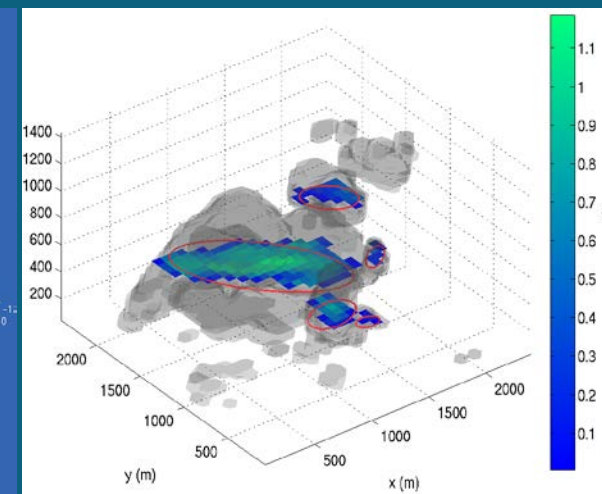
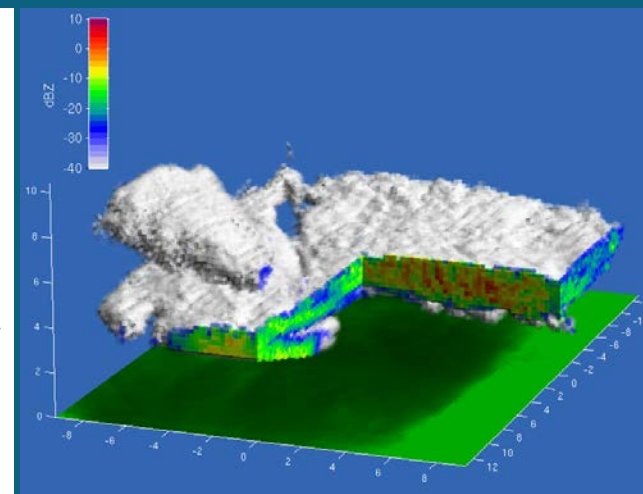
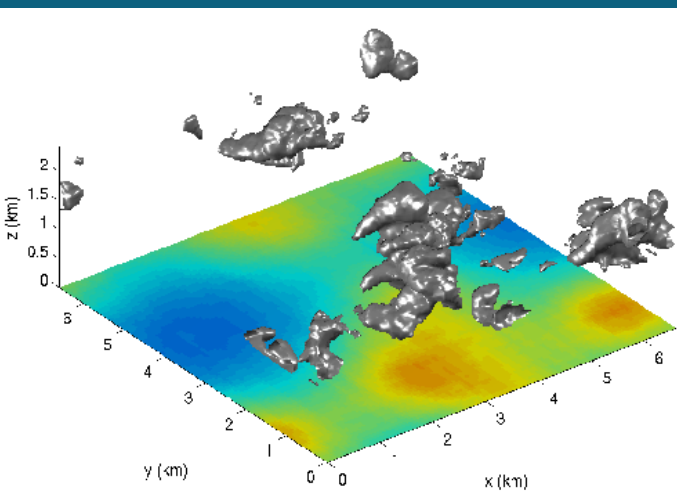


3D cloud-radiation interaction

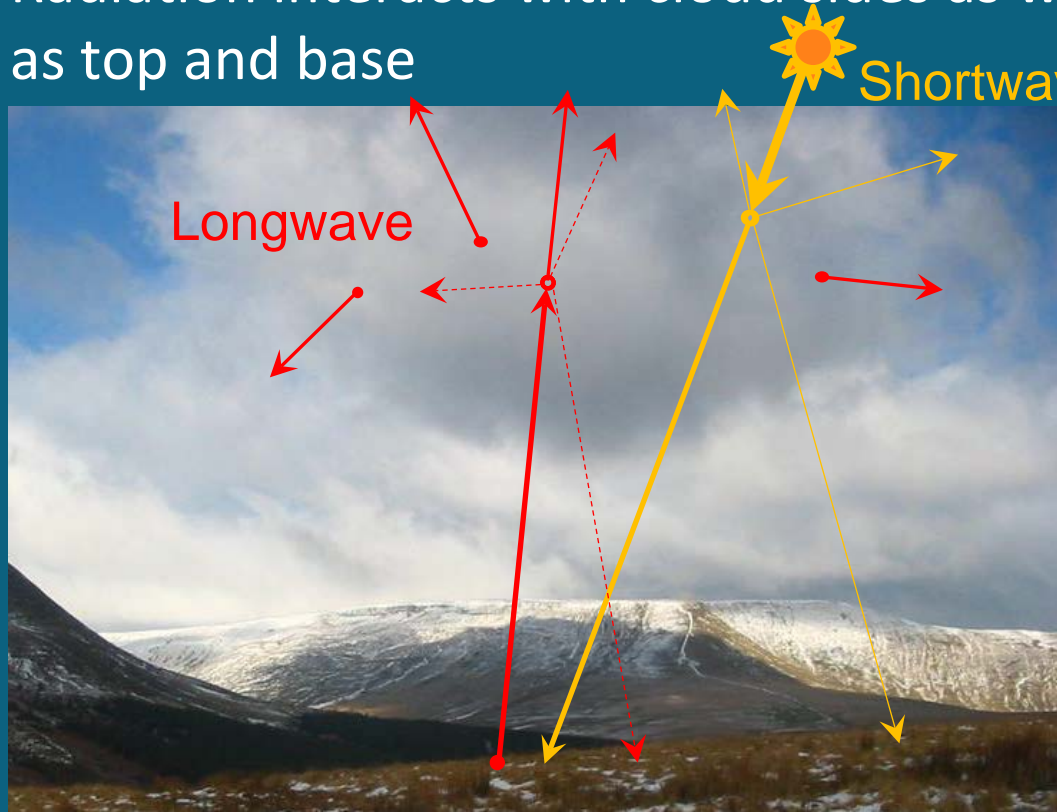
Sophia Schäfer

Contributions from Robin Hogan (ECMWF),
Bernhard Mayer and Carolin Klinger (LMU Munich)

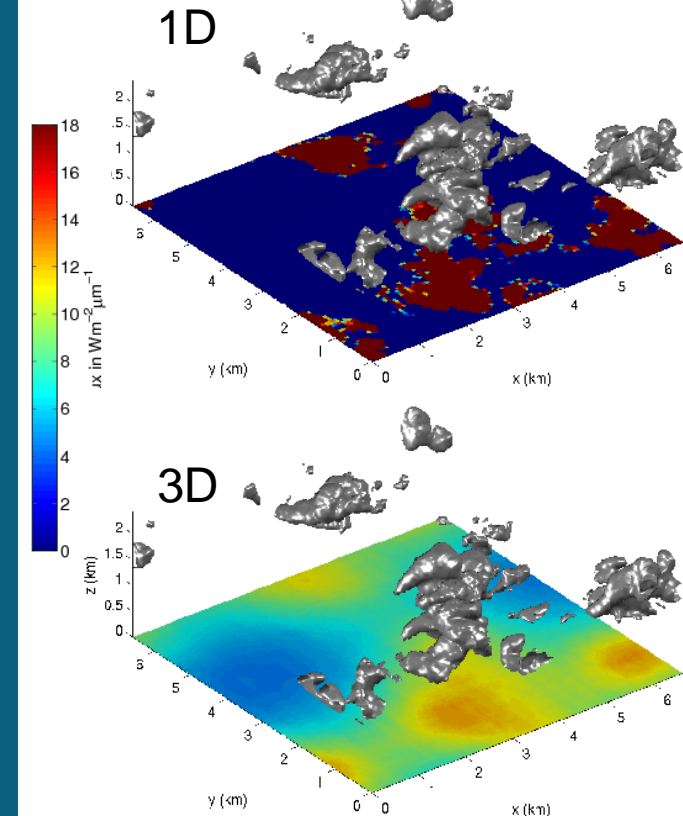


3D cloud-radiation effects

Radiation interacts with cloud sides as well as top and base

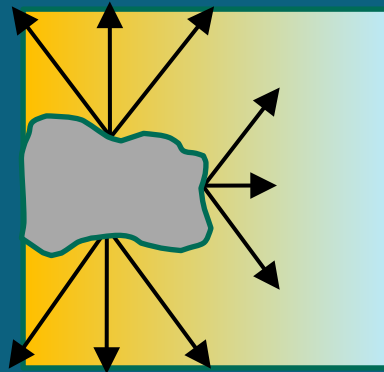


Downwelling longwave flux from cumulus clouds



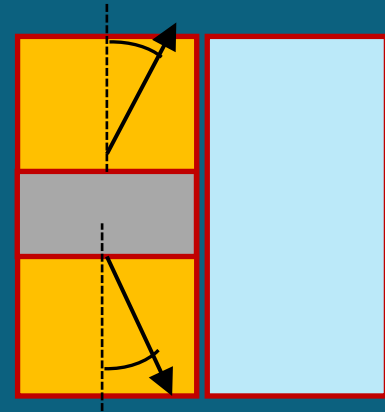
Can change total cloud effect by -25% to +100% in shortwave or +30% in longwave locally – how important globally?

3D effects neglected in most radiation models (1D)



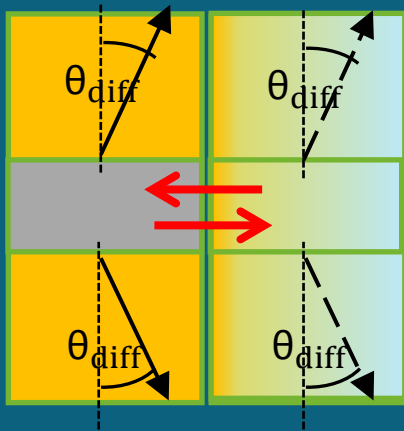
Reality

Global model's 2-stream scheme



SPARTACUS: Incorporating 3D effects in a new rapid radiation scheme

(SPeedy Algorithm for Radiative TRansfer through CloUd Sides, proposed by Hogan and Shonk, 2013)



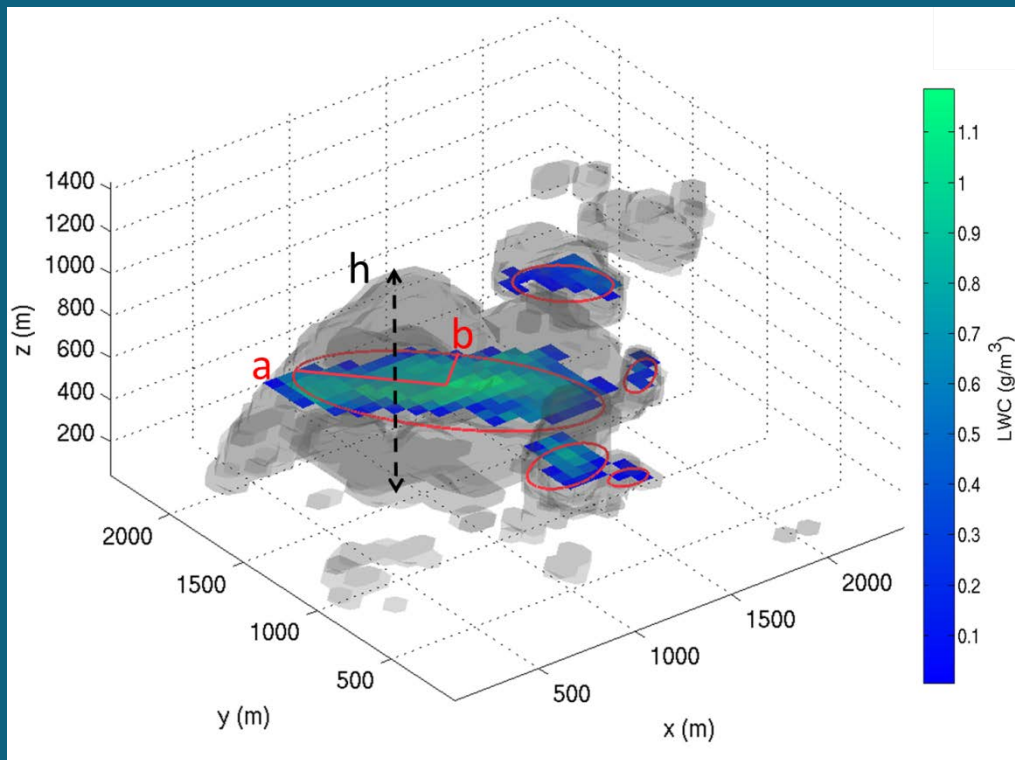
Based on 2-stream calculation, incorporates 3D effects as additional transfer terms between clouds and clear sky through cloud sides

Numerical cost ca 2x that of standard 2-stream scheme

Cloud geometry parameters

Cloud side transfer terms \propto Effective cloud edge length - smoother than measured edge length (Radiative smoothing, Marshak et al., J.G.R. 1995)

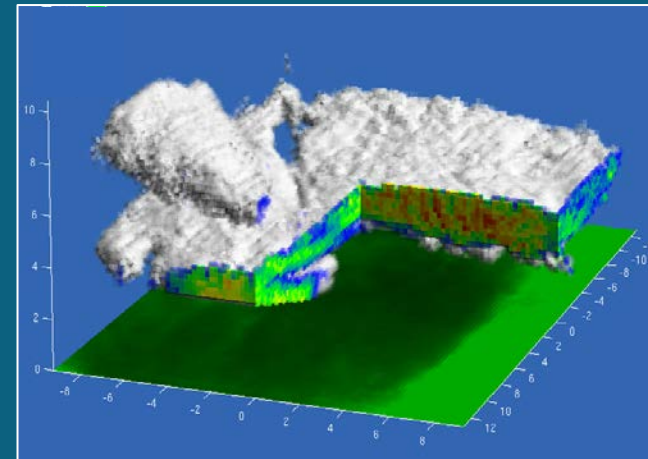
Good approximation: Ellipses



Also need to consider clustering of clouds, which determines how much cloud-side emission is intercepted by other clouds

Cloud structure observations

- Scanning cloud radar observations from Jülich Observatory for Cloud Evolution (JOYCE) and A-train satellites
- Derive effective edge length and clustering



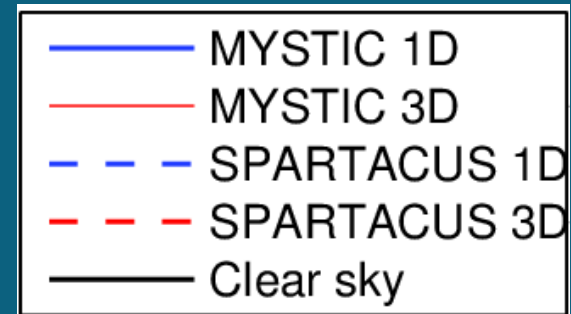
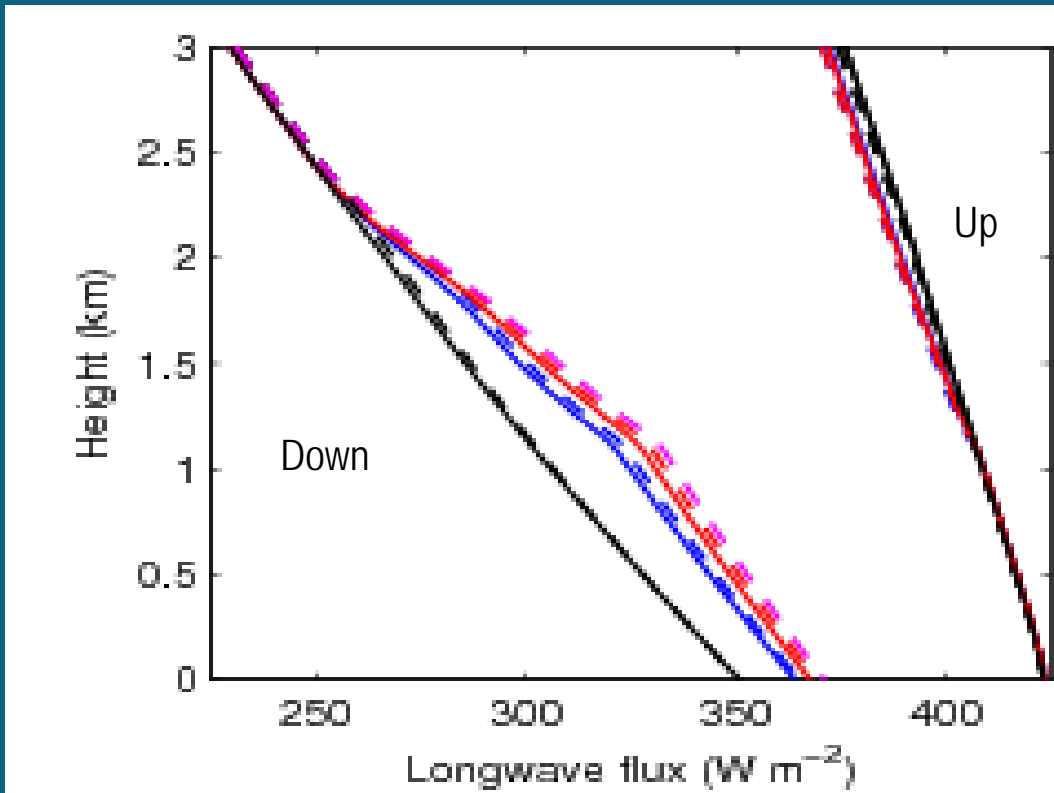
MIRA scanning cloud radar



3D Cloud field from MIRA data, visualisation courtesy of M. Fielding

SPARTACUS performance

Broadband longwave fluxes

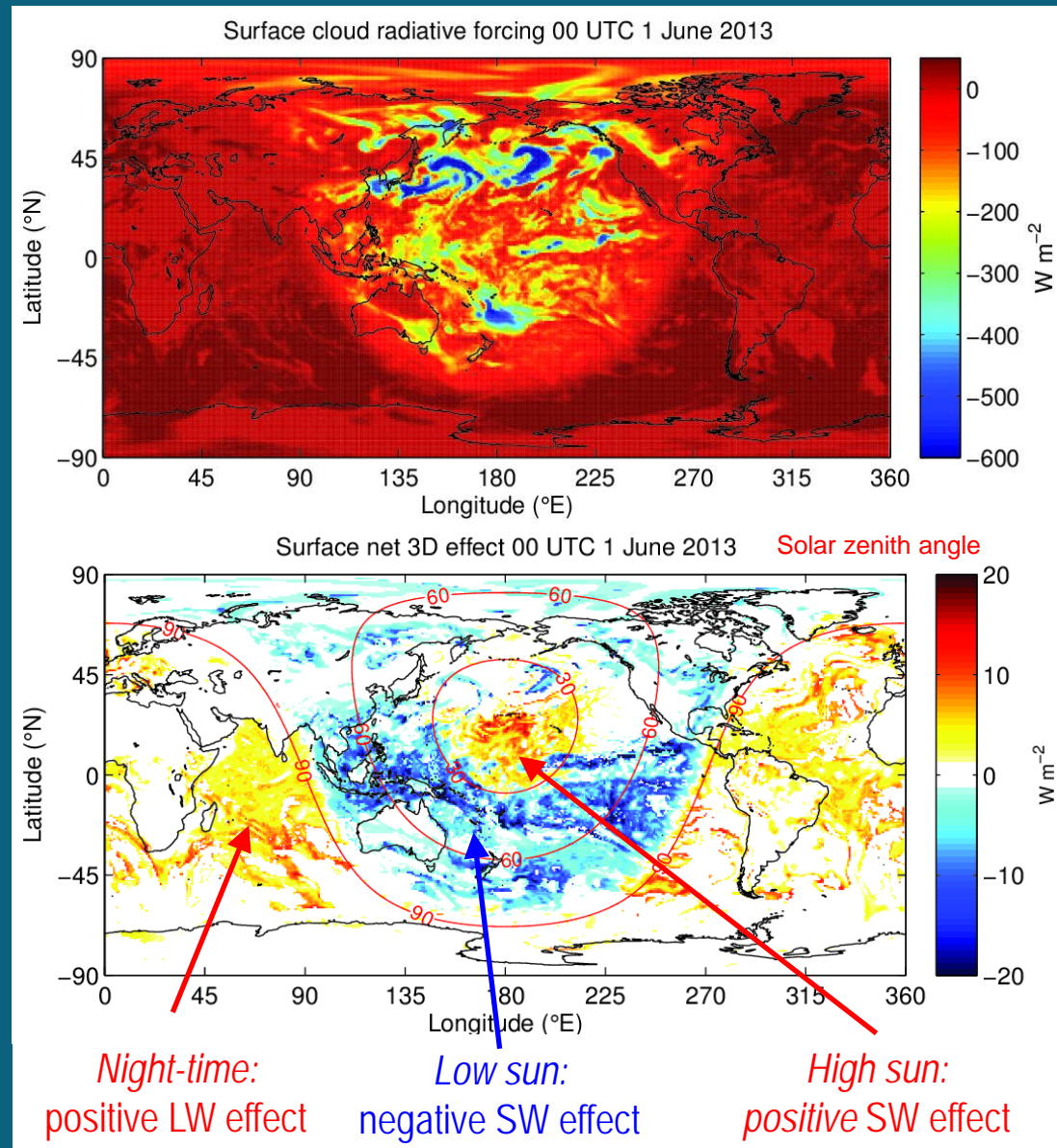


MYSTIC calculations by
C. Klinger and B. Mayer,
LMU Munich

- SPARTACUS and fully 3D Monte Carlo MYSTIC agree to within 10%
- better if we compensate for clustering
- SPARTACUS $10^4 - 10^7 \times$ cheaper

Global 3D effects

- SPARTACUS is efficient enough for global model – implemented in version of ECMWF's IFS radiation code
- 3D effects globally appreciable!
- Effects depend on cloud structure and solar zenith angle



Thank you for your attention !



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