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A unified approach to cirrus microphysics, remote sensing and climate prediction, and its impact in a climate model

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Current operational GCM assumes single ice crystal model (Edwards et al. 2007)

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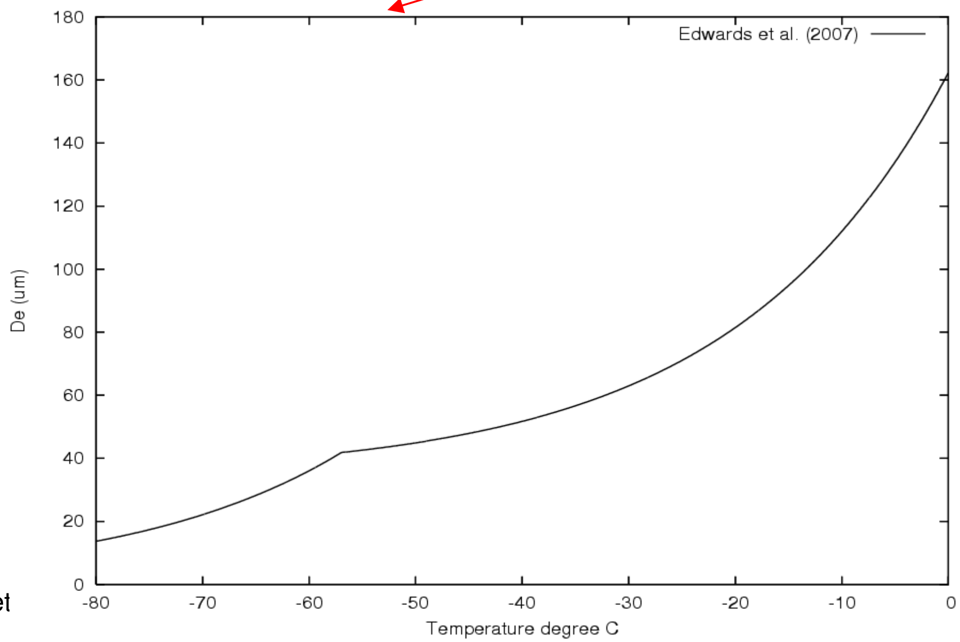
$$\omega_0, g \;\&\; K_{ext}$$

Prognostic variable

Diagnosed variable

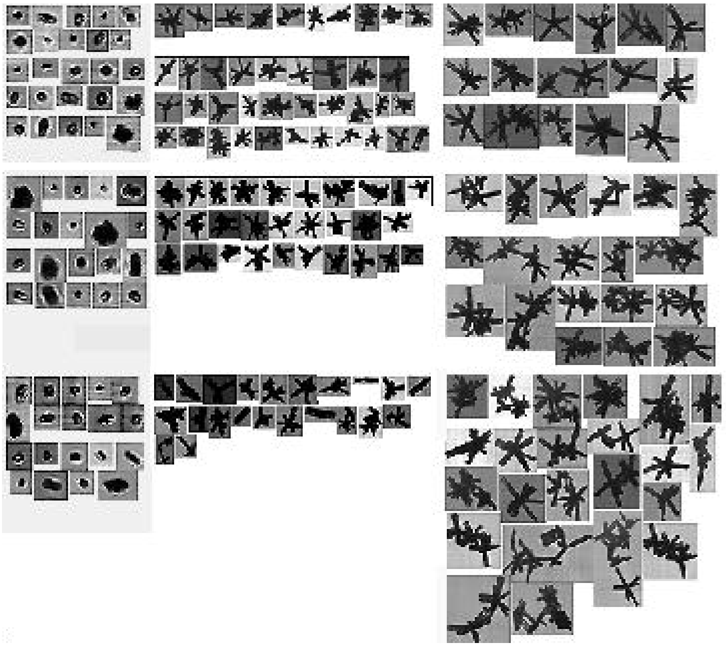
$$K_{ext} \sim \frac{q_i}{D_e(T_c)}$$



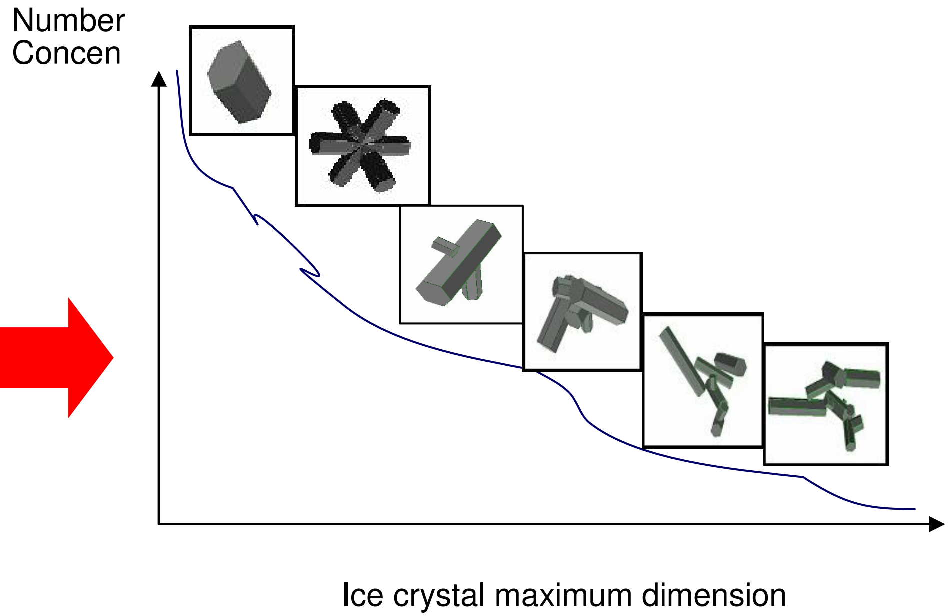
- Inconsistent PSDs
- D_e not the same
- $K_{ext} \propto 1/D_e$ not general across spectrum
- Single models not consistent across spectrum (UV-Radar)

Generalise (Baran and Labonnote 2007)

An example image



T-matrix and GO (random orientation)



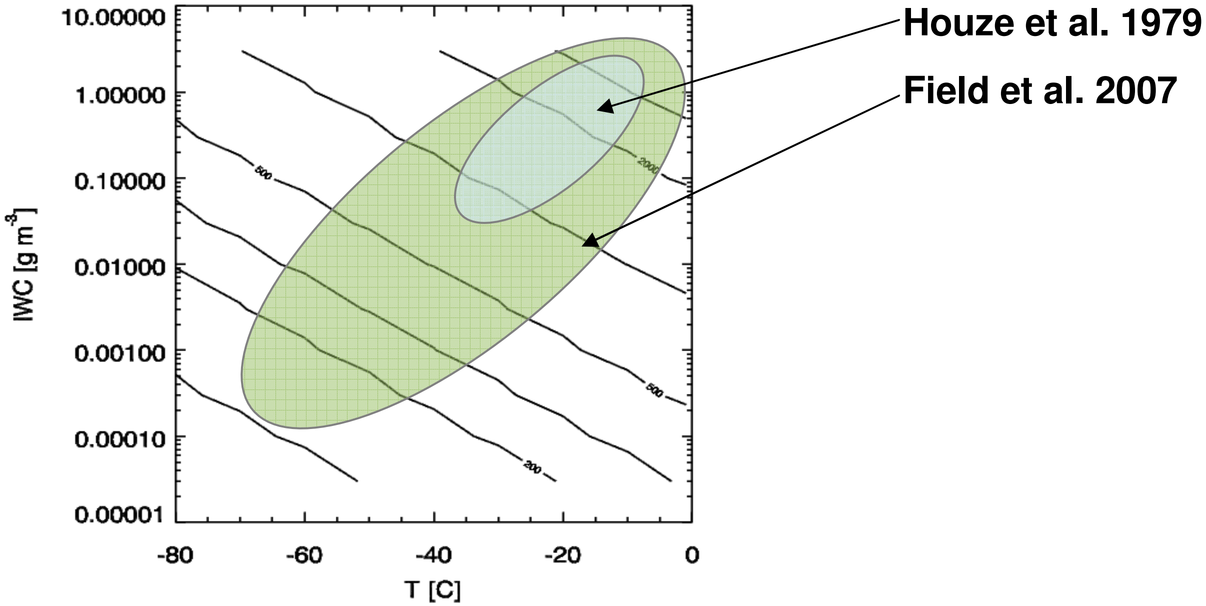
$$\langle K_{ext/sca} \rangle = \int_{D_{min}}^{D_{max}} [\sum_{j=1}^{j=6} w_j k_j(D)] n(D) dD$$

Shown to possess right area & mass size dependency & simulate active & radiometric measurements (UV- 35 GHz)(Baran et al. 2014)

Moment estimation parameterization, Field et al. (2007)

$$\mathcal{M}_n = A(n)\exp[B(n)T_c]\,M_2^{C(n)}$$

$M_2 = aD^b$ in expts a=0.0257 b=2 (Cotton et al. 2013)



Links PSD to ice mass (climate model prediction) and T_c. Moments are used to predict cloud evolution

PSDs in climate model cloud microphysics scheme same as radiation scheme & mass-D relationship same in both

Bulk optical properties & parametrization

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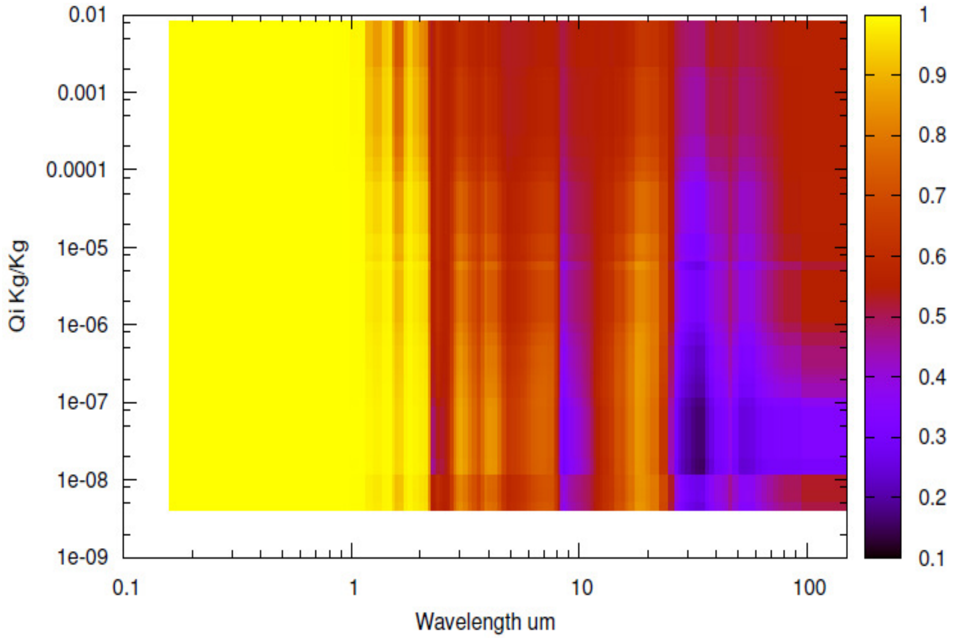
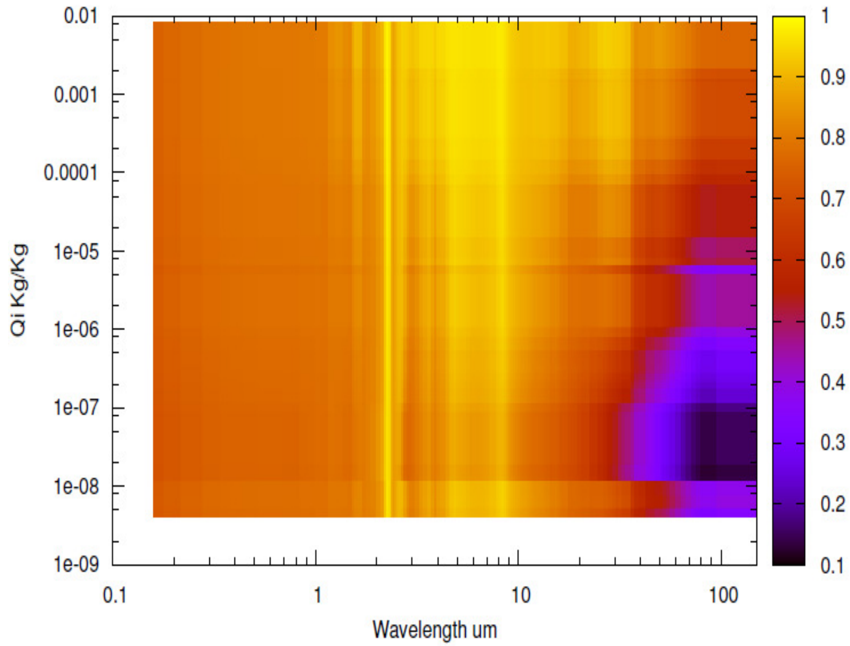
$$K(\lambda,q_i)_{ext(sca)}=a_\lambda q_i \quad : \quad g(\lambda,q_i)=b_\lambda q_i^{c(\lambda)} \quad : \quad \omega_0(\lambda,q_i)=K_{sca}(\lambda,q_i)/K_{ext}(\lambda,q_i)$$

ω_0

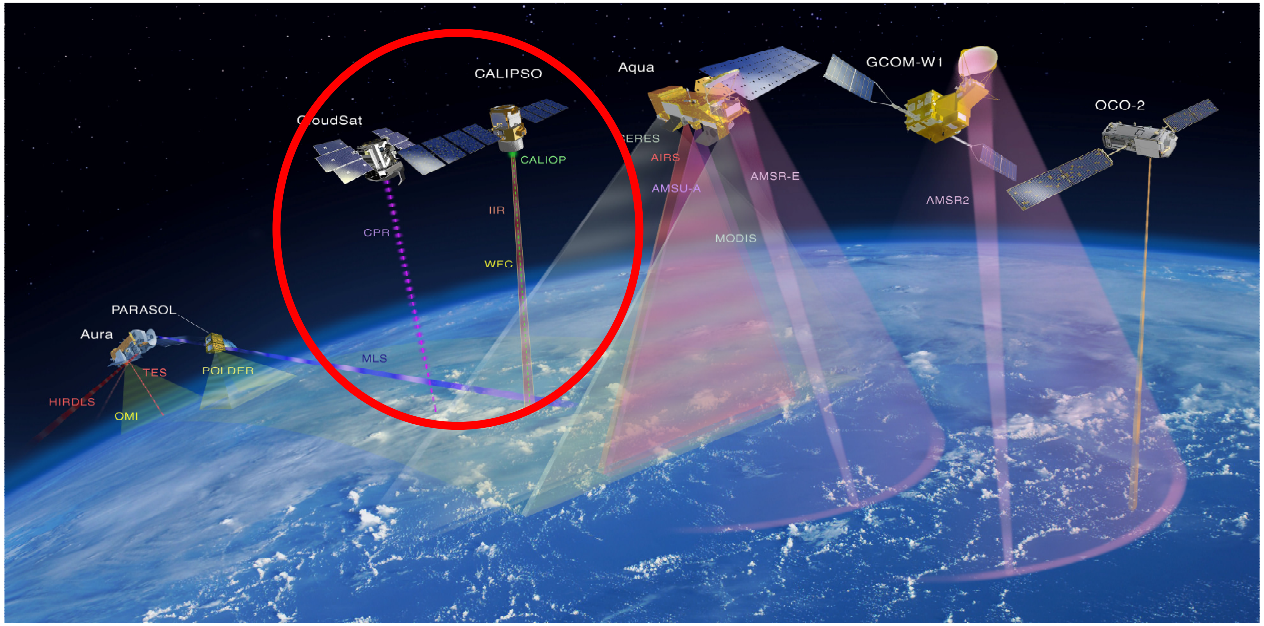


g



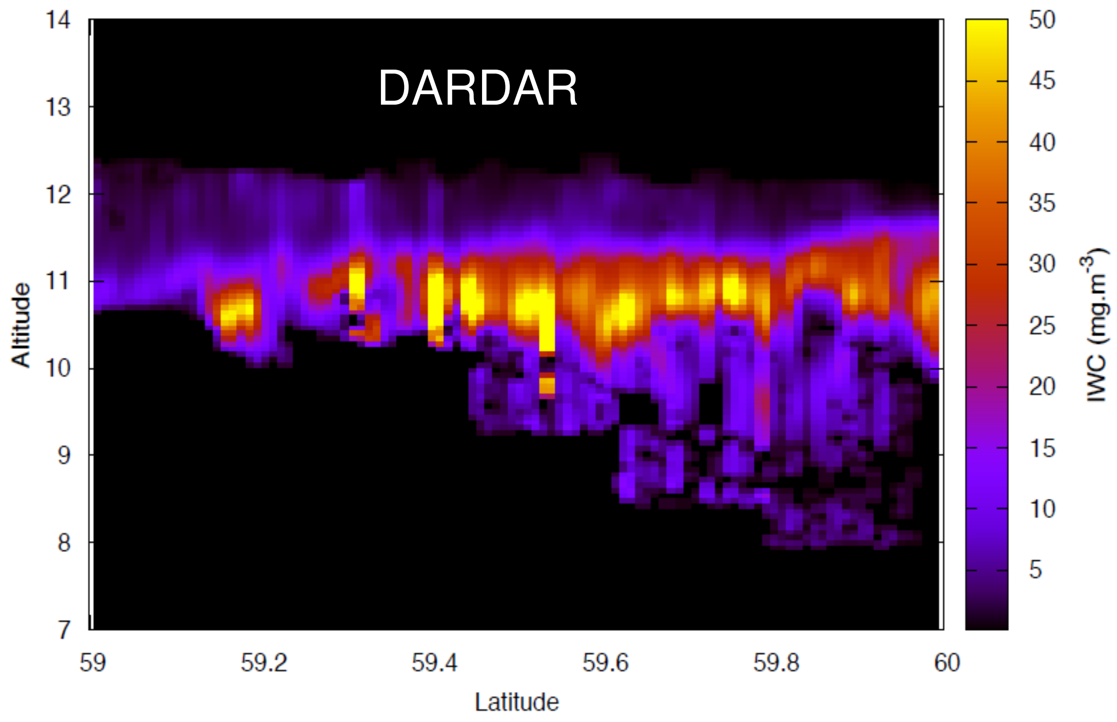
The bulk optical properties were obtained from 20662 PSDs estimated from a number of field campaigns including CAESAR (UK), CEPEX (Tropics), FRAMZY (Europe) then parametrized as simple functions

Combine radar and lidar to obtain cloud profiles (Jerome Vidot)



- BT Observations from IIR (CALIPSO) at 8.7, 10.6 and 12 microns (pixel size ~1km, calib. error ±1K)
- BT Simulations from Ice cloud profiles (IWC, D_{eff}) from CPR/CloudSat and CALIOP/CALIPSO combined product and ECMWF fields
- Combine 2C-ICE (Deng et al., 2010) & DARDAR (Delanoe and Hogan, 2010)
- CF=1 (2C-ICE and DARDAR spatial resolution is 1.4 km)

Cloud profiles of IWC from DARDAR & 2C-ICE products (Jerome Vidot)



CASE SELECTION

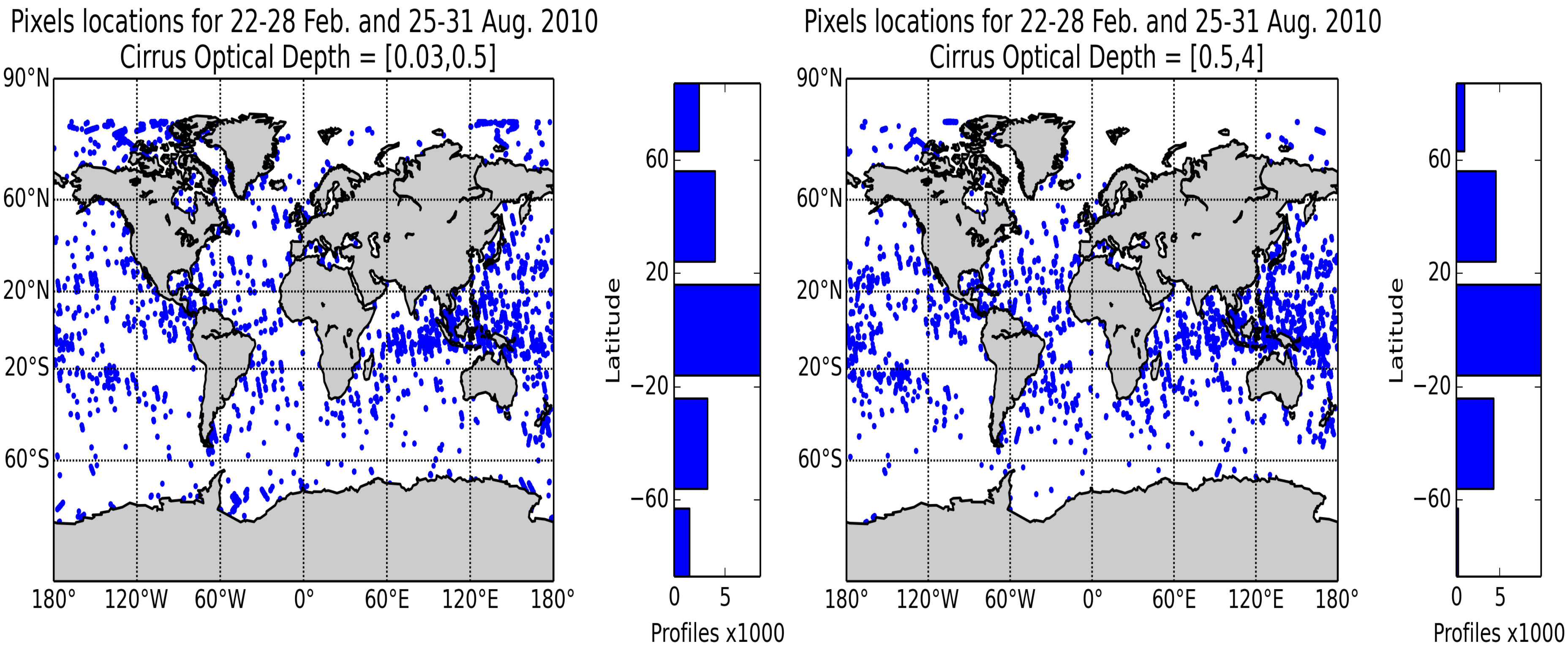
- DARDAR cloud mask (remove aerosols-contaminated profiles)
- only over oceans (reduce the surface emissivity error)
- cloud pressure within 440 and 50 hPa
- visible Cloud Optical Depth: 0.03--4

Global distribution of cirrus cases (Jerome Vidot)

N=26791 (1 week in February & 1 week in August 2010)

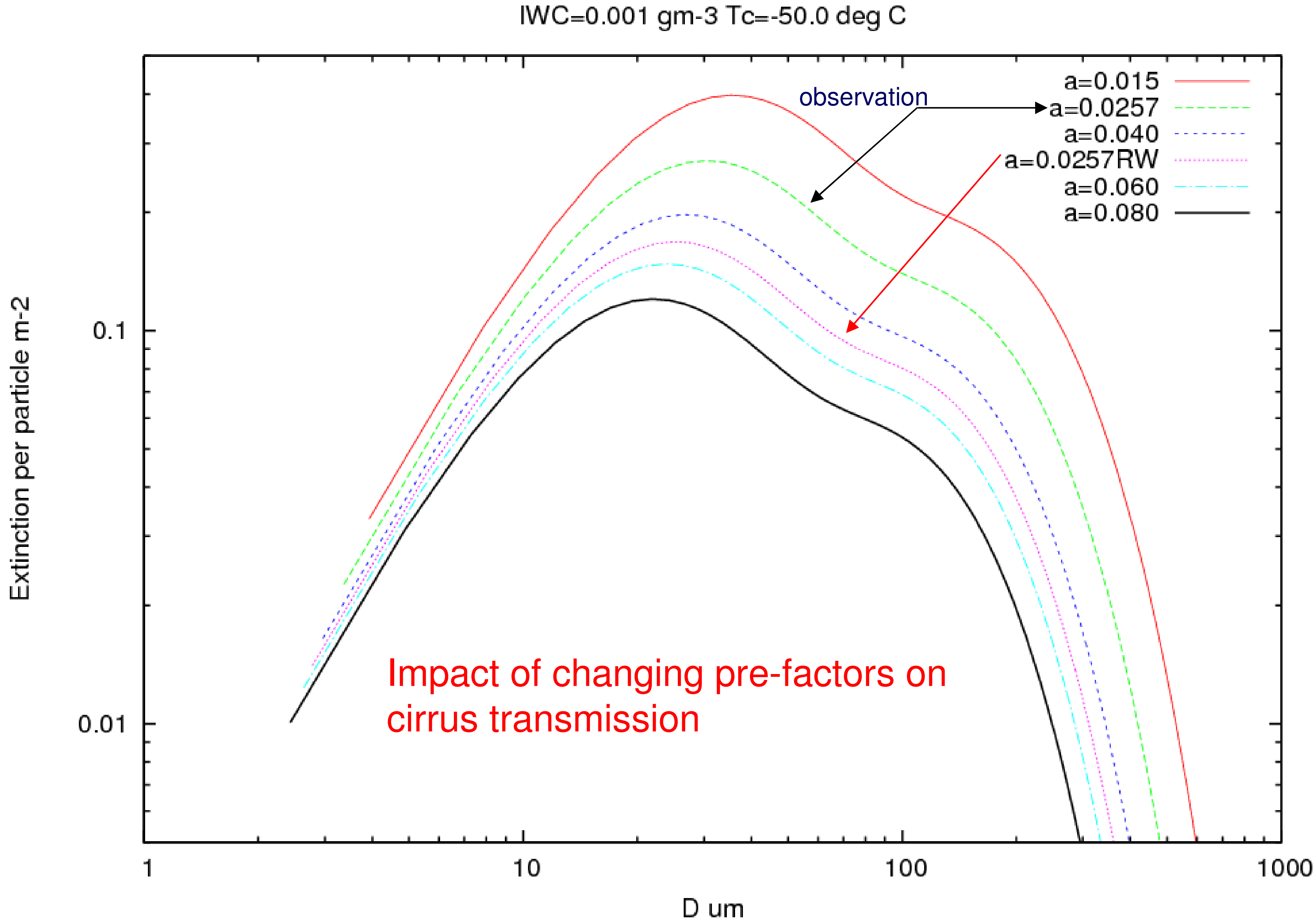
0.03 <τ <4 Semi-transparent cirrus

Altitudes 440 hPa – 50 hPa



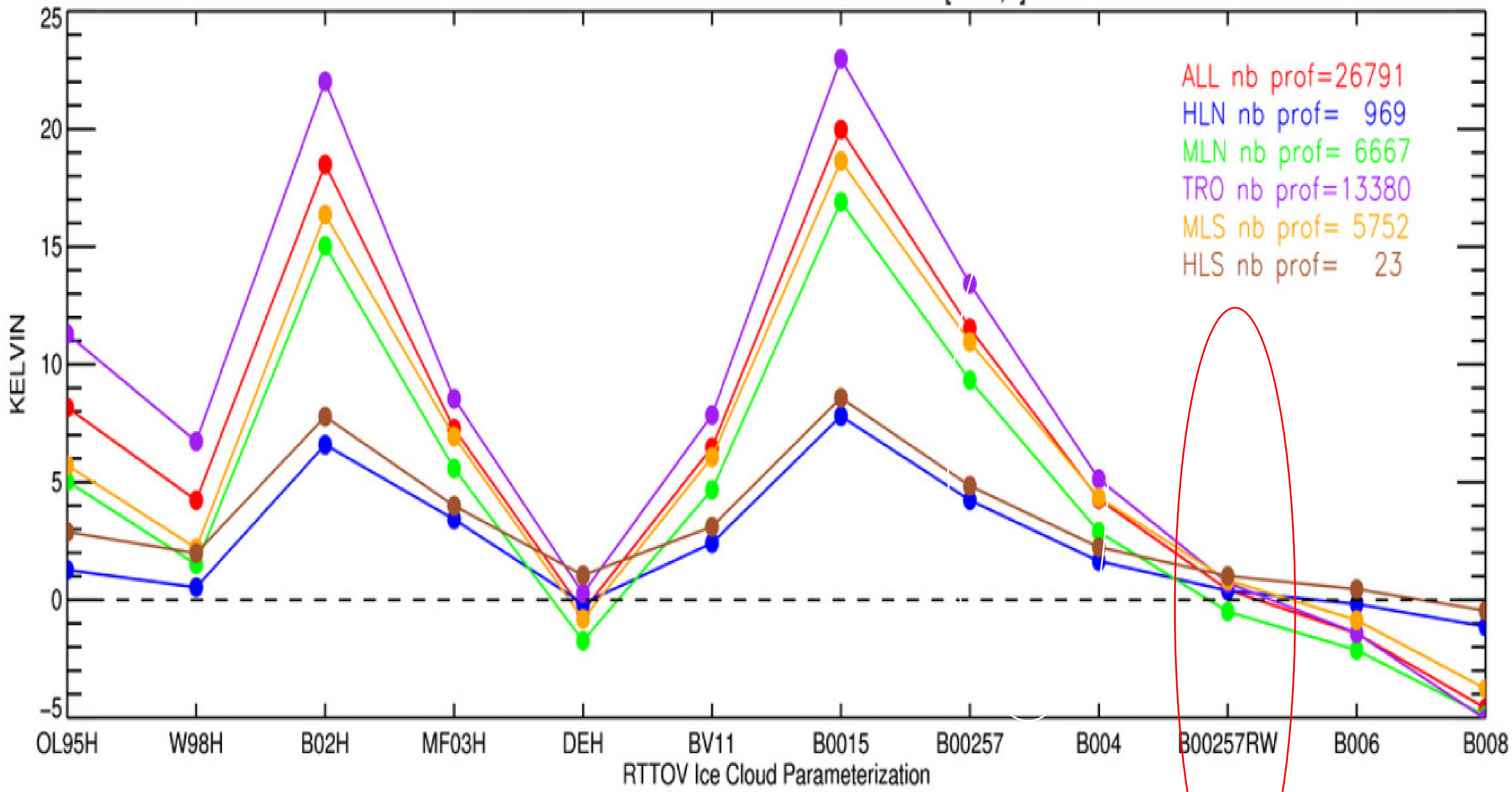
Simulate brightness temperatures using RTTOV-11

Field 2007 PSD [mass=$0.0257D^2$]



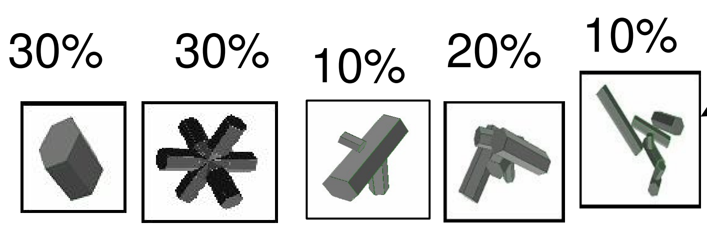
Results: Mean bias

Measurement - Simulation



Mean Bias=0.43K

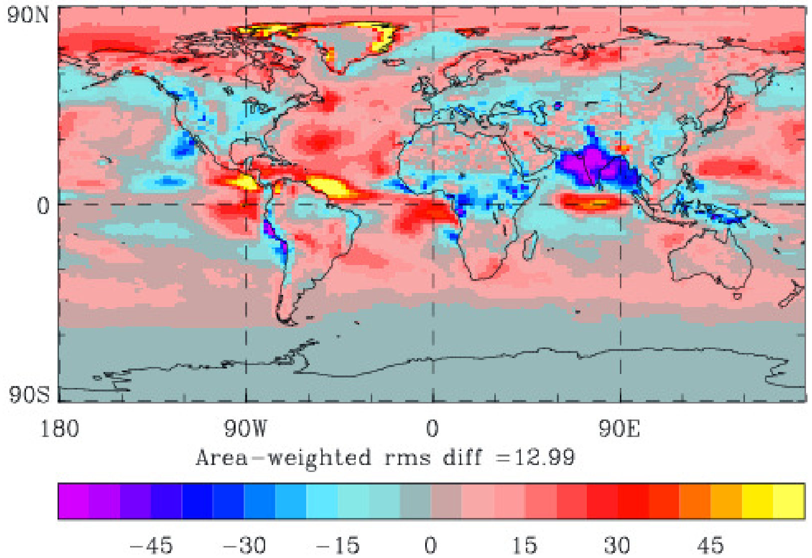
STD=6.85 K



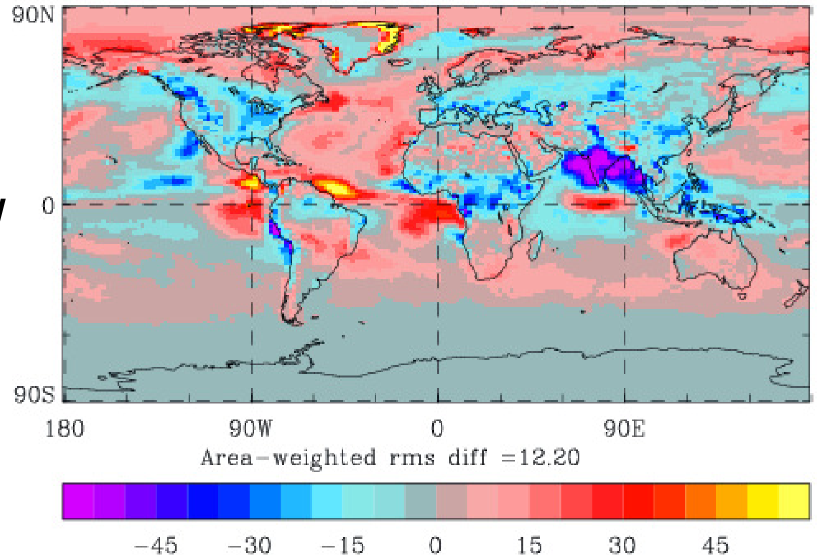
GCM 20 yr averaged SW & LW flux @ TOA – Measurements at TOA (EBAF): JJA

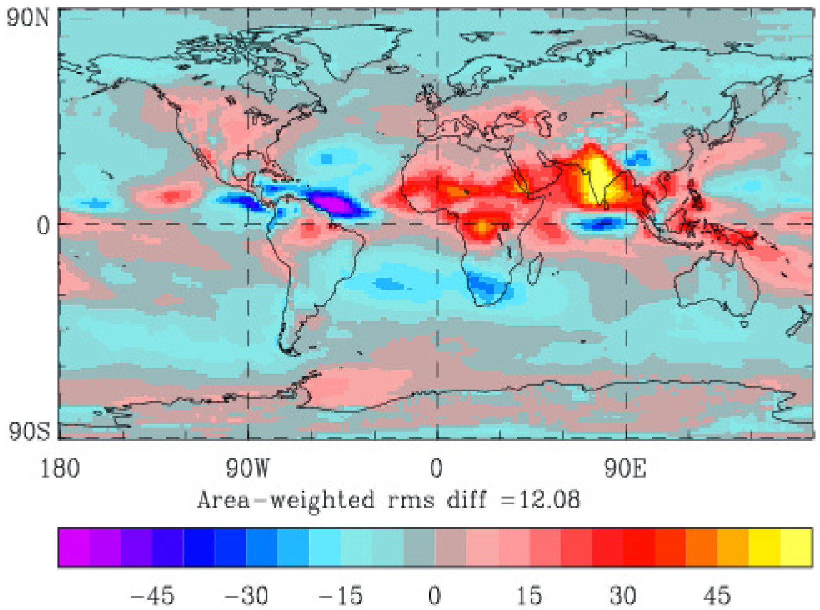
Inconsistent in terms of cirrus microphysics & radiation (GA6 next operational GCM)

Consistent cirrus microphysics & radiation

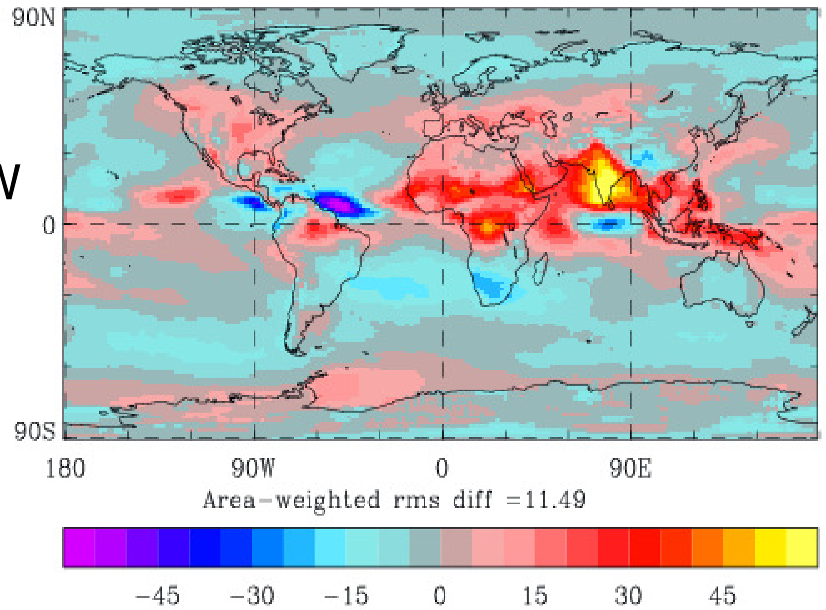


SW





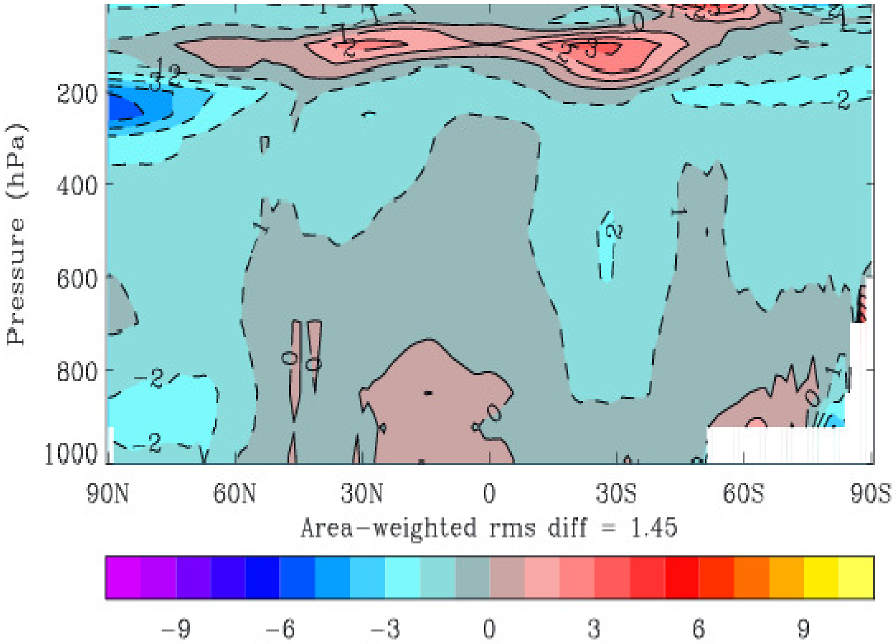
LW

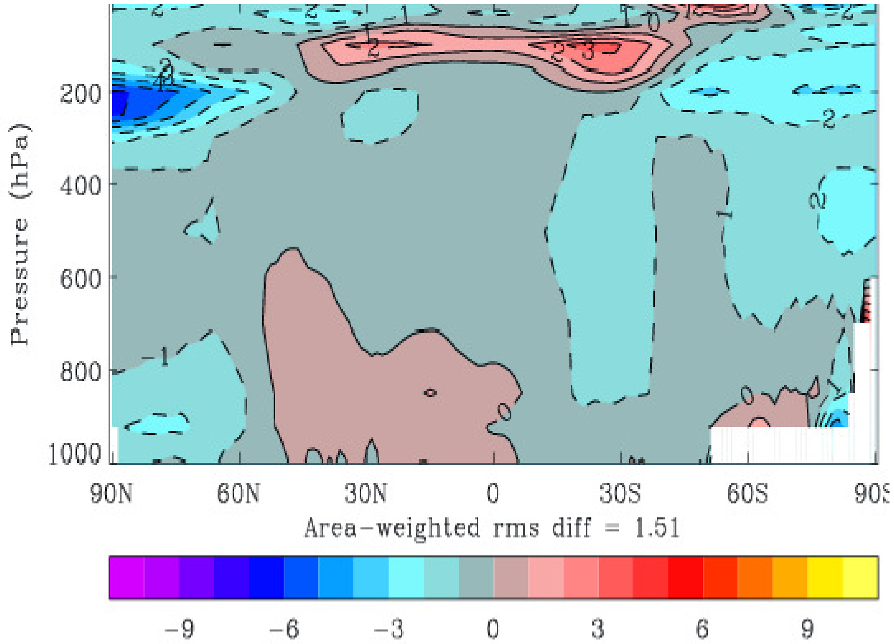


Impact on temperature structure of the atmosphere (JJA)

Inconsistent in terms of cirrus microphysics & radiation (GA6 next operational GCM)

Consistent cirrus microphysics & radiation





Model - ERA INTERIM

A consistent approach between cirrus microphysics, radiation & remote sensing can improve a climate model with respect to

- radiative fluxes (reduction in area-weighted rms at TOA and surface)
- Temperature structure of the troposphere especially in the tropics
- The approach replaces a diagnosed quantity with a prognostic variable
- Directly related to radiative measurements
- Uncertainties small particle ice PSD need to be resolved
- Apply same remote sensing approach to short-wave radiometric observations & over a wider range of wavelengths
- However, no single unified light scattering method as yet

Global model over Geostationary area (Thomas Blackmore)
RTTOV-11

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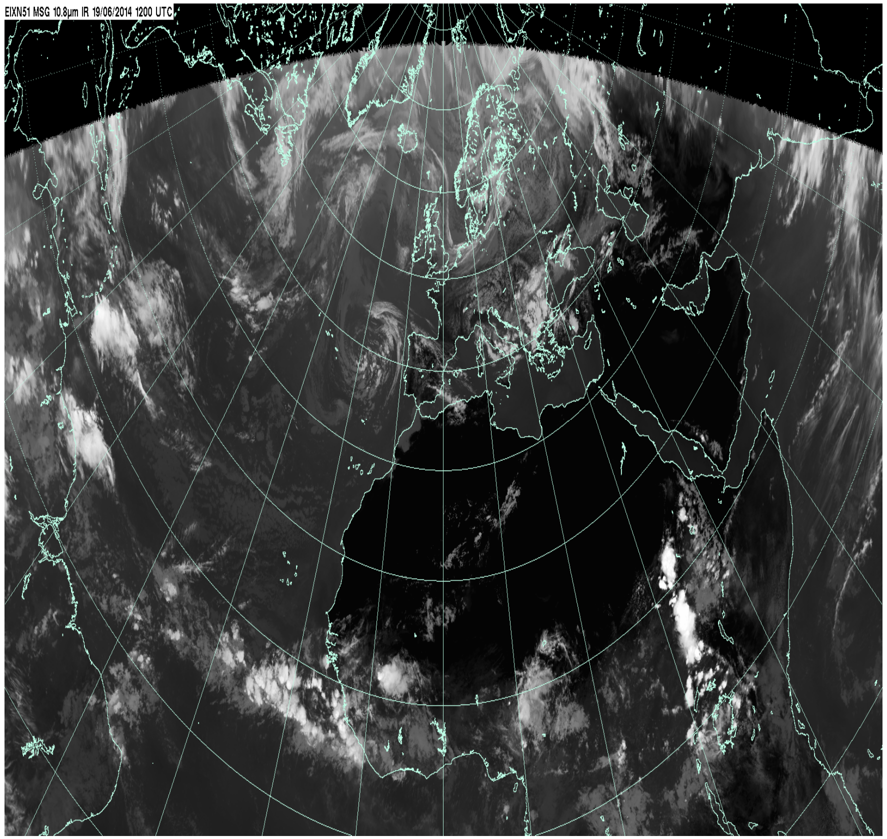
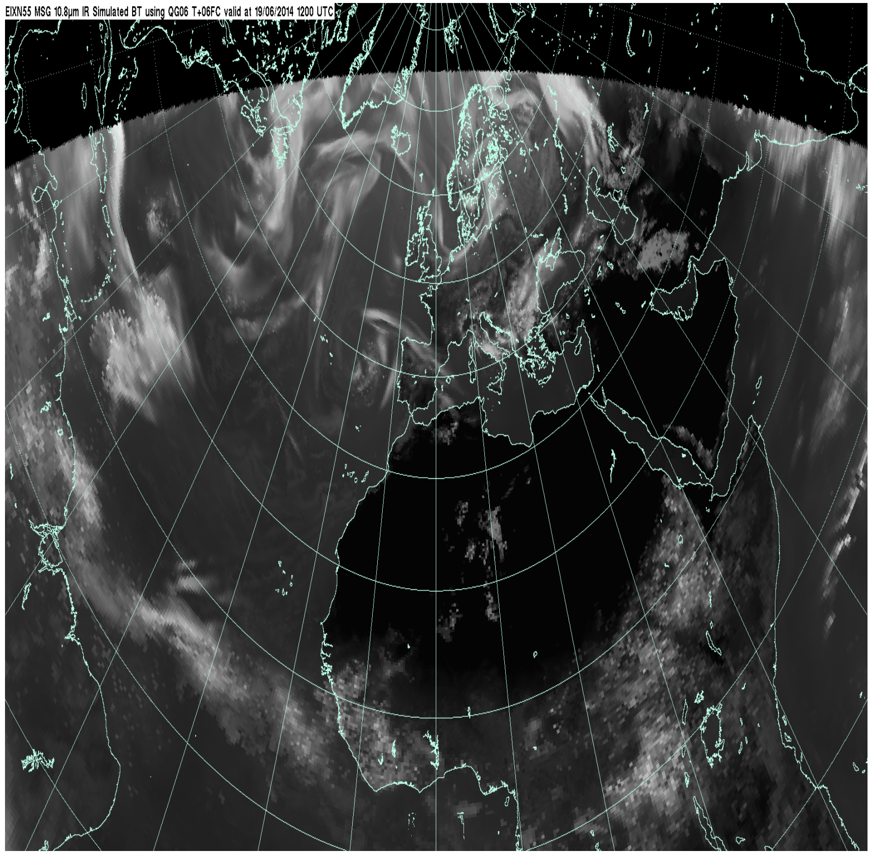
MSG 10.8 um 1200 UTC 19/06/14

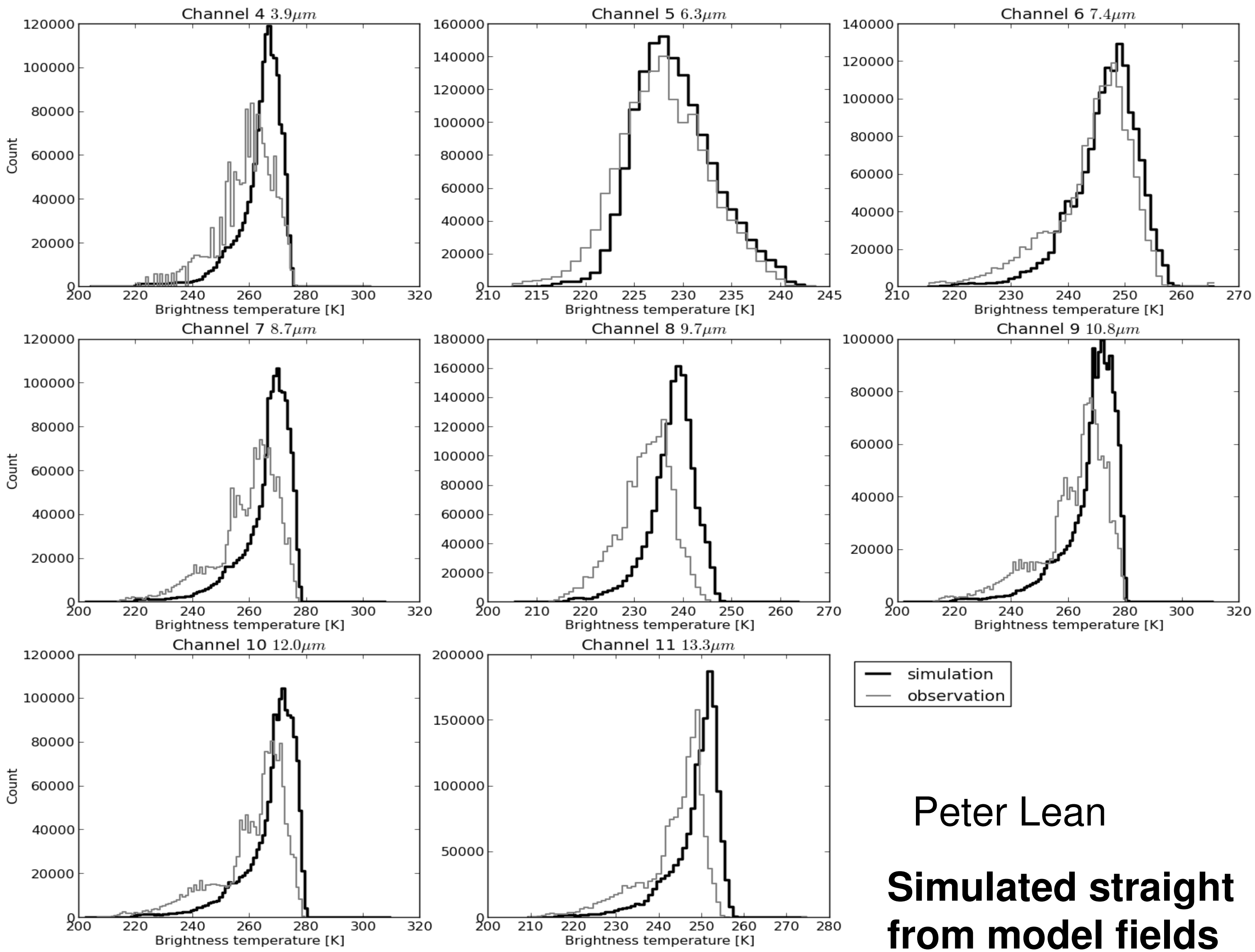
MSG IMAGE



SIMULATION



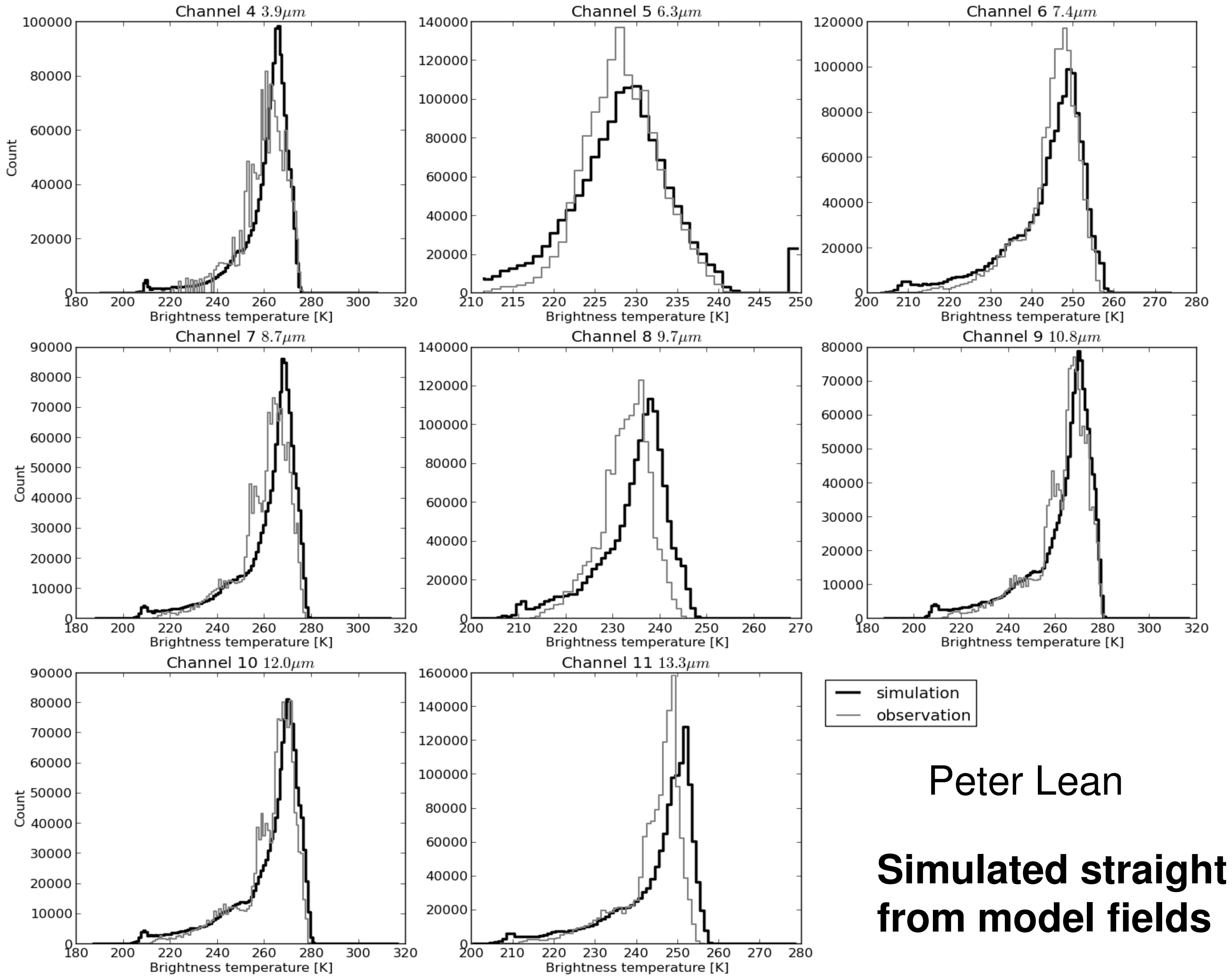
Brightness Temperature histograms UKV – 1 month data – RTTOV-9



Peter Lean

Simulated straight from model fields

Brightness Temperature histograms UKV – 1 month data : RTTOV-11



Peter Lean

Simulated straight from model fields

Ice optics + Fiels 2007 PSDs

Temperature profiles