Kalman Filter Retrieval of Surface Temperature from SEVIRI: Improved Forward Modeling, Validation and Inter-Comparison Case Studies

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Spectro

Outline

- 1. Background
- 2. Aim and scope
- 3. Description of the Methodology
 - Physical Retrieval
 - Forward Model
- 4. Results
 - Surface Temperature (ST) and Emissivity (ε)
 - Comparison
 - With ECMWF analysis
 - With Ground Based Measurements
 - With MODIS Products
- 5. Conclusions

Why we developed the KF for SEVIRI

The work originated within EUMETSAT (P. Watts)

- Objective: To study and formulate a general strategy to apply spatial and temporal constraints to the estimation of geophysical parameters from radiance measurements made from geostationary platforms, to apply the strategy to a particular example problem and to recommend a way forward to more general application to MTG FCI imager and IRS sounder data.
- The study was also motivated by the quest of methodologies capable to perform a dimensionality reduction of the data space
 - In NWP the numbers of observations varies considerably, but global models perhaps assimilate of order 10⁶ observations per 12 hour window. With SEVIRI the number of observations is of order 10⁸ per 15 minutes

Background

.. Introduction

 Continuity is felt important in order to dynamically separate emissivity from temperature. In order words, try to exploit the different variability time scale of the two: minutes for temperature, days for emissivity.
 Dimensionality reduction is felt important also in view of MTG: FCI and IRS mission.

Kalman Filter

KF is an assimilation system (may incorporate the basic physics involved in the problem: radiative transfer and dynamics).

- Acting on the dynamics, we can put appropriate constraint in order to take advantage of the different time scale of emissivity and temperature.
- Exploiting the time sequential architecture of KF, the dimensionality of the data space is kept scalar in time, i.e., observations are processed as they come and are not accumulated as it would be in an ordinary static Optimal Estimation method.

KF development for SEVIRI, funding

Since 2011, The analysis has been performed under the projects:

EUMETSAT

- EUM/CO/14/4600001329/PDW
- EUM/CO/11/4600000996/PDW
- CNR/MIUR,
 - RITMARE (CNR/MIUR) Ricerca ITaliana per il MARE
- Regione Basilicata,
 - PO FSE Basilicata 2007-2013
- LSA SAF
 - IPMA, Instituto Portugues do Mar e da Atmosfera LSASAF_VS2016-02



Inverse Model: Kalman filter + persistence



Forward Model: σ-SEVIRI

(σ-SEVIRI) is a general purpose σ-IASI pseudomonochromatic radiative transfer model: It computes Spectral High-resolution quantities for RTE • $R(\theta_r, \varphi_r, \sigma) = \varepsilon(\theta_r, \varphi_r, \sigma)\tau_0(\theta_r, \varphi_r, \sigma)B(T_s) + R_u(\theta_r, \varphi_r, \sigma) + R_r(\theta_r, \varphi_r, \sigma)$ $R_u(\theta_r,\varphi_r,\sigma) = \int B(T) \frac{\partial \tau}{\partial h} dh$ $R_r(\theta_r,\varphi_r,\sigma) = \tau_0(\theta_r,\varphi_r,\sigma) \int_0^{2\pi} d\varphi_i \int_0^{\frac{\pi}{2}} f(\theta_r,\varphi_r,\theta_i,\varphi_i,\sigma) R_i(\theta_i,\varphi_i,\sigma) \cos \theta_i \sin \theta_i d\theta_i$ It takes into account both Specular and Lambertian reflection $\chi_{iN\sigma} = \rho_{iN} \left(C_{iN0\sigma} + C_{iN1\sigma} \Delta T_i + C_{iN2\sigma} \Delta T_i^2 \right)$ It is based on look-up table of optical depth + interpolation

Simple dependence of the Optical Depth with respect to the • Temperature and the gas concentration Analytical derivative, Fast and Accurate

procedure

2. Methodology

3. Results

Speed up the Forward Model: σ-SEVIRI

- PCA (Principal Component Analysis) based approach to Radiative Transfer Model for SEVIRI
- Spectral High-res quantities are computed for a selected number of predictors (n_p)

(JA ED)

- That, with a PCA based approach, are represented with a limited number of Principal Components (n_c)
- It convolves at SEVIRI ISRF with linear regression
- Very Fast and Accurate





Atmos. Meas. Tech., 6, 3613–3634, 2013 www.atmos-meas-tech.net/6/3613/2013/ doi:10.5194/amt-6-3613-2013 © Author(s) 2013. CC Attribution 3.0 License.



Kalman filter physical retrieval of surface emissivity and temperature from geostationary infrared radiances

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Atmos. Meas. Tech., 8, 2981–2997, 2015 www.atmos-meas-tech.net/8/2981/2015/ doi:10.5194/amt-8-2981-2015 @ Author(s) 2015. CC Attribution 3.0 License. Atmospheric Measurement Techniques

Kalman filter physical retrieval of surface emissivity and temperature from SEVIRI infrared channels: a validation and intercomparison study

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Tethys 2016, **13**, 3–10 www.tethys.cat ISSN-1697-1523 eISSN-1139-3394 DOI:10.3369/tethys.2016.13.01 Journal edited by **ACAM**

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Surface parameters from SEVIRI observations through a Kalman filter approach: application and evaluation of the scheme in Southern Italy

M. G. Blasi¹, G. Liuzzi¹, G. Masiello¹, C. Serio¹, V. Telesca¹ and S. Venafra¹ ¹School of Engineering, University of Basilicata, Italy Received: 12-V-2015 – Accepted: 21-1-2016 – Original version

Correspondence to: sara venafra@unibas it

 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

SEVIRI channels used in this analysis

- To retrieve Surface Temperature and emissivity we used IR SEVIRI window Channels $(n_l = 4)$
- 4 @ 8.7 μ m, ($n_p = 30, n_c = 9$)
- 5 @ 9.7 μ m, (n_p = 40, n_c = 14)
- 6 @ 10.8 μ m, ($n_p = 20, n_c = 5$)
- 7 @ 12 μ m , ($n_p = 30, n_c = 6$)



Conclusions

1. Introduction

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Results

Background Information, Atmospheric State



ECMWF, Surface temperature

ECMWF Operation Analysis from MARS platform.

HighspatialResolution(0.125x0.125)

• 60/91/137 Pressure levels

- ST, Surface Temperature
- SP, Surface Pressure
- TCC, Total Cloud Cover
- T, Temperature
- Q, Specific Humidity
- 03, Specific Ozone

Background Information, Emissivity



0.95 0.9 0.9 0.85 0.85 0.8 0.75 0.7

UW/BFEMIS Emissivity Mean, September, ch @ 8.7 um



UW/BFEMIS, database, Monthly mean and covariance computed for the 14 years period 2003-2016.

Validation Stations: Acknowledgements

Isabel Trigo, Instituto Portugues do Mar e da Atmosfera IP, Land SAF, Lisbon, Portugal > Frank M. Göttsche, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany



Dahra test site Background

Established 2001

Funded by the Danish Research Councils and Department of Geography

Operated in collaboration with ISE UCAD, Dakar, and ISRA, Dahra Senega

Major updates in 2004 and 2008

Since 2005 part of AMMA

In 2007 collaboration with KI7 (former FZK) was established ω

Comparison with in situ measurements

	Mean difference with in situ data (°C)	Standard deviation of the difference (°C)
Dahra, Janto Oct. 2011	-0.70	0.96
Evora, Jan. to Dec. 2010	+0.91	1.62
Gobabeb, Jan. to Dec. 2010	+0.86	1.18

Summary of the Results from the three LSA SAF validation stations
 Comparison with in situ Surface Temperature

Conclusions

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Comparison with in situ measurements: Dahra



An example from Dahra station (Time series of 4 days – step 15 min)

FRM4STS - Guido Masiello, NPL, Teddington, 17 October 2017

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Comparison with in situ measurements: Evora



Evora station. 1 year Scatter plot (Left). 17 days long time serie with 15 min step (Right) 4. Conclusions

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Comparison with in situ measurements: Gobabeb



Gobabeb station. 1 year Scatter plot (Left). 11 days long time serie with 15 min step (Right)

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Comparison with in situ measurements: Gobabeb



Gobabeb station. ε@10.8 - 1 year long time series with 15 min step

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Land cover change detection with IR SEVIRI channels



Land cover change detection, an example: Dahra



4.

Conclusions

Validation for the Sea



- > The scheme works for the SEVIRI full disk
- The case study shown here is an area surrounding Basilicata Region, including Mediterranean Sea (Tyrrhenian, Ionian and Adriatic Seas)

Comparison with ECMWF



 Comparison with ECMWF data show excellent agreement (statistics based on 2,754,238 data points, 1 year)

Comparison with MODIS

Bias 0.07 °C

Std 1.05 °C



Comparison with MODIS (statistics based on 3,230,710 data points 1 year)

Bias

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-Standard Deviatio

FRM4STS - Guido Masiello, NPL, Teddington, 17 October 2017

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Number of events

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18

-19

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Bias: -0.07 °C

Stand Dev: 1.05 °C Data Points: 3230710 15

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15

16

Longitude (°)

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18

19

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http://www2.unibas.it/gmasiello/assite/rep/Med_2013-2016_T.gif

Conclusions

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Results

Retrieved Skin Temperature, 1 Day of August

The animation shows Evolution of Surface Temperature for the 2 of August 2013 at the temporal resolution of SEVIRI (15')



http://www2.unibas.it/gmasiello/assite/basilicata_Aug_2013.gif

Current and Future Data Availability

The Monthly mean data are freely available at web site http://www2.unibas.it/gmasiello/assite/as/products.html

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SEVIRI LE	EVEL 2 PRODUCTS									
This web pa	ge hosts SEVIRI Level 2	2 products of sea skin temperature for th	he Mediterranean area (-10° ÷ 42° E;	29° ÷ 49° N) for a tem	poral coverage o	f four years (2013-2016).				
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- At the moment they are organized in compressed ASCII files (1 per month)
- We are processing SEVIRI data for 2017 (Results will be available on line as soon as possible) We plan to process SEVIRI data back to 2003
 - We are implementing a new web portal that simplify data request enabling download of the full time resolution results. (Master Thesis of A. Coviello)



Applications to Full Disk

The scheme works for the SEVIRI full disk

> Full Disk (VZA<=70°):</pre>

- > Total 3,545,871 pixels
- > 3,488,328 Land pixels
- > 57,543 In Land Water pixels



November 2007 surface temperature

Monthly mean surface temperature



FRM4STS - Guido Masiello, NPL, Teddington, 17 October 2017

November 2007 Emissivity

Monthly mean surface emissivity



4.

FRM4STS - Guido Masiello, NPL, Teddington, 17 October 2017

Computational Performances

The code can run from the level of the single pixel up to the SEVIRI full disk scale





- 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 exploiting 8 threads and considering all pixels as clear sky (Ifort Compiler)
- Integrated and tested on IPMA LSA-SAF virtual machine for full disk retrieval of surface temperature and emissivity.
- Mediterranean Sea:
- > Total 225962 pixels
- A single SEVIRI Mediterranean Sea run will take about 8 min exploiting 1 thread and considering all pixels as clear sky (Ifort Compiler)

ntrc

Full Disk (VZA<=70°):</p>

Results

Conclusions

- The Kalman filter (KF) retrieval system is one of the first physically based schemes for the simultaneous retrieval of surface emissivity and temperature.
- The KF retrieval is unique in its capability to exploit the time continuity of geostationary infrared observations.
- The SEVIRI KF retrieval is fully characterized in terms of its variancecovariance structure. The theoretical precision is better than 0.2 K for sea and land surface.
- Potentially, the scheme can accommodate time-spatial constraints in case they are available. For now we use a simple *persistence model* for the state equation.
- Comparison with in situ, ECMWF, polar satellite observations shows a very good agreement for temperature.
- The KF methodology developed for SEVIRI is robust even at the full time resolution of 15 minutes
- The algorithm can be specialized for land or sea or both and a landbased version has been integrated and tested on IPMA LSA-SAF virtual machine for full disk retrieval of surface temperature and emissivity.

4. Conclusions