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Wind wave statistics from specular reflections

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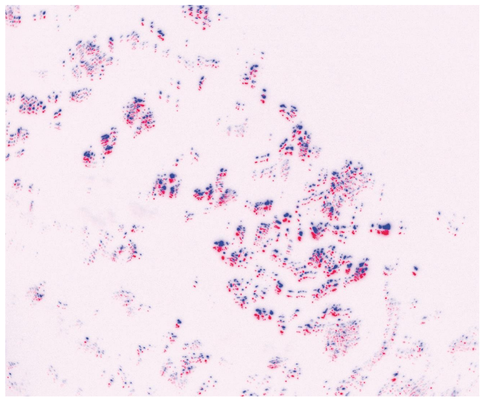
Reflection-based wave measurements



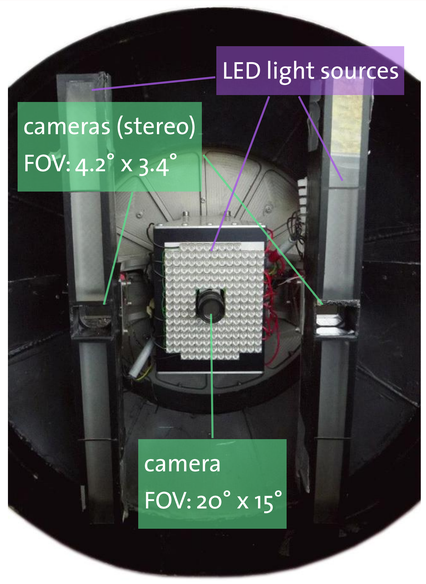
Stereo image pair with reflections of the instrument's light sources (see right)

Height
stereo disparity

→ OSM 2012 / [3]

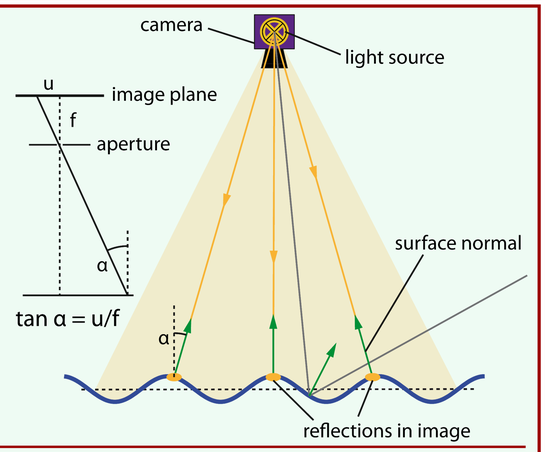
Slope
reflection distribution

Curvature
reflection brightness

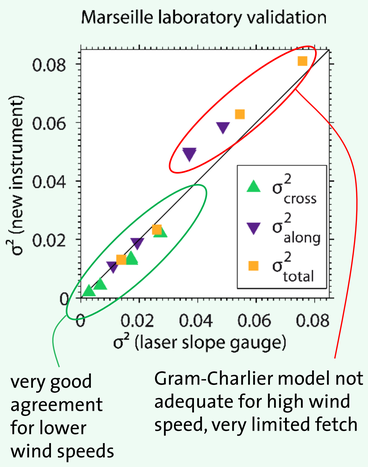


Slope measurement

- Slope measurement: Like Cox & Munk (CM) sun glitter measurements [1], but with artificial light source!
- Area of water surface is illuminated, but reflections are only visible when surface normal points to camera/light source
- Surface slope at points of reflection can be computed from position in image **u** and focal length of lens **f**: tan α = u/f
- Average distribution of reflections = **slope probability density function**! [2]

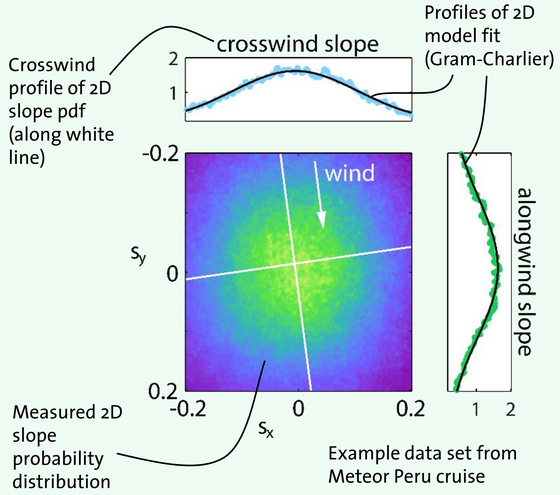


Laboratory validation



- Fit Gram-Charlier model to data; similar to CM (left) → extract mean square slope σ^2
- Lab comparison to laser slope gauge [4]: works fine at lower wind speeds
- high wind speeds and very limited fetch: Gram-Charlier model not adequate, leading to an overestimation of mss

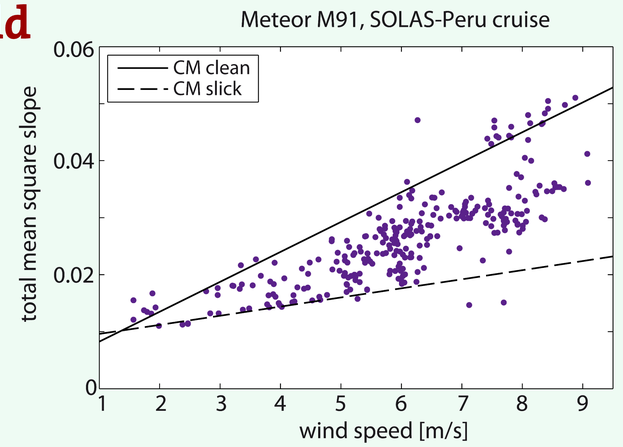
PDF measurement



Mean square slope in the field

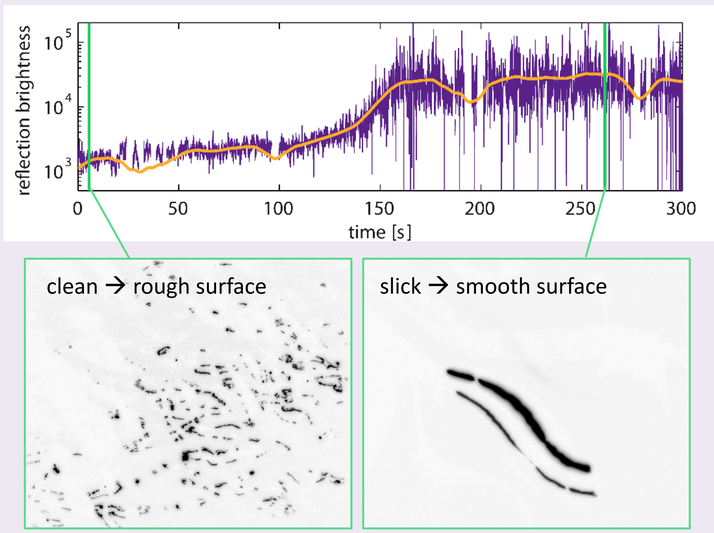
Instrument (under yellow hat) at the bow of FS Meteor off the coast of Peru

- 4 week experiment off the coast of Peru
- Ship motion correction applied to wave data
- Moderate wind speeds, changing presence of surfactants
- Changes in surface roughness possible on small spatial scales, < 100 m
- Surfactants will likely have big impact on air-sea gas exchange rates



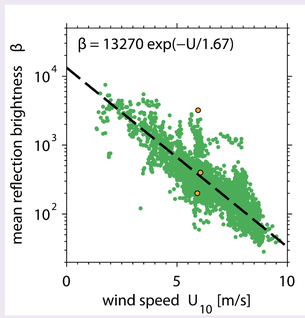
Mean square slope measurements from Peru experiment. Large variability of conditions due to changing presence of surfactants. Data points mostly lie between the CM parameterizations for clean water (solid) and slick (dashed).

Curvature measurement



Example reflection images, grayscale inverted for visibility

- brightness of individual reflections is linked to small scale surface curvature
- Curvature is very sensitive to changes in environmental conditions
- Left: Ship is entering area with surface slick at t = 150 s, curvature decreases, reflection brightness increases
- Below: Reflection brightness also has a strong dependence on wind speed



Reflection brightness decreases strongly with wind speed, large variability due to surfactants.

Data from Meteor M91, SOLAS-Peru cruise to the upwelling regions off the Peruvian coast.

Conclusion and Outlook

- New reflection-based instrument capable of measuring slope probability distribution and slick sensitive curvature parameters
- Easy to deploy and operate
- Robust measurements, day and night
- Provides important information on wave field in air-sea interaction experiments

PDF?

References:

[1] **Cox, C. and Munk, W. (1954)**. *Measurements of the Roughness of the Sea Surface from Photographs of the Sun's Glitter,* J. Opt. Soc. Am. 44(11), pp. 838-850.
[2] **Kiefhaber, D. (2011).** *Improved optical instrument for the measurement of water wave statistics in the field*, In Komori et al. (eds.): Gas Transfer at Water Surfaces, Kyoto Univ. Press, *pp. 358-367*
[3] **Kiefhaber, D. (2014).** *Optical measurement of short wind waves – from the laboratory to the field,* Dissertation, Universität Heidelberg, Germany
[4] **Caulliez, G. (2011).** Unpublished data from laser slope gauge measurements in the large Marseille *Pytheas* wind-wave facility, kindly provided by personal communication

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