Applied Spectroscopy

Kalman filter for surface emissivity and temperature. Update of the application to the SEVIRI full disk

Sara Venafra, Carmine Serio, Guido Masiello,

Giuliano Liuzzi, Maria Grazia Blasi

Presented by Sara Venafra

School of Engineering, University of Basilicata, Potenza, Italy

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  EUM/CO/14/4600001329/PDW
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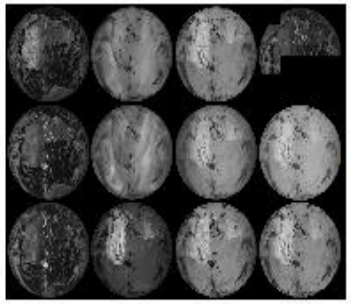
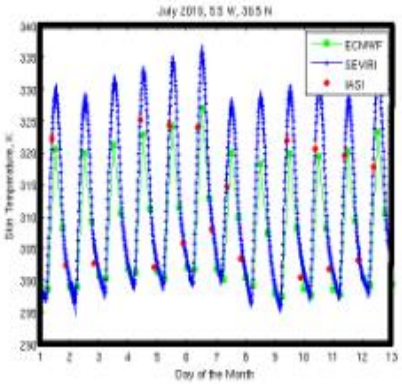
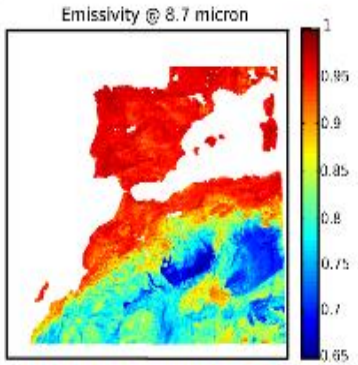
Outline

- Brief description of SEVIRI instrument;
- Implementation of Kalman filter (KF) methodology for the physical retrieval of surface temperature and emissivity from SEVIRI infrared radiances;
- The SEVIRI Full Disk;
- New Applications: emissivity contrast index (ECI) and analysis of emissivity-soil moisture relation (Negev case study);
- Conclusions

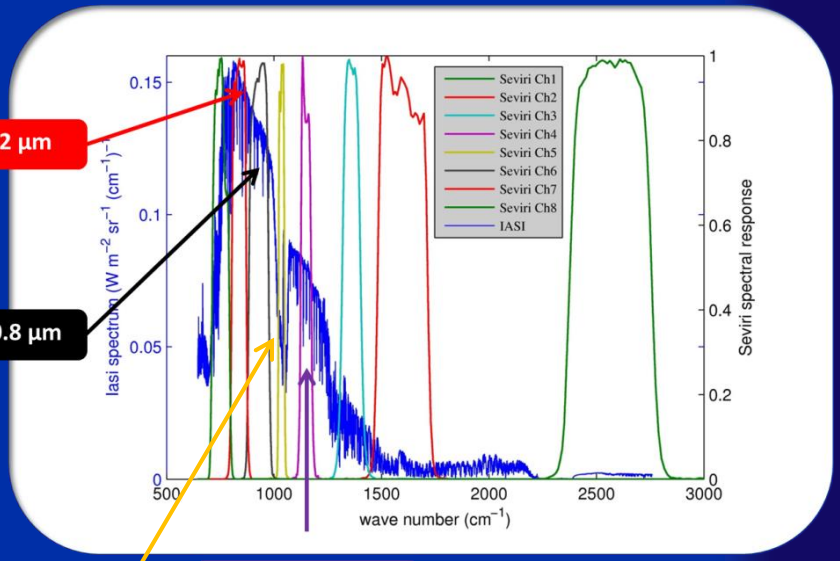
Instrument Description
SEVIRI
(Spinning Enhanced Visible and Infrared Imager)







Orbit Type: Geostationary
Time resolution: 15 minutes
Pixel Size: 3 Km x 3 Km



Channel Number	wave number (cm^{-1})	wave number (μm
1	2564.10	3.9
2	1612.90	6.2
3	1369.90	7.3
4	1149.40	8.7
5	1030.9	9.7
6	925.90	10.8
7	833.30	12.0
8	746.30	13.4

The retrieval framework

- The SEVIRI forward model: **σ-SEVIRI**

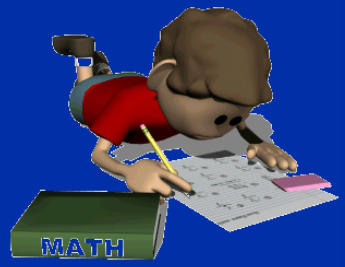
$$R(\theta_r, \phi_r, \sigma) = \varepsilon(\theta_r, \phi_r, \sigma)\tau_0(\theta_r, \phi_r, \sigma)B(T_s) + R_u(\theta_r, \phi_r, \sigma) + R_r(\theta_r, \phi_r, \sigma)$$

$$R_u(\theta_r, \phi_r, \sigma) = \int_0^{+\infty} B(T)\frac{\partial \tau}{\partial h}dh$$

$$R_r(\theta_r, \phi_r, \sigma) = \tau_0(\theta_r, \phi_r, \sigma)\int_0^{2\pi} d\phi_i \int_0^{\frac{\pi}{2}} f(\theta_r, \phi_r, \theta_i, \phi_i, \sigma) R_i(\theta_i, \phi_i, \sigma)cos(\theta_i)sin(\theta_i)d\theta_i$$

Lambertian Reflection

Specular Reflection



- The SEVIRI inverse model: **δ-SEVIRI**

Kalman Filter + simple persistence model

KF methodology + persistence model for surface temperature and emissivity retrieval

$$\begin{cases} \mathbf{R_t} = F(\mathbf{v_t}) + \boldsymbol{\varepsilon_t} \\ \mathbf{v_{t+1}} = \mathbf{H v_t} + \boldsymbol{\eta_t} \end{cases}$$

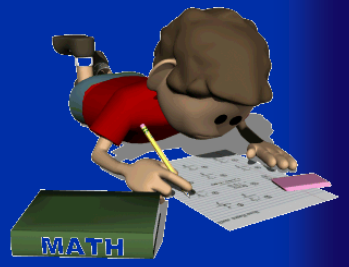
observation equation

state/evolution equation

analysis at time t

update or analysis

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



forecast at time t

forecast

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

covariance of η_t

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

- Application to SEVIRI window channels, for the retrieval of Ts and ε

  Masiello, G. et al. 2013, Atmos. Meas. Tech., doi:10.5194/amt-6-3613-2013

  Masiello, G. et al. 2015, Atmos. Meas. Tech., doi:10.5194/amt-8-2981-2015

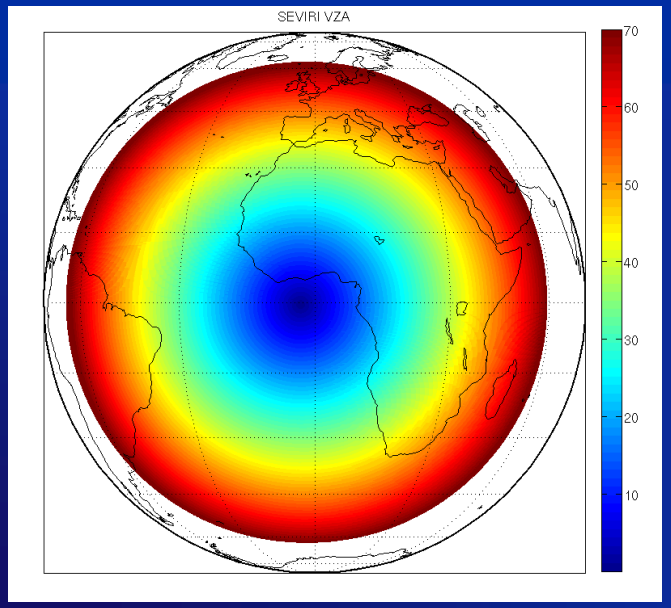
  Blasi, M.G. et al. 2016, Tethys, doi:10.3369/tethys.2016.13.01

The new σ-SEVIRI forward model

PCA (Principal Component Analysis) based approach to Radiative Transfer Model for SEVIRI

Linear Regression

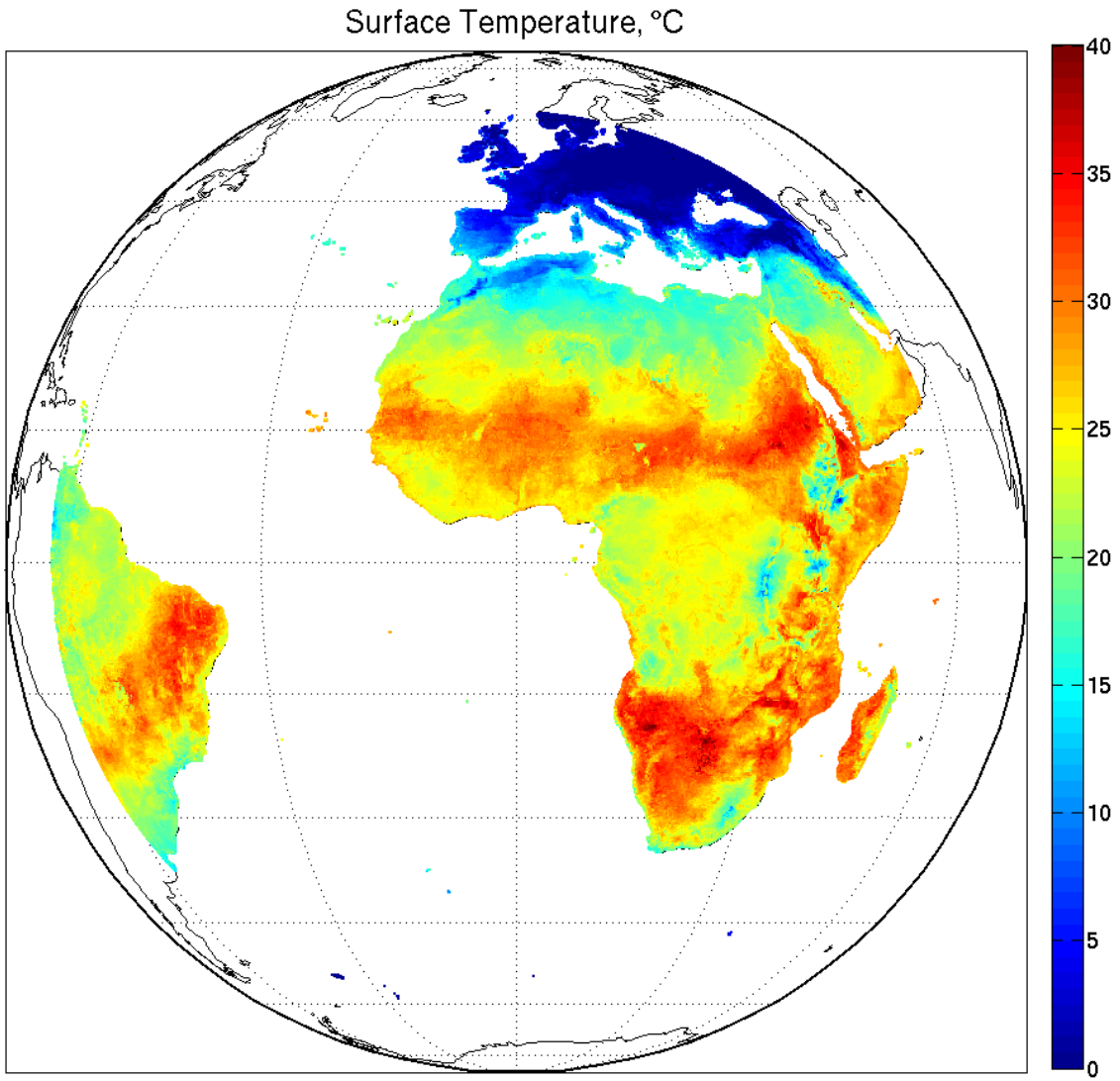
About 7 times faster than older σ-SEVIRI version



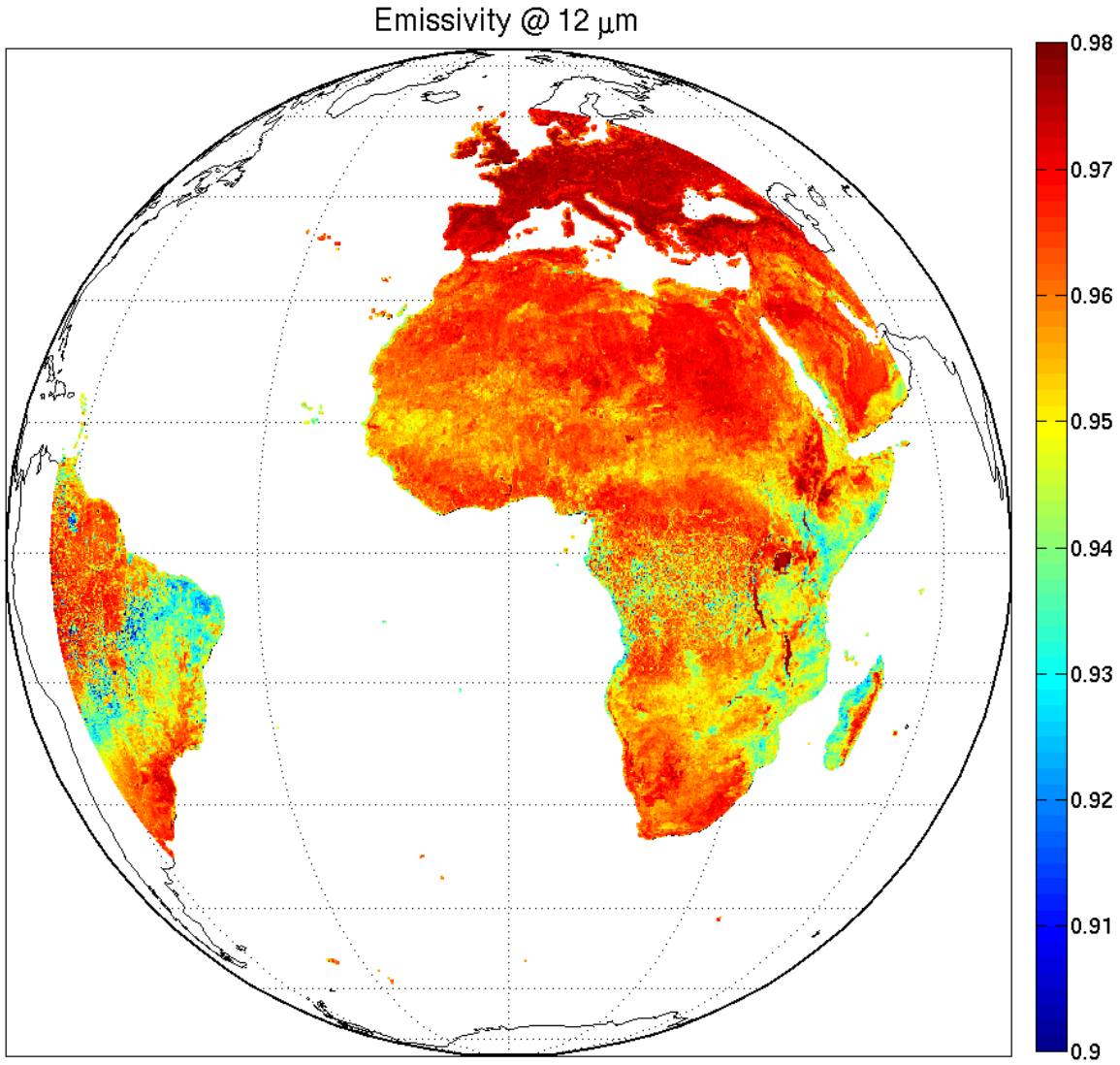
Full Disk (VZA<=70°):
Total 3,545,871 pixels
3,488,328 Land pixels
57,543 In Land Water pixels

A single SEVIRI FD run will take about 30 min (against about 2.8 h for older version) exploiting 8 threads and considering all pixels as clear sky (Ifort Compiler)

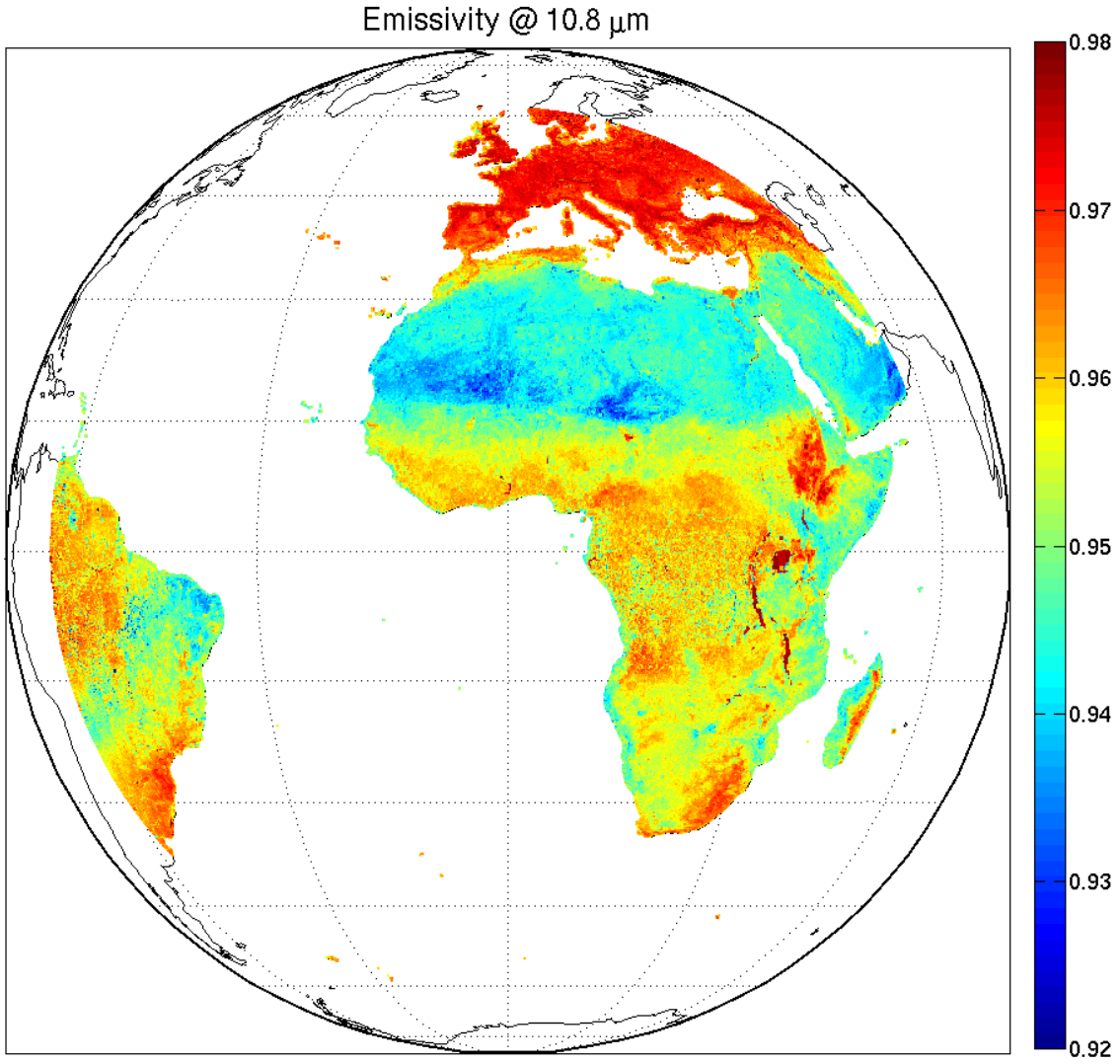
SEVIRI Full Disk: Nov 2007 Surface Temperature



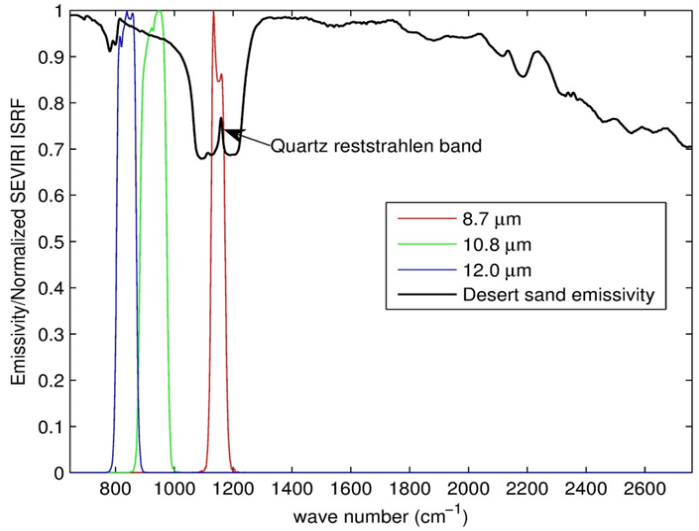
SEVIRI Full Disk: Nov 2007 Emissivity @12 μm

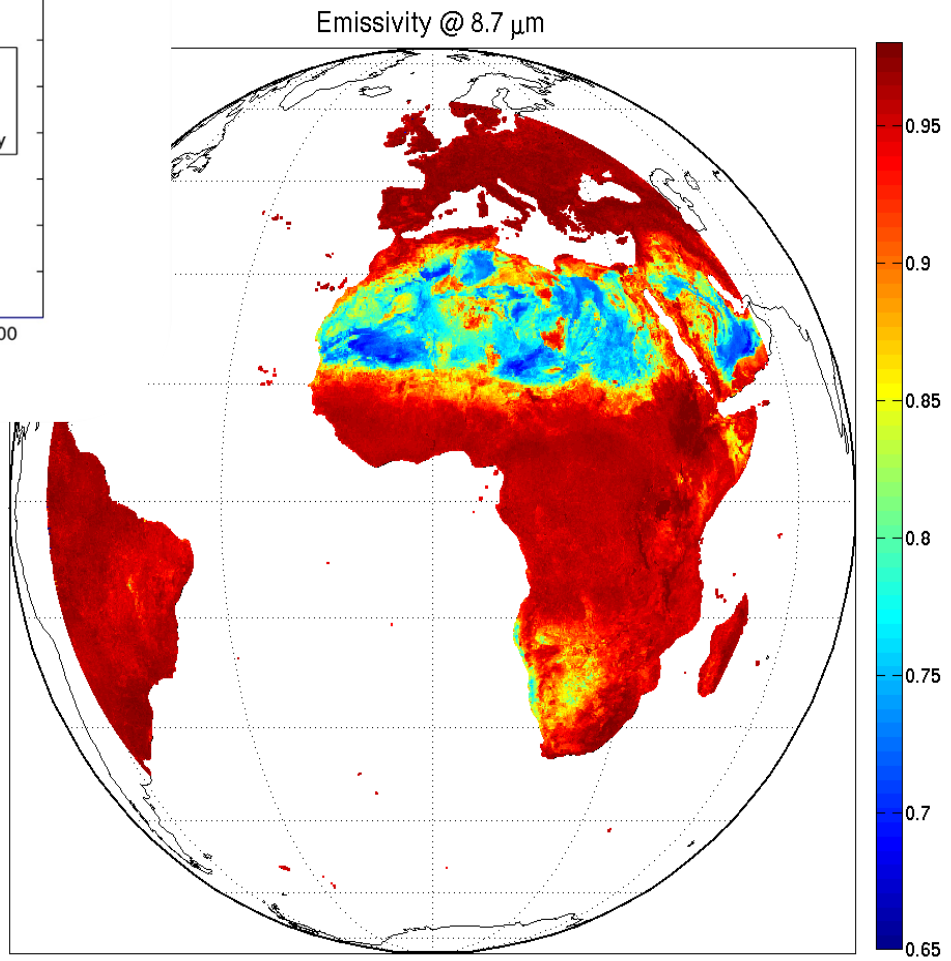


SEVIRI Full Disk: Nov 2007 Emissivity @10.8 μm

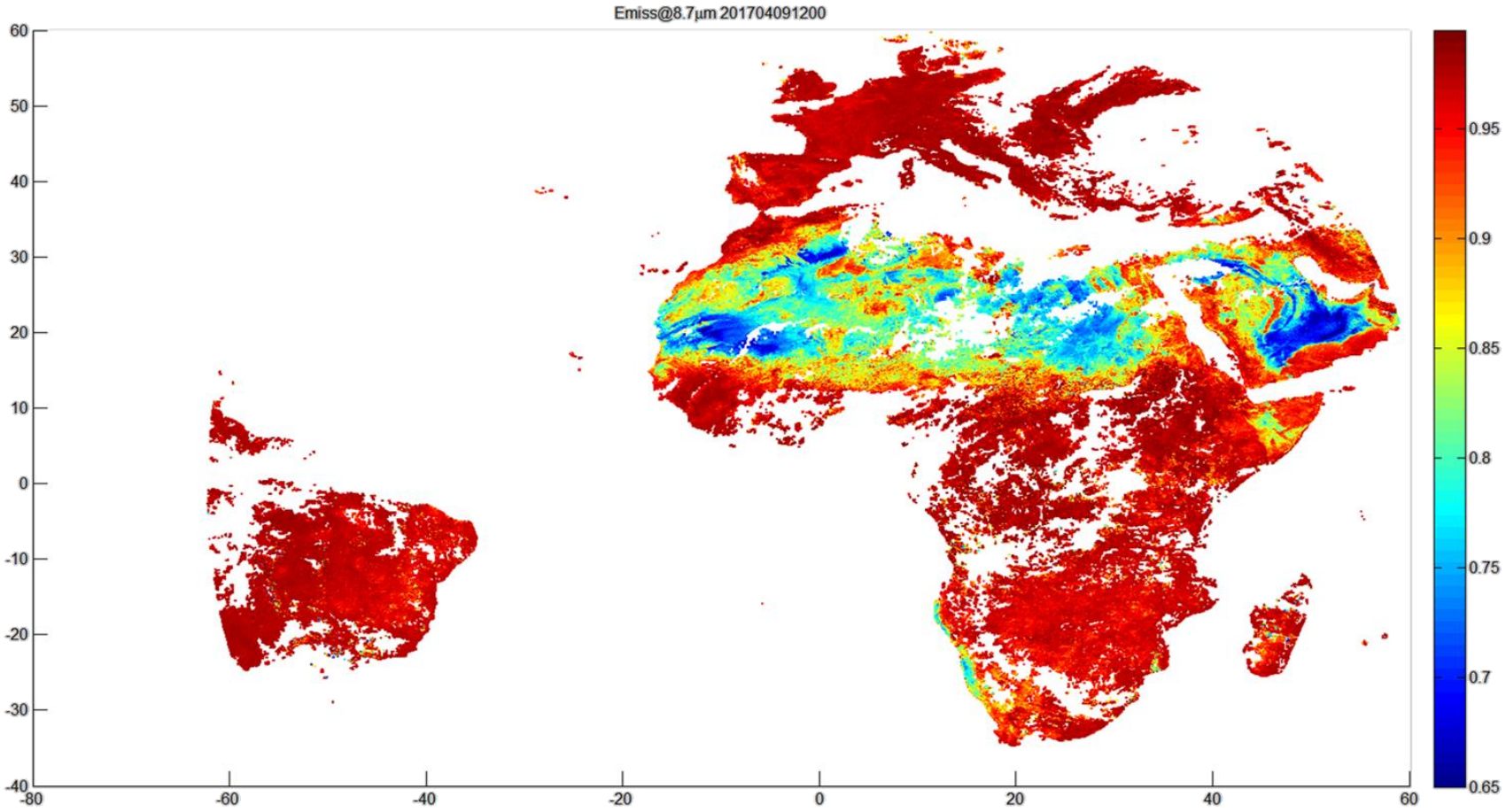


SEVIRI Full Disk: Nov 2007 Emissivity @8.7 μm

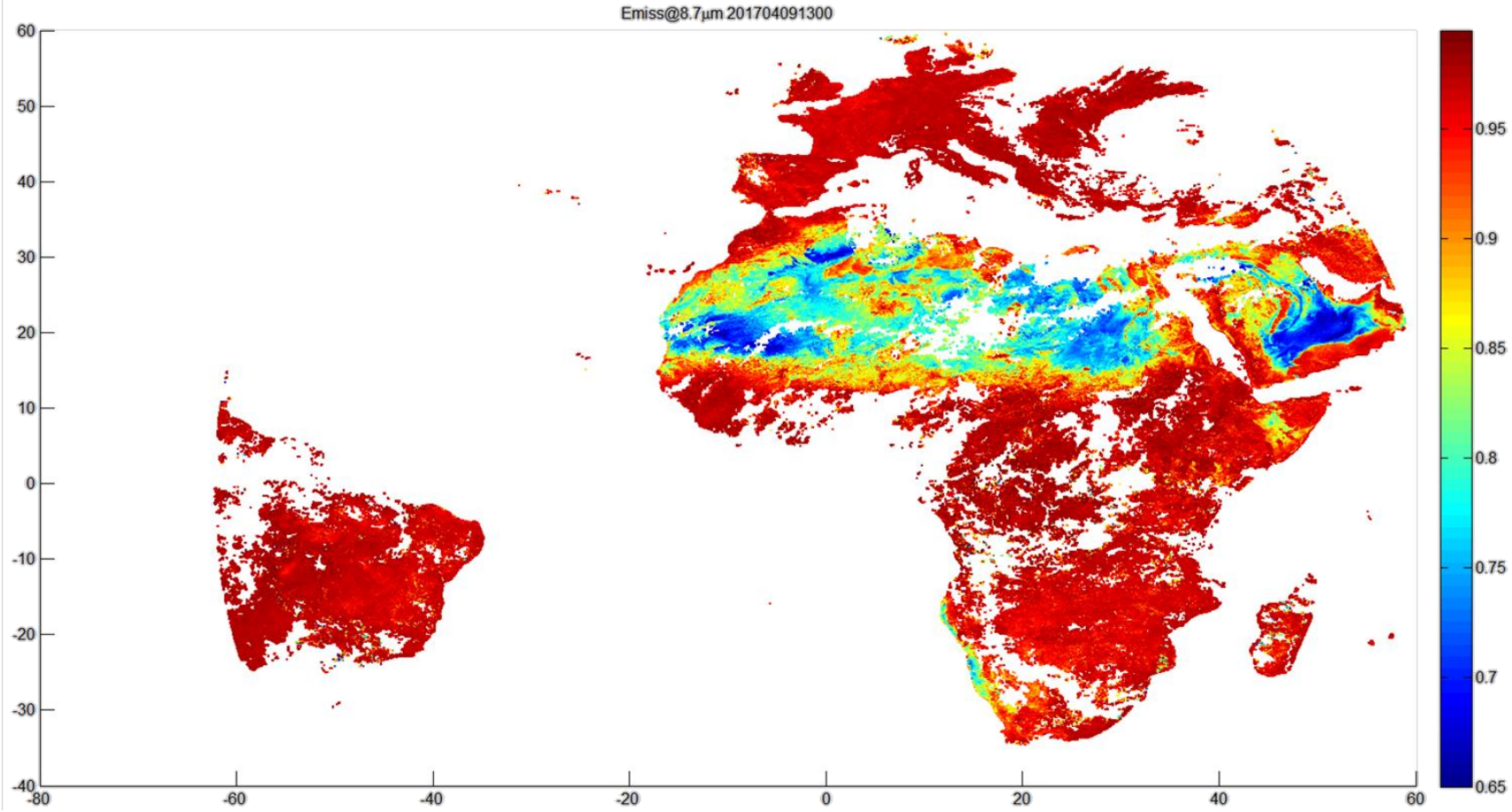




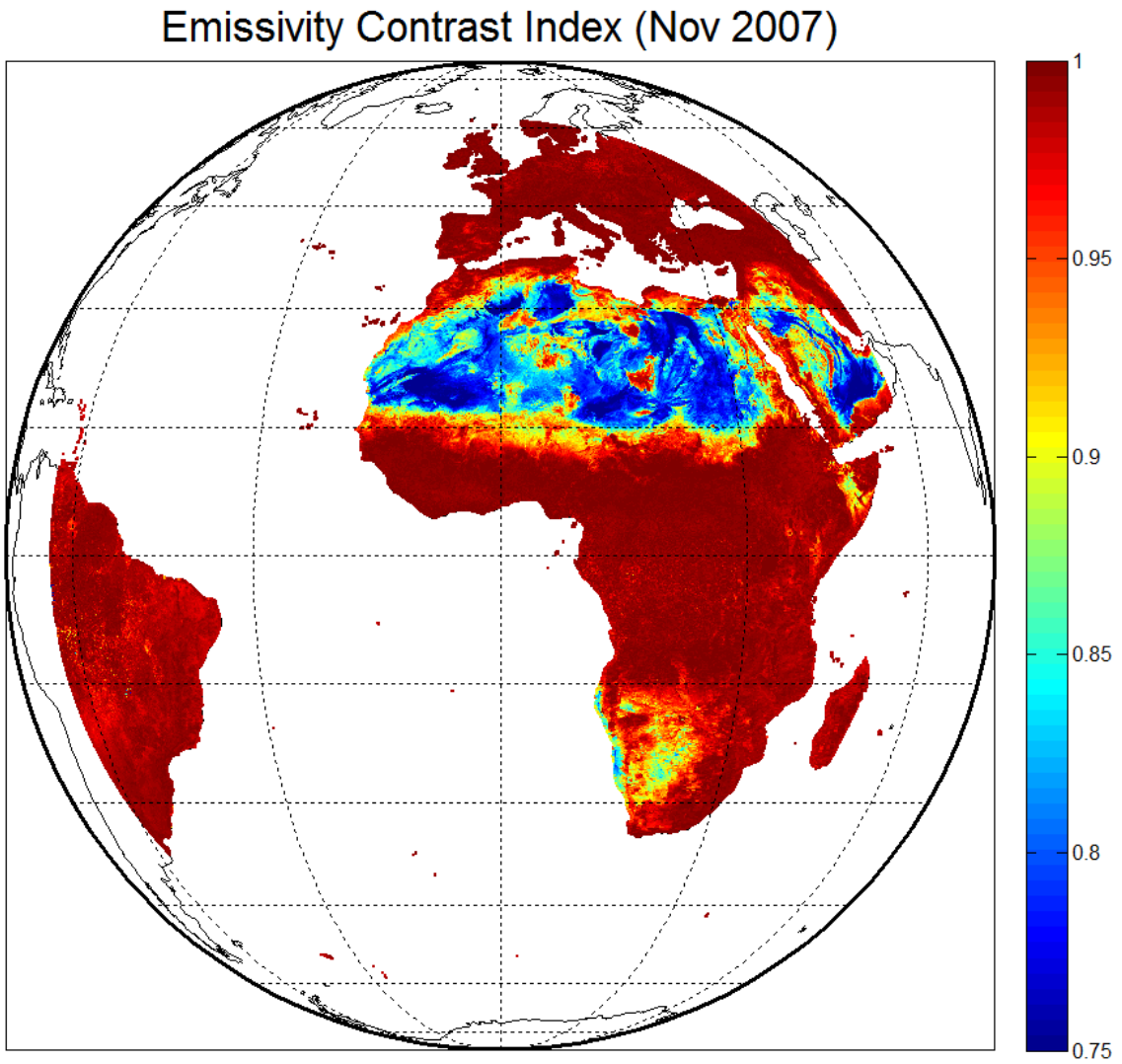
SEVIRI Full Disk: Run at IPMA machines
Emissivity @8.7 μm 09/04/2017 12:00 UTC



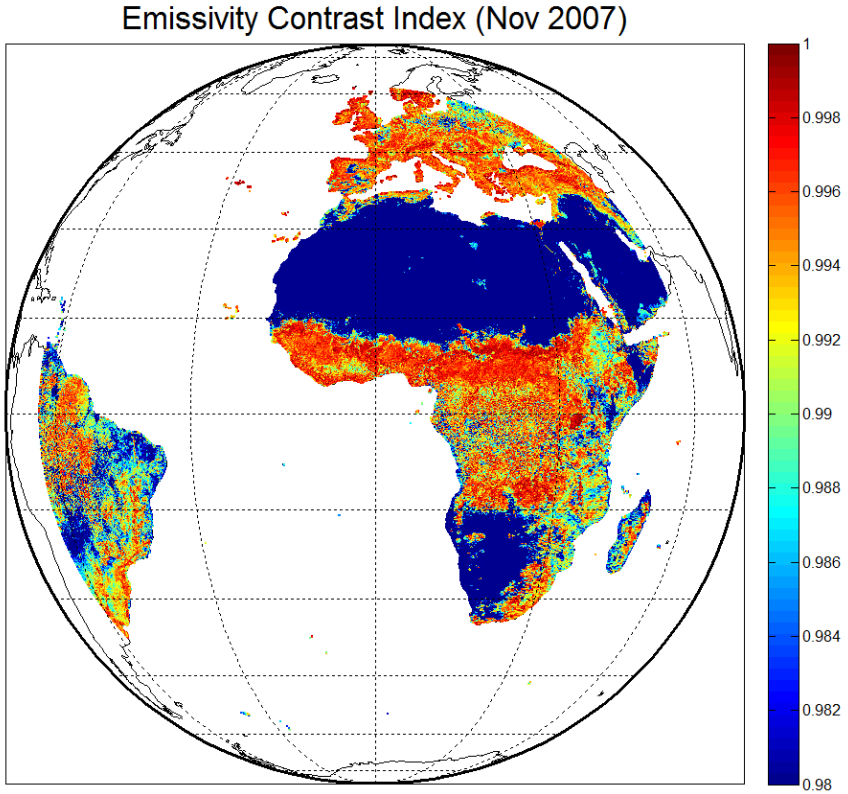
SEVIRI Full Disk: Run at IPMA machines
Emissivity @8.7 μm 09/04/2017 13:00 UTC

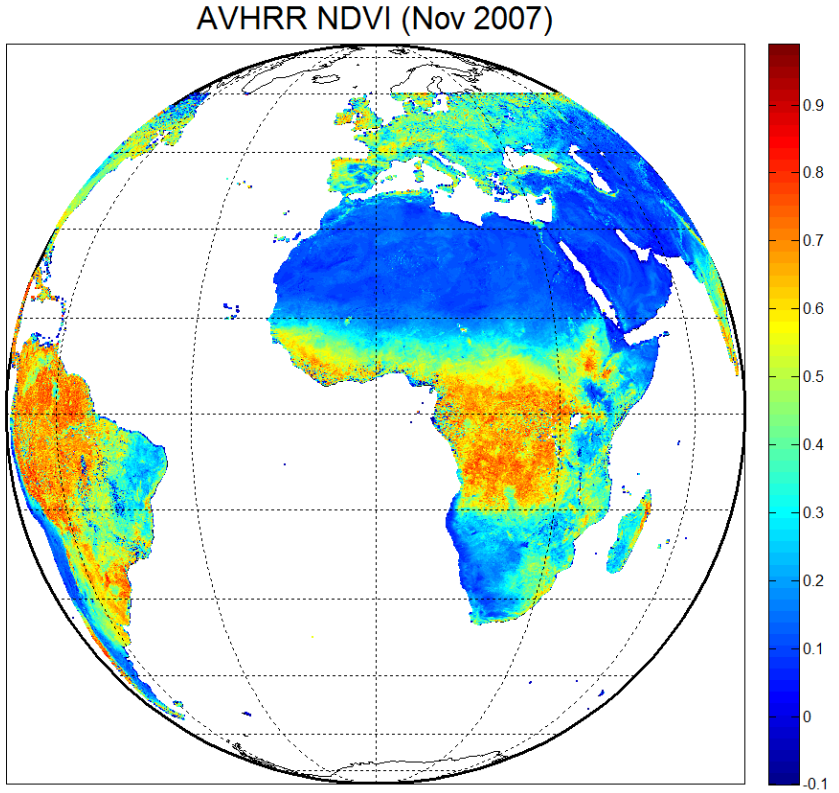


SEVIRI Full Disk: Nov 2007
NEW!!! Emissivity Contrast Index (ECI)

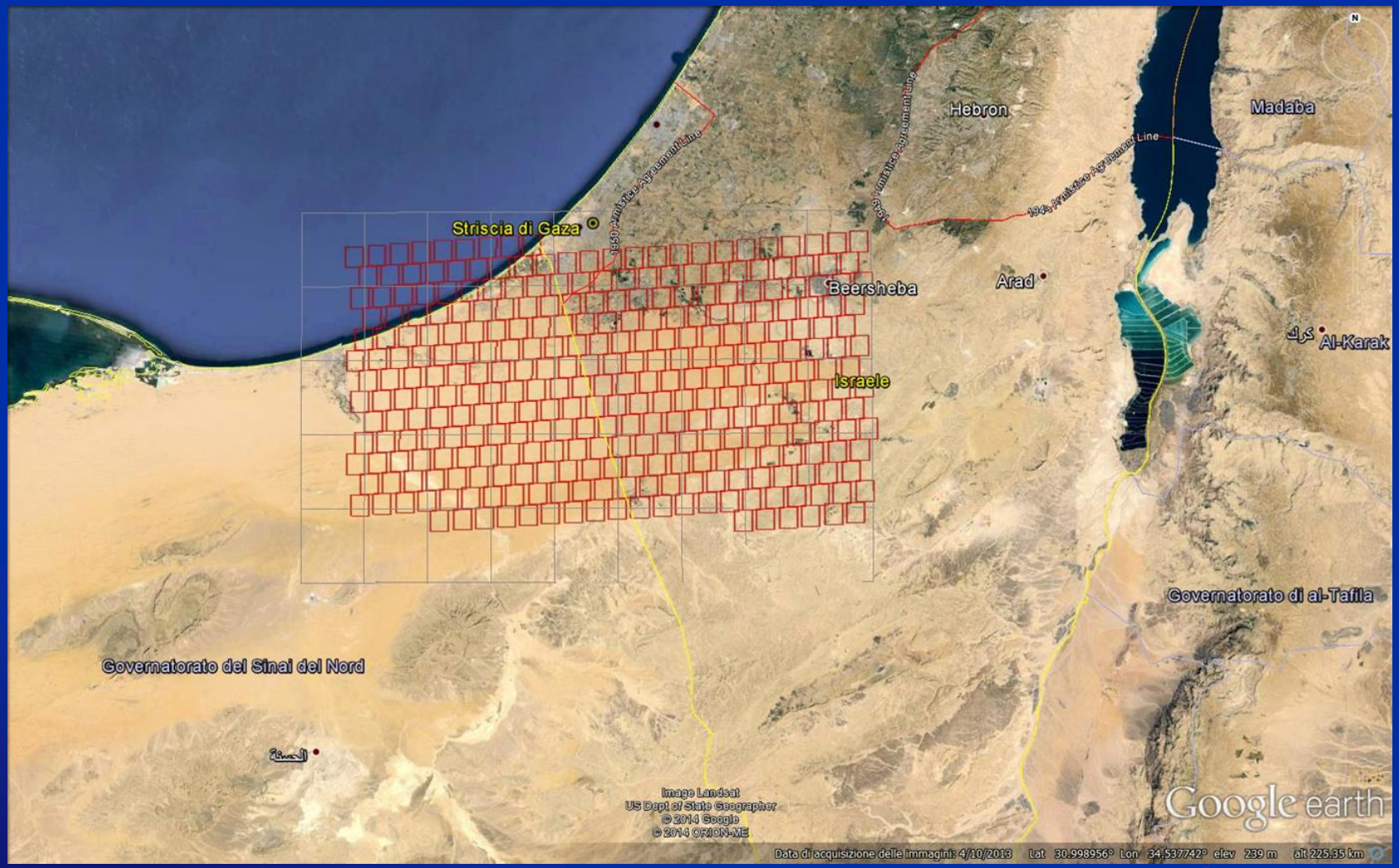


SEVIRI Full Disk: Nov 2007
Emissivity Contrast Index vs NDVI





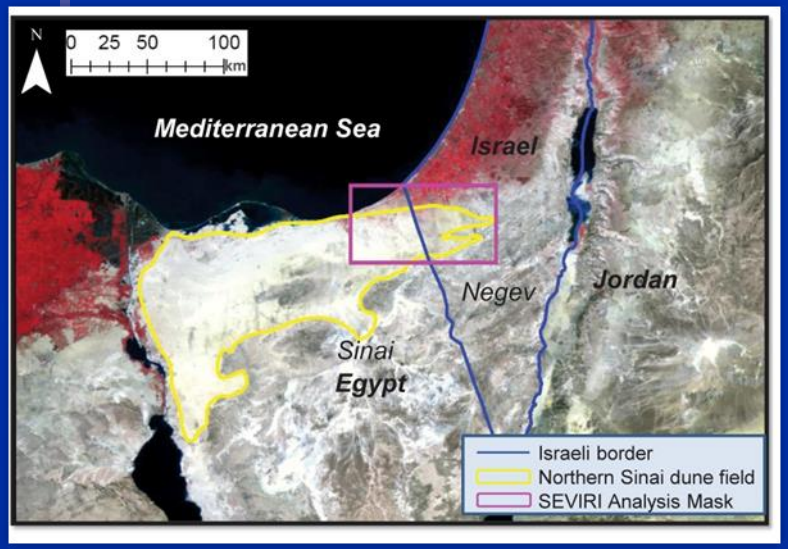
Negev Case Study: Target Area

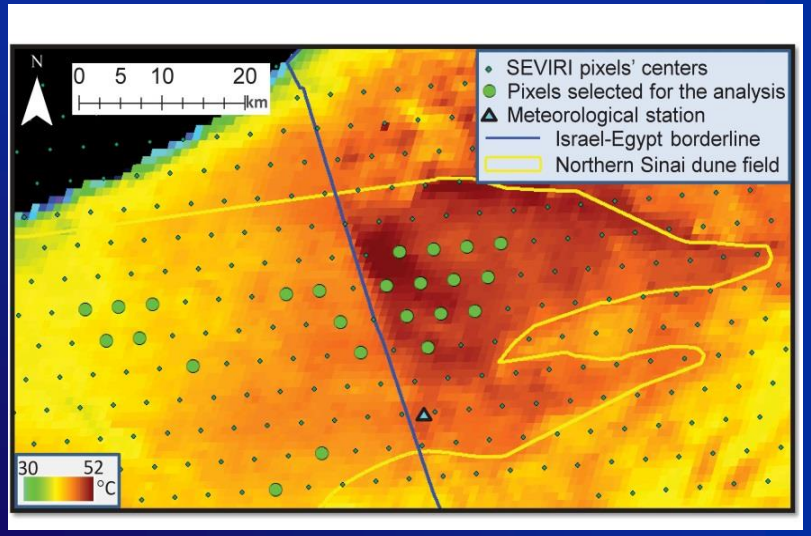


- SEVIRI observations recorded from June to November 2015
- The target area presents a mixture of land cover type

Negev Case Study

Work in collaboration

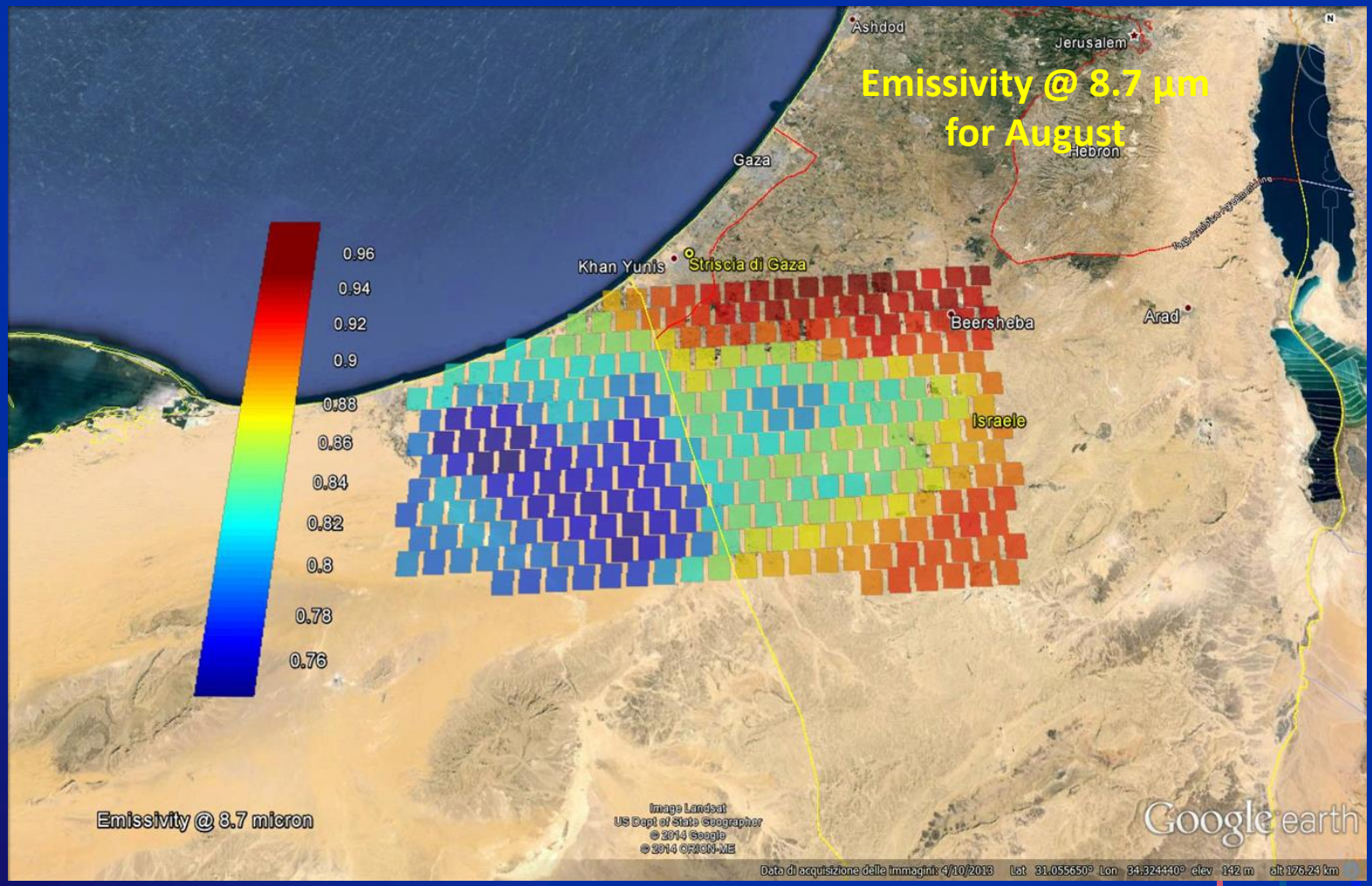




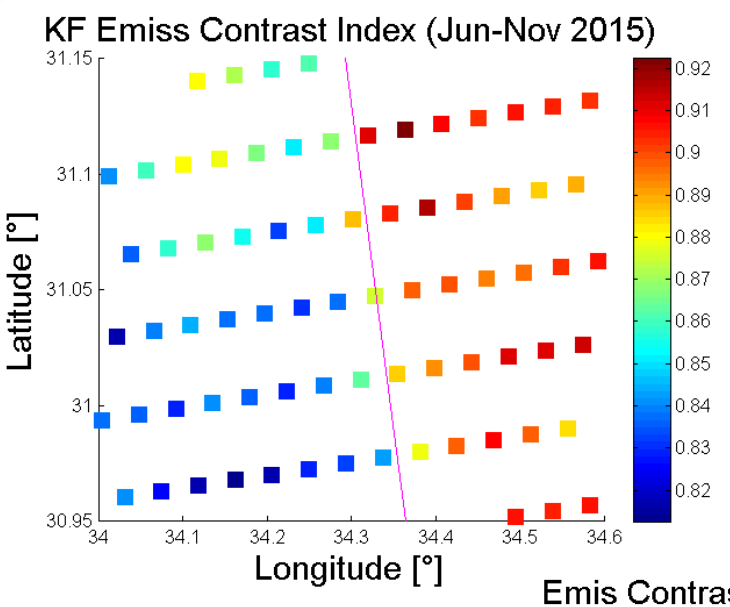
- **"Diurnal Emissivity Dynamics in Active Sand Dunes vs. Dunes Stabilized by Biocrust"**
- Offer Rozenstein[1], Nurit Agam[1], Carmine Serio[2], Guido Masiello[2], Sara Venafra[2], Stephen Achal[3], Eldon Puckrin[4], and Arnon Karnieli[1]*

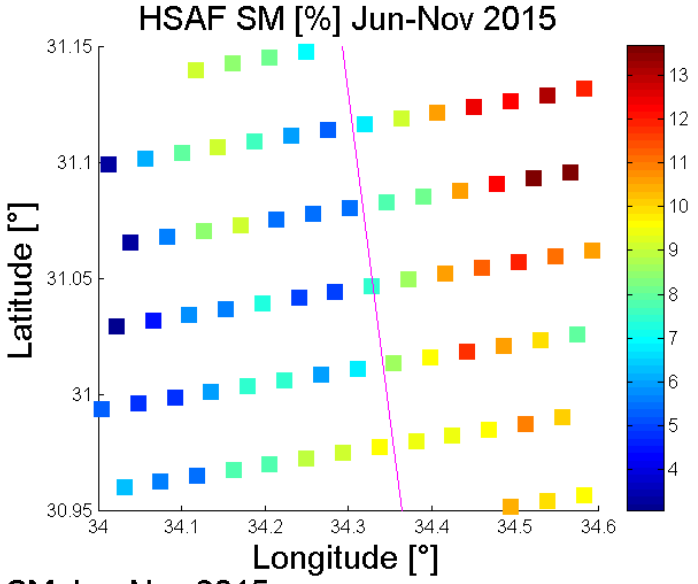
1. Jacob Blaustein Institutes for Desert Research, Ben-Gurion University of the Negev, Sede Boker Campus 84990, Israel.
2. School of Engineering and CNISM, Potenza Research Unit, University of Basilicata, Potenza, Italy.
3. ITRES Research Ltd. #110, 3553 31st Street N.W. Calgary, Alberta, T2L 2K7, Canada.
4. Defence Research and Development Canada (DRDC) - Valcartier, 2459 de la Bravoure, Québec, QC, G3J 1X5, Canada.

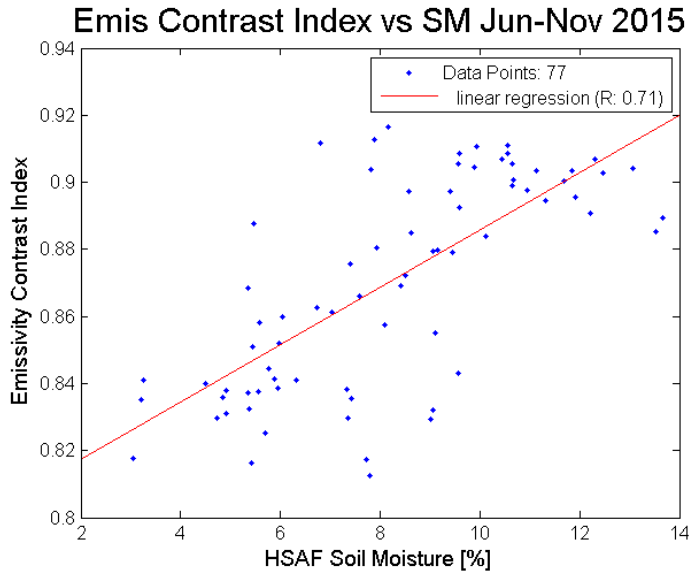
Negev Case Study
Anthropogenic activity on the Israel side has changed surface emissivity



Negev Case Study
Emissivity Contrast Index (ECI) vs Soil Moisture







Conclusions

- The physical retrieval of surface emissivity and temperature has been applied to the SEVIRI full disk;
- The new σ-SEVIRI forward model and code optimization have been developed improving considerably the computational performances;
- The new KF code has been adapted to the LSA SAF guidelines in the Algorithm Plug Interface Document (APID);
- The new code has been integrated and tested in IPMA virtual machines with success;
- The new retrieval system is more robust and stable if compared to the older version;
- The new Level 2 SEVIRI processor is very fast, making this very attractive for real-time applications;
- The new emissivity contrast index (ECI) has been defined to perform land cover classification and to analyze its sensitivity to soil moisture.

Thanks for your attention