Identification of travelling ionospheric disturbances in the ionosphere using GPS - with independent verification

Ionospheric Effects Symposium 2017

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Motivation

- TIDs studied for 70 years but very little in the way of wide area studies over continental scales
- Today by far the most numerous ionospheric data source is GPS
- Notable good case studies showing TIDs in GPS TEC but lacking an automated and reliable approach
- Investigate approaches to the analysis and look for ways forward

Plan

Simulations

- Using of dual-frequency GPS observations
- Using single frequency SBAS GEO GPS observations
- Data assimilation using MIDAS

  Use of both phase observations and time-dependence together

Observations

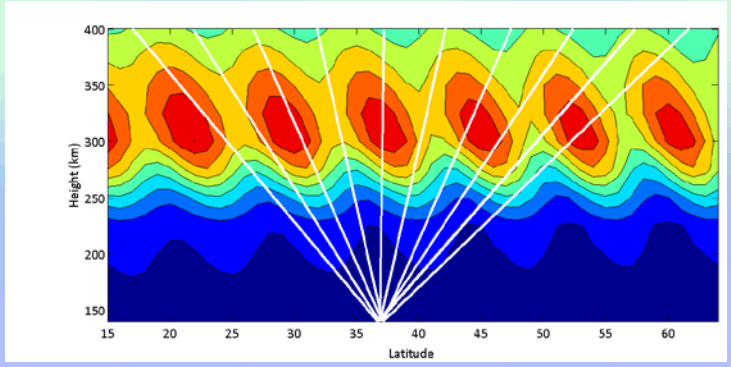
- Validation of SBAS GEO GPS observations by ionosonde
- Validation of data assimilation by ionosonde
- What does the ionosphere really look like?

Approach

Simulation

Simulate the ionosphere using the IRI plus the Hooke model of TIDs – 4D simulation, i.e. time dependent

Integrate through this model from real GPS receiver locations to actual satellite positions every 60s



1000 km wavelength, 140 m/s, s-w direction

Amplitude 10%

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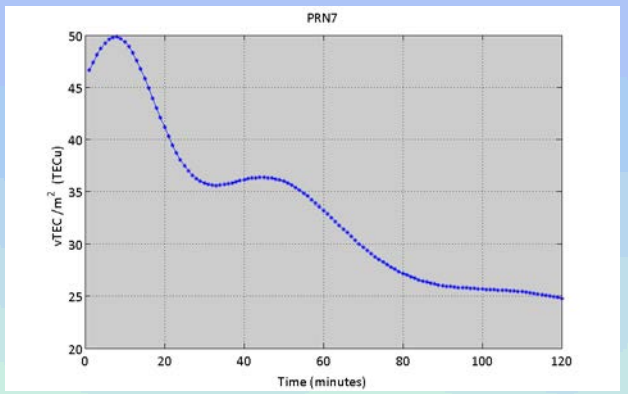
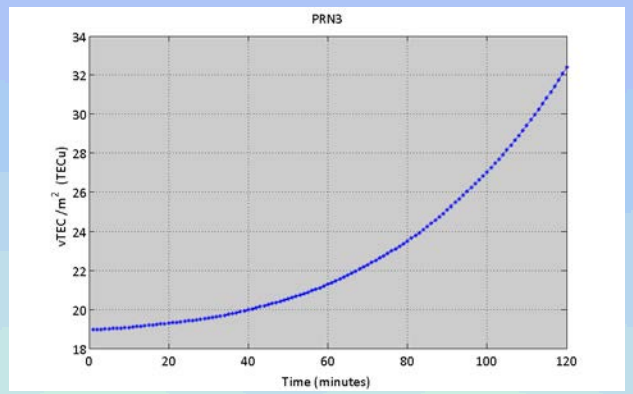
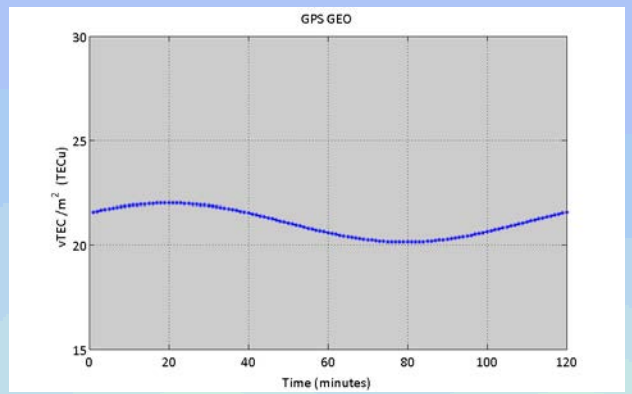
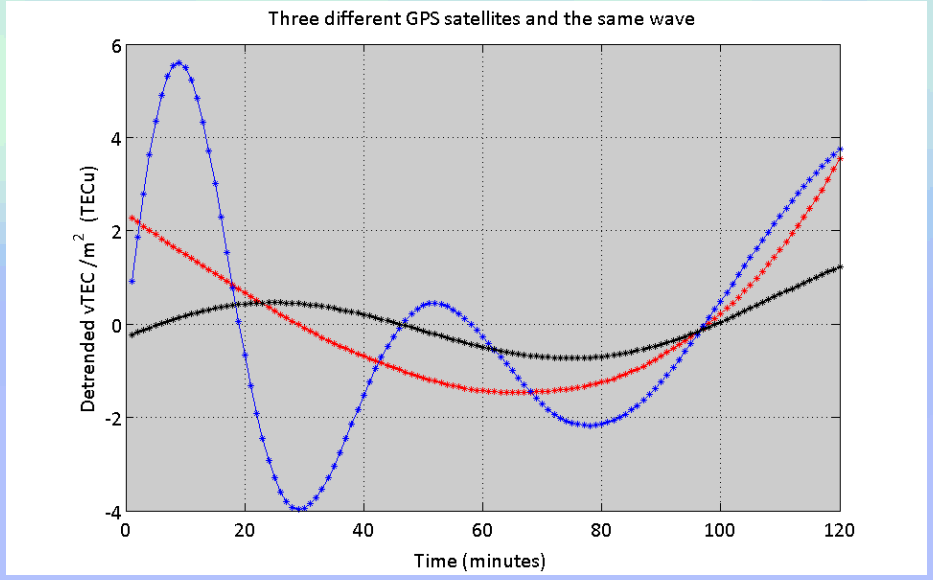
Results

Simulations of TEC produced simply by integration through the Hooke TID model to three different GPS satellites – which one shows the correct wave period?









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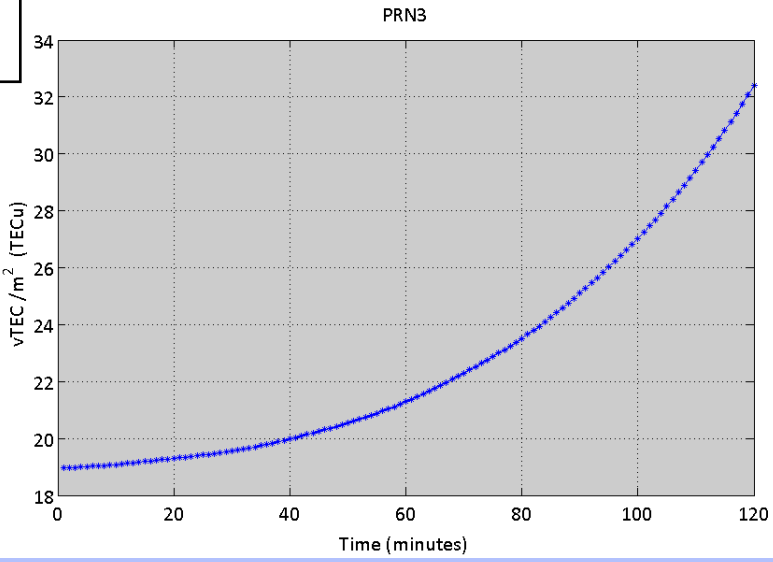
PRN 3

Simulation



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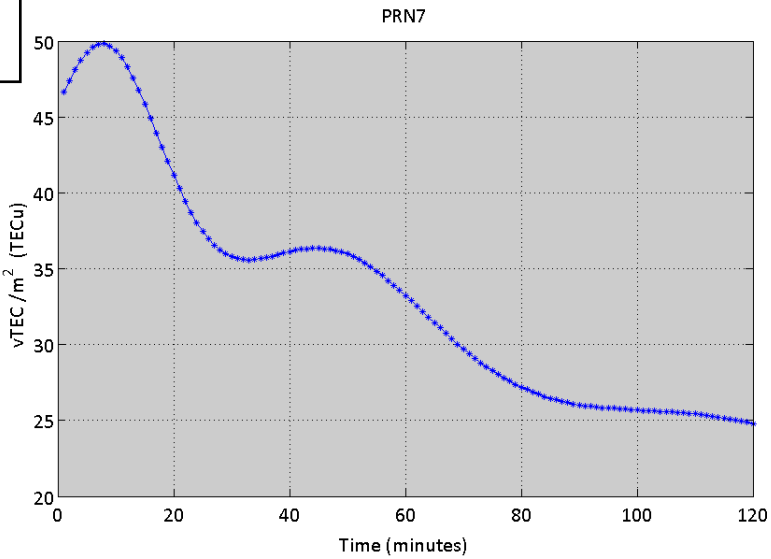
PRN 7

Simulation



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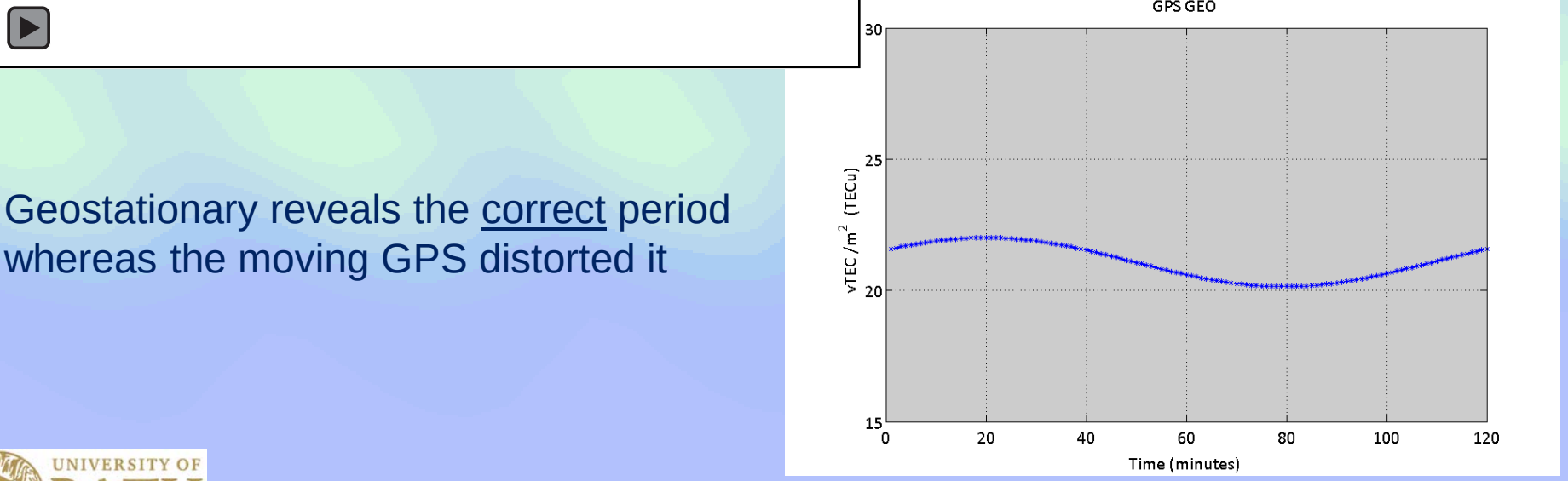
GPS GEO

Simulation



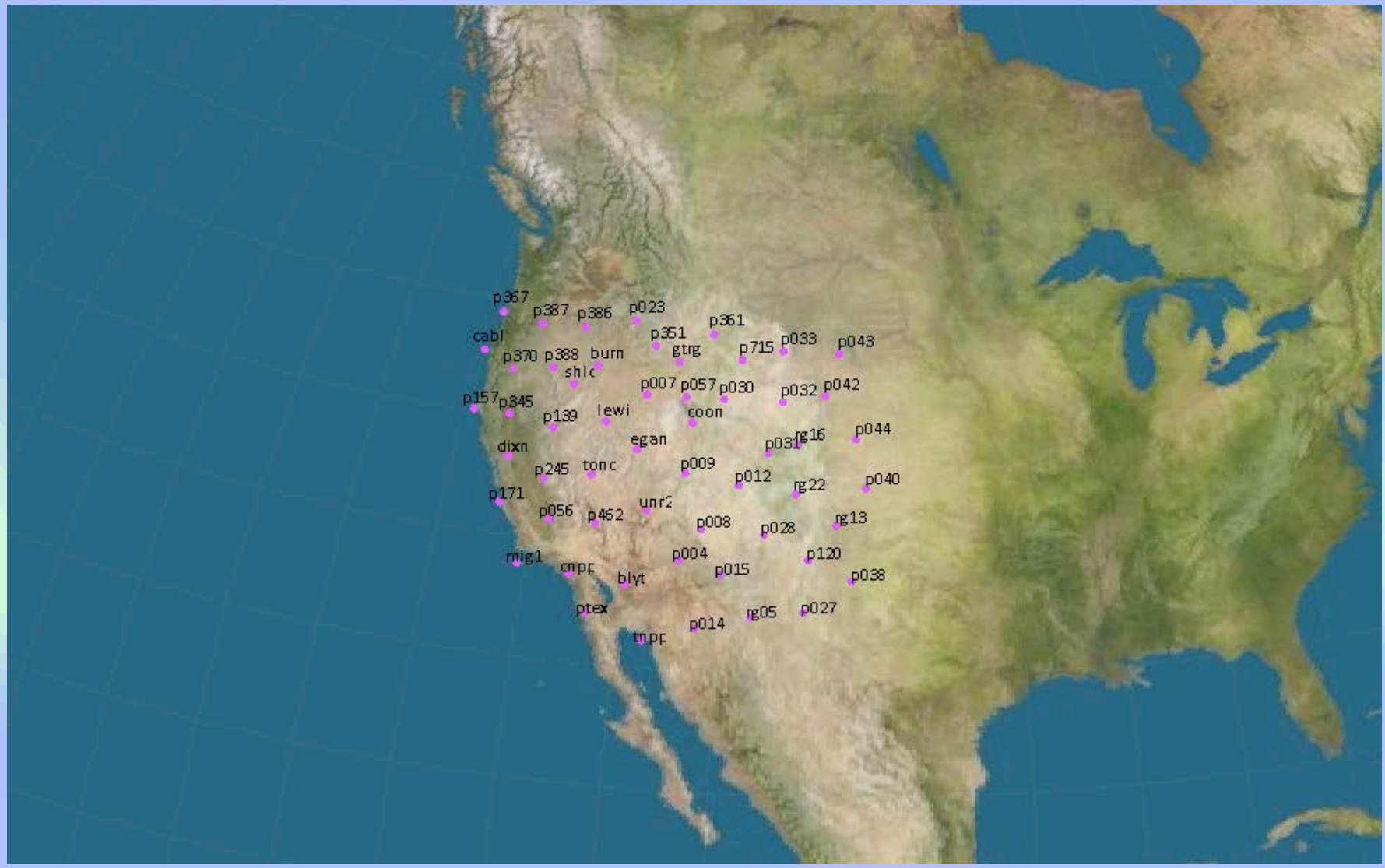
Geostationary reveals the correct period whereas the moving GPS distorted it

What next?

- Some cases will work – TIDS moving much faster than the GPS ray-paths - then provided the wave field were coherent across a large region this could be determined by comparing all satellites – if they all see the same period then great
- Or we can use a GEO to provide a reference
- And can we do anything more general?

MIDAS data assimilation

Simulation



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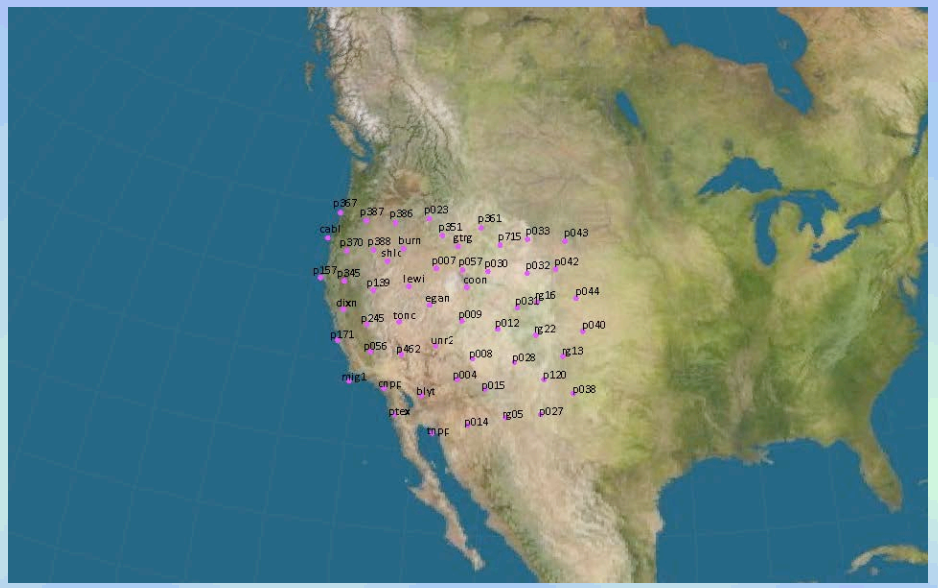
TID MIDAS reconstruction

Simulation



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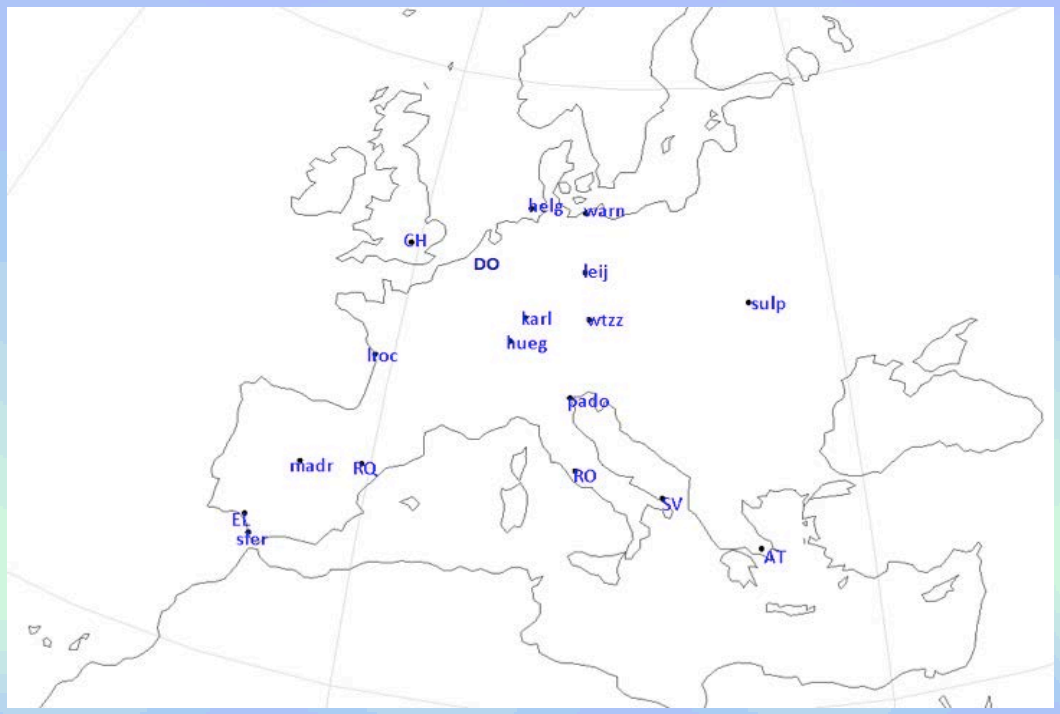
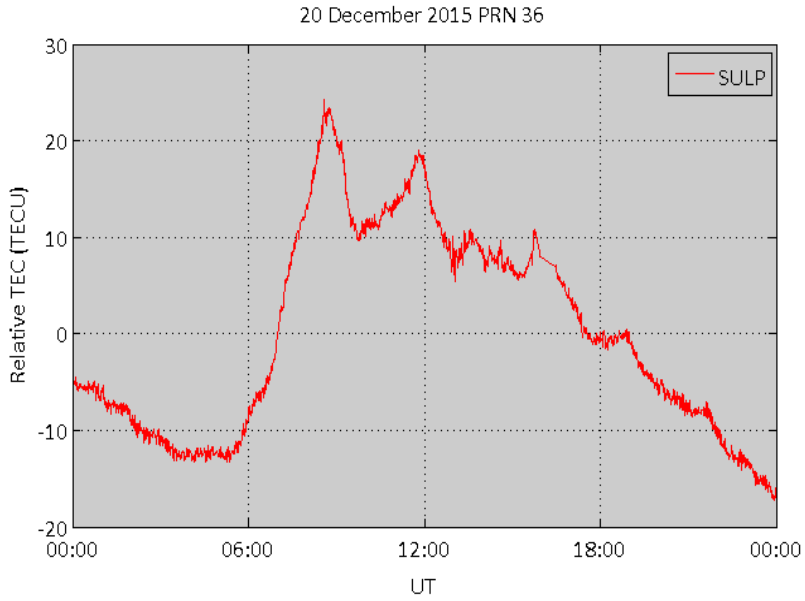
What next?

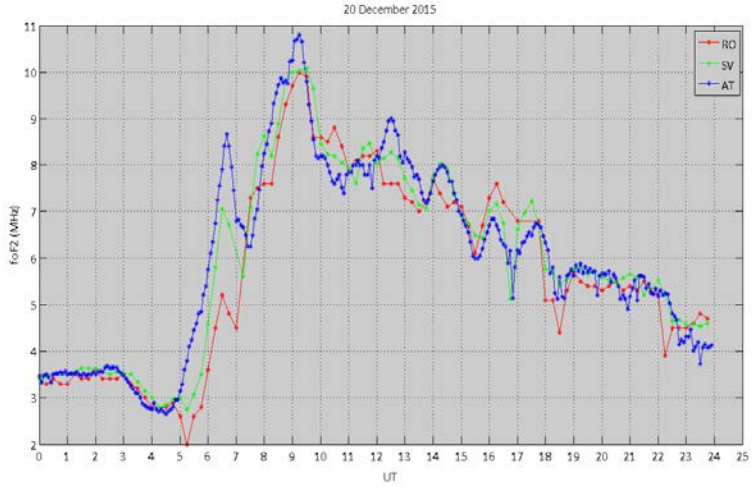
- But are large-scale waves coherent across such a region?
- Maybe in a geomagnetic storm?
- 20 December 2015 over Europe – good ionosonde and GPS GEO coverage

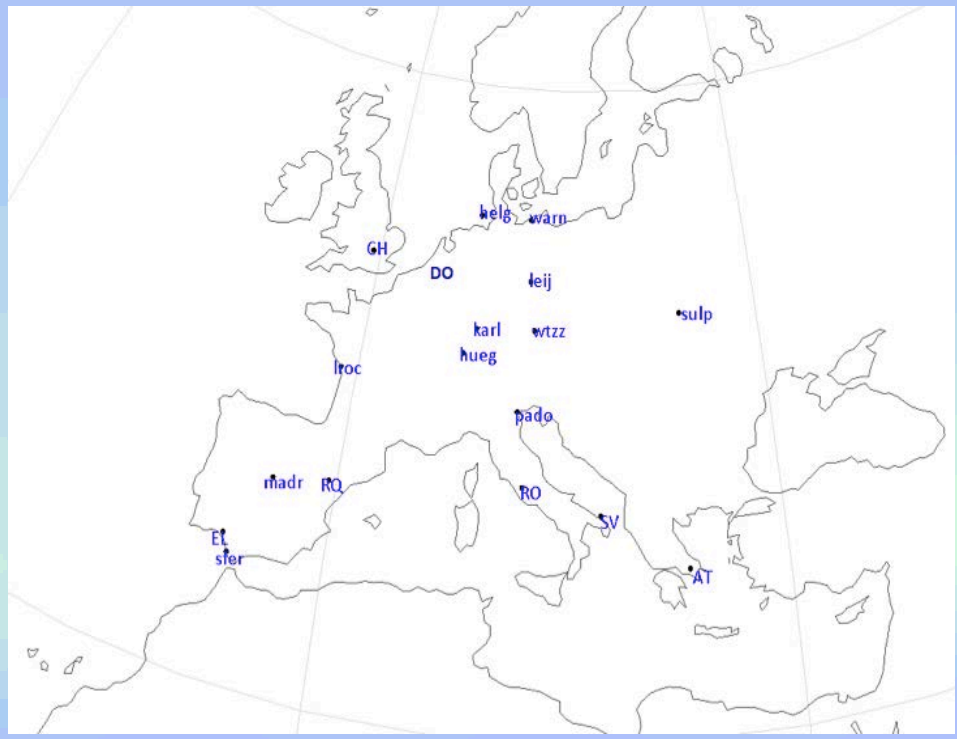


GEO compared to ionosonde

Real experiment







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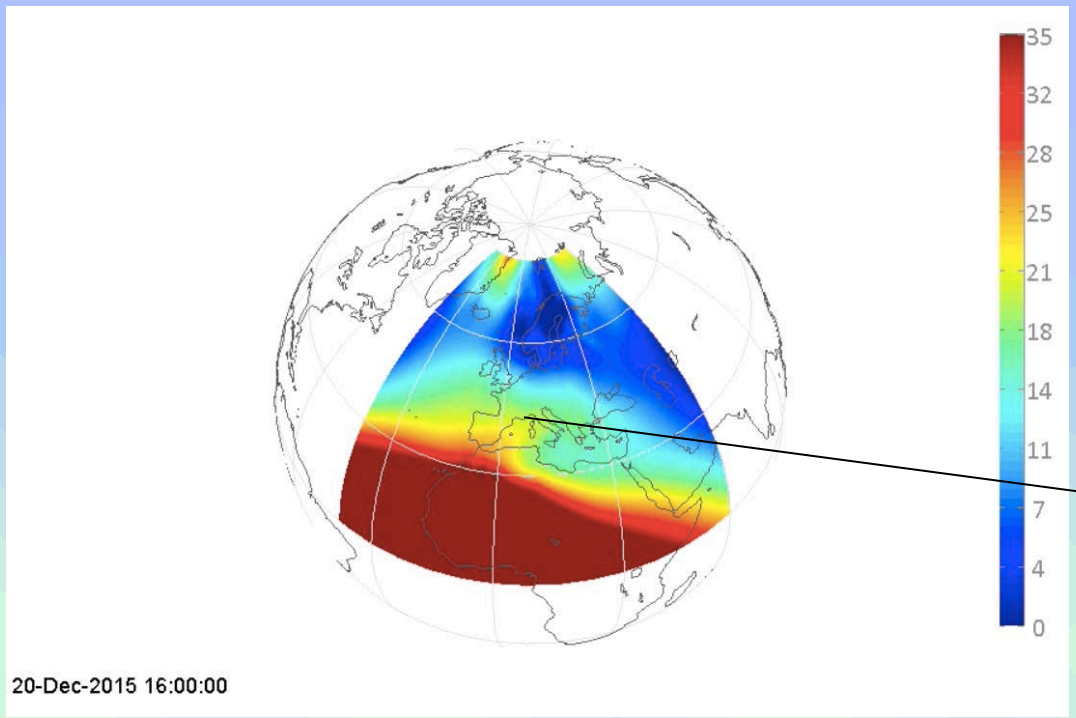
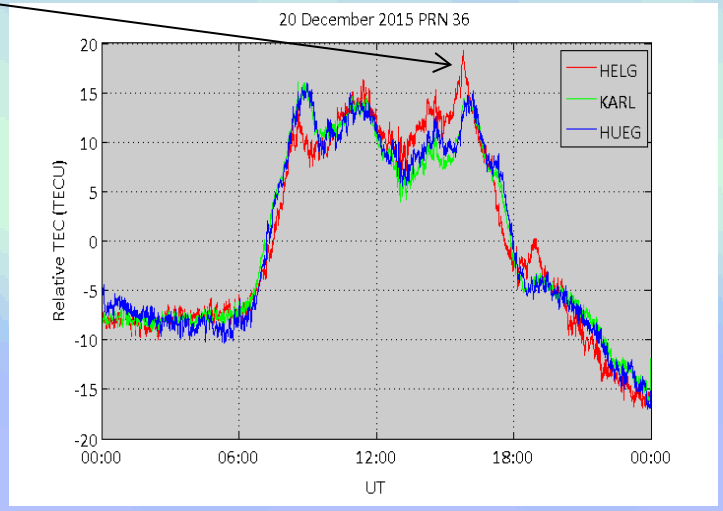
MIDAS compared to GEO

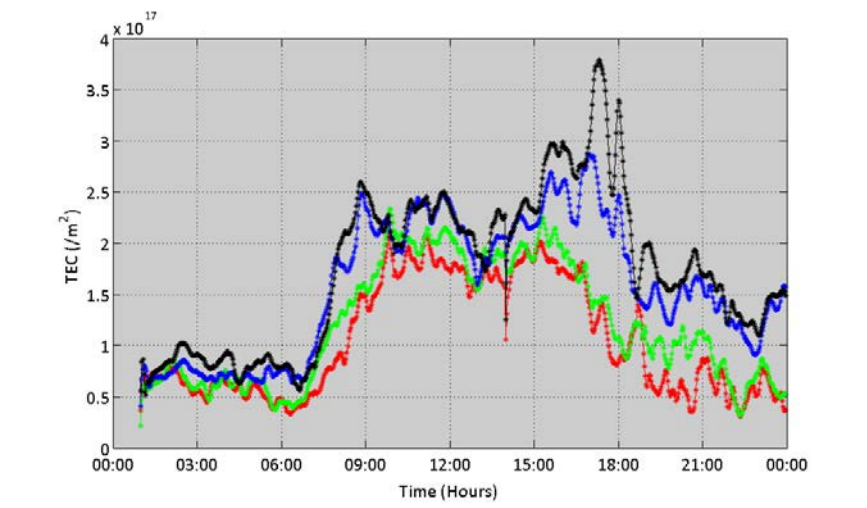
Real experiment

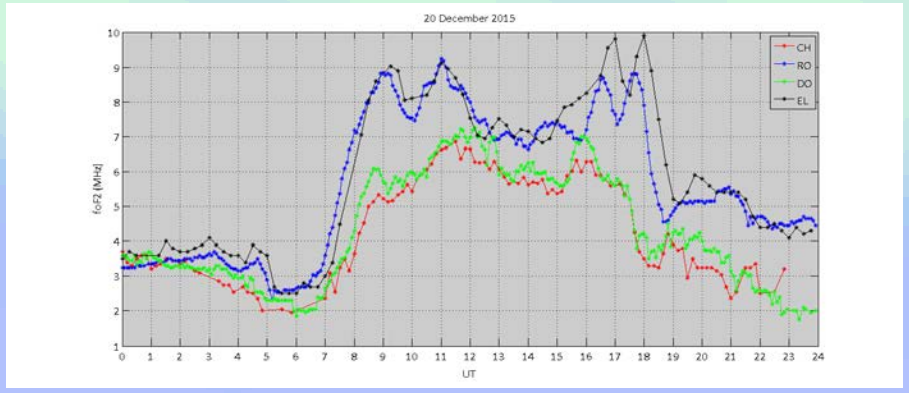


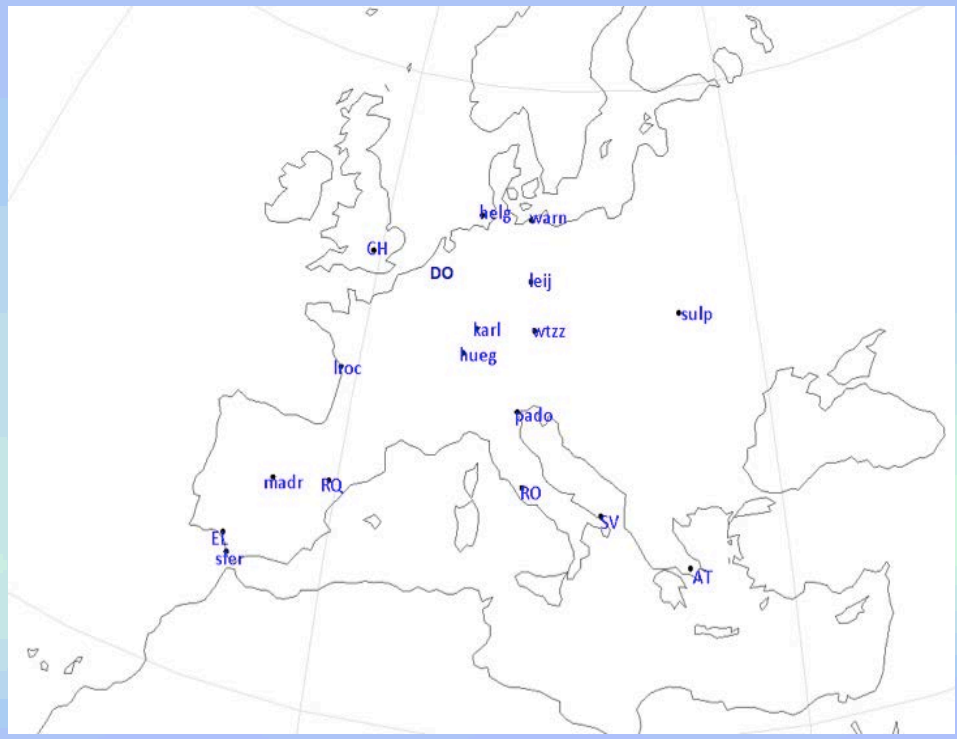


MIDAS compared to ionosonde

Real experiment







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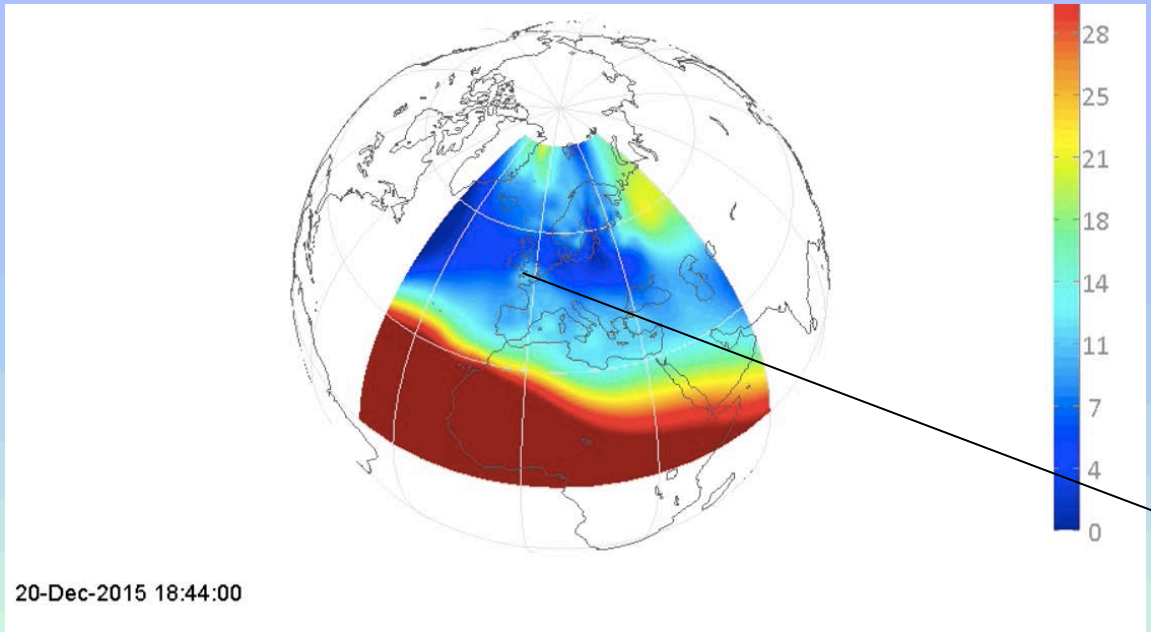
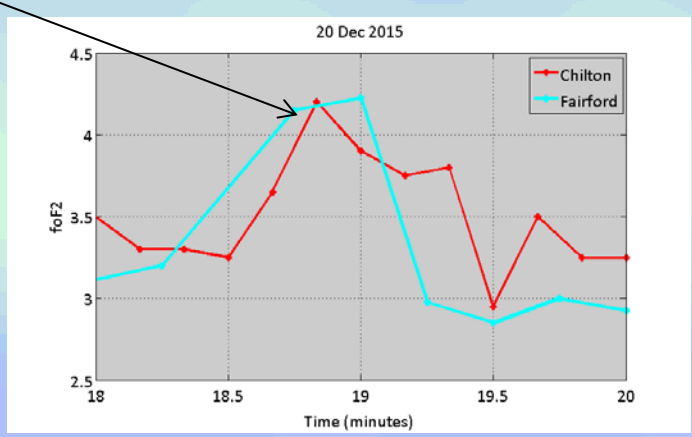
MIDAS compared to ionosonde

Real experiment





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MIDAS TEC movie

Real experiment

Conclusions

- We are really close to having a full 3D time dependent picture of TIDs across continental-scale regions
- There are often hundreds of GNSS receivers across a region but only a few satellites limiting our viewing geometry – there will be more multi-constellation GNSS receivers in the future
- GPS receivers monitoring the geostationary signals are really useful because they can be used to reliably extract TID periods– at present we are using single frequency L1 but dual frequency will soon be routinely used (L1 L5)
- The first results here indicate that the full 3D time dependent picture of TIDs may not be *quite* as simple as we imagined

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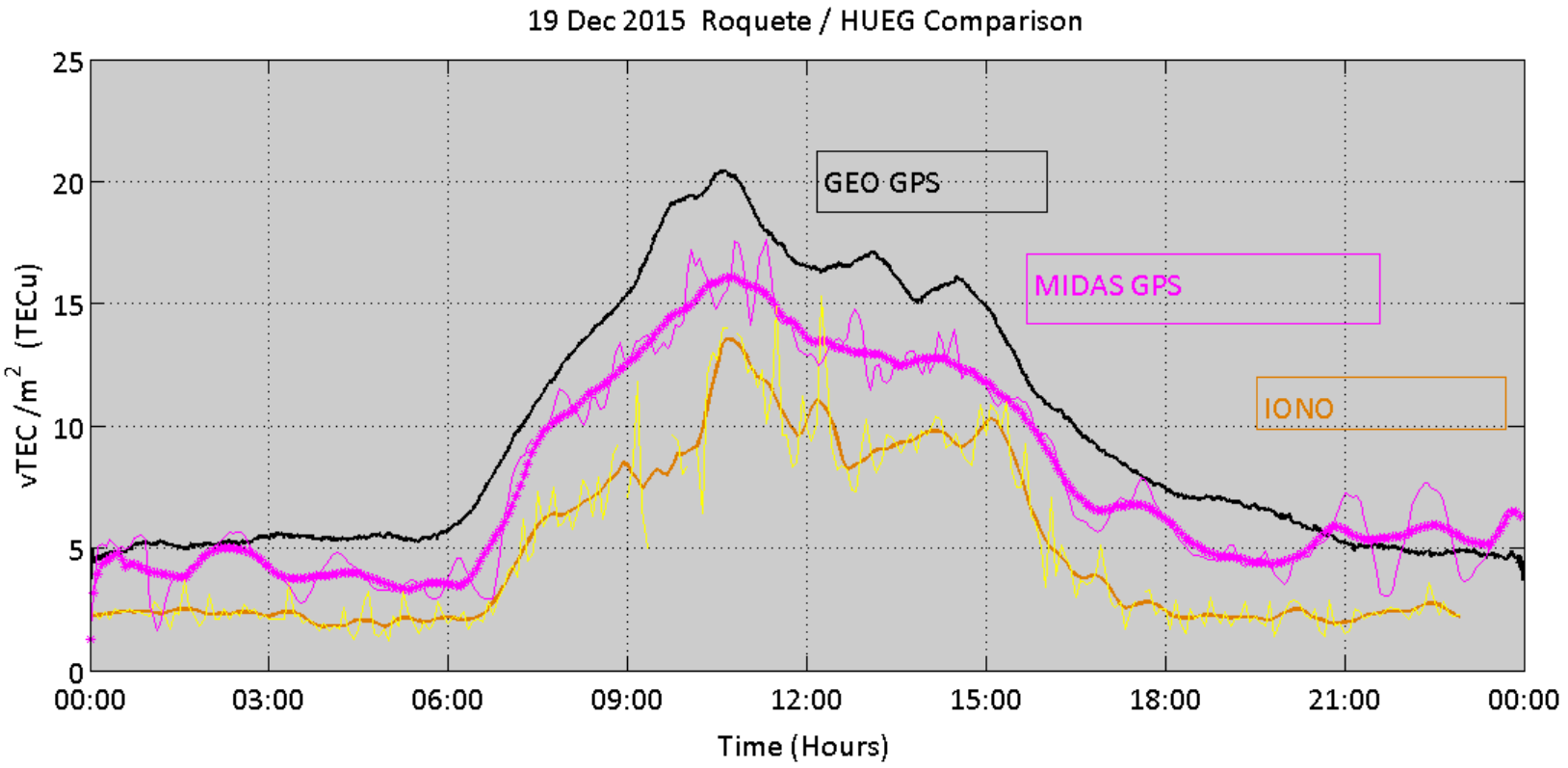
General Case



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