Wetland inventory and variability over the last two decades at a global scale

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Outline

- Estimating the surface water extent and dynamics
- Evaluating the surface water extent and dynamics
- Applications for SWOT preparation

How to estimate the global inundated wetlands and their dynamics?

- a large variety of environments, from the Tropics to the Boreal regions
- not even a unique definition

Ria Celestun, Mexico

Pantanal, Brazil

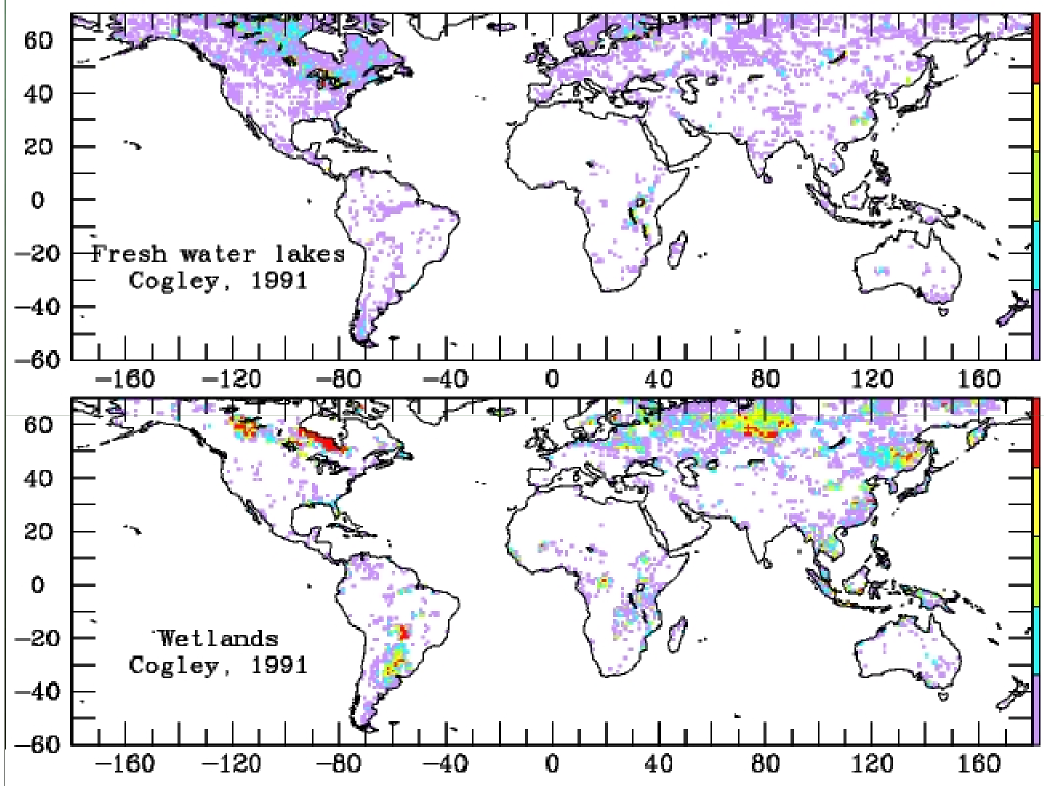
Dyje forest, Czech republic

Lena delta, Russia

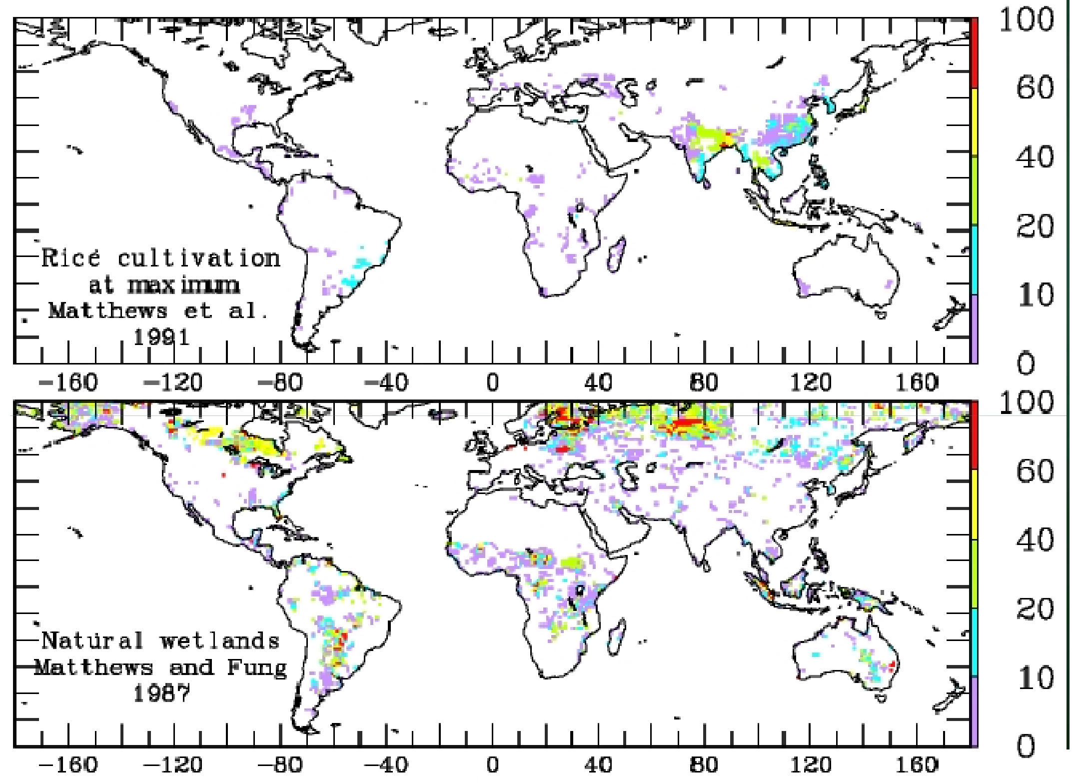
Existing static inventories of wetland (1/2)

- no seasonal or inter-annual variations except for rice paddies that have a seasonal variation
- usually assumed to represent the wetland maximum extent
- the ‘historical’ ones : Matthews et al. (1987, 1991), Cogley (1991), with a 1° spatial resolution

Cogley



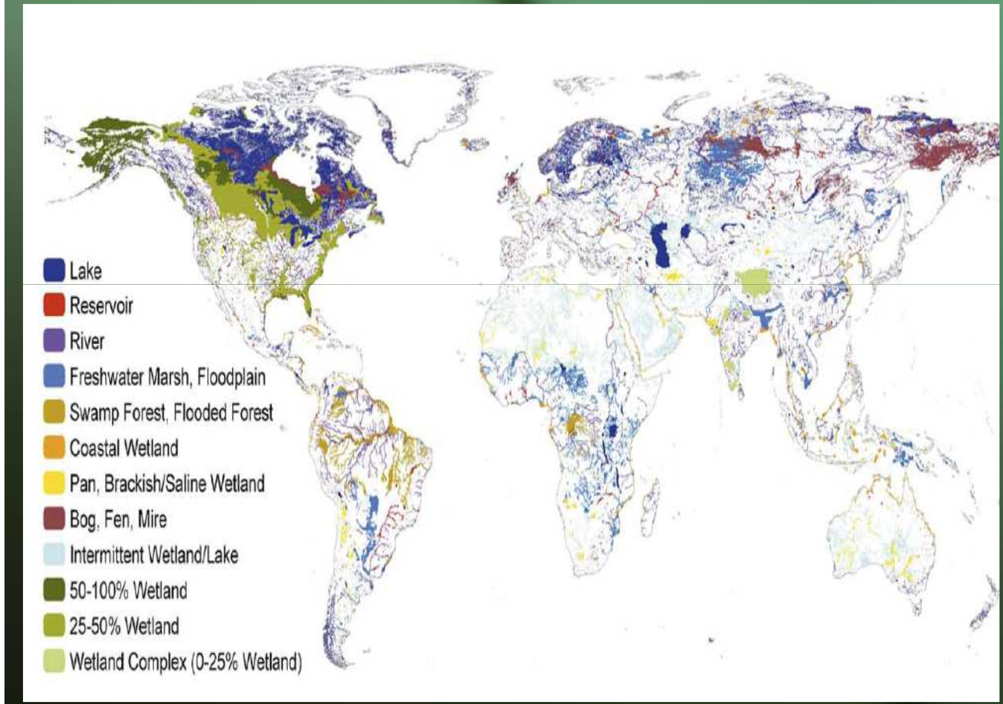
Matthews et al.



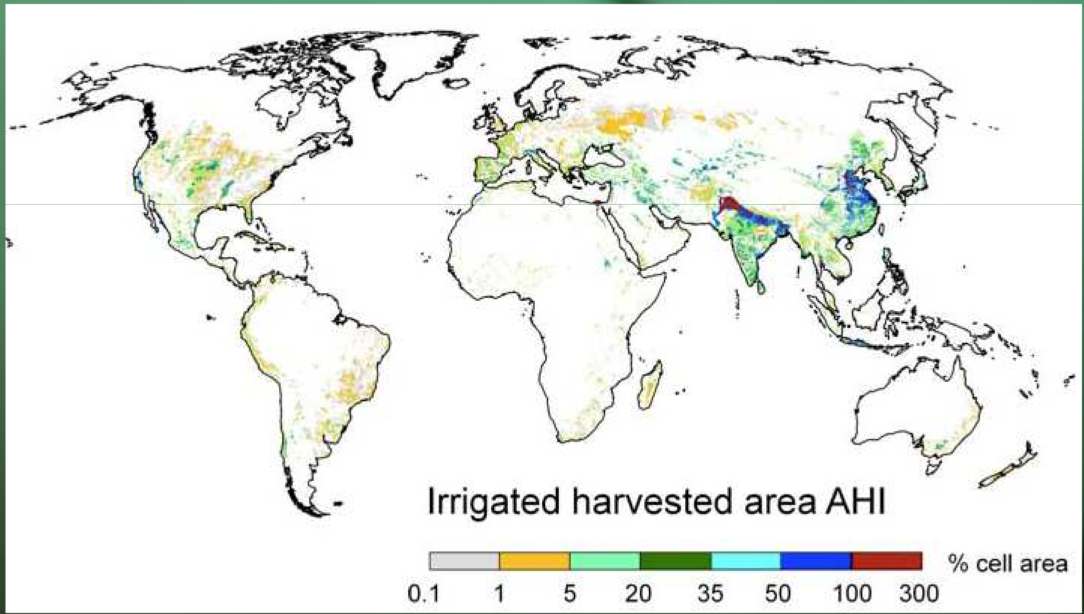
Existing static inventories of wetland (2/2)

- no seasonal or inter-annual variations except for rice paddies that have a seasonal variation
- usually assumed to represent the wetland maximum extent
- the new ones : Lehner and Doll (2004), Portmann et al. (2010)

Global Lakes and Wetlands Database
30s resolution
Lehner and Doll (2004)



MIRCA 2000
5min resolution
Portmann et al. (2010)



Remote sensing techniques (1/2)

- based on differences between water and soil properties
  - in reflection and emission (due to differences in refraction index, emissivity and / or differences in surface roughness)
  - in thermal inertia

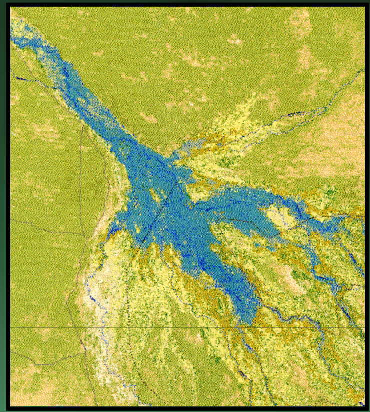
- varying degrees of success depending on the wavelengths and the environments
  - vegetation contribution?
  - water fraction within a given field-of-view?
  - cloud cover during wet season?

- local applications usually, when using one remote sensing technique only

Remote sensing techniques (2/2)

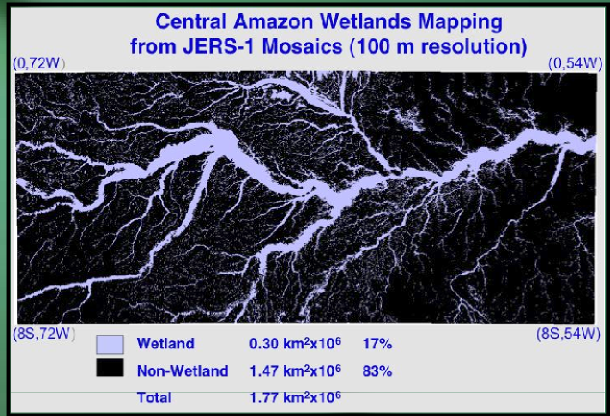
Visible and infrared (e.g. AVHRR)

• high spatial resolutions
•unable to penetrate vegetation and clouds
• very useful in semi-arid environments
Ex: the Okavango, McCarthy et al., 2000



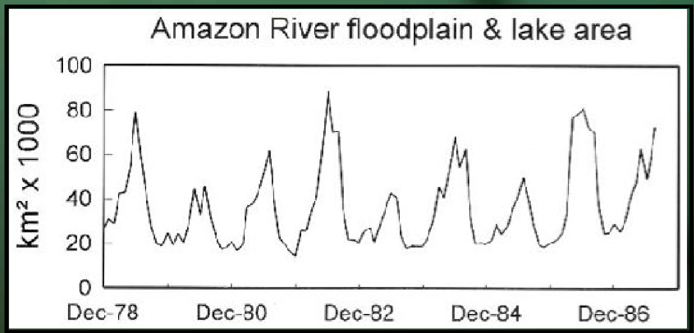
Active microwave (SAR)

• very high spatial resolution
• large data volume: difficult to handle for global analysis
• few time samples: difficult to assess the dynamic
Ex: the Amazon, Hess et al., 2003



Passive microwave (SSMR, SSM/I…)

• water reduces emissivities in both linear polarizations
• difficult to account for vegetation contribution when used alone
• low spatial resolution (~ 20 km)
Ex: the Amazon, Sippel et al., 1998



A multi-satellite method (1/6)

The idea: to merge satellite data from different wavelengths

- to benefit from their different sensitivities
- to help separate the contributions of the various parameters within a pixel (standing water, dry soil, vegetation…)

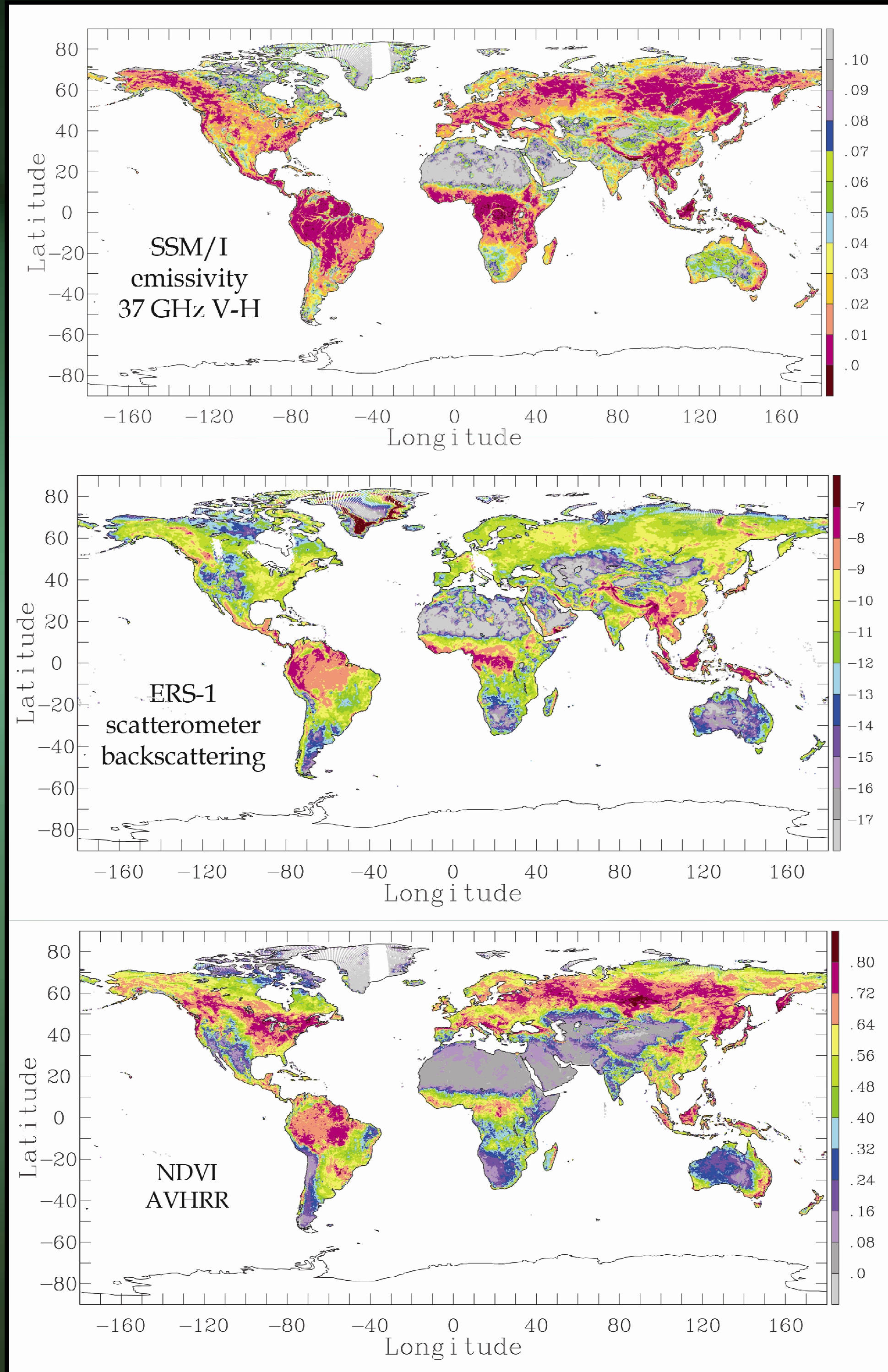
Merging of basic observations to benefit from their synergy. Different from the a posteriori blending of already retrieved products.

It includes satellite data:

- available on a global basis with spatial resolution compatible with climate studies
- available over long time series (>10 years)

The selected data sets:

- Passive microwaves
- Active microwaves
- Visible and near-IR reflectances



A multi-satellite method (2/6)

Cloud-screening and subtraction of the atmospheric effects, when relevant.

Data sets mapped on an equal-area grid of $0.25^\circ \times 0.25^\circ$ resolution at equator

Unsupervised classification of the merged satellite data to detect inundated pixels

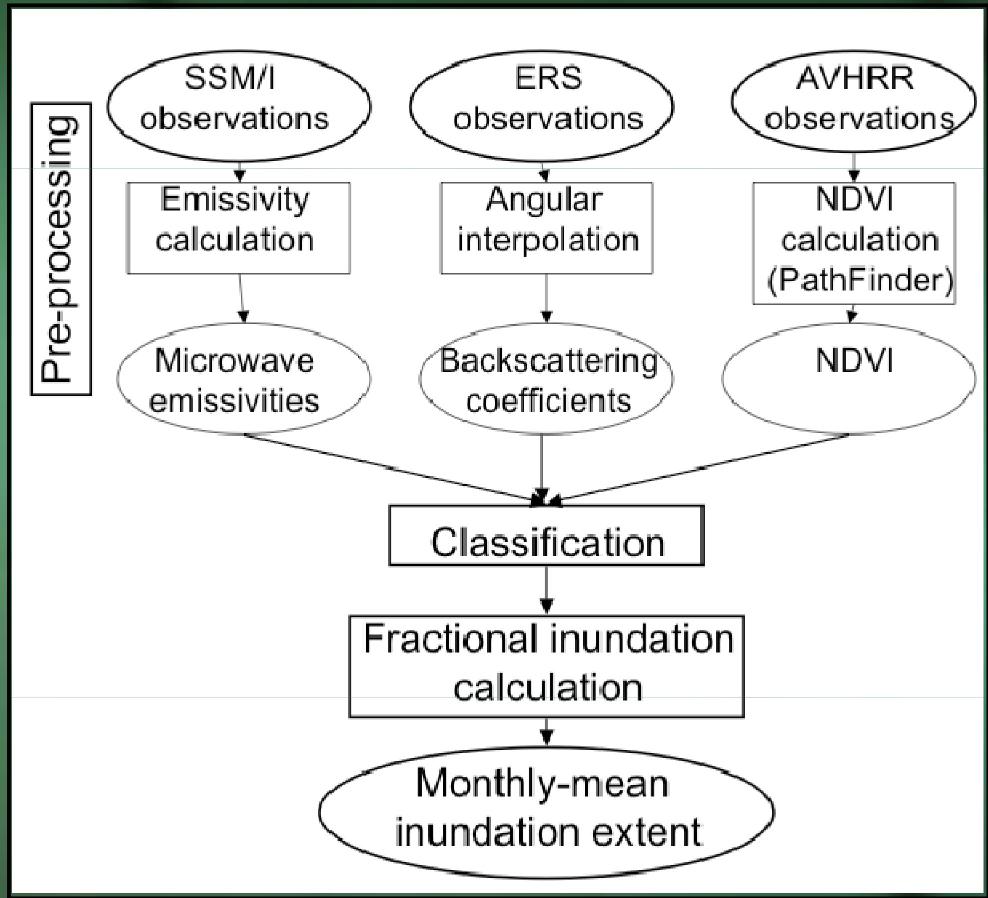
Fractional coverage of flooding estimated from a linear mixture model with end members calibrated with radar observations to account for vegetation

(Prigent et al., GRL, 2001; JGR, 2007; Papa et al., 2010)

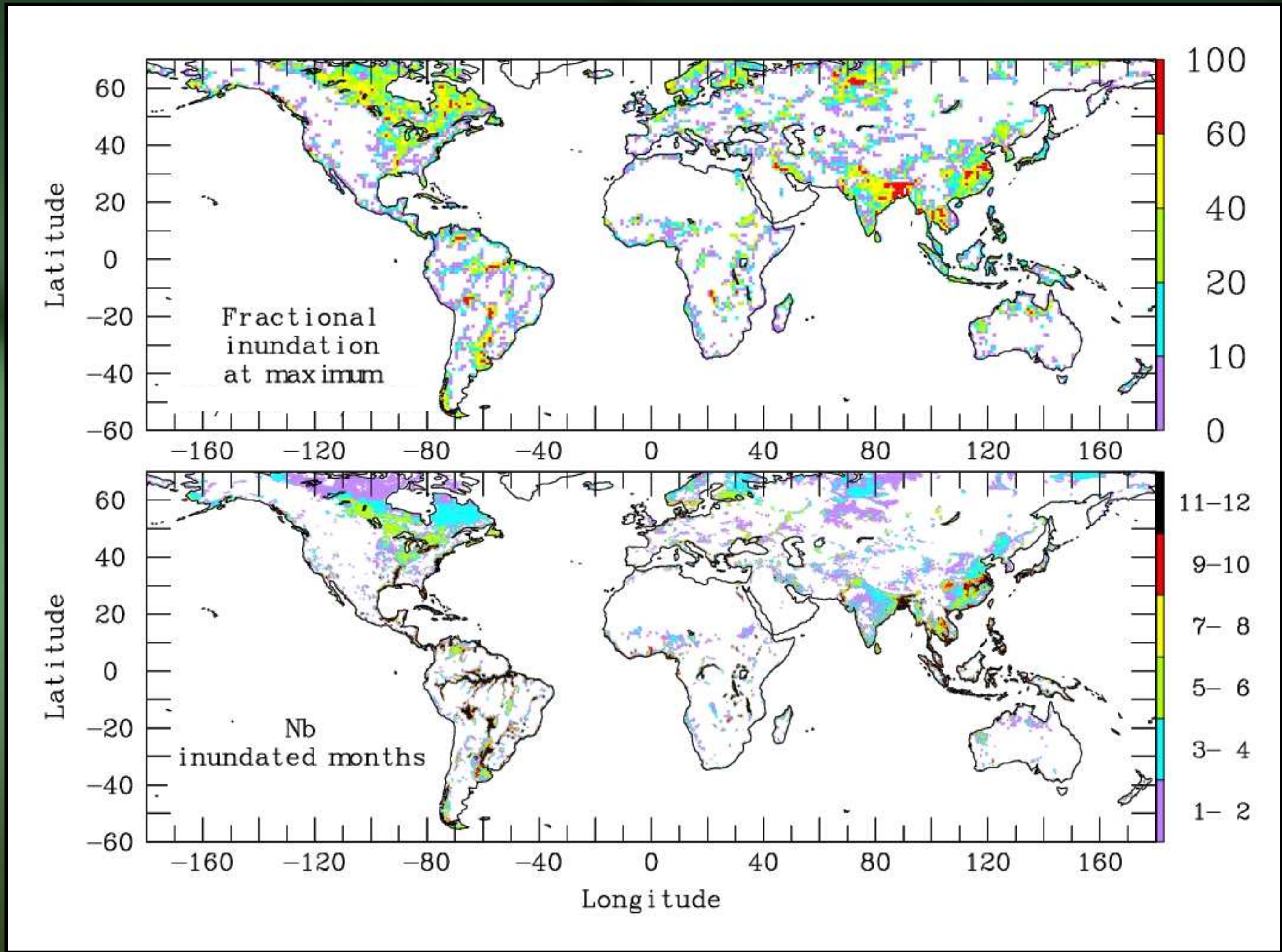
Passive microwave

Active microwave

Vis and near-IR reflectances



A multi-satellite method (3/6)



- On the large scale, estimates show realistic structures
- Results capture well major wetland areas (Ob River, Amazon basin, North of Canada, India…)
- Include natural wetlands as well as rice paddies and small lakes

A multi-satellite method (4/6)

• A first version of the data set produced from 1993 to 2001

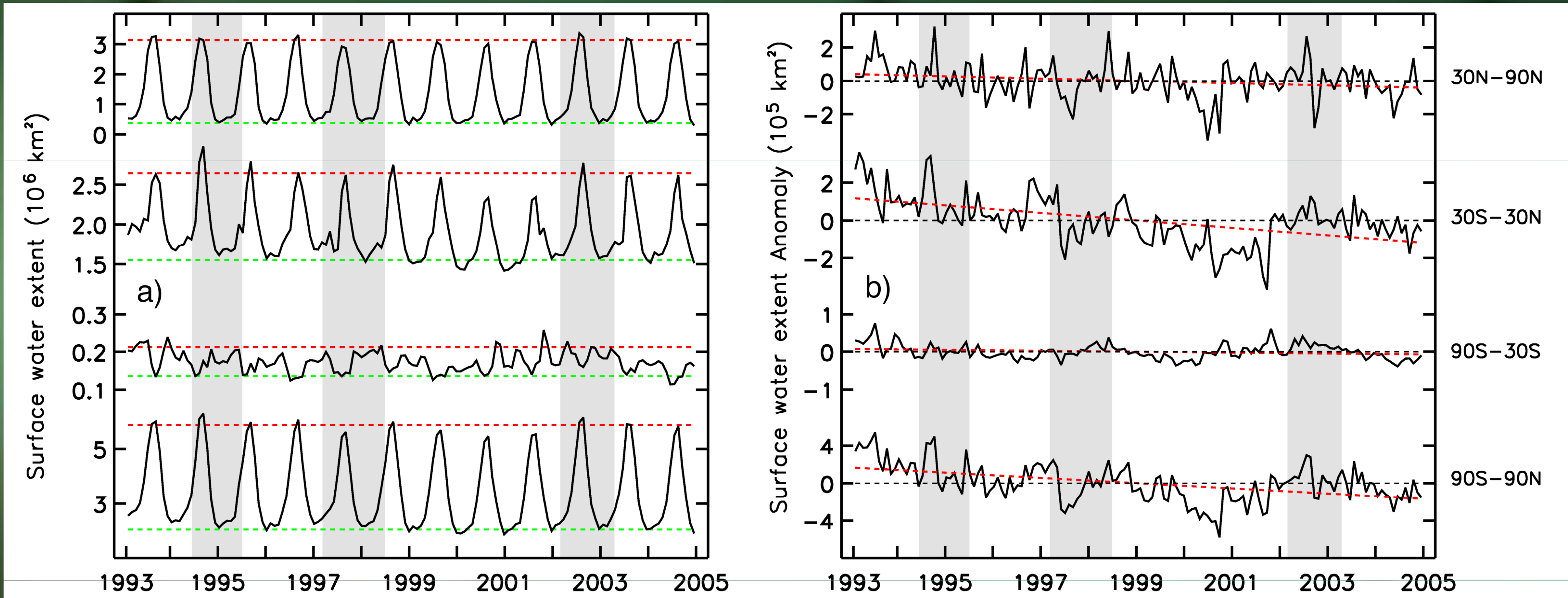
• Adjustments to the methodology necessary to extent the time record

- ERS scatterometer not available after 2001
- AVHRR calibration problems
- problem with an ancillary input (Ts) used in the processing of the passive microwave observations

⇒ Several adjustments performed on the initial processing, each one having been very carefully checked (Papa et al., JGR, 2010).

A multi-satellite method (5/6)

Global and zonal temporal variations of inundated surfaces extent



<u>Global results</u>:

-maximum extent of ~6.7 million km²

-strong seasonal cycle and inter-annual variability

-capture well phenomena such El Nino / La Nina episodes.

<u>Deseasonalized anomalies</u>:

-overall decrease of surface water extent, especially over the Tropics at a rate of ~6% in 12 years, with decrease in the 1990's and increase from 2000

(Papa et al., JGR, 2010)

A multi-satellite method (6/6)

Applications:

-- hydrology modeling (Decharme et al., JGR, 1998; JC, 2010)

-- estimation of water storage and river discharge (Papa et al., JGR, 2007; SG, 2008; GRL, 2008; Frappart et al., JGR, 2008)

- methane emission modelling (Bousquet et al., Nature, 2006; Petrescu et al., GBC, 2010; Ringeval et al., GBC, 2010)

Evaluation of global inundation estimates (1/7)

Comparison with static estimates

Direct evaluation for specific regions:

- **Comparison with JERS mosaics over the Amazon**

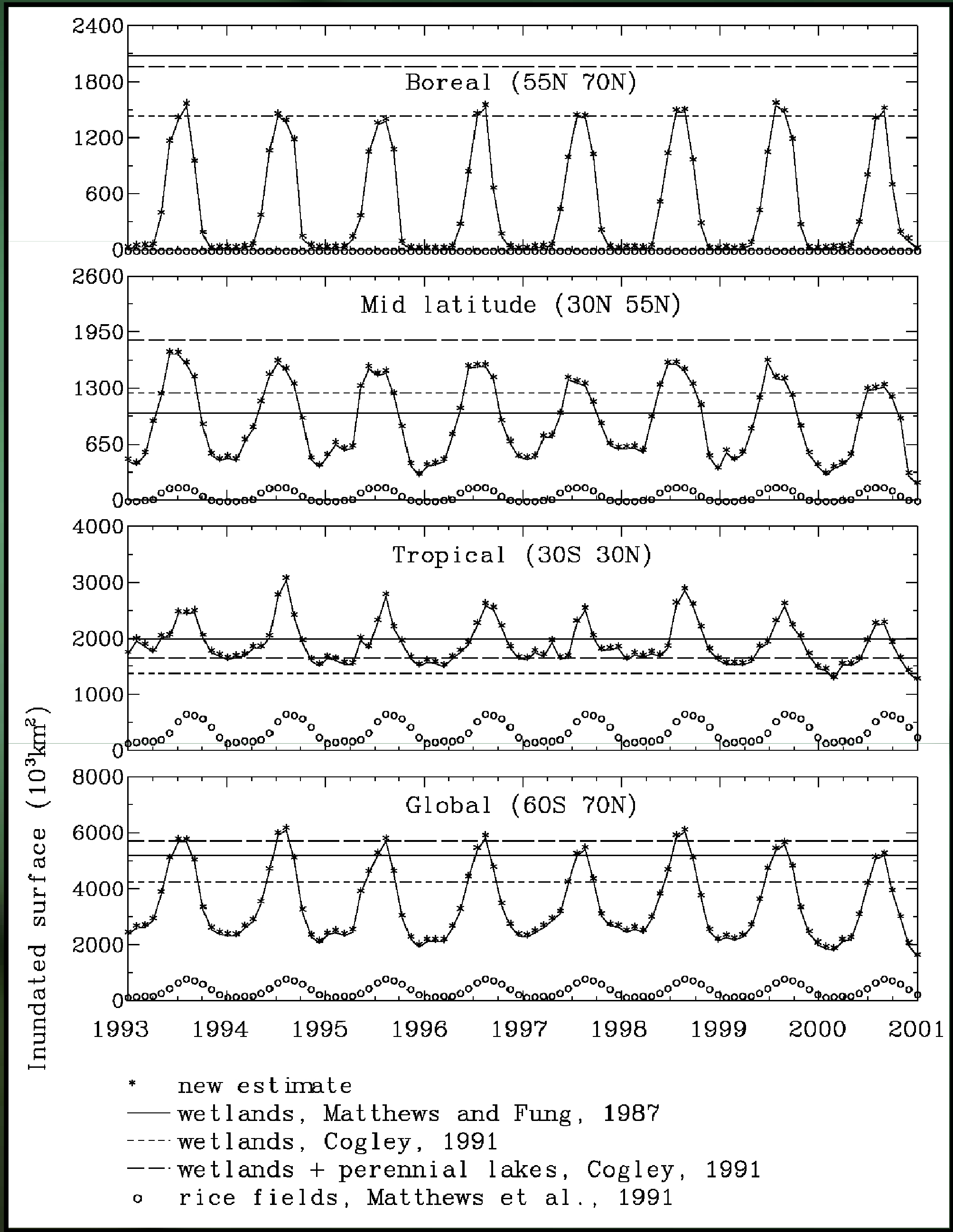
Indirect evaluation:

- **Correlation with precipitation**
- **Consistency with river level measurements (in situ and altimeter)**

Evaluation of global inundation estimates (2/7)

Direct comparison with static estimates of Matthews et al. (1987, 1991) and Cogley (2003)

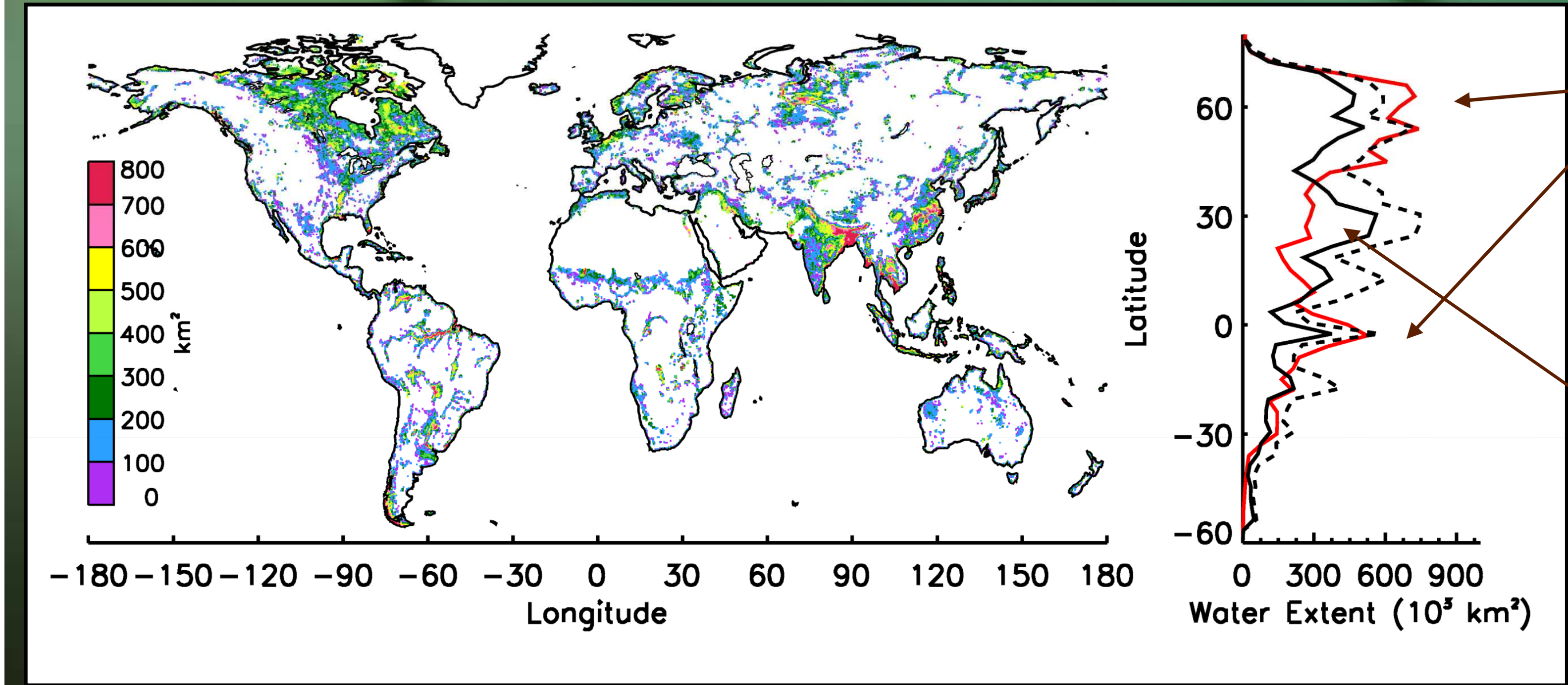
Maximum extents agree reasonably well with the static estimates



Evaluation of global inundation estimates (3/7)

Direct comparison with static estimates:

Global Lakes and Wetlands Database (Lehner and Doll, 2004)



Good agreement in the Boreal regions and Tropics

GLWD does not take into account irrigated agriculture (MIRCA to be added)

Satellite derived (mean annual maximum)

Satellite-derived (maximum surface water extent)

GLWD

Evaluation of global inundation estimates (4/7)

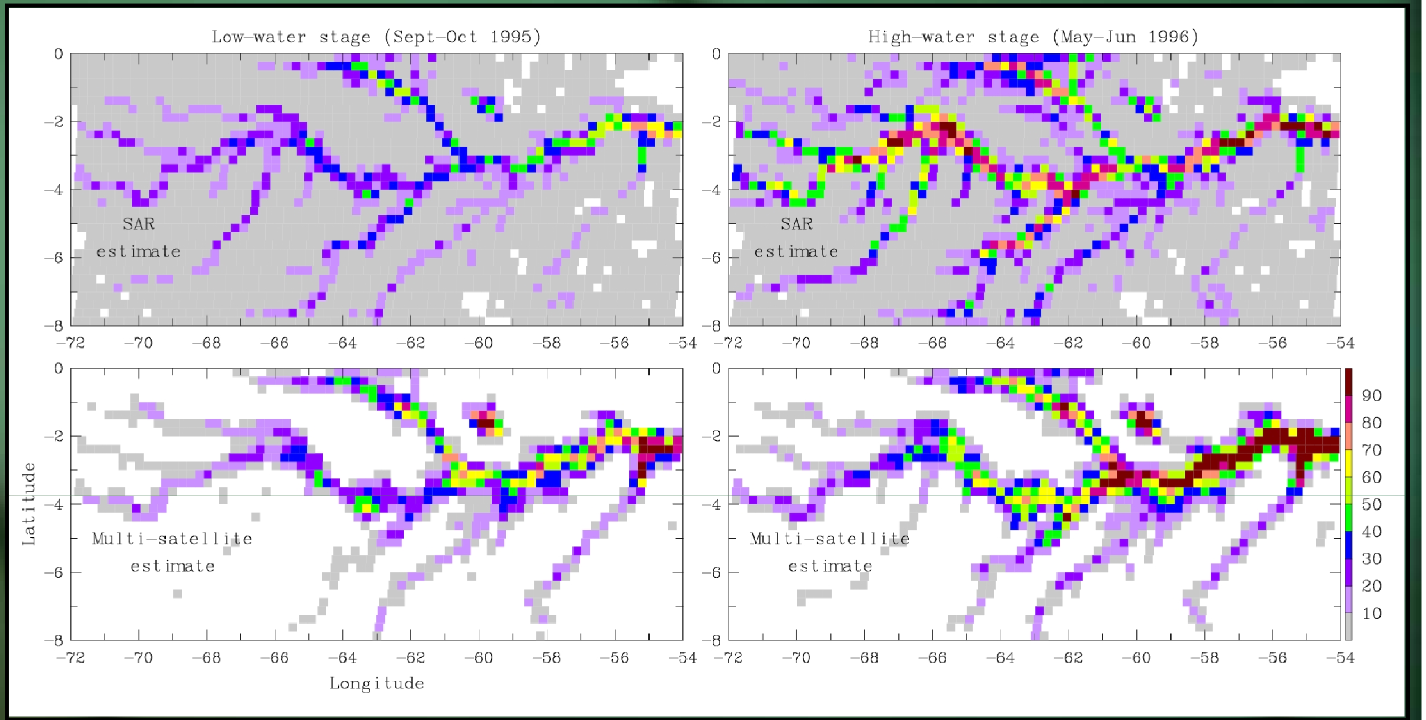
Direct evaluation for specific regions:

Comparison with high resolution (100m) JERS mosaics over the Amazon (Hess et al., 2003)

Low water stage High water stage

SAR estimates
(≈100m resolution)
($118000km^2$ - $243000km^2$)

Multi-satellite estimates
(≈25km resolution)
($105000km^2$ - $171000km^2$)



• General good agreement between the SAR-derived estimates and the multi-satellites derived estimates
• Some differences for small and large extents (<10% and >90%)

Evaluation of global inundation estimates (5/7)

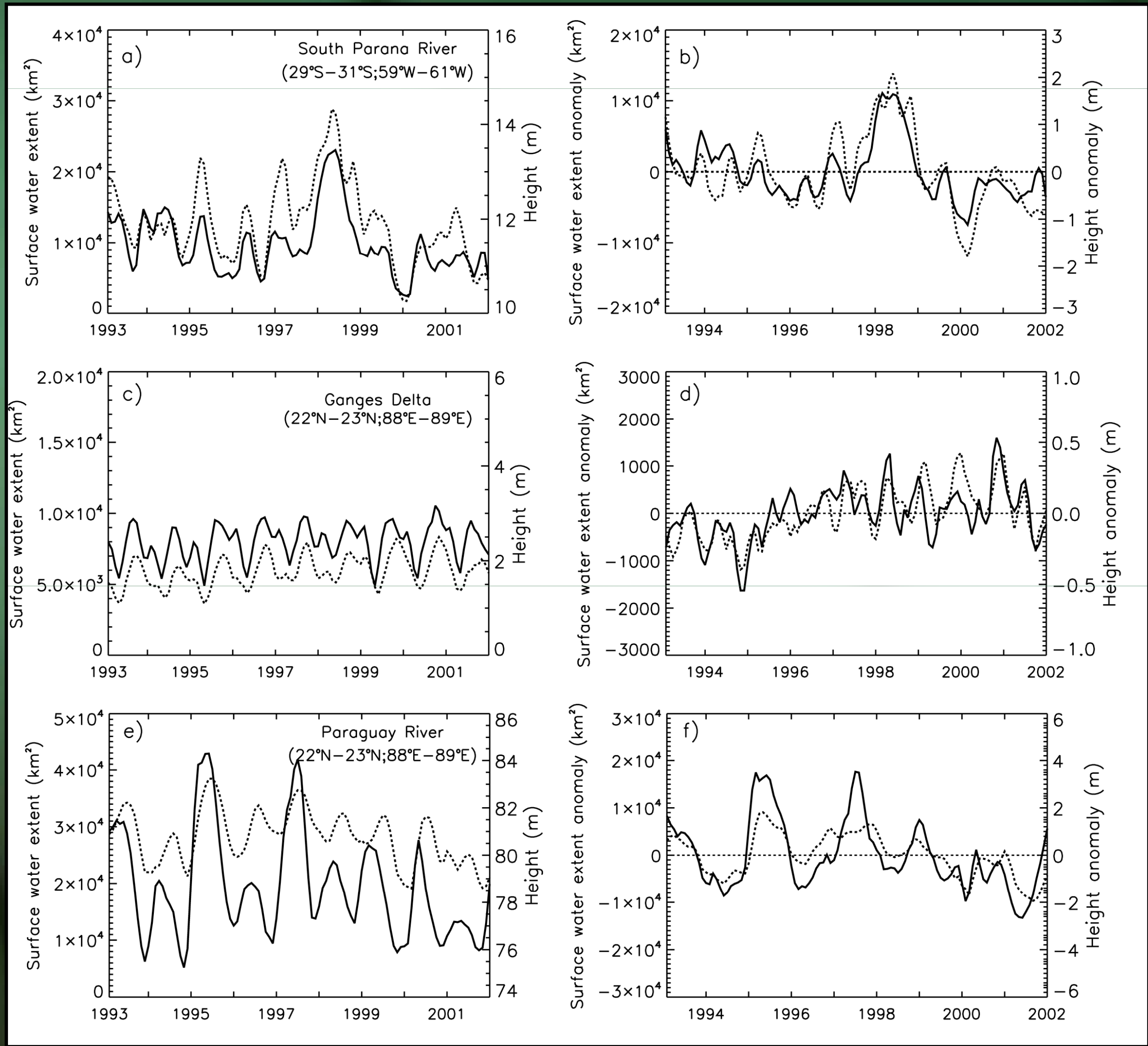
Indirect evaluation:

Consistency with river level measurements from the satellite altimeter Topex-Poseidon (Generro et al., www.legos.obs-mip.fr/soa/hydrologie/hydroweb)

South Parana

Ganges Delta

Paraguay River

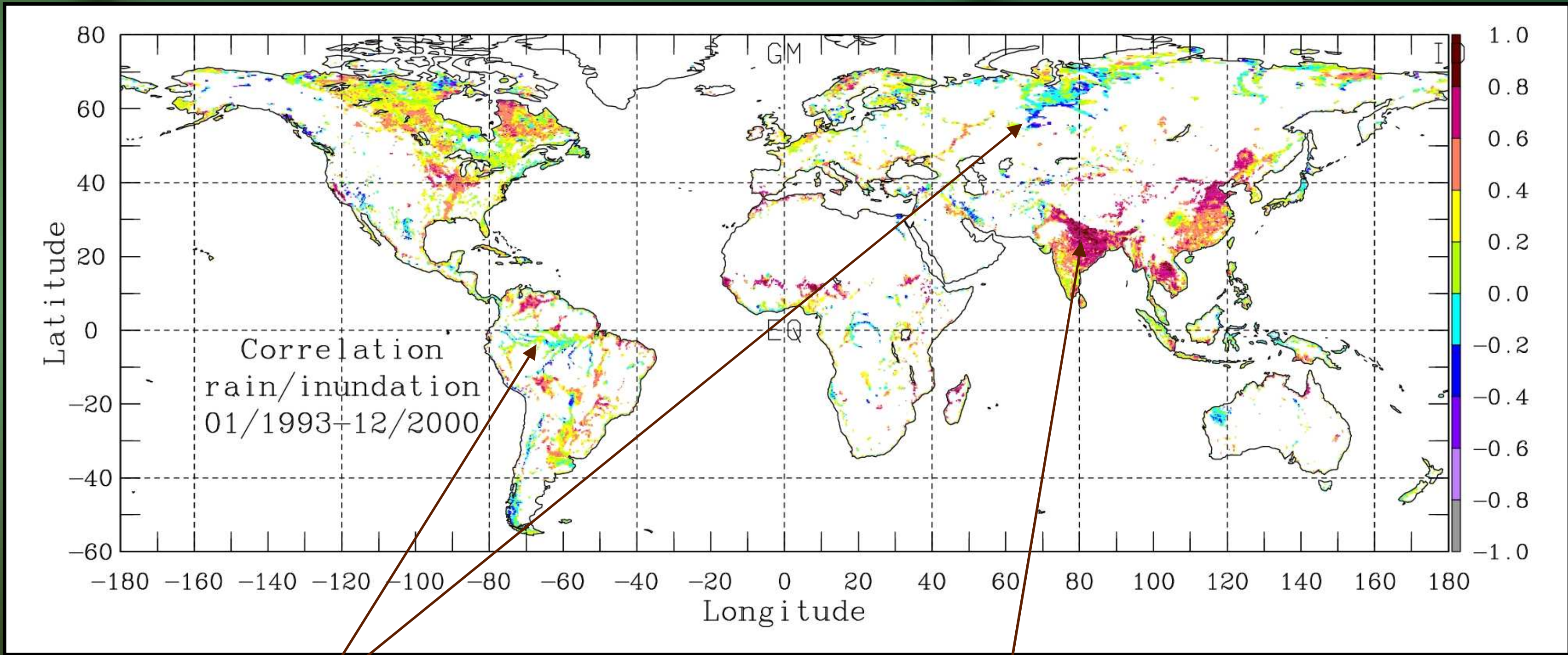


• **Good agreement with the water level estimated from an independent satellite altimeter, regardless of the environment**

Evaluation of global inundation estimates (6/7)

Indirect evaluation:

Correlation with precipitation (GPCP, Adler et al., 2003)



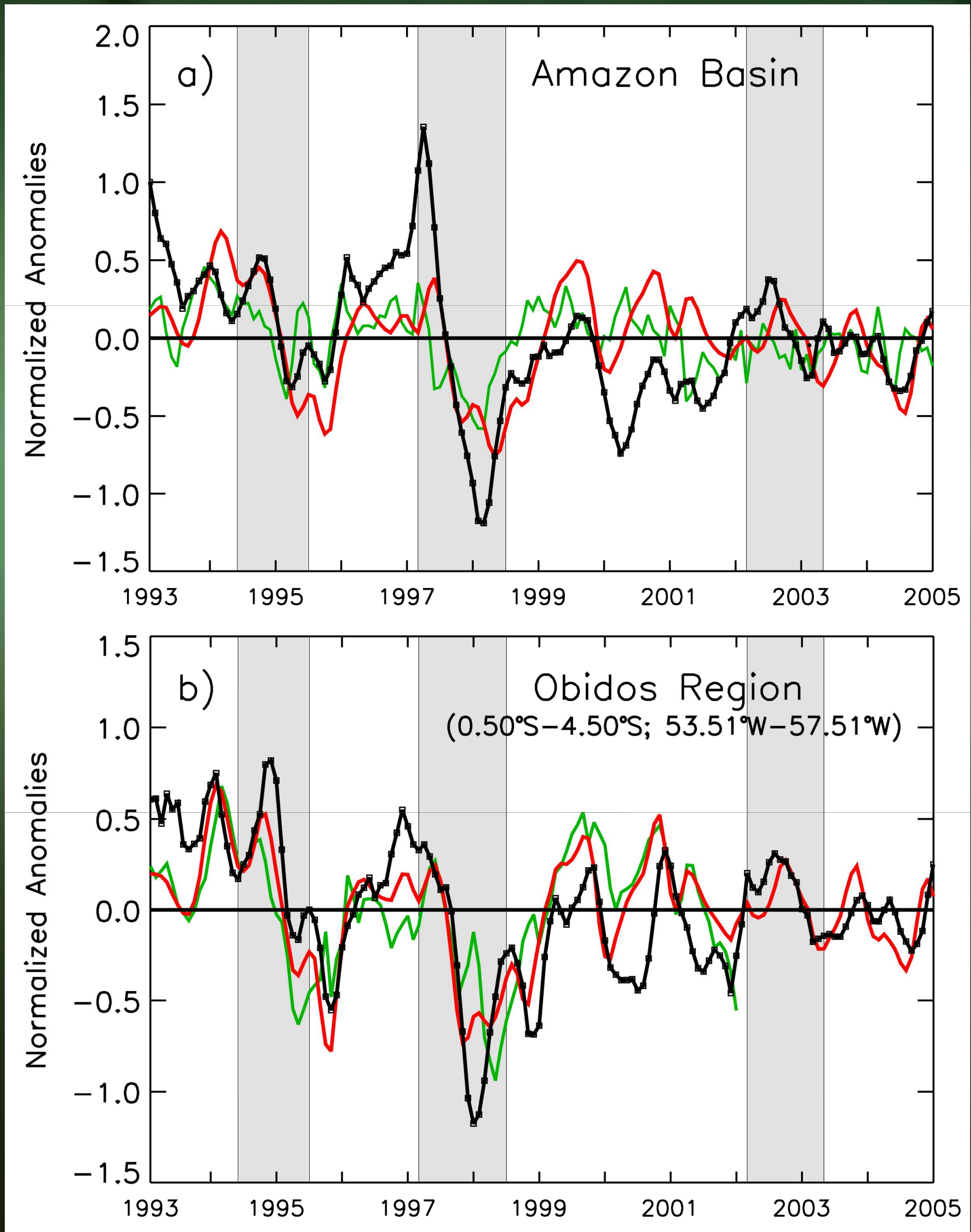
Different regimes:

-wetlands related to snow-melt or rain in upstream locations (low correlation with local precipitation)

- rain-fed wetlands with direct rain at the location (high correlation with local precipitation)

=> Insight into the global hydrological processes

Evaluation of global inundation estimates (7/7)



Good agreement with related hydrological variables

- GPCC rain
- Surface water extent
- In situ river discharge

- Surface water extent
- River height from altimeter
- In situ river level height

Application to the SWOT preparation

In order to prepare the SWAT mission, possible downscaling of the data set of dynamic wetland extent :

- to help dimension the mission
- to provide a realist data set for the algorithm development
- to serve as reference for the calibration/validation phase

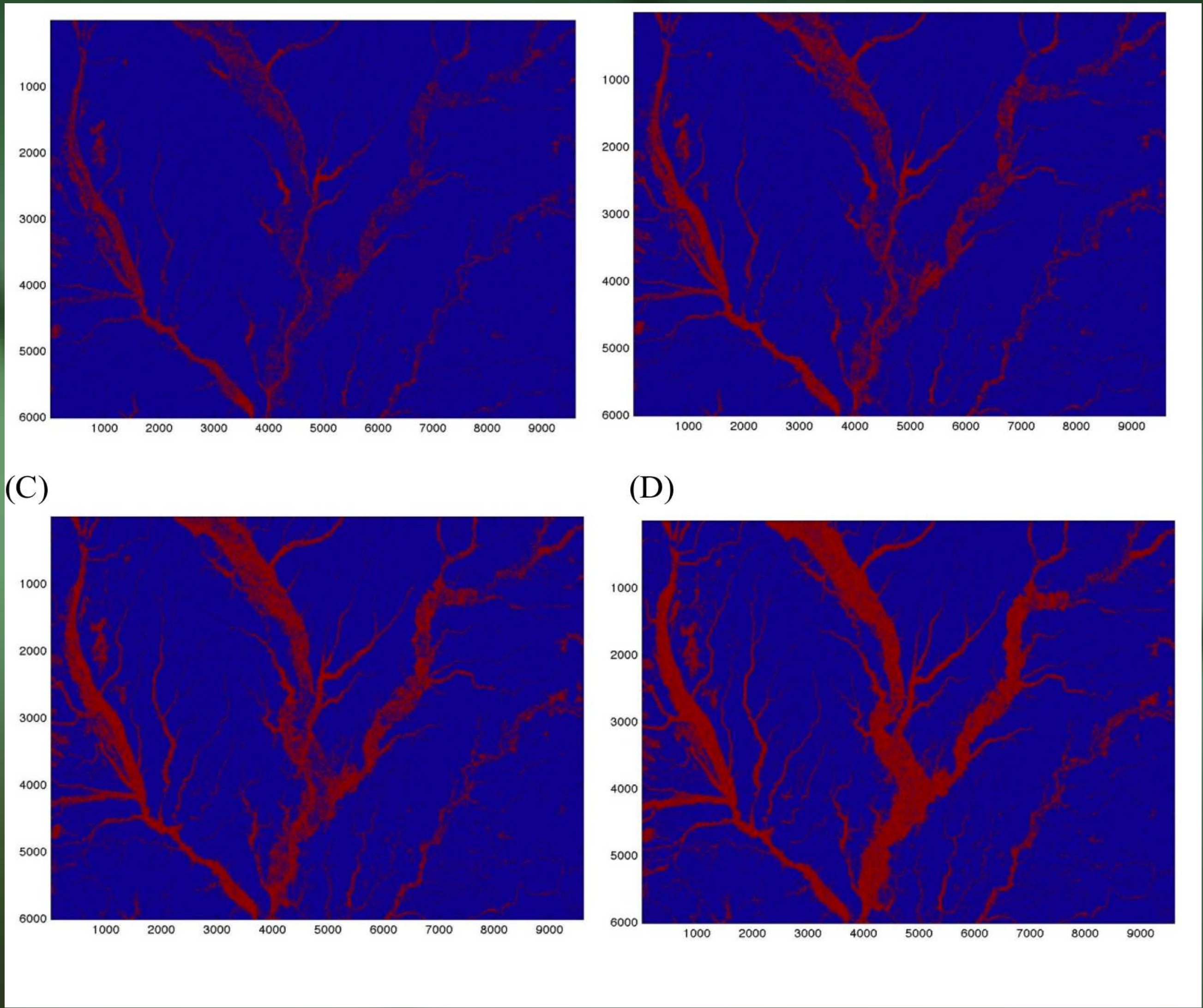
Different downscaling approaches could be tested:

- statistical methods using high spatial resolution datasets of the inundation from VIS or SAR observations to calibrate the model
-physical ranking method using high resolution DEMs

Application to the SWOT preparation

Low stage

Extrapolated using the low resolution constraint



Extrapolated using the low resolution constraint

High stage

An exemple of donscaling from two extreme values of high resolution data using statistical techniques (Markov field), contrained with the low resolution data

Conclusions

Existing satellite observations have potential to estimate wetland dynamics at global scale with spatial resolution of ~ 25 km and temporal sampling of one month (possibly 10 days). Data base from 1993 to 2008.

Static estimates are now available with high spatial resolution.

Regional estimates are under development, from SAR observations (e.g., ASCAT, PALSAR). For example, the MEASURE project (NASA) or the ALANIS project (ESA).

Downscaling method could be applied to the climatological low resolution record to provide a realistic datasets to prepare the SWOT mission.

Thank you!

Publications available at
http://aramis.obspm.fr/~prigent/publication.html

For more information, contact catherine.prigent@obspm.fr