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Correction to "Atmospheric Effects and Spurious Signals in GPS Analyses"

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Abstract. *Tregoning and Watson* [2009] provided a comprehensive study of the effects of improved mapping functions, a priori hydrostatic delay modelling, non-tidal and tidal atmospheric pressure loading on coordinate estimates from GPS observations. We have recently discovered that, due to a bug in the implementation of the atmospheric tidal loading, one result of that study was in error: the amplitude of the propagated annual and semi-annual draconitic signals seen in the difference between applying and not applying the atmospheric tidal model was largely an artifact of a coding error. We present here the corrected results, which show that propagated draconitic signals are still induced by failing to model atmospheric tidal loading, although applying the model has a smaller effect than previously reported.

1. Introduction

Tregoning and Watson [2009] showed how the application of the diurnal and semi-diurnal atmospheric tidal loading deformation model of *Ponte and Ray* [2002] in the analysis of Global Positioning System (GPS) observations reduced spurious low frequency periodic signals in GPS time series. The implementation of the atmospheric tidal loading (ATL) used by *Tregoning and Watson* [2009] was in error, brought about by an inconsistency in coding between the development code and the release of the GAMIT software to the broader community. The periodic deformations due to the S1 and S2 atmospheric tides for the up, north and east components were applied to the north, east and up components, respectively. In essence, the largest magnitude signal was applied to the wrong component, while only a small correction was applied to the component containing the largest actual signal.

This coding error had no effect on the conclusions of the study of *Tregoning and Watson* [2009] that related to the mapping functions, modelling of the a priori hydrostatic delays or of the application of the non-tidal atmospheric pressure loading. It has, however, affected the comparisons of the solutions with and without the atmospheric tidal loading included. In particular, the majority of the signal shown in Figures 9 and 10 of *Tregoning and Watson* [2009] resulted from applying the wrong loading signal to the wrong component.

Figure 1 shows stacked spectra of the difference in coordinate estimates between solutions when the atmospheric tidal loading is applied correctly. Note that there are clear peaks at the semi-annual GPS draconitic period ($\sim$174.5 days) across up, east and north components, although the peaks are less energetic than previously shown (for clarity, the variances used for normalizing the spectral power are in this case 4 mm^2 for each coordinate component). There is also a small peak at the draconitic annual period in the up component but this is not visible in the horizontal components. The noise structure does, in general, not show any time correlation (that is, the spectra are largely indicative of white noise) but the propagation of the diurnal and semi-diurnal atmospheric tides into the annual and semi-annual draconitic periods remains [*Penna et al.*, 2007; *Tregoning and Watson*, 2009].

Tregoning and Watson [2009] computed the amplitude of the semi-annual draconitic signals as a function of latitude and showed a bimodal dependence, with peaks of around 0.7 mm in the mid-latitudes for the combined effect of modelling both the S1 and S2 tides (see their Figure 10). We have repeated this analysis with the ATL applied to the correct components (note that we have included additional sites beyond those used in the previous study). Figure 2 shows that there is still a latitudinal dependence but that the amplitude is significantly smaller, reaching only around 0.2 mm. A 0.2 mm amplitude signal equates to between 5 and 40% of the total amplitude of semi-annual draconitic signals at some sites (average amplitude is ∼1.9 mm).

Modelling the atmospheric tidal loading correctly reduces the spurious draconitic semi-annual periodic signals, thus confirming the conclusions of *Tregoning and Watson* [2009] that not modelling the tidal deformations will lead to biases in the estimates of real geophysical signals at or near to these frequencies. The solution with the ATL applied correctly has less power at the draconitic harmonic frequencies in the coordinate time series (whereas previously the solution with the ATL applied was actually more in error than the solution uncorrected for ATL).

Comparison of the two analyses further demonstrates that failure to model real diurnal and semi-diurnal periodic signals into GPS analyses causes significant excitation at low frequencies in resulting time series of GPS site coordinates. Thus, it can be inferred that any remaining errors in the S1 and S2 tidal models (ocean, atmosphere) will be contributing to the low frequency draconitic periodic signals still seen in GPS solutions today.

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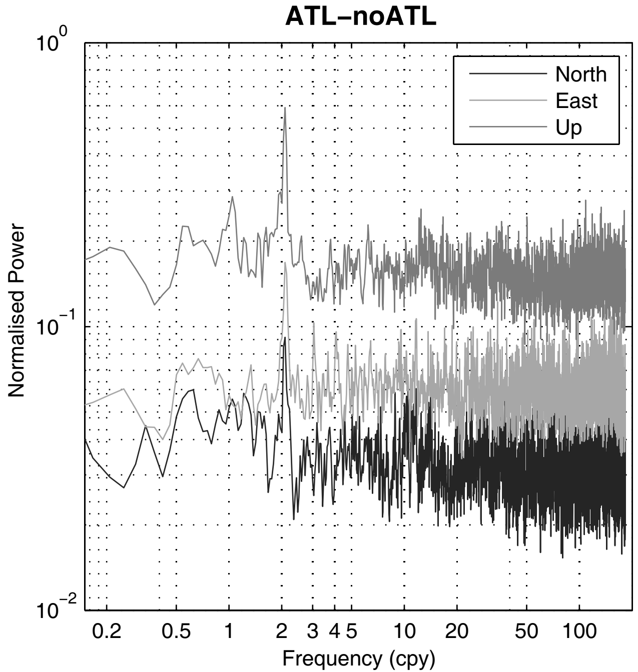
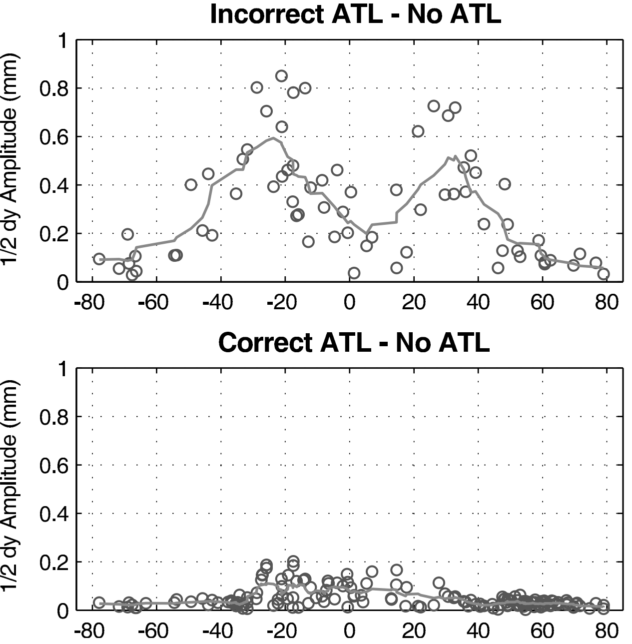
Figure 1. Stacked power spectra of the difference between time series with and without the atmospheric tidal loading deformation correctly accounted for. Note the peak corresponding to frequency of 2 cycles per draconic year (i.e. period $\sim$174.5 days). All individual spectra across each component are normalized using a variance of 4 mm^2

Figure 2. Bimodal latitudinal dependence of the amplitude of the semi-annual draconitic periodic signal of the incorrectly applied ATL used in *Tregoning and Watson* [2009] (top) and the model applied correctly (bottom).



ATL–noATL
10^0
10^-1
10^-2
Normalised Power
North
East
Up
0.2
0.5
1
2
3
4
5
10
20
50
100
Frequency (cpy)



Incorrect ATL - No ATL
1/2 dy Amplitude (mm)
1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80
Correct ATL - No ATL
1/2 dy Amplitude (mm)
1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80