Emerging Needs and Opportunities in Ocean Remote Sensing

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&
David Cotton, Ellis Ash
Satellite Oceanographic Consultants Ltd

Why the oceans matter

71% of the Earth's Surface

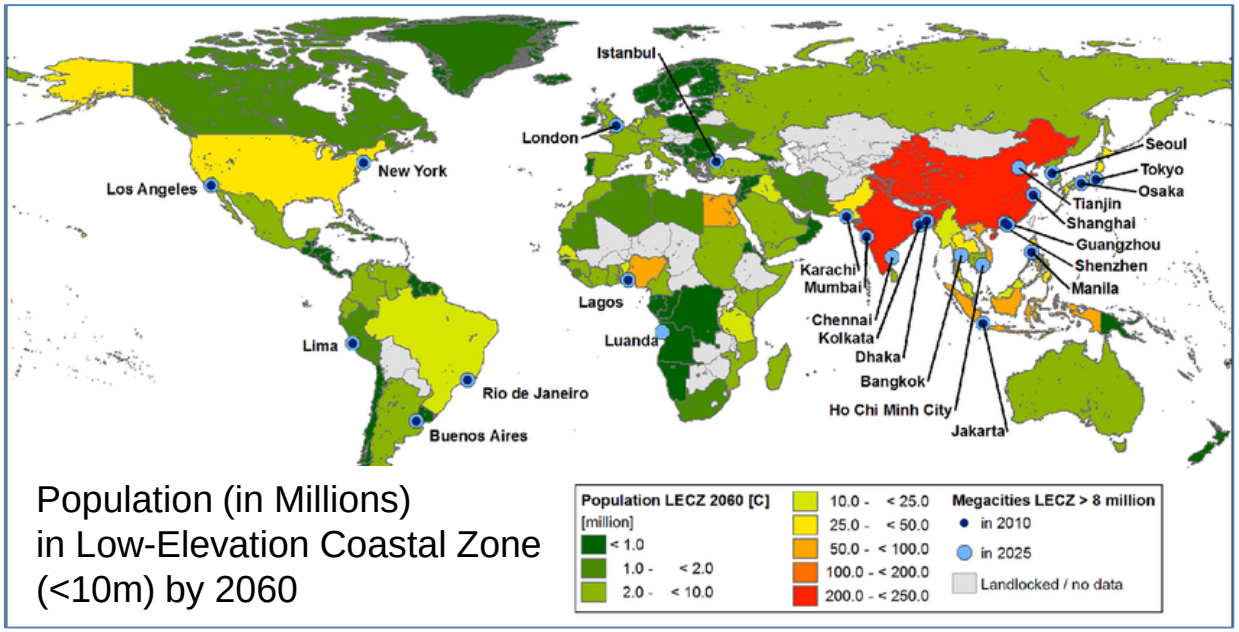
97% of the Earth's water

>90% of global trade carried by sea

Primary source of protein for >3 billion people

40% of world population live within 100km of ocean

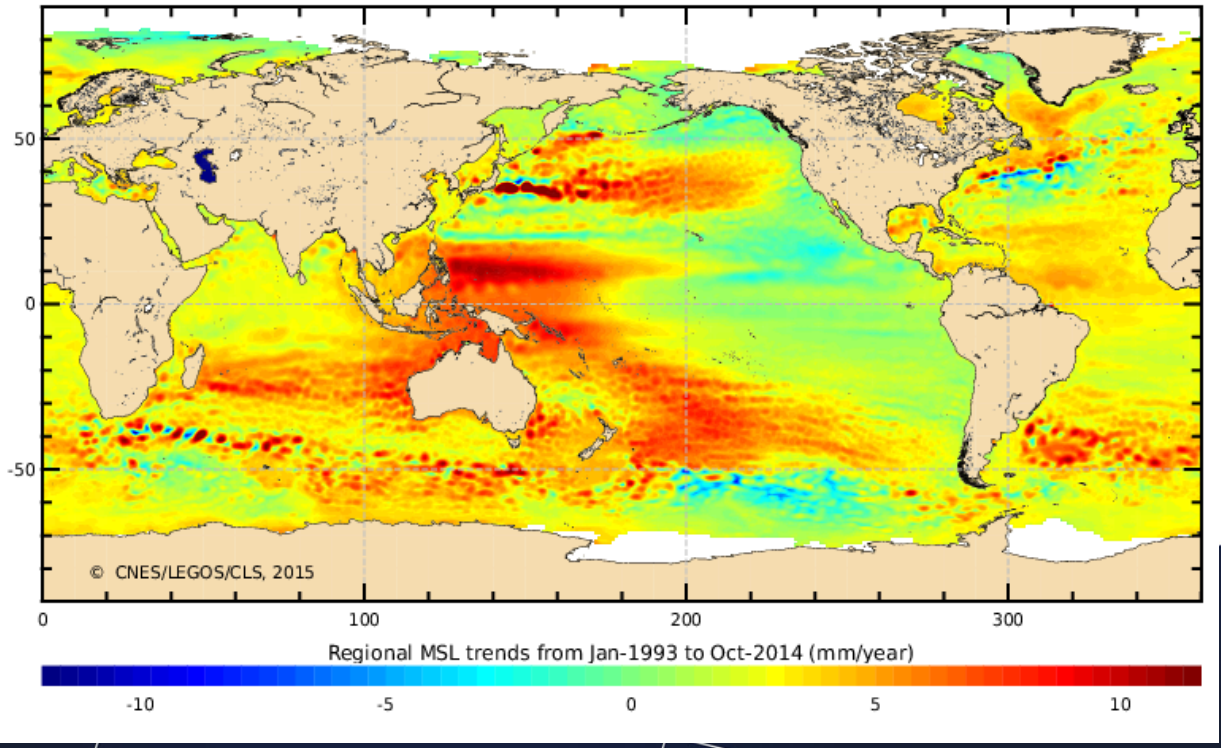
Sources: IMO; World Bank



Population (in Millions) in Low-Elevation Coastal Zone (<10m) by 2060

From Neumann et al., 2015

Sea level rise



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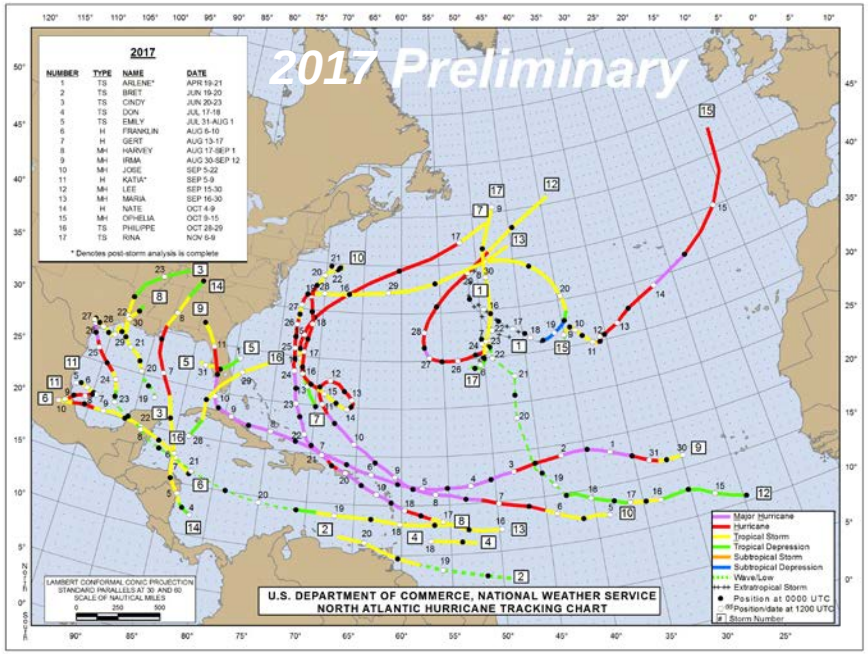
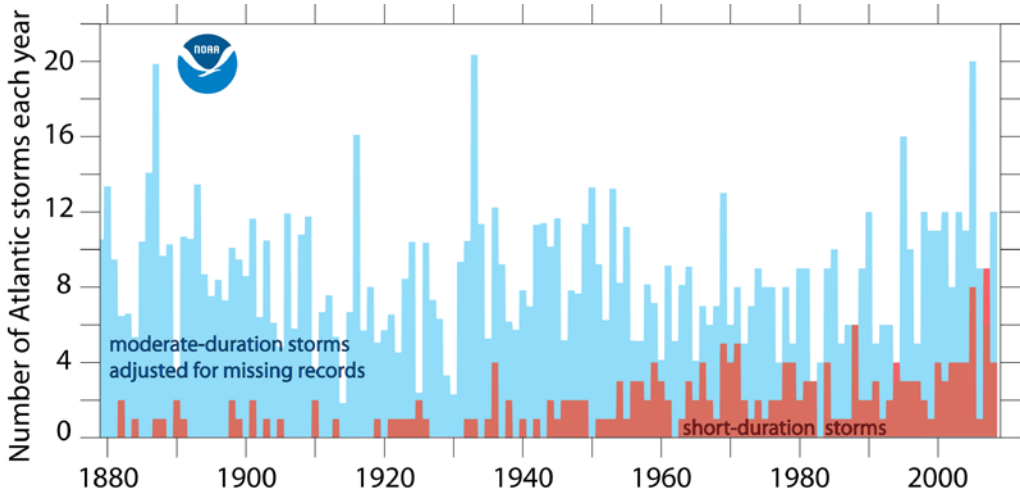
Extreme weather events





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Marine pollution and ocean currents

The Great Pacific Garbage Patch (2009)

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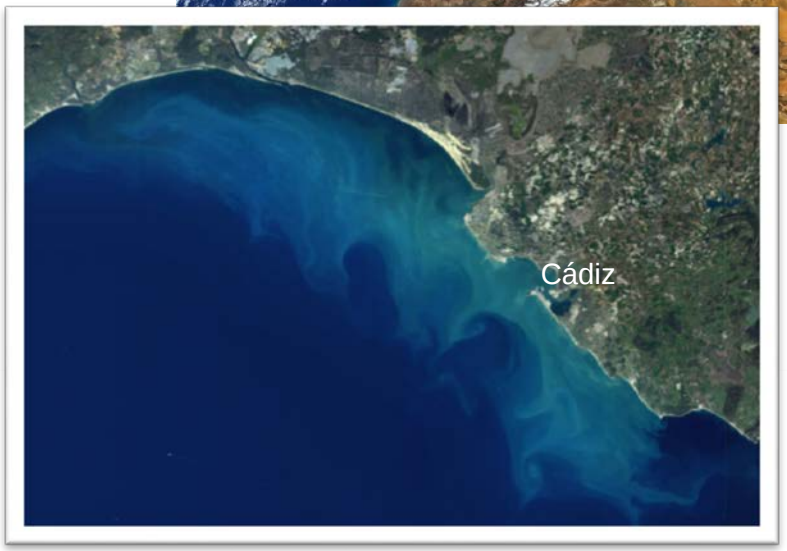
Opportunities in ocean remote sensing

- Three examples
  1. new missions to measure something new
  2. Paradigm shifts… measuring differently something we already do… but better/more often
  3. New products & services from existing data for developing countries

1. new missions to measure something new

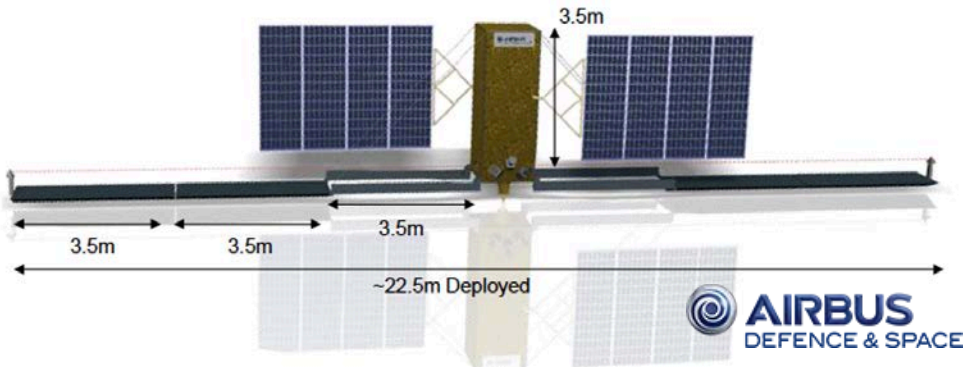
SEASTAR: a new mission to measure total ocean surface current vectors

- In preparation for submission to ESA Earth Explorer 10
- Aimed at measuring **total** ocean surface current **vectors** at **1km** with **unprecedented precision**
  - With **collocated wind and waves**
- Focus on coastal, shelf & polar seas
- Opportunities for:
  - Exciting new science
  - Industry (technological innovation)
  - Modelling & Forecasting
  - Applications to societal needs



SEASTAR Instrument & Platform

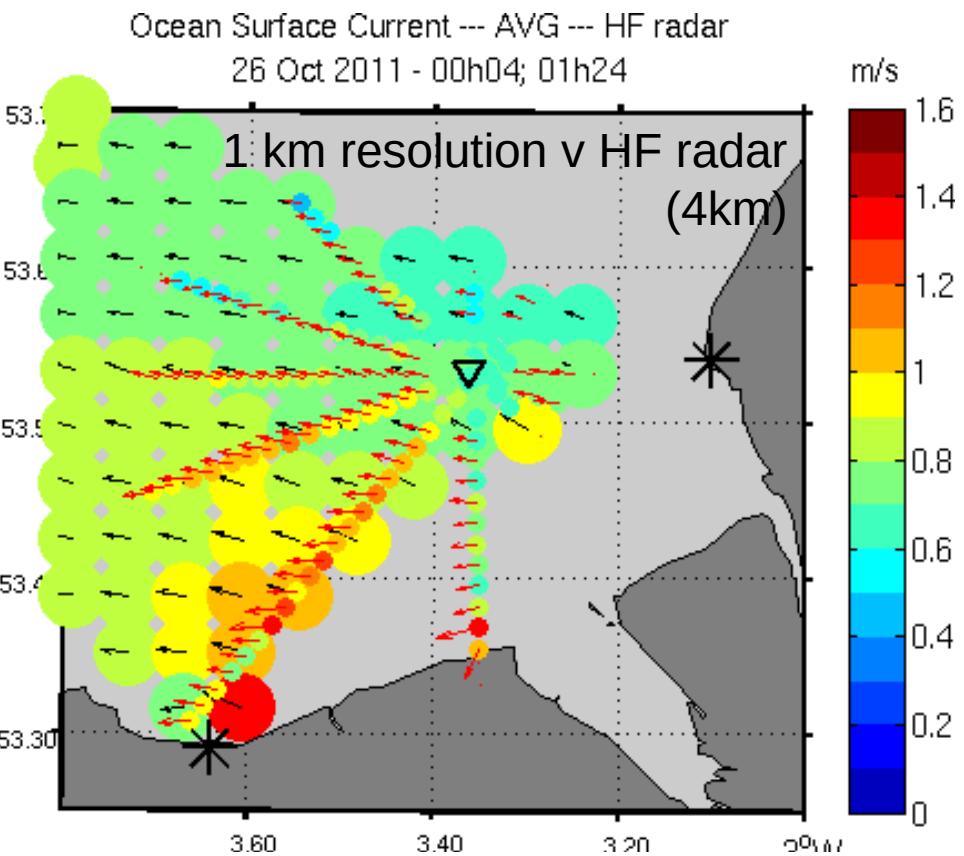
- Squinted along-track Interferometric SAR
- Never previously flown in space
- Large, expensive but feasible
  - Physical baseline 15m
  - Deployed length ~22.5m
  - VV and HH polarisation
  - Javelin configuration
  - Leaky waveguide antennas
  - Elevation beam shaping

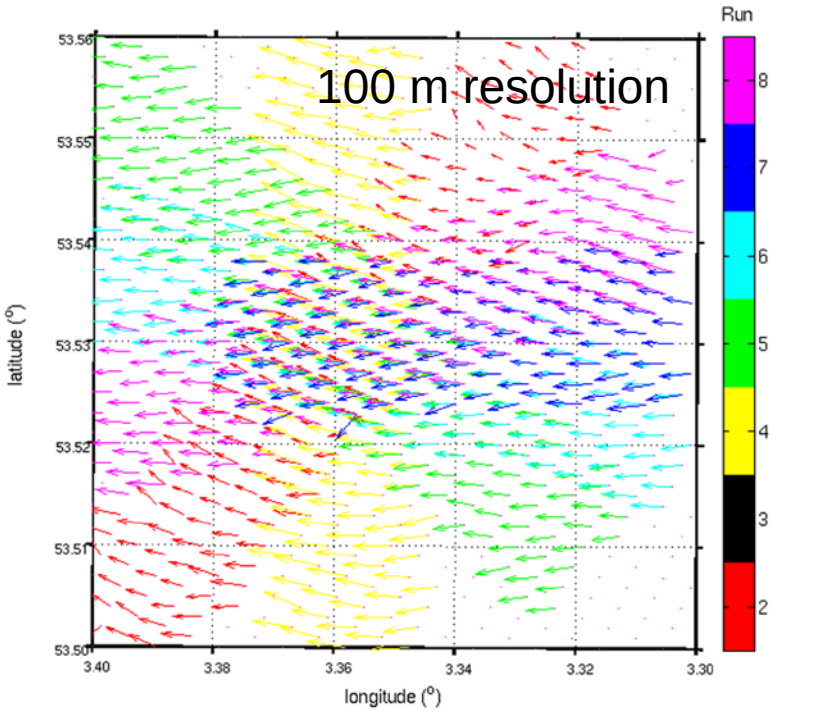


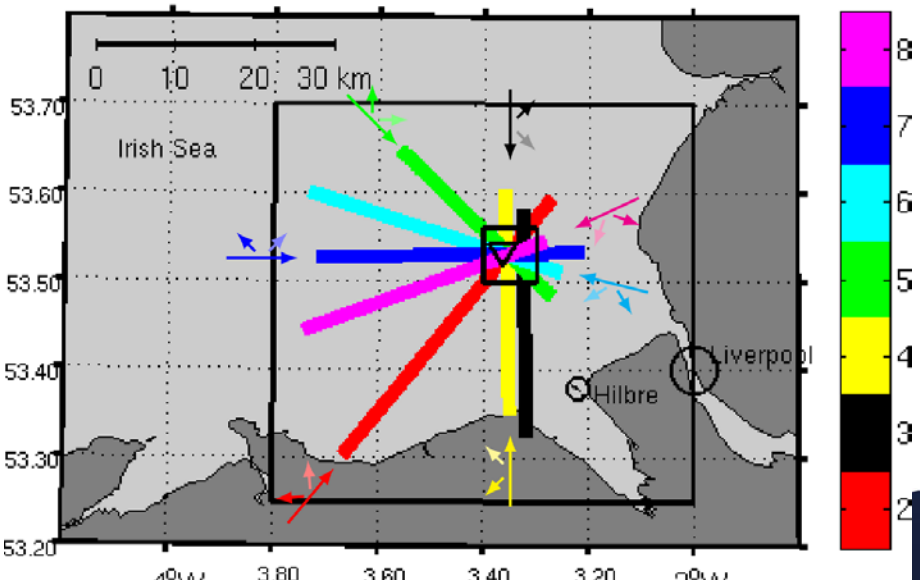
- **<u>Earth Explorer Core class mission</u>**

Airborne demonstration & validation

Martin & Gommenginger, RSE, 2017





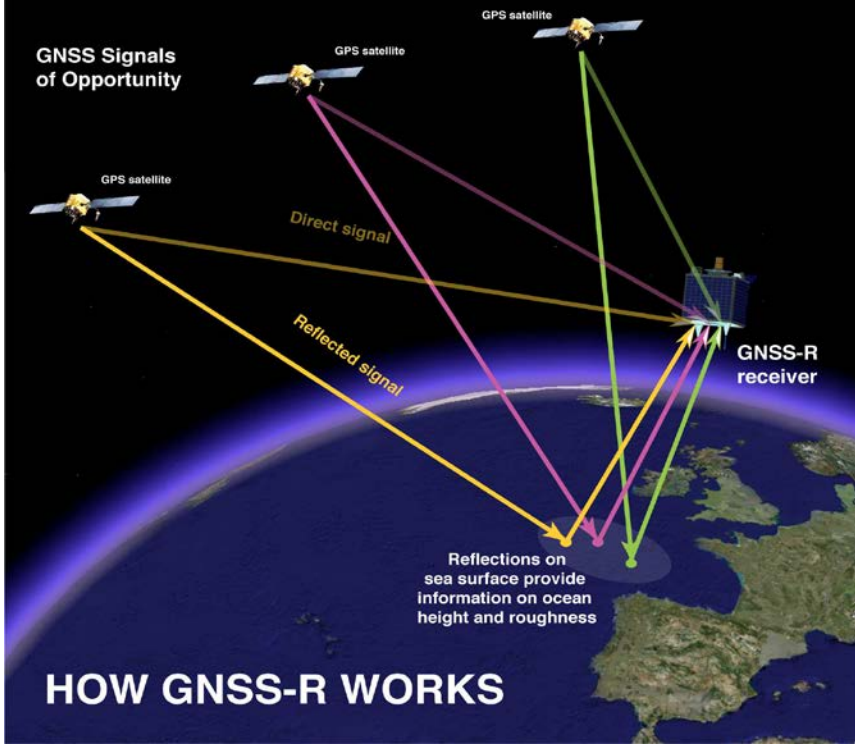


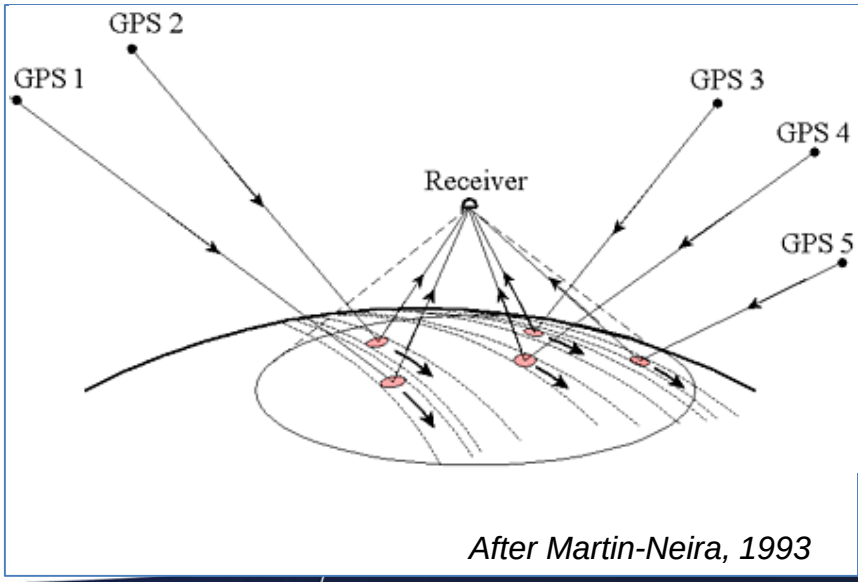
Typical performance for current vectors @ 1.5 km resolution against HF radar:
Bias: less than 0.06 m/s; 10° Precision: better than 0.1 m/s; 7°

2. Paradigm shifts… measuring differently something we already do… but better/more often

GNSS-Reflectometry

- Global Navigation Satellite Systems
  - Global, ubiquitous signals of opportunity
  - E.g. GPS, GLONASS, Beidou, Galileo
- GNSS-R for Earth Observation
  - Ocean winds, sea surface height, soil moisture, sea ice, ionosphere,…
- Small, low-power & low-cost receivers
  - Suitable for small satellites, constellations or as passenger payload
- L-band (~20 cm wavelength)
  - lower sensitivity to precipitation compared to higher frequencies

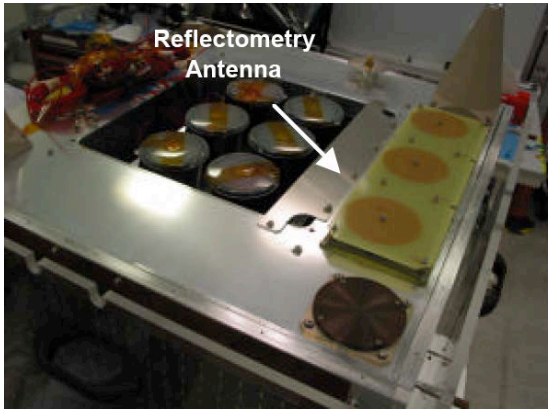


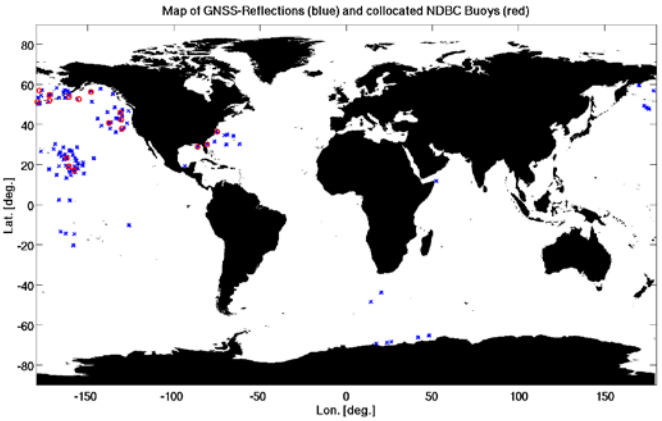


After Martin-Neira, 1993

A long-term partnership between academia & industry

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





Collected ~ 50 data points over ocean

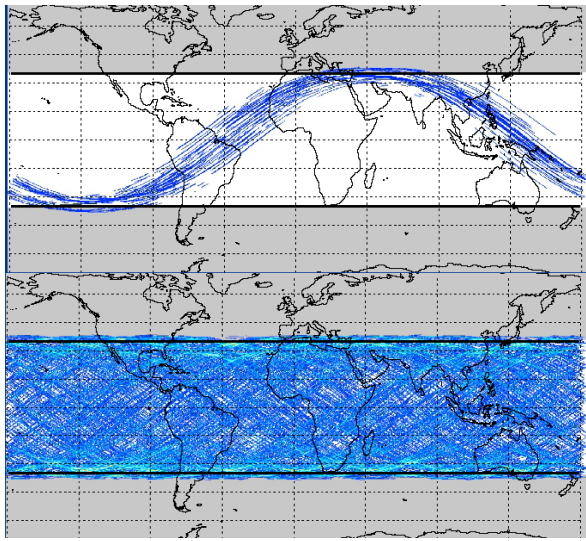
CEOI

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

SURREY SATELLITE TECHNOLOGY LTD

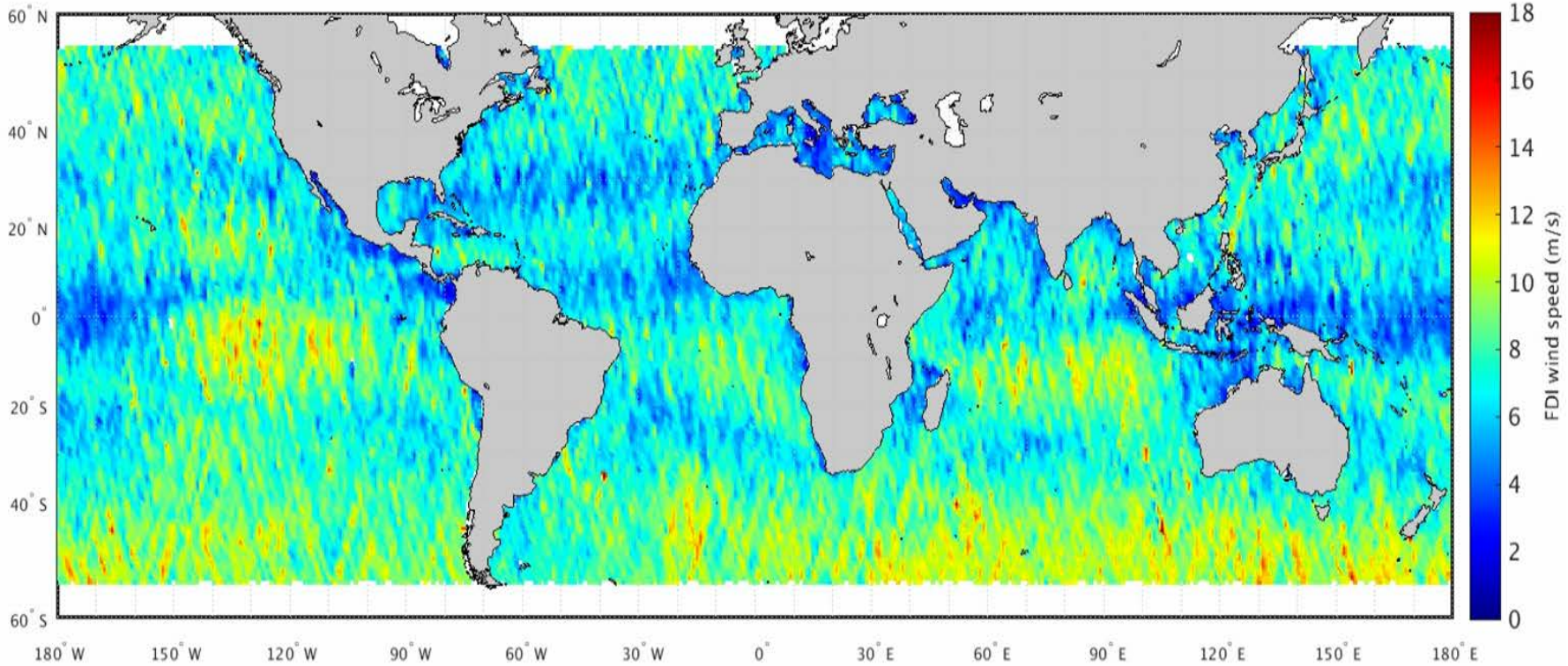
15 Dec 2016
NASA Cyclone Global Navigation Satellite System (CYGNSS) mission

Constellation of 8 SGR-ReSI



Aims for mean revisit time ~ 4 hours

First global GNSS-R winds from TechDemoSat-1

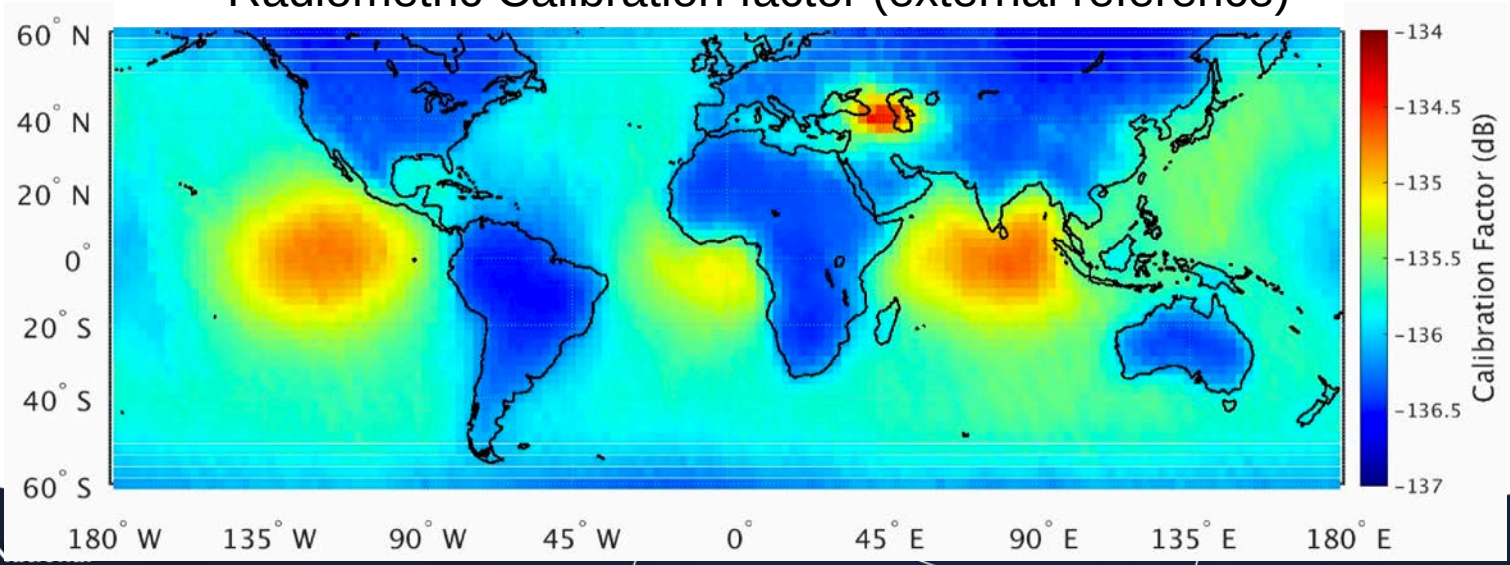


- Level 2 winds available on http://www.merrbys.co.uk/
- Ground processing, L2 inversion & data portal funded by ESA

First in-flight vicarious radiometric calibration of GNSS-R data

- New 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)



First spaceborne GNSS-Reflectometry observations of hurricanes from the UK TechDemoSat-1 mission.

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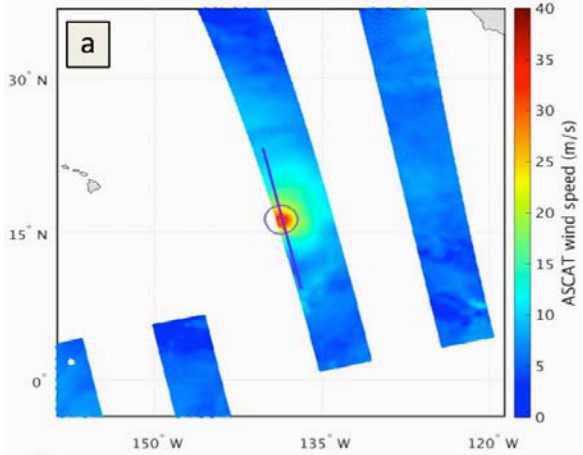
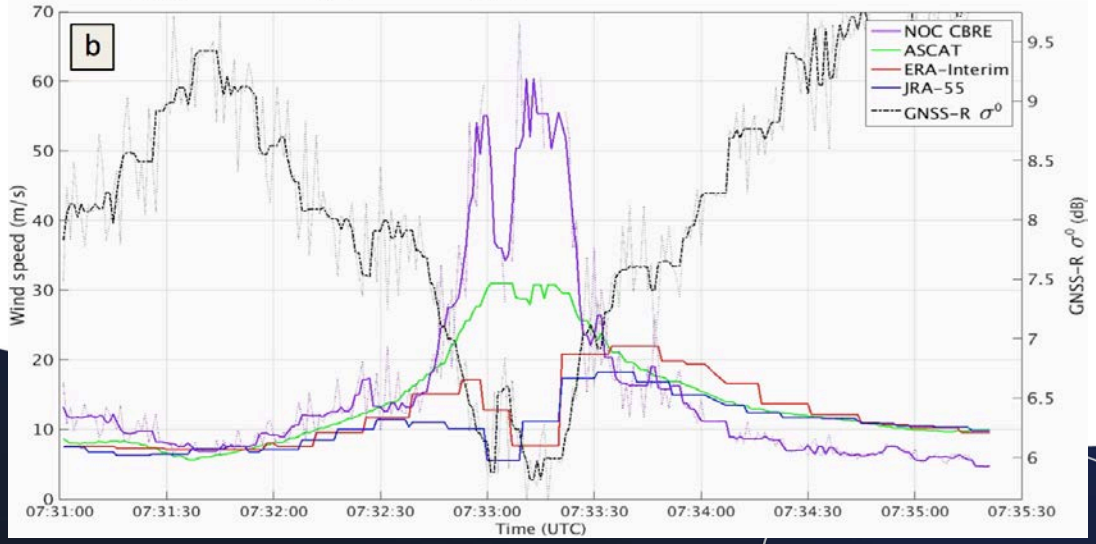
Accepted for publication in GRL





- What next for GNSS-R?
  - A constellation of GNSS-R receivers in high-inclination orbit?

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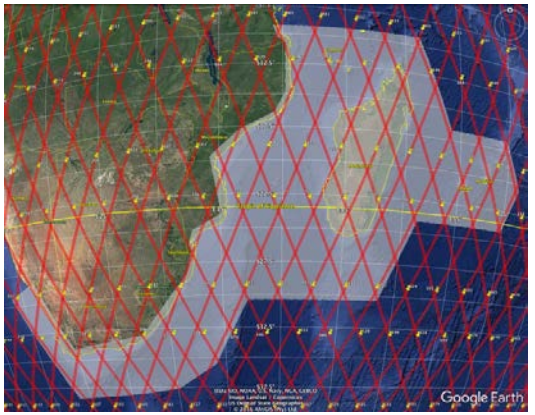
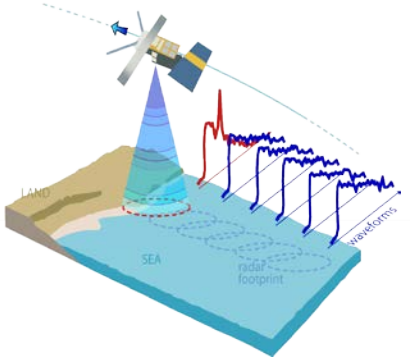
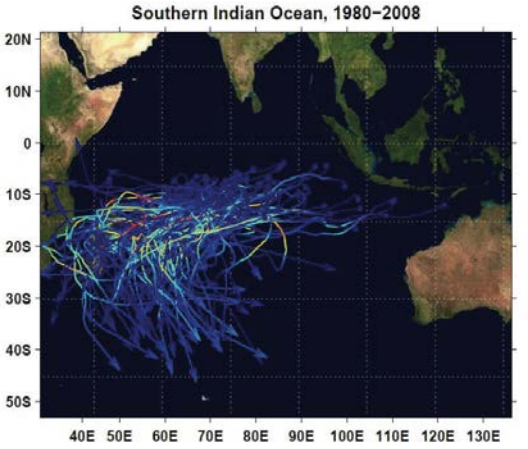
3. New products & services from existing data for developing countries

C-RISe Coastal Risk Information Service

UKSA International Partnership Programme







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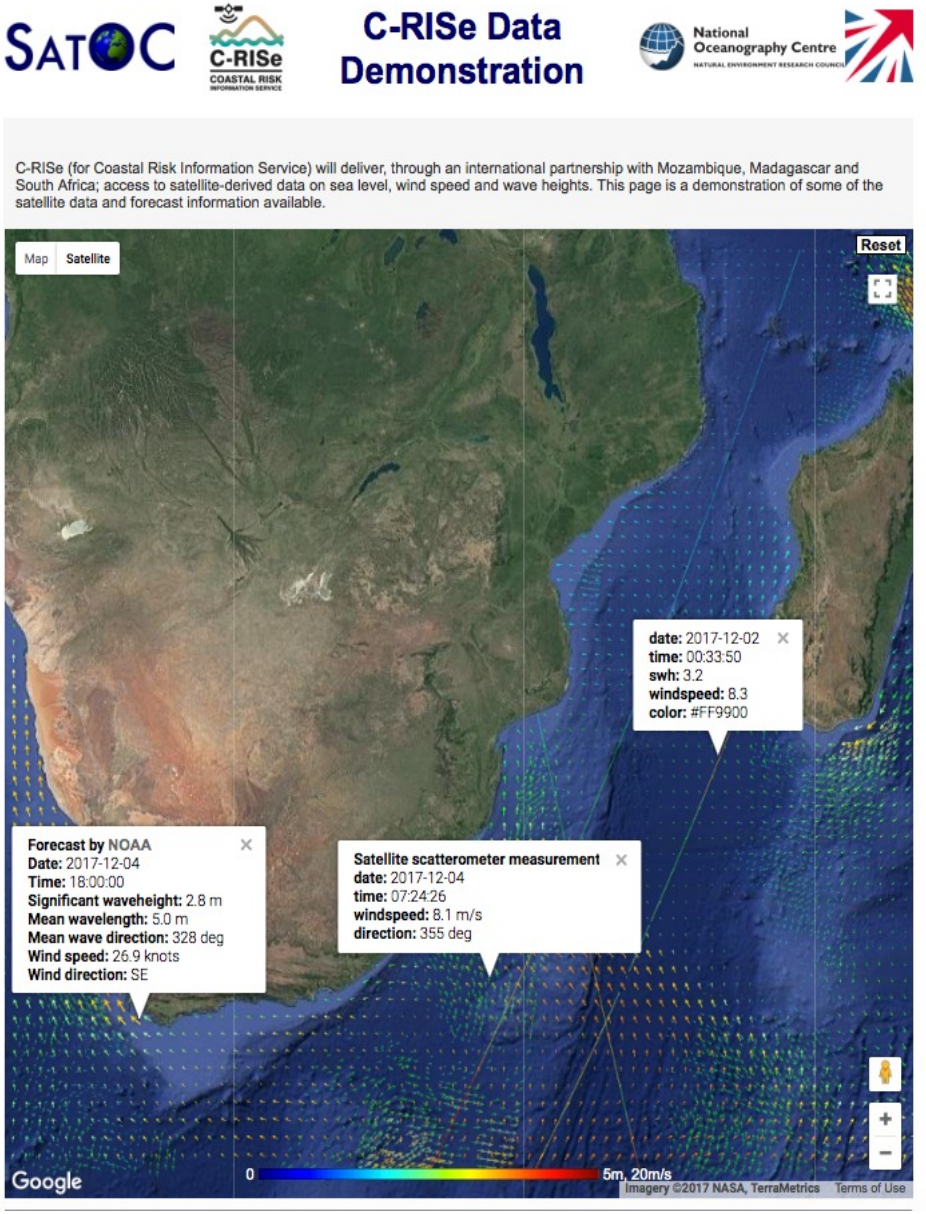
C-RISe

- Mozambique, Madagascar and South Africa have large coastal populations vulnerable to environmental changes
  - Exposure to regular coastal flooding due to cyclones
  - Reliance on economically important coastal ecosystems sensitive to climate change
- New satellite-derived products for coastal sea level, wind speed and wave heights complemented by model and in situ data where available
  - 20+ years of satellite data
  - simple visualisation tools developed in partnership between industry, academia and local partners in Africa.
  - regional, seasonal and inter-annual variability & trends
  - local training to promote long-term uptake of EO data



http://www.satoc.eu/projects/c-rise/

Summary & Conclusions

- Environmental changes in the marine environment raise new monitoring challenges that Earth Observation is well placed to address.
- The scientific, economic and societal importance of the coastal zone offers many opportunities for Earth Observation.
- Opportunities arise through different Earth Observation pathways
  - “traditional” routes e.g. ESA Earth Explorer
  - Paradigm shifts e.g. disruptive technology like GNSS-R
  - New satellite-derived services for new users in developing countries
- Challenges
  - Long lead-in time from concept to fruition assumes long-term stability and continuity
  - Business model for non-conventional pathways is unclear
    - Challenging established ways
    - Competing in a world of free data
    - Quantifying the added-value of new observations

Thank you