

# Emerging Needs and Opportunities in Ocean Remote Sensing

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With thanks to: Chris Banks, Val Byfield, Paolo Cipollini, Nadim Dayoub,  
Giuseppe Foti, Adrien Martin, Meric Srokosz

&

David Cotton, Ellis Ash

Satellite Oceanographic Consultants Ltd



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**NERC** SCIENCE OF THE  
ENVIRONMENT

# Why the oceans matter

71% of the Earth's Surface

97% of the Earth's water

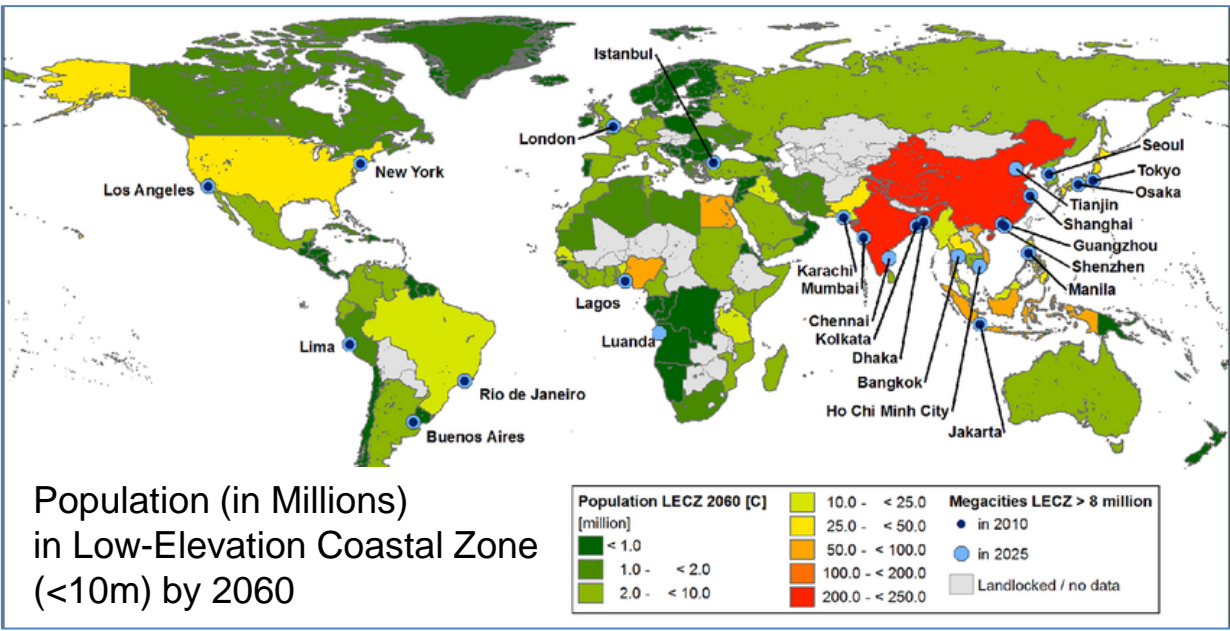
>90% of global trade carried by sea

Primary source of protein for >3 billion people

40% of world population live within 100km of ocean

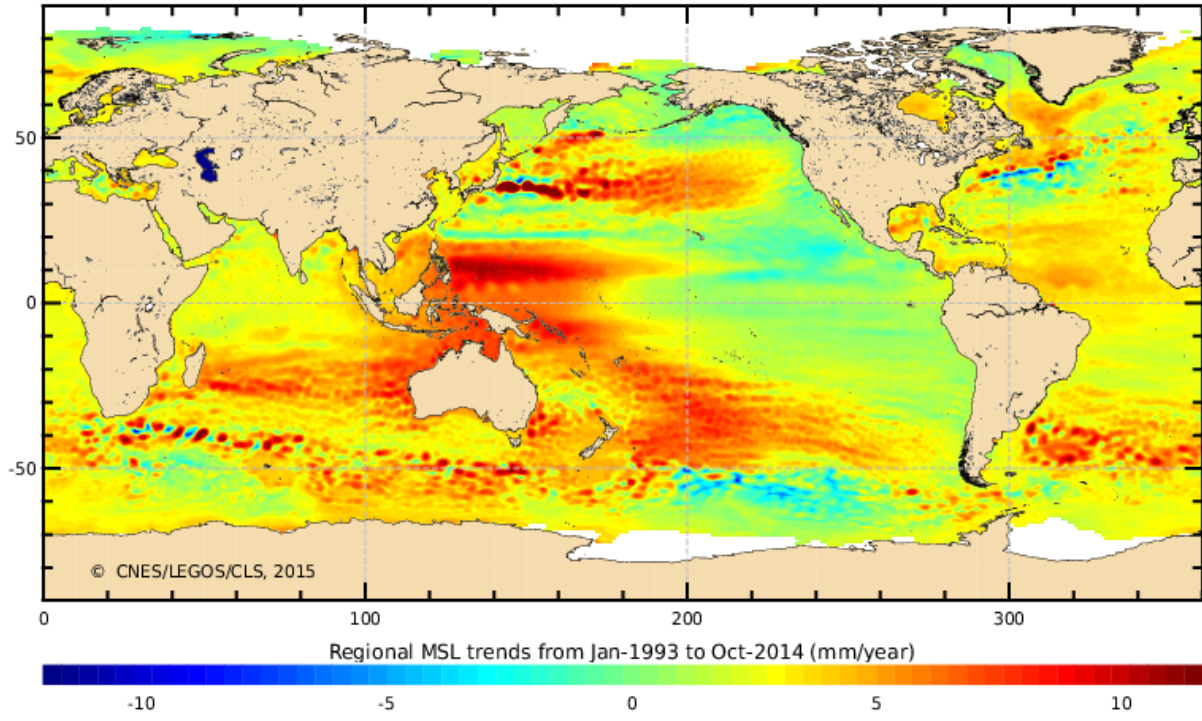
*Sources: IMO; World Bank*



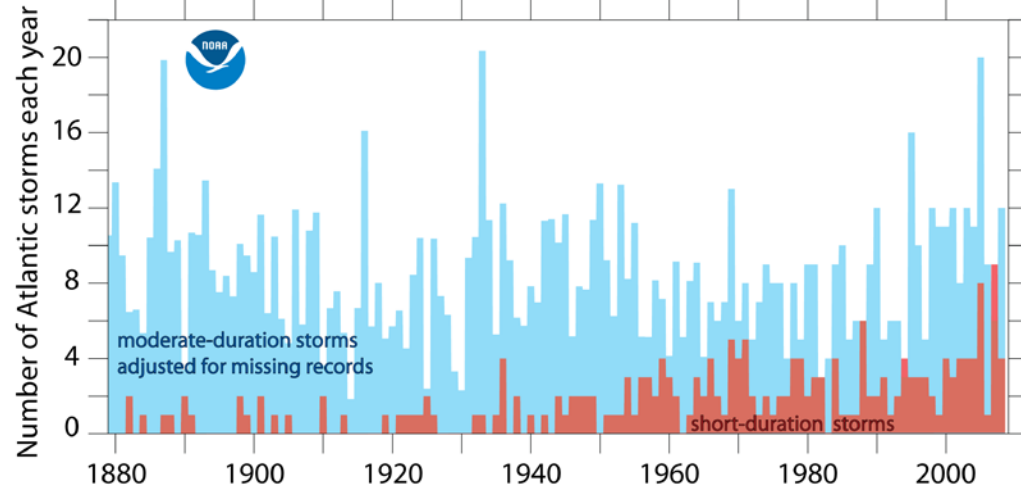
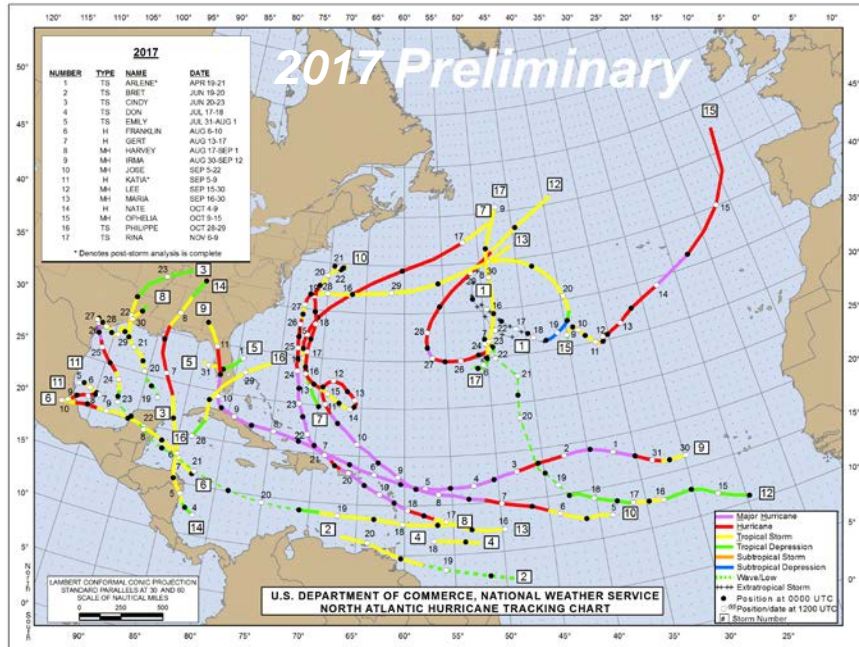


From Neumann et al., 2015

# Sea level rise



# Extreme weather events



# Marine pollution and ocean currents



# Opportunities in ocean remote sensing

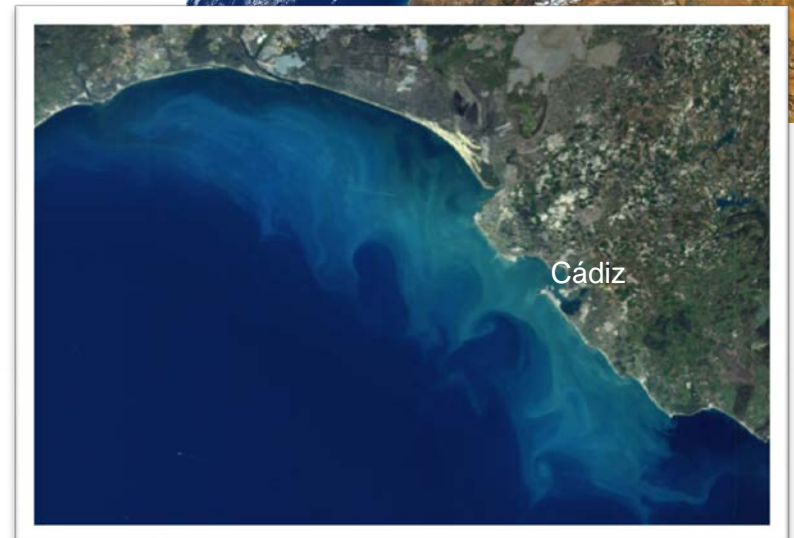
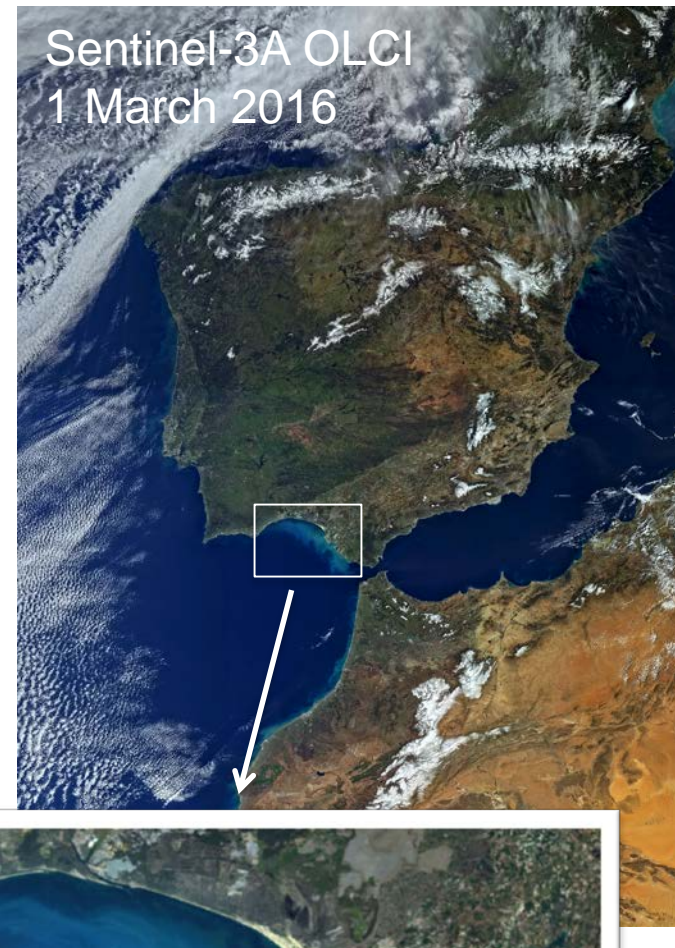
- Three examples
  1. new missions to measure something new
  2. Paradigm shifts... measuring differently something we already do... but better/more often
  3. New products & services from existing data for developing countries

1. new missions to measure something new



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

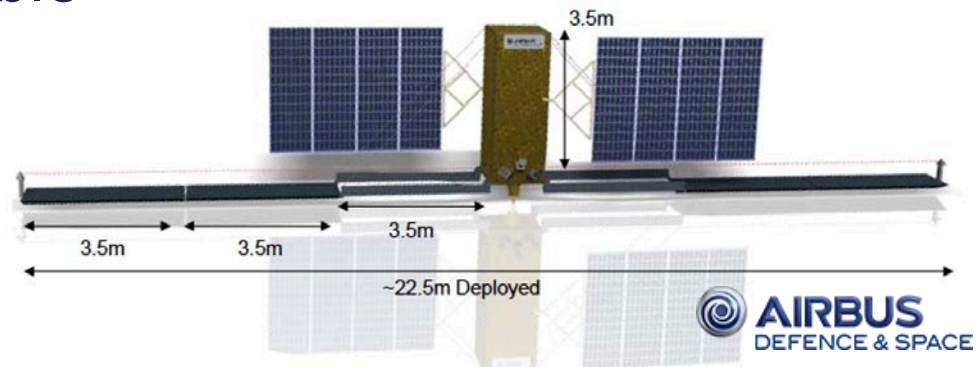
- In preparation for submission to ESA Earth Explorer 10
- Aimed at measuring **total** ocean surface current **vectors** at **1km** with **unprecedented precision**
  - With **collocated wind and waves**
- Focus on coastal, shelf & polar seas
- Opportunities for:
  - Exciting new science
  - Industry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

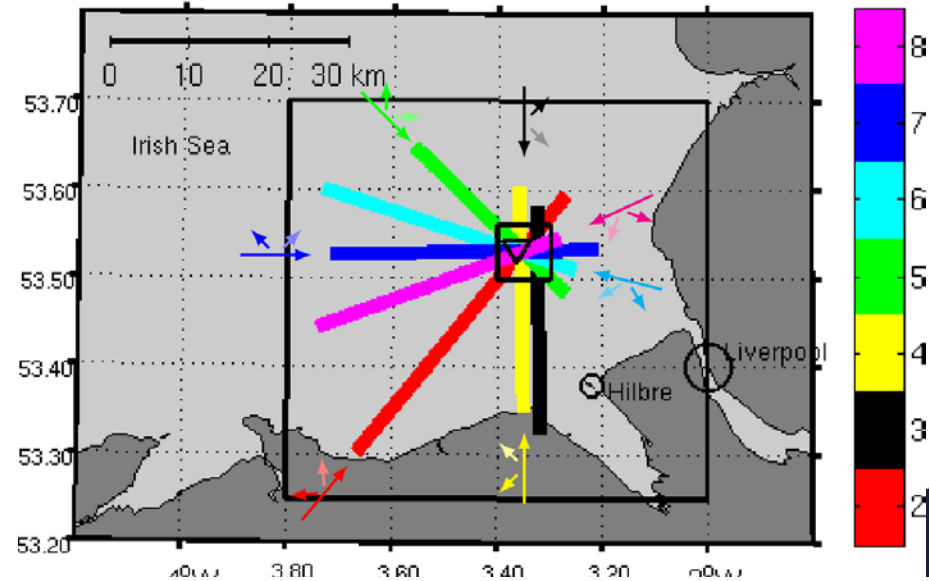
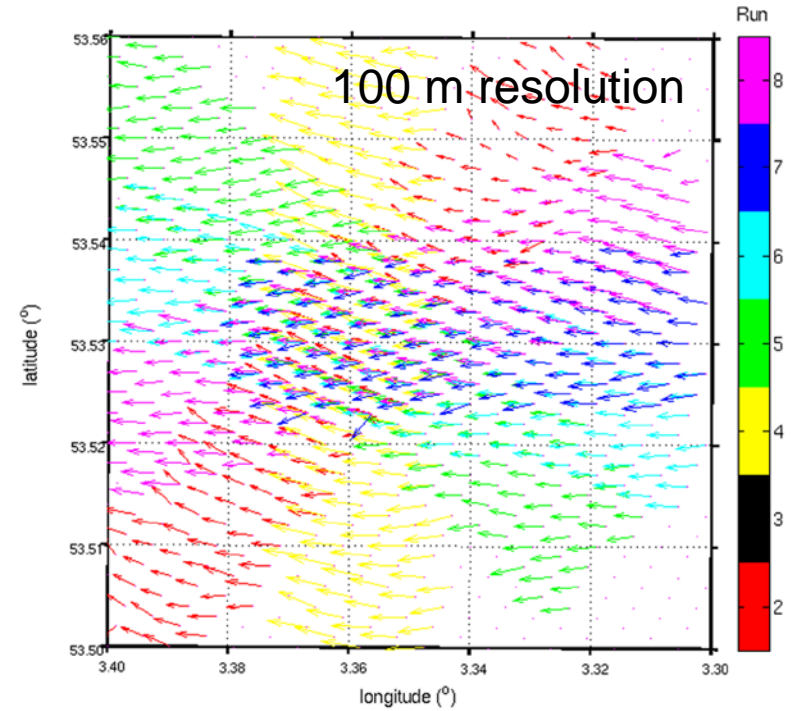
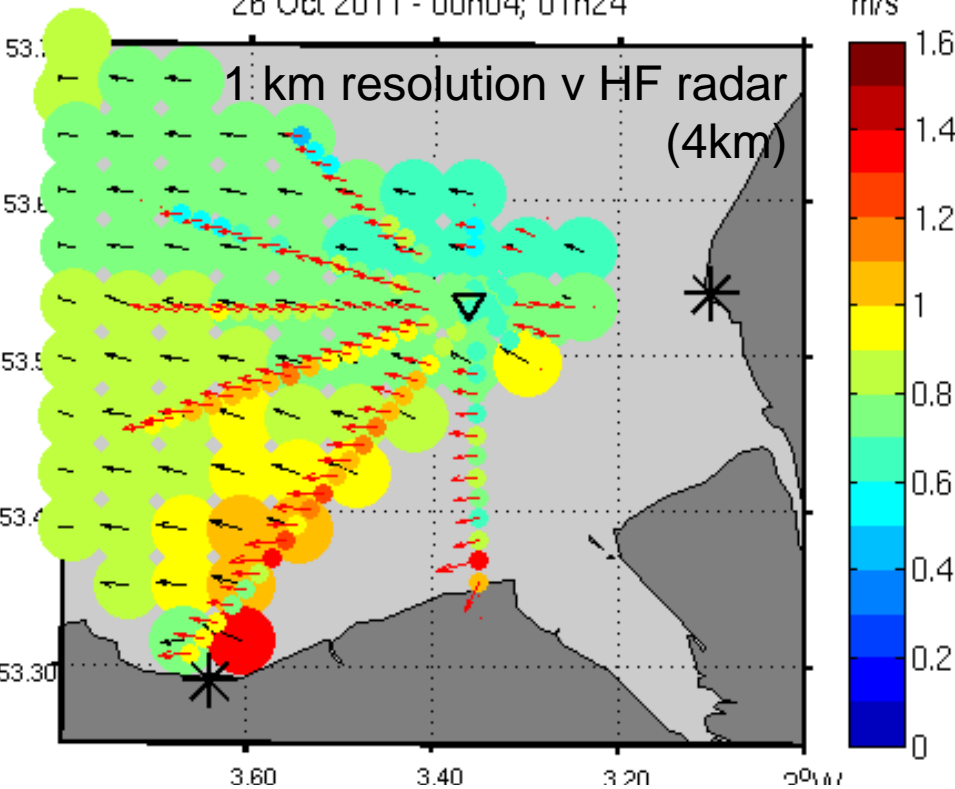


- Earth Explorer Core class mission

# Airborne demonstration & validation

*Martin & Gommenginger, RSE, 2017*

Ocean Surface Current --- AVG --- HF radar  
26 Oct 2011 - 00h04; 01h24



Typical performance for current vectors @ 1.5 km resolution against HF radar:

Bias: less than 0.06 m/s; 10°

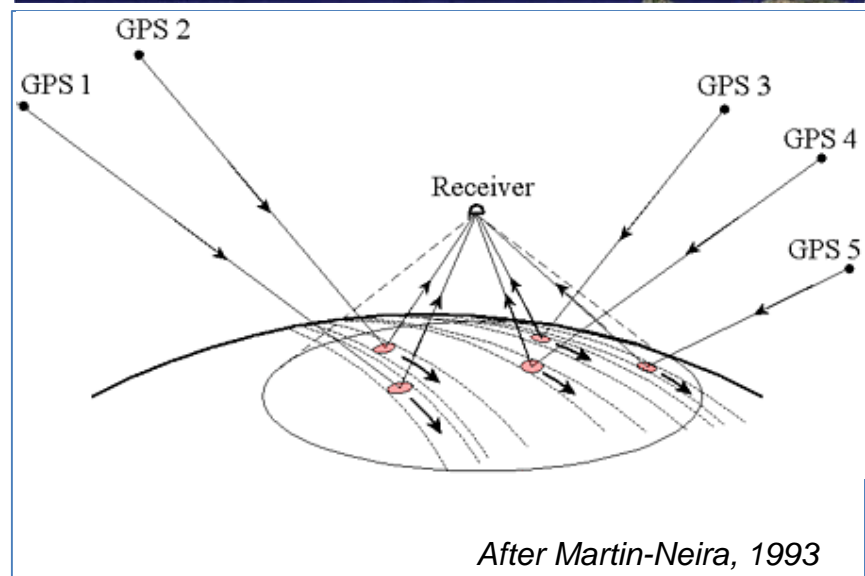
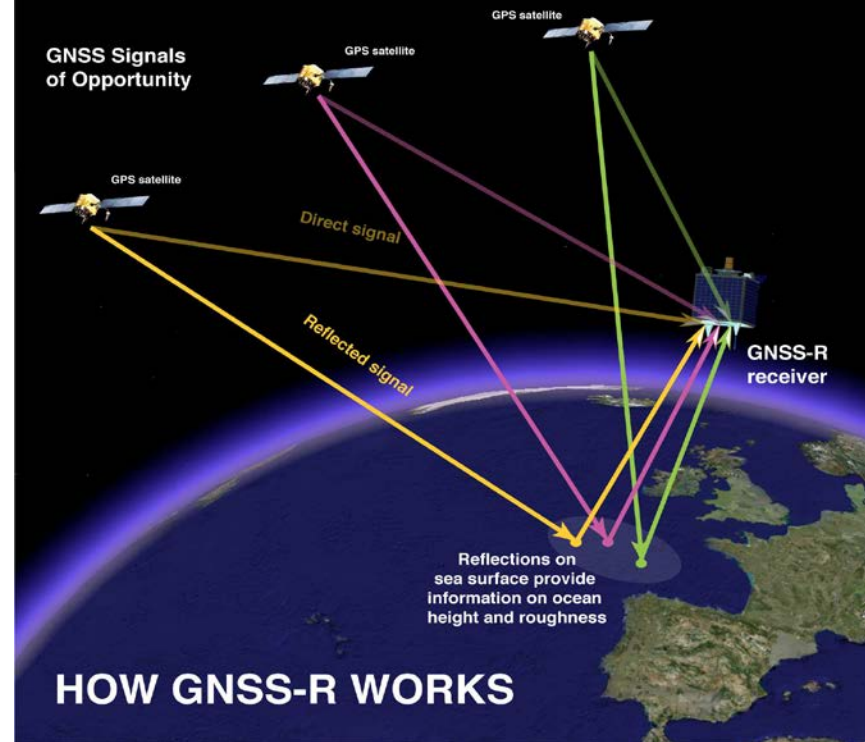
Precision: better than 0.1 m/s; 7°

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

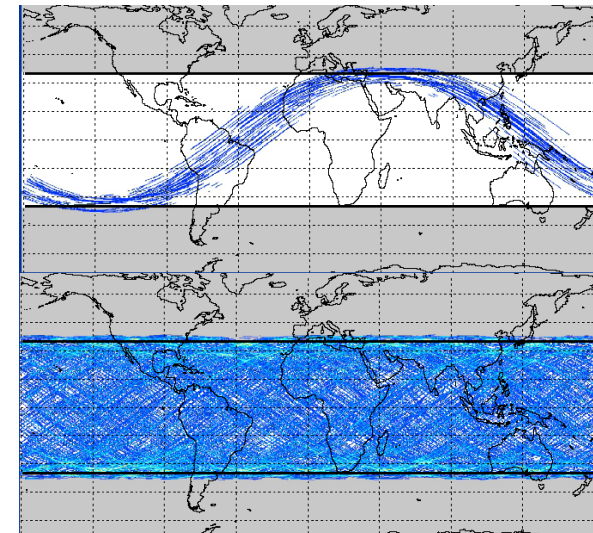
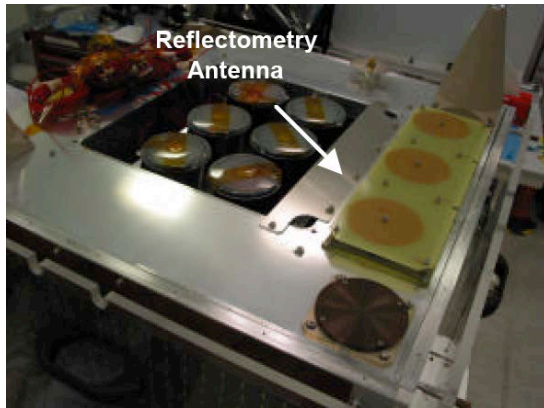
2003  
Proof-of-concept on  
SSTL's UK-DMC



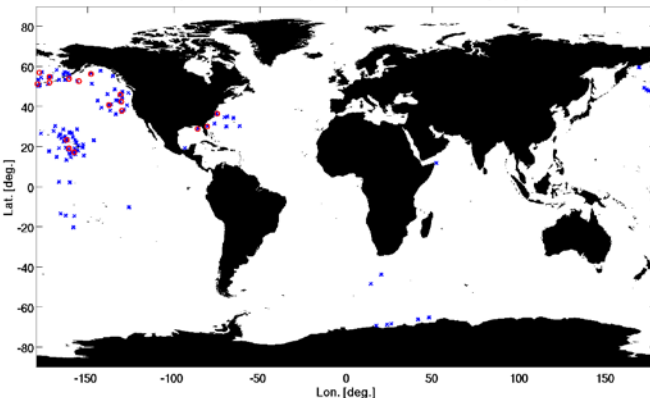
8 July 2014  
UK TechDemoSat-1  
launch with SGR-ReSI  
GPS-R payload

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

Constellation of  
8 SGR-ReSI



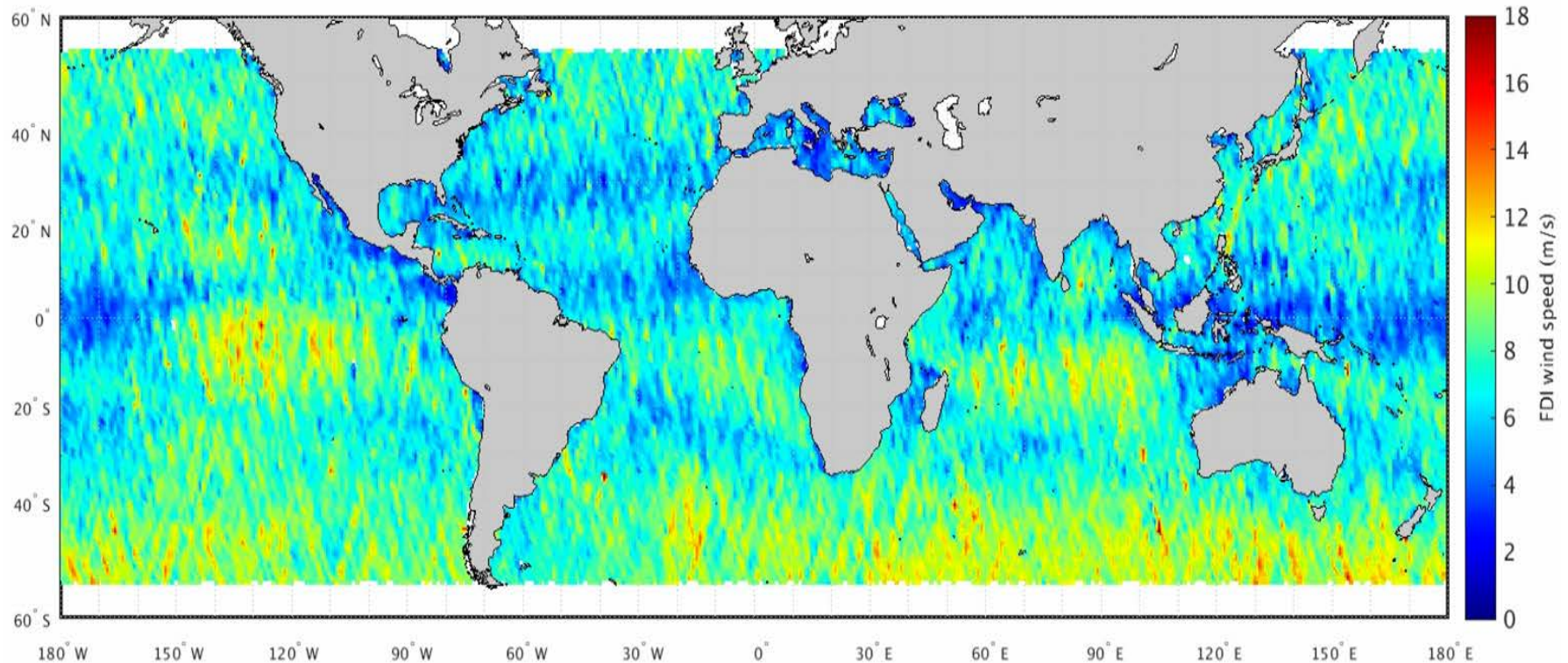
Map of GNSS-Reflections (blue) and collocated NDBC Buoys (red)



Collected ~ 50 data points  
over ocean

Aims for mean revisit  
time ~ 4 hours

# First global GNSS-R winds from TechDemoSat-1

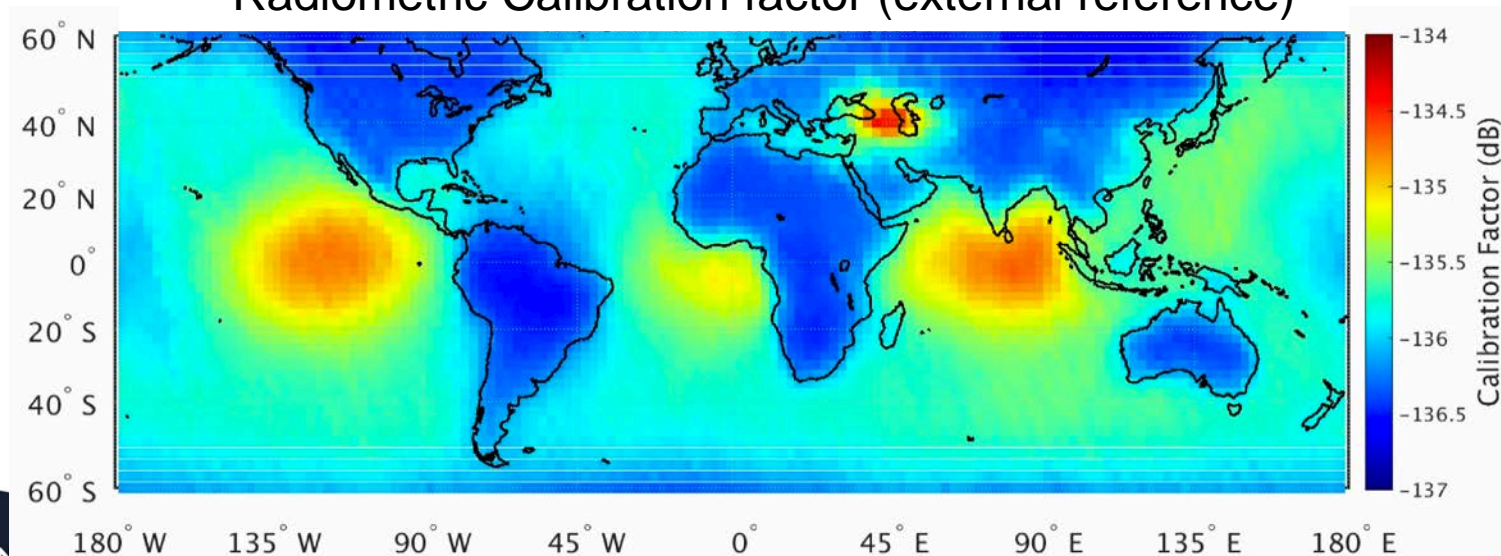


- Level 2 winds available on <http://www.merrbys.co.uk/>
- Ground processing, L2 inversion & data portal funded by ESA

# 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)



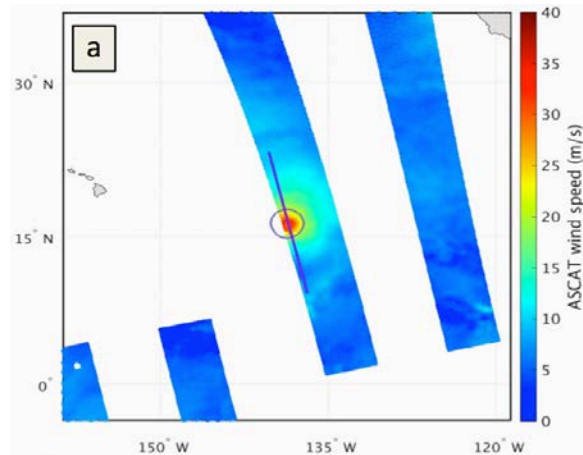
# First spaceborne GNSS-Reflectometry observations of hurricanes from the UK TechDemoSat-1 mission.

Giuseppe Foti<sup>1</sup>, Christine Gommenginger<sup>1</sup> and Meric Srokosz<sup>1</sup>

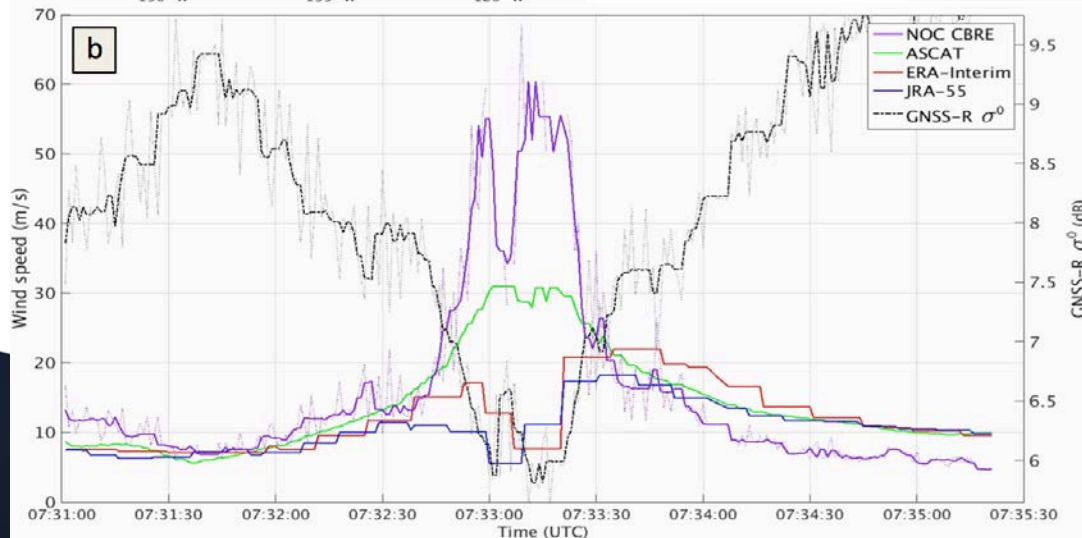
*Accepted for publication in GRL*

<sup>1</sup>National Oceanography Centre (UK)

Corresponding author: Giuseppe Foti ([g.foti@noc.ac.uk](mailto:g.foti@noc.ac.uk))



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

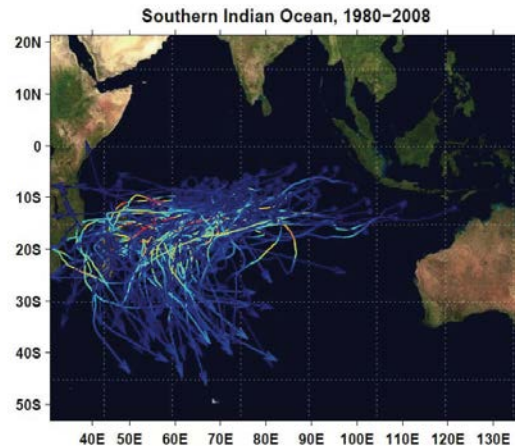
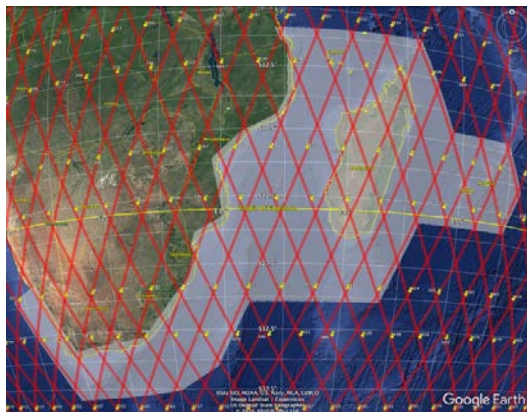




### 3. New products & services from existing data for developing countries



# C-RISe Coastal Risk Information Service UKSA International Partnership Programme



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 2013, Neumann et al

**WWF FACTSHEET**  
 APRIL 2016

**WWF MDCO priority landscapes**  
**Northern Mozambique Channel Seas**  
 A hotspot of marine and coastal biodiversity and one of the large marine sanctuaries in the Western Indian Ocean

**STUDY REPORT**  
 SEPTEMBER 2010

**MANGROVES**

**Mangrove ecosystems in western Madagascar: an analysis of vulnerability to climate change**

**AT A GLANCE**

- **Issue:** Increasing sea level rise
- **Population:** 20 million
- **Importance:** coral reefs, mangroves, coastal wetlands, seagrass, islands and lakes, dry forest, coastal forests
- **Landscapes:** the second largest land coral biodiversity hotspot in the world, large Blue and Purple National Parks, Malakal Marine Park, natural gas deposits
- **Key species:** coral, mangrove crab, sea turtle, humpback whale, shark, whale sharks

**Promoting integrated ocean management for sustainable development**

The Northern Mozambique Channel (NMC) region is one of the world's outstanding natural heritage hotspots and a biological treasure for all East African coastal areas. Biological and oceanographic values of the NMC are part of global treasures as evidenced by multiple reports including the 2002 assessment of Ecologically or Biologically Significant Areas. The economic importance of the NMC has increased as a result of rapid coastal development on a scale not previously realized in East Africa, due to the high fertility of the Mozambique coastal ocean. Failure of publicly supported coastal development for coastal tourism development. Accelerating population growth in the NMC is anticipated. It is important to assess the vulnerability of coastal ecosystems, which are the growing opportunities for economic growth and building prosperity.

The region is threatened by increasing pressures of marine resources, including but not limited to overfishing, increasing expansion of illegal fishing, inappropriate public land use, and other threats.

**Vision and Goals**

**Vision:** By 2030, the people, activities and resources of the Northern Mozambique Channel prosper in a sustainable future provided on the natural and cultural assets and diversity of the region.

**Goal 1:** By 2020, the NMC countries have enhanced, at the local to state level, regional integrated management policy of place or action oriented to securing critical habitats for biodiversity and food security.

**Goal 2:** By 2020, integrated coastal management (ICM) is applied to three NMC countries and these countries are explicitly integrating their ocean management policies.

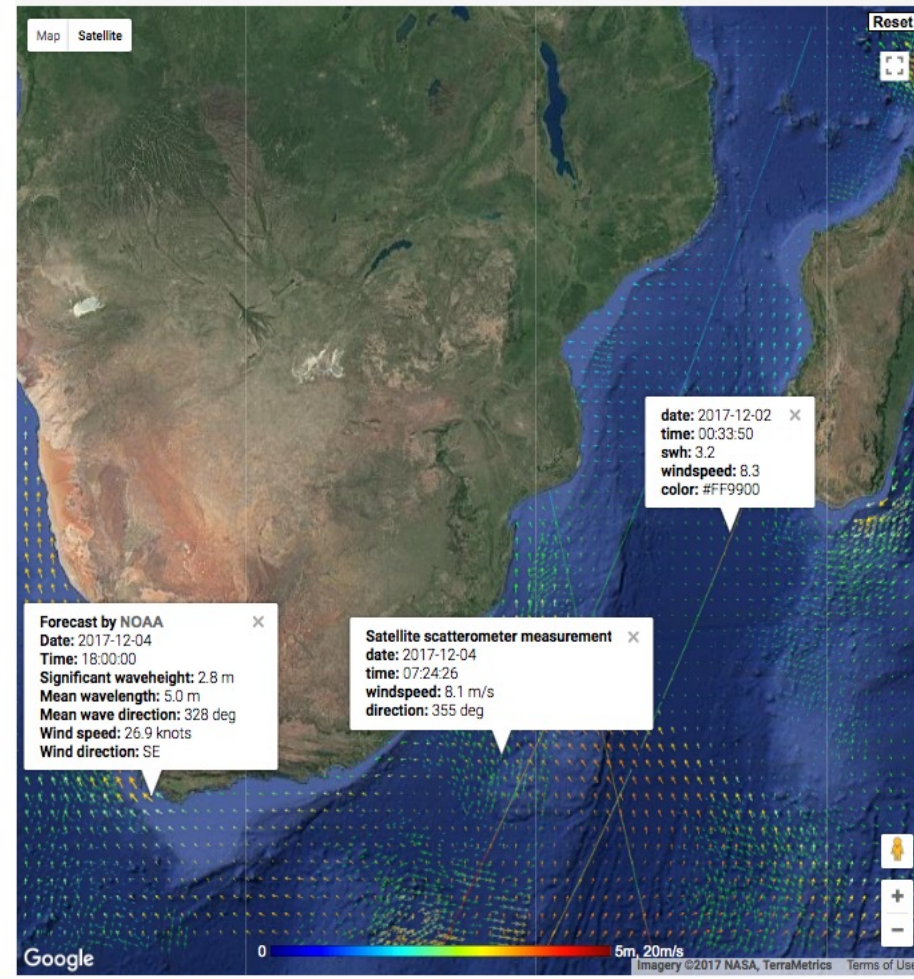
**Goal 3:** By 2030, participatory partnerships or funding support the monitoring, maintenance and progress to implementing the regional plans for the NMC area to coherent practice.

Copyright WWF  
 2010, 2016

# 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

C-RISe (for Coastal Risk Information Service) will deliver, through an international partnership with Mozambique, Madagascar and South Africa; access to satellite-derived data on sea level, wind speed and wave heights. This page is a demonstration of some of the satellite data and forecast information available.



# 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



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