Atmospheric monitoring with a new GNSS network in the south-central Andes

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Motivation

The Central Andes are characterized by steep climatic and environmental gradients with large spatial and temporal variations of associated hydrometeorological parameters. There are two main atmospheric processes that influence climate conditions in our study area in the south-central Andes: the South American Monsoon System that transports moisture via the low-level jet and the orographic barrier of the Eastern Cordillera that forces orographic rainfall at the windward facing slopes.

The main objectives of this study are:

1) Monitoring of Integrated Water Vapour (IWV) using an extended GNSS network.
2) Examination of IWV behaviour across the climatic gradient.
3) Tracking and analysis of water vapour propagation.
4) Correlation between wet gradient and surface wind vectors.

IWV Propagation

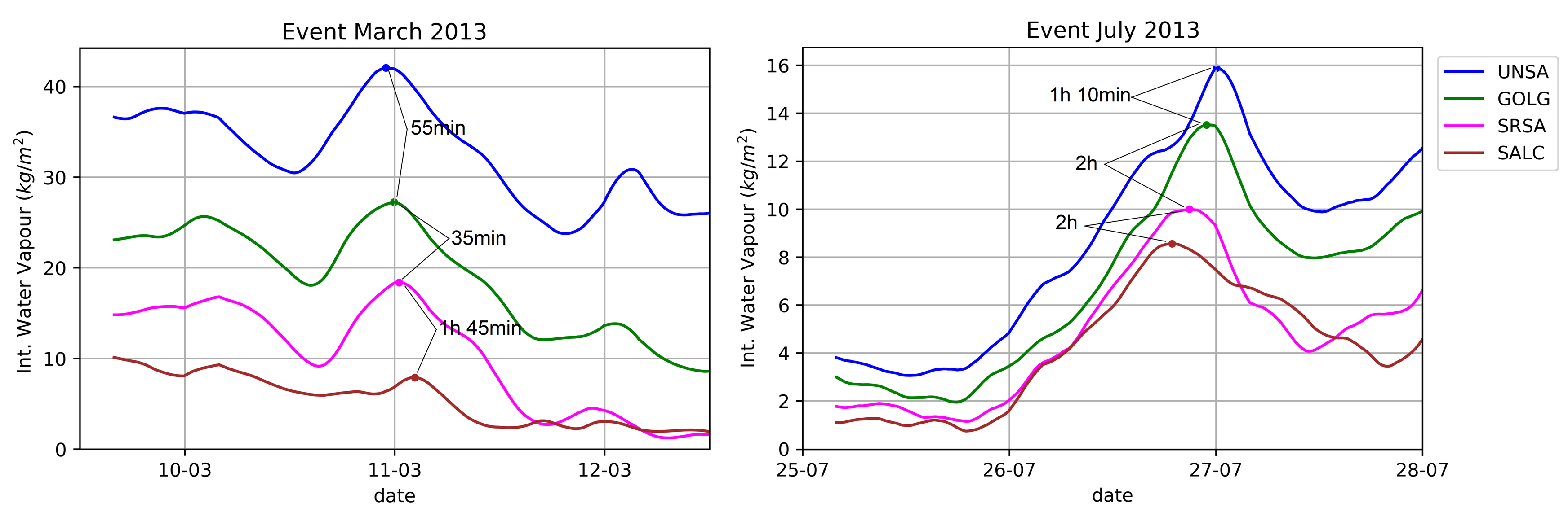


Figure 1: GNSS-derived IWV estimates from four stations lying across East-West direction and along the topographic gradient during two events in 2013. The location of the stations is shown in Figure 3 with the two corresponding colors.

On the left side of Figure 1 it is shown that there is a clear propagation direction from East to the West, which coincides with the seasonal trend of the wind directions during Austral summer. On the right side, the moisture propagation is from West to East, because of a reversed pressure gradient during the Austral winter..

Data Filtering

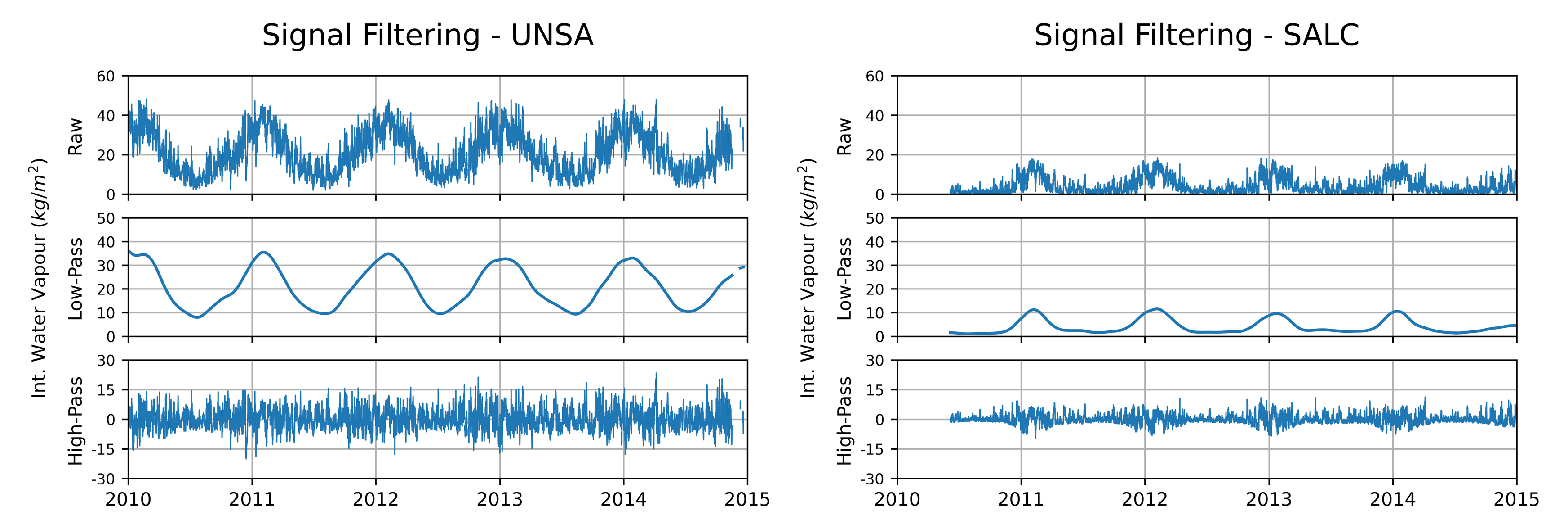


Figure 2: IWV time series decomposition for the stations UNSA and SALC, according to their spectral patterns.

The IWV time series were separated into signals corresponding to low and high frequencies, using a 2nd order Butterworth filter. The prior show signals that have periods longer than 100 days and they are related to the seasonal oscillation. The latter are related to shorter periods and they can be associated with synoptic weather events. The behaviour of each time series is highly dependent on the location of the corresponding station. At UNSA station (left), which is located on the foothills of the Andes, the signal oscillates sinusoidally and the amplitude of its high-frequency responses (residuals) is slightly smaller during winter period. At SALC station (right), which is located in the Andean plateau at a high altitude, the signal flattens during winter and rises during summer period. Additionally, the amplitude of its residuals is significantly larger during summer.

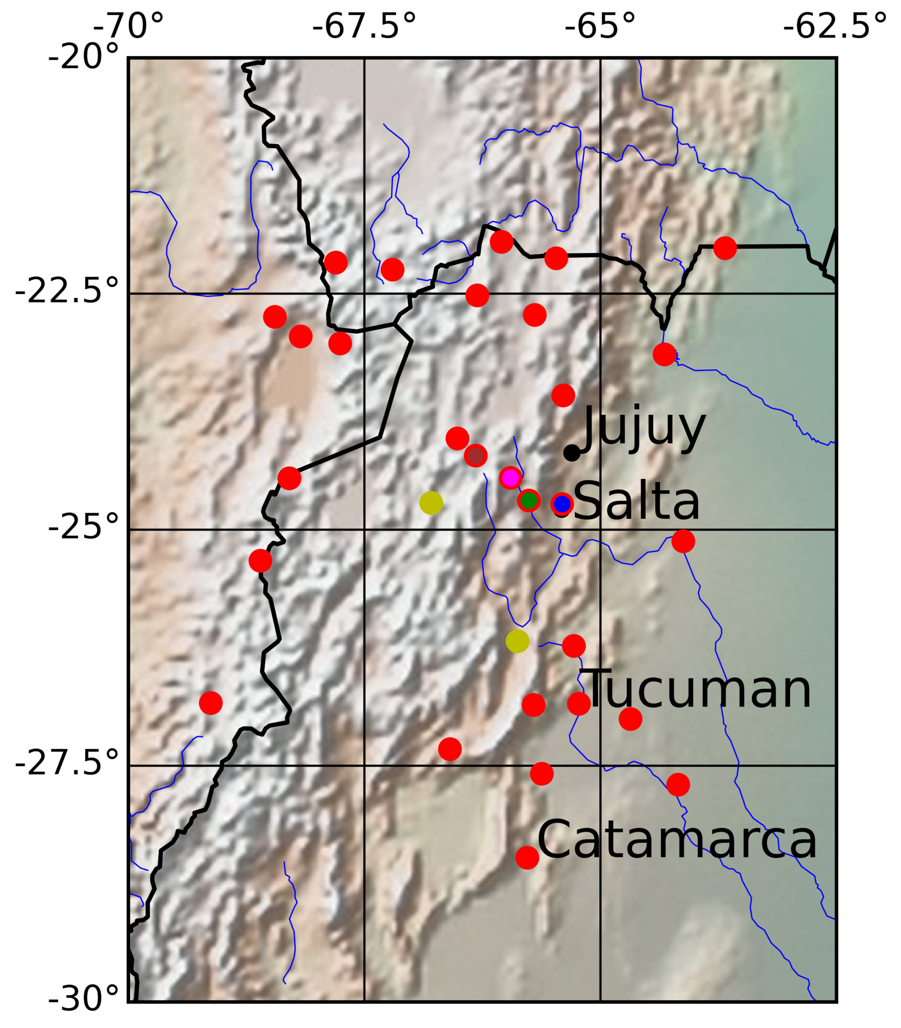
Conclusions

- GNSS can track moisture propagation with better temporal resolution than reanalysis data.
- IWV follows seasonal patterns and their shape depends on the topography of the station.
- Wet gradients are affected by the topography in the vicinity of the station.
- Wind directions can be traced by wet gradients over both long and short periods.

Aknowledgements

This work was supported by the DFG in the framework of StRATEGy project. GNSS atmospheric delays for 29 stations were retrieved from the Nevada Geodetic Laboratory. Meteorological data were retrieved from ECMWF's ERA5 and ERA5-Land for the period between 2010 and 2020.

Data Calculation



All data was calculated with the following strategy:

- GNSS data were used for the calculation of zenith delays and gradients
- ECMWF's ERA5 reanalysis data inserted in ray-tracing algorithm for the calculation of zenith dry delays and their gradient components
- The wet delays were calculated as follows:

$$D_{Wet} = D_{Total\text{-}GNSS} - D_{Dry\text{-}ERA5}$$

Figure 3: GNSS ground stations installed in March 2019 (yellow) and ground stations from Nevada Geodetic Laboratory network (red) located in the wider area of northwestern Argentina.

Water Vapour Tracking

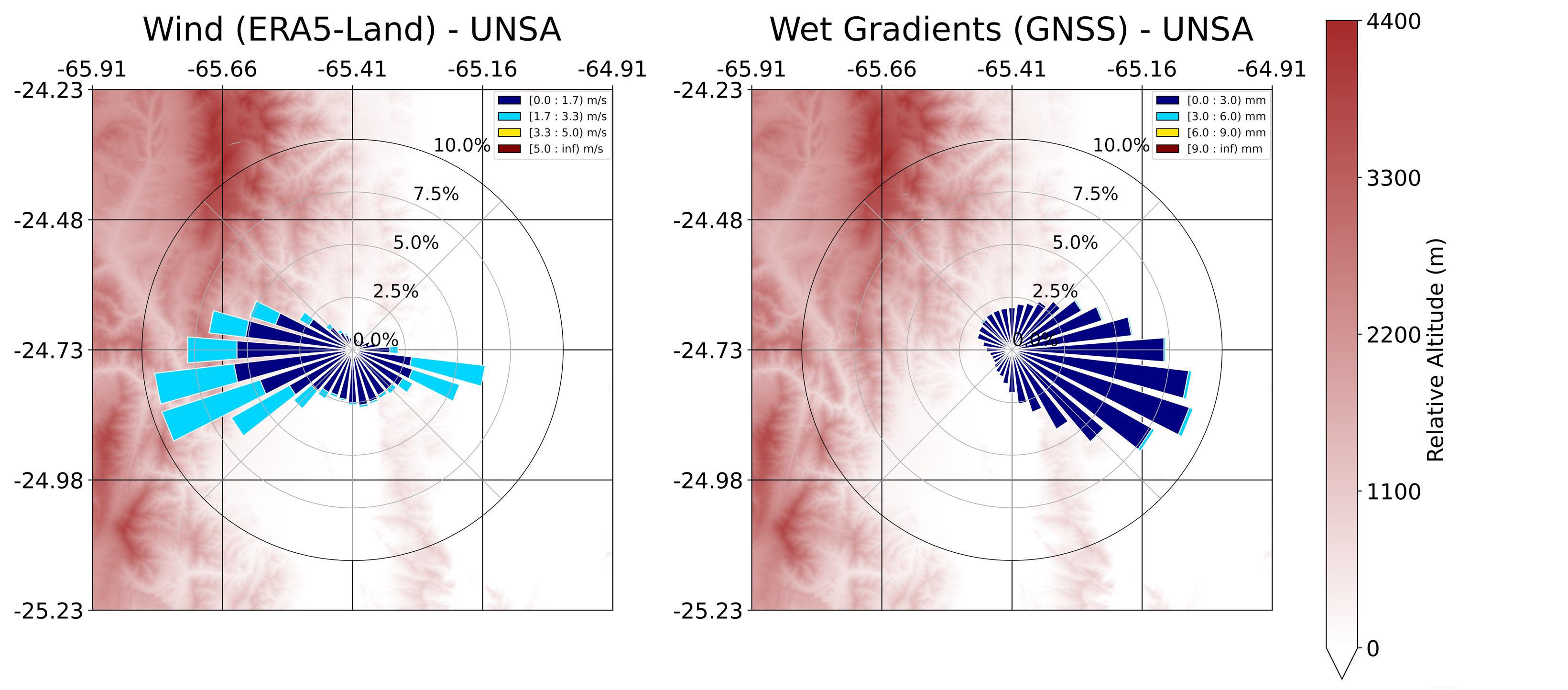


Figure 4: Wind (left) and wet gradient (right) direction distributions plotted together with the topographic shielding.

Our analysis shows a clear corrleation between the reversed wind vectors and wet gradients calculated from GNSS and ERA5 data. We show that water vapour and rain can be tracked during both winter and summer season.

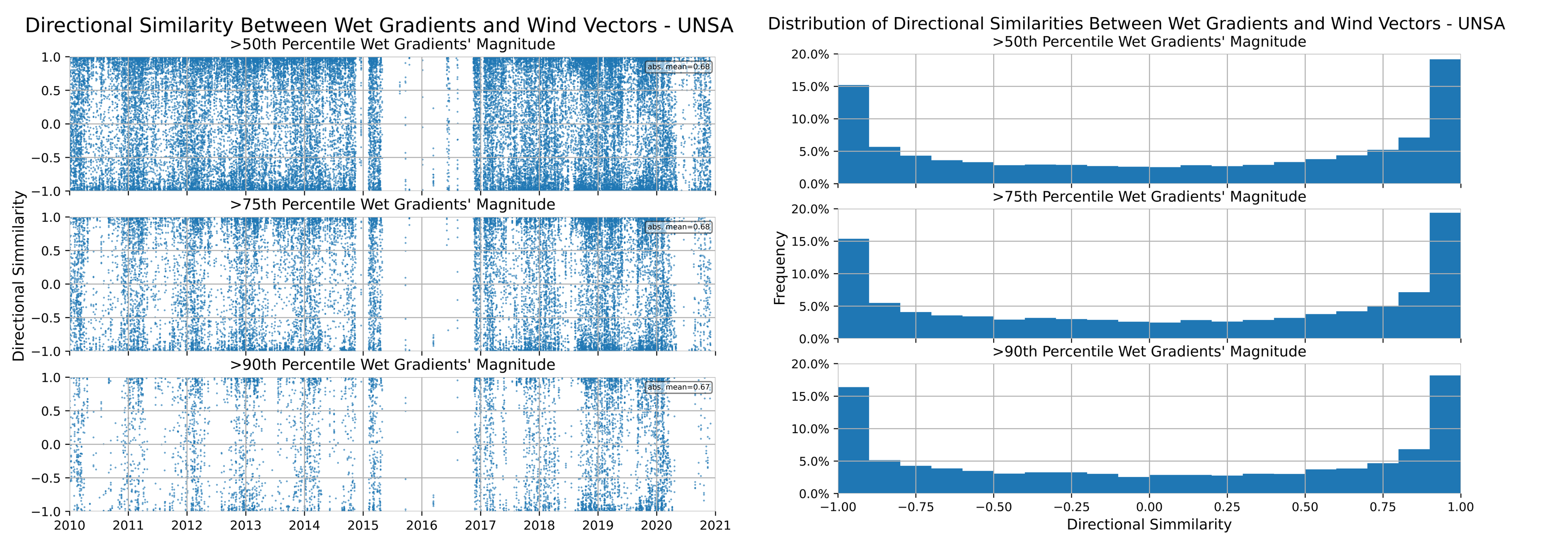


Figure 5: Single-epoch directional similarities between wet gradients and wind vectors (left) and their distribution (right).

The next step of our research was the single-epoch comparison of the wet gradient's directions and the wind vectors. In order to define a similarity measure, we calculated the cosine of the angle between both directions. The wet gradients with small magnitudes were excluded because the impact of random errors on their directions is high. Similarity values close to 1 show that the vectors are anti-parallel, while values close to -1 show that the vectors are collinear. Both graphs in Figure 5 show that there is high probability of having either very high or very low directional similatiry. In the first case we can track moisture traveling towards the GNSS station, while in the second case the masses tracked are leaving the station behind.

References

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