A global and long-term inundation extent dataset from multiple-satellite observations: towards high spatial resolution

Filipe Aires, Estellus, France
Catherine Prigent, LERMA, Observatoire de Paris, France
Fabrice Papa, LEGOS, IRD, France, and IFCWS, Bangalore, India
Etienne Fluet-Chouinard, University of Wisconsin, USA
Bernhard Lehner, McGill University, Canada

Estellus

l'Observatoire de Paris

IRD
Institut de recherche pour le développement

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

McGill
UNIVERSITY

Studying the global surface water extent and its dynamics

A wide range of applications and users, with different requirements in terms of spatial and temporal resolutions:

Science community:

- Hydrology
- Climatology
- Ecology
- Epidemiology…

End-users:

- Security and risk management
- Water management
- Environment agencies
- Wetland conservation
- Health agencies
- Fisheries…

How to build a surface water database consistent across the different scales, globally, and over a long time period?

Global Inundation Extent from Multiple-Satellites (GIEMS)

Merging of satellite data at different wavelengths and modes

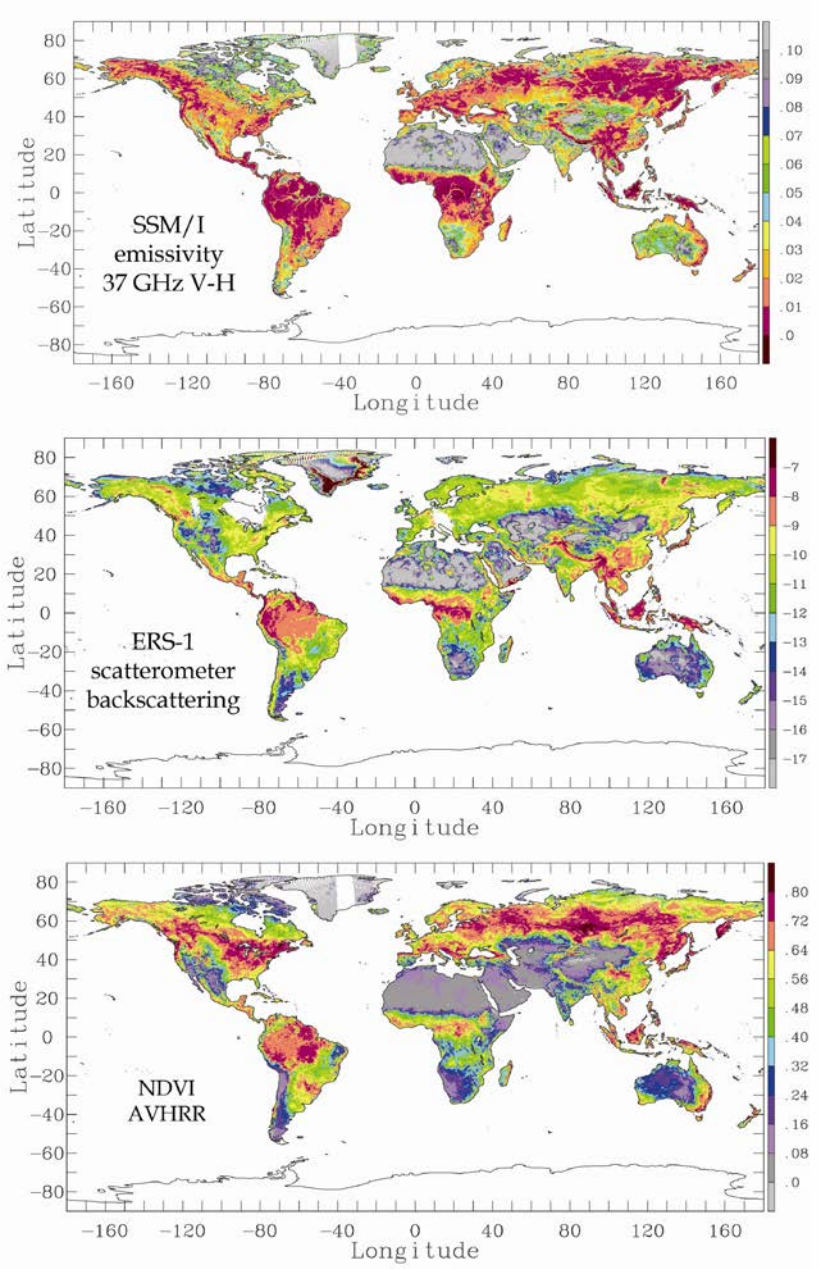
- to benefit from their different sensitivities
- to help separate different effects in a pixel (water, soil, vegetation…)

Includes satellite data:

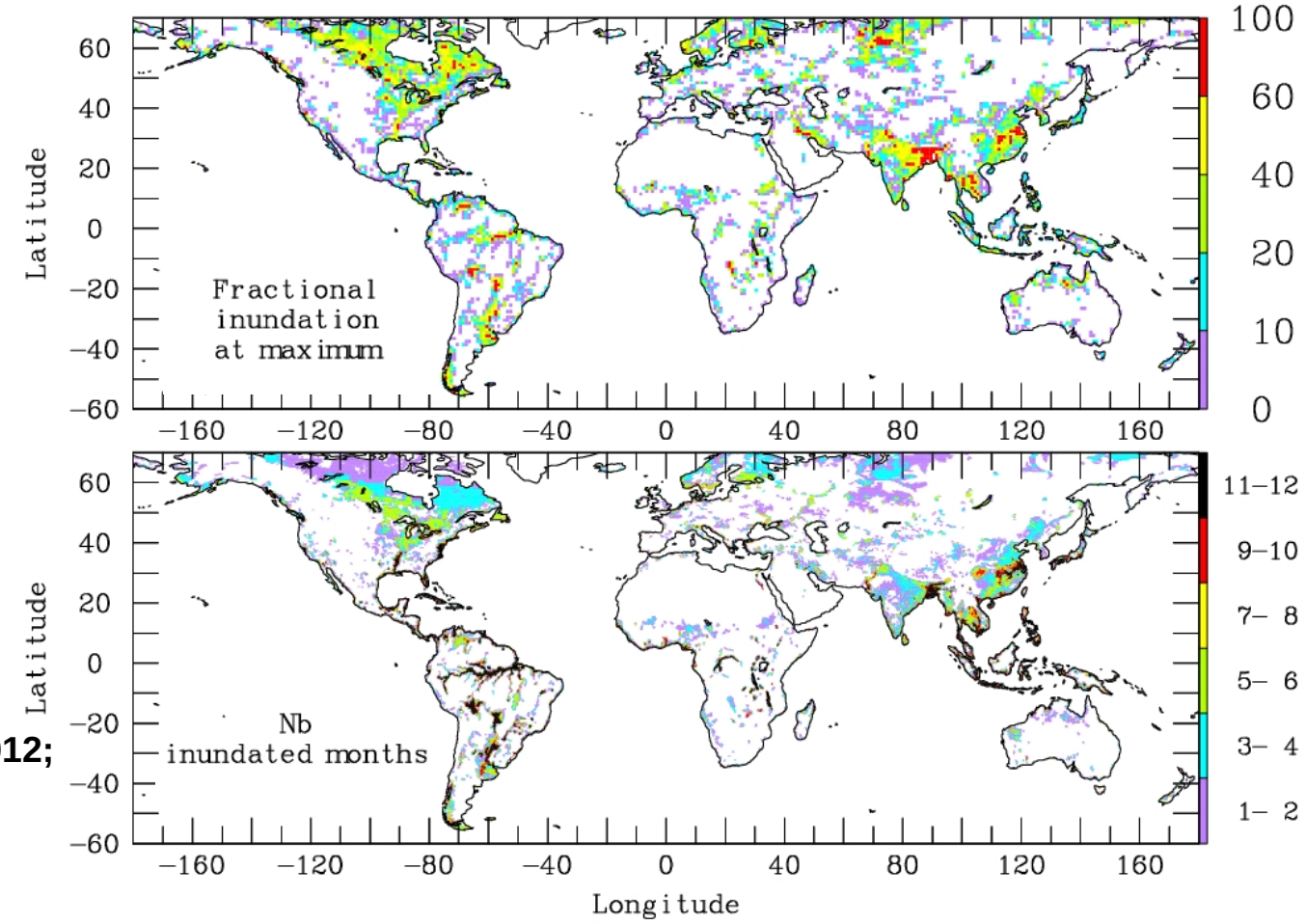
- available globally with resolution compatible with climate studies
- available over long time series (>15 ys)

The selected data sets:

- Passive microwaves (SSMI / AMSR)
- Active microwaves (SAR / ASCAT)
- Visible and near-IR reflectances (AVHRR / MODIS)



Global Inundation Extent from Multiple-Satellites (GIEMS)



(**Prigent et al., 2001; 2007; 2012; Papa et al., 2006, 2010...**)

- **Spatial resolution of 0.25°x0.25° at the equator (equal area pixels of 773 km^2)**
- **Monthly mean values (as well as 10 day average)**

- **Includes natural wetlands as well as rice paddies and small lakes**
- **Extensively evaluated and used in different applications**

Global Inundation Extent from Multiple-Satellites (GIEMS)

The limitation:

The spatial resolution is not high enough for a large range of applications

The solution:

Development of downscaling methodologies and merging with complementary data sets at high spatial resolution such as:

- other satellite observations (SAR images, visible and near infrared data)
- topographic information (Digital Elevation Model)

Downscaling methodologies

The problem:

Depends on the availability and characteristics of the high resolution information

Contrarily to atmosphere, difficult to use a physical dynamical model…

Different methods can be developed and tested

I) Image-processing methods, when limited temporal information is available

II) Algebraic method, when good temporal sampling is available at high resolution

III) Topographic information that is globally available

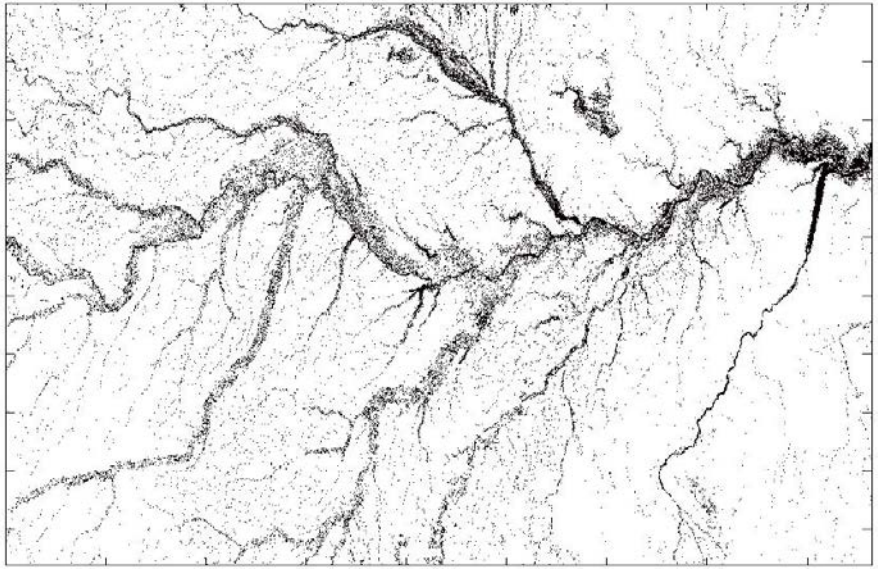
I – Downscaling using an image-processing method

With the SAR, very high spatial resolution images, but so far limited temporal sampling.

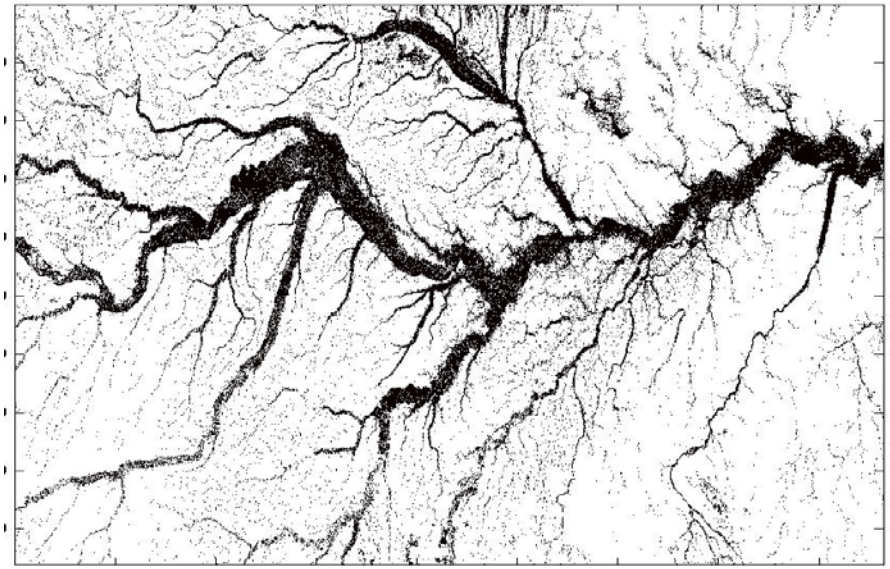
For instance, from Hess et al. (2003) over the Amazon, only two estimates of the water extent, at low and high water stages.

How to interpolate this high resolution information between these two stages, to downscale the low spatial resolution dataset at better temporal sampling?

SAR Low water



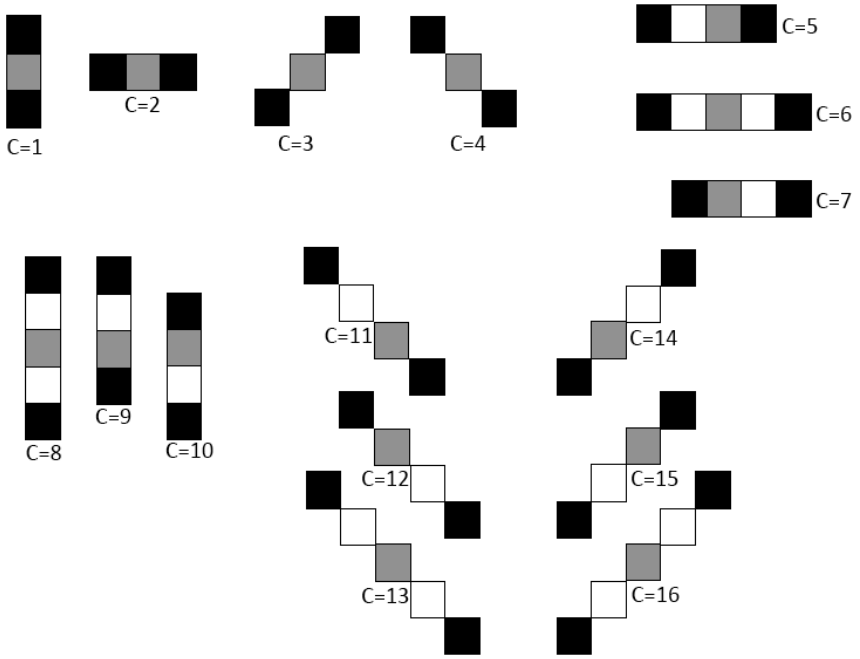
SAR High water



I – Downscaling using an image-processing method

Neighborhood system for the image processing downscaling

The probability of a grey pixel to be inundated given a particular pixel configuration P(P=I/Config) is estimated on the SAR Low and High water images.



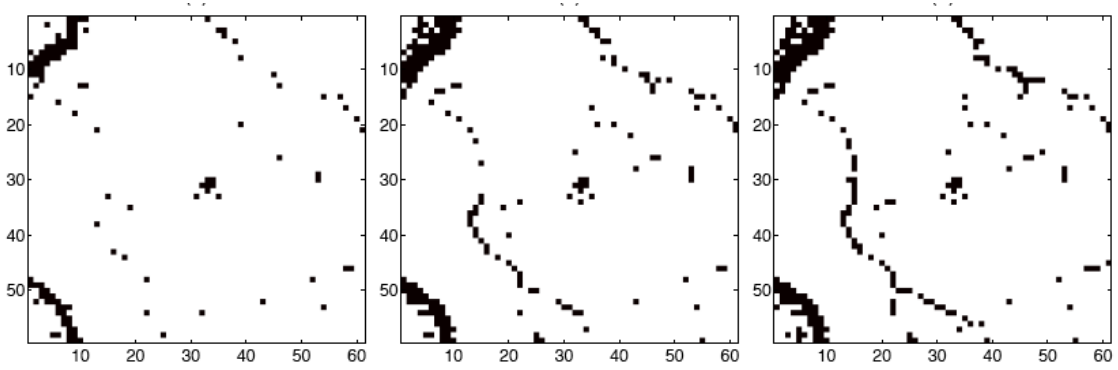
- Black=inundated
- Grey=to be determined
- White=not inundated

Algorithm

- The SAR Low and High water images are associated to the minimal and the maximal extent of GIEMS (at the pixel or at the basin level).
- The dynamical behaviour of GIEMS allows « oscillation » between the SAR Low and High water extent using a « dilatation factor », driven by the inundation probability.

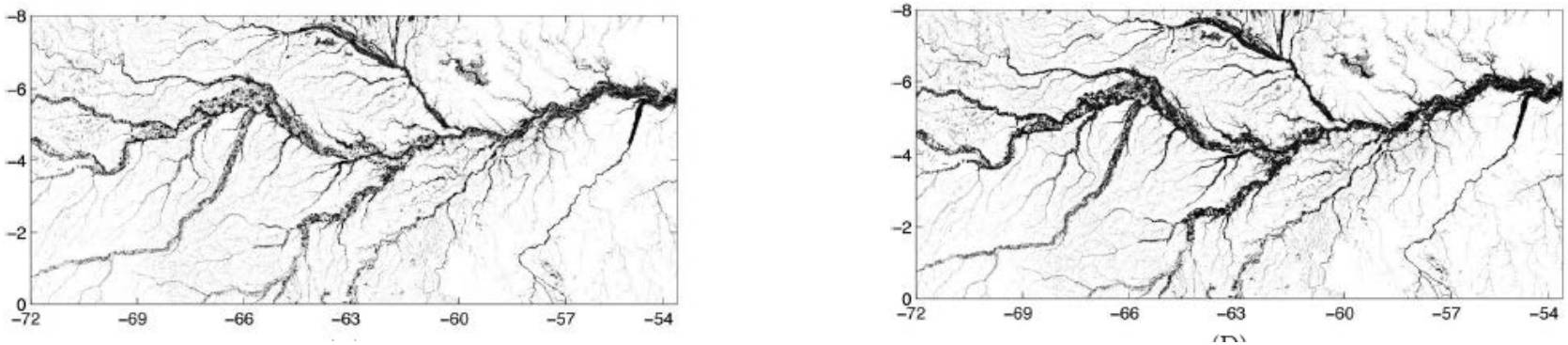
I – Downscaling using an image-processing method

SAR Low water dilatation=70% SAR High water



- Results in **a long time series (1993-2007) of monthly mean water extent at 500 m resolution**.
- Follows the spatial structure of the SAR data coupled to the dynamics of the GIEMS data.

January July



Aires et al. , J. Hydrometeorol., 2013.

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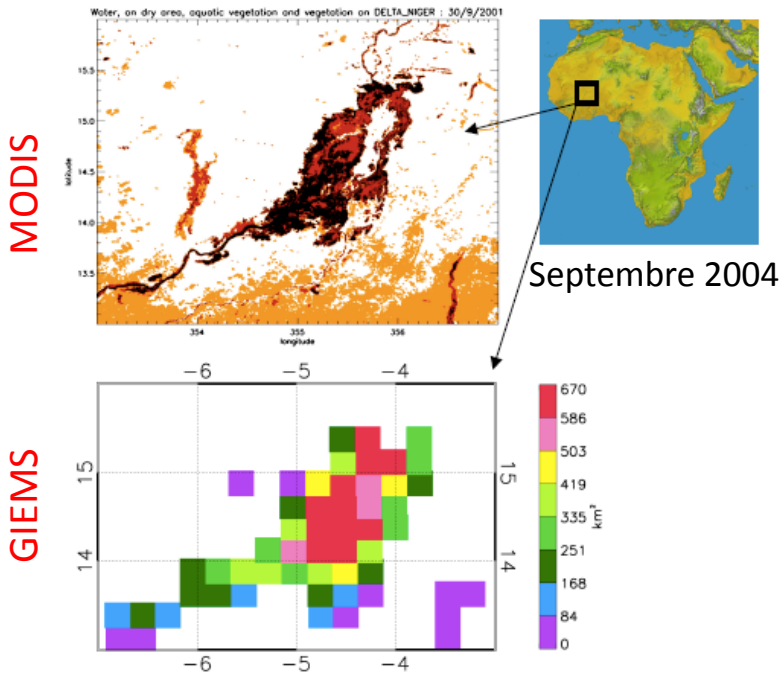
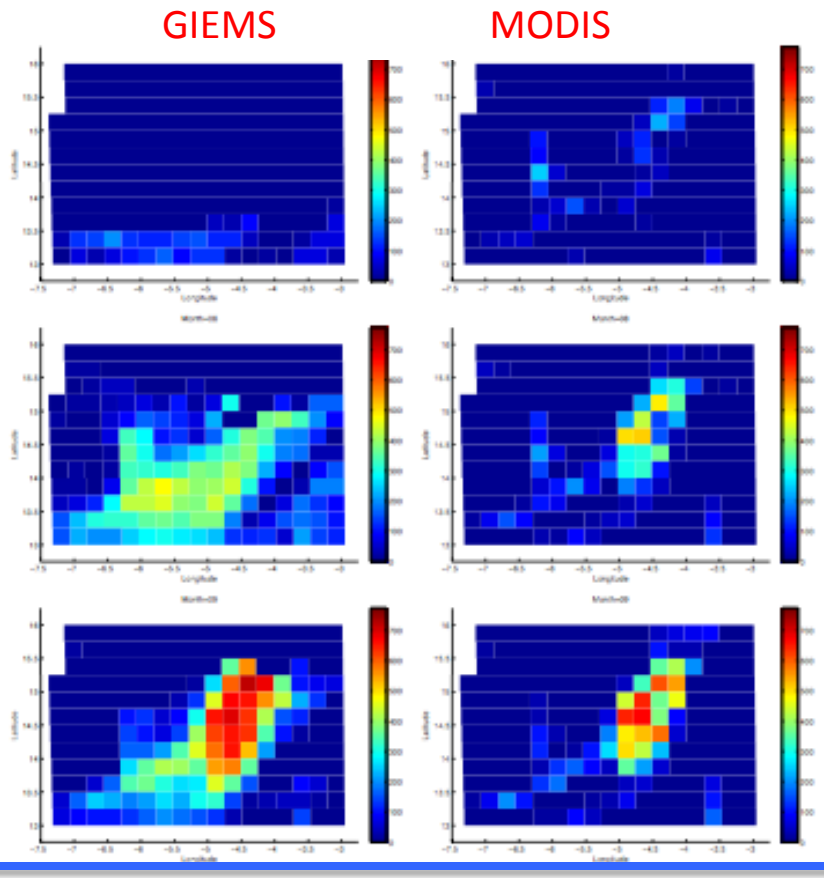
II – Downscaling using an algebraic method

With the visible / infrared, high temporal sampling of wetlands under clear sky condition and when the vegetation density is low.

For instance, weekly estimate of the water extent in the Niger delta with MODIS, from 2000 to 2011, at 500m resolution (Crétaux et al. 2014).

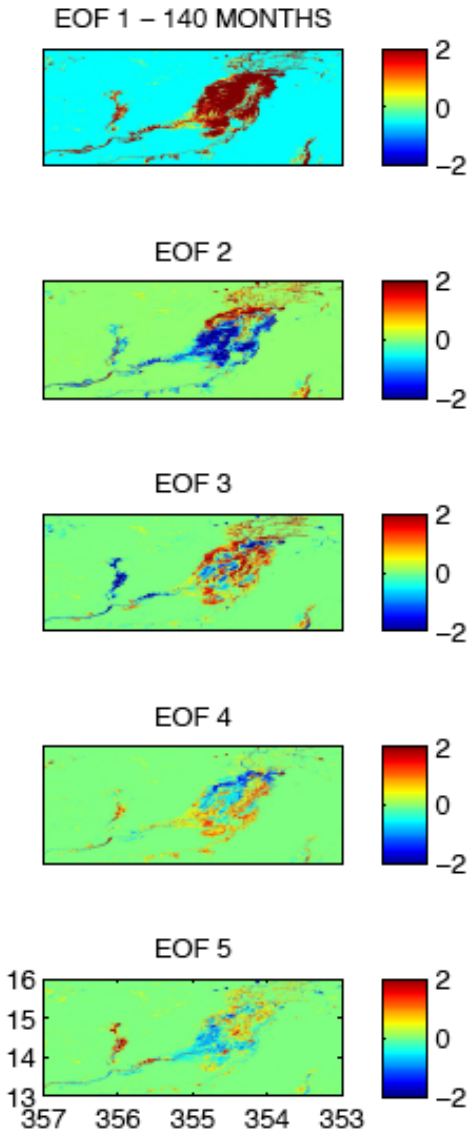
More temporal information than with SAR. This temporal information can be exploited

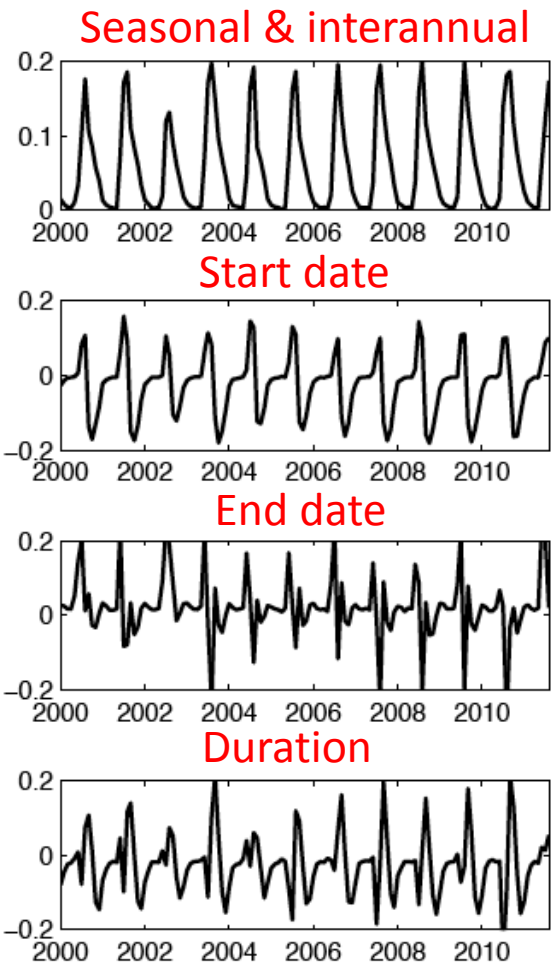


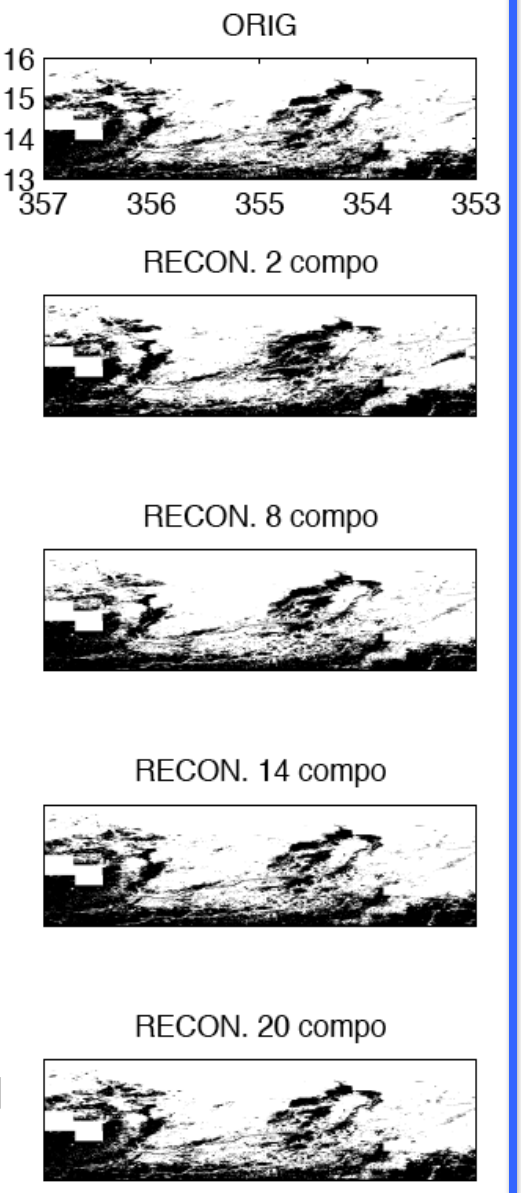


II – Downscaling using an algebraic method

PCA analysis of the high-resolution inundation







Key information on the spatial and temporal hydrological behavior in the basin.

II – Downscaling using an algebraic method

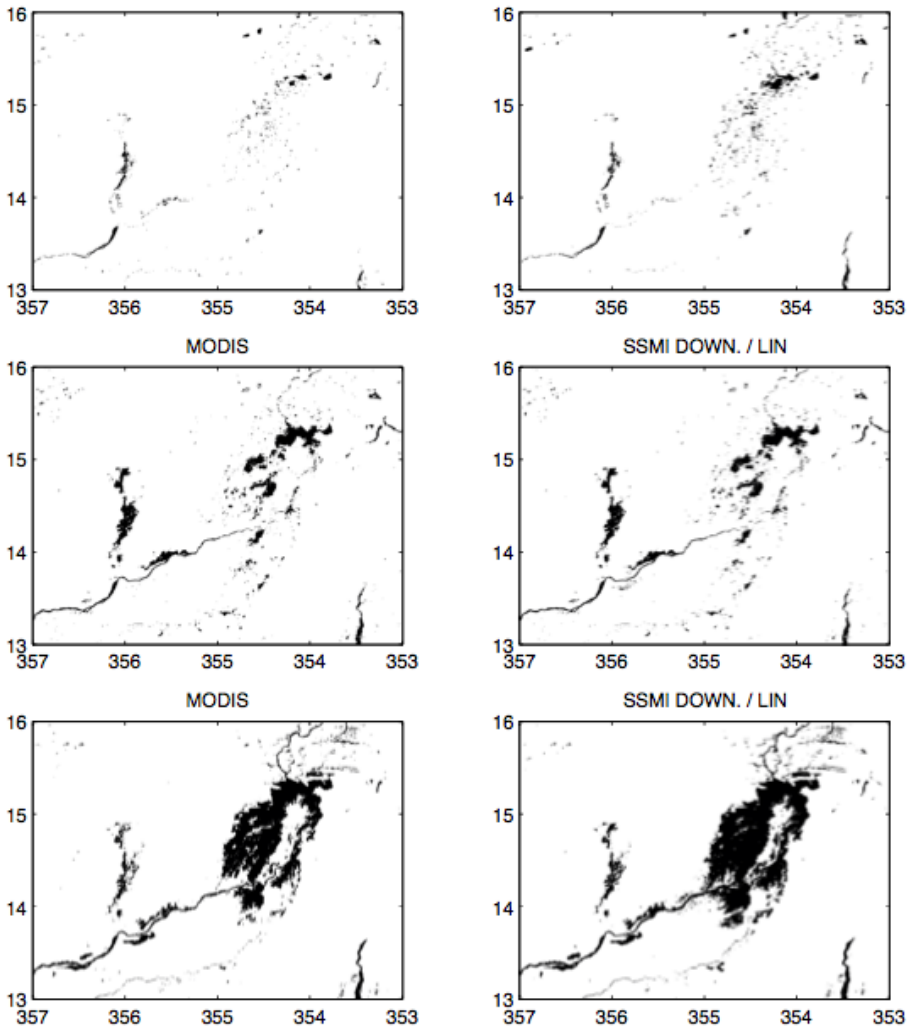
Comparisons between the original MODIS estimates and the downscaled images

- The GIEMS estimates in this area can be **downscaled to produce a 20 year time record.**
- Could be applied on much shorter time series (one year)
- Could accommodate missing data in the time series.

Aires et al., J. Hydromet, 2014

Original MODIS

Downscaled data from GIEMS



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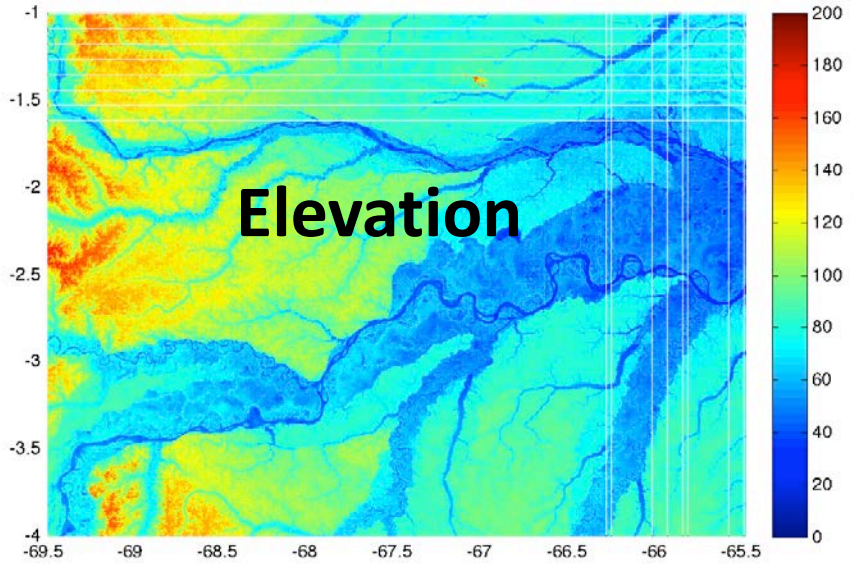
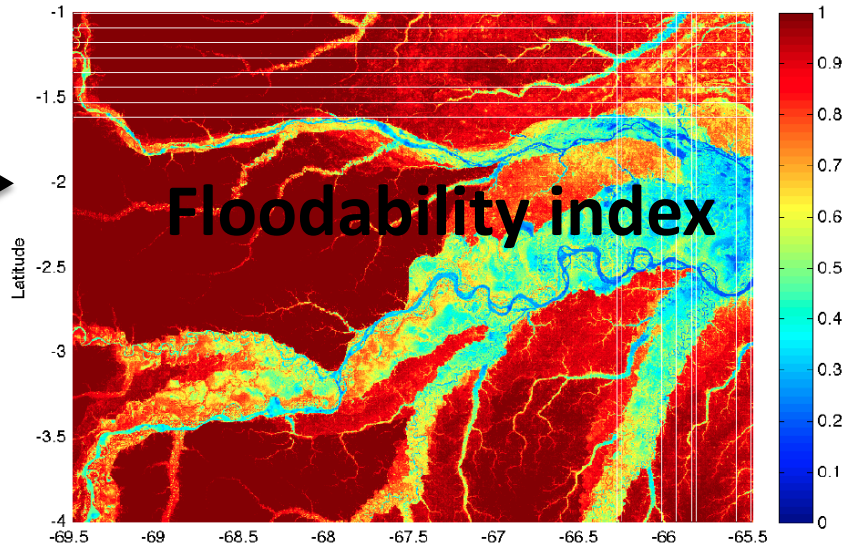
III – Downscaling using topography

HydroSHEDS

- Derived from SRTM
- Resolution 3s (90 m) at global scale
- From -60° to +60°

  HYDRO1K (USGS) to cover the boreal region
- Products: elevation, direction

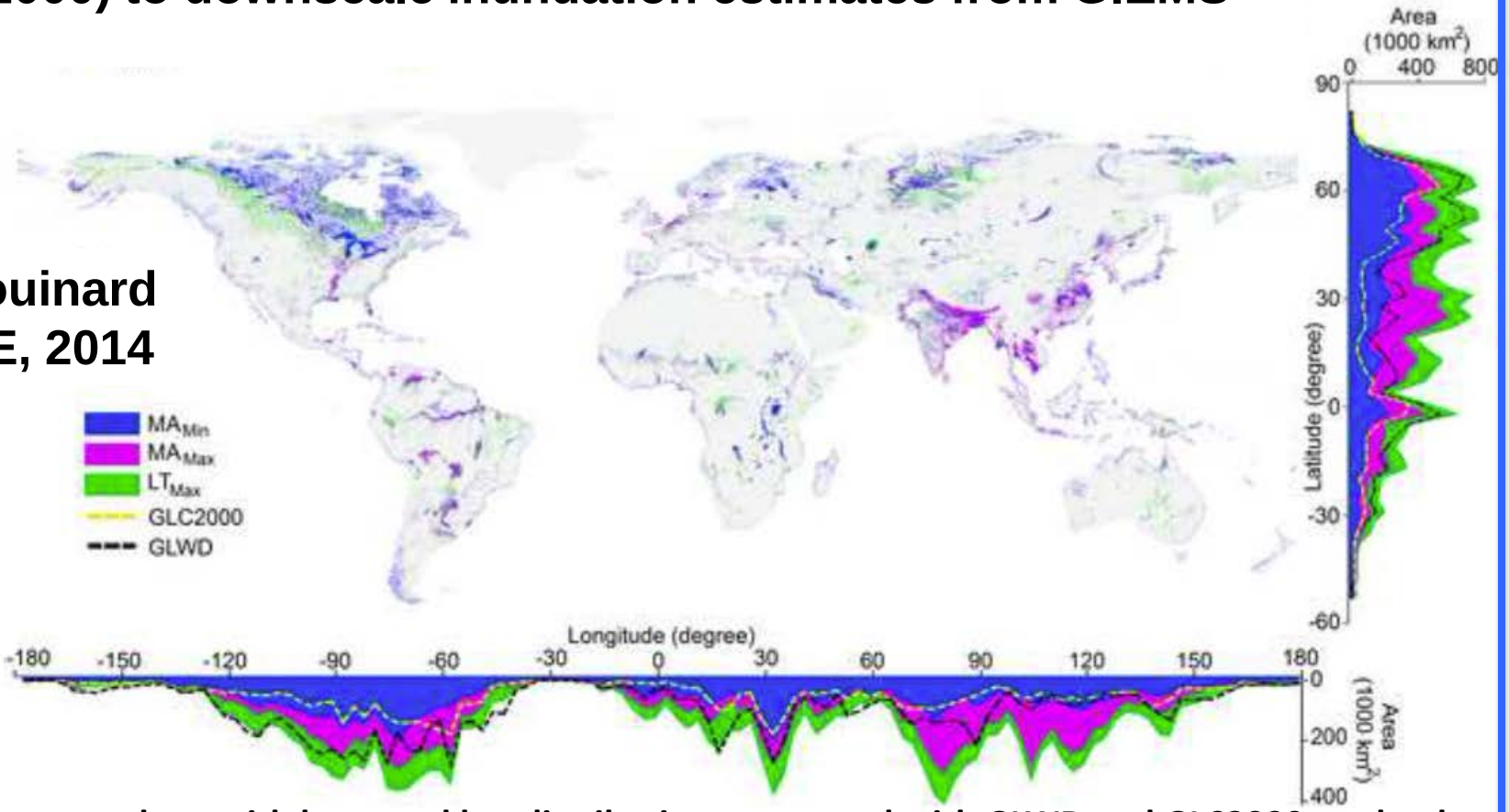




GIEMS-D15

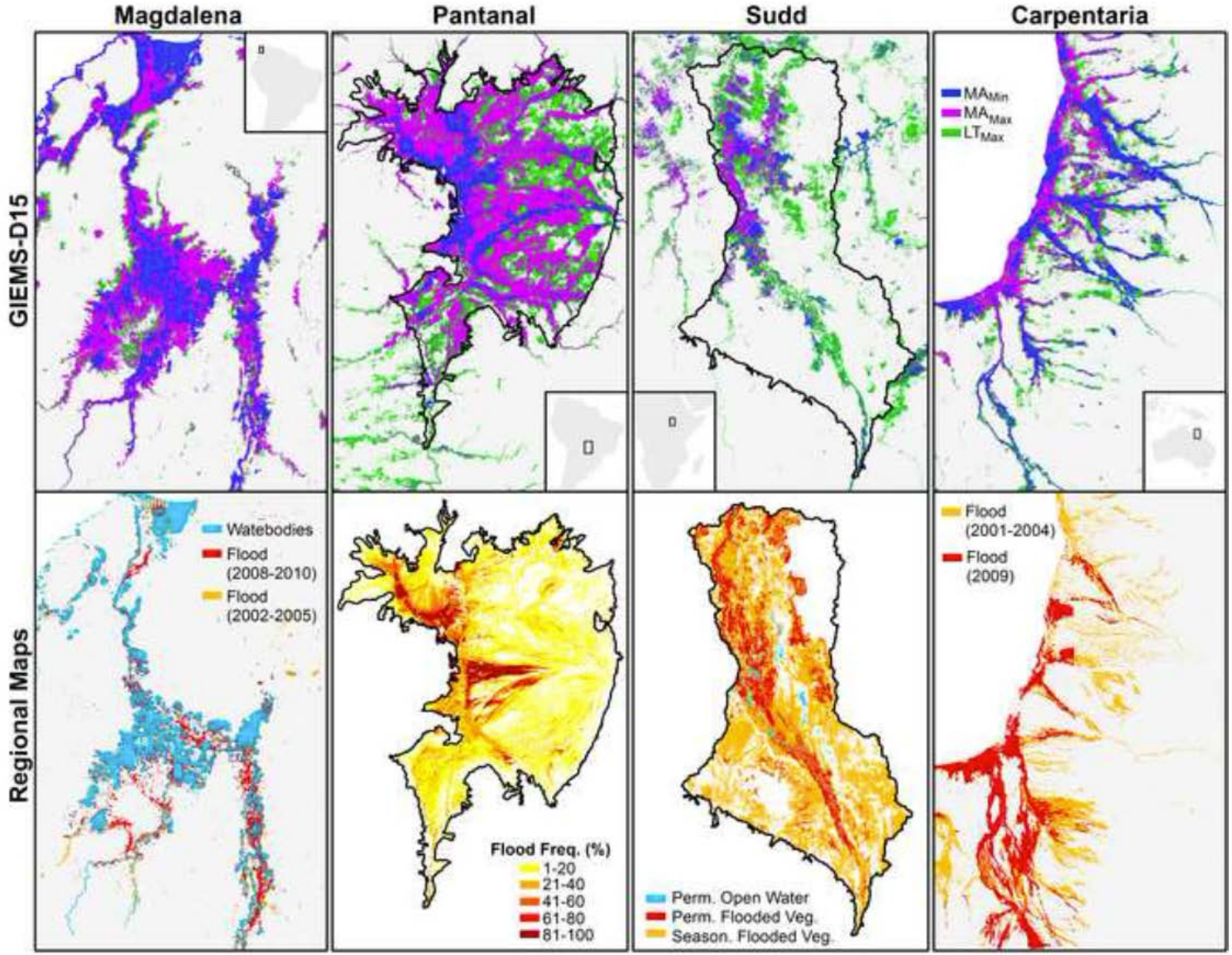
- **GIEMS-D15 (15”): 500 m**
- **Use HydroSHEDS topography and the global Land Cover 2000 (GLC2000) to downscale inundation estimates from GIEMS**

Fluet-Chouinard *et al.*, RSE, 2014



3 inundation states along with long. and lat. distribution, compared with GLWD and GLC2000 wetland:

- **minimum inundation area MA_{Min}**
- **maximum inundation area MA_{Max},**
- **long-term maximum inundation area LT_{Max}.**



Magdalena River Valley in Colombia (MODIS-based mapping, modified from Dartmouth Flood Observatory; Brakenridge & Anderson, 2006)

Pantanal in Brazil, Bolivia and Paraguay (MODIS-based mapping, modified from Padovani 2010)

Sudd Marshes in South Sudan (SAR-based mapping, modified from Rebelo et al., 2012)

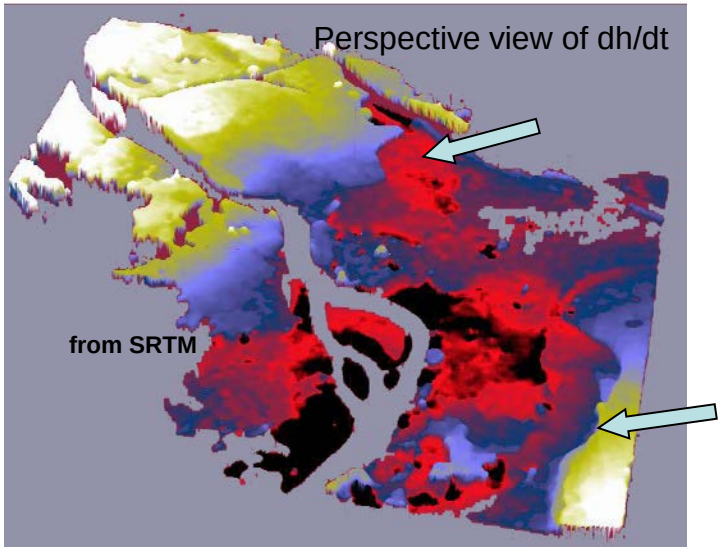
Southeastern coast of the Gulf of Carpentaria in Australia (MODIS-based mapping, modified from Dartmouth Flood Observatory; Brakenridge & Anderson, 2006).

The SWOT mission

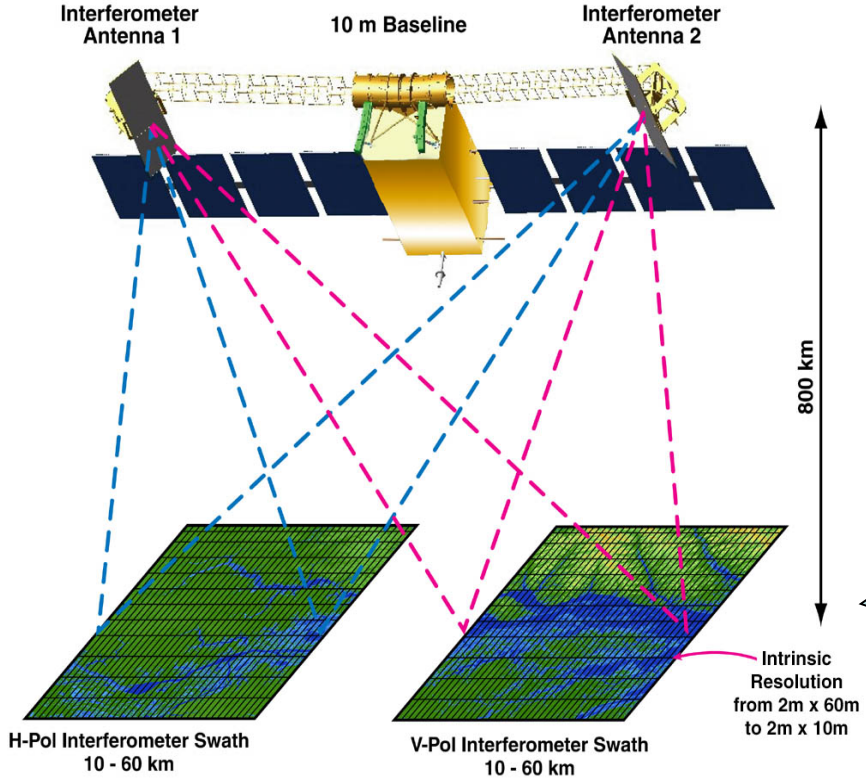
Surface Water Ocean Topography:

High-resolution measurements of the temporal and spatial variations in inundation extent, and in water volumes stored in rivers, lakes, and wetlands

- NASA/CNES
- Launch in 2019-2020
- Advanced altimetry
- Spatial resolution: 100 m



Maps of h, which give maps of dh/dt and dh/dx



Ka-band Radar Interferometer. Maps of h globally and ~weekly with 100m resolution.

Conclusions and perspectives

- Downscaling methods developed using
  - High resolution satellite data
  - Topography information (DEM)

- A first version of downscaled GIEMS (GIEMS-D15) available that provides min and max inundation, based on topography information. Work underway to derive the dynamic database at high resolution.

- With Sentinel 1 and 2, possibility to use the satellite observations to downscale GIEMS and provide a consistent long time record of high spatial resolution surface water extent (backward propagation of the information).

II – Downscaling using an algebraic method

The algorithm: