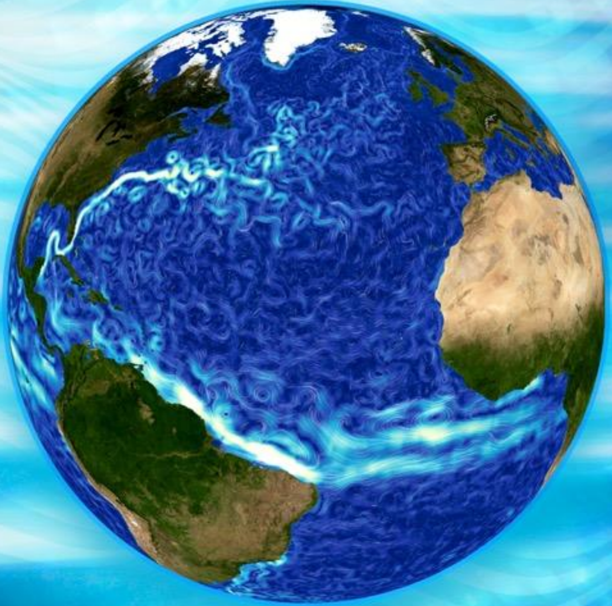
esa



skim

→ UNDERSTANDING OCEAN SURFACE MOTION

Upgrading SWIM? The SKIM design

Presented by F. Ardhuin on behalf of SKIM Team

CFOSAT Science Team Meeting, March 2021

The ESA Earth Explorer 9 context

The “Sea surface KInematis Multiscale monitoring” mission candidate was a finalist for the EE9 competition…

but FORUM, the other candidate was selected in Sept. 2019

For implementation as EE9.

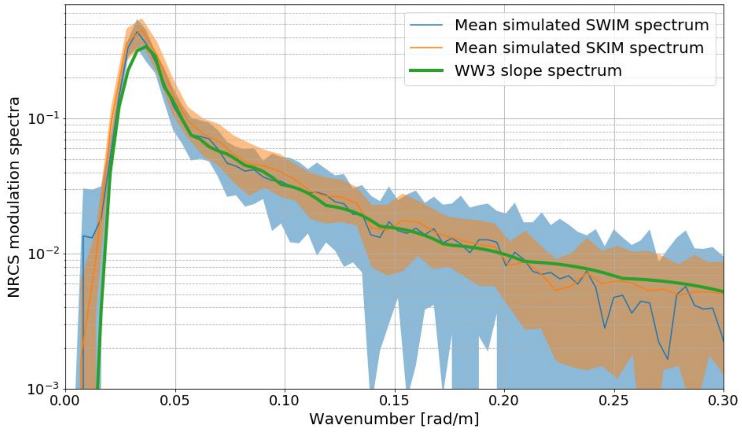
However, the successful phase A led to a recommendation to ”find other ways and means” to implement SKIM.

Possible operational follow-up of SWIM on S3NG.

NB: SKIM’s goal for EE9 was focused on surface current, sea state was another important objective. Please see the ”Report for Mission Selection” for full details.

SKIM vs SWIM

SKIM design is different from SWIM in many ways:
most important: **PRF (less noise), footprint size (less directive), Doppler**



- WW3 spectrum (input to R3S simulator)
- Simulated SWIM spectra (100 realisations)
- Simulated SKIM spectra (100 realisations)

SWIM : Surface Waves Investigation and Monitoring (CNES)

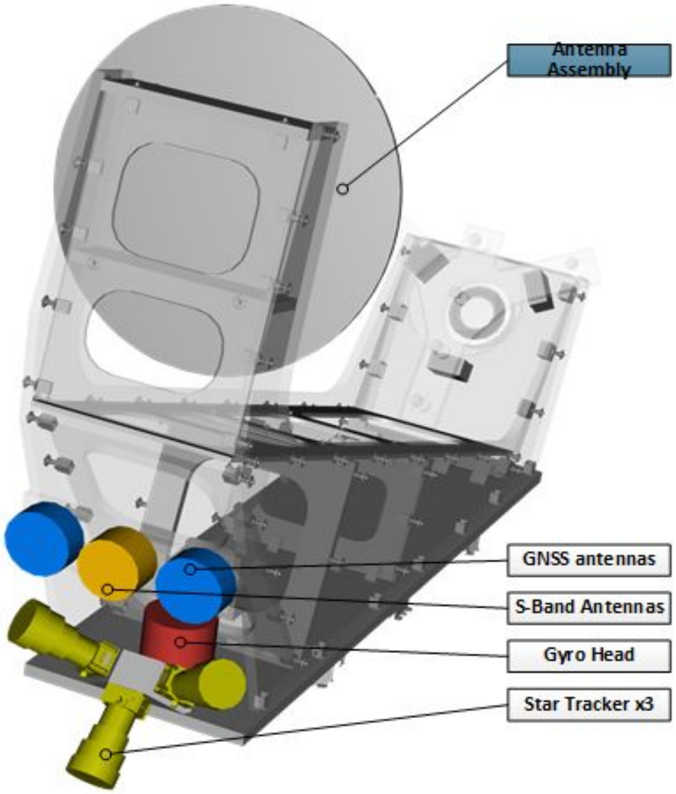
- Rotating range resolved radar
- Ku-band (13.5 GHz)
- ~ 200 pulses / cycle
- 10 degree incidence
- **PRF : 5.2 kHz**
- Altitude : ~ 519 km
- **18 km x 18 km beam footprint**

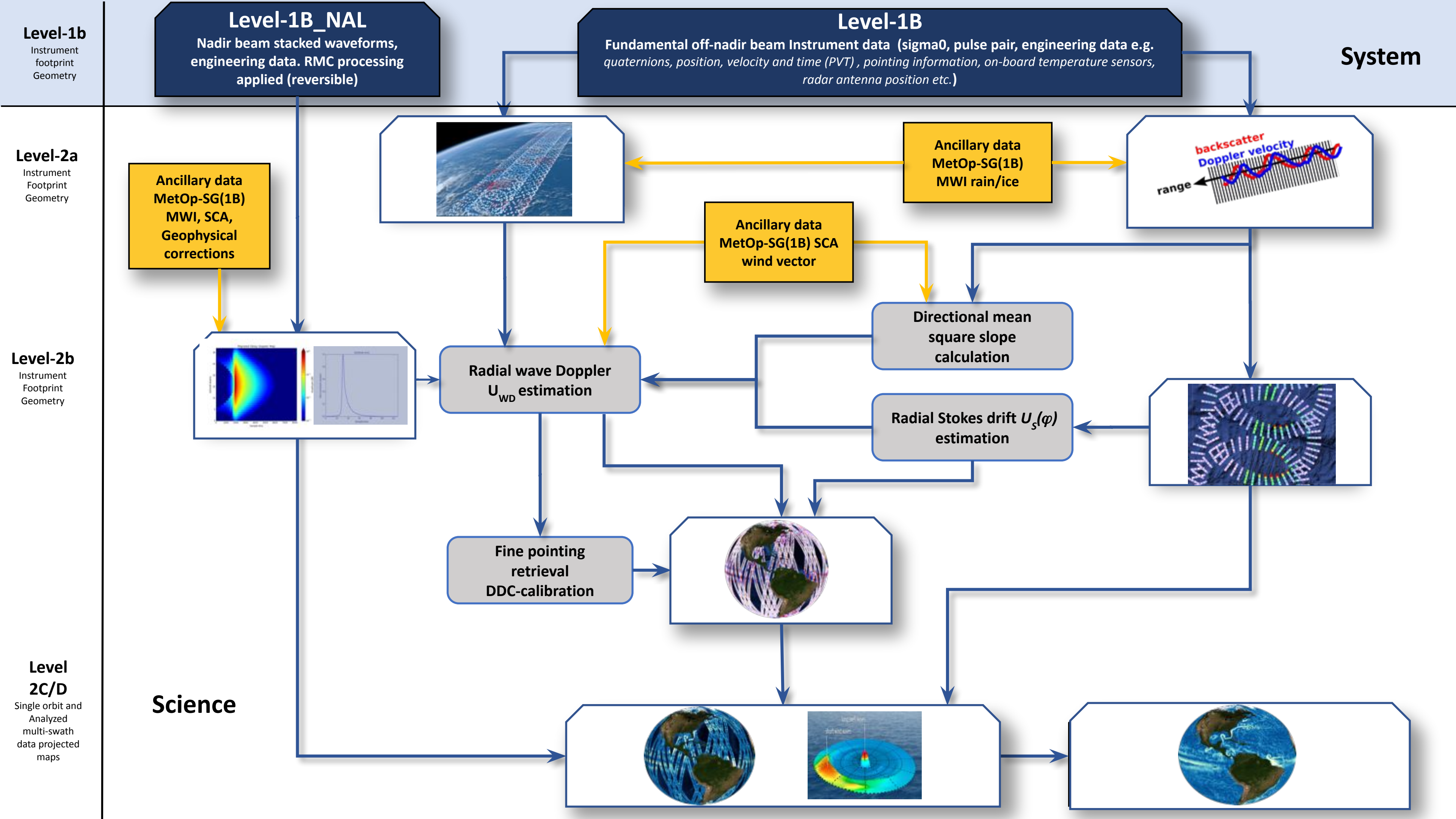
SKIM : Sea surface KInematics Multiscale monitoring (ESA EE9)

- **Doppler** enabled SWIM-like sensor
- Ka-band (35 GHz)
- 1024 pulses / cycle
- 12 degree incidence
- **PRF : 32 kHz**
- Altitude : ~ 838 km
- **6 km x 6 km beam footprint**

Fine pointing: Fundamental to a Doppler mission

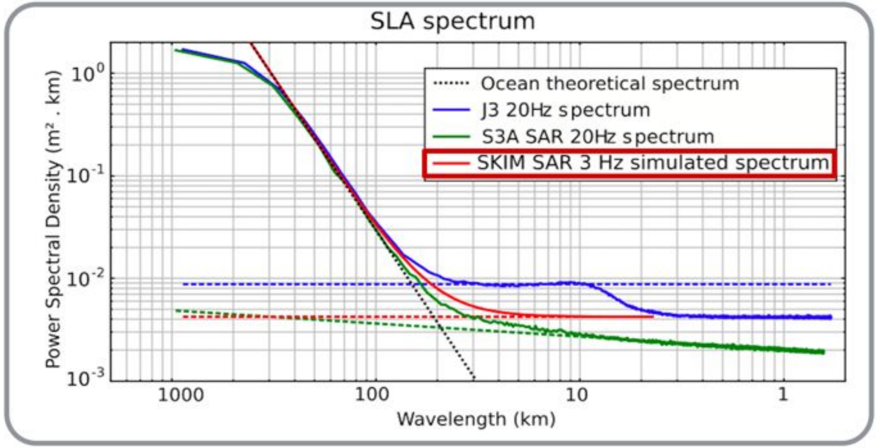
- Accurate pointing Knowledge is fundamental to the SKIM mission
- By placing the AOCS sensors on the antenna, the main residual pointing uncertainty is from thermo-elastic deformations of the antenna.




Level-1b
Instrument footprint Geometry
Level-1B_NAL
Nadir beam stacked waveforms, engineering data. RMC processing applied (reversible)
Level-1B
Fundamental off-nadir beam Instrument data (sigma0, pulse pair, engineering data e.g. *quaternions, position, velocity and time (PVT) , pointing information, on-board temperature sensors, radar antenna position etc.*)
System
Level-2a
Instrument Footprint Geometry
Ancillary data MetOp-SG(1B) MWI, SCA, Geophysical corrections
Ancillary data MetOp-SG(1B) MWI rain/ice
backscatter
Doppler velocity
range
Ancillary data MetOp-SG(1B) SCA wind vector
Directional mean square slope calculation
Level-2b
Instrument Footprint Geometry
Radial wave Doppler U_{WD} estimation
Radial Stokes drift $U_s(\varphi)$ estimation
Fine pointing retrieval DDC-calibration
Level 2C/D
Single orbit and Analyzed multi-swath data projected maps
Science

Level-2 nadir altimetry performance

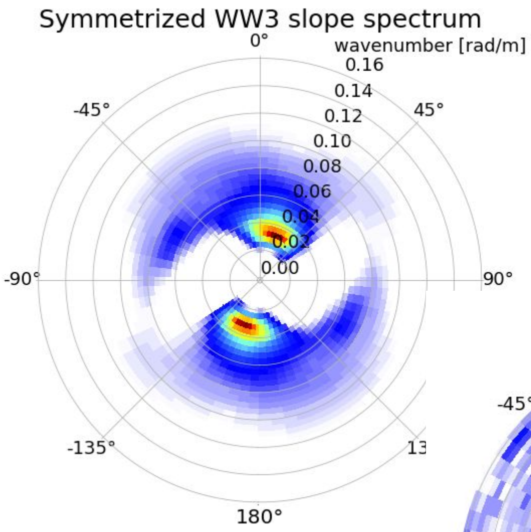
- **Scenario:** 1 month of simulated L1b data using the ESA/CNES/CLS Sentinel-3 simulation tool (configured for SKIM radar parameters) realistic scene.
- **Metric M6:** Total RSS uncertainty of sea surface height computed for the nadir beam ≤3.2 cm after all geophysical corrections are made.

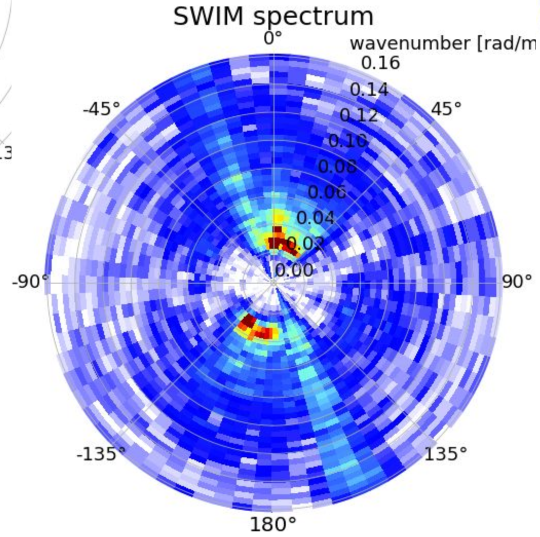


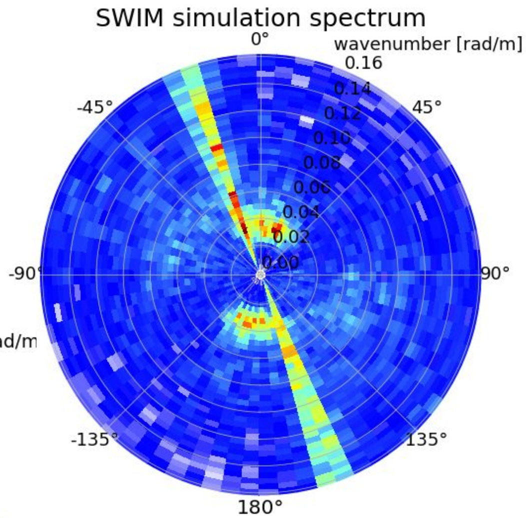
Parameter	SKIM nadir beam uncertainty (cm)	JASON-3 GDR uncertainty (cm)
Altimeter noise	<1.4	1.7
Ionosphere	0.3 (1)	0.5
Sea State Bias	2.0 (1)	2.0
Dry Troposphere	0.7 (1)	0.7
Wet Troposphere	1.5 (2)	1.2
RSS Altimeter range	3.0	3.0
RMS Orbit (radial component)	1.0 (3)	1.0
Total RSS Sea Surface Height	**3.2**	**3.2**
Total RSS Significant wave height *(Hs)*	**9.5(4)**	**11.2**

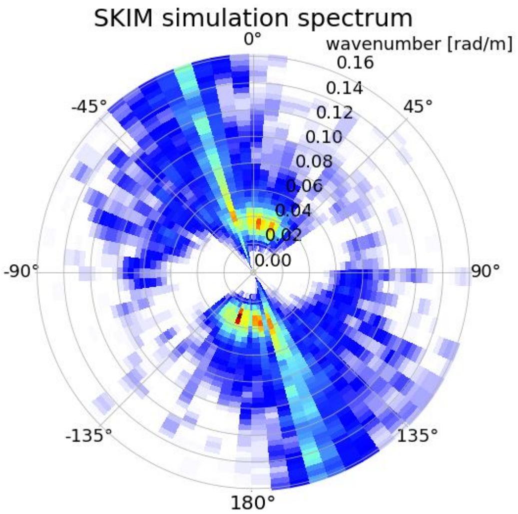
SKIM can meet Level-2 nadir altimetry performance requirements

Wave directional spectrum: example

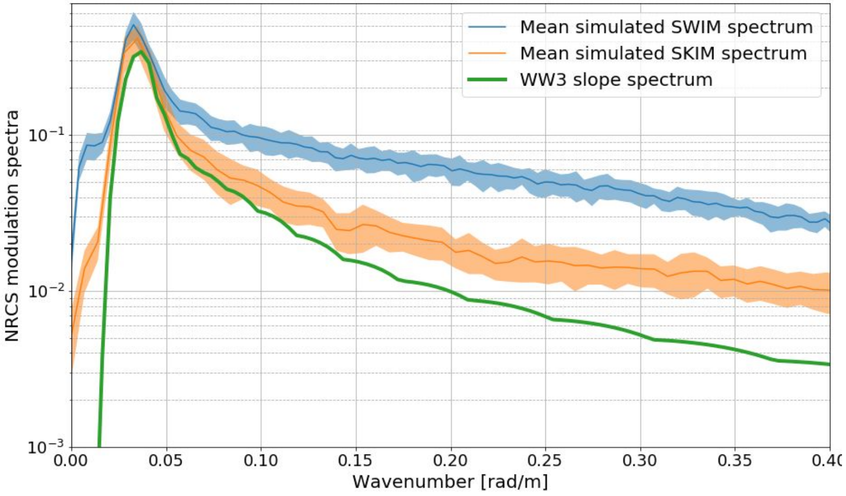




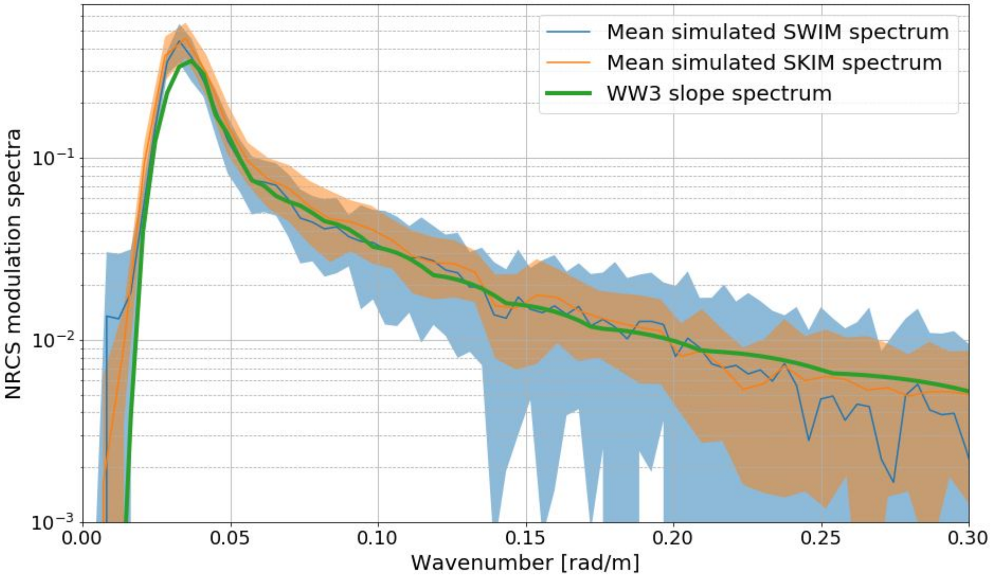




Wave directional spectrum: example



After speckle removal

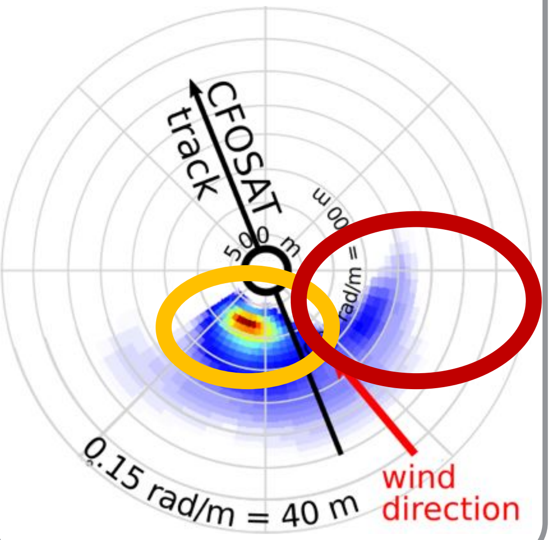


- WW3 spectrum
- Simulated SWIM spectra (100 realisations)
- Simulated SKIM spectra (100 realisations)

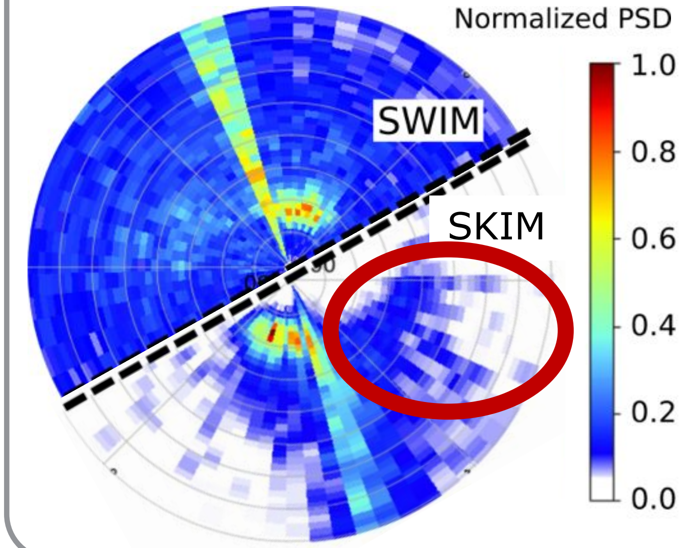
Spectrum variance is smaller on SKIM leading to better performances in terms of retreived maximum wavenumber limits.

Wave directional spectrum

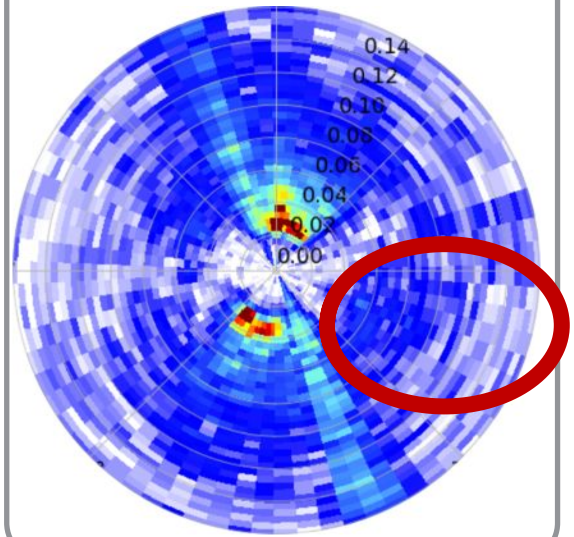
input to R3S: Wave Model WW3 K^2 E(k,φ)



R3S Simulation of SWIM (Ku) and SKIM (Ka)



Measurements: CFOSAT SWIM 29/04/19

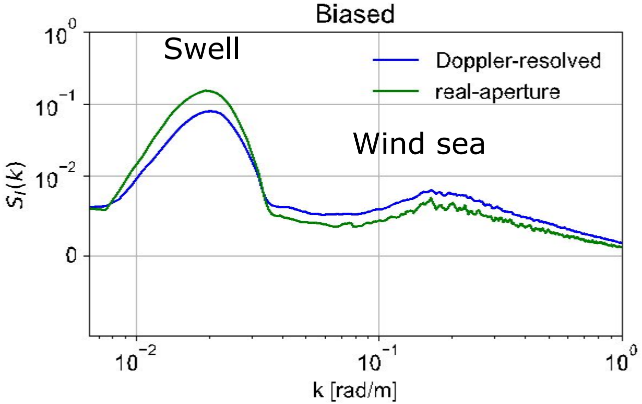


SKIM can meet wave mission performance requirements

1D range-resolved wave spectral intensity

Scenario: Simulated range-resolved intensity spectra <u>before</u> bias removal for a mean sea state with 12° degree beam at 45° azimuth to the swell-direction.

Results: mean of 100 simulations, with the shaded area indicated the 1-σ interval. The blue lines correspond to the Doppler-resolved case.

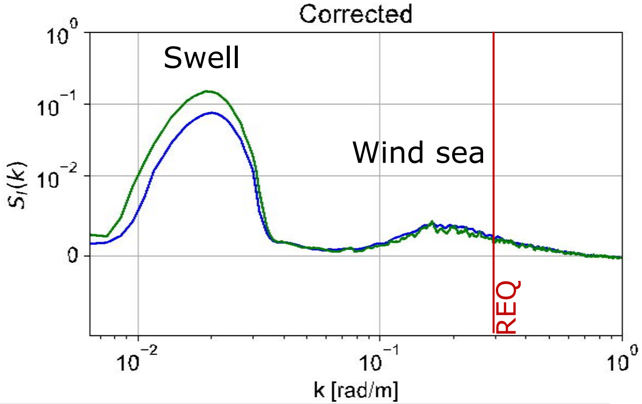


SKIM can meet wave spectral intensity performance requirements

1D range resolved wave spectral intensity

Scenario: Simulated intensity spectra after bias removal for a mean sea state with 12° degree beam at 45° azimuth to the swell-direction.

Results: mean of 100 simulations, with the shaded area indicated the 1-σ interval. The blue lines correspond to the Doppler-resolved case.



Metric M5: RMS difference between the wave spectral moment P=[0, 1, 1.5 and 2] compared to truth <10%.

Quantity				
Dominant direction, Doppler-resolved	5.5%	5.5%	5.5%	5.5%
Dominant direction, real-aperture	10.9%	10.7%	10.9%	11.2%
45° azimuth, Doppler-resolved	3%	2.5%	2.5%	2.6%
45° azimuth, real-aperture	8%	3.7%	3.6%	3.7%

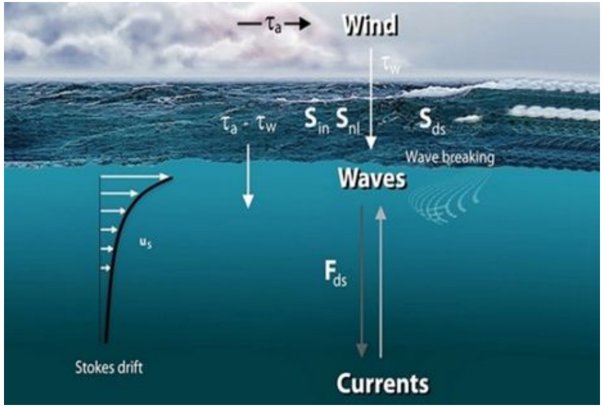
P0 = Hs^2
P1 = wave orbital velocity variance
P1.5 = Stokes drift
P2 = mean square slope

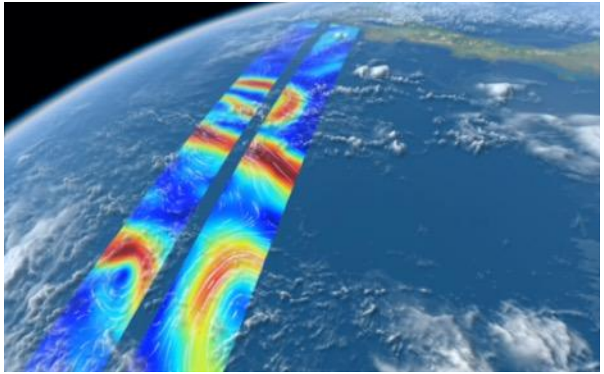
SKIM can retrieve wave-spectra for wavelengths under 10 m, exceeding the requirement (30 m).

SKIM vs SWIM: Summary and Conclusions

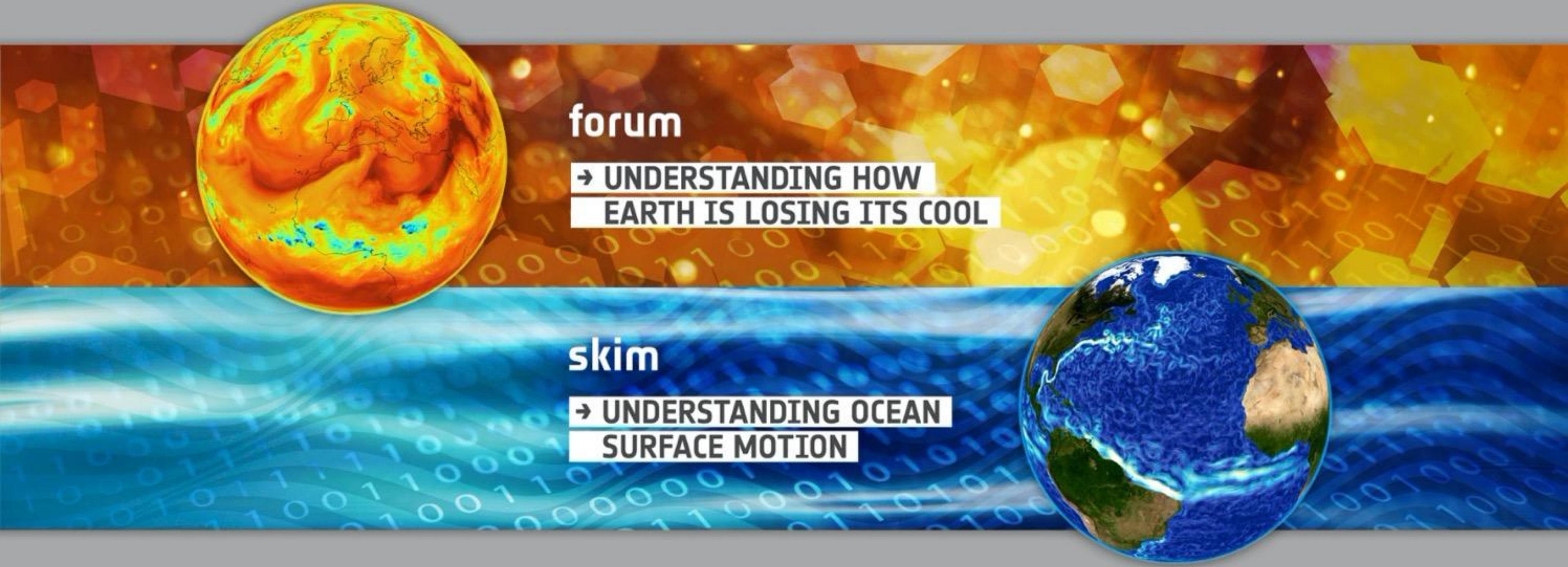
- First global coverage Doppler Mission: *HF-radar in space*
- **Higher PRF gives lower noise: possible to resolve shorter wave components (good for Stokes drift or msv)**
- **Smaller footprint: less directive spectrum, even more so with Doppler beam sharpening**
  - **- possible deconvolution of measured spectrum by known system response**
  - **- allows mapping waves where azimuth does not match wave azimuth: filling the swath**
- Choice of Ka-band has benefits for atmospheric effects on

SKIM is a high-performance scientific mission with long term implications for future science and societal applications and Doppler oceanography.





Questions


forum
→ UNDERSTANDING HOW
EARTH IS LOSING ITS COOL
skim
→ UNDERSTANDING OCEAN
SURFACE MOTION

Team SKIM