Infrared brightness temperature assimilation using an LETKF at convection-resolving resolutions

1. Introduction

Clouds and atmospheric water vapor strongly influence sensitive weather conditions through their combined effect on surface temperatures and precipitation. Small changes in the water vapor and cloud distributions can have a profound impact on the generation and subsequent evolution of high impact weather events, such as severe thunderstorms, heavy rainfall and tropical cyclones. Thus, an accurate and spatially representative specification of clouds and water vapor in datasets used to initialize high-resolution numerical weather prediction models is essential to produce accurate forecasts of cloud cover, precipitation, and storm evolution.

Challenges:
- Direct assimilation of cloud-affected SEVIRI radiances
- Model: high-resolution COSMO-DE, a non-hydrostatic limited area model run at 2.8 km horizontal resolution; 50 vertical layers with explicit deep convection
- Data assimilation method: Local Ensemble Transform Kalman Filter (LETKF; Hunt et al., 2007) with RTTOV 10 as forward operator.

Observations: MSG SEVIRI brightness temperatures

2. Assimilation of SEVIRI radiances with LETKF

Motivation:
- Direct assimilation of SEVIRI radiances (instead of retrievals)
- Assimilation of all-sky brightness temperatures (water vapor and window channels) with LETKF for the regional COSMO-DE model of Germany
- Improved understanding of how the assimilation of water vapor sensitive infrared brightness temperatures impacts the analysis and forecast accuracy
- Position of clouds with the assimilation of window band brightness temperatures
- Results readily transferable to other assimilation systems (like the ABI/GOES-R or AHI/Himawari-8 observations become available)
- Examine the sensitivity of the ensemble system to observation error and horizontal localization radius
- Explore the impact of new vertical localization techniques as it is one of the challenges in the assimilation of satellite observations with Ensemble Kalman Filter methods

3. Monitoring experiments with LETKF

Water vapor (WV 6.2, WV 7.3) and window channel (R 8.7) brightness temperatures monitoring test case from 2011-06-01 00:00 to 2011-06-06 12:00

Flow regimes based on cloud evolution, during the 6-day period:
- 01 - high clouds initially, lots of low clouds later
- 02 - low clouds with extensive clear sky areas
- 03 - high clouds with extensive clear sky areas
- 04 - clear skies initially, then lots of convection in south
- 05 - clear skies, then widespread convection in west
- 06 - widespread convection in north, mixture of clouds later

Clear-sky bias varies from -3 to -1 K

Fig 8-10: Strong biases with high-level clouds reaching maximum values in presence of storms. Clear-sky bias varies from -3 to -1 K. The bias variability with time supports the implementation of time-evolving bias correction.

4. Cloud dependent Bias Correction

Observation minus Background

- In Fig 8-10 are represented Observation minus Background for the 6-day period for water vapor bands and window channel, computed hourly
- Cloud dependent statistics evaluation: clear sky, low, medium and high level clouds

WV073 Assimilation Experiments
- 12 hours assimilation, hourly, from 2011-06-04 12:00 UTC to 2011-06-05 00:00 UTC
- Bias correction value applied to the simulated observation (rather than to the real observations)

Model-simulated cloud field from a given ensemble member is used to determine the cloud top height

Bias statistics from the 3-day period results to the assimilation date

Optimal settings: Observation error 3.5 K, horizontal and vertical localization radii 35 km and 0.7 kg pm units

5. Conclusions/Outlook

- Assimilation of cloudy-brightness temperatures with LETKF, with an adequate bias correction, improves the analysis and the skill assimilation cycle
- Distinguish between ice-clouds and water-clouds
- Develop a time-dependent bias correction values for each cloud type (use of predictors)

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