# libRadtran user course, lecture # 6

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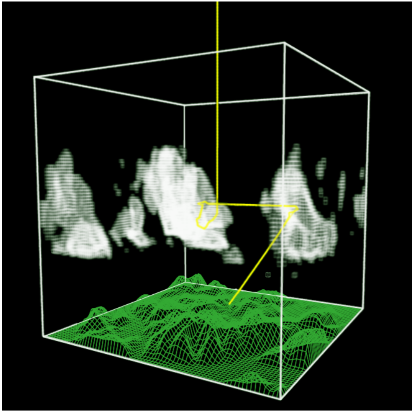
# 3D Radiative transfer

Why 3D?

- Clouds are generally 3D in nature.
- Earth's surface is not flat.
- 1D models can not transport photons horizontally
- 1D model can not handle shadow effects (clouds, topography).

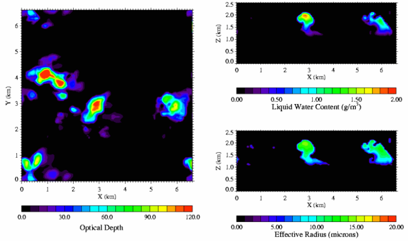


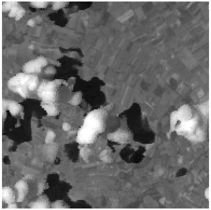
Does it matter? Depends on application. The more one averages over spatial and temporal scales, the less 3D effects matter in general.

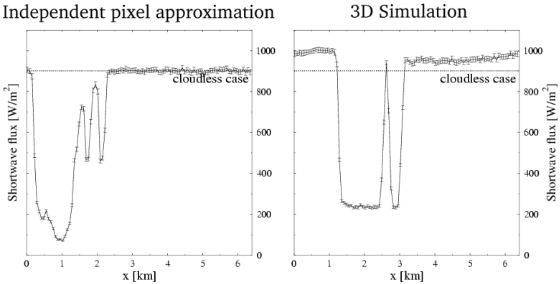
Why 1D?

- Computationally fast
- Simpler to handle in all ways (input, output)

# 3D Radiative transfer, an example

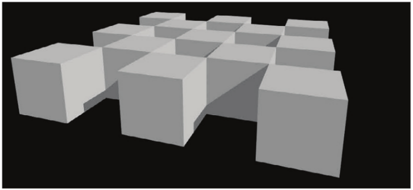


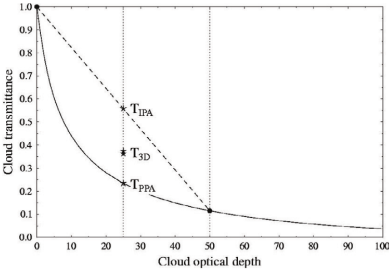






See `bmayer.de` for more.

# 3D Radiative transfer, and one more

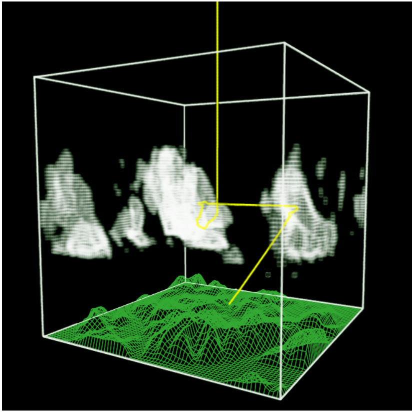





From Mayer (2009).

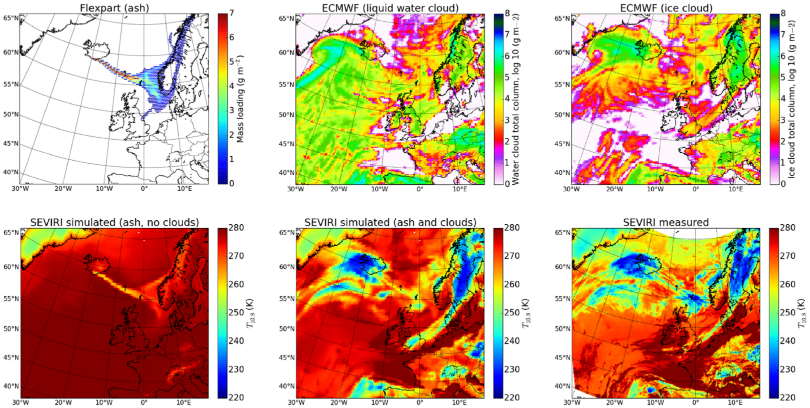
# Solution of the RTE in 3D: Monte Carlo

- Discretesize 3D atmosphere into rectangular cuboids
- For each voxel specify absorption and scattering properties (clouds, aerosol, trace gases)
- 1D atmosphere above and below 3D volume
- Specify altitude and albedo/BRDF of surface
- Specify photon source (solar, thermal, wavelength etc.)
- Solve by Monte Carlo method. Use enough photons to get results with acceptable statistical noise.
- Careful with circular horizontal boundary conditions!



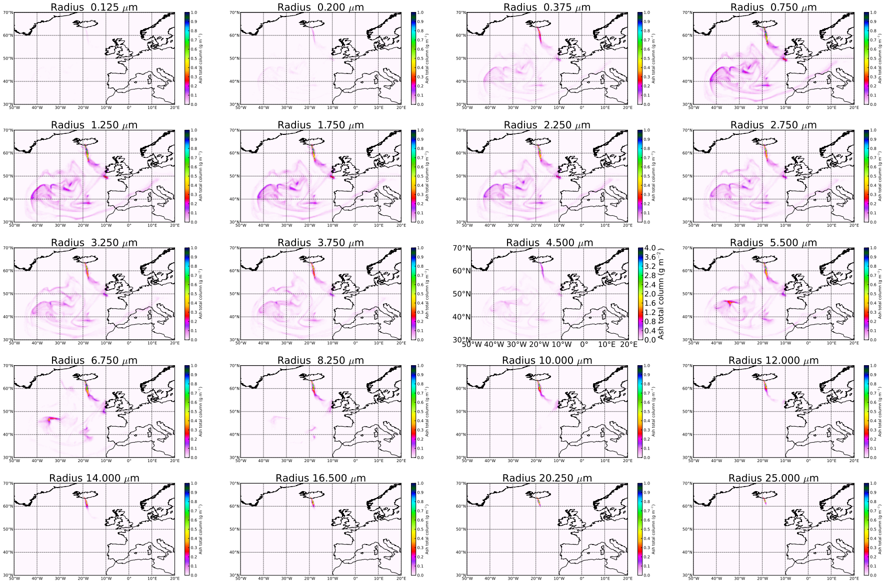
See Mayer (2009) for a description of how the MYSTIC model works.

# MYSTIC example I

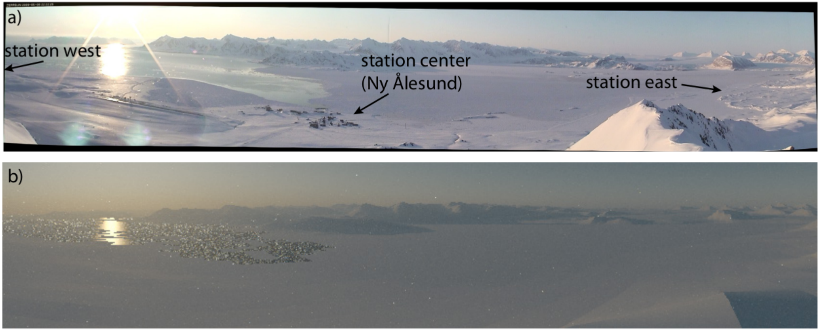



From Kylling et al. (2015).

# Ash cloud for various particle radii



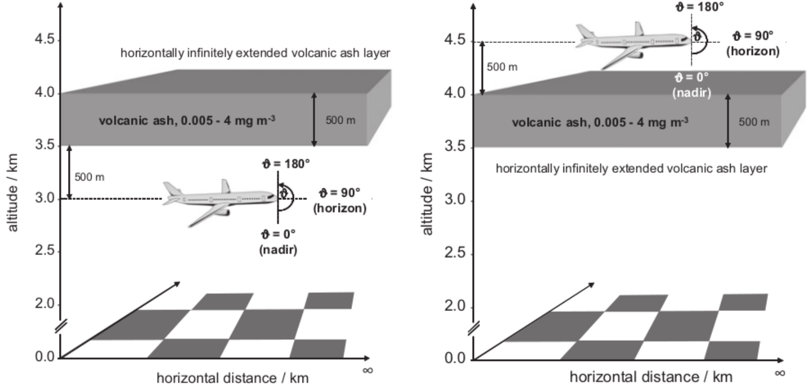
# MYSTIC example II




(a) Webcam view towards the north from Zeppelin moun- tain overlooking Ny lesund on 8 May 2009, 22:00 UTC. The locations of two stations are visible, station west is further to the west. Due to low wind speed, a pronounced sun glint is visible over the ocean. (b) With MYSTIC, the simulated radiances (RGB) with a BRDF model for water reflection (Cox and Munk, 1954, with 2 m/s wind speed) ) show the same effect and indicate a realistically modeled scene.

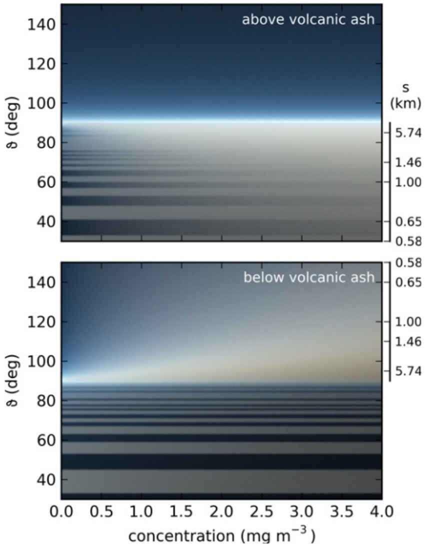
From Kreuter et al. (2014).

Airborne volcanic ash and mineral dust from the pilots perspective in flight



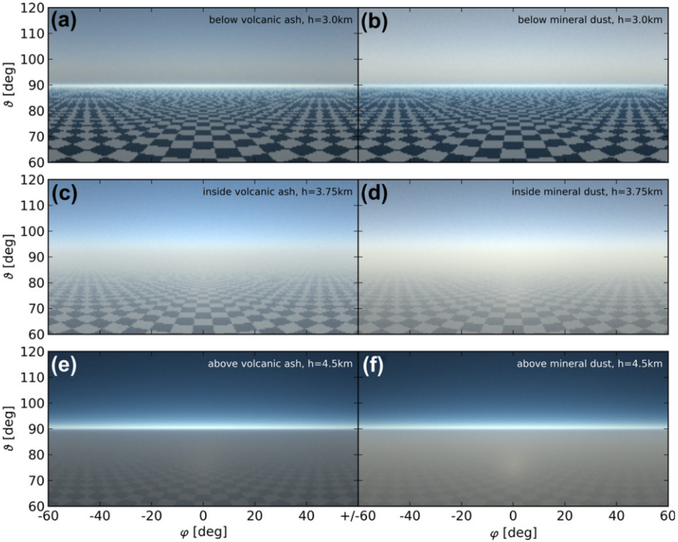

From Weinzierl et al. (2012).

# MYSTIC example III, cont'd




From Weinzierl et al. (2012).

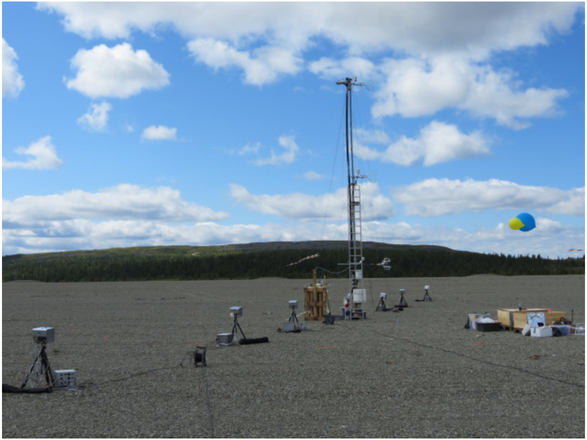
# MYSTIC example III, cont'd




From Weinzierl et al. (2012).

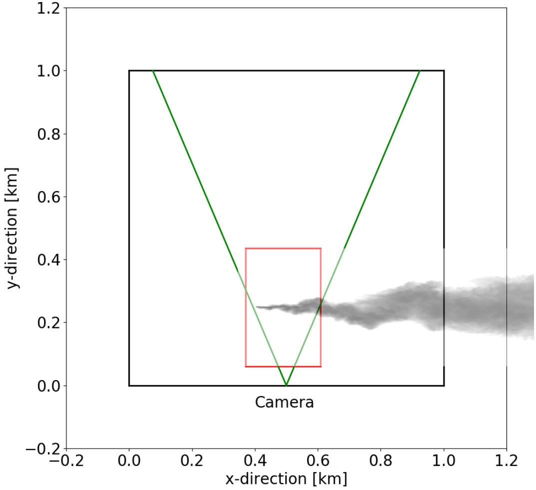
# MYSTIC example IV, COMTESSA

Camera Observation and Modelling of 4D Tracer Dispersion in the Atmosphere

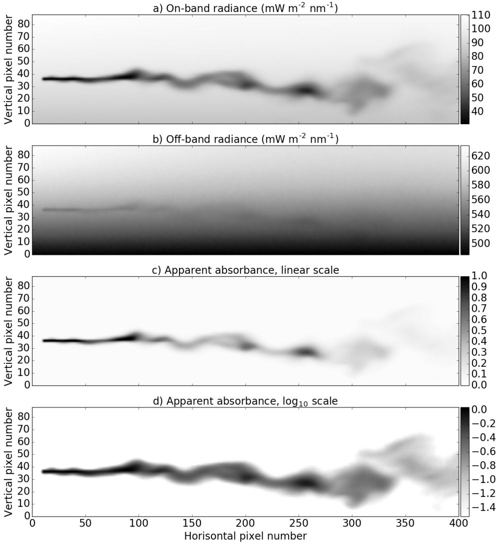


See `https://comtessa-turbulence.net/` for more.

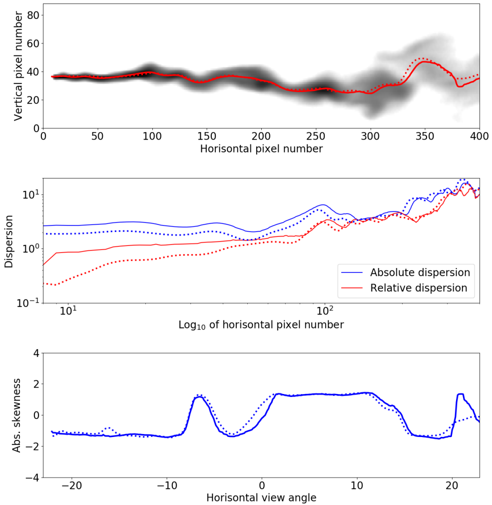
UV camera viewing $SO_2$ plume.



# MYSTIC example IV, cont'd



# MYSTIC example IV, cont'd

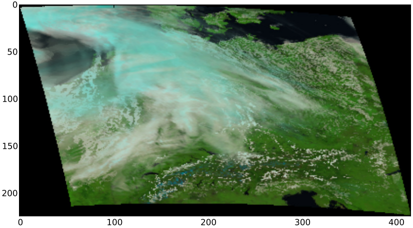


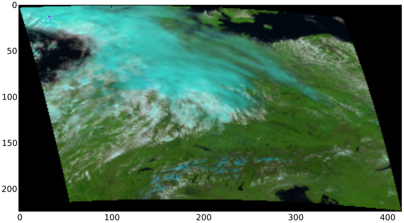
# Sample MYSTIC input file

```
data_files_path /xnilu_wrk/users/aky/develop/libRadtran_njord/data/
atmosphere_file /xnilu_wrk/users/aky/develop/libRadtran_njord/data/atmmod/afglms.dat
sza 40.0
albedo 0.0
umu -0.995000
phi0 45.0
phi 180.000000
wavelength 300.0 350.5
wavelength_grid_file ../Data/XSections/uvspec_SO2_wavelength_grid_file
source solar /xnilu_wrk/users/aky/develop/libRadtran_njord/data/solar_flux/kurudz_0.1nm.dat
profile_file Plumeyfilz 3d  ../Experiments/palm_tomo_Rena/W310TSO2SUNSZA40NWQBLC005.profile
profile_properties Plumeyfilz ../Data/XSections/SO2_Hermans_298_air_MYSTIC interpolate
mol_abs_param crs
rte_solver montecarlo
mc_sample_grid 400 88
mc_backward
mc_std
mc_minphotons 200
mc_sensorposition    500.0      0.0      1.0
mc_panorama_view 157.000000 203.000000 86.000000 96.000000
mc_panorama_alignment mu
mc_photons 200
mc_vroom on
mc_basename tmp_mystic_Camokmpj.out_NP_0
```

Postprocess to include filter functions to get output for the two UV-cameras.

# Validation (?): satellite images




Quiz: which image is simulated and which is measured?

# MYSTIC to do

# Today's exercises:

- By modifying `UVSPEC_MC.INP`, can you get the solar irradiance at the bottom of the atmosphere above the cloudless maximum value?
- Compare 1D, IPA, and 3D

Hints:

- example input files: `UVSPEC_MC.INP`
- options `mc_*`

# References I


Cox, C. and Munk, W.: Measurement of the roughness of the sea surface from photographs of the Sun's glitter, J. Opt. Soc. Am., 44, 838–850, 1954.

Kreuter, A., Buras, R., Mayer, B., Webb, A., Kift, R., Bais, A., Kouremeti, N., and Blumthaler, M.: Solar irradiance in the heterogeneous albedo environment of the Arctic coast: measurements and a 3-D model study, Atmospheric Chemistry and Physics, 14, 5989–6002, https://doi.org/10.5194/acp-14-5989-2014, URL `http://www.atmos-chem-phys.net/14/5989/2014/`, 2014.

Kylling, A., Kristiansen, N., Stohl, A., Buras-Schnell, R., Emde, C., and Gasteiger, J.: A model sensitivity study of the impact of clouds on satellite detection and retrieval of volcanic ash, Atmospheric Measurement Techniques, 8, 1935–1949, https://doi.org/10.5194/amt-8-1935-2015, URL `http://www.atmos-meas-tech.net/8/1935/2015/`, 2015.

Mayer, B.: Radiative transfer in the cloudy atmosphere, Eur. Phys. J. Conferences, 1, 75–99, 2009.

Weinzierl, B., Sauer, D., Minikin, A., Reitebuch, O., Dahlkötter, F., Mayer, B., Emde, C., Tegen, I., Gasteiger, J., Petzold, A., Veira, A., Kueppers, U., and Schumann, U.: On the visibility of airborne volcanic ash and mineral dust from the pilot's perspective in flight, Phys. Chem. Earth, 45-46, 87–102, 2012.