Watershed method for detection of wave components in 2D wave spectra for SWIM data processing of CFOSAT

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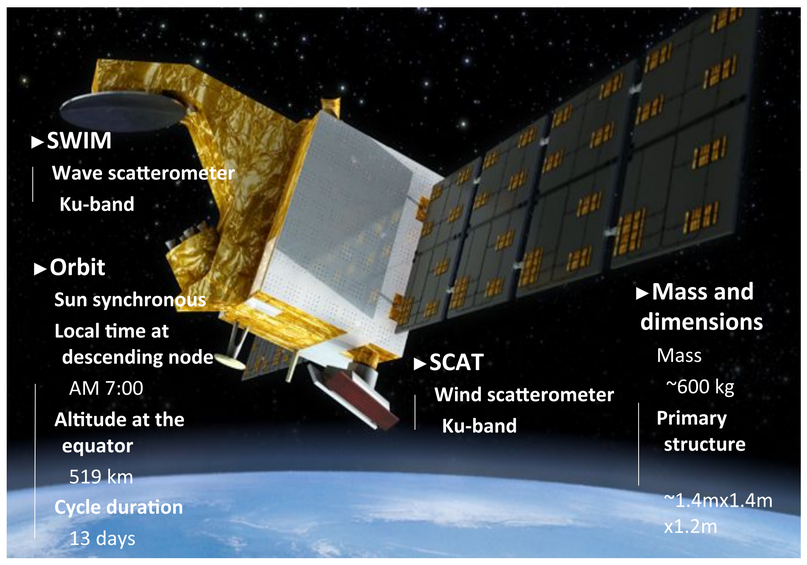
CFOSAT Mission (China France Oceanography SATellite) Overview



Scientific objectives and requirements:

►Global observation of ocean wind and waves with high temporal coverage

► To improve wind and wave forecast and sea-state monitoring

► To improve the knowledge and the modeling of sea-surface processes

► To get a simultaneous wind and wave measures for coupling effects characterization

►Secondary objectives (for SWIM): Land surface monitoring (soil moisture and soil roughness) and polar ice sheet characteristics

Partitioning spectrum: principle

A method to detect automatically wave components in 2D wave slope spectrum:

- based on a **watershed algorithm** improved and adapted to process Level 2 SWIM data
- get wave parameters: significant wave height, wavelength, direction for each detected partition
- identify wind sea and swell

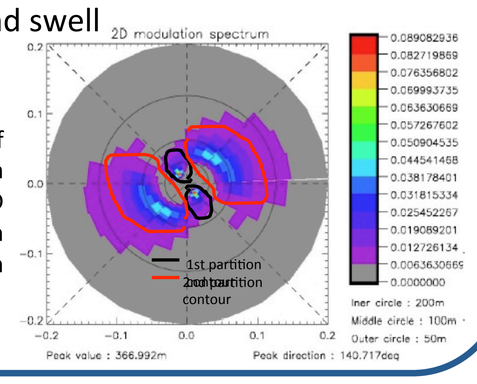


Figure: Illustration of component found in a symmetric 2D modulation spectrum

Watershed method and improvement:

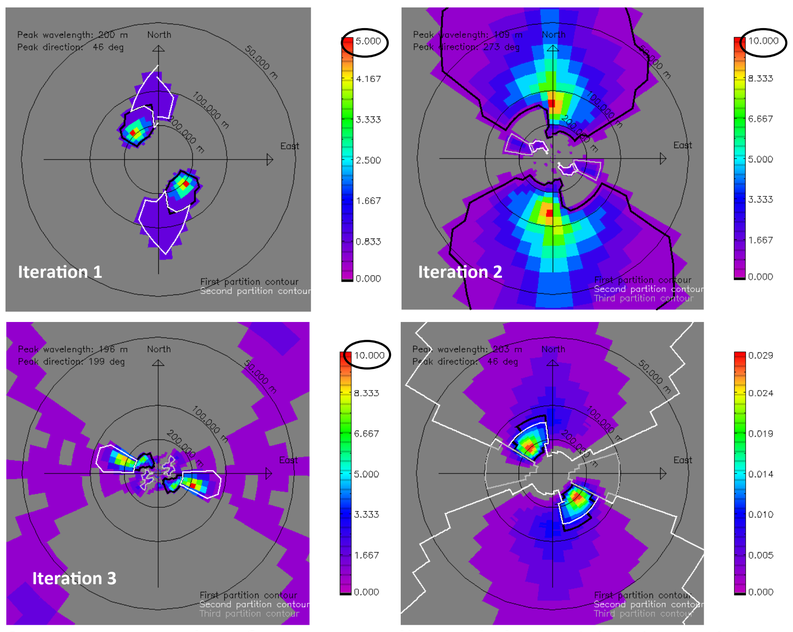


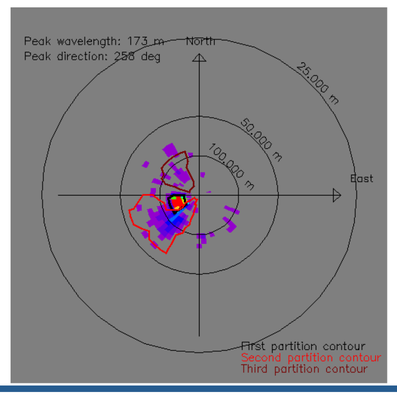
Figure: Example of PM + swell model partitioning with the iterative watershed method

- **Step 1 Noise reduction**:
  - Resampling in wave number on a logarithmic grid fixed at nk = 50 so that dk/k = 0.1 and Gaussian smoothing in k and ϕ
  - Discrete energy levels (number of levels dependent of the noise): variance increases with signal intensity ⇒ Number of energy levels must be adjusted to improve partitioning:
    - *Strong signal → higher variance → number of levels = 5*
    - *Weaker signal → lower variance → number of levels = 10*
- **Step 2 watersheding:**
  - Iterative partitioning: watersheding done 3 times, to get a maximum of 3 partitions
  - Partition merger with a weak contrast (maximum energy level on the boundary of the partition spectral domain compared with maximum energy level on the whole partition domain): threshold fixed at 95%
  - For each iteration, we keep only the most energetic partition and remove it from the initial spectrum before a new loop (as show on the figure)
- **Step 3 wave parameters:**
  - parameter computation done slope spectrum

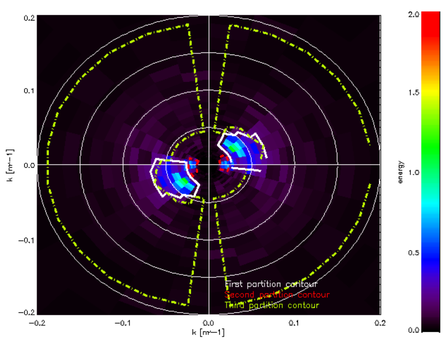
KuROS : example on real data

KuROS is an airborne Ku-band Doppler radar to prepare the CFOSAT satellite mission .
Directional sea wave slope spectrum obtained from a 30 s sample of KuROS observations (case of March 6th 2013 12:26:31). The ambiguity in the propagation direction has been removed. Energy density is in colour code. Concentric black circles indicate the wavelength. Direction is in the meteo-oceanic convention (North towards top of the figure). Three partitions are identified, sorted by decreasing energy.

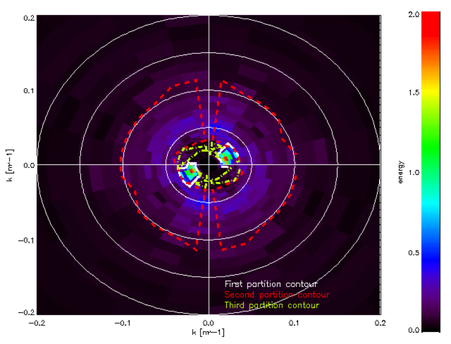
Partition	SWH (m)	λ (m)	Φ (°)
Total	4.2	173	250
Partition 1	2.9	178	250
Partition 2	2.3	168	230
Partition 3	1.1	139	320



Simulated SWIM data



Partition	SWH (m)	λ (m)	Φ (°)
Total	4.4	170	46
Partition 1	2.9	165	47
Partition 2	2.0	340	80
Partition 3	2.2	117	100



Partition	SWH (m)	λ (m)	Φ (°)
Total	5.3	284	57
Partition 1	3.4	280	57
Partition 2	3.3	125	1
Partition 3	1.6	316	24

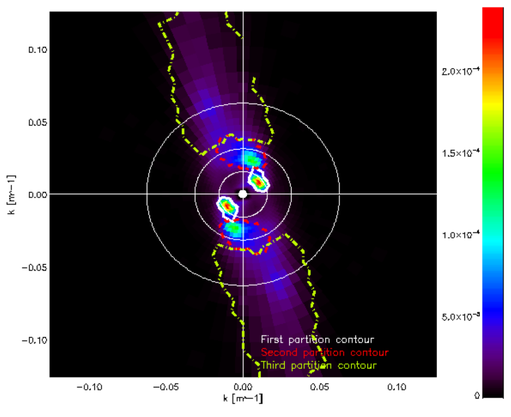
Two examples of 2D slope spectrum obtained from the simulation SWIM data with MFWAM inputs. The data have been processed up to level 2. Contours show detected partitions.

Compared to refence Météo-France model, we retrieve the wave number peak with an accuracy better than 10%, the direction better than 15°, in agreement with requirements. Energy of partitions have still a difference larger than requirements (~30% instead of less than 20%).

Conclusion and limits of watersheding

- **Improved watershed** method works relatively well on tested cases on real data as well as simulated spectra.
- **Limits of the method**: problems appear on too noisy spectra, partition boundaries are strict and we can not quantify errors and uncertainty with watersheding.
- **Proposed alternative** in progress based on a Bayesian approach to fit superposed theoretical spectral forms without resampling spectra and with estimated errors.

Sentinel 1A data



First data of Sentinel 1A satellite : Directional cross-spectrum in which we detect 3 partitions.

Partition	E (m)	λ (m)	Φ (°)
Total	0.078	457	40
Partition 1/4	0.035	471	40/220
Partition 2/5	0.027	255	75/255
Partition 3/6	0.018	135	92/272