Water Vapour variability measured from GNSS instruments as an indication of severe weather: a potential path to explore GNSS versus GRUAN sonde biases

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GNSS Measurements

- Satellite navigation signals traversing the troposphere are slowed by water vapor
- This delay is used routinely to estimate column-integrated water vapor at more than 10,000 permanent GNSS stations worldwide
- The rapid fluctuations of this delay, normally discarded as noise, encode information about boundary layer turbulence that evolves before and during convective storms
- Analyzing these fluctuations, we extract two spectral parameters that track different aspects of the convective cycle.

Summary

1. GNSS rapid fluctuation measurements

2. GNSS TCWV biases with respect to GRUAN Sondes

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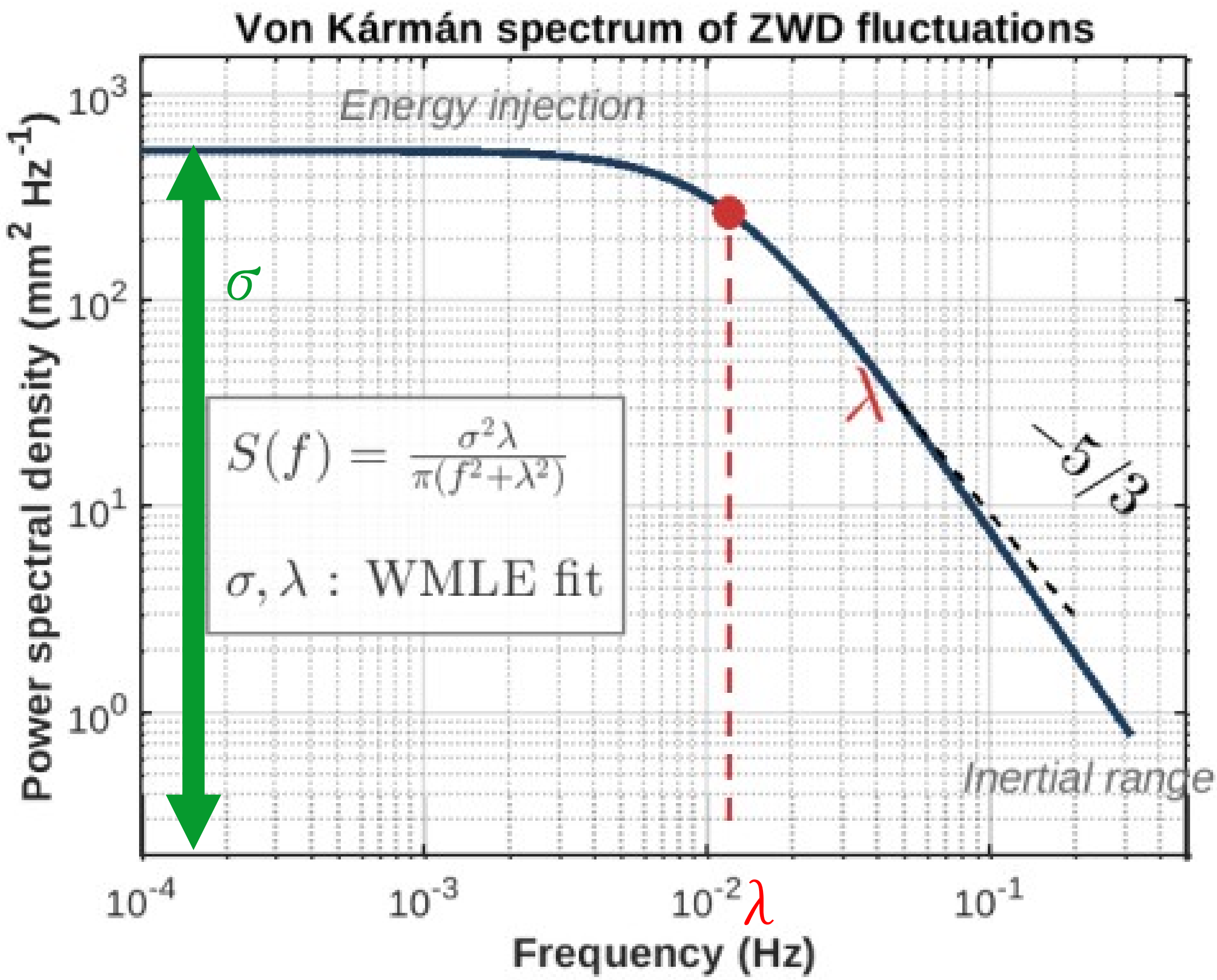
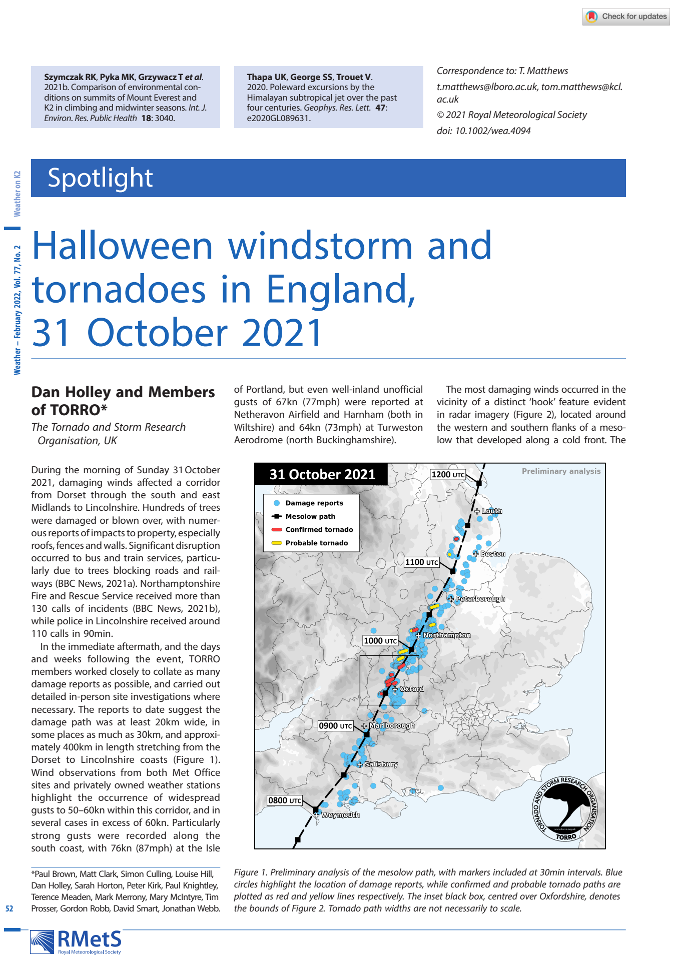
Power spectral density of GNSS

- The cutoff frequency λ is sensitive to the scale of turbulent eddies

- The fluctuation amplitude σ is sensitive to moisture variability



Halloween Storms: UK 31 Oct 2021



Check for updates

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Spotlight

Halloween windstorm and tornadoes in England, 31 October 2021

Dan Holley and Members of TORRO*

The Tornado and Storm Research Organisation, UK

During the morning of Sunday 31 October 2021, damaging winds affected a corridor from Dorset through the south and east Midlands to Lincolnshire. Hundreds of trees were damaged or blown over, with numerous reports of impacts to property, especially roofs, fences and walls. Significant disruption occurred to bus and train services, particularly due to trees blocking roads and railways (BBC News, 2021a). Northamptonshire Fire and Rescue Service received more than 130 calls of incidents (BBC News, 2021b), while police in Lincolnshire received around 110 calls in 90min.

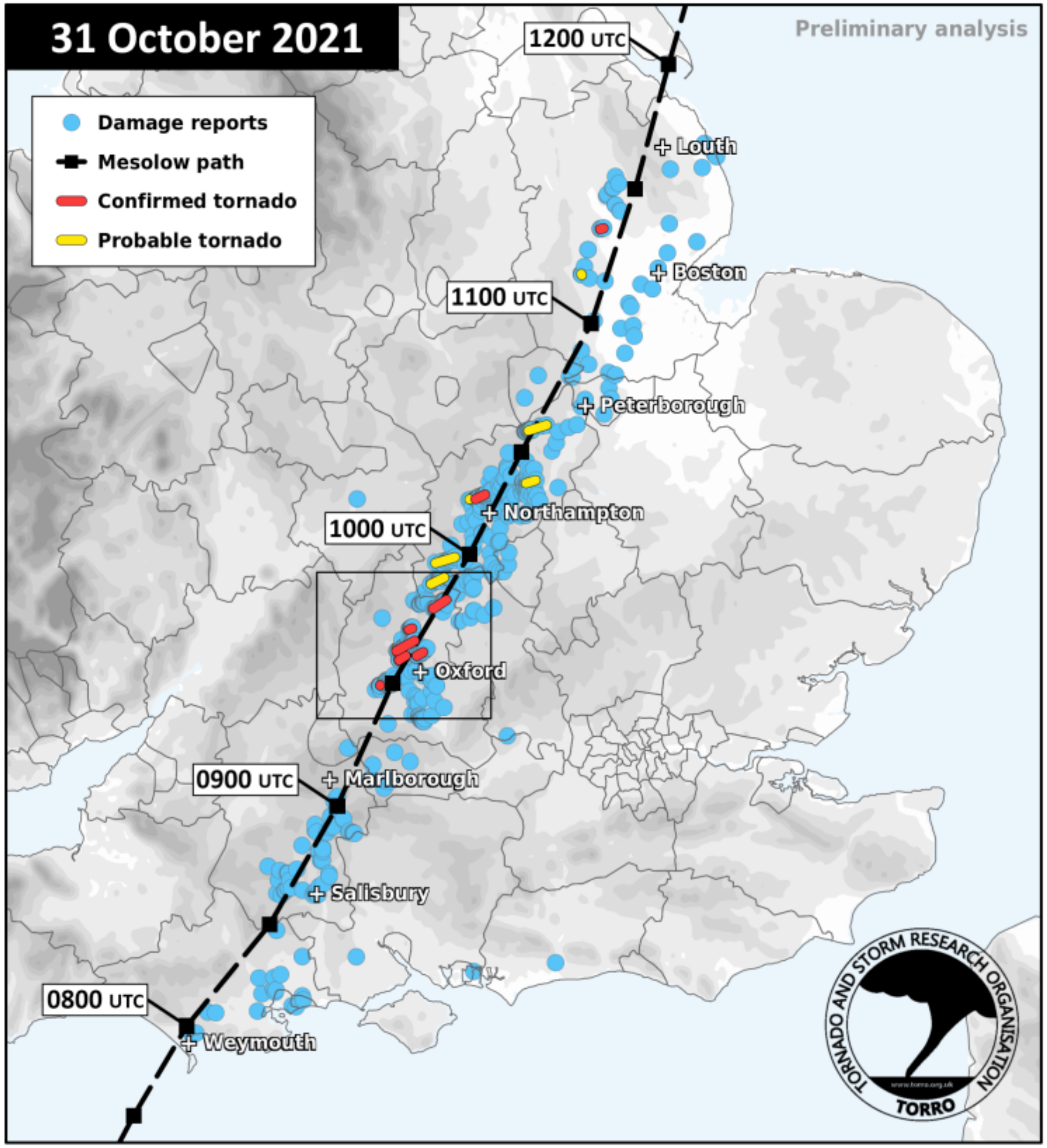
In the immediate aftermath, and the days and weeks following the event, TORRO members worked closely to collate as many damage reports as possible, and carried out detailed in-person site investigations where necessary. The reports to date suggest the damage path was at least 20km wide, in some places as much as 30km, and approximately 400km in length stretching from the Dorset to Lincolnshire coasts (Figure 1). Wind observations from both Met Office sites and privately owned weather stations highlight the occurrence of widespread gusts to 50–60kn within this corridor, and in several cases in excess of 60kn. Particularly strong gusts were recorded along the south coast, with 76kn (87mph) at the Isle of Portland, but even well-inland unofficial gusts of 67kn (77mph) were reported at Netheravon Airfield and Harnham (both in Wiltshire) and 64kn (73mph) at Turweston Aerodrome (north Buckinghamshire).

The most damaging winds occurred in the vicinity of a distinct 'hook' feature evident in radar imagery (Figure 2), located around the western and southern flanks of a meso-low that developed along a cold front. The

Figure 1. Preliminary analysis of the mesolow path, with markers included at 30min intervals. Blue circles highlight the location of damage reports, while confirmed and probable tornado paths are plotted as red and yellow lines respectively. The inset black box, centred over Oxfordshire, denotes the bounds of Figure 2. Tornado path widths are not necessarily to scale.

*Paul Brown, Matt Clark, Simon Culling, Louise Hill, Dan Holley, Sarah Horton, Peter Kirk, Paul Knightley, Terence Meaden, Mark Merrony, Mary McIntyre, Tim Prosser, Gordon Robb, David Smart, Jonathan Webb.

RMetS Royal Meteorological Society



Halloween Storms: GNSS Spectral Analysis

Meteosat-11
SEVIRI
10.8 μ m channel

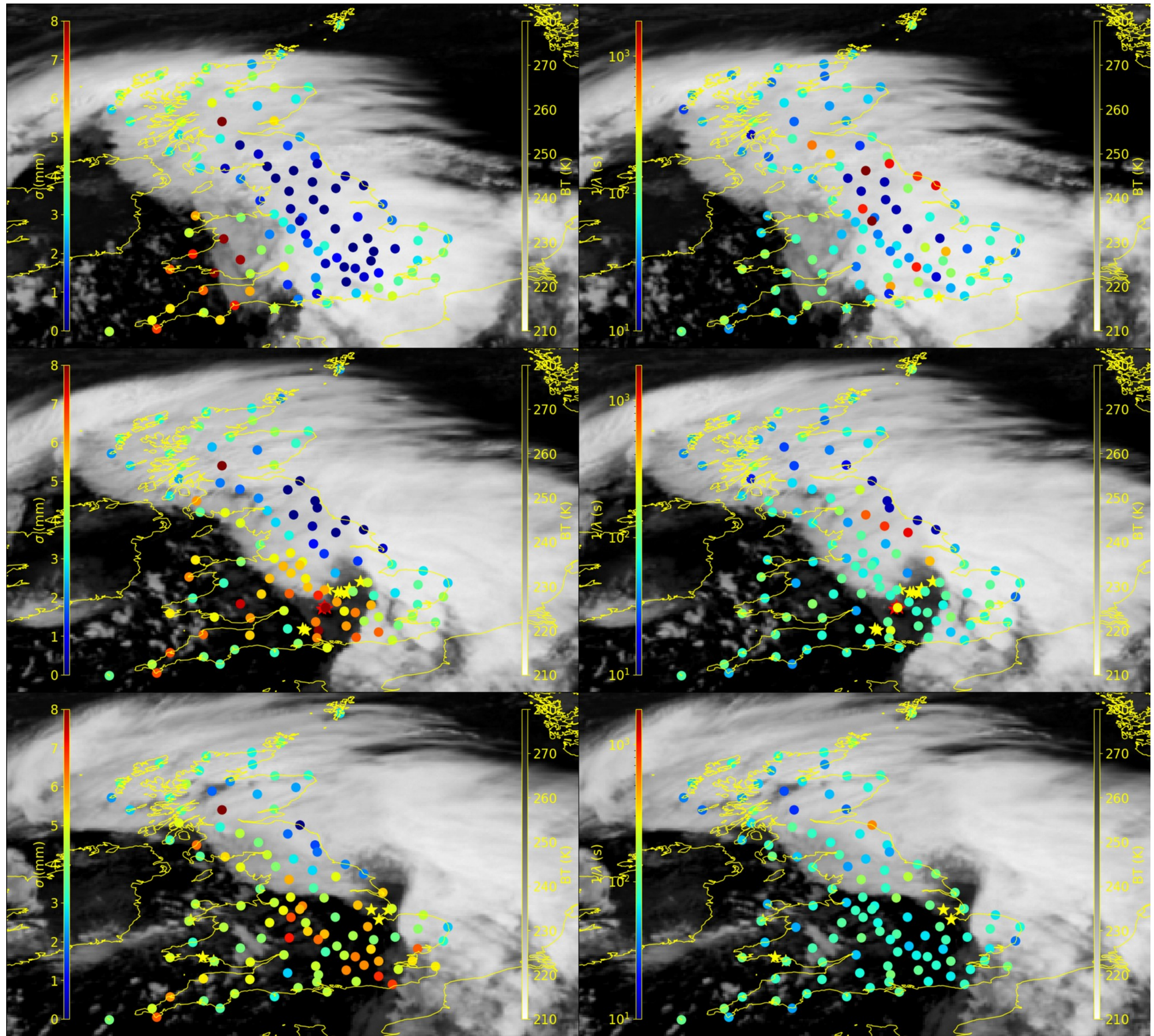
Stars are ESWD reports:
red:Tornado,
yellow:wind

σ $1/\lambda$

8:00Z

10:00Z

11:45Z



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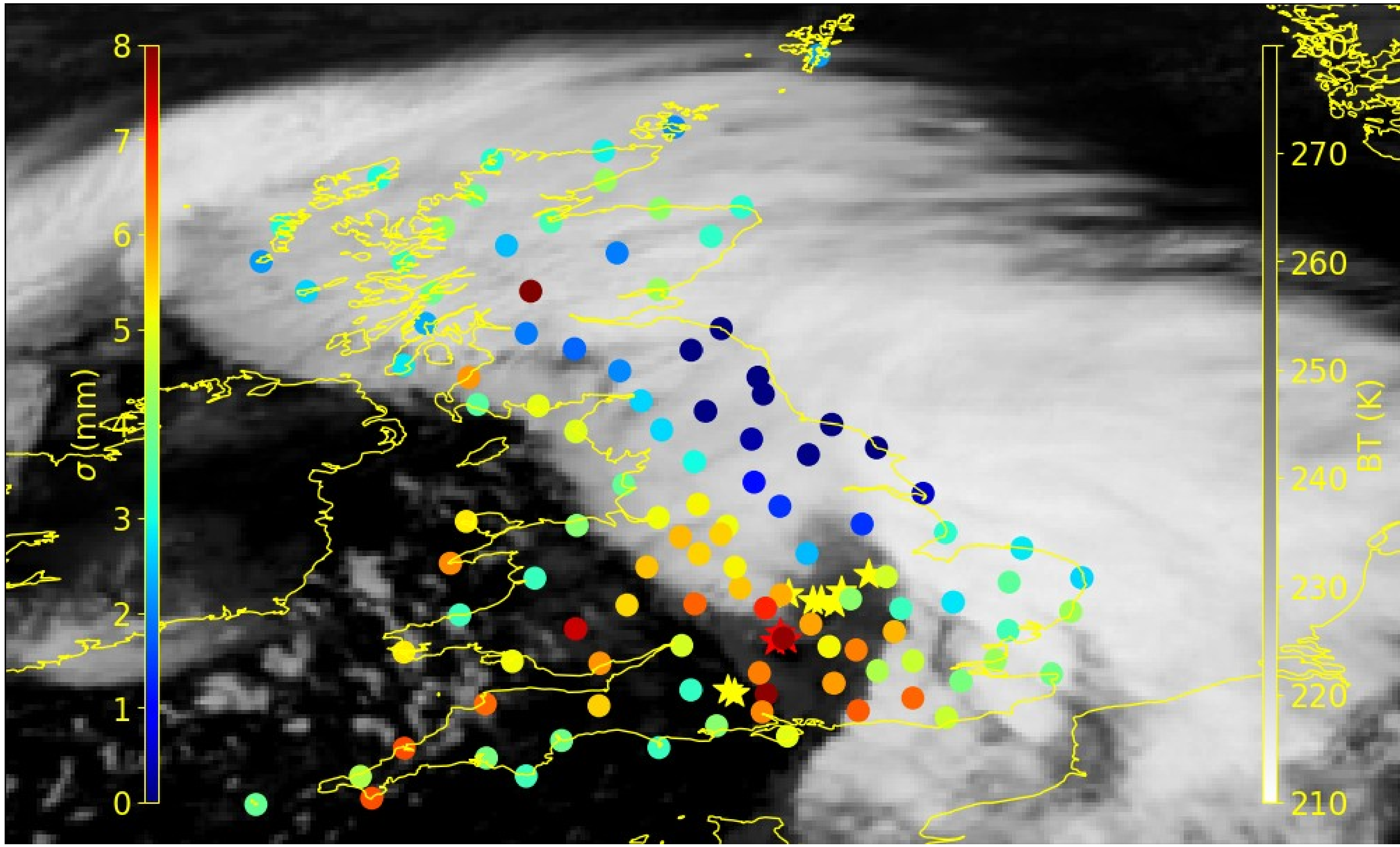
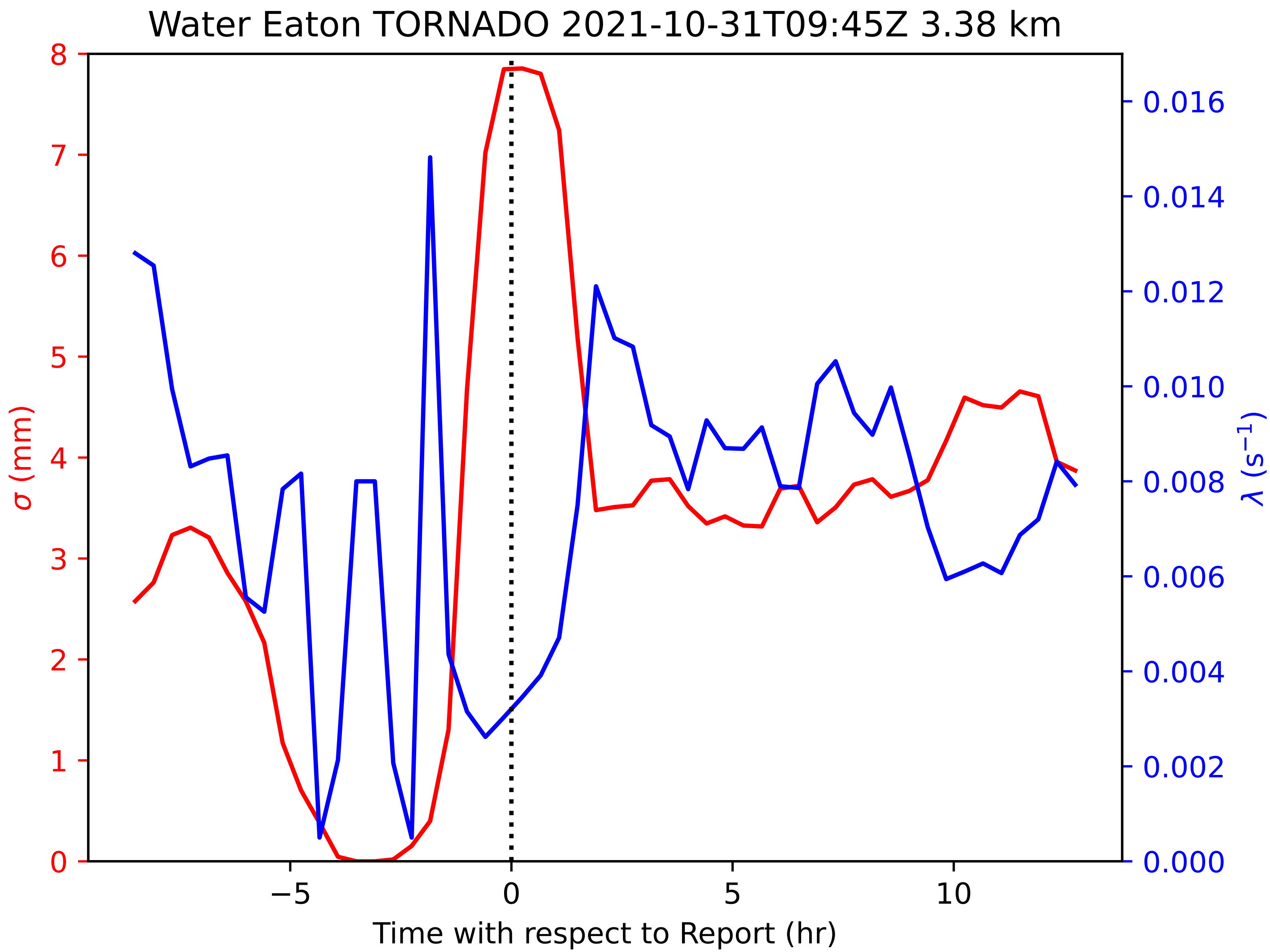


Halloween Storms: GNSS Time Series



GNSS Measurements: Conclusion

- The rapid fluctuations of GNSS delay can be used as a detection, or even precursor, of severe weather (convection)

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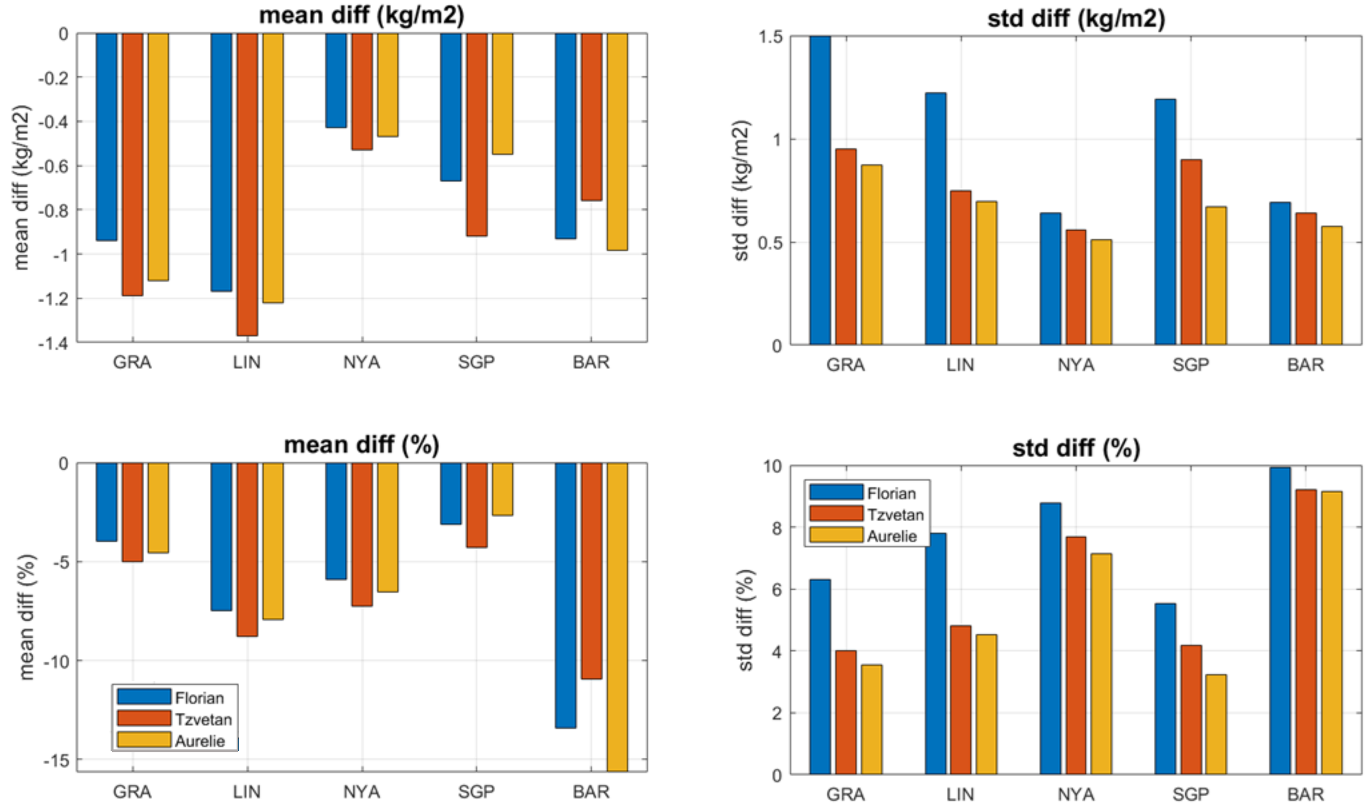
GNSS TCWV biases with respect to GRUAN Sondes

4. Comparison of results (1/2)



GNSS – RS41.GDP comparisons (various periods)

GNSS TCWV biases with respect to GRUAN Sondes

4. Comparison of results (2/2)

- All three studies found:
  - an overall dry bias in GNSS PW vs RS41.GPD PW of – 0.5 kg/m2 or –5 % (and also vs RS92.GDP and MWR)
  - site-to-site variability in bias ± 0.5 kg/m2 (GNSS site/equipt-dependent errors)
- But results don't fully agree:
  - dispersion between studies, in bias and stdev, due to differences in:
    - GNSS ZTD data products (≈ ± 5 mm ≈ ± 0.75 kg/m2 random),
    - GNSS ZTD to PW conversion (≈ ± 0.2 to 0.5 kg/m2 bias + random),
    - correction for height difference btw sonde and GNSS (10m ≈ 0.1 kg/m2),
    - other methodological details (outliers removal, check for missing layers in sonde data...)
- Metrological closure cannot be satisfied
  - biases and outliers in data sets
  - std(Δ) ≈ 1.2 to 1.7 x mean(uc(Δ))
  - GNSS PW uc is probably under-estimated (what about RS PW uc ?)

GNSS TCWV biases with respect to GRUAN Sondes

• In a similar way to Infrared (i.e. IASI) and Microwave (i.e. MHS) passive sensors, could the WV variability inside the Field Of View (FOV) bias the measurement?

•Hypothesis: Could the GNSS variability contribute to the GNSS biases?

• Now we have a way to measure and quantify the variability, we can check whether this hypothesis is consistent with data →
We could plot variability (σ) versus bias →

CONTRIBUTIONS WELCOME!!