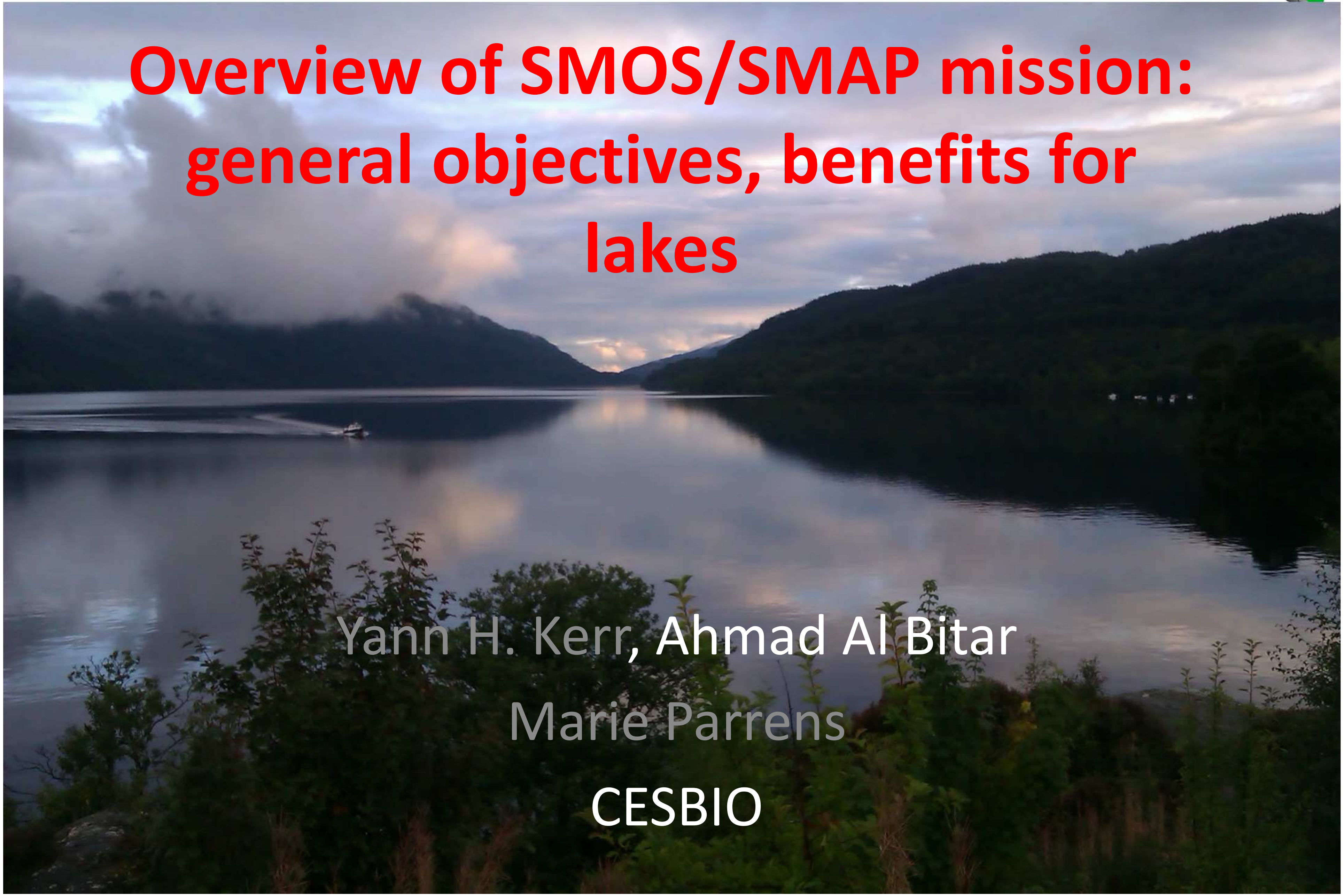
Overview of SMOS/SMAP mission: general objectives, benefits for lakes



Yann H. Kerr, Ahmad Al Bitar

Marie Parrens

CESBIO

SMOS & SMAP for Lakes & wetlands

A- SMOS and SMAP status

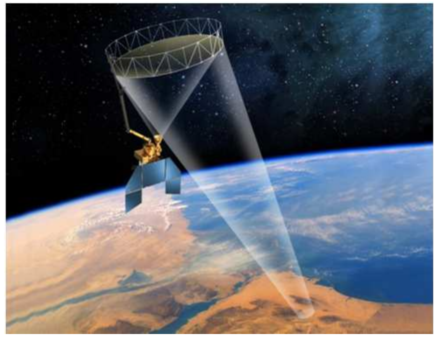
B- Wetlands and lakes

1- Enhancing the water budget component

2- Monitoring wetlands dynamics

SMOS and SMAP

	SMOS	SMAP
	➢ Interferometer	Scanning fixed angle
	➢ Always same point	almost same point
	➢ Passive only	active and passive
❑ Spatio temporal resolution		
	➢ 30-55 km, a/b<1.5	51 X 47km
	➢ 3 day	3 day
❑ Sampling		
	➢ 15 km (L2) 25 km (L3)	36 km
❑ Disaggregation		
	➢ 1 km	*3,* 9 km (global)
❑ Sensitivity		
	➢ 3. 4 K	1.3 K
❑ Angles		
	➢ Up to 120 (0- 60°)	1 angle (40°)
❑ Span		
	➢ 2010 --	2015 --



Differences

- SMOS
  - Many angles
    - Better retrievals
  - No active system
    - needs other approaches to disaggregate
  - RFI
    - More data losses, errors
    - Drier retrievals
  - Better spatial resolution

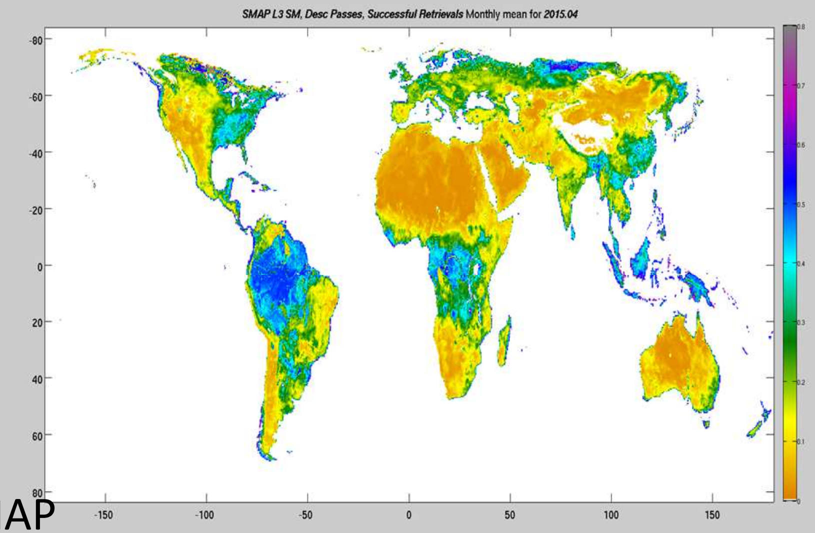
- SMAP
  - One angle
    - Needs aux data
  - *Active system*
    - *Can dis aggregate*
    - *Freeze thaw*
  - RFI
    - Better identification and filtering
  - Better sensitivity

But the proof is in the pudding

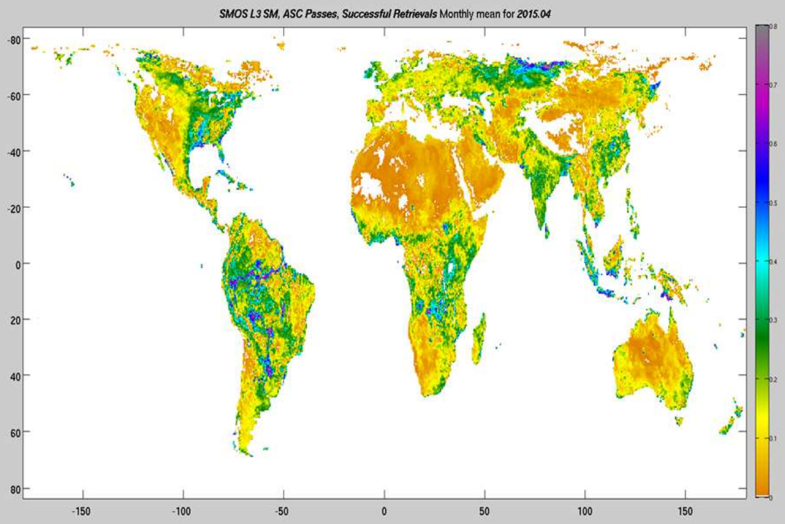
SMAP - SMOS

- SMAP and SMOS use Mironov model as dielectric mixing model
- SMAP like SMOS use τ-ω model, but on single V channel only. The algorithm is simplified in some ways:
  - The **TB** is corrected for **fixed water bodies** (if < 50%) using MOD44W product (this is based on SRTM data)
  - The **Emissivity** of the emitting layer is then computed based on this **TB** and a surrogate for the **physical temperature** of the emitting layer (e= TB/Tphys)
  - The **Emissivity** of the soil layer is then obtained using **Emissivity** of the emitting layer by correcting for **vegetation** (based on NDVI climatological database, 13-year), surface **roughness** (ancillary data), and various weights based on IGBP classsification
  - The **Dielectric constant** of soil layer is then obtained using **Fresnel equations** from **soil emissivity**
  - At last **Soil moisture** is computed using **Mironov dielectric mixing model** from **dielectric constant**
- All computations seem to be carried out over a single 36 km^2 grid versus SMOS which performs a weighted sum over a 35 x 35 mesh of DFFG cells (approximately 4 km^2 each) using the weights of the antenna pattern.

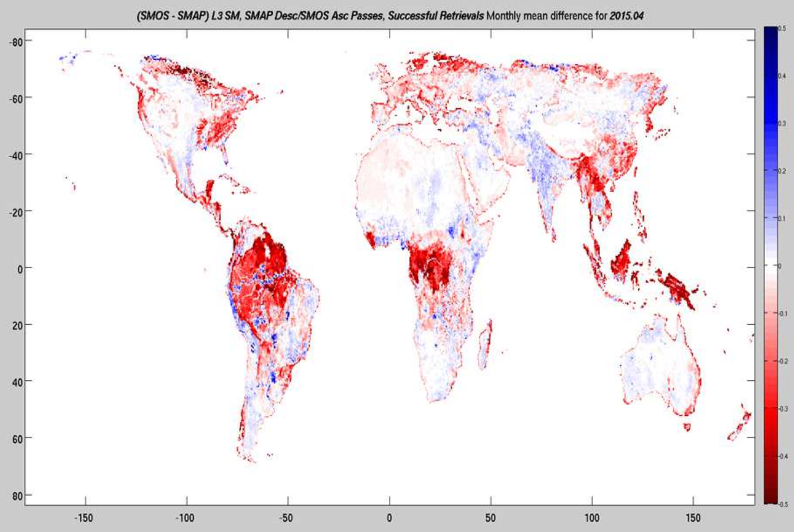
SMOS -SMAP, Successful Retrievals Monthly Animation: 2015.04-2016.05



SMAP



SMOS

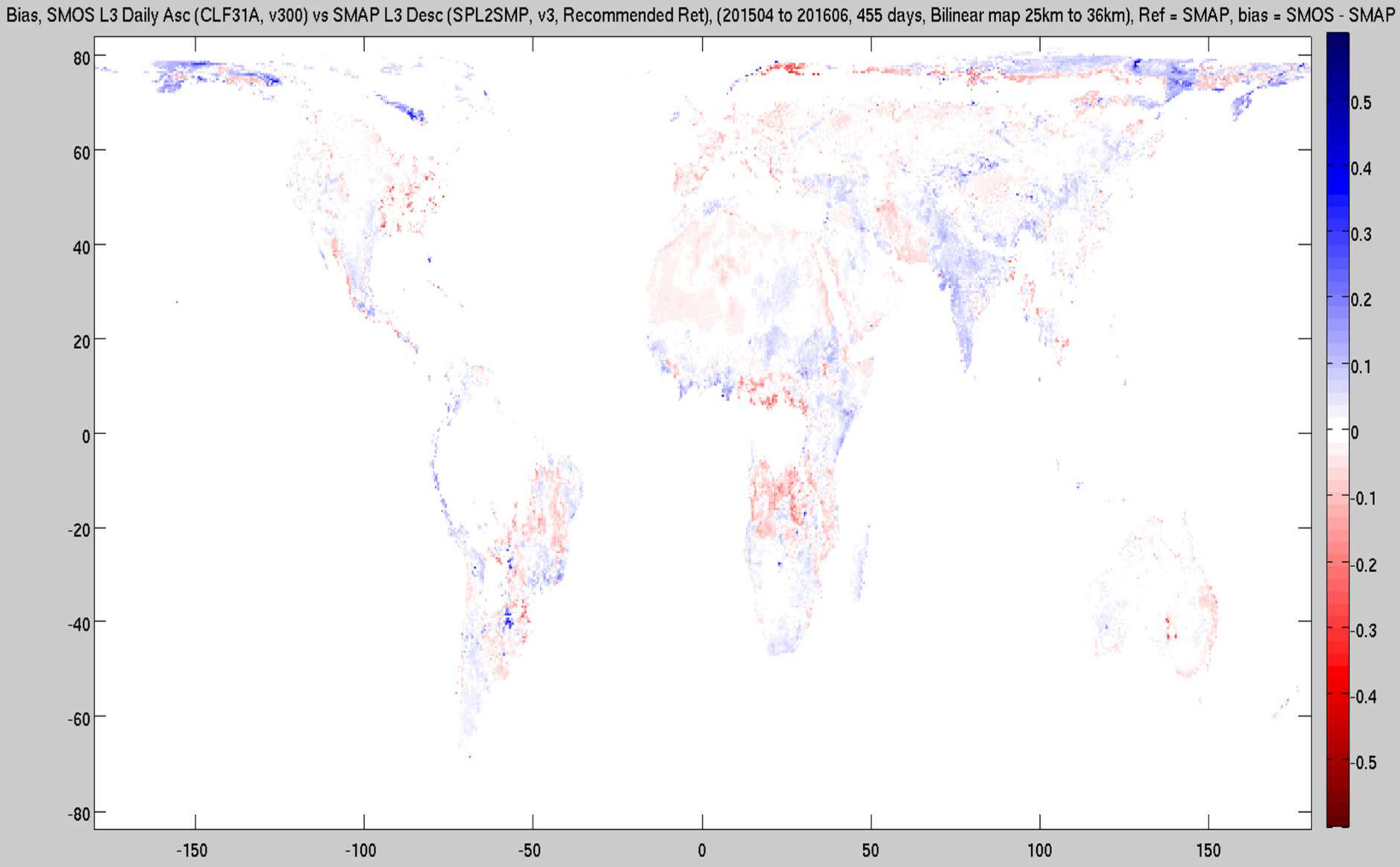


SMOS-SMAP

Mahmoodi A.

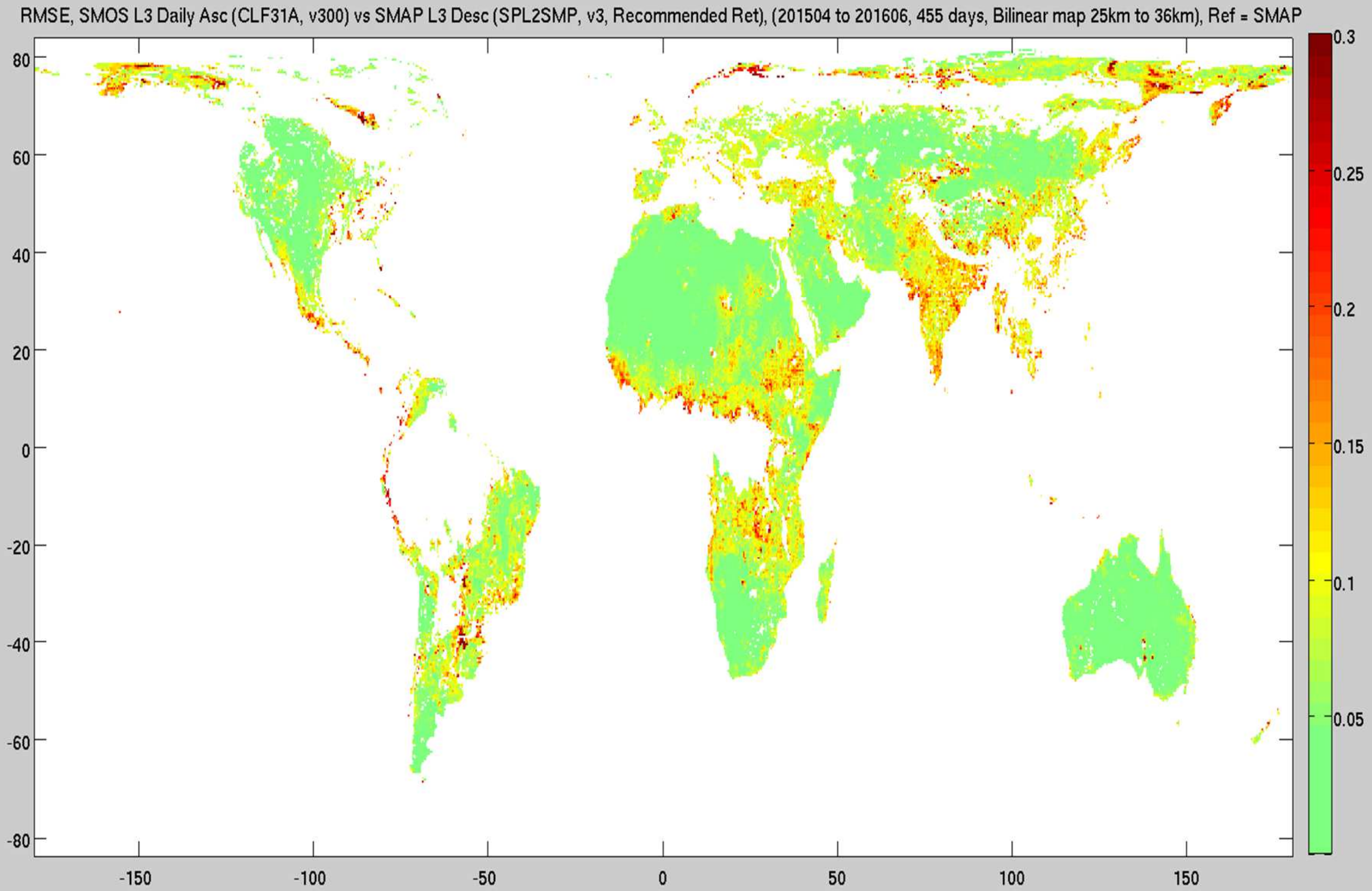
Lakers_2017 06 01 YHK, AA, MP

Bias: L3 SM, SMOS Successful Rets & SMAP Recommended Rets



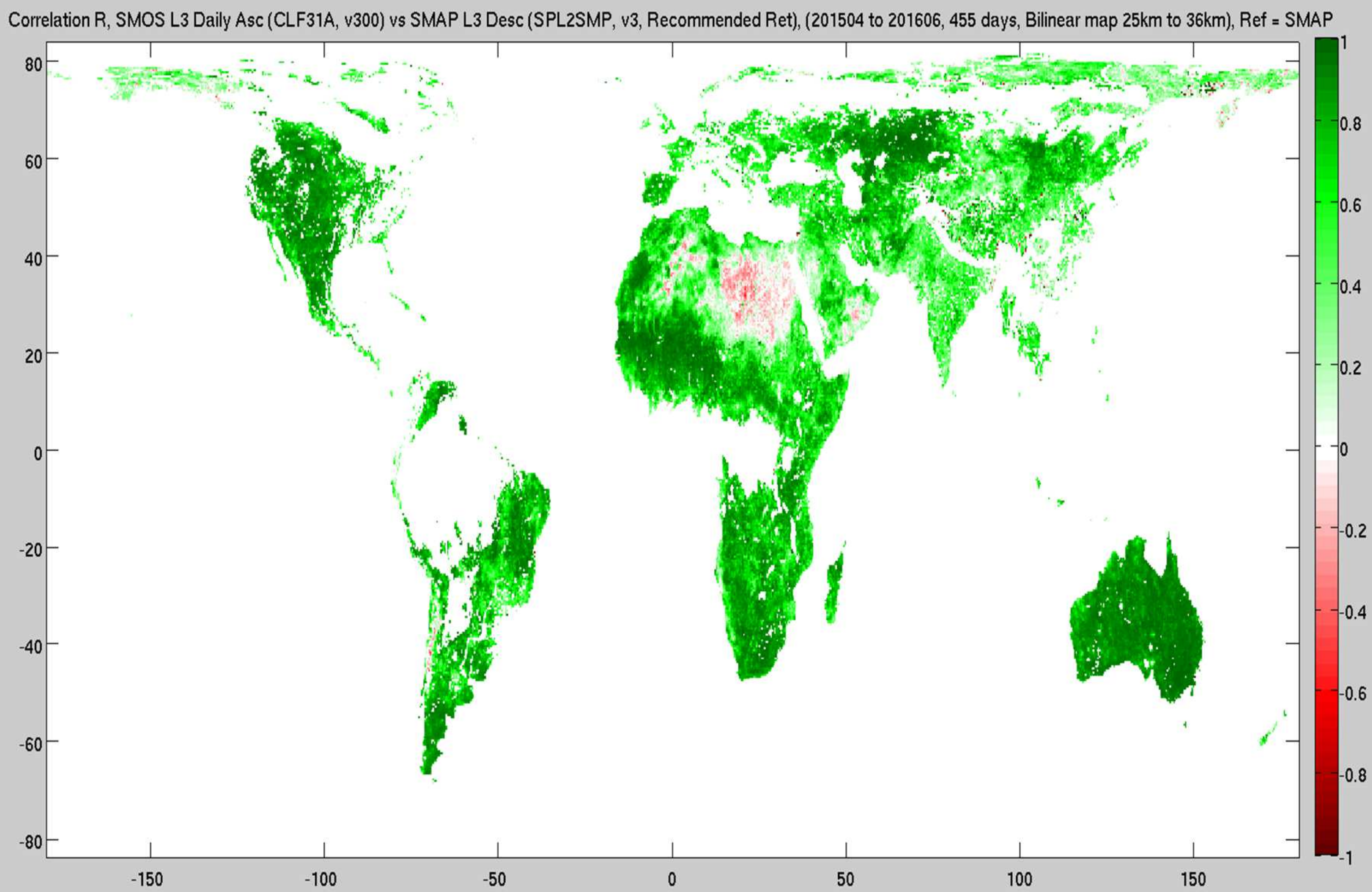
Mahmoodi A.

RMSE : L3 SM, SMOS Successful Rets & SMAP Recommended Rets



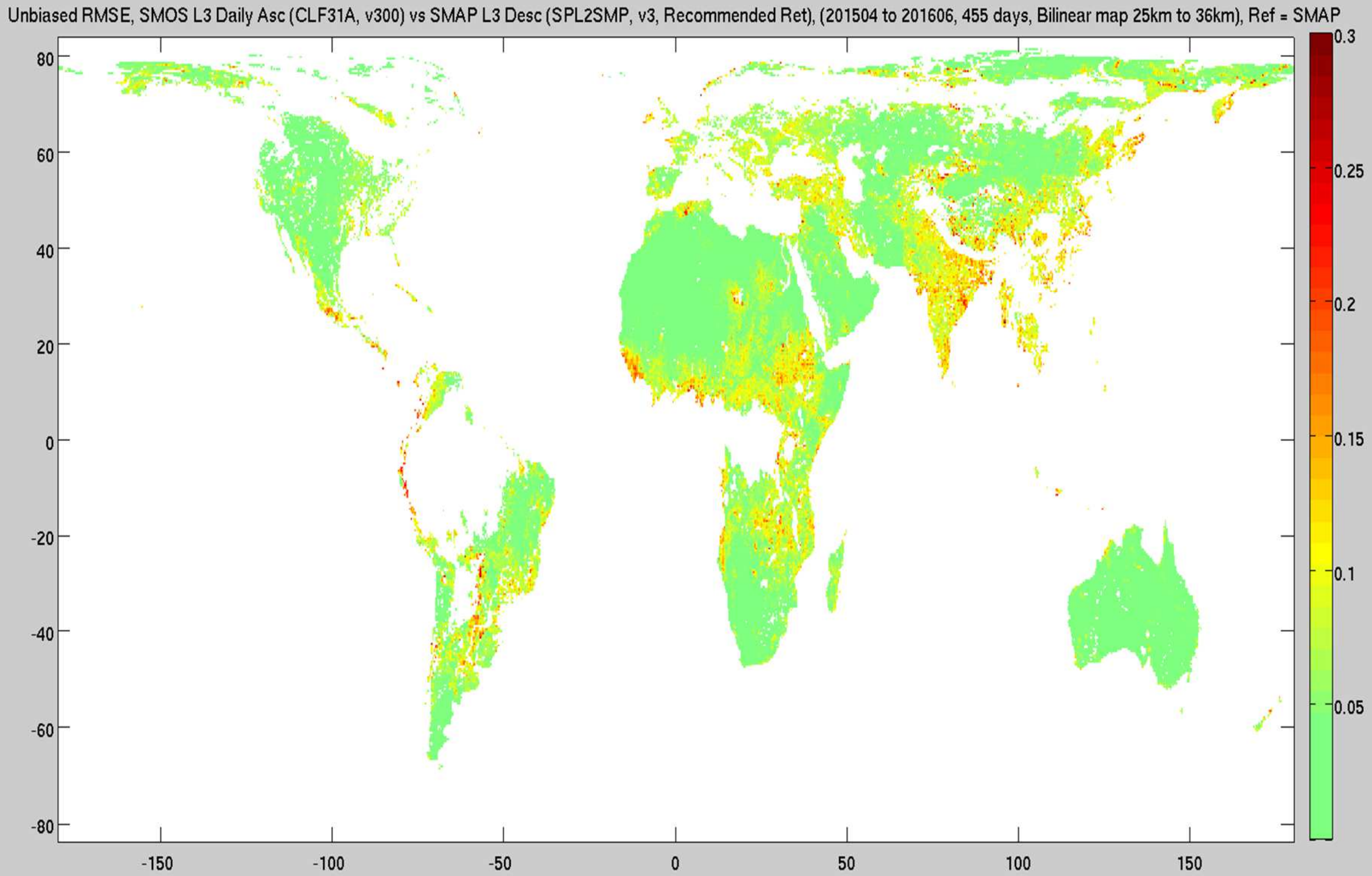
Mahmoodi A.

Corr R: L3 SM, SMOS Successful Rets & SMAP Recommended Rets



Mahmoodi A.

ubRMSE: L3 SM, SMOS Successful Rets & SMAP Recommended Rets



Mahmoodi A.

SMOS- SMAP DIS-AGGREGATION

Lakers_2017 06 01 YHK, AA, MP

Context

- L band radiometers vs Radar
  - Pros
    - Measures SM
    - Global coverage
    - High revisit
  - Cons
    - Low spatial resolution
- Solutions
  - Use higher resolution complementary data
    - Optical/ thermal
      - Revisit / clouds
    - Radar

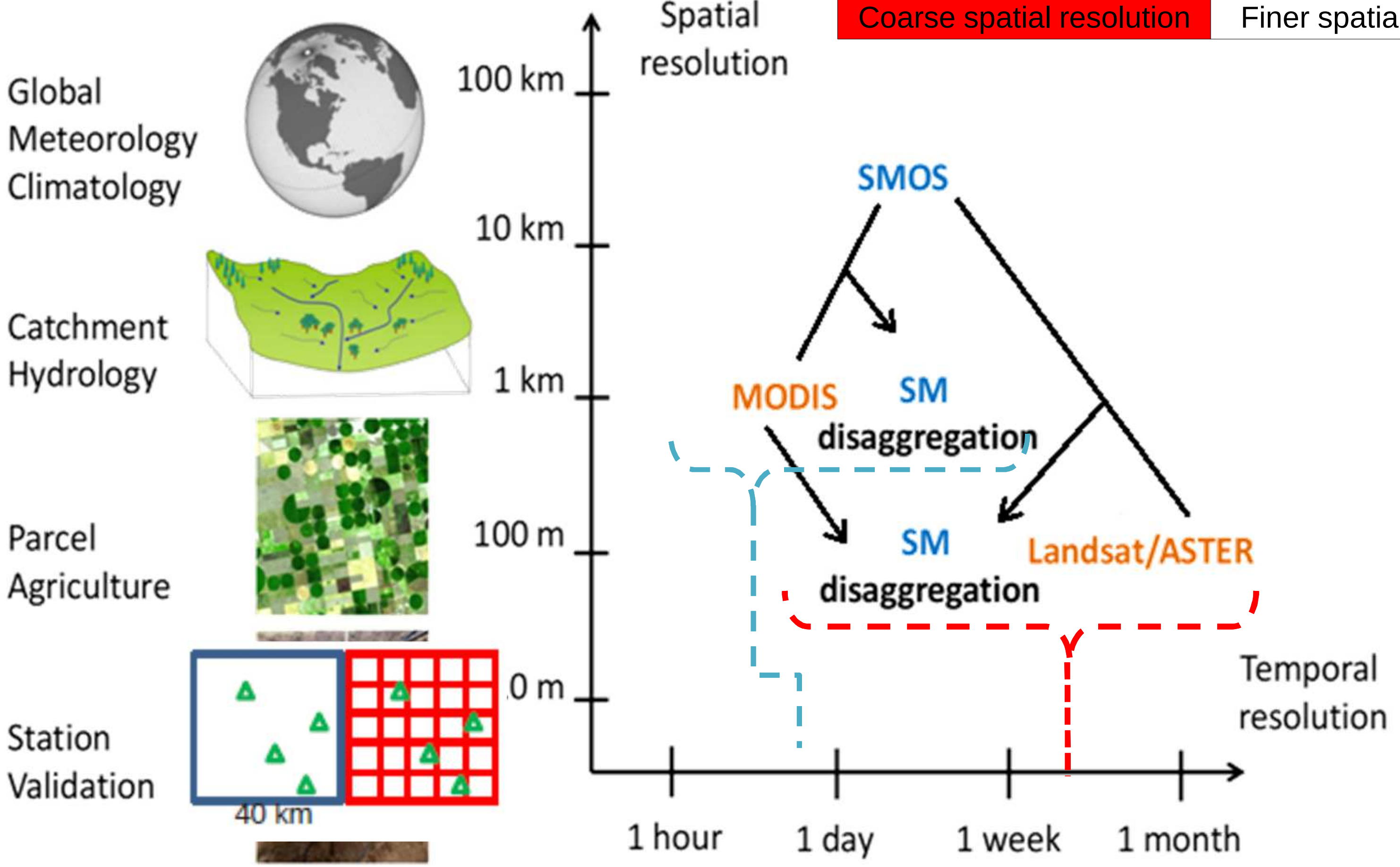
Approaches

- SMAP
  - *Synchronous Colocated Radar*
    - Das et al.
    - Leroux et al.
  - Use of S1
- SMOS
  - Use of model and topography / vegetation
    - Pellenq et al.2003 JoH
  - Use of Vis / Tir data
    - Merlin et al. 2006, 2008, 2009, 2012, 2013
    - Djamai et al. 2015
    - Verhoest et al. 2015
    - Molero et al. 2016
  - Use of Radar
    - Kumar et al. 2015, 2017

Microwave – optical merging - 1/2

The DISPATCH algorithm (O. Merlin)

Microwave observations	Optical observations
Not affected by clouds, aerosol and water vapor	Critically affected by clouds, aerosol and water vapor
Coarse spatial resolution	Finer spatial resolution

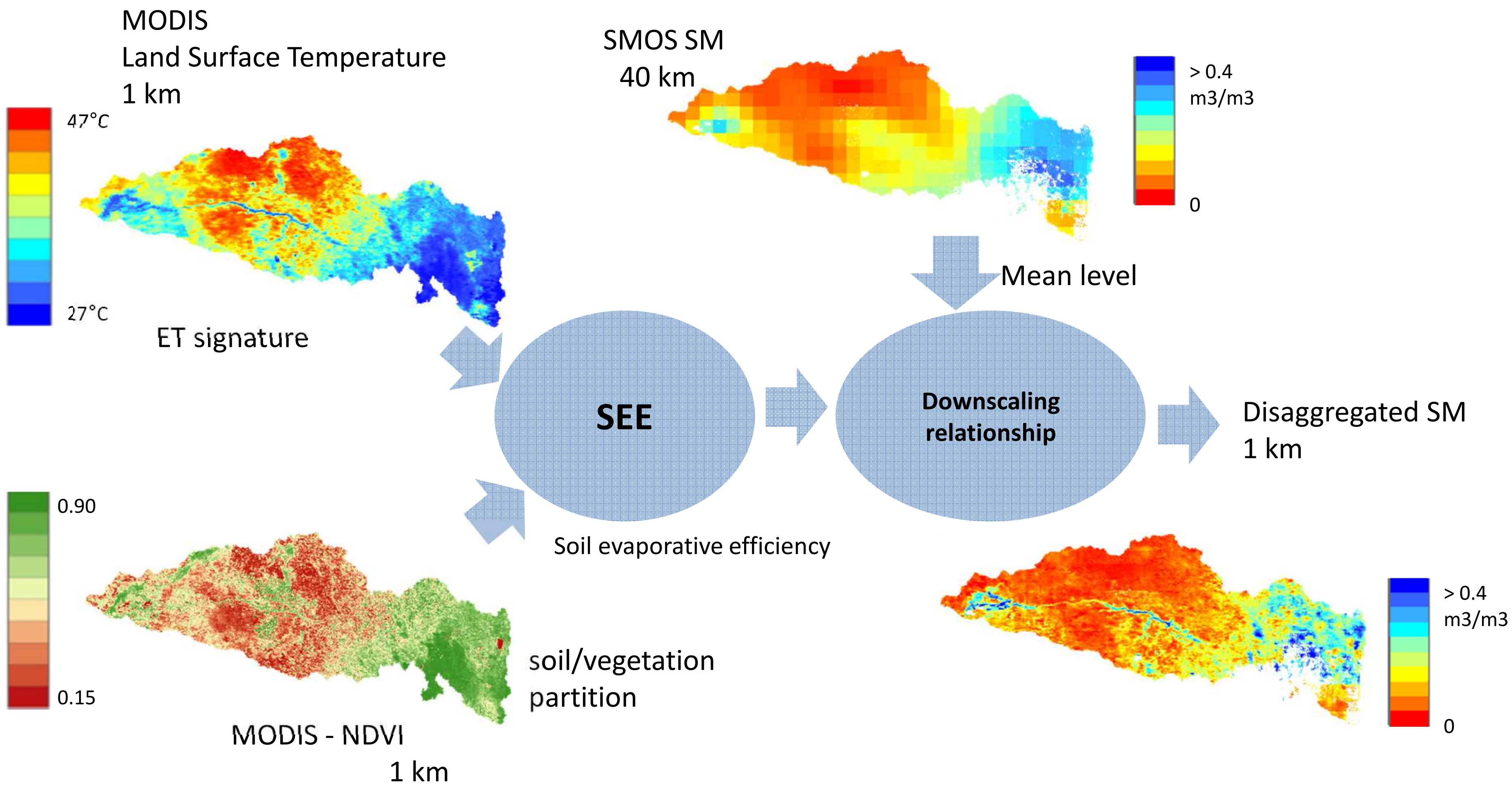


From O.Merlin's presentation, at *Remote Sensing of the Terrestrial Water Cycle, San Francisco, Dec. 2013*

Merlin O., 2010, 2011, 2012a, 2012b

DisPATCh

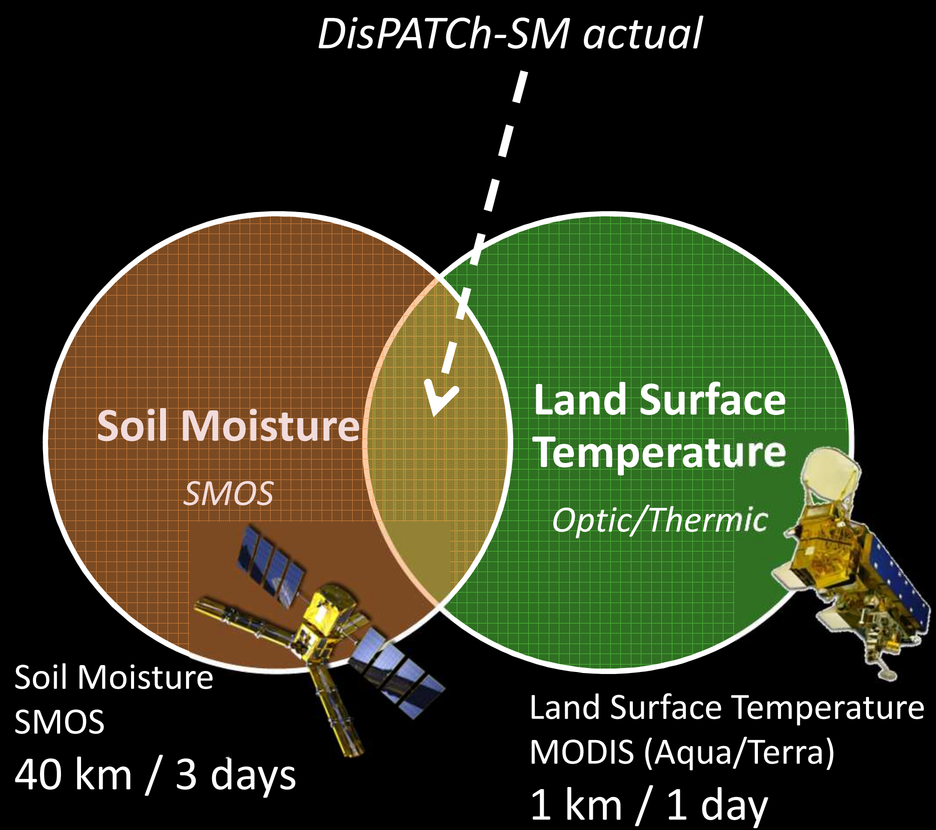
DISaggregation based on **P**hysical **A**nd **T**heoretical scale **CH**ange

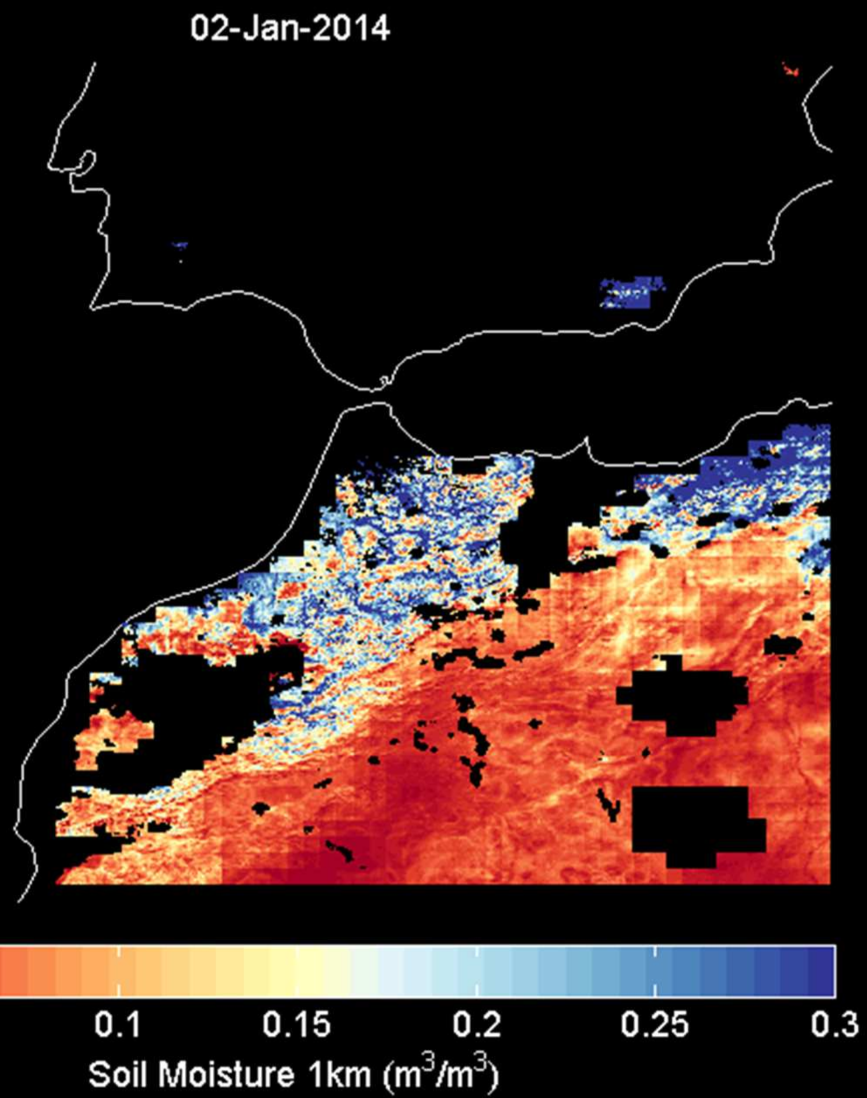


MALBETEAU Y.

J. Malbeteau

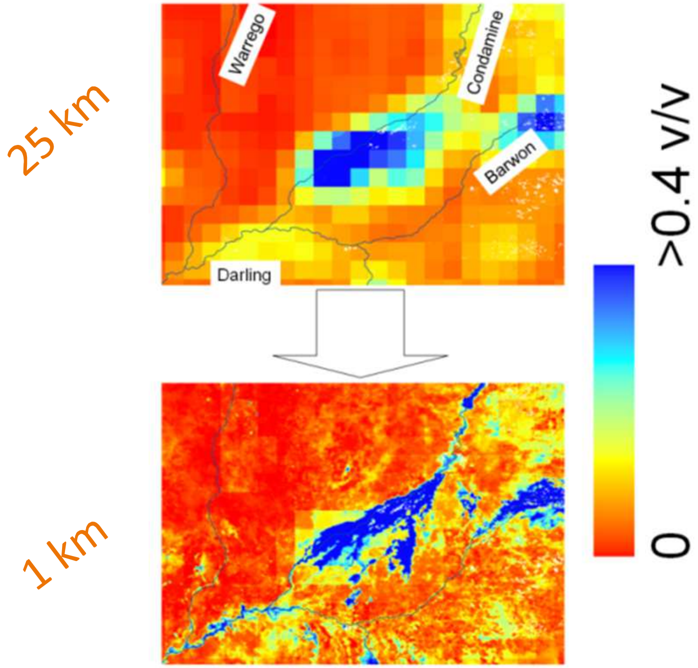
Soil Moisture 1 km Morocco





Example of Dispatch application

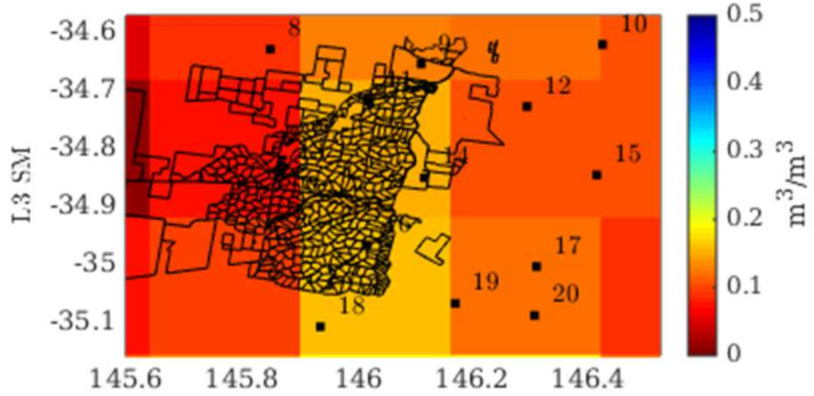
❑ **SMOS & optical sensors**



(Merlin et al. 2012) (Molero et al., RSE, 2016)

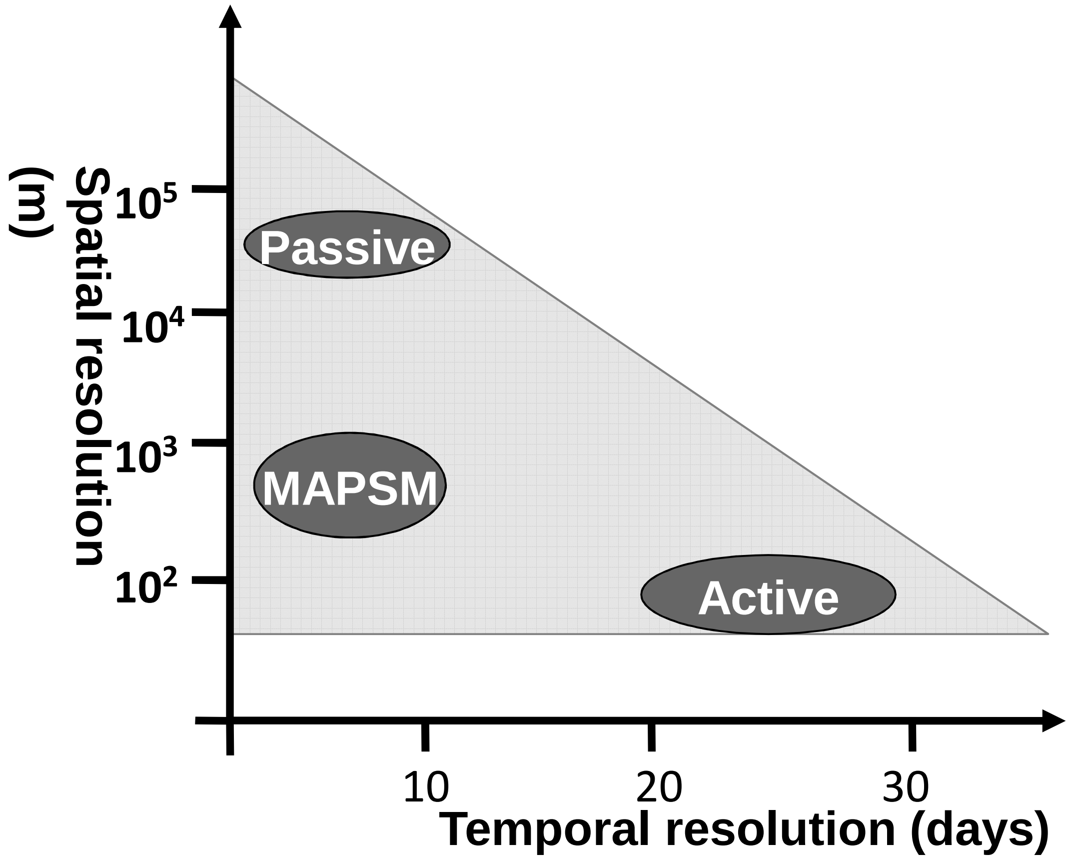
Murrumbegee basin Australia

Example of Dispatch application



Lakers_2017 06 01 YHK, AA, MP

Merging Active and Passive Soil Moisture (MAPSM)



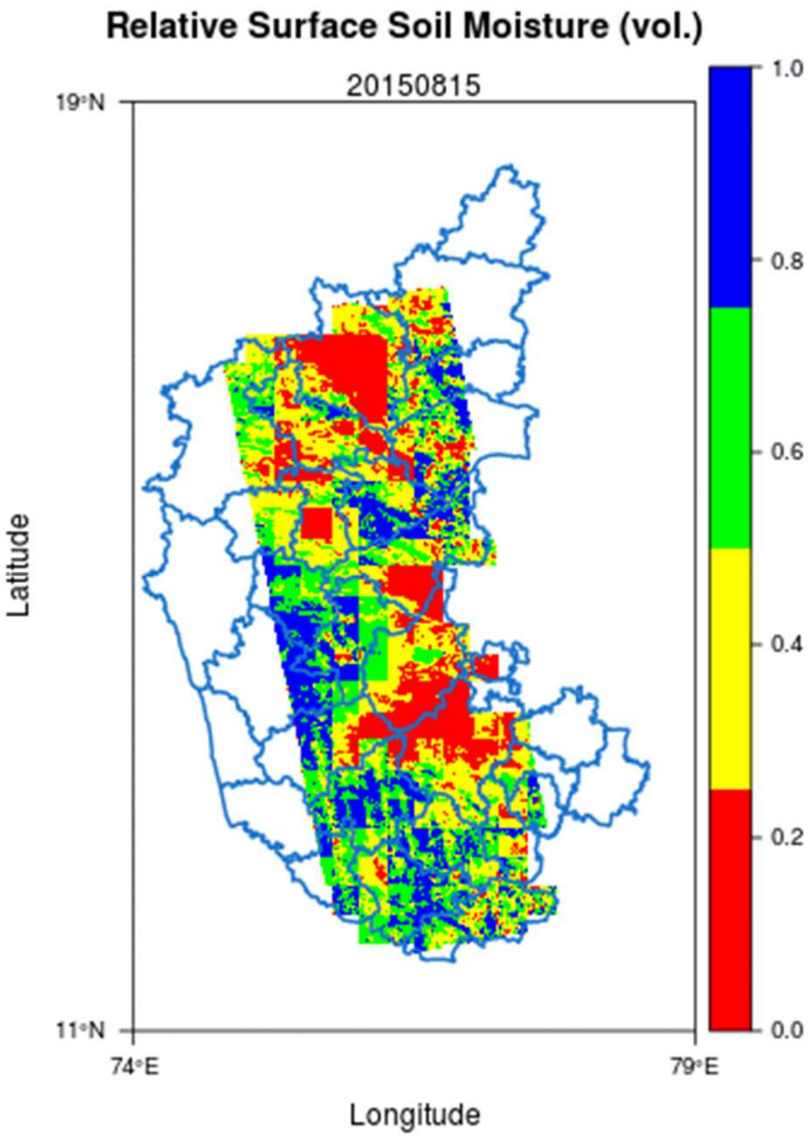
Passive microwave:
- ❑ SMOS
- ❑ SMAP
- ❑ AMSR2

Active microwave:
- ❑ RISAT
- ❑ RADARSAT-2
- ❑ PALSAR
- ❑ Sentinel 2

- **Passive** microwave has good temporal resolution (1-3 days), but poor spatial resolution (~40 km)
- **Active** microwave has good spatial resolution (less than 100 m), but poor temporal resolution (~ 30 days)
- **MAPSM** provides soil moisture at both good temporal (3 days) and spatial resolution (less than 500 m)

Sat Kumar Tomer

SMOS+Risat C-Band



Kabini Basin, Karnataka, India

(Tomer et al., RS, 2015, 2016)
sat@aapahinnovations.com

SMOS & SMAP for Lakes & wetlands

1- Enhancing the water budget component

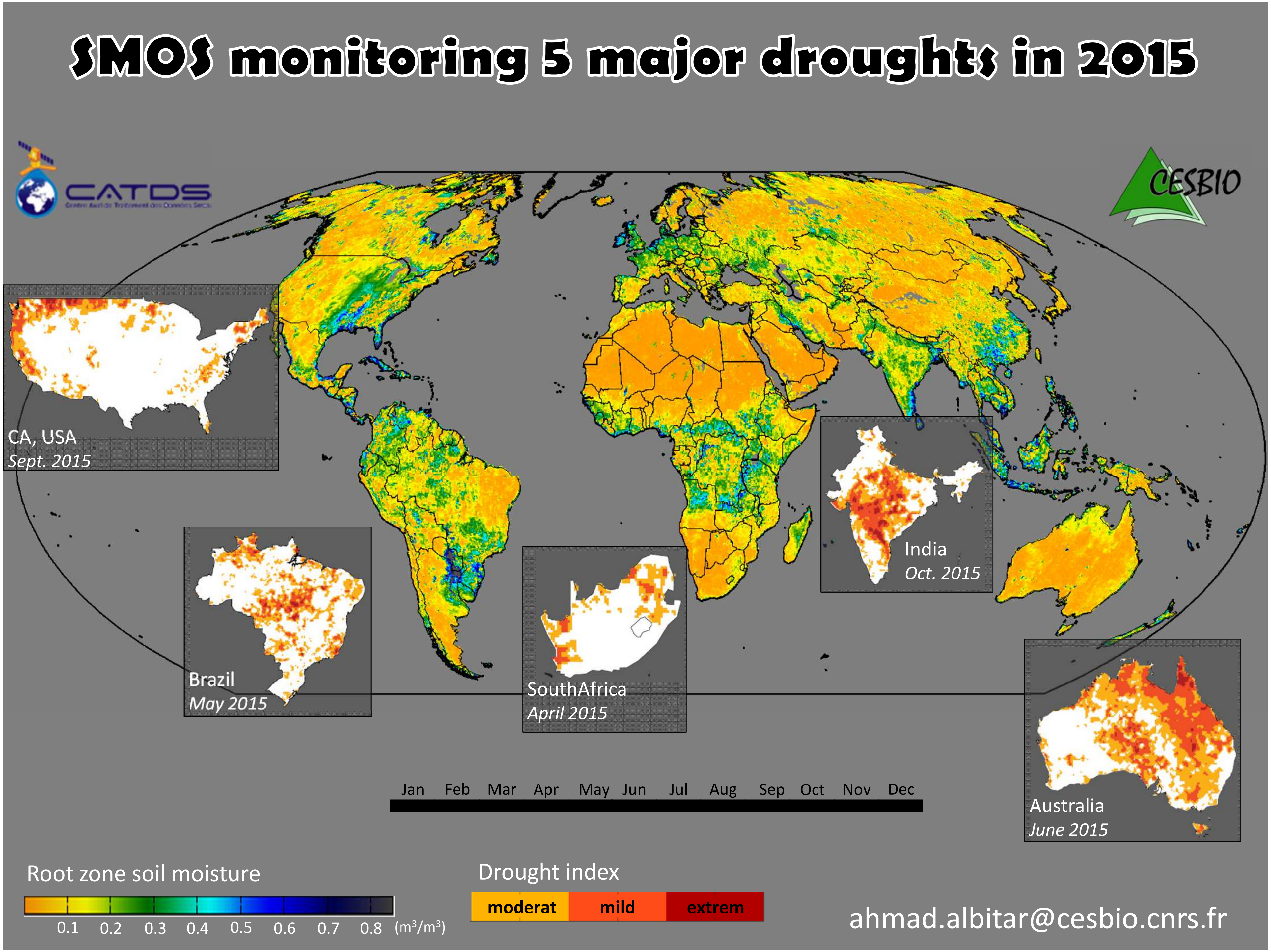
2- Monitoring wetlands dynamics

SMOS & SMAP for Lakes & wetlands

1- Enhancing the component of the water budget

Enhancing the component of the water budget

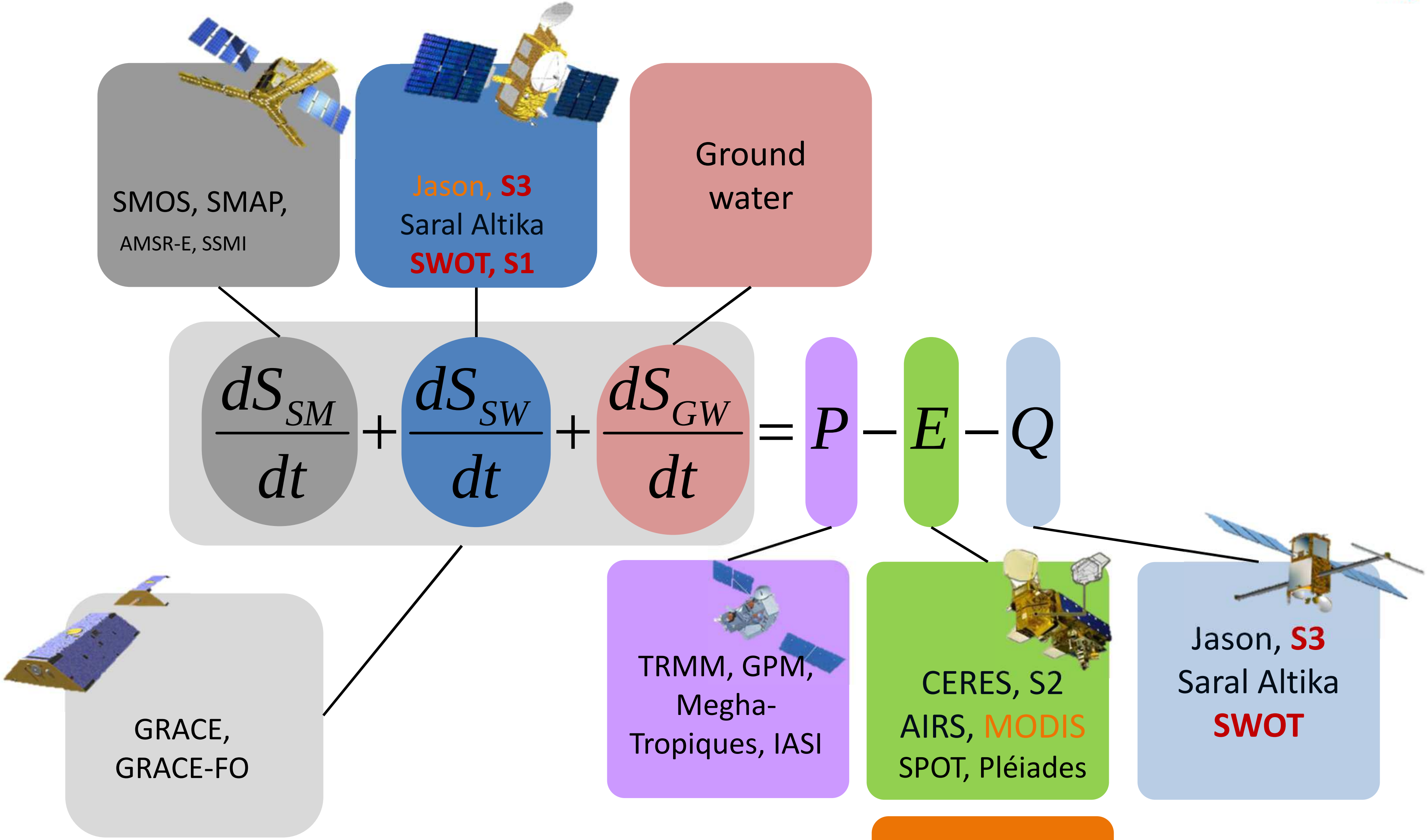
- ❑ Monitoring root zone soil moisture and thus water demand (irrigation).
- ❑ Assimilation of Soil moisture measurements into hydrological models for improving discharge.
- ❑ Hydrological model calibration.


SMOS monitoring 5 major droughts in 2015
CATDS
CESBIO
CA, USA
Sept. 2015
Brazil
May 2015
SouthAfrica
April 2015
India
Oct. 2015
Australia
June 2015
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Root zone soil moisture
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 (m³/m³)
Drought index
moderat
mild
extrem
ahmad.albitar@cesbio.cnrs.fr

Enhancing the component of the water budget

- ❑Monitoring root zone soil moisture and thus water demand (irrigation).
- ❑Assimilation of Soil moisture measurements into hydrological models for improving discharge.
- ❑Hydrological model calibration.

Satellite measurements and water cycle



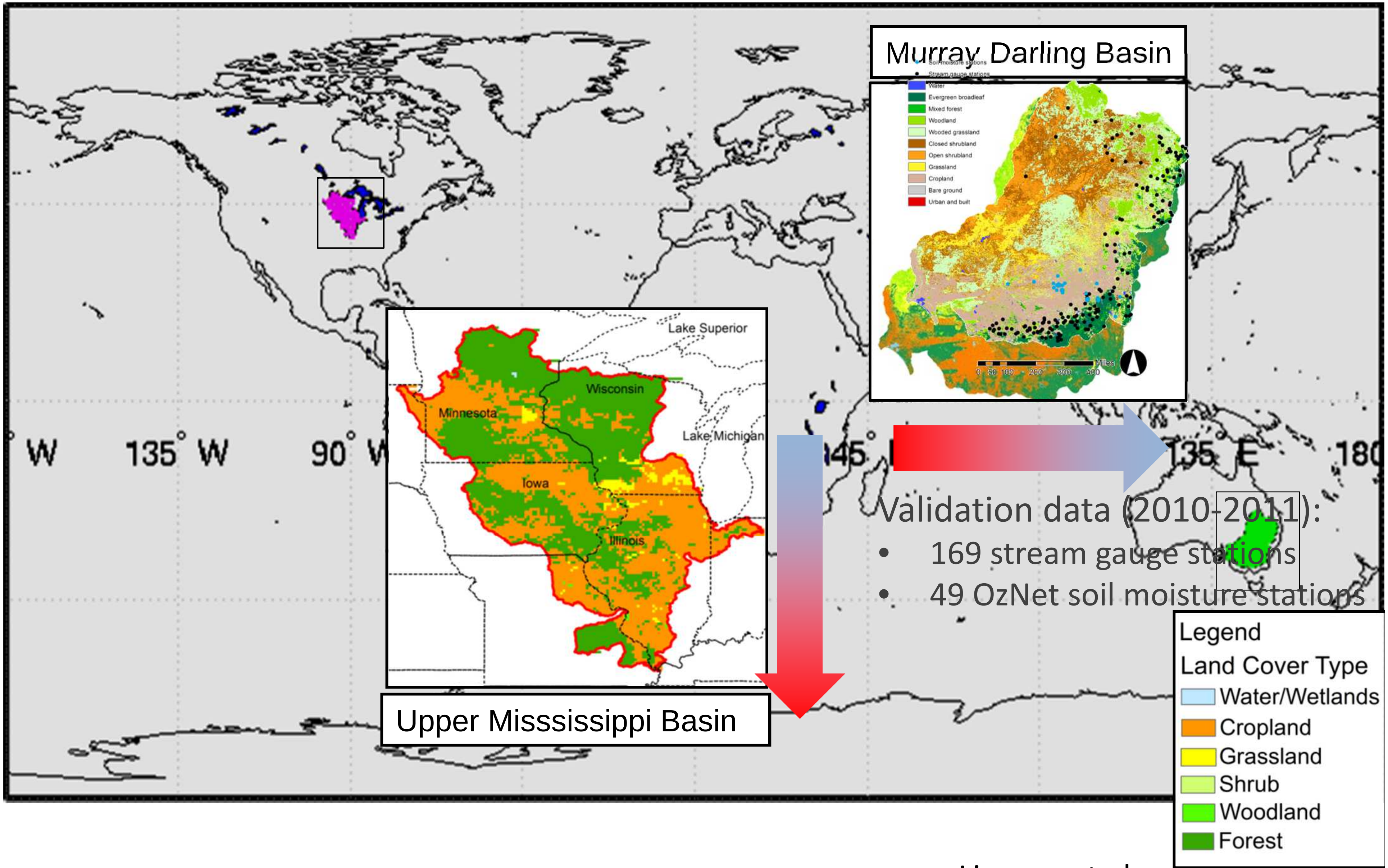
Vis, NIR, TIR

Not all components are observed at the desired resolution and accuracy

Al Bitar, A.

Lakers_2017 06 01 YHK, AA, MP

SMOS+Hydro: Assimilation of SMOS data into VIC model

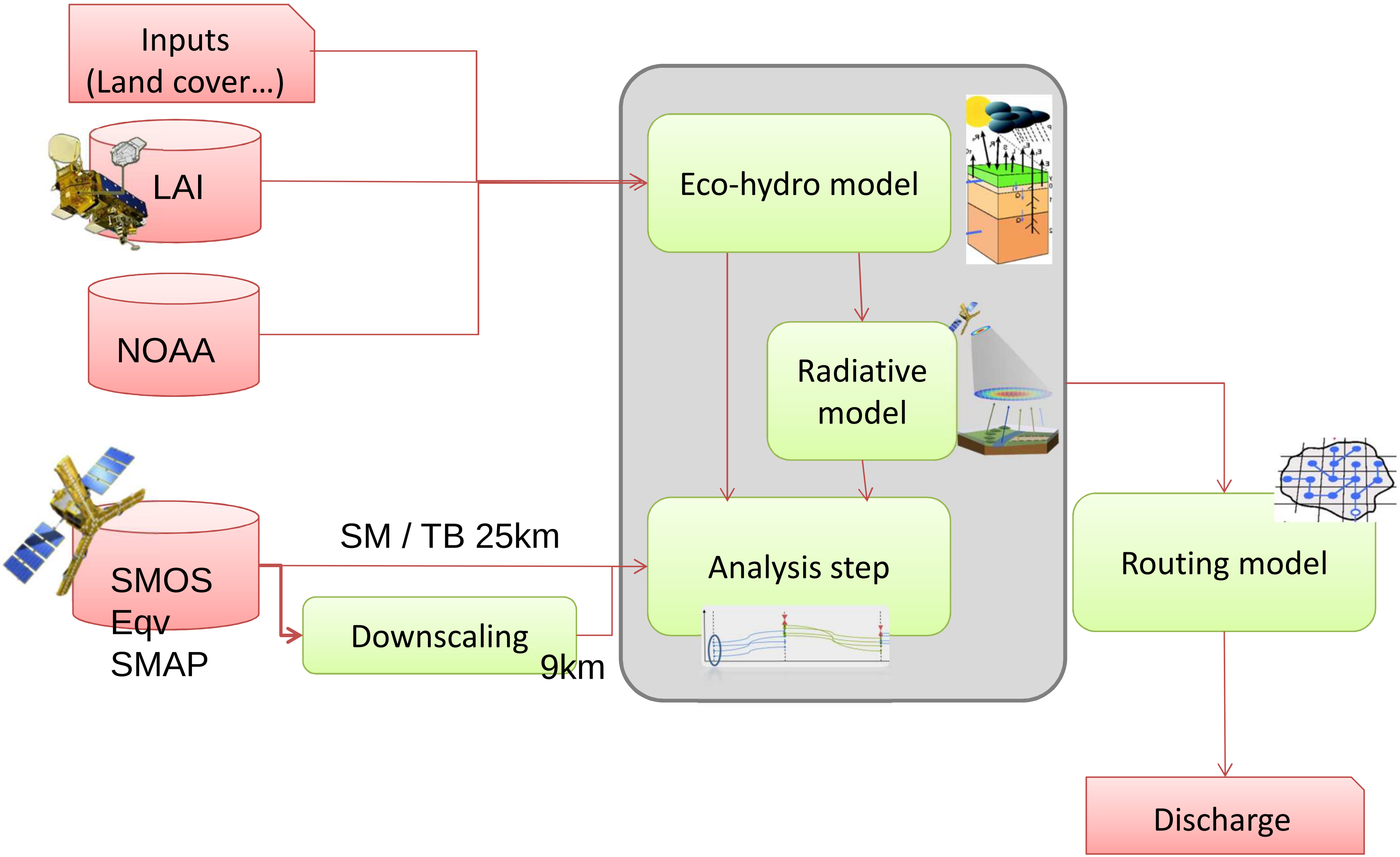


Validation data (2010-2011):

- 169 stream gauge stations
- 49 OzNet soil moisture stations

Lievens et al.

Overview of the LDAS



Al Bitar, A.

Impact of Soil moisture predictions

SM record	RMSE m^3/m^3	R (-)
SMOS	0.045	0.726
VIC open loop	0.058	0.549
DA SM coarse	0.045	0.713
DA SM downscaled	0.047	0.727
DA TB SMOS	0.050	0.661
DA TB SMAP	0.046	0.700

The assimilation of SMOS data improves the soil moisture prediction .
For hydrosystem with lakes, this leads to a better estimates of the lakes budgets.

Lievens et al. 2015 (a,b) (RSE)

SMOS & SMAP for Lakes & wetlands

1- Enhancing the water budget component

2- Monitoring wetlands dynamics

Advantage of Microwave radiometry

L-band

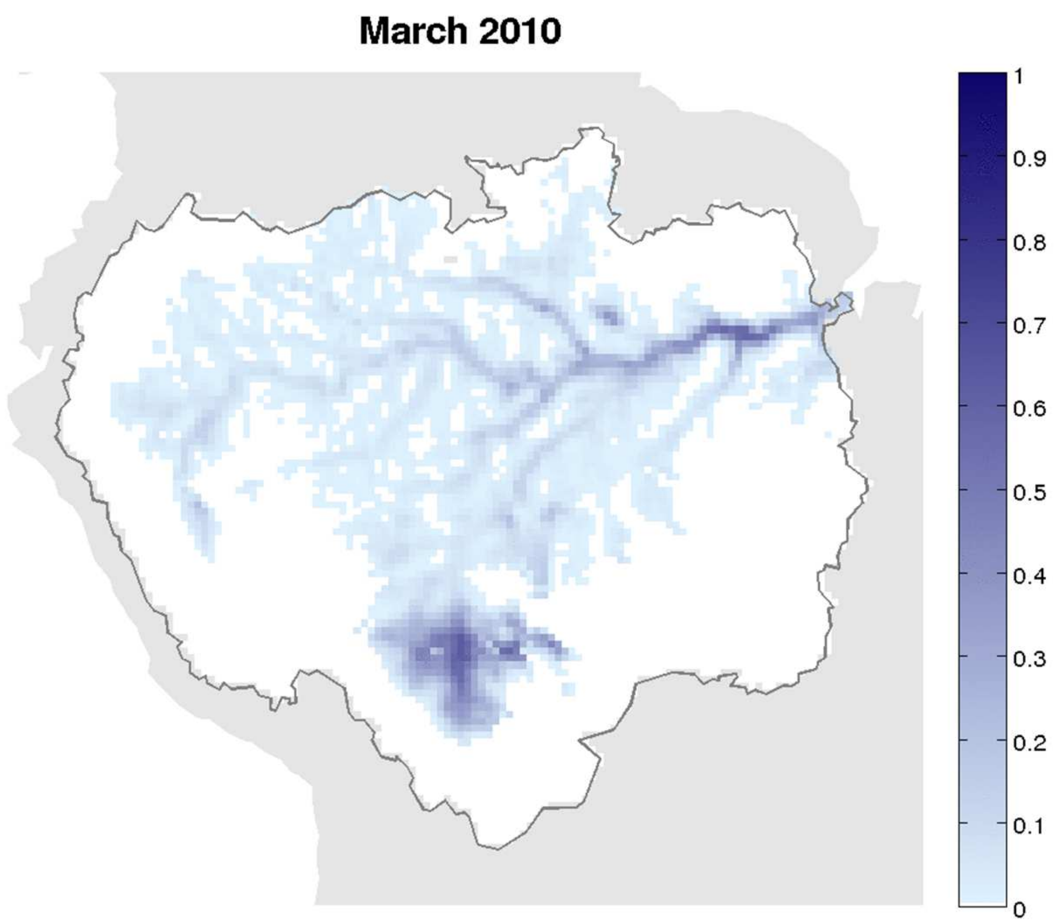
- The impact of vegetation is lower at L-band.
- The impact of heavy rainfall (and clouds) is also much lower than at C- Band.
- Multi angular and full polarisation acquisitions are available

<u>But :</u>

- What is the exact saturation level (vegetation density? It is still an open question (Rahmoune et al. 2015, Parrens et al. 2015).

Monitoring wetland dynamics

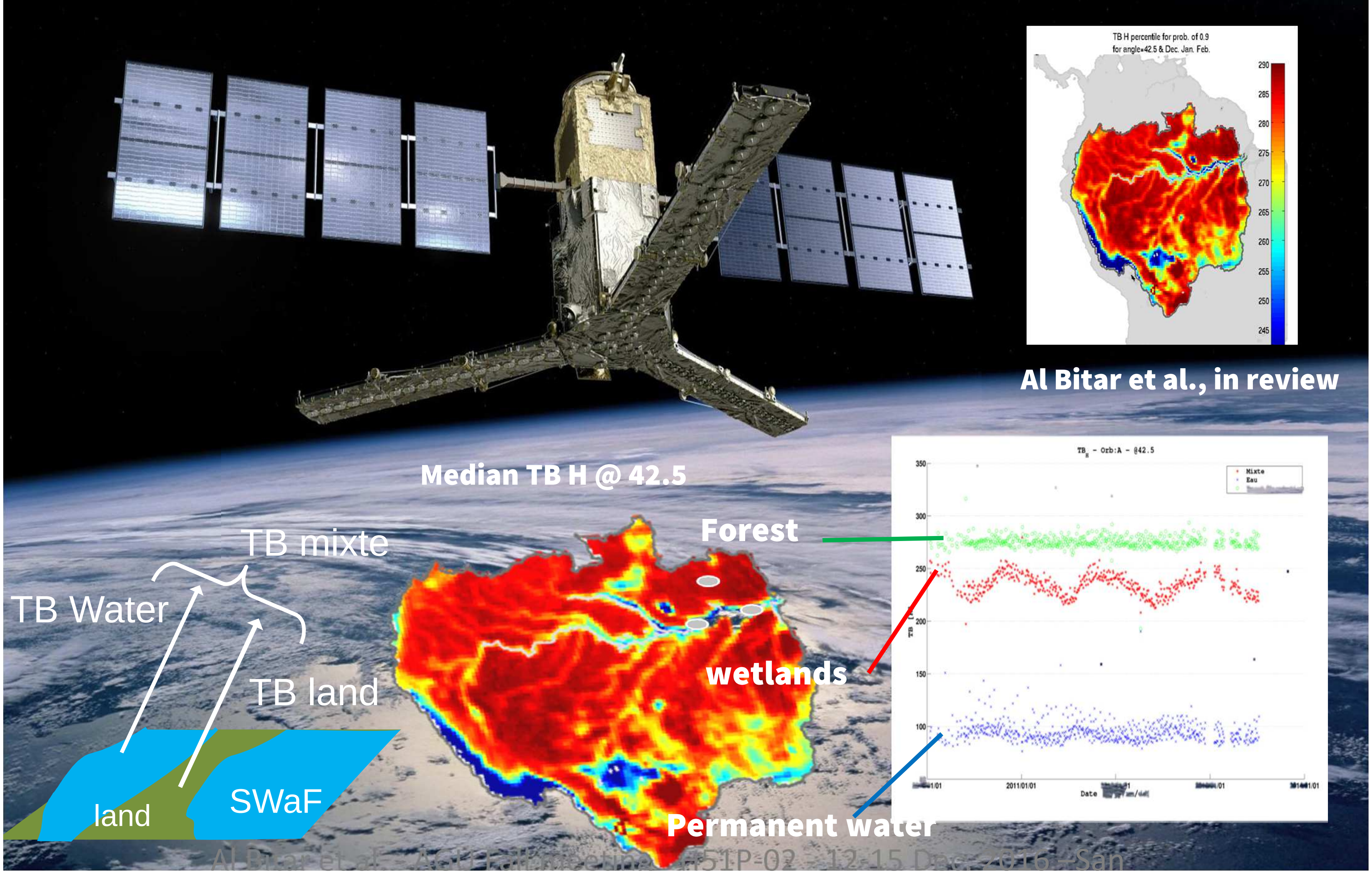
Water Fraction under dense vegetation



Lakers_2017 06 01 YHK, AA, MP

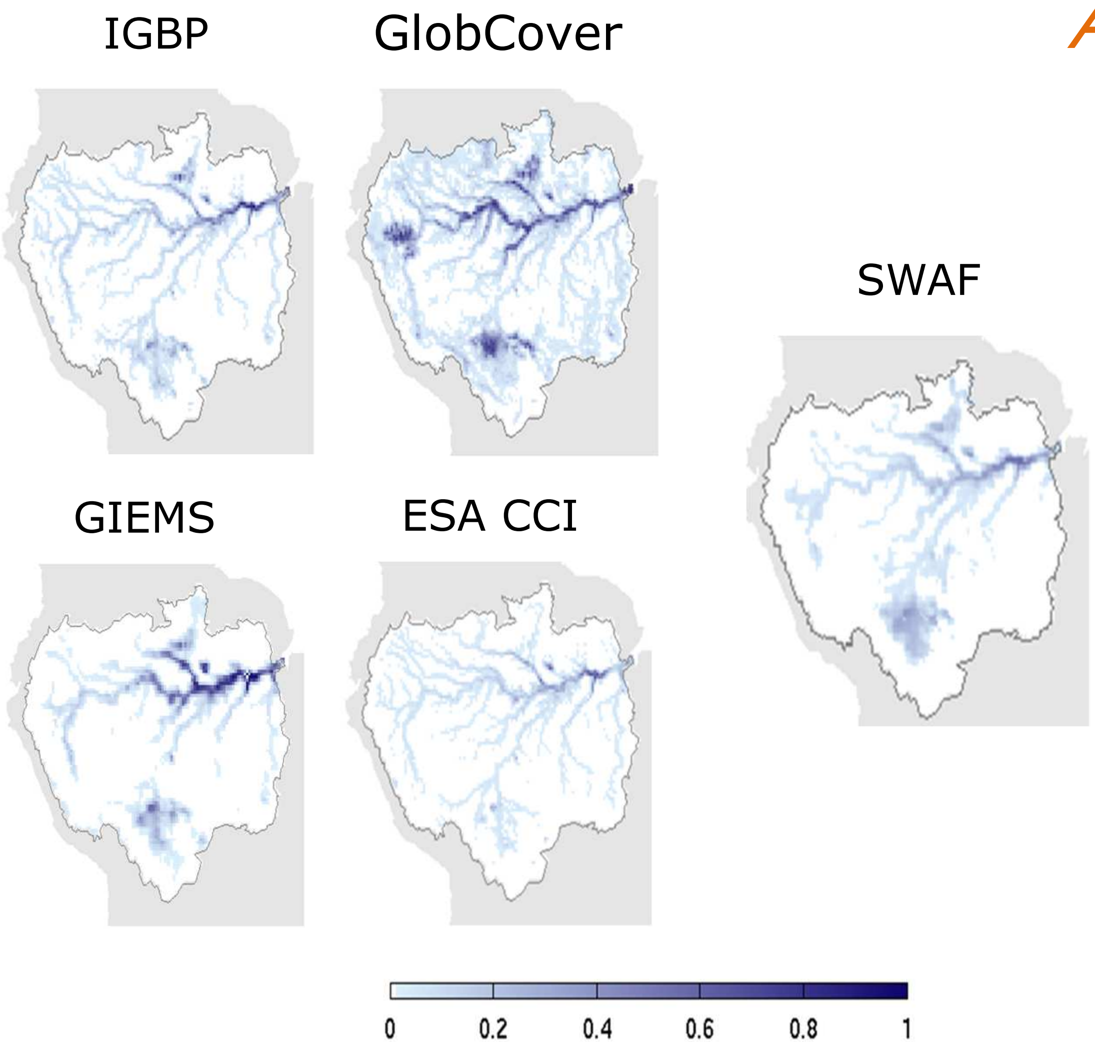
TOSCA –SOLE
Al Bitar & Parrens

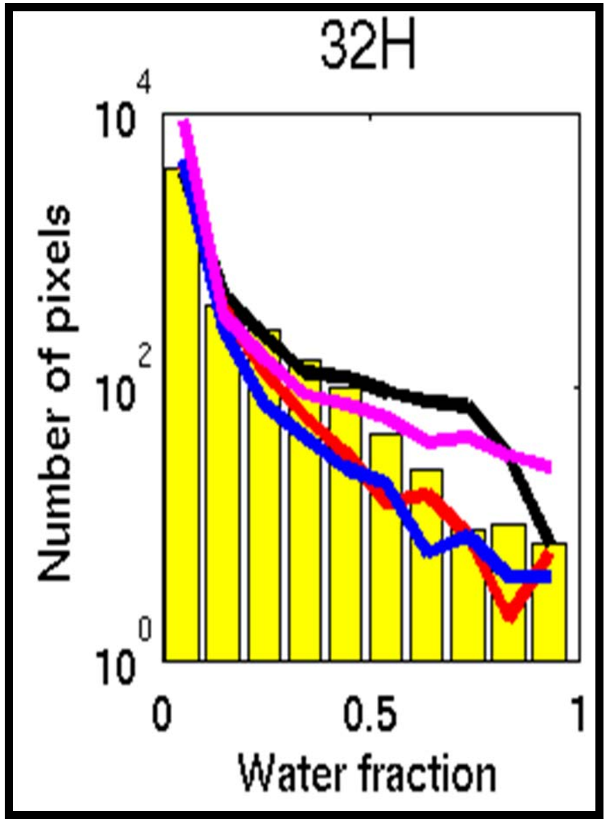
SWAF - Water fraction using SMOS data



Validation of the SMOS Water fraction

Against static maps



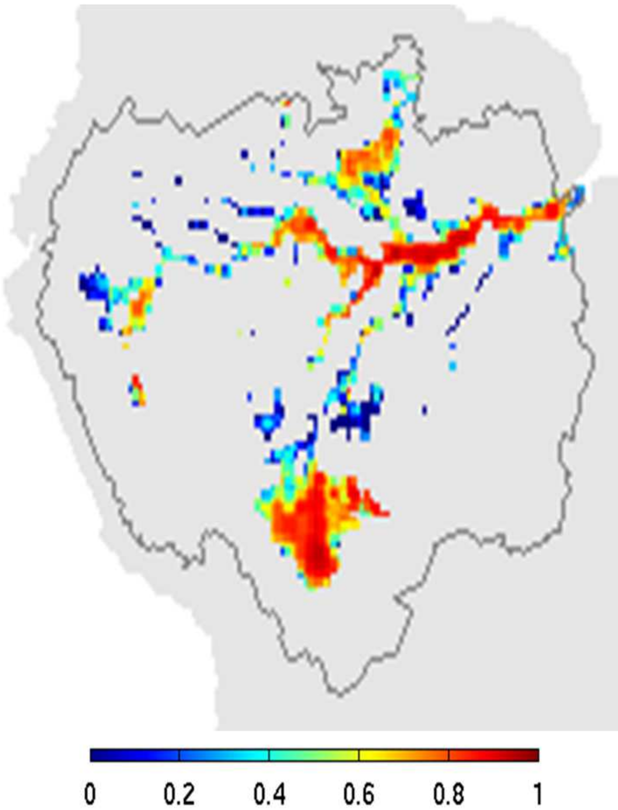


Parrens M.

Validation of the SMOS Water fraction

Against dynamic maps

Temporal correlation between SWAMPS and SWAF products



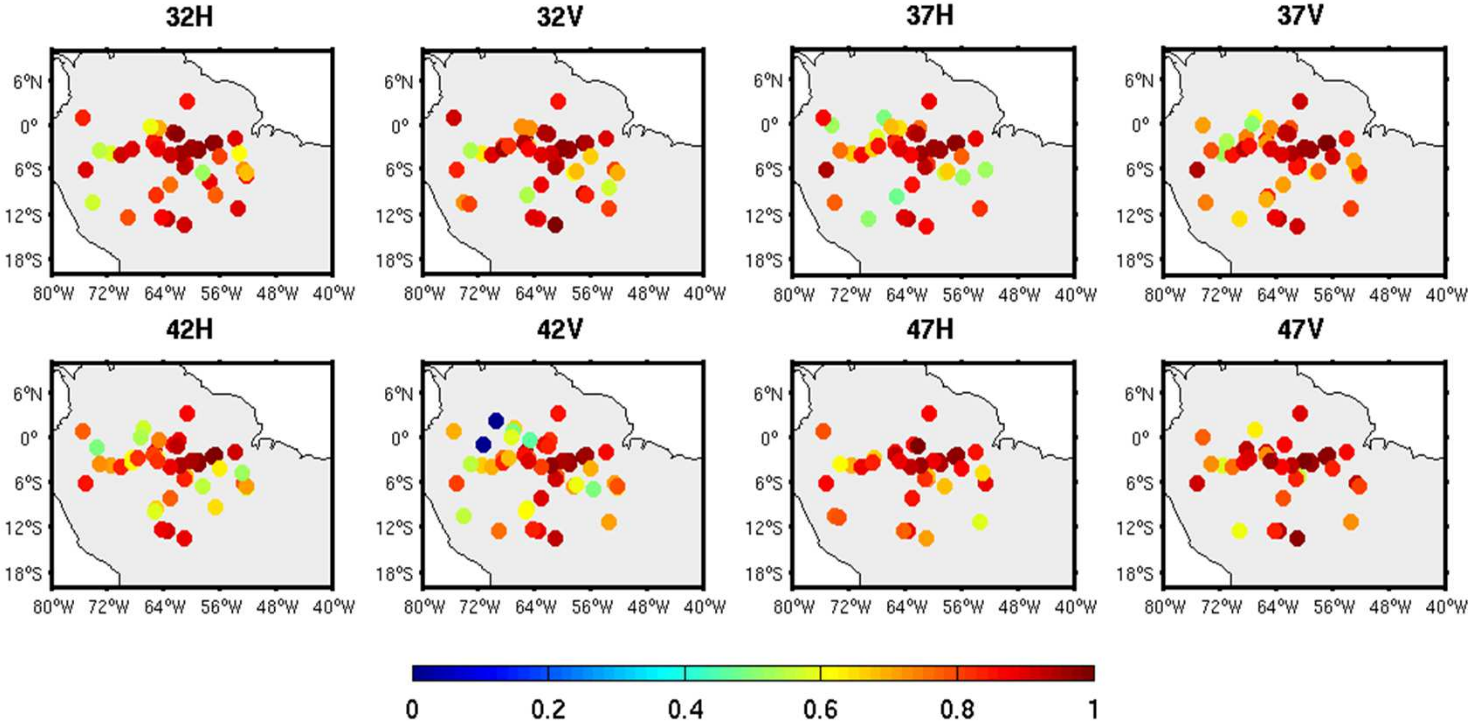
Parrens M.

Lakers_2017 06 01 YHK, AA, MP

Validation of the SMOS Water fraction

Against water levels derived from altimetry

Correlation between Jason-2 water heights and SWAF

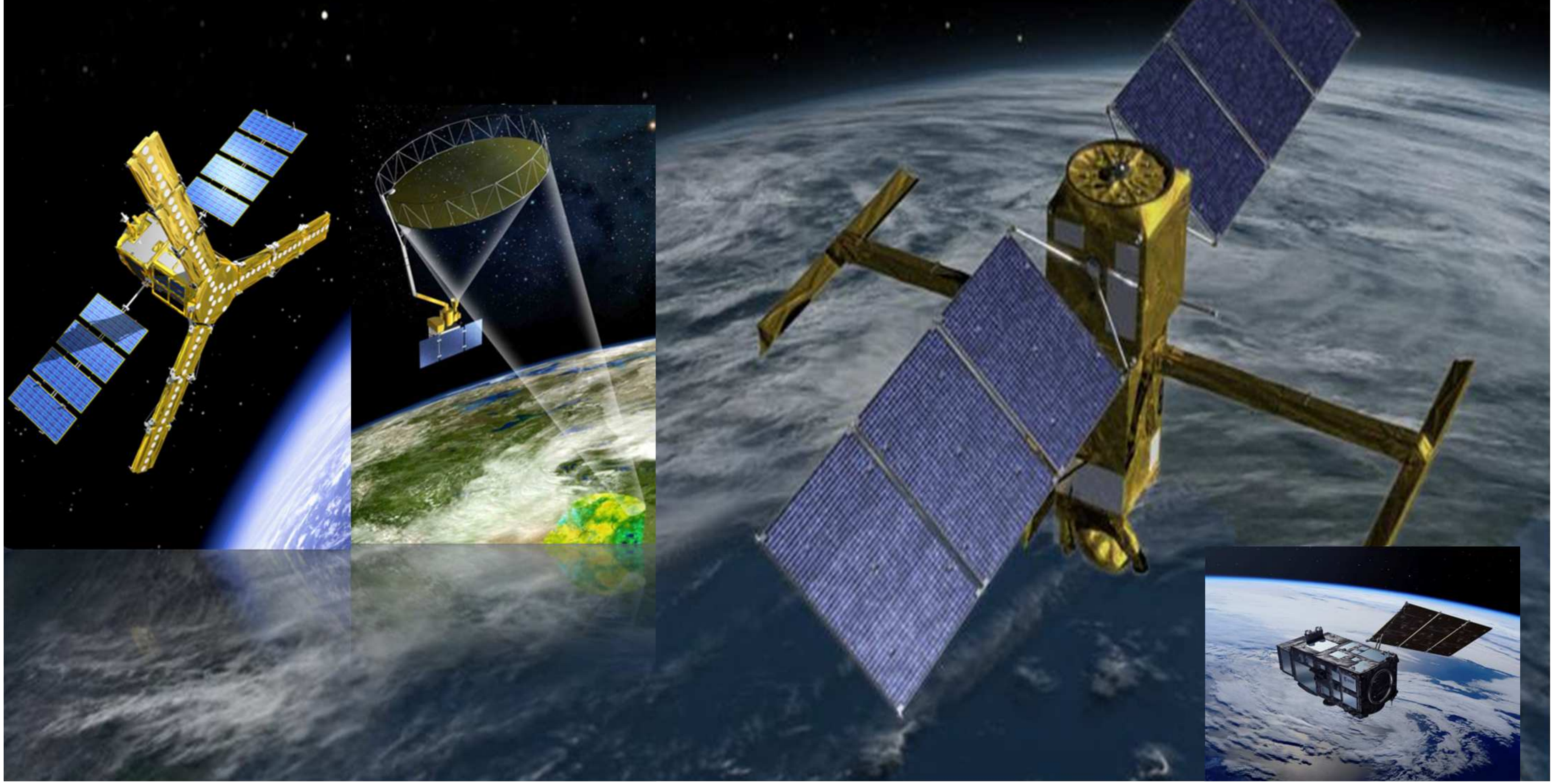


Nodes with high topography are excluded

Parrens M.

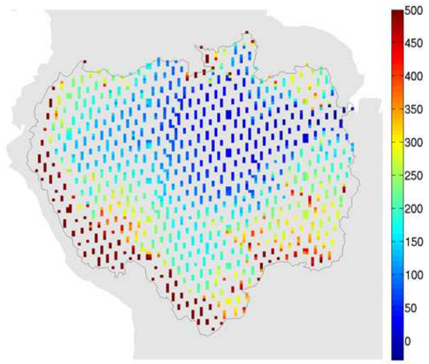
Futur work

Synergistic use of L-band and altimeters mission data (Sentinel-3, SWOT) has the potential to raise tropical water surfaces monitoring to an unprecedent level of accuracy, spatial and temporal sampling.

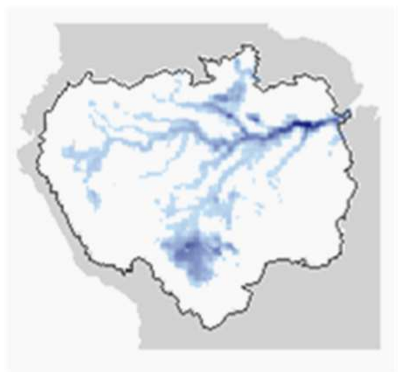


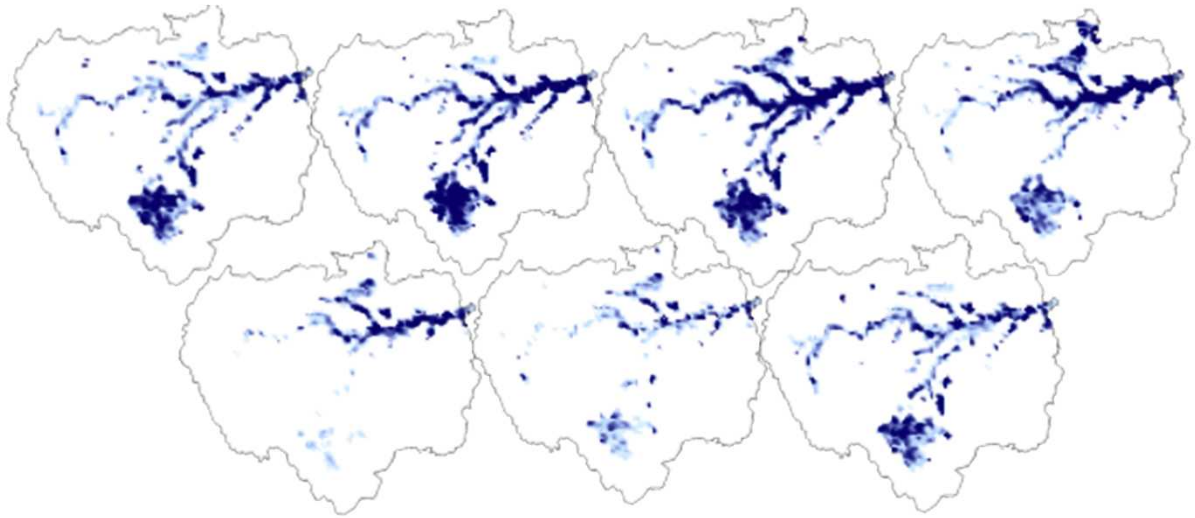
Volume changes using altimeters and L-band radiometers

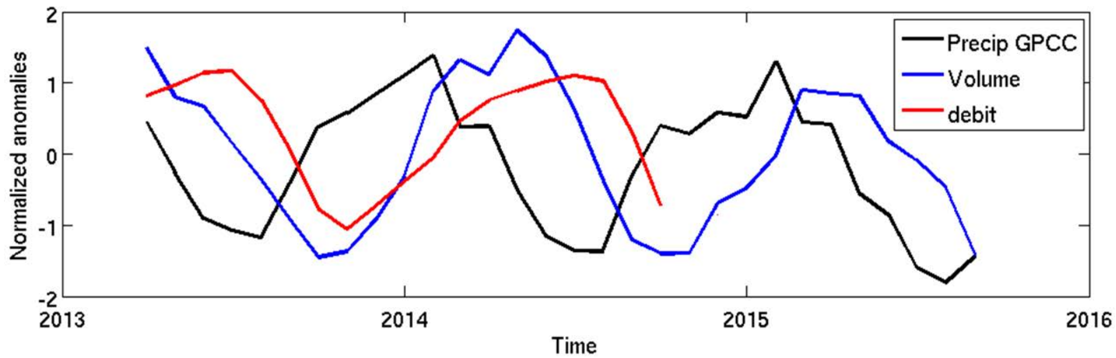
SARAL Altika



SWAF







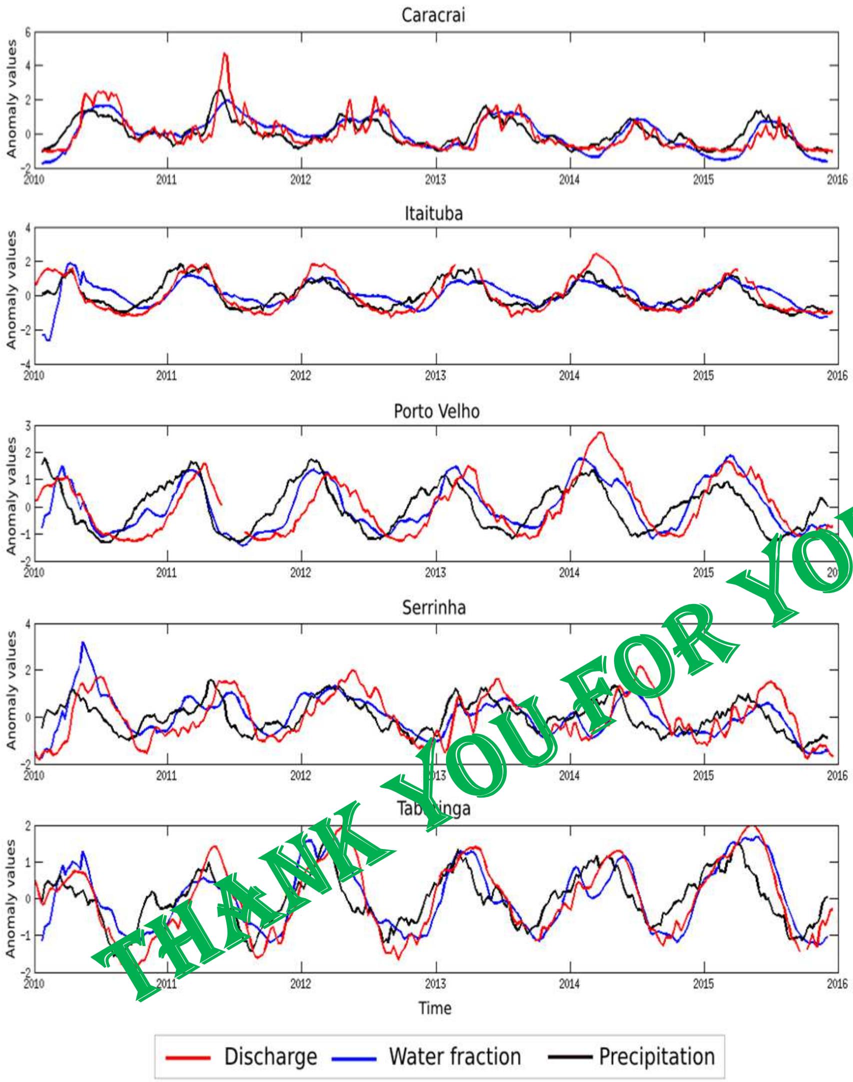
TOSCA –SOLE
Al Bitar & Parrens

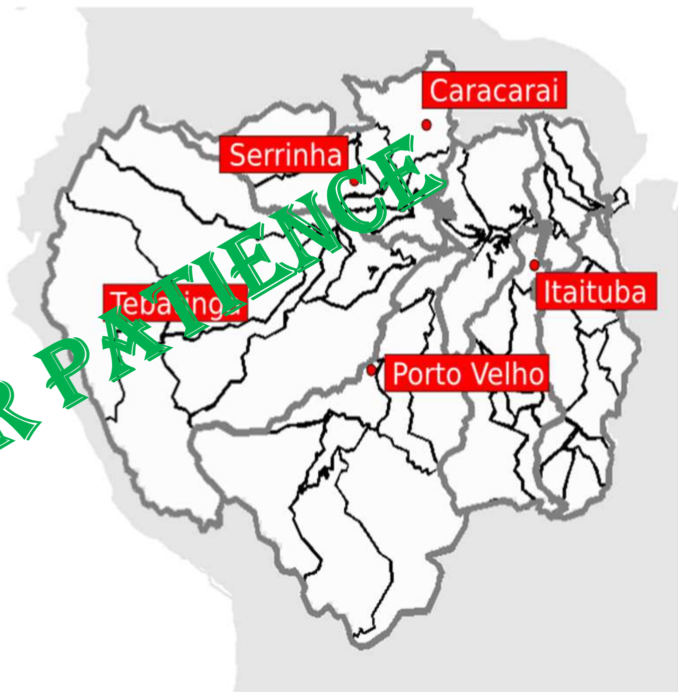
Lakers_2017 06 01 YHK, AA, MP

Summary

- SMOS SMAP intercomparison
  - same results overall
    - Two instruments do give very similar results
  - Allow for higher temporal coverage
  - BUT NO FOLLOW-ON PLANNED !!!!
- L Band radiometry useful contribution to lake and wetlands monitoring
  - Only few examples shown
  - Also activities at high latitude (melt, peat lands, …)
- Many venues to explore

Link between Discharge and SWAF





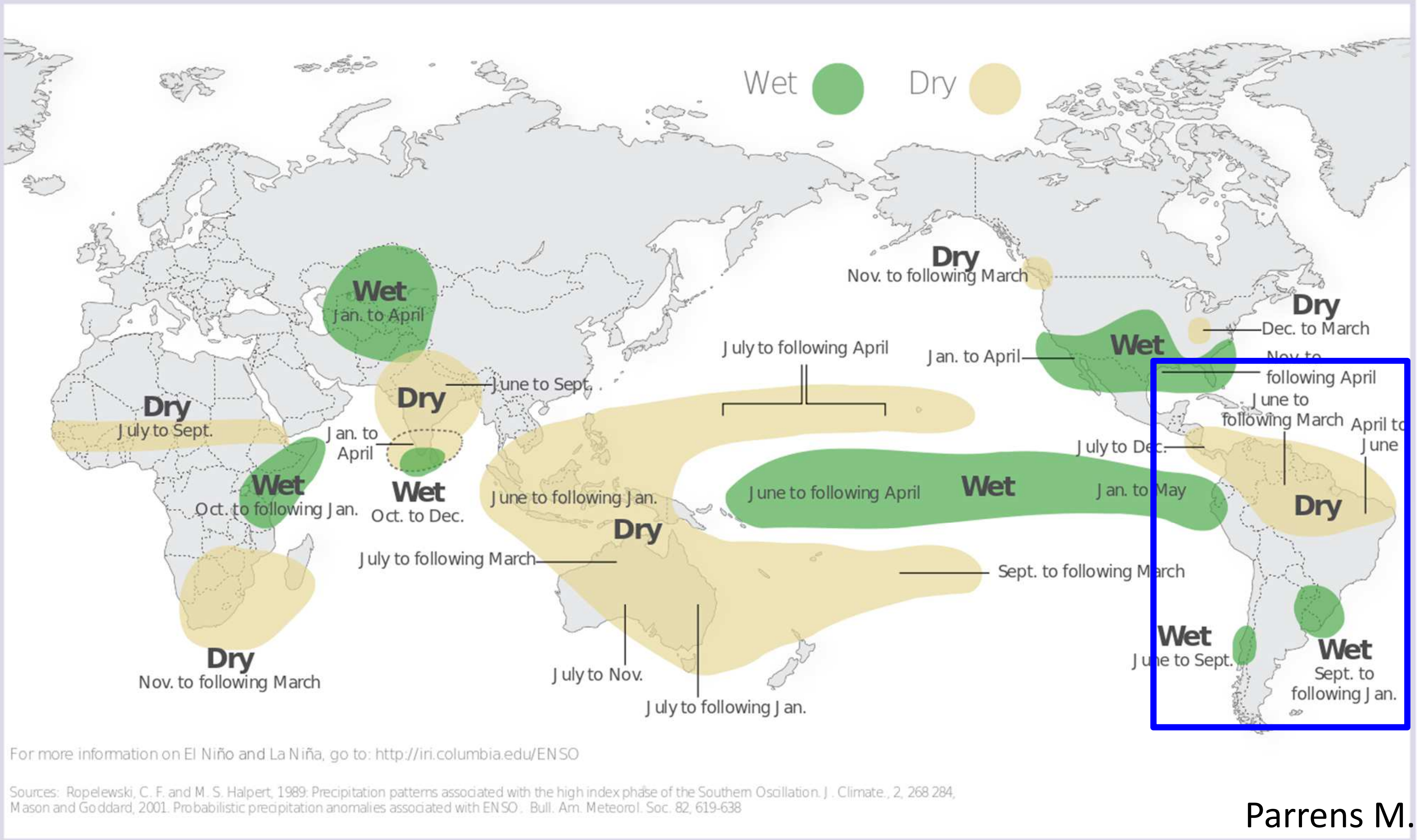
THANK YOU FOR YOUR PATIENCE

Parrens M.

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.



Parrens M.

wetlands
over tropical basins
extreme hydrological events

Why monitor wetlands
and
How can we achieve this ?

What does it tell us about Droughts and ENSO dynamics ?

Droughts of 2010

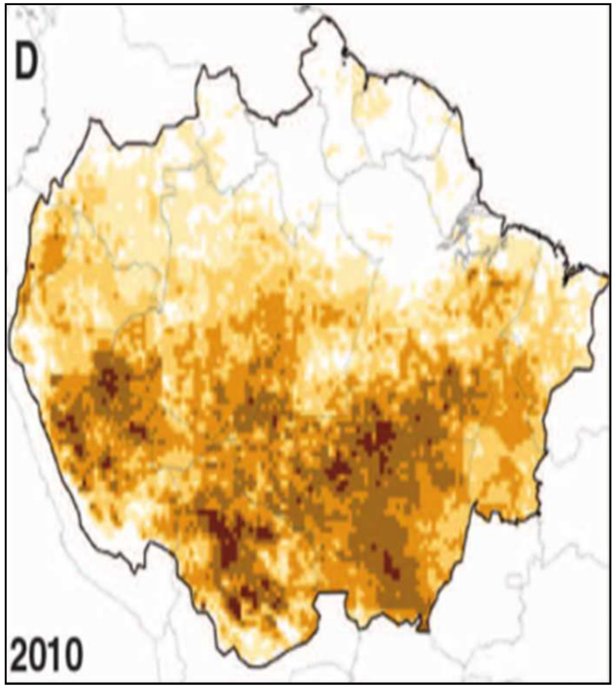
Clim. Water. Index

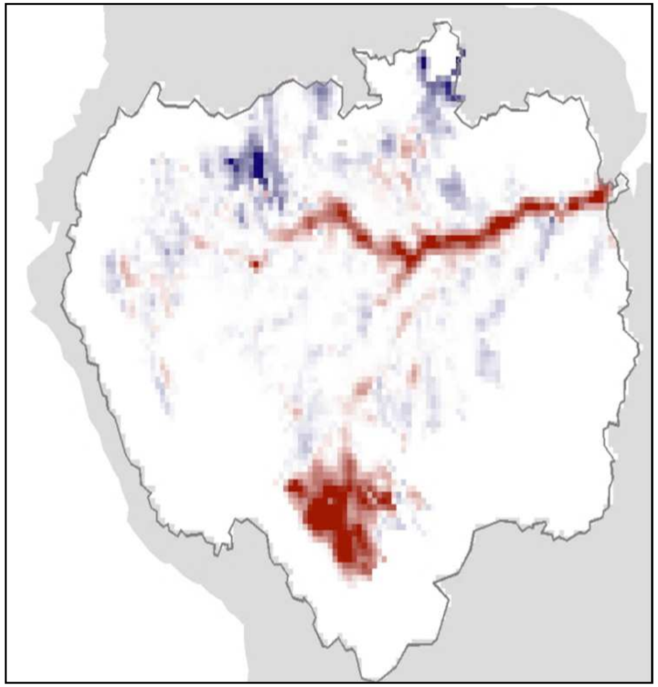
Parrens M.

Anomaly of water fraction

Jul. – Sept. 2010

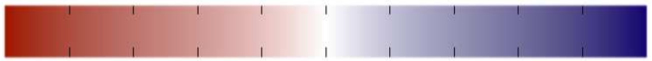
Drought depicted for the South amazone but also for the innundation plains, which can not be detected using the Clim. Water Index which is based on optical data.





water deficit

anomaly of SMOS water fraction



abnormaly dry *abnormaly wet*

(Lewis et al., Science 2011)

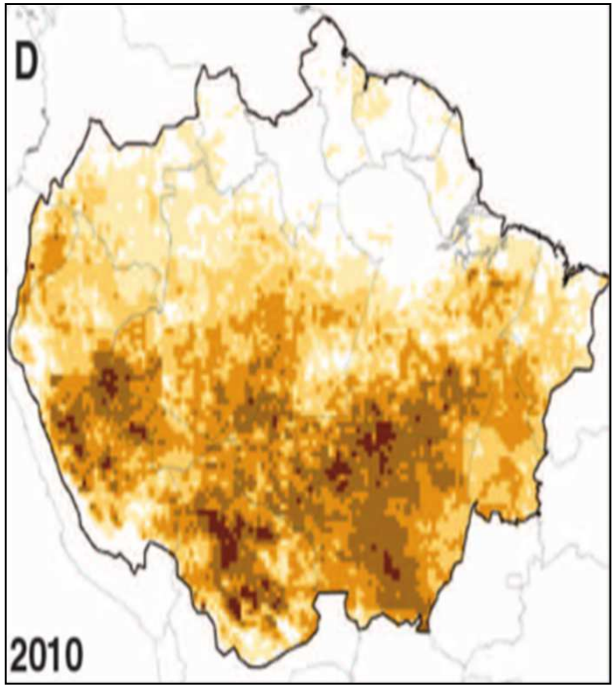
Reuters ©

Lakers_2017 06 01 YHK, AA, MP

Droughts of 2010 vs 2015

Clim. Water. Index

Parrens M.

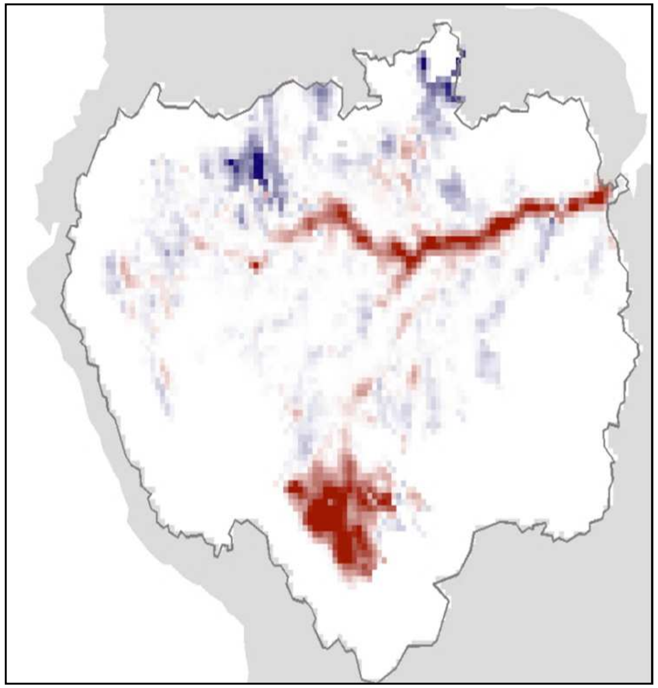


water deficit

(Lewis et al., Science 2011)

Anomaly of water fraction

Jul. – Sept. 2010

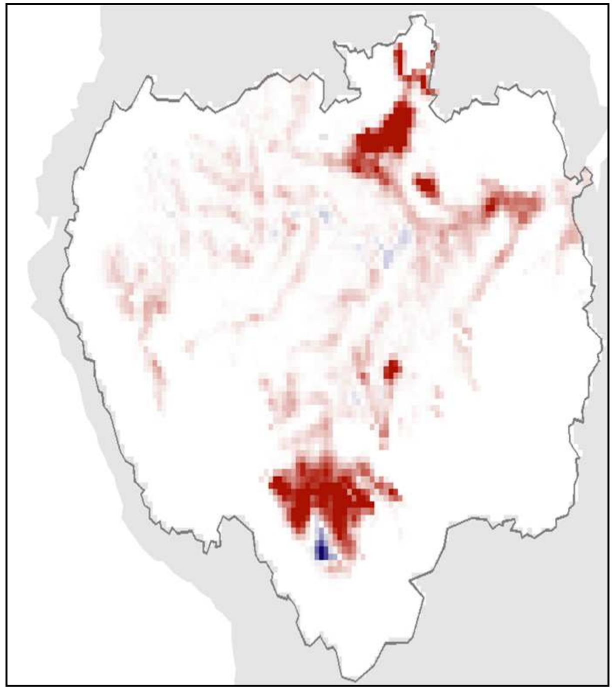


anomaly of SMOS water fraction

abnormaly dry *abnormaly wet*

Anomaly of water fraction

Oct. – Dec. 2015



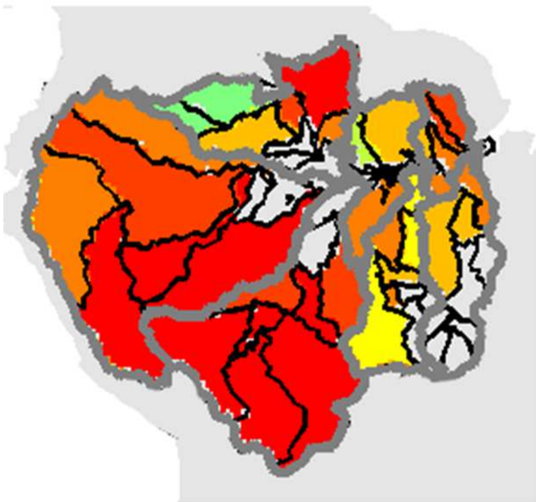
anomaly of SMOS water fraction

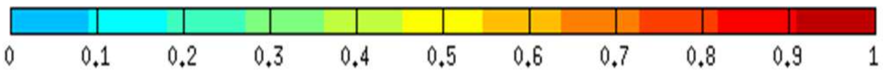
abnormaly dry *abnormaly wet*

Lakers_2017 06 01 YHK, AA, MP

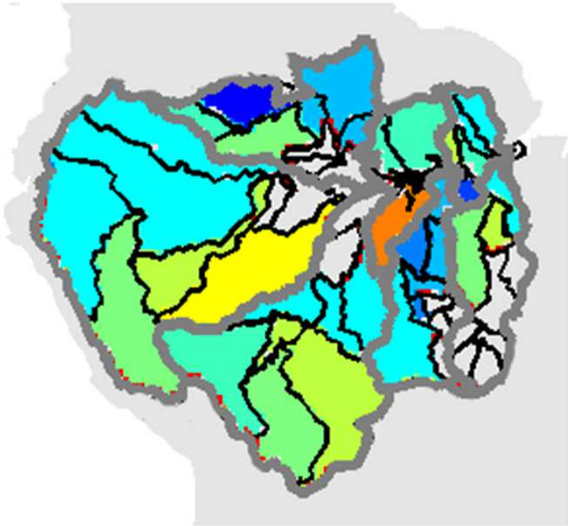
Link between Precipitation and SWAF

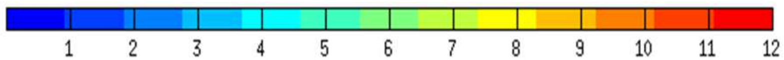
Correlation value (r)





Time lag (weeks)



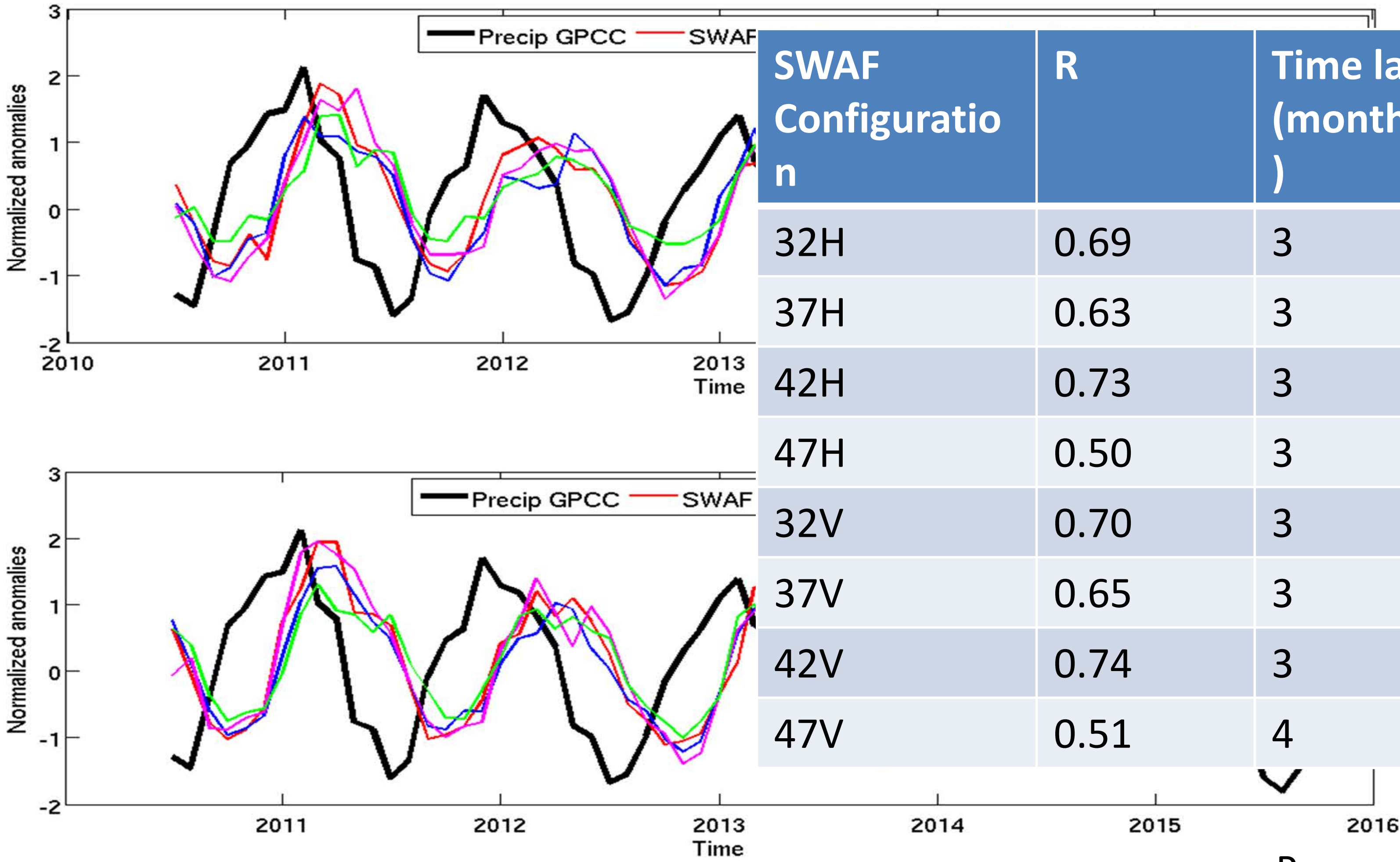


Parrens M.

Lakers_2017 06 01 YHK, AA, MP

Comparison of the SMOS water fraction

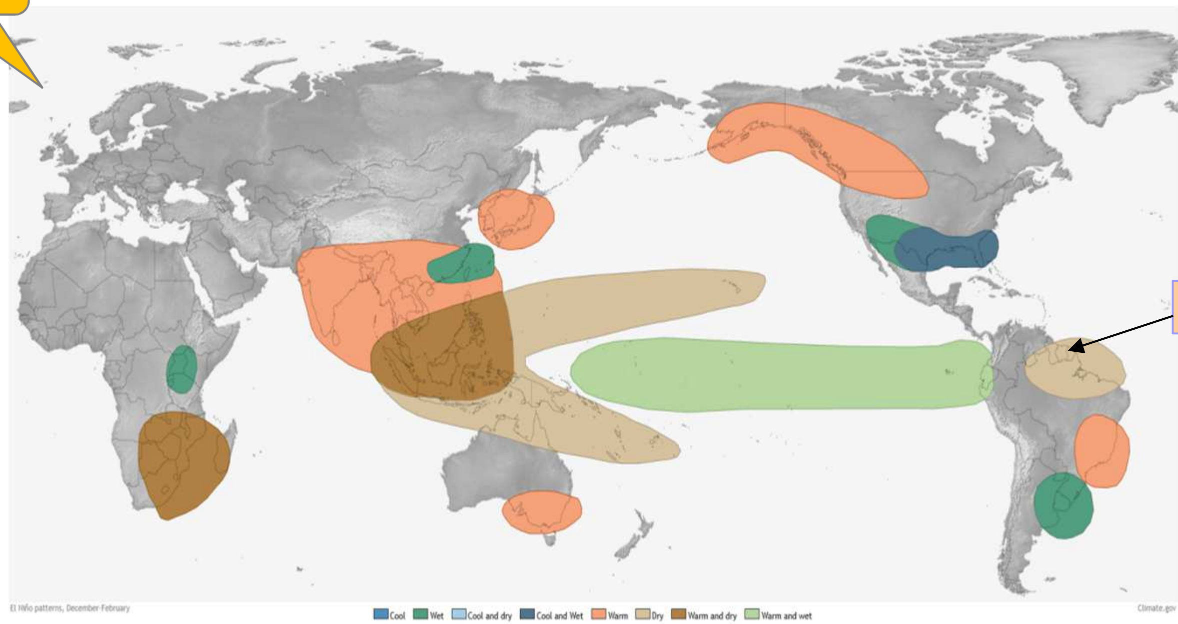
With precipitation data (GPCC – monthly products)

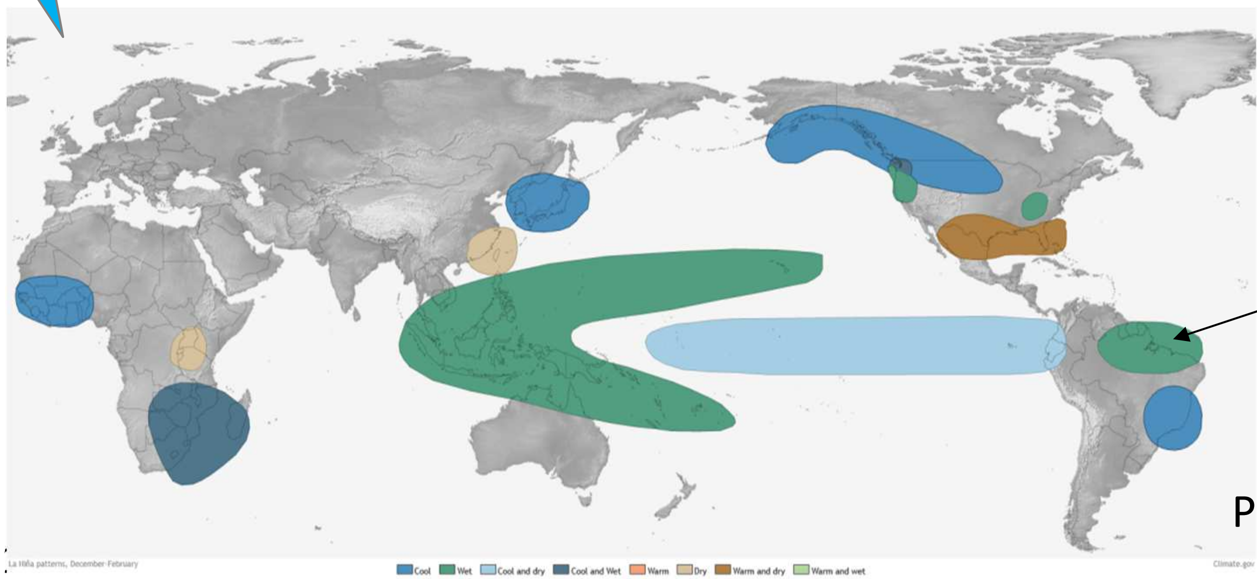


SWAF Configuration	R	Time lag (months)
32H	0.69	3
37H	0.63	3
42H	0.73	3
47H	0.50	3
32V	0.70	3
37V	0.65	3
42V	0.74	3
47V	0.51	4

Parrens M.

What are the changes during ENSO years ?

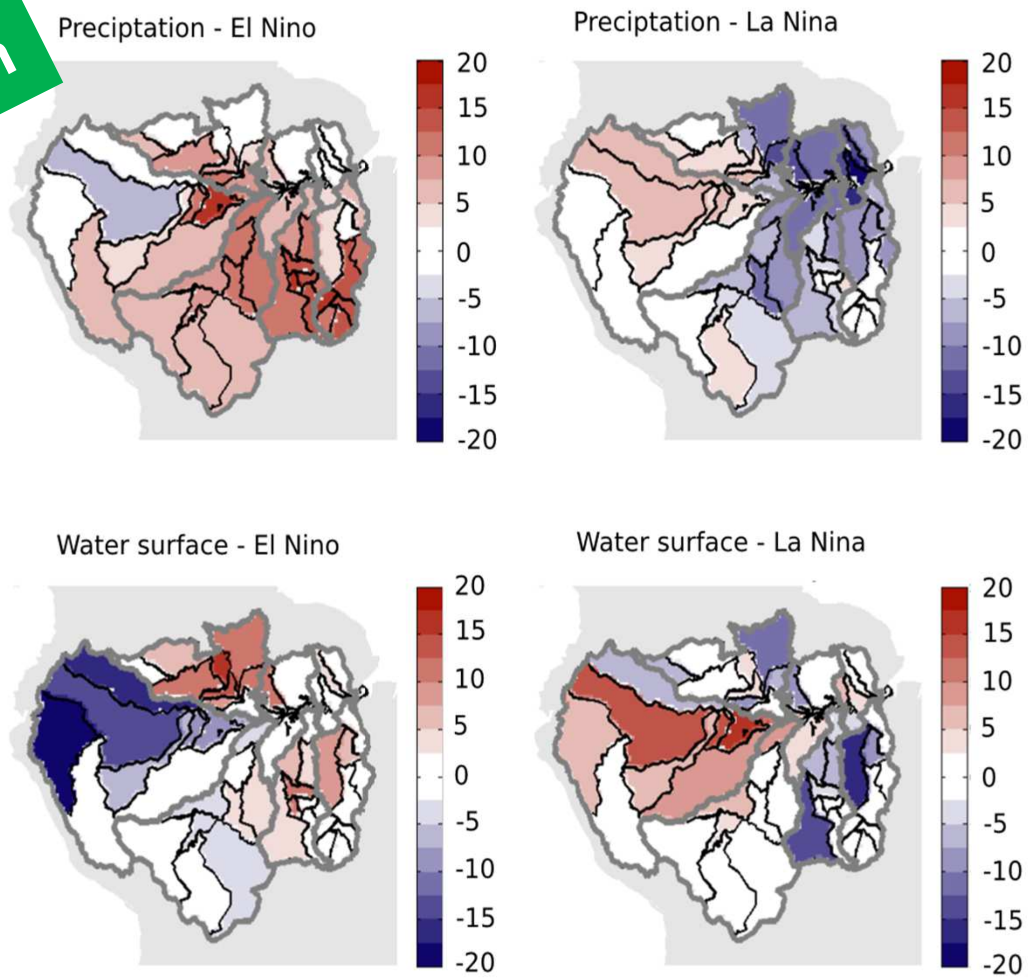




Parrens M.

Difference of anomaly of integrated water surfaces

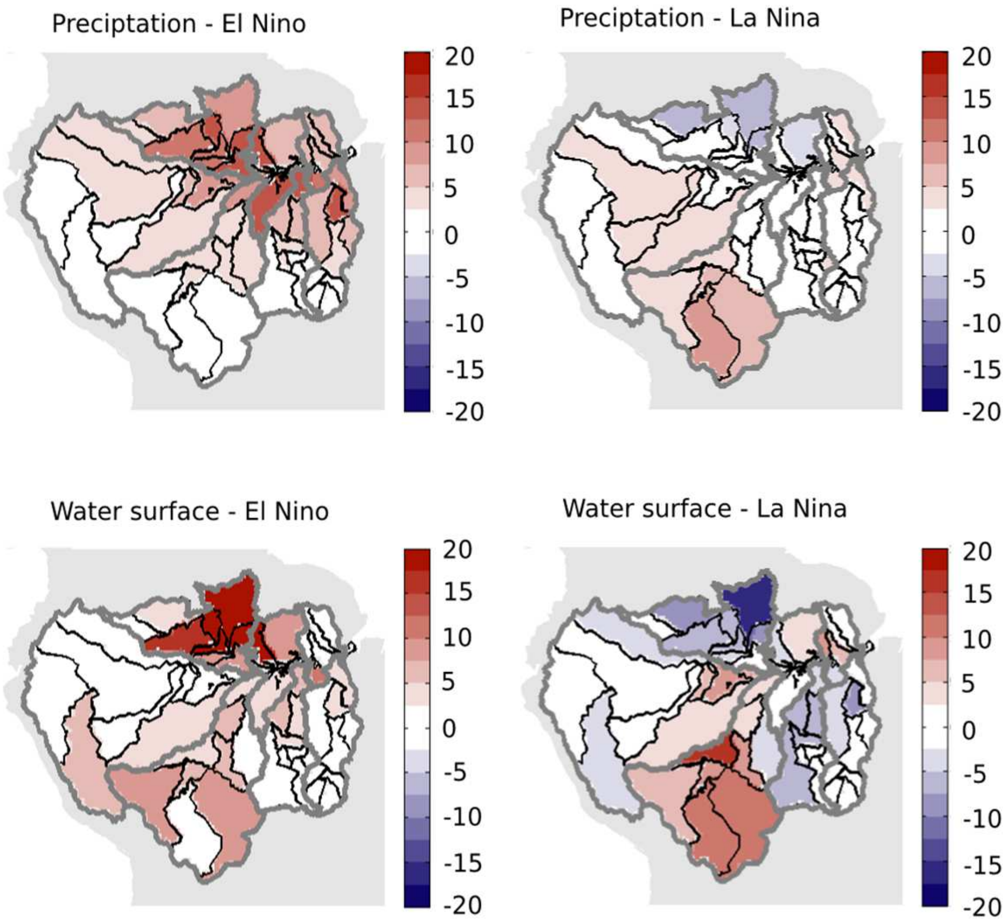
rainy season



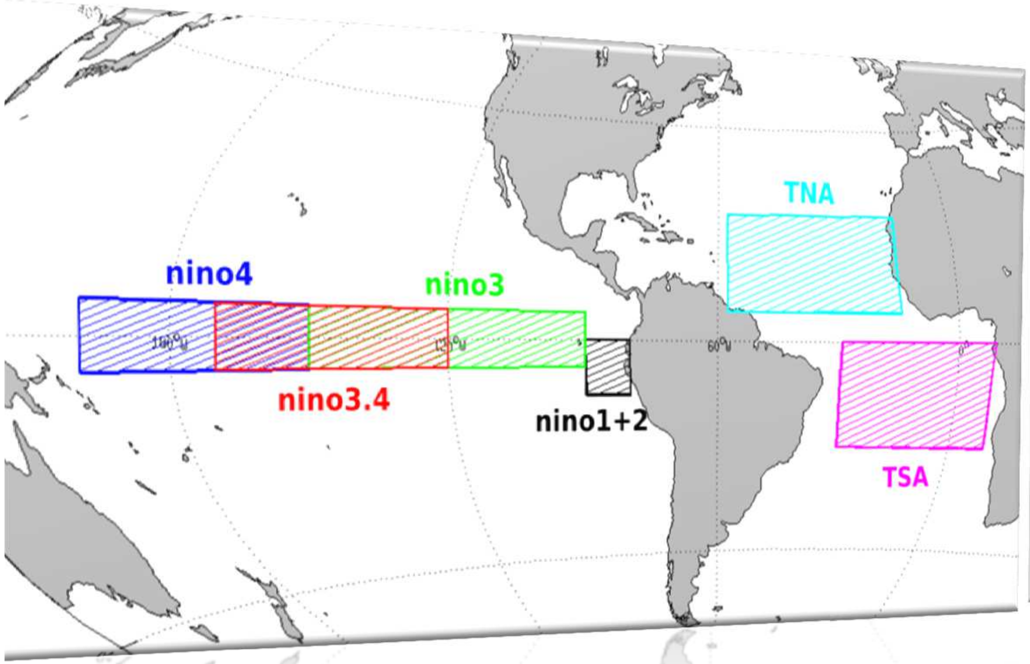
Parrens M.

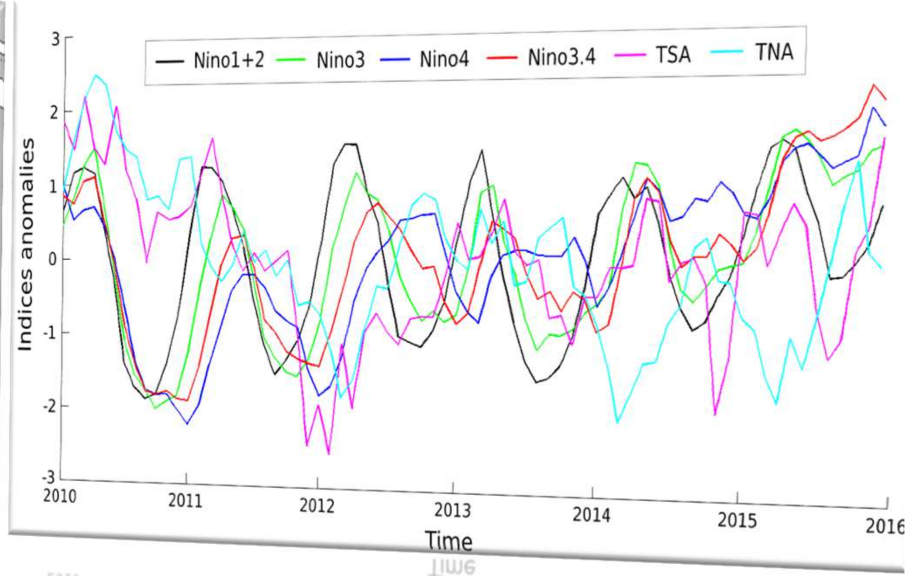
Difference of anomaly of integrated water surfaces

dry season



Parrens M.





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			

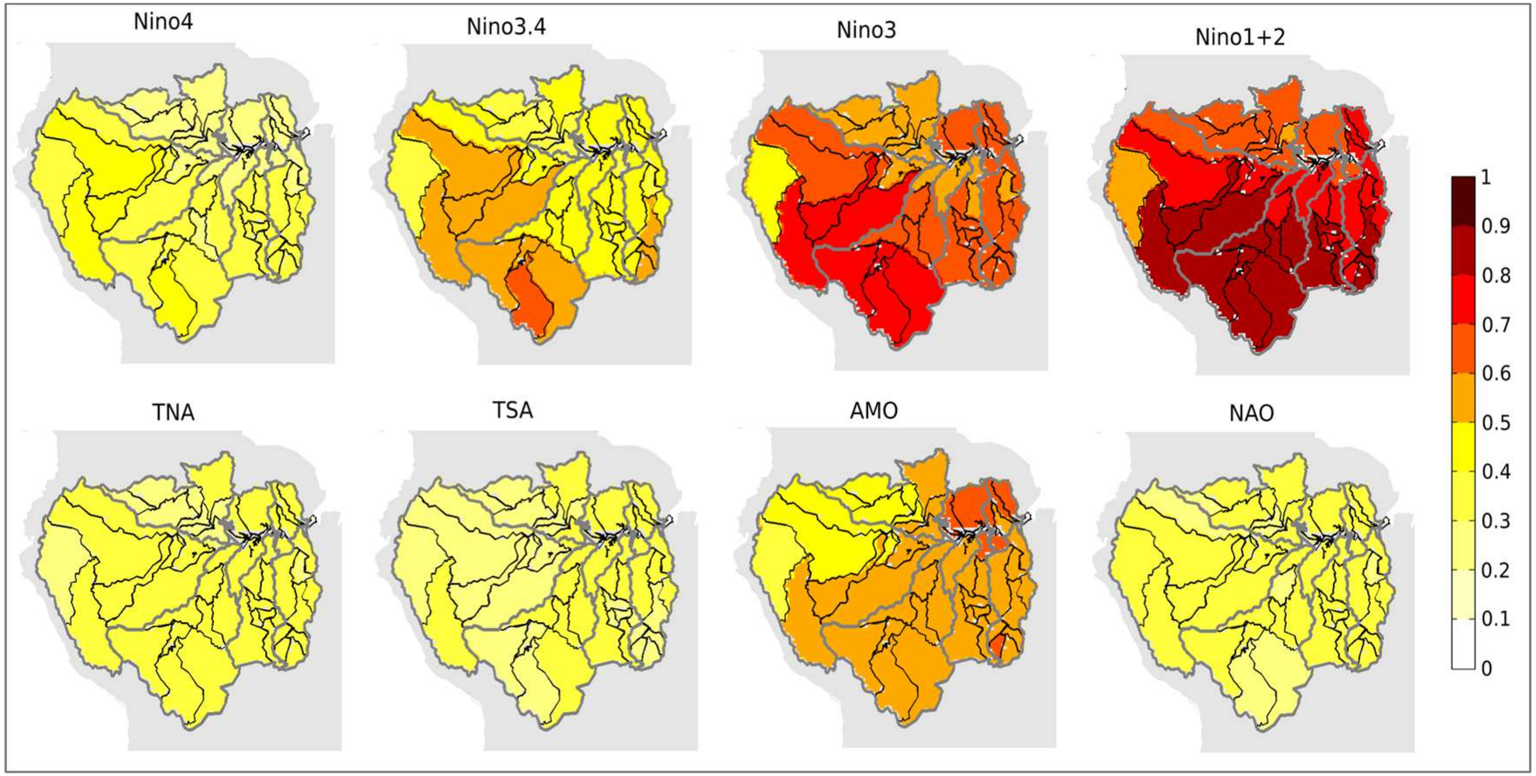
El nino year : 2015
La nina year : 2011

Parrens M.

Lagged correlation between

SST indices and TRMM precipitation data

Teleconnexion

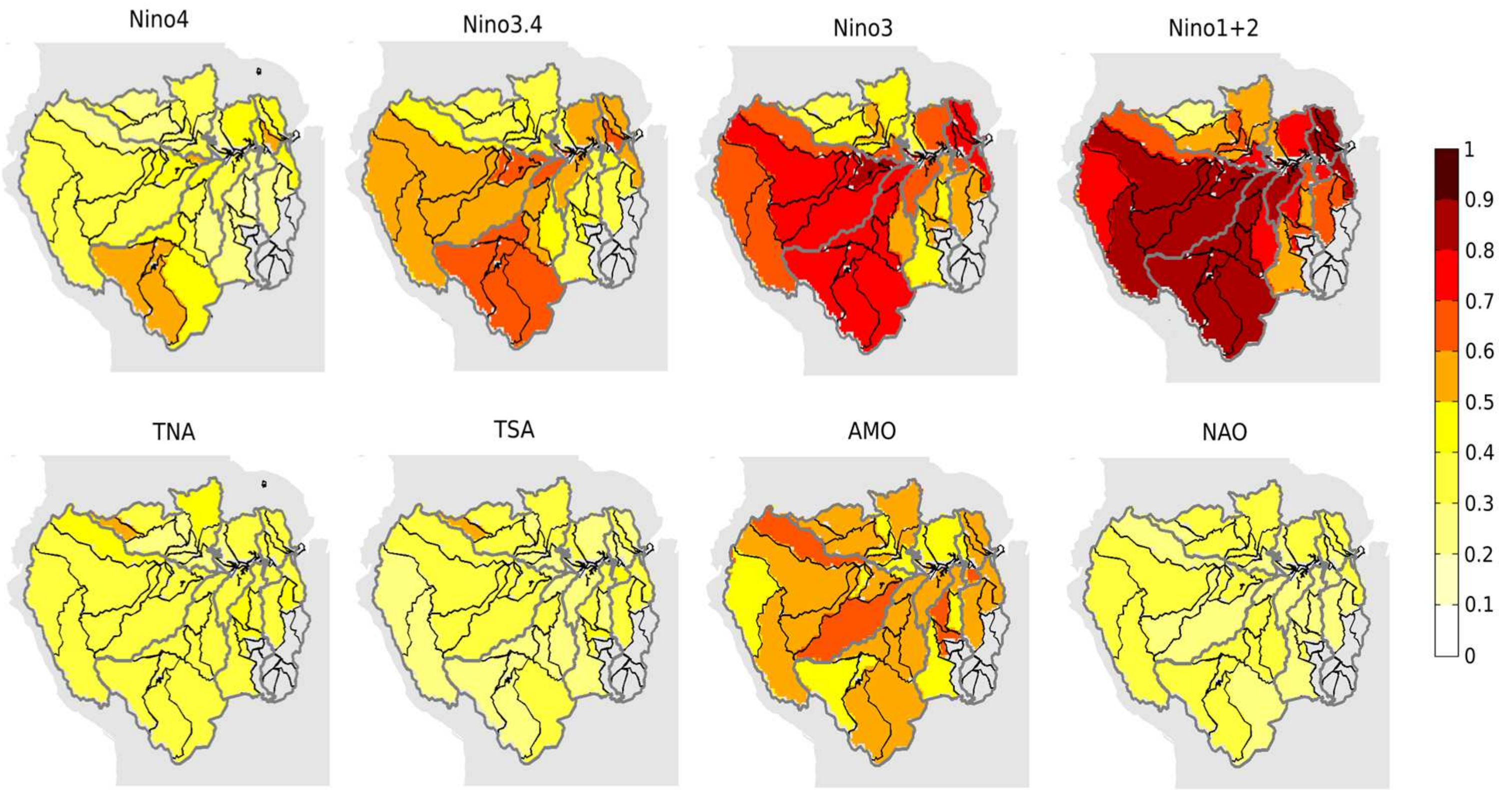


Parrens M.

Teleconnexion

SMOS

Lagged correlation between SST indices and SWAF surface water fraction data



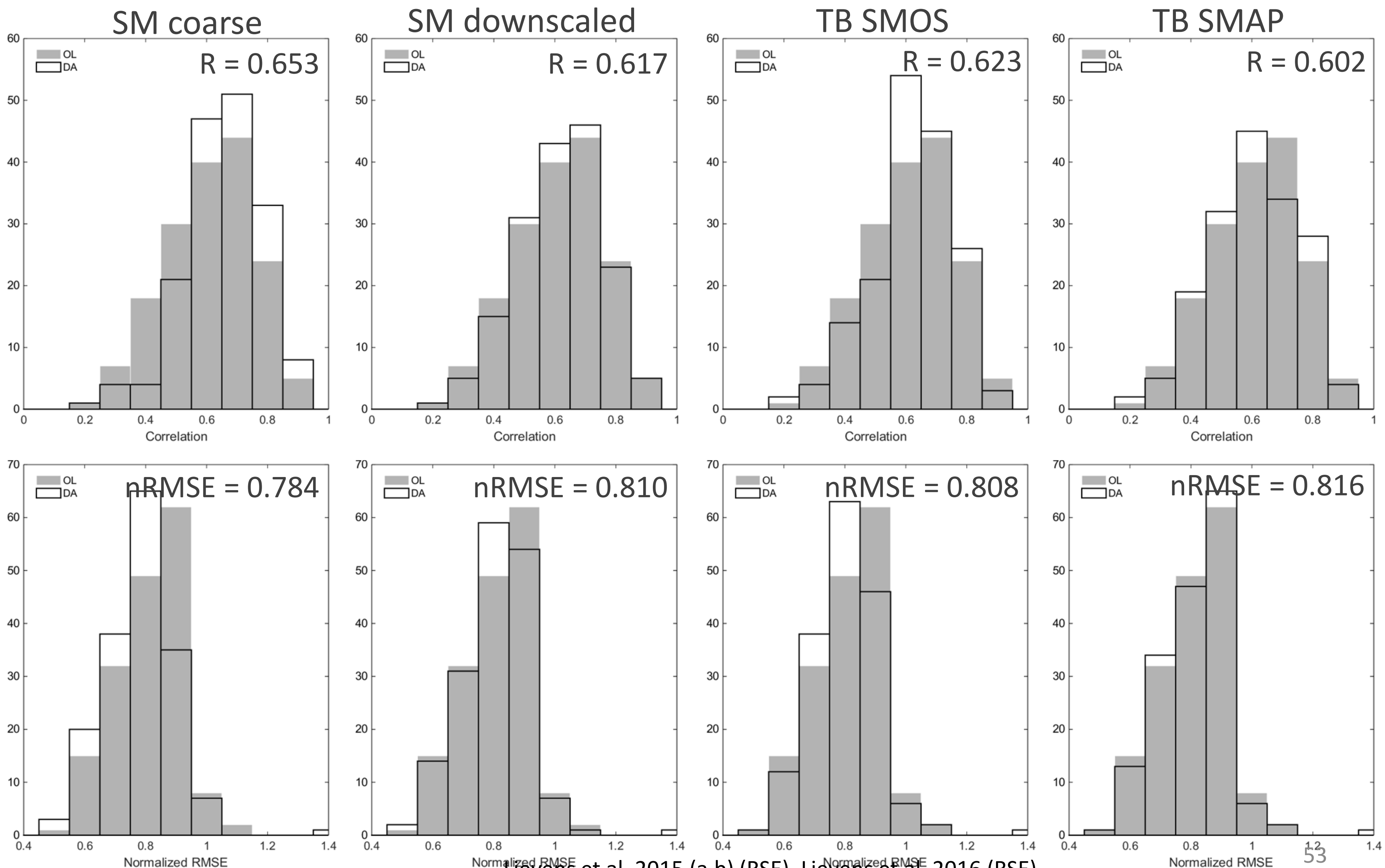
Parrens M.

Lakers_2017 06 01 YHK, AA, MP

STREAM FLOW ANALYSIS

Comparison of DA experiments

Open loop: R = 0.608 / nRMSE = 0.812



Lievens et al. 2015 (a,b) (RSE), Lievens et al. 2016 (RSE)