The publicly available single scattering and radiative transfer codes at IFM-GEOMAR: Example applications from the UV to the Microwave

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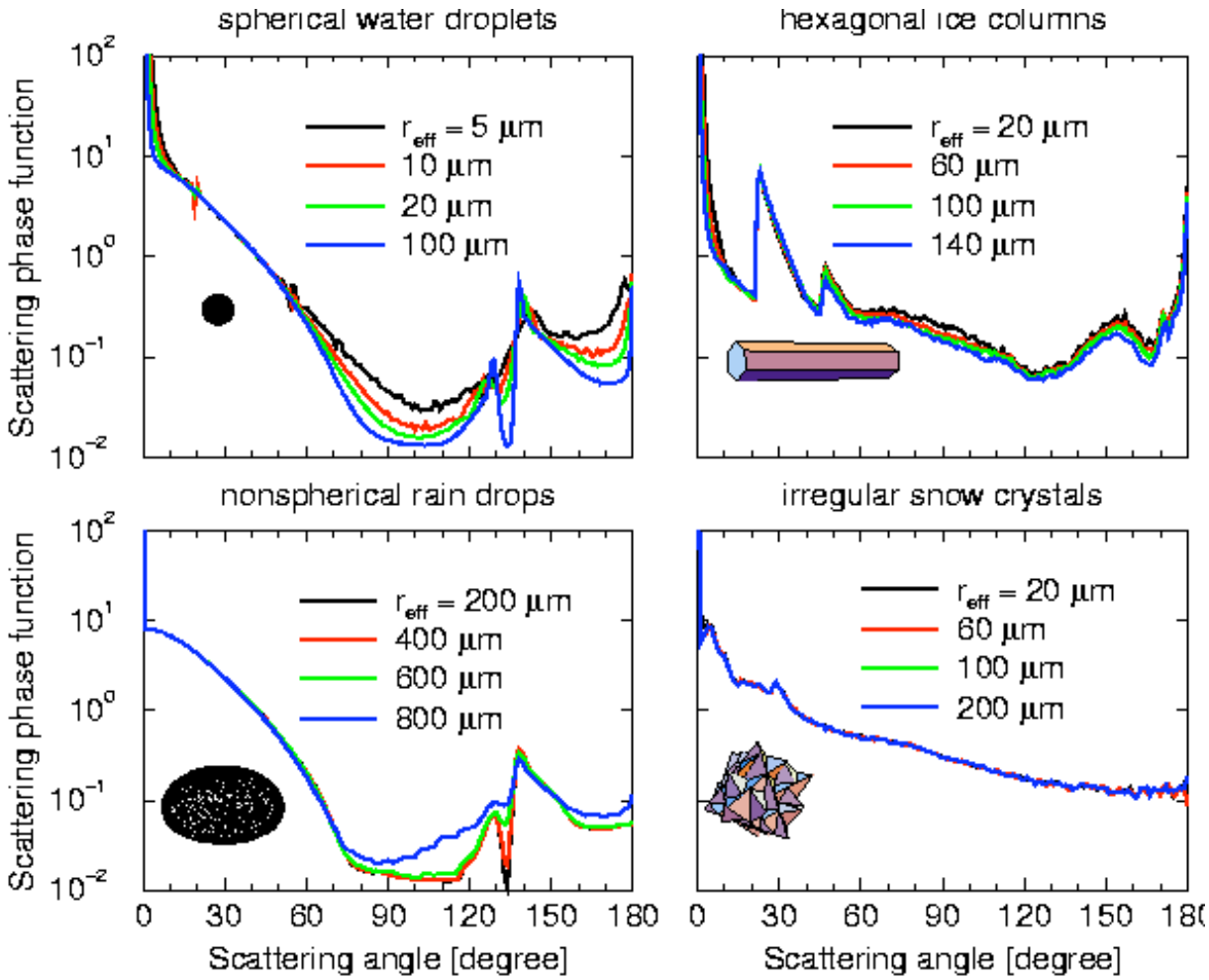
Overview

- **Single scattering codes (geometric optics)**
  - **rt.f90**: ray-tracing at randomly oriented polyhedral particle
  - **rt-2d.f90**: same for horizontal or partly tilted particle orientation
  - **rt-mc.f90**: as rt.f90 with internal scattering/absorbing inclusions
  - **rt-ellipsoid.f90**: ray-tracing at randomly oriented ellipsoid
  - **rt-raindrop.f90**: ray-tracing at rotational symmetric particle defined by Chebychef polynomial expansion
- **Radiative transfer codes (Monte-Carlo)**
  - **mc-unik.f90**: forward Monte-Carlo, estimate for radiance calc.
  - **GRIMALDI**: MC package incl. documentation, gas abs., scattering library
  - **3rad-unik**: MC package for 3d microwave and thermal radiative transfer

Scattering phase functions



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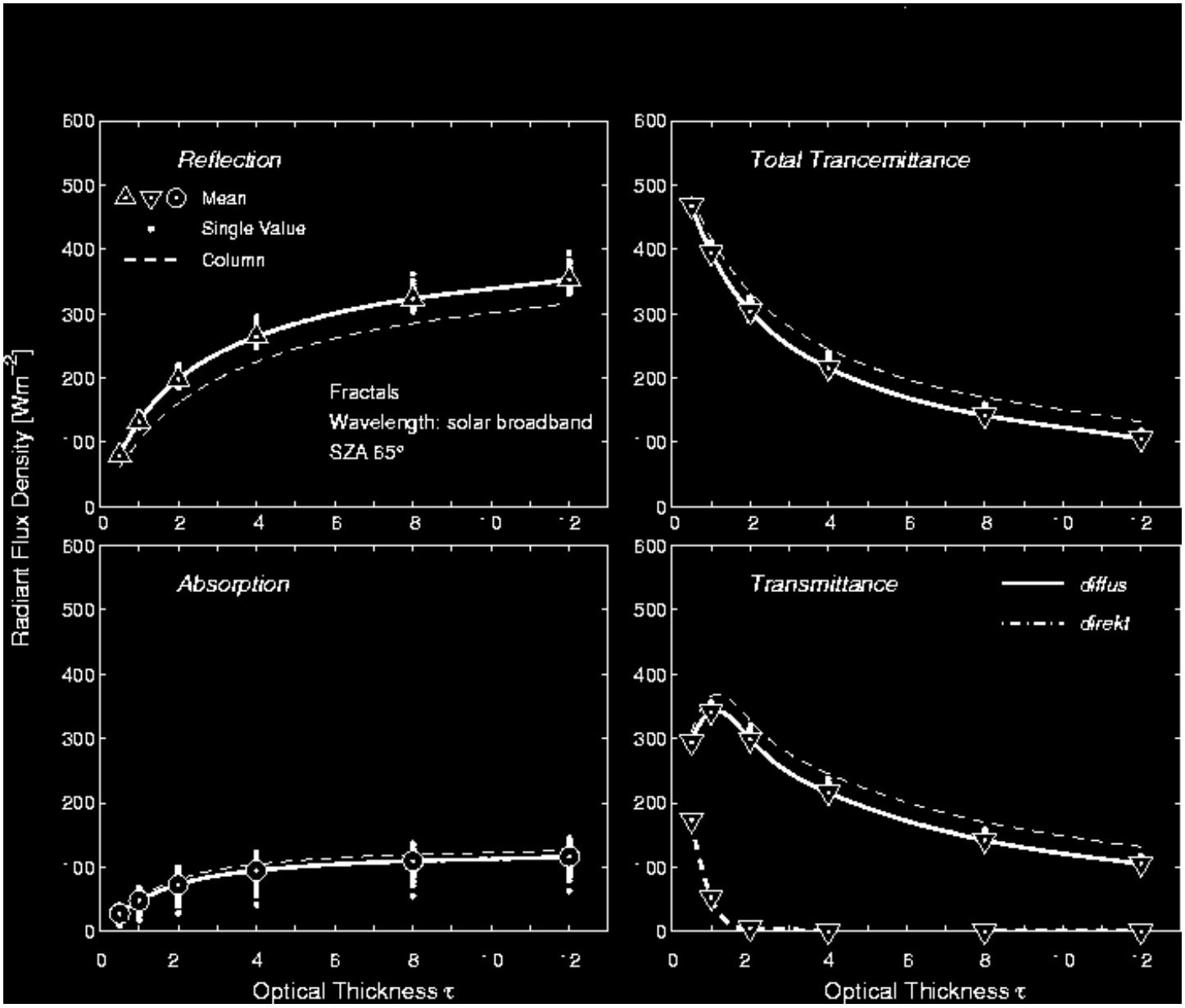
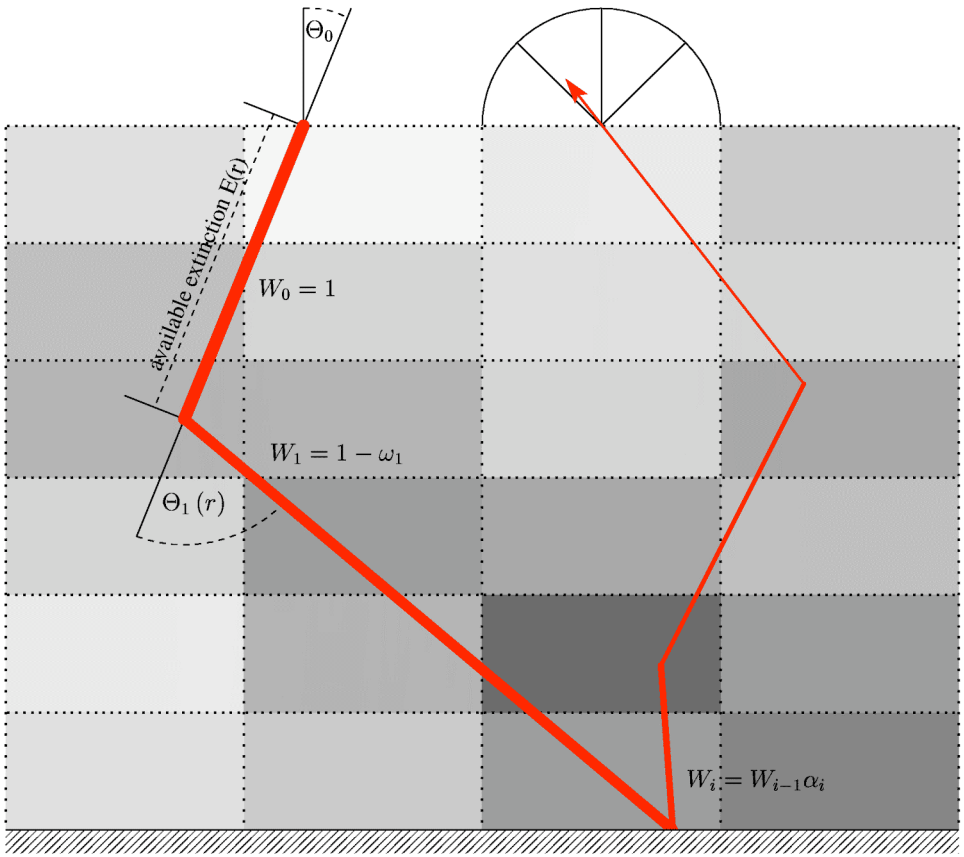
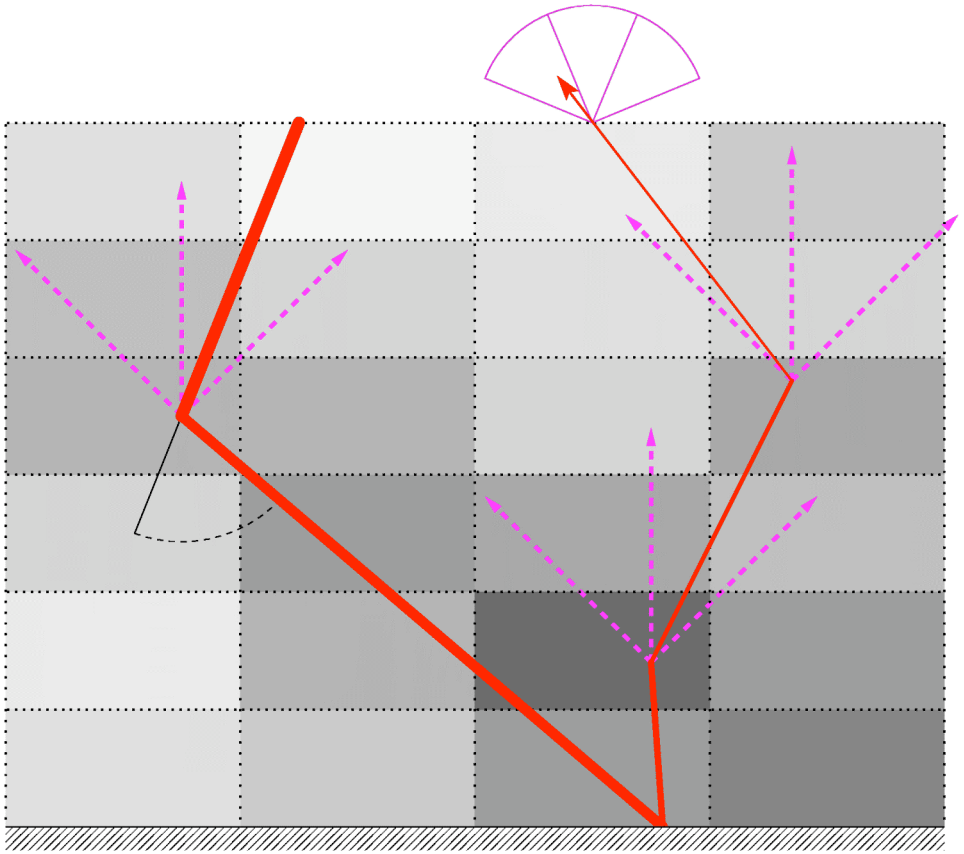

Reflection
Mean
Single Value
Column
Fractals
Wavelength: solar broadband
SZA 65°
Total Trancemittance
Absorption
Transmittance
diffus
direkt
Radiant Flux Density [Wm^{-2}]
Optical Thickness τ
Optical Thickness τ

Complete MC package (GRIMALDI)



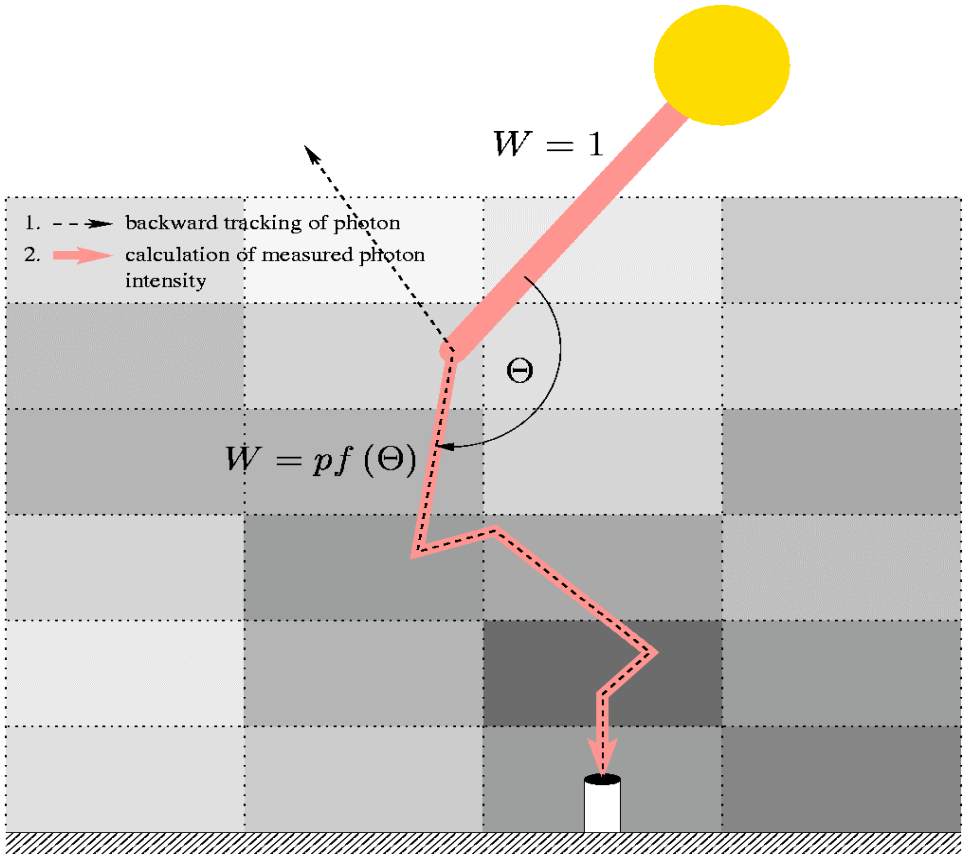
- forward scheme to solve radiative transfer in 3d scattering and absorbing atmosphere with directed (solar) illumination
- **preprocessor for absorption properties of atmospheric gases**
- monochromatic and **spectral band fluxes** and radiances for finite sized angular bins
- photon path length pdf for finite sized angular bins
- data base for scattering phase functions and single scattering albedos for spherical and non-spherical cloud particles

Forward Local Estimate MC (MC-UNIK)



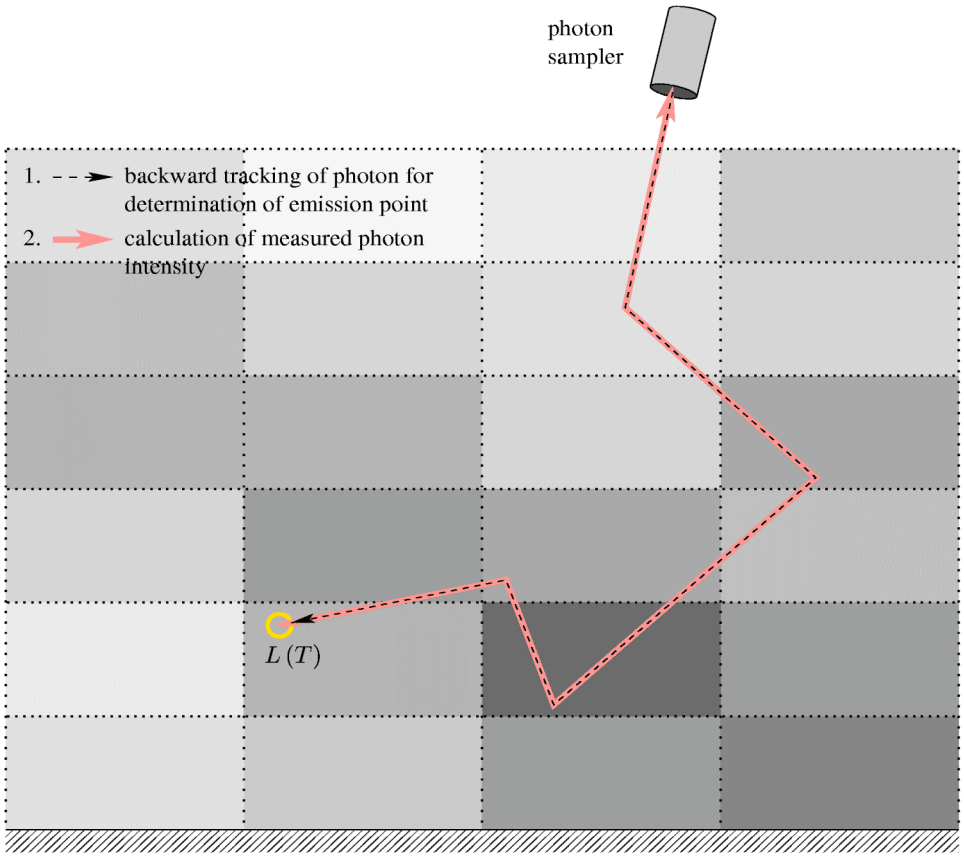
- forward scheme to solve radiative transfer in 3d scattering and absorbing atmosphere with directed (solar) illumination
- **monochromatic fluxes and radiances for discrete directions (Local Estimate scheme)**
- data base for scattering phase functions and single scattering albedos for spherical and non-spherical cloud particles

Backward Local Estimate MC (MC-UNIK-BW)



- backward scheme to solve radiative transfer in 3d scattering and absorbing atmosphere with directed (solar) illumination
- monochromatic radiances for discrete directions (Local Estimate scheme)
- **photon pathlength pdf for predefined viewing geometries and viewing locations**
- data base for scattering phase functions and single scattering albedos for spherical and non-spherical cloud particles

Backward MC (3RAD-UNIK)



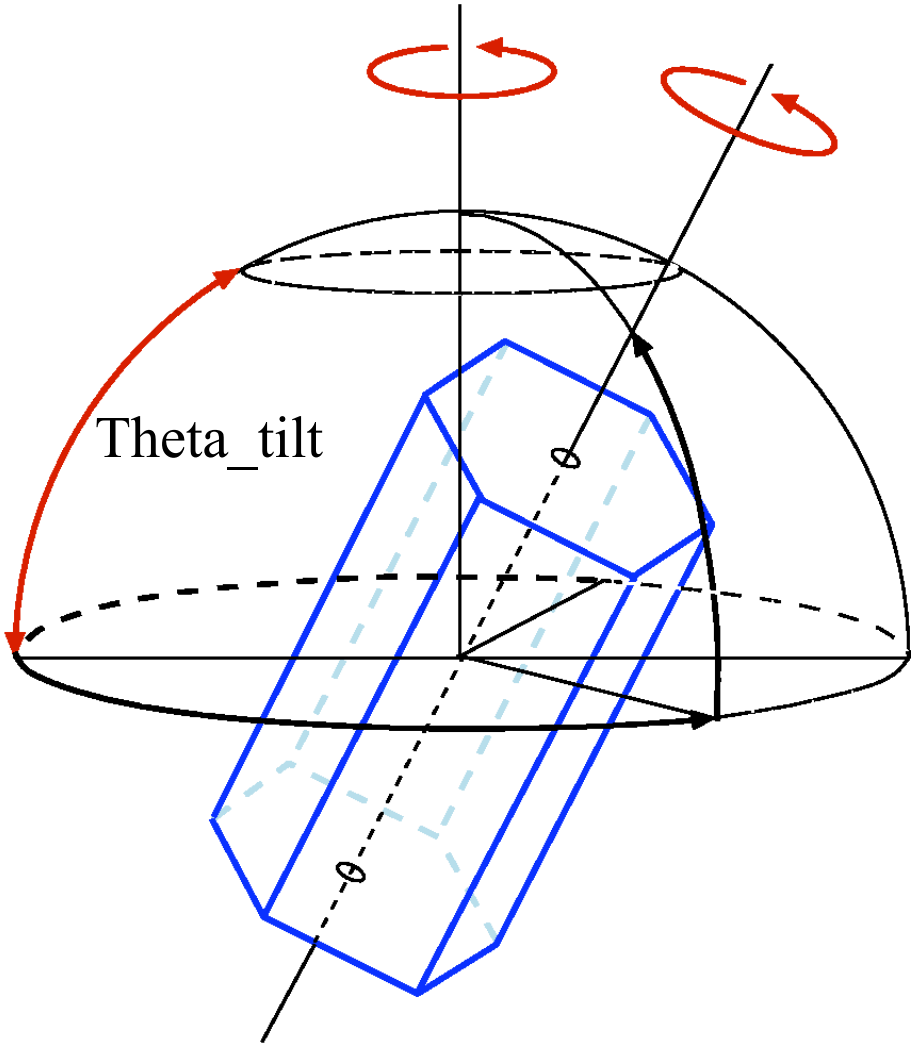
- backward scheme to solve radiative transfer in 3d scattering, absorbing and **emitting** atmosphere
- monochromatic radiances for discrete directions
- **preprocessor for gas absorption from the thermal to the microwave**
- data base for scattering phase functions and single scattering albedos for spherical cloud particles

Codes available at:

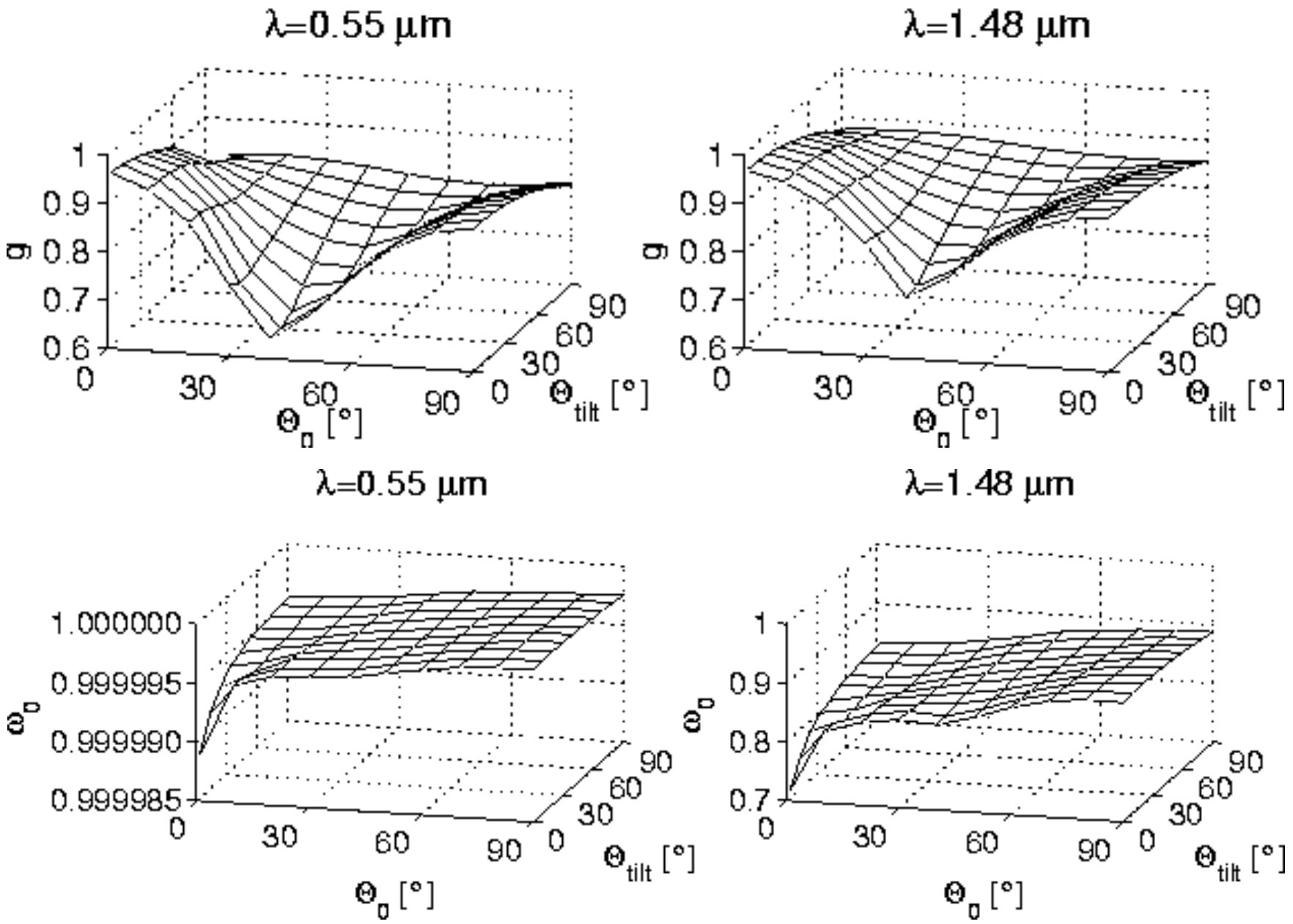
http://www.ifm-geomar.de

http://www.ifm-geomar.de/index.php?id=981&L=1

Orientation of hexagonal columns



Klotzsche and Macke (2005), Appl. Opt.

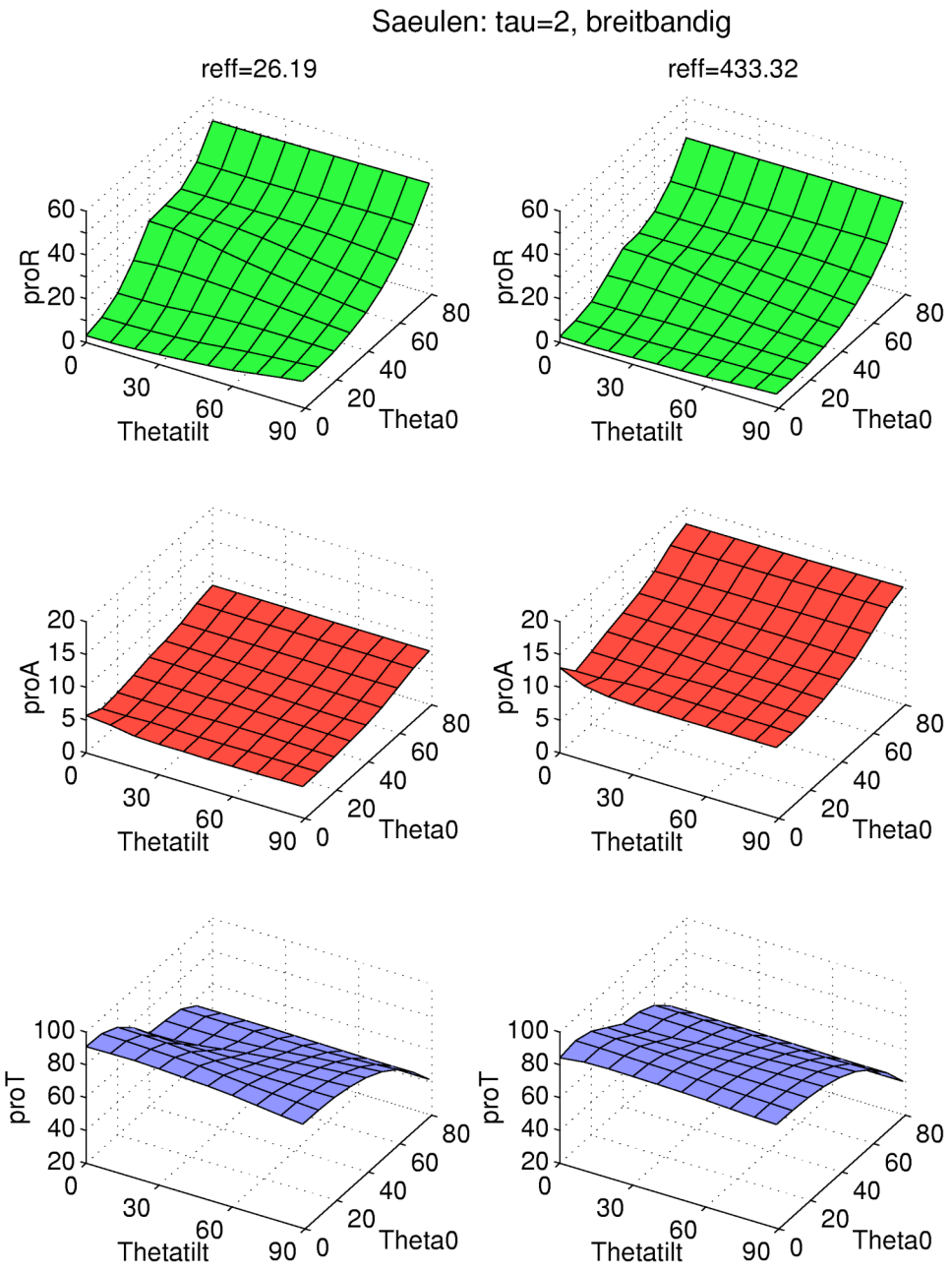

λ=0.55 µm
λ=1.48 µm
λ=0.55 µm
λ=1.48 µm
g
ω0
Θ0 [°]
Θtilt [°]
0
30
60
90
0.6
0.7
0.8
0.9
1
1.000000
0.999995
0.999990
0.999985

Solar broadband radiative fluxes of oriented hexagonal columns

Reflection

Absorption

Transmission



Solar zenith angle ->

Maximum tilt angle ->

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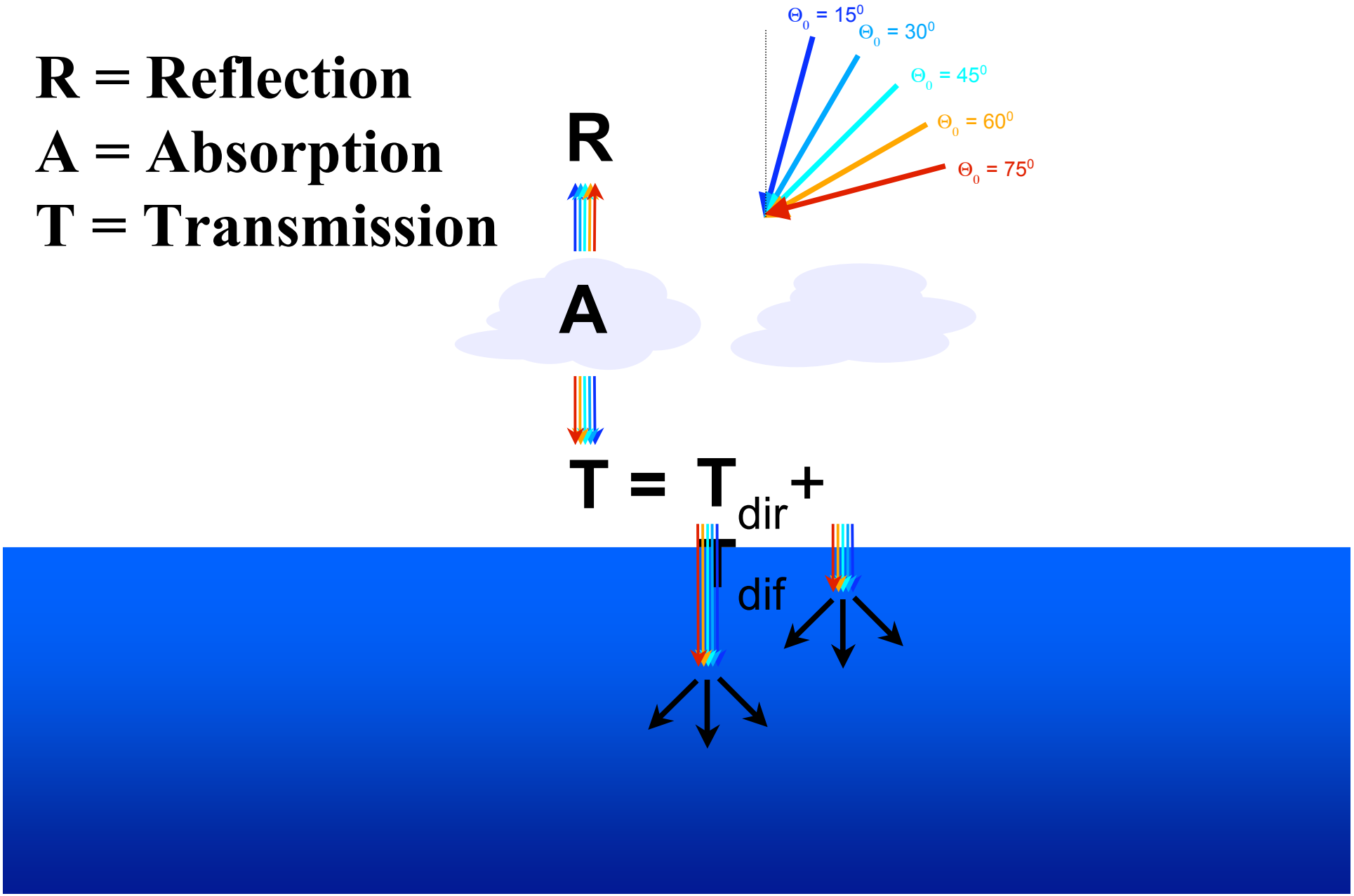
Solar radiation budget

R = Reflection

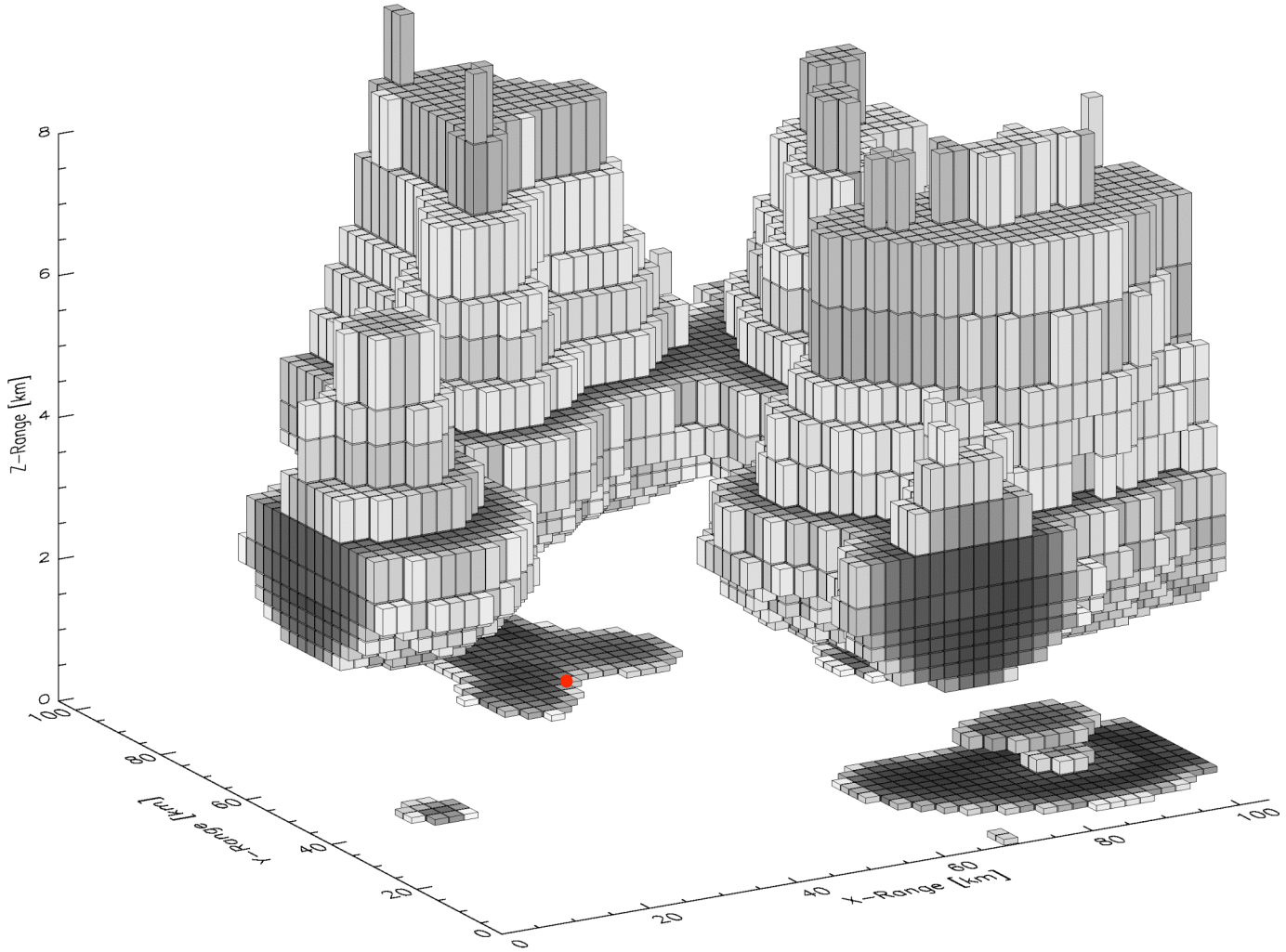
A = Absorption

T = Transmission



GESIMA: 3d, non-hydrostatic, bulk cloud physics

cloud water, rain, ice, snow/graupel



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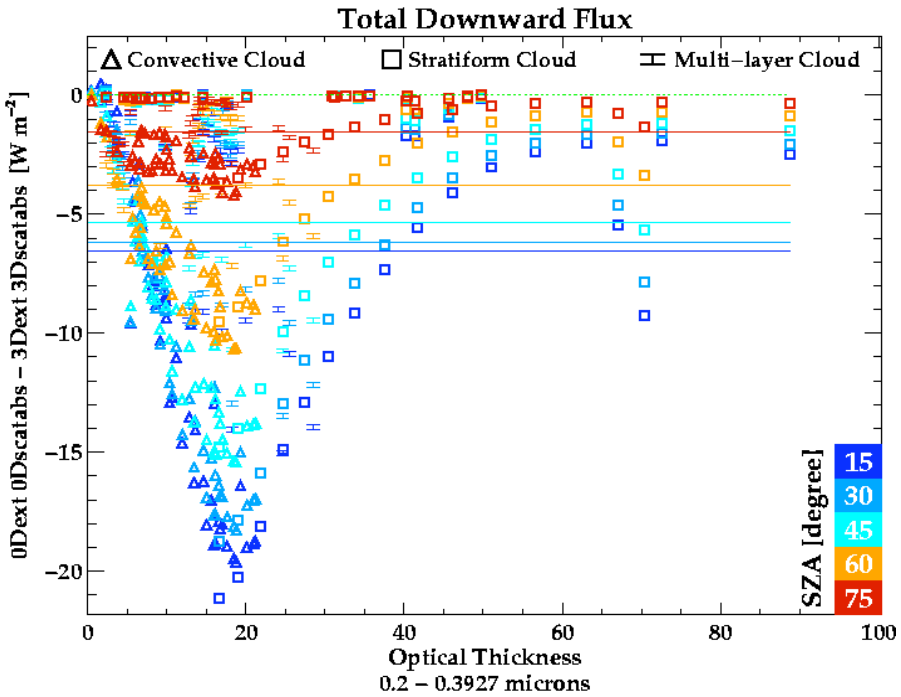
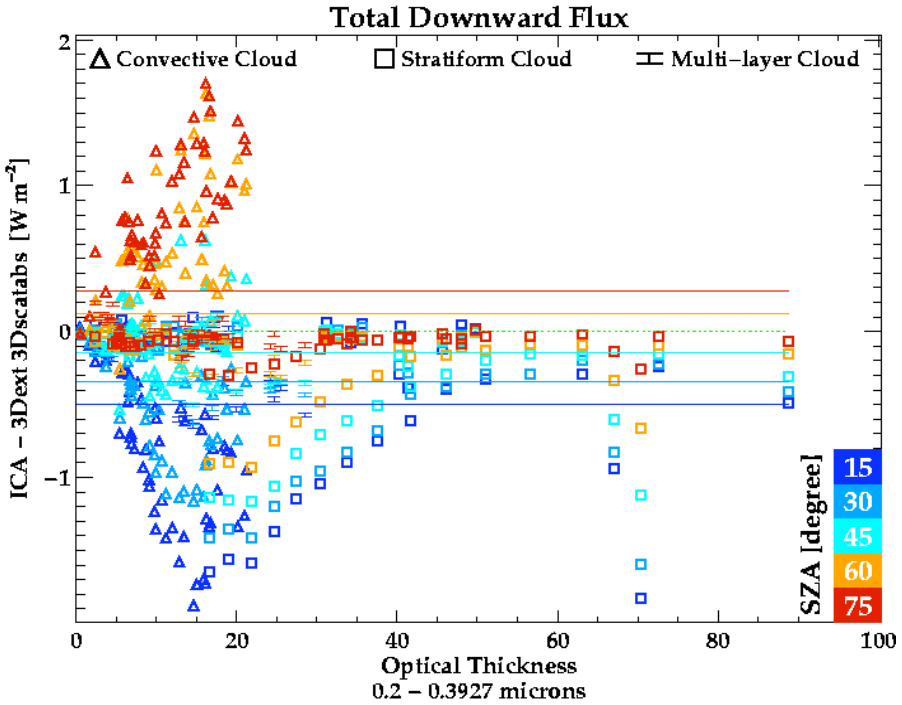
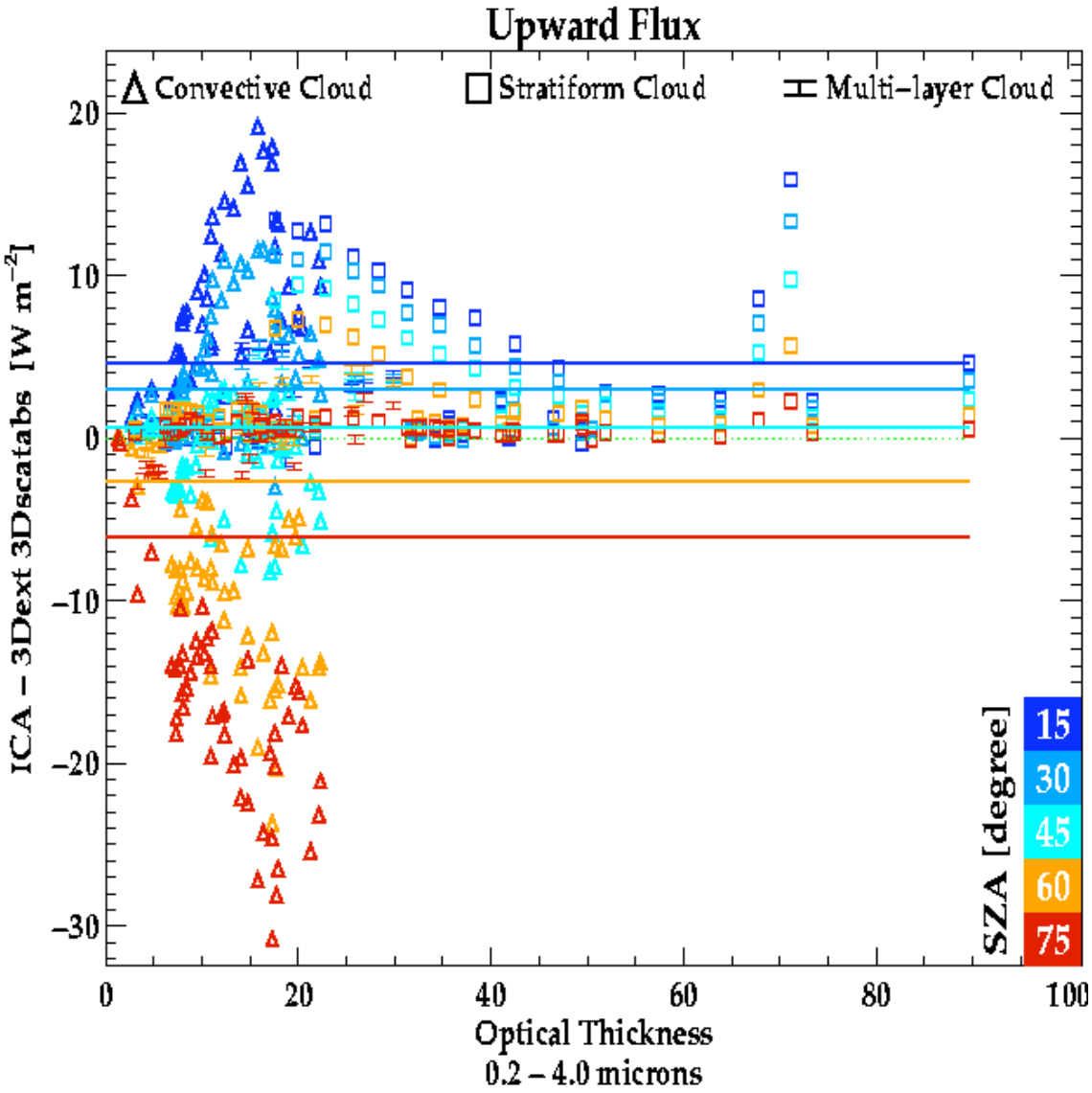
Clouds & UV total downward flux



HOM - 3D



ICA - 3D


Upward Flux
Convective Cloud
Stratiform Cloud
Multi–layer Cloud
ICA – 3Dext 3Dscatabs [W m^{-2}]
20
10
0
–10
–20
–30
0
20
40
60
80
100
Optical Thickness
0.2 – 4.0 microns
SZA [degree]
15
30
45
60
75

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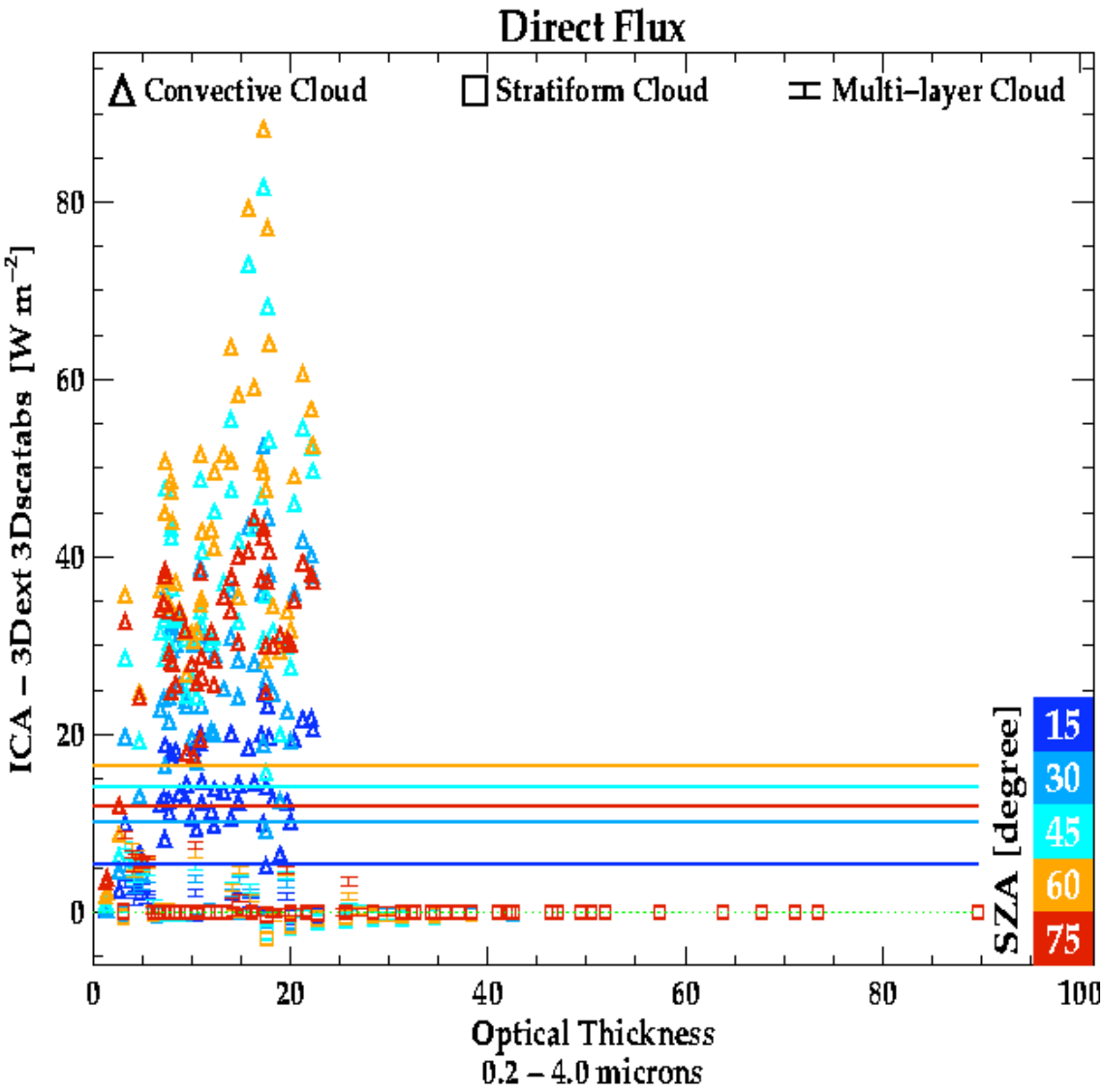
Direct Flux
Convective Cloud
Stratiform Cloud
Multi-layer Cloud
ICA – 3Dext 3Dscatabs [W m^{-2}]
0
20
40
60
80
0
20
40
60
80
100
Optical Thickness
0.2 – 4.0 microns
SZA [degree]
15
30
45
60
75

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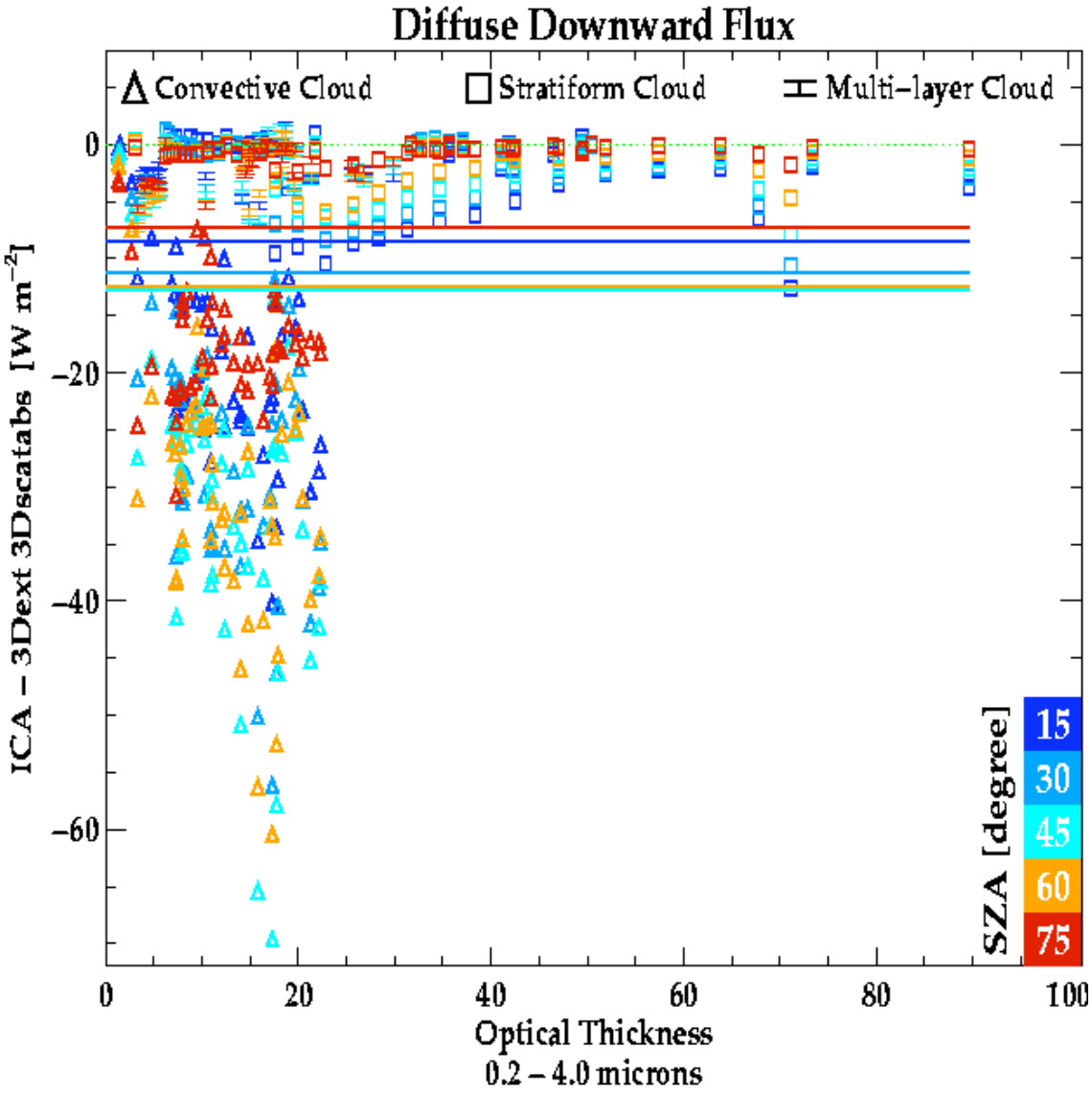
Diffuse Downward Flux
Convective Cloud
Stratiform Cloud
Multi–layer Cloud
ICA – 3Dext 3Dscatabs [W m^{-2}]
0
–20
–40
–60
0
20
40
60
80
100
Optical Thickness
0.2 – 4.0 microns
SZA [degree]
15
30
45
60
75

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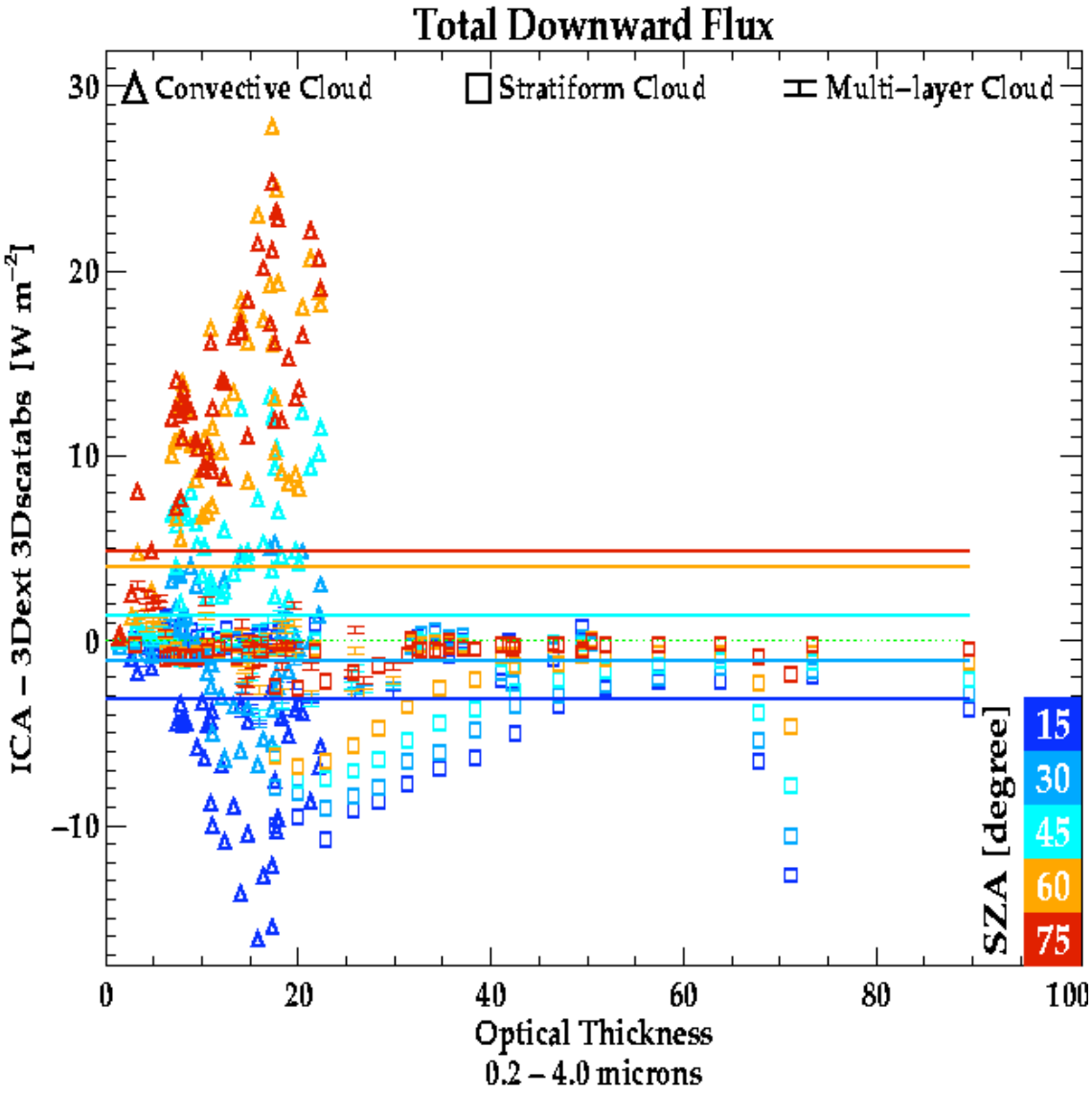
Total Downward Flux
Convective Cloud
Stratiform Cloud
Multi–layer Cloud
ICA – 3Dext 3Dscatabs [W m^{-2}]
30
20
10
0
–10
0
20
40
60
80
100
Optical Thickness
0.2 – 4.0 microns
SZA [degree]
15
30
45
60
75

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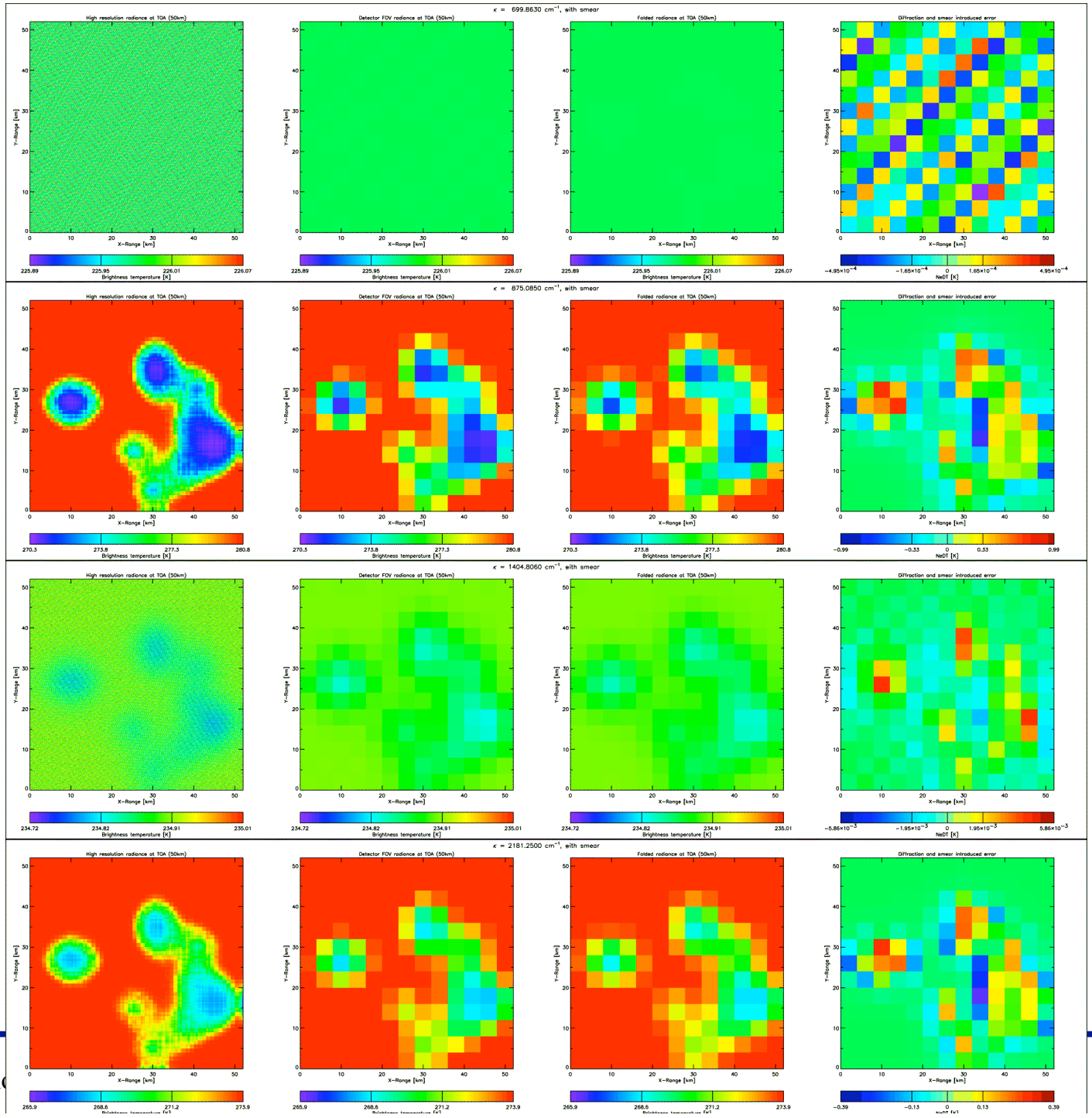
MTG Infrared Sounder Simulator

IR-Sounding from Geostationary Orbit ->
Diffraction induced Point Spread Function


κ = 699.8630 cm⁻¹, with smear
High resolution radiance at TOA (50km)
Detector FOV radiance at TOA (50km)
Folded radiance at TOA (50km)
Diffraction and smear introduced error
κ = 875.0850 cm⁻¹, with smear
κ = 1404.8060 cm⁻¹, with smear
κ = 2181.2500 cm⁻¹, with smear
X-Range [km]
Y-Range [km]
Brightness temperature [K]
NeDT [K]