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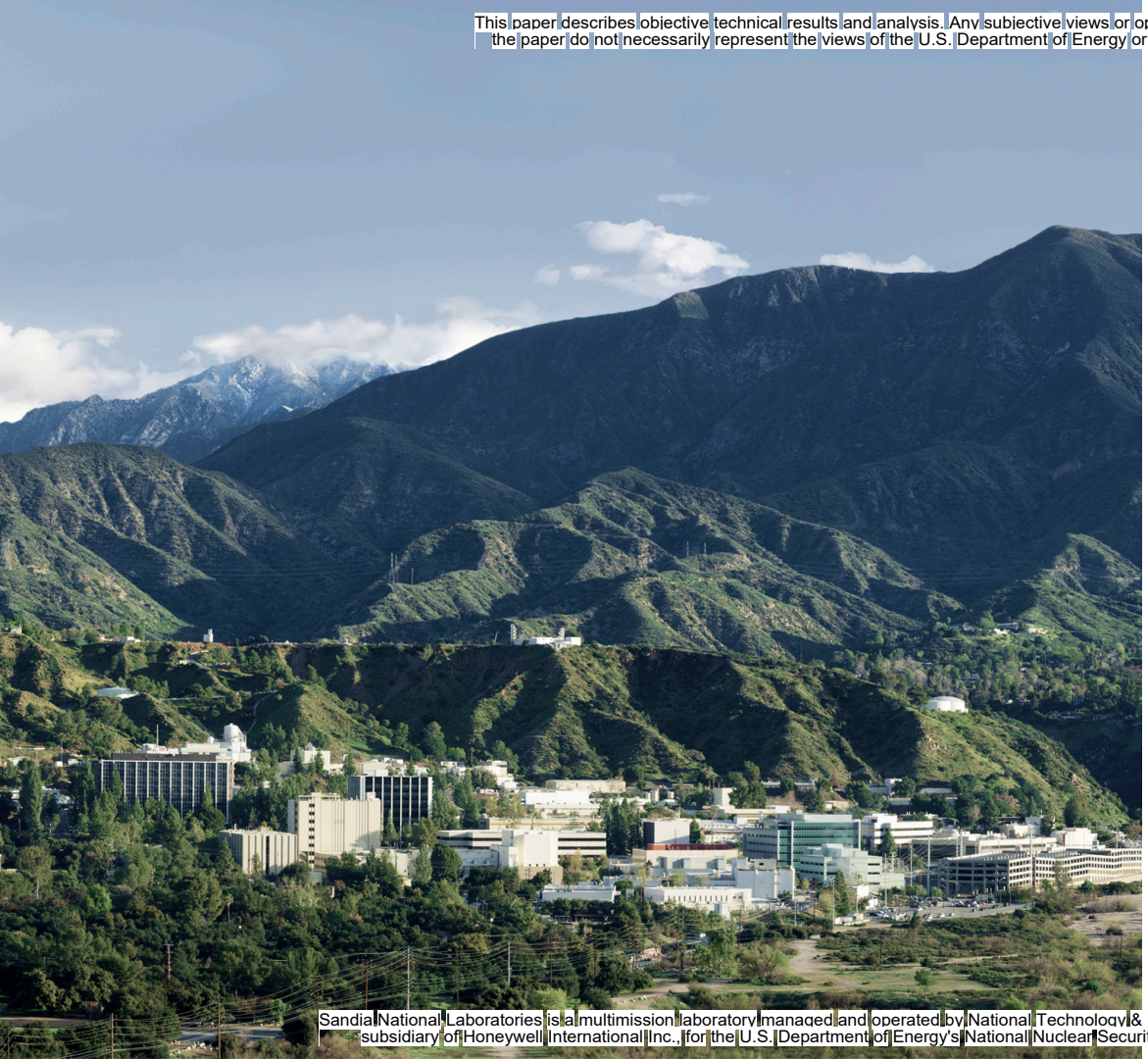

Automated Detection of Dust-Devil Induced Pressure Signals

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Outline

- Background
- Synthetic Testing
- Results from Observational Data
- Future Work

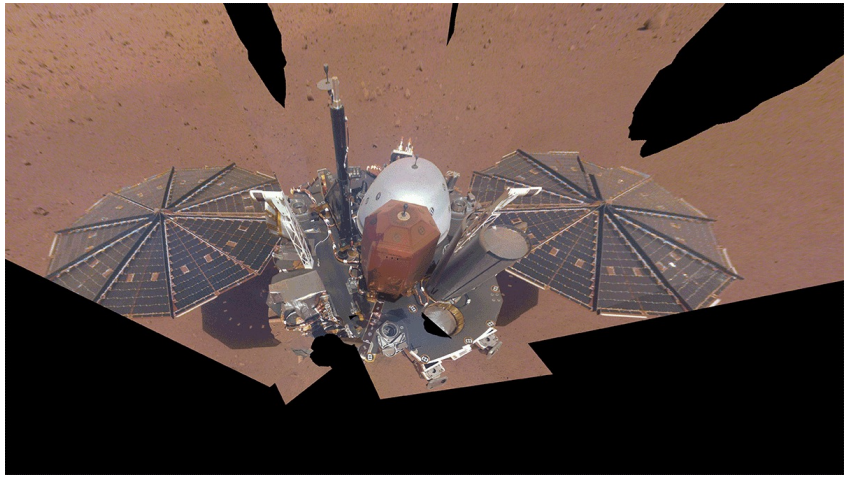
Dust devils captured by Spirit rover.
Credit: NASA

Introduction to Vortices

- Formed by warm pockets of air
- At least a meter in height and last at least 10 seconds (Oke et al, 2007)
- Dust devils unique in that they are dust-laden
- Notable dip in pressure near their centers
- Frequently observed on Mars by surface landers and orbiters

Dust devil observed by the Curiosity rover. Credit: NASA

Dust Devils on Mars

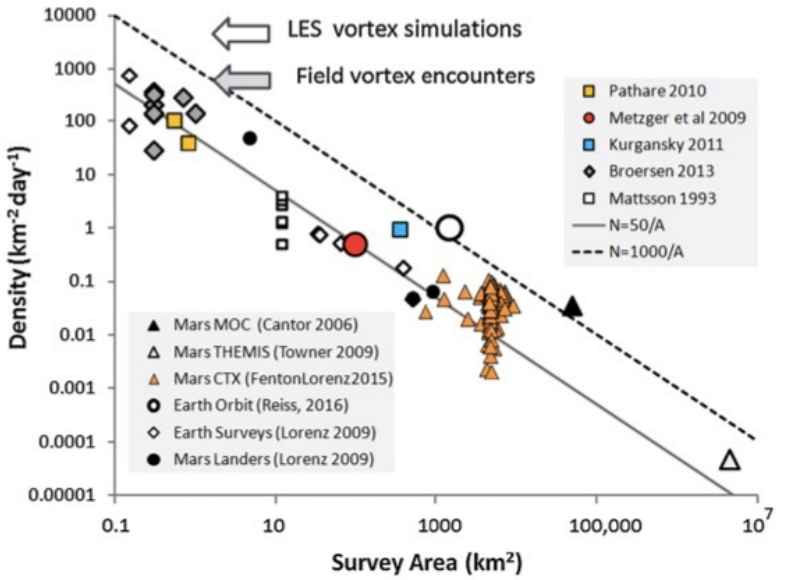


Mars InSight first and final selfies
Credit: NASA

- Dust loading plays a primary role in Martian atmospheric dynamics
- Wind erosion could play a role in affecting biosignatures preserved in rock
- Dust devils could affect the longevity and efficacy of Martian landers and eventual human missions

Challenges in Studying Martian Dust Devils

- Lack of an in-depth record poses a problem given prevalence of dust devils on Mars
- Low station density
- Formation characteristics can be studied through the development of a catalog
- “ …deployment of sensor networks that produce a variety of data streams with high spatial and time resolution.” Jackson et al. (2018)



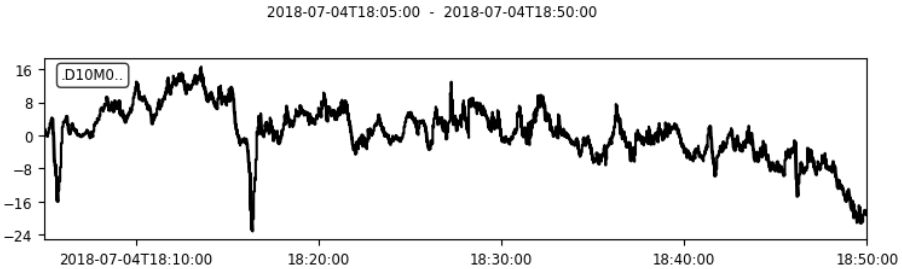
Dust devil density plot in Lorenz and Jackson (2016)

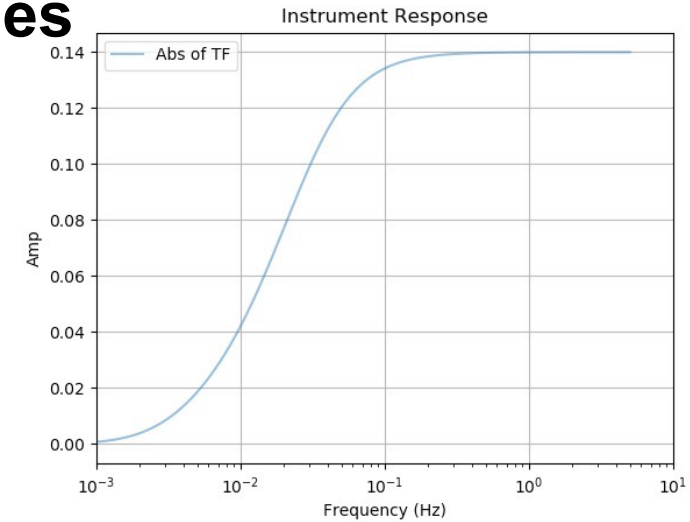
An Analog Study

- 7-year deployment of seismometers and infrasound microbarometers at Nevada National Security Site (NNSS) in Mojave desert
- 32 microbarometers, 20 broadband seismometers, 100 geophones
- 10^4 station-days of data
- Unique landscape pockmarked with craters
- Atmospheric scaling from Earth to Mars

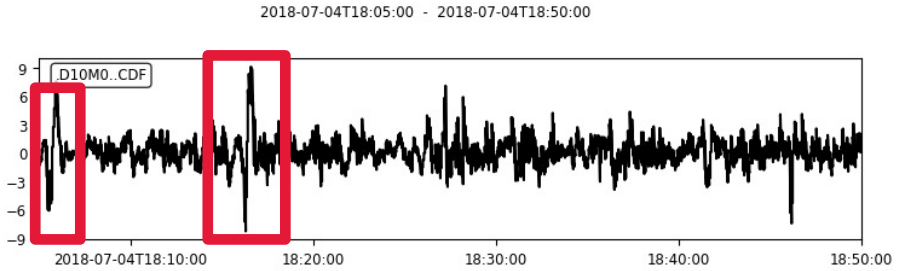
$$\Delta p \approx \frac{\gamma \eta c_p \Delta T p_\infty}{R T_\infty}$$

Signatures in Time-Pressure Series

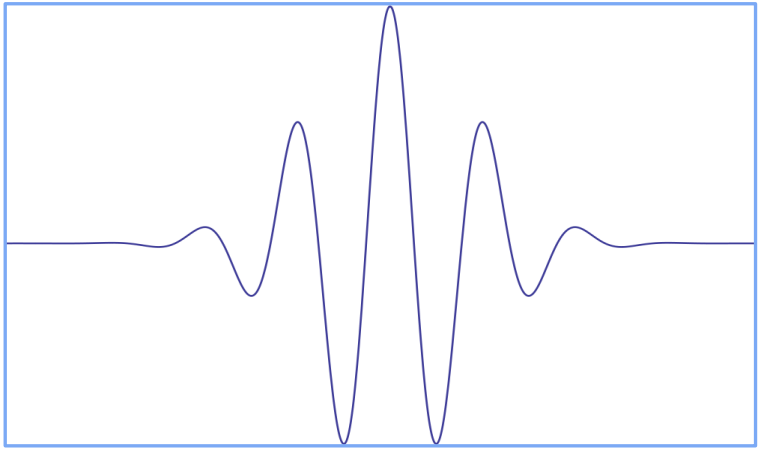




- Unique “heartbeat” signature good for correlation detector, consequence of **convolving signal with instrument response**
- Occur within 10^{-3} to 10^{-1} Hz frequency band
- Distinct in time



Detector Architecture

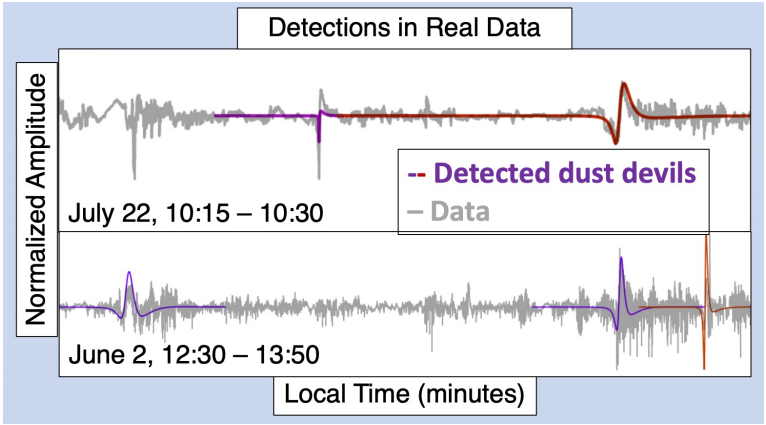


Wavelet Detector

- Not as sensitive to noise compared to correlation detector
- Expensive
- Detections not specific to dust devils

Correlation Detector

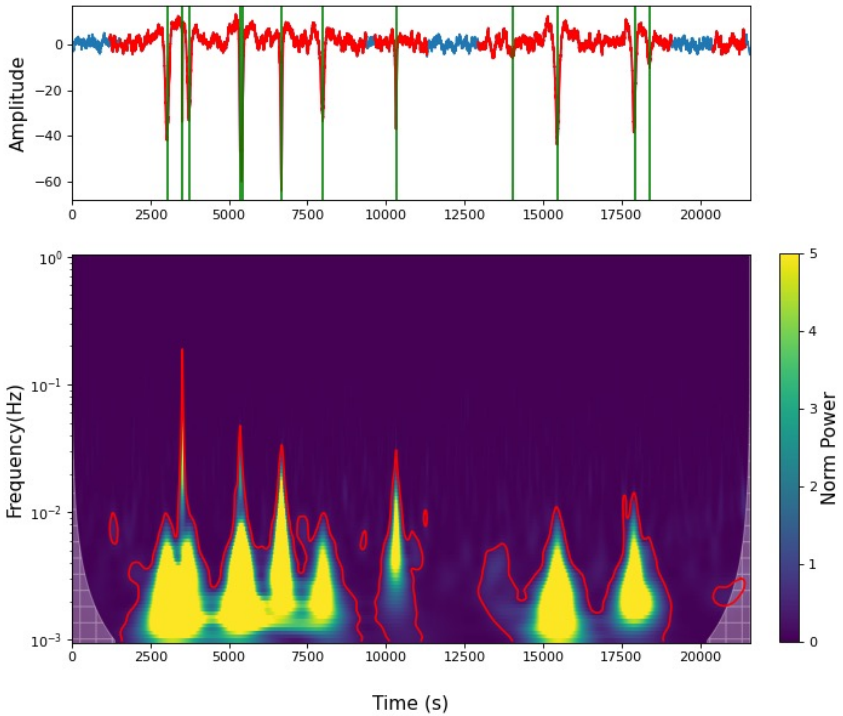
- Pressure-time series signatures are great candidates
- Sensitive to noise



Wavelet Detector

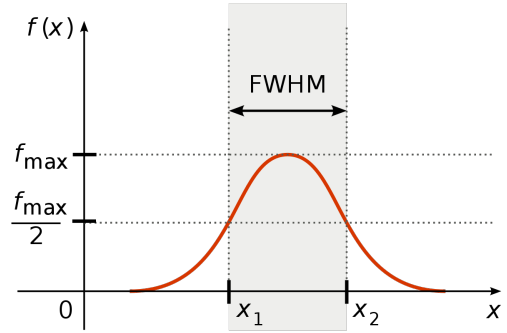
$$\frac{|W_n(s)|^2}{\sigma^2 P_k} \rightarrow \frac{\chi_2^2}{2}$$

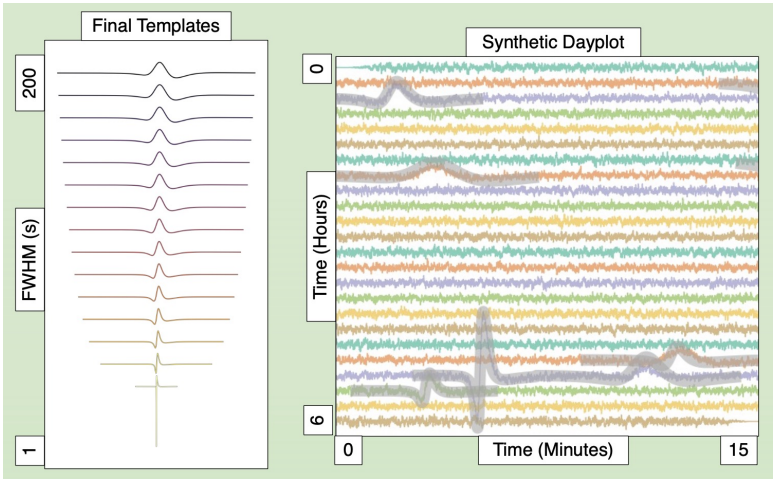
- Confidence testing in spectral domain
- Deconvolve instrument response
- Smoothed in scale
- Removed segments that lie above .1 Hz and less than 20 seconds in length
- Removed redundant detections
- Recalculated variance to remove bias against small dust devils



Correlation Detector

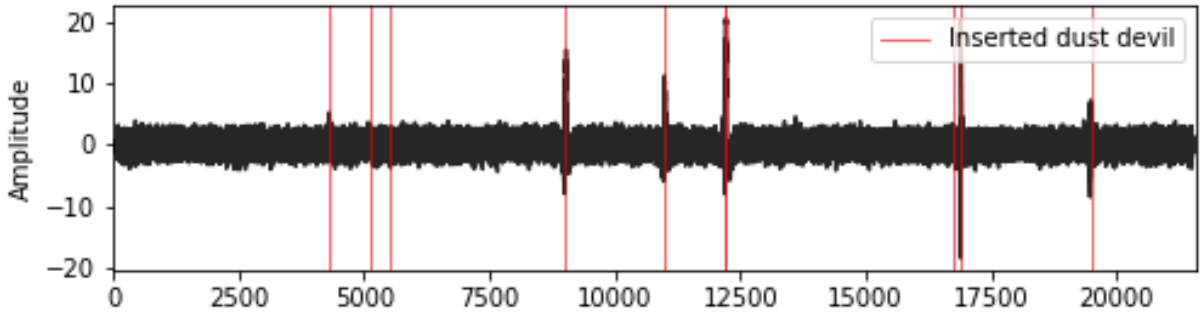
- Unique signature lends itself to correlation
- 15 templates of varying FWHM
- Convolve instrument response with pressure profile outlined by Jackson and Lorenz (2015)
- Cross correlate templates with time series





Testing Methodology

- 6 hour synthetics with random number of **non-overlapping** dust devils inserted at random points
- Dip (1-100 Pa), FWHM (1-300 seconds)
- Naturally observed dip 10-100 pa, FWHM 10-100s
- Unique red noise profiles for each synthetic
- Recall and efficiency analysis



Synthetic Run Summary

- Run on 10,000 synthetics
- Conducted only with white noise characterization in wavelet detector

Wavelet Detector

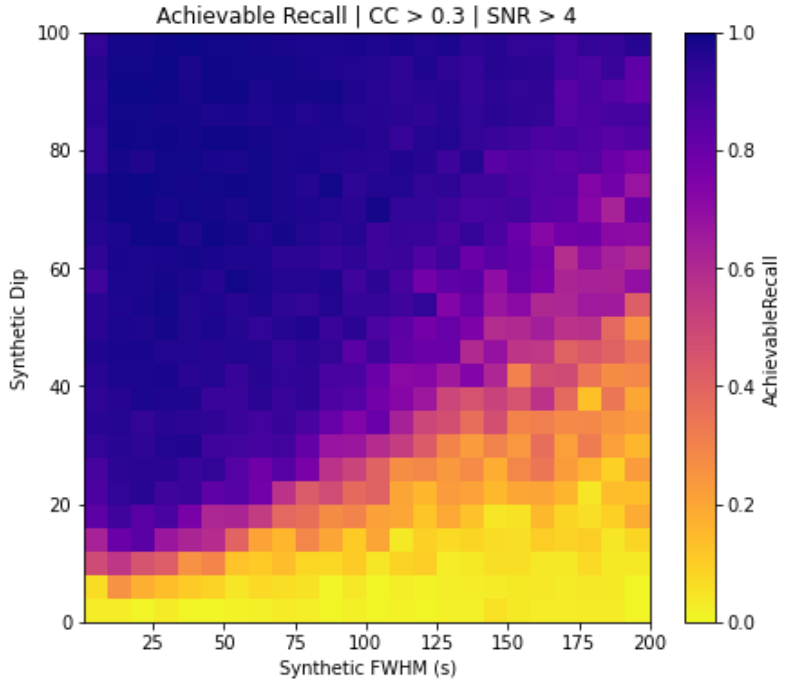
95.92 percent of dust devils were detected

Correlation Detector

83 percent of dust devils were detected

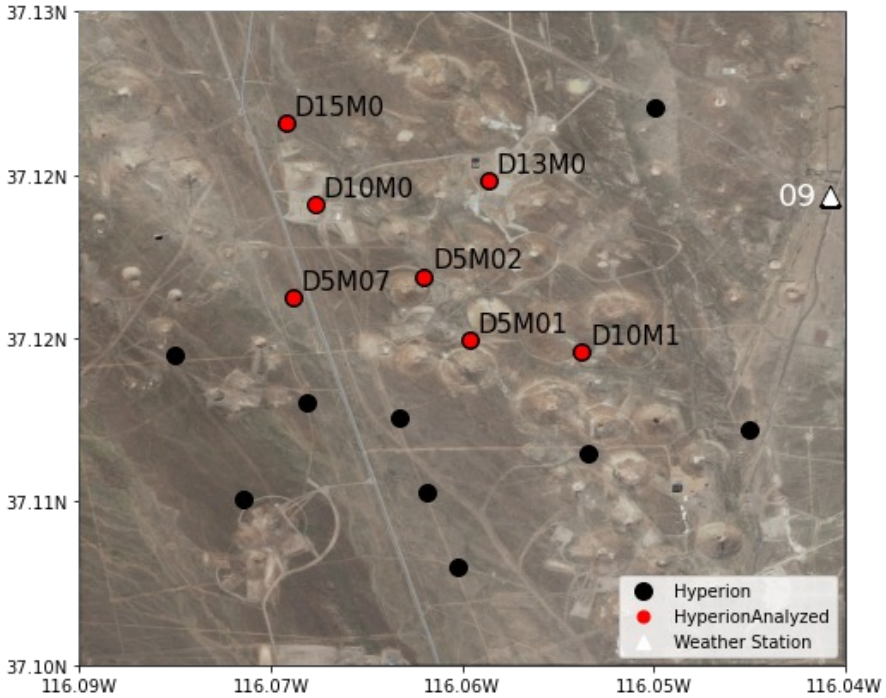
Joint Detector

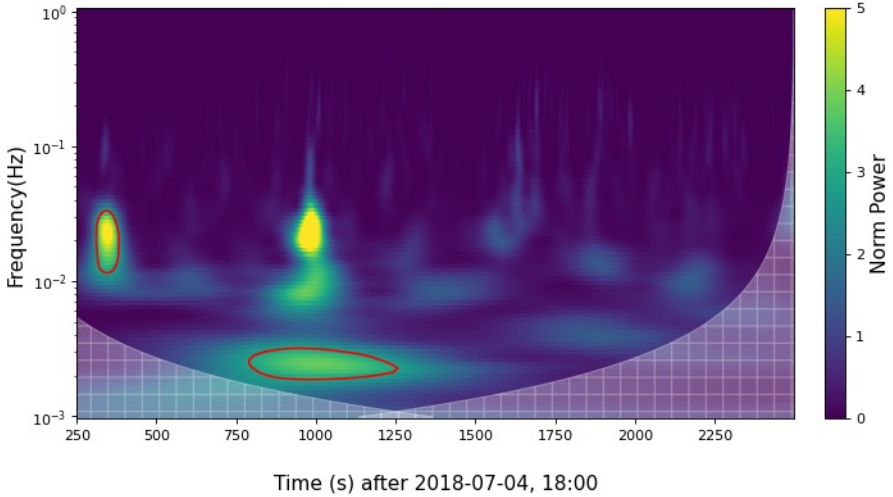
With 99 percent precision, 91 percent of dust devils were detected



Detector	Precision(%)	Recall (%)
Wavelet	74	95
Correlation	98	83
Wavelet+Correlation	99	91

Observational Data Trial (NNSS)





- 62 days of data
- 7 stations
- 5976 detections in total

Conclusion

- Dust devils play an important role in the Martian environment, but population is hard to study
- A heavily-instrumented analog densely populated with arrays is available for analysis
- A parallel, automated detection scheme has been developed and characterized using 10,000 synthetics, yielding promising results

Future Work

Dust devil from Lorenz et al. (2016)

- Generate full catalog for 7 years of data
- Analysis on formation and dynamics on large N dataset
- Release catalog of dust devils through NASA PDS
- Extrapolate results to Mars based on atmospheric scaling relations

Acknowledgements

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