Assimilation of atmospheric infrasound data to constrain tropospheric and stratospheric winds

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Summary

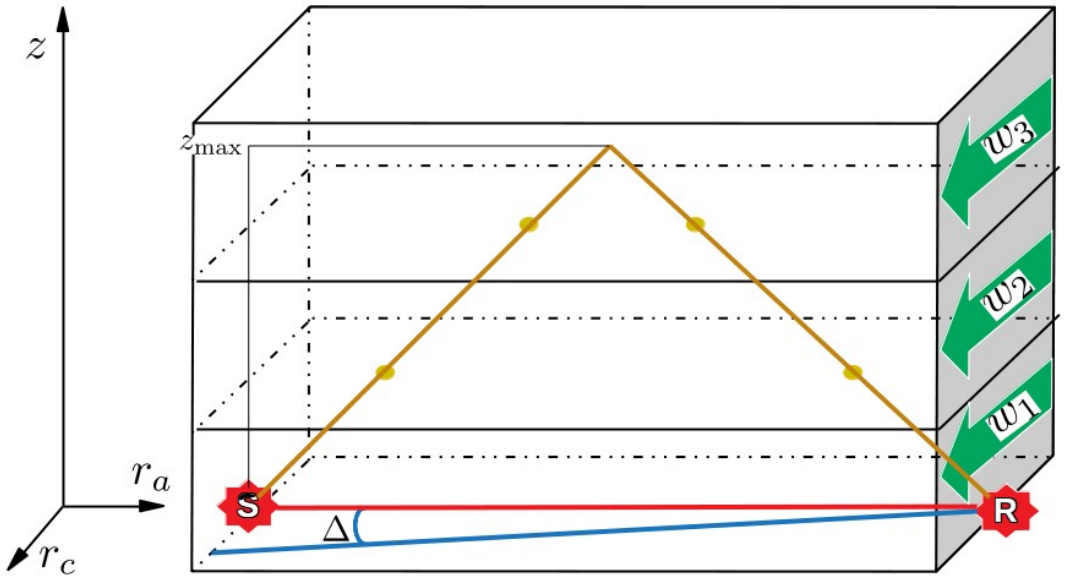
- Infrasound waves are emitted at the surface by explosions. They have a vertical and a horizontal component. Vertically, they travel up to a certain height, were they are partially reflected back to the surface. They are detected there by a receptor.

- The horizontal wind component perpendicular to the trajectory alters (bends) the wavefront. When received, they infrasound signals have a shift angle with respect to the real source.

- Using this angle to infer the wind through the trajectory is an inverse problem. We use data assimilation (DA), in particular an Ensemble Kalman Filter, to get posterior estimates of the cross wind. Our prior information comes from ERA 5 ensemble reanalysis.

The “effective” wind

$$\Delta\theta = \arctan\left(\frac{w_e}{\nu}\right) + \eta$$



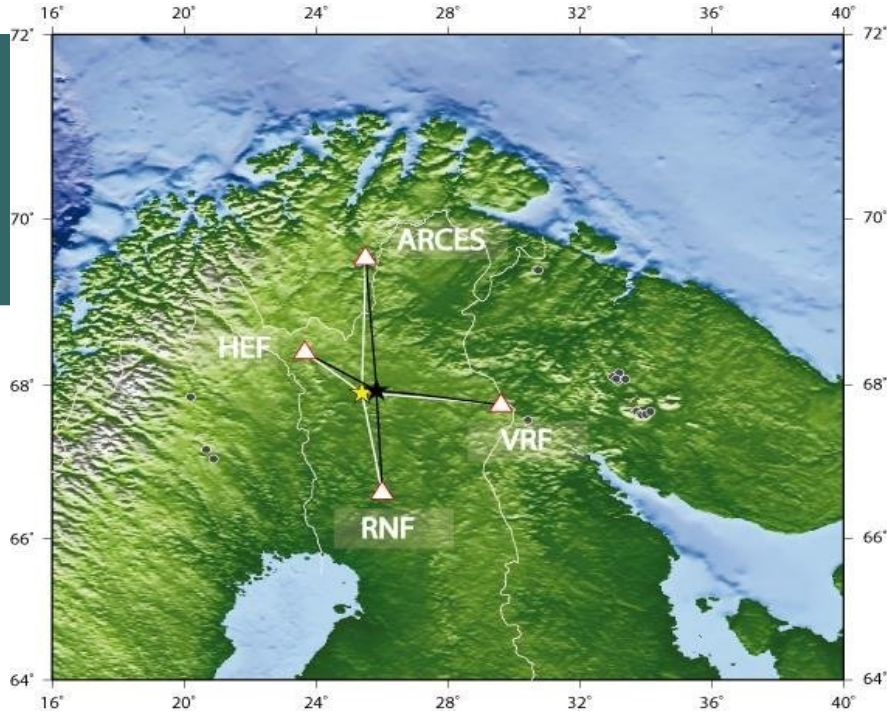
$$w_e = \int_0^{z_{\max}} \alpha(z) w_c(z) z,$$

$$\mathbf{w} = \begin{bmatrix} w_1 & w_2 & \cdots & w_{N_z} \end{bmatrix}^{\mathbf{T}}$$

$$w_e = \boldsymbol{\alpha}^{\mathbf{T}}\mathbf{w} = \sum_{j=1}^{N_z} \alpha_j w_j,$$

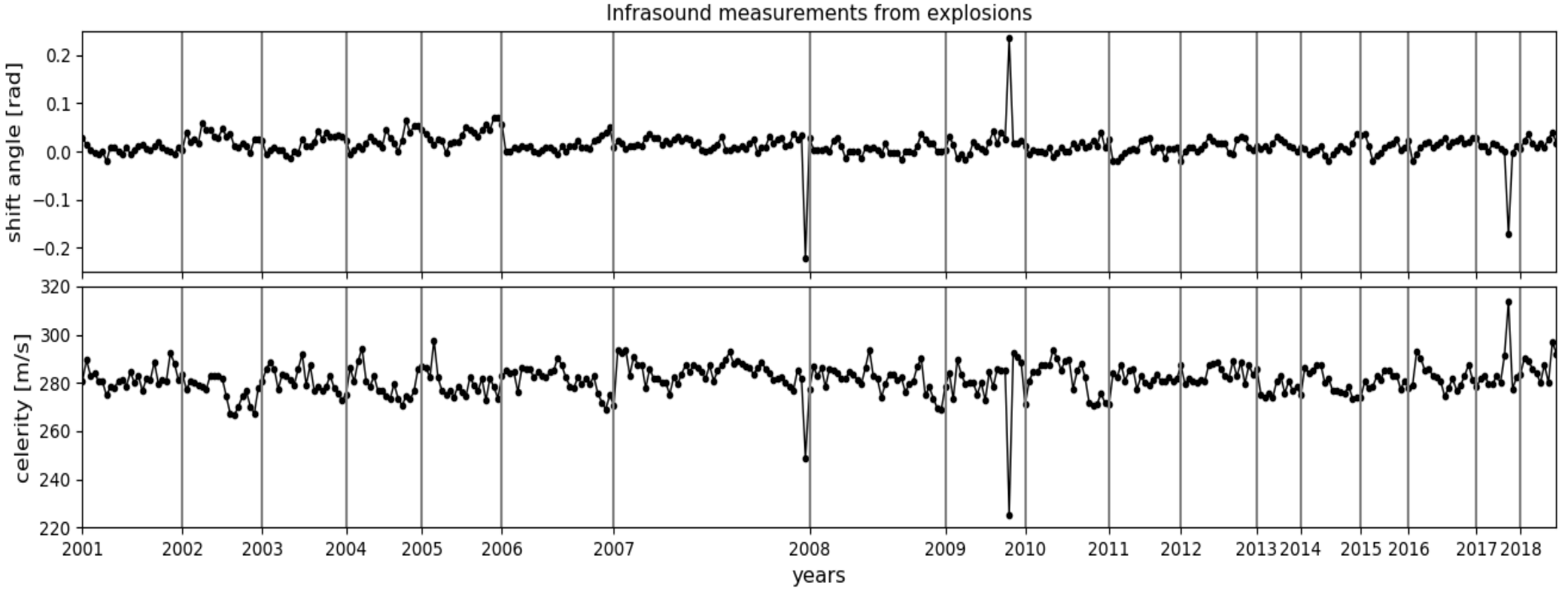
Schematic showing the infrasound trajectory. For this study, we focus on the along-track-averaged horizontal cross-wind in different vertical slabs.

Observations



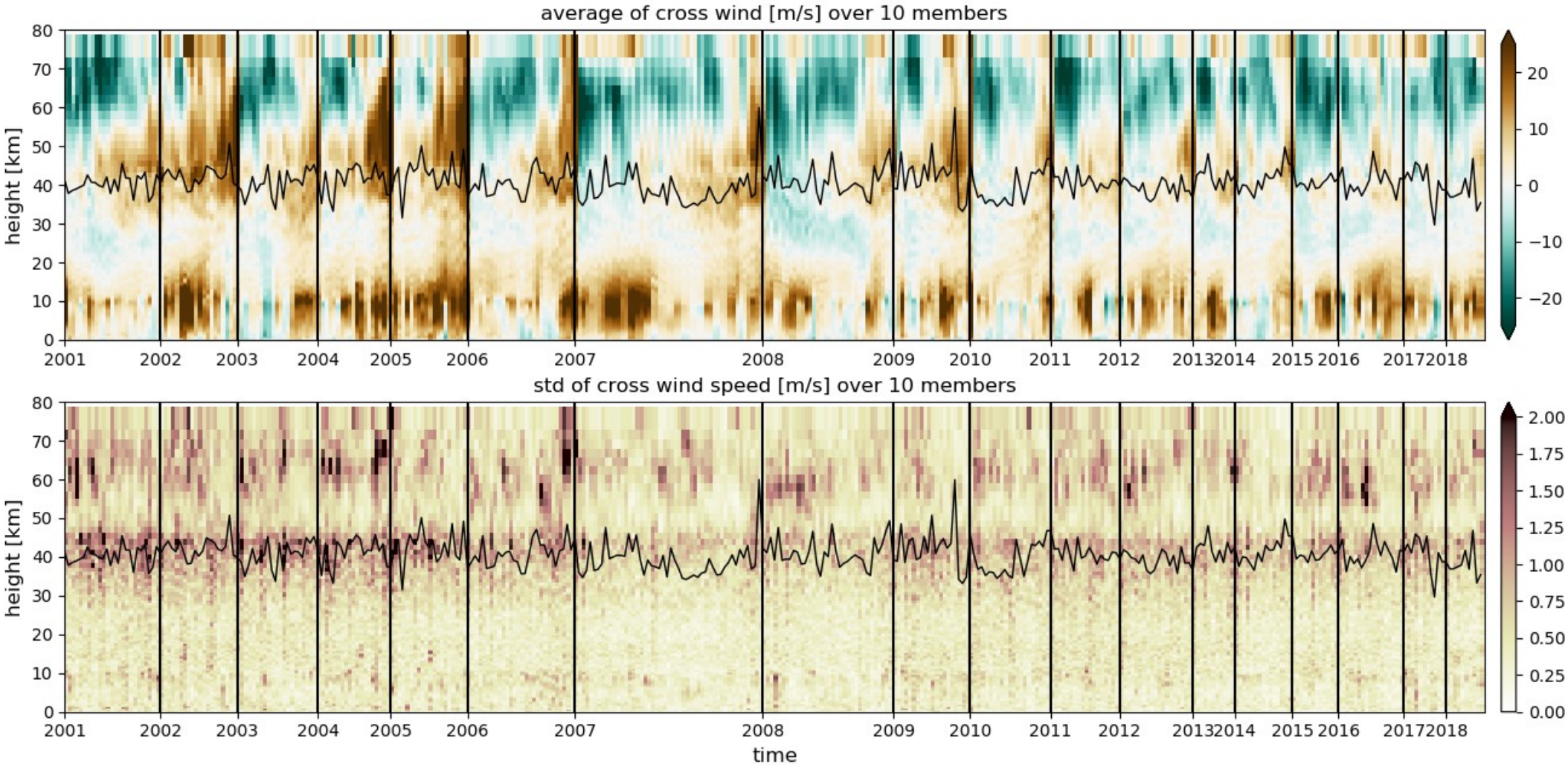
For the real case we have 18 years of explosions.

We know the perfect location of the source and receivers, and the shift angle is measured. For a natural source (e.g. swell) this would be more difficult to know,



Background values

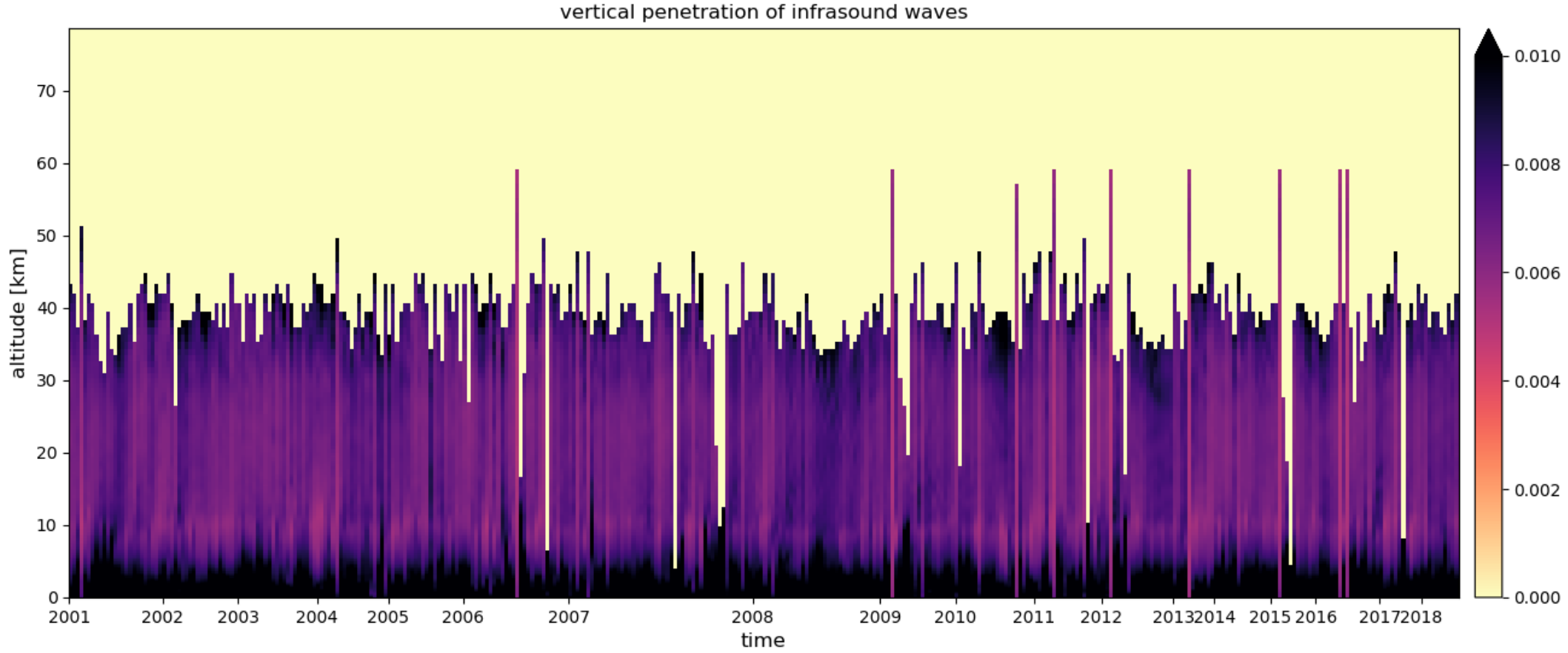
ERA-5 winds. 10 ensemble members, 127 vertical levels.



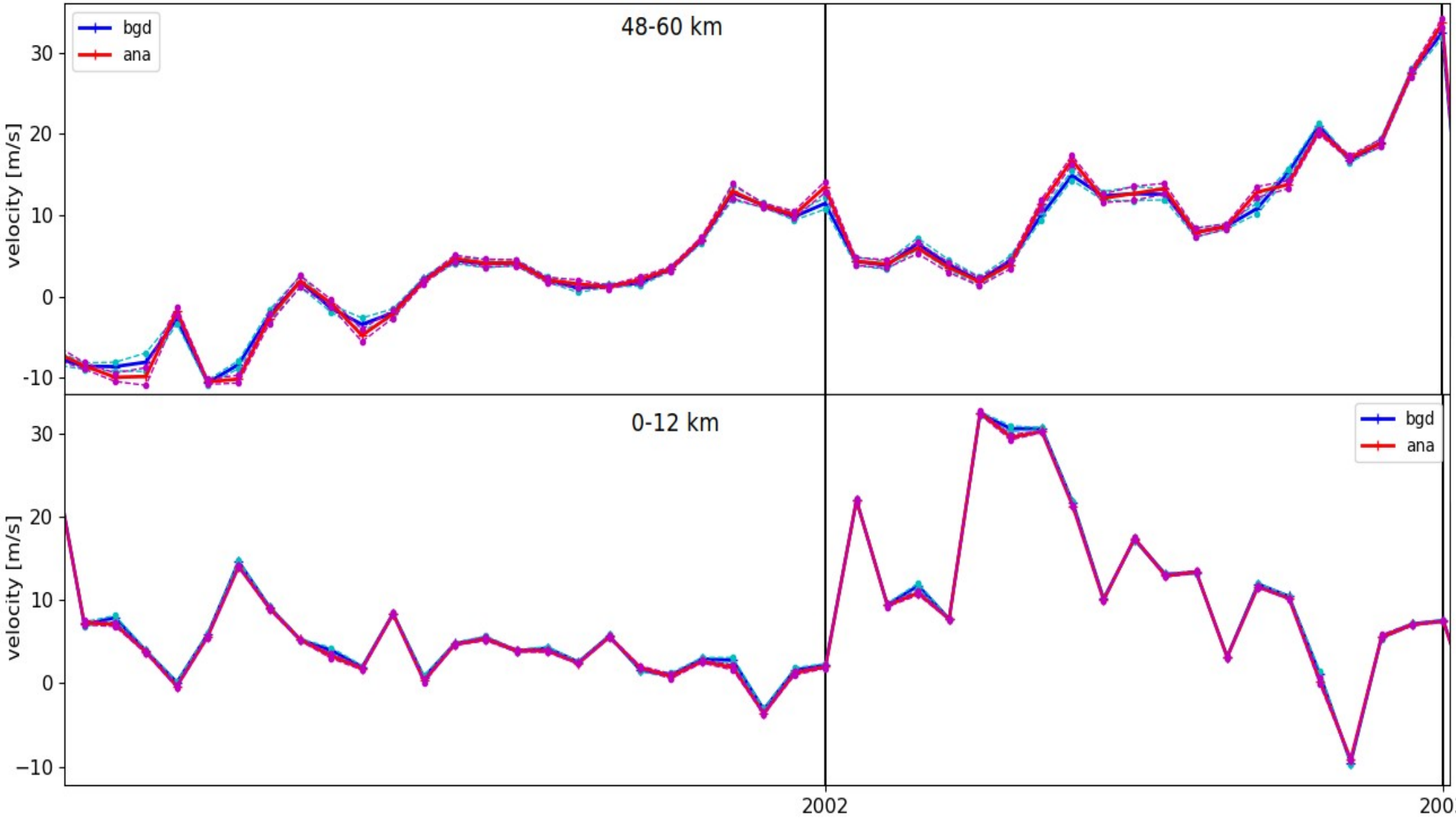
We reduce the problem to 6 ‘distinctive’ vertical layers.

Vertical penetration and sensitivity

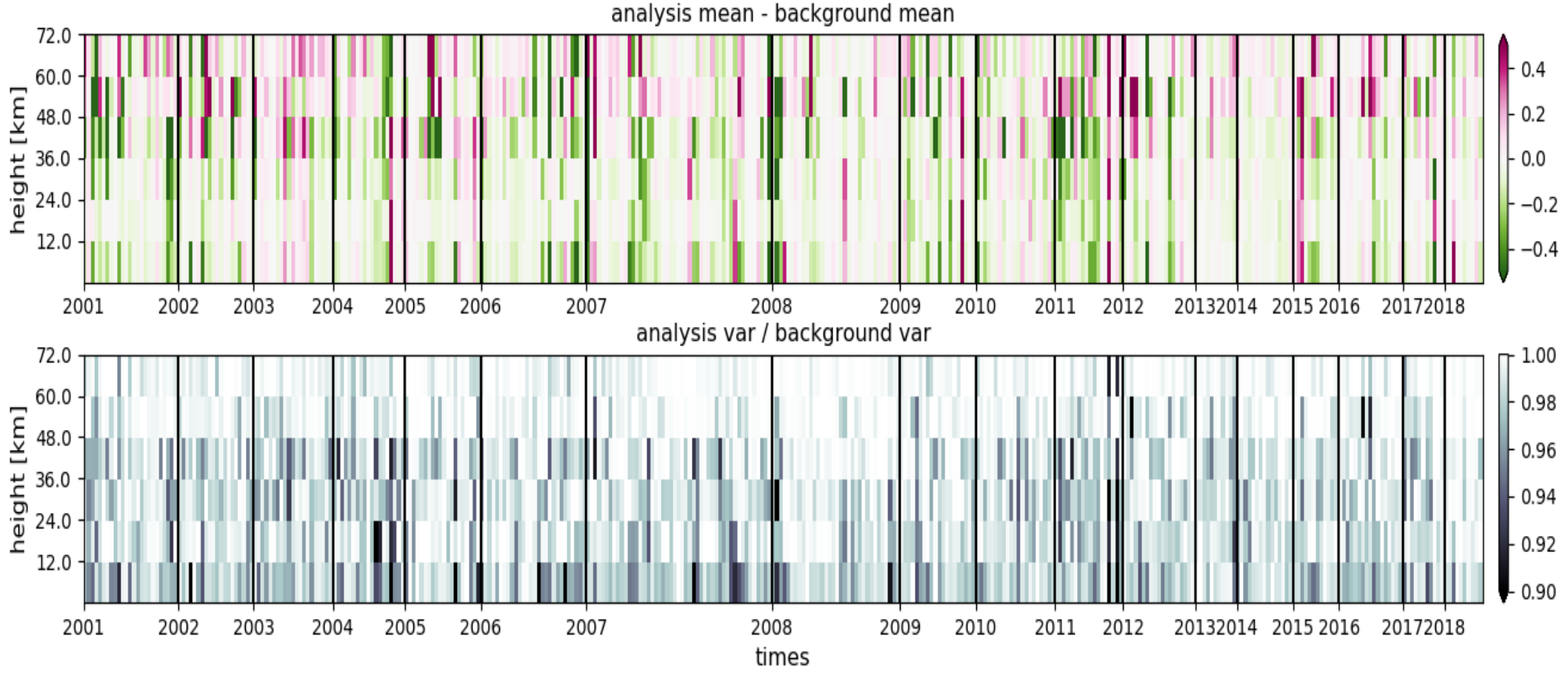
A wave-tracing model allows us to estimate the vertical penetration of the waves coming from each explosion, as well as the fraction of time they spend in each height.



Results: analysis in 2 layers

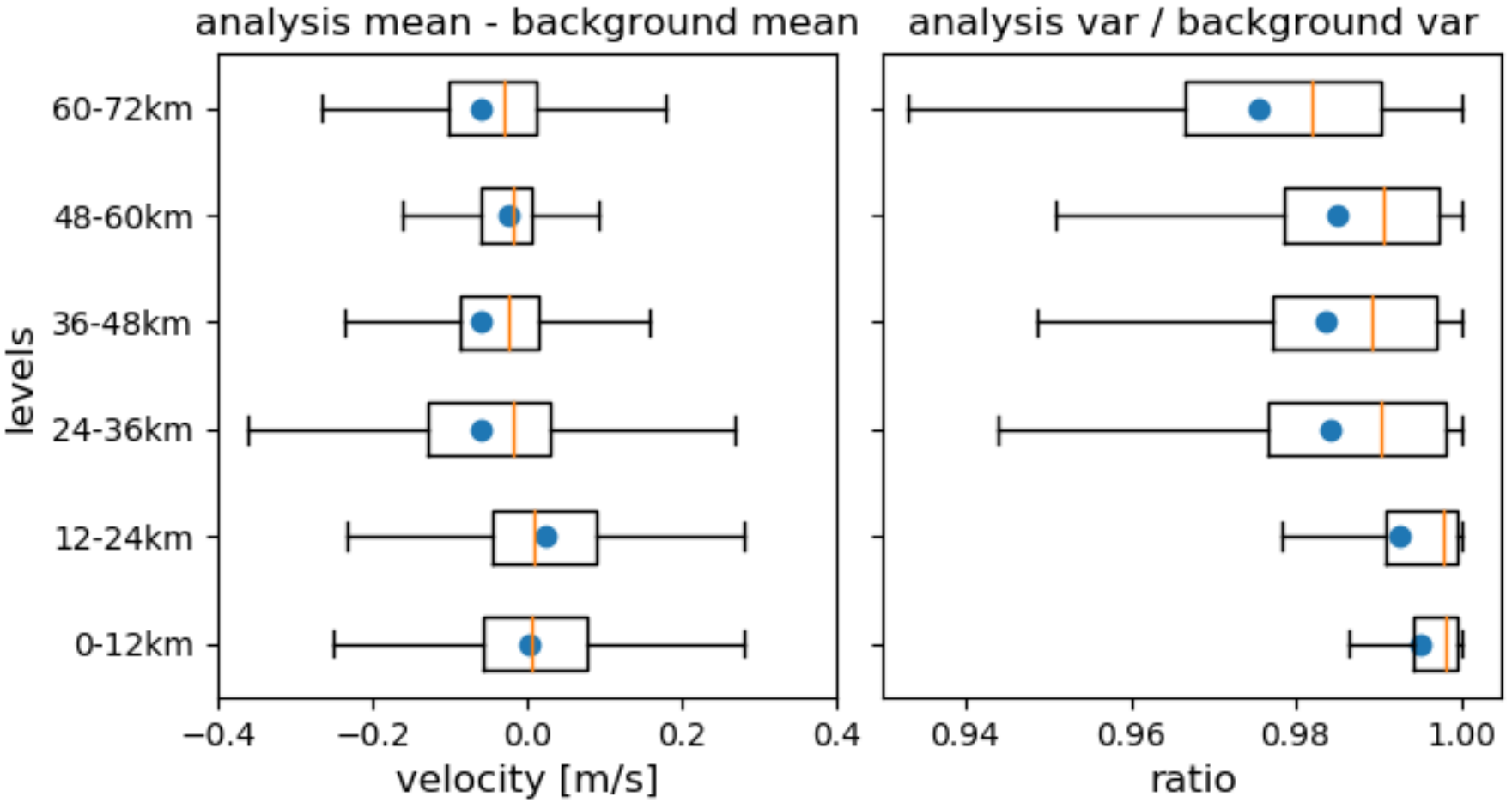


Diagnostics

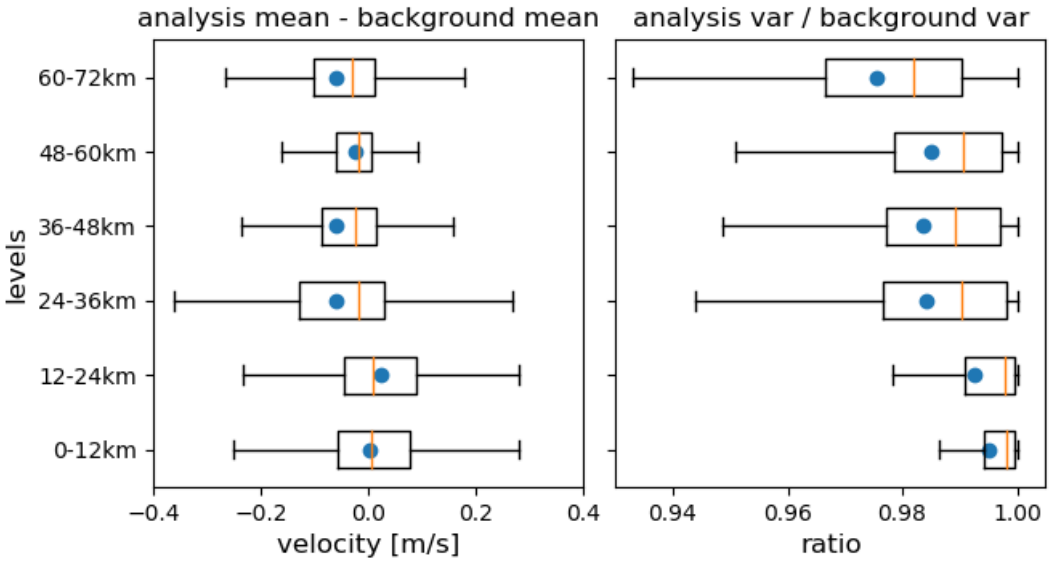


Top: analysis-background difference for the mean.
Bottom: analysis/bacground ratio for the standard deviation.

Summary: impacts



Comments



- Assimilating infra-sound waves to constrain winds is possible.

- We did not verify the analysis. Against what? Independent observations, another reanalysis? AEOLUS.

- When experimenting with inflation the impact was larger. Is it necessary?

- Analyse diagnostic quantities.

- The impacts were small since we departed from reanalysis data. In practice, departing from a forecast will lead to larger impacts.