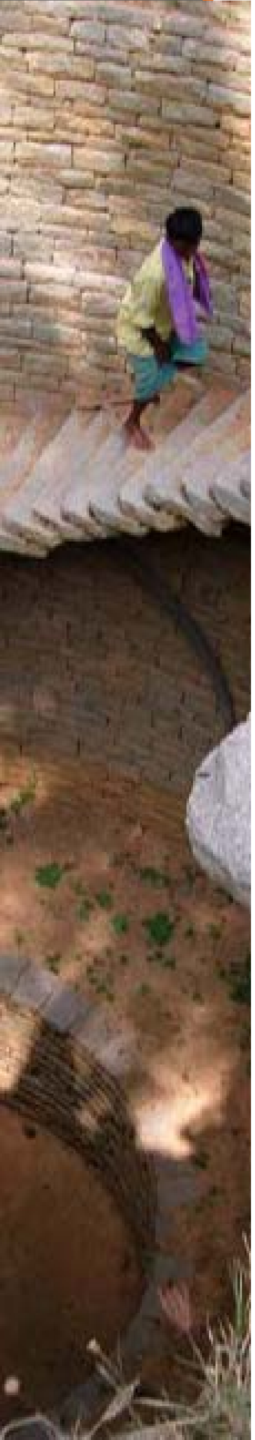

Surface Freshwater Extent and Storage Variability at Basin-to-Global Scale from Multi-Satellite Observations

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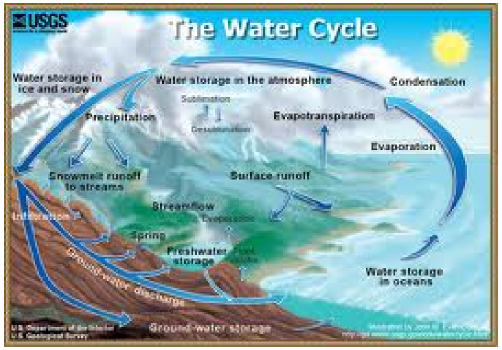
The continental water cycle

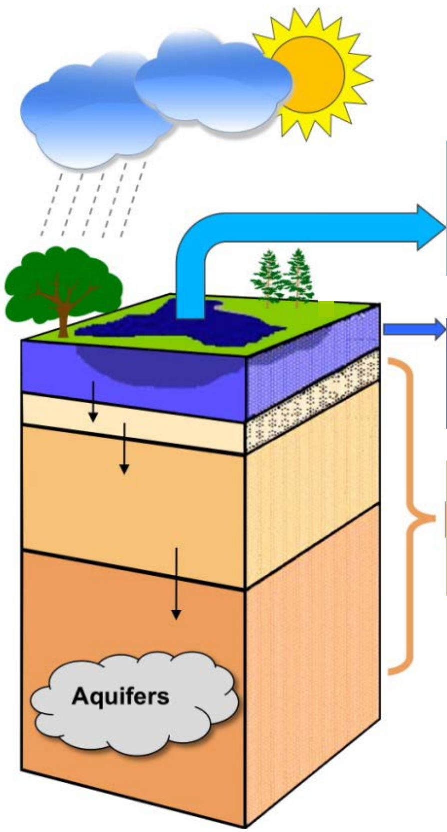


Basin-scale water balance equation

$$dW/dt = P - E - Q$$

Total Water Storage | Precipitation | Evapotransp. | Discharge

=



Surface water ?

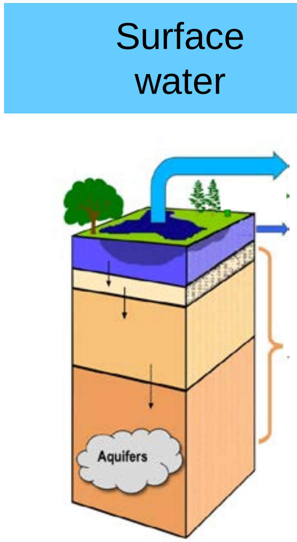
Soil Moisture ?

Ground Water ??

- Large uncertainties
- Limited in situ observations
- Individual contribution to the total storage, their variability, and their interactions poorly known

Surface waters from space

Today, no satellite mission specifically dedicated to the evaluation of the surface waters, but complementary satellite missions can help better characterize and understand surface water dynamics at global scale:



Surface water extent and its dynamics:

Global Inundation Extent from Multi-Satellites (GIEMS)

The variations of the surface water storage:

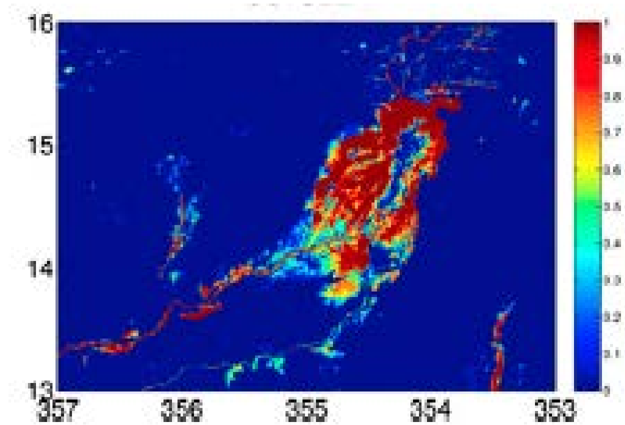
Example of the Amazon basin

Surface water extent and its dynamics

Visible and infrared (e.g. AVHRR, MODIS)

- high spatial resolutions
- unable to penetrate vegetation and clouds
- very useful in semi-arid environments

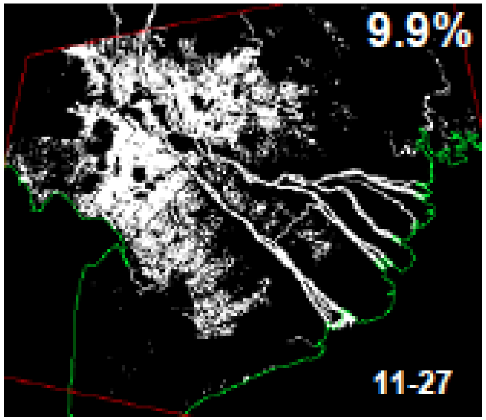
Ex: the Niger inner delta, Crétaux et al., 2014



Active microwave (SAR)

- very high spatial resolution
- large data volume: difficult to handle for global analysis
- few time samples so far: difficult to assess the dynamic

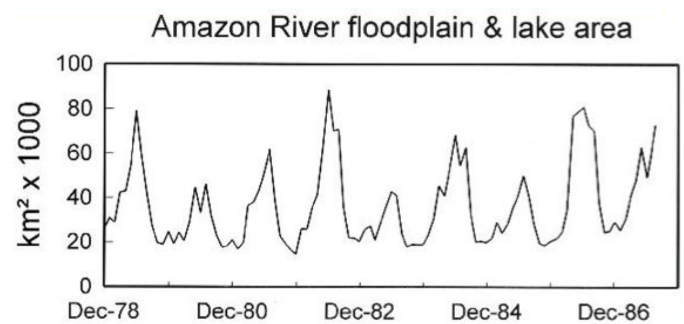
Ex: the Mekong delta, Kuenzer et al., 2013



Passive microwave (e.g., SSM/I, AMSR)

- 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



Dynamics of surface water extent at global scale from multi-satellites

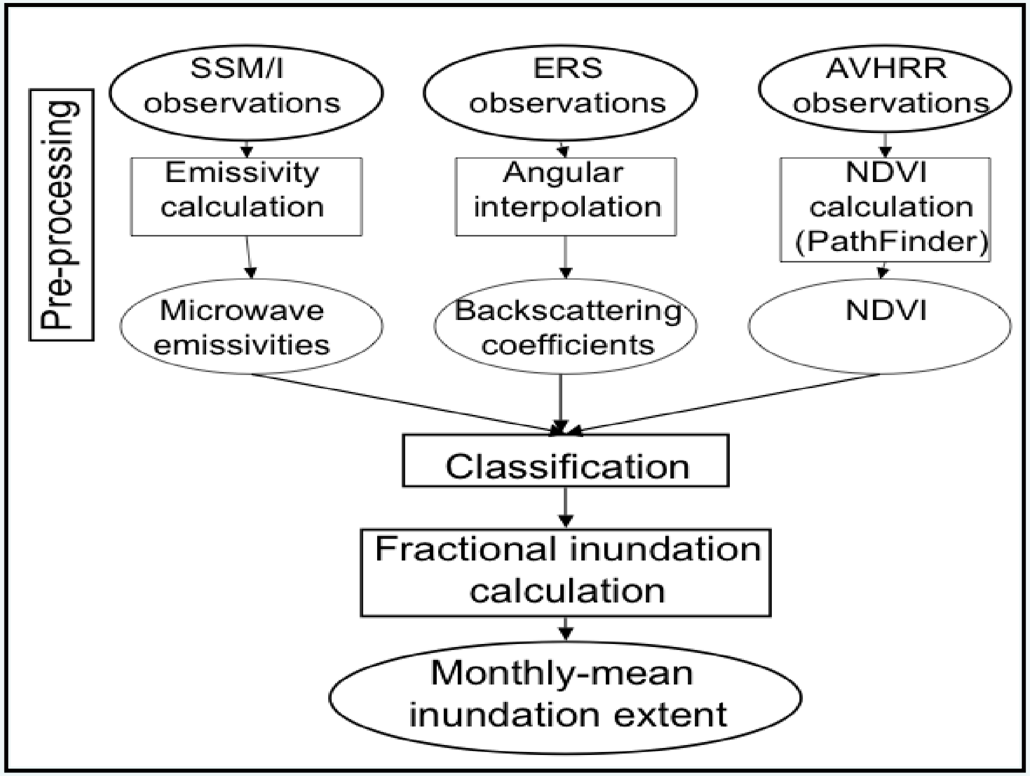
Development of a multi-satellite technique that quantifies the monthly extent of surface water at the global scale

Merging of satellite data at different wavelengths to benefit from their synergy

Passive microwave (SSM/I, SSM/IS)
emissivities at 19, 37 GHz, H and V polarizations

Active microwave (ERS, ASCAT)
scatterometer backscattering coefficient at 5.25 GHz

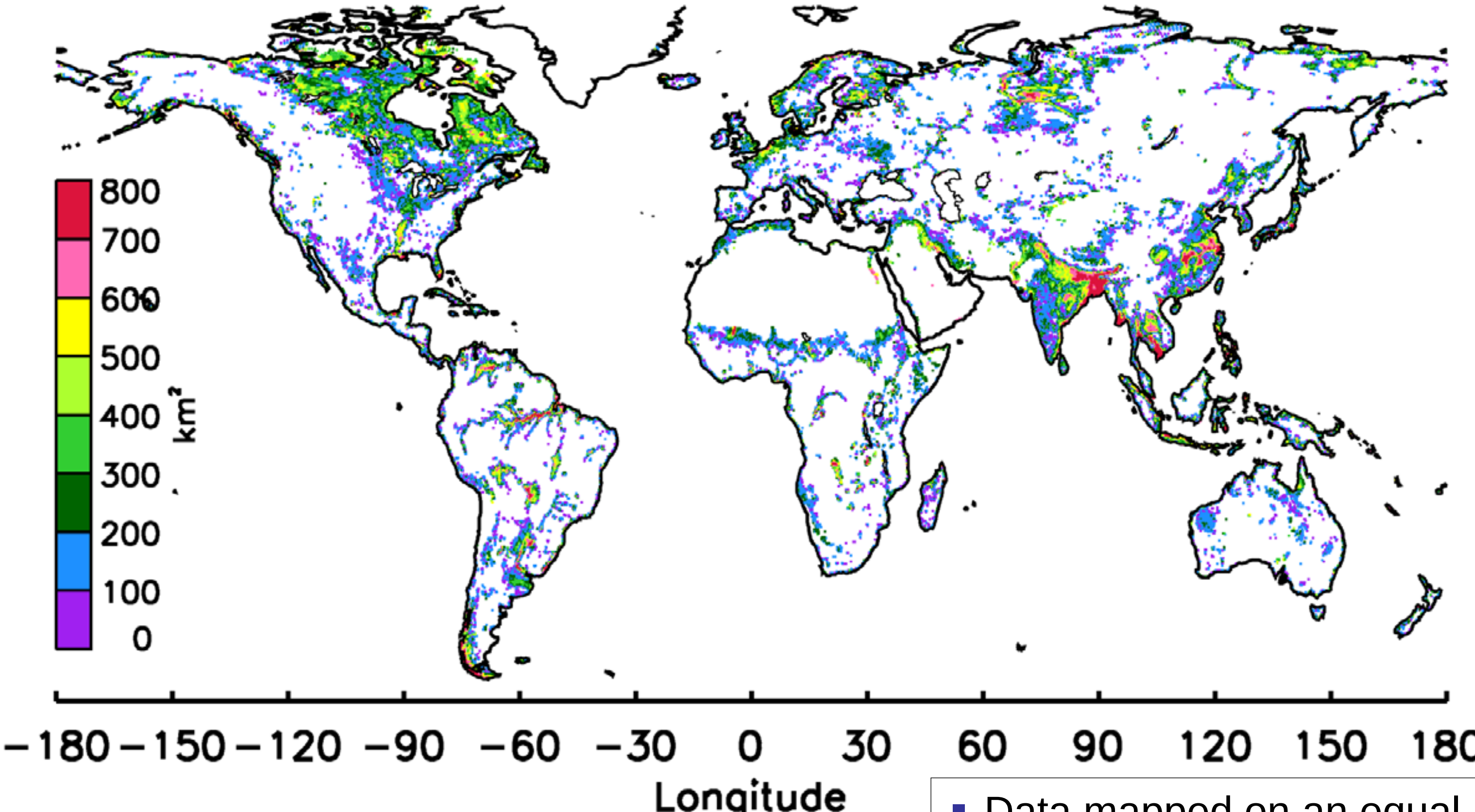
Visible, near infrared (AVHRR, MODIS)
visible and near-infrared reflectances and NDVI



Prigent et al, 2001, 2007, 2012
Papa et al., 2006b, 2007,2008a,b, 2010

Dynamics of surface water extent at global scale from multi-satellites

Mean fractional surface water extent at annual maximum

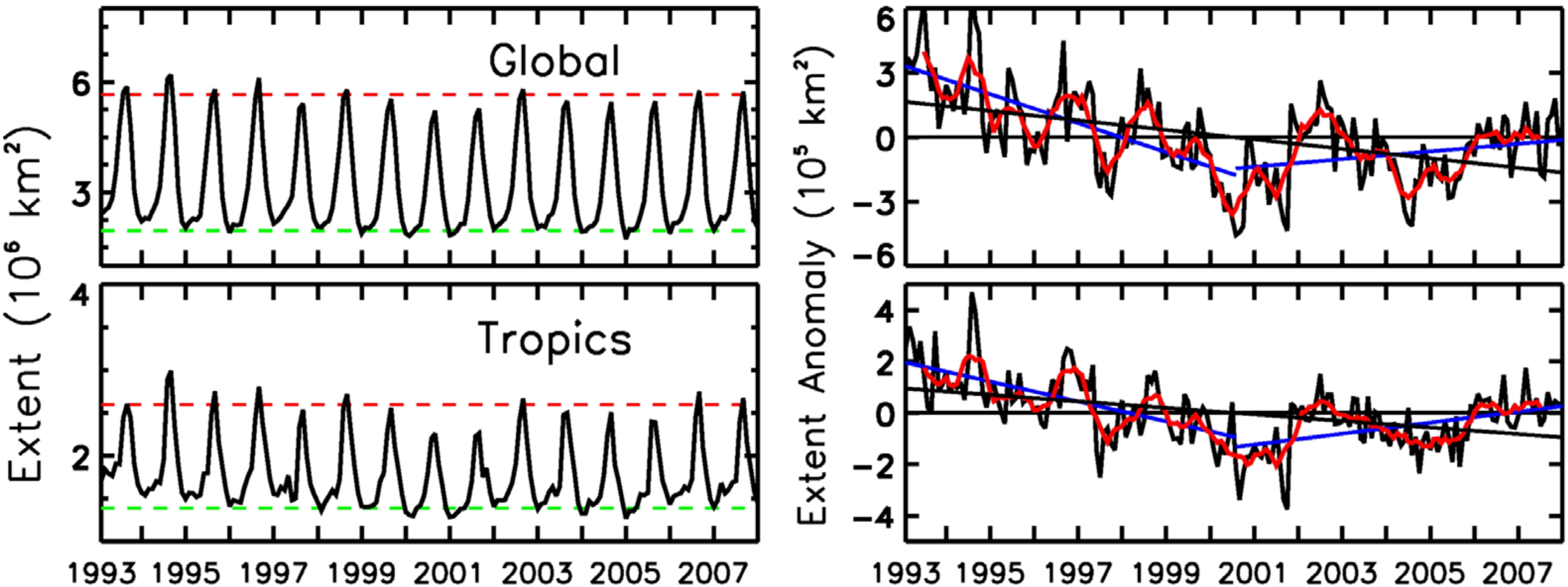


- Data mapped on an equal-area grid of 0.25° x0.25° at the equator (773 km²)
- Monthly and 10-day average for 1993-2007 and currently being extended topresent
- Intensively evaluated. Uncertainty ~10% with underestimation in area with low water extent

Prigent et al, 2001; 2007; 2012
Papa et al., 2006, 2007, 2008a,b, 2010, 2011

Dynamics of surface water extent at global scale from multi-satellites

Global and zonal temporal variations of inundated surface extent

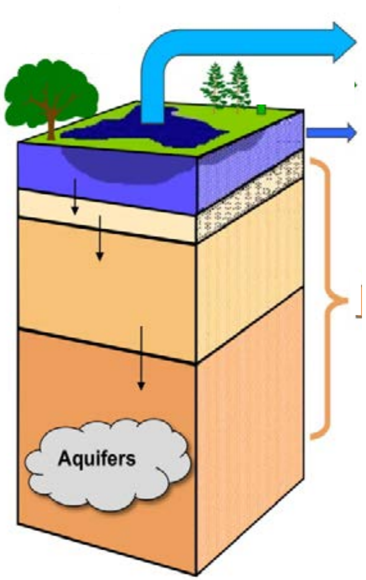


Prigent et al, 2012

Strong seasonal cycle and inter-annual variability.
Overall decrease of surface water extent, especially over **the Tropics at a rate of ~6% in 15 years**. Decrease especially **in the 1990's** and located essentially **in region of large population increase**.

Variations of surface water storage

Surface water



Once we have the **surface water extent**, how to derive the **surface water volume** change?

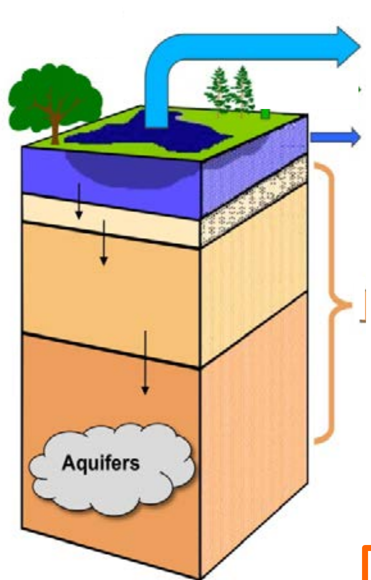
Two methods:

To combine global surface water extent with water height from **altimeter data** (Frappart et al., 2008, 2010, 2011, 2012)

To combine global surface water extent with topography information from a **Digital Elevation Model (DEM)** (Papa et al., 2013)

Variations of surface water storage

Surface water



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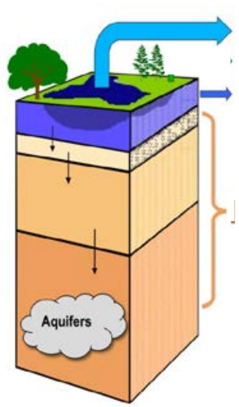
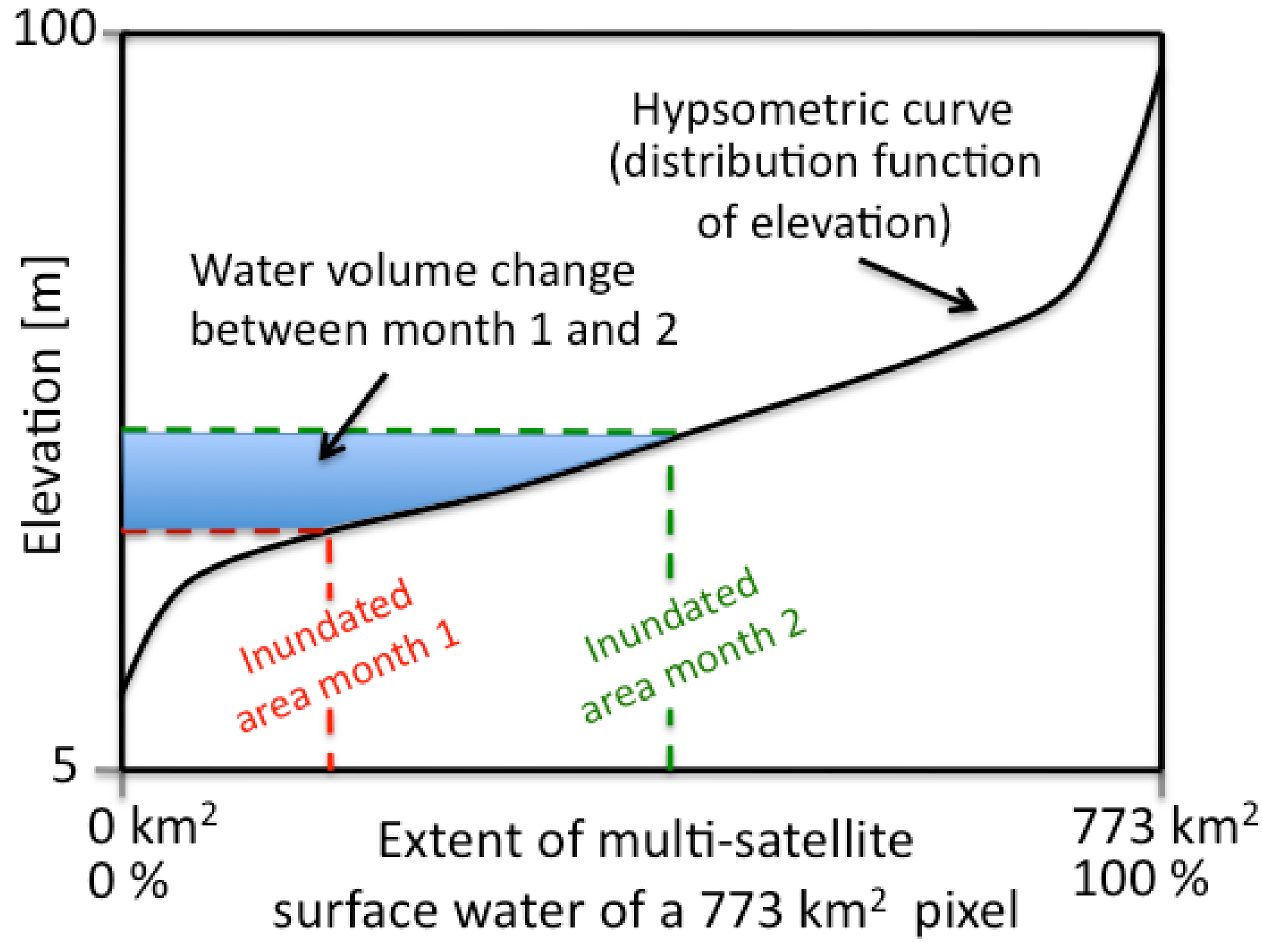
Variations of surface water storage

Surface water



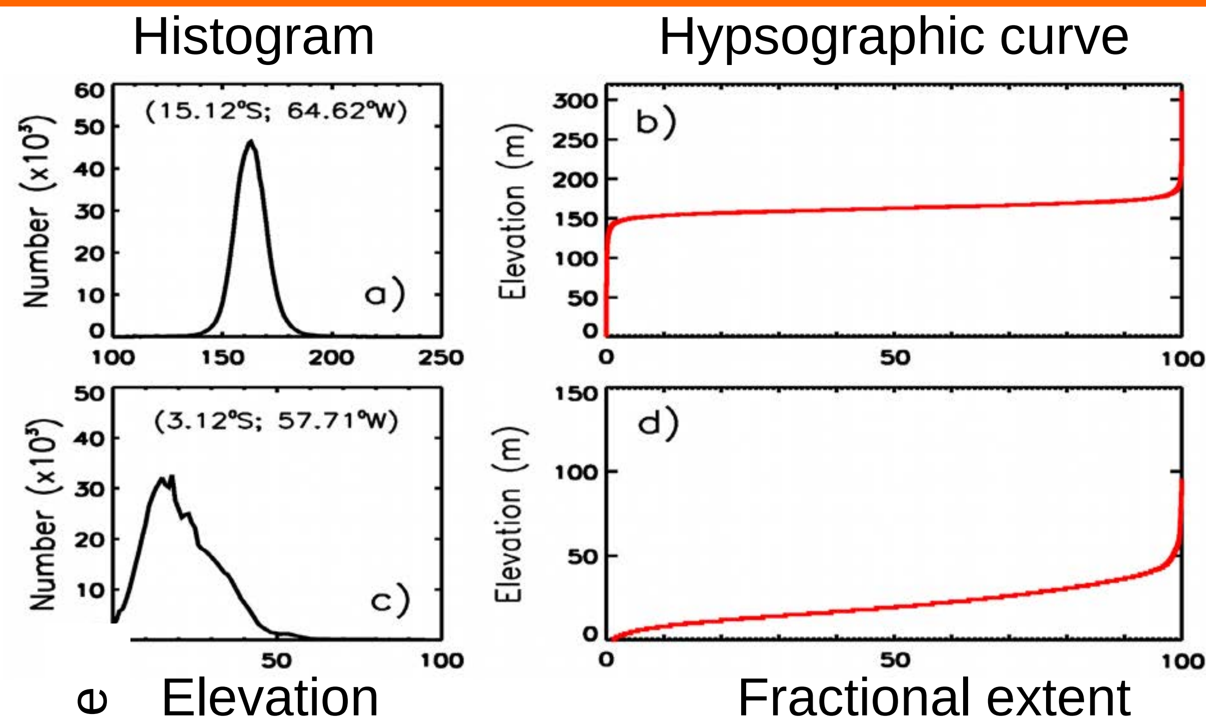
Combination of the ASTER-GDEM at 30 m resolution with estimates of the global surface water extent (GIEMS) using an **hypsographic curve approach** to relate the flooded area to the elevation.



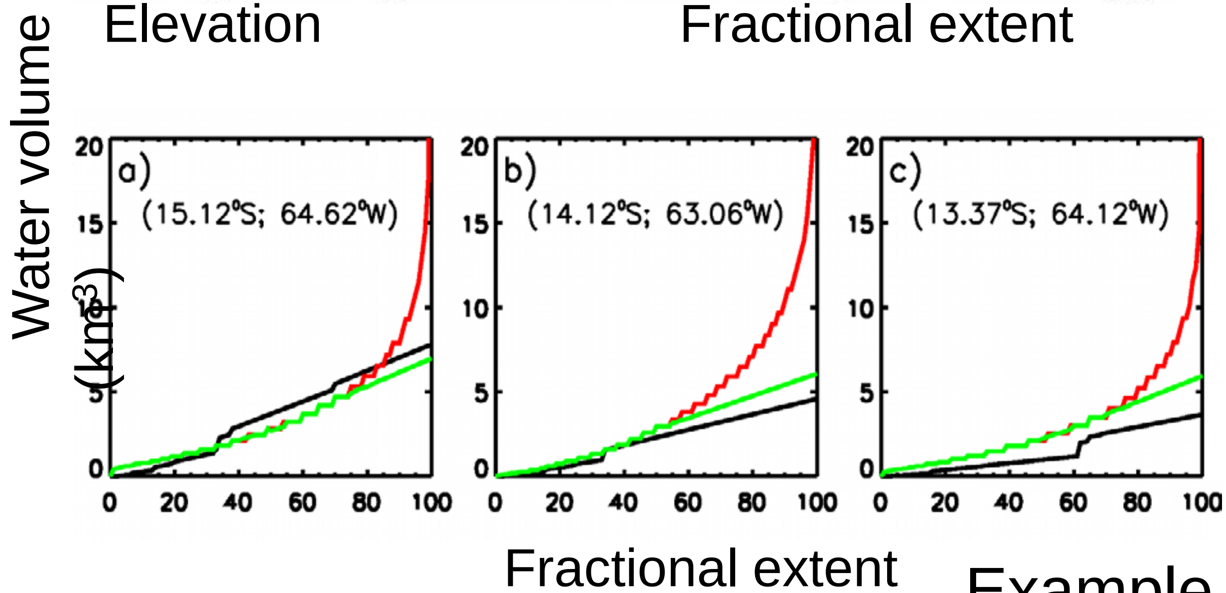
- Areas of lower elevations inundated first
- Applicable globally

Papa et al., JGR, 2013

Variations of surface water storage



Distribution of DEM elevation in ascending order for all ASTER data within a GIEMS pixel.

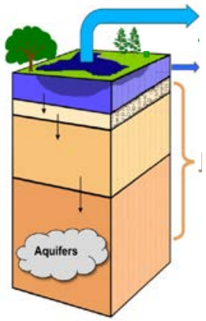


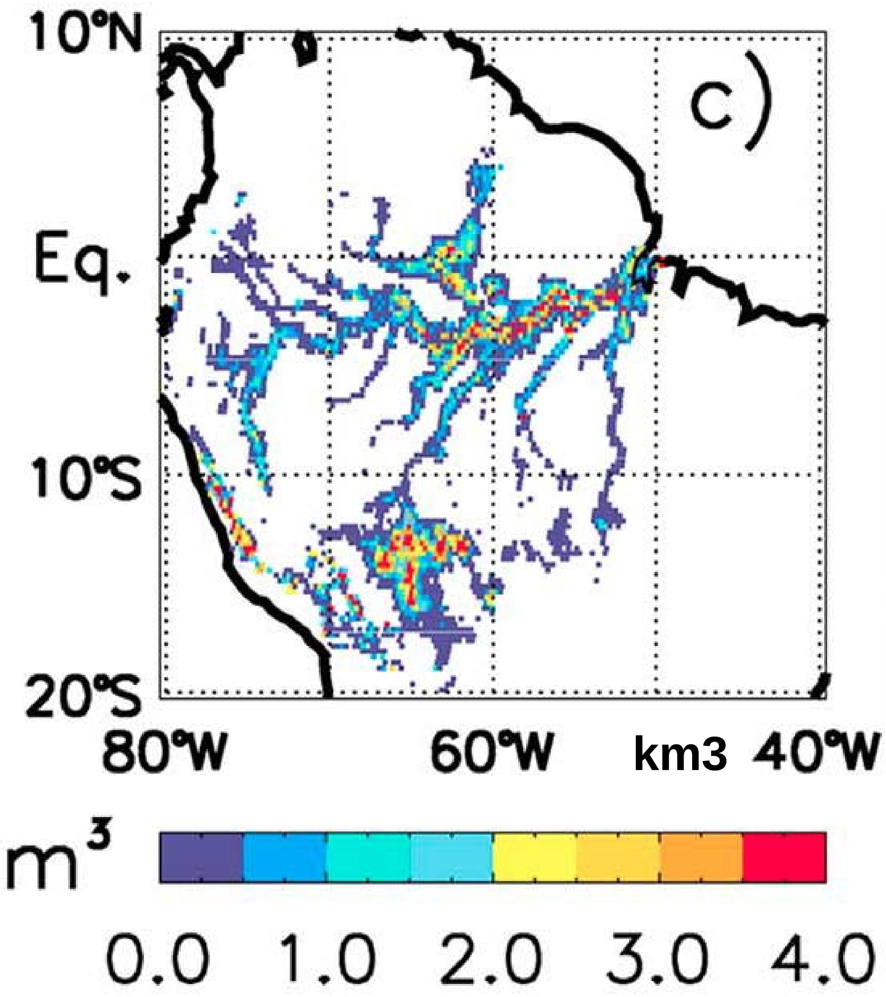
Hypsographic curve from ASTER (red), ENVISAT (green) and ASTER-corrected (black)

<u>Example for the Amazon River basin</u>

Variations of surface water storage over the Amazon

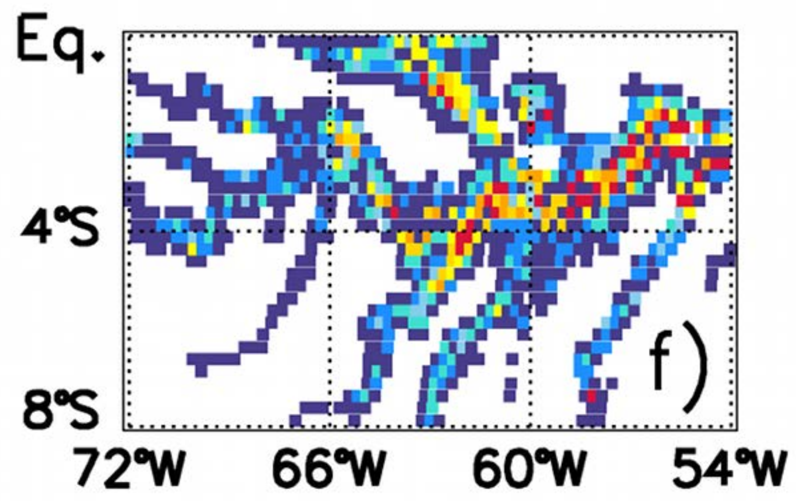
Surface water





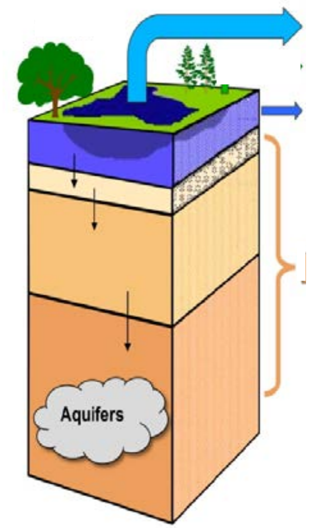
Mean Annual maximum amplitude

(Zoom on the main corridor)

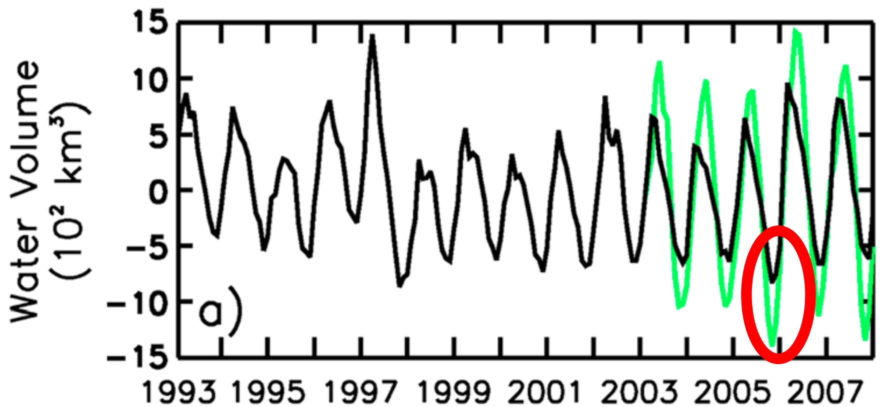


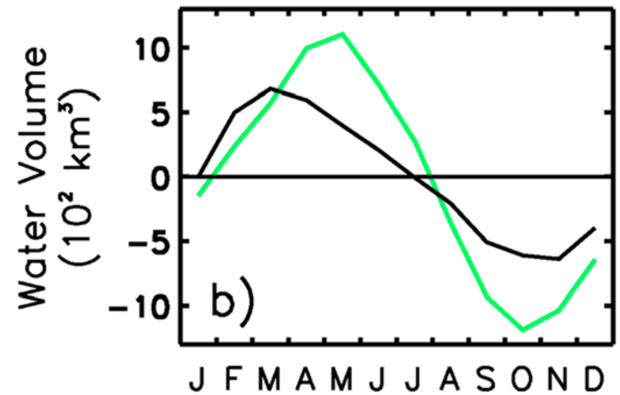
Variations of surface water storage over the Amazon

Surface water

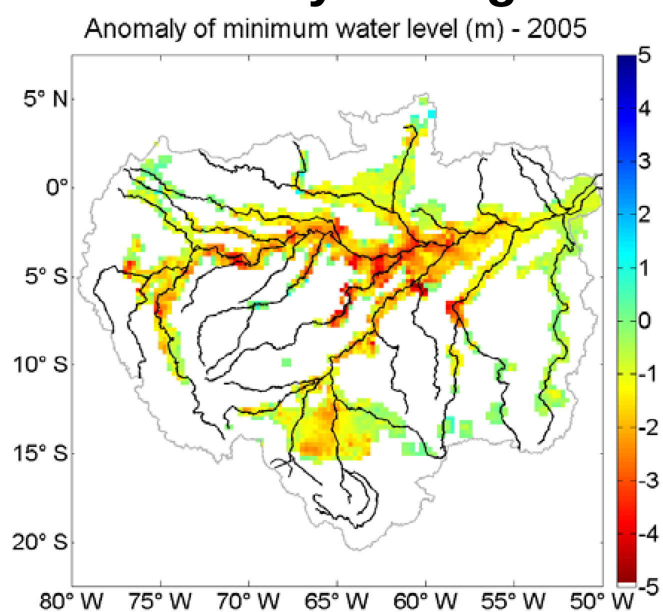


Monthly Surface freshwater storage 1993-2007 versus GRACE Total Water Storage variations (2002-2007)





Water level anomaly during the 2005 drought



Papa et al., 2013
Frappart et al, 2008, 2011 2012

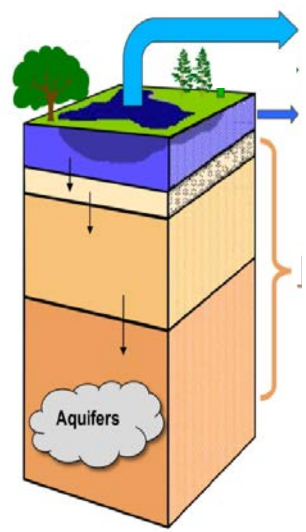
Extensively evaluated against In situ data

Water levels sometimes 8m below the 2002-2007 average.

Variations of continental water storage over the Amazon

The groundwater as the residual of the water budget

Total water storage (GRACE)



Surface water → **Storage** = GIEMS + radar altimetry (Frappart et al. 2008-10-11-12)
GIEMS+ DEM: hypsometric approach (Papa et al, 2013)

Soil moisture → **Storage**= AMSR-E, WACMOS, SMOS, modeling results (GLDAS)

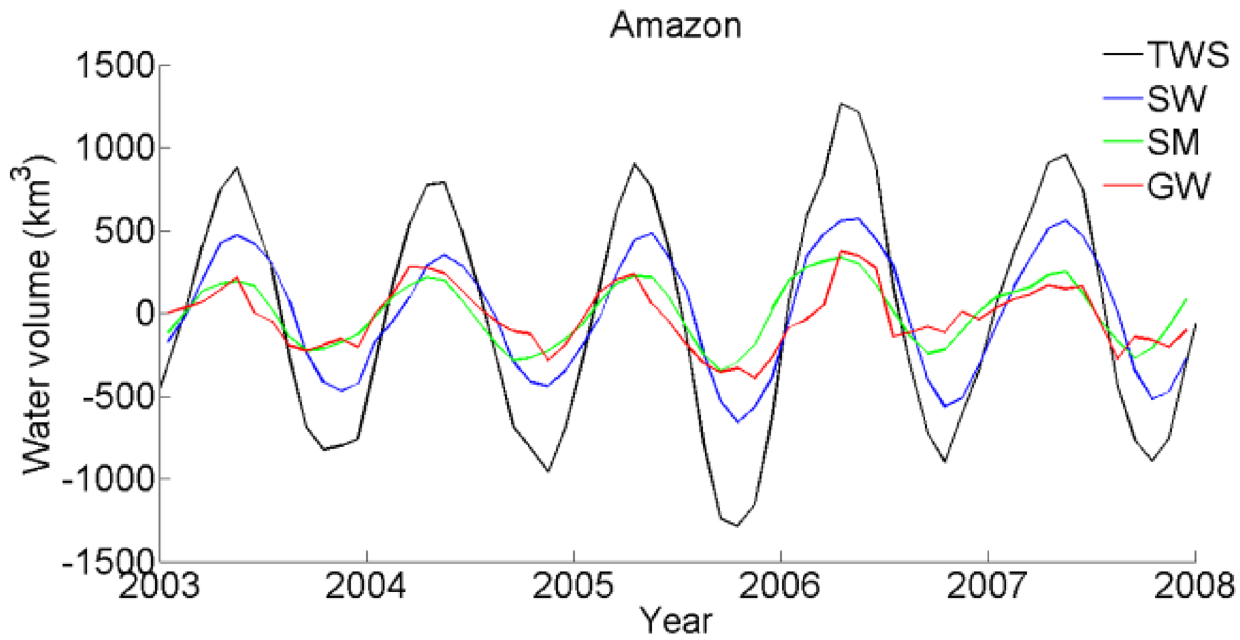
To **isolate the “groundwater” components:**

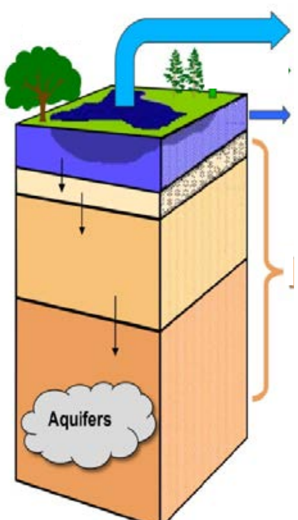
Ground-water → $\boxed{\textbf{Storage} = \text{GRACE TWS} - (\text{Surface water} + \text{Soil moisture})}$

Understanding processes / Variability / Trend.
Better closure of the terrestrial water budget.

Variations of continental water storage over the Amazon

The decomposition of continental water storage components





Surface water — **~50% of TWS variations**

Soil moisture RZ — **~25% of TWS variations**

Ground-water — **~25% of TWS variations**

Conclusions and perspectives

A global data base of surface water extent and dynamics developed from multi-satellite observations, at 25 km spatial resolution, on a monthly basis from 1993 to 2007 (GIEMS)

- **10-day estimates under evaluation.**
- **Extension to present under way**

This dataset widely used for modeling activities (Decharme et al., 2008, 2012, Ringeval et al. 2010, 2012, Melton et al., 2014…)

Combined with altimetric or topographic (DEM) information, it can provide the surface water volume change. Tested on the Amazon Basin.

The hypsometric methodology under development at global scale.

The groundwater volume change can be deduced as the residual from the total water change (Grace) minus the soil moisture variation and the surface water volume change data