School of Earth and Environment

Institute of Geophysics and Tectonics

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Statistical comparison of troposphere correction methods for InSAR

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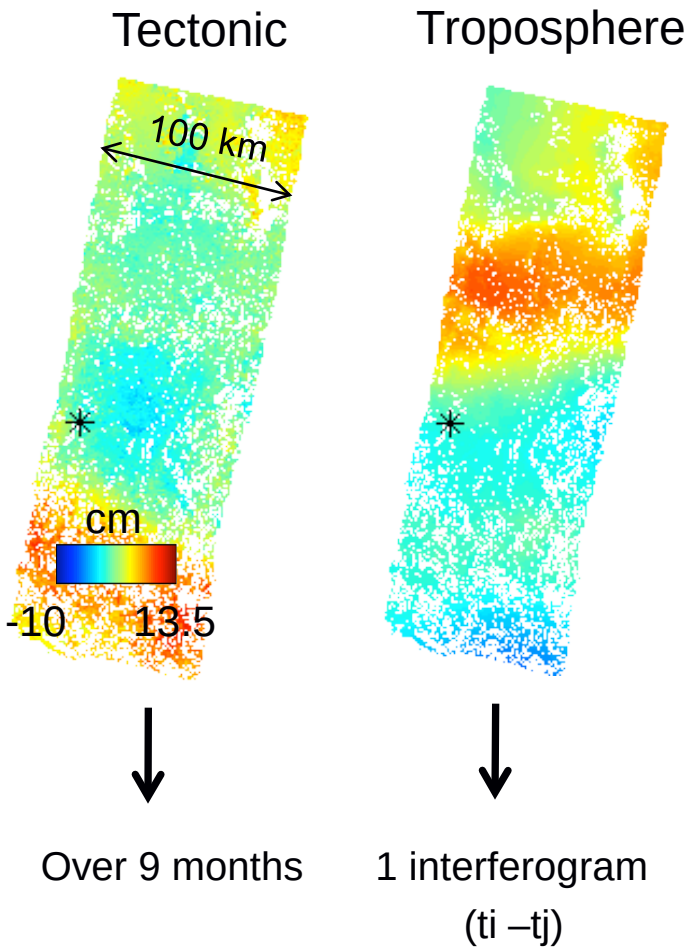
Why a tropospheric correction for InSAR?

To extract smaller deformation signals

Tropospheric delays can reach up to 15 cm

With the tropospheric delay a superposition of

- Short wavelength turbulent component
- Topography correlated component
- Long wavelength component



Tropospheric correction methods

Spectrometers:

- MERIS (Envisat) = REF
- MODIS (AQUA and TERRA)

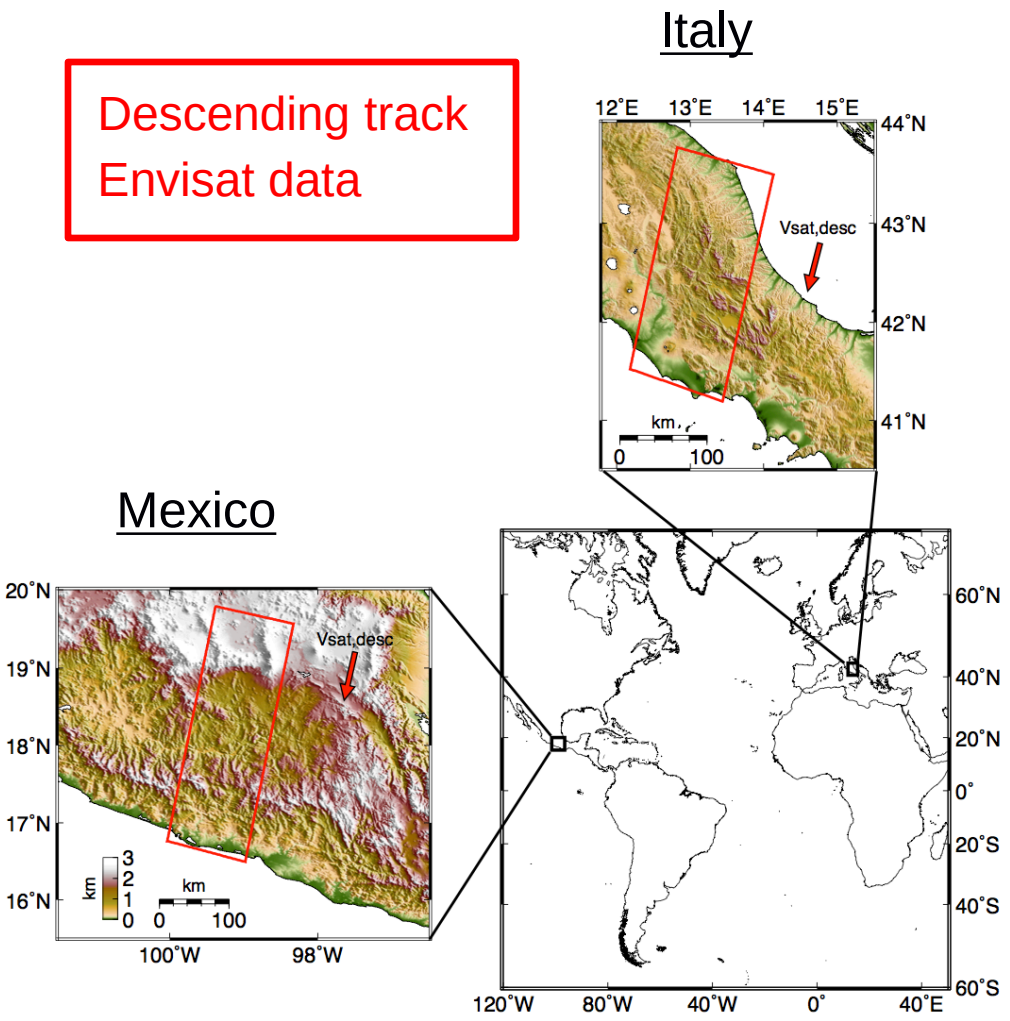
Weather model

- ERA-I
- WRF

Phase-based

- Uniform correction
- Non-uniform correction

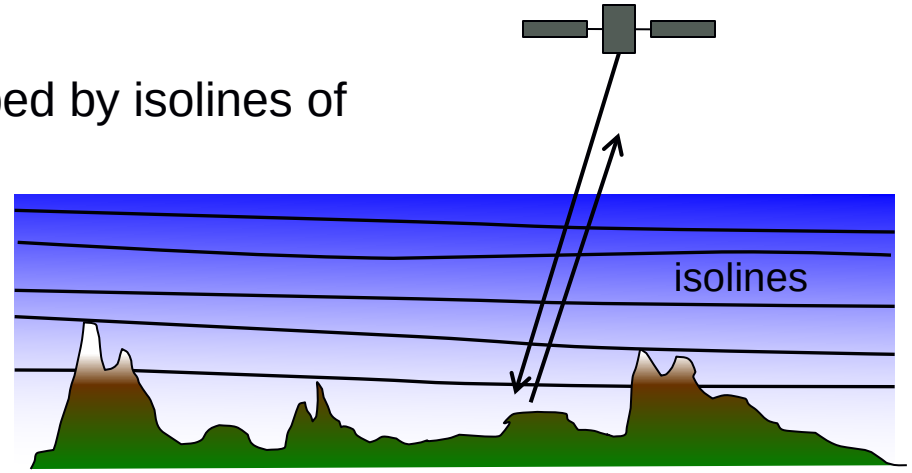
Descending track
Envisat data



Tropospheric delays from refractivity

The **troposphere** is mainly described by isolines of

- Temperature (*T*)
- Pressure (*P*)
- Water vapor (*e*)



And can be computed by integrating the refractivity *N* with height

$$\phi_{\text{tropo}} = \frac{-4\pi}{\lambda} \frac{1}{10^6 \cos\theta} \int_{h=h_1}^{\infty} N\,dh$$

$$N = \left[k_1 \frac{P}{T} \right]_{\text{hydr}} + \left[k'_2 \frac{e}{T} + k_3 \frac{e}{T^2} \right]_{\text{wet}}$$

constants

Tropospheric delays from weather models

$$\phi_{tropo} = \frac{-4\pi}{\lambda} \frac{1}{10^6 \cos\theta} \int_{h=h_1}^{\infty} N dh \qquad N = \left[k_1 \frac{P}{T} \right]_{hydr} + \left[k'_2 \frac{e}{T} + k_3 \frac{e}{T^2} \right]_{wet}$$

Use pressure, temperature and relative humidity

Interpolate in time and compute the interferometric delay

Available models e.g.:

Used in this study

ECMWF

70 km (6hrs)

NCEP

32 km (3hrs)

WRF

Locally run at 7km

Tropospheric delays from spectrometers

$$\phi_{\text{tropo}} = \frac{-4\pi}{\lambda} \frac{1}{10^6 \cos\theta} \int_{h=h_1}^{\infty} \text{Ndh} \qquad \text{N} = \left[k_1 \frac{\text{P}}{\text{T}} \right]_{\text{hydr}} + \left[k_2' \frac{\text{e}}{\text{T}} + k_3 \frac{\text{e}}{\text{T}^2} \right]_{\text{wet}}$$

Observations of Precipitable Water Vapor: $\text{PWV} = \frac{1}{\rho_{\text{lw}} \text{R}_{\text{v}}} \int_{h}^{\infty} \frac{\text{e}}{\text{T}} \text{dh}$

$$\phi_{\text{tropo}}^{\text{wet}} = \frac{-4\pi}{\lambda} \frac{1}{\cos\theta} \Pi * \text{PWV}$$

Interpolate in time and compute the interferometric delay

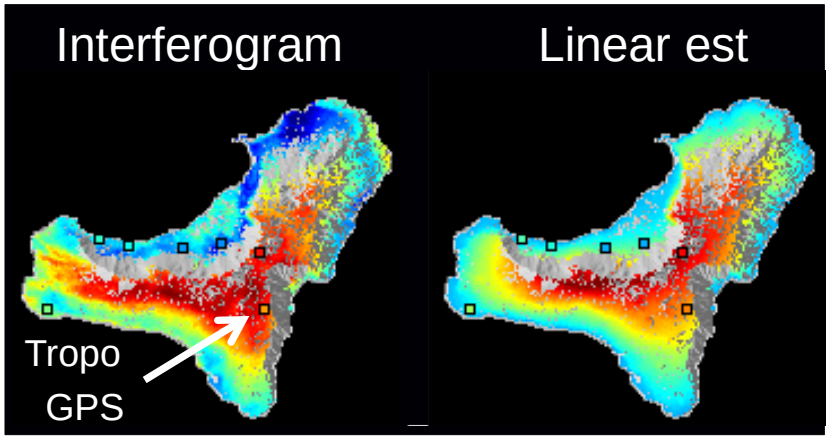
Available sources: MERIS and MODIS

Tropospheric delays from a linear relationship

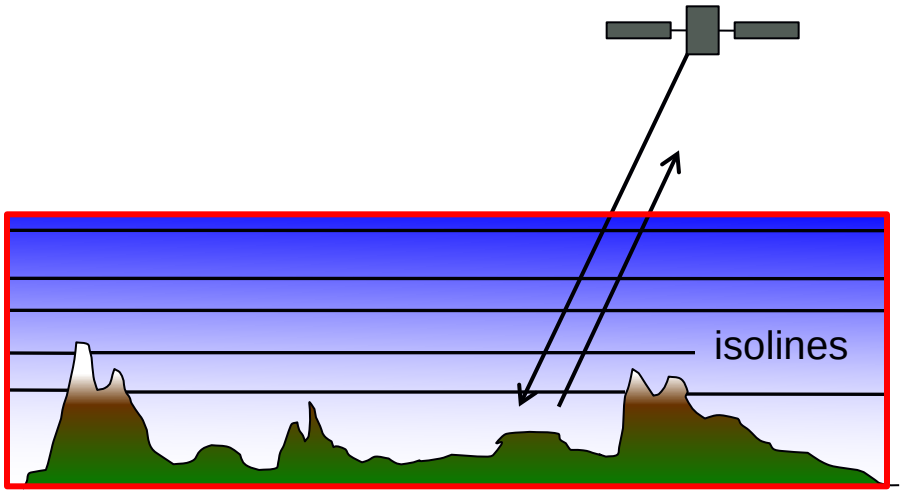
Wet and hydrostatic delay combined

$$\Delta\phi_{tropo}^{uniform} = K_{uniform} \cdot h + \cancel{Const}$$

Assumes a uniform troposphere



InSAR and GPS data property of IGN



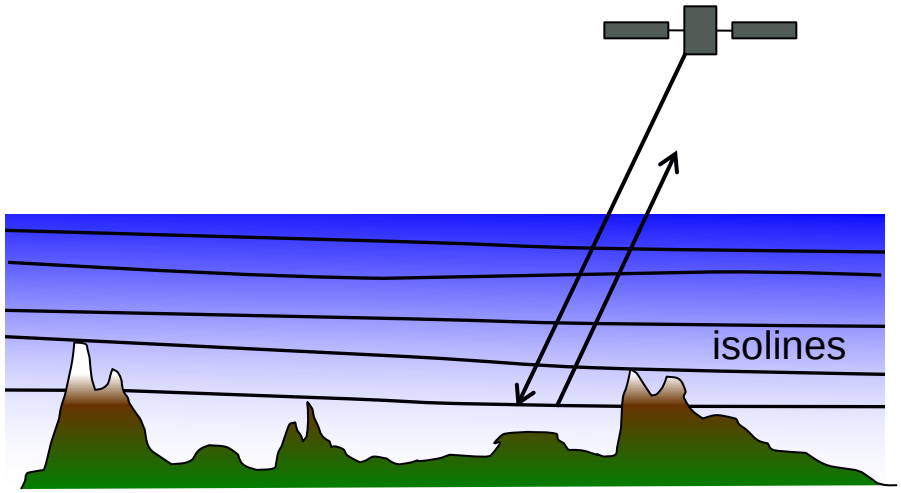
Tropospheric delays from a power-law relationship

[Bekaert et al., JGR 2015a]

Wet and hydrostatic delay combined

$$\Delta\phi_{\text{tropo}}^{\text{spatial}} = \mathrm{K}_{\text{spatial}} \cdot \left(\mathrm{h}_0 - \mathrm{h}\right)^{\alpha}$$

Assumes a spatially-varying troposphere



Tropospheric delays from a power-law relationship

[Bekaert et al., JGR 2015a]

Wet and hydrostatic delay combined

$$\Delta\phi_{\text{tropo}}^{\text{spatial}} = \mathrm{K}_{\text{spatial}} \cdot \left(\mathrm{h}_0 - \mathrm{h}\right)^{\alpha}$$

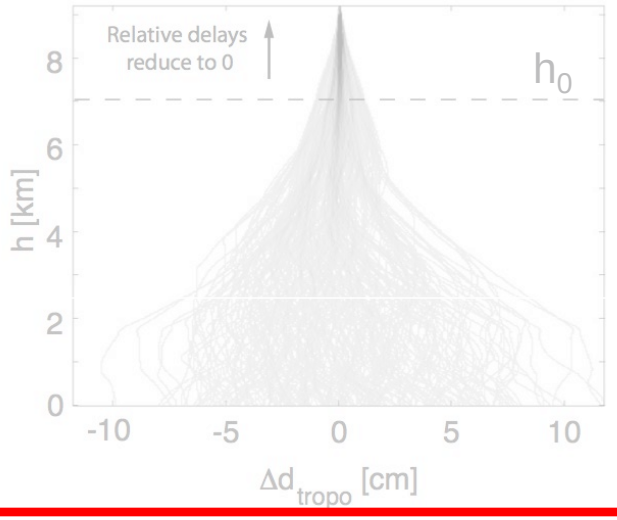
With $\mathbf{h_0}$ the lowest height at which the relative tropospheric delays ~0

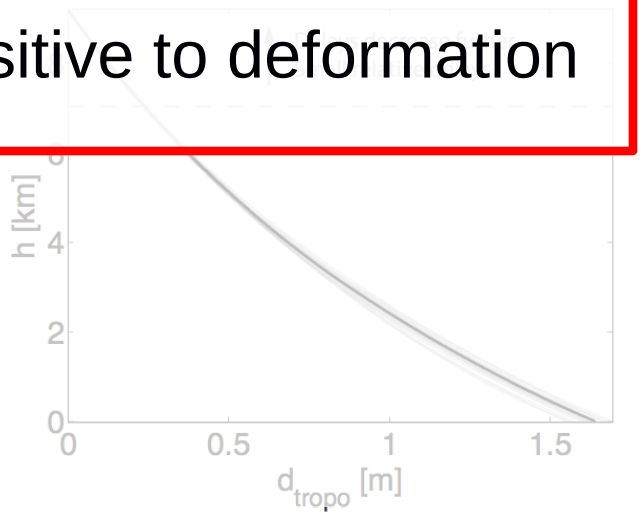
- 7-14 km from balloon sounding

Estimate $\mathrm{K}_{\text{spatial}}$ in a band-insensitive to deformation

With α a power-law describing the decay of the tropospheric delay

- 1.3-2 from balloon sounding data



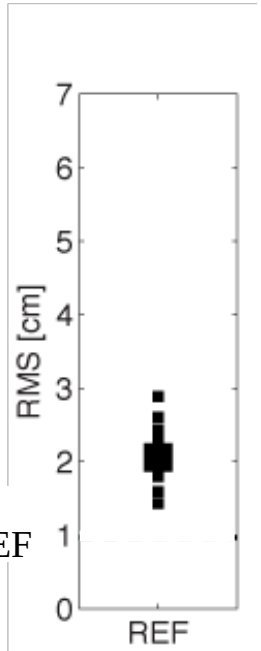


Sounding data provided by the University of Wyoming

Signal $\Delta\phi_{\mathrm{REF}}$

$$\Delta\phi_{\mathrm{MERIS}} + \Delta\phi_{\mathrm{ERA}}^{\mathrm{hydro}}$$

[Bekaert et al., in prep]



σ_{REF}

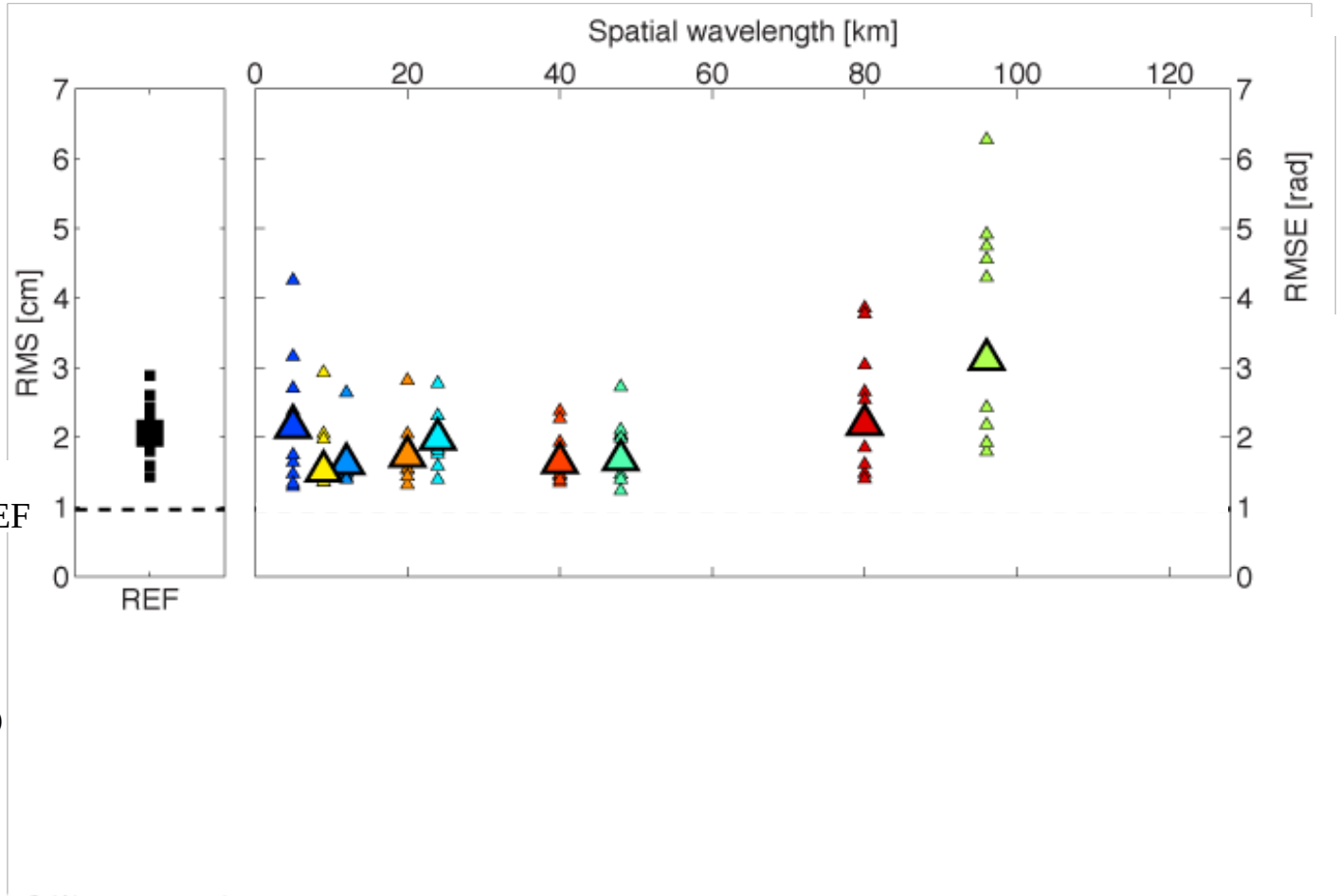
//

MERIS Accuracy

(Z. Li et al, 2009)

Signal $\Delta\phi_{\mathrm{REF}}$	Error
$\Delta\phi_{\mathrm{MERIS}} + \Delta\phi_{\mathrm{ERA}}^{\mathrm{hydro}}$	$\Delta\phi_{\mathrm{REF}} - \Delta\phi_{\mathrm{tropo}}^{\mathrm{spatial}}$

[Bekaert et al., in prep]

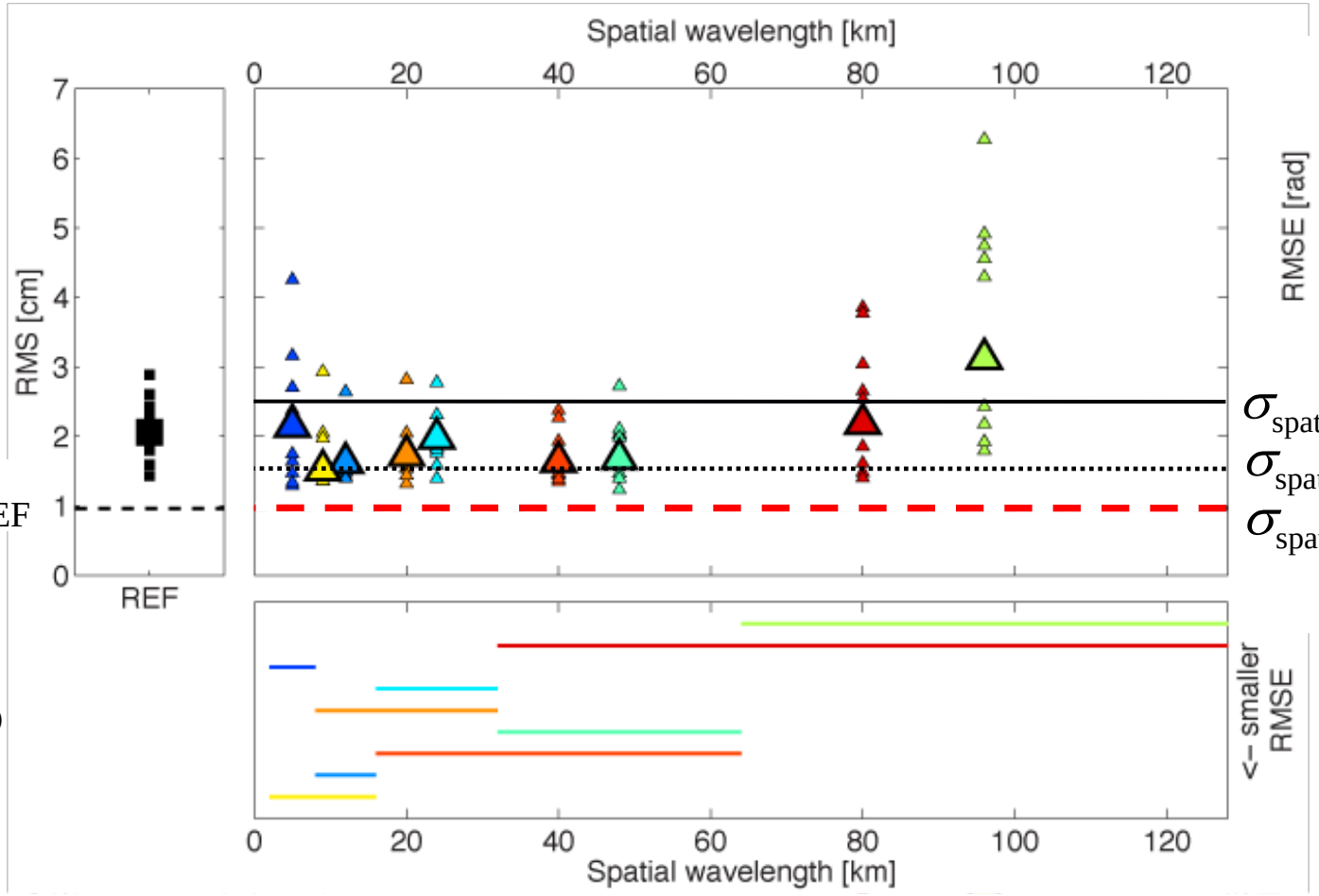


σ_{REF} = MERIS Accuracy (Z. Li et al, 2009)

[Bekaert et al., in prep]

Signal $\Delta\phi_{\mathrm{REF}}$	Error
$\Delta\phi_{\mathrm{MERIS}} + \Delta\phi_{\mathrm{ERA}}^{\mathrm{hydro}}$	$\Delta\phi_{\mathrm{REF}} - \Delta\phi_{\mathrm{tropo}}^{\mathrm{spatial}}$

$$\sigma_{\mathrm{Error}} = \sqrt{\sigma_{\mathrm{REF}}^2 + \sigma_{\mathrm{spatial}}^2}$$



$\sigma_{\mathrm{spatial}} = 2\sigma_{\mathrm{REF}}$

$\sigma_{\mathrm{spatial}} = \sigma_{\mathrm{REF}}$

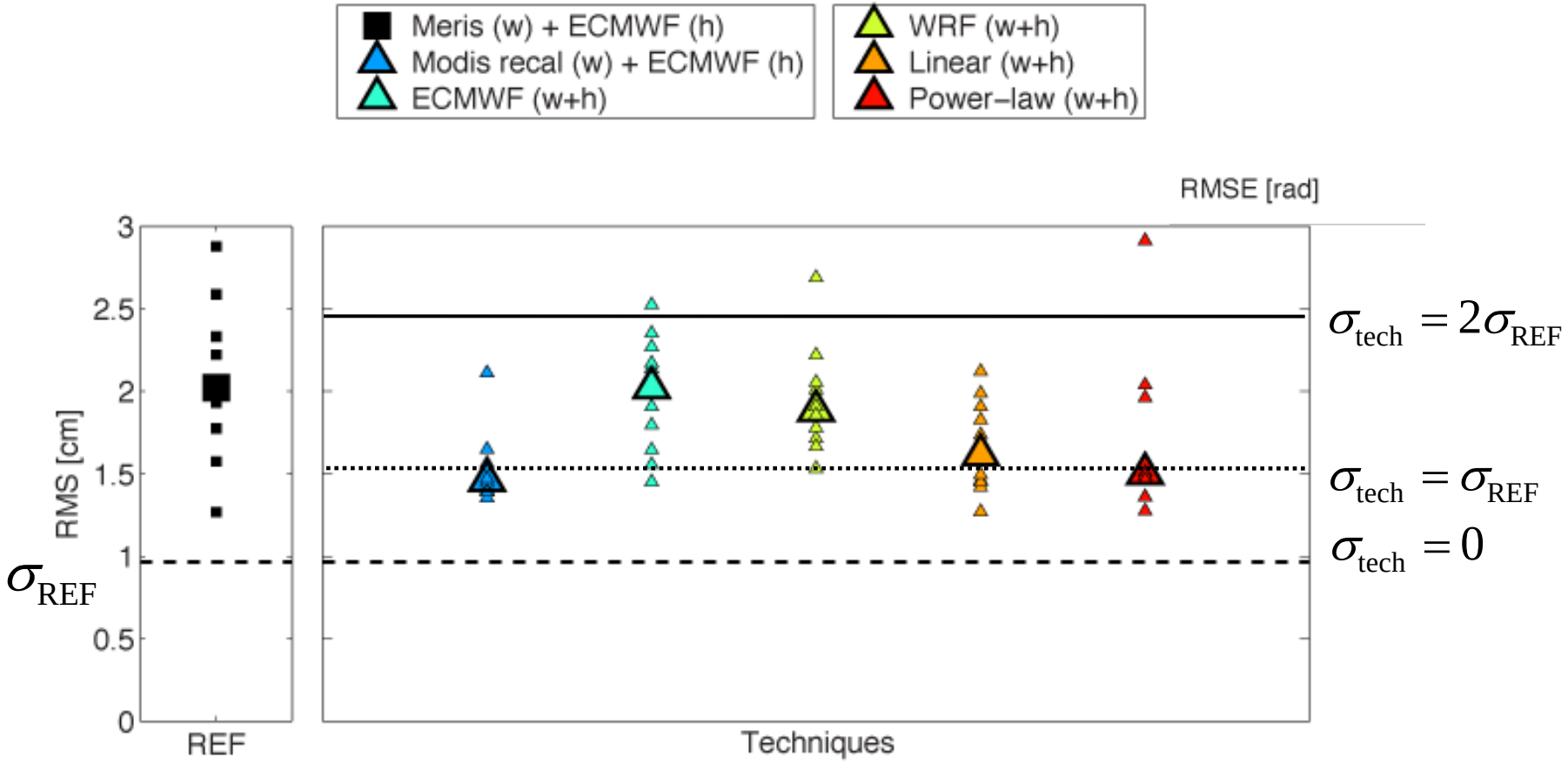
$\sigma_{\mathrm{spatial}} = 0$

σ_{REF} =

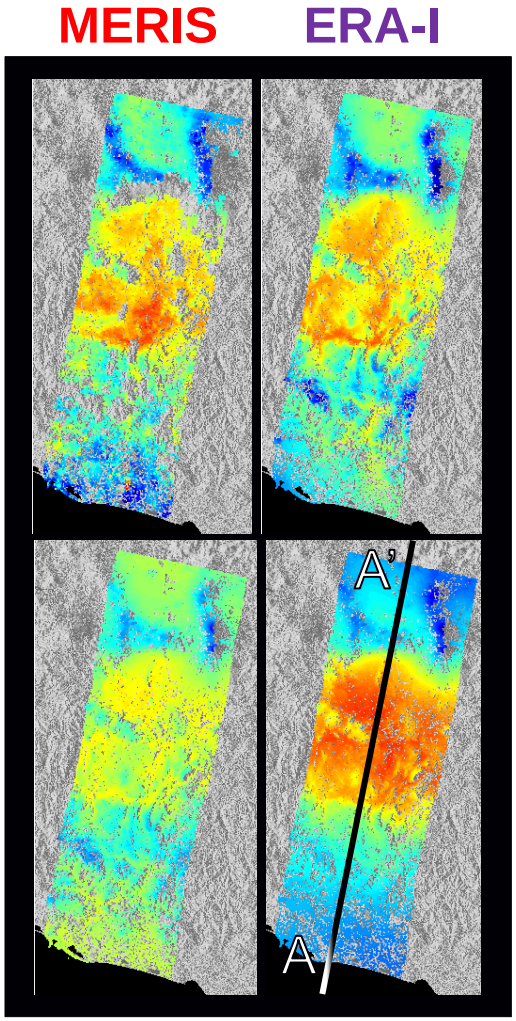
MERIS Accuracy
(Z. Li et al, 2009)

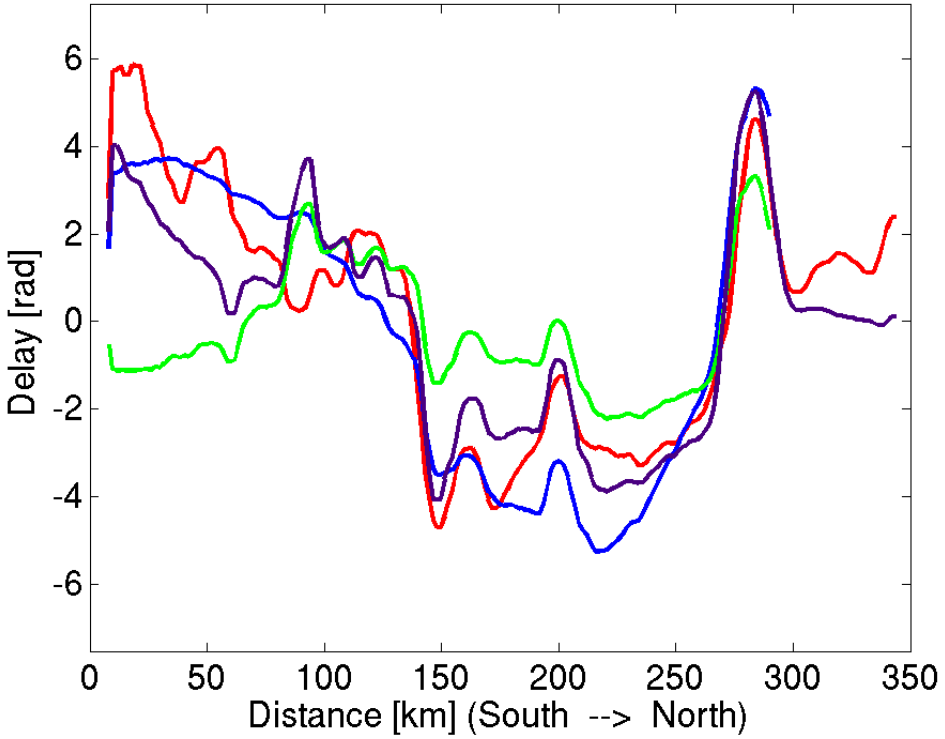
Comparing techniques over Mexico

[Bekaert et al., in prep]



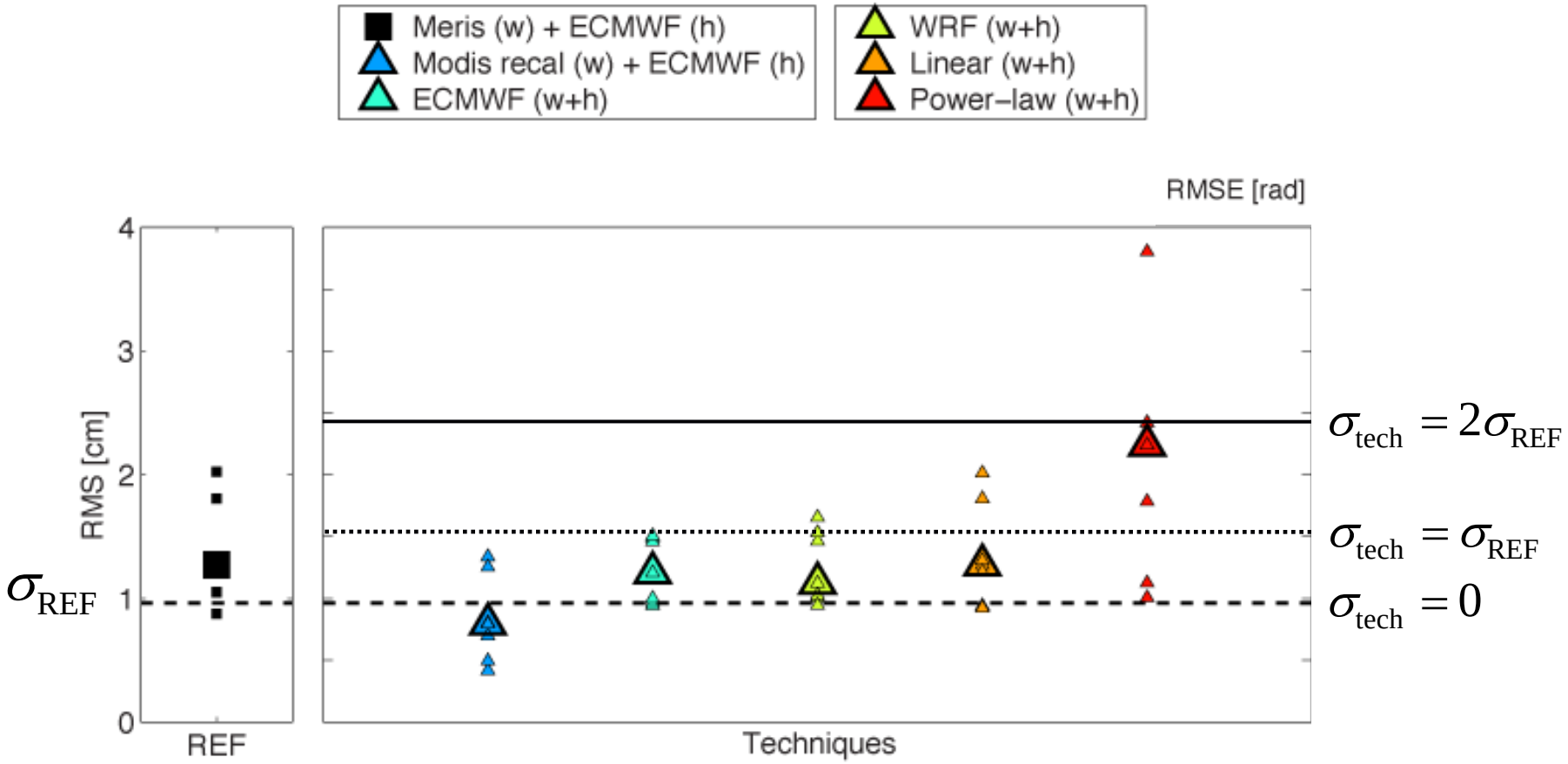
Interferogram example





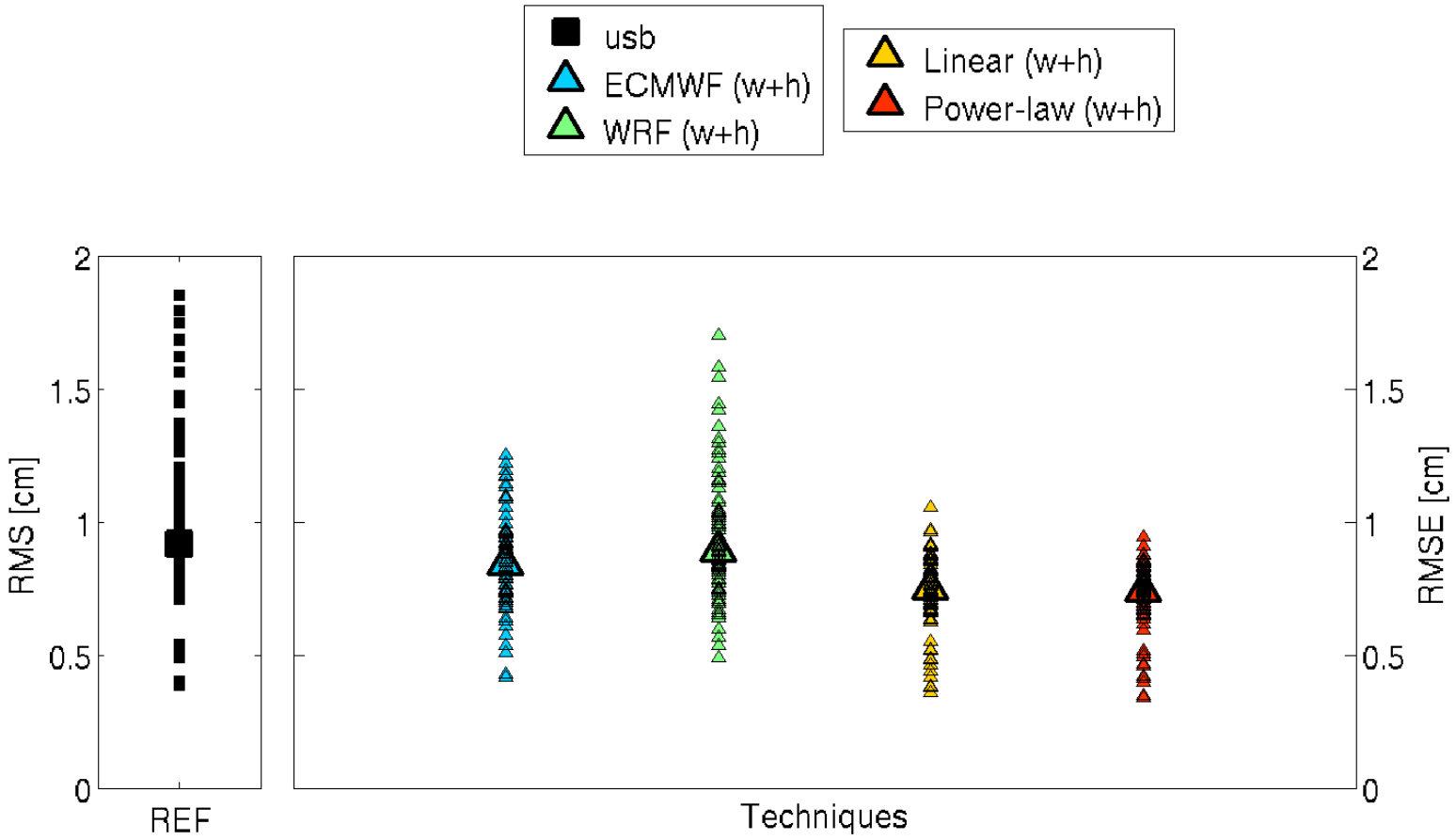
Comparing techniques over Italy

[Bekaert et al., in prep]



Comparing techniques over El Hierro

[Bekaert et al., in prep]



Automated tropospheric corrections

- Each technique has its own:
  - Limitations
  - Accuracy
  - Sensitivity for tropospheric components

No method is exclusive in being best for reducing tropospheric noise

- Towards automated correction:
  - Data assimilation of all observations
  - Let methods constrain and complement each other
  - Invert for a physical tropospheric quantity

Account for method accuracy by weighting

Summary/Conclusions

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- Different methods correct for different components of the troposphere
- All methods have there own limitations with varying accuracy
- No method is exclusive the best in reducing tropospheric delays
  - Assuming e.g. not using MERIS for Envisat
- Rather than opting for a single method, jointly invert for tropospheric properties such different technique constrain each other
  - This will require relative weighting, quality measure of methods

(Talk by Richard Walters at 12.30hr in this room)

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Toolbox for Reducing Atmopsheric InSAR Noise = ***TRAIN***

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