Wind, *buoyancy* and fetch dependent gas transfer velocity in an Arctic sea-ice lead determined from eddy covariance CO_2 flux measurements

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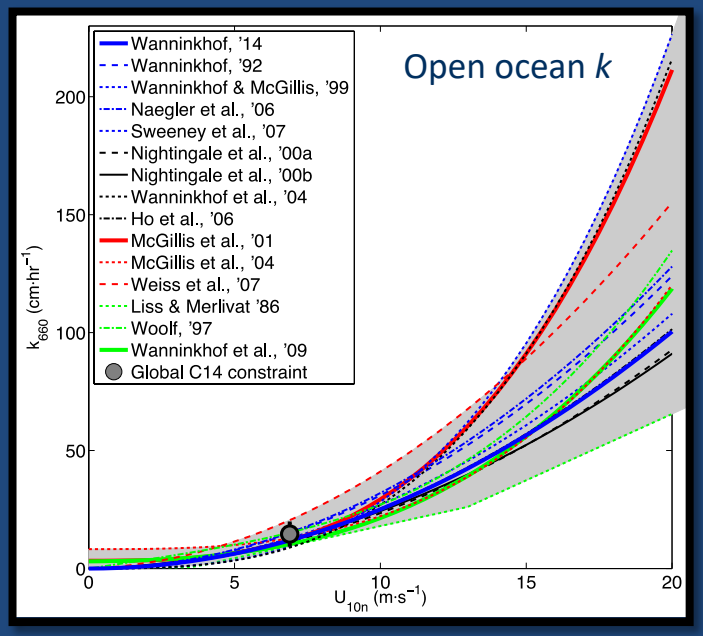
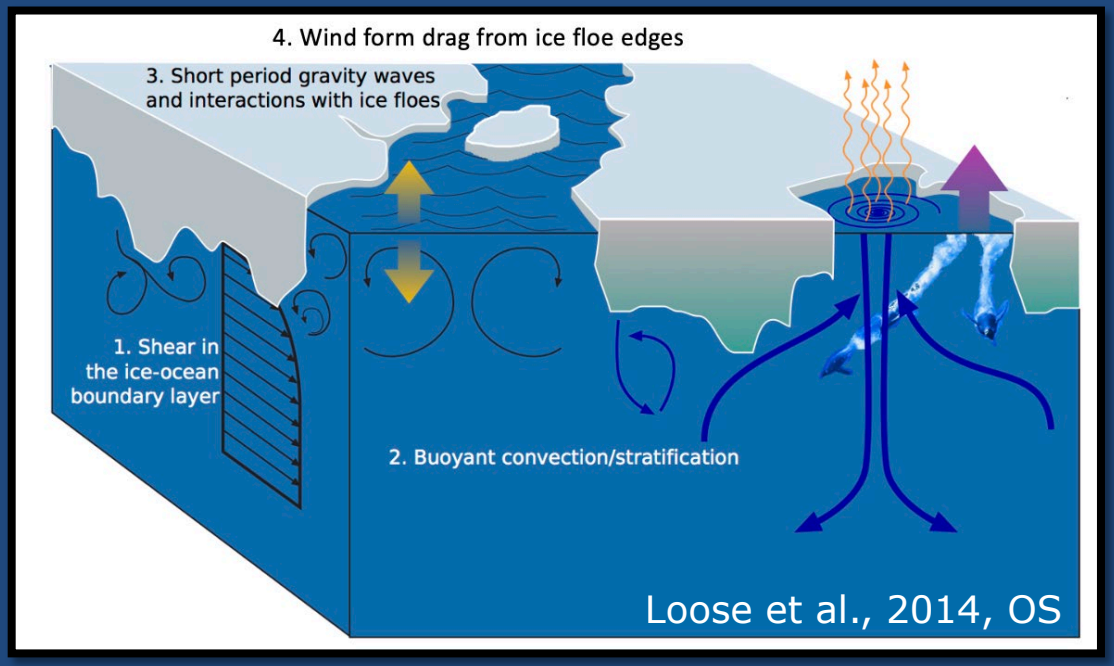
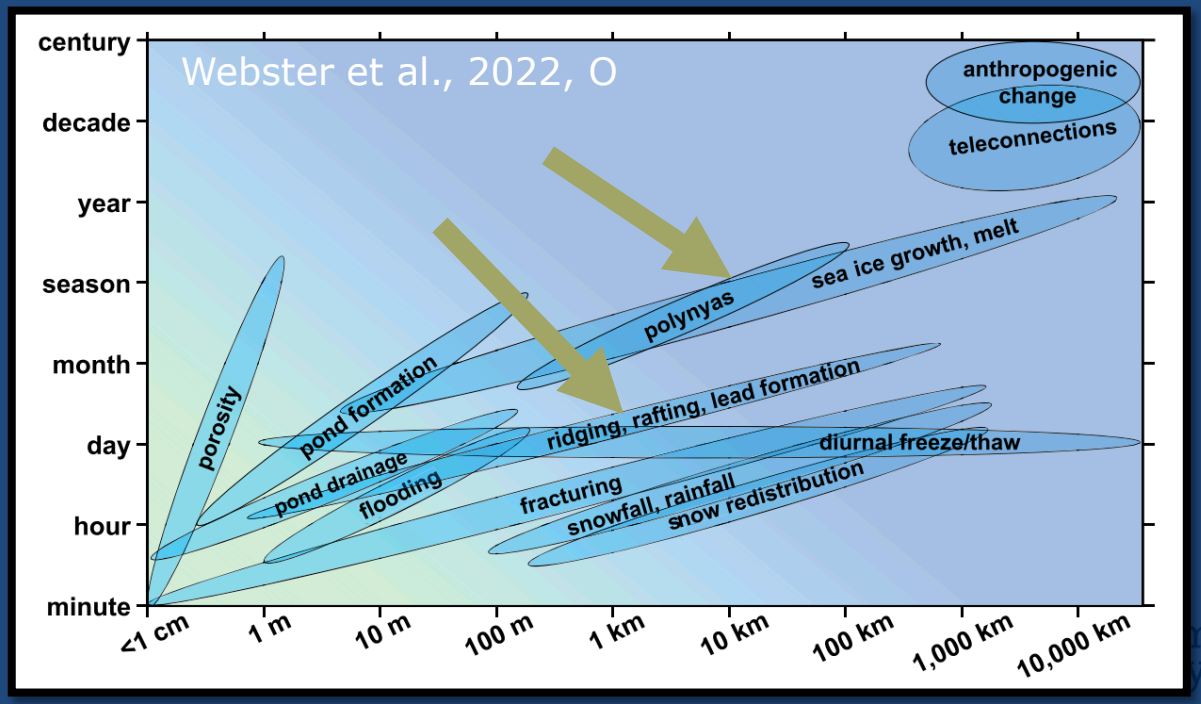
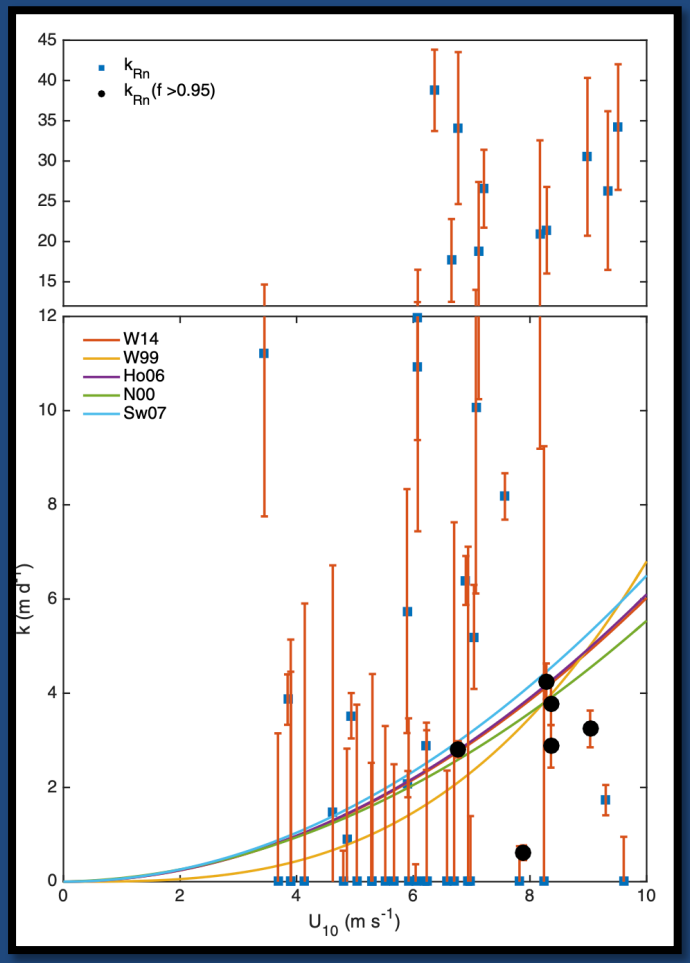






_k_ in sea-ice regions: challenges



Loose et al., 2017, JGR

k in sea-ice regions: observations

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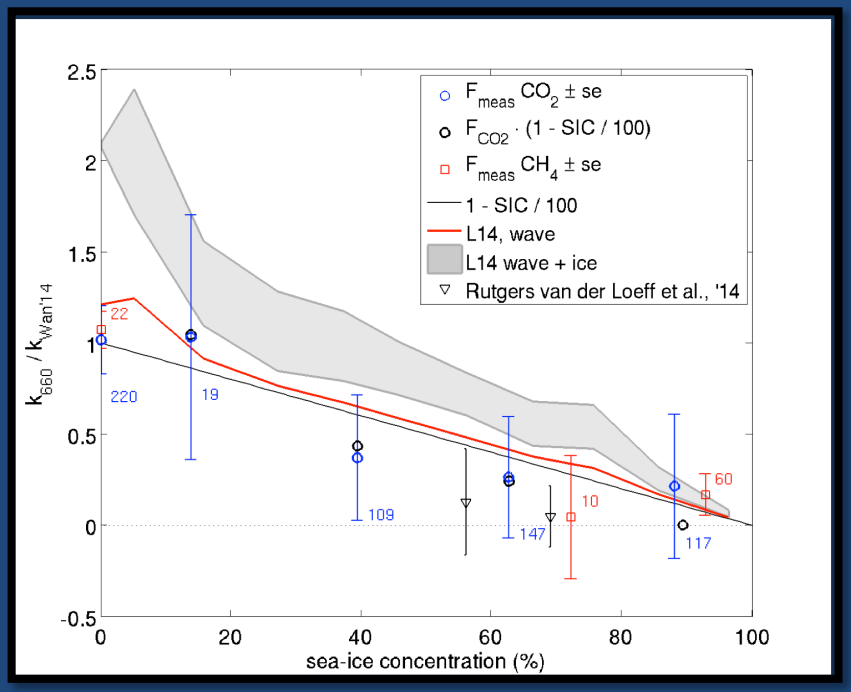
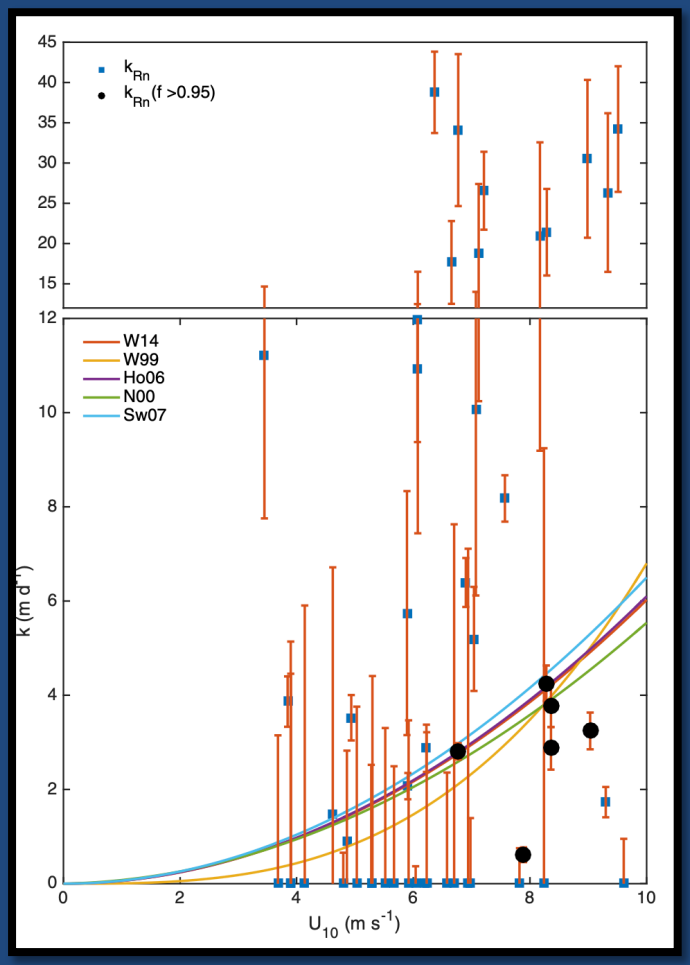
Prytherch et al., 2017, GRL





Loose et al., 2017, JGR

_k_ in sea-ice regions: observations

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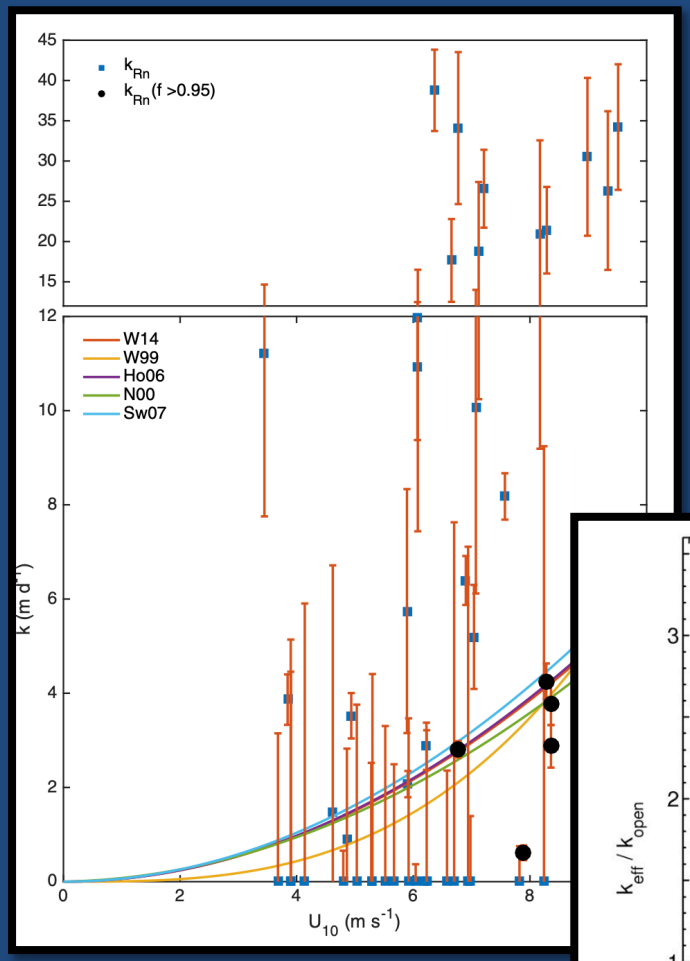
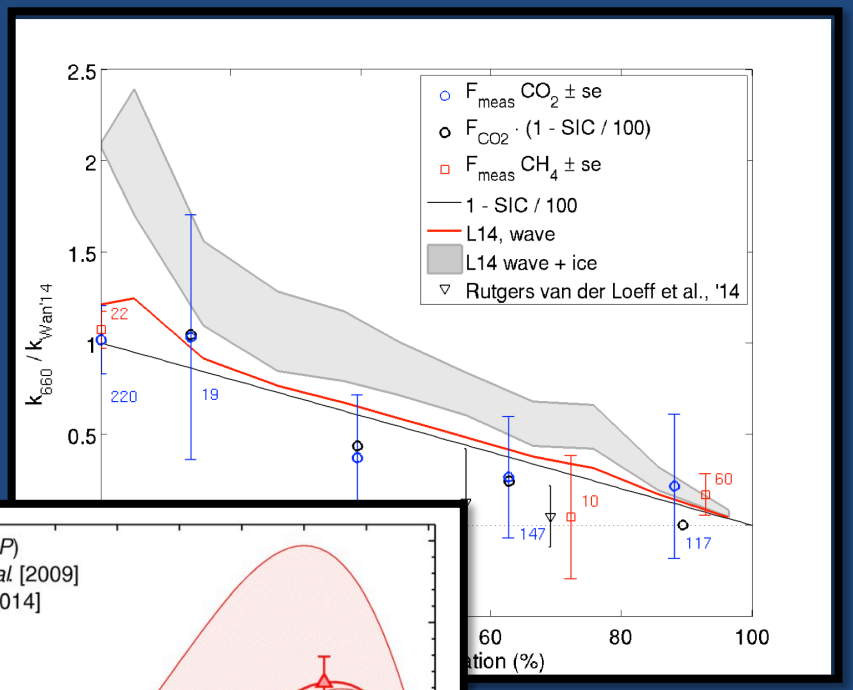
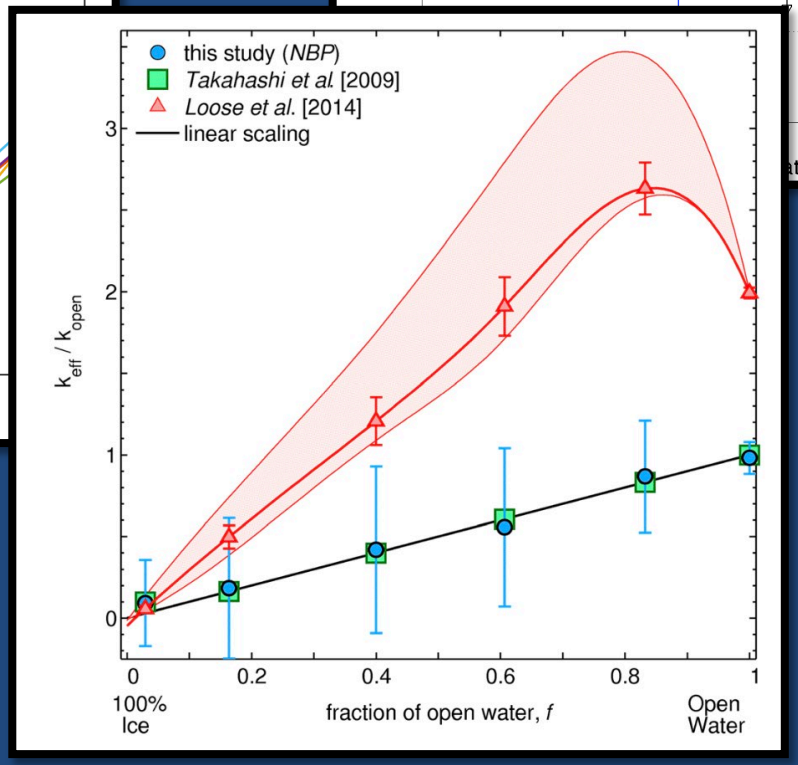


Loose et al., 2017, JGR





Butterworth and Miller, 2016, GRL

_k_ in sea-ice regions: observations

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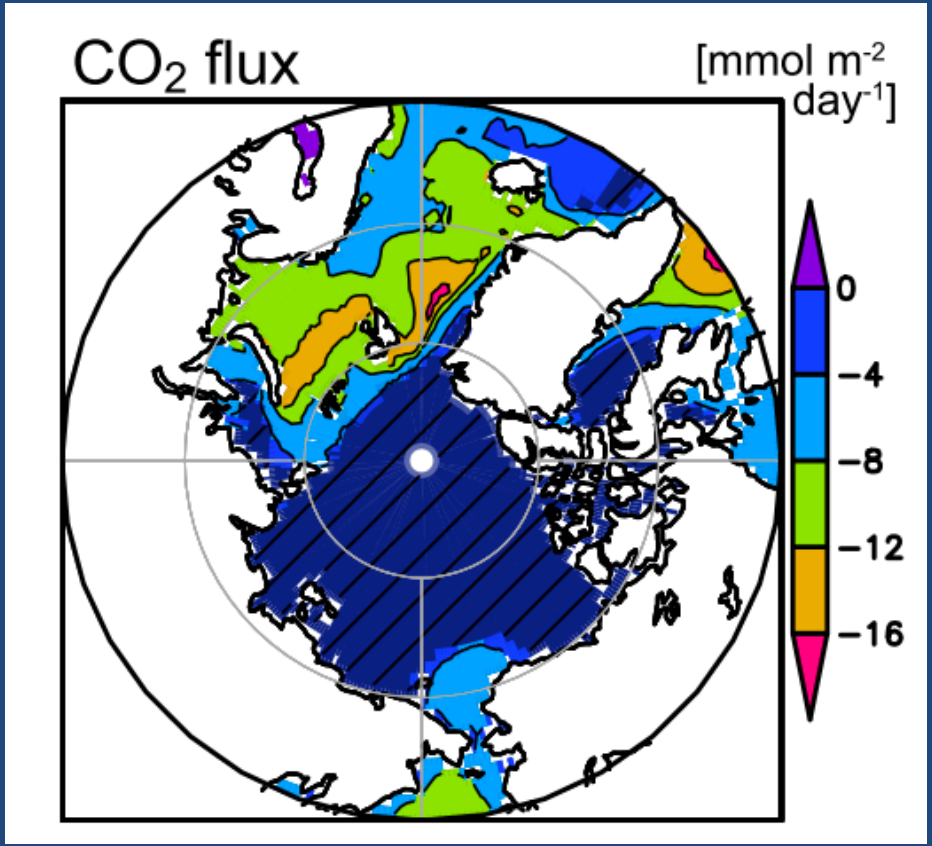
k in sea-ice regions: impacts

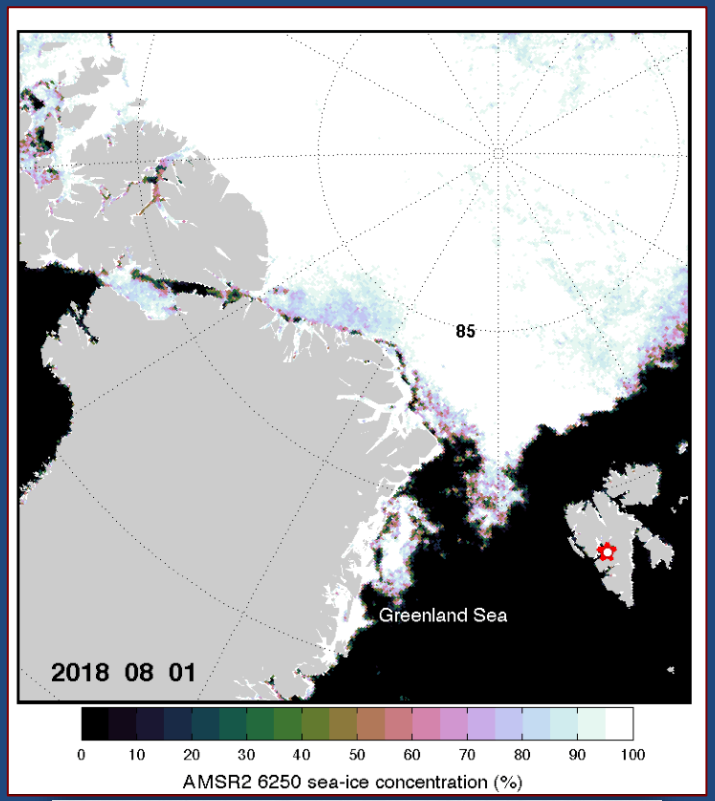


Data-based (self-organizing map inc' SOCATv4 fCO_2 and *chl-a*) Arctic Ocean flux estimate

Enhanced *k* in sea ice (Loose et al., 2009): 180 ± 130 Tg C yr^{-1} (~12% net global uptake)
Linearly scaled *k* in sea ice: 130 ± 110 Tg C yr^{-1}

Yasunaka et al., 2018, Bg

Arctic Ocean 2018 expedition



open lead measurement site

Oden's mooring

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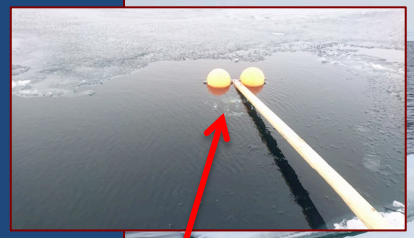
Open lead 2.5 m flux tower

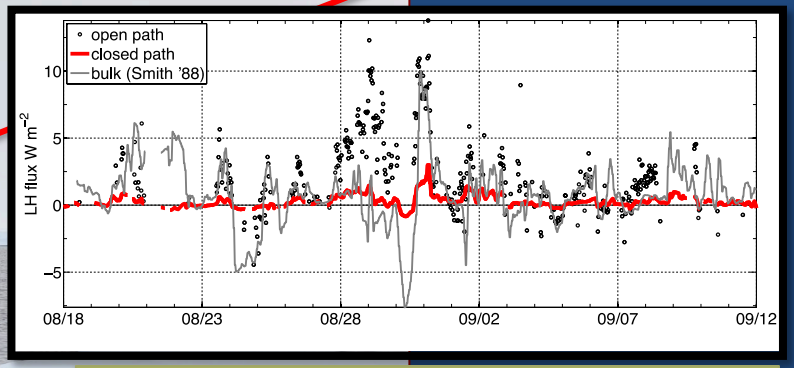
Lead surface temperature sensor (IR)

Closed-path (CO_2) and open-path (H_2O) IR gas analysers

Heated 3D sonic anemometer

Aspirated T RH





Water vapor cross-sensitivity can be a significant challenge for EC CO2

Here, v low humidity flux: humidity bias < 1% (Blomquist et al., 2014 BLM)

photo: M. Hoppmann, AWI.

pCO_2w sensor

GPS

12V / 24V battery power

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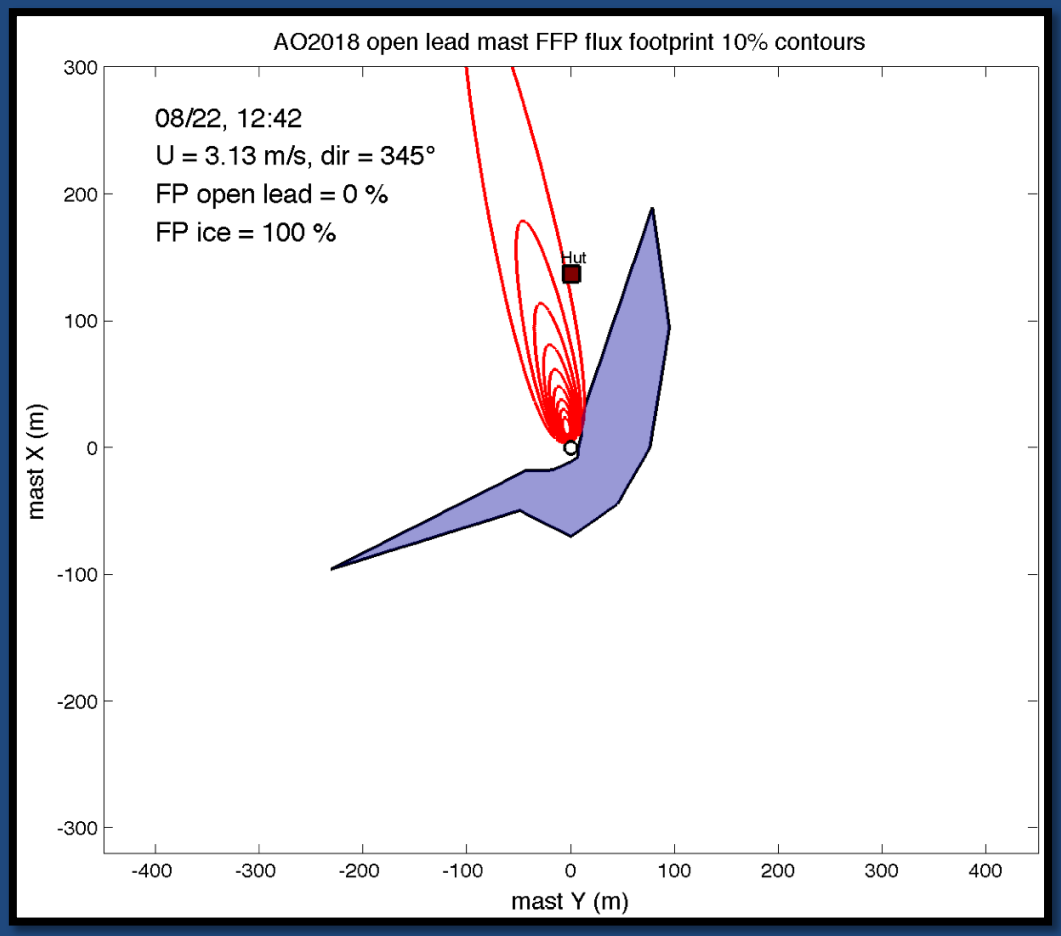
Lead dimensions and flux footprint



2D footprint model (Kljun et al., 2015, GMD)

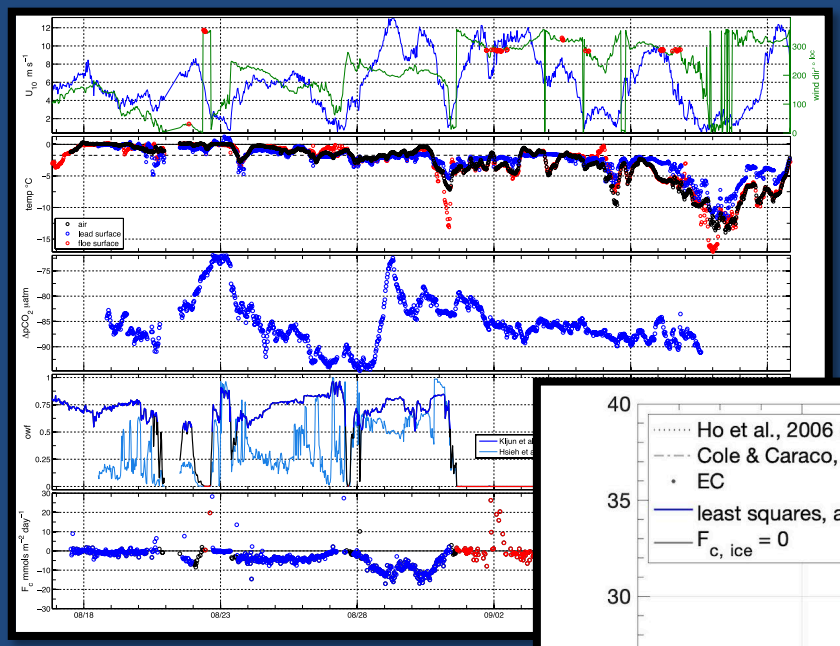
Use footprint surface fraction (FP) analysis to determine flux (F) through lead water.

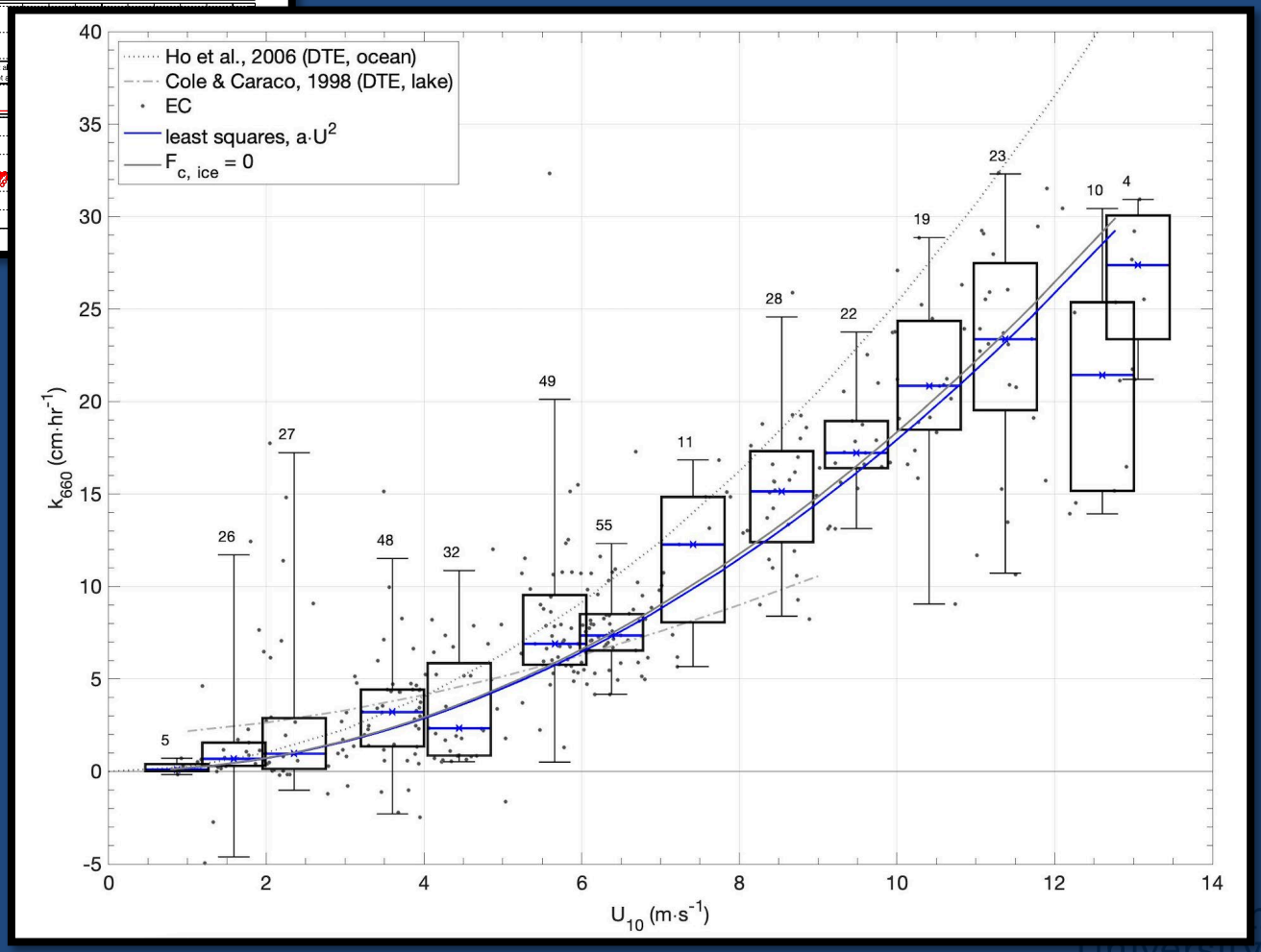
$$F_{measured} = F_{water} * FP_{openlead} + F_{ice} * FP_{ice}$$

F_{ice} determined from average of $F_{measured}$ when FP_{ice} = 100%

Wind driven *k* in a sea-ice lead

>> In leads, *k* reduced relative to open ocean



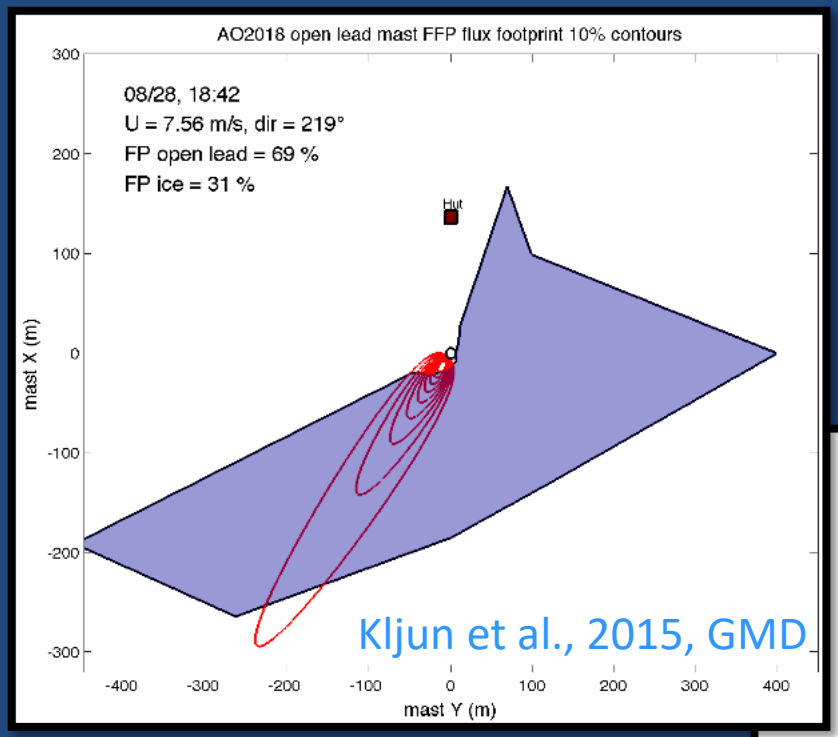


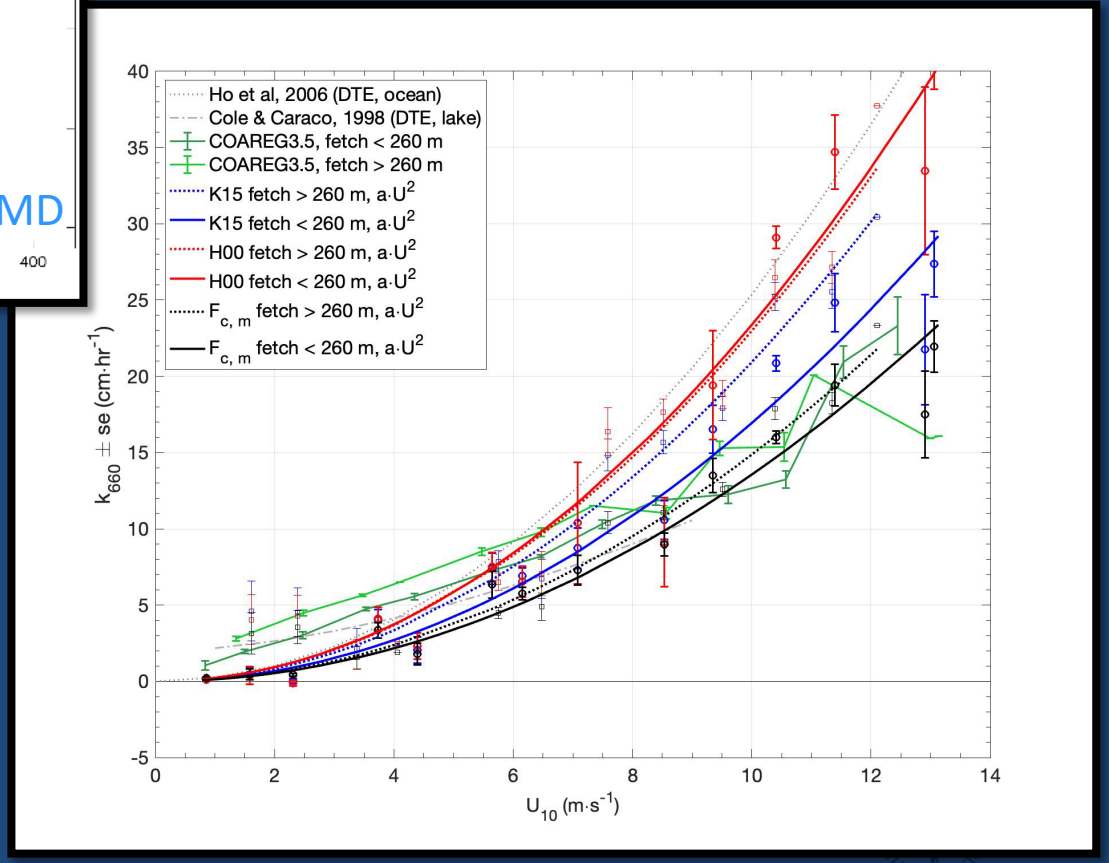
= 359 30-min fluxes
fit / H06 = 0.71
If $F_{c,\ ice} = 0$, ratio 0.73

Prytherch & Yelland, 2021, GBC

Fetch dependence

- Relatively large fetch and high winds: small breaking waves and whitecaps observed.
- Fetch dependence is FP model-dependent.
- No FP model validated in a sea-ice environment.





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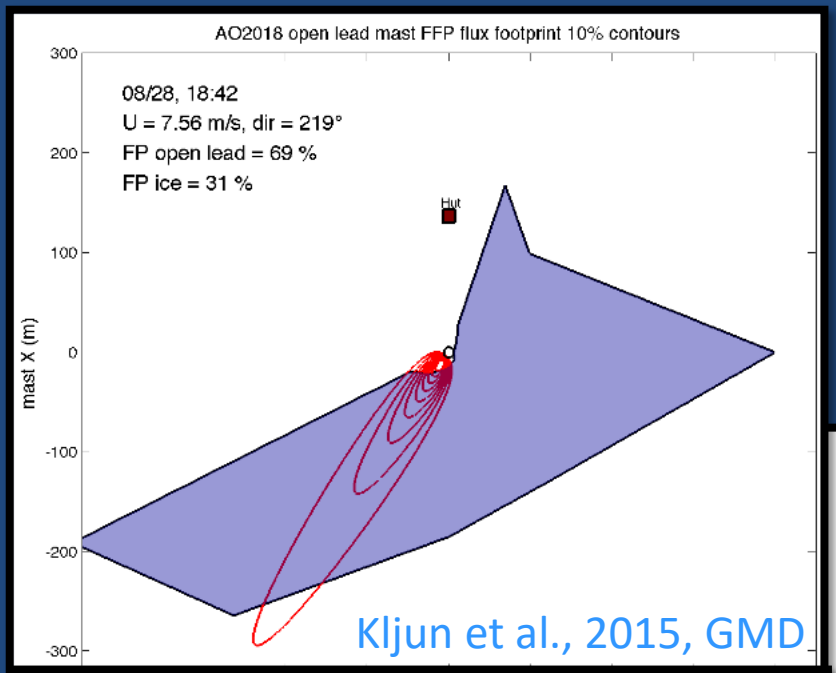

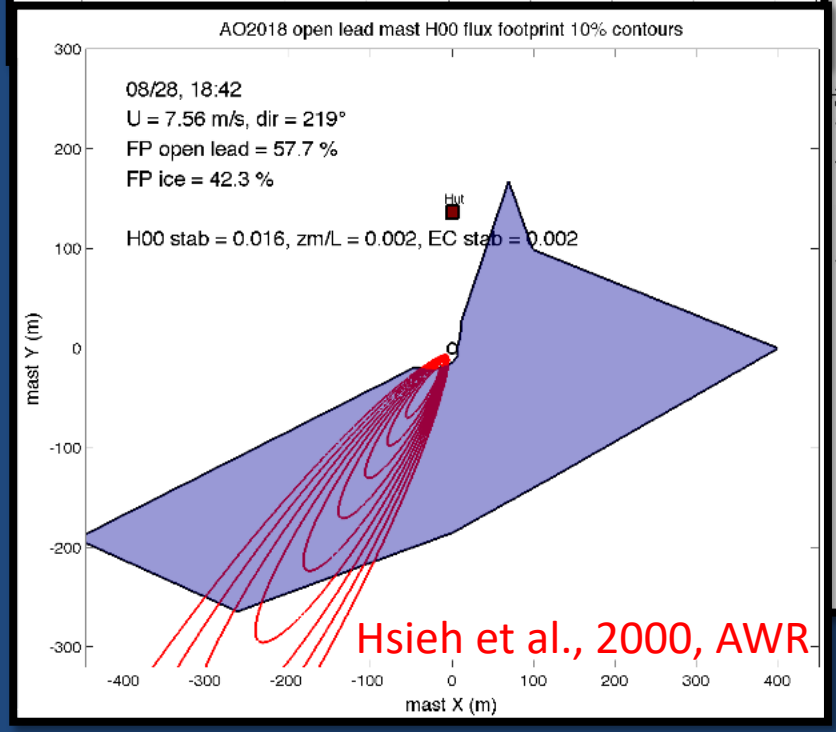

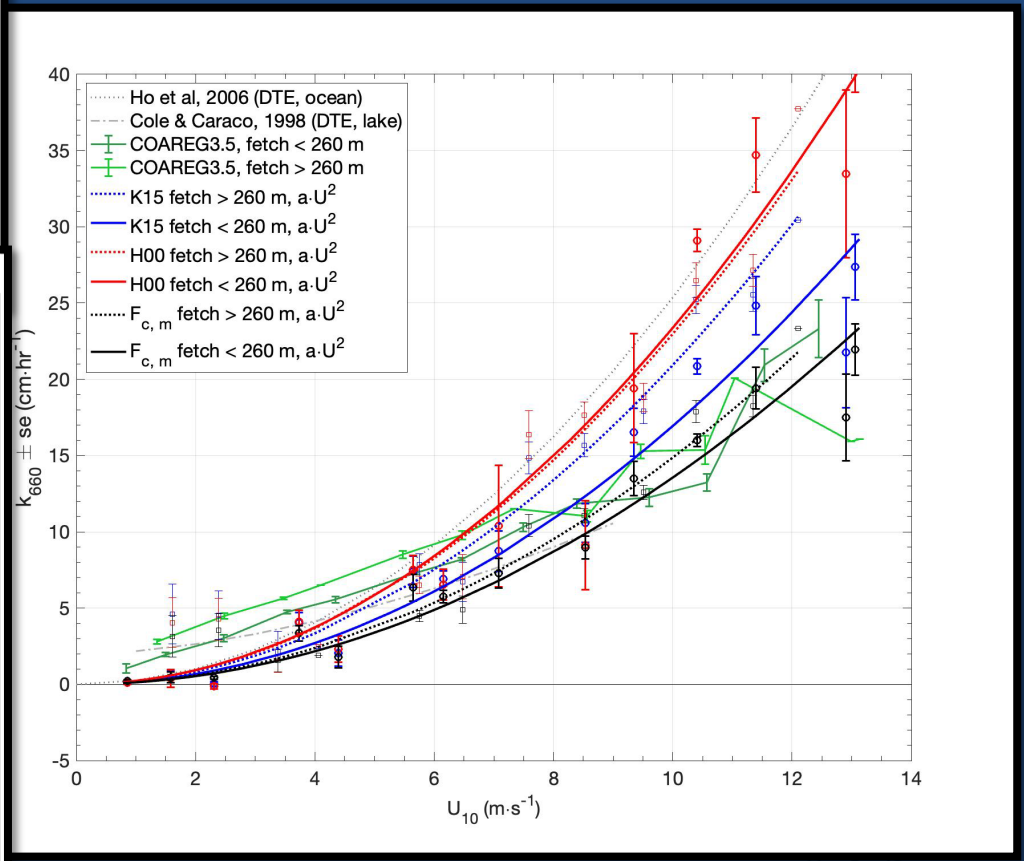

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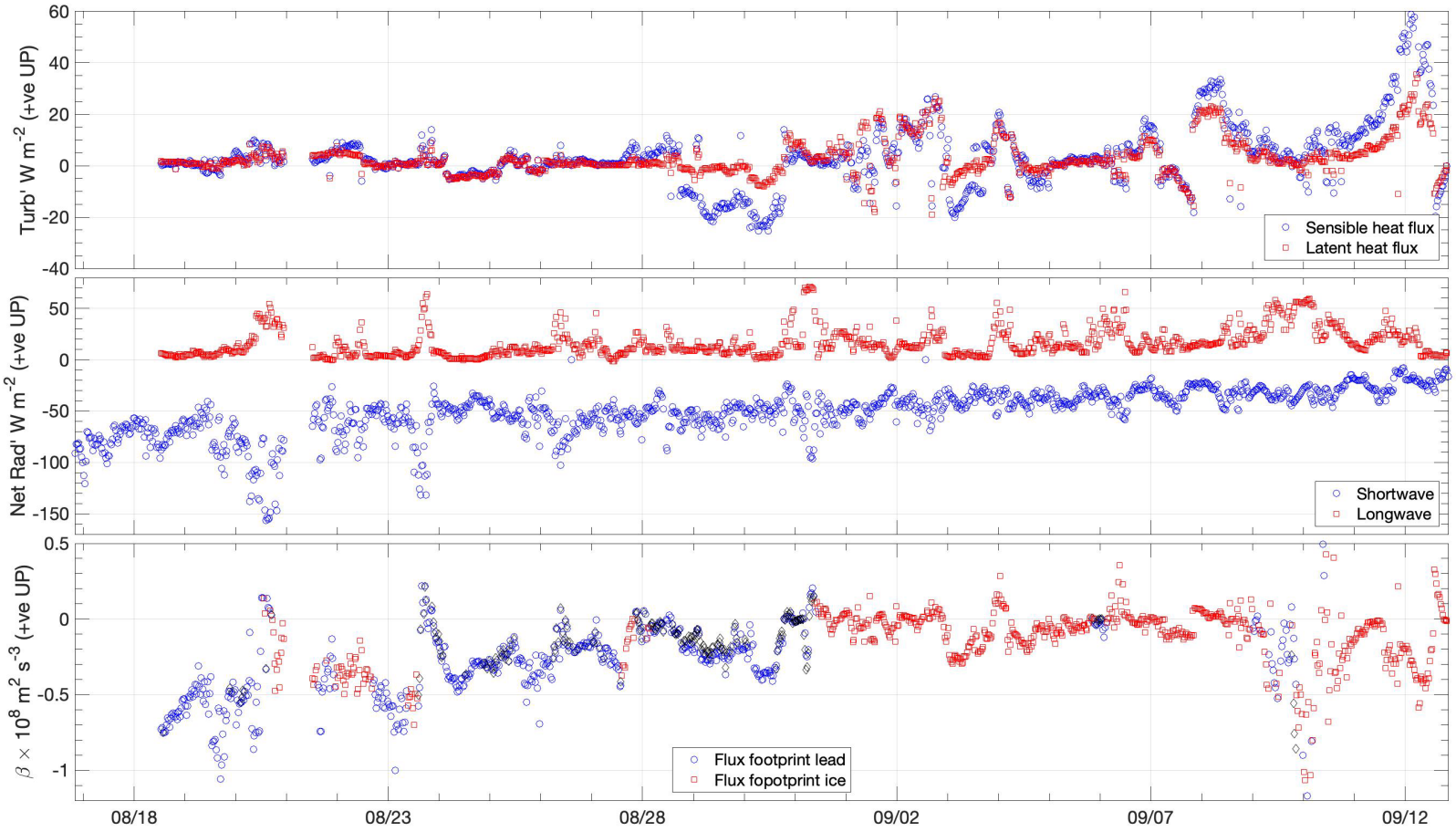
Buoyancy



$$B = H^* g \alpha C_p^{-1} \rho^{-1}$$

H* = SHF + LHF + net LW + net SW

e.g. MacIntyre et al., 2009 L&O

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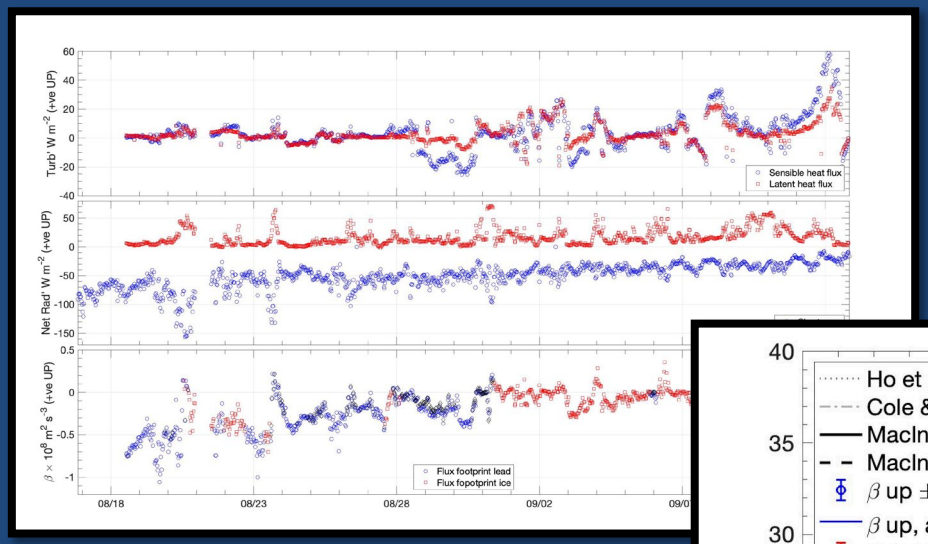
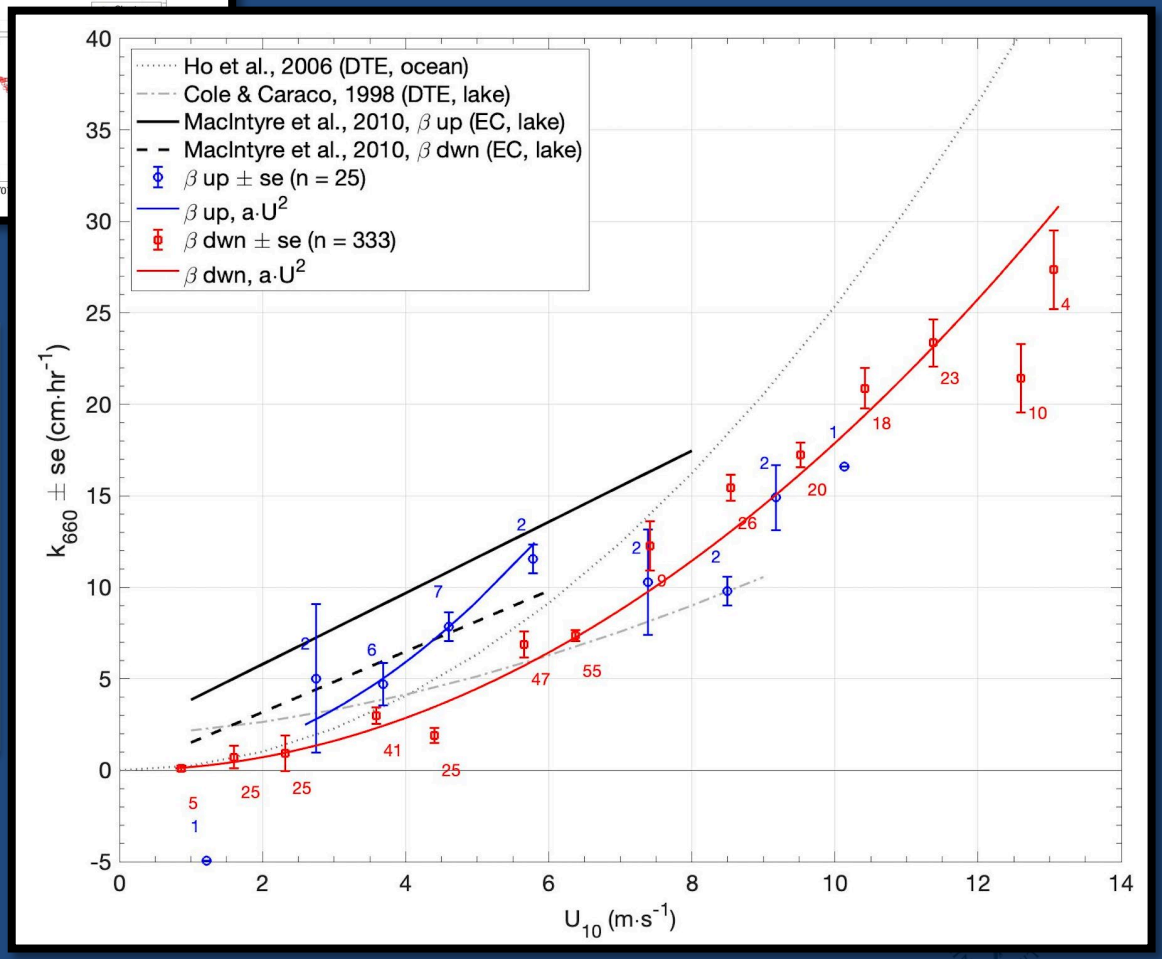
Buoyancy





Associated with autumn freeze-up and winter lead opening.

Summer convective periods occur during (infrequent) clear-sky conditions

$$B = H^* g \alpha C_p^{-1} \rho^{-1}$$

H* = SHF + LHF + LW + SW

e.g. MacIntyre et al., 2009 L&O

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Conclusions

- Observed wind-speed dependent *k* in a sea-ice lead, but reduced ~30% relative to typical ocean values
- Buoyancy-driven enhancement of k observed during surface cooling periods associated with clear-sky conditions
- Relating fluxes, forcing and measurements across a range of scales is a challenge

Poster: preliminary sea-ice lead chamber flux measurements

Thanks for listening!

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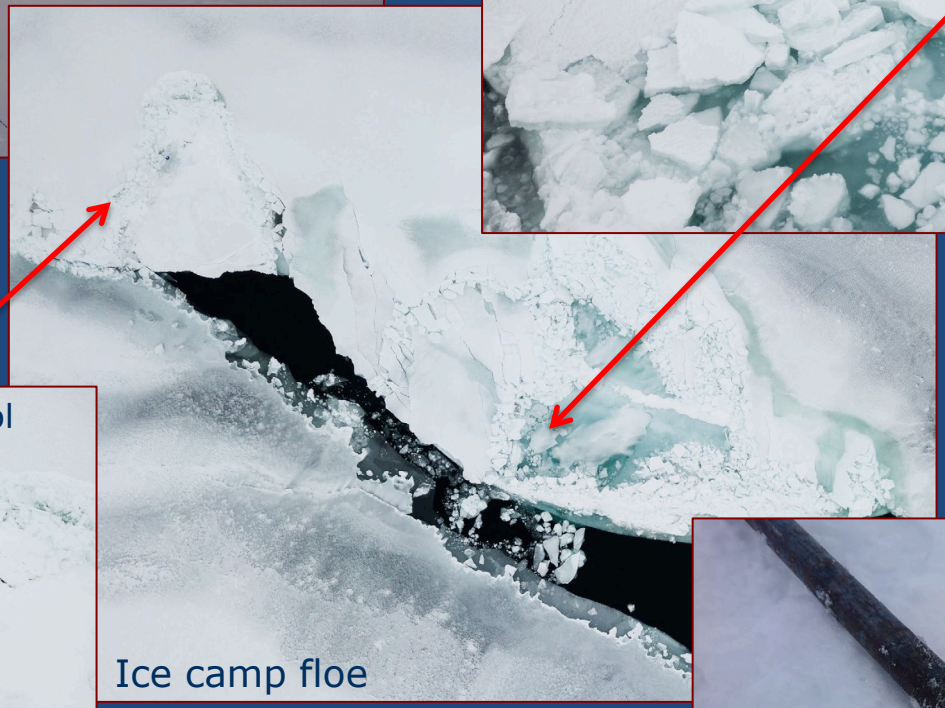
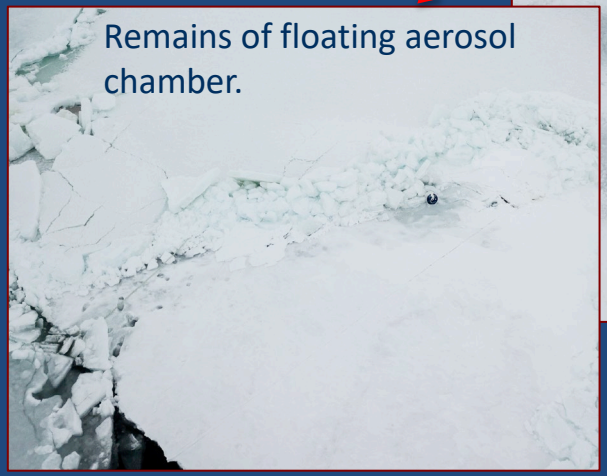
Challenges of working on sea ice

Pressure ridge forming

Flux mast aluminium boxes



Ice camp floe



Remains of floating aerosol chamber.

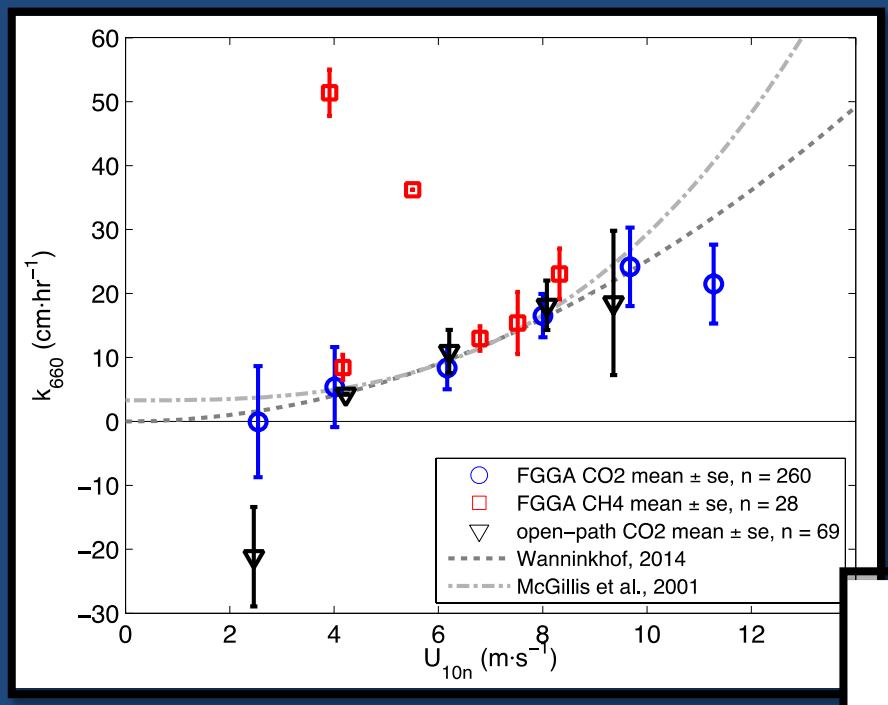
Sheared-off shackle on ice anchor

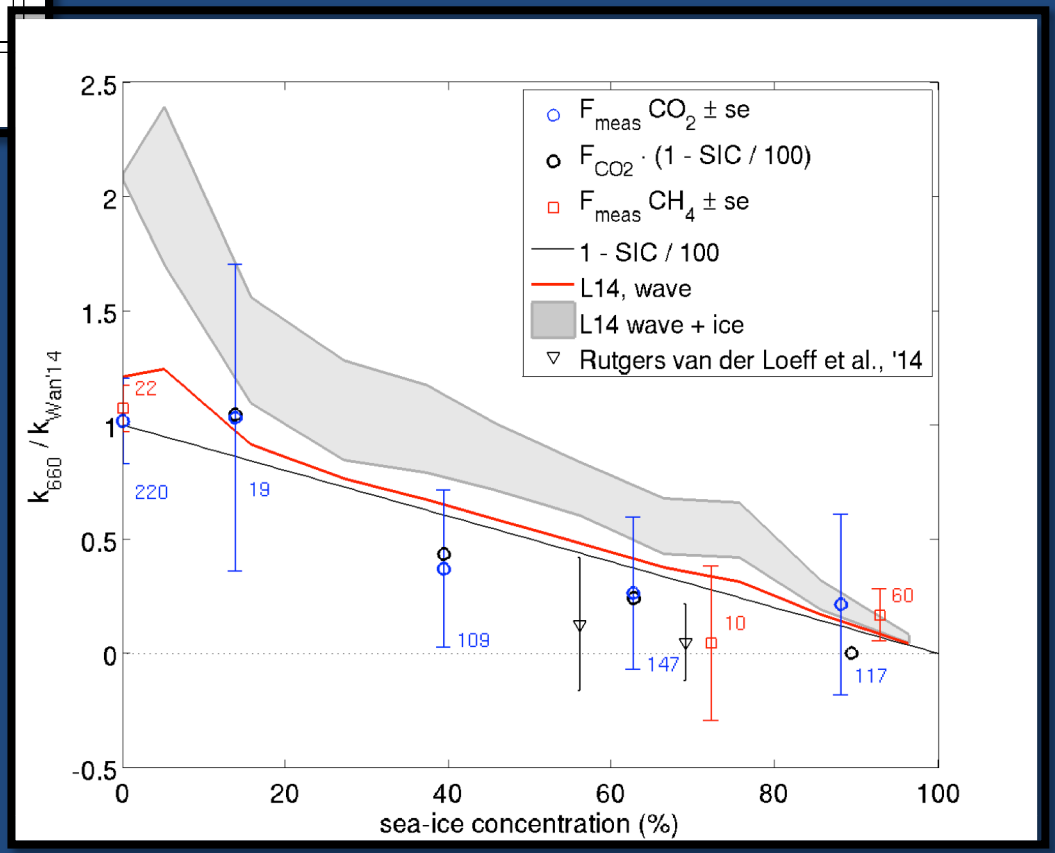
SWERUS-C3 gas transfer rate

Siberian shelf seas, 2014

Open ocean CO_2 fluxes (k) agree with bulk parameterisations.

CH_4 fluxes from seeps: footprint vs pCH_4w measurement location





Only ship-based EC CO_2 flux measurements in Arctic sea ice

Flux through ice surface and melt ponds estimated.

Prytherch et al., 2017, GRL

Icebreaker Oden eddy covariance CO_2 CH_4 flux system

- Operational since 2014 (5 Arctic expeditions to date …)
- Motion-corrected winds (Edson et al., 1998, JTech; Prytherch et al., 2015, ACP)