Development of cloud algorithm for GEMS: Synthetic cloud data

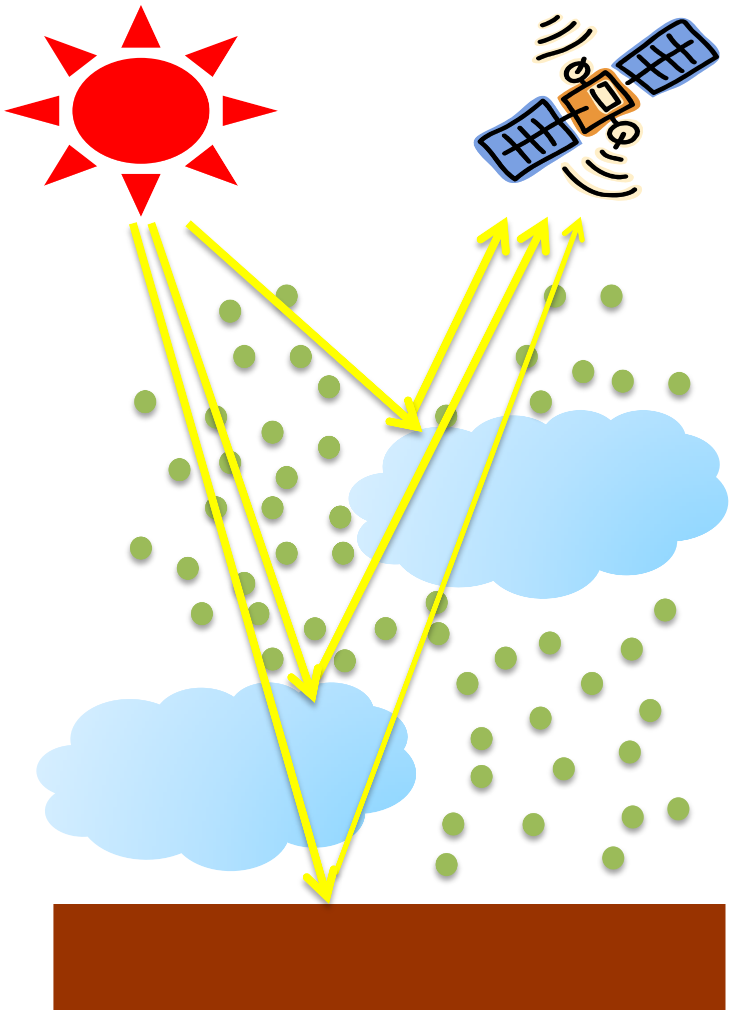
Yong-Sang Choi[1], Bo-Ram Kim[1], Heeje Cho[2]

[1]Ewha Womans University

[2]Seoul National University

Climate System Laboratory

Introduction



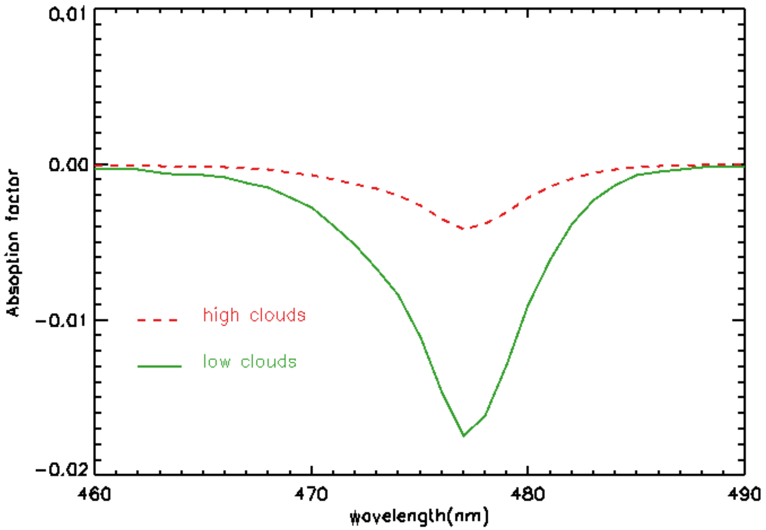
- Cloud contamination causes
  ➔ errors in air mass factor
  ➔ errors in gas/aerosol retrievals

- Accurate cloud data will serve to
  ➔ better **cloud screening** for gas/aerosol retrieval
  ➔ better **cloudy-sky gas/aerosol retrievals***

****Vasilkov et al. (2004) Improving total column ozone retrievals by using cloud pressures derived from Raman scattering in the UV"***

Theoretical background for cloud pressure retrieval

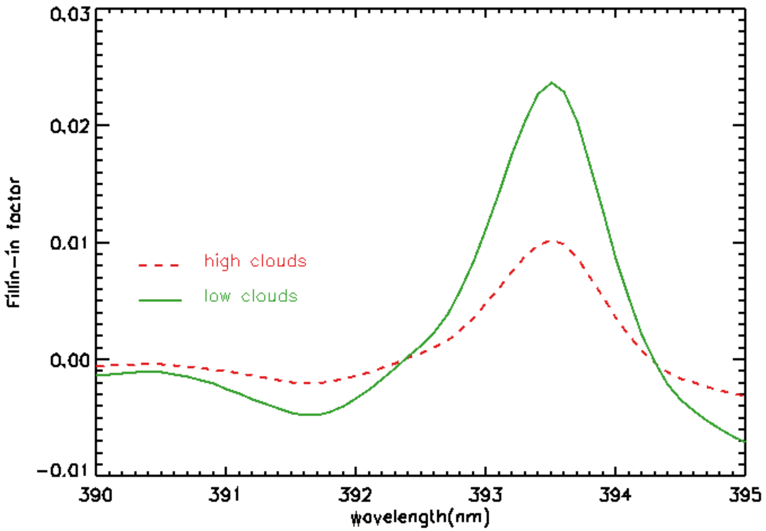
O_2-O_2 absorption (477 nm)



$$A(\lambda) = \left[R_m(\lambda) - R_f(\lambda)\right]/R_f(\lambda)$$

- $R_m(\lambda)$: the measured reflectance
- $R_f(\lambda)$: the calculated reflectance using without O_2-O_2 absorption

Rotational Raman scattering (393.6 nm)



$$k(\lambda) = \left[I_m(\lambda) - I_R(\lambda)\right]/I_R(\lambda)$$

- $I_m(\lambda)$: the measured radiance
- $I_R(\lambda)$: the calculated radiance using only Rayleigh scattering

The cloud retrieval algorithm and its validation problems

Input Data
- Radiance and spectral reflectance($R = \pi L / E$) of 300~500 nm
- Location (longitude, latitude, local time)
- Calculated scattering angle from location data

Using O_2-O_2 absorption band at 477 nm

Calculating cloud effective fraction

$$c = \frac{(R_{meas} - R_{clear})}{(R_{cloud} - R_{clear})}$$

- R_{meas} : the measured reflectance
- R_{clear} : the reflectance for clear sky from surface albedo database
- R_{cloud} : the calculated reflectance of a completed cloudy pixel

Calculating cloud pressure

1. DOAS fit : to determine the continuum reflectance and the slant column density O_2-O_2
2. A look-up table : to determine the altitude, z_L
3. The cloud altitude z_L is translated to the cloud pressure, $p_L(O_2)$

Using Ring effect at 393.6 nm

Calculating cloud effective fraction

$$f = \frac{(I_{clear} - I_{meas})}{(I_{clear} - I_{cloud})}$$

- I_{meas} : the measured TOA radiance
- I_{clear} : the calculated radiance for clear sky
- I_{cloud} : the calculated radiance of a completed cloudy pixel

Calculating cloud pressure

1. Filling-in factor, k : to quantify the RRS (Rotational Raman Scattering) effect on radiance

$$k(\lambda) = [I_m(\lambda) - I_R(\lambda)]/I_R(\lambda)$$

- $I_m(\lambda)$: the measured radiance
- $I_R(\lambda)$: the calculated radiance using only Rayleigh scattering

2. A look-up table : to determine the altitude, z_L
3. The cloud altitude z_L is translated to the cloud pressure, p_L(RRS)

Output data
- Cloud effective fraction
- Cloud pressure

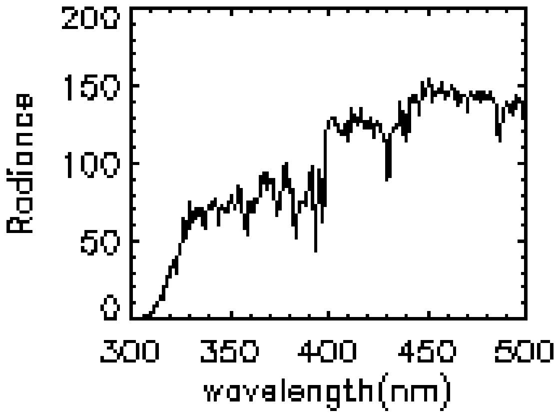
Is the cloud retrieval algorithm correctly working?

- To validate the cloud retrieval algorithm, we need cloud data, which is physically consistent with radiance data.

(*Problem 1*)
Every cloud data has observational errors.

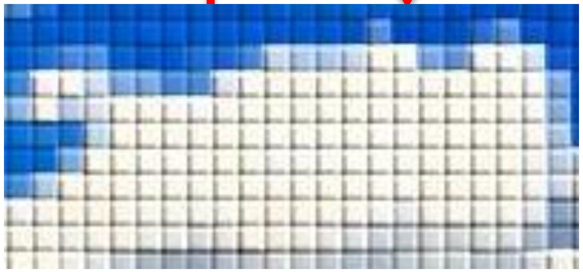
(*Problem 2*)
No geostationary spectral UV/VIS radiance observations exist.

Concept of synthetic (or proxy) data



Forward RT simulation

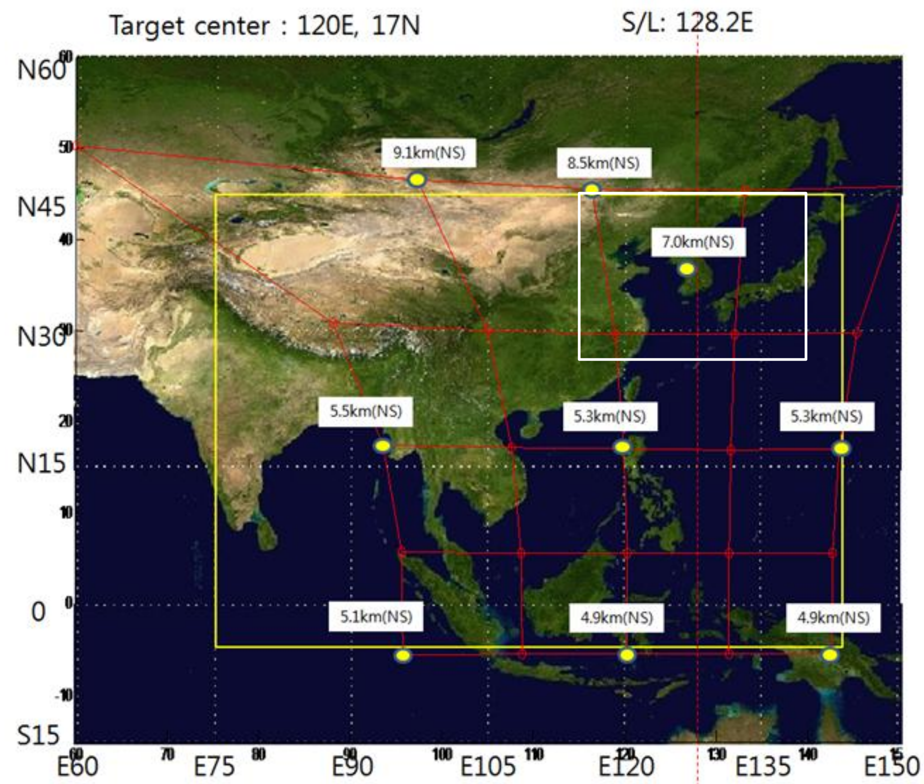
Retrievals by our cloud algorithm



Known (WRF) cloud profiles

WRF (Weather Research & Forecasting Model) Data

Area: 25°−45° N, 110° −140° E



Region of interest

Simulated region

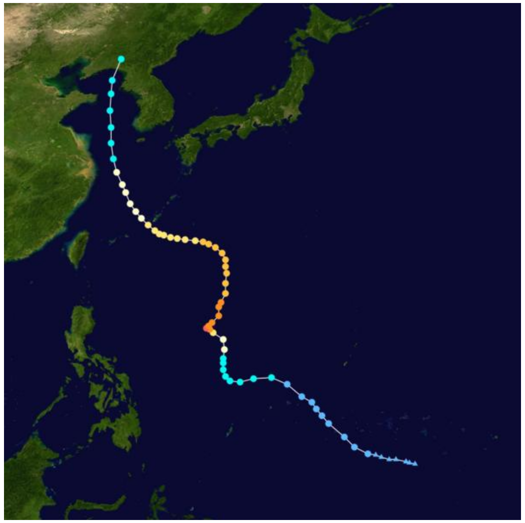
Projected FOV

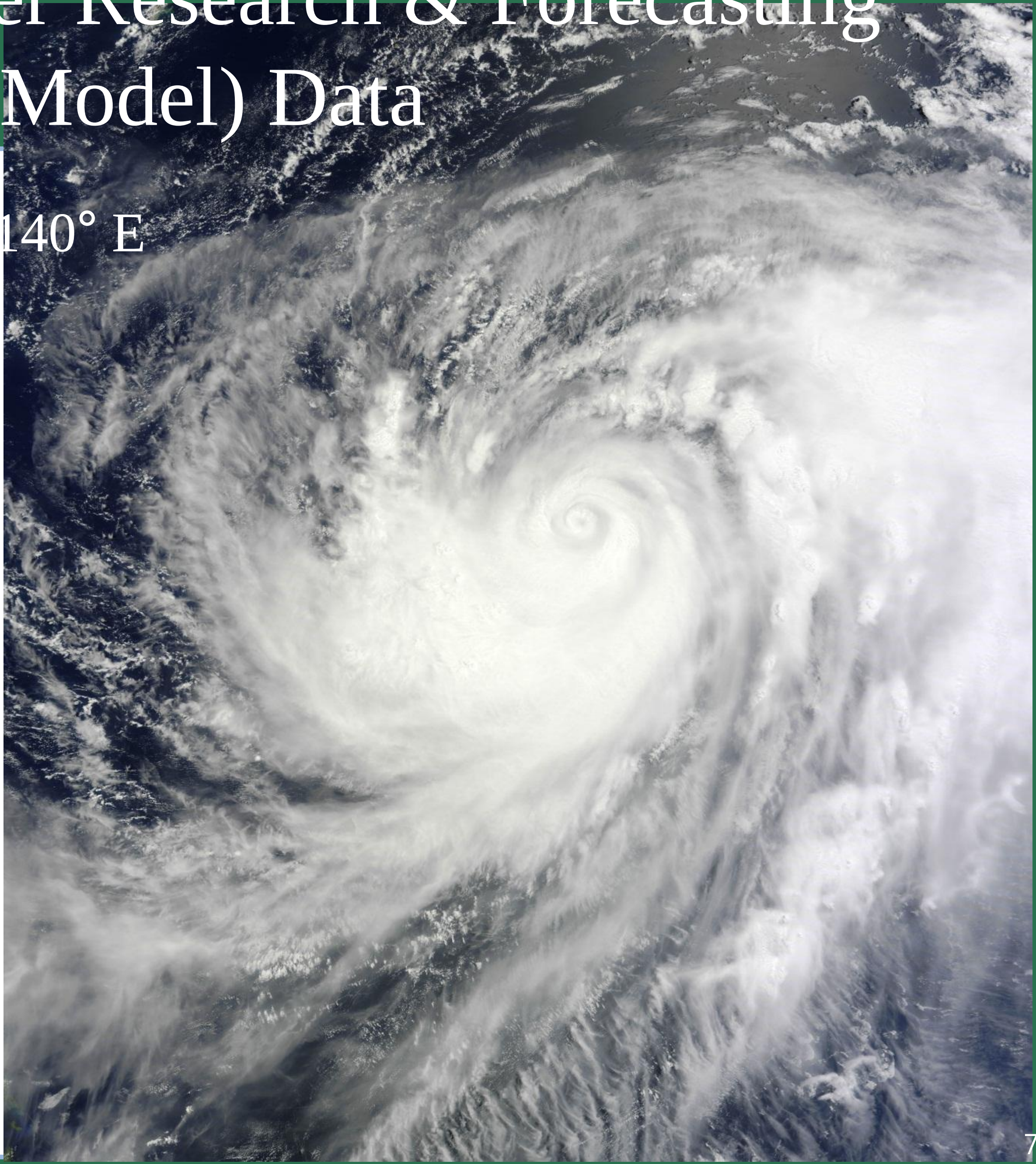
WRF (Weather Research & Forecasting Model) Data

Area: 25°–45° N, 110° – 140° E

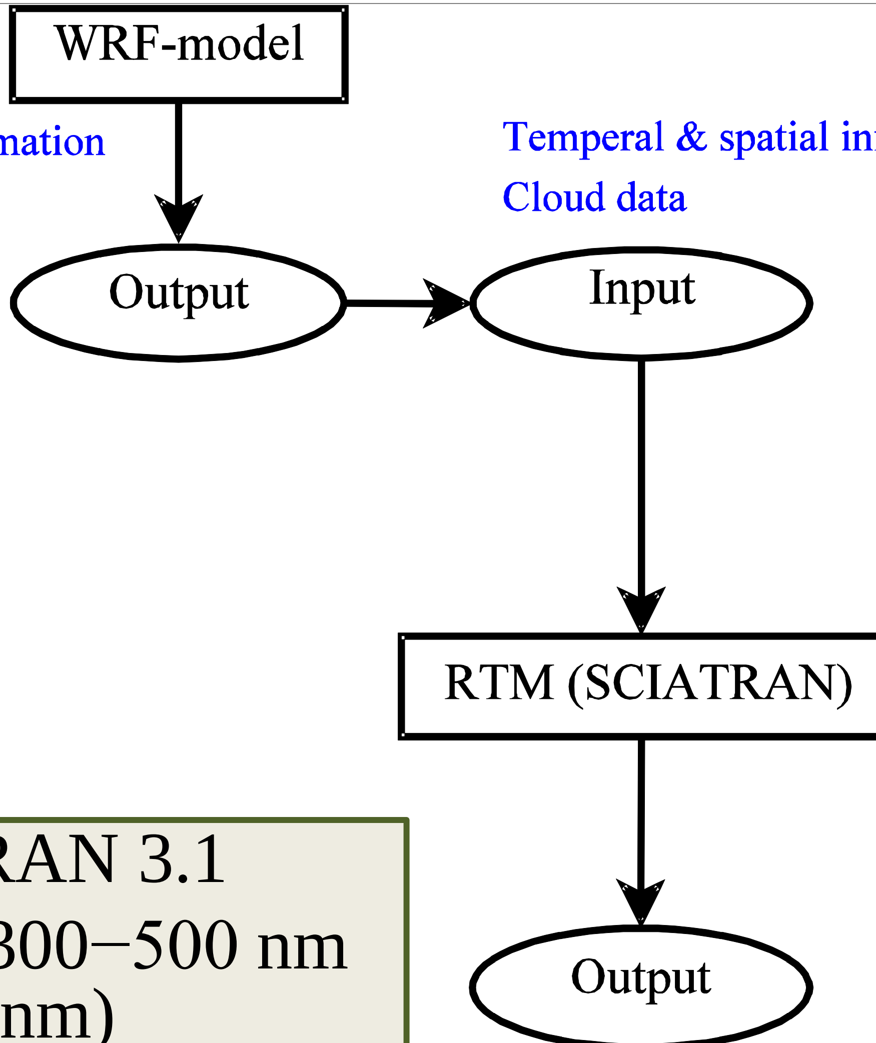
Period: Aug. 6–7, 2011

(Typhoon Muifa)





Radiative transfer simulation



Temperal & spatial information
Meteorological variables

- Filename (date, time)
- XLAT (degree_north)
- XLON (degree_east)
- PH (pertubation geopotential)
- PHB (base state geopotential)
- P (perturbation pressure)
- PB (base stat pressre)
- T (perturbation potential temperature)
- T00 (base state temperature)
- HGT (terrain height)
- QCLOUD (cloud water mixing ratio)
- QICE (ice mixing ratio)
- QVAPOR (water vapor mixing ratio)
- LU_INDEX (land use category)

Temperal & spatial information
Cloud data

- Latitude
- Longitude
- Surface albedo
- Height above sea level
- Date
- Solar zenith angle
- Viewing angle
- Azimuth angle
- Field of view size
- Cloud layer base and top
- Cloud vertical profile (optical thickness/water path/ water content)
- Thermodynamic state
- Scattering & absorption coeff.
- Phase function of cloud layers

Synthetic satellite level1 data

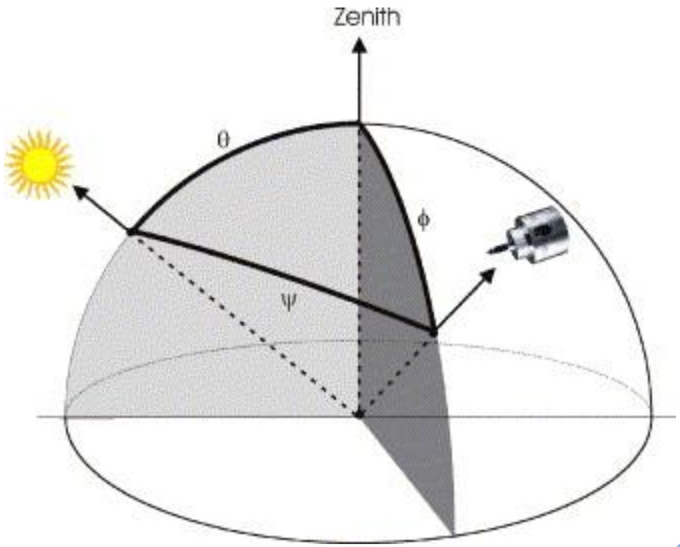
Model: SCIATRAN 3.1
spectral range: 300−500 nm
(resolution: 0.6 nm)

Assumptions for RT simulation

- Land use type
  - sand, snow, water, vegetation, or soil
- Cloud
  - All clouds are composed of 1-layer and **vertically homogeneous** (due to vertical inhomogeneity errors in SCIATRAN)
  - Size of liquid particle: 12 μm
  - Size of ice particle: 100 μm
  - Shape of ice particle: "fractal" (SCIATRAN 3.1)

Angle geometry

- RT simulations are performed with due considerations of the angle geometry.
  - $Solar\ zenith\ angle = F(lat, lon, date, time)$
  - $Satellite\ viewing\ angle = F(lat, lon, lon_{sat})$
  - $Relative\ azimuth\ angle = F(lat, lon, lon_{sat}, time, date)$



Cloud water/ ice mixing ratio → water/ ice contents

Using ideal gas law ($P = \rho RT$),

$$mixing\ ratio\ (g/g) = \frac{water\ (ice)\ mass}{dry\ air\ mass}$$

$$mixing\ ratio\ \left(n^{th}\ level\right) \times \rho_n\ (dry\ air\ density) = water\ (ice)\ content\ (g/m^3)$$

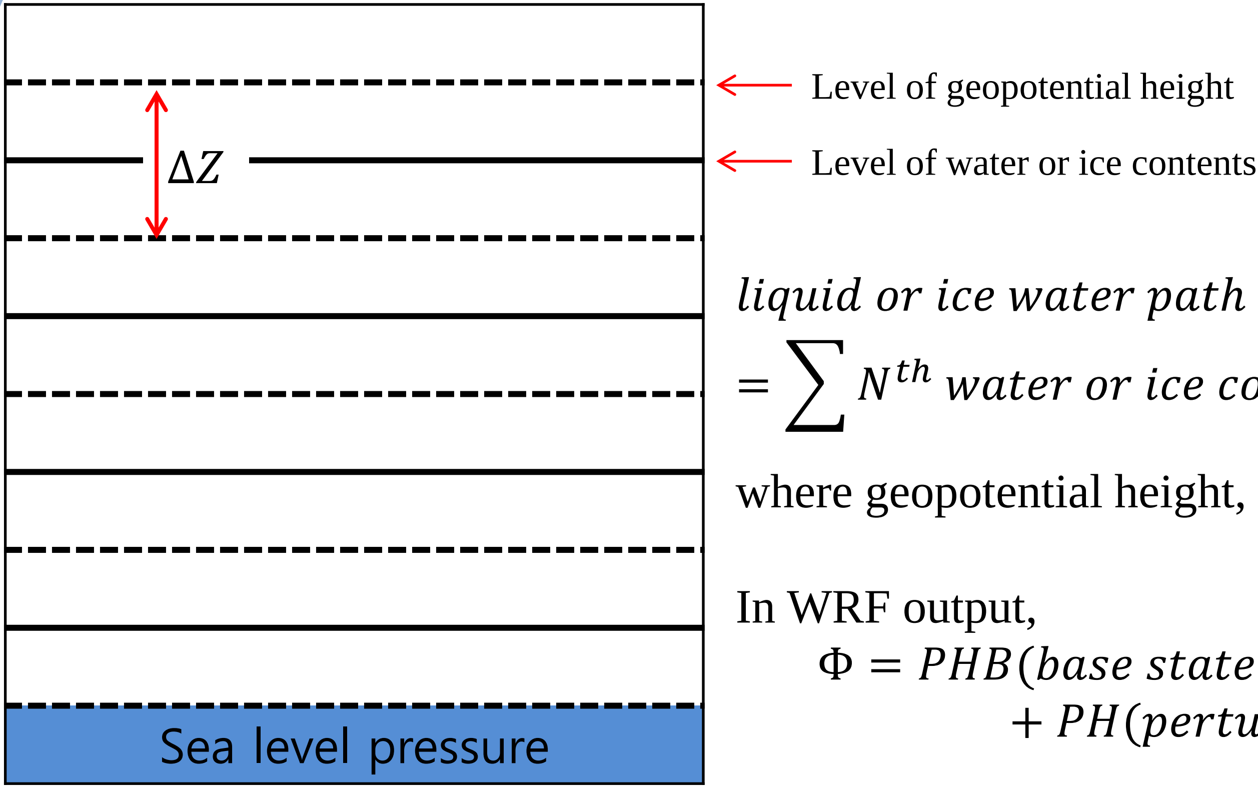
$$\text{where } \rho_n = \rho_0 \times \frac{P_n}{P_0} \times \frac{T_0}{T_n}, \qquad \rho_0 = 1.29\ kg/m^3,$$

$$P_0 = 1013.25\ hPa,\ T_0 = 273.15K,$$

$$P_n = P + PB, T_n = (T00 + T)\left(\frac{1000hPa}{P_n}\right)^{-\frac{R}{C_p}}$$

P (perturbation pressure)	*T* (perturbation potential temperature)
PB (base state pressure)	*T00* (base state temperature)

Vertical coordinate



$$liquid\ or\ ice\ water\ path\ (g/m^2)$$
$$= \sum N^{th}\ water\ or\ ice\ contents\ (g/m^3) \times \Delta Z_N(m)$$

where geopotential height, $Z \equiv \Phi/g_0$

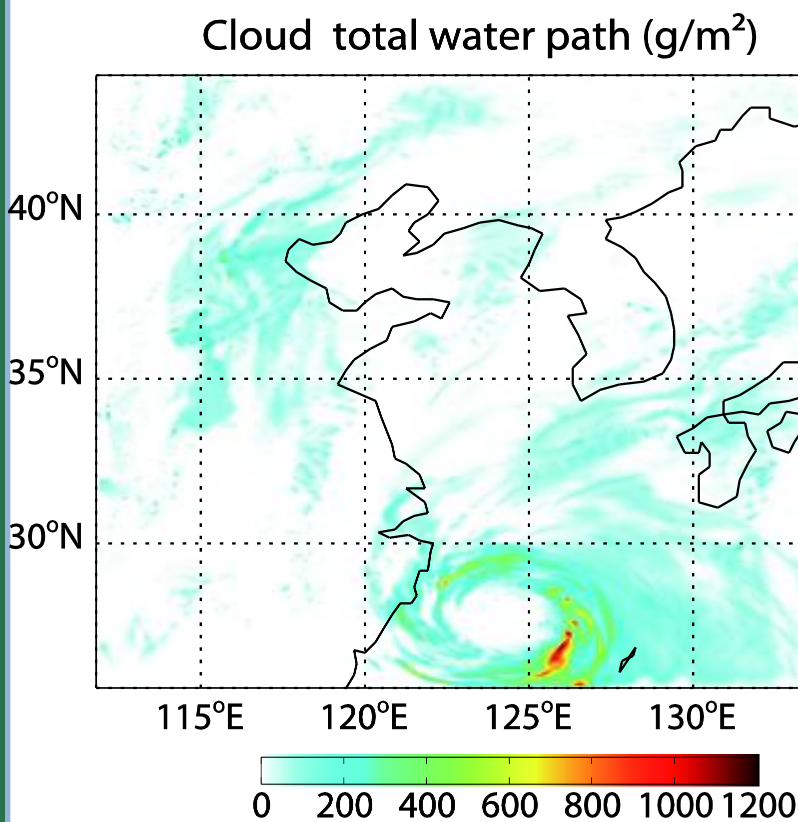
In WRF output,

$$\Phi = PHB(base\ state\ potential) + PH(perturbation\ geopotential)$$

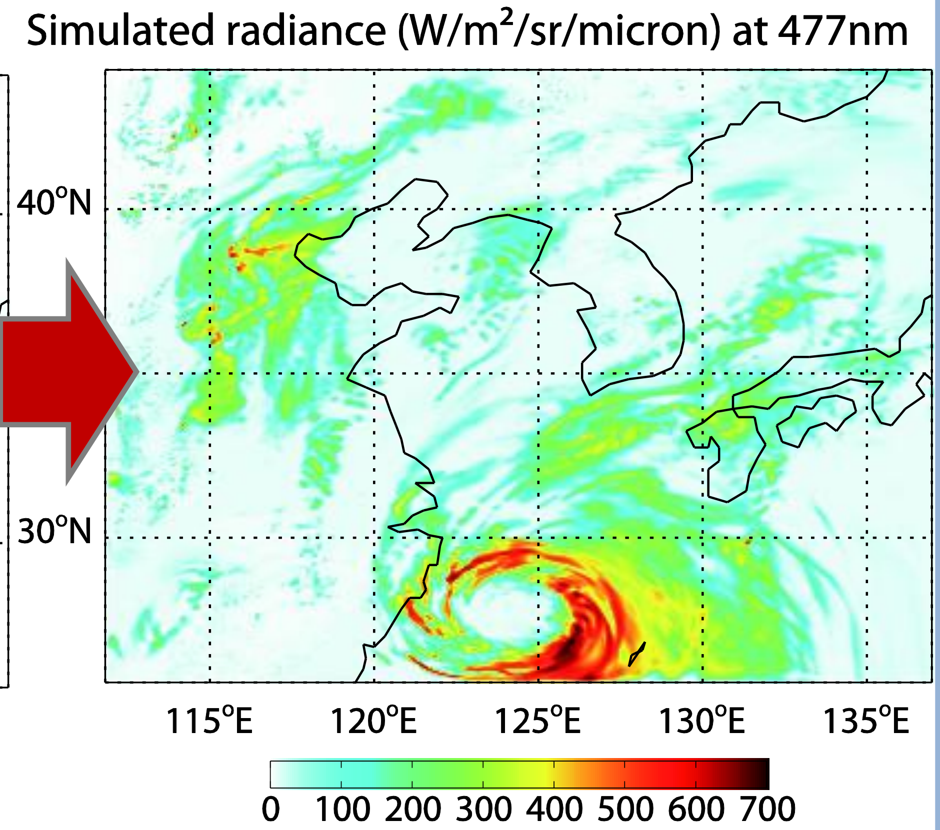
Solid line: unstaggered level
Dashed line: staggered level

An example of simulations

Cloud water path (converted from WRF out)

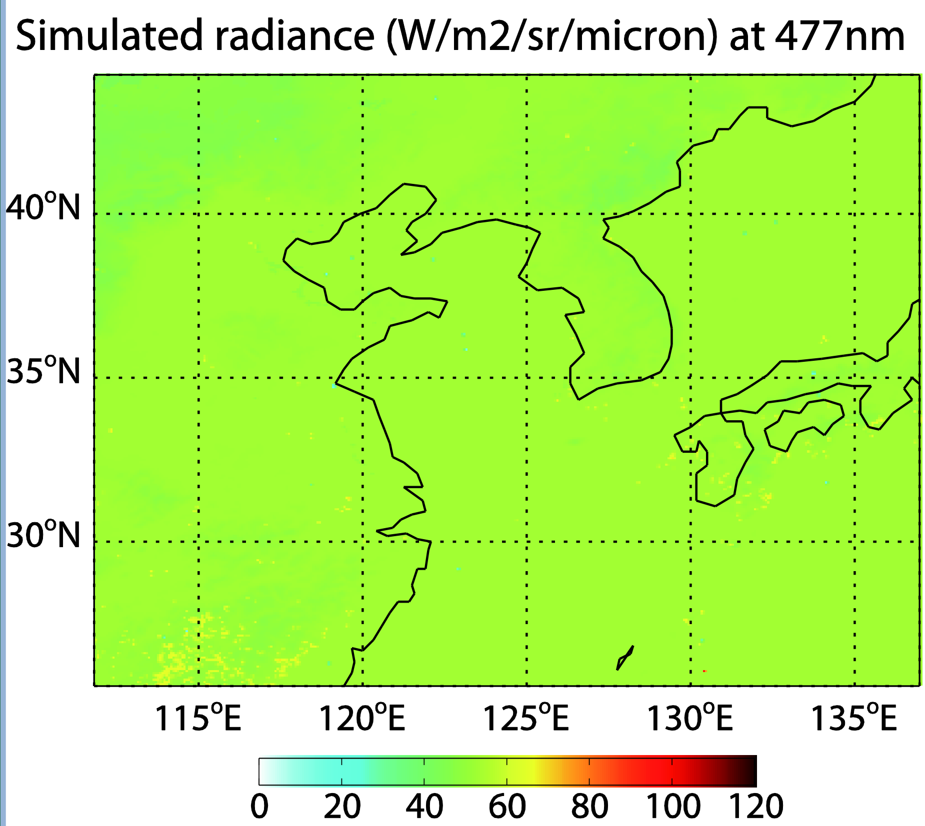


477-nm Radiance (Total sky)

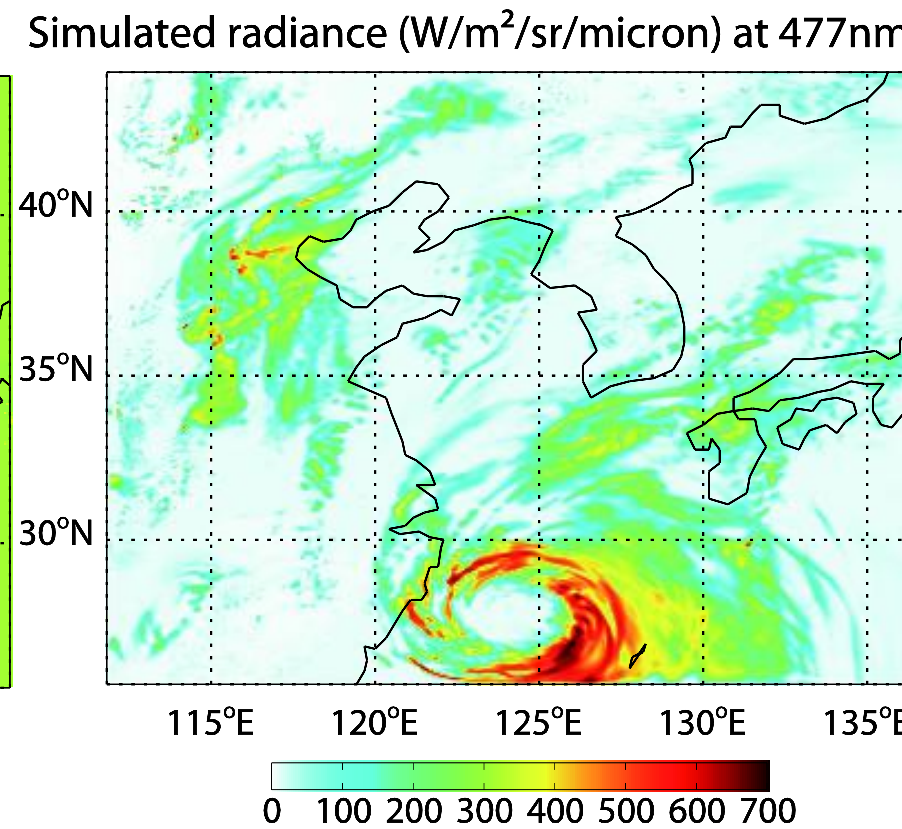


An example of simulations

477-nm Radiance (Clear sky)



477-nm Radiance (Total sky)



Summary & Future Works

Summary

- ► RT simulations from WRF output is ongoing…

Future works include

- ► Simulations for the full spectral range of GEMS
- ► Simulation of vertically inhomogeneous multi-layer clouds
- ► Comparing the retrieved cloud data with the WRF's cloud data
- ►Applying the synthetic data to the cloud algorithm

Papers in 2012 supported by this program

- Cho, H., C.-H. Ho, and Y.-S. Choi (2012), The observed variation in cloud-induced longwave radiation in response to sea surface temperature over the Pacific warm pool from MTSAT-1R imagery, Geophys. Res. Lett., 39, L18802.
- Oh, H.-R., C.-H. Ho, and Y.-S. Choi (2012), Comments on "Direct radiative forcing of anthropogenic aerosols over oceans from satellite observation", Advances in Atmos. Sci. (*in press*)