Institute of Oceanology PAS –
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Centre for Polar Studies

Comparing mass, momentum and air-sea CO_2 fluxes for the North Atlantic and the European Arctic

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10.6 Air-sea interaction at high latitudes – 20th Air-sea Interaction Conference

Oceanflux Greenhouse Gases Evolution

oceanflux evolution
support to science element

Outline

- Background
- Motivation
- Momentum fluxes
- Whitecapping
- Air-sea CO_2 fluxes
- Conclusion
- Future work

Effect of gas-transfer velocity parameterization choice on air-sea CO_2 fluxes in the NA and the EA – Ocean Science, 12,2591-2616, doi:10.5194/osd-12-2591-2015,2015,

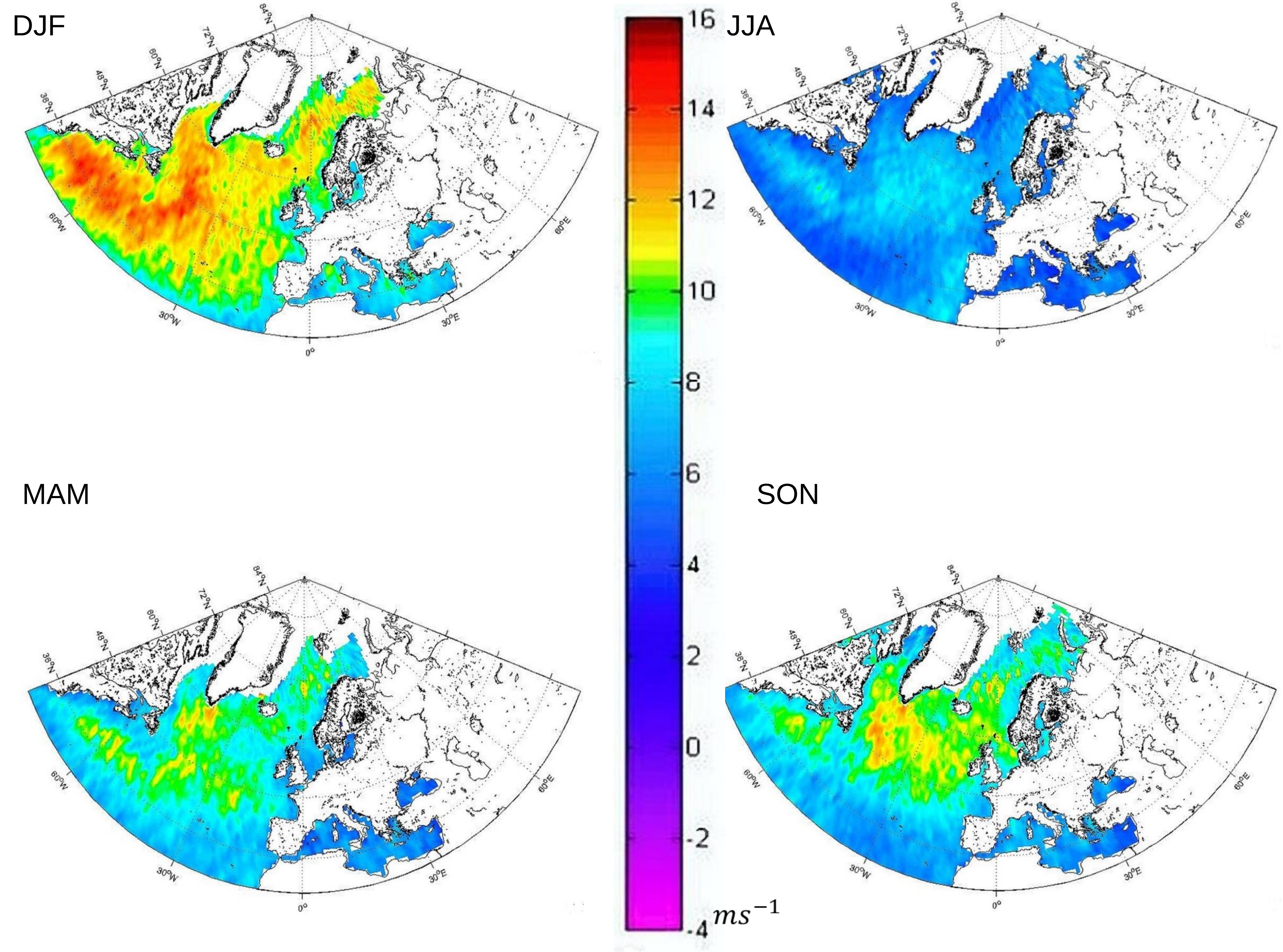
Monthly dynamics of the carbon dioxide exchange in the Artic Ocean as effect of changes in the gas transfer velocity and partial pressure of CO_2 in seawater, during 2010 – Oceanologia, 2016 in review

Background

- All input data are 1° x 1° global monthly composites.

Parameter	Dataset (current number of datasets)	Uncertainty	Years
SST	NOAA AVHRR, ESA CCI, GHRSST datasets (4)	yes	1992-2010
U10	ESA GlobWave archive (2+)	yes	1992-2010
Hs	ESA GlobWave archive (1+)	yes	1992-2010
pCO_2/fCO_2	LDEO Takahashi 2002, LDEO Takahashi 2009, OceanFlux/SOCATv1.5, OceanFlux/SOCATv2 (4)	majority	2000 2010
Rain	GPCP, TRMM, SSMI (4)	yes	1992-2012
Chl-a	ESA GlobColour, ESA Ocean Colour CCI (2)	yes	1997-2011

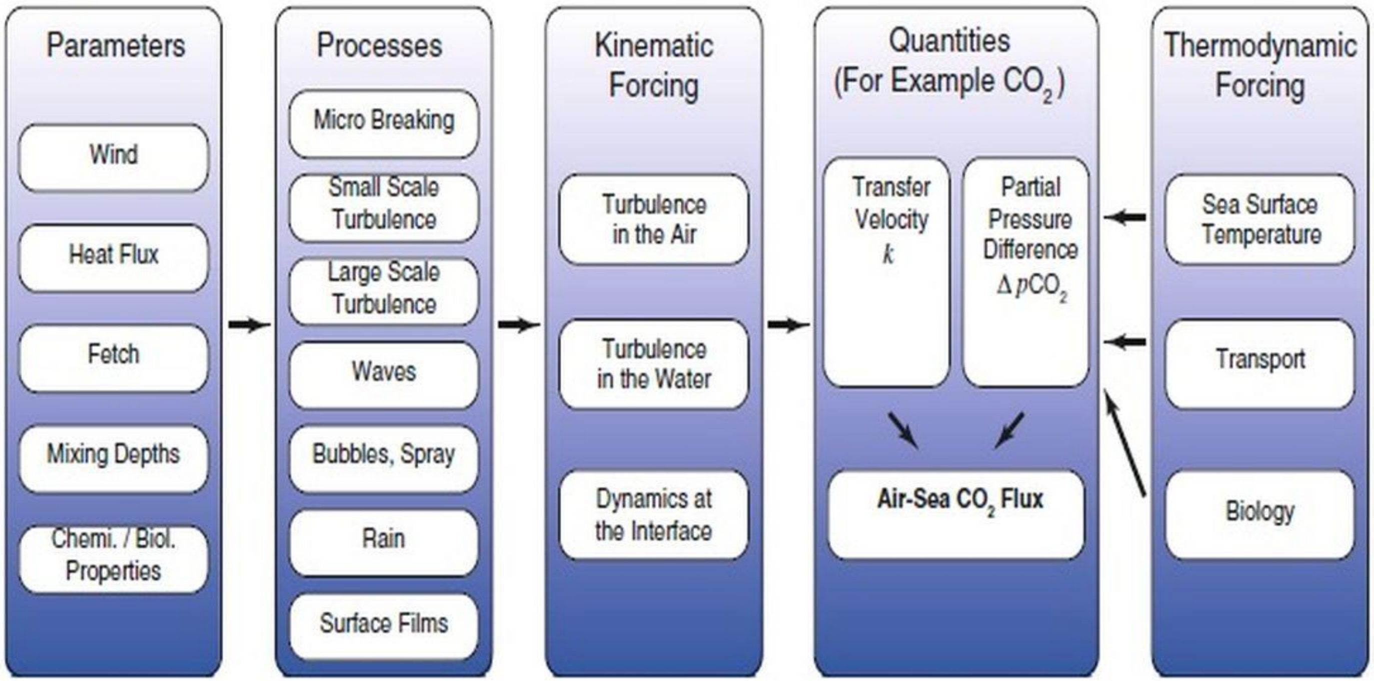
http://www.oceanflux-ghg.org/content/download/73011/949145/file/Shutler_AirSeaGaz-Brest2013.pdf



DJF
JJA
MAM
SON
16
14
12
10
8
6
4
2
0
-2
-4
ms^{-1}
84°N
72°N
60°N
48°N
36°N
60°W
30°W
0°
30°E
60°E

Motivation

Seasonal sea ice coverage, especially in winter, reduces the exchange of energy, mass and gas between the atmosphere and ocean, and also affects negative for the penetration of sunlight into the ocean.



Arctic is the most changing part of our world

Oceanic whitecaps mark areas of enchance air-sea gas exchange and knowledge of the variation of whitecapping can therefore improve the calculation of gas fluxes between ocean and atmosphere

Anguelova and Webster, 2006

Whitecapping parameterizations

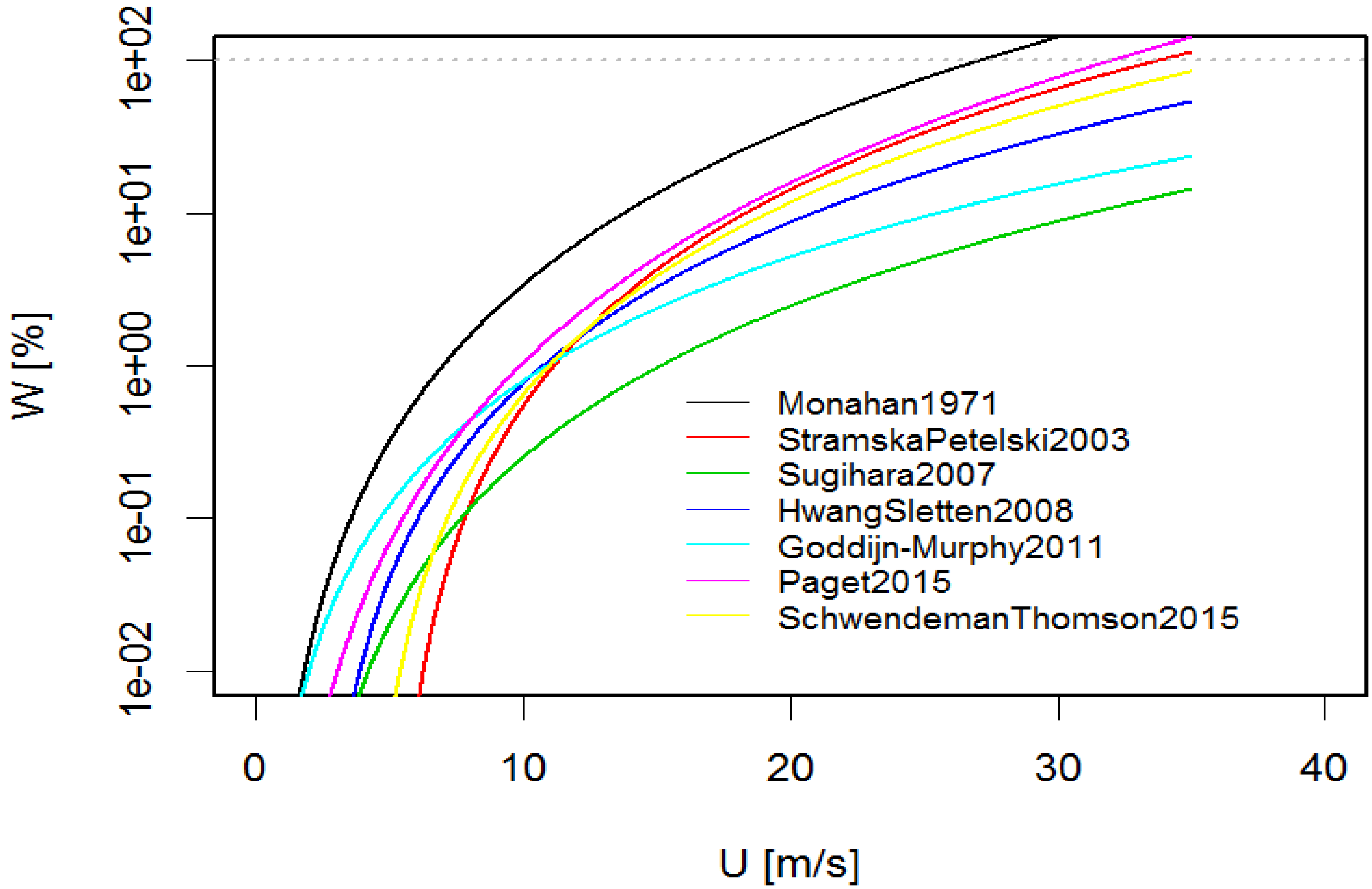
1. Monahan, 1971:

2. Stran

3. Sugih

4. Hwar

5. Godd



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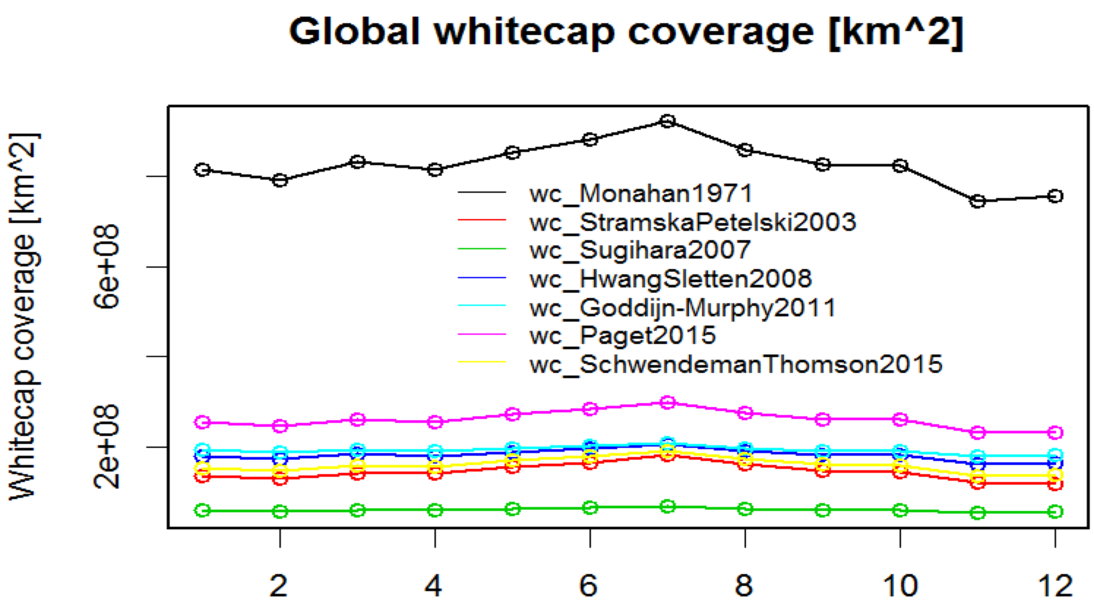
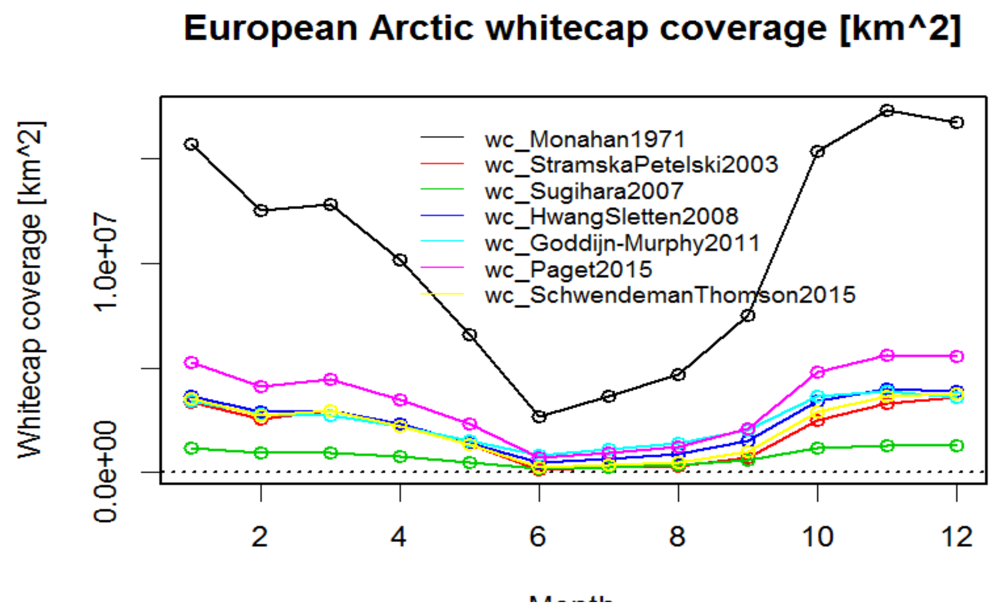
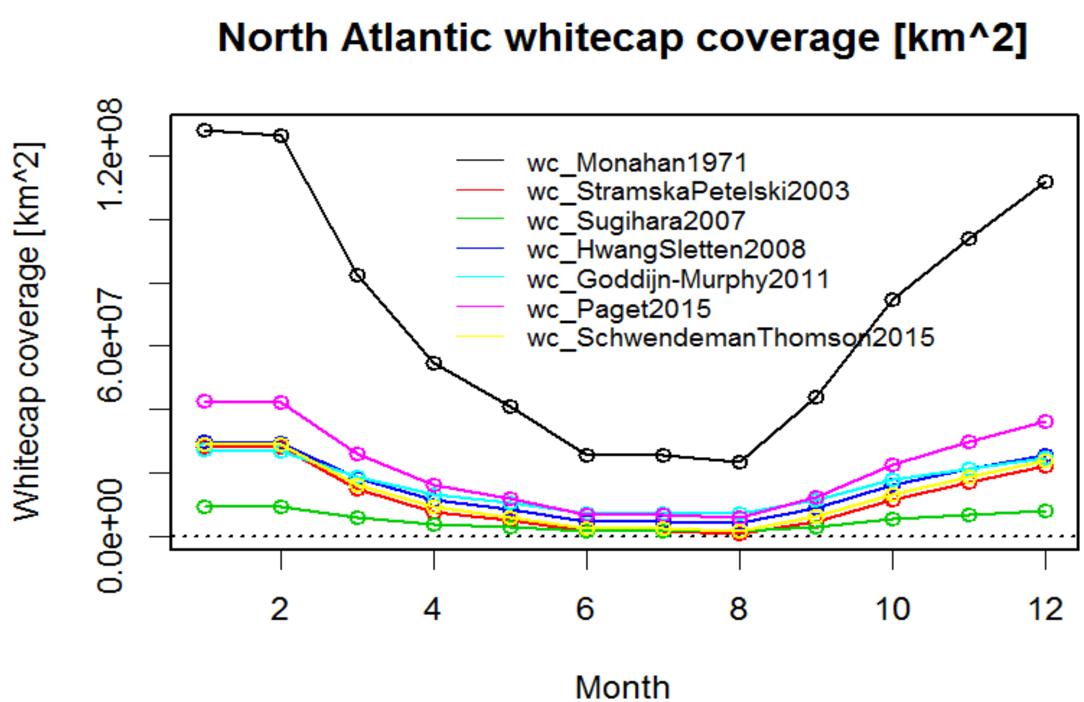
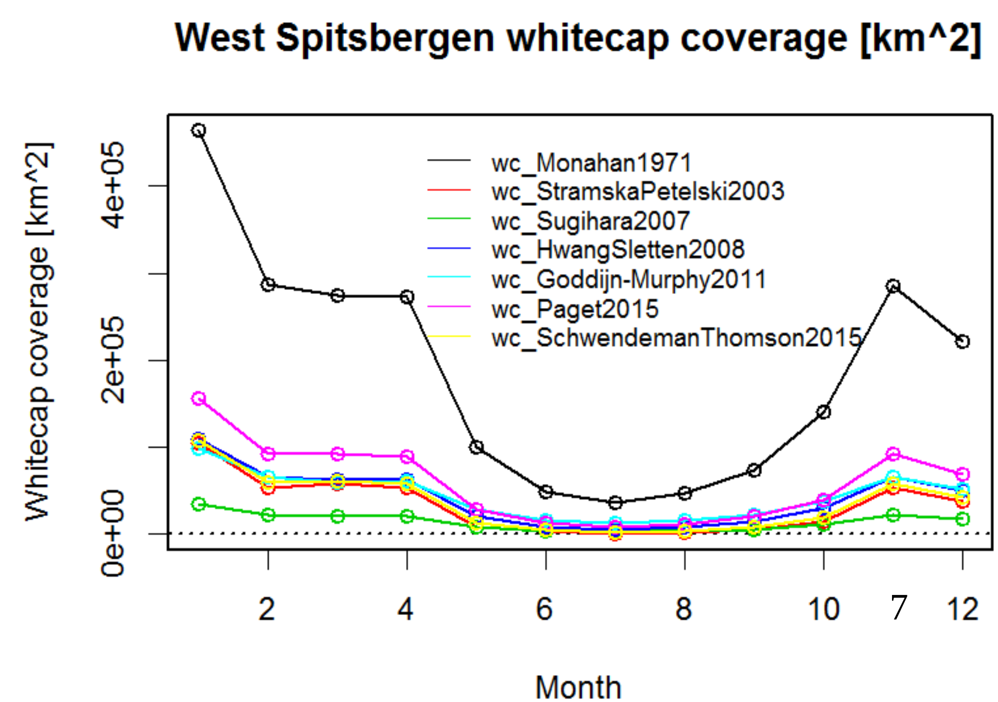








Momentum fluxes

1. Wu, 1969:

$C_D = 0.5\, U_{10}^{1/2} * 10^{-3}$ for "light wind" 1 ms-1< U10 < 15 ms-1

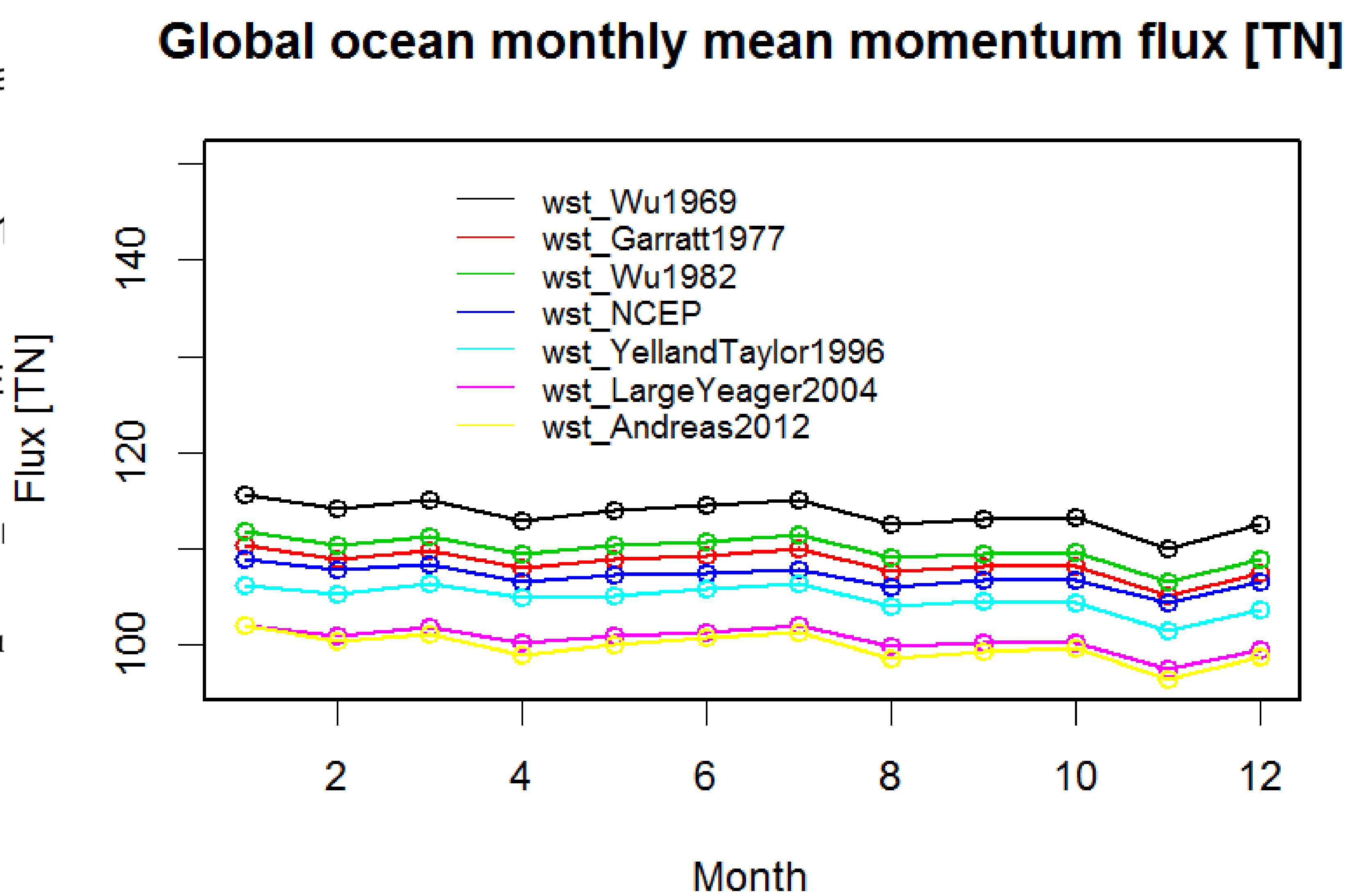
2. Garra

3. Wu, 1

4. NCE

5. Yella

ms-1



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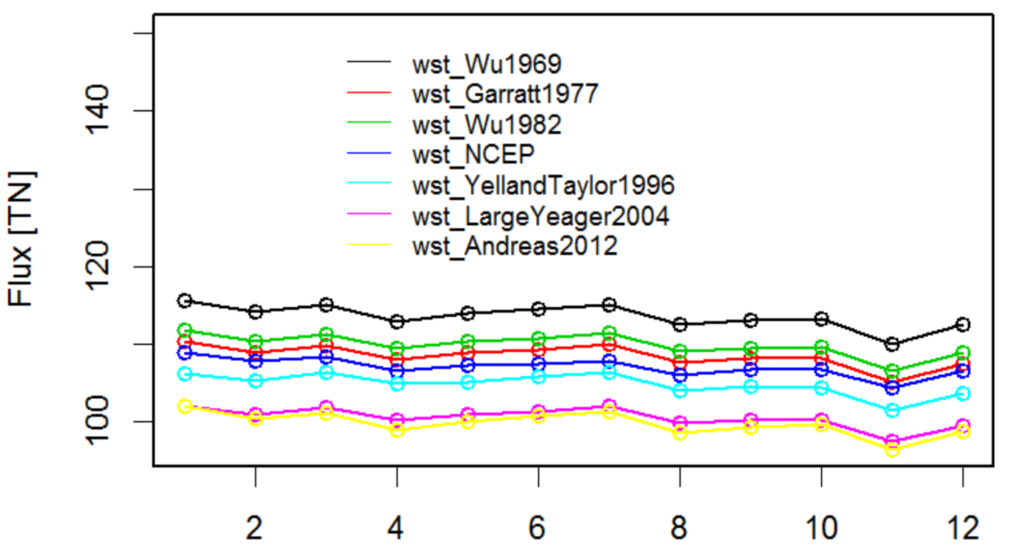
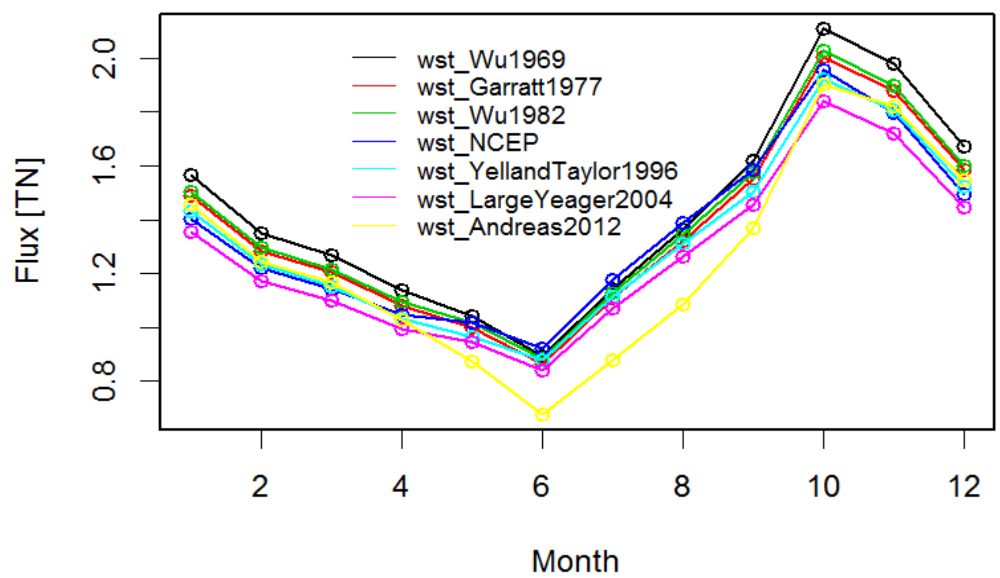
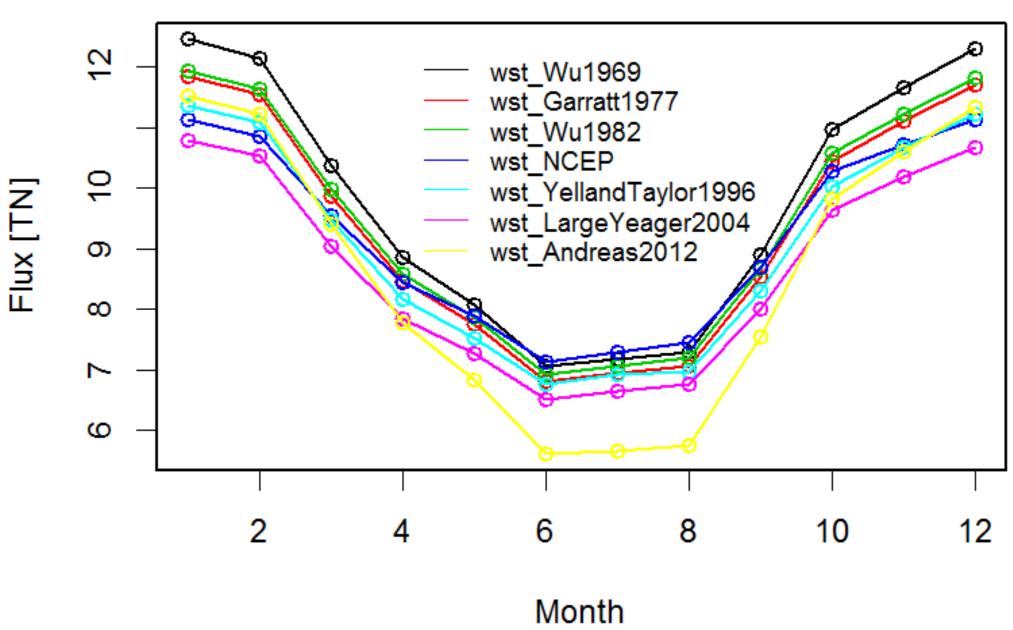
Global ocean monthly mean momentum flux [TN]



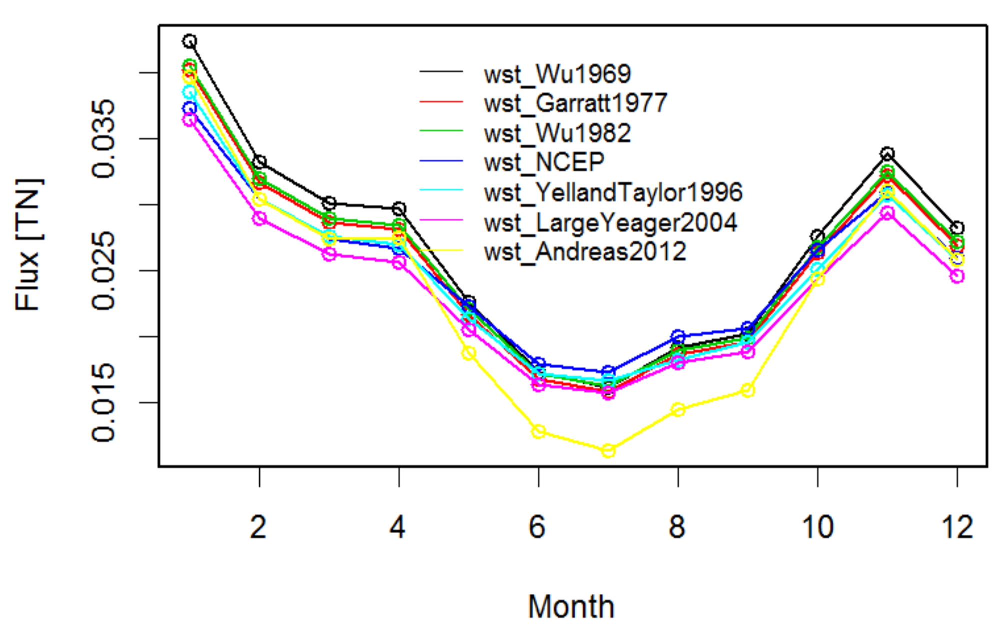
European Arctic monthly mean momentum flux [TN]



North Atlantic monthly mean momentum flux [TN]



West Spitsbergen monthly mean momentum flux [TN]



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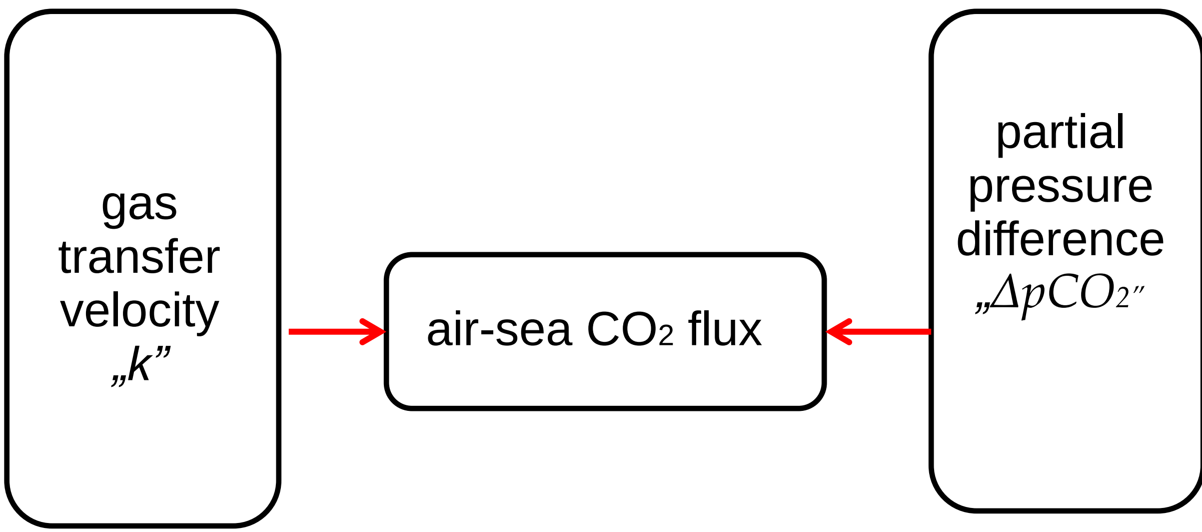
Millions of CO2 partial pressure measurements are used to create climatologies of net air-sea fluxes. However the flux calculations depend of still uncertain physical formula for gas transfer velocity. **Our motivation** is to check how the choice of *k* formula affects fluxes in North Atlantic and the European Arcticas as well as compare air-sea CO2 fluxes with ΔpCO2 and wind speed

$$F = k * pCO_{2air} - pCO_{2water}$$



Ho et al 2006

$$k = \sqrt{(600.0/Sc_{skin})} * 0.266\ U_{10}^2$$

Nightingale et al., 2000

$$k = \sqrt{(600.0/Sc_{skin})} * (0.222\ U_{10}^2 + 0.333\ U_{10})$$

Wanninkhof and McGillis 1999

$$k = \sqrt{(600.0/Sc_{skin})} * 0.0283\ U_{10}^3$$

Wanninkhof, 2013

$$k = \sqrt{(660.0/Sc_{skin})} * 0.251 * U_{10}^2$$

McGillis et al., 2001

$$k = \sqrt{(600.0/Sc_{skin})} * (3.3 + 0.026\ U_{10}^3)$$

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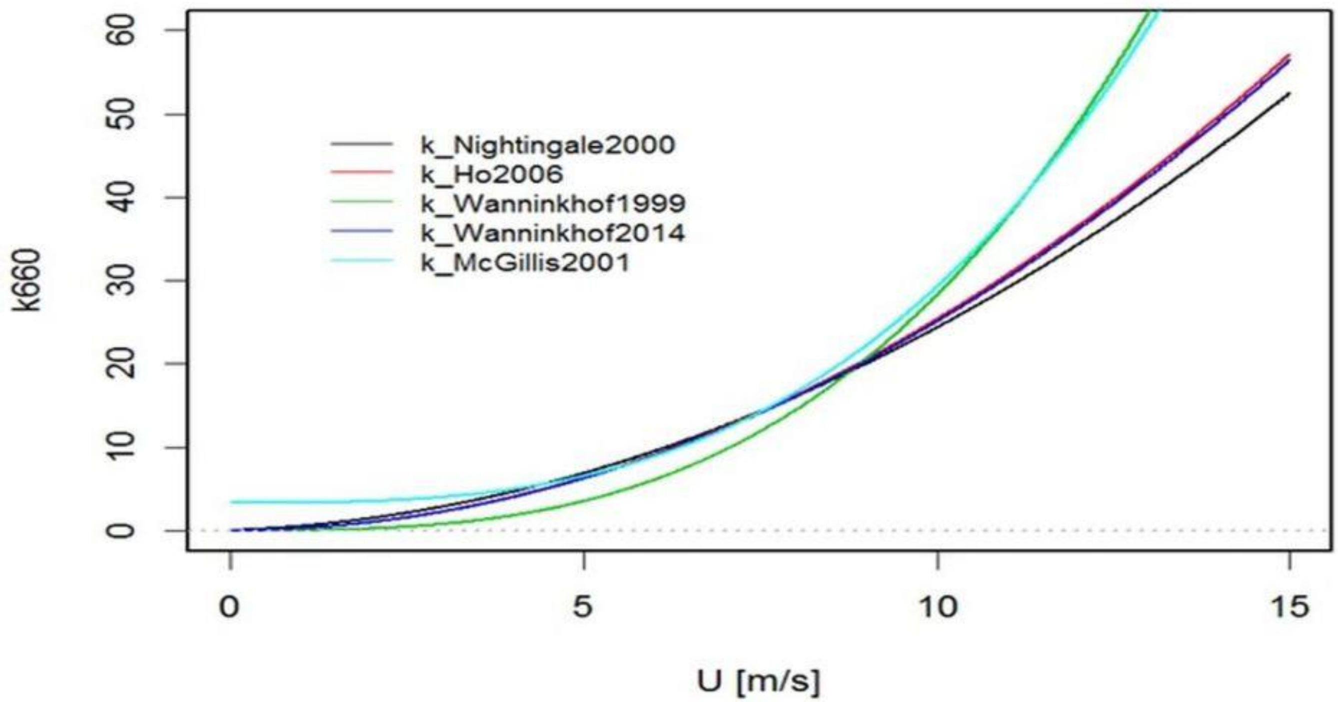
k / WS	**CO_2 / pCO_{2W}**	**F / k**	**F / ΔpCO_2**	**F / pCO_{2W}**	**F / pCO_{2A}**
$r^2 = 0.99$	$r^2 = 0.88$	$r^2 = 0.93$	$r^2 = 0.55$	$r^2 = 0.64$	$r^2 = 0.3$

	Global
Nightingale et al., 2000	-1.30 (1.00)
Ho et al., 2006	-1.42 (1.09)
Wanninkhof and McGillis, 1999	-1.73 (1.33)
Wanninkhof, 2014	-1.40 (1.08)
McGillis et al., 2001	-2.15 (1.65)



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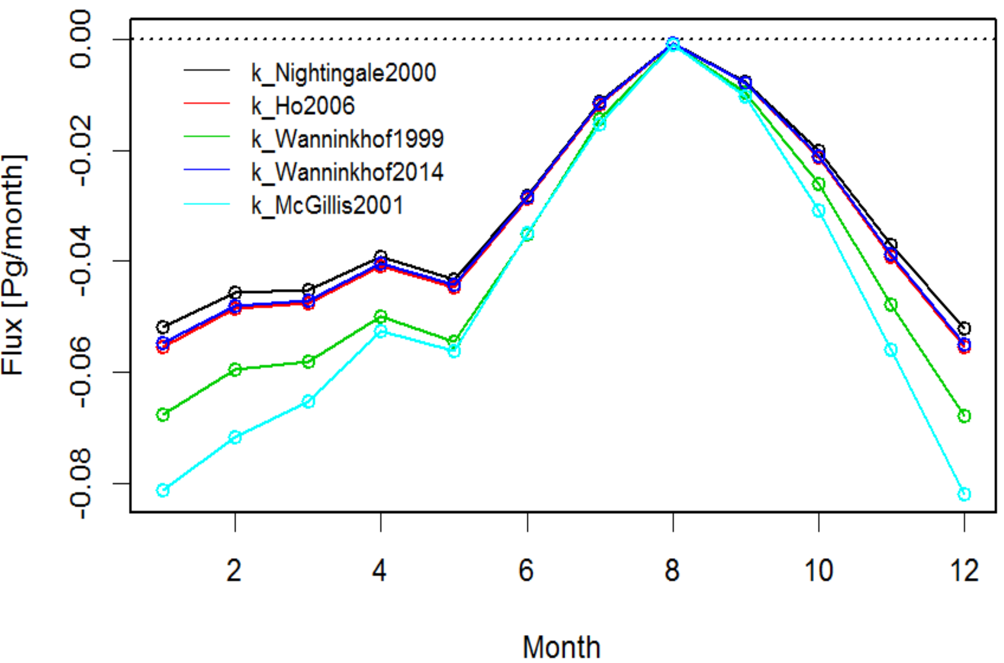
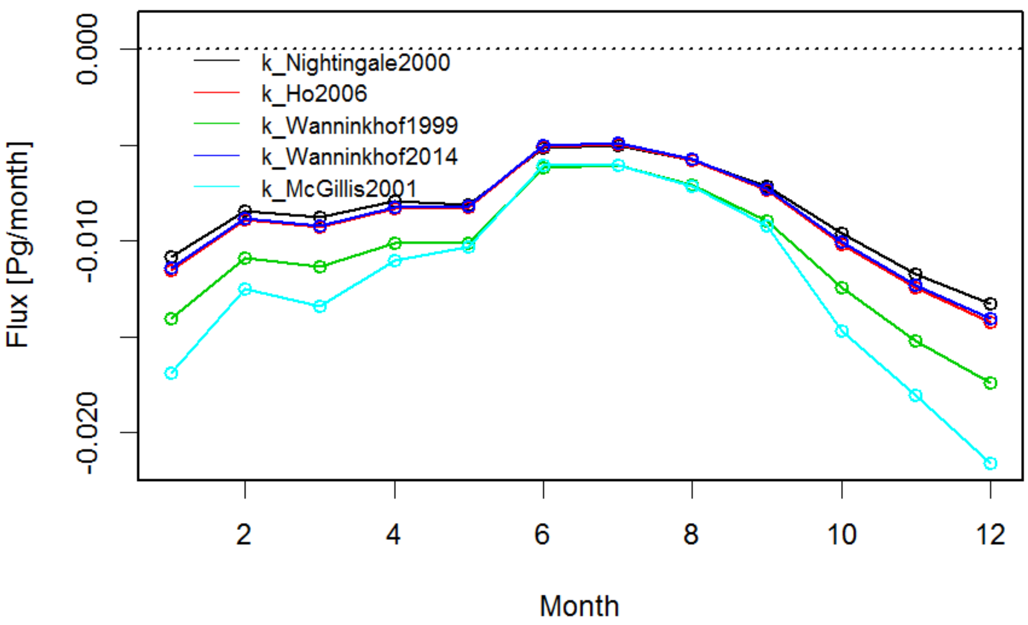
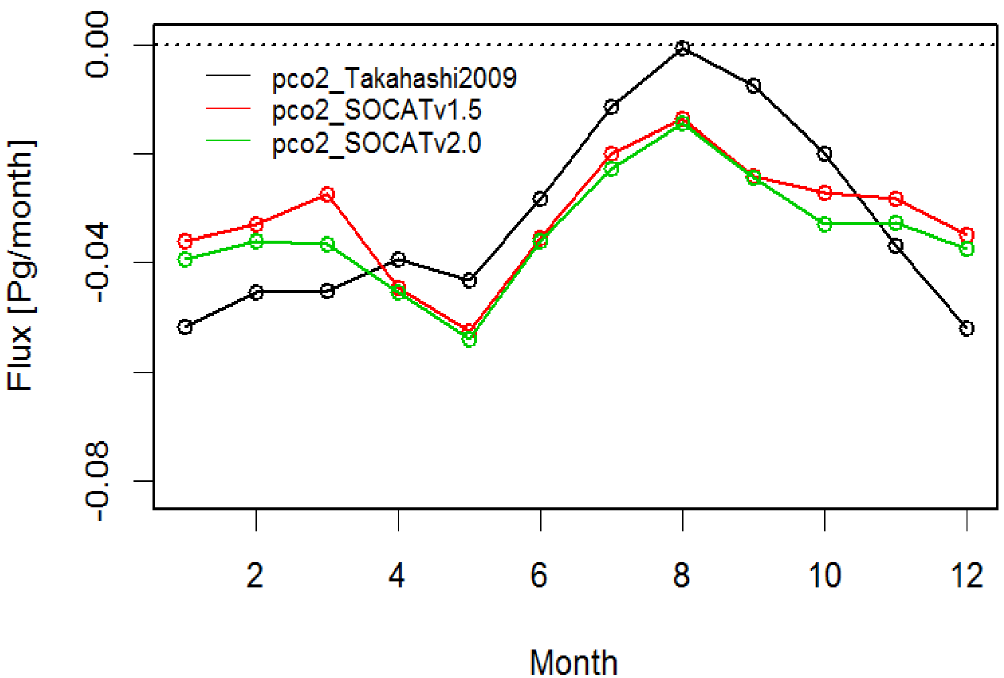
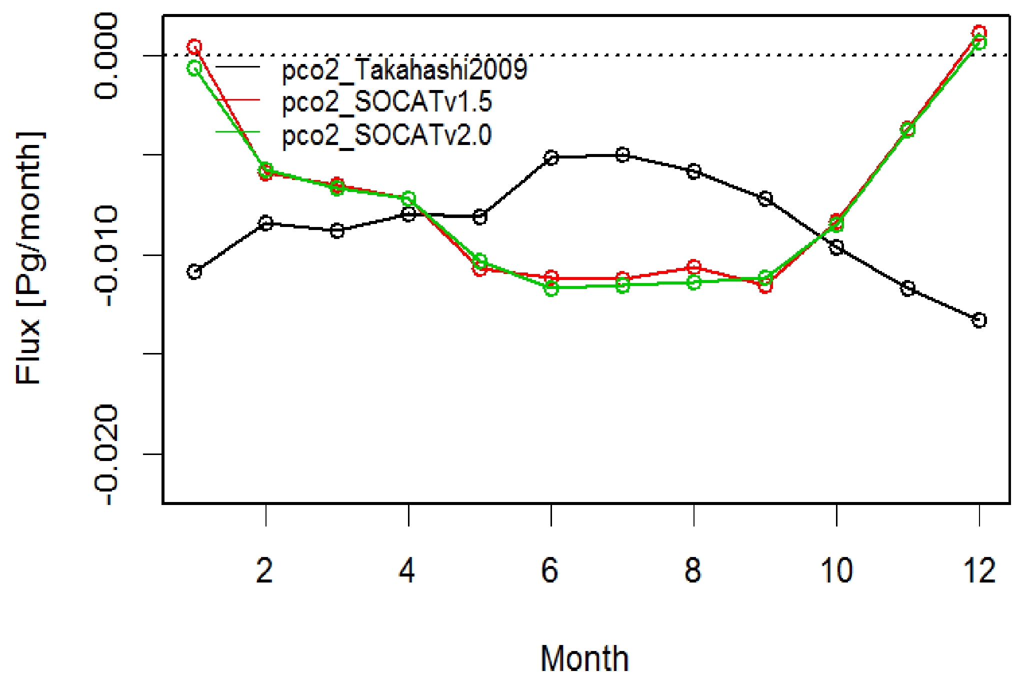
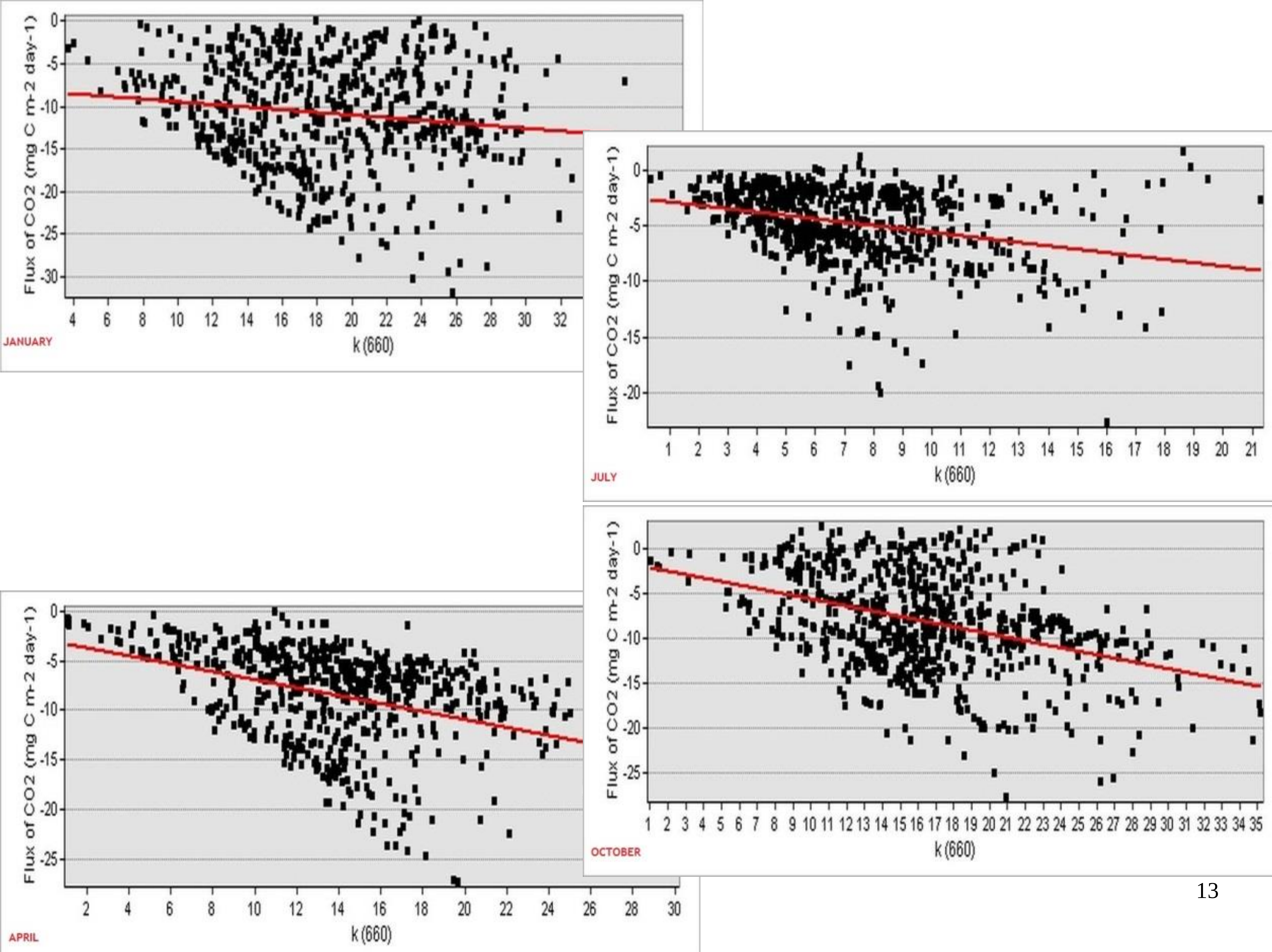
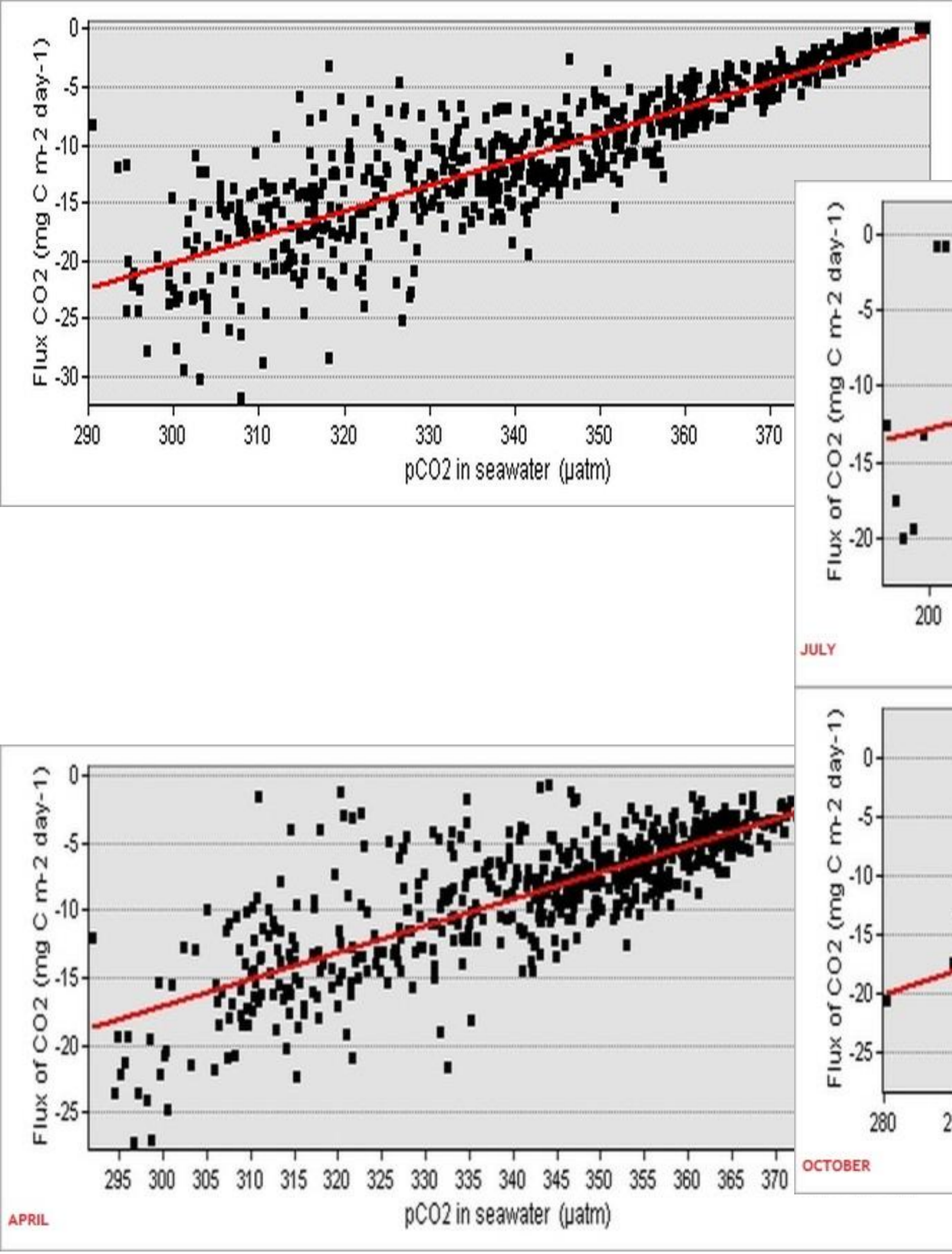


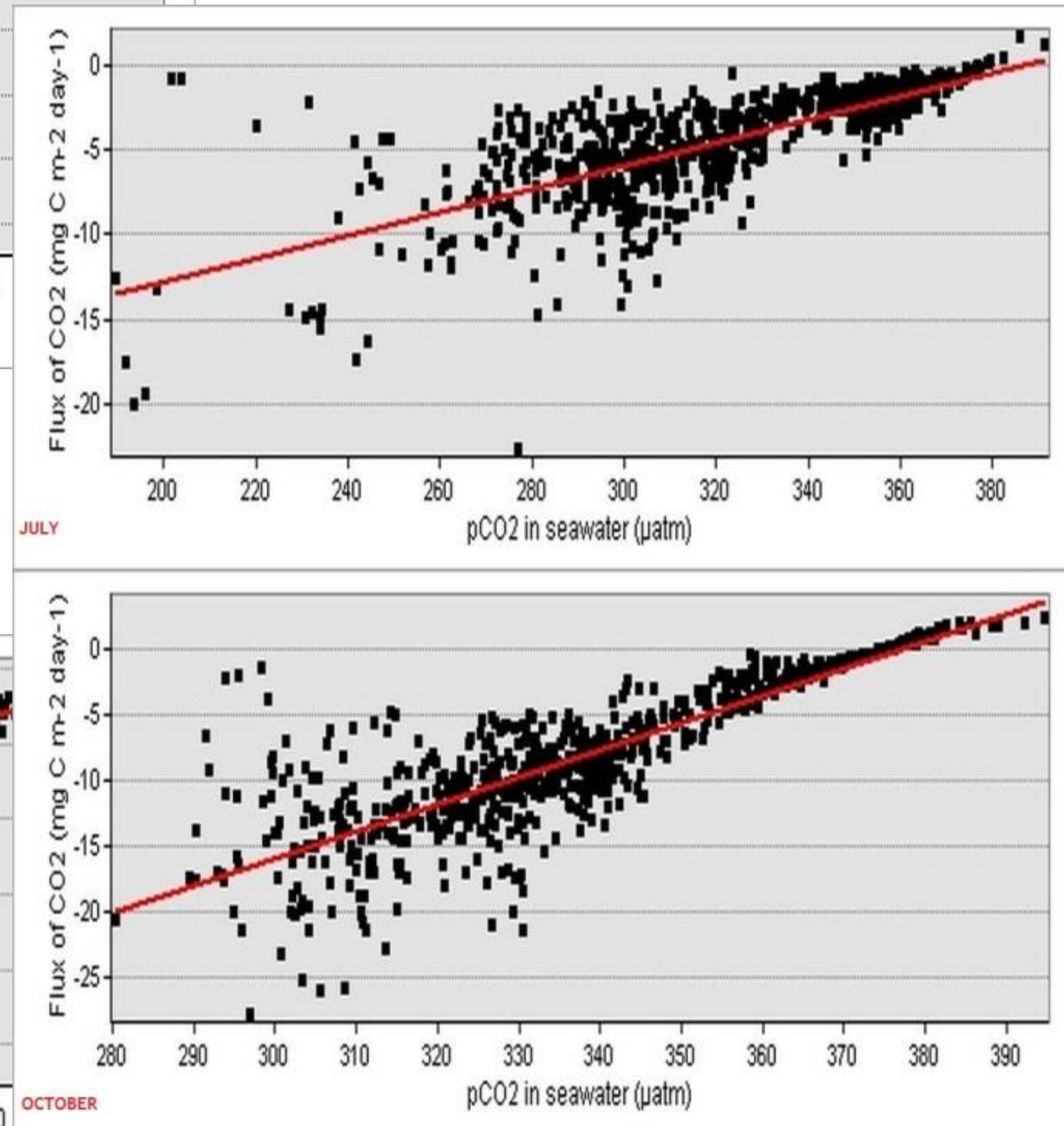


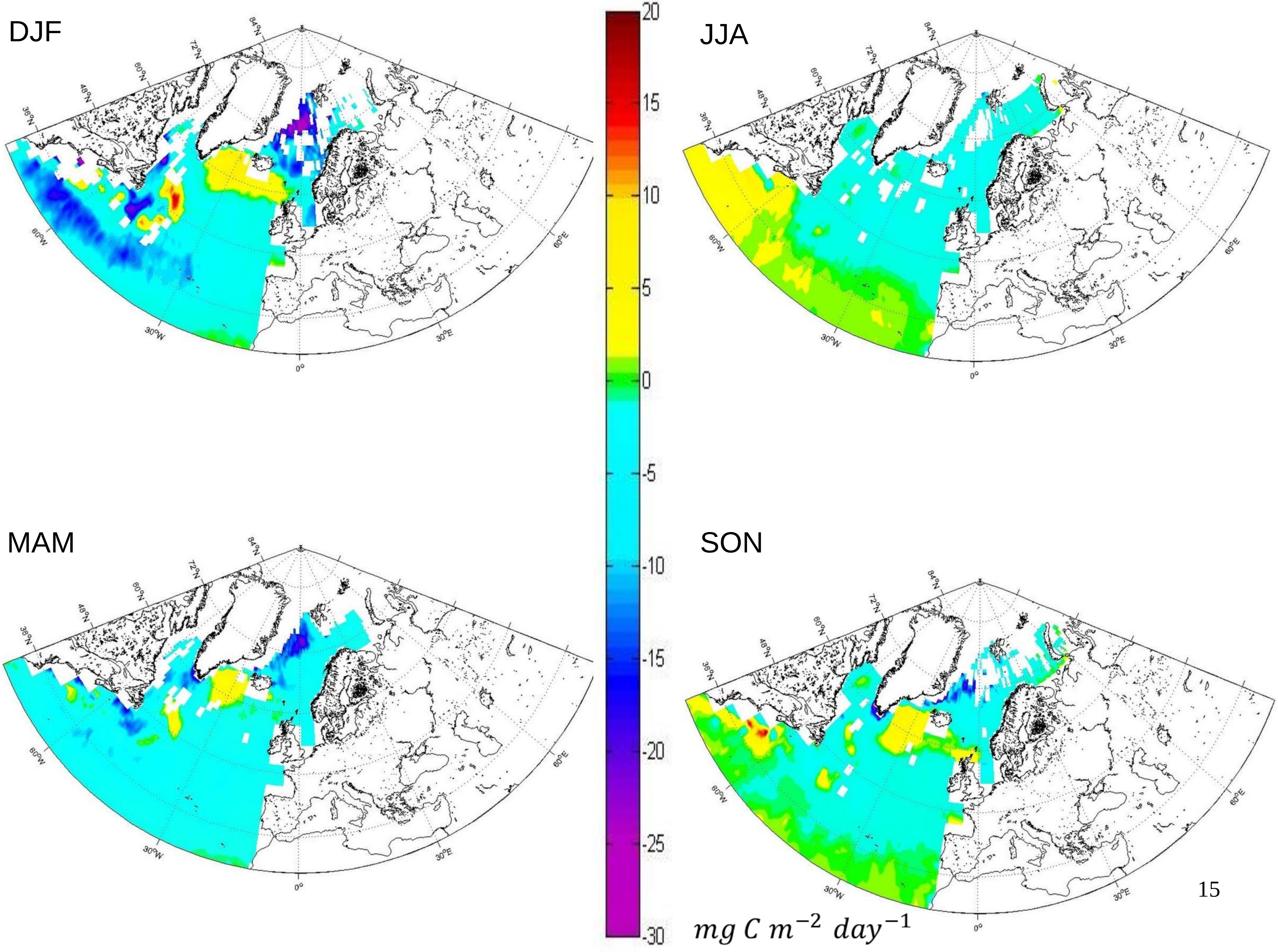





Flux of CO2 (mg C m-2 day-1)
k (660)
JANUARY
Flux of CO2 (mg C m-2 day-1)
k (660)
JULY
Flux of CO2 (mg C m-2 day-1)
k (660)
APRIL
Flux of CO2 (mg C m-2 day-1)
k (660)
OCTOBER


Flux CO2 (mg C m-2 day-1)
pCO2 in seawater (µatm)
Flux of CO2 (mg C m-2 day-1)
pCO2 in seawater (µatm)
APRIL


Flux of CO2 (mg C m-2 day-1)
pCO2 in seawater (µatm)
JULY
Flux of CO2 (mg C m-2 day-1)
pCO2 in seawater (µatm)
OCTOBER


DJF
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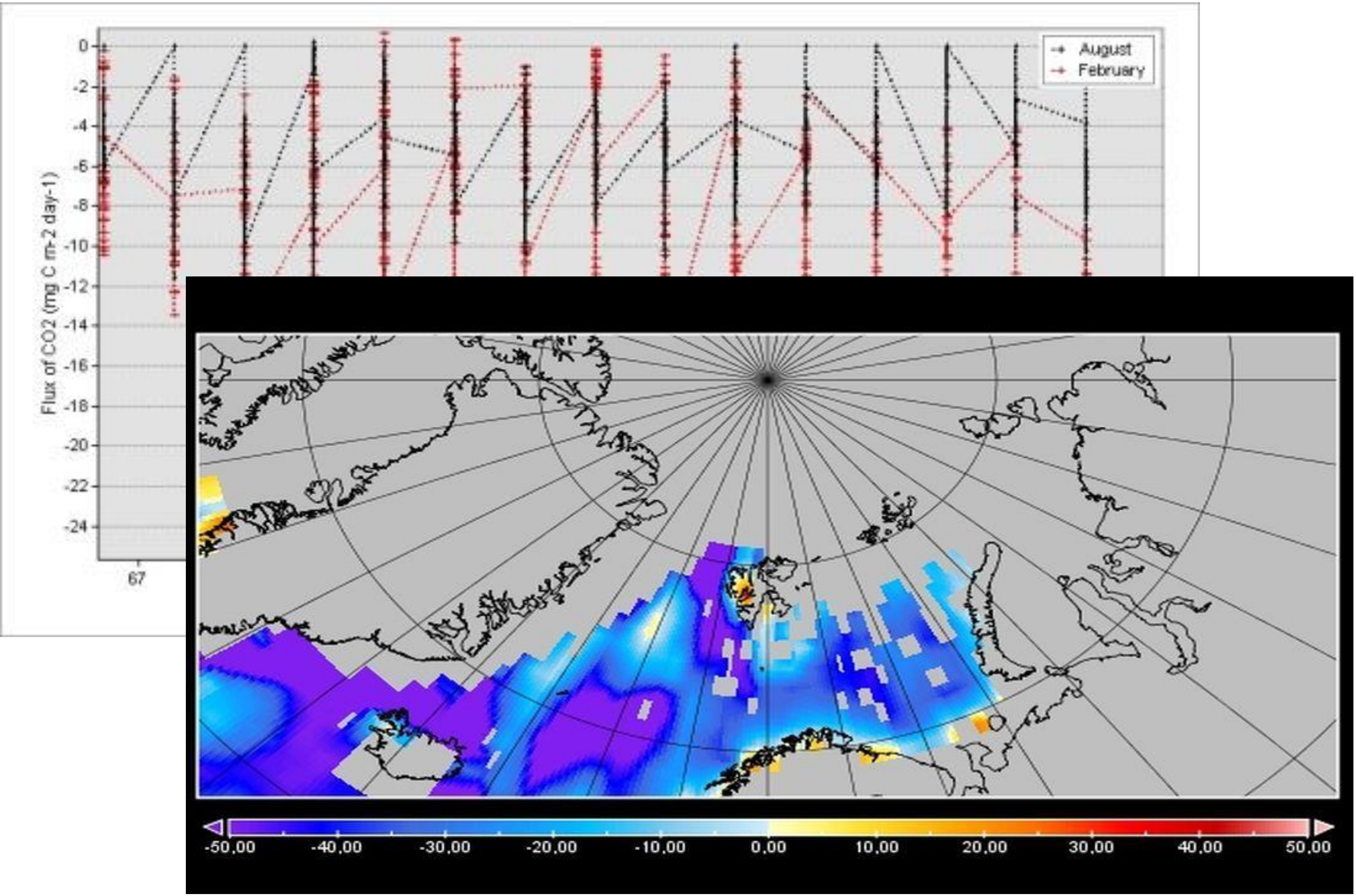
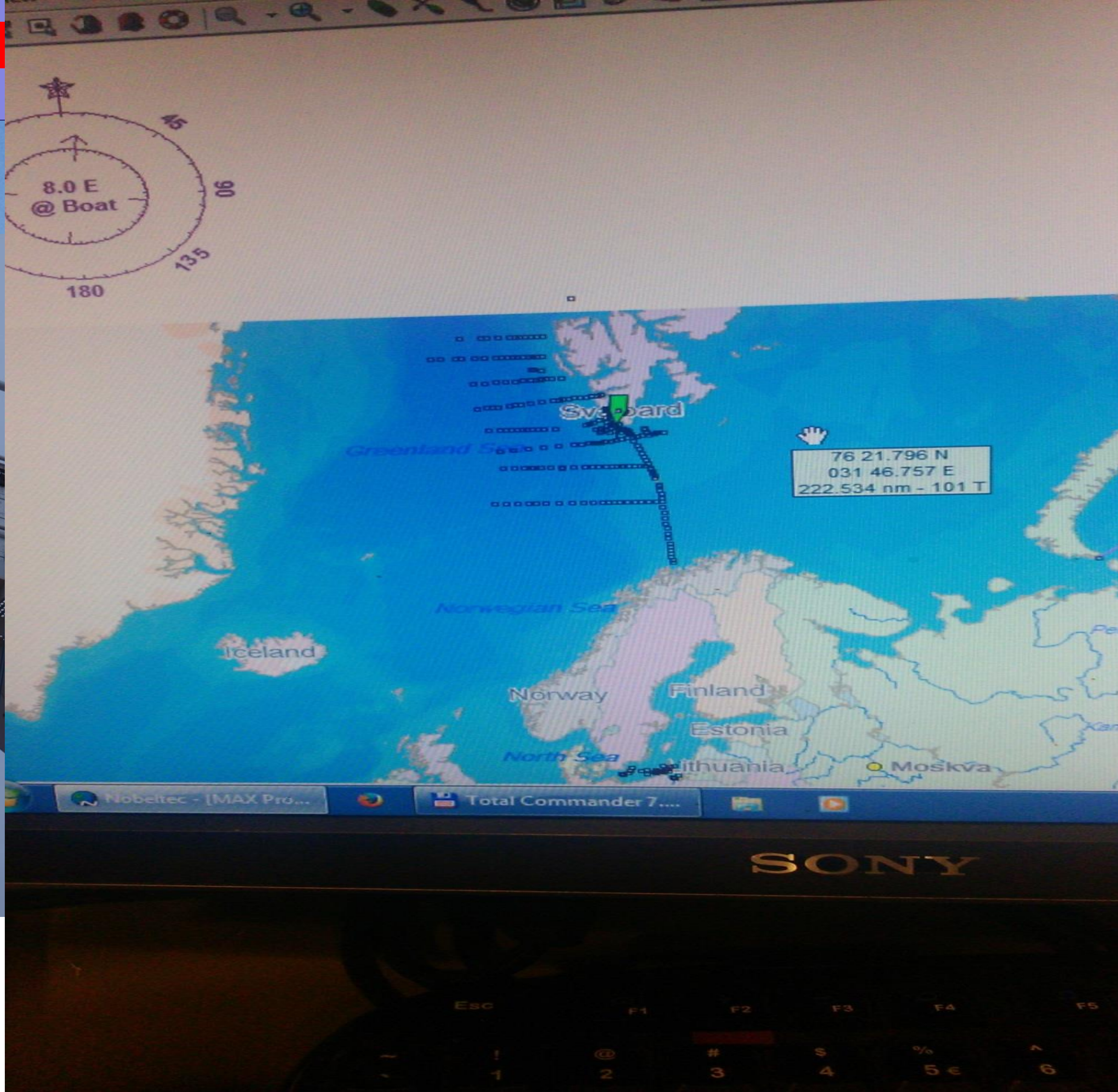
84°N
72°N
60°N
48°N
36°N
60°W
30°W
0°
30°E
60°E
$mg\ C\ m^{-2}\ day^{-1}$


August
February
Flux of CO2 (mg C m-2 day-1)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
67
-50,00
-40,00
-30,00
-20,00
-10,00
0,00
10,00
20,00
30,00
40,00
50,00

Some conclusions

- Gas transfer velocity *k* parameterizations using U^3 result in larger net fluxes in all studied areas comparing to the (mostly newer) U^2 parameterizations.
- The difference between net fluxes in U^2 and U^3 parameterizations is smaller in the North Atlantic and Arctic regions (~ 20%) than globally (~ 30%) contrary to our expectations (stronger winds!).
- Both, the constant direction of the air-sea CO_2 fluxes in all seasons and the typical NA wind speeds of about 9 m/s, accidently make the NA an area where the choic of k parameterizations causes very small flux uncertainy an annual fluxes.
- In monthly scale air-sea CO_2 fluxes are strongly dependent on gast transfer velocity than pCO_2.

Futu



8.0 E
@ Boat
45
90
135
180
Greenland Sea
Norwegian Sea
Iceland
Norway
Finland
Estonia
North Sea
Moskva
76 21.796 N
031 46.757 E
222.534 nm - 101 T
Total Commander 7....
SONY

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Thank you