

DLRs Sentinel-1 InSAR Browse Service on the Geohazards Exploitation Platform

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Knowledge for Tomorrow



Overview

- DLRs Sentinel-1 InSAR Browse Service on GEP (Geohazards Exploitation Platform)
- TOPS Stack Coregistration: Joint Estimation Approaches and Experiments



Geohazards TEP – Sentinel-1 InSAR Browse Services Pilot Project



- GEP heritage: SuperSite Exploitation Platform (SSEP) in support of CEOS WG Disasters Pilots on seismic hazards and volcanoes.

Goal: Automatic and systematic provision of InSAR browse products over seismically active areas and active volcanoes using DLR's Integrated Wide Area Processor (IWAP) running on and using the data provisioning services of Terradue's cloud computing platform with products viewable in the [GeoBrowser](#).

- Target users: Geohazards community (earthquakes, volcanoes, landslides, floods), InSAR users
- Evaluating impact of earthquakes, flood, fire →

Poster Session 1, Tuesday 6th June, 16:00-19:00
[Paper 149 / Poster 159: Martinis et al., "The use of the Sentinel-1 InSAR Browse Service on ESA's Geohazards Exploitation Platform for improved disaster monitoring"](#)





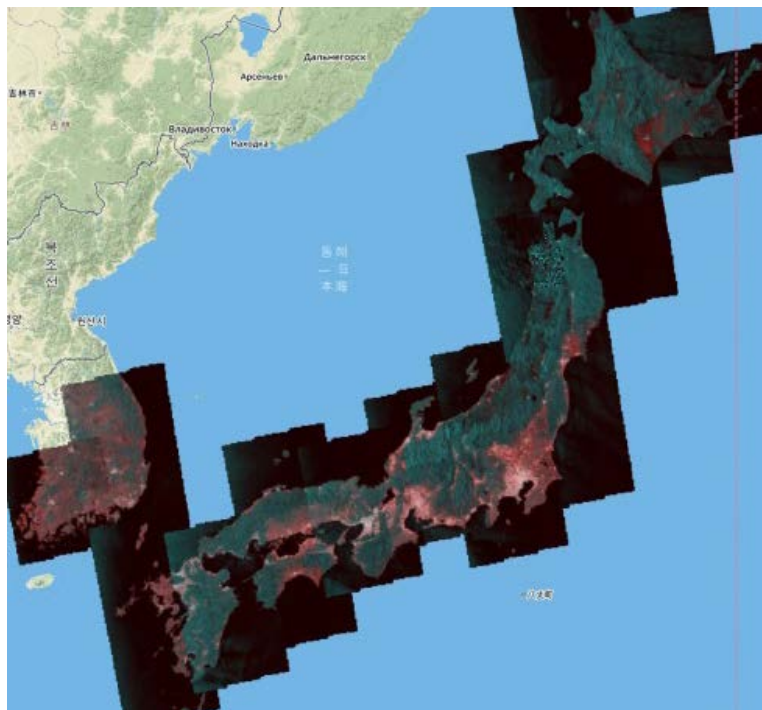
Sentinel-1 InSAR Browse Services

	Sentinel-1 Medium-Resolution InSAR Browse Service	Sentinel-1 High-Resolution InSAR Browse Service
Triggering Mechanism	Systematic + on-request for major events	
Coverage	20% CEOS seismic active area mask, ramping-up to 35%	22 active volcanoes in Latin America (14), South East Asia (4), Europe (3), Africa (1)
Resolution	100m	50m
Product Layers	master and slave calibrated amplitude terrain corrected coherence and phase coherence amplitude and amplitude change composites	
Product Visibility	All	GEP registered users
Product Download	GEP registered users	



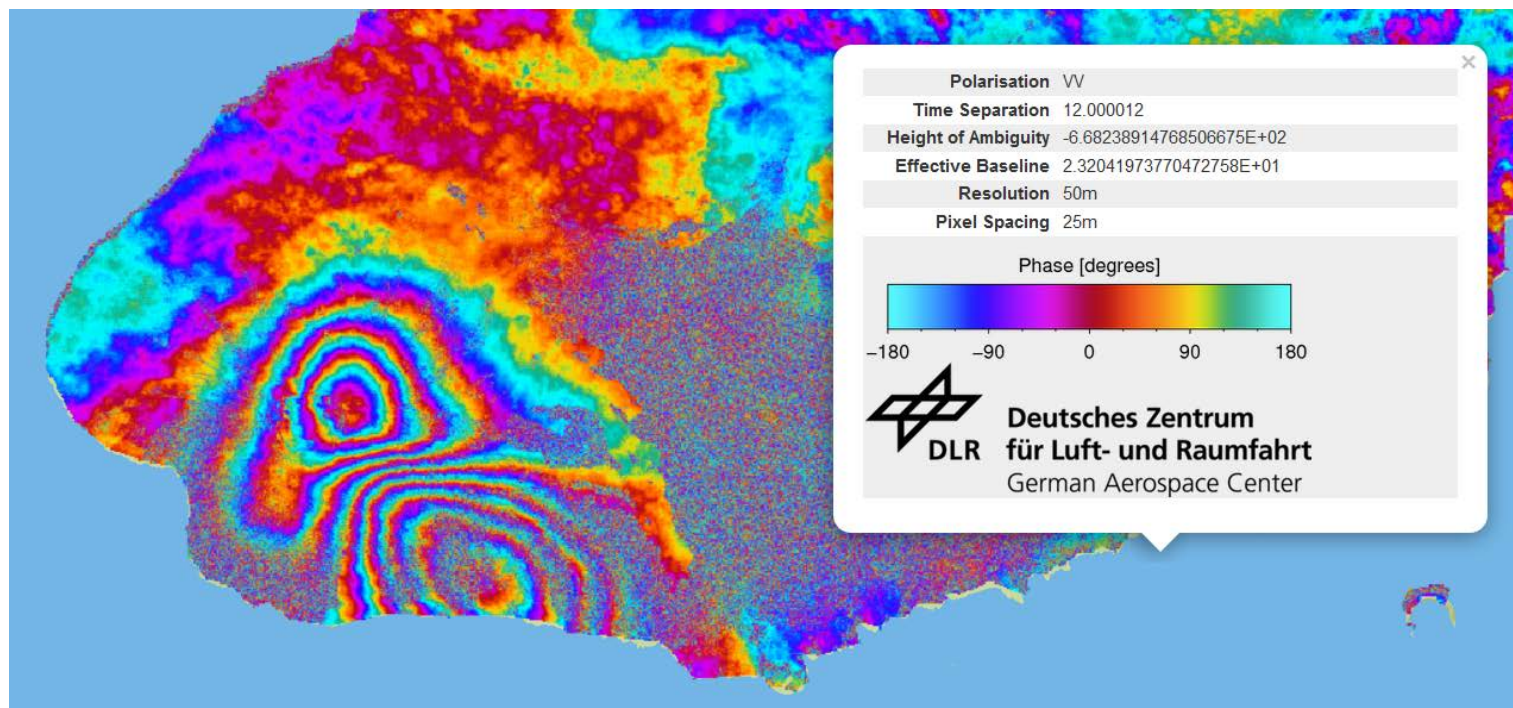
Examples

Sentinel-1 Medium-Resolution InSAR Browse Service Japan and South Korea



Amplitude and coherence composite image

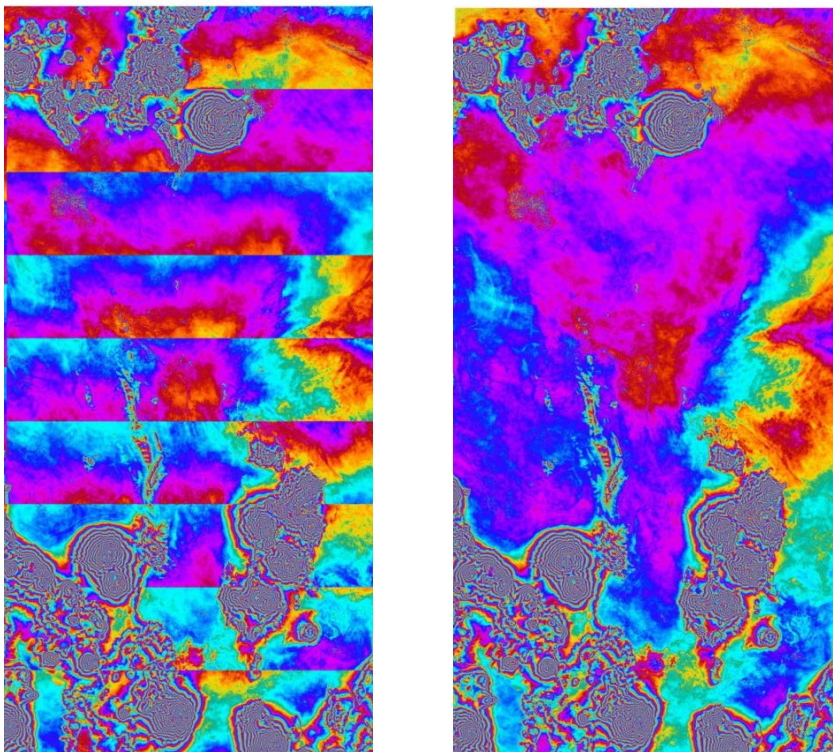
Sentinel-1 High-Res InSAR Browse Service (DRR Trial) Cerro Azul Volcano, Galápagos Island of Isabela, Ecuador 8th – 20th March 2017, relative orbit 128, descending



Terrain corrected phase image of a magma intrusion under Cerro Azul. Fringes correspond to a deformation of about 10cm.

Overview

- DLRs Sentinel-1 InSAR Browse Service on GEP (Geohazards Exploitation Platform)
- **TOPS Stack Coregistration: Joint Estimation Approaches and Experiments**



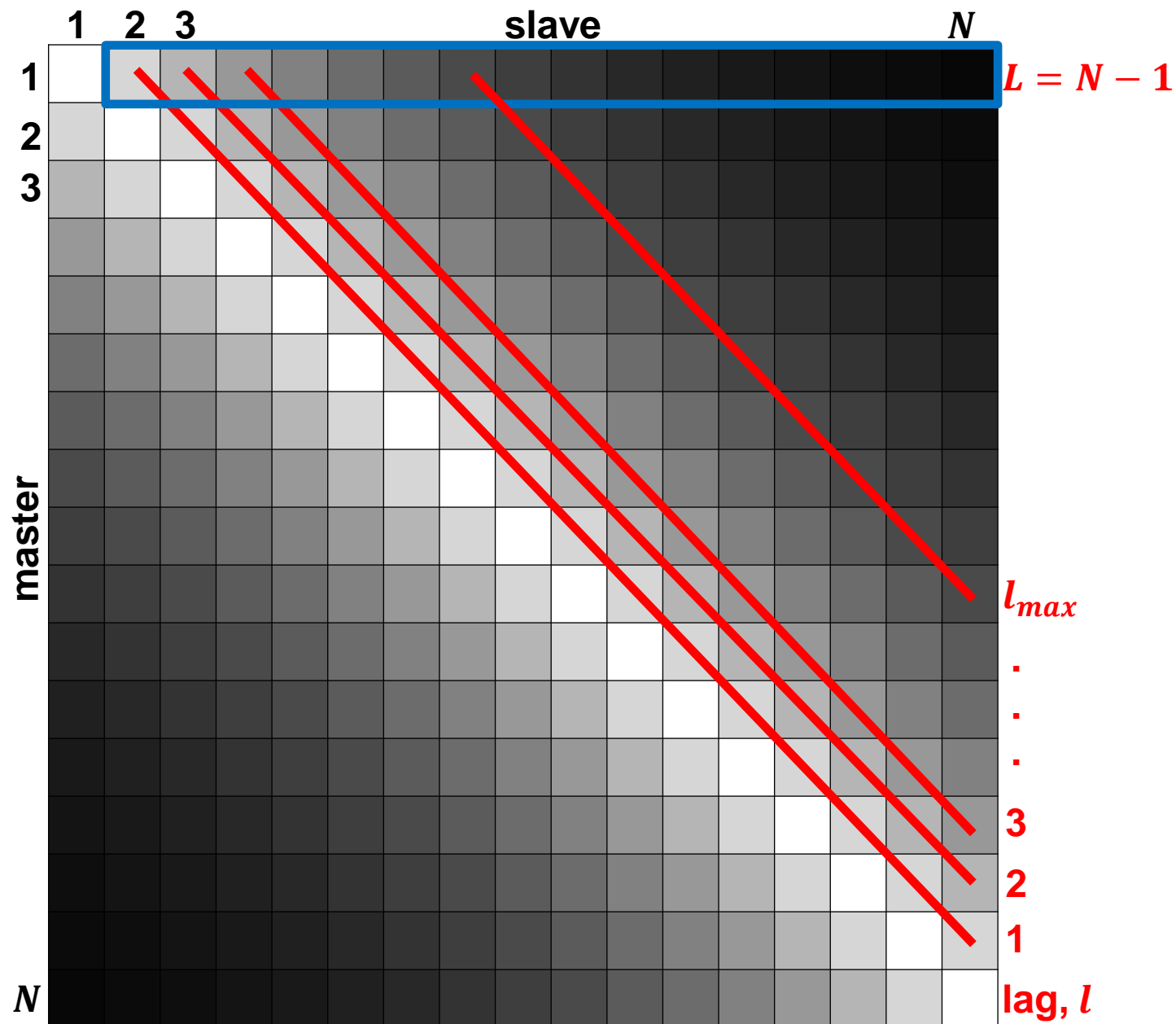
- Azimuth coregistration accuracy for S1 IWS:
1 milli-pixel = 0.01 cycle phase error at burst edge
- ESD (Enhanced Spectral Diversity) is coherence dependent
- Large S1 IWS stacks → large temporal baselines → temporal decorrelation → impact on direct pairwise ESD
- Explore joint estimation approaches



Shift Estimation

- **Direct estimator** uses all elements on one row: common master with lags $l = 1, \dots, N - 1$.
- Shifts, Δ_l , are the ESD estimates.
- **Joint estimator** uses all elements on diagonal(s): $l = 1, \dots, l_{max}, l_{max} \leq L$.
- Shifts from LS inversion of ESD estimates.
- Temporal baseline ~ constant on diagonal
- Proportion of data used by joint estimator

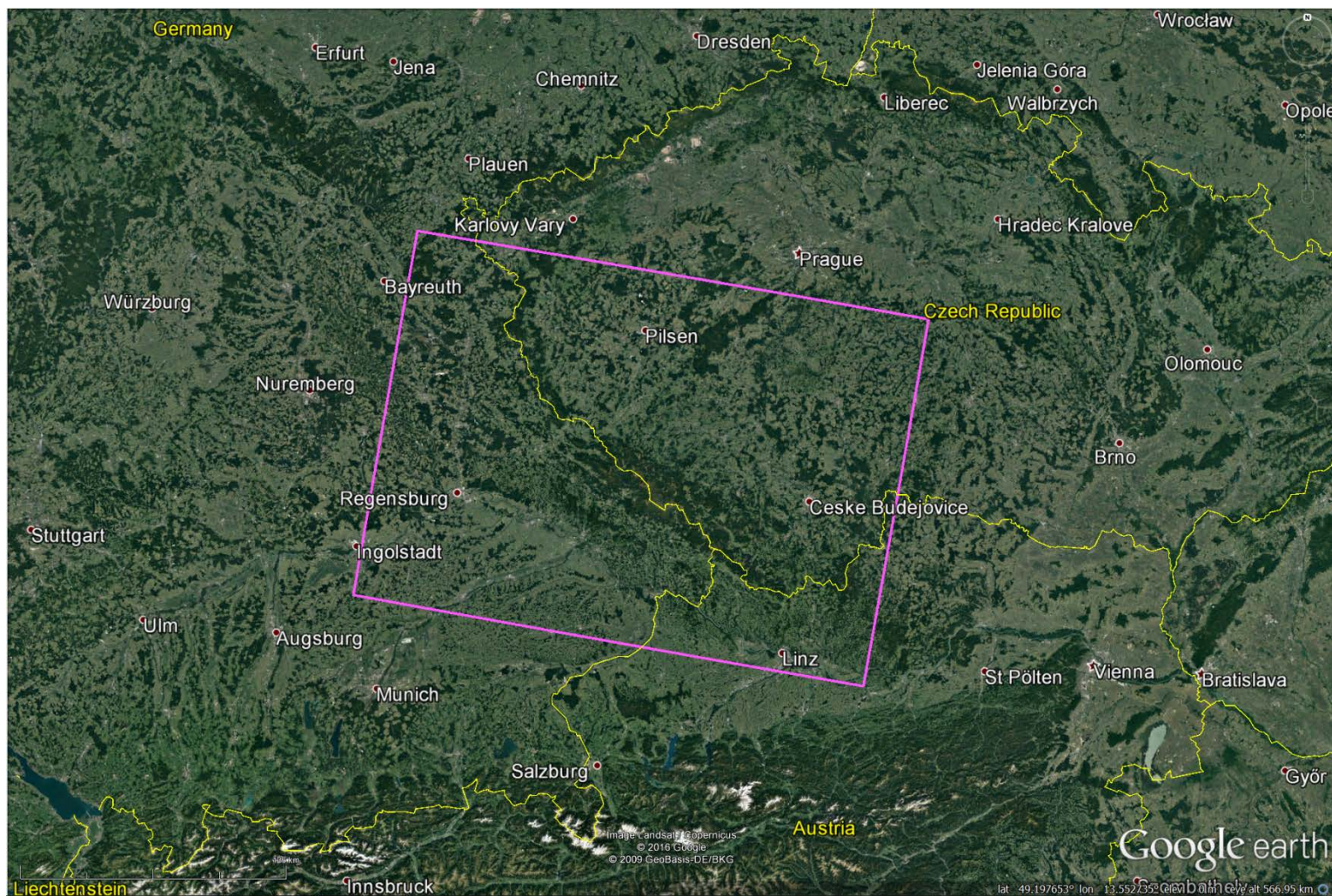
$$\sim \frac{l_{max}}{L} \left(2 - \frac{l_{max}}{L} \right)$$





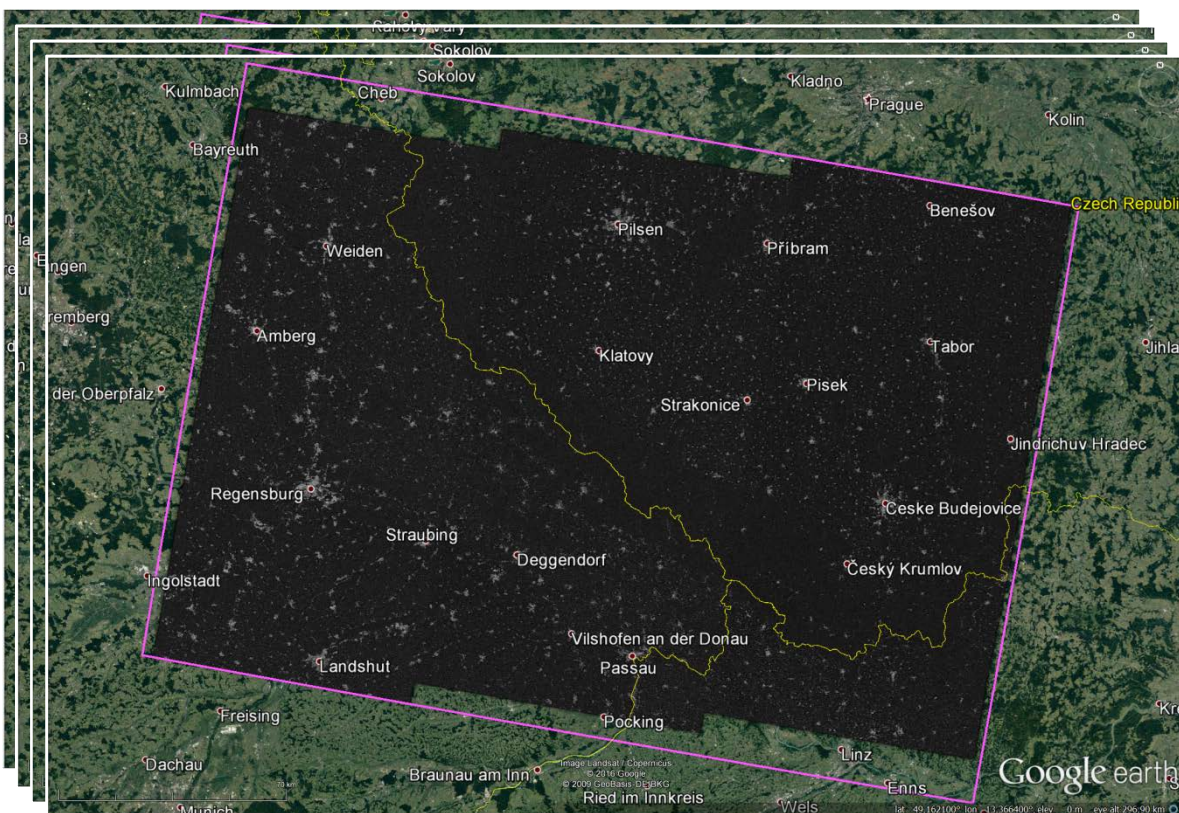
Experiments on S1-A/B Stack

- Sentinel-1A/B stack of **78 IWS images**, VV, descending, relative orbit 95
- Acquired 2014-11-17 – 2017-03-18, 876 days, **2.4 years**
- Contains
 - Urban centres
 - Rural areas
 - Mountains (Bohemian Massif)
 - Forests (Bohemian and Bavarian)
- Representative for Germany and Central Europe

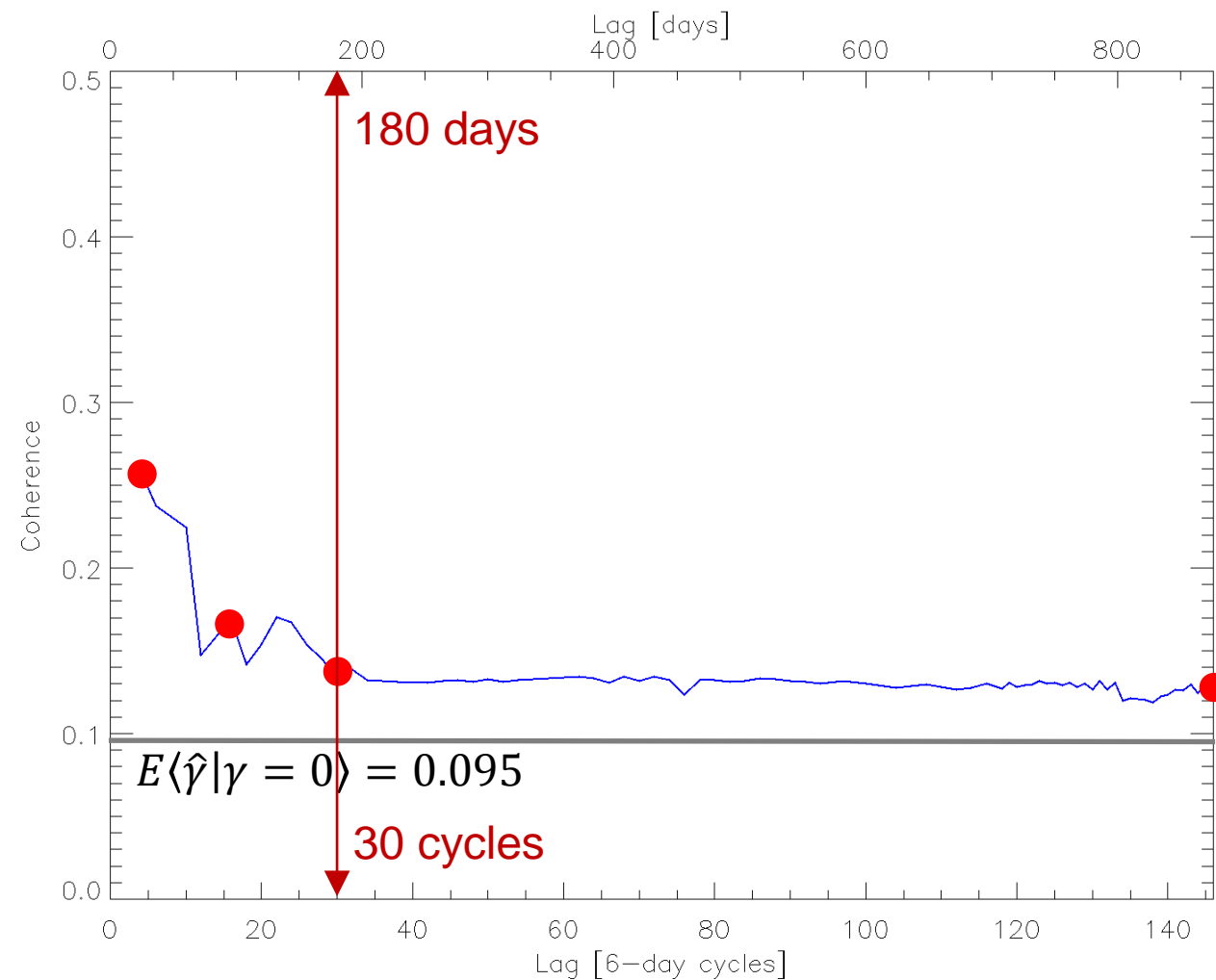


Stack Average Coherence (Overlap Areas)

- Stack exhibits long-term coherence 0.13 for temporal baselines > 1/2 year
- 33 day time constant typical for C-band



common master pairs

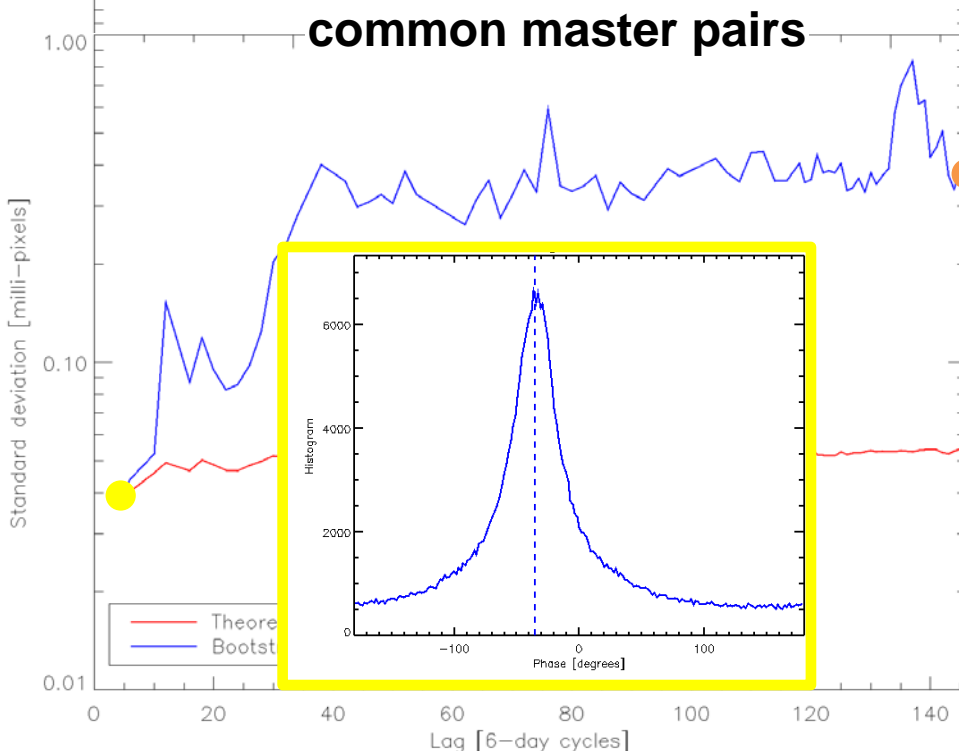
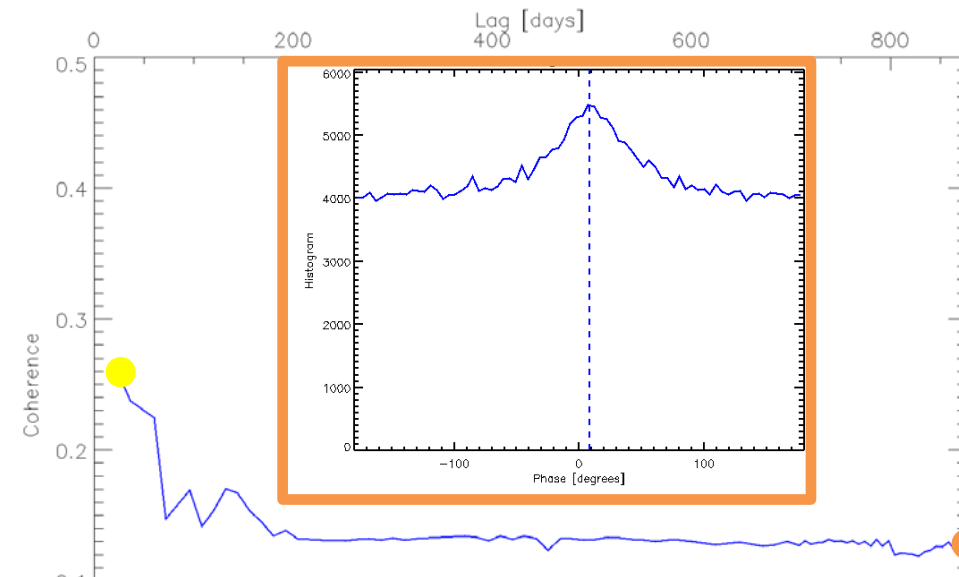


Direct Estimator

- Direct ESD estimates: $-20 \leq \Delta \leq 20$ milli-pixels
- Coherence higher in winter
- Theoretical formula under-estimates σ for low γ : $0.02 \leq \sigma \leq 0.06$ milli-pixels

$$\sigma_{\phi}^2 = \frac{1}{N} \frac{1 - \gamma^2}{\gamma^2}$$

- Bootstrap estimate of σ reliable for low γ : $0.01 \leq \sigma \leq 1$ milli-pixels
- Long-term coherence \rightarrow direct estimator **attains required 1 milli-pixel precision, but only just**



Joint Estimator – Least Squares Inversion – Variance-Covariance Matrix

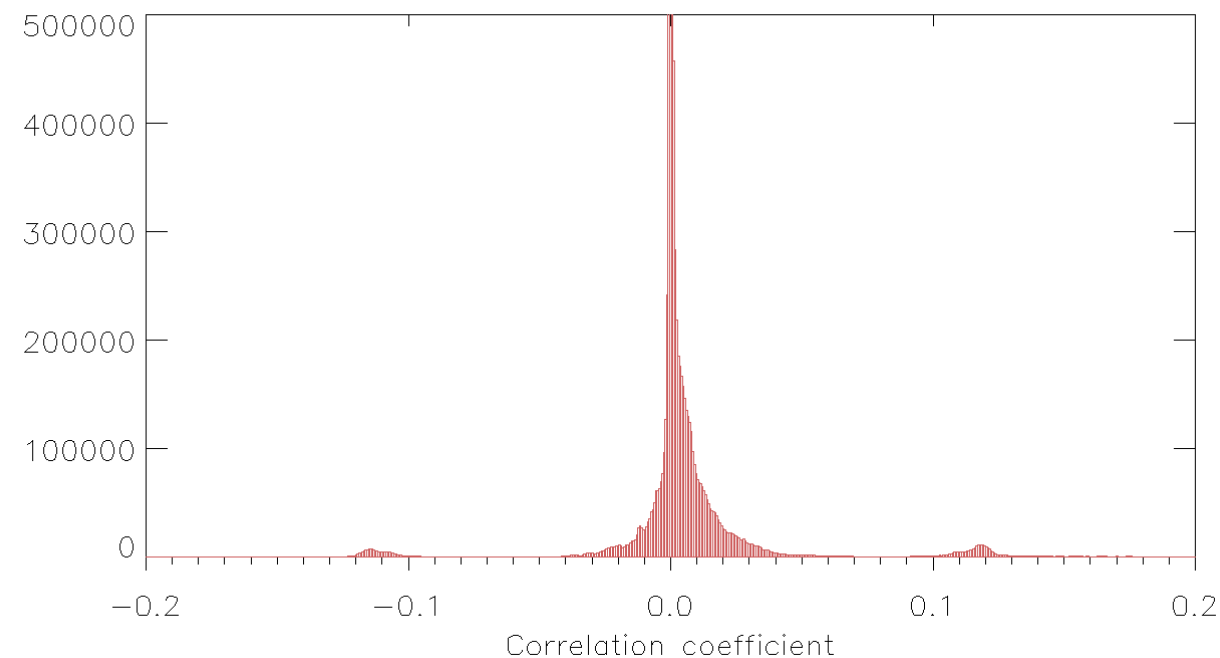
- Weighted LS (WLS) requires variances
- Generalised LS requires variance-covariance matrix

$$\rho(\Delta_{ij}, \Delta_{kp}) = \frac{\gamma_{ik}\gamma_{jp} - \gamma_{ip}\gamma_{jk}}{\sqrt{(1 - \gamma_{ij}^2)(1 - \gamma_{kp}^2)}}$$

$$\text{cov}(\Delta_{ij}, \Delta_{kp}) = \sigma_{ij}\sigma_{kp}\rho(\Delta_{ij}, \Delta_{kp})$$

Δ_{ij} : ESD estimate for master i , slave j

- All ESD estimates: $l_{max} = L = 77 \rightarrow 3003$ shifts
- Obtain ρ from $\hat{\gamma}$
- Obtain σ from $\hat{\gamma}$ (theoretical formula) or bootstrap

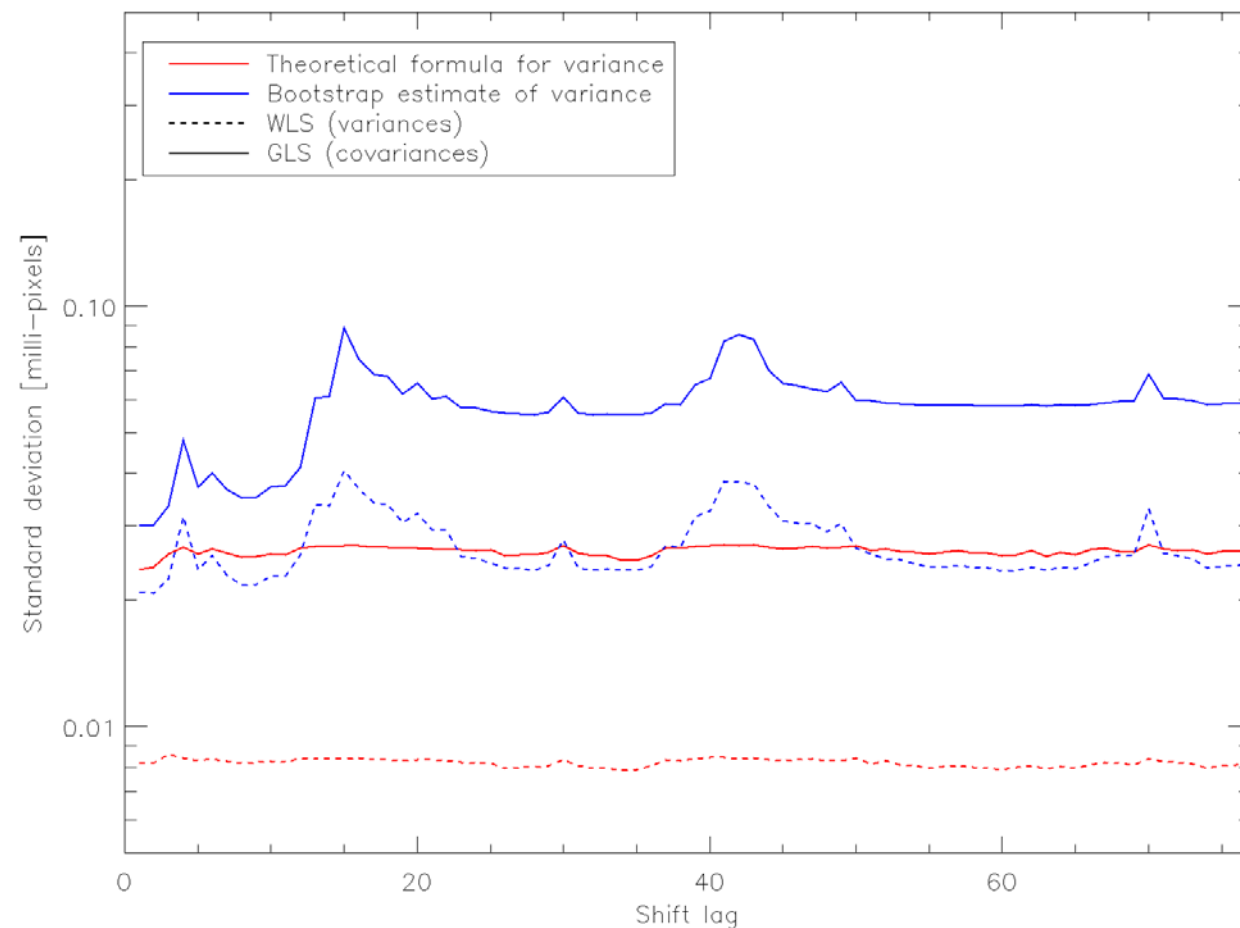


Joint and Direct Estimators – Comparison

- Difference between
 - joint estimator utilising maximum number of ESD shift estimates ($l_{max} = L$) and
 - direct estimator reaches milli-pixel level

- Small differences among joint estimators using
 - theoretical or bootstrap variances
 - WLS or GLS

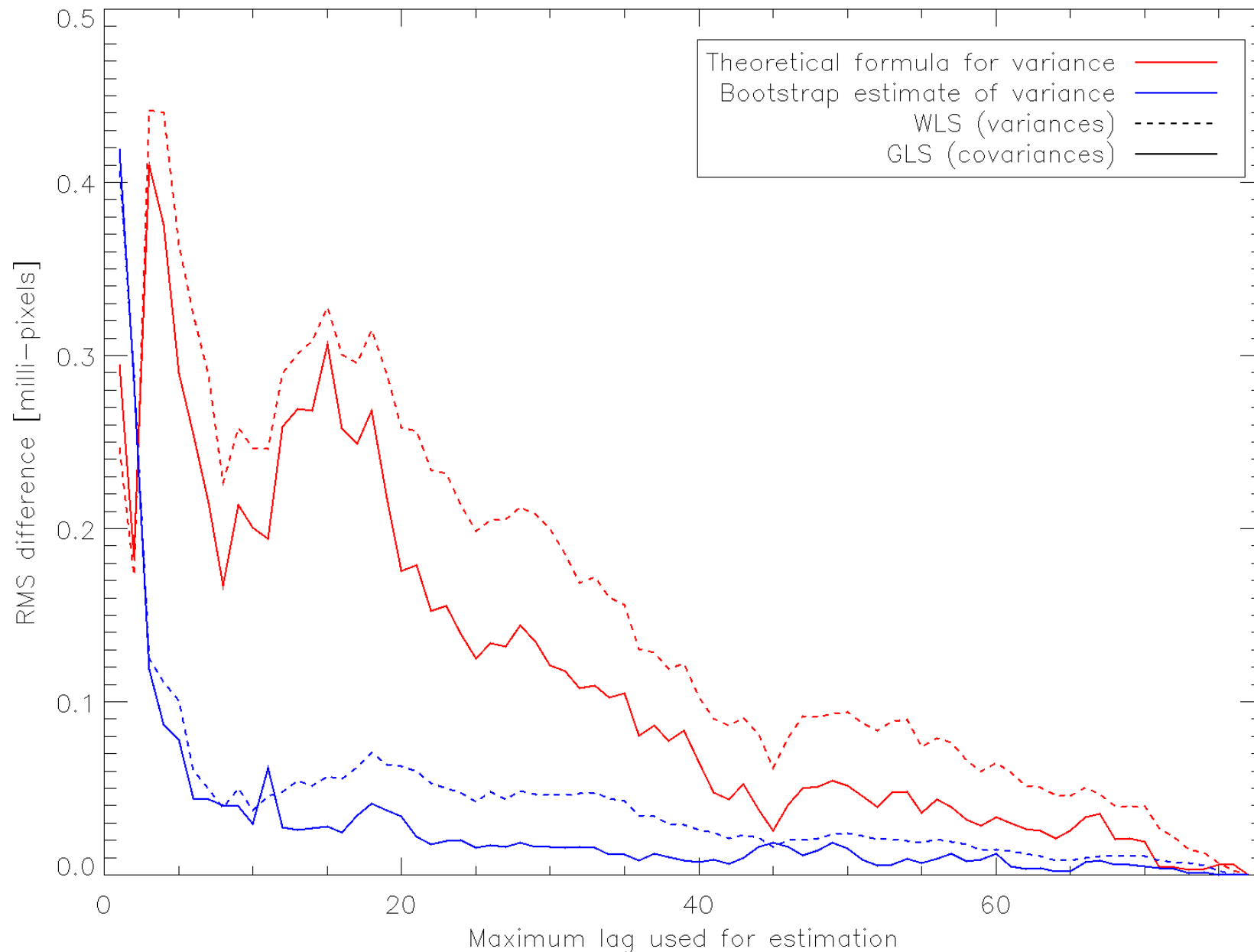
- σ under-estimated (x3 \rightarrow 10dB) when using
 - theoretical variances
 - WLS instead of GLS





Joint Estimator – Convergence

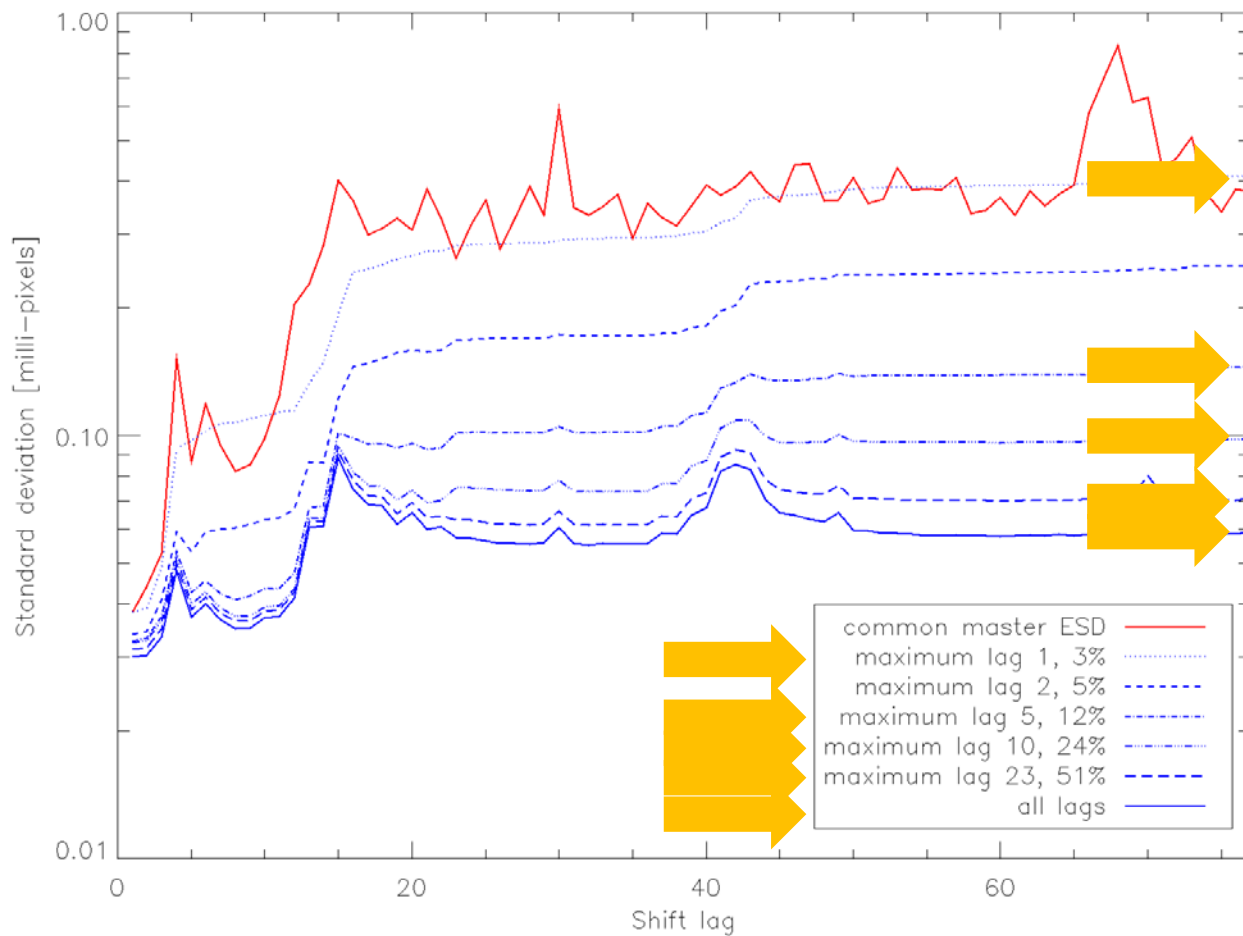
- Vary l_{max} from $1, \dots, L$
- Observe convergence of shift estimates to values at $l_{max} = L$
- Theoretical variance over-weights poor ESD shift estimates \rightarrow slow
- Bootstrap converges faster
- GLS slightly faster than WLS
- RMS difference over all shifts summarises this clearly



Joint Estimator – Trade-offs

- Small l_{max} reduces complexity but must be large enough to ensure convergence
- RMS difference between direct and joint estimators suggests $10 \leq l_{max} \leq 20$
- RMS σ of joint estimators suggests same
- Consider $\hat{\sigma}(\hat{\Delta}_L)$ from GLS using bootstrap

l_{max}	utilisation of ESD estimates	gain over direct estimator [dB]
1	3%	0, optimal $\gamma_\infty = 0$
5	12%	8
10	24%	12
23	51%	14
77	100%	16, optimal $\gamma_\infty > 0$



Conclusions

- Germany and Central Europe: direct ESD may suffice over long time spans given long term coherence
- Joint estimator offers potentially large gains over direct estimator for long time spans
- Recommendations:
 - bootstrap for accurate estimates of shift variances and faster convergence
 - GLS for accurate estimates of shift variances
 - use 25% – 50% of all possible ESD estimates ($13\% \leq l_{max}/L \leq 30\%$) → depends on γ_∞
- Continue experiments over Germany and areas with low γ_∞ to find best trade-off for l_{max}



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