

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

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**EUMETSAT**

# AIM

1. Present and describe SEVIRI  $T_s - \varepsilon$  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** -  $T_s$ ,  $T(p)$ ,  $O(p)$ ,  $Q(p)$  canonical hours 0:00, 6:00, 12:00 and 18:00 - for the same data and target area. Horizontal spatial resolution:  $0.5^\circ \times 0.5^\circ \rightarrow$  in each ECMWF grid box there are on average  $\approx 200$  SEVIRI pixels  $\rightarrow$  assume that the atmospheric state vector is the co-located ECMWF analysis (First Guess).

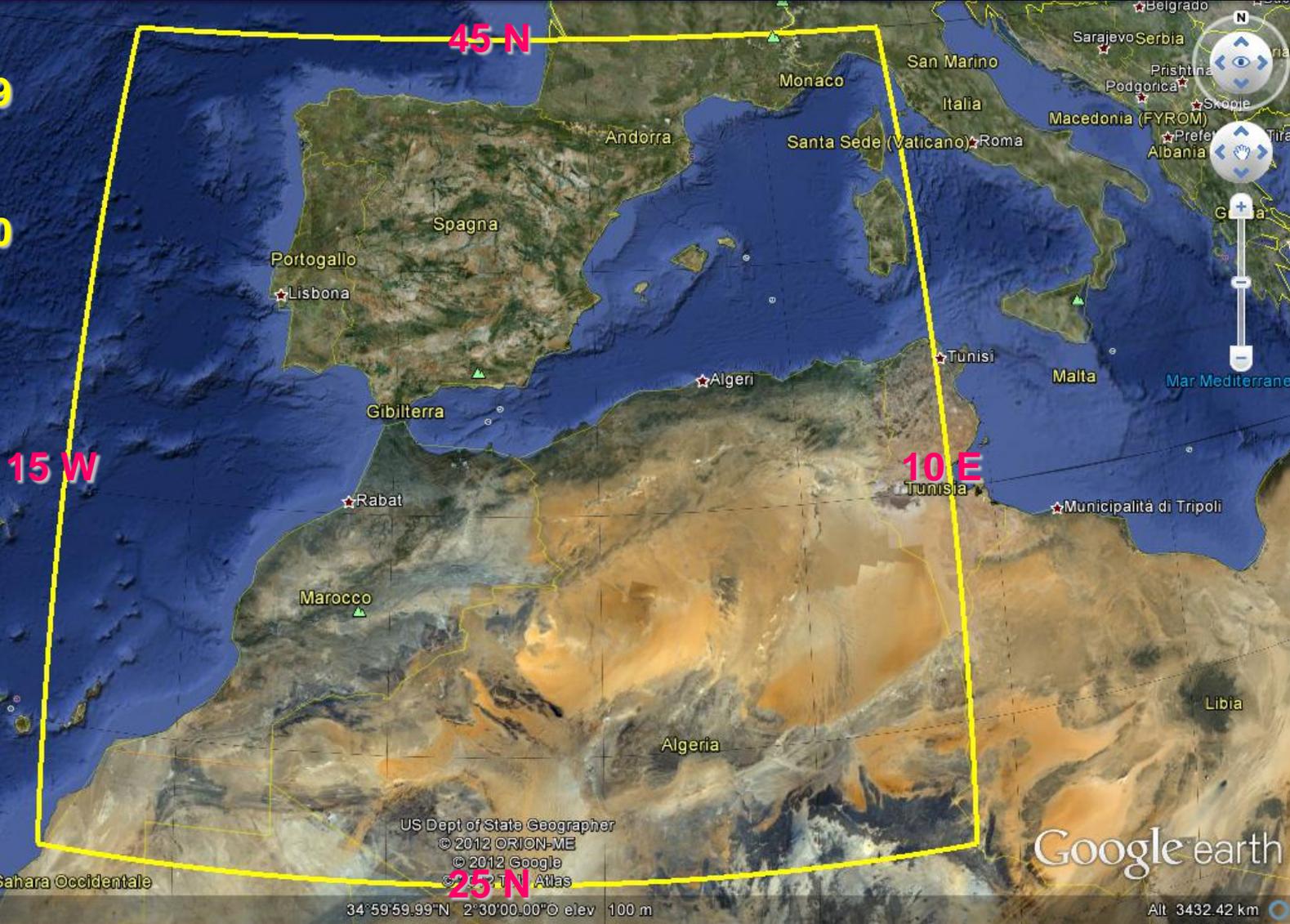
**ANCILLARY INFORMATION used to build up  
the emissivity background**

- **Emissivity database:** Global Infrared Land Surface Emissivity (e.g. <http://cimss.ssec.wisc.edu/iremisp/>) 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  $0.05^\circ \times 0.05^\circ$  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  $\mu\text{m}$ .

# Target Area

392088 MSG-9  
SEVIRI Pixel

1-31 July 2010



## PREPROCESSING

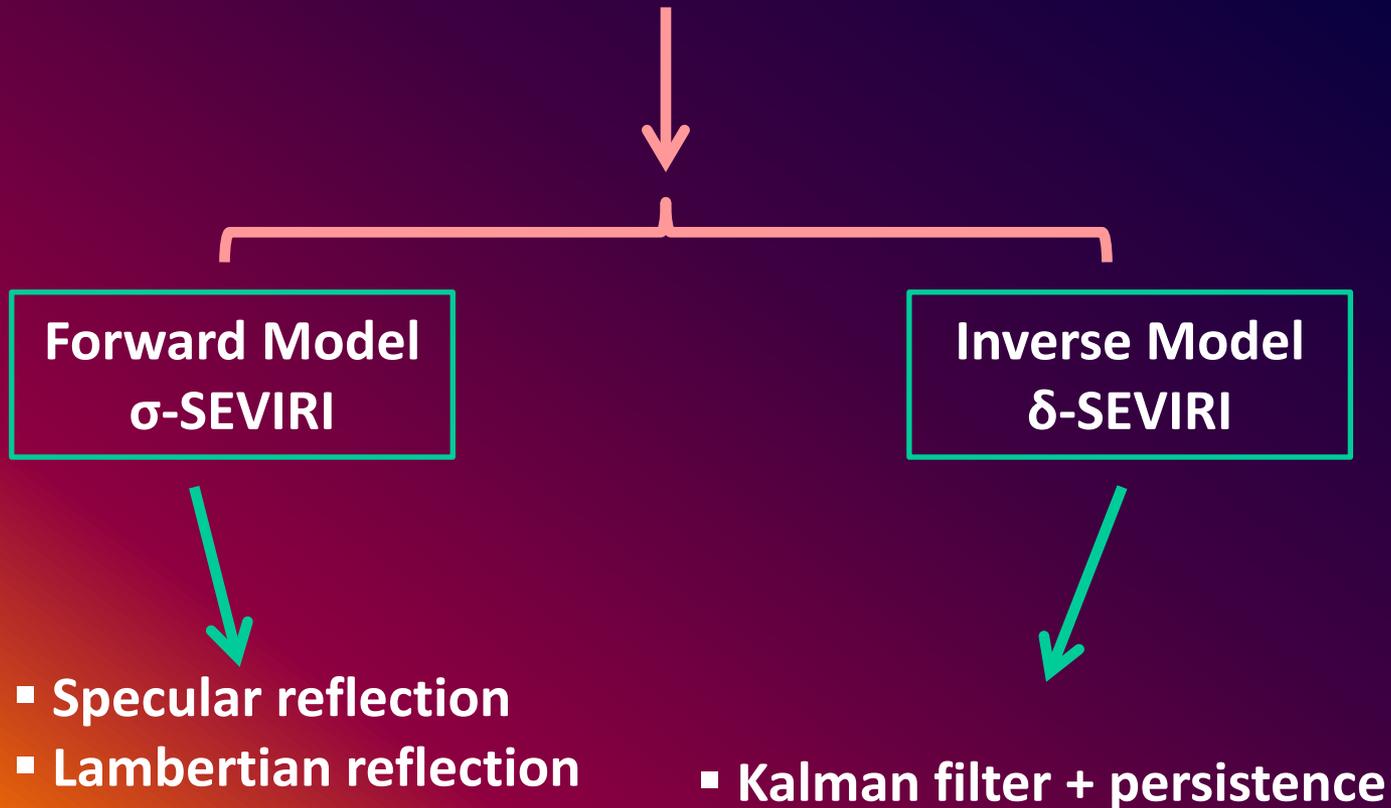
- **ECMWF analyses:** linear interpolation of the atmospheric state vector on the temporal MSG resolution grid (acquisition each 15 minutes, for a total of 96 daily time points).
- **Emissivity database:** double step procedure.
  1. interpolation of the ten-hinge-points-emissivity vector on the MODIS 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  $\mu\text{m}$ ); 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



# Kalman filter + persistence

$$\begin{cases} \mathbf{R}_t = F(\mathbf{v}_t) + \boldsymbol{\varepsilon}_t \\ \mathbf{v}_{t+1} = \mathbf{H}\mathbf{v}_t + \boldsymbol{\eta}_t \end{cases}$$

observation equation  
state/evolution equation

analysis  
at time t

update or analysis

$$\begin{cases} \hat{\mathbf{v}}_t = \hat{\mathbf{v}}_a + (\mathbf{K}_t^T \mathbf{S}_\varepsilon^{-1} \mathbf{K}_t + \mathbf{S}_a^{-1})^{-1} \mathbf{K}_t^T \mathbf{S}_\varepsilon^{-1} (\mathbf{y}_t - \mathbf{K}_t (\hat{\mathbf{v}}_a - \mathbf{v}_o)) \\ \mathbf{S}_t = (\mathbf{K}_t^T \mathbf{S}_\varepsilon^{-1} \mathbf{K}_t + \mathbf{S}_a^{-1})^{-1} \end{cases}$$

forecast

forecast  
at time t

$$\begin{cases} \hat{\mathbf{v}}_{t+1}^f = \mathbf{H}\hat{\mathbf{v}}_t \\ \hat{\mathbf{S}}_{t+1}^f = \mathbf{H}\hat{\mathbf{S}}_t\mathbf{H}^T + \mathbf{S}_\eta \end{cases}$$

covariance of  $\boldsymbol{\eta}_t$

$$\begin{cases} \mathbf{v}_a = \hat{\mathbf{v}}_{t+1}^f \\ \mathbf{S}_a = \hat{\mathbf{S}}_{t+1}^f \end{cases}$$

# 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



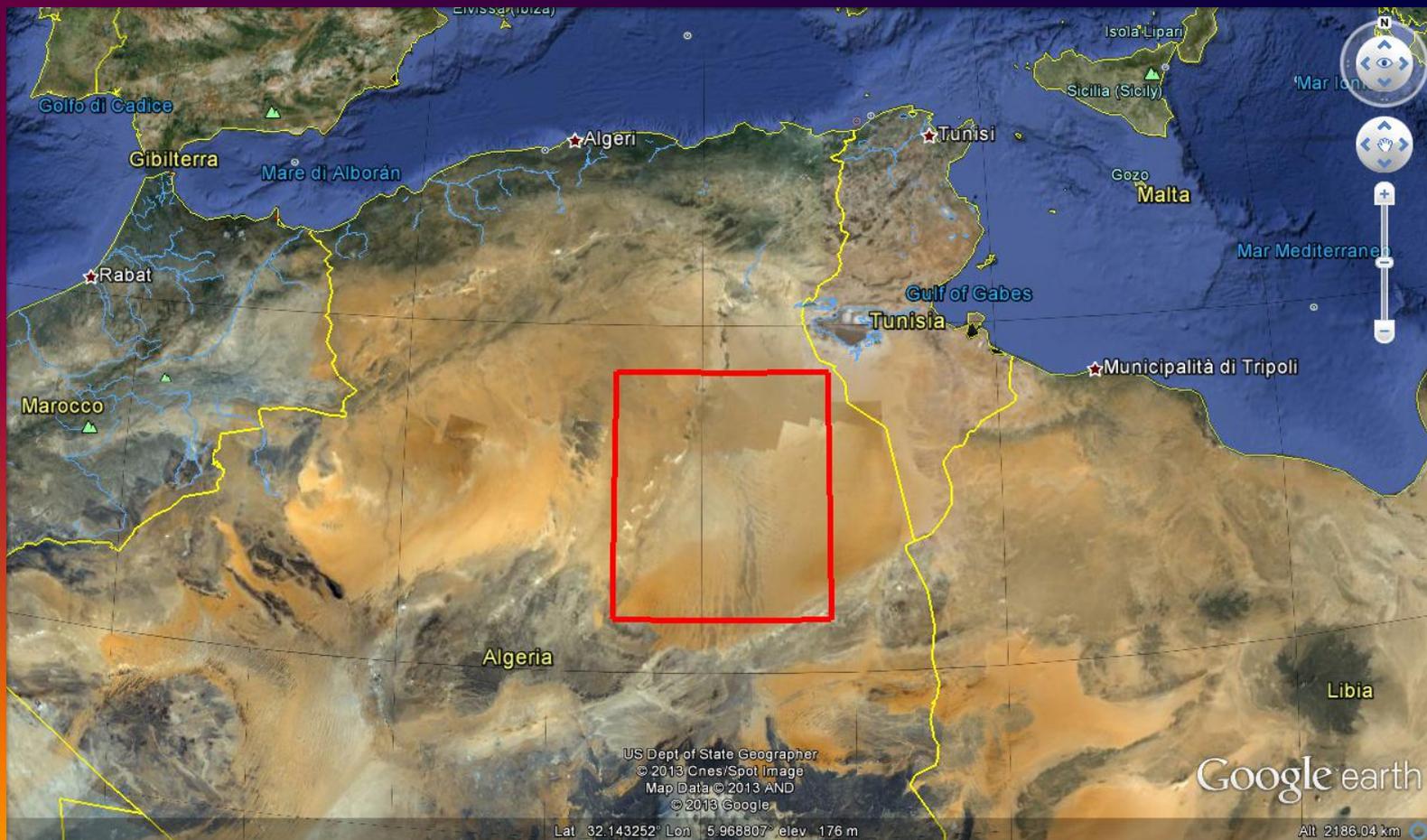
$$\min_{\mathbf{v}} \left[ \frac{1}{2} (\mathbf{R} - F(\mathbf{v}))^T \mathbf{S}_{\varepsilon}^{-1} (\mathbf{R} - F(\mathbf{v})) + \frac{1}{2} (\mathbf{v} - \mathbf{v}_a)^T \mathbf{S}_{\varepsilon}^{-1} (\mathbf{v} - \mathbf{v}_a) \right]$$

## Comparing TS - $\epsilon$ retrievals for SEVIRI and IASI

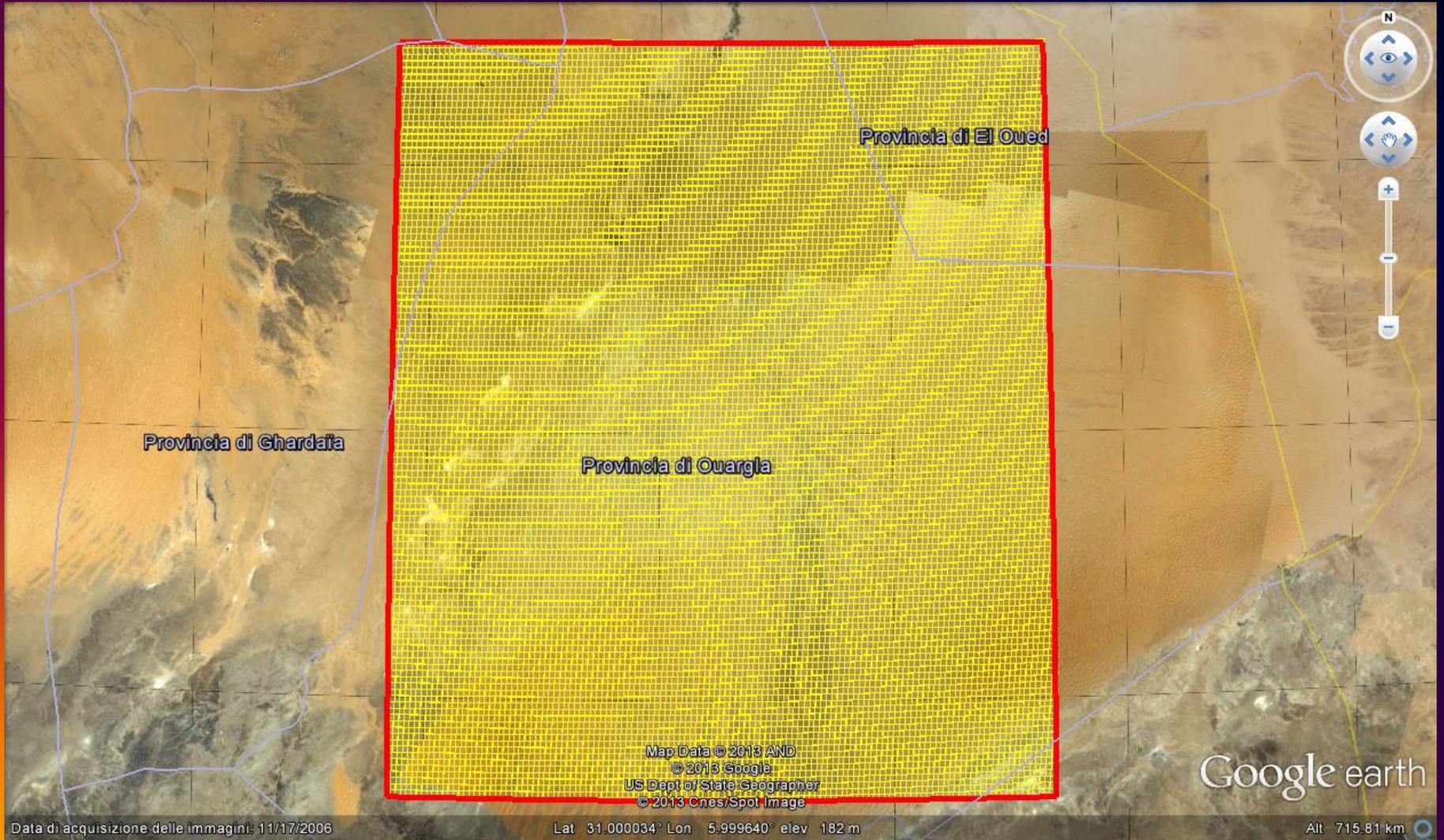
- SEVIRI pixels and IASI footprints (spatial co-location)
- IASI Retrieved Emissivity
  - IASI emissivity spectrum convolved @ SEVIRI channels
- Comparison SEVIRI-IASI
  - 2010, July, 10, AM & PM
  - 2010, July, 4, AM
  - Skin Temperature, full month

## Comparing $T_s - \epsilon$ retrievals for SEVIRI and IASI TARGET AREA:

- ✓ Desert region of Ouargla Province, Algeria
- ✓  $4^\circ \leq \text{Longitude} \leq 8^\circ$ ;  $29^\circ \leq \text{Latitude} \leq 33^\circ$
- ✓ SEVIRI Channels used for emissivity retrieval: 8.7, 10.8 & 12  $\mu\text{m}$



# 14266 SEVIRI Pixels



Data di acquisizione delle immagini: 11/17/2006

Lat 31.000034° Lon 5.999640° elev 182 m

Google earth

Alt 715.81 km

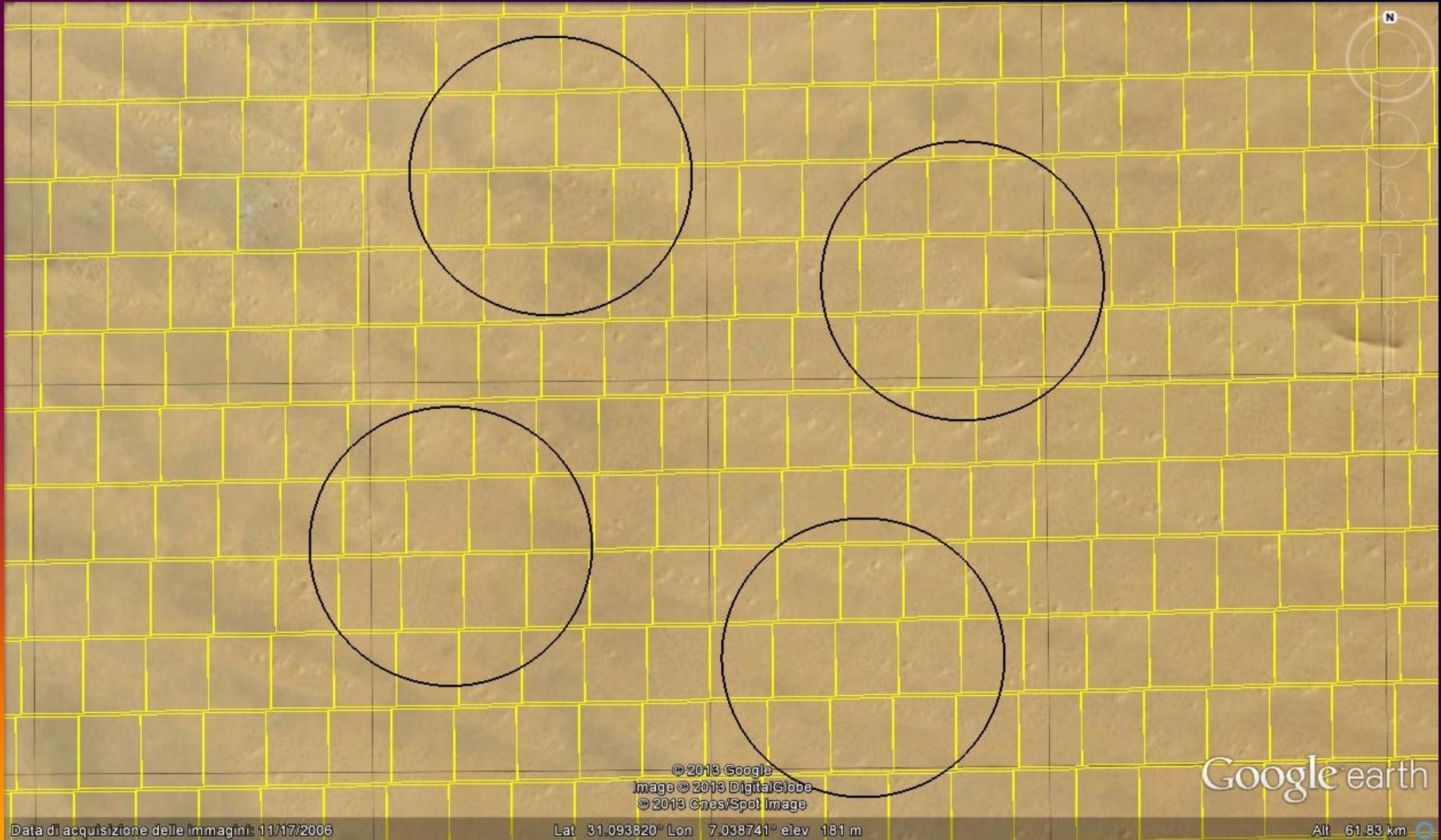
Map Data © 2013 AND  
© 2013 Google  
US Dept of State Geographer  
© 2013 Ches/Spot Image

# IASI 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



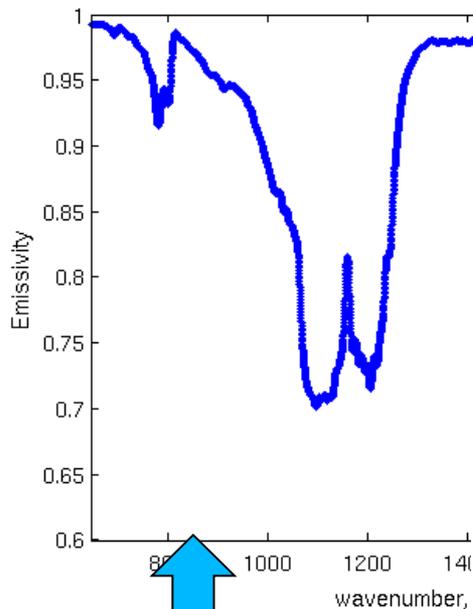
Data di acquisizione delle immagini: 11/17/2006

Lat 31.093820° Lon 7.038741° elev 181 m

Alt 61.83 km

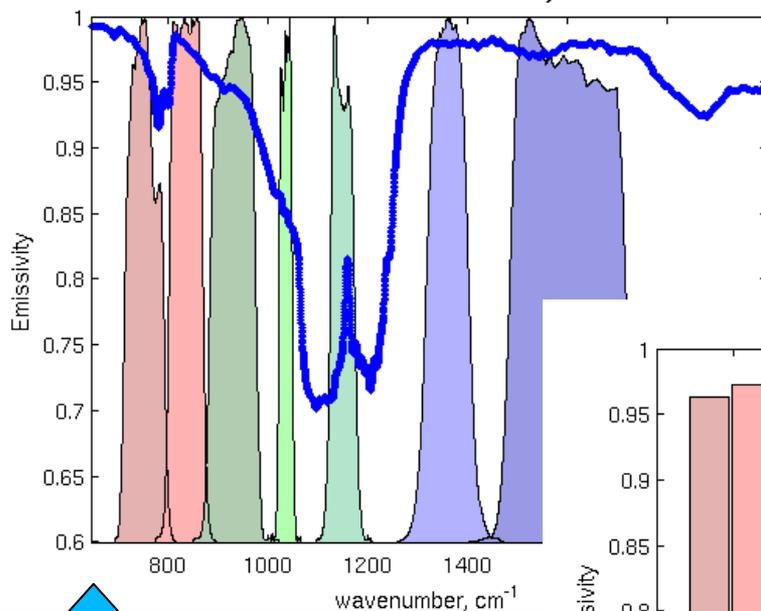
# From IASI Emissivity Spectrum to SEVIRI channels Emissivity

IASI Retrieved Emissivity

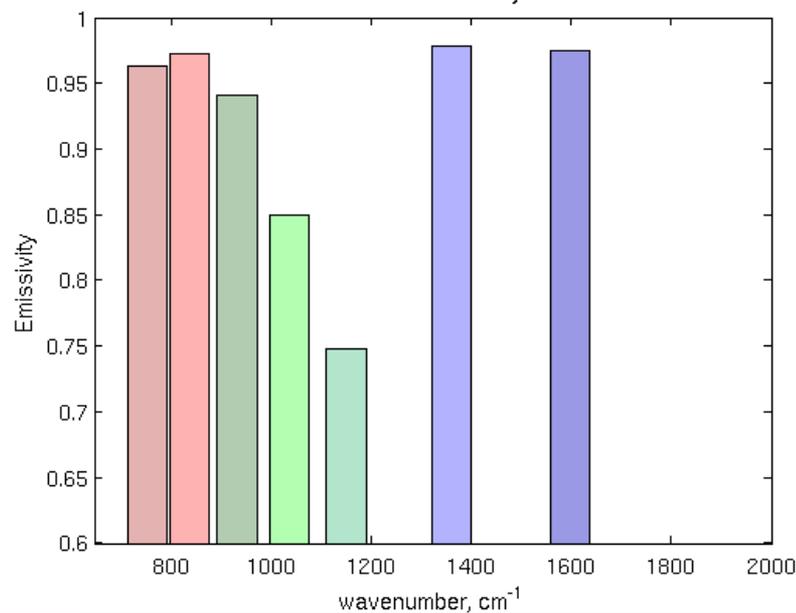


$$\varepsilon^S(\sigma_{ch}) = ISRF(\sigma_{ch}, \sigma) * \varepsilon^I(\sigma)$$

IASI Retrieved Emissivity



SEVIRI Emissivity

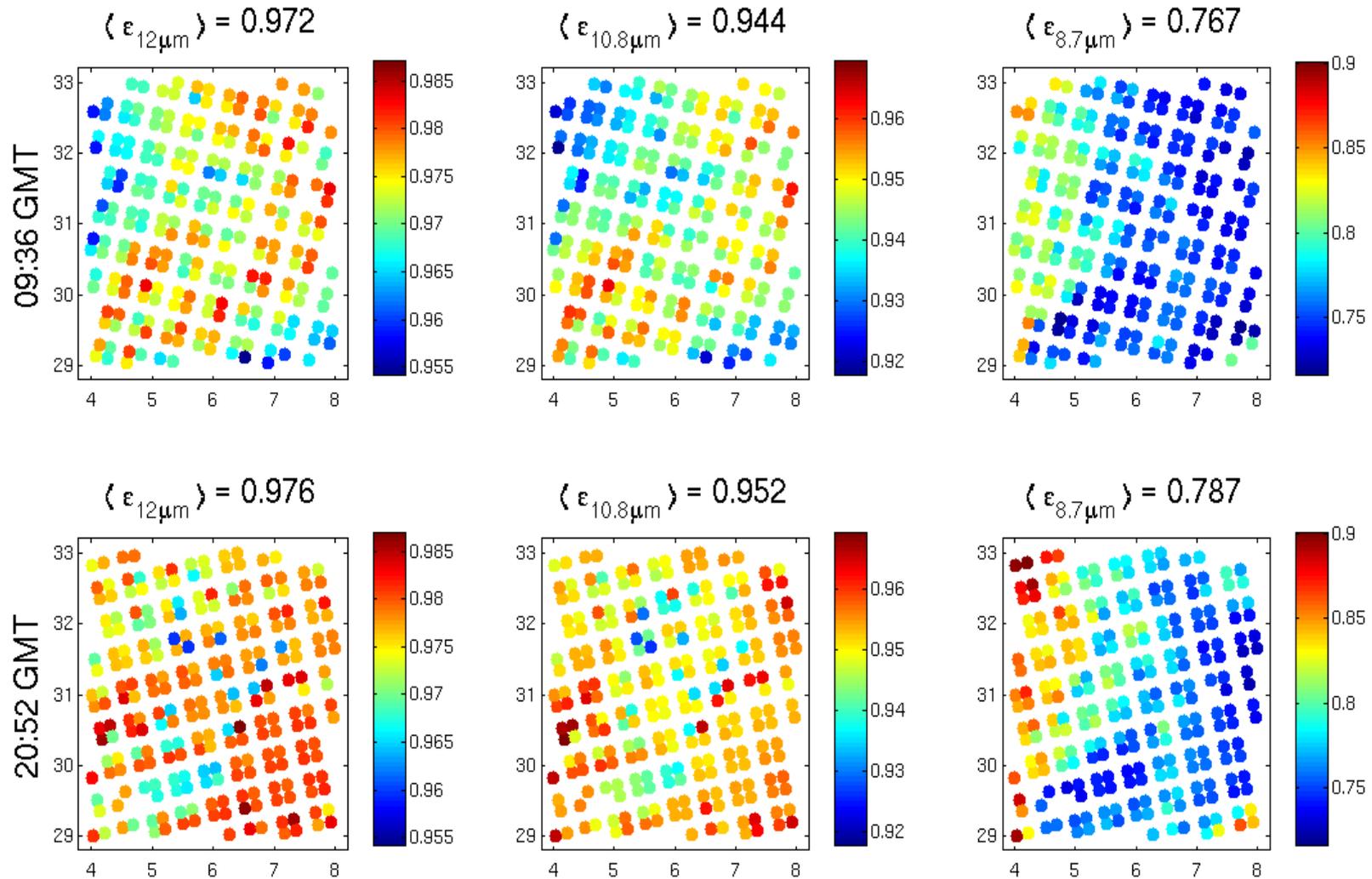


Emissivity  
Spectrum

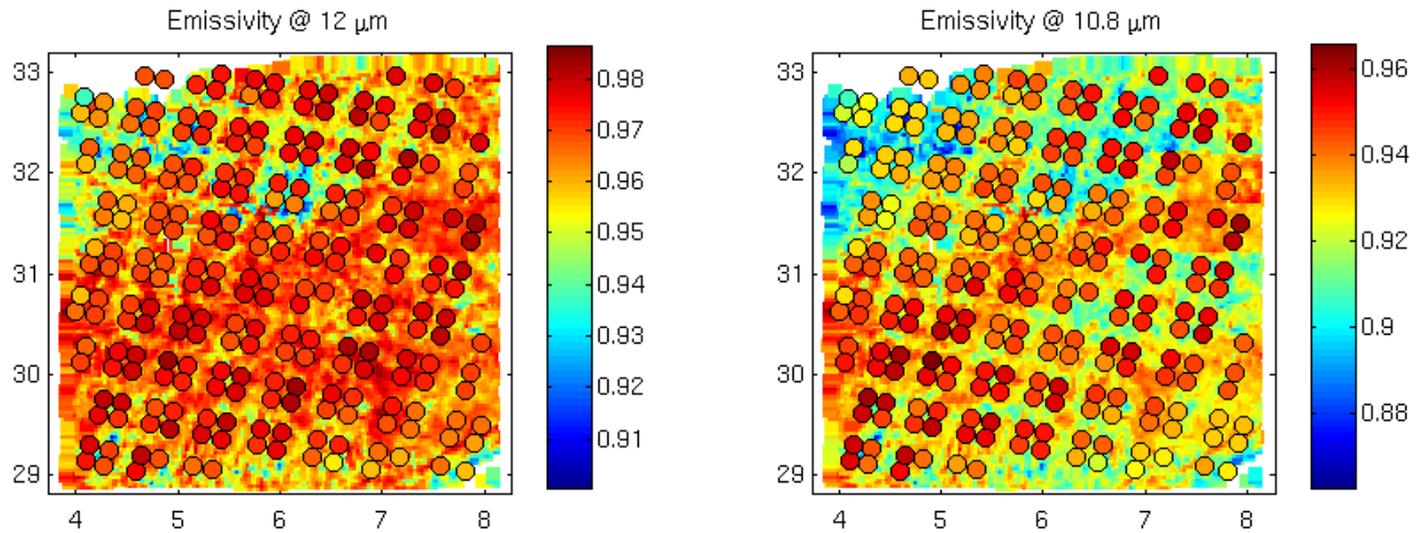
SEVIRI ISRF

SEVIRI Channels Emissivity

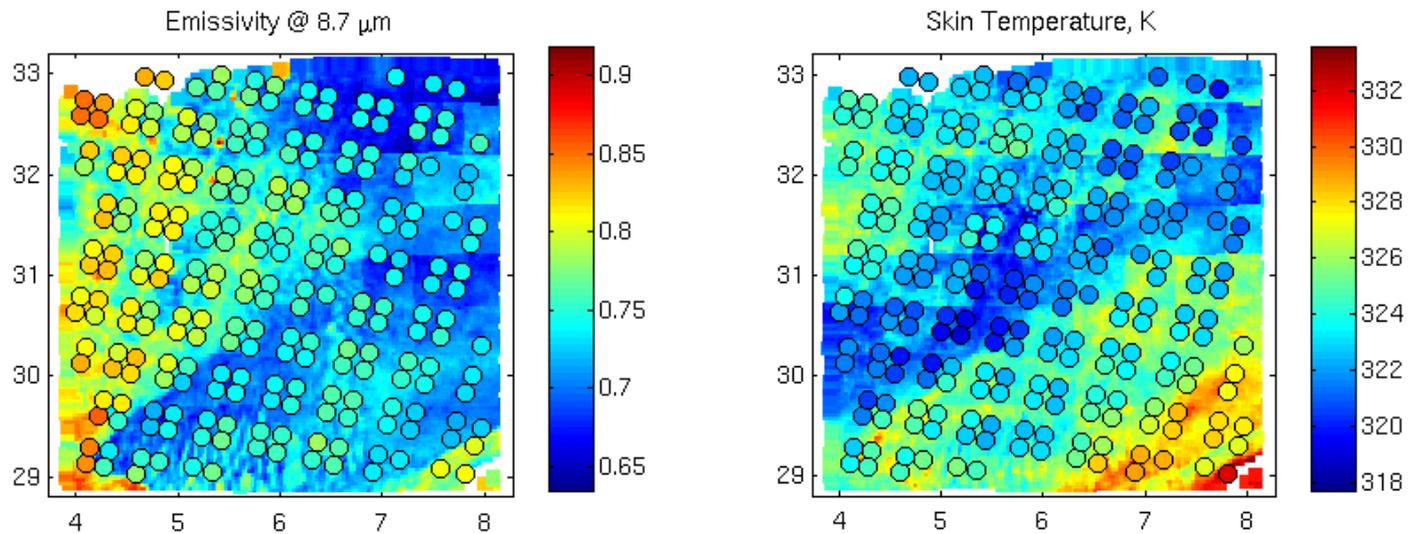
# IASI derived SEVIRI channels emissivity, 10 July 2010, AM and PM



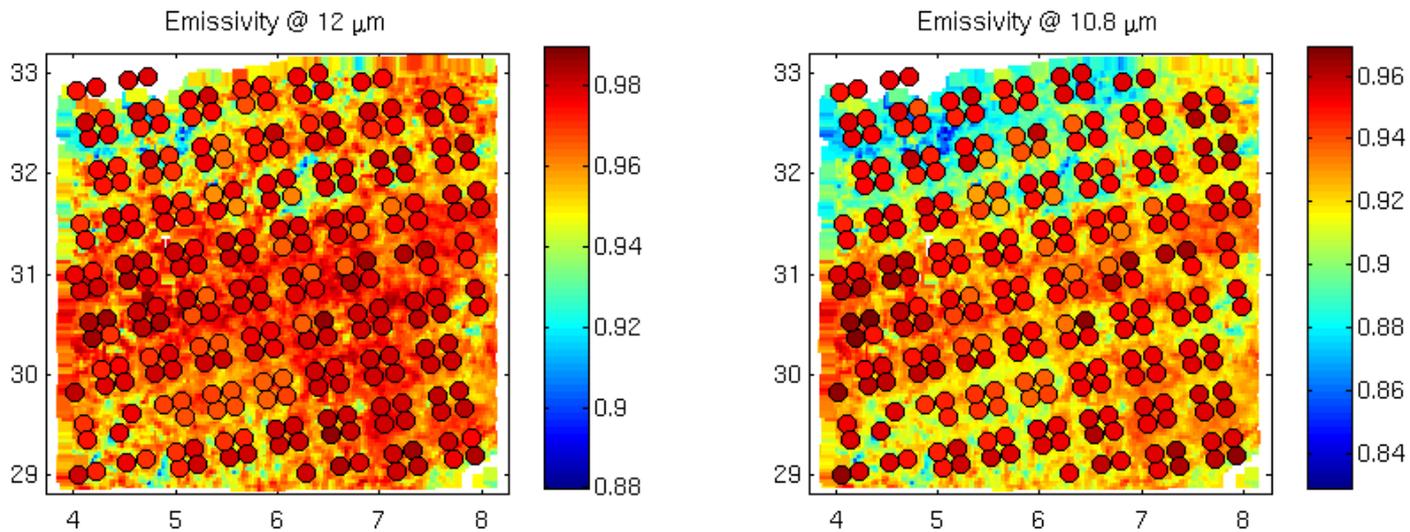
# 10 July, AM, KF, 237 IASI Spectra



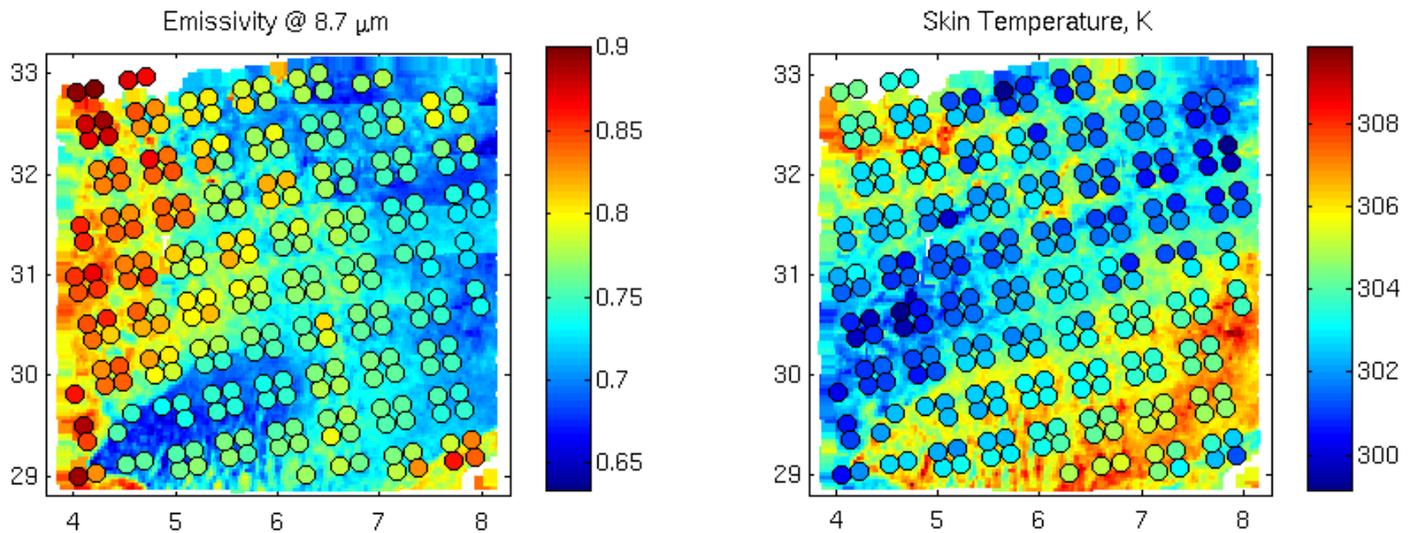
10-Jul-2010, SEVIRI 09:37:00, IASI 09:36:15



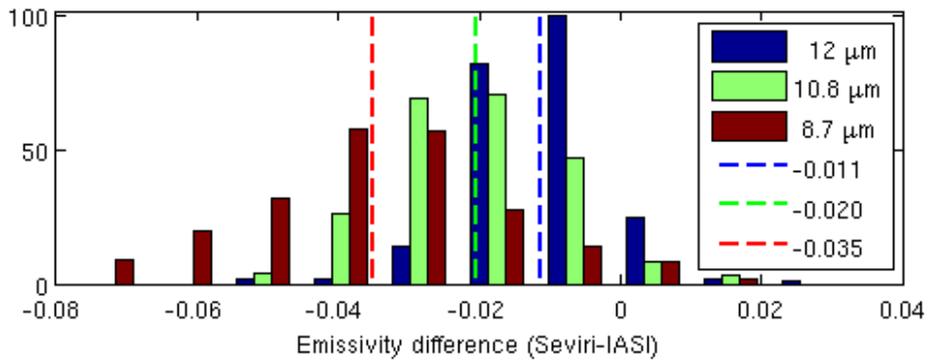
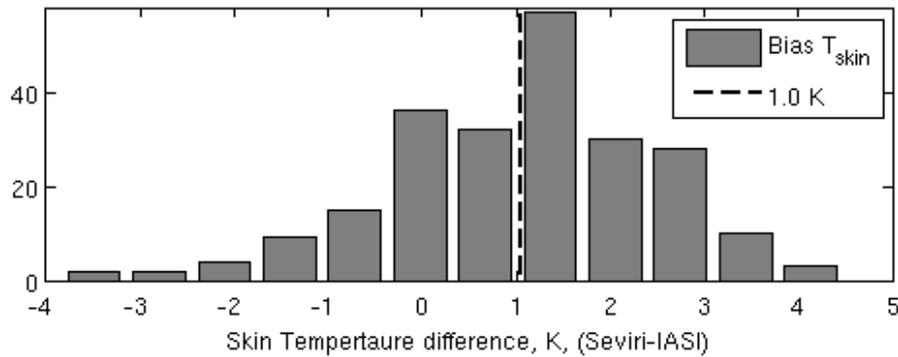
# 10 July, PM, KF, 246 IASI Spectra



10-Jul-2010, SEVIRI 20:52:00, IASI 20:52:45

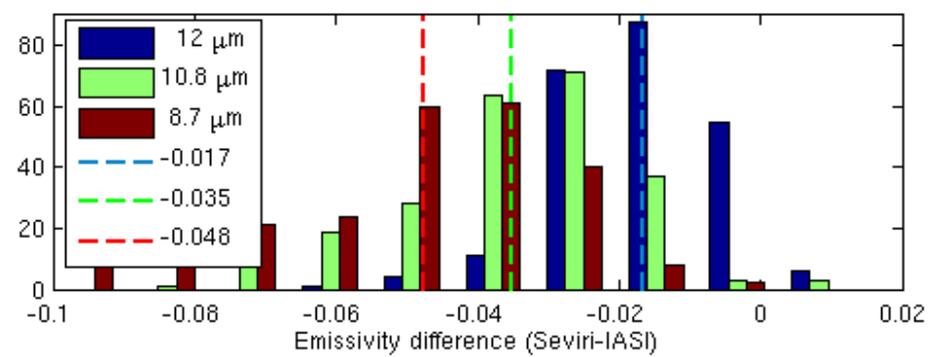
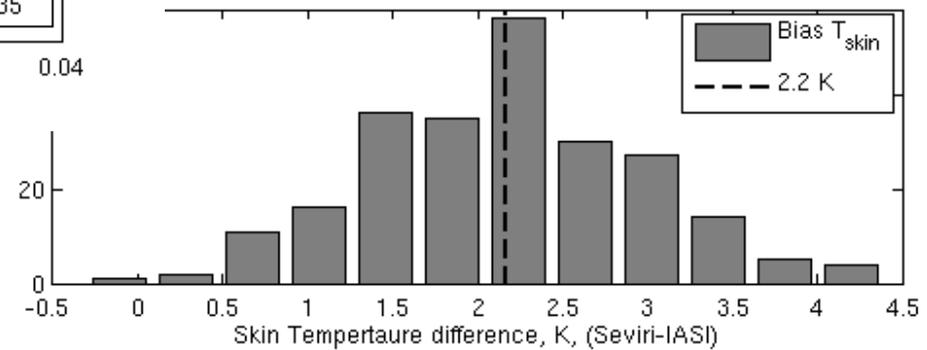


10-Jul-2010, SEVIRI 09:30:00, IASI 09:36:15

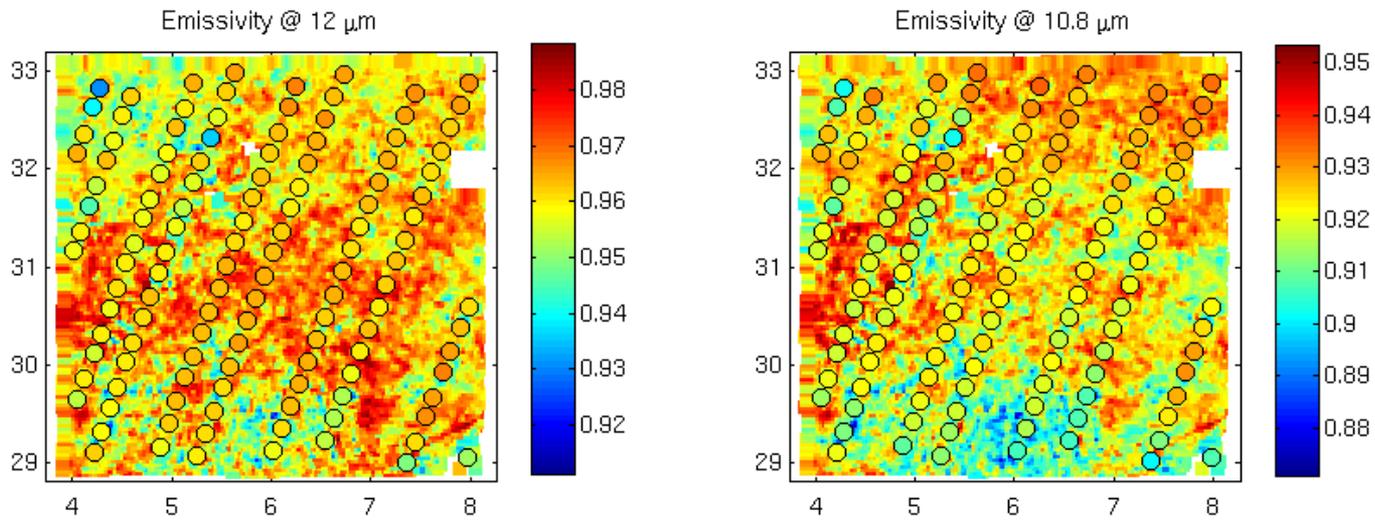


# 10 July, AM & PM

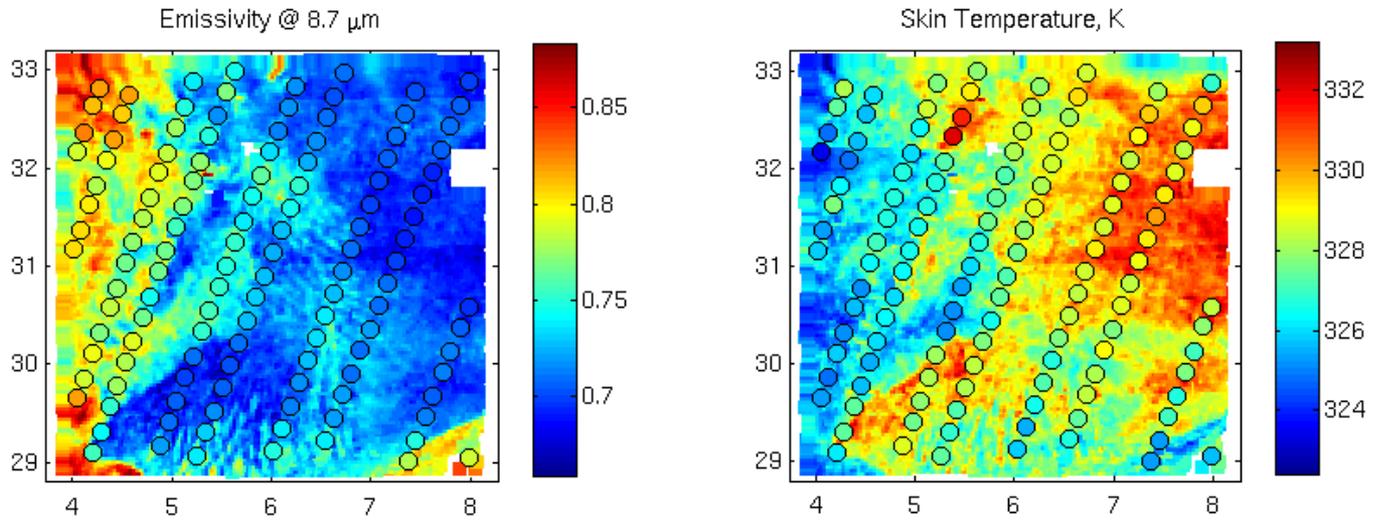
10-Jul-2010, SEVIRI 20:52:00, IASI 20:52:45



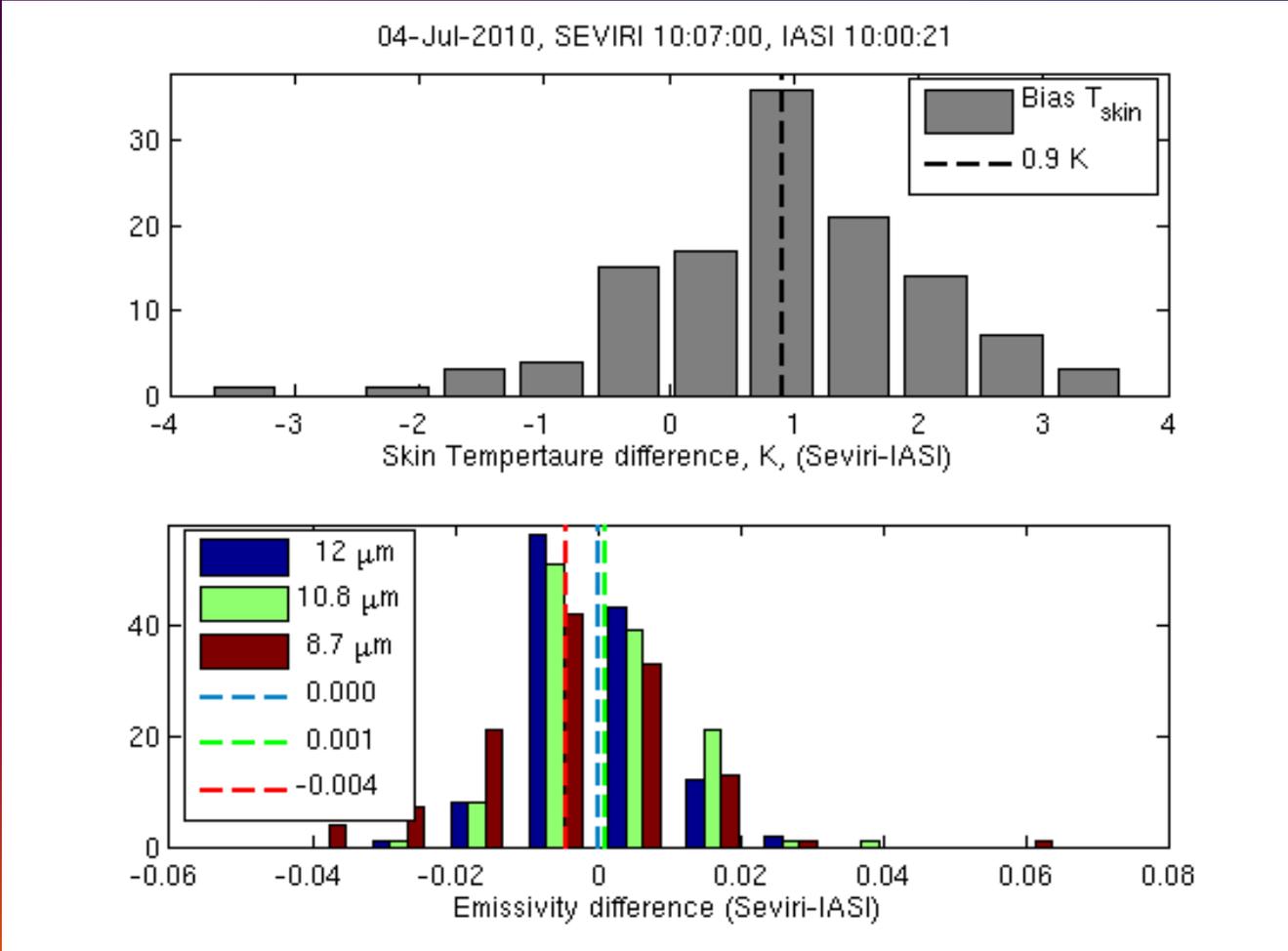
# 4 July, AM, KF, 123 IASI Spectra



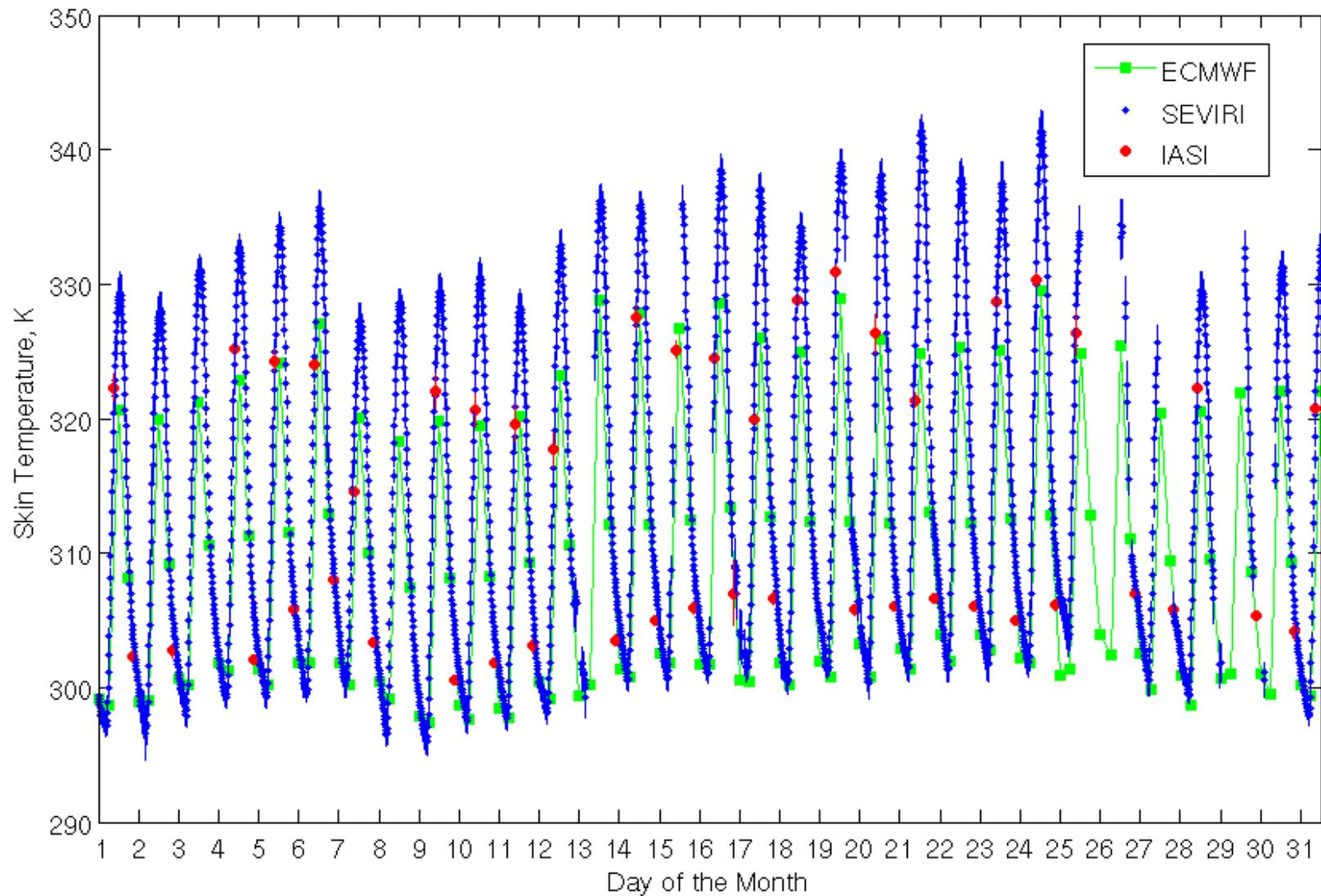
04-Jul-2010, SEVIRI 10:07:00, IASI 10:00:21



# 4 July, AM, KF, 123 IASI Spectra



July 2010, 5.5 W, 30.5 N



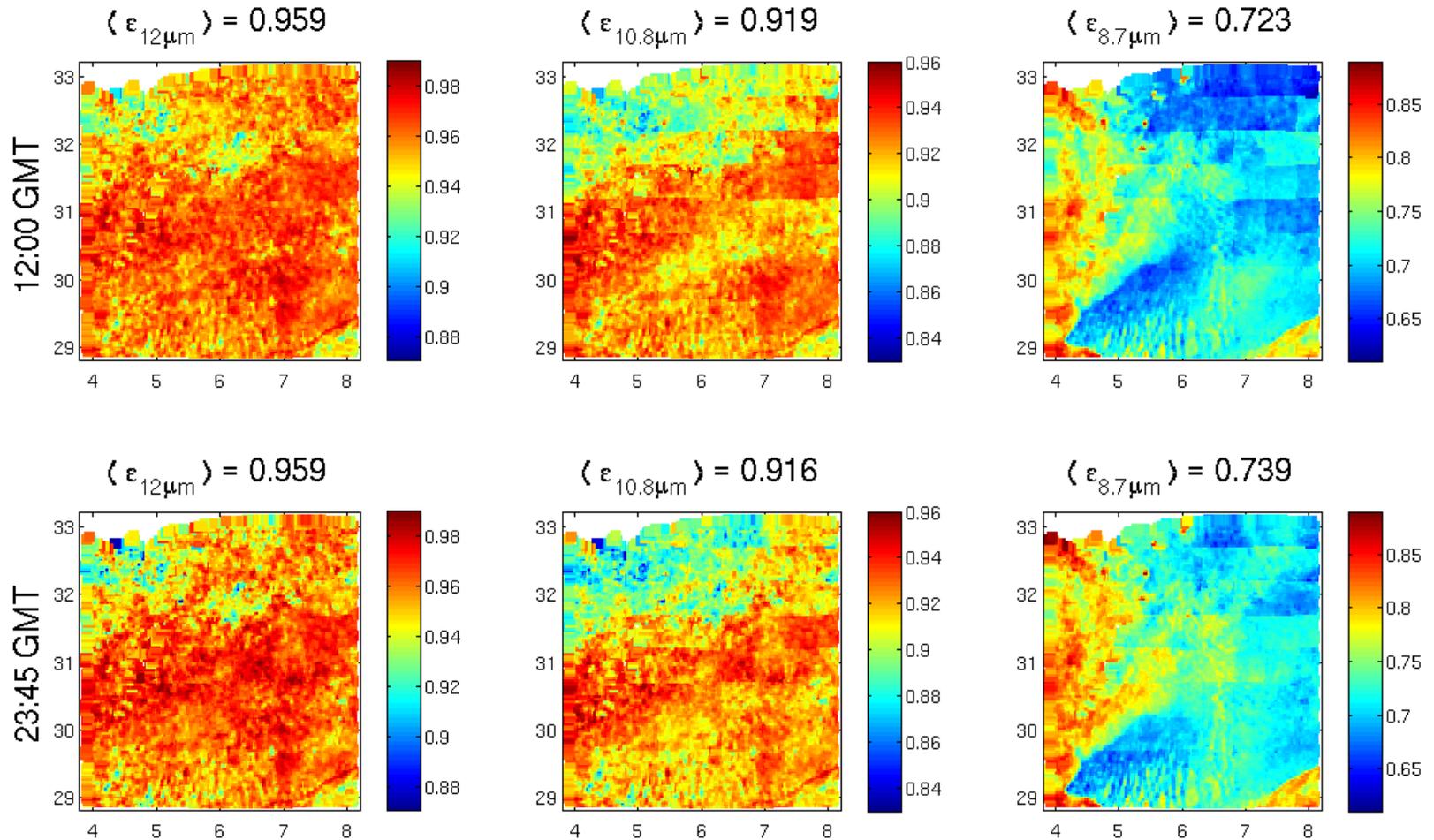
**Li, Z., Li, J., Li, Y., Zhang, Y., Schmit, T. J., Zhou, L., Goldberg, M. D.  
and Menzel, W. P. (2012)**

**Determining diurnal variation of land surface emissivity from  
geostationary satellites.**

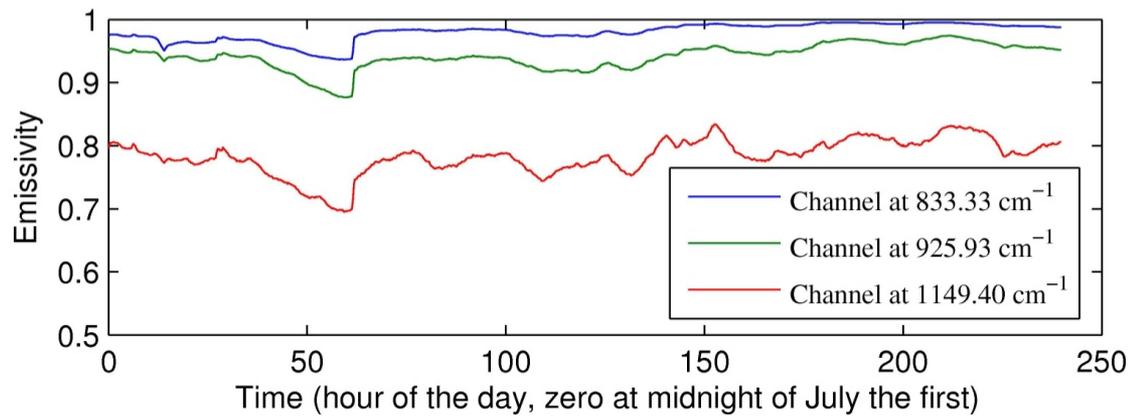
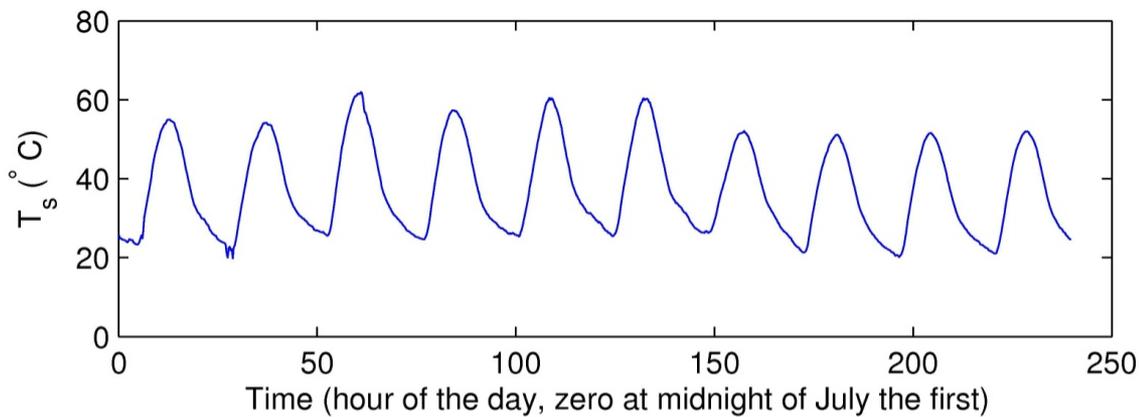
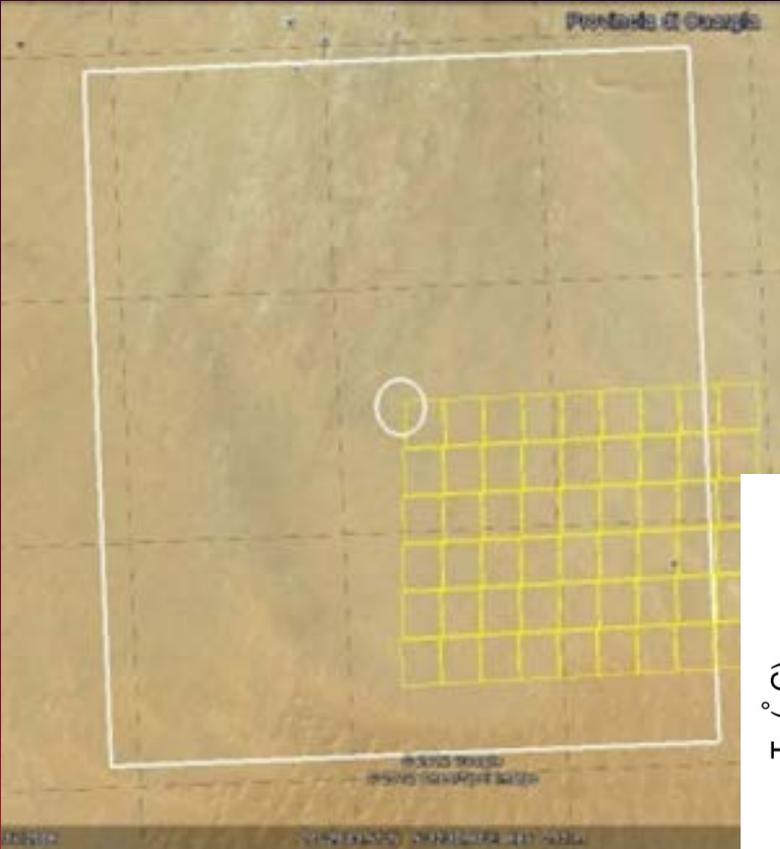
**JGR, 117, D23302, doi:10.1029/2012JD018279**

**DAILY-NIGHT EMISSIVITY VARIATION  
OVER THE SAHARA DESERT ON THE DRY  
SEASON**

# SEVIRI retrieved day/night emissivity



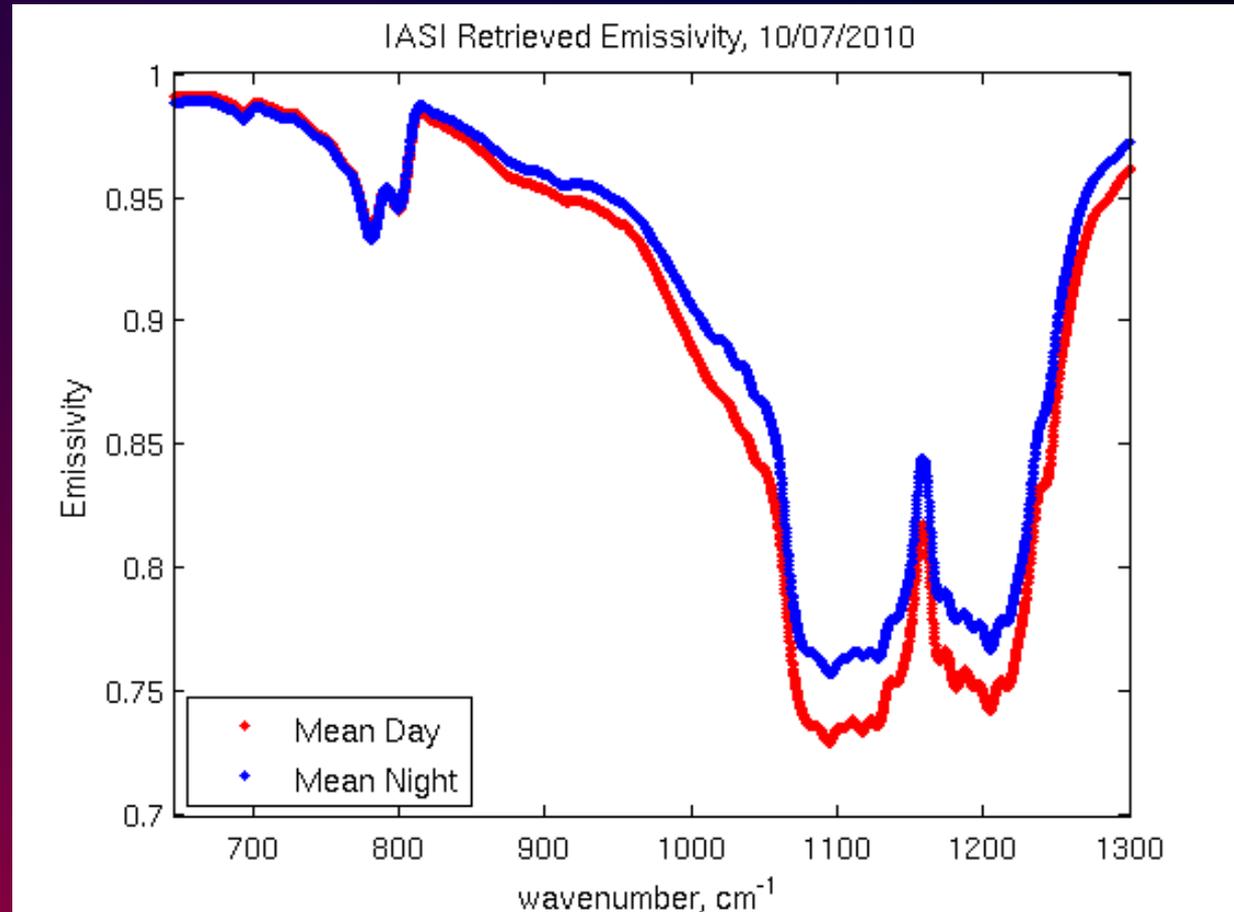
# Retrieval of $T_s$ - $\epsilon$ by KF running over a long time period (10 days)



## IASI retrieved emissivity spectrum

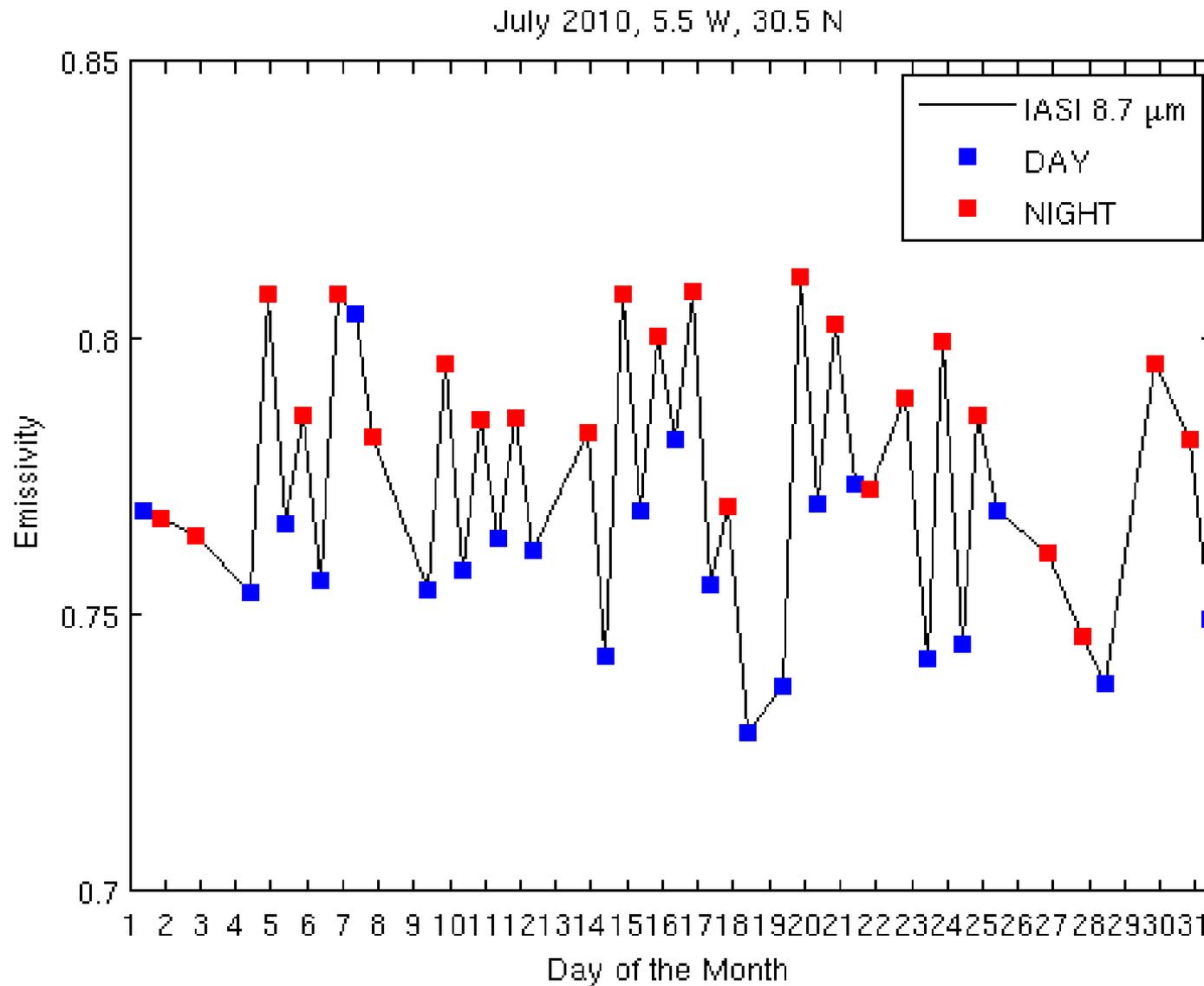
**Red:** IASI Emissivity spectrum averaged over 229 footprints recorded during Daytime (09:36 GMT)

**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 $\mu\text{m}$



# 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.**