WDAC-3 Meeting NUIG

SOLAS and Surface Fluxes

Brian Ward

AirSea Lab, National University of Ireland, Galway

Wifi

NUIGWiFi
Username: 9876001T
Password: ypzce6897

Dinner

- Icebreaker here at 18:00-18:30
- Dinner in a local restaurant at 19:30 this evening, after the icebreaker
- Lunch will be held in a campus restaurant

Future SOLAS

- SOLAS will come to an end in December 2015
- The last SSC meeting in Japan (May 2013) it was decided that we should apply for a 10-year extension
- SOLAS will seek to continue our relationship with current sponsors SCOR, WCRP and iCACGP. The IGBP is winding down, and we have been invited to seek sponsorship from the new Future Earth initiative.
- The SOLAS Scientific Steering Committee has identified 8 research themes

Future SOLAS Themes

1. **Greenhouse gases and the oceans** The natural cycles of greenhouse gases in the oceans and troposphere interact with these unprecedented direct inputs and lead to climatic feedbacks as well as environmental impacts, which need to be identified, quantified, and predicted on local to global scale and on a variety of different time scales.
2. **The air-sea interface and fluxes of mass, energy** Air-sea transfer is mostly modelled by various functional dependencies of the wind speed, but more sophisticated measurement techniques and physically based parameterisations are required to adequately describe air-sea fluxes.
3. **Atmospheric nutrient and particles supply to the surface ocean** Despite significant laboratory, field and modelling work over the past decade, the links between atmospheric deposition, nutrient availability, ocean productivity (up to high trophic levels), carbon cycling and feedbacks to climate are still poorly understood and modelled.

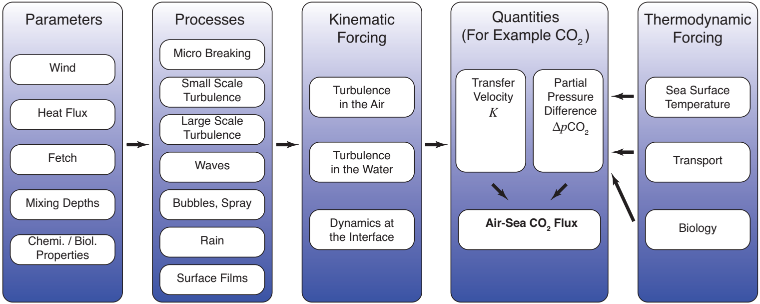
Future SOLAS Themes

4. **Interconnections between aerosols, clouds and ecosystems**
   Interconnections between ocean-derived aerosols, clouds, and marine ecosystems are not well understood. Assessing the system as a whole is required for an accurate understanding of how a change in one component is manifested in another as well as the potentially complex web of associated feedbacks.
5. **Ocean emissions and tropospheric oxidizing capacity**
   Compounds that can affect the tropospheric oxidation power are being exchanged across the air-sea interface. This includes reactive (inorganic) halogens, sulphur-containing compounds, halocarbons with lifetimes of minutes to weeks, halogen-containing aerosol particles, certain organic gases, nitrogen-containing gases as well as organic aerosol.

Future SOLAS Themes

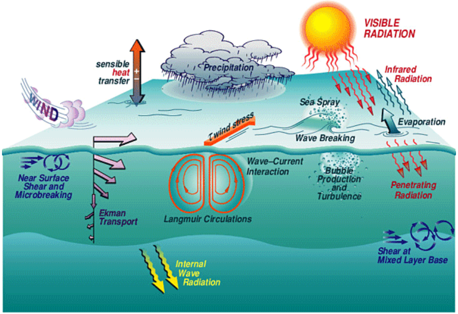
6. **Interconnections between ocean biogeochemistry and stratospheric chemistry** Reactive gases emitted from the sea surface are transported to the stratosphere in the tropics, where they can influence photochemistry and chemistry and catalytically destroy ozone. The chemical composition and spatial/temporal distributions of these emissions, and the biogeochemical factors controlling them are not well understood.
7. **Multiple stressors and ocean ecosystems** Over the last century, the ocean ecosystems have been experiencing unprecedented changes driven by both natural and anthropogenic stressors such as temperature rising, eutrophication, deoxygenation/hypoxia, plastic litter and ocean acidification.
8. **High Sensitivity Systems** In the global context Eastern Boundary Upwelling Systems (EBUSs) and Polar systems have been identified as hot spots for air-sea exchange research, because of their significant role in the ocean ecosystems and global biogeochemical cycles.

- One of the primary efforts of SOLAS is to better quantify air-sea CO_2 fluxes



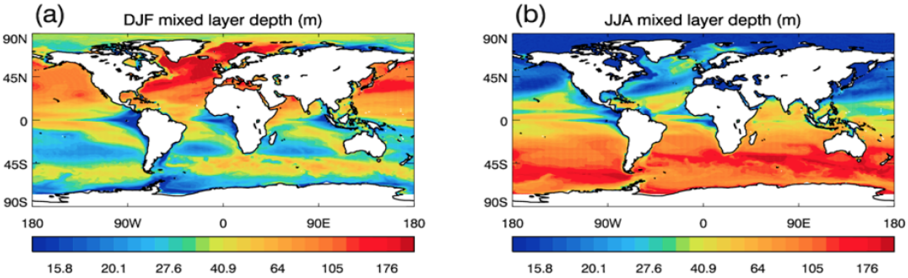
- Air-sea transfer is mostly modelled by various functional dependencies of the wind speed, but more sophisticated measurement techniques and physically based parameterisations are required to adequately describe air-sea fluxes.

Air-Sea Fluxes: Mixed layer depth and Turbulence



- Turbulence in the ocean surface boundary ayer (OSBL) $O(100m)$ control the air-sea fluxes of heat, GHG's, and momentum
- Exchanges in the OSBL heavily control the ability of the oceans to regulate climate
- The OSBL is therefore critical in determining the role of global ocean circulation on climate.

- Mixed layer depths in winter and summer over 20 years from a climate model

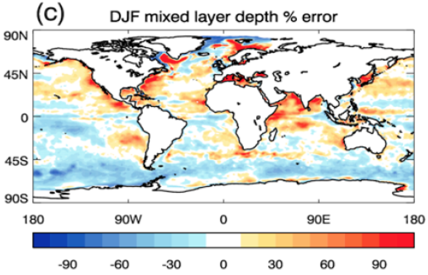


Belcher, S. E., et al. (2012), A global perspective on Langmuir turbulence in the ocean surface boundary layer, Geophys. Res. Lett., 39, L18605, doi:10.1029/2012GL052932.

- MLD errors -> SST errors -> errors in potential vorticity, temperature and salinity, and in transport of passive tracers such as CFC-11, because they are not subducted along the correct isopycnals.

Seasonal Variation in the OSBL Depth

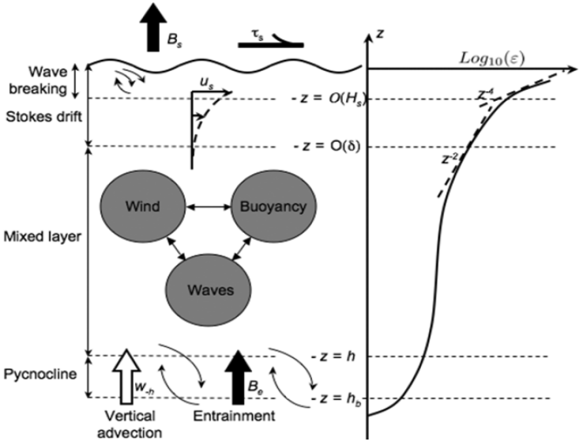
- Errors relative to the Argo float data up to 2008 - up to 100%



- In the Northern Hemisphere the errors in mixed layer depth are of both signs.
- Southern Ocean mixed layer is generally too shallow compared to the observations, particularly in the Indian and east Pacific regions
- There are corresponding errors in sea surface temperature — 3-4°C in the Southern Ocean.

Processes Deepening the OSBL

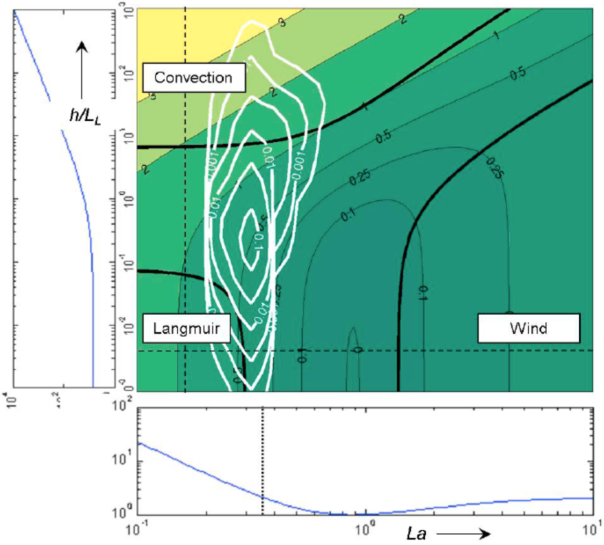
Vertical structure of the OSBL and the processes that deepen it



- Three sources of turbulence: wind, buoyancy and waves
- Motivation: quantitative understanding of the turbulent processes in the OSBL is likely to be the key to understanding the shallow biases in mixed layer depth

Belcher, S. E., et al. (2012), A global perspective on Langmuir turbulence in the ocean surface boundary layer, Geophys. Res. Lett., 39, L18605, doi:10.1029/2012GL052932.

Turbulence Regimes



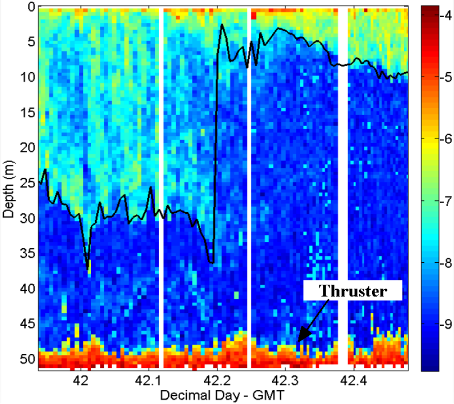
- Colored contours show turbulent dissipation rate $\log_{10}(\epsilon h/u_*^3)$
- Thick solid lines divide the regime diagram into regions where single forcings produce greater that 90% of total dissipation

From belcher et al. (2012)

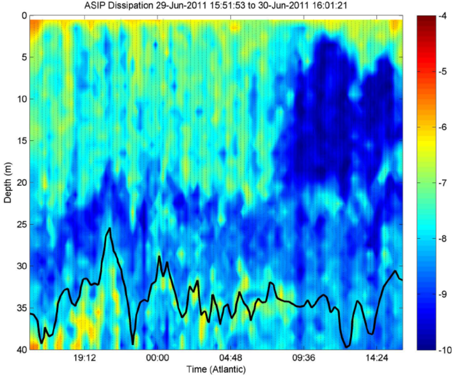
Upper Ocean Mixing: Two Deployments

- Two separate deployments show remarkably similar mixing characteristics: mixing layer shoals after heat flux changes sign, and layer gradually deepens during the day

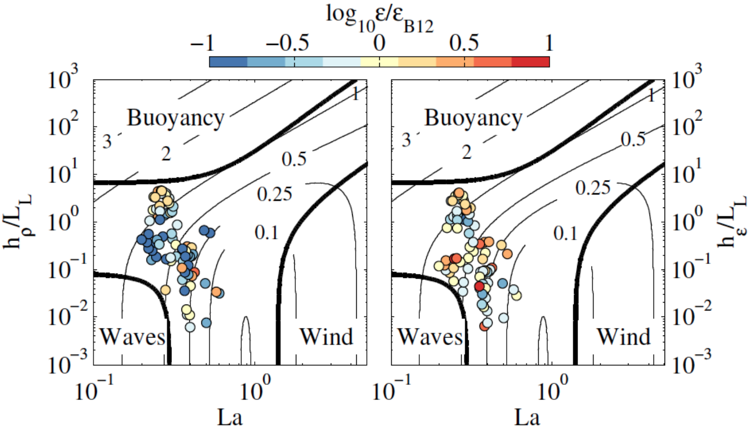
Indian Ocean 2007



North Atlantic 2011

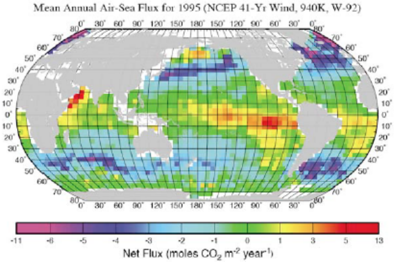


Measured values of ϵ at $z = h/2$ for MLD using ρ and ϵ thesholds



- MLD_ϵ shifts the data towards the wave-produced turbulence compared to the MLD_ρ, which is more influenced by buoyancy

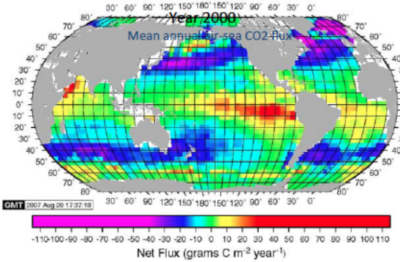
Takahashi Climatology of ocean pCO_2 Measurements



Globally integrated flux: 2.2 ± 1.2 PgC yr^{-1}

Published in 2002

Climatology for 1995

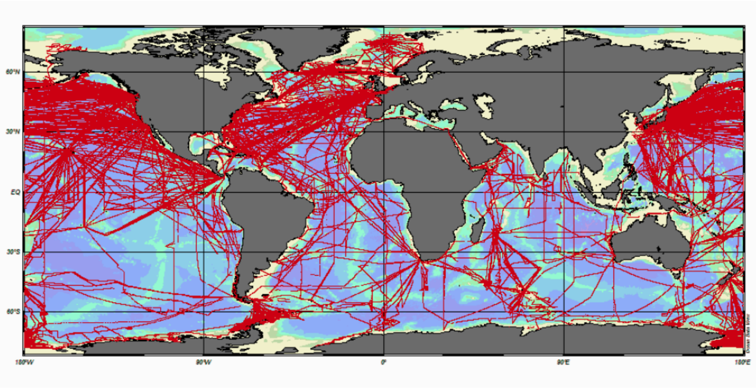


Globally integrated flux: 2.0 ± 0.7 PgC yr^{-1}

Takahashi et al. Deep Sea Research II, 2009.

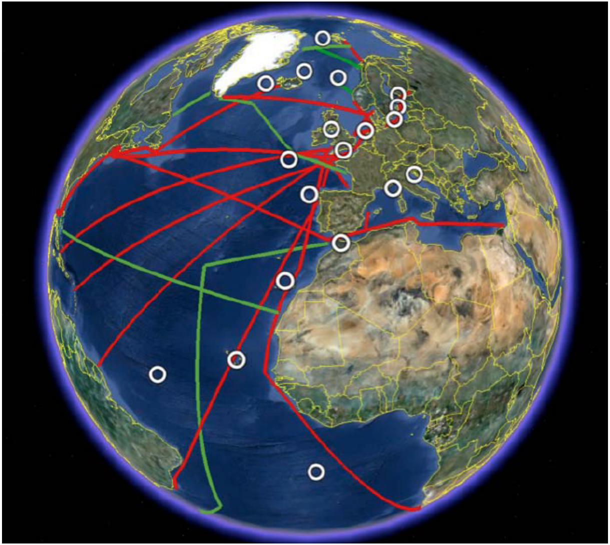
Climatology for 2000

Surface Ocean fCO2 Global database



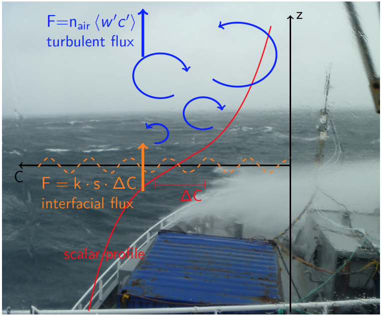
SOCAT, Pfeil and Olsen et al, ongoing.

Marine-ICOS - Integrated Carbon Integrated System

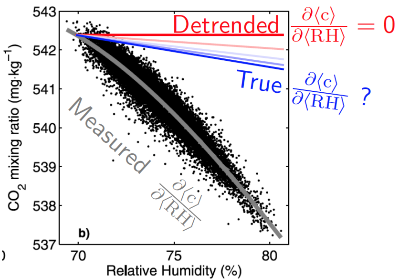


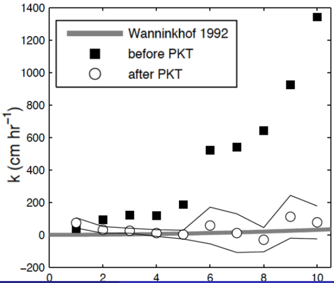
- Suggested network of stations for pCO_2 measurements
- Circles = Fixed ocean stations; Red = ships of opportunity; Green = Repeat sections

Eddy Correlation Air-Sea Fluxes of CO_2

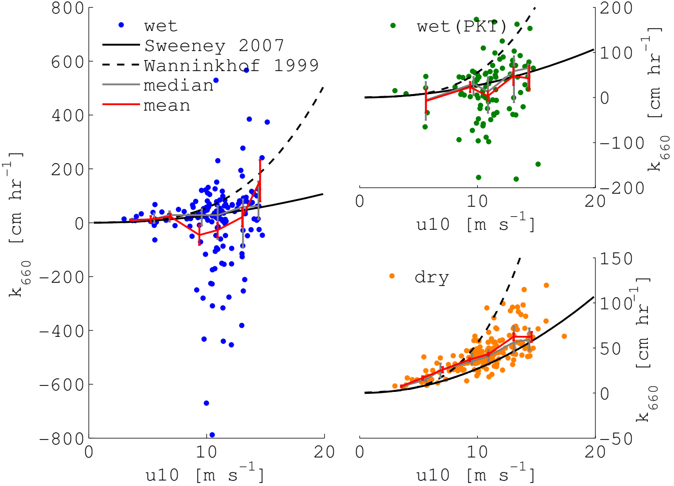


- Eddy correlation is a method for direct determination of air-sea fluxes using fast measurements of vertical velocity and CO_2 concentration
- A post processing correction method - PKT (Prytherch et al. 2010) - allowed for correction of a bias related to water vapour





Drying Reduces the Scatter in k



- PKT correction does not remove this bias, and addressing this bias requires the removal of water vapour fluctuations

Summary

- Routine measurements of upper ocean turbulence will improve modelling efforts for mixed layer dynamics
- Mixing layer depths more appropriate lengthscale than mixed layer depth?
- Surface gravity waves have a meaningful impact on OSBL dynamics and there is a need for full directional wave data measured simultaneously with turbulence parameters in the OSBL to resolve the extent to which waves impact the entire OBL
- Current efforts are progressing to oncrease the number of ocean surface pCO_2 measurements to quantify the oceanic uptake - gas transfer coefficient not well paramaterised
- Eddy covariance measurements can provide direct flux measurements and therefore gas transfer coefficient; however current gas analyser instrumentation for CO_2 is not adequate for air-sea direct flux measurements

SOLAS Open Science Conference 2015

ESA-SOLAS Conference 2014