Comparison of three *a priori* inundation datasets at global scale

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Outline

- Rational
- Available surface water data sets today (not exhaustive)
- Presentation of the GIEMS / GIEMS-D3 datasets
- Comparison of G3WBM, GSWO and GIEMS-D3

Needs for an *a priori* dataset

Various goals of the *a priori* dataset:

- Water mask to define the "pixel clouds" (should include all the hydrologicaly interesting areas)

But also:

- First guess information in the retrieval
- Auxiliary information to be combined in the retrieval scheme (Markov Random Fields)
- Reduce noise/errors
- Fill missing values

Solution so far: Use GSWO (Pekel et al. 2017) form Landsat

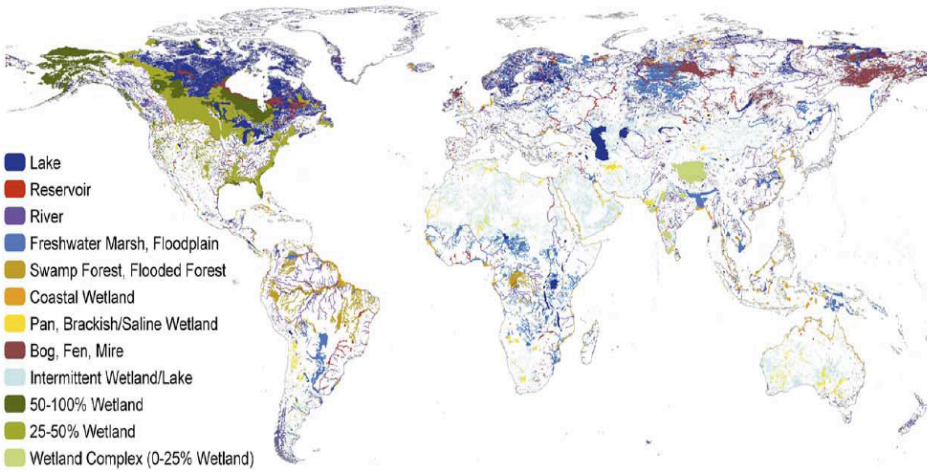
- with P(I)>0 for the mask
- or using Prob(I)

➔Is this enough?

Available surface water datasets today (not exhaustive)

High-resolution inundation extent datasets

- **Global but static**
  - From inventories collection: GLWD, (Lehner & Doll 2004, at 30s)



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  - From satellite observations in the visible/IR images, only under clear conditions and low vegetation density, but with good temporal sampling

    (e.g., Bergen-Nguyen et al., 2008, over the Niger delta, weekly for years, at 500m resolution)
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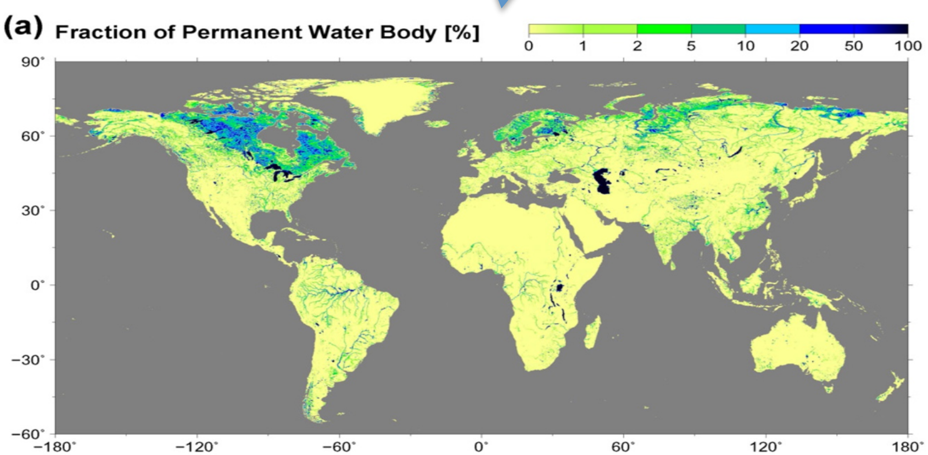

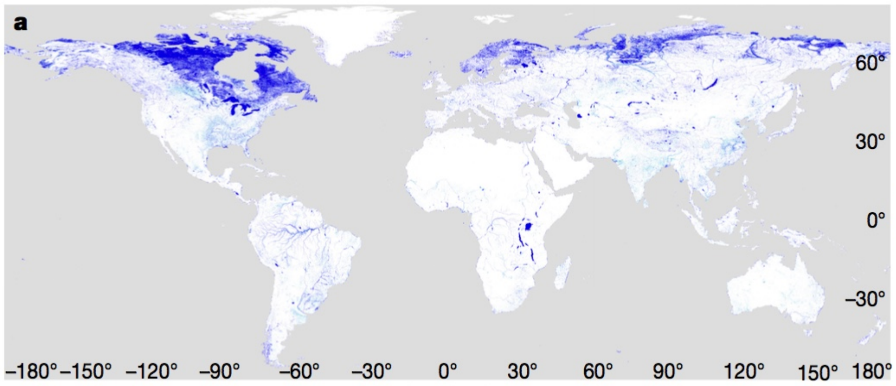

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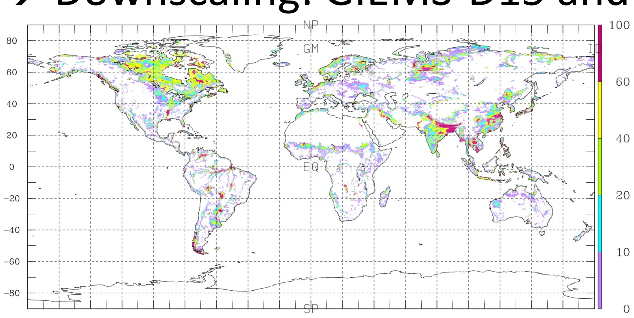
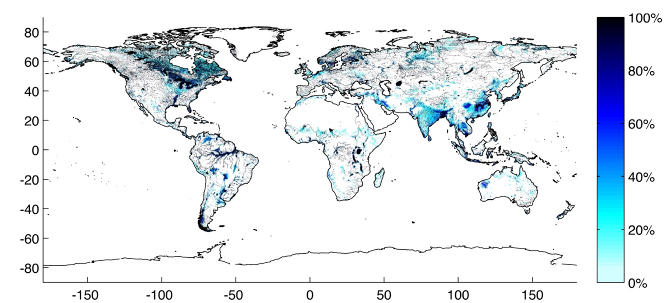
Low resolution inundation extent datasets

- **Global and dynamic**
  - From multiple satellite observations: GIEMS (Prigent et al., 2012, 25km, monthly, 1993-2007)

    → Downscaling: GIEMS-D15 and GIEMS-D3 (Aires et al. 2017, 90m, monthly, 1993-2007)





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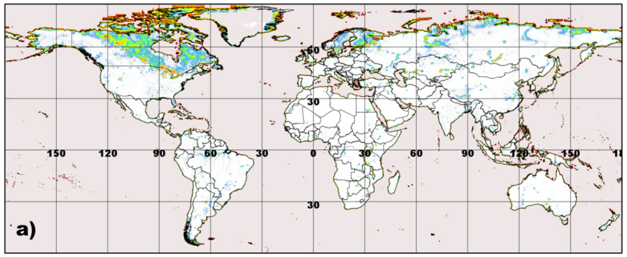
    → Downscaling: GIEMS-D15 and GIEMS-D3 (Aires et al. 2017, 90m, monthly, 1993-2007)
  - SWAMPS (Schroeder et al. 2016), from NASA/JPL: recent years, coarse resolution but not really evaluated…



Not exploitable
(Pham-Duc, Prigent, Aires and Papa, Comparison of global terrestrial surface water datasets over 15 years, JH, 2017)

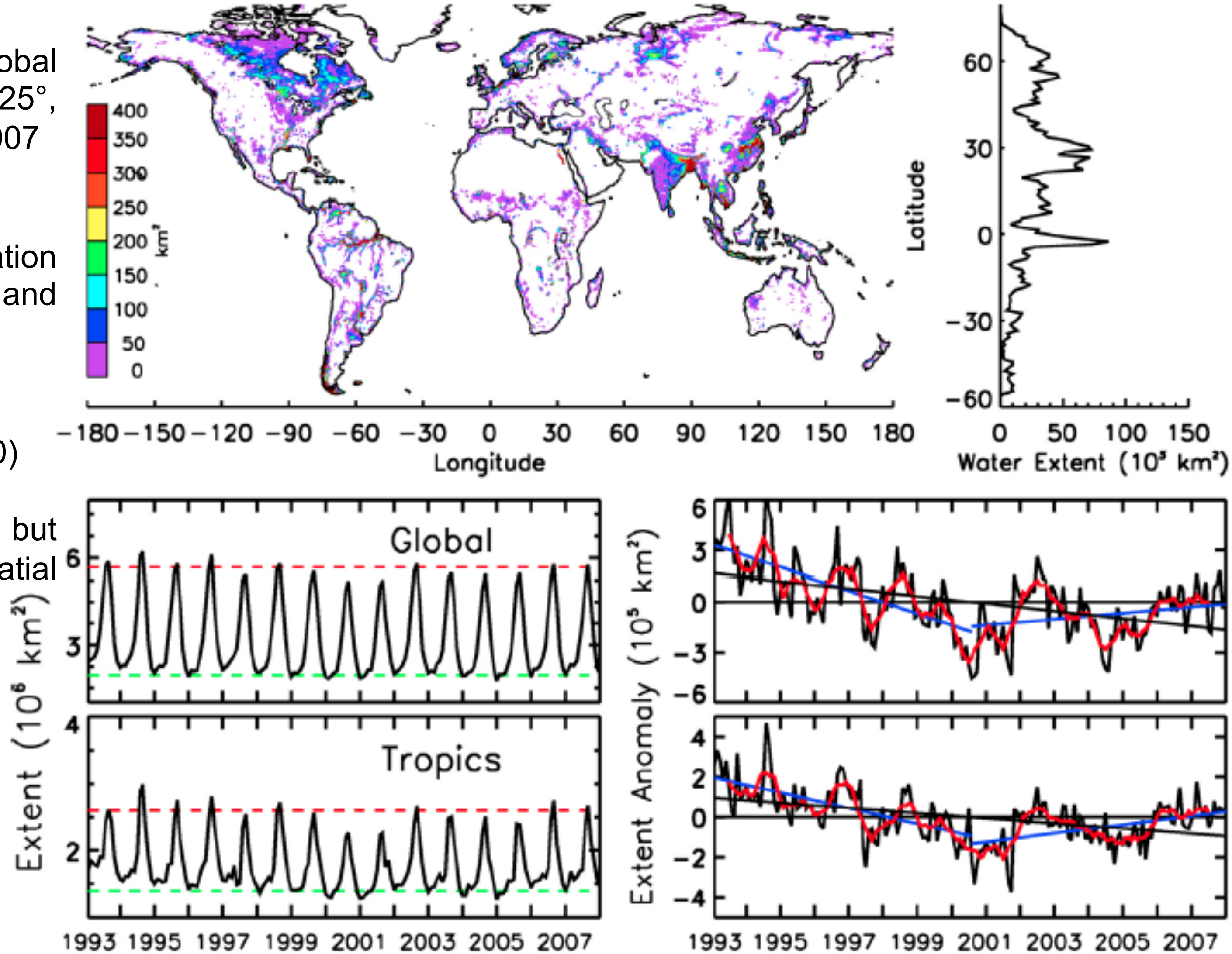
GIEMS: Global Inundation Extent from Multi-Satellite

A unique data base of global surface water, at 0.25°×0.25°, monthly-mean over 1993-2007 (Prigent et al. 2012)

Derived from the combination of passive, active, visible, and infrared observations.

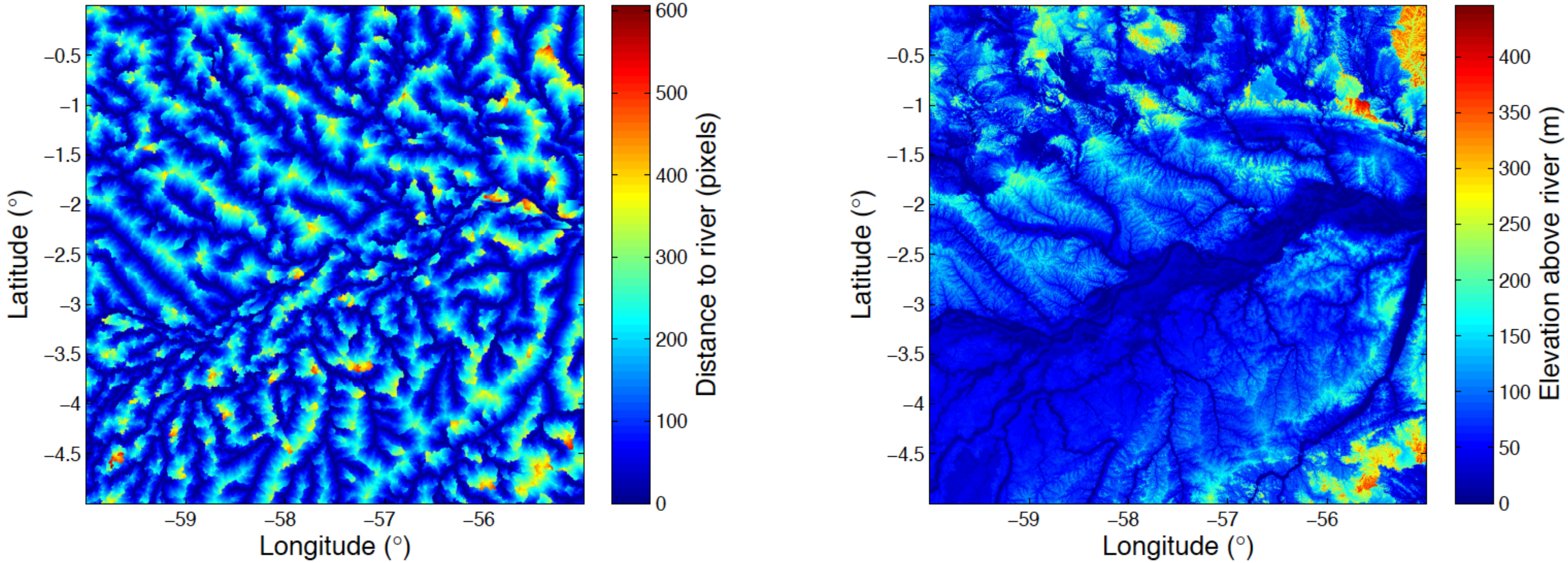
Thoroughly evaluated (e.g., Papa et al. 2008, 2010)

Used for many applications, but some limitations due to spatial resolution



GIEMS-D3

- Downscaling based again on topography (Hydroshed)



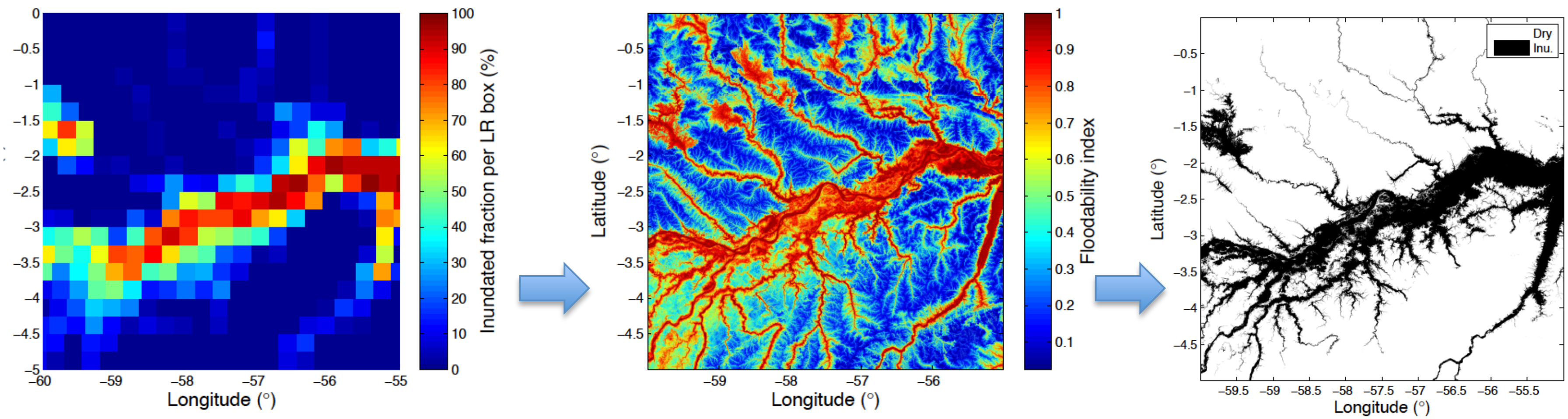
(a) Distance to the flow-direction nearest river of size 10000

(b) Elevation above the flow-direction nearest river of size 100000

(Aires, Miolane, Prigent, Fluet-Chouinard, Lehner & Papa, A global, long-term and high spatial resolution inundation extent database, J. Hydrology, 2017)

GIEMS-D3

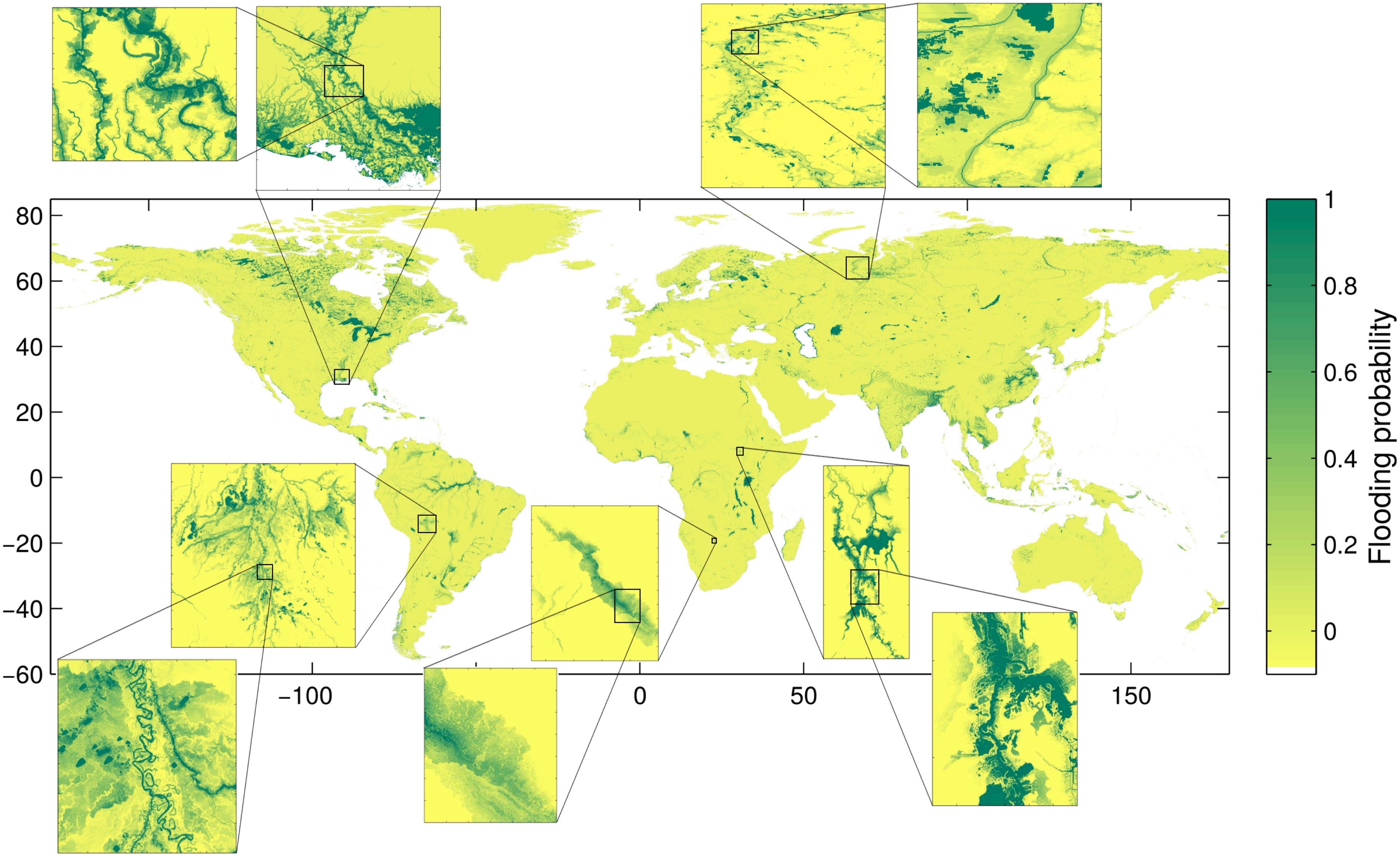
- Downscaling based again on topography (Hydroshed)
- A floodability index is based on topography information
- Not only Min and Max over the GIEMS record, but dynamic monthly values from 1993 to 2007
- Better downscaling procedure:
  - Smoothing
  - Coasts
  - 90 m instead of 250 m (GIEMS-D15)



(a) Inundation extends from the GIEMS database (b) Floodability index (d) Downscaled map with smoothing procedure

(Aires, Miolane, Prigent, Fluet-Chouinard, Lehner & Papa, A global, long-term and high spatial resolution inundation extent database, J. Hydrology, 2017)

GIEMS-D3 – Inundation occurence



GIEMS-D3

Monthly dynamics

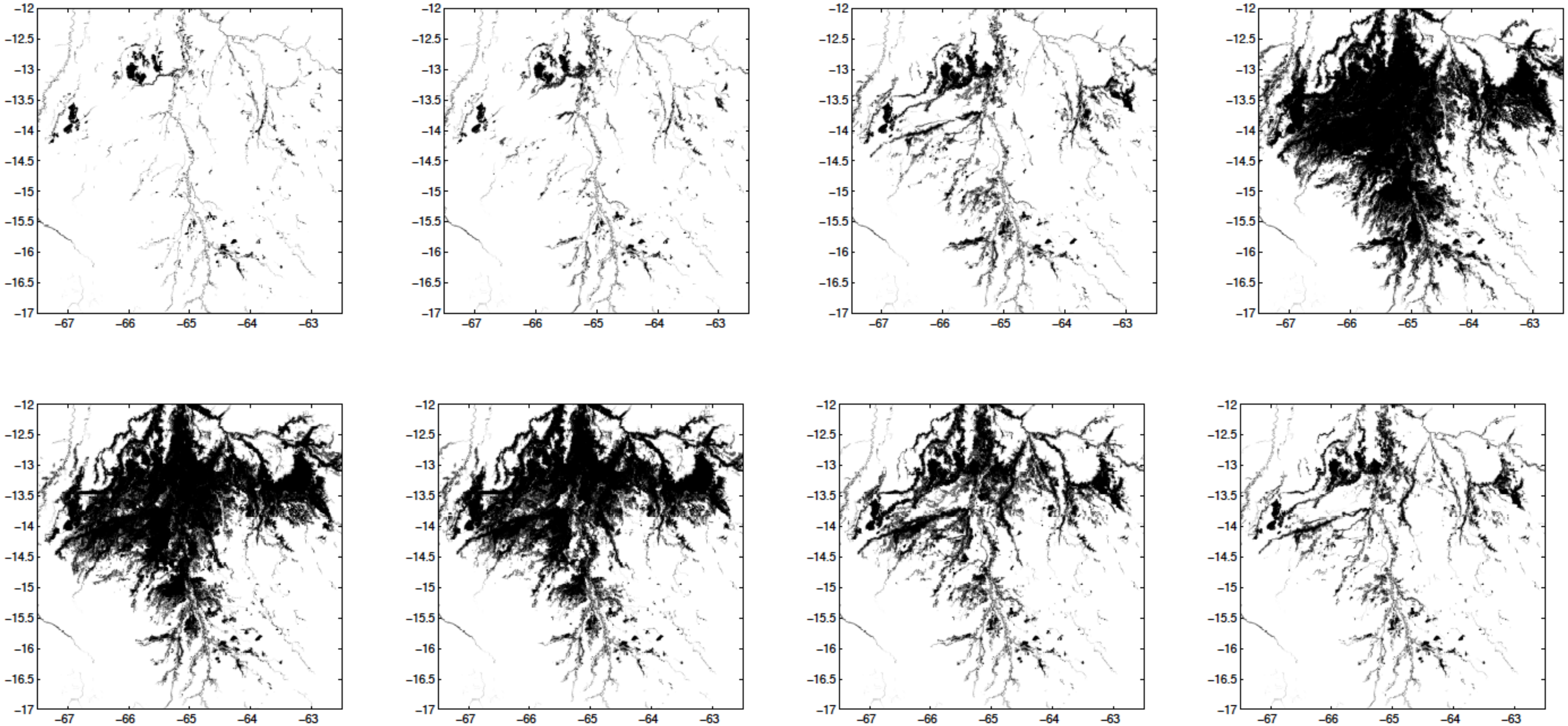
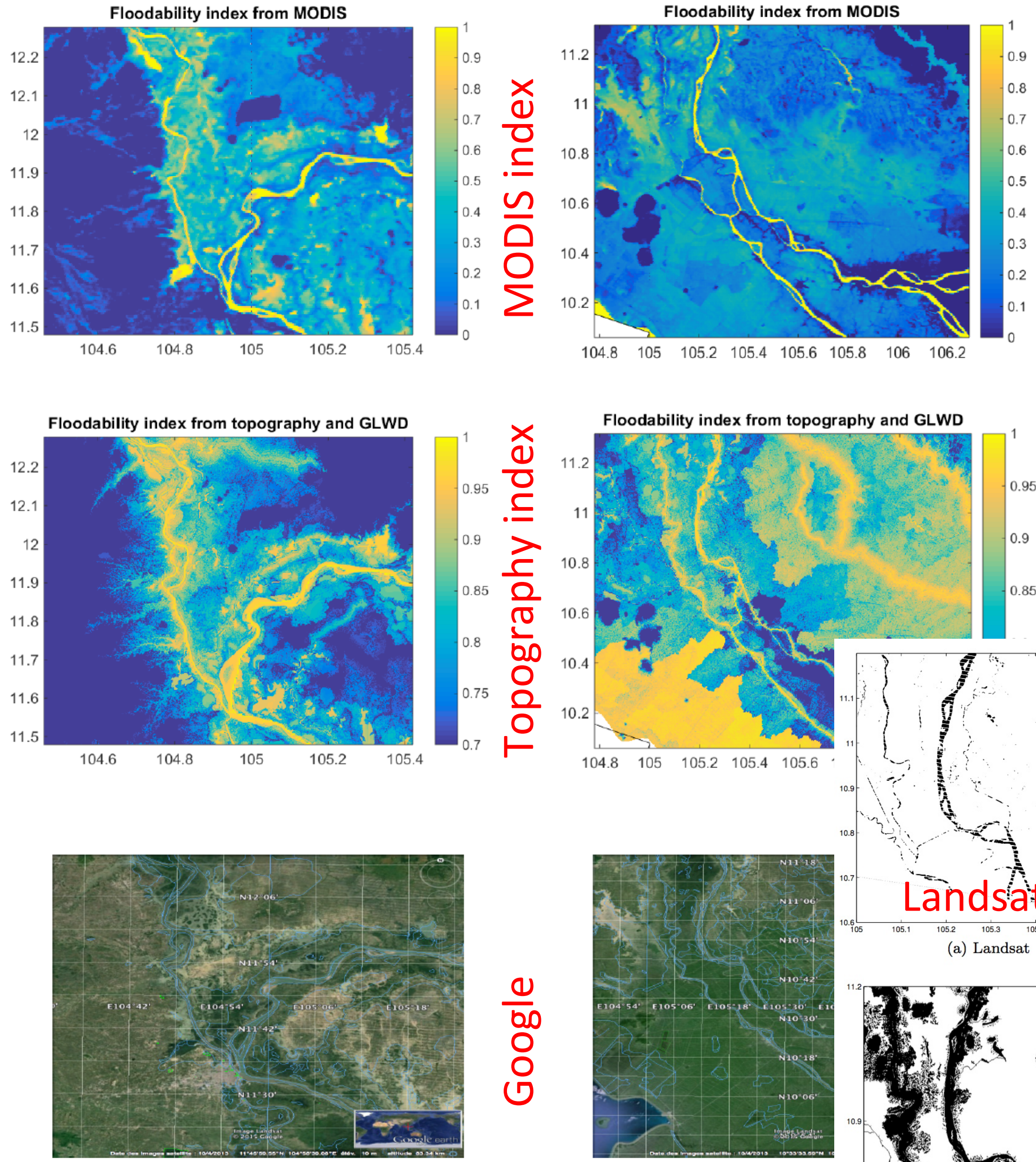


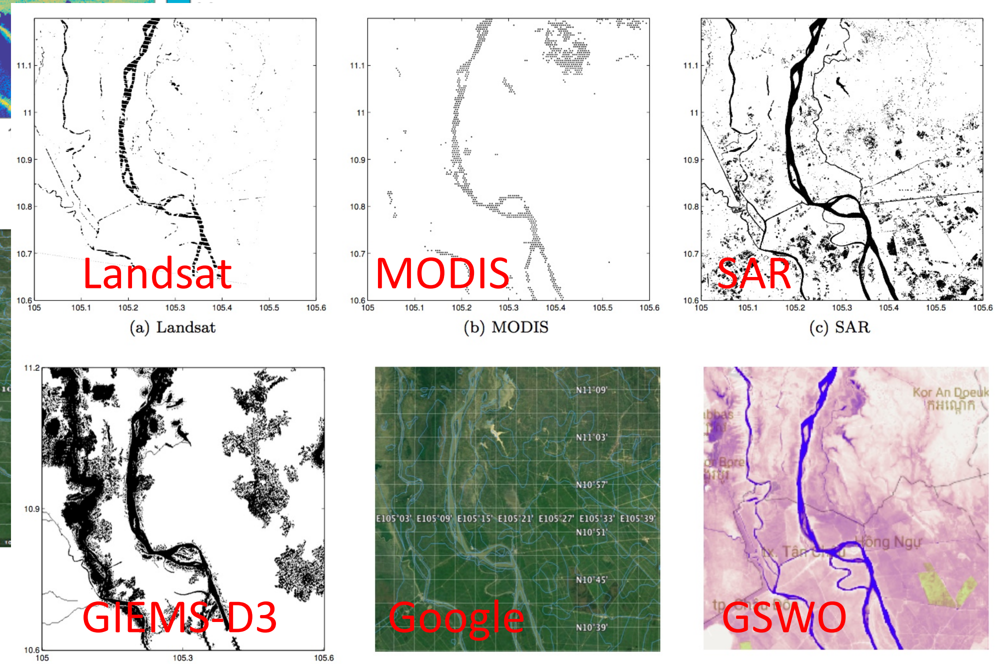
FIG. 6. From top to bottom, and fInundation dynamics for Oct., Nov., Dec., Feb., Mar., May, Jun. of the 1993-1994 wet season over a region in South-America: Lat=-17/-12°, Lon=-68/-62°W.

Evaluation

- SAR/Sentinel
- MODIS
- Landsat
- Google Earth
- GSWO

- River discharge
- Altimeter





(a) Landsat (b) MODIS (c) SAR

(d) GIEMS-D3 (e) Google Earth (f) Surface water occurence from Landsat

Three global datasets

	G3WBM	GSWO	GIEMS-D3	GLWD
Reference	(Yamazaki et al., 2015b)	(Pekel et al., 2016)	(Aires et al., 2017)	(Lehner and Grill, 2013)
Observations	Landsat	Landsat	downscaled / multi-sensor	compiled maps & charts
Period	1990, 95, 2000, 01	1984-2015	1993-2007	Pre-1990s
Resolution	3 arc-sec	3 arc-sec	3 arc-sec	30 arc-sec
Detect	open water bodies	open water bodies	All surface inundation	Waterbodies & natural wetlands
Perm. water (million km^2)	3.25	2.78^a	...	3.04
Tempor. water (million km^2)	0.49	0.81^a	...	8.31

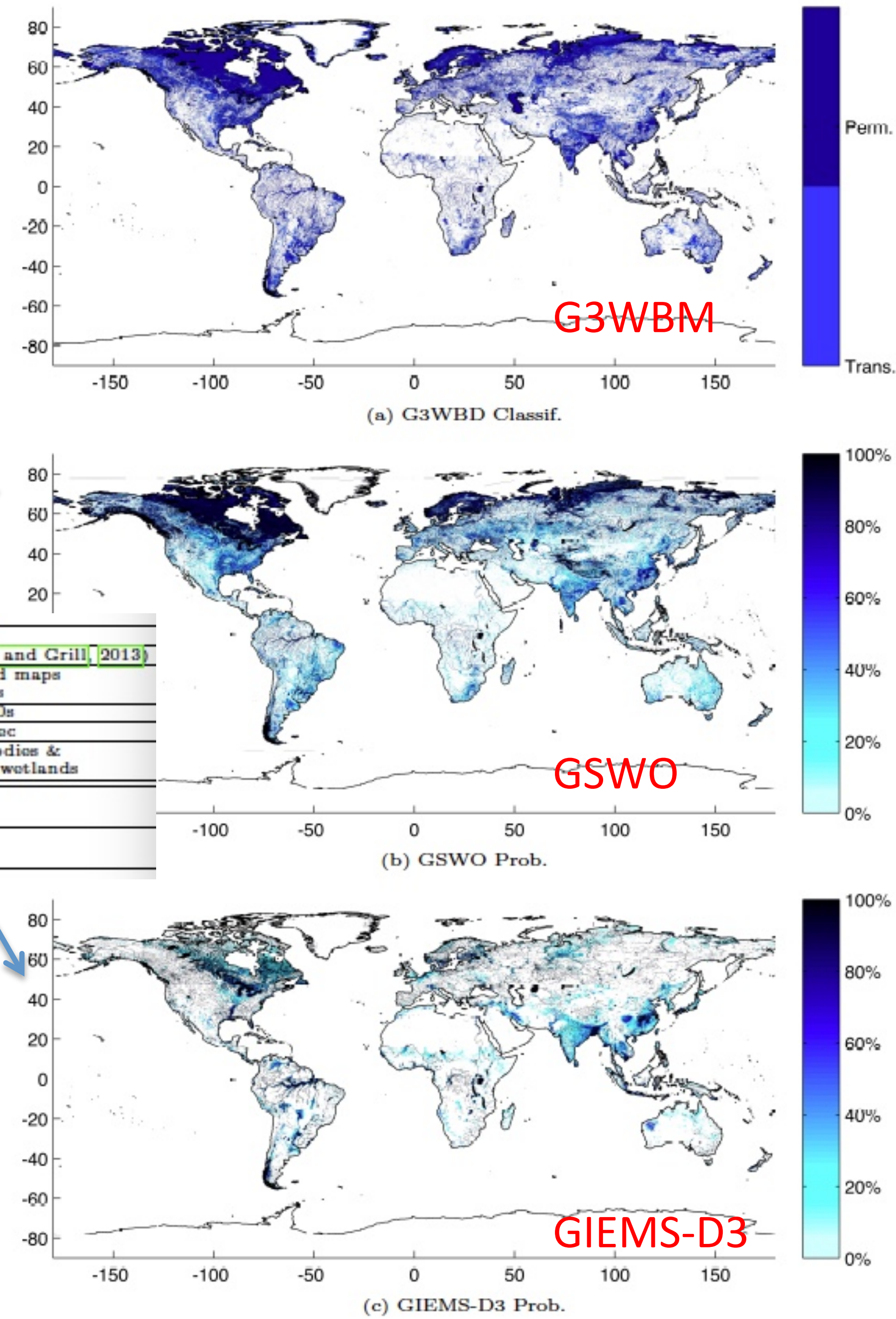
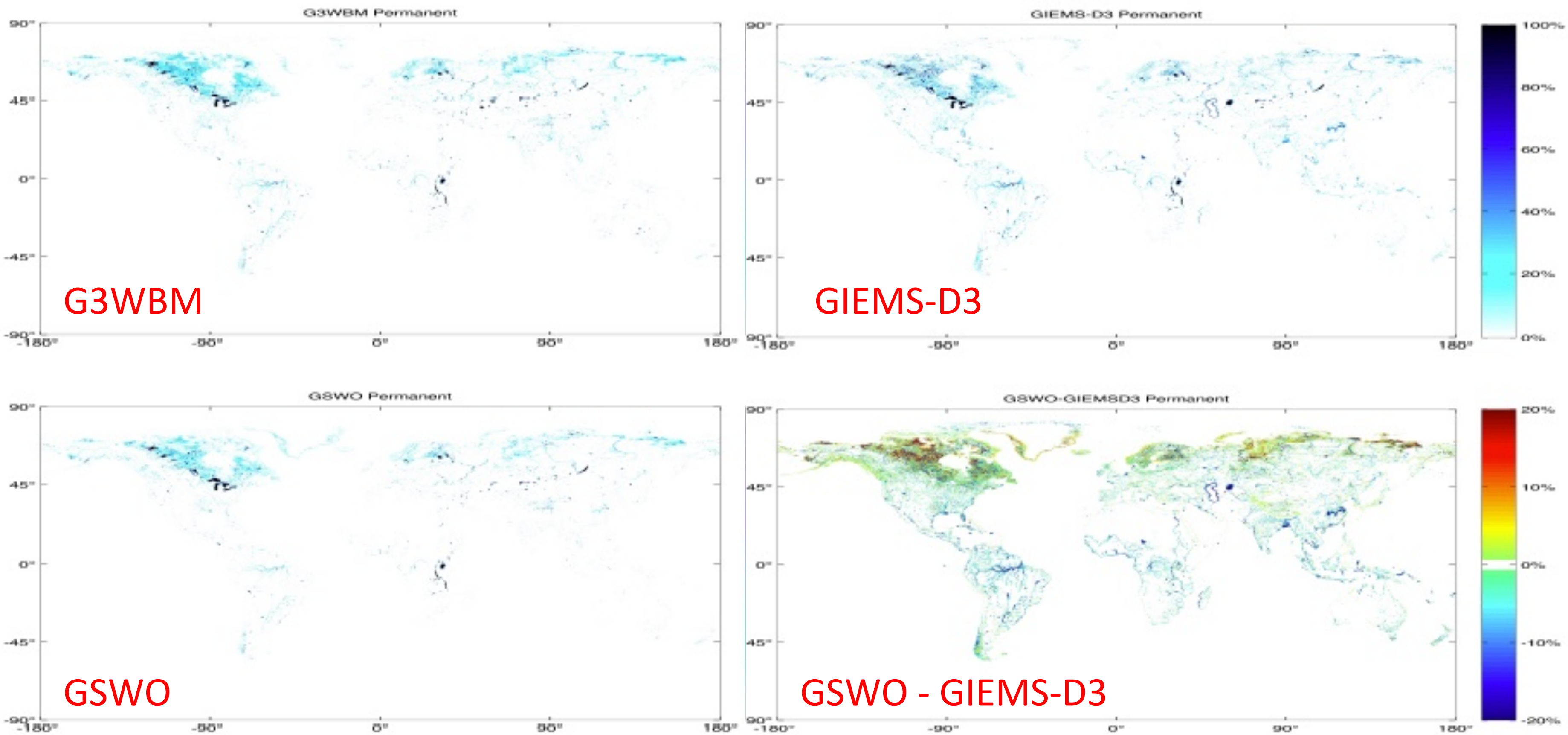


Figure 1: From top to bottom: G3WBD classification into permanent and transitory inundation (0-1), the GSWO inundation probability (0-100%), and the GIEMS-D3 probability (0-100%).

Permanent waters

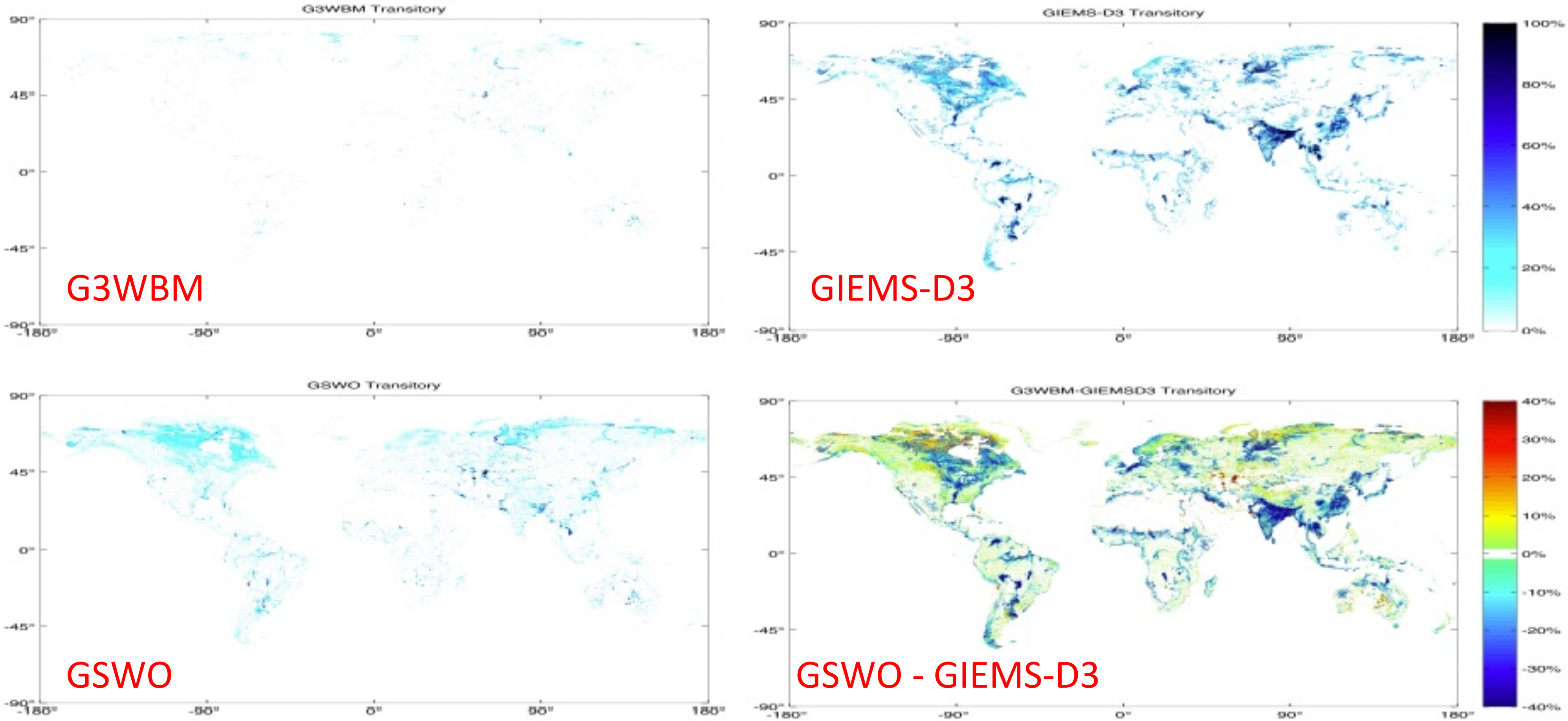


Datasets are in good agreement but:

- GIEMS-D3 less over high-latitudes
- GIMES-D3 more on Tropics than Landsat estimates

Transitory Waters

Figure 3: From top to bottom: Area-fraction (in %) of transitory inundation states over 0.1°× 0.1° pixels, for G3WBM, GSWO, and GIEMS-D3. The bottom figure represents the area differences (in %) of GSWO minus GIEMS-D3, and a small histogram of differences over the entire globe is also provided.



- G3WBM has limited transitory, due to lack of time sampling
- GIEMS-D3 has more transitory than GSWO, in particular over vegetated areas and high cloudiness

Lat/Lon Comparisons

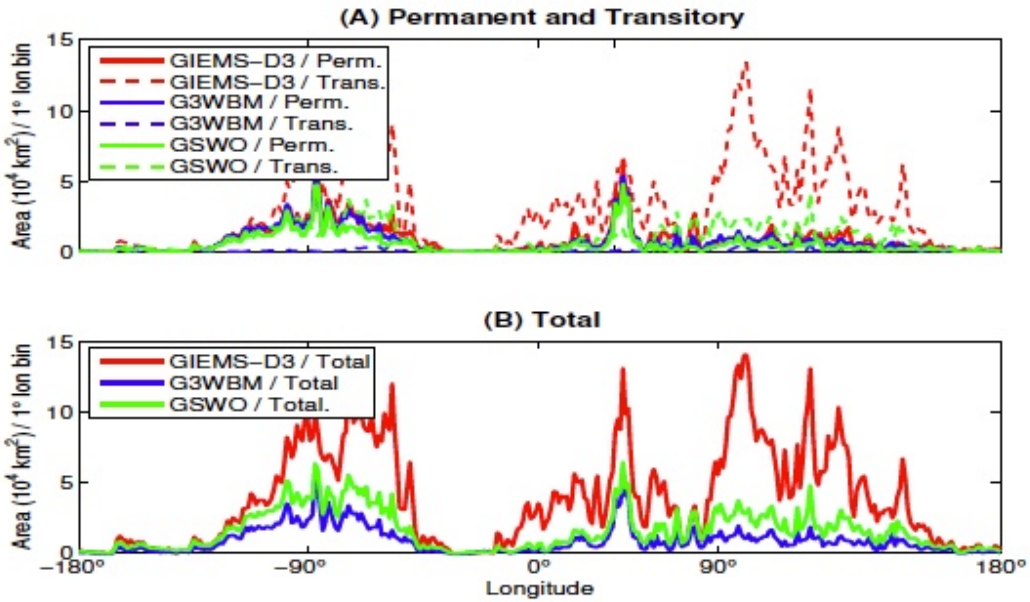
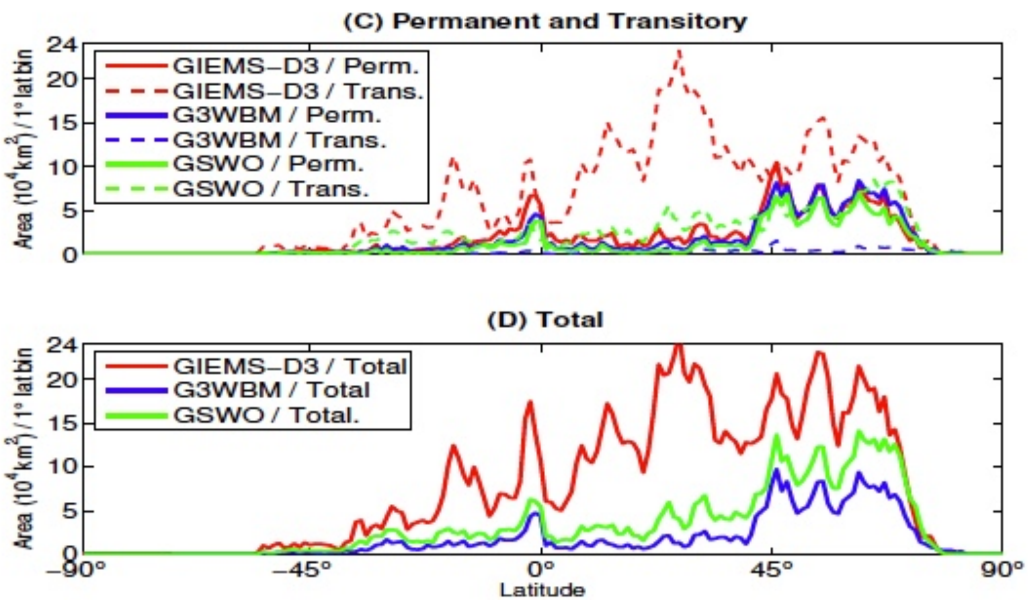
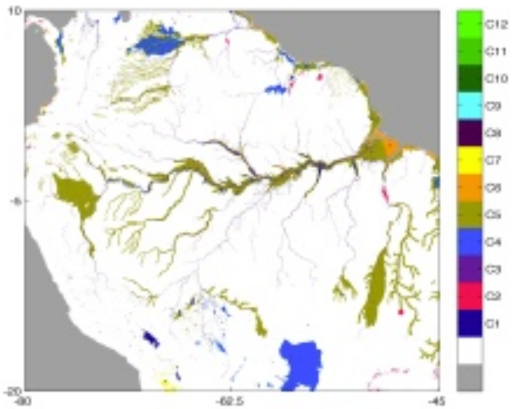


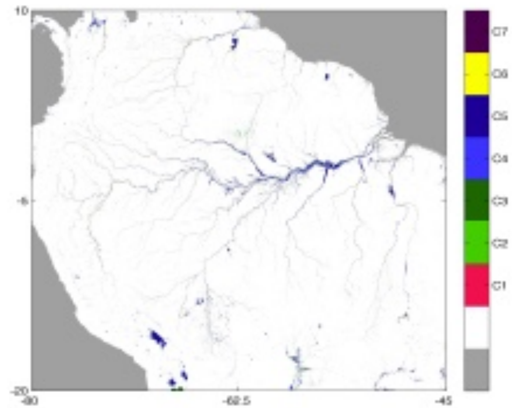
Figure 4: Averaged longitudinal (upper part) and latitudinal (bottom part) surface water extents (in 10^4 km^2 per 1° bin), for G3WBM, GSWO, and GIEMS-D3 estimates. The statistics are provided for the permanent, transitory surface water, and for their sum.



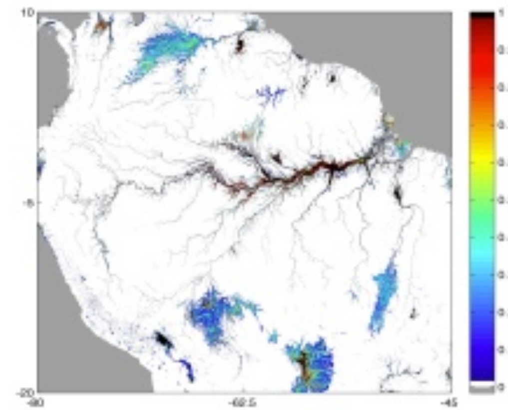
Amazon



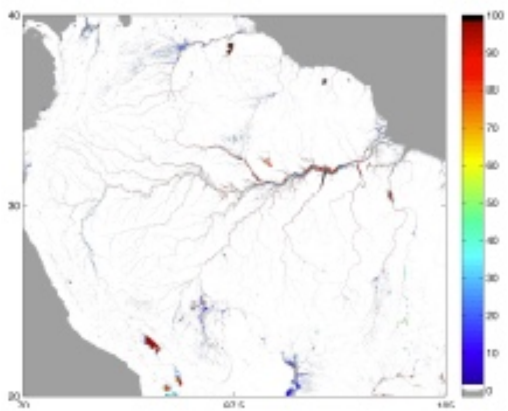
(a) GLWD Classif.



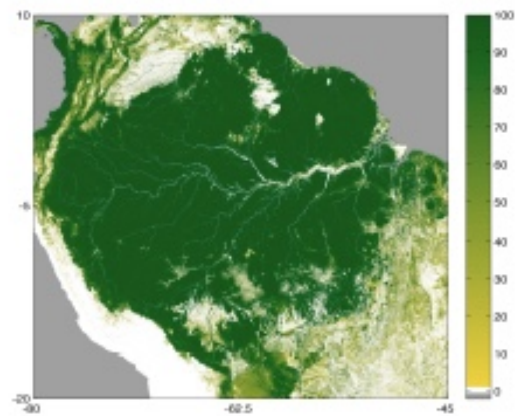
(b) G3WBM Classif.



(c) GIEMS-D3 Prob.

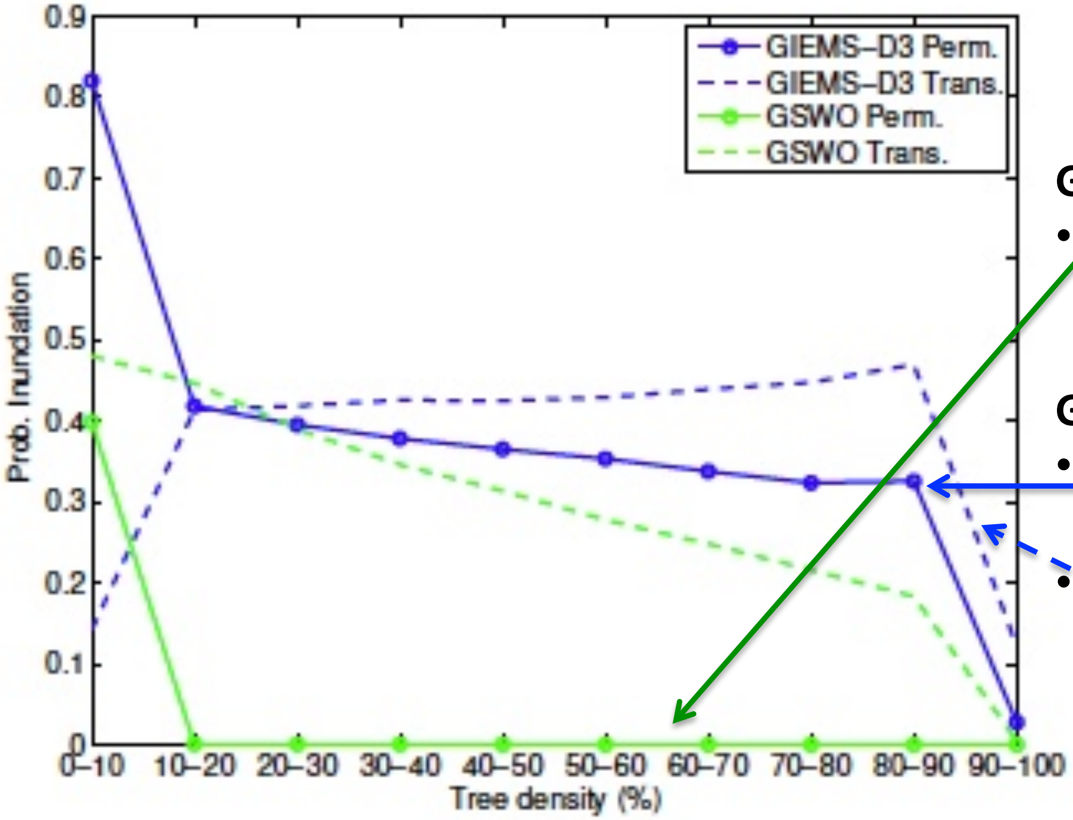


(d) GSWO Prob.



(e) Tree density

Floodability index



GSWO:

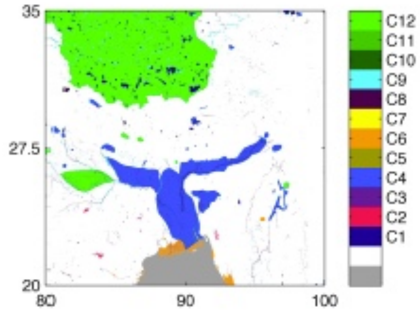
- No permanent water under vegetation

GIEMS-D3:

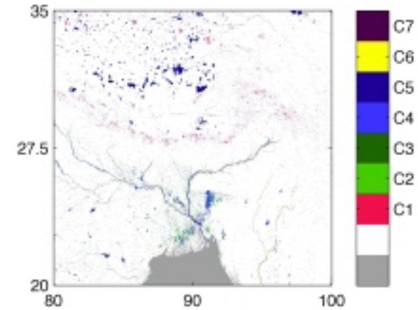
- Much more permanent waters (over Amazon)
- More transitory waters under vegetation

Figure 7: Probability of inundation for ten tree density ranges (0-10% to 90-100%), over a 5° × 5° cell in the Amazon region (-5°S:0°S; -70°W:-65°W). The probability of being inundated (permanently or transitory) is estimated for each tree density bin.

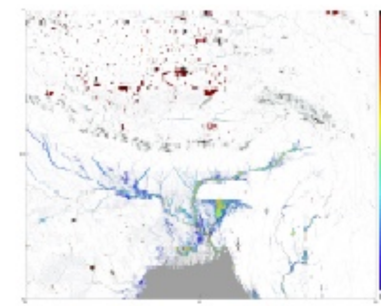
Ganges-Bramahputra



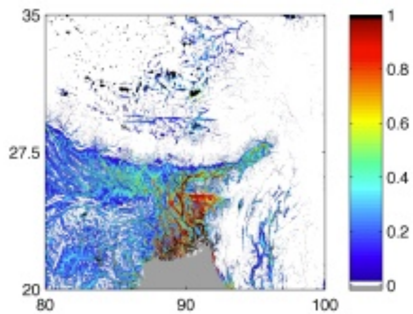
(a) GLWD Classif. (1-12)



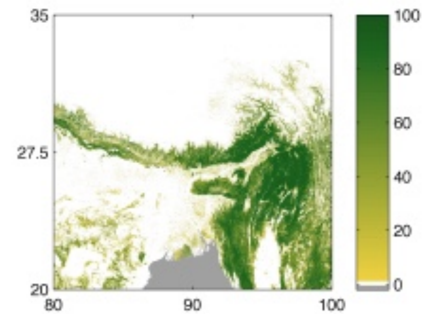
(b) G3WBM Classif. (1-7)



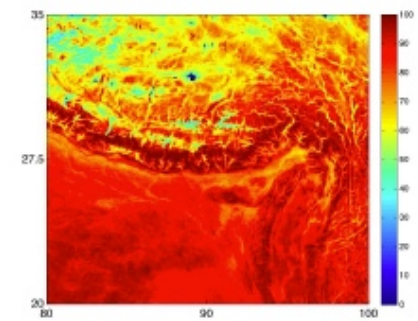
(c) GSWO Prob. (0-1)



(d) GIEMS-D3 Prob. (0-1)



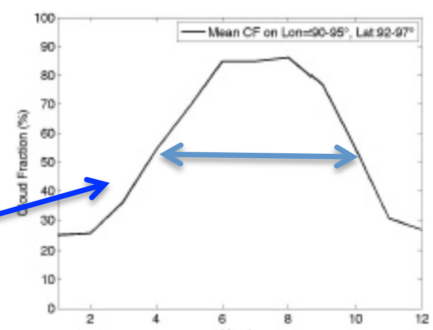
(e) Tree density (%)



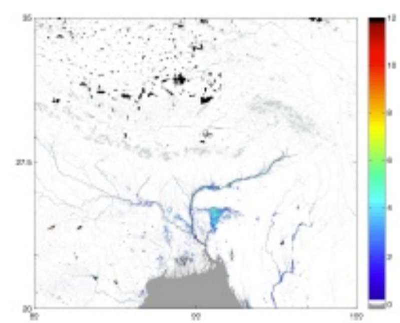
(f) Cloud Fraction (%) August

Cloud Fraction can be close to 100% in:

- some regions
- & some periods (raining season!)

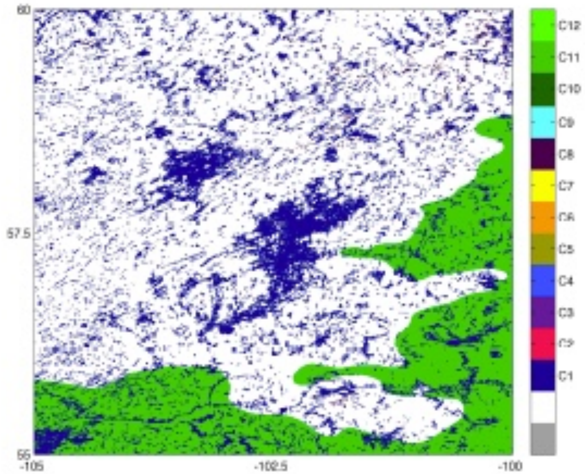


(g) Cloud Fraction Season

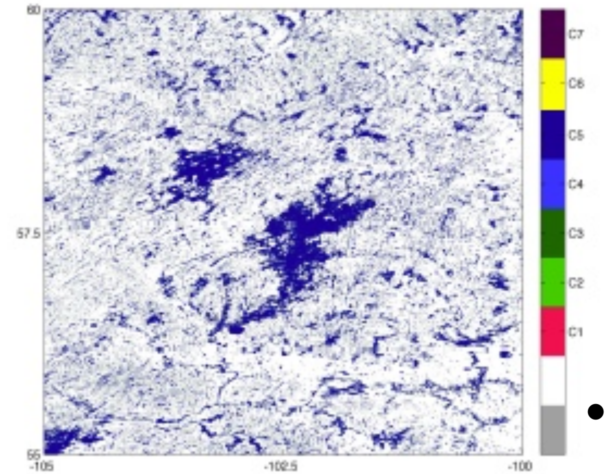


(h) GSWO Season (month)

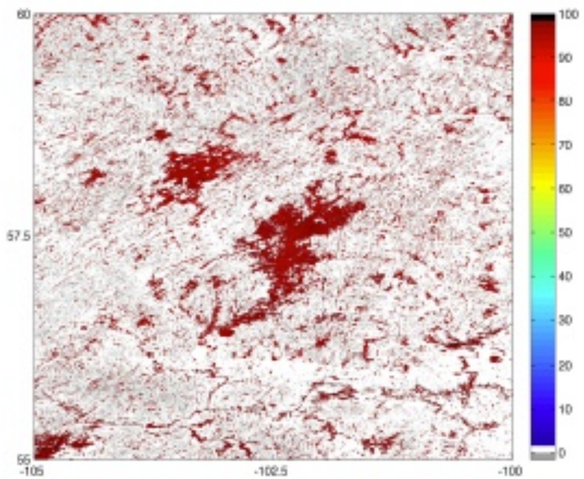
High-Latitudes



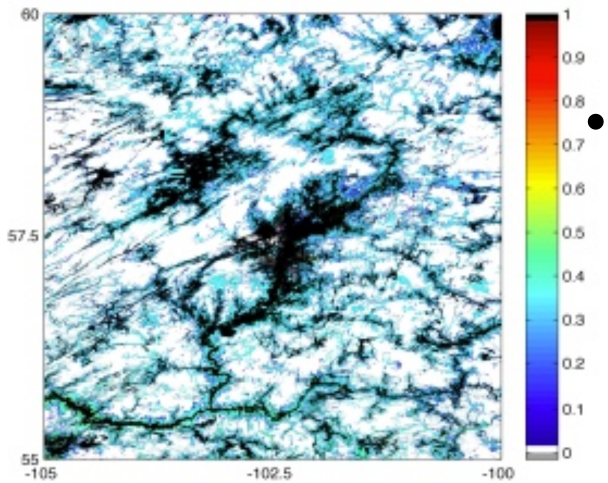
(a) GLWD Classif.



(b) G3WBM Classif.



(c) GSWO Prob.



(d) GIEMS-D3 Prob.

- GIEMS-D3 cannot retrieve small & isolated inundations
- Landsat estimates are much more "diffusive"

Conclusion

GIEMS-D3:

- GIEMS should be extended from 2007 to present
- DEM and hydrologic dataset could be improved
- Downscaling process could also be improved (various types of environments)

Comparison of the three datasets:

- When no clouds & no vegetation, Visible (Landsat) is best
- When vegetation or clouds, microwave (GIEMS-D3) can supplement Visible

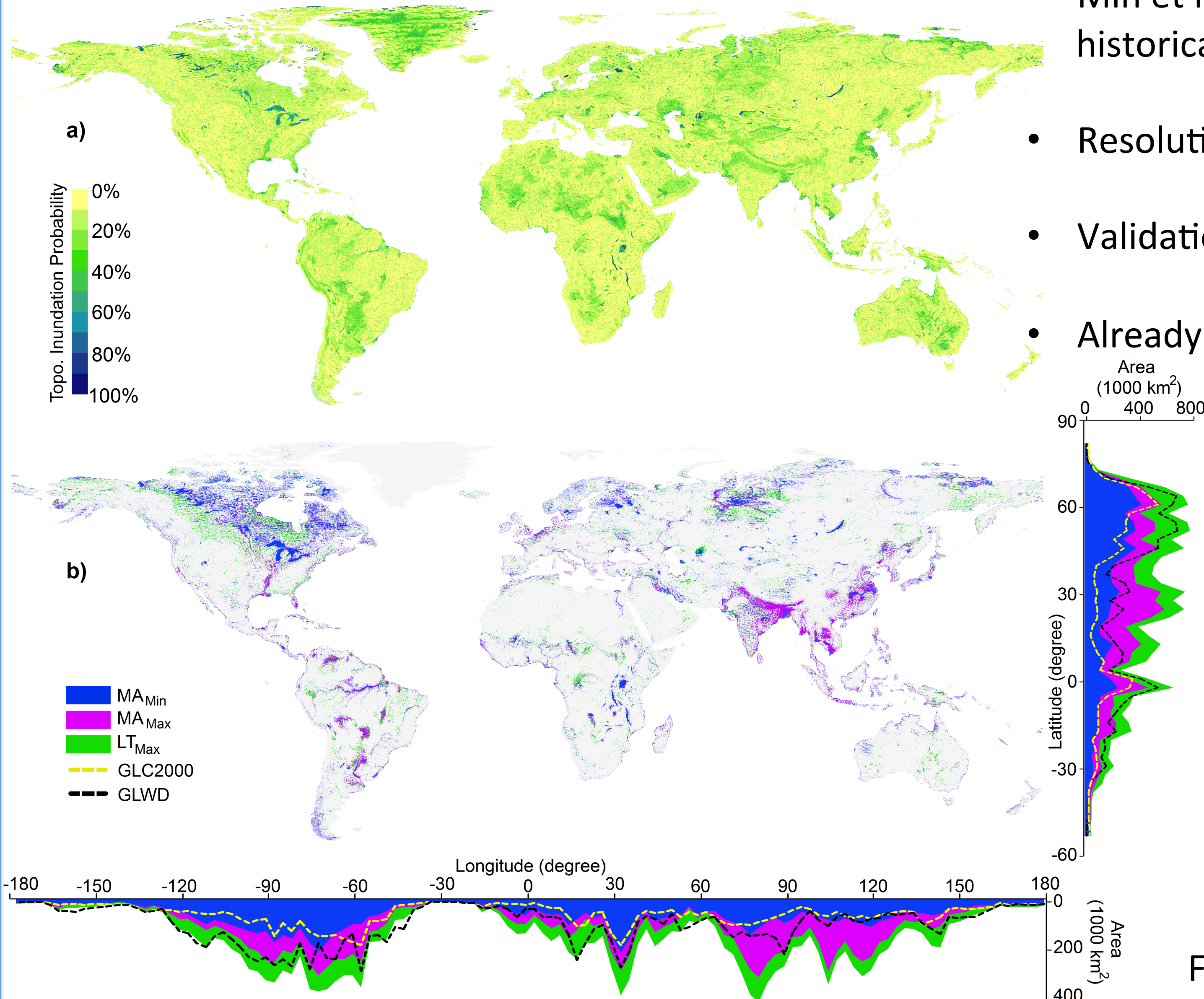
For SWOT:

- Could use combination of GSWO and GIEMS-D3
  - Binary or probability forms
- GIEMS-D3 could be downscaled using SWOT retrievals (or SAR) when available: coherent backward extrapolation in time
- Floodability index from topography could also be used as a priori

Backup slides

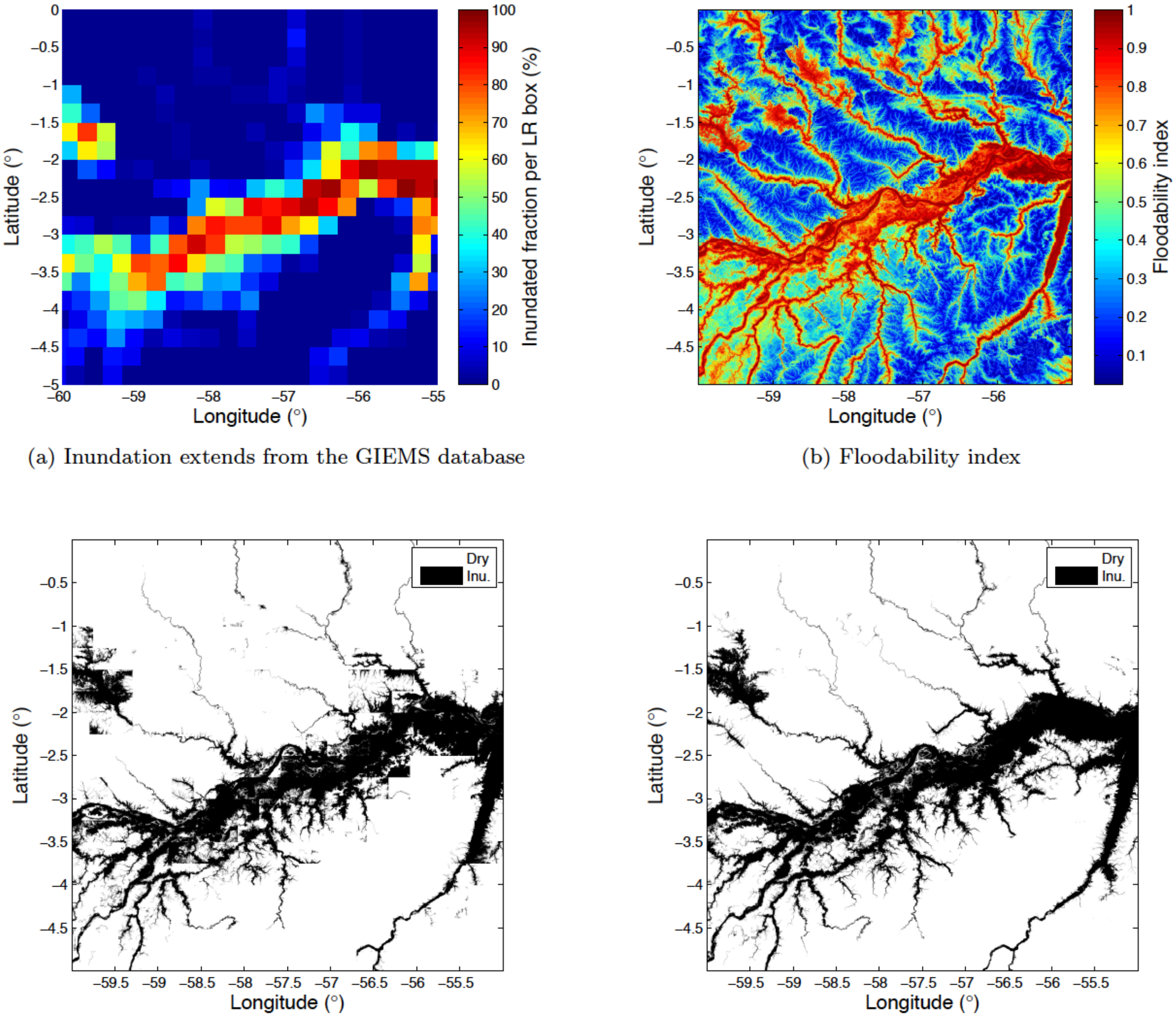
GIEMS-D15

- Downscaling de GIEMS base using topography (Hydroshed)
- Min et Max over GIEMS historical record
- Resolution of 250m
- Validation over several basins
- Already used by many groups



Fluet et al., RSE, 2015

GIEMS-D3



(a) Inundation extends from the GIEMS database

(b) Floodability index

(c) Downscaled map without smoothing procedure

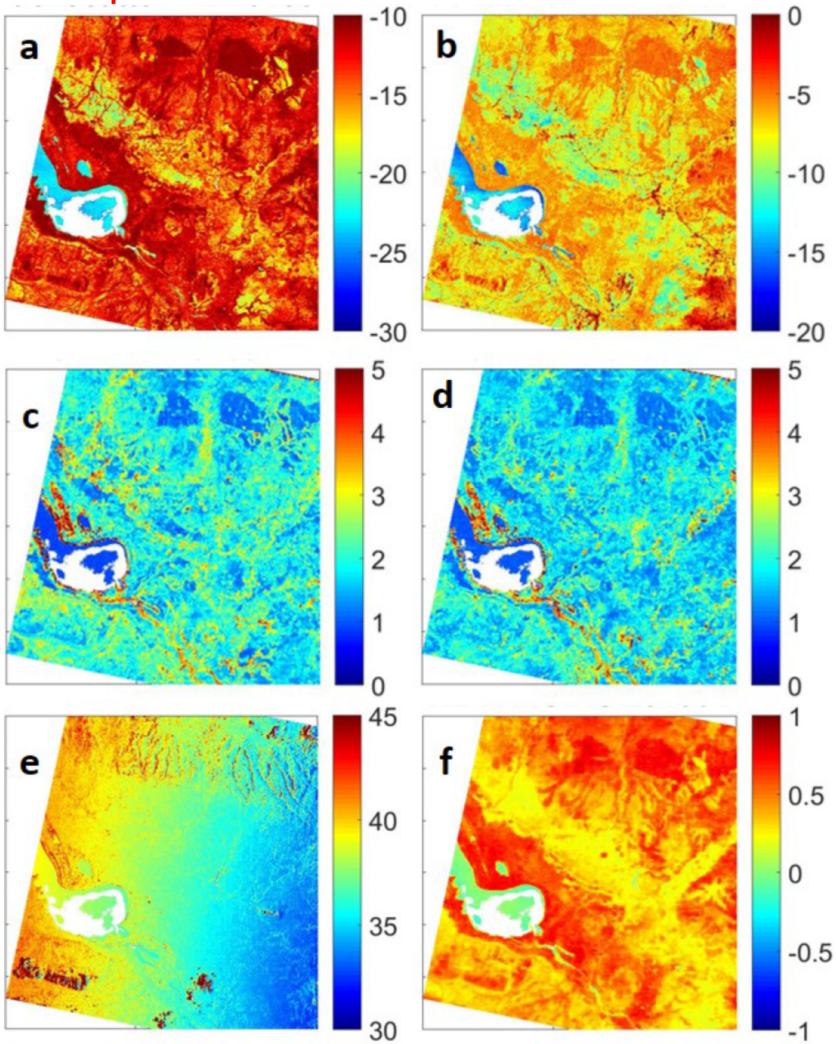
(d) Downscaled map with smoothing procedure

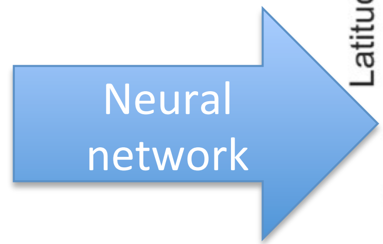
Smoothing

FIG. 3. Illustration of the downscaling procedures in the Amazon (0-5°S, 55-60°W)

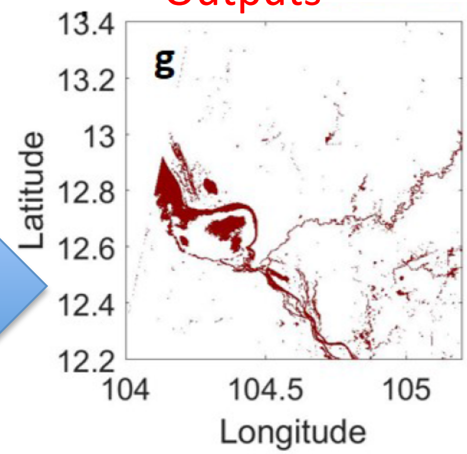
SAR/Sentinel-1 retrieval scheme

6 inputs





Outputs



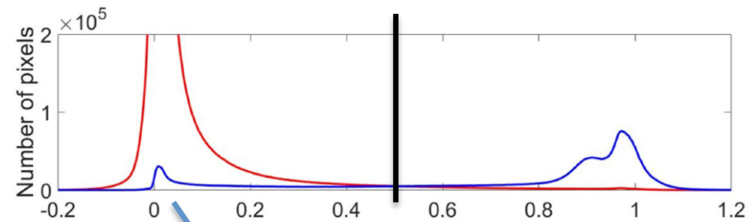


Figure 8: Same as Figure 7 but without equalizing the training dataset.

	Non-water(0) (Predicted)	**Water**(1) (Predicted)
Non-water(0) (Actual)	98.5%	1.5%
Water(1) (Actual)	16%	84%

SAR / LANDSAT

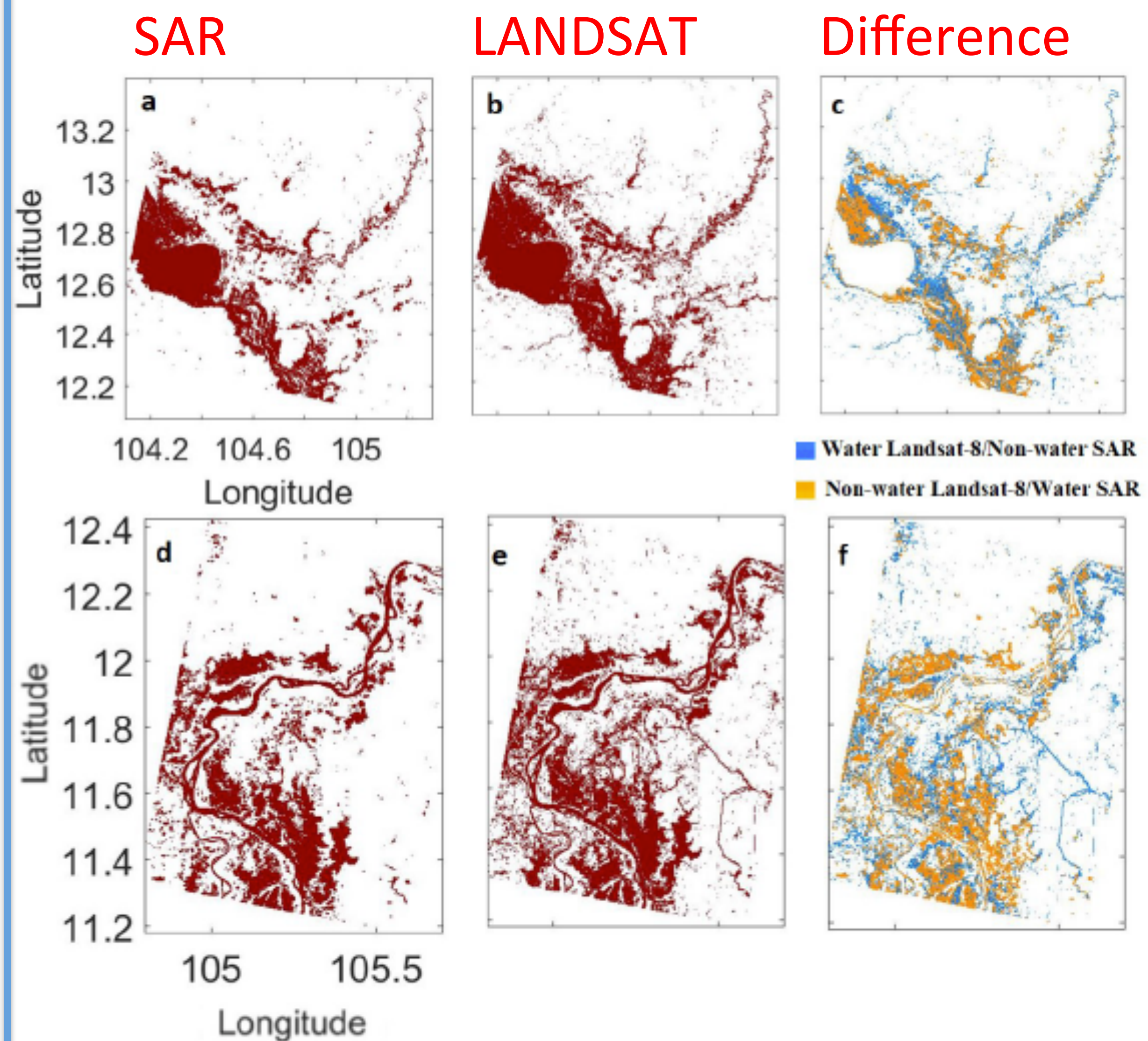


Figure 10: **(a)** and **(d)** SAR surface water maps; **(b)** and **(e)** Landsat-8 surface water maps; and **(c)** and **(f)** their differences; over the Tonle Sap Lake in November, 2015 (top), and over the Mekong river in October, 2015 (bottom).

SAR / MODIS

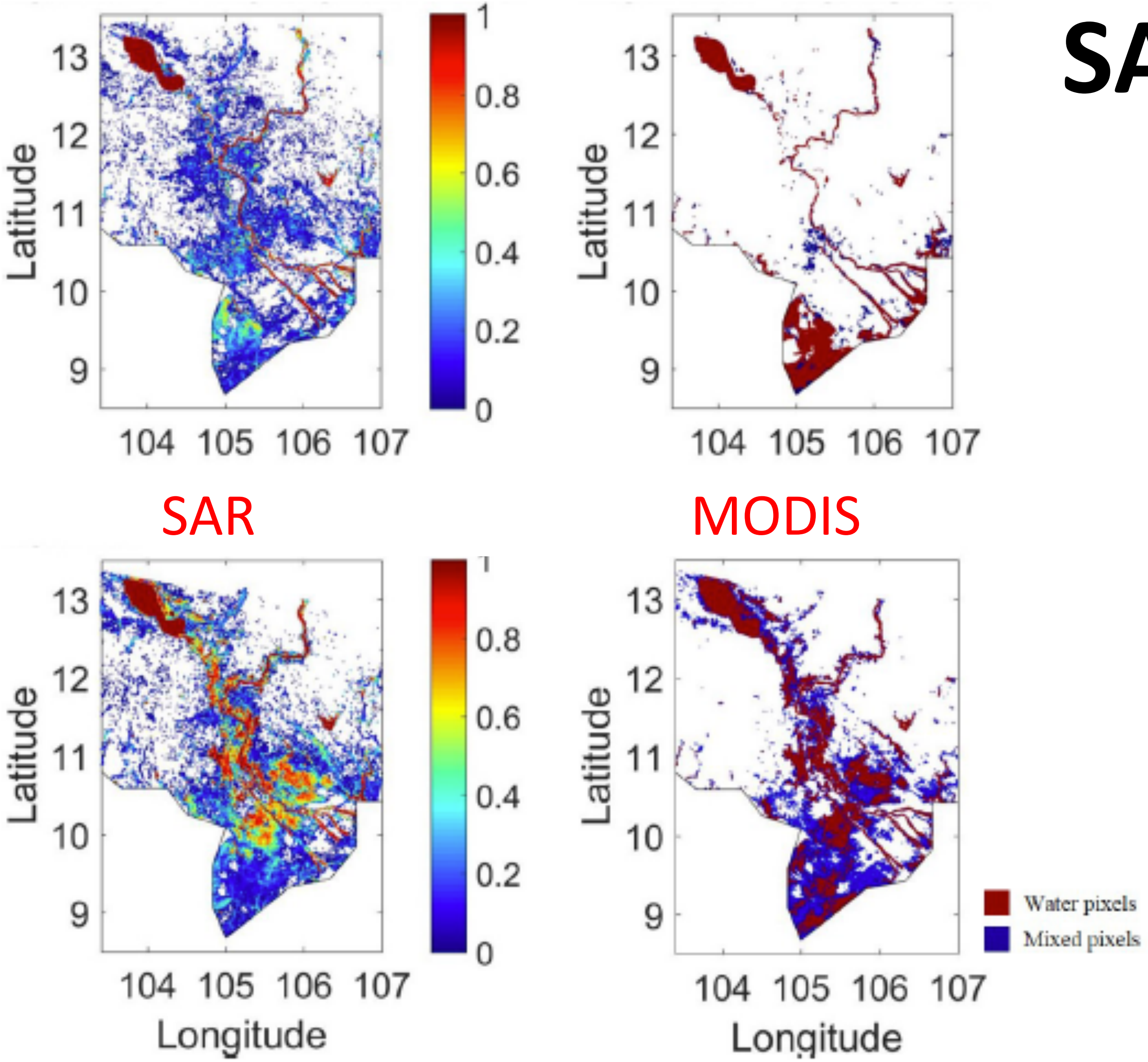


Figure 14: SAR (left) and MODIS (right) surface water maps at 500 m resolution over the Mekong delta in May (top) and October (bottom) 2015.

Floodability index

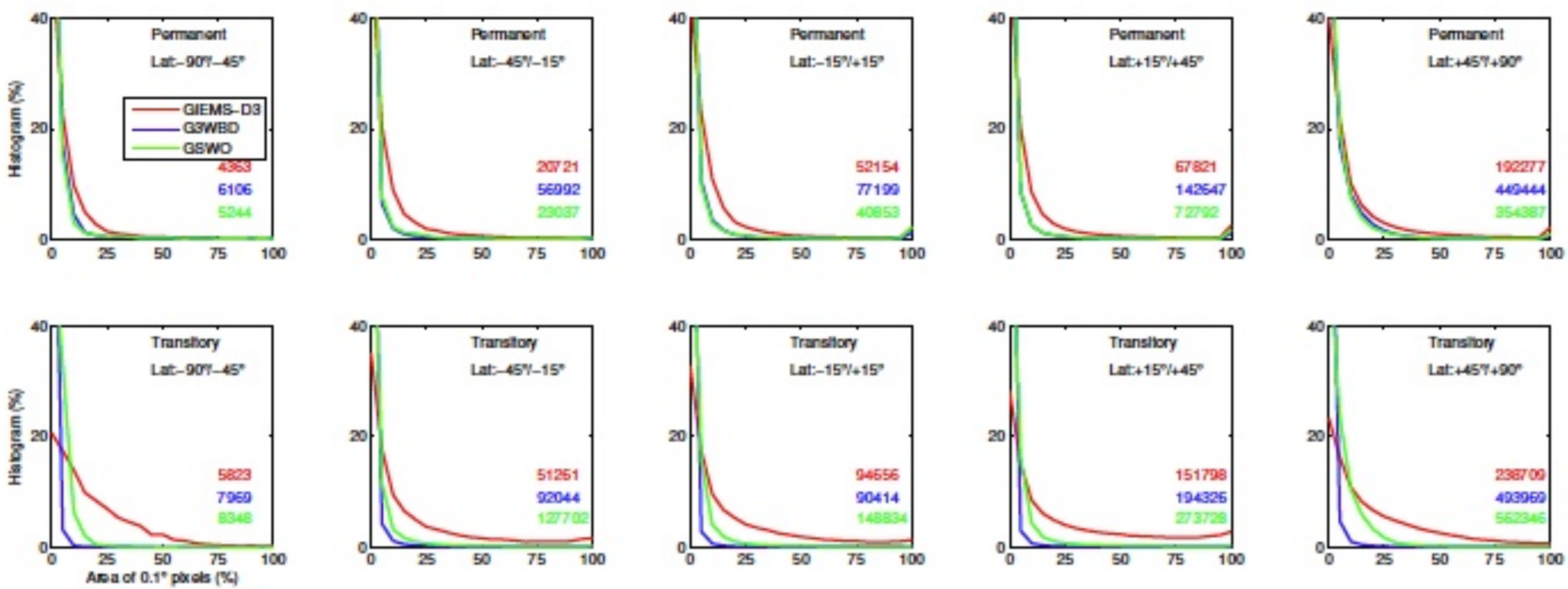


Figure 5: Histogram of the permanent (TOP) and transitory (BOTTOM) surface water percentage over 0.1°× 0.1° pixels, for GIEMS-D3, G3WBM, and GSWO. From left to right: for -90°/-45°, -45°/-15°, -15°/+15°, +15°/+45°, and +45°/+90° latitudinal bands. The number of 0.1°× 0.1° pixels for each dataset is also indicated.