Assimilation of cloudy infrared radiances of MTSAT-1R

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1. Background and Purpose
- Hyperspectral infrared sounders have been successfully assimilated in limited cloudy conditions in several NWPs centres using a simple radiative transfer model (RTM; Bauer et al. 2011)
- The simple RTM models cloud effects using only two parameters of cloud top pressure (p) and effective fraction of cloud (f), which assumes
  - Single-layer cloud
  - Applicability of single-layer to different channels (i.e. Nearly constant cloud emissivity)

Applying this approach to infrared radiances on geostationary satellites can offer the advantage of using information that is frequently available, in spite of limitation of available channels.

The key to this development is to select appropriate data that are well simulated by the simple RTM and background from NWPs model. Thus, this study focuses on
- Creating and characterising spatially averaged radiances (super-ob) to obtain better match of channel and spatial representativeness between model and measurement
- Developing quality control (QC) procedures to secure small homogeneity and ch-independency

2. Characteristics of MTSAT-1R super-ob radiances
- Each super-ob was constructed at model grid point by averaging infrared pixels within a circle of a predefined radius r
- The frequency distribution of super-ob Brightness Temperatures (BTs) and the Standard Deviation (SD) of pixel BTs in each super-ob varies with the size of the super-ob. (Fig. 2.1, Fig. 2.2)
  - An appropriate selection of the super-ob size is important for the representative scale of assimilation, especially when cloud variables from model are used

For example, the super-ob scale is smaller than twice the model representation, even a perfect model might fail to simulate very high or low BTs of the super-ob.

In this study, we simply set r to the model resolution (30km)
- The inconsistency between model and super-ob was small because cloud variables were extracted from super-ob themselves (see next section).

3. Simulation of cloudy radiances and QC
- Simple RTM: (\( R = R_e + R_i \) (\( R_i \) is the clear sky radiance of channel ) and \( R_i \) is a completely overcast radiance from a blackbody cloud at cloud top pressure \( p \))
- We calculate \( R_e \) and \( R_i \) with RTTOV-9.3 (Maricic et al., 2004; Saunders et al., 2010)
- \( R_e \) and \( R_i \) are determined so as to minimise radiance residual from measurement \( R_m \), defined with
  \[
  J = \sum_{i=1}^{n} (R_m - R_e - R_i)^2
  \]
- Channels IR1 and IR2 were chosen to avoid as much wavelength dependence of \( R_m \) as possible
- Validation of \( R_e \) with CloudSat
- The MTSAT super-ob cloud-top height well agrees with the CloudSat value when \( N_e \geq 0.8 \) (Fig.3.1)
- Correlation coefficient=0.972, RMSE=1.000 km

In this study, the super-ob radiances that meet the below criteria are called OSRs (Overcast Super-ob Radiances) and will be assimilated after passing all QC.
- \( N_e \geq 0.8 \)
- clear-sky radiance < 5% and pixel SDs < 4.5 K (Homogeneity check)
- OSRs are rejected if
  - \( p_e \geq 160 \) or \( p_e > 160 \) K, because those data have ch-dependent biases (Fig.3.2)
- over land, coast and sea ice areas
- local zenith angle > 62.5°

4. Assimilation of OSRs
- CNTRL: a low-resolution version of JMA’s operational global data assimilation system as of Jul 2011
  - Model Resolution: T319/640 (~40km)
  - Analysis: 6-Var with inner loop T416/120km (~12km)
  - 6-h assimilation window
- Assimilated radiances data - ATOV5, SSMIS,AMSU and ECMWF in clear conditions and Clear Sky Radiances (CSR) of geostationary satellites
- Analysis variables - temperature, vector wind, logarithm of specific humidity, surface pressure, all coefficients and all coefficients are analysed
- 219-h forecasts made at 00 UTC
- TEST: add MTSAT-1R OSRs to CNTRL
- Assimilate IR1 only, no bias correction, observation error set to 0.2 K
- Thin to one per 3 global grid boxes (~60x3x180km) in almost every time slot (5 out of 6 slots)
- TEST: same as TEST but OSRs are assimilated in every second time slot (3 out of 6 slots). Experiment period

5.1. Results and Summary
- In order to make use of cloudy infrared radiances from geostationary satellites, we have created OSRs and assimilated them in the presence of single-layer cloud
- QC is crucial to meet the assumption of the single-layer cloud RTM, including homogeneity and ch-independency

Advantages of OSRs from geostationary satellites are expected to include
- (1) Having temperature information that is highly vertically resolved at the cloud top (Fig.4.1, Fig.4.2)
- (2) Availability in cloudy regions (complementary to CSR and , to some extent , MW-sounders) (Fig.4.3, 4.4)
- (3) Improved measurements

We confirmed (1) and (2) but have hardly found clear evidence of (3) so far.

Assimilation of OSRs improved the forecast skill of upper tropospheric temperature and lower tropospheric wind (Fig.4.4), although the impact was small and random for most geophysical variables

5.2. Discussions and Plans
- More data (i.e. more channels and less limited \( P_e \) ) should be assimilated by applying bias correction to decrease inconsistency between channels
- Estimated cloud parameters estimated might be adjusted excessively so that errors in model and measurements are cancelled out. Analyzing those parameters in 4-5 Variance probably can alleviate this overfitting problem.

Applying this approach in regional data assimilation systems would be more beneficial than in global assimilation systems as the systems are more frequently updated and operate with shorter cut-off time.

Investigation on assimilating radiances in more general cloudy conditions such as multi-layer clouds is underway.

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