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Exploring Air-Sea Gas Transfer by Active Thermography

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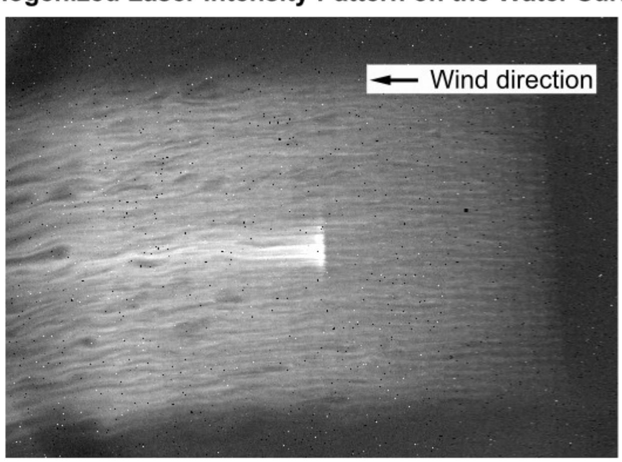
Active thermography has been used for almost 30 years to explore air-sea gas transfer both in laboratory and field experiments [Jähne et al., 1989]. In the early 2000s, some doubt arose whether it was possible to extrapolate heat transfer velocities to gas transfer velocities [Asher et al., 2004]. Because of the large difference in the molecular diffusivity, different mechanisms may govern the transfer of heat and mass. However, in a recent experimental study at the large annular wind-wave tank in Heidelberg, the Aeolotron, Nagel et al. [2014] could show that heat transfer velocities can be scaled to gas transfer velocities with an accuracy of better than 10%, provided the Schmidt number exponent is known. These measurements were performed using the original active thermographic technique proposed by Jähne et al. [1989], by heating a rather large area at the water surface of up to one square meter. This is required to ensure that water parcels stay longer in the heated patch than the response time of heat transfer across the boundary layer.

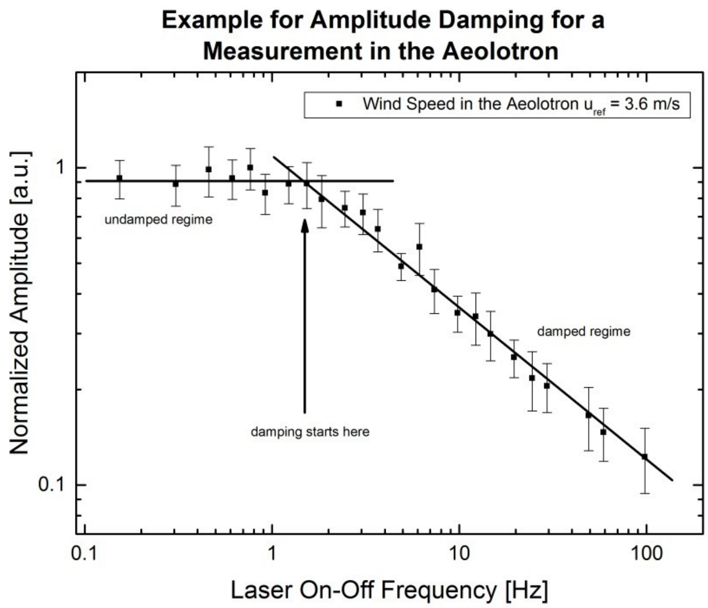
The setup used by Nagel et al. [2014] still had one disadvantage. The heated patch showed some inhomogeneity in cross-wind direction, caused by the method to expand the beam of the CO_2 laser. By using a holographic beam expander manufactured by Holo/Or Ltd., Rehovot, Israel, a much more homogeneous irradiation could be achieved. With this improvement it was possible to acquire significantly more accurate heat transfer measurements.

Homogenized Laser Intensity Pattern on the Water Surface



The temperature difference between the white, heated areas and the dark, unheated areas is roughly 0.5 K. The wind speed in the Aeolotron in this example is about 2.7 m/s.

We used the approach of probing the temperature response of the water surface with different laser on-off frequencies. In this way we measure the damping rate of the heating process for different heating frequencies. For low laser on-off frequencies there will be no damping as the system has enough time to reach a thermal equilibrium, whereas for higher frequencies the damping will become more and more pronounced.



In November 2014 this technique was used in air-sea gas exchange measurements using natural seawater from the North Atlantic with various degrees of contamination by natural surface films at the Heidelberg Aeolotron, within the BMBF project SOPRAN (Surface Ocean Processes in the Anthropocene). First results from this experiment will be shown.

References

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