Spatio-temporal constraints for emissivity and surface temperature retrieval: preliminary results and comparisons for SEVIRI and IASI observation

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AIM

1. Present and describe SEVIRI $T_s - \epsilon$ retrievals based on an original Kalman filter approach
2. Intercompare with IASI retrievals
DATA Space

- **SEVIRI observations** (Meteosat 9 high rate SEVIRI level 1.5 image data, July 2010).

ANCILLARY INFORMATION used to characterize the atmospheric component

- **ECMWF analyses** - Ts, T(p), O(p), Q(p) canonical hours 0:00, 6:00, 12:00 and 18:00 - for the same data and target area. Horizontal spatial resolution: $0.5^\circ \times 0.5^\circ$ → in each ECMWF grid box there are on average $\approx 200$ SEVIRI pixels → assume that the atmospheric state vector is the co-located ECMWF analysis (First Guess).
ANCILLARY INFORMATION used to build up the emissivity background

- **Emissivity database:** Global Infrared Land Surface Emissivity (e.g. http://cimss.ssec.wisc.edu/iremis/) developed at CIMSS, University of Wisconsin. It is derived by MODIS observations and is available from the year 2003 till 2011. The emissivity is made available on monthly basis, at 10 wavelength points (or hinge points) on a 0.05° × 0.05° grid. The wavelengths are 3.6, 4.3, 5.0, 5.8, 7.6, 8.3, 9.3, 10.8, 12.1, and 14.3 µm.
Target Area

392088 MSG-9 SEVIRI Pixel

1-31 July 2010
**PREPROCESSING**

- **ECMWF analyses:** linear interpolation of the atmospheric state vector on the temporal MSG resolution grid (acquisition each 15 minutes, for a total of 96 daily time points).

- **Emissivity database:** double step procedure.
  1. Interpolation of the ten-hinge-points-emissivity vector on the MODIS grid to IASI spectral resolution, convolution with the SEVIRI ISRF to the 8 SEVIRI channels (3.9, 6.2, 7.3, 8.7, 9.7, 10.8, 12, and 13.4 \( \mu m \)); this step yields SEVIRI emissivity in the MODIS grid.
  2. Bilinear interpolation to remap the SEVIRI emissivity spectra from the MODIS grid to the SEVIRI grid.

Estimation of the emissivity a-priori covariance matrix for each point of the SEVIRI grid on the target area.
Methods: SEVIRI

AUTOMATIC PIPELINE

Forward Model
- σ-SEVIRI
  - Specular reflection
  - Lambertian reflection

Inverse Model
- δ-SEVIRI
  - Kalman filter + persistence
Kalman filter + persistence

\[ \begin{align*}
R_t &= F(v_t) + \varepsilon_t \\
v_{t+1} &= H v_t + \eta_t
\end{align*} \]

observation equation
state/evolution equation

update or analysis

forecast

analysis at time t

forecast at time t

covariance of \( \eta_t \)
Methods: IASI

Optimal estimation with emissivity spectrum represented with a truncated Fourier transform series. Emissivity coefficients, $T_s$ and atmospheric parameters $(T,Q,O)$ are simultaneously retrieved.

$$\min_v \left[ \frac{1}{2} (R - F(v))^T S_\varepsilon^{-1} (R - F(v)) + \frac{1}{2} (v - v_a)^T S_\varepsilon^{-1} (v - v_a) \right]$$
Comparing TS - ε retrievals for SEVIRI and IASI

- SEVIRI pixels and IASI footprints (spatial co-location)
- IASI Retrieved Emissivity
  - IASI emissivity spectrum convolved @ SEVIRI channels
- Comparison SEVIRI-IASI
  - 2010, July, 10, AM & PM
  - 2010, July, 4, AM
  - Skin Temperature, full month
Comparing $T_s - \varepsilon$ retrievals for SEVIRI and IASI

TARGET AREA:

- Desert region of Ouargla Province, Algeria
- $4^\circ \leq$ Longitude $\leq 8^\circ$; $29^\circ \leq$ Latitude $\leq 33^\circ$
- SEVIRI Channels used for emissivity retrieval: 8.7, 10.8 & 12 $\mu$m
14266 SEVIRI Pixels
- 2 MetOp Orbits (1 Day ~9 AM, 1 Night ~8 PM), ~10 IASI Scan lines, in the box.
- More than 400 (200 Day, 200 Night) IASI footprints for day.
IASI Pixels
From IASI Emissivity Spectrum to SEVIRI channels Emissivity

\[ \varepsilon^S(\sigma_{ch}) = ISRF(\sigma_{ch}, \sigma) \ast \varepsilon^I(\sigma) \]
IASI derived SEVIRI channels emissivity, 10 July 2010, AM and PM
10 July, AM, KF, 237 IASI Spectra

10-Jul-2010, SEVIRI 09:37:00, IASI 09:36:15
10 July, PM, KF, 246 IASI Spectra

10-Jul-2010, SEVIRI 20:52:00, IASI 20:52:45
4 July, AM, KF, 123 IASI Spectra

04-Jul-2010, SEVIRI 10:07:00, IASI 10:00:21

Emissivity @ 12 μm

Emissivity @ 10.8 μm

Emissivity @ 8.7 μm

Skin Temperature, K

DAILY-NIGHT EMISSIVITY VARIATION OVER THE SAHARA DESERT ON THE DRY SEASON
SEVIRI retrieved day/night emissivity

\[ \langle e_{12\mu m} \rangle = 0.959 \]

\[ \langle e_{10.8\mu m} \rangle = 0.919 \]

\[ \langle e_{8.7\mu m} \rangle = 0.723 \]

\[ \langle e_{12\mu m} \rangle = 0.959 \]

\[ \langle e_{10.8\mu m} \rangle = 0.916 \]

\[ \langle e_{8.7\mu m} \rangle = 0.739 \]
Retrieval of $T_s - \varepsilon$ by KF running over a long time period (10 days)
IASI retrieved emissivity spectrum

Red: IASI Emissivity spectrum averaged over 229 footprints recorded during Daytime (09:36 GMT)

Blue: IASI Emissivity spectrum averaged over 205 footprints recorded during Nighttime (20:52 GMT)

Day-Night IASI Emissivity spectra show a diurnal variability
IASI retrieved emissivity at 8.7 μm

July 2010, 5.5 W, 30.5 N

Emissivity

Day of the Month
Conclusions

• The intercomparisons between IASI and SEVIRI show a very good agreement;
• The Kalman filter methodology developed for SEVIRI is robust even at the full time resolution of 15 minutes;
• The scheme for SEVIRI can be easily incorporated in an operational framework;
• We plan to build a full disk SEVIRI emissivity database.