Crustal motion geodesy in Bolivia

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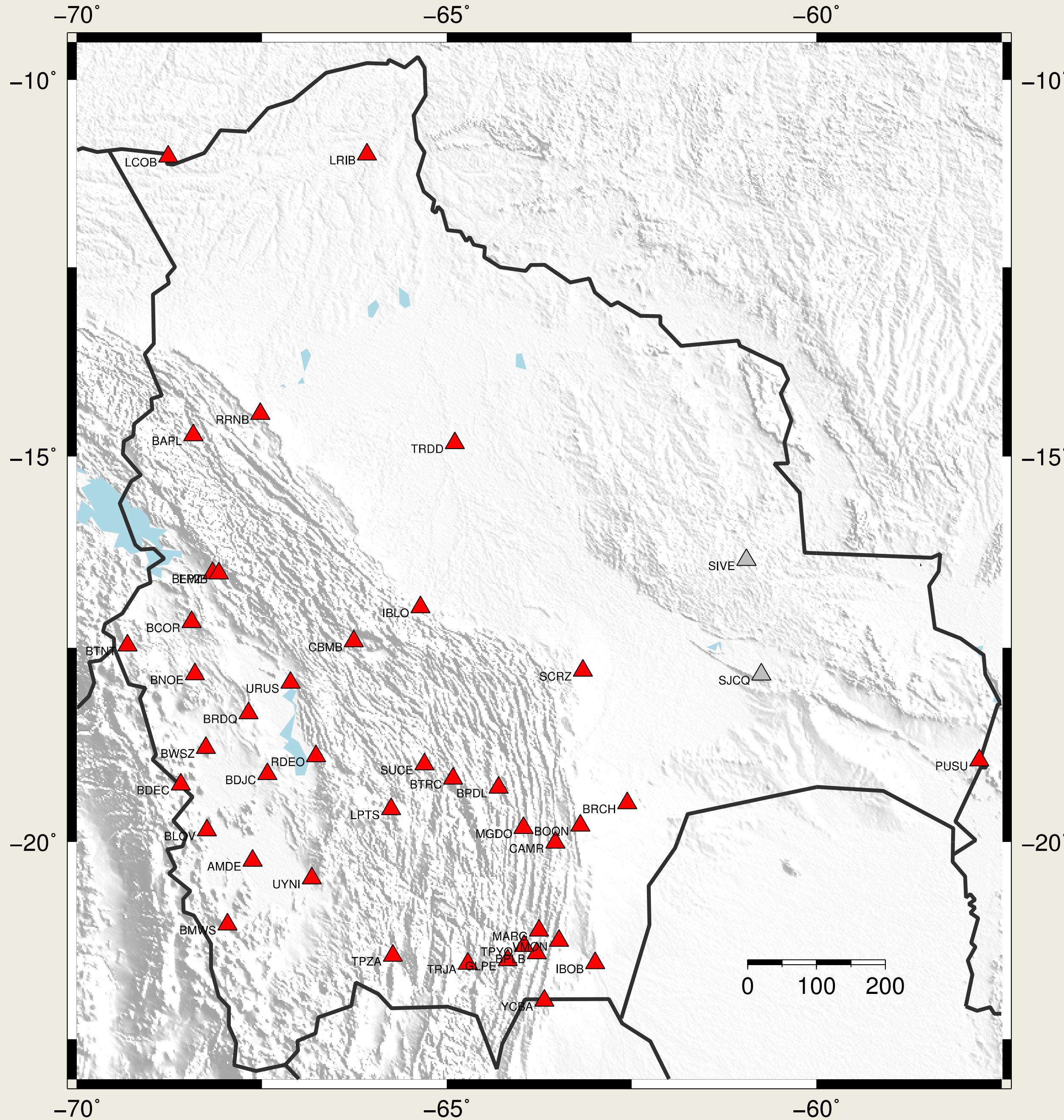
Overview

- Current state of Bolivian CGPS network
- Current state of Bolivian Survey GPS network
- An analysis of vertical displacement cycles in Bolivia and the Amazon Basin, Brazil

CGPS network

- 43 CGPS stations
- Maintained by CAP (OSU, IGM-Bolivia, UH, BC)
- 11 GPS stns recently installed in response to the Pisagua M8.2 Earthquake on 1 April 2014
- All CAP stations are incorporated into the National Spatial Reference systems of the host countries (Bolivia, Chile and Argentina)

CGPS Network



CAP/IGMB CGPS Stations

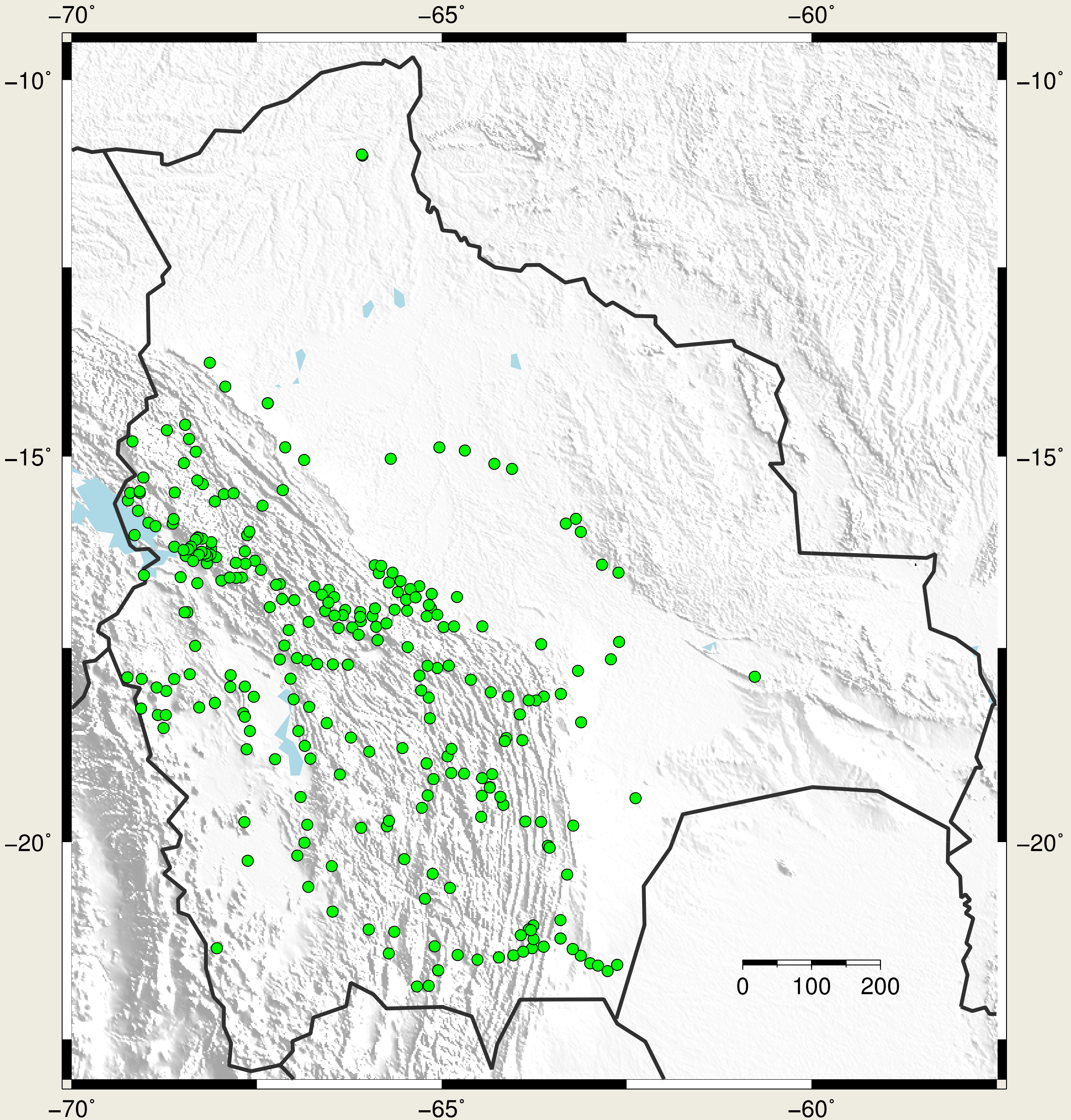
Rurrenabaque

Llica (Altiplano)

Survey GPS network

- More than 280 stations, still growing
- 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

Survey GPS Network



Survey GPS network

- Fixed-height antenna mast

The Tech2K Antenna Mast offers several advantages over a tripod : more stable in high winds, a self-calibrating level, and it eliminates antenna height reporting errors. We use the mast rather than ground-based antenna monuments (anchors) because they work in soil and rock, and they provide for good visibility. CAP uses these masts in Chile, Argentina and Bolivia.

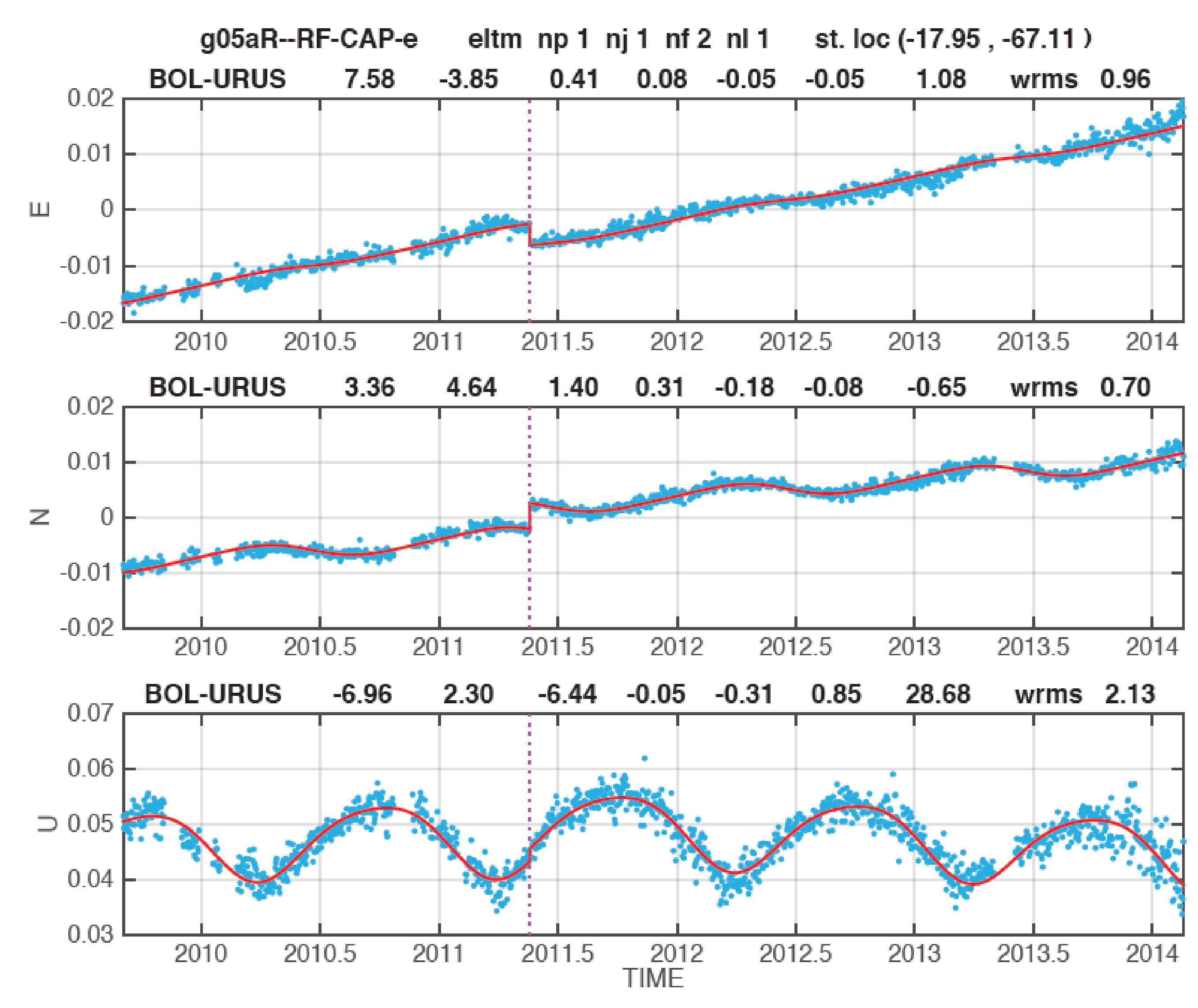
Analysis of vertical crustal motion

- Lowland Bolivian stations, and Amazon Basin stations Brazil have unusually large vertical displacement cycles
- These manifest earths elastic response to seasonal changes in the mass of water (in soils, lakes and rivers)
- We will present a short overview of this topic in which geodesy is being used to characterize the hydrological cycle (and climate change)

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

Example times series from URUS (Oruro) Bolivia. This station is recording a postseismic transient throughout its lifetime (the Tocopilla event, Chile)



The Standard Linear Trajectory Model (SLTM)

Bevis and Brown, 2014
J. Geodesy

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

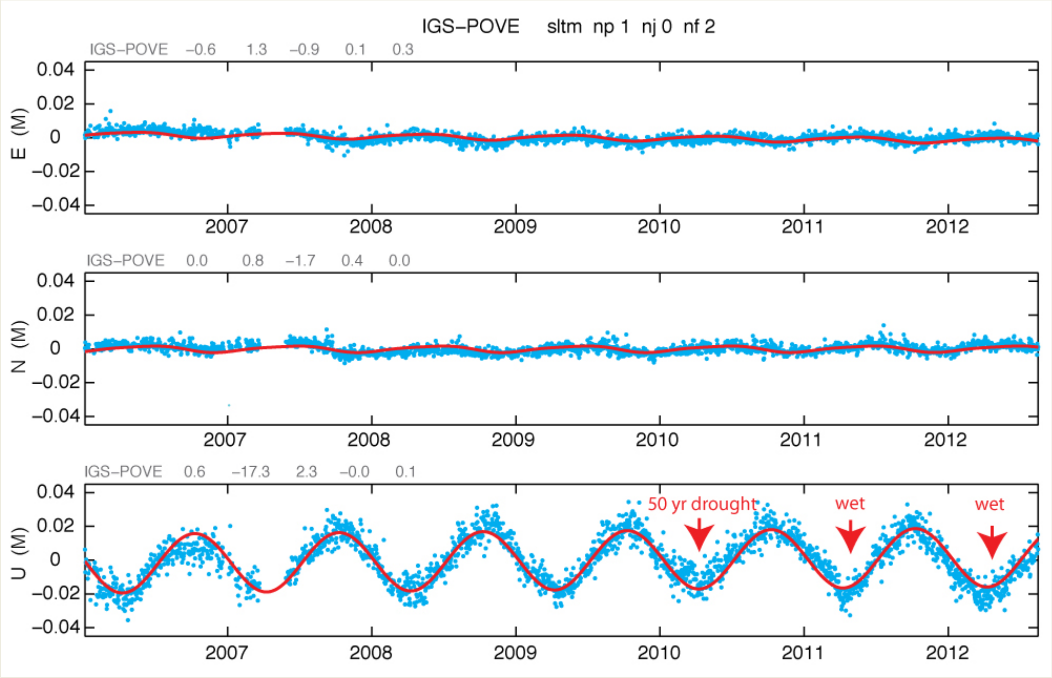
where

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

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

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

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



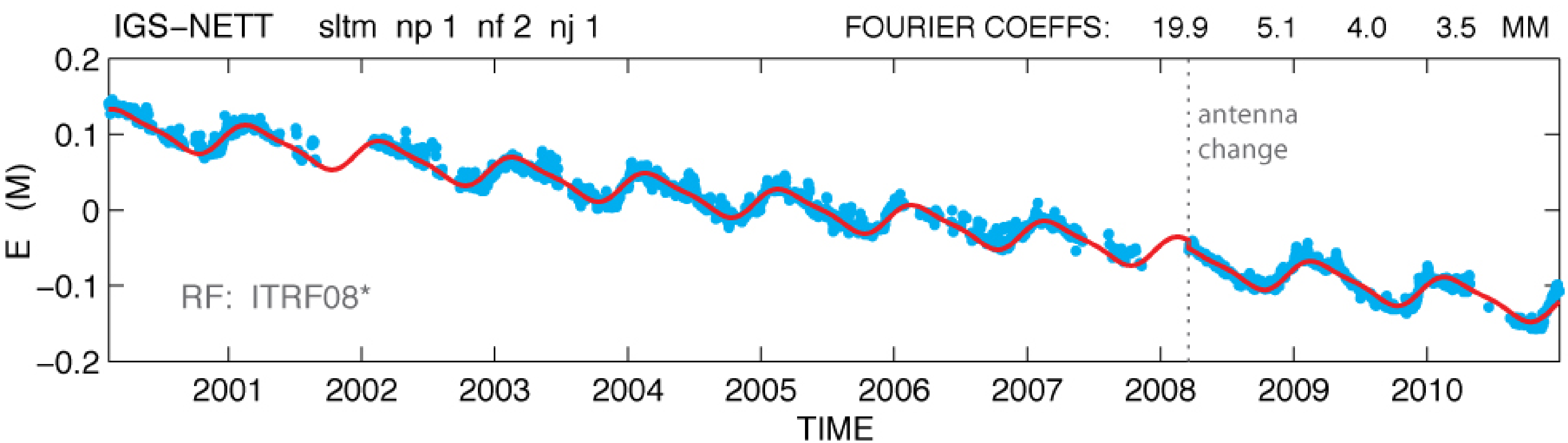
This station has a large vertical displacement cycle.

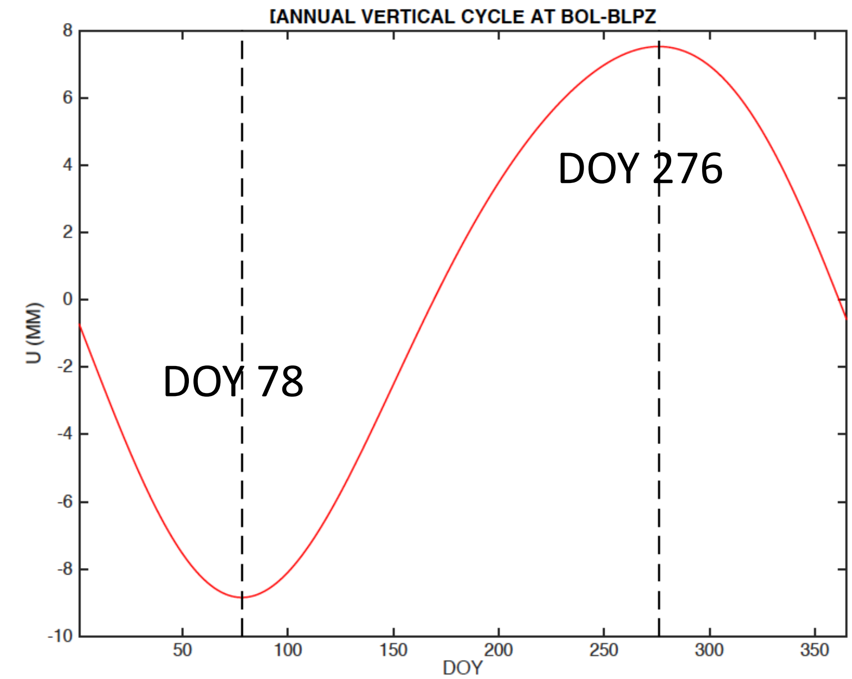
If the secular trend model is linear in time, it is a 'constant velocity' model

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

A rare example of a very strong horizontal cycle

East component of motion at station NETT in the Southern Alps of New Zealand

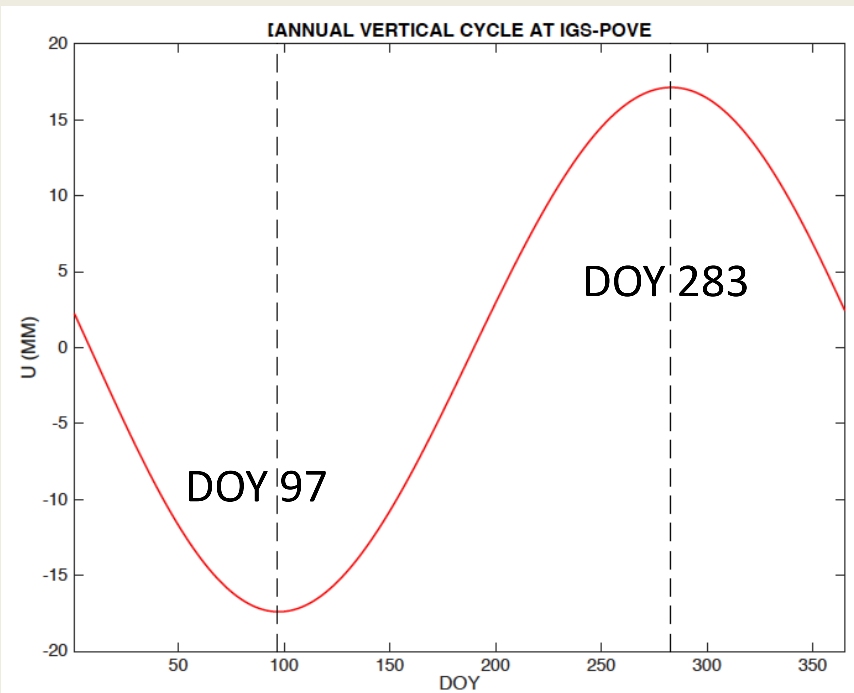


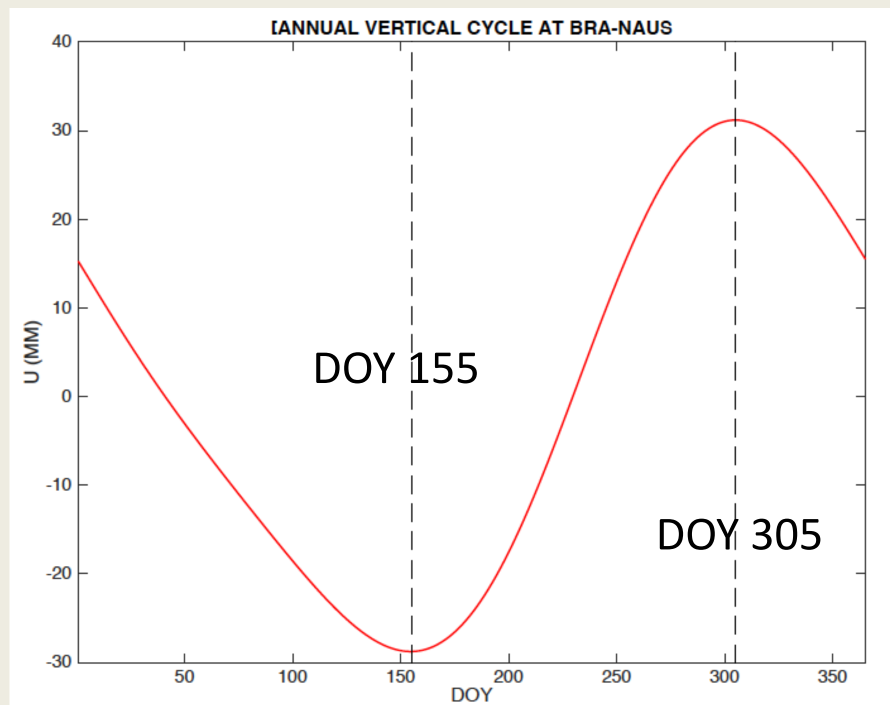


Models of the annual vertical displacement cycle, which use a 4-term Fourier Series. There are two terms (sin & cos) with a period of 1 year, and two terms with a period of 0.5 years.

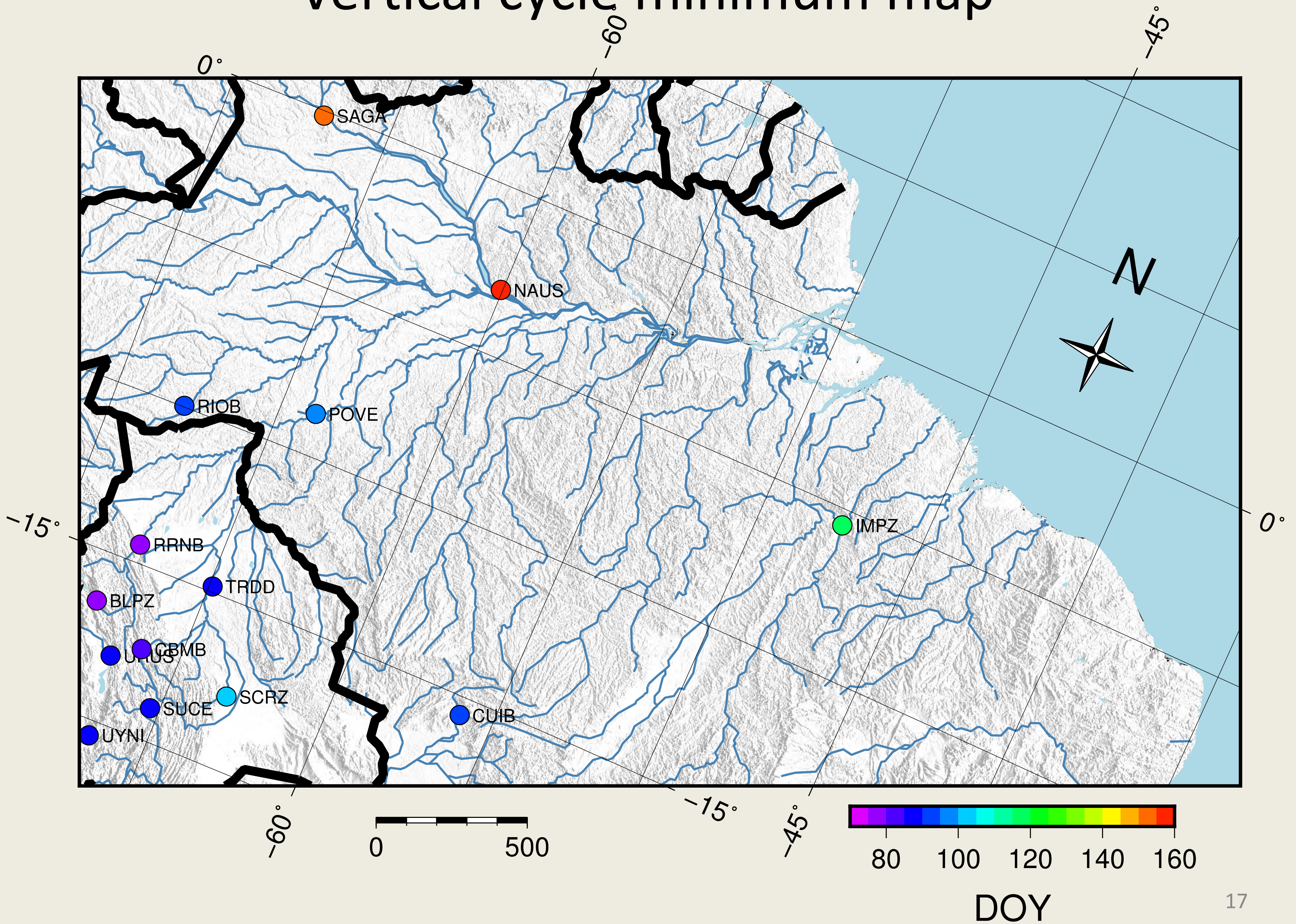
Here you can see that the timing of the maxima and minima varies in space, as does the peak-to-peak amplitude of the cycle (= 60 mm for Manaus!).

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.

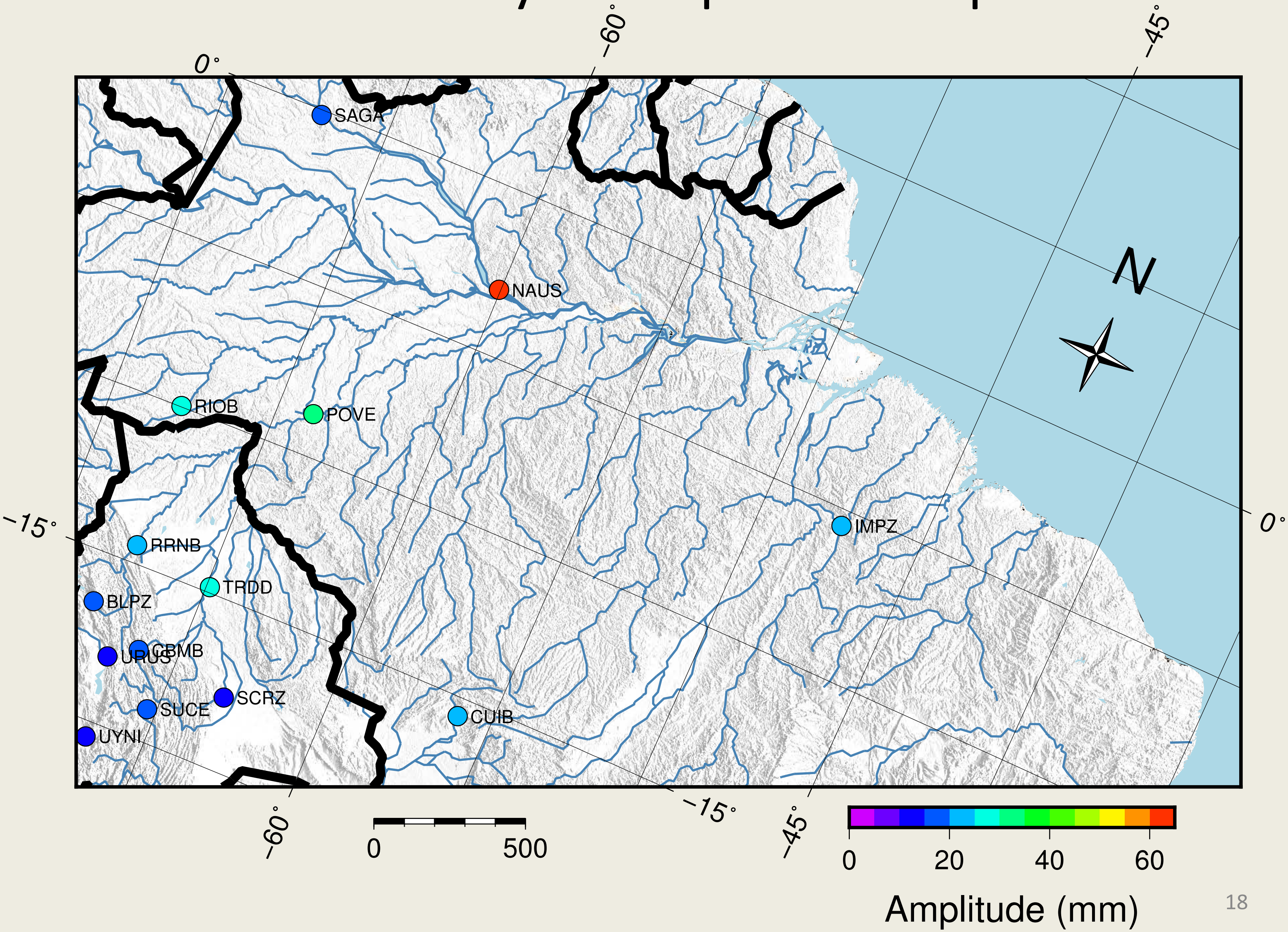




Vertical cycle minimum map



Vertical cycle amplitude map



References on Annual Displacement Cycles and the Hydrological Cycle

- Bevis et. al., 2005. Seasonal fluctuations in the mass of the Amazon River system and Earth's elastic response, Geophysical Res. Letters
- Steckler et. al., 2010. Modeling Earth deformation from monsoonal flooding in Bangladesh using hydrographic, GPS, and GRACE data, J Geophys. Research
- Bevis and Brown, 2014 Trajectory models and reference frames for crustal motion geodesy, J. Geodesy

Questions?