The Copernicus Polar Ice and Snow Topography Mission

Robert Cullen (ESA)

OSTST 2018

ESA response to Copernicus expansion requirements

- **Anthropogenic CO2 monitoring mission**
  As a key priority, this mission allows analysis of man-made CO2 emissions
- **High Spatio-Temporal Resolution Land Surface Temperature**
  Complementing the current visible (VIS) and near-infrared (NIR) observations
- **Polar Ice and Snow Topographic Mission**
  Providing measures of land ice elevation, sea ice thickness and snow depth with complementary global ocean and coastal ocean parameters.
- **Polar Passive Microwave Imaging Mission**
  Providing, as a user priority, improved continuity of sea ice concentration.
- **HyperSpectral Imaging Mission**
  Precise spectroscopic measurements to derive quantitative surface characteristics
- **Polar L-Band SAR Mission**
  Land, vegetation and cryosphere monitoring.

Copernicus Polar Ice and Snow Topographic Mission - Priorities and Objectives

- To address the points raised in the Arctic Policy paper issued by EU in 2016, a driver for the preparation of the Terms of Reference of the Polar Expert Group that has defined the priorities for polar observations
- The top priority of the Copernicus programme is on the provision of operational, reliable and timely products and services in response to the Copernicus Regulation.
- The focus of Copernicus services for polar zones is for continuous monitoring.

2017 Copernicus Polar Expert Group (PEG) Reports

Mission Parameters and Objectives

The following set of **high priority mission parameters** have been identified:

- MP1: Sea Ice Thickness and Change (Ku SAR interferometry+ Ka SAR)
- MP2: Land Ice Elevation and Change (Ku SAR interferometry+ Ka SAR)
- MP3: Snow Depth on sea ice (Ku SAR interferometry+ Ka SAR)
- MP4: Ice Shelf Volume and Change (Ku SAR interferometry+ Ka SAR)
- MP5: Grounding Line Location (Ku SAR interferometry+ Ka SAR)
- MP6: Ocean Topography, Waves, and Wind (Ku + Ka SAR + High Res radiometer)

Objectives:

Provide high-resolution sea ice thickness and land ice elevation measurements with the capability to determine properties of snow cover on ice and other surfaces to serve Copernicus' operational products and services of direct relevance to the Polar zones.

Payload Complement

The mission draws from the heritage experience of several in-orbit missions and from the on-going development of the Sentinel-6 and MetOp-SG programmes


CryoSat-2


AltiKA


MetOp-SG

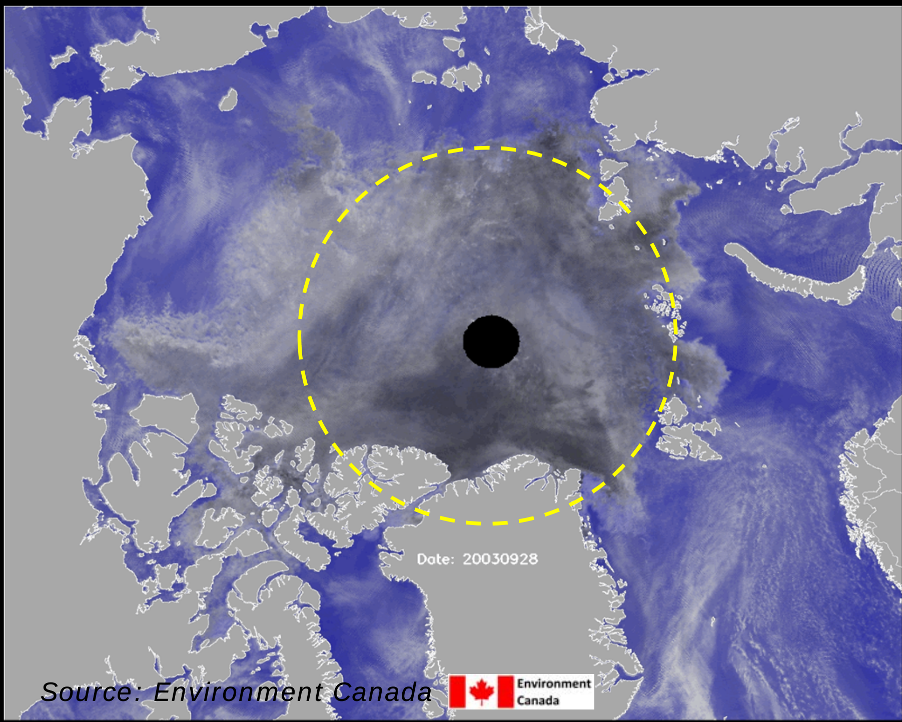

Sentinel-6


Sentinel-3

- A synthetic aperture interferometric radar altimeter (Ku-and SAR Ka-band) to make observations of sea ice and land ice elevations expanded to cover the major land ice sheets and provide data that allow improved coverage by means of on-ground swath algorithms
- High resolution passive microwave radiometer with capability provide data allowing global ocean retrieval of Total Column Water Vapour up to typically 10-20 km from the coast
- GPS/GALILEO compatible GNSS
- Laser Retro-reflector Array

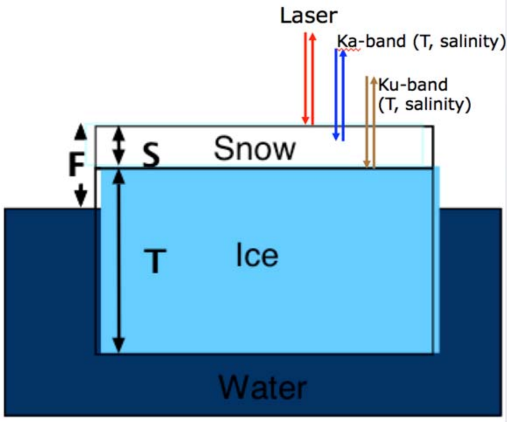
Status of the Copernicus Polar Ice and Snow Topography Mission – System status

- **Phase A/B1 parallel studies** commenced in April 2018
    - MRD answers to EC Polar Expert Group (PEG) 1 and 2 reports and issue 1 in approval.
    - System requirements evolving to meet MRD
- **Phase A Mid term check point (held Sept 2018)** to trade-off high level concepts and focus the design for Phase B
- **Preliminary Requirements Review** Dec 2018
- **Intermediate System Requirements Review** July 2019 in anticipation of a potential mission implementation start beginning 2020.



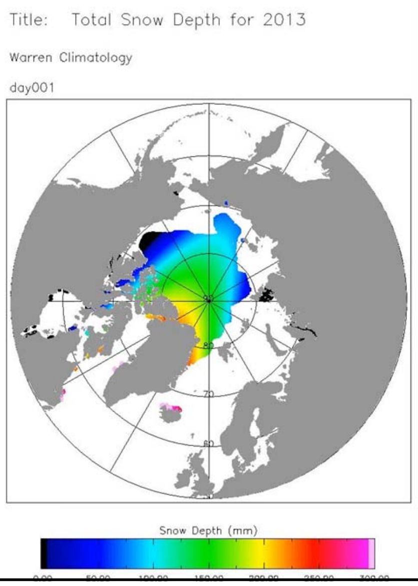
Advantage of Ku + Ka band

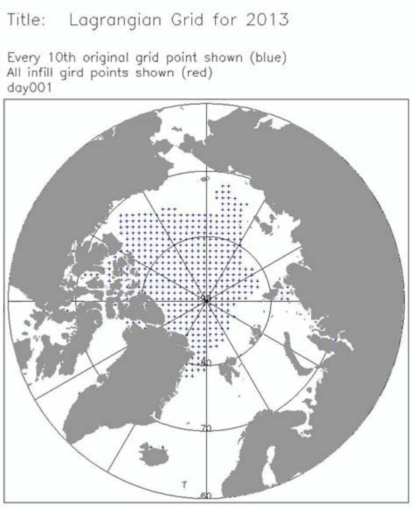
- Uncertainty in snow depth on sea ice is a limiting factor in retrieval of sea ice thickness
- Operational solutions employ reanalysis data and sea ice type, drift, etc.
- Addition of ka-band altimeter will provide a second scattering horizon within snowpack
- First field campaign has taken place



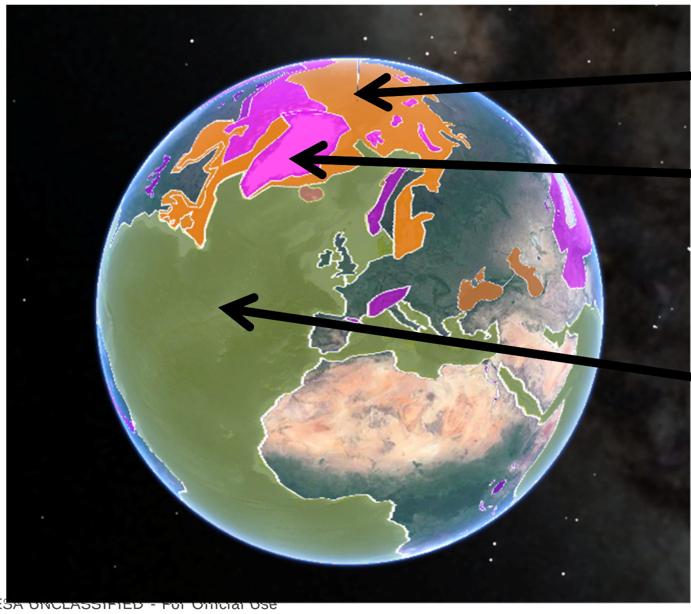
Dynamic snow load

Snow climatology	Lagrangian drift	Dynamic snow load





Study concepts – Baseline Ku band sizing mask



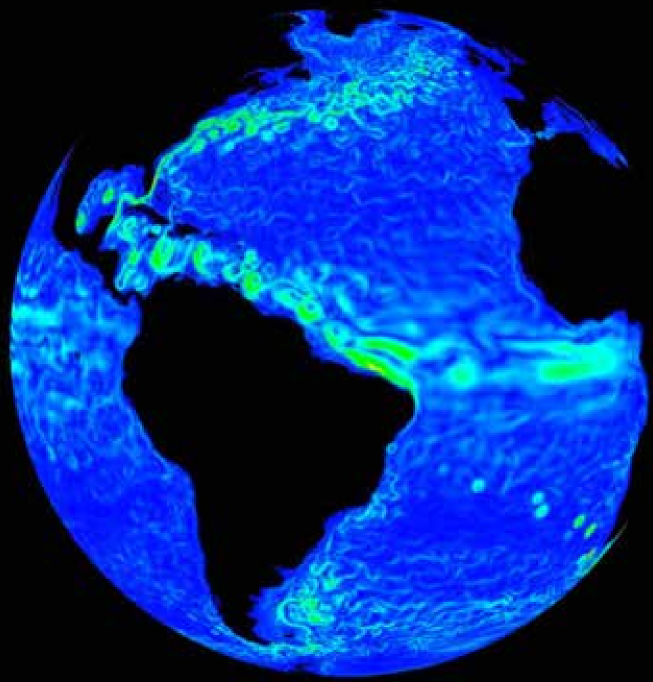
Sea-Ice SARin *open* bursts* (improved retrieval)

Land-Ice SARIn x4 *closed* bursts vs CS2 (improved retrieval)

Ocean SAR closed bursts TBC. Open burst also investigated with SAR and SARIn

Ka band may have similar mask but may not operated everywhere – priority sea-ice snow

* Open burst=continuous pulsing



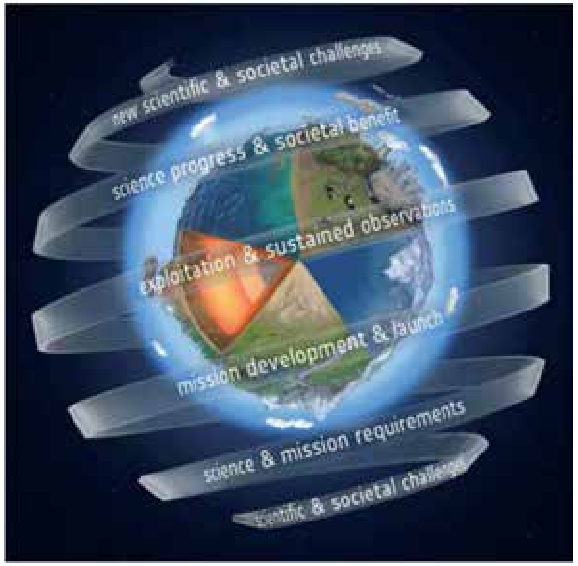
The ESA Sea Surface Kinematics Multiscale Monitoring (SKIM) Mission

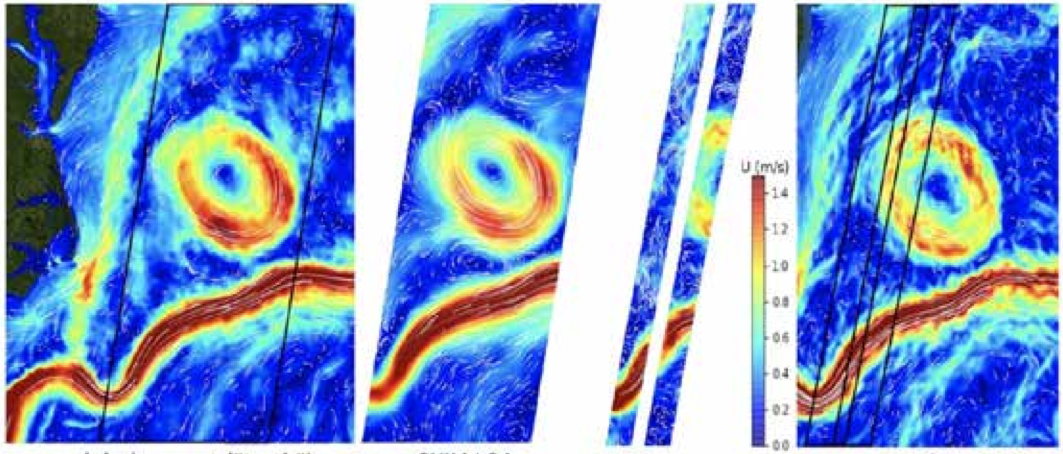
C. Donlon (SKIM Mission Scientist), F. Ardhuin (SKIM PI),
T. Casal (SKIM campaign manager)

OSTST 2018, Ponta Delgada, São Miguel Island, Azores Archipelago, Portugal, 24-29 September 2018

EARTH EXPLORER 9

- ESA Earth Explorer program
- Science drivers
- SKIM measurement principles
- Orbit and coverage
- SKIM instrument
- SKIM campaign
- EE9 Schedule



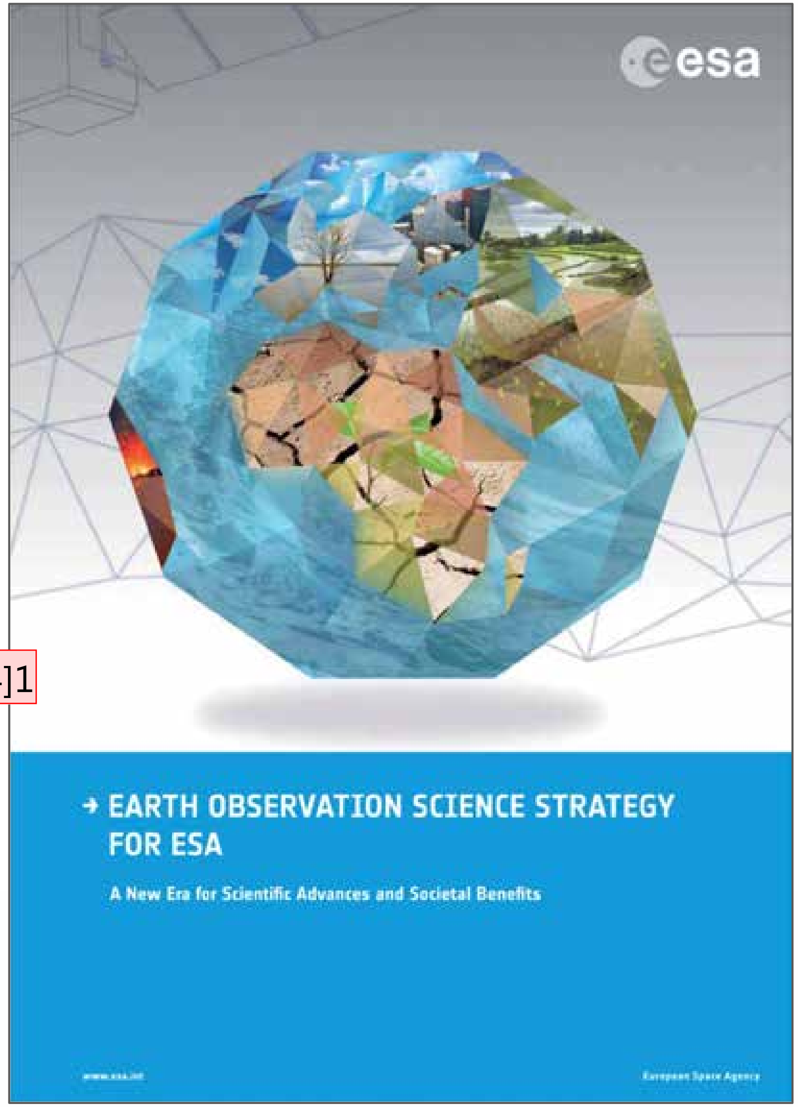


CD [3]1

Earth Explorer 9

- Call for a "Fast Track" Earth Explorer mission **to be launched by 2025**
- Maximum cost at completion (CaC) of the mission **not exceeding 260 M€** CD1 c. 2016) at the end of Phase E1 (in-orbit commissioning).
- **Vega-C dual-launch configuration**

- Call Issued on 13 December 2016 with a deadline for full proposals on 1 June 2017.
- **Proposals to demonstrate technical and scientific maturity** CD [4]1



Two candidate missions selected:

1. Far-infrared Outgoing Radiation Understanding and Monitoring **(FORUM)**
2. Sea-surface Kinematics Multiscale monitoring **(SKIM)**

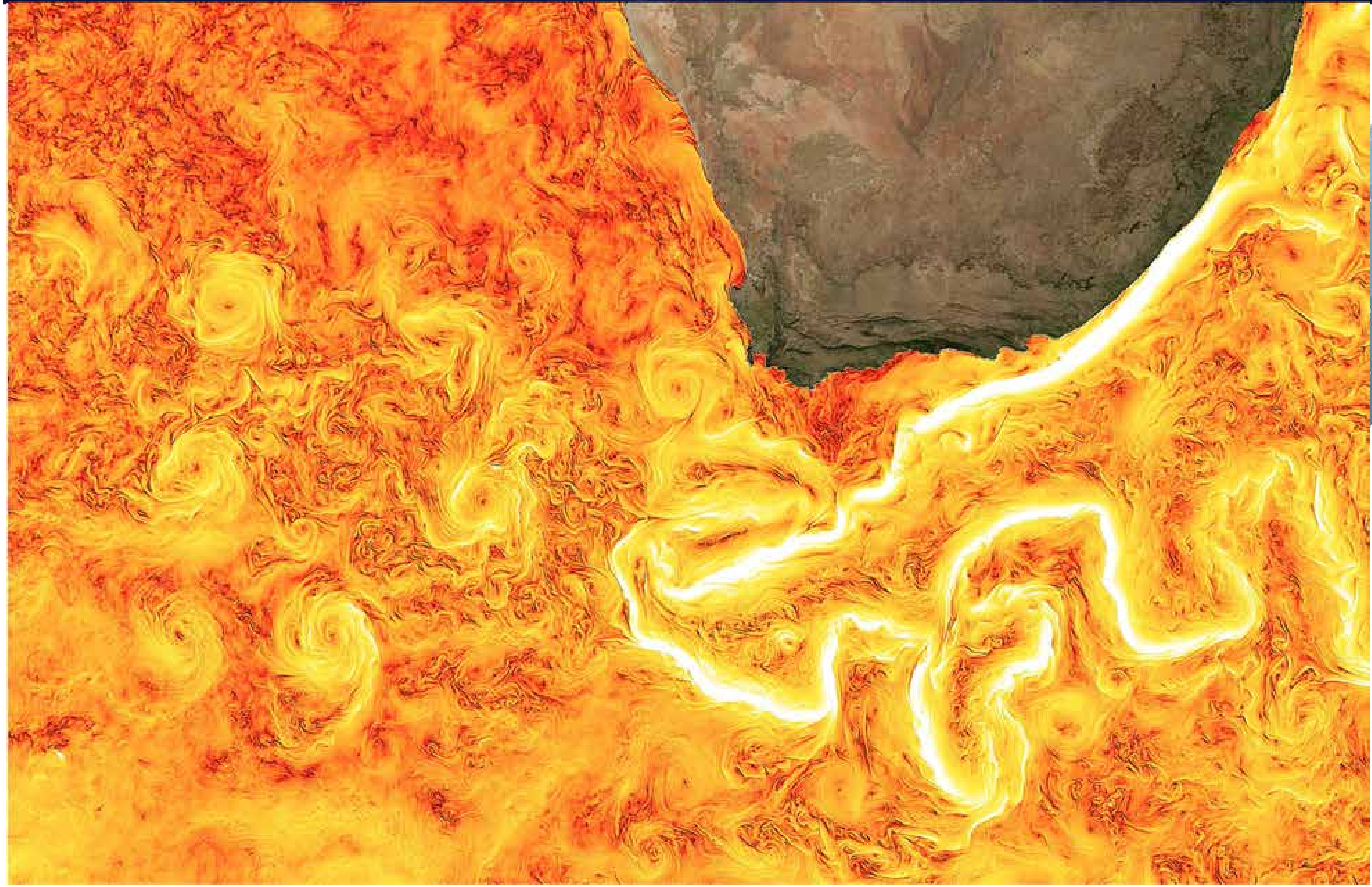
Diapositive 3

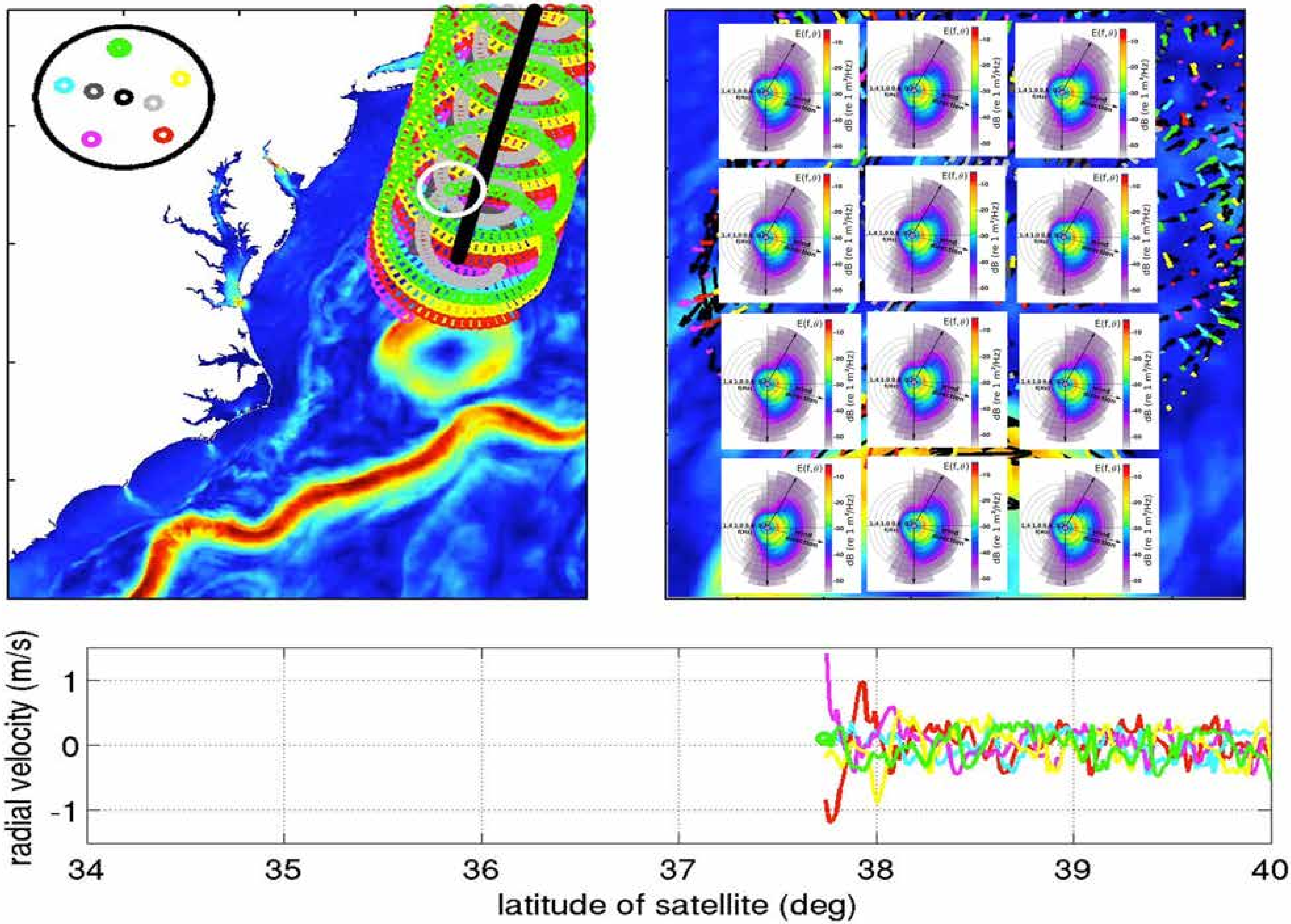
CD1 Craig James Donlon; 26/09/2018

CD [3]1 There was a remark in the SKIM presentation today that the CaC was 250M€
Craig James Donlon; 26/09/2018

CD [4]1 You will need to explain this verbally
Craig James Donlon; 26/09/2018

SKIM Background





E(f,θ)
dB (re 1 m²/Hz)
radial velocity (m/s)
1
0
-1
34
35
36
37
38
39
40
latitude of satellite (deg)

Instrument Concept – Surface velocity measurements

SKaR is the Ka-band swath instrument combining

- Accurate Nadir altimeter POS-4 heritage (very low noise for sea level, Hs, R&L, ice freeboard…)
- Conical scanning (<10 rpm) off-Nadir beams (rotating plate with 7 horns at 6°, 12° and nadir)
- 32 KHz PRF pulses for Doppler analysis (surface currents, ice drift & wave orbital velocities

Geophysical signal to be extracted from instrument signal

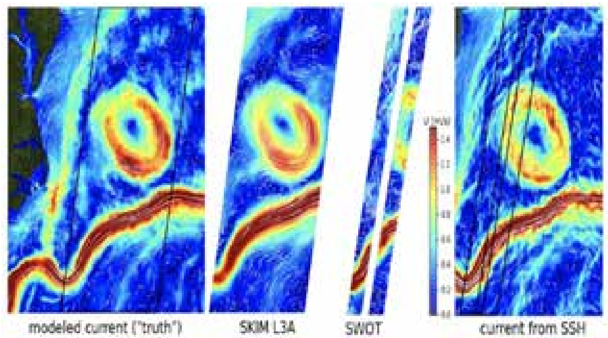
- Non-geophysical Doppler: velocity bias due to satellite velocity
- Wave bias: particle movement due to wave (orbital velocities)

$$U_{LOS\ radar}(r,\alpha,pso) = \left(U_{sat}(r,\alpha,pso)\right) + \left[U_{current}(r,\alpha) + U_{wave\ bias}(r,\alpha)\right] x \sin\left(\theta_i(r)\right)$$

r	range
α	azimuth
θi	incidence
pso	satellite orbital position

Non Geophysical Doppler (U_{NG}): Satellite movement, Earth Rotation, Orbit diving

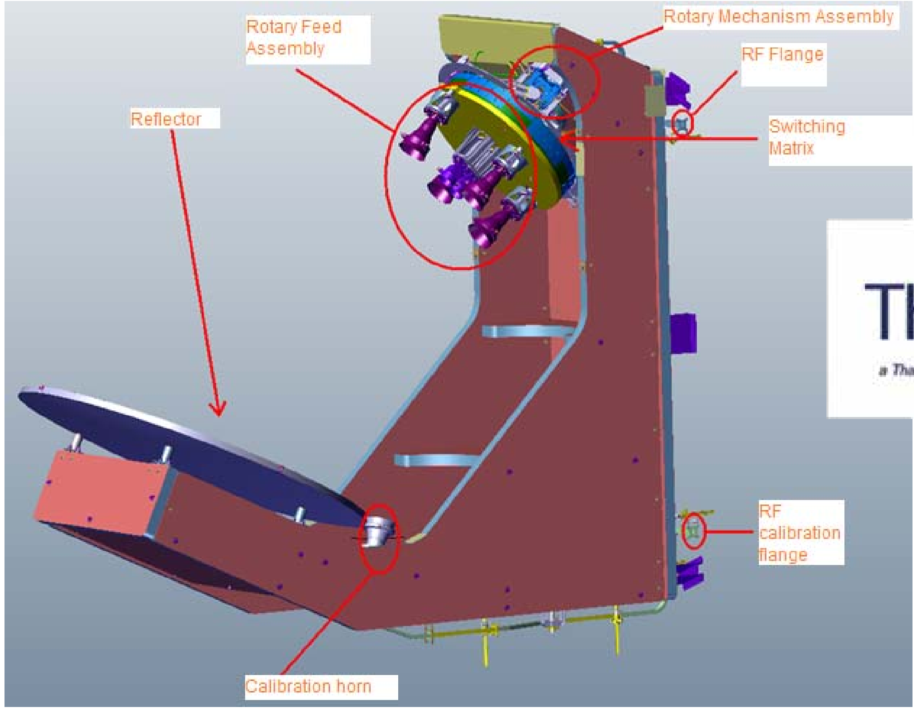
Geophysical Doppler (U_{GD}): Total Surface Current Velocity, Sea wave bias

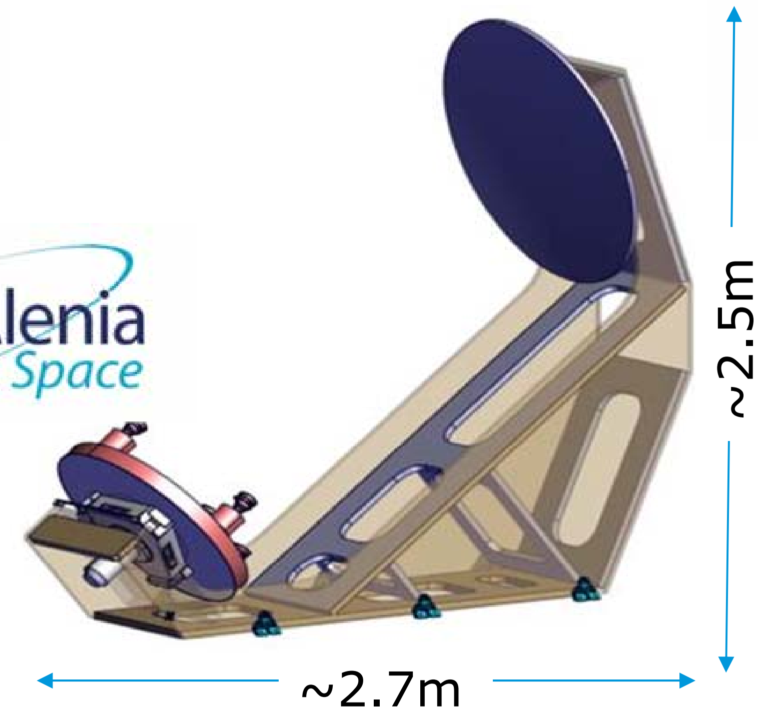


Anticipated instrument radial velocity measurement performance

- Instrument measurement noise: 2mdeg ≈ 1cm/s
- Antenna pointing knowledge: 0.36'' ≈ 1cm/s

SKIM Ka-band Radar (SKaR) instrument



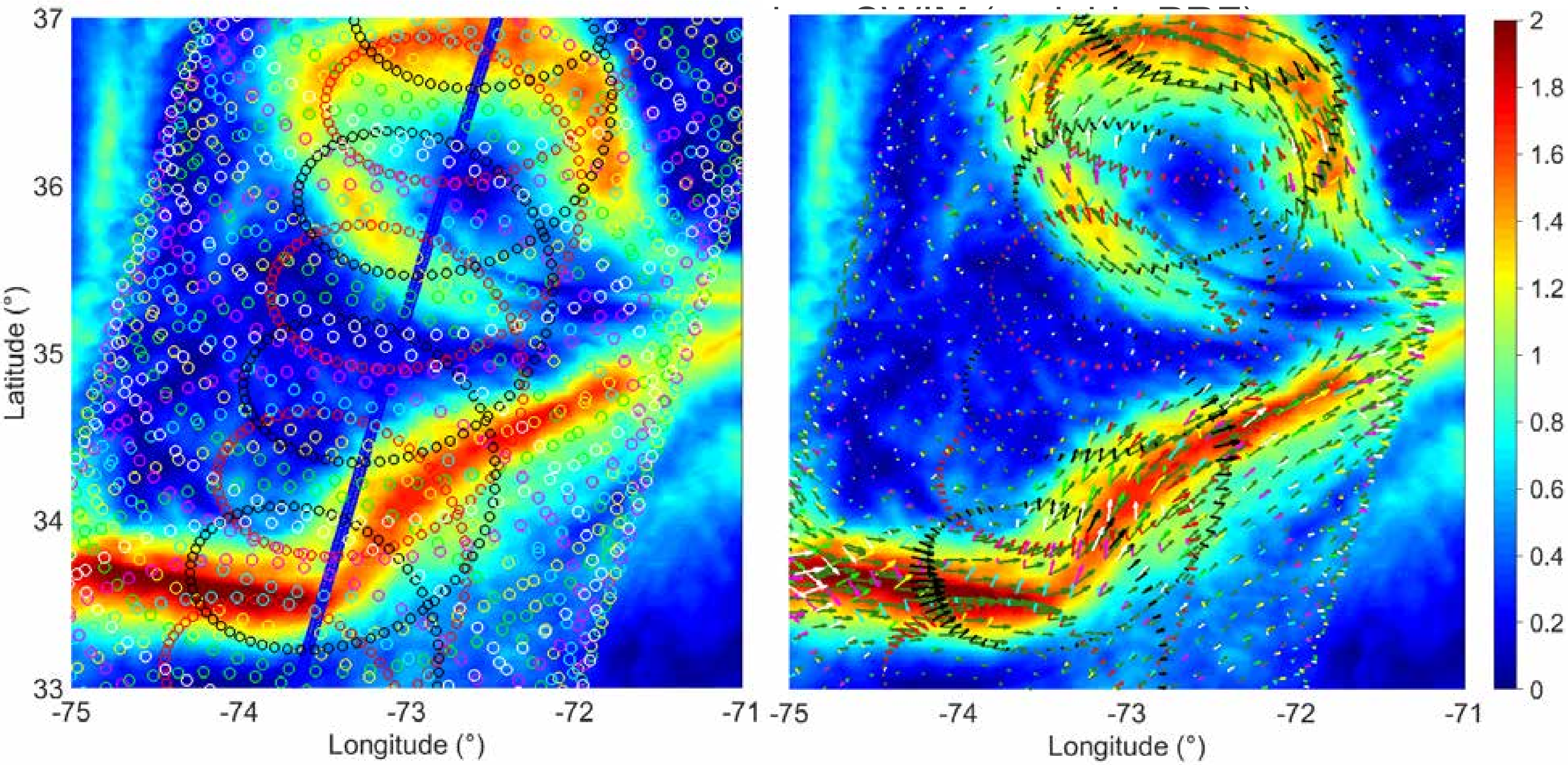


- **Fixed single offset antenna with feeds located on a rotating feed assembly (RFA)**
  - 1 RFA including Switch matrix (ferrite), 6-8 (TBC) horns for each beam
  - 1 parabolic reflector
  - 1 mechanical structure
  - A calibration horn (for power level only)

- **Instrument final configuration still in evolution**

Instrument operation: Sequential chronogram

- Pulses are transmitted and received on one beam (=cycle) before switching to next one
- Cycle = succession of Tx & Rx pulses on the same beam
- Macro-cycle = succession of cycles on all consecutive beams

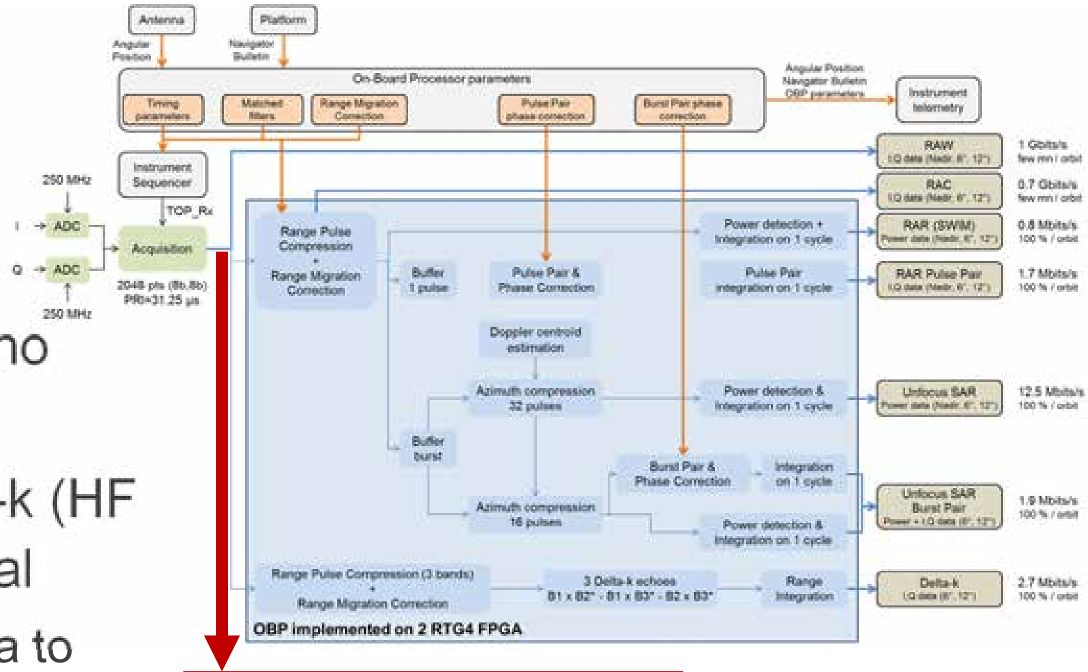


SKIM Instrument

Parameter	Value
Frequency	35.75 GHz
Antenna diameter	1.2 m
Polarization	Radial VV
Bandwidth	200 MHz
Pulse Repetition Frequency	32 kHz +/- 6% (OP) 32 kHz (CB)
Observation geometry	Conical scan
Number of beams	1 Nadir – 2 x 6° - 5 x 12°
Rotation speed	3 to 10 rpm
Beam cycle duration	38 ms (OP) - 11 ms (CB) (programmable)
Pulses per cycle (beam)	1024 (OP) - 170 (CB) (Programmable)
Peak Power (EIK output)	> 1500 W
Pulse length	1.56 to 3.2 µs (fixed)

- **Main processing: correlation of two successive echoes (RAR Pulse Pair and SAR Burst Pair)**

  - Phase of the complex echo proportional to mean Line of Sight Doppler frequency/velocity
  - Amplitude proportional to echo power & correlation
  - Advanced processing: Delta-k (HF radar emulation) experimental
  - Downlink of RAW (no OBP) data to ground per orbit
  - On-board processor in FPGA (TBC) allowing complete flexibility on-board.



1-9 mins (TBC) of RAW data per orbit from ADC before OBP

Ocean Sci., 14, 337–354, 2018
https://doi.org/10.5194/os-14-337-2018

Ocean Science
Open Access
EGU

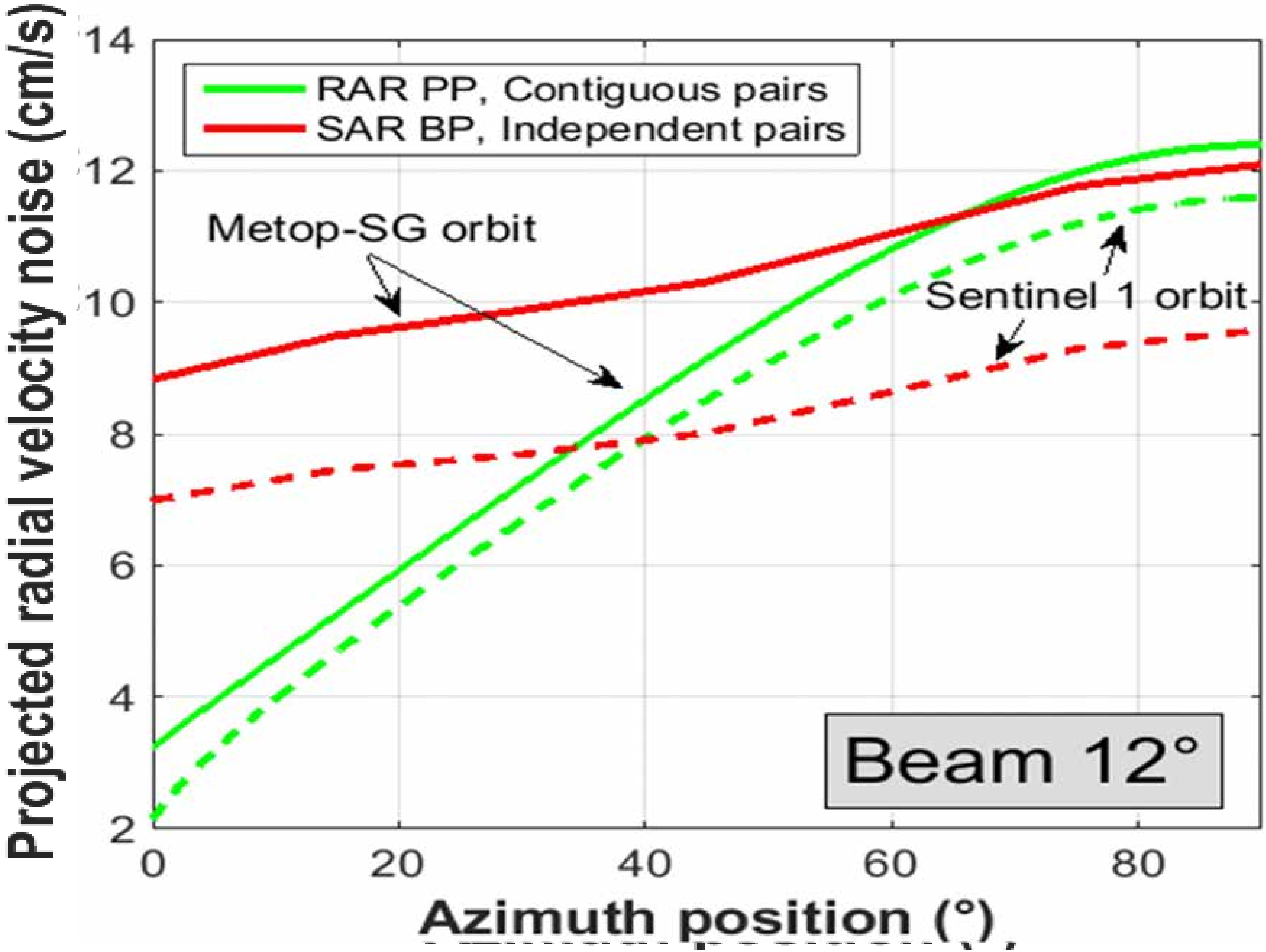
Measuring currents, ice drift, and waves from space: the Sea surface KInematics Multiscale monitoring (SKIM) concept

Fabrice Ardhuin[1], Yevgueny Aksenov[2], Alvise Benetazzo[3], Laurent Bertino[4], Peter Brandt[5], Eric Caubet[6], Bertrand Chapron[1], Fabrice Collard[7], Sophie Cravatte[8], Jean-Marc Delouis[1], Frederic Dias[9], Gérald Dibarboure[10], Lucile Gaultier[7], Johnny Johannessen[4], Anton Korosov[4], Georgy Manucharyan[11], Dimitris Menemenlis[12], Melisa Menendez[13], Goulven Monnier[14], Alexis Mouche[1], Frédéric Nouguier[1], George Nurser[2], Pierre Rampal[4], Ad Reniers[15], Ernesto Rodriguez[12], Justin Stopa[1], Céline Tison[10], Clément Ubelmann[15], Erik van Sebille[16], and Jiping Xie[4]

Ocean Topography (SWOT) Mission.

the functions of moments of the surface elevation spectrum.

Instrument performance



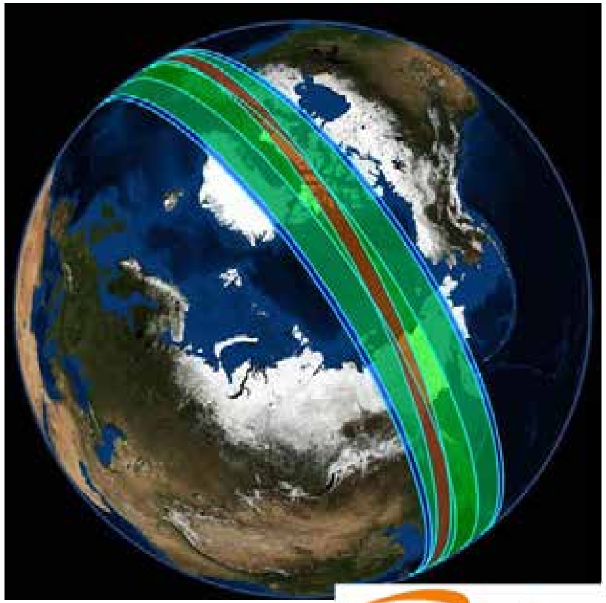
SKIM orbit, revisit and coverage

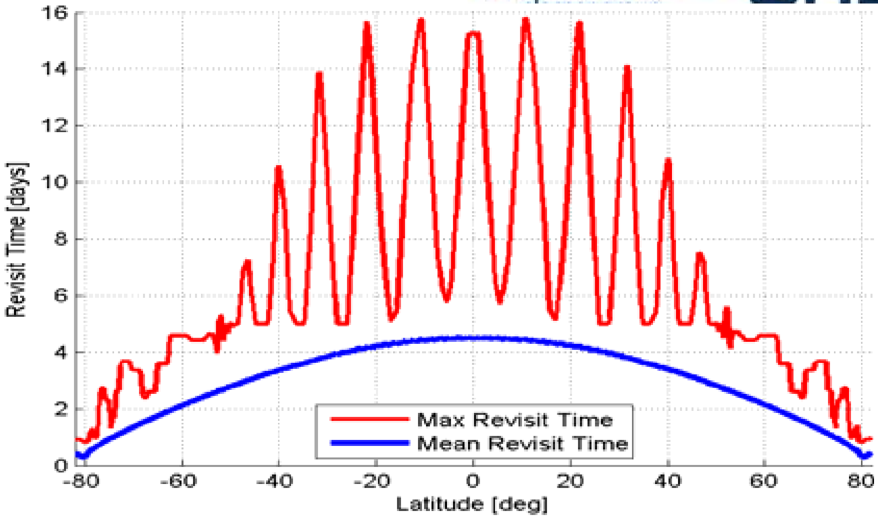
- **Scientific Synergy with MetOp-SG(B) MWI and SCA** (Note there is ***no dependency*** for SKIM)

- **Option 1: Fly in formation with MetOp-SG(B)** maintaining contemporaneous and co-located coverage with MWI and SCA within +/- 10 mins
    - Achieves total overlap of SKIM & MWI swaths at all latitudes
    - Overlap with SCA swath at equator up to mid latitudes (Partial overlap from 47.5º to 75.5º)

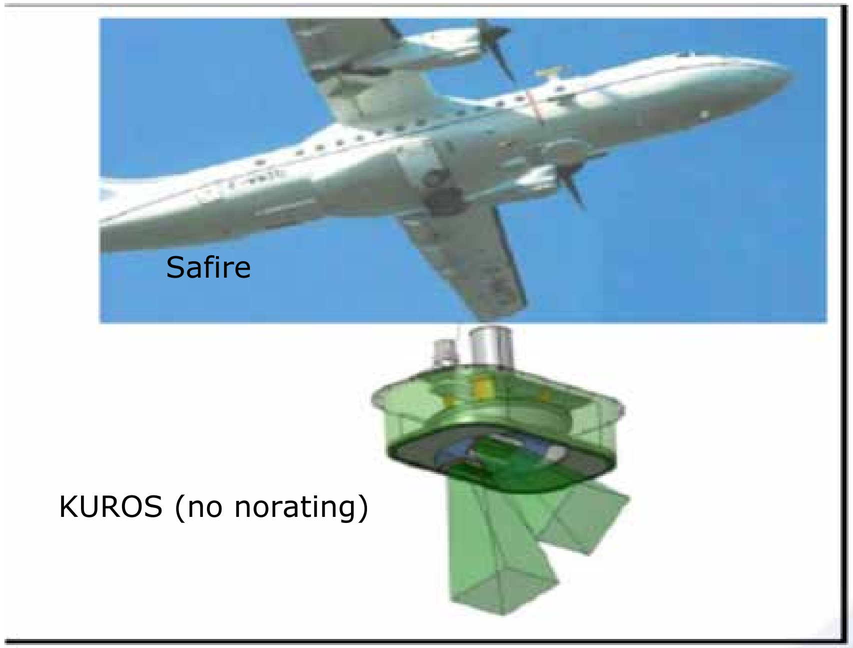
- **Option 2: Dawn-Dusk MetOp-SG(B) orbit** (SKIM LTDN: 6h00 MetOp-SG LTDN: 9h30). No contemporaneous data (difference of > 3 hours).

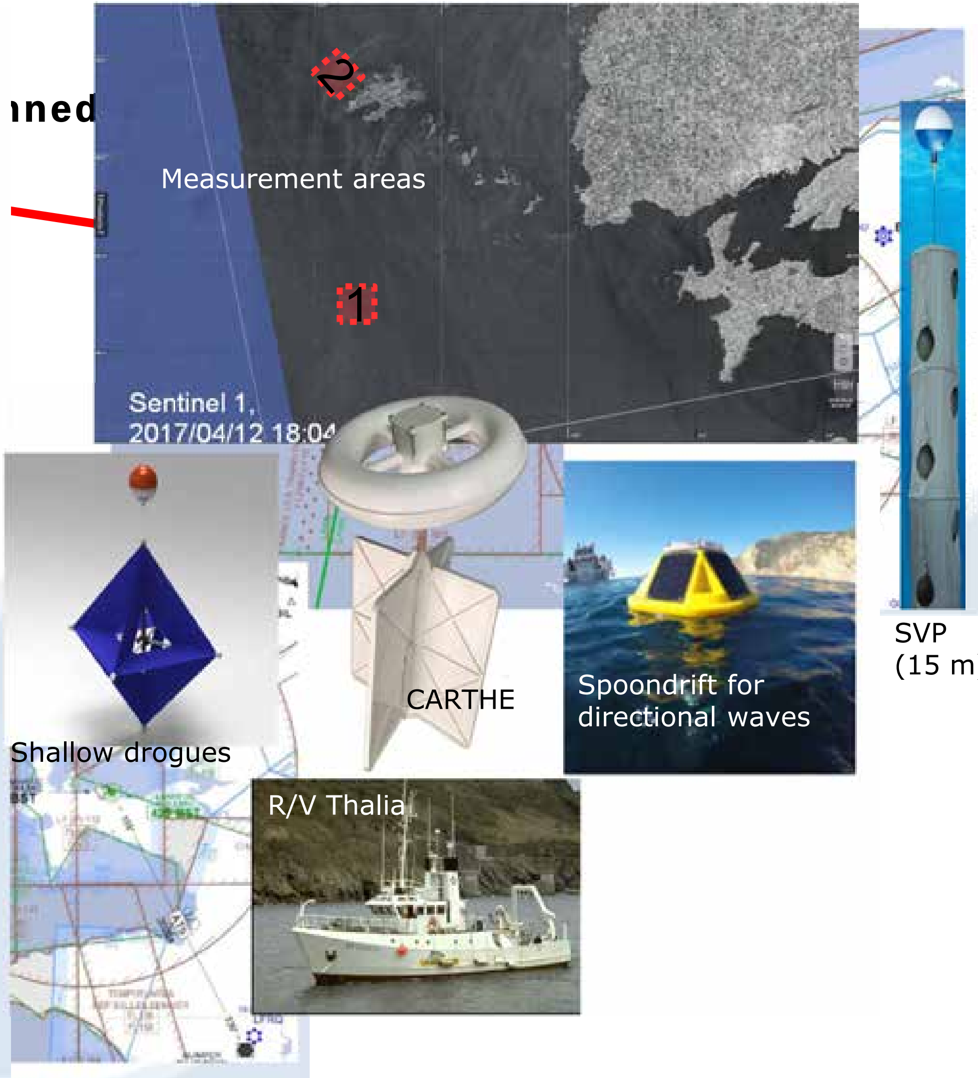
- **Final configuration still under study subject to cost and technical constraints**





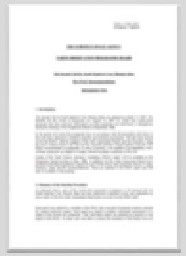
EE9: Airborne SKIM campaign, **November 2018**





EE9 Key dates – a Challenge!

Phase A

Step 1	Step 2	Step 3	Step 4	Step 5
Industry produces: Technical notes with evidence on technical concept and feasibility (TRL) **Science support activities / campaigns** produces: Technical notes on scientific concept, scientific performance and feasibility (SRL)	**Based on the input from the activities, ESA** produces with the help of the **MAG**: • **Report for Mission Selection** • Consolidated **Mission Requirements Document** (not input for UCM) 	**User Consultation Meeting** Presentations from MAG and ESA	Evaluation and recommendation of the candidate mission  Evidence that SRL≥ 5 TRL≥ 5 reachable at the end of Phase B1	Down-selection of a single candidate mission and start of Phase B1 

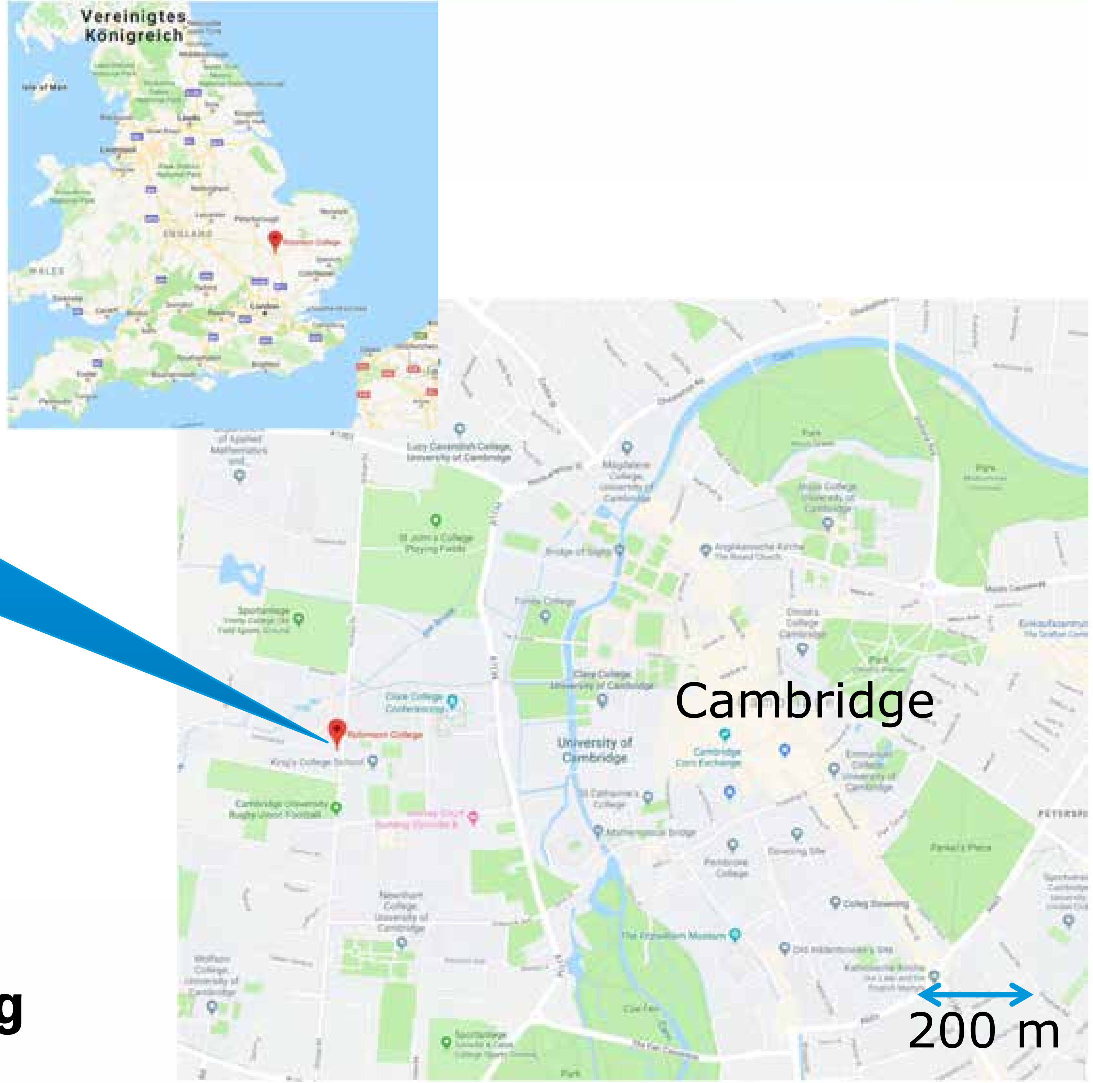
Jan 2018

16-17 July 2019!!

Mission implementation (phase B2/C/D/E) after confirmation that the necessary conditions (TRL, SRL, cost, schedule) are met at the end of Phase B1

Launch 2025

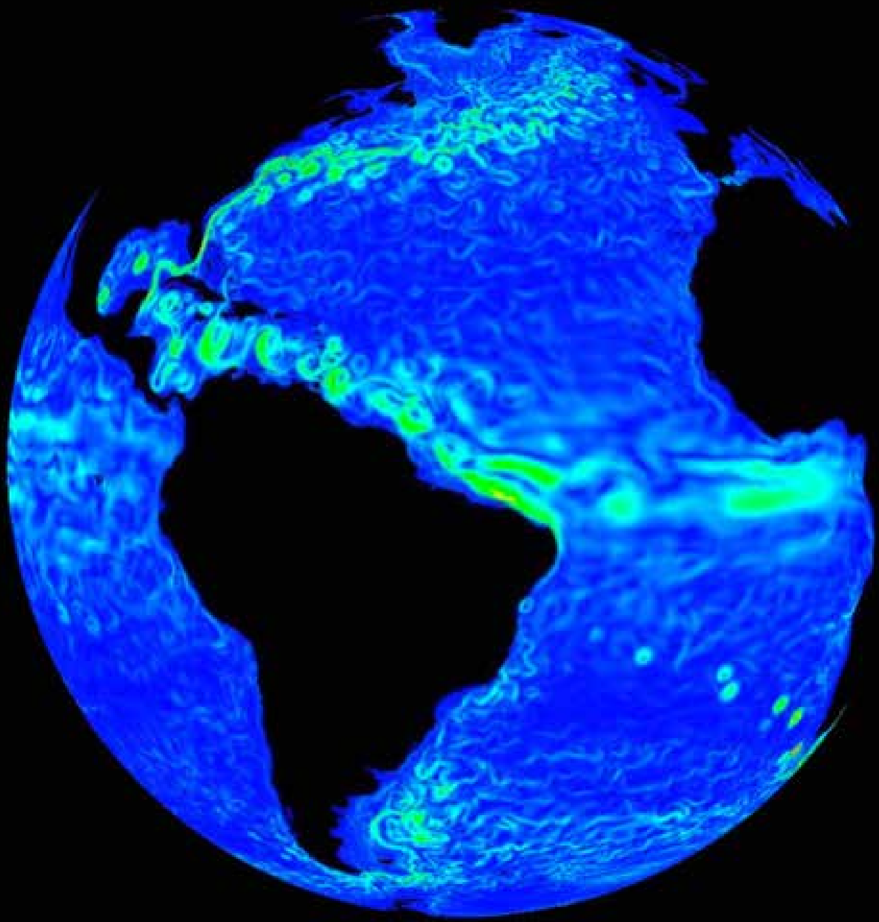
Robinson College
University of Cambridge



Robinson College,
Cambridge

Grand Road, Cambridge
CB3 9AN, UK

Please consider attending to support SKIM!



The ESA Sea Surface Kinematics Multiscale Monitoring (SKIM) Mission

Questions?

FORUM: Far-infrared-Outgoing-Radiation Understanding and Monitoring

- FORUM is the other EE9 candidate mission

- FORUM will provide the first global, spectrally resolved observations of the outgoing longwave radiation from 100 to 1600 cm^{-1} (100 – 6.25 µm) with a resolution of 0.3 cm^{-1} and 0.1 K accuracy to improve climate models.

- More than half of the energy in the Earth's outgoing longwave radiation is emitted in the far infrared range of 100 – 667 cm^{-1}.
- FORUM will provide unique insight into processes that are active in the far infrared:
  - o water vapour in the upper troposphere,
  - o cirrus clouds microphysics, and
  - o ice/snow surface emissivity