Experiment of Ionospheric Corrections to ALOS L-Band Interferograms

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Outline

- Example: Interferograms of 2008 Wenchuan earthquake displayed waves and ramps, which is probably associated with ionospheric disturbance.

- Attempt to correct the ionospheric phase for L-band ALOS PALSAR data using available ionosphere models.
  - 20 images near PFO, Southern California
  - Theory and method
  - Ionospheric models: GIM, USTEC, TEC-DAWN

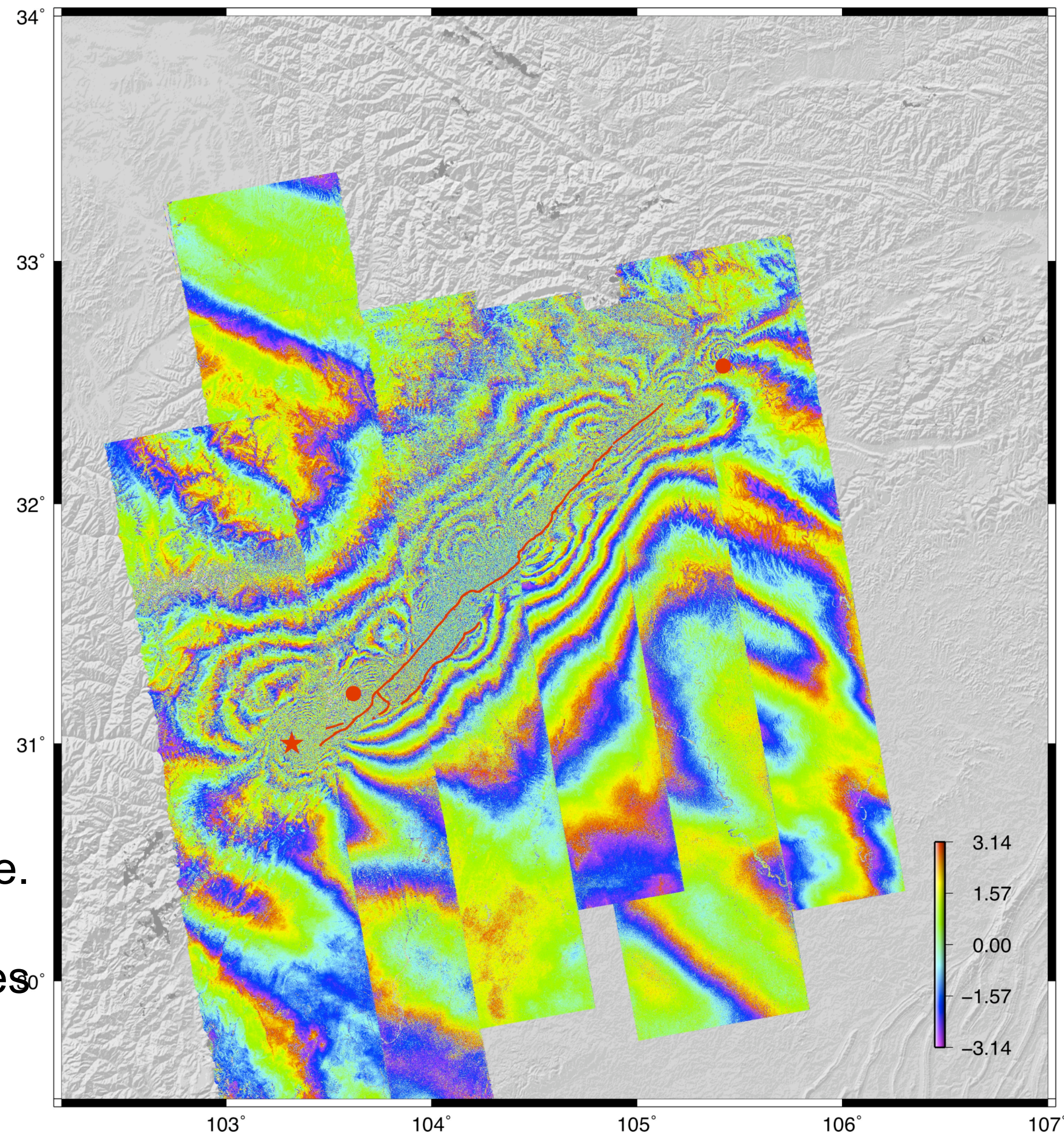
- Results and a summary

Example

• Ionospheric phase ramps and waves are evident in coseismic interferometry of 2008 Wenchuan earthquake.

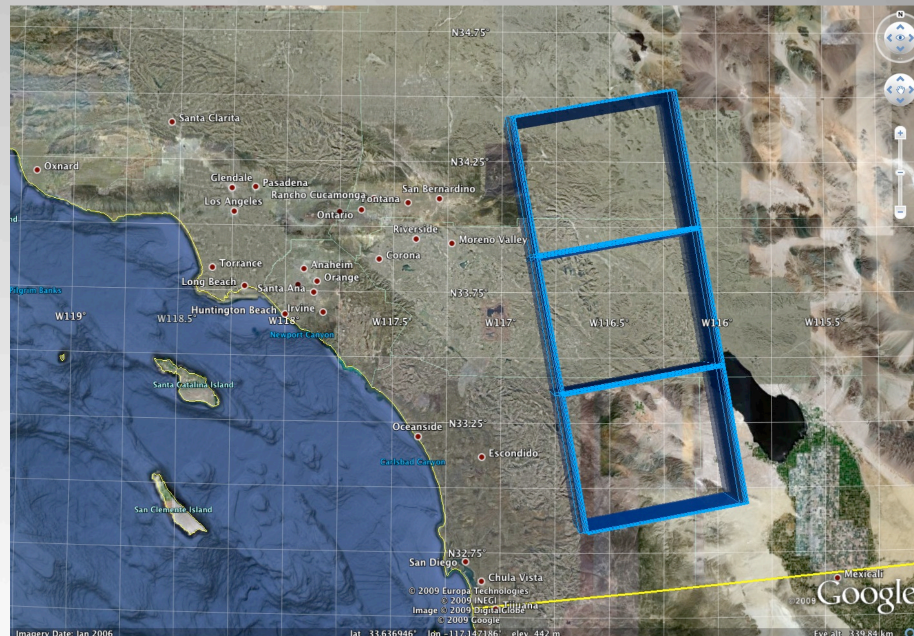
• Ionospheric waves cause azimuth shifts resulting in wave-like areas of lower coherence.

• Similar phase anomalies are observed in other areas: Japan, Canada, Antarctic.



[Tong et al., revised for JGR, 2009]

ALOS L-band PALSAR Data



- T213 F650~670
- 20 ascending acquisitions
- Time span: 2006 to 2009

- Process 11 interferograms to residual phase, many of them exhibit phase ramps and waves.
- Select short spatial baseline pairs (< 514m) to reduce potential orbital error.
- Neglect the interferograms that have large turbulent tropospheric signature.

- Motivation: Can global or regional ionospheric models be used to correct the phase ramps ?

Theory : Effects of Ionosphere on Range

index of refraction

$$n = \sqrt{\varepsilon} = \sqrt{1 - \frac{\lambda^2 e^2 N_e}{4\pi^2 m \varepsilon_0 c^2}} \approx 1 - \frac{1}{2}\frac{\lambda^2 e^2 N_e}{4\pi^2 m \varepsilon_0 c^2} = 1 - K\lambda^2 N_e$$

phase velocity > c

$$v_p = c / n$$

N_e - electron density
e - electron charge
m - electron mass
λ - radar wavelength
c - speed of light
ε_o - permittivity of free space

vertical travel time change

$$\Delta\tau = \int_0^H (1/v_p - 1/c)\,dz = -\frac{K\lambda^2}{c}\int_0^H N_e(z)\,dz = -\frac{K\lambda^2}{c} TEC$$

range change (1-way vetical)

$$\Delta\rho = -K\lambda^2 TEC$$

L-band example
(1-way vertical)

$$\Delta\rho = -25cm * \mathrm{TECU}$$

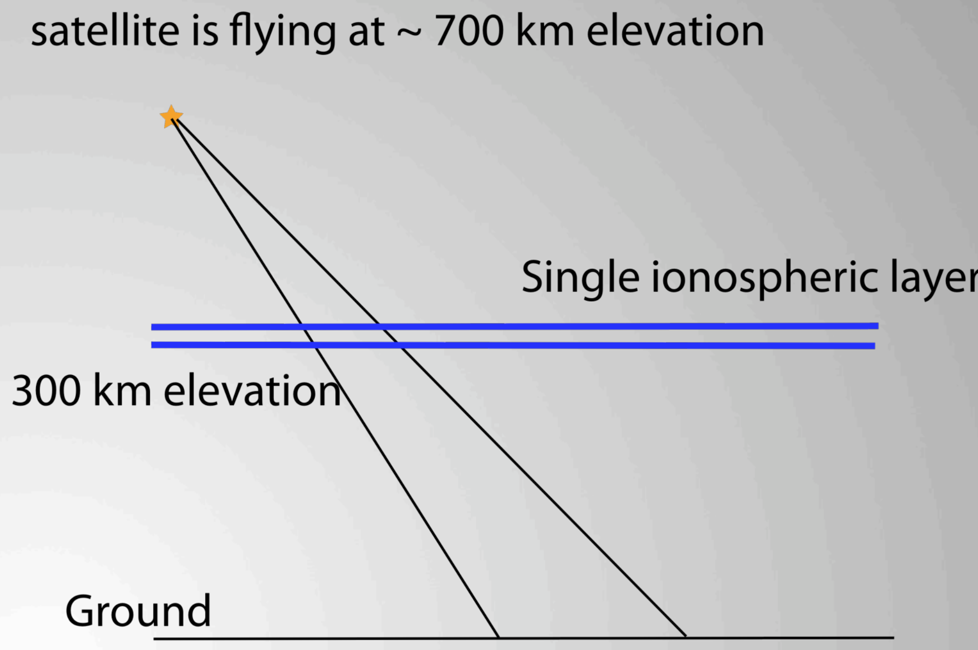
[Gray et al., 2000; Rees, 2001]

Method

• Extract vertical TEC value from three TEC models respectively.

• Compute geographic coordinates at ~300 km elevation that correspond to the ground-level image based on looking angles and the satellite orbit.

• Interpolate the TEC model and produce ionospheric phase corrections based on the formula.



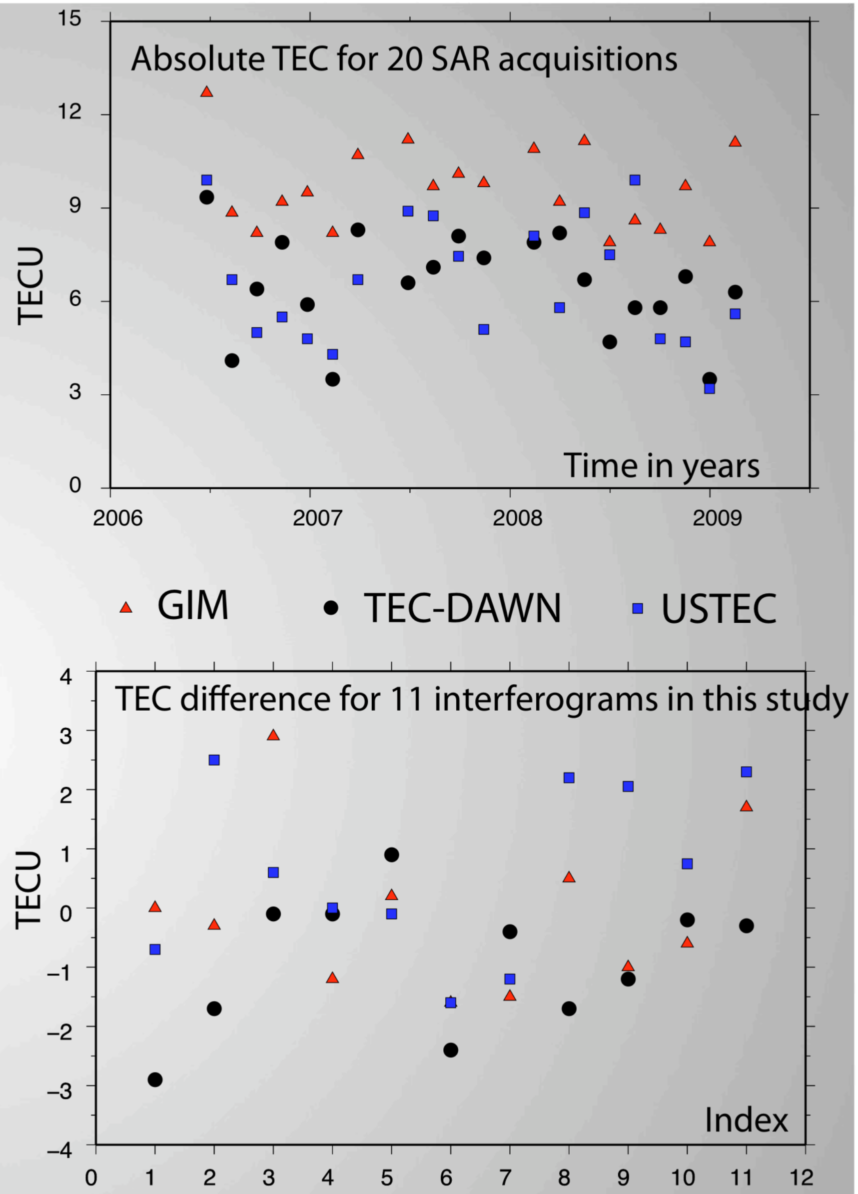
$$\Delta\phi = -4\pi K\lambda * TEC_{vertical} / \cos(E)$$

Two components in this ionospheric phase correction:

A. Spatial variations in TEC **difference** will map directly into range differences.
B. Uniform TEC **difference** across the area will map indirectly according to the increasing range across the swath.

TEC Models

GIM (Global Ionospheric Maps)	hourly	5 deg (lon) x 2.5 deg (lat) pixel spacing	Global
USTEC	15 mins	1 deg x 1 deg pixel spacing	North America
TEC-DAWN	30 secs	0.15x0.15 deg with 7x7 pixel smoothing	U.S.A

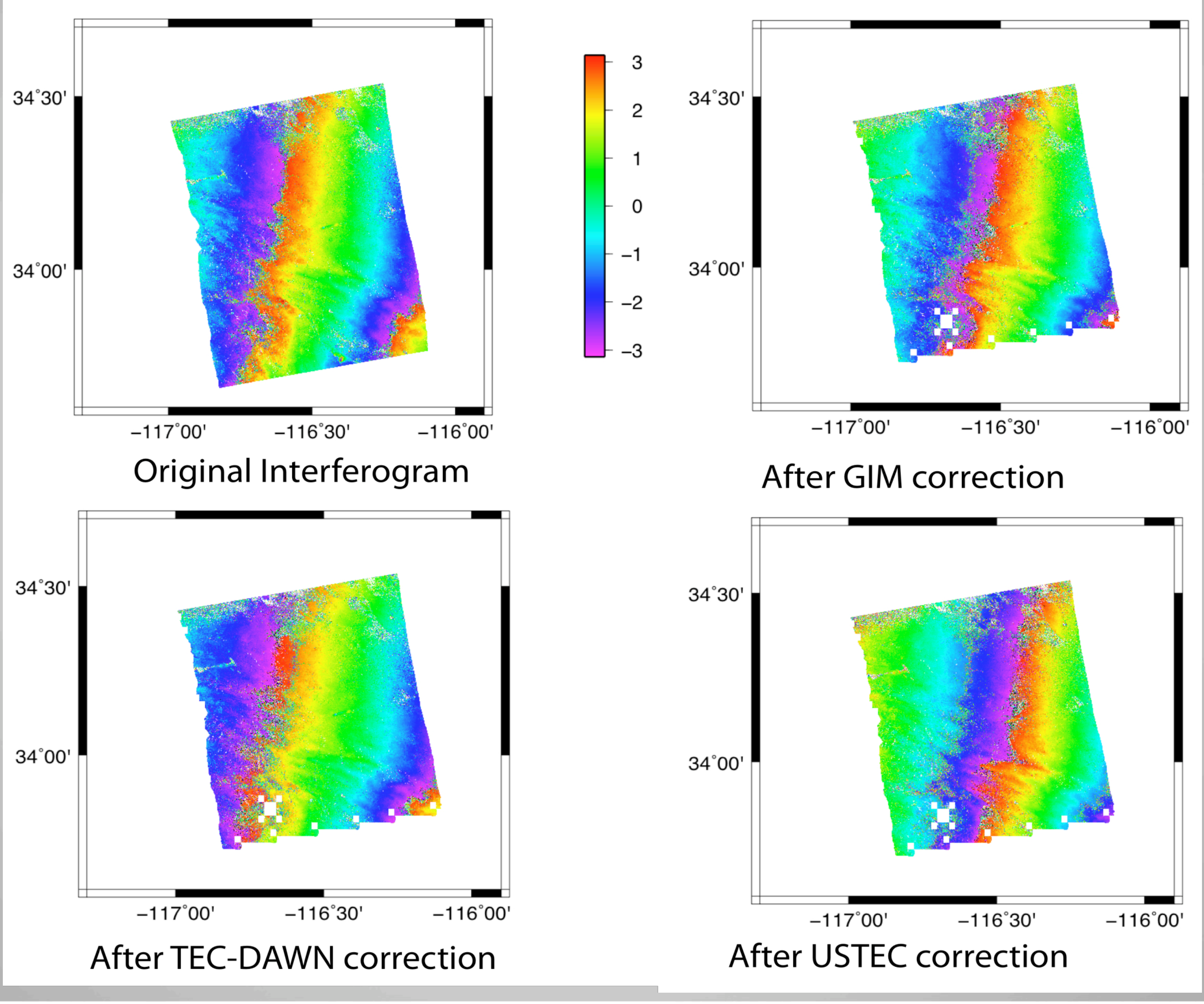


• The overall temporal variation for each model (RMS about the mean): 1.1~1.4 TECU

• The overall disagreement (RMS after differencing between models): 1.5~1.7 TECU

• GIM has an mean offset of 3.1 TECU compared to the other two models.

Results (Example with only a constant TEC difference)



Original Interferogram

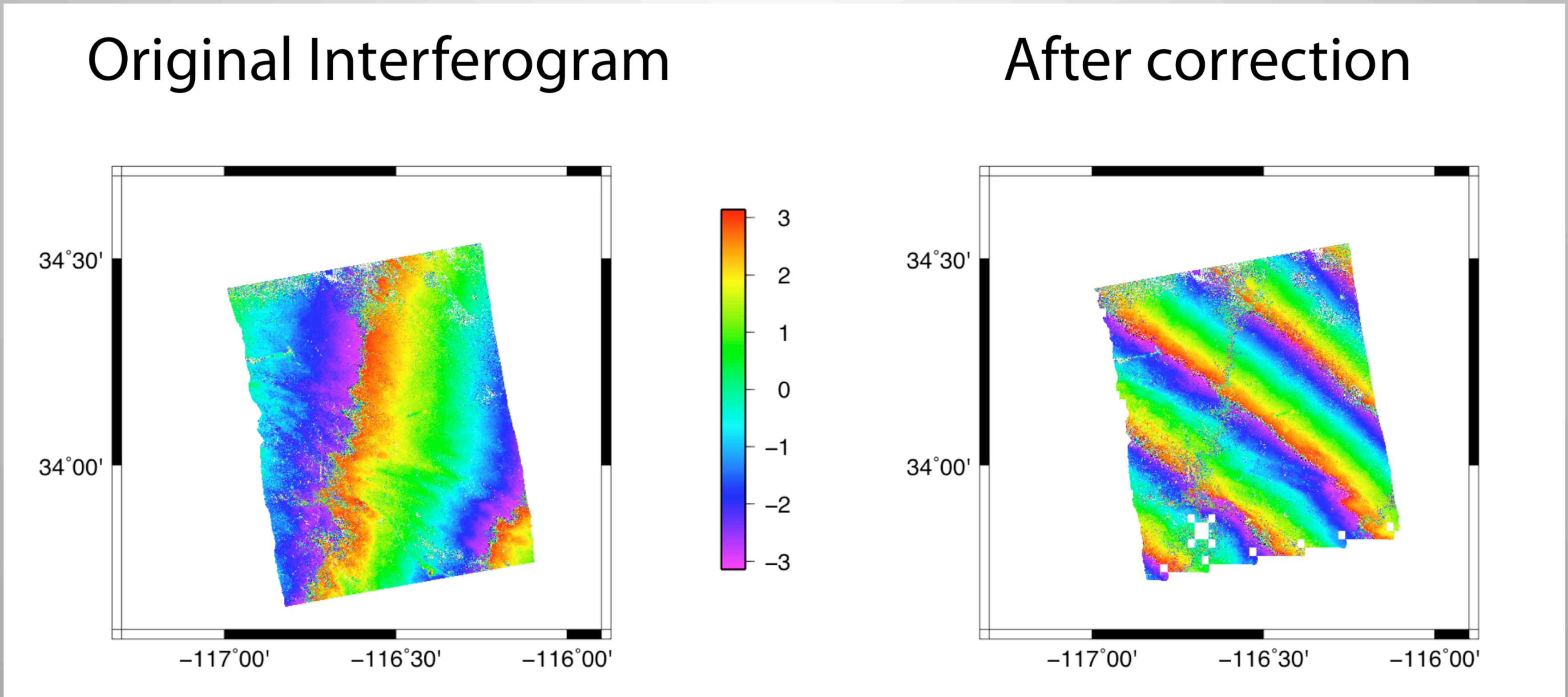
After GIM correction

After TEC-DAWN correction

After USTEC correction

Results (Example with a linear TEC model in both range and azimuth)

• Fit a bilinear function based on finer resolution TEC-DAWN model to account for the spatial variation of TEC within one interferogram.
• TEC-DAWN become more noisy near coastline which can be a problem.



Summary

- Typical ionospheric variations will produce ramps in phase across interferograms of 0~2 fringes that could be confused with orbit error.
- We were not successful in removing phase ramps in range using uniform TEC differences derived from three different ionospheric models.
- The three models provide a constant TEC difference but they have an overall disagreement at 1.5~1.7 TECU, which maps into 0.5~0.6 fringes in range.
- We also tried to correct range and azimuth ramps using the finer resolution TEC-DAWN model but were not successful.
- We conclude that none of the current TEC models are accurate enough to correct phase ramps in interferograms.