Terrestrial Water Dynamics over the Congo Basin from GRACE and Other Remote Sensing Measurements

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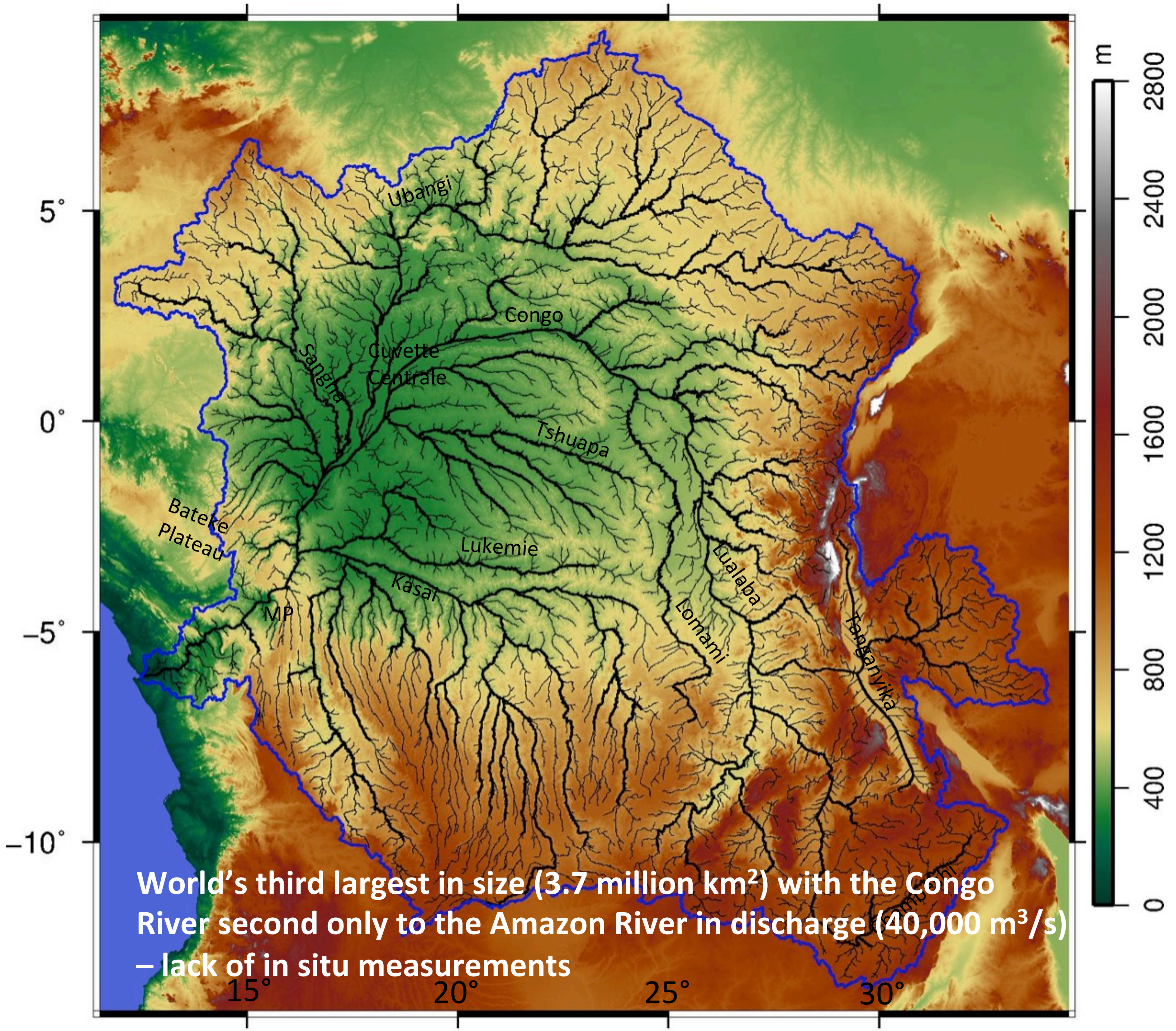

Ubangi
Congo
Cuvette Centrale
Sangha
Tshuapa
Bateke Plateau
Lukemie
Kasai
MP
Lualaba
Lomami
Tanganyika
5°
0°
−5°
−10°
15°
20°
25°
30°
m
2800
2400
2000
1600
1200
800
400
0
World's third largest in size (3.7 million km^2) with the Congo River second only to the Amazon River in discharge (40,000 m^3/s) – lack of in situ measurements

Study Objective I

- **How much water is stored and drained from the Congo wetlands?**

- **Where does the water come from?**

- **Datasets**
  - Total storage anomalies from GRACE RL05 (CSR, GFZ, JPL products)
  - River storage anomalies from Envisat altimeter and GRFM
  - Precipitation (P) from GPCP
  - Model-based Evapotranspiration (ET) from Hillslope River Routing (HRR) (Beighley et al., 2009)
  - Hydrological maps from HydroSHEDS (Lehner and Döll, 2004)
  - Inundated area from GRFM mosaic, SRTM and MODIS mosaic (Jung et al., 2010)

Lee et al., RSE, 2011

Study Objective II

- **What is the control of total storage changes over the central Congo? Surface or subsurface storage changes?**

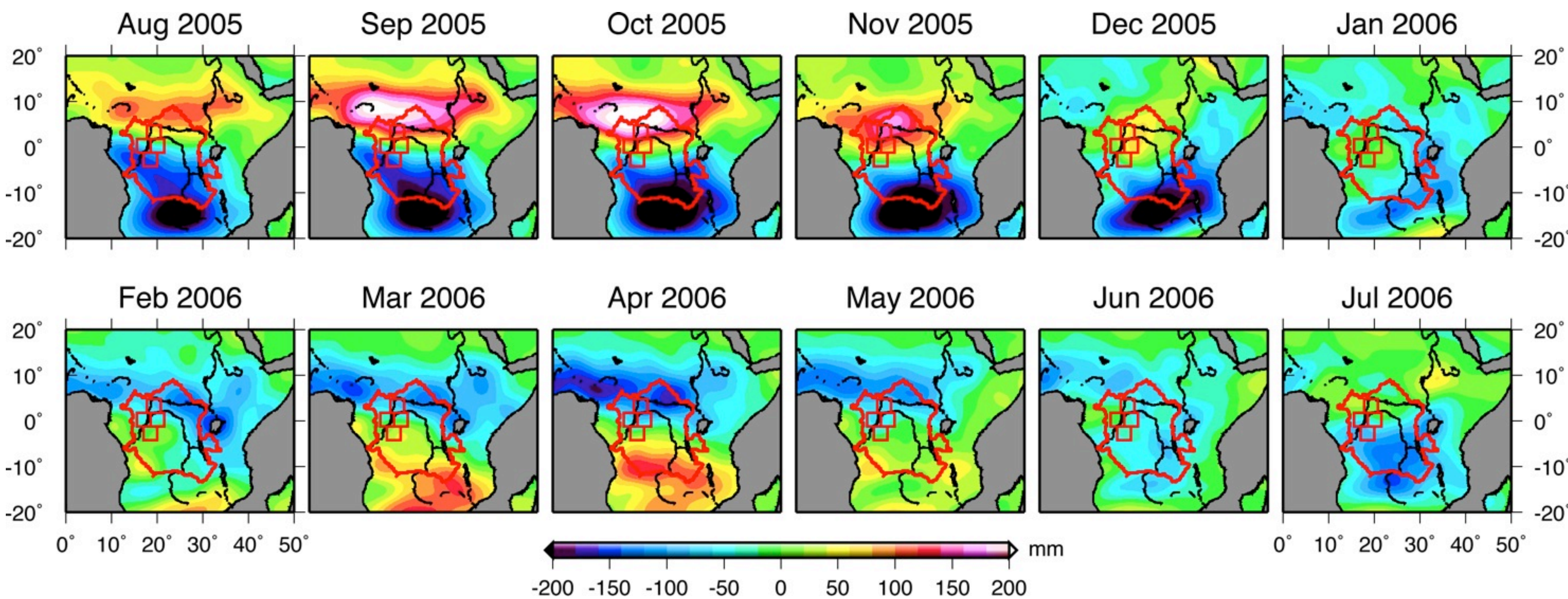
- **Datasets**
  - Total storage anomalies from GRACE RL05 (CSR, GFZ, JPL products)
  - Water height changes from Envisat
  - Changes in flooded extents from ALOS PALSAR ScanSAR images

Study Objective I

- **How much water is stored and drained from the Congo wetlands?**

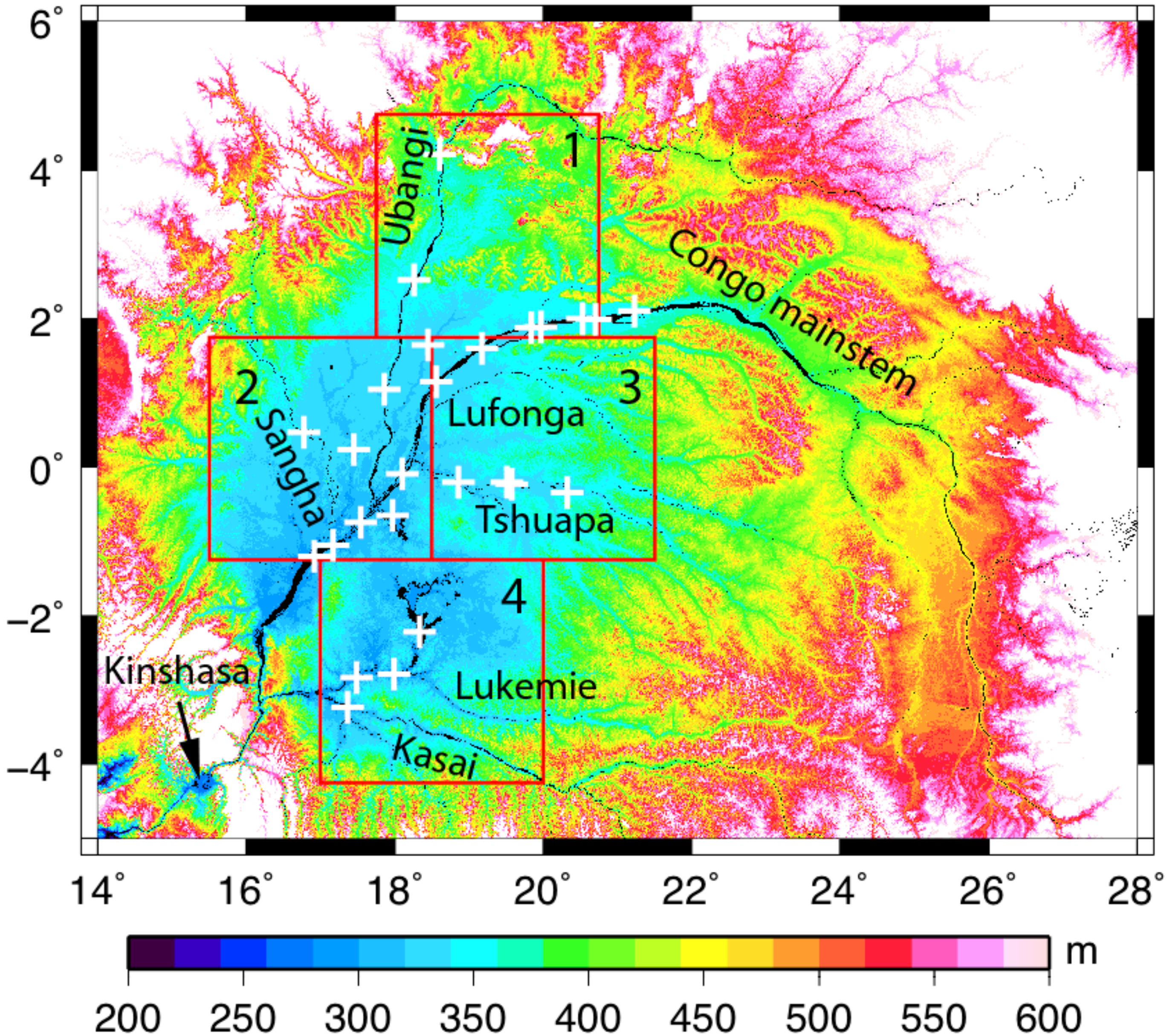
- **Where does the water come from?**

GRACE Measurements over the Congo



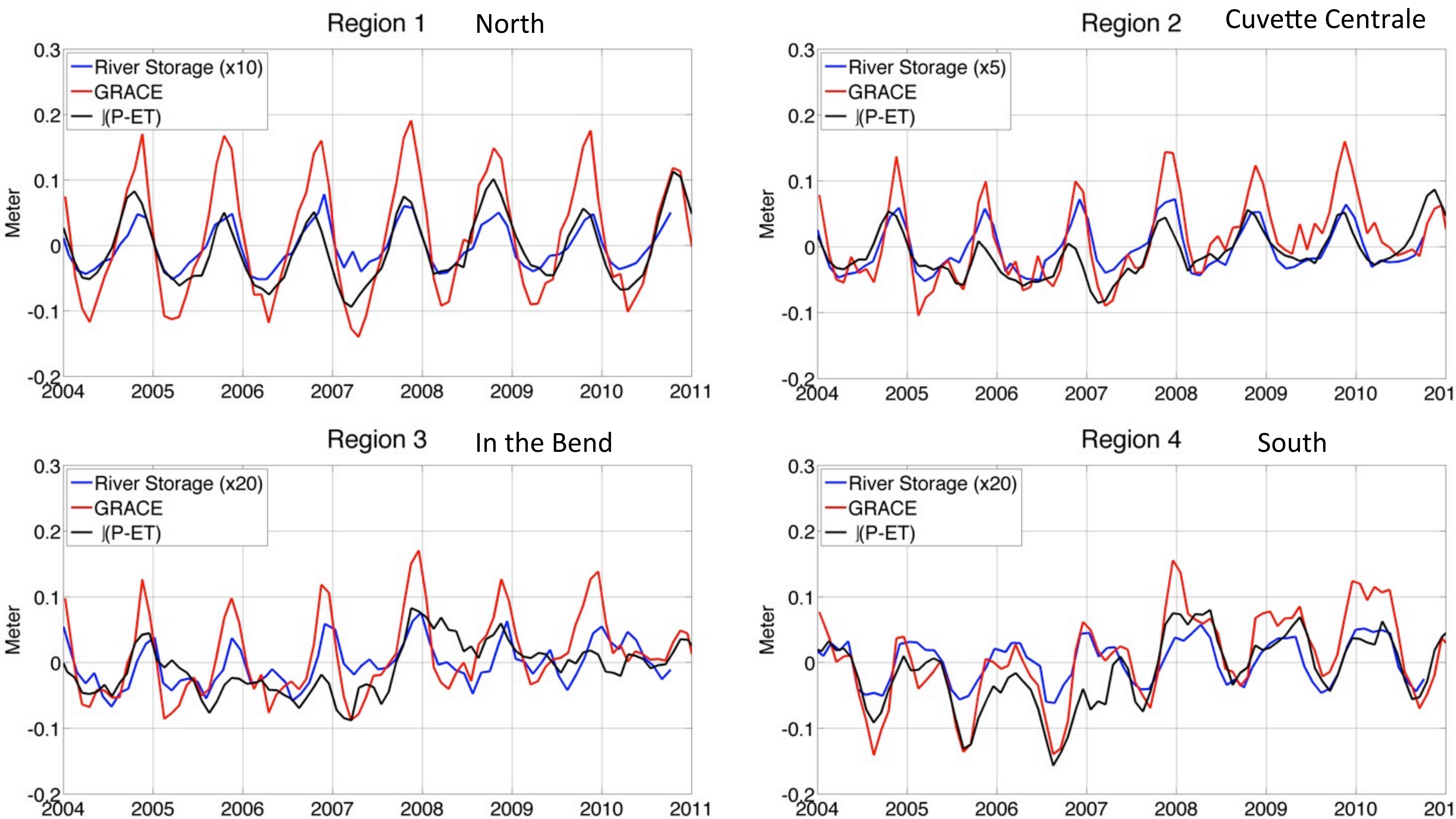
- Monthly Equivalent Water Height (EWH) anomalies from the CSR GRACE product after decorrelation (Duan et al., 2009) and 3-degree radius Gaussian smoothing (Guo et al., 2010).
- Congo Basin is shown with a red outer boundary. Red rectangles indicate study regions.
- Notice that red-positive anomalies are well timed with the locations of the ITCZ, e.g., rainfall during Feb-May in south and rainfall in Sep-Nov in north.

Study Areas



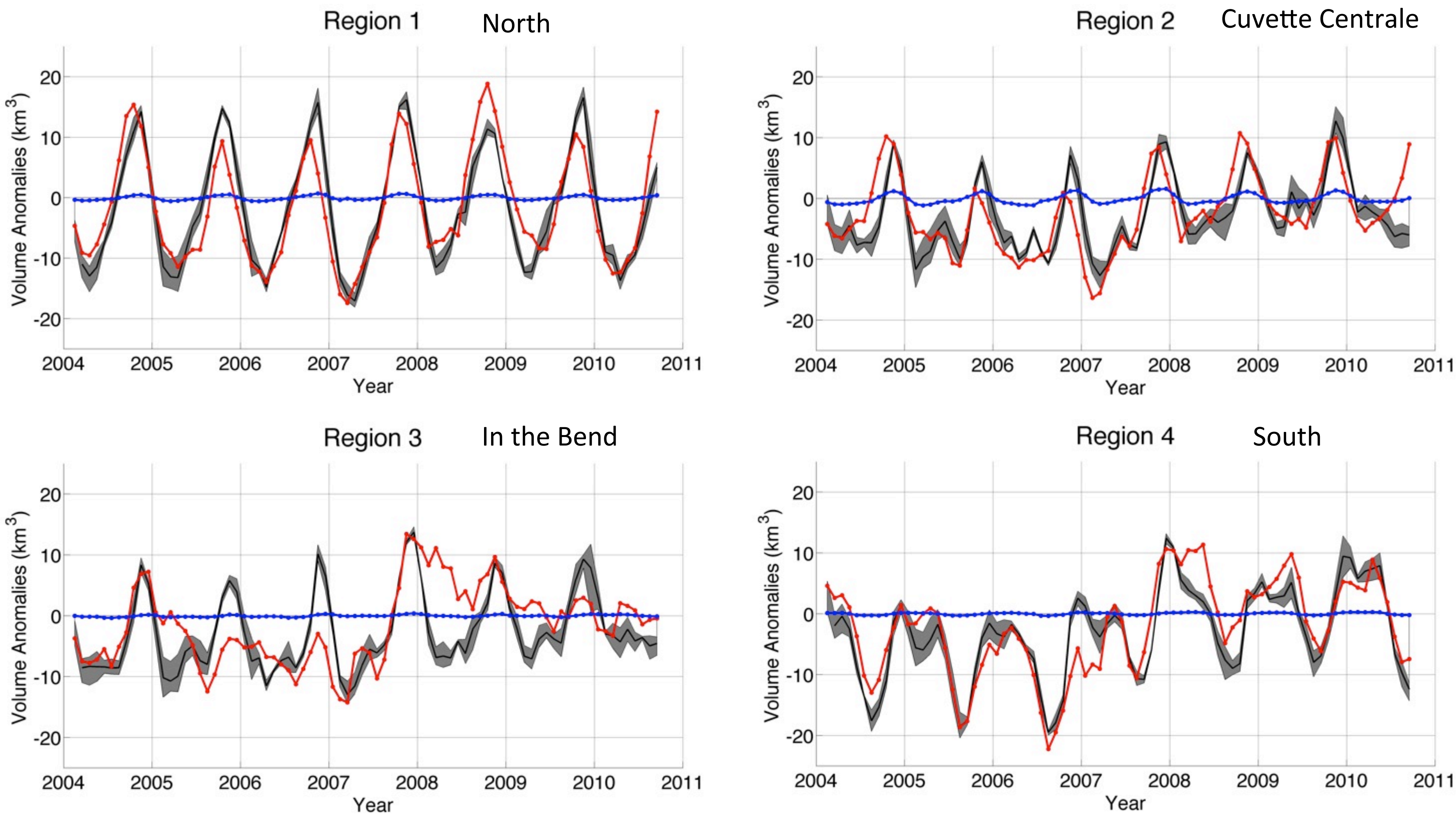
6°
4°
2°
0°
−2°
−4°
14°
16°
18°
20°
22°
24°
26°
28°
1
2
3
4
Ubangi
Congo mainstem
Sangha
Lufonga
Tshuapa
Kinshasa
Lukemie
Kasai
m
200
250
300
350
400
450
500
550
600

Congo GRACE, P-ET, and River Storage Anomalies



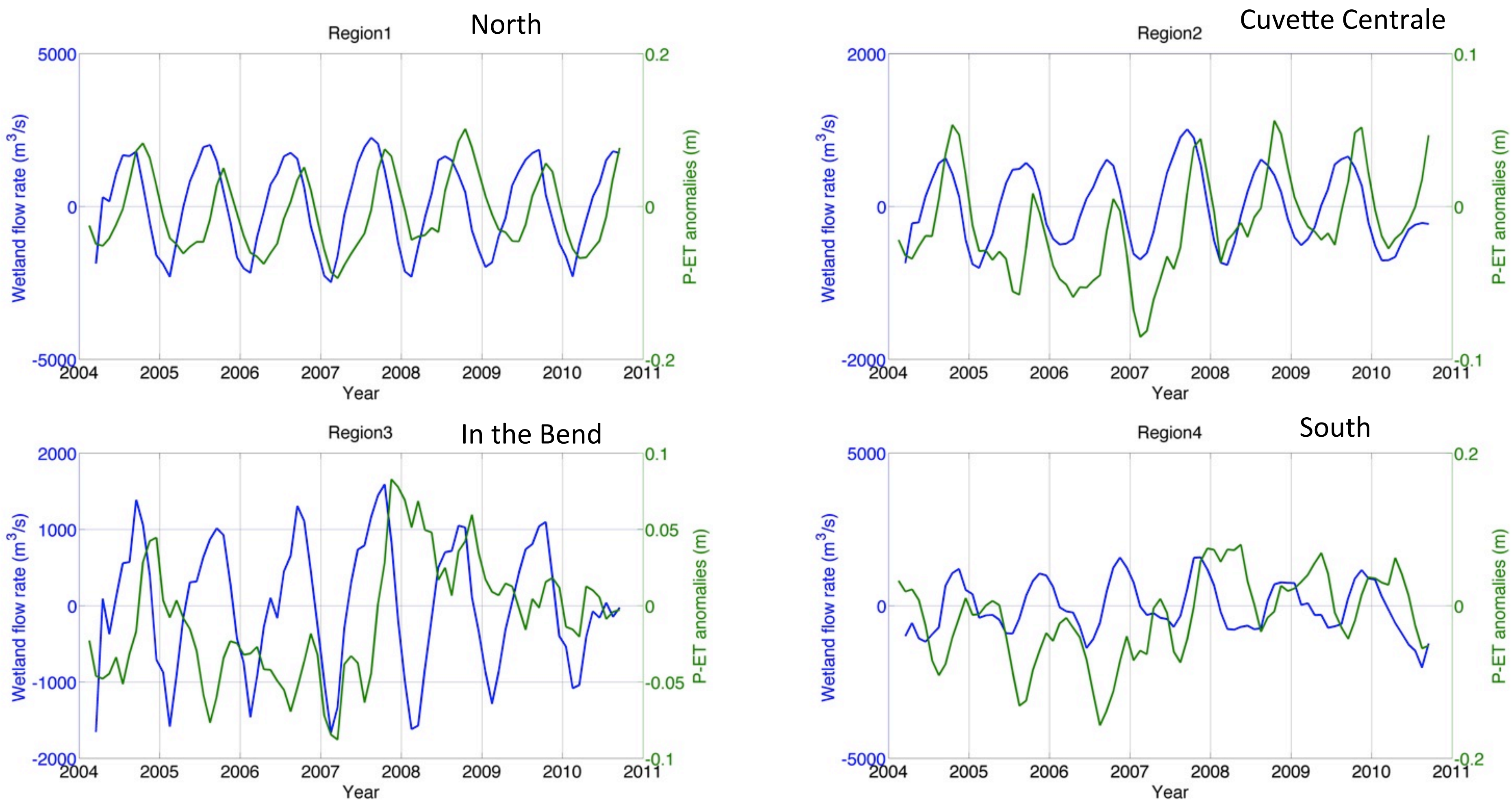
- All three observations are well timed, but river storage can not account for the GRACE anomalies (rivers have a multiplier) whereas P-ET amplitudes are closer to GRACE.
- Given the amplitudes and timing, processes that are driven by P-ET are likely responsible for the GRACE anomalies, e.g., wetland water storage.

Wetland Volume Anomalies



- River anomalies in blue, P-ET driven runoff to wetlands in red, 3 GRACE datasets in grey with average in black
- Regions 1, 2 and 4: generally good agreement between GRACE and P-ET driven runoff
- Region 3: timing and amplitudes are not consistent
- Note Beighley et al. 2011 results showing poor match of some satellite rainfall data and gauge discharge

Wetland Flow Rates from GRACE



- Wetland infilling and emptying rates from the temporal derivative of GRACE derived (blue) ΔS = Qin - Qout
- Regions 1, 2, 4: P−ET increases when wetland flux rates change from negative to positive, thus P−ET comes before the wetland filling. From a temporal perspective, the wetland infilling starts with the P−ET runoff from the surrounding uplands.
- When the wetland flux rates switch from positive to negative, P−ET is on the decreasing limb of the annual rainfall. This again is expected where the wetland receives the majority of its water from upland runoff.

Conclusion (1/2)

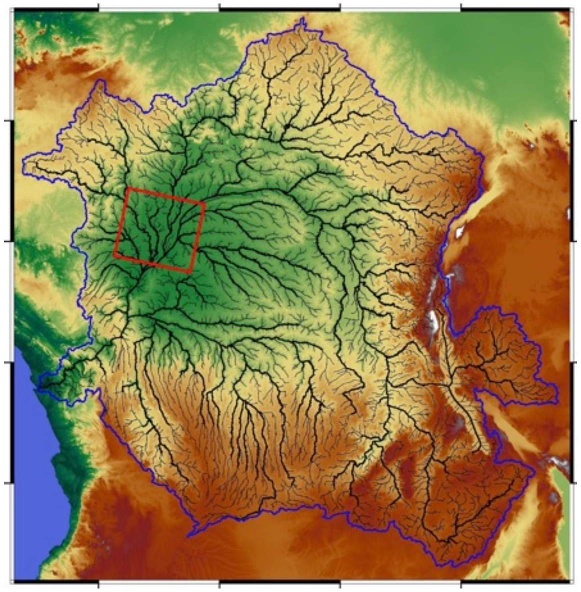
1) We find that the amount of water annually filling and draining the Congo wetlands is 111 ± 5 km^3, which is about one-third the size of the water volumes found on the mainstem Amazon floodplain (Alsdorf et al., 2010).

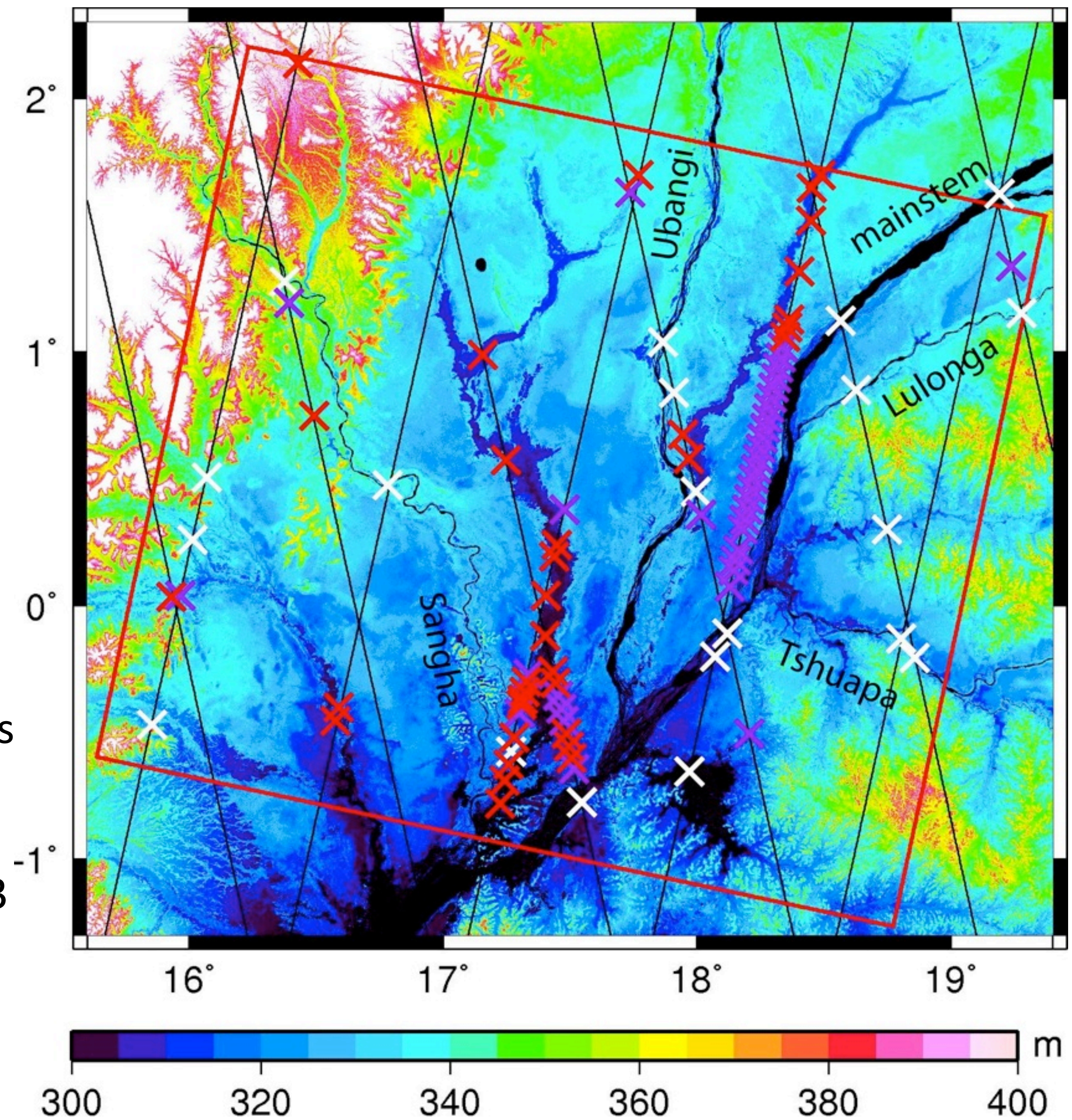
2) Based on amplitude comparisons among the water volume changes and timing comparisons among their fluxes, we conclude that the local upland runoff is the main source of the Congo wetland water, not the fluvial process of the river-floodplain water exchange as in the Amazon.

Study Objective II

What is the control of total storage changes over the central Congo?

ScanSAR Coverage with Envisat Tracks

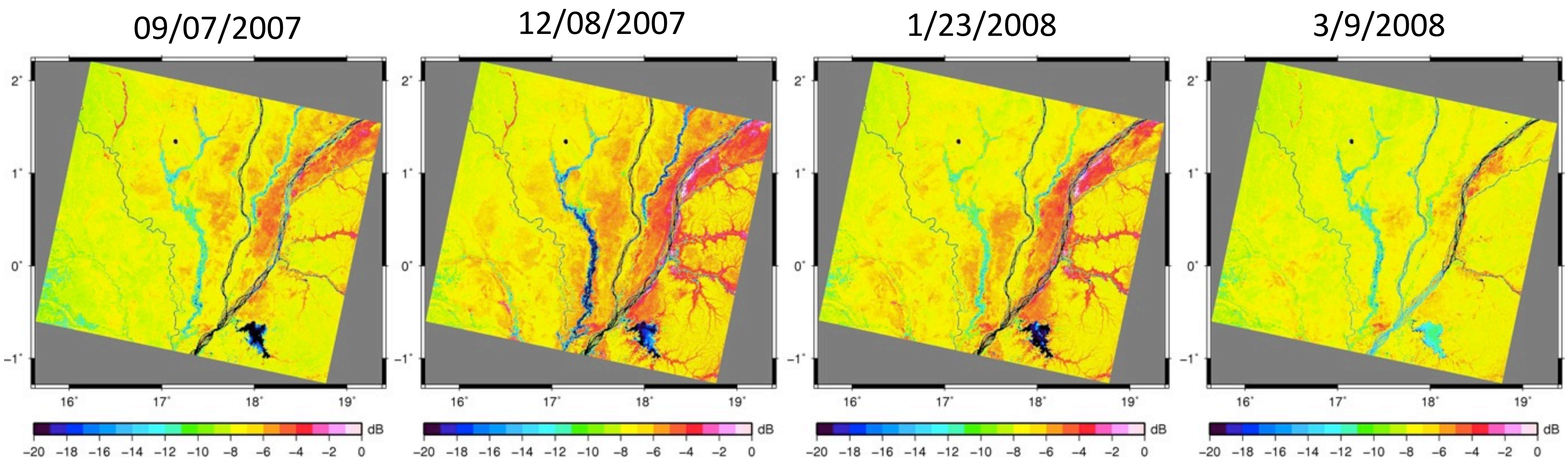




ALOS PALSAR L-band ScanSAR images

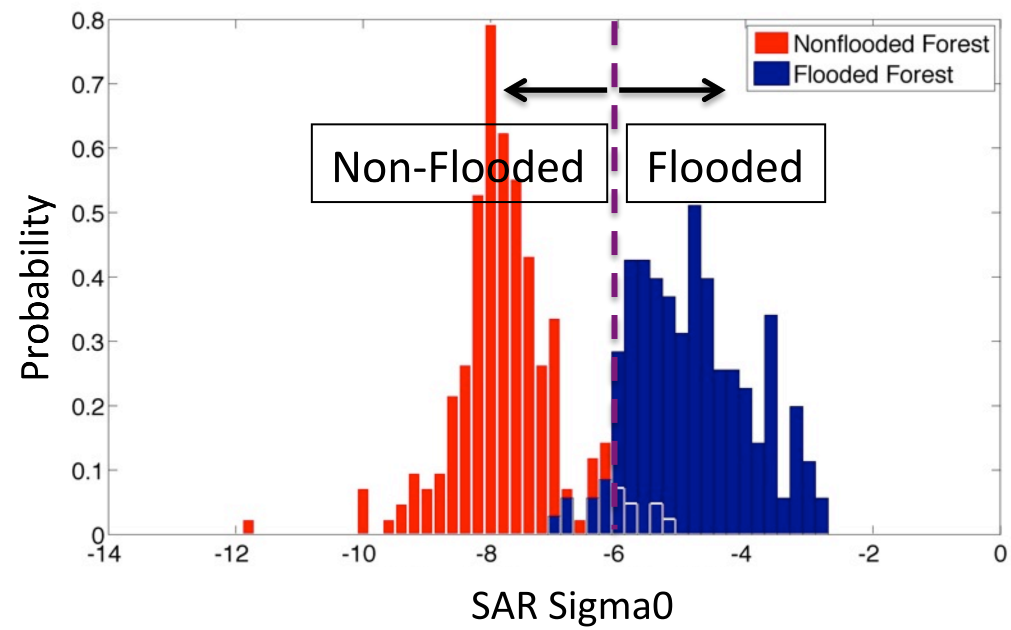
- 350 km swath width
- 100 m spatial resolution
- speckle noise reduced by 3x3 median filter

ScanSAR Backscattering Coefficients

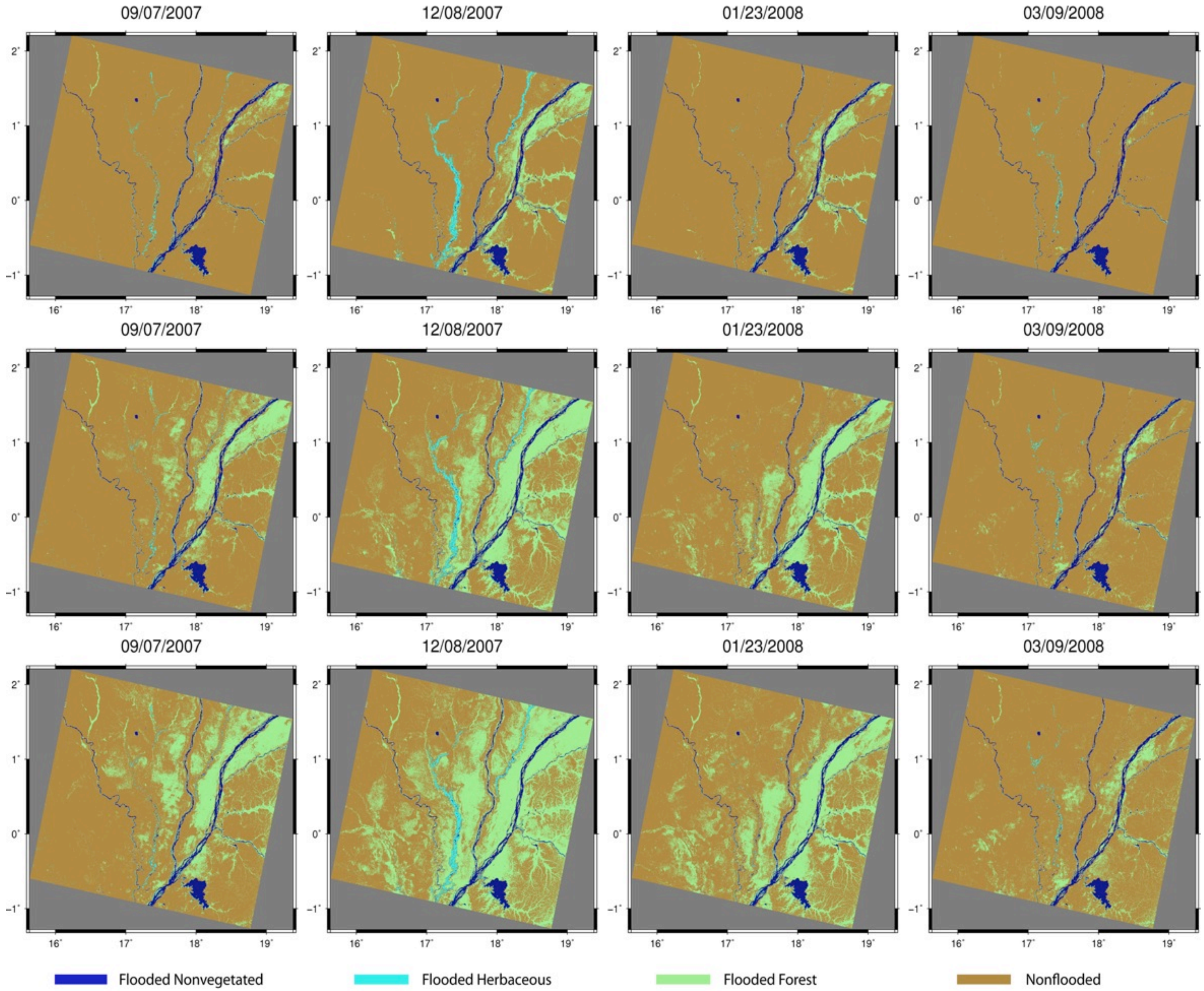


Open water: MODIS-derived land cover map (Hansen et al., 2008)

Herbaceous: SAR $\sigma_0 < -14$ dB following Hess et al., 2003 for Amazon



Classification of Inundated Areas

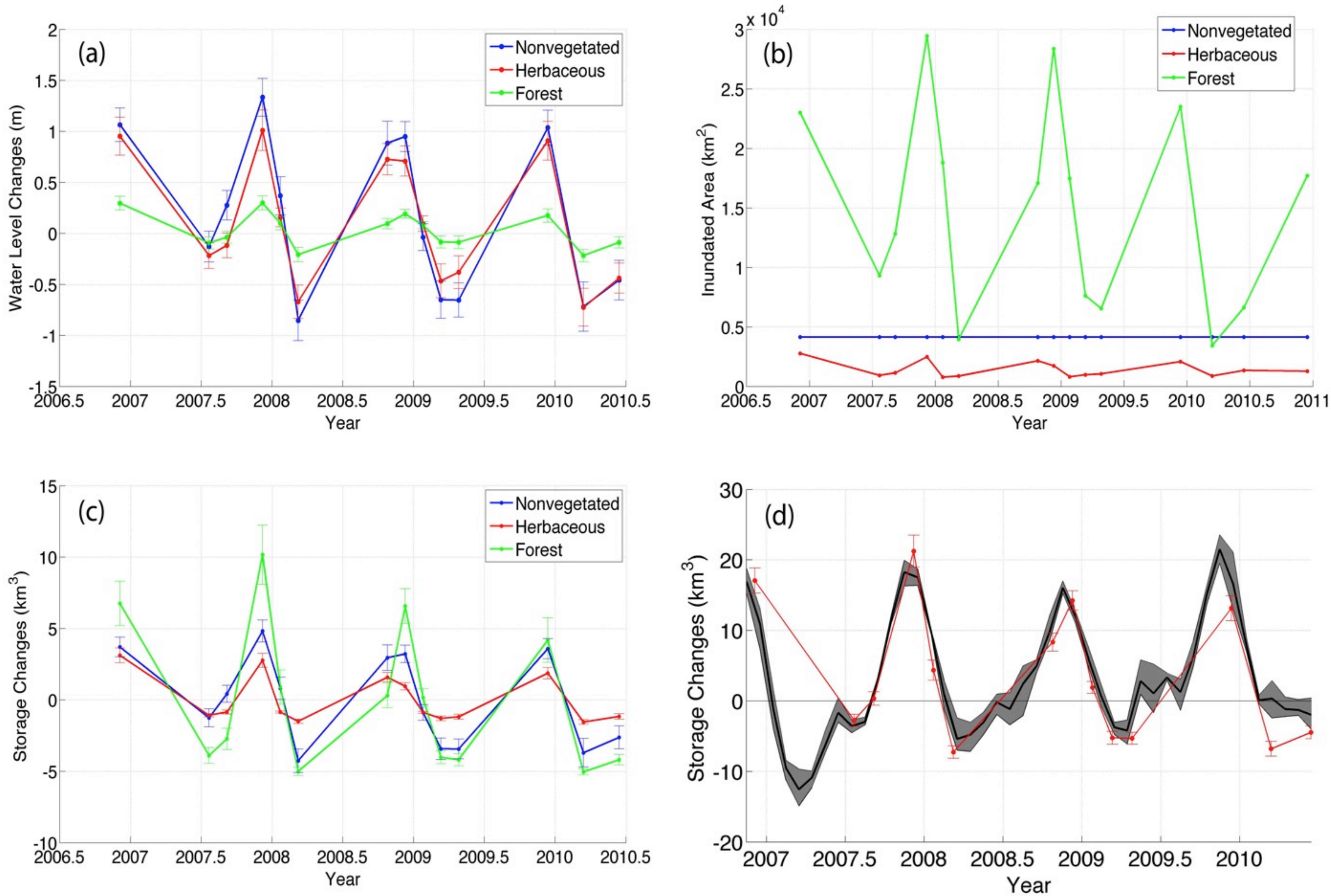


Using -4.6 dB
Rosenqvist 2008

Using -6.0 dB
This study

Using -6.5 dB
Hess et al., 2003

TWS and Surface Storage Anomalies



Conclusion (2/2)

1) The annual variations of the TWS changes over the central Congo during the period of 2007 – 2010 range between 21 km^3 and 31 km^3, and mostly controlled by surface storage changes.

2) Our result is in contrast with a study over the Negro River Basin (Frappart et al., 2011), where the amplitude of the subsurface storage changes represents more than a third of the amplitude of TWS changes.