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Remote sensing algorithm for sea surface CO_2 in the Baltic Sea

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Context

- Monitoring the oceanic pCO_2 at a monthly or seasonal time-scale is important to estimate regional air-sea fluxes of CO_2
- Problem for the quantification of the oceanic sink is thus the spatial and temporal distribution of available in-situ pCO_2 data
- Constrain the carbon fluxes in the Baltic sea remains particularly challenging
- Worldwide networks of measurements of surface water pCO_2 have been initiated in the 1990s (Poisson et al. 1993; Takahashi et al., 1993-2009 Jamet et al, 2007…).
- Data available can be use to this type of study in the Baltic Sea

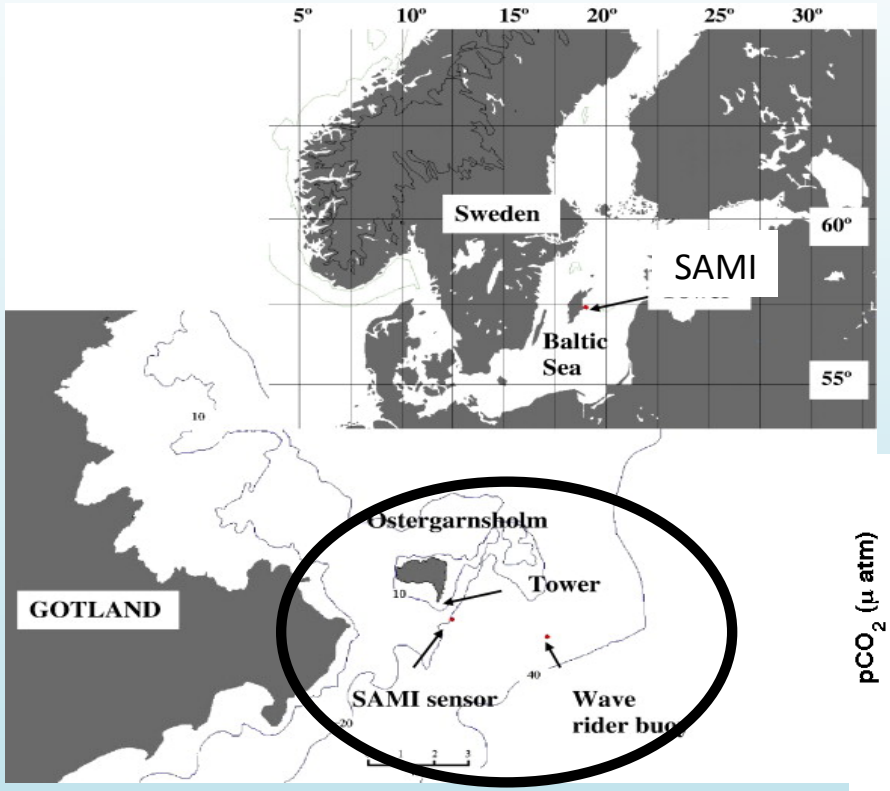
Aim

Estimate pCO_2 variability in the global Baltic Sea with satellite data

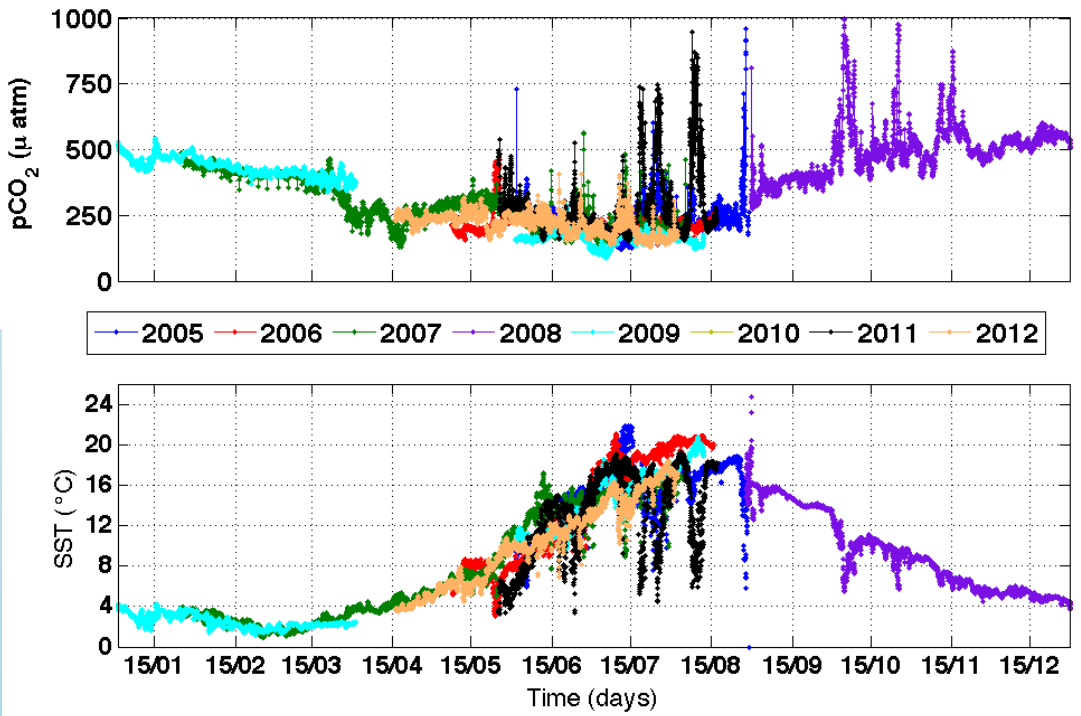
Content

- Data availability and validation
  - In situ data (Mooring, ship)
  - Satellite data
- Method
  - Linear relationship
  - Self Organising Maps: Statistical Neuronal Approach
- Conclusions and Perspectives

Data: Availability and Validation



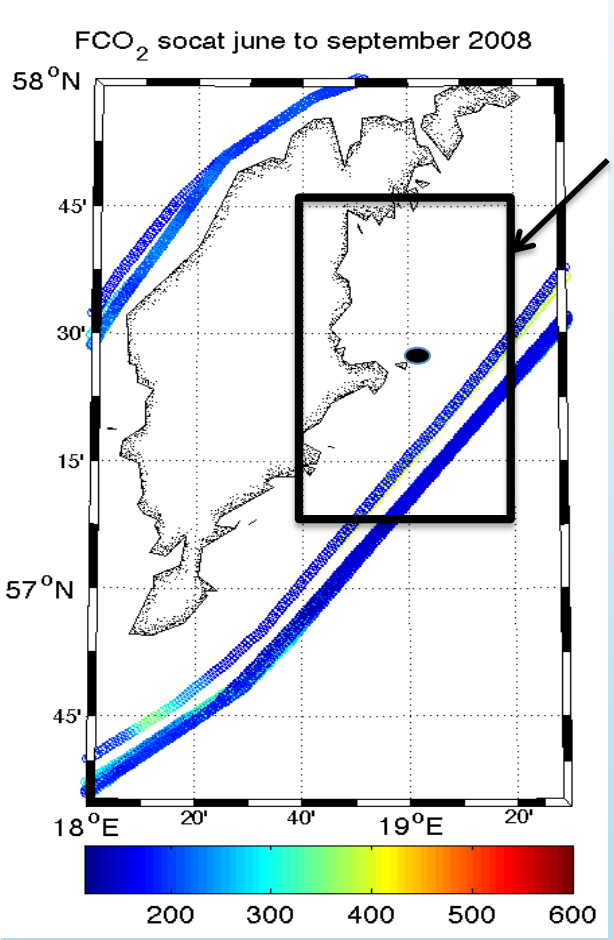
- Measurement of pCO_2 (SAMI sensor) and SST (4 m depth) at Östergarnsholm station since June 2005-July 2012
- Wave mooring (SST (0.5 m))



- Strong variation of SST and pCO_2 → upwelling events

→ Validation of the data is required

In situ data validation : VOS and SMHI



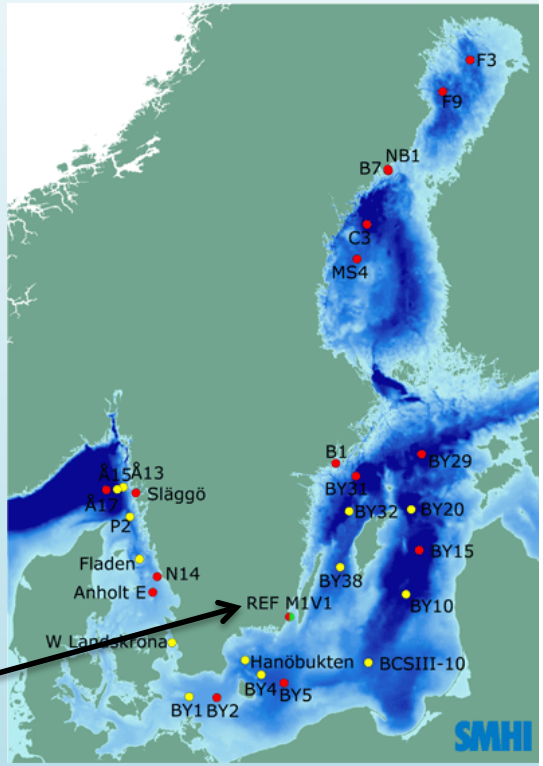
Ship measurements VOS comparison with the SAMI data (CDIAC+SOCAT database (Schneider et al,2006)

Comparison :

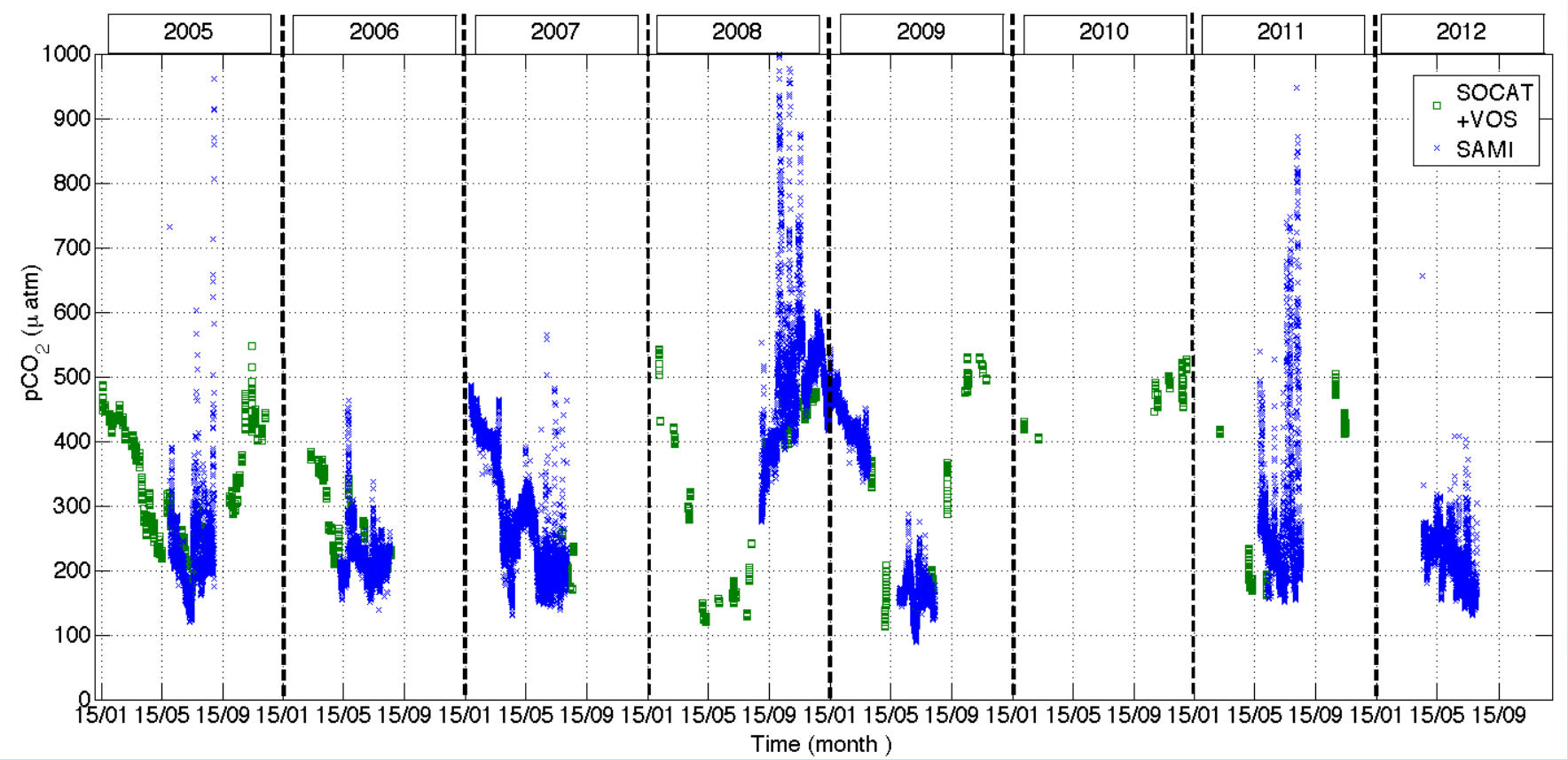
- 0.2° around the SAMI sensor (black square)
- Time

SMHI mooring in Baltic sea compare to SAMI data (Not show here)

- pCO_2 compute with carbonate relation (TA and pH)



In situ data validation : VOS

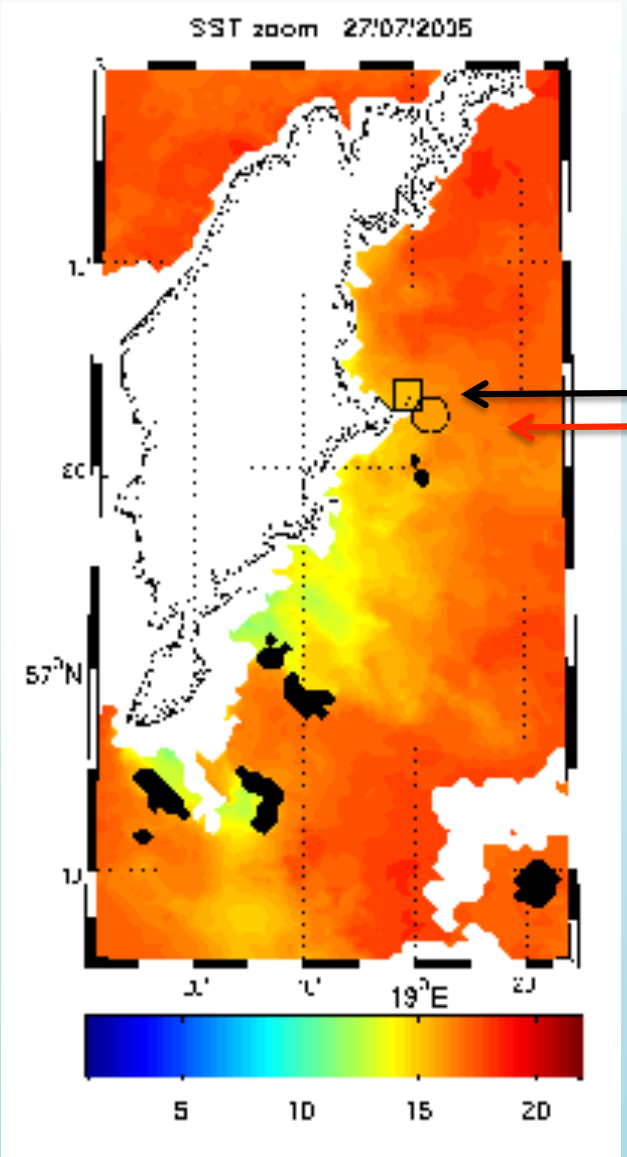


- Comparison with pCO_2 SAMI and pCO_2 VOS
- Quite good correlation factor (0.98) and STD=9 µatm
- Difference mainly due to the upwelling events → quite strong on SAMI data

Satellite DATA

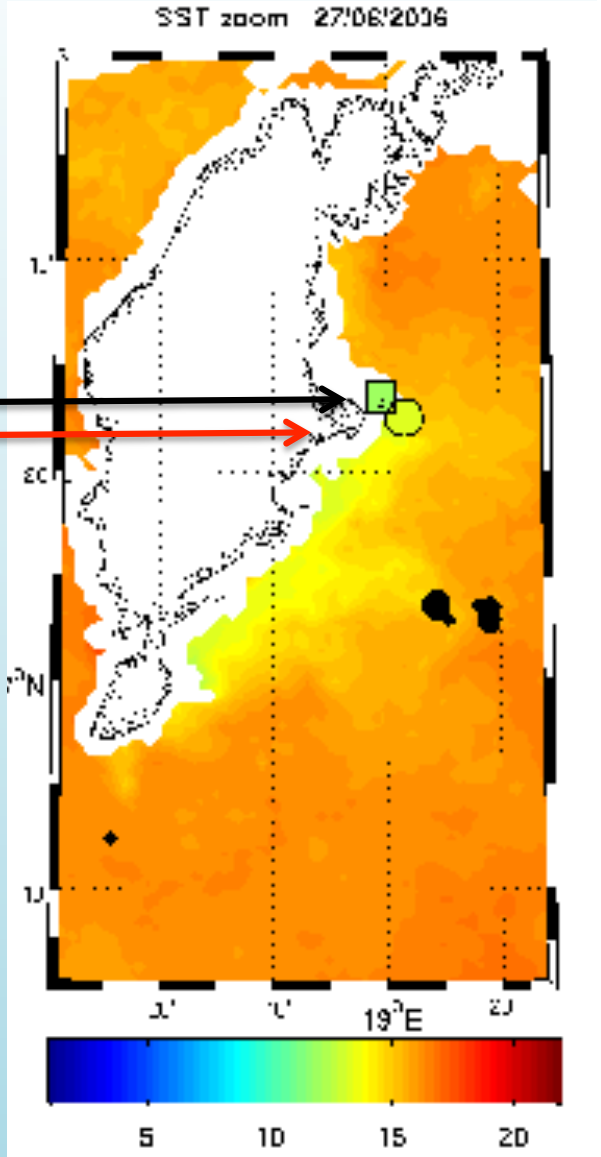
- Monthly & Daily:
  - SST: Federal Maritime and Hydrographic Agency (BSH) processing the data from AVHRR-NOAA ,
  - Chlorophyll : JRC MERSEA Ocean Colour Products :
    - SeaWiFS: standard OC4-V4 algorithm, reprocessing 5.1 by the Goddard Space Flight Center (NASA)
    - MODIS-AQUA : reprocessing 1.1 by the Goddard Space Flight Center (NASA)
- Monthly
  - Photosynthetically Active Radiation (PAR): Averages from:
    - SeaWiFS (Sept. 1997 - Dec. 2004) 4 km monthly
    - MODIS-Aqua (Jul. 2002 - Jun. 2011) 4 km monthly,
  - Primary Production: Source: http://oceancolor.gsfc.nasa.gov
    - SeaDAS 6.2
- NOT Satellite Data :
  - Mixed Layer Depth: hydrodynamic modelGeneral Estuarine Transport Model - www.getm.eu)

Validation : SST satellite + Wave data

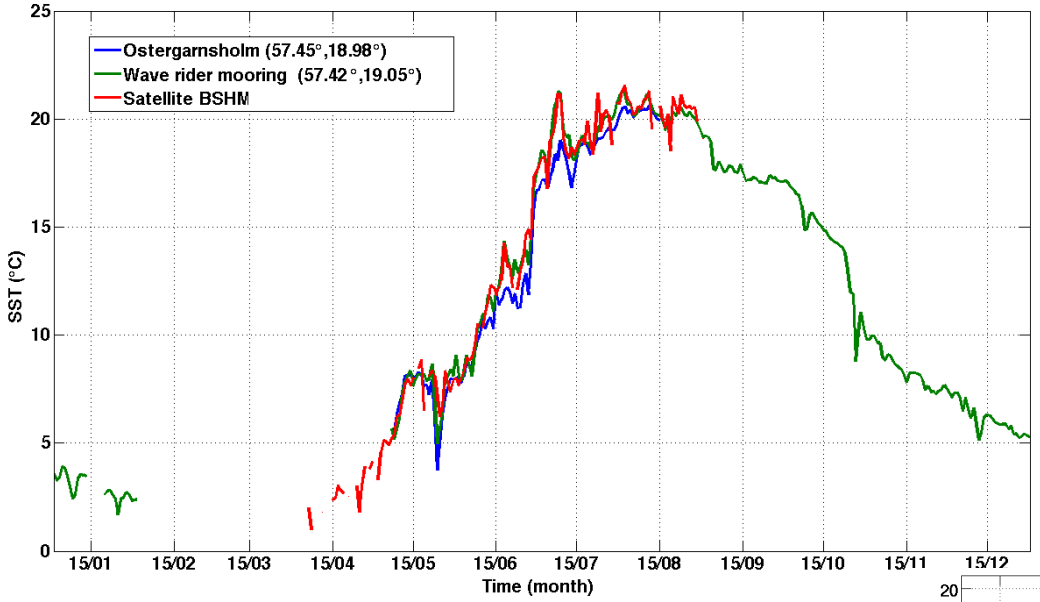


SAMI sensor (4 m depth)

Wave mooring (1 m depth)



Validation SST : temporal variation

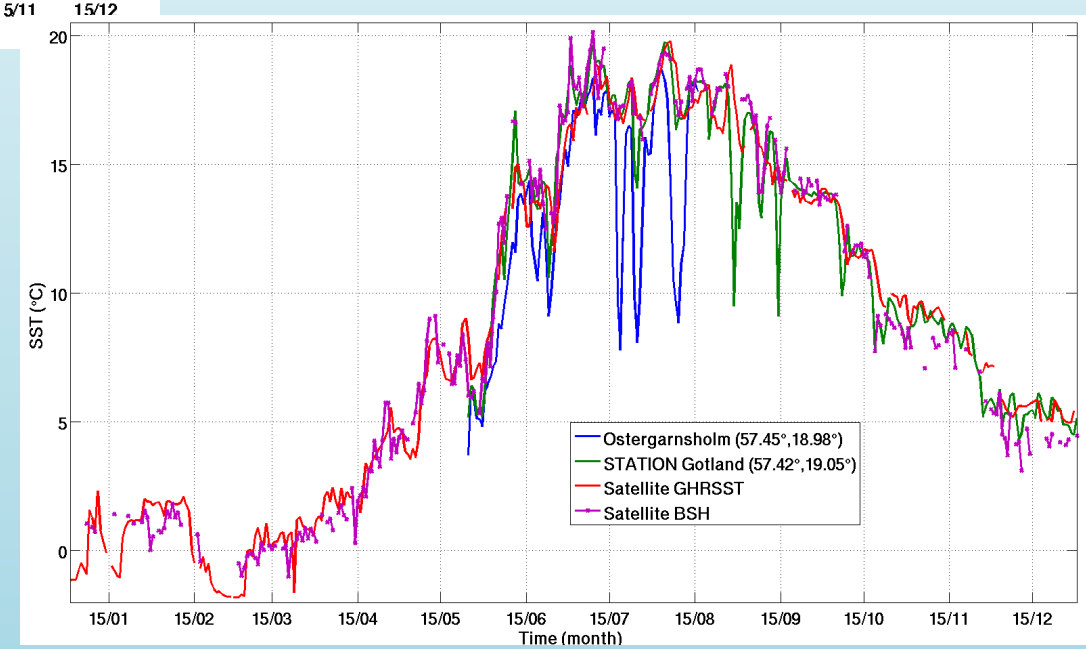


- Daily comparison for 2005

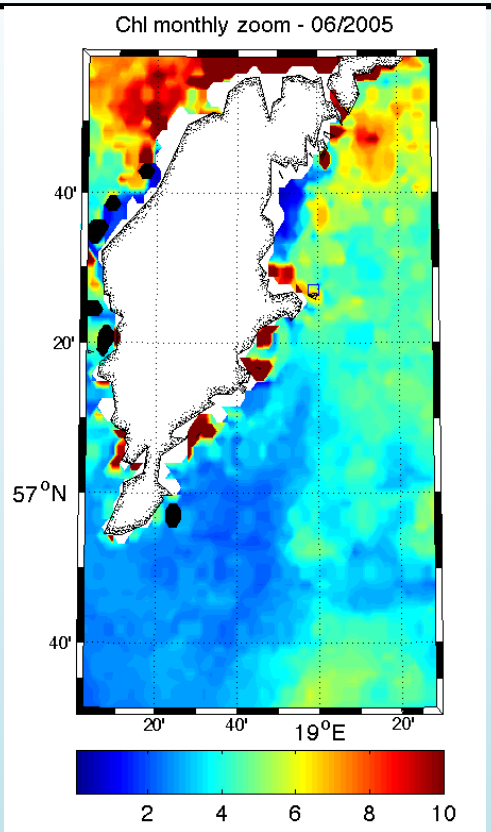
- Wave mooring, satellite and SAMI
- Good correlation (0.95)

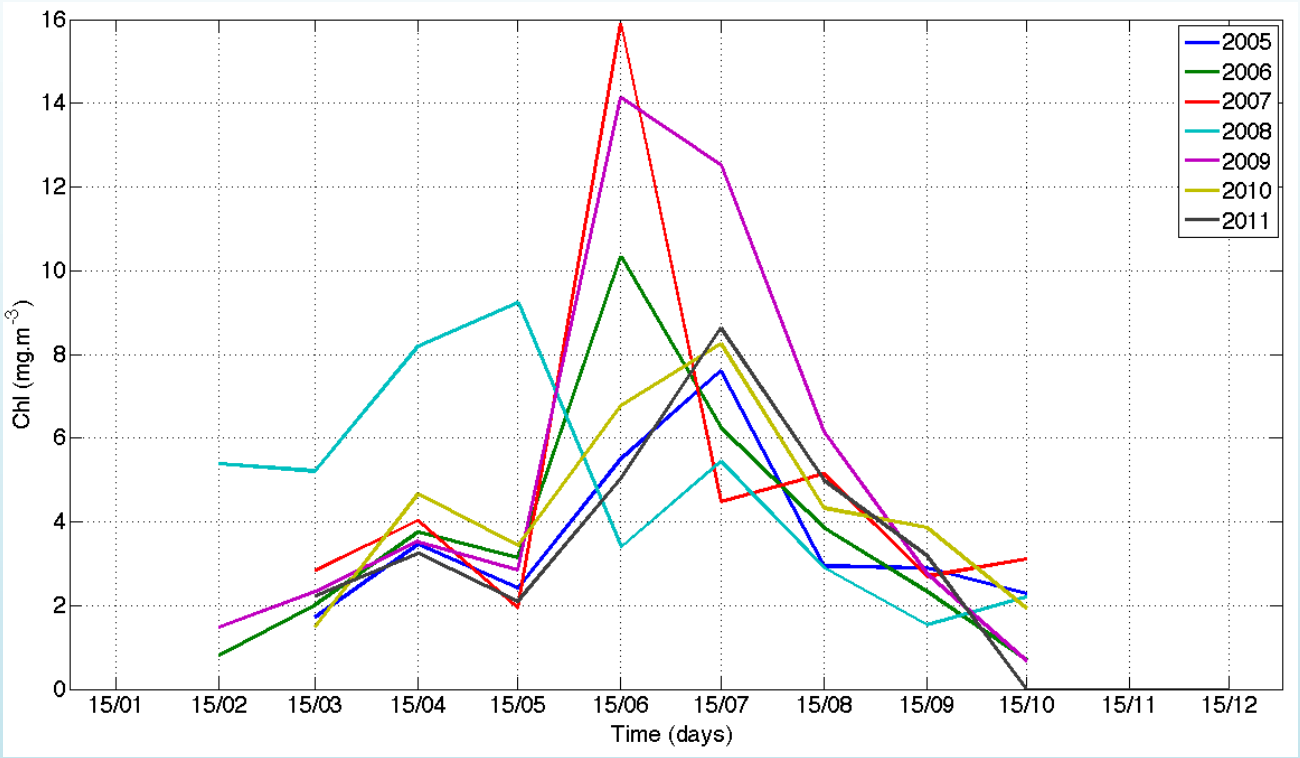
Trend of SST → Good correspondence between mooring and satellite

→ Problem with strong variation :
order of magnitude lower on satellite data



Chlorophyll data : monthly data





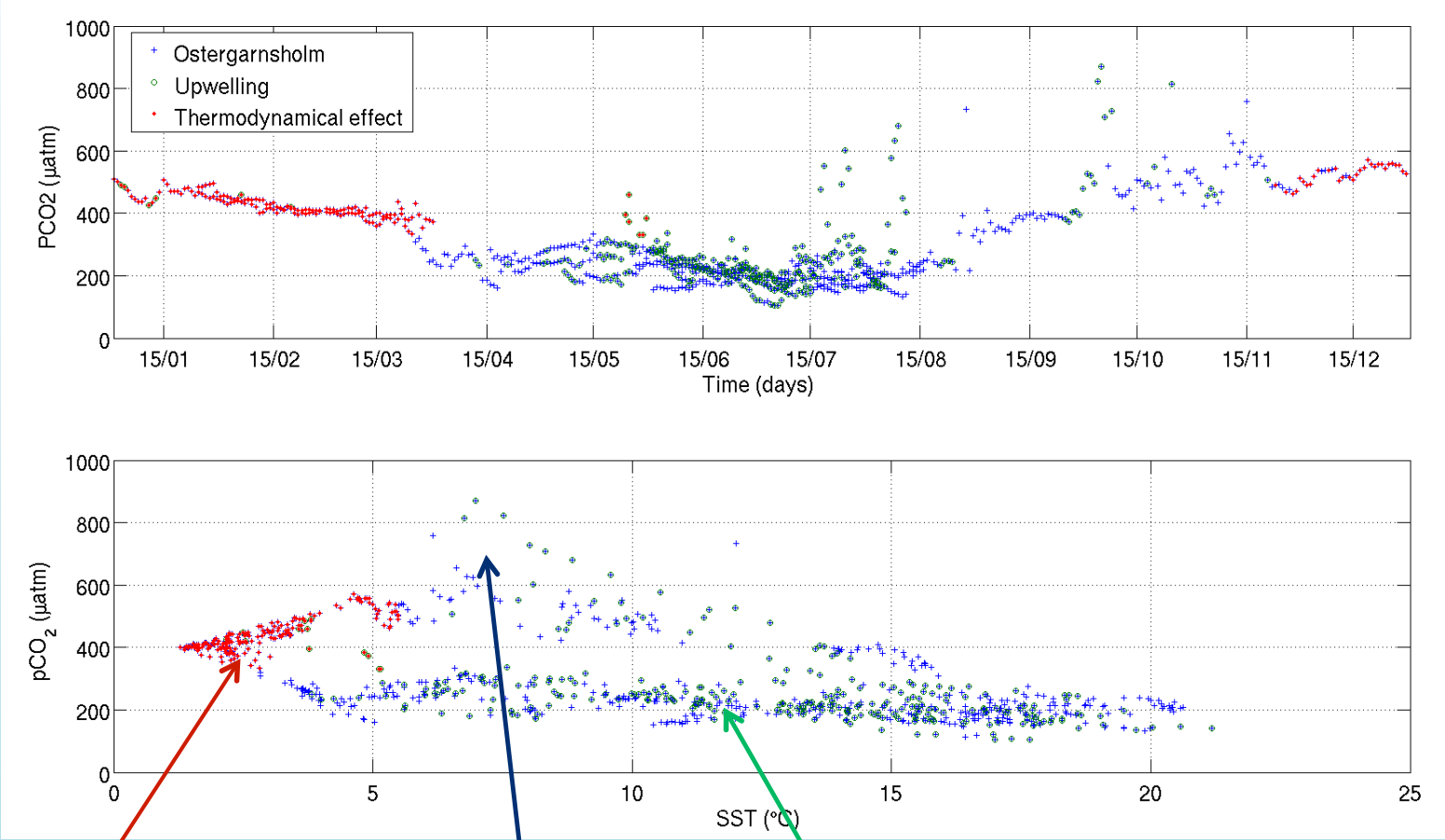
At the mooring low chlorophyll in 2005 with maximum in July

- strong chlorophyll in 2007 with maximum in June
- 2008 different compare to the other year

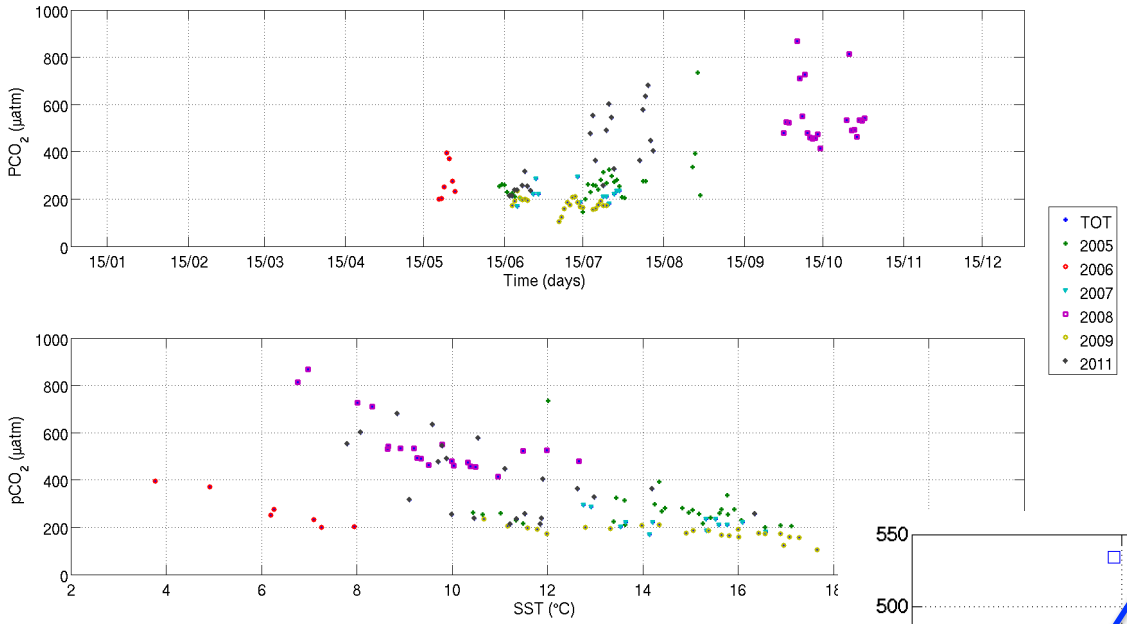
→ Study at monthly scale : can give an information on CO_2 variation in the Baltic sea

Method: Linear relationship

Define differents periods : 3 types of relationship

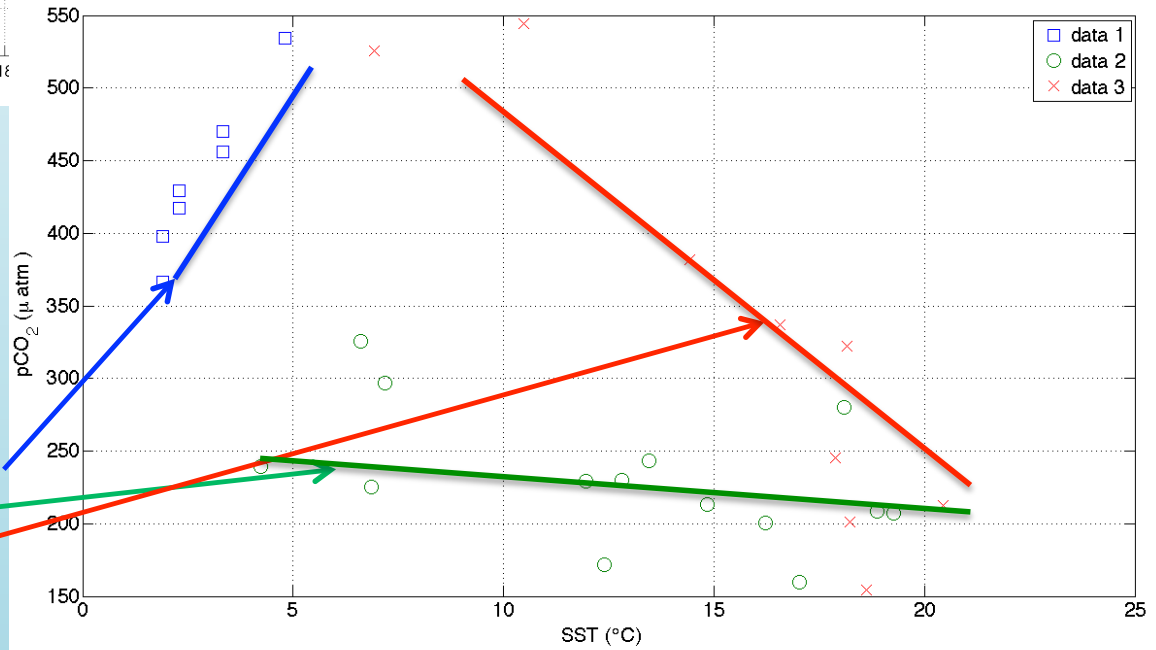


Linear relationship : Upwelling events



Isolation of upwelling events

- Two type of relationship between pCO_2 and SST
- Same relationship without upwelling events

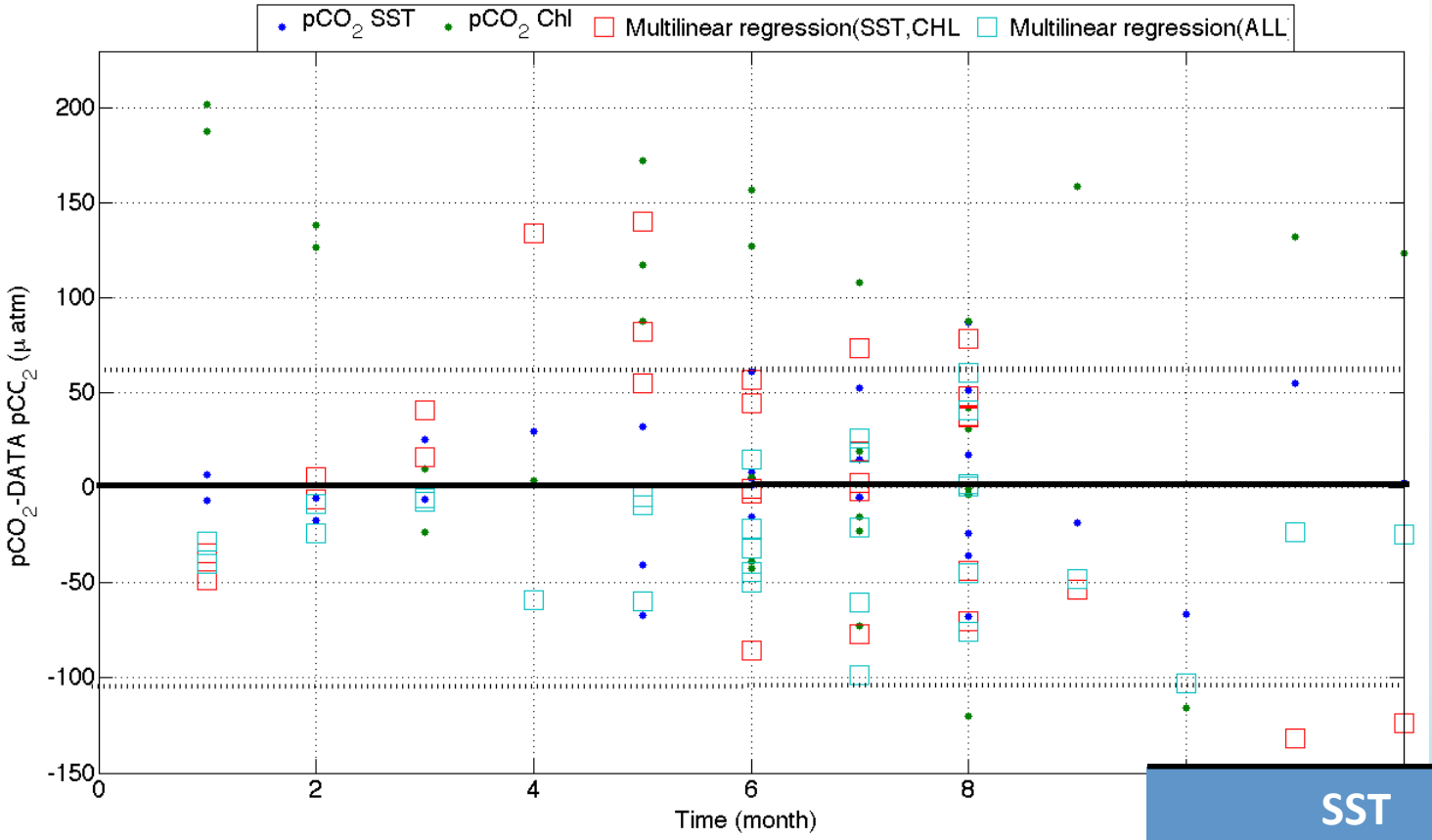


To remove the upwelling events effect : monthly mean

3 types of relationship :

- DEC-MAR : ≈thermodynamical effect
- APR-JUL: low slope
- AUG-NOV: Strong slope

Linear relationship: First result



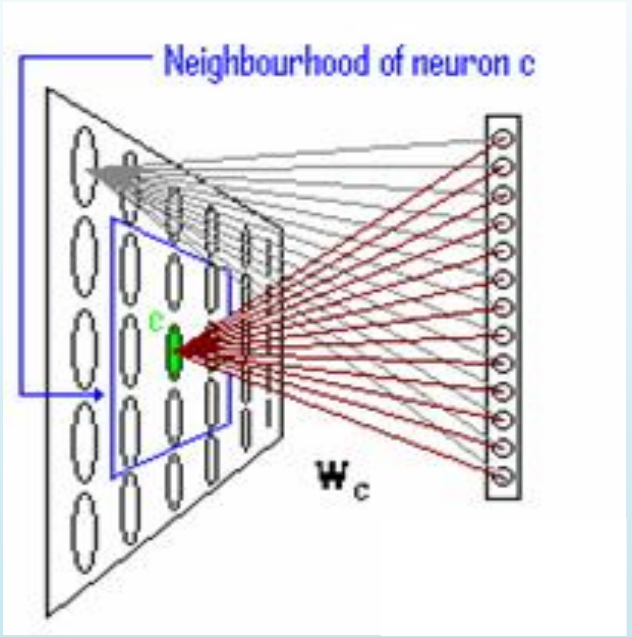
- Variation too strong between April and September
- Take into account several parameters is better for construction at the mooring

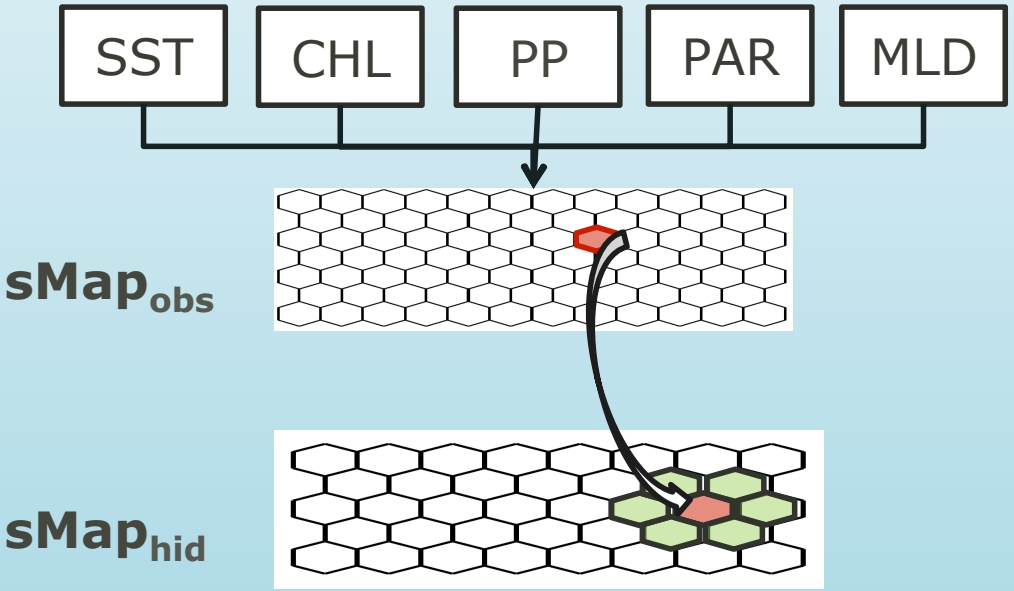
	SST	CHL	SST-CHL	ALL
R^2	0.93	0.84	0.76	0.94
ΔSTD (T-D)	7	46	28	9
RMSE	39	103	75	44

➢ Study with high frequency variation could be improve the representation of the variation between May and September : The upwelling period

Method : Self Organising Maps

- Input: Multidimensional Data
- Output: A clusterization of the data through projection on a topologically organised 2D map, in a way that respects the underlying variability of the higher dimension.

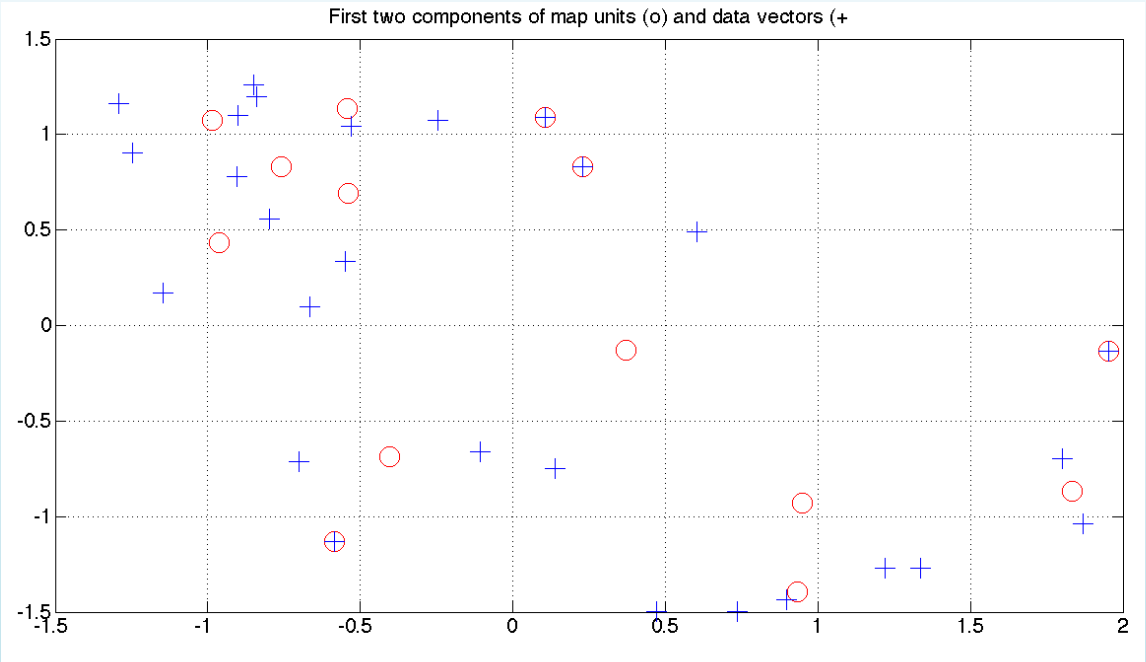




Self Organising Maps: First result

- First test Monthly data : (pCO_2, SST, PAR, PP, Chl, MLD)
- 2 data bases :
  - Construct the Map
  - Validate (≈10%)
- Validation difficult
  - pCO_2 ± 20 µatm

→ High error but not enough data to conclude



→ Future test with higher frequency (daily or weekly), all Baltic sea

→ Need higher frequency for PP, PAR and MLD

Conclusion and Perspectives

- Data validation and availability:
  - SST and pCO_2 quite good compare to other data→ Verify in all Baltic Sea
  - Difficult to validate: Chlorophyll data
  - Other satellite product at daily scale ?
- First method: linear relationship between the satellite data and the pCO_2 measurement
  - Climatology for one year good but at higher frequency difficult
  - Better with several parameter but high error at one point
  - Difficult to apply in all Baltic sea
- Second method: Not enough data
  - Experiment with daily data at the mooring (Chl, SST)
  - Same experiment on all Baltic sea after all validation

Linear relationship

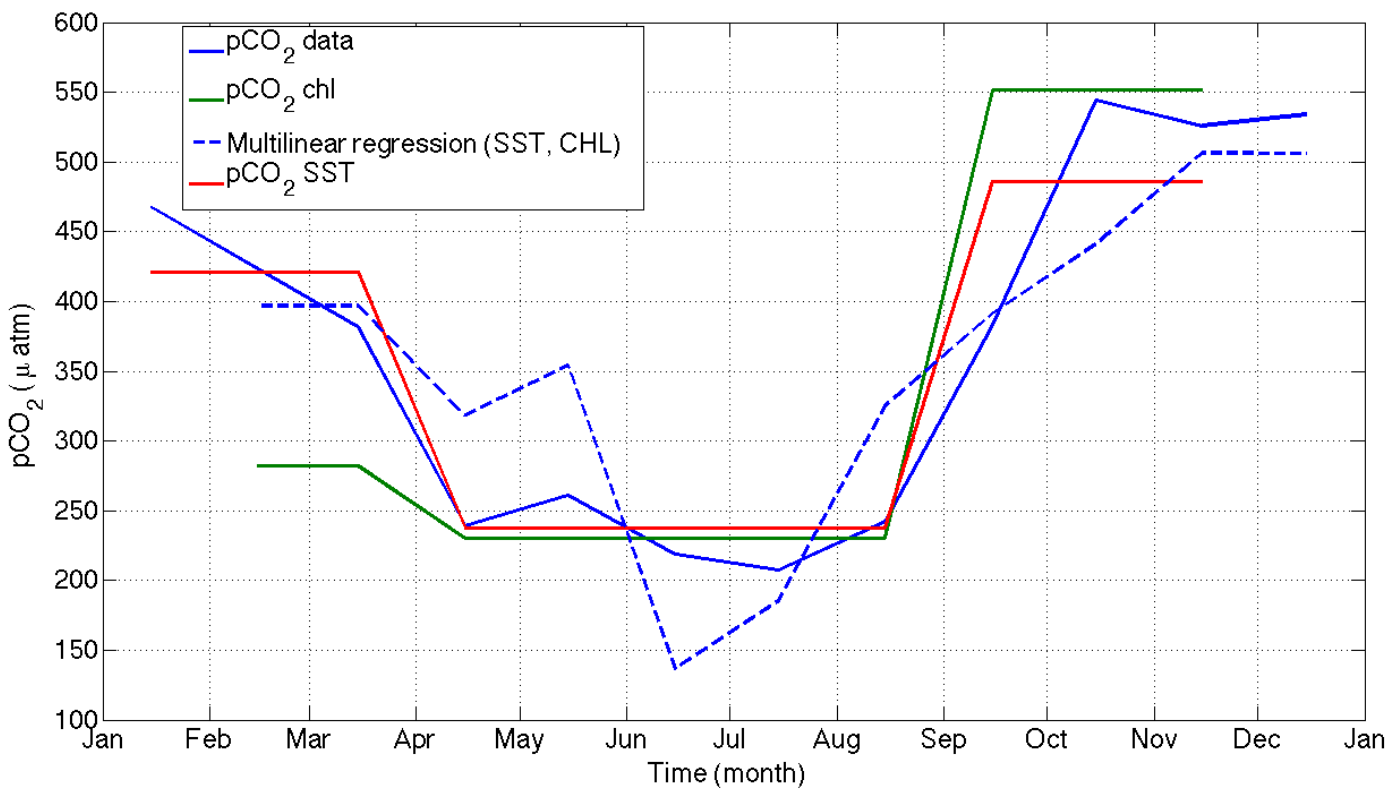
First estimation of pCO_2

- Relationship between SST (R^2=0.93) and Chl (R^2=0.92)

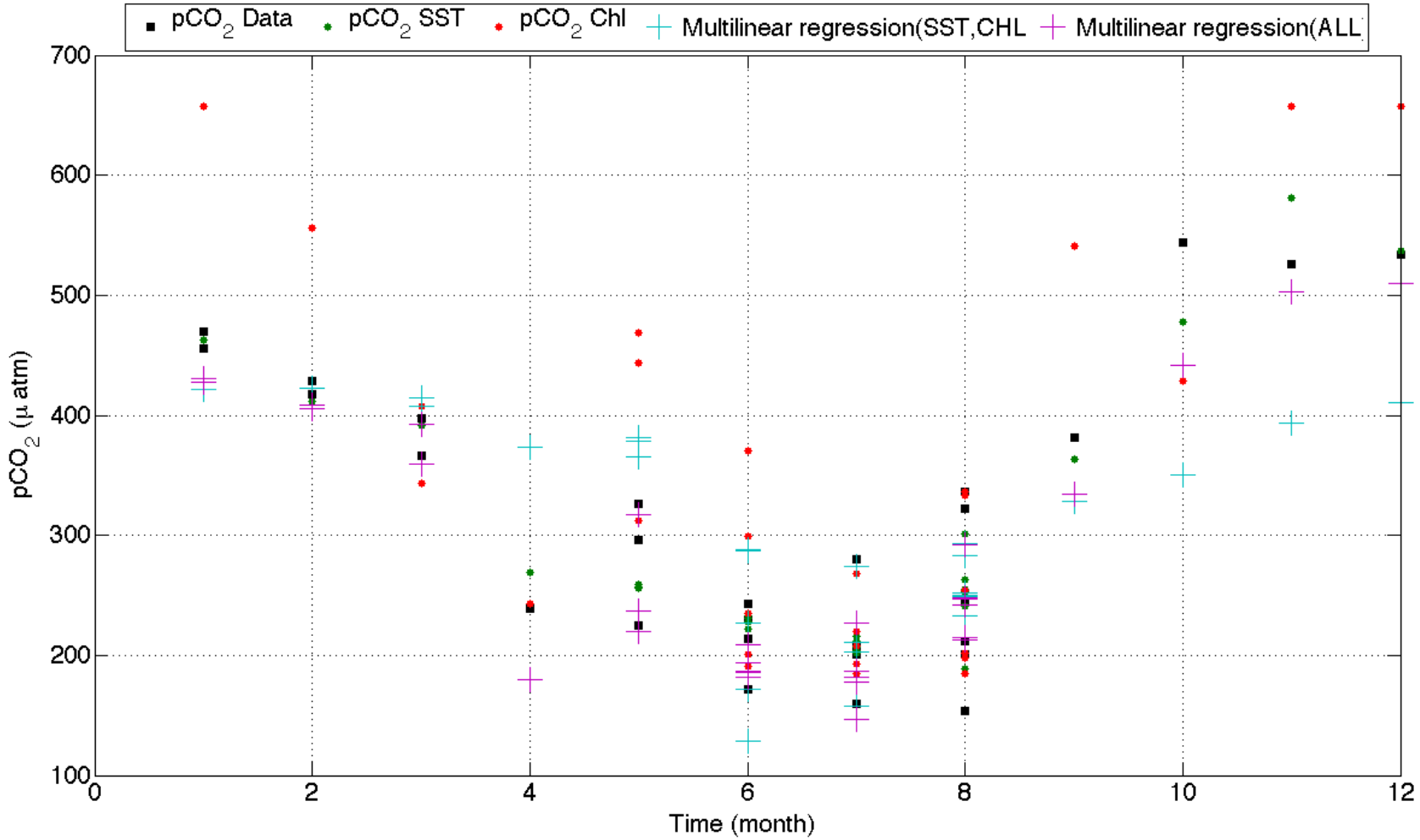
→ good seasonal variation separately

- Multilinear regression : R^2=0.87

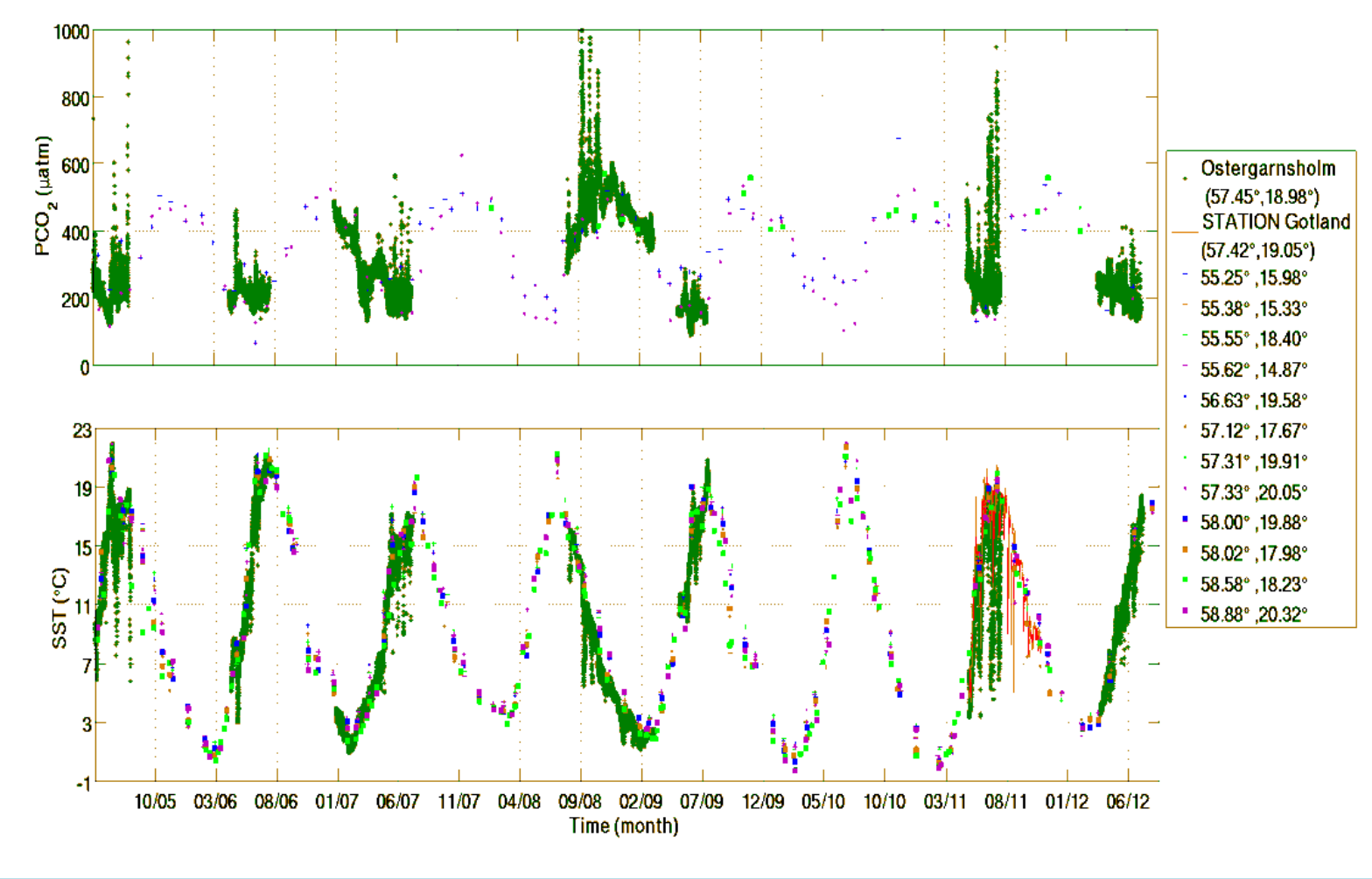
→ Variation too strong between May and September



- Improve with several parameters ? → Maybe take in count primary production, mixed layer depth.
- Study with high frequency variation could be improve the representation of the variation between May and September : The upwelling period


pCO2 Data
pCO2 SST
pCO2 Chl
Multilinear regression(SST,CHL
Multilinear regression(ALL
700
600
500
400
300
200
100
pCO2 (μ atm)
0
2
4
6
8
10
12
Time (month)

In situ data validation : SMHI



- All year comparisons with SMHI station
  - Seasonal variation similar except upwelling events → far from the SAMI
  - Good database for all Baltic sea study