Crustal displacements due to seasonal cycles and longer-term trends in surface loading of the solid earth

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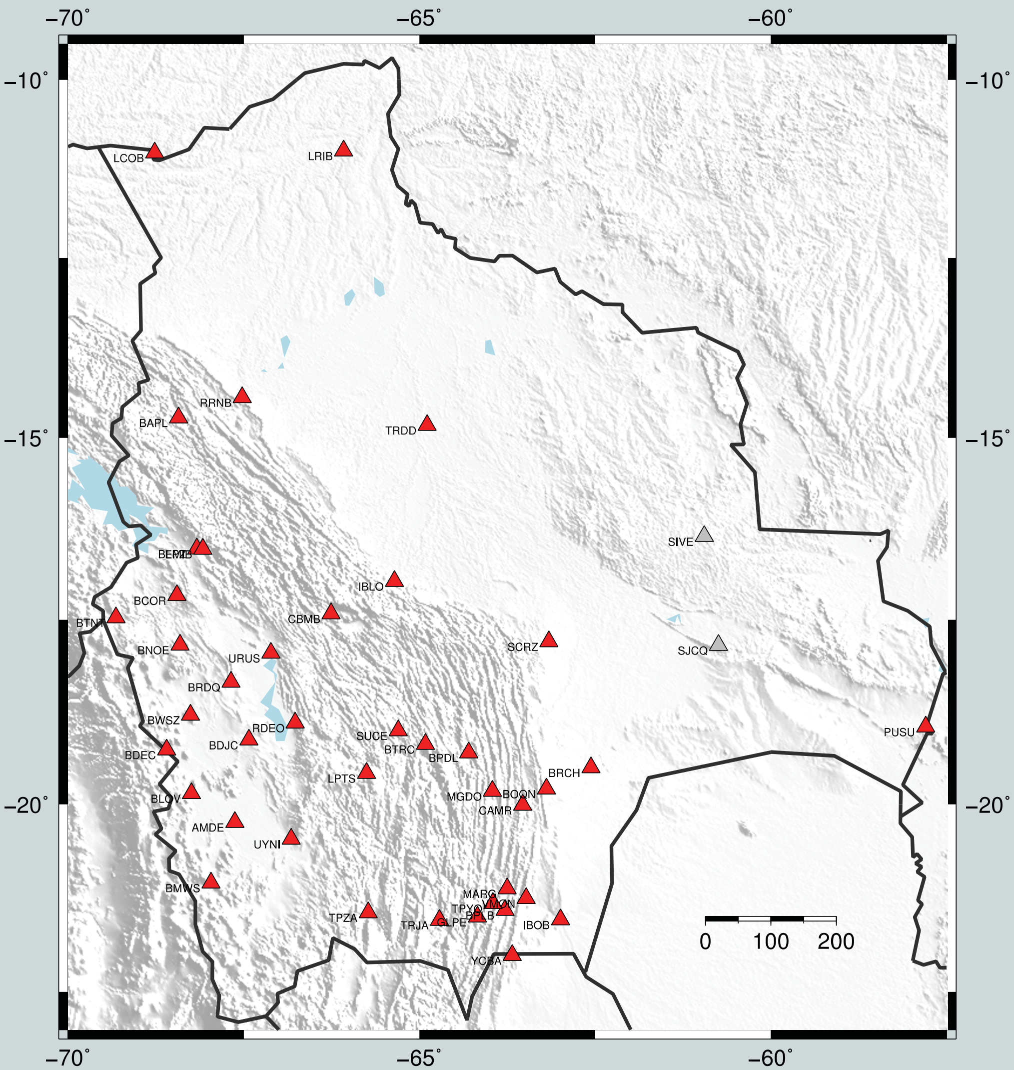
Overview

- Current state of Bolivian CGPS and Survey GPS networks
- We can use GPS to observe (weigh) water
- Inspection of vertical displacement trends and cycles in Amazon Basin of Brazil and Bolivia

CGPS Network



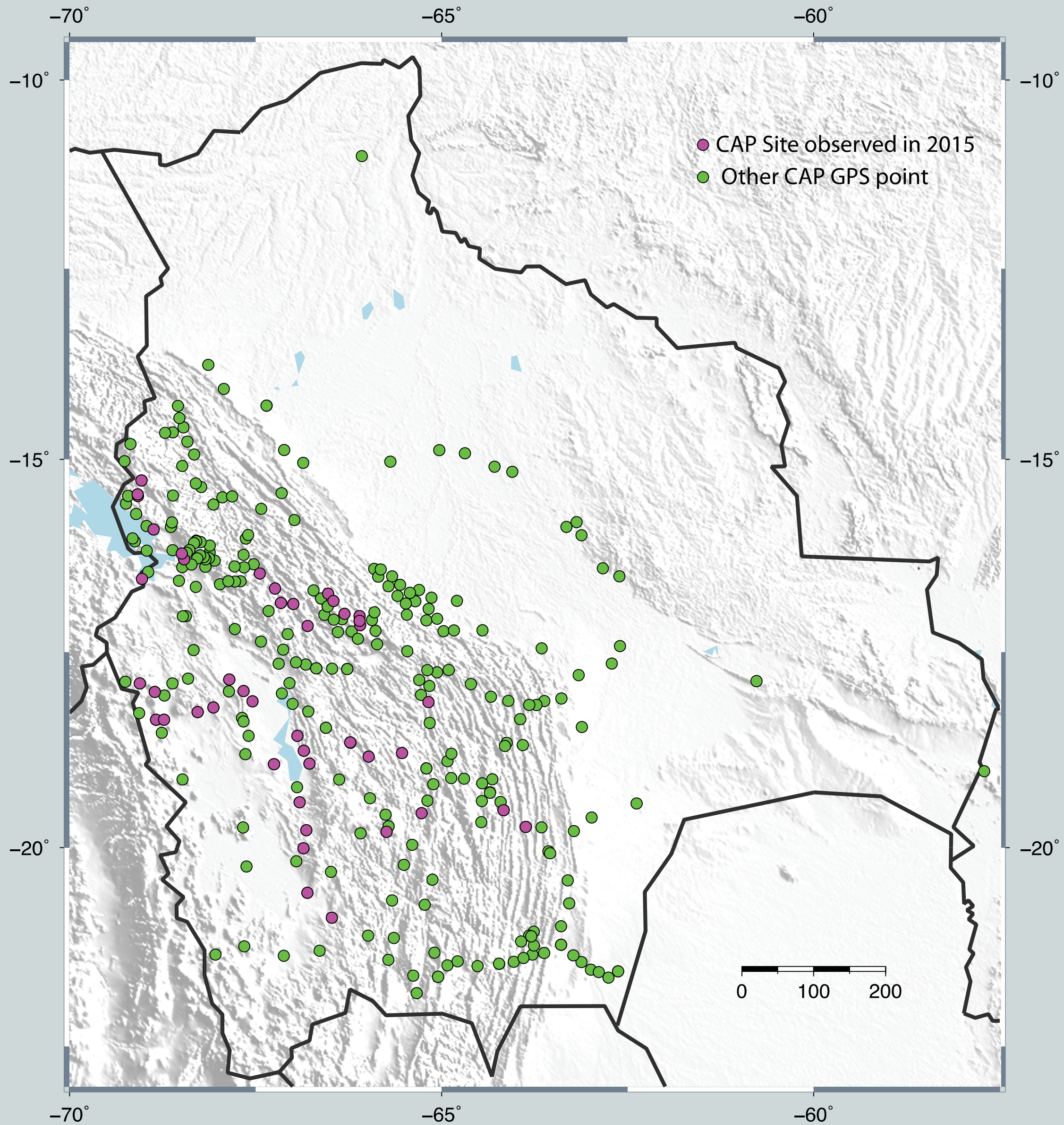
- 43 Continuous stations operational throughout Bolivia maintained by project CAP (OSU, IGM, BC, U. Hawaii)
- Next step is to make permanent stations out of the tripod sites (SJCQ, SIVE).

CGPS Network

BNOE

CBMB

Survey GPS network



Survey GPS network

- 290 stations
- Various types of monuments – depending on the ground type (rock, friable rock or soil)
- Observed intermittently, typically for 48 hours (2 UTC days), using a fixed-height antenna mast and dual-frequency GPS equipment

Analysis of vertical crustal motion

- Unusually large vertical displacement cycles present throughout Lowland Bolivian stations, and Amazon Basin stations Brazil
- We propose an elastic response to seasonal changes in the mass of water (in soils, lakes and rivers) magnifying the vertical motion cycles in the Amazon region

The Standard Linear Trajectory Model (SLTM)

Bevis and Brown, 2014
J. Geodesy

$$x_{sltm}(t) = x_{trend}(t) + x_{jump}(t) + x_{osc}(t)$$

where

$$x_{trend}(t) = \sum_{i=1}^{np+1} m_i (t - t_R)^{i-1}$$

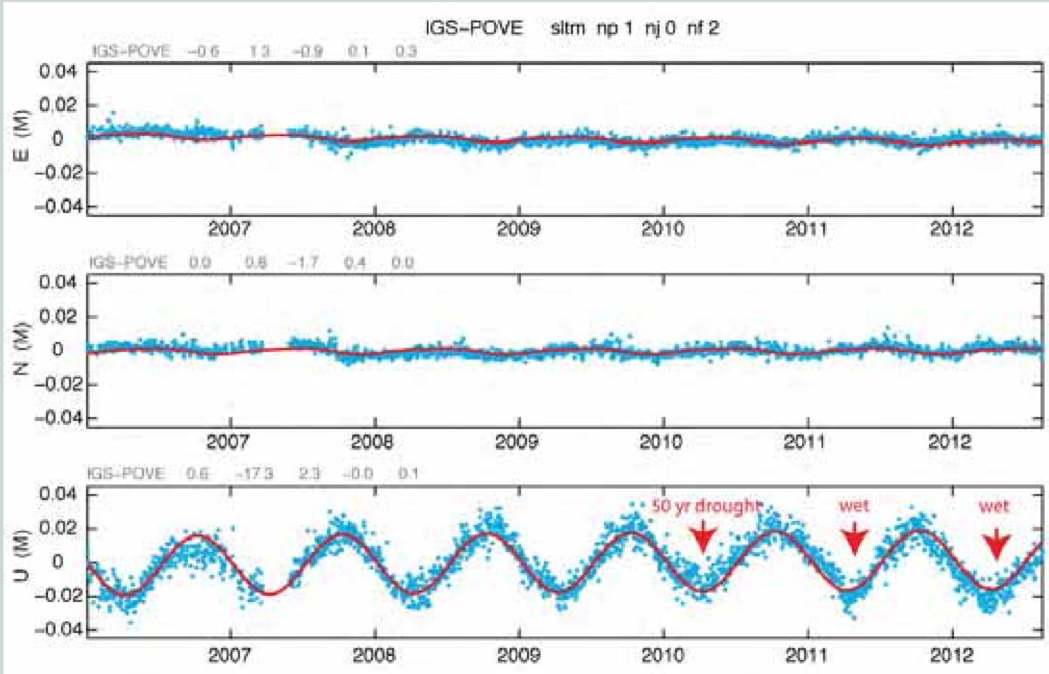
$$x_{jump}(t) = \sum_{j=1}^{nj} a_j H(t - t_j)$$

$$x_{osc}(t) = \sum_{k=1}^{nf} s_k \sin(\frac{2\pi kt}{\tau_k}) + \cos(\frac{2\pi kt}{\tau_k})$$

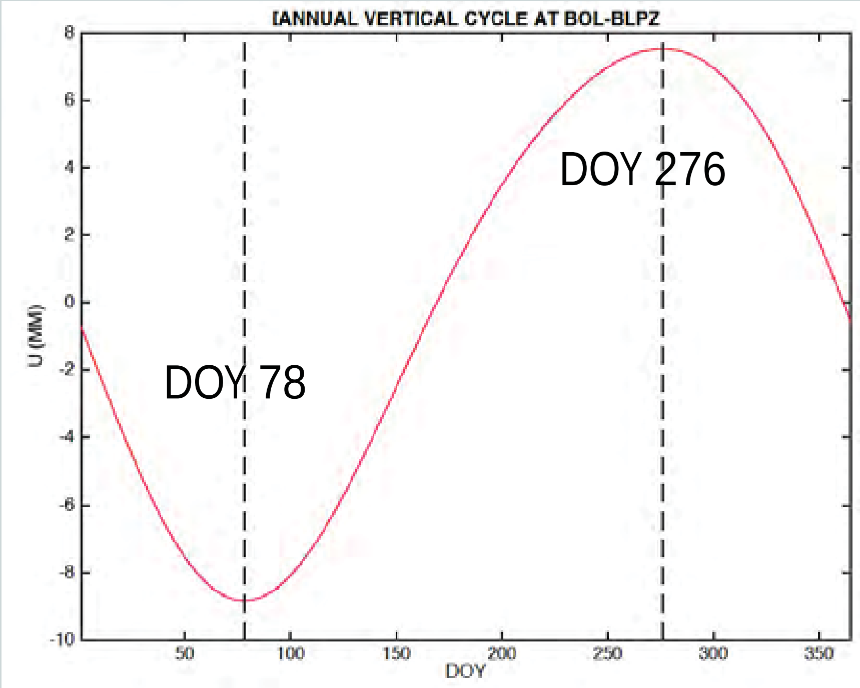
If the secular trend model is linear in time, it is a ‘constant velocity’ model

If the secular trend model is quadratic in time, it is a ‘constant acceleration’ model

EXAMPLE: Porto Vehlo, Brazil. CVM (*np*=1), no jumps (*nj*=0), 4-term Fourier series



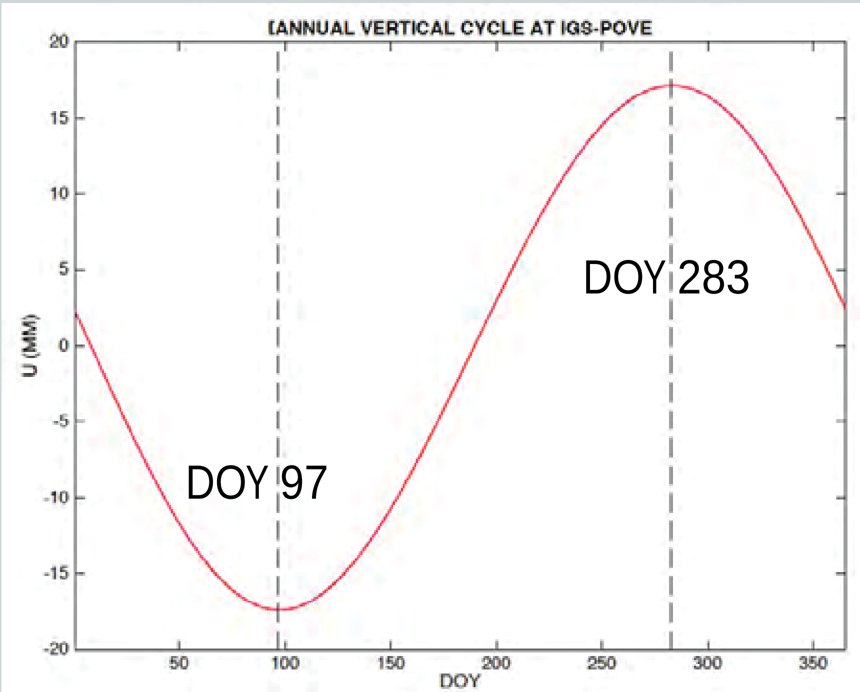
This station has a large vertical displacement cycle.

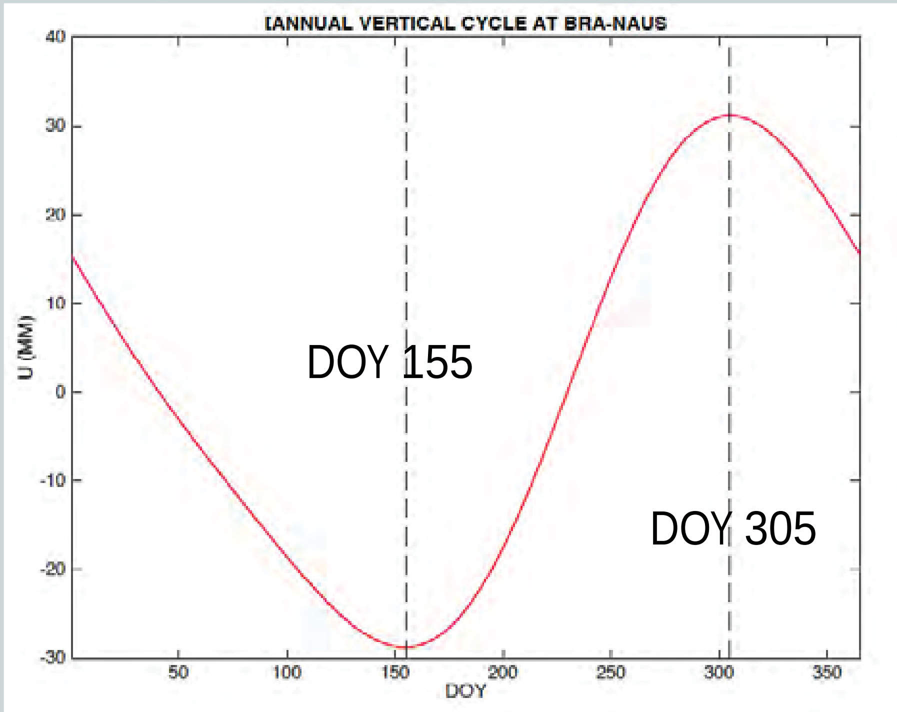


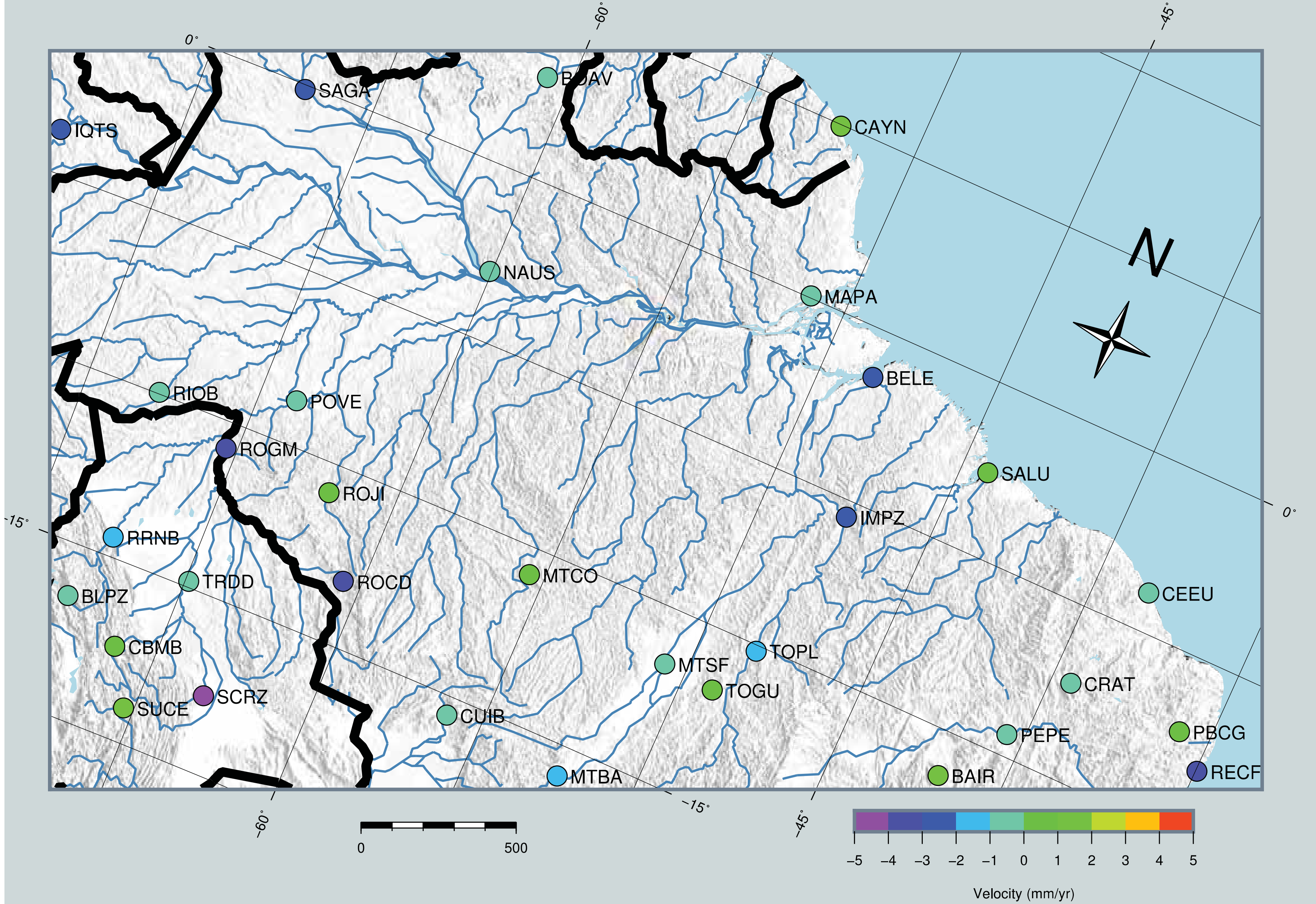
Models of the annual vertical displacement cycle, which use a 4-term Fourier Series. There are two terms (sin & cos) with a period of 1 year, and two terms with a period of 0.5 years.

Here you can see that the timing of the maxima and minima varies in space, as does the peak-to-peak amplitude of the cycle (= 60 mm for Manaus!).

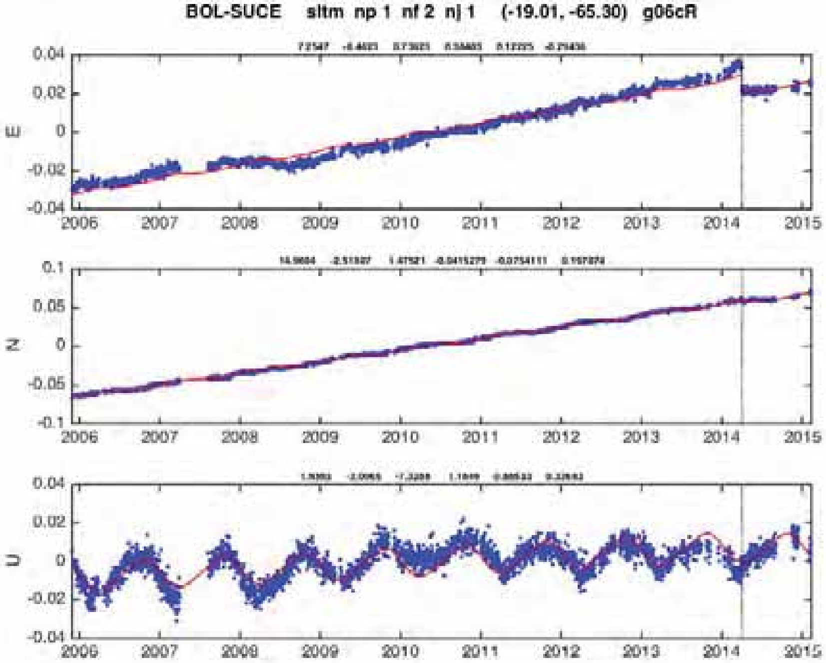
We are interested in the timing of the cycle low, which is thought to reflect the epoch of maximum hydrological loading of the Earth's crust.







IQTS
SAGA
BOAV
CAYN
NAUS
MAPA
BELE
RIOB
POVE
ROGM
ROJI
SALU
IMPZ
RRNB
TRDD
ROCD
MTCO
BLPZ
CEEU
CBMB
MTSF
TOPL
TOGU
SCRZ
SUCE
CUIB
CRAT
PEPE
PBCG
MTBA
BAIR
RECF
N
0°
−60°
−45°
−15°
0
500
−5 −4 −3 −2 −1 0 1 2 3 4 5
Velocity (mm/yr)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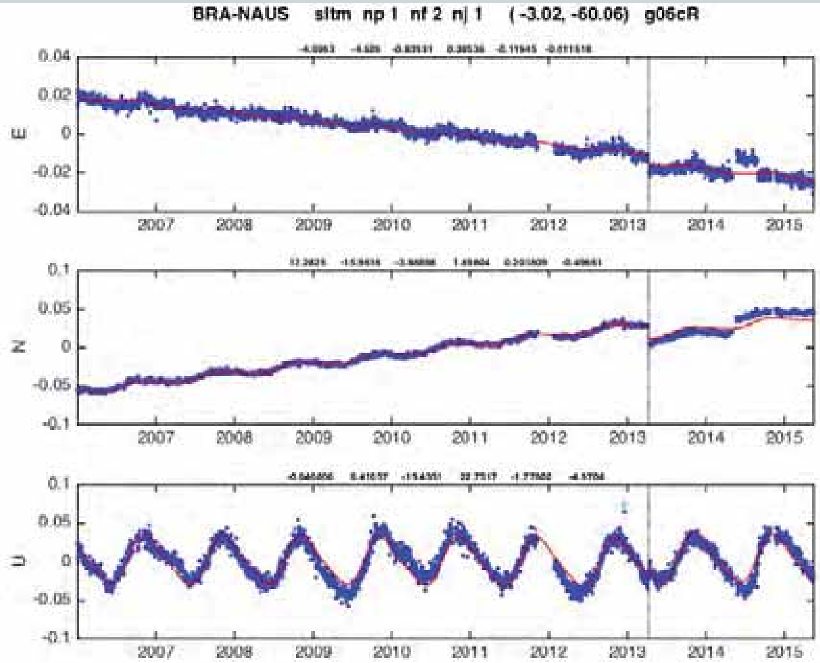
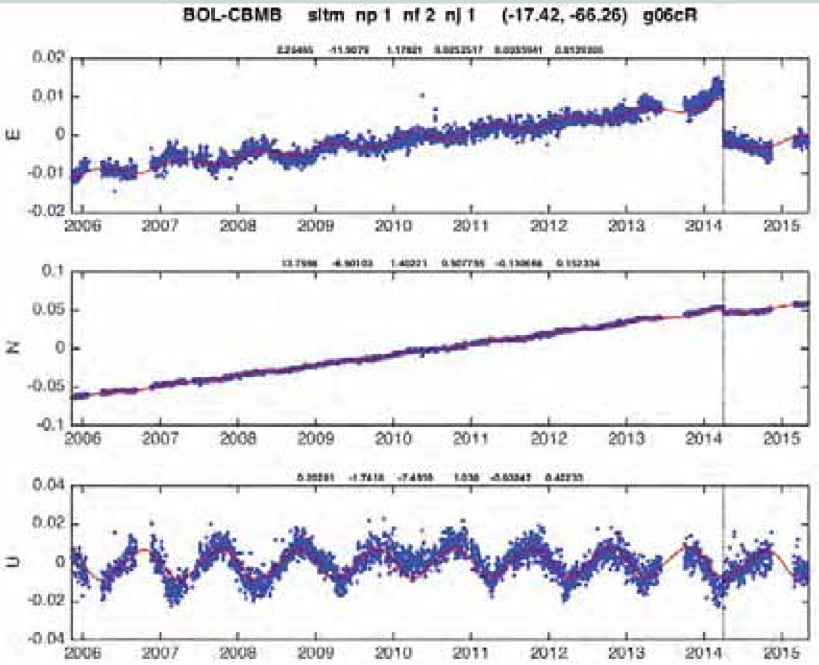
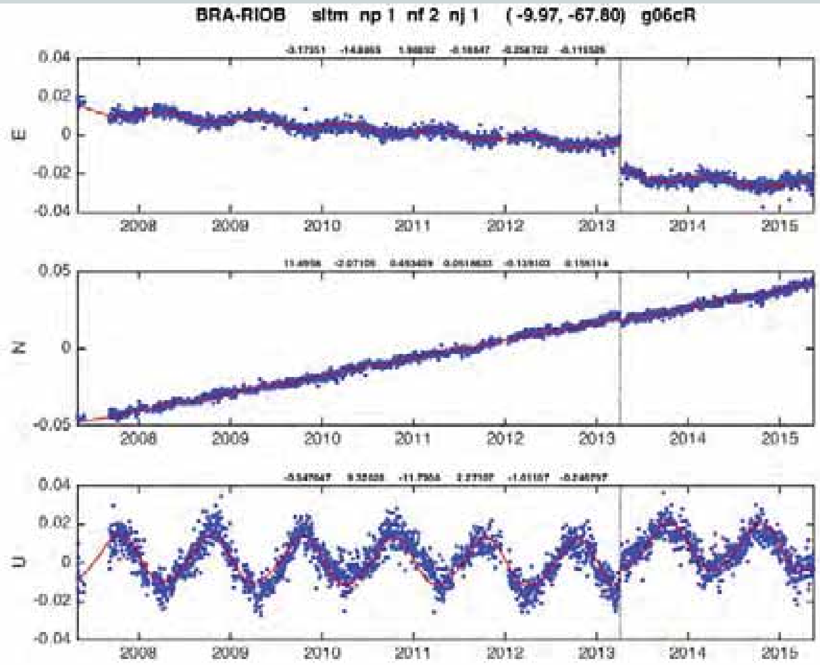
E
N
U


BRA-NAUS sltm np 1 nf 2 nj 1 (-3.02, -60.06) g06cR
E
N
U


BOL-CBMB sltm np 1 nf 2 nj 1 (-17.42, -66.26) g06cR
E
N
U


BRA-RIOB sltm np 1 nf 2 nj 1 (-9.97, -67.80) g06cR
E
N
U

Conclusions

- Openly available GPS is being used to observe changes in regional water storage
- Geodetic observations show water distribution on a local and regional and scale
- Geodesy is an important and fundamental tool for observation, and changes in climate cycles and changes. The public needs to be educated and brought to recognize the importance of geodesy in observing the earth

Questions?

GPS data processing

- Processed using GAMIT/GLOBK in the OSU08 Reference Frame, which is a refined, internally more consistent version of ITRF2008
- Station trajectories are parameterized using the formalism of Bevis and Brown (2014), in which annual cycles are modeled using 4-term Fourier Series

References

- Bevis et. al., 2005. Seasonal fluctuations in the mass of the Amazon River system and Earth's elastic response, Geophysical Res. Letters
- Bevis and Brown, 2014 Trajectory models and reference frames for crustal motion geodesy, J. Geodesy
- Borsa, et. al., 2014. Ongoing drought-induced uplift in the Western United States, Science