The Wind-Wave Tank of Univ Hamburg

An Overview of Four Decades of Studies of Air-Sea Interactions

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Outline

Wind Wave Tank

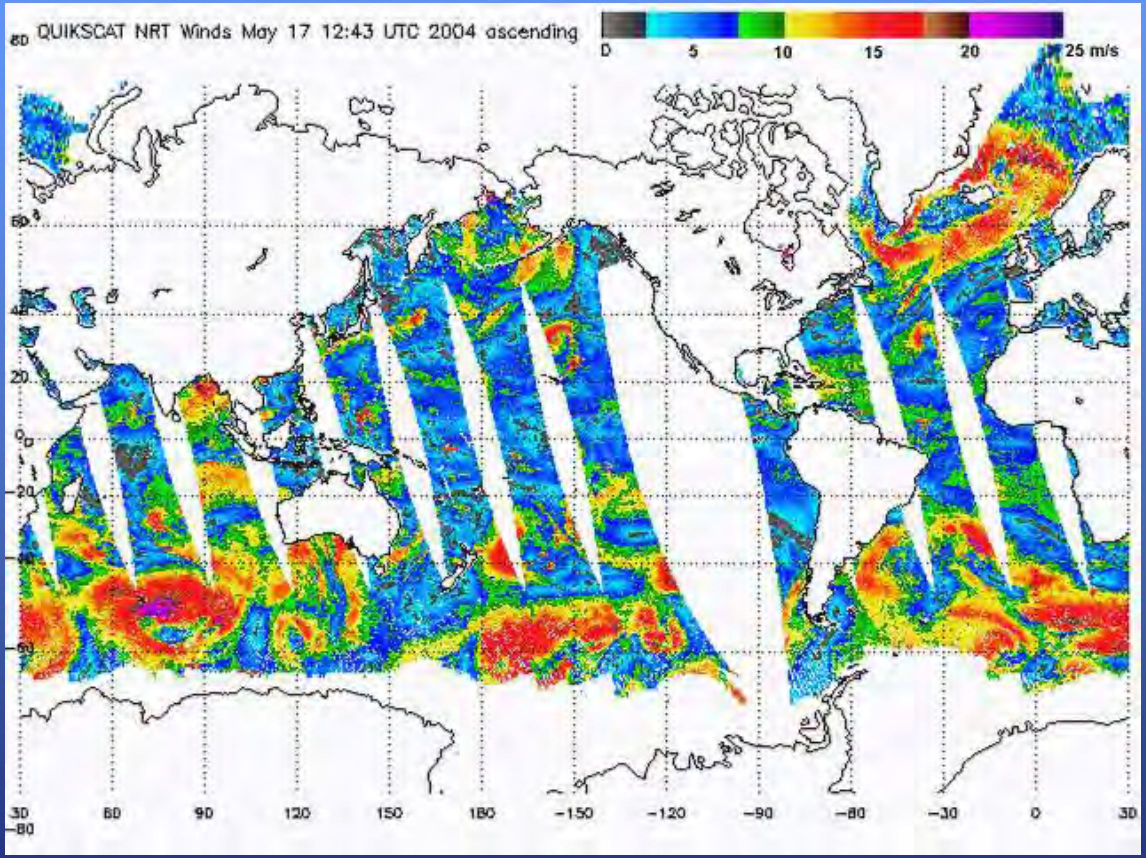
70s and 80s:
- monomoleculare surface films
- Gas transfer

80s and 90s:
- Wave damping
- Radar backscattering
- Rain

Recent Work:
- Small-scale phenomena
- Gas transfer

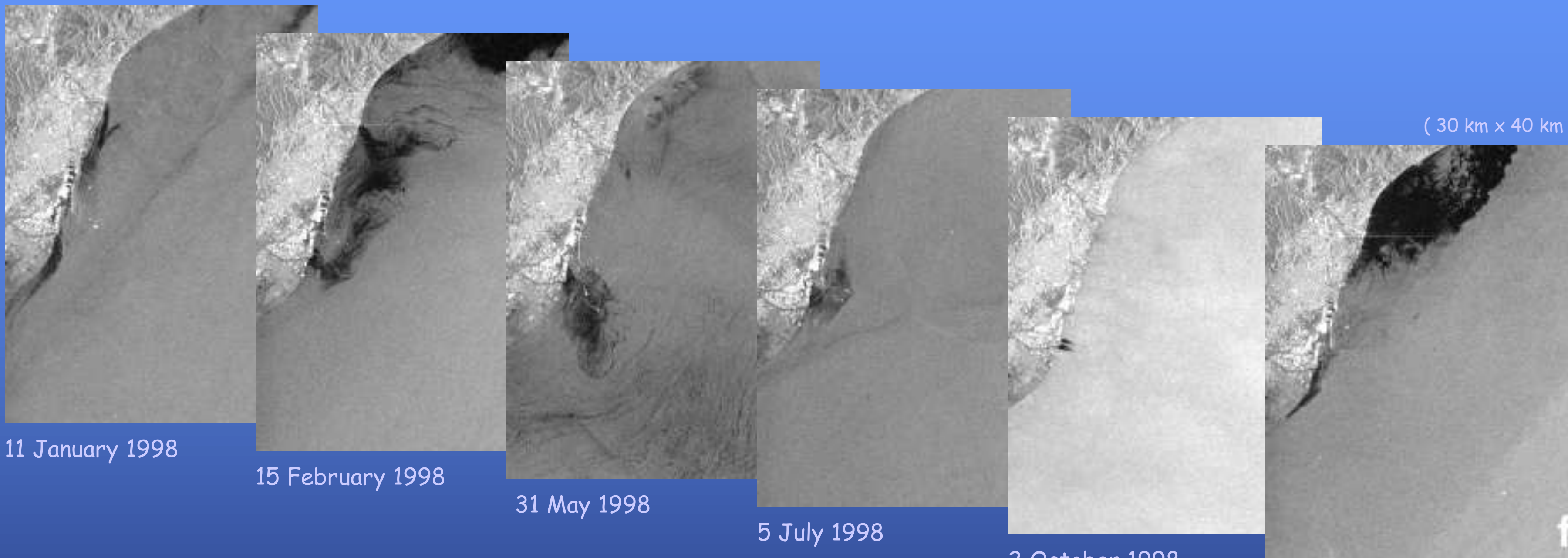
Summary

Remote Sensing of the World's Oceans



Global wind fields from QUIKSCAT satellite data

Remote Sensing of the Sea



11 January 1998

15 February 1998

31 May 1998

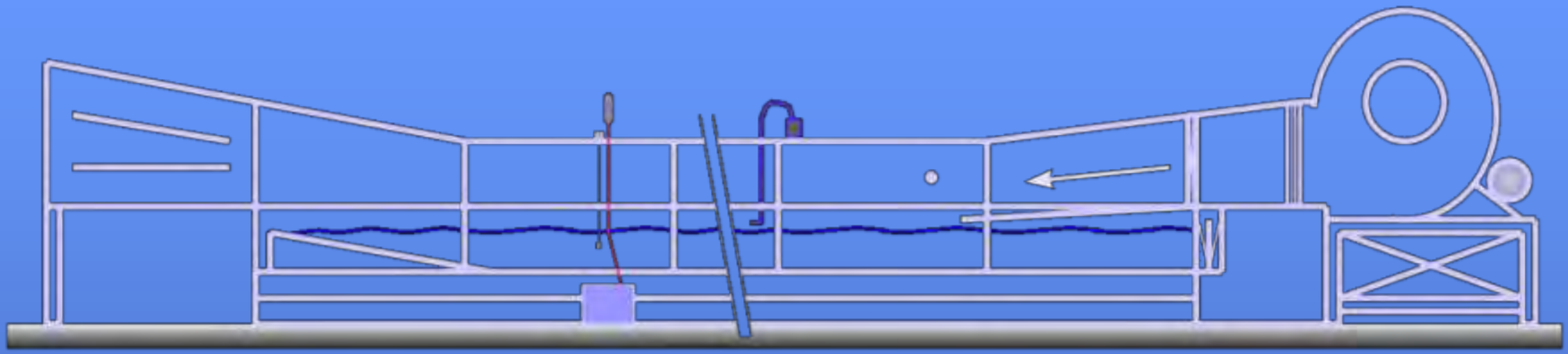
5 July 1998

2 October 1998

18 October 1998

Observation of river outflow using ERS-2 SAR imagery

Wind Wave Tank



26 m × 1 m × 1.5 m

Fresh water @ 0.5 m

2 – 20 m/s Wind speed

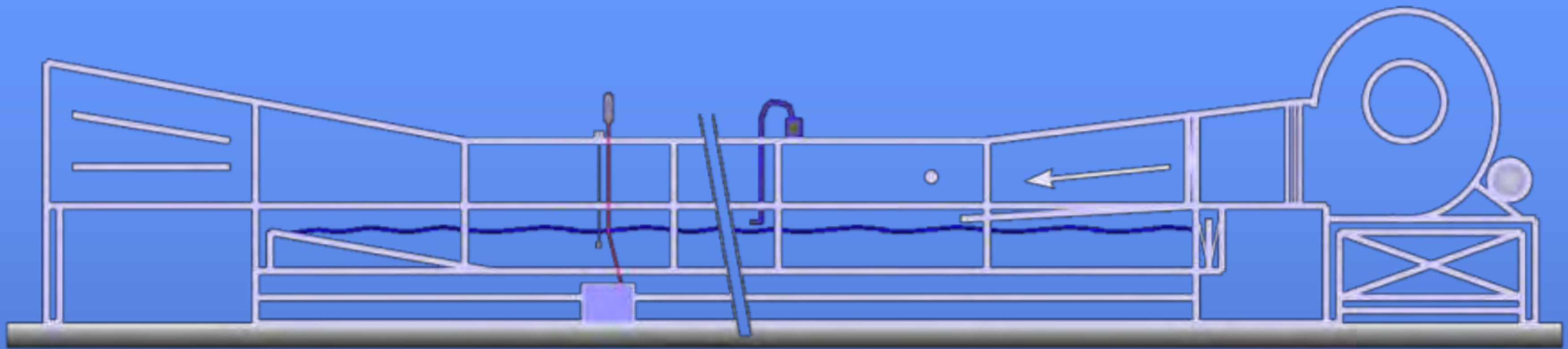
0.7 – 2 Hz mech. waves

Slicks @ 5.5 m

Rain @ 12.5 – 14.8 m

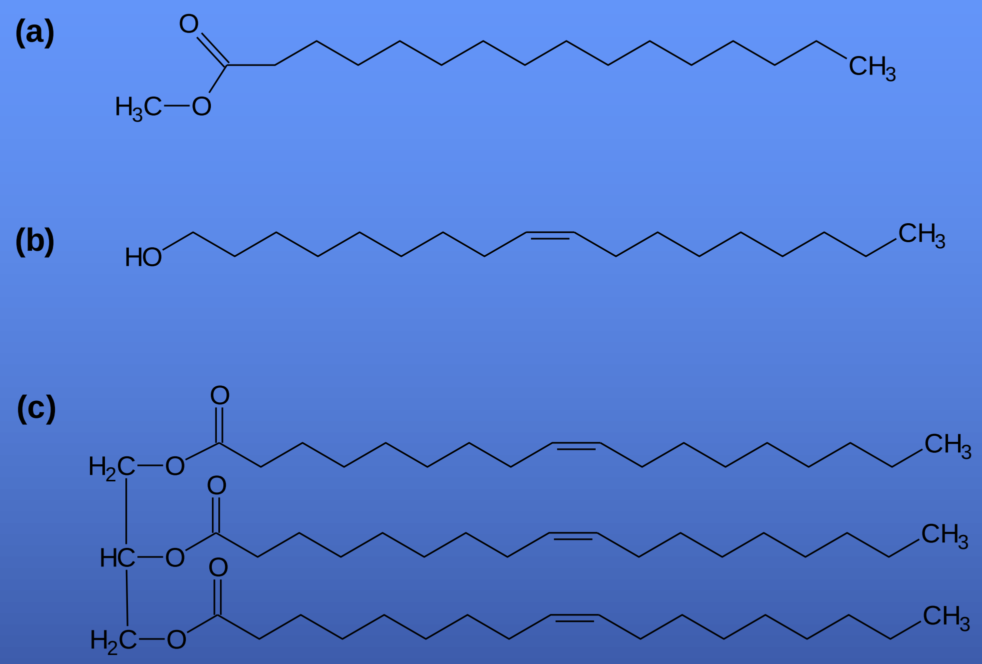
Air re-circulation (2006)

Wind Wave Tank



1970s and 1980s

70s and 80s: Monomolecular Surface Films



a) PME

b) OLA

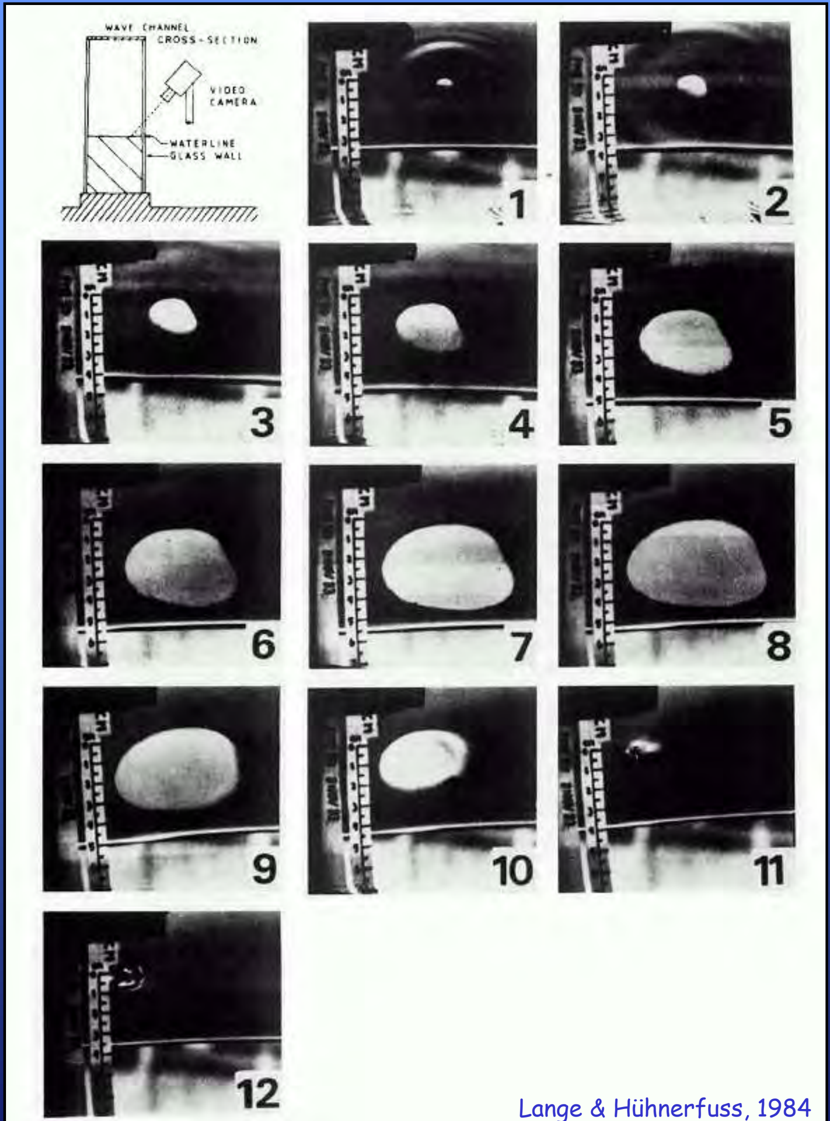
c) TOLG

Dedicated substances to represent main compounds of marine surface films

Hydrophobic part (long alkyl chain) – hydrophylic head group

Substances accumulate on water surface as monomolecular film

70s and 80s: Monomolecular Surface Films



Lange & Hühnerfuss, 1984

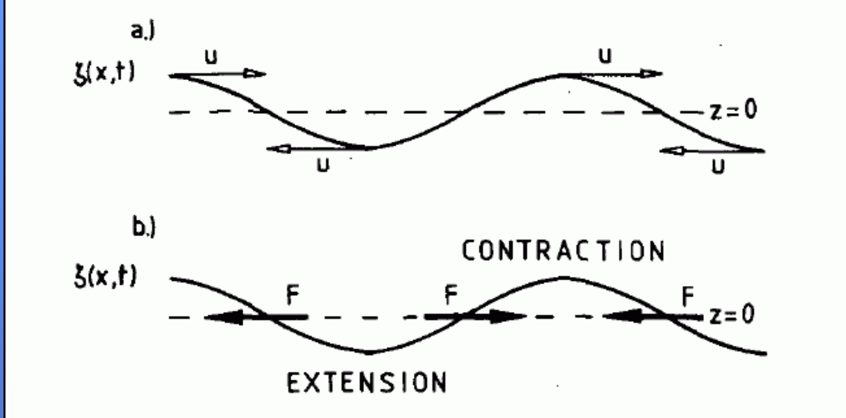


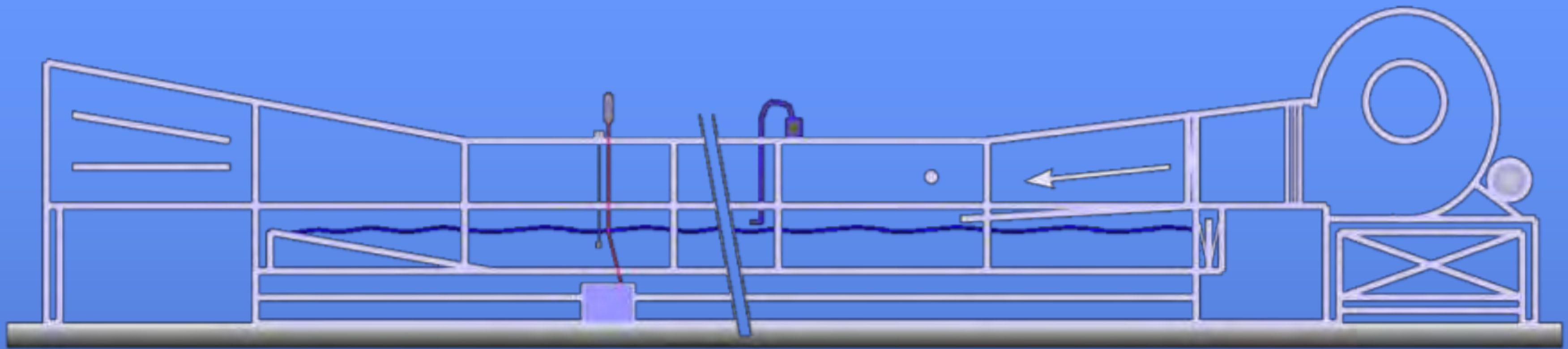
FIG. 4. Horizontal velocity (a) and force (b) components acting on the surface of a gravity water wave propagating from left to right.

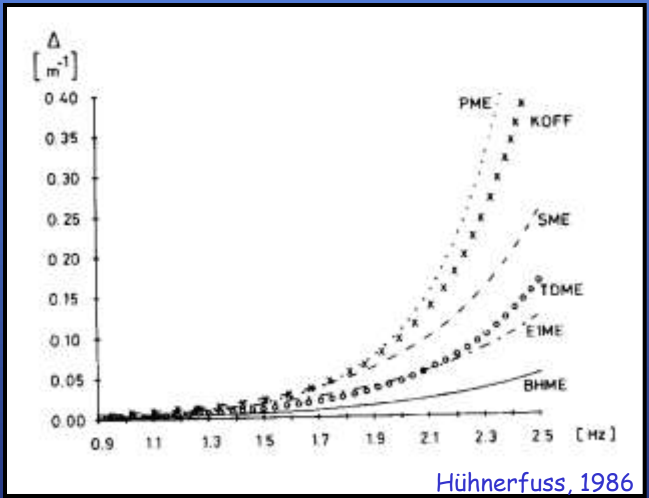
Lange & Hühnerfuss, 1984

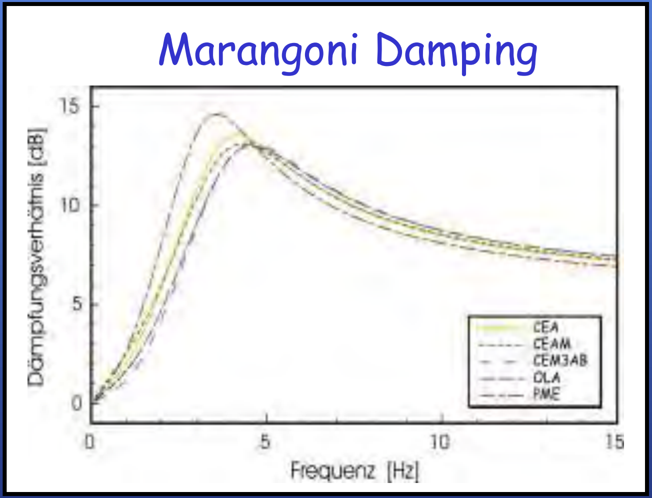
Horizontal surface tension gradients !
Longitudinal surface waves as additional solution of the Navier-Stokes-Equations ("Marangoni waves")

70s and 80s: Monomolecular Surface Films

70s and 80s: Monomolecular Surface Films

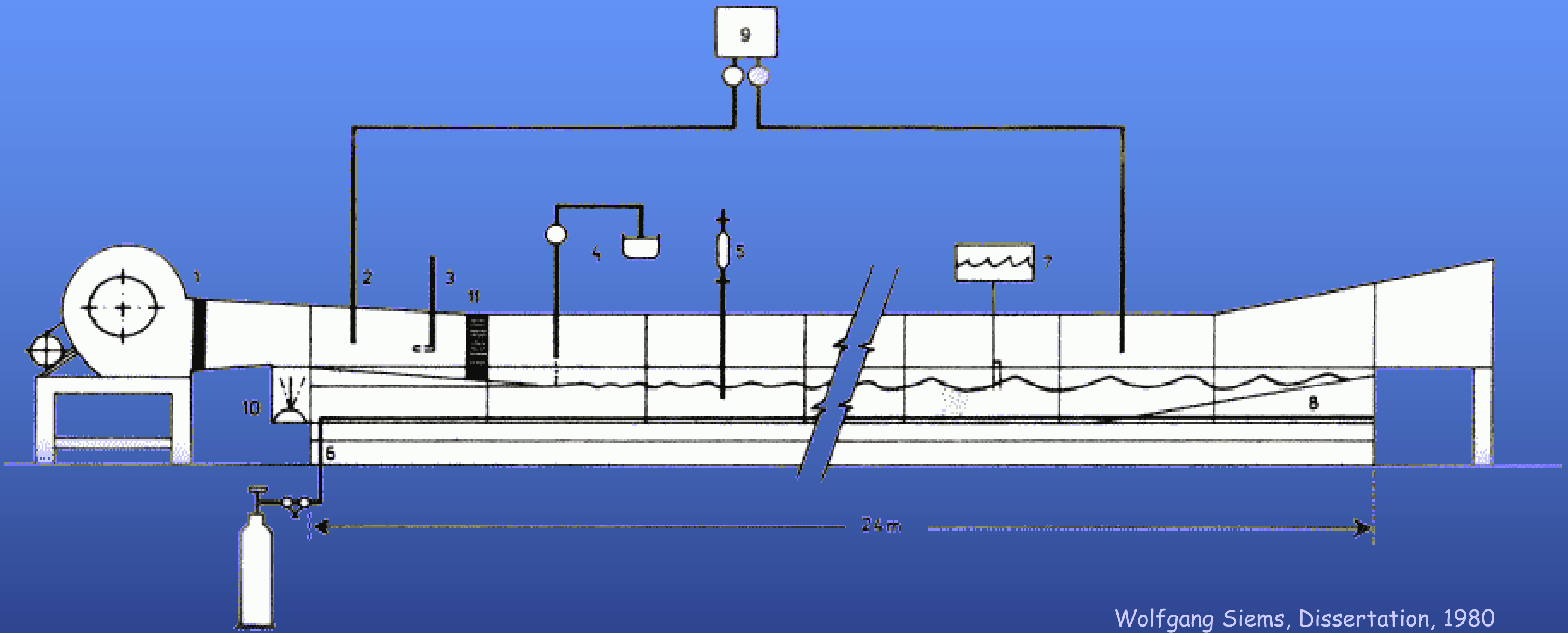






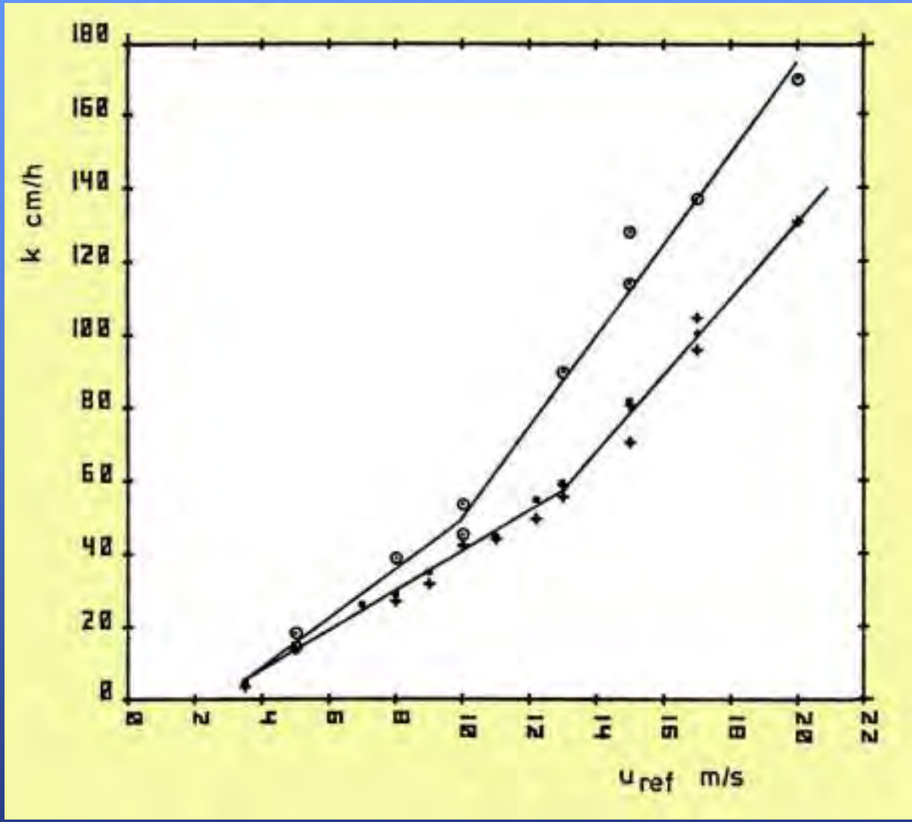
Theory of (relative) wave damping by monomoleculare surface film
Characteristic damping maximum at 4-5 Hz

70s and 80s: Gas Transfer



Wolfgang Siems, Dissertation, 1980

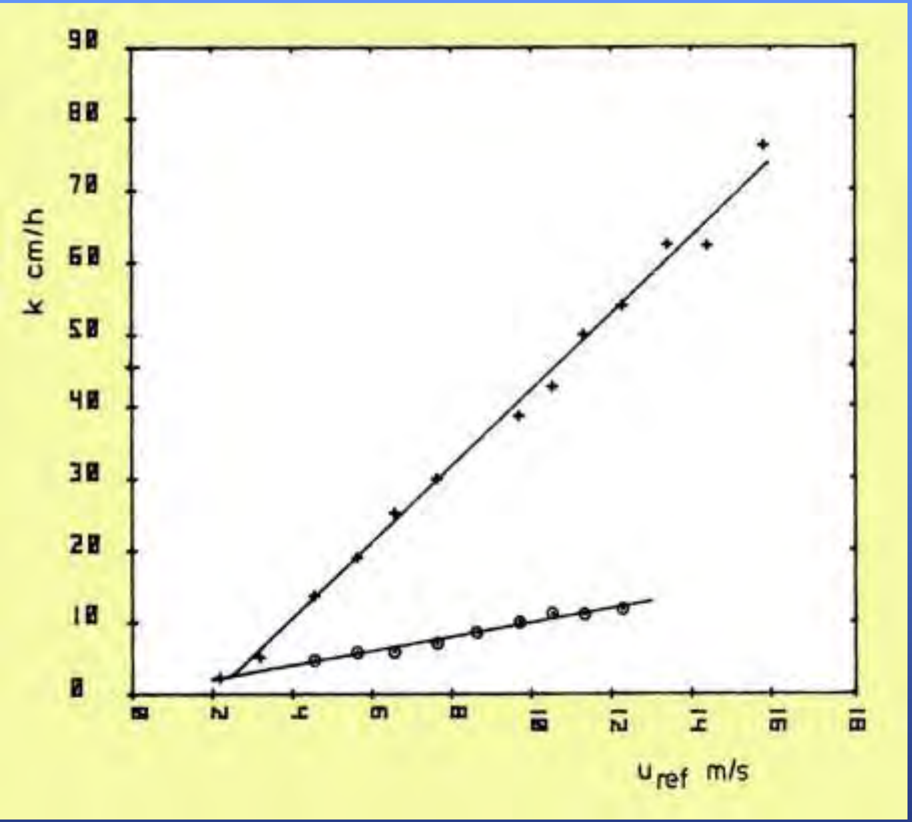
70s and 80s: Gas Transfer



Siems, 1980

Gas transfer velocity of O_2 (o) and CO_2 (+) at filmfree water surface. Characteristic kink between 10 m/s and 14 m/s: Generation of bubbles by wave breaking

70s and 80s: Gas Transfer



Siems, 1980

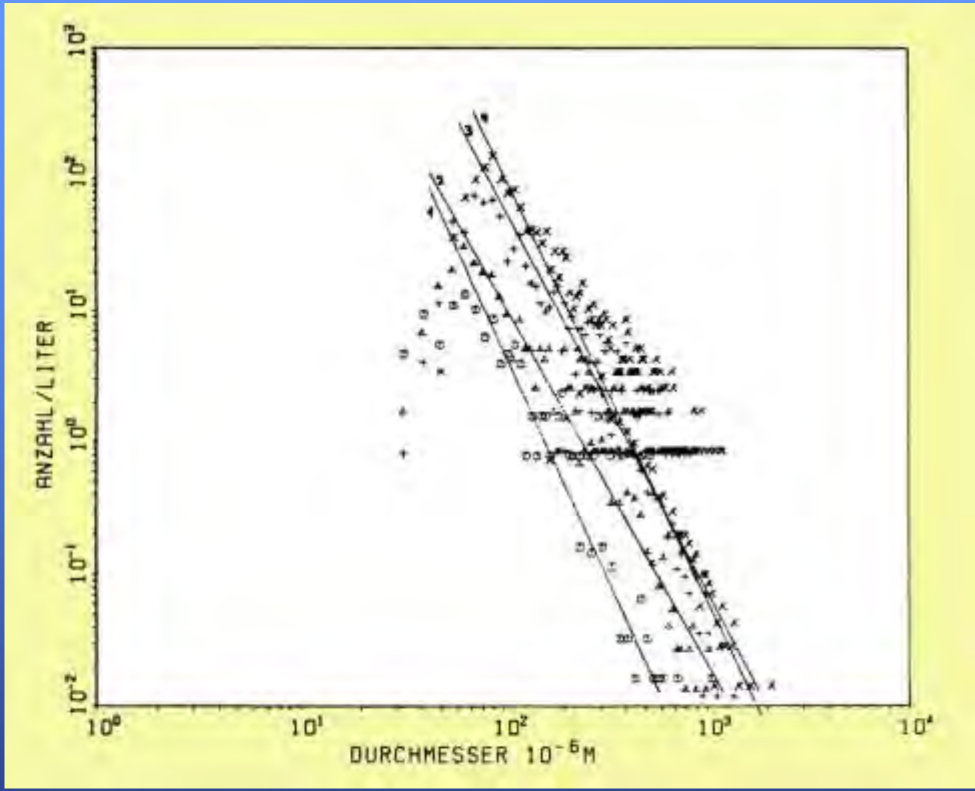
Gas transfer velocity of CO_2 at filmfree (+) and film covered (o) water surface

Strong reduction in gas transfer in the presence of surface films

70s and 80s: Gas Transfer

Siems, 1980

Size distribution of gas bubbles derived with optical methods



Siems, 1980

Size distribution of gas bubbles in water at 13 m/s (o), 15 m/s (Δ), 17 m/s (+), 19 m/s (x)

Summary: 70s and 80s

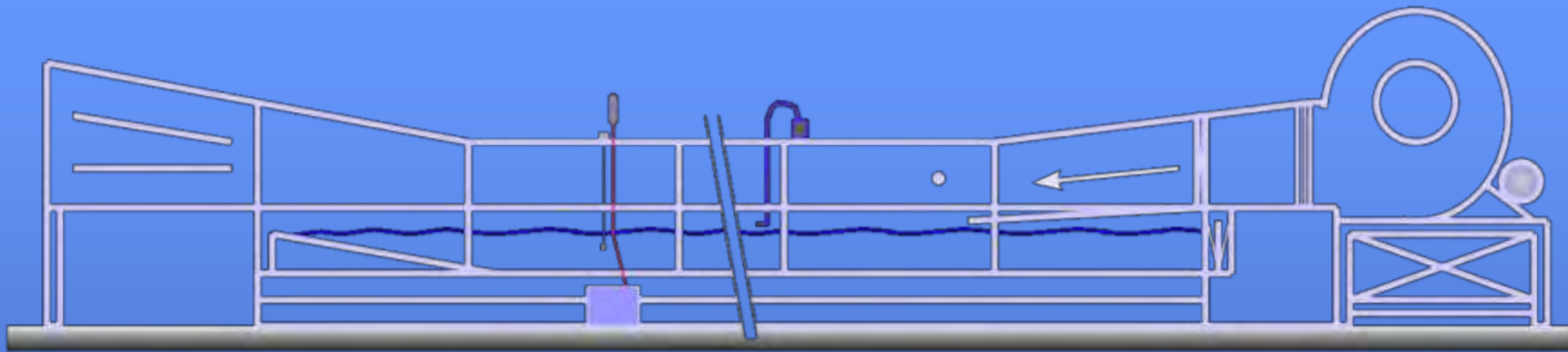
Thorough studies of physico-chemical properties of monomolecular surface films

Particularly of the influence of film coverage on wave damping and gas transfer from water into the air

Important basics for later field experiments and for the interpretation of satellite data

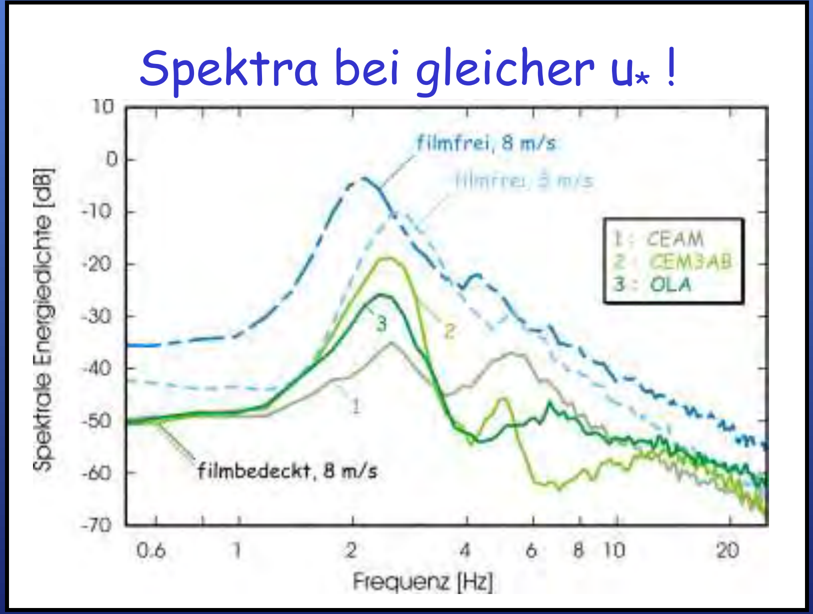
1980s and 1990s

80s and 90s: Wave Damping



Reduced energy input by the wind, because of reduced friction velocity (u_*)

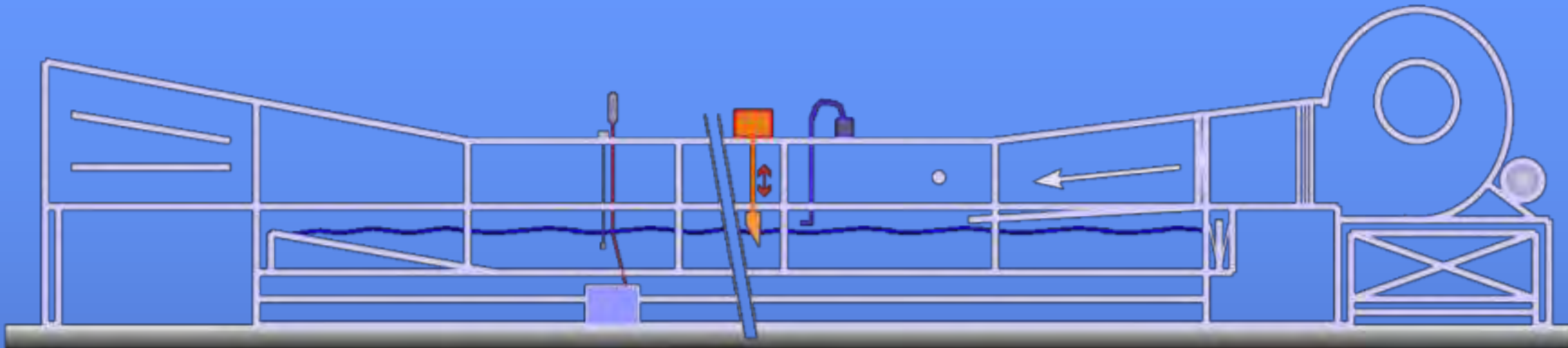
Influence of film coverage on all source terms of Action Balance Equation !

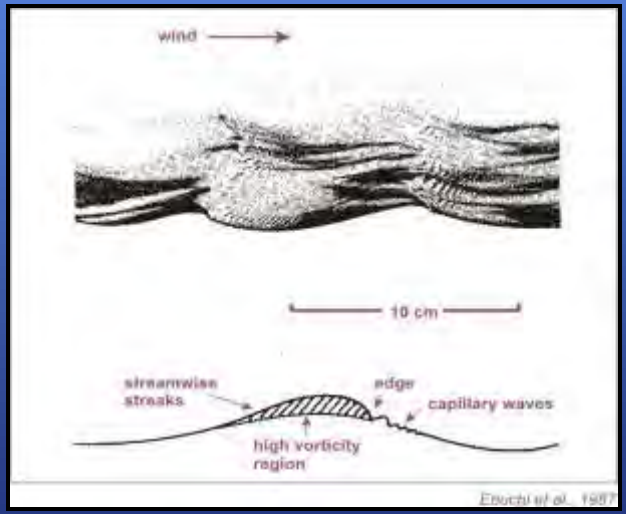


80s and 90s: Wave Damping

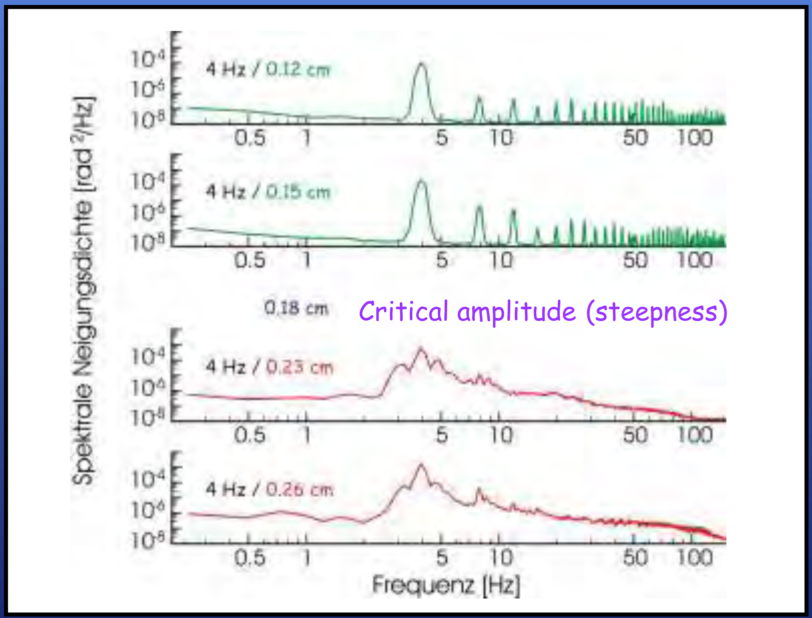
1st visits of S.A. Ermakov

80s and 90s: Wave Damping

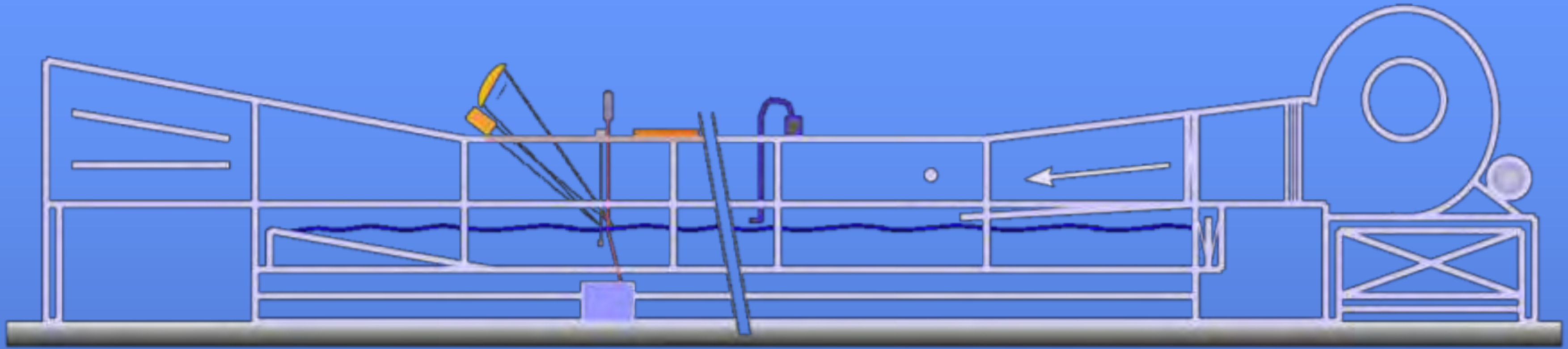


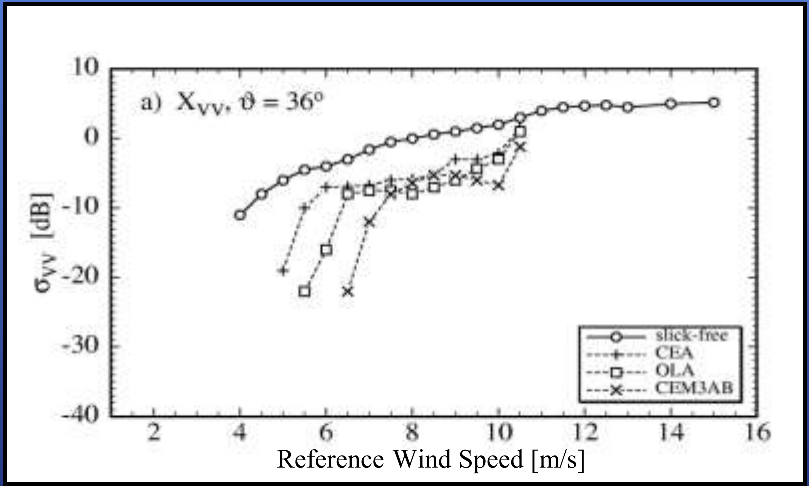


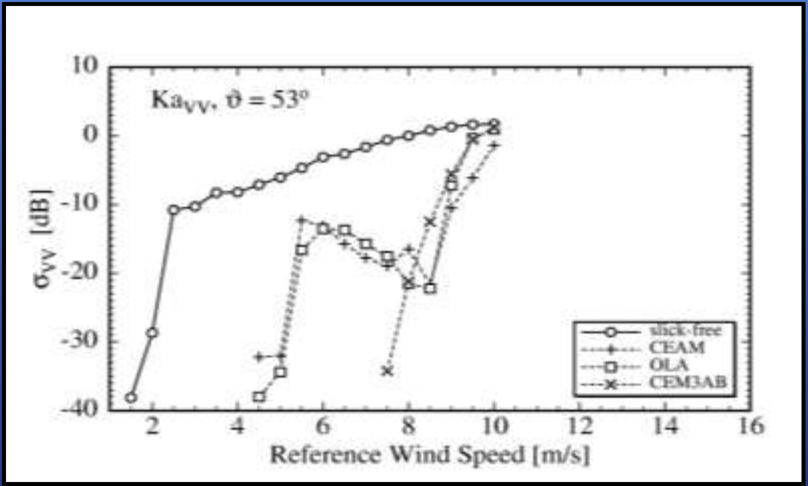
Generation of bound (parasitic) waves at the wave crests (high local "pressure")



80s and 90s: Radar Backscattering



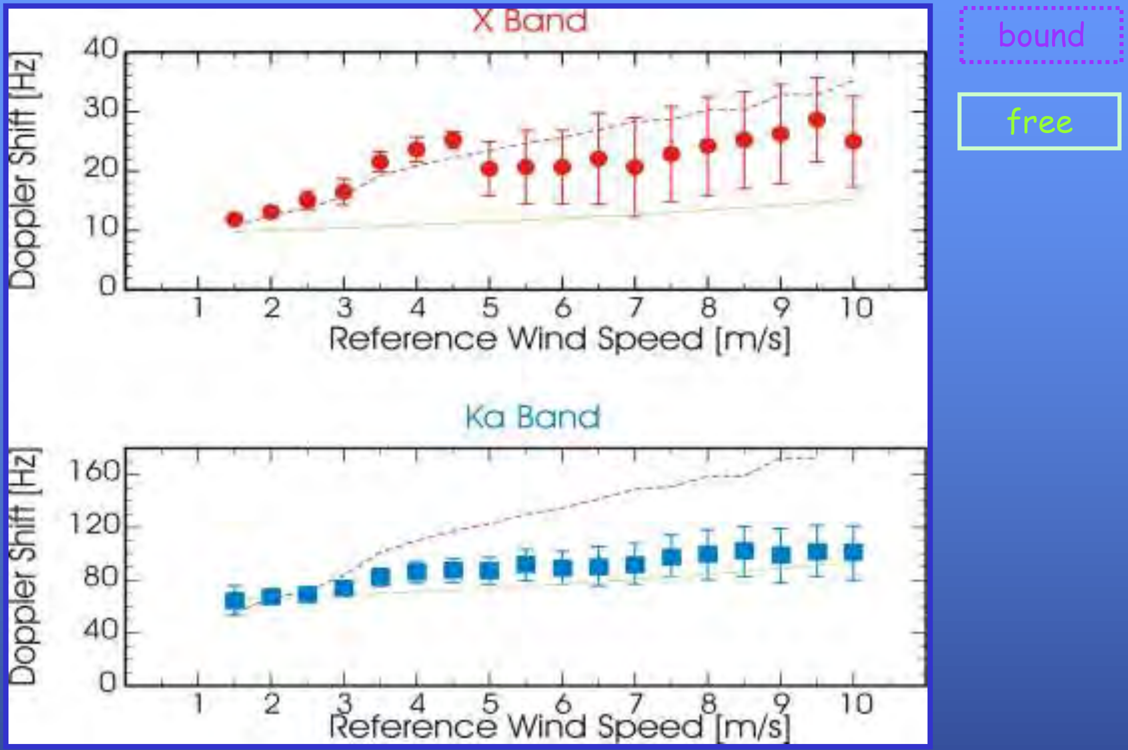




Feindt, 1985

Measured radar contrast at X band (9.8 GHz, Λ_B = 3 cm) and Ka band (37 GHz, Λ_B = 0.8 cm) cannot be explained by pure Marangoni damping !

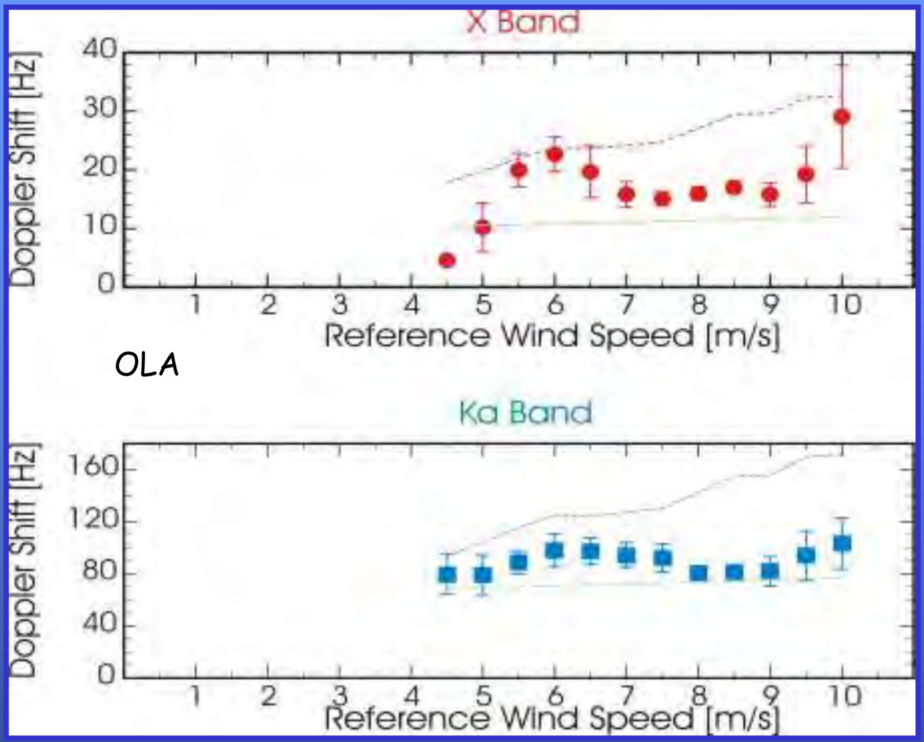
80s and 90s: Radar Backscattering



Analyses of radar Doppler shifts to derive propagation speed of scatterers:

At low wind speeds (up to approx. 5 m/s) bound waves are dominating the radar backscattering.

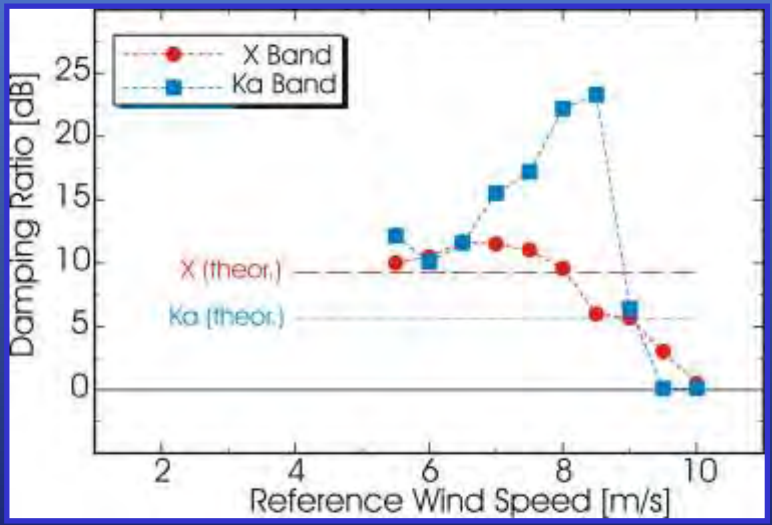
80s and 90s: Radar Backscattering



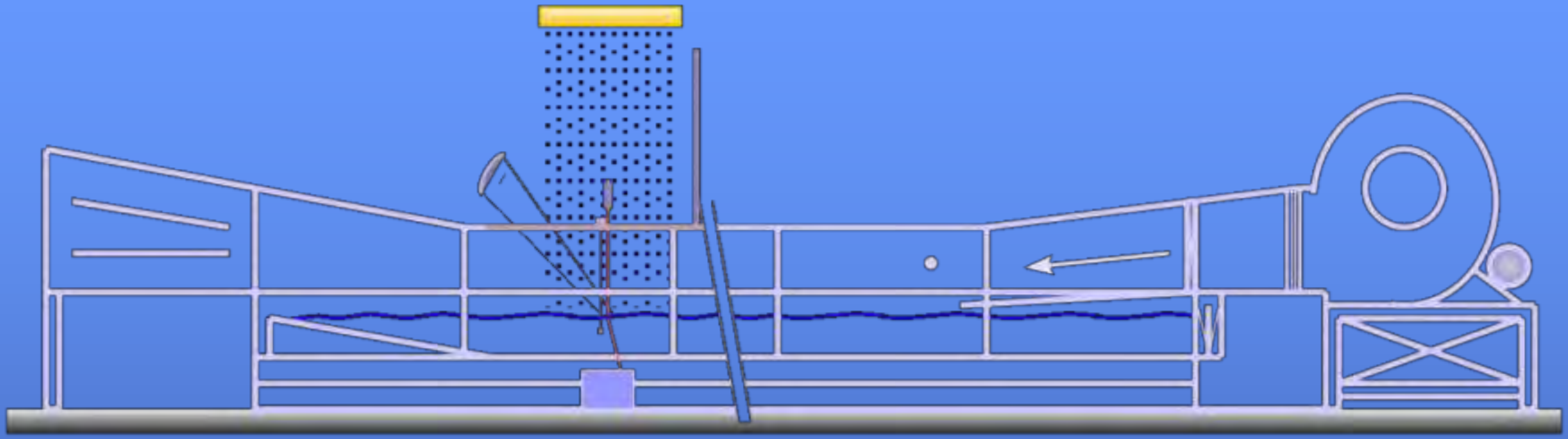
bound

free

Strong wave damping at moderate wind speeds (7 m/s – 9 m/s) through reduced generation of bound waves !



80s and 90s: Rain



Rain area: 2.3 m x 1 m

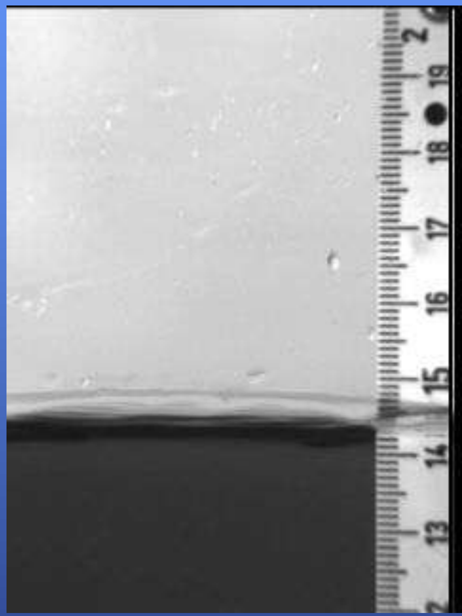
Fall height: 4.5 m

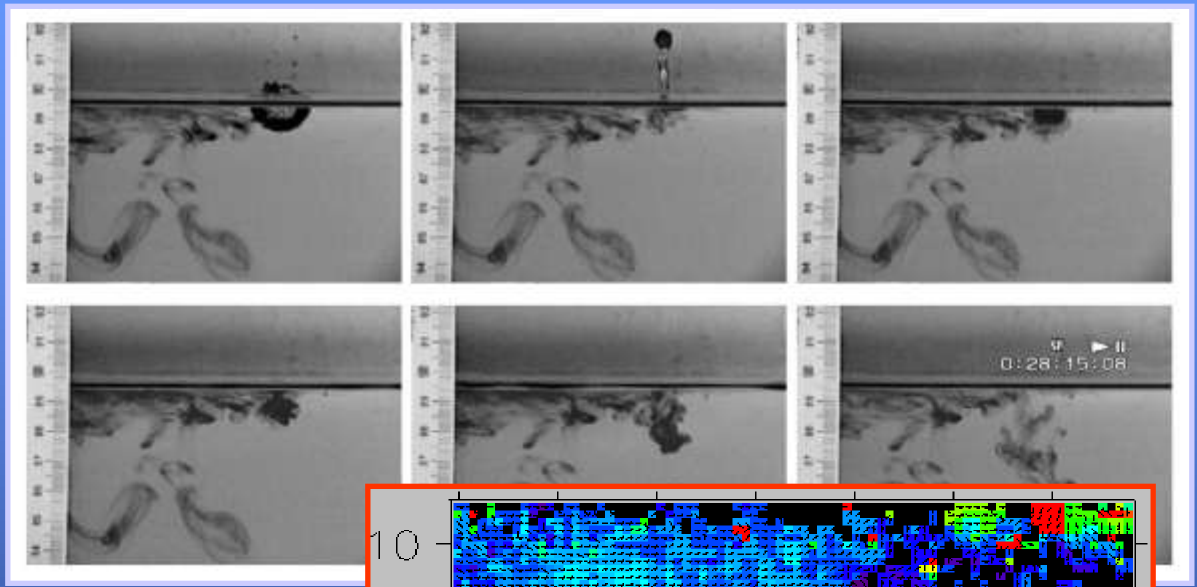
Drop size: 2.1 – 2.9 mm Ø

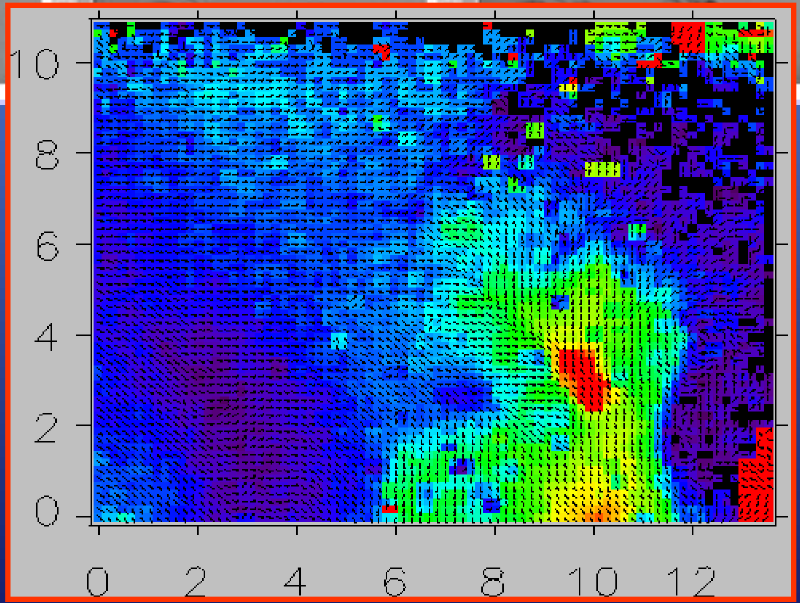
Rain rates: bis 300 mm/h

> 80% of terminal velocity

80s and 90s: Rain



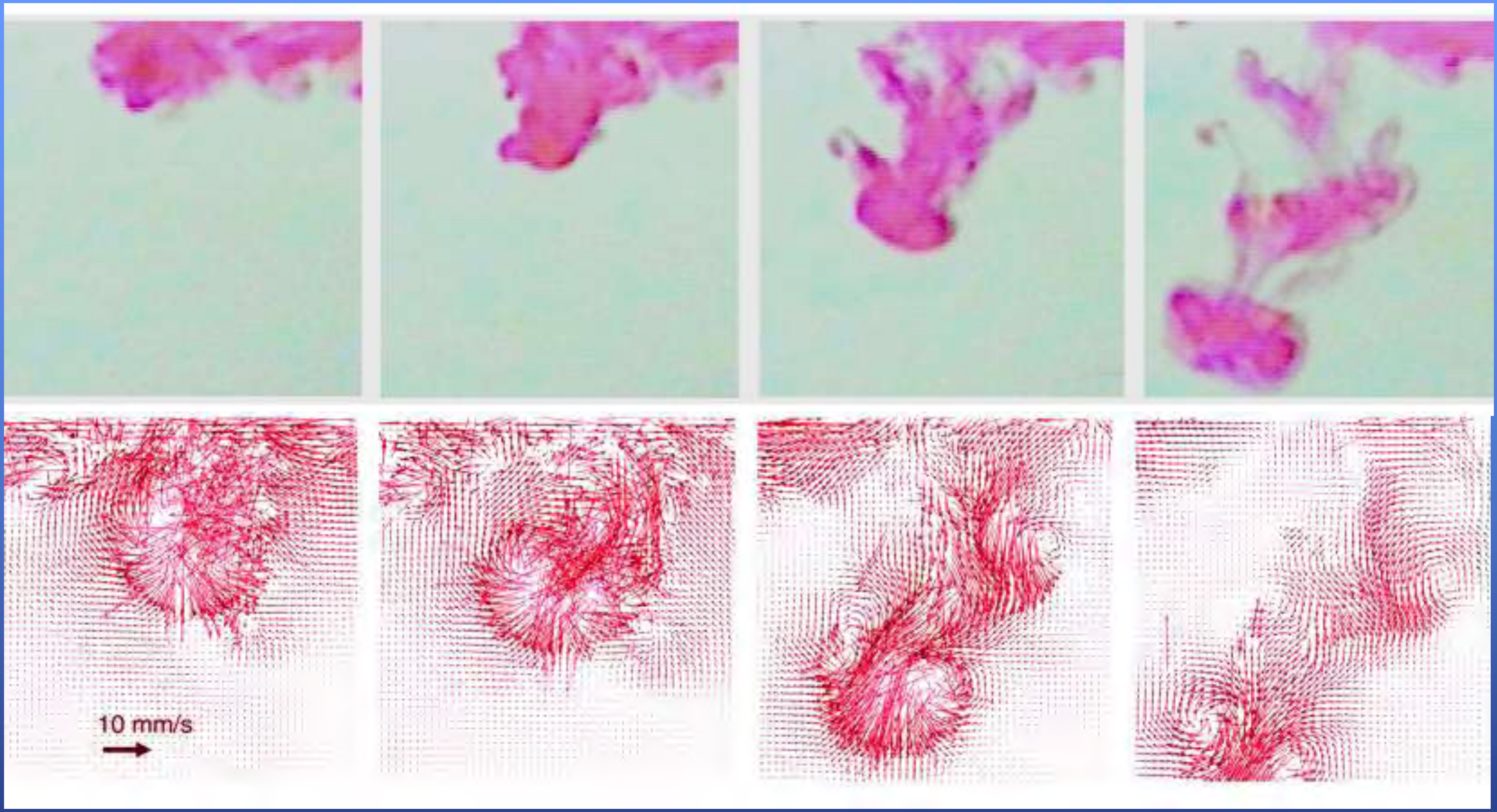




Investigation of rain-induced turbulence in the upper water layer using Particle Image Velocimeter (PIV) and Acoustic Doppler Velocimeter (ADV) sensors

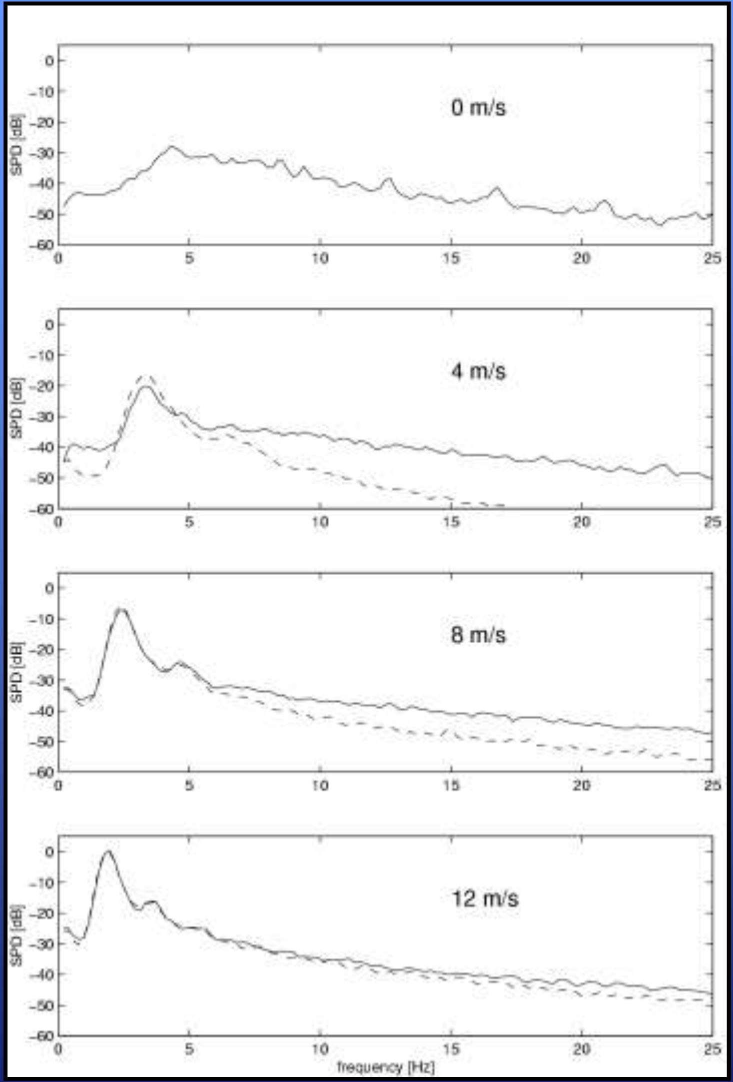
80s and 90s: Rain

Depth
6 cm



Top: development of ring vortex by dyed rain drop. Time difference between pictures: 0.12, 0.36 and 1.12 seconds.
Bottom: similar ring vortex, observed with PIV.
Time differences 0.125, 0.125 and 0.25 seconds.

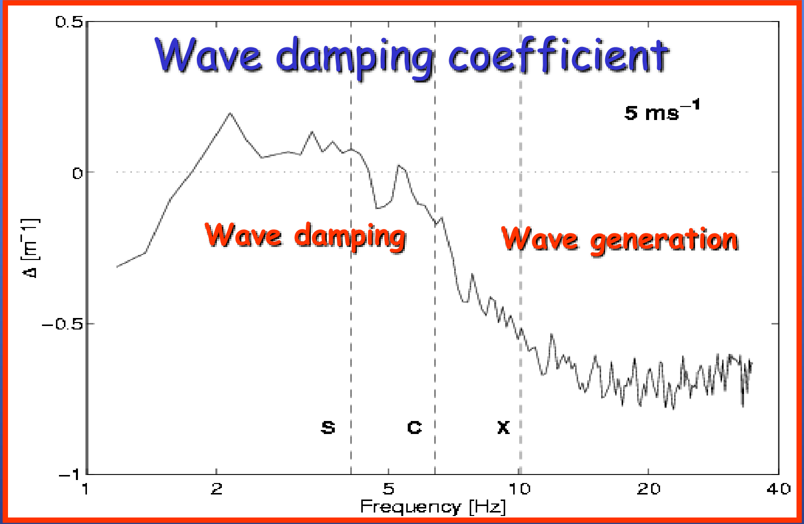
80s and 90s: Rain



Braun, 2002

Only wind

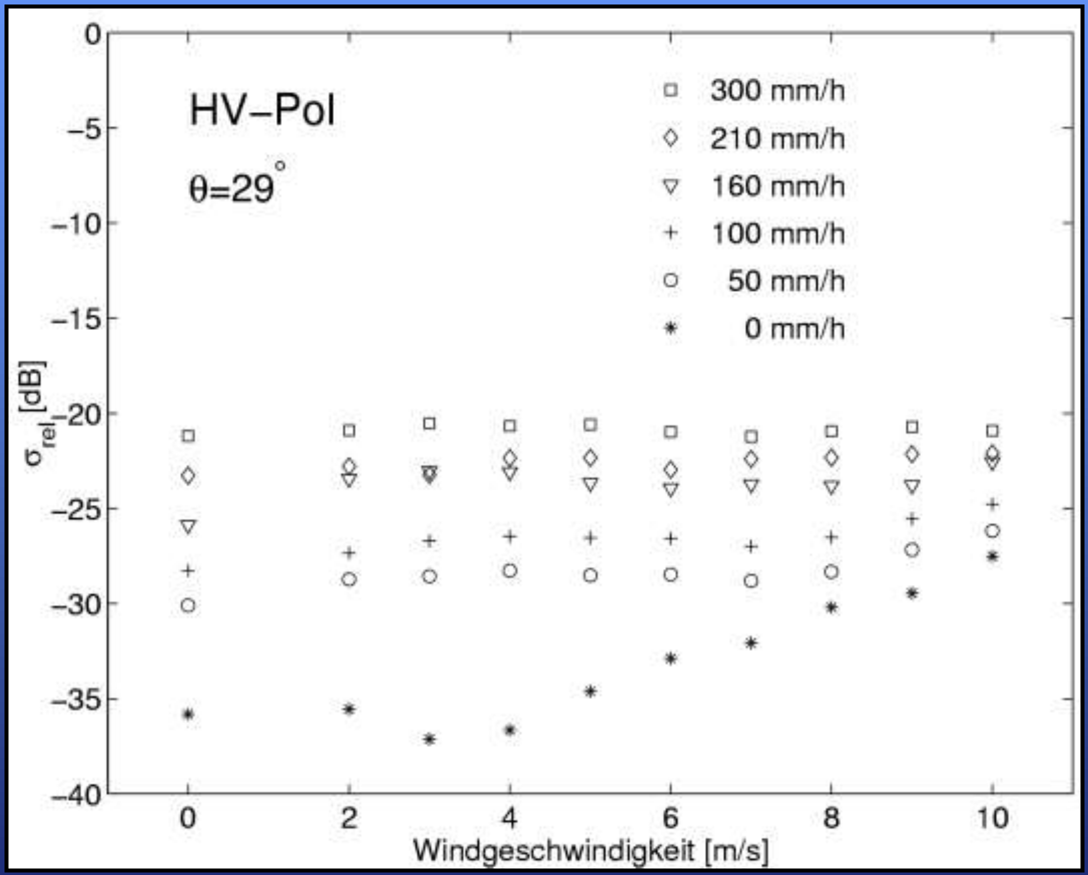
Wind and Rain



Damping of long waves (f < 5 Hz)

Generation of short waves (f > 5 Hz)

80s and 90s: Rain



Braun, 2002

Local, rain-generated products (stalks, secondary drops, etc.) cause a strong dependency of the cross-pol radar backscattering on rain rate

Summary: 80s and 90s

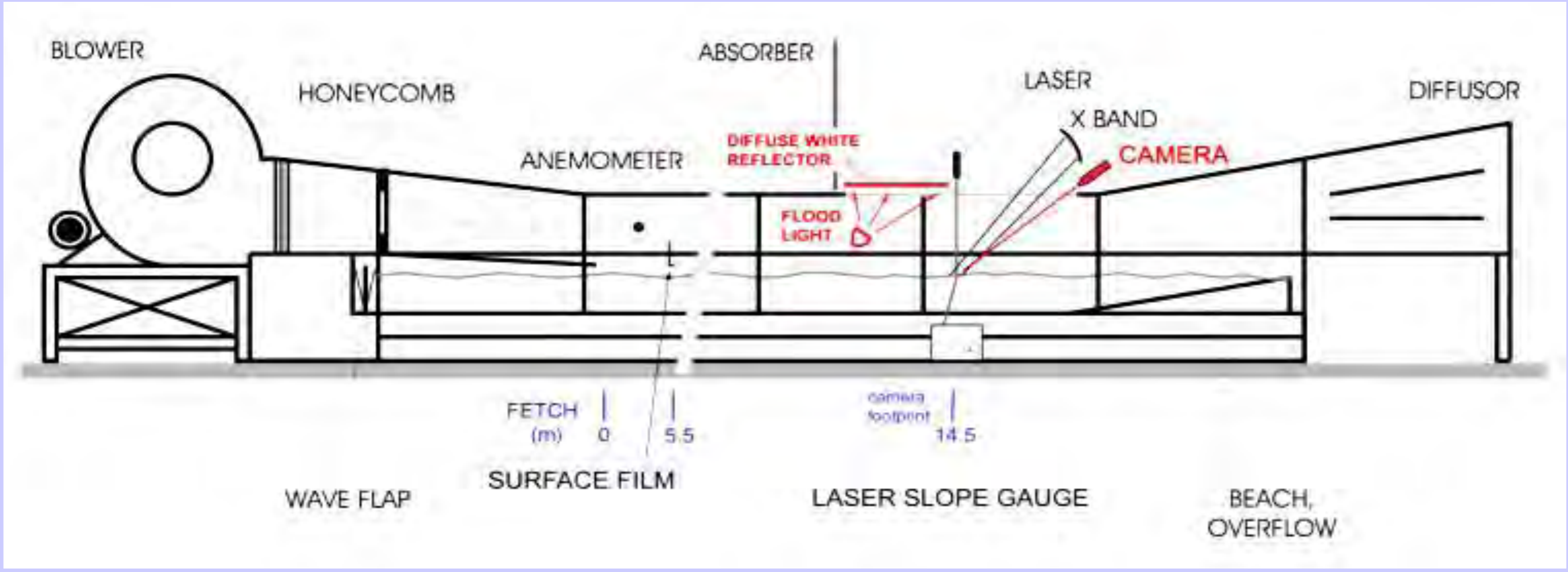
Further investigations of damping characteristics of monomolecularen surface films

New insights on the influence of the local wave field on the radar backscattering

First laboratory experiments in the presence of wind and rain

2000s: Recent Work

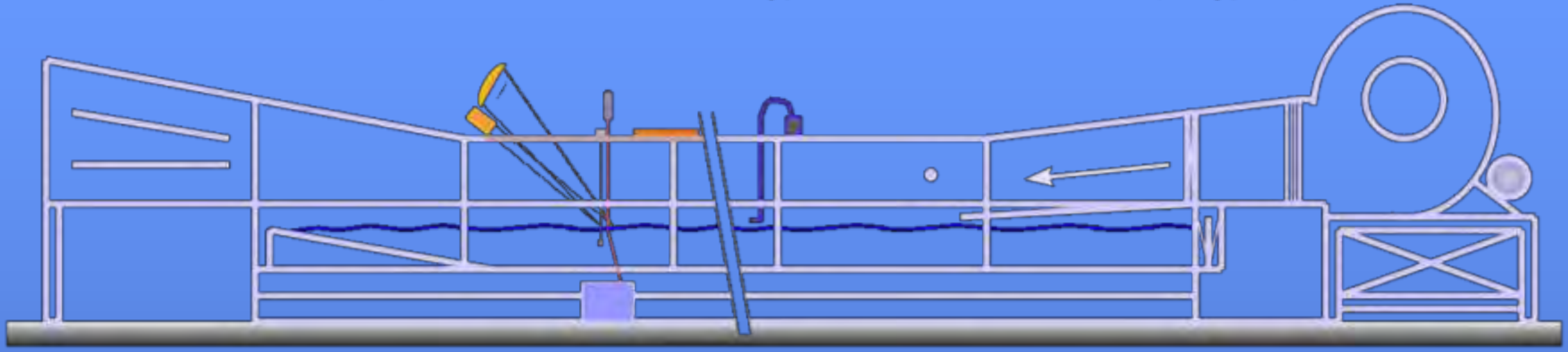
Bound & Free Waves @ Slick Edges



Experiments with small slick patches consisting of oleyl alcohol (OLA) and palmitic acid methyl ester (PME)

Purpose: study the wave field at slick edges; deliver data for EU project dealing with automated detection of sea (surface) pollution

Recent Research: Small-Scale Phenomena



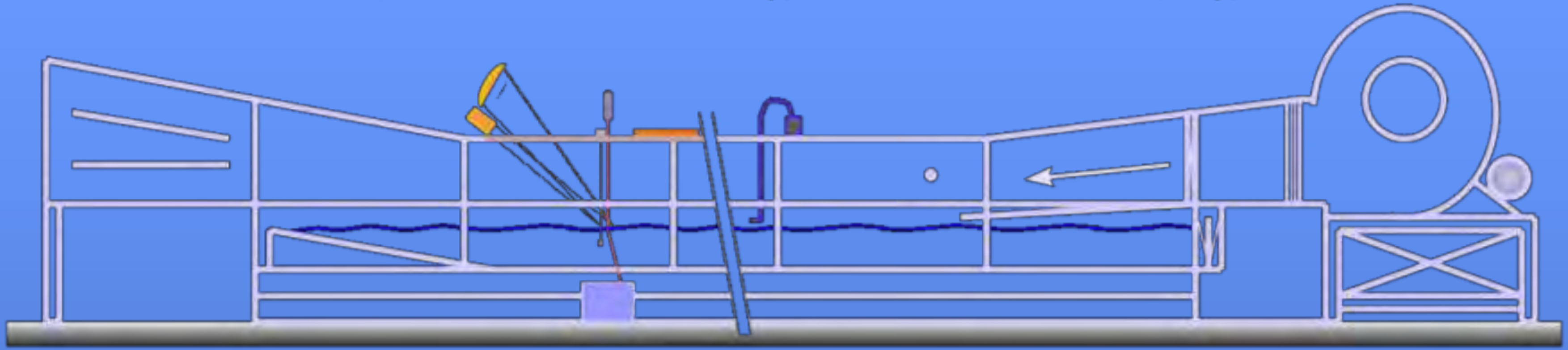
Short-term deployment of substances to study phenomena at slick edges

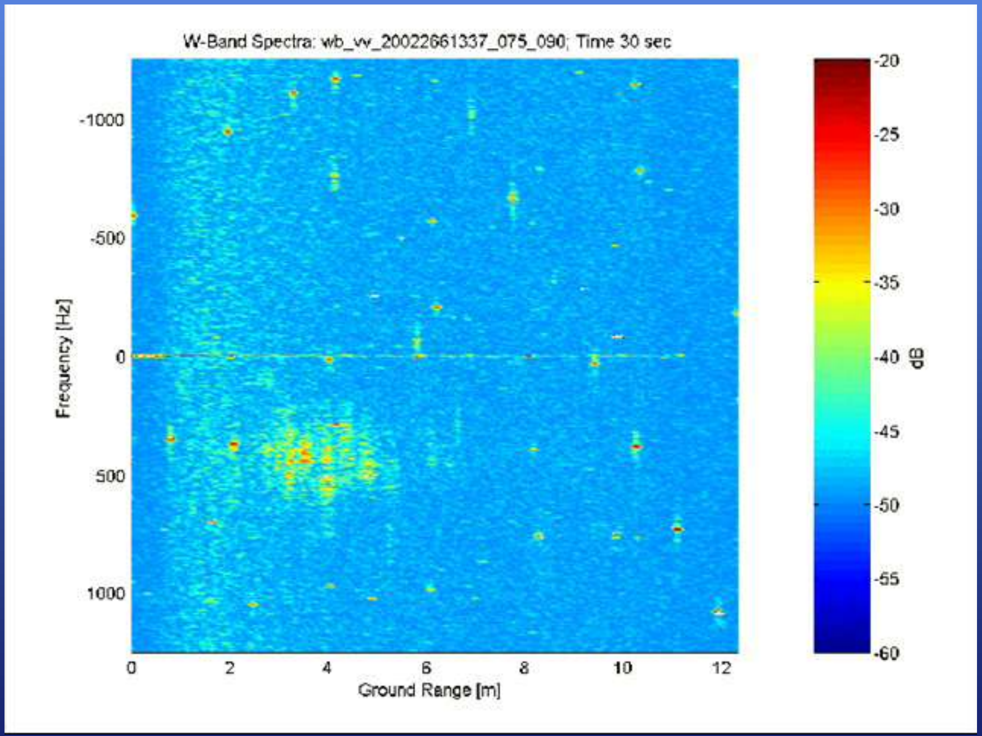
e.g. OLA @ 5 m/s

Front edge: sharp

Rear edge: tethered

Recent Research: Small-Scale Phenomena

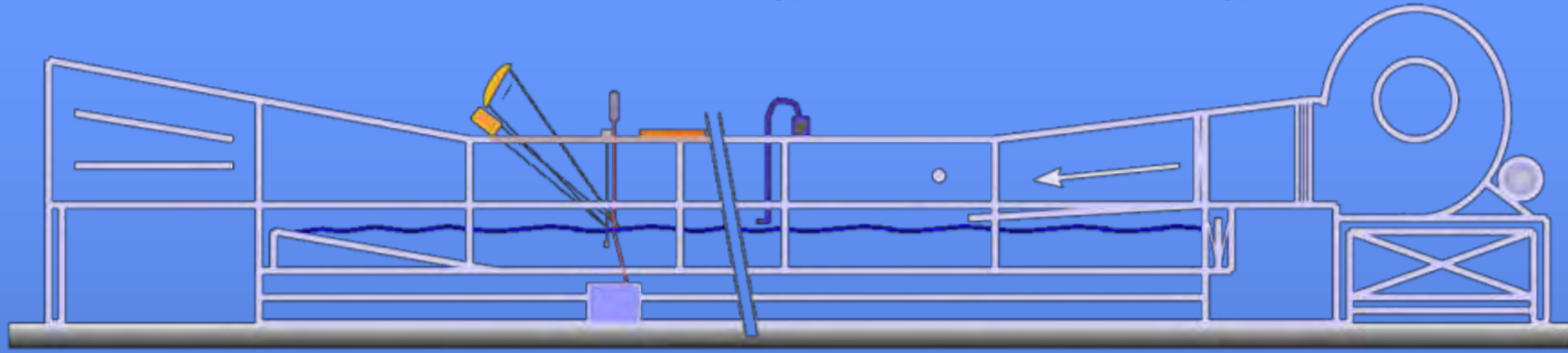


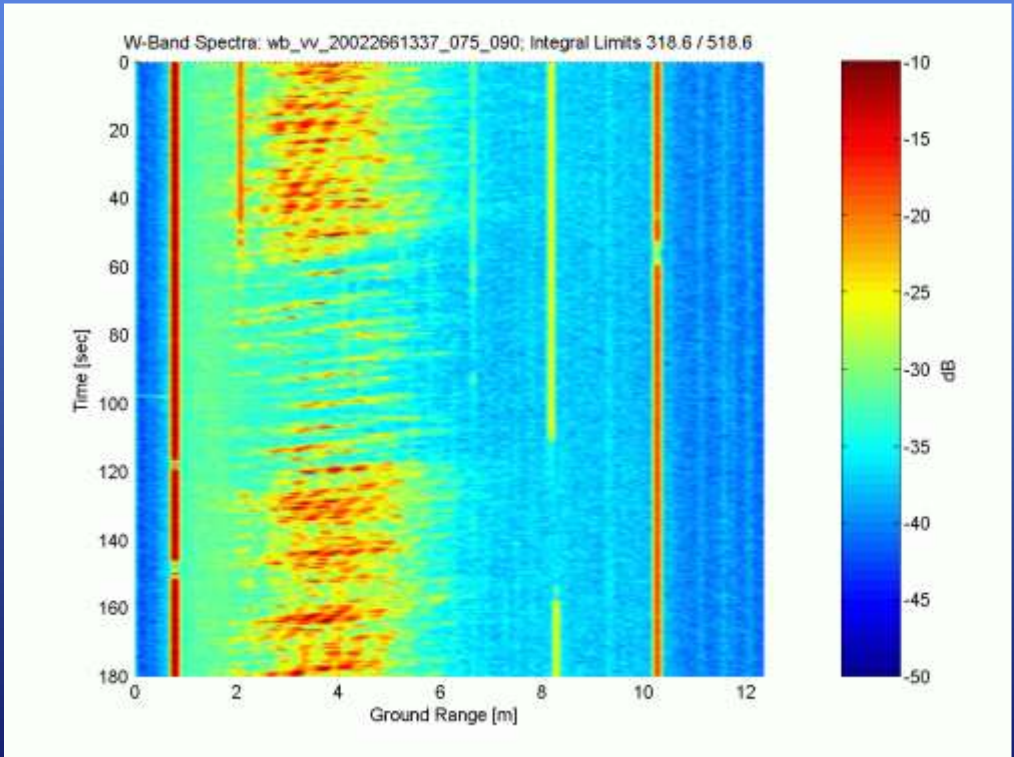


Entfernungsauflösendes W-Band
94 GHz (λ_B = 3 mm)
z.B. OLA @ 9 m/s

Beobachtung von kleinskaliger Phänomenen (Mikrobrechen) an der Wasseroberfläche

Recent Research: Small-Scale Phenomena

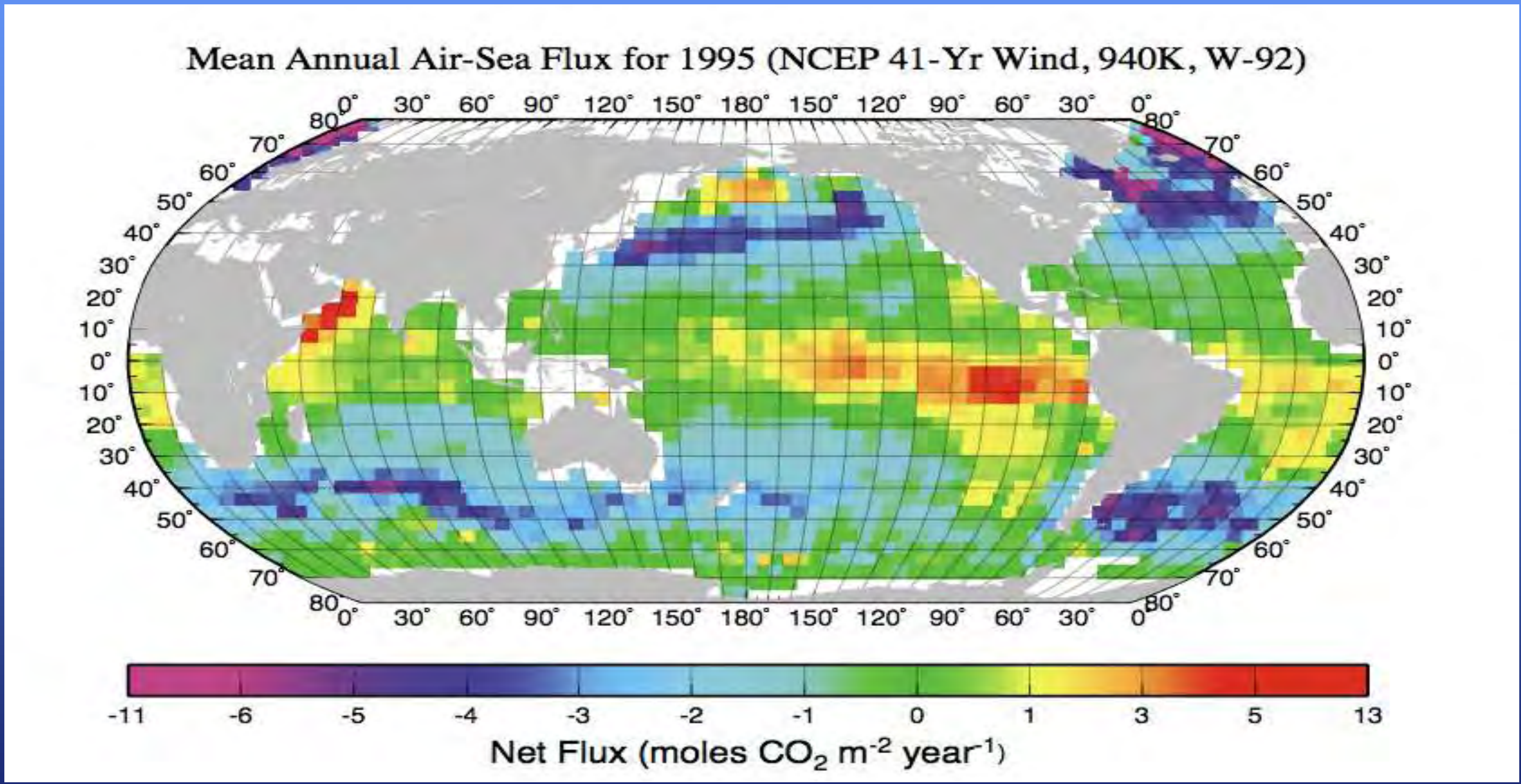




Beobachtung der raumzeitlichen Entstehung und Verteilung von kleinskaligen Phänomenen

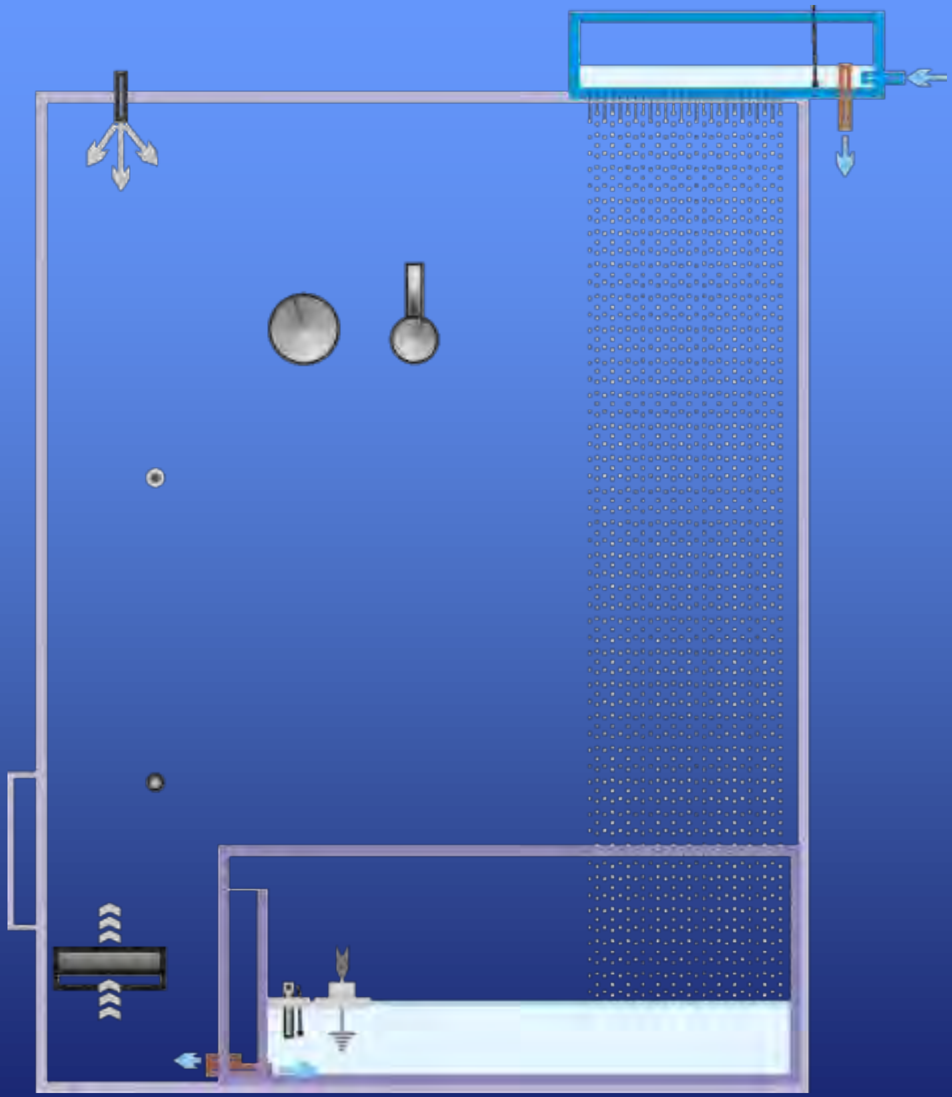
Gas Transfer

Greenhouse Gas CO_2



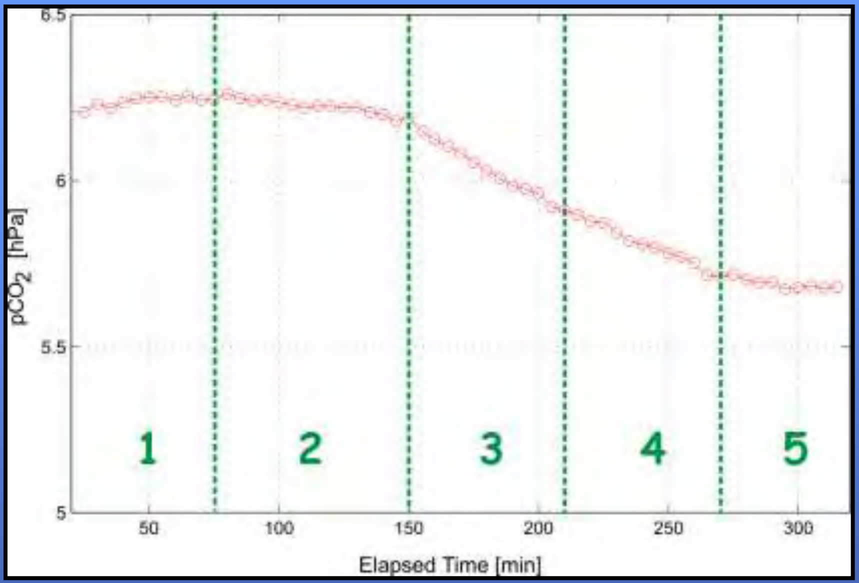
Takahashi et al [2002]

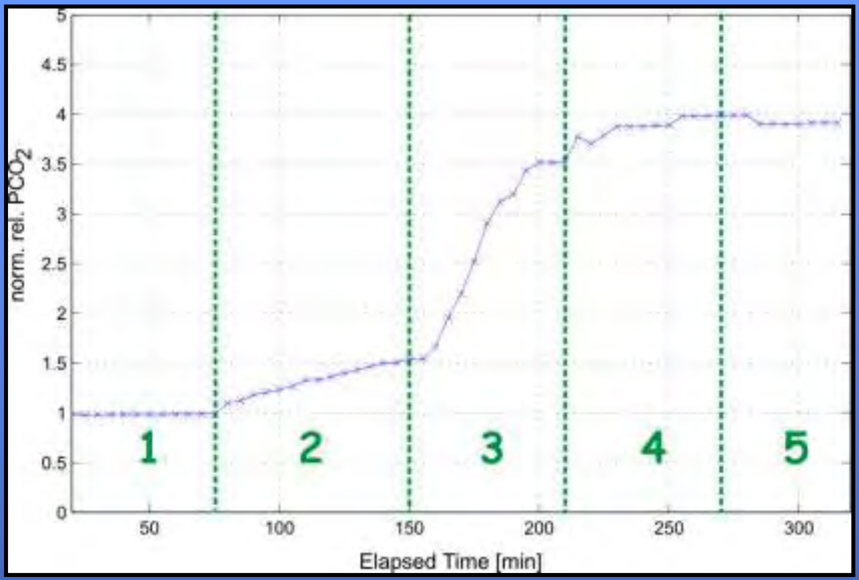
Gas Transfer



CO_2 invasion in the presence of artificial rain

Gas Transfer





1: no rain, no turbulence

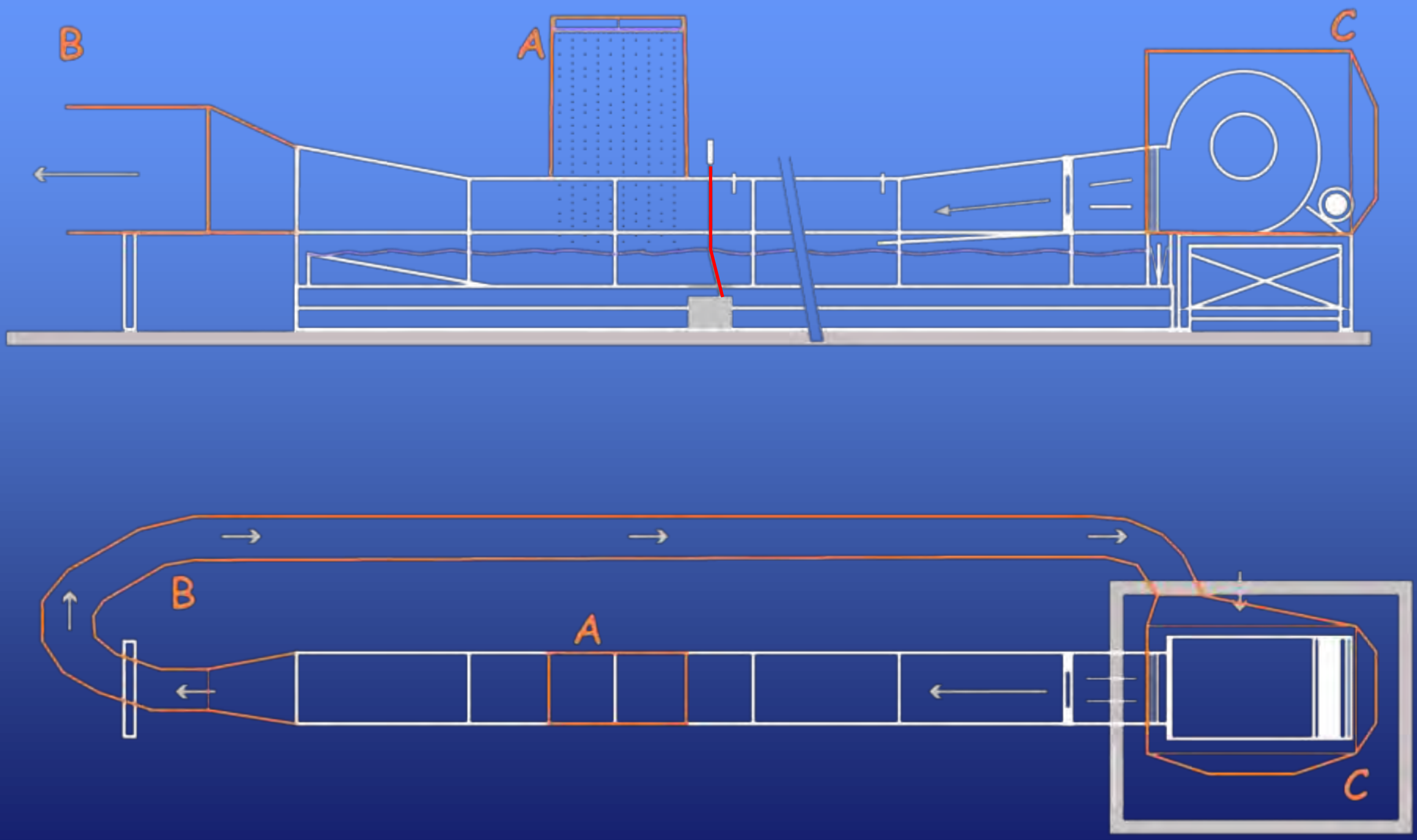
2: turbulence

3: rain 180 mm/h

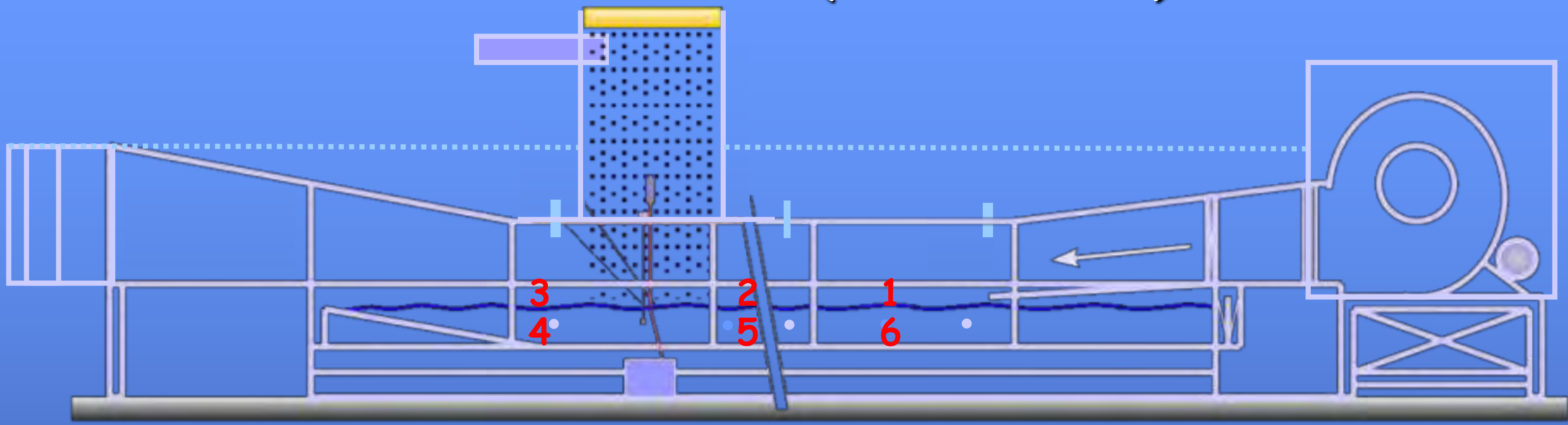
4: rain 270 mm/h

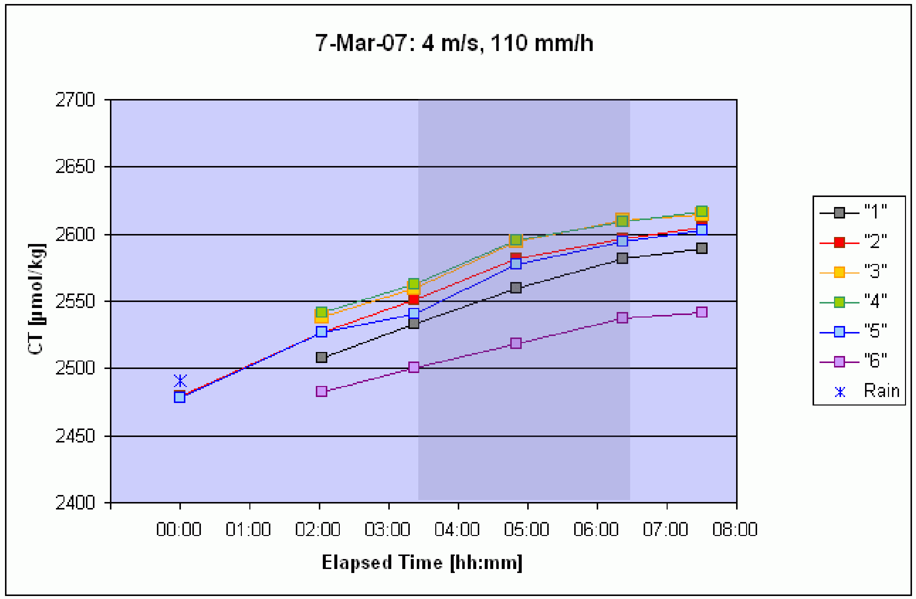
5: rain switched off

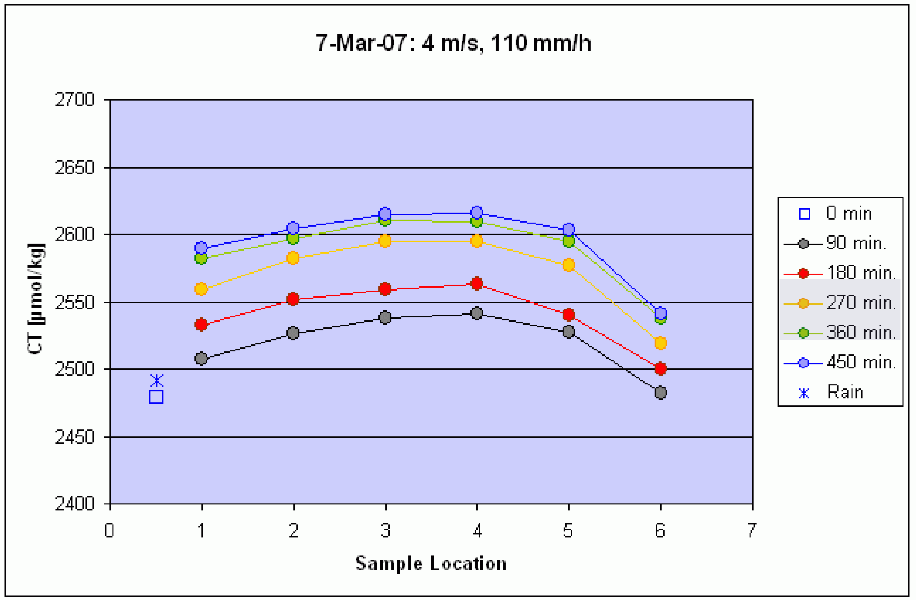
Gas Transfer



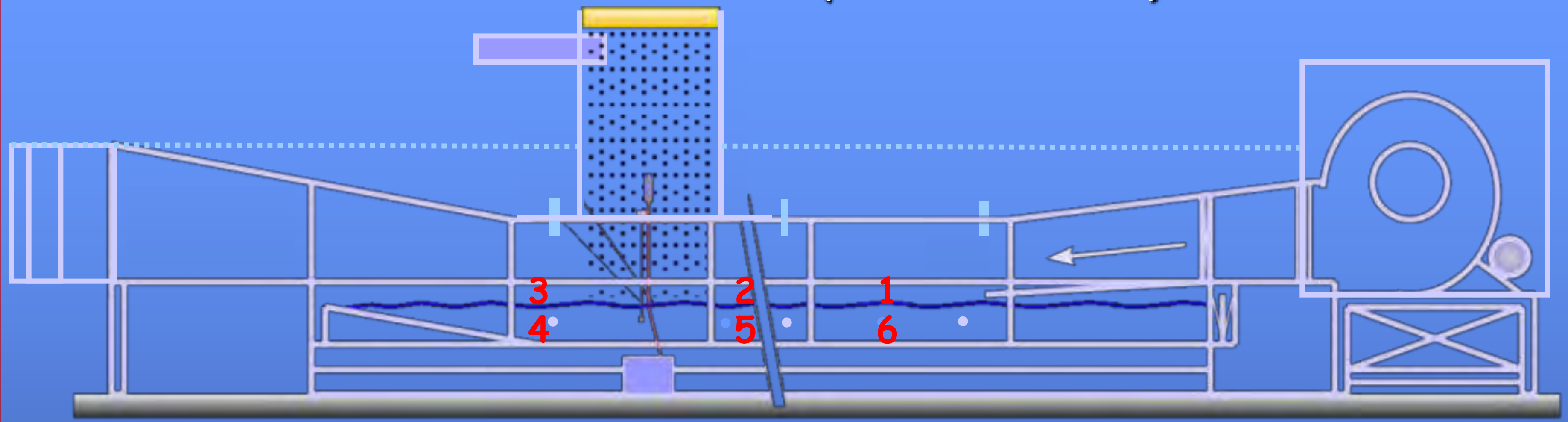
Gas Transfer (UHH + IOW)

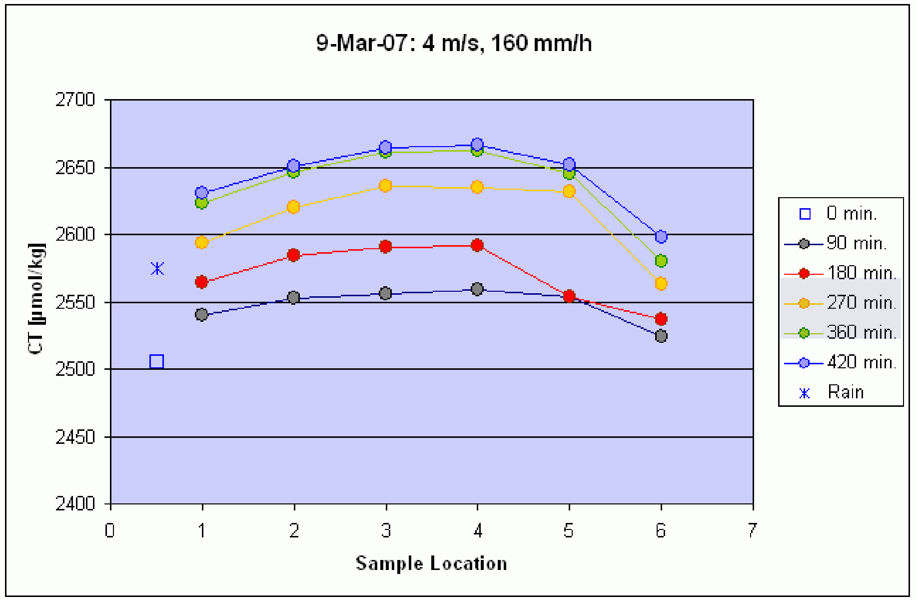


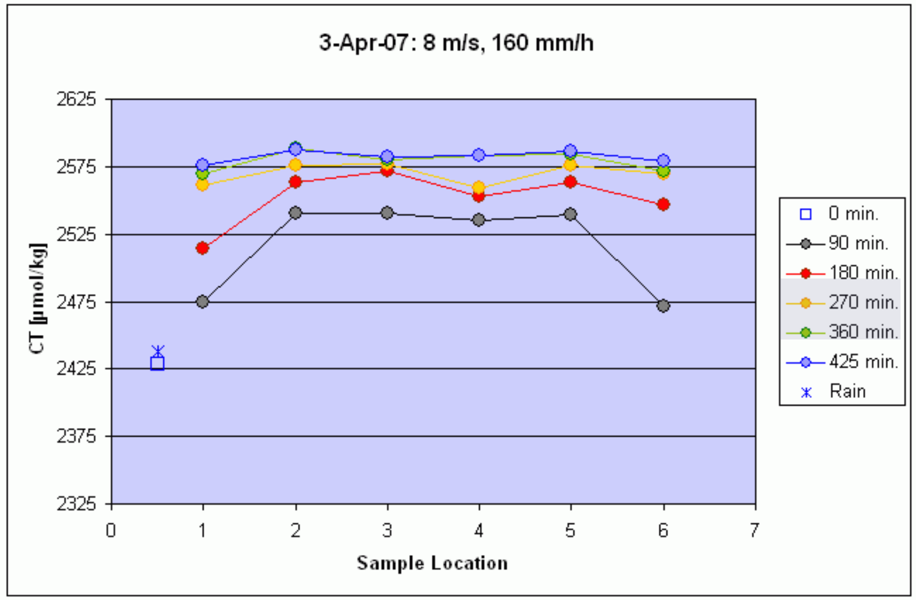




Gas Transfer (UHH + IOW)

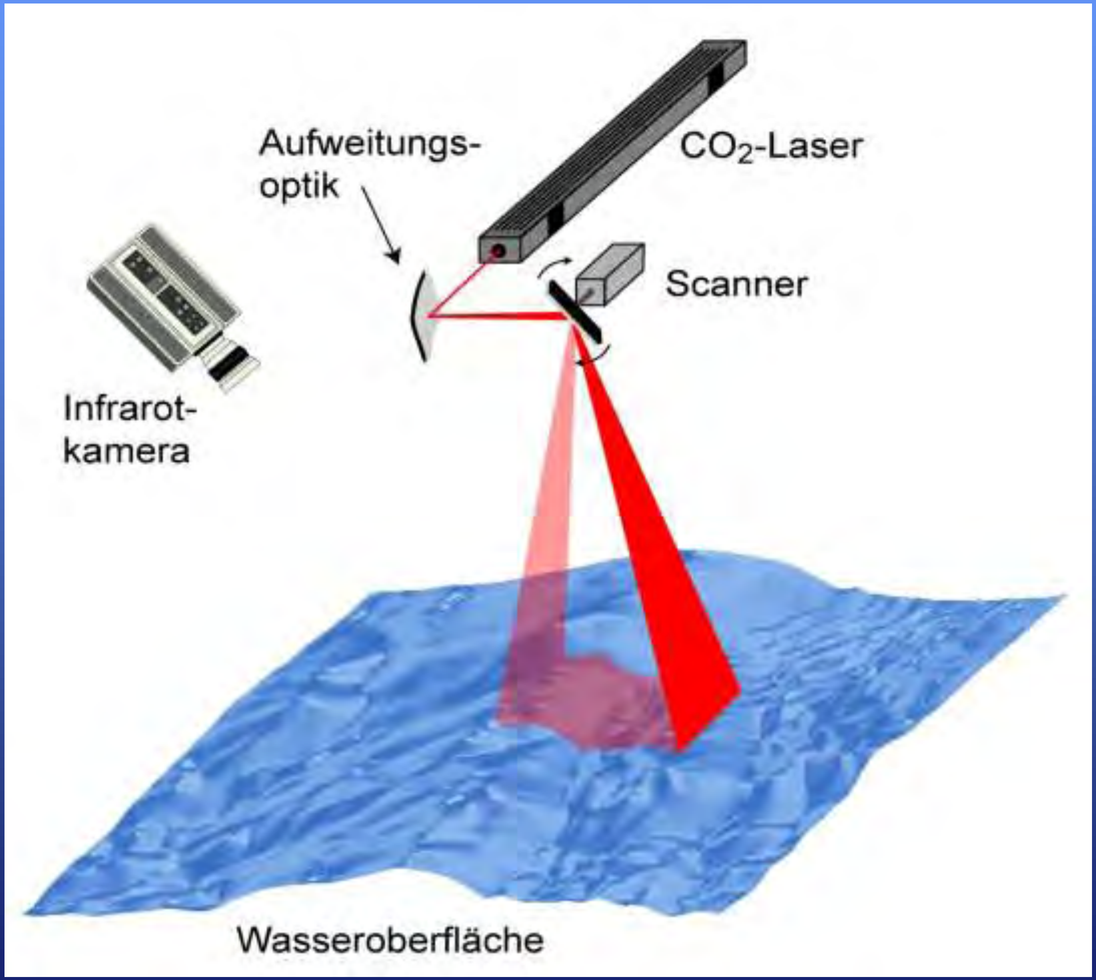






WiSSCy: Joint Experiments with U Heidelberg

Schematic of ACFT (Active Controlled Flux Technique)



WiSSCy: Joint Experiments with U Heidelberg

IR Image Sequence of Water Surface

Wind speed: 1.45 m/s

40 cm

60 cm

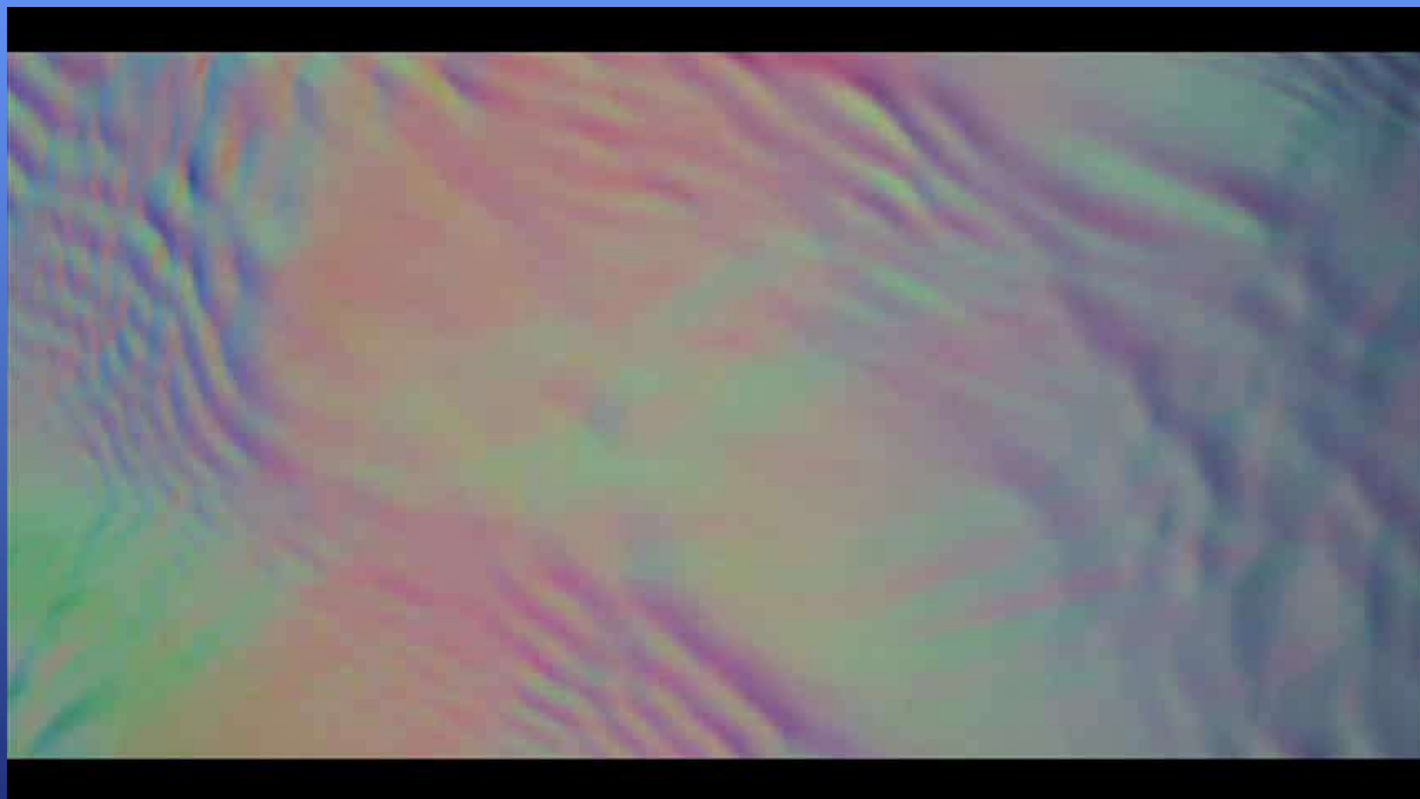
15.2 ºC **SST** **15.7 ºC**

WiSSCy: Joint Experiments with U Heidelberg

2d measurements on water surface

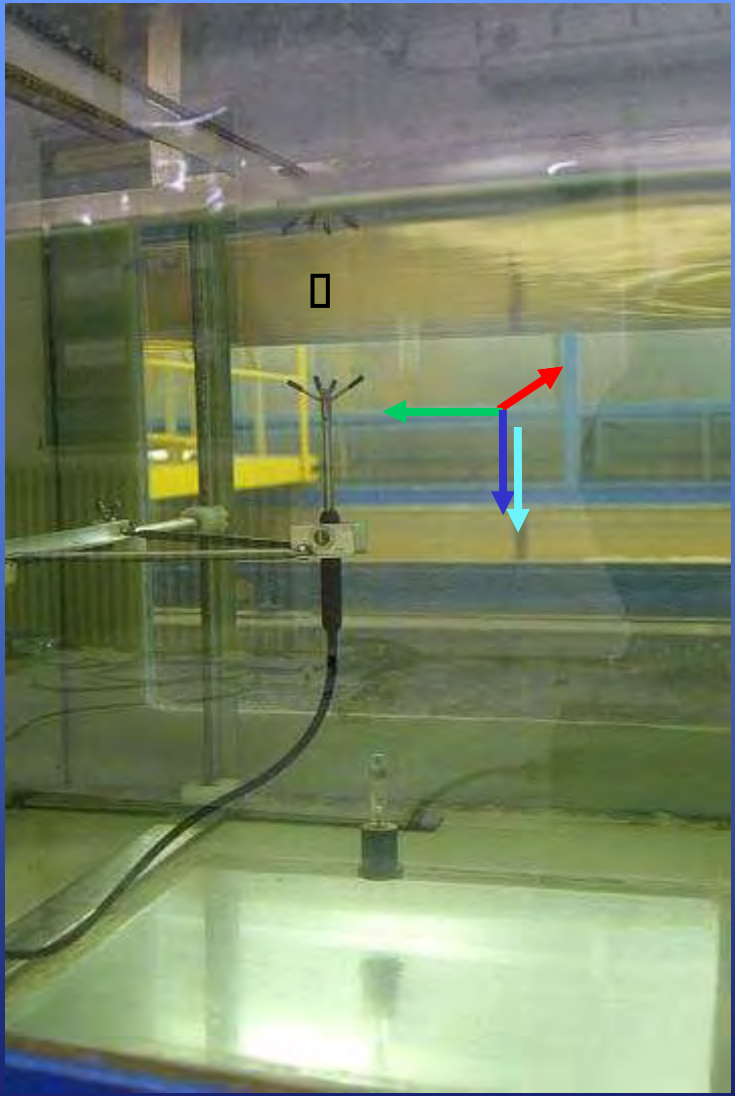
Wind speed: 4 m/s
image rate : 312 Hz

11 cm



24 cm

Measurements of 3d Current Profiles



ADV gauge:

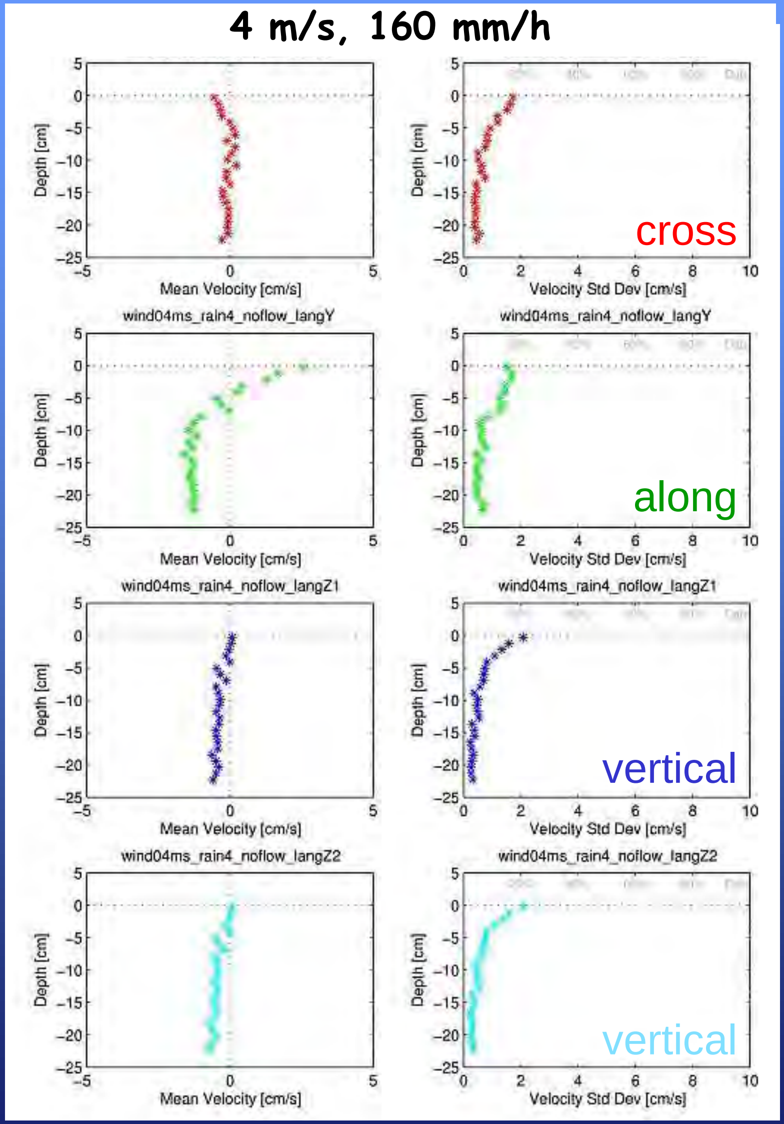
NORTEK Vectrino+

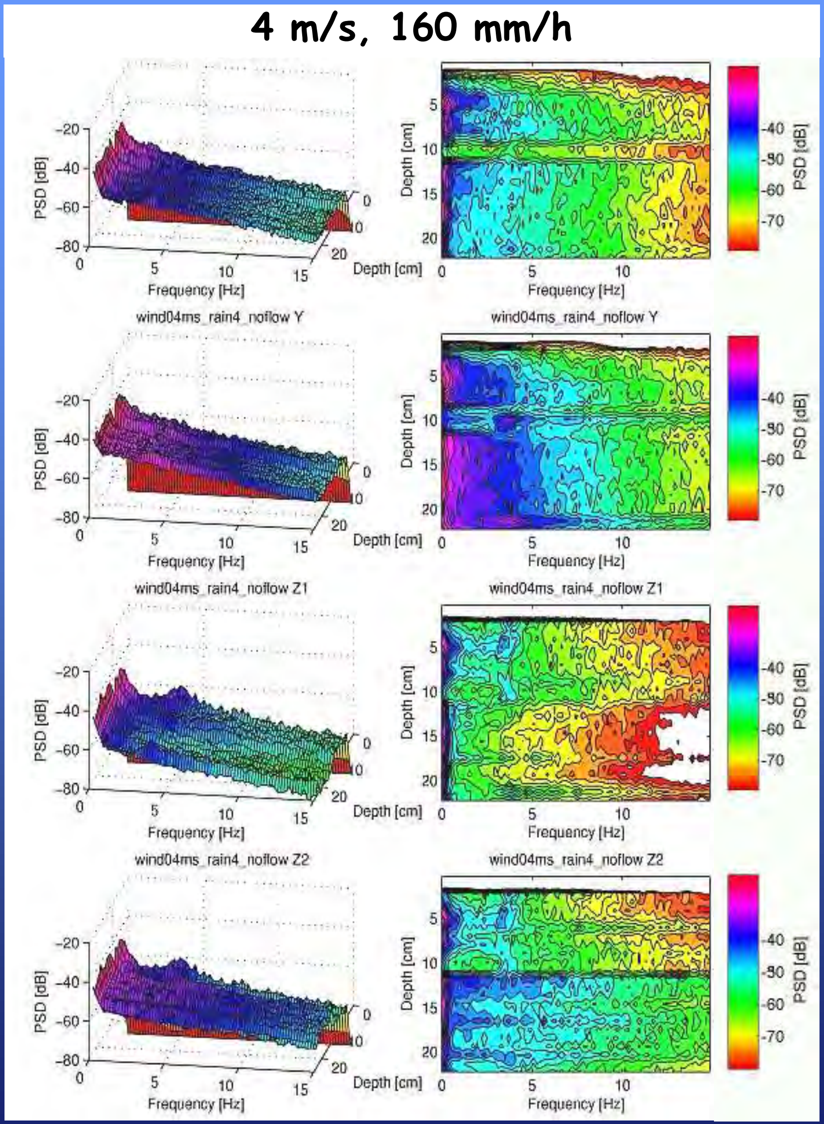
Measurement volume: ~ 1 cm^3

Sample rate: < 200 Hz

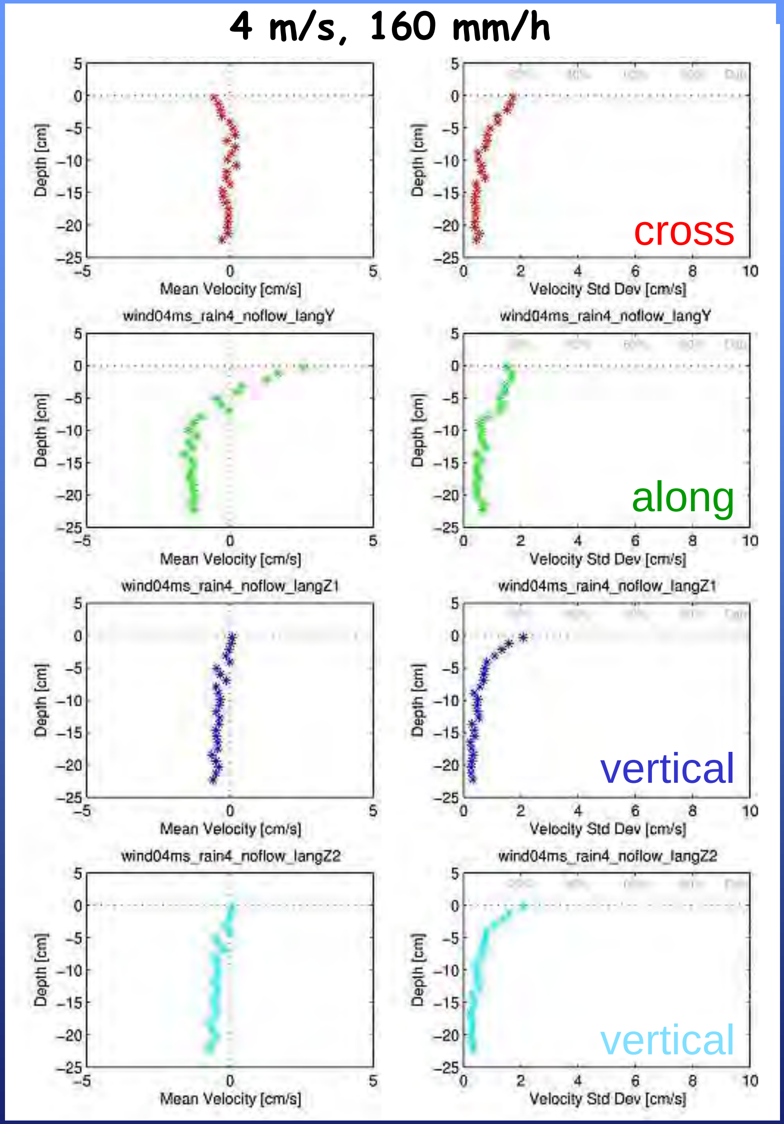
Depths: < 1cm .. 23 cm

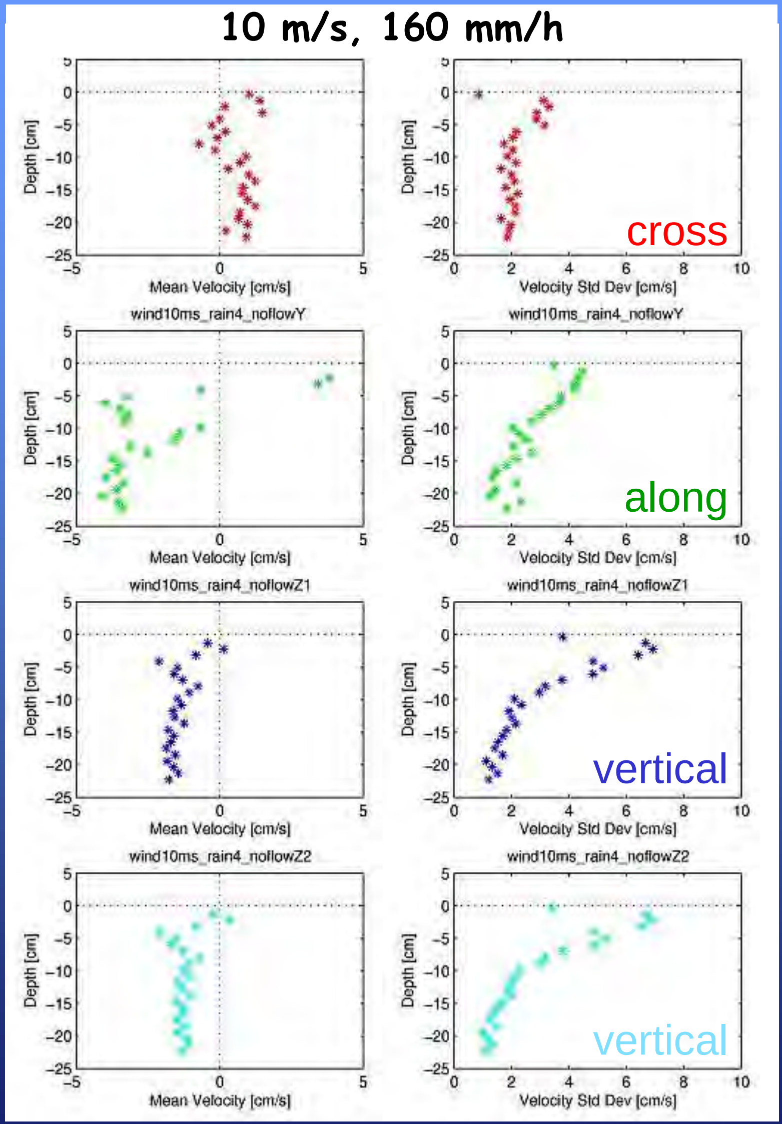
Current profiles : 4 m/s, 160 mm/h Rain



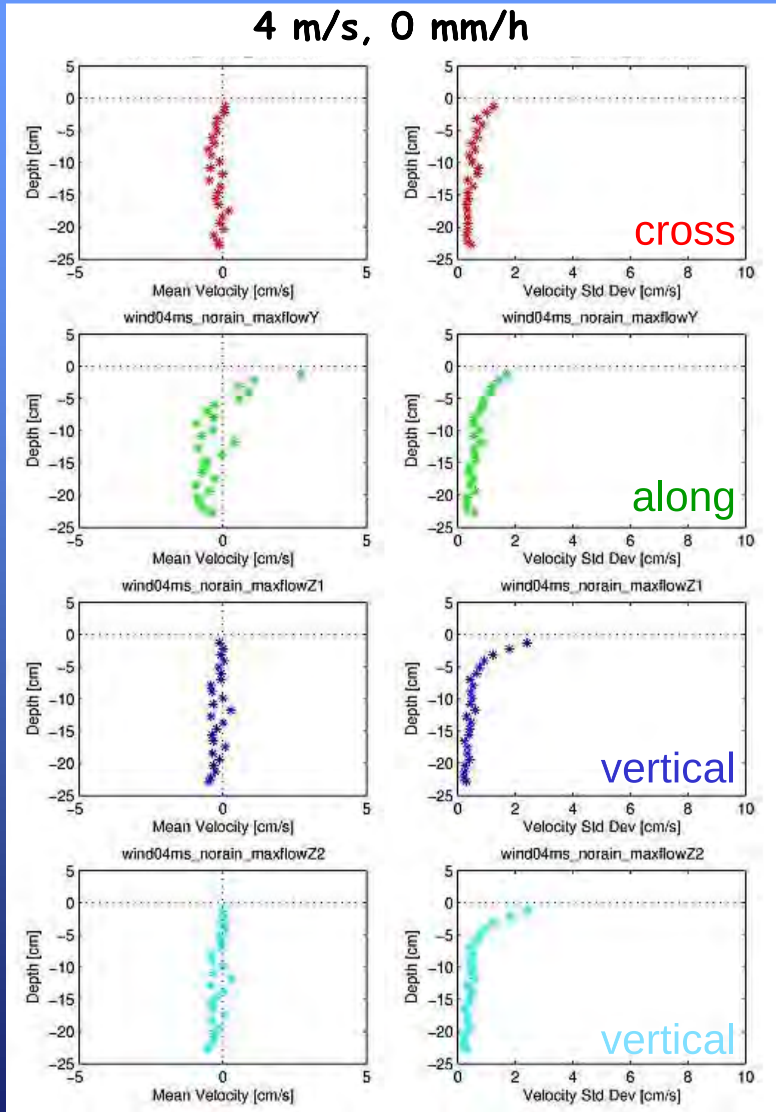


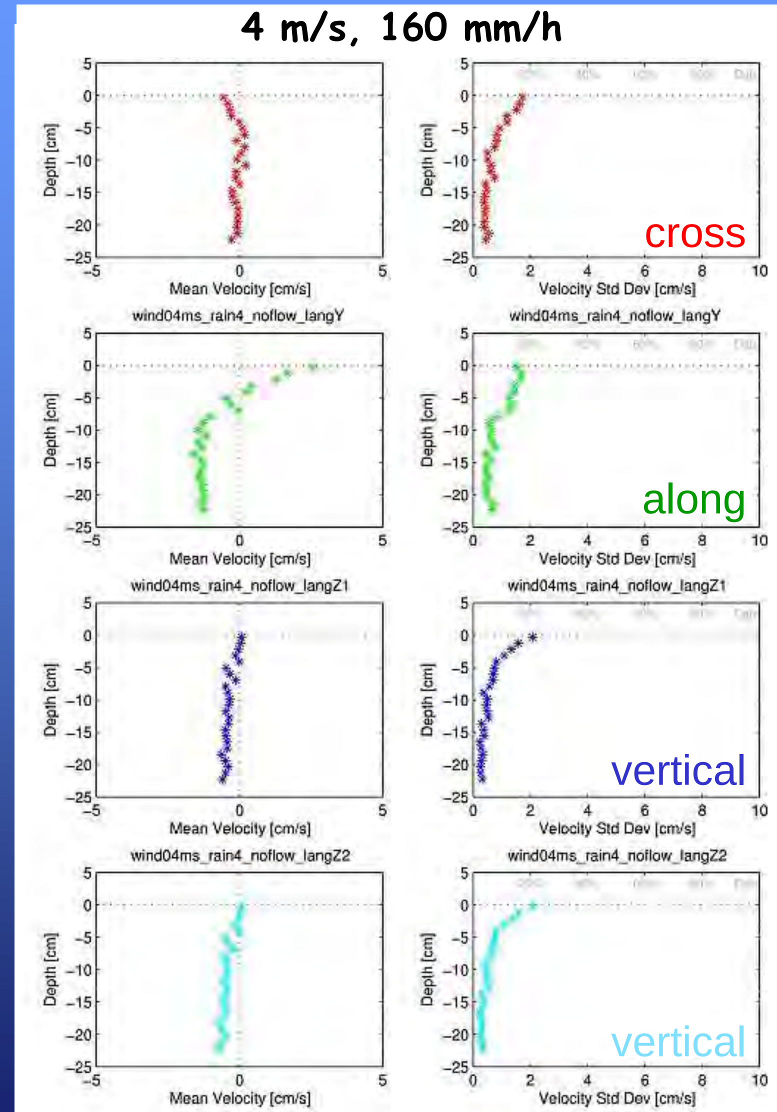
Current Profiles: Wind Influence





Current Profiles: Rain Influence





Summary

WWT of Uni HH since early 1970s
(Inst. f. Organische Chemie & Inst. f. Meereskunde)

Basics for improved interpretation of remote sensing data

Measurements with wave, gas and radar sensors

- Wave damping by surface films
- Influence of heavy rain
- Gas transfer between water and air
- Recently: influence of small-scale phenomena (turbulence) on gas transfer and radar backscattering

Благодарю за внимание !

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