WMO RAVI Hydrological Forum 2016
Workshop on hydrological modelling, forecasting and warnings
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LSA-SAF evapotranspiration products and on-going research at RMI

by
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Belgium

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

EUMETSAT
Monitoring weather and climate from space
Surveiller le temps et le climat depuis l'espace

belspo

RMI

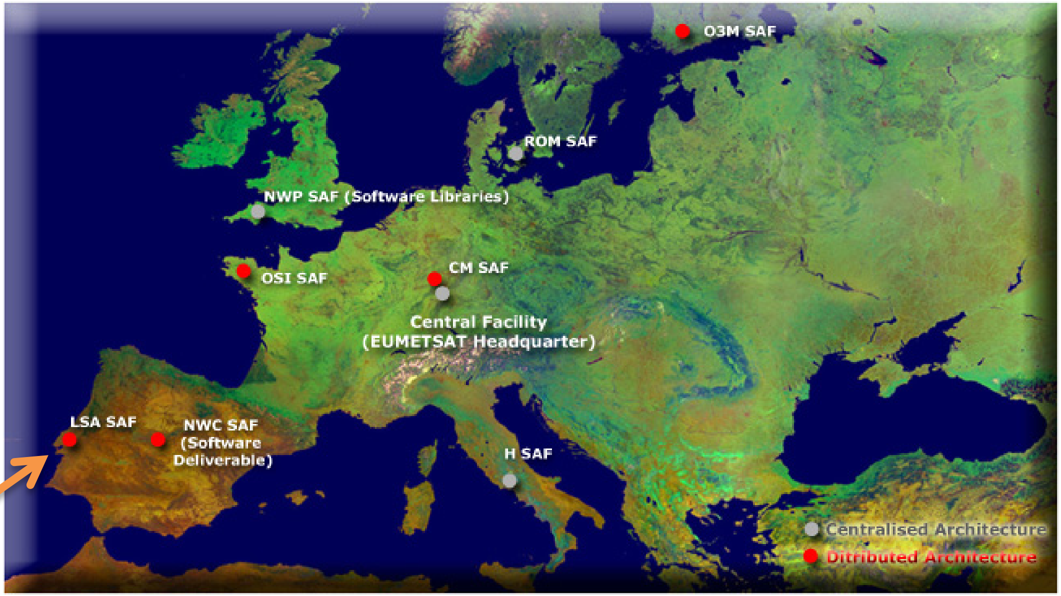
Content

- Introduction: what is LSA-SAF ?
- ET methodology and current operational products
- On-going research activities (2012-2017)
- Plans for the next period (2017-2022)
- Conclusions

Introduction

- EUMETSAT Satellite Application Facilities (SAFs) network
  - The Satellite Application Facilities (SAFs) are a distributed network of thematic application facilities responsible for necessary research, development, and operational activities not carried out by the central facility. The SAFs are located within the National Meteorological Services (NMS) of EUMETSAT Member States, or other agreed entities linked to a user community.

SAF


O3M SAF
ROM SAF
NWP SAF (Software Libraries)
OSI SAF
CM SAF
Central Facility
(EUMETSAT Headquarter)
LSA SAF
NWC SAF
(Software
Deliverable)
H SAF
● Centralised Architecture
● Ditributed Architecture

ipma
instituto português do
mar e da atmosfera

- Land Surface Analysis (LSA) SAF

Introduction

- LSA-SAF project team

Cooperating entities during CDOP-2 (2012-2017):

- **Instituto Português do Mar e da Atmosfera, IP (IPMA)**, Portugal
- Météo-France (MF), France
- **Royal Meteorological Institute (RMIB), Belgium**
- Karlsruhe Institute of Technology (KIT), Germany
- Fundacao da Faculdade de Ciencias da Universidade de Lisboa, FP, Instituto Dom Luiz (IDL), Portugal
- King’s College London (KCL), United Kingdom
- University of Valencia (UV), Spain
- VITO, Belgium

In the future:

- Slovenian Environment Agency (ARSO), Slovenia
- National Institute of Meteorology and Hydrology (NIMH), Bulgaria

Introduction

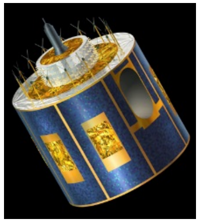
- LSA-SAF (http://landsaf.meteo.pt/)

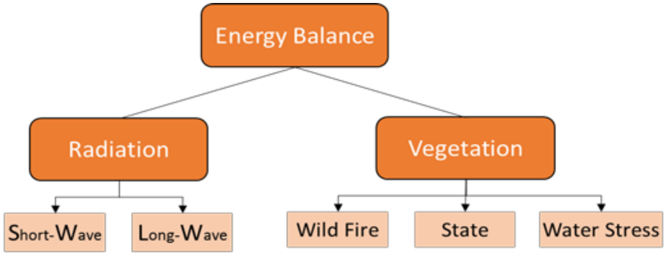
Objectives

– to be a leading centre for r**etrieval of information on land surfaces from remote sensing data**, with emphasis on EUMETSAT satellites (MSG, Metop).

– To provides **near-real-time** and **offline products** and user support for a wide range of **land surface variables** related with:

- surface radiation, both long- and short-wave components;
- vegetation, including state, stress and wild fires;
- energy budget at the surface and mass exchange, combining information on the radiation budget and vegetation state.





Energy Balance

Radiation

Vegetation

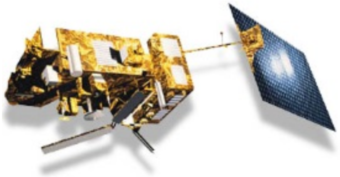
Short-Wave

Long-Wave

Wild Fire

State

Water Stress

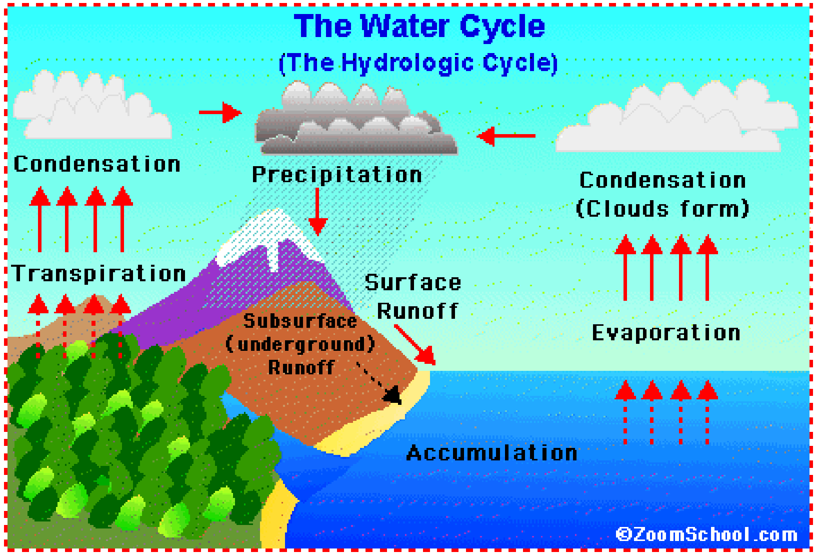


SAF user community

- The design of LSA SAF products was initially driven by the needs of the **meteorological,** particularly NWP, community. There is, however, a growing number of other important areas, including **agricultural** and **forestry** applications, **land use**, and the broader topics of **climate** and **environment monitoring**.

Introduction

- Royal Meteorological Institute (RMI) of Belgium contribution to LSA-SAF
  - Development of **evapotranspiration** (operational)

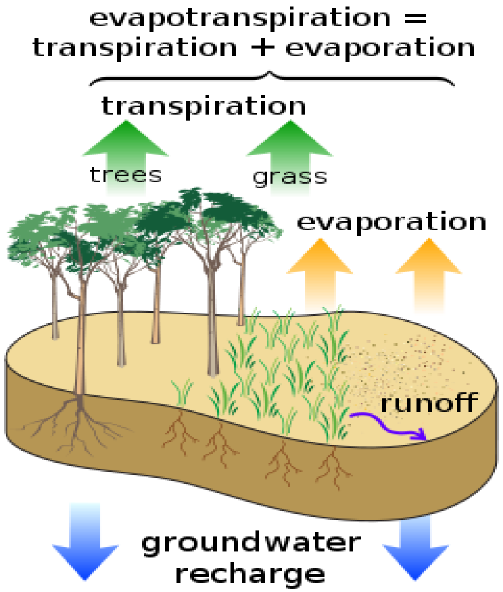

The Water Cycle
(The Hydrologic Cycle)
Condensation
Precipitation
Condensation
(Clouds form)
Transpiration
Surface
Runoff
Subsurface
(underground)
Runoff
Evaporation
Accumulation
©ZoomSchool.com

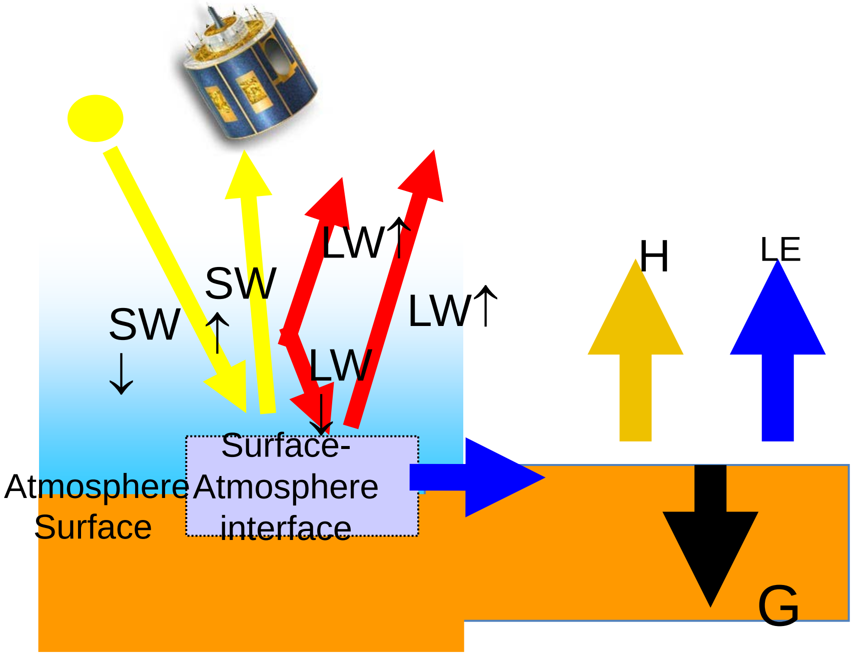
But also:

- Development of latent and sensible heat fluxes
- Collaboration with other LSA-SAF teams (development of LST all-weather, GPP)
- Collaboration with other SAFs (H-SAF and CM-SAF)

ET methodology and operational products

- Physics: water and energy budget


evapotranspiration =
transpiration + evaporation
transpiration
trees
grass
evaporation
runoff
groundwater
recharge


SW ↓
SW ↑
LW↑
LW ↓
LW↑
H
LE
Atmosphere
Surface
Surface-Atmosphere interface
G

ET methodology and operational products

- ## Methodology

MSG SEVIRI pixel

Tiles:

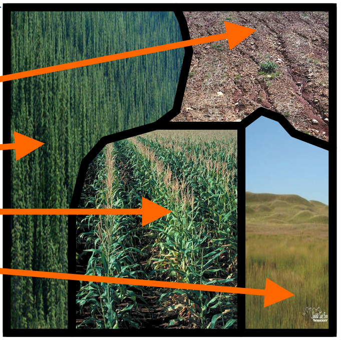
Bare soil

Forest

Crops

Grassland

…



For each tile i of image k

$$LE_i = \frac{L_v \rho_a}{\left(r_{a_i} + r_{c_i}\right)} \left[q_{sat}\left(T_{sk,i}\right) - q_a\left(T_a\right)\right]$$

$$H_i = \frac{\rho_a}{r_{a\,i}} \left[c_p (T_{sk,i} - T_a) - g z_a\right]$$

$$G_i = \beta_i Rn_i \qquad \beta_i = f(LAI_i)$$

$$Rn_i - H_i - LE_i - G_i = 0$$

$$Rn_i = (1-\alpha) S_\downarrow + \varepsilon (L_\downarrow - \sigma T_{sk,i}^4)$$

Parameterizations adapted from ECMWF TESSEL model (van den Hurk et al, 2000; Ghilain et al, 2011)

For each pixel of image k

$$LE_k = \sum_i \zeta_i LE_i$$

Evapotranspiration [mm h^{-1}]

$ET_k = 3600\, LE_k / L_v$

→ MET product

For each pixel of day d

Evapotranspiration [mm d^{-1}]

$ET_d = \Sigma\, ET_k$

→ DMET product

Link between LE and ET:

$LE = L_v\, ET$

LE: latent heat flux [W m^{-2}]

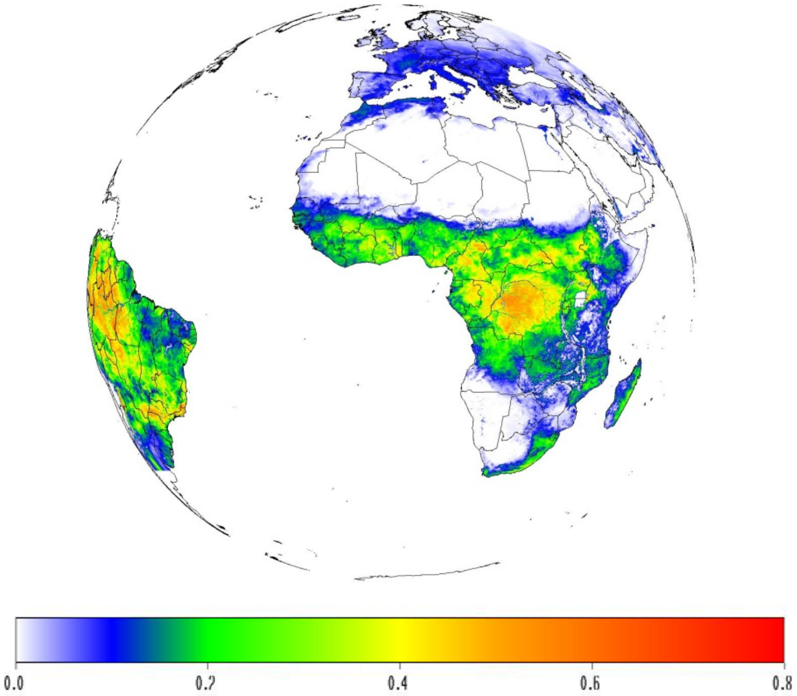
ET: evapotranspiration [kg m^{-2} s^{-1}]

L_v : latent heat of vaporisation

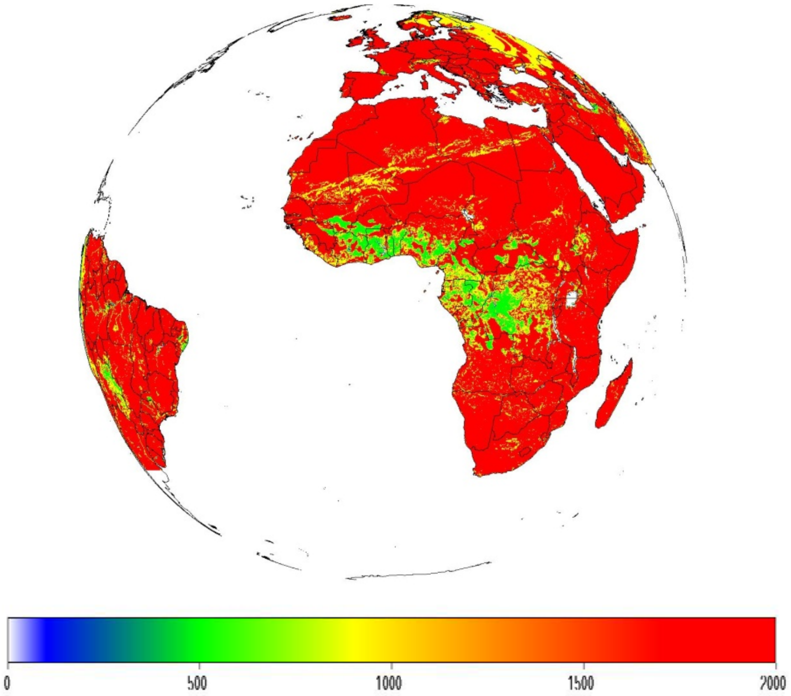
L_v ~ 2,5 10^6 J kg^{-1}

ET methodology and operational products

Two images are generated: the first one contains instantaneous ET estimates in mm/h while the second one is the quality flag image, provides information on the quality of estimates pixel by pixel



ET (mm/h) for 2010/10/29 at 12:00 UTC



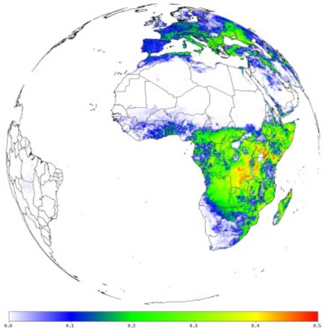
Associated quality flag (-)

ET methodology and operational products

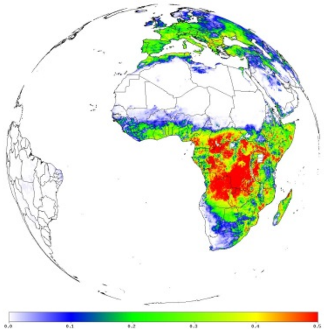
• Evapotranspiration (ET): example of products

MET (mm h^{-1}): available each 30 min

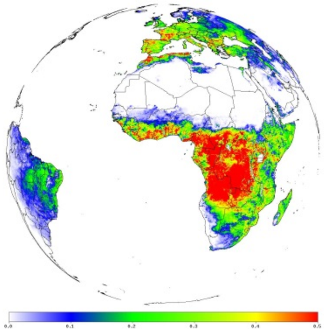
Example: 28th April 2010 (different hours (UTC) from left to right).


0,0
0,1
0,2
0,3
0,4
0,5

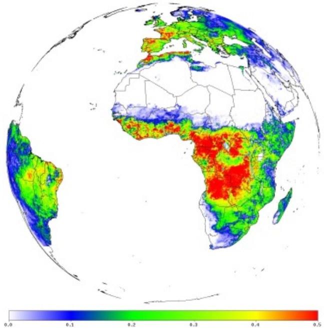
06:00


0,0
0,1
0,2
0,3
0,4
0,5

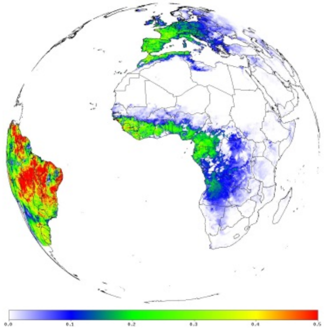
09:00


0,0
0,1
0,2
0,3
0,4
0,5

12:00


0,0
0,1
0,2
0,3
0,4
0,5

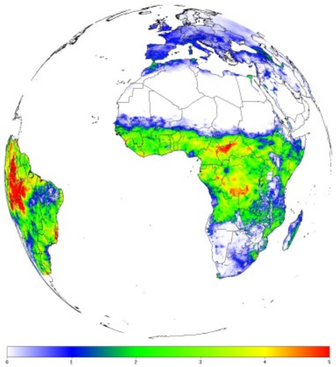
15:00


0,0
0,1
0,2
0,3
0,4
0,5

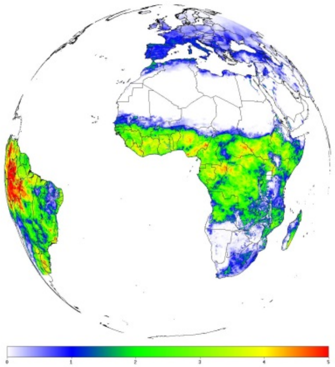
18:00

DMET (mm d^{-1}): available daily

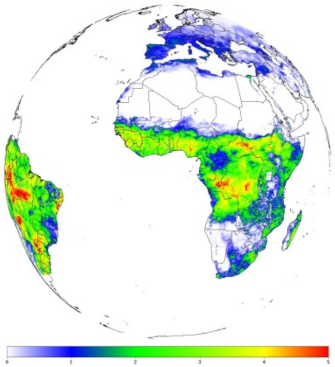
Example: 8th to 12th September 2011 (from left to right).



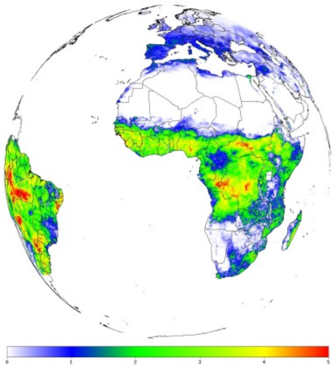
8/9/2011



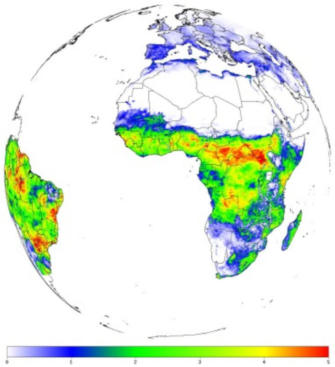
9/9/2011



10/9/2011



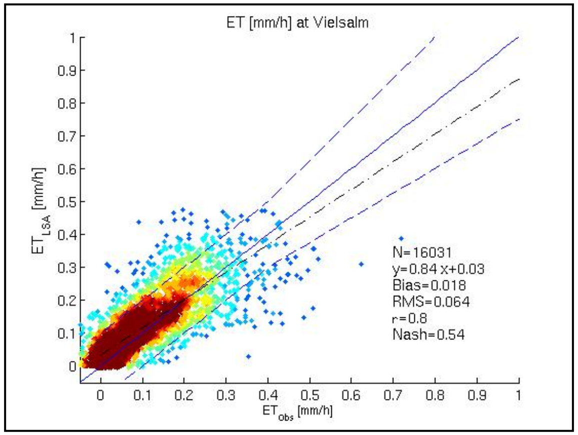
11/9/2011



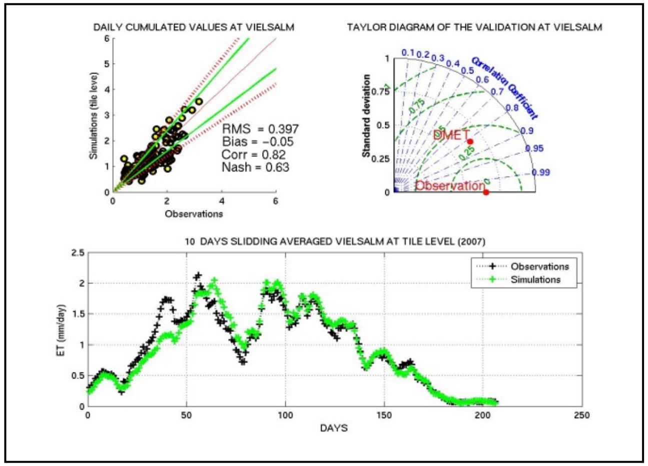
12/9/2011

ET methodology and operational products

- Scientific validation and operational quality monitoring
  - Update scientific validation → Validation Report

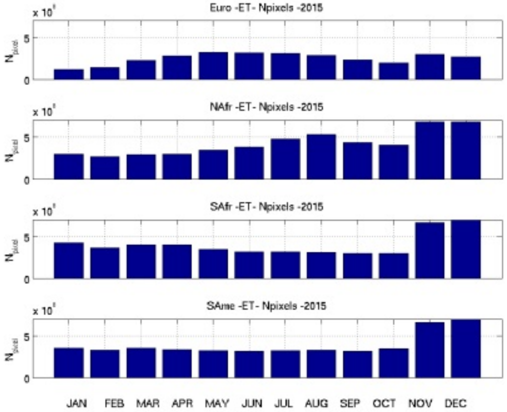


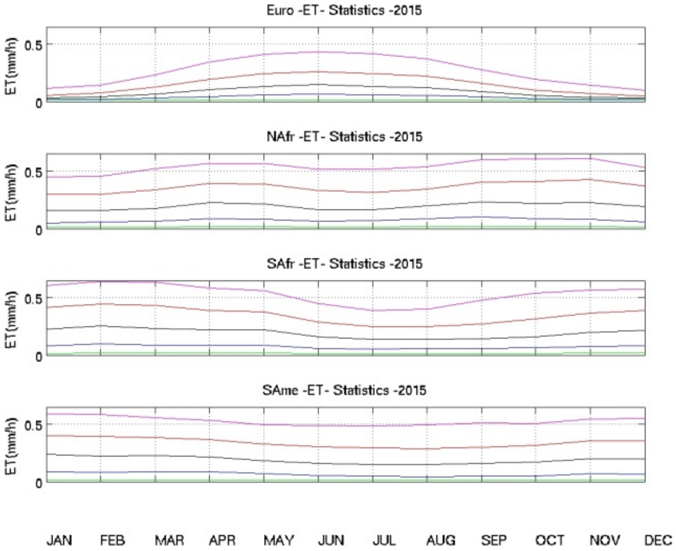
Vielsalm (BE) - mixed forest



  - Quality monitoring (each 6 months)

    → Quality Monitoring Report



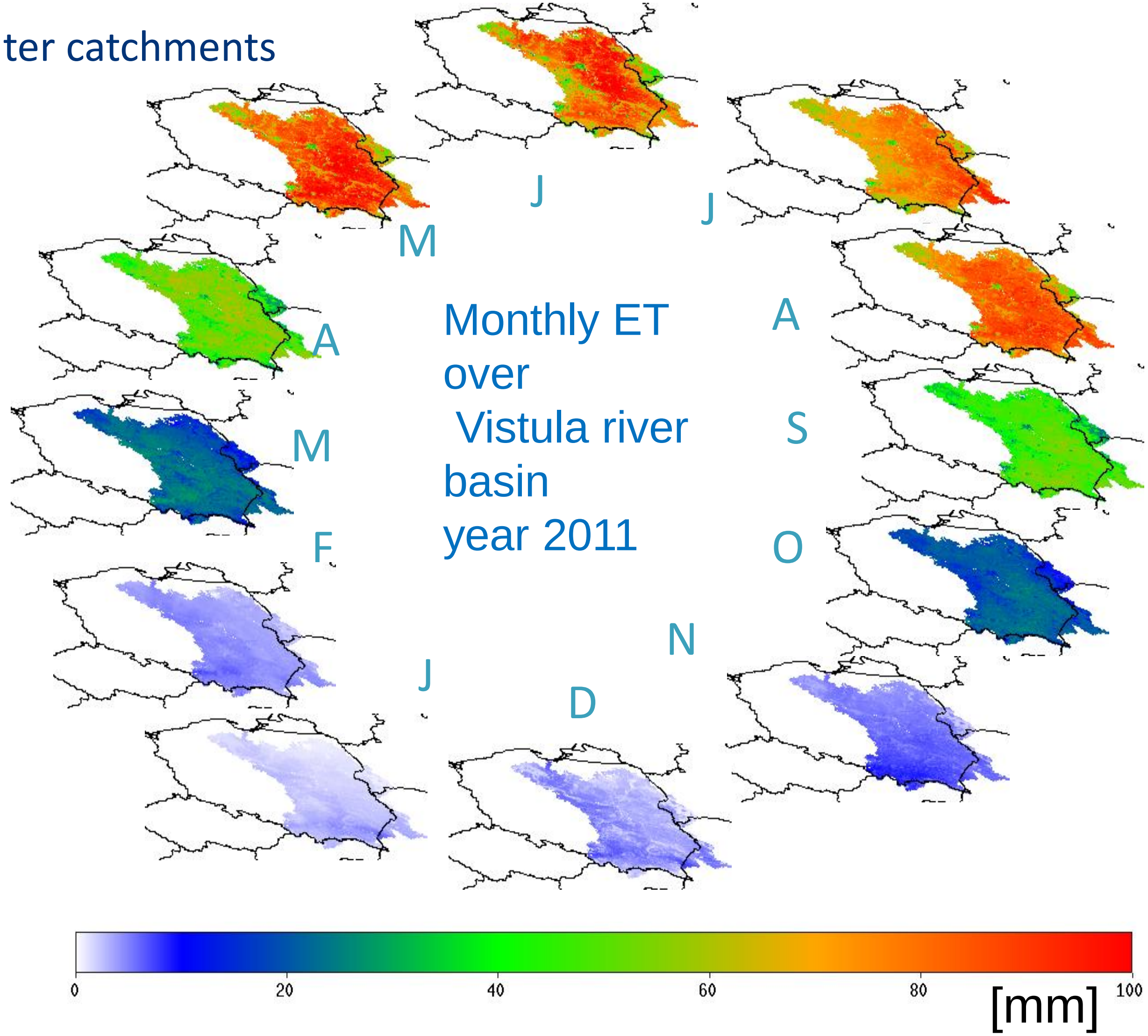


ET methodology and operational products

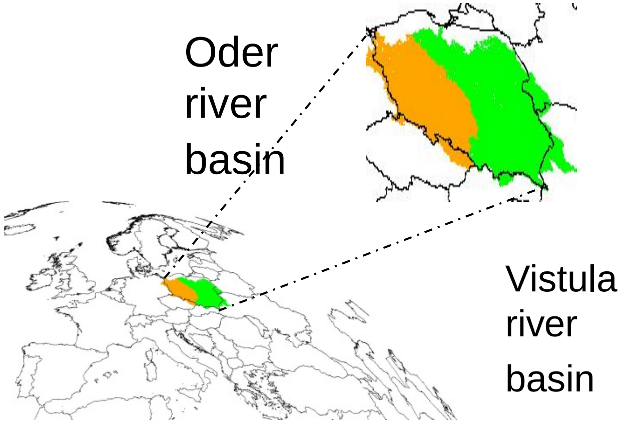
- Publications and conferences
  - E.g.: Ghilain, N., Arboleda, A., Trigo, I.F., Batelaan, O.and Gellens-Meulenberghs, F., 2015b: Tracking down soil moisture from MSG SEVIRI: fullfilling the promises of geostationnary satellites, Remote Sens. Environ., in review.
  - E.g. 2015: EUMETSAT user conference, Toulouse (FR); GEWEX/ESA workshop on EO of the water cycle, Frascati (IT).
- Collaboration with users and participation to trainings
  - A few users' publications:
    - Sepulcre Canto, G., Vogt, J., Arboleda, A, Antofie, T., 2014: Assessment of the EUMETSAT LSA-SAF evapotranspiration product for drought monitoring in Europe, Int. J. Applied EO Geoinf, 30, 190-202.
    - Hu, G., Jia, L., & Menenti, M. 2015: Comparison of MOD16 and LSA-SAF MSG evapotranspiration products over Europe for 2011, Remote Sens. Environ., 156, 510-526.
    - Romaguera, M., Krol, M. S., Salama, M. S., Su, Z., & Hoekstra, A. Y., 2014a: Application of a remote sensing method for estimating monthly blue water evapotranspiration in irrigated agriculture, Remote Sensing, 6(10), 10033-10050.
  - Trainings: e.g. 2015: EUMETSAT/WMO "Land SAF/Satellite Products Training Course on Applications in Agro Meteorology », 23-27/03/2015, Addis Ababa, Ethiopia. Lectures on Land SAF concepts; Evapotranspiration – Concepts and exercices of using LSA-SAf ET products.
  - LSA-SAF Users Workshops: e.g. 2015: Reading (UK).

ET methodology and operational products

- Example of application 1
  - ET integration over water catchments


Monthly ET over
Vistula river basin
year 2011

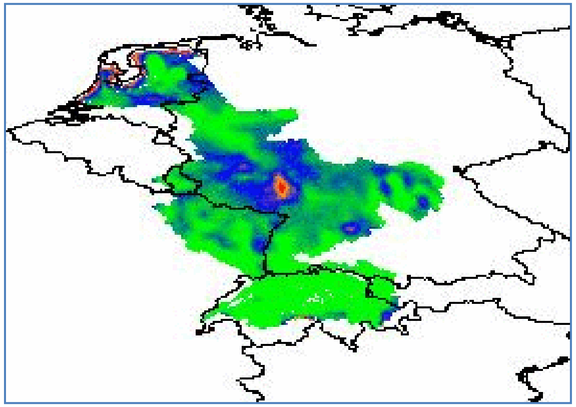
J
F
M
A
M
J
J
A
S
O
N
D
0
20
40
60
80
100
[mm]


Oder river basin
Vistula river basin

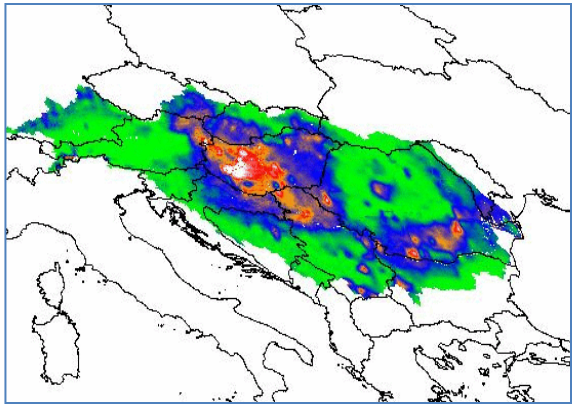
ET methodology and operational products

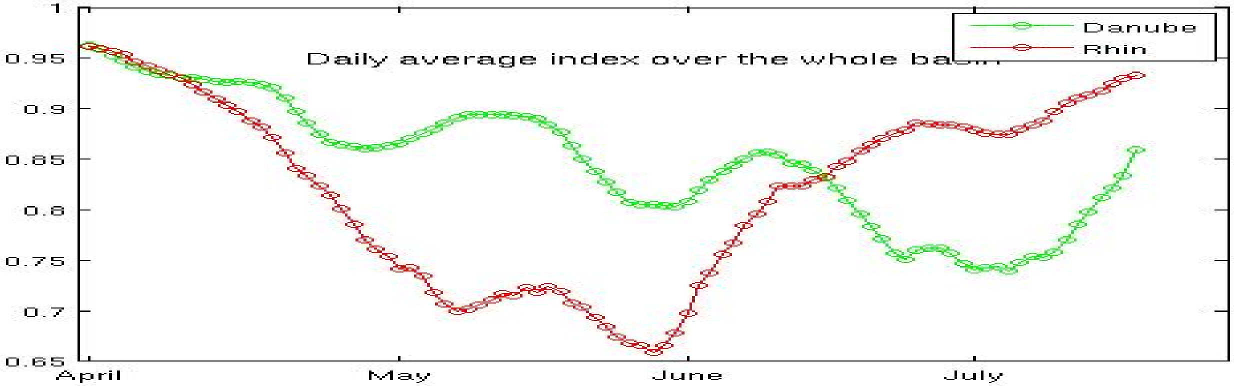
- Example of application 2
  - Drought monitoring

Rhin river basin



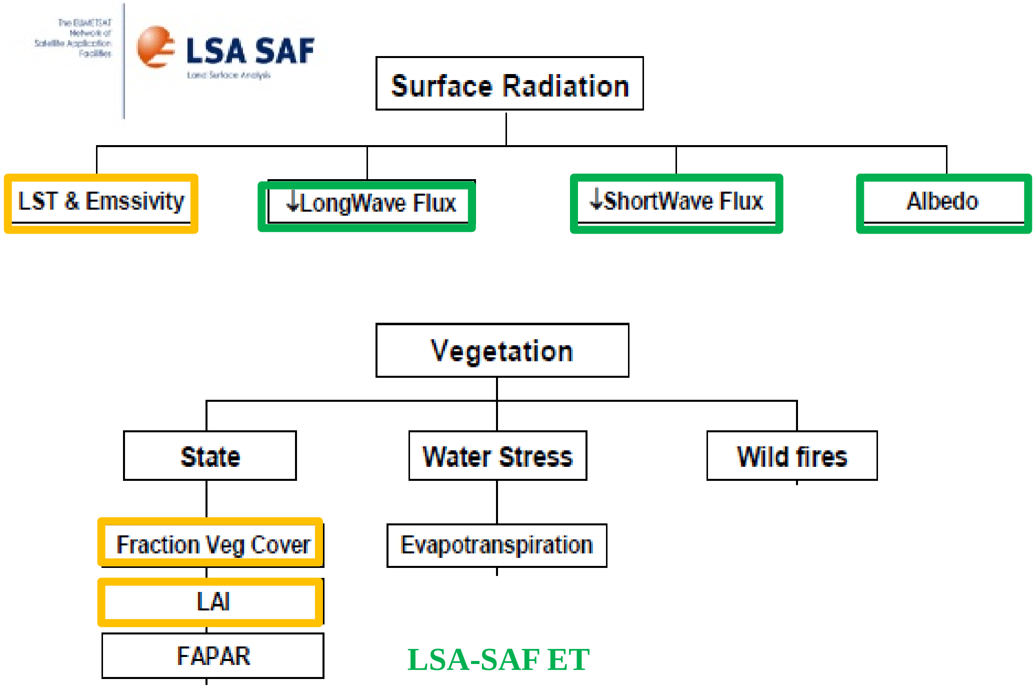
Danube river basin





On-going research activities (2012-2017)

- Recent activities
  - Improvement of ET product in arid and semi-arid areas (using additional satellite input)


The EUMETSAT Network of Satellite Application Facilities
LSA SAF
Land Surface Analysis
Surface Radiation
LST & Emssivity
↓LongWave Flux
↓ShortWave Flux
Albedo
Vegetation
State
Water Stress
Wild fires
Fraction Veg Cover
LAI
FAPAR
Evapotranspiration

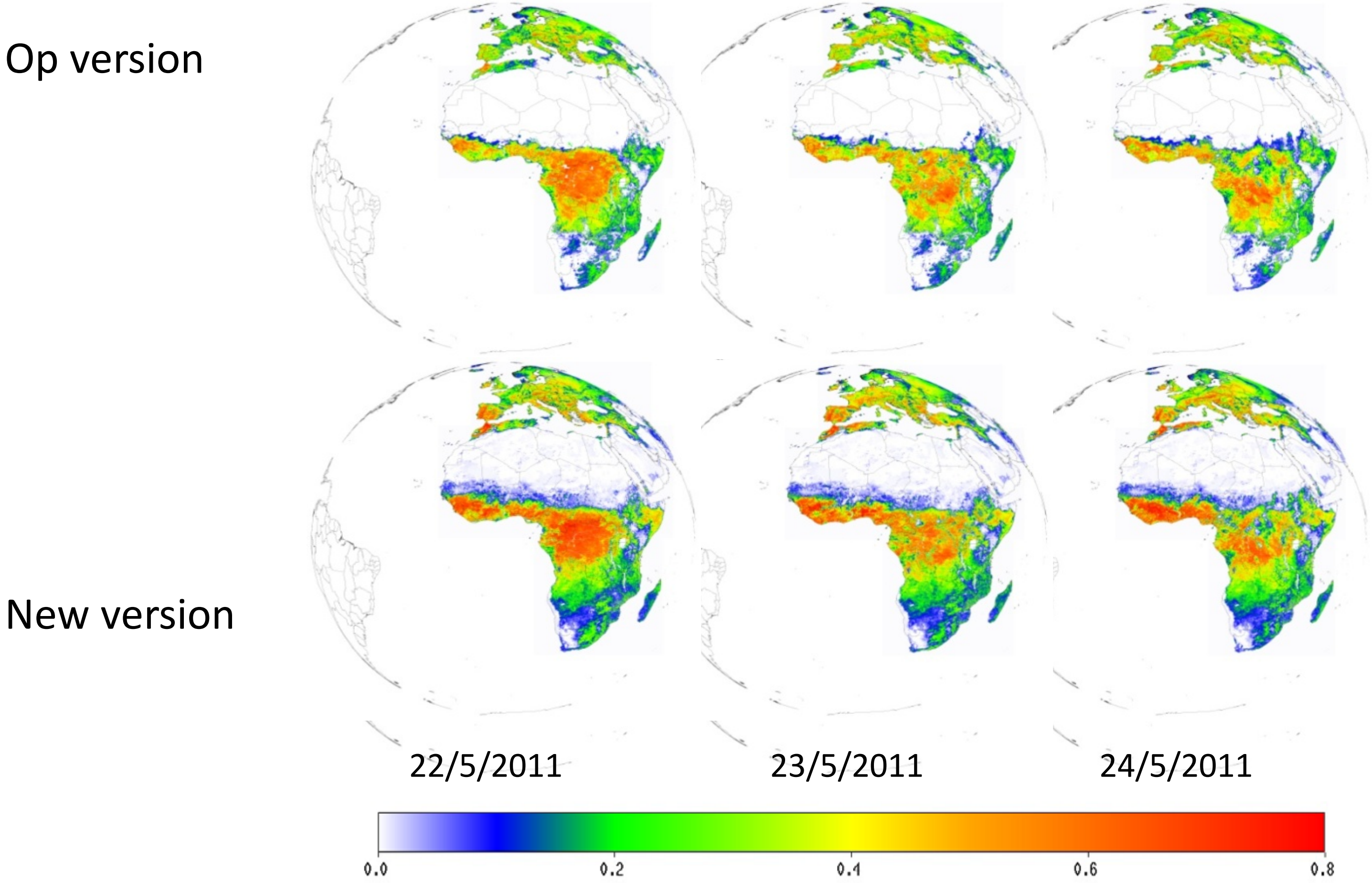
LSA-SAF ET

LSA-SAF ET V2

On-going research activities (2012-2017)

- Step 1: introduction vegetation indices from MSG SEVIRI

  [Leaf area index (LAI), fraction of vegetation cover]


Op version
New version
22/5/2011
23/5/2011
24/5/2011
0.0
0.2
0.4
0.6
0.8

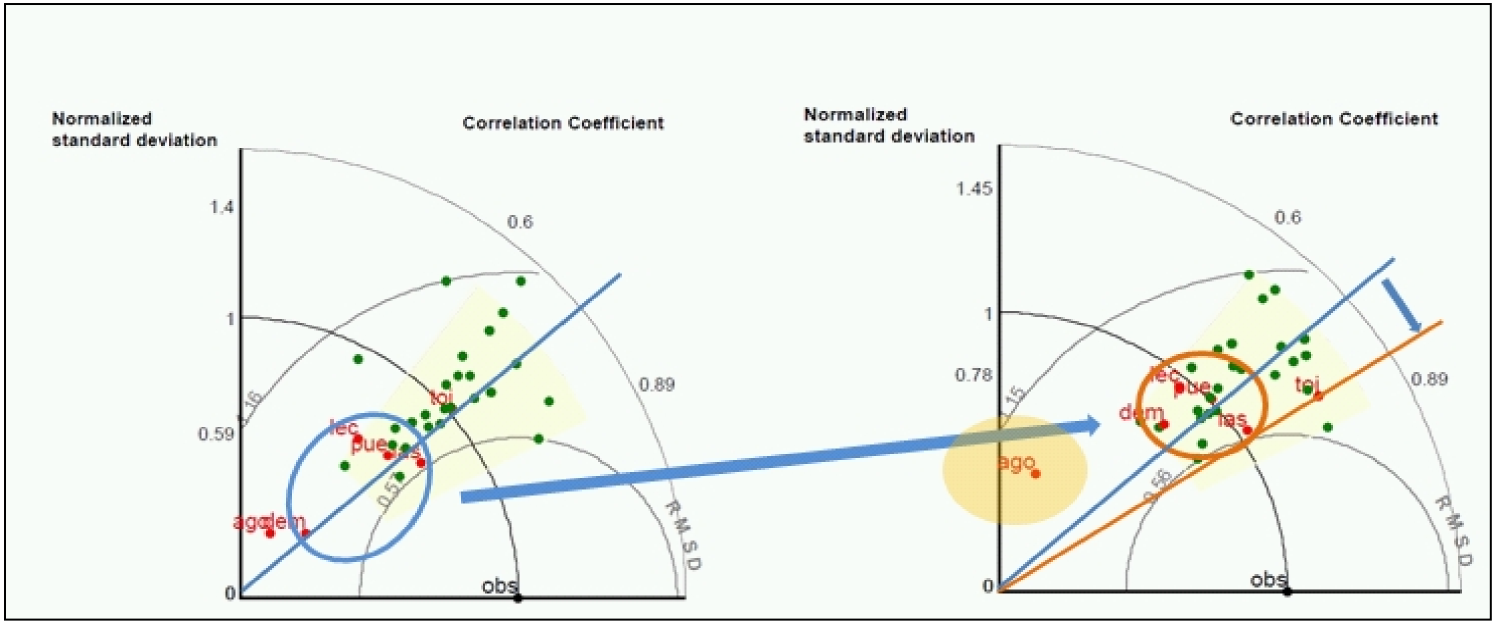
Results obtained with the new remote-sensing variables produce higher ET values over arid/semi-arid areas with low or no impact on tempered regions of Europe.

On-going research activities (2012-2017)

- Step 1: introduction vegetation indices from MSG SEVIRI

  [Leaf area index (LAI), fraction of vegetation cover]

The result of the comparison between the old and new version to ground observations shows a clear improvement over semi-arid areas : correlation scores have been improved, and variability is comparable to the observations.



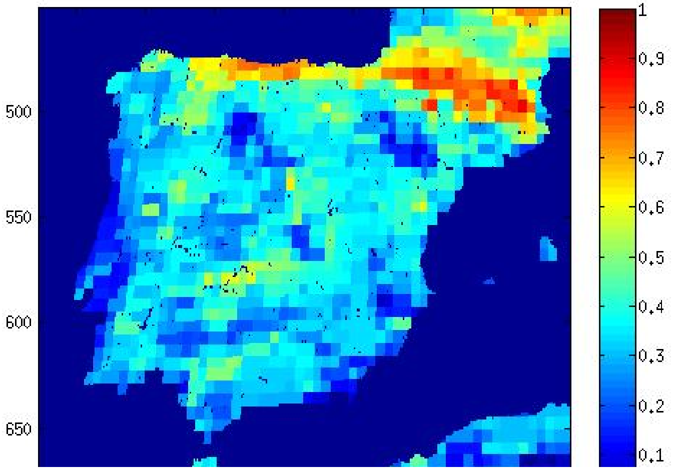
However, the scores at Sahelian sites have been found to be still very low, showing that the model is quite more sensitive to soil water availability than vegetation input and that the current soil moisture information was not adequate for those regions.

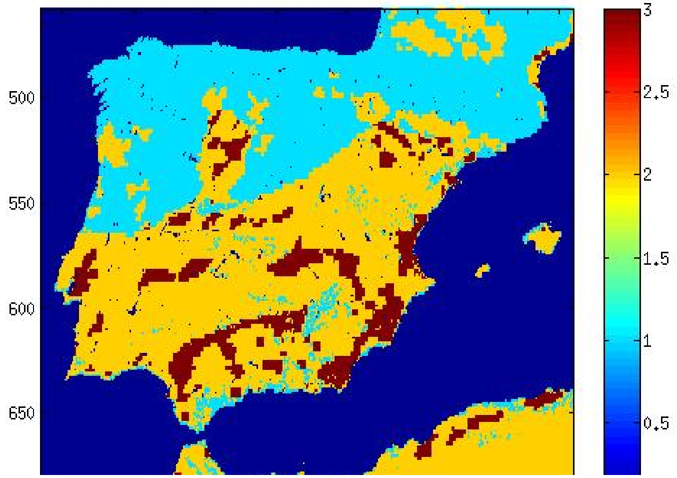
On-going research activities (2012-2017)

- Step 2: assessment of SSM from LST derived heating rates

14/8/2011

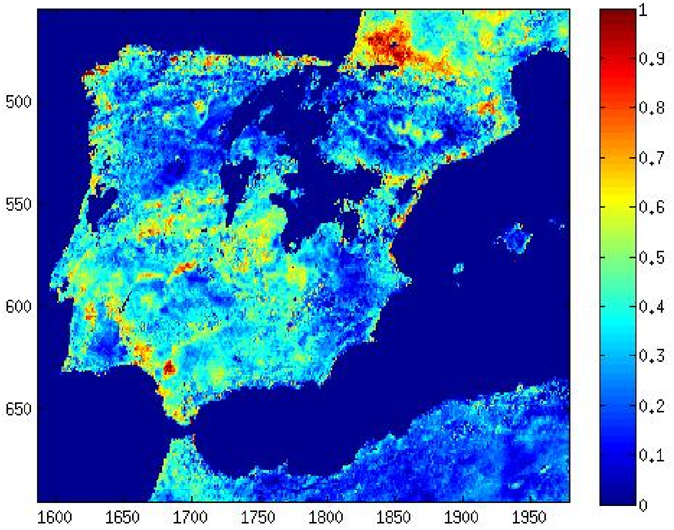
H SAF H 14
SSM (SMDAS-2
real time)

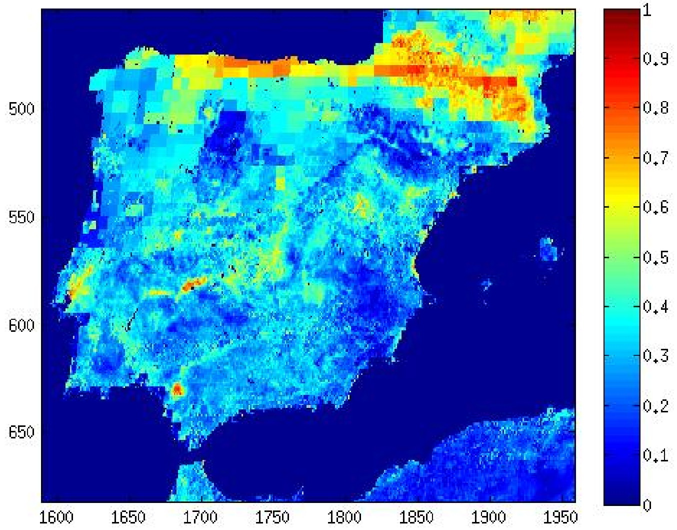

500
550
600
650
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


500
550
600
650
3
2.5
2
1.5
1
0.5

Background
decision
map

SSM – MSG LST


500
550
600
650
1600
1650
1700
1750
1800
1850
1900
1950
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0


500
550
600
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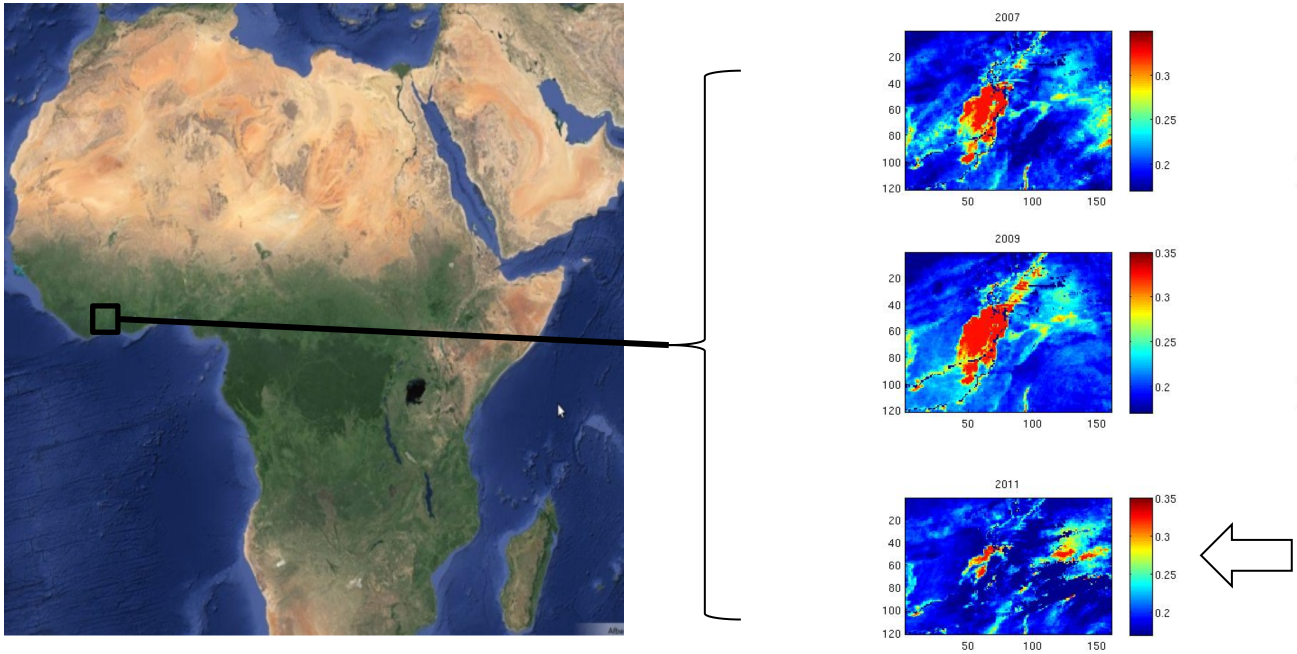
1600
1650
1700
1750
1800
1850
1900
1950
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

SSM
merged

On-going research activities (2012-2017)

- Step 2: assessment of SSM from LST derived heating rates

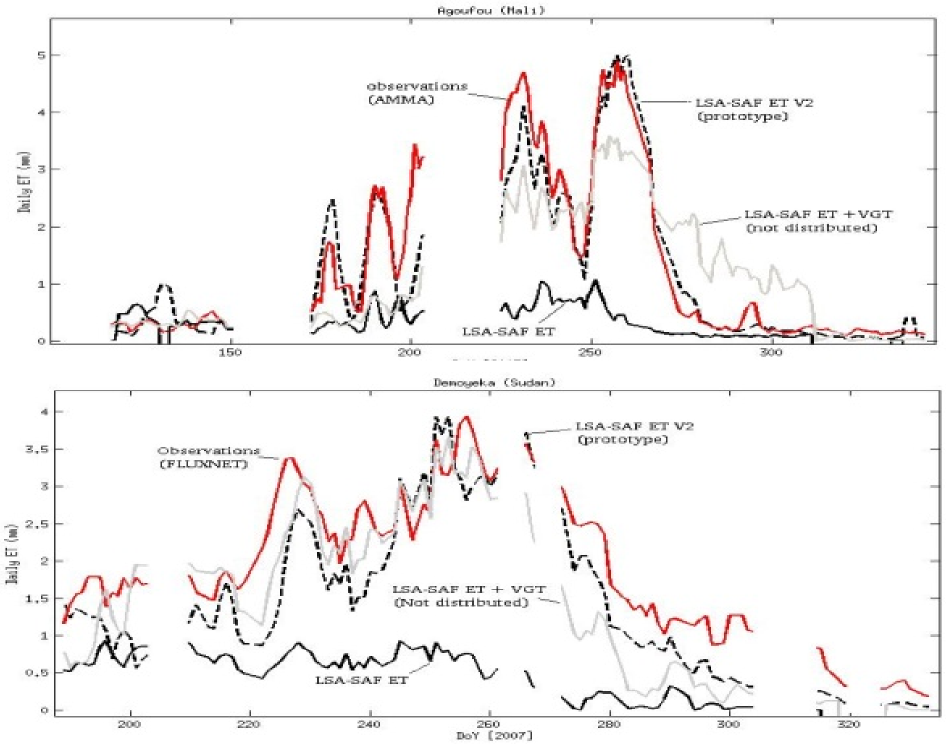
On the SM derived from LST, soil moisture patterns like annually wetlands extends/shrinks emerge as in this example over the Niger inner delta for the month of November from 2007 to 2011


2007
2008
2009
2010
2011
20
40
60
80
100
120
50
100
150
0.2
0.25
0.3
0.35

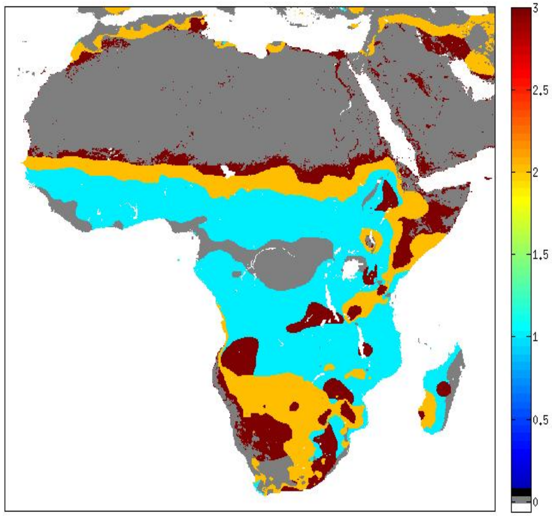
Detected drought in 2011

On-going research activities (2012-2017)

- Step2: assessment of SSM from LST derived heating rates



Background decision map

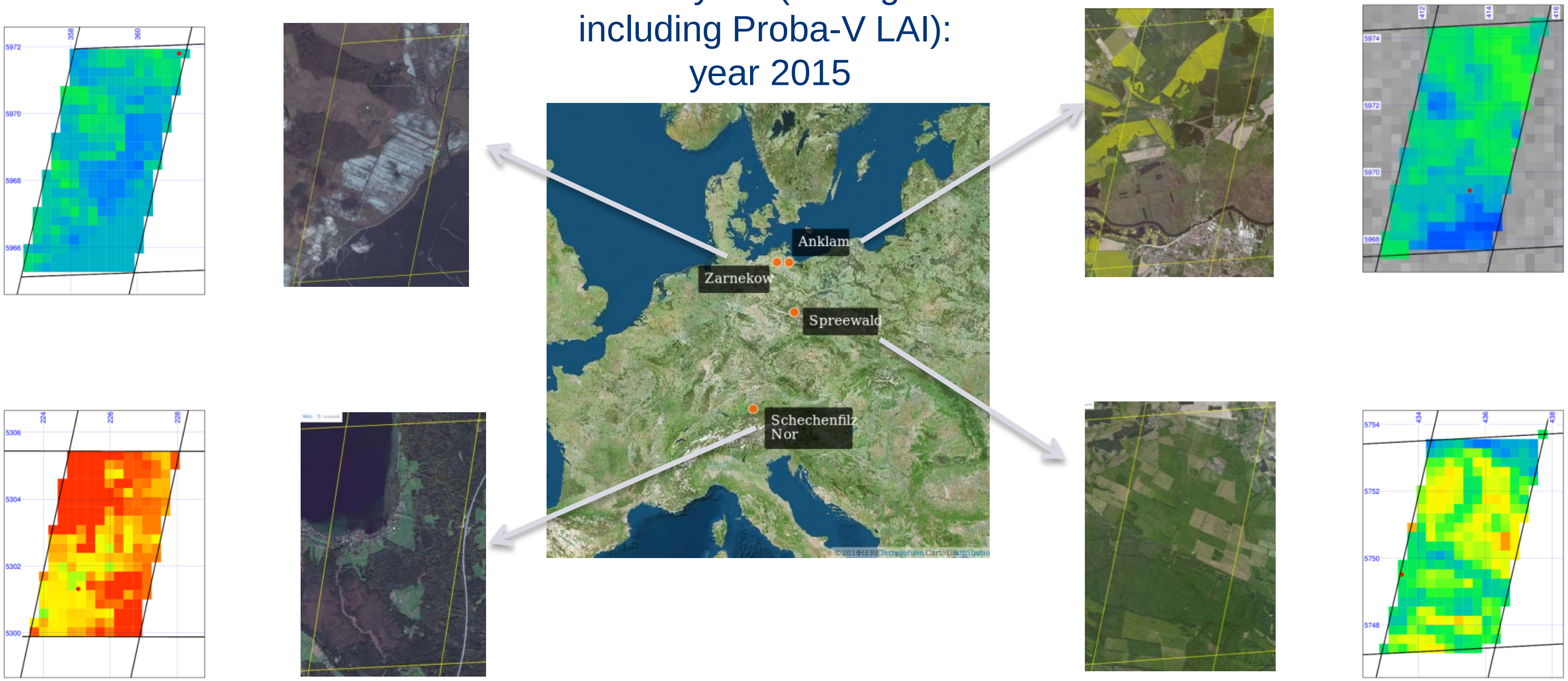


→improved performances using LST based SSM in Savannah.

On-going research activities (2012-2017)

- Other activities: through a combination of geostationary and polar satellites
  - Exploration of use of vegetation products direved from polar satellite

Daily ET (forcing including Proba-V LAI): year 2015



Case of wetlands:
An ongoing specific project (Belspo ‘HiWET project’, see http://hydr.squarespace.com/projecthiwet/) is dedicated to the study of ET in wetlands allowing to concentrate research on relationship between ET, vegetation characteristics and ecosystem health.

Plans for the next period (2017-2022)

- LSA-SAF CDOP3 phase (2017-2022)
  - Continuation of CDOP-2 on-going activities for MSG op. product
  - **Reprocessing of full MSG archive (from 2004)**
    - → homogeneous data set (request extensive validation)
    - Expected to be ready in 2020
  - **New developments for MTG FCI**
  - Publications and conferences
  - Collaboration with users and participation to trainings
- CM-SAF CDOP3 phase (2017-2022)
  - Development of new datasets (ET and surface fluxes) over the Meteosat archive (from 1983)
- Research continuation on ET based on EO with an increased spatial resolution
  - Investigation of visible, thermal and microwave based products from Proba-V and Sentinels satellites to derive ET.
- Developing new operational products (from 2017)
  - Participation to Copernicus Global Land Monitoring

Conclusions

- ET cannot be directly observed through EO;
- Nevertheless, satellite EO allows to characterize land surface variables able to improve ET modelling;
- Research is on-going at RMI since years to assess ET by assimilation of geostationary and polar EO data;
- Operational products are already available in the frame of LSA-SAF and are expected to be useful in a large set of applications including hydrology;
- Contact with users in encouraged in view to develop products fitted to their needs.

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Thanks for your attention !

Any questions ?