Improved Hydrological Loading Models in South-America: Analysis of 3D GPS Displacements using M-SSA

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- About 50% of the water is stored by surface water (rivers, flood plains…) in the Amazon river basin. This component is not included in most of global hydrology models (GLDAS, MERRA, etc.).
- We derive river storage variations by re-routing runoffs of these global hydrology models.
- We compute loading contributions due to atmosphere (ECMWF), induced ocean response (TUGOm) and hydrology (GLDAS and MERRA with or without the river model, but also derived from GRACE).
- We compare the seasonal variations (extracted with M-SSA) at of 247 permanent GNSS in South America (UNR/NGL solution).

Modelling surface water contribution

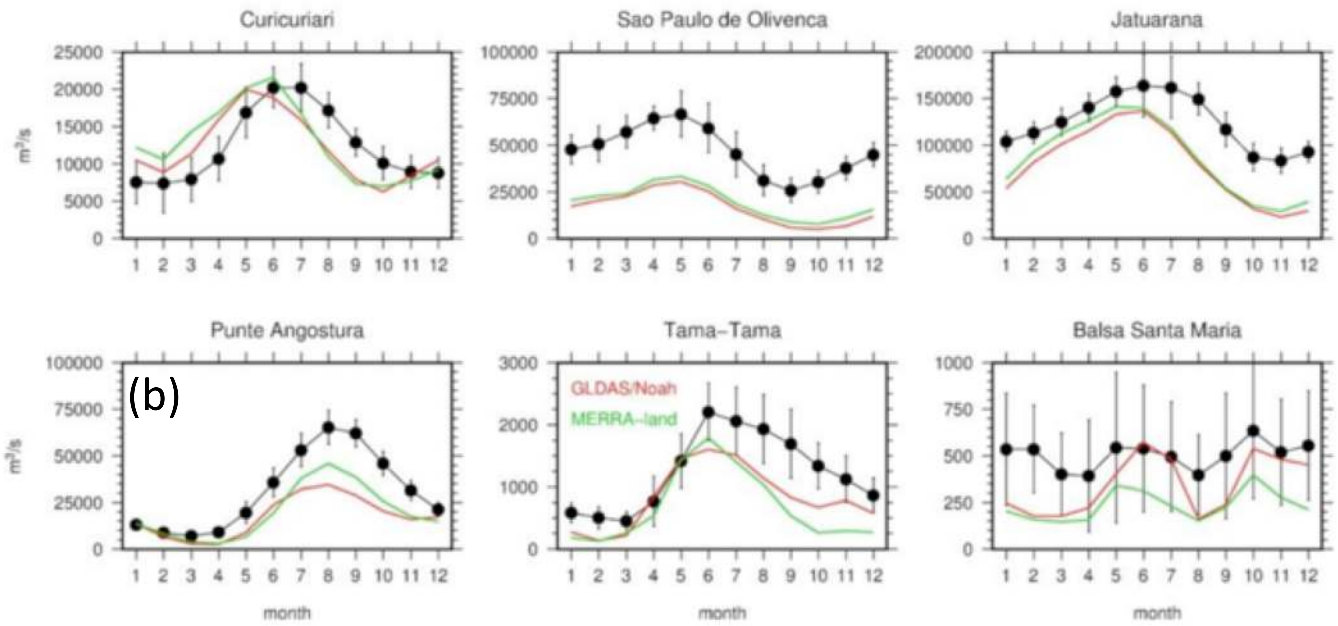
Water balance in hydrology models: $$\frac{\partial W}{\partial t} = P(t) - E(t) - Q(t)$$

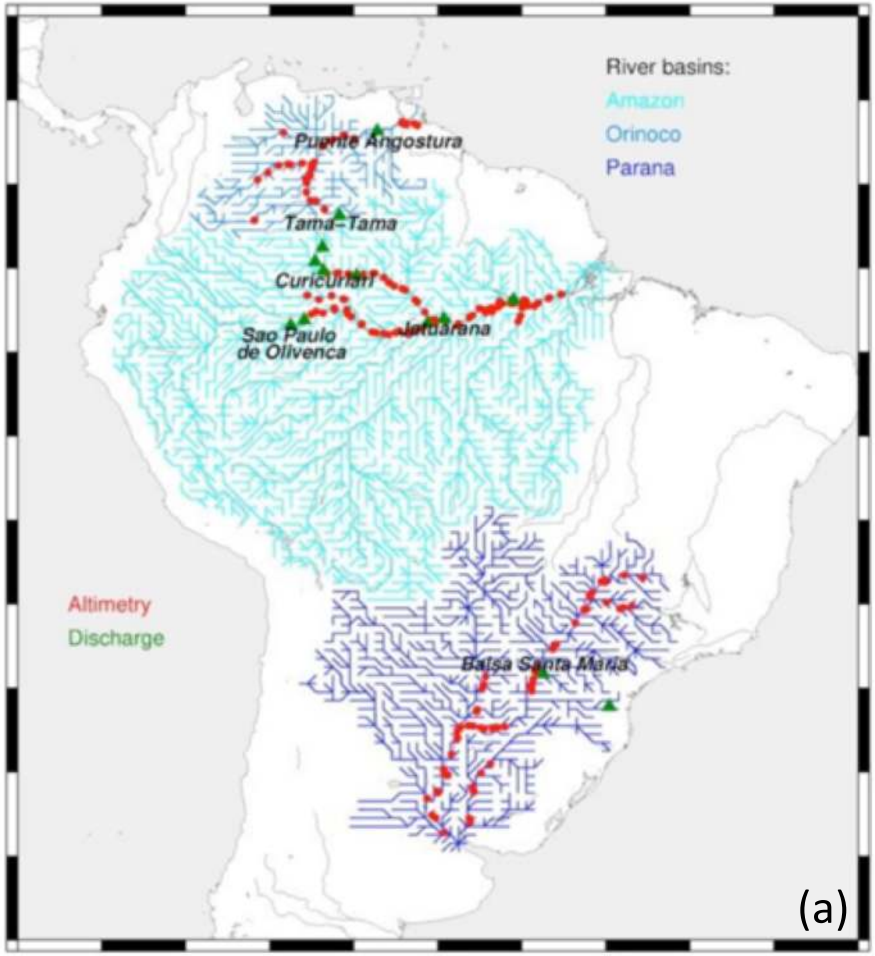
Re-routing of runoffs through rivers: $$\frac{\partial h}{\partial t} + \frac{u}{L} h(t) - \sum_i \frac{u_i}{L_i} h_i(t) = Q(t)$$

Hydrology models:
GLDAS/Noah & MERRA-land

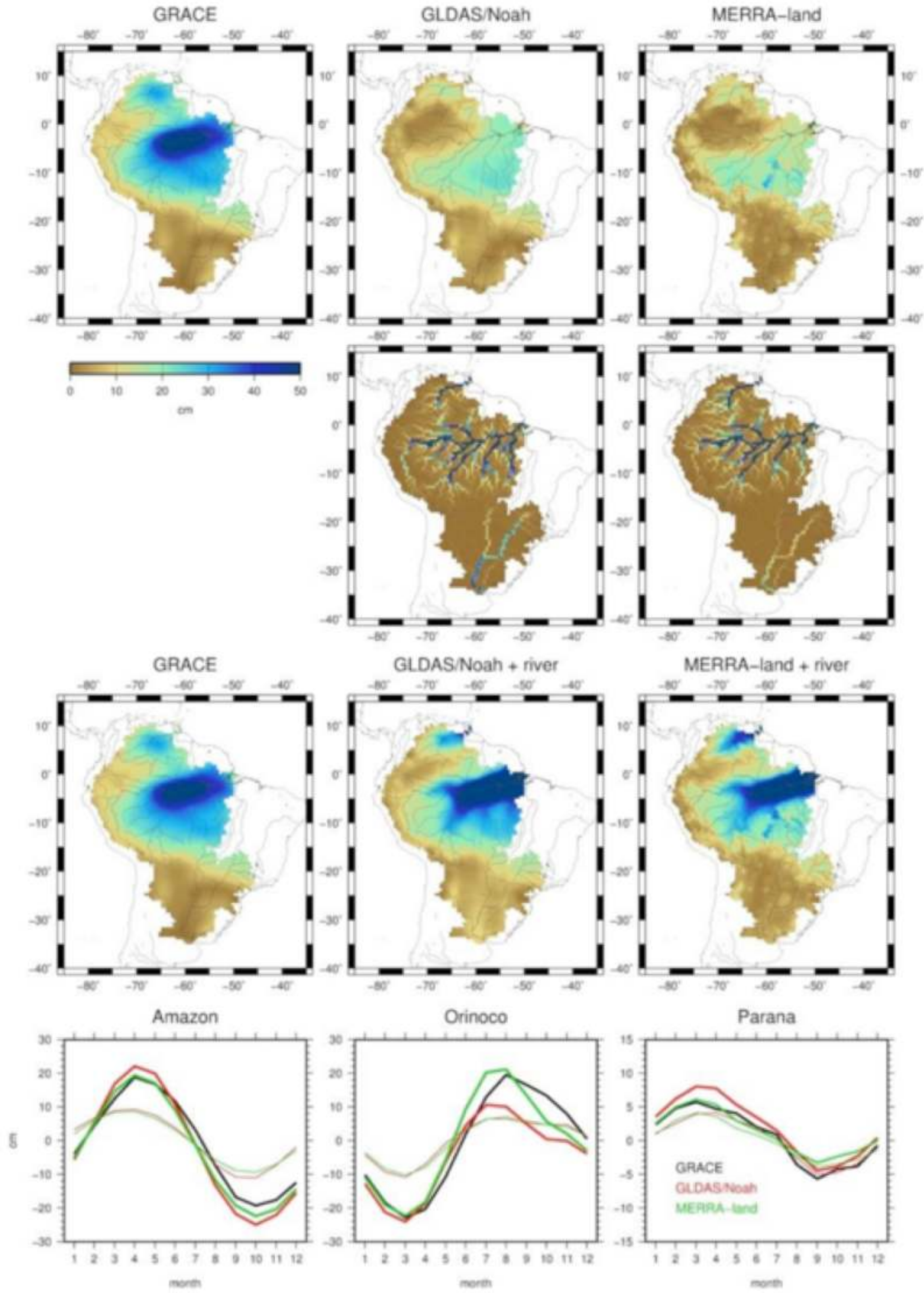
- The flow velocity *u* is the only unknown, and is adjusted using radar altimetry virtual station and MODIS imagery (a).
- Validation using water discharge observations (b).

(Oki et al., 1999; Han et al., 2010; Nicolas et al., 2021)





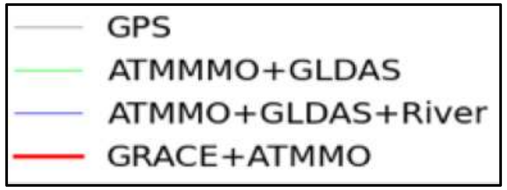
Total river basin storage



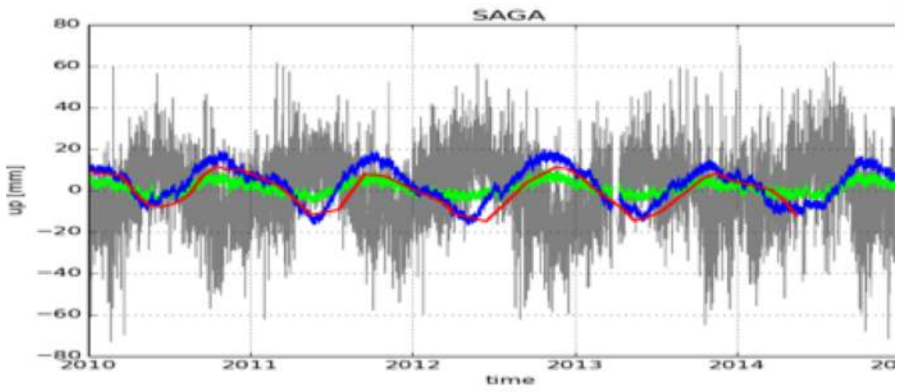
GRACE and modeled soil moisture (GLDAS/Noah & MERRA-land)

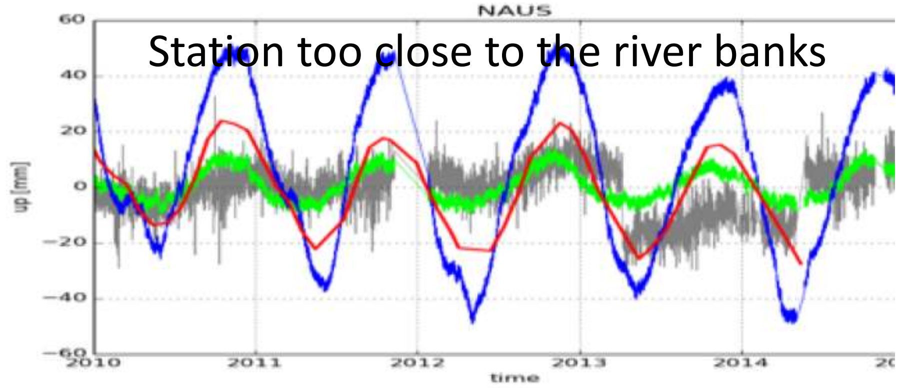
“high resolution” river storage

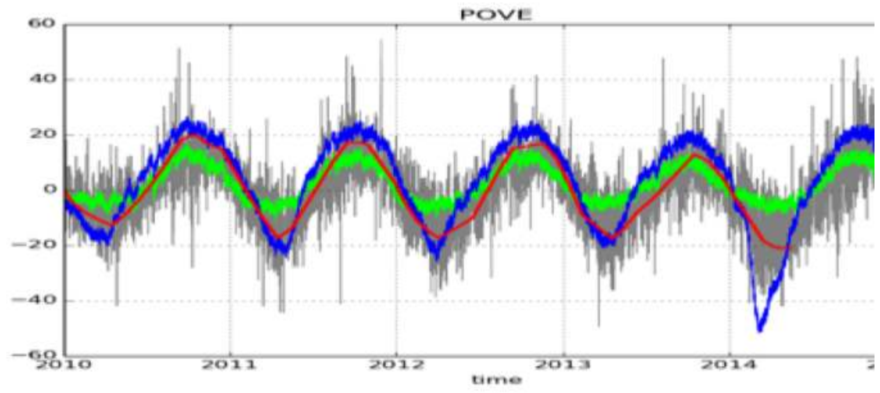
GRACE and total hydrology (GLDAS/Noah & MERRA-land + “filtered” rivers)

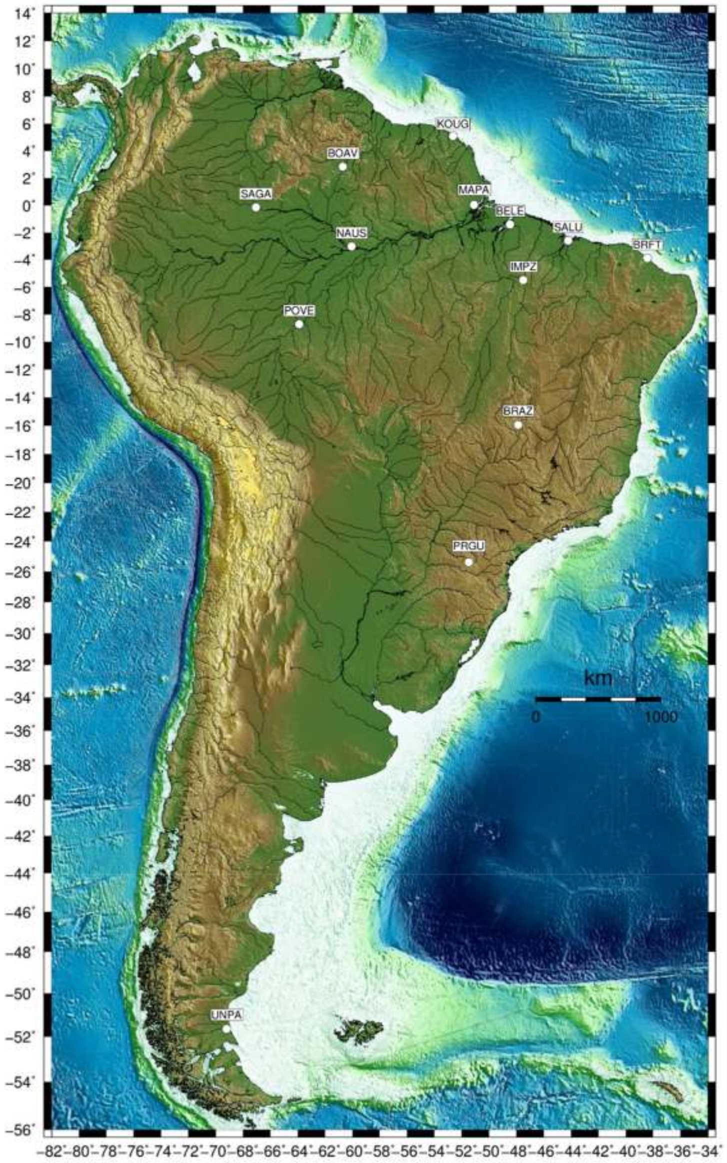


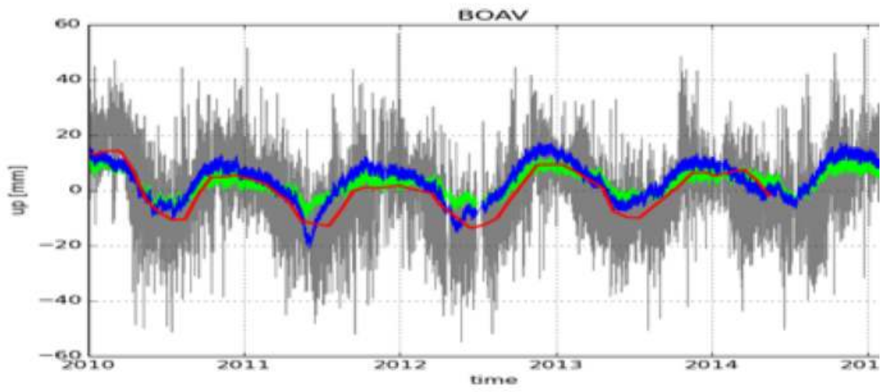
Vertical displacements (2010-2015)

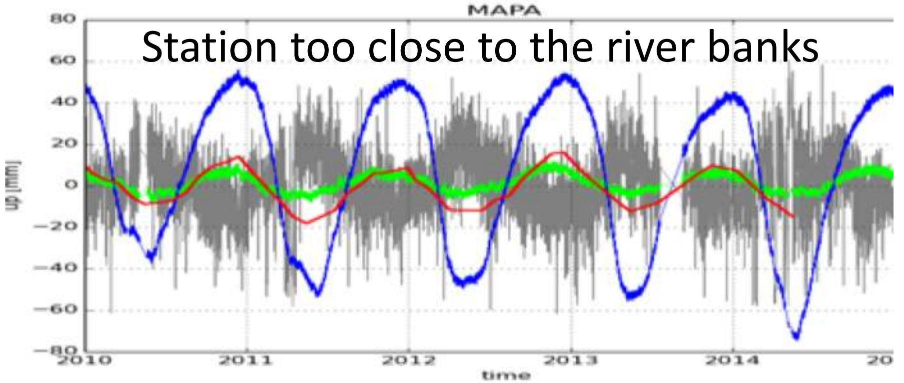


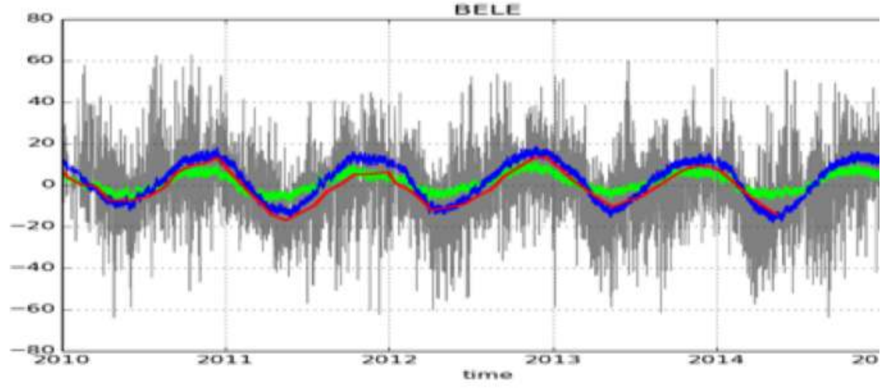




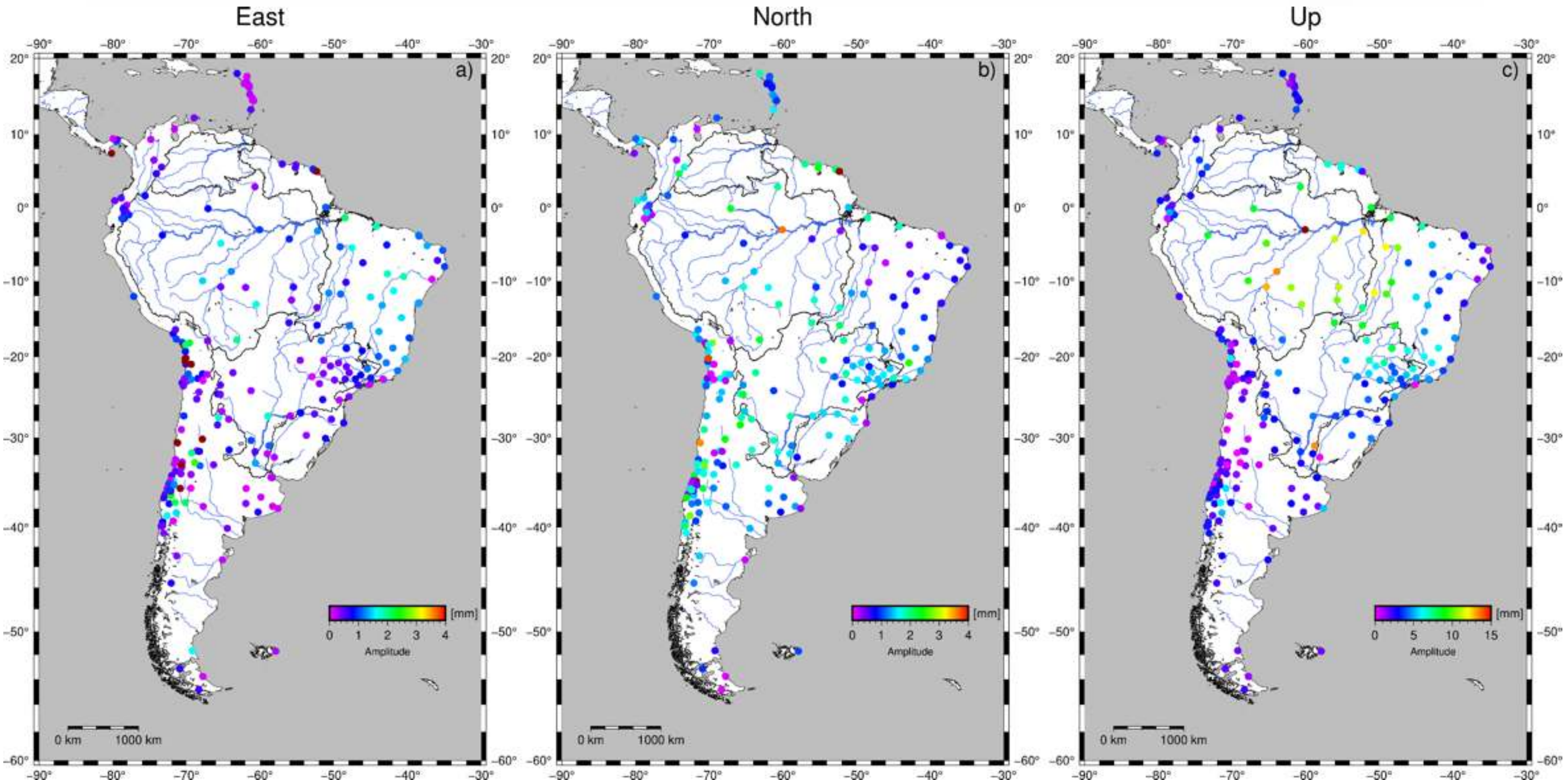




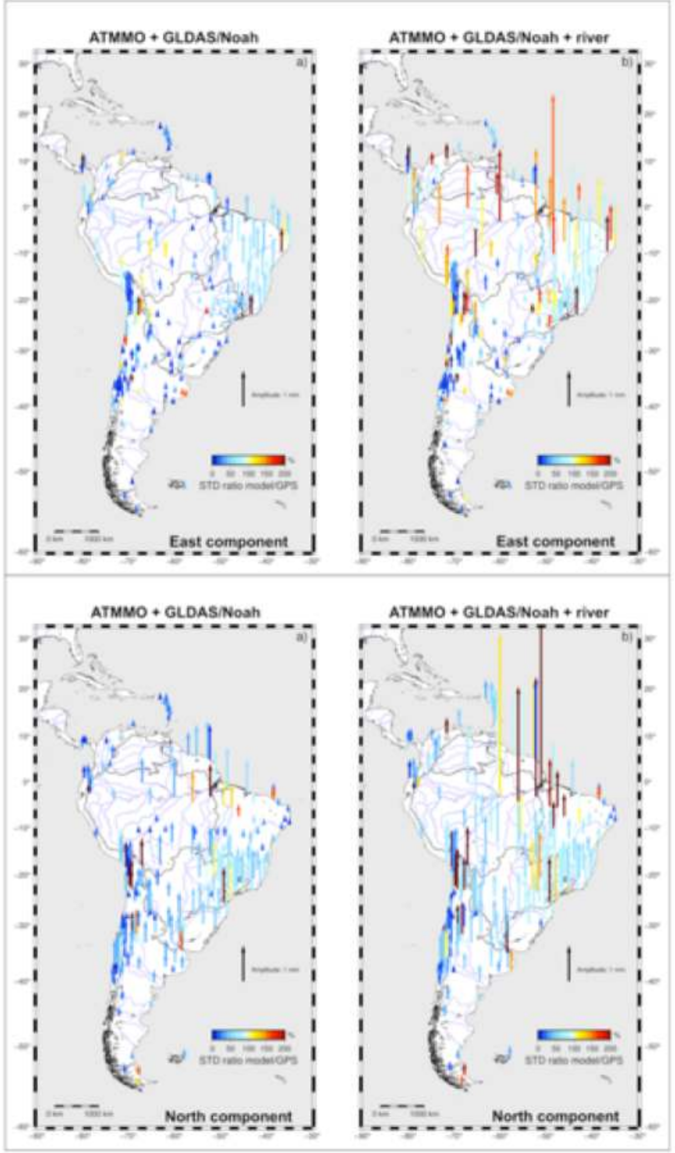


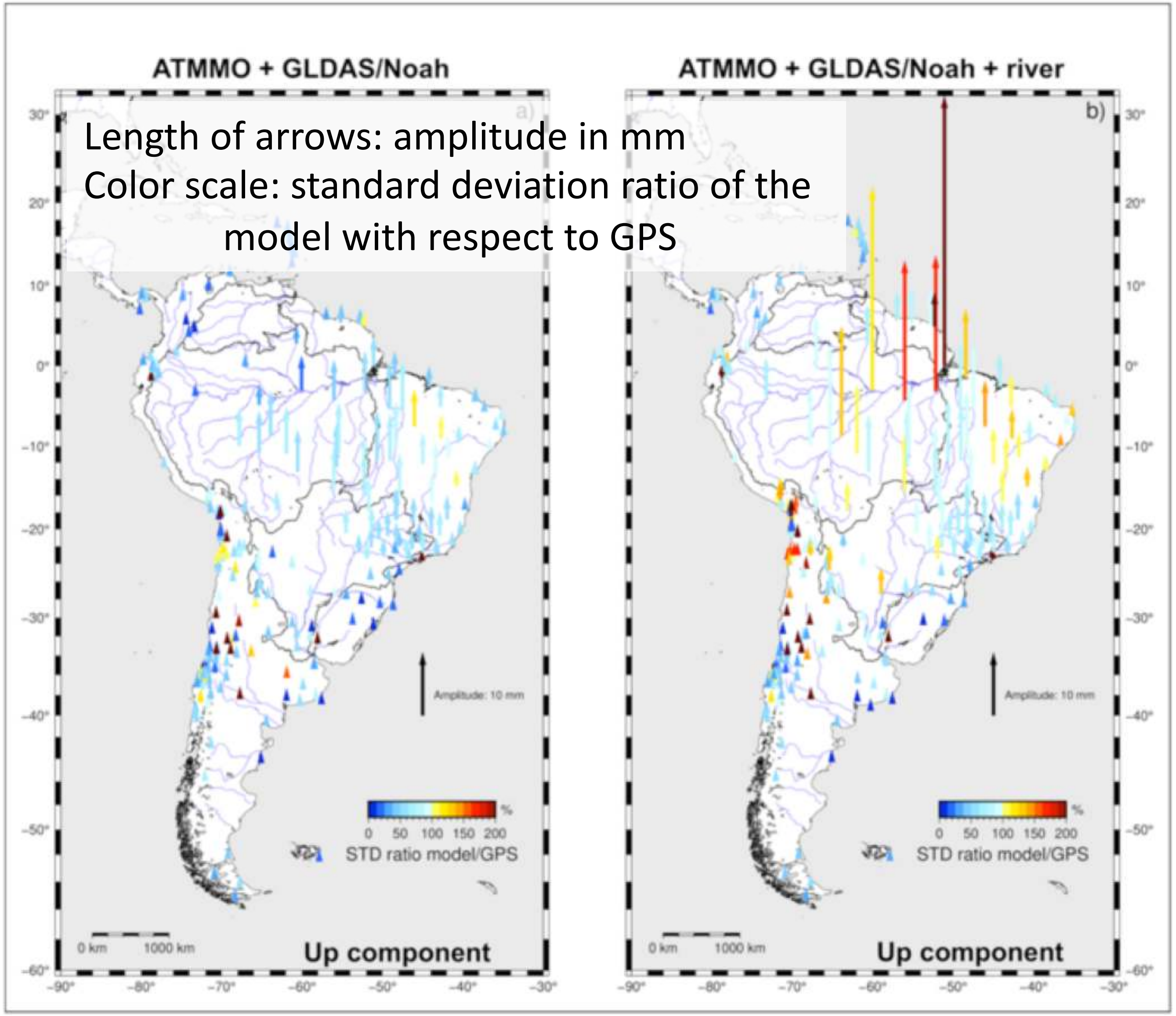


Observed GPS annual signal (extracted from M-SSA)



Annual loading model & deviation with GPS observations



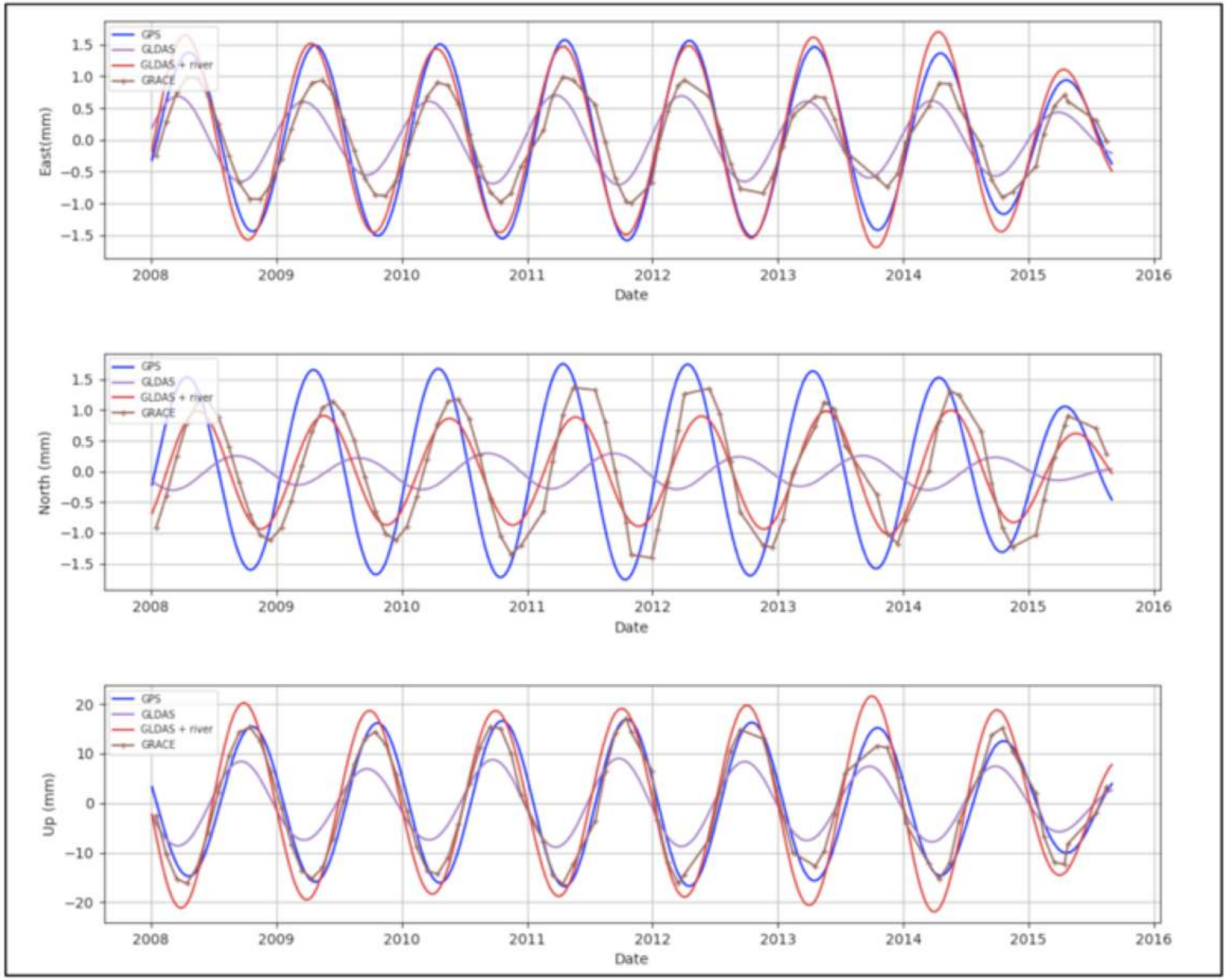


Length of arrows: amplitude in mm
Color scale: standard deviation ratio of the model with respect to GPS

ATMMO : ECMWF + TUGO-m barotropic ocean (derived from Carrère and Lyard, 2003).

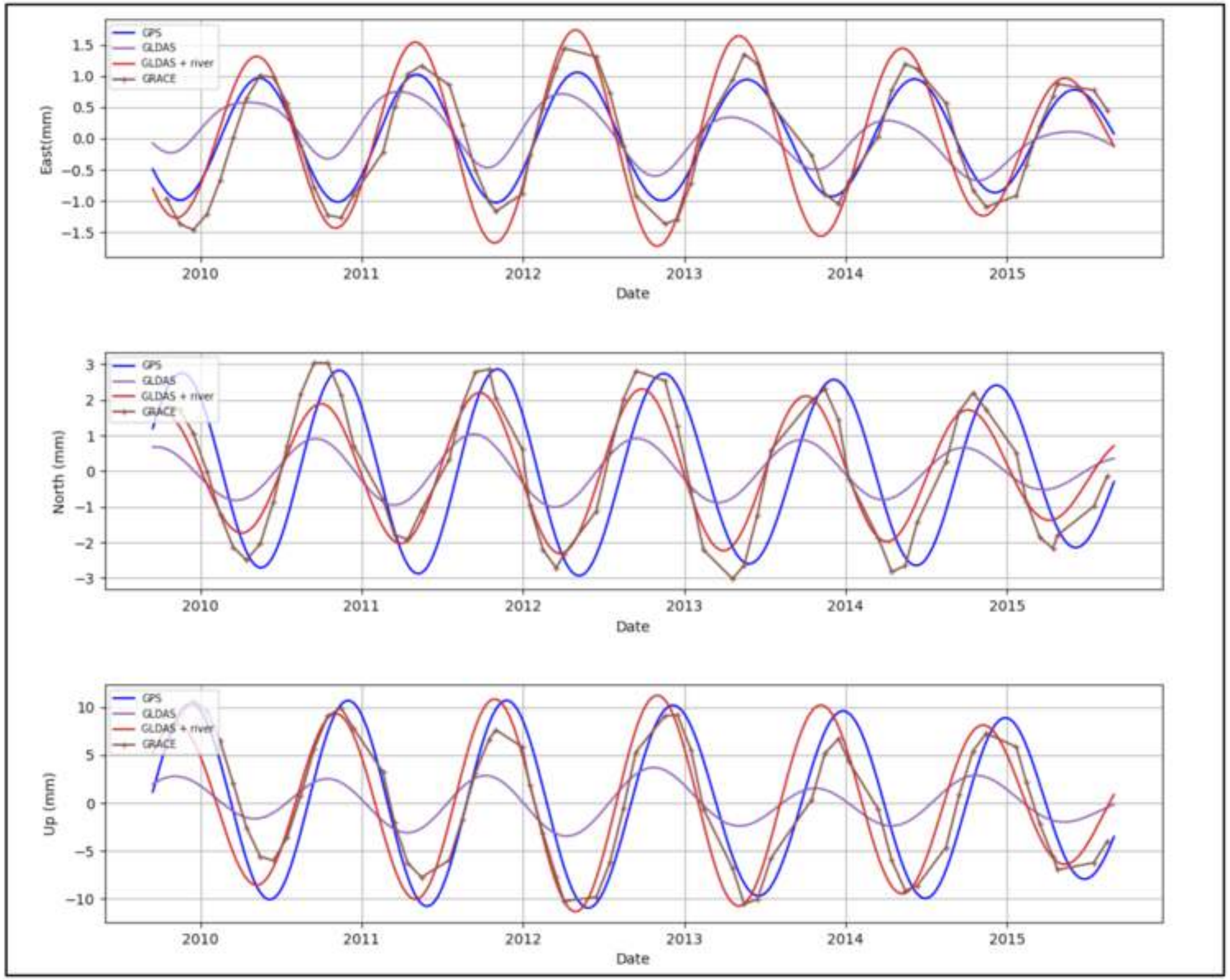
Porto Velho (POVE)

GPS GRACE
GLDAS GLDAS+river

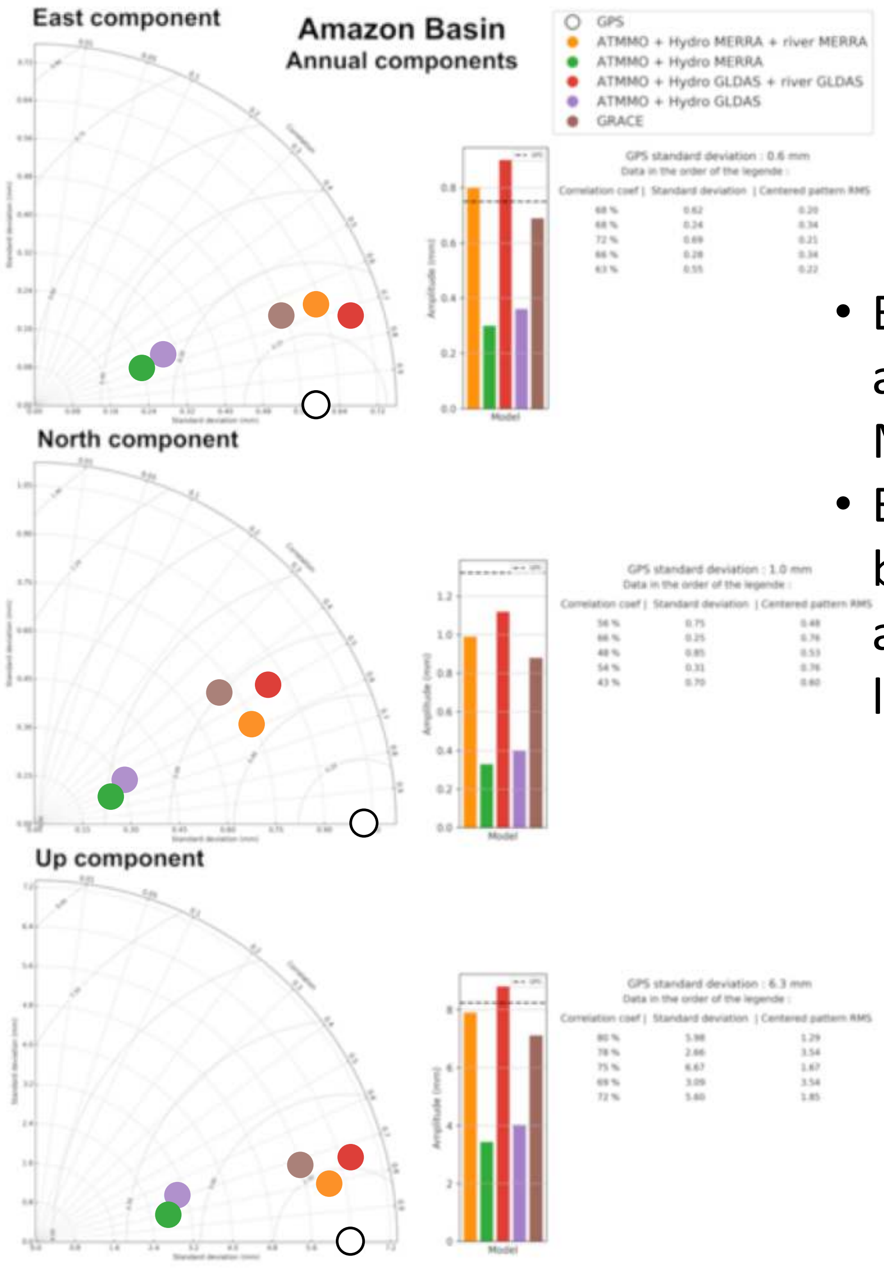


Sao Gabriel (SAGA)

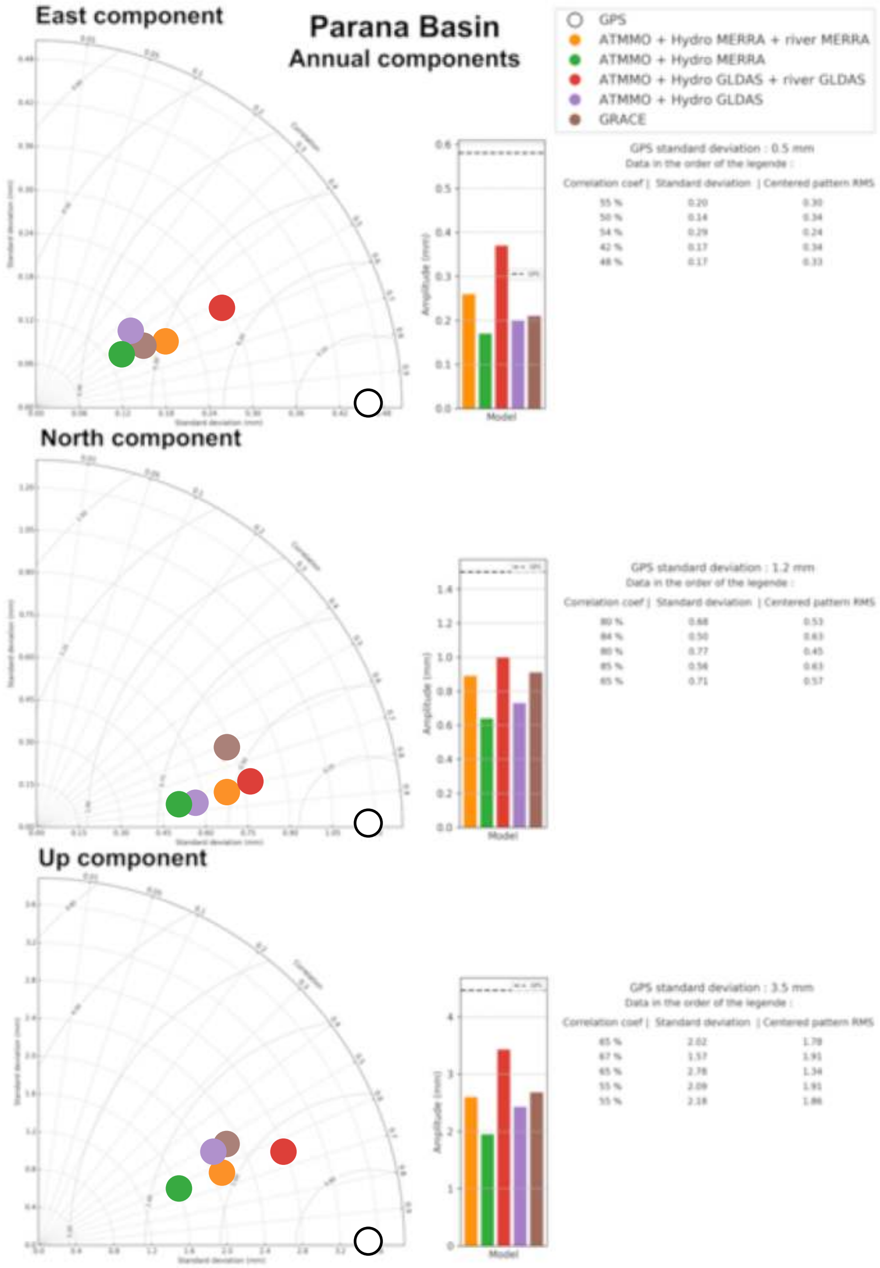
GPS GRACE
GLDAS GLDAS+river



Annual loading model & deviation with GPS observations



- Better agreement when rivers are considered (GLDAS & MERRA)
- Better results for the Amazon basin than the Parana, but amplitudes are about 3 times larger.



GPS GRACE
ATMMO + MERRA
ATMMO + MERRA + river
ATMMO + GLDAS
ATMMO + GLDAS + river

Conclusion and perspective

- M-SSA allows to extract the common observed signal, filtering out any local perturbation.
- Modeling river storage using a simple re-routing scheme of runoffs from hydrology models allows:
  - a better agreement between hydro. models and GRACE/GRACE,
  - a better agreement between full environmental loading effects (atmosphere, ocean and hydrology) and GNSS observations in South-America, especially in the Amazon river basin.
- The coarse resolution (0.5°) of the river scheme is not sufficient for stations close to the river banks (ex: Manaus).

See Nicolas et al., 2021 (https://doi.org/10.3390/rs13091605) for more details