# Klimatförändringar och statistik – orsaker? Konsekvenser !

Några erfarenheter från (bl a) EU FP6 Marie Curie Research Training Network SEAMOCS

Georg Lindgren

# SEAMOCS

- Applied Stochastic Models for Ocean engineering, Climate and Safe transportation
- Ett ”Interdisciplinary and Intersectorial network” som kombinerar statististik, marin  och kust-teknik, meteorologi och försäkring, 2005-2010
- Workshop, Malta 18-20 Mars 2009, + PIMS + STINT + Quest4D + Encora

# SEAMOCS partner

- Mathematical statistics, Lund university, Jörg Wegener, (wave modelling), Per Andreas Brodtkorb, safety computation (WAFO), Pal Rakonzai (multiple extremes)
- Statistics and Probability, University of Sheffield
- Statistics, Université Paul Sabatier, Toulouse, Mary Ana Allen, (Change point detection)
- Coastal Engineering, K.U. Leuven, Layla Loffredo (sea models and ship design), Albin Ullmann, (sea surge variation)
- Marine science, Chalmers, Wengang Mao, (ship fatigue), Thomas Galtier (ship response distributions)
- Coastal Engineering, Tallinn, Ira Didenkulova, …, (ship wakes and coastal wave impacts)
- KNMI, De Bilt, Simone Russo (local climate models coastal safety and wave impact)
- SMHI, Norrköping, Jörg Wegener
- Det Norske Veritas, Alessandro Toffoli (non-linear wave models and impact on ship regulations)

# SEAMOCS teman

- Problem på global skala: globala klimatmodeller och vad de säger om vind- och vågklimat på världshaven
- Problem på lokal skala: vindgenererade vågor, linjär och icke-linjär teori för havsvågor och deras statistiska egenskaper
- Global and lokala effekter på marin säkerhet: utmattning på fartyg och offshore installationer, respons, klassificering, påverkan på kustområden, översvämning

# Hur passar SEAMOCS teman in i klimatforskarnas värld?

- Speglar SEAMOCS teman enbart vår (statistikers i Lund) bild av vad som är viktigt?
- Hur ser klimatforskares önskelista ut?

## *MERGE (ModElling the Regional and Global Earth system)*

- Ett strategisk forskningsinitiativ med Lunds universitet, Göteborgs universitet o Chalmers, KTH, Linné universitetet (Kalmar), SMHI, Start 2010
- Koordinator: Markku Rummukainen, SMHI och LU
- Tema 2.1: Advanced statistics for model evaluation, simulation set-up and analysis
  - Statistical treatment of space-time data, for interpolation, parametrization, and estimation (vegetation, wind and precipitation, paleo-climate, up/down scaling)
  - Extreme events under changing climate; regional, non-pointwise, extremes
  - Model evaluation, Design and analysis of computer and other experiments, Bayesian and other techniques

# MERGE teman

**START med**

- RA1.1 “Development, modelling and evaluation of climate-vegetation processes in Earth System Models”
- RA1.3 ”Terrestrial carbon cycle and aerosol–cloud–climate interaction”
- RA2.1 “Advanced statistics for model evaluation, simulation set-up and analysis”

**SENARE:**

- RA1.2 … model evaluation; studies of climate-vegetation/land-cover feedbacks; Modelling of natural climate change.
- RA2.2 Local-scale effects and feedback
- RA2.3 Modelling of coastal impact

# Scenarier för det kommande århundradet

- (Växthusgaser, mm) =>
- Temperaturförändringar =>
- Havsnivå och vindmönster påverkas =>
- Högvatten – extrema vågor =>
- Översvämningar, permanent och temporärt, skeppsbrott
- Ett komplext problem: Gilbert T Walker arbetade 20 år som chef för Indiska Met Department – uppfann Yule-Walker ekvationerna för att förutsäga monsunregnen

# Global skala – lokal skala – respons – nya modeller

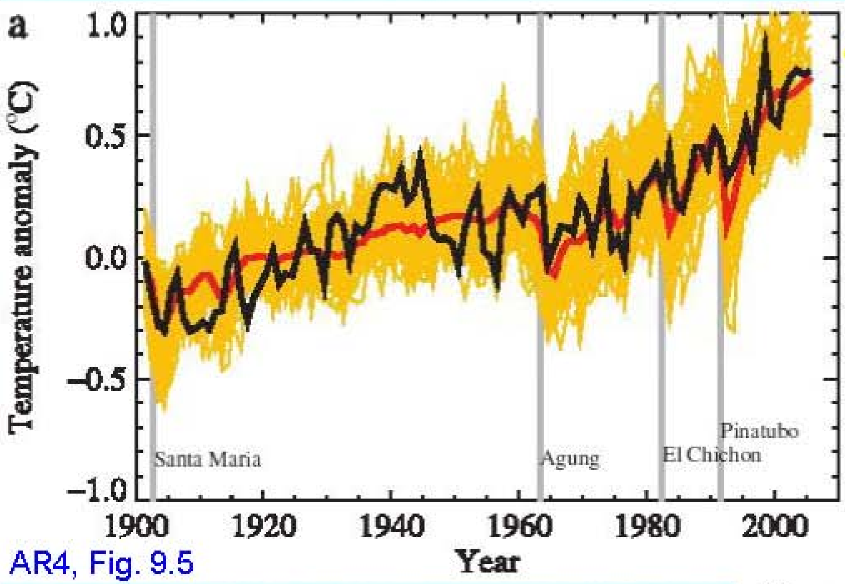
1. Vindklimat – medelvind, styrka och riktning, extremer
2. Vågklimat – hur påverkas det av förändringar i lågtrycksbanor och vindklimatändringar
3. Vågklimat och kust
4. Nya modeller för geofysiska data

# 1+2: Möjliga framtida vind- och vågklimat

- Simone Russo och Andreas Sterl, KNMI
- Erik Kjellström, SMHI

# Simulations

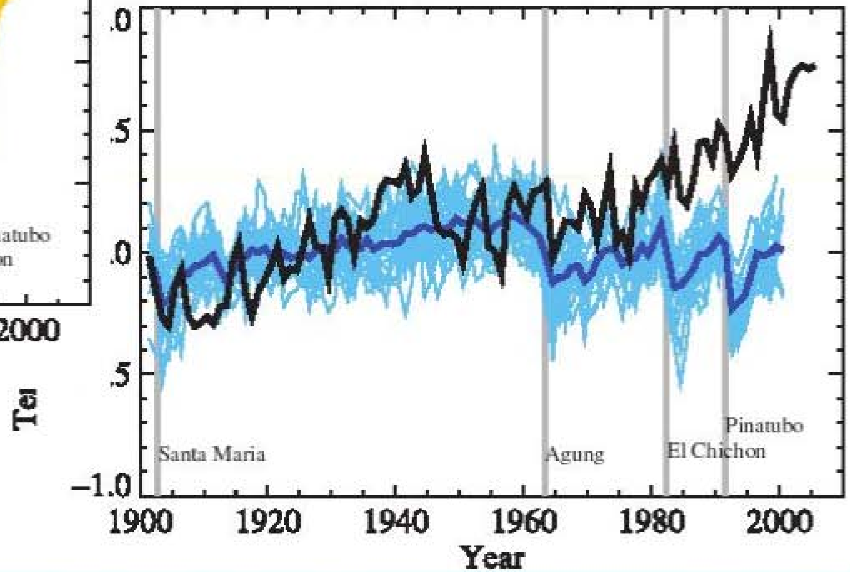
KNMI




<= multi model, all forcings

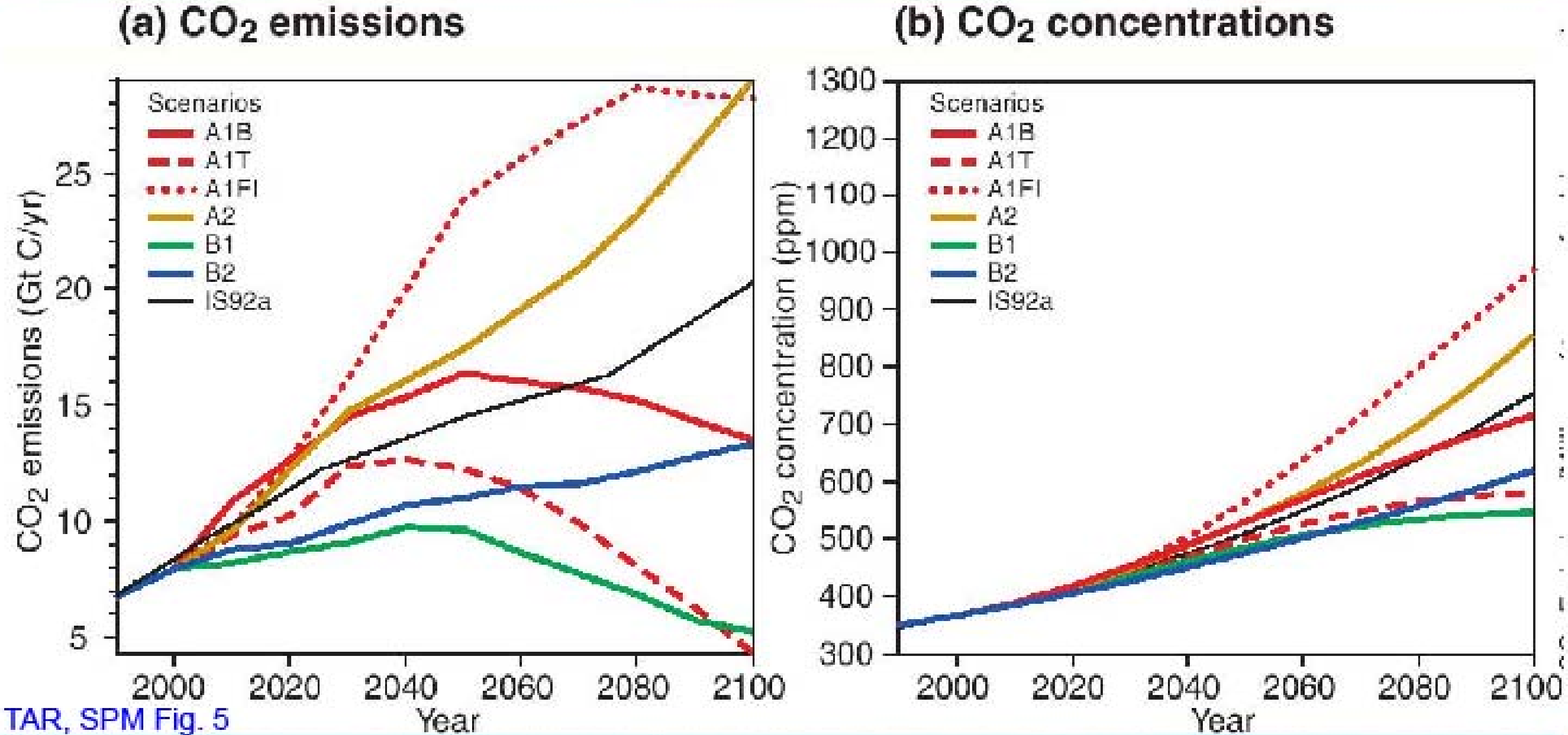
AR4, Fig. 9.5

Multi model, natural forcings =>



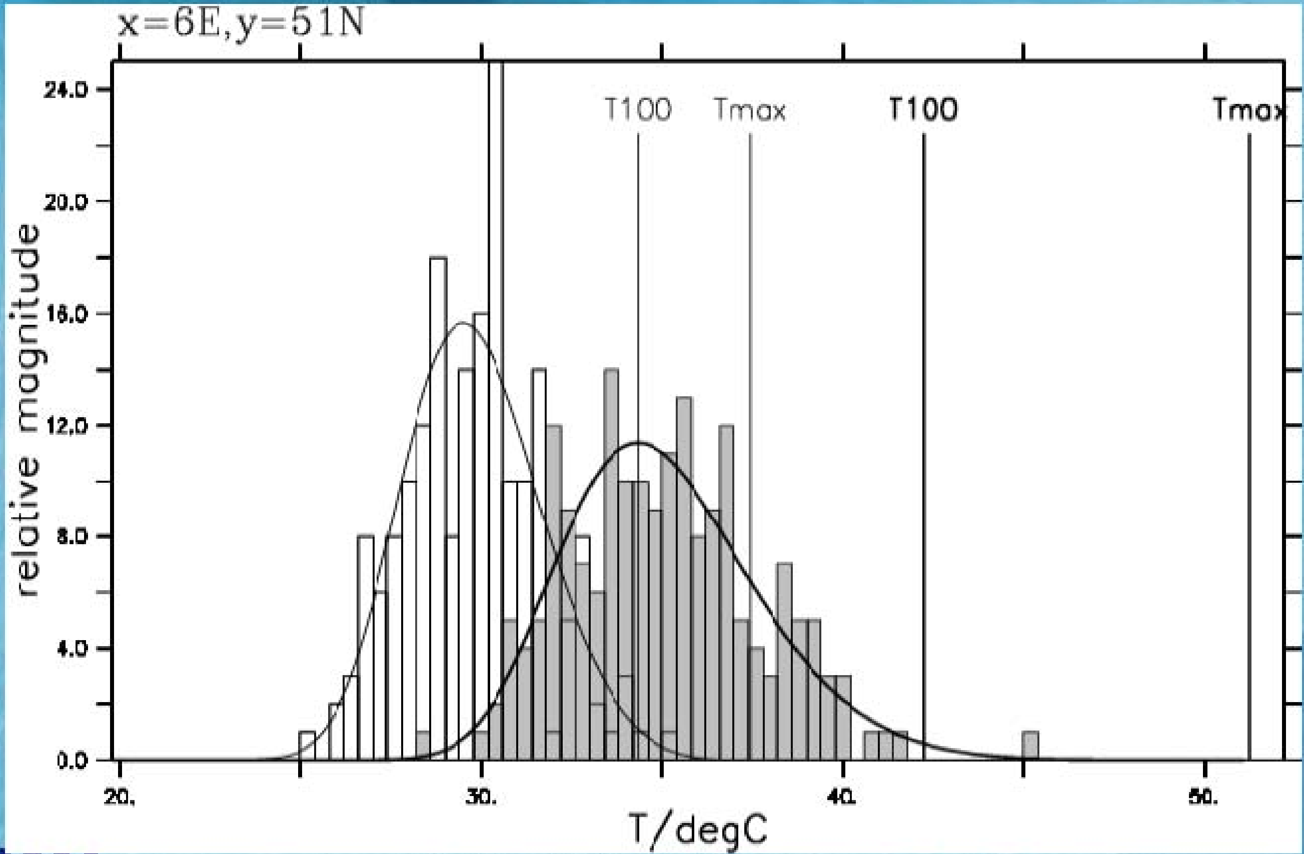

Andreas Sterl, SEAMOCS,
Malta, 17.03.2009

# Emission scenarios



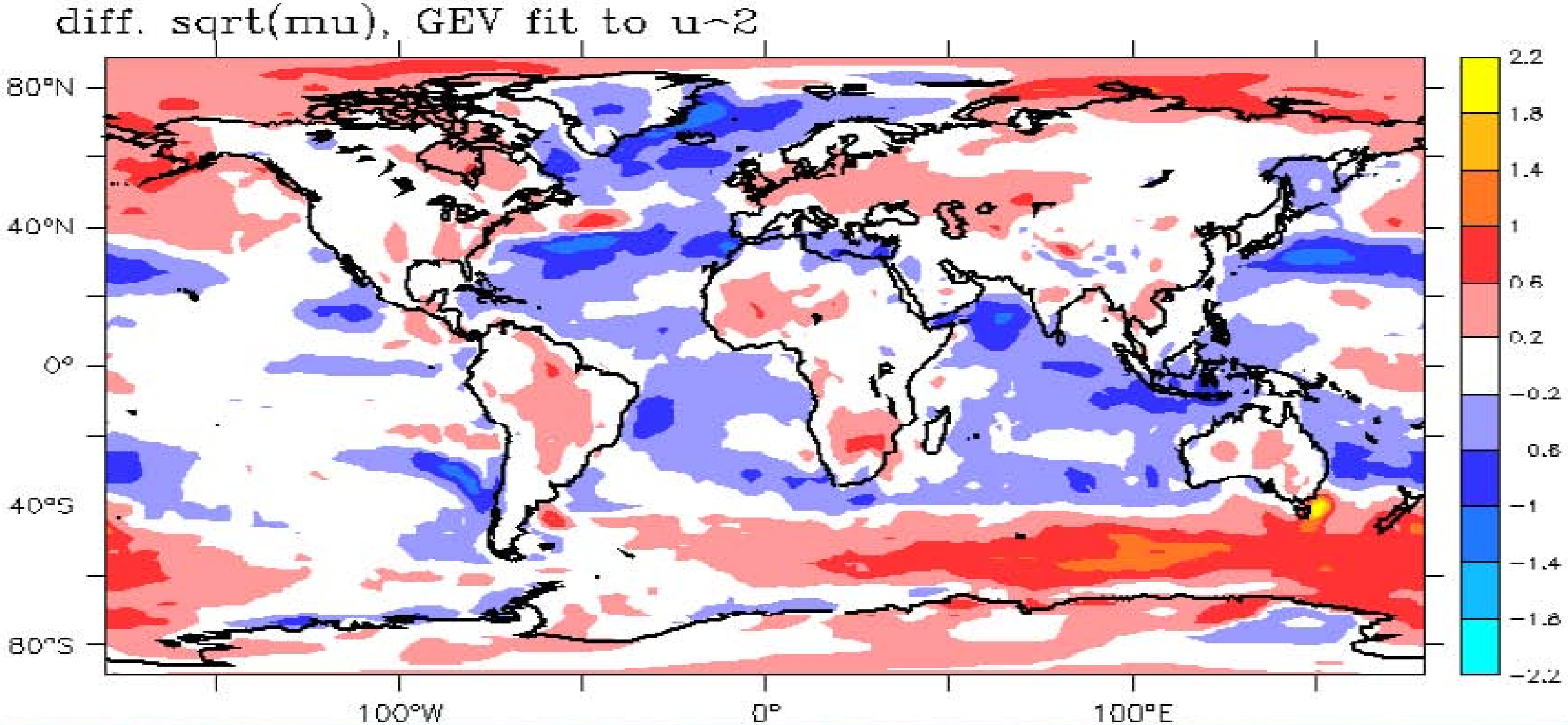

TAR, SPM Fig. 5

# Example: Netherlands




Andreas Sterl, SEAMOCS,
Malta, 17.03.2009

# Extreme winds




Andreas Sterl, SEAMOCS,
Malta, 17.03.2009

SMHI

# Summary

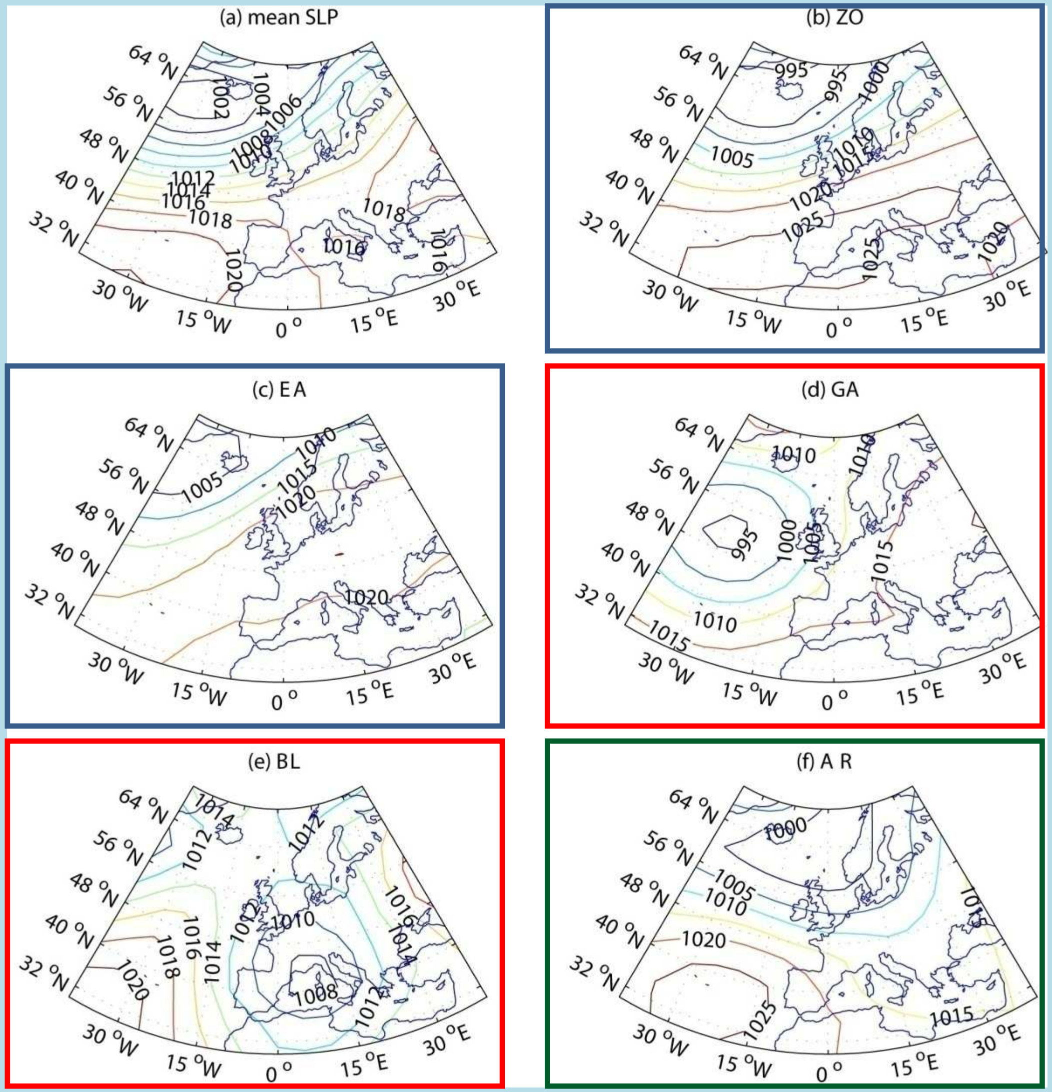
- **No observed long-term trend in storminess**
- **Observed poleward migration of storm tracks**
- **Possible decrease in mean wind speed in Sweden**
- **Geostrophic wind may be used instead of wind obs.**
- **GCMs indicate continued poleward migration of storm tracks**
- **Regional climate models can provide valuable information on local/regional scales**
- **Need to sample uncertainties in forcing, models and natural variability**

# 3. Vågklimat och kust

- Albin Ullmann, Coastal Engineering, K.U. Leuven

## 2.3. Sea surges and weather regimes

**5 weather regimes <u>to summarize the atmospheric circulation</u> over Northern Atlantic and Europe.**




*Mean sea-level pressure (a) of the period 1925-2000, (b) for « Zonal » (c) « East Atlantic », (d) « Greenland above », (e) « Blocking » and (f) « Atlantic Ridge » days*

**Acceleration of the westerly flow over Atlantic:**

**. « Zonal » (ZO)**

**. « East-Atlantic » (EA)**

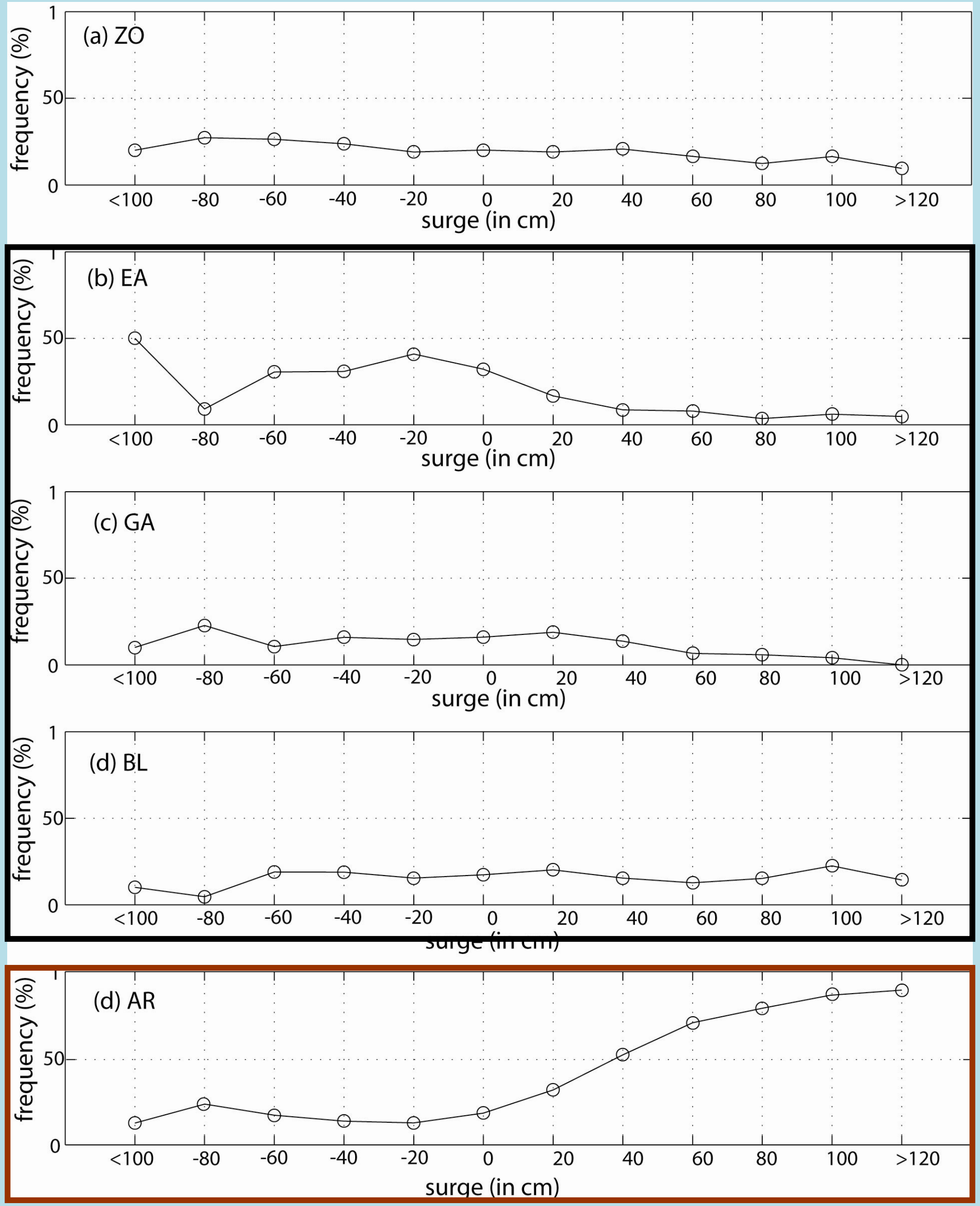
**Southerly shif of the main stormtrack over the Atlantic:**

**. « Greenland Above » (GA)**

**. « Blocking » (BL)**

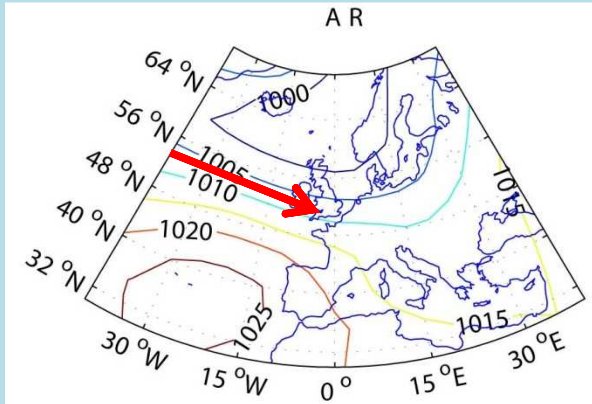
**Ridge over Atlantic + trough from Scandinavia to the Mediterranean Sea :**

**. « Atlantic Ridge » (AR) .**




Mean frequency of (a) « Zonal » , (b) « East Atlantic », (c) « Greenland above », (d) « Blocking « and (e) « Atlantic Ridge » days for sea surges different thresholds

**Highest surges almost never occur during « East Atlantic », « Greenland Above » and « Blocking »**

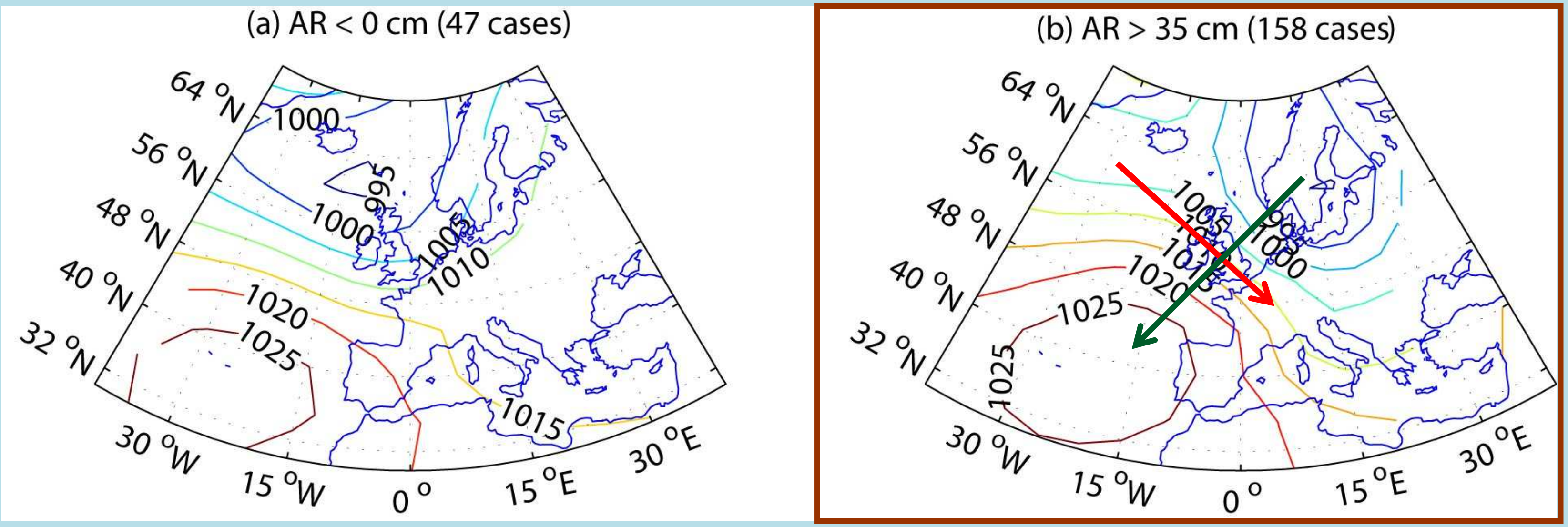



**Sea surges at Ostend are mainly associated with « Atlantic Ridge » weather regime showing a North-westerly flow over belgian coast**

## But all « Atlantic Ridge » days are not always associated with sea surges at Ostend….

**…Only when the northerly depression move from Iceland to Scandinavia =**

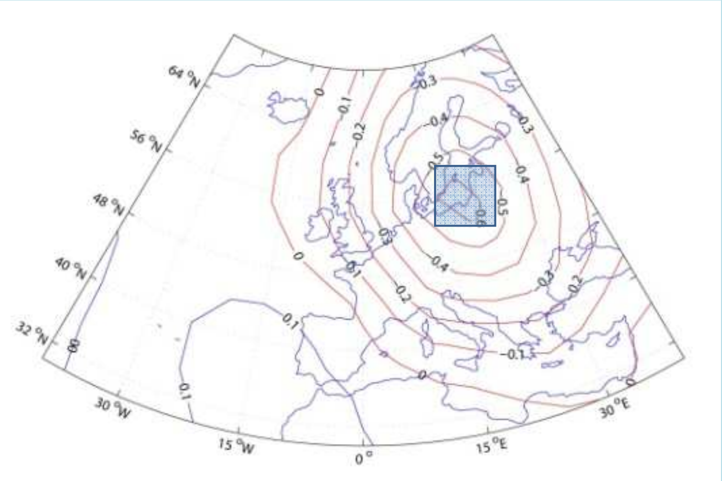
- **South-westward barometric gradient**
- **North-westerly flow over Northern Europe**



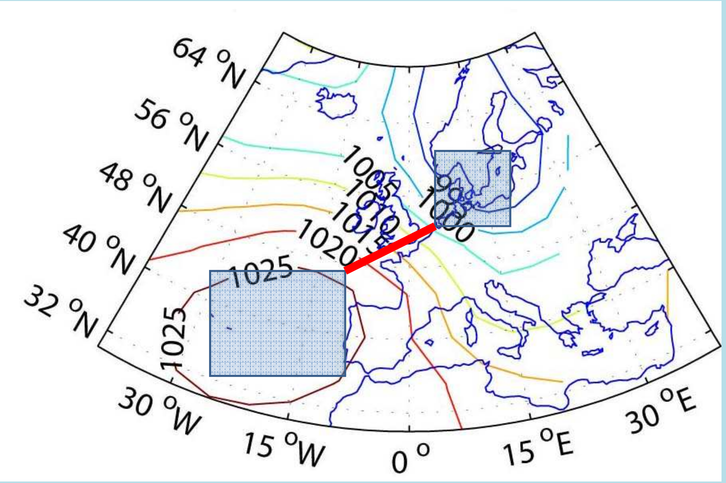

*Mean sea-level pressure field when « Atlantic Ridge » days are associated with surges (a) < 0 cm and (b) > 35 cm at Ostend*

# Linear regression  with two « atmospheric predictors » of daily surge height:

1. **Daily sea-level pressure over the Baltic Sea** ([30°-15°W], [35°-45°N])

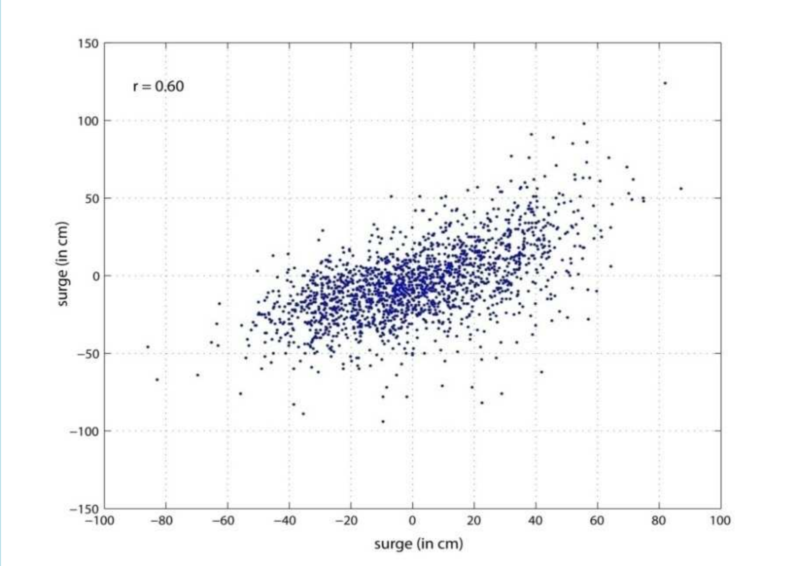



2. **Daily pressure gradient: Baltic Sea** ([15°-20°E], [52°-55°N]) **- Atlantic near Iberian Pen. and British Islands** ([30°-15°W], [35°-45°N])



# Cross-validation (period 1980-2000)

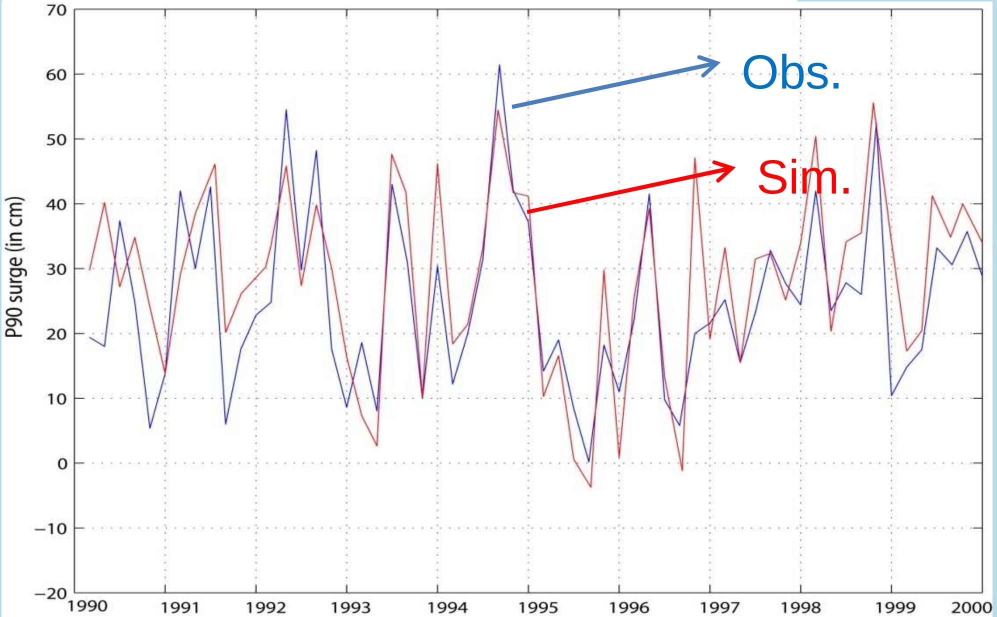
## 1. Learning on 1980-1990 and validation on 1990-2000




**Daily surge height:**

**r. (obs vs simu) = 0.60*****

*Scatter plot between daily surge height observed at Ostend and simulated by the linear regression on the period 1990-2000 (with coefficient learned on the period 1980-1990).*




**Monthly 90th percentile:**

**r (obs vs simu) = 0.81*****

**Std_obs = 14.2 cm**

**Std_simu = 15.9 cm**

**Rmse = 6.5 cm**

*Monthly 90th percentile of surge height observed at Ostend from 1990 to 2000 (in blue line) and as derived from the linear regression (in red line) with coefficient learned on the period 1980-1990.*

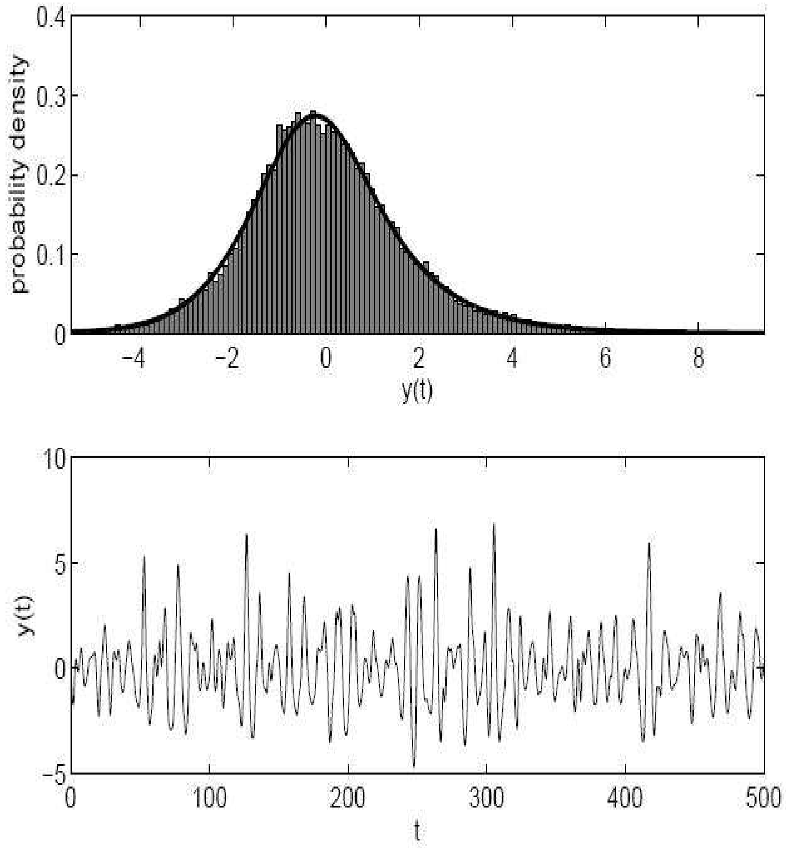
# 4. Nya modeller för geofysiska data

- Jörg Wegener, Mathematical statistics, Lund
- Thomas Galtier, Mathematical statistics, Chalmers

- Using the Laplace Motion we can define the Laplace Moving Average (LMA) :

$$X(t) = \int_{-\infty}^{+\infty} f(t-x)\,d\Delta(x)$$

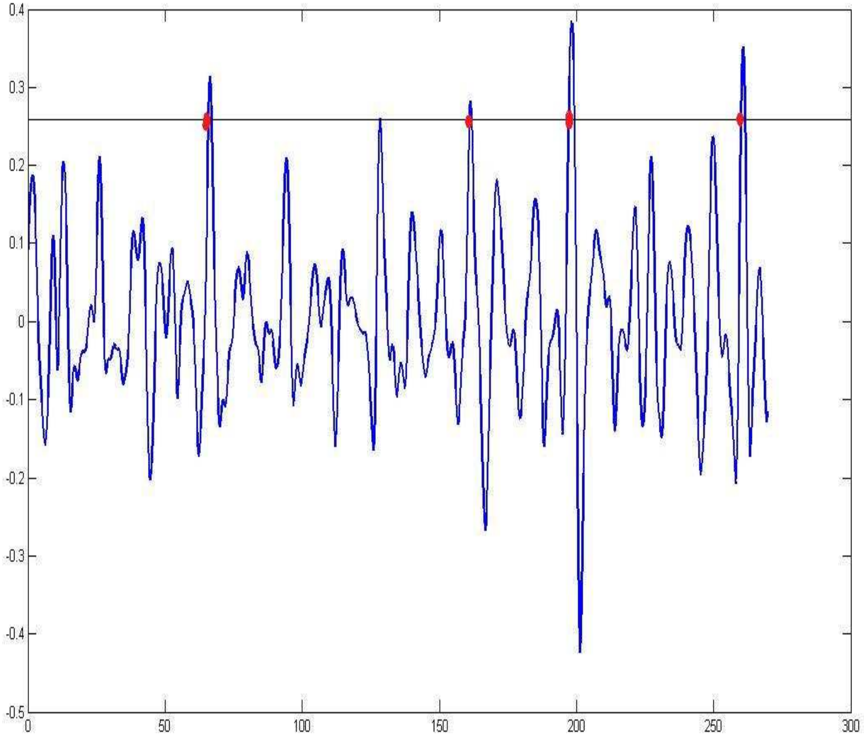
- The LMA can be seen as a convolution
- Time domain and frequency domain simulation possible



# Rice Formula

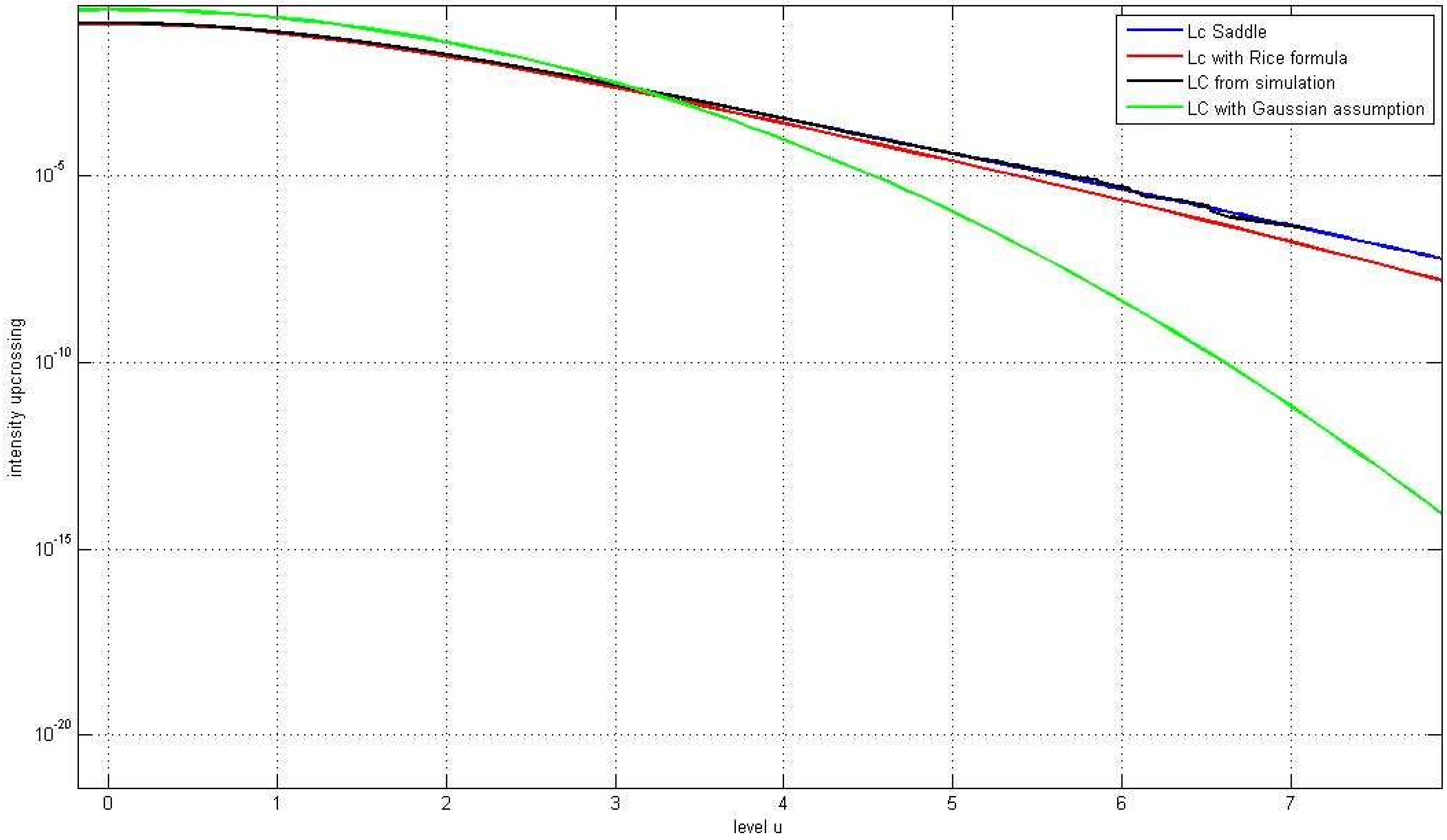
- Important for fatigue for example
- Compute the expected number of upcrossing for a level u
- Upcrossing Intensity :

$$\mu^+(u) = \int_0^{+\infty} z f_{\eta(0),\dot{\eta}(0)}(u,z)\,dz$$



## Results

# Upcrossing intensity for sea surace elevation



# Example: SLP in Stockholm

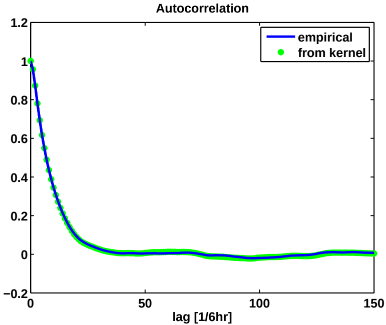



Figure: Correlation functions (left), PDFs (right).

# Example: Precipitation data

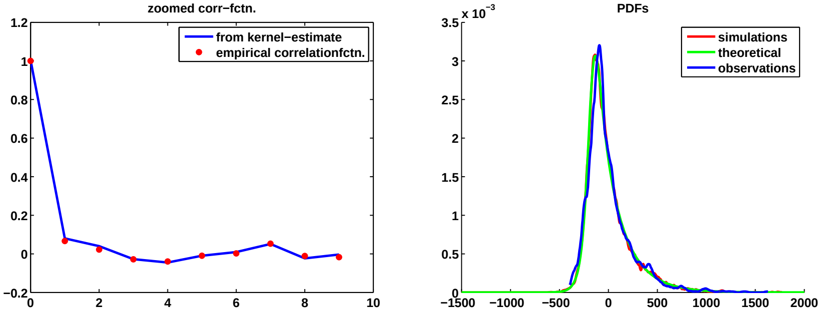



Figure: Correlation functions (left), PDFs of anomalies (right).