# What do we learn about the impact of extreme hydrological events on tropical wetlands from the synergistic use of altimetry from Sentinel-3/SARAL-Altika and L-Band radiometry from SMOS/SMAP ?

Ahmad Al Bitar, Marie Parrens, Frederic Frappart, Rodrigo Cauduro Dias de Paiva, Fabrice Papa, Yann Kerr

EGU 2017 – HS 6.3

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Why monitor wetlands
and
How can we achieve this ?

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# Why, monitor Tropical wetlands ?

*Case of the Amazon*

**Water budget**

The Amazon River contributes to **18%** of the global river discharge to the ocean and almost 5% of all the continental masses.

So It is important to map the water surfaces in Tropical regions to understand the underlying processes (Alsdorf et al., 2007 ; Bakker, 2012 ; Finlayson et al., 1999 Vorosmarty et al., 2015; Costanza et al., 2014)

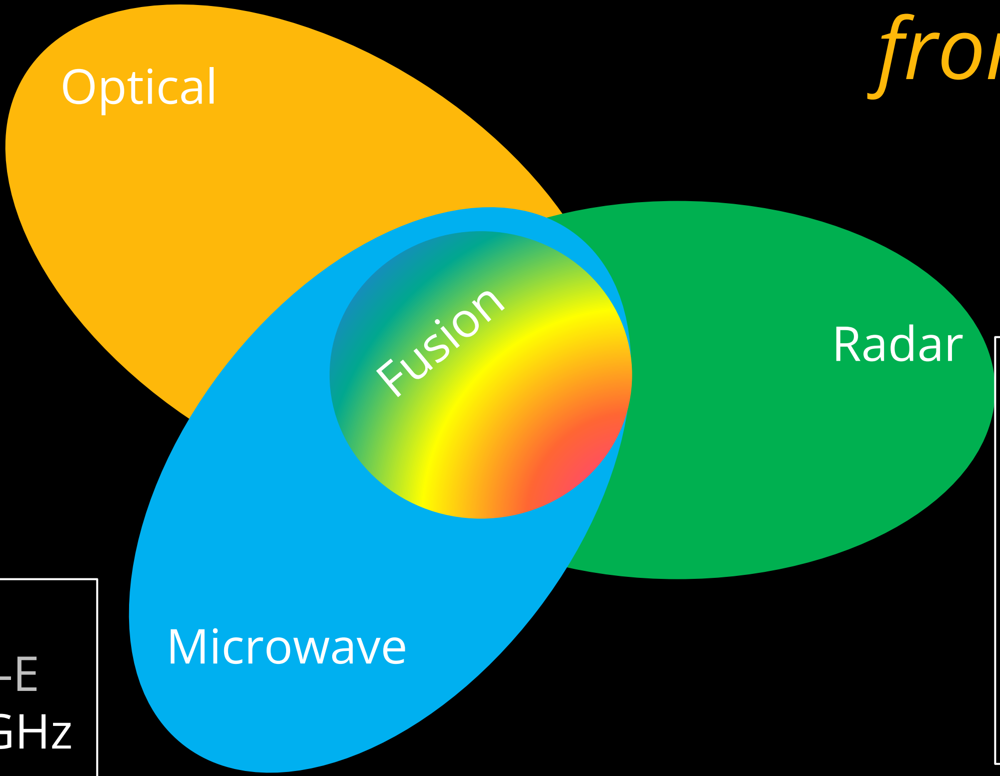
**CO2 budget**

"Outgassing of $CO_2$ from rivers and wetlands constitut a carbon loss of 1.2 Mg C $ha^{-1}$ $yr^{-1}$. Overall carbon budget of rainforests, summed across terrestrial and aquatic environments closer to being in balance " (*Richey et al. Nature 2002*)

"…a sediment load of 3 million tons near its mouth" (Molinier et al.,IAHS 1996)

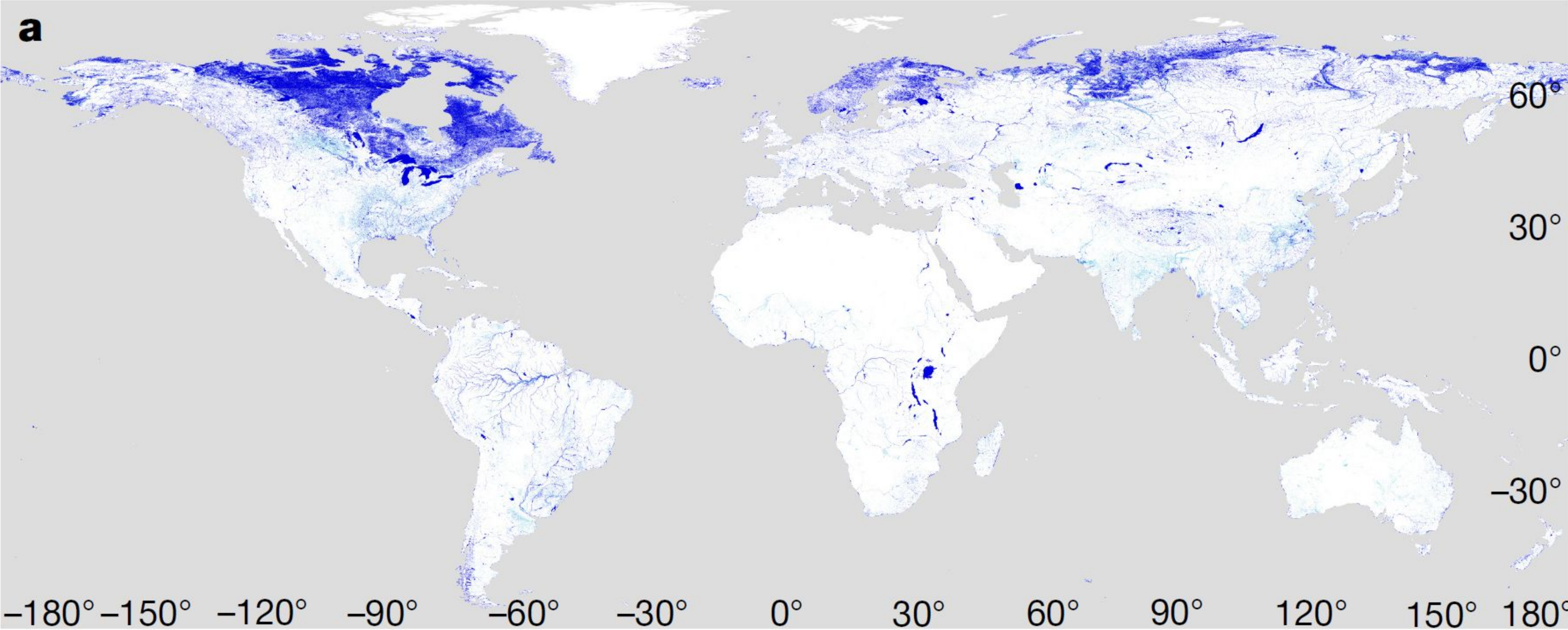
# How can we monitor wetlands surfaces from space ?

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

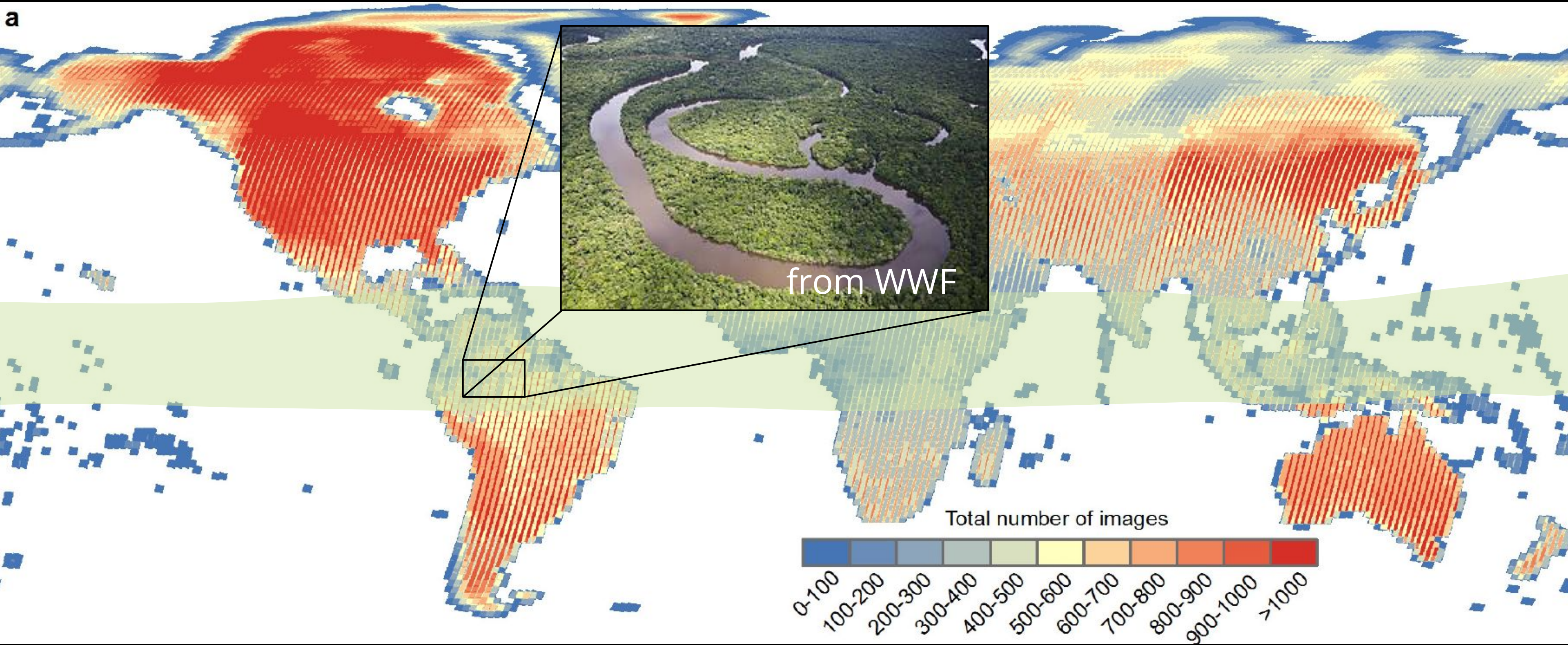



- C-band
  - *Sentinel 1*
  - *RadarSAT*
- L-band
  - *PALSAR*
- X-band
  - *TERRASAR*

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




from Pekel et al. Nature, 2016




from Pekel et al. Nature, 2016

# Advantage of Microwave RS

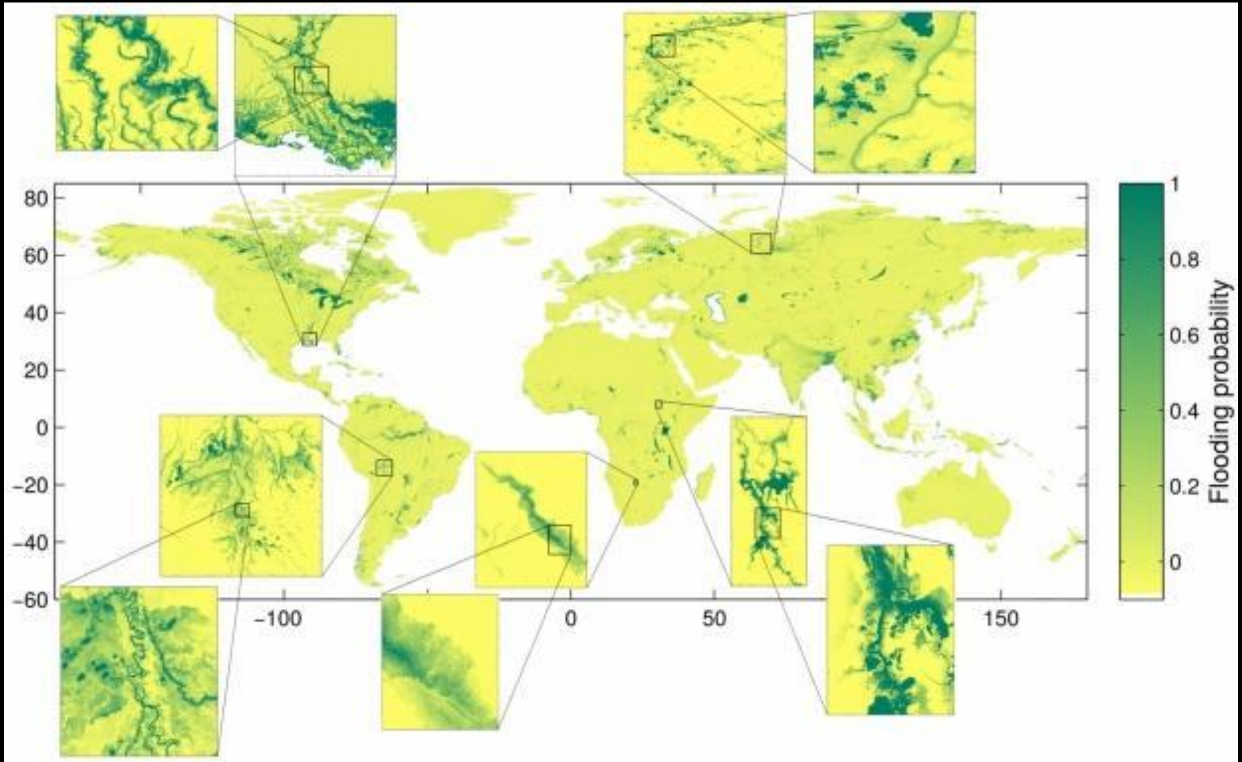
- Microwave has all weather capabilities.
- Sensors have a high revisit frequency (1-3 days).
- The Can provide signal underneath the vegetation (depending on frequency).
- Proof of concept and products exist since more than a decade.

<u>But :</u>

- Microwave sensors have a low spatial resolution : ~0.25° .

<u>So :</u>

- Synergistic approached need to be privielaged (Prigent et al., 2008 ).




Aires et al. 2017

# Advantage of Microwave RS

*L-band*

- The  impact of vegetation is lower in L-band.

- The impact of heavy rainfall is also lower than C-band.

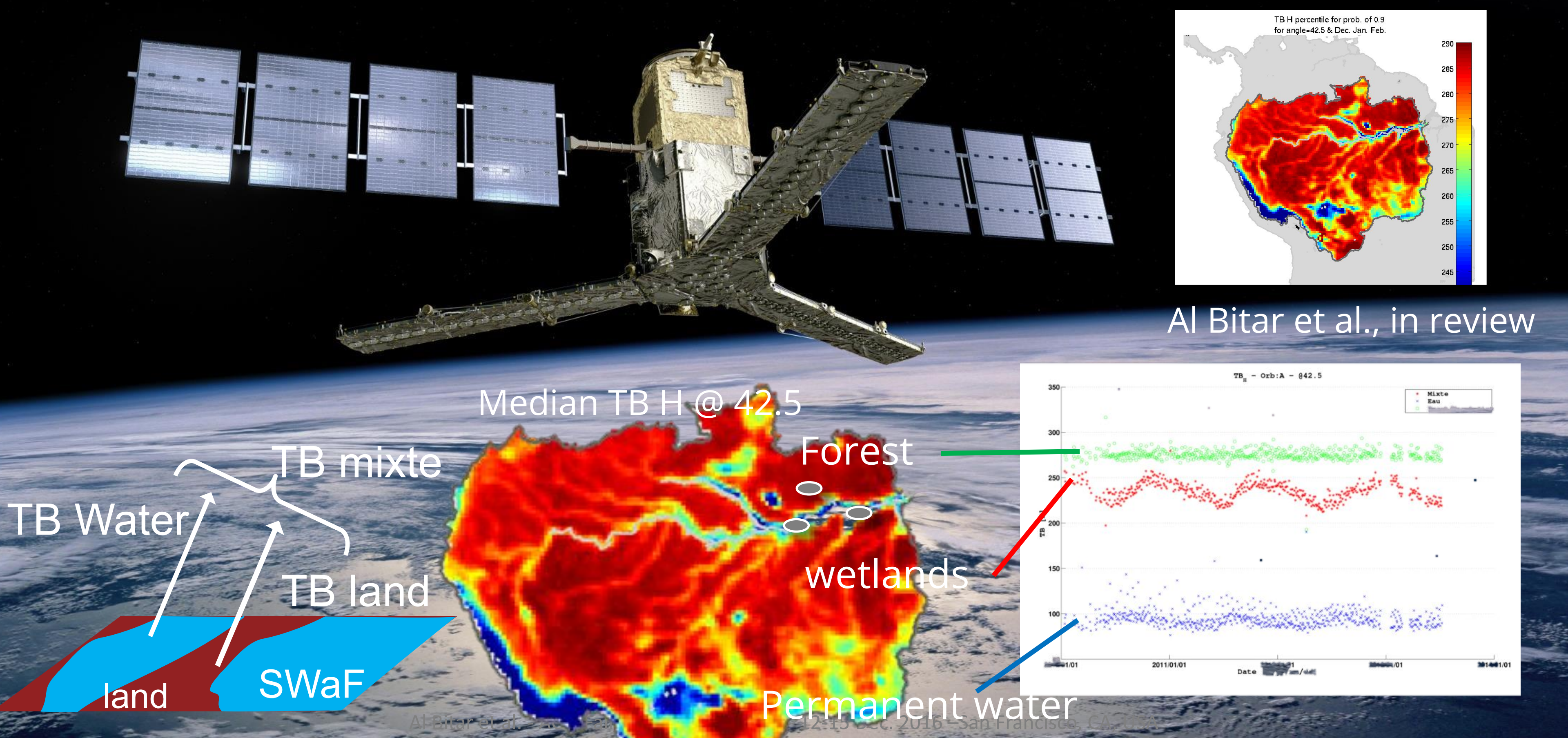
- Multi angular and full polarisation acquisitions are available

<u>But :</u>

- At which vegetation density it is still an open question

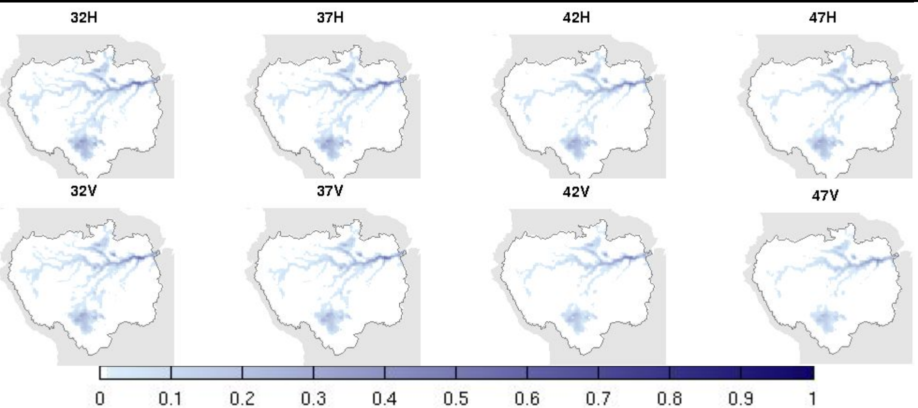
(Rahmoun et al. 2015, Parrens et al. 2015).

# SWAF - Water fraction using SMOS data

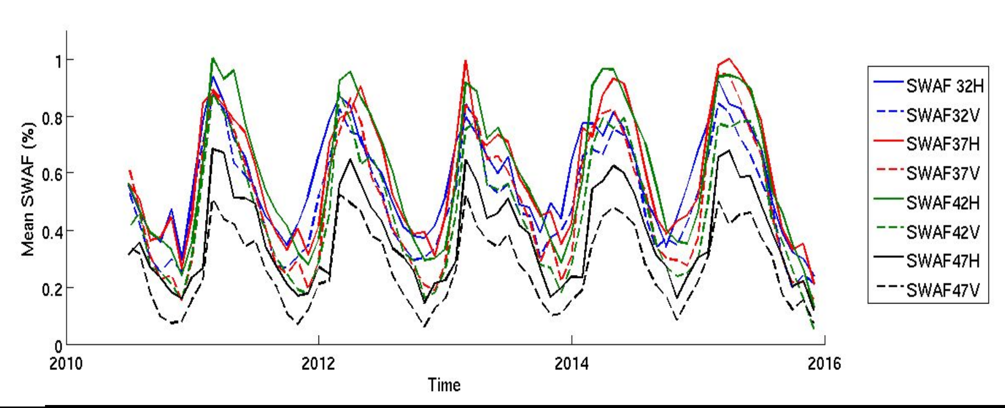


# Impact of polarisation and incidence angle

## Mean SWAF for 2010 - 2016




## Timeseries over entire basin

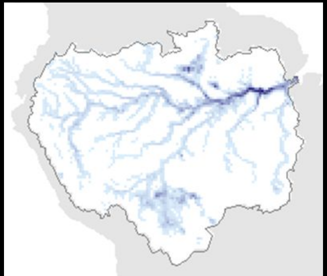



Parrens et al. 2017

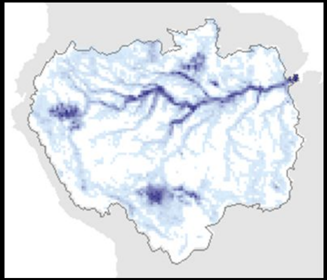
# Validation of the SMOS Water fraction

*Against static maps*

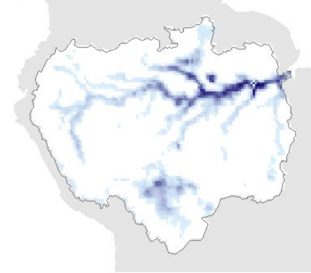
IGBP



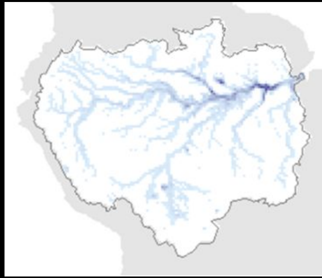
GlobCover



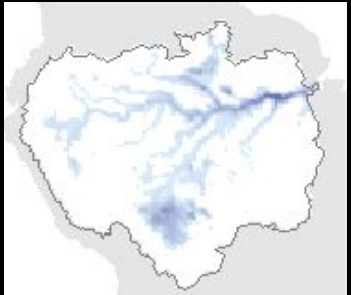
GIEMS

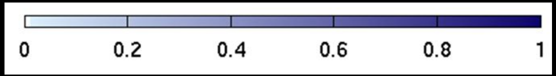


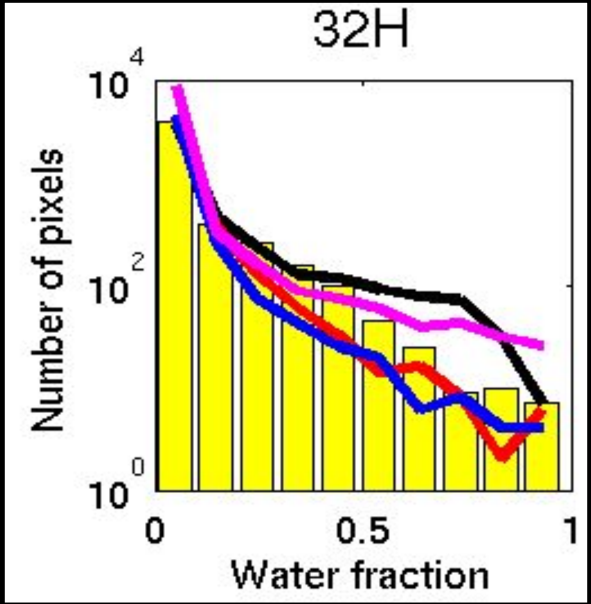
ESA CCI



SWAF



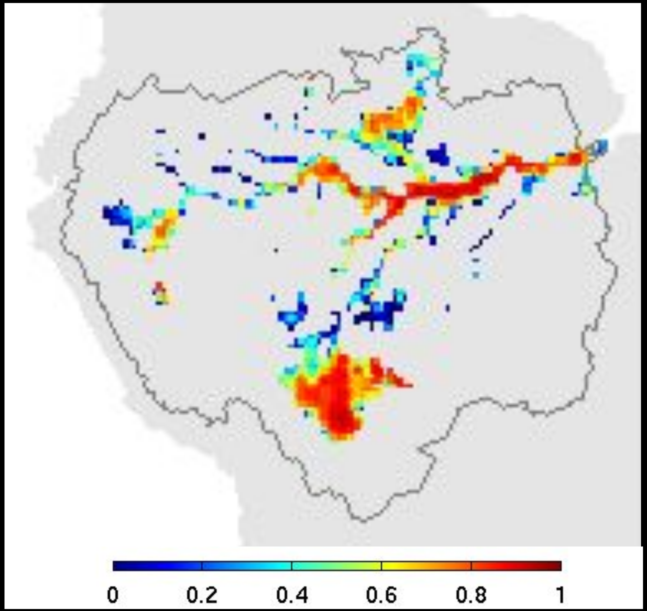


# Validation of the SMOS Water fraction

## *Against dynamic maps*

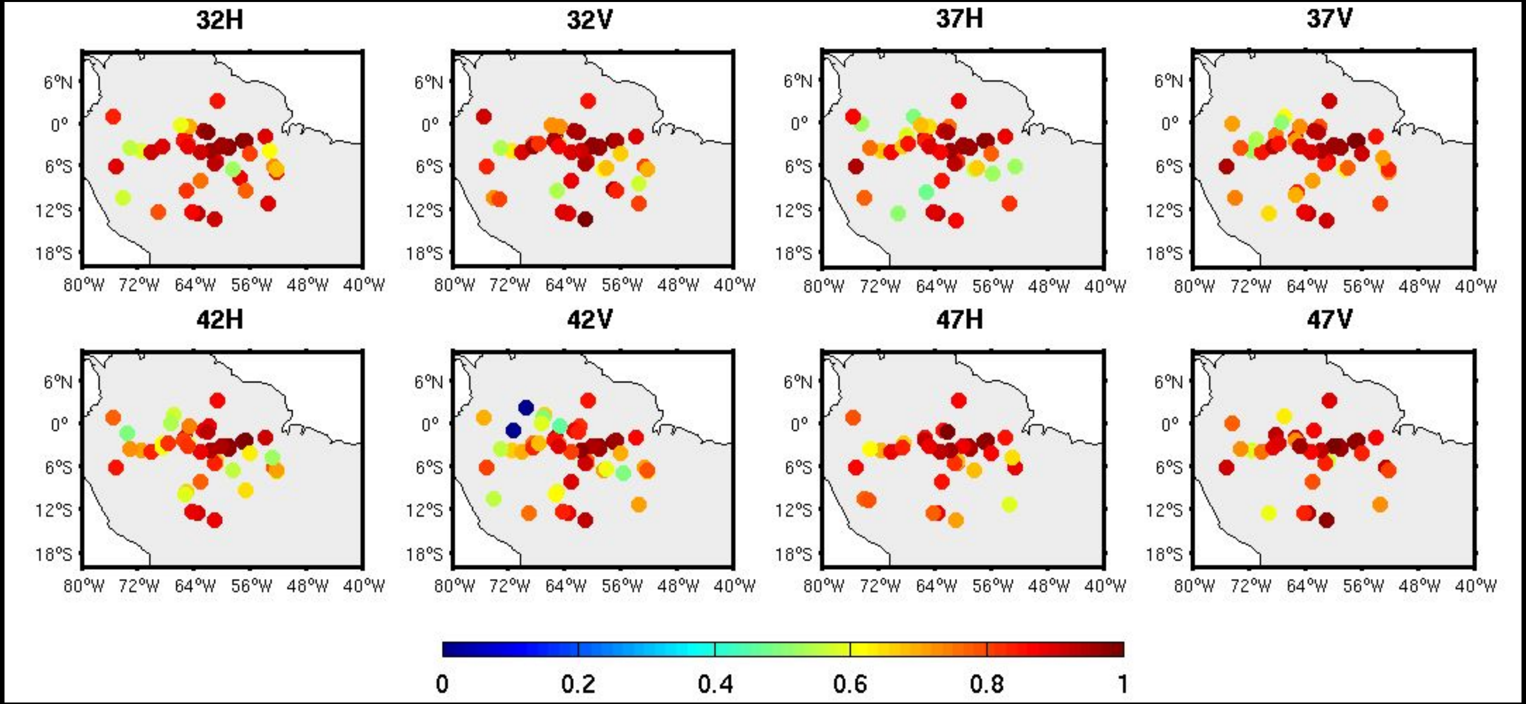
Temporal correlation between SWAMPS and SWAF products



# Validation of the SMOS Water fraction

## *Against heights from altimetry*

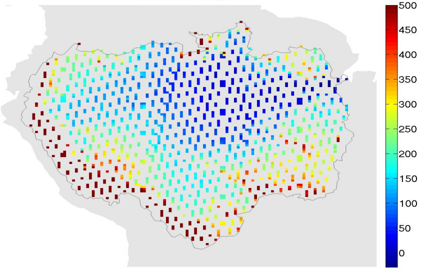
Correlation between Jason-2 water heights and SWAF



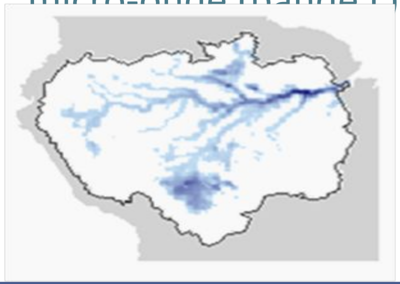

Nodes with high topography are excluded

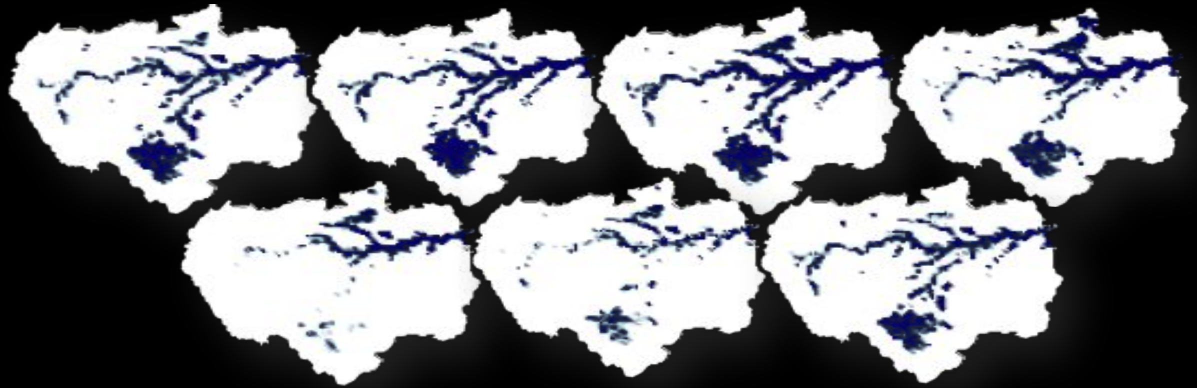
# Water storage from Altimeters and L-band
# SARAL-Altika / SMOS

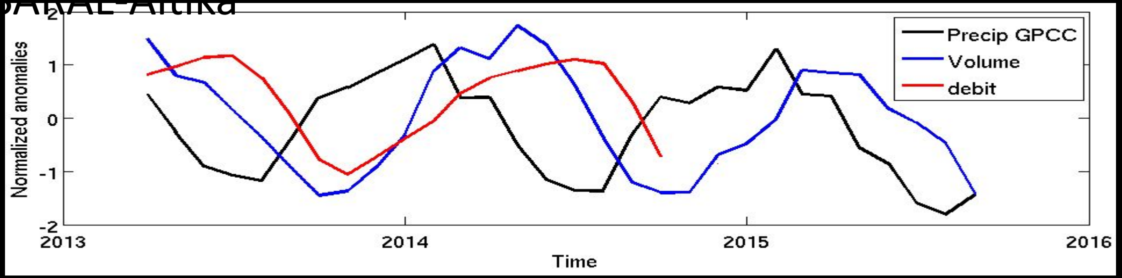
Hauteur d’eau par altimétrie spatiale



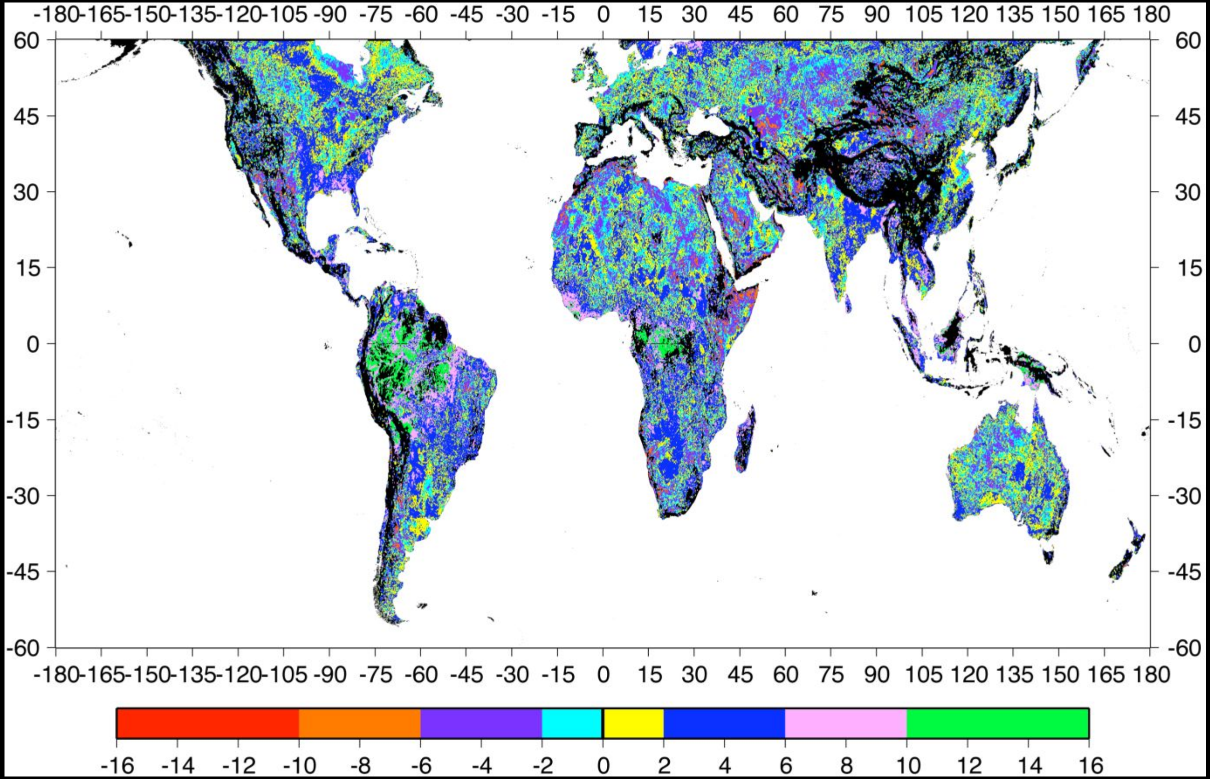

Surface en eau par micro-onde (bande L)

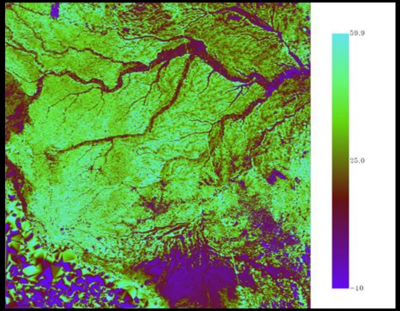




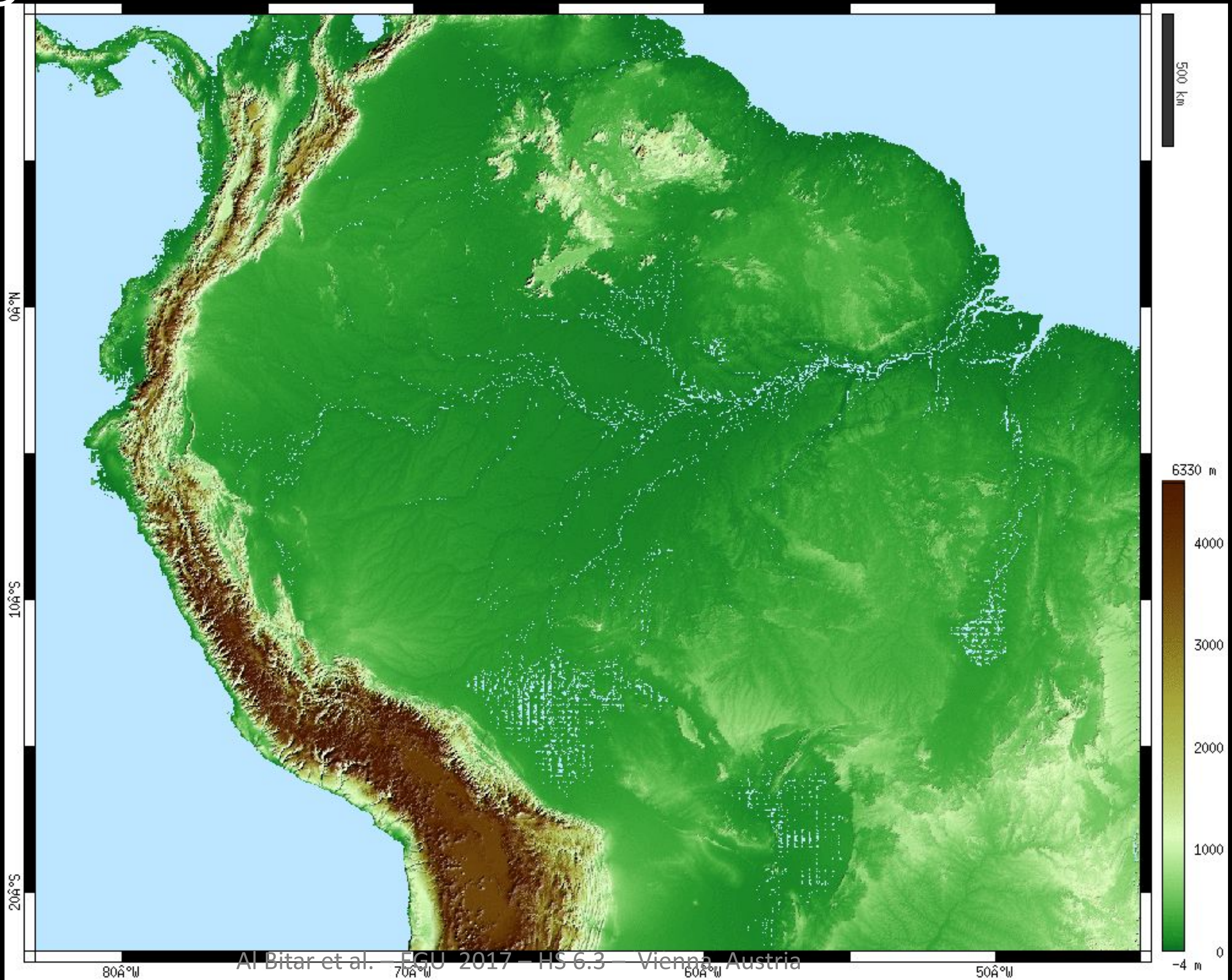


# GDEM dataset ACE2



# Toward high resolution water volumes from L-Band



# How are the wetlands over tropical basins impacted by the extreme hydrological events ?

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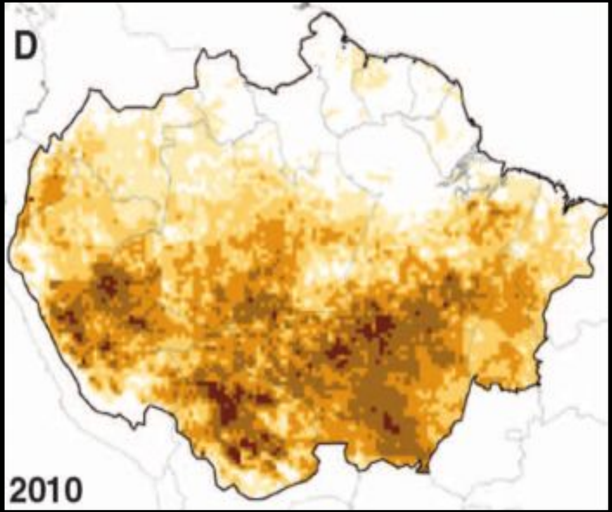
What does it tell us about Droughts and ENSO dynamics ?

# Droughts of 2010

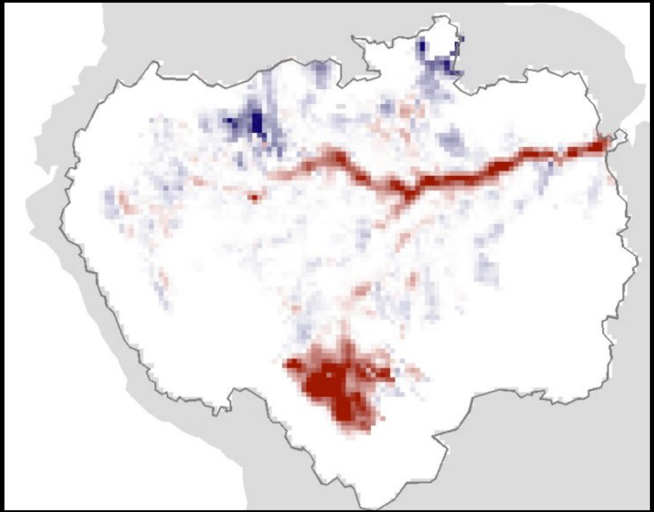
**Clim. Water. Index**




water deficit

(Lewis et al., Science 2011)

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



anomaly of SMOS water fraction

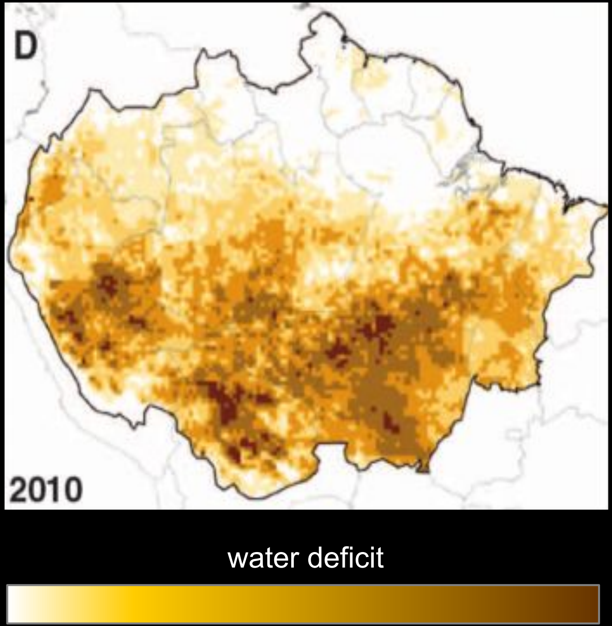
*abnormaly dry* *abnormaly wet*

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.

Reuters ©

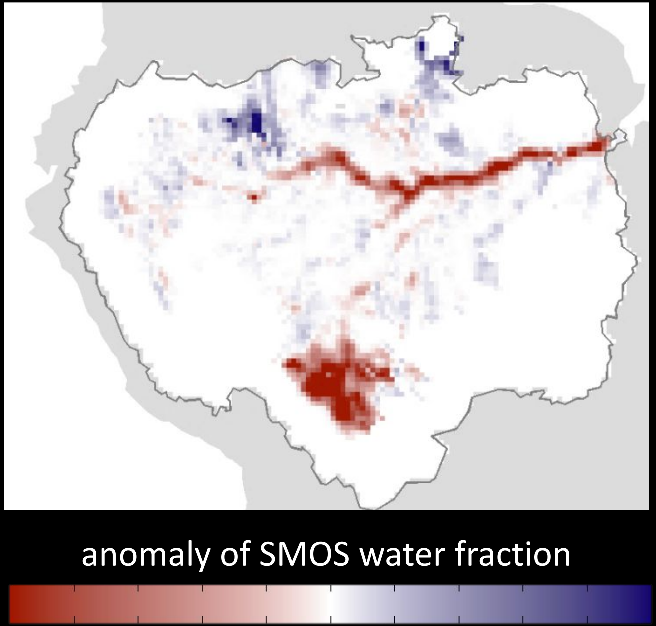
# Droughts of 2010 vs 2015

**Clim. Water. Index**



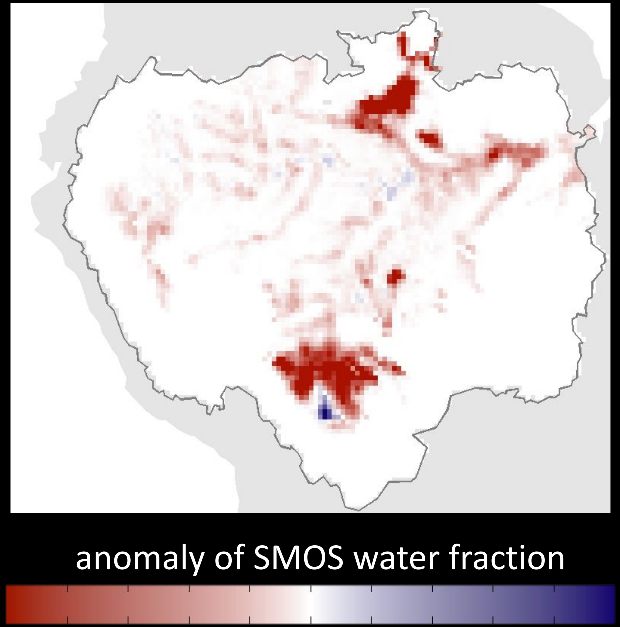

(Lewis et al., Science 2011)

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




*abnormaly dry* *abnormaly wet*

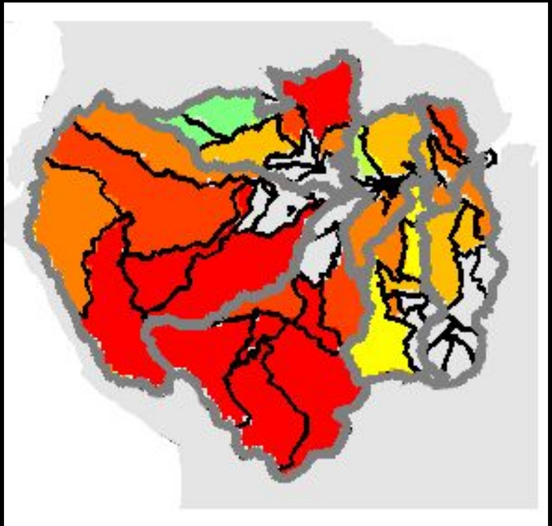
**Anomaly of water fraction**
Oct. – Dec. 2015



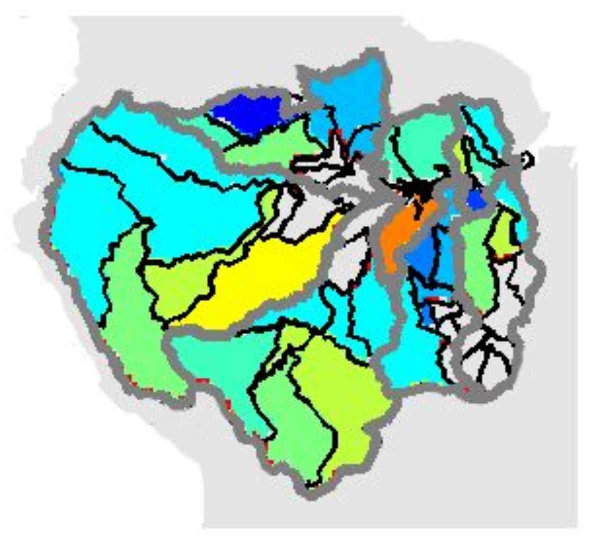

*abnormaly dry* *abnormaly wet*

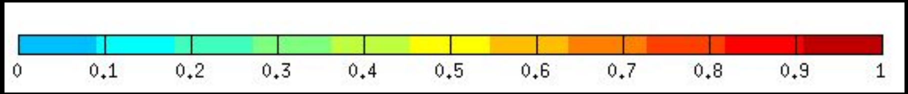
# Link between Precipitation and SWAF

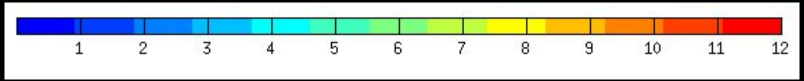
Correlation value (r)



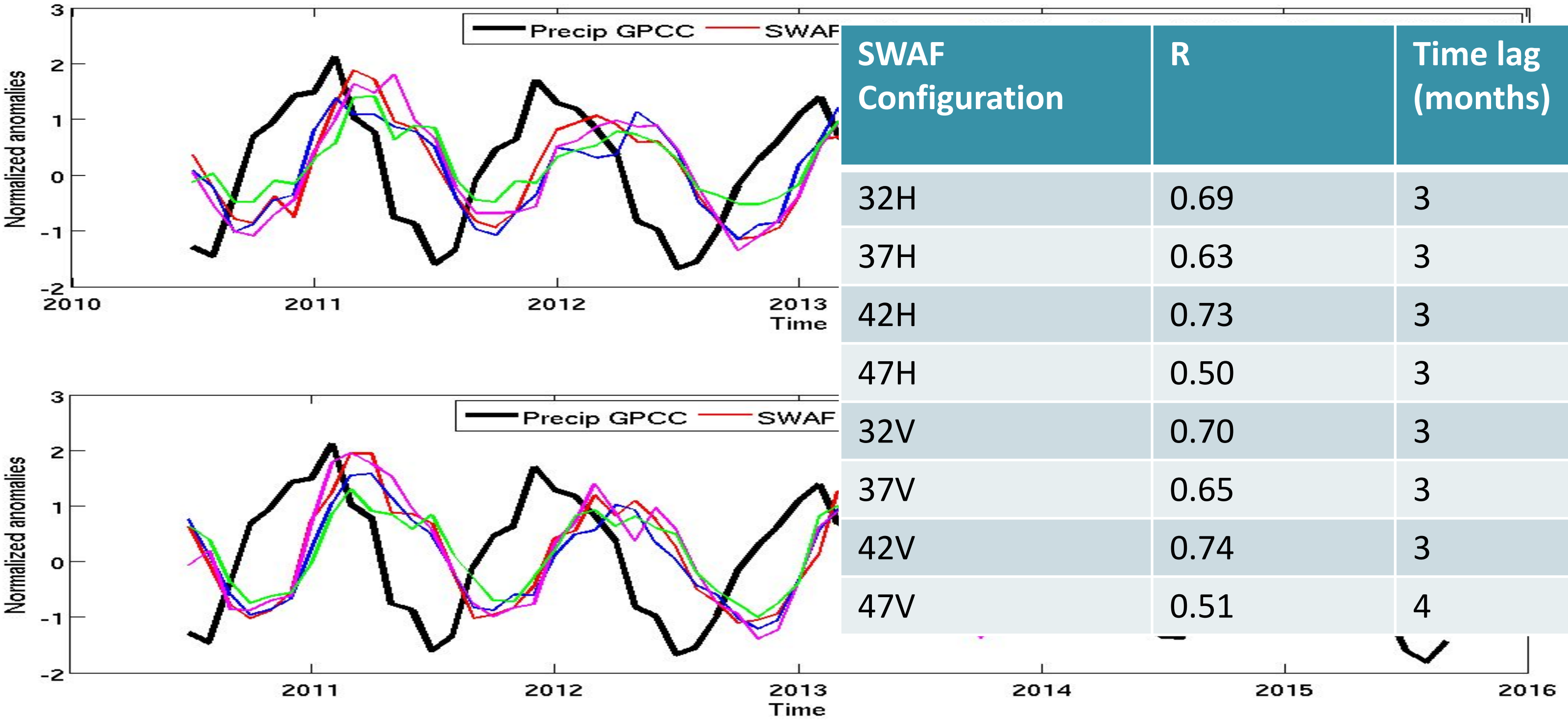
Time lag (weeks)





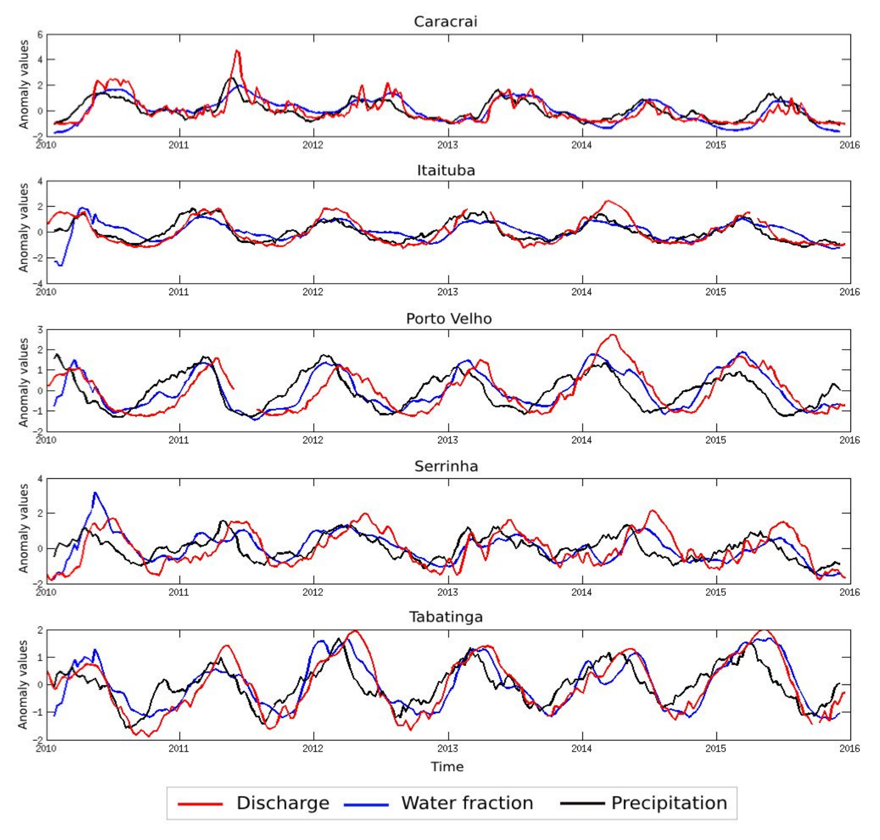



# Comparison of the SMOS water fraction
## With precipitation data (GPCC – monthly products)



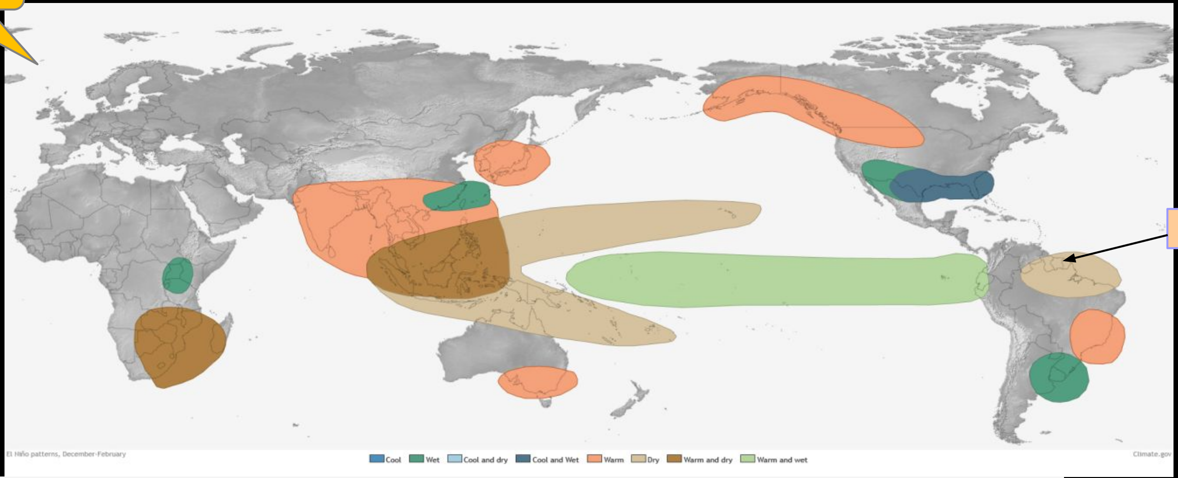

| SWAF Configuration | R | Time lag (months) |
|---|---|---|
| 32H | 0.69 | 3 |
| 37H | 0.63 | 3 |
| 42H | 0.73 | 3 |
| 47H | 0.50 | 3 |
| 32V | 0.70 | 3 |
| 37V | 0.65 | 3 |
| 42V | 0.74 | 3 |
| 47V | 0.51 | 4 |

# Link between Discharge and SWAF



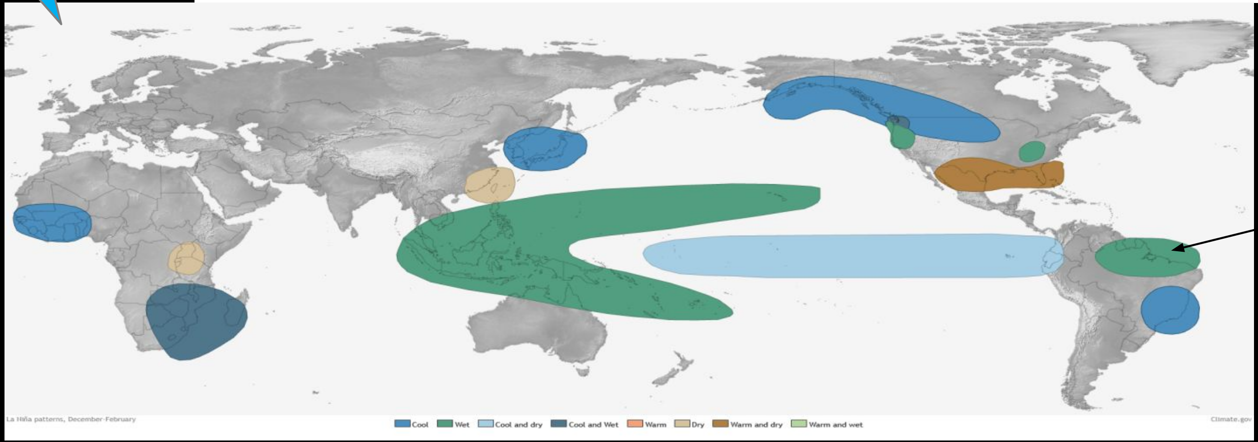

# What are the changes during ENSO years ?

El Nino




Dry

La Nina

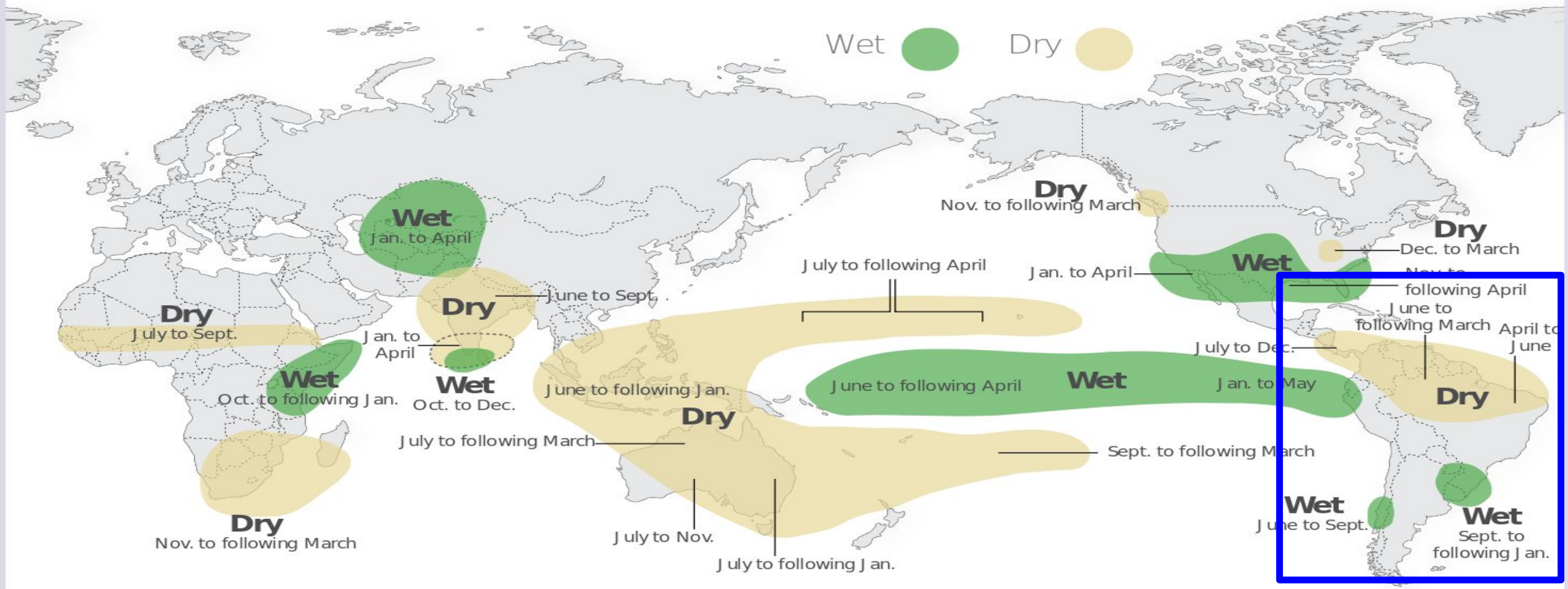



Wet

# What are the changes during ENSO years ?

## El Niño and Rainfall

El Niño conditions in the tropical Pacific are known to shift rainfall patterns in many different parts of the world. Although they vary somewhat from one El Niño to the next, the strongest shifts remain fairly consistent in the regions and seasons shown on the map below.

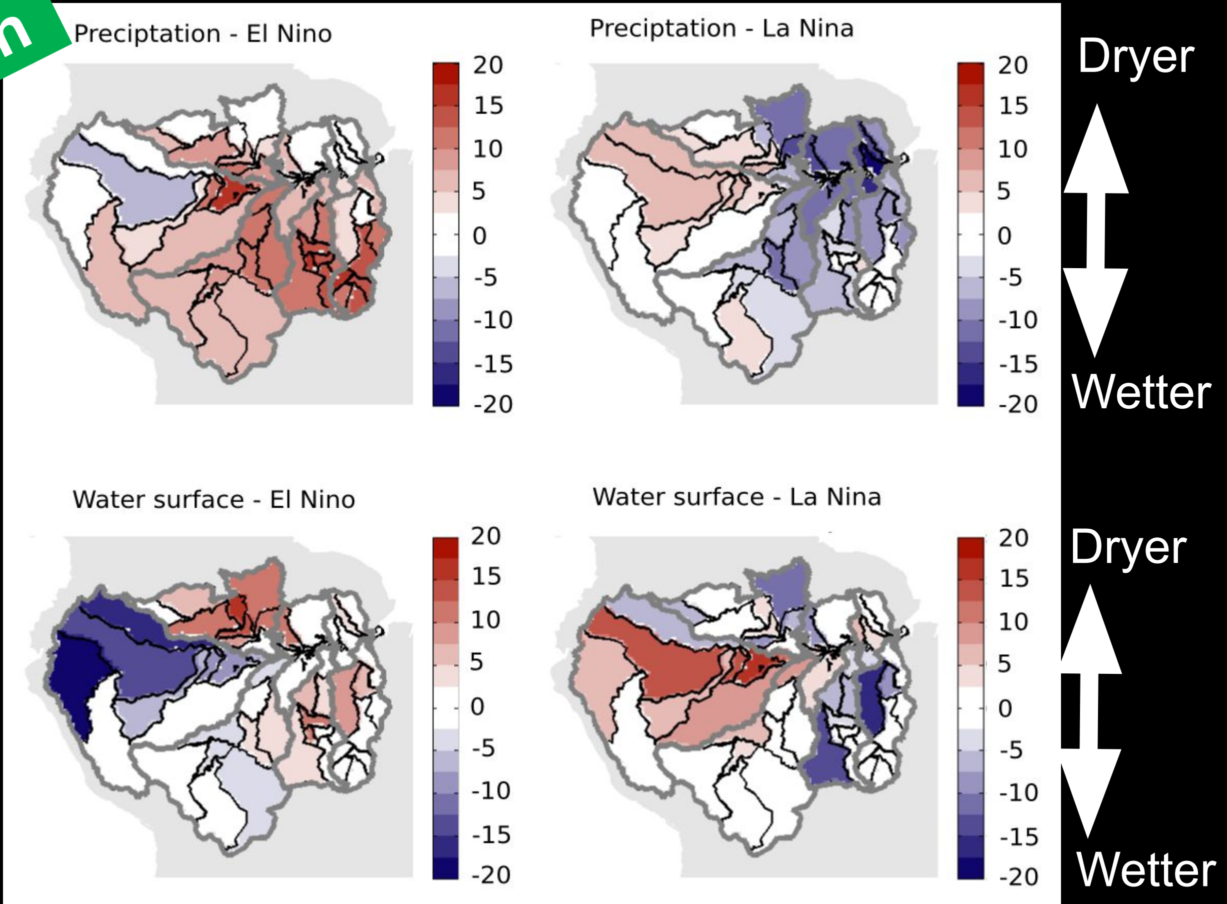



For more information on El Niño and La Niña, go to: http://iri.columbia.edu/ENSO

Sources: Ropelewski, C. F. and M. S. Halpert, 1989: Precipitation patterns associated with the high index phase of the Southern Oscillation. J. Climate., 2, 268-284, Mason and Goddard, 2001. Probabilistic precipitation anomalies associated with ENSO. Bull. Am. Meteorol. Soc. 82, 619-638

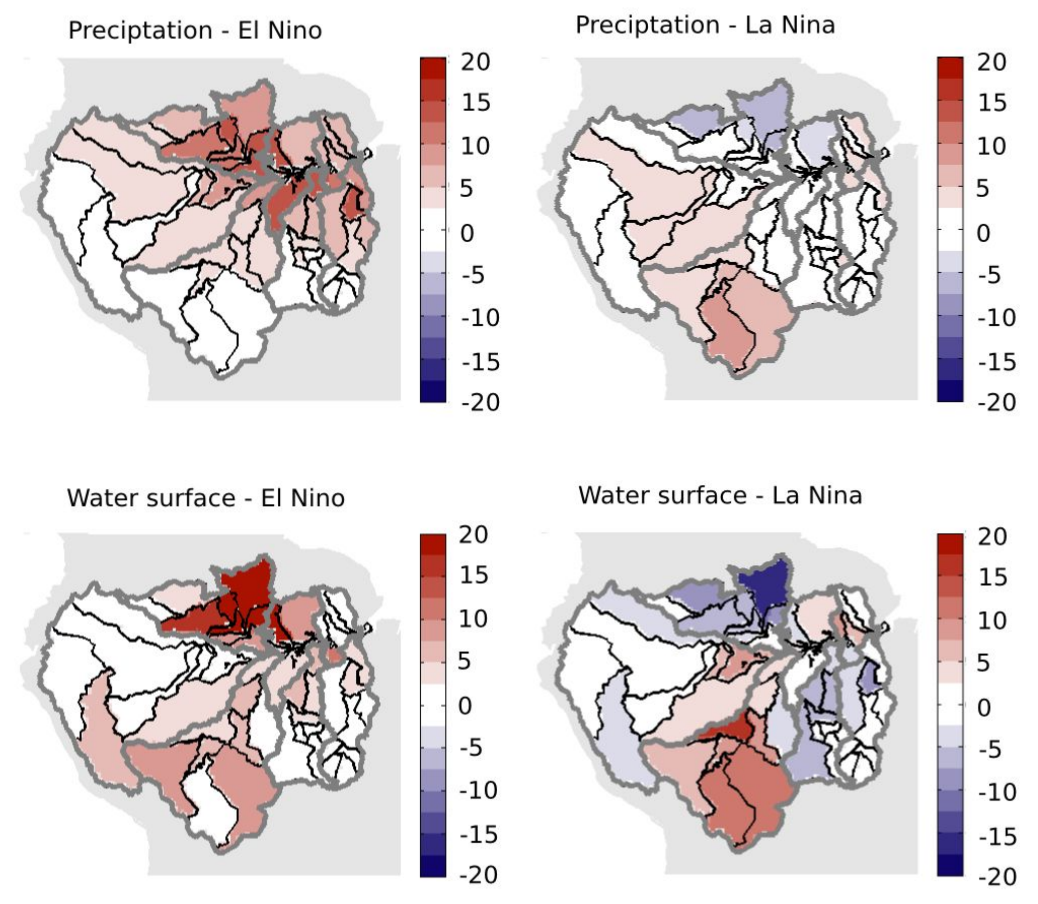
# Difference of anomaly of integrated water surfaces

rainy season



# Difference of anomaly of integrated water surfaces

dry season



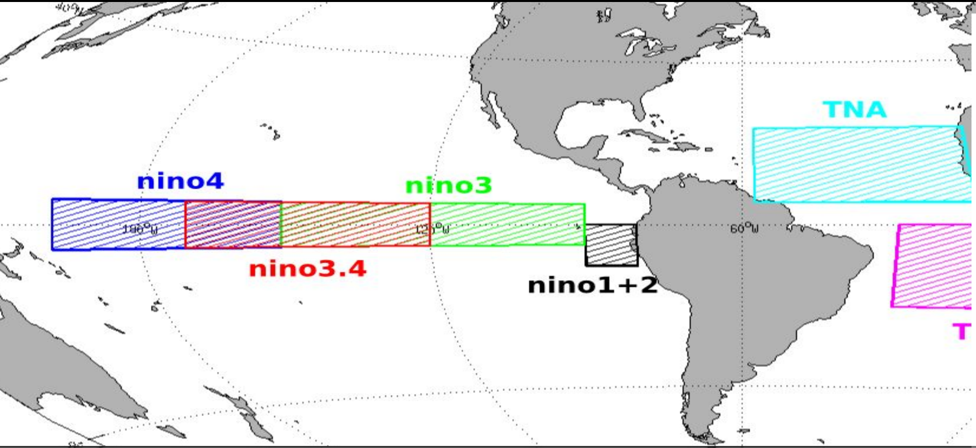

Dryer

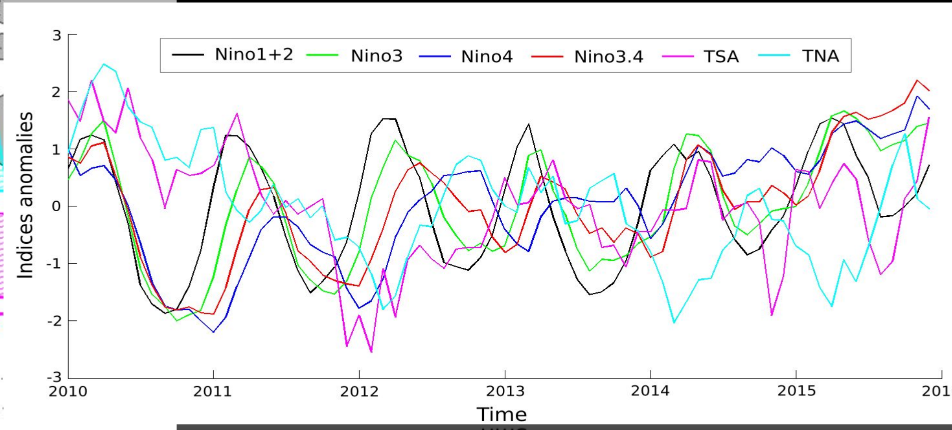
Wetter

Dryer

Wetter

# ENSO - SST indices




TNA: Tropical Northern Atlantic Index
TSA: Tropical South Atlantic Index

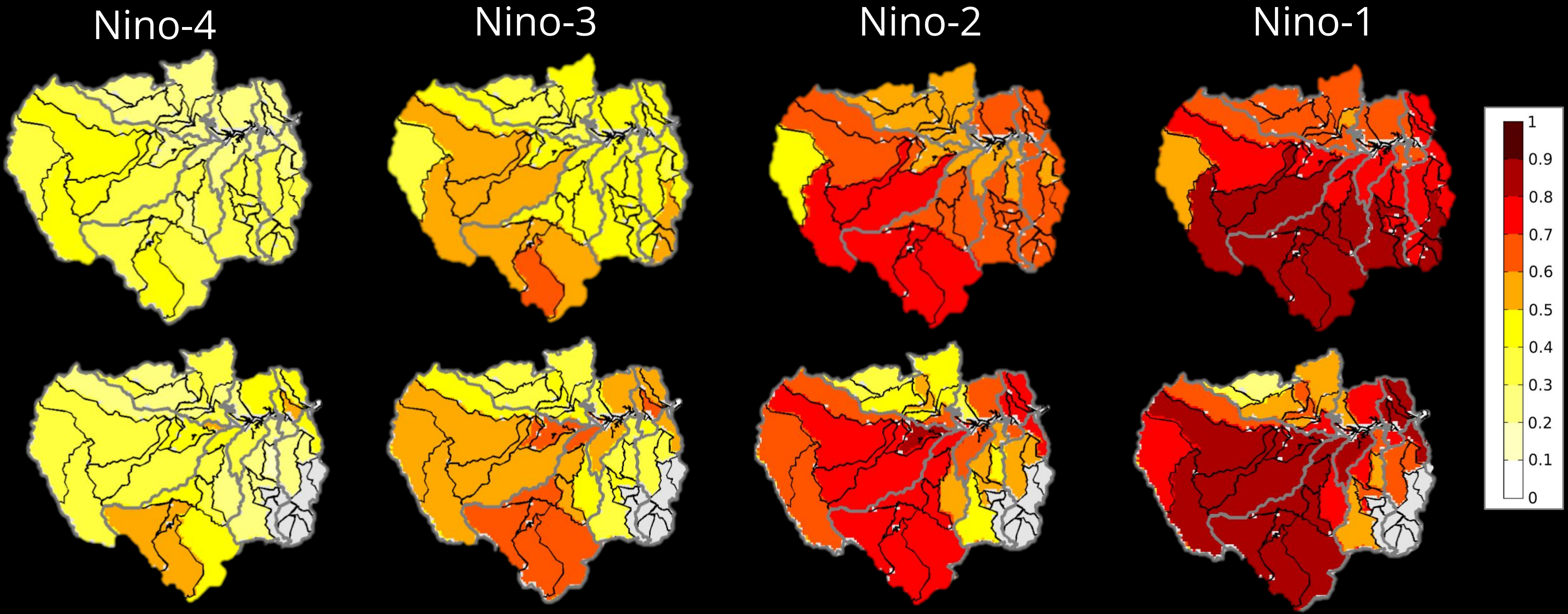
ONI : Oceanic Nino Index

| Year | DJF | JFM | FMA | MAM | AMJ | MJJ | JJA | JAS | ASO | SON | OND | NDJ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2010 | 1.3 | 1.2 | 0.9 | 0.5 | 0.0 | -0.4 | -0.9 | -1.2 | -1.4 | -1.5 | -1.4 | -1.4 |
| 2011 | -1.3 | -1.0 | -0.7 | -0.5 | -0.4 | -0.3 | -0.3 | -0.6 | -0.8 | -0.9 | -1.0 | -0.9 |
| 2012 | -0.7 | -0.5 | -0.4 | -0.4 | -0.3 | -0.1 | 0.1 | 0.3 | 0.3 | 0.3 | 0.1 | -0.2 |
| 2013 | -0.4 | -0.4 | -0.3 | -0.2 | -0.2 | -0.2 | -0.3 | -0.3 | -0.2 | -0.3 | -0.3 | -0.3 |
| 2014 | -0.5 | -0.5 | -0.4 | -0.2 | -0.1 | 0.0 | -0.1 | 0.0 | 0.1 | 0.4 | 0.5 | 0.6 |
| 2015 | 0.6 | 0.5 | 0.6 | 0.7 | 0.8 | 1.0 | 1.2 | 1.4 | 1.7 | 2.0 | 2.2 | 2.3 |
| 2016 | 2.2 | 2.0 | 1.6 | 1.1 | 0.6 | 0.1 | -0.3 | -0.6 | -0.7 | | | |

**Normal years : 2012, 2013, 2014**
**El nino year : 2015**
**La nina year : 2011**

# Lagged correlation with SST indices

TRMM precipitation



# Summary

## On the technics in monitoring tropical wetlands surfaces

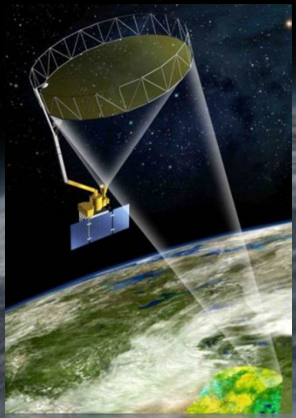
- SMOS L-band microwave can deliver accurate water surface maps at coarse scale and 7 days frequency over Tropical basins.
- Distributed as a L4 product from SMOS - http://www.catds.fr

## On the impact of extremes events and ENSO dynamics

- Water surface dynamics show a distinct signal compared to rainfalll
- The predictibility of ENSO from Water surface anomalies is higher than that of Rainfall using nino1+2

# Futur work

Synergistic use of L-band and new generation of altemiters, Jason CS, Sentinel-3, **SWOT**.

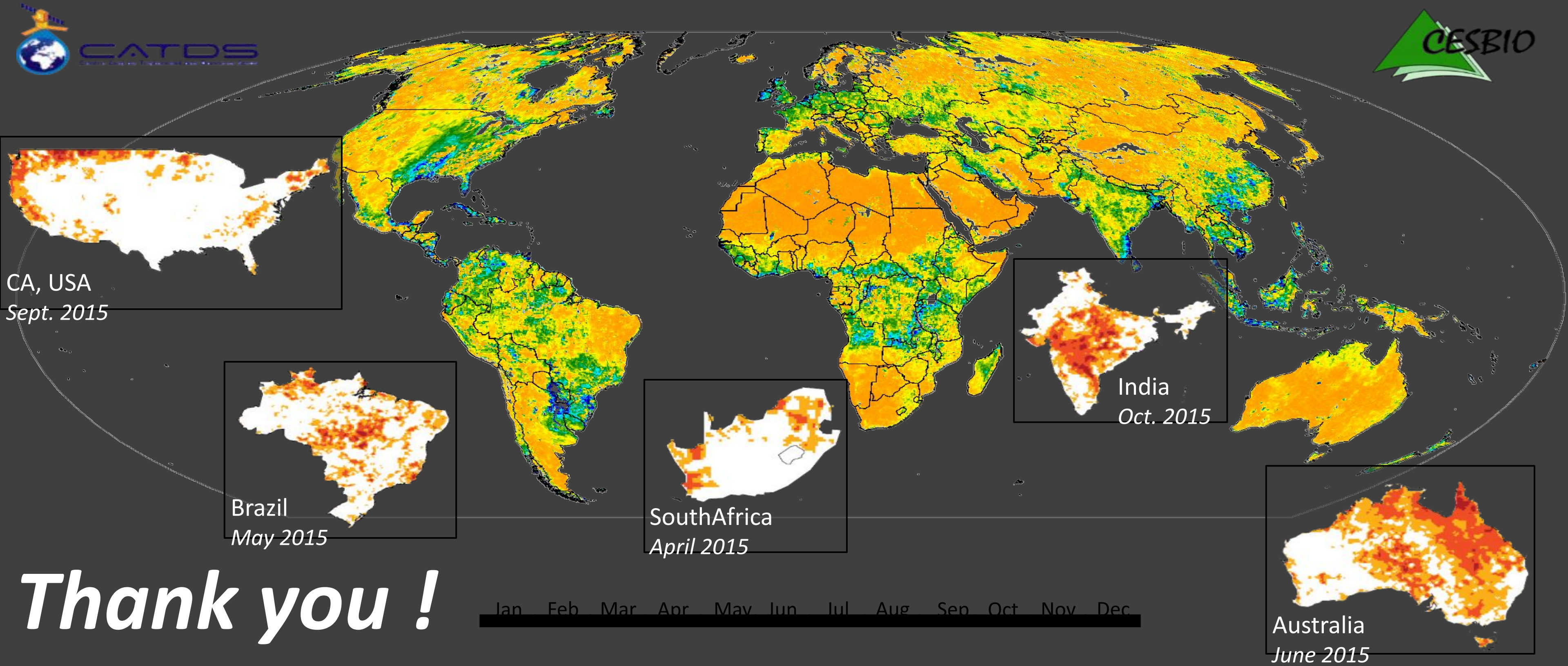


Thank you

## Acknowledgements

Support from the CNES TOSCA SOLE and TOSCA SMOS grants. Dr. Marie Parrens was financed by the CNES post -doctoral program. The altimetric Jason-2 data was aquired using the Theia Hydroweb database. The SARAL-Altika data was aquired using the CLS AVISO+. The SMOS data was delivered by the CATDS (Ifremer/CNES) center.

# SMOS monitoring 5 major droughts in 2015




***Thank you !***

Root zone soil moisture

0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 ($m^3/m^3$)

Drought index

**moderat** **mild** **extrem**

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