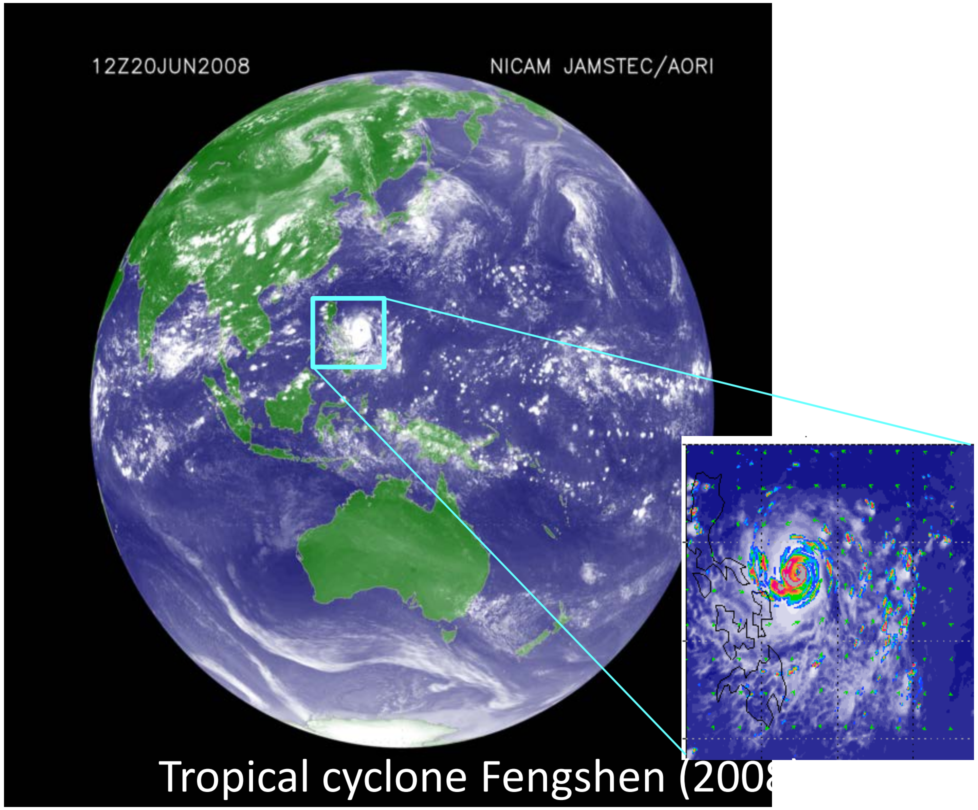
Evaluation and Improvement of Clouds Simulated by the Global Nonhydrostatic Model NICAM and Satellite Data

NICAM: dx=3.5 km simulations



EarthCARE satellite mission (2016?)

Joint Simulator for Satellite Sensors

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T. Hashino, W. Roh, T. Nasuno

CFMIP/EUCLIPSE meeting, Hotel Zuiderduin, Egmond aan Zee, 8-11th July 2014

http://www.euclipse.eu/meeting_July2014_Netherlands.html

EarthCARE
Earth **C**louds,
Aerosols and
Radiation **E**xplorer
and
Joint Simulator for Satellite Sensors

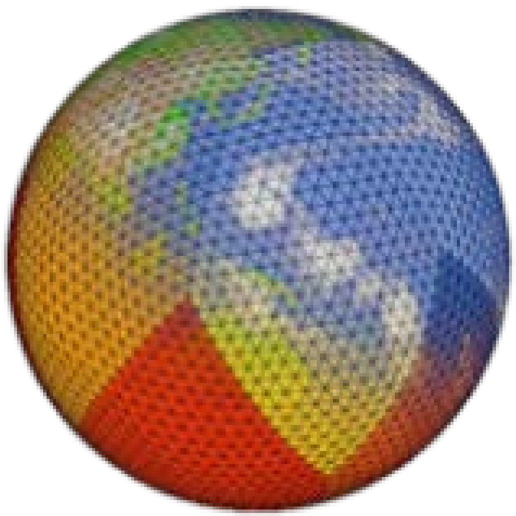
- Visible and infrared imager (MSI)
  - RSTAR6b (Nakajima & Tanaka 1986, 1988)
    - Discrete-ordinate method/adding method
    - K-distribution table with HITRAN2004
- Microwave radiometer and sounder
  - Kummerow (1993)
    - Edington approximation
- Dopplar Radar (CPR)
  - Masunaga & Kummerow (2005)
  - EASE (Okamoto et al. 2007, 2008; Nishizawa et al. 2008)
- Lidar (ATLID)
  - Matsui et al. (2009)
  - EASE (Okamoto et al. 2007, 2008; Nishizawa et al. 2008)
- Broadband radiometer (BBR)
  - CLIRAD (Chou and Suarez 1994, 1999; Chou et al. 2001)
    - delta-Eddington approximation/adding method (two stream)
    - K-distribution method with HITRAN1996
    - 21 bands
  - MSTRN-X (Sekiguchi and Nakajima 2008)
    - Discrete-ordinate method/adding method (two stream)
    - Correlated-k distribution method with HITRAN2004
    - 18, 29, or 37 bands.

Joint Simulator for Satellite Sensors
Joint-Simulator

Joint Simulator for Satellite Sensors

Hashino et al. (2013, *J. Geophys. Res.*)

NICAM



MSI RSTAR6b

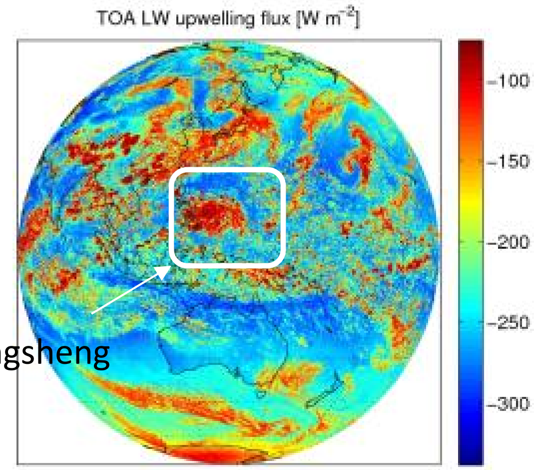
Nakajima & Tanaka (1986,1988)

VIS 0.62 μm

Background: Blue Marble: Next Generation, NASA

BBR MSTRN-X

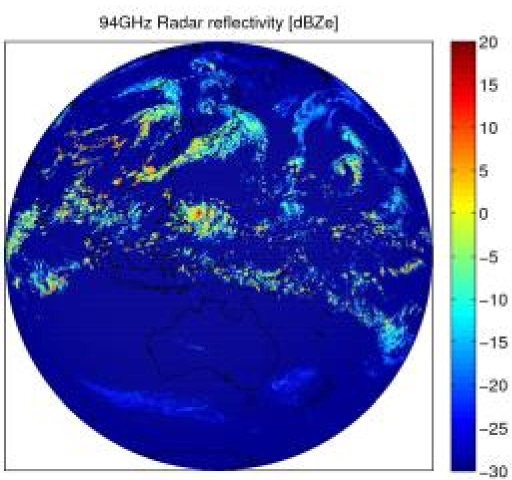
Sekiguchi & Nakajima (2008)

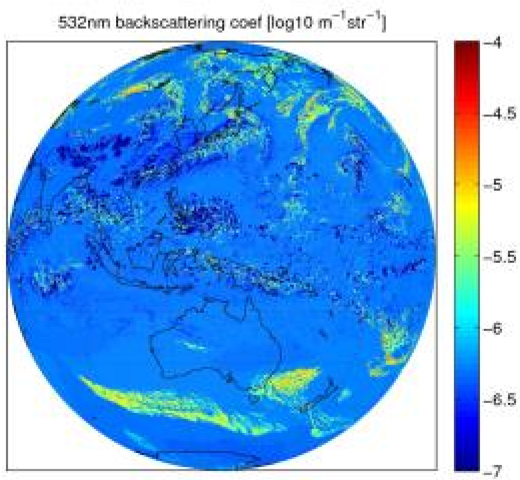


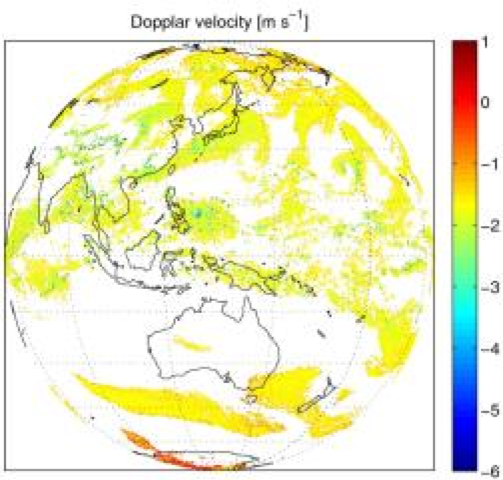
TC Fengsheng

CPR & ATLID, dopplar velocity

EarthCARE Active SEnsor simulator (EASE)







Okamoto et al., (2007, 2008); Nishizawa et al., (2008)

Signals at 10km

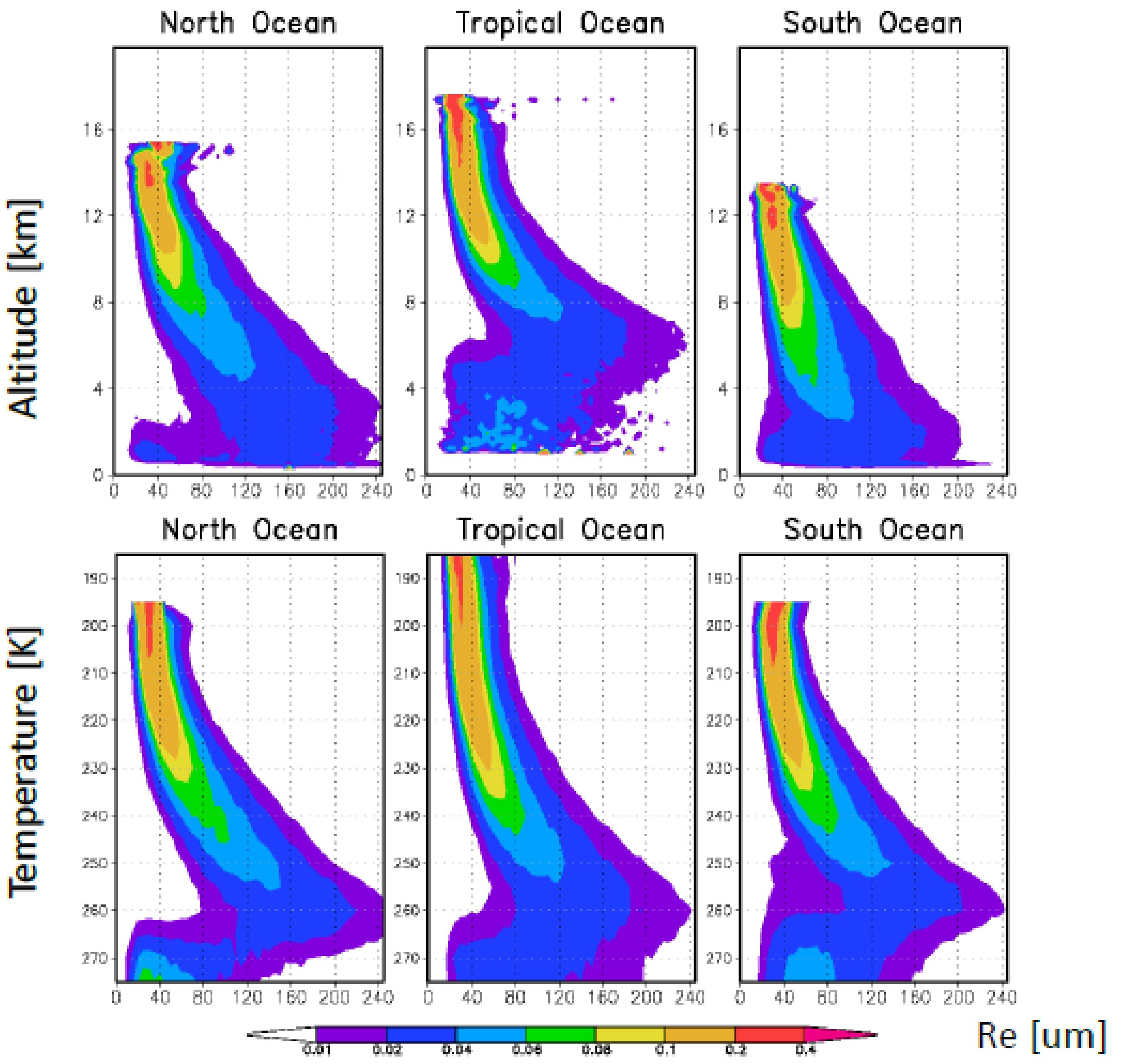
Cloud evaluation diagnosis

1. Contoured Frequency by Temperature Diagram (CFED)

2. BETTER (cloud-top beta-temperature radar-conditioned) diagram

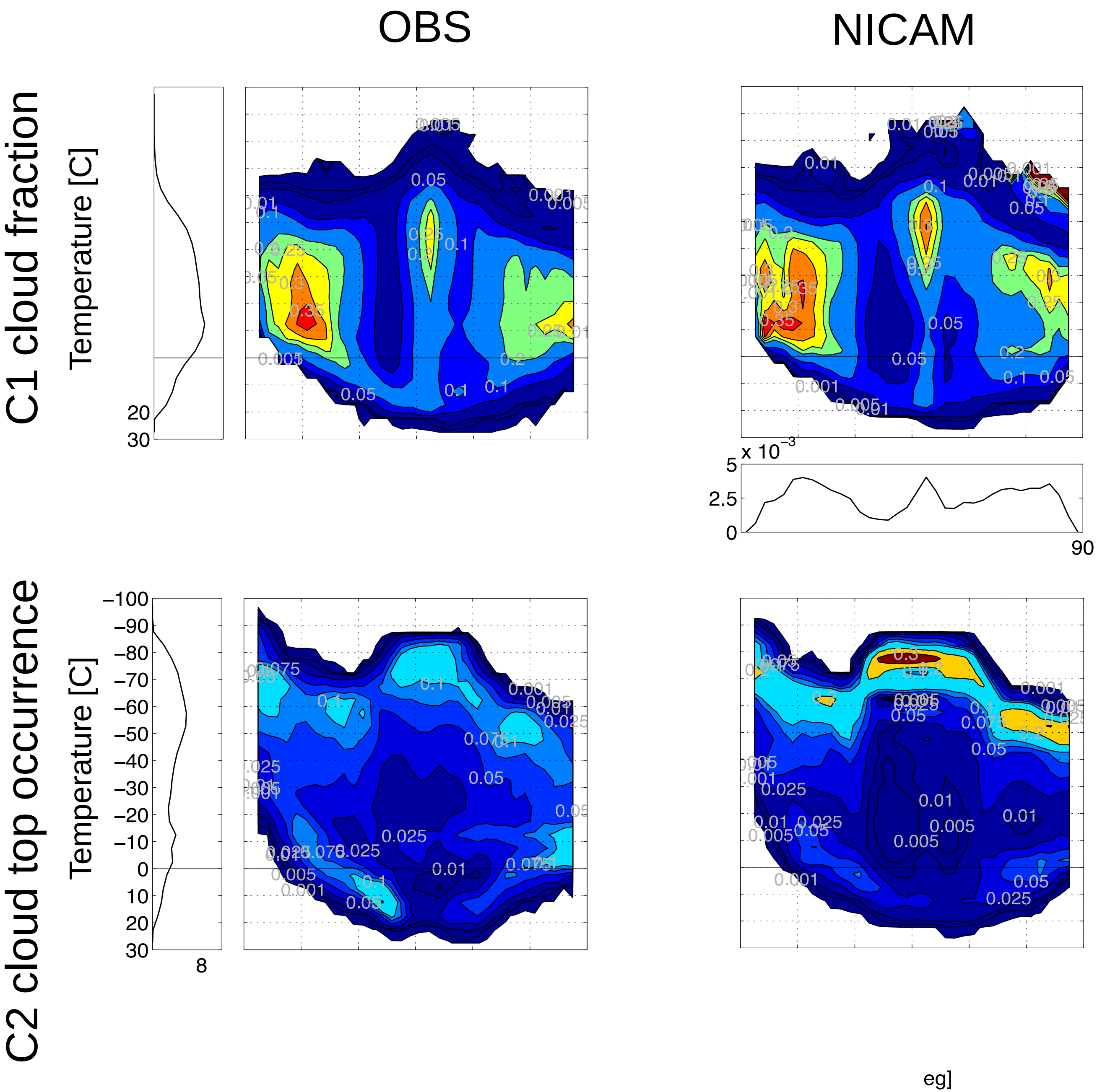
3. Cloud Classification & Cloud radiative forcing analysis

CFAD（obs） of Cloud Ice Effective Radius



CloudSat–CALIPSO merged dataset (CSCA-MD) [Hagihara et al. 2010, JGR; Okamoto et al. 2010]

Meridional-Temperature distribution



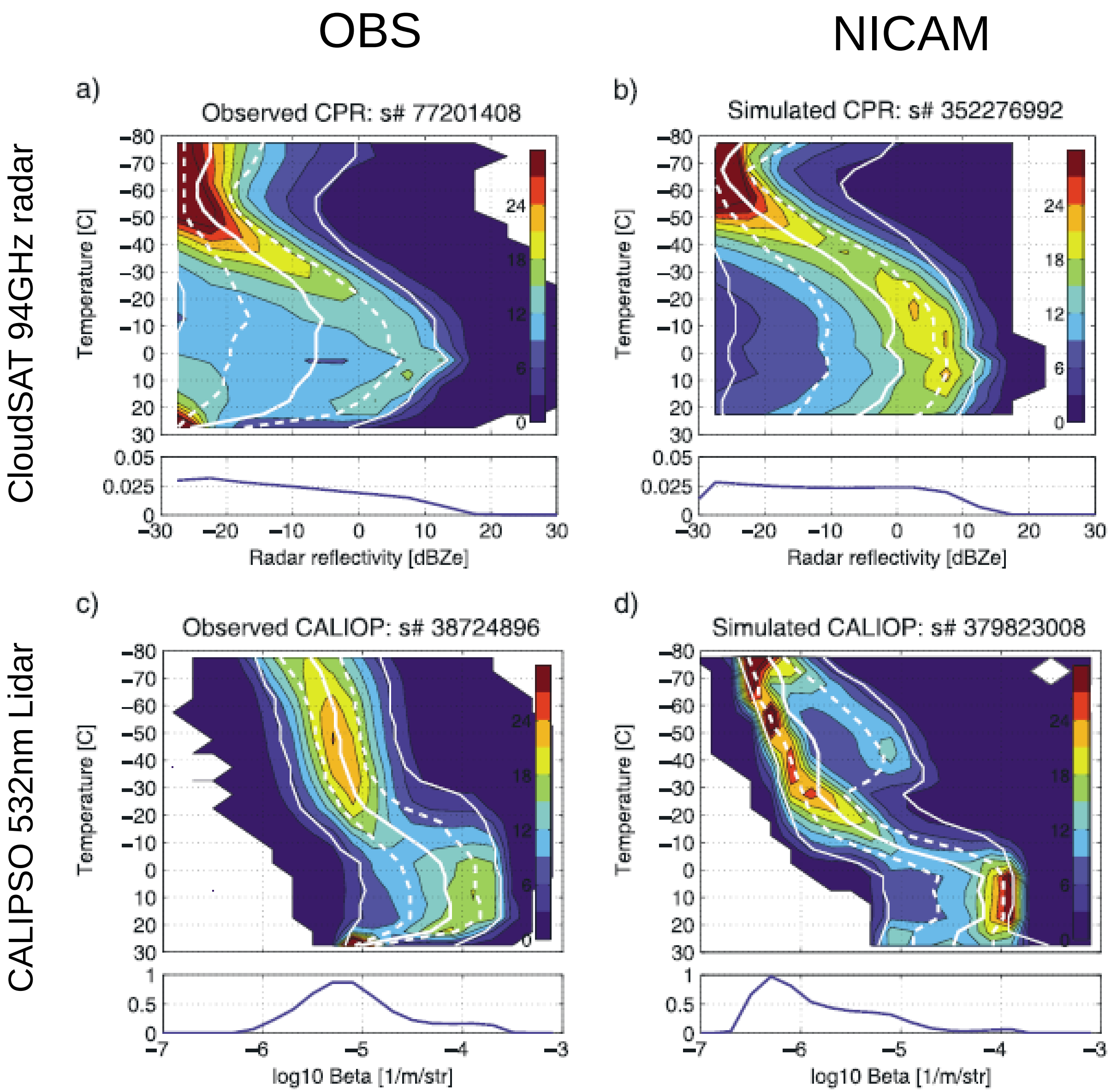
NICAM

- C1 CF: generally good agreement with OBS (R=0.88).
- Captures the max CF in the tropics.
- Overestimates
  - ✓ high clouds at T < -30° C over most of the latitudes.
  - ✓ low-level clouds in high latitudes.
- Underestimates
  - ✓ subtropical warm clouds

Further info on cloud types

- C2 CTO: poor agreement with OBS.
- Captures the high and low clouds qualitatively.
- Misses middle clouds (-20 < cloud top T < -10C) in the tropics and northern mid latitudes.
- Polar stratospheric clouds are simulated.
- Higher relative occurrences of high clouds.

Global Contoured Frequency by tEmperature Diagram (CFED)



OBS

- one single dominant mode for a given T at T < -10C (z as vertical axis does not show it)

NICAM

- High occurrences of small dBZe especially at -60<T< -30° C.
- Overestimates the occurrence of 0 < dBZe' < 10 dB.
- The 95th quantile smaller at T < -40 ° C and -20 < T < 10 ° C.
- The 50th quantile larger at -35 < T < 0 ° C.

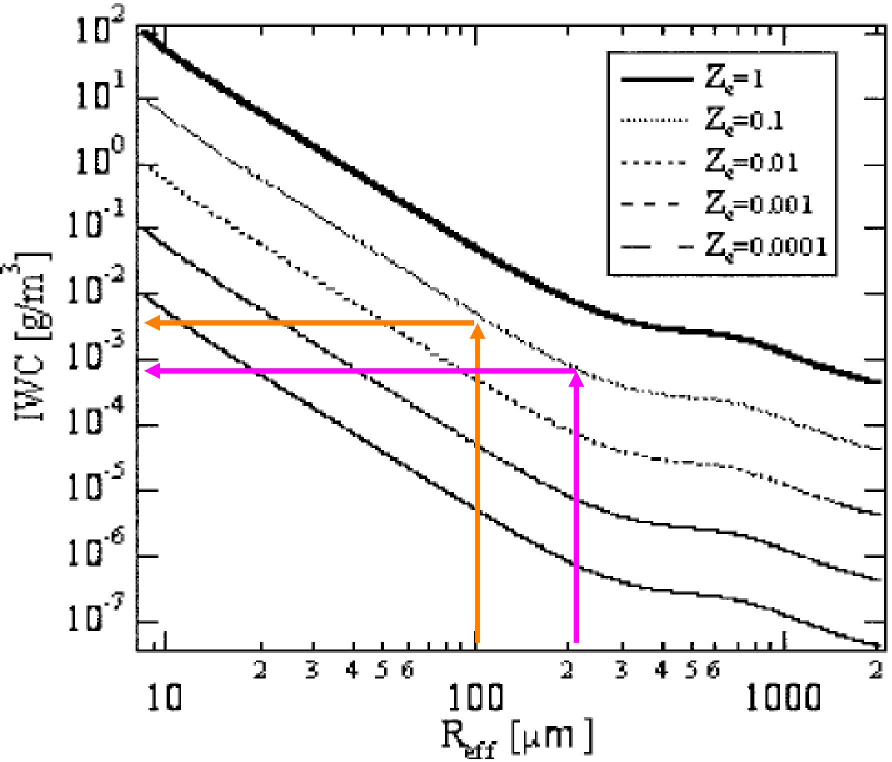
- Two modes exist for $\log10(\beta_{532})$ at T < -40° C level.
- the 75th and 95th quantiles underestimated for liquid

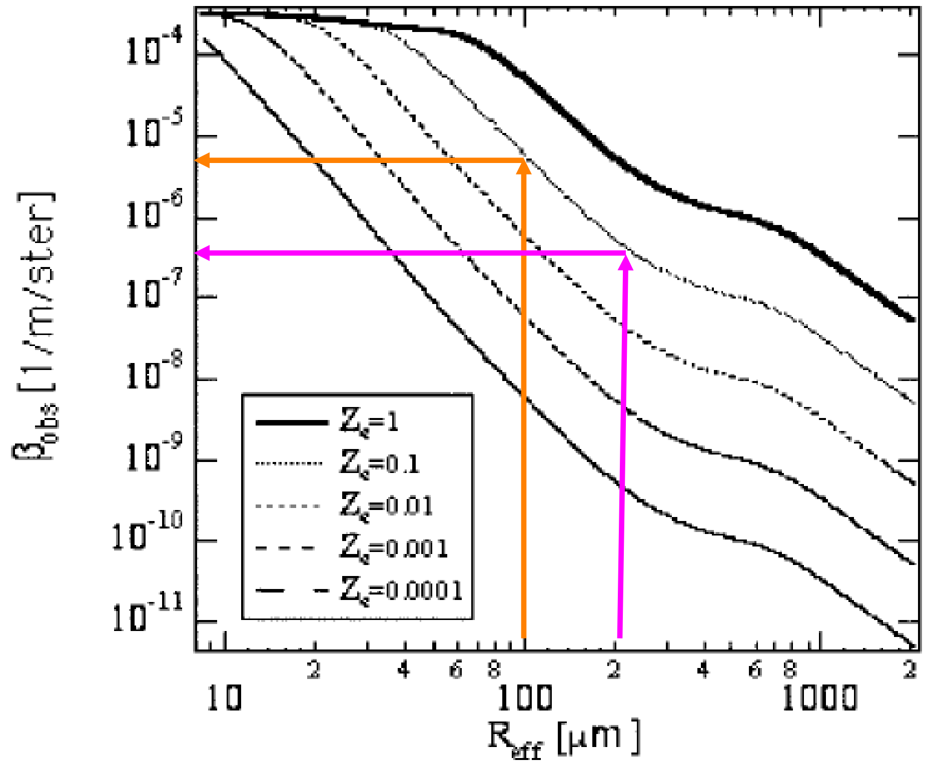
Contribution of each hydrometeor category

Cloud ice
Cloud droplets
Snow
Rain
Graupel

BETa-TEmperature Radar-conditioned diagram (BETTER)

Okamoto et al. (2003) *Aim: obtain the relative information on size and IWC.*

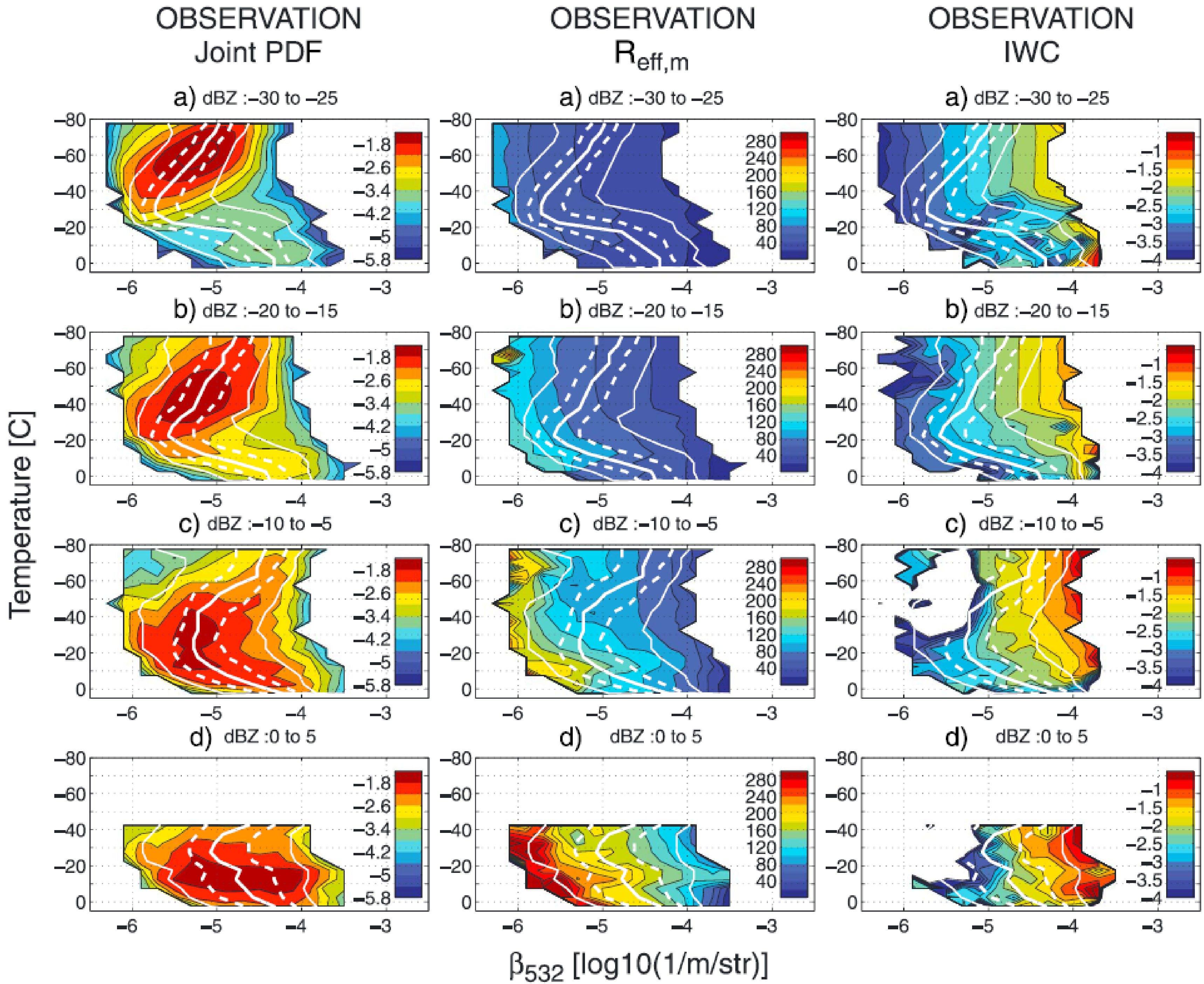


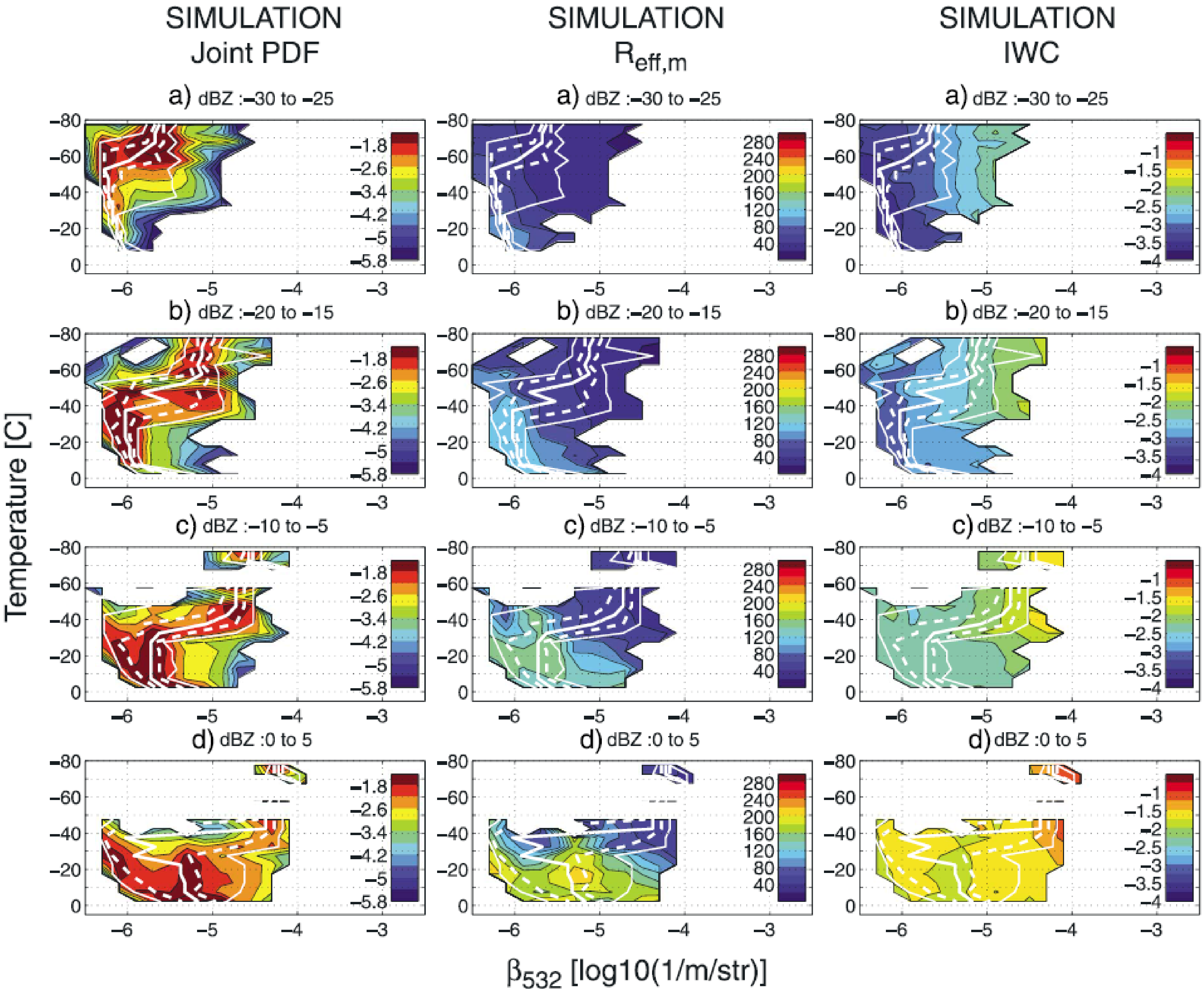


If Z_e are the same among two grid boxes, smaller R_{532} means larger $R_{eff,m}$ and smaller IWC

Assumption

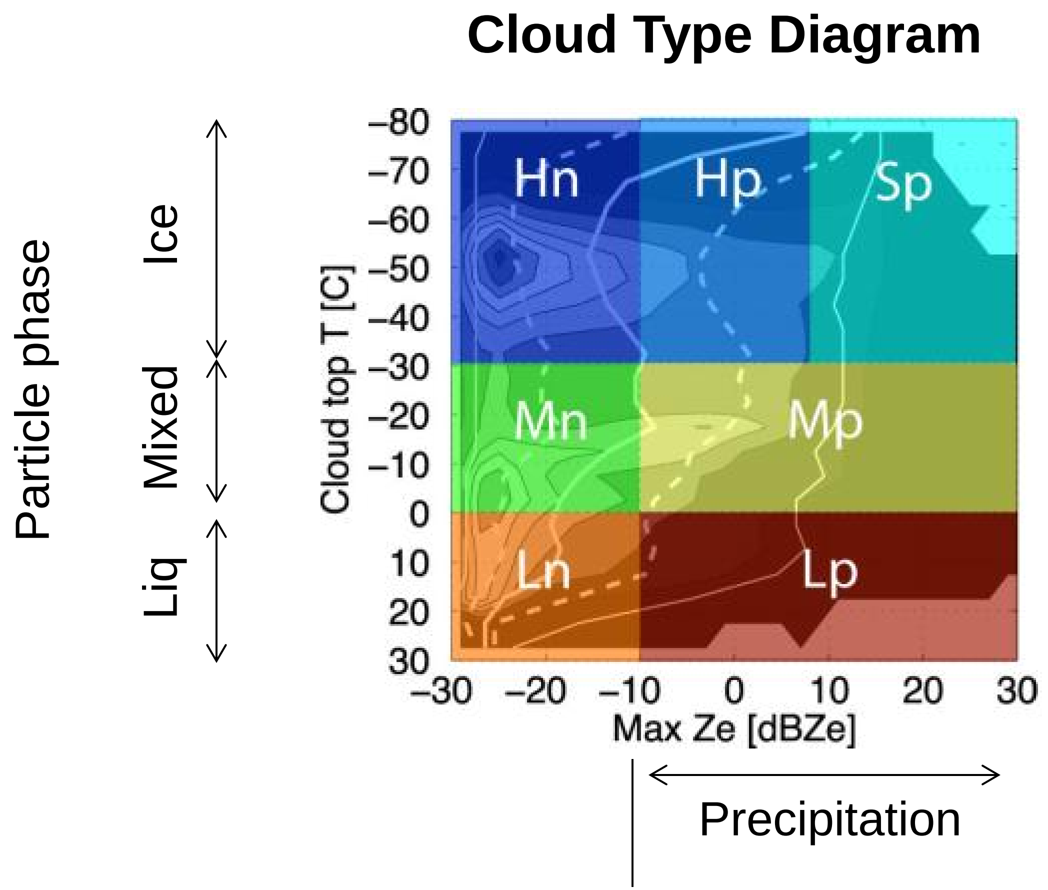
Both the observation and simulation follow a similar R_{532} - $R_{eff,m}$ and IWC - $R_{eff,m}$ relationship for a given Z_e.

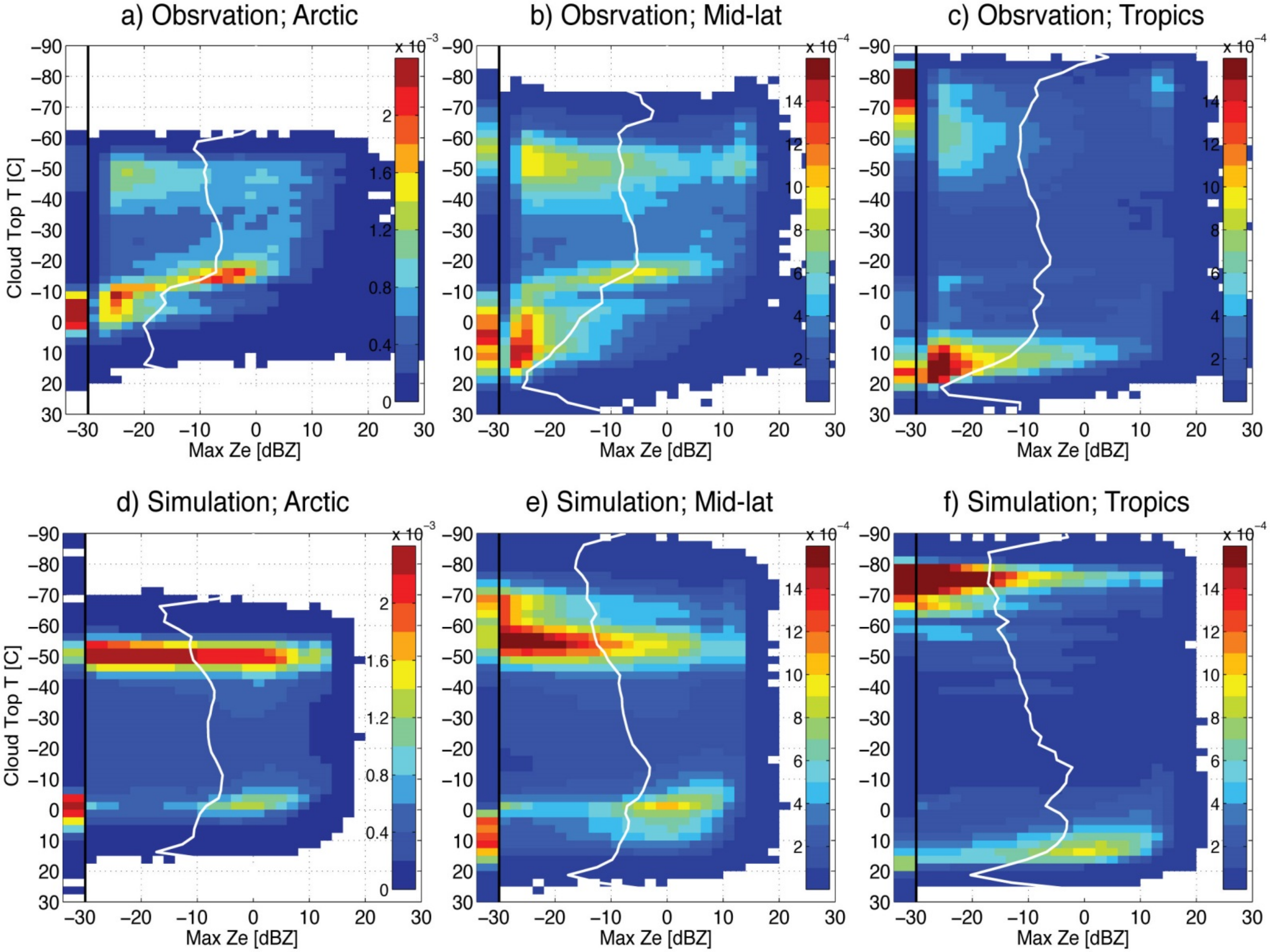

OBSERVATION
Joint PDF
OBSERVATION
$R_{eff,m}$
OBSERVATION
IWC
a) dBZ :–30 to –25
b) dBZ :–20 to –15
c) dBZ :–10 to –5
d) dBZ :0 to 5
Temperature [C]
β_{532} [log10(1/m/str)]


SIMULATION
Joint PDF
SIMULATION
$R_{eff,m}$
SIMULATION
IWC
a) dBZ :−30 to −25
b) dBZ :−20 to −15
c) dBZ :−10 to −5
d) dBZ :0 to 5
Temperature [C]
β_{532} [log10(1/m/str)]

Proposed cloud type diagram

Define Cloud Type by separating the domain of Cloud top T and max Ze into seven sub-domains. H: High, S: Storm, M: Mixed-phase, L: liquid. p is for precipitating, n is for non-precipitating.

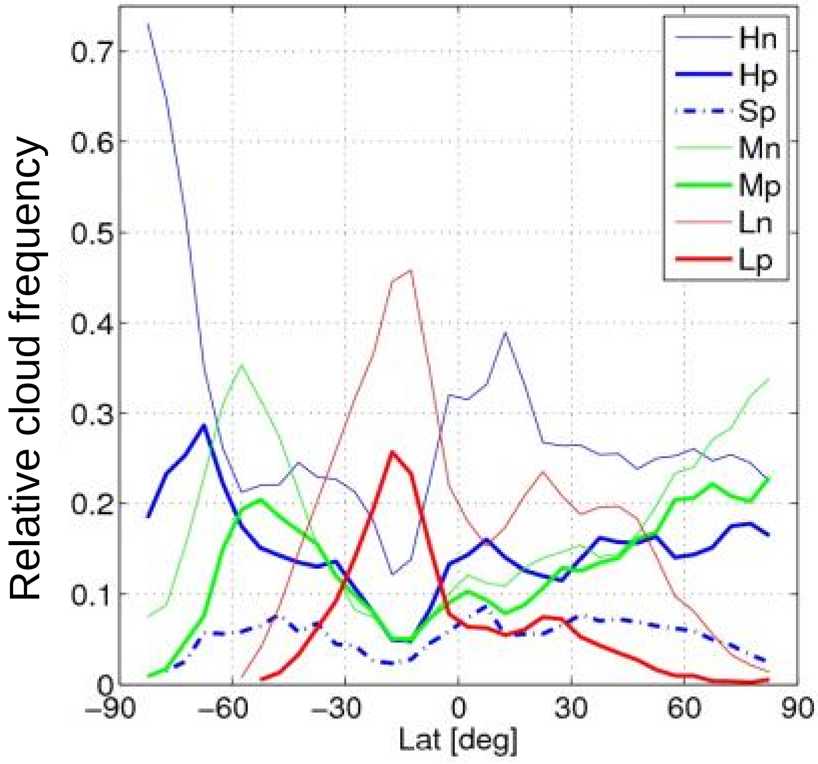




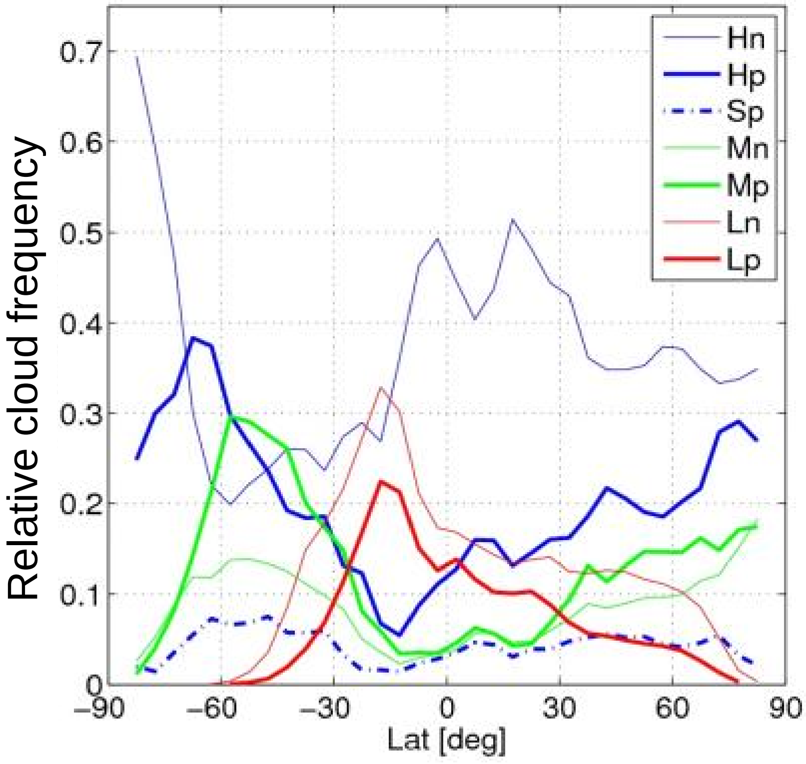
a) Obsrvation; Arctic
b) Obsrvation; Mid-lat
c) Obsrvation; Tropics
d) Simulation; Arctic
e) Simulation; Mid-lat
f) Simulation; Tropics
Cloud Top T [C]
Max Ze [dBZ]
x 10^-3
x 10^-4

Zonal cloud occurrence by cloud type

OBS



SIM



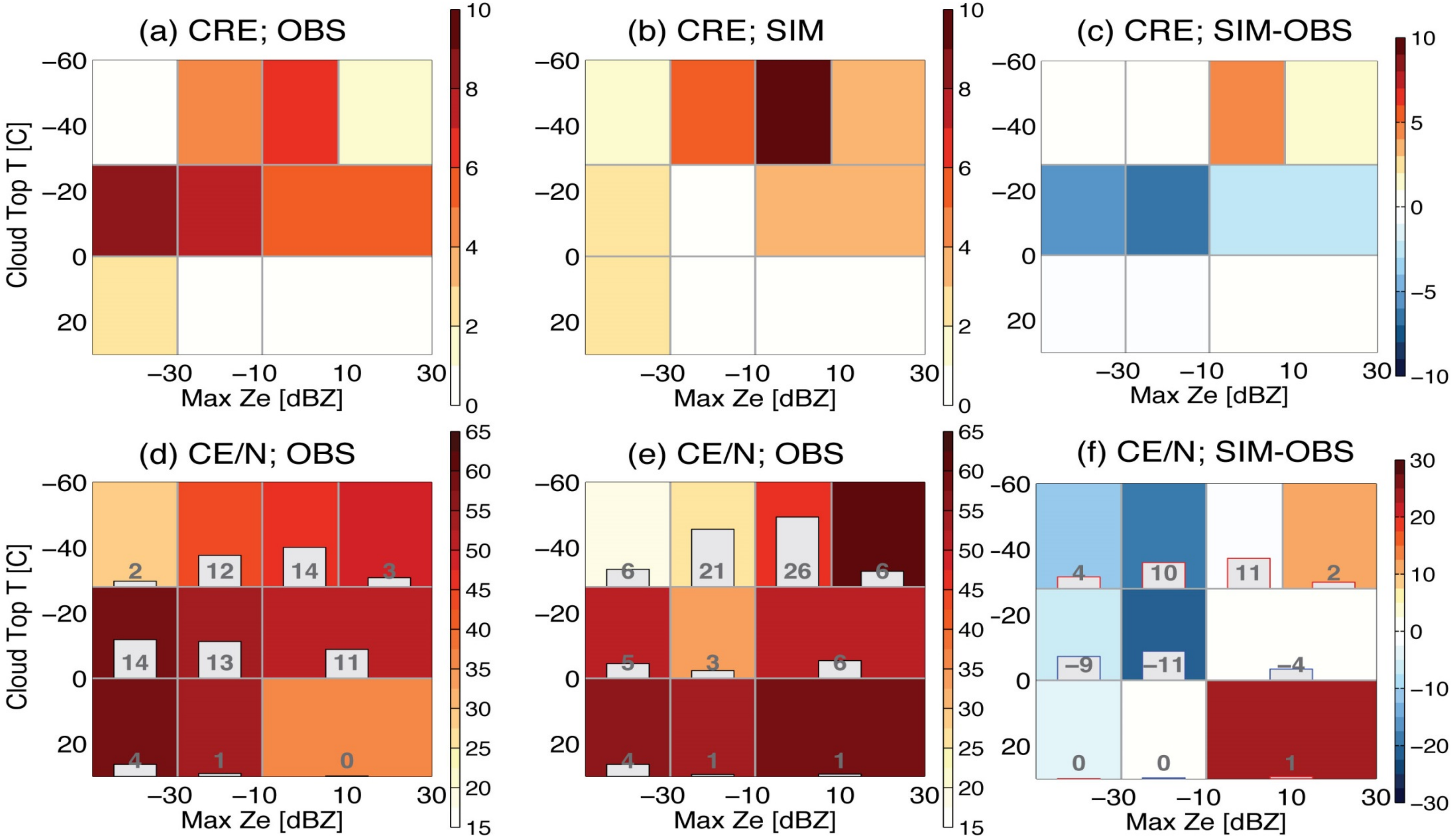
- Hn dominate at Antarctic, Northern latitudes.
- Mn & Mp peaks at 60S and Arctic.
- Ln & Lp peaks at 15S.

- Both of Hn and Hp are overestimated.
- Mp occurs more than Mn.
- Ln is underestimated.

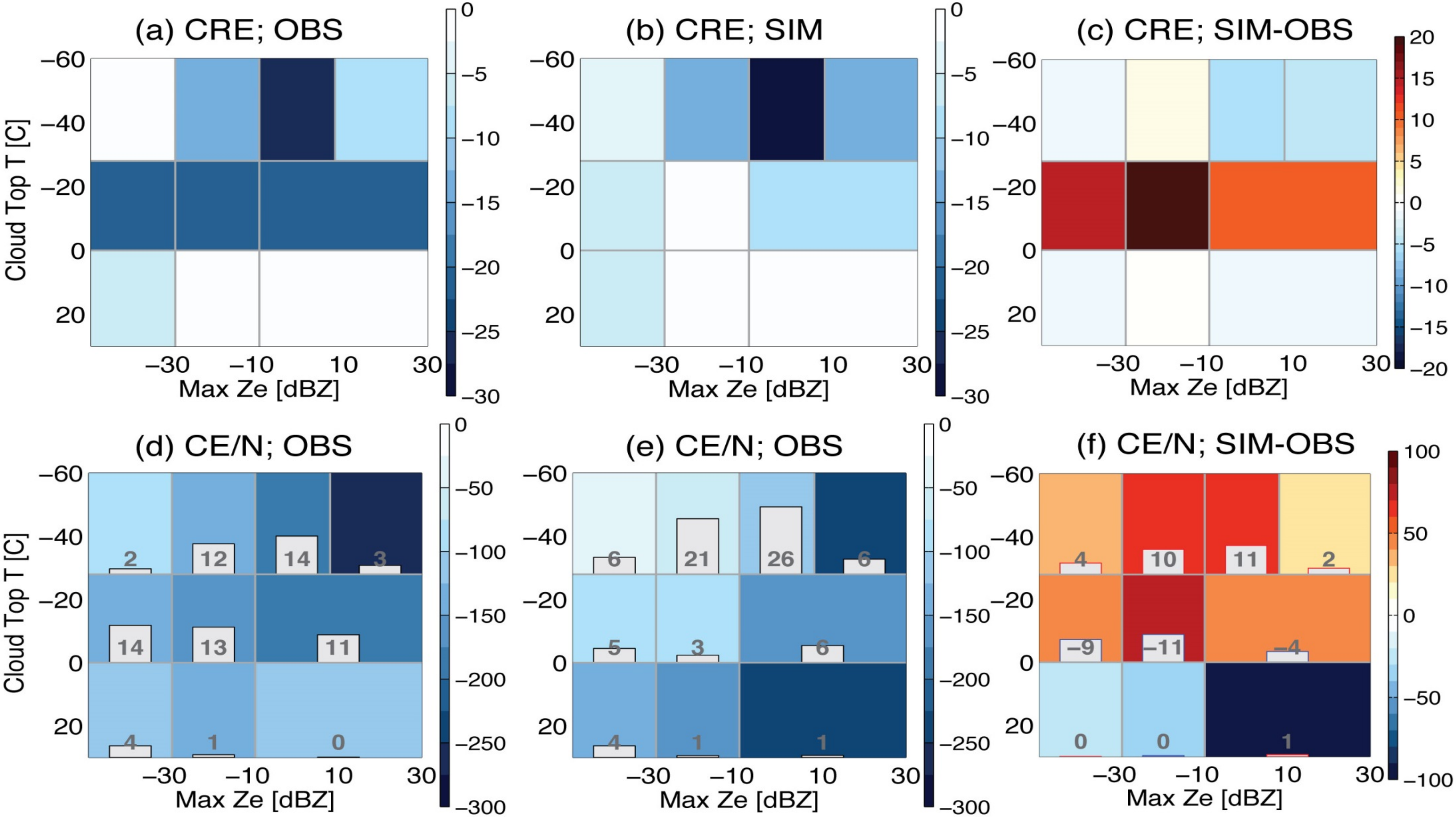
Long Wave Cloud Radiative Effects

$$C = \sum_{i=1}^{10} C_i,$$
$$= \sum_{i=1}^{10} N_i \cdot CE_i,$$

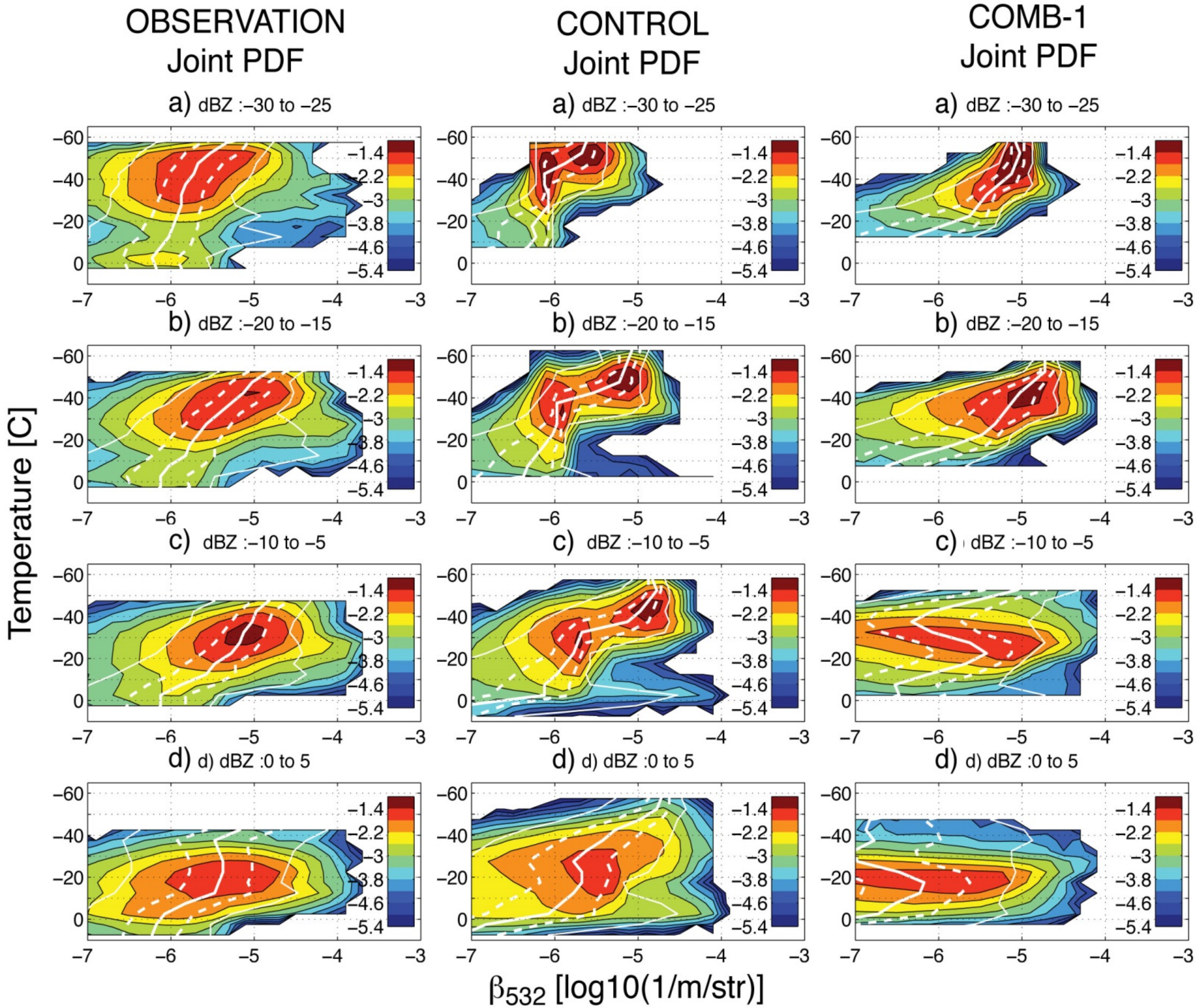
over the Arctic band (65-82N)



Short Wave Cloud Radiative Effects over the Arctic band (65-82N)



Sp type

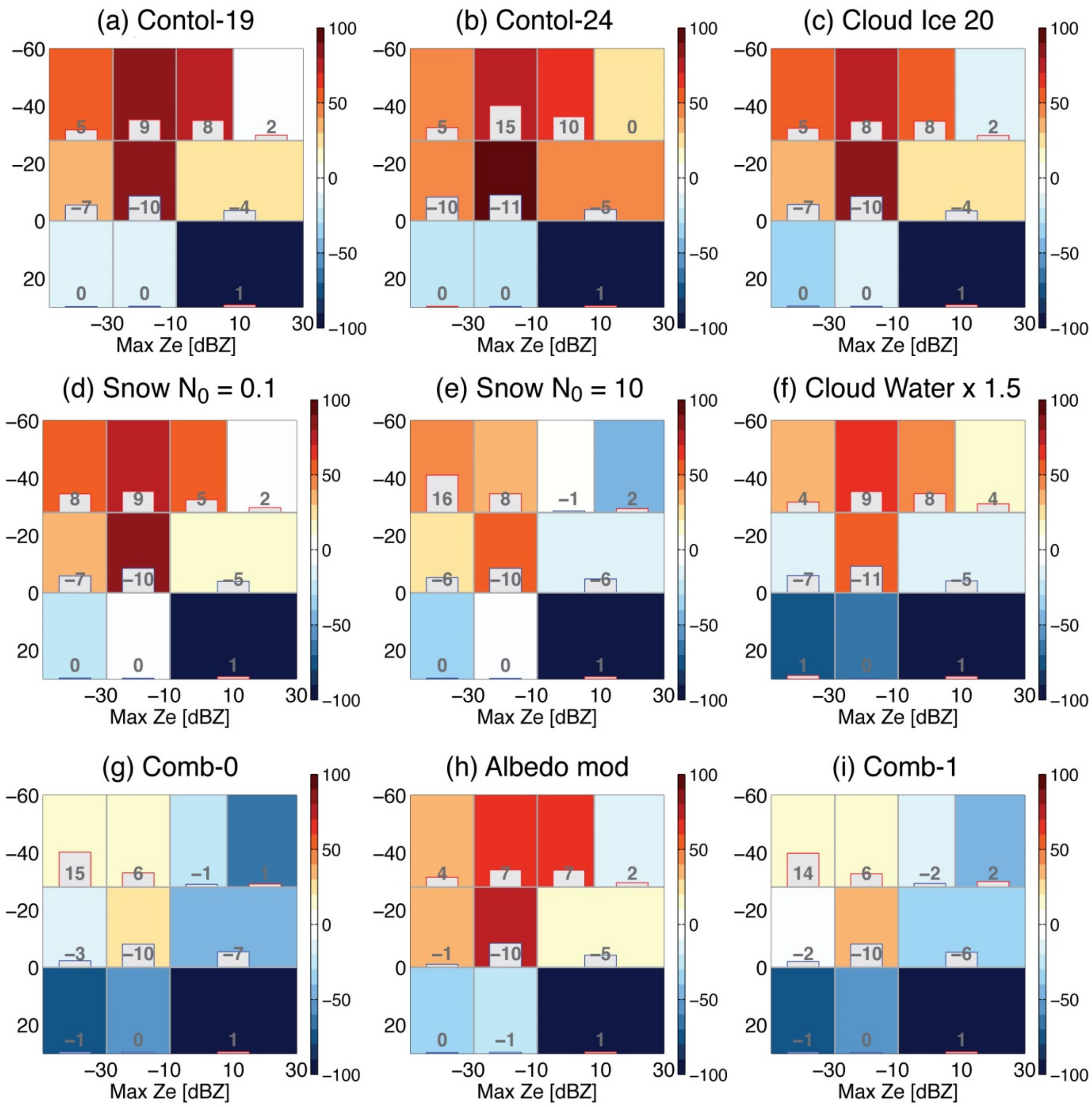


The combined parameter set (snow N_0 = 10 cm^{-4} and cloud water × 1.5)

Beta-temperature radar-conditioned (BETTER) diagram for observation (left), control (middle), and comb1 (right) for Sp cloud layers in the Arctic.

The color fills indicate joint probability density function with logarithmic scale. The white lines denote 5th, 25th, 50th, 75th, and 95th percentiles.

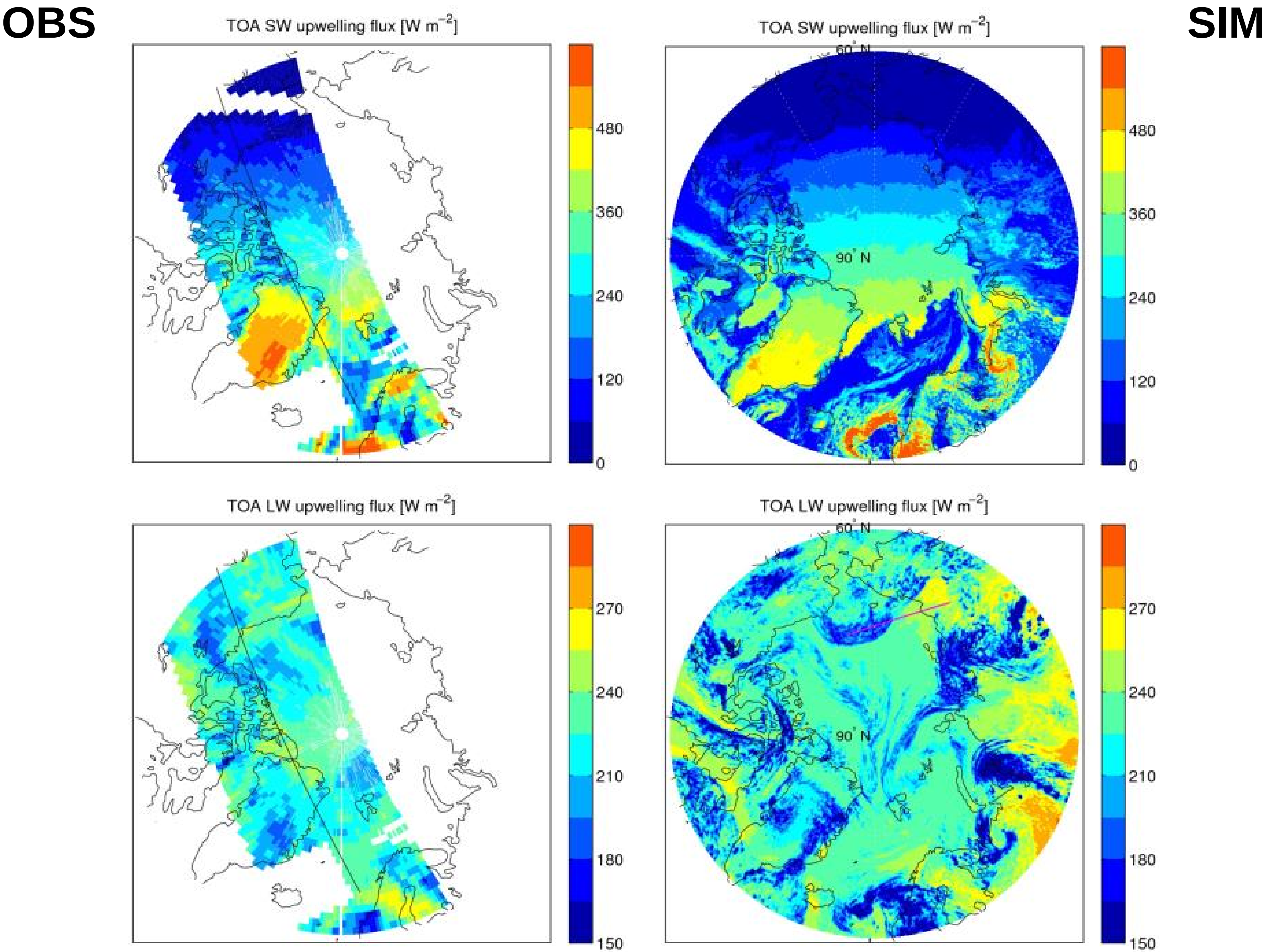
Sensitivity to parameters of the forward models

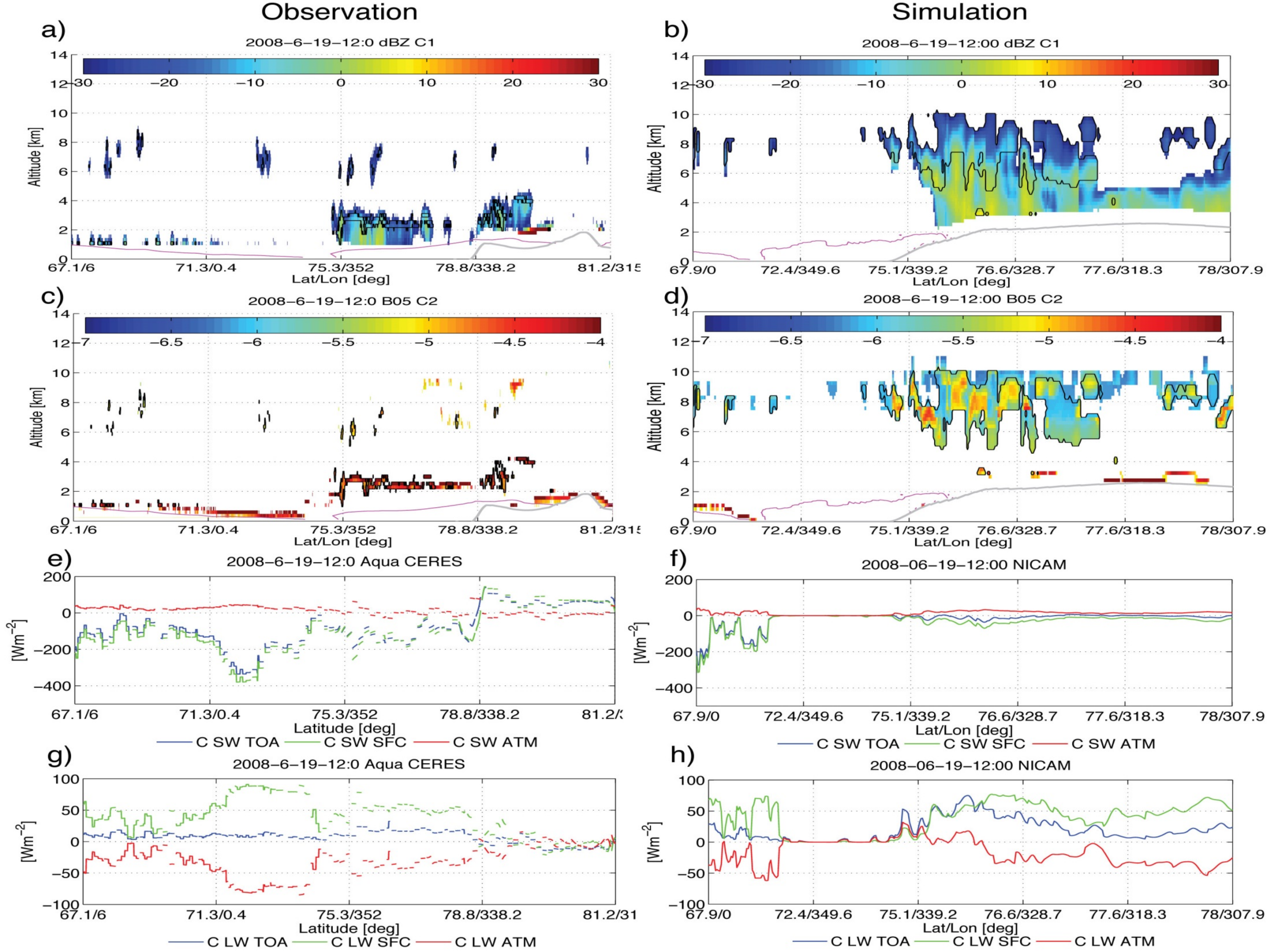


shortwave surface downward flux and cloud fractions

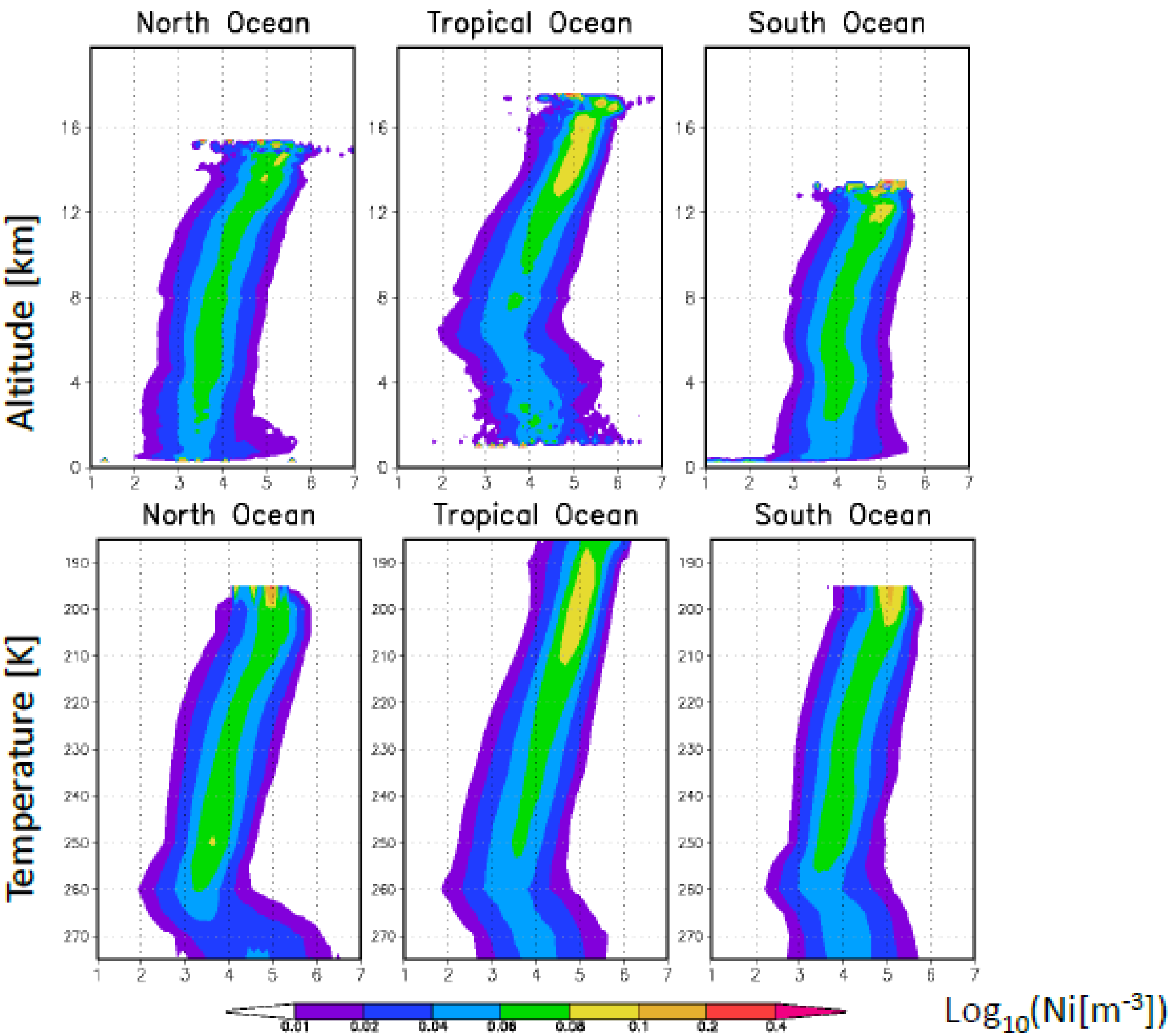
Summary of the studies

- **Evaluation & improvement of cloud microphysics schemes, comparison and development**
  - Hashino et al. (2013) Evaluating cloud microphysics from the NICAM against CloudSat and CALIPSO. J. Geophys. Res., 118, 7273-7293
  - Hashino et al.(2014) Evaluating Cloud Radiative Effects simulated by NICAM with A-train. in prep.
  - Roh and Satoh (2014) Evaluation of precipitating hydrometeor parameterizations in a single-moment bulk microphysics scheme for deep convective systems over the tropical open ocean. J. Atmos. Sci., 71, 2654-2673.
- **Analyze and evaluate cloud changes associated with convective systems (tropical cyclones, extratropical cyclones, cloud clusters, MJOs)**
  - Tropical cyclones (Yamada and Satoh, 2013 JCLI)
  - Cloud clusters & upper clouds (Noda et al. 2014, in review)
  - Extratropical cyclones (Kodama et al., 2014, GRL)

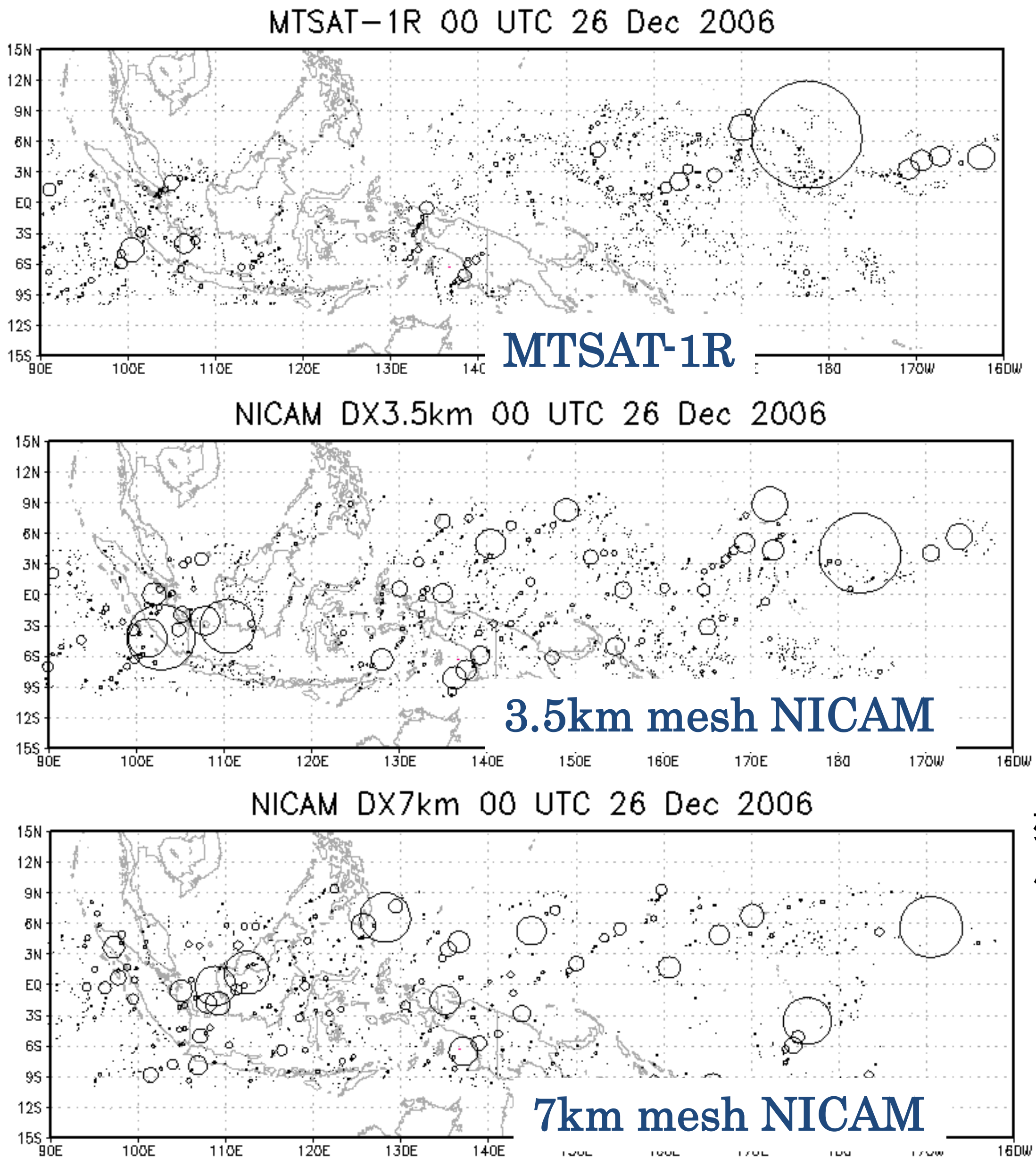

OBS
SIM
TOA SW upwelling flux [W m⁻²]
TOA SW upwelling flux [W m⁻²]
60° N
90° N
480
360
240
120
0
TOA LW upwelling flux [W m⁻²]
TOA LW upwelling flux [W m⁻²]
60° N
90° N
270
240
210
180
150


Observation
Simulation
a)
2008-6-19-12:0 dBZ C1
b)
2008-6-19-12:00 dBZ C1
Altitude [km]
Lat/Lon [deg]
c)
2008-6-19-12:0 B05 C2
d)
2008-6-19-12:00 B05 C2
e)
2008-6-19-12:0 Aqua CERES
f)
2008-06-19-12:00 NICAM
[Wm-2]
Latitude [deg]
C SW TOA
C SW SFC
C SW ATM
g)
2008-6-19-12:0 Aqua CERES
h)
2008-06-19-12:00 NICAM
C LW TOA
C LW SFC
C LW ATM

CFAD of Cloud Ice number (obs)



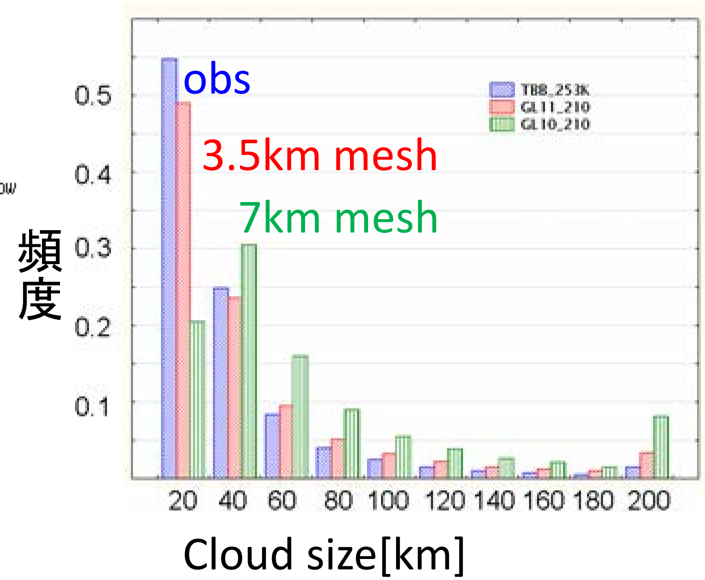
Statistics of cloud size of upper clouds



Inoue et al. (2008, JMSJ)

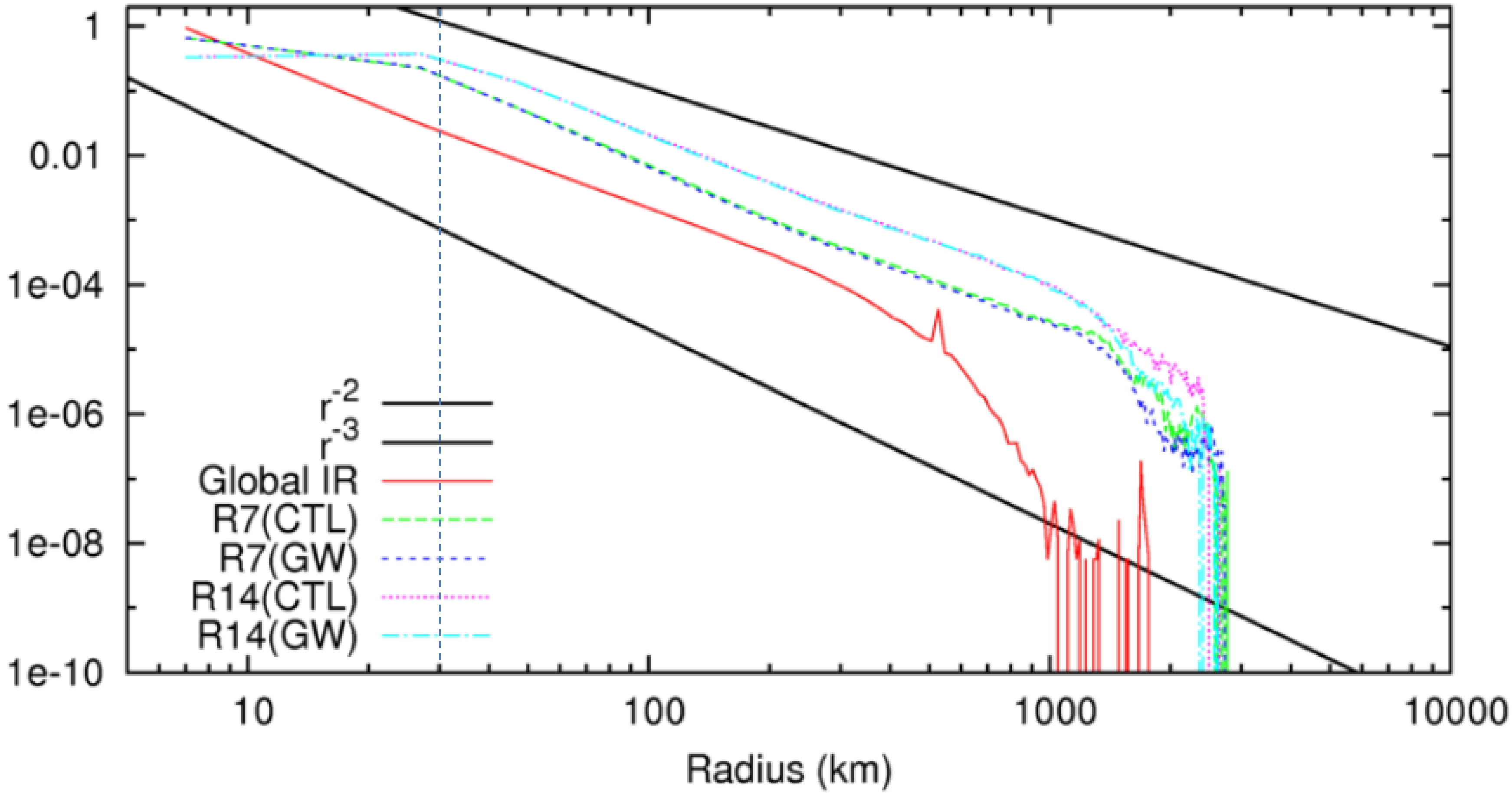
cf. Mapes and Houze (1993, MWR)

High clouds:
•TOA energy balance
•Size related microphysics parameters: tunable



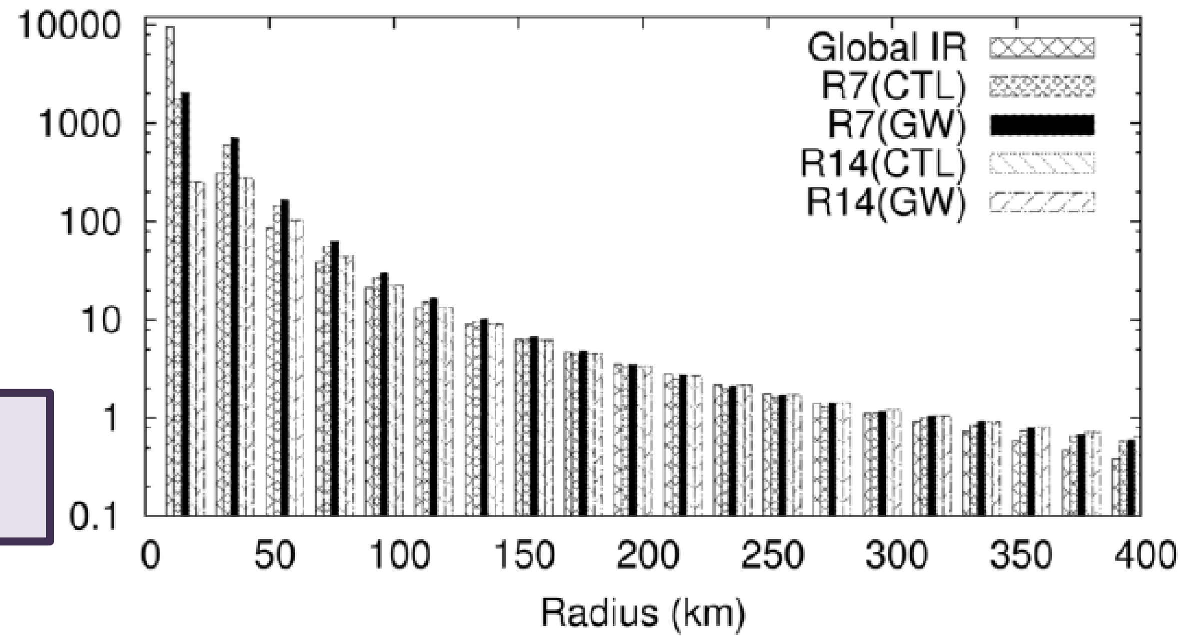
PDFs of high-cloud numbers as a function of cloud size

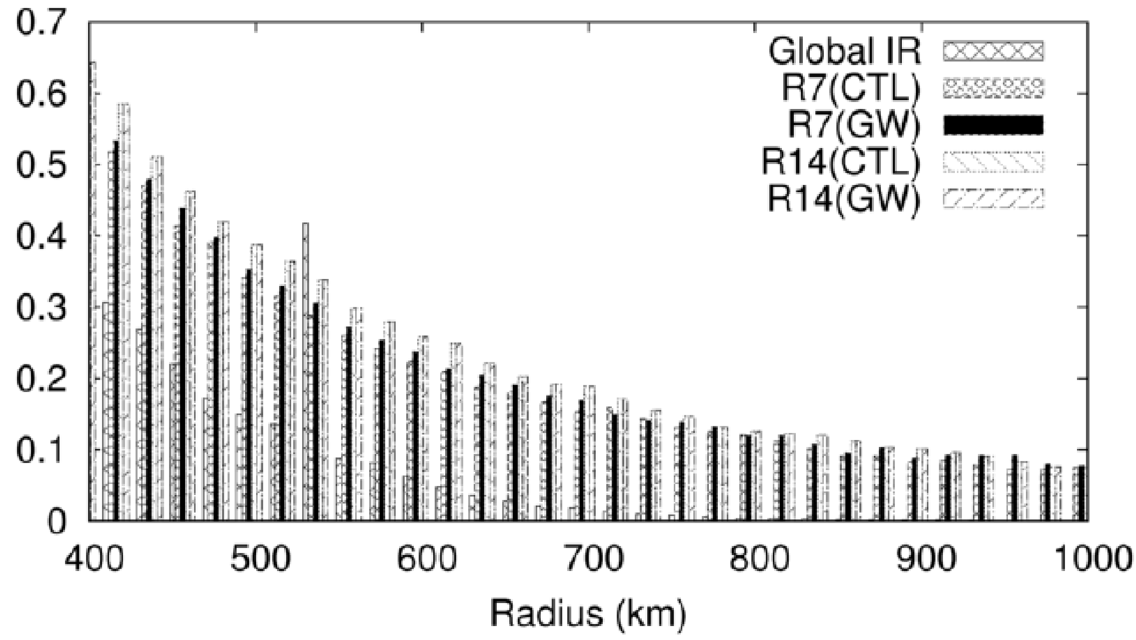
Obs. the global infrared data (Global-IR)
R7 (dx=7km) and R14 (dx=14km) runs of the one-year CTL and GW simulations
Cloud size (radius) is binned every 20 km, and the sum of all values is unity.



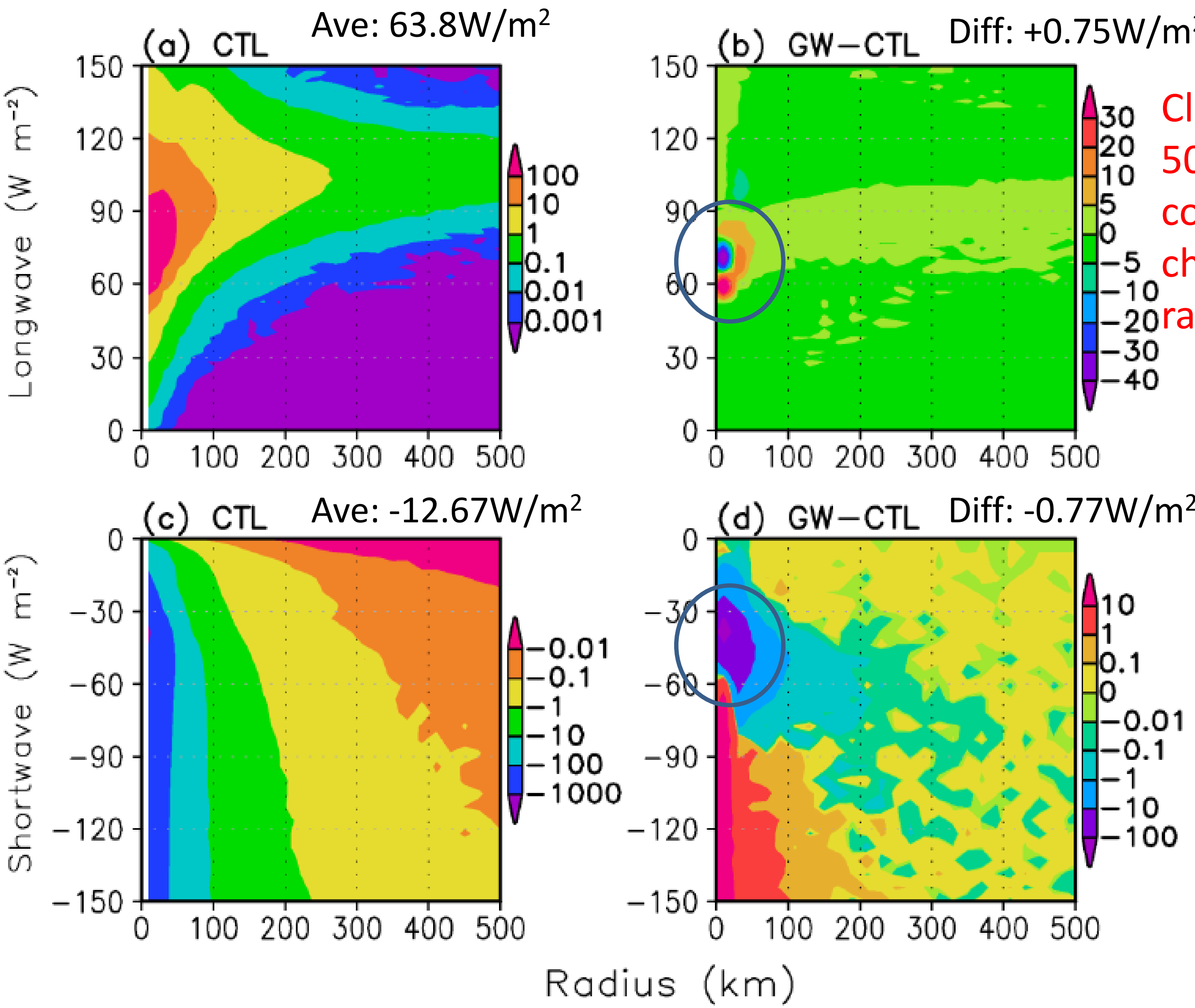
Change in numbers of each size of upper clouds

More anvil numbers
in all size categories





Cloud radiative forcing contributed by each size of high clouds



Clouds smaller than 50 km mostly contribute to changes in cloud radiative forcing