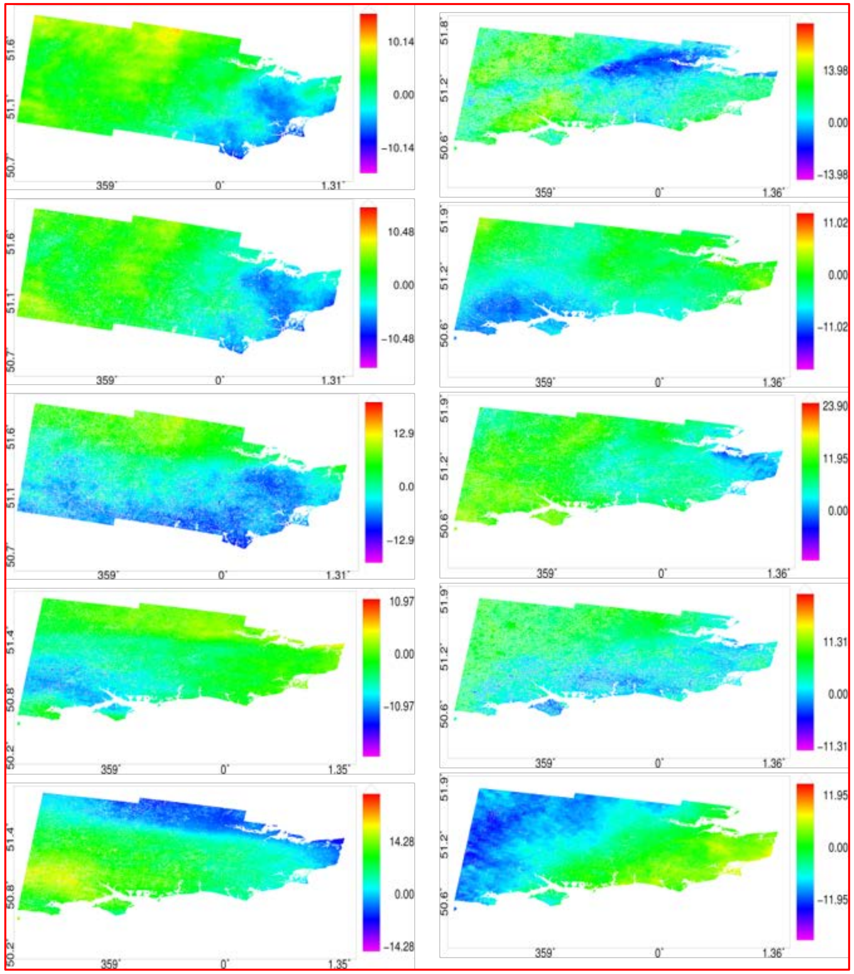
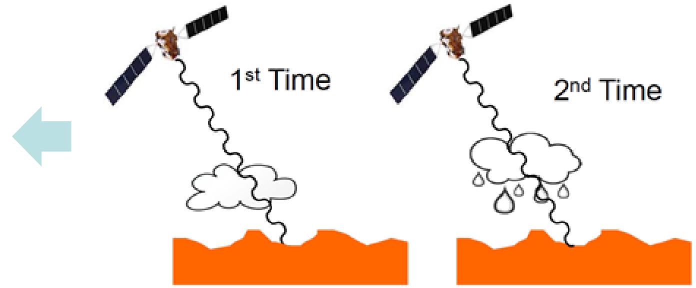
Generic InSAR atmospheric water vapour correction model

Zhenhong, Li, Chen Yu; Paola Crippa; Nigel Penna
COMET, School of Civil Engineering and Geosciences
Newcastle University
(Emails: Zhenhong.Li@newcastle.ac.uk)

Motivation





❖ Spatio-temporal variations in T, P and water vapour.

❖ Surface displacement due to tectonic/volcanic activities can be easily masked.

❖ Crucial in time series analysis.

$$\phi_{ifg} = [\phi_{defo} + \boxed{\phi_{tropo}} + \phi_{iono} + \phi_{dem} + \phi_{base} + \phi_{noise}]_{2\pi}$$

Quantifying the **performance of tropospheric correction methods** is vital for InSAR

Contents

Data evaluation

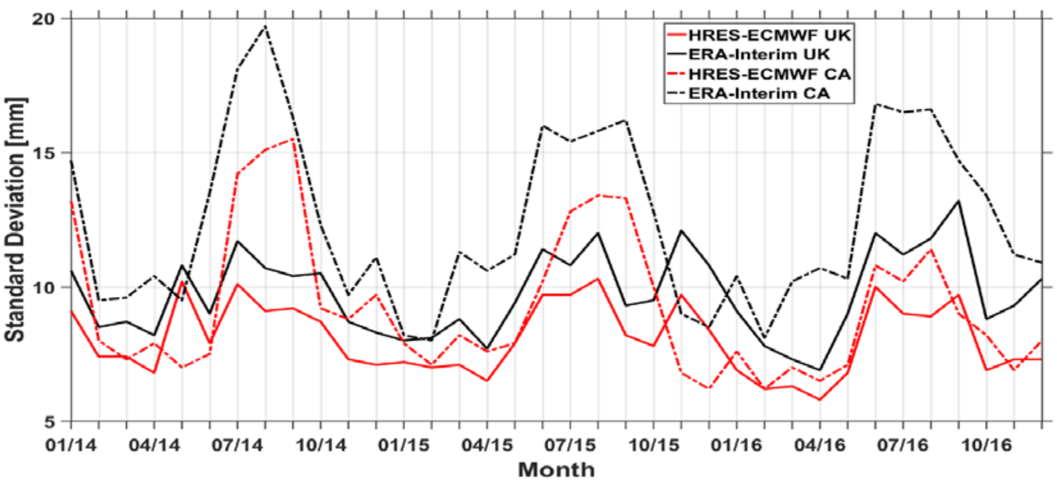
Datasets	Features
MERIS	Global coverage, affected by clouds
MODIS	Global coverage, affected by clouds
ERA-Interim	Global coverage 4 times a day, intermediate spatial res.
WRF	Regional coverage, high spatial res.
HRES-ECMWF	Global coverage 4 times a day, high spatial res.
GPS	High frequency, limited coverage and density

Careful validations have been made to investigate:

1. Advantages of operational HRES-ECMWF against with ERA-Interim;
2. Performance of HRES-ECMWF against with GPS;
3. How to integrate HRES-ECMWF and GPS;

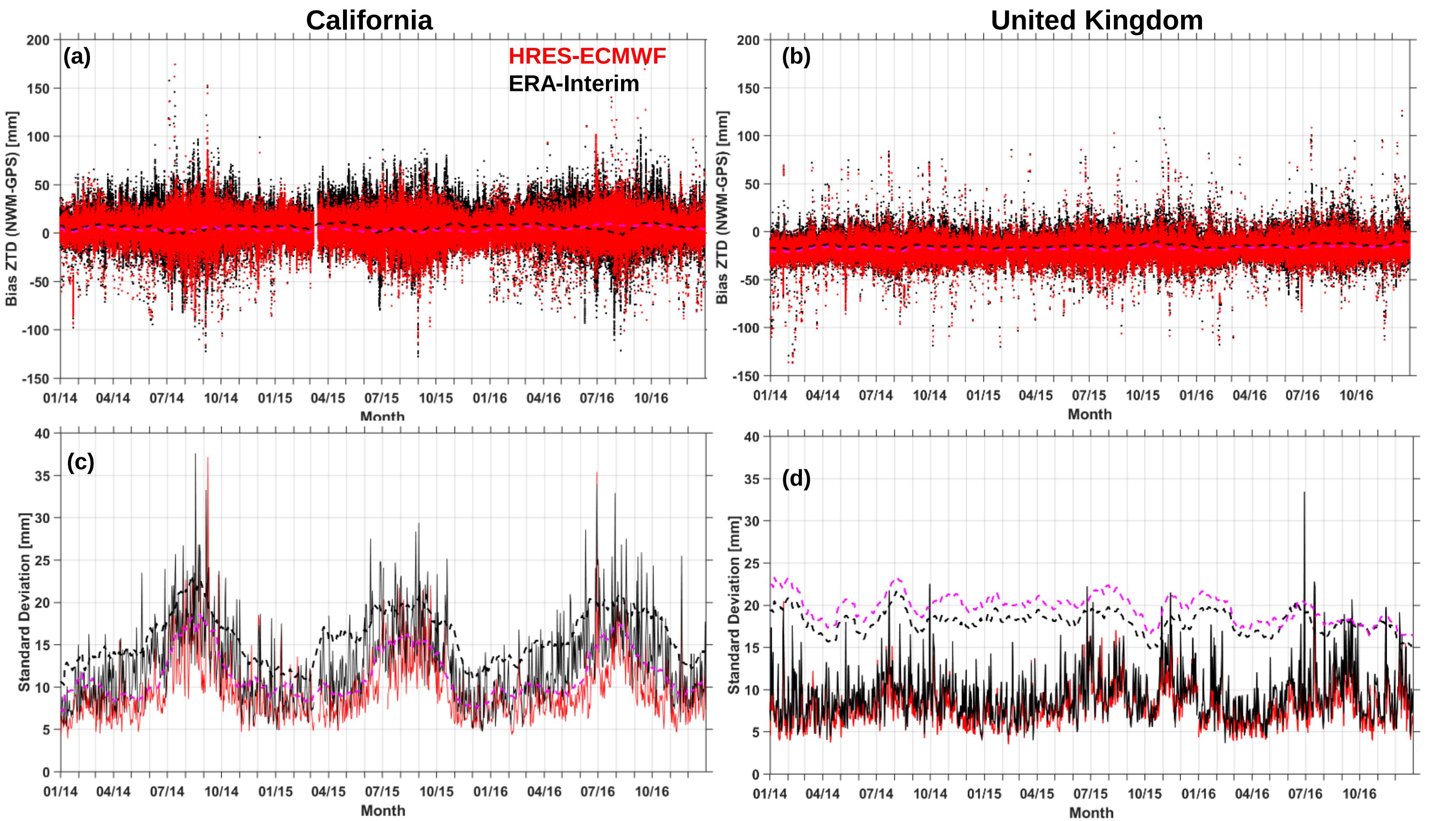
ERA-Interim vs HRES-ECMWF

	HRES-ECMWF	ERA-Interim
Horizontal Resolution	~16 km	~75 km
Vertical Resolution	137 levels	61 levels
Output frequency	00,06,12,18 UTC	00,06,12,18 UTC
Data availability	Near real-time	Delayed 3-4 months
Data access	Free with authorization	Free
Computational requirements	Very Low	Very Low



Region	RMS [mm]	Bias [mm]	STD [mm]
California HRES-ECMWF	**11.37**	**4.16**	**9.60**
California ERA-Interim	15.86	6.16	12.71
UK HRES-ECMWF	**19.62**	**-17.66**	**8.02**
UK ERA-Interim	18.02	-14.95	9.28

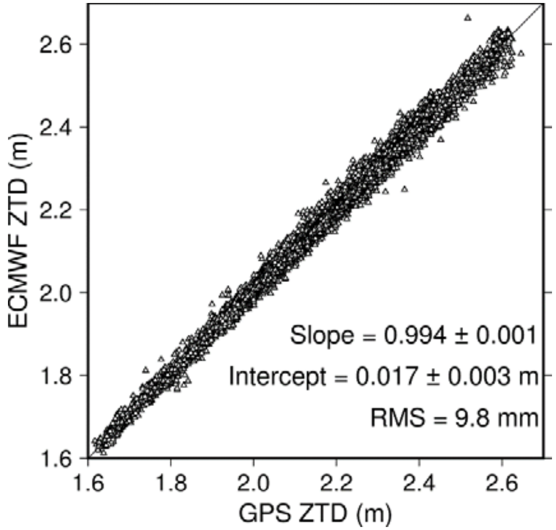
ERA-Interim vs HRES-ECMWF

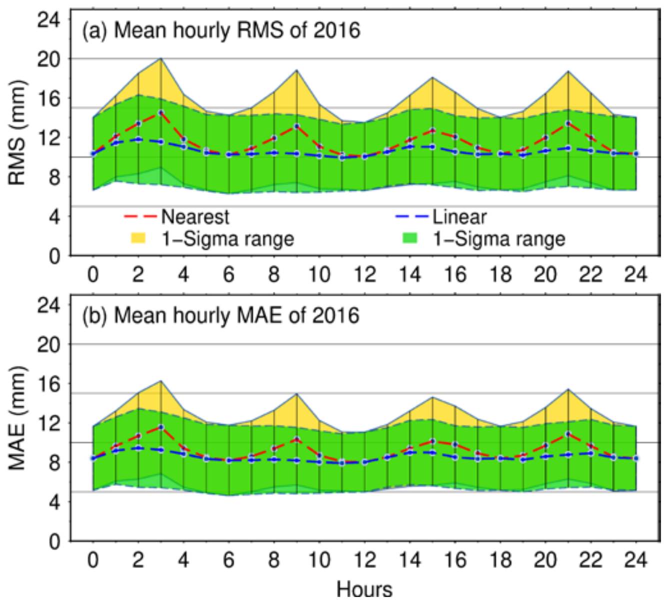


- HRES-ECMWF provides improved estimates of ZTDs than ERA-Interim.
- Improved description of high frequency variations in atmospheric water vapor.

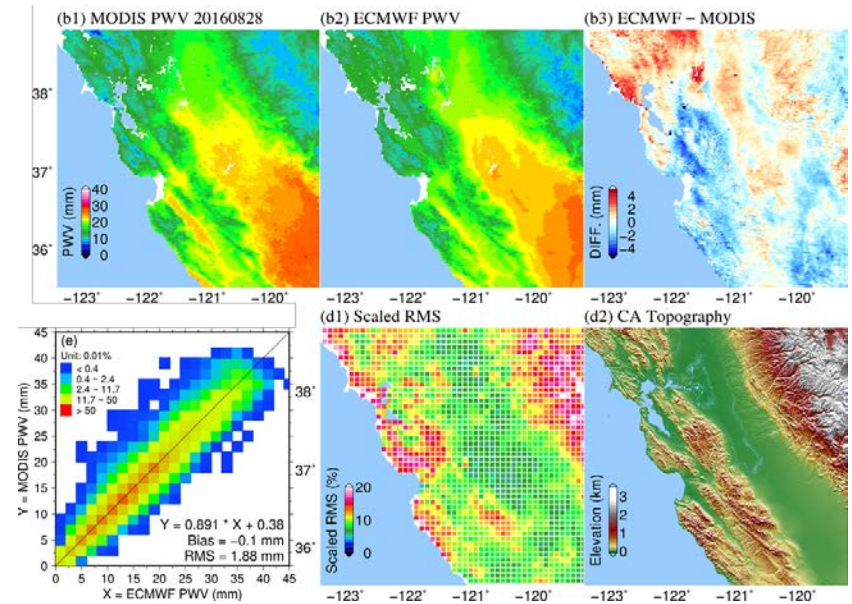
Validation of GPS and HRES-ECMWF

~1cm ZTD RMS (GPS vs HRES ECMWF)

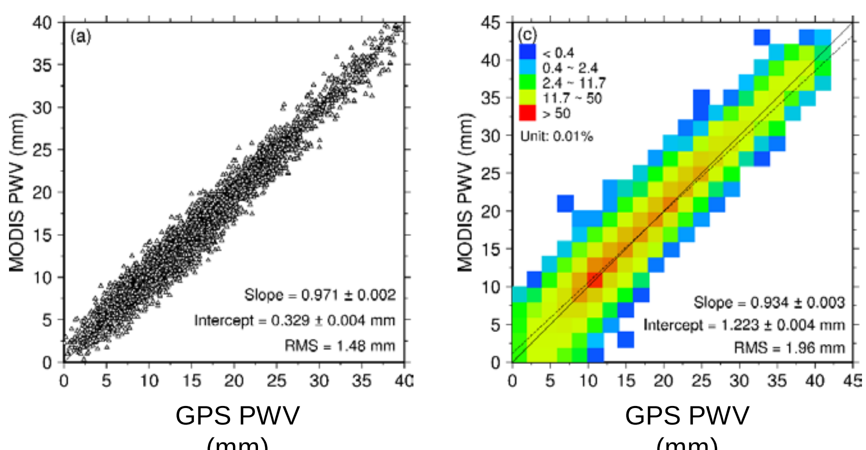




~2mm PWV RMS (MODIS vs HRES ECMWF)



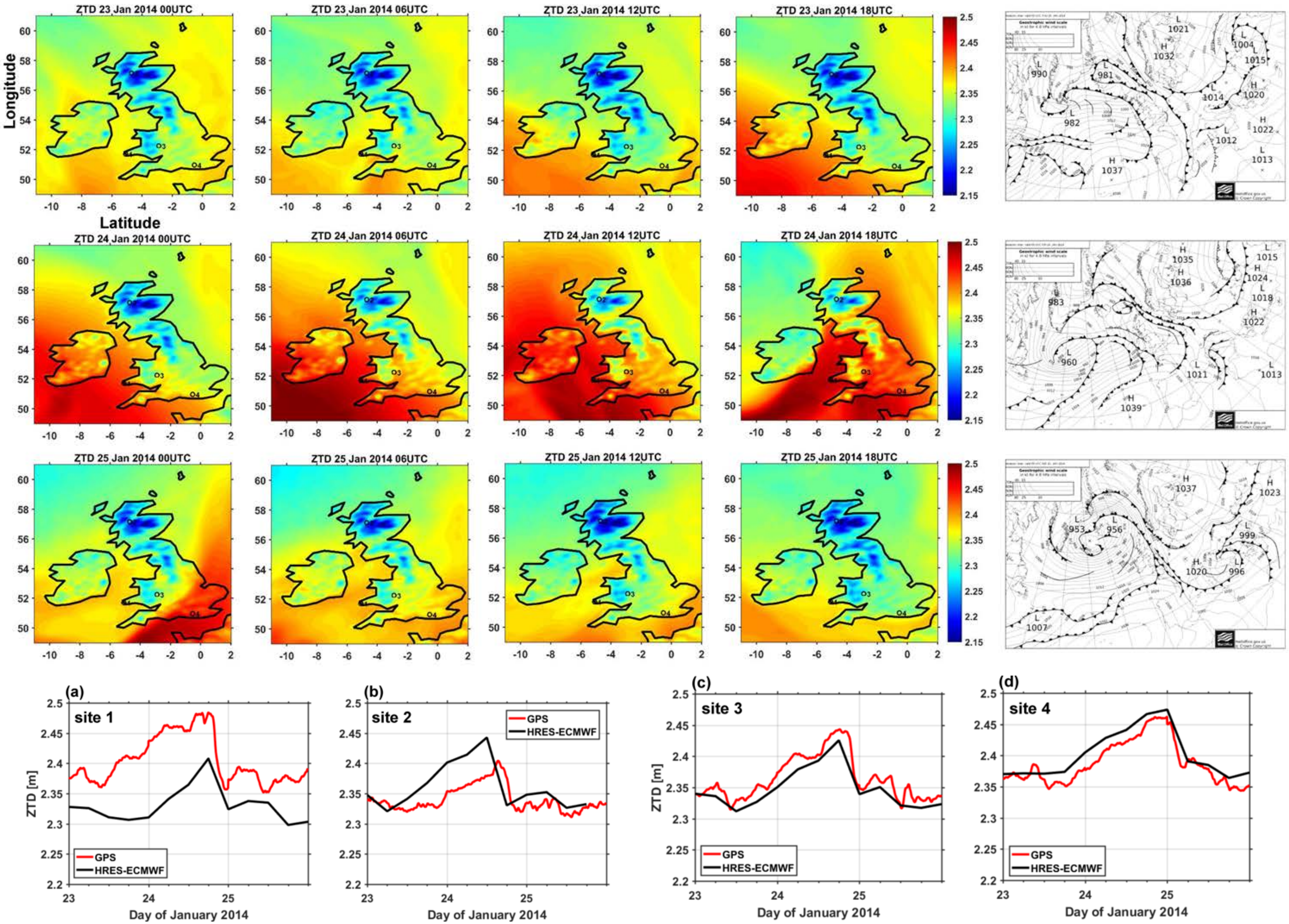
~1.5mm PWV RMS (MODIS vs HRES ECMWF)



Newcastle University

Capacity to capture extreme weather

UK winter storm January 2014



Contents

Newcastle University

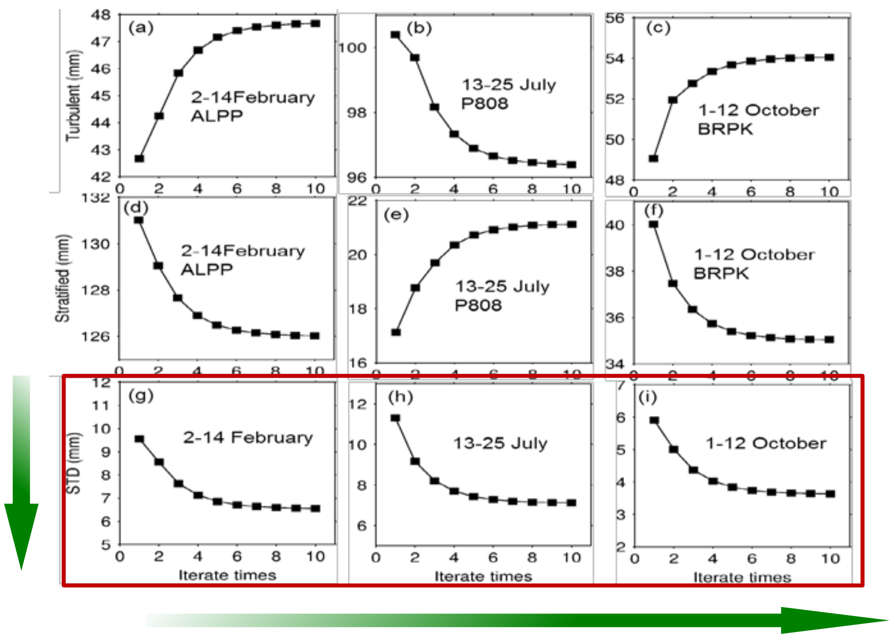
Interpolation Model: ITD

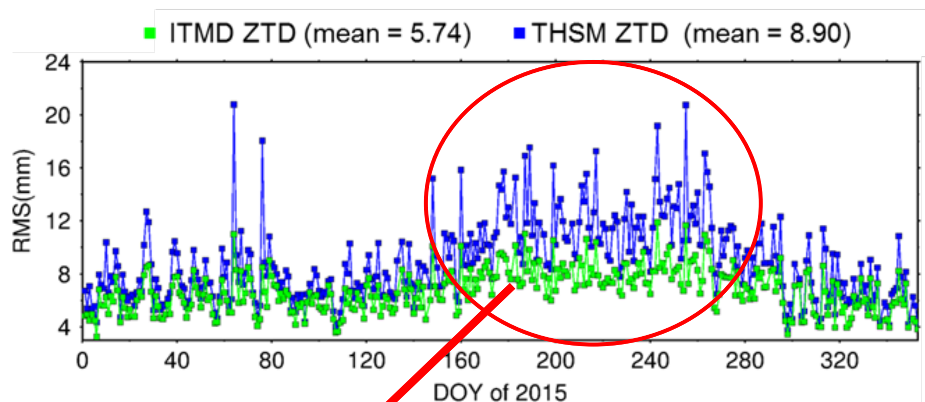
Iterative Tropospheric Decomposition (ITD)

$$\text{V}L_{ij}^{k} = \underbrace{T(\mathbf{x}^{k})}_{\text{Turbulent}} + \underbrace{L_0 e^{-\beta h^{k}}}_{\text{Stratified}} + \varepsilon$$

(Chen et al., 2017, JGR)

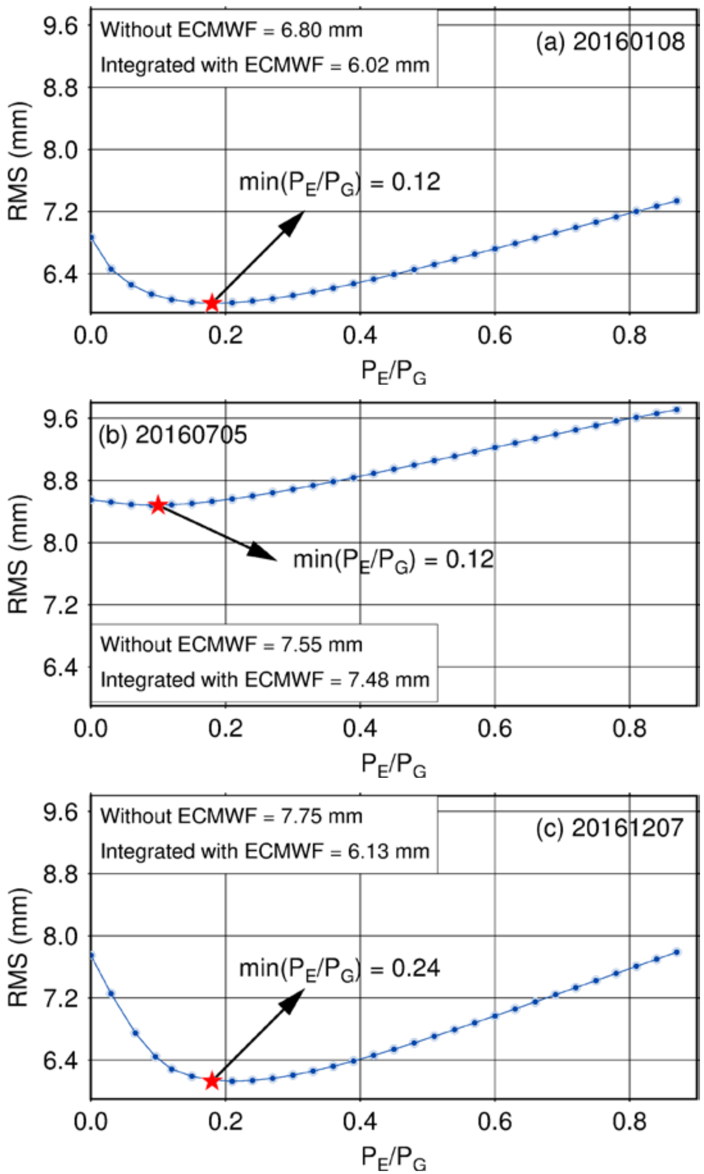
- ❖ A stratified component highly correlated with topography;
- ❖ A turbulent component resulting from disturbance processes in the troposphere.





More improvements in strong turbulence seasons

Integration of GPS and HRES-ECMWF



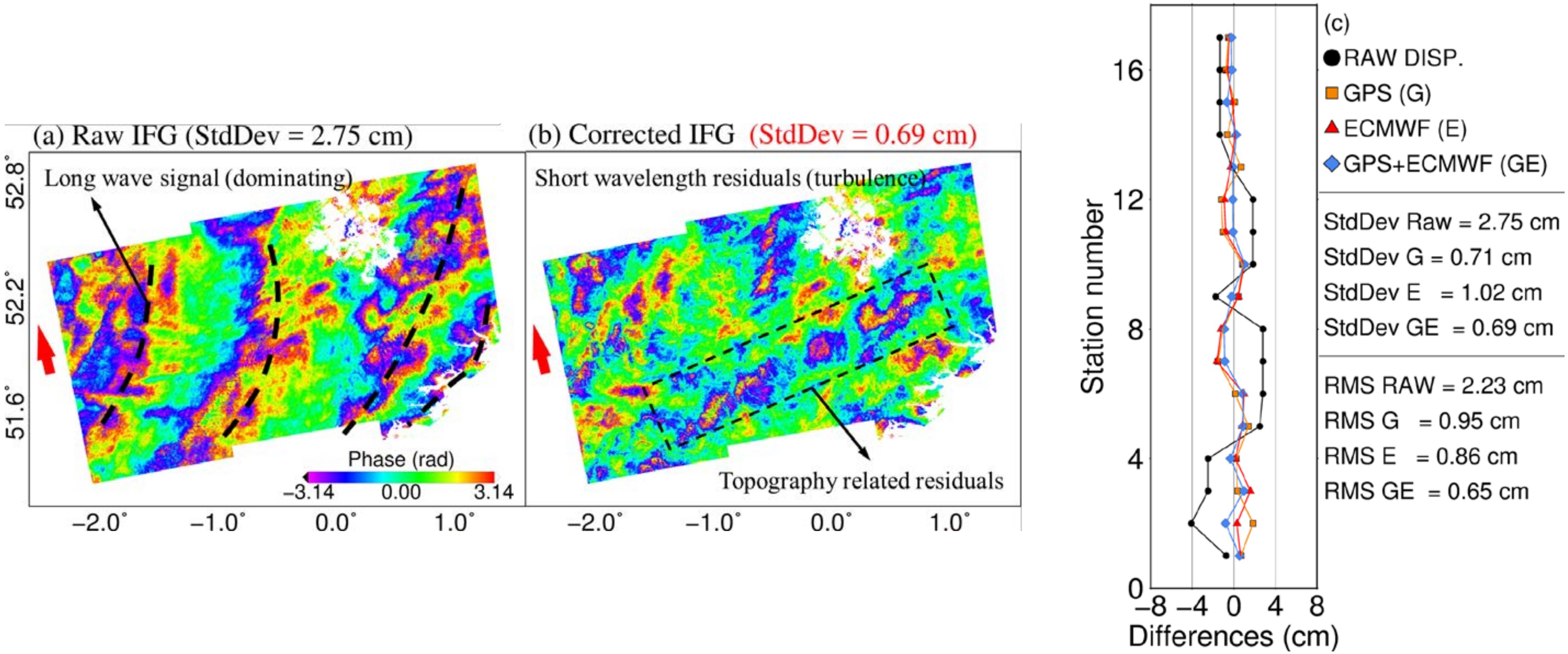
$$S = L_0 e^{-\beta h} \Rightarrow \begin{cases} S_m^G = L_0 e^{-\beta h_m} \\ S_n^E = L_0 e^{-\beta h_n} \end{cases}, \quad \boxed{P_S = \begin{bmatrix} P_G & 0 \\ 0 & P_E \end{bmatrix}}$$

$$T_u = \sum_{i=1}^{n} w_{ui} T(\mathbf{x}_i), \quad w_{ui} = \boxed{p_i} d_{ui}^{-2} \Big/ \sum_{i=1}^{n} p_i d_{ui}^{-2}$$

- GPS and HRES-ECMWF are integrated with proper weighting to generate reliable ZTD correction maps.
- The relative weighting between GPS and HRES-ECMWF are controlled by the precision and station distribution of the GPS network.

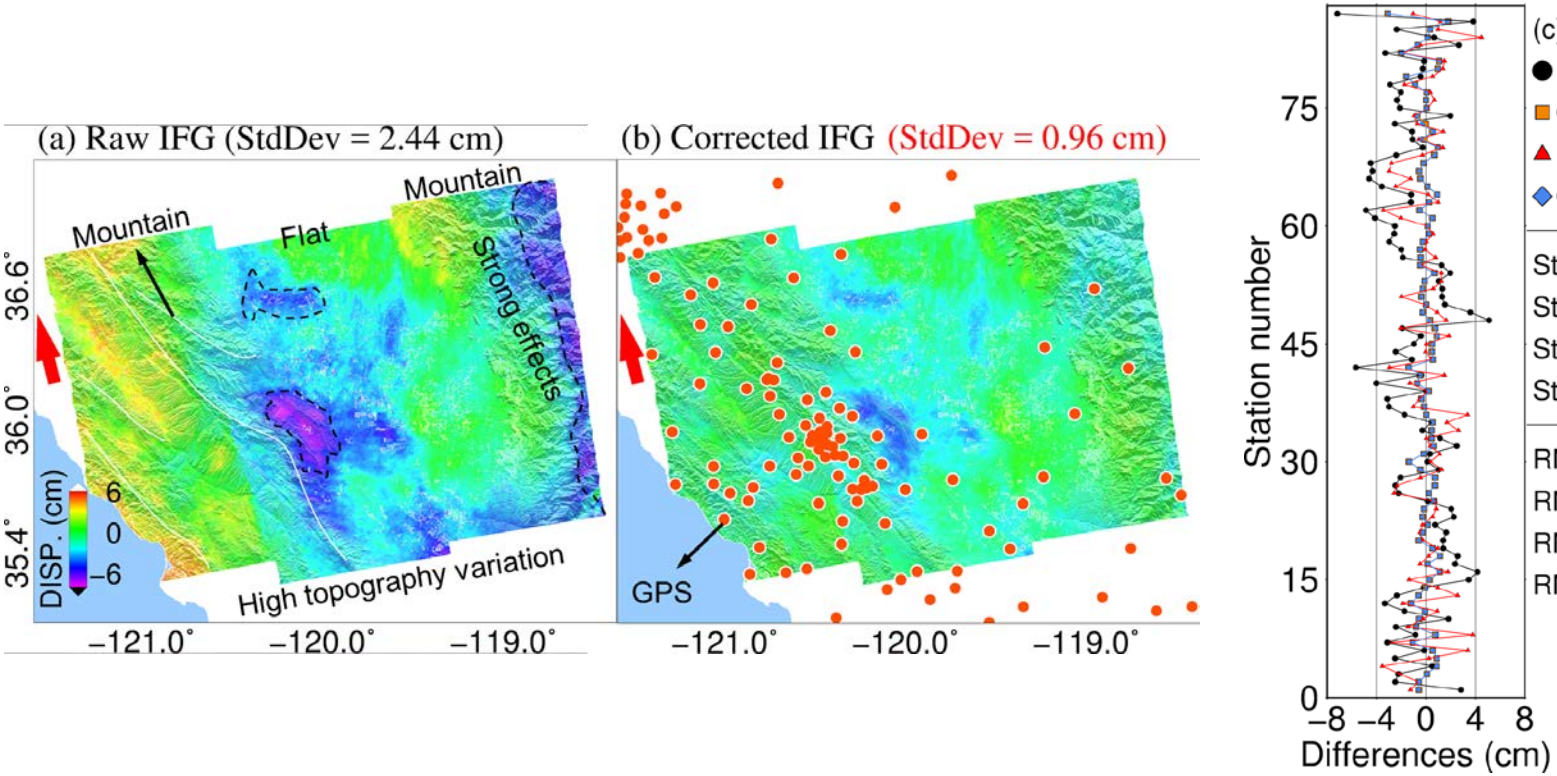
Contents

Case study 1: Southern England



- 12-day temporal baseline, assuming no displacement occuring;
- Long wavelength atmosphere delay signals are dominating;
- StdDev: Phase Standard Deviation;
- RMS: Displacement differences between GPS and InSAR.

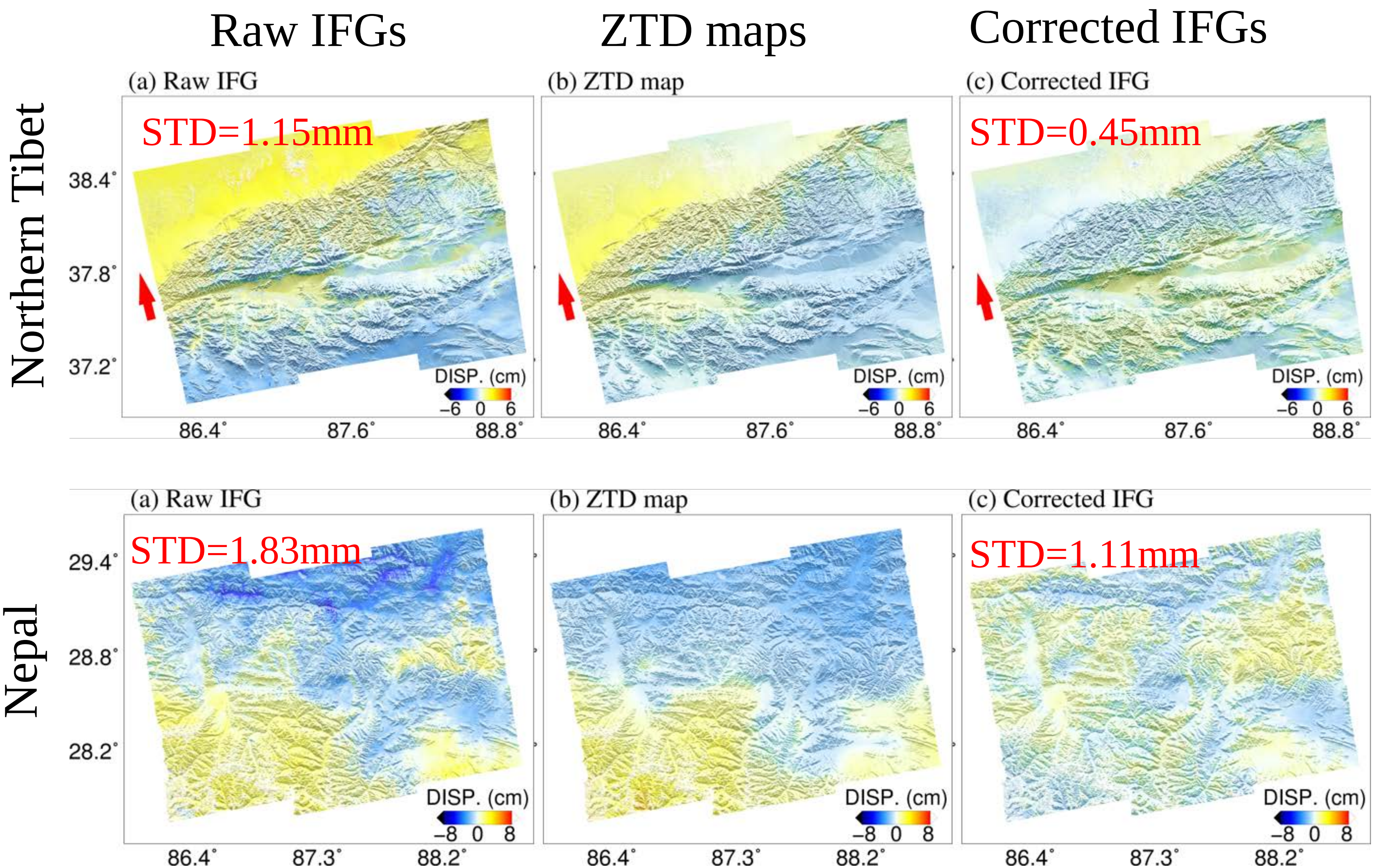
Case study 2: Central California



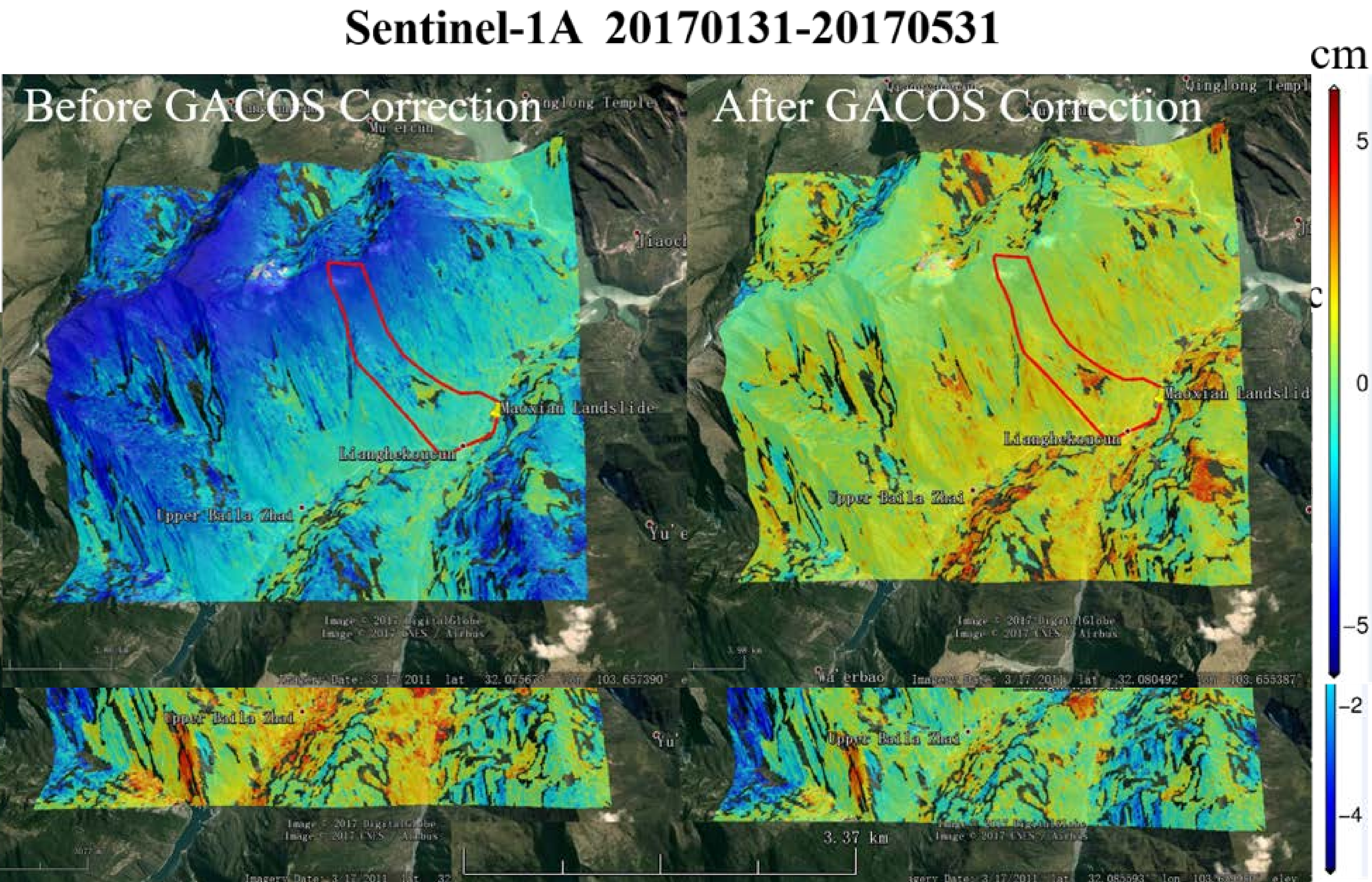
❖ The topography related atmosphere errors in the east and west mountain areas are significantly mitigated.

❖ The residuals in central area were most likely related to un-modelled tropospheric turbulence.

Case studies 3/4: Northern Tibet & Nepal



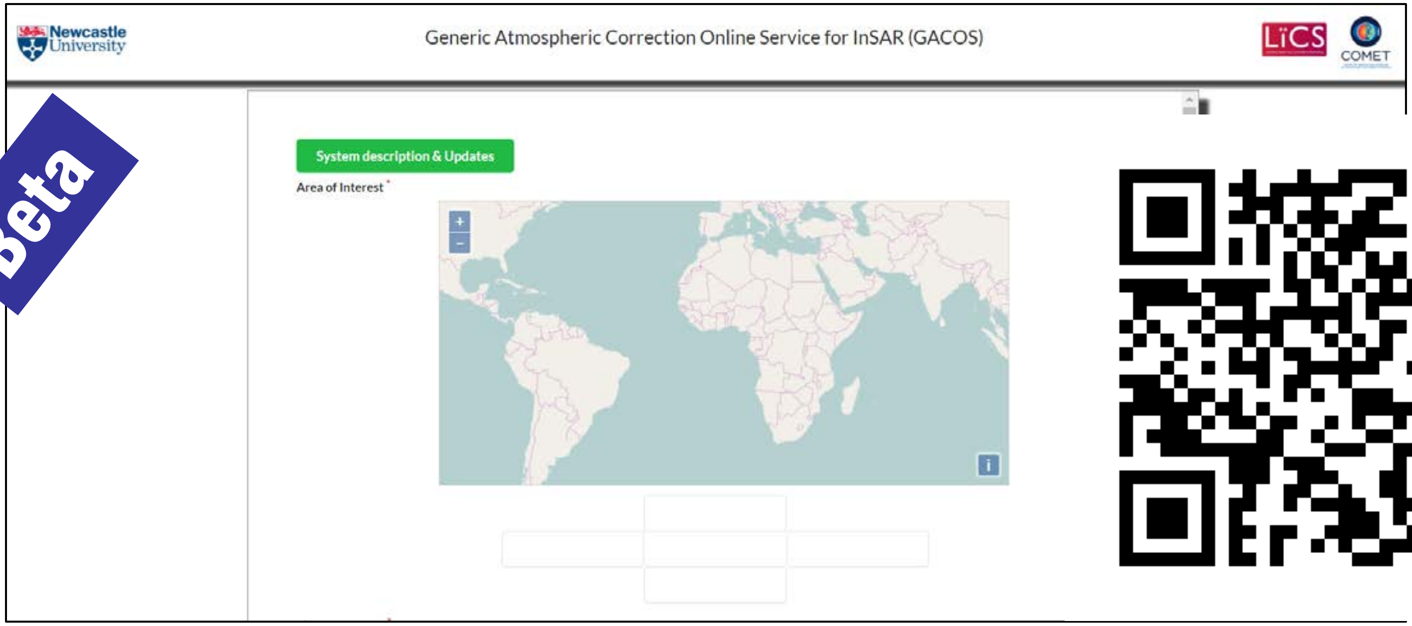
Case study 5: Maoxian Landslide, China



Contents

GACOS: Generic Atmospheric Correction Online Service for InSAR

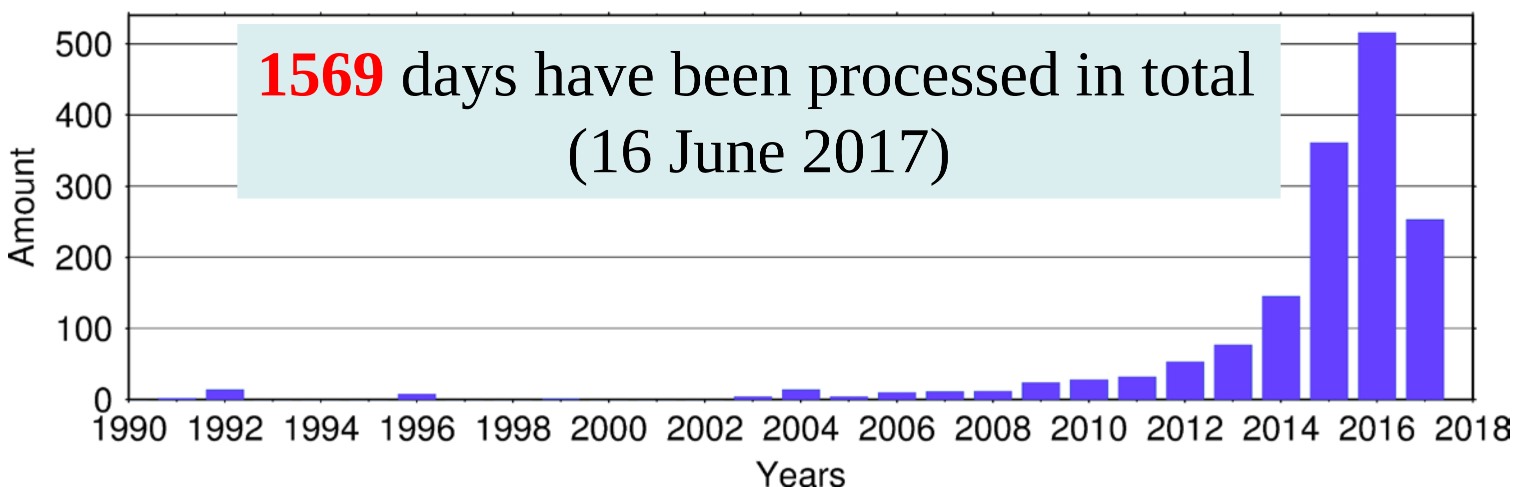
Beta



- ❖ Global coverage
- ❖ Operational in near real time
- ❖ Easy to implement
- ❖ Performance indicators

- ❖ High Resolution ECMWF (0.125, 6 hours);
- ❖ GNSS (soon to be released)
- ❖ 90m SRTM and ASTER GDEM

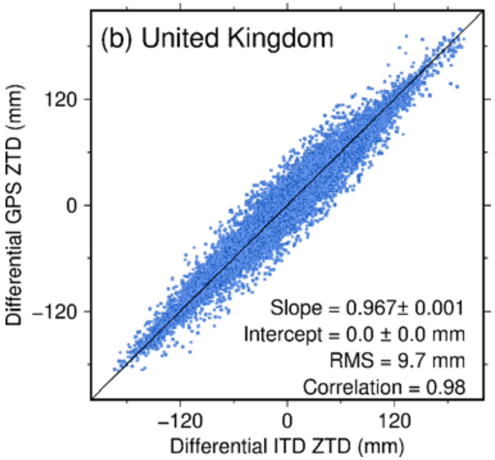
GACOS: Usages



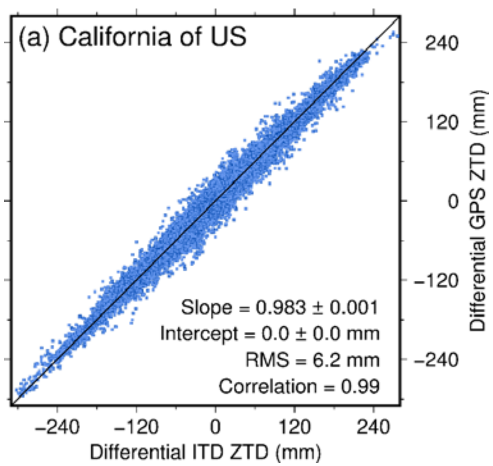
Contents

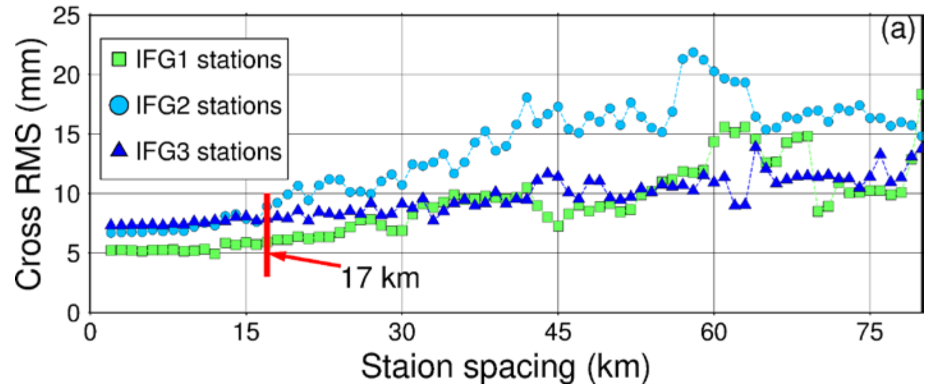
Performance indicator: Cross RMS

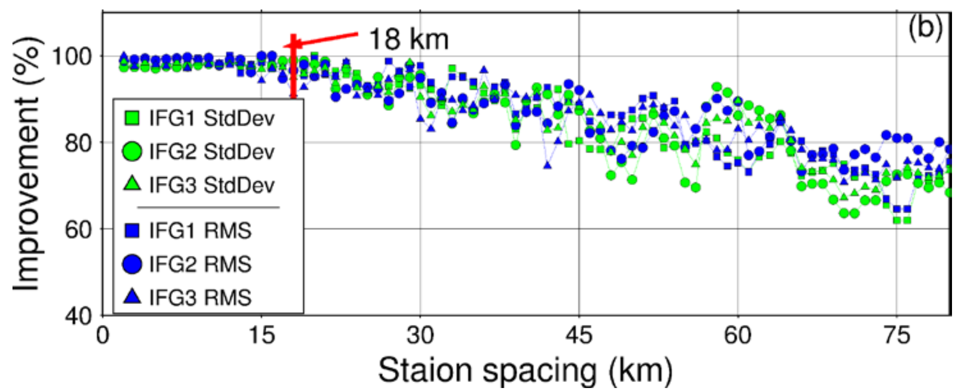
UK Network (> 50 km)
RMS = 9.7 mm



California Network (~ 10 km)
RMS = 6.2 mm



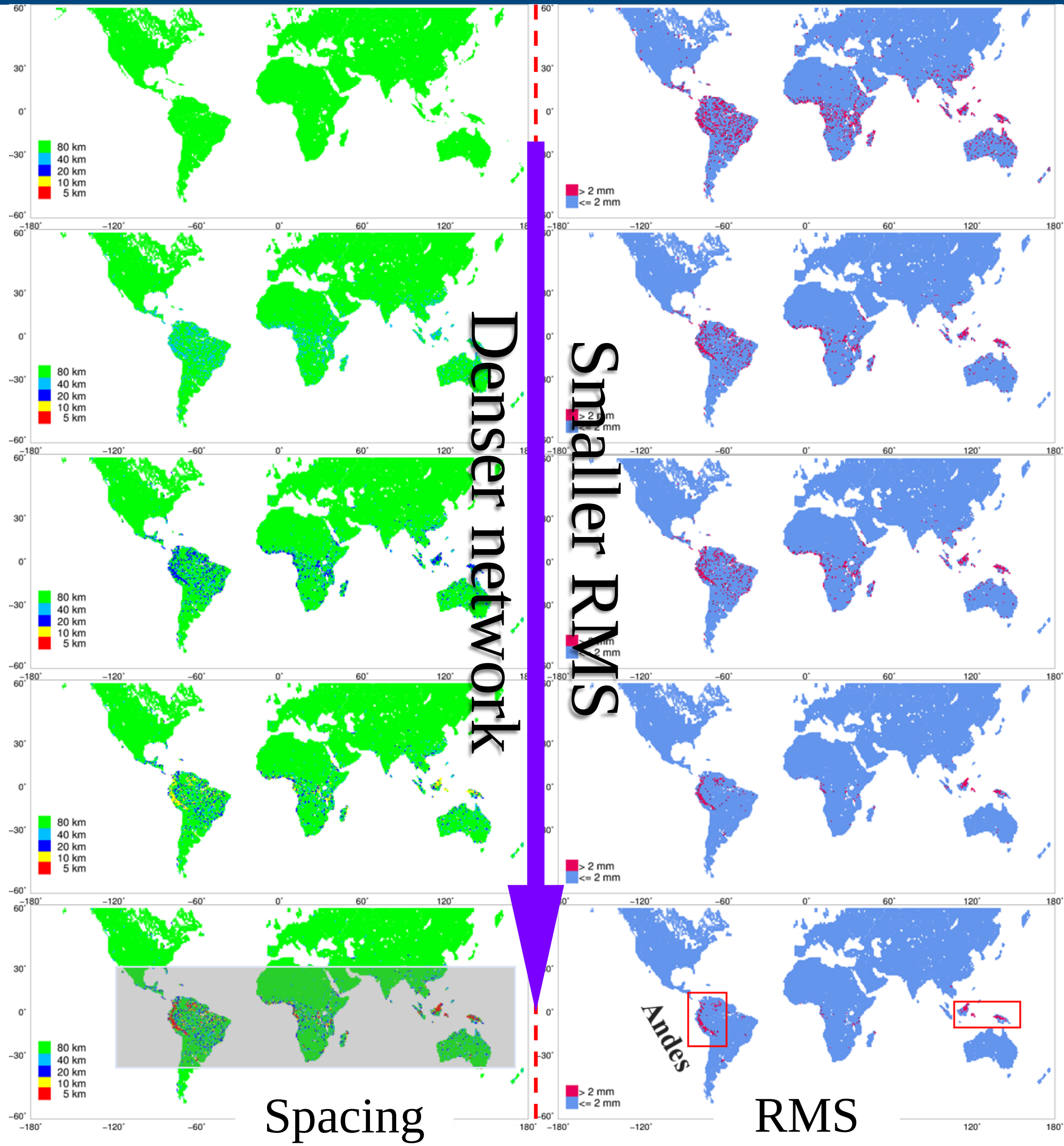




❖ Model performance decreases as Cross RMS increases.

Newcastle University

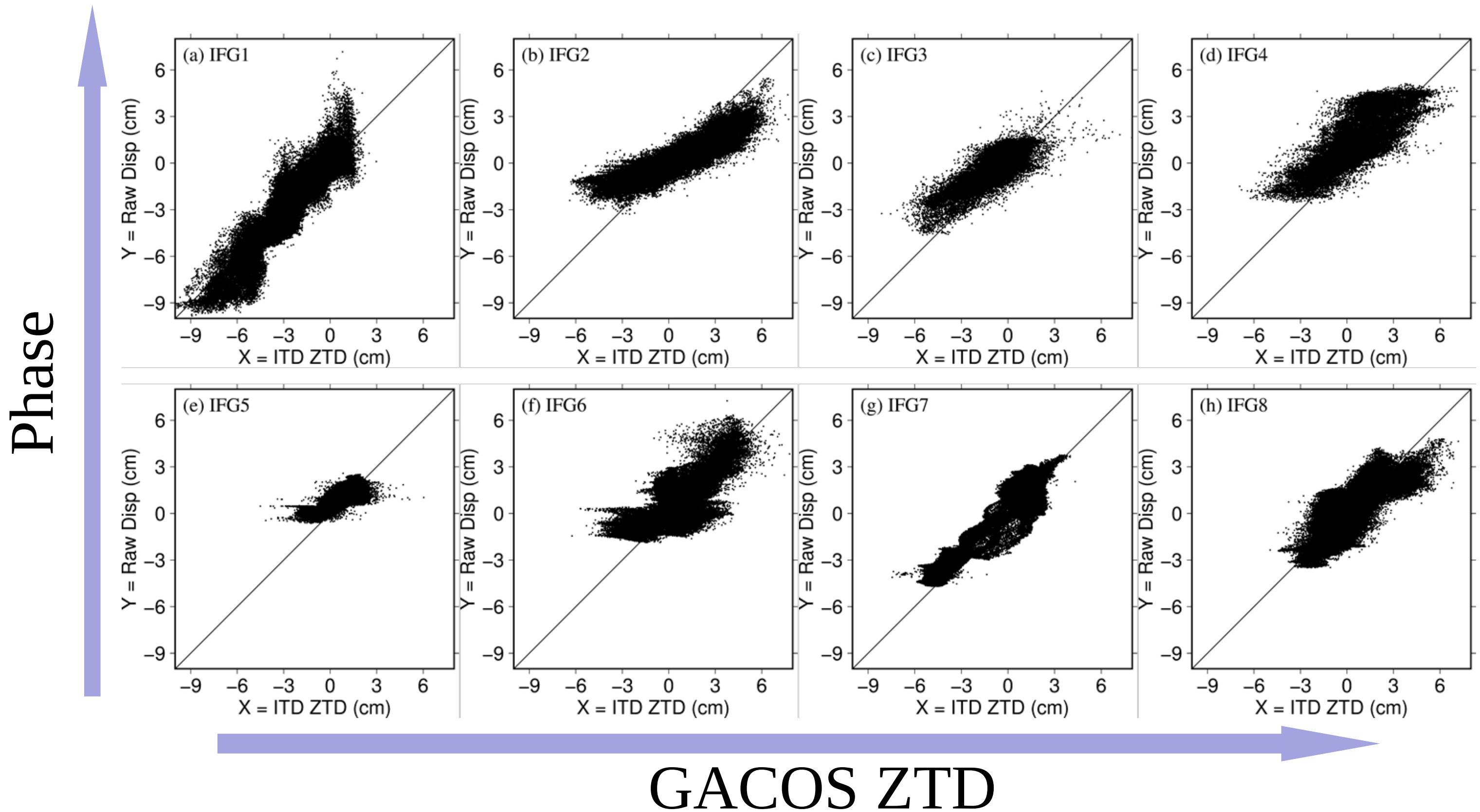
Simulation with MODIS: Station spacing



- 5 km Spacing
- 10 km Spacing
- 20 km Spacing
- 40 km Spacing
- 80 km Spacing

High water vapor contents and strong topography variations require small station spacings

Performance indicator： Correlation



❖ The higher the correlation between phase and ZTD, the more likely the raw interferogram is dominated by atmospheric errors.

Performance Matrix (Indicators)

- Cross RMS
- Correlation coefficients
- ECMWF time difference
- Topography variation
- Extreme Weather

Newcastle University

Conclusions

1. Generic Atmospheric Correction Online Service for InSAR (GACOS) was released in the 2017 FRINGE workshop for research purposes (http://ceg-research.ncl.ac.uk/v2/gacos/).
2. Our GPS/HRES-ECMWF integrated model can achieve over 50% improvement with RMS < 1 cm for InSAR displacement, which can be applied globally and at all times, in near real time.
3. Indicators such as correlation analysis, cross test and time differences have been developed to assess model performances, which can inform users when and where atmospheric correction is feasible.

We are seeking
more collaborative opportunities……