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


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(2) NSOAS, Beijing, China,
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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
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
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

► SCAT
- Wind scatterometer
- Ku-band

► Mass and dimensions
- Mass: ~600 kg
- Primary structure: ~1.4mx1.4mx1.2m
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
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► SWIM data products
► Preparation of data analysis and geophysical validation
► Synergy of multi-incidence observations
► 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
The CFOSAT mission
- Scientific objectives
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The SWIM instrument

SWIM data products

- Preparation of data analysis and geophysical validation
- Synergy of multi-incidence observations
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° 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

Power w(r)  →  Modulation m(r)  →  Modulation m(X)  →  Modulation spectrum $P_m(k)$

Compensation of mean power  →  Ground projection  →  Spectral density

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

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 propagation path
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The SWIM instrument

SWIM data products

Preparation of data analysis and geophysical validation

Synergy of multi-incidence observations
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

► SCAT

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

work still going on for: $\sigma_0$ regrouping on regular grid to optimize the wind retrieval

Airborne SCAT

New L2-L3-L4 products from Sentinel 1 (and ASAR-ENVISAT)
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 $\sigma_0$-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, on-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!