# Investigation Of Air-Sea Gas Exchange

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# Introduction

- Air-Sea interactions are very important in understanding of the Earth's weather and climate systems. The interactions takes place by exchange of heat, momentum and mass across the surface.
- Gas exchanges are important in terms of global budget of many gases, influences air, weather and water quality, affects atmospheric radiative transfer.
- The flux of the slightly soluble non-reactive gases across the air sea interface, $F$ is defined as the product of gas transfer velocity, $k$ and the concentration difference between the liquid boundary layers,

$$F = k\,(C_w - \alpha C_a)$$

where $\alpha$ is the dimensionless solubility constant.

- Transfer velocity $k$ is given as ratio of the flux to the concentration difference. It depends on Schmidt number ($Sc = v/D$, $v$ is the kinematic viscosity and $D$ is the molecular mass diffusivity) and the dimensionless solubility $\alpha$, and friction velocity $u_*$

$$k = \beta u_* Sc^n$$

- The major processes influencing the air-sea transfer of gases are wave breaking, small and large scale turbulence, waves, bubbles, spray, surfactants, rain, chemical and biological properties.

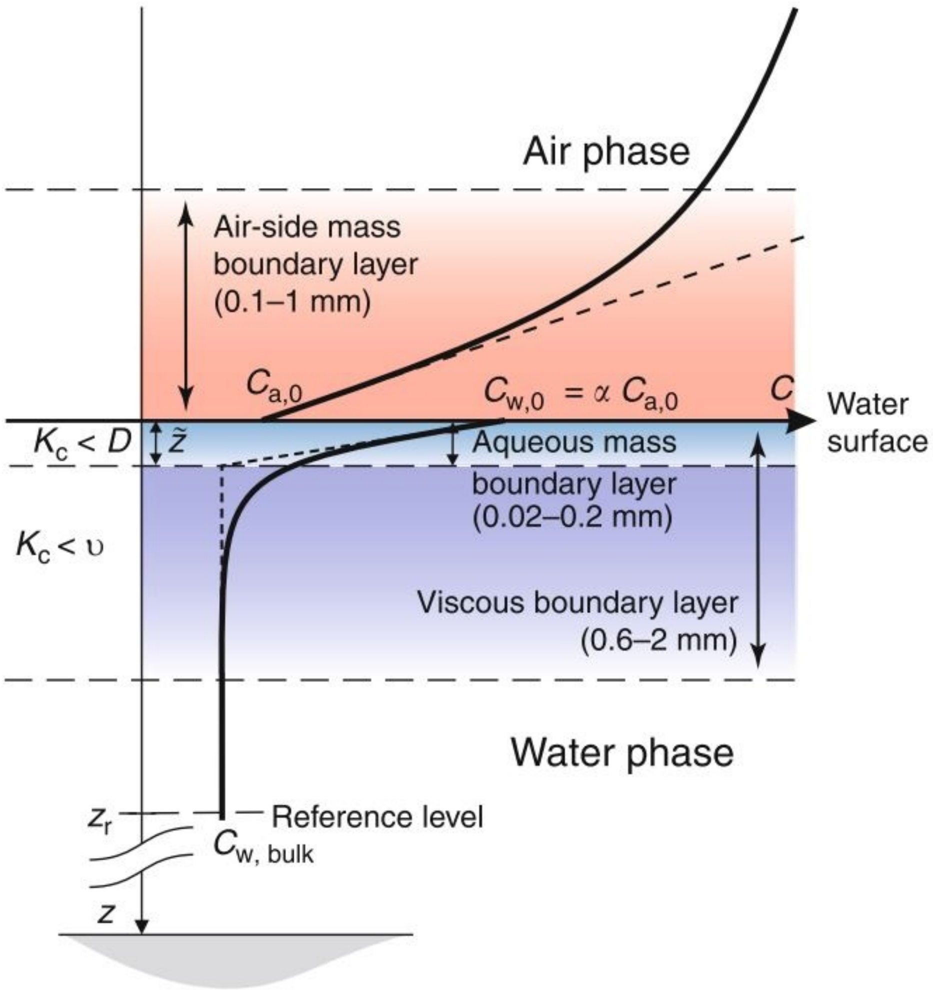



Fig: Schematic graph of the mass boundary layers at the interface for a tracer with a solubility α = 3.(Jhane 2009)

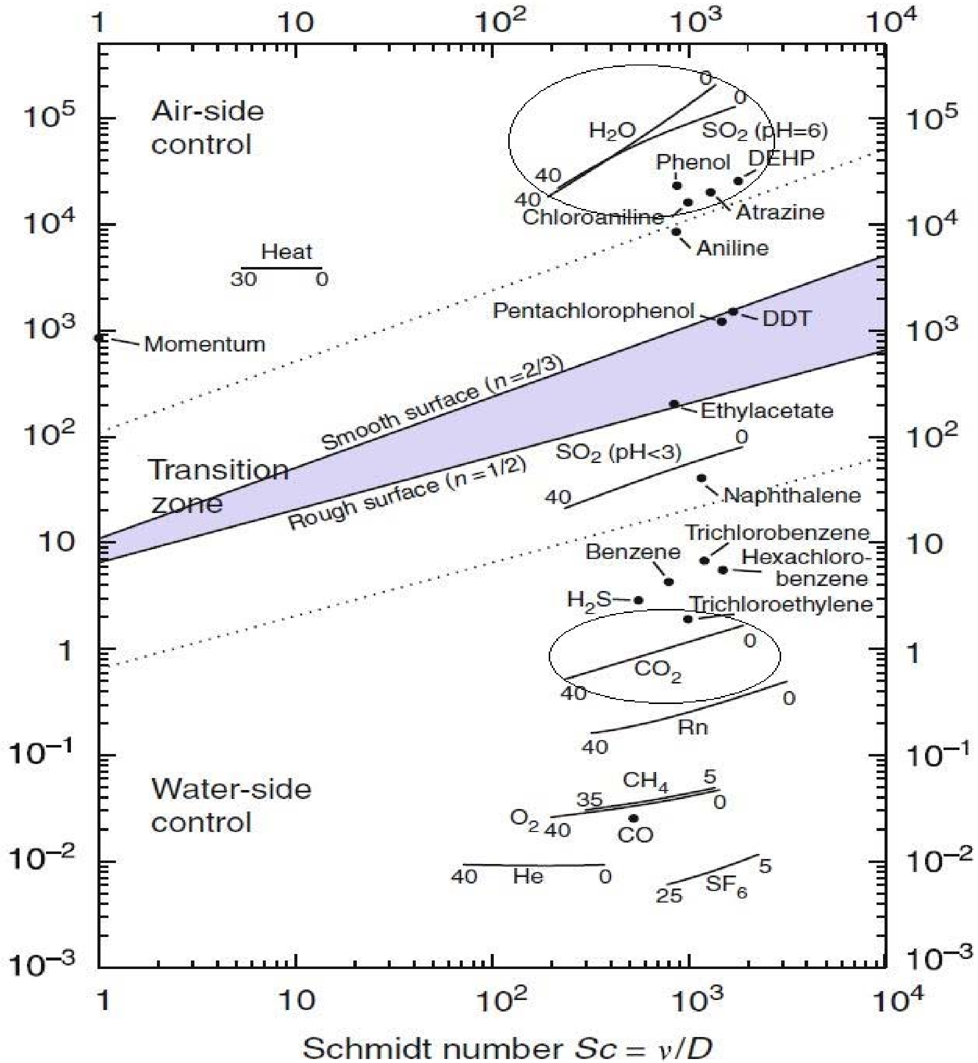



Fig: Schmidt number/solubility diagram for volatile tracers, momentum, and heat for a temperature range.(Jähne and Haußecker 1998)

# Literature Review

- Wind generates turbulence at air-water interface through shear or through waves. Waves affects roughness and group speeds and cannot be given only by the wind speeds.
- The gas transfer rate is better correlated with the ‘mean square slope’ of the waves as an integral measure for the nonlinearity of the wind wave field than with the wind speed.
- Transfer across the interface may not occur only through molecular diffusion but also through wavebreaking, bubbles and sea spray. Bubbles are primarily generated by the air entrainment within breaking waves. Bubbles and wavebreaking enhance surface turbulence and may enhance gas transfer rates.
- It is suggested that bubble mediated transfer is highly effective for less soluble gases like $CO_2$ compared to that of more soluble gases like DMS. The dependence of bubble mediated transfer of gases for more soluble gases is yet to be known.

- Surfactants inhibit gas exchange by either forming a insoluble surfactant film, by forming a condensed monolayer on the surface or by providing a additional liquid surface that provides resistance to mass transfer.
- Surfactants reduce the roughness there by reducing the turbulence and wave breaking however it is not clear the effect of surfactants over high winds as the surfactants are brought back to surface by bubbles.
- Rain has an effect on gas transfer rates based on drop size and rate. The effect is due to enhancement of surface turbulence and bubbles formation due to rain drops hence it is important in the regions of high precipitation regions. But the effect of rain on gas exchange on a global scale is less.

# Measurement Techniques

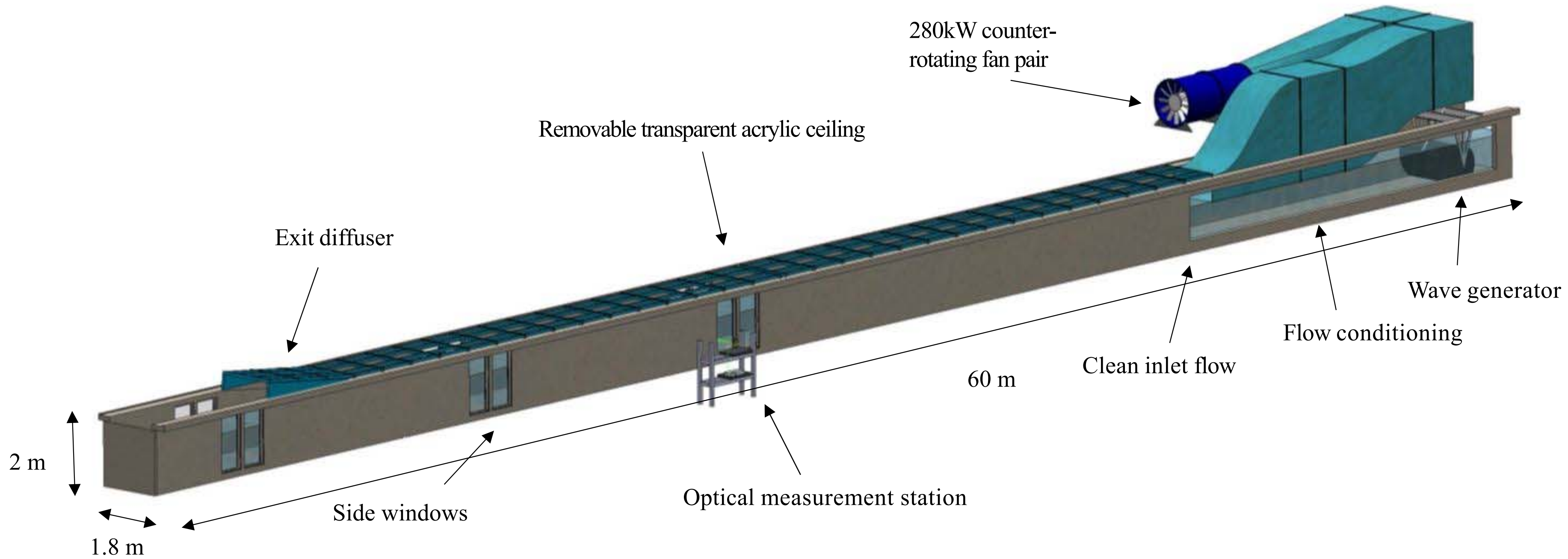
- Direct Flux Measurements
  - Eddy Covariance Technique
  - Relaxed Eddy Accumulation
  - Profile Method
- Mass Balance Techniques
  - Natural perturbations (Oxygen and Radon)
  - Deliberate Tracers

# Objectives

- Calculate the gas transfer velocities across air-water interface over different wind speed regimes.
- Evaluate the obtained experimental results with the field observations through Eddy-Covariance method.
- Implementing the obtained parameterization in a climate model.

# EASI Facility

- The dimensions of the tank are 60 × 2 × 1.8 m with a working section length of 35 m. It is designed to simulate the ocean with air blowing over a tank of water at speeds of up to 30 ms$^{-1}$.



- Integral Conservation Method: The amount of heat lost by the water body to the air as air is blown over the surface is used to determine the moist enthalpy flux through the interface on the basis of a heat content budget applied to a control volume of water.

$$H_K = -c_p \rho_l \frac{\partial T_W}{\partial t} \frac{V_W}{A}$$

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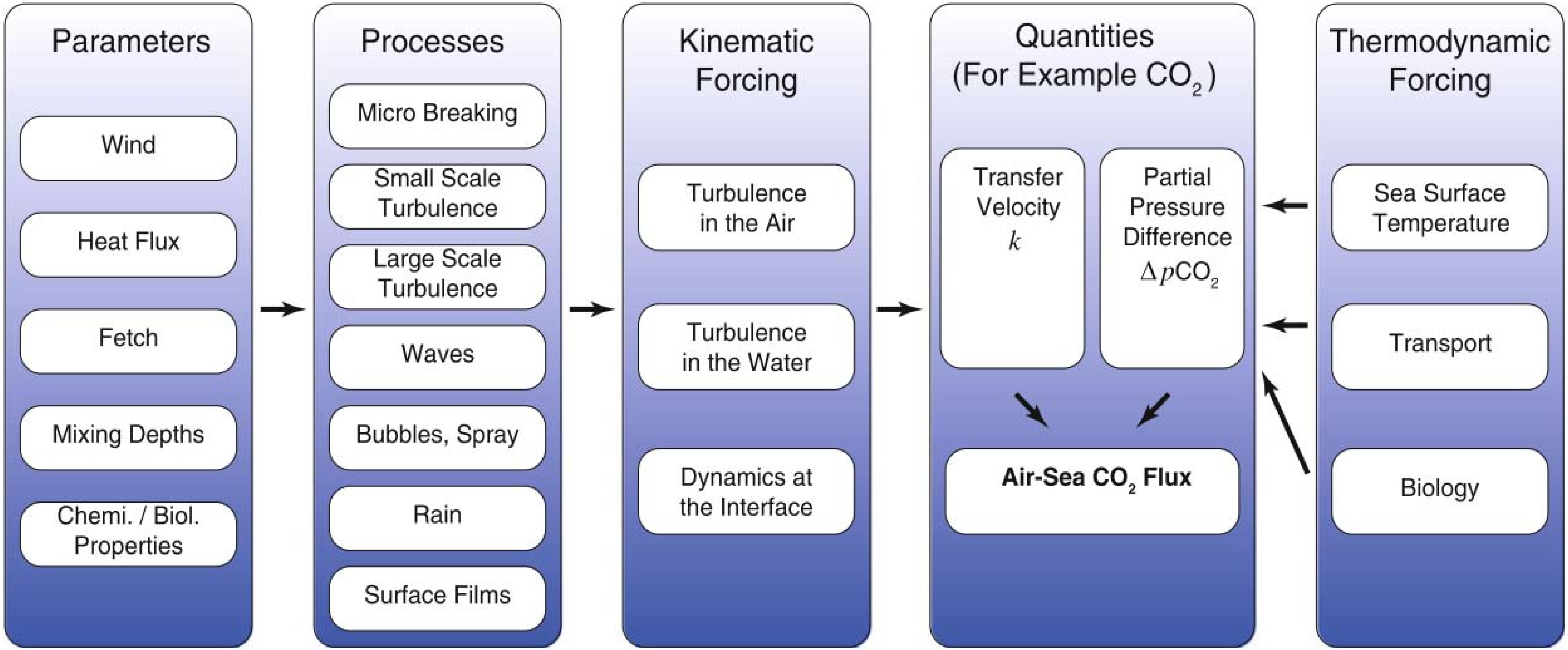


Fig: Schematic of factors influencing air-sea $CO_2$ fluxes.(Garbe.et.al. 2014)