



# Wavemill: a new mission for highresolution mapping of Total Ocean Current Vectors

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**National  
Oceanography Centre**  
NATURAL ENVIRONMENT RESEARCH COUNCIL



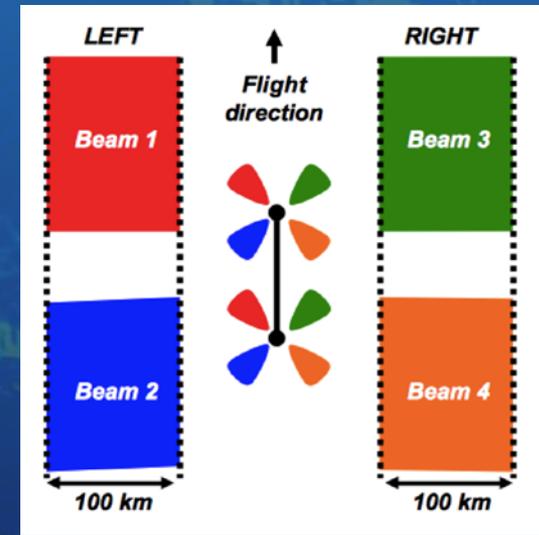
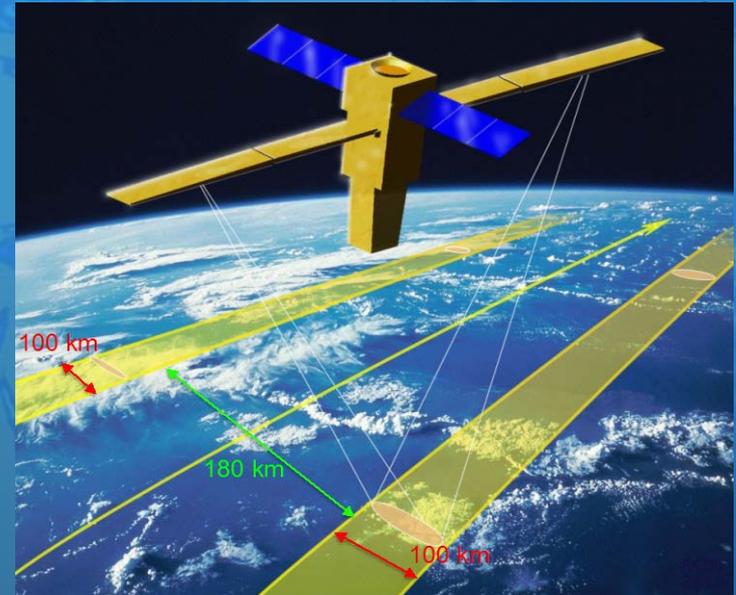
**AIRBUS**  
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**Starlab**  
Living Science

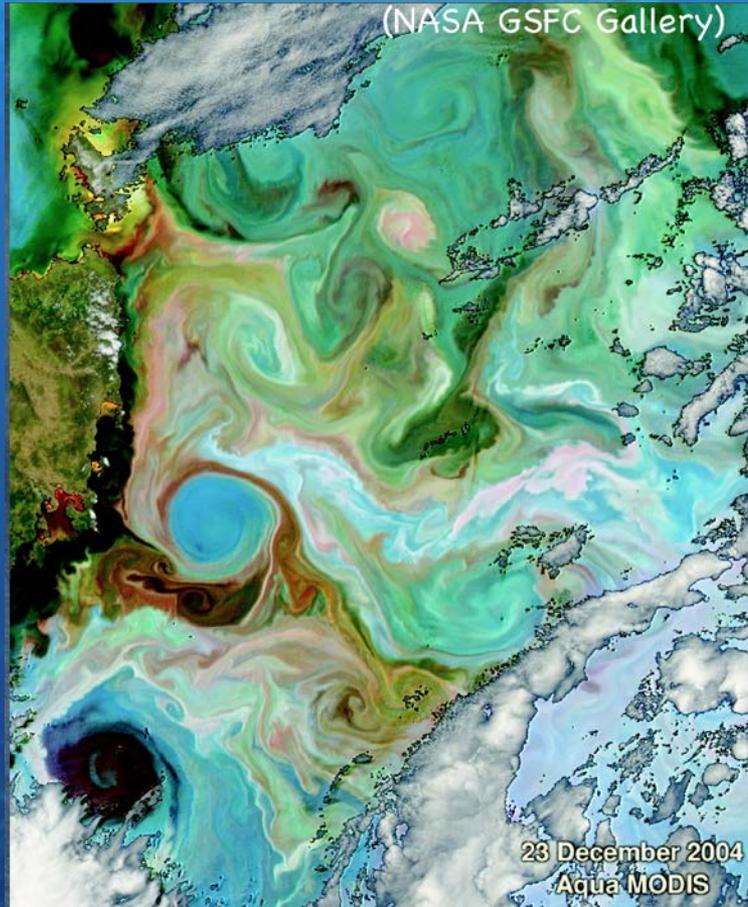
**SATOC**

# Wavemill: the concept

- Interferometric SAR
- Four squinted beams; Ku-band
- Originally both ATI and XTI
  - XTI now dropped!
- Prime objective:
  - high-res total ocean surface current vectors
- Secondary objectives include:
  - high-res wind vectors & swell
- Requirements: 2 x 100 km swath (TBD)
  - 1km resolution; 5 cm/s accuracy
- Various instrument & mission configurations currently under study (two ESA OSCM studies)
- ESA Earth Explorer 9 mission proposal in prep.



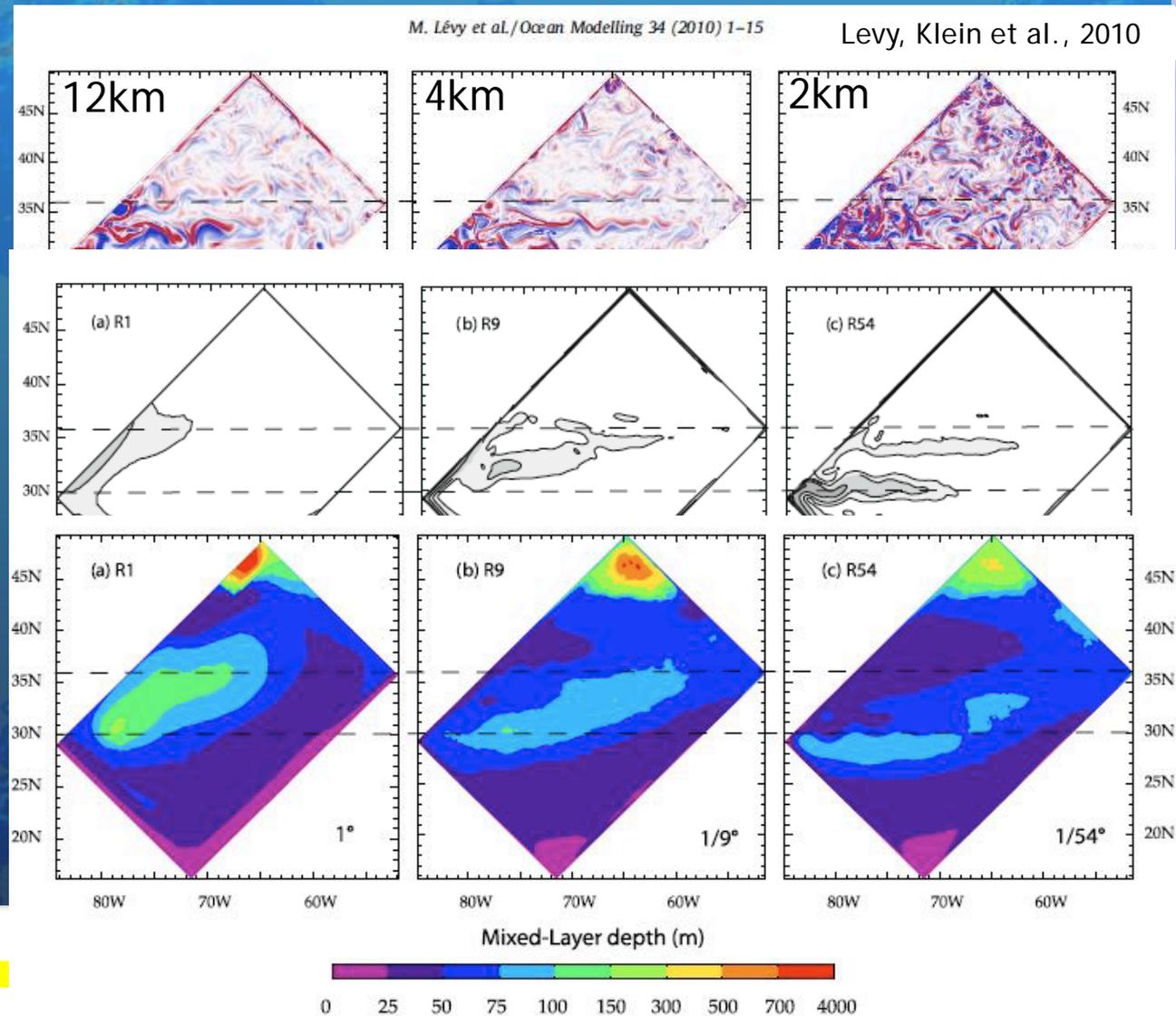
# Wavemill: the science case



- Ocean is dominated by ubiquitous features at the mesoscale and sub-mesoscale
  - Mesoscale (10-100km)
  - Sub-mesoscale (1-10km)
- Seen in high-res IR sea surface temperature and ocean colour
- little/no data from space on ocean dynamics at these scales
- Relevant to:
  - Horizontal and vertical ocean mixing, large scale ocean transport, ocean biology
  - Atmosphere/wave/ocean exchanges

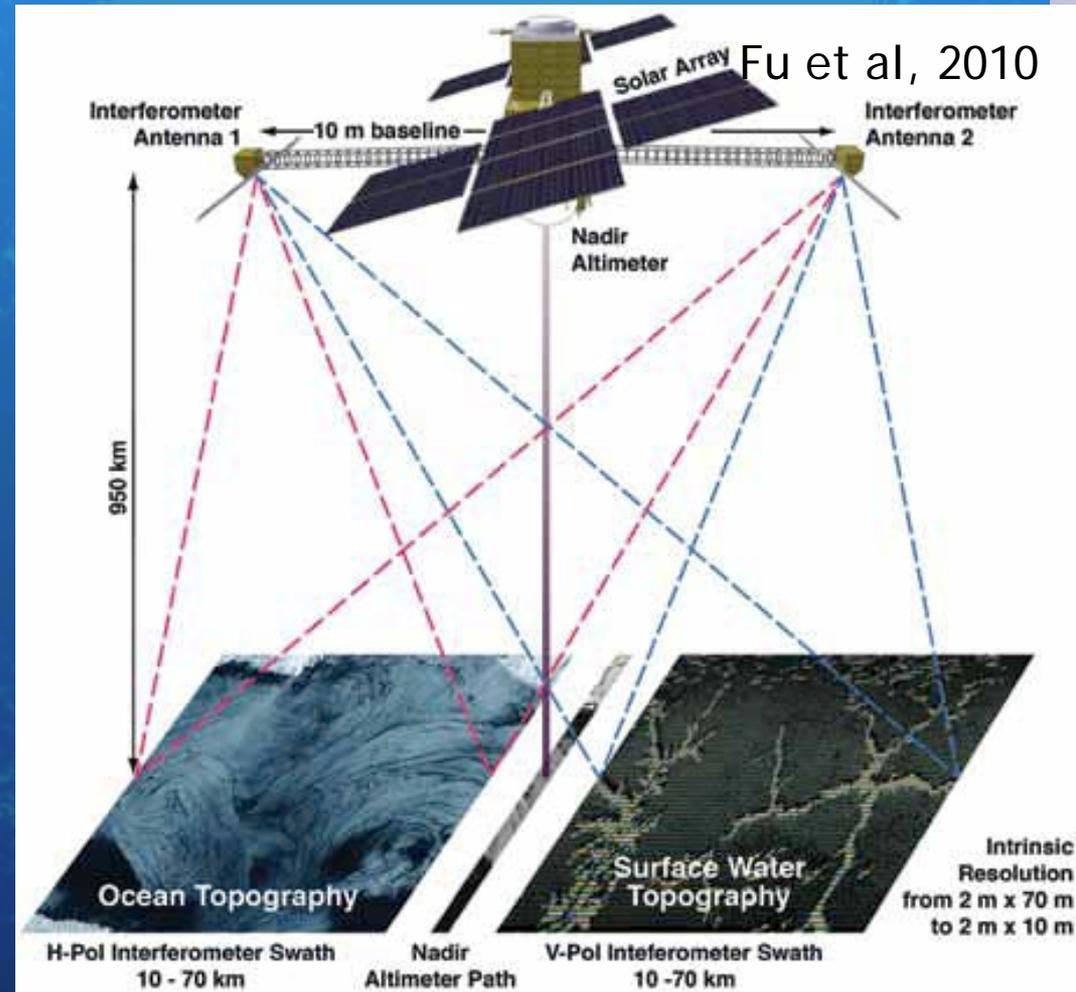
# The impact of the oceanic sub-mesoscale

- Growing evidence about the importance of small scale ocean variability & wind/eddy interactions
- E.g. 100-year ocean model run at 3 resolutions shows impact on:
  - large scale ocean circulation
  - thermohaline circulation
  - meridional heat transport
  - mixed layer depth
  - ocean biogeochemistry & ecosystems



# Surface Water & Ocean Topography mission (SWOT)

- Resolving small ocean scales is also the motivation for NASA/CNES SWOT mission
- High resolution 2D maps of Sea Surface Height
  - SSH => geostrophic currents
  - XTI; Ka-band
  - SSH precision: 1cm @ 1km
  - ocean variability at 10-25 km scales
- Strong **complementarity** with Wavemill 2D total currents
  - Geostrophic/ageostrophic



# Wavemill: the challenges



- Large instrument, large power requirements, large data volumes
  - Cutting-edge yet feasible; Big budget!
- Need clear strategy for phase calibration
  - Any error in interferometric phase = error in retrieved current
- Open questions on geophysical inversion & correcting for unwanted ocean surface motion effects
  - Demonstration with Wavemill airborne demonstrator
  - Direct implications for instrument and mission definition

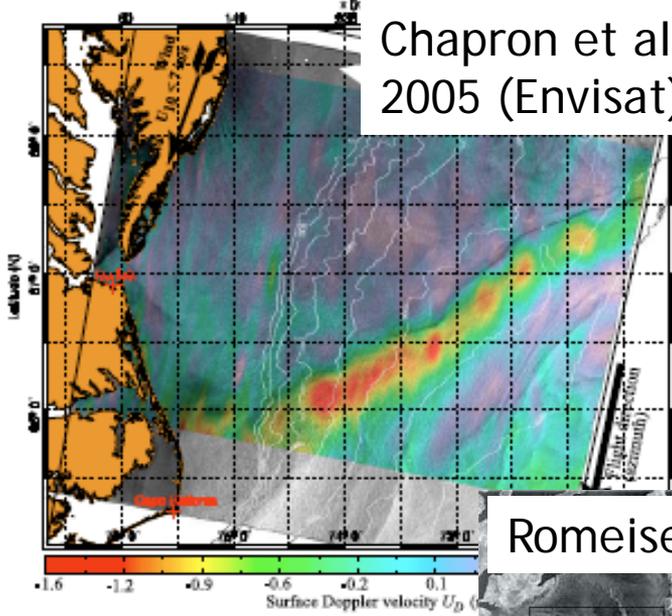


# Surface motion effects and geophysical inversion

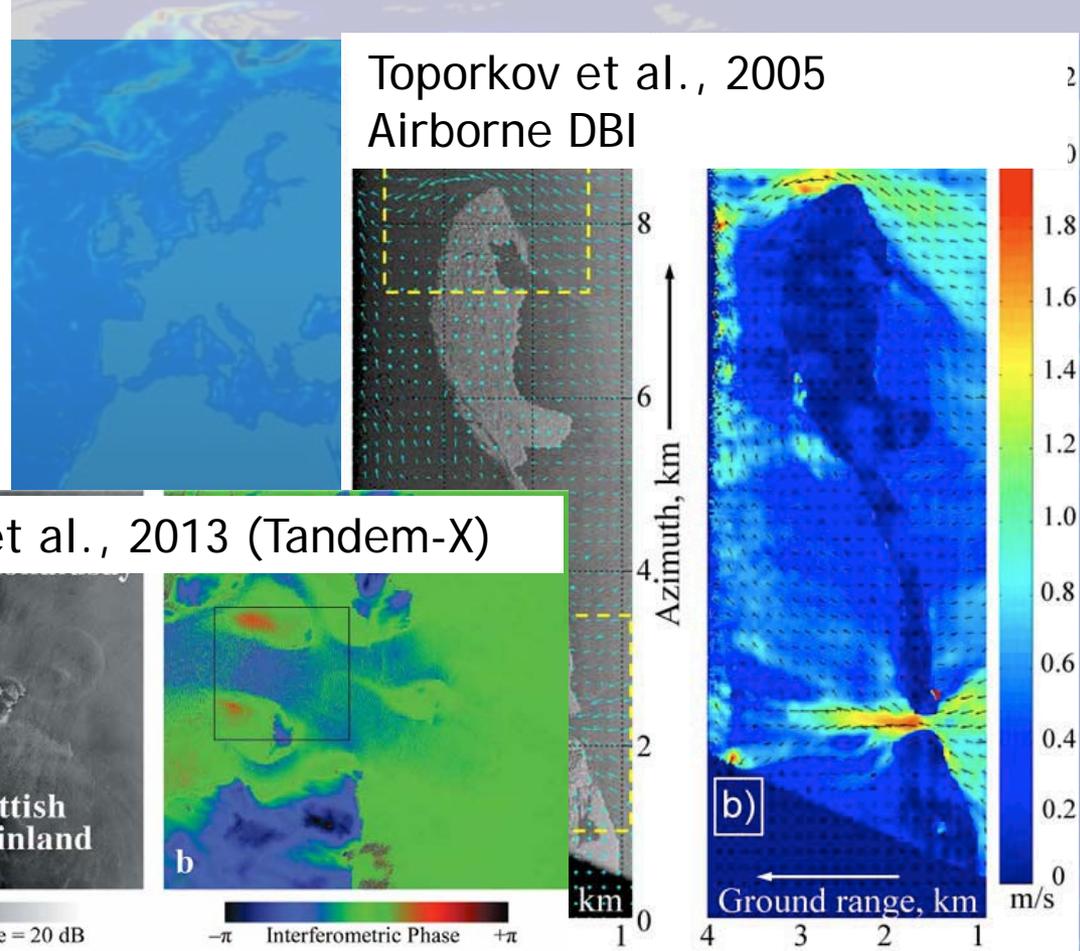
Wavemill airborne proof-of-concept

See poster by Adrien Martin:  
"Wavemill: Interpretation of the airborne proof-of-concept total ocean  
surface current measurements"

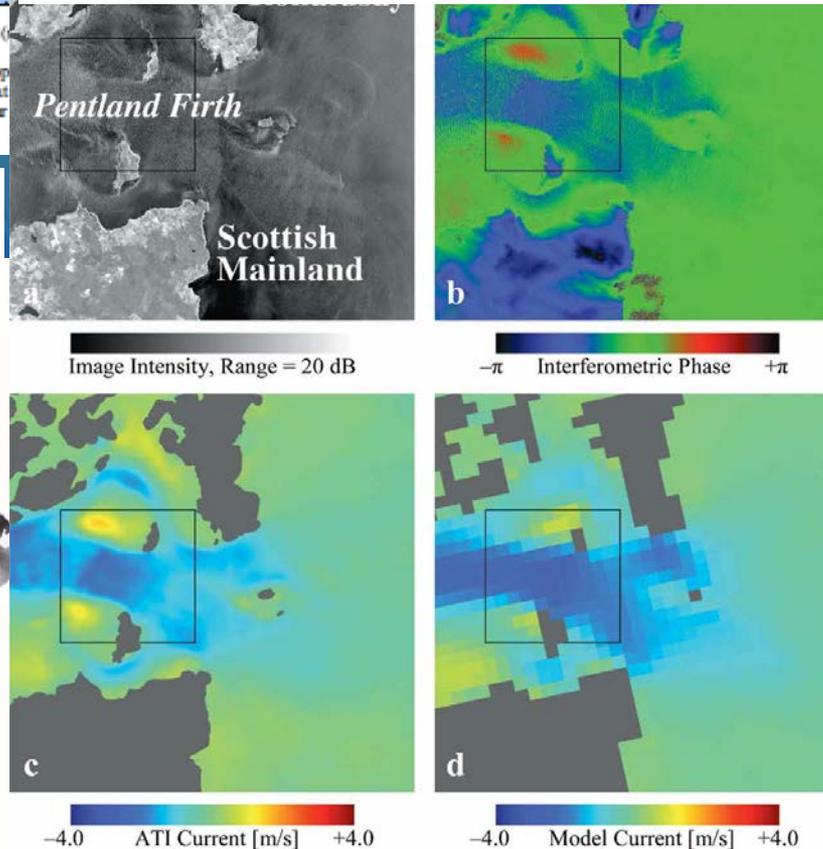
Chapron et al.,  
2005 (Envisat)



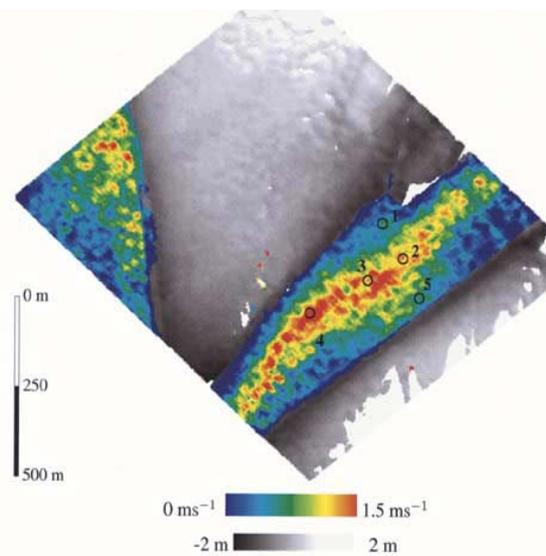
Toporkov et al., 2005  
Airborne DBI



Romeiser et al., 2013 (Tandem-X)



Siegmund et al. 2004  
Airborne ATI/XTI



- Many examples, airborne & spaceborne
- All report unwanted wave effects

# Wavemill airborne proof of concept

Irish Sea

Liverpool Bay

Anglesey

Menai Strait

R11, R10, R12, R13, R1, R2, R3, R4, R5, R6, R7, R8

Wavemill airborne demonstrator

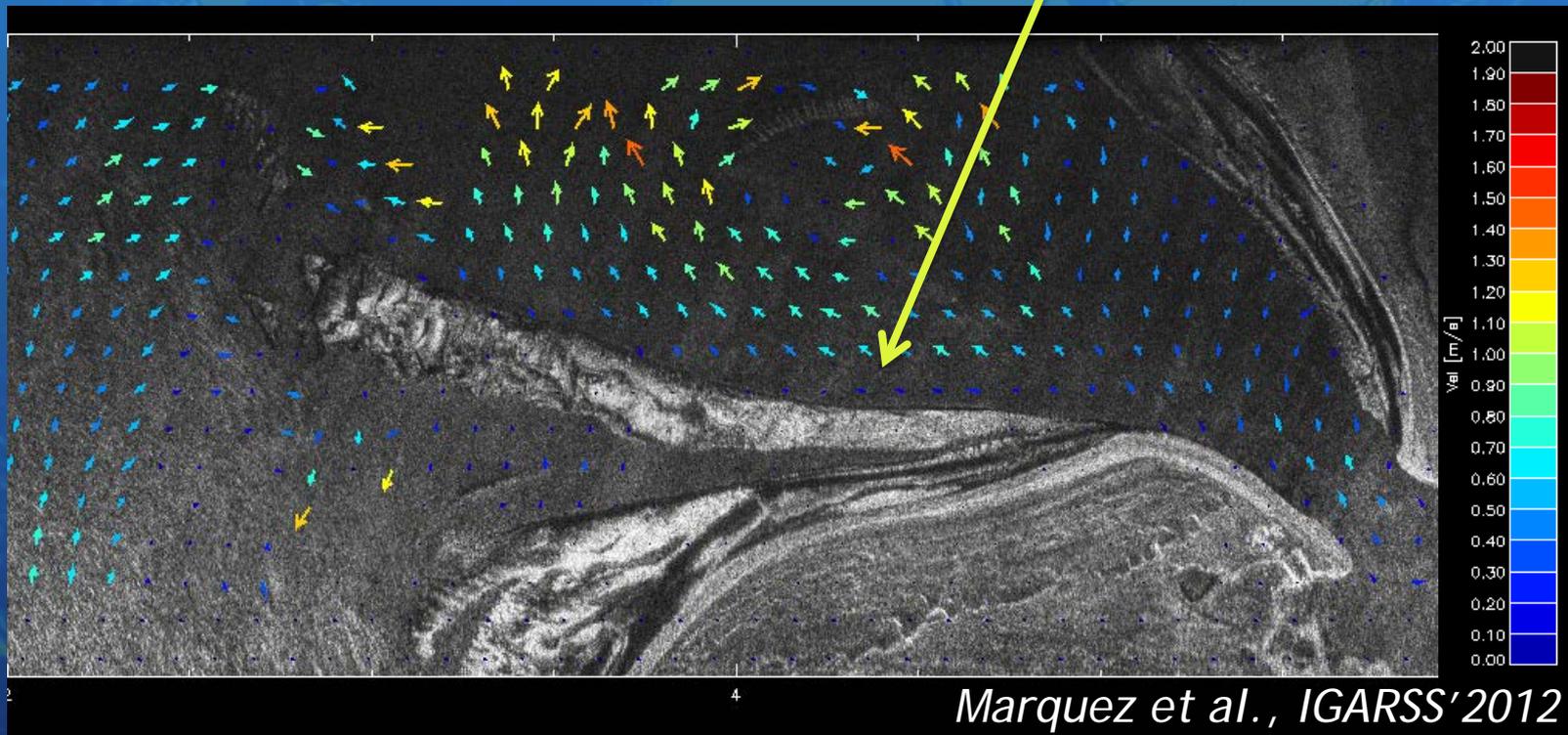
- October 26th, 2011
- Javelin Configuration



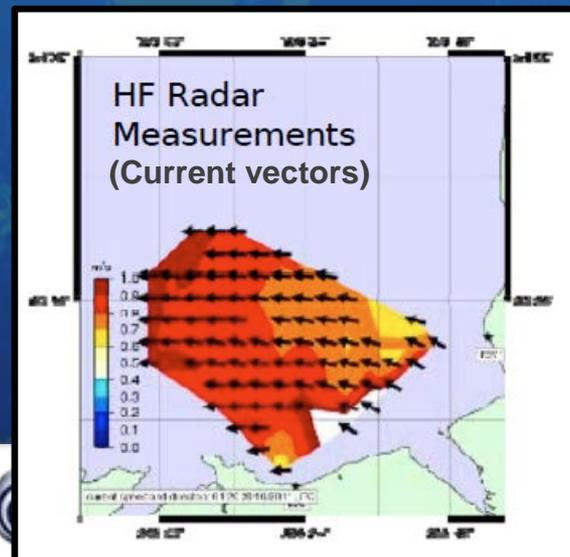
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# Over Menai Strait

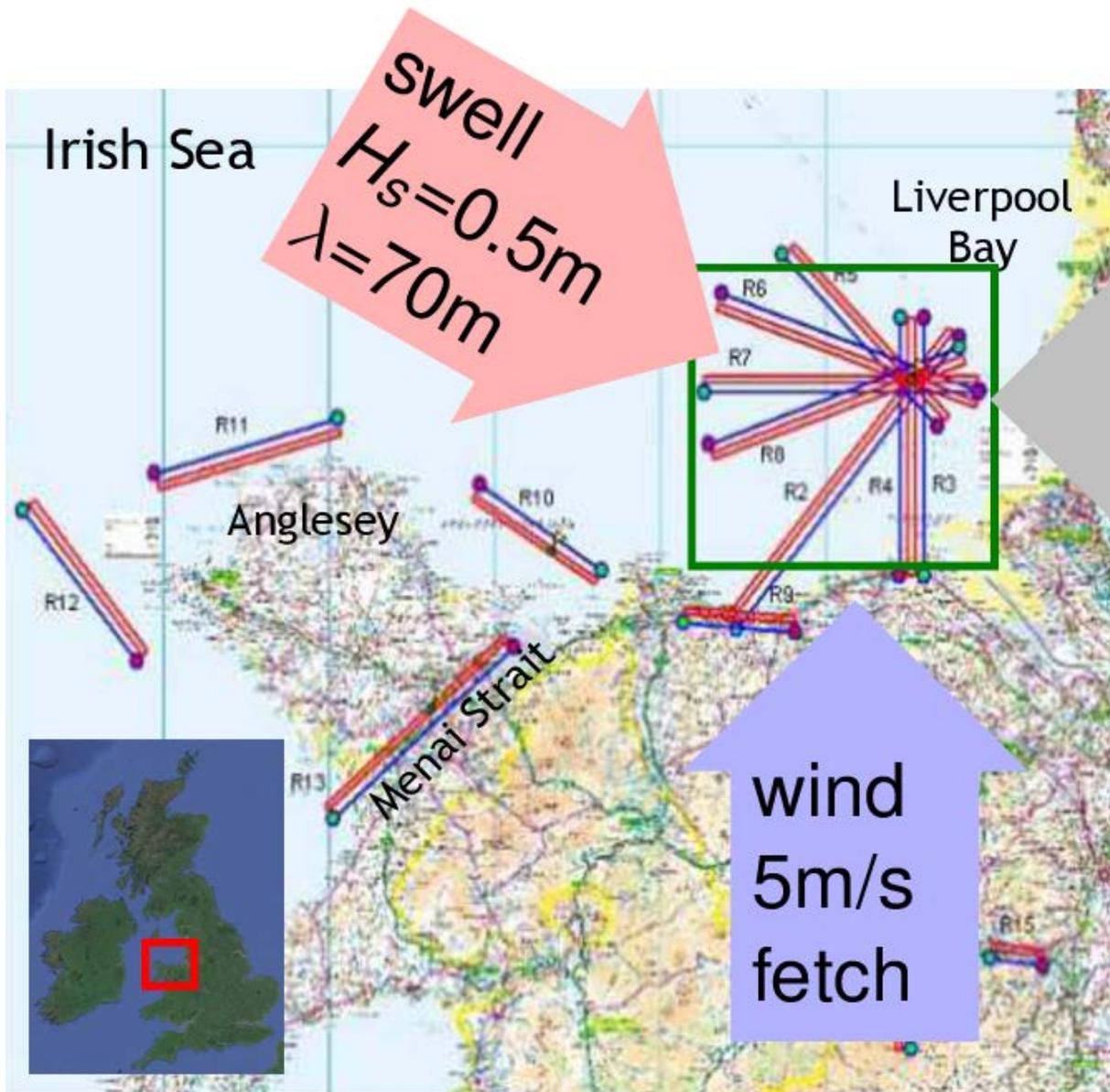
Measurements right up to the coast



# Validation over Liverpool Bay



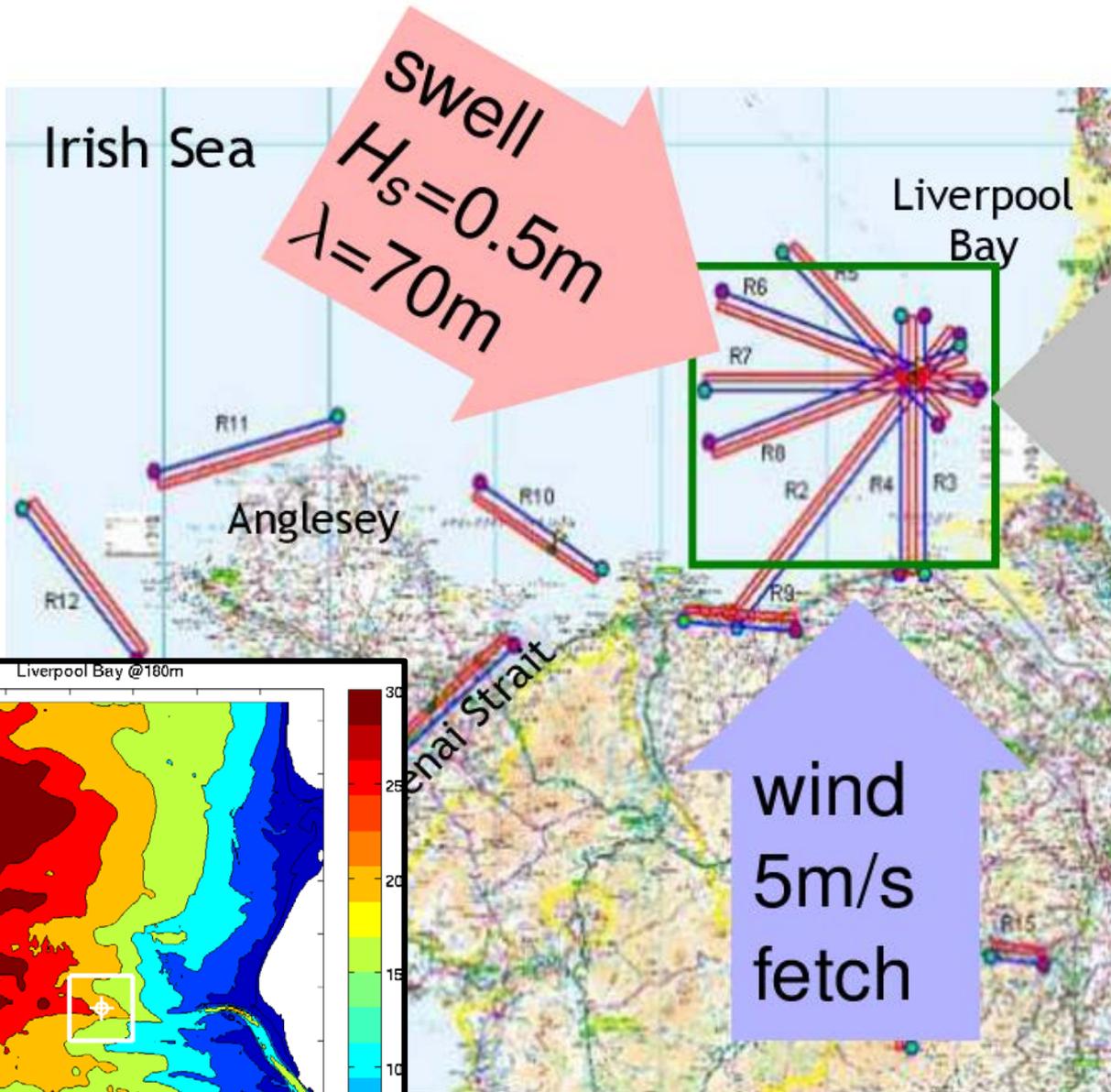
+ hourly winds from UK Met Office atmospheric model (1.5 km)



Environmental conditions on 26 Oct 2011

current  
 $0.7\text{m/s}$

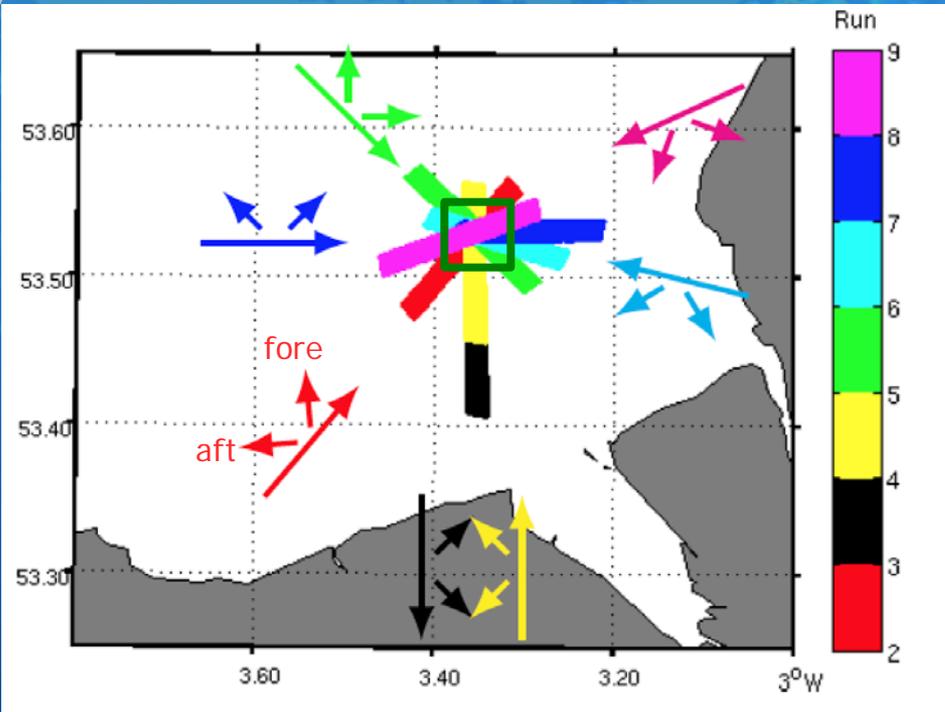
- Westward tidal current
- Light wind from the south
  - short fetch
- Low energy swell from NW



Environmental conditions on 26 Oct 2011

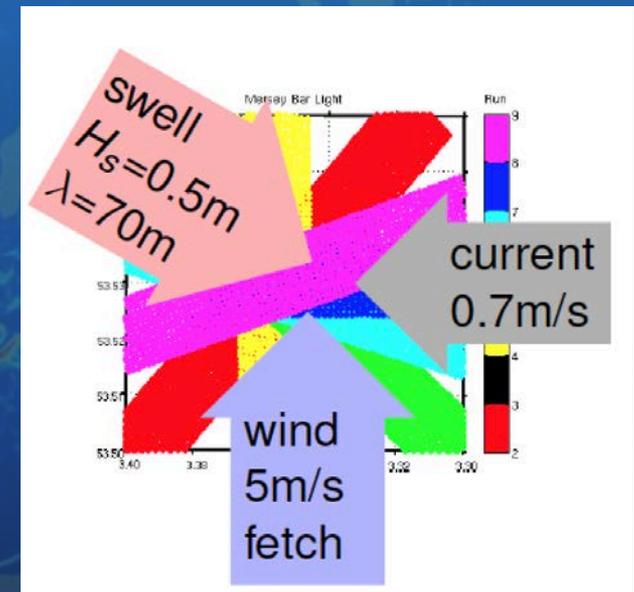
current  
 $0.7\text{m/s}$

- Westward tidal current
- Light wind from the south
  - short fetch
- Low energy swell from NW
- Shallow waters

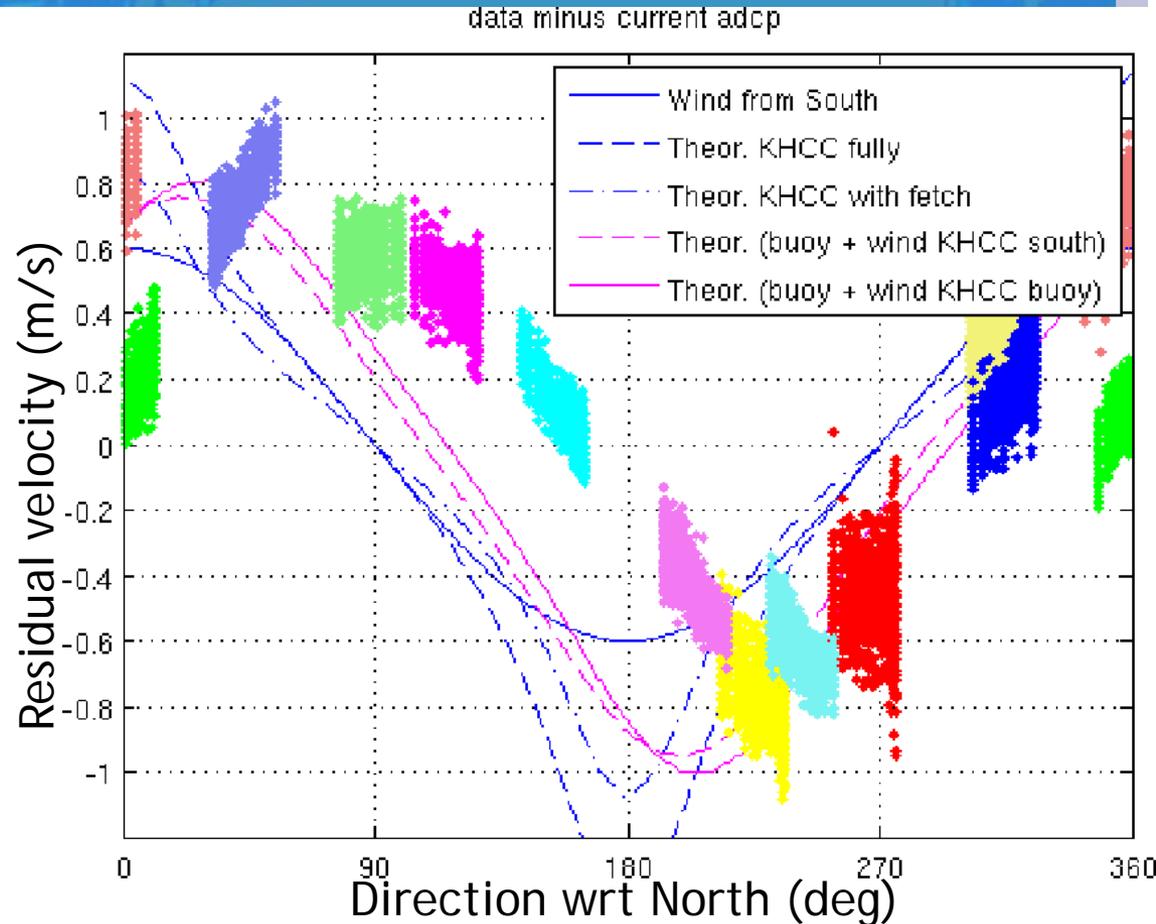
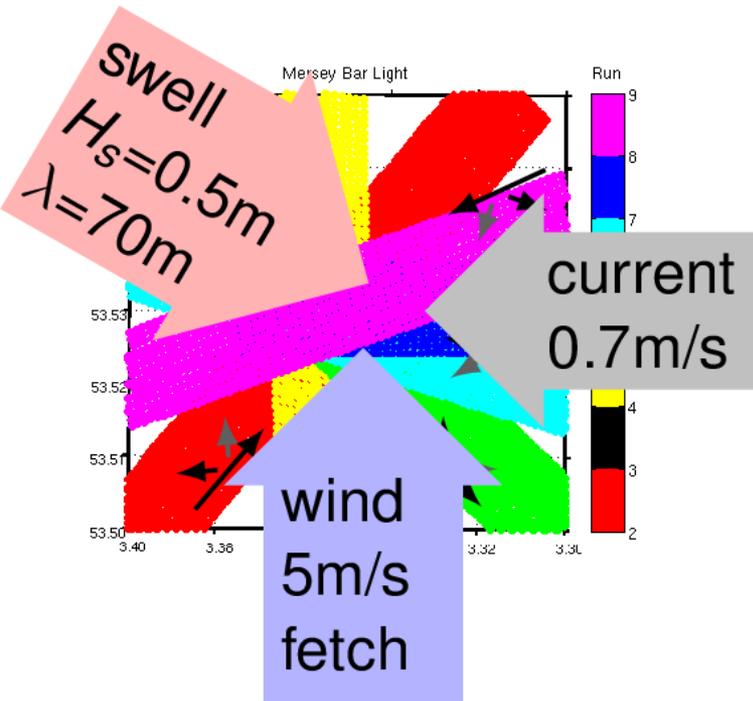


- X-band; Incidence: 25-45 deg
- Two look directions per flight (fore & aft)
- Currents @ 100m resolution

- Select 6 km x 6 km box around Mersey Bar
- All flights within 1 hour
- Conditions assumed uniform over the box



# Theoretical modelling of surface wave motions



Theoretical model explains most (but not all) residual signal

# Implications for the mission

- Theoretical modelling shows encouraging results to remove unwanted wave effects...
- ...but geophysical inversion requires knowledge of wind vector or directional wave spectrum
- Where to get the necessary information ?
  - SAR directional spectrum does not see short waves (10-100m)
  - Wind from operational model (last-resort!)
    - OR
  - Additional payload for scatterometry (e.g. third antenna)
  - Multiple polarisation (under investigation)
- Major change of emphasis towards higher incidence angles (30+), wider swath (200km) and multi-polarisation

# Wavemill: present status

- ESA Ocean Surface Current mission study
  - Led by ADS
  - Trade-offs between science needs, instrument choices & mission constraints
  - Complex relations between instrument configuration, resolution, measurement error, power, swath width, coverage, re-visit time, data volumes,...
  
- CEOI study on Phase calibration strategy
  - Recently kicked-off; Led by NOC, with Starlab UK & ADS
  - One-side v two-side viewing configuration



# Wavemill: still to do

- Seeking opportunities for new Wavemill airborne flights
  - Exploit Satellite Catapult AIRSAR capability
  - Develop new airborne demonstrator
    - to test phase calibration strategy
    - to investigate polarisation for improved geophysical inversion
- Build the international science team
  - Work in progress
- Secure national support for the science
- Wait for the ESA EE9 call
  - and hope the budget is compatible with a large Core mission !

# Summary & Conclusions

- Strong scientific case for new satellite observations of ocean dynamics at the mesoscale and sub-mesoscale
  - Importance of ageostrophic currents and wind/eddy interactions
- Wavemill would deliver high-resolution currents and winds, right up to the coast
  - 2D current vector in single-pass, including ageostrophic currents
  - Coincident measurements of wind and swell
  - Complementary with SWOT
- Successfully demonstrated in airborne flights over Irish Sea
  - Geophysical inversion & instrument/mission definition still under investigation
  - More airborne flights needed
- Waiting for news about the Earth Explorer 9 call...

# Thank You

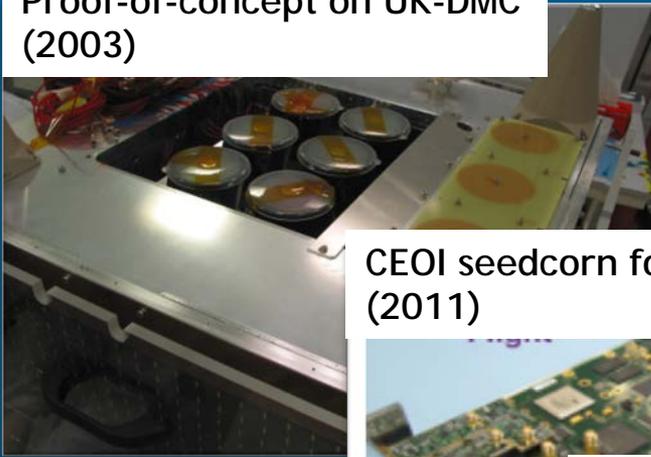
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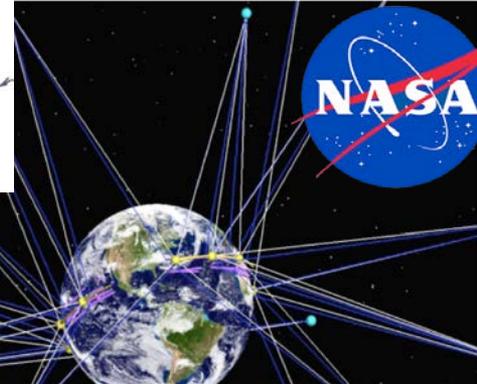
Proof-of-concept on UK-DMC  
(2003)



CEOI seedcorn for SGR\_ReSI  
(2011)



SGR-ReSI on TechDemoSat-1  
(Launch confirmed: 8 July 2014)



SGR-ReSI on NASA CYGNSS (2016)

