# How is L-Band sensing contributing to agricultural applications ?

**Ahmad AL Bitar**

CNRS / CESBIO

with contributions from Marie Parrens, Sat K. Tomer, Olivier Merlin, Christophe Suer, Jeremy Guillerm

partners from ECOLAB, CESBIO, IGE, CNES, APAAH innovation.

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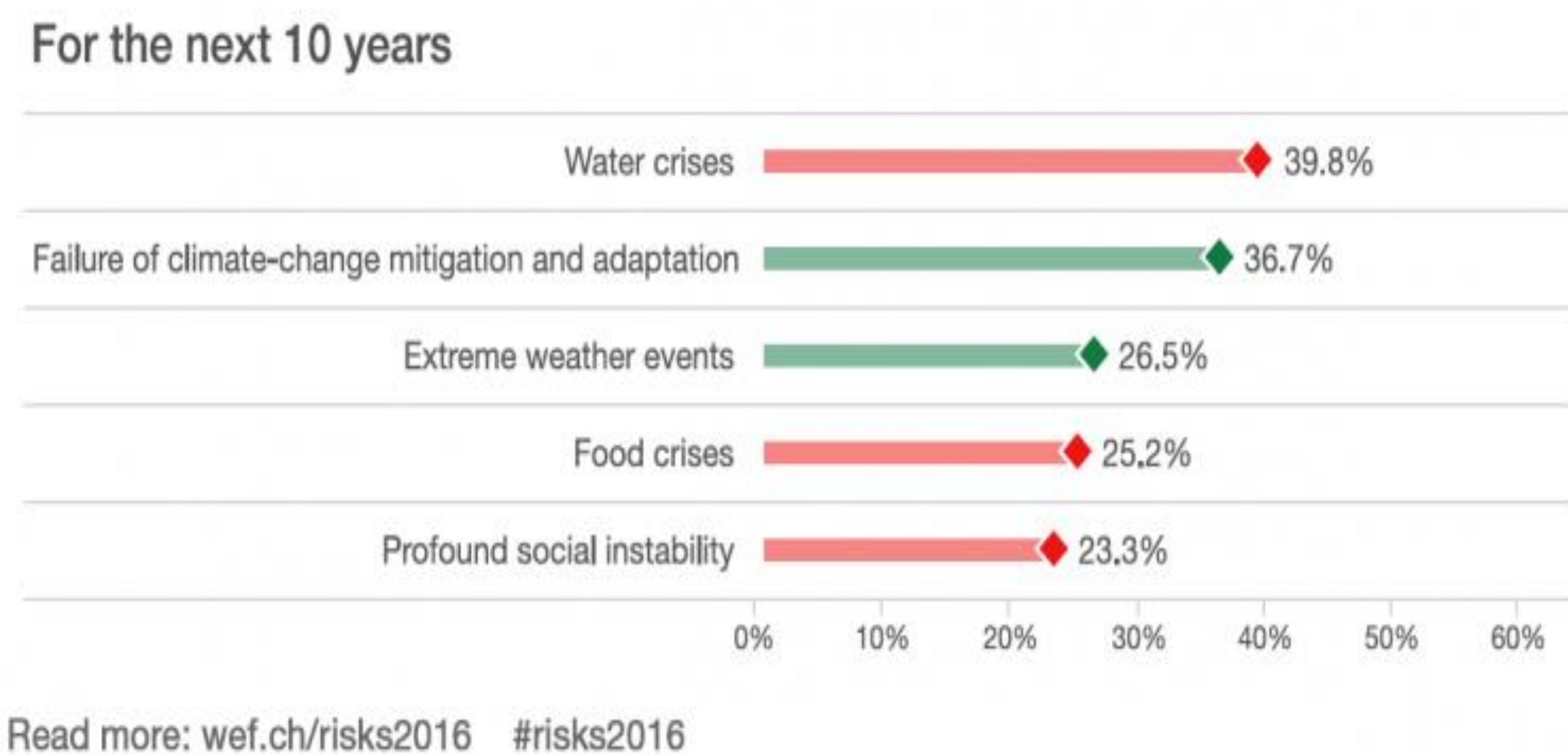
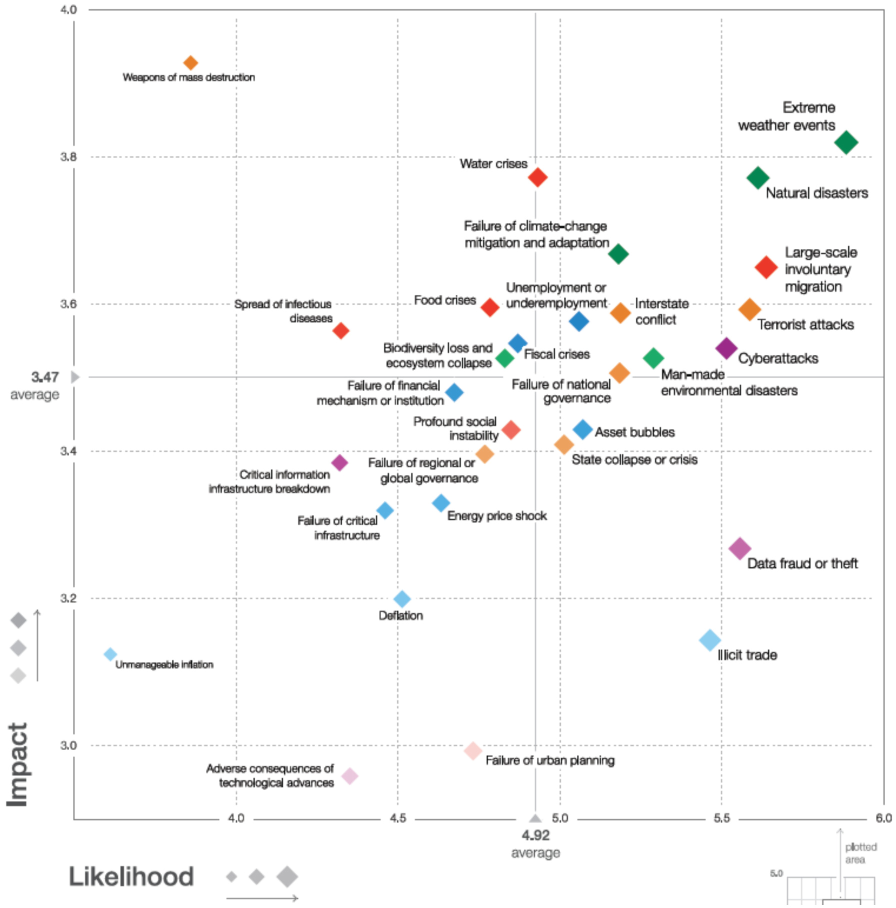
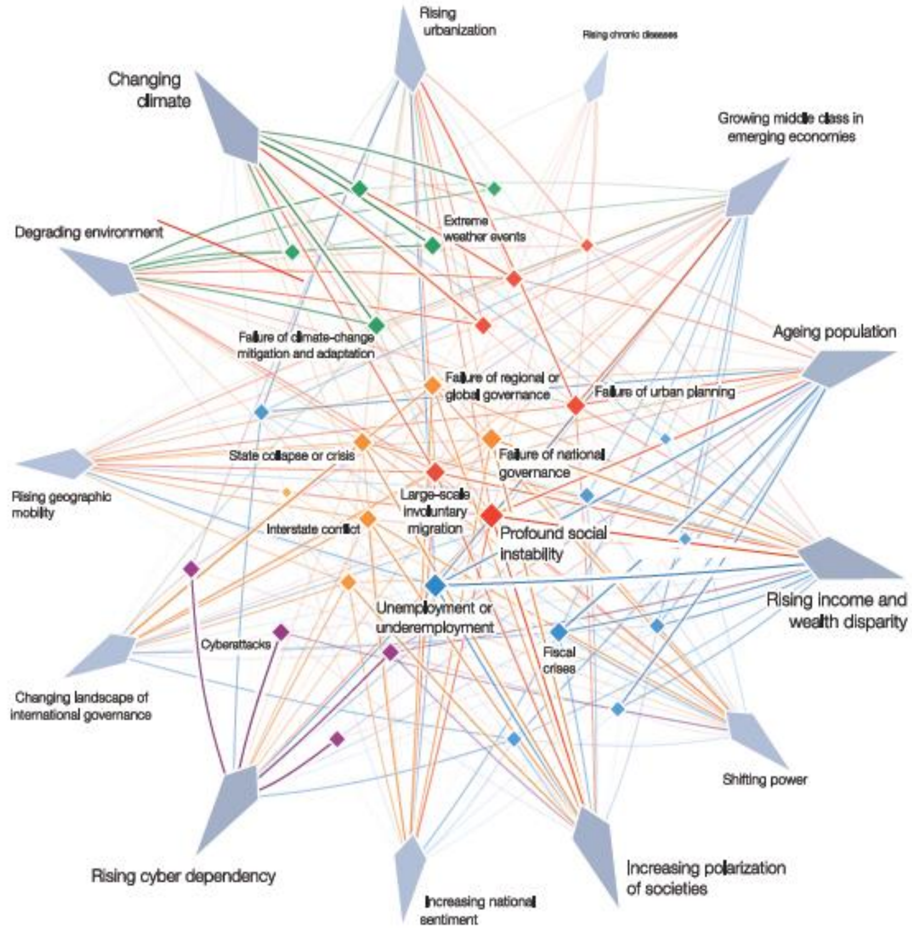
World Economic Forum - Global Risks Perception Survey



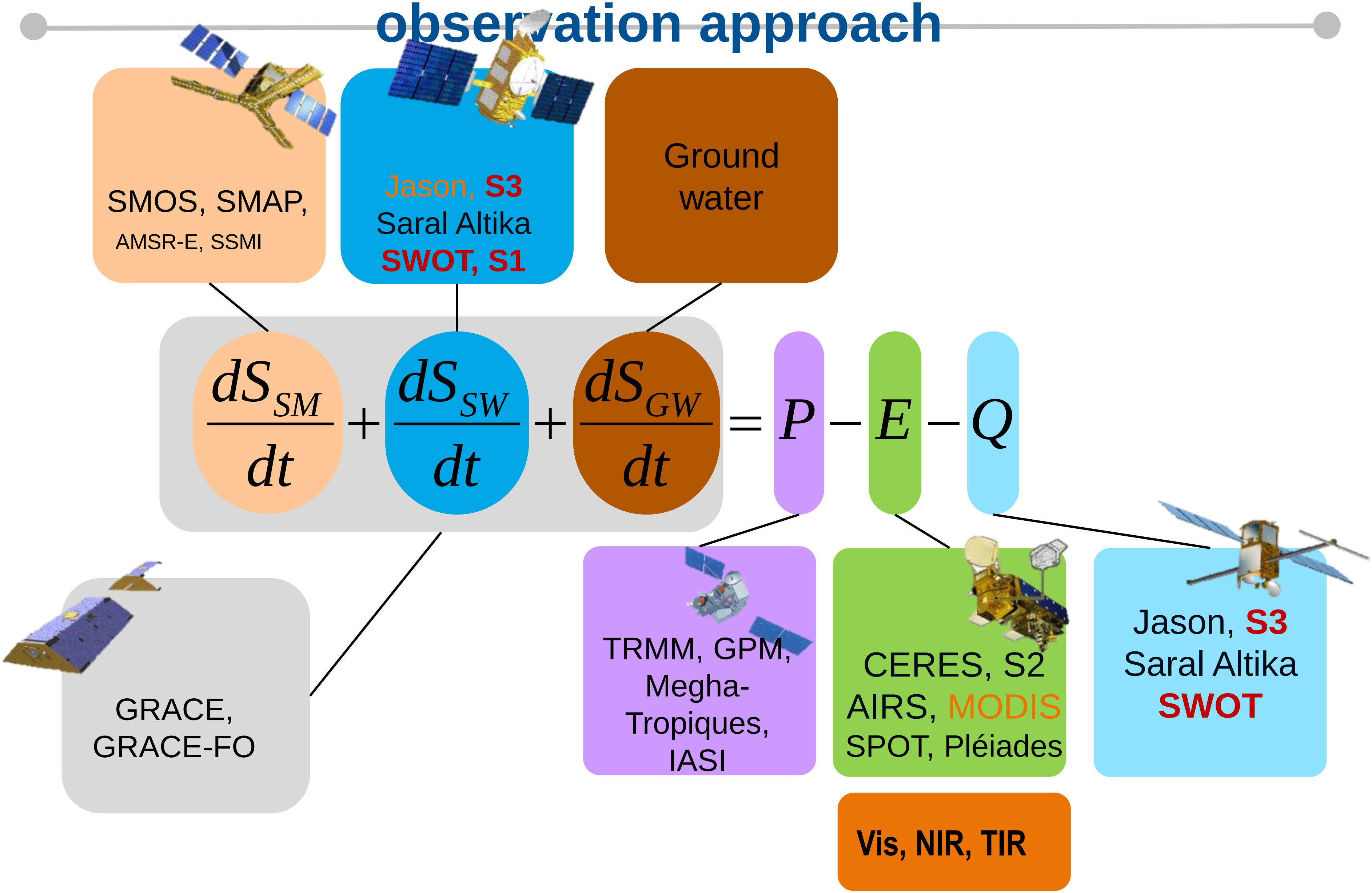

Agricultural sector uses 70-80% of the total extracted water ressources

# The situation in 2017 from WEF report



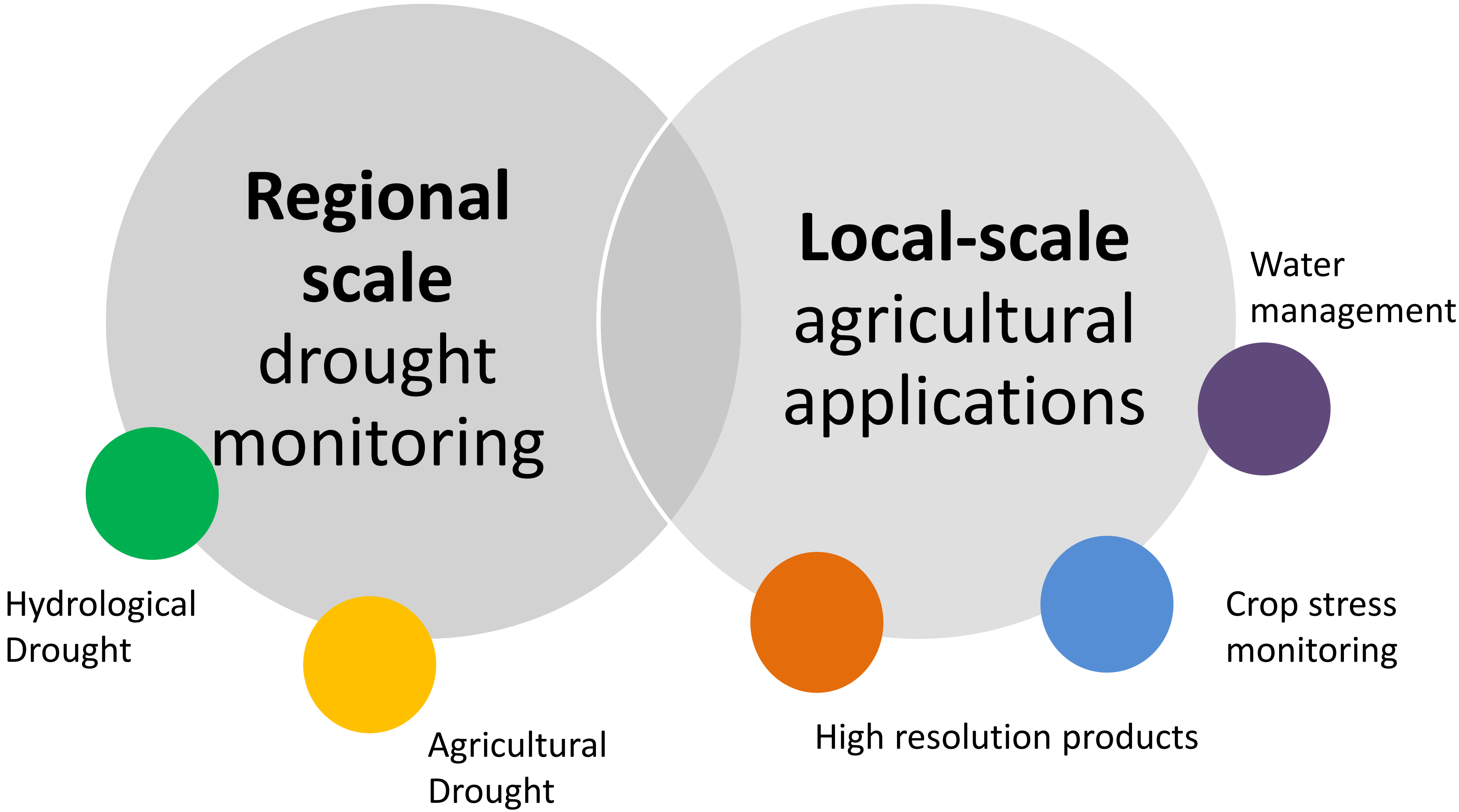



# Hydrology in the context of Earth System observation approach

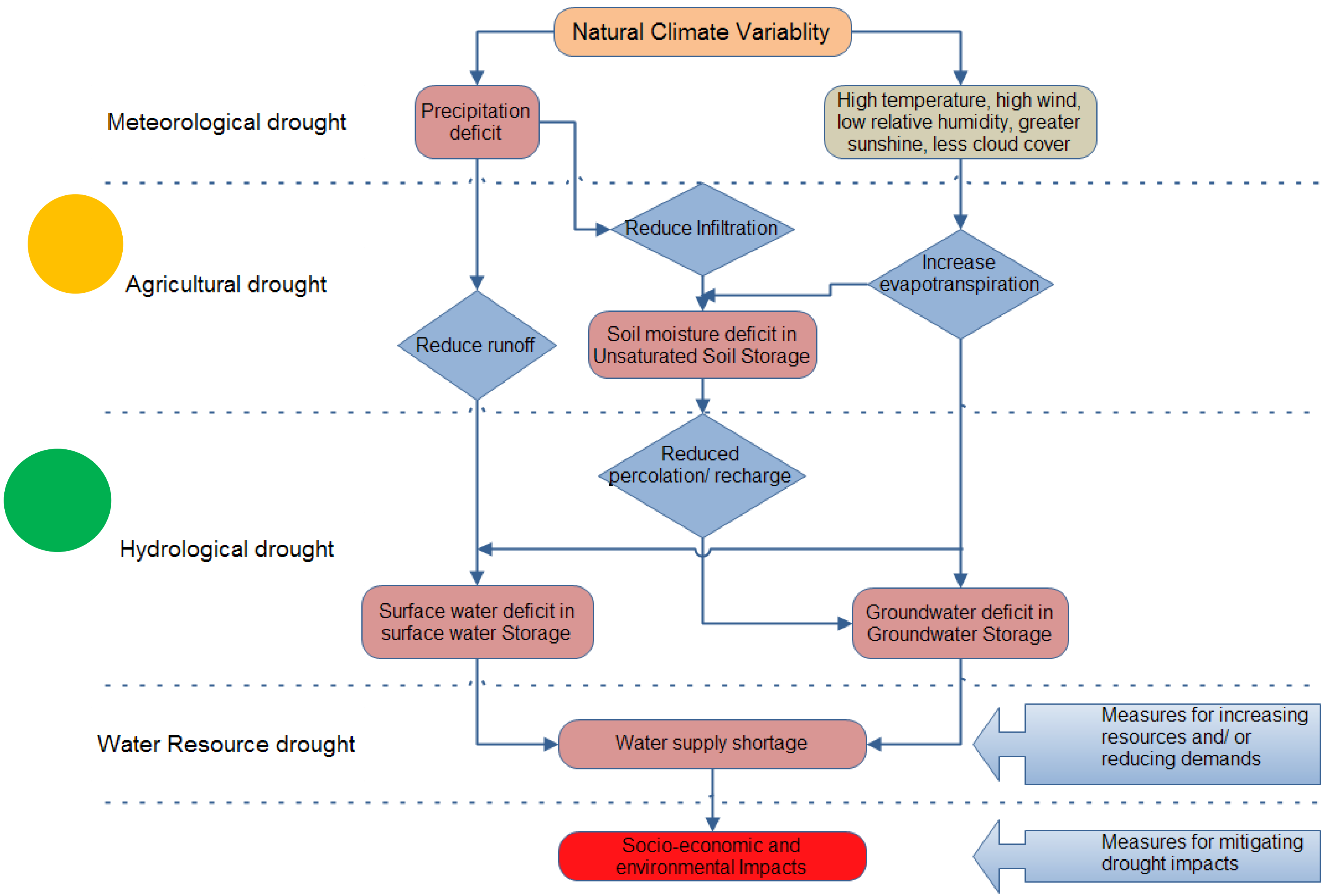



Not all components are observed at the desired resolution and accuracy

# Outline

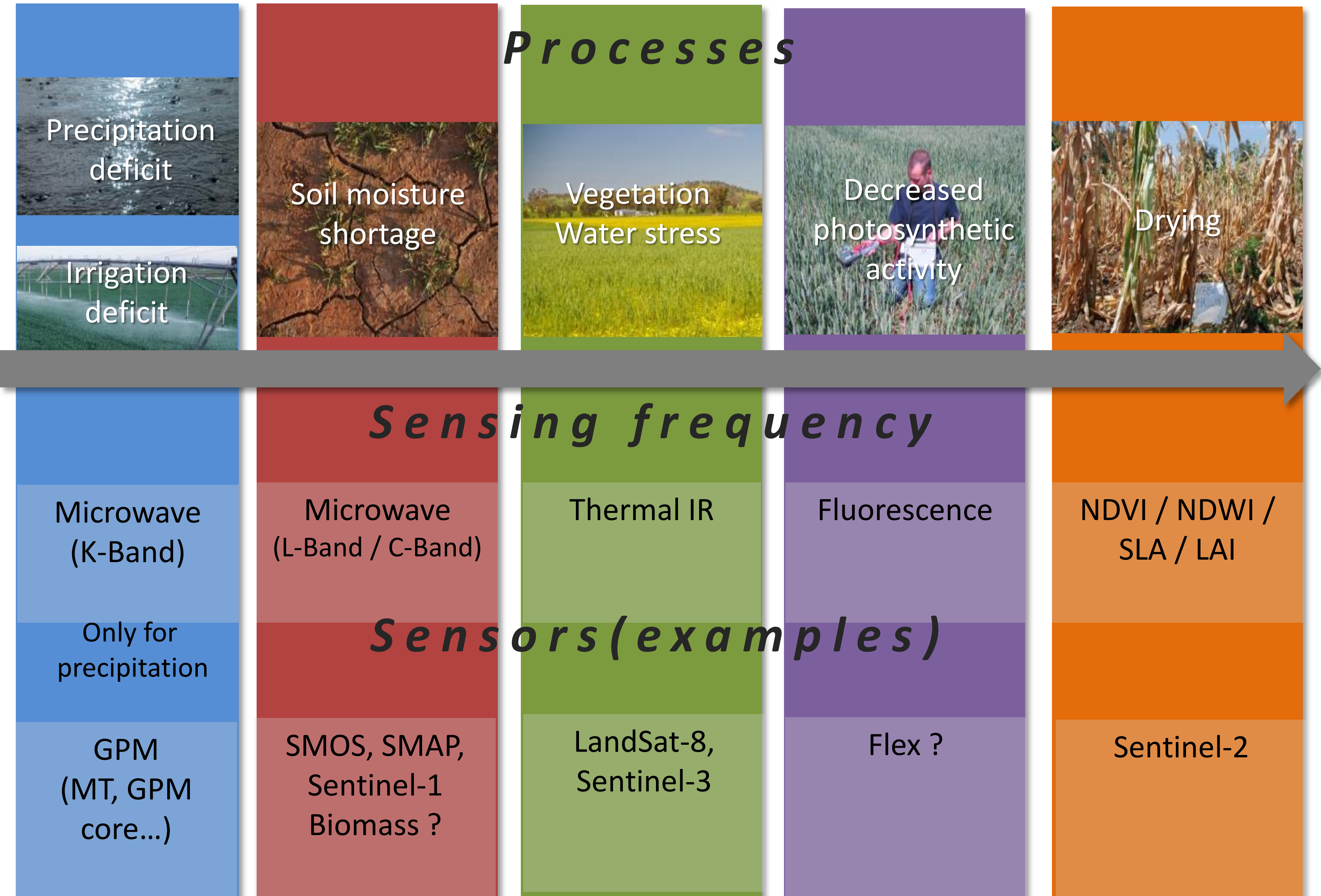

Regional scale drought monitoring
Local-scale agricultural applications
Water management
Hydrological Drought
Agricultural Drought
High resolution products
Crop stress monitoring

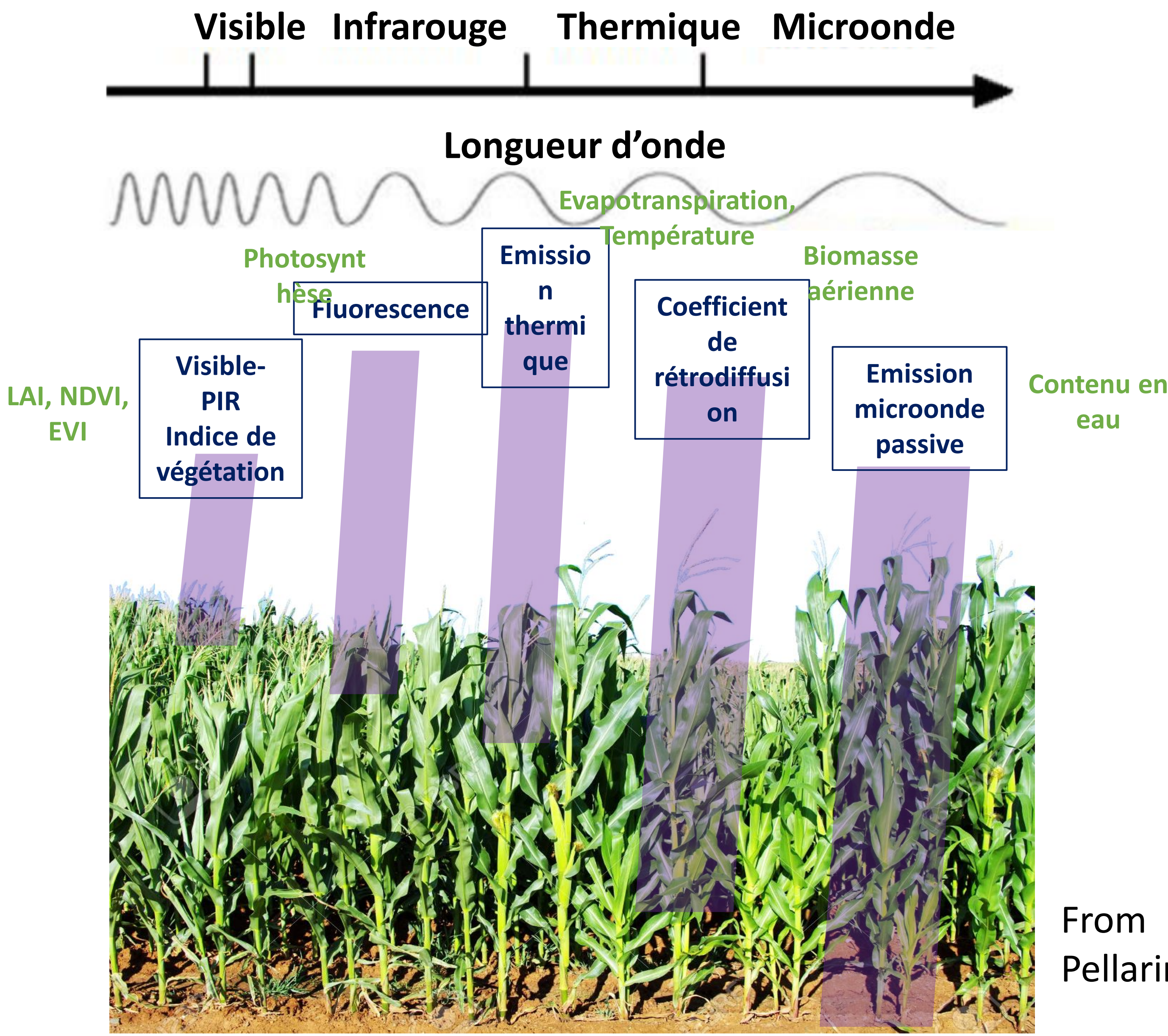
# Types of drought




Adapted from Types of drought
Source: Cullmann Adopted from National Drought Mitigation Centre, and G. Rossi, B. Bonaccorso, A. Cancelliere, (2003)

# Stages of agricultural drought





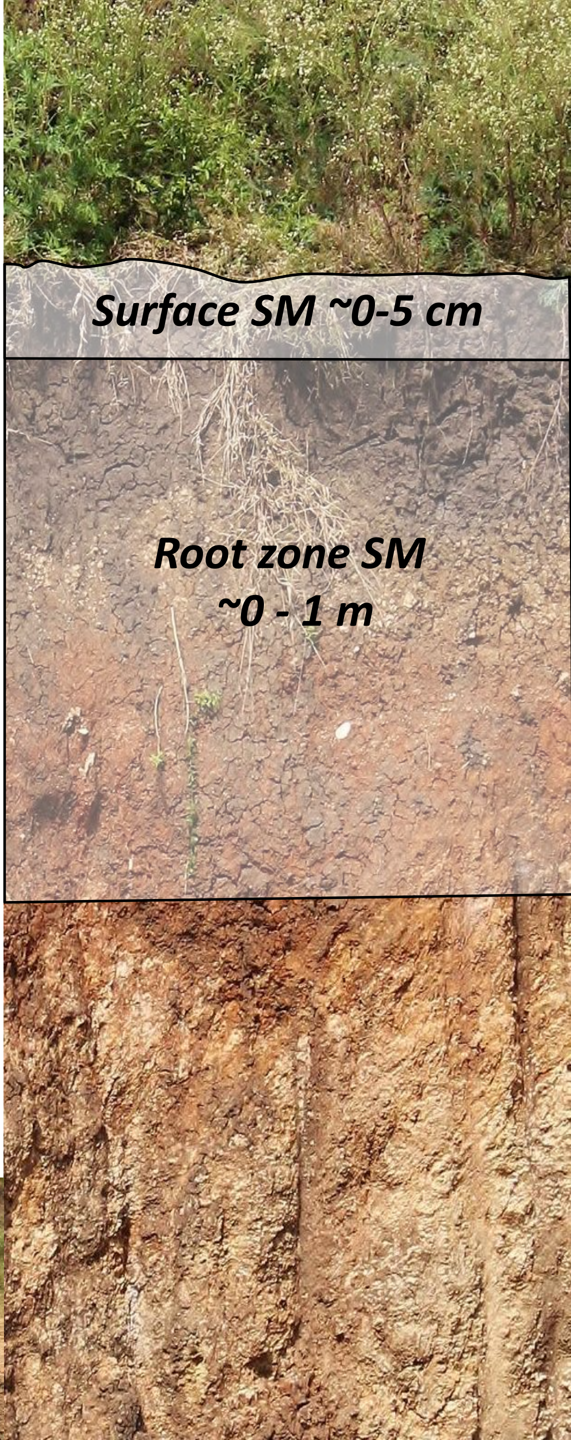

From
Pellarin T. 2017

# Root zone soil moisture

**Root zone soil moisture** is a very usefull information to access agricultural drought in an **early warning system**

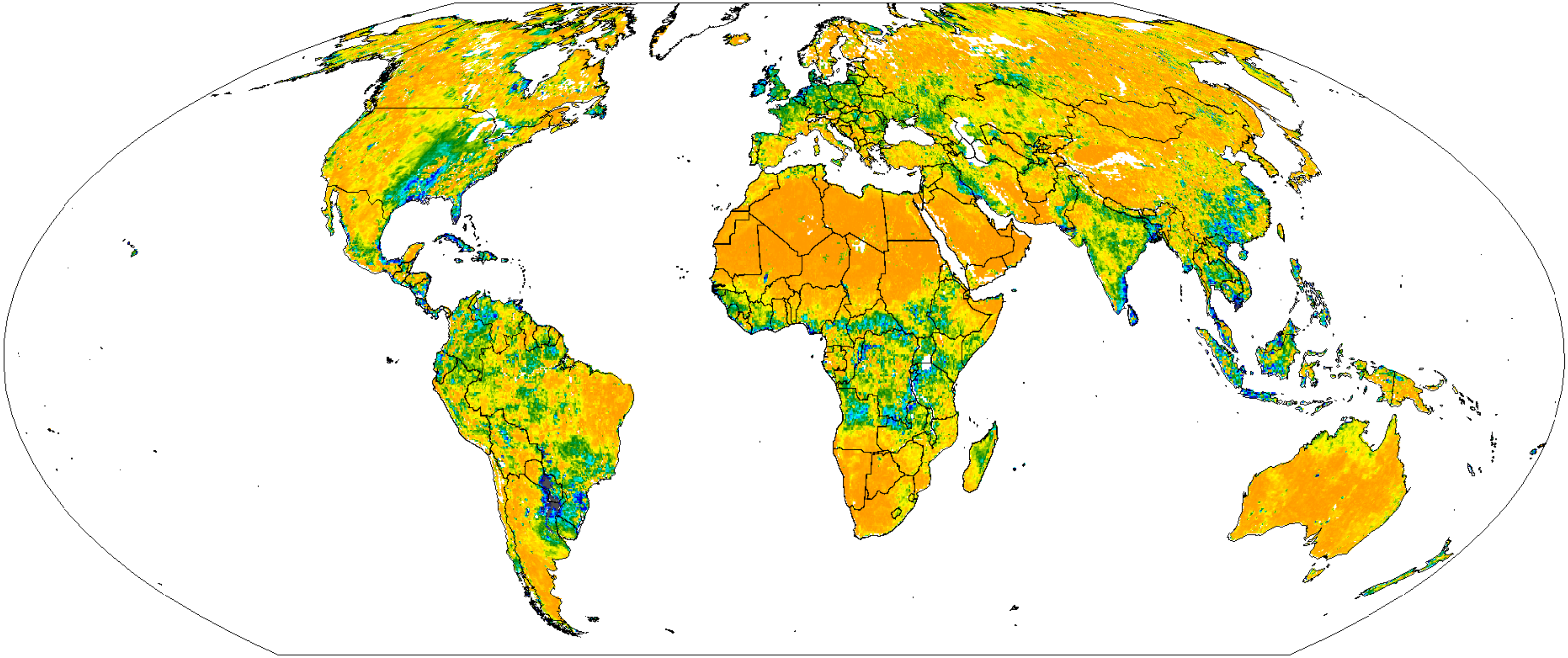
SMOS measures surface soil moisture, root zone soil moisture need to be modeled

At CESBIO **SMOS surface soil moisture** and MODIS LAI are assimilated into a double bucket model to compute **root zone soil moisture**.
(Al Bitar et al. 2013, Kerr et al. 2016)




# SMOS global root zone soil moisture maps

May 2016



Al Bitar et al., 2013, Kerr et al. 2016

available on www.catds.fr

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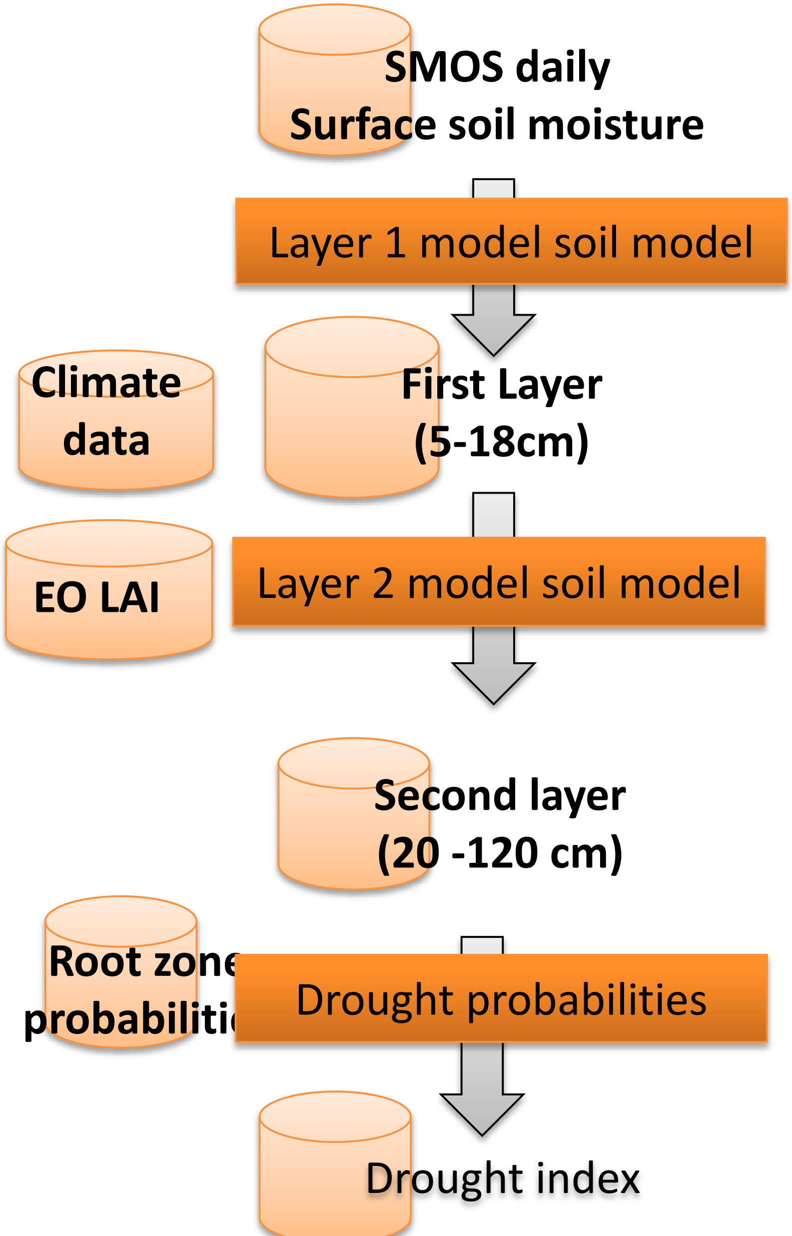
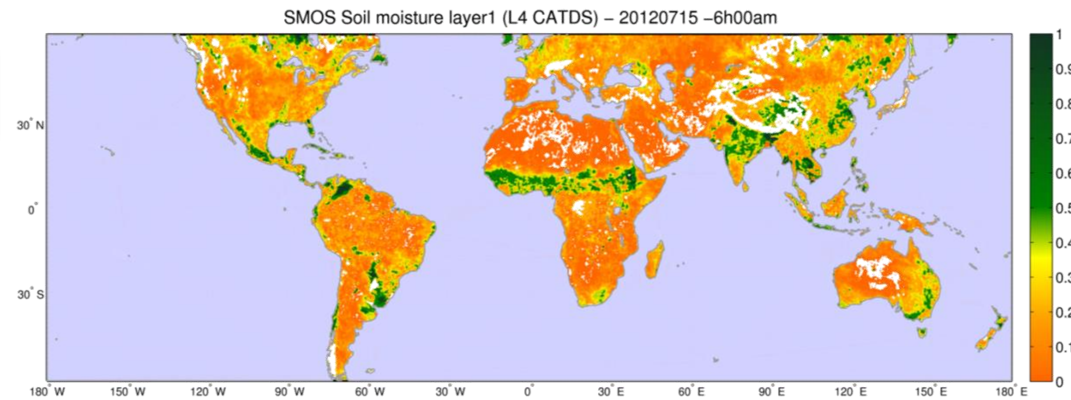
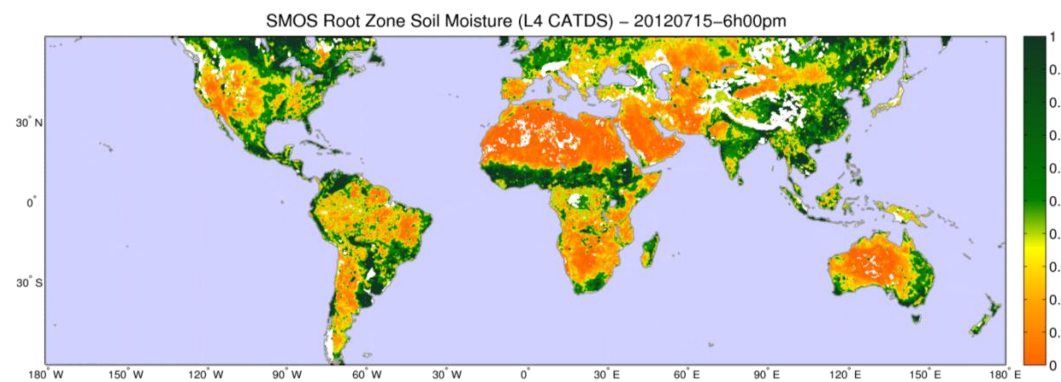
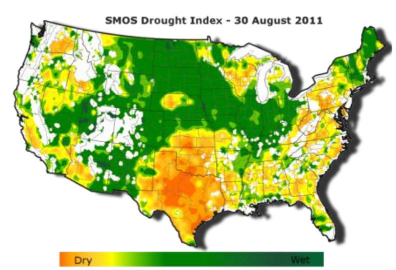
# The approach




web application
+
Netcdf products :
EASE grid 25km

Al Bitar et al., 2013

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# SMOS L3 products

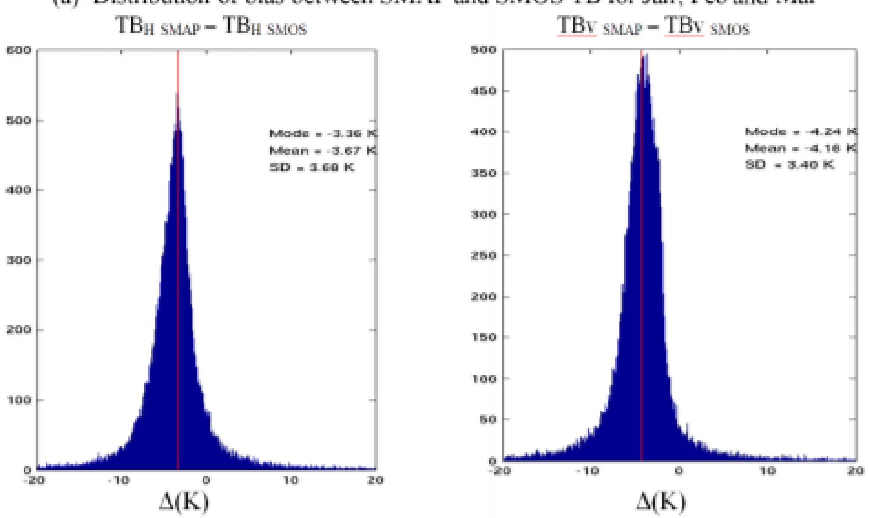
Earth Syst. Sci. Data, 9, 293–315, 2017
https://doi.org/10.5194/essd-9-293-2017


Open Access
Earth System Science Data

## The global SMOS Level 3 daily soil moisture and brightness temperature maps

Ahmad Al Bitar[1,2], Arnaud Mialon[1,2], Yann H. Kerr[1,3], François Cabot[1,3], Philippe Richaume[1], Elsa Jacquette[3], Arnaud Quesney[4], Ali Mahmoodi[1], Stéphane Tarot[5], Marie Parrens[1], Amen Al-Yaari[6], Thierry Pellarin[7], Nemesio Rodriguez-Fernandez[1], and Jean-Pierre Wigneron[6]

(a) Distribution of bias between SMAP and SMOS TB for Jan, Feb and Mar



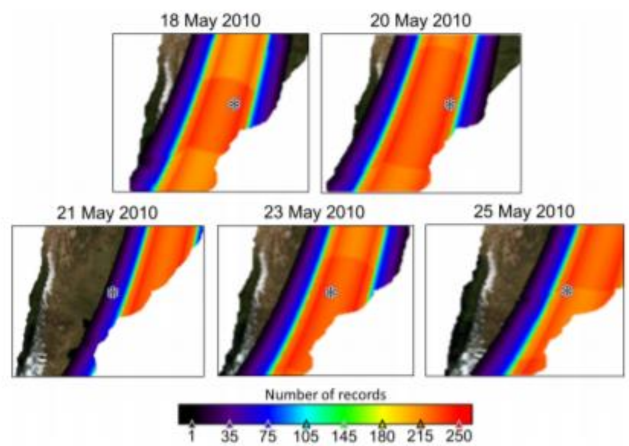
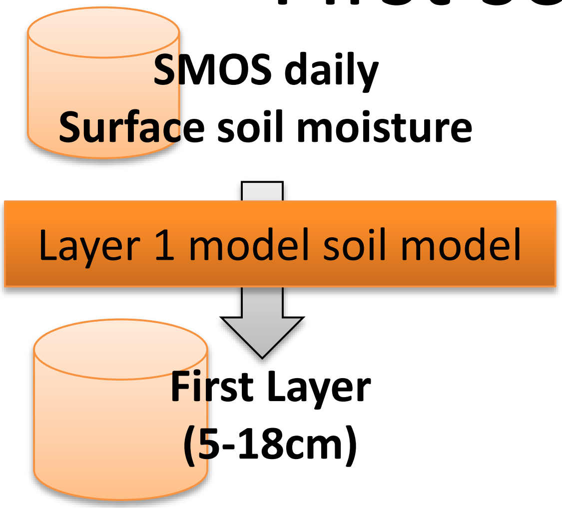
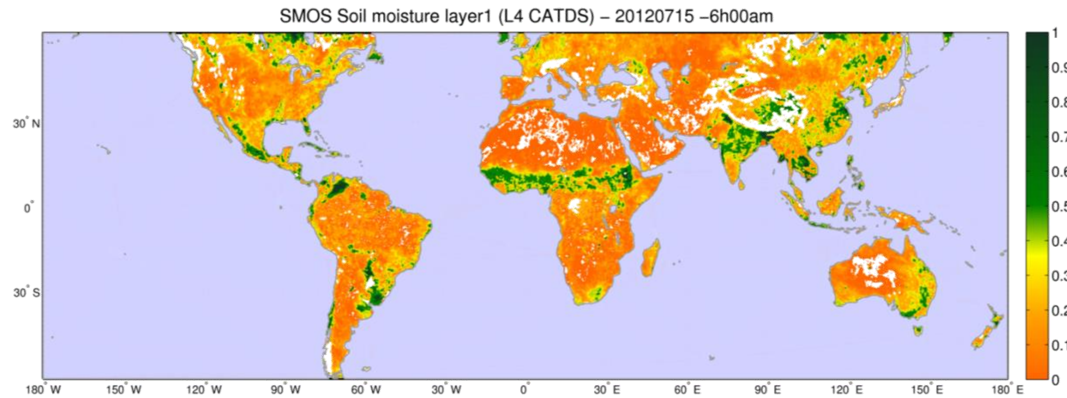




**Figure 1.** Number of TB records across the swath for a period of 8 days – from 18 to 25 May 2010 – over the area of La Plata, Argentina.

(Al Bitar et al., ESSD, 2017)

# First soil layer model




(Al bitar et al. 2017 ESSD
Kerr et al. TBD, 2013)

## from surface to ~20 cm

sequential formulation of the exponential filter

Based on Albergel et al. (2006)

**But doesn't take into account the capillary effect (interaction between the different layers) and vegetation transpiration**

Al Bitar et al., 2013

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# Second layer model: 20cm – 1.5 m

Theta based Richards Equation

$$\frac{\partial \theta(h,\mathbf{x})}{\partial t} - T = \nabla.\left[\mathbf{K}\ \nabla h\right] - \nabla.\left[\mathbf{K}\ \mathbf{g}_B\right]$$

h : capilary pressure in (m)

Θ : water content ( m3/m-3

K : hydraulique conductivity (m/s)

g : unit gravity vertor

T : vegetation transpiration ($m^3/m^3/s$)

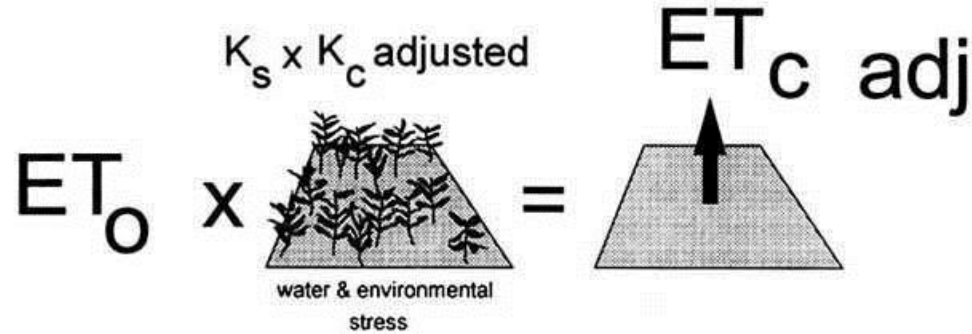
A linearized (force restore) formulation is used

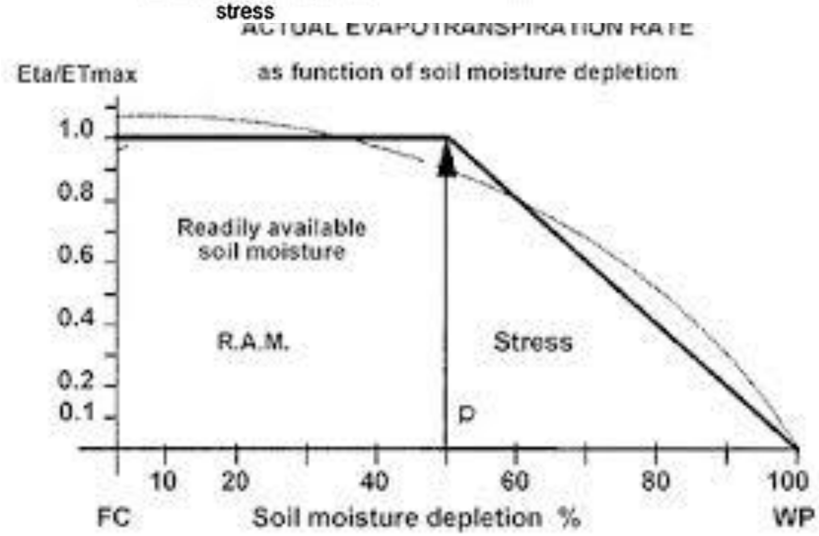
# Vegetation transpiration model (T)

T : Transpiration of the vegetation ($m^3/j$)

computed using FAO-56 method forced by NDVI
and air temperature

Kcb=a exp (b. NDVI)
adapted from Er-Raki et al. (2010)

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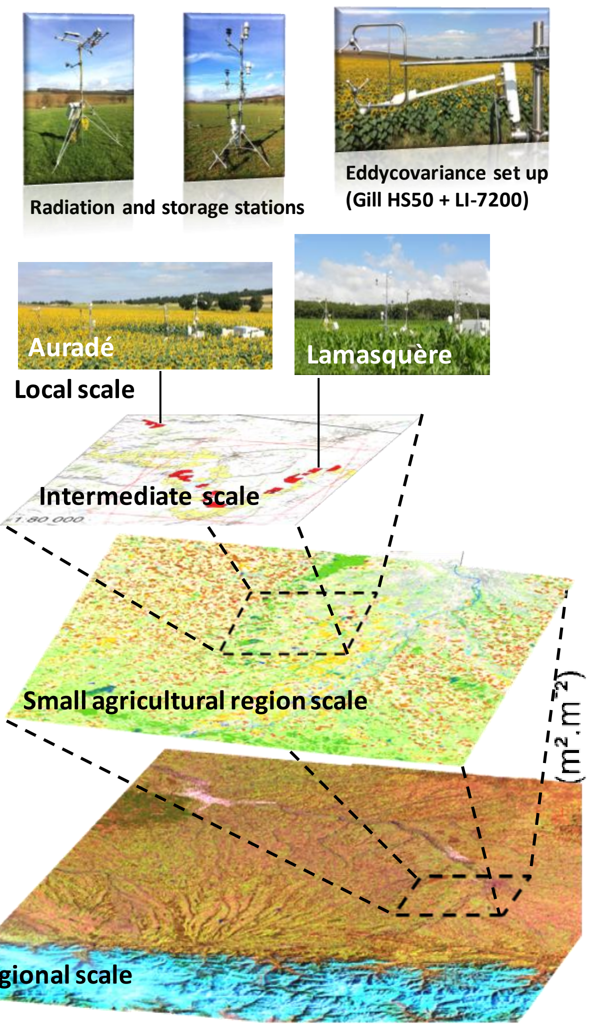
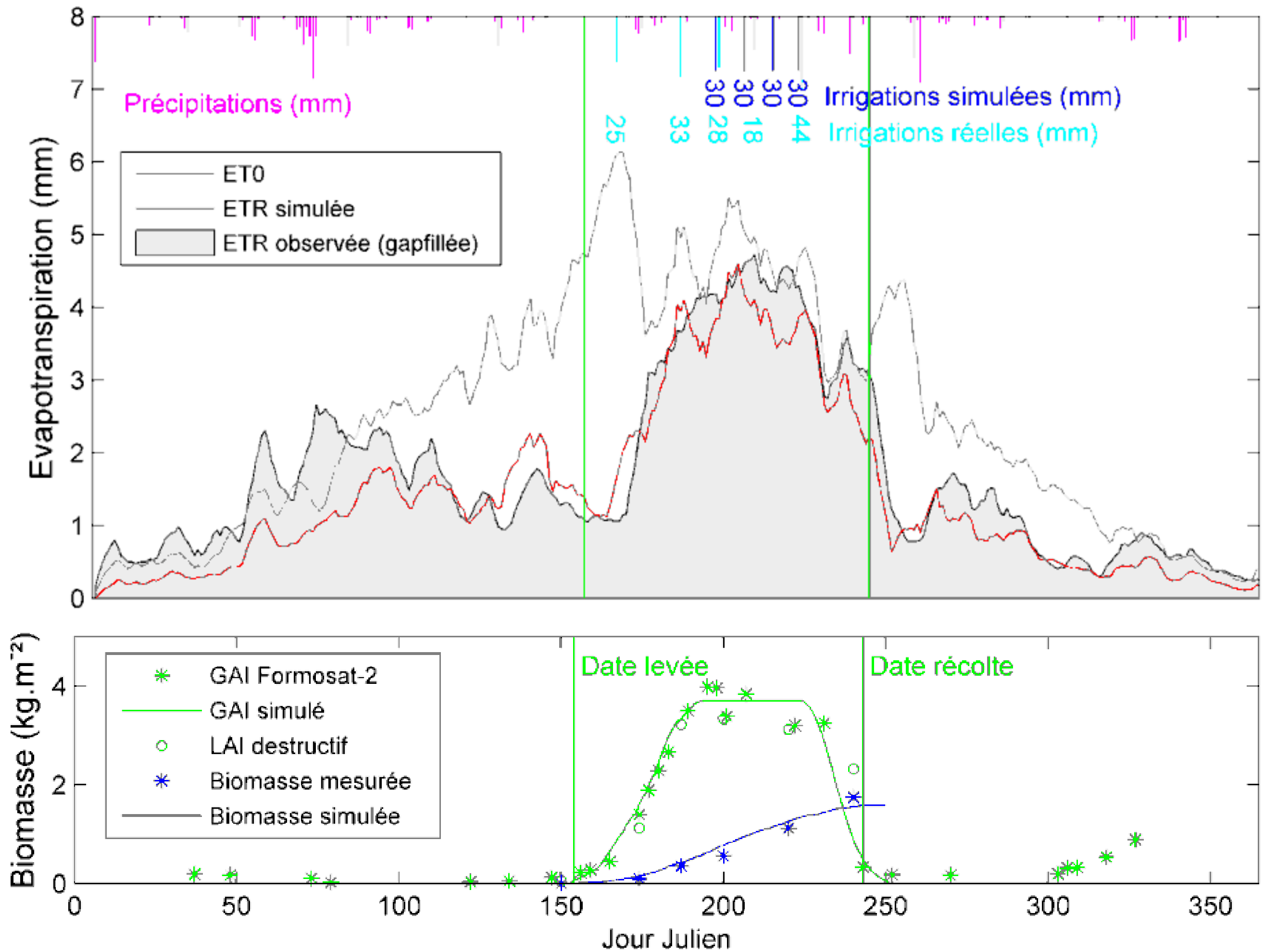
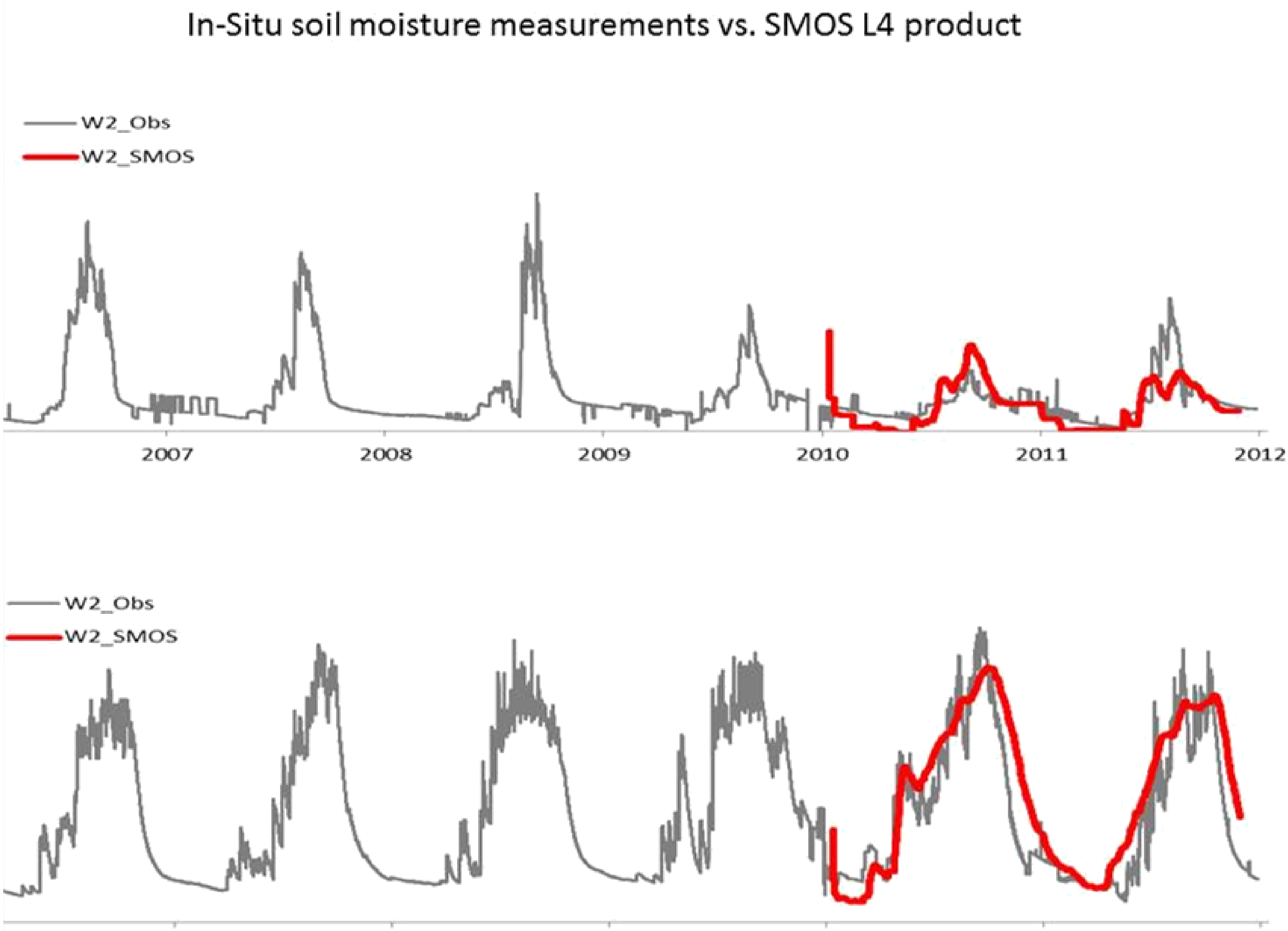
# Why are we using the remote sensing driven FAO approach ?




(Battude, Al Bitar et al. AWM 2017)

# Validation over AMMA sites (Benin and Niger)




Pellarin, T., de Rosnay, P., Albergel, C., Abdalla, S., & Al Bitar, A. H-SAF Visiting Scientist Program HSAF_CDOP2_VS12_02, 2013.

# Comparision to root zone products

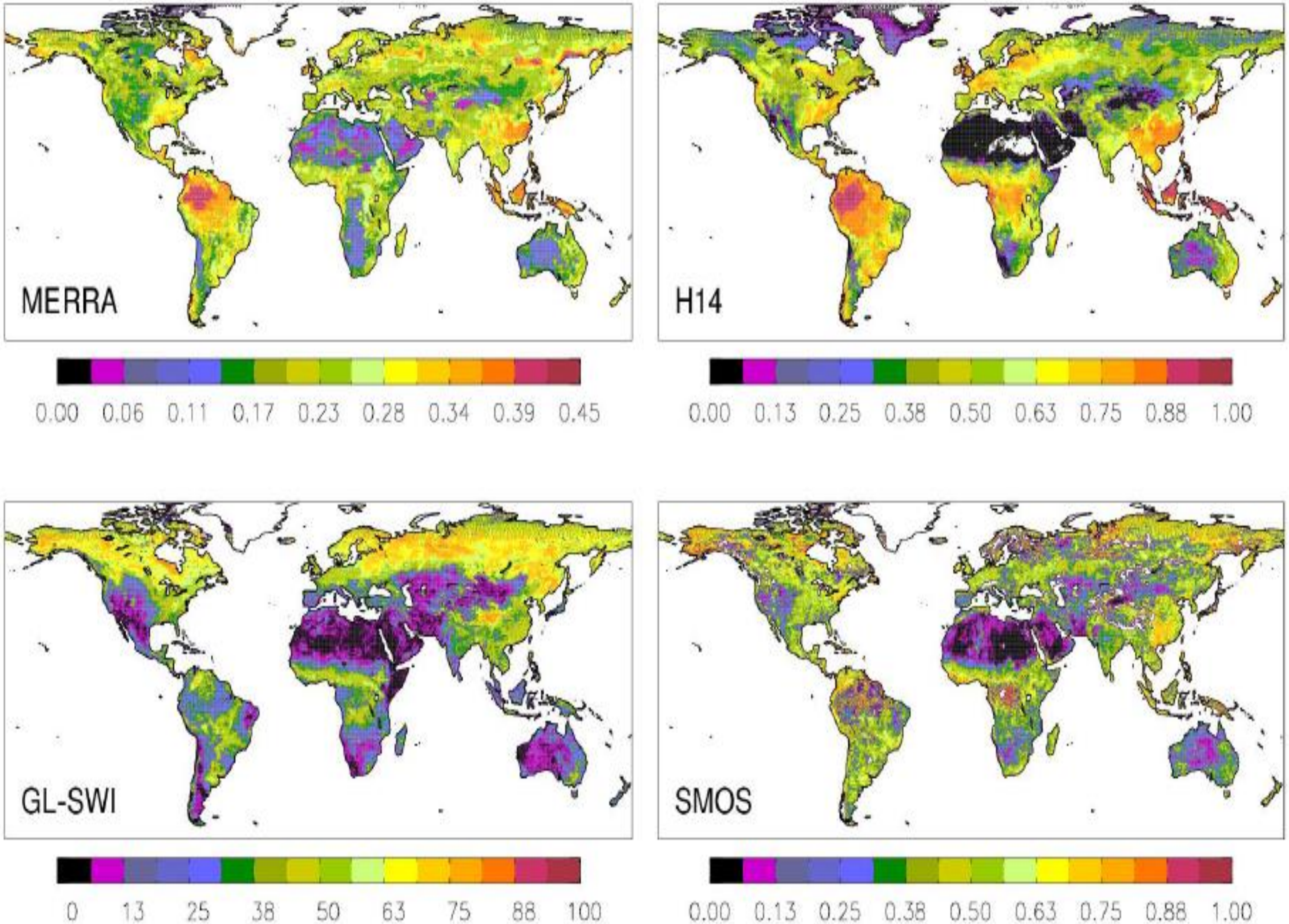
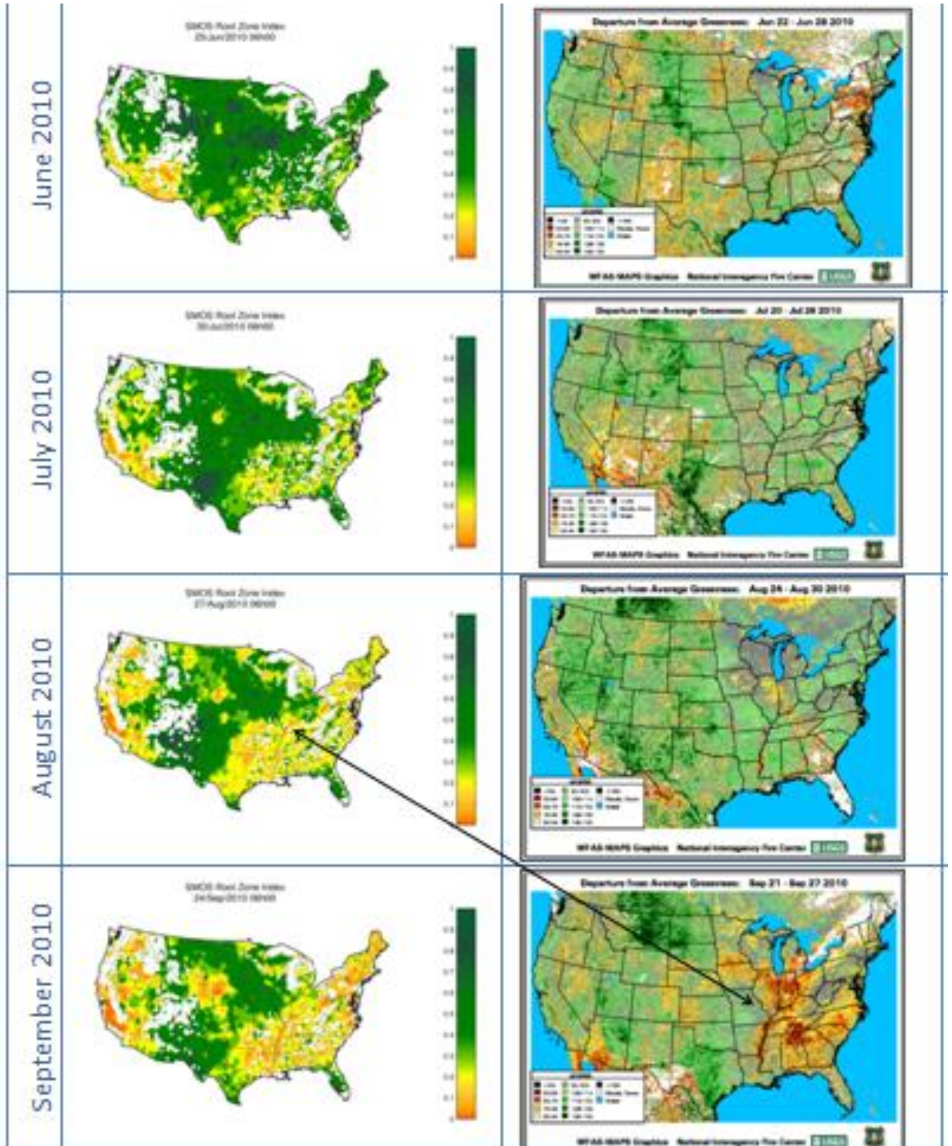



*Figure 1: Annual mean root-zone soil moisture maps for MERRA, H14, GL-SWI and SMOS.*

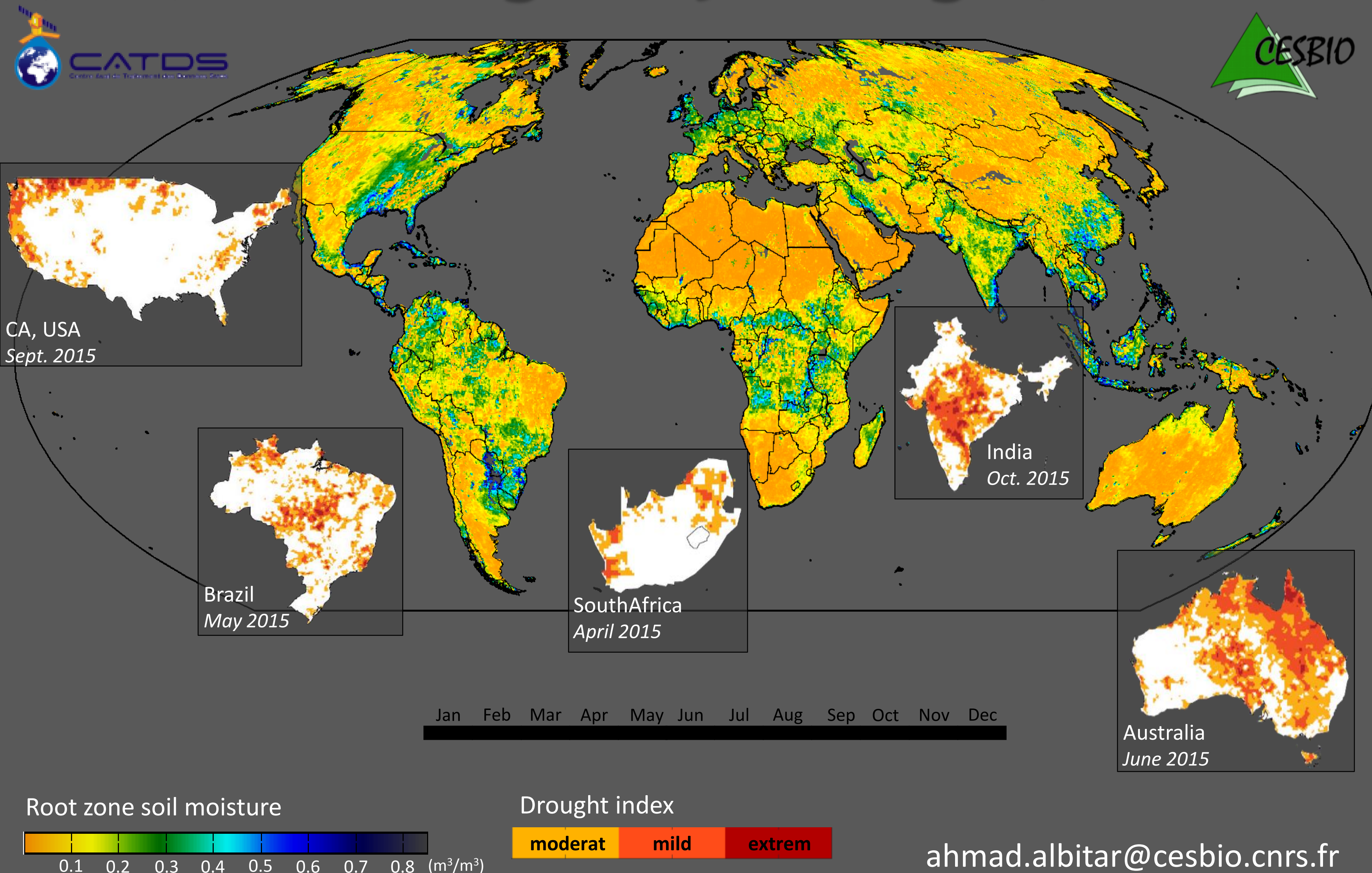
Pellarin, T., de Rosnay, P., Albergel, C., Abdalla, S., & Al Bitar, A. H-SAF Visiting Scientist Program HSAF_CDOP2_VS12_02, 2013.

# Vegetation and Root zone soil moisture

SMOS Drought Index AVHRR NDVI



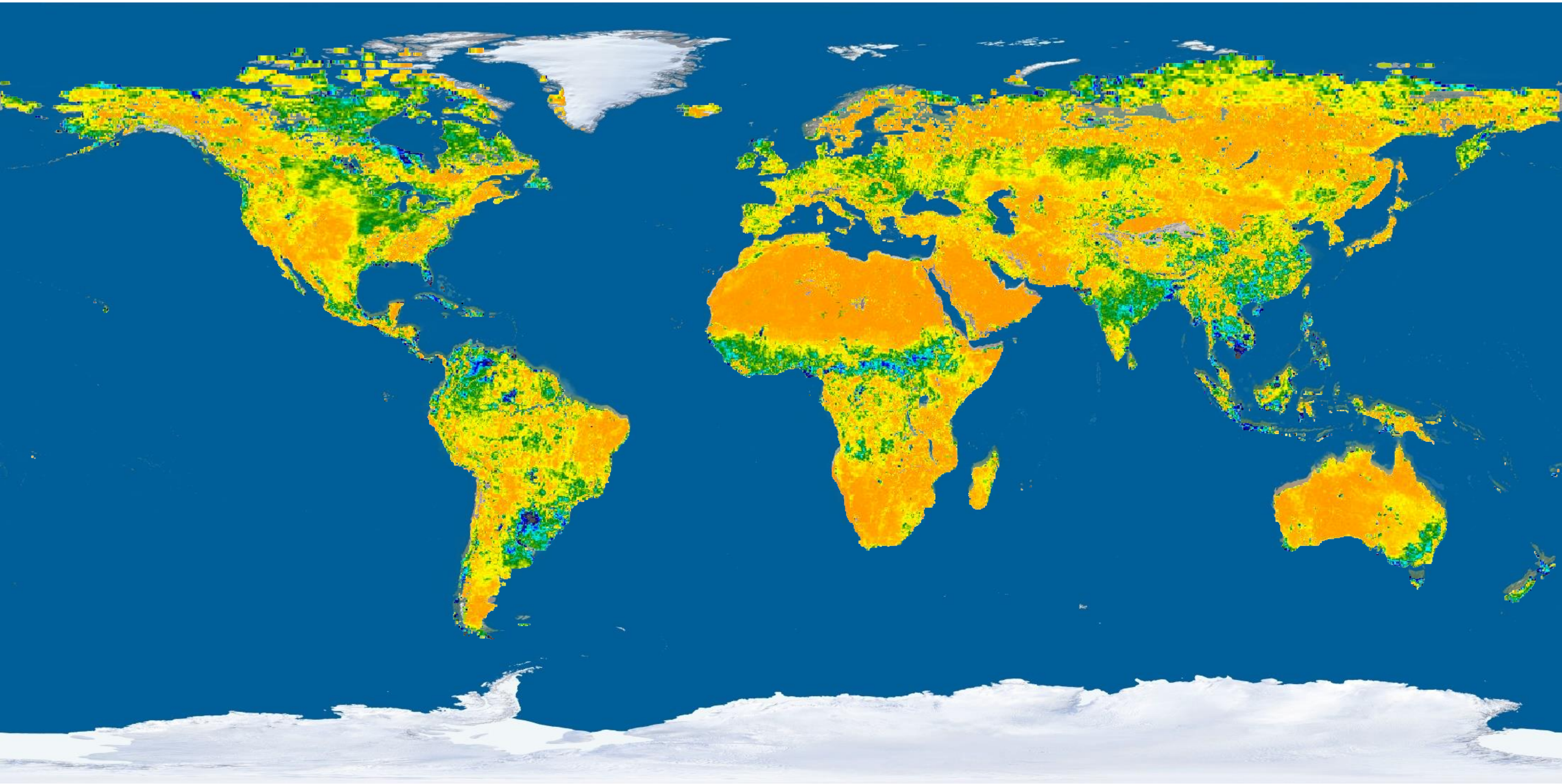
# SMOS monitoring 5 major droughts in 2015




ahmad.albitar@cesbio.cnrs.fr

# Root zone soil moisture in 2016

Feb. / May / Aug. / Nov/ 2016



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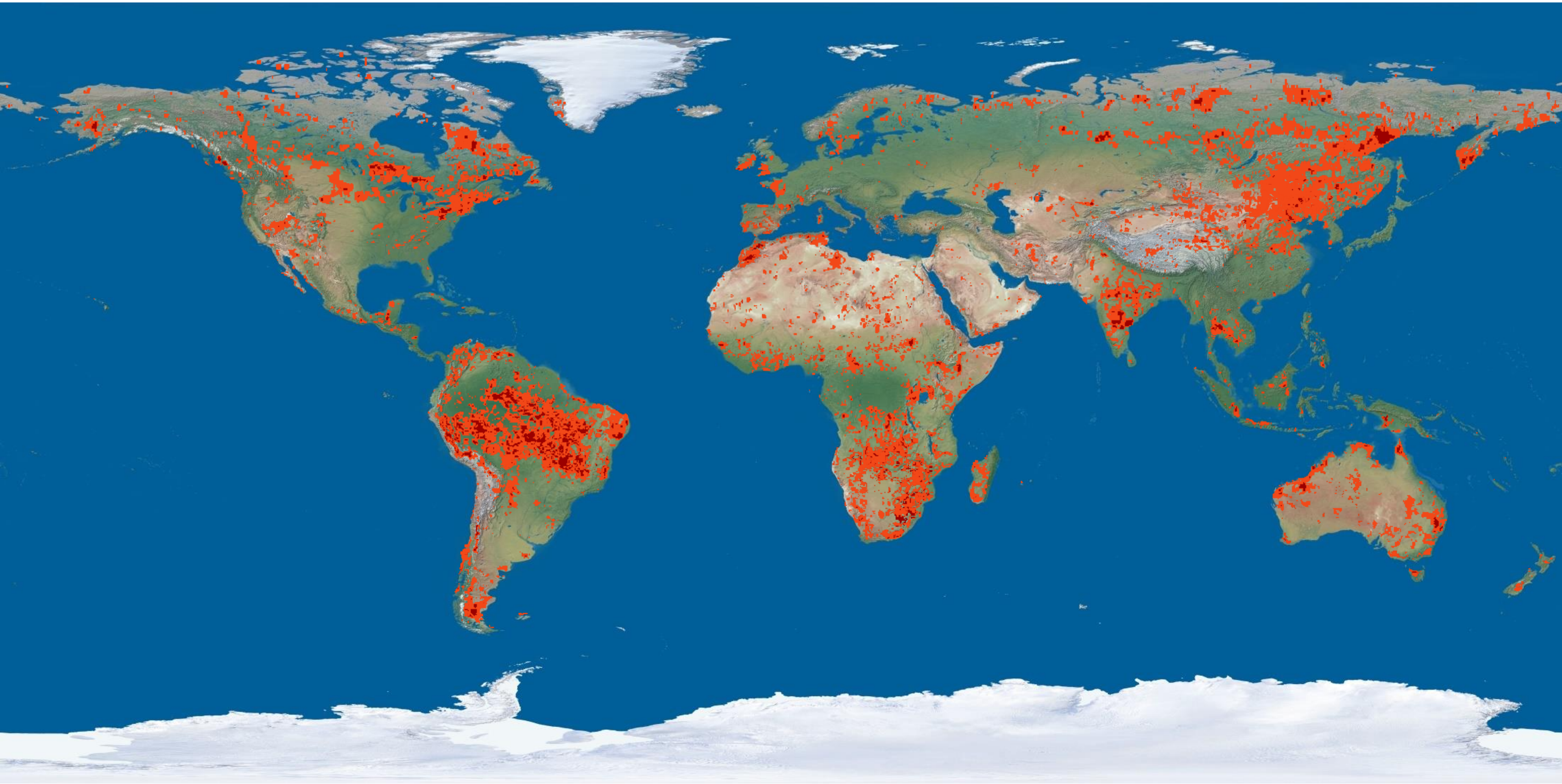
Droughts from Root zone soil moisture anomalies 2016

Feb. / May / Aug. / Nov/ 2016



What is looming a world food crises because of prolonged drought conditions, that can be driven from socio-climatique situations.

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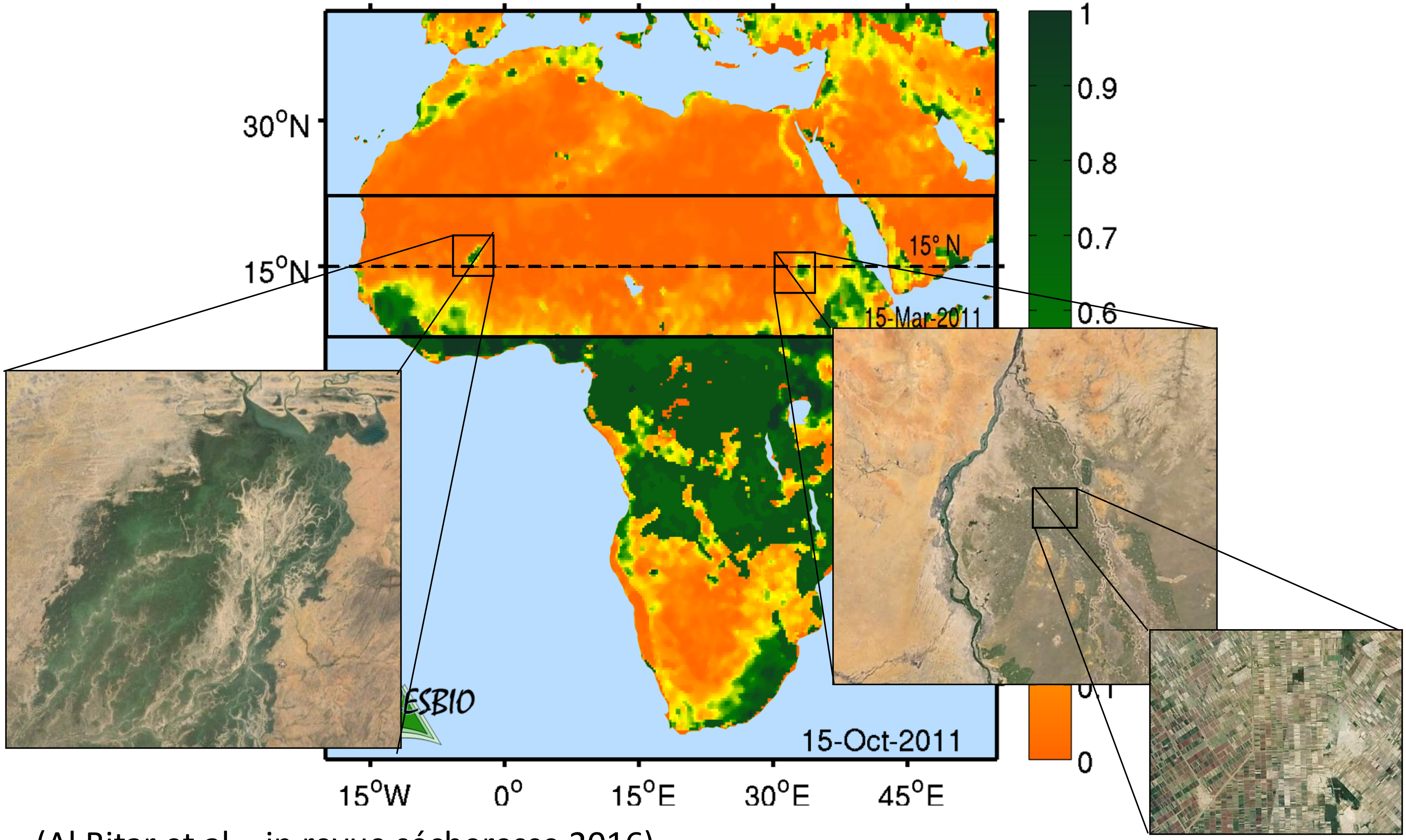
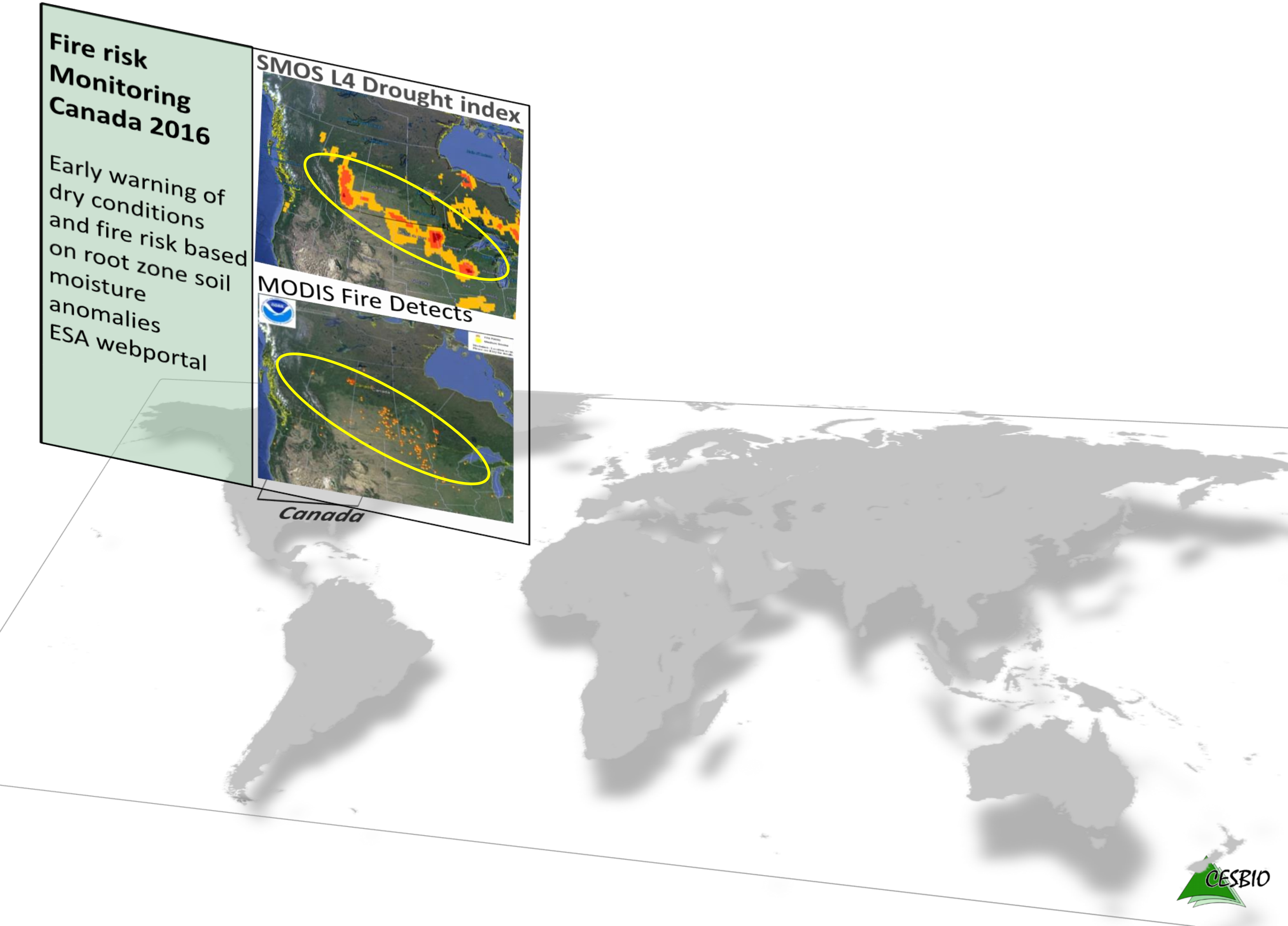
# Drought in the horn of Affrica




(Al Bitar et al. , in revue sécheresse 2016)



Al Bitar, R. Escadafald, Kerr Y. Revue Sécheresse , 2014


Fire risk
Monitoring
Canada 2016
Early warning of
dry conditions
and fire risk based
on root zone soil
moisture
anomalies
ESA webportal
SMOS L4 Drought index
MODIS Fire Detects
Canada
CESBIO

# Way forward

**Standarized Precipitation Index and PDI Palmer Drought Index are currently the most used drought indexes.**

SDI Soil moisture drought index has proven to be a very reliable index for Drought Early warning sytems.

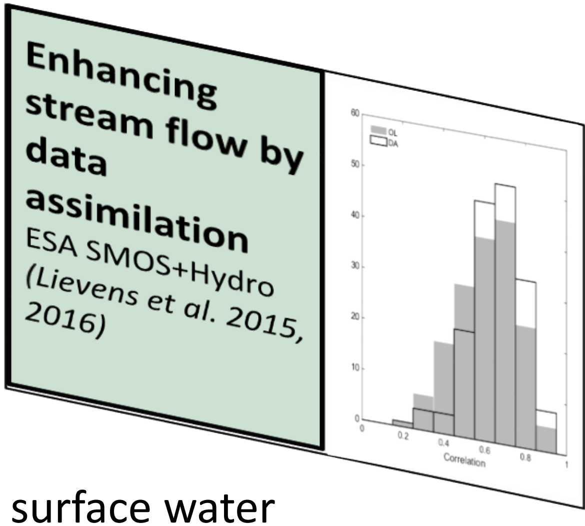
Adding soil moisture related indexes is spreading across gouverenmental agencies and we can imagine in the futur that international organisations( WMO, FAO…) consider it as part of the panel of indexes.

**…but then the continuity of the most adapted frequencire like L-Band should be ensured.**

# Hydrological drought

Contribution to SMOS in the prediction of hydrological drought can be assessed by many means:

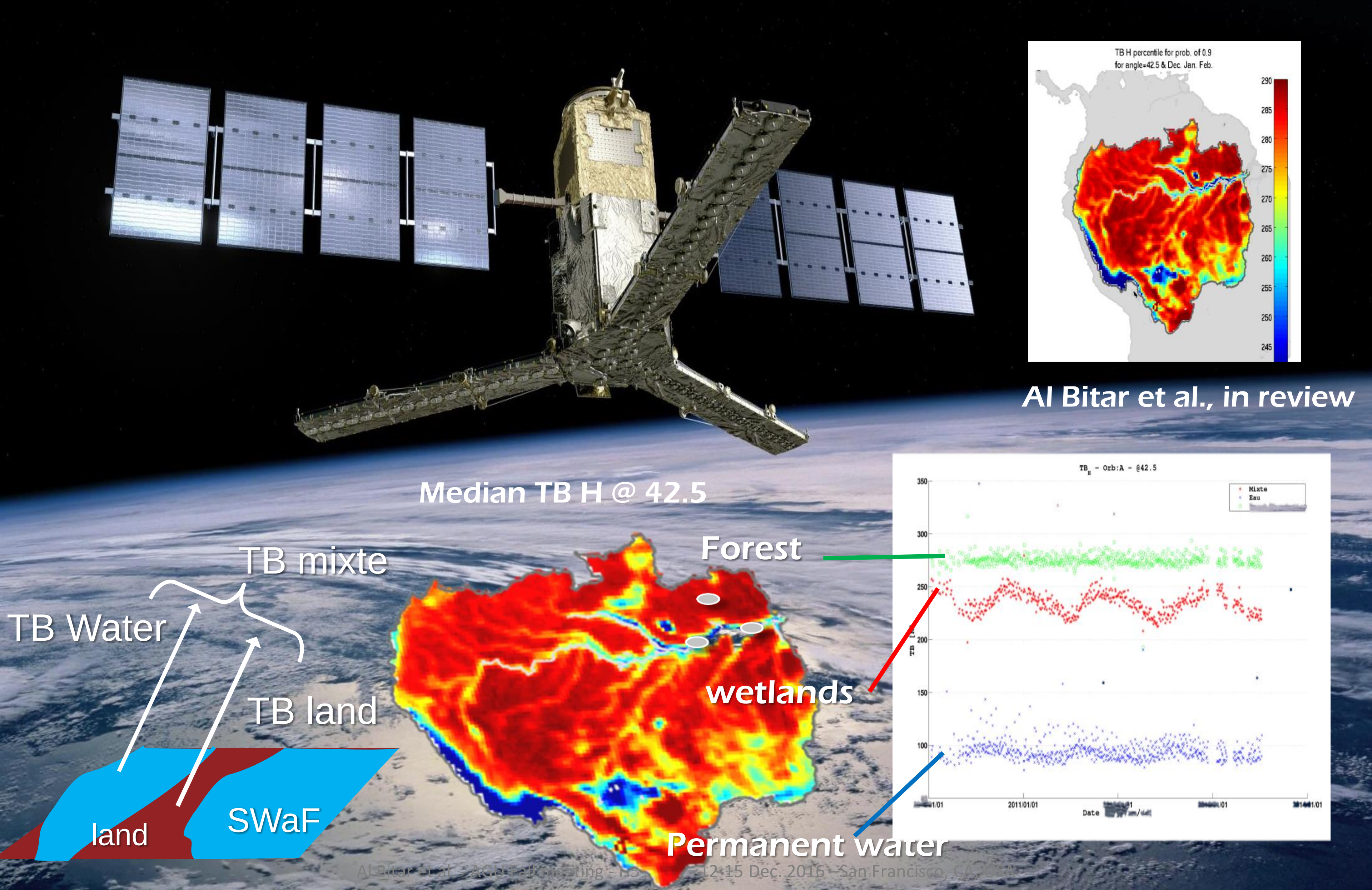
1) through the enhancement of the predictibility of discharge of a hydrological model due to the assimilation of SMOS data in LSM. (SMOS+Hydro project
Lievens et al. 2015 RSE, 2016 RSE, Wanders et al. 2014, Leroux et al. HESS 2016. )




2) Another alternative  in tropical basins is to monitor of water surface water extents.
(Al Bitar, Parrens, et al., AGU 2016)   (Parrens, Al Bitar, et al. Water, 2017)

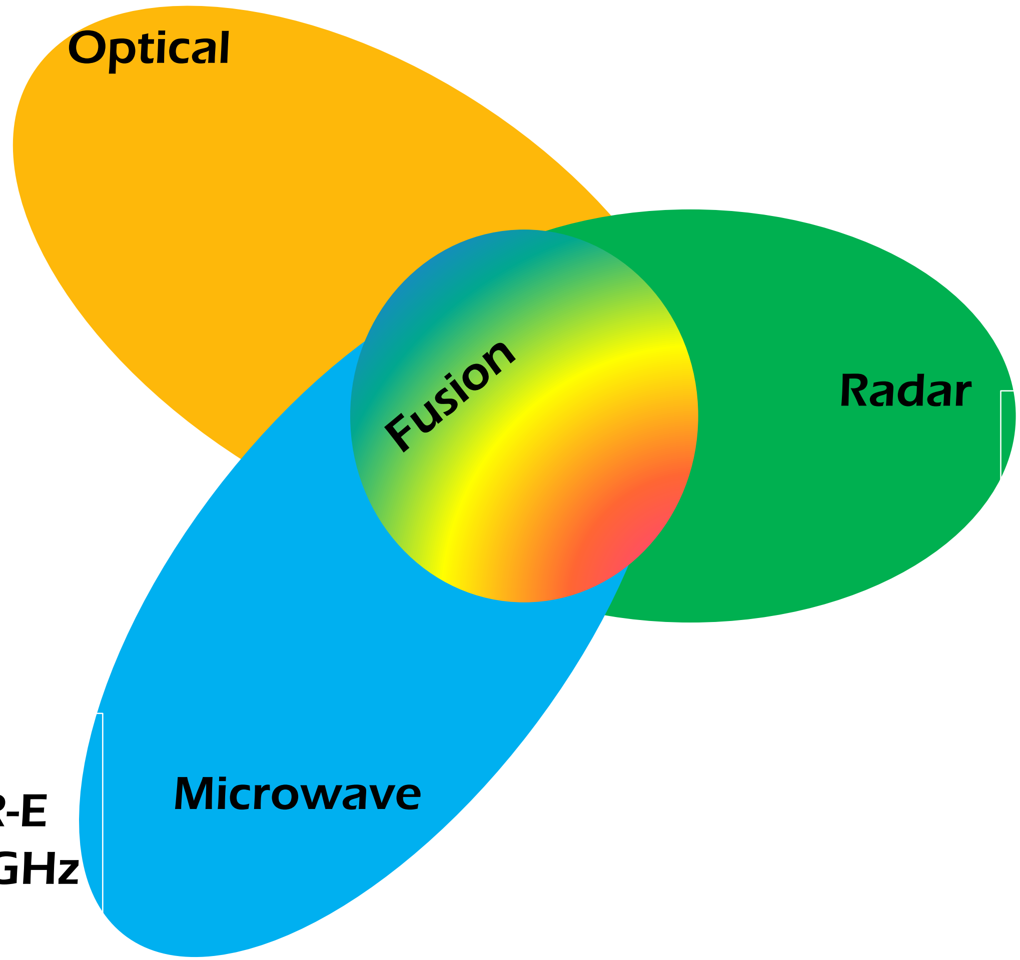



# SWAF - Water fraction using SMOS data



# Monitoring of water surfaces *from space*

- Visible
  - *Sentinel-2*
  - *MODIS*
  - *LANDSAT*
- NIR
  - *LANDSAT*



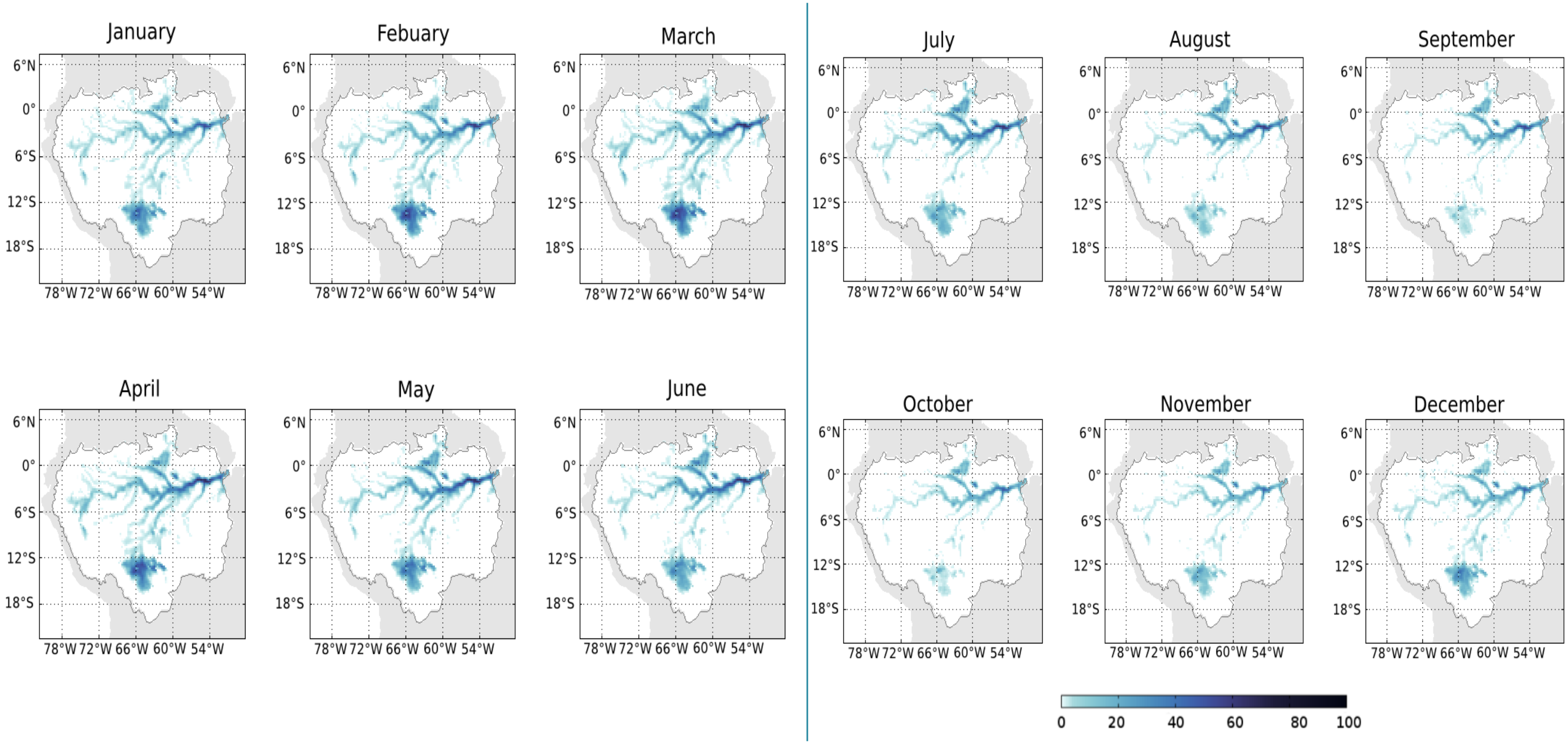

- C-band
  - *Sentinel 1*
  - *RadarSAT*
- L-band
  - *PALSAR*
- X-band
  - *TERRASAR*

-C-band
  AMSR-E
- K - ka GHz
- SSMI

Pecklet al. 2017, Aires et al. 2017, Ferrant et al. 2017, Parrens et al. 2017

# Impact of polarisation and incidence angle

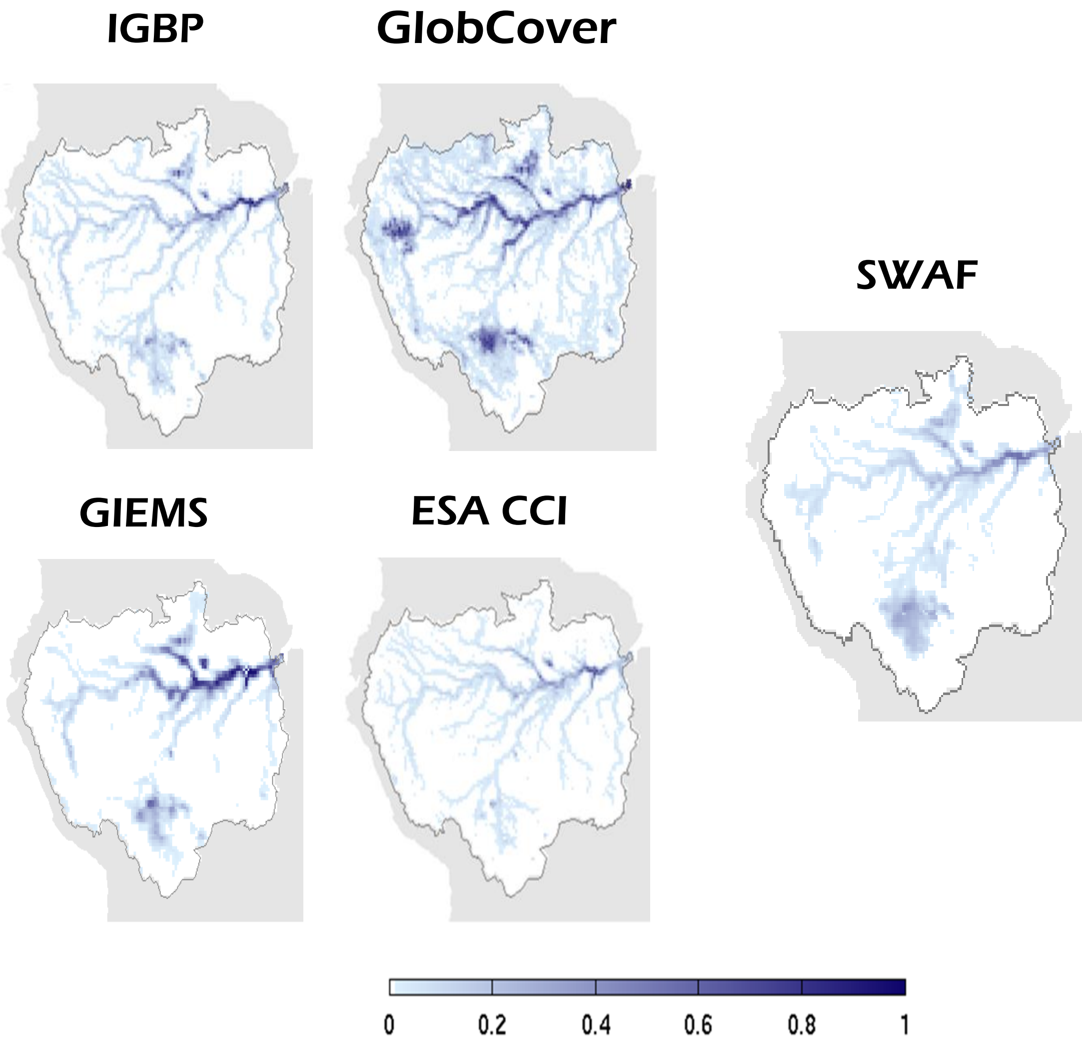
## Mean SWAF for 2010 - 2016

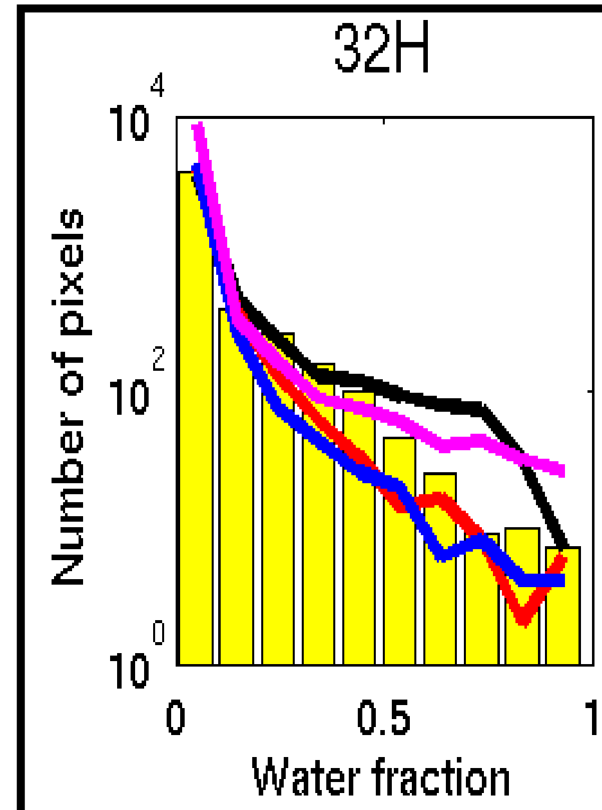



Parrens et al. Waters 2017

# Validation of the SMOS Water fraction

## *Against static maps*

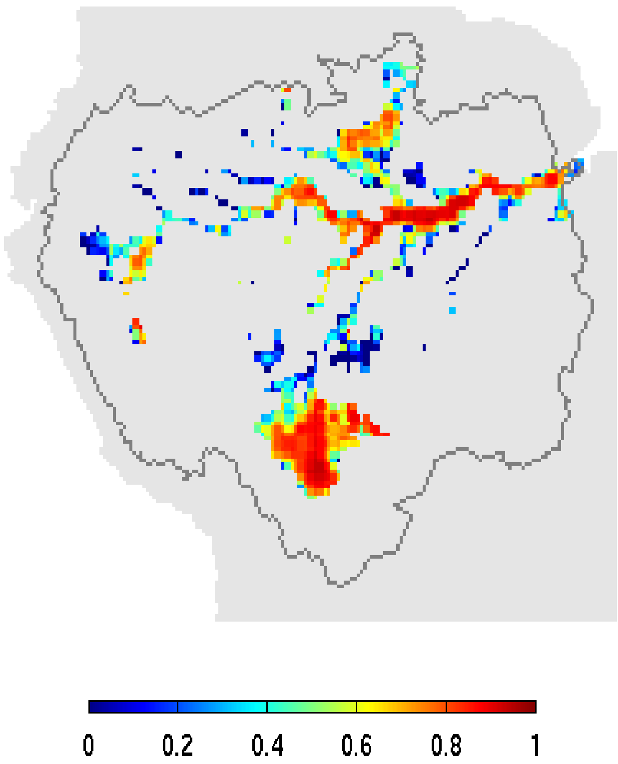


# Validation of the SMOS Water fraction

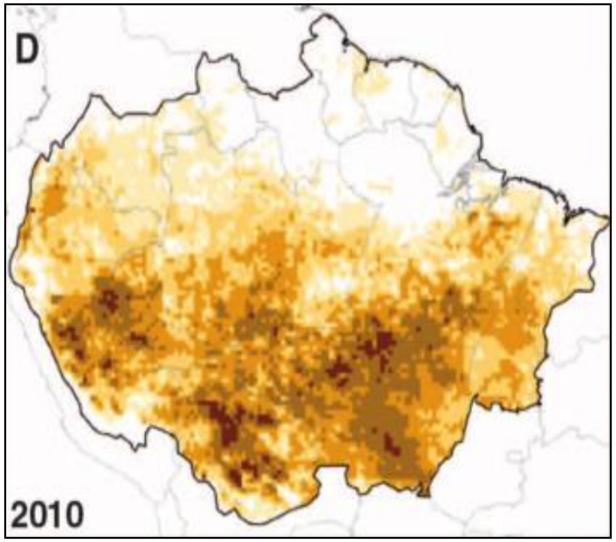
## *Against dynamic maps*

**Temporal correlation between SWAMPS and SWAF products**



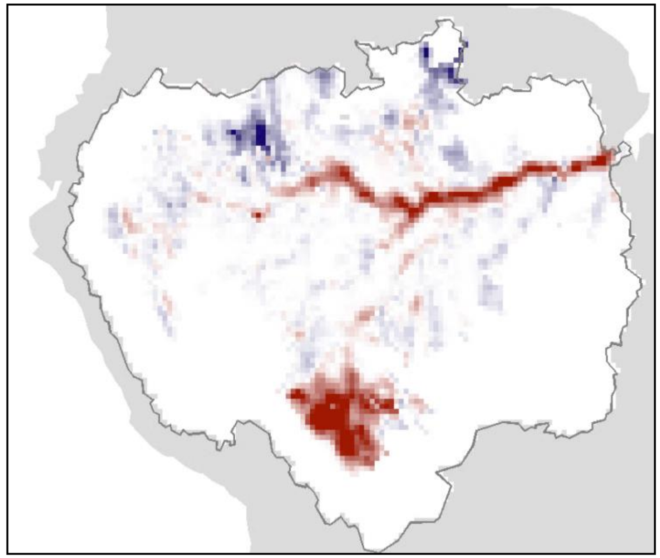

# Droughts of 2010

**Clim. Water. Index**




**Anomaly of water fraction**

Jul. – Sept. 2010

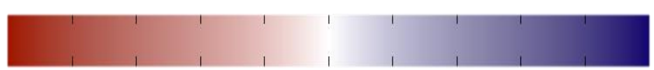


**Drought depicted for the South amazone but also for the innundation plains, which can not be detected using the Clim. Water Index which is based on optical data.**

water deficit

(Lewis et al., Science 2011)

anomaly of SMOS water fraction

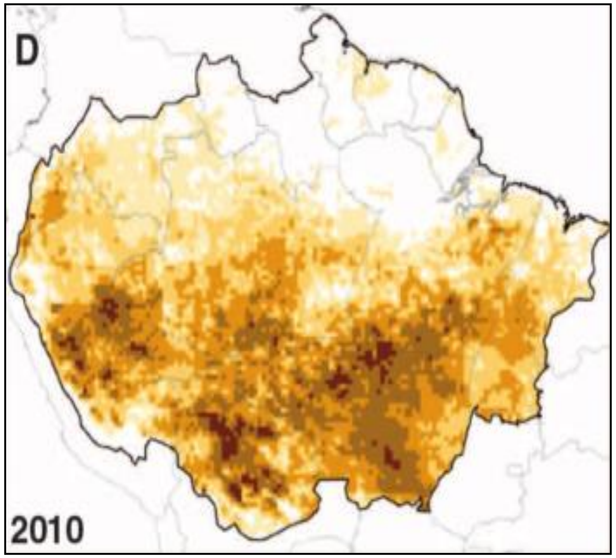


*abnormaly dry* *abnormaly wet*

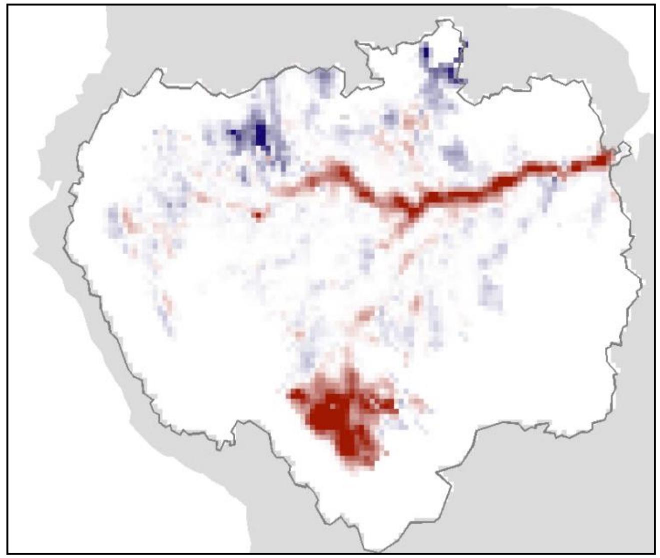
**Reuters ©**

# Droughts of 2010 vs 2015

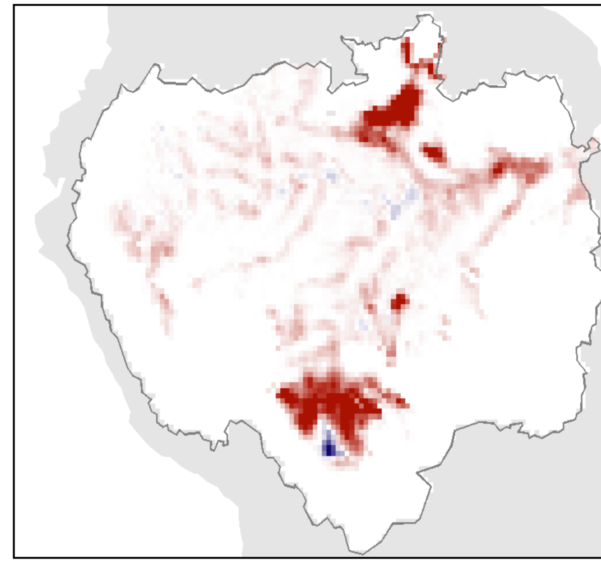
**Clim. Water. Index**




**Anomaly of water fraction**
Jul. – Sept. 2010



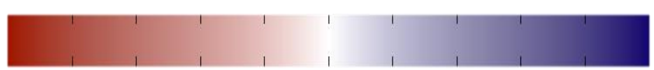
**Anomaly of water fraction**
Oct. – Dec. 2015



water deficit

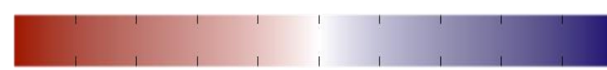
(Lewis et al., Science 2011)

anomaly of SMOS water fraction



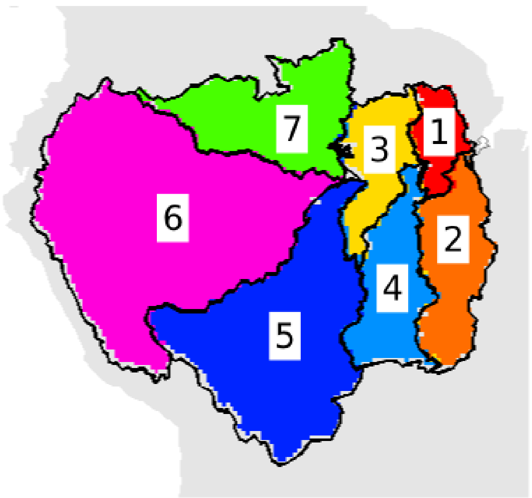
*abnormaly dry* *abnormaly wet*

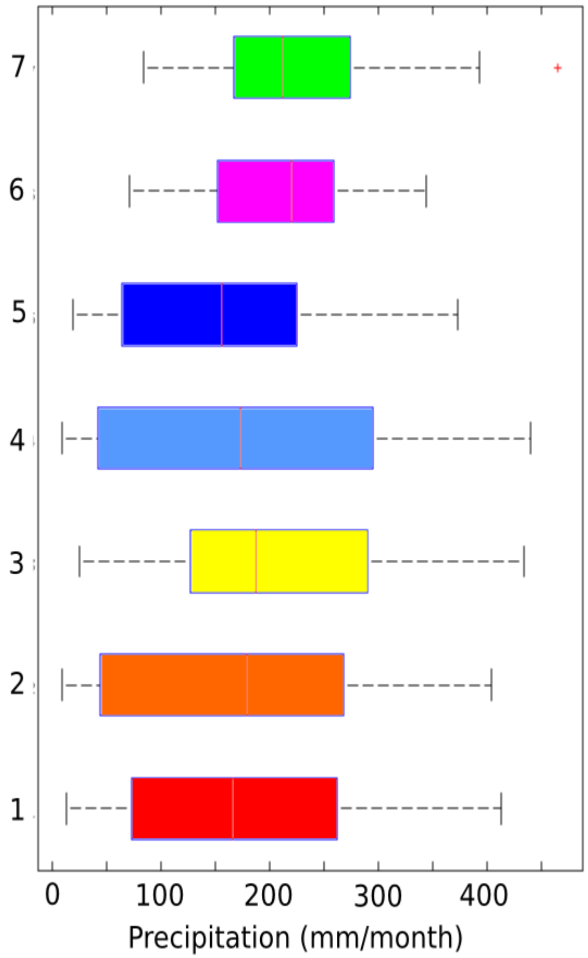
anomaly of SMOS water fraction

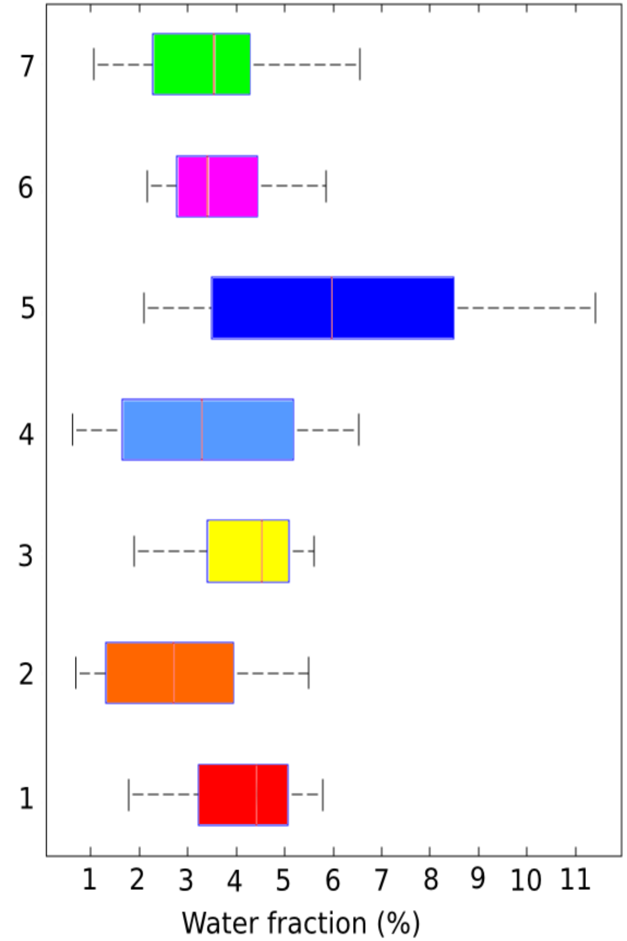


*abnormaly dry* *abnormaly wet*

# Differentiating impact of precipitation and water surfaces

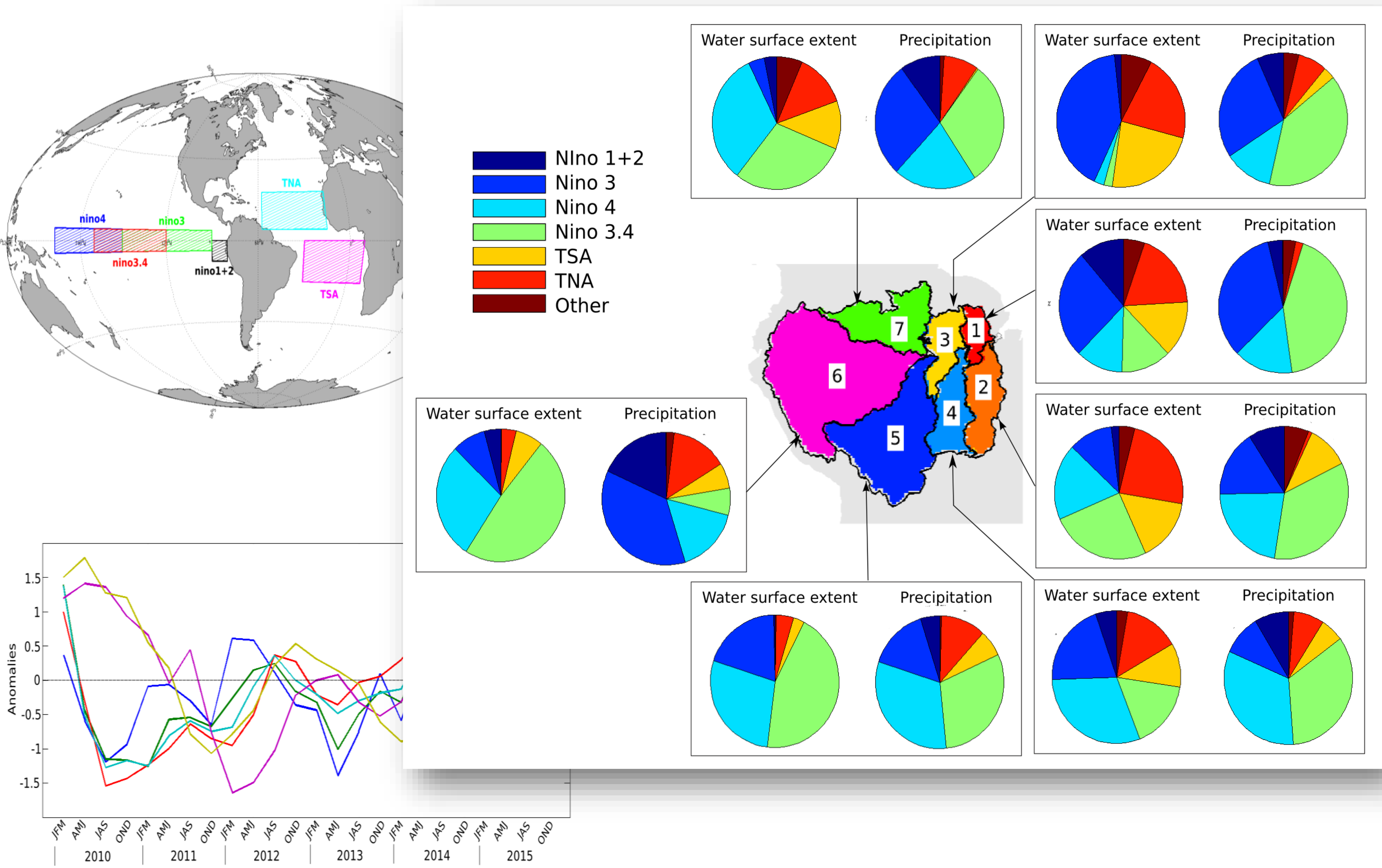


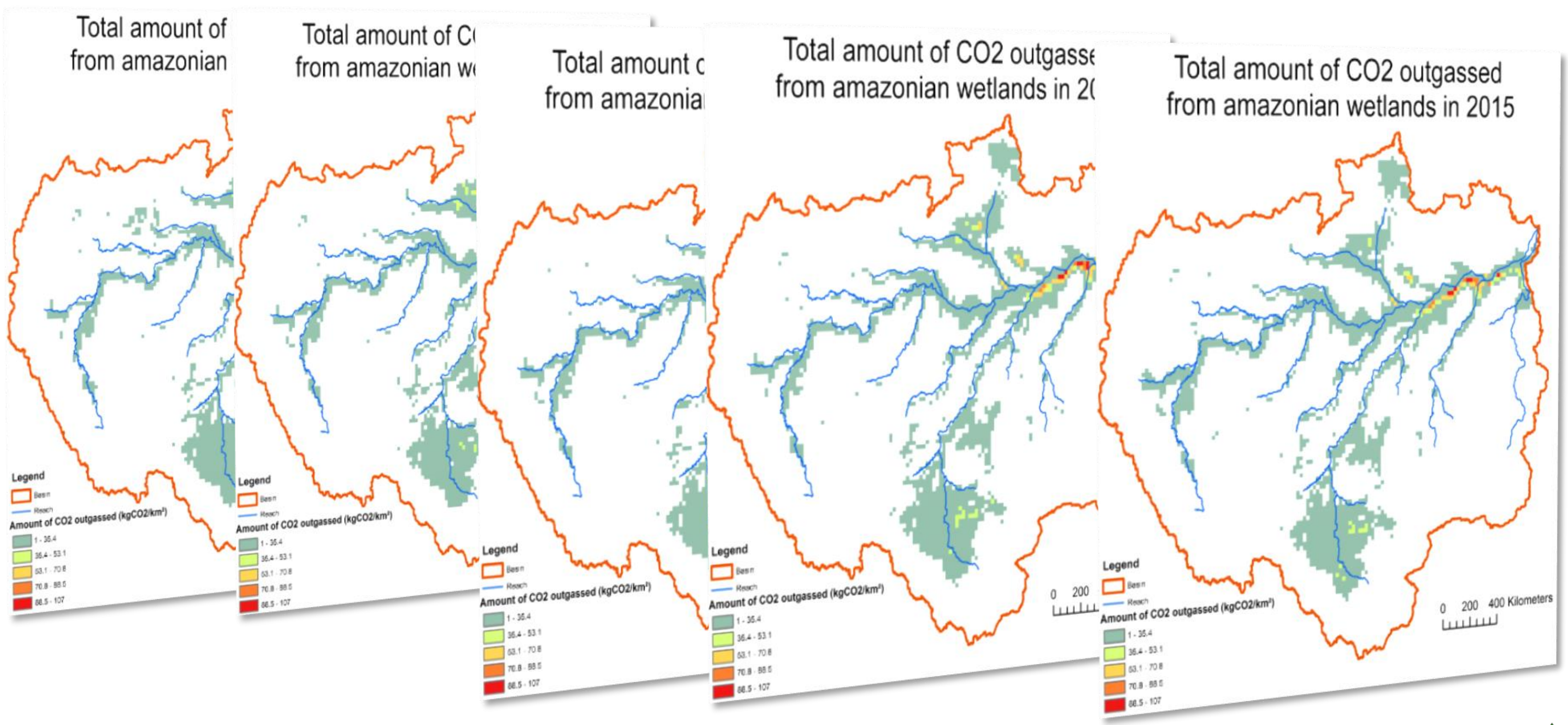

Parrens , Al Bitar
et al. submitted)

# Lien avec les SST sur les 5 dernières années



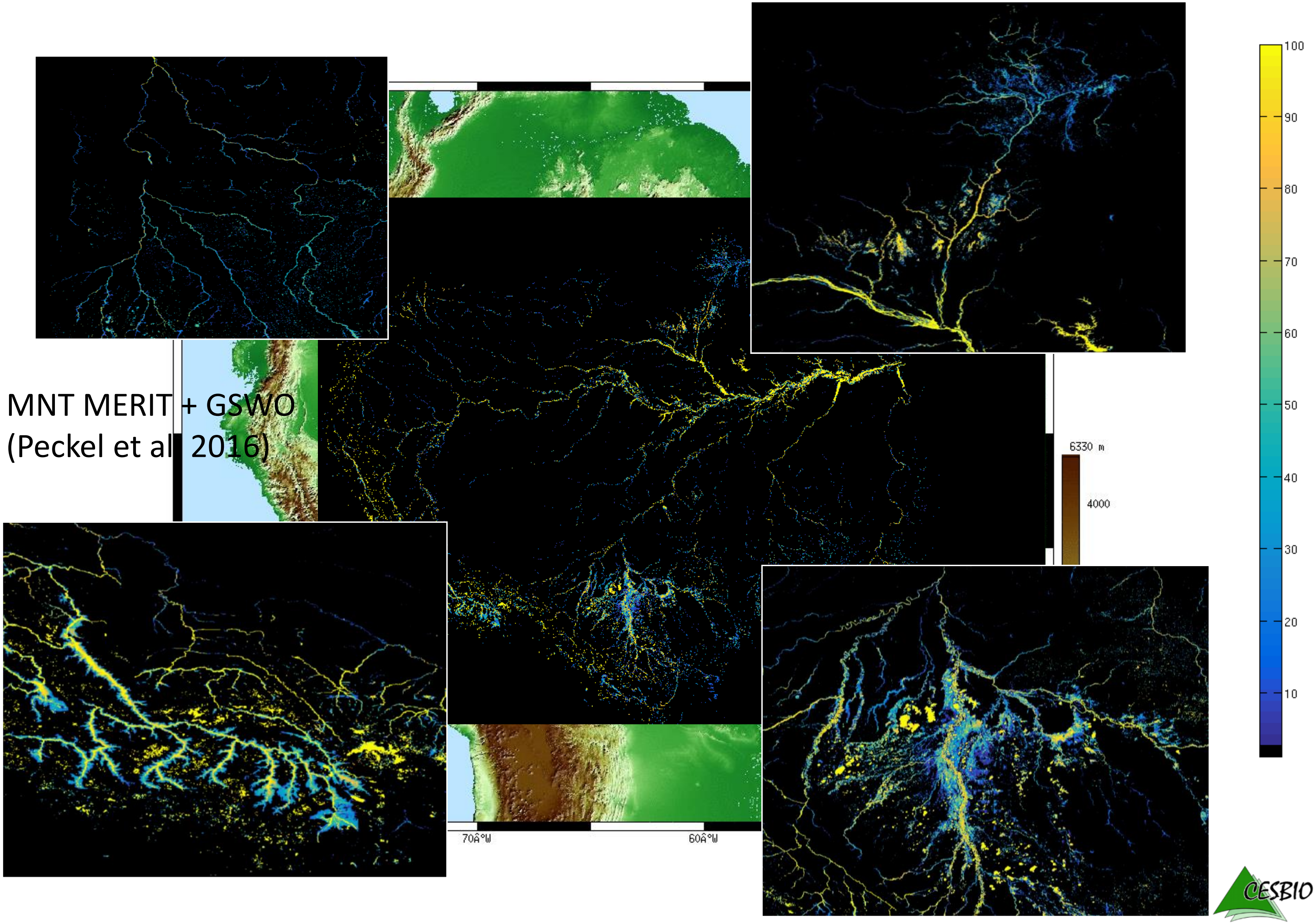
# Nitrogen and Carbon fluxes of inland water surfaces

Denitrification rate was estimated as following (Peyrard et al. 2011): $\boldsymbol{R_{NO_3} = -0.8\left(\rho.\frac{1-\varphi}{\varphi}\cdot k_{POC}[POC]\cdot\frac{10^6}{M_C}\right.} +$

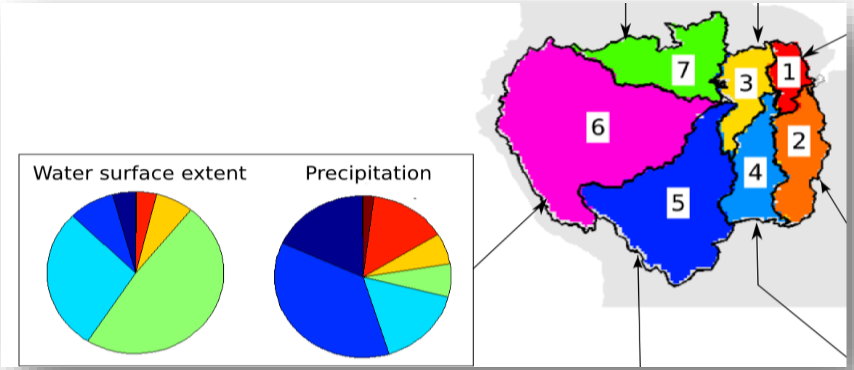


# L4 Water Surfaces at High resolution (New)

MNT MERIT + GSWO
(Peckel et al. 2016)



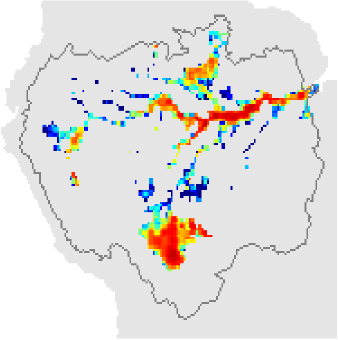
## Water surfaces dynamics not the same as precipitation and stream flow



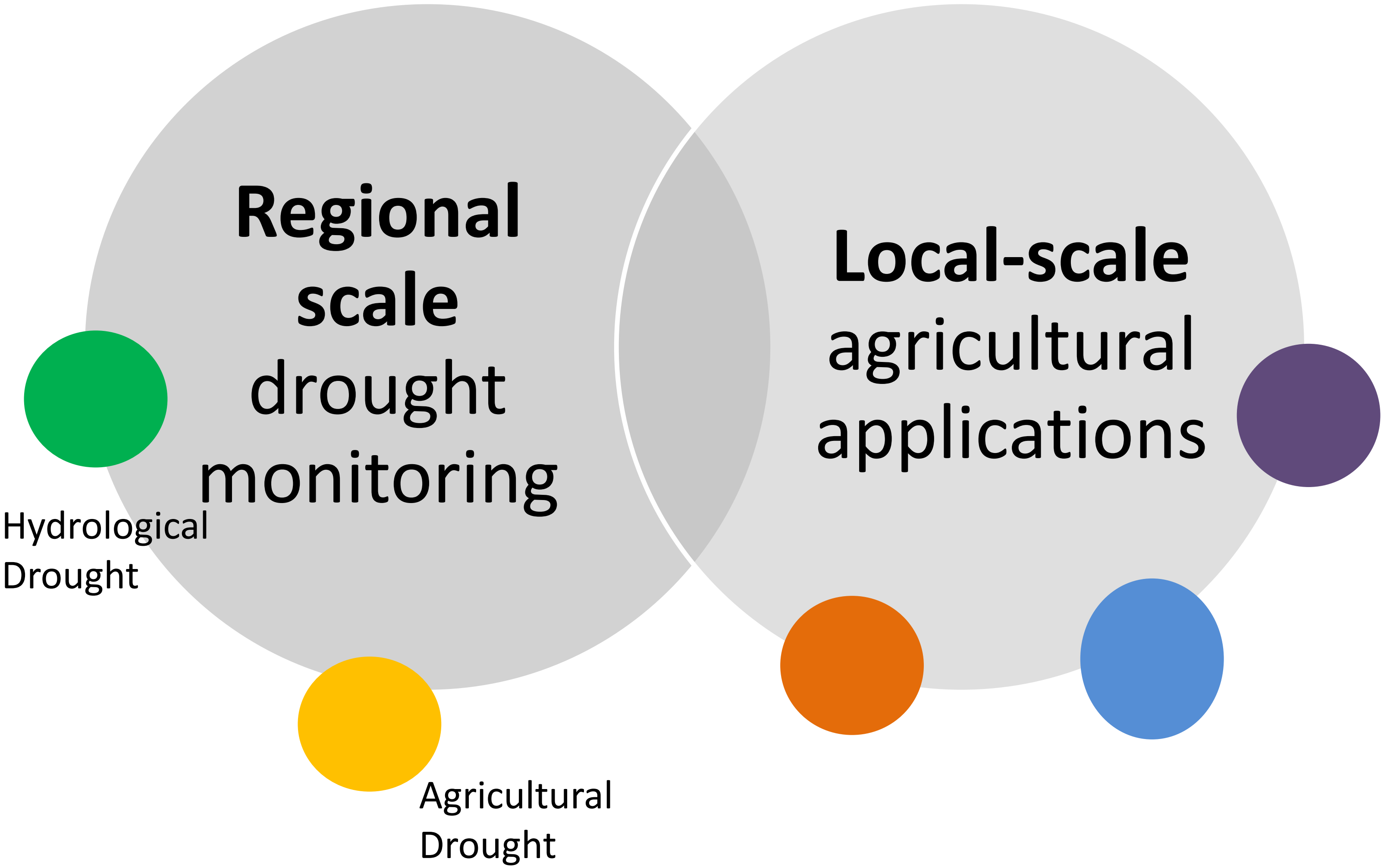

## Many ecosysteme services depend on water surfaces in dense tropical regions, and only L-Band can provide this information.

Credits Green Christian

**More precisely,**
**L-Band puches the limits of observability over these areas compared to C-Band or active P-Band.**



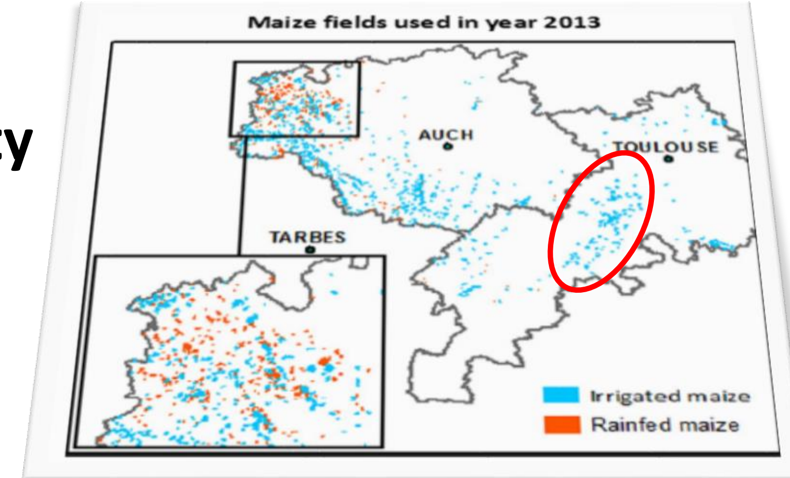
# Back to the outline



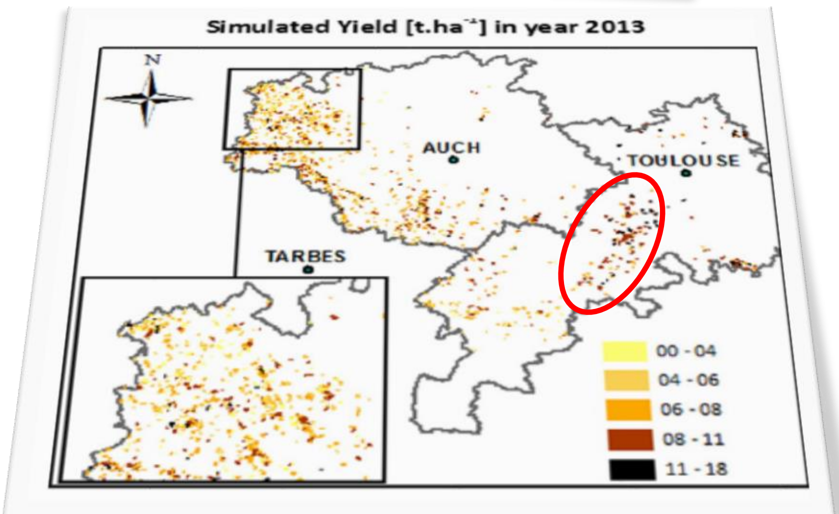
# The need for high resolution SM

**Yield and soil moisture availability are highly correlated.**

**Irrigation accounts for about 70% of water ressources uses.**




Gravitary irrigation in South India

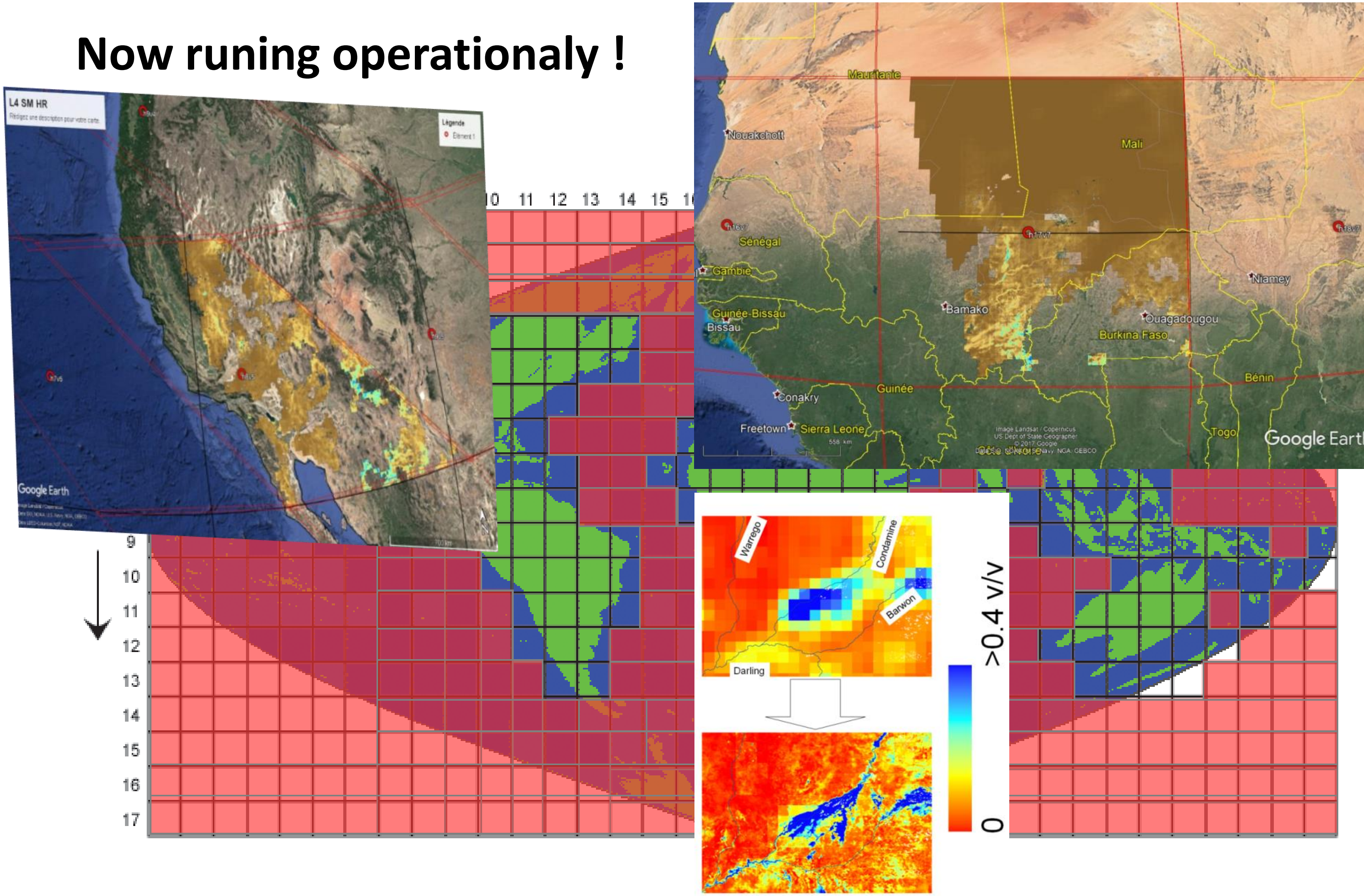



(Battude, Al Bitar et al. RSE 2016, AWM 2017)

➔ But Irrigation and yield applications will need high resolution (sub kilometric products while conserving revisit).

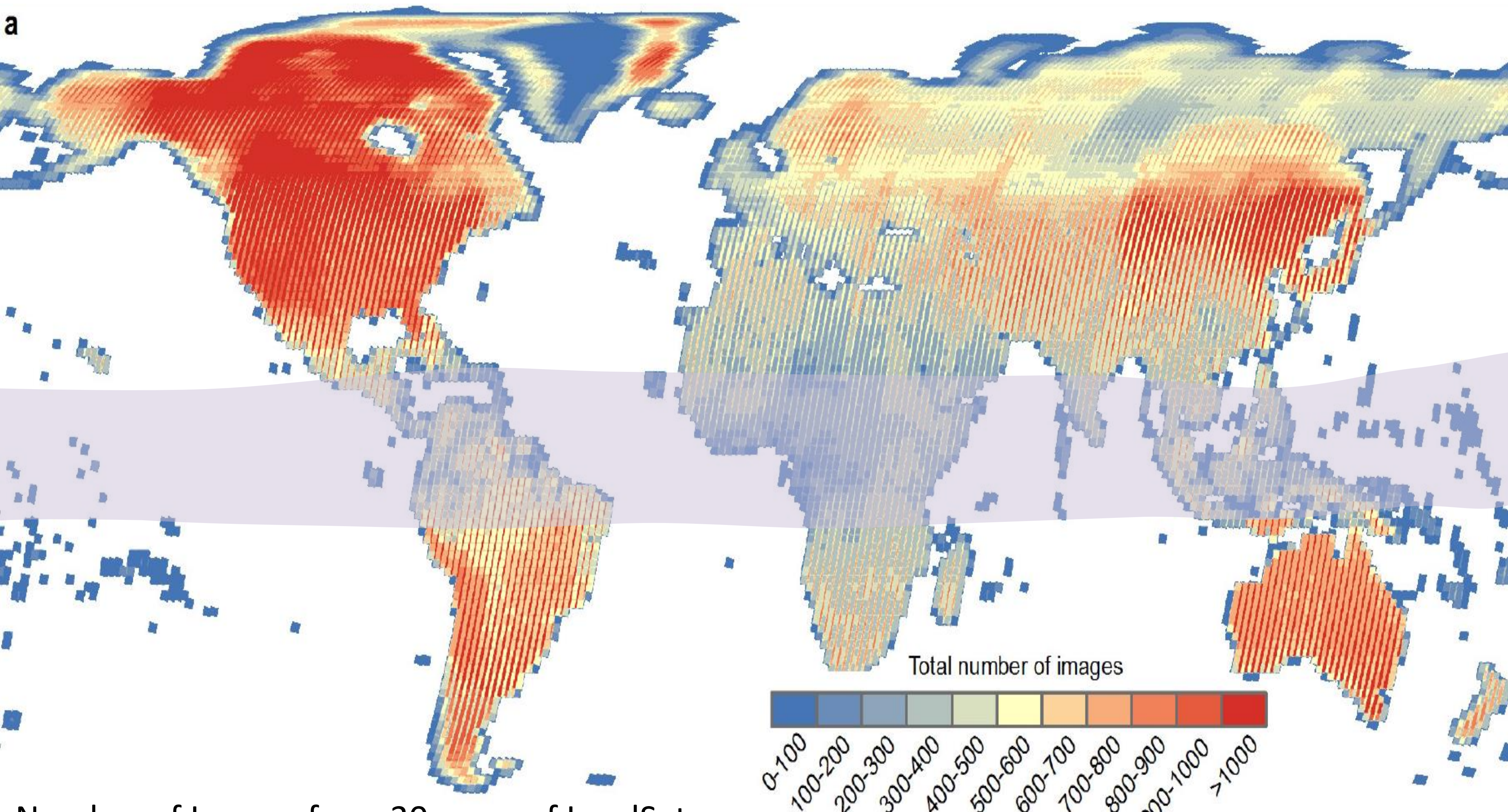
# C4DIS - L4 high resolution soil moisture

**Now runing operationaly !**




Dispatch is a disaggregation algorithm using microwave + optical (visible & thermal) remote sensing (Merlin et al. 2012) (Molero et al., RSE, 2016)

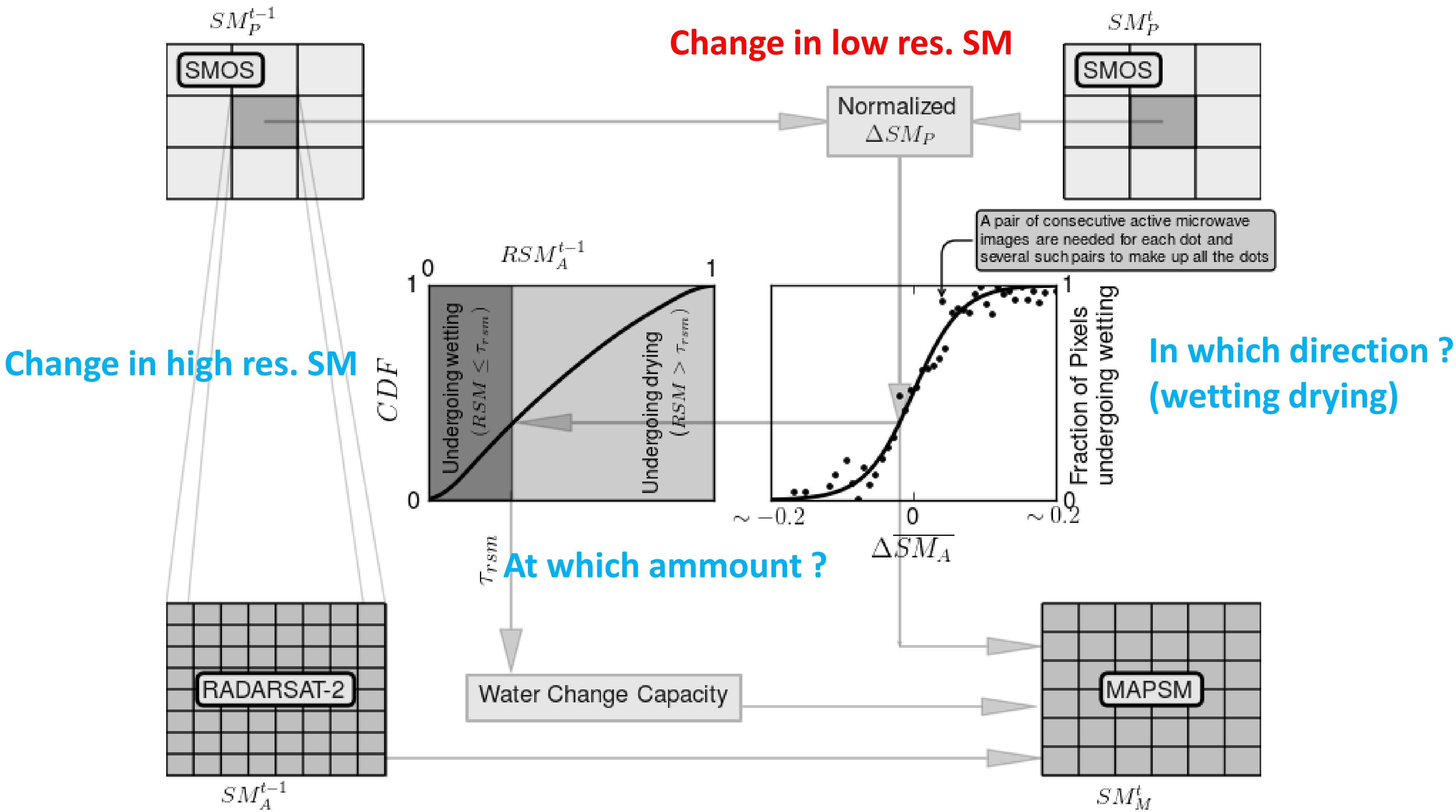
# But fusion with active is still needed




Number of Images from 30 years of LandSat

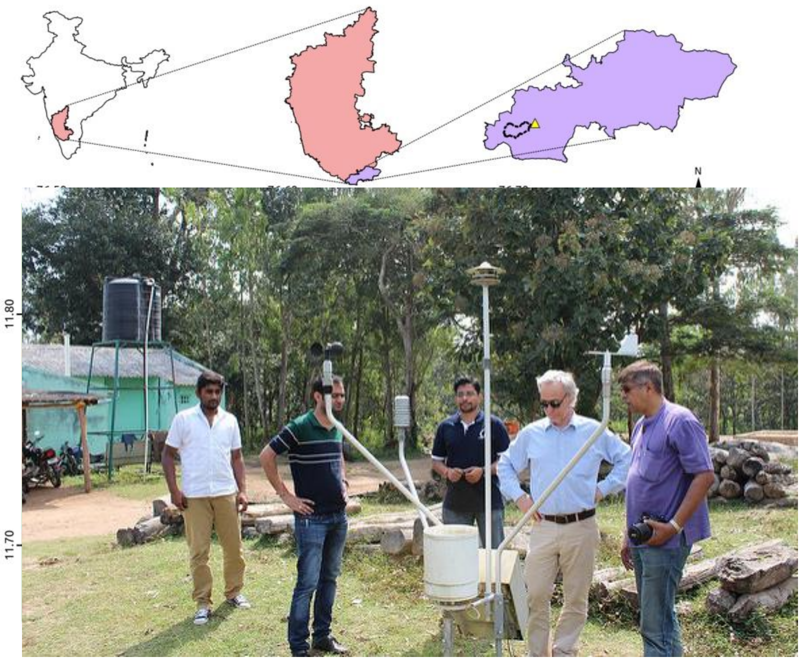
From Peckel et al., Nature, 2017

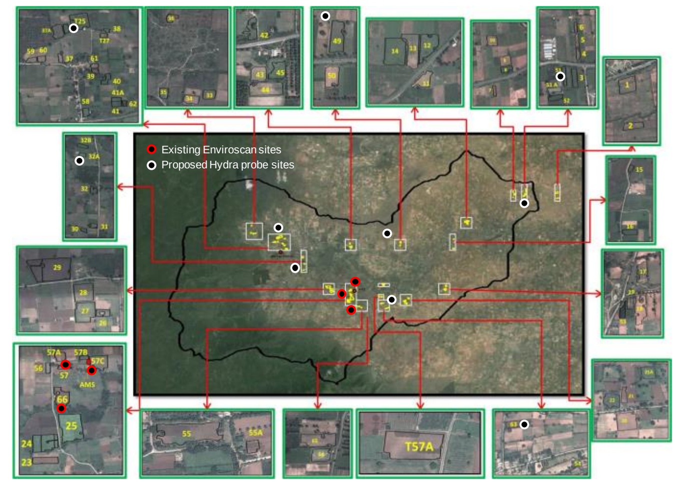
# MAPSM: Active-Passive fusion

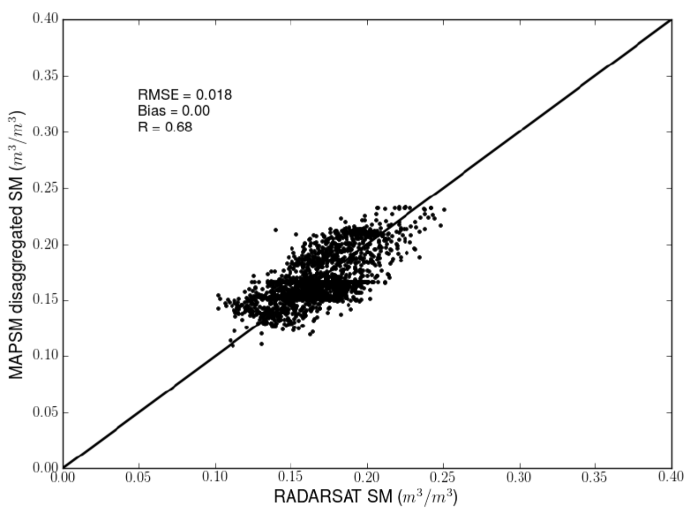


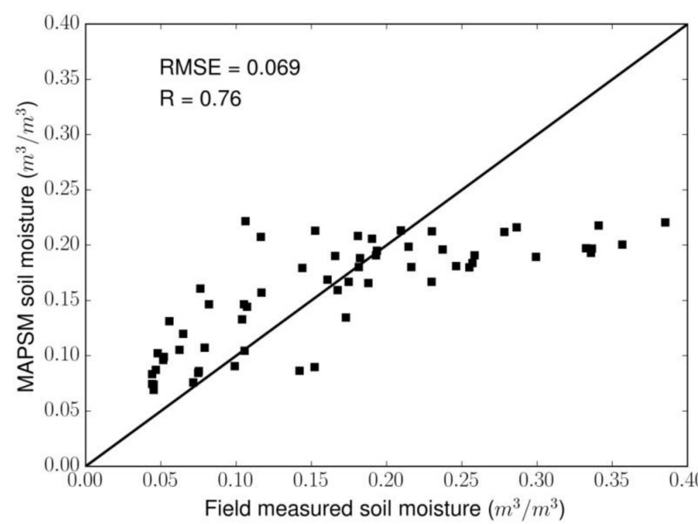

- Tomer, S. K., Al Bitar, A., Sekhar, M., Zribi, M., Bandyopadhyay, S., & Kerr, Y. (2016). MAPSM: A spatio-temporal algorithm for merging soil moisture from active and passive microwave remote sensing. Remote Sensing, 8(12), 990.
- Tomer, S. K., Al Bitar, A., Sekhar, M., Zribi, M., Bandyopadhyay, S., Sreelash, K., ... & Kerr, Y. (2015). Retrieval and multi-scale validation of soil moisture from multi-temporal SAR data in a semi-arid tropical region. Remote Sensing, 7(6), 8128-8153.

# Validation MAPSM: SMOS+Radarsat2



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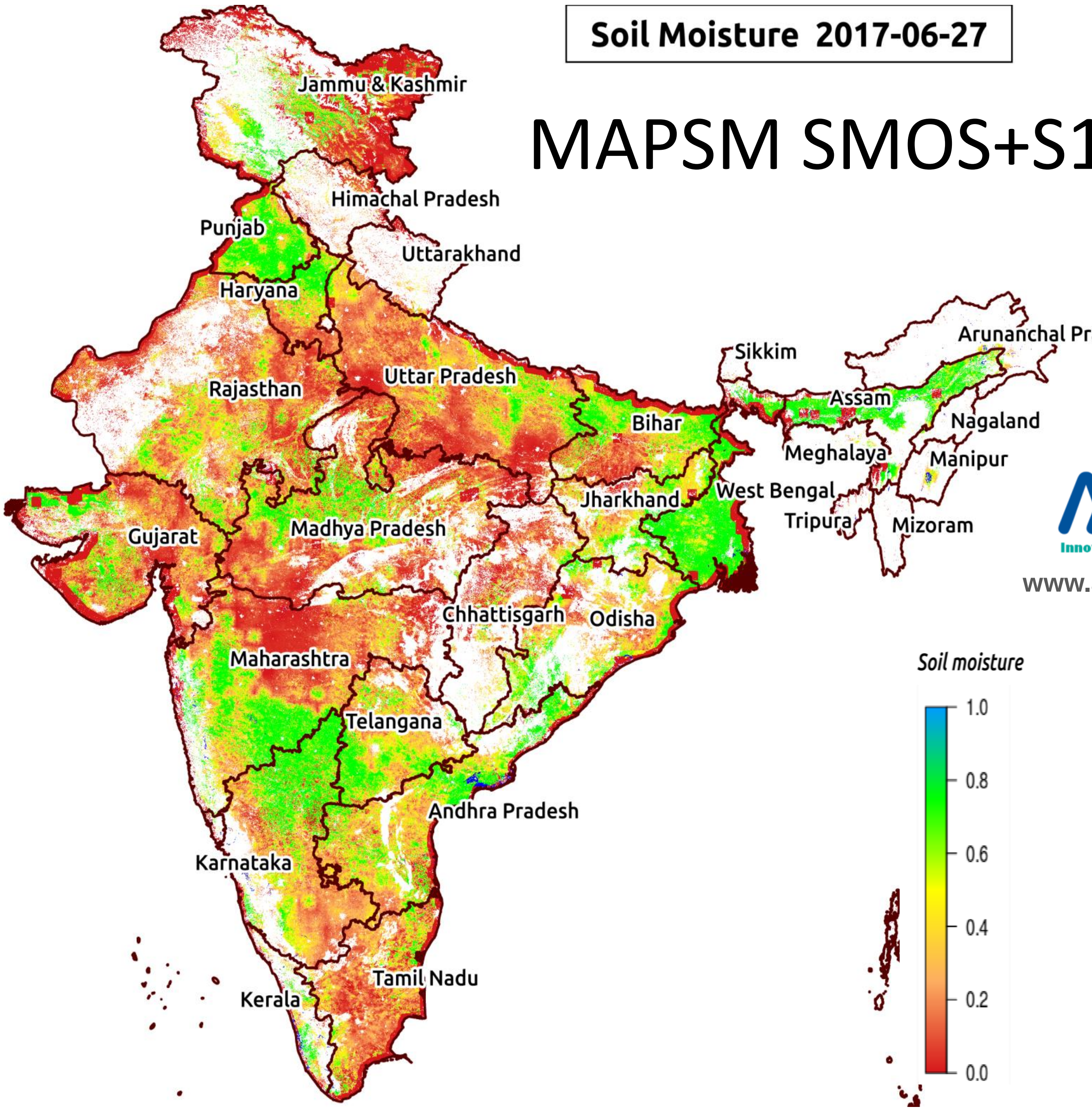
# Soil Moisture 2017-06-27

# MAPSM SMOS+S1 (500m)

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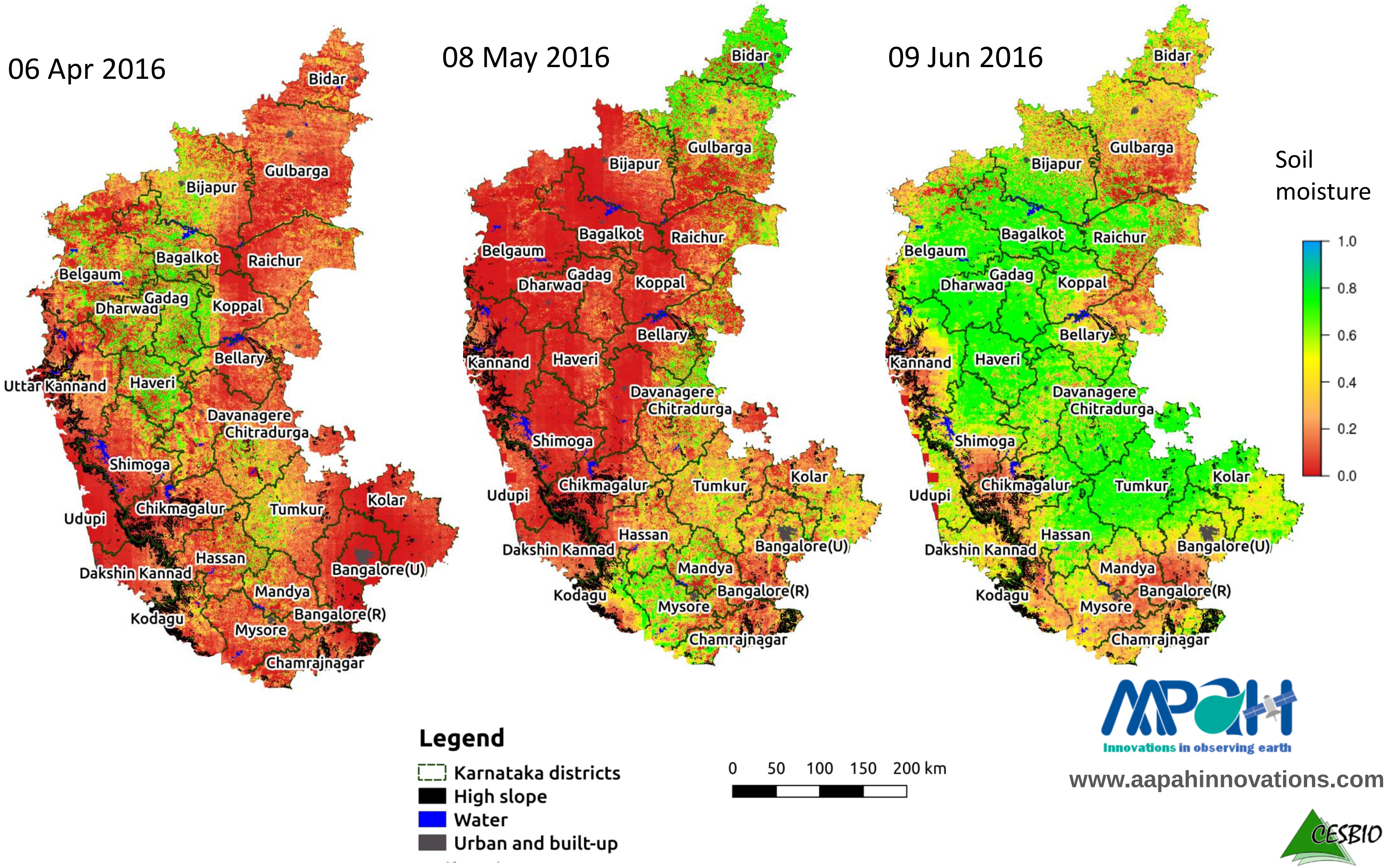
# Remote Sensed high resolution relative soil moisture for Karnataka

**Spatial resolution: 500 m; Temporal resolution: 1 day**

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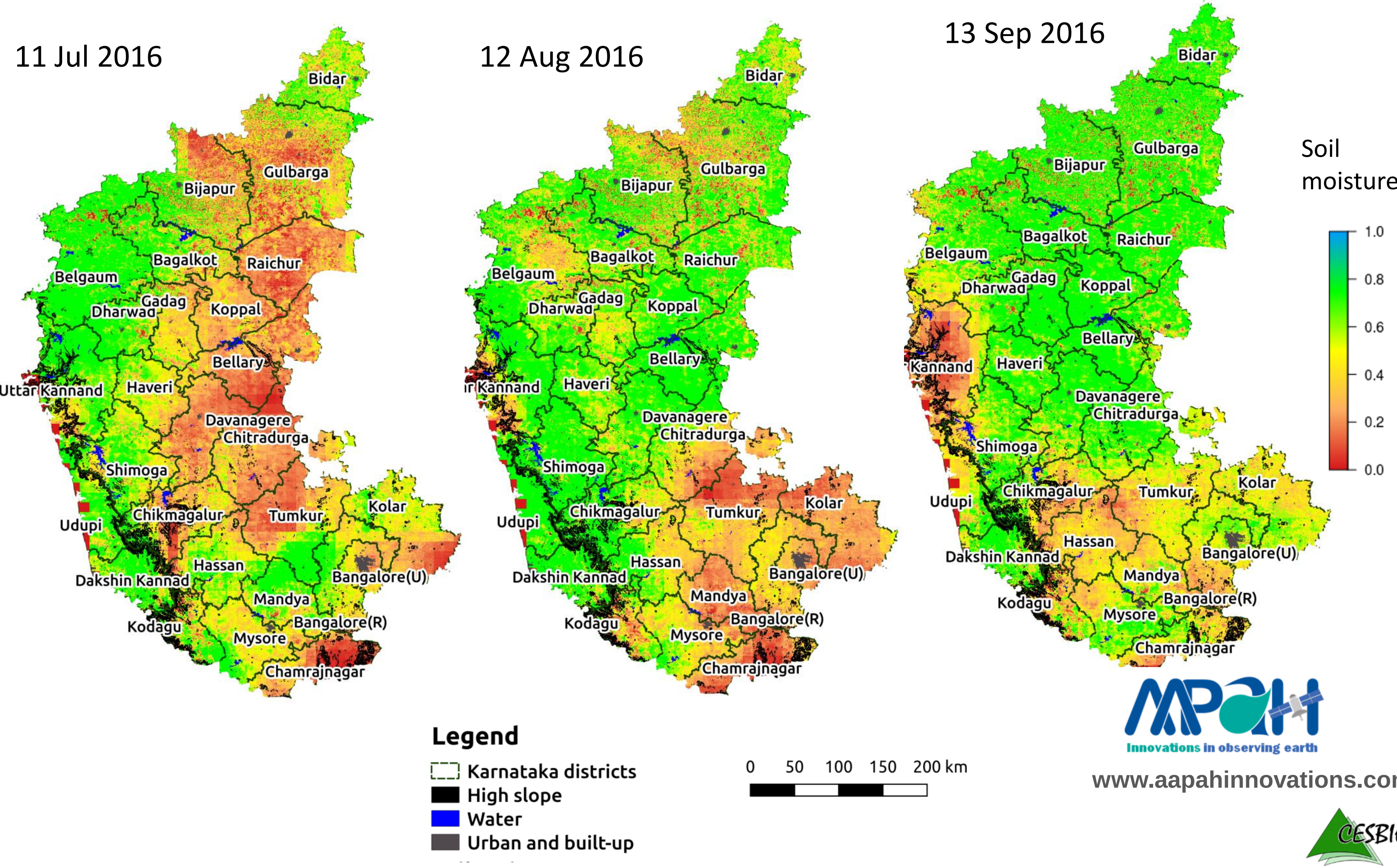


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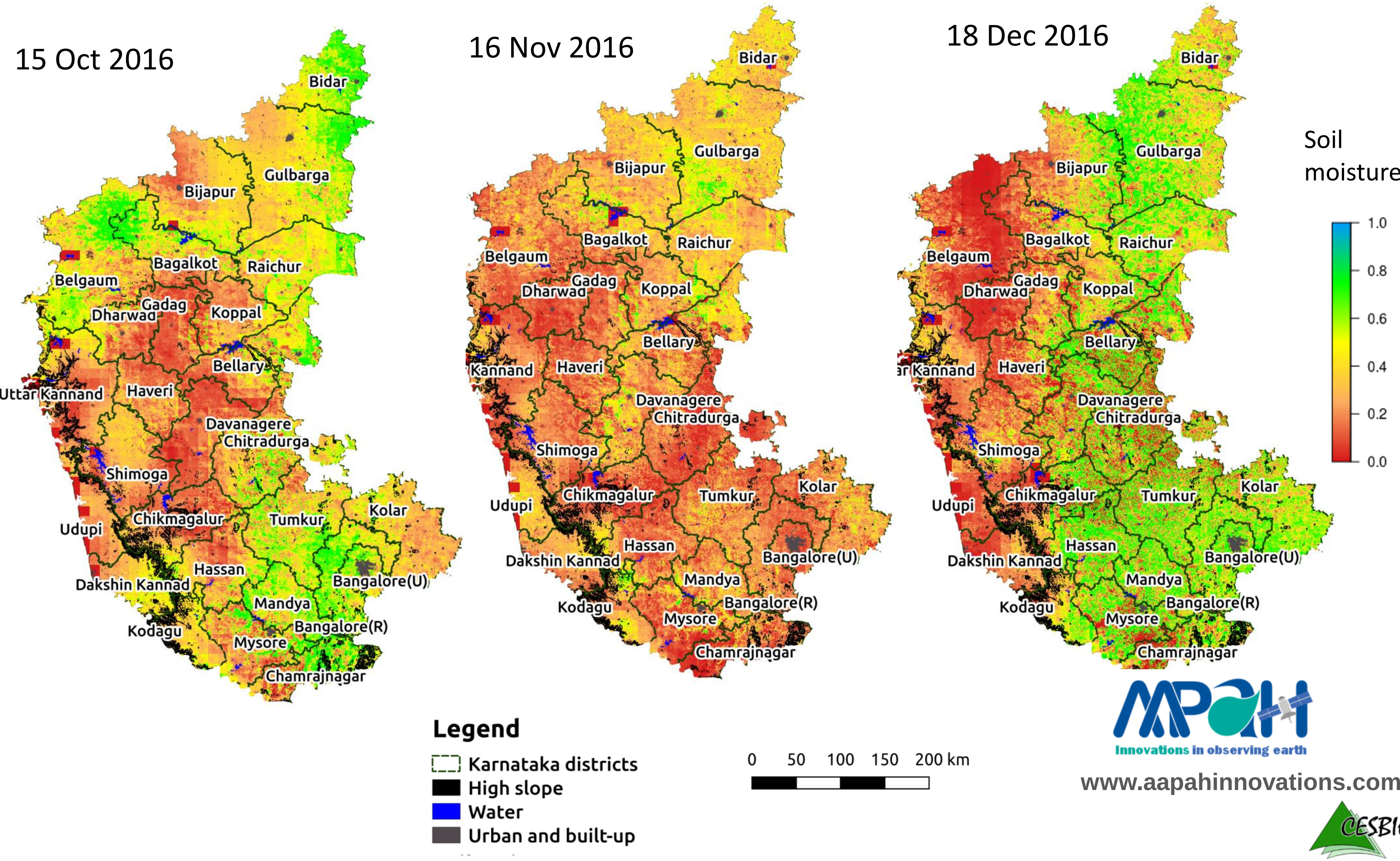


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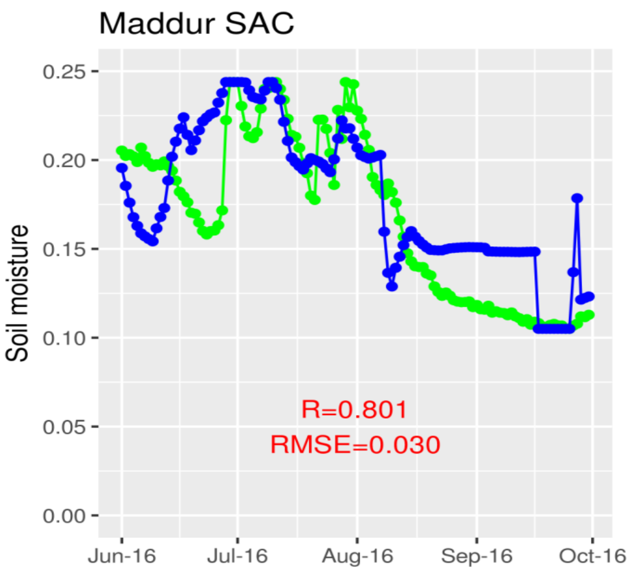
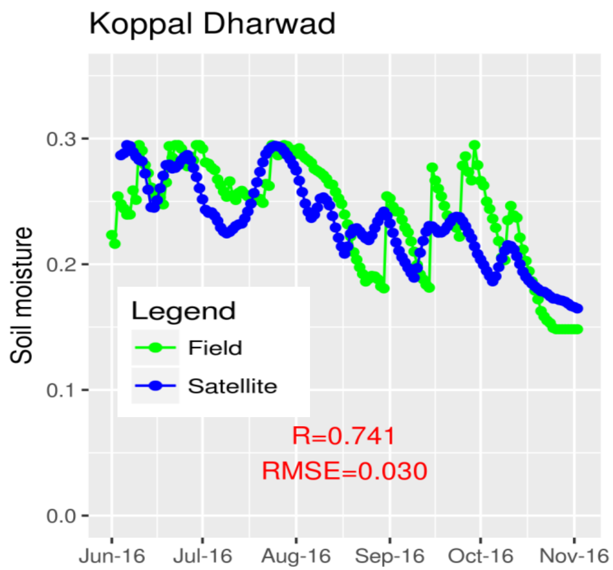
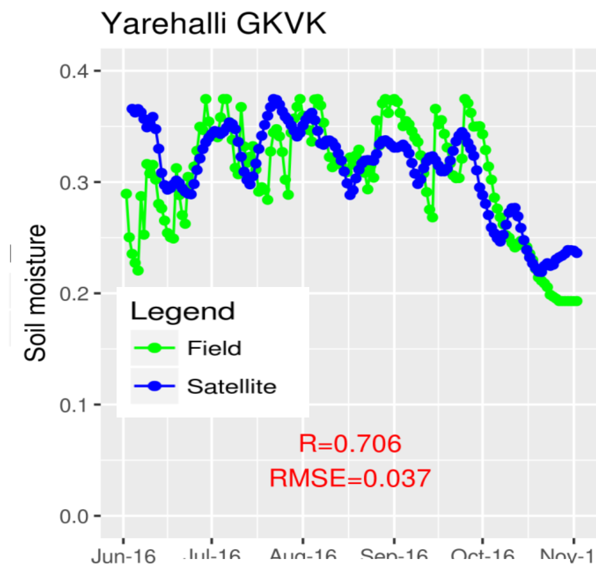
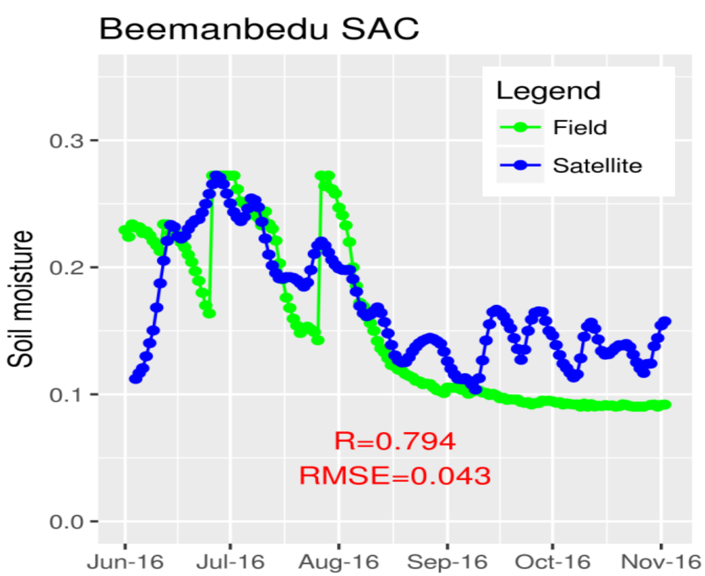
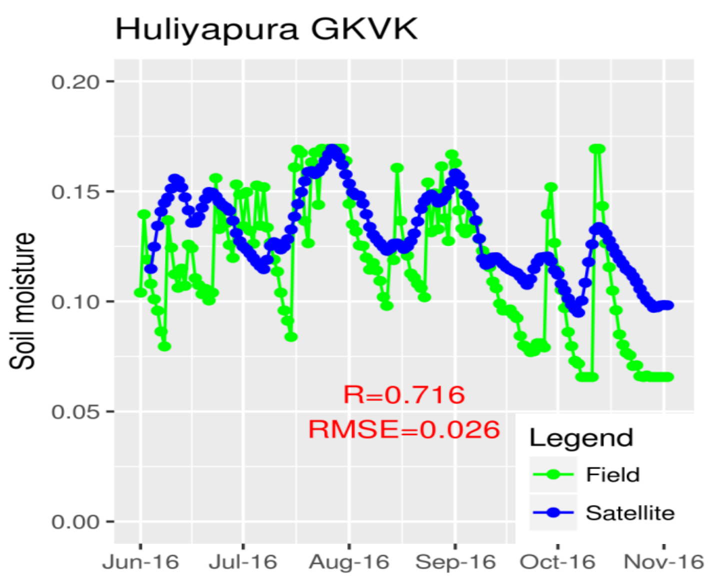
# Validation of MAPSM: SMOS+S1

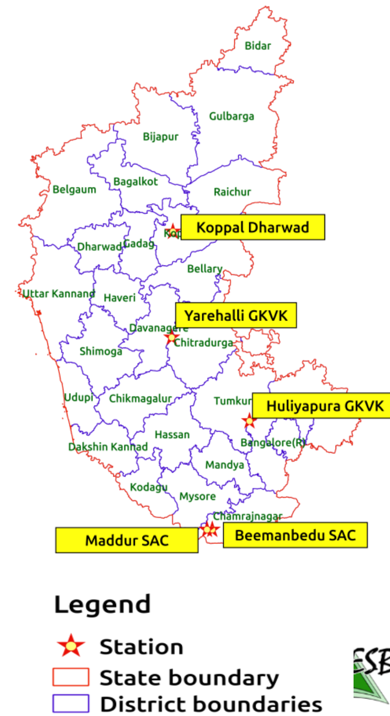


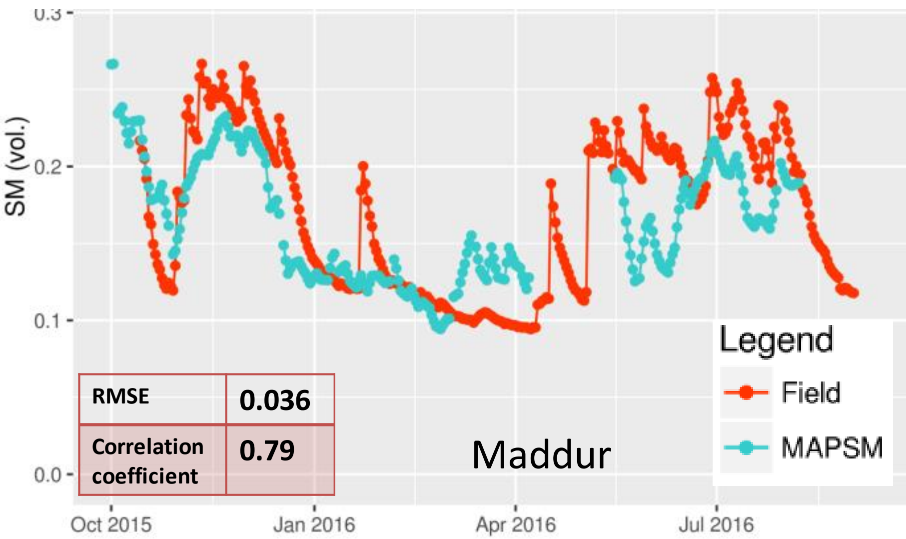



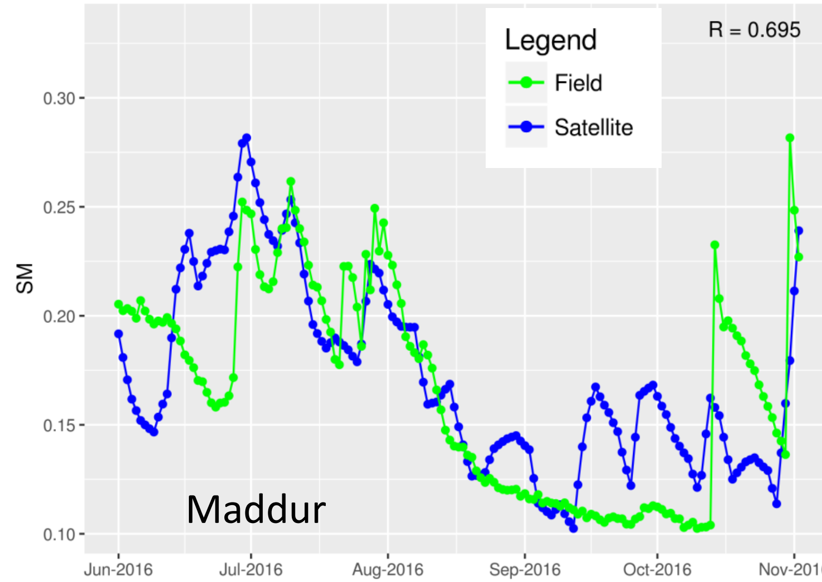



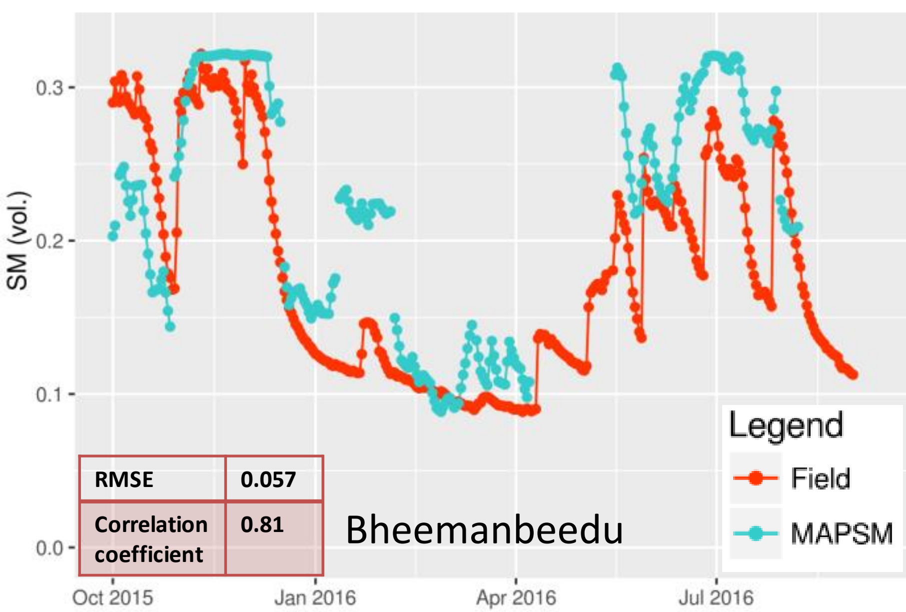



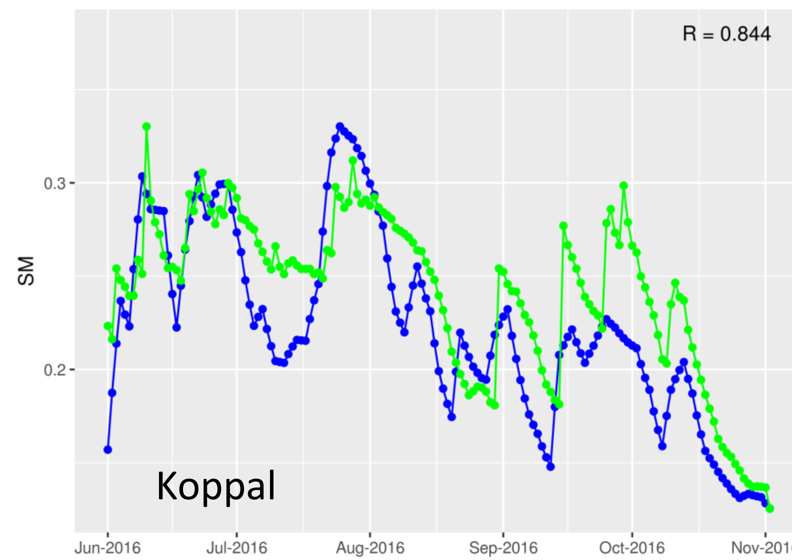



# Validation with ground sensors

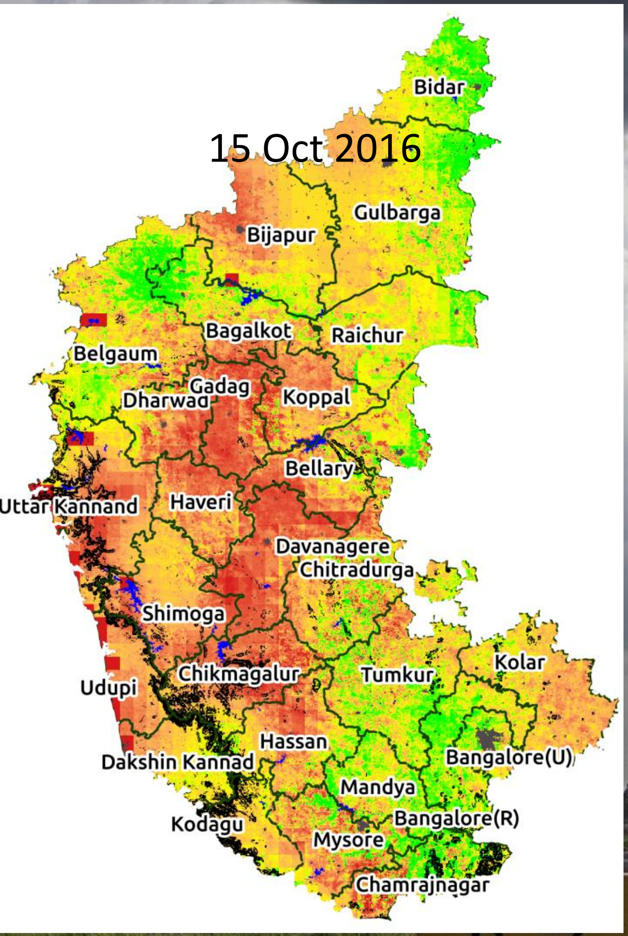


# Determining optimal Cloud seeding pogramatic

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Cloud seeding aircraft -Blomberg ®

# Interstate water management –
# The case of Cauvery Basin south india

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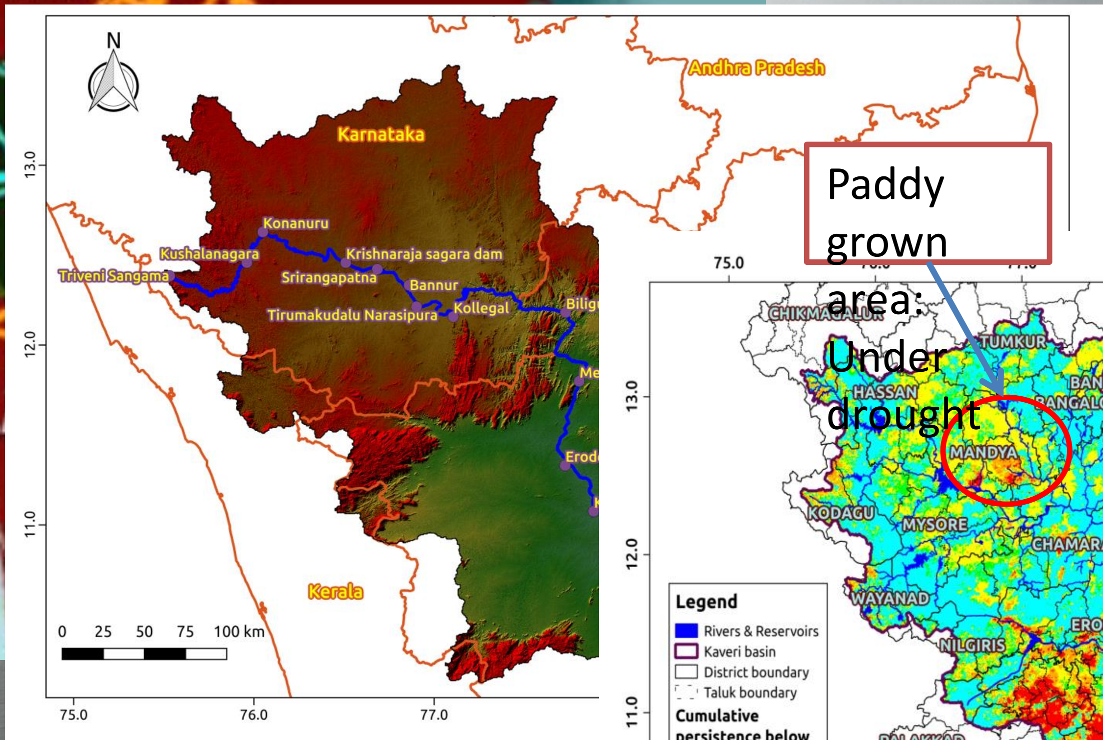
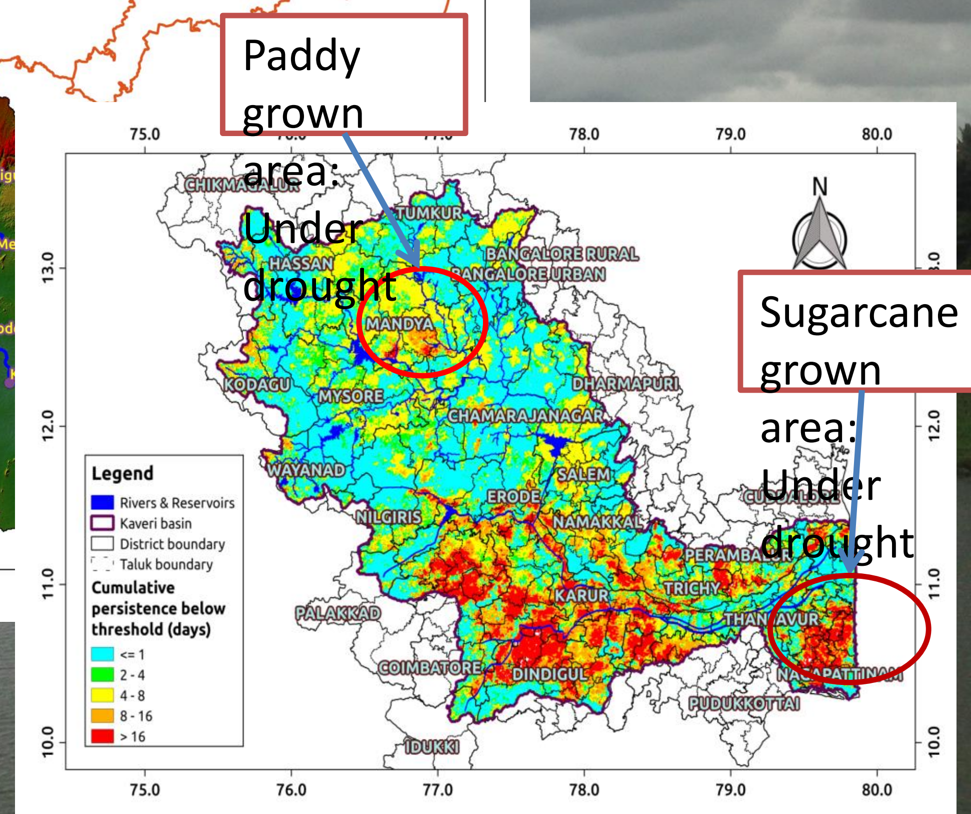
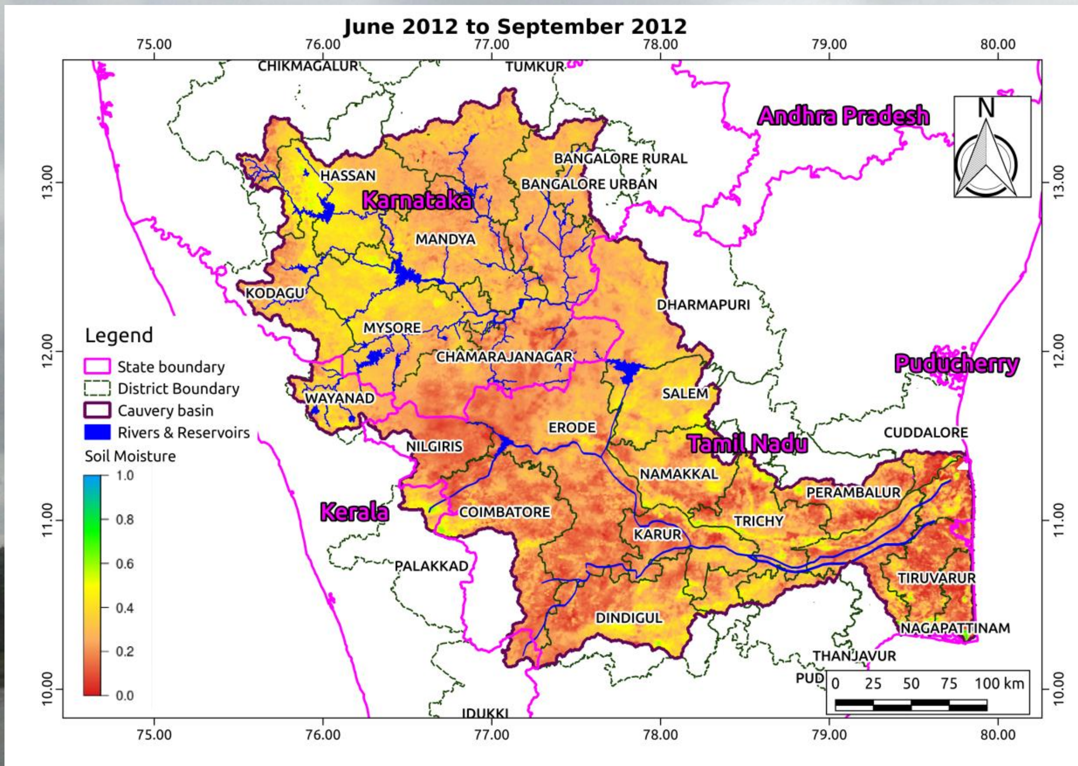


# Cauvery river basin

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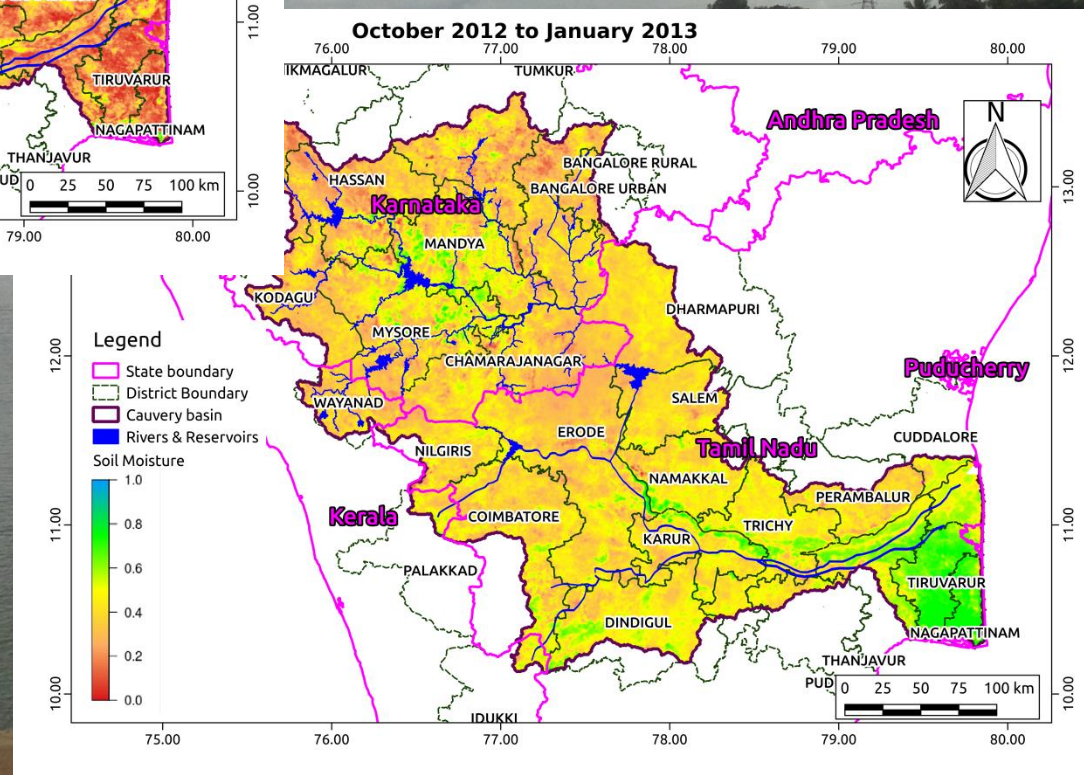
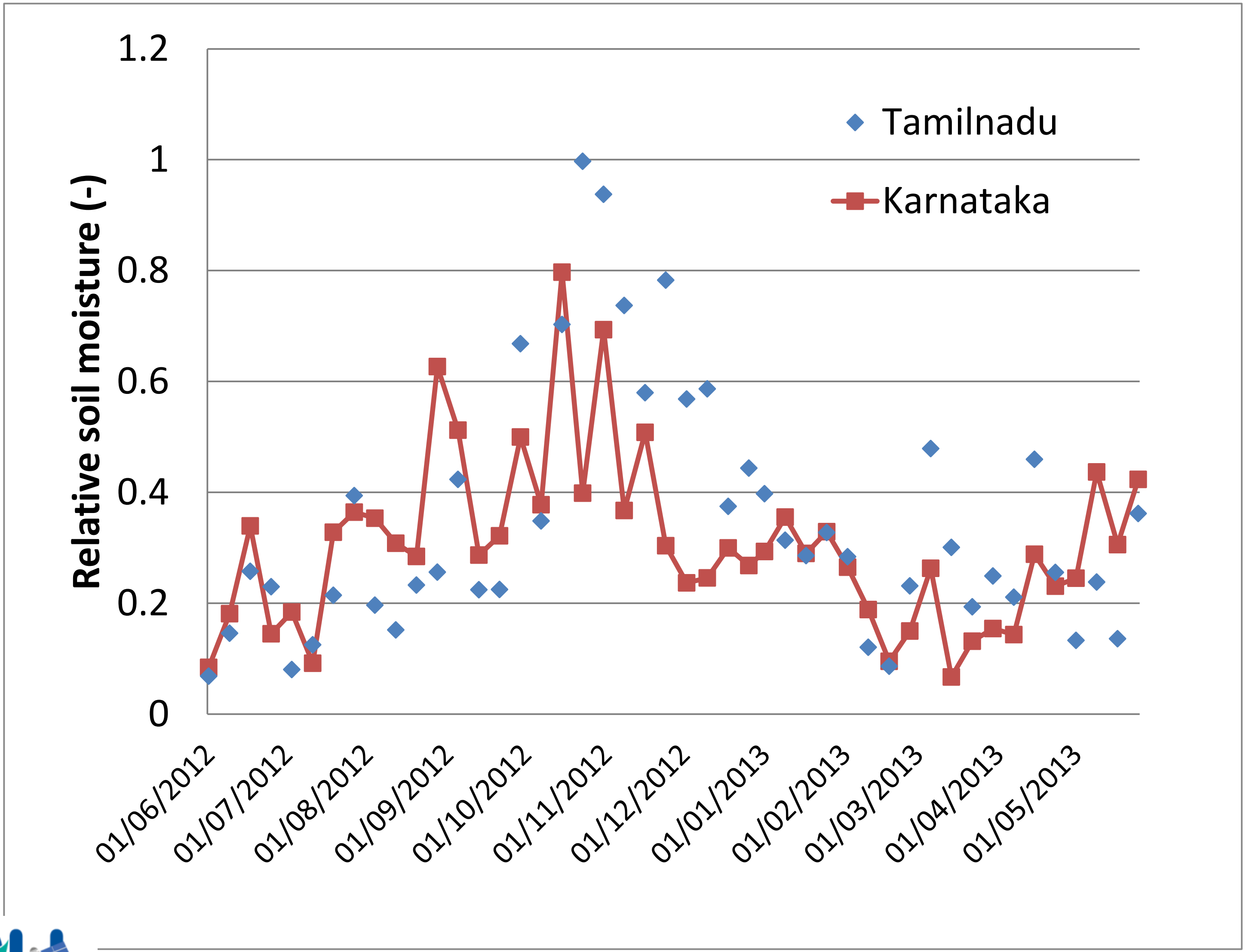


# Cauvery river basin



# General:

- ❑ The assessment methodology should take into account the spatio-temporal variability.
- ❑ Satellite data provides a way to assess the impact of spatio-temporal variability.
- ❑ Analysis was carried out in Odisha over a large number of water tanks.
- ❑ Average impact is presented in the below figure.

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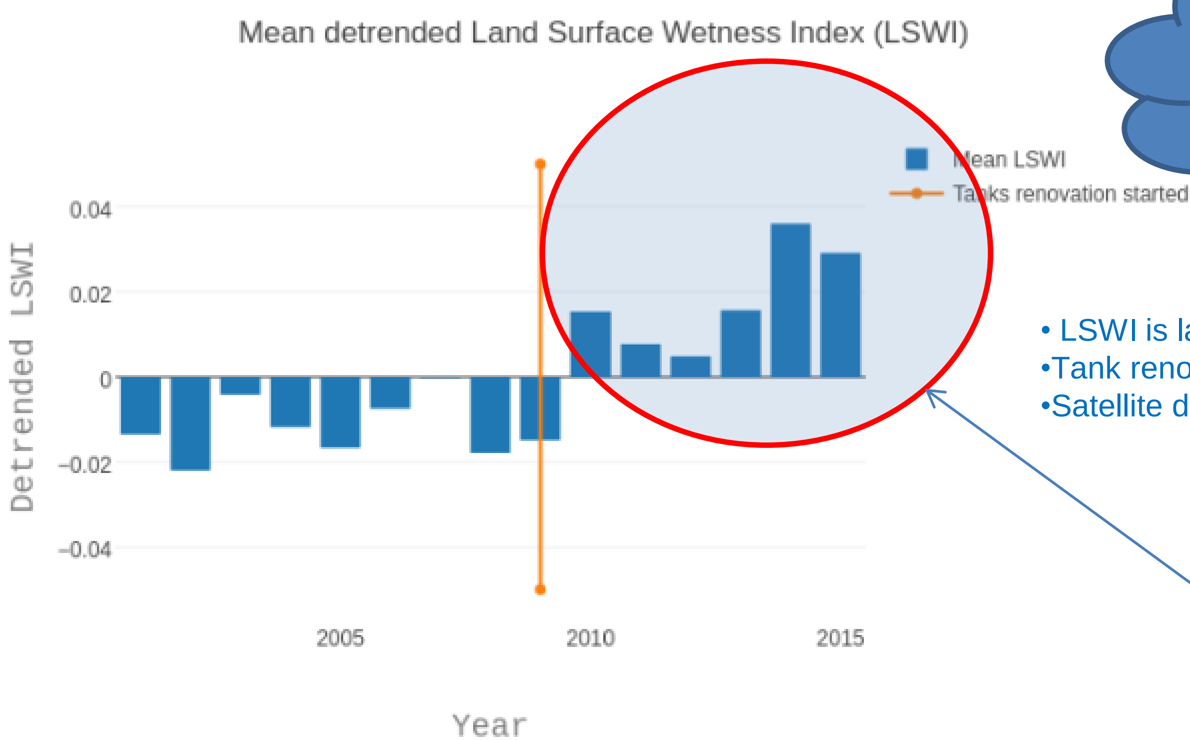


Useful for quantifying the impact of irrigation projects e.g. reservoirs, canal, tank renovation, dip irrigation

- LSWI is land surface water index estimated using satellite d
- Tank renovation project started in 2009
- Satellite data is detrended with respect to rainfall

A clear improvement after the tank renovations

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# On SMOS for high resolution soil moisture for agricultural ap

« SMOS data brings the needed leverage to provide clients requirements from crop issurance and water management sectors »

Dr.Sat K.Tomer, CTO AAPAH, Hyderabad, India

« South-india has one of the highest stress indexes on water ressources use, groundwater is highly over exploited »

Prof. Muddu Sekhar, IISc, India

« Disaster risk management linked to water ressources in top prority in Karnataka state, it is linked to major economic, societal and polictical issues »

Karnataka State Disaster Monitoring Center

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# Summary

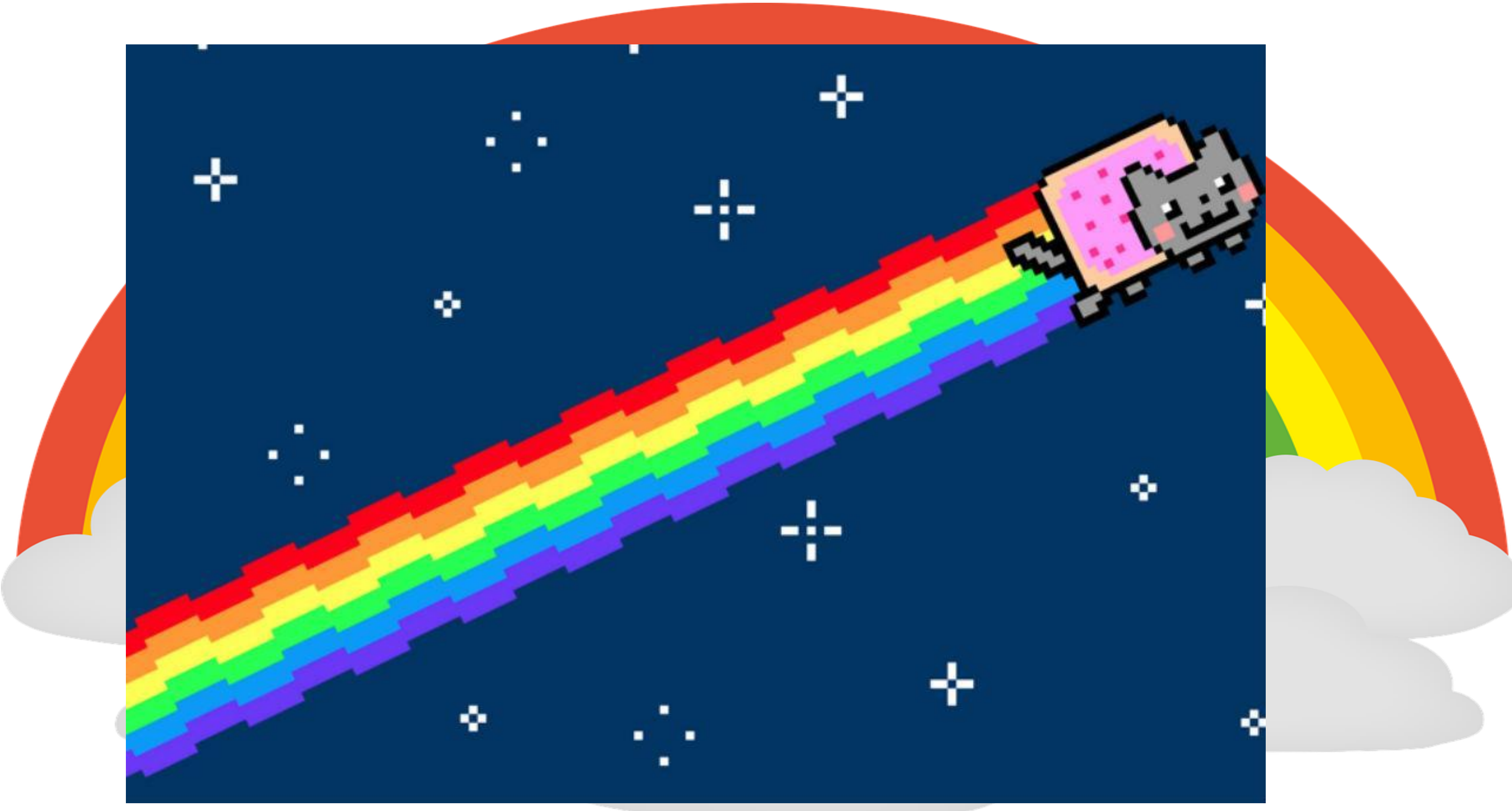
L-Band provides an array of products for Land, we presented here: water surfaces, root zone soil moisture, High res. SM.

These products have positif impact on agro-hydrological applications and ecosystem monitoring.

But we need to convince this case to drive futur

L-Band next to existing frequencies (C-Band)

# Save the microwave raindow



**We need** L-Band as part of a **spectrum of microwave observations** to tackle the most important **risks facing humanity** in a earth system framework

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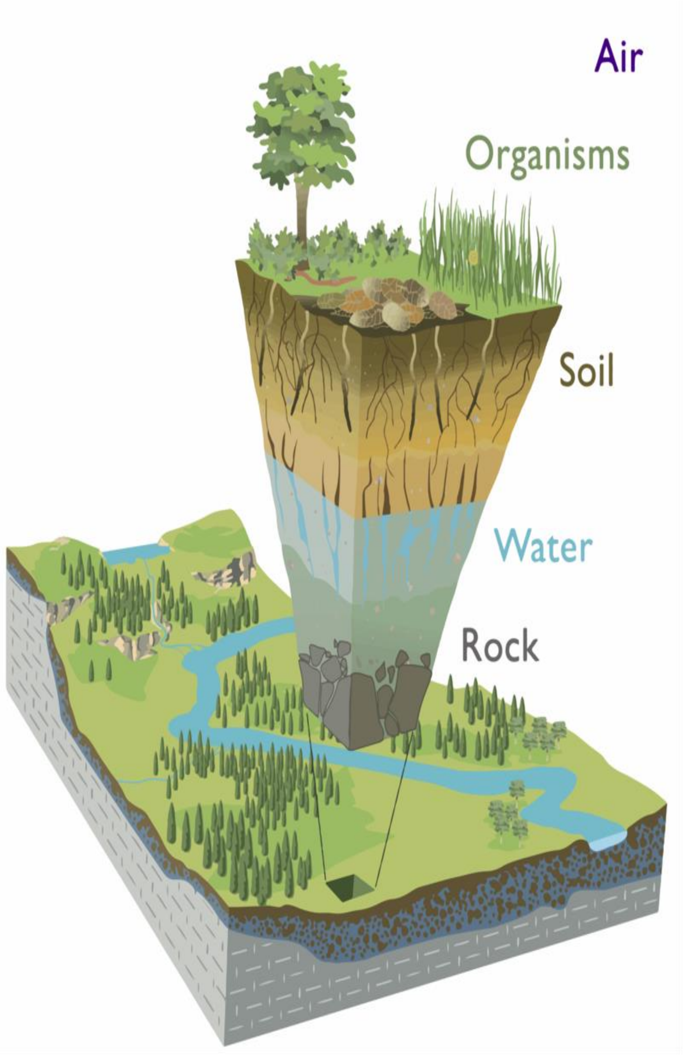
Acknowledgment:

INSU-CNRS

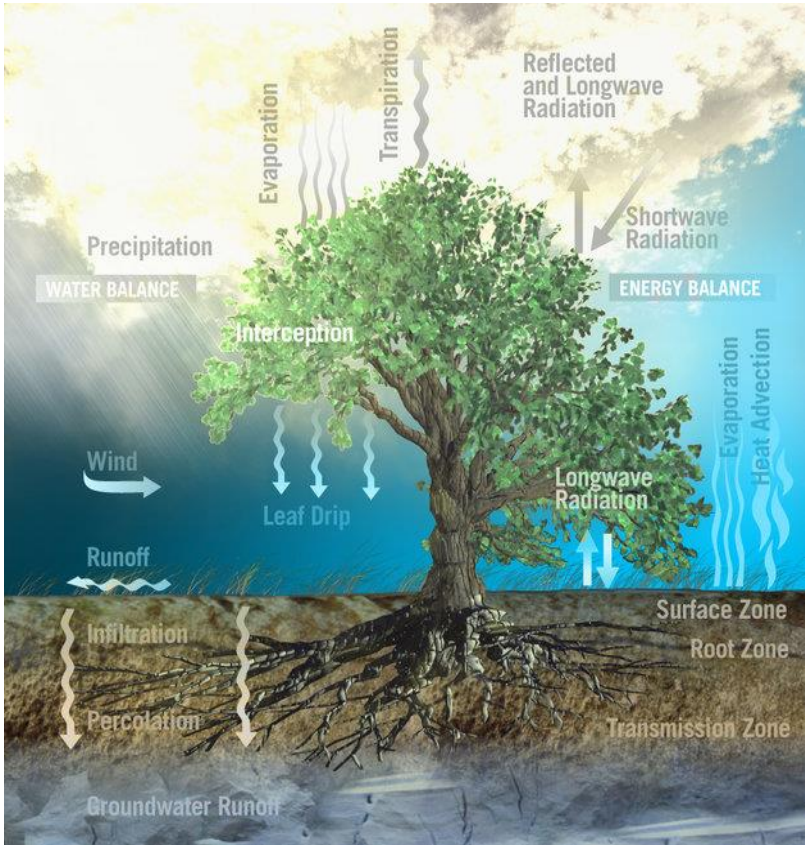
CNES TOSCA SOLE, TOSCA SMOS

AAPAH Innovation / CEFIRSE

# The Critical zone concept




Critical Zone (Chorover et. al. 2007)

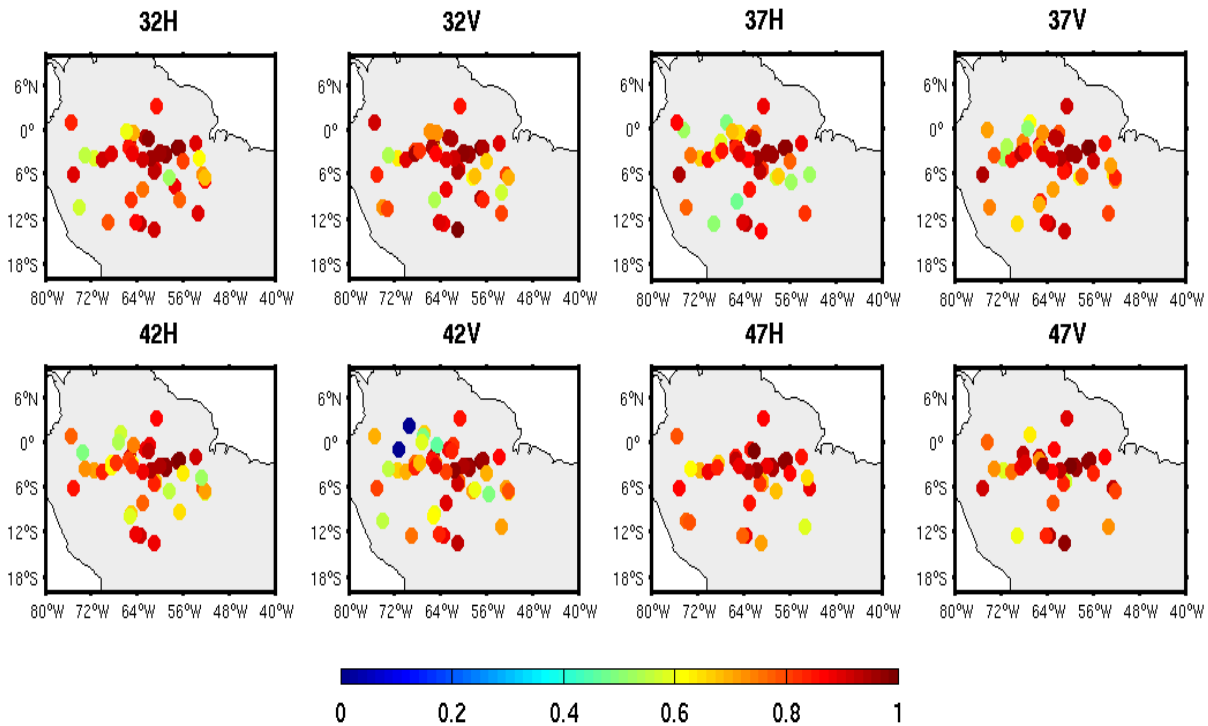



Surface Layer processes (ESA)

# Validation of the SMOS Water fraction

## *Against heights from altimetry*

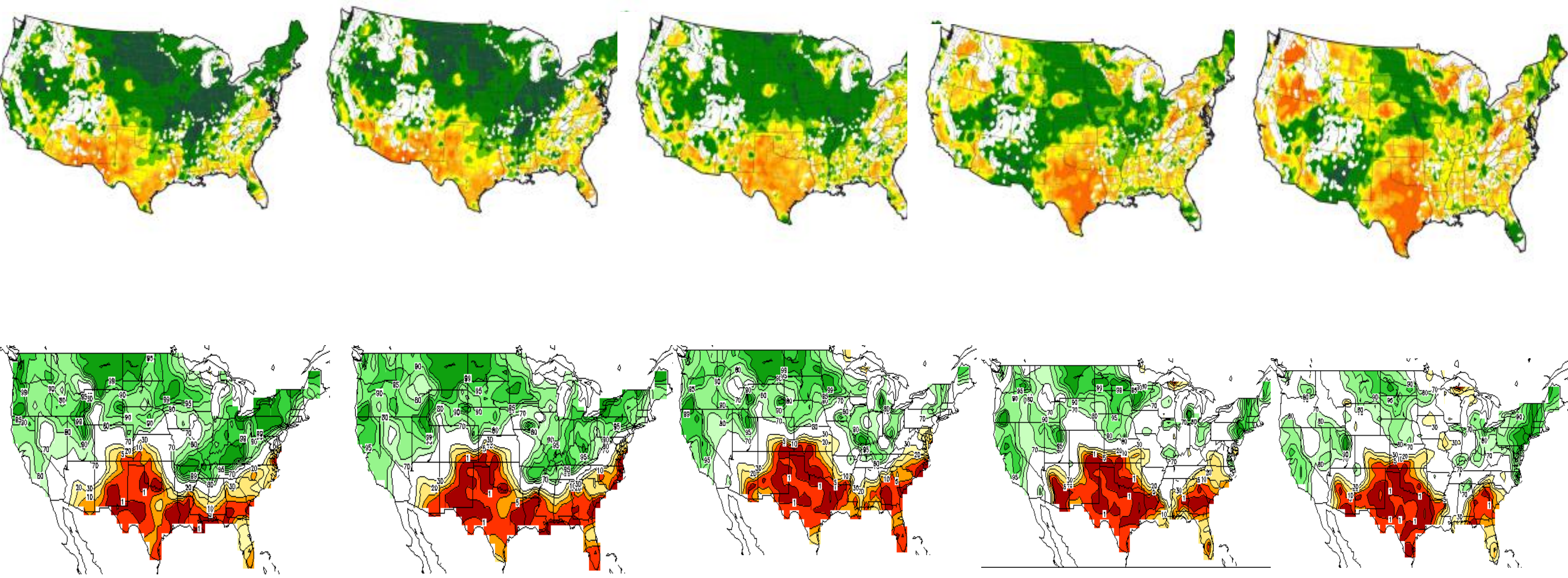
### Correlation between Jason-2 water heights and SWAF



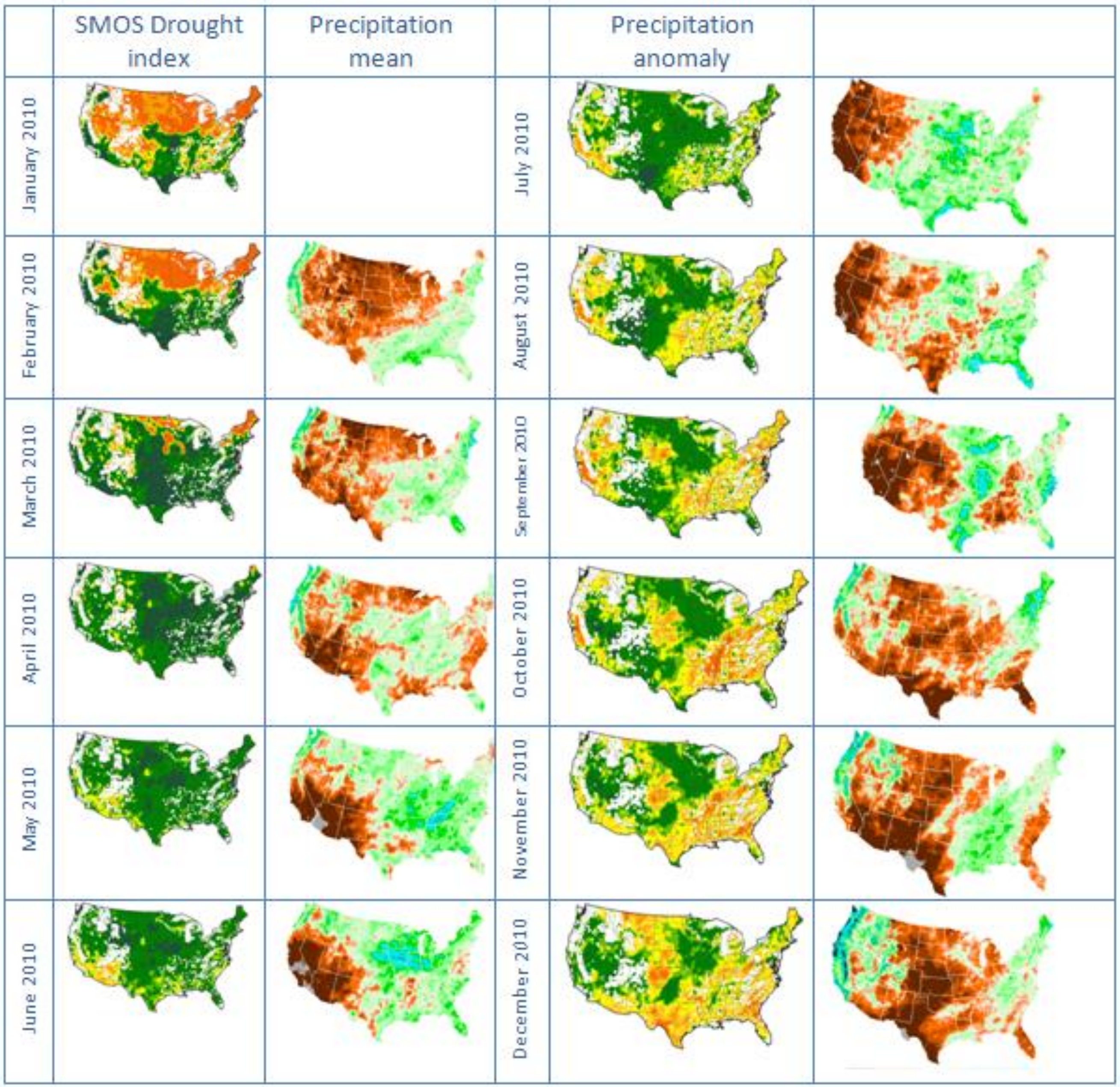

**Nodes with high topography are excluded**

# RZ soil moisture vs NOAA NCEP Bucket model

May 2011 | June 2011 | July 2011 | August2011 | September 2011



# Drought Index vs Precipitation anomaly



# Can we see the current flods in Niger ?

Sécurité

## Niamey menacée d'inondation selon l'Autorité du bassin du fleuve Niger

Soyez le premier à commenter! | Commentaires - mardi, 05 septembre 2017 17:58

EMAIL FACEBOOK LINKEDIN TWITTER

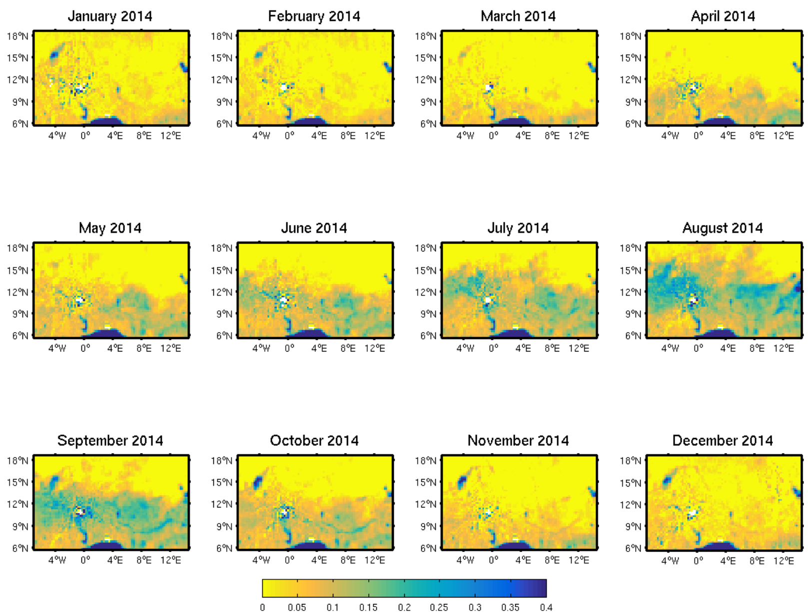
(Niamey et les 2 jours) - L'Autorité du bassin du fleuve Niger (ABN) a lancé mardi une alerte sur des risques d'inondation dans la capitale du Niger, Niamey, où des pluies torrentielles ont déjà fait 17 morts depuis juin, rapporte VOA. « *Les risques de montée d'eau rapide sont réels, la vigilance doit être de mise* », prévient l'ABN.

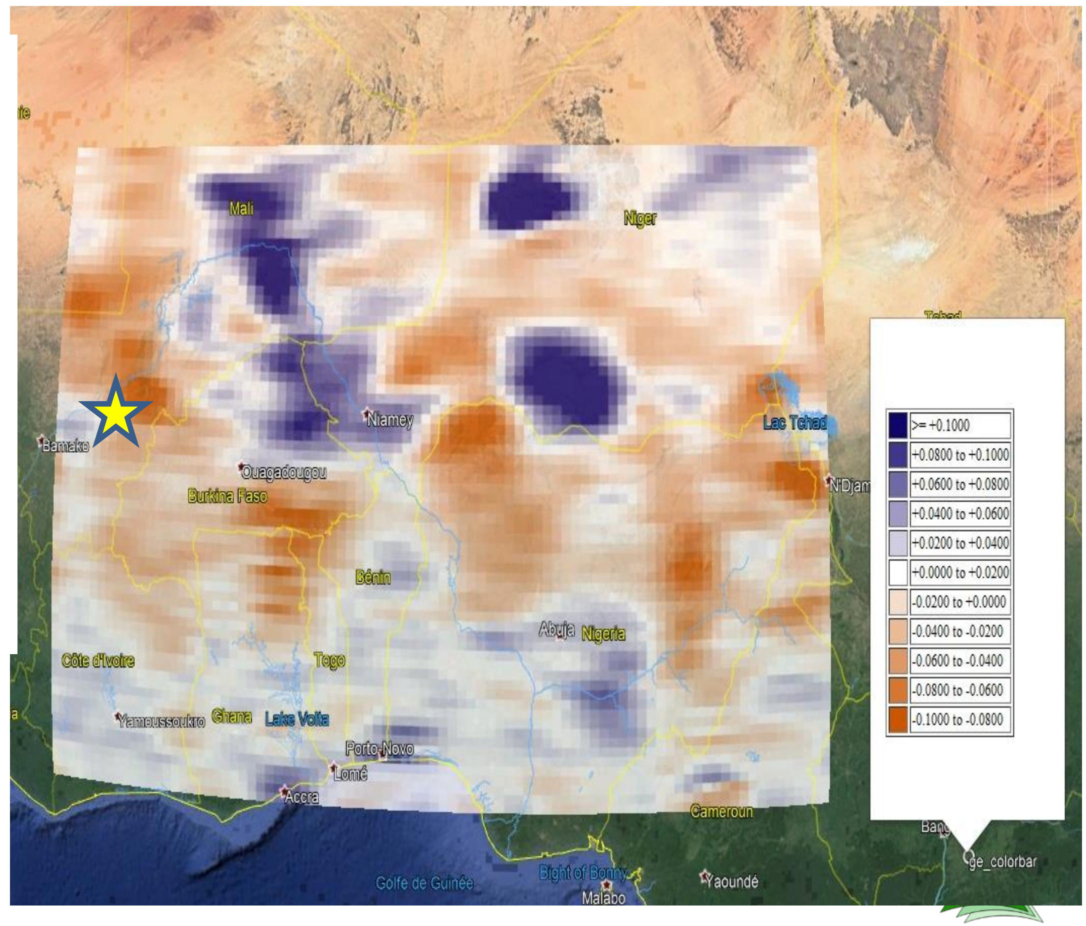
Follow @etles2jours

WHATSAPP

# Last flood detection on August-Sept 2017

- Comparison between SWAF (28th August – 4th September 2017) and SWAF during the same days from 2011 to 2016

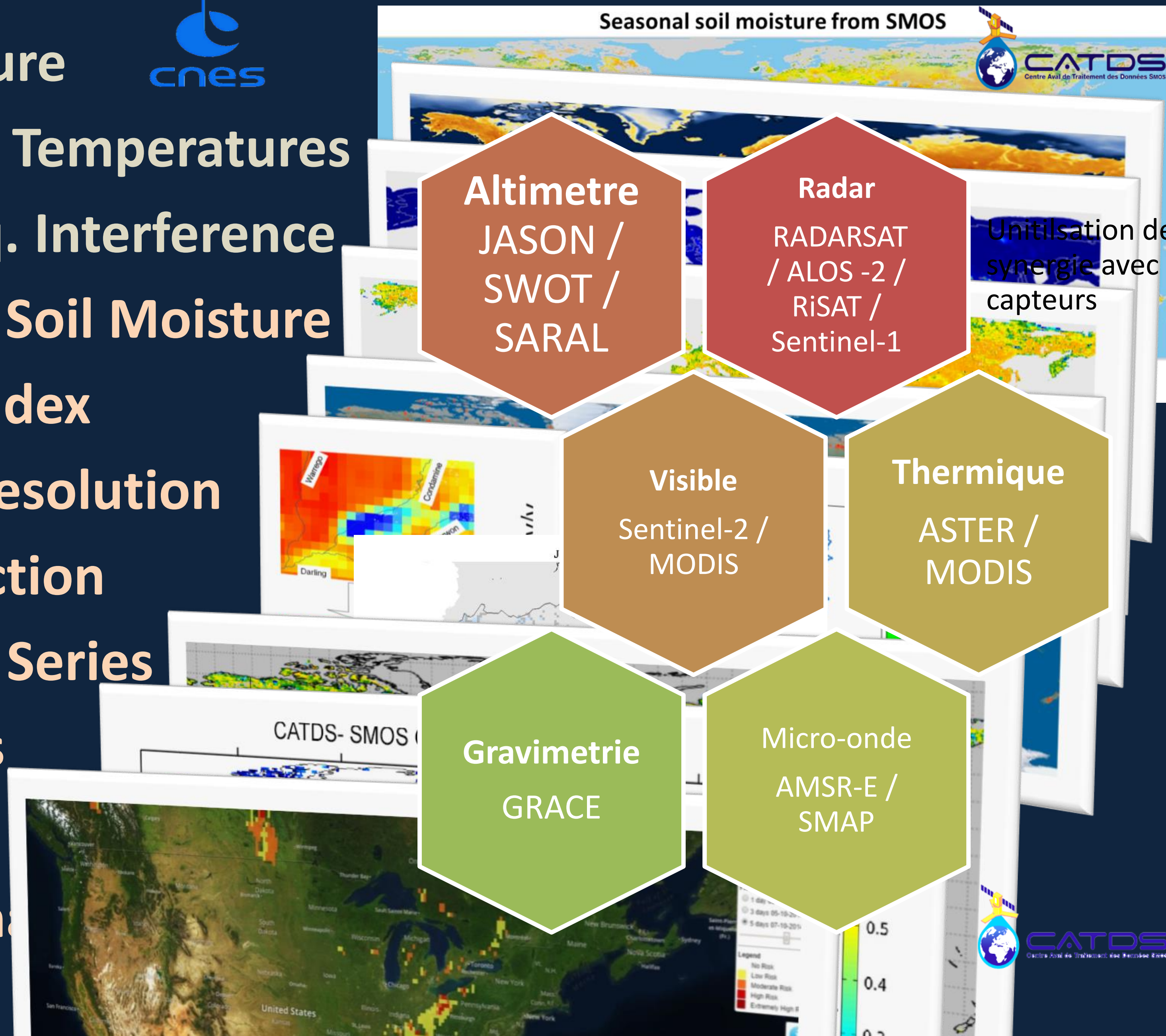


# An array of products from synergistic use

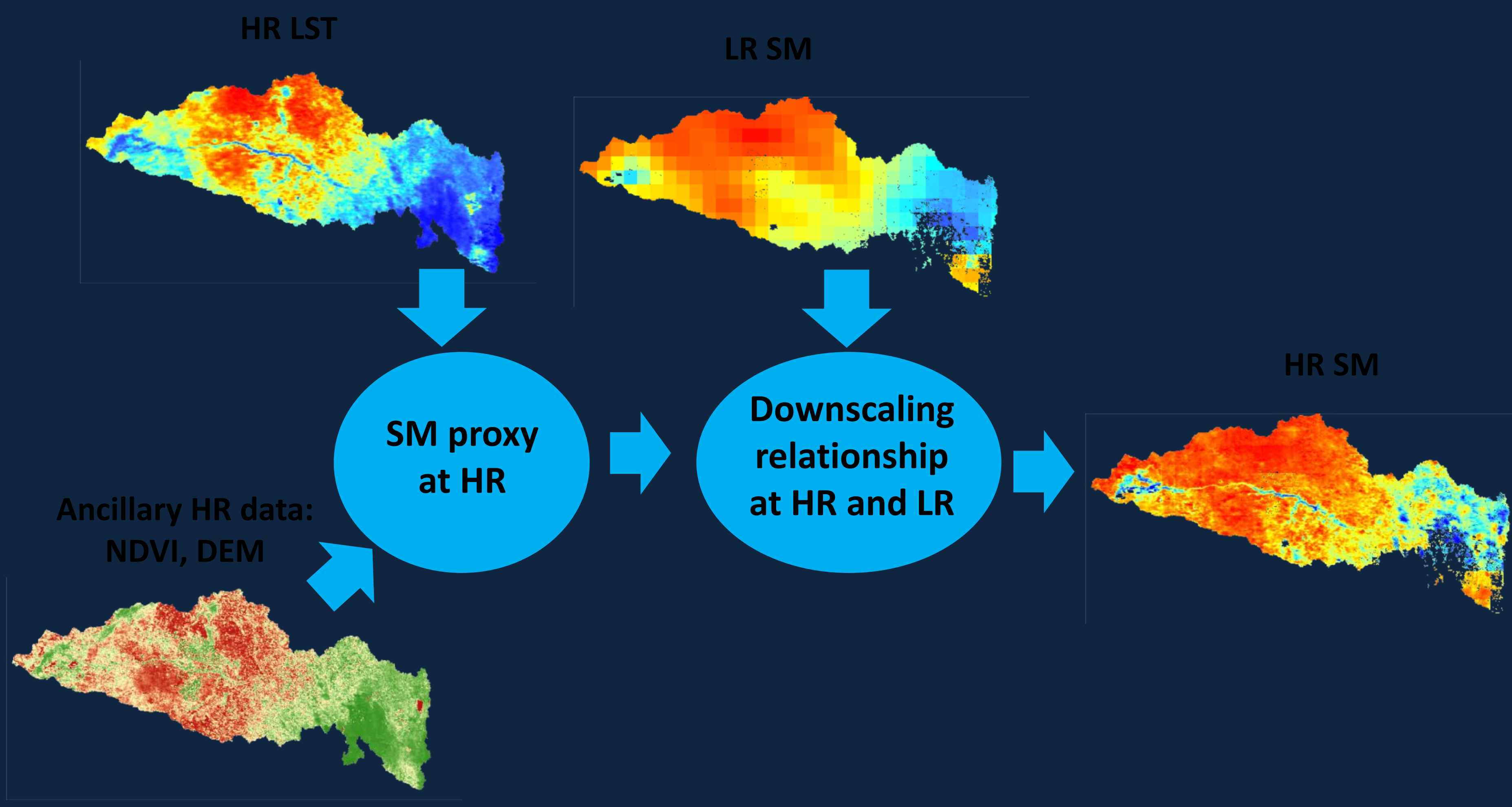
- L3 Soil Moisture
- L3 Brightness Temperatures
- L3 Radio Freq. Interference
- L4 Root Zone Soil Moisture
- L4 Drought Index
- L4 SM High Resolution
- L4 Water Fraction
- L4 Long Time Series
- L4 Roughness
- L4 Flood Risk
- + Rainfall Enh

…



# Rationale for evaporation-based SM downscaling

## *Generic scheme*




Merlin et al.

# DISPATCH method

*DISaggregation based on Physical And Theoretical scale CHange*

1) SEE = Soil Evaporative Efficiency = LEs/LEp,s

= (Ts,dry - Ts)/(Ts,dry – Ts,wet)

***Normalizes LST*** for Vegetation Cover = fc and Meteo forcing

2) Semi-physical SEEmod( SM )

3) Downscaling relationship

$$SM_{HR} = SM_{LR} + \left(\frac{\partial SEE_{\mathrm{mod}}}{\partial SM}\right)^{-1}_{LR} \times \left(SEE_{HR} - SEE_{LR}\right)$$

Merlin et al. RSE 2008; TGRS 2012; RSE 2013