
Carbon balance, eddy covariance and buoys
Ankur R Desai
University of Wisconsin-Madison
Atmospheric and Oceanic Sciences
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AGU/Flikr

Do flux towers have a home in NTL study lakes and buoys?

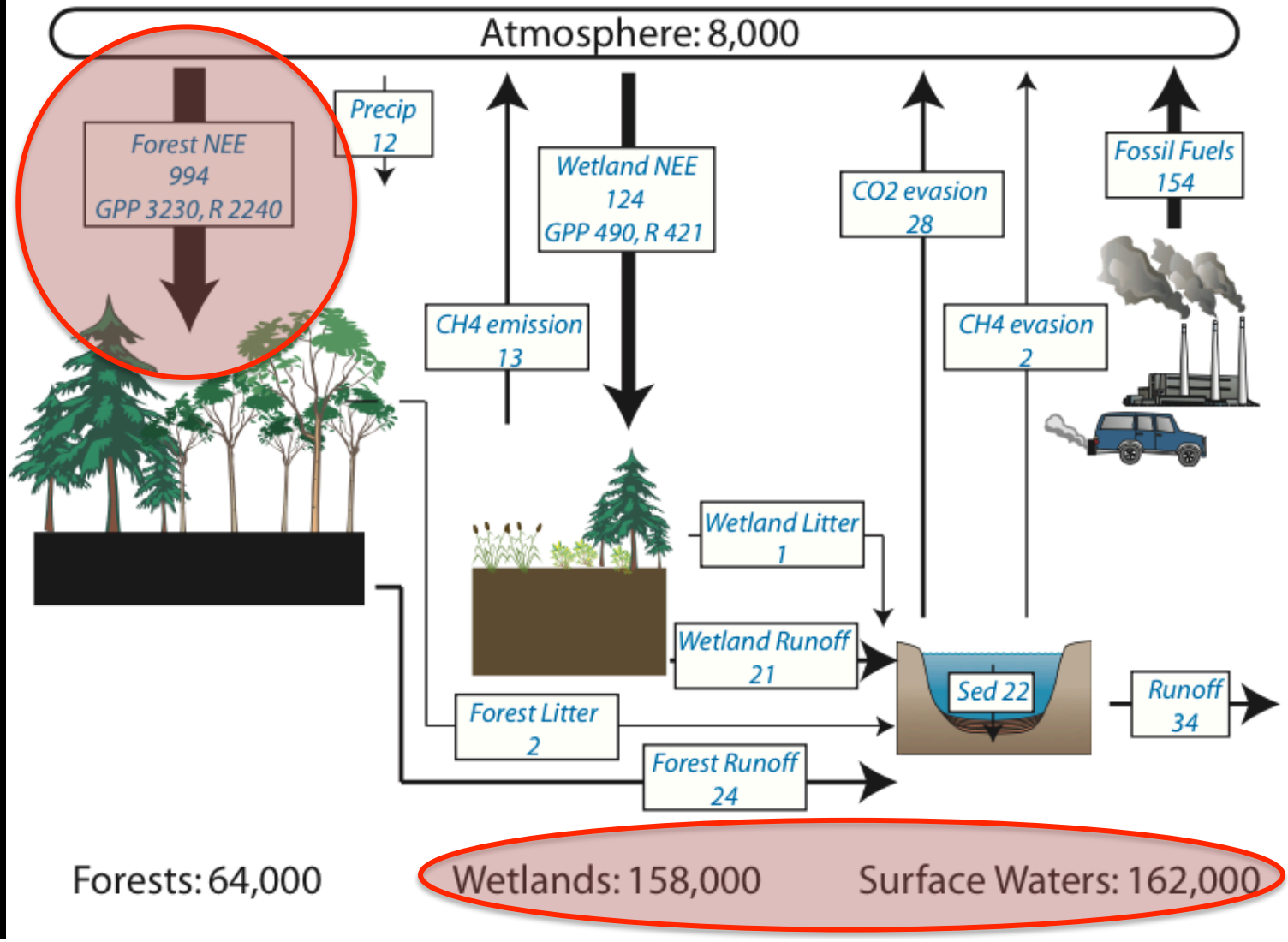
Trout Lake(Oligotrophic)

Lake Mendota(Eutrophic)

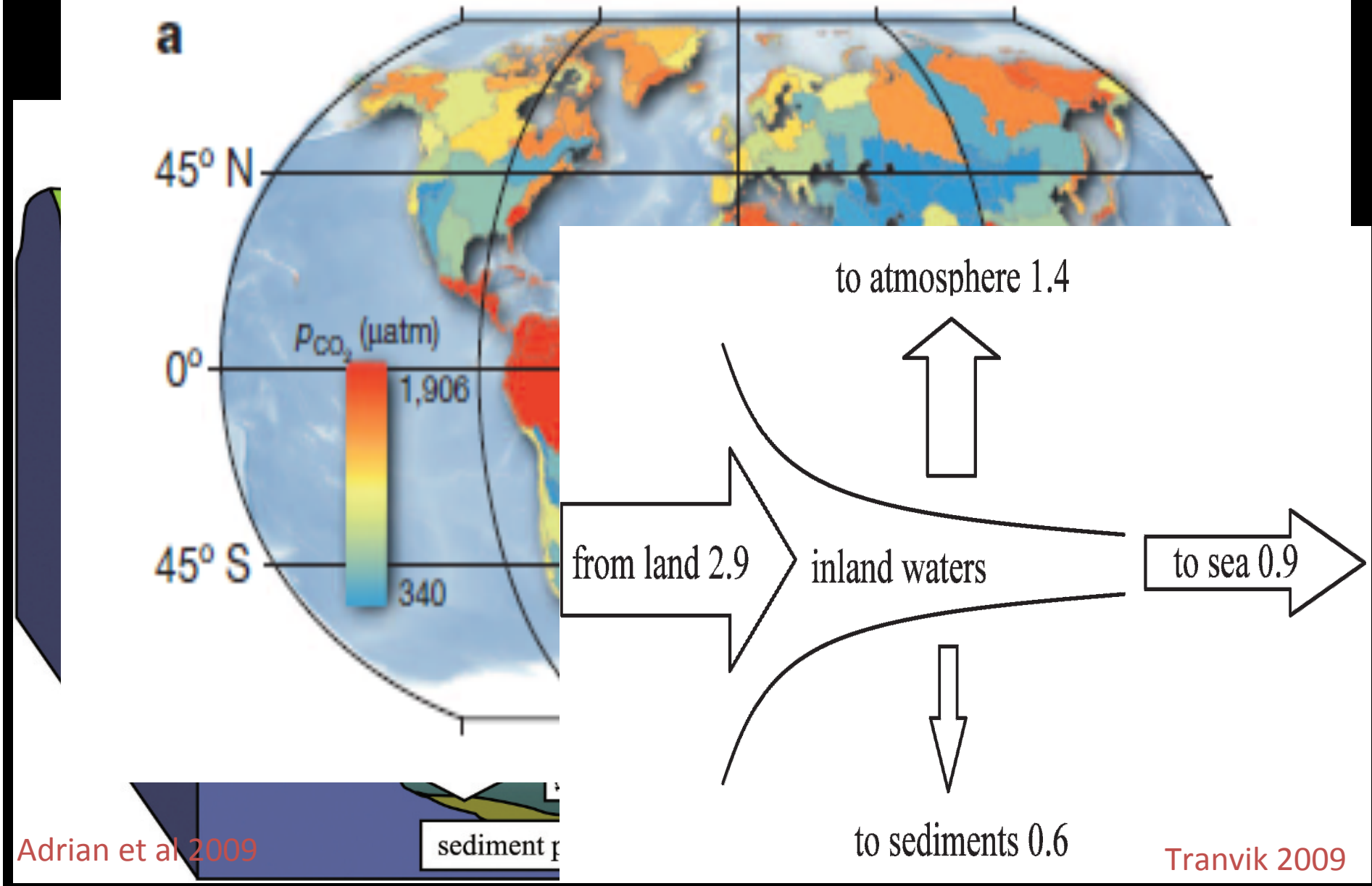
Buffam et al., 2011, GCB

Flux rates in Gg-C yr-1

Pool sizes in Gg-C



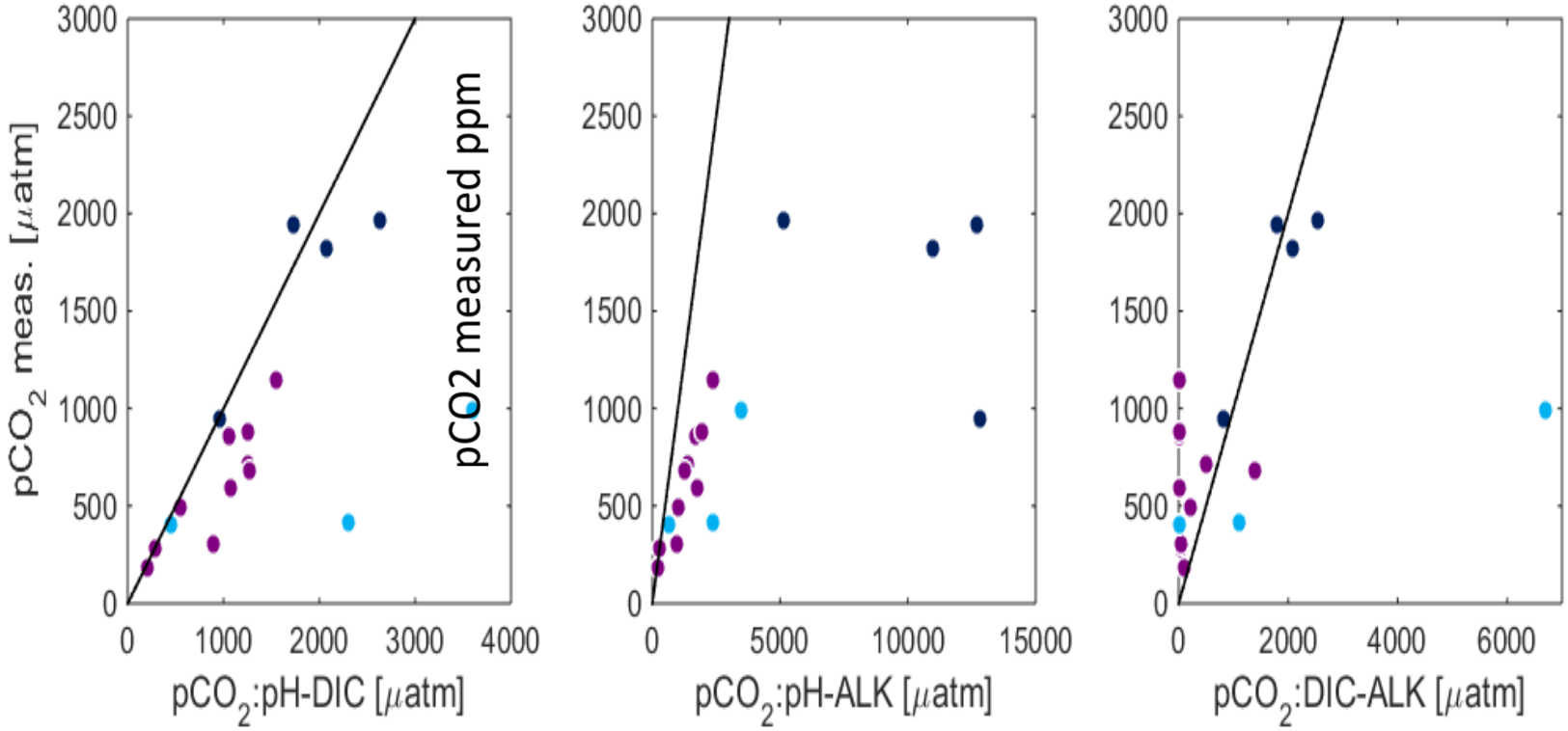
Raymond et al., 2013



Adrian et al 2009

Tranvik 2009

Significant uncertainties in these global estimates owing to methodological and spatial sampling issues



M. Golub, UW

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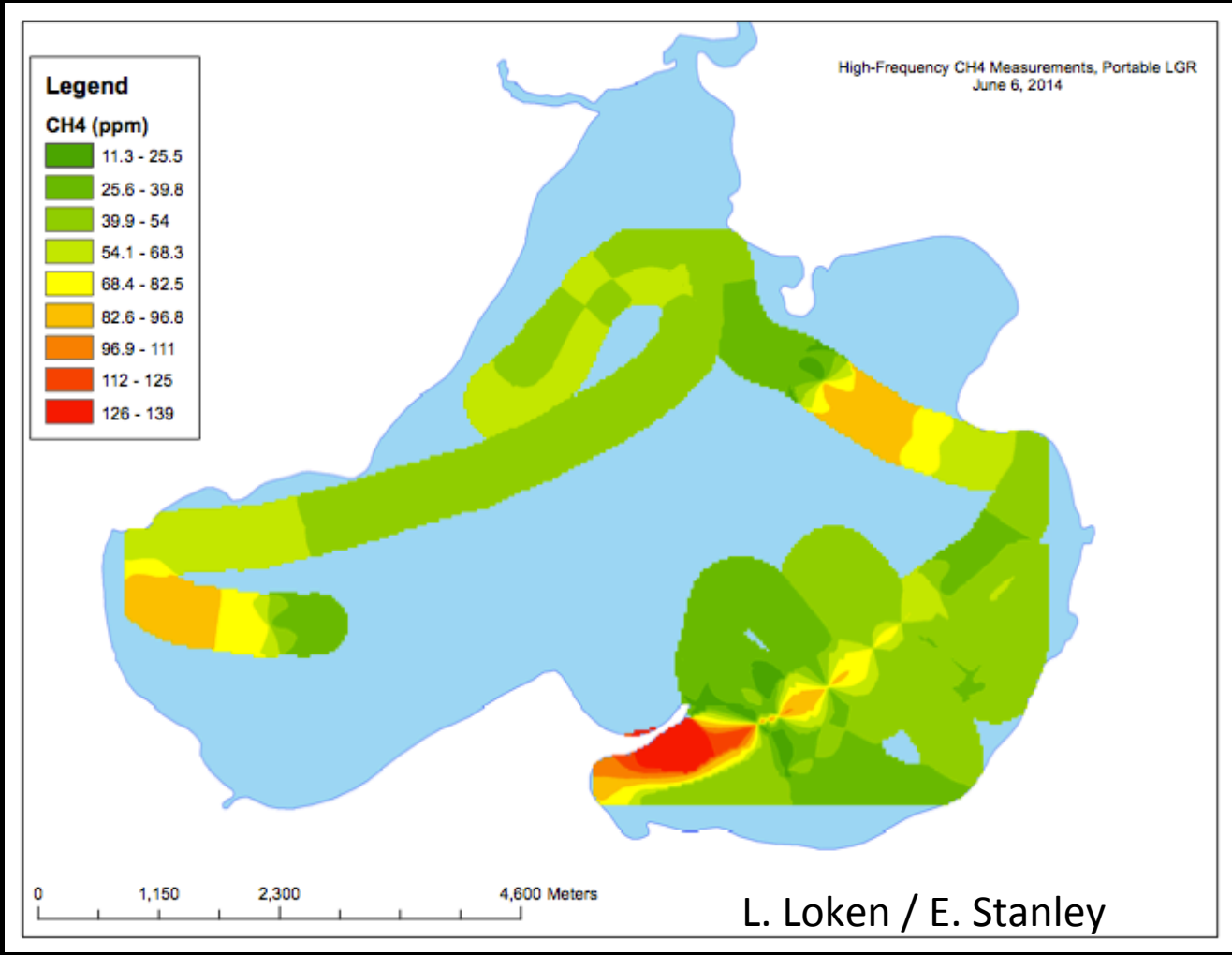
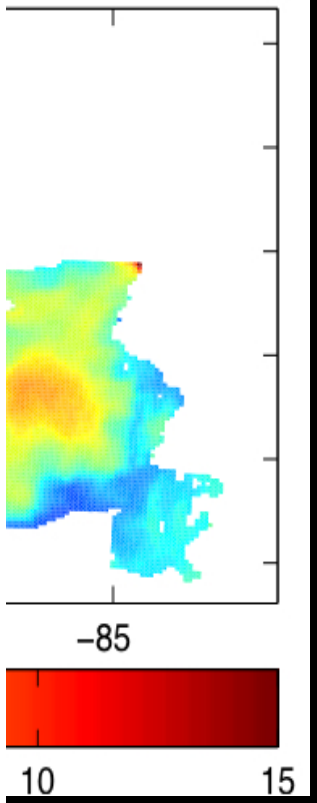
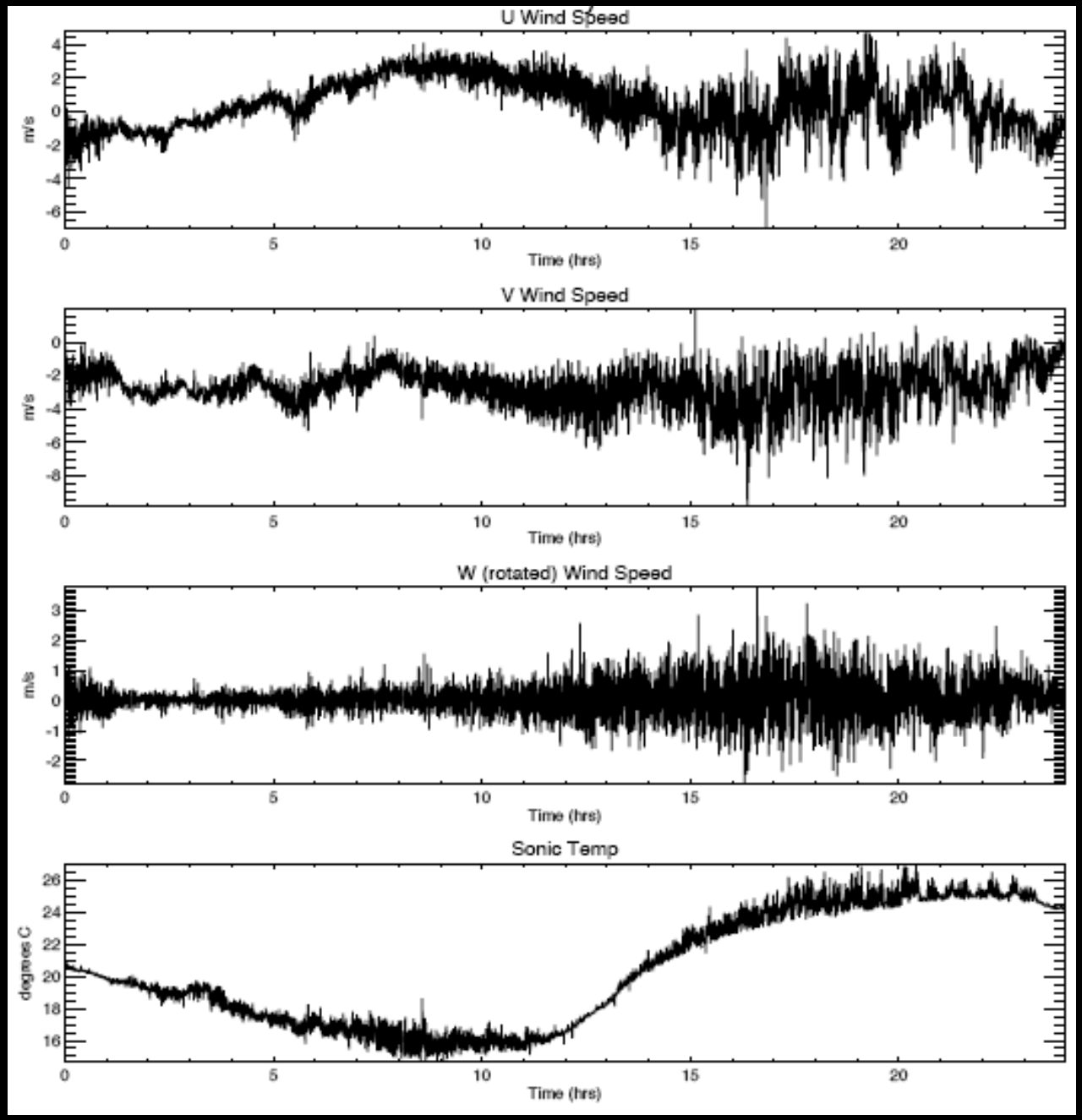
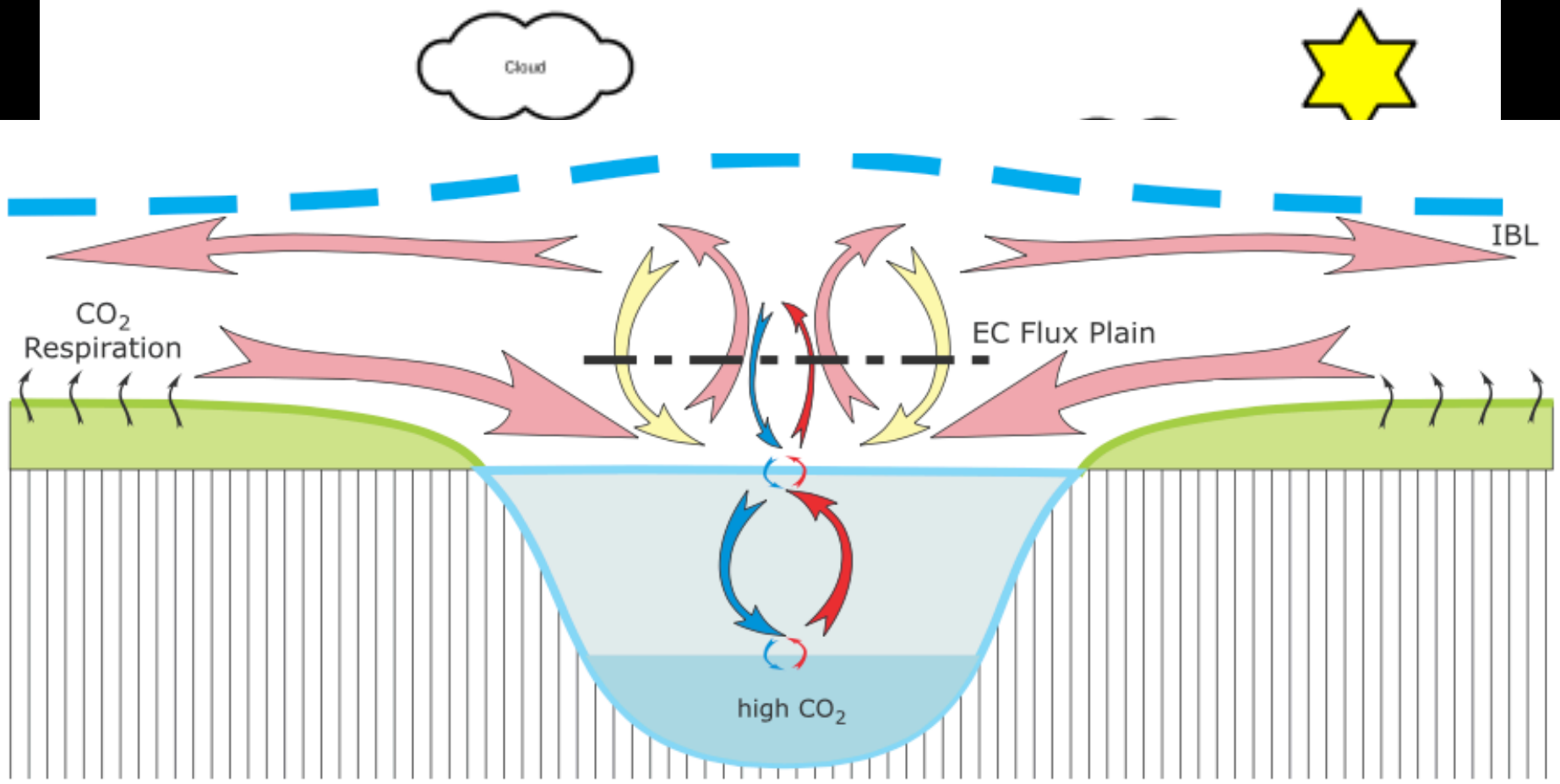


L. Loken / E. Stanley



V. Bennington

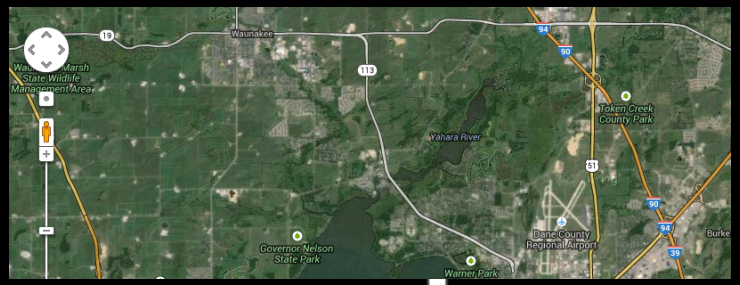

U Wind Speed
m/s
Time (hrs)
V Wind Speed
m/s
Time (hrs)
W (rotated) Wind Speed
m/s
Time (hrs)
Sonic Temp
degrees C
Time (hrs)

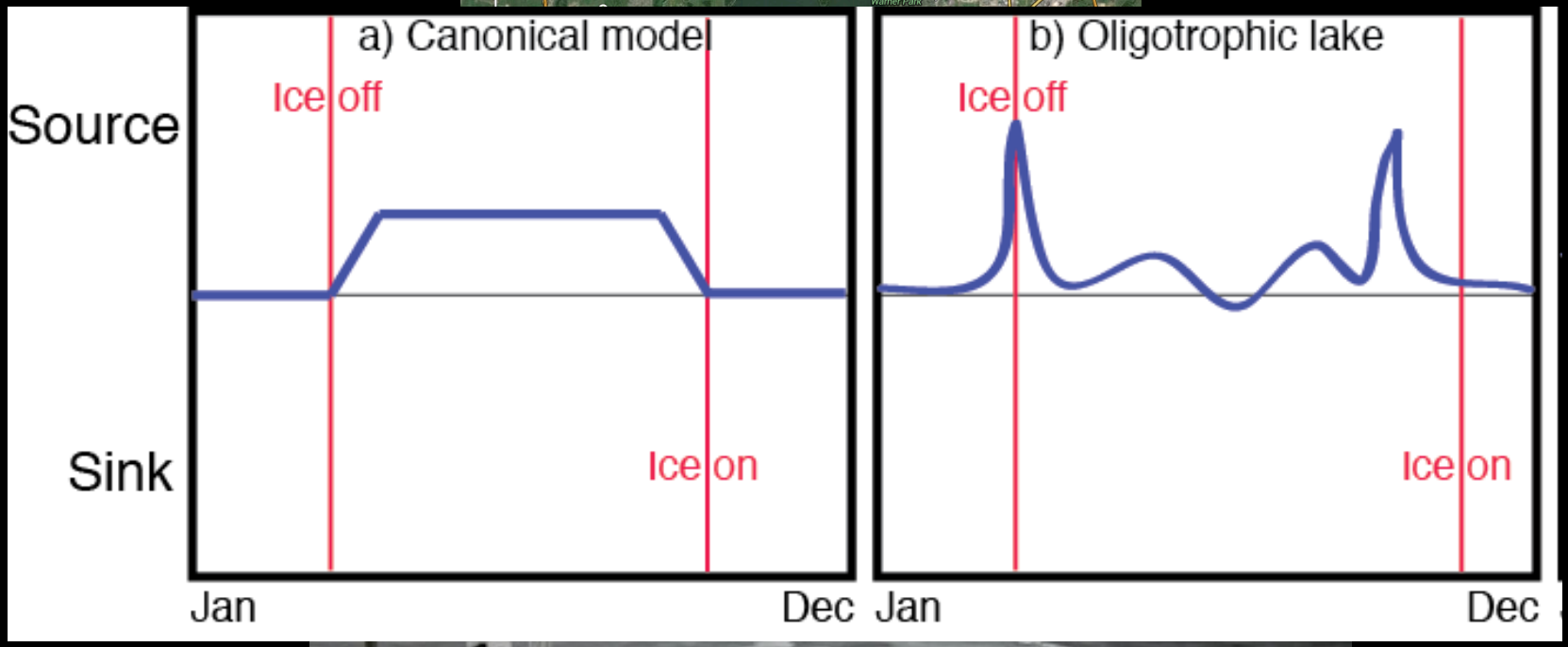


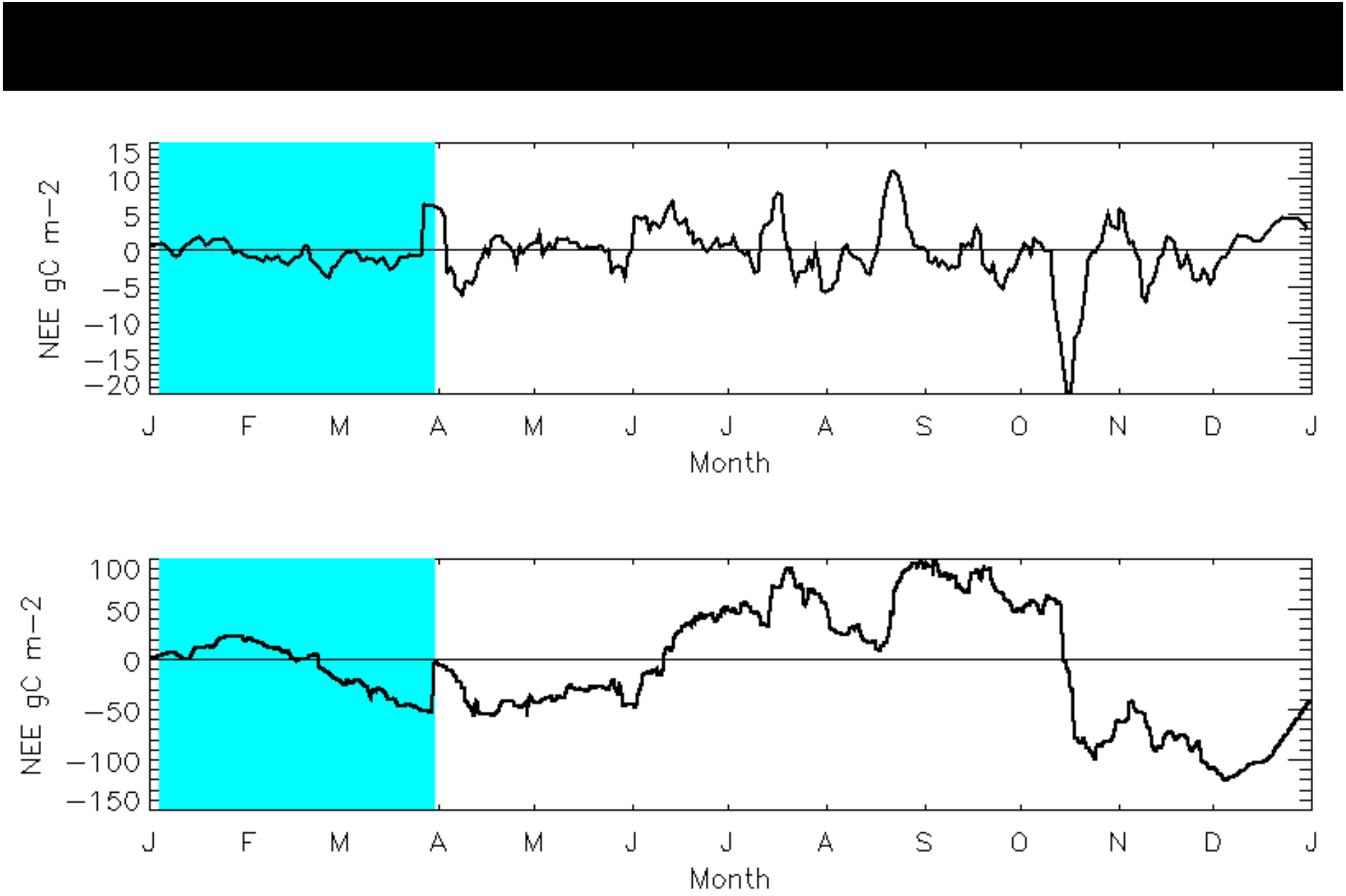
W. Eugster/ ETH Zurich

D. Baldocchi

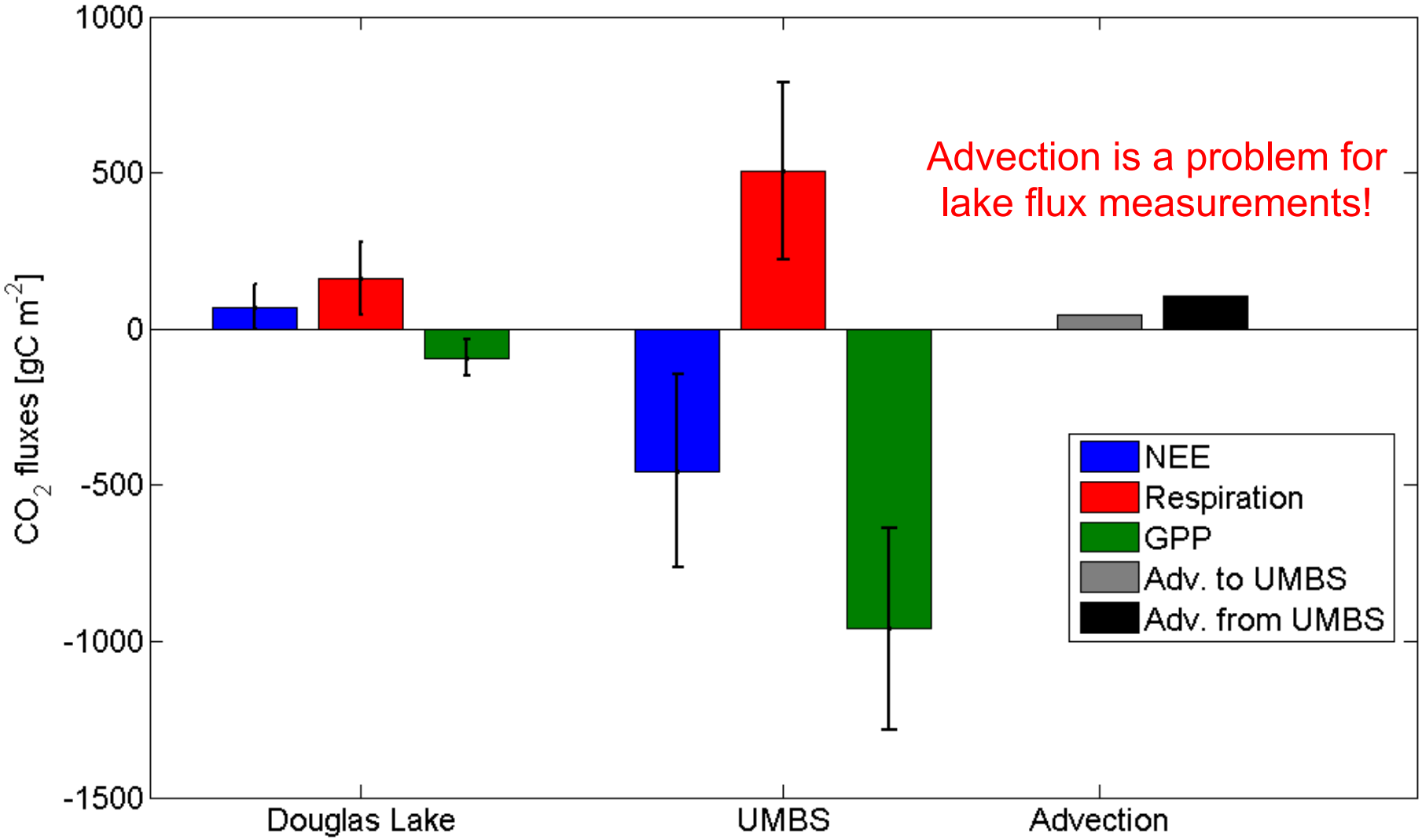
What does it see?


Waunakee
Yahara River
Token Creek County Park
Governor Nelson State Park
Dane County Regional Airport
Warner Park
Burke


a) Canonical model
b) Oligotrophic lake
Source
Sink
Ice off
Ice on
Ice off
Ice on
Jan
Dec
Jan
Dec

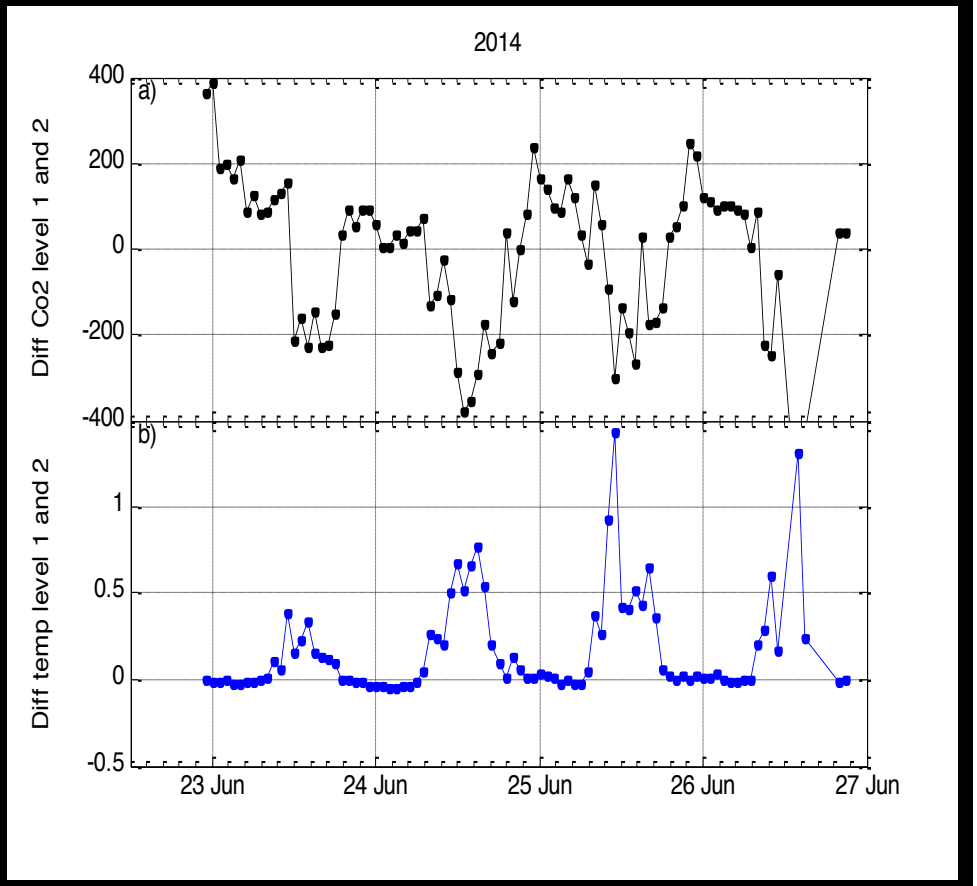

15
10
5
0
−5
−10
−15
−20
NEE gC m−2
J
F
M
A
M
J
J
A
S
O
N
D
J
Month
100
50
0
−50
−100
−150
NEE gC m−2
J
F
M
A
M
J
J
A
S
O
N
D
J
Month

Seasonal Carbon budgets in UMBS



Problems with EC and convective mixing

- Convective mixing relative to other mechansism (wind, surfactants, waves…)
- Vertical variability of pCO_{2w}.
- Horisontal homogeneity.
- Flux footprint
- Small lakes, low winds



Difference lev1 (10 cm), lev 2 (30 cm)

Sahlée et al 2014, in Prep.

Net CO_2 Flux	Soppensee		Toolik Lake	
	N	CO_2 Flux	N	CO_2 Flux
A: stratified periods	33	240 ± 82	59	51 ± 42
B: convective periods	54	319 ± 242	105	150 ± 45
Bx: very convective periods[b]	35	1117 ± 236	–	–
A + B: total net flux	87	289 ± 153	164	114 ± 33
Floating chamber[c]	–	–	8	365 ± 61
Concurrent EC flux[d]	–	–	16	150 ± 78
Boundary layer model[e]	–	–	602	131 ± 2
Surface renewal model[f]	–	–	597	153 ± 3
Model calculation[g]	–	164	–	–

Sally's

Eugster et al. (2003) JGR
doi:10.1029/2002JD002653

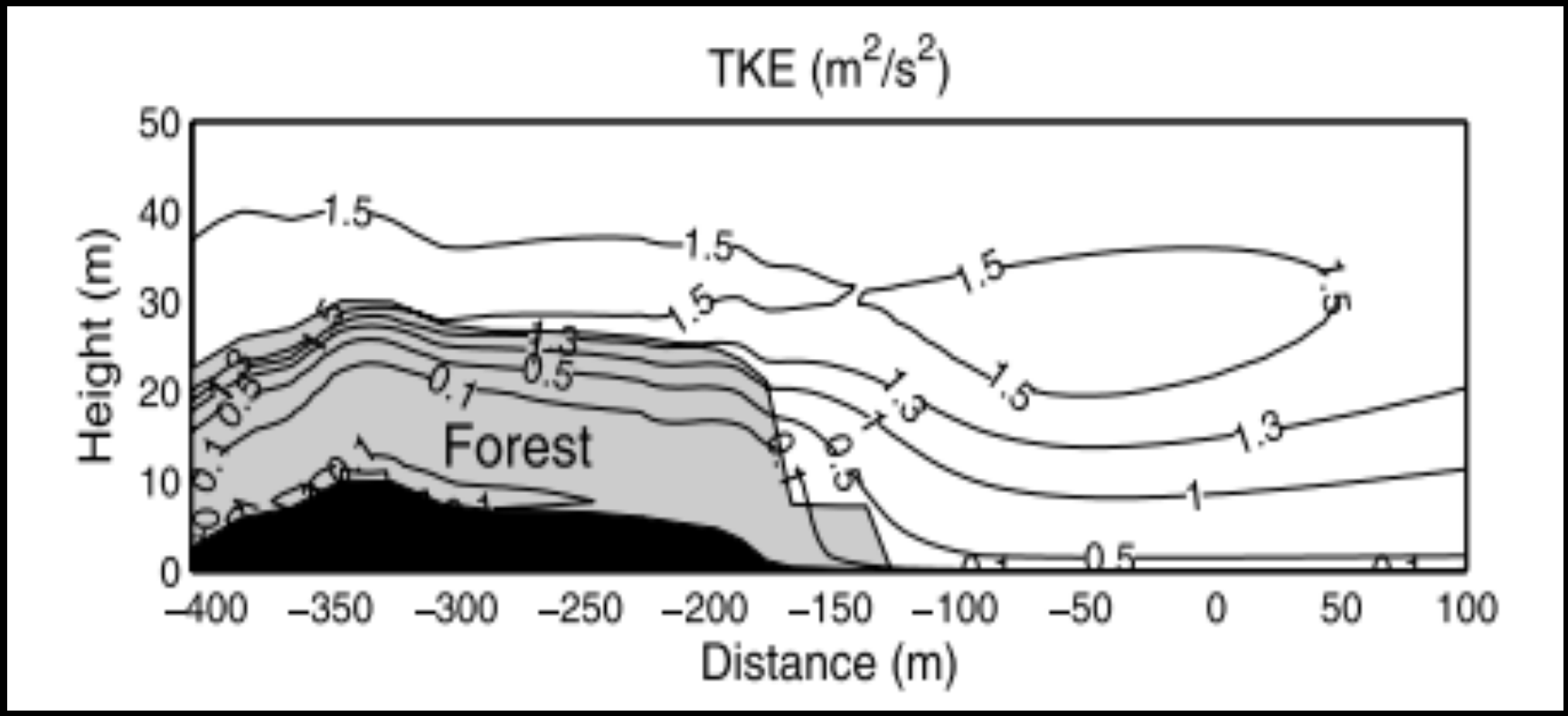
sc | nat

ETH Zurich

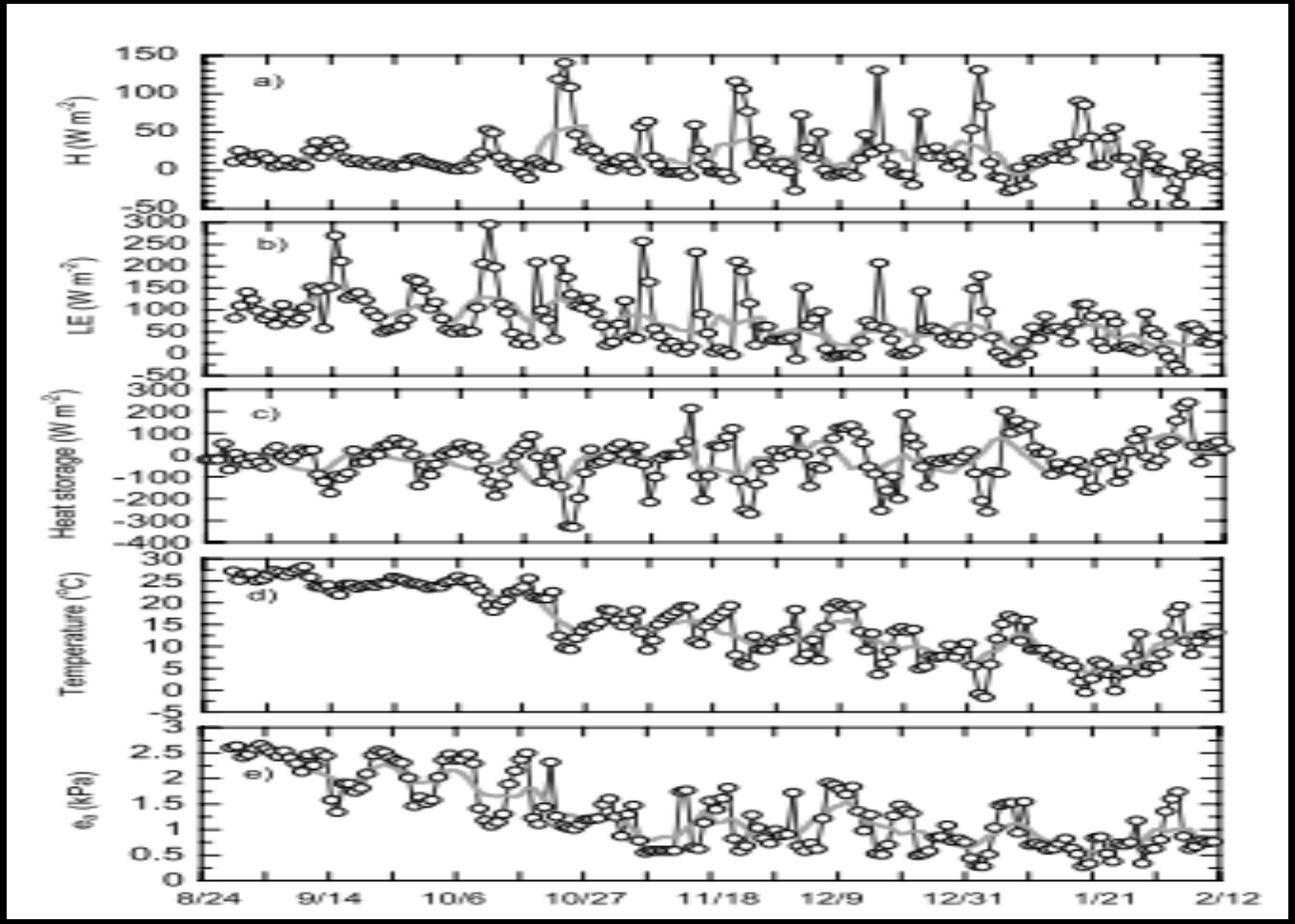
E. Podgrasjek

Edge effects are a bugger

- Vesala, 2006

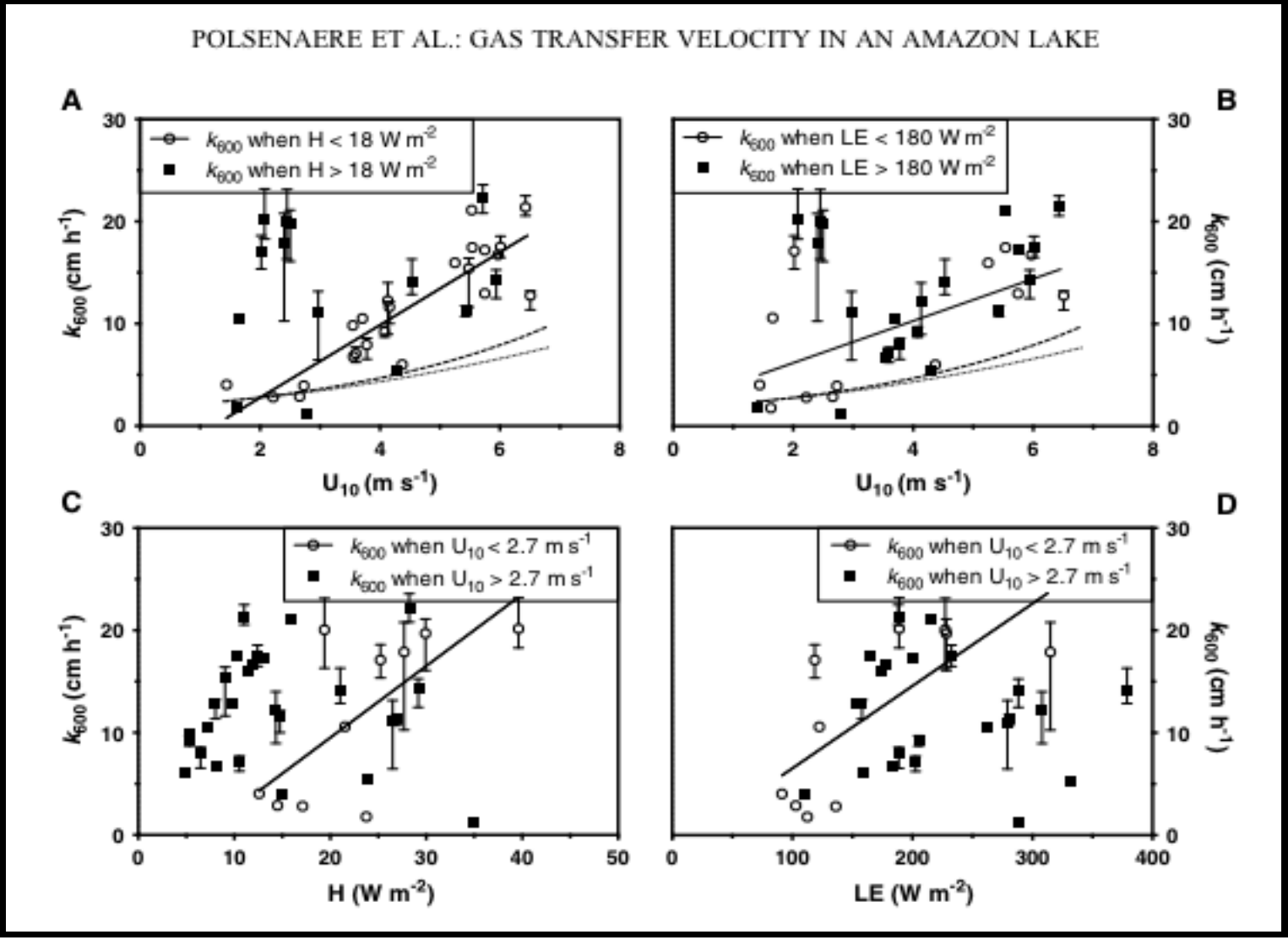


Negative latent heat fluxes are not uncommon



- Liu, 2009

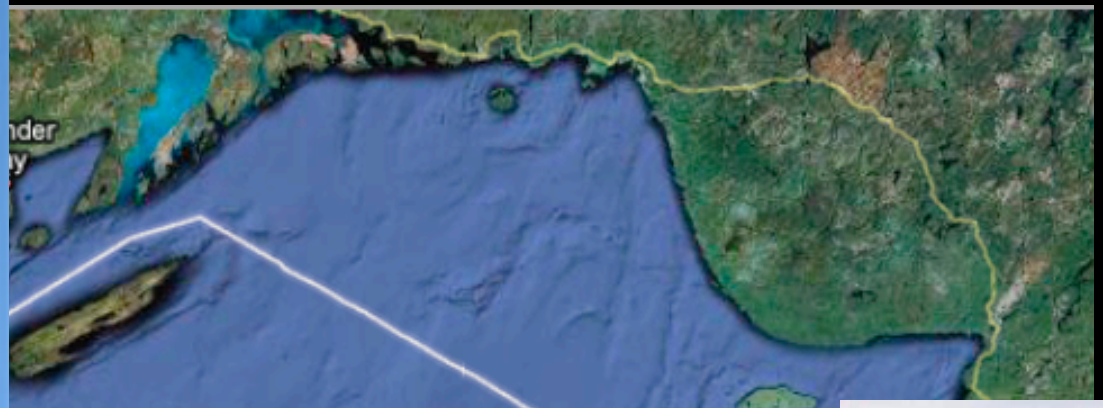
But using these data to parameterize gradient transfer shows promise



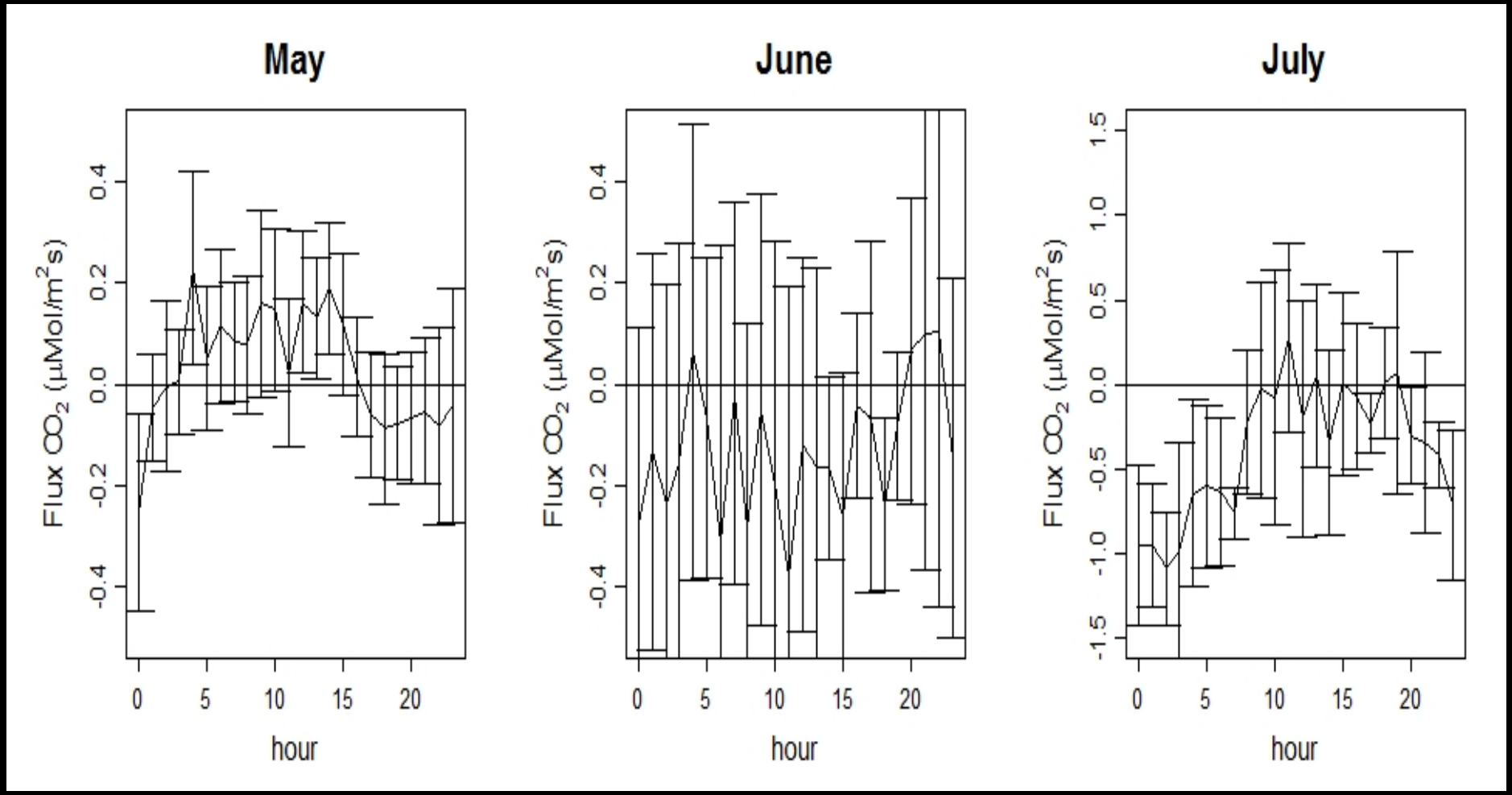

Arctic Ocean
Greenland
Iceland
Sweden
Norway
Russia
United Kingdom
Poland
Germany
Ukraine
Kazakhstan
Mongolia
France
Italy
Spain
Turkey
China
Japan
South Korea
Canada
United States
North Pacific Ocean
North Atlantic Ocean
Afghanistan
Iraq
Iran
Pakistan
India
Thailand
Algeria
Libya
Egypt
Saudi Arabia
Mexico
Mali
Niger
Sudan
Chad
Nigeria
Ethiopia
Venezuela
Colombia
DR Congo
Tanzania
Indonesia
Papua New Guinea
Peru
Brazil
Angola
Namibia
Botswana
Madagascar
Bolivia
Chile
South Pacific Ocean
South Atlantic Ocean
Indian Ocean
Australia
South Africa
Argentina
New Zealand
Google

W. Eugster / S. Macintyre

P. Blanken and J. Lenters

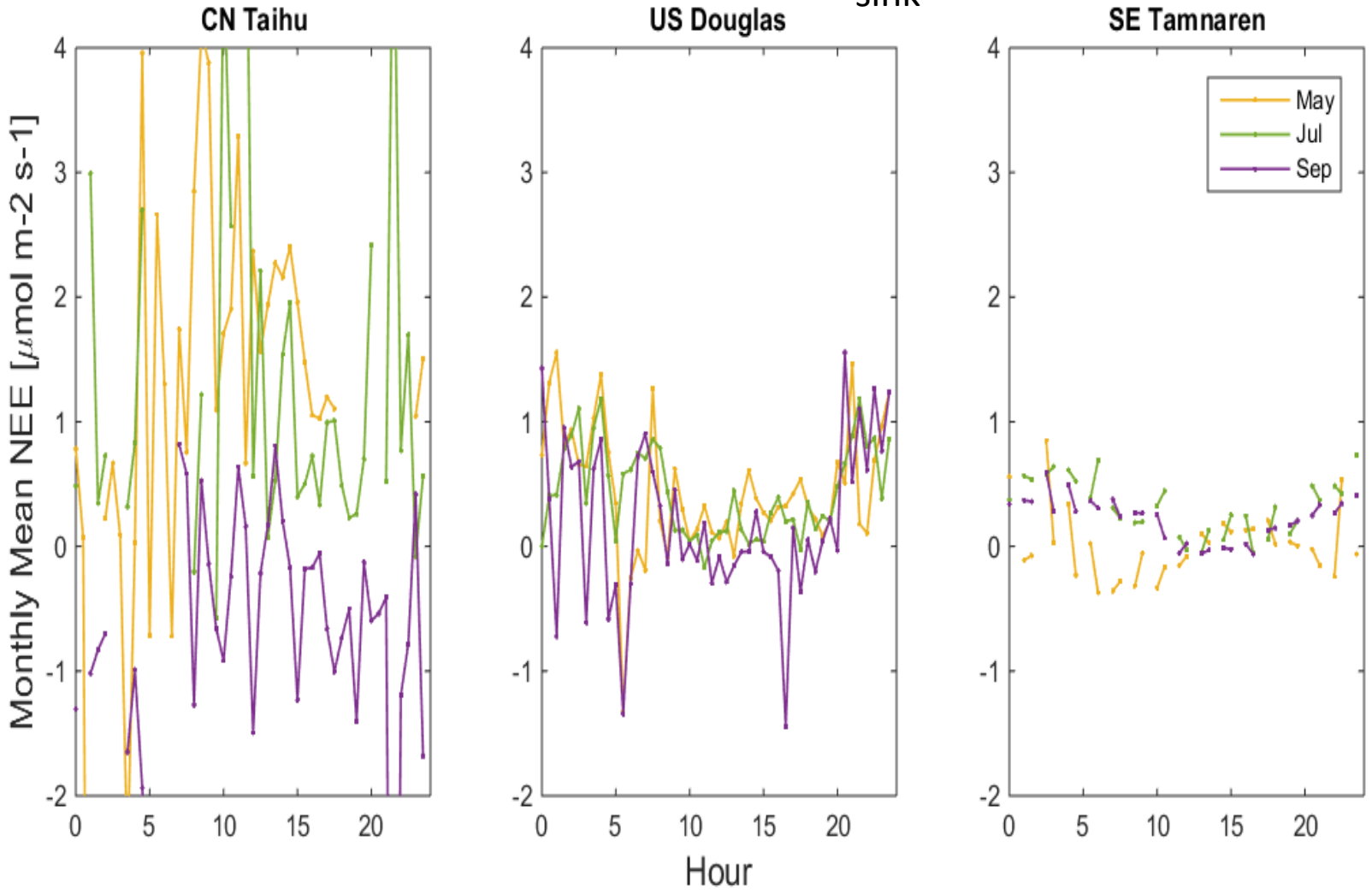


Trout Lake

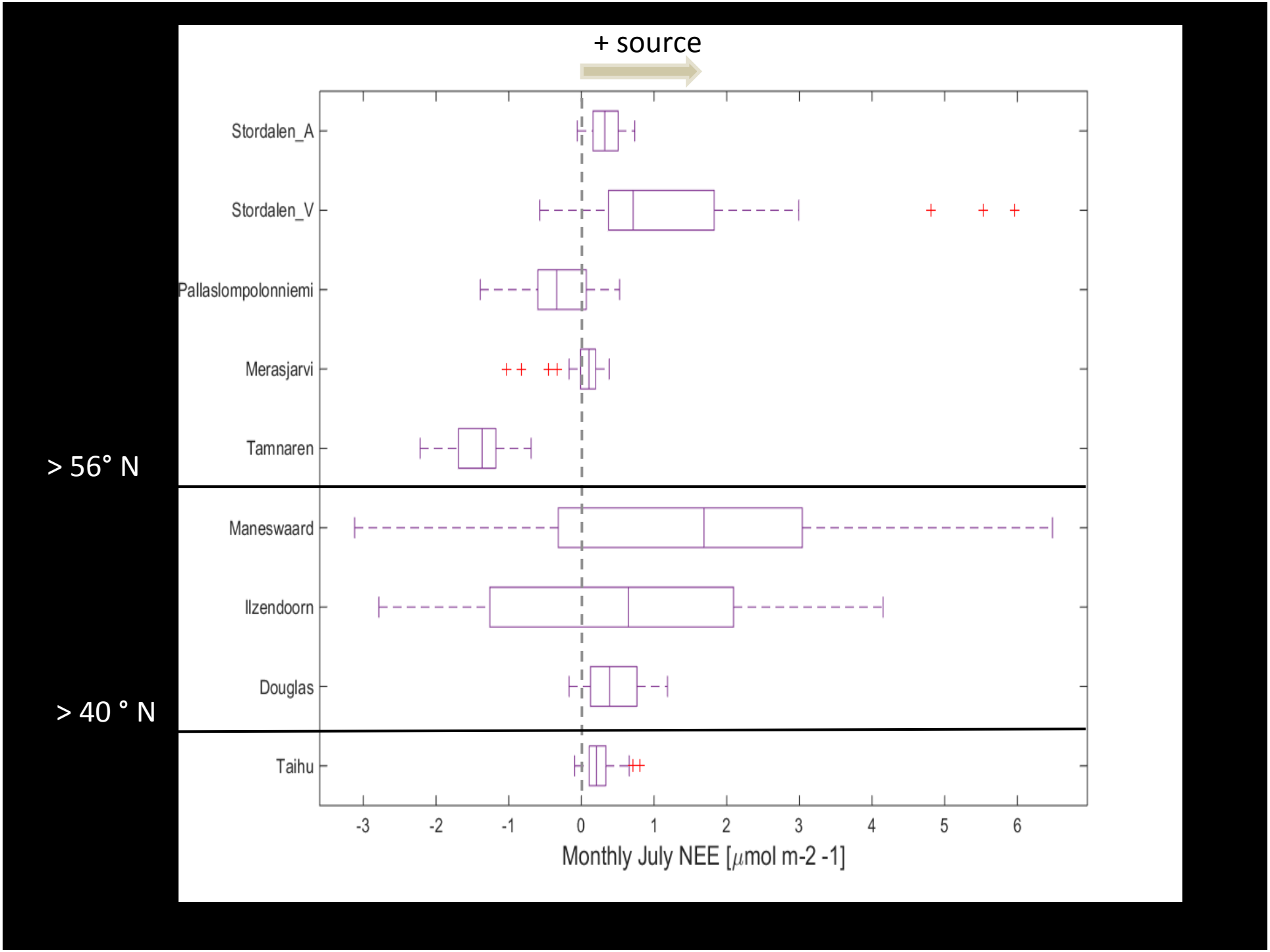


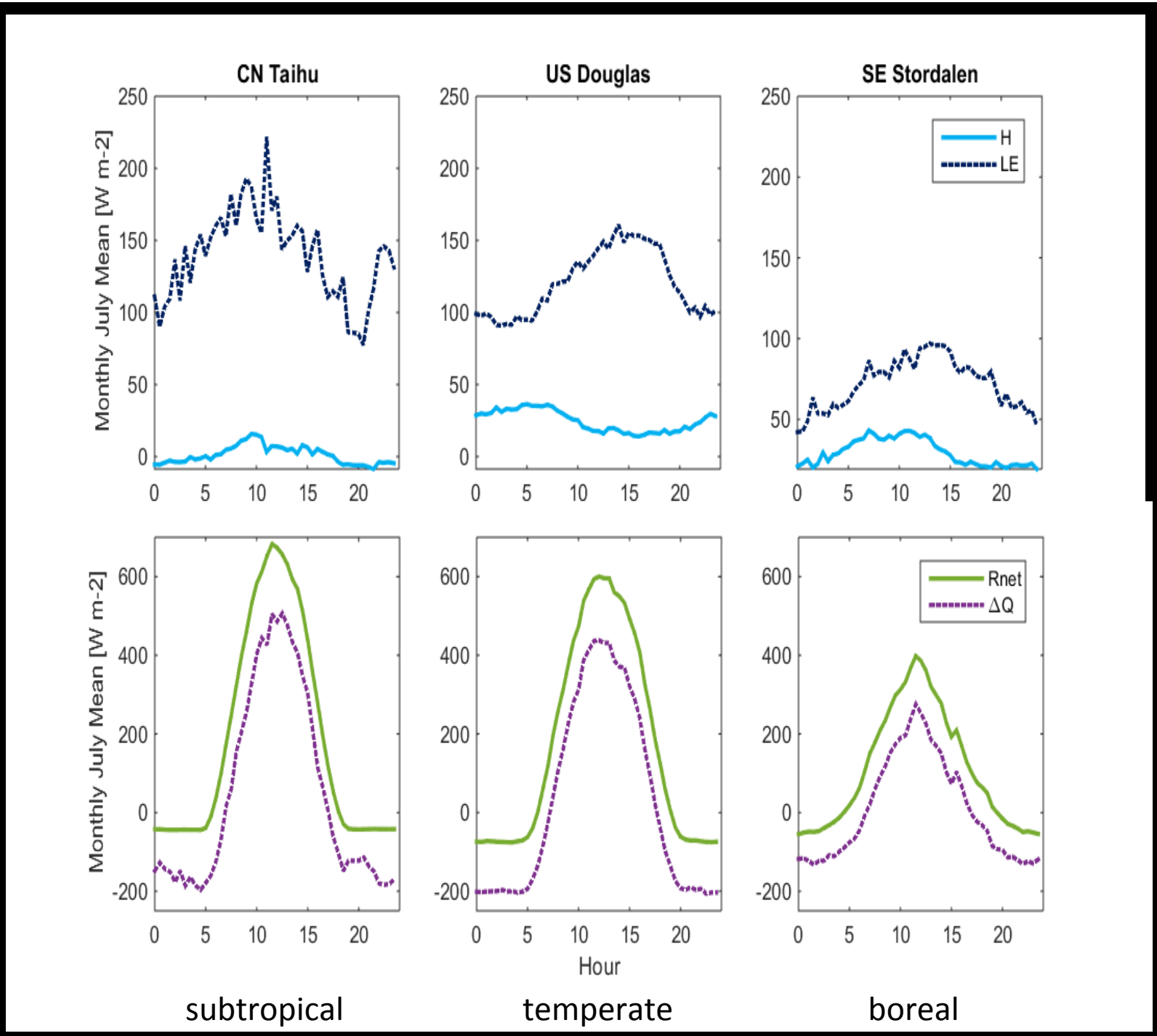
M. Balliett, UW

- sink


CN Taihu
US Douglas
SE Tamnaren
Monthly Mean NEE [μmol m-2 s-1]
Hour
May
Jul
Sep

M. Golub


+ source
Stordalen_A
Stordalen_V
Pallaslompolonniemi
Merasjarvi
Tamnaren
Maneswaard
Ilzendoorn
Douglas
Taihu
-3
-2
-1
0
1
2
3
4
5
6
Monthly July NEE [μmol m-2 -1]
> 56° N
> 40 ° N


CN Taihu
US Douglas
SE Stordalen
H
LE
Rnet
ΔQ
Monthly July Mean [W m-2]
Monthly July Mean [W m-2]
Hour
subtropical
temperate
boreal

Required measurements/criteria for comprehensive lake GHG flux site

- Eddy flux:
  - Fixed platform or island away from shoreline (pre-assessment vs target of opportunity), inclination, accelerometer? Inclinometer (not needed?)? Anemometer angle
  - CO2. CH4 (closed-path preferred because of small fluxes – Webb correction, sensor heating?) H2O (to avoid Webb correction in closed path) – if main power. Trade-off. N2O
  - Humidity/dew point (for flux corrections, calibration), barometer (for density), precipitation (ask modeler)
  - Sonic – moisture deposition issue. Technical specifications, not brand.
  - Storage flux? Concentration is useful. Short towers – may be not essential. Could be useful for diagnosing chimney effect. QC. How to deal episodic fluxes
  - Concentration – pCO2 profile in water pCH4 profile – semi-continuous. DO (oxygen). pN2O (more for rivers/ ag/)? Depends on analyzer too (GCMS, QCL,) – if you had to choose…
    - equilibrator vs diffusive vs chemical
    - Gradient – at least two levels (top and bottom)
  - 2-3 4x4 transects Floating chamber. For spatial variability, campaign based (at least one) CO2, CH4, N2O*. Lake dependent (preliminary assessment then experimental design)
    - Use chamber campaign to assess homogeneity of footprint (depending on question) spatiotemporal
  - Temperature
    - Air – above surface (in addition to sonic T)
    - Water -> profile, at least, near surface, thermocline, bottom – more? 5 depths or Every 1 m (< 1 m near surface), SST
    - Sediment
  - Density of plants/OM in water – chlorophyll, Secchi depth/turbidity, CDOM -> campaign. Weekly. Camera based method?
  - Water chemistry – pH, conductivity, Alk, DIC, DOC, [TP], [TN]?, Oxidation reduction potential, sediment gas concentration (??) methane is mostly in sediment (pore water membrane)? profiles? Salinity* (careful with monitoring program vars)
  - Radiation – 4-component broadband. PAR? (depend on lake type) diffuse – probably not required?
  - Water current (flow magnitude/direction) – sensors? Lateral transport, water u*, waves for roughness, K
  - Inflow/outflow – DOC/DIC, current magnitude – campaign? pCO2? pCH4?
  - Lake level – same instrument as wave
  - Stratification and ice phenology
  - Morphometry/Bathymetry – mean/max lake depth, area,
  - Metadata – location in tower vs location of lake center, lake boundary outline (polygon), catchment vegetation, stratification (dimictic vs polymictic, …), nutrient type (eutrophic, oligotrophic), substrate (sediment, bedrock)

Minimum measurements/criteria for a lake GHG flux site

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  - ~~Fixed platform or island away from shoreline (pre-assessment vs target of opportunity), inclination,~~ accelerometer~~? Inclinometer (not needed?)?~~ Anemometer angle
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    - equilibrator vs diffusive vs chemical
    - ~~Gradient – at least two levels (top and bottom)~~
  - ~~Floating chamber? For spatial variability, campaign based (at least one)~~
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    - ~~Sediment~~
  - Density of plants/OM in water – ~~chlorophyll,~~ Secchi depth~~/turbidity, CDOM -> campaign. Weekly. Camera based method?~~
  - Water chemistry – pH, ~~conductivity~~, ~~Alk~~, DIC, ~~DOC, [P], [N]?, Oxidation reduction potential, sediment gas concentration (??) methane is mostly in sediment (pore water membrane)? profiles?~~ monthly
  - Radiation – ~~4-component broadband.~~ PAR~~? (depend on lake type) diffuse – probably not required?,~~ net radiation
  - ~~Water current (flow magnitude/direction) – sensors? Lateral transport, water u* (ADCP, ??), waves for roughness L?~~
  - ~~Inflow/outflow – DOC/DIC, current magnitude – campaign? pCO2? pCH4?~~
  - Water sampling for sending samples to a facility for chemical analysis
  - ~~Lake level – same instrument as wave~~
  - Stratification and ice phenology
  - Morphometry/Bathymetry – mean~~/max~~ lake depth, area,
  - Metadata – location in tower ~~vs location of lake center, lake boundary outline (polygon)~~, catchment vegetation, stratification (dimictic vs polymictic, …), nutrient type (eutrophic, oligotrophic), ~~substrate (sediment, bedrock)~~

Thank you!

Acknowledgements: Desai Lab and collaborators, National Science Foundation & North Temperate Lakes LTER