Spaceborne GNSS-R: Results from the UK TechDemoSat-1 mission

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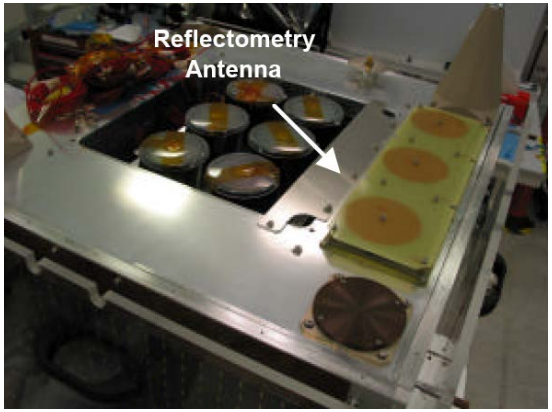
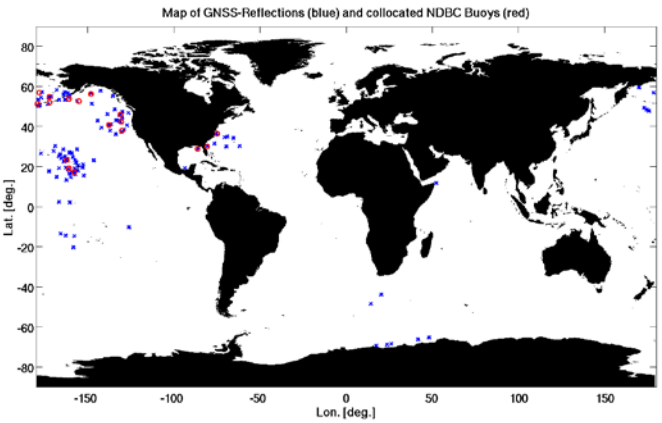
SSTL & NOC: a long-term partnership

2003
Proof-of-concept on
SSTL's UK-DMC





Collected ~ 50 data points
over ocean

8 July 2014
UK TechDemoSat-1
launch with SGR-ReSI
GPS-R payload

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Dec 2016
NASA Cyclone Global
Navigation Satellite
System (CYGNSS) mission

Constellation of
8 SGR-ReSI

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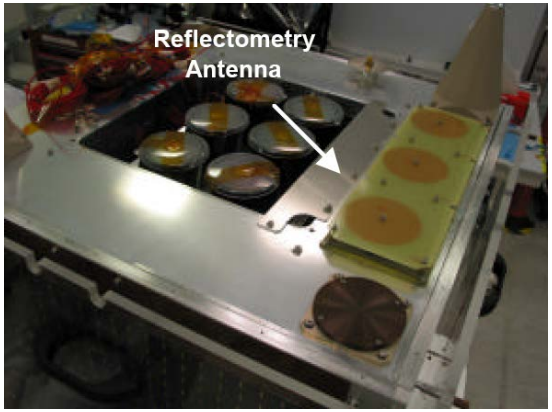

CEOI

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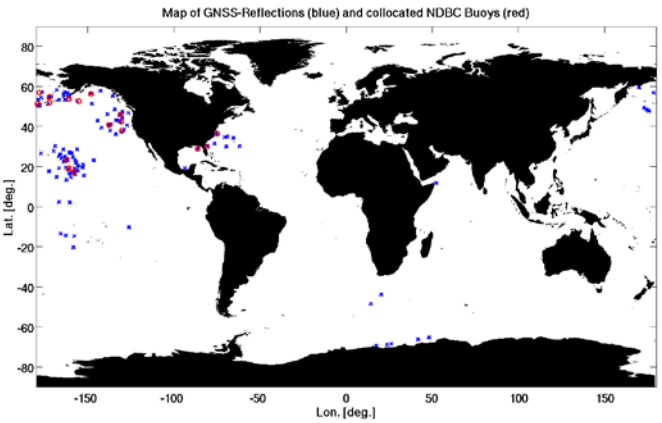

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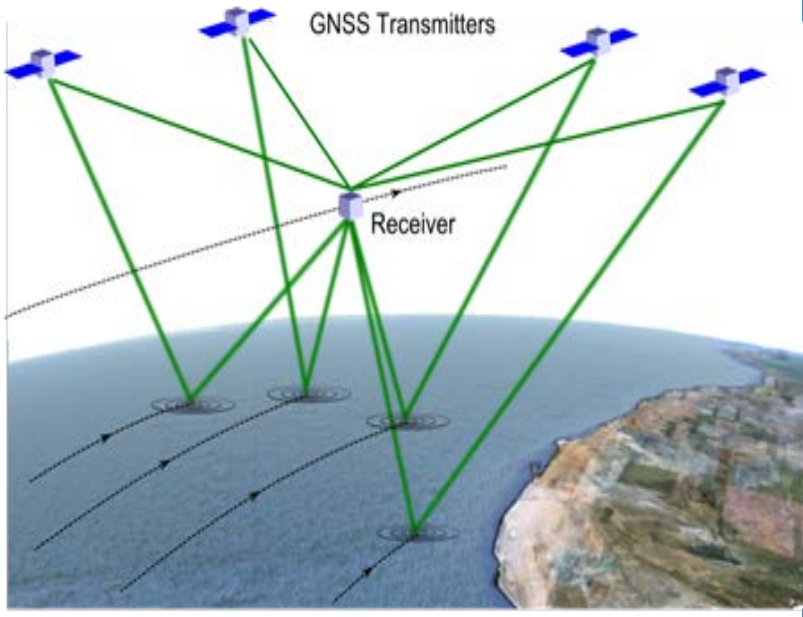
WEATHER MEASUREMENTS FROM SPACE

- Weather knowledge more important, globally, than ever before
  - Cyclones/storms, climate prediction, blue economy
- Small Satellites can offer great complement to flagship missions
  - Spatial and temporal resolution
- Potential for GNSS remote sensing EO recognised
  - Via GNSS Radio-Occultation

GNSS REFLECTOMETRY



GPS / GNSS satellites continually transmit towards Earth, globally

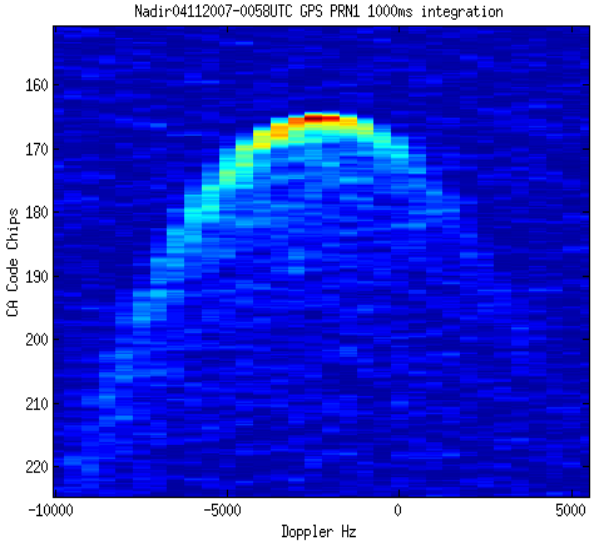
- Some 120 signal sources

UK-DMC satellite demonstrated GNSS reflections can be collected

- Weak signals, but contain imprint of wind-driven waves
- Can measure **wind speed** over ocean

RADAR scatterometer satellite – without transmitter!

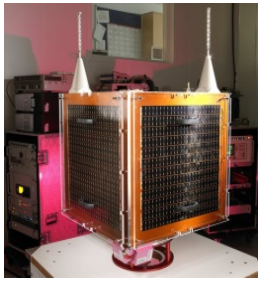
- Ideal for small satellites



UK-LED PROGRESS TOWARDS SERVICE

UK-DMC Satellite (2003)

Feasibility demo



SGR-ReSI Development (2010)

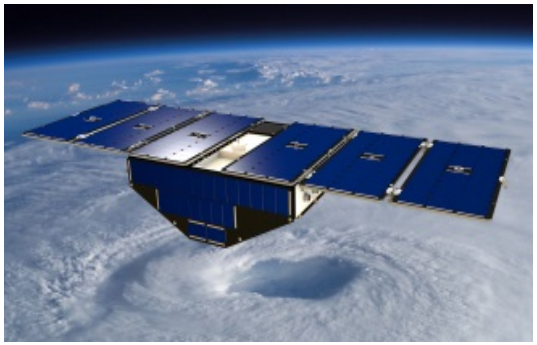
GNSS-R Instrument

UK TechDemoSat-1 (2014)

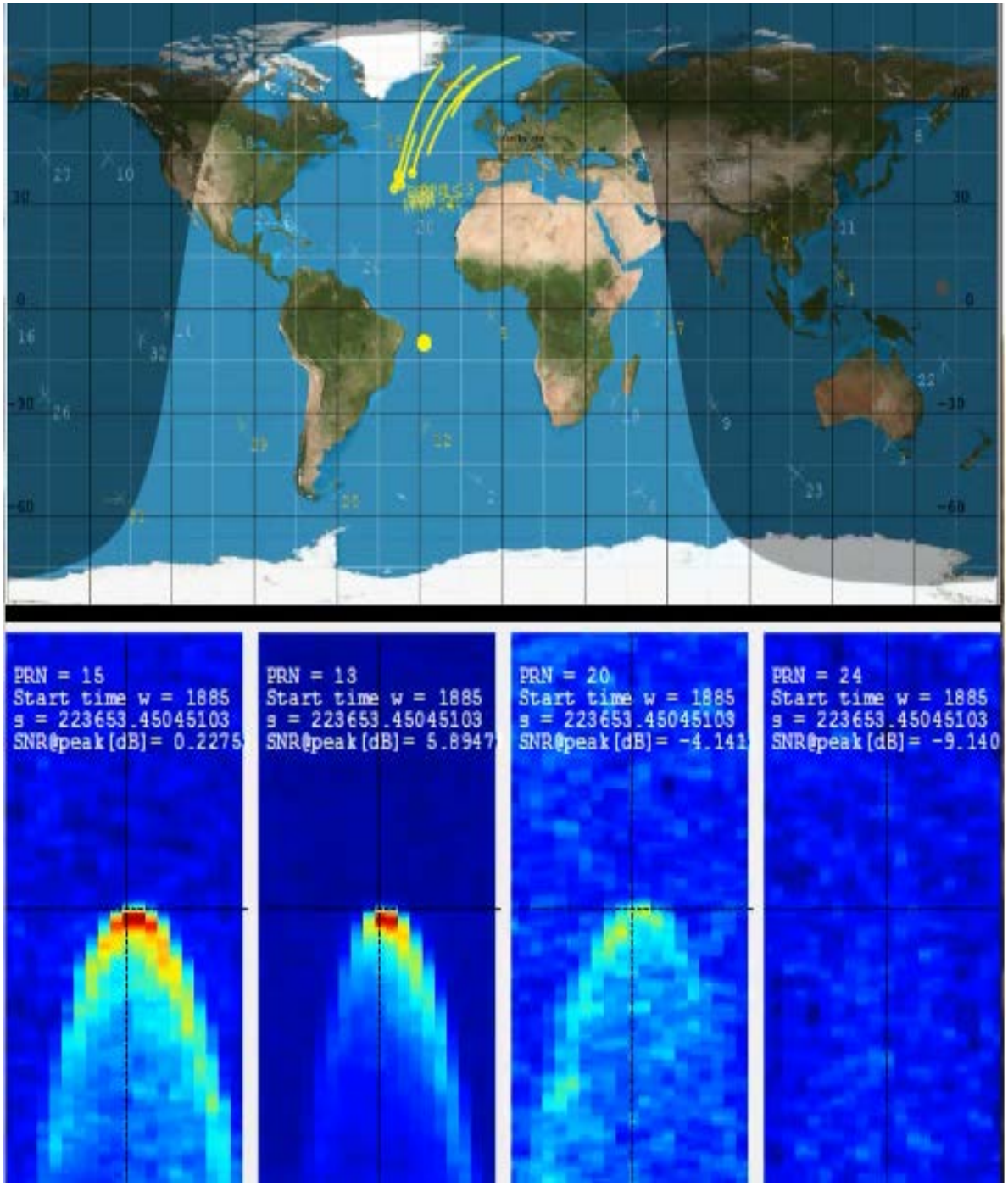
First flight of SGR-ReSI

NASA CYGNSS (2016)

Using SGR-ReSI for cyclone sensing

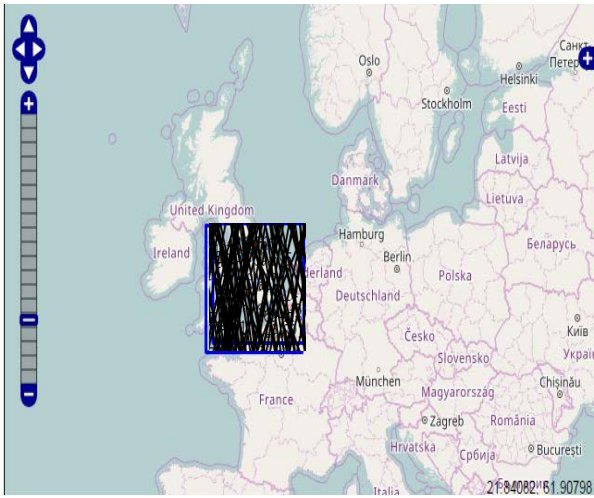


Demo of GNSS Reflectometry with TDS-1



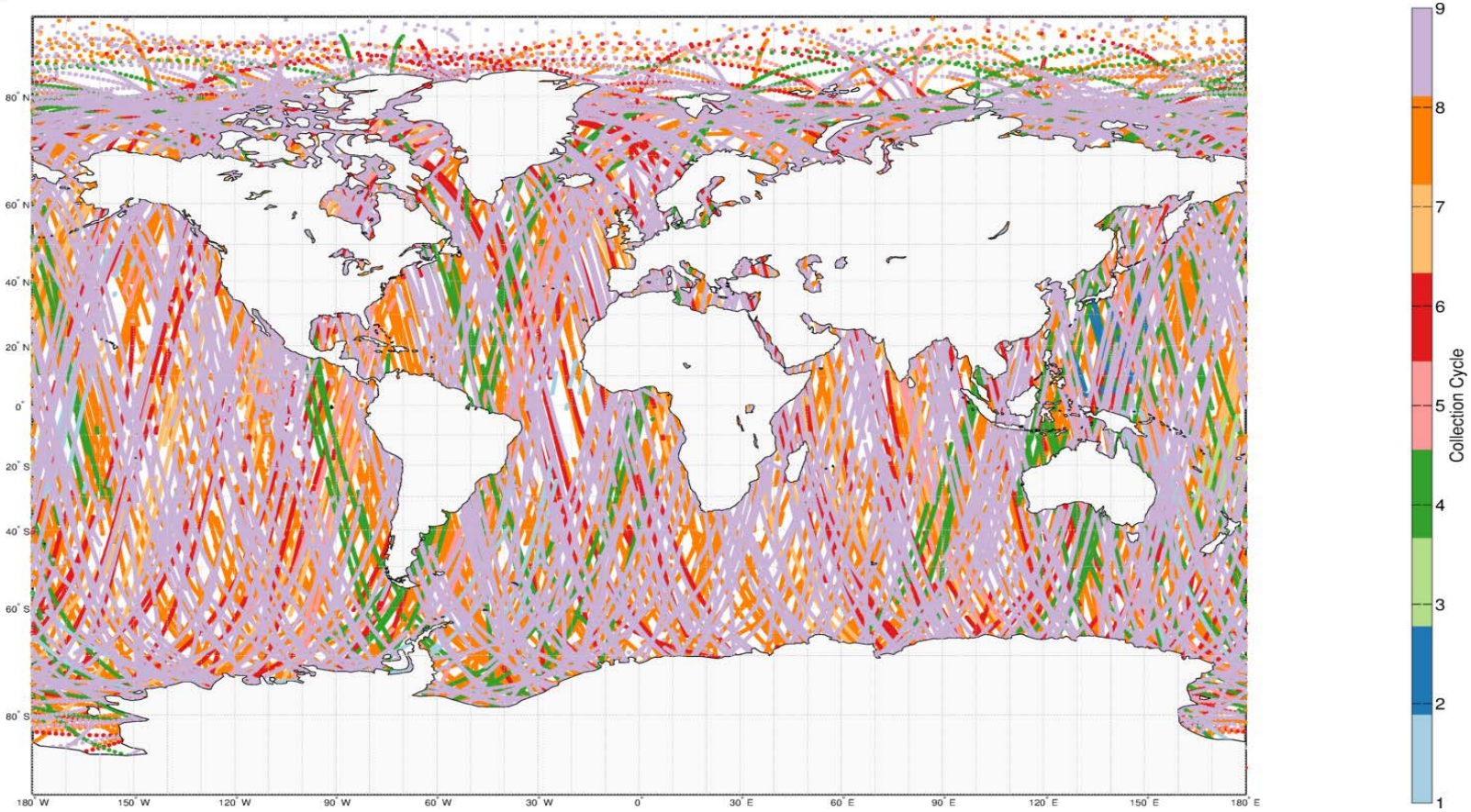
EXPLOITING SGR-ReSI on TDS-1

1. Share data with scientific partners
   SSC (Uni.Surrey), National Oceanography Centre
2. Develop, validate products (wind speed)
   Accuracy of 2 m/s is feasible
3. Develop web catalogue access
   Searchable database, or FTP
4. Share data with wider community
   Free non-commercial licence (non-real-time)



First global spaceborne GNSS-R data from receiver on TDS-1

World First

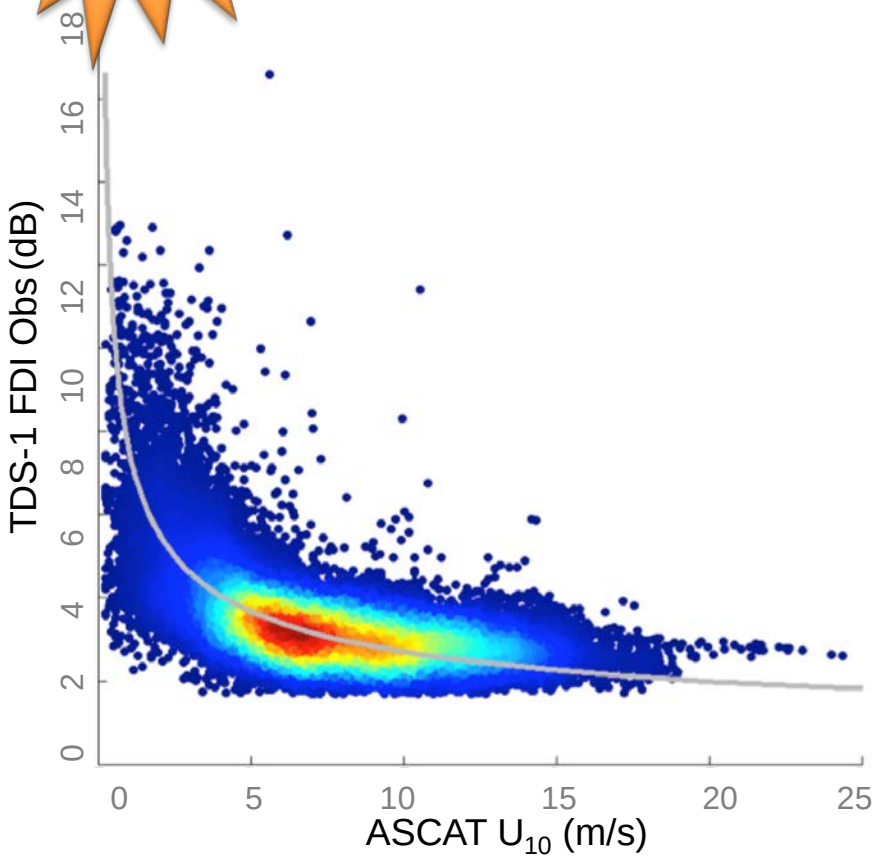


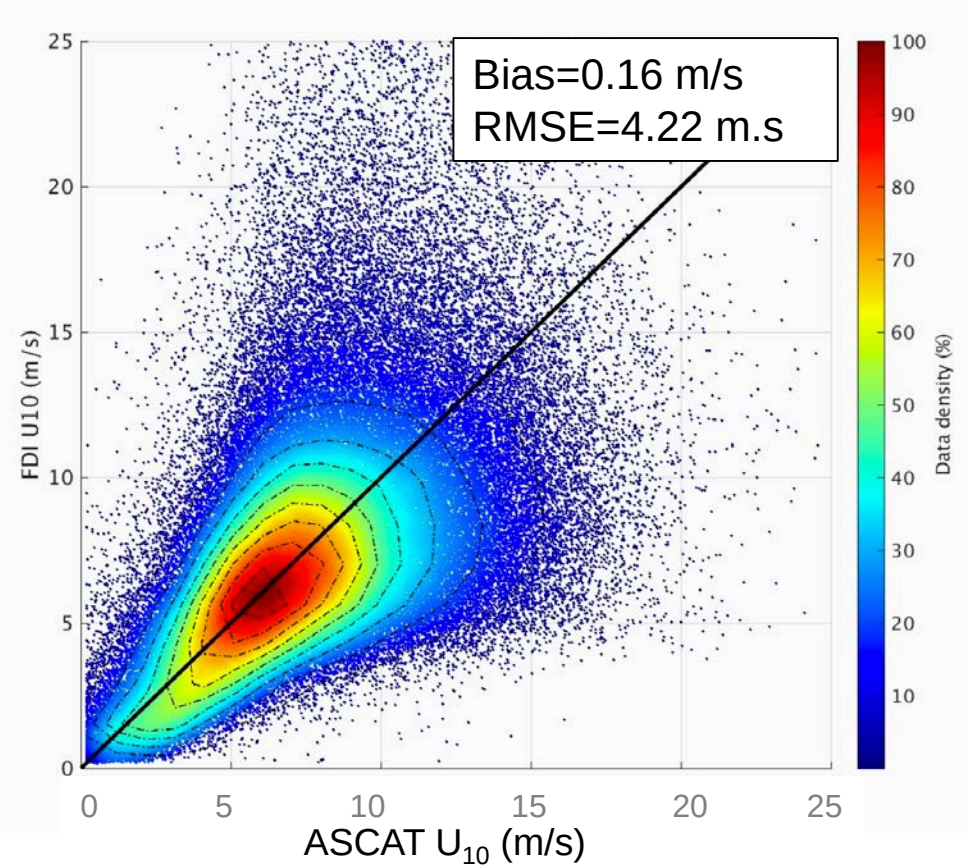
- Large global GNSS-R dataset => Massive data uptake worldwide => many new applications
- Dedicated GNSS-R workshops and sessions at international conferences; Scientific journal special issue on TDS-1 in IEEE JSTARS
- Unwin et al (2016) TDS-1 paper wins JSTARS 2017 Best Paper Award (IGARSS'2017)

World First

First GNSS-R winds

(all reflections in antenna footprint)



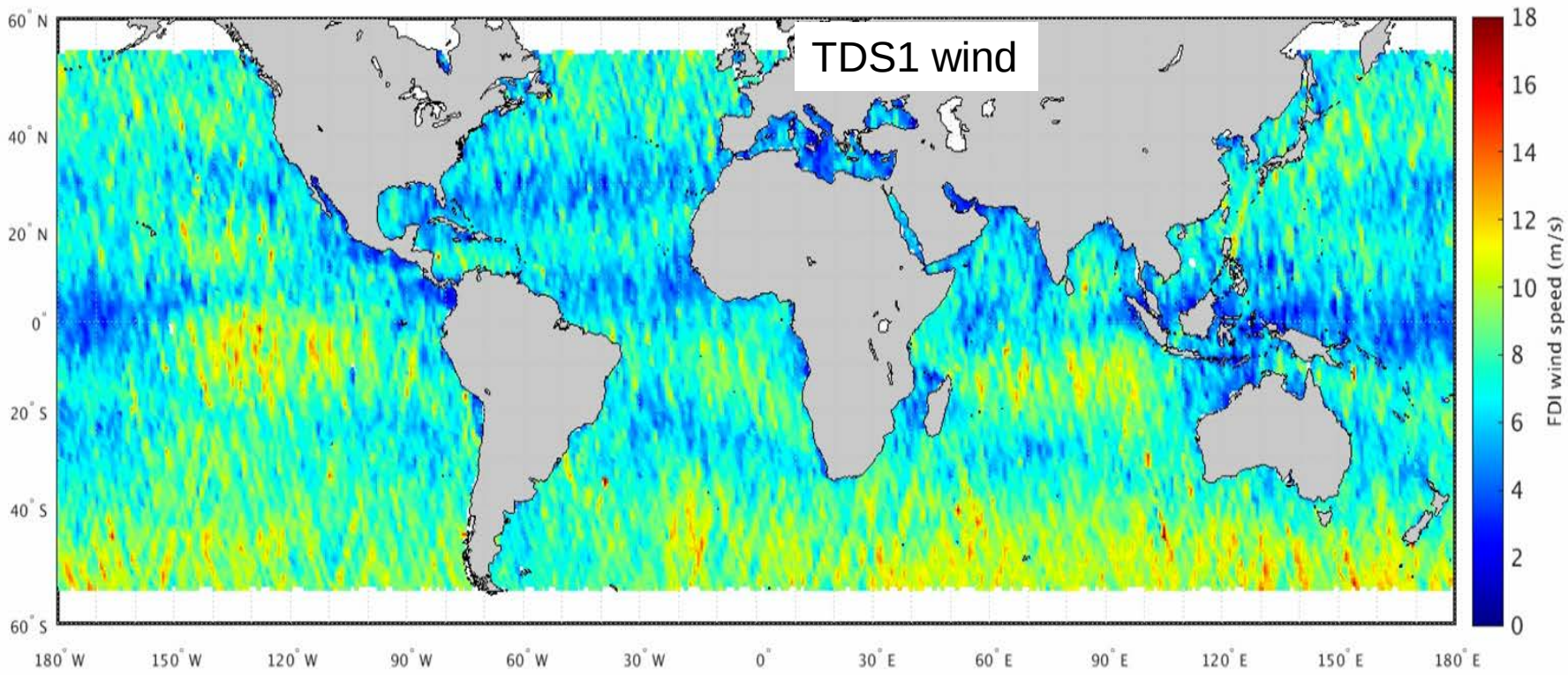


- Level 2 winds available on http://www.merrbys.co.uk/

Unwin et al, JSTARS, 2016

World First

First global GNSS-R winds



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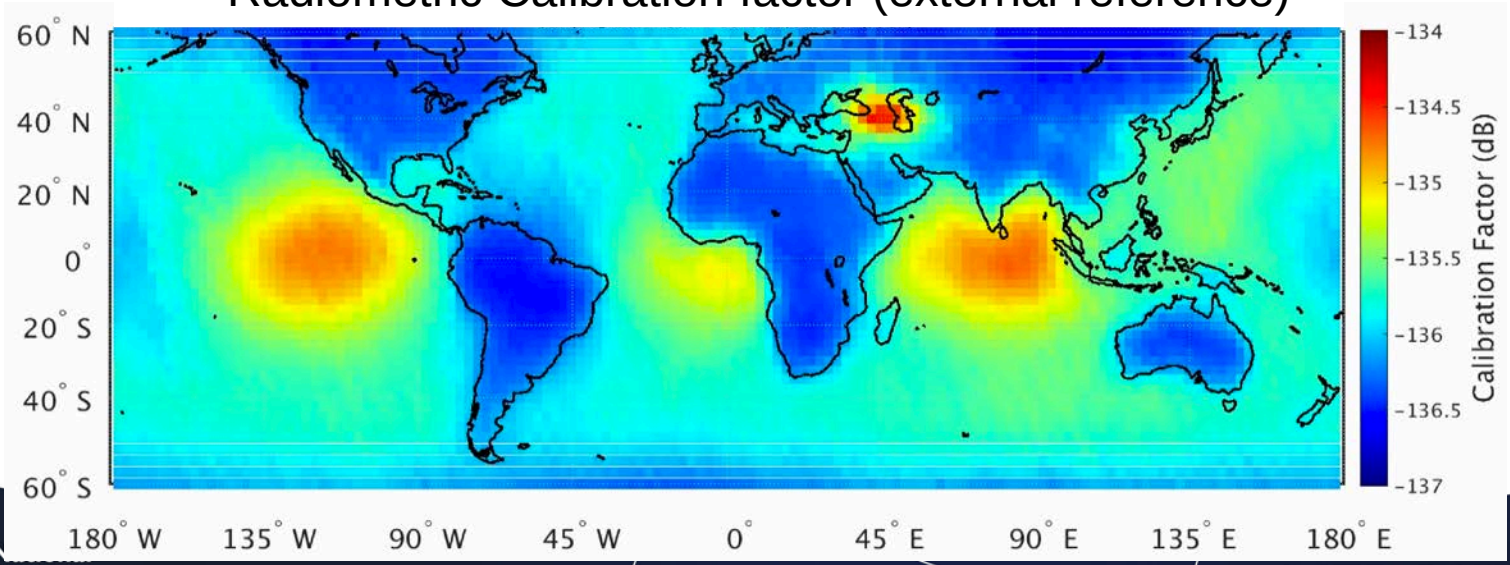
World First

In-flight GNSS-R radiometric calibration

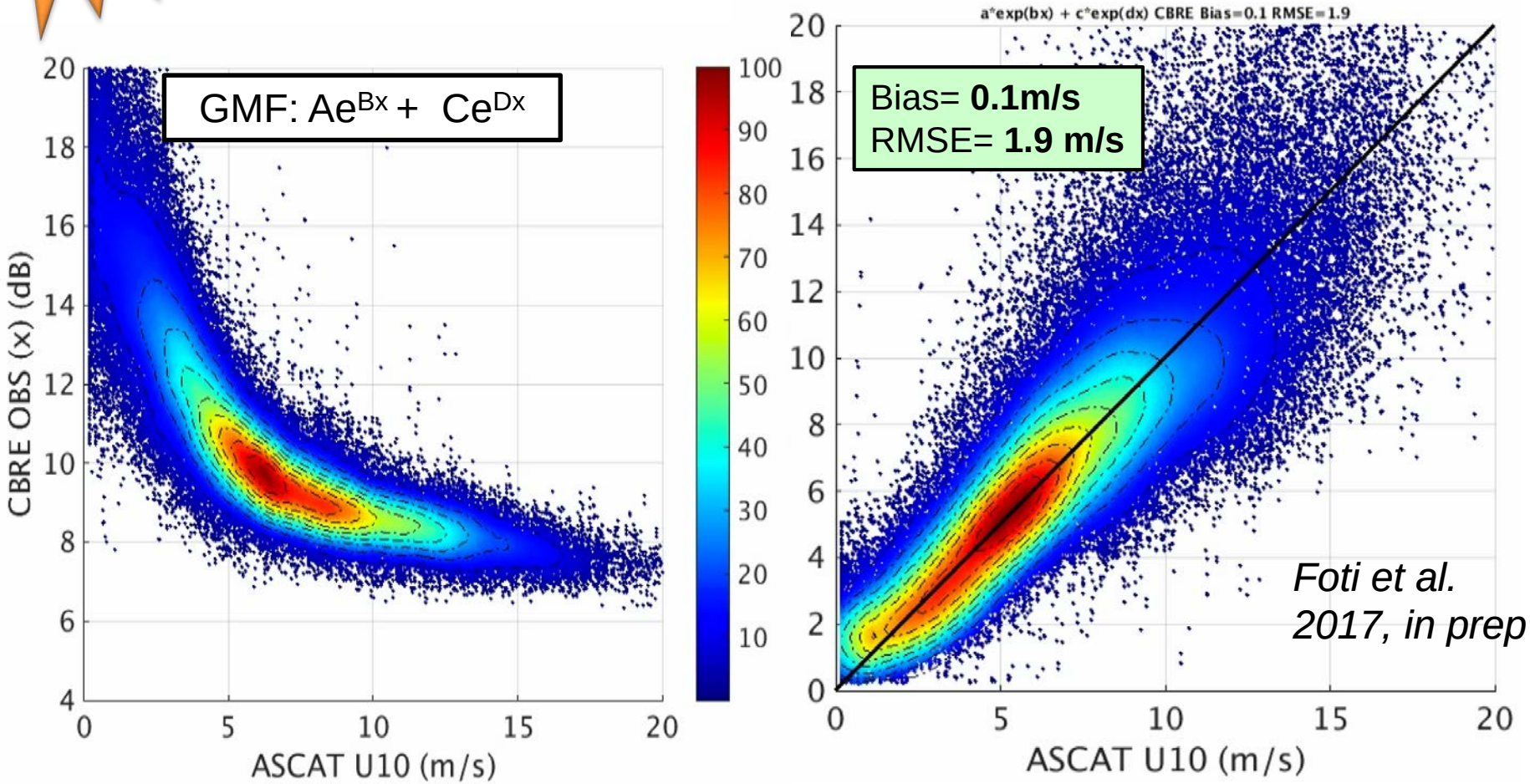
- Two radiometric calibration methods demonstrated in-flight by SSTL
  - Calibration with onboard black-body load switching (like CYGNSS)
  - Vicarious calibration using external reference (Dome-C, Antarctica)
- Vicarious calibration now implemented by NOC to mitigate equatorial biases linked to GNSS hotspots

Radiometric Calibration factor (external reference)



World First

NOC advanced wind inversion



$$\left\langle \left| Y(\hat{\tau},\hat{f}) \right|^2 \right\rangle = \frac{T_i^2 P_T G_T \lambda^2}{(4\pi)^3} \iint_A \frac{G_R \Lambda^2(\hat{\tau}-\tau) S^2(\hat{f}-f)}{R_R^2 R_T^2} \sigma^0 dA$$

National Oceanograp
NATURAL ENVIRONMEN

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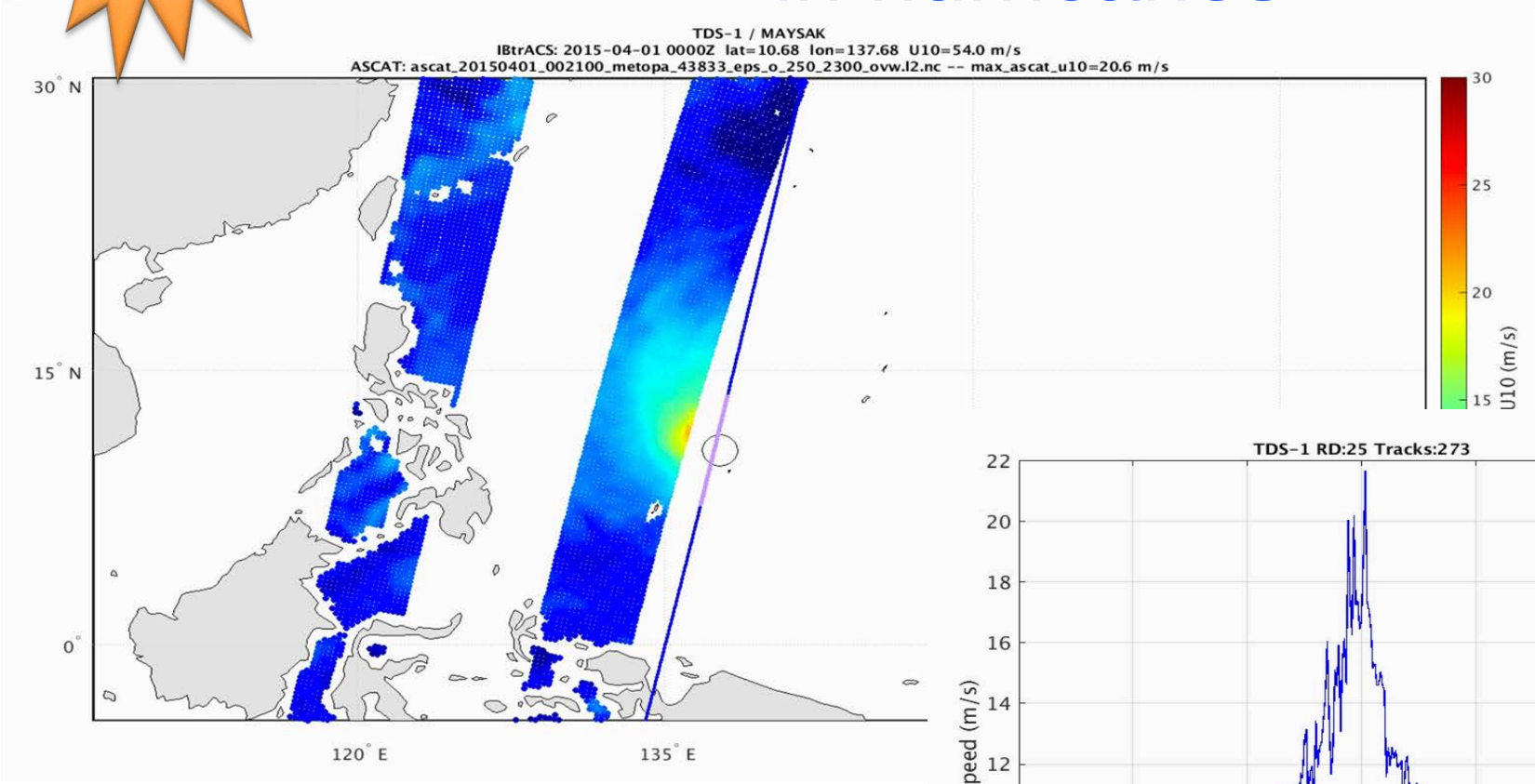
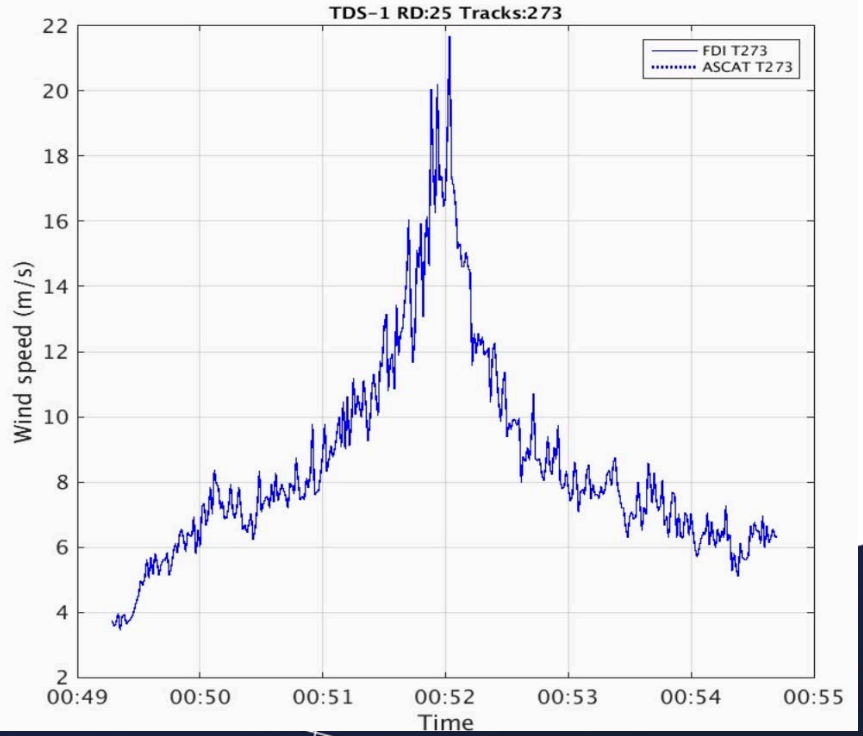
World First

First spaceborne GNSS-R data in hurricanes





- Directly relevant to the NASA CYGNSS mission !

BUT THAT'S NOT ALL…

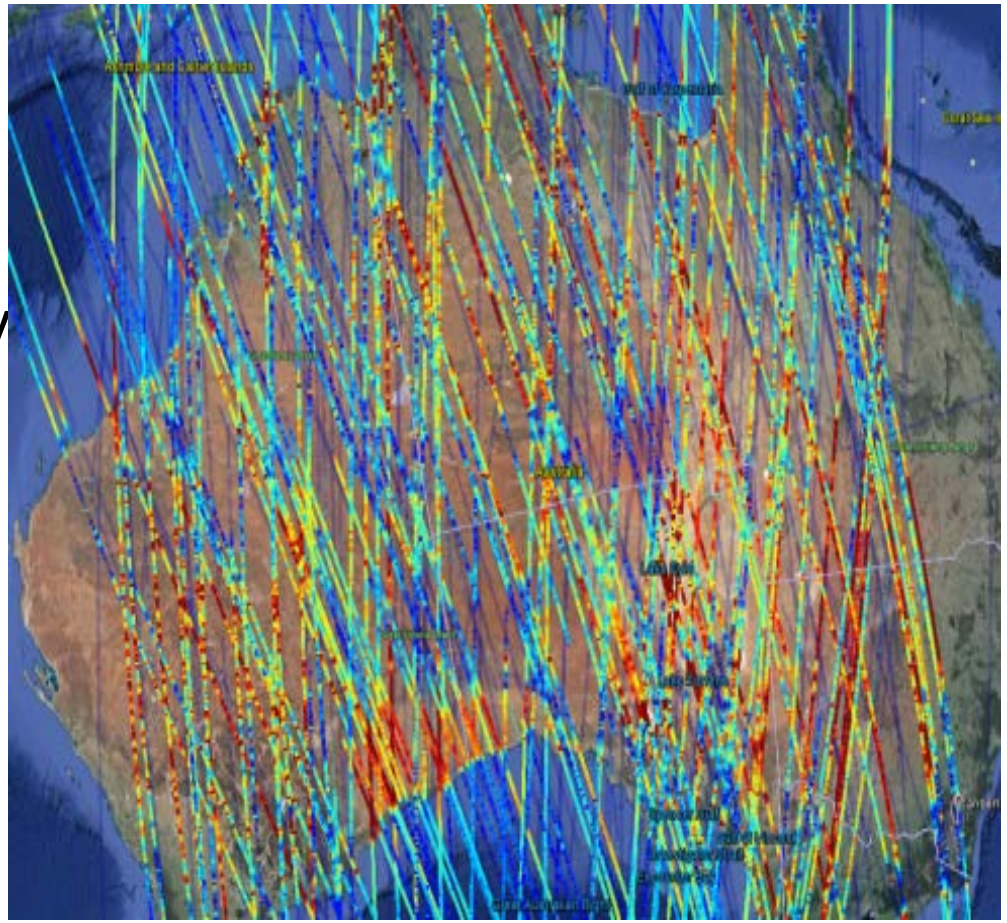
Other GNSS-R applications

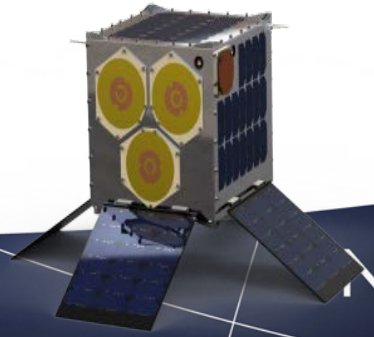
Sea Surface Height (Altimetry
- Ocean currents (geostrophic)

Ice sensing
- Ice extent, ice concentration
- Ice height / thickness

Land Sensing
- Soil Moisture & Flood warning
- Biomass

Atmospheric Sensing
- Combining GNSS-R with GNSS-RO



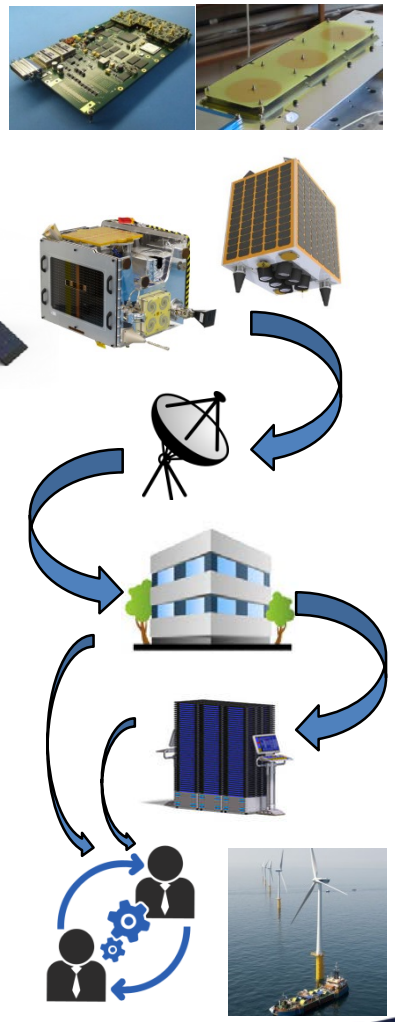


GNSS-R: The way forward

- TDS-1 GNSS-R has had major impact
  - New low cost way to measure global ocean winds to ~ 2 m/s
  - Enabled NASA CYGNSS Constellation => cyclone sensing
  - Numerous journal papers emerging => ocean, land, ice sensing
- In the meantime…TDS-1 reaching end of life
  - Contract ends 8th July 2017, **i.e. 8 days' time!**
  - Original plan to deploy Cranfield's de-orbit sail
- Reflectometry capability could be lost?
  - No GNSS-R missions planned, reflectometry no longer "new" to science
  - Need to navigate "valley of death" by developing value chain
- Proposed life extension of TDS-1
  - 24/7 pilot GNSS-R wind data service
    - Demonstrate utility to weather and marine forecasting users
  - Further science goals - demonstrate Galileo reflections, L2C signals, continuity with CYGNSS, GNSS-R data at high latitudes & polar regions

Future GNSS-R Service

- After TDS-1, potential for flying GNSS-R as hosted payload on existing satellites
  - Similar to Iridium NEXT ideas, but lower cost
  - Every satellite going up could carry GNSS-R
  - Constellation built up incrementally
- Institutional / commercial value chain rqd
  - Provision of fast data service for subscribers
  - Delayed data still available for researchers
  - Requires assimilation & forecasting => users
- Longer term – dedicated constellation
  - Established market enables PPP proposal
  - Can combine Reflectometry & Radio-Occultation
  - ESA supported “ORORO”, instrument development



Thank You