Verification of cloud physical properties

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Abstract

For the first time, field verification of NWP cloud physical properties against measurements from the MSG satellite are presented. In classical observations clouds are described in terms of 1/8 fractions of cloud cover. The cloud fraction, however, is only one of the factors that determine the reflectance and transmittance of a cloud field. The other factors are the inherent cloud physical properties. These are particularly important with respect to shortwave radiative transfer. Therefore, satellite measurements of cloud physical properties, much improves the capability of cloud verification. With these measurements, processes such as aerosol indirect effects can also be assessed in detail. Results will be presented and discussed.

Introduction

- Clouds are affected by virtually all processes in the atmosphere;
- Cloud prediction is essential for prediction of radiative forcing and precipitation;
- New satellite data give 3D-information on clouds.

Theory

The equation of radiative transfer:

$$\mu\frac{dI_\lambda(\tau,\mu,\phi)}{d\tau} = I_\lambda(\tau,\mu,\phi) - (1-a)B_\lambda(T;\tau) - \frac{a}{4\pi}\int_{4\pi} d\omega' p(\tau,\mu',\phi')I_\lambda(\tau,\mu,\phi) - S^*_\lambda(\tau,\mu,\phi) \quad (1)$$

Inherent optical properties (IOPs):

- τ: Optical depth [-], the integrated extinction;
- a: Single scattering albedo = 1 - emittance [-];
- p: Phase function [-], in practice a function only of the asymmetry factor g (Henyey & Greenstein 1941);
- Lower boundary albedo / BRDF [-].
- "Cloud albedo" is not an inherent optical property!

The good news is that the cloud IOPs can be adequately derived from only two physical quatities

- Cloud liquid water path (CLWP) [kg/m^2];
- Effective cloud drop radius (r_e) [μm].

In the visible spectral range the following inherent optical properties can be derived from Mie-Debye theory.

$$\tau_{vis} = \frac{3CLWP}{2r_e\rho_l}, \quad a_{vis} = 1, \quad g_{vis} = 0.85 \quad (2)$$

$$r_e \equiv \int_0^\infty drn(r)r^3 / \int_0^\infty drn(r)r^2 \quad (3)$$

Satellite data

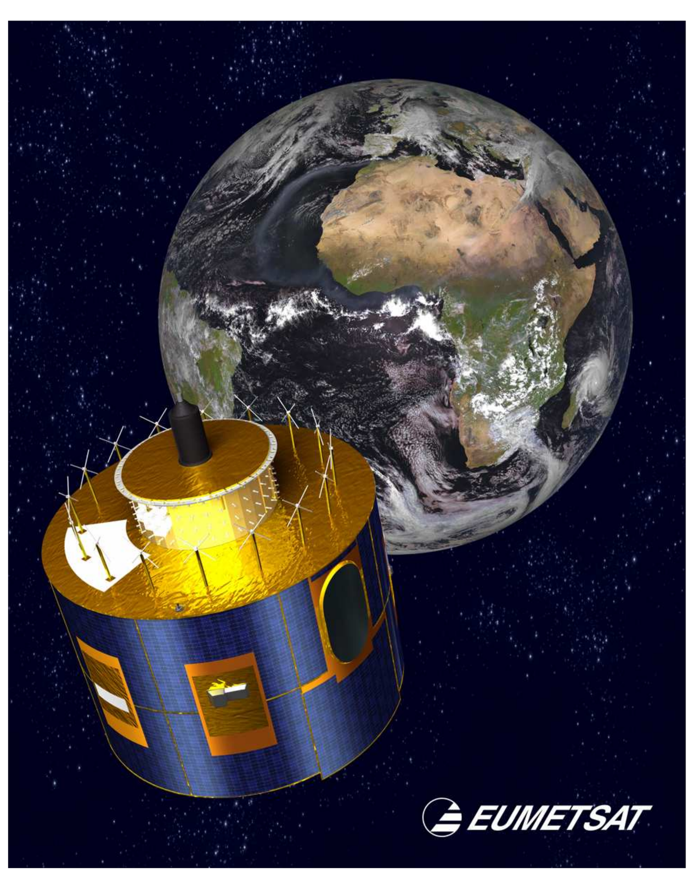

FIGURE 1: Meteosat Second Generation satellite.

- MSG Cloud mask;
- MSG Cloud physical products (CPP);
- CloudSat.

Results

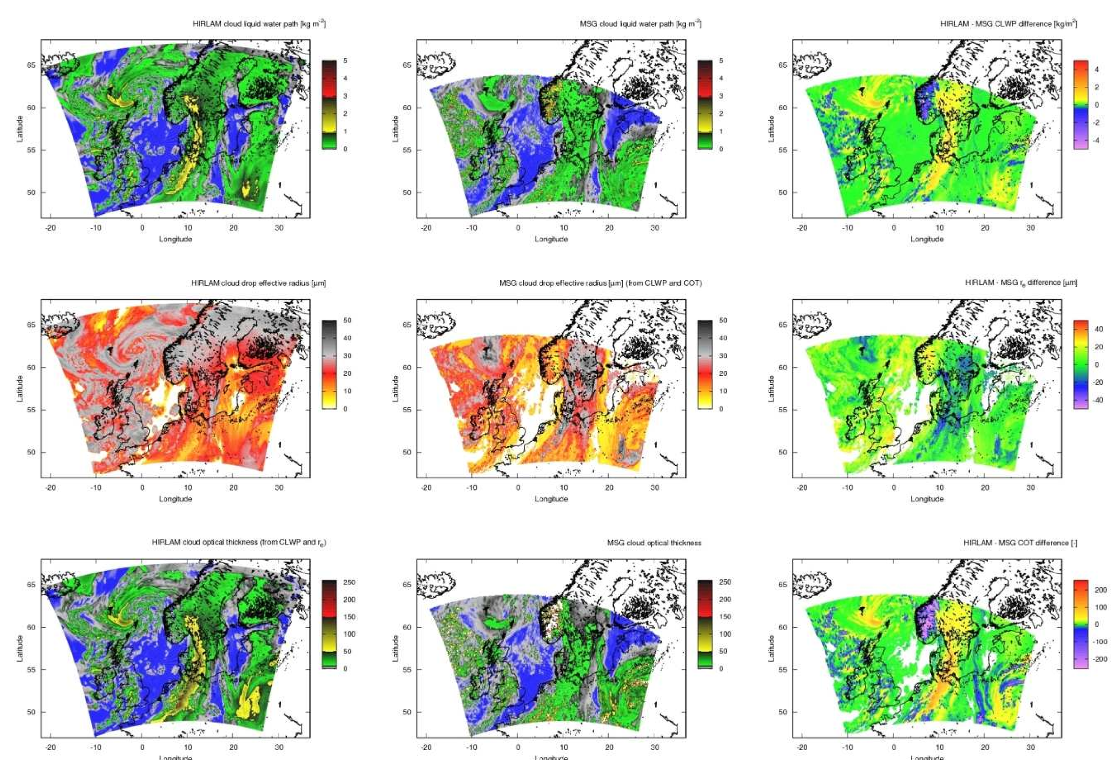

FIGURE 2: Comparision of DMI-HIRLAM forecast (2009-03-08 00:00 +12h) and MSG CPP data.

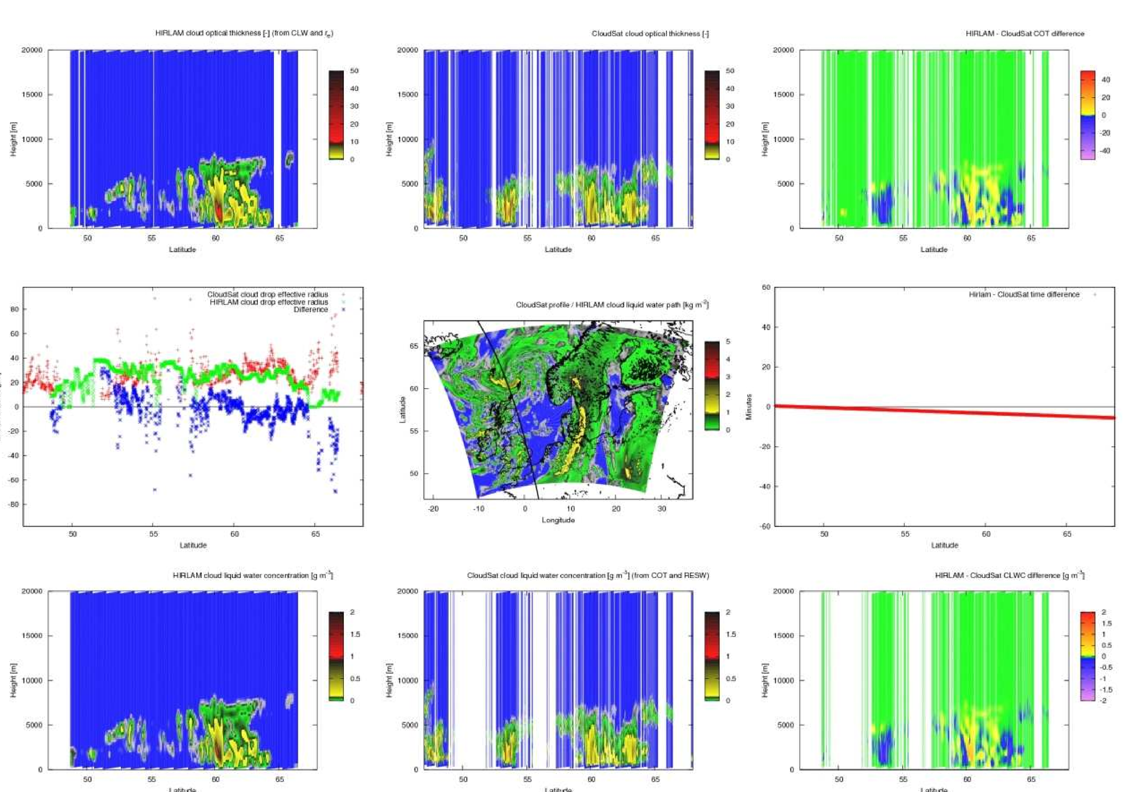

FIGURE 3: Comparision of DMI-HIRLAM forecast (2009-03-08 00:00 +13h) and Cloudsat CPP data.

Discussion and conclusion

- New satellite products with CPPs are very valuable in NWP verification;
- Continous variables - can be quantified;
- Possible MSG CPP issues:
  - Snow cover in northern Scandinavia - albedo bias.
  - Low sensitivity to high optical thickness ($\tau > 50$).
- Vertical variations of r_e not (yet) available;

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