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Novel Technique for 3D-Space Visualization of Concentration Fields of Air-Water Gas Transfer

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Measuring Technique

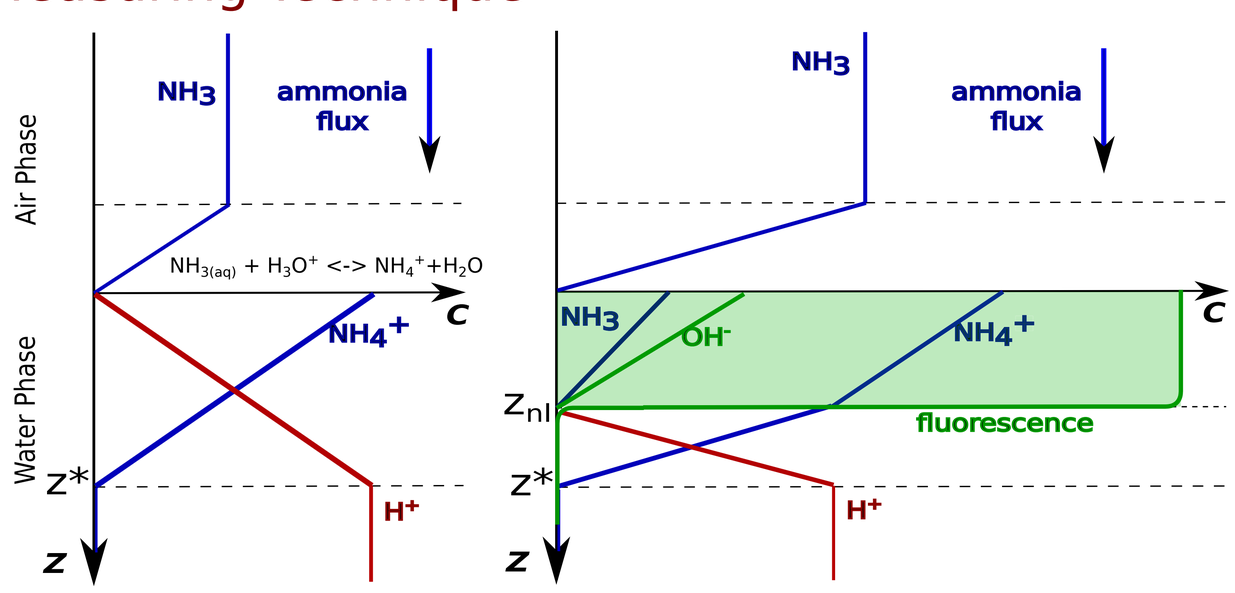
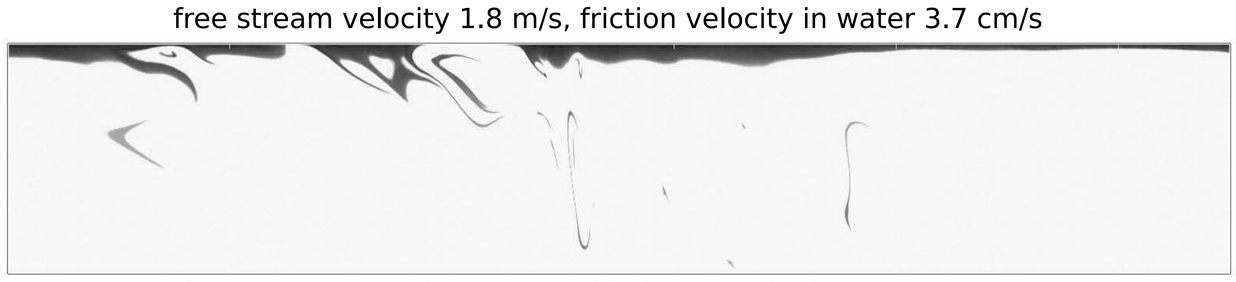


Fig.1. Sketch of NH_3 invasion into the acid water for low and high concentrations of NH_3.

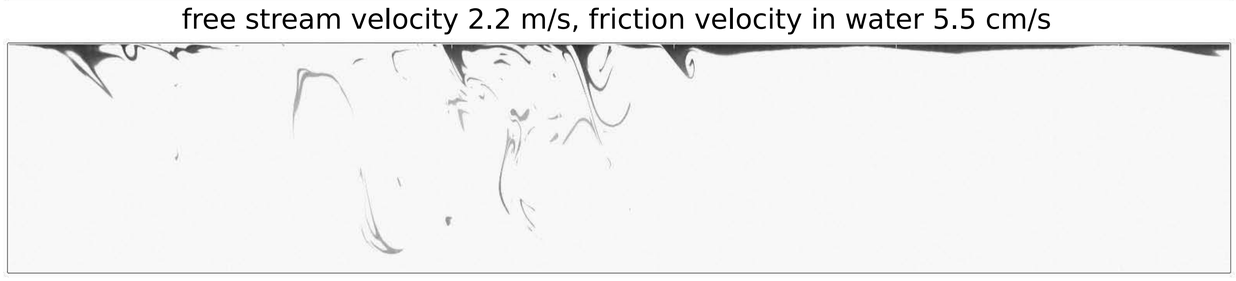
The main objective of modified LIF technique is to gain simplified shape of concentration fields of observed molecules. This can be achived by demanding the vertical concentration profiles to have a steep decay at the certain depth resulting in binary fields.

1D Measurements: Results

free stream velocity 1.8 m/s, friction velocity in water 3.7 cm/s



free stream velocity 2.2 m/s, friction velocity in water 5.5 cm/s



free stream velocity 2.6 m/s, friction velocity in water 6.4 cm/s

Fig.3. Time-depth images of the temporal fluctuations of ammonia in the water. The size of the vertical coordinte is 9.25 mm and horizontal coordinate - 13.75 sec.

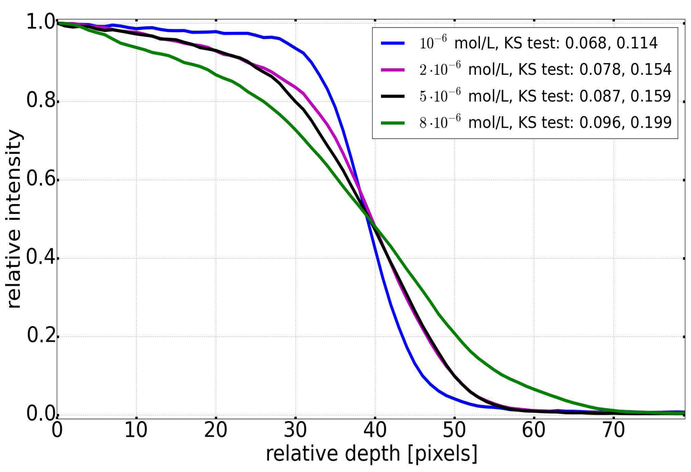


Fig.4. Experimental profiles for different Pyranine concentration

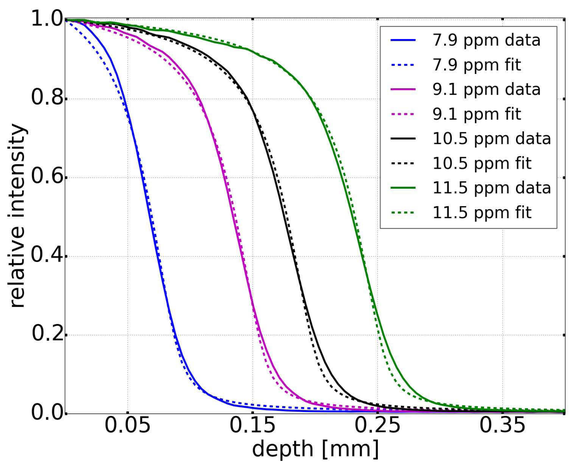


Fig.5. Experimental profiles for different ammonia concentration with fitted functions that comply with small-eddy model

Conclusion:

- The experimental technique for mass boundary layer visualization was verified with the measurements of concentration profiles at the linear wind-wave facility with high spatial and temporal resolution.
- The binary representation of concentration fields can be achieved with Pyranine concentration of 10^{-5} mol/L and initial pH value of 4. Varying ammonia concentrations in the air, the fraction of mass boundary layer can be investigated.
- The technique allows observation of binary concentration fields at larger spatial scales. The invasion of ammonia was viewed with multiple camera set-up from underneath the facility. The third dimension was reconstructed using stereo algorithm, benefiting the picture of a gas exchange through the air-water interface in four dimensions.

1D Measurements: Experimental Set-up

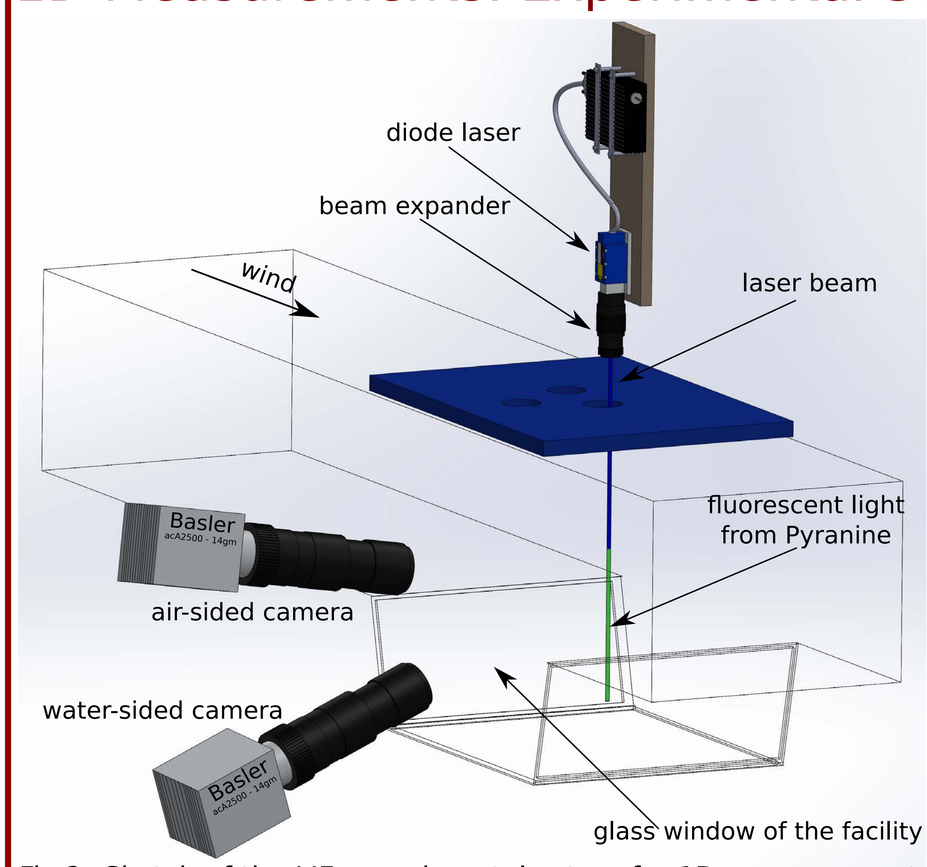


Fig.2. Sketch of the LIF experimental set-up for 1D measurements

Wind-wave facility:
Lenght = 1.75 m
Width = 25 cm
Depth = 20 cm
Water volume ≈ 22 L
Air volume ≈ 220 L

Optical Set-up:
·Diode laser:
wavelength - 445 nm

·Galileo expander

·Basler cameras:
2592×16 AOI
2.2×2.2 µm pixel size
350Hz frame rate

·Scheimpflug optics
magnification:
0.43 air-side
0.32 water-side

3D Measurements: Experimental Set-up

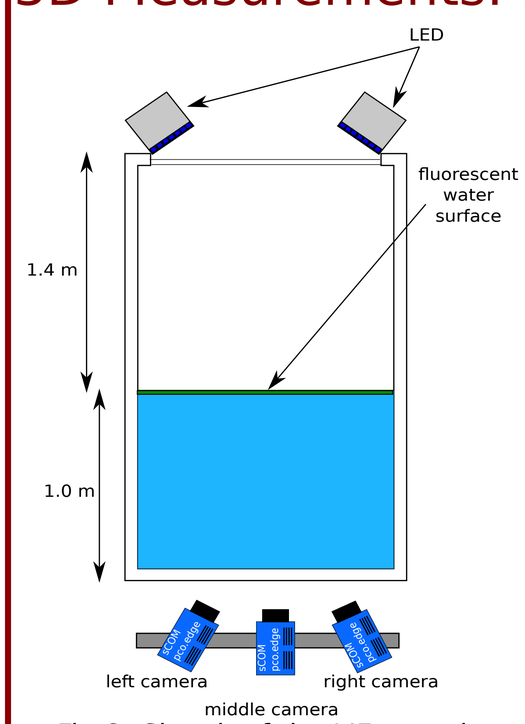


Fig.6. Sketch of the LIF experimental set-up for 3D measurements

Large Annual Aeolotron Facility:
Height = 2.41 m
Width = 60 cm
Water volume ≈ 18000 L
Air volume ≈ 25000 L

Optical Set-up:
·blue high power LEDs (wavelength - 455 nm)
·sCMOS cameras pco.edge
2160×2560 resolution
6.5×6.5 µm pixel size
100Hz frame rate

Full Camera Calibration: estimation of intrinsic and extrinsic parameters for each camera

Dense Reconstruction: every image was rectified to compute the disparity map using images from left and right camera. Block matching algorithm is used to find correspondence between the images.

3D Measurements: Results

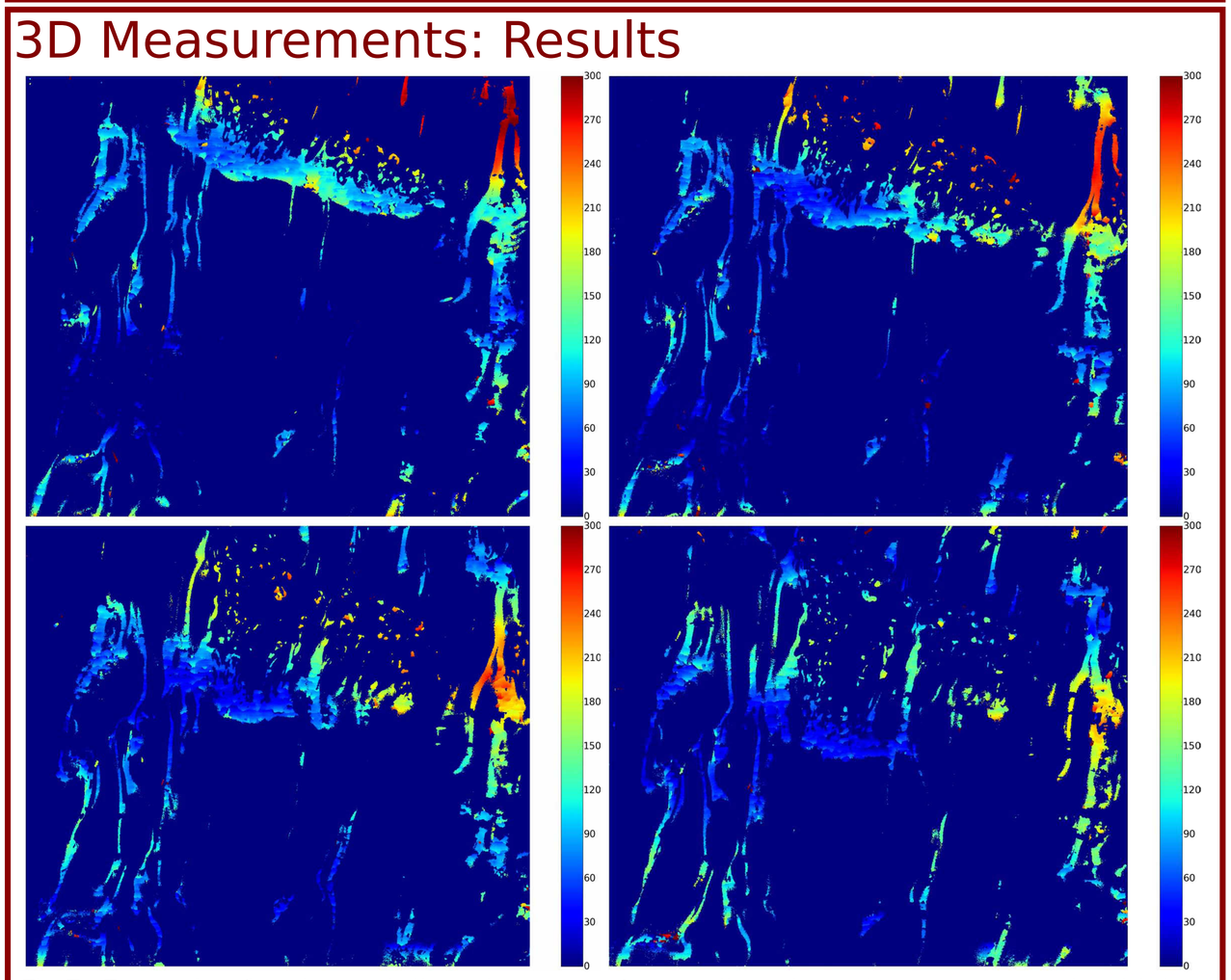


Fig.7. Example of estimated disparity maps. Lower disparity values correspond to higher distances. The images are 0.6s apart. The wave breaking event is visible.