We understand air-sea exchange, iron cycle and weathering

State of today

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- Choose between two setups:
  - OMIP `if lomip`
    - Schmidt-numbers and Solubility as in OMIP CMIP6 Protocol
      - Based on Wannikhof (2014)
  - NOT OMIP `if not.lomip`
    - Older model version, older references; just backup; won‘t stay in code
- Choose where to calc CO2flux:
  - atmospheric side in ECHAM (see ECHAM mo_co2.f90)
  - ocean side in HAMOCC carchm.f90

  → difference in coupling frequency

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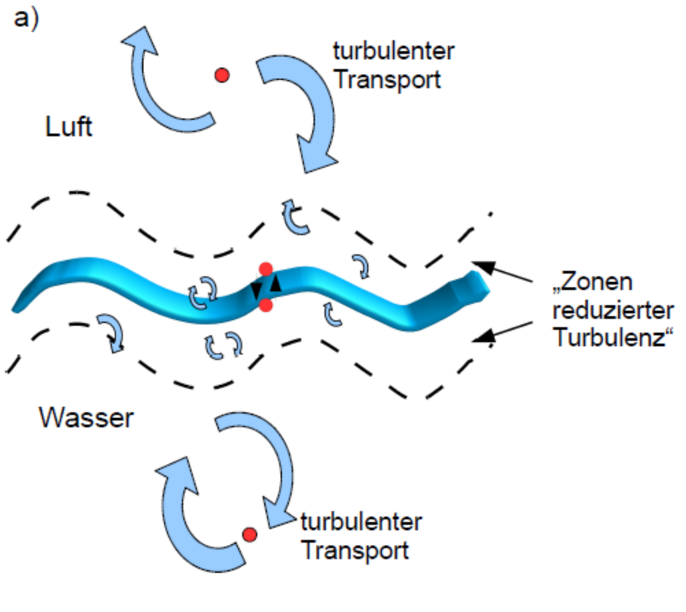
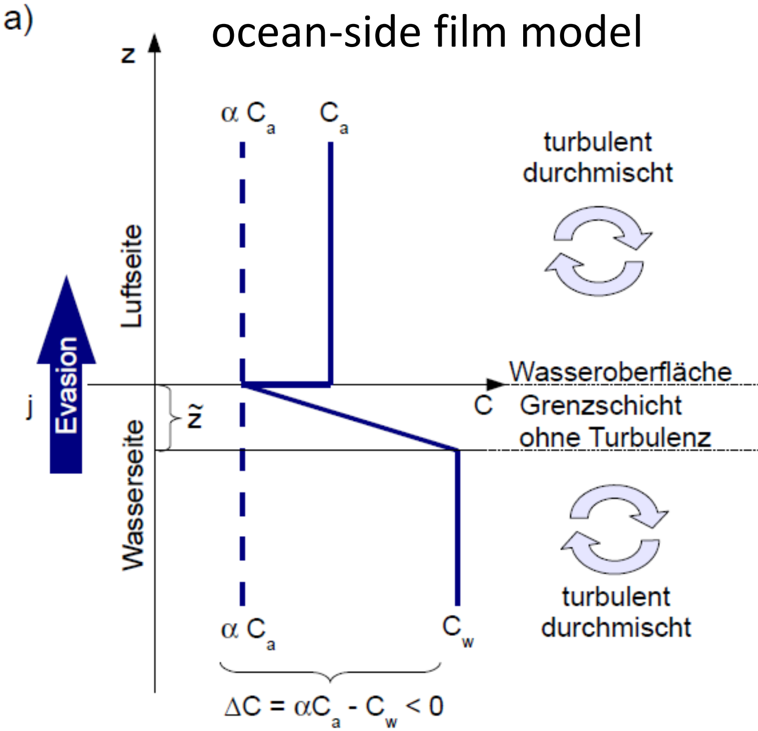
Air-sea exchange implementation

2-side film model



ocean-side film model



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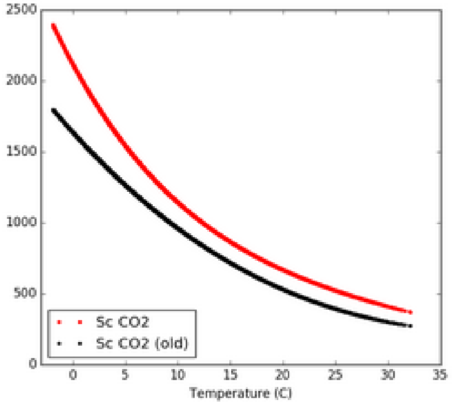
Air-sea exchange: The concept

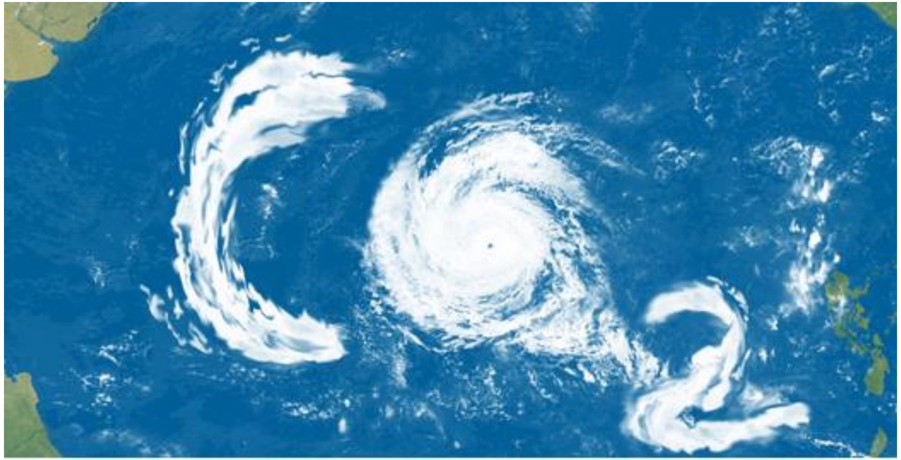
- X = CO_2, O_2, DMS, N_2, N_2O concentation in ocean [ppmv]
- $\dfrac{\Delta X}{\Delta t} = \dfrac{-V_X}{\Delta z_1}\left(X - S_X \dfrac{pX^{atm}}{const}\right)$
- S_X = Solubility in seawater – Meerwasserlöslichkeit
- V_X = $a \left(\frac{Sc}{660}\right)^{-1/2} u^2 (1-f_i)$ transfer velocity [m/s]
- Sc =Schmidt-number ~4th order polynomial of T
- u: wind velocity, f_i: sea-ice cover, a: conversion factor (new OMIP)



CO_2

$$\frac{\Delta C_T^{12}}{\Delta t} = \frac{V_{CO2}}{\Delta z_1^t} S_{CO2} \left(pCO_2^{atm} - pCO_2^{water}\right)$$

- New: pressure effect (Weiss 1974)
  $*(p_{total,atm} - p_{1013})$ not implemented yet



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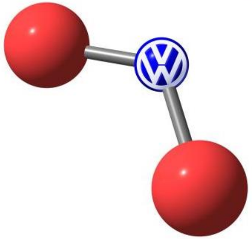
O_2

- As in Meiner-Reimer et. al, 2005, Eq. 74
- Solubility S_{O2} from Weiss (1970)
- pressure effect Weiss (1974)

  $*(p_{total,atm} - p_{1013})$

$$\frac{\Delta \mathrm{O}_2}{\Delta t} = \frac{-V_{\mathrm{O}_2}}{\Delta z_1^t} \left(\mathrm{O}_2 - S_{\mathrm{O}_2} \frac{pO_2^{atm}}{196800} \right)$$



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N_2O and N_2

- follows Meiner-Reimer et. al, 2005, Eq. 75
- S_{N2} from Weiss (1974)
- same piston velocity as for O_2
- Sc and piston velocity are same from N_2O and N_2

$$\frac{\Delta \mathrm{N_2}}{\Delta t} = \frac{-V_{\mathrm{O_2}}}{\Delta z_1^t}\left(\mathrm{N_2} - S_{\mathrm{N_2}}\,\frac{pN_2^{atm}}{802000}\right)$$

$$\frac{\Delta \mathrm{N_2O}}{\Delta t} = \frac{-V_{\mathrm{O_2}}}{\Delta z_1^t}\left(\mathrm{N_2O} - S_{\mathrm{N_2O}}\right)$$

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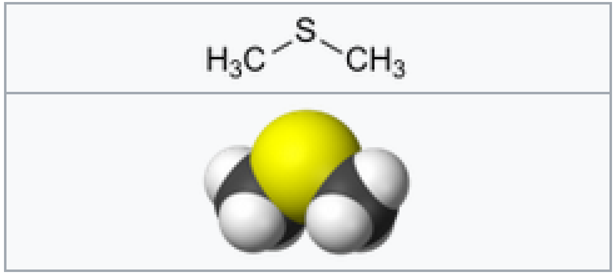
DMS

- after Meiner-Reimer et. al, 2005, Eq. 77
- assumes p_{DMS_atm}= 0

$$\frac{\Delta \mathrm{DMS}}{\Delta t} = \frac{-V_{\mathrm{DMS}}}{\Delta z_1^t}\,\mathrm{DMS}$$

Dimethyl sulfide



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Iron Cycle

- Dust deposition (Dep_d) added to surface layer as FDUST [kg m-3]
  - Climatology
  - Alternative dust fields possible
- Dust particles have same diameter and sinking speed

$$\frac{\Delta \mathrm{FDUST}}{\Delta t} = \frac{Dep_d}{\Delta z_1^t}$$

Life of iron

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$$\frac{\Delta \mathrm{FE}}{\Delta t} = \frac{Dep_d}{\Delta z_1^t} \times \epsilon_{Fe} \times S_{Fe}$$

- Dissolves (FE) 3.5% partly (ϵ_{Fe}) at const. solubility S_{Fe} 1%
- Relaxation time constant λ_{Fe} (Johnson et al. 1997)
  - Dissolved iron is complexed by strong iron binding ligands, hence lost for bio

$$\frac{\Delta \mathrm{FE}}{\Delta t} = \frac{\Delta \mathrm{PO}_4}{\Delta t} R_{Fe:P} - \lambda_{\mathrm{FE}} \max\left(0, \mathrm{FE} - \mathrm{FE}_0\right)$$

- Chemically inert: only sinks to sediment
- FE needed for phytosynthesis, released by remineralization at fixed Redfield ratio $R_{Fe:P}$

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Weathering

- To adjust for losses to sediment
- Aims for stable nondrifting runs
- According to a uniform rate deltasil/org/calc to be adjusted in the runscript
- Gets added to pools in top layer
  - calc into DIC
  - 2*calc into alkali $CO3^{--}$
  - org into DOC
  - sil into silicate

Literature citations in code

- Johnson et al., (1997), What controls dissolved iron concentrations in the world ocean?, Mar. Chemistry 57, 137-161
- Orr et al. (2016), Geosci. Model Dev. Discuss., CMIP6 Protocol
- Meiner-Reimer et. Al., (2005)
- Wanninkhof (1992, J. Geophys. Res., 97, 7373-7382)
- Weiss, R.F. (1974). Carbon dioxide in water and sea water: The solubility of a non-ideal gas. Marine Chem., 2, 203–215.
- Wanninkhof, R.: Relationship between wind speed and gas exchange over the ocean revisited, Limnol. Oceanogr. Methods, 12, 351–362, (2014)