



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

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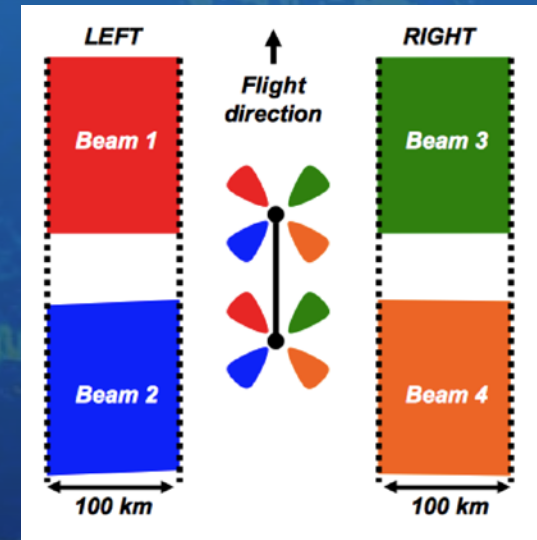
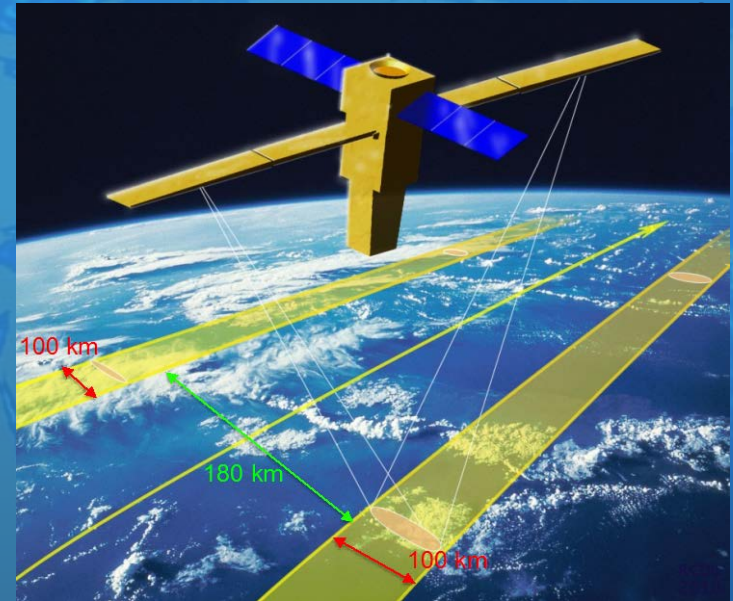
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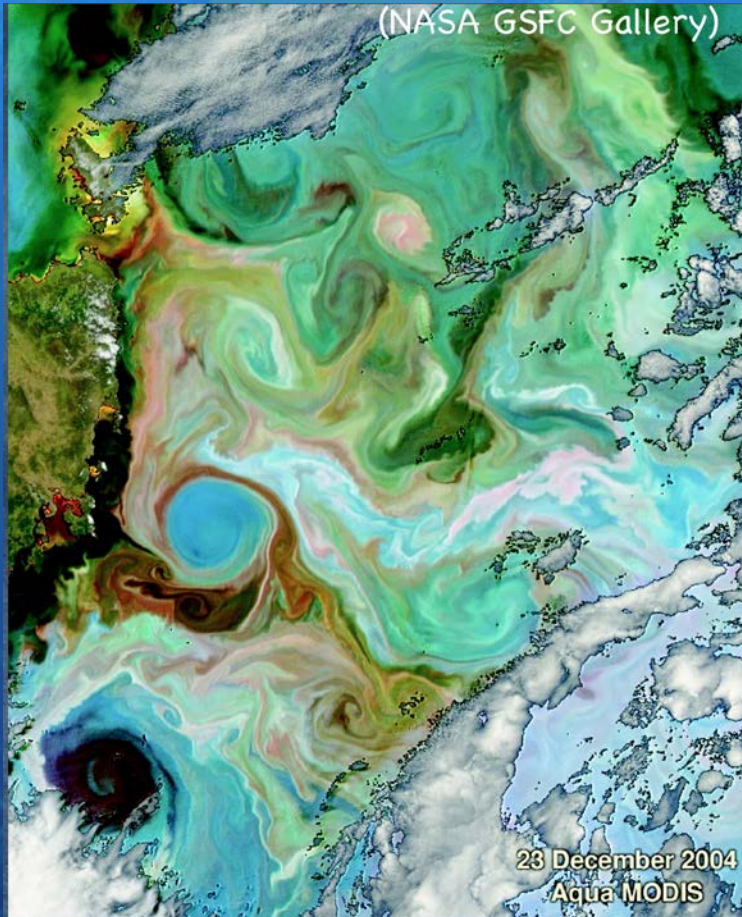
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Wavemill: the concept

- 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.



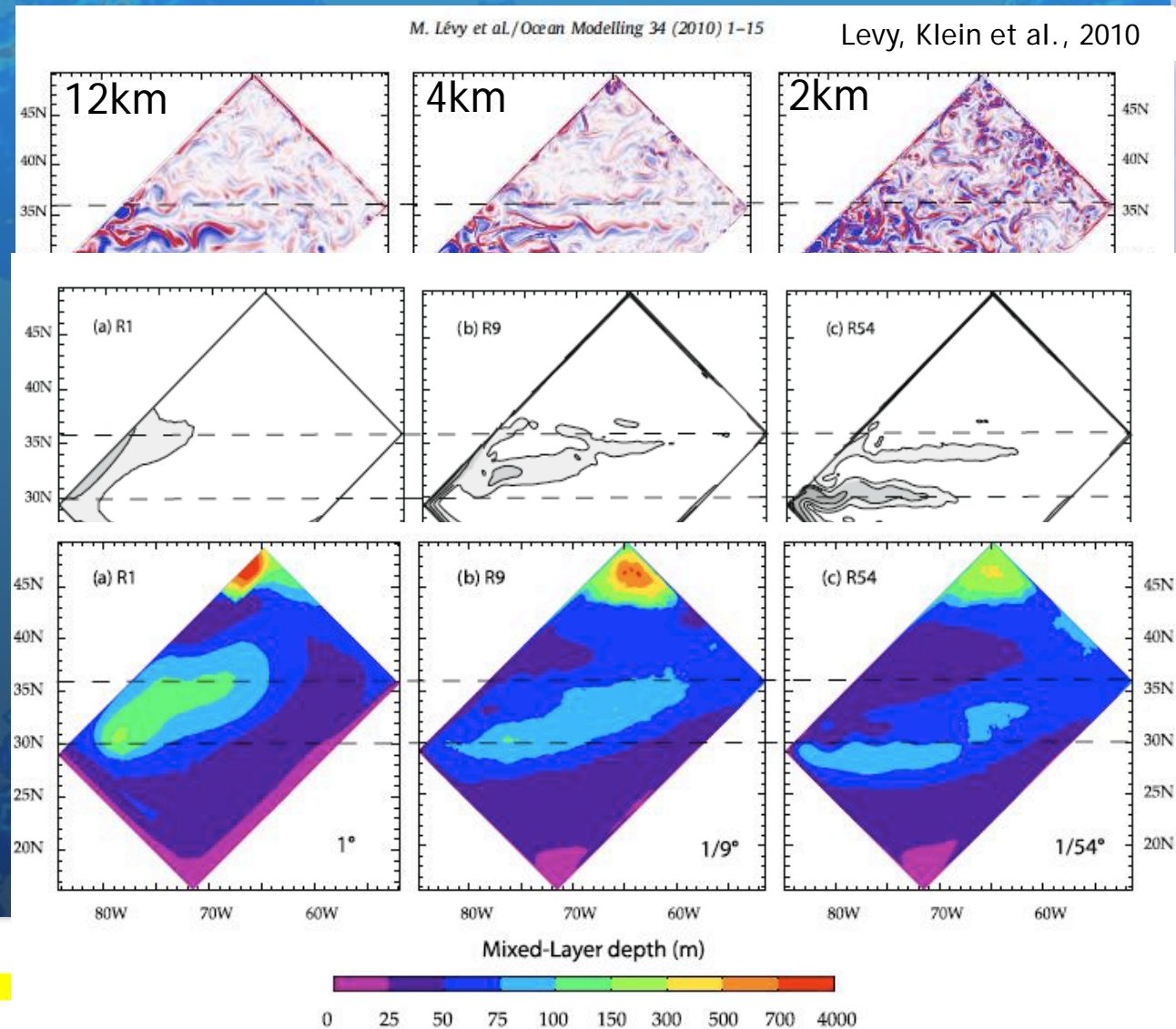
Wavemill: the science case



- 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

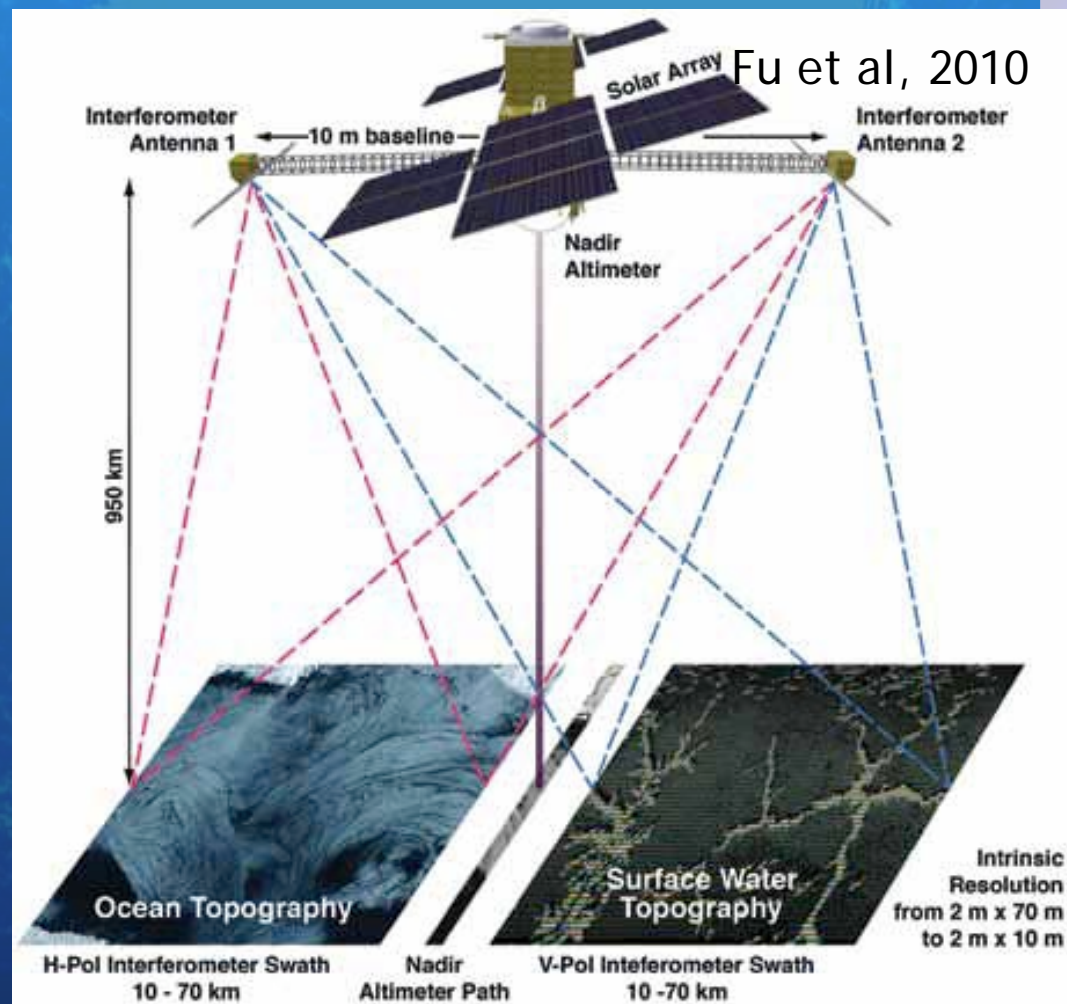
The impact of the oceanic sub-mesoscale

- 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”



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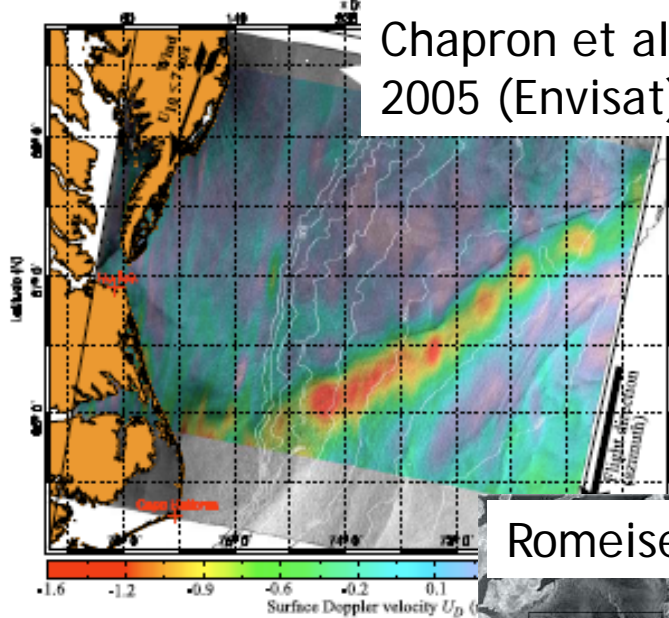


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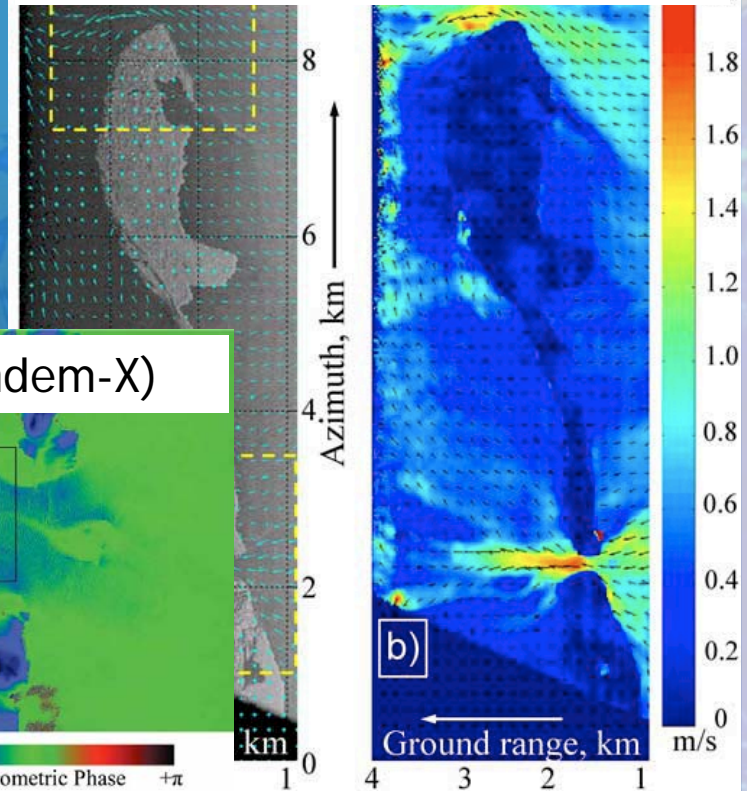
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Chapron et al.,
2005 (Envisat)



Toporkov et al., 2005
Airborne DBI



Romeiser et al., 2013 (Tandem-X)

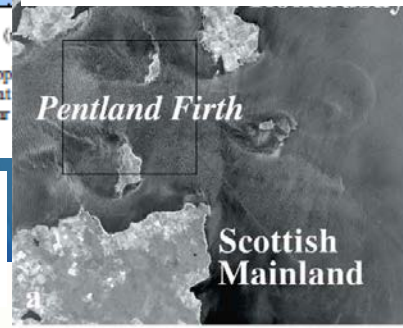
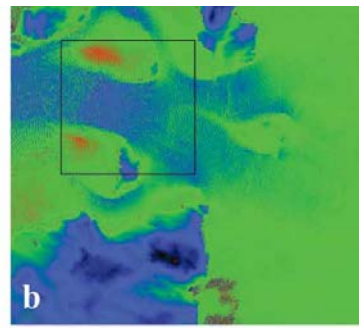
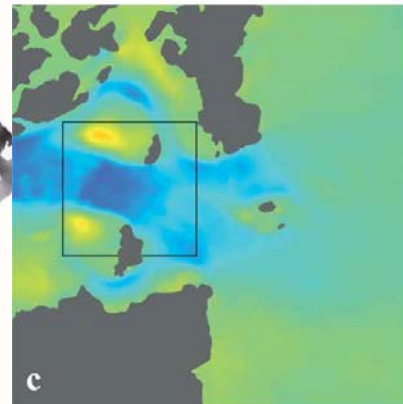


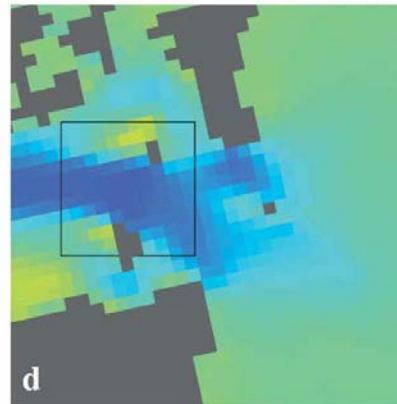
Image Intensity, Range = 20 dB



$-\pi$ Interferometric Phase $+\pi$



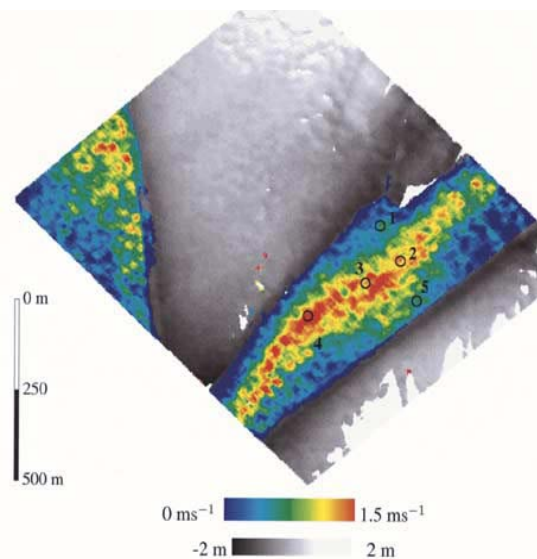
-4.0 ATI Current [m/s] +4.0



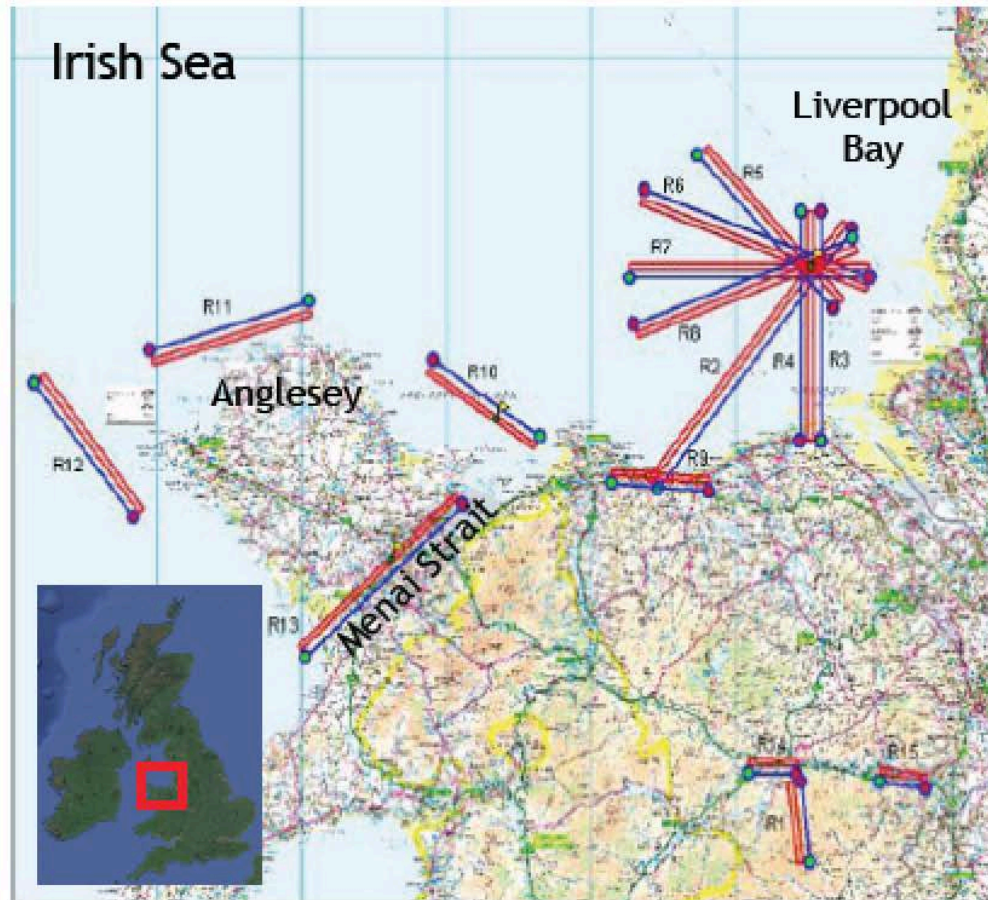
-4.0 Model Current [m/s] +4.0

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

Siegmund et al. 2004
Airborne ATI/XTI



Wavemill airborne proof of concept

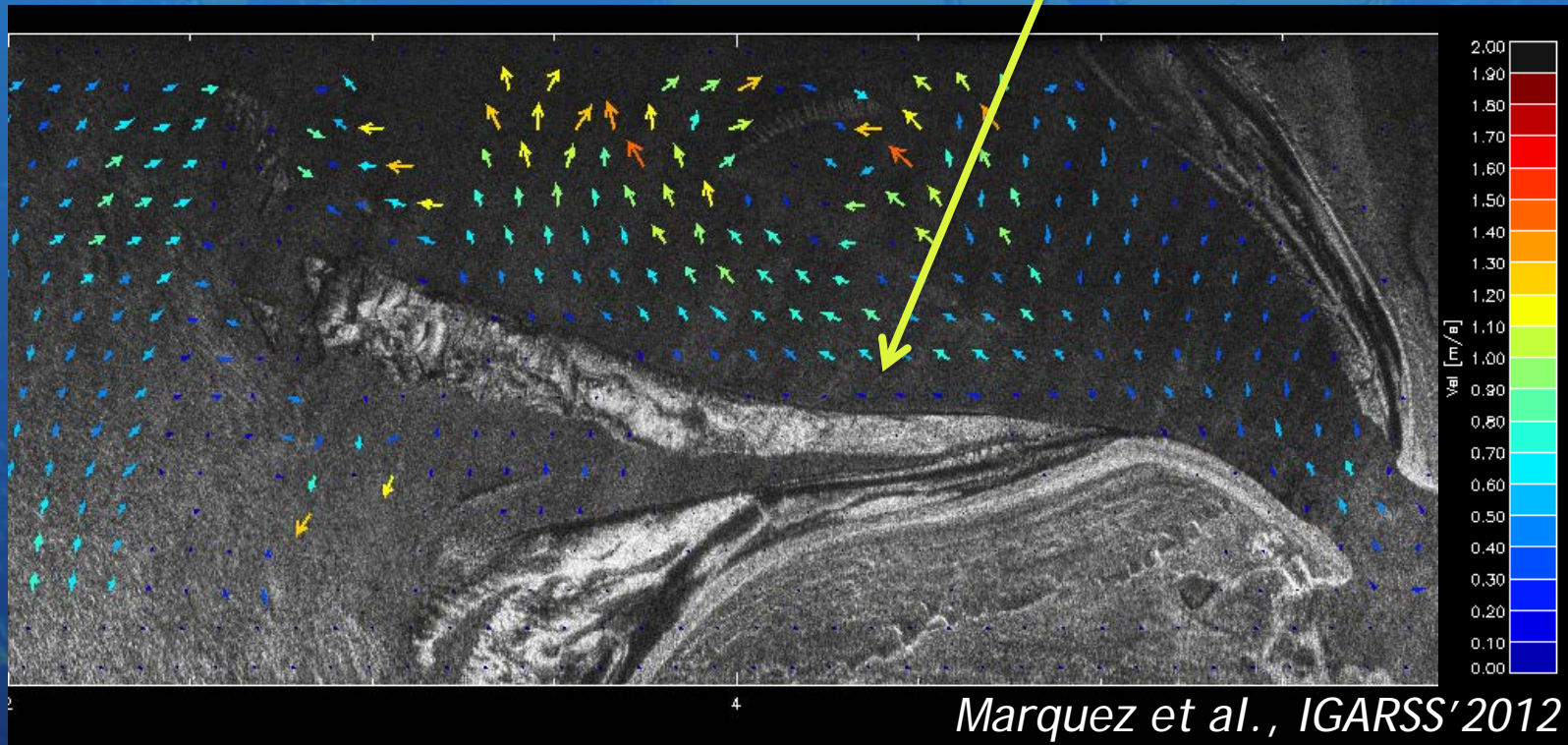


- October 26th, 2011
- Javelin Configuration



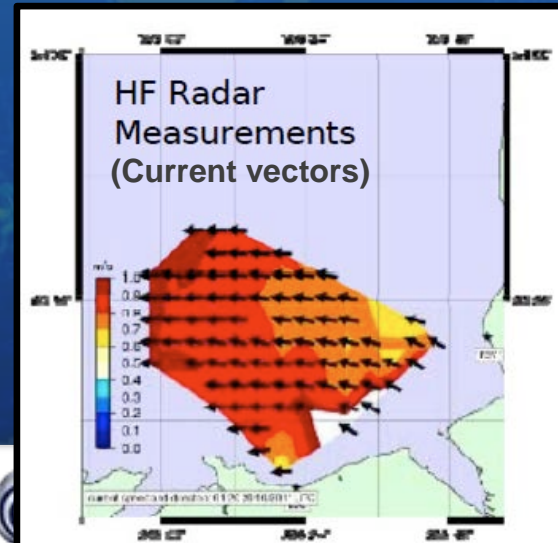
Over Menai Strait

Measurements right up to the coast

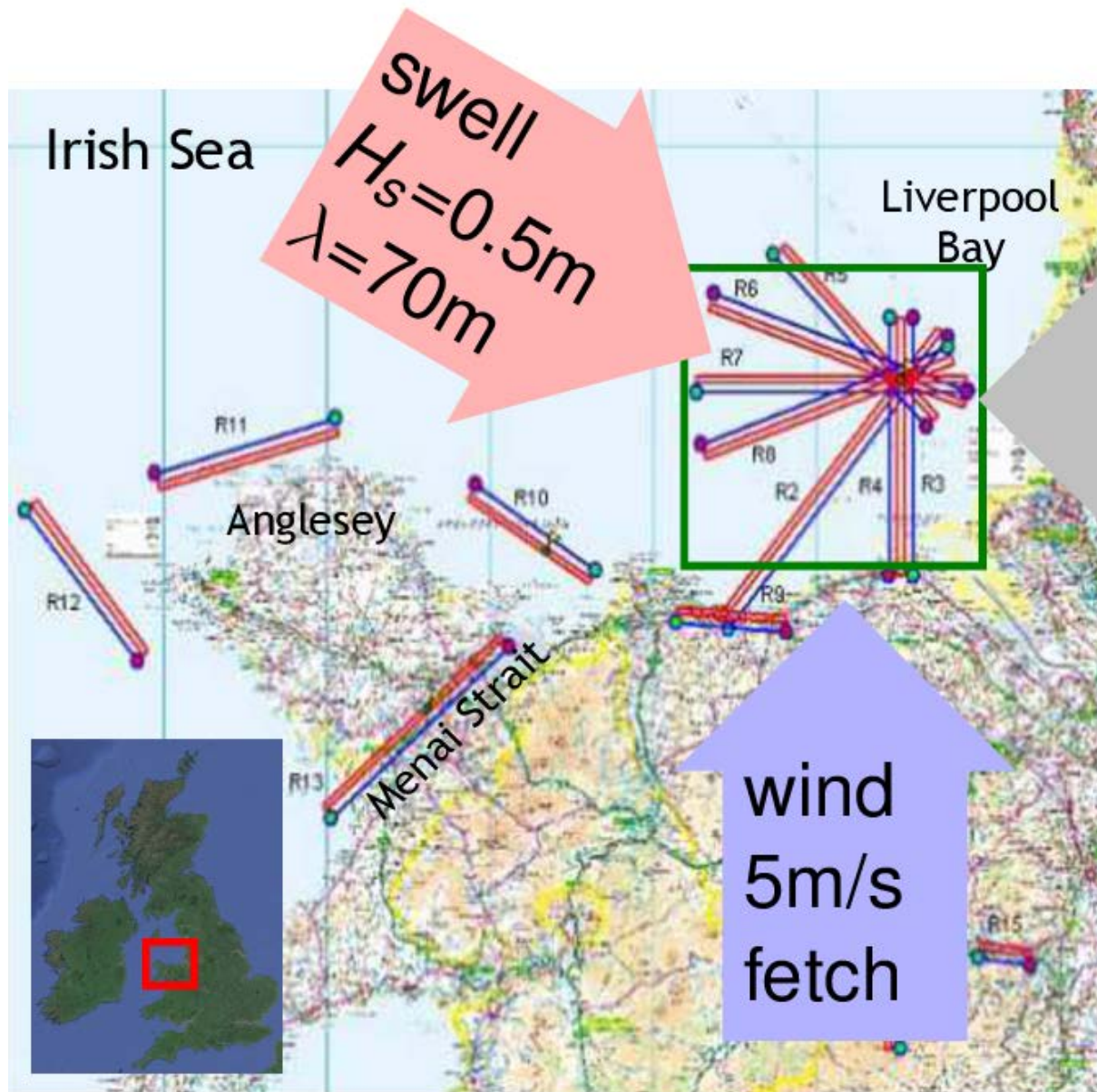


Marquez et al., IGARSS'2012

Validation over Liverpool Bay



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



Environmental
conditions
on 26 Oct 2011

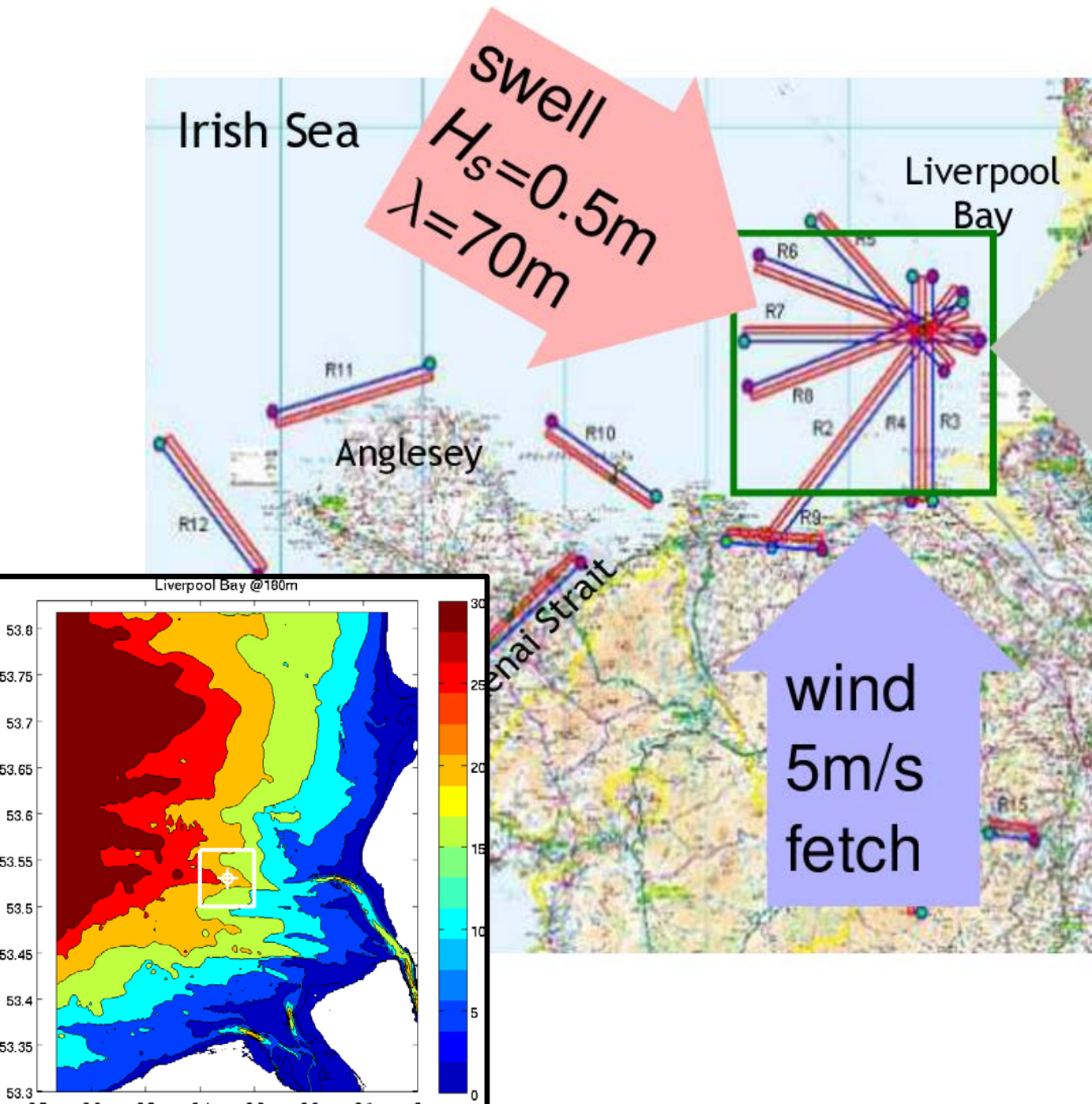
current
 $0.7m/s$

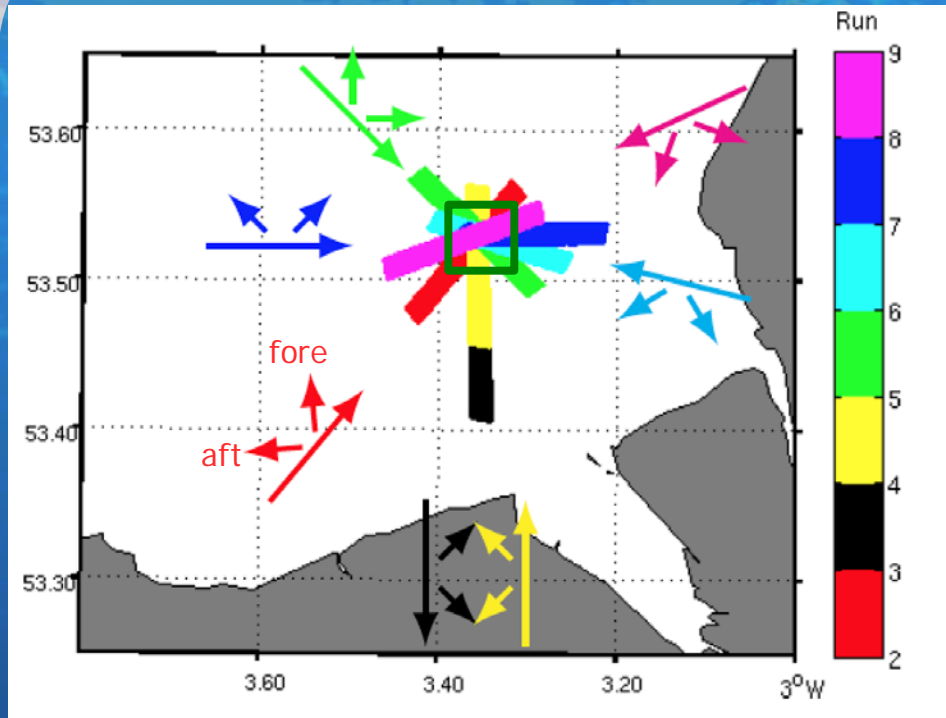
- Westward tidal current
- Light wind from the south
 - short fetch
- Low energy swell from NW

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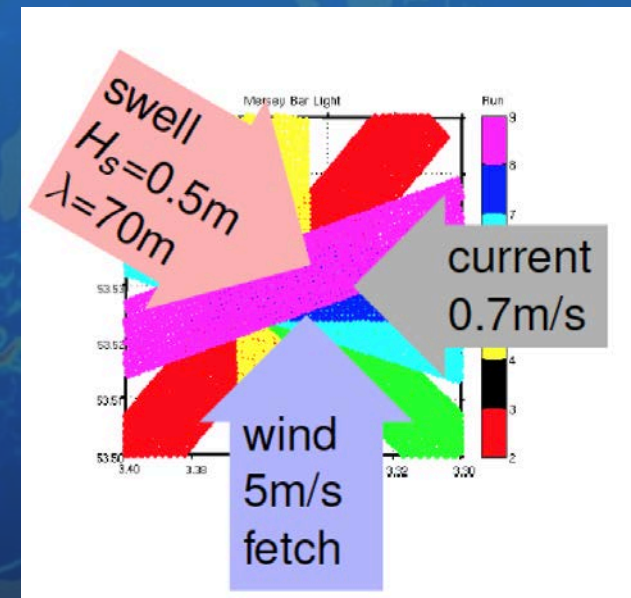
- Westward tidal current
- Light wind from the south
 - short fetch
- Low energy swell from NW
- Shallow waters



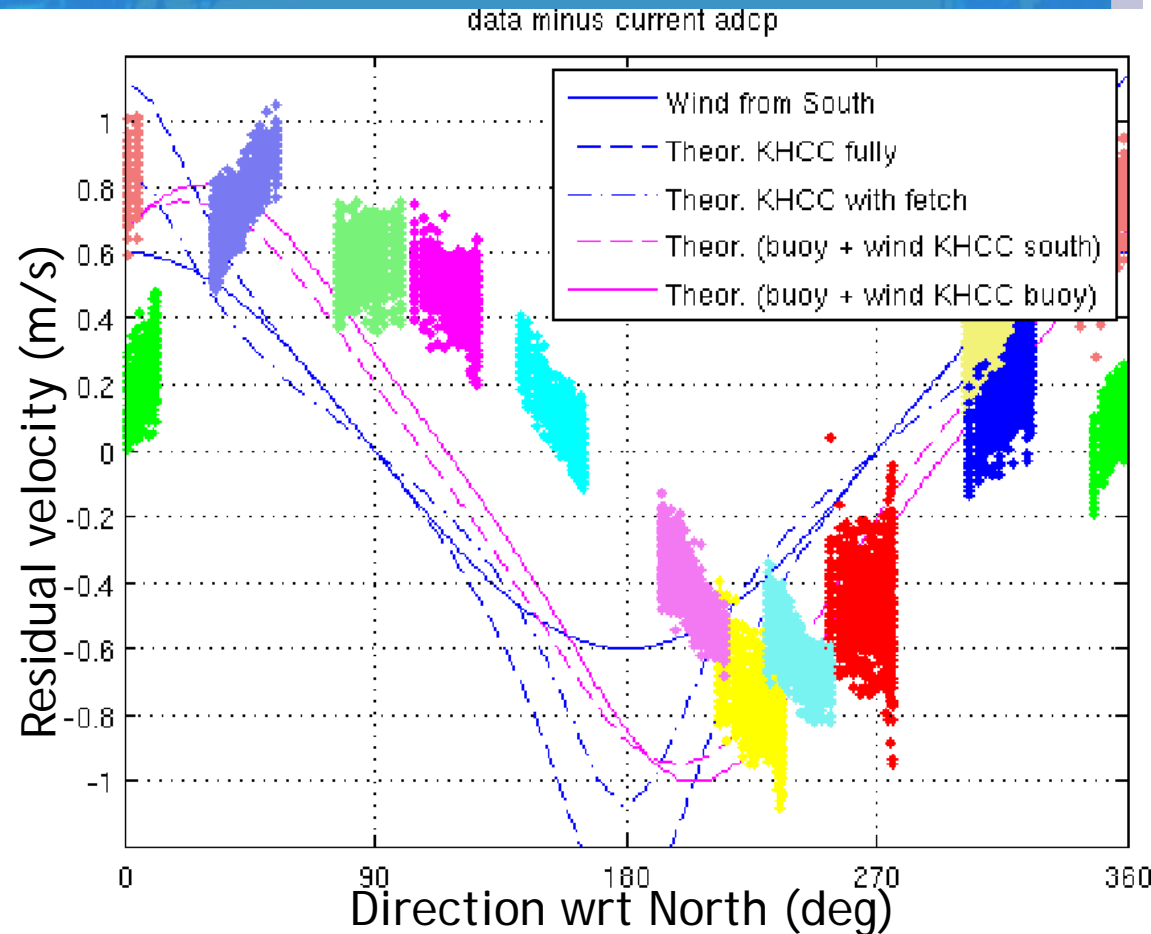
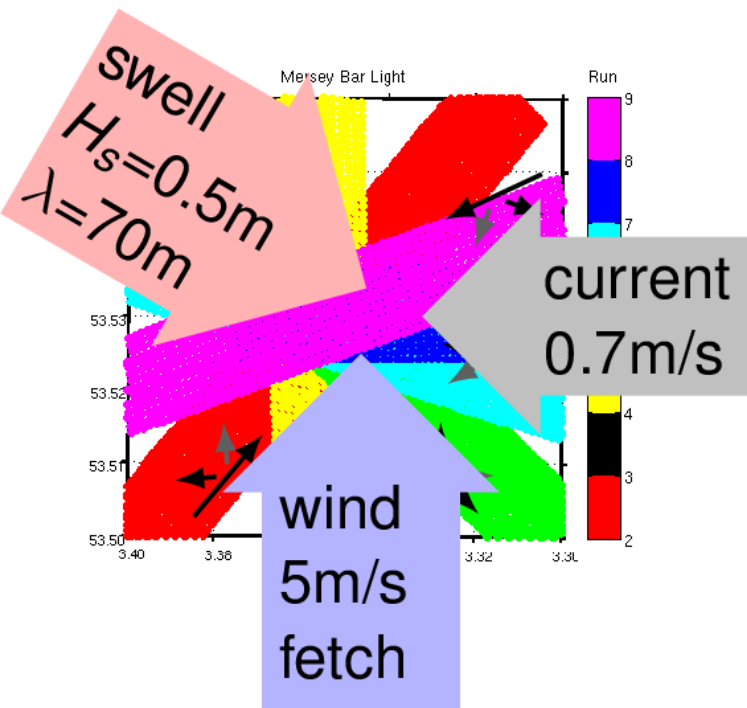


- X-band; Incidence: 25-45 deg
- Two look directions per flight (fore & aft)
- Currents @ 100m resolution

- 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

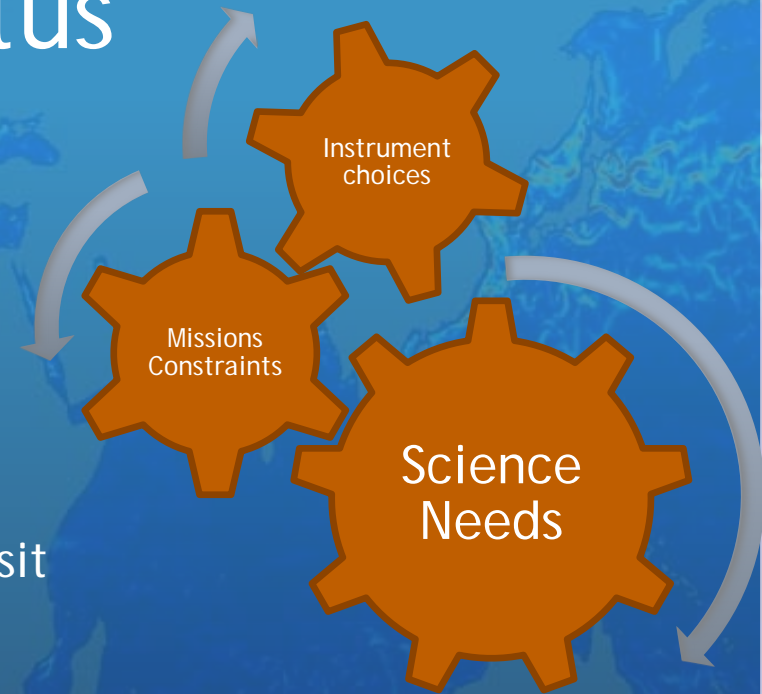
Implications for the mission

- 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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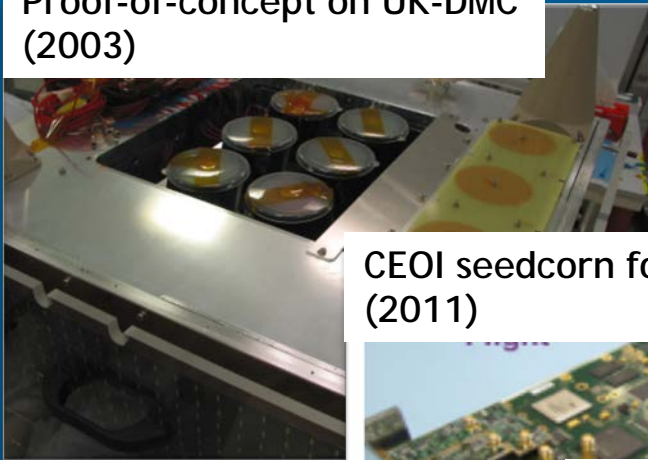


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Proof-of-concept on UK-DMC
(2003)

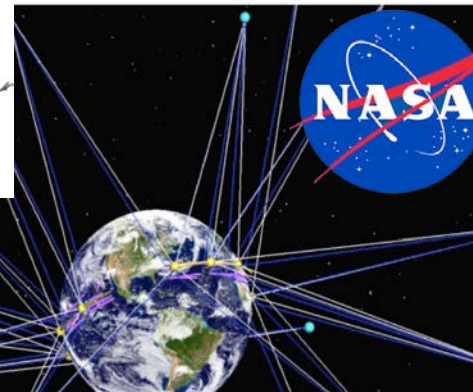


CEOI seedcorn for SGR_ReSI
(2011)



GNSS-Reflectometry: a UK success story

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



SGR-ReSI on NASA CYGNSS (2016)