Preparing test data for the IRS Level 2 processor

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SUMMARY

The Meteosat Third Generation (MTG) programme is EUMETSAT follow up of the Meteosat Second Generation (MSG), to guarantee continuity of access to space-acquired meteorological data until at least the late 2030s. It consists of three axes stabilised platforms, allowing instruments to be pointed at the Earth for 100% of their in-orbit time. The satellite series will comprise four imaging (MTG-I) and two sounding satellites (MTG-S). The Infra-Red Sounder (MTG-IRS) is based on an imaging Fourier-interferometer with a hyperspectral resolution of 0.625 cm^{-1} wave-number. It will deliver hyperspectral infrared measurements over the Full Disk in the Long-Wave InfraRed (LWIR), between 700 and 1210 cm^{-1} (14.3–8.3 µm) and in the Mid-Wave InfraRed (MWIR), between 1600 and 2175 cm^{-1} (6.25–4.6 µm) with a half-hour repeat cycle over Europe. The IRS spectra will enable the monitoring of atmospheric temperature, humidity, ozone vertical distributions and some other atmospheric constituents such as SO_2, CO, aerosol, as well as the retrieval of surface parameters: sea-and land-surface temperature and land surface emissivity.

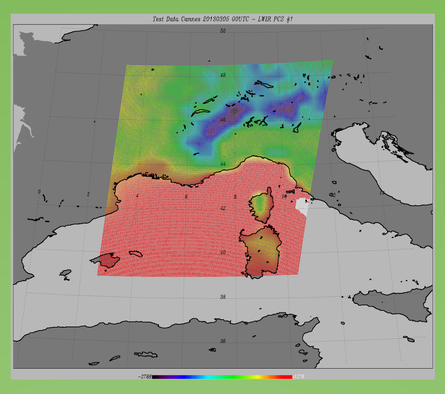
There is a large heritage in hyperspectral infrared missions from Polar orbits (e.g. AIRS, IASI, CrIS) with a number a directly applicable experience to the generation of IRS principal components and Level 2 products. Some aspects specific to the geostationary (GEO) acquisition (e.g. viewing geometry from Nadir to quasi limb sounding, very high temporal sampling, data volume) and to this instrument (spectral resolution and coverage coarser than IASI, high spatial resolution) need to be studied to adapt legacy algorithms, develop new ones where needed and exploit the opportunities that the IRS sensing offers in complement to low-Earth orbit missions. Test data are required more generally also to verify and test the implementation of the prototype and future operational processors. We present here early test data development and results, involving high spatial resolution geophysical state from regional numerical models and simulated data with radiative transfer models to evaluate the domain of applicability of heritage algorithms and prepare for the testing and verification of the IRS L2 prototype processor.

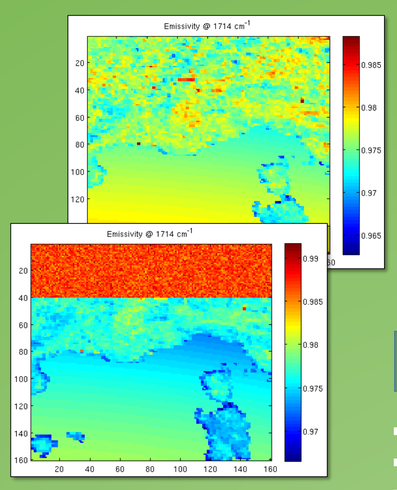
REGIONAL SYNTHETIC RADIANCES

Cannes dataset

Purpose

- Time-varying surface conditions to test possible time-based algorithms, e.g. Kalman filter
- Large range of realistic surface type and elevation within a single dwell (160x160 pixels)
- One pseudo dwell in LAC4, simulated for a full day, every 30 mn
- Principal Components products + eigenvectors (from Full Disk)





Content

- 15/03/2016, full day (48 dwells)
- Radiative Transfer Model: OSS[1] clear-sky
- Atmosphere State Vector: ECMWF 6h analyses with T, q, O_3 on 137 hybrid levels and surface temperature, @ 0.125° resolution, interpolated in time
- Surface emissivity:
  - sea ISEM-6[2]
  - land MODIS-ASTER atlas[3] (University of Wisconsin)

  and crude modelling of snow fall and melt
- Nominal MTG-IRS Gaussian noise added
- Radiances in former MTG-IRS L1b format

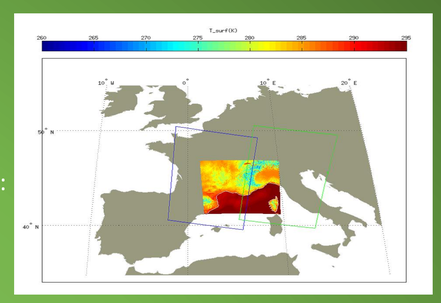
Possible evolution

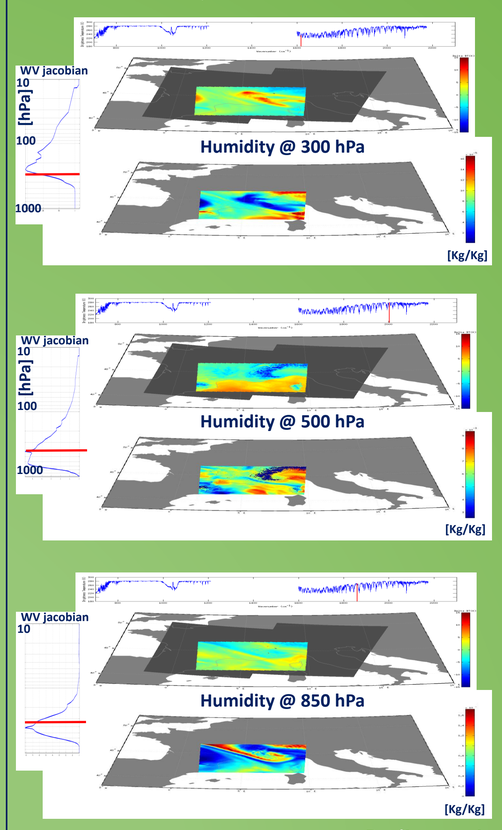
- Higher underlying spatial resolution with regional model
- Realistic dwells and geolocations, viewing angles, following dwell numbering and viewing convention
- Introduce cloudy radiances
- Simulation with RTTOV

High-resolution dataset

Purpose

- High spatial resolution
- Realistic atmospheric scenes and surface elevation & types
- Ultimately study effect of instrument effects:
  - LWIR/MWIR misalignment
  - Spread function ➔ cross-talk with neighbouring pixel (e.g. cloud signal intrusion...)





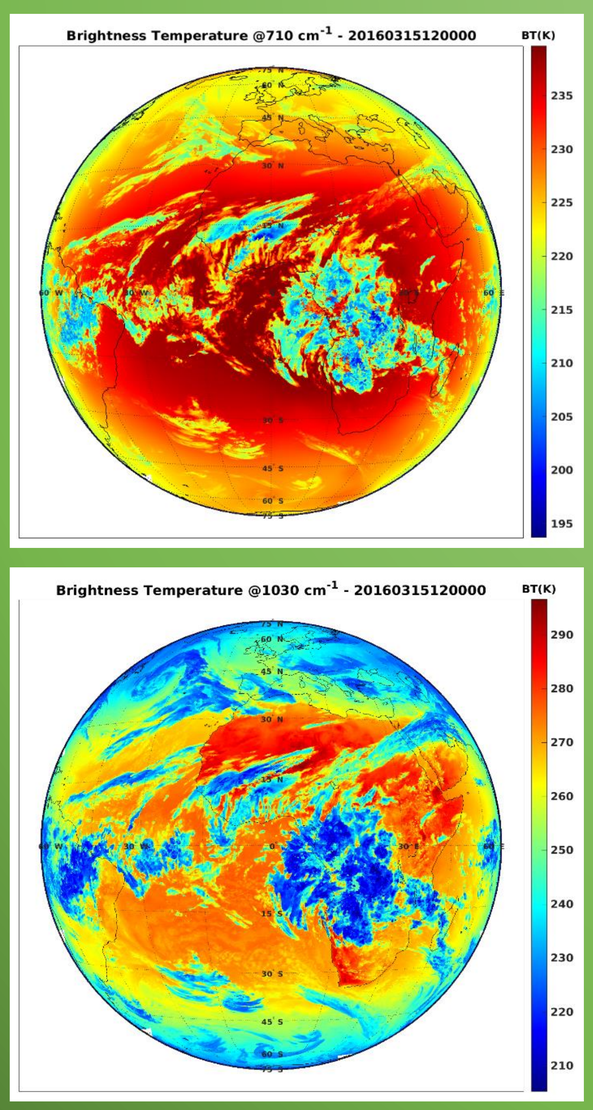
Content

- 03/10/2015 at 00:00 UTC for region overlapping dwells 56 and 57
- RTM: OSS[1] clear-sky
- Geophysical State Vector:
  - Météo-France high resolution model (500m): air temperature, humidity up to ~14 hPa, surface temperature Ts and surface pressure Ps
  - ECMWF analyses above Météo-France model top + O_3 @ 0.5° resolution, oversampled
  - surface emissivity: sea ISEM-6[2], land MODIS-ASTER atlas[3] (U.Wisc.)
- Realistic viewing geometry and on-ground geolocations
- Radiances in former MTG-IRS L1b format

Possible evolution

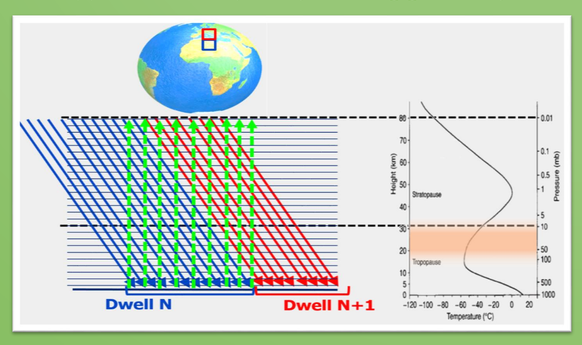
- More scenes, e.g. Germany with DWD high-res. Model (~150m)
- Radiance simulation at high spectral resolution
- Cloudy radiances
- Simulation with RTTOV

FULL EARTH DISC'S SIMULATIONS

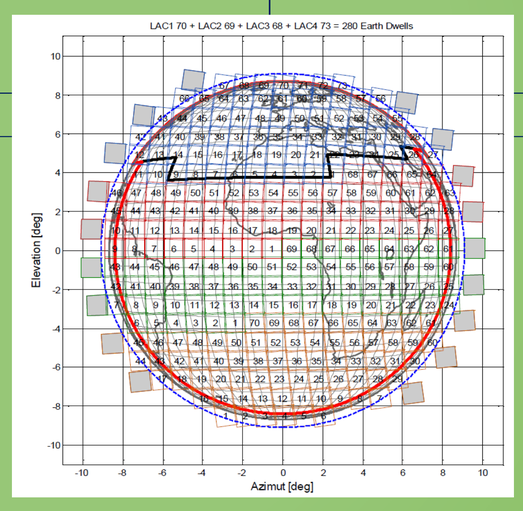


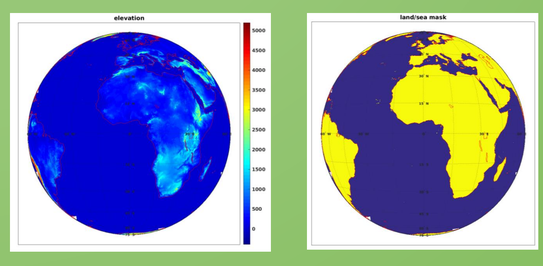
Purpose

- Full coverage of the Earth's disc as seen by MTG-IRS
- Cloudy scenes
- Take account of the Atmospheric state along the geostationary line of sight
- Support sensitivity study viewing geometry



The vertical atmospheric profiles are reconstructed from the collocated ECMWF profile variables on the slanted satellite's line of sight

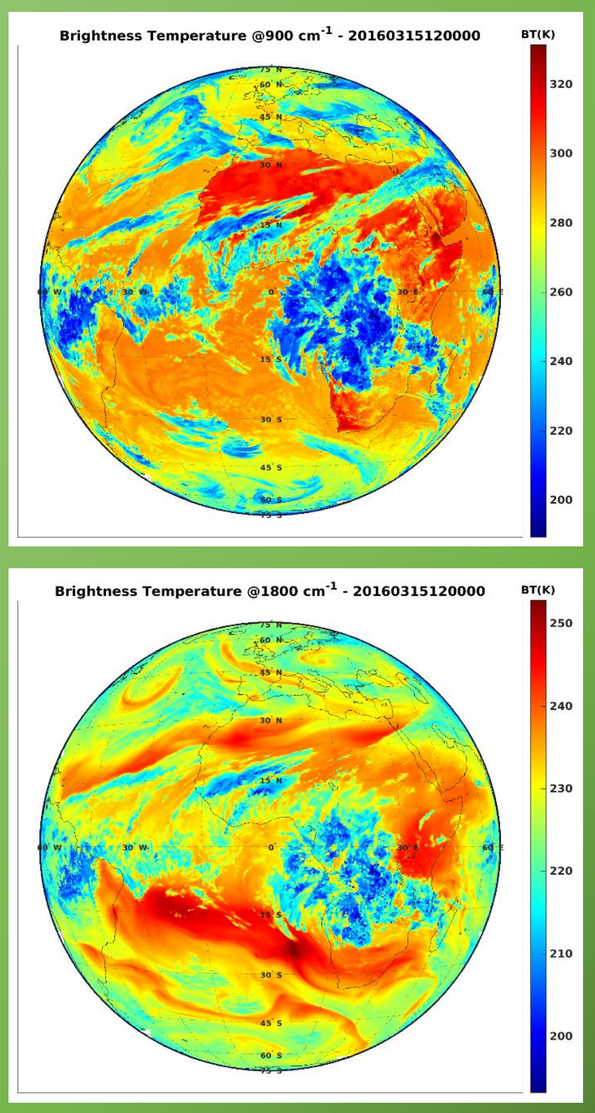




Elevation and land-sea mask extracted from topography data. Elevation and LSM for a dwell pixel are the average of all the values in a cell delimited by the 4 nearest pixels.

Content

- March 15, 2016 at 12:00:00 UTC
- Full Earth's disc coverage: 4 LACs, 280 dwells in total
- Realistic viewing angles
- Radiative transfer model: RTTOV[4] with training coefficients tailored for MTG-IRS and allowing radiative transfer calculation for satellite zenith angles up to 85°
- Atmosphere State Vector: ECMWF analysis with T, q, O_3 on 137 hybrid levels and surface temperature, @ 0.125° resolution
- Simple cloud model as built into RTTOV: single-layered, opaque and homogenous defined by cloud top pressure and coverage fraction
- Stack of 3 simple clouds (low, medium and high cloud) on line of sight with cloud top pressure determined from ECMWF definition
- Radiance at the top of the atmosphere is a linear combination of upwelling radiances above low+mid+high cloud calculated with cloud fraction=1, and in clear sky

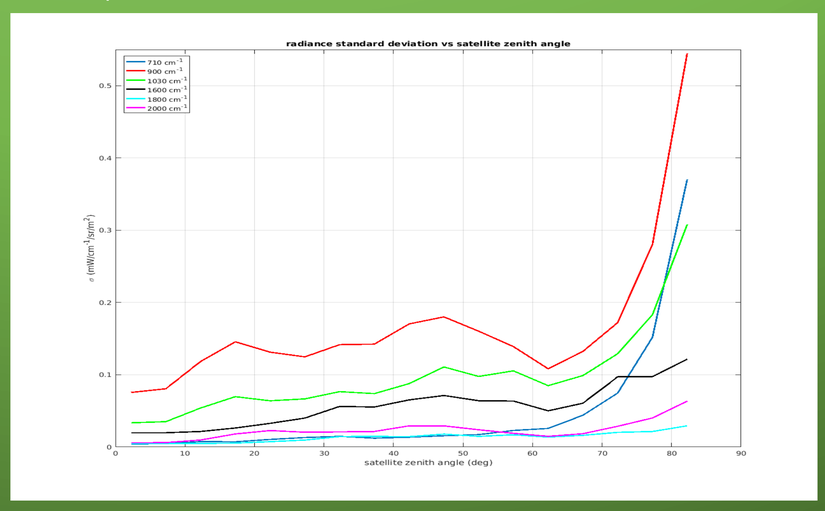


Possible evolution

- Full day, hourly discs. In progress
- Radiative transfer calculation with more realistic cloud model (use of microphysics and optical properties in cloud profiles)
- Use of topographic source exhibiting inland waters
- Ideally, comply with the foreseen operational scanning mode of MTG-IRS: use forecasts/analyses for each LAC, time-spaced by 30 mn from one another in the scanning sequence

Sensitivity to satellite zenith angle

- statistical intercomparison performed on the calculated radiance of the profiles reconstructed from the slanted views and the original ECMWF vertical profiles.
- standard deviation of the radiance averaged on the full Earth's disc against the satellite zenith angle.
- Approximation of using vertical profiles loses validity beyond ~65°



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2. **ISEM-6: Infrared surface emissivity model for RTTOV-6**. Forecasting Research Technical Report No.299, Sherlock, V.J., UK Met. Office, NWP division, 1999.
3. **Development of a Global Infrared Land Surface Emissivity Database for Application to Clear Sky Sounding Retrievals from Multispectral Satellite Radiance Measurements**, Seeman, Borbas et al., J. App. Meteor. Climatol., 47, 2008.
4. **RTTOV**: https://nwpsaf.eu/site/software/rttov/

Acknowledgements: NWP SAF (James Hocking, Pascal Brunel, Jérôme Vidot) for providing RTTOV-IRS coefficients, extended to 85° zenith angle.

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