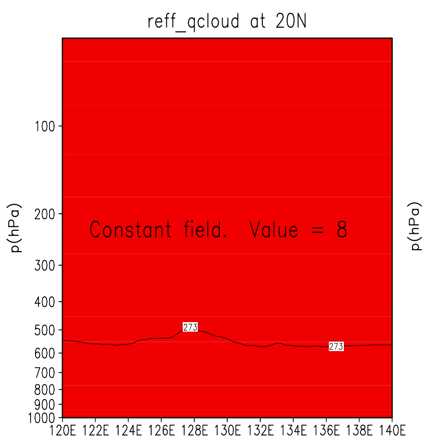
Input of RT model from background

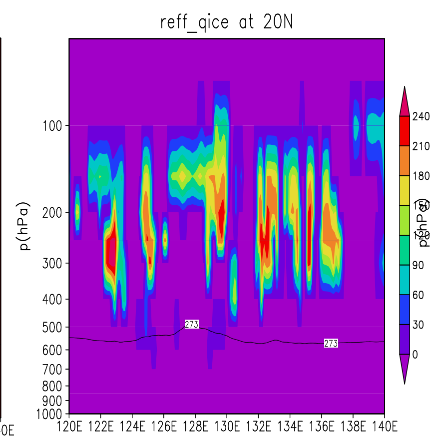
mean profile

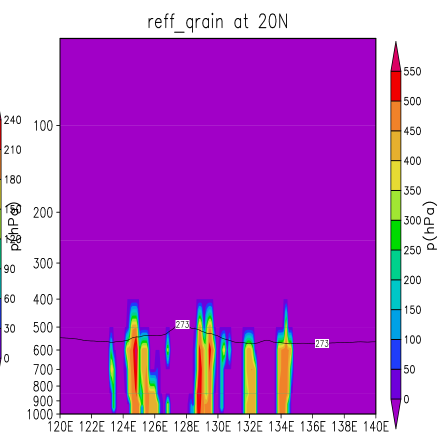


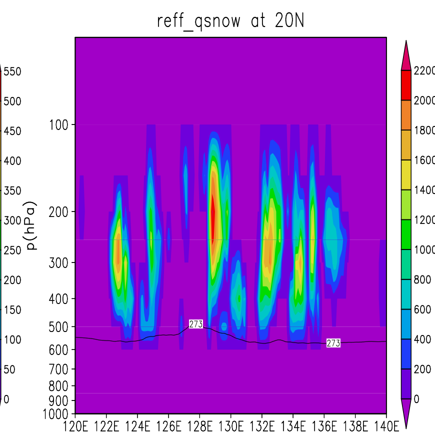


cloud fraction





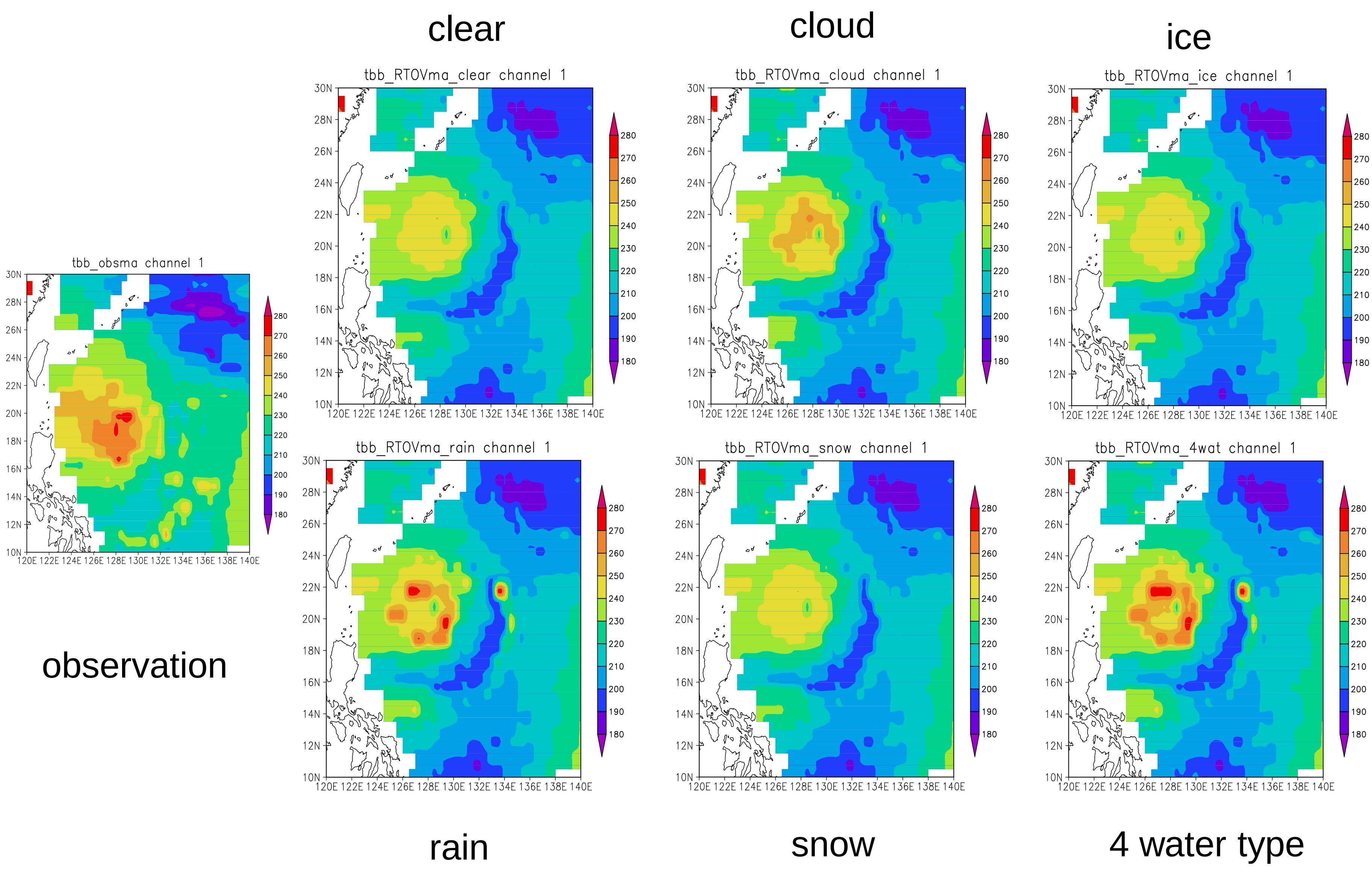




cloud ice rain snow

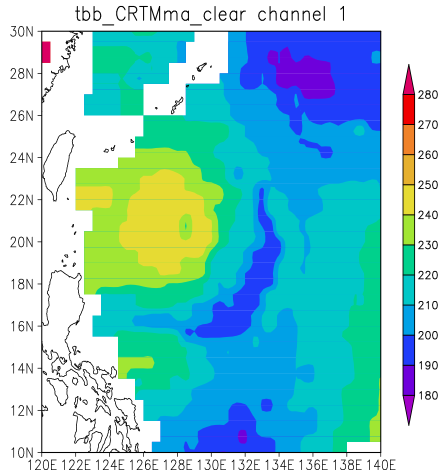
Along 20N, Effective Radius, Unit: **um**

RTTOV AMSUA CH1: diff. cloud type

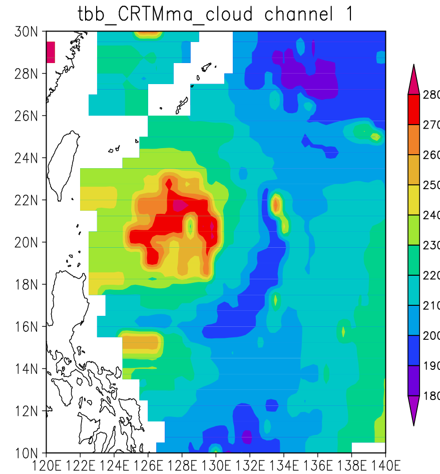


CRTM AMSUA CH1: diff. cloud type

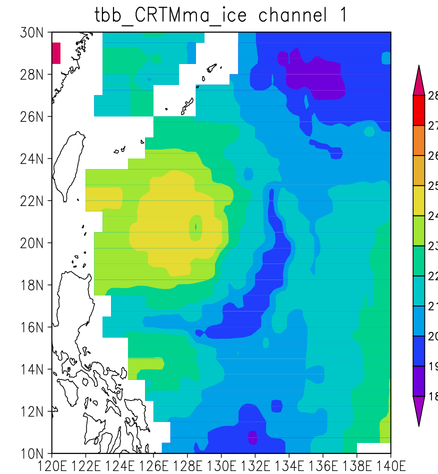
clear

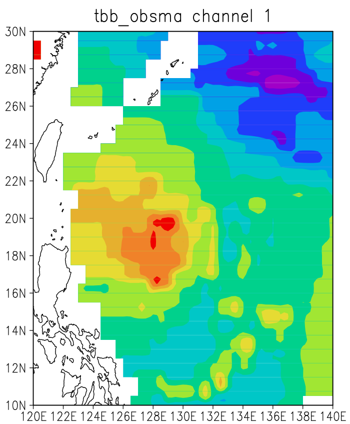


cloud

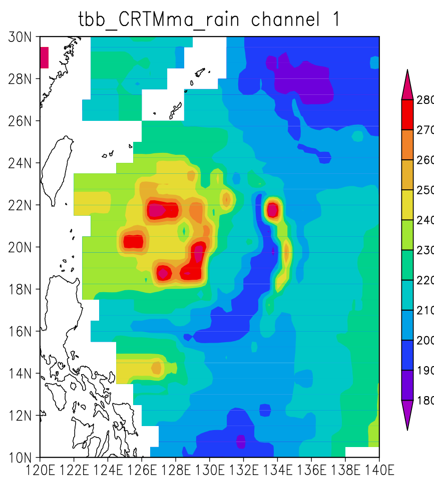


ice

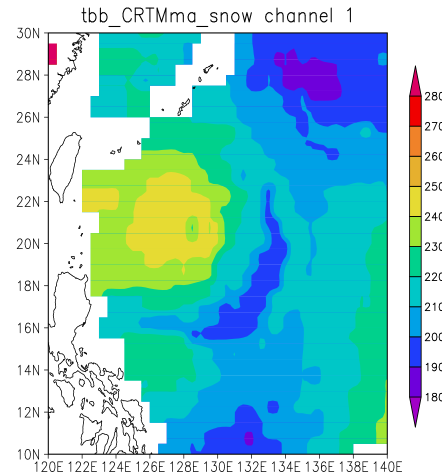




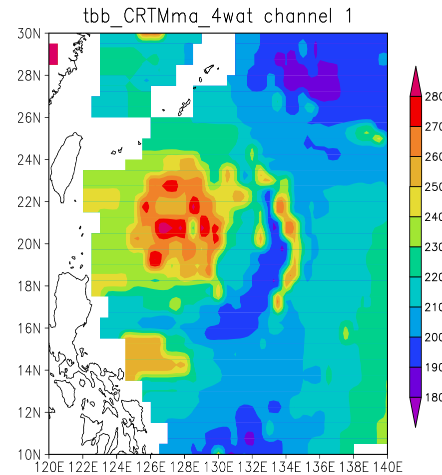
observation



rain



snow



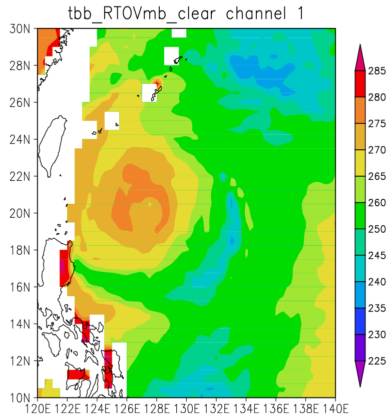
4 water type

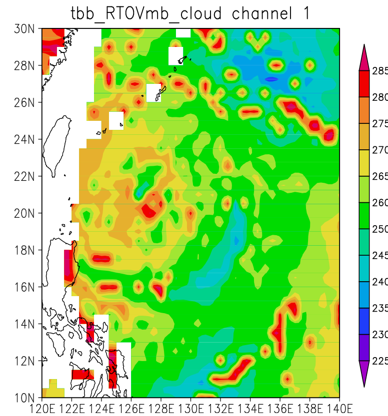
RTTOV AMSUB CH1: diff. cloud type

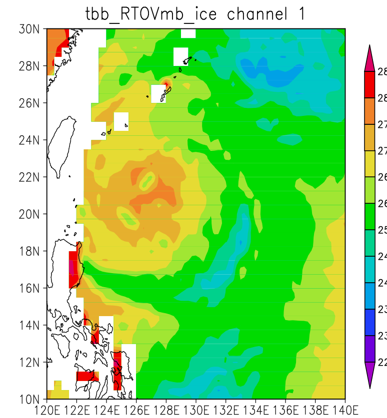
clear

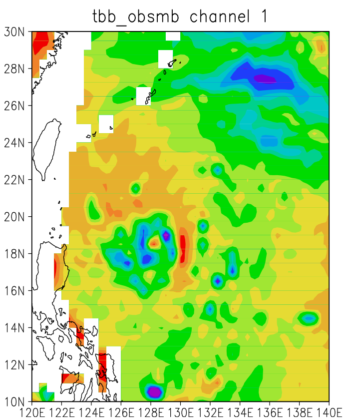
cloud

ice

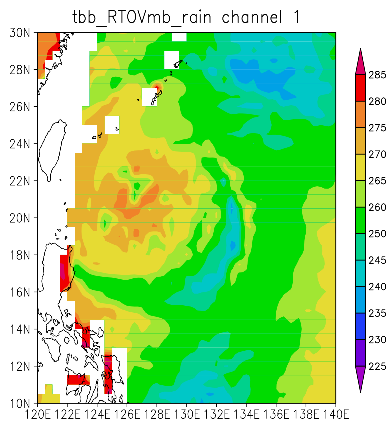


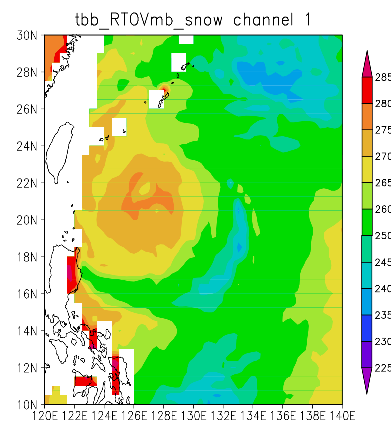


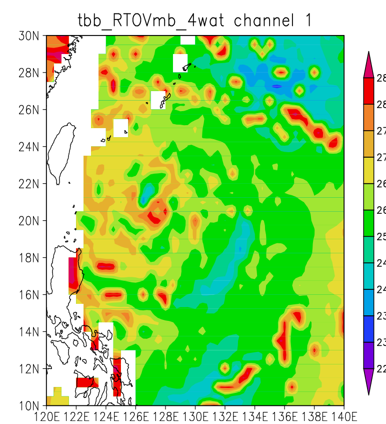




observation







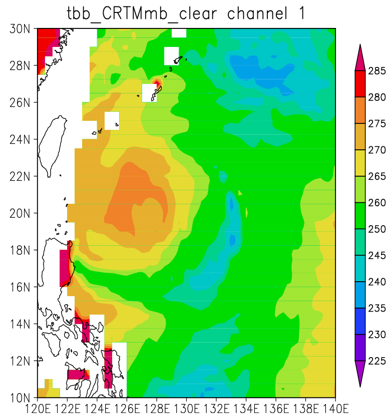
rain

snow

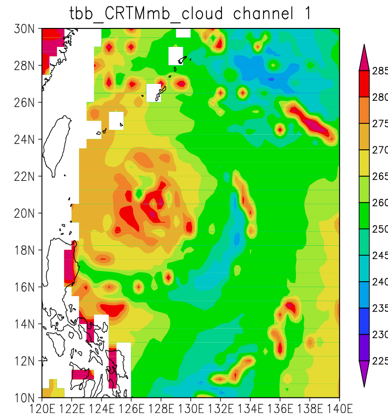
4 water type

CRTM AMSUB CH1: diff. cloud type

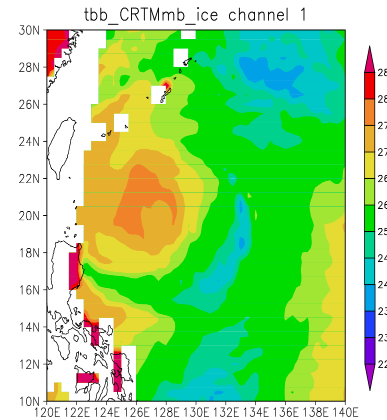
clear

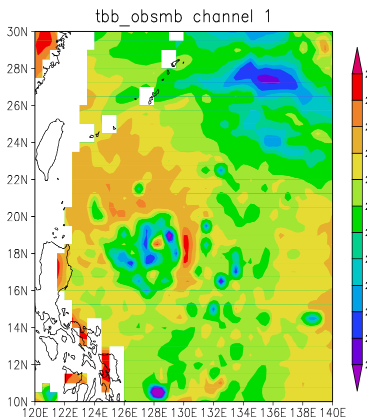


cloud

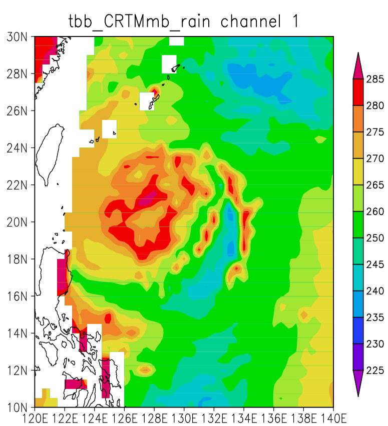


ice

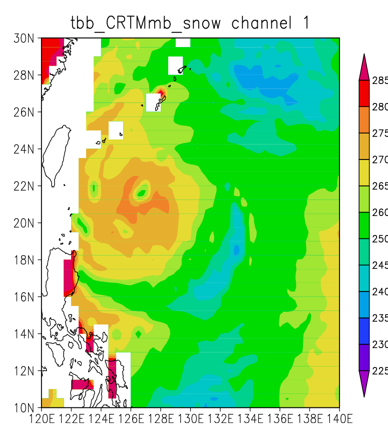




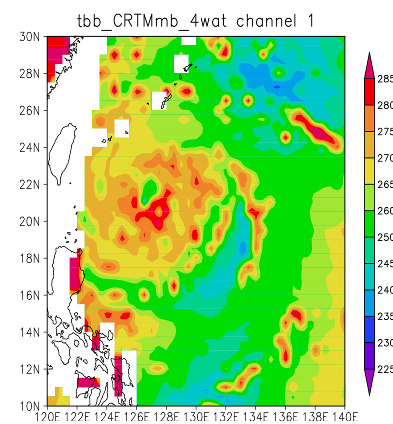
observation



rain



snow



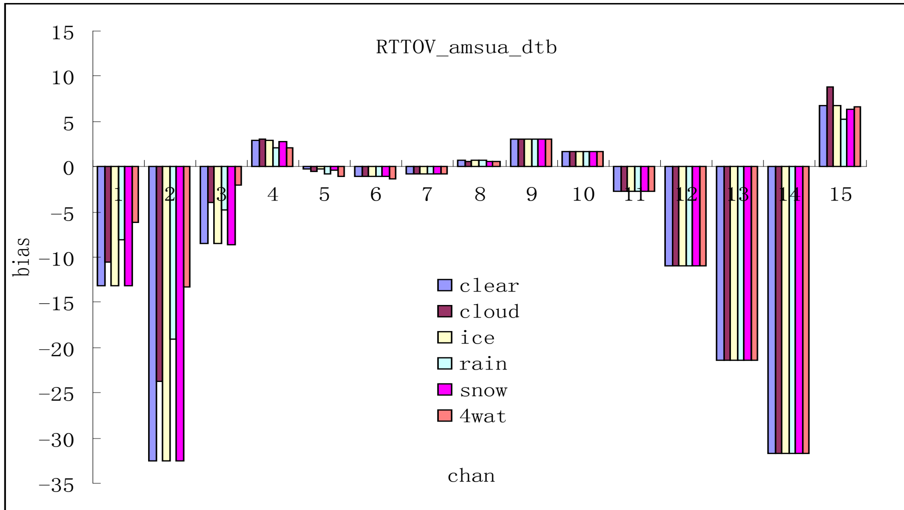
4 water type

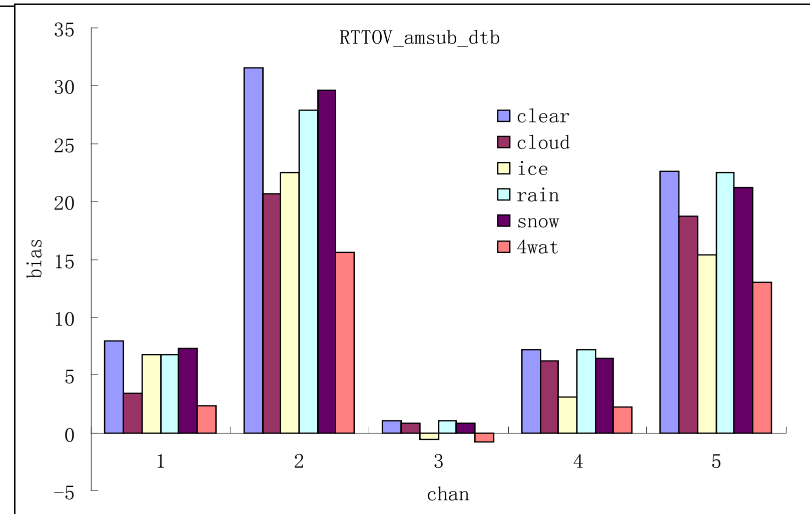
Impact of water content on O-B

AMSUA

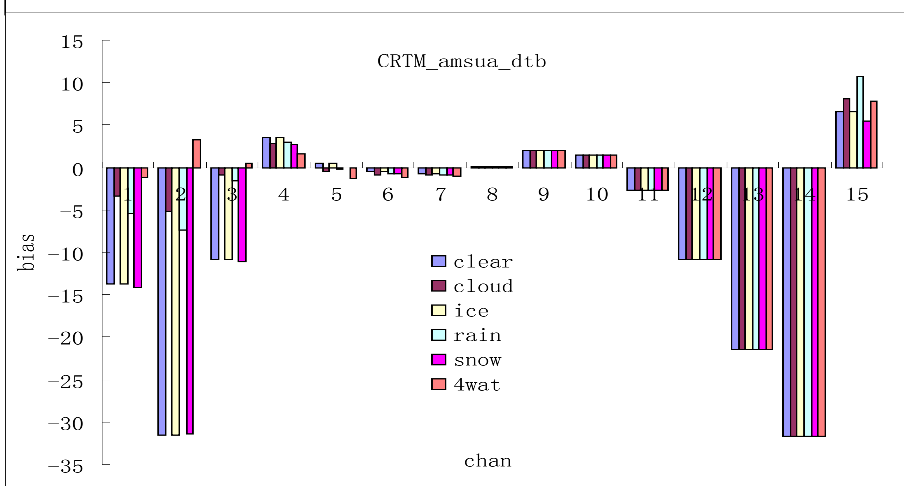
AMSUB

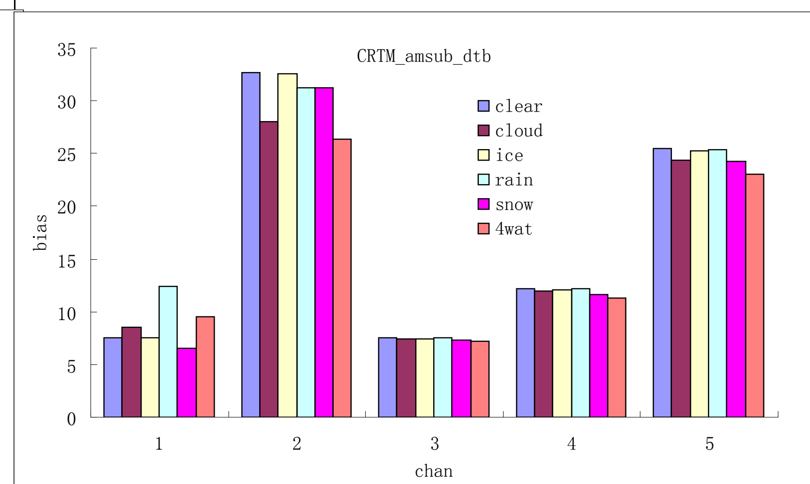
RTTOV



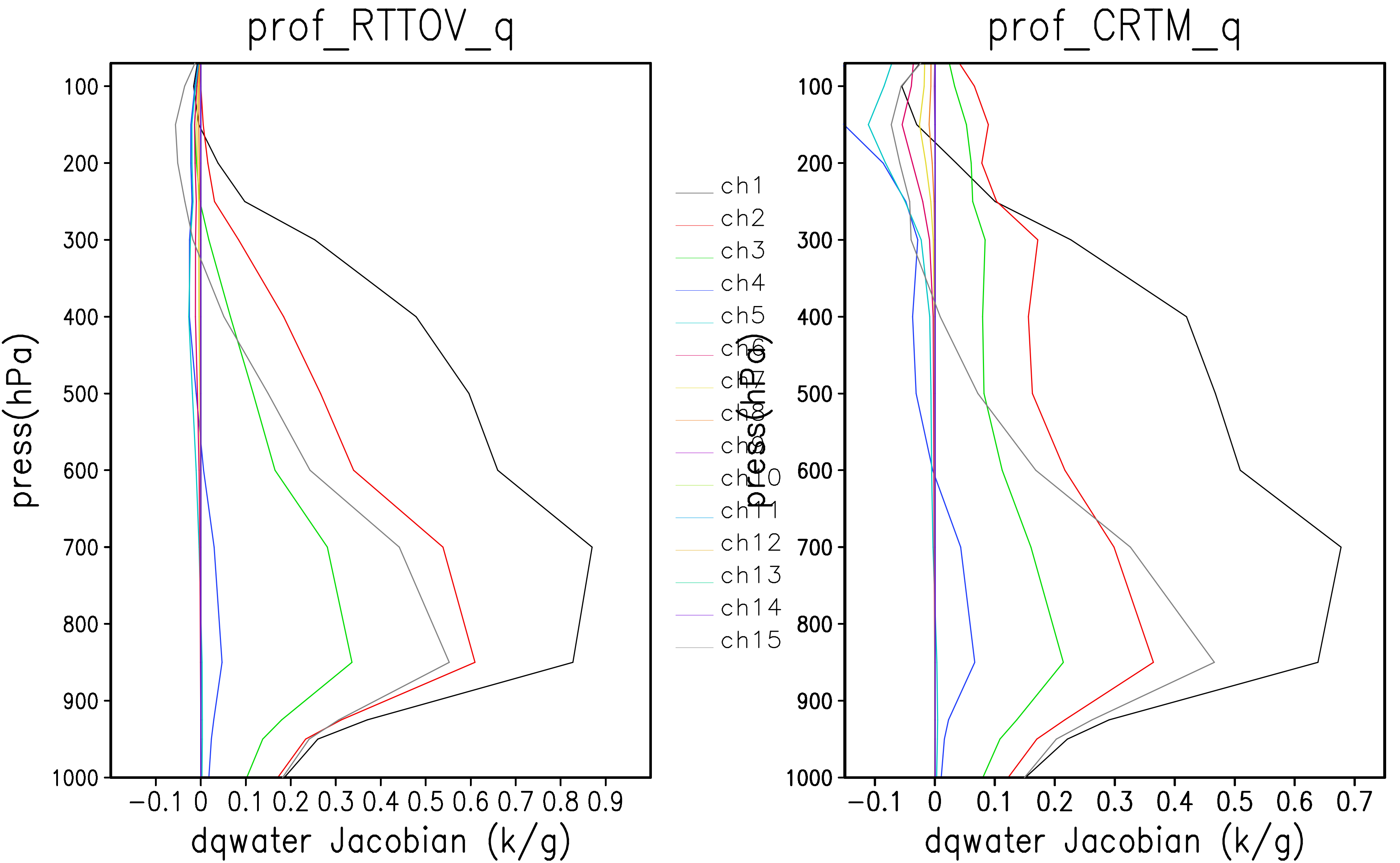


CRTM

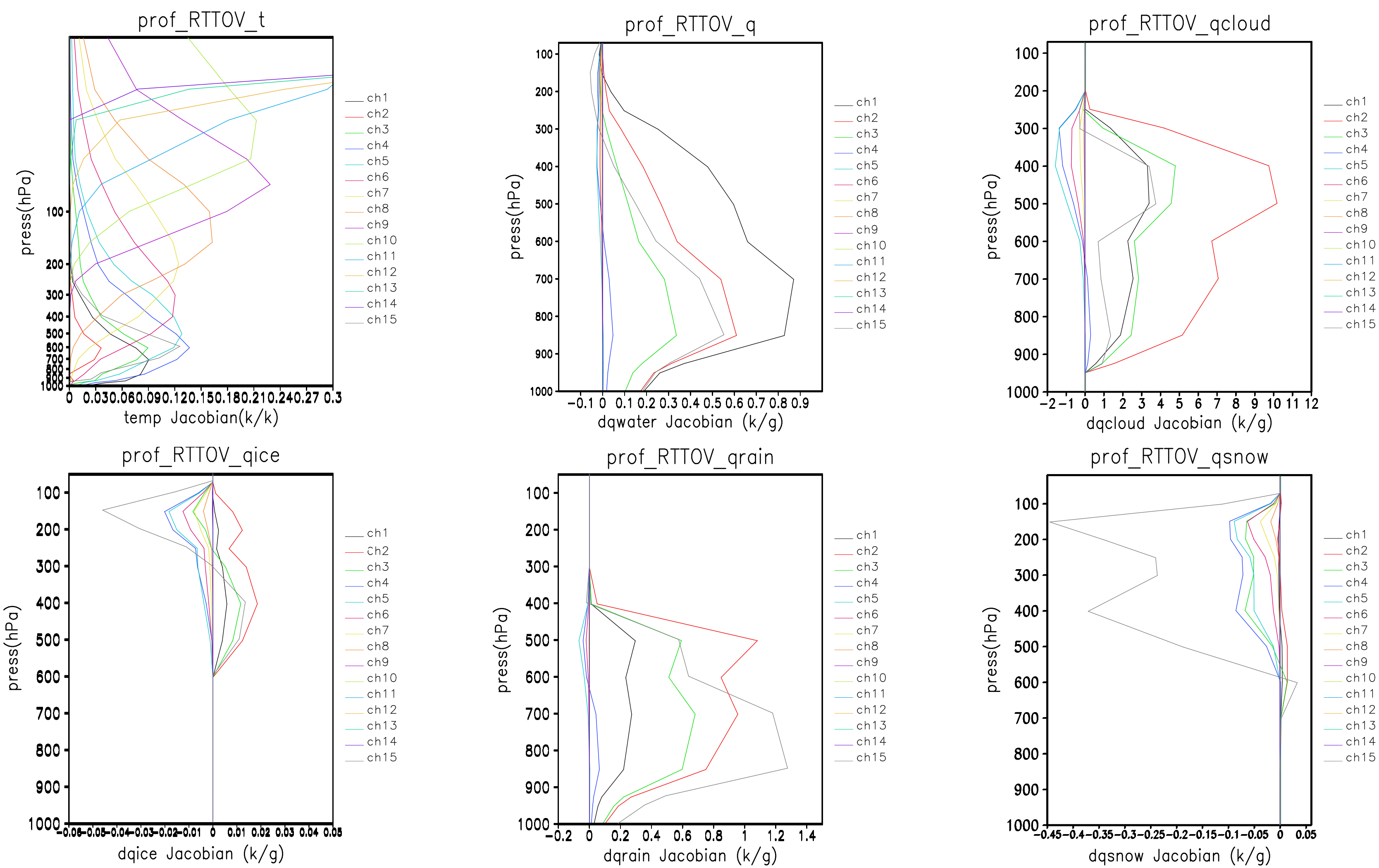




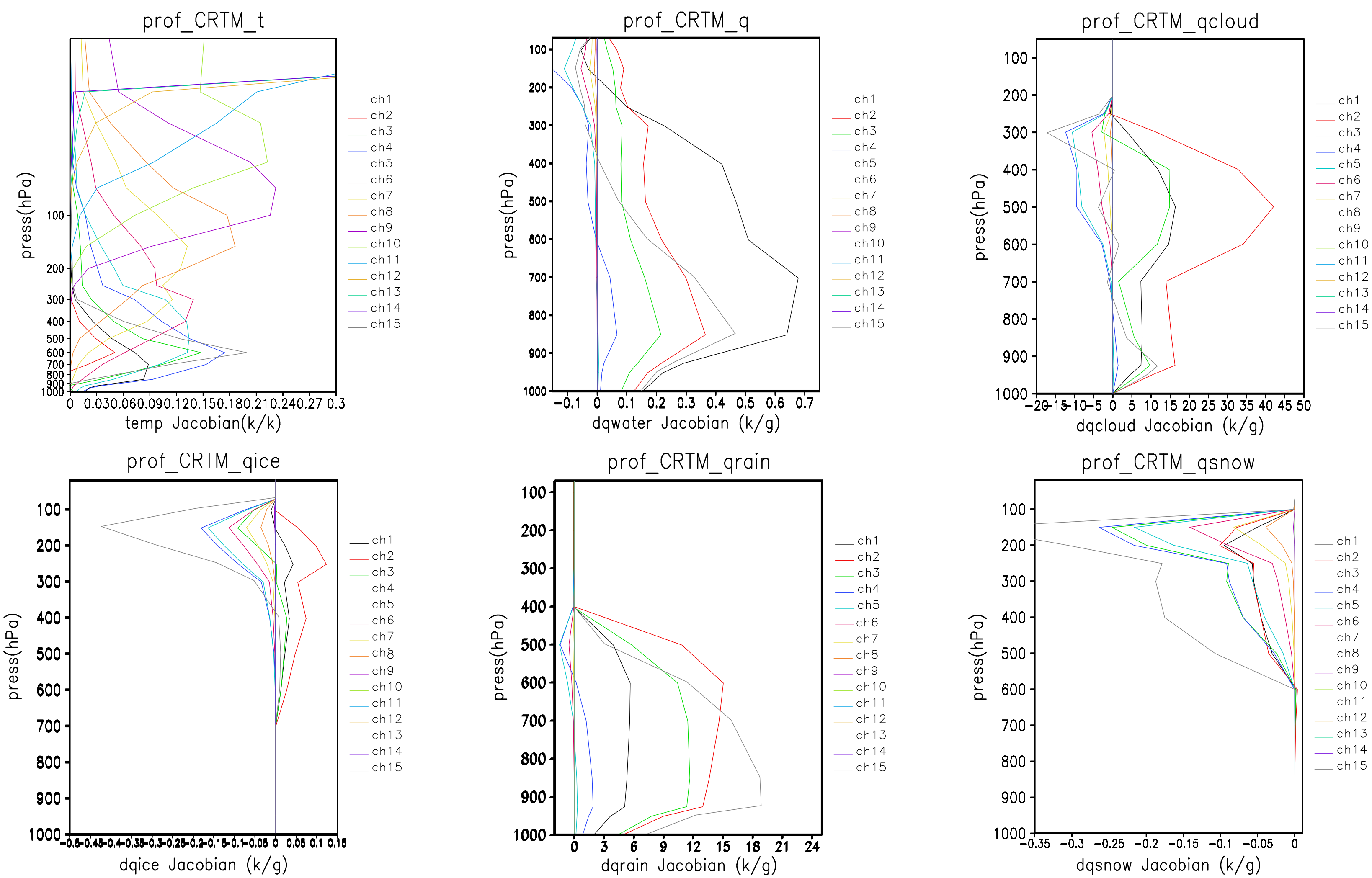
AMSUA: water vapor Jacobian



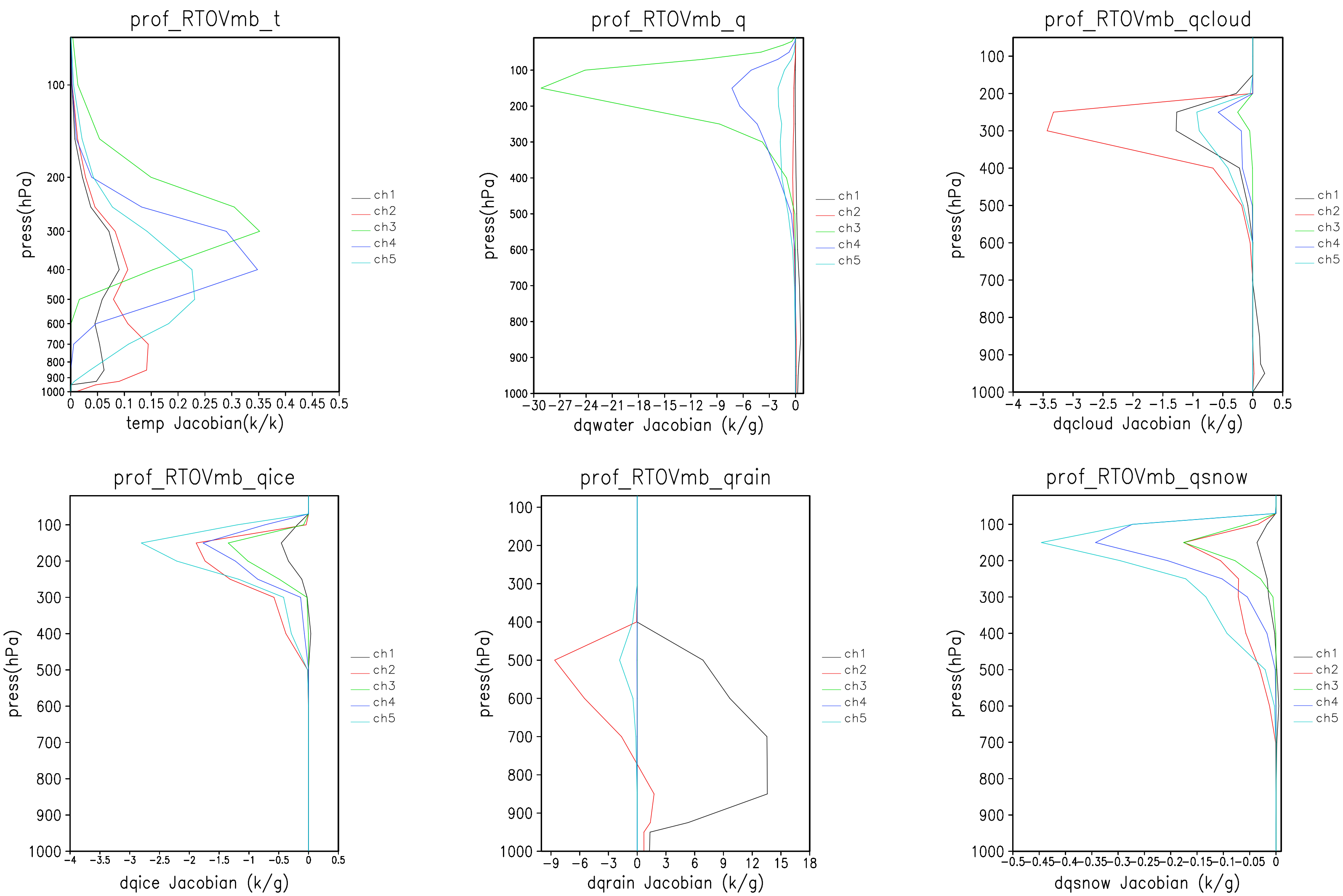
RTTOV Jacobian:T,Qv,Qc,Qi,Qr,Qs AMSUA



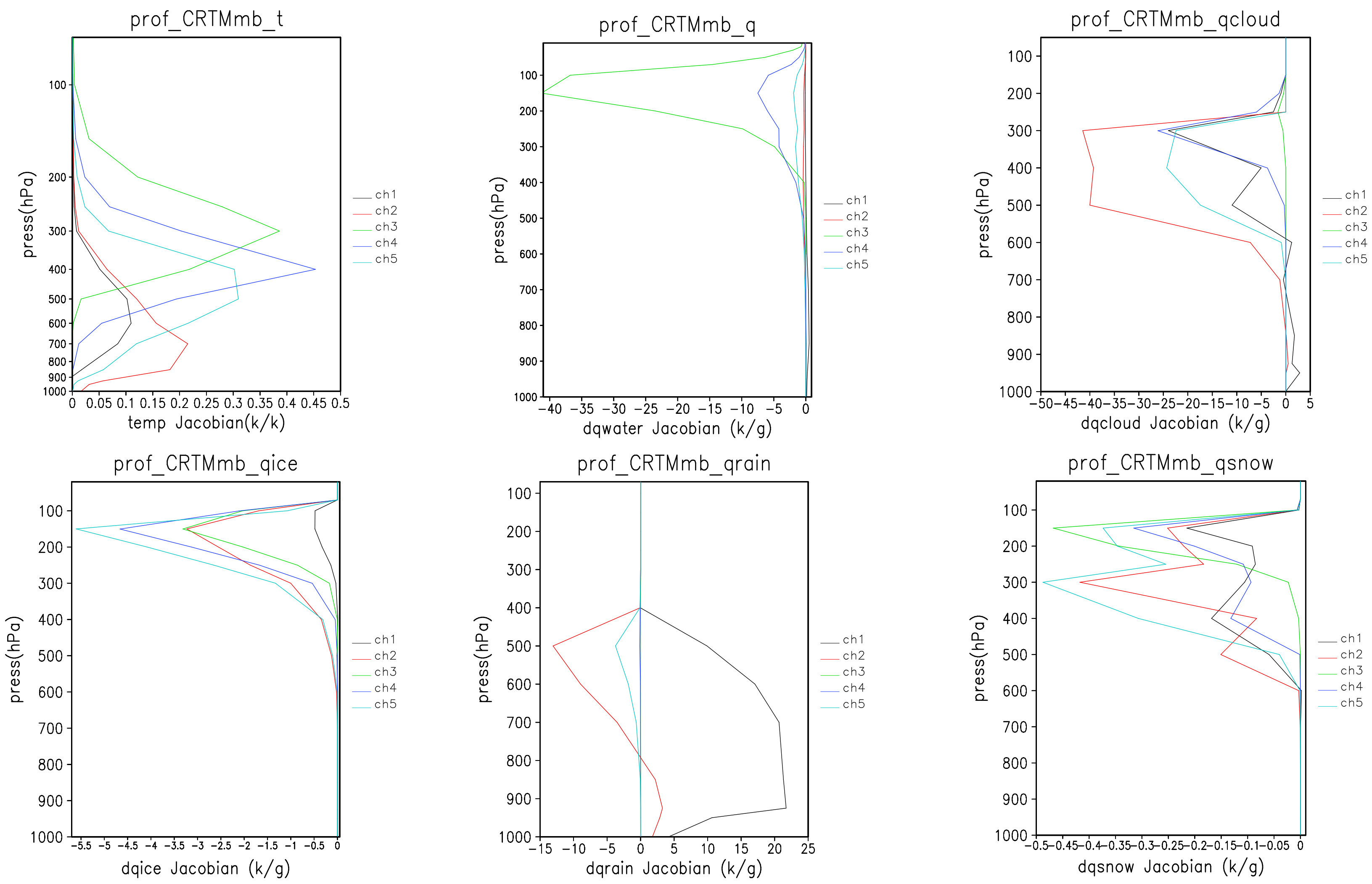
CRTM Jacobian:T,Qv,Qc,Qi,Qr,Qs AMSUA



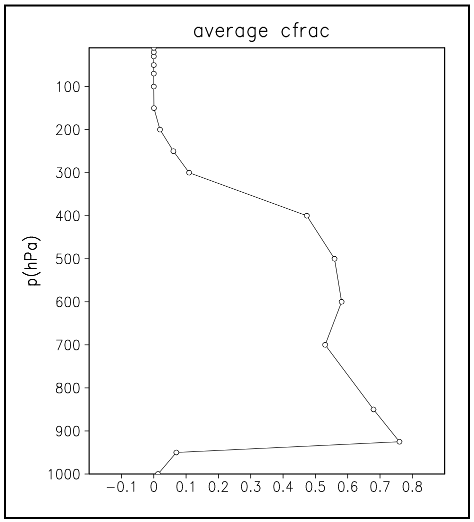
RTTOV Jacobian:T,Qv,Qc,Qi,Qr,Qs AMSUB

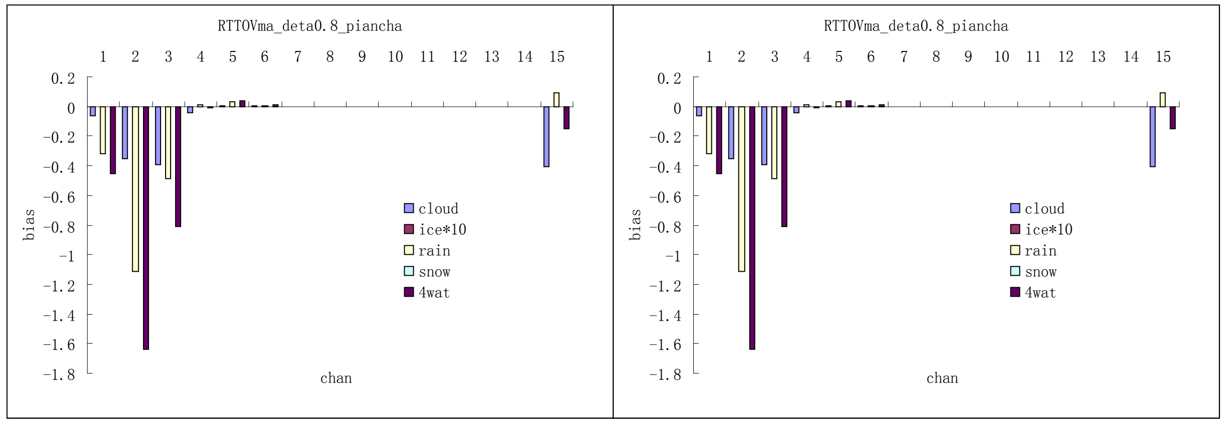


CRTM Jacobian:T,Qv,Qc,Qi,Qr,Qs   AMSUB

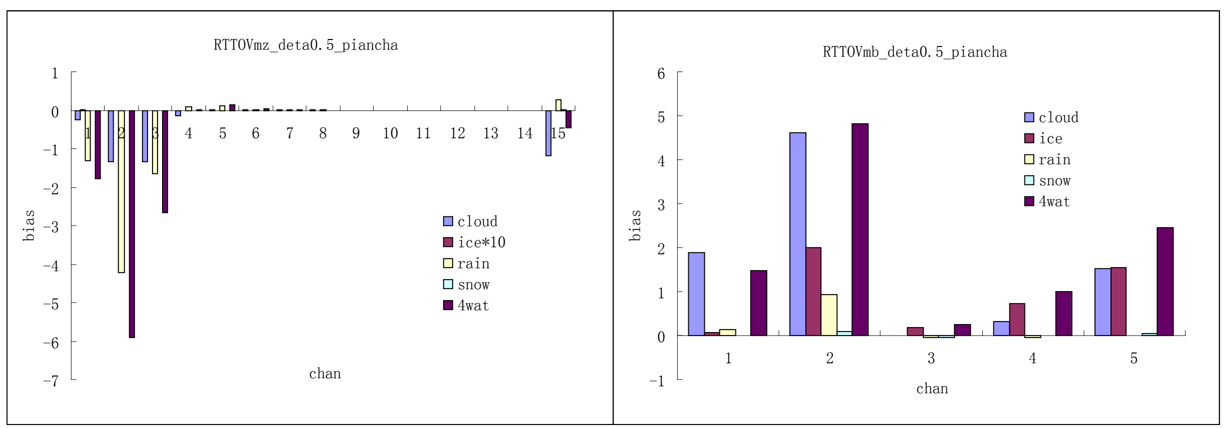


Impact of cloud fraction on simulted Tb:RTTOV





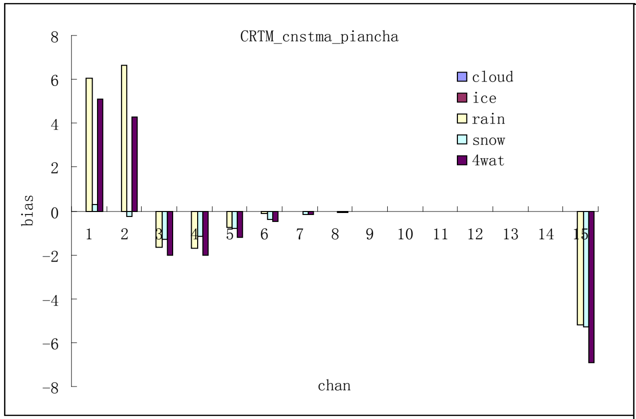
0.8

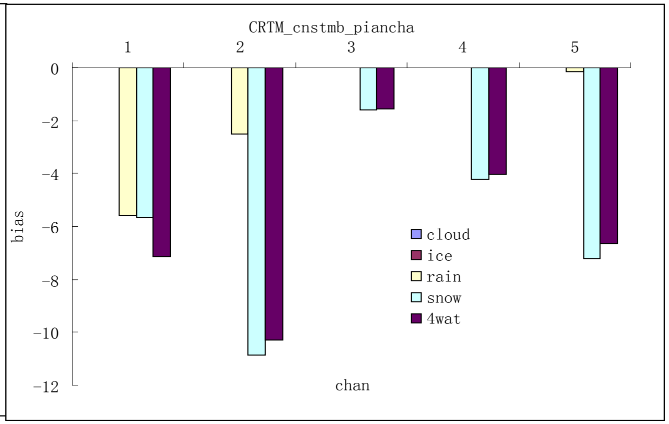


0.5

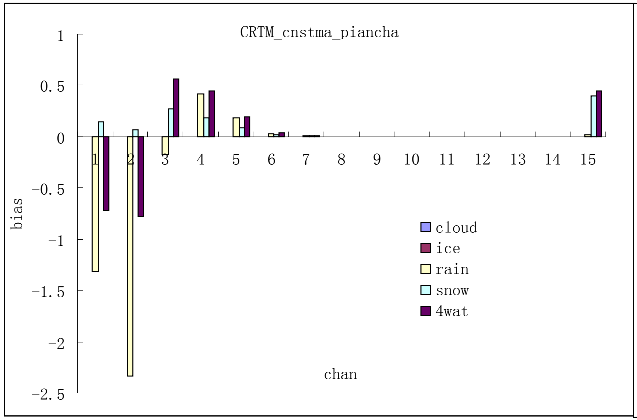
Impact of effective radius on simulted Tb: CRTM

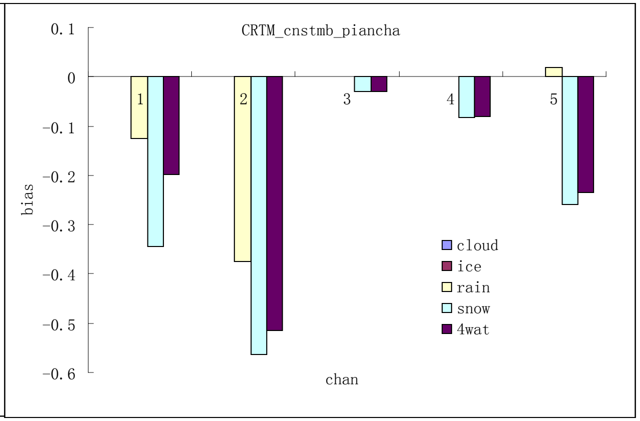
cloud:15, ice:30,rain:200, snow:200 um





cloud:8, ice:240,rain:500, snow:1400 um





Summary

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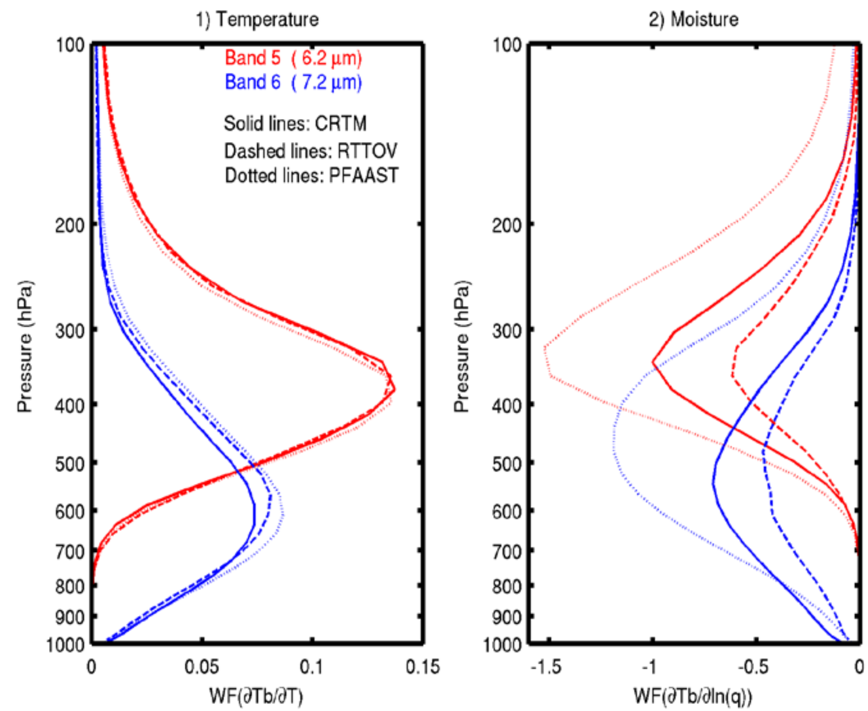
  - **Cloudy Radiance assimilation: onging Research**
- **Comparisons of RTTOV and CRTM for Cloudy Radiance**
  - **Input from 24h forecast**
  - **Jacobians**
- **Discussion**
  - **Jacobian uncertainties for water content in RT models**
  - **Inter comparison studies?**
  - **OSSE: unknowns and obs. information content for cloudy radiance(IR+MW). Could it be conducted by ITWG?**

Garand et al,2001:Radiance and Jacobian intercomparison of radiative transfer models applied to HIRS and AMSU channels, JGR,106, 24017-24031

CRTM Jacobian Calculations Compared with RTTOV

- **RTTOV is another fast radiative transfer model use by NWP community for satellite data assimilation**
- **Radiance Jacobians at 6.2 and 7.2 micron water vapor channels (GOES-R ABI and MSG SEVIRI) are derived frc CRTM & RTTOV**
- **Both models produce Jacobian profiles peaked at the same altitude**
- **But the magnitudes are slightly different between two fast models**



Assumption: surface emissivity = 0.98, local zenith angle = 0 deg., and skin temperature = 300 K

From Fengzhung Weng,2011