

Empirical stochastic modeling of observation noise in global GNSS network processing

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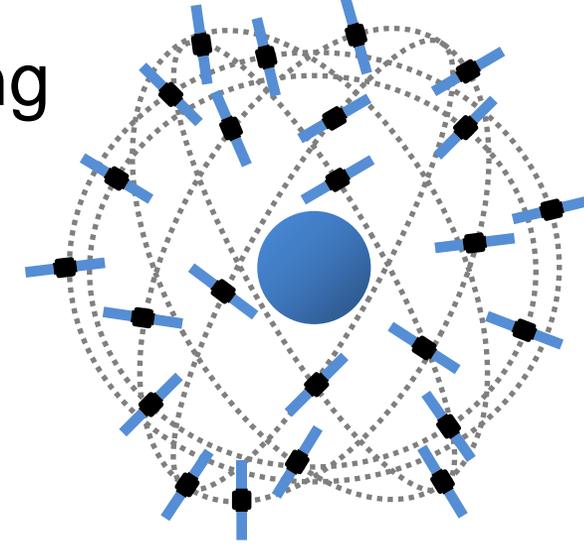
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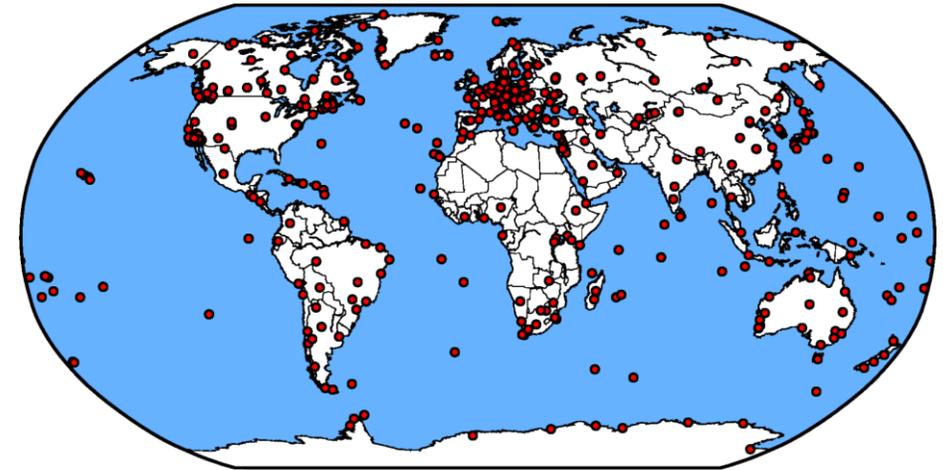
Global GNSS processing and stochastic modeling

- Combined processing in a least squares adjustment. of
 - GNSS constellation
 - Ground station network

- Currently very simple variance weighting scheme at TUG
 - TUG repro3
 - $\sigma_{phase} = 1mm / \cos(\zeta)$
 - $\sigma_{code} = 220mm / \cos(\zeta)$
 - Neglect of covariances



GNSS constellation



IGS station network

IGS INTERNATIONAL
GNSS SERVICE

Estimating temporal covariance model using post-fit residuals

- Based on the approach of Luo et al. (2012)
 - Adapted for multi-GNSS with multipath-hemispheric-maps (MHM)

Basic 4 steps:

- Create accuracy patterns and normalize
 - Accuracy patterns generated by

$$\hat{\sigma}(A, E) = \sqrt{\frac{\sum_i e_i^2(A, E)}{\sum_i r_i(A, E)}}$$

- Removes heteroskedasticity

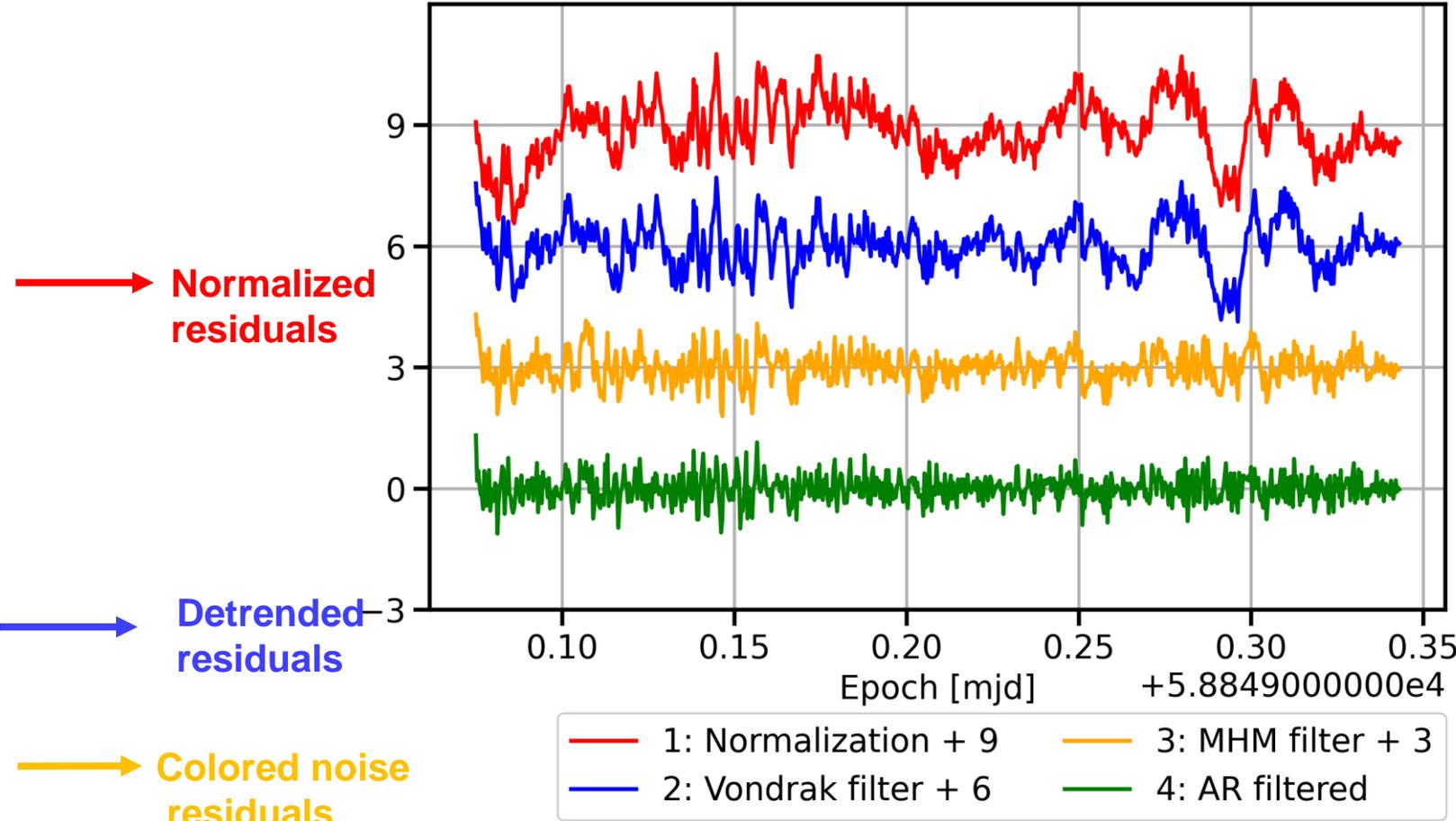
- Vondrak filter

- Removes daily trend components

- MHM stack the residuals and filter

- Eliminates elevation and azimuth dependent systematic station biases

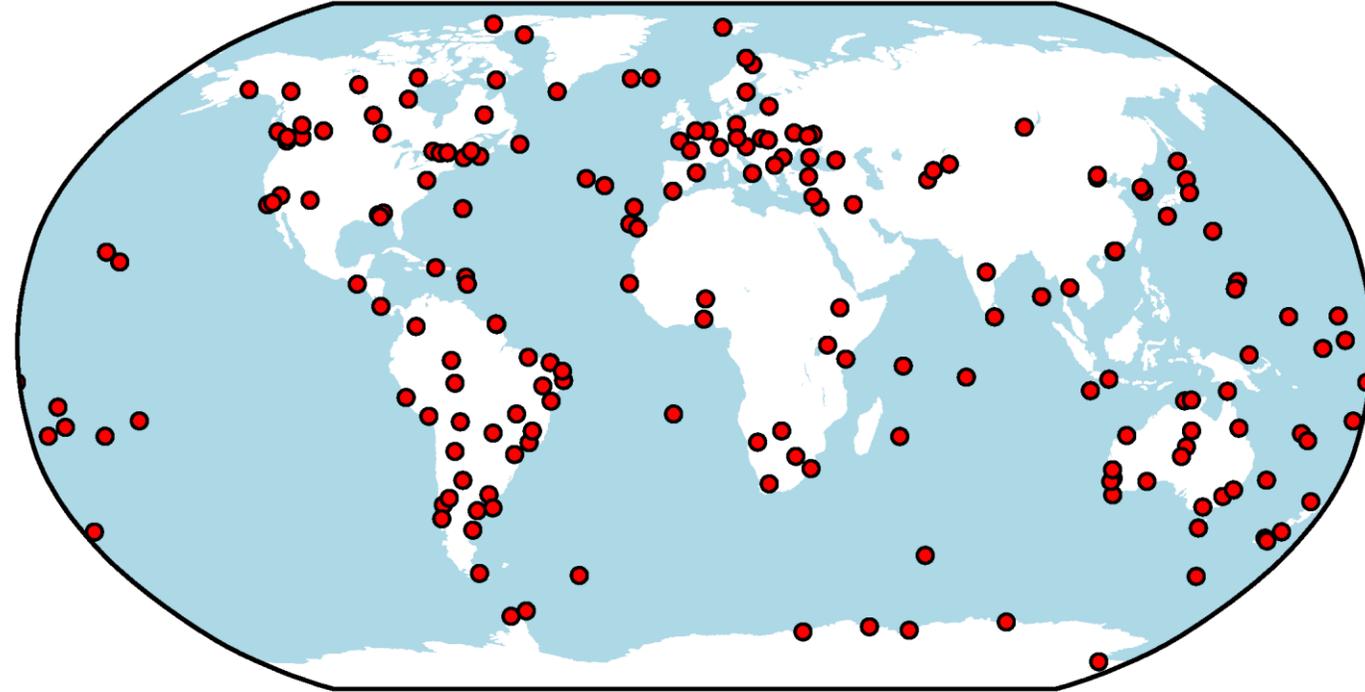
- Estimate Autoregressive Moving average (ARMA) process into colored noise



Residuals after each processing step for station Graz
From 60 days of residuals

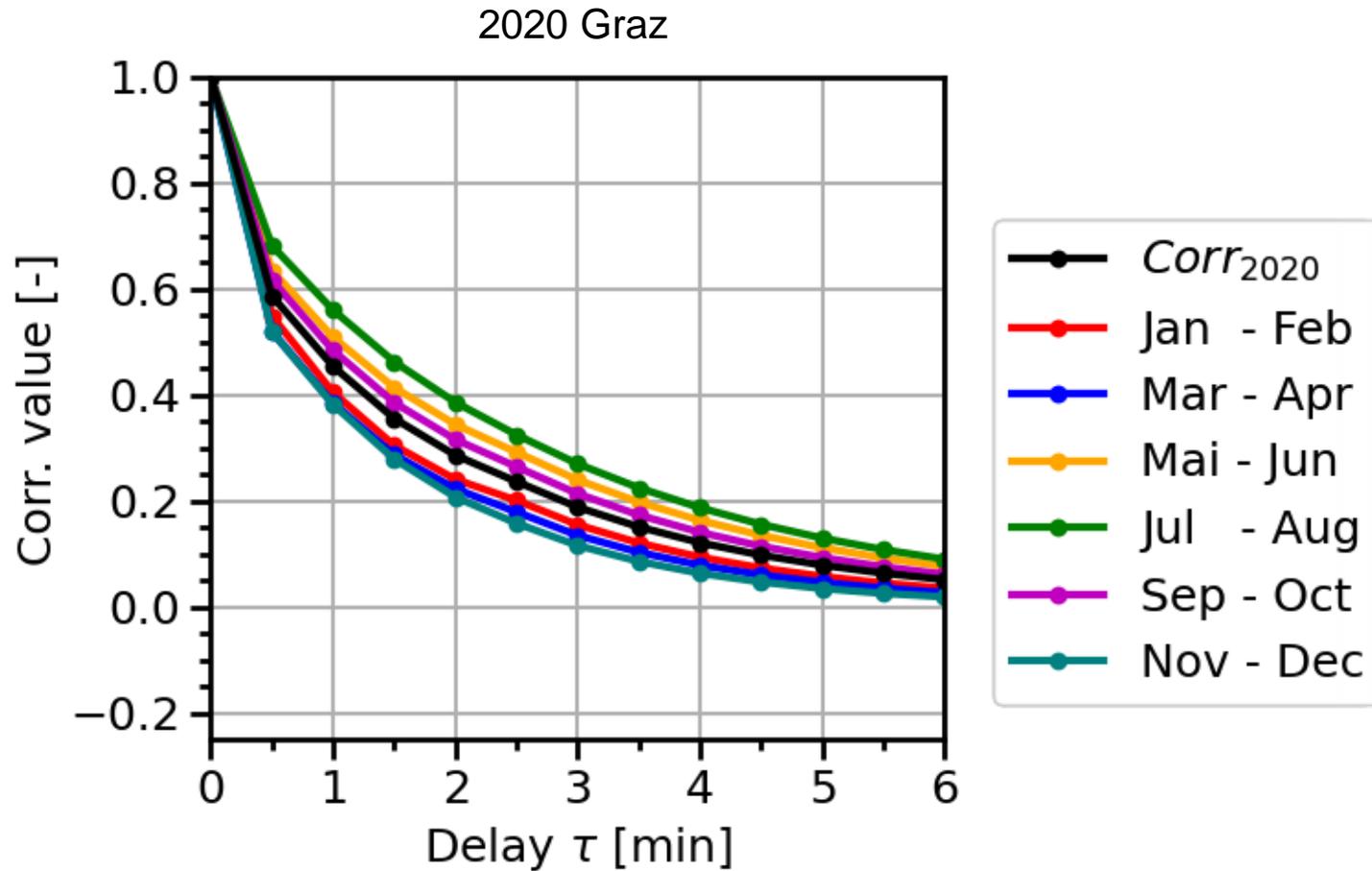
Analysis setup

- Generated residuals by a global network estimation with ~200 stations
- Same models, procedures as was used in the repro3
- Year 2011, 2016 and 2020 are computed
- Each year is separated into **60 days intervals** for the stochastic model estimation and compared to the **full year** estimation
- Only AR processes are estimated

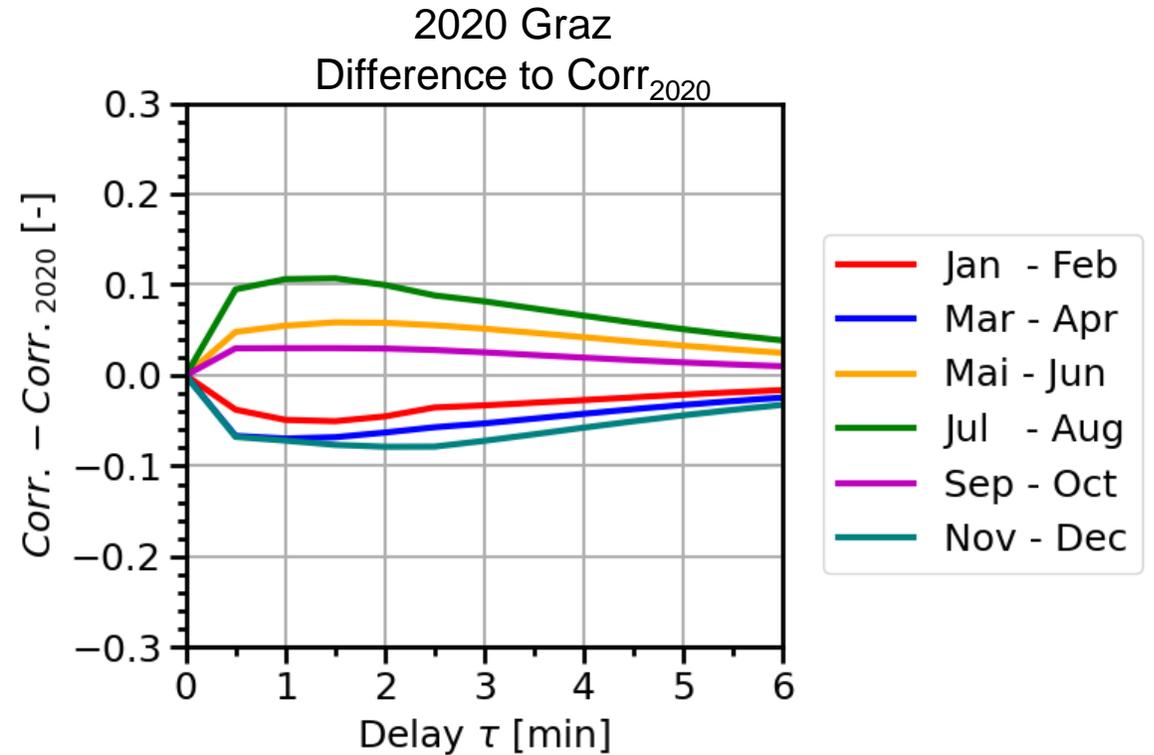
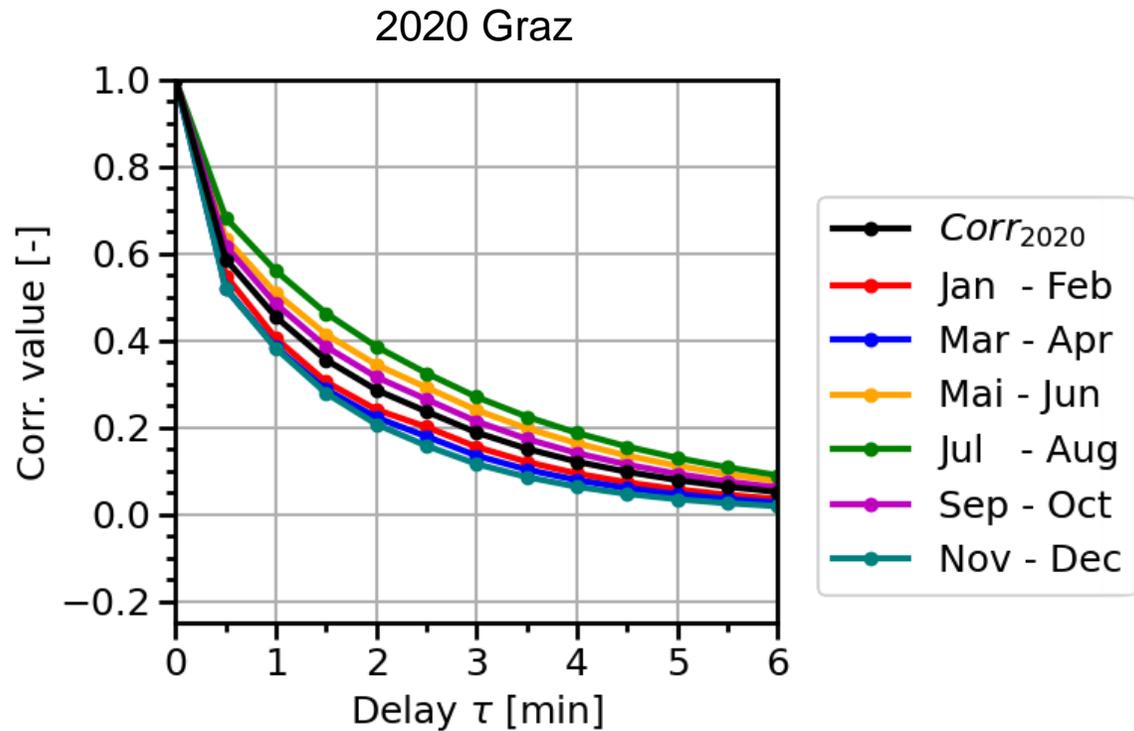


Selected stations for the analysis setup

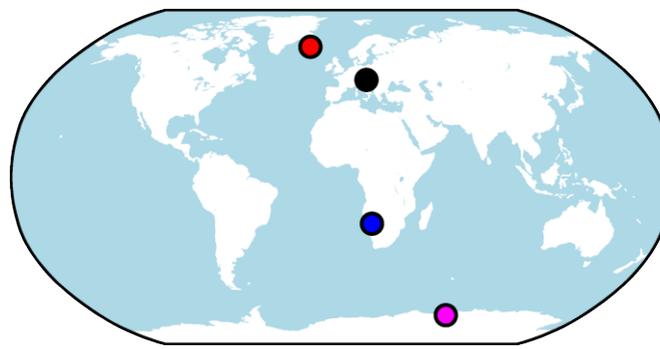
Estimated L1 temporal correlations Graz



Estimated L1 temporal correlations Graz



Estimated L1 Temporal correlations global

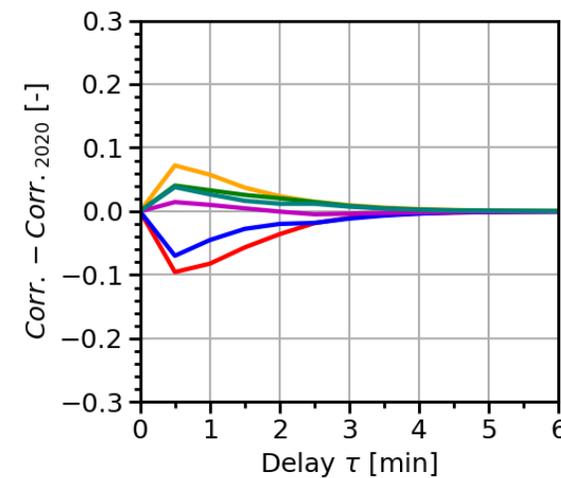
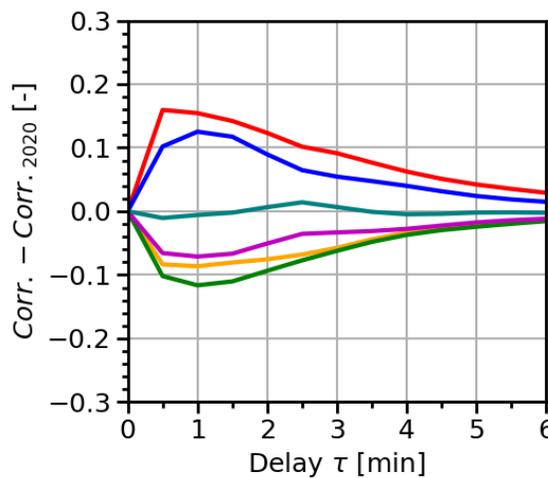
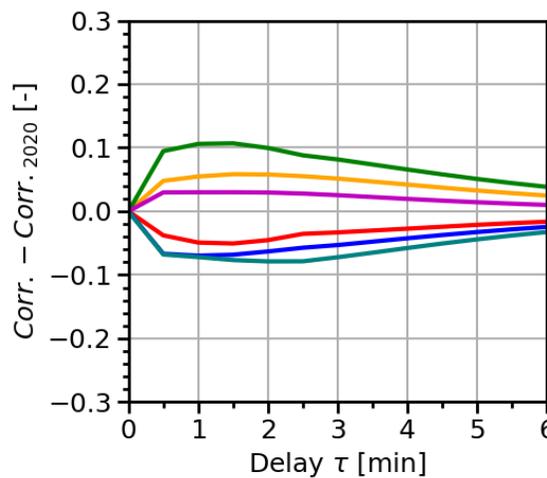
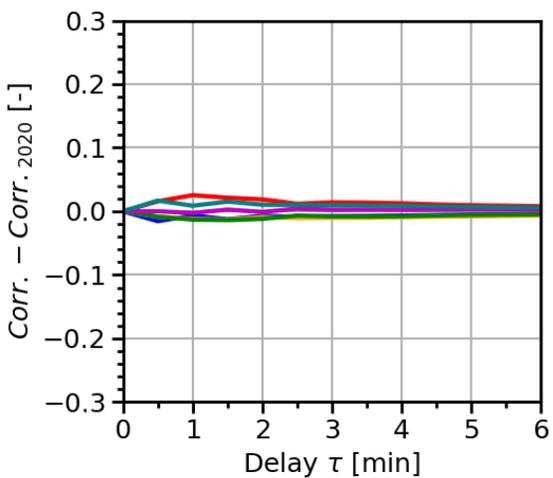
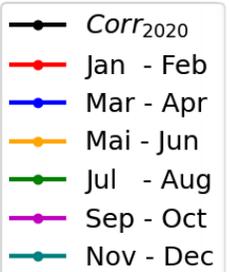
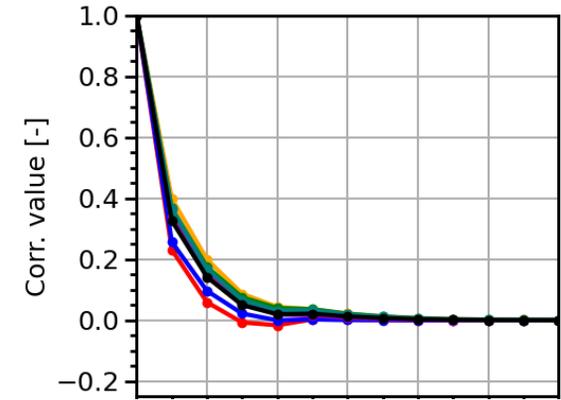
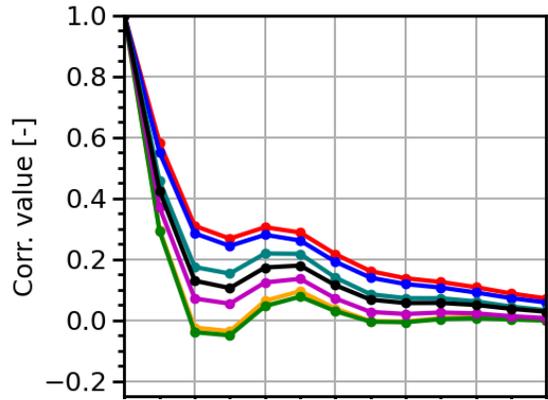
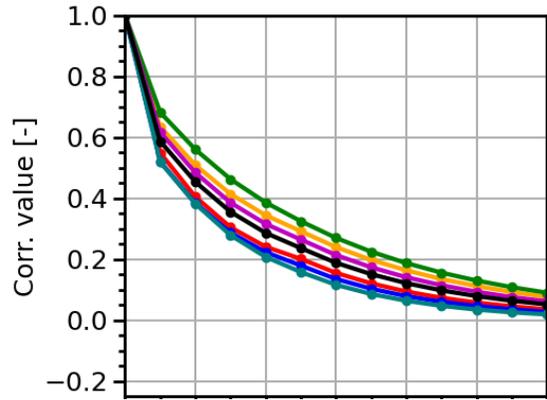
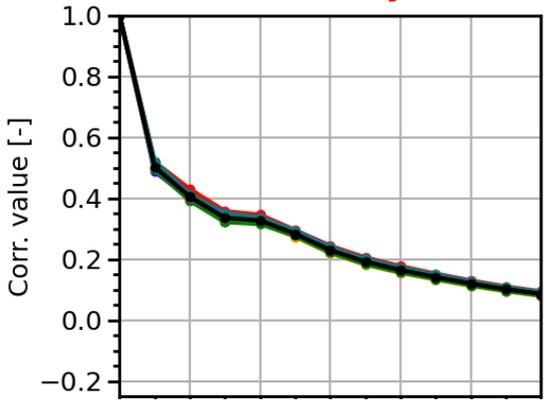


2020 Reyk

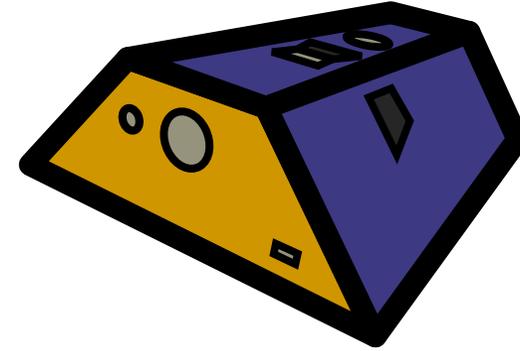
2020 Graz

2020 Wind

2020 Dav1



Summary

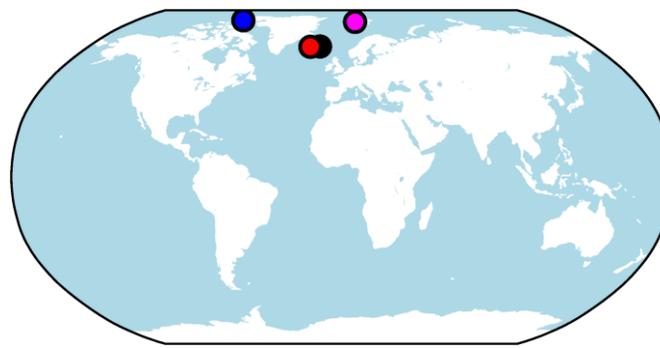


- Current stochastic model inadequate
- Estimated Co/Variances show annual seasonality
- Far north and far south show little variations
- Stations located in the northern and southern hemisphere have opposite seasonal behavior due to winter/summer environmental changes
 - In winter months the phase observations are more precise and correlate less than in the summer months
- Seasonality observable throughout all frequency (L1, L2, L5 ...) and in all analyzed years (2011, 2016, 2020)

<https://github.com/groops-devs/groops/>

Estimated L1 covariance models global comparison

Estimated L1 Temporal correlations Far North 2020

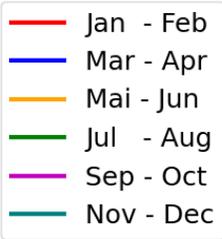
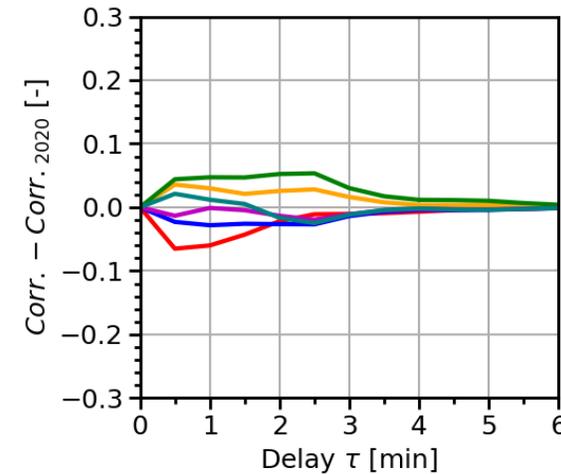
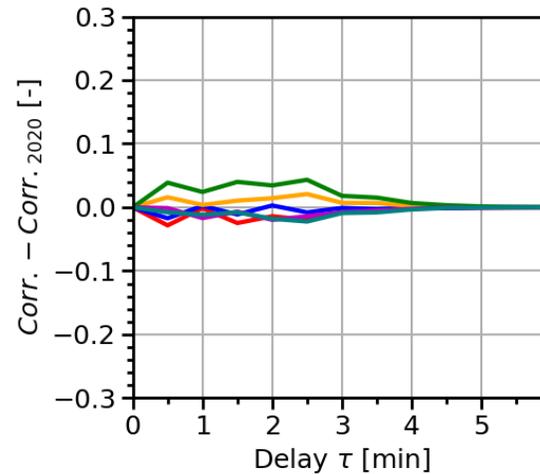
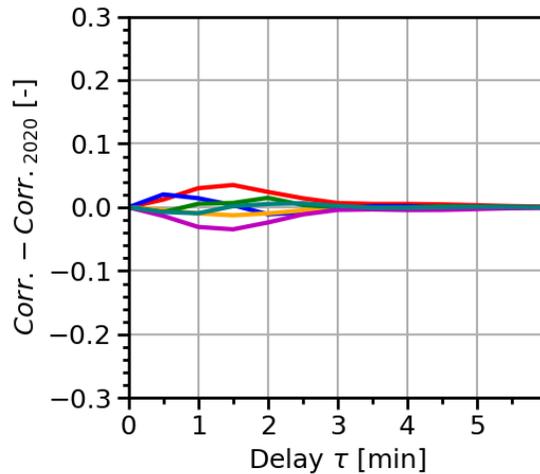
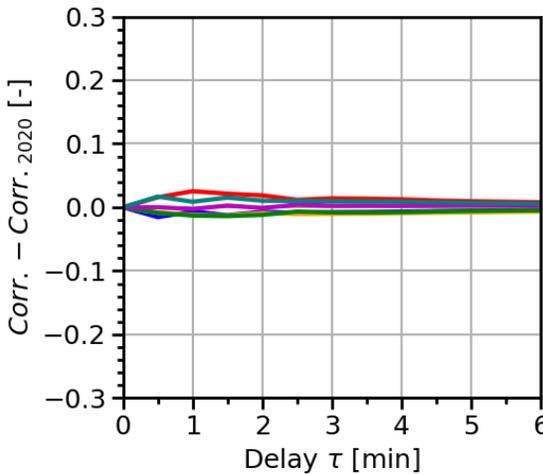
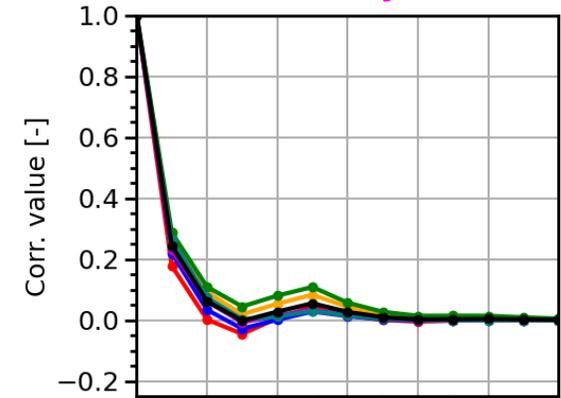
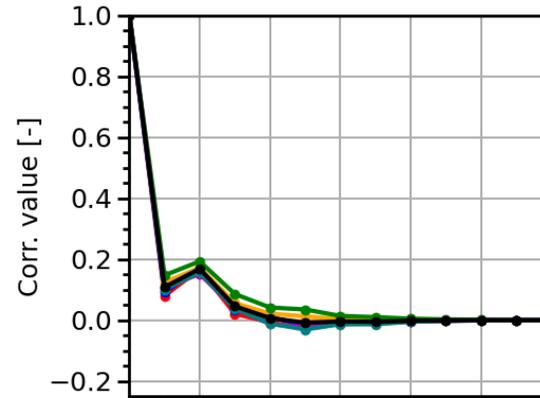
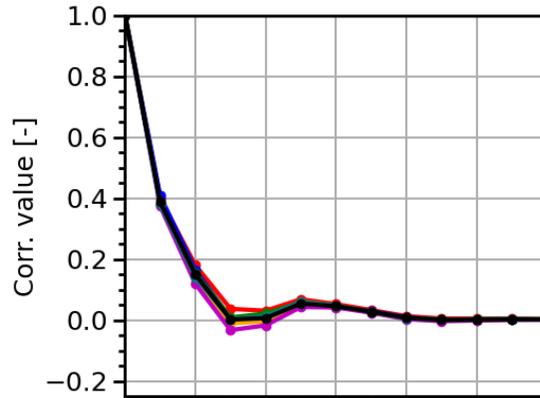
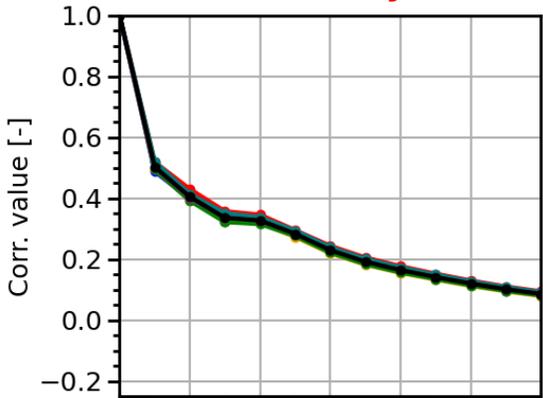


2020 Reyk

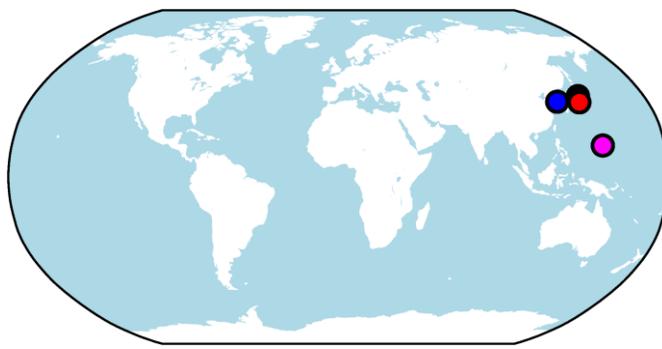
2020 Hofn

2020 Eur2

2020 Nya1



Estimated L1 Temporal correlations East Asia 2020

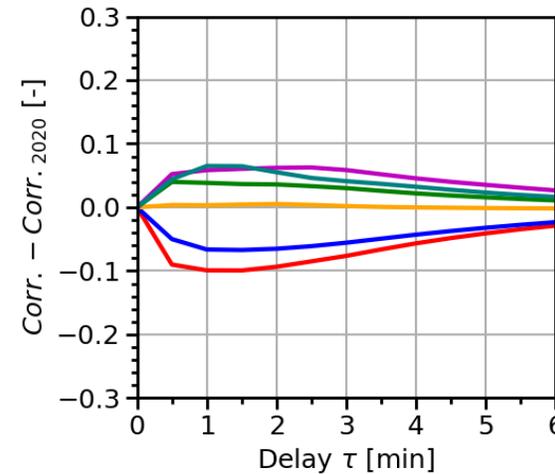
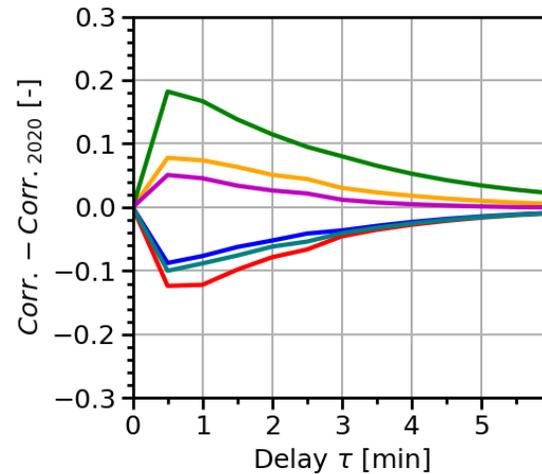
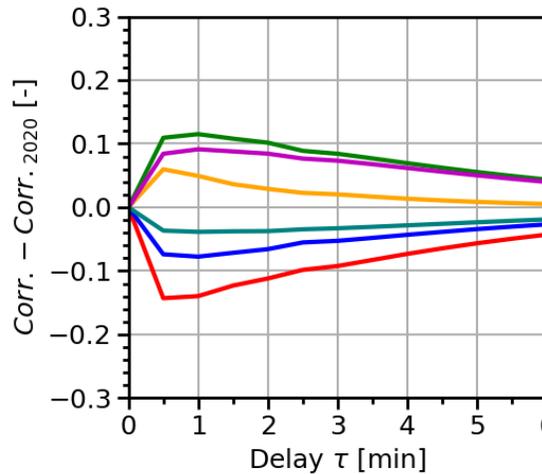
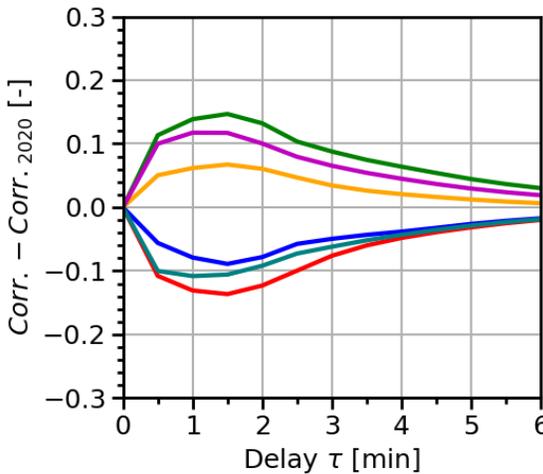
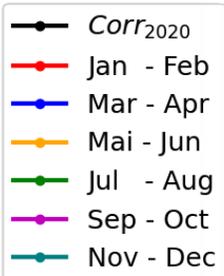
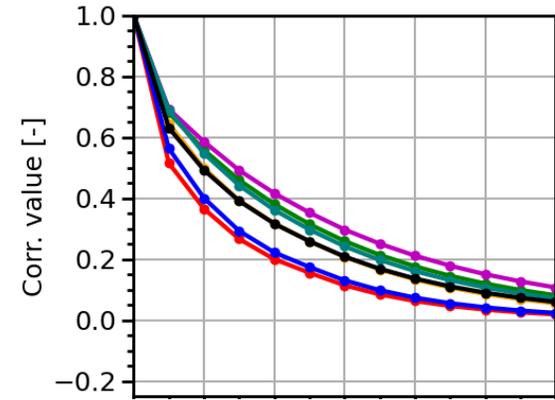
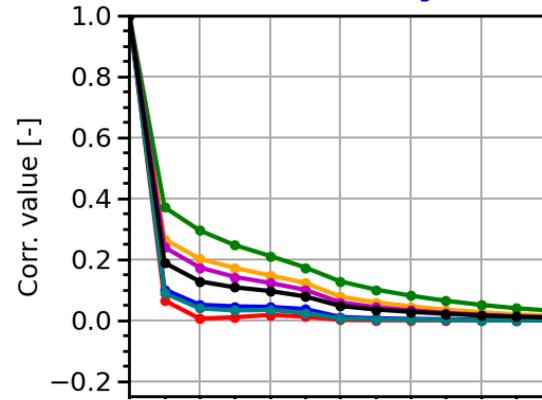
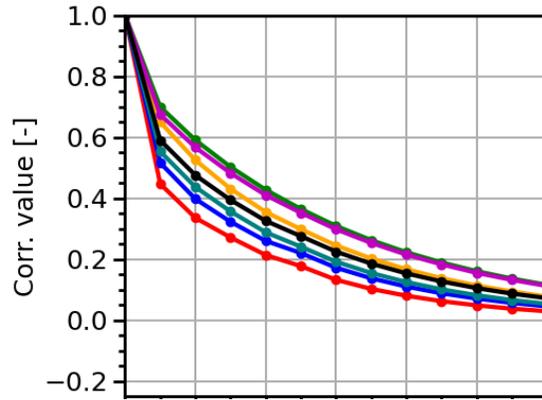
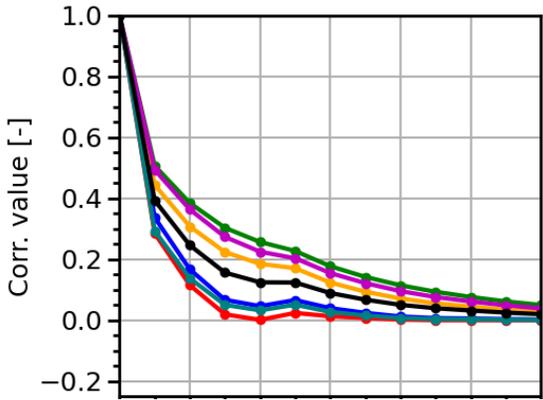


2020 Tsk2

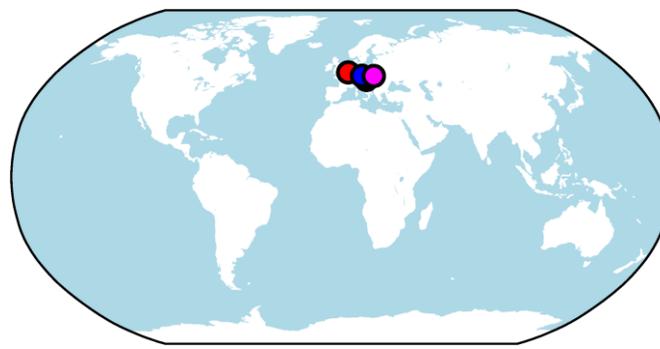
2020 Mizu

2020 Daej

2020 Guam



Estimated L1 Temporal correlations Europe 2020

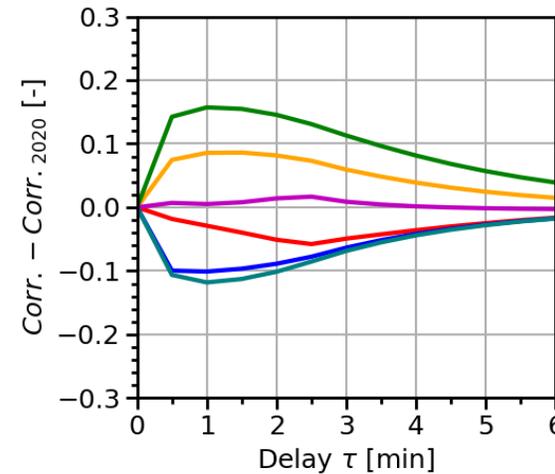
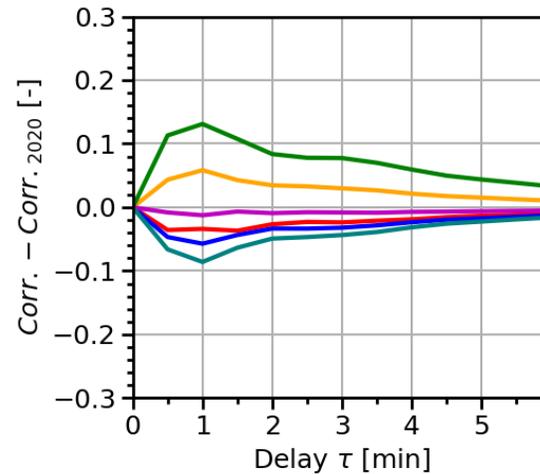
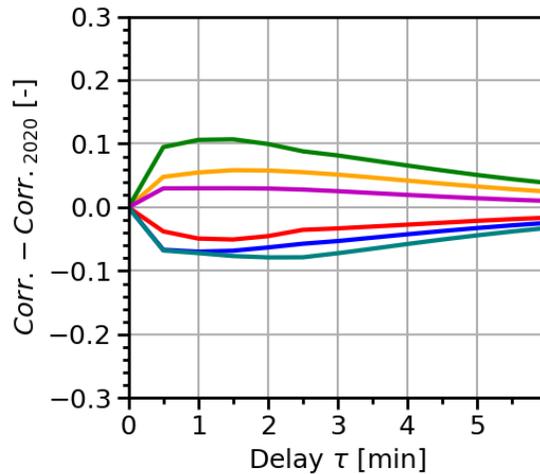
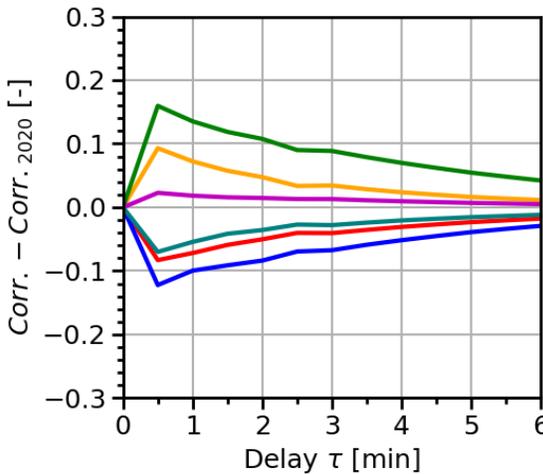
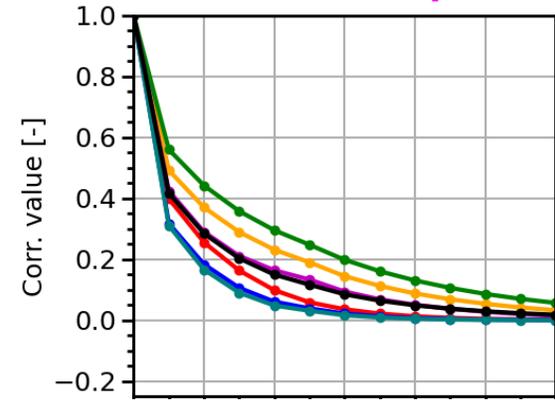
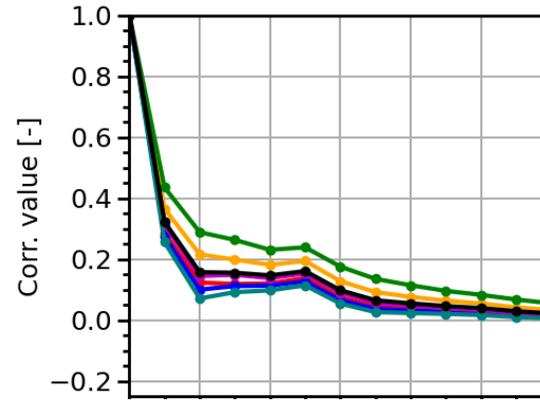
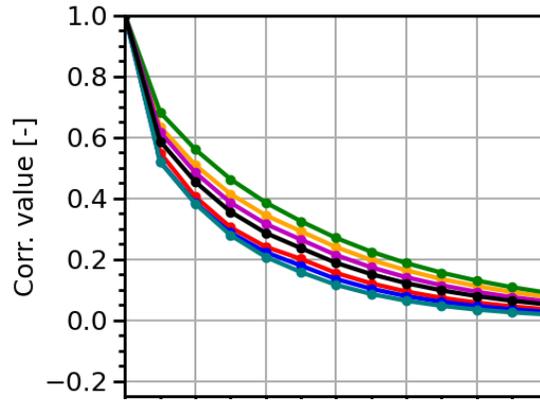
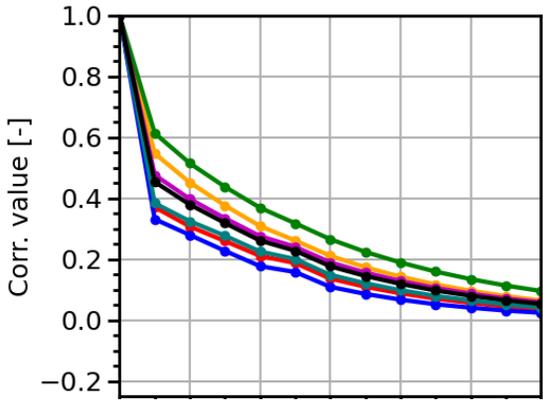


2020 Brux

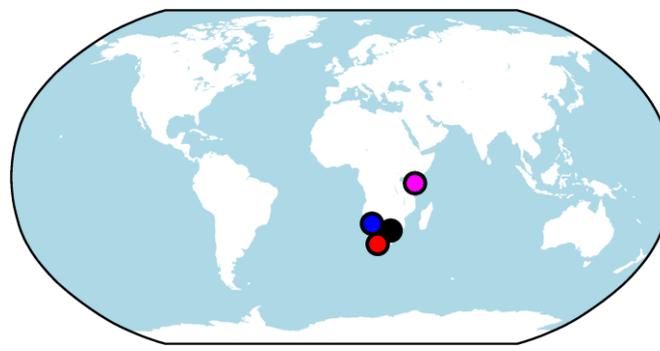
2020 Graz

2020 Wtzt

2020 Ganp



Estimated L1 Temporal correlations South Africa 2020

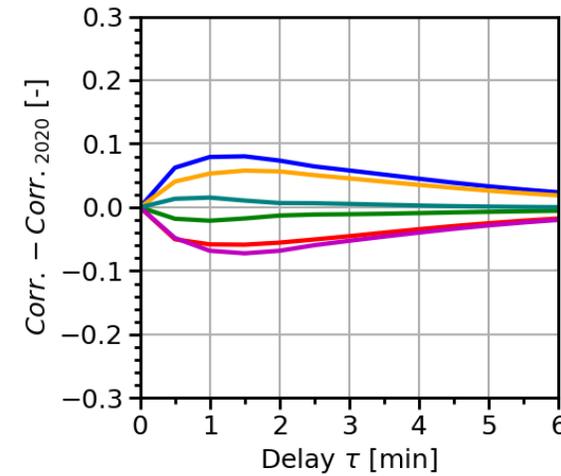
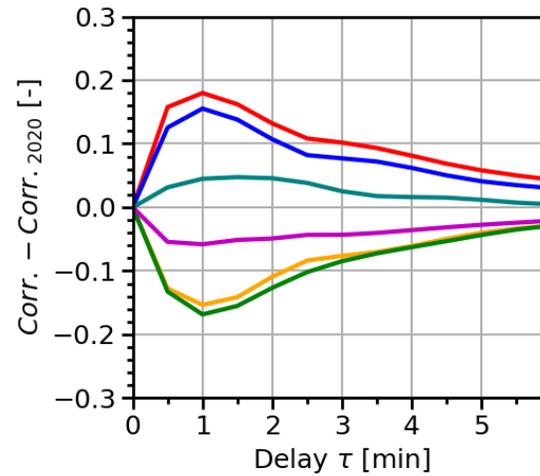
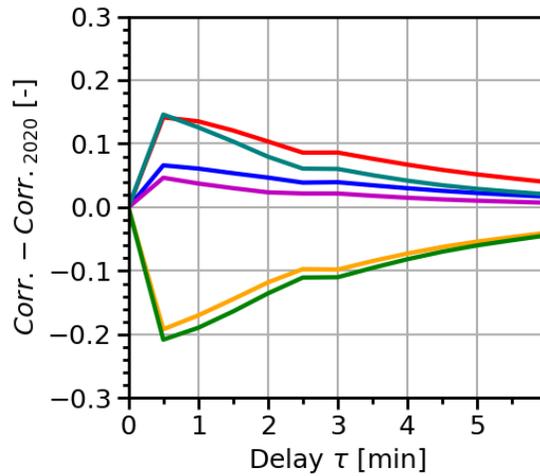
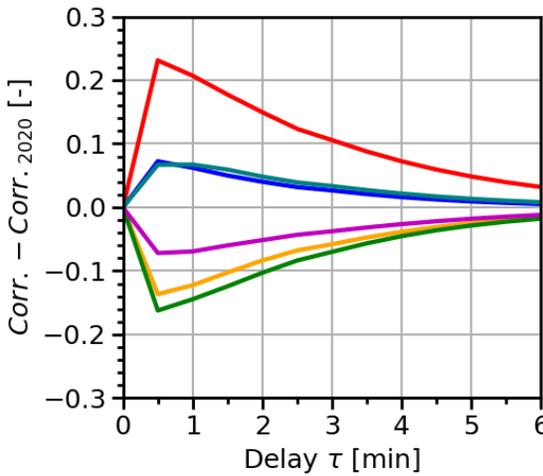
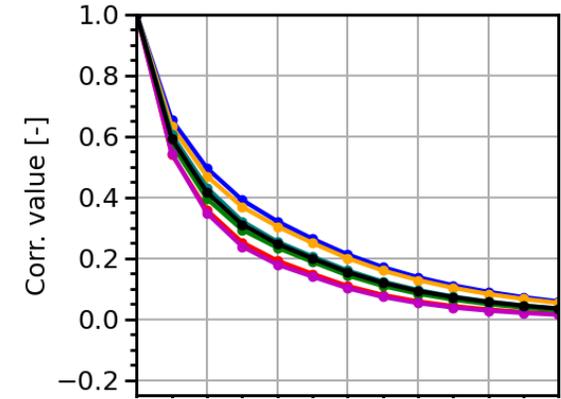
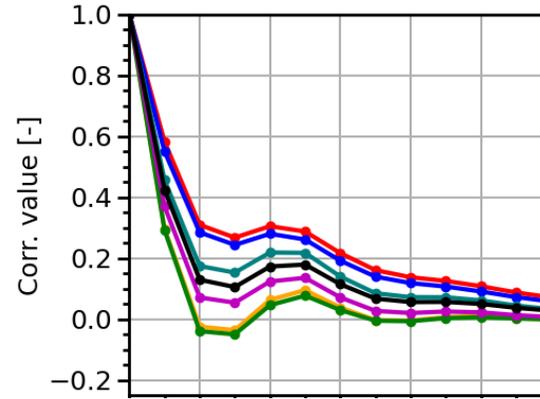
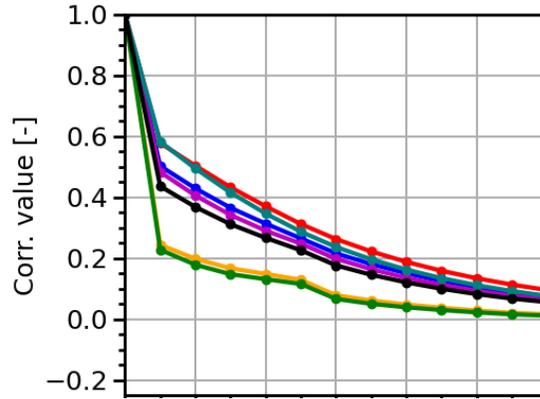
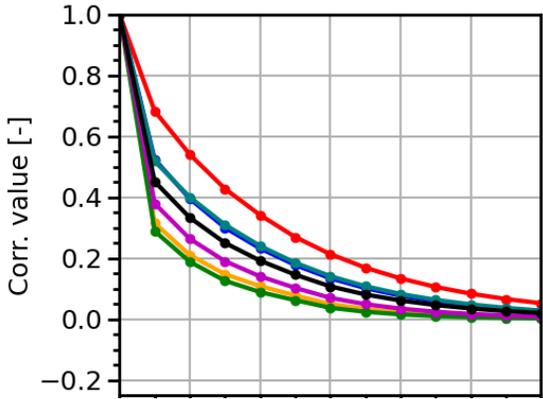


2020 Sutm

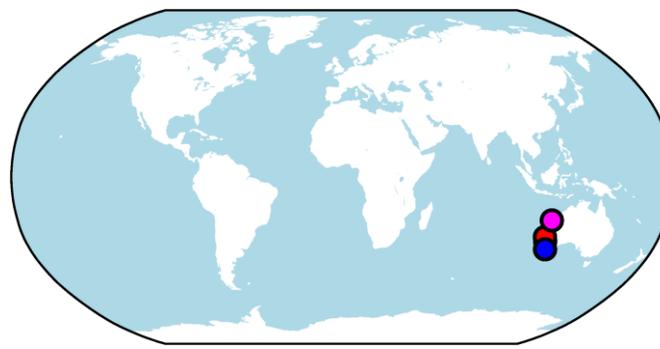
2020 Hrao

2020 Wind

2020 Mal2



Estimated L1 Temporal correlations Australia 2020

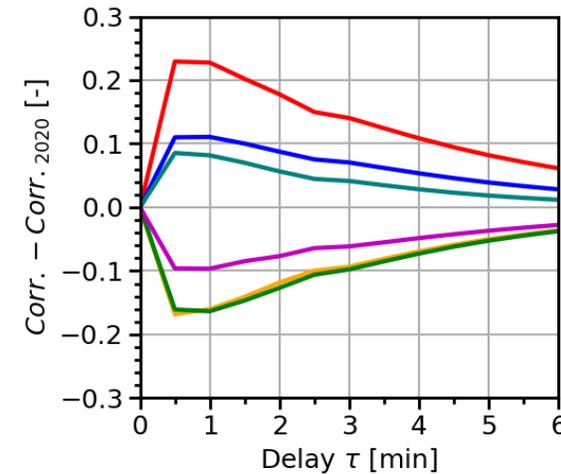
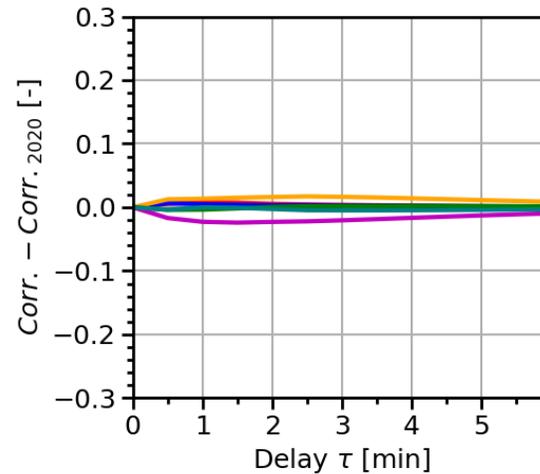
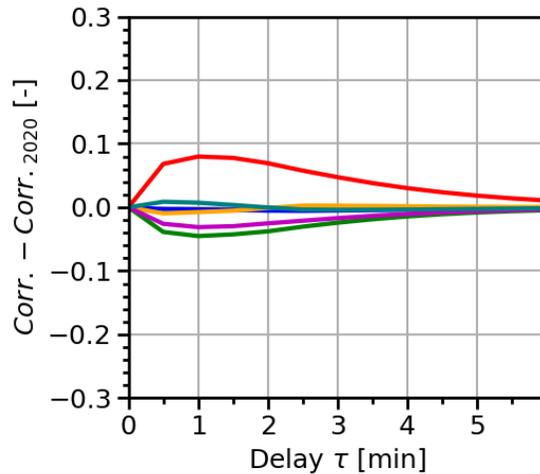
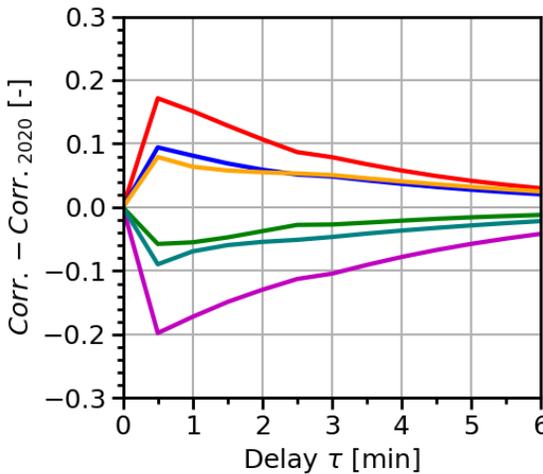
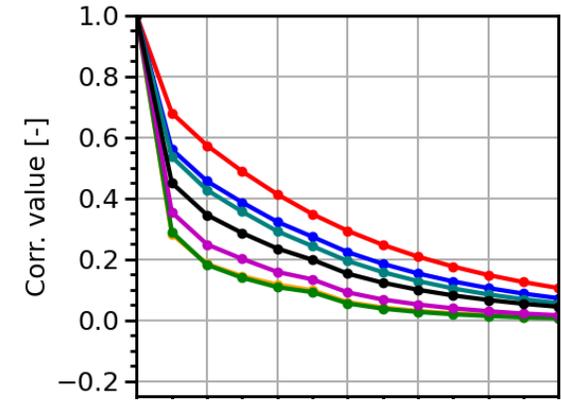
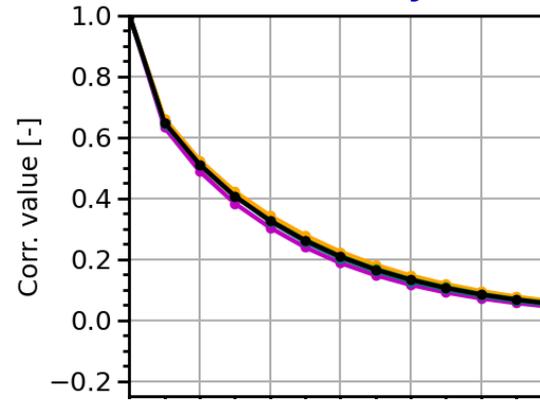
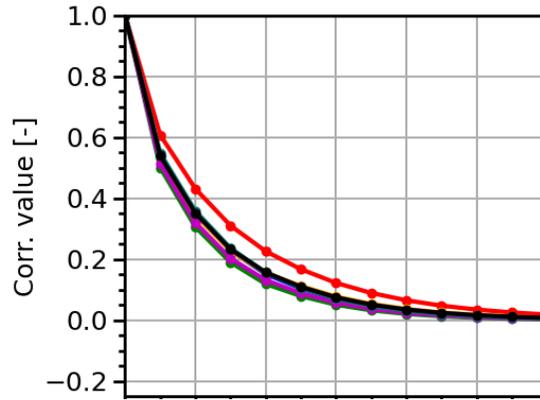
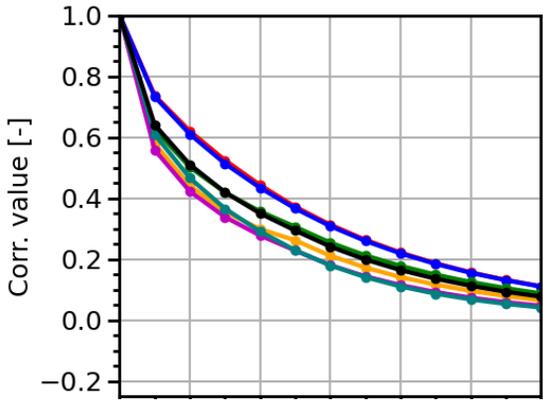


2020 Yar2

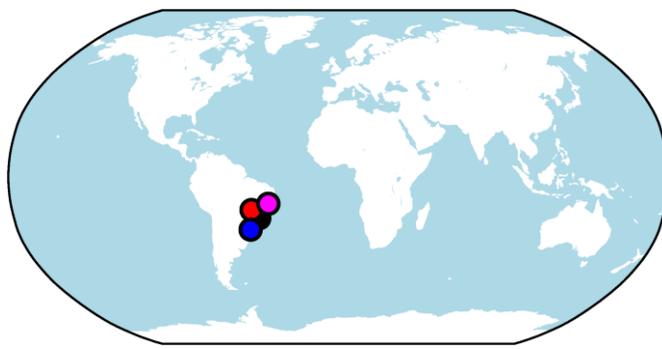
2020 Nnor

2020 Alby

2020 Karr



Estimated L1 Temporal correlations South America 2020

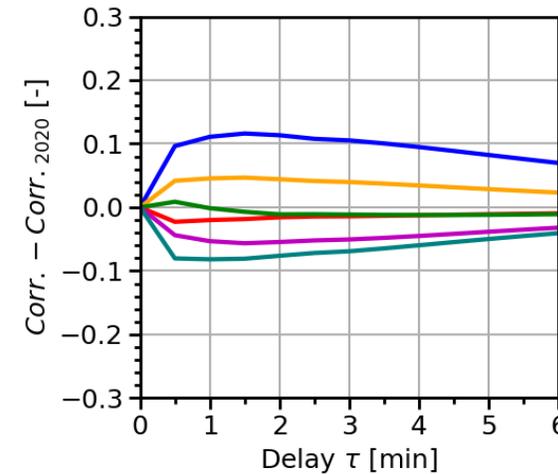
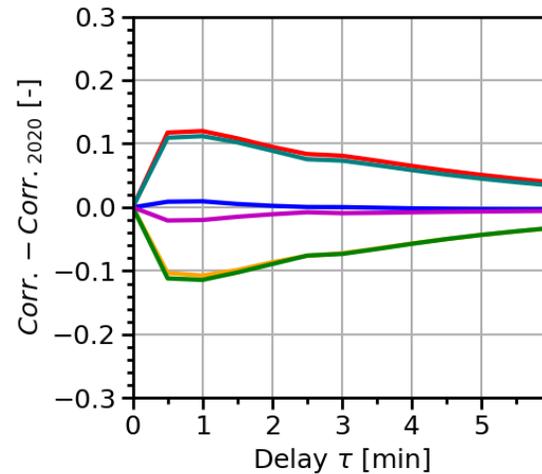
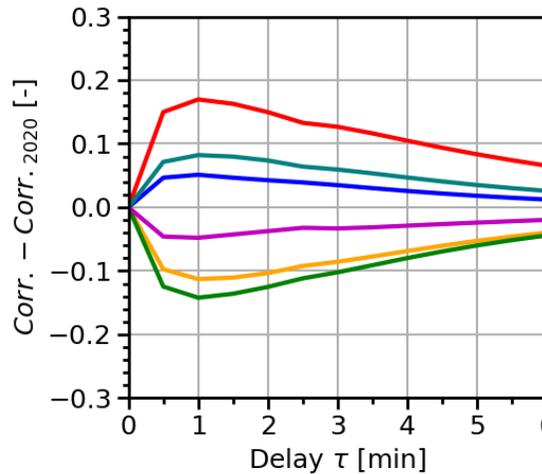
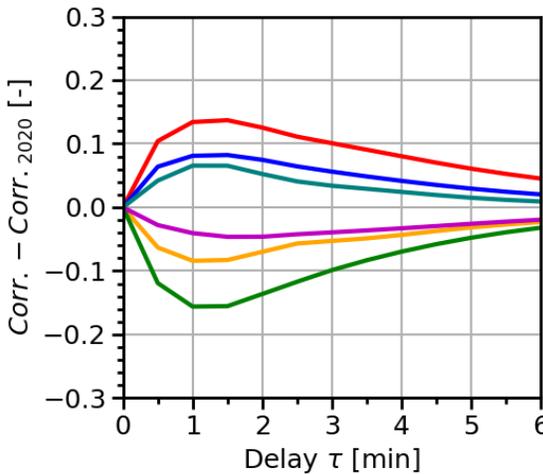
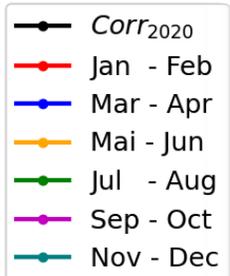
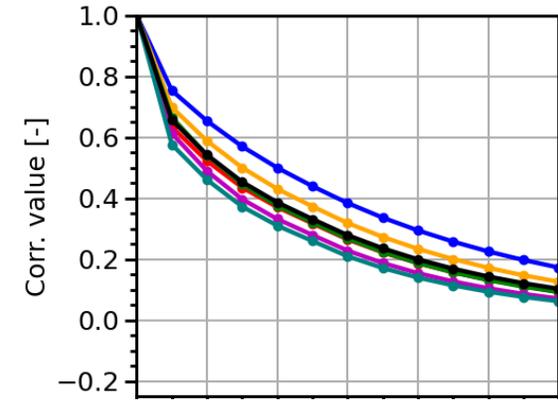
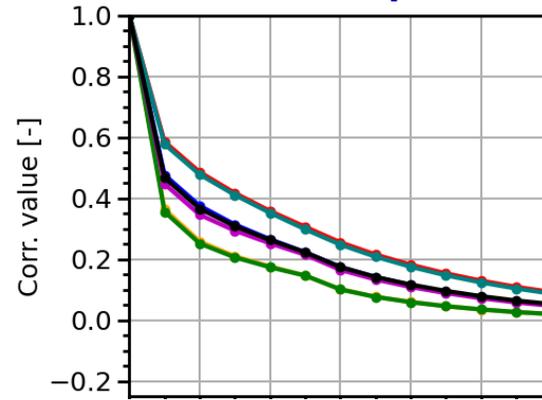
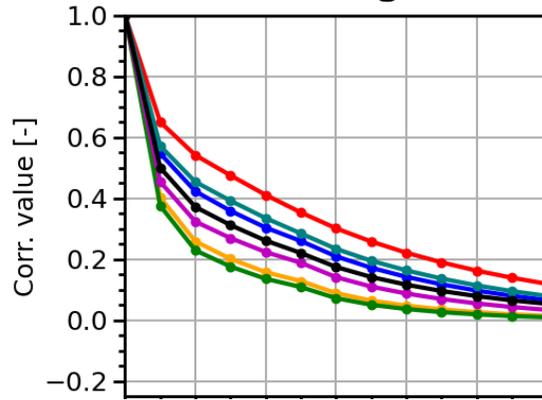
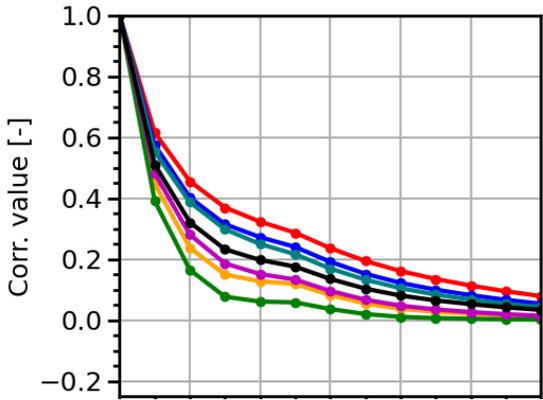


2020 Braz

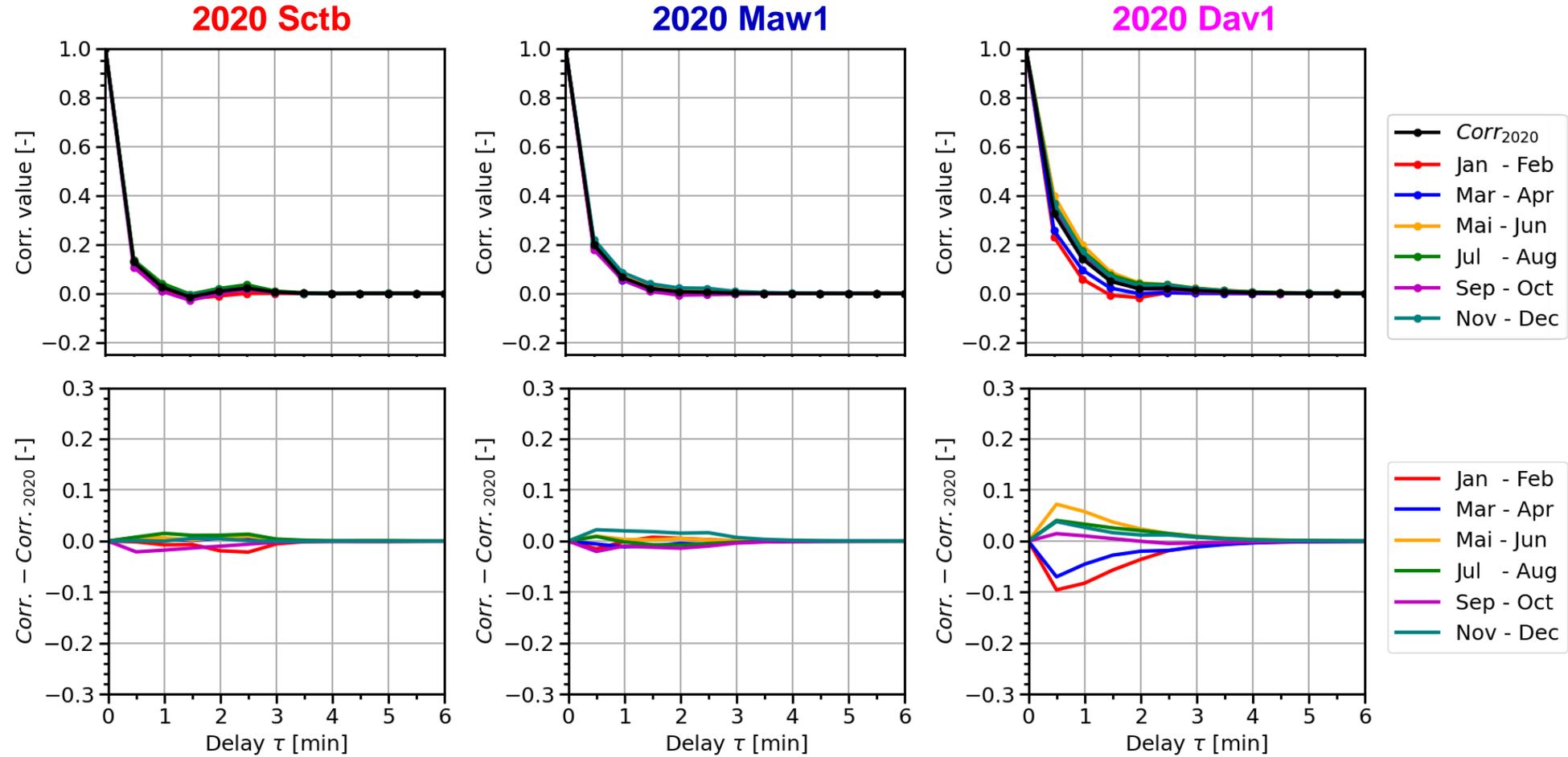
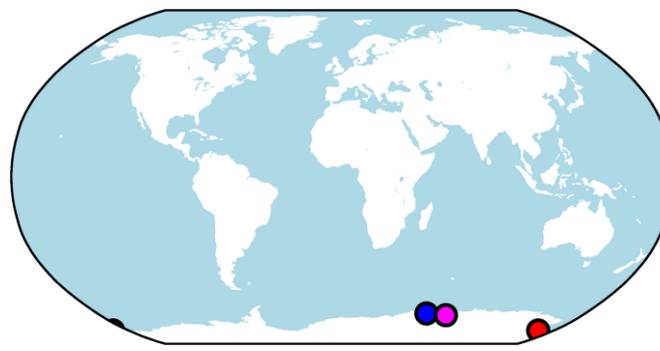
2020 Mgbh

2020 Ufpr

2020 Savo



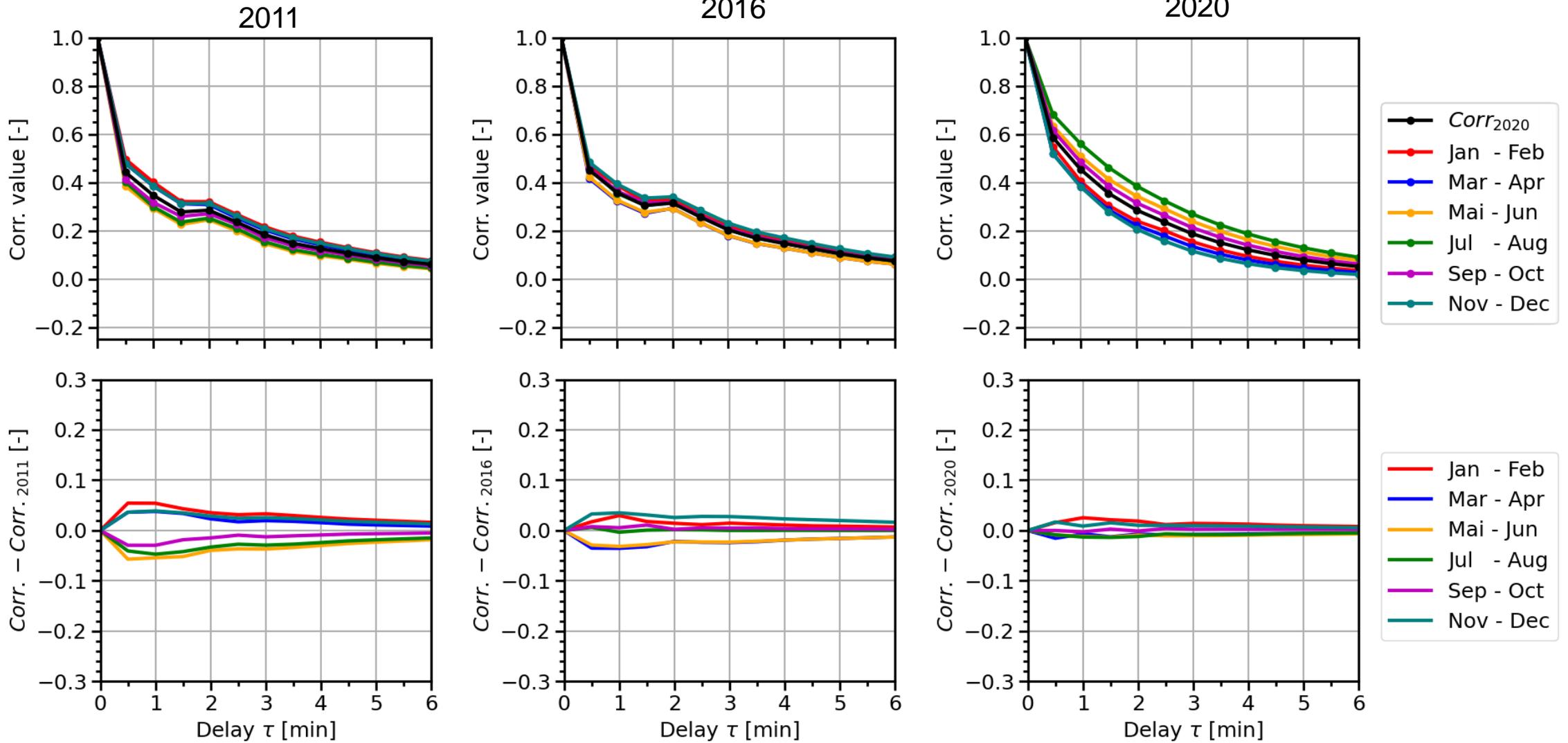
Estimated L1 Temporal correlations Far South 2020



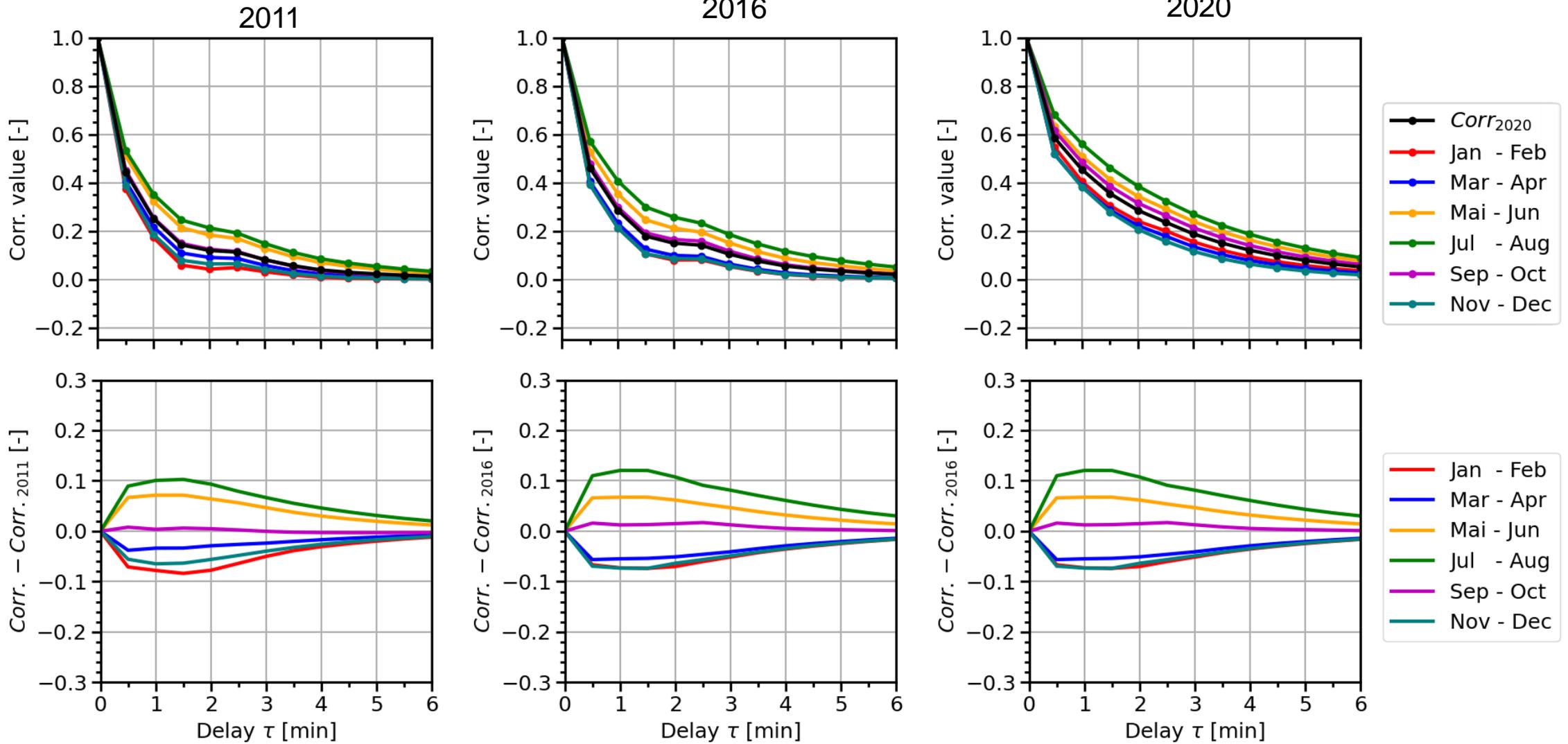
Estimated L1 temporal correlation differences 2011, 2016, 2020

Selected stations

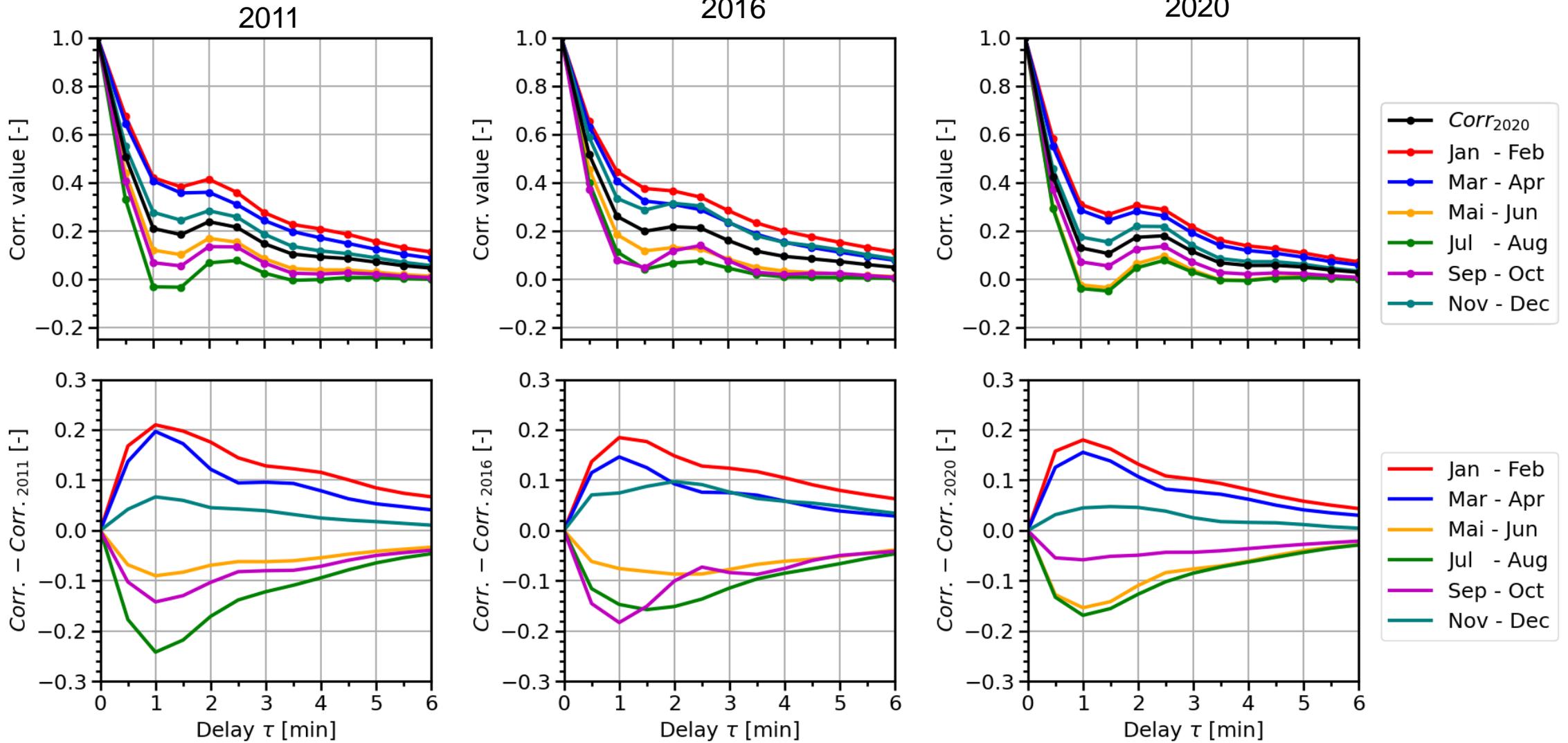
Estimated L1 temporal correlations Reyk



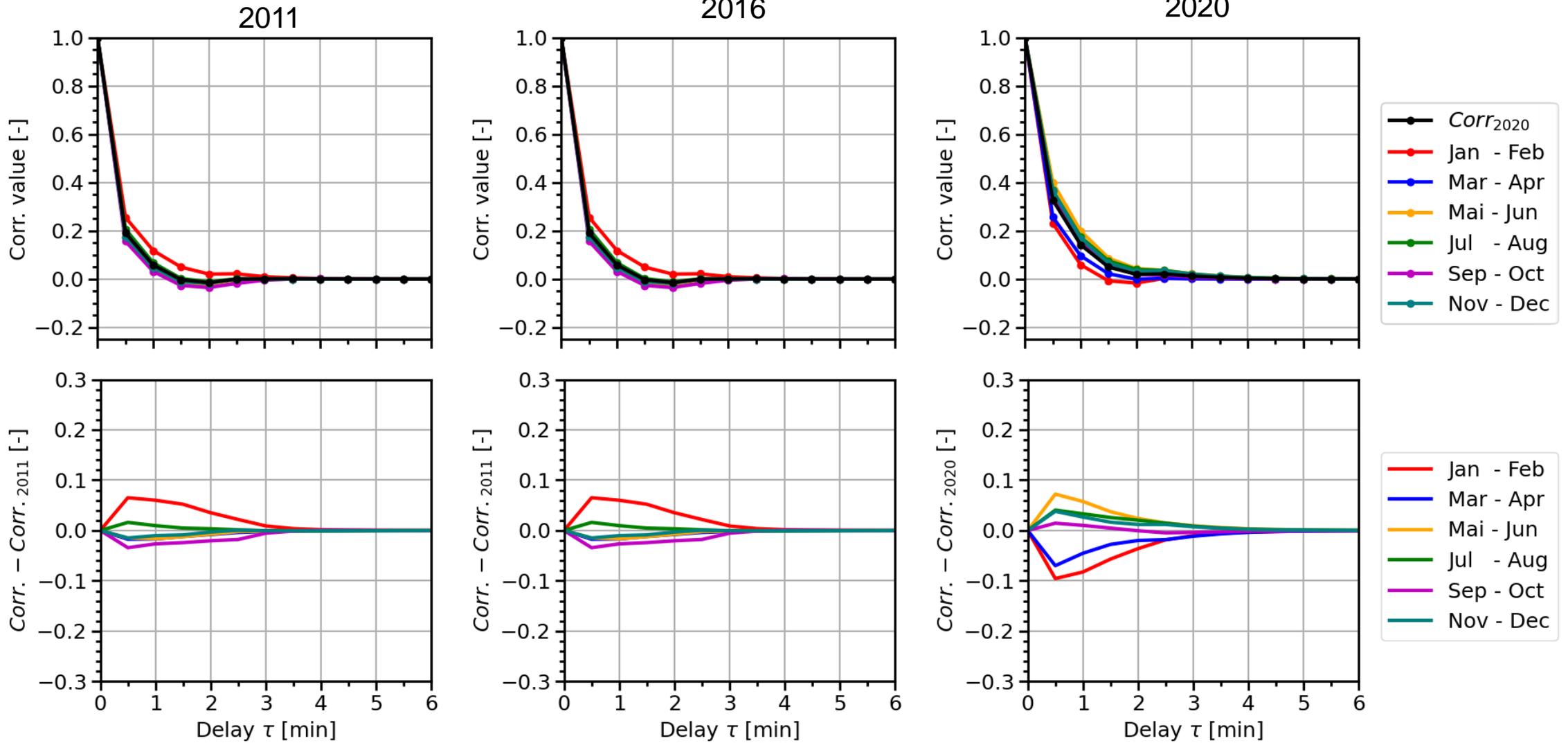
Estimated L1 temporal correlations Graz



Estimated L1 temporal correlations Wind



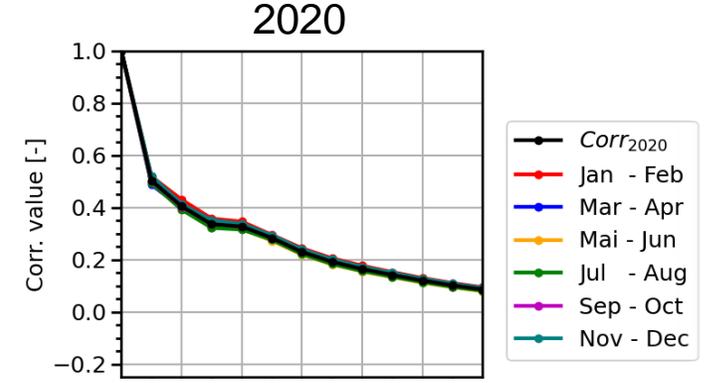
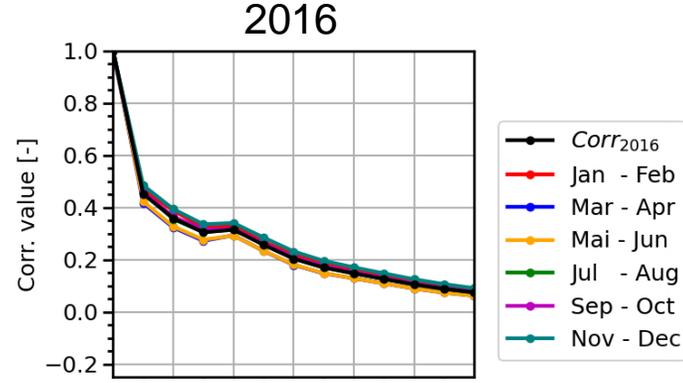
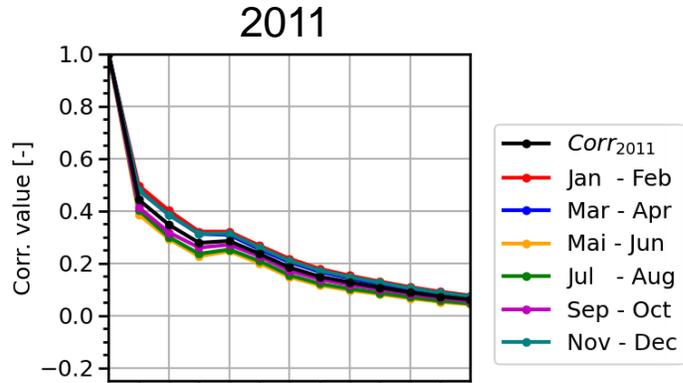
Estimated L1 temporal correlations Dav1



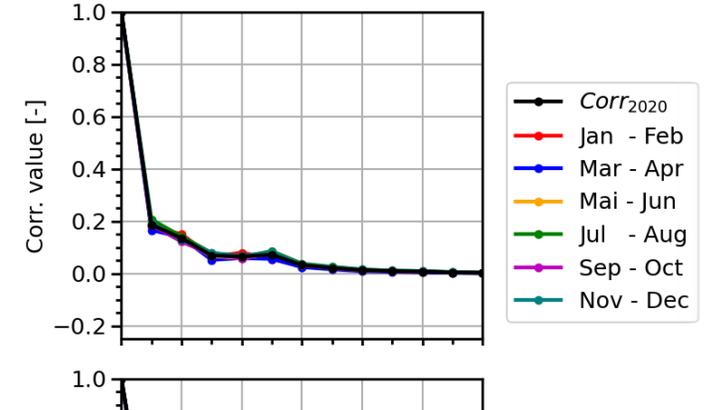
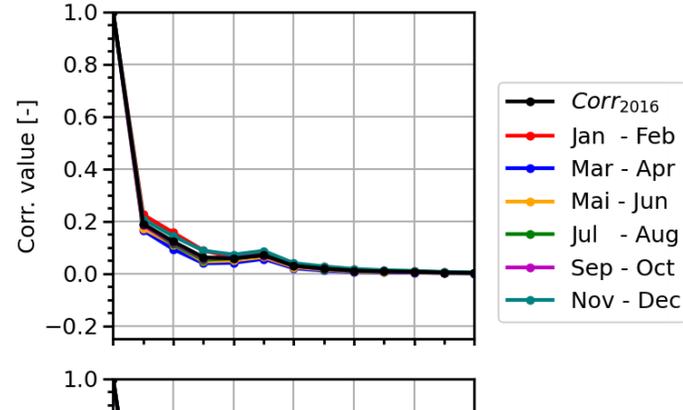
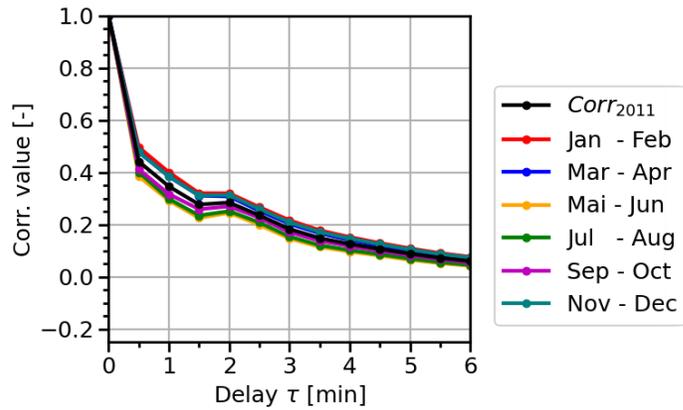
Comparison of temporal correlations for different centre frequencies 2011, 2016, 2020 Selected stations

Comparison of phase observations Reyk

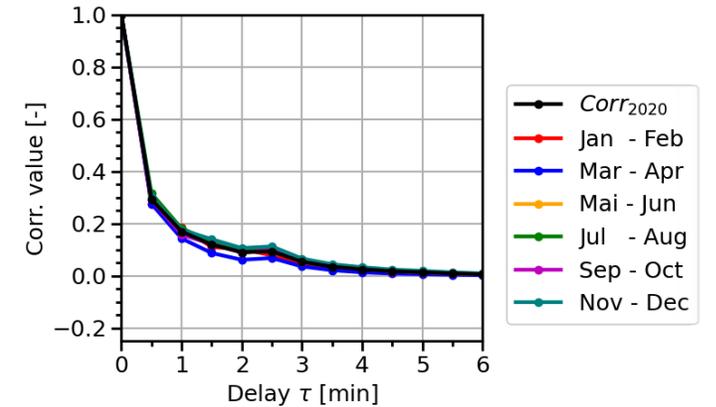
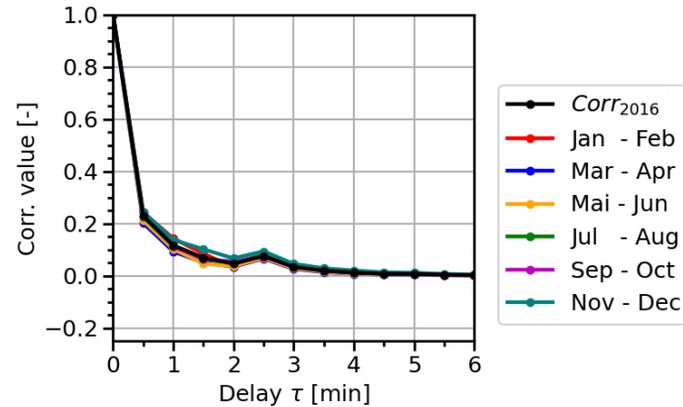
L1



L2

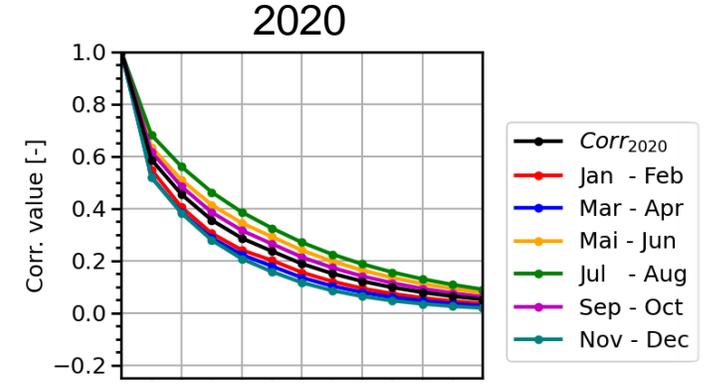
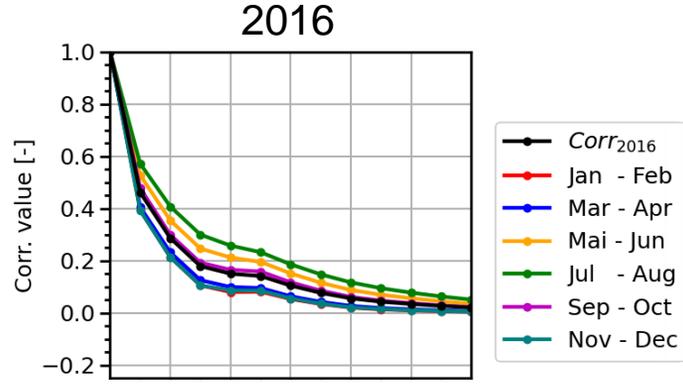
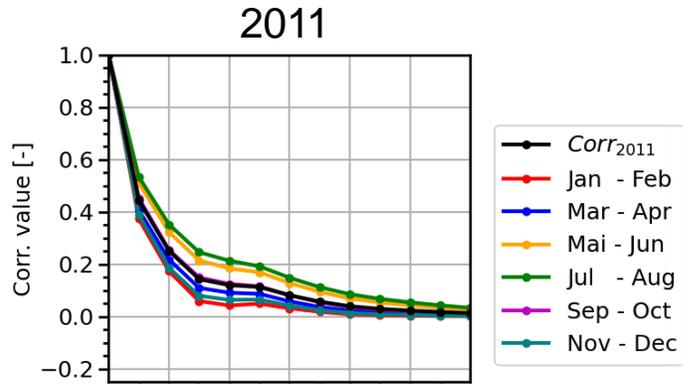


L5

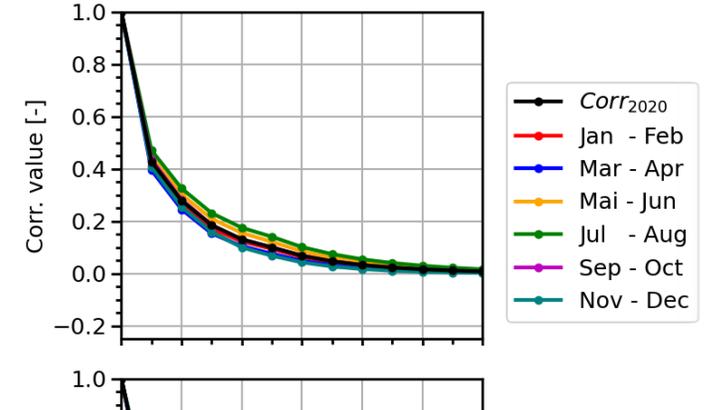
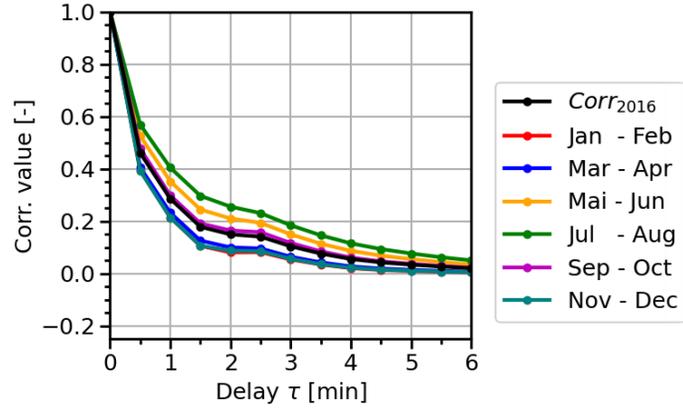
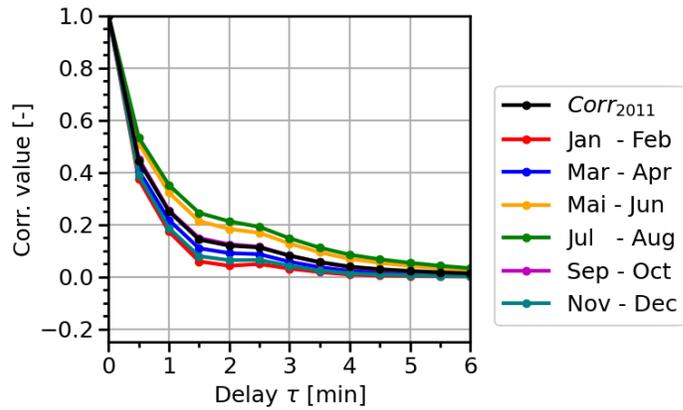


Comparison of phase observations Graz

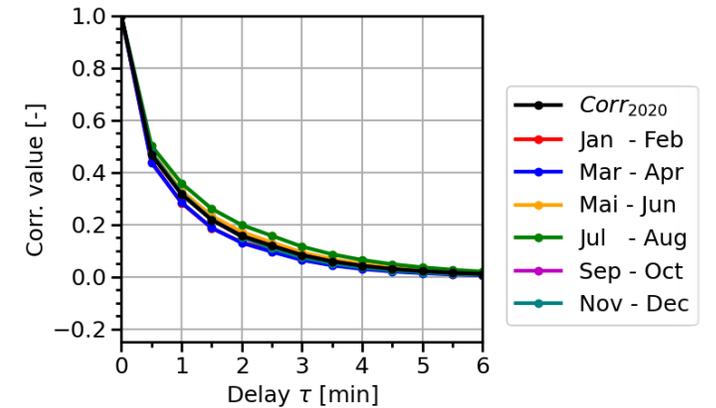
L1



L2

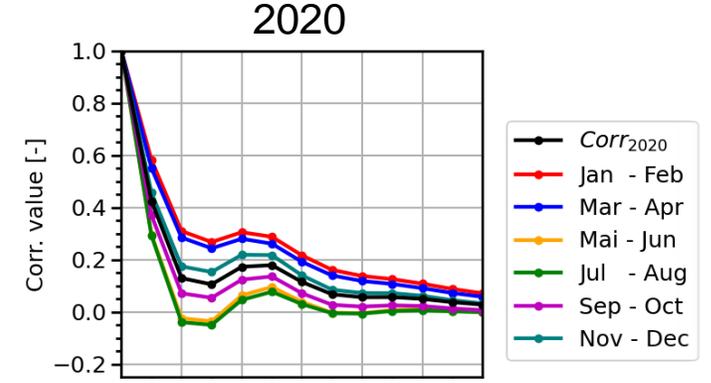
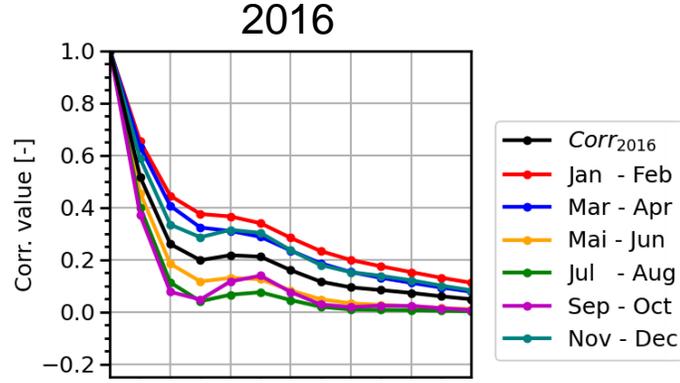
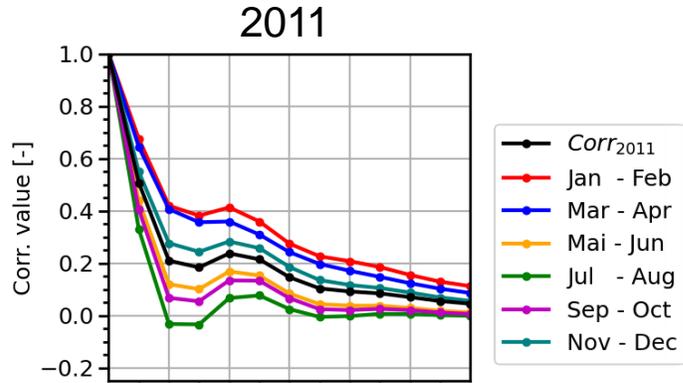


L5

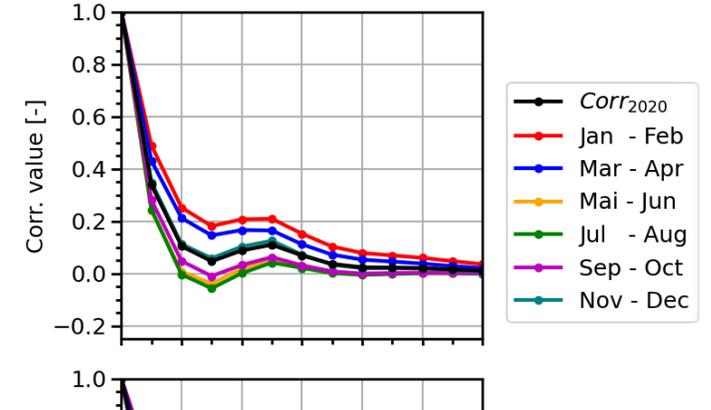
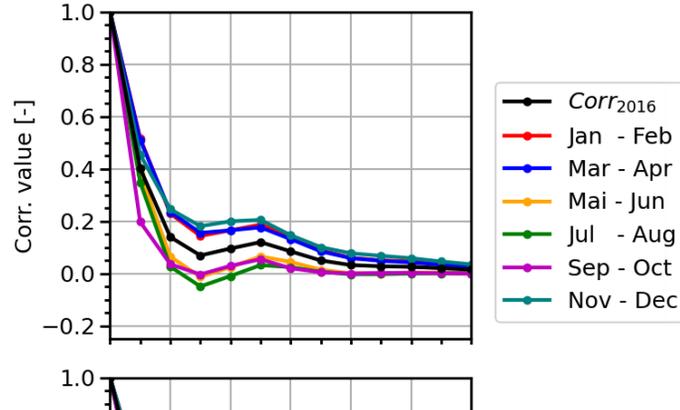
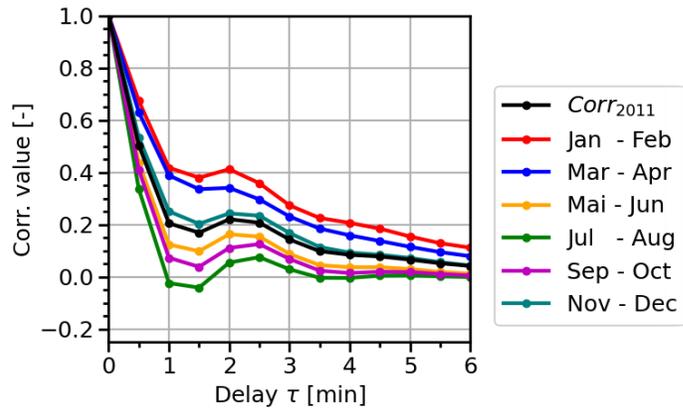


Comparison of phase observations Wind

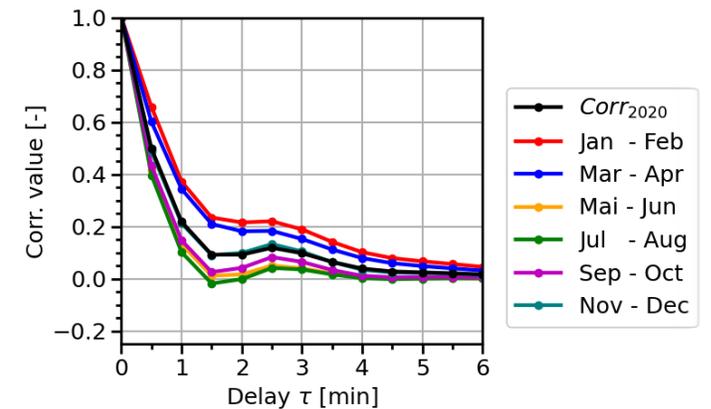
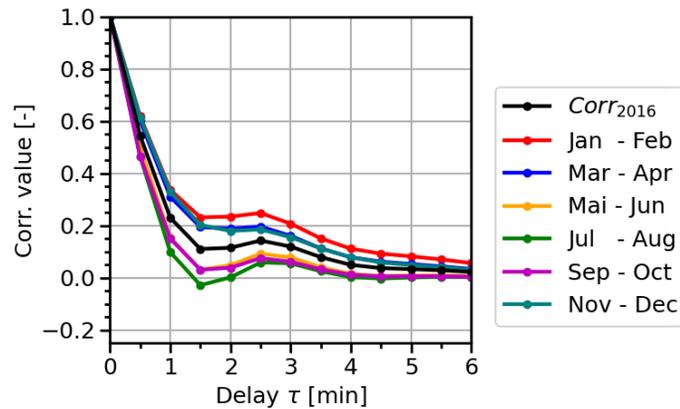
L1



L2



L5



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