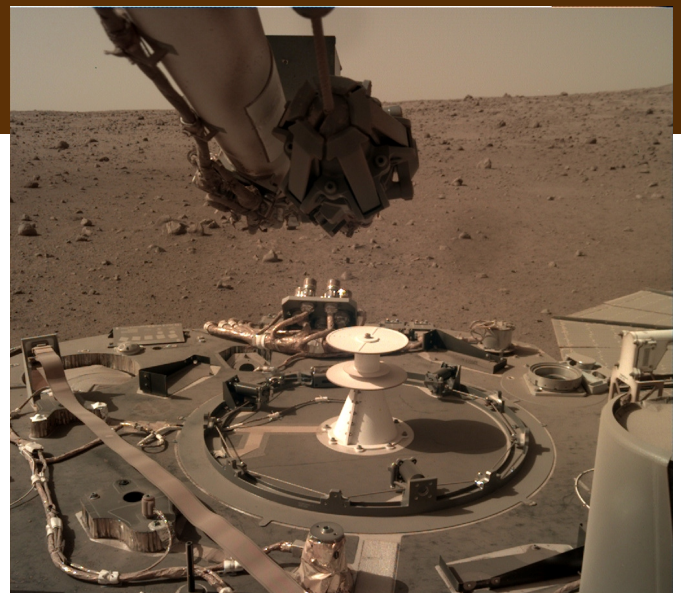
Pressure effects on SEIS instrument,

improvement of seismic records and characterization of gravity waves from ground displacements

Raphael F. Garcia, B. Kenda, T. Kawamura, A. Spiga, N. Murdoch, P. Lognonné, R. Widmer-Schnidrig, D. Banfield, T. Pike, W.B. Banerdt and the INSIGHT Science Team

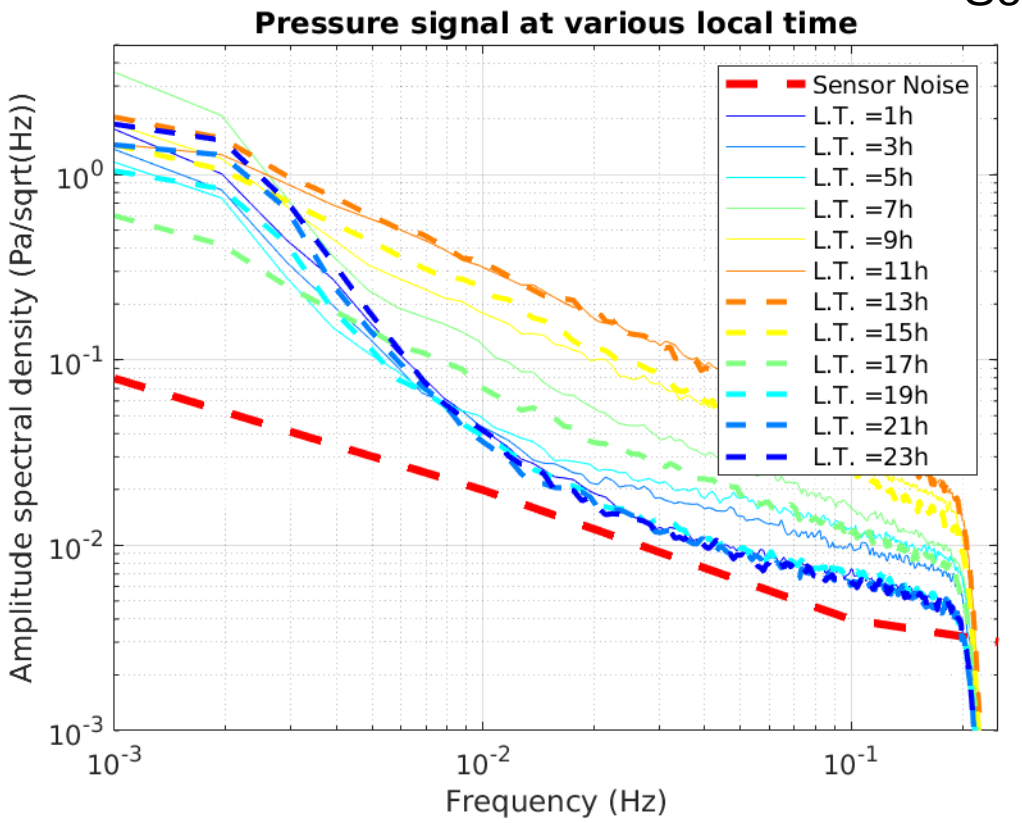
May 5, 2020

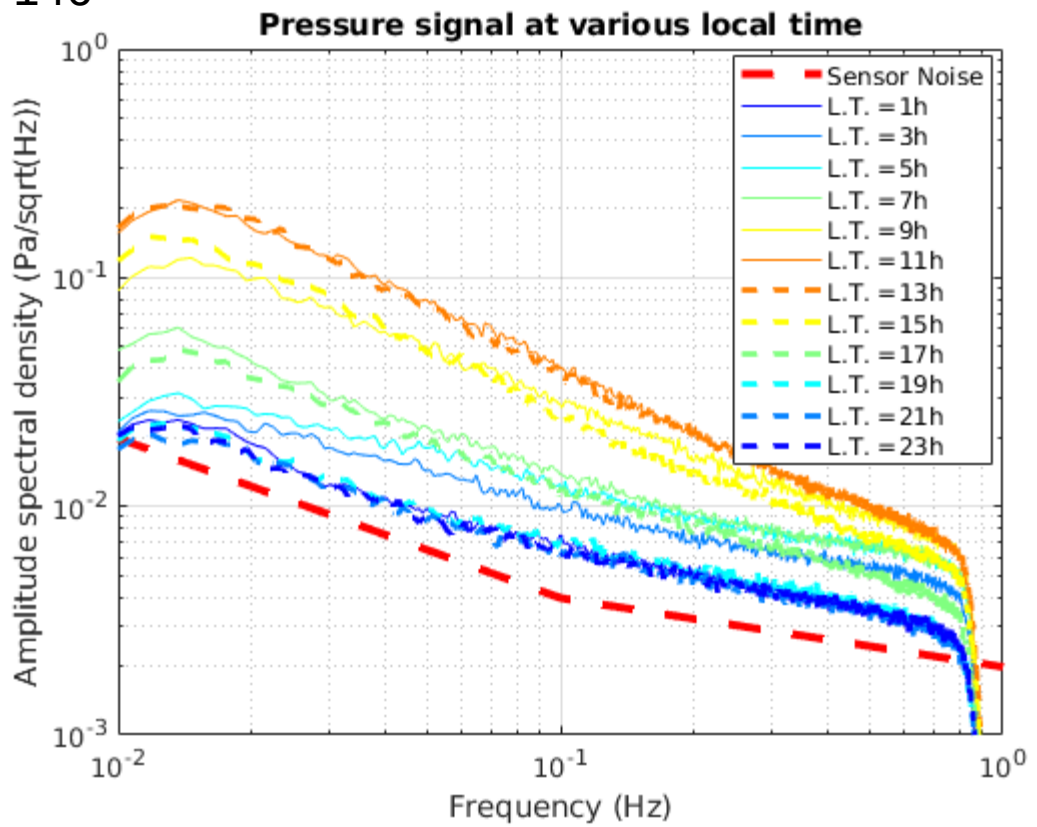
Pressure signals as a function of Local Time



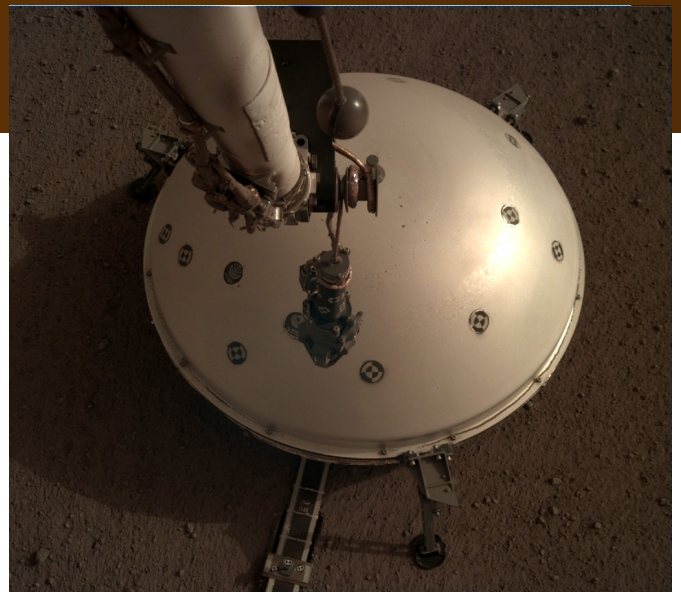
- Day time convective activity
- Night time long period gravity waves observed

Sol 123-146



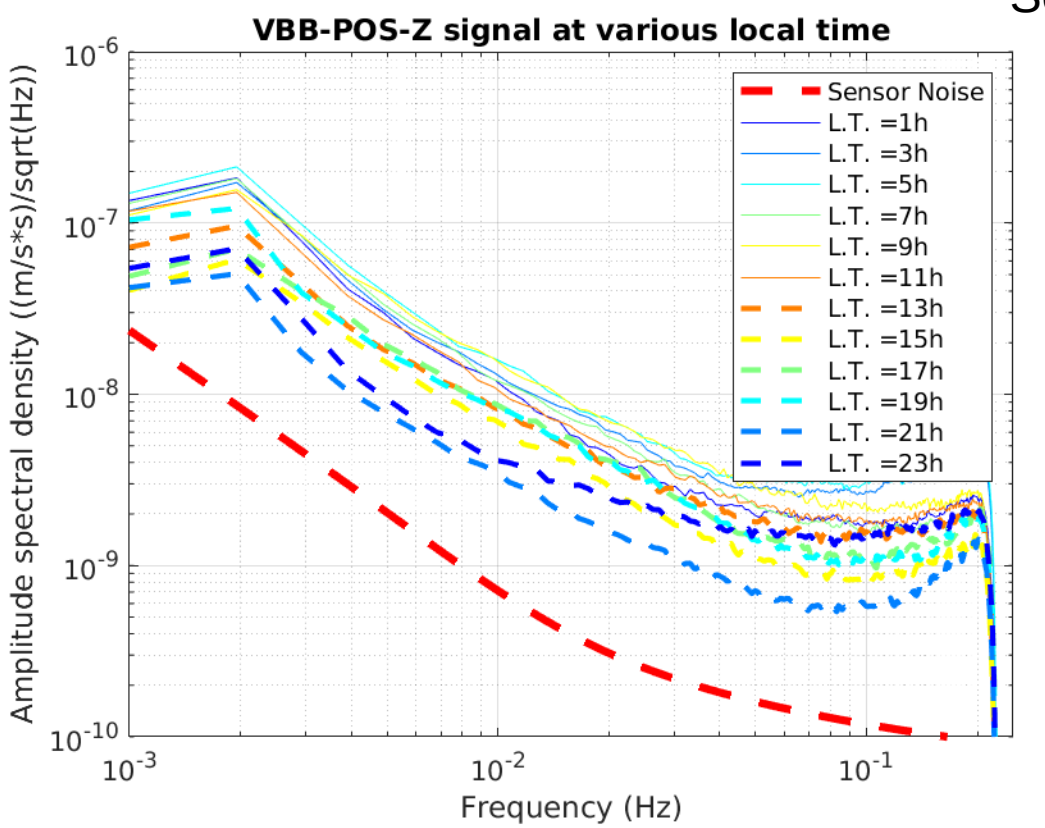


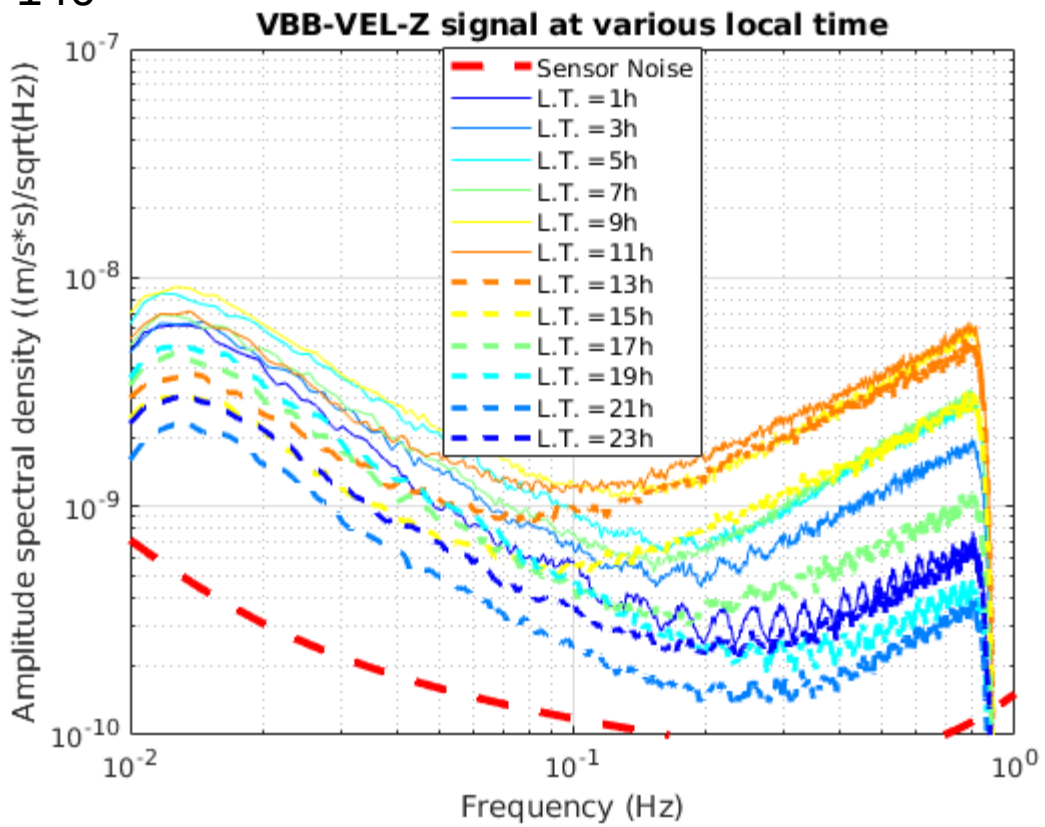
SEIS signals as a function of Local Time



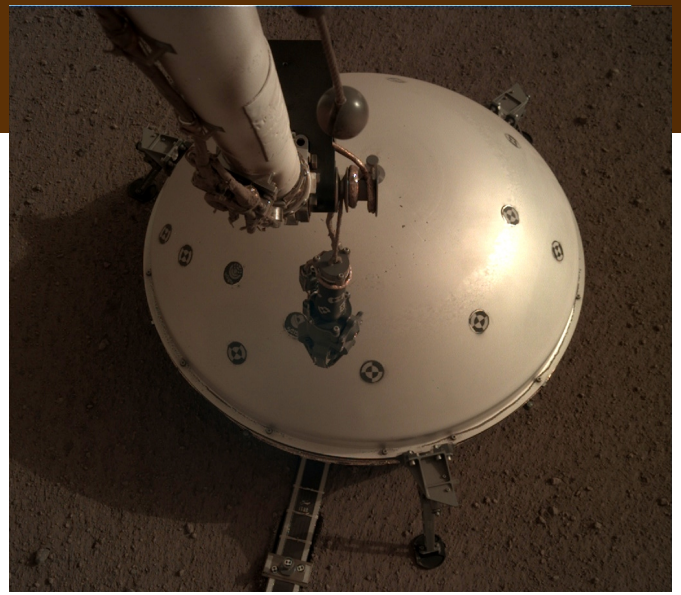
- **Vertical ground velocity**
- Above 0.1 Hz => vibrations due to wind drag on the lander
- => day/night wind variability
- Below 0.1 Hz => more complex...

Sol 123-146



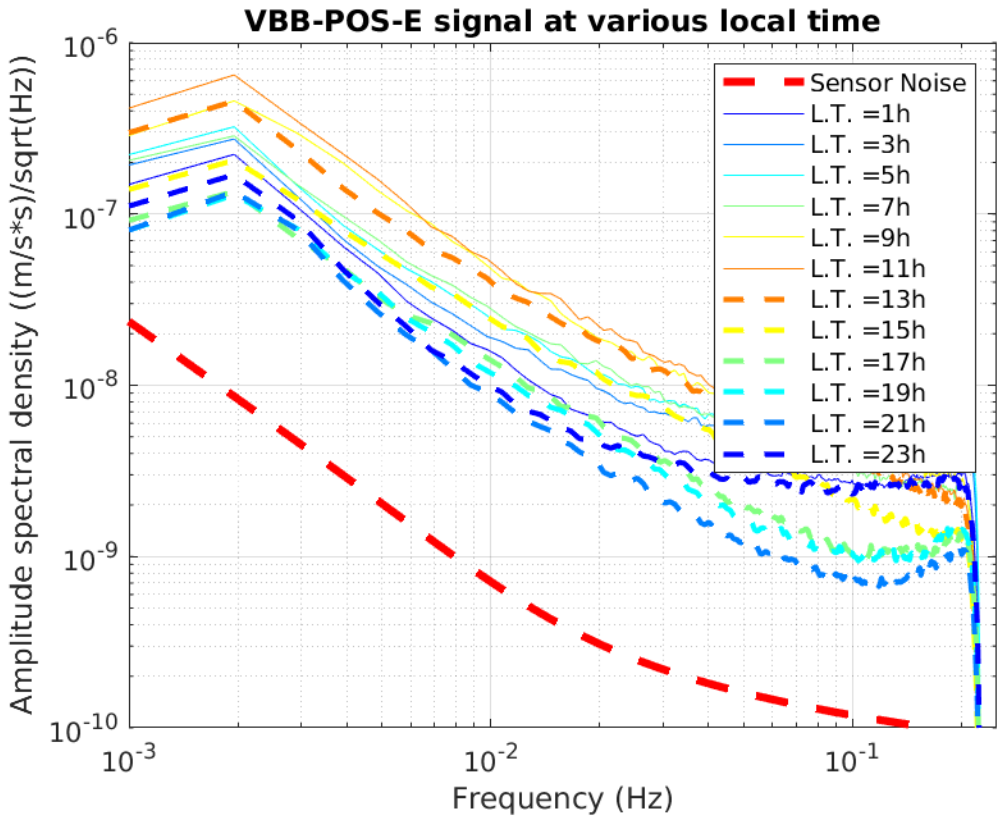


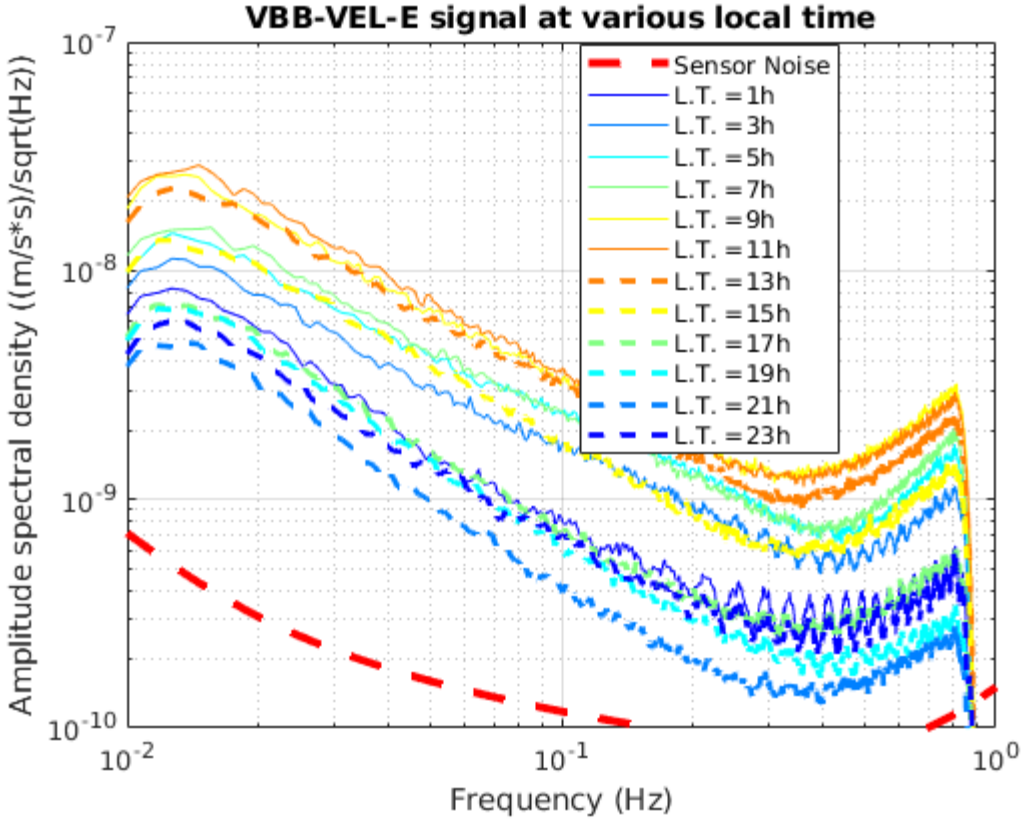
SEIS signals as a function of Local Time



- **Horizontal ground velocity**
- Above 0.4 Hz => vibrations due to wind drag on the lander
- => day/night wind variability
- Below 0.4 Hz => Wind/lander + Pressure

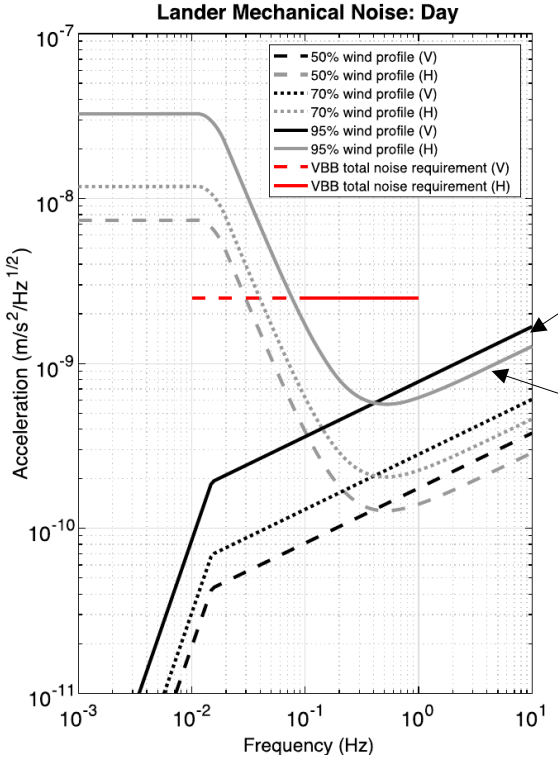
Sol 123-146





Wind and SEIS signals

- Wind is the dominant noise source
- Lander vibrations do to wind drag explain the main features (Murdoch et al., 2017):
  - Vz> Vh above 0.2 Hz
  - Amplitude scaling with ~ Wind^2
  - Vz/Vh phase shift under modeling effort



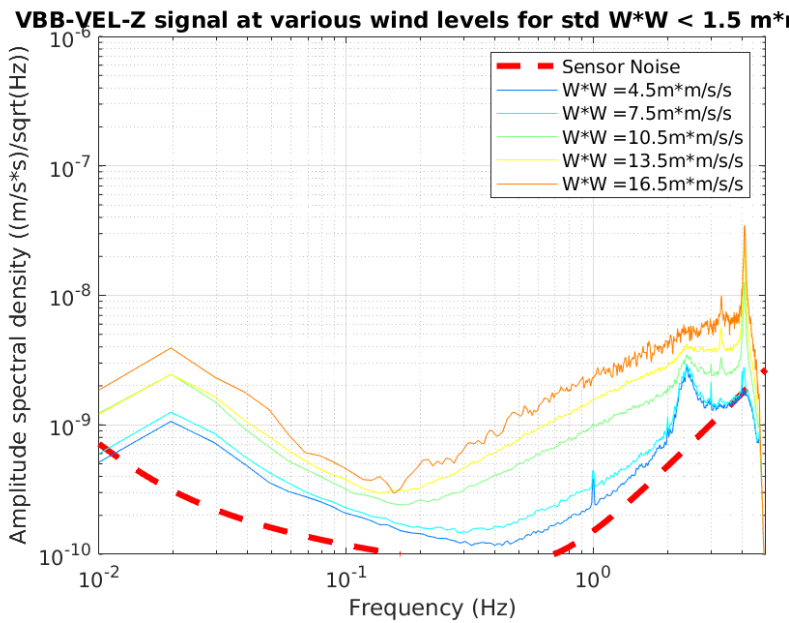
Murdoch et al. (2017)

Vertical

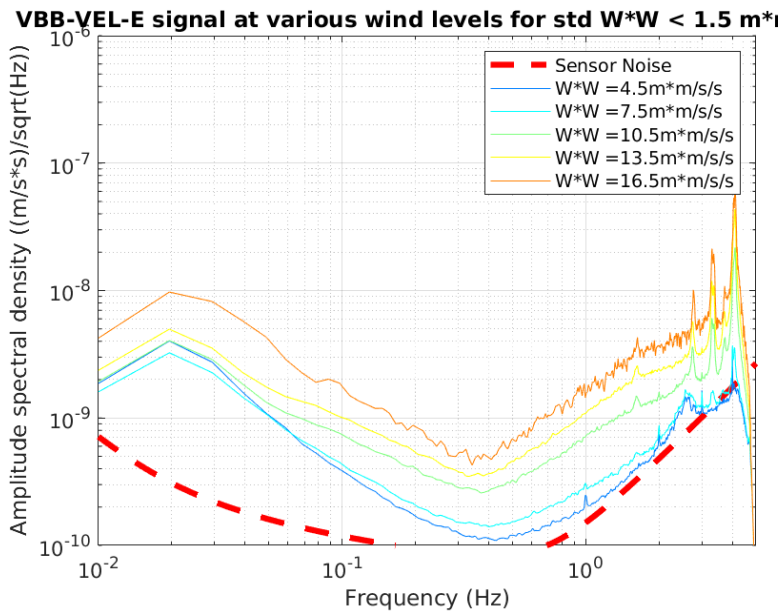
Horizontal

SEIS background noise at different wind speeds (<W*W> bins) (Lognonne et al., under review)

Vertical



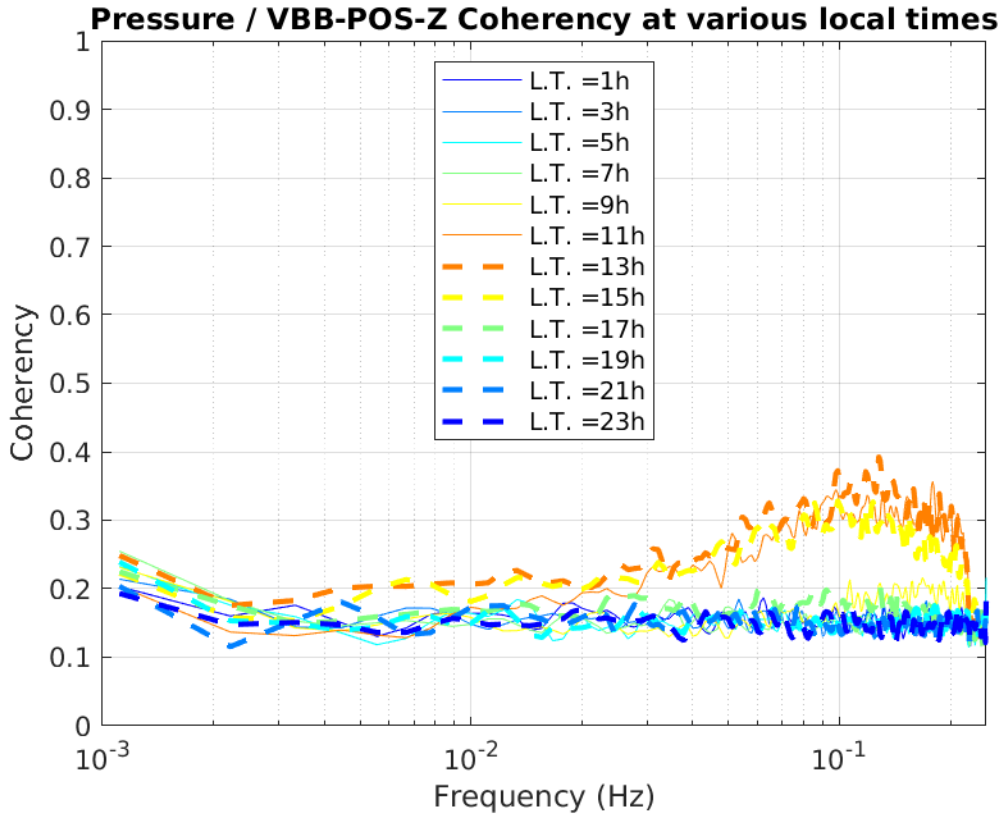
Horizontal (East)

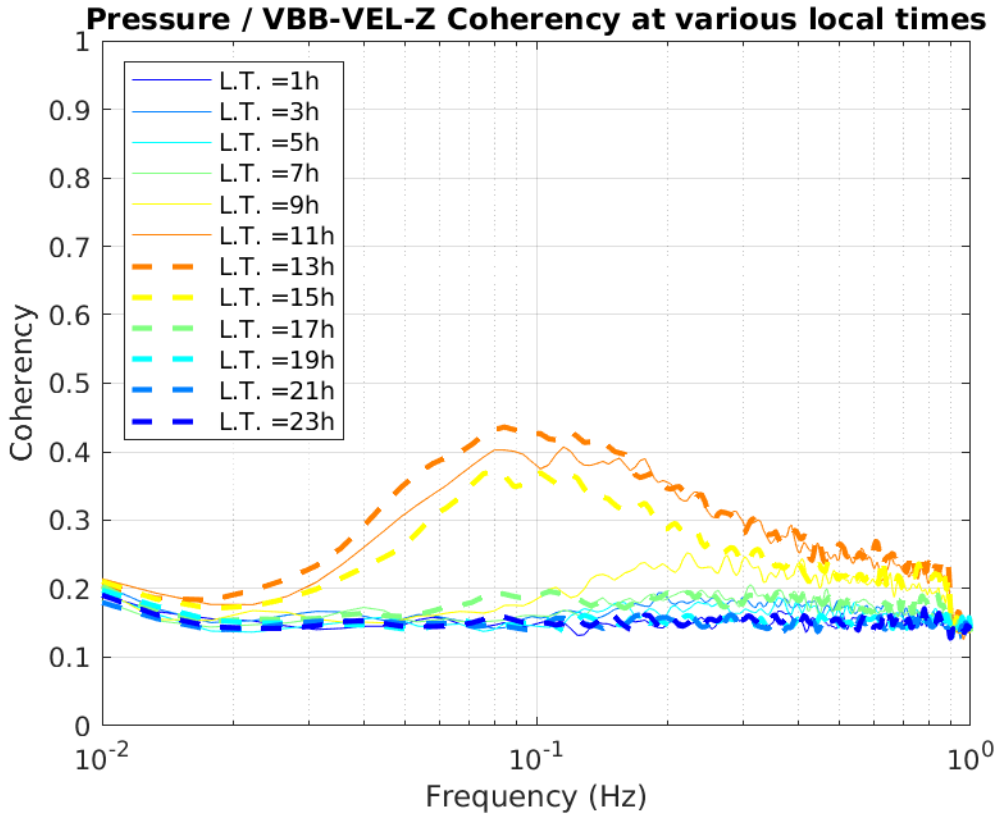


Pressure / SEIS coherent signals

- Coherence between Pressure/Ground. Vel.
- P/Vz-**Vertical component**:
  - Day time activity around 0.1 Hz => convective vortex

Sol 123-146

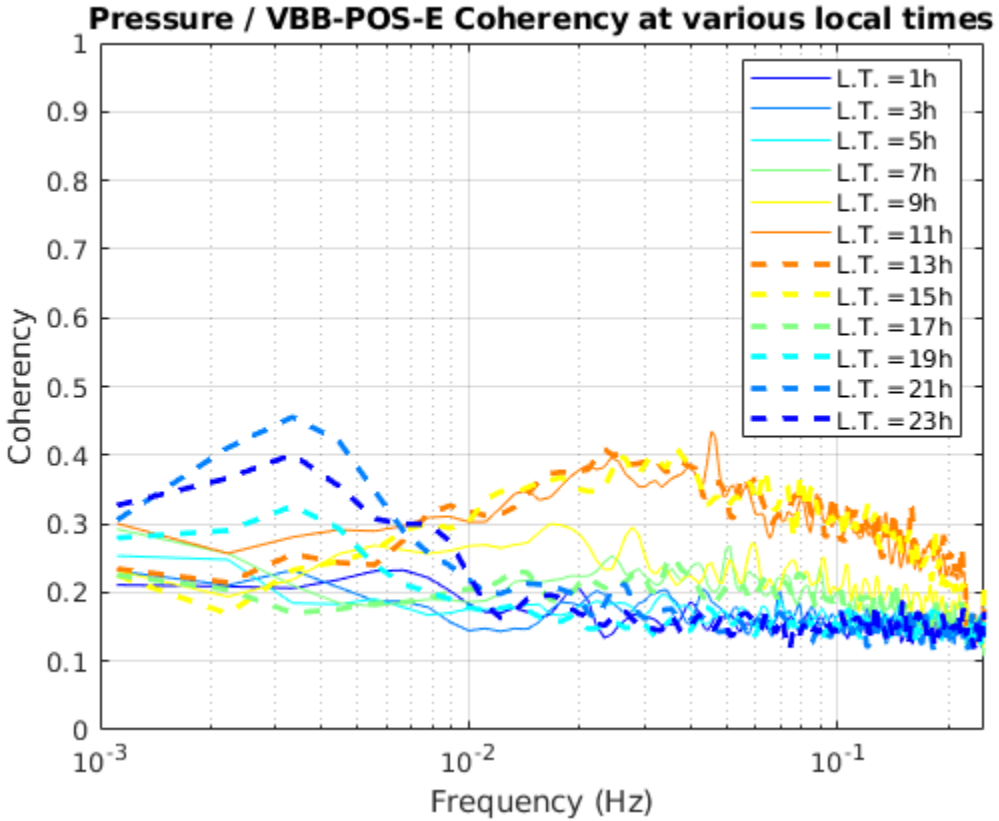


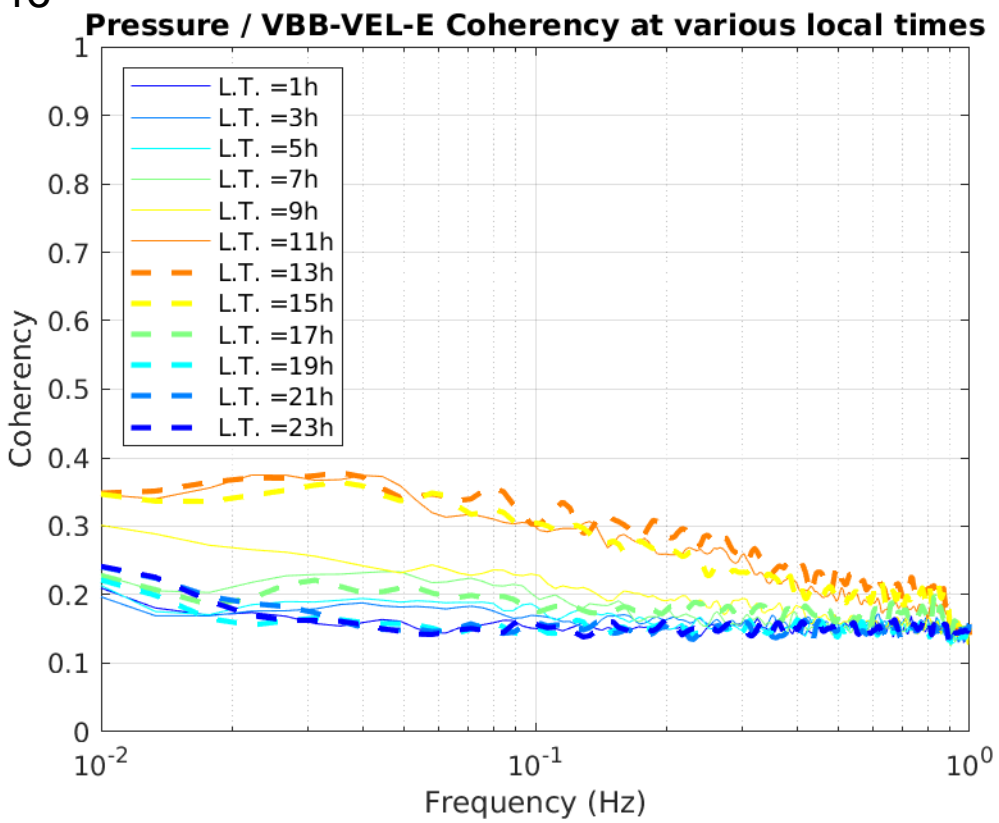


Pressure / SEIS coherent signals

- Coherence between Pressure/Ground. Vel.
- P/Vh-**East component**:
  - Day time activity 10^{-2}Hz - 0.2Hz => convective vortex
  - Night time in mHz range => gravity waves

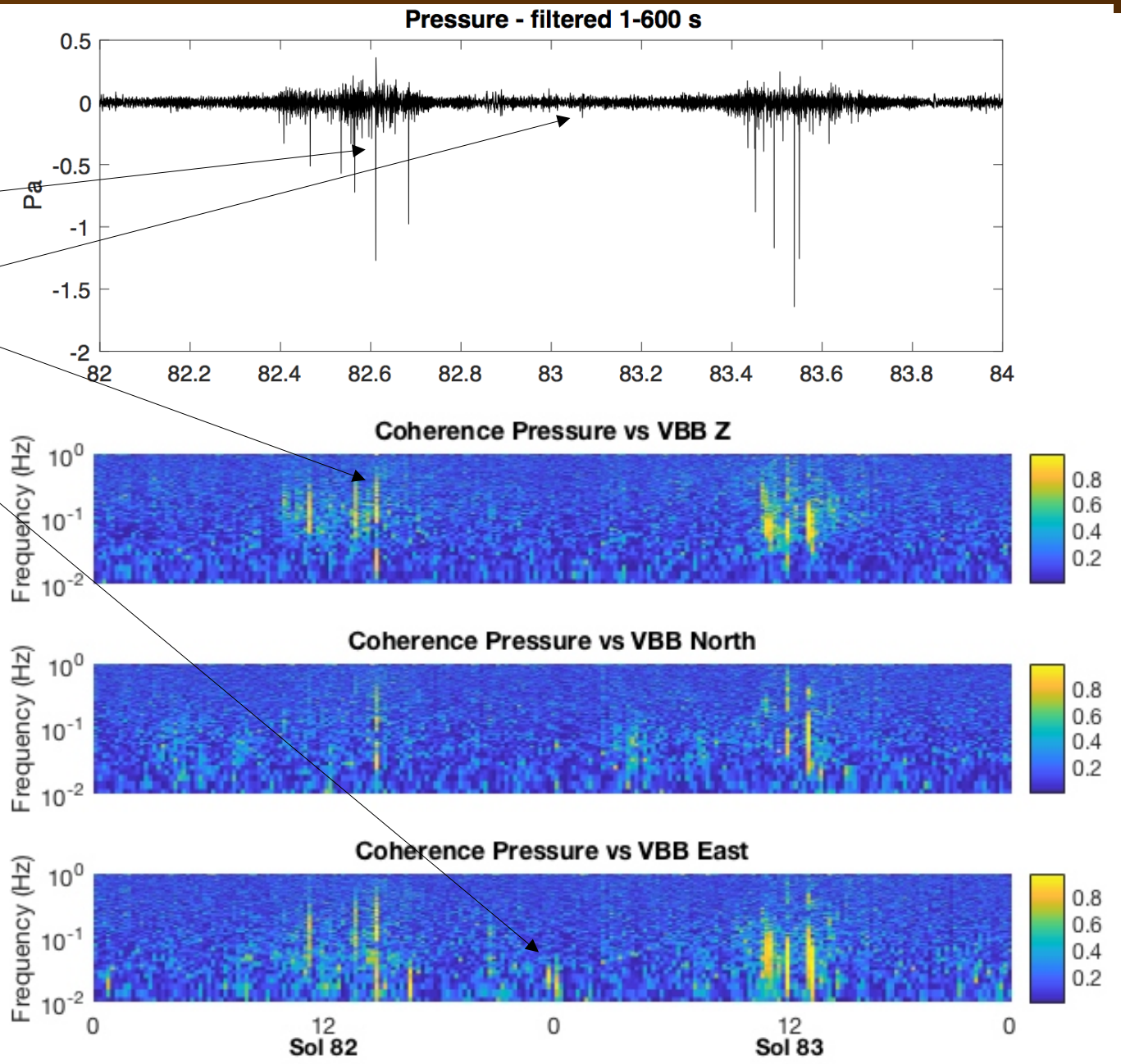
Sol 123-146





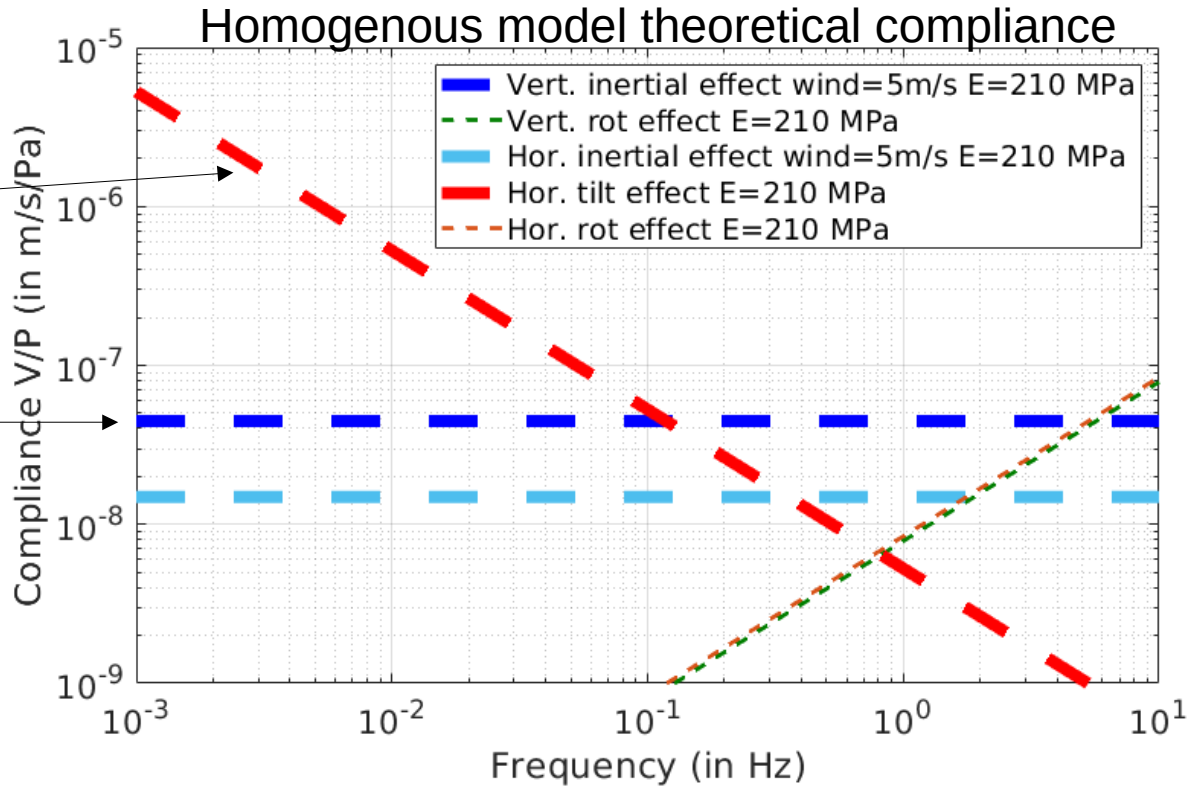
Pressure / SEIS coherent signals

- Coherence Pressure/Ground. Vel.
- **Dominated by Large pressure events**
  - Convective vortex
  - Night time gravity waves



Why Pressure/SEIS coherent signals?

- Observed features are explained by **compliance effects**:
- **Tilt effects** are dominating on the **horizontal** components (enhanced at low frequencies)
- **Inertial effects** are dominating on the **vertical** component



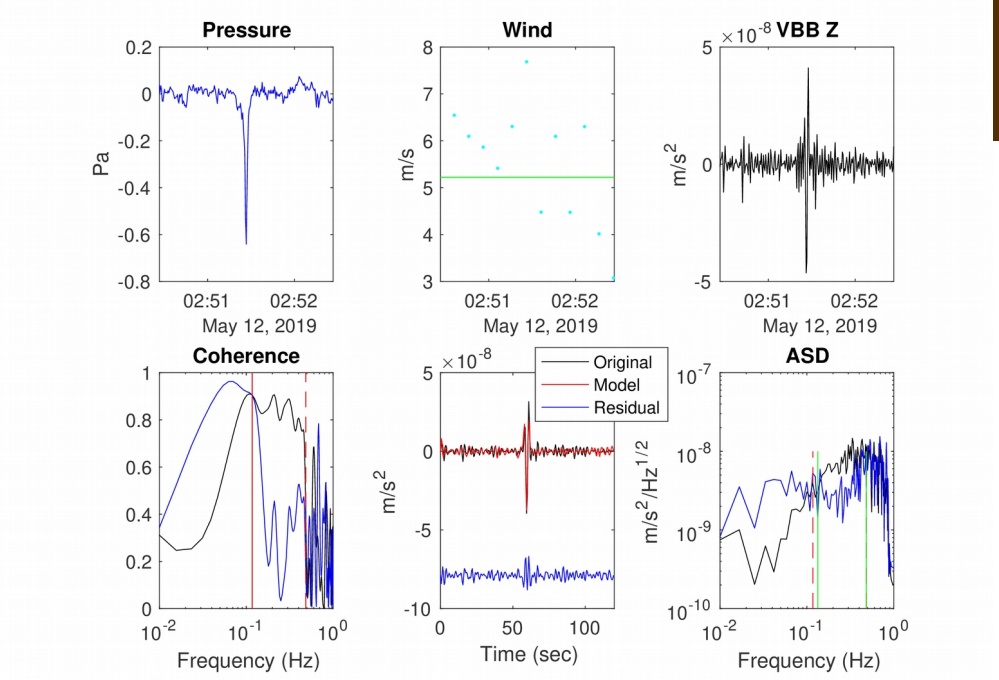
Removing pressure noise of SEIS records

- In order to detect more seismic waves...
- Two methods implemented:

1- **Scaling factor between P and Vz** during convective vortex events: $V_z(f) = ic \cdot C_z(f) \cdot P(f)$

- Estimate per event in a given freq. range

- Only Z component, not continuous



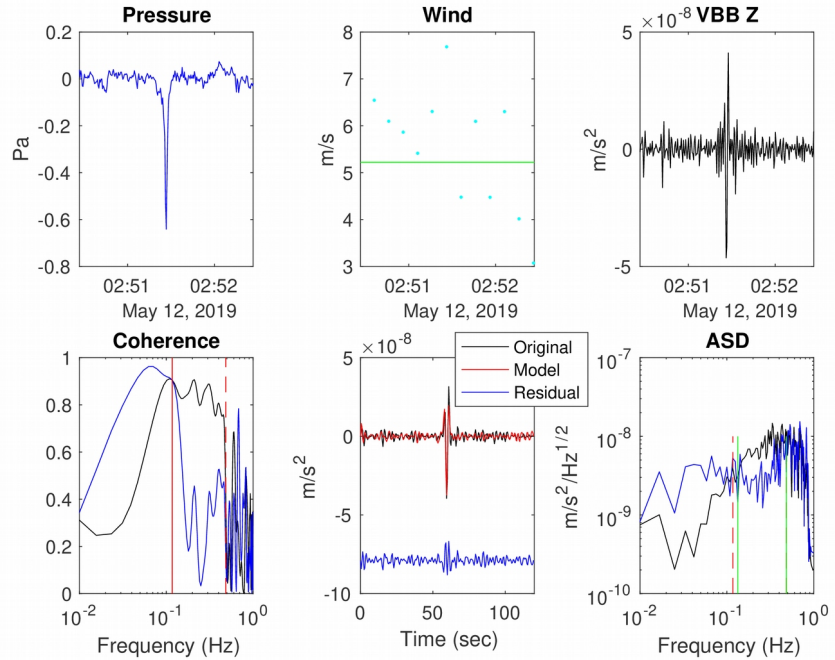
Removing pressure noise of SEIS records

- In order to detect more seismic waves...
- Two methods implemented:

1- **Scaling factor between P and Vz** during convective vortex events: $V_z(f) = ic \cdot C_z(f) \cdot P(f)$

- Estimate per event in a given freq. range

- Only Z component, not continuous

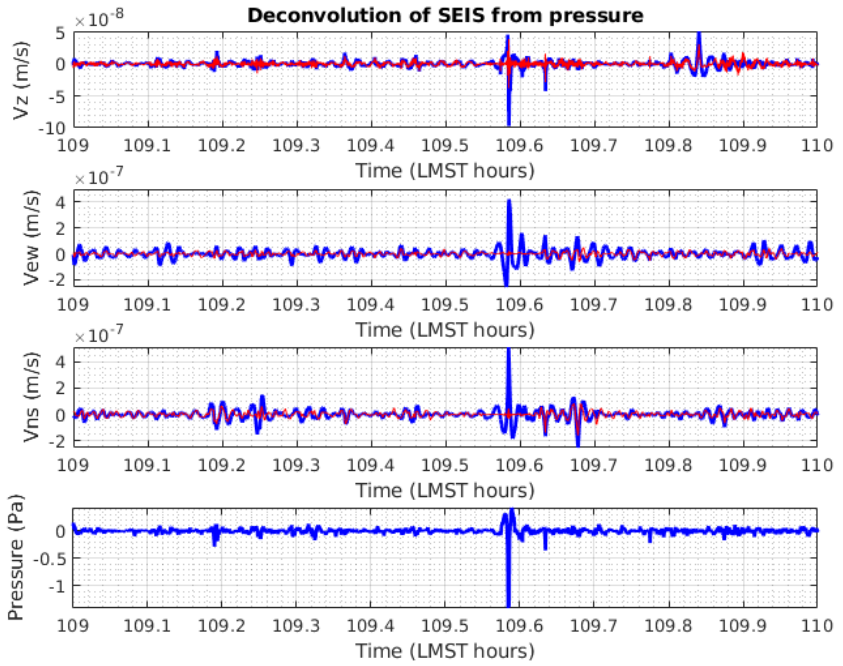


2- **Adaptative LMS filter** between P and SEIS ground velocities (Z, N, E):

$$V_i(n) = \sum_{k=-N/2}^{N/2} C_i(k) P(n-k)$$

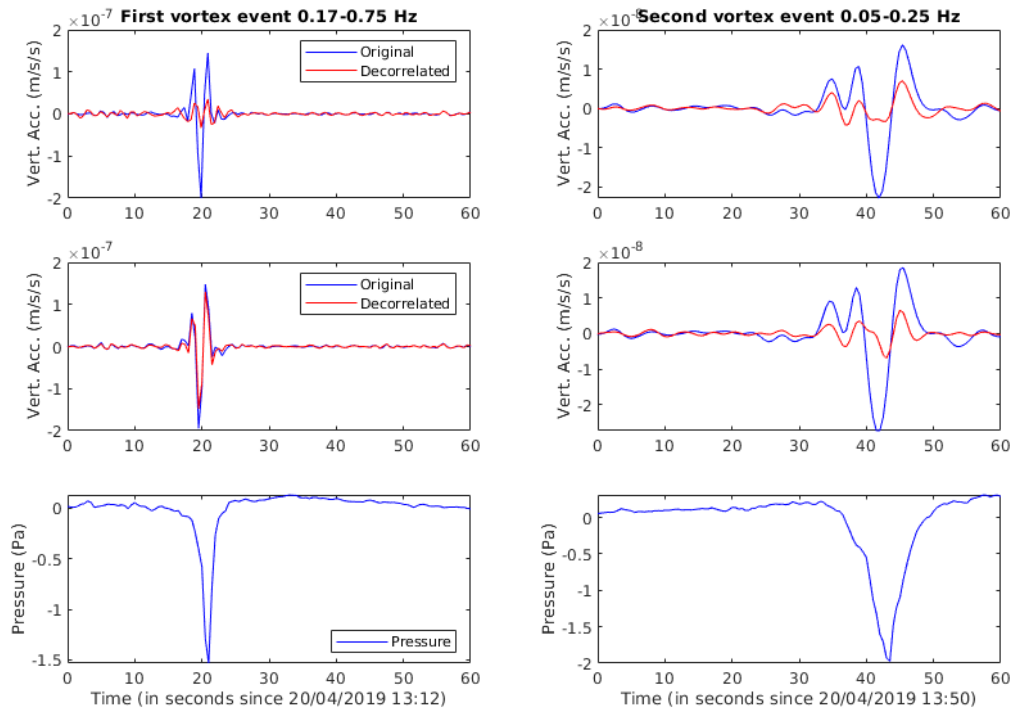
- Continous, all components

- Run by freq. bands, Compliance estimates biased by other noise sources, worse on vertical than for horizontal components



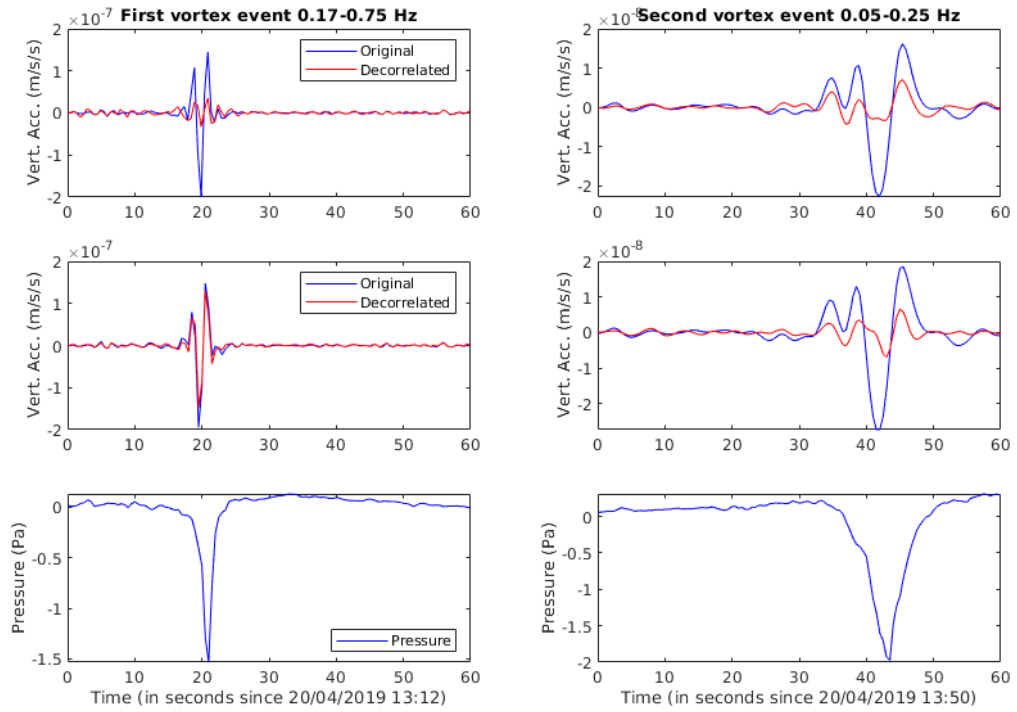
Removing pressure noise of SEIS records

- Comparison of the two methods for two events:
  - Method 1 better at high frequency
  - Similar results at lower frequencies

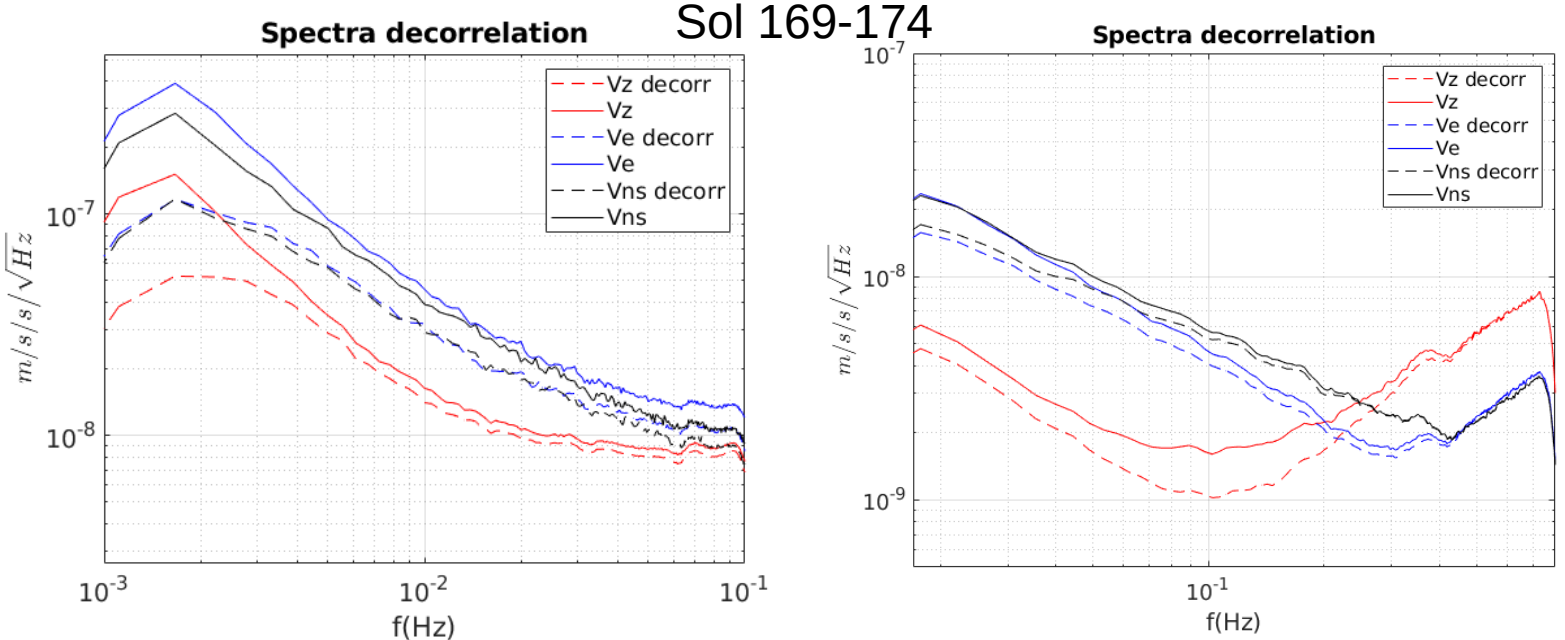


Removing pressure noise of SEIS records

- Comparison of the two methods for two events:
  - Method 1 better at high frequency
  - Similar results at lower frequencies
- Adaptative LMS method efficiency:
  - Good results in freq. ranges with high P/V coherence
  - Best results in mHz range



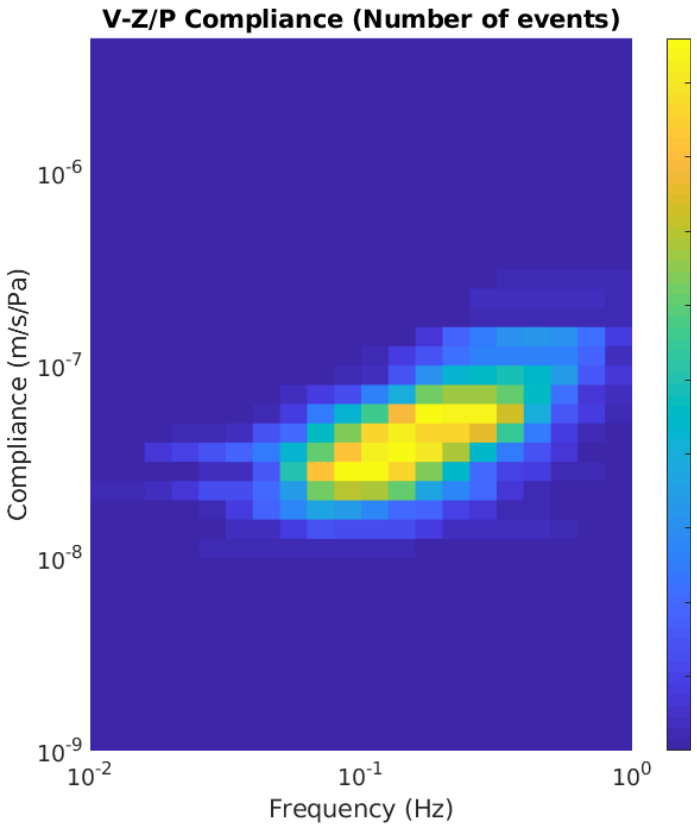
Sol 169-174



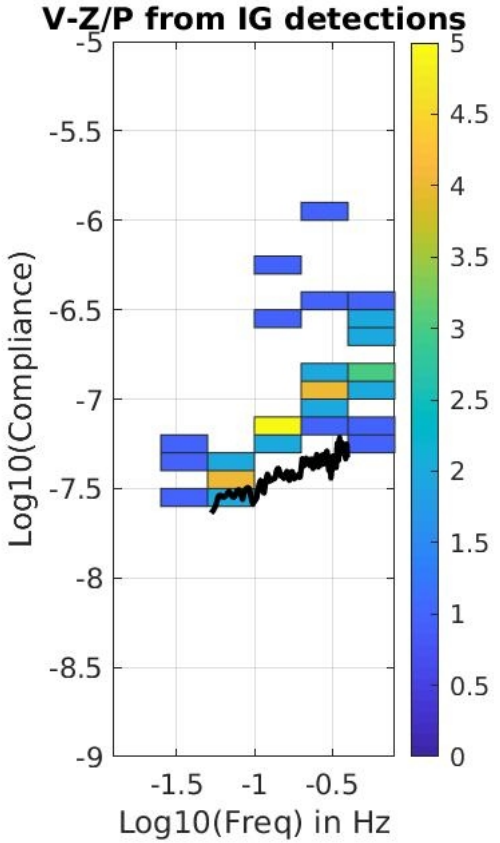
Ground compliance estimates

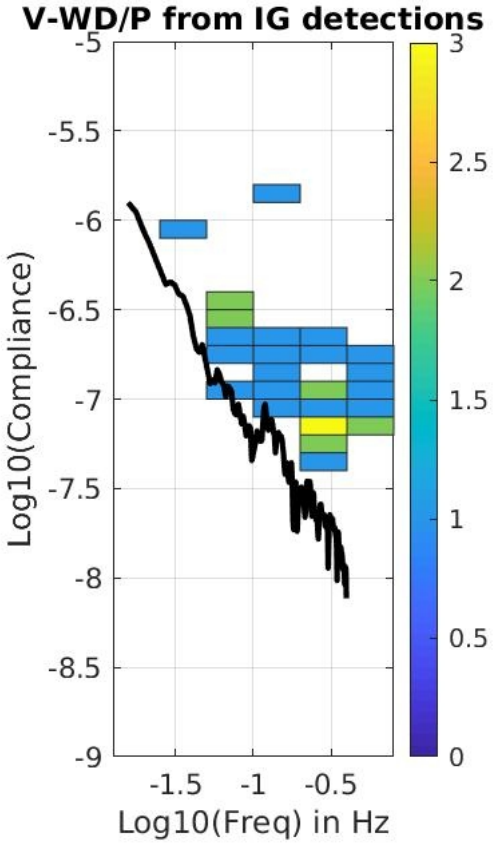
- Adaptative LMS under-estimate compliance => another automated method implemented (based on a compliance marker)
- Similar vertical compliance estimates between the two methods
- Values inverted for sub-surface imaging => Kenda et al. (in prep)

All events



Sol 169-174

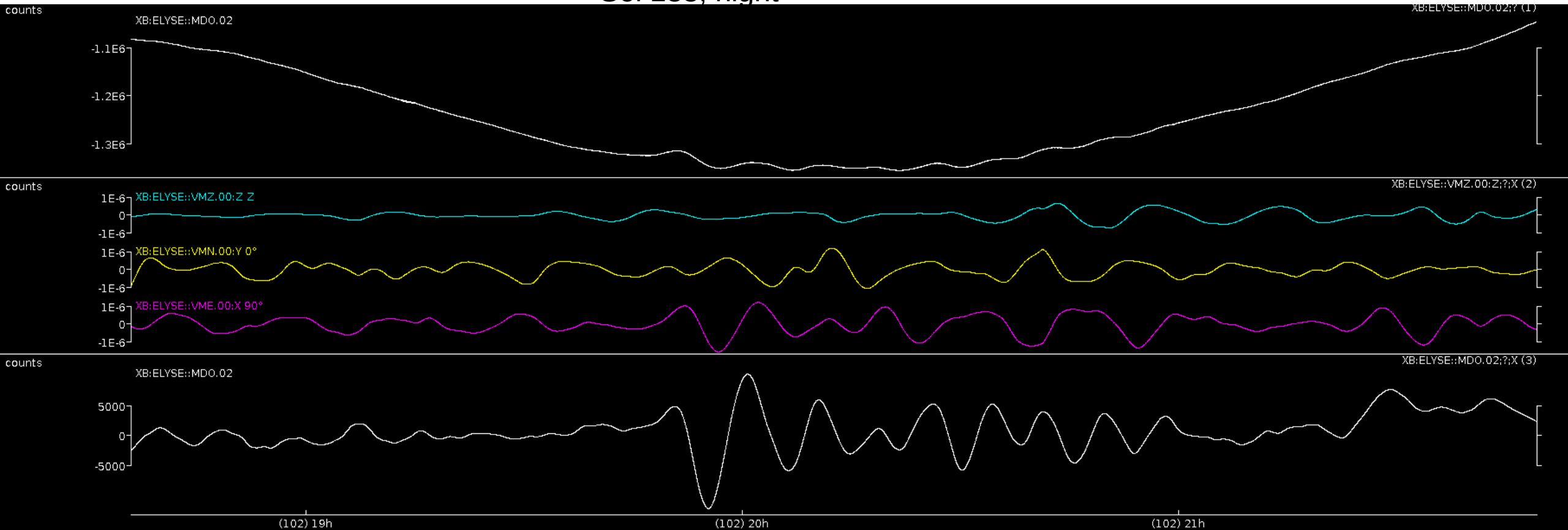




Atmospheric science with SEIS

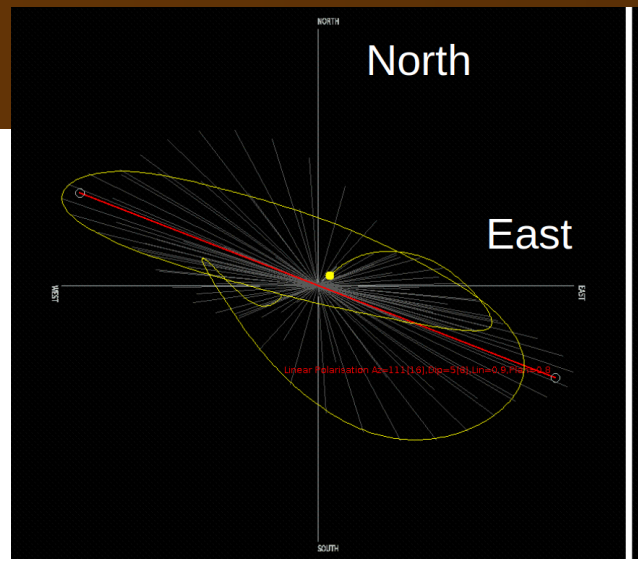
- Gravity waves detected on horizontal components of SEIS

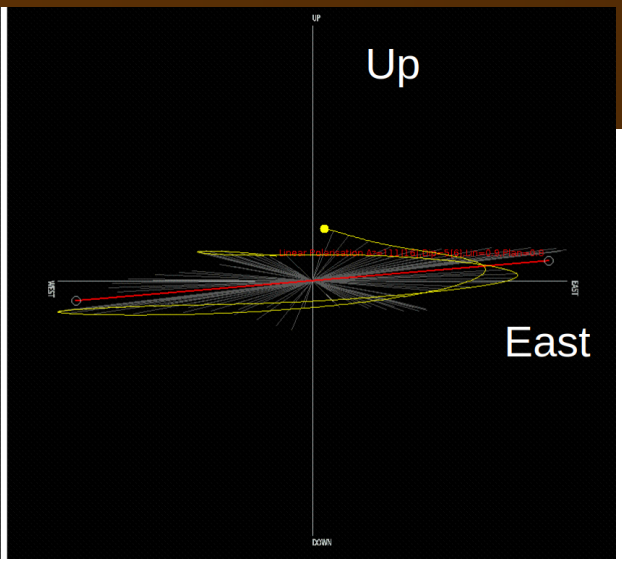
Sol 133, night



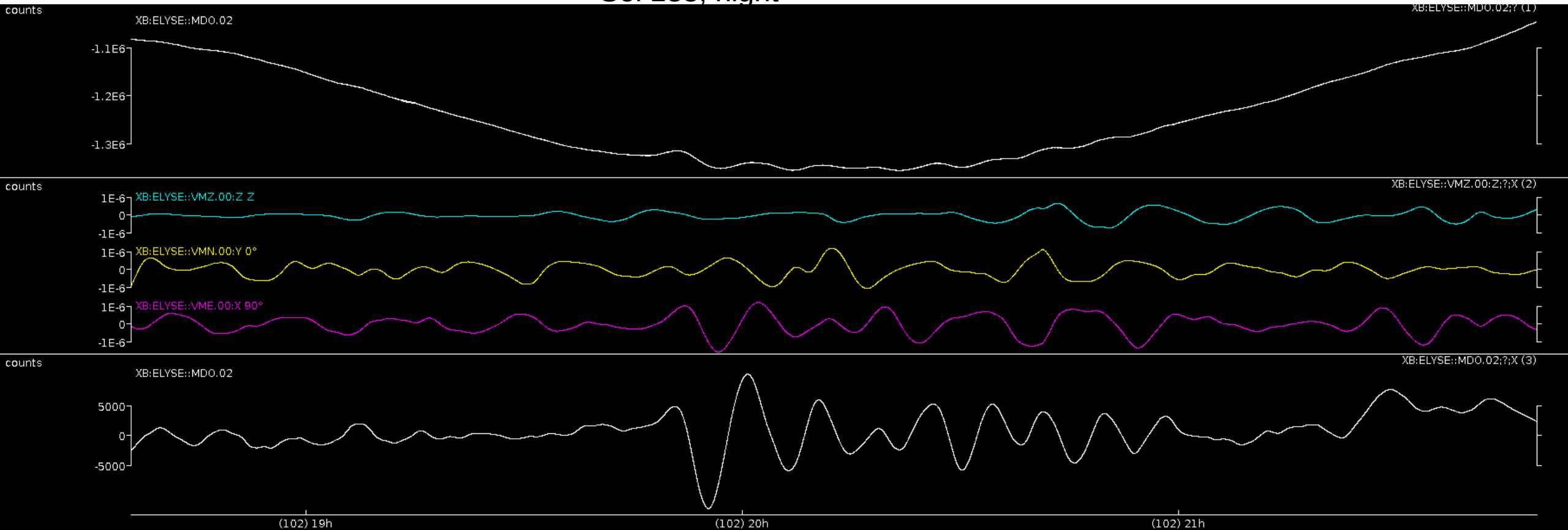
Atmospheric science with SEIS

- Gravity waves detected on horizontal components of SEIS
- Polarization analysis allows to recover the apparent arrival azimuth of gravity waves
- Consistent with wind azimuth





Sol 133, night

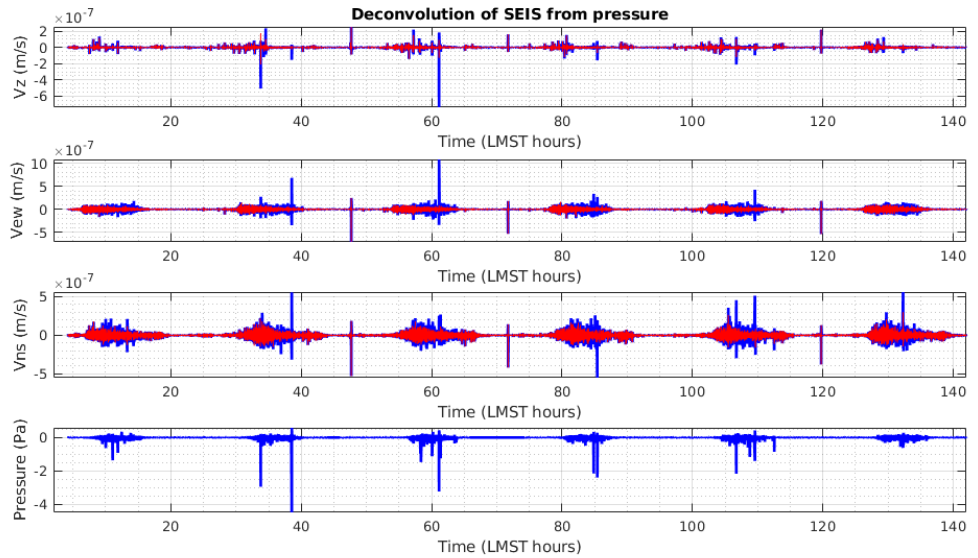


Conclusions

- Coherent signals between P and SEIS explained by compliance effects and atmospheric forcing sources
- Pressure decorrelation methods efficiently remove large pressure signals (in particular for convective vortex and mHz range)
- Gravity wave apparent azimuth can be retrieved from SEIS polarization
- Limitation:
    - wind noise is dominant noise most of the time
- Prospects:
    - decorrelation of other environment effects (Temperature, Wind, Magnetic field...)

Sol 169-174 decorrelation

VEL channels



POS channels