Ionosphere Scintillation:
Carrier Phase and Deep Fades

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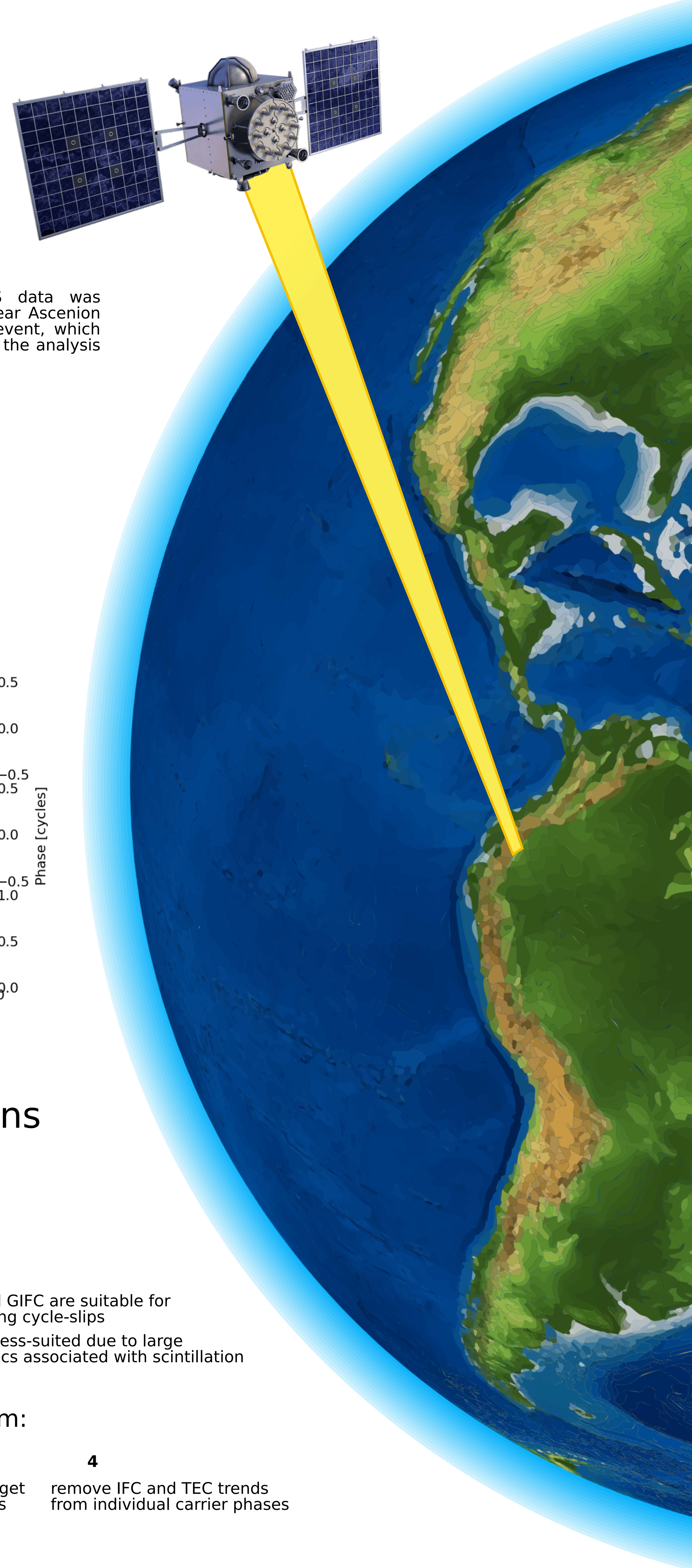
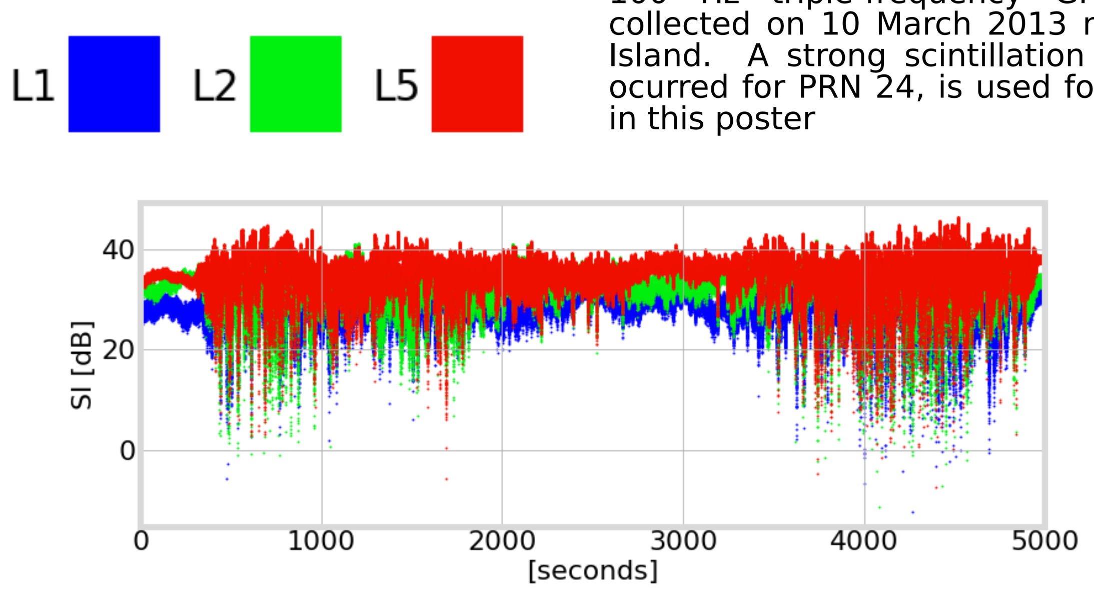


Motivation

- **ionosphere scintillation** caused by signal propagation through **plasma irregularities**
- strong scintillation leads to **deep fades** and associated **cycle slips**, which adversely affect navigation and remote-sensing applications
- traditional cycle-slip detection and correction approaches *will not work during strong scintillation*

OBJECTIVE: *achieve manual visual cycle-slip correction* as a first step towards developing robust carrier-phase correction algorithms for application during strong scintillation

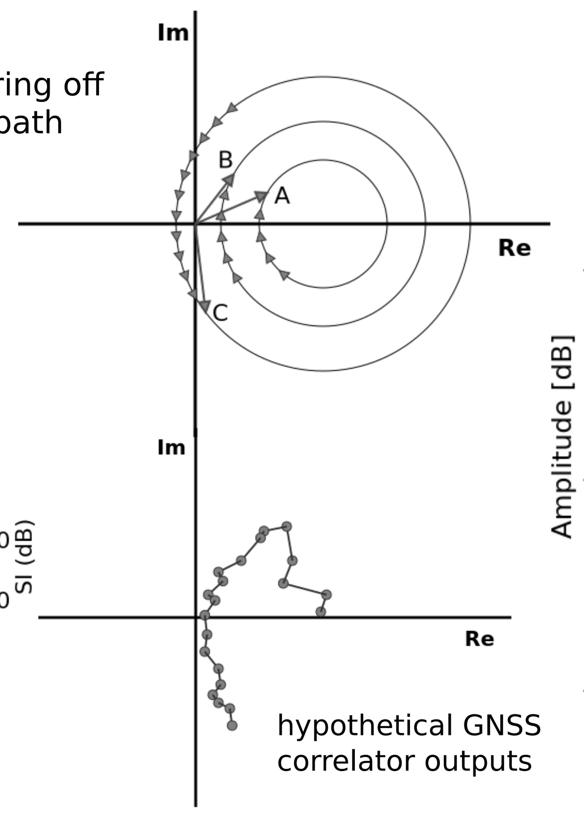
100 Hz triple-frequency GPS data was collected on 10 March 2013 near Ascenion Island. A strong scintillation event, which ocurred for PRN 24, is used for the analysis in this poster

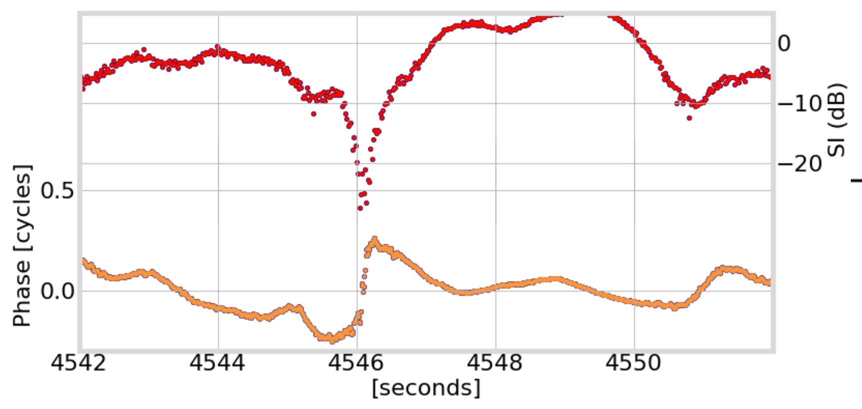


Canonical Fades

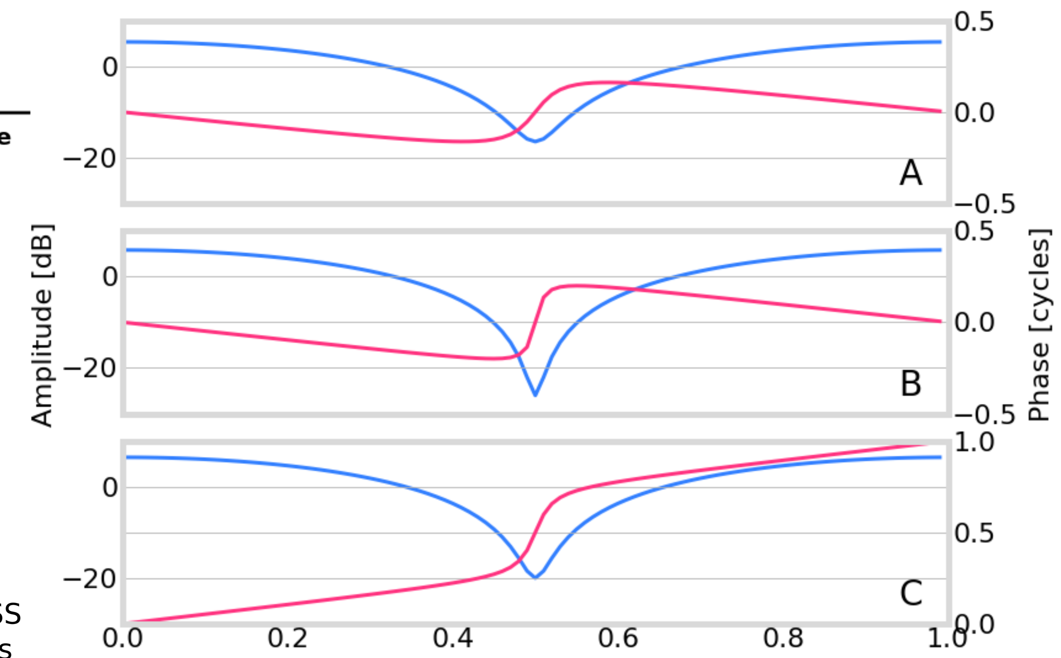
- strong ionosphere scintillation caused by scattering off irregularities can essentially be treated as multipath
- this suggests two-tone interference as model to understand deep fades

$$A\exp(i\phi) + \tilde{A}\exp\left(i\tilde{\phi}\right)$$
$$= A\exp(i\phi)\left[1 + \alpha\exp(i\Delta\phi)\right]$$





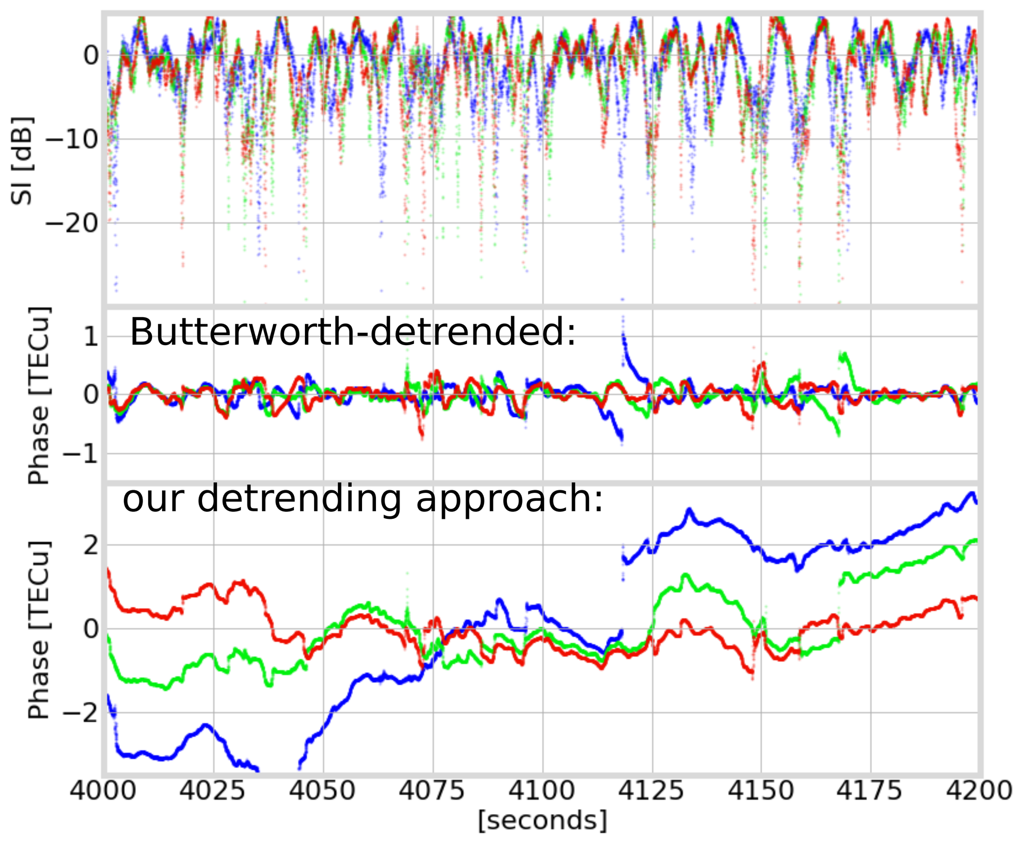
Two-tone Interference Scenarios



Phase Detrending

- nominal methods of phase detrending do a poor job of exposing cycle-slips
- a new detrending method is developed that takes advantage of triple-frequency signals

Detrending Comparison



Multi-Frequency Phase Combinations

$$\Phi_i = G + I_i + \lambda_i N_i \qquad I_i = \frac{\kappa}{f_i^2}\mathrm{TEC}$$

phase [m]; G: geometry (non-dispersive); I_i: ionosphere; $\lambda_i N_i$: cycle ambiguity

$$\mathrm{IFC} = 2.765\ \Phi_{L1} - 2.732\ \Phi_{L2} + 0.967\ \Phi_{L5}$$
$$\mathrm{TEC} = 8.294\ \Phi_{L1} - 2.883\ \Phi_{L2} - 5.411\ \Phi_{L5}$$
$$\mathrm{GIFC} = 1.000\ \Phi_{L1} - 5.421\ \Phi_{L2} + 4.421\ \Phi_{L5}$$

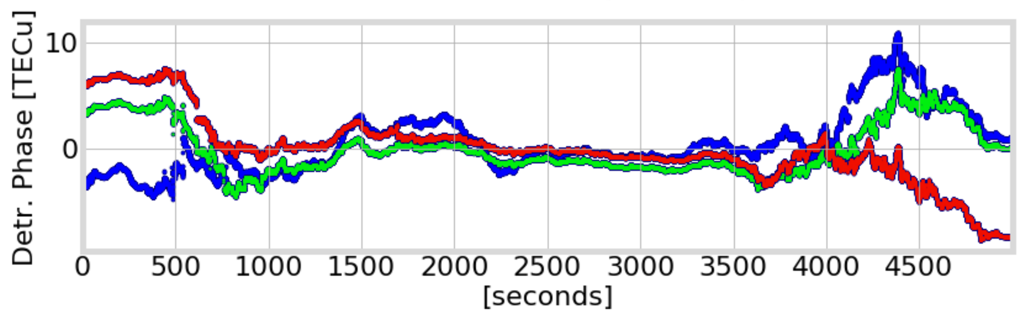
IFC and GIFC are suitable for detecting cycle-slips

TEC is less-suited due to large dynamics associated with scintillation

Our Phase Detrending Algorithm:

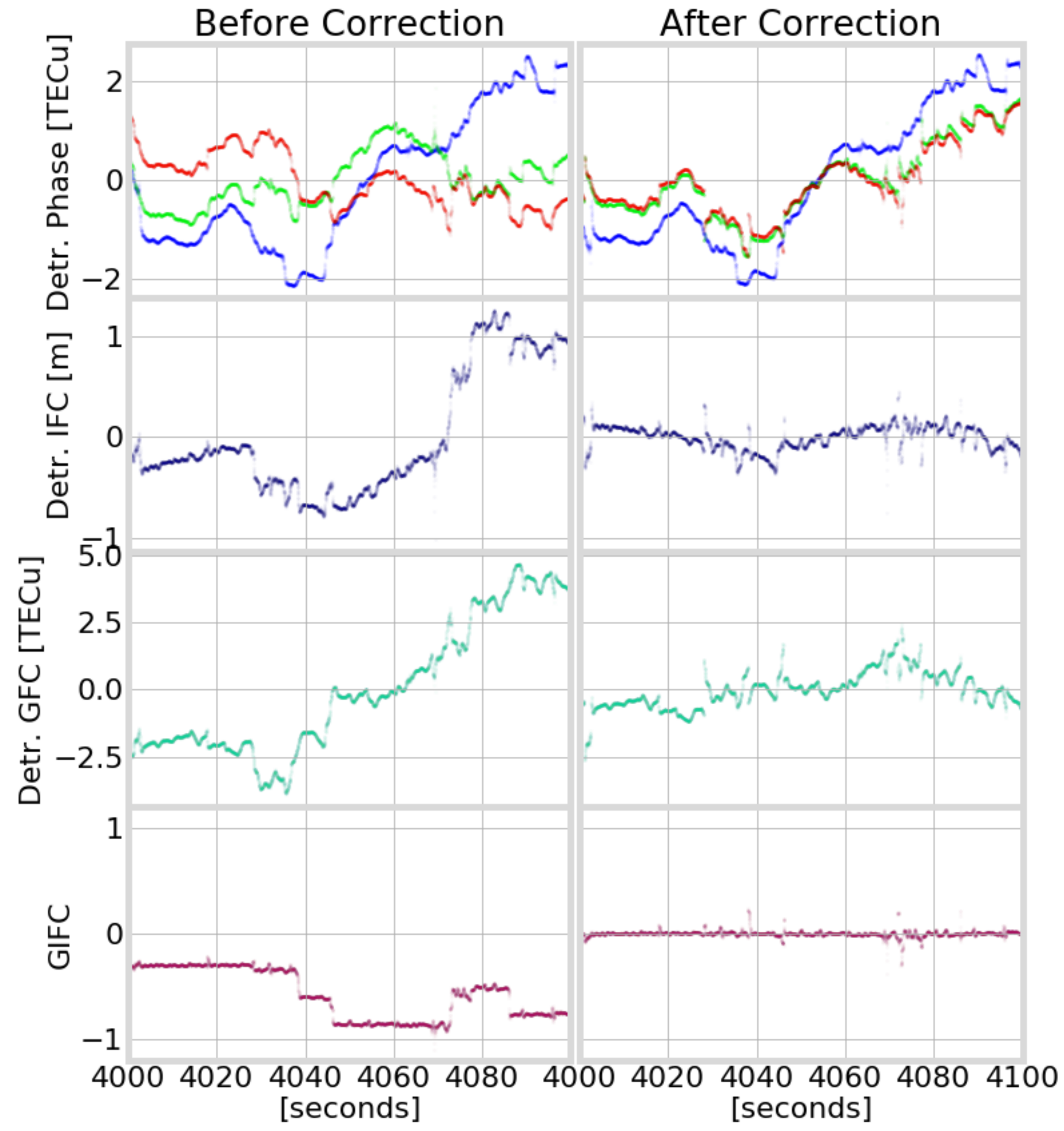
1. compute triple-frequency IFC and TEC
2. spline-fit derivatives, removing any outliers
3. integrate splines to get cycle-slip-free trends
4. remove IFC and TEC trends from individual carrier phases

Detrended Phase with Cycle Slips Intact

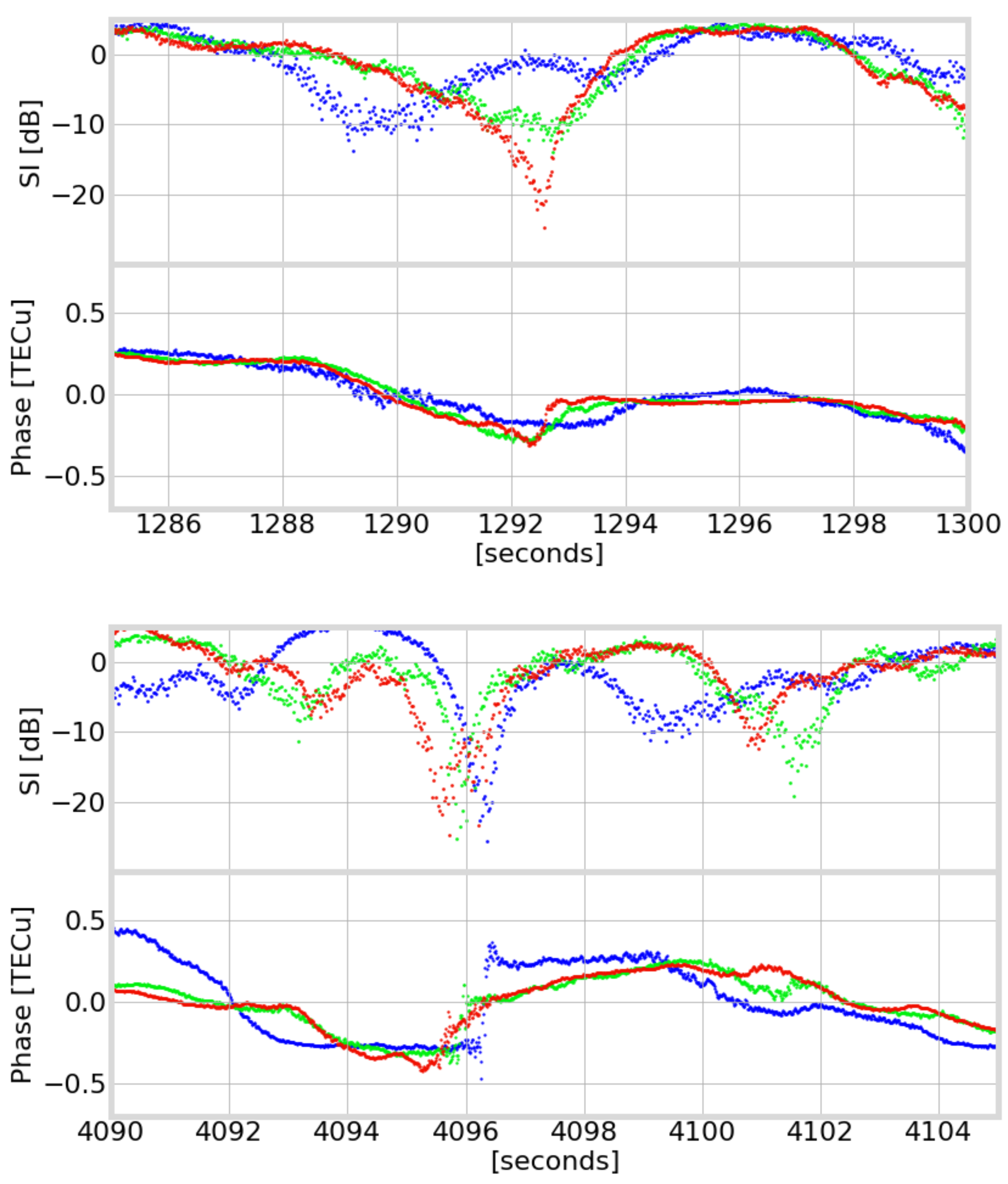


Manual Cycle-Slip Correction

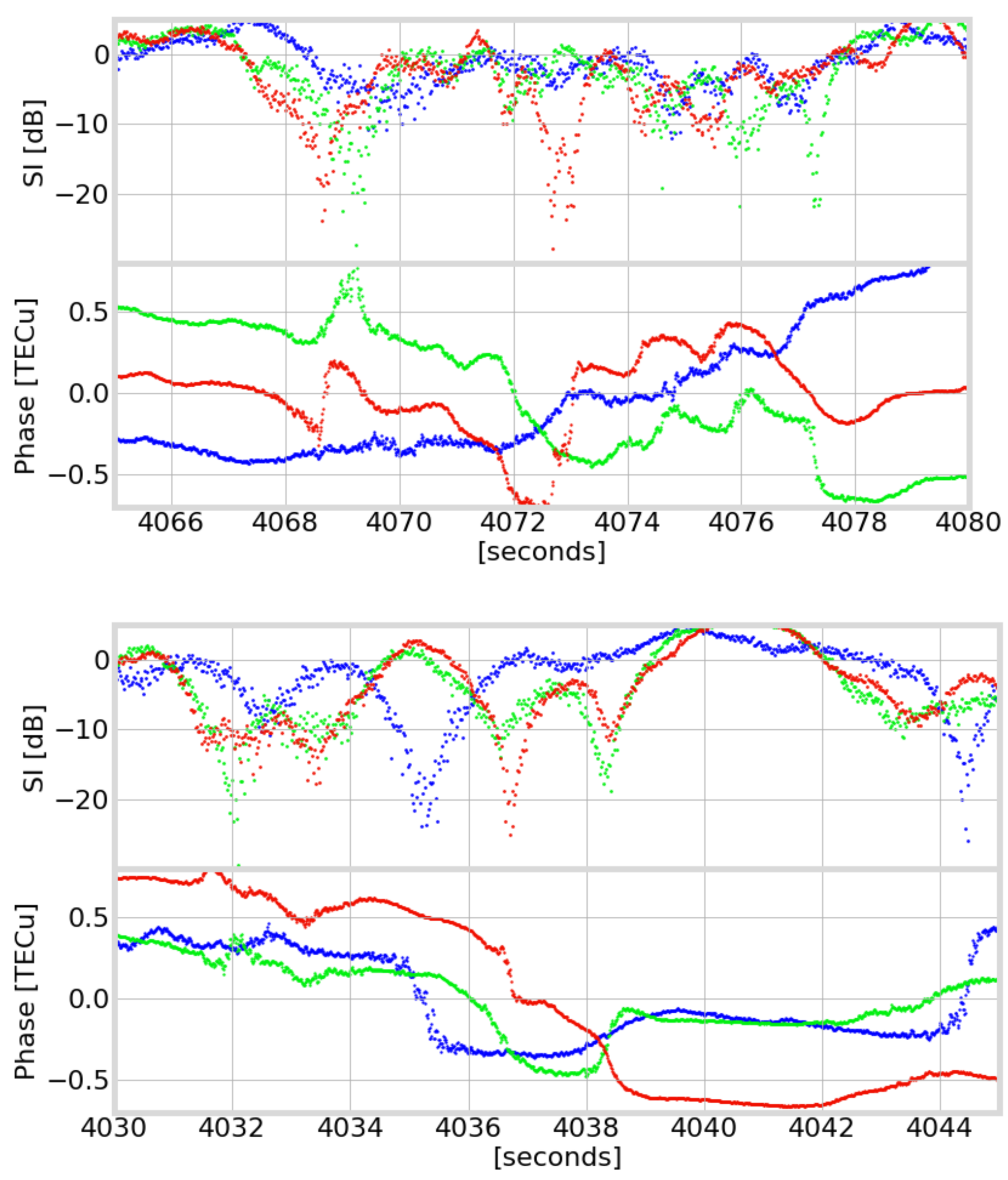
total number of jumps	L1	L2	L5
	18	36	42



Deep Fade, No Slips



Deep Fade with Slips



Want to know more?

[1] Y. Jiao, D. Xu, Y. Morton, and C. Rino, “Equatorial ScintillationAmplitude Fading Characteristics Across the GPS Frequency Bands,”vol. 63, no. 3, pp. 267–281.
[2] M. Carroll, Y. J. Morton, and E. Vinande, “Triple frequency GPS signaltracking during strong ionospheric scintillations over Ascension Island,”in2014 IEEE/ION Position, Location and Navigation Symposium -PLANS 2014, pp. 43–49.
[3] D. Xu and Y. T. Morton, “A Semi-Open Loop GNSS Carrier TrackingAlgorithm for Monitoring Strong Equatorial Scintillation,” vol. PP,no. 99, pp. 1–1.
[4] B. Breitsch, “Linear Combinations of GNSS Phase Observables toImprove and Assess TEC Estimation Precision.”
[5] C. S. Carrano, K. M. Groves, W. J. McNeil, and P. H. Doherty, “Directmeasurement of the residual in the ionosphere-free linear combinationduring scintillation,” inProceedings of the 2013 Institute of NavigationION NTM Meeting, San Diego, CA.
[6] Y. Jiao, Y. Morton, S. Taylor, and M. Carroll, “Characteristics of low-latitude signal fading across the GPS frequency bands.

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