Hybrid Approach for the Assessment of Changes of Extreme Waves at the German Baltic Sea Coast on the Basis of Regional Climate Model Data

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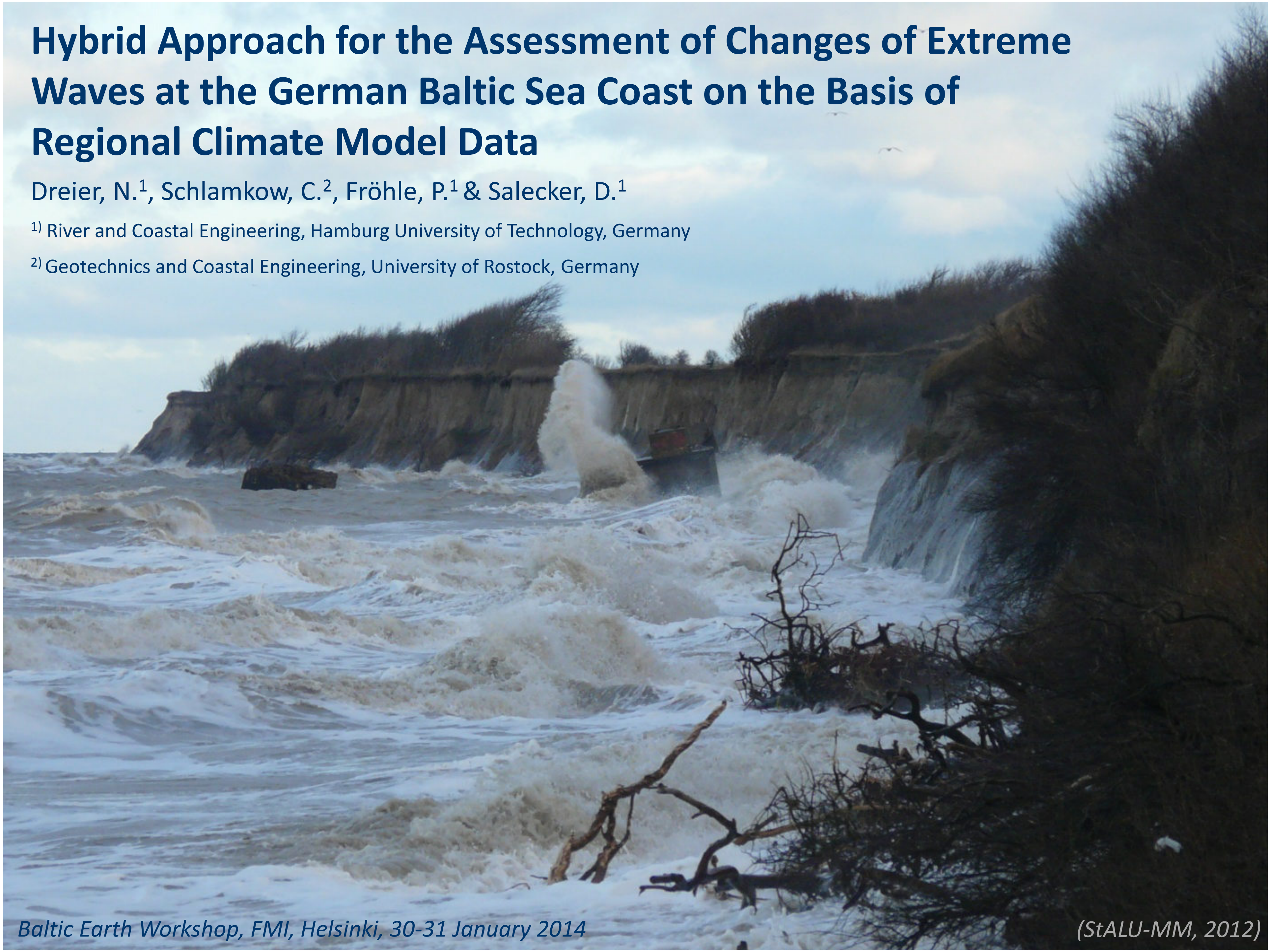
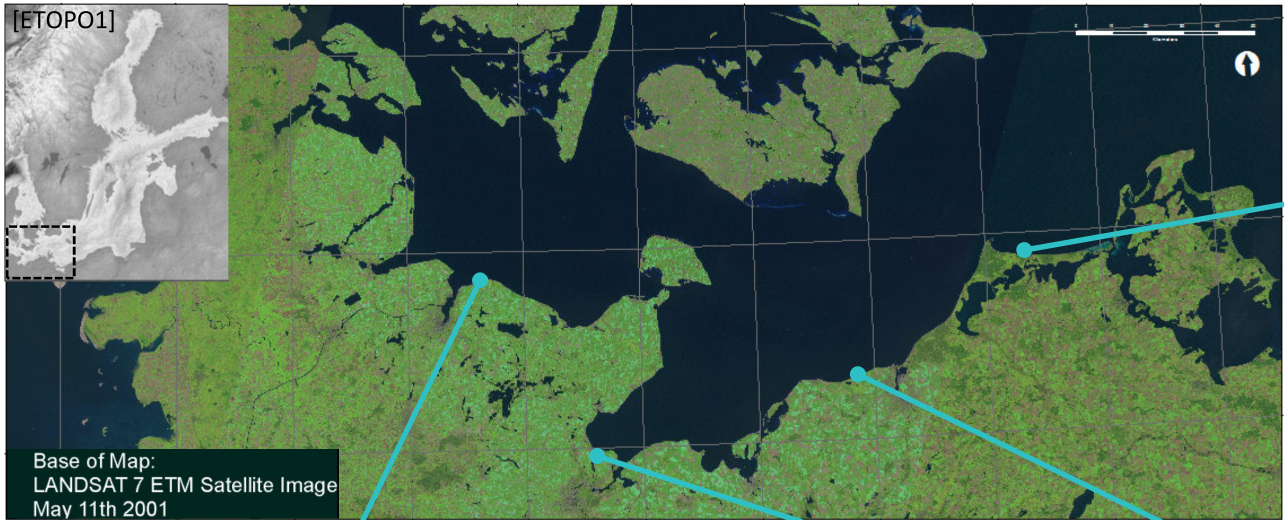


Baltic Earth Workshop, FMI, Helsinki, 30-31 January 2014

(StALU-MM, 2012)

Climate Adaptation Project (09-2014)

I. Effects of climate change → wave climate, sediment transport
II. Effectiveness and safety of structures
III. Strategies, methods and local adaptation measures



RA:dOst
Regional Adaptation Strategies for the German Baltic Sea Coast

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KLIMZUG
climate change in regions

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Constructional/Functional Design of Coastal and Flood Protection

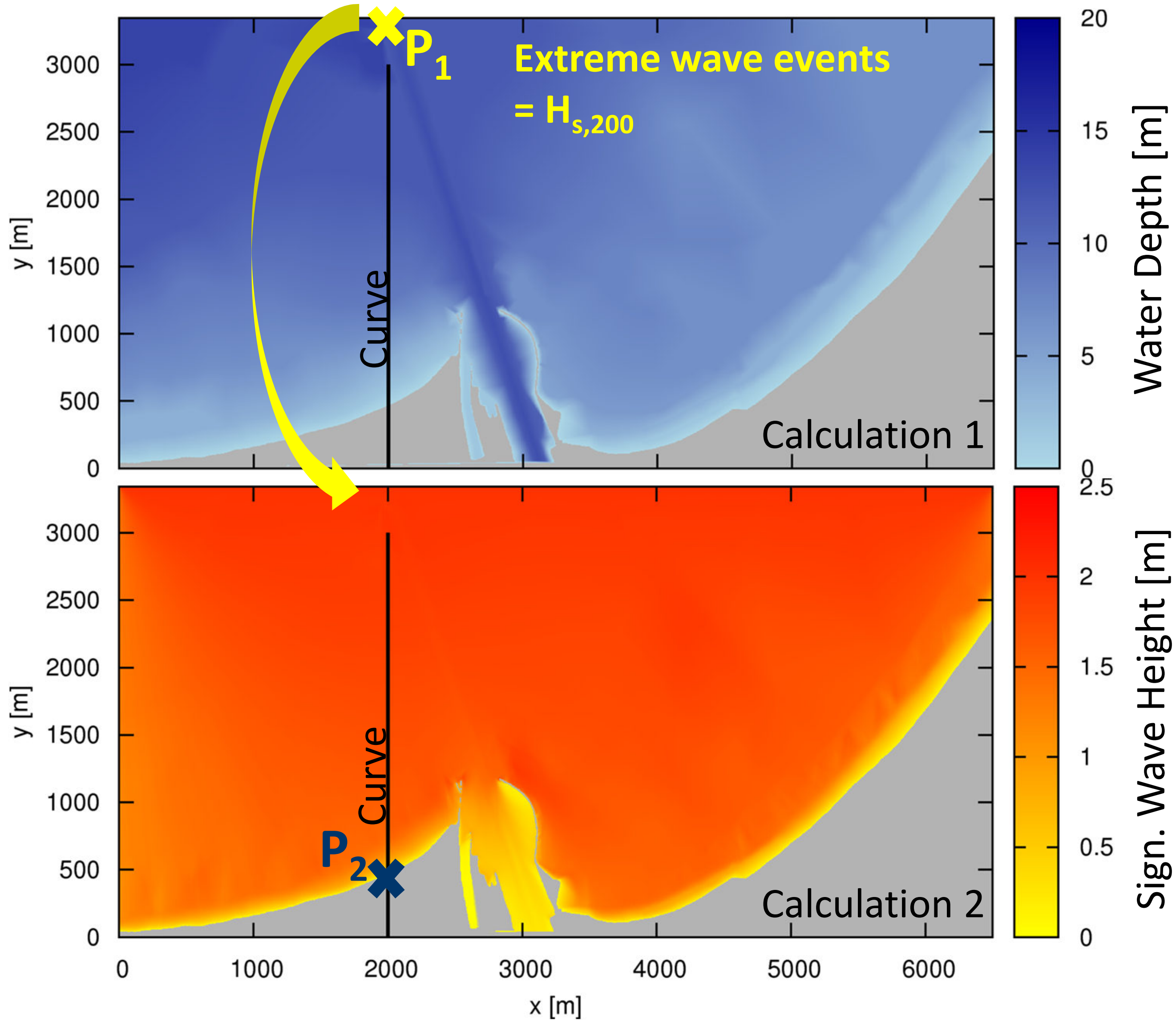

Fig.: Water depth (top) and sign. wave heights (bottom), Warnemünde Germany (University of Rostock)

	2009 Actual condit.	2100 Future condit.
$H_{s,200}$	3.66m	+ x ?
T_{m02}	6.23s	+ x ?
Θ_m	0°	+ x ?

Combination with sceanrios of future storm surge levels $HW_{200}+\Delta W(SLR)$

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Hybrid Approach

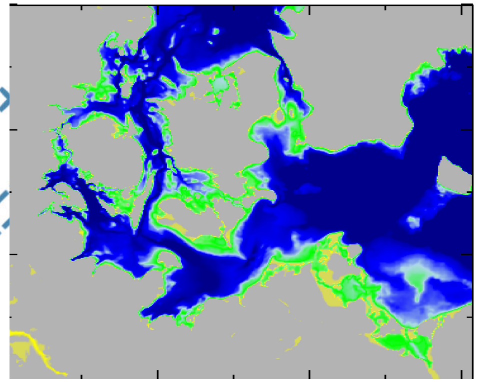
RCM: Cosmo-CLM*
4 Long-term time series of hourly near-surface wind velocity and direction (1960-2100) C20 + SRES scenarios A1B, B1 (2x)

*) [Rockel et al., 2008],
[Lautenschlager et al., 2009]
[Nakićenović et al., 2000]

(1)

Wind-wave-correlations = statistical correlations from measurements of waves and wind
[Fröhle & Fittschen 1999; Fröhle 2000]

Numerical simulations:
stationary runs of SWAN wave model
[Booij et al., 1999]



(2)

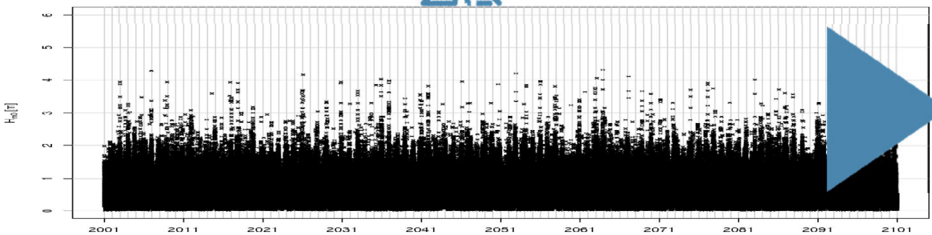
U_{cut}

Note: all calculations at MSL (deep water conditions)

appr. 97%

appr. 3%

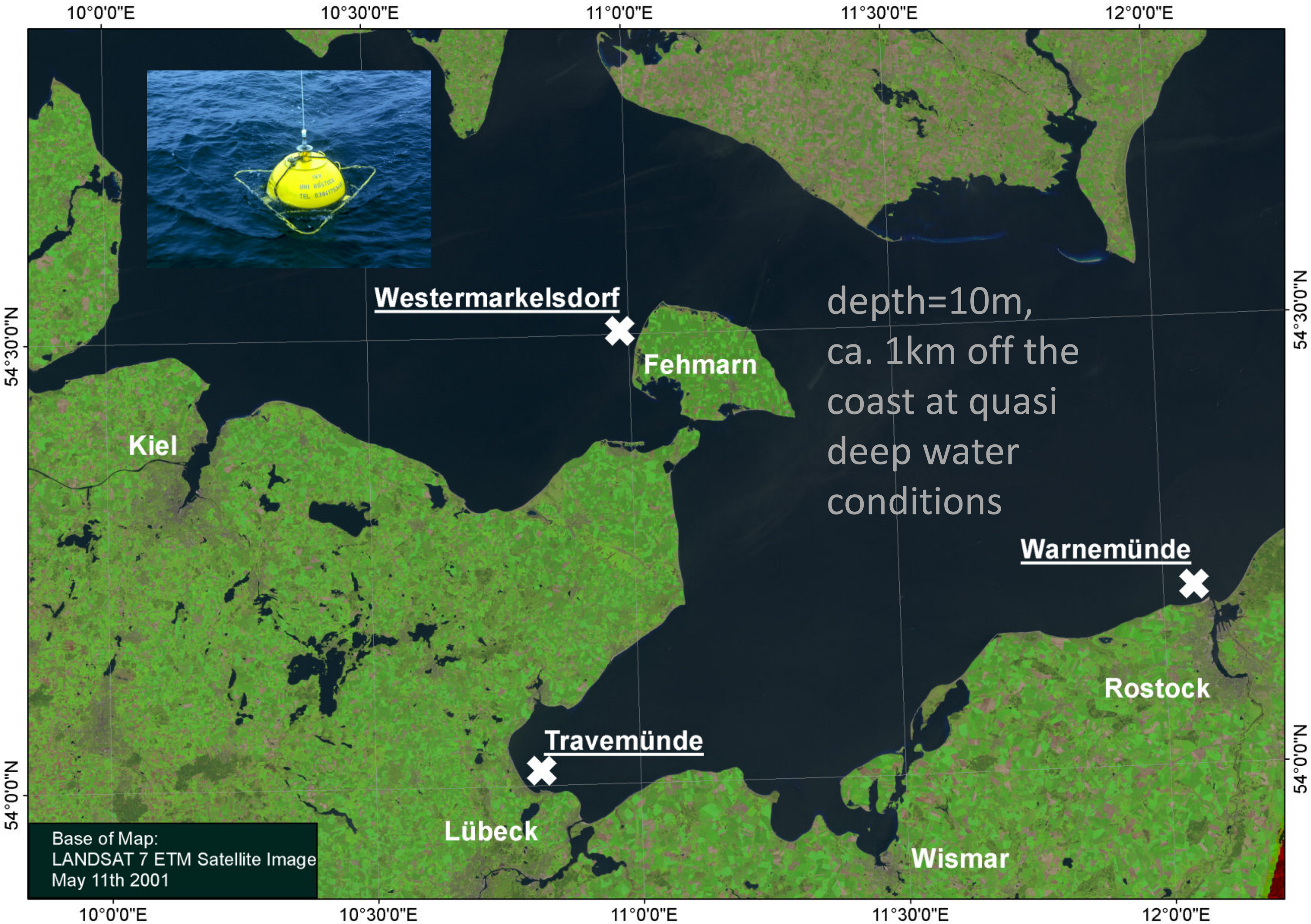
4 Long-term time series of hourly significant wave heights, mean wave periods and mean wave directions (1960-2100)



(3)

Statistical analyses:
changes of average wave conditions & extreme events

Short-Term Measurements of Wind and Wave Conditions



depth=10m, ca. 1km off the coast at quasi deep water conditions

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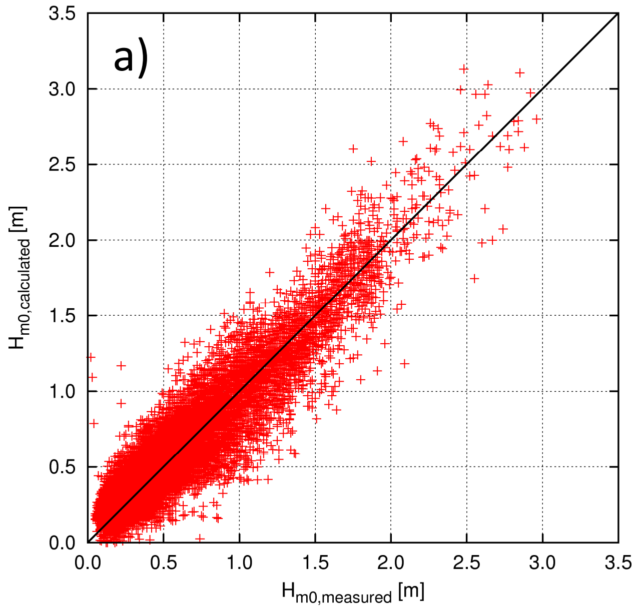
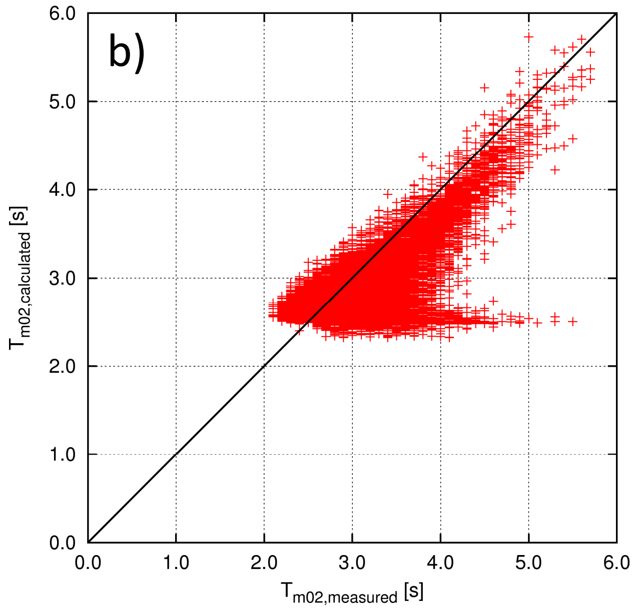
Comparison of Calculated and Observed Wave Parameters (WWC)

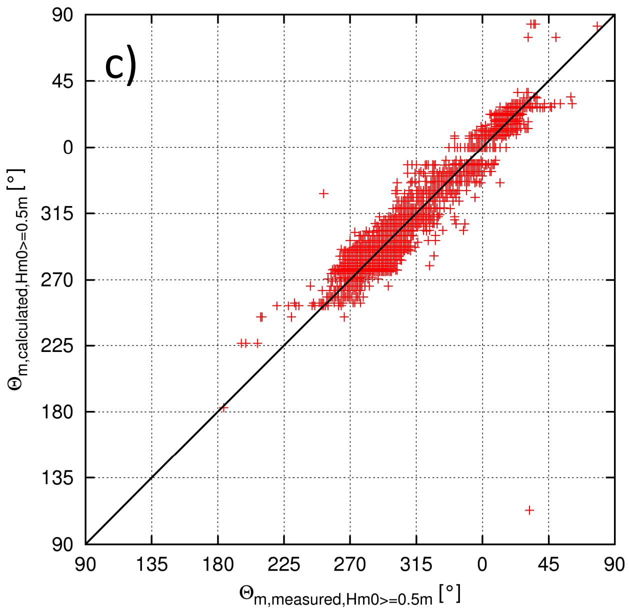
Significant Wave Height (Warnemünde)





Mean Wave Period (Warnemünde)

Mean Wave Direction Hs≥0.5m (Warnemünde)



Mean absolute deviations

	$\|\Delta H_{m0}\|$ [m]	$\|\Delta T_{m02}\|$ [s]	$\|\Delta \Theta_m\|$ [°]
Warnemünde	0.10473	0.44819	6.48415
Travemünde	0.08785	0.45050	7.44012
Wester-markelsdorf	0.07481	0.21654	7.01464

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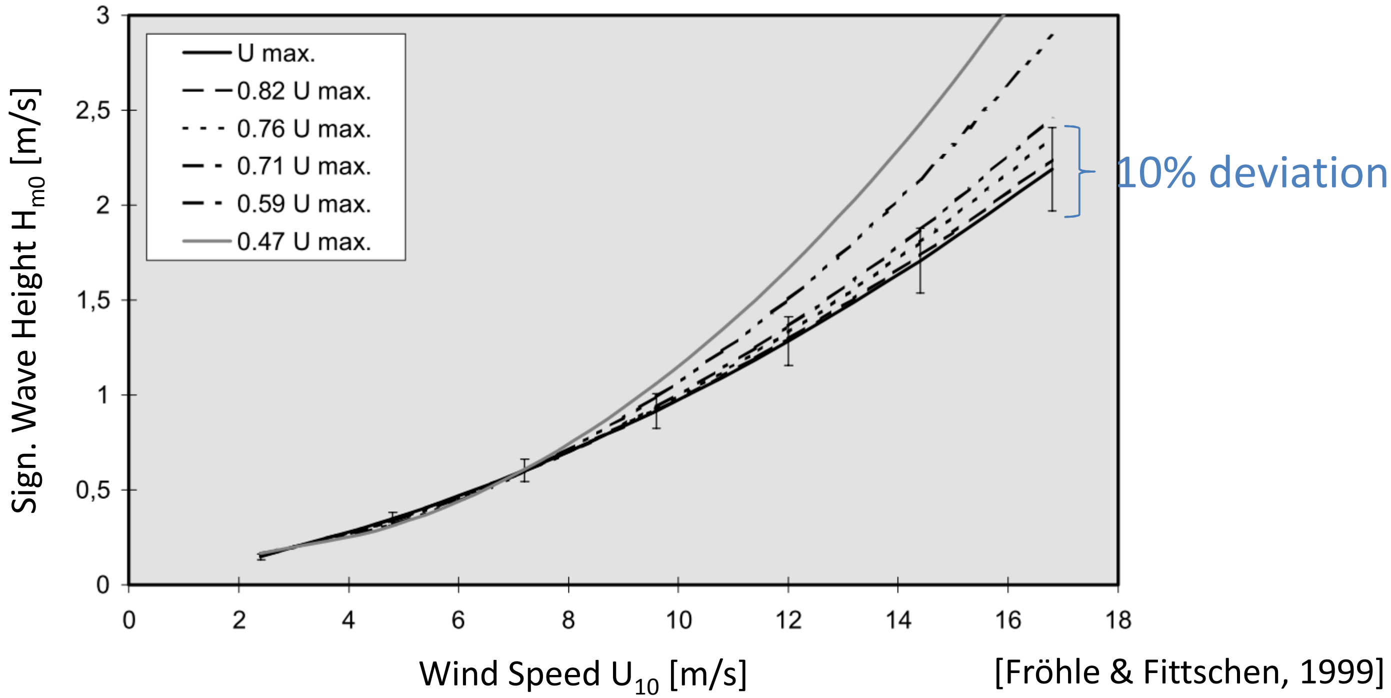
Limitation of Wind-Wave-Correlations



[Fröhle & Fittschen, 1999]

	Threshold of Wind Velocity $U_{threshold}$ [m/s]			
Area|Deviation	10%	7.5%	5%	2.5%
Schönhagen	0.75 U_{max}	0.81 U_{max}	0.86 U_{max}	0.93 U_{max}
Heiligenhafen	0.76 U_{max}	0.81 U_{max}	0.86 U_{max}	0.95 U_{max}
Brodten	0.76 U_{max}	0.81 U_{max}	0.91 U_{max}	0.97 U_{max}

$$U_{cut,0.05} \leq 1/(0.86 * U_{max}) = 1.16 * U_{max}$$

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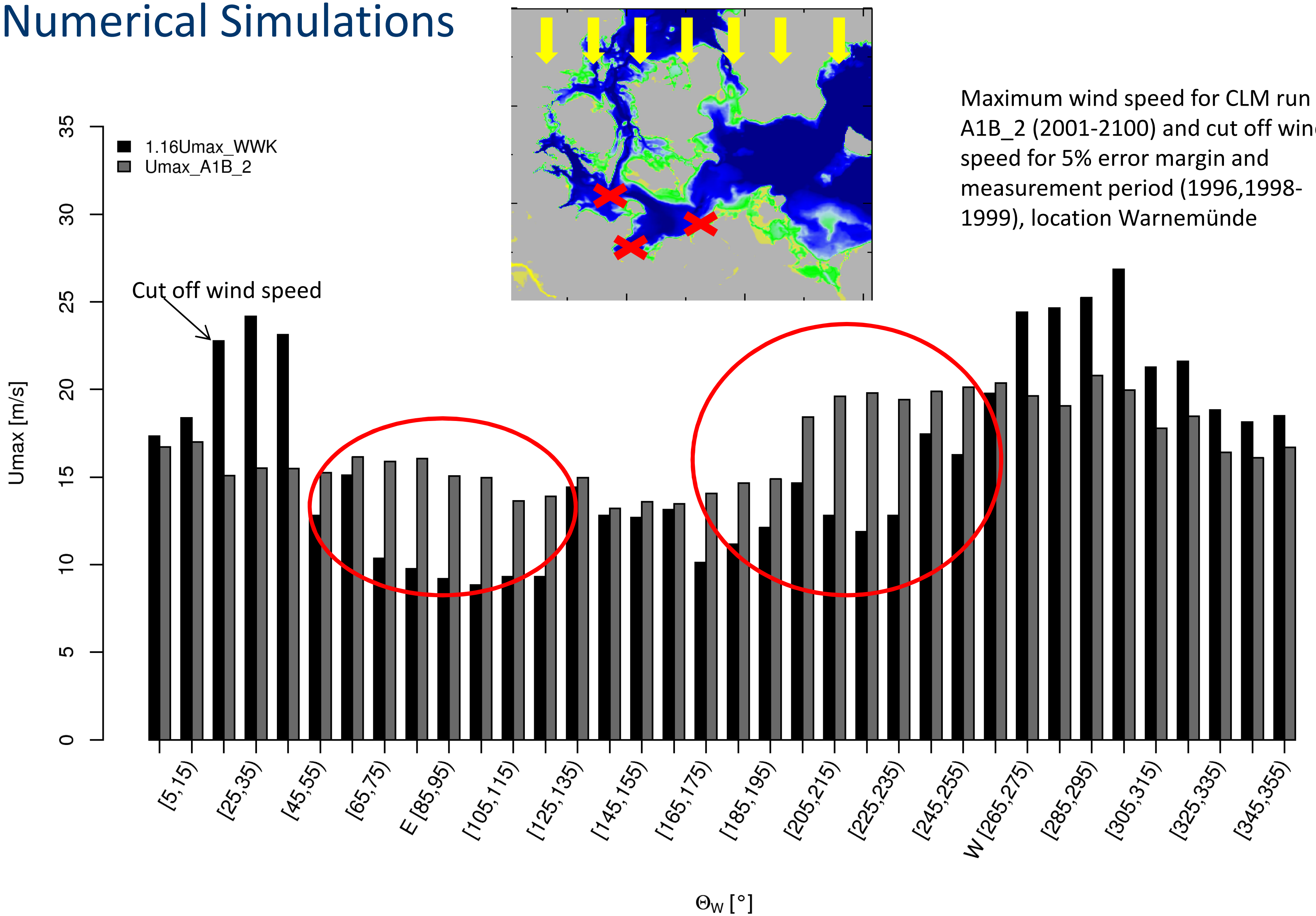
Numerical Simulations

Maximum wind speed for CLM run A1B_2 (2001-2100) and cut off wind speed for 5% error margin and measurement period (1996,1998-1999), location Warnemünde



stationary mode and constant wind field over the area

resolution of wind boundary: ΔU_{10}=1m/s, $\Delta \Theta_w$=10°

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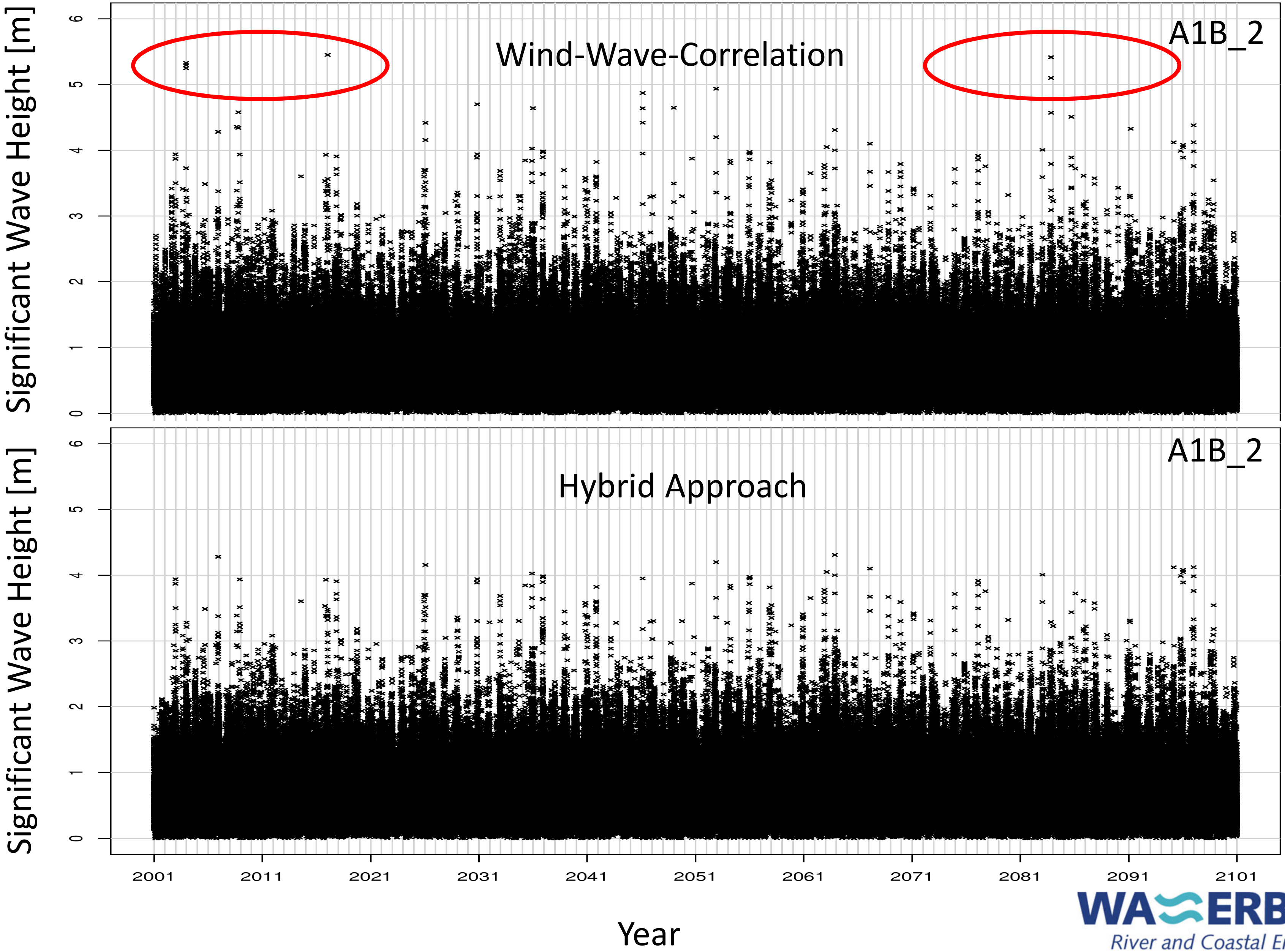
Comparison of Calculated Long-Term Time Series of Wave Heights



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Statistical Analyses of Changes of Extreme Wave Heights

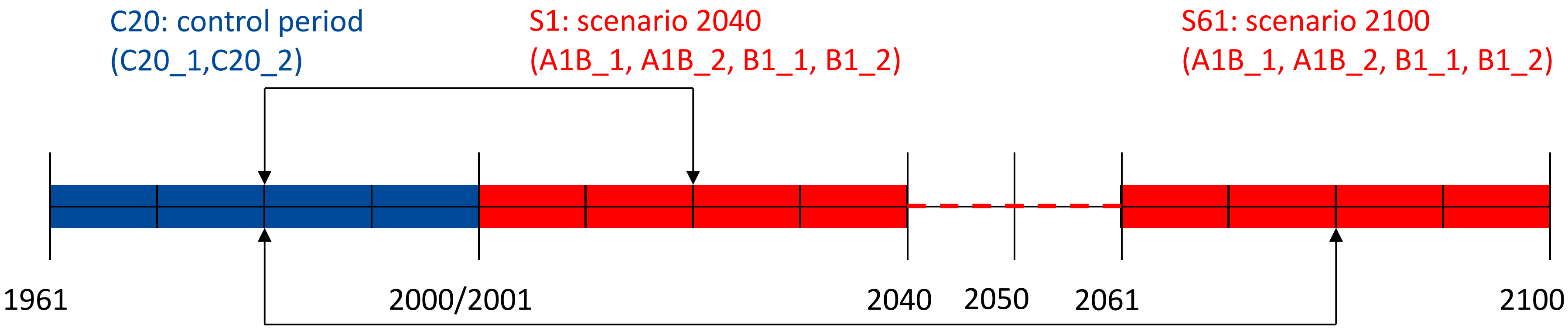
(1) Sample Selection: **annual maximum values** , time periods of 40 years, 4 long-term time series of wave heights

(2) Fitting: Extreme Value Distributions (EVDs) **Gumbel, Weibull, Log-Normal and GEV** using MLE (Maximum Likelihood Estimate)

(3) Goodness of fit-tests (comparison of empirical & theoretical CDF)

→ Log-Normal = best

(4) Relative change of significant wave heights (return-level 200years)



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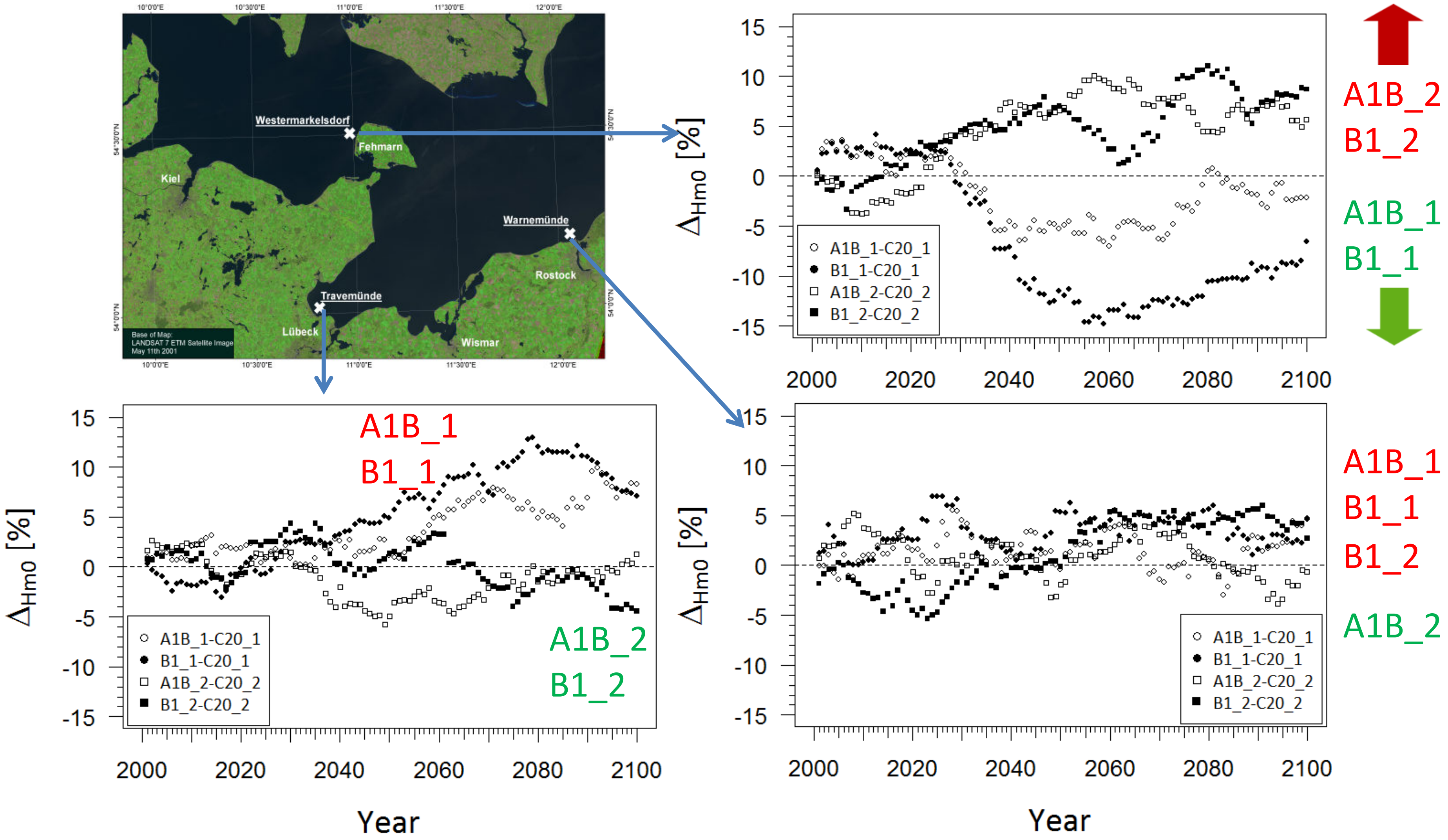
Results: Change of Significant Wave Height (40yr, Log-Normal, RL=200)



3 different signals of change depending on the location and scenario run!

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Comparison With Results from Other Studies

Changes of the wave climate for the whole Baltic Sea from Groll, Hünicke and Weisse (HZG, 2013)

→ WAM* (5.5km, 1hr) 1960-2100, Cosmo-CLM: C20, A1B, B1 (2x) *)[Hasselmann et al., 1988]

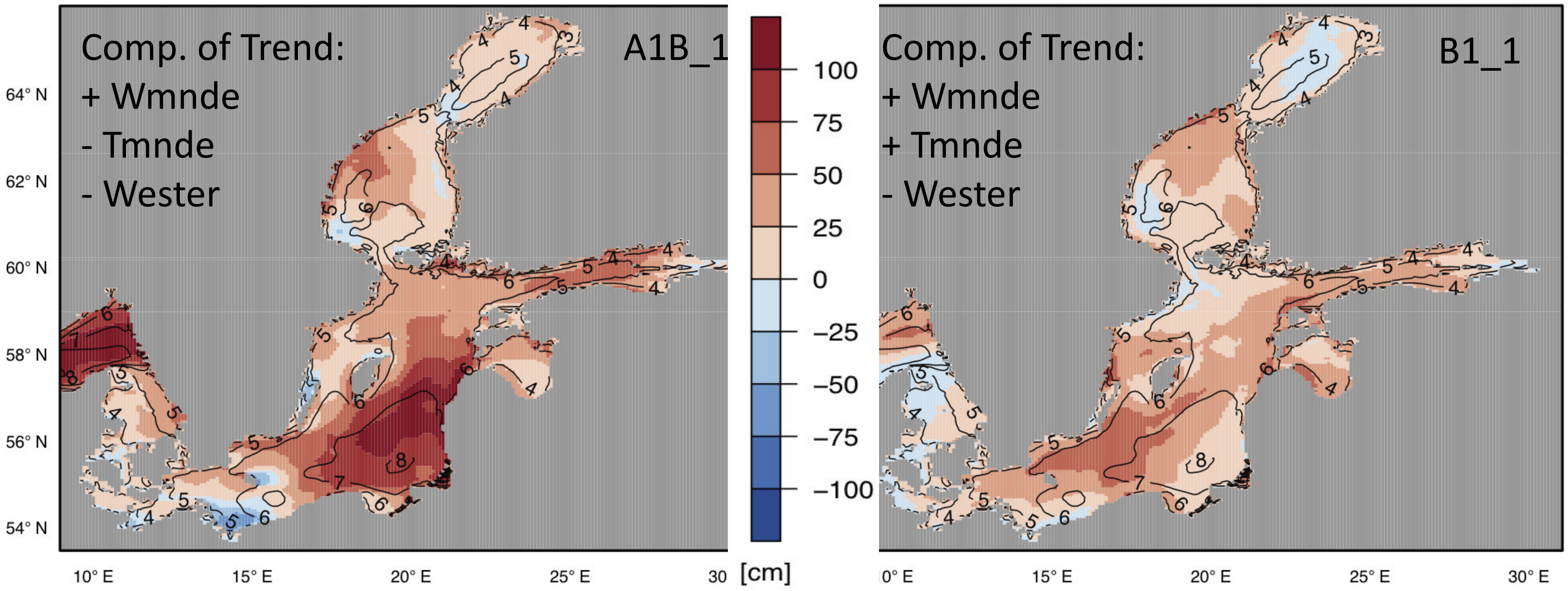

Fig. Changes of annual maxima of significant wave height 2071-2100 vs. 1961-1990 for 1st realisation of A1B and B1 [Groll, Hünicke and Weisse, 2013]

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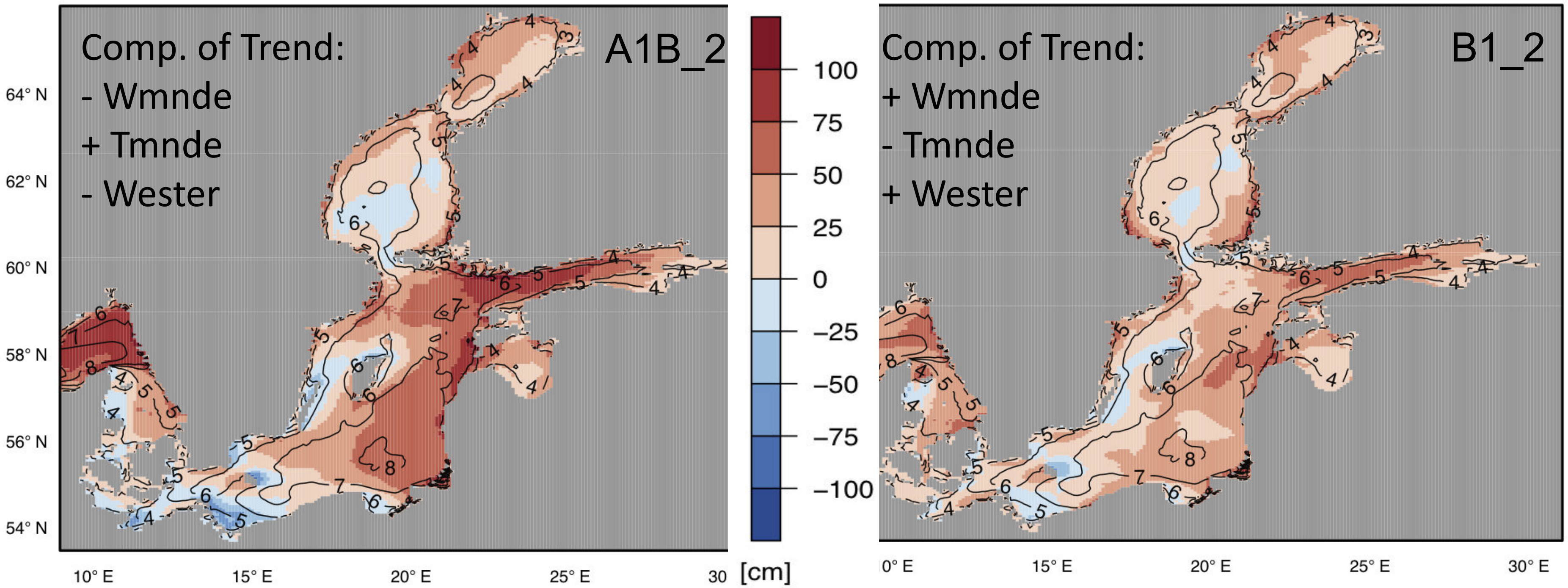
Comparison With Results from Other Studies

Fig. Changes of annual maxima of significant wave height 2071-2100 vs. 1961-1990 for 2nd realisation of A1B and B1 [Groll, Hühnicke and Weisse, 2013]



No comparison of trend possible: different parameter of the wave climate (Hmax), reference period (1961-1990) and offshore wave conditions!

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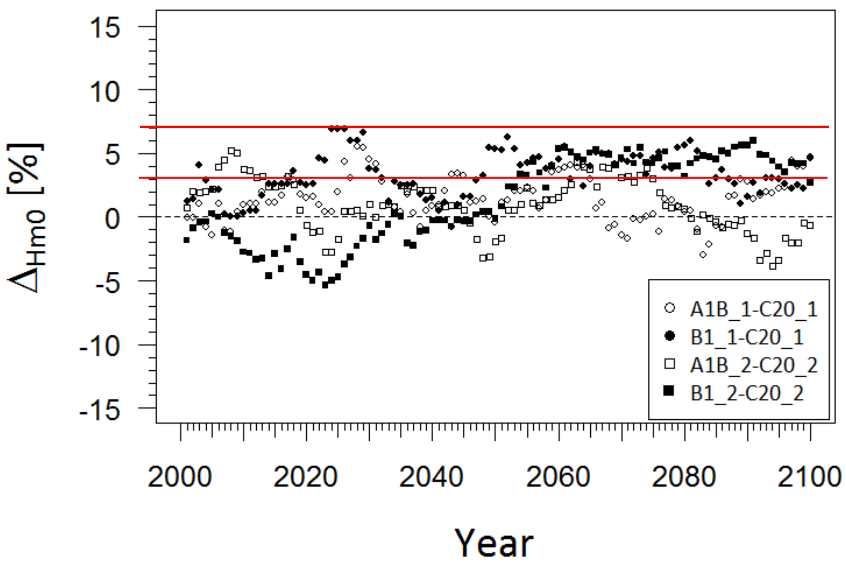
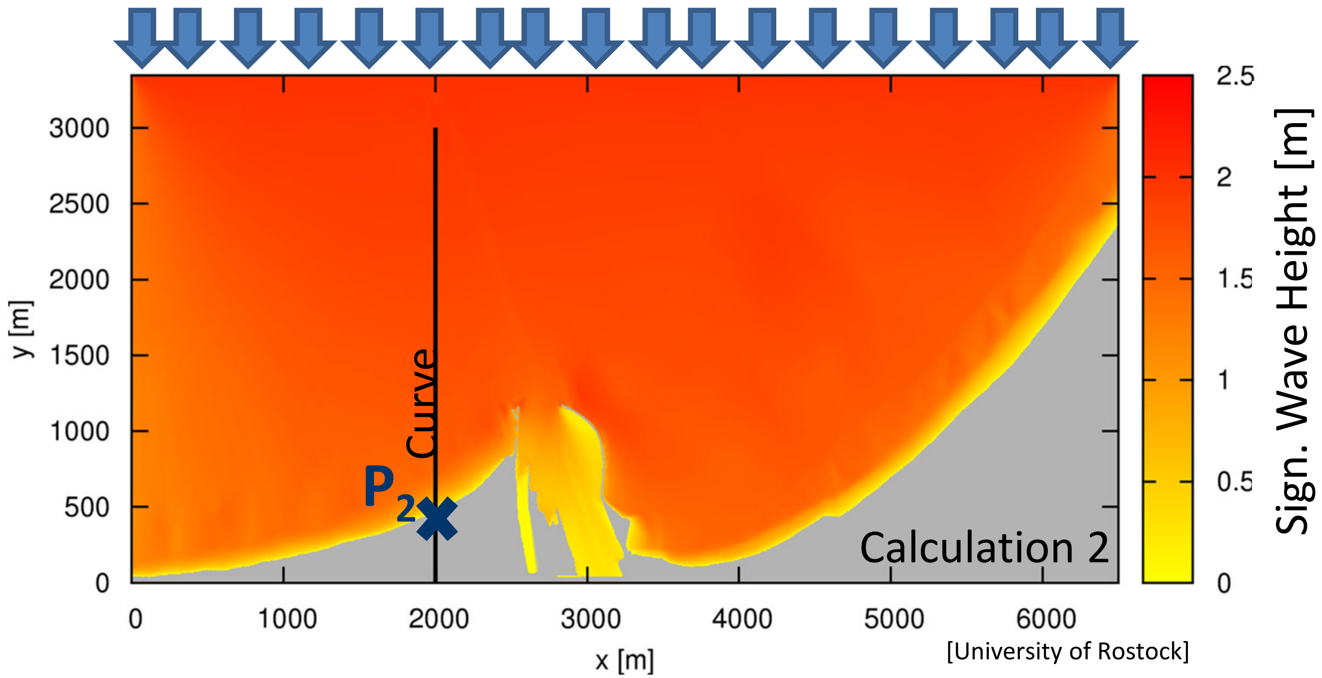


Scenario	Water Levels	Wave Conditions
„Moderate“	+ 30 cm	No Significant Changes
„Average“	+ 60 cm	$H_{s,200}$ + 3 %= 3.77m; T_{m02}= 6.32s; Dir=0°
„High“	+ 90 cm	$H_{s,200}$ + 7 %= 3.92m; T_{m02}= 6.44s; Dir=0°



[University of Rostock]

2009:
$H_{s,200}$=3.66m
T_{m02}=6.23s
Dir=0°

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Summary and Outlook

Results:

- Four long-term time series (1960-2100) of wave parameters for different locations and climate change scenarios A1Bx2, B1x2 (RCM Cosmo-CLM) at the German Baltic Sea Coast
- Different signal of change/trend depending on location and scenario run
- Changes of sign. wave height up to +14% → different loads on coastal structures

Pros and Cons:

\+ Fast in comparison with instationary numerical simulations 1960-2100
\+ Timeseries are applicable for EVA
\- Wind and wave measurements
\- Uncertainty of stationary numerical simulation

Next Steps:

EVA of time series from instationary numerical simulations for the Western Baltic Sea → SWAN* (1km, 1hr) 1960-2100, Cosmo-CLM: C20, A1B, B1 (2x)

*) [Booij et al., 1999]

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Questions/Remarks?

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