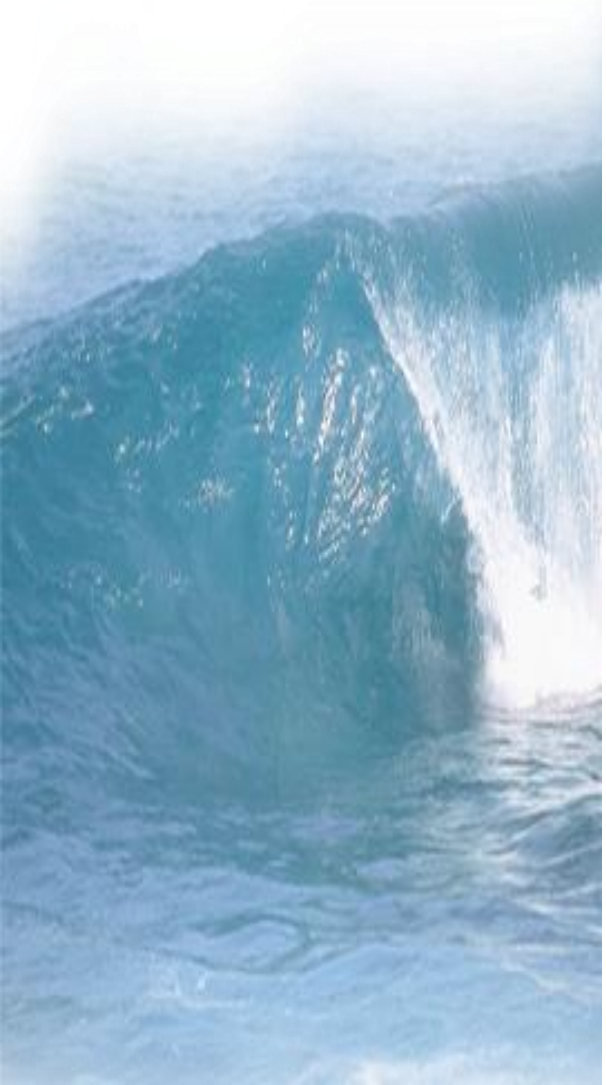
CFOSAT (Chinese-French Oceanic SATellite): an innovative mission combining surface ocean wind and wave measurements from Ku-Band scatterometry

Hauser D.[1], Liu Jianqiang [2], Dong Xiaolong [3], Zhu Di [3], Tison C.[4], Lambin J. [4], Amiot T.[4], Castillan P. [4], Mouche A.[5], Chapron B. [5], Ardhuin F. [5], Lefèvre JM. [6], Aouf L. [6],Mahfouf JF[6]

(1) LATMOS- CNRS –UVSQ-UPMC , France
(2) NSOAS, Beijing, China,
(3) MiRS-NSSC-CAS, Beijing China
(4) CNES, Toulouse, France
(5) IFREMER; Brest, France
(6) Météo-France, Toulouse, France

Overview



- The CFOSAT mission
  - Scientific objectives
  - Mission overview
  - Observation requirements
  - Key dates and organization
- The SWIM instrument
- SWIM data products
- Preparation of data analysis and geophysical validation
- Synergy of multi-incidence observations

Scientific objectives

- **Main objective: to provide ocean surface wind and wave observations at the global scale**
  - To improve wind and wave forecast and sea-state monitoring
  - To improve the knowledge and the modeling of surface waves
  - To get simultaneous wind and wave measurements for characterization and modeling of air/sea coupled effects
  - To improve description of surface conditions for atmospheric models (assimilation, see e.g. presentation by Payan yesterday) and oceanic models (forcing conditions)

- **Secondary objectives**

  Land surface monitoring (soil moisture and soil roughness)

  Polar ice sheet and sea ice characteristics

Mission overview

- **Two Instruments**
  - SWIM: Surface Waves Investigation and Monitoring (France)

    Ku-Band rotating scatterometer at small incidence (0-10°)

    => Directional wave spectra (+ Hs and wind speed)
  - SCAT (China)

    Ku-Band rotating fan-beam scatterometer (RFSCAT) at medium incidences (20-46°) – concept Lin et al, TGRS 2000

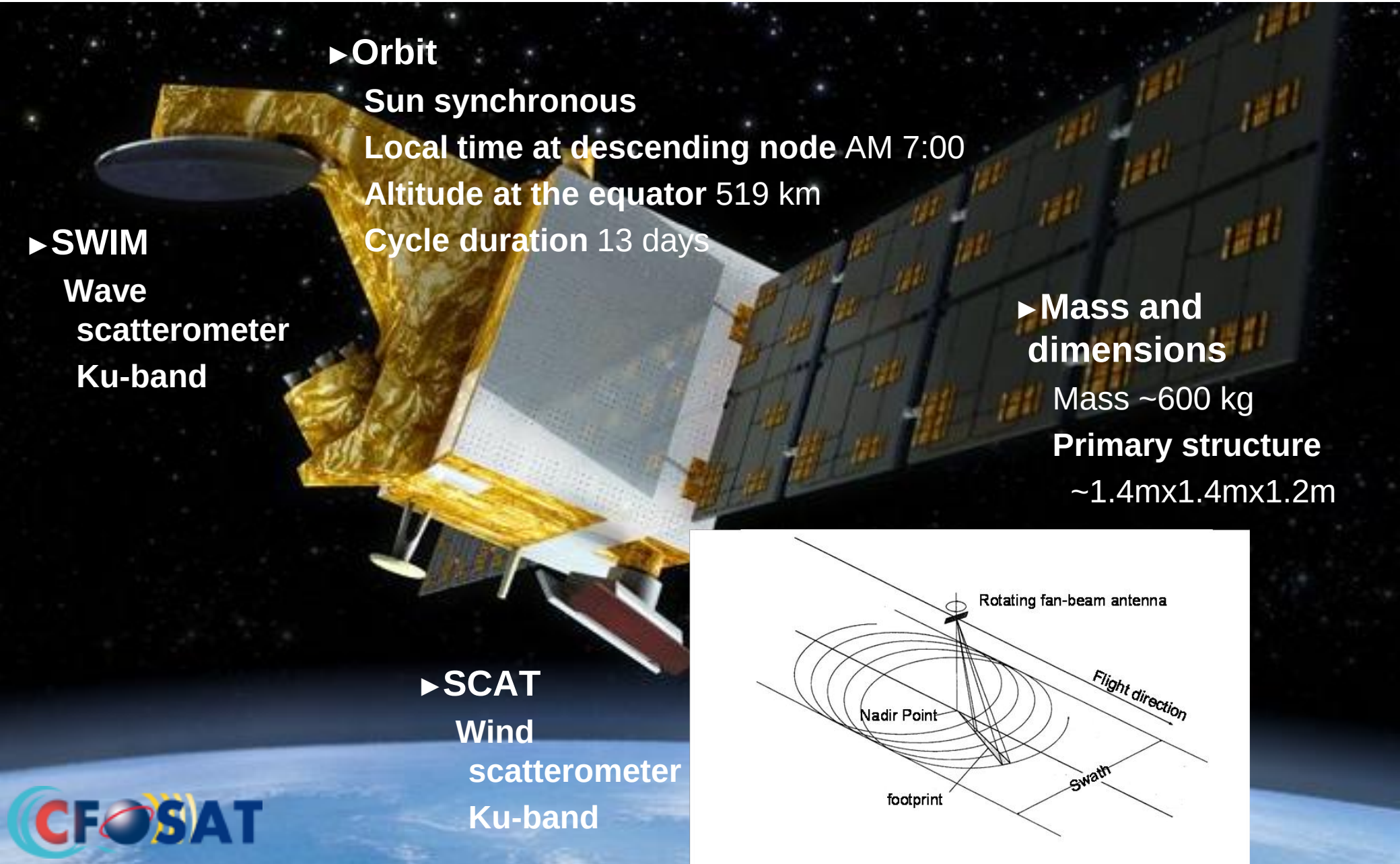
    => wind vector (± 500 km across-track swath)

- **Near-Polar Orbit, 520 km, 13 day repeat cycle**

- **Minimum duration: 3 years**

- **Near Real time processing + advanced differed-time products**

Mission overview



►**Orbit**

Sun synchronous

Local time at descending node AM 7:00

Altitude at the equator 519 km

Cycle duration 13 days

►**SWIM**

Wave scatterometer

Ku-band

►**Mass and dimensions**

Mass ~600 kg

Primary structure

~1.4mx1.4mx1.2m

►**SCAT**

Wind scatterometer

Ku-band

Observation requirements

▸SWIM measurements and requirements

Directional wave spectra at a scale of 70 x 90 km

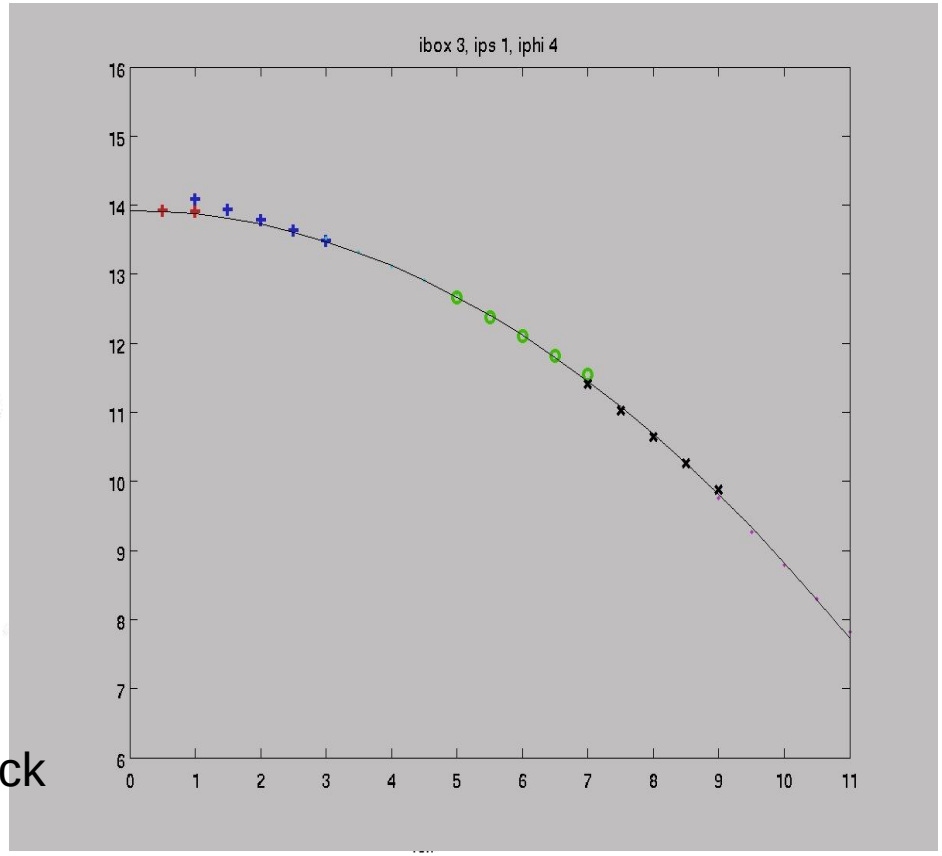
- Wavelength range 70m-500m
- 10% accuracy on wavelength, 15° accuracy on direction

Significant wave height and wind speed along-track

- 10% on SWH (or 50 cm whichever is better)
- rms <2 m/s on wind speed

Normalized radar cross-section from 0° to 10°

- Absolute accuracy of ±1 dB
- Relative accuracy between incidences ± 0.1 dB



▸SCAT measurements and requirements

Wind vector over swath of ± ~600 km across-track

50 km resolution cell (25 km experimental)

accuracy: 2m/s rms @5~24m/s, 20° wind direction

Backscattering coefficient **:** ± 0,5 to 1 dB

Key dates

2006

- Signature of the Memorandum Of Understanding (China-France) on CFOSAT

2007- 2008

- Phase A CFOSAT

  Feasibility demonstration

2009-2010

- Phase B CFOSAT

  Preliminary design

2011-2016 (2017)

- Phases C/D CFOSAT

  Detailed design

  Manufacturing of qualification models and flight model

2018

- Operational system in orbit

Organization (1/2)

Principal Investigators
D.Hauser – CNRS/LATMOS
Liu Jianqiang - NSOAS

CFOSAT system – science & data

Launch / campaign

Satellite

Platform
CNSA/DFH

SWIM
CNES
Contract : Thales Alenia Space

SCAT
CNSA/CAS (CSSAR)

X-band TM
CNSA/CNES
Contract : Thales Alenia Space

Satellite control

Stations
CNSA

Control center
CNSA

Network
CNSA

Operations
CNSA

Operations / Mission

X-band stations
CNSA/NSOAS

Chinese mission center
CHOGS
CNSA/NSOAS

Differed time products

Near-Real time products (regional)

Polar X-band stations
CNES
Contract : SSC

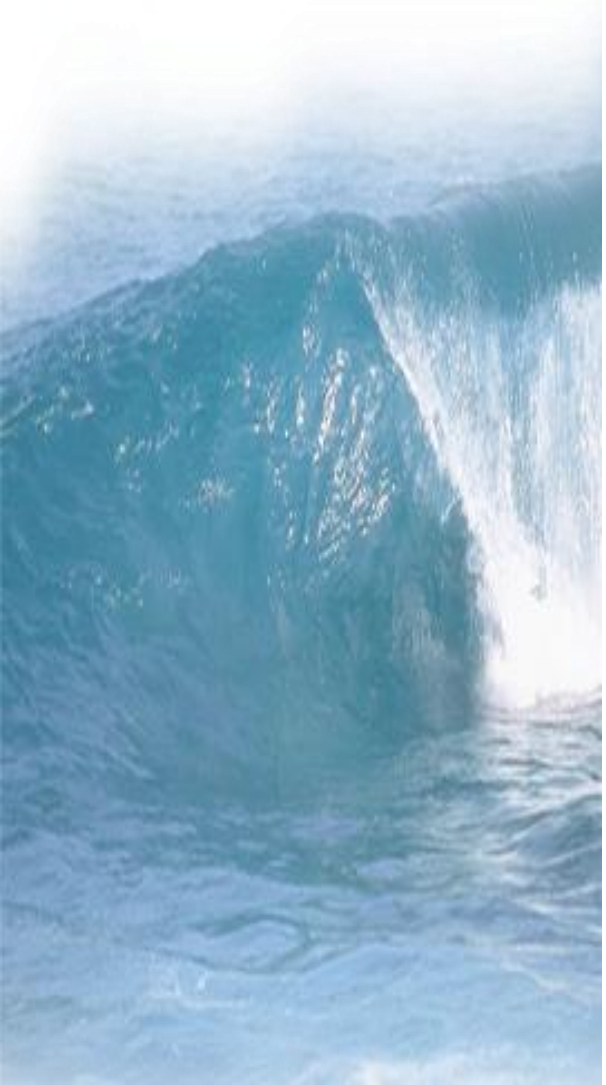
French mission center
FROGS
CNES/IFREMER

Near-Real time products (global)

Differed time products

1

Overview



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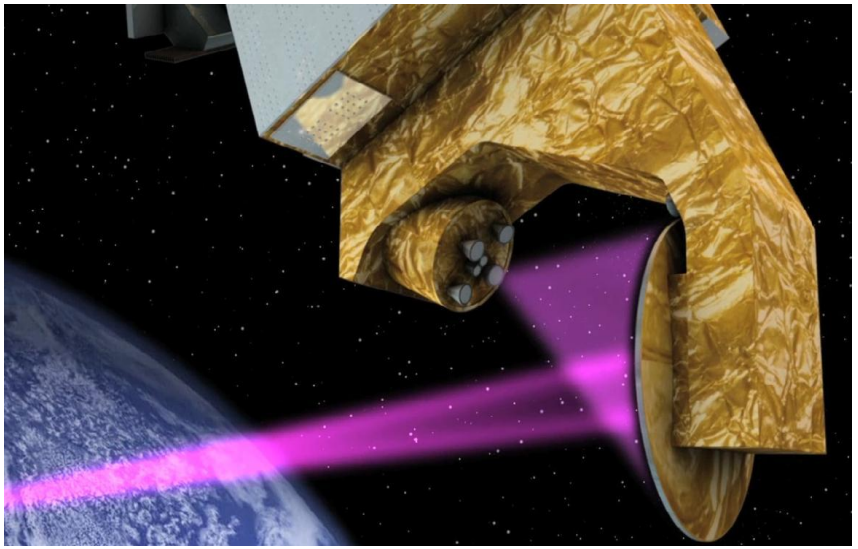
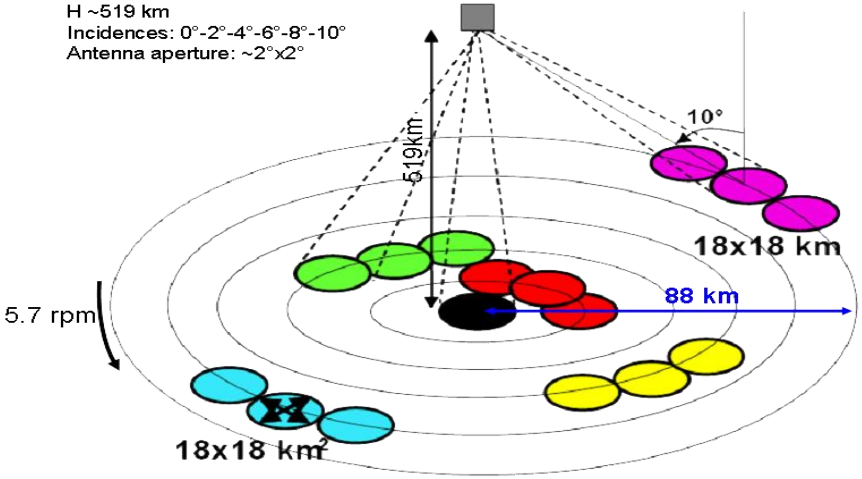
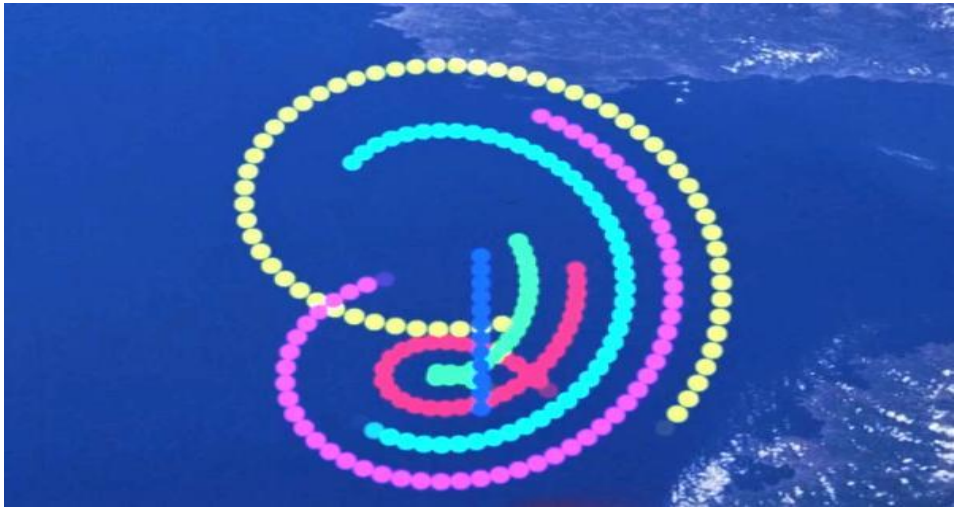
SWIM instrument

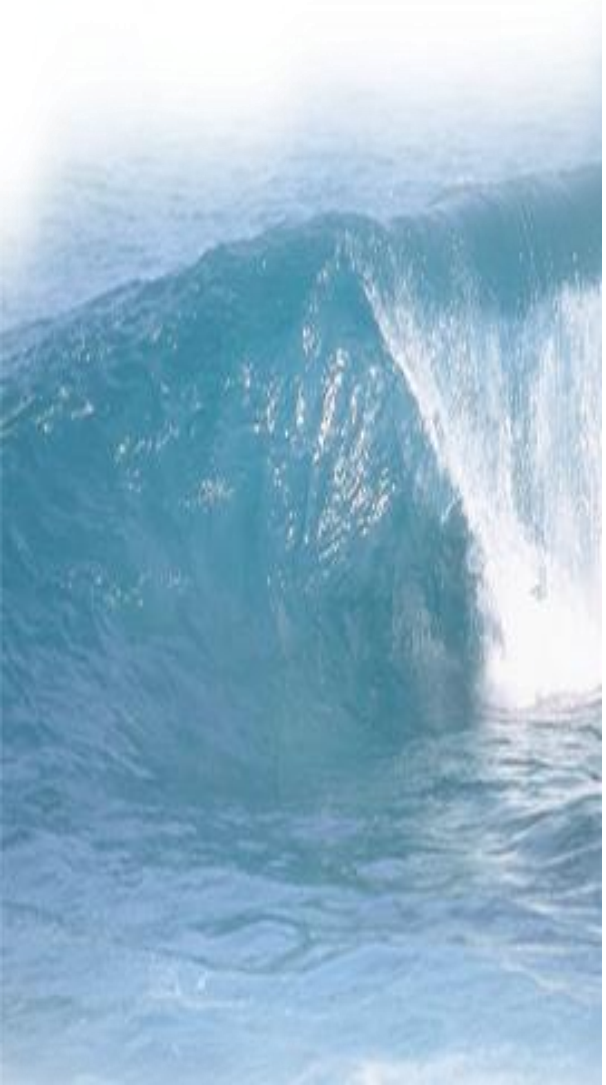


- Real aperture radar
  - Ku-band (320 MHz bandwidth)
  - On-board digital processing
  - 6 distinct beams between nadir and 10° incidence
  - Rotating antenna at 5.6 complete rotations/min



Ground track





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Overview of SWIM products

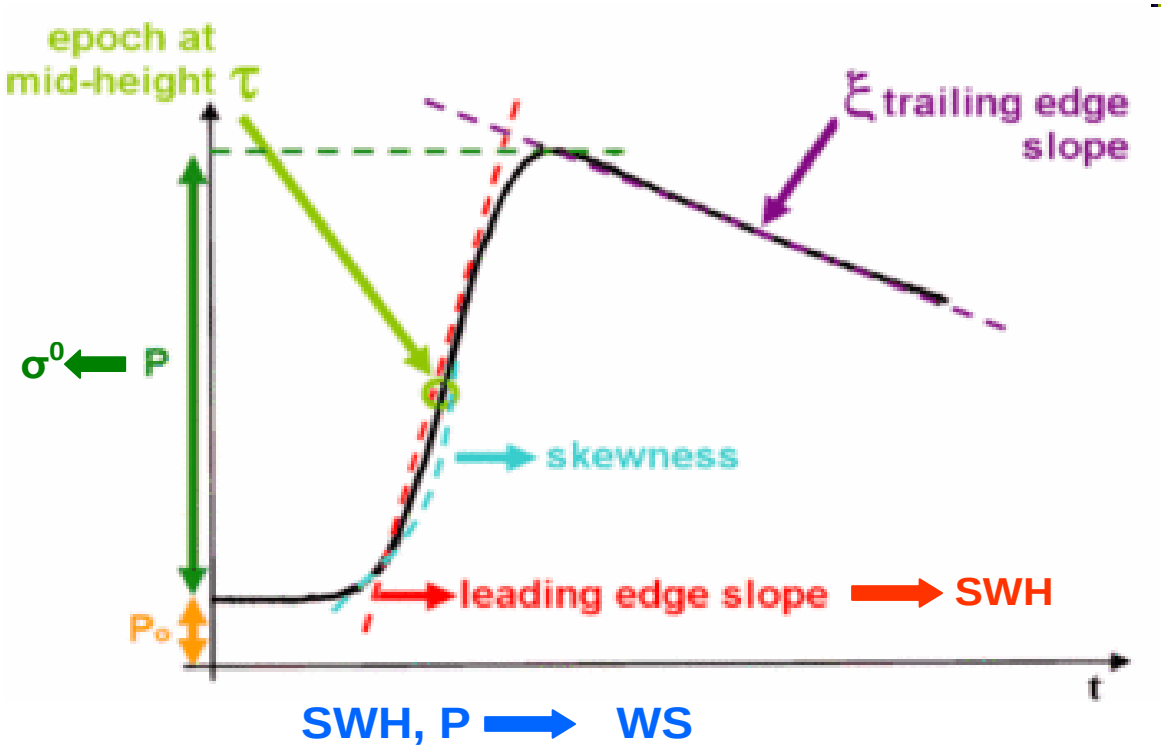
Level 0: raw data (backscattered power versus range) @ 0, 2, 4, 6, 8, 10°

Nadir products (0°)

Wave products (6°, 8°, 10°)

σ^0 products
(0°, 2°, 4°, 6°, 8°, 10°)

Level 2a,
Near Real Time (3h)
calibrated nadir waveform:
SWH (Significant Wave Height)
WS (Wind speed)
SIGMA0 (at nadir)
+ice and land parameters (TBD)



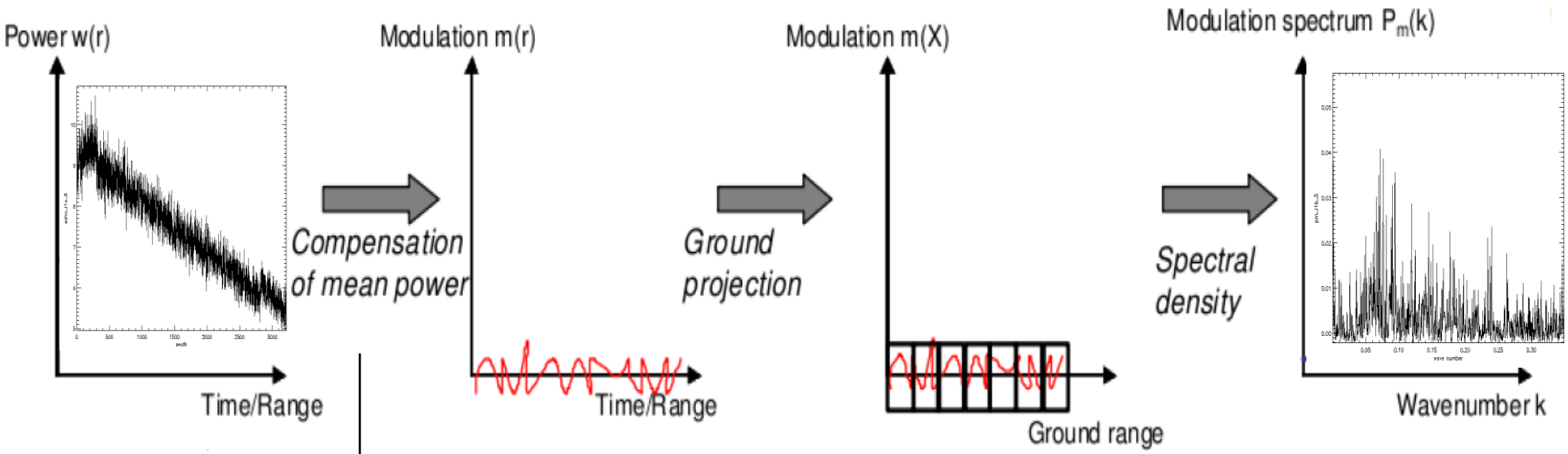
Wave products (1/2)

Level 0: raw data (backscattered power versus range) @ 0, 2, 4, 6, 8, 10°

Wave products (6°, 8°, 10°)

L1b
Modulation spectrum

Signal analysis in each footprint



Mean trend (for the MTF and wave spectra)

+

Speckle estimate/correction
smoothing

σ^0 products

Level 0: raw data (backscattered power versus range) @ 0, 2, 4, 6, 8, 10°

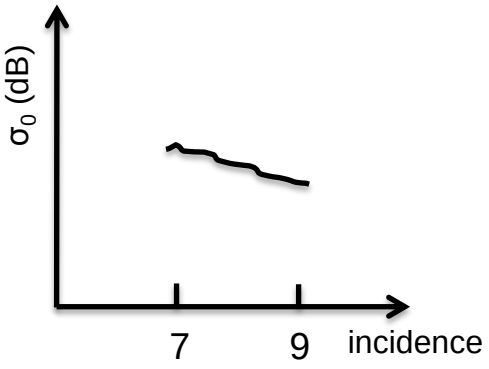
Nadir products (0°)

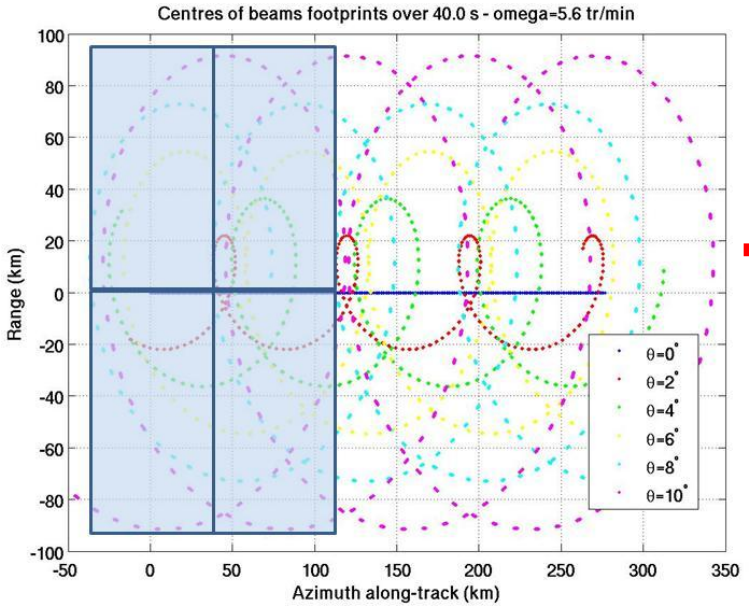
σ^0 products
(0°, 2°, 4°, 6°, 8°, 10°)

Level 1a: Calibrated wave form, geocoded

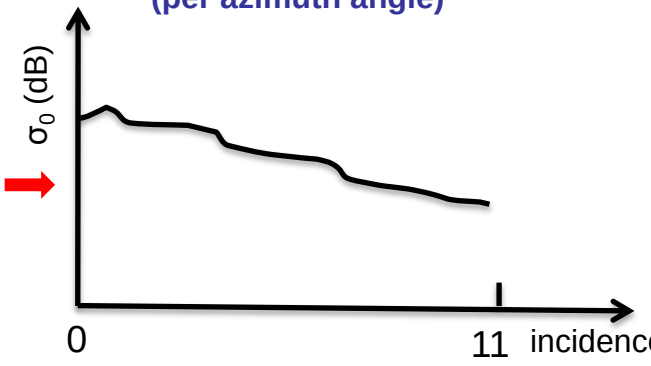
Level 2a

σ0 average on steps of 0.5° of incidence angle and 15° of azimuth on boxes of 70 km x 90 km





Normalized radar cross-section profiles from 0° to 11° (per azimuth angle)



Wave products (2/2)

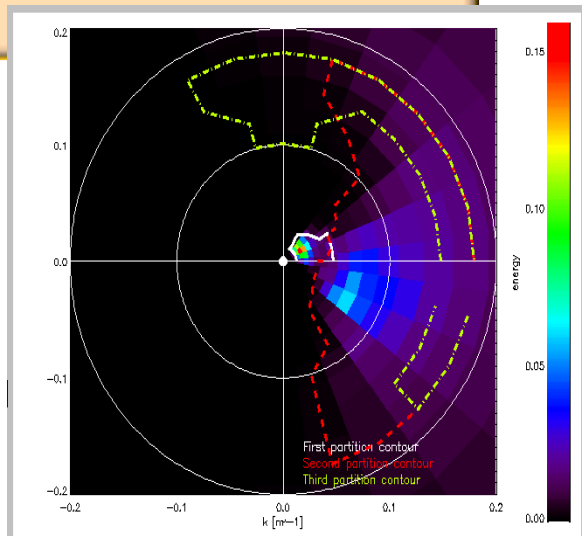
Level 0: raw data (backscattered power versus range) @ 0, 2, 4, 6, 8, 10°

Wave products (6°, 8°, 10°)

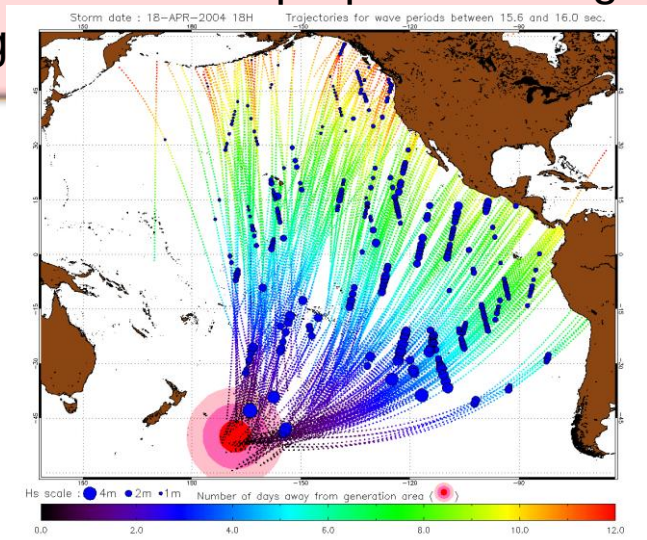
Near Real Time

Differed Time

L2:
- 2D wave spectra
(for each radar beam and combined)
- partitioning and associated parameters (energy, peak wavelength, and direction of propagation,…)



L2S:
Alternative signal analysis
L3-L4:
Advanced products such as:
extrapolated wave properties along propag



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Preparation for data analysis and geophysical CAL/VAL (1/2)

▶SWIM

End to End simulator: surface 2D topography (from wave spectra) + wind , platform/orbit conditions => radar signal => inversion

work still going on : speckle corrections, Modulation transfer function, alternative signal processing, data fusion, full-orbit simulation

Airborne radar (KuROS, SWIM+SCAT geometry)

Assimilation schemes and impact studies in wave prediction models

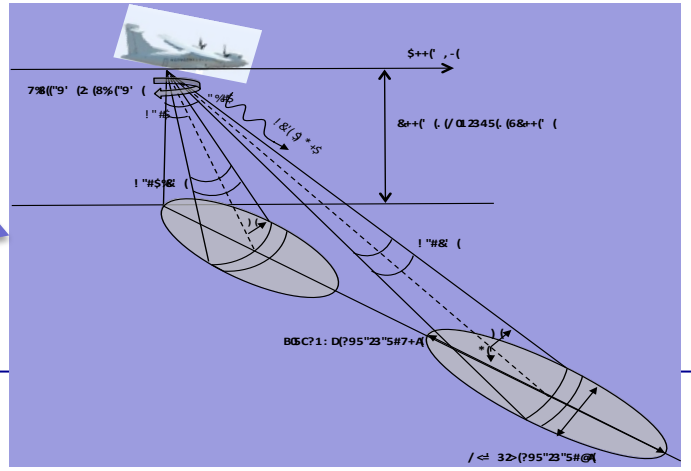
New L2-L3-L4 products from Sentinel 1 (and ASAR-ENVISAT)

▶SCAT

End to end simulator: wind fields (acamedic), platform/orbit conditions => radar signal => inversion

work still going on for: σ_0 regrouping on regular grid to optimize the wind retrieval

Airborne SCAT



Preparation for data analysis and geophysical CAL/VAL (2/2)

- CAL/VAL (2018)

  - External CAL
    - Homogeneous extended targets (wind forest,…)
    - ground receivers (SCAT)

  - Geophysical VAL (SWIM and SCAT)
    - Use of global data sets (in situ observations, other satellite missions, models,..)
    - specific campaigns (Europe, China (TBC) ,..)
    - **Call for opportunity to be issued (2015) : will be open to the community**

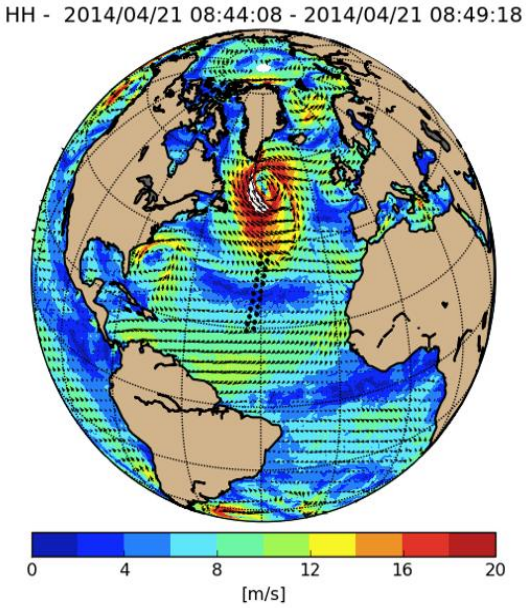
Synergy of multi-incidence observations (1/2)

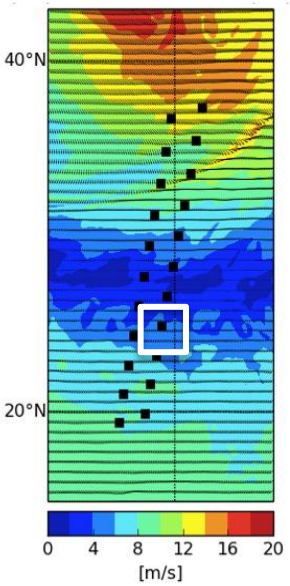
- To improve or extend inversion of geophysical products from Ku-Band observations
  - Influence of long waves or wave development on σ_0-wind relationship (SWIM+SCAT)- see poster by He Wang (HY-2 SCAT winds)
  - Combine SWIM (wind wave direction) and SCAT(wind vector) data to extend the domain or the accuracy of measurement: short wind waves (20-50 m in wavelength for SWIM, wind vector close to nadir for SCAT (where diversity of azimuth is small)
  - Estimate new parameters which impact air/sea exchanges:
    - Wave age, (wave development), mean steepness (SWIM-SCAT)
    - Statistics of ocean surface waves (slope pdf) (SWIM nadir + off-nadir)
  - Refine the influence of spectral properties of ocean waves on altimeter sea state bias (SWIM nadir + off-nadir + other altimeter missions

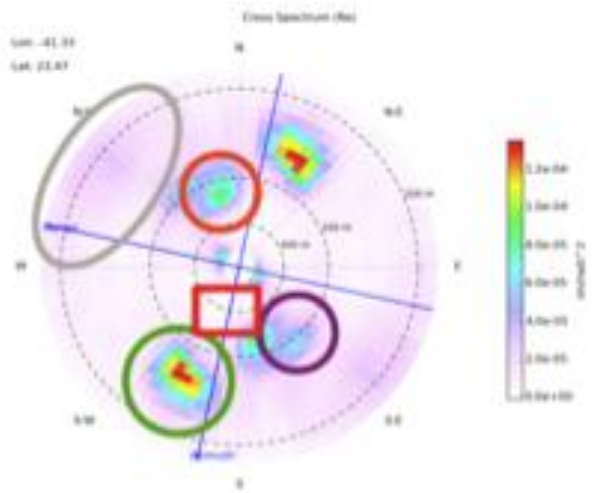
Synergy of multi-incidence observations (2/2)

► To study and model wave physics and coupling at the interface

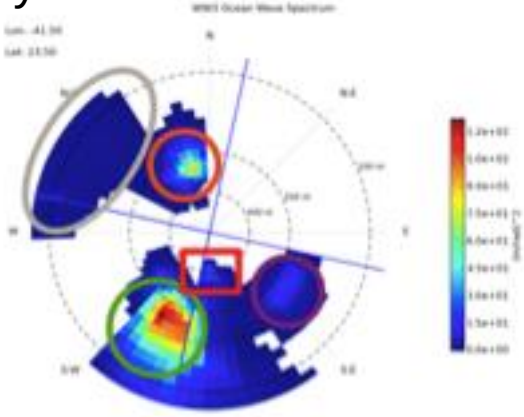
- Impact of long waves on stress
- Swell dissipation (ocean and air component)
- Short wave properties in presence of long waves
- Wind-waves and swell, complex sea situations







4 wave system from Sentiell 1 SAR



5 wave system from WW3 model !

Conclusion

- CFOSAT is a **world premiere mission** : simultaneous measurements of wind (SCAT) and directional spectra of ocean waves (SWIM)

- Access for the first time in space to **2D wave spectrum over the whole energetic spectrum (~70-500m)** at global scale, potential for complex sea situations (multi-wave systems)

- SCAT: implementation of a **new type** of Scat (Rotating Fan-Beam)

- SWIM is a **new spaceborne instrument** with technological innovations
  - Rotating antenna, n-board advanced digital processing

- CFOSAT, as a new component contributing to spatial oceanography systems, will:
  - Serve the operational community (wind/wave forecast, ocean surface analysis for ocean model forcing)
  - Serve the scientific meteo-oceanographic community (new data for studying wind/wave/flux/boundary layers interactions)
  - Reinforce international multi-mission observation strategy for a better survey of the ocean surface

Invitations to tender to be issued for science & applications (non-real time data at least)

Thank you!