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Air-Sea Fluxes of CH_4 and CO_2 from the Penlee Point Atmospheric Observatory (PPAO)

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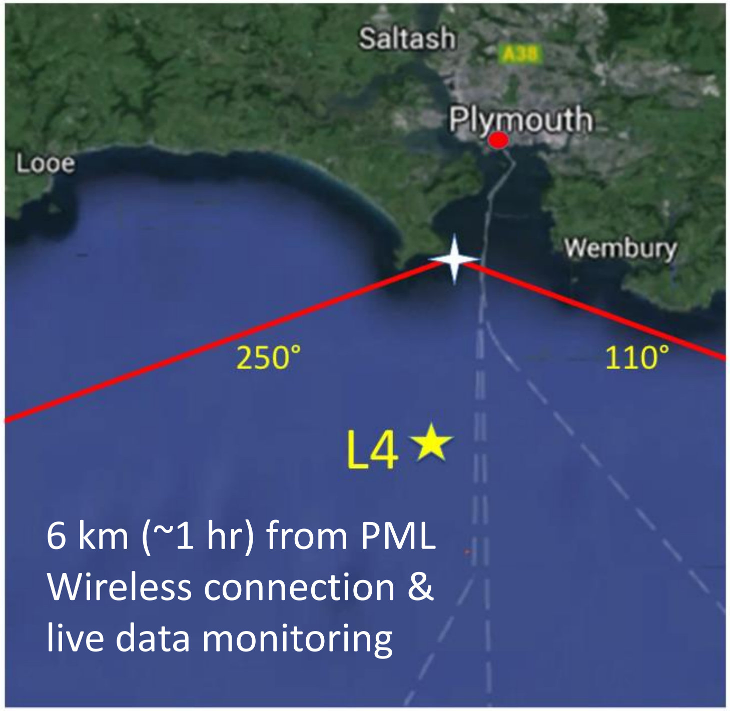
Outline

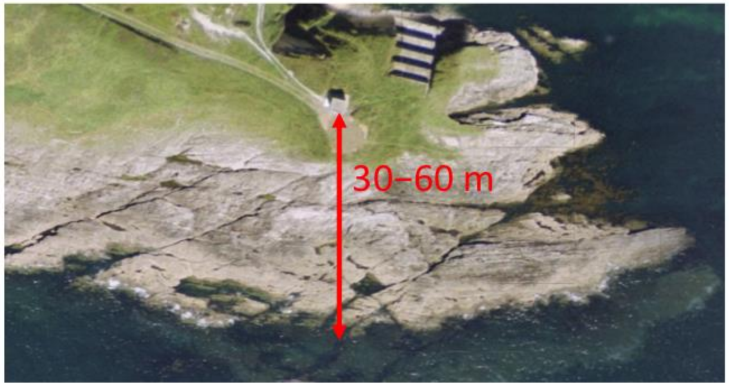
1. Variability in eddy covariance CH_4 and CO_2 fluxes from Penlee Point Atmospheric Observatory

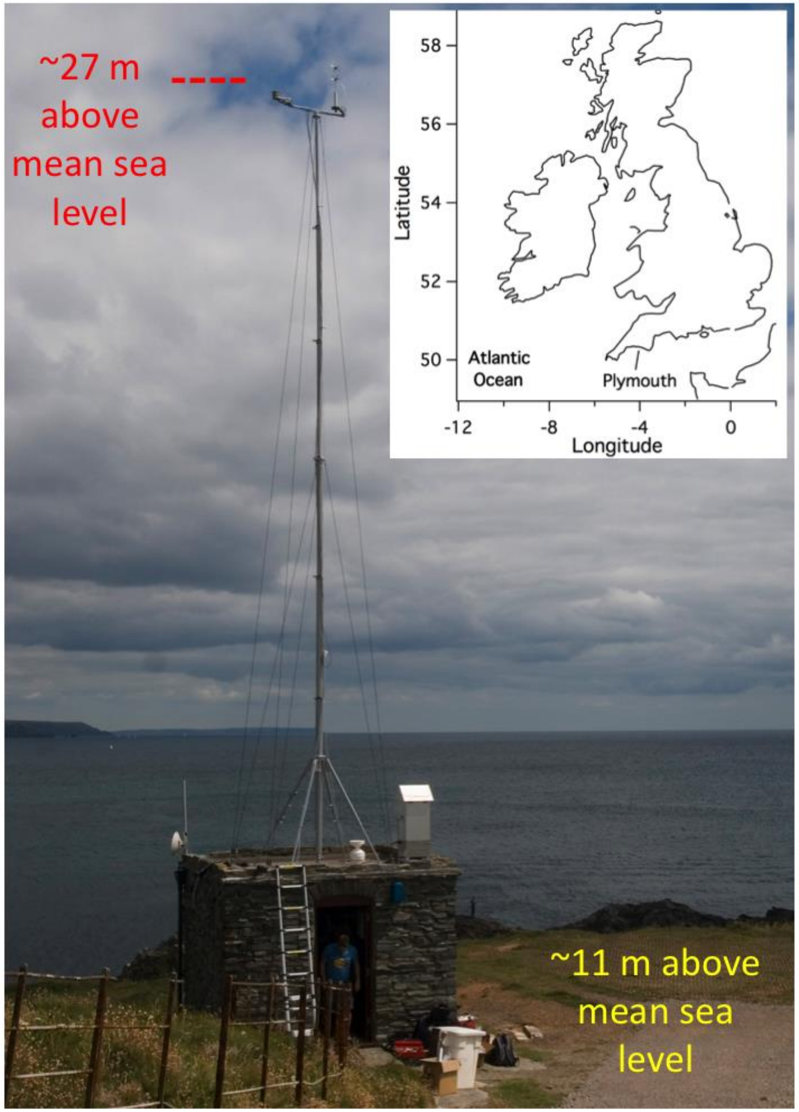
2. Inter-comparison between Picarro G2311f and Los Gatos Research FGGA sensors for measuring CH_4 and CO_2 fluxes

Penlee Point Atmospheric Observatory (est. 2014)

http://www.westernchannelobservatory.org.uk/penlee/





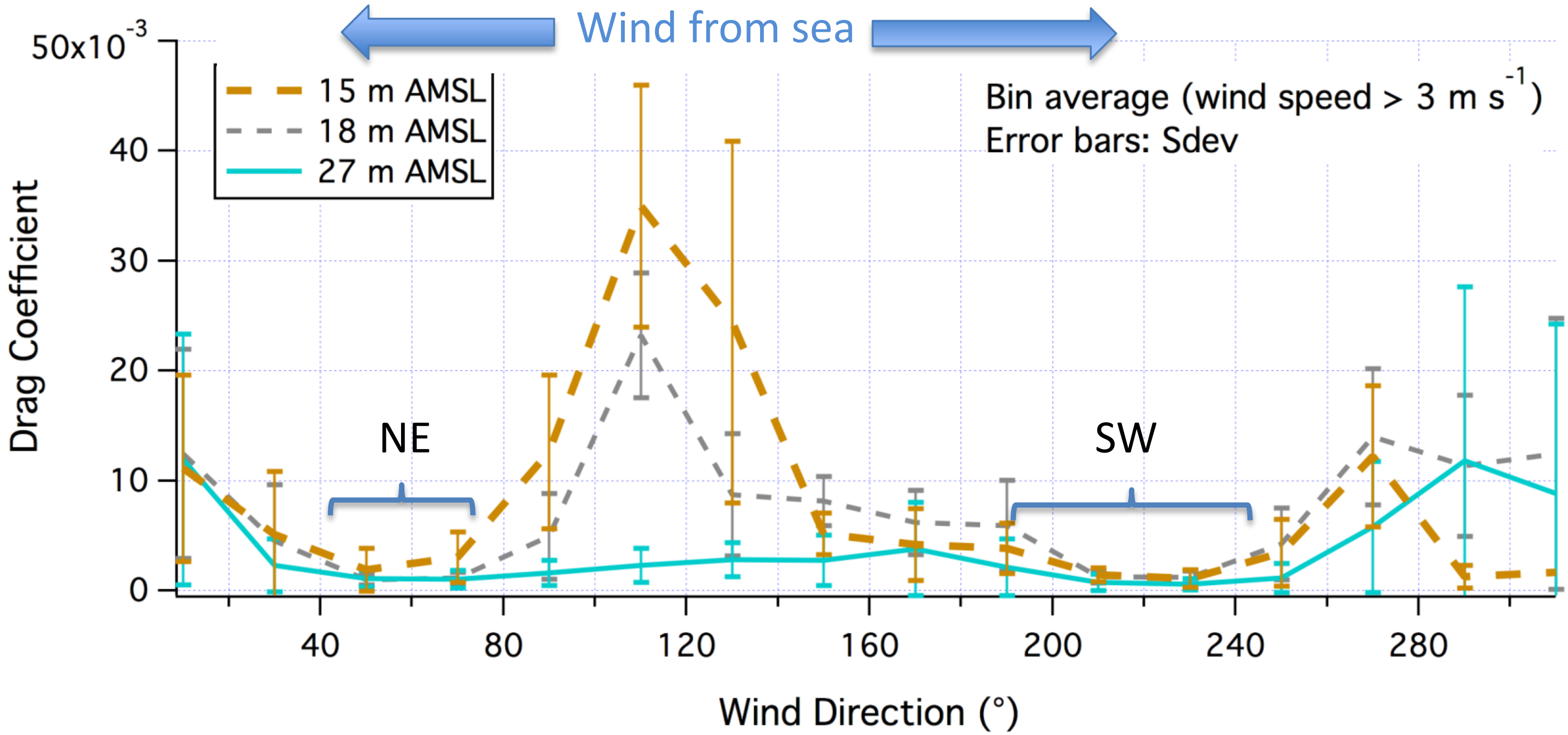


Observations	Instrumentation/Methods	Period
Meteorology	*Gill Metpak Pro*	May 2014 –
Momentum/Heat Flux	*Gill WMP/R3 w/ EC*	May 2014 –
CO_2/CH_4 Flux	*Picarro G2311-f w/ EC*	May 2014 – Oct 2015
CO_2/CH_4 Flux	*Los Gatos Research FGGA w/ EC*	Sep 2015 –
Total Aerosol Number Flux	*TSI 3025 ultrafine CPC (>3 nm) w/ EC*	Feb 2015 –
Aerosol Size Distributed Flux	*CLASP (0.2–18 micron) w/ EC*	Feb 2015 –
Aerosol Chemistry	*IC & ICPMS*	Jan 2015 –
SO_2	*TS Pulsed Fluorescence 43i*	May 2014 –
O_3	*2B UV Absorption 205*	May 2014 –
NO_2/CH_2O/CHOCHO/IO..	*MAX-DOAS*	Apr 2015 – Mar 2016
NO/NO_2	*EnviroTechnology T200*	Apr – June 2015
CO	*EnviroTechnology T300U*	Apr – June 2015
$ClNO_2$	*CIMS*	Apr – June 2015
N_2O_5/NO_3	*Heated Cavity*	Apr – June 2015

CO_2 and CH_4: Closed path sensors with eddy covariance (EC) technique

Site Validation for EC Flux Measurements

Two wind sectors for air-sea fluxes:
SW (open water) and NE (Plymouth Sound)



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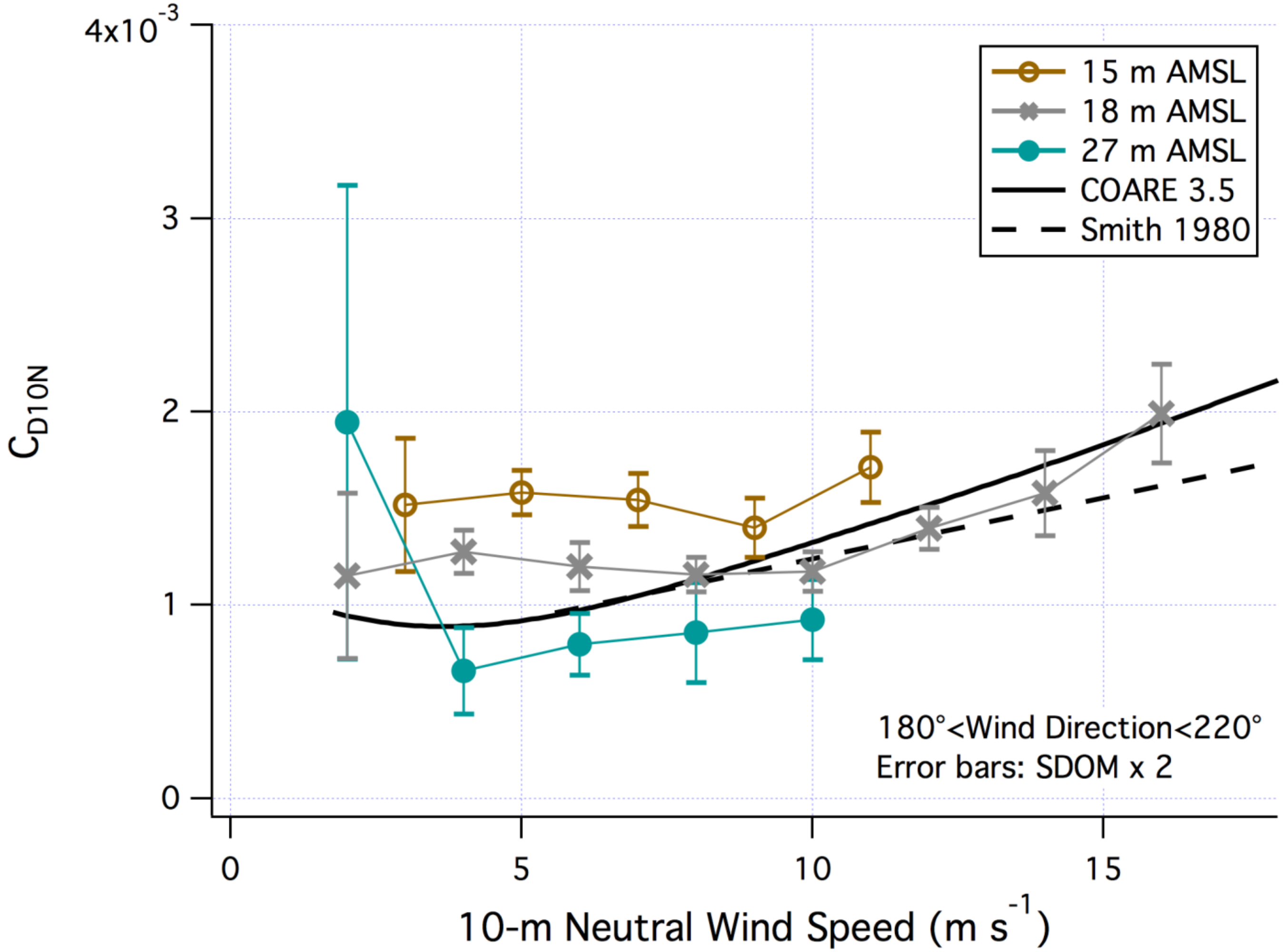
C_{D10n} within 20% of open ocean estimates when ≥ 18 m AMSL

- Majority of flux footprint over water 20 m deep
- No obvious tidal dependence when mast raised



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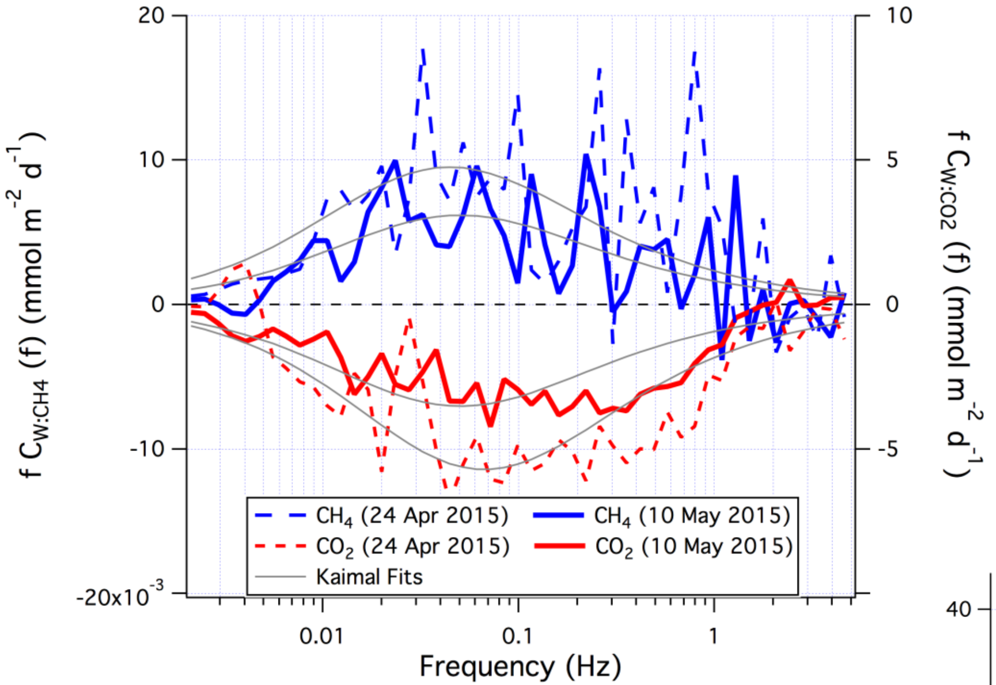
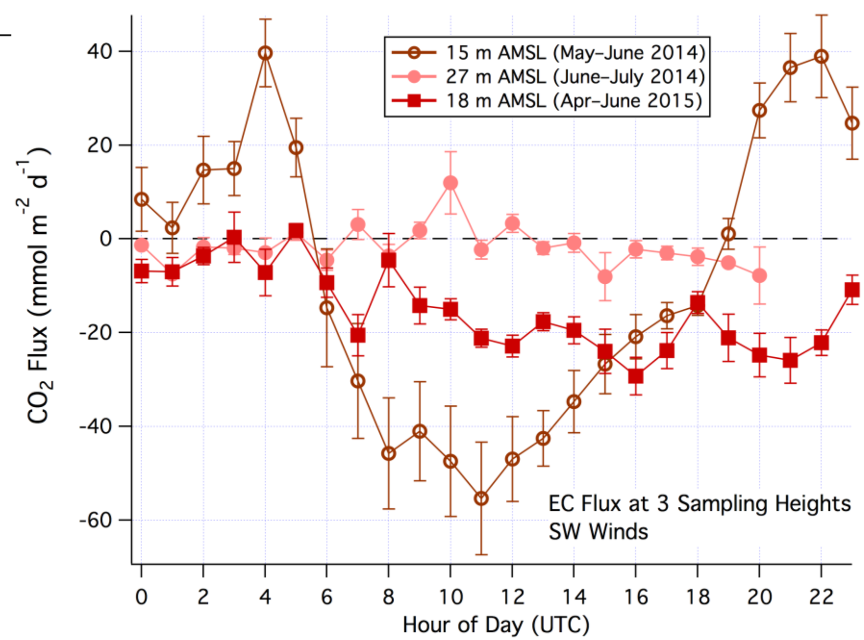
Further Sanity Checks: Cospectra and Diel Variability



Cospectra of CO_2 and CH_4 consistent with theoretical Kaimal fits for atmospheric turbulent transport

Higher mast (≥ 18 m AMSL):

- Weaker diurnal cycle
- better agreement w/ expected air-sea CO_2 flux
- Significantly reduced local impact (grass/algae)



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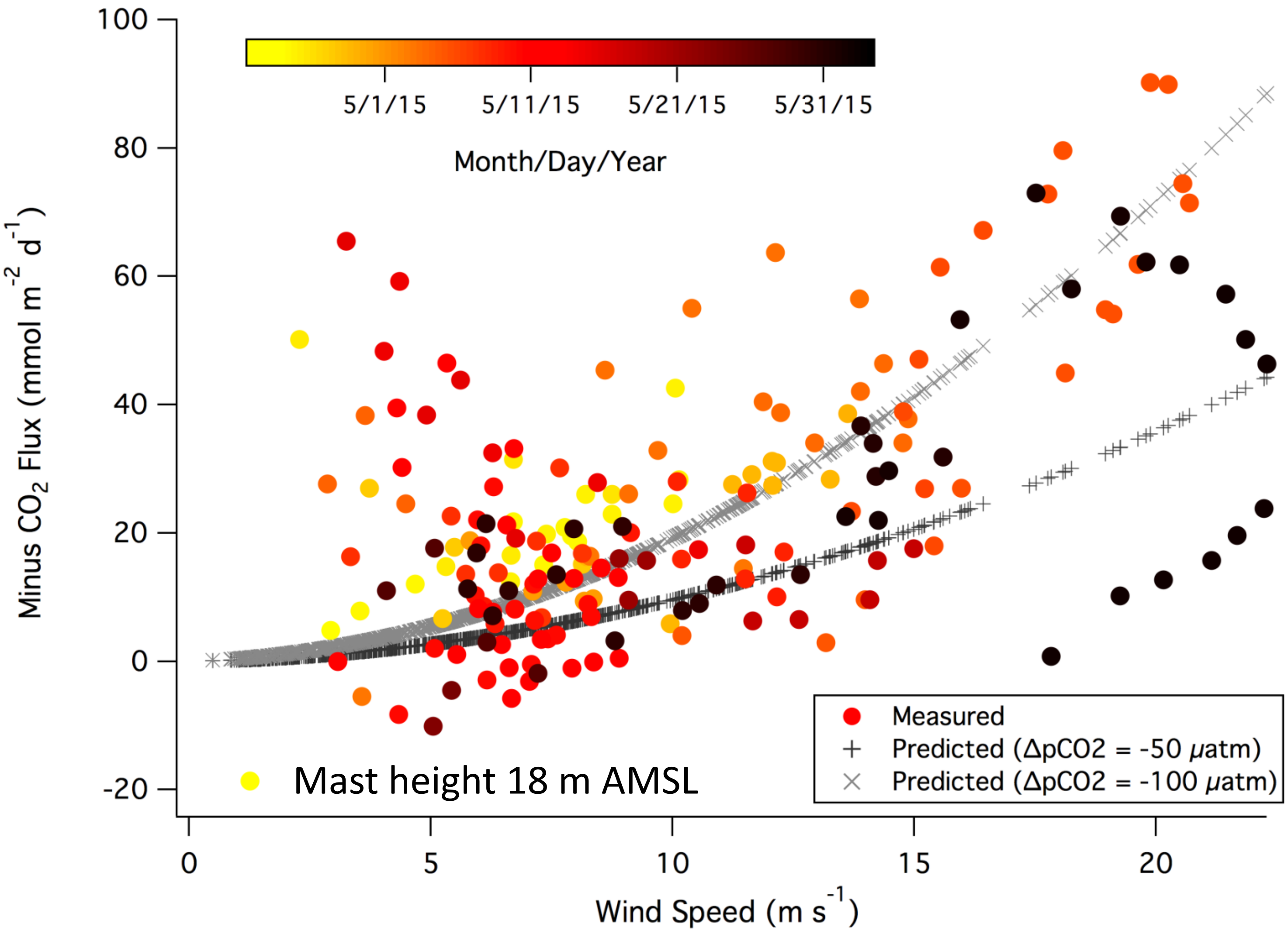
CO_2 air-to-sea flux increases with wind speed and shows strong temporal variability



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First Report of Eddy Covariance CH_4 Flux Measurements from a Marine System

Mast Height	Period	Mean Flux (SE)
15 m AMSL	May-June 2014	0.016 (0.002)
27 m AMSL	June-July 2014	0.025 (0.004)
18 m AMSL	Apr-June 2015	0.030 (0.002)

Fluxes from open water sector (SW)
Units = mmole m^{-2} d^{-1}; + = sea-to-air emission

Greater flux at higher mast height suggests the source of CH_4 is seawater, not foreshore

Estimated open ocean CH4 emission: typically <0.01 mmole m^{-2} d^{-1}

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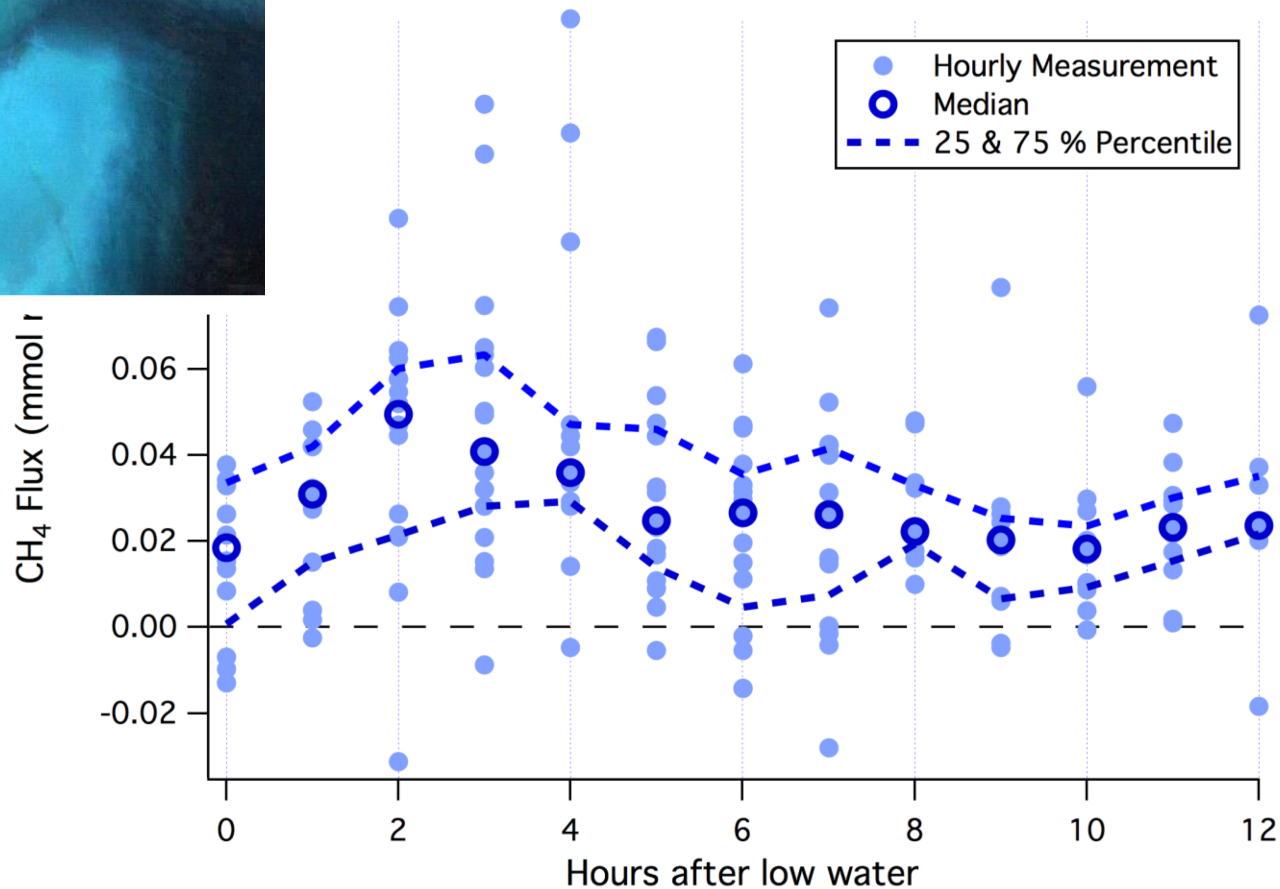
Tidal (semi-diurnal) dependence in CH_4 flux

Greater CH_4 flux during rising tide, likely because the tide influences the extent of estuary outflow within the flux footprint



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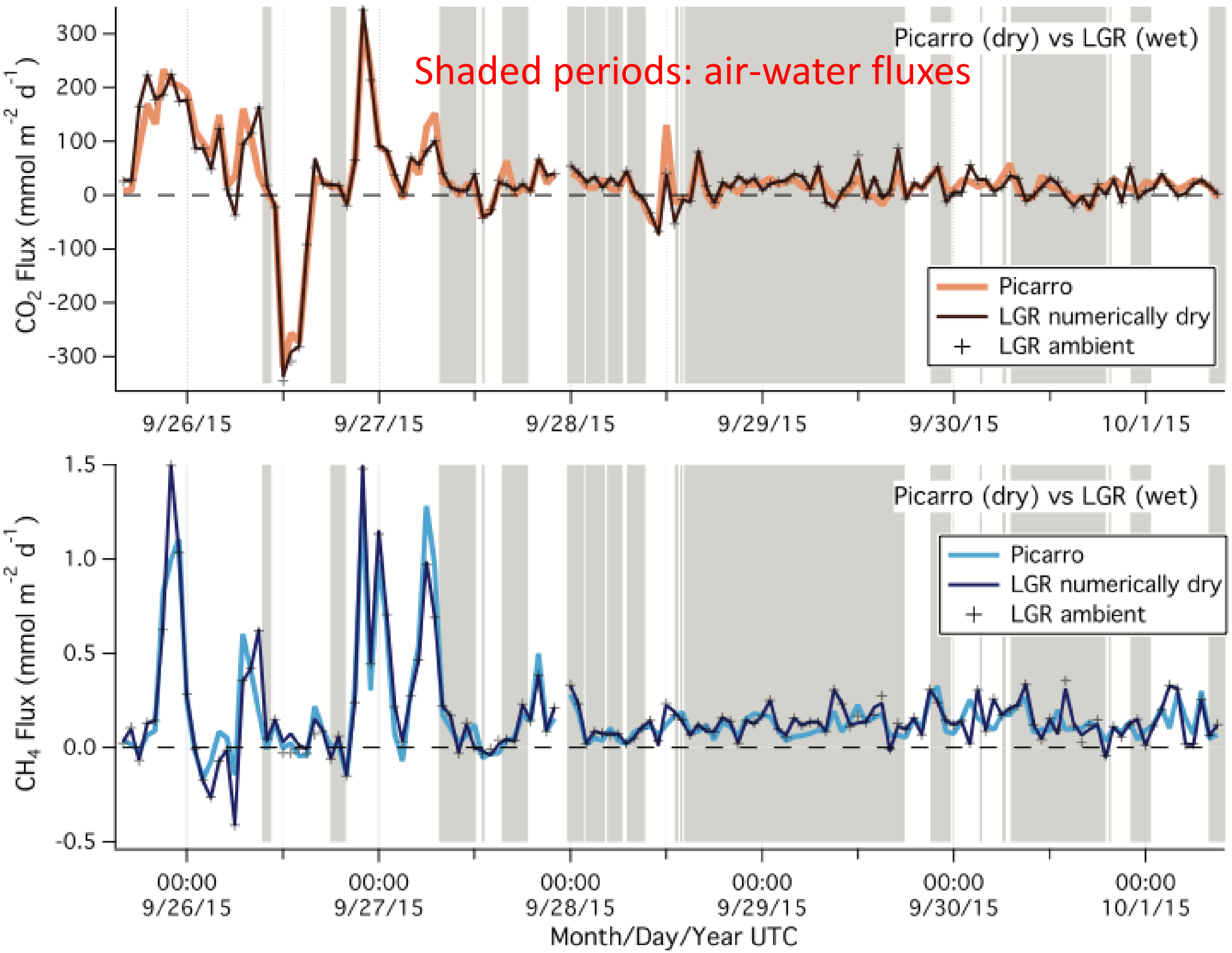
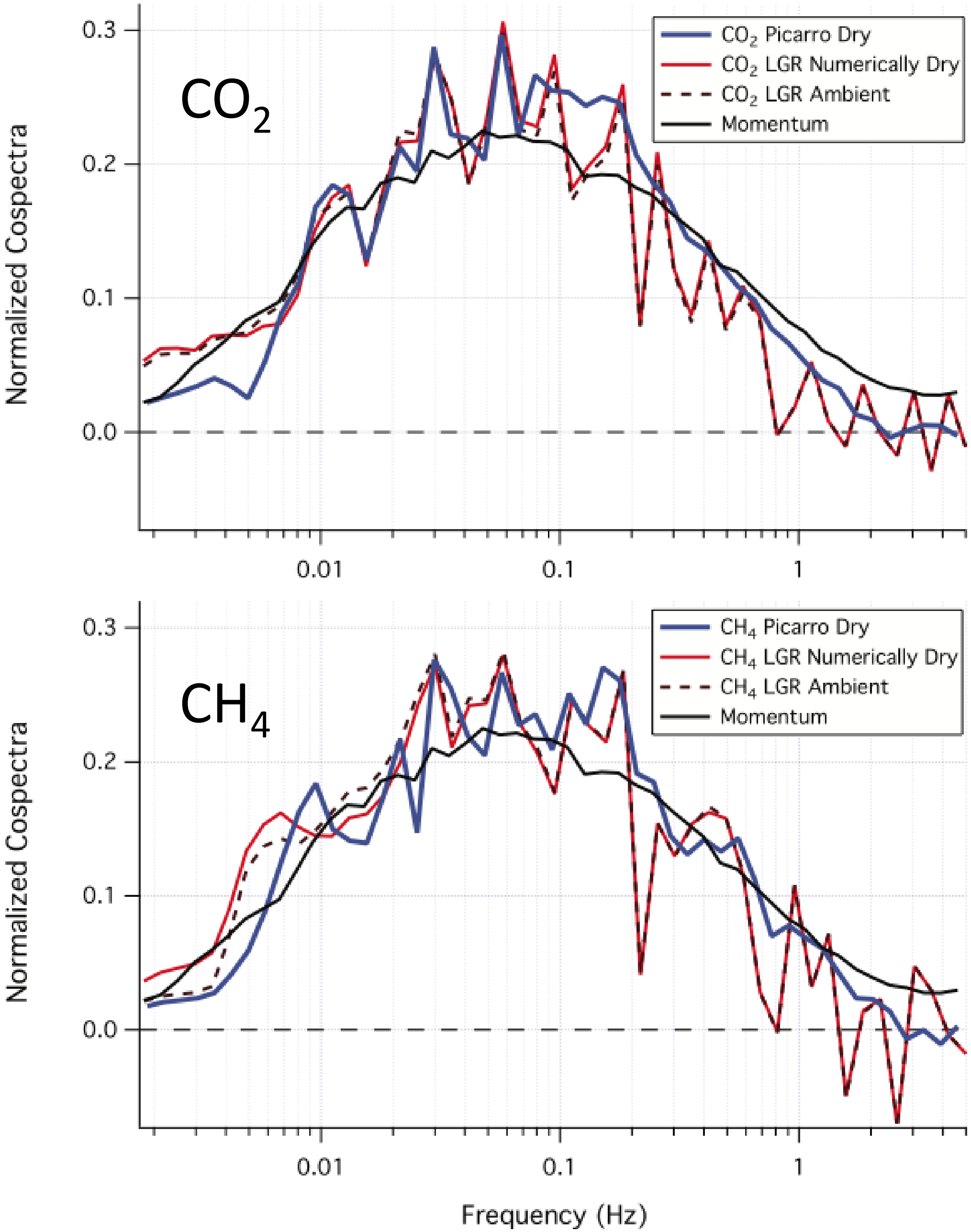
Analyzer Intercomparison: Picarro (physically dried) vs. Los Gatos Research (‘numerically dried’)



Yang et al. Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2016-215, in review, 2016



Reasonable Agreement in Mean Cospectra

- High frequency flux loss ≤ 10% for both analyzers
- LGR cospectra noisier at high frequencies
- Numerical water vapor correction in LGR only noticable at low frequencies

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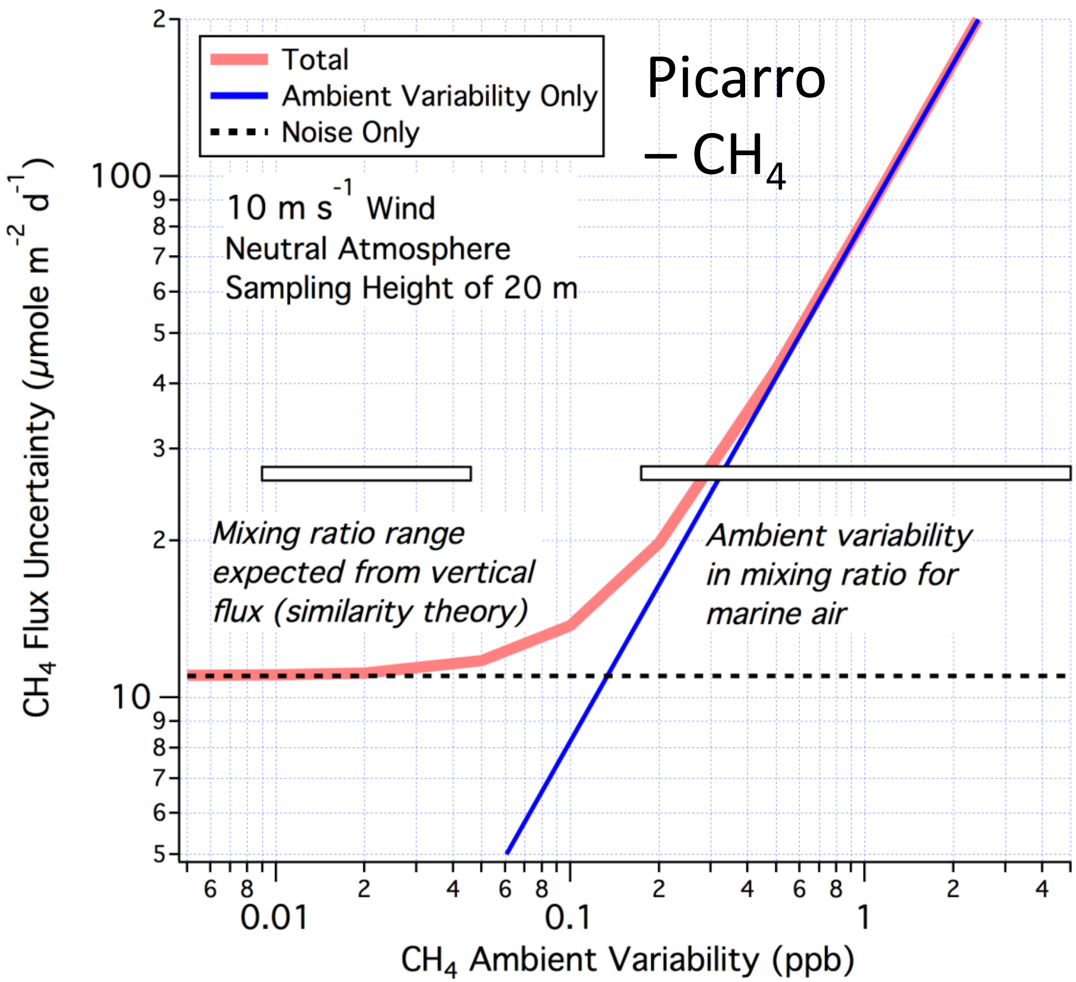
Eddy Covariance Hourly Flux Detection Limits



Hourly flux certainty (estimated following Blomquist et al. 2010) comparable to sea-to-air flux

Most of uncertainty in CH_4 covariance flux driven by natural variability in CH_4 mixing ratio, rather than instrument noise

Yang et al. Atmos. Chem. Phys., 16, 5745-5761, 2016

Picarro has significantly better precision and so lower flux detection limits than LGR

CO_2	Precision (10 Hz) [ppm]	Flux Detection Limit [mmol m^{-2} d^{-1}]
Picarro G2311-f	0.15	2
LGR FGGA	1.4	8

CH_4	Precision (10 Hz) [ppb]	Flux Detection Limit (mmol m^{-2} d^{-1})
Picarro G2311-f	1.1	0.02
LGR FGGA	5.5	0.05

Estimated open ocean CH4 emission: typically <0.01 mmole m^{-2} d^{-1}

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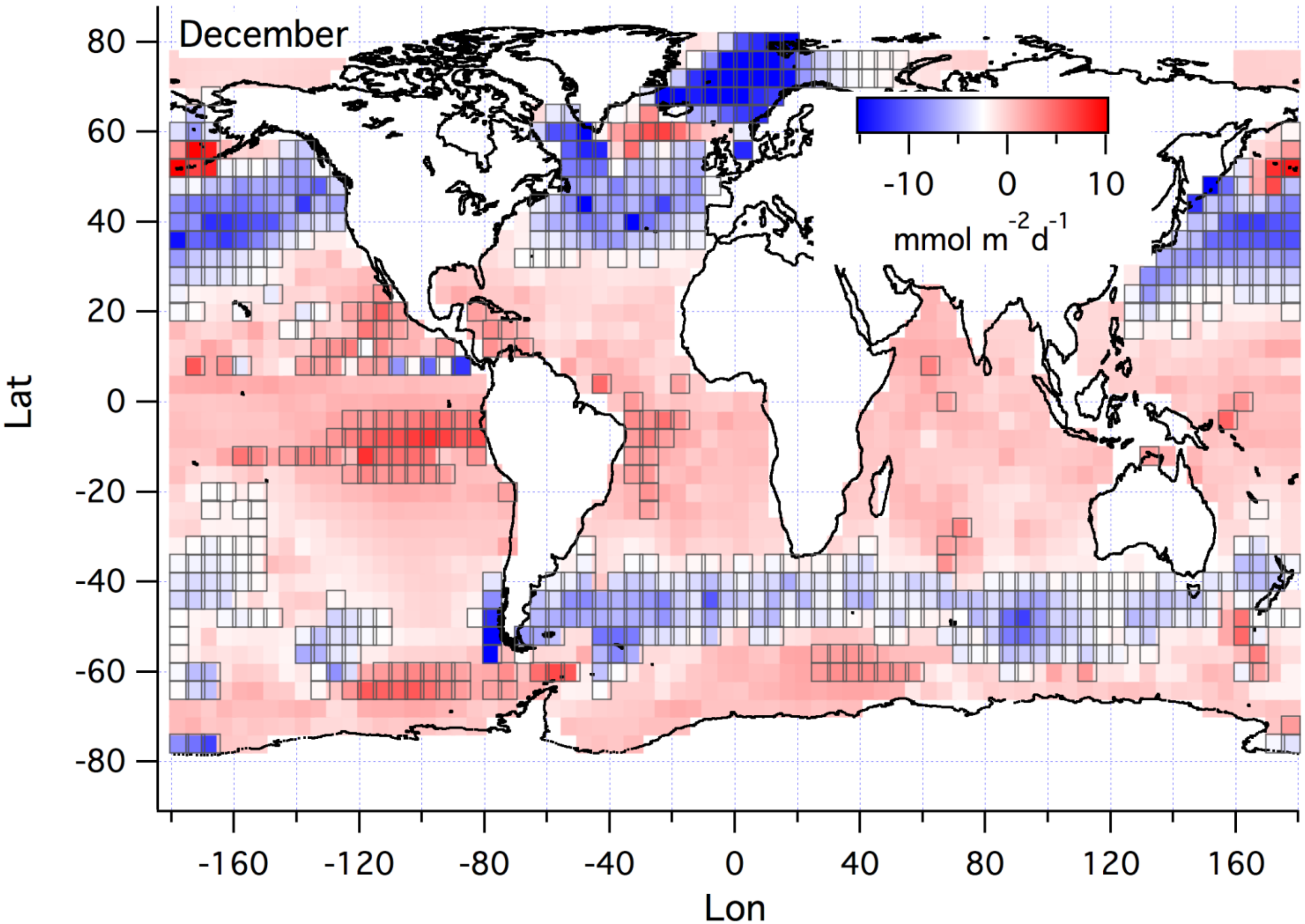
What does this mean for direct flux measurements globally?



Estimated global air-sea CO_2 flux maps from NOAA (Park et al. 2010)

Gray squares: above hourly detection limit of Picarro (~40% of global oceans)

Longer averaging necessary in regions of lower flux or if using LGR

Summary

- Penlee Point Atmospheric Observatory suitable for eddy covariance measurements of fluxes between atmosphere and coastal seas
- CO_2 and CH_4 fluxes highly variable temporally (CH_4 flux appears to be tidal dependent)
- Picarro better precision (lower flux detection limit) than LGR

Publications from Penlee Point Atmospheric Observatory

- Air-sea CO_2 and CH_4 fluxes (Yang et al. Atmos. Chem. Phys, 16, 5745–5761, 2016)
- Flux comparison of two greenhouse gas analysers (Yang et al. Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2016-215, in review, 2016)
- SO_2 emission from ships and DMS (Yang et al. Atmos. Chem. Phys, 16, 4771–4783, 2016) – See poster

Looking Forward…

- Seasonal variability in CO_2 and CH_4 fluxes
- Measurements of waterside CO_2 and CH_4 concentrations in EC flux footprints ➔ transfer velocities
- Impacts of surfactants on gas exchange?
- Aerosol fluxes (total and size-distributed number)
- Other gases (organics, ozone, ammonia)

Interested in collaborating?

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NERC SCIENCE OF THE ENVIRONMENT

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