the Sea Surface Kinematics Multiscale monitoring (SKIM) mission:
a pathfinder radar mission for mapping currents and waves
1. What is SKIM?

It is a combination of Ka-band radar altimeter, disco ball, and speed gun ...

- « altimeter on steroids » : best ever flown
  (Ka-band, 32 Khz PRF, 200 MHz bandwidth, SAR unfocused)
  → low noise for sea level, wave height, ice freeboard ...

- « disco ball » : well... reflector is fixed (1.2 m parabola – in pink) but the « spotlights »
  are turning (horn feeds on a rotating plate near focal point).
Result : radar beams dancing around ground track

Preliminary design :
1 nadir beam (classic altimeter)
7 other beams
at 6 and 12° incidence
As the plate rotates on the spacecraft, beams illuminate different footprints.

Switching from one beam to another we measure the « radial current » (in color: 12°, grey: 6°), that is a projection of the current vector (in black).

The result is a map of currents with a full vector at least every 20 km in most of the swath.

SKIM also measures:
- wave spectrum
- sea level
2. How the speed gun works: Multiscale

SKIM measurement pattern gives an **incomplete** map of the surface Doppler and roughness:

instead of one continuous SAR image we get a **collection of “postage stamps”** 6 km in diameter, scattered across the ~ 280 km wide swath.

**We can thus resolve scales**
- between the pixel resolution (4m in range by 300 m in azimuth with unfocused SAR) and the footprint size (6 km)
-  *-> used for wave measurement, but can also yield sub-footprint gradients (see figure ->)*
- between ~ 25 km (depends on various instrument choices) and the swath width

example of surface convergence at \( L < 10 \) km, from ship-borne X-band radar (B. Lund, RSMAS)
Inematics… because the ocean moves!
- where is it all going?
- plankton, plastics, heat, salt, sea ice, man overboard …
- How much and where winds work on ocean?
- What are wave heights, periods & directions?
  wave impacts on extreme sea level at the coast?
- How waves and currents interact?
- How waves and sea ice interact?

Multiscale:
from meters (waves, Stokes drift …)
to global scales (garbage patches …)
4. Got current?

Models give currents… but poorly constrained by
- sea level variability from altimeters
- gravimetry (GOCE / GRACE)
- in situ drifters (used in Mean Dynamic Topography)

Especially near & under sea ice … and in tropics
5. Yes we can measure currents from space with a Doppler radar

From Collard et al. (SEASAR 2008) See also Chapron et al. (JGR 2005), Rouault et al. (JGR 2010)

Section at 120°W
6. Sampling the oceans from space

2021: SWOT will make a big step towards high res. (SSH + back-scatter, see Rascle et al. 2017)

2025: **SKIM** can give good space & time sampling (dx = 30 km, dt = 4 days), fully map mesoscale a pathfinder for Doppler vector Oceanography

202x: WaCM can extend space & time resolution

Ideal combination for **SKIM**?
SWOT
+ SKIM
+ MetOp SGB
+ CIMR (Microwave radiometer considered for future Sentinels)
These last 2 could be in a “train” on the same orbit
7. How do we know it works?

simulations!.. Which are supported by data including AirSWOT data (airborne instrument)

Doppler in Ka band (12° incidence) responds to currents in range direction:

Nougier et al. (IEEE TGRS, in press)
7. How well will it work?

Unprecedented resolution for
- mesoscale flows
- tropical currents  
  (including divergence)
- near ice currents
The **Arctic** is becoming a giant **marginal ice zone** (Aksenov et al., Marine Policy 2017): wave & drift data needed by 2025 to observe this regime shift

→ Excellent SKIM revisit:
example of 1-day coverage

What can be measured:
- drift in marginal ice zone
- good nadir beam quality → ice freeboard and ice thickness
- wave spectra across the ice edge
9. Mission objectives

SKIM will measure and investigate simultaneously:

- the **total surface current velocity vector** (TSCV) over the global ocean and inland seas from 82°S to 82°N at a spatial resolution \( \text{dx} \leq 40 \text{ km} \) with a revisit of \( \leq 10 \text{ days} \) and a combined uncertainty of \( \leq 0.1 \text{ m/s} \) for each component.

- the **directional wave spectrum** at a resolution of \( \leq 70 \text{ km} \) over global ocean and inland seas from 82°S to 82°N every 10 days or less. \( H_s \) shall have a combined uncertainty \( \leq 30 \text{ cm} \) (TBC) or 8% (TBC) (whichever is greater) for \( H_s \) between 1 and 10 m. Directional resolution \( \leq 7° \) (TBC), and wavelengths 30 - 500 m (TBC).
What science goals to we will achieve with such data & synergies with other sensors:

- Map Equatorial ocean currents and their impact on the coupled ocean-atmosphere system, including upwelling, at intra-seasonal to inter-annual time scales.

- quantify the time-varying surface transport globally (plastics, biological species…)

- characterise the wave-current-sea ice interaction (i.e. break-up, growth, kinematics) at sub-daily timescales together with collocated surface characteristics (eg. sea ice thickness, dynamic ocean topography) from the nadir-pointing beam.

- quantify impact of ocean surface multiscale kinematics (i.e. waves, fronts, large-scale TSCV) and on ocean-atmosphere exchange and dynamics of momentum, heat, mass, CO2, in complex heterogeneous regions (e.g. polar regions continental shelves, large frontal regions).

- Characterise and quantify the difference between total surface current vector measurements at mesoscales (ie. including near-inertial currents, Stokes drift, Eckman currents, mean ageostrophic currents, etc.) compared to 10-day mean geostrophic currents from altimetry
10. Ongoing work

- System studies
- Science studies
- Campaigns

- Coordination with U.S. WaCM proposal (many shared goals)
SKIM adds new variable for Earth monitoring: surface current vector (total surface velocity)
focus: strong currents (in particular tropics) & marginal ice zones

SKIM will strongly improve the measurement of ocean wave spectra:
new applications from nearshore to solid Earth monitoring.

Launch for SKIM or FORUM: mid-2025 on VEGA from Kourou.

Papers in press: Ardhuin et al. (2017): Measuring currents, ice drift, and waves from space: the Sea Surface Kinematics Multiscale monitoring (SKIM) concept. doi:
10.5194/os-2017-65

Nouguier et al.: Sea surface kinematics from near-nadir radar measurements

Paper in review: Ubelmann et al.: Mapping surface currents from Doppler measurements...
#SKIM4EE9 @FabriceArdhuin

http://tinyurl.com/SKIMonRG