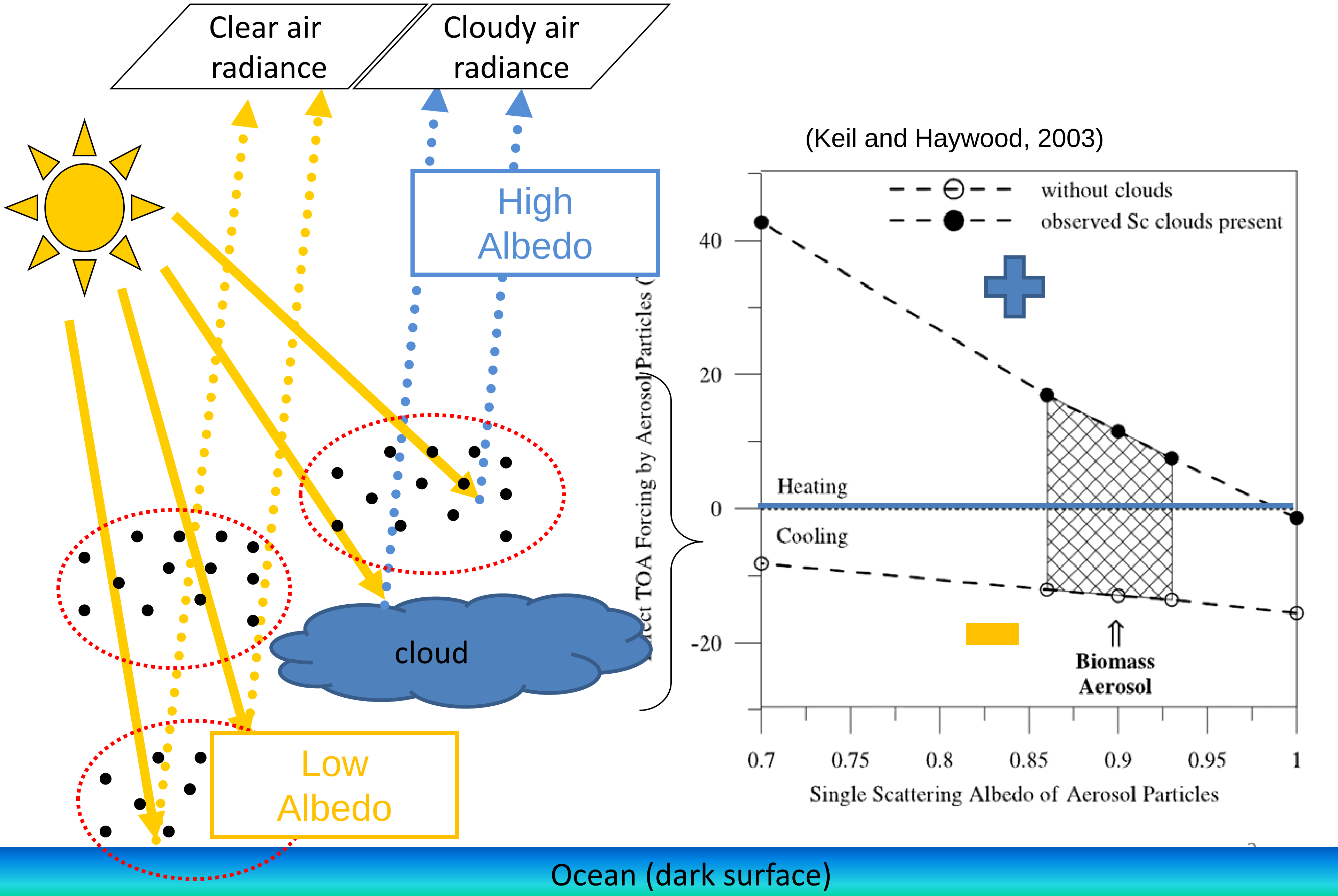
Direct radiative impact of aerosols for vertical structures of aerosols above clouds.

Theoretical studies and application to absorbing aerosols above water clouds detected by A-Train measurements

L. Doppler (1,2), D. Josset (3), and J. Fischer (2)

(1) LOA, Université de Lille-1, Villeneuve d'Ascq, France (2) Freie Universität Berlin, Institut für Weltraumwissenschaften, Berlin, Germany, (3) SSAI, NASA LaRC, United States

Aerosol direct effect on climate



1-D Radiative transfer in the atmosphere: MOMO

- Radiative transfer code MOMO (Matrix Operator Model)

-> Fischer and Grassl, AO 1986; Fell and Fischer JQSRT 2001

- k-distribution method (without corr approx)

-> Bennartz and Fischer JQSRT 2000; Doppler et al. JQSRT 2014

- Full range: 200 nm – 100 µm

-> Doppler et al. JQSRT 2013 (in revision)

- Emission, Transmission, scattering, multi-scattering (gas, aerosol, clouds)

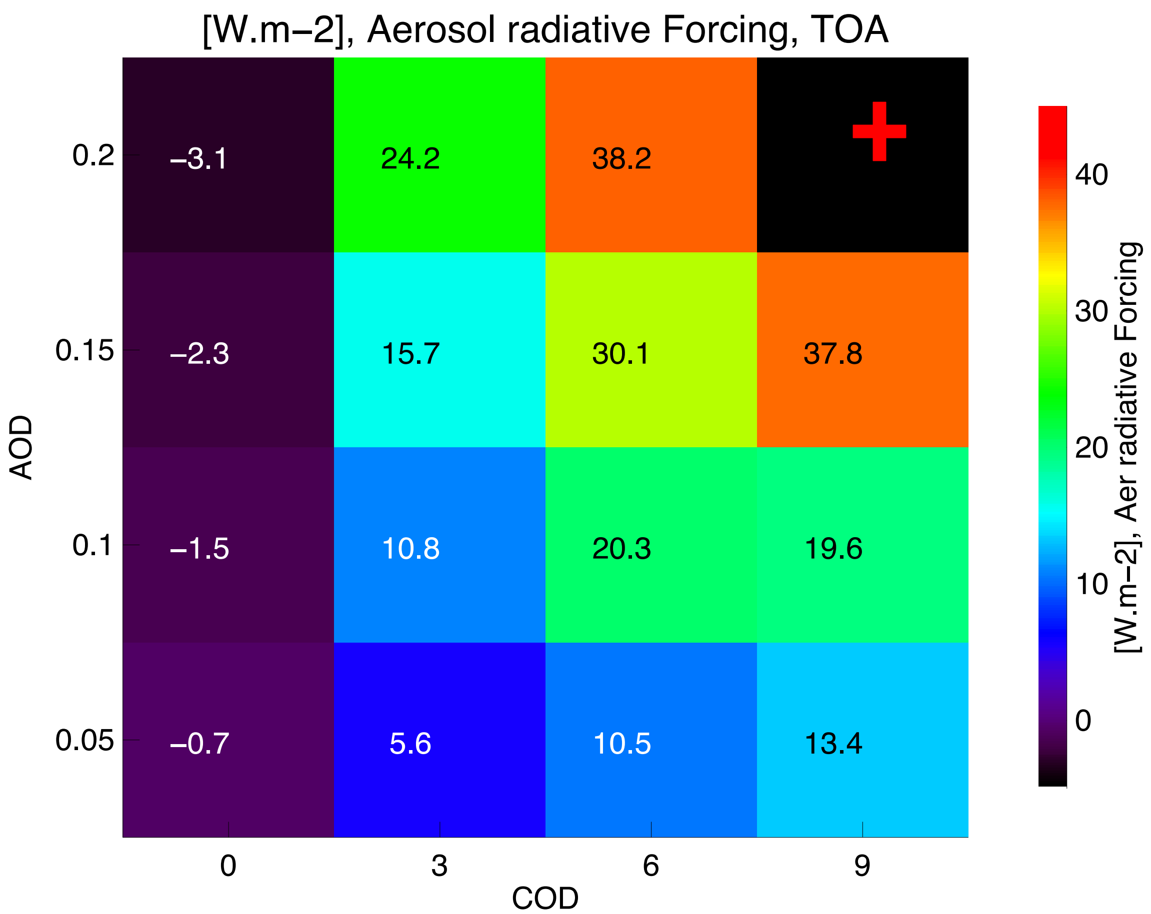
- Versatility: Remote sensing, radiative forcing /Heat-Rates

Outline

- Aerosol radiative forcing / heating rates for clouds and aerosols vertical structures.
- Aerosols above clouds detected by the A-train: case studies for the Guinea Bay and Island Volcanic Ash
- The difficulties of simulating the aerosol/clouds mixed layers.

Simple aerosol layer above cloud

TOA radiative forcing (black ocean, SZA = 30°)



Doppler et al, IRS 2012, Berlin: TOA forcings=f(COD, AOD)

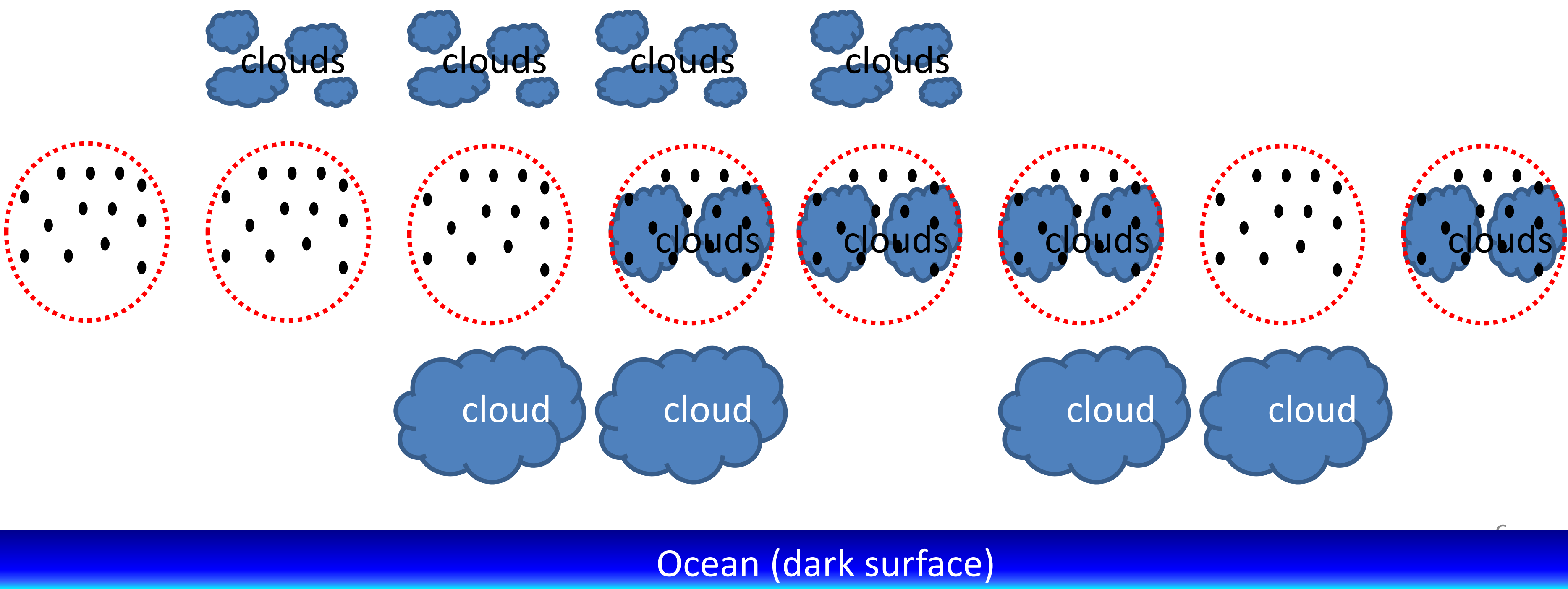
Also: *Keil and Haywood, JGR 2003*

Simulations on 24 theoretical structures

ØØØ	HØØ	HØL	HML	HMØ	ØML	ØØL	ØMØ

COD(H) = 9.6
COD(M) = 12.7

COD(L) = 22.2
AOD_{550}= 0 or 0.11 or 0.34

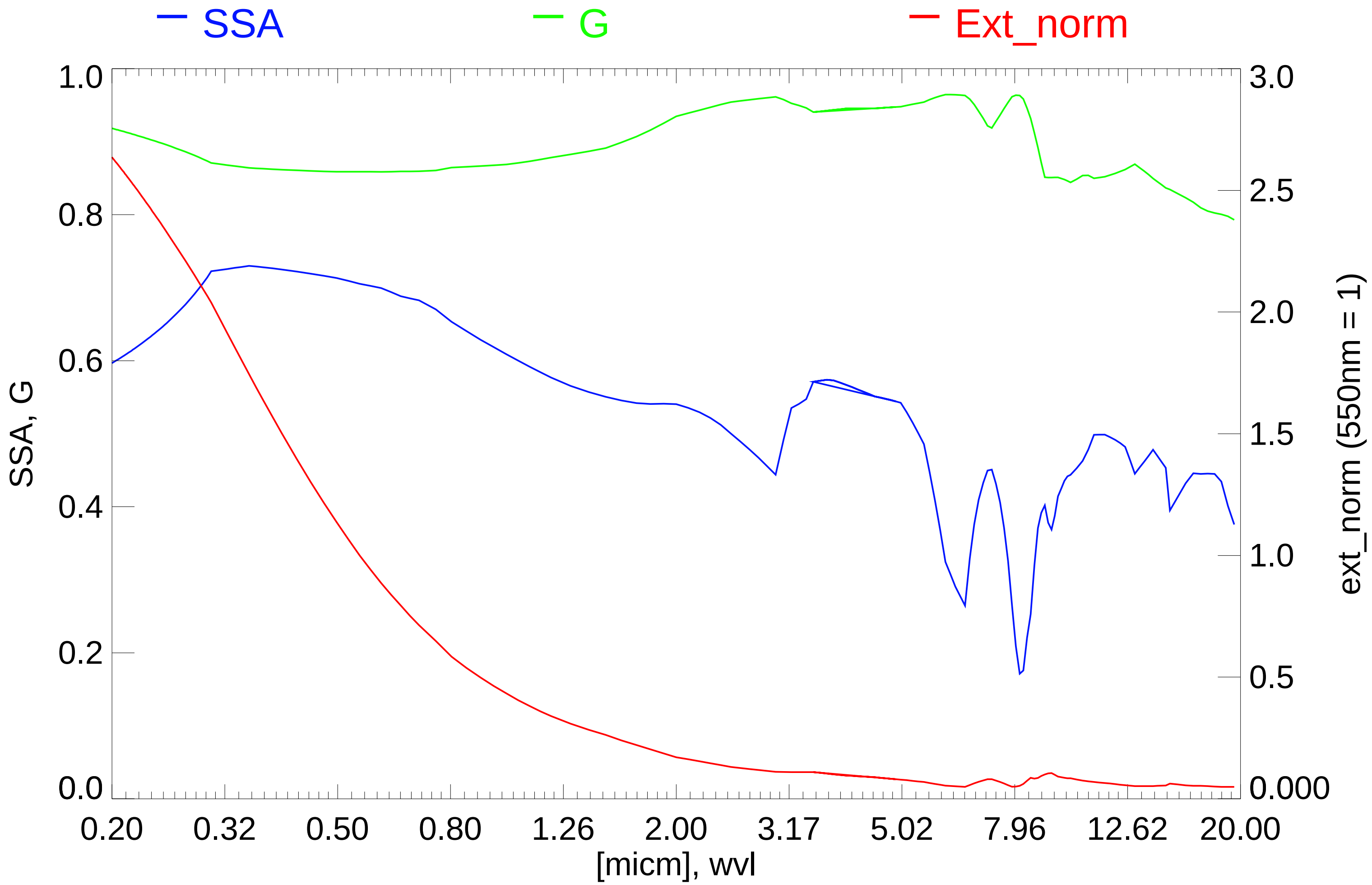


Aerosol Model

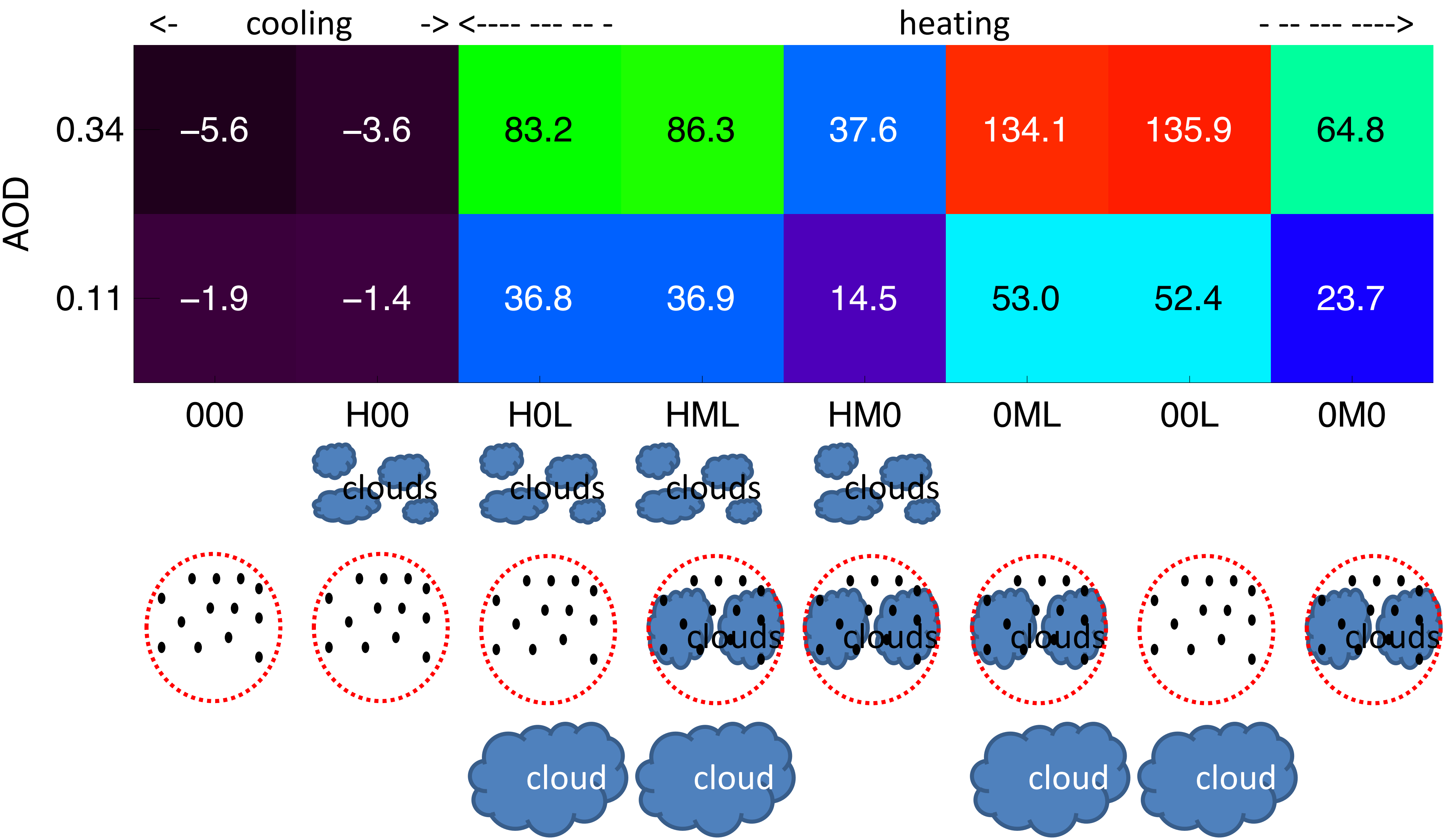
- OPAC aerosol model (mix of water soluble = 21.4%, insoluble = 0.12% and soot = 78.6%)

→Mie code gives the associated phase function and SSA

SSA_{550}=0.71 **g_{550}=0.86**



TOA Aerosol direct radiative forcings SW

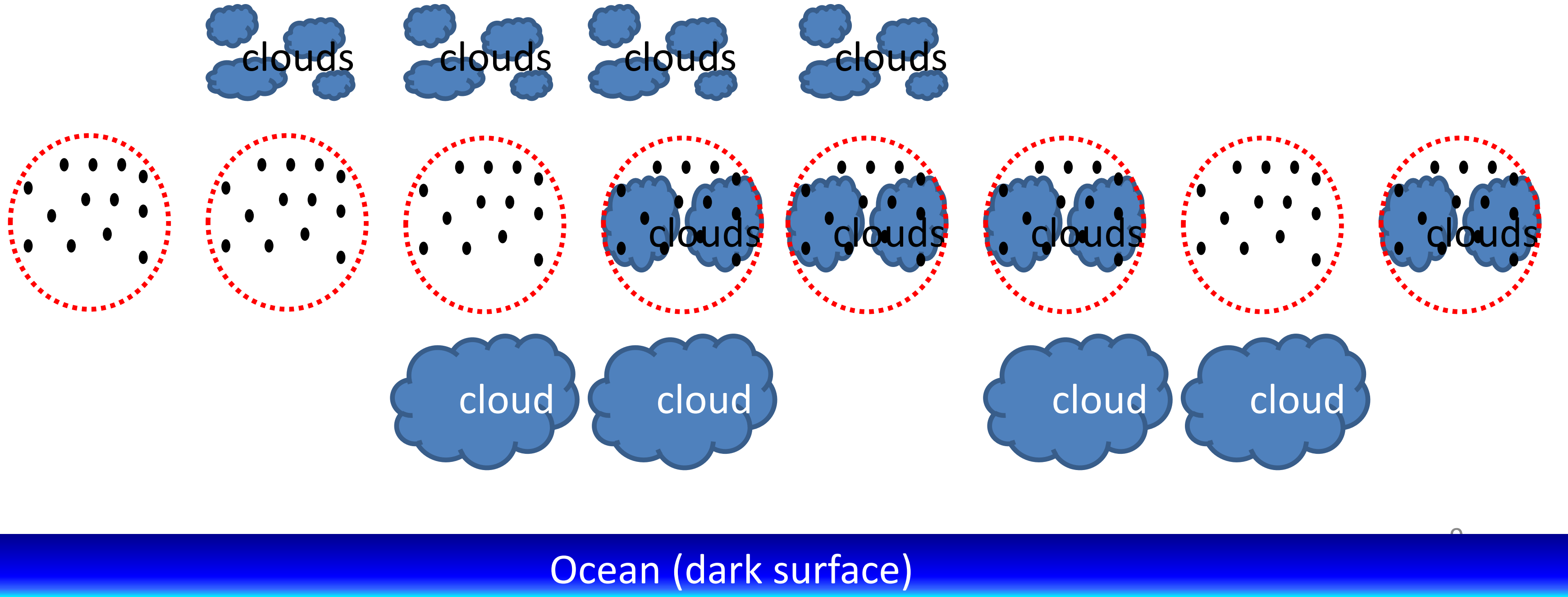


Ocean (dark surface)

TOA Aerosol direct radiative forcings LW

Everywhere heating, low values (excepted the cloud-free case)

AOD	000	H00	H0L	HML	HM0	0ML	00L	0M0
0.34	0.91	0.00	0.00	0.00	0.00	0.10	0.65	0.10
0.11	0.31	0.00	0.00	0.00	0.00	0.03	0.22	0.03



First conclusions

- Vertical structure => define sign and order of magnitude of radiative forcing

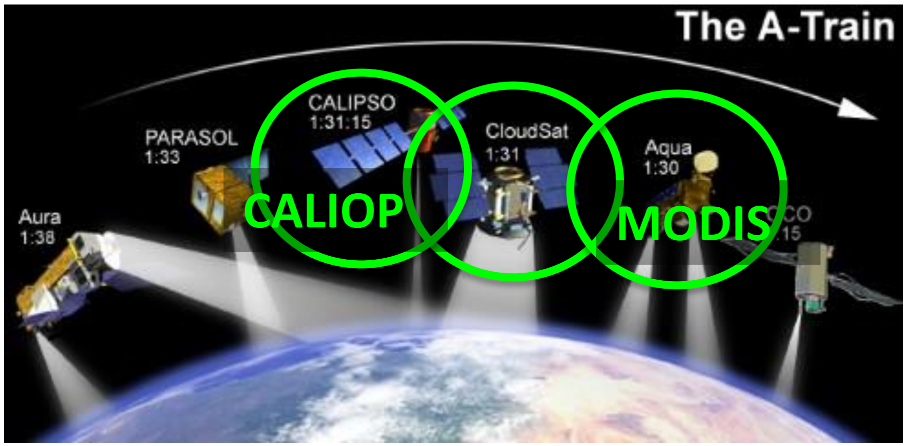
- Unlinearity: mean(forcing**s**(different structure**s**)

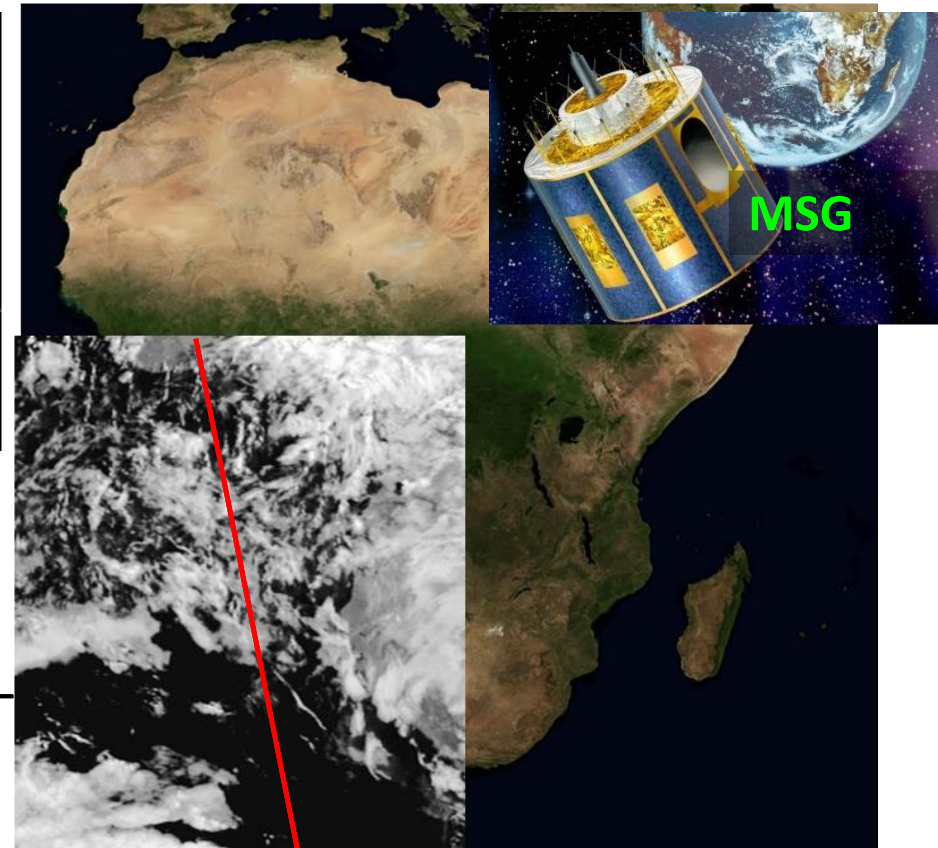
≠ forcing(mean structure)

- Caution: GCM, maps of forcing, with grid approach!!

-> Study the structure variability within a grid-cell !

BB aerosol above clouds (Guinea Bay)

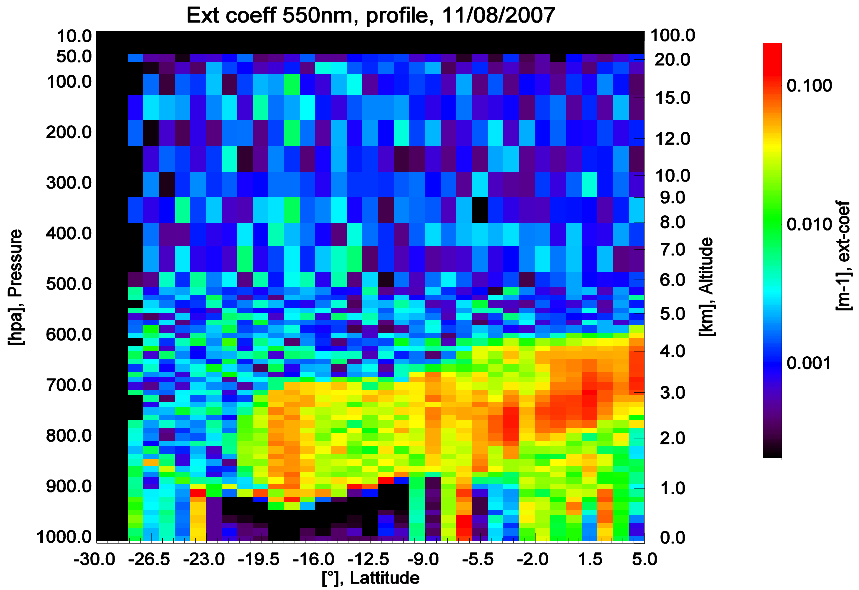


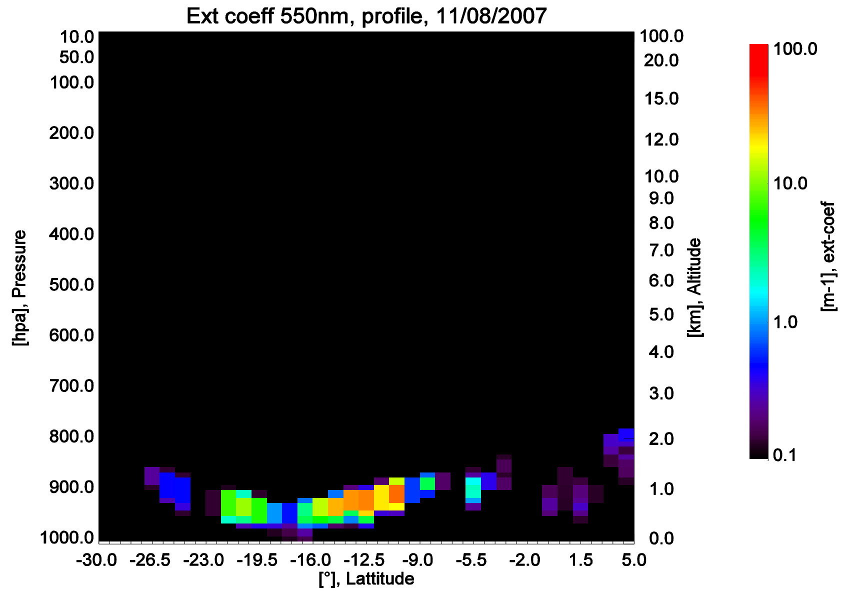


- Josset, Doppler et al. 2012, IRS, Berlin
- Case study 11/08/2007, from -30° to 5° (lat)
- **Instruments:** Lidar CALIOP (CALIPSO), radar (Cloudsat), radiometer MODIS (Aqua), MSG.
- **Method:** Satellite synergy, MOMO RT scheme
- **Objective:** Radiative impact of BB aerosols above clouds

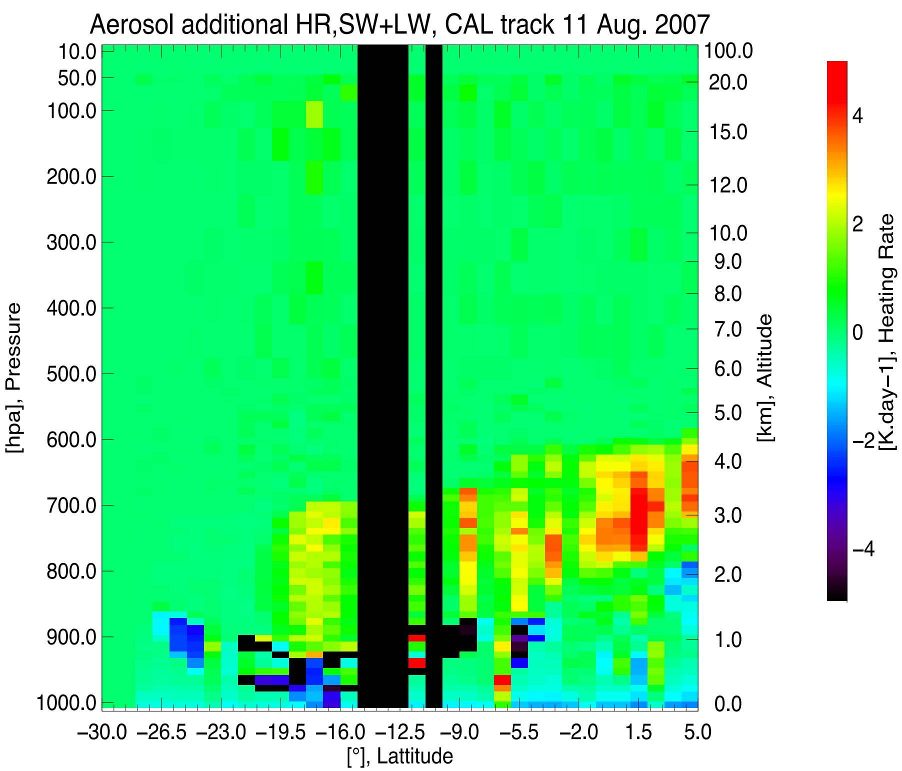
Vertical profile of Heating Rates

Inputs

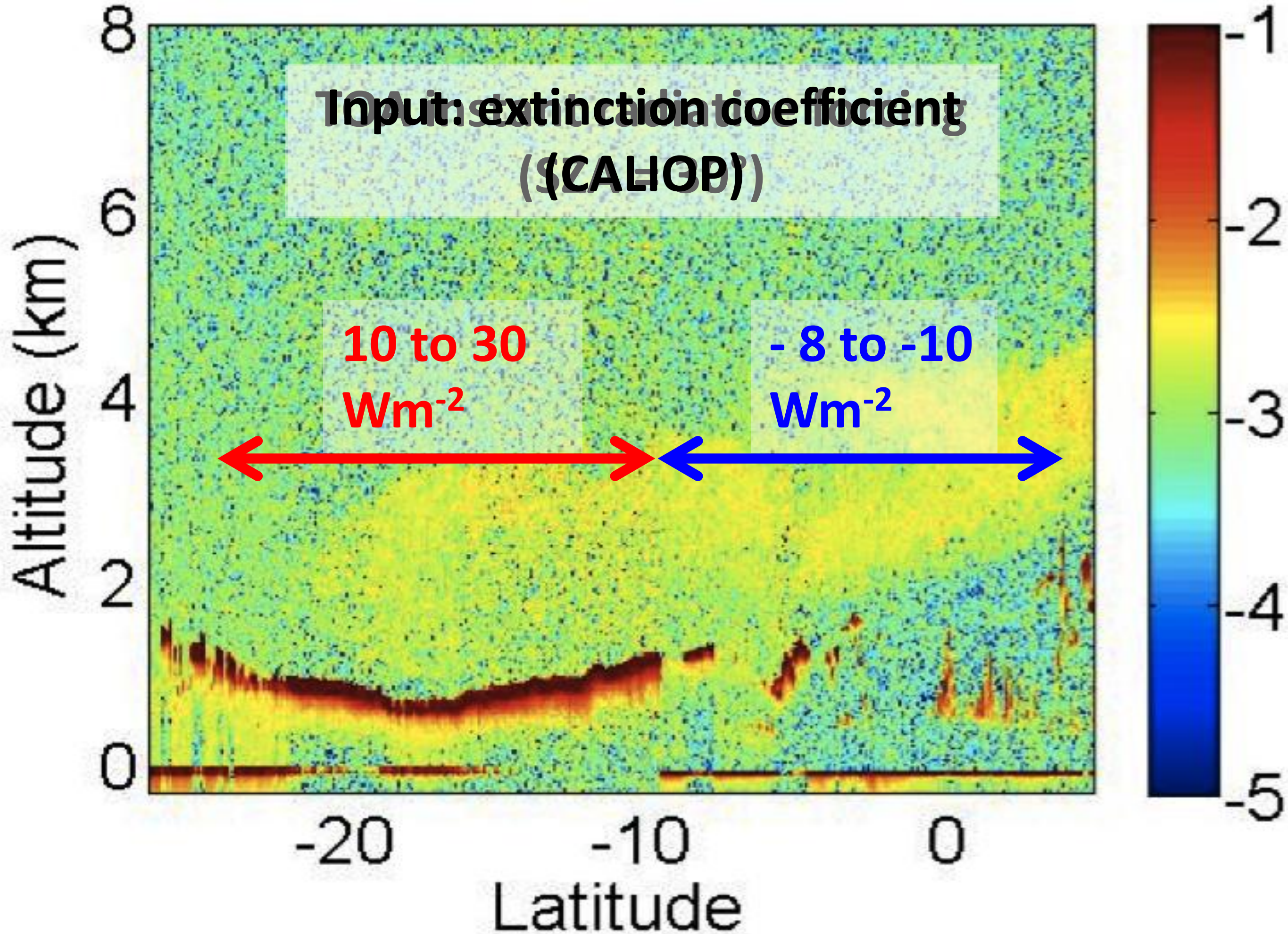




Result



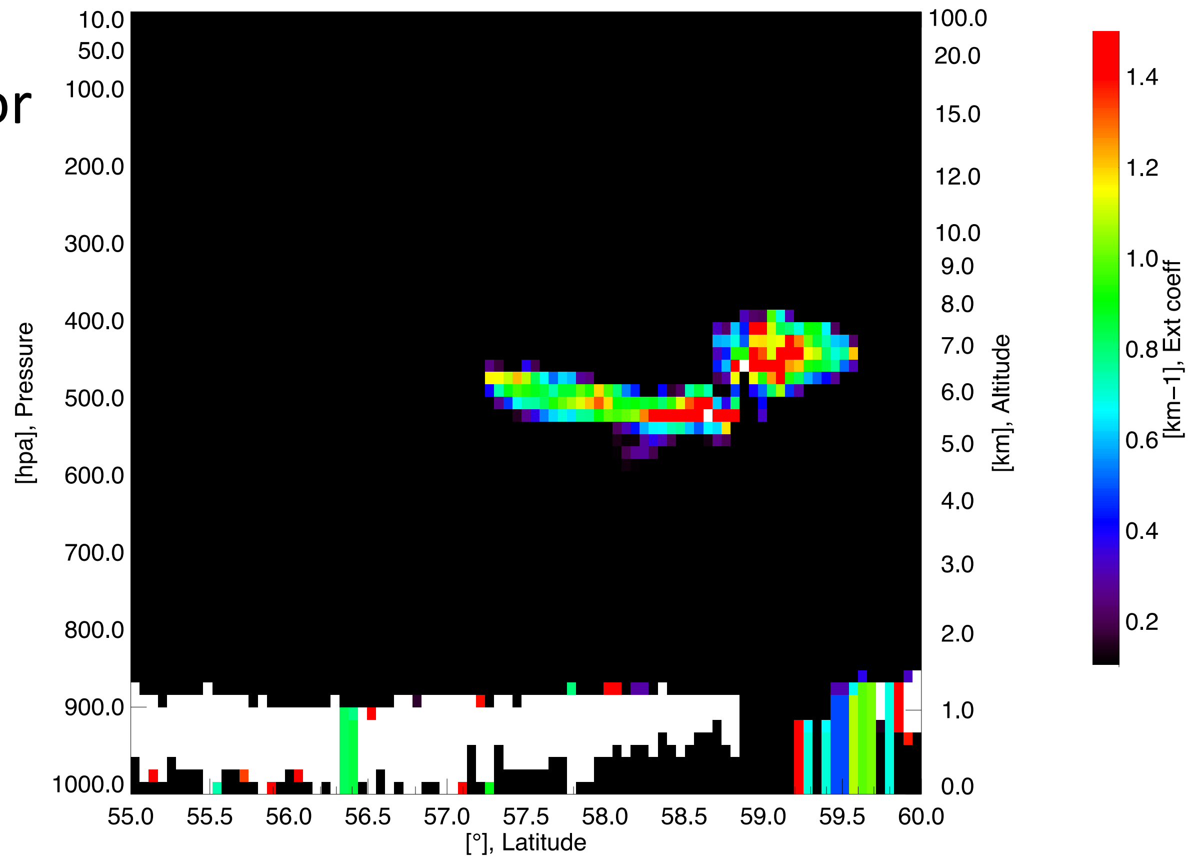
Radiative forcings



- **Result:** Presence of clouds (COT > 6) change the sign of the aerosol radiative forcing (*Haywood and Shine* 1997).
- **Limitation:** Discrimination aerosol/clouds. => Need POLDER!

Volcanic Ash above water clouds: the **Eyjafjallajökull volcano eruption**

- Between Scotland and Island, 6 Mai 2010
- Same instruments as for the Guinea Bay study:
- MODIS
- CloudSat
- CALIPSO (lidar)
- MSG



- In addition:
- CALIPSO (IIR)
- PARASOL (Polder)

- **Poster of D. Josset** (Josset, Pelon, Garnier, Hu, Waquet, Doppler, Riedi, Fischer, Dubuisson, Zhai), **AGU 2013**.

Volcanic Ash: Macroscopic properties

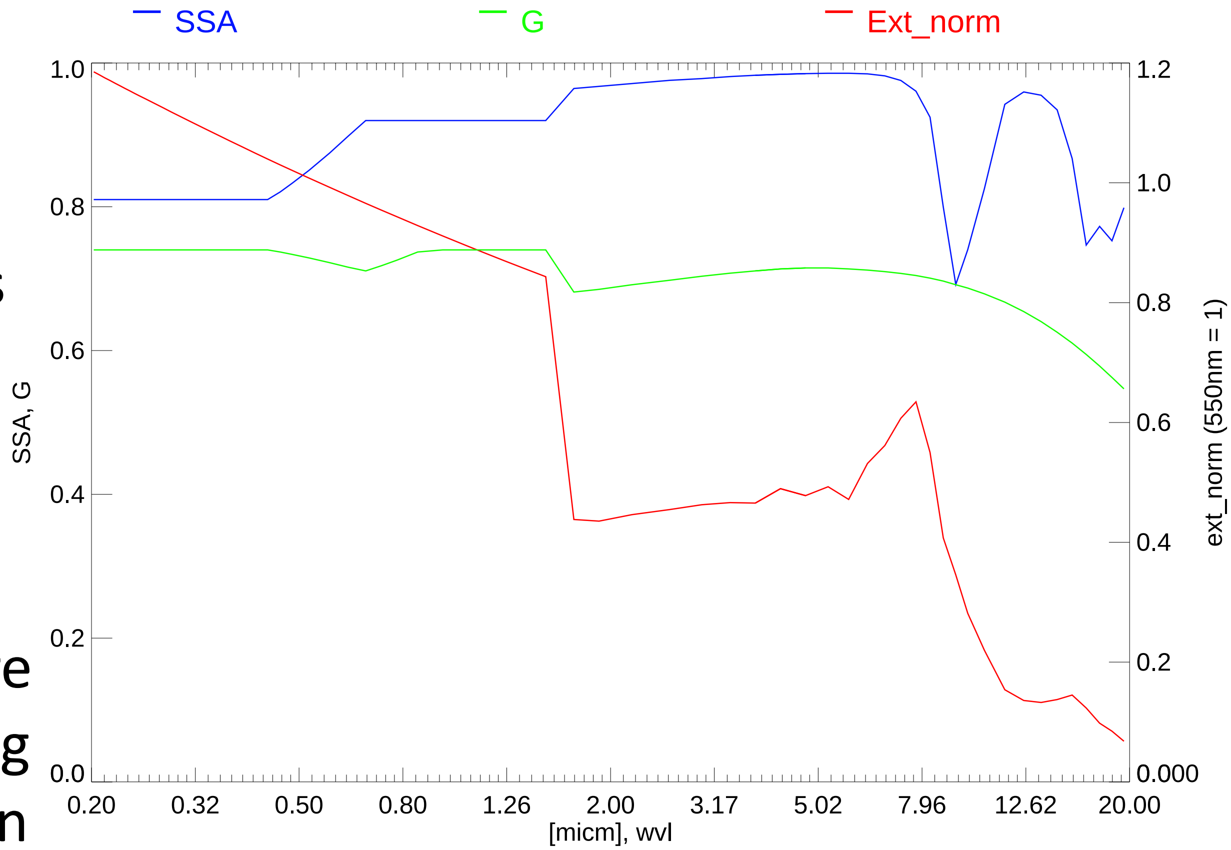
- Large particles

⇒ Influence in LW

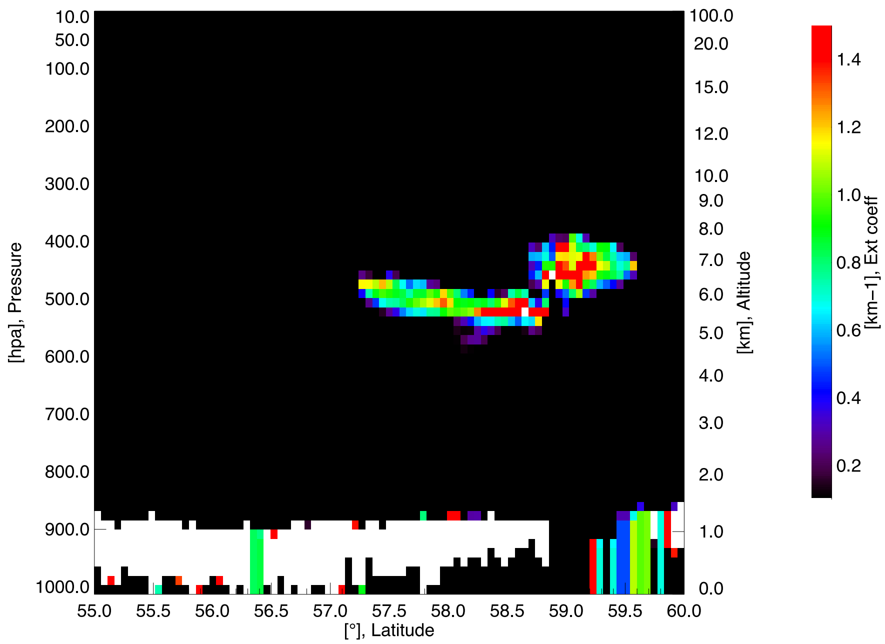
- Non-Spherical particles

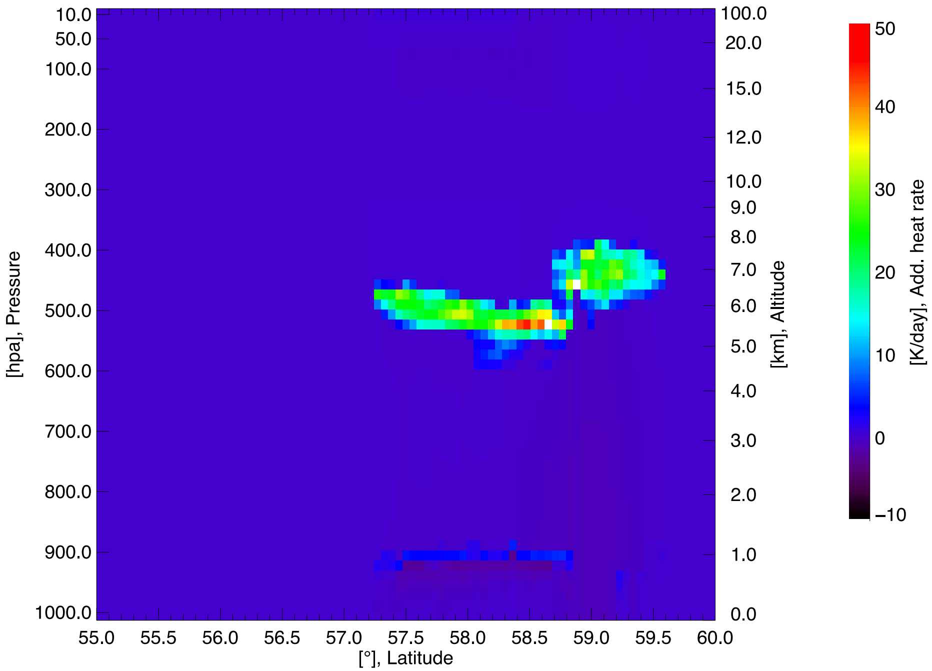
⇒ Mie Code not appropriated (Henyey-Greenstein)

- The AOD (close to 1) are much larger than during the BB aerosols event in Guinea Bay



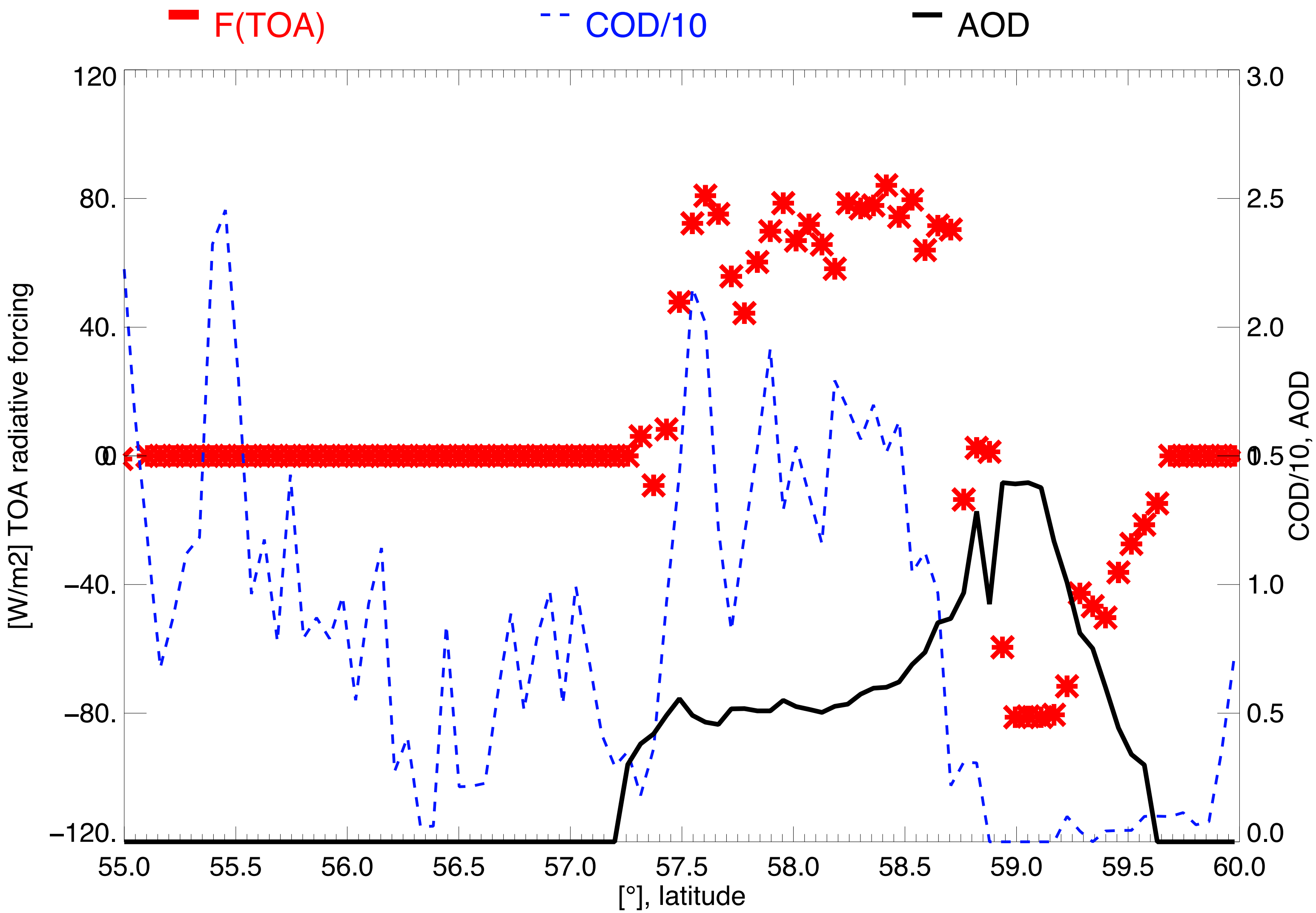
Results, volcanic ash





- Much larger values than for the BB events in SW.
- Longwave cannot be neglected.

Results: Radiative forcing

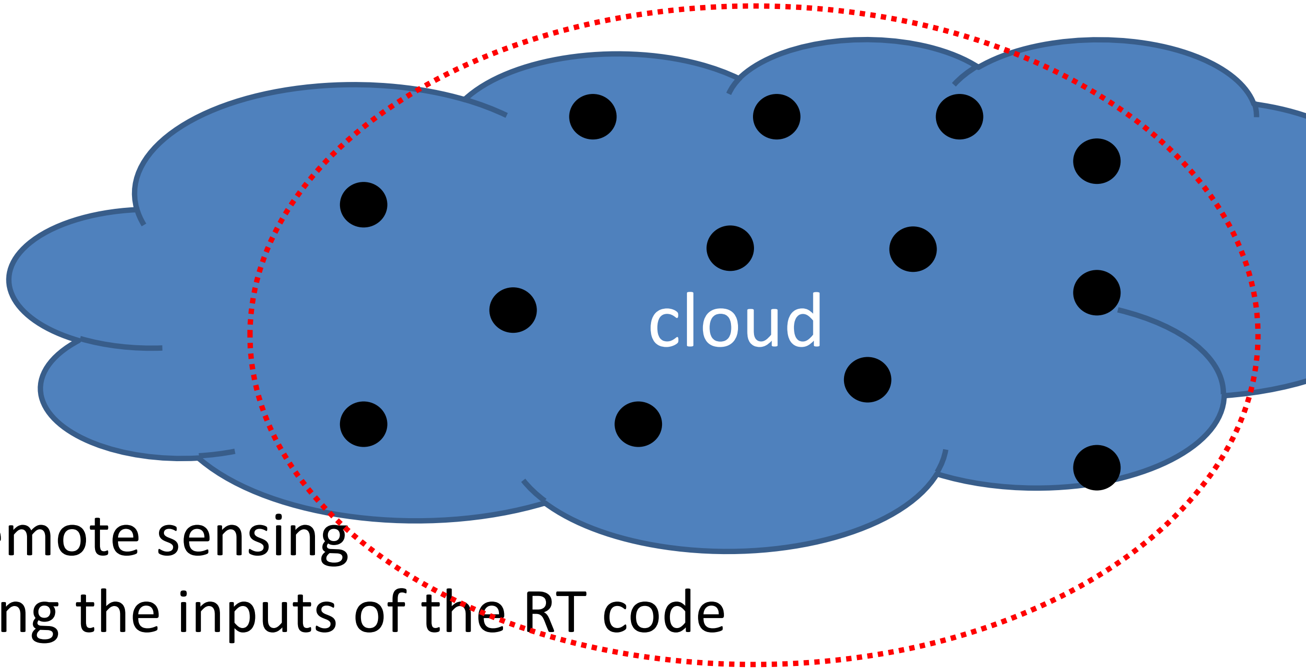


- Again, the presence of clouds change the sign of the forcing
- LW is responsible of 10 to 15% of the forcing

Second conclusions

- Synergy of satellite observations allows the characterization the vertical structure
- All inputs of RT code are provided
- Importance of the polarization for the discrimination
- RT code MOMO allows the computation of radiative fluxes and radiation budget very well
- Large particle => LW influence also
- Need of RT computing for non spherical particles

Aerosol and clouds in the same layer



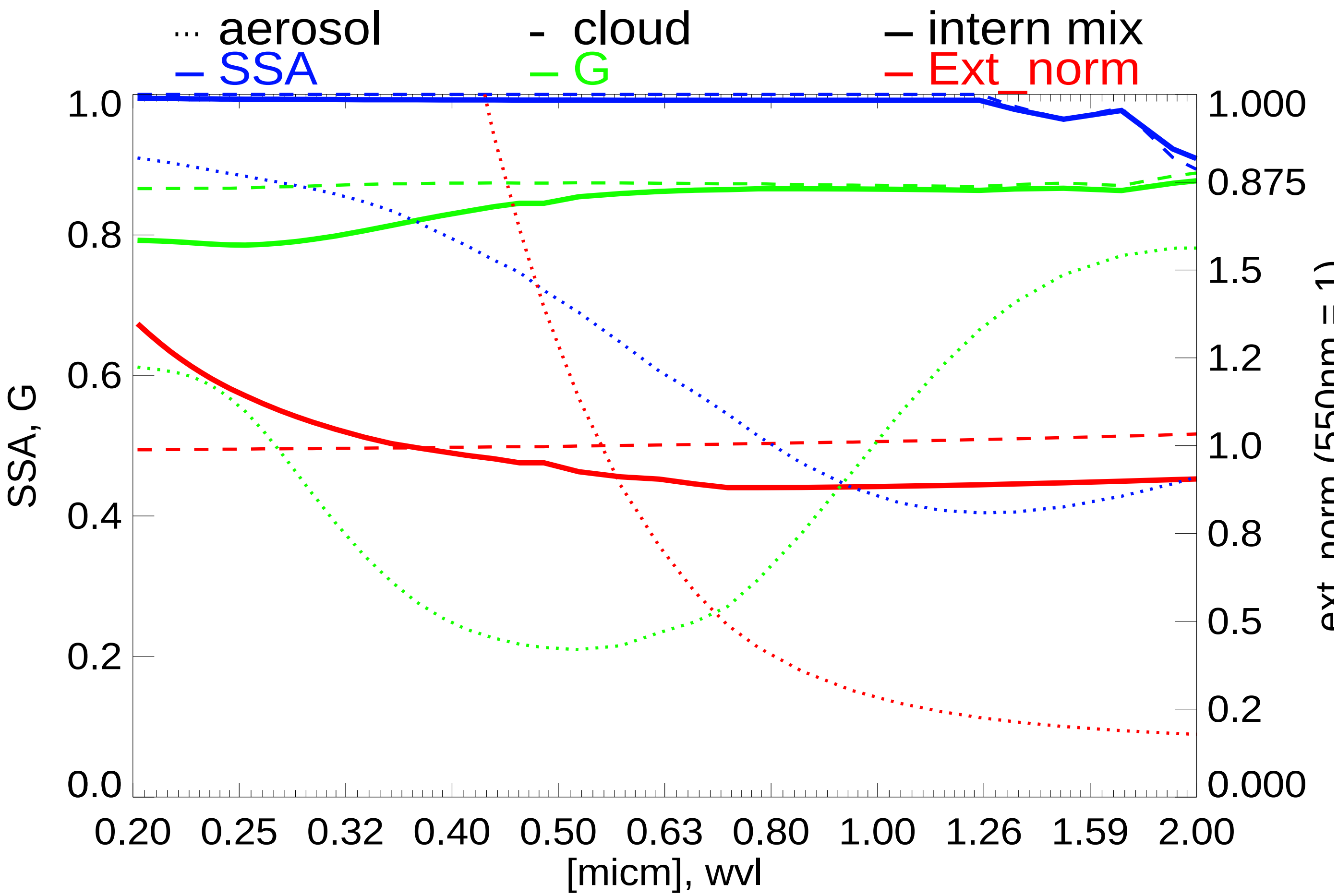
- Difficulty for the remote sensing
- Difficulty for defining the inputs of the RT code

- Idea: build an “internal mixture” with 10 % aerosols (volume conc) and 90 % clouds (volume conc.). OD total = 22

(Instead of “external mixture” with COD = 20 and AOD = 2)

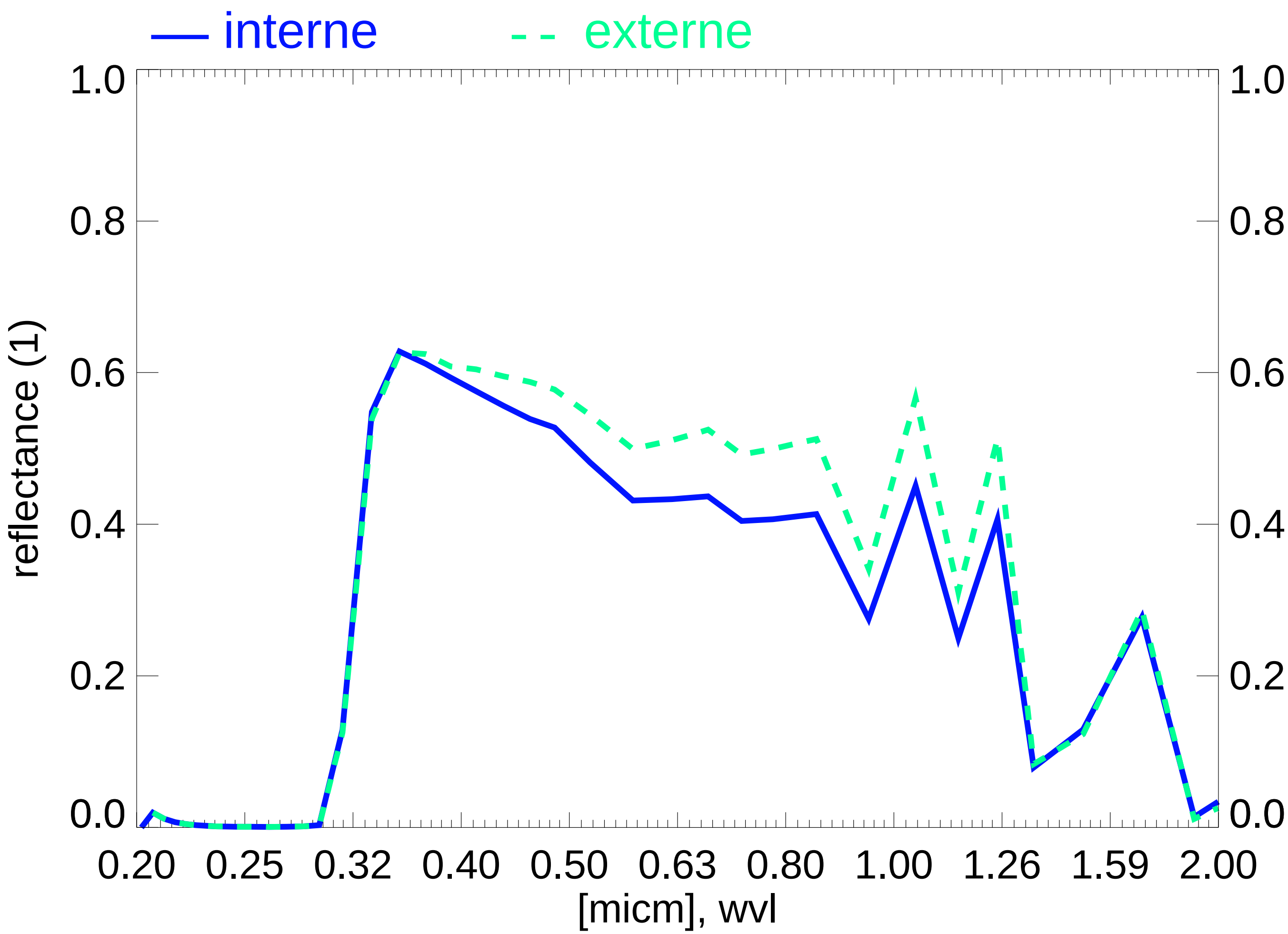
- Layer between 1 and 2 km of altitude

Macroscopic properties



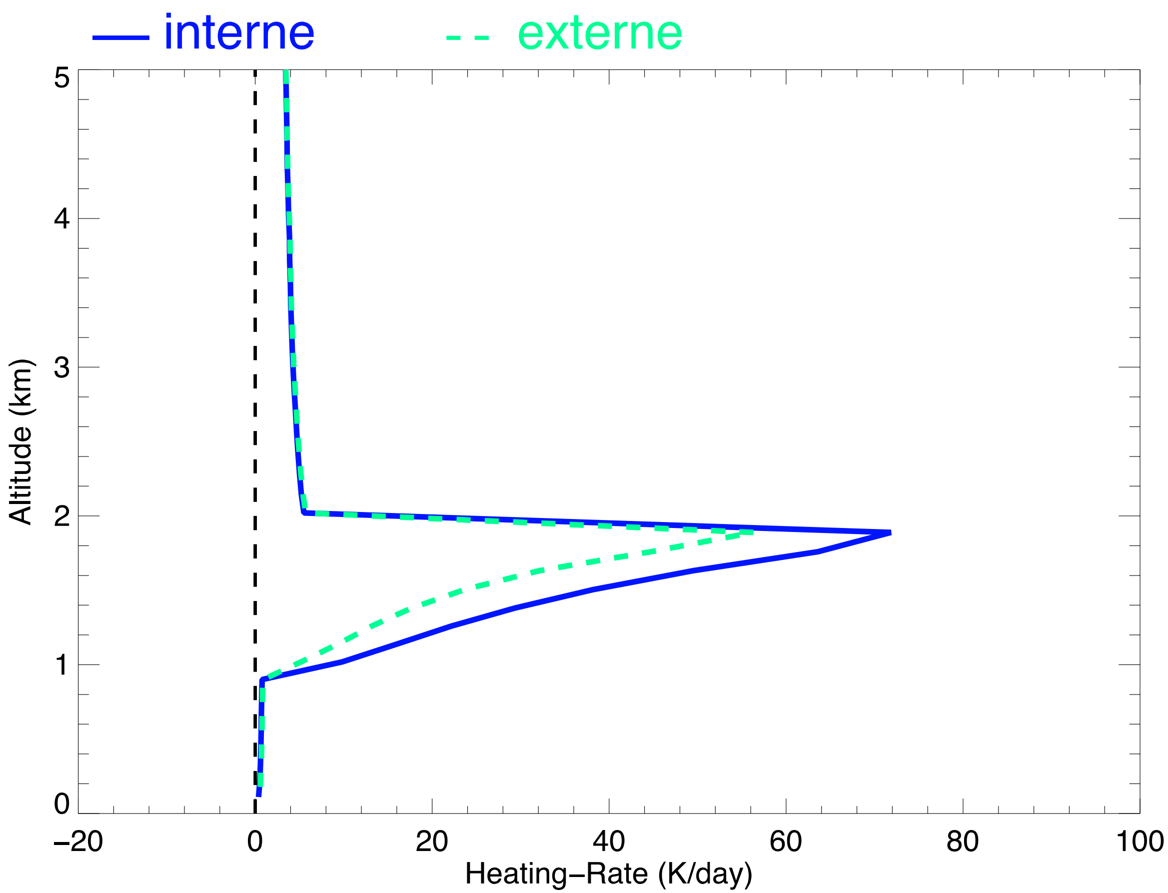
- SSA close to the SSA of the clouds
- Angström between clouds and aerosols
- High value of the assymetry parameter (front scattering)

Results on the reflectance



- External mixture have a higher reflectance (SSA larger, less absorption more back-scattering)
- The concentration ratio is not optimal but the approximation is consistent for reflectance -> large SSA compensate by large g?

Results: Vertical profile of heating rates



- The (radiative) energy budget is not the same (25 % difference)
- The concentration ratio must be studied with precision
- ???? HOW? ????

Summary

- 1-D radiative transfer simulations allow to:
- Compute the radiation budget
- Give recommendation to “grid models” (theoretical study)
- Compute radiation budget for real case studies (satellites)
- MOMO is a good tool to realize these simulations (balance precision/rapidity)
- Satellite synergy provides the complete information necessary for the case of aerosol above clouds
- Importance of the microscopy properties (size/shape of aerosol)
- RT code + Satellite measurements fail for layers “mixed” (aerosol + clouds)

Perspectives

- Develop set of LUT (concentration ratio for OD ratio)?