Towards The Assimilation Of SEVIRI Observations Over Land

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1. INTRODUCTION

The radiometer SEVIRI (Spinning Enhanced Visible and Infrared Imager) is onboard the latest geostationary-orbiting satellite: METEOSAT SECOND GENERATION (MSG) developed by the European Space Agency (ESA) and EUMETSAT (European Organisation for the Exploitation of Meteorological Satellites). 12 spectral channels covering the visible to infrared provide useful information about tropospheric humidity and temperature for weather forecasting system (Schmetz et al., 2002). However, in most of Numerical Weather Prediction (NWP) centres, only high-peaking Water Vapour SEVIRI observations are assimilated because these channels are not sensitive to the surface (Kopken et al., 2004; Szyndel et al., 2004; Stengel, 2008). IR SEVIRI assimilation are still limited to sea surfaces (Montmerle et al., 2007). The surface uncertainties (land surface emissivity (LSE) and land surface temperature (LST)) restrict the use of satellite data over land. In Karbou et al. (2006), several land surface parameterization were tested to assimilate more micro-wave satellite data over land . Following one of these methods, Météo-France sets about to assimilate more IR SEVIRI data assimilation over land.

In this work, SEVIRI radiances and land surface emissivities processed by the LAND-SAF are used to retrieve the LST parameter from SEVIRI windows channels. New SEVIRI LSTs are evaluated against independent measurements. Simulations of SEVIRI radiances using updated emissivity and/or updated LST parameters are compared to observed SEVIRI radiances to study effects of changing surface parameters on radiances simulations. Preliminary configurations of assimilation experiment are presented.

2. DATA & METHOD

A. ALADIN 3D-VAR : Configuration

The ALADIN meso-scale model is running operationally at METEO-FRANCE (2005)

- Geographic domain : Europe
- Lateral boundary conditions are provided by the global ARPEGE model.
- Resolutions : Horizontal 7.5 km, Vertical 70 levels
- The 3D-Var assimilation system is used to produce 4 daily analyses.
- Observation operator for radiances : RTTOV-8
- Bias monitoring and correction : VarBC (Variational Bias Correction)

B. IR SEVIRI radiances

SEVIRI, onboard MSG, provide full-hearth disk image each 15 min in 6 IR channels with a resolution of 3 km (Schmetz et al., 2002).

Tab 1: SEVIRI *IR channels and characteritics*

IR3.9	IR8.7	IR9.7	IR10.8	IR12.0	IR13.4
Window	Window	Ozone	Window	Window	CO2

Current condition of use and pre-processing (Montmerle et al, 2007) :

- In ALADIN 3D-Var, all IR channels are blacklisted over land
- IR8.7, IR10.8 and IR12.0 are assimilated in clear sky conditions and over sea surface

⇒ 1 pixel out of 5 is used, thinning within 70 km boxes, σ_o=0.25, 3 Predictors for VarBC (1000-300 hPa & 200-50 hPa thickness and total column WV content)

C. Land-SAF surface emissivity atlas

Cloud-free SEVIRI observations are used by the Satellite Application Facility on Land Surface Analysis (LSA-SAF) to produce daily Land Surface Emissivity (Trigo et al., 2008 and www://landsaf.meteo.pt). The algorithm relies on the vegetation cover method and uses the Fraction of Vegetation Cover product. LSE are available for all SEVIRI IR window frequencies and also for a broadband (3-14 µm).

In this work, daily Land-SAF LSE maps were averaged for the period of 15-July to 15-August 2009. Figure 1 compares LSE for channel IR3.9, IR8.7, IR10.8, IR12.0, Broadband (BB) and also the current operational emissivity scheme implemented in the ALADIN system.

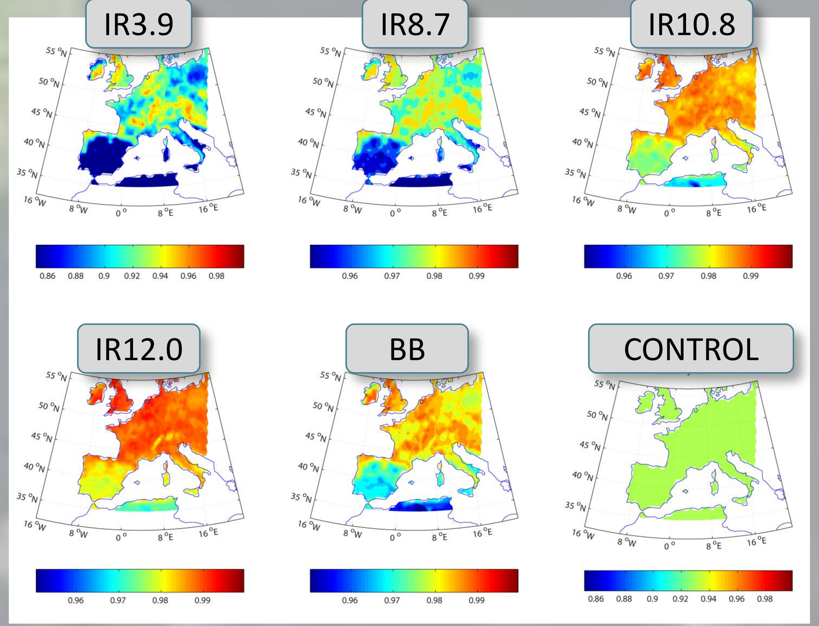

Fig. 1*: Average of daily Land Surface Emissivity maps produced by the LSA-SAF for the period of 15-July to 15-August over Europe. Maps are for SEVIRI window channels IR3.9, IR8.7, IR10.8, IR12.0 and BroadBand (BB). Current static emissivity map implemented in ALADIN system is also presented*

D. Land surface temperature retrievals

LSE and clear sky observed Tbs from IR SEVIRI window channels were used as input in the RTTOV radiative transfer model to retrieve dynamically LST.

- The radiance L_i measured in an infrared channel i with a view zenith angle θ_v at Top Of the Atmosphere (TOA) is given by:

$$L_i(T_i,\theta_v)=\tau_i(\theta_v)[(\varepsilon_{atlas(i)}(\theta_v)L_i(LST)+(1-\varepsilon_{atlas(i)}(\theta_v))T_{atm\downarrow i}]+T_{atm\uparrow}(\theta_v) \quad \text{(eq.1)}$$

- Inverting eq. 1, LST can be retrieved using the single channel method :

$$LST=L^{-1}\left[\frac{L_i(T_i,\theta_v)-L_{atm\uparrow i}(\theta_v)-\tau_i(\theta_v)(1-\varepsilon_{atlas(i)}(\theta_v))T_{atm\uparrow i}(\theta_v)}{\tau_i(\theta_v)(\varepsilon_{atlas(i)})(\theta_v)}\right] \quad \text{(eq.2)}$$

LST : Land Surface Temperature , L^{-1} : the inversion of the Planck function

ε_{atlas} : Land-SAF spectral surface emissivity atlas and $T_{atm\uparrow}$,$T_{atm\downarrow}$ and τ: Atmospheric parameters

Result :4 LST field per day were retrieved and compared to independent LST field

3. EVALUATION OF LAND SURFACE TEMPERATURE

A. LST comparison to independent observations/retrievals

LST retrieved from SEVIRI radiances against independent observations :

1) LST analysed by the ALADIN system 2) LST provided by the Land-SAF 3) retrievals from MODIS (MOD11_L2) (Wan, 2007)

cycle: 0h N=12131		Model ALADIN	Observations SAF	MODIS	SEVIRI Retrievals IR3.9	IR8.7	IR10.8	IR12.0
Mean		291,28	289,73	290,25	290,52	289,87	289,64	289,22
STD		4,60	4,44	3,32	5,32	4,94	**4,70**	4,94
Corr.	*SAF*	0,90	1,00	0,75	0,97	0,97	0,97	0,95
	MODIS	0,68	0,75	1,00	0,75	0,74	0,74	0,73
Bias	*SAF*	1,55	0,00	0,53	-0,79	-0,14	**0,09**	0,50
	MODIS	1,02	0,53	0,00	-0,26	**0,39**	0,62	1,03
RMSE	*SAF*	2,53	0,00	3,01	1,70	1,23	**1,12**	1,64
	MODIS	3,54	3,01	0,00	3,58	3,35	**3,22**	3,53

≠ 5K

cycle: 12h N=7570		Model ALADIN	Observations SAF	MODIS	SEVIRI Retrievals IR3.9	IR8.7	IR10.8	IR12.0
Mean		308,31	314,17	307,95	319,79	313,46	312,87	311,80
STD		6,10	8,88	7,52	10,38	9,44	9,28	9,62
Corr.	*SAF*	0,84	1,00	0,77	0,96	0,98	0,97	0,95
	MODIS	0,71	0,77	1,00	0,78	0,77	0,76	0,74
Bias	*SAF*	-5,86	0,00	-6,22	-5,62	0,72	1,30	2,37
	MODIS	0,36	-6,22	0,00	-11,84	-5,50	-4,92	-3,85
RMSE	*SAF*	7,74	0,00	8,41	6,41	2,23	2,54	3,74
	MODIS	5,38	8,41	0,00	13,52	8,20	7,82	7,51

Tab. 2 & 3: Night-time (day-time on the right) statistics between LST analysed by ALADIN, Land-SAF, MODIS and our retrievals from SEVIRI. Data are for the period of 15-July to 15-August

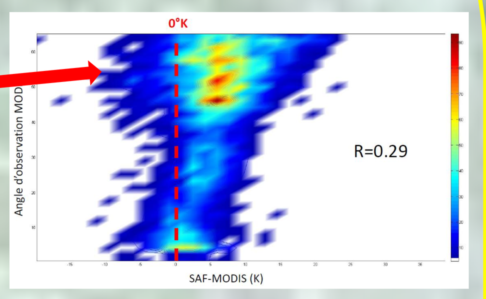

Fig 2: Scatterplot of LST SAF minus LST MODIS as a function of MODIS viewing angle obs. Data are for the period of 15-July to 15-August at 12h. R is the correlation. Low (high) frequencies are in blue (red).

⇒ Night-time retrievals are quite coherent with observations (tab. 1)

⇒ Differences in day-time are mainly due to obs. geometric viewing angle (fig. 2)

⇒ Channel IR3.9 overestimates LST probably due to solar contamination

⇒ The transmission for channels IR12.0 is too low because of atmospheric water vapour sensitivity.

Conclusion : 2 candidates channels for the LST retrievals : IR8.7 and IR10.8. Choice will be made on RTTOV performances

B. Tbs simulations for SEVIRI channels

RTTOV has been used to simulate 1 month of IR SEVIRI Tbs using as input Land-SAF LSE and/or updated LST. Simulated Tbs (Tb_{sim}) are compared with Observed Tbs (Tb_{obs}) for the Control and 3 configurations :

1) ATLAS-Only
2) ATLAS + LST_IR8.7
3) ATLAS + LST_IR10.8

⇒Configurations 2) and 3) improve fg-Departures (fig.3) and correlations between *Tbobs & Tbsim* (fig.4) with respect to the CONTROL

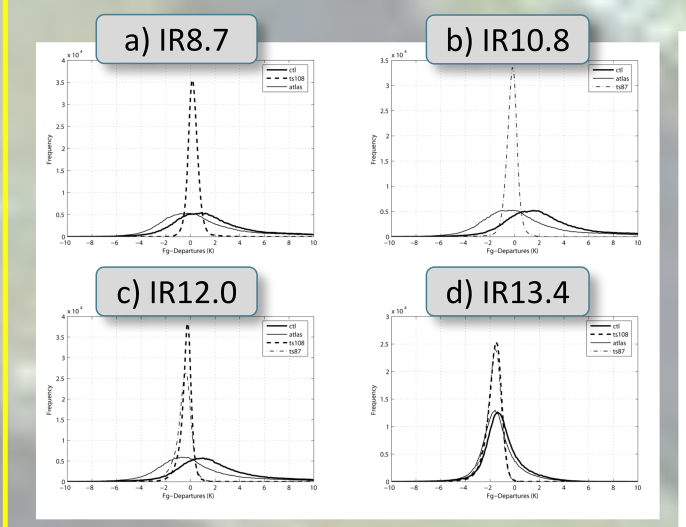

Fig.3*: Fg-Departures (Tb_{obs}-Tb_{sim}) histograms of channel a) IR8.7, b) IR10.8, c) IR12.0 and d) IR13.4 for 15-July to 15-August 2009. Configurations : 1) The control (ctl), 2) Land-SAF emissivity atlas (atlas), 3) atlas emissivity and LST calculated from IR8.7 (ts87), 4) and atlas emissivity and LST calculated from IR10.8 (ts108).*

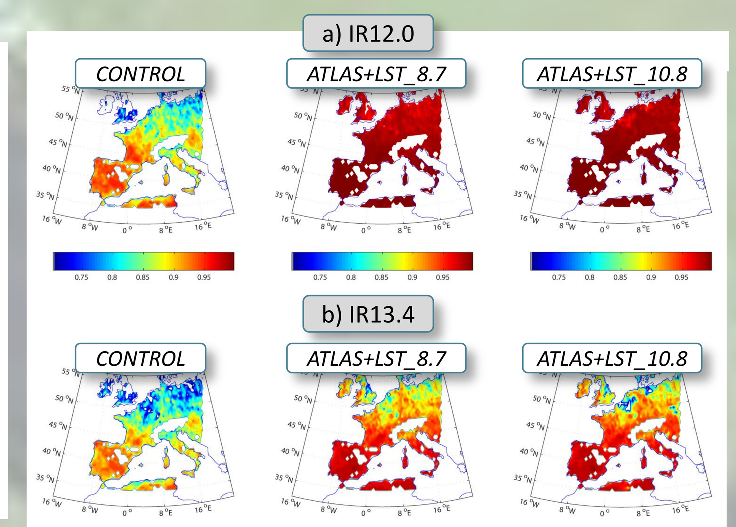

Fig. 4*: Maps of correlations between Tb_{obs} and Tb_{sim} of SEVIRI channel a) IR12.0 and b) IR13.4. The correlation have been computed using data falling in a grid cell of 2°x2° from 15-July to 15-August 2009. LAND-SAF emissivity atlas and LST computed using SEVIRI channel IR10.8 or IR8.7 are used to simulated Tbs. The Control use the curent operational configuration.*

Tab. 3 *: Correlation (r), bias and STD between Tb_{obs} and Tb_{sim} for IR SEVIRI channels. Statistics are computed for the CONTROL and 2 configurations. Data are for the period of 15-July to 15-August 2009.*

	CONTROL r	bias	std	ATLAS+LST_8.7 r	bias	std	ATLAS+LST_10.8 r	bias	std
IR3.9	0,927	1,23	4,84	0,980	2,47	2,70	**0,983**	**2,25**	**2,48**
IR8.7	0,943	1,15	3,30	NaN	NaN	NaN	0,998	0,18	0,71
IR9.7	0,949	2,64	2,85	0,979	1,86	1,61	**0,982**	**1,74**	**1,46**
IR10.8	0,938	1,78	3,50	0,996	-0,19	0,53	NaN	NaN	NaN
IR12.0	0,937	1,17	3,25	0,995	**-0,43**	0,79	**0,998**	-0,58	**0,77**
IR13.4	0,963	-1,40	1,42	0,985	**-1,75**	0,86	**0,988**	-1,81	**0,79**

Conclusion : The best configuration seems to be ATLAS + LST_IR10.8 (tab.3)

C. Preliminary assimilation experiment

- The ATLAS + LST_IR10.8 configuration has been implemented in the ALADIN 3D-VAR assimilation system.
- VarBC modifications for assimilation of IR SEVIRI over land (additional predictors and update depending on the time of the assimilation cycle (0-6-12-18))
- Current STEP : Monitoring of SEVIRI channel IR8.7, IR10.8, IR12.0 and additional IR13.4 over land

⇒ Next step : Assimilation experiment to study impacts on atmospheric analysis and forecast

4. CONCLUSION & FUTURE PLANS

This work aims to extend the use of IR SEVIRI data over land to better constrain the meso-scale model. The modelisation of surface parameters were investigated. Emissivity atlas and observed IR SEVIRI Tb were used to dynamically retrieve LSTs. LST Retrievals were first evaluated against independent LST observations and then used to simulate the remaining IR SEVIRI Tbs. All configurations provide significant improvements with respect to the CONTROL. However, the best configuration uses the emissivity atlas and LST retrieved from observed IR10.8 Tbs. The current monitoring of IR SEVIRI channel over land will be followed soon by several assimilation experiments. Assimilation of SEVIRI observations in cloudy conditions is also planned.

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