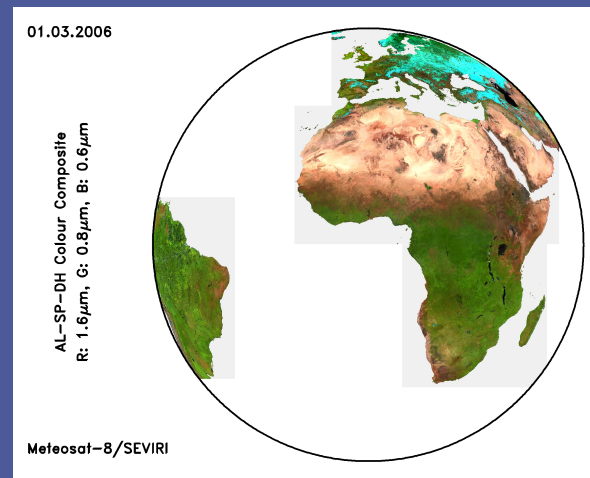# LAND SURFACE ALBEDO FROM MSG GEOSTATIONARY SATELLITE:
METHOD FOR RETRIEVAL, VALIDATION, AND APPLICATION FOR WEATHER FORECAST

Dominique Carrer, Jean-Louis Roujean, Jure Cedilnik, Jean-François Mahfouf,
*Olivier Hautecoeur, Laurent Franchistéguy, Bernhard Geiger, and Catherine Meurey*

OUTLINE

- LSA SAF project

- Surface Albedo Products
    - *method for retrieval*
    - *evaluation*
    - *application for weather forecast*

- Perspectives

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Toujours un temps d'avance

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OUTLINE

- LSA-SAF project

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  - *method for retrieval*
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LSA-SAF CHRONOGRAM

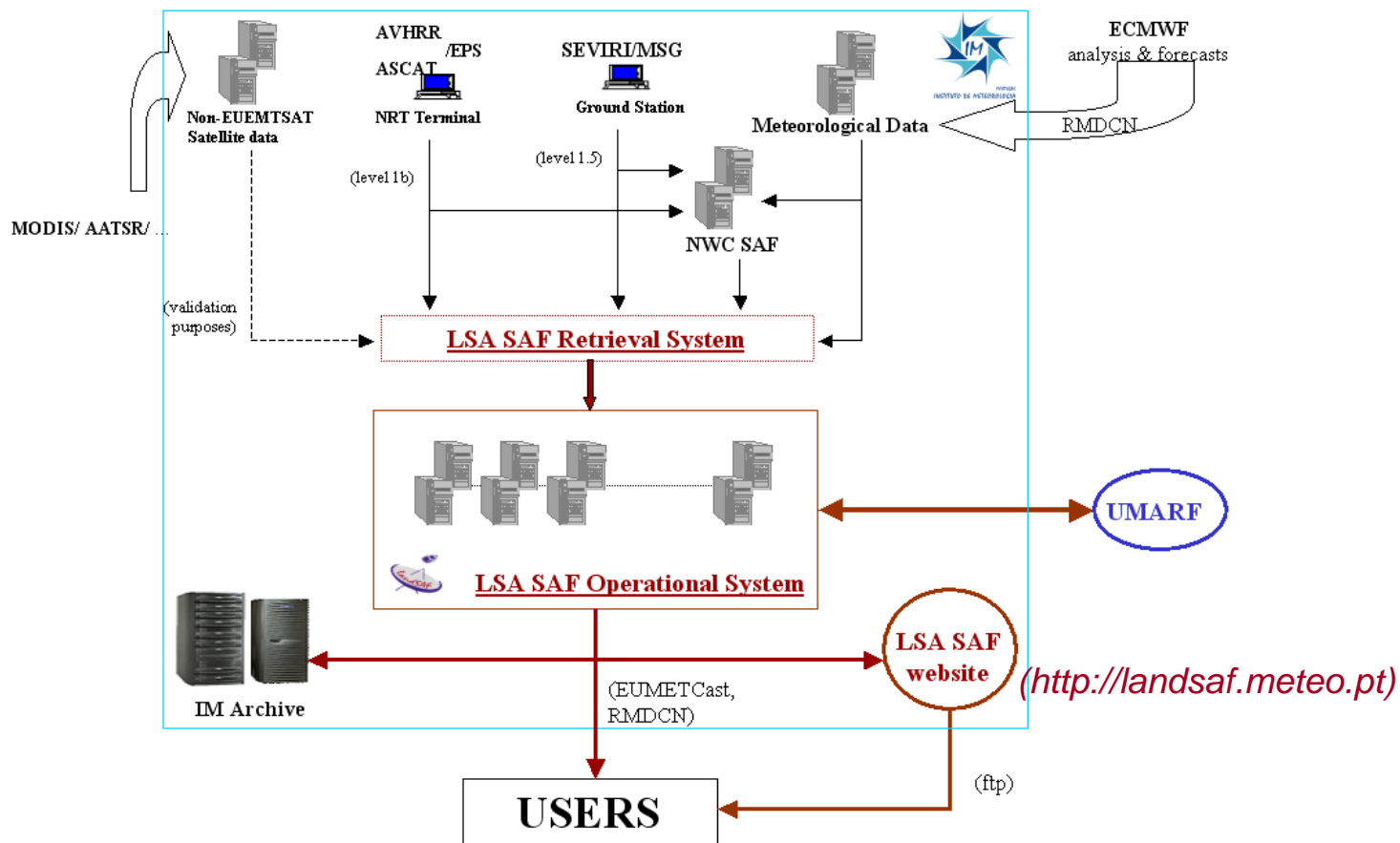LSA-SAF: Satellite Application Facility on Land Surface Analysis
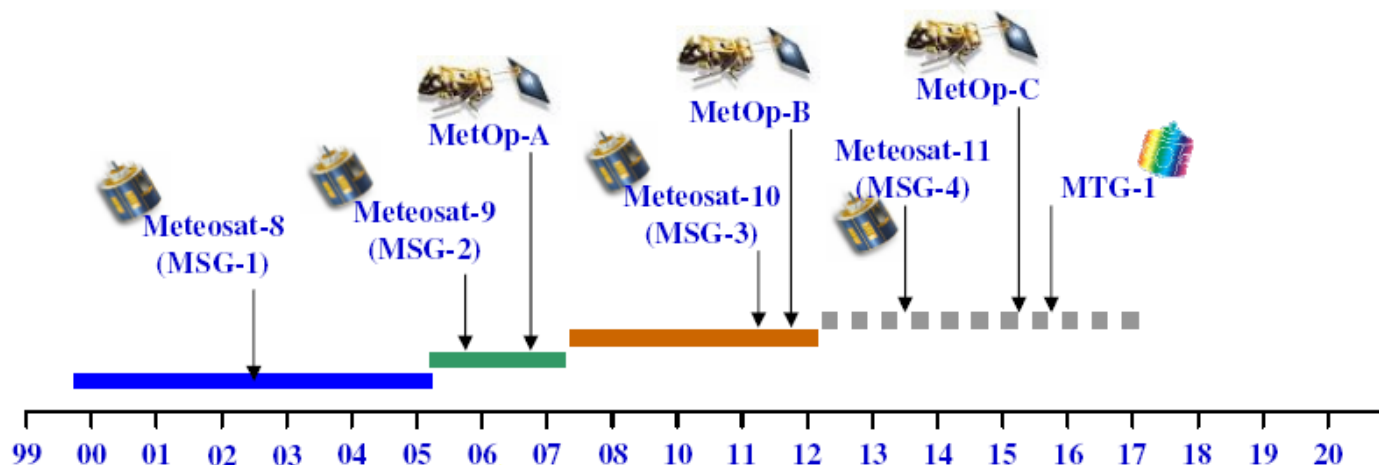
Development Phase: Sep 1999

Initial Operations Phase: Feb 2005

Continuous Development & Operations Phase Mar 2007

CNRS · EUMETSAT · saf The EUMETSAT SAF Network · METEO FRANCE Toujours un temps d'avance

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OPERATIONAL SYSTEM

(http://landsaf.meteo.pt)

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THE Land-SAF CONSORTIUM

- **Instituto de Meteorologia (IM), Portugal**
- **Meteo-France (MF), France**
- **Royal Meteorological Institute (RMI), Belgium**
- **Finnish Meteorological Institute (FMI), Finland**
- **IMK, University of Karlsruhe**
- **IDL, University of Lisbon**
- **UV, University of Valencia**

- **Organisation principles**
  - **Algorithms developped at one of the participating Institutes**
  - **Algorithms handed over to IM for integration and production**

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THE PRODUCTS

Wild Fires
Fire Radiative Power - PIXEL
Fire Radiative Power - GRID
Fire Risk Map
Fire Detection and Monitoring

Vegetation Parameters
Fraction of Vegetation Cover
Leaf Area Index
Fraction of Absorbed Photosynthetic Active Radiation

Snow Cover
Snow Cover (daily)
Snow Cover (15 mins)

Other
Bi-Directional Reflectance Factor
Land Surface Emissivity

Albedo
Surface Albedo

Land Surface Temperature
Land Surface Temperature (15 mins)

Down-welling Surface Fluxes
Down-welling Surface Short-wave Radiation Flux
Down-welling Surface Long-wave Radiation Flux
Daily Downward Surface Shortwave Flux
Daily Downward Surface Longwave Flux

Evapotranspiration
Evapotranspiration (30 mins)
Daily Evapotranspiration

MetOp/AVHRR based products
Land Surface Temperature
EPS - Land Surface Temperature

Down-welling Surface Fluxes
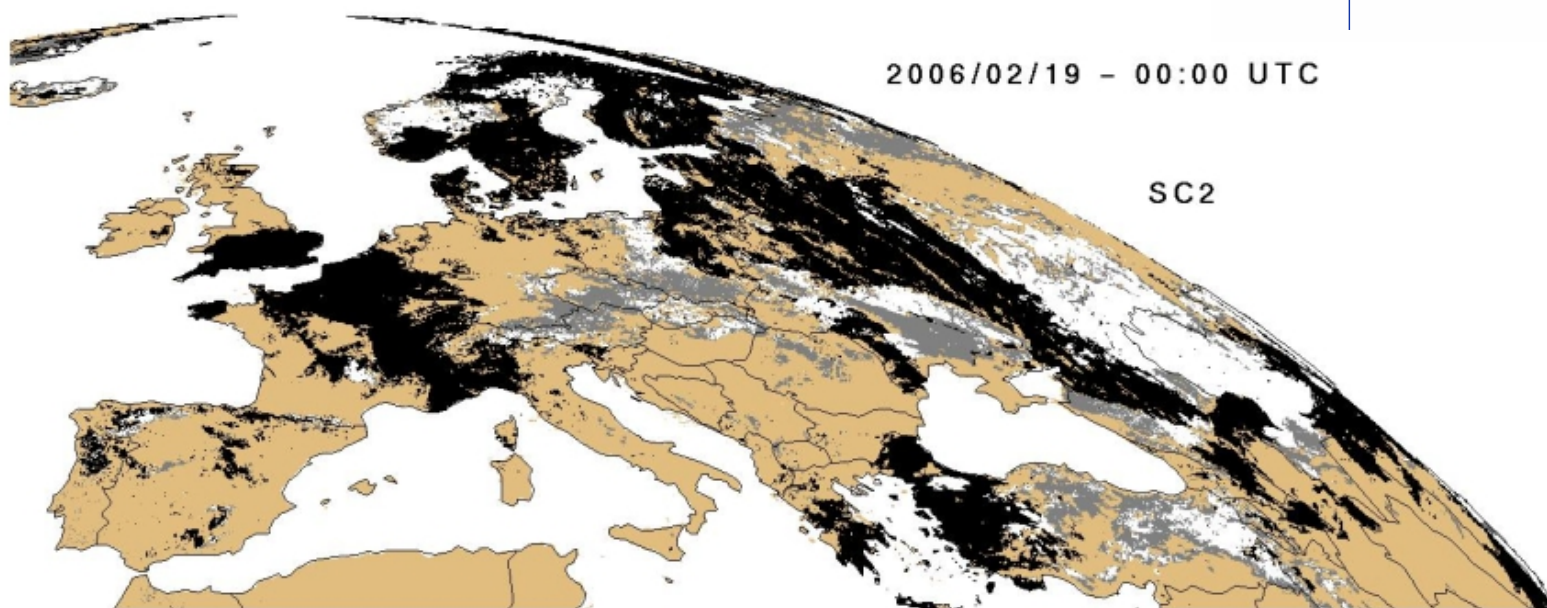Down-welling Surface Long-wave Radiation Flux

Caption
Internal | Develop. | Demo. | Pre-Operat. | Operat.

Acronym	Institution
AL	MF
BRDF	MF
LST	IM
TSP	IMK
EM	ICAT
DSSF	MF
DSLF	IM
SC	SMHI
ET	RMI
FVC	UV
LAI	UV
RFM	IDL
FRP&FRE	
fAPAR	UV

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SNOW COVER

SURFACE ALBEDO

LAND SURFACE TEMPERATURE

SHORT-WAVE RADIANCE

LONG-WAVE RADIANCE

The EUMETSAT
Network of
Satellite Application
Facilities
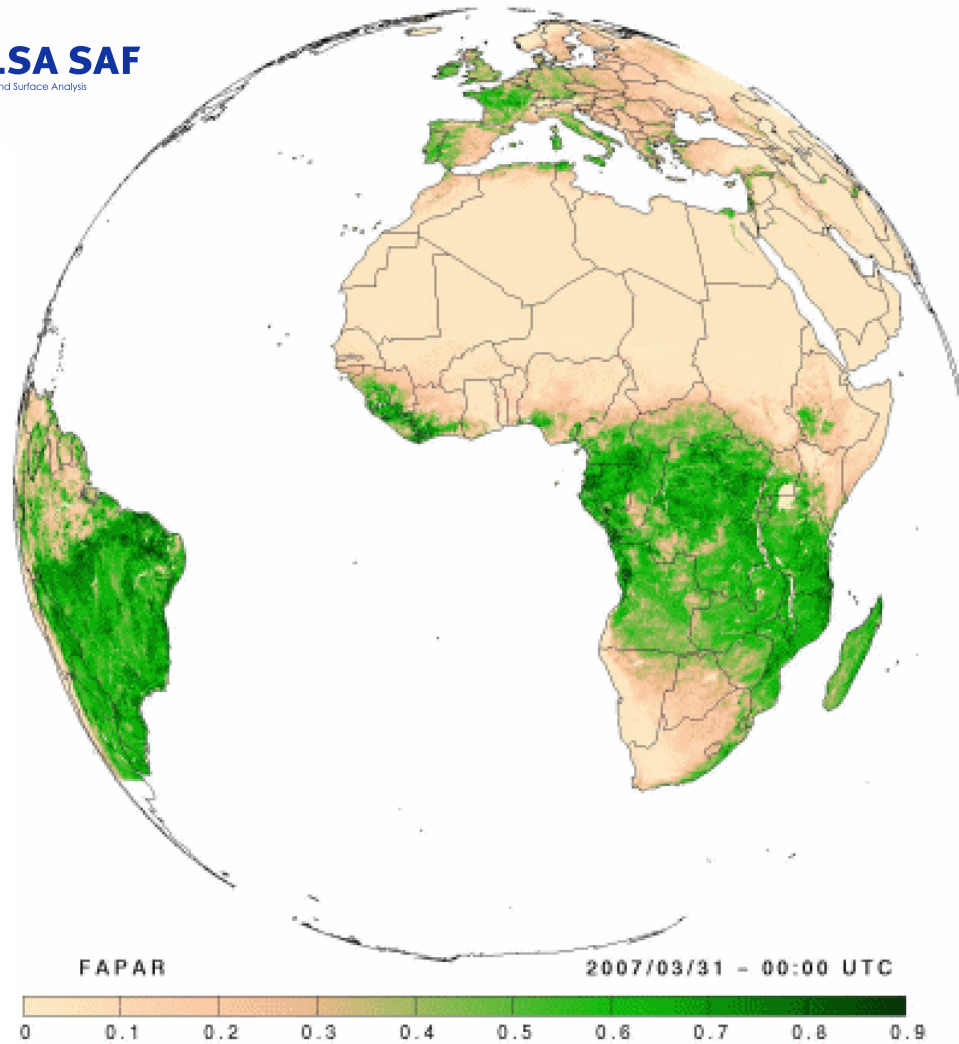
LSA SAF
Land Surface Analysis

FRACTIONAL VEGETATION COVER

LEAF AREA INDEX

fAPAR

FAPAR   2007/03/31 – 00:00 UTC

0   0.1   0.2   0.3   0.4   0.5   0.6   0.7   0.8   0.9

OUTLINE

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Introduction

Definition

• **Surface albedo is the fraction of incoming solar radiation that is reflected back into the atmosphere. It quantifies the fraction of solar radiative energy absorbed by the surface of the Earth.**

• **Pielke and Avissar (1990) found that a 4% increase in land surface albedo would result about 0.7° decrease in Earth equilibrium temperature, which is of the same magnitude as the current expected effect of the greenhouse gas warming.**
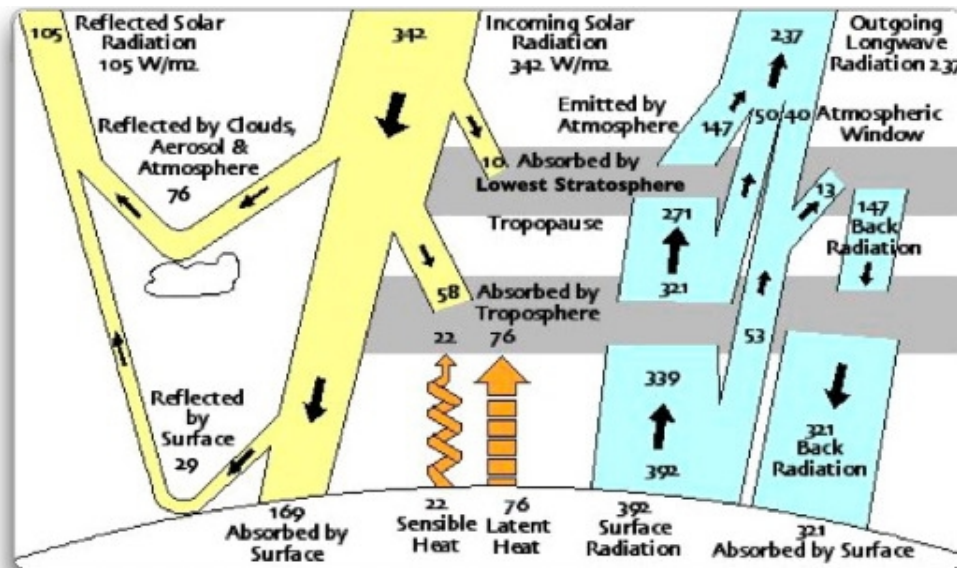
PRODUCT CHARACTERISTICS (AL)

01.03.2006

AL-SP-DH Colour Composite
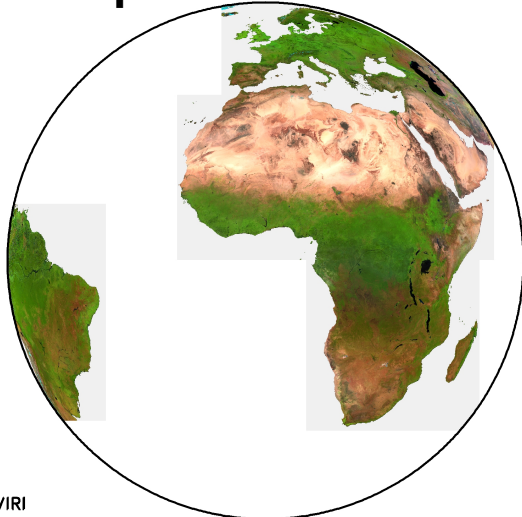R: 1.6µm, G: 0.8µm, B: 0.6µm
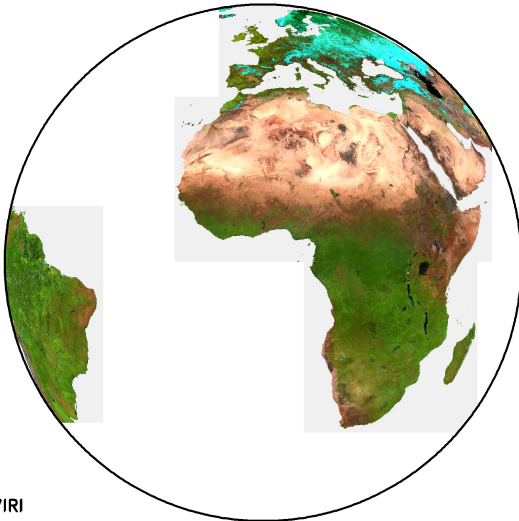
Meteosat−8/SEVIRI

Colour Composite Of Spectral Albedo

01.07.2006

AL-SP-DH Colour Composite
R: 1.6µm, G: 0.8µm, B: 0.6µm

Meteosat−8/SEVIRI

Spatial Resolution: 3km at the Sub-Satellite Point

Projection: native MSG/SEVIRI Projection

Production Frequency: Daily

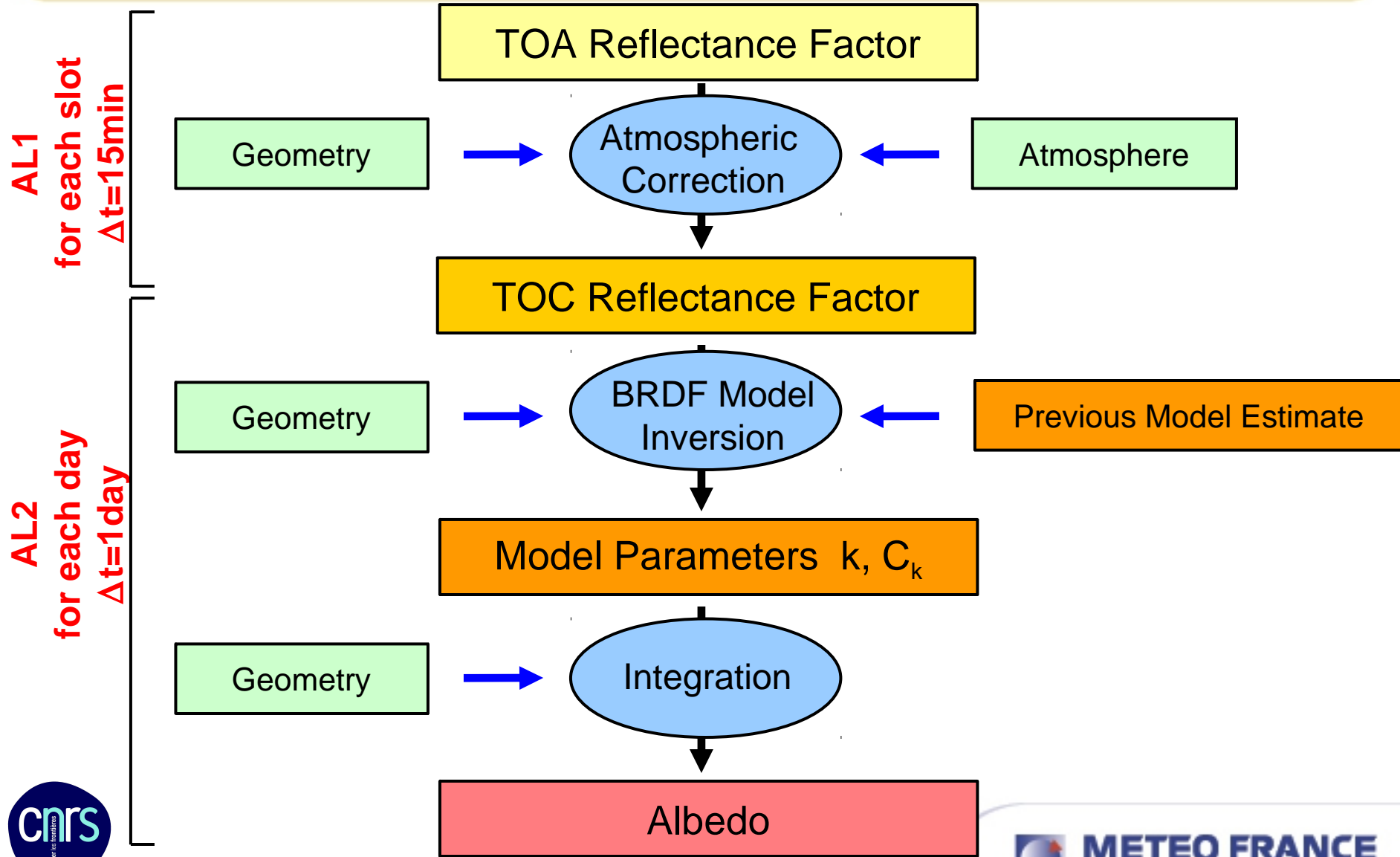**Effective Temporal Resolution:** 5 Days (in the near future also monthly)

Format: HDF5

Timeliness: 3 hours

Dissemination: EUMETSAT broadcast system (EUMETCast), and project website (http://landsaf.meteo.pt)

Spectral Albedo (6): 0.6µm, 0.8µm, and 1.6µm (DH&BH)

BroandBand Albedo (4): VIS-DH ([0.4µm, 0.7µm]), NIR-DH ([0.7µm, 4.0µm]), SW-DH ([0.3µm, 4.0µm]), SW-BH ([0.3µm, 4.0µm])

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METHOD FOR RETRIEVAL

AL1
for each slot
Δt=15min

AL2
for each day
Δt=1day

TOA Reflectance Factor

Geometry → Atmospheric Correction ← Atmosphere

TOC Reflectance Factor

Geometry → BRDF Model Inversion ← Previous Model Estimate

Model Parameters k, C_k

Geometry → Integration

Albedo

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ALBEDO INPUT DATA

- **MSG Data: 0.6µm, 0.8µm, 1.6µm**

- **Solar and View Angles**

- **Land/Sea Mask**

- **Cloud Mask (SAF-NWC software)**

- **Total Column Water Vapour, and Pressure (ECMWF)**

- **Ozone Content (Climatology)**

- **Aerosol Optical Thickness (Climatology or MACC)**

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Europe: July 2005 – June 2006

01.06.2006

METEO FRANCE

AL-SP-DH Colour Composite
R: 1.6μm, G: 0.8μm, B: 0.6μm

Meteosat-8/SEVIRI

LandSAF

METEO FRANCE
Toujours un temps d'avance

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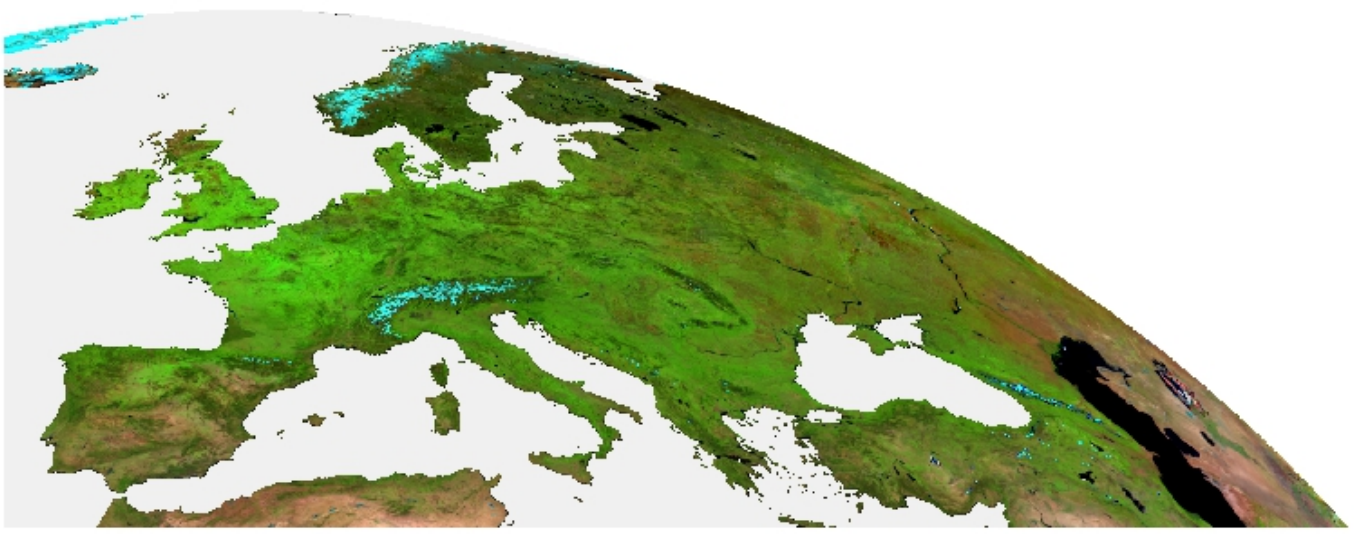
COMPARISON WITH MODIS ALBEDO (1/2)
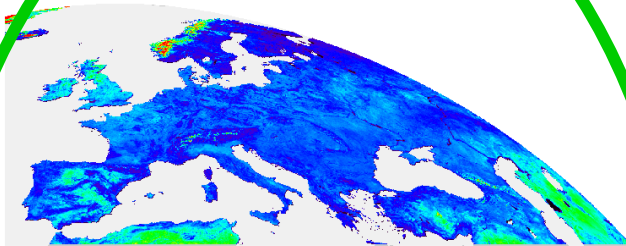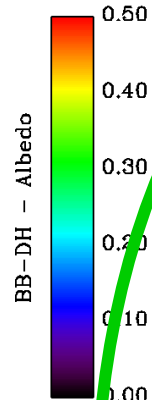
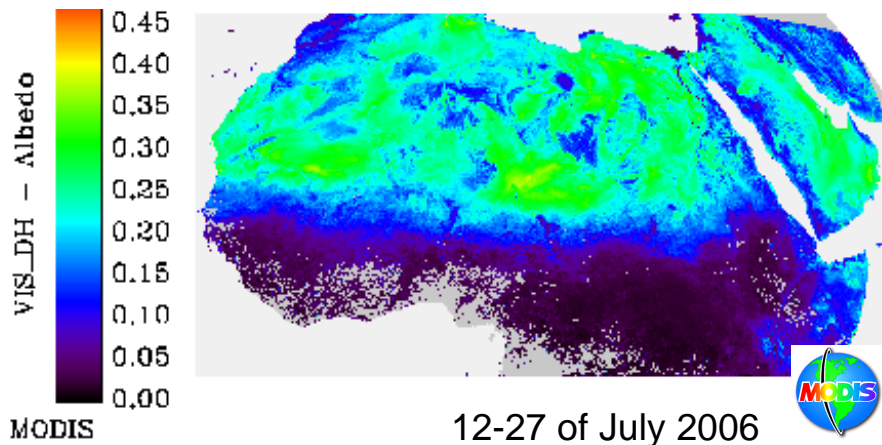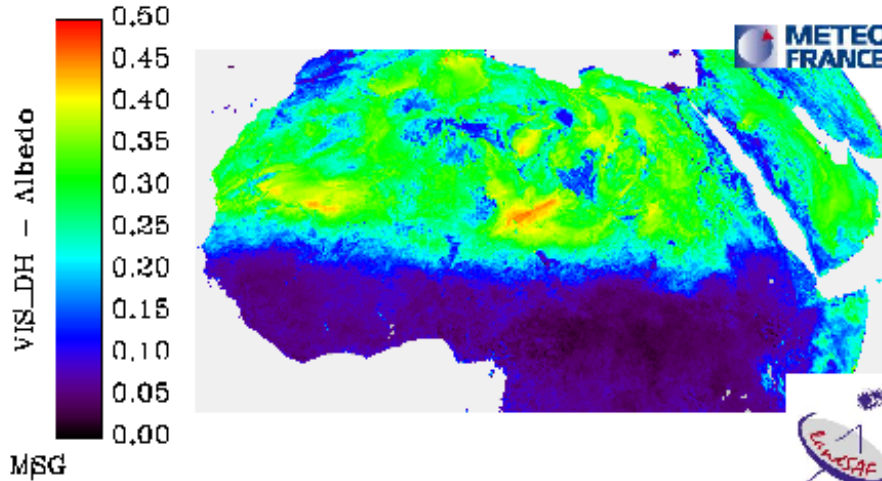**16-day average MSG Albedo –**

MODIS albedo projected on SEVIRI grid
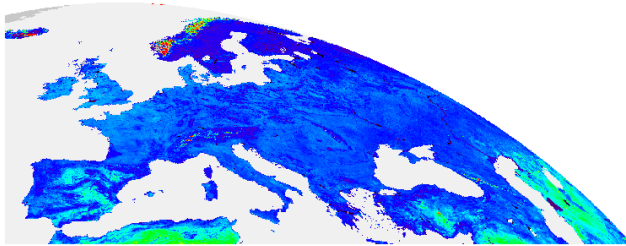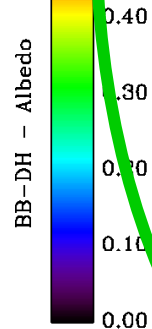
10-25 of June 2006

over Europe (from 2005-06-01 to 2006-10-01)

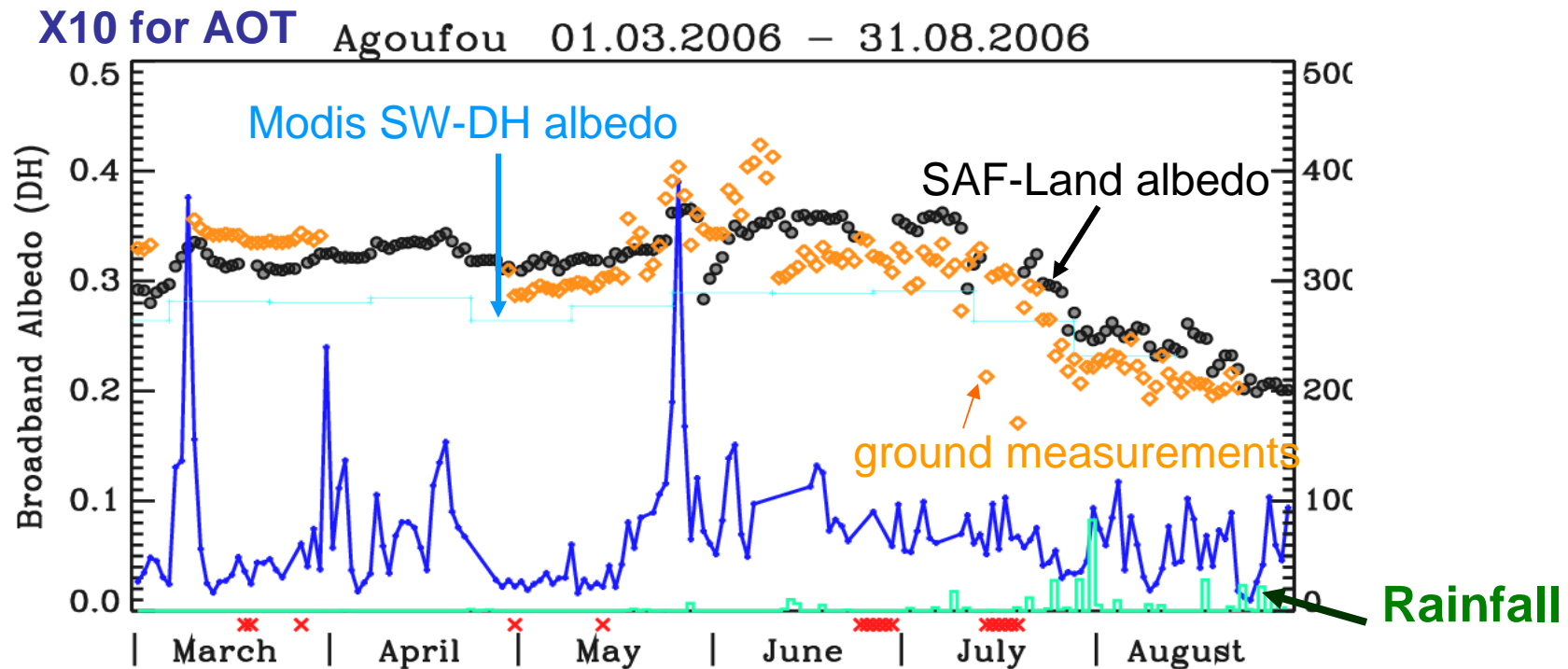MSG–MODIS   VI–DH

[0.4µm,0.7µm]

MSG–MODIS   NI–DH

[0.7µm,4µm]

MSG–MODIS   BB–DH

[0.3µm,4µm]

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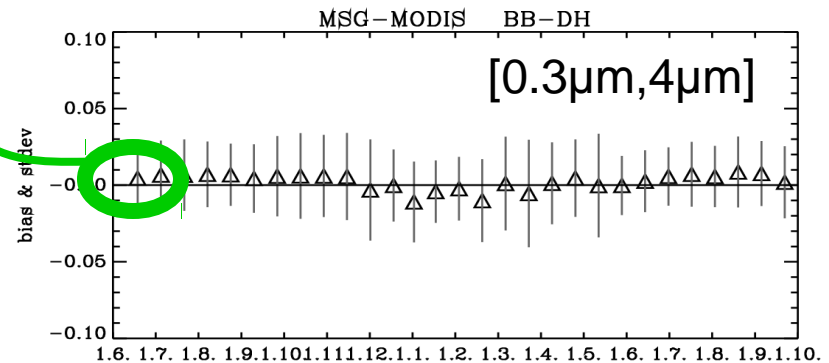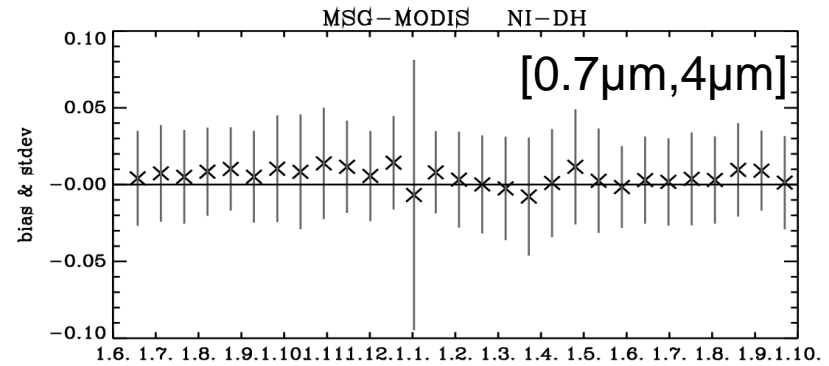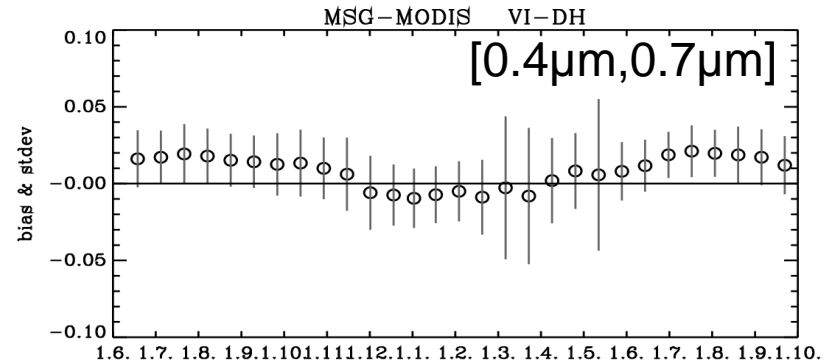
COMPARISON WITH MODIS ALBEDO (2/2)

12-27 of July 2006
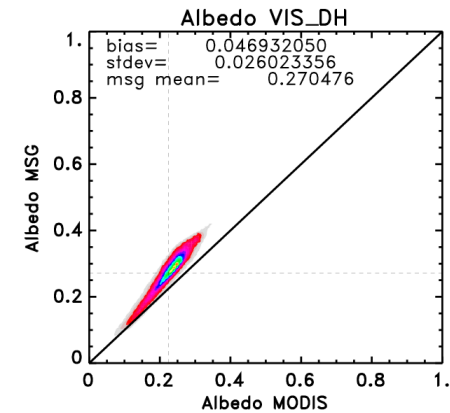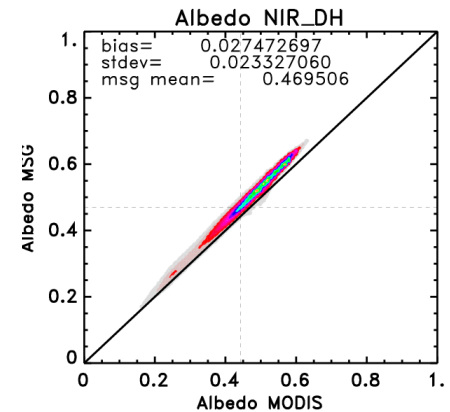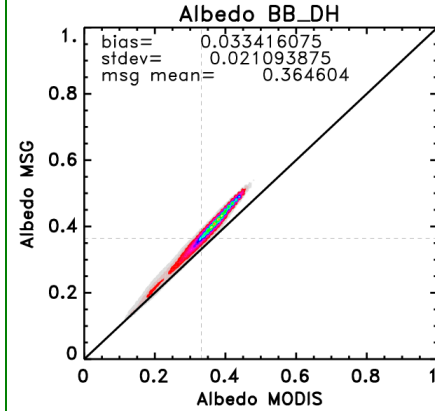
ALBEDO TIME SERIES (snowfall episodes)

Toravere   01.09.2005 — 30.06.2006 (Estonia) (boreal forest)

Modis SW-BH albedo

MSG albedo

ground measurements

Mehrstedt   01.09.2005 — 30.06.2006 (Germany) (mixed shrub/tree)

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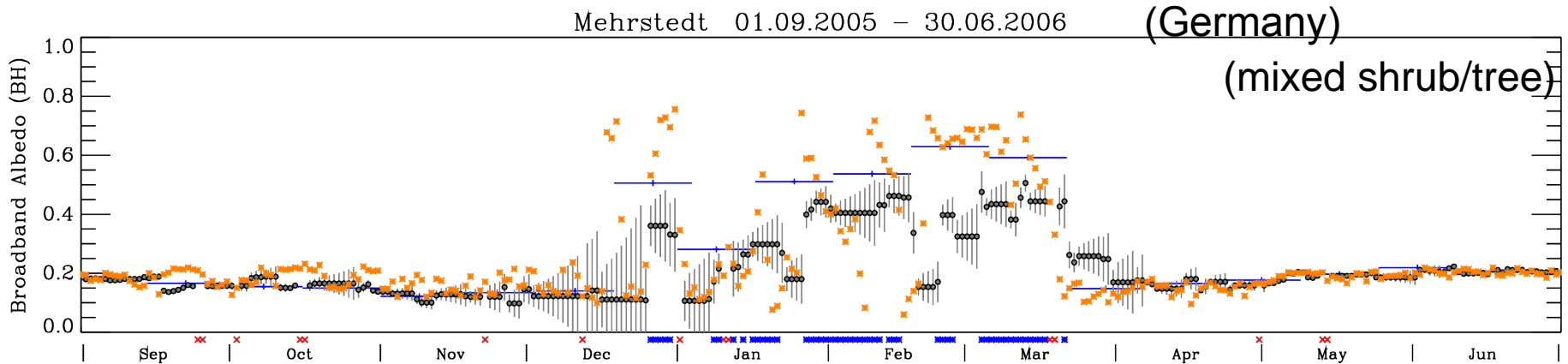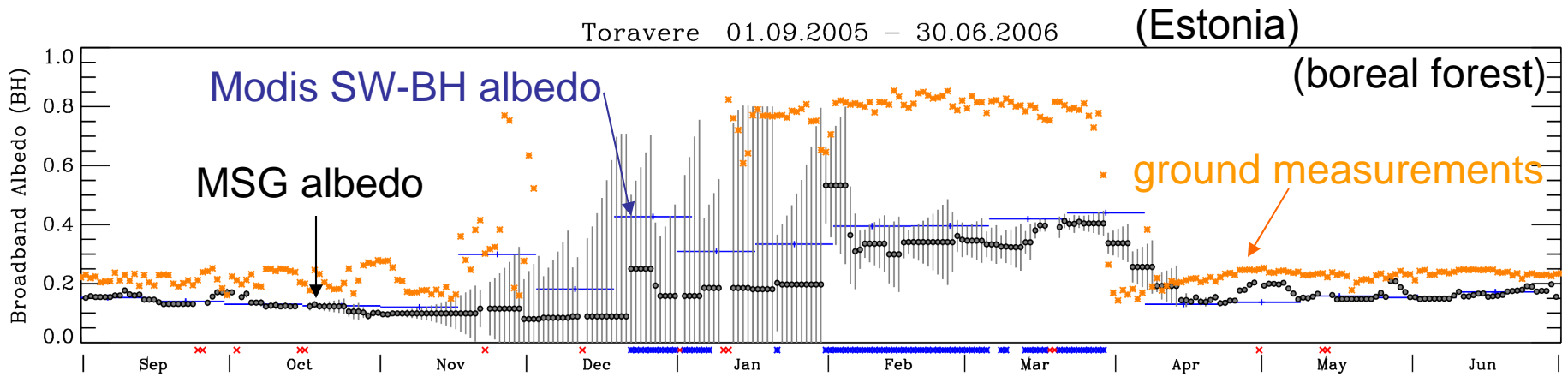
ALBEDO TIME SERIES (aerosol events)

The temporal evolution of the albedo estimate is related to the evolution of surface properties (typically rainfall). The spurious fluctuations appear to be caused by aerosol effects.

SUMMARY OF PERFORMANCES (AL)

Accuracy

Over mid-latitude region:

bias: 5% in relative units for SW and NIR broadband albedo (except for snow/ice pixels) **– bellow 0.01 in absolute unit**

20% for VIS broadband albedo (potentially due to the use of different BRDF models and aerosol products)

stdev: 0.015 for VIS and 0.030 for NIR and SW (or BB)

Over brightening surfaces (North Africa): no degradation in relative units

Publications:

Geiger, B., Carrer D., Franchistéguy L., Roujean J.-L., Meurey C., 2008, "*Land Surface Albedo derived on a daily basis from Meteosat Second Generation Observations*", IEEE Transactions on Geoscience and Remote Sensing, 46, 3841–3856, doi:10.1109/TGRS.2008.2001798.

Carrer, D., Roujean J.-L., Meurey C., "Evaluating operational MSG/SEVIRI land surface albedo products from LSA-SAF with ground measurements and MODIS", IEEE Transactions on Geoscience and Remote Sensing, doi:10.1109/TGRS.2009.2034530.

(Product User Manual, and Validation Report, internal documents)

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dépasser les frontières

METEO FRANCE
Toujours un temps d'avance

OUTLINE

- LSA-SAF project

- Surface Albedo Products
    method for retrieval
    evaluation
    application for weather forecast

- Perspectives

Kalman Filter Based Albedo Analysis

Method: KF to generate a daily analysis of the surface albedo components

Satellite product: total surface albedo and its uncertainty

Required model input fields: -bare soil albedo

-vegetation albedo

$$x_i^a = x_i^b + K_i[y_i - Hx_i^b]$$

$$K_i = A_i^b H^T [H A_i^b H^T + R_i]^{-1}$$

state vector ………………….. $\quad x_i^a = [a_{veg}^a, a_{sn}^a]^T$

obs. vector ………. $\quad y_i = [a_{veg}^{clim}, a_{sn}^{clim}, a_{tot}^{saf}]^T$

obs. operator..…… $\quad H = \begin{vmatrix} 1 & 0 \\ 0 & 1 \\ veg^{clim} & 1-veg^{clim} \end{vmatrix}$

obs. error ……... $\quad R_i = \begin{bmatrix} (\sigma_{veg}^{clim})^2 & 0 & 0 \\ 0 & (\sigma_{sn}^{clim})^2 & 0 \\ 0 & 0 & (\sigma_{tot}^{saf})^2 \end{bmatrix}$

15.02.2006

AL-9P-DH Colour Composite
R: 1.6µm, G: 0.8µm, B: 0.6µm

Meteosat-8/SEVIRI

$\leftarrow a_{tot}^{saf}$

METEO FRANCE
Toujours un temps d'avance
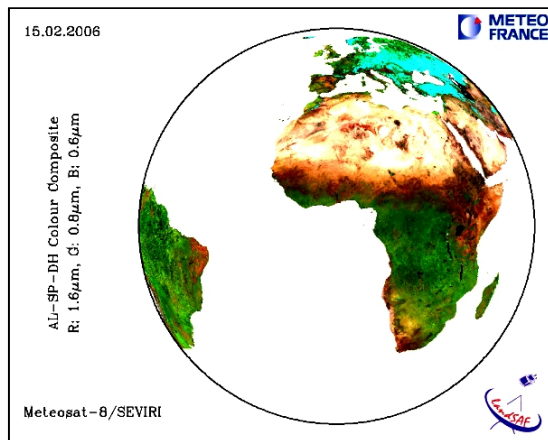
Analysis Example

Analysis of surface albedo on October 1st, 2006

Ecoclimap Albedo

Analysed Albédo

Bare Soil

Veg

Évora Station
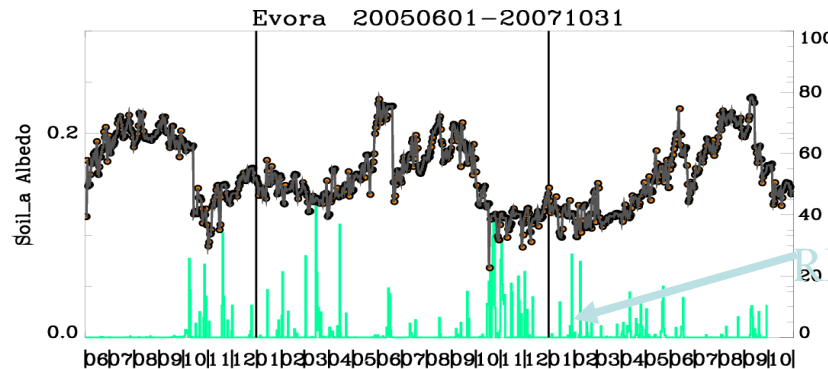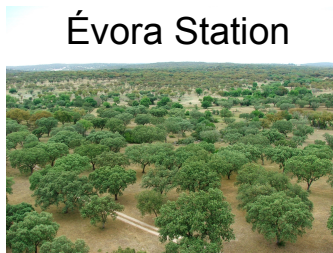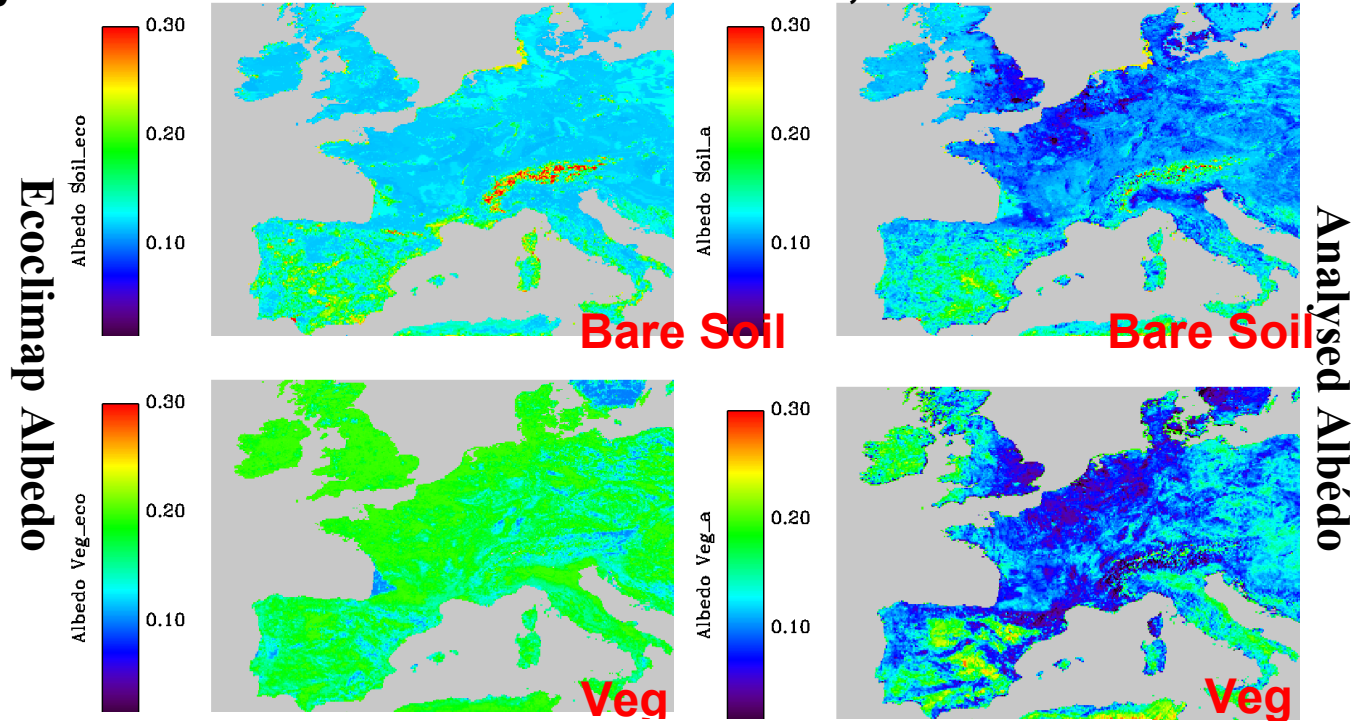
(wheras clim. bare soil alb is 0.14)

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APPLICATION FOR LSM (OFFLINE)

JJA: maximum difference (Alb Eco vs Alb SAF)

reference-LandSAF

Mean Eco. JJA   Max Alb(SAF-Eco)
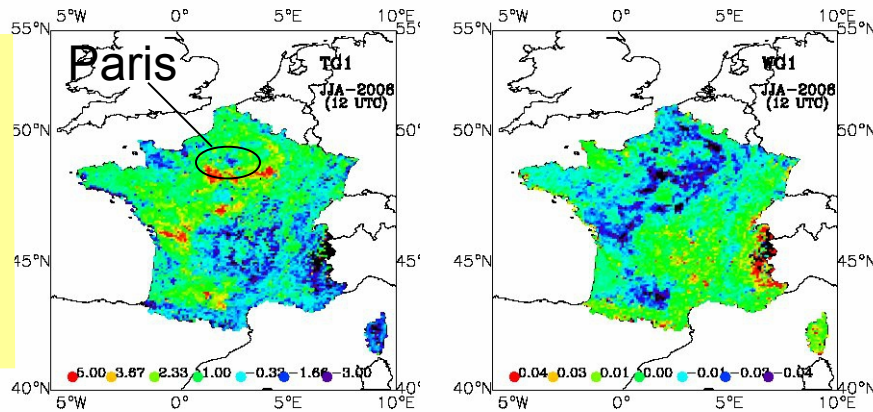
Land surface model: ISBA (~9.5km) forced by SAFRAN atmospheric analysis.
Two experiments: with Ecoclimap albedo and with LSA-SAF albedo analysis
Run every day at 00h (2006) – in offline mode

JJA:
-ΔALB between -0.1 and 0.1

Impact on:
-ΔTG1 between -3 and +6°K
-ΔTG2 between -1 and +2°K
-ΔWG1 between –0.04 and +0.04 m3/m3
-ΔWG2 < 0.01 m3/m3

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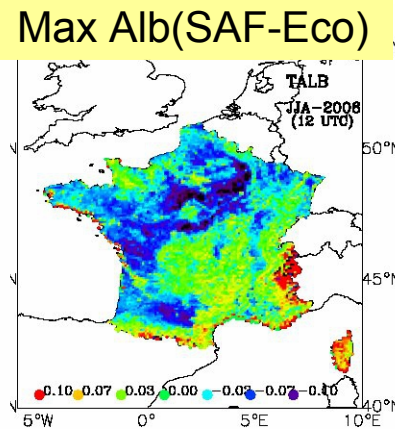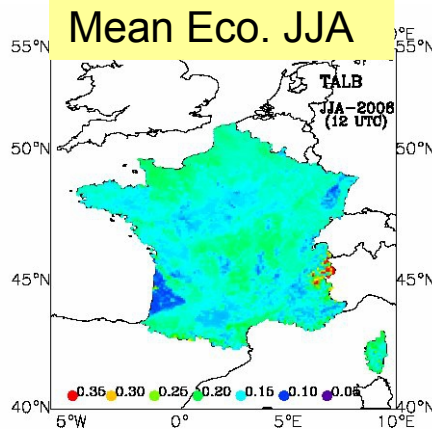
APPLICATION FOR WEATHER FORECAST (ONLINE)

Weather forcast model: ALADIN (~9.5km)
Two experiments: with ALADIN albedo and with LSA-SAF albedo analysis
Run every day at 00h (2007) - 54h forcast

Surface albedo 15022007 00UTC+12 LandSAF-reference

no assimilation of snow/ice pixels

2m temperature 15022007 00UTC+12 LandSAF-reference

LandSAF albedo is lower than Aladin albedo

a lower albedo induced warmer atmospheric T2m

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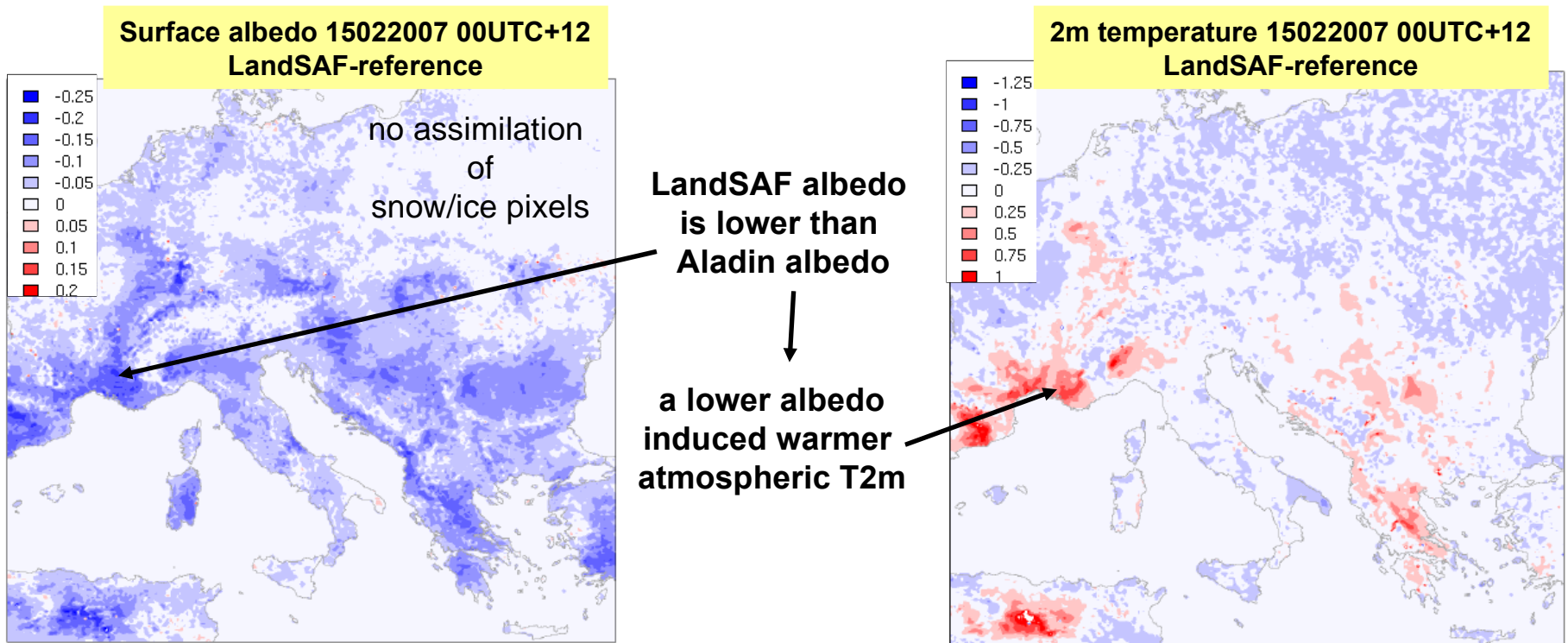
APPLICATION FOR NWP

Domain average total albedo
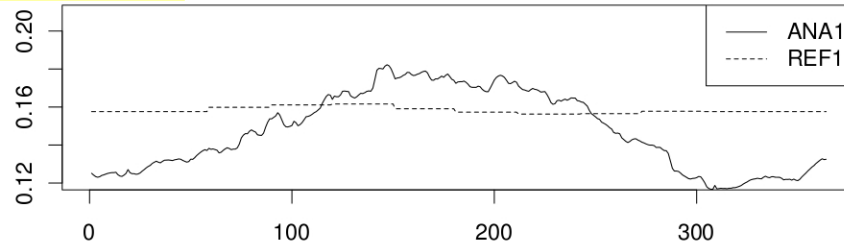
Day in year 2007

Domain average surface temperature anomaly
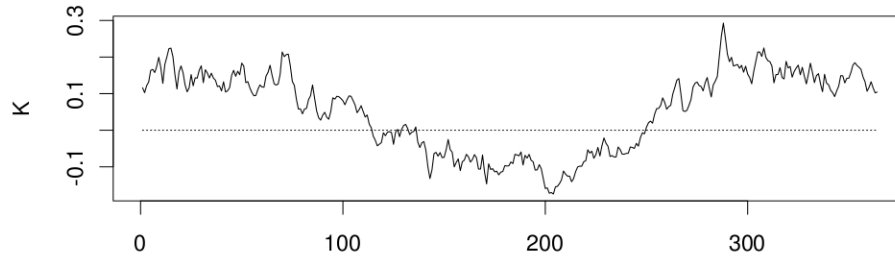
Day in year 2007

Domain averaged daily convective precipitation anomaly
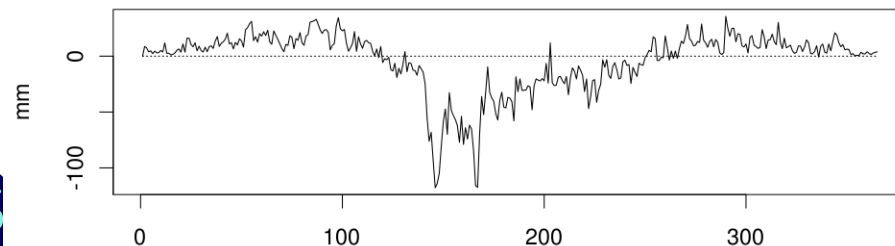
Day in year 2007

Conclusion of Score Study:
weather model has a significant cold bias in winter. Satellite data permit to reduce this bais.

(J. Cedilnik, D. Carrer, J.-F. Mahfouf, and J.-L. Roujean, "Analysis of satellite derived surface albedo for numerical weather prediction", **in revision**)

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Kalman Filter Based LAI Analysis

Method: KF to generate a daily analysis of LAI (for each tile)

$$x_i^a = x_i^b + K_i [y_i - H x_i^b]$$

$$K_i = A_i^b H^T [H A_i^b H^T + R_i]^{-1}$$

state vector ……………….. $\quad x_i^a = [lai_{tile1}^a, ..., lai_{tile12}^a]^T$

obs. vector ………. $\quad y_i = [lai^{isba}, lai^{saf}]^T$

obs. operator .…….

$$H = \begin{bmatrix} frac_{tile1} & ... & frac_{tile12} \\ frac_{tile1} & ... & frac_{tile12} \end{bmatrix}$$

obs. error ..

$$R_i = \begin{bmatrix} (\sigma_{lai}^{isba})^2 & 0 \\ 0 & (\sigma_{lai}^{saf})^2 \end{bmatrix}$$

$\leftarrow lai^{isaf}$

LAI
0 1 2 3 4 5 6

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Toujours un temps d'avance
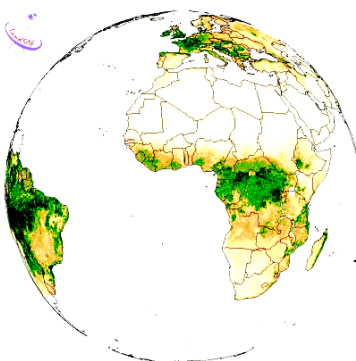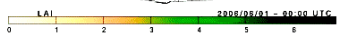
LSA-SAF LAI analysis

One analysis per month, the 16th at 06TU
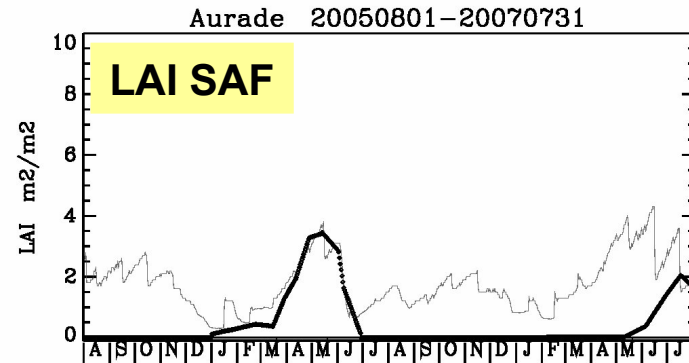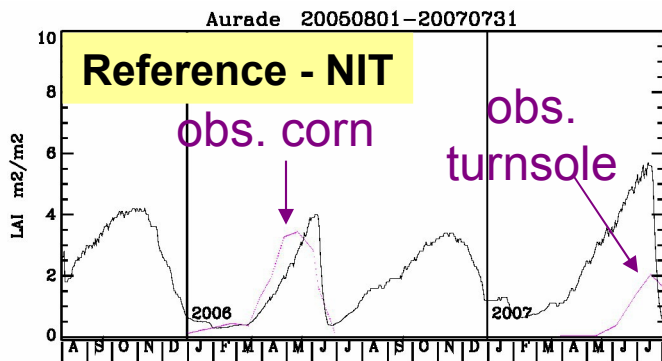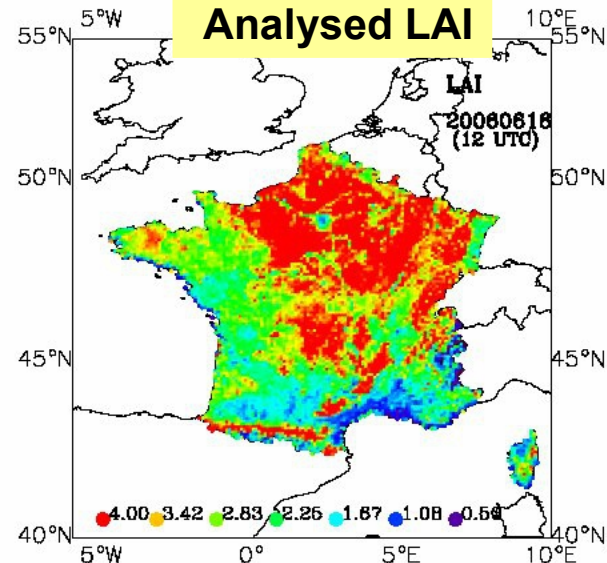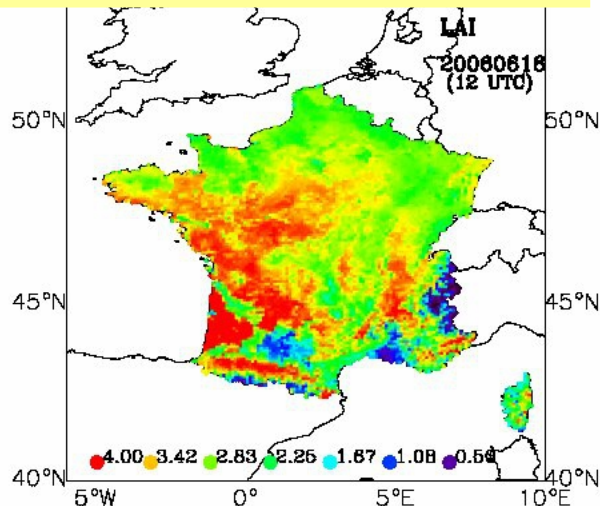
OUTLINE

- LSA-SAF project

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    - *evaluation*
    - *application for weather forecast*

- **Perspectives**

OPEN ISSUES AND FURTHER DEVELOPMENTS

•**2012-2013:**
1/ tuning of algorithms
2/ high latitude coverage: extension achieved due to the merging of
                                        MSG and MetOp data.
3/ uptdate albedo fields (bare soil and vegetation) in Ecoclimap database (C. Meurey).

Modis 2008
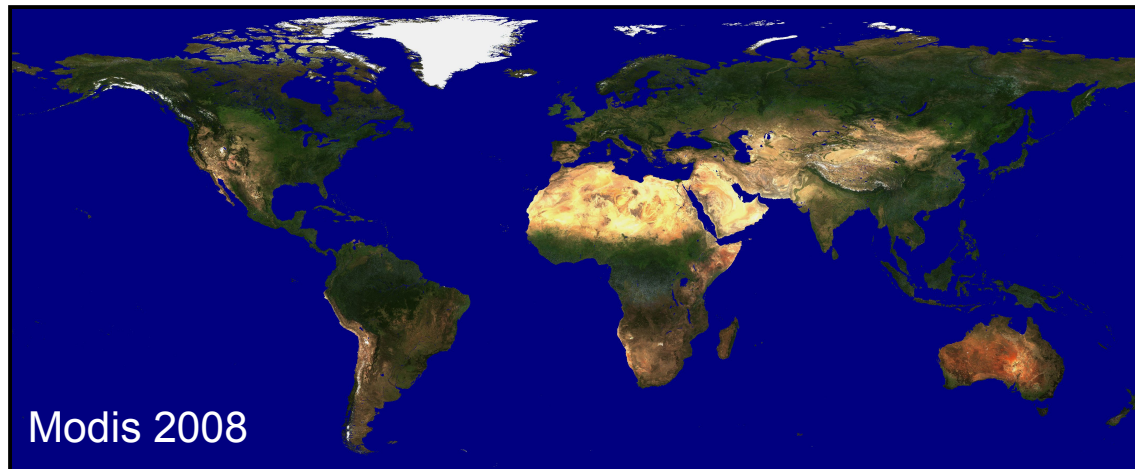
4/ comparison of daily spectral soil albedo over France from MODIS and MSG (S. Liu).
5/ use of the satellite albedo in AROME, the new high resolution model of Météo-France (S. Jebali).

•**Until 2019:**
=> The LSA-SAF program provides a mean to constrain the climate trend in Europe, Africa, and South America thanks to the insurance of a constant production foreseen until at least 2019.

e-mail: dominique.carrer@meteo.fr

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MANY THANKS