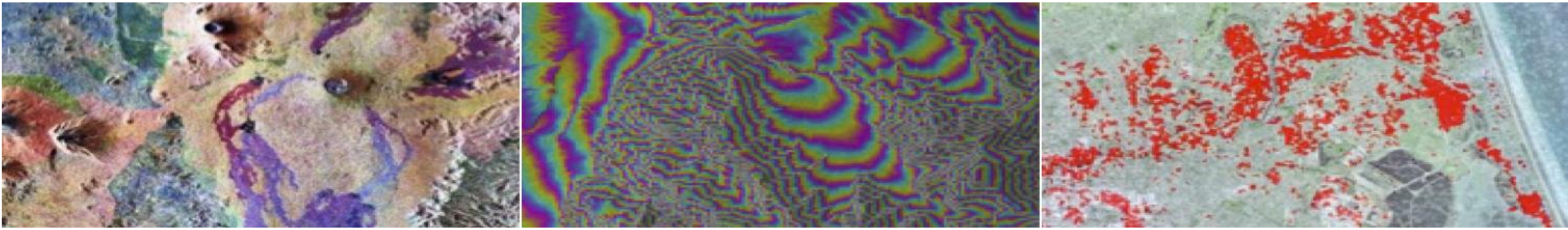

Tropospheric and Ionsopheric delays

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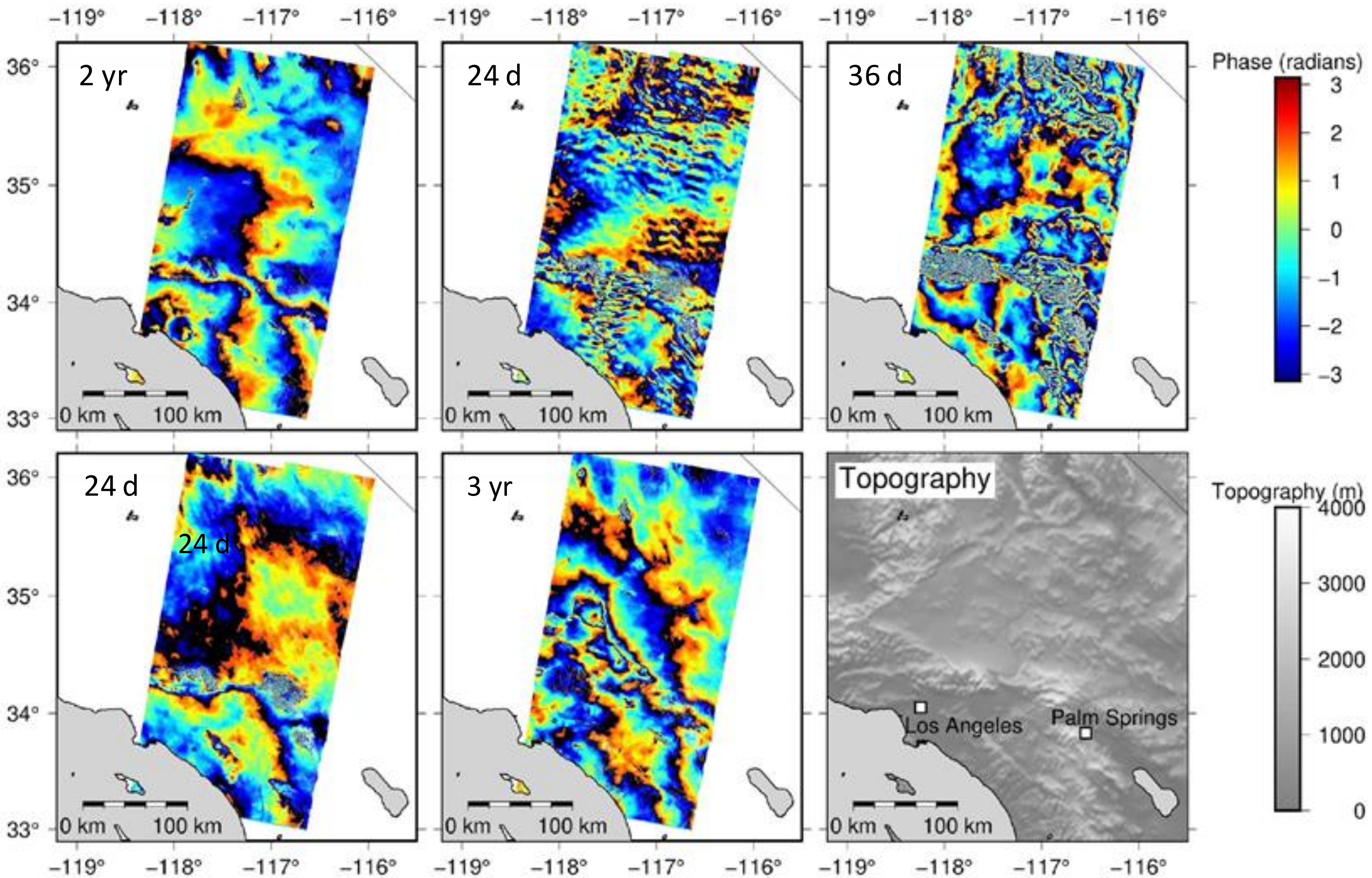
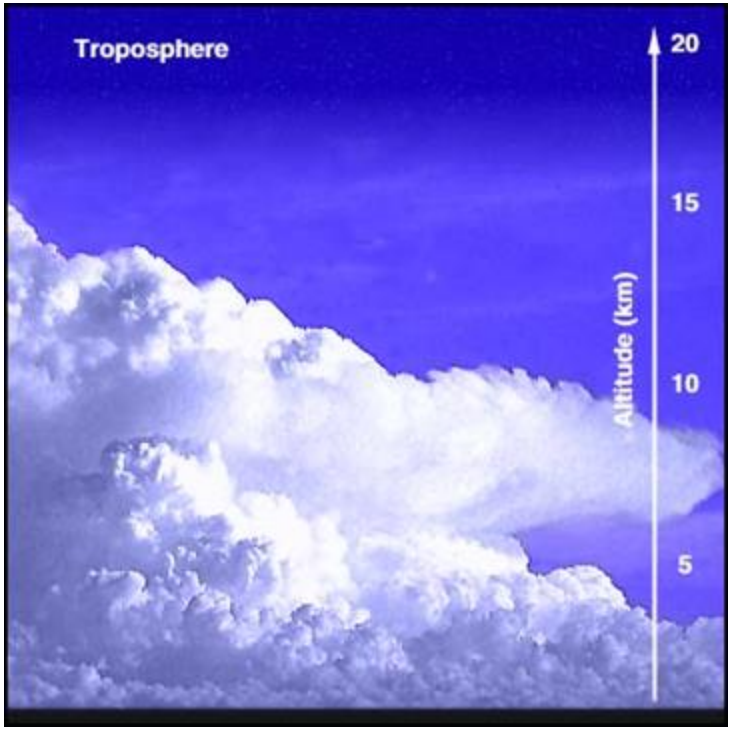
** With contributions from many colleagues: Heresh Fattahi, Eric Fielding, David Bekaert, Simran Sangha, Roger Michaelides, David Sandwell*

Example interferograms:
QUIZ - where is the tectonic signal?

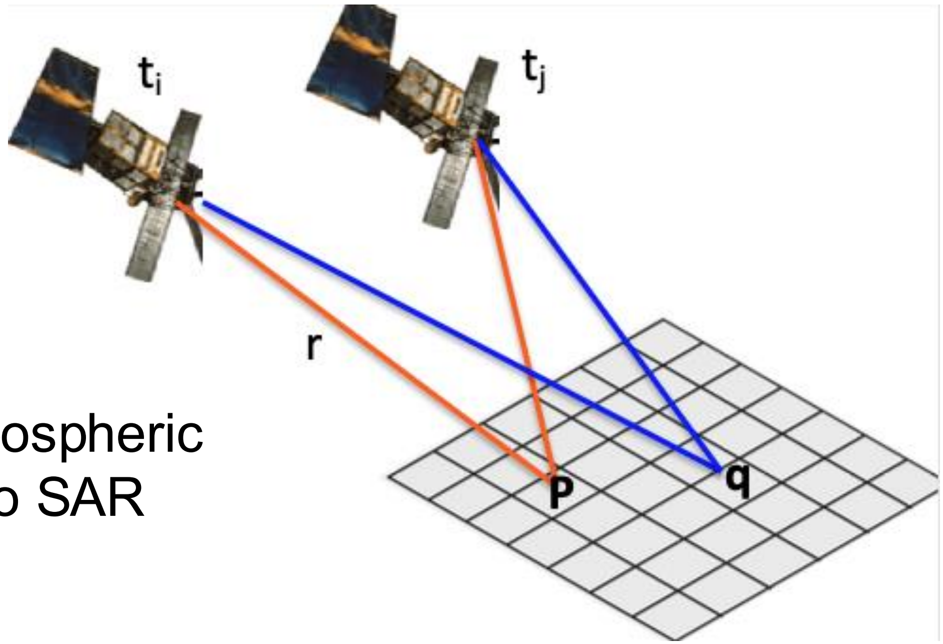
Sentinel-1
1 fringe = 28 mm



Troposphere

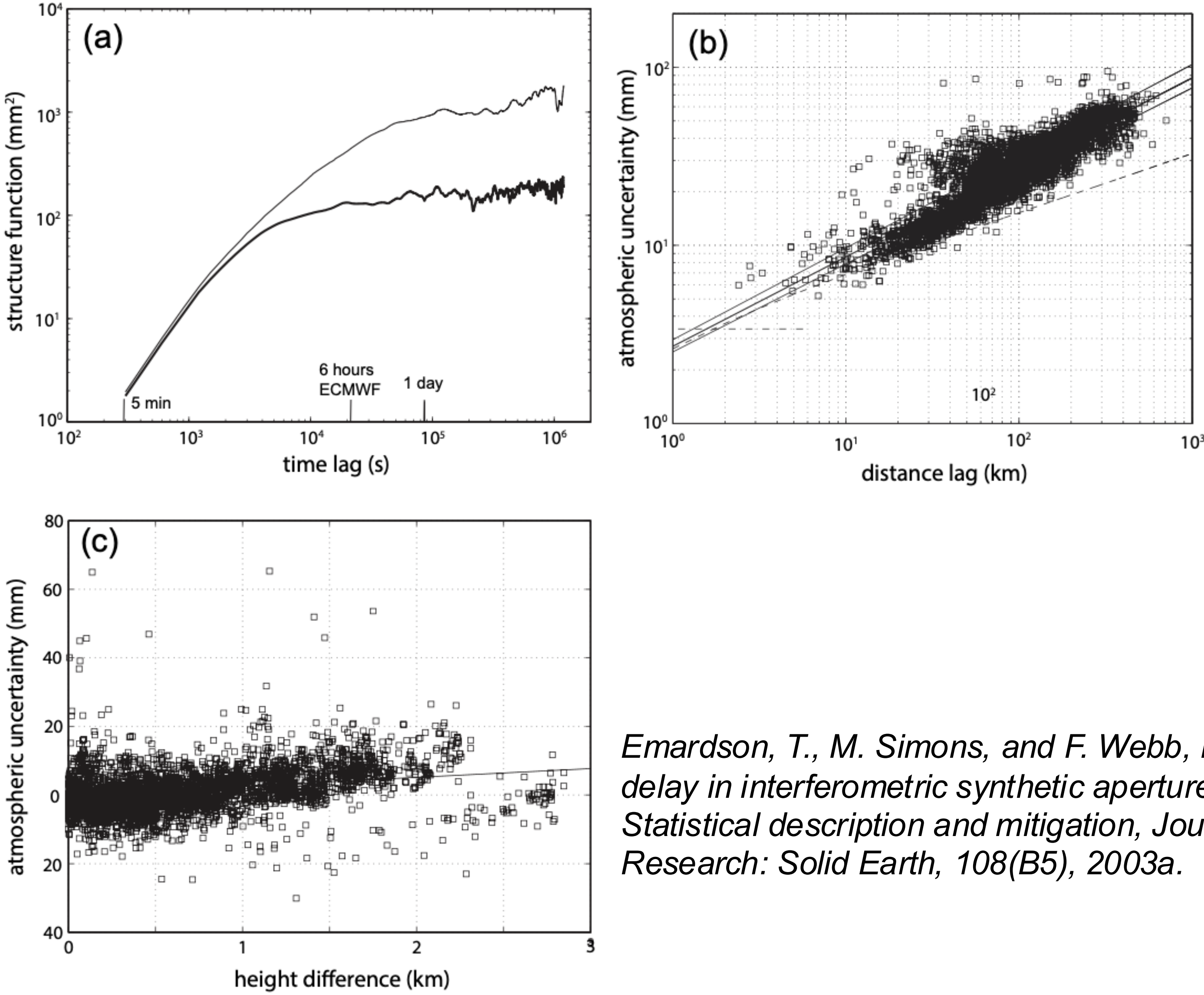


- ***Radar waves are refracted***
  - Pressure
  - Temperature
  - Water vapor



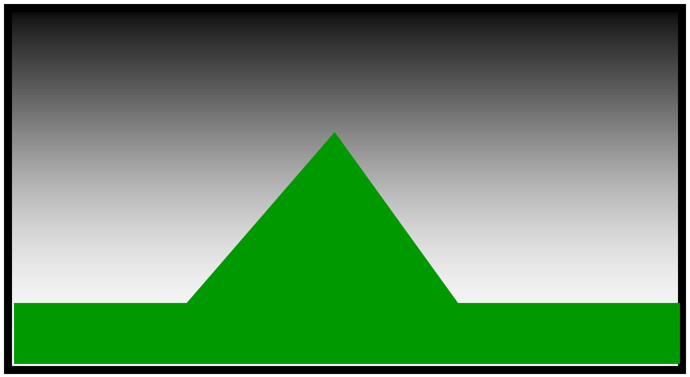
It is the double difference in tropospheric delays between two pixels at two SAR acquisition times that matters!

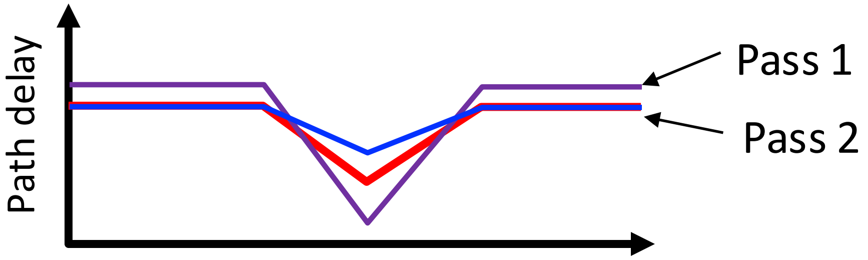
Tropospheric noise characteristics



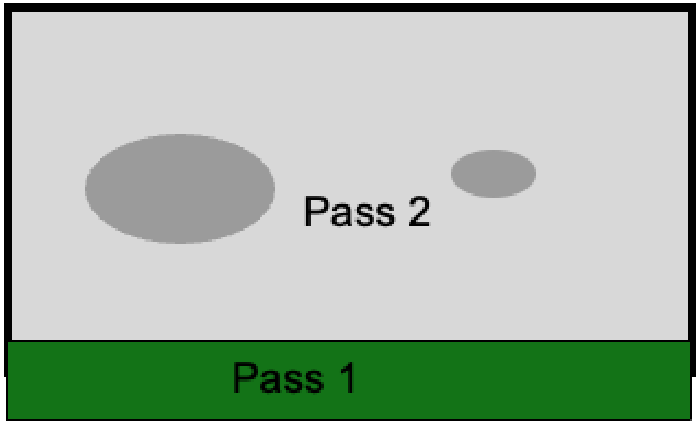
Emardson, T., M. Simons, and F. Webb, Neutral atmospheric delay in interferometric synthetic aperture radar applications: Statistical description and mitigation, Journal of Geophysical Research: Solid Earth, 108(B5), 2003a.

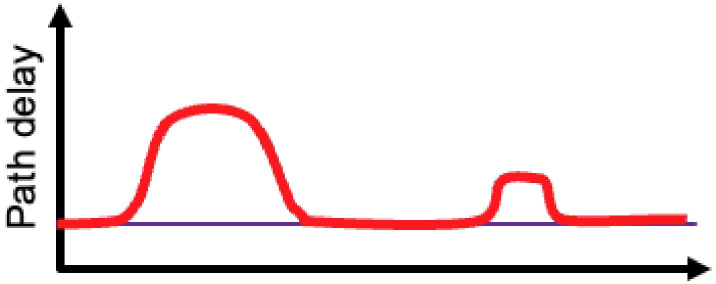
Stratified tropospheric delays





Turbulent tropospheric delays





- Uncorrelated in time
- Almost unpredictable
- Power-law spectrum

Atmospheric correction

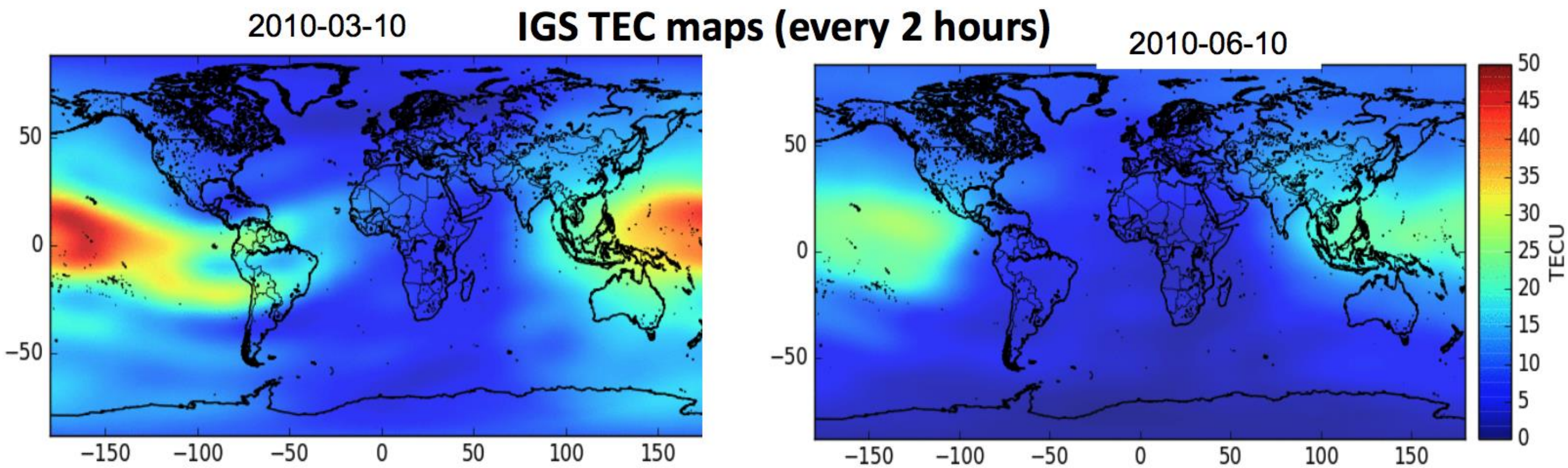
- Options:
  - Weather models

    May not have enough accuracy and/or temporal and spatial resolution
  - Filtering (in time or space or both)

    May remove real deformation signals e.g., earthquakes
  - Topography-correlated models

    May remove real deformation signals e.g., volcano inflation

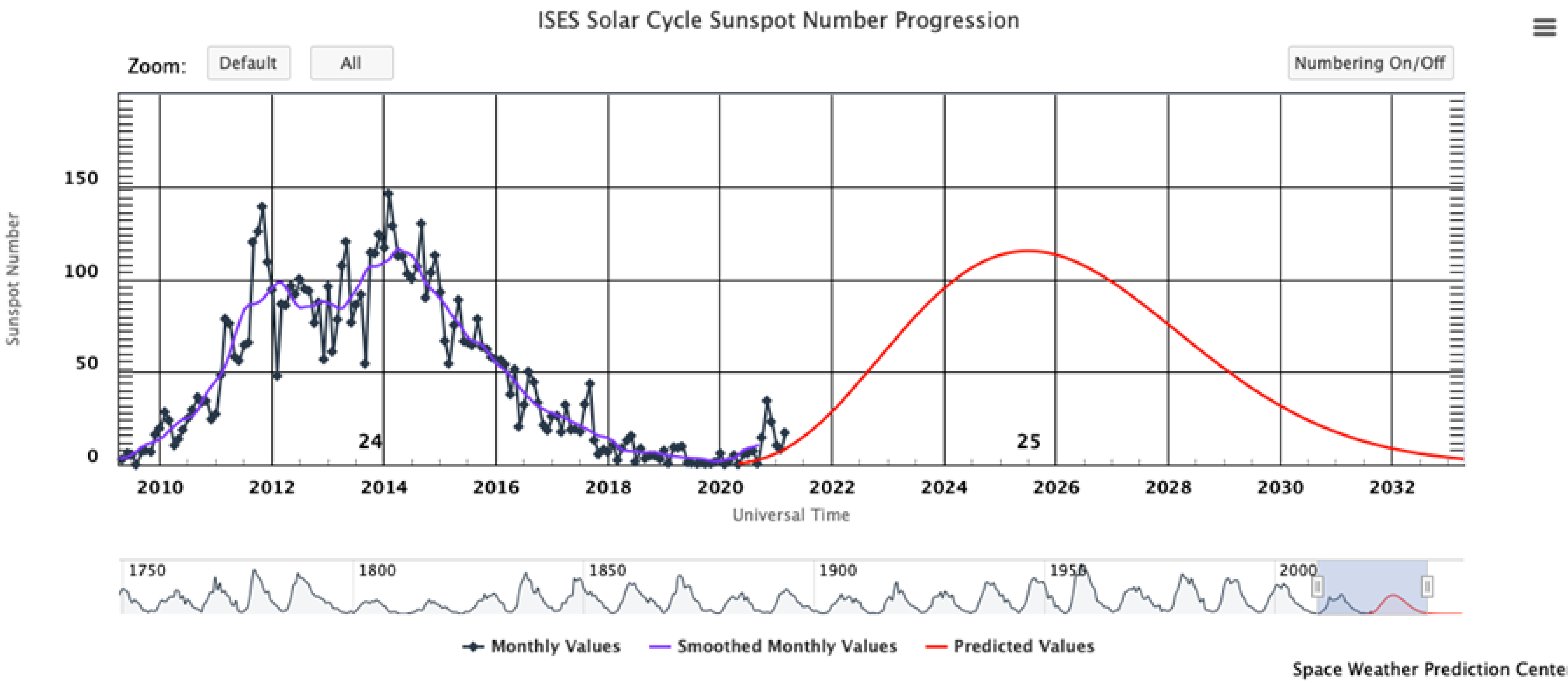
Ionospheric delay in repeat-pass interferometry



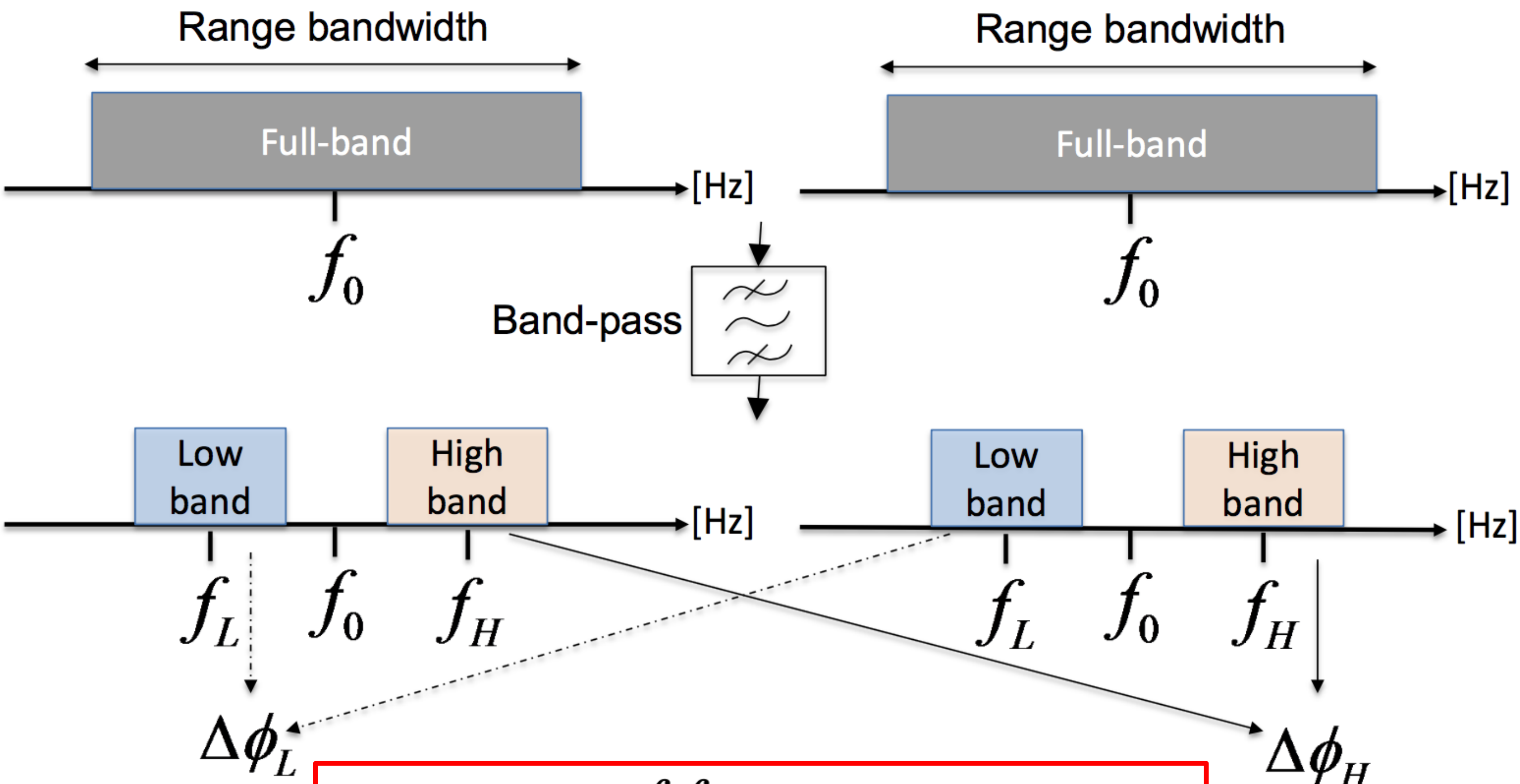
Ionospheric delay is dispersive:

$$\Delta r_{iono} = -\frac{40.3}{f^2} TEC$$

TEC – varies daily and with the 11-year solar cycle



Ionospheric delay correction using split-spectrum method

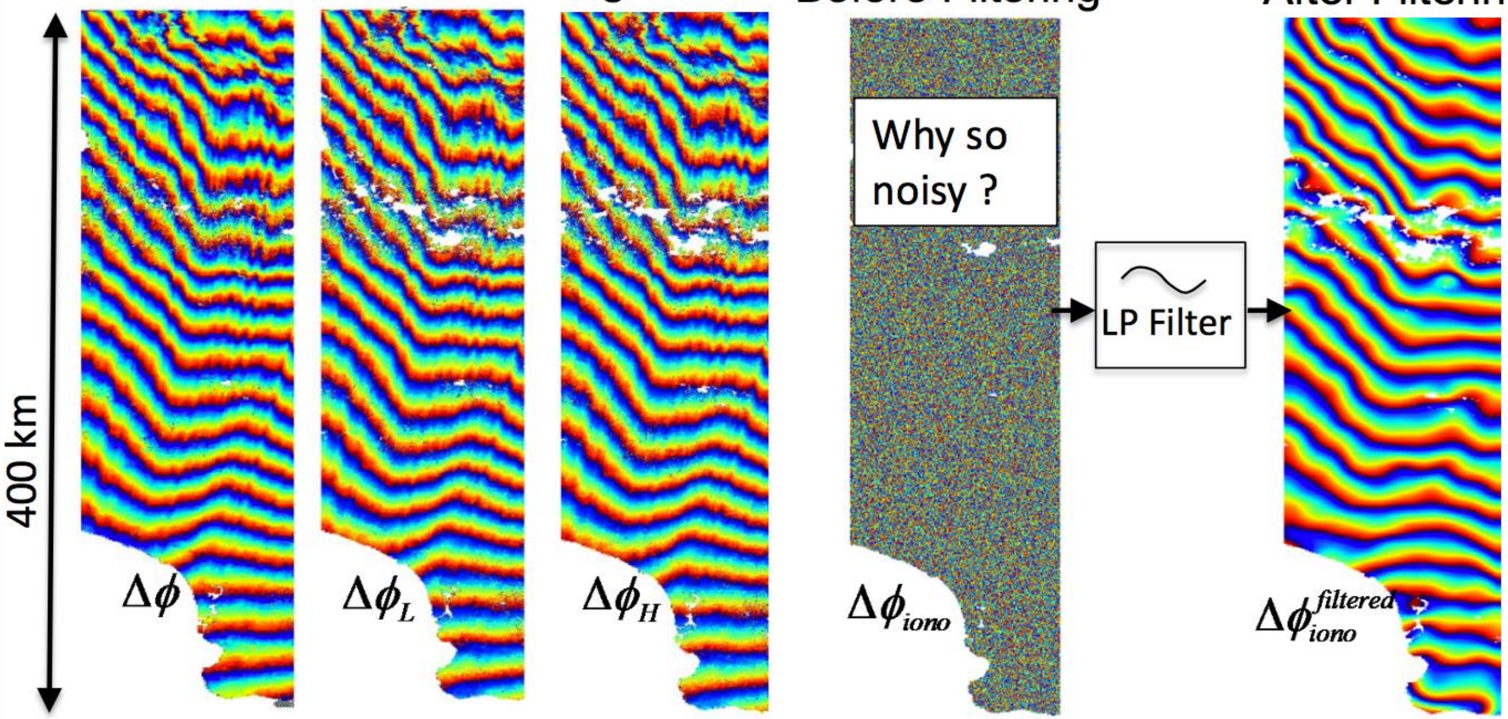


$$\boxed{\Delta\phi_{ion} = \frac{f_l f_u}{f_o\left(f_u^2 - f_l^2\right)}\Delta\phi_l f_u - \Delta\phi_u f_l}$$

Interferometric phase

Estimated Ionospheric phase delay

Full-band Low-band High-band Before Filtering After Filtering



Due to small difference between f_L and f_H, small noise in $\Delta\phi_{L,H}$ amplifies in $\Delta\phi_{iono}$

Variance of the estimated ionospheric delay

$$\sigma_{iono}^2 = \sigma_{\Delta\phi_{L,H}}^2 \frac{f_L^2 f_H^2}{(f_H^2 - f_L^2)^2} \frac{f_L^2 + f_H^2}{f_0^2}$$

ALOS-1 (FBD)

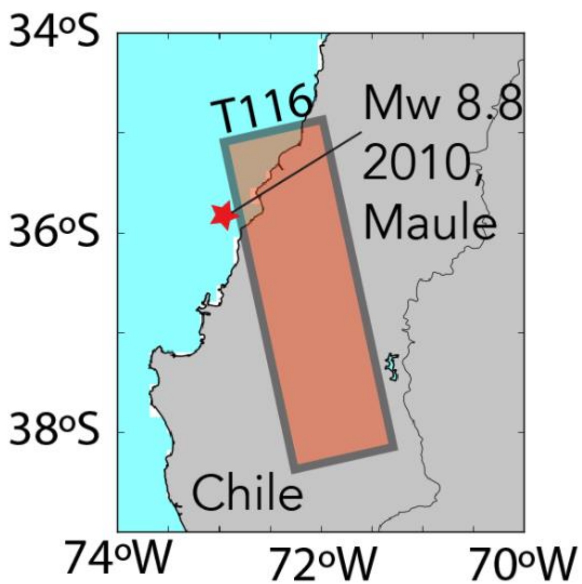
$$\begin{cases} f_0 = 1.3GHz \\ f_L = 1.3GHz - 3.5MHz \\ f_H = 1.3GHz + 3.5MHz \end{cases}$$

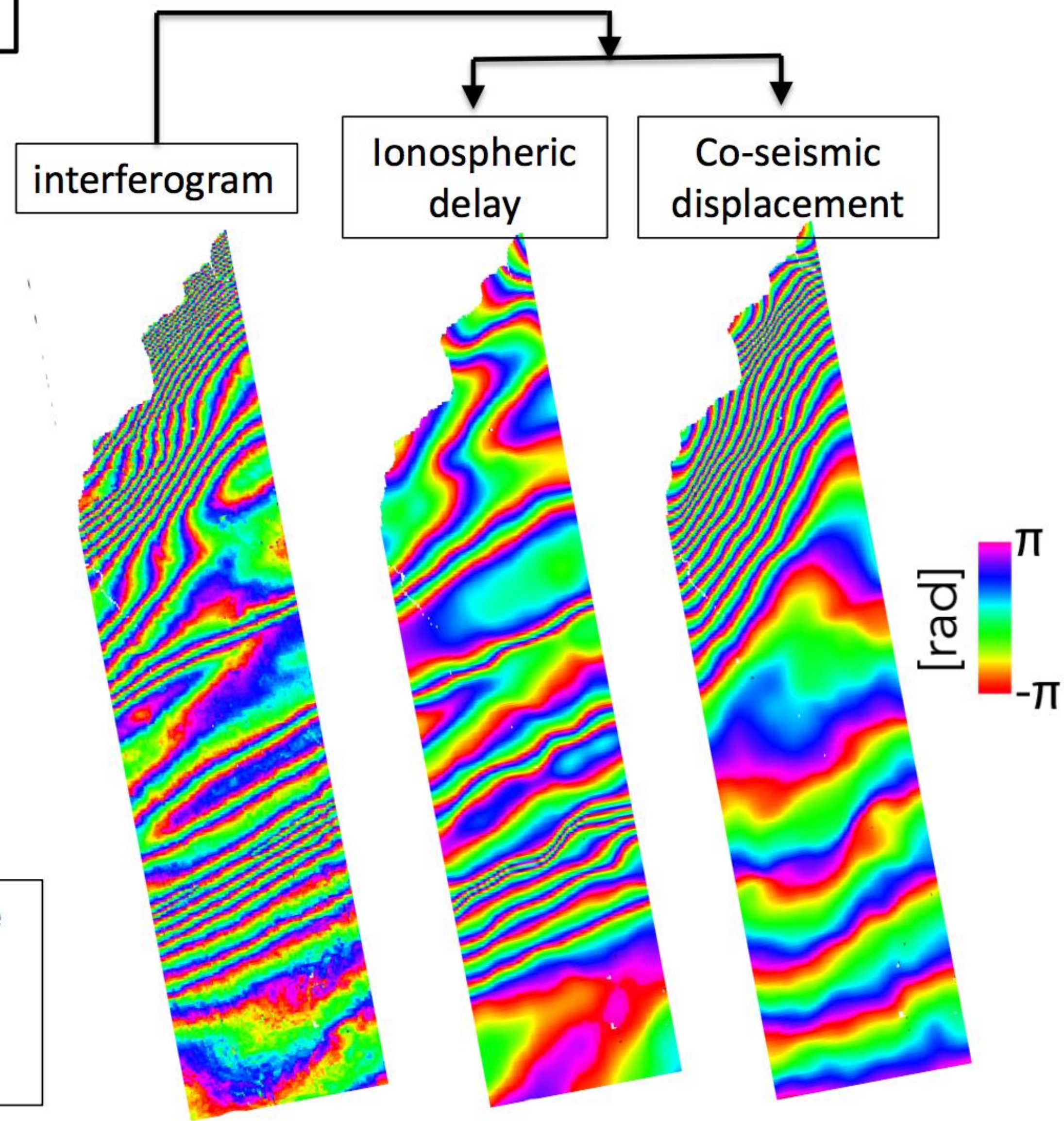
$\sigma_{\Delta\phi_{L,H}} = 1$ radian

$\sigma_{iono} = 131$ radian

Mw 8.8 2010 Maule

ALOS-1
FBS (28 MHz)
20100225-20100412





Split range-spectrum technique was used to decouple the ionospheric delay from ground displacement signal.

Ionosphere ramp for L-band ALOS-2