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## WP1 – Task 1.1: Global 20th century analysis

Development of the ocean carbon component

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[UVSQ/LSCE] Marion Gehlen





# Objectives and Strategy

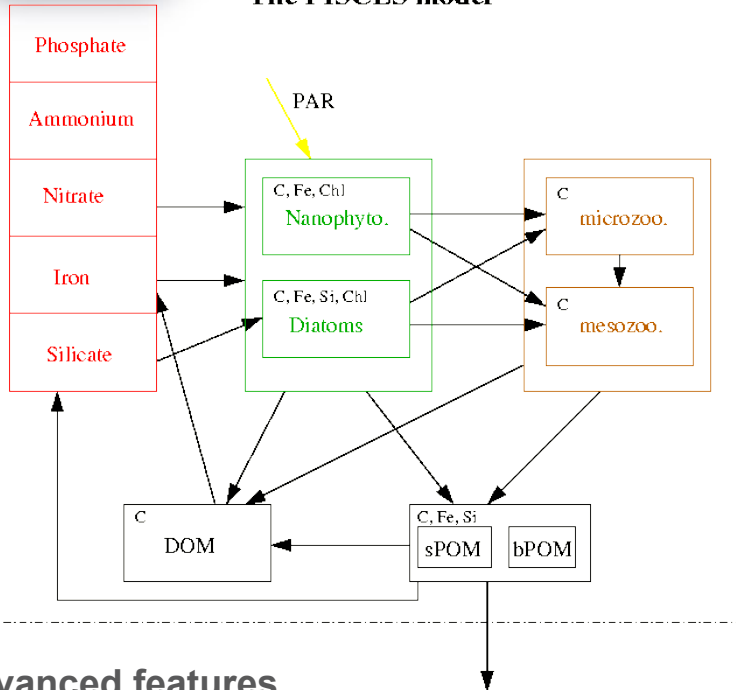
## Objectives:

- set up of the coupling of Ocean Biogeochemistry with CERA-20C
- run 20th century analyses of ocean biogeochemistry



# Objectives and Strategy

The PISCES model



## Advanced features

- Redfieldian model (constant C/N/P ratio)
- variable C / Chl, C/Fe, C/Si ratios
- Carbon and oxygen cycles
- No feedback of chlorophyll concentration on temperature profile

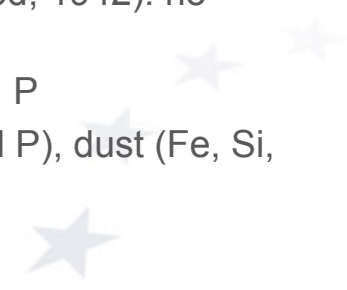
## Basic Features

- PISCES = model of the low trophic levels embedded in a model of ocean circulation
- 24 prognostic variables, 5 limiting nutrients, 2 phytoplankton and 2 zooplankton species, 3 detrital compartments
- Ocean dynamics (mostly vertical transport) put together/split nutrients and light (inversely distributed in the water column) which allow phytoplankton to do photosynthesis

## Community model

Available on the NEMO platform:  
<http://www.nemo-ocean.eu/>

- Mixed Monod/Quota model (Monod, 1942): no diurnal cycle
- Closed mass balance for C, N, Si, P
- External inputs: rivers (Fe, Si, and P), dust (Fe, Si, P, N) and sedimentary iron

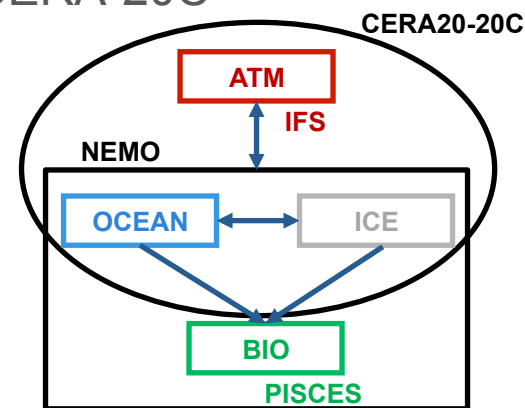


## Objectives:

- set up of the coupling of Ocean Biogeochemistry with CERA-20C
- run 20th century analyses of ocean biogeochemistry

## 3 strategies for the coupling were considered:

(contribution to WP2 – Task 2.4)



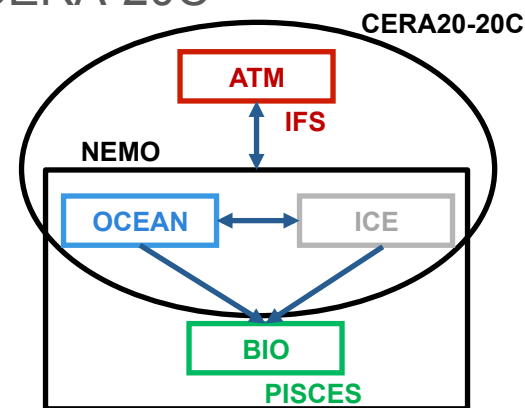
- online coupling : we provide code, namelists & biogeochemical inputs and ECMWF integrates PISCES in CERA-20C
- offline coupling : CERA-20C ocean & atmospheric outputs as forcings
- “offline” NEMO-PISCES : CERA-20C atmospheric outputs as forcings

## Objectives:

- set up of the coupling of Ocean Biogeochemistry with CERA-20C
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- offline coupling : CERA-20C ocean & atmospheric outputs as forcings
- “offline” NEMO-PISCES : CERA-20C atmospheric outputs as forcings

The “offline” NEMO-PISCES approach was selected after a series of tests with different parameter settings and NEMO versions



# Configuration

## The “offline” NEMO-PISCES configuration:

- Atmospheric Forcing: ERA-20C (CERA-20C not ready at that time)
- Time period: 1900 - 2009
- Latest NEMO 3.6, PISCES v2 (Aumont et al., 2015), LIM3 for ice
- New set-up from IPSL configuration (OR1L3PIS-V1)
- 75 vertical levels, vvl option (water column volume variable)
- Updated external input fluxes: river input, sediment Fe supply, atmospheric deposition of Fe, Si, N and P, Fe input from sea ice
  
- Initial state from OR1L3PIS-V1 (after 100 yrs of climatological simulation)
- Spin-up 1870-1900 with climatological ERA-20C atmospheric forcing, and then interannual ERA-20C (1870 = beginning of industrial era)





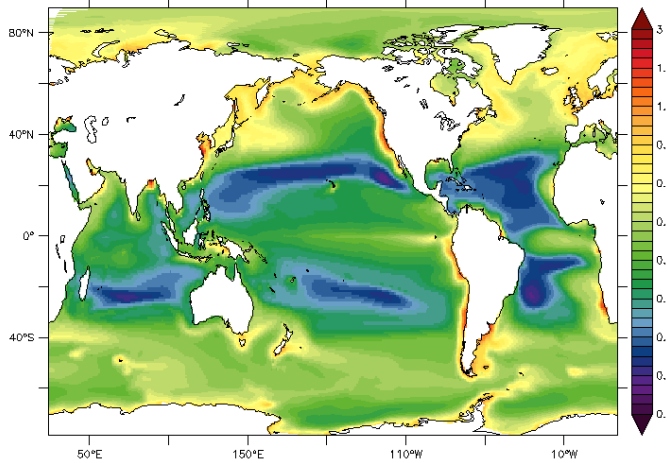
# Assessment of the ERA-20C/Carbon run

## Surface annual mean

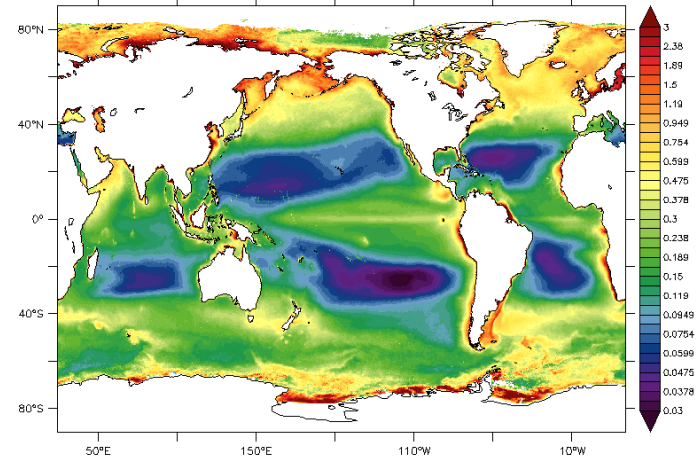
### Satisfying CHL and CO<sub>2</sub> fluxes

CHL  
(mg/m<sup>3</sup>)

MODEL clim 1998 - 2009

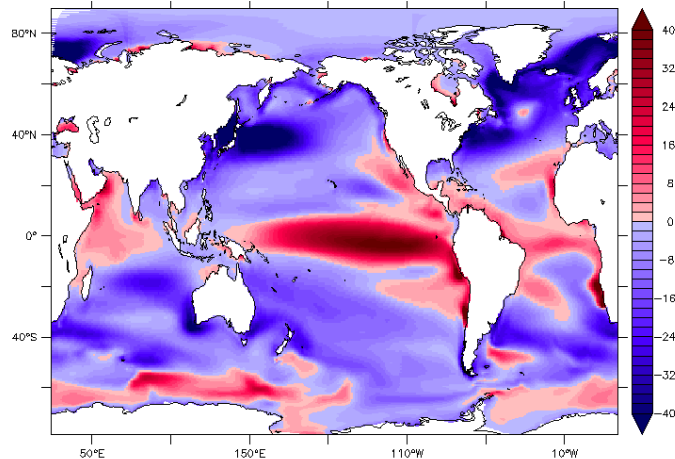


Globcolour DATA clim 1998 - 2009

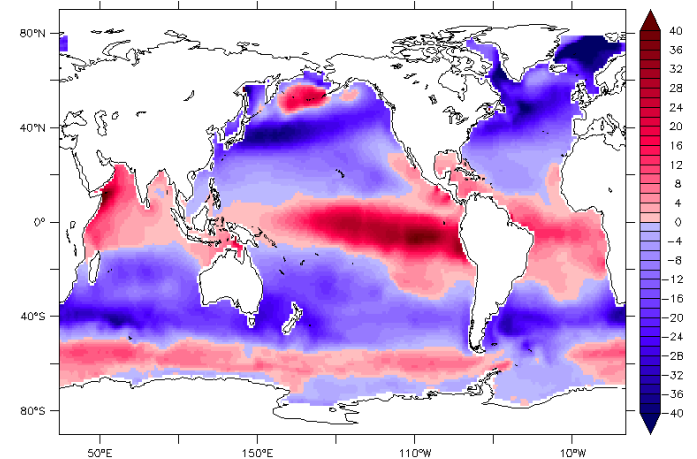


Sea-to-air  
CO<sub>2</sub> flux  
(gC/m<sup>2</sup>/yr)

MODEL clim 1998 - 2009



Landschützer clim 1998 - 2009





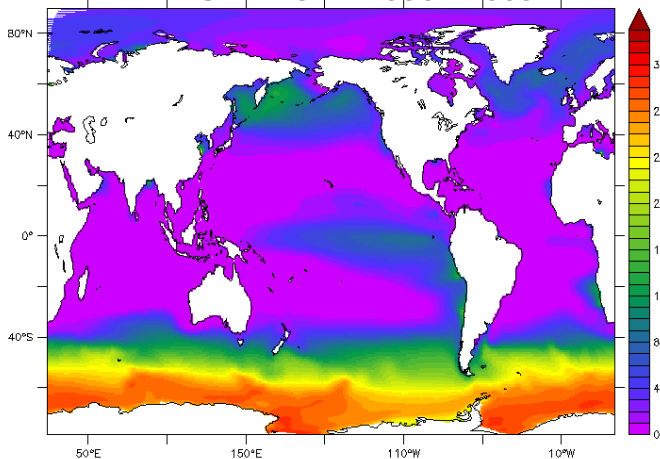
# Assessment of the ERA-20C/Carbon run

## Surface annual mean

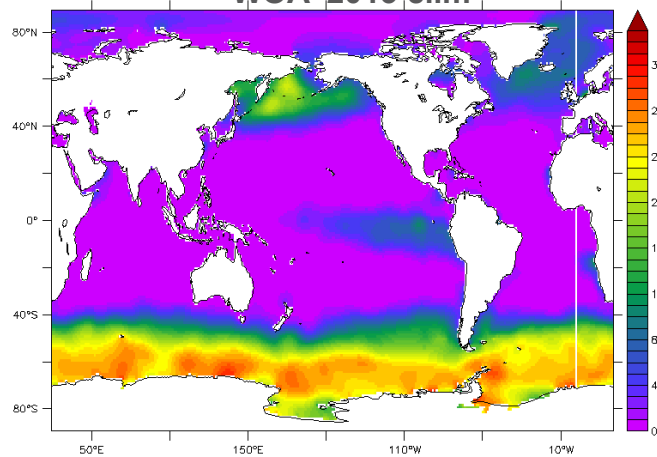
### Accordance of large scale structures

**NO<sub>3</sub>**  
(mmol/m<sup>3</sup>)

MODEL clim 1998 - 2009

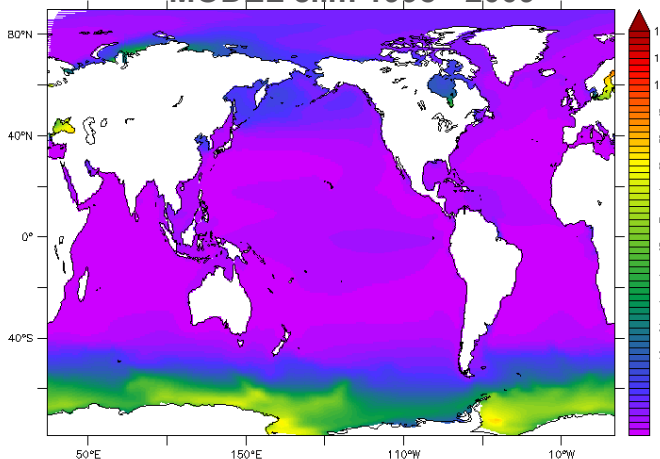


WOA 2013 clim

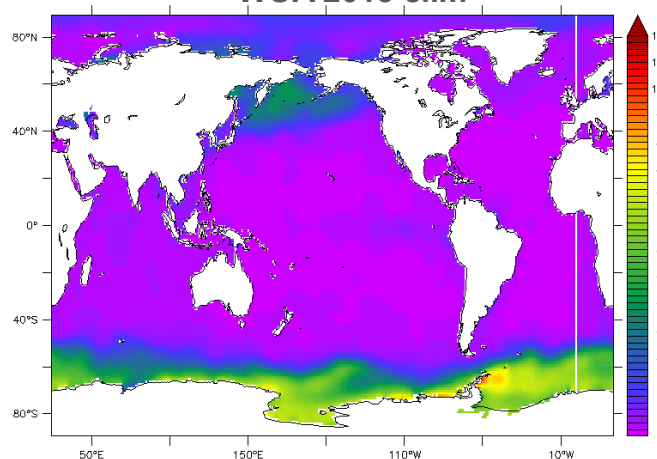


**Si(OH)<sub>4</sub>**  
(mmol/m<sup>3</sup>)

MODEL clim 1998 - 2009



WOA 2013 clim



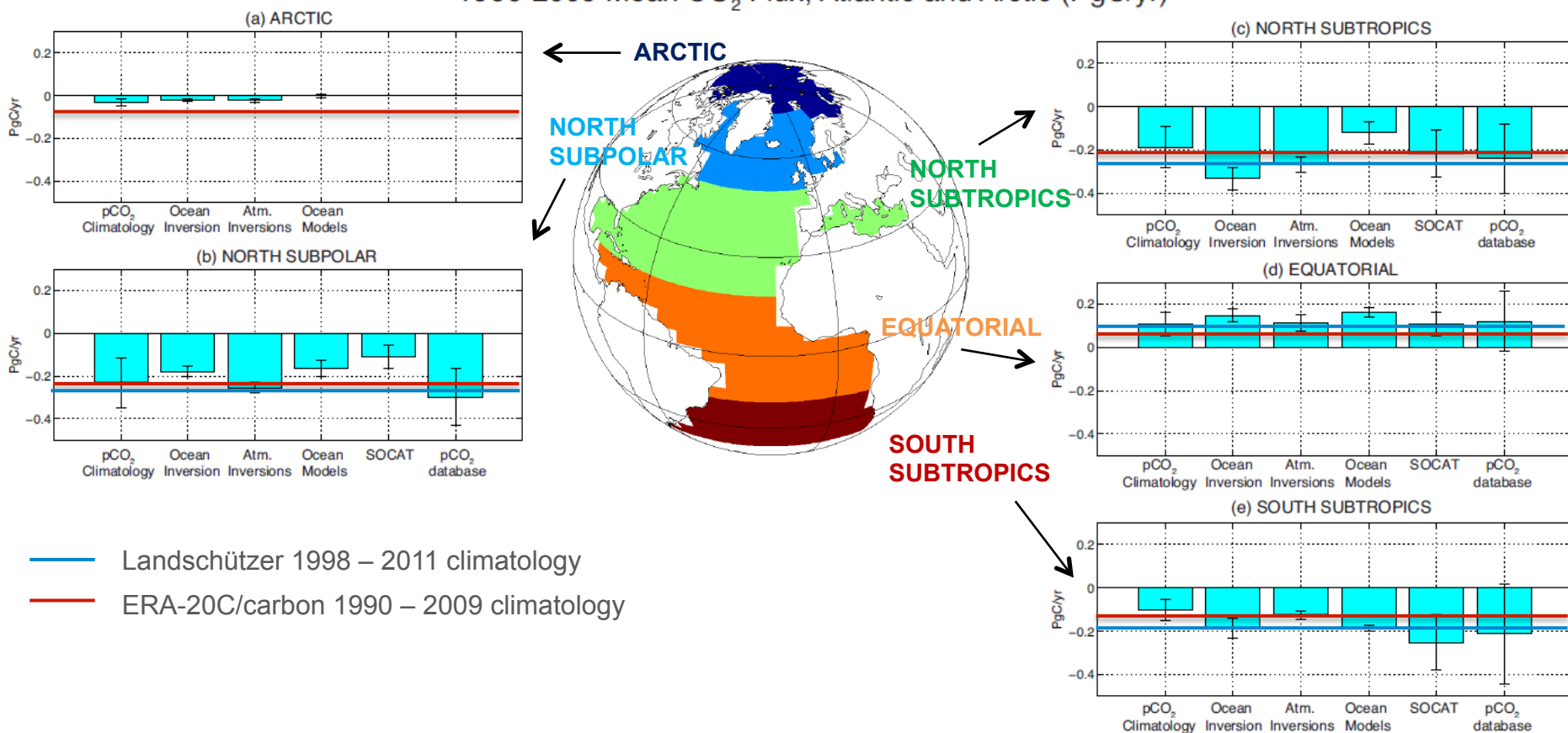


# Assessment of the ERA-20C/Carbon run

## Atlantic sea-to-air CO<sub>2</sub> fluxes

Regional CO<sub>2</sub> sinks and sources in line with published estimates

From Schuster et al. (2013)  
1990-2009 Mean CO<sub>2</sub> Flux, Atlantic and Arctic (PgC/yr)



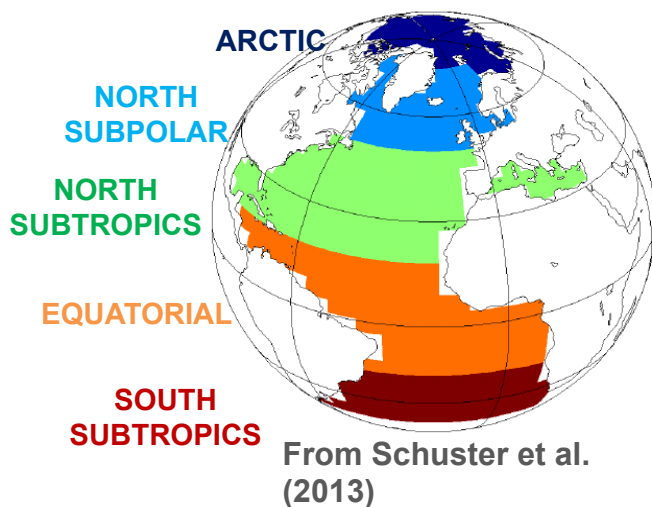


# Assessment of the ERA-20C/Carbon run

## Atlantic sea-to-air CO<sub>2</sub> fluxes

Regional sources and sinks in line with published estimates

	Arctic		North Subpolar		North Subtropics		Equatorial		South Subtropics	
Units	PgC y <sup>-1</sup>	mol m <sup>-2</sup> y <sup>-1</sup>	PgC y <sup>-1</sup>	mol m <sup>-2</sup> y <sup>-1</sup>	PgC y <sup>-1</sup>	mol m <sup>-2</sup> y <sup>-1</sup>	PgC y <sup>-1</sup>	mol m <sup>-2</sup> y <sup>-1</sup>	PgC y <sup>-1</sup>	mol m <sup>-2</sup> y <sup>-1</sup>
Model	-0.07	-0.59	-0.25	-1.91	-0.22	-0.72	0.05	0.16	-0.15	-0.66
Landschützer			-0.28	-2.14	-0.26	-0.86	0.11	0.36	-0.17	-0.76



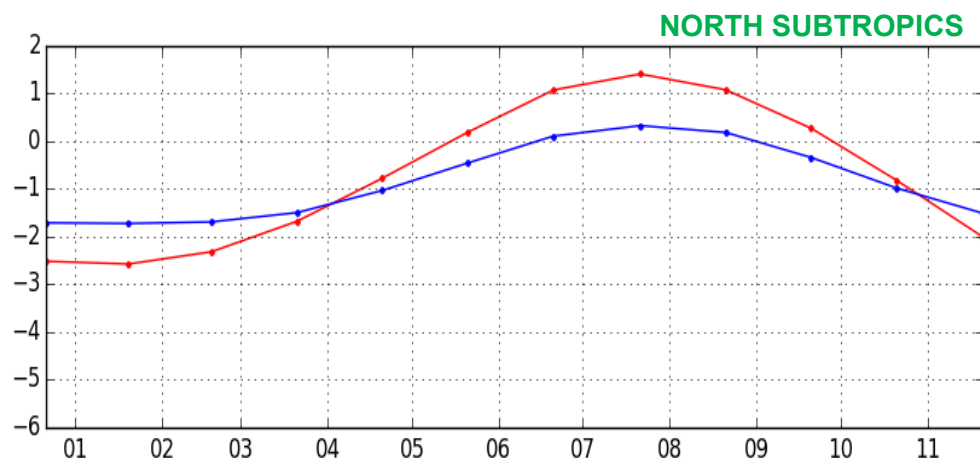
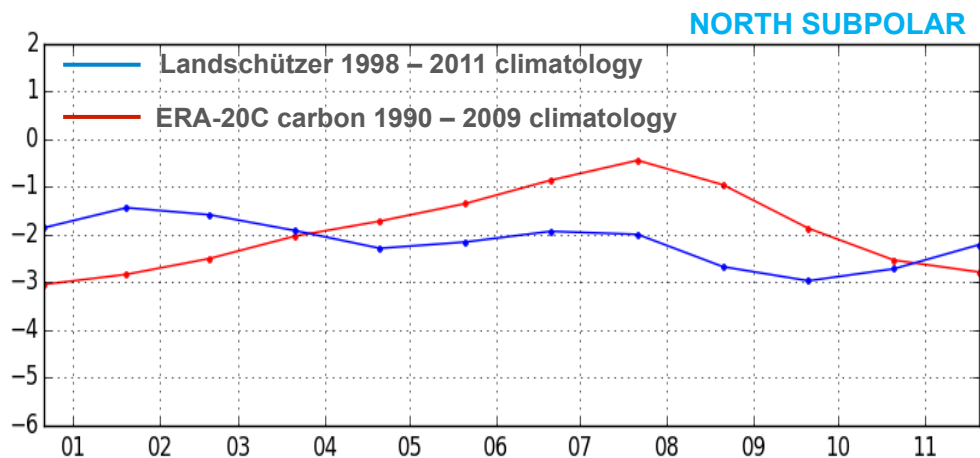
Underestimation of equatorial source



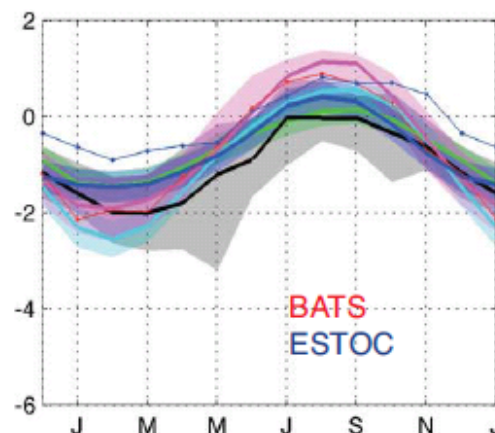
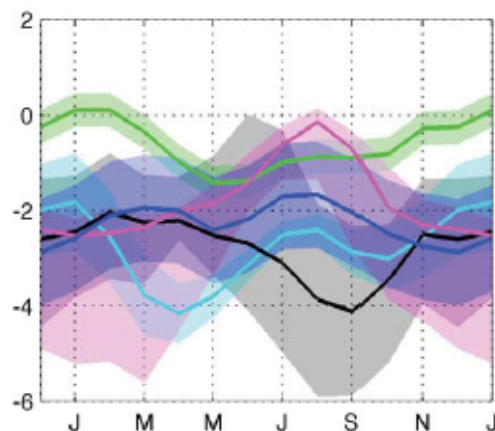
# Assessment of the ERA-20C/Carbon run

## Seasonal cycle of sea-to-air CO<sub>2</sub> flux in Atlantic

Good consistency in subtropical gyre, and less in subpolar gyre  
But the products in Schuster et al. are also very scattered in this region



From Schuster et al. (2013)



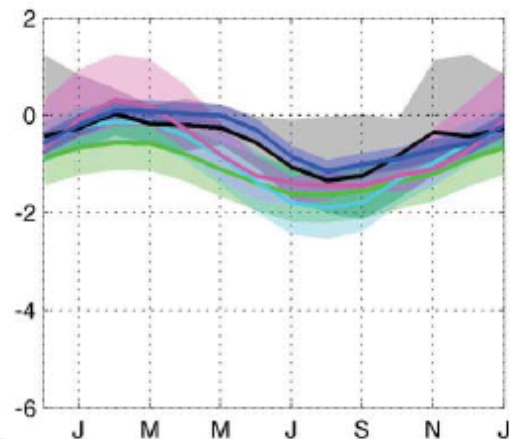
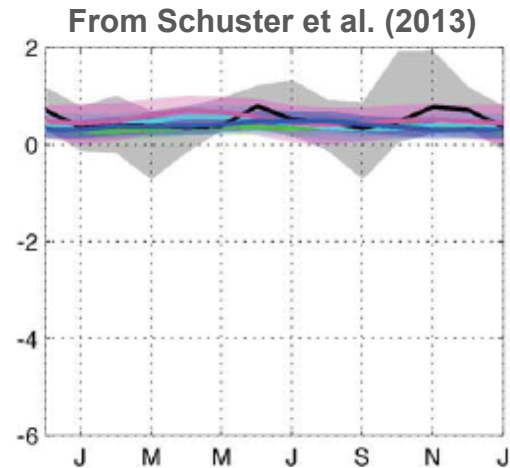
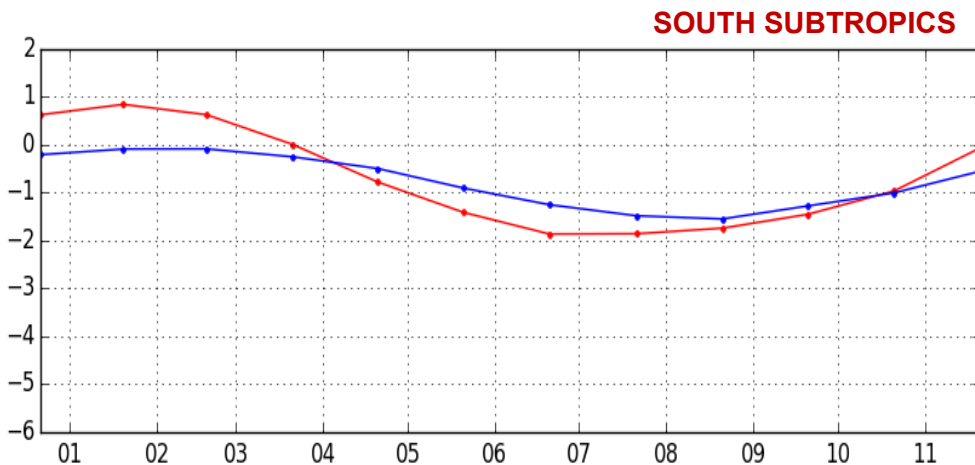
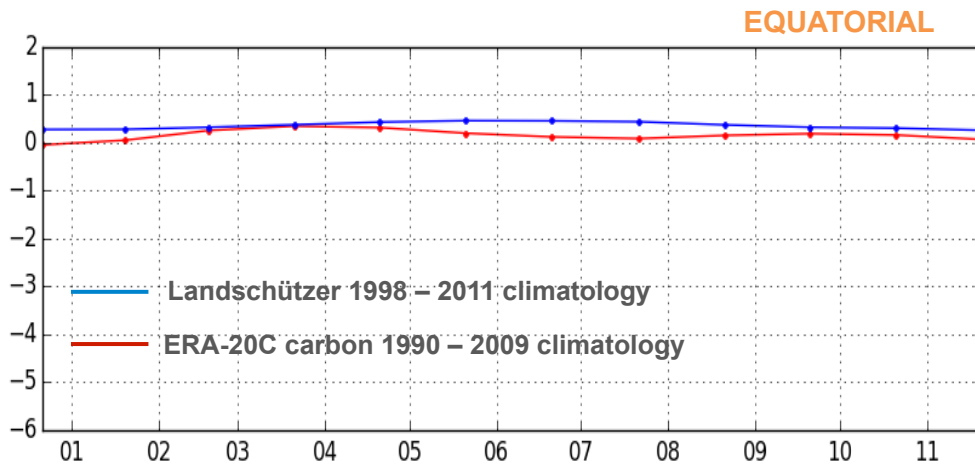
Pco2 clim  
Atm inversion  
Ocean models  
SOCAT MPR  
pCO2 database



# Assessment of the ERA-20C/Carbon run

## Seasonal cycle of sea-to-air CO<sub>2</sub> flux in Atlantic

Equatorial band = low source of CO<sub>2</sub>, no clear seasonal cycle  
South subtropics = in line with obs. and previous studies



Pco2 clim  
Atm inversion  
Ocean models  
SOCAT MPR  
pCO2 database

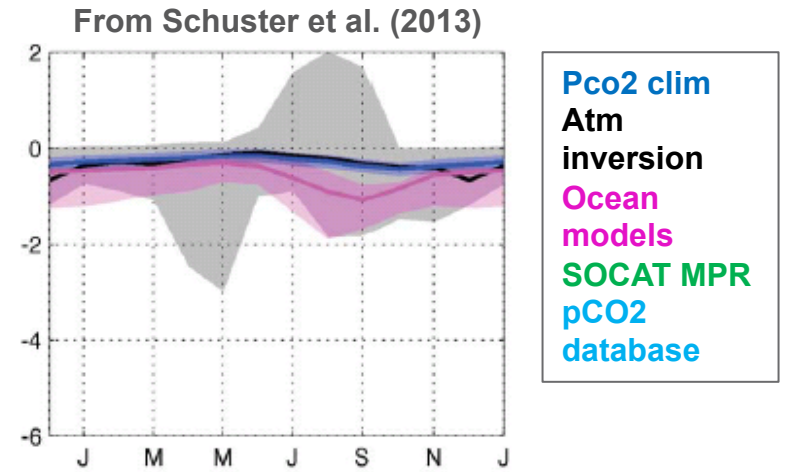
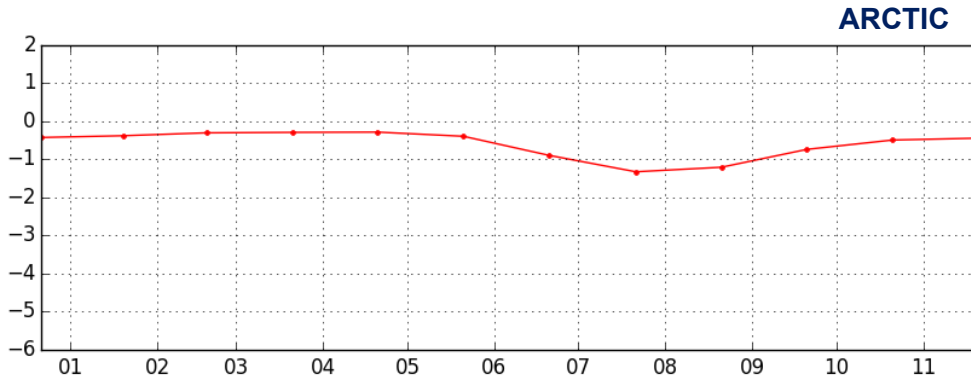




# Assessment of the ERA-20C/Carbon run

## Seasonal cycle of sea-to-air CO<sub>2</sub> flux in Atlantic

Arctic region: model very close to model ensemble of Schuster et al. (2013)

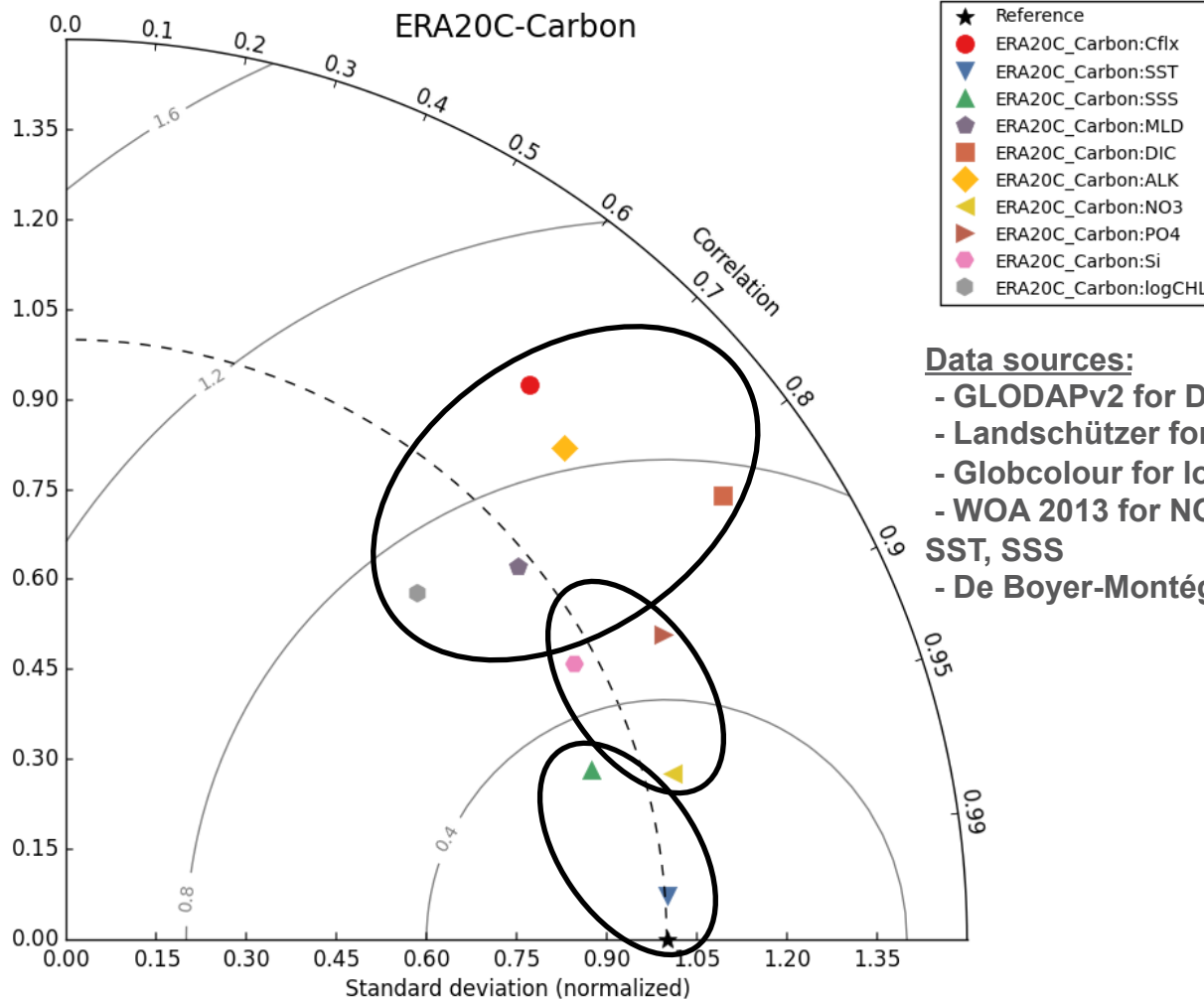




# Assessment of the ERA-20C/Carbon run

## Global statistics: Taylor diagram

SST, SSS: +++  
 Nutrients ++  
 Chl, MLD, carbon variables:  
 significant correlations but still work to do (on data and model)



### Data sources:

- GLODAPv2 for DIC, ALK
- Landschützer for Cflx = CO<sub>2</sub> flux
- Globcolour for logCHL
- WOA 2013 for NO<sub>3</sub>, O<sub>2</sub>, PO<sub>4</sub>, Si, SST, SSS
- De Boyer-Montégut for MLD

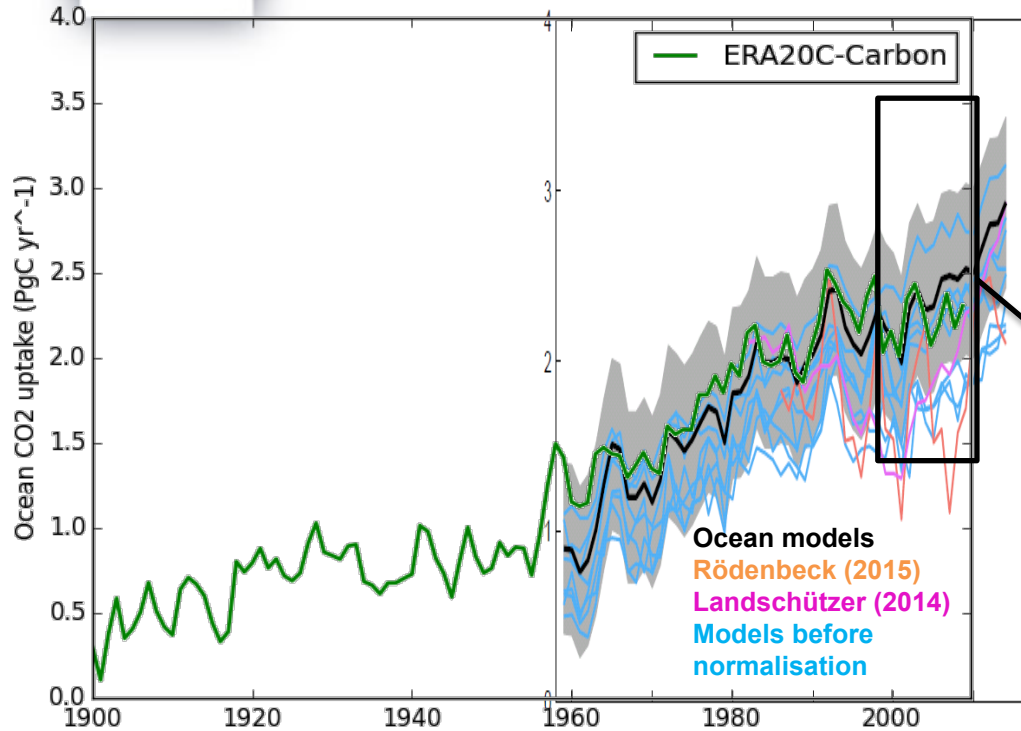
Taylor diagram computed with surface monthly climatologies (1998 – 2009 years if available)

# Assessment of the ERA-20C/Carbon run

## Interannual time series of the CO<sub>2</sub> flux



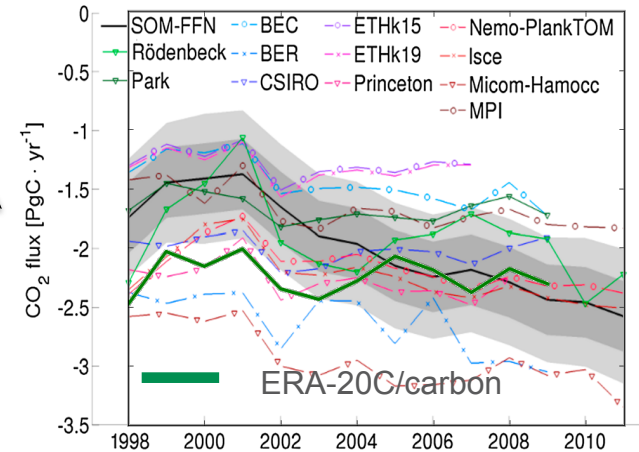
Anthropogenic air-to-sea CO<sub>2</sub> flux



From Le Quéré et al. (2015)

x (-1)

Anthropogenic Sea-to-Air CO<sub>2</sub> flux



From Landschützer et al. (2014):  
Mixed models and data



# Conclusions & Perspectives

## Conclusion:

- Evaluation of ERA20C/Carbon gave rather promising results over the period covered by observations (1998 – 2009)
  - At the global scale (annual mean, Taylor)
  - At the scale of Atlantic basin: seasonal cycle and subbasin integrated values
  - Globally yearly integrated air-to-sea flux of CO<sub>2</sub> over the period 1960 to 2009
- Interannual variability needs to be further assessed (comparison of ERA20C/Carbon to model output having contributed to Global Carbon Project)

## Perspectives:

- Run an “offline” NEMO/PISCES simulation forced by **CERA20C**
  - Scheduled during the second semester of 2017 (should be produced by Mercator)
  - We will use the same parameter settings as for ERA20C/Carbon run







# Thank you for your attention !

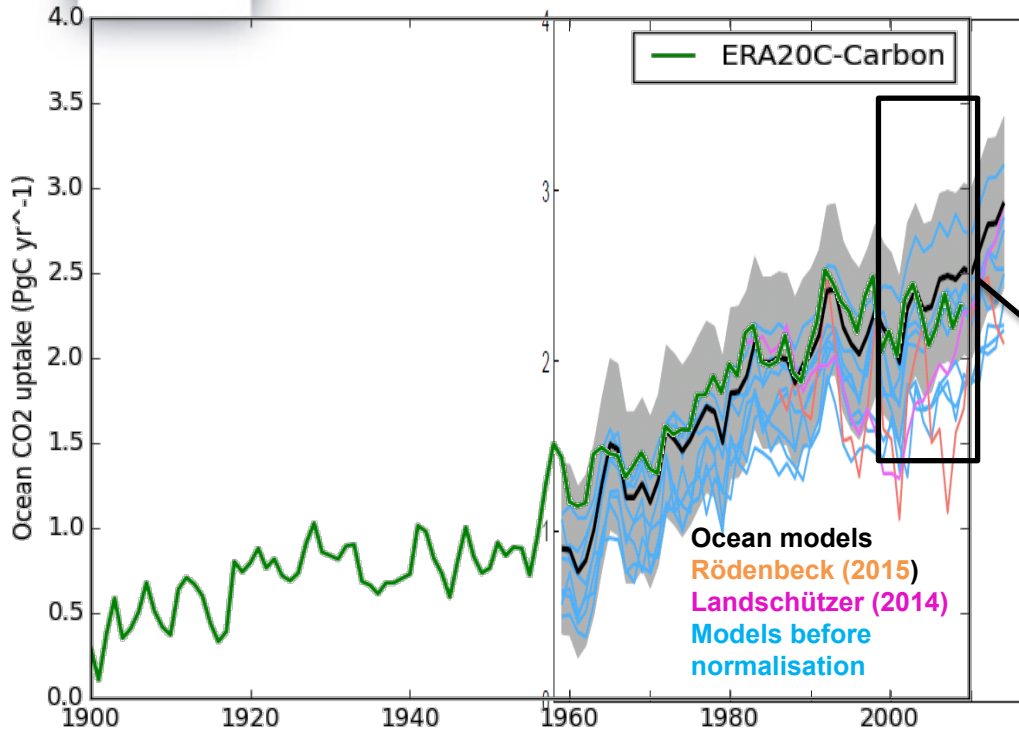


# Assessment of the ERA-20C/Carbon run

## Interannual time series of the CO<sub>2</sub> flux



Air-to-Sea CO<sub>2</sub> flux

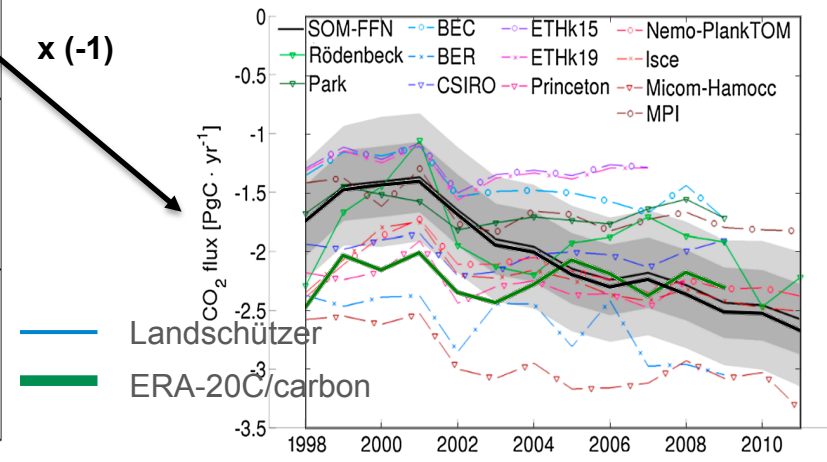


From Le Quéré et al. (2015)

- River outgassing = 0.45 PgC/yr (Jacobson et al., 2007)
- Arctic = - 0.12 PgC/yr (Schuster et al., 2013)

x (-1)

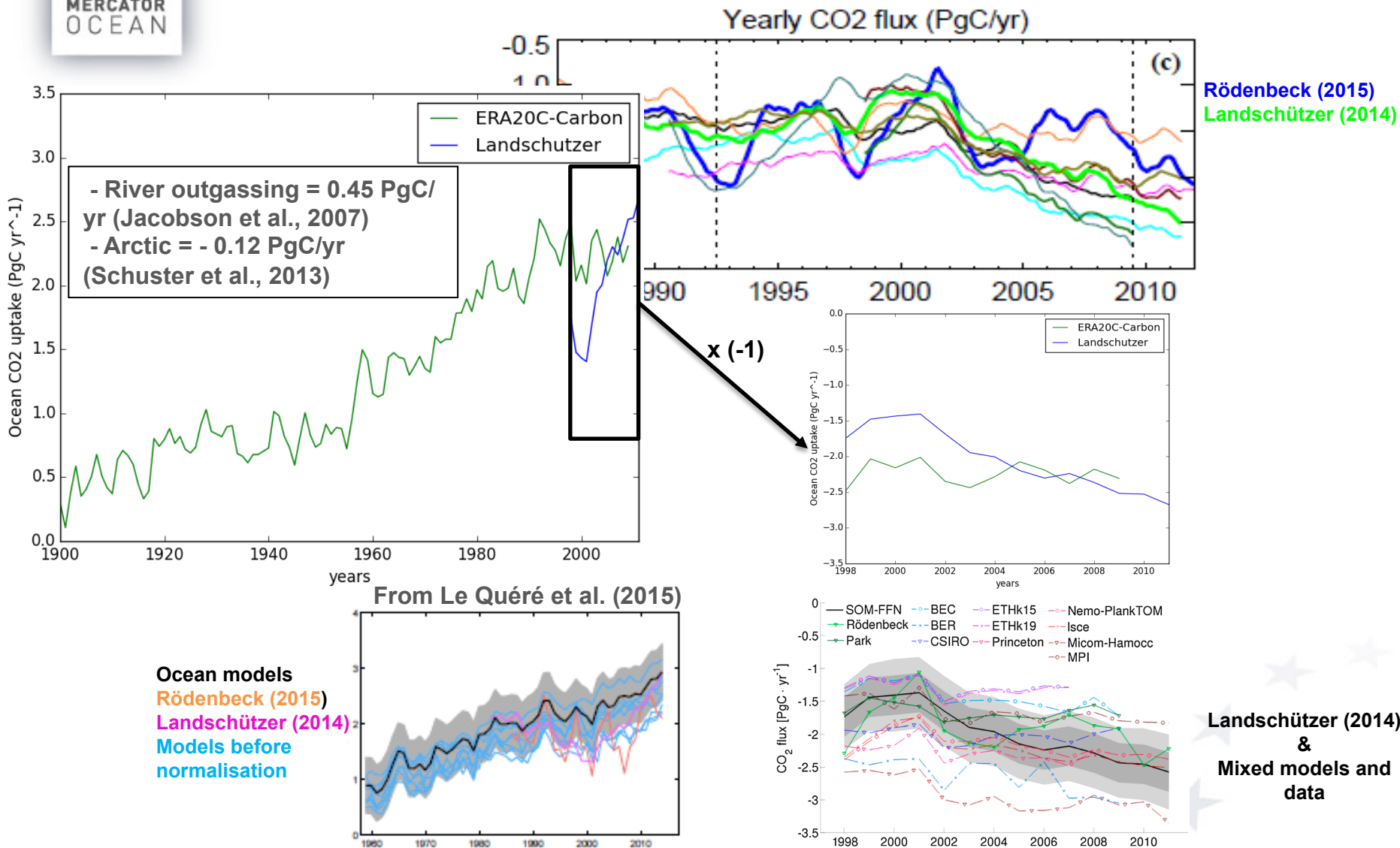
Sea-to-Air CO<sub>2</sub> flux



From Landschützer et al. (2014) & Mixed models and data

# Assessment of the ERA-20C/Carbon run

## Interannual time series of the ocean CO<sub>2</sub> uptake



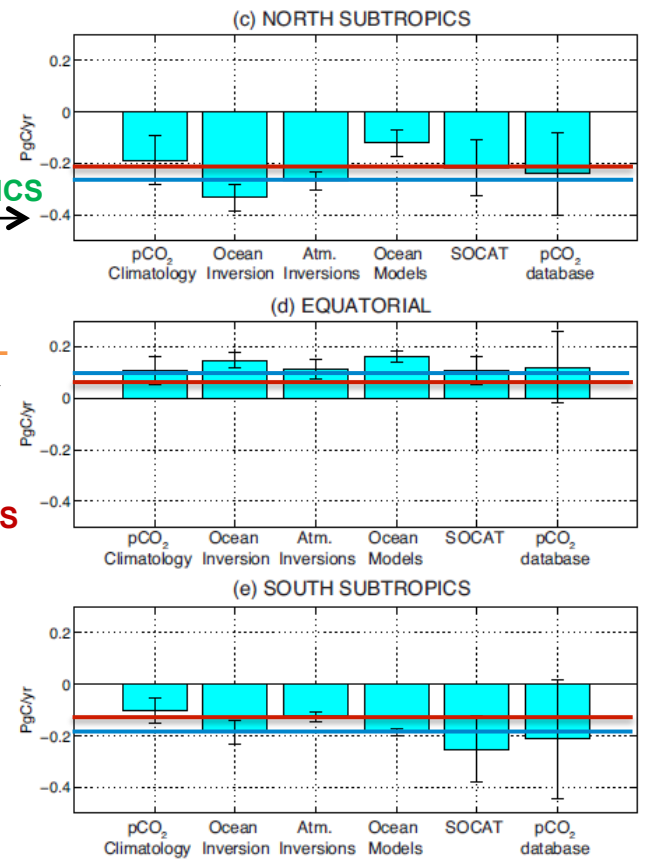
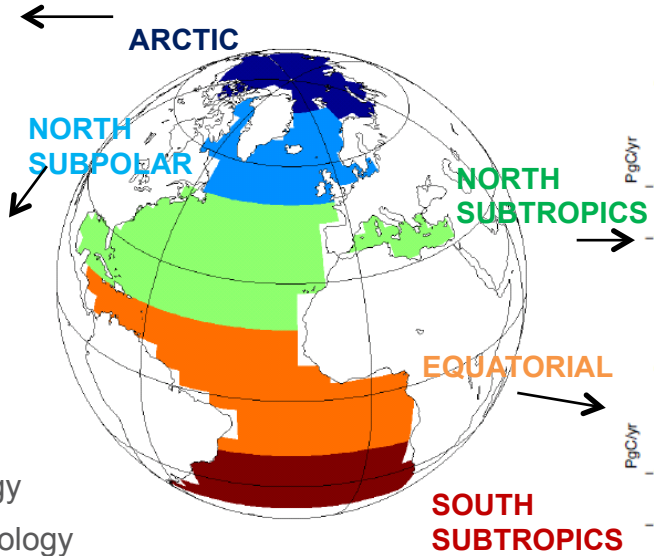
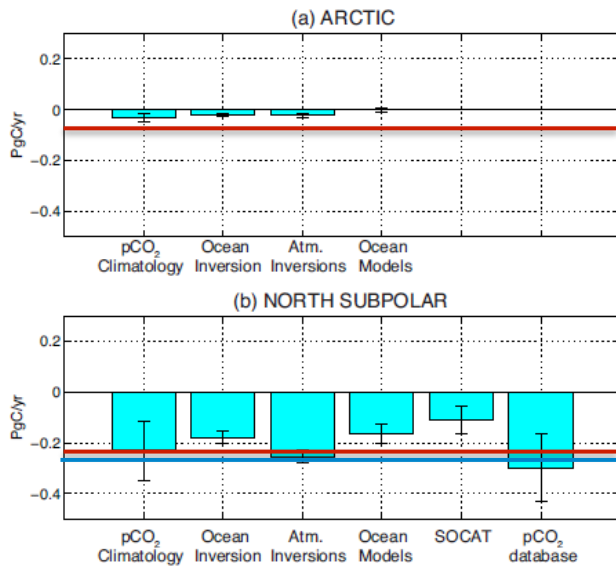
# Assessment of the ERA-20C/Carbon run

## Atlantic sea-to-air CO<sub>2</sub> fluxes

Regional CO<sub>2</sub> sinks and sources in line with published estimates

1990-2009 Mean CO<sub>2</sub> Flux, Atlantic and Arctic (PgC/yr)

From Schuster et al. (2013)



— Landschützer 1990 – 2011 climatology  
 — ERA-20C/carbon 1990 – 2009 climatology

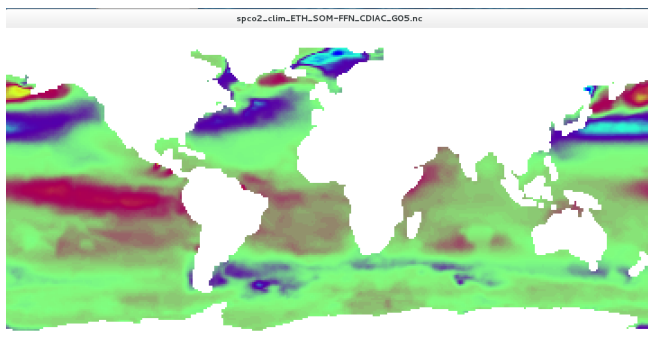
### Definition and area of the above subregions

Basin	Latitude boundaries	Longitudinal boundaries	Area [10 <sup>12</sup> m <sup>2</sup> ]
Arctic	76° N to 90° N	excl. Baffin Bay and Nordic Seas (SW of 76° N, 19° E)	9.61
North Subpolar	49° N to 76° N	West of 19°E	8.63
North Subtropics	18° N to 49° N		23.68
Equatorial	18° S to 18° N		23.49
South Subtropics	44° S to 18° S	West of 19° E	18.44

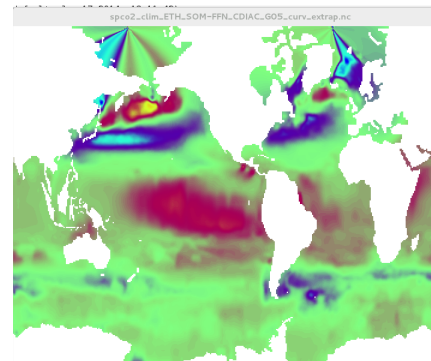
**ERA-20C carbon**  
**10.41**  
**10.95**  
**25.74**  
**24.64**  
**18.72**

Total 83.84

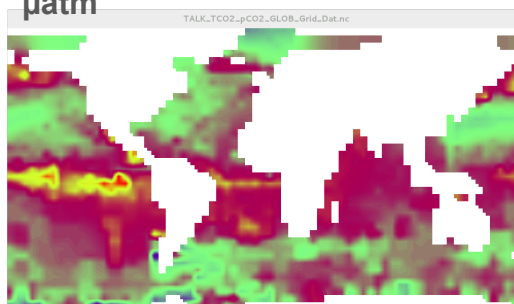
Landschutzer clim monthly  
1998-2011  
Cflx mol/m2/yr



Après extrapolation et interpolation



Takahashi clim monthly (année  
ref 2005): CO2 partial pressure  
at sst estimated for year 2005  
 $\mu\text{atm}$

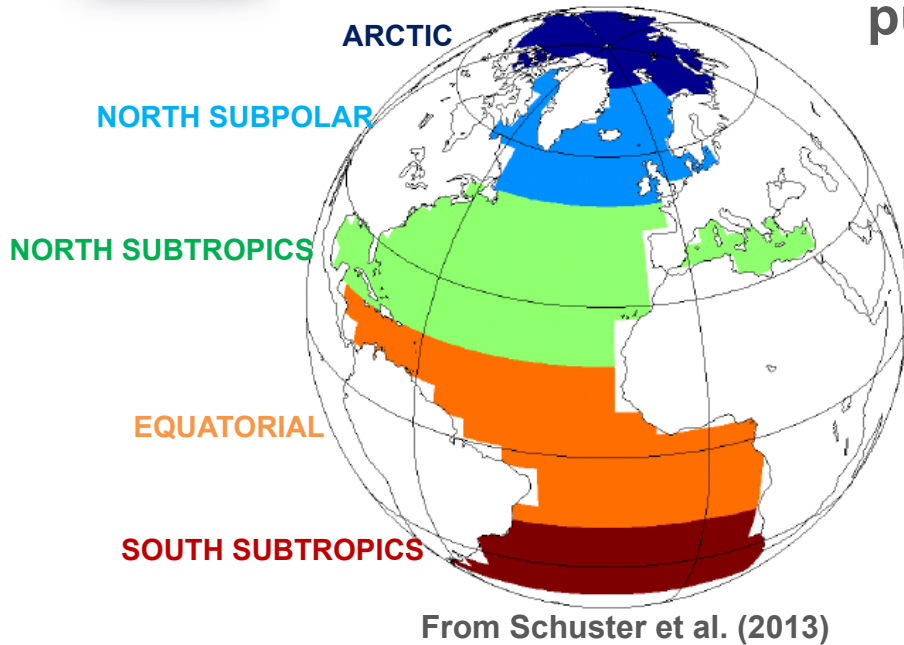




# Assessment of the ERA-20C/Carbon run

## Atlantic sea-to-air CO<sub>2</sub> fluxes

Representation of regional CO<sub>2</sub> sinks and sources in line with published estimates



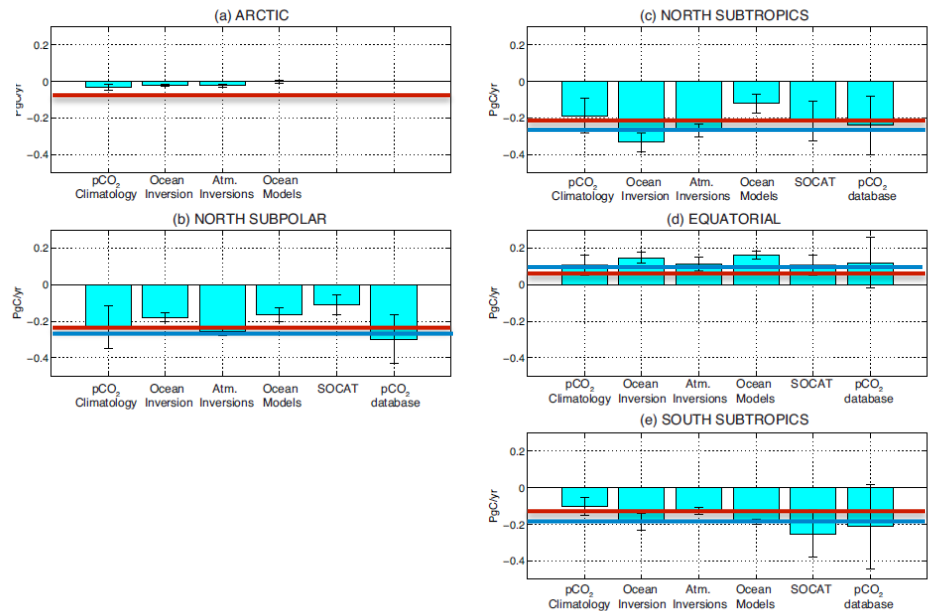
### Definition and area of the above subregions

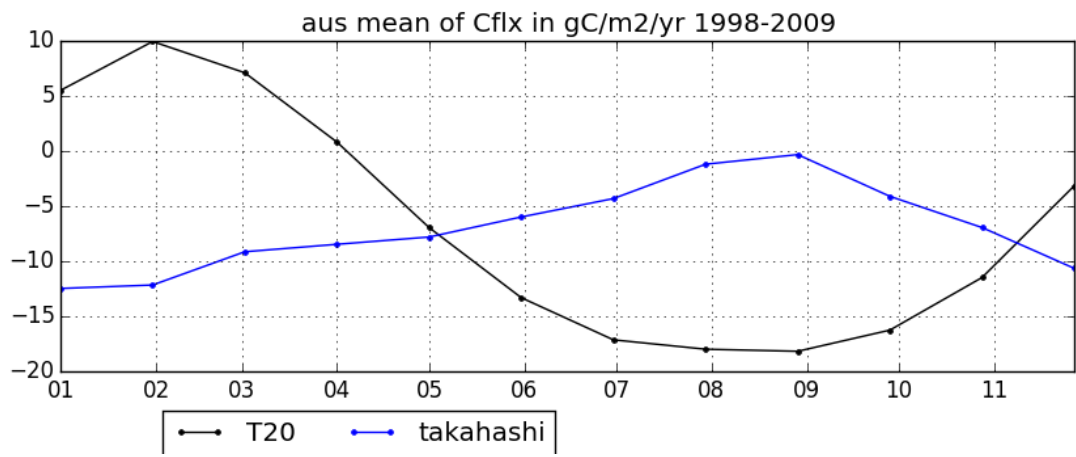
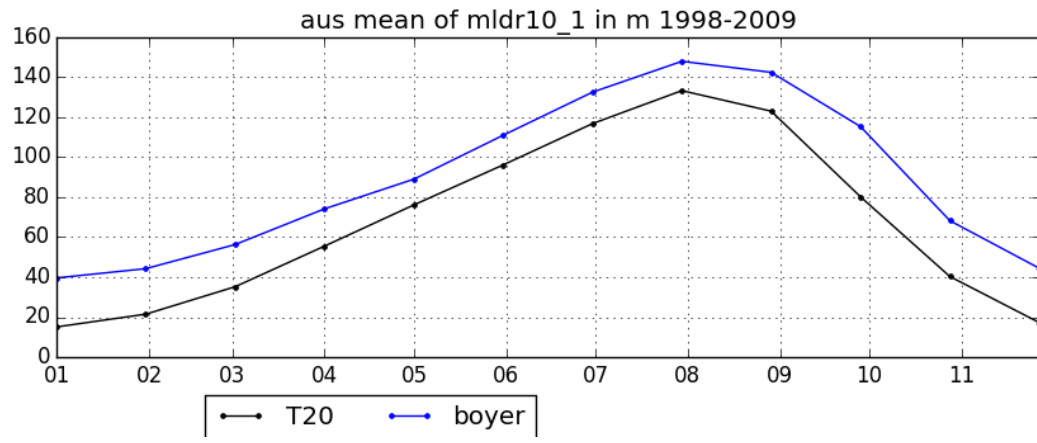
Basin	Latitude boundaries	Longitudinal boundaries	Area [10 <sup>12</sup> m <sup>2</sup> ]	ERA-20 carbon
Arctic	76° N to 90° N	excl. Baffin Bay and Nordic Seas (SW of 76° N, 19° E)	9.61	<b>10.41</b>
North Subpolar	49° N to 76° N	West of 19° E	8.63	<b>10.95</b>
North Subtropics	18° N to 49° N		23.68	<b>25.74</b>
Equatorial	18° S to 18° N		23.49	<b>24.64</b>
South Subtropics	44° S to 18° S	West of 19° E	18.44	<b>18.72</b>
Total			83.84	

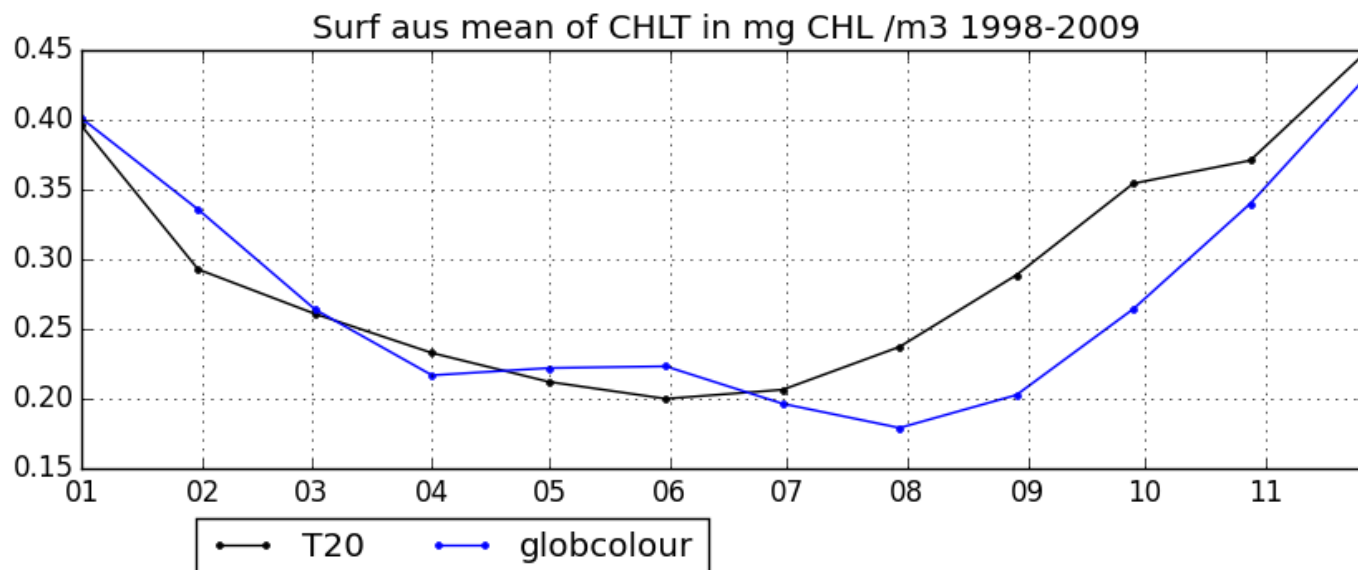
Atlantic subregions of Schuster et al. (2013)

- Landschützer 1990 – 2011 climatology
- ERA-20C/carbon 1990 – 2009 climatology

1990-2009 Mean CO<sub>2</sub> Flux, Atlantic and Arctic (PgC/yr)

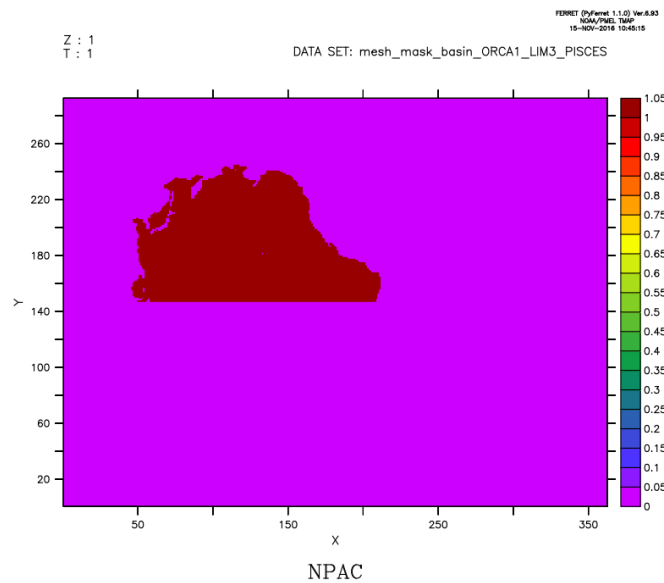
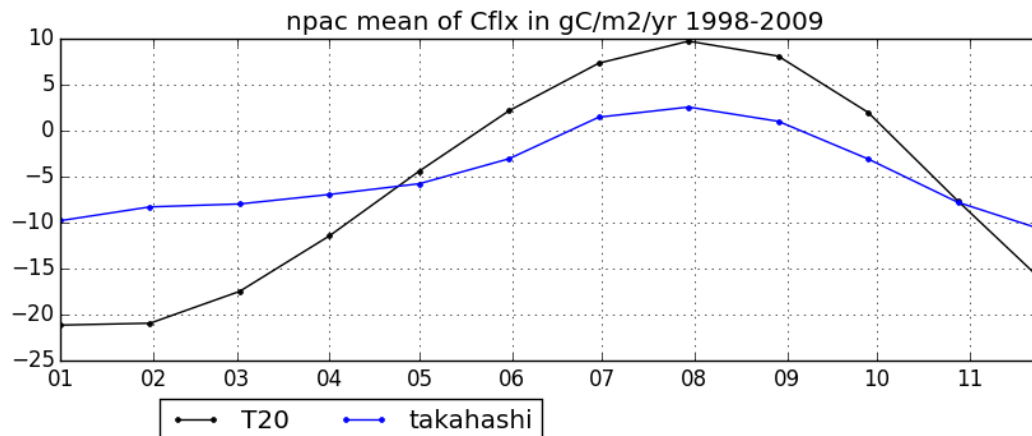




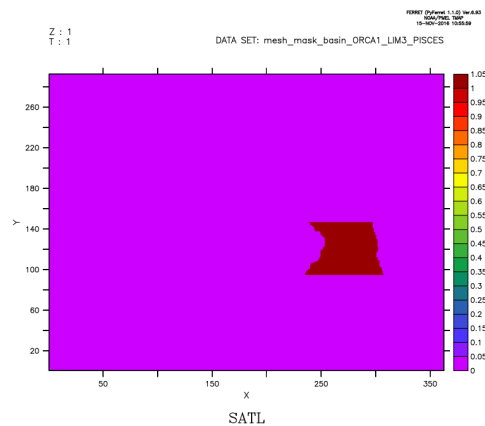
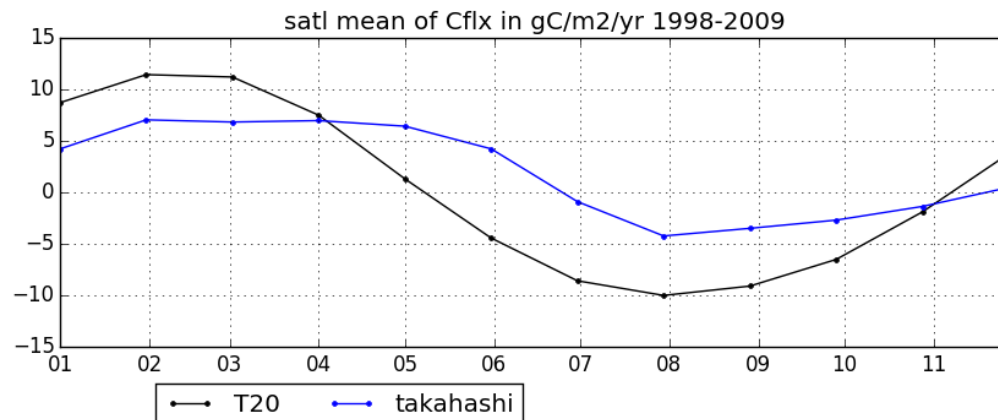




# Seasonal cycle north Pacific



# Seasonal cycle South Atlantic



# Seasonal cycle Indian Ocean

