# Spatial Coherence between Ferrybox Fluorescence measurements

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# How can cyanobacteria blooms be detected from Ferrybox data?

**Challenge:**

Measurements from *in situ* and remote sensing are not reliable during strong stratification:

- Ferryboxes sample at ~5 m depth
- Remote sensing bio-optical algorithms assume vertically mixed water columns

**Hypotheses:**

1. Within a cyanobacteria bloom, Chlorophyll a (CHLa) and Phycocyanin (PC) fluorescence vary *coherently*, independent of the concentrations.

2. This coherence can be spatially resolved with *continuous wavelet transform*.

We show this for a summer bloom in the Baltic Sea.

# Cyanobacterial Fluorescence

| Ferrybox Fl. | $R^2$ |
|---|---|
| CHLa | 0.39 |
| PC | 0.76 |
| CHLa, PC | 0.82 |

Seppälä2007: Explained variability of CHLa lab samples during summer bloom 2005 in the Baltic Sea

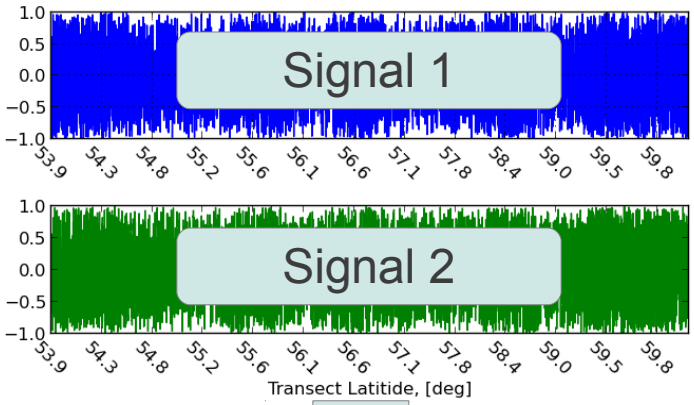
**All** cyanobacteria include CHLa pigment. **High %** in *non-fluorescing* PSI.
**All** cyanobacteria include PC pigment in *fluorescing* PSII

In a cyanobacteria dominated bloom:

→ CHLa fl. present but low
→ CHLa and PC fl. are *varying coherently*

**Where** on a Ferrybox transect CHLa and PC fl. are *varying coherently*?

# Wavelet Coherence

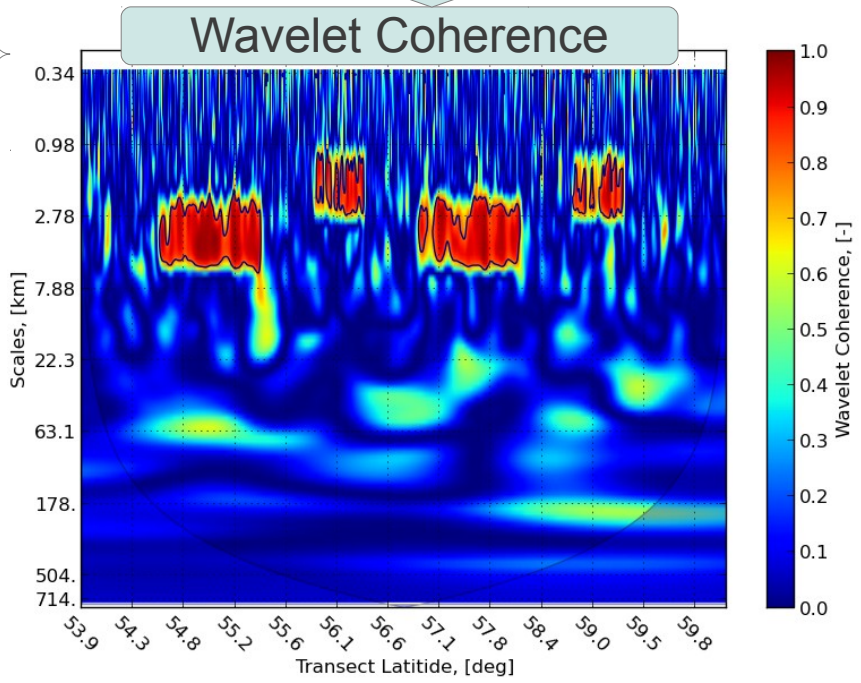



**Fourier Transform**
- Decomposes signal in *frequencies*
- Works only on *stationary* data

**Continuous Wavelet Transform**
- Decomposes signal in *frequency* AND *space*
- *No stationarity* assumption

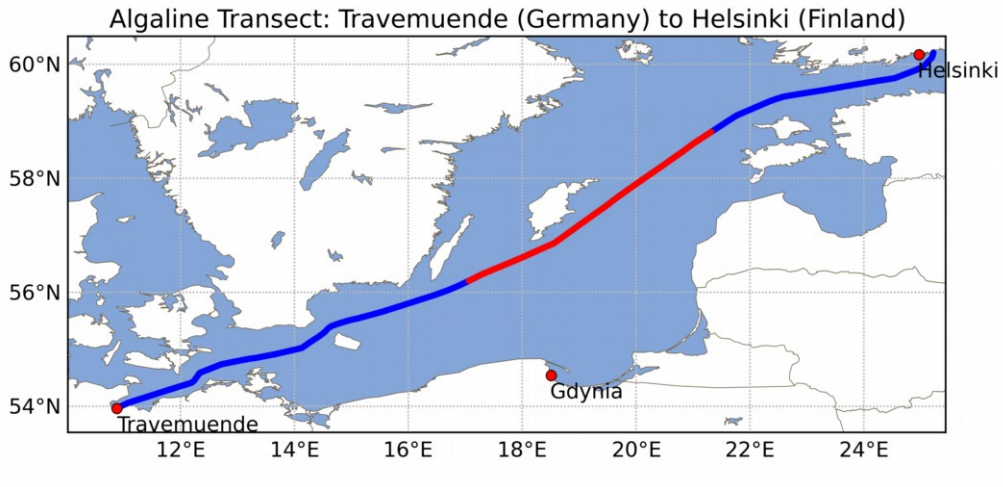
**Wavelet Coherence Transform**

Measure of *coherence* between two *wavelet transformed* signals

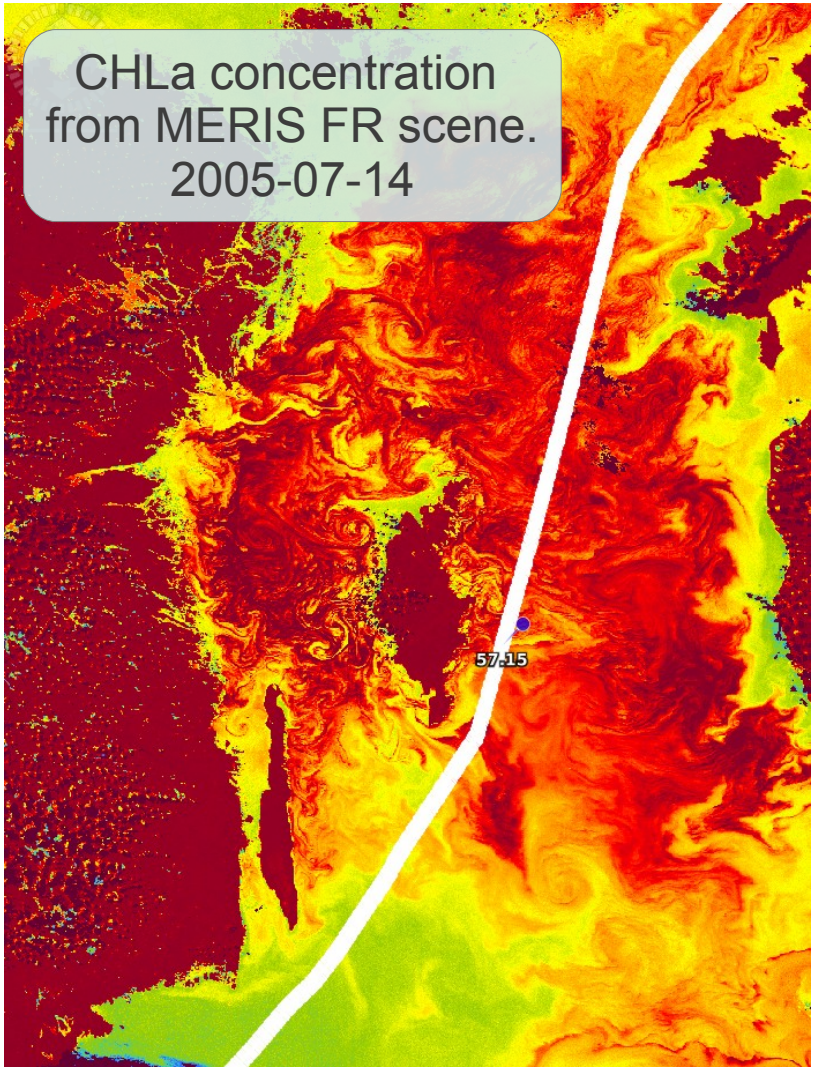



**Where** and **at what scales** are two signals *varying coherently*

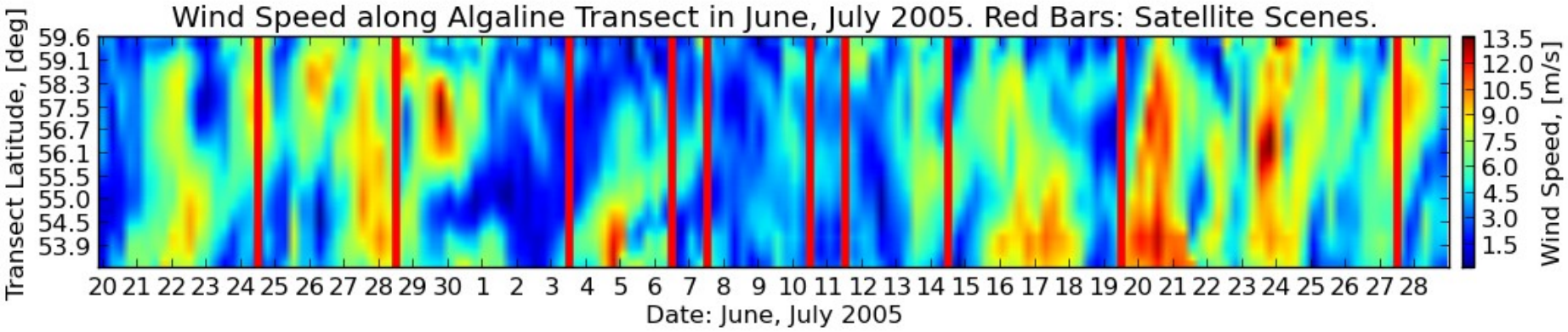
# Case Study: Baltic Sea Summer Bloom 2005 (June, July)

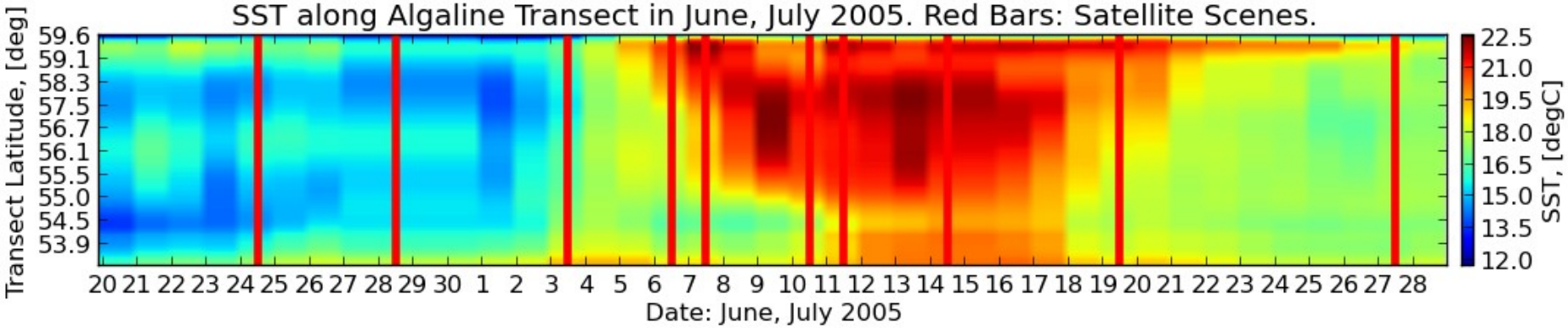



- 10 Ferrybox transects (East of Gotland)
  - Travemünde (Germany) - Helsinki (Finland)
  - CHLa, PC fluorescence, turbidity, temperature, salinity
  - Measurement depth: 5 m
  - Described in Seppälä2007
- 10 MERIS FR scenes (processed with WeW/FUB)
- ECMWF interim reanalysis: wind speed, SST

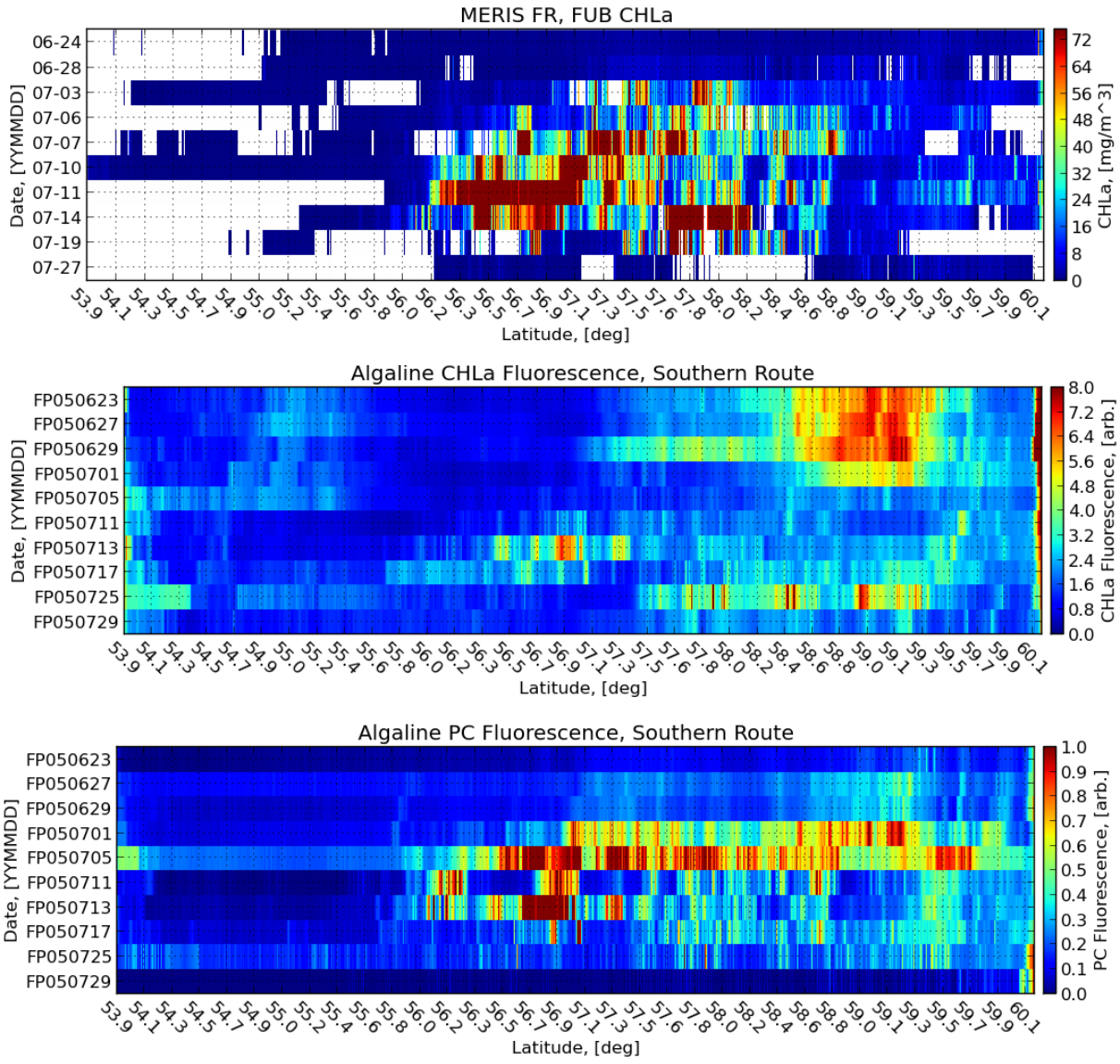


# Meteorological Situation

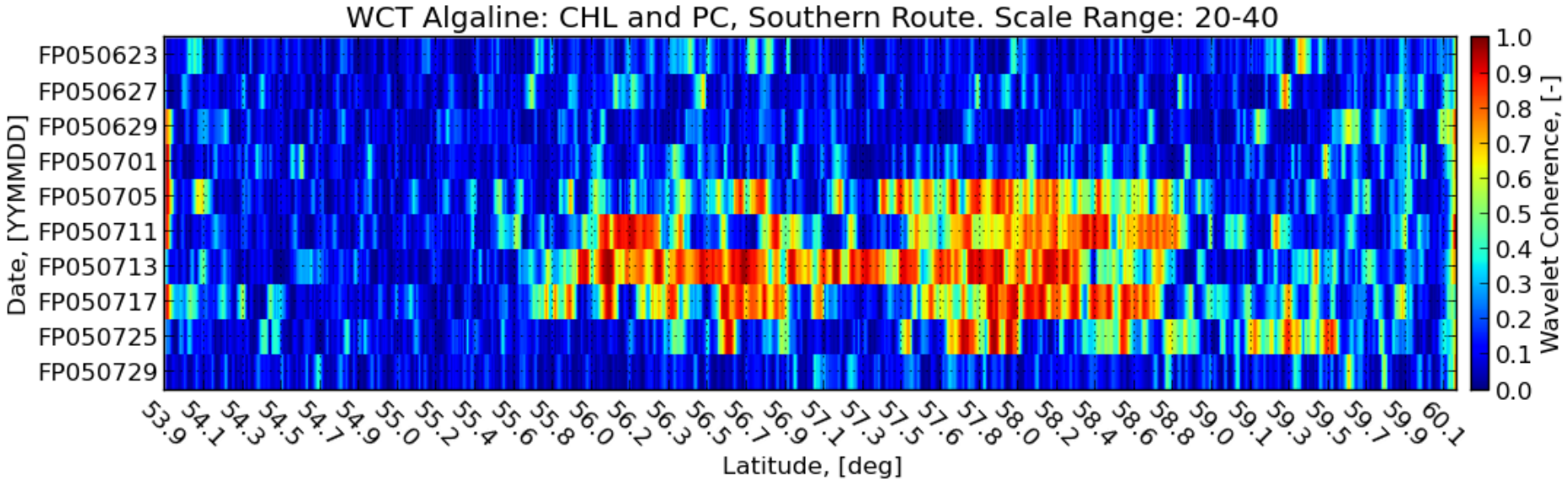


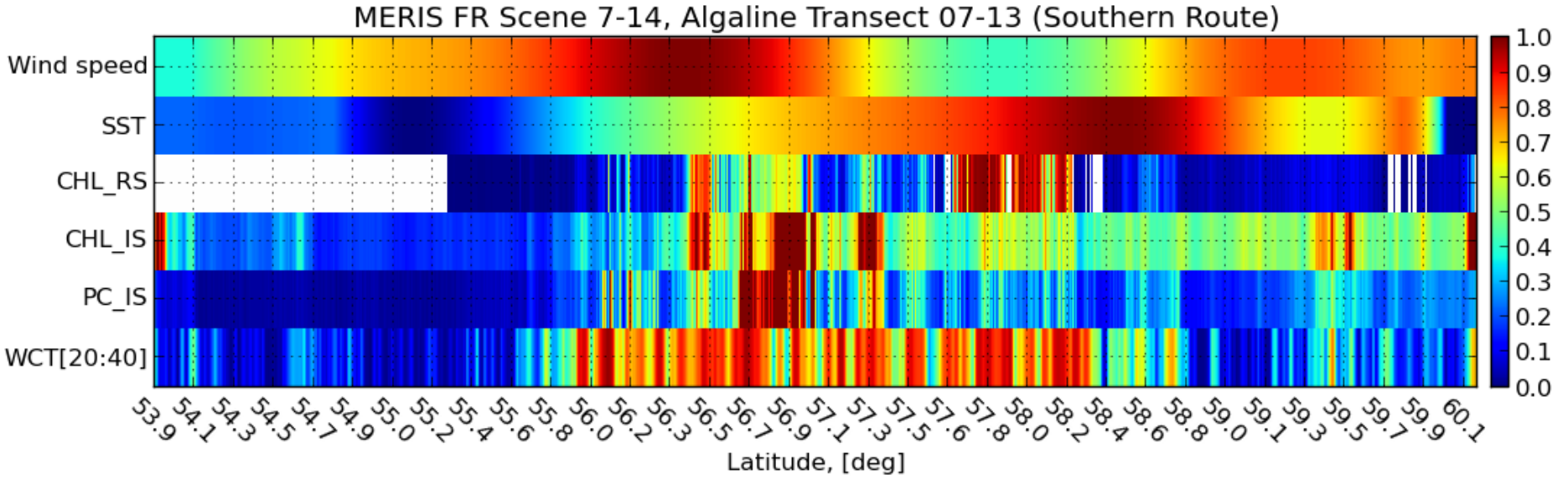
# Remote Sensing and Ferrybox Measurements



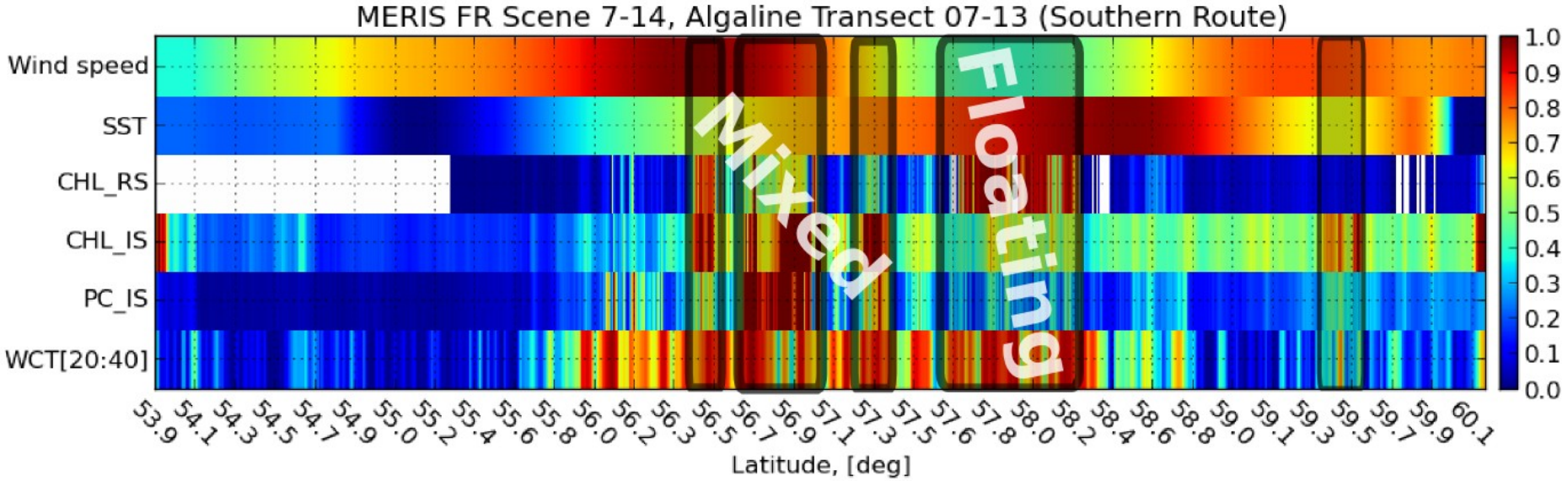
# Wavelet Coherence: CHLa, PC fluorescence



# Synopsis


MERIS FR Scene 7-14, Algaline Transect 07-13 (Southern Route)
Wind speed
SST
CHL_RS
CHL_IS
PC_IS
WCT[20:40]
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
53.9 54.1 54.3 54.5 54.7 54.9 55.0 55.2 55.4 55.6 55.8 56.0 56.2 56.3 56.5 56.7 56.9 57.1 57.3 57.5 57.6 57.8 58.0 58.2 58.4 58.6 58.8 59.0 59.1 59.3 59.5 59.7 59.9 60.1
Latitude, [deg]

# Synopsis


MERIS FR Scene 7-14, Algaline Transect 07-13 (Southern Route)
Wind speed
SST
CHL_RS
CHL_IS
PC_IS
WCT[20:40]
Mixed
Floating
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
53.9 54.1 54.3 54.5 54.7 54.9 55.0 55.2 55.4 55.6 55.8 56.0 56.2 56.3 56.5 56.7 56.9 57.1 57.3 57.5 57.6 57.8 58.0 58.2 58.4 58.6 58.8 59.0 59.1 59.3 59.5 59.7 59.9 60.1
Latitude, [deg]

# Summary, Application and Open Questions

## Summary

- Wavelet coherence between CHLa and PC fluorescence is calculated
- Coherence is high in cyanobacteria dominated transect-sections
- Stratification situation can be estimated

## Direct Applications

- Water samples from cyanobacteria dominated sections can be flagged for the calibration of CHLa fluorescence.
- Stratified sections can be dealt with separately during the validation with remote sensing data

## Open Questions

- Distribution of Ferrybox CHLa and PC fl. is not Gaussian. Typical tests for significance of wavelet coherence rely on Gaussian distribution.
- What can the scale distribution of the wavelet coherence tell us?

# Acknowledgements

WaterS

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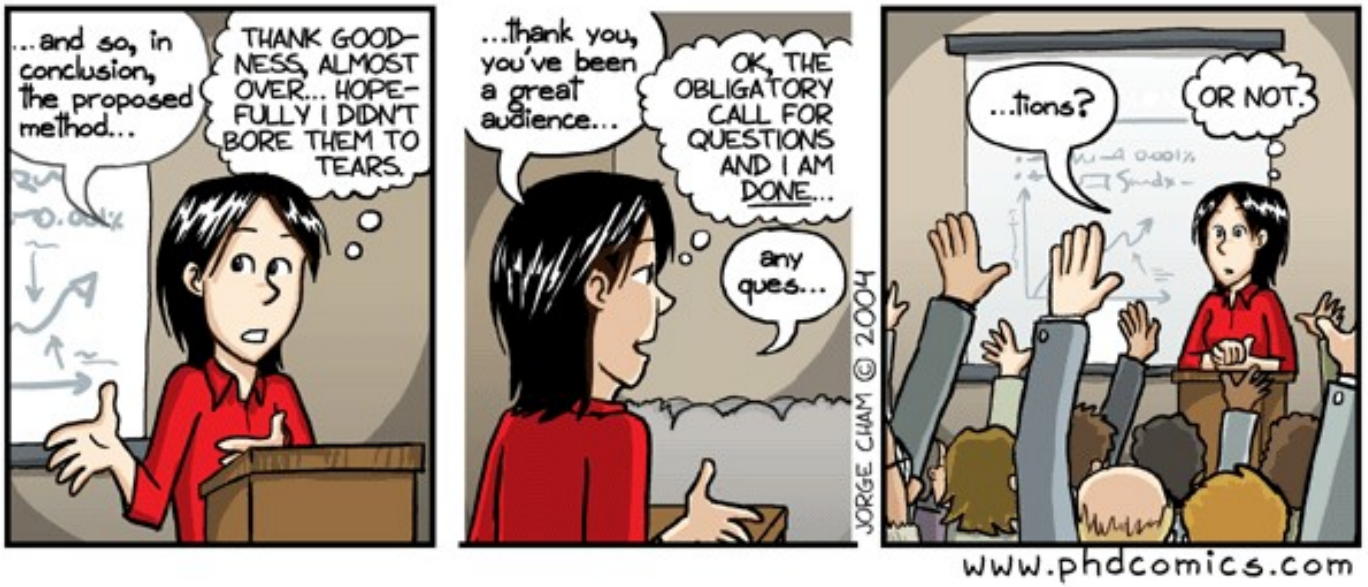
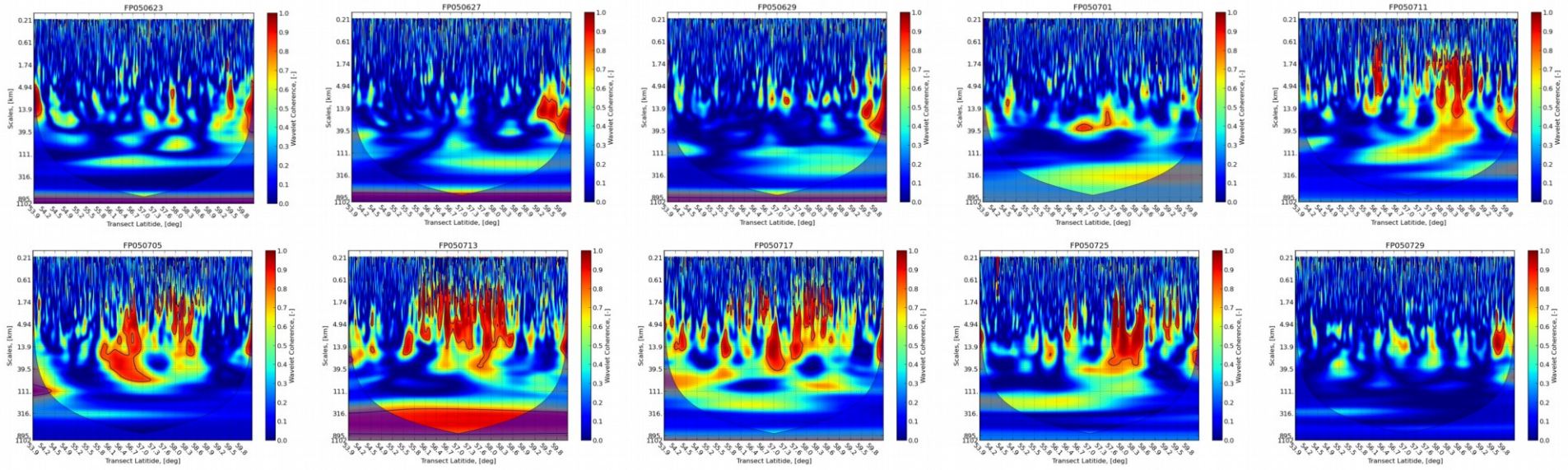
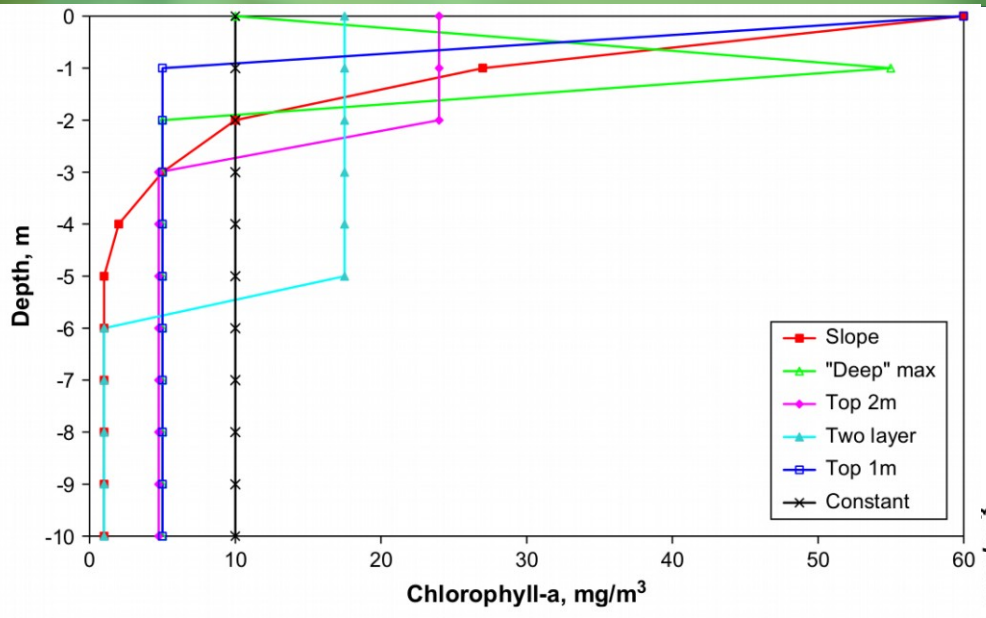
# Thank you for your attention – feedback is very welcome!!



# Wavelet Coherence: CHLa, PC fluorescence



# Vertical Distribution of the Water Column



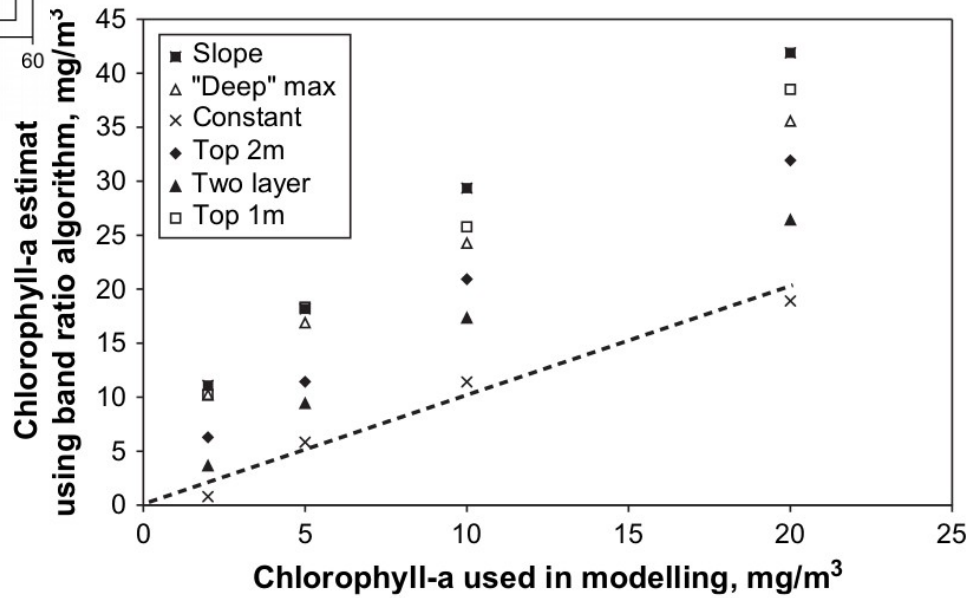

- Water remote sensing: **2D** snapshots of **3D** systems
- Vertical dimension **NOT** directly observable through remote sensing

→ Assumptions necessary

Most common assumption:

**Vertically homogeneous water column**

→ High uncertainties






Kutser, T., Metsamaa, L., & Dekker, A. G. (2008). Influence of the vertical distribution of cyanobacteria in the water column on the remote sensing signal. Estuarine, Coastal and Shelf Science, 78(4), 649-654. doi:10.1016/j.ecss.2008.02.024