Water Surface Topography Measurements with the RSSG

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The Reflective Stereo Slope Gauge

- Multi-scale wave measurements:
  - Statistical surface roughness measurements (similar to Cox & Munk [1] sun glitter technique) for short waves
  - Water height measurements from stereo triangulation for long waves
- Active technique → measurements independent of natural light
- Reflection based → non-intrusive & easy to employ, no submerged parts necessary
- Built to provide wave measurements at the footprint of heat transfer velocity measurements with the active controlled flux technique (ACFT) [2]
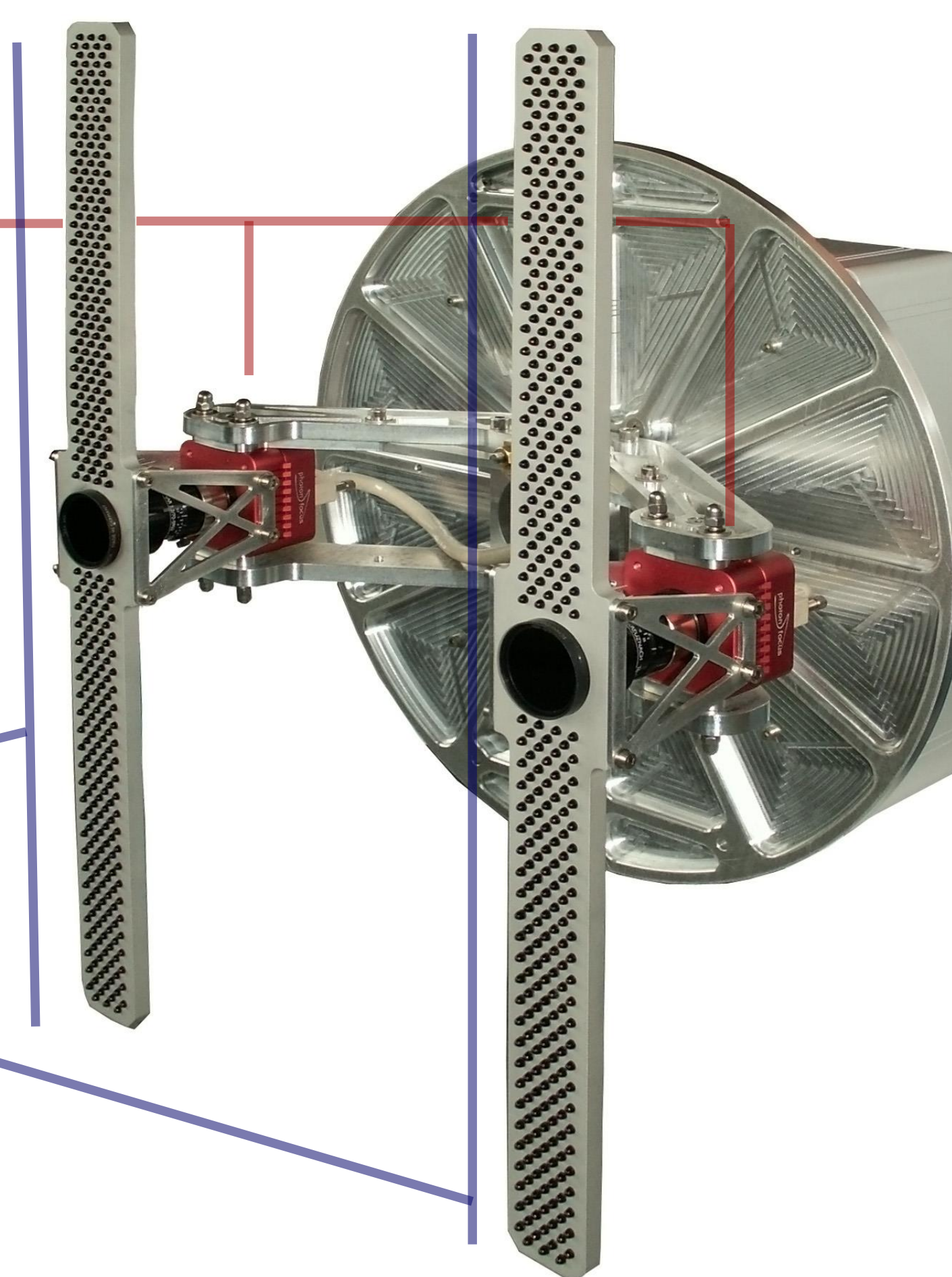
Imaging system

Cameras:

- 1.4 mega pixel
- Up to 108 fps
- Extended near-IR sensitivity (up to 1100 nm)
- Field of view: 117 cm x 96 cm in 8 m distance (4.2° x 3.4°)

Light sources:

- 2 x 350 IR-LEDs (λ_{Peak} = 950 nm)
- matched to water absorption peak to suppress upwelling light

Experiment

- The RSSG (yellow, cameras looking down) was part of the boom instrumentation during the 2011 OSSPRE cruise on R/V Kilo Moana.
- The ten day cruise offered variety of wind speeds and swell sizes, ideal for testing the instrument
- Reference measurements were available from a Riegl laser altimeter
- Instrumentation for micro-meteorological measurements including an IMU for motion correction
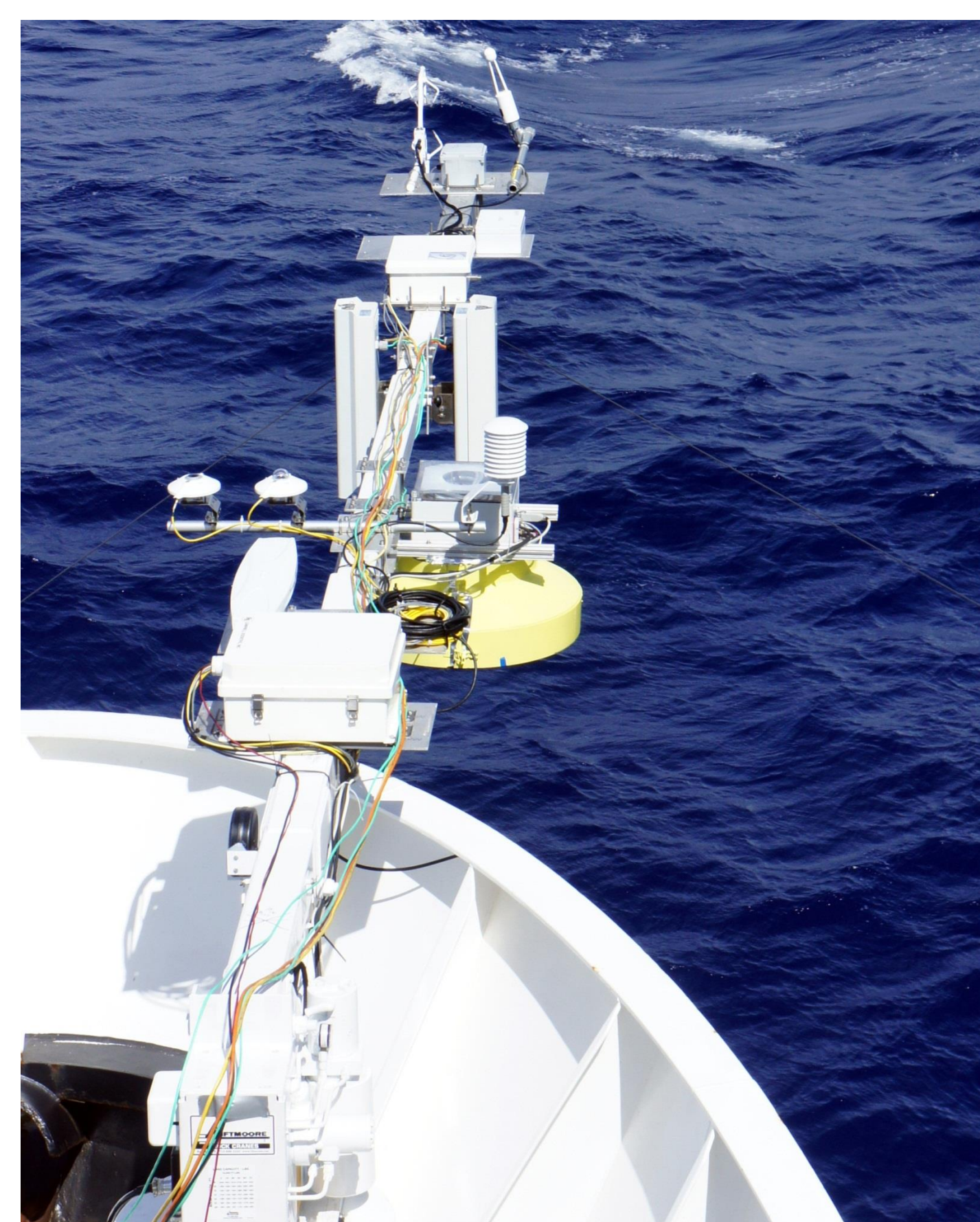
## Surface distance measurements
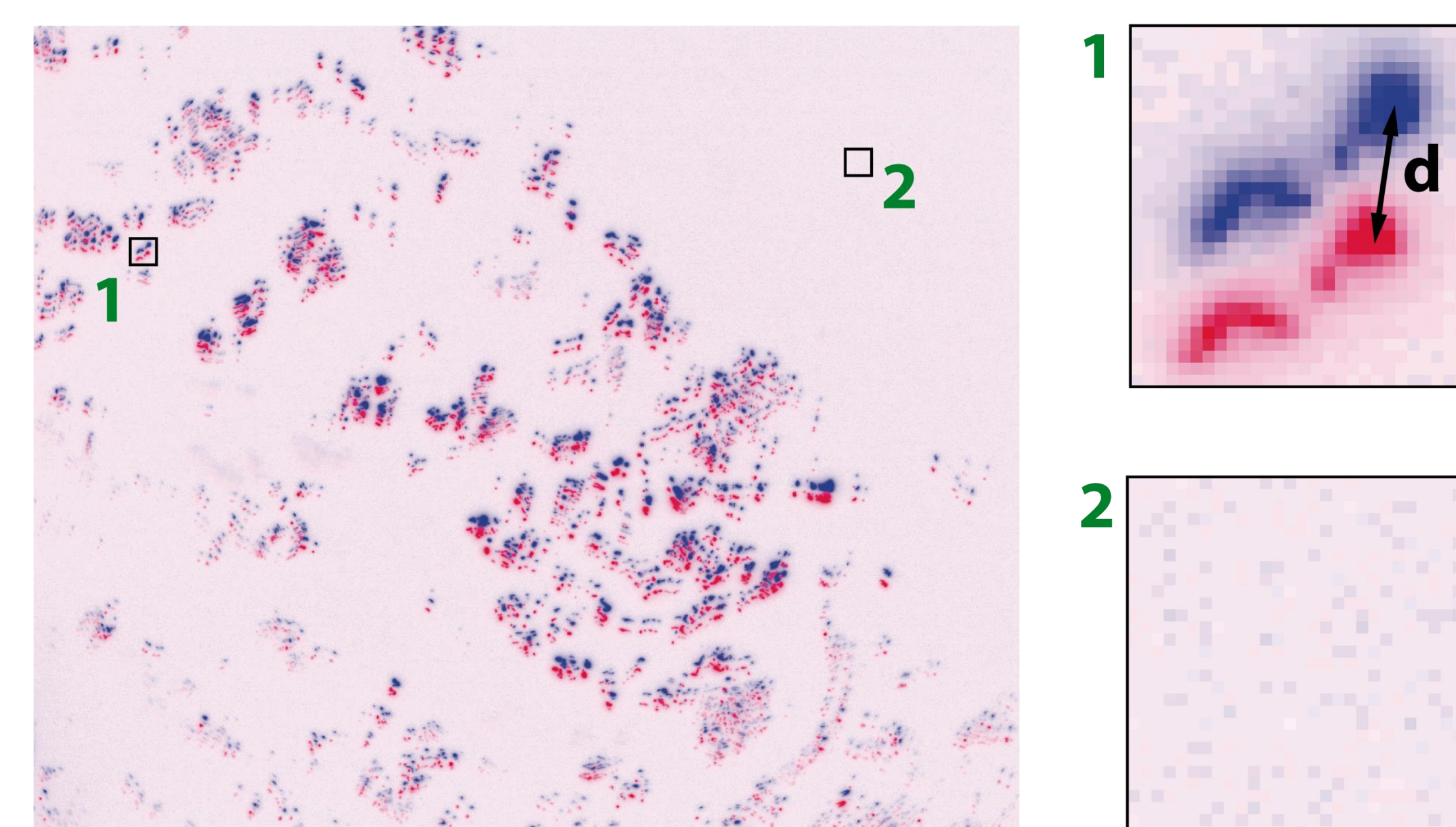
- Typical RSSG stereo image (inverted false-color overlay of two monochrome images, left camera: red, right camera: blue)
- The stereo disparity d (see detail 1) is unambiguously related to the water surface distance
- In some parts of the image, there are no specular reflections (detail 2), distance measurements are not possible

Two-dimensional topography

(1 pixel ≈ 1 mm)
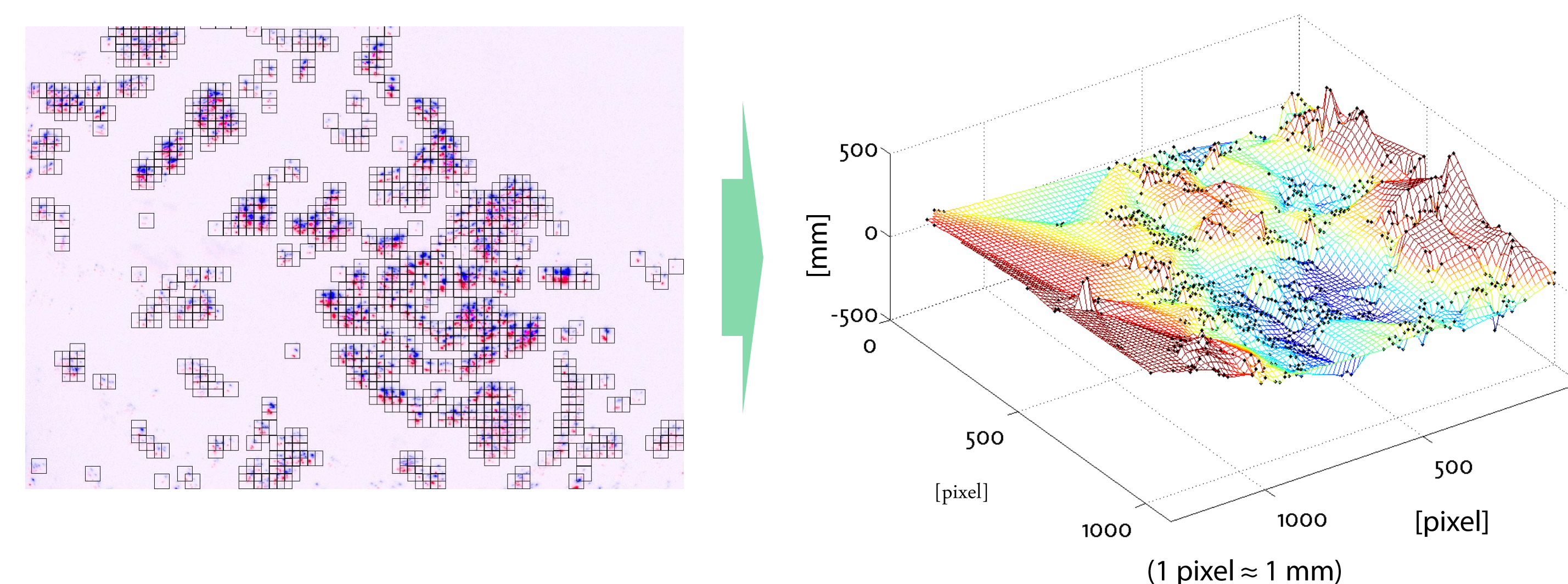
- In principle, the RSSG can measure the surface topography in 2D, which would allow to extract wavenumber spectra of waves with wavelengths comparable to or smaller than the footprint of the RSSG (approx. 1 m²)
- *Left:* Determine water surface distance from stereo disparity for all specular reflections, which occur at point with near zero slope
- *Right:* Get 2D water surface from interpolation of data points (Delauney triangulation)
- Amplitudes are very small (few centimeters) and large amplitudes of swell (meters) and ship motion are superimposed
- Need to develop reliable and accurate algorithm with sufficient accuracy and good suppression of outliers

Surface elevation
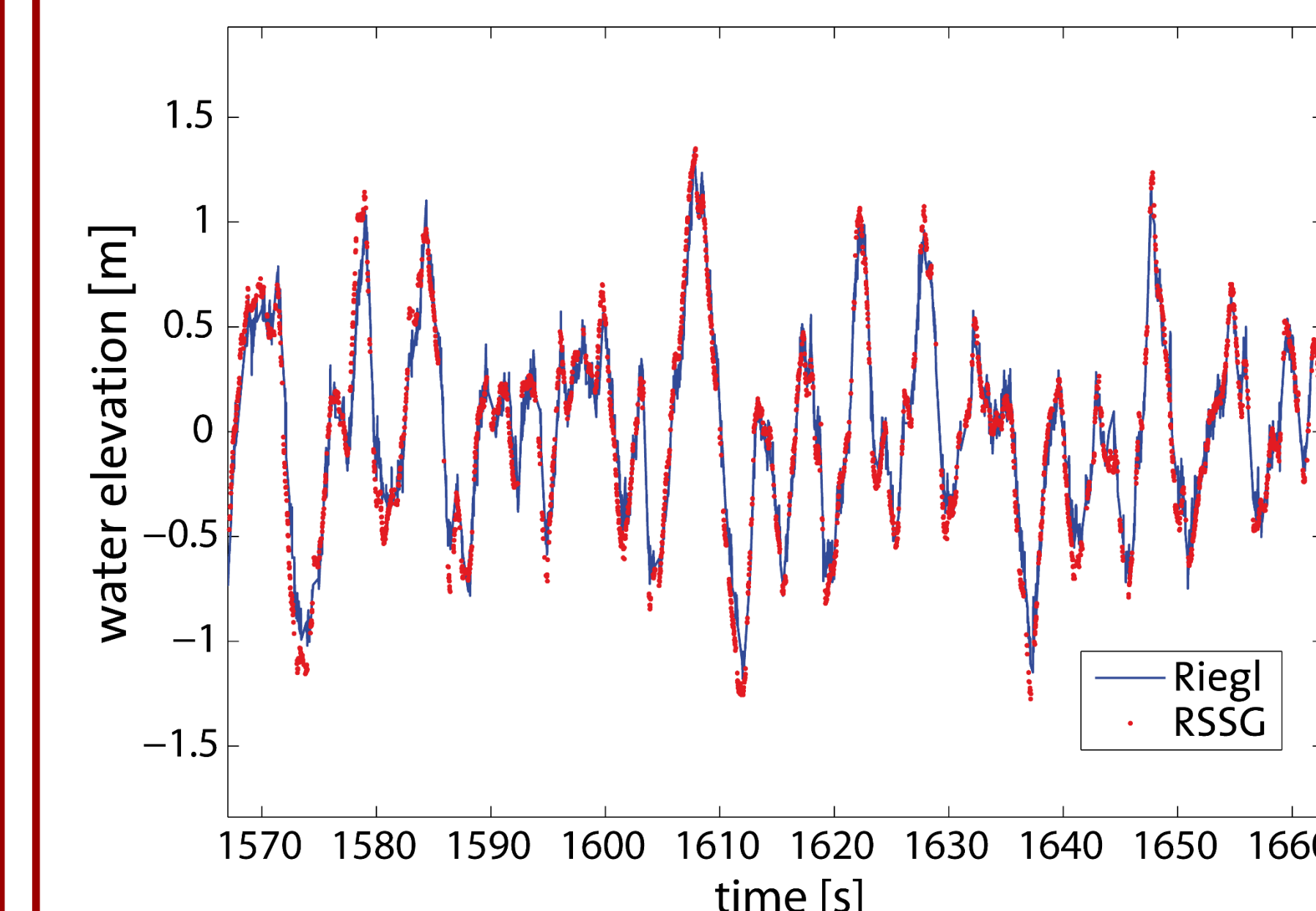
Comparison of Riegl laser altimeter (blue line) and surface elevation from stereo with the RSSG (red dots) during the OSSPRE cruise on R/V Kilo Moana.

- Determined average disparity over footprint of ca. 0.2 x 0.2 m, compared to Riegl laser altimeter → good match
- For single pairs of specular reflections, the height resolution is a few mm, but need to average over finite interrogation window
- smaller windows lead to higher dropout (no reflections in window), larger windows decrease the measurement accuracy

Surface slope (mss)
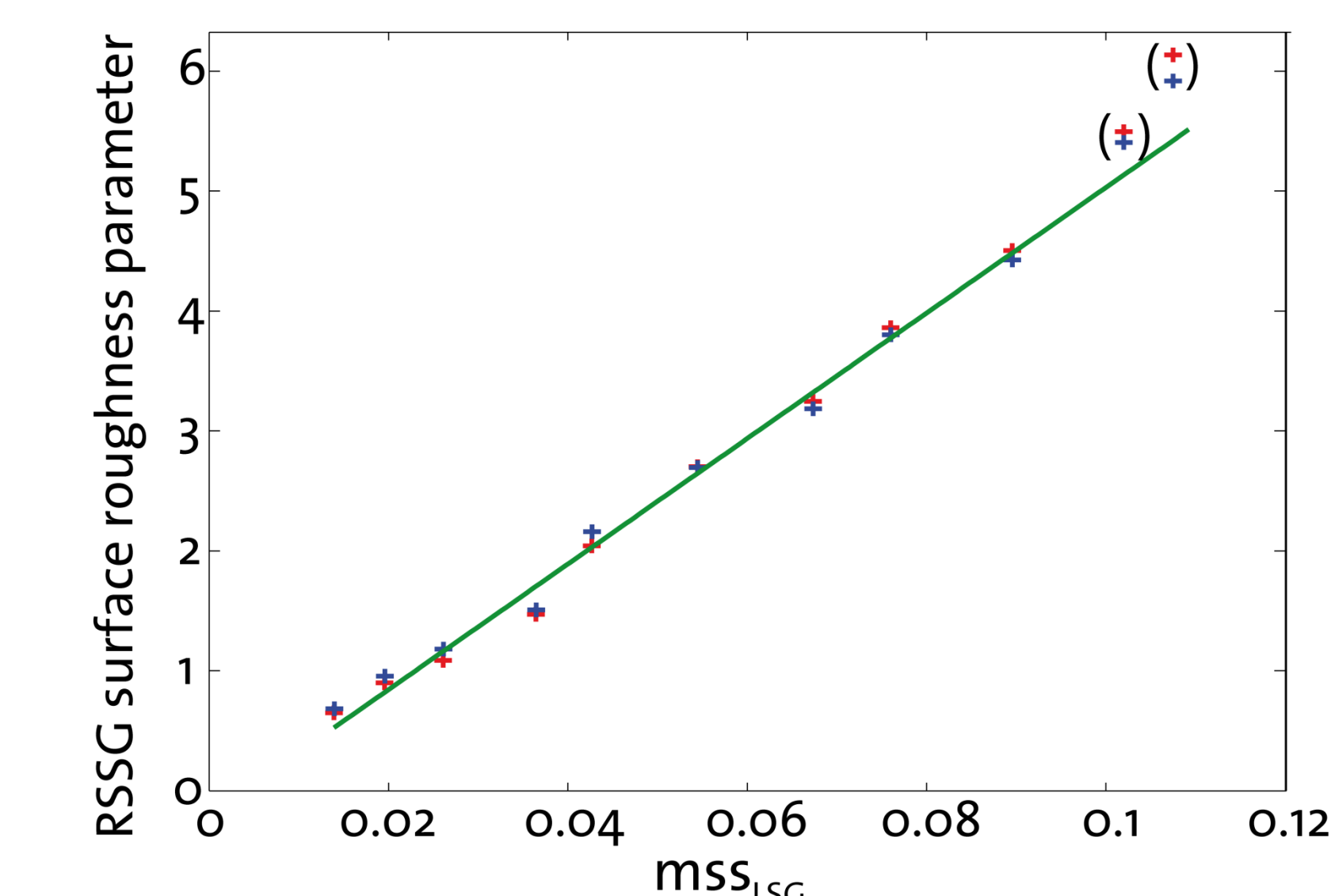
Comparison of the RSSG surface roughness parameter to mean square slope measured with a laser slope gauge [4]. Data from experiment at Marseille wind-wave facility (red and blue crosses from different days).

- The surface roughness parameter from the statistical slope measurement that is similar to the Cox & Munk sun glitter technique is proportional to mean square slope [3]
- surface roughness parameter related to inverse mean gray value of images, at very high wind speeds the illumination brightness is not sufficient, causing a slight overestimation of mss.

Outlook

- Combined gas exchange and wave measurements planned for December 2012 in the Peruvian upwelling zone on R/V Meteor
- Use RSSG/ACFT system to identify key wave parameters for gas exchange parameterization

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] **Schimpf, U. et al. (2011)**. *First results of the 2009 SOPRAN active thermography pilot experiment in the Baltic Sea.* In Komori et al. (eds.): Gas Transfer at Water Surfaces, Kyoto University Press, *pp. 524–534*
[3] **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 University Press, pp. 358-367
[4] **Caulliez, G. (2011)**. *Personal communication.*

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