Regional Climate Models Add Value to Global Model Data

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Climate = statistics of weather
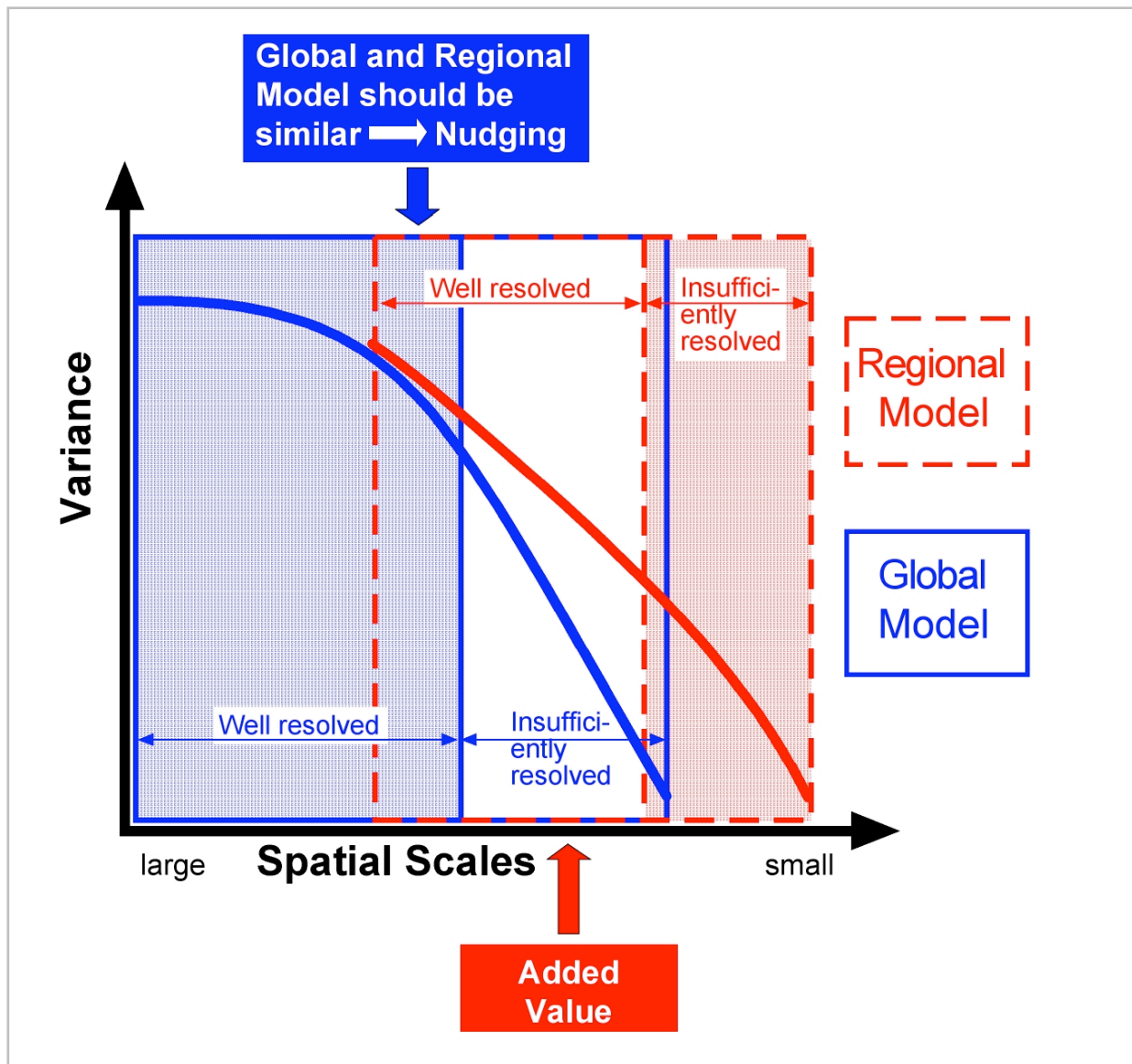
The genesis of climate

$$C_s = f(C_l, \Phi_s) \qquad \Leftarrow \text{ "downscaling"}$$

with

C_l = larger scale climate

C_s = smaller scale climate

Φ_s = physiographic detail at smaller scale

Model variance as a function of spatial scales. The rectangles show well and insufficiently resolved spatial scales of the global and regional model.

Added value in reconstructions using spectral nudging

Improved representation of

- variability at medium scales.

- effect of physiographic detail *(coasts)*

- of sub-synoptic phenomena *(polar lows, medicanes)*

- forcing fields for impact models *(ocean waves, storm surges)*

Improved presentation of variability at medium scales

- NCEP-driven multidecadal simulation with RCM REMO
- Employing spectral nudging (wind above 850 hPa, for scales > 800 km)
- Usage of German Weather Service (DWD) regional analysis for a few years as reference to determine skill
- Considering ratios $\sigma^2_{DWD}:\sigma^2_{NCEP}$ and $\sigma^2_{DWD}:\sigma^2_{RCM}$
- Determining mean spatial correlation patterns between DWD, NCEP and RCM representations, ´for different spatial scales.

Ratio of standard deviations of 2m temperature
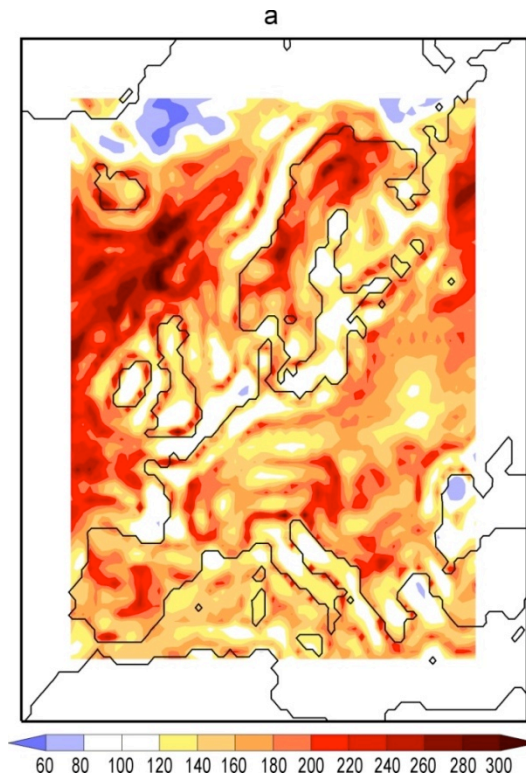
DWD-analysis/
NCEP reanalysis
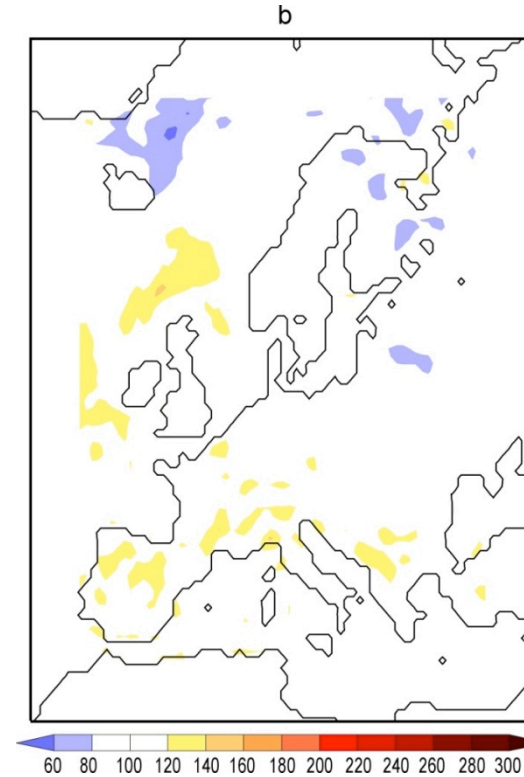
DWD-analysis /
regional simulation

DJF 1992 – 1999, at the regional scale, %

Feser, MWR 2006

Pattern correlation coefficients [PCC, %]

PCC DWD and NCEP

Anomaly fields

PCC improvement/ deterioration

REMO Nudge

var	season	field	$P_{DWD}(NCEP)$	$\Delta_{sn,NCEP}$	$\Delta_{nn,NCEP}$
SLP	DJF	unfiltered	99.1	-0.9 *	-2.9*
		low pass	99.3	-1.3*	-4.2*
		medium pass	89.6	**1.0***	-2.0*
SLP	JJA	unfiltered	98.3	-1.9*	-8.9*
		low pass	98.6	-2.7*	-12.9*
		medium pass	84.9	**2.6***	-3.0*
T	DJF	unfiltered	70.7	**9.8***	**6.2***
		low pass	79.2	**5.5***	-0.5*
		medium pass	27.0	**21.5***	**15.5***
T	JJA	unfiltered	70.2	**13.2***	**7.8***
		low pass	80.2	**6.3***	-2.5*
		medium pass	36.0	**30.4***	**24.3***

PCC improvement/ deterioration

REMO Standard

Positive values show added value provided by the regional model.

95% significant deviations are marked by a *.

Feser, MWR 2006

Improved presentation of effect of physiographic detail

- NCEP-driven multidecadal simulation with RCM REMO
- Employing spectral nudging (wind above 850 hPa, for scales > 800 km)
- Usage of Quikscat-windfields (Q) over sea.
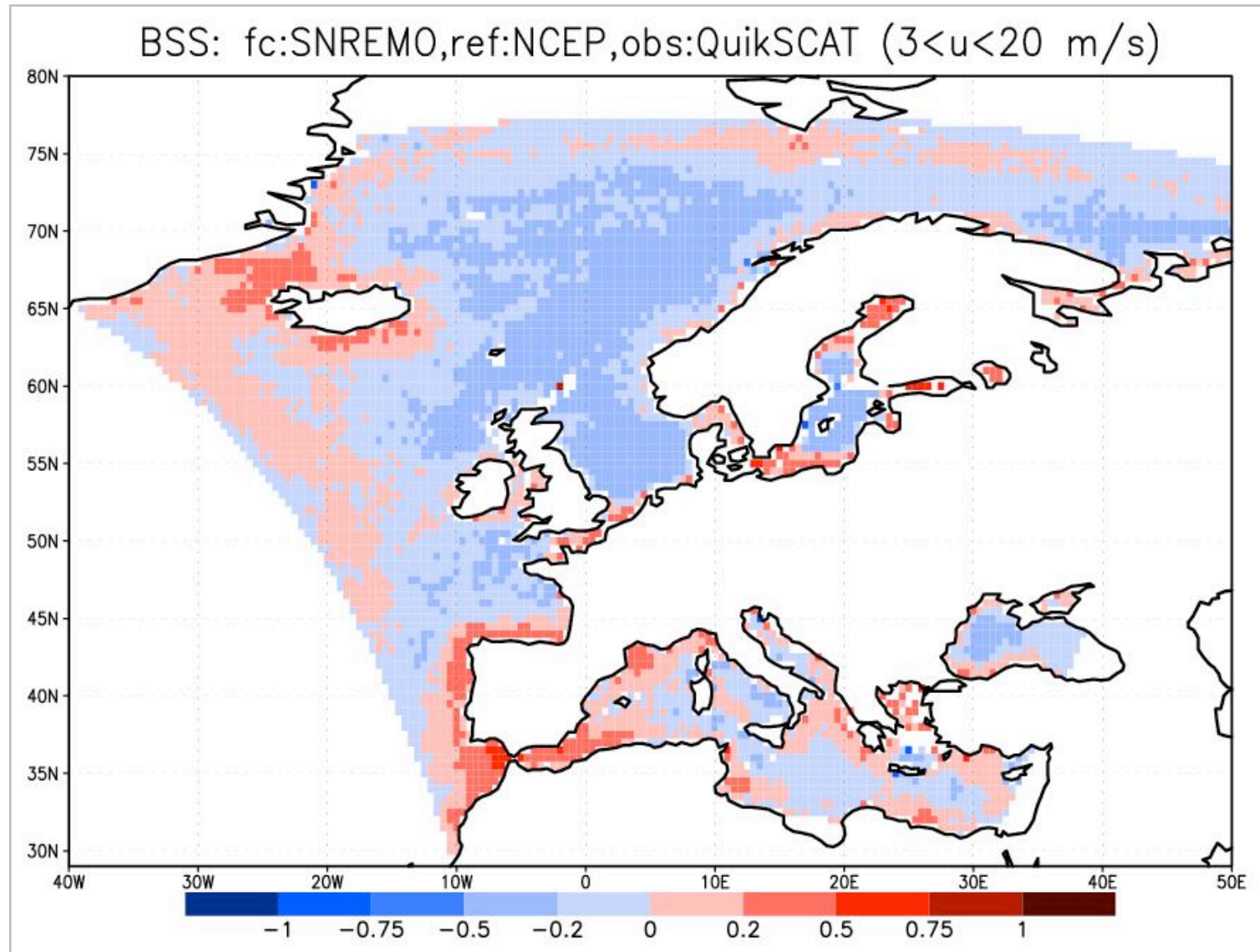- Determining Brier Skill score

$$B = 1 - (RCM\text{-}Q)^2 / (NCEP\text{-}Q)^2$$

for all marine grid boxes

QuikSCAT: Added Value - BSS

Open Ocean:
No value added
by dynamical
downscaling

Coastal region:
Added Value
in complex
coastal areas

BSS: fc:SNREMO,ref:NCEP,obs:QuikSCAT (3<u<20 m/s)

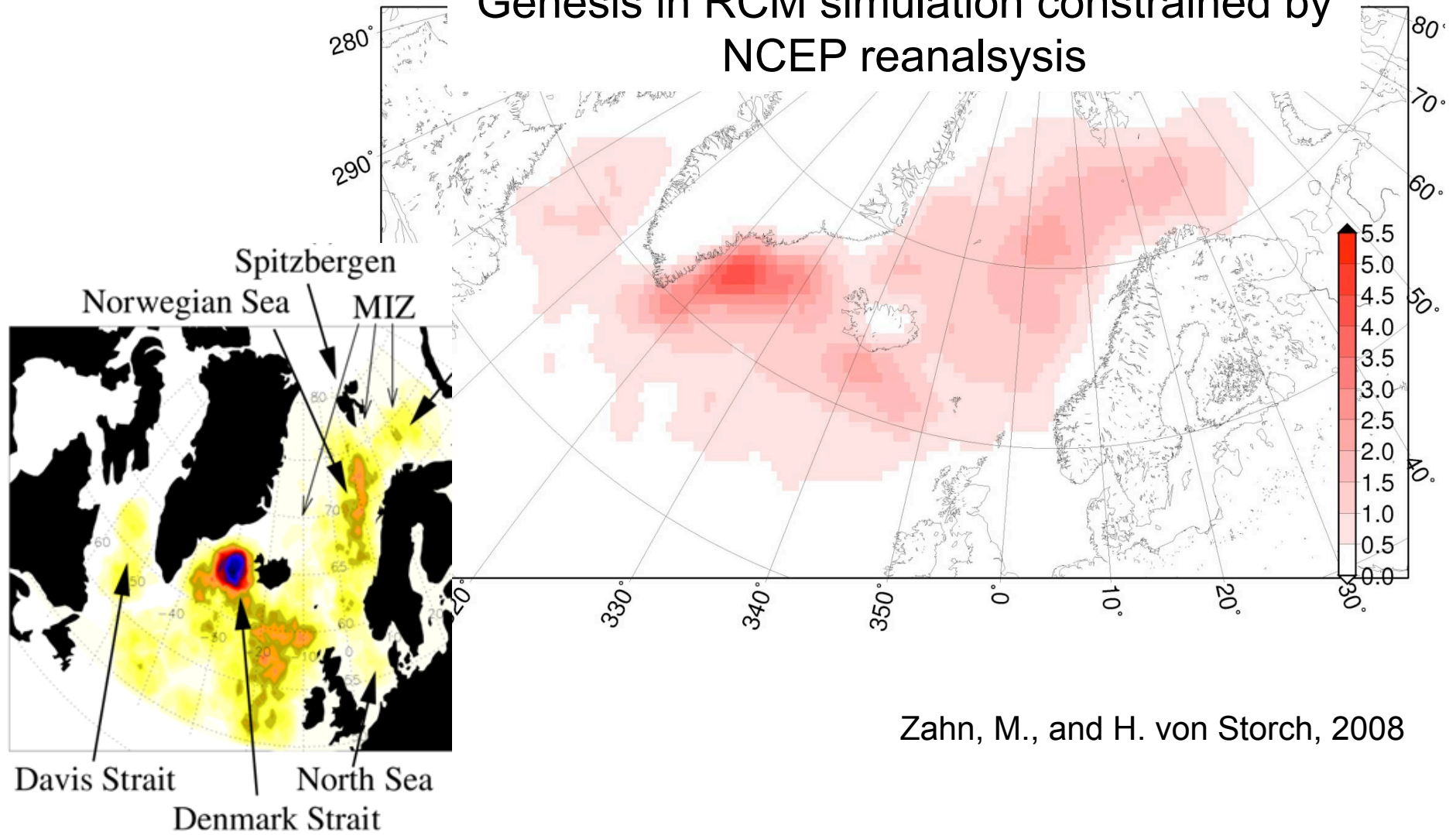Winterfeldt and Weisse, MWR 2009

Improved representation of sub-synoptic phenomena

- NCEP-driven multidecadal simulation with RCM CLM
- Employing spectral nudging (wind above 850 hPa, for scales > 800 km)
- Simulation of sub-synoptic phenomena
- Polar lows in the Northern North Atlantic
- Polar lows in the North Pacific
- Medicanes in the Mediterranean Sea
- Typhoons in the West Pacific (not shown)

Density of polar low genesis
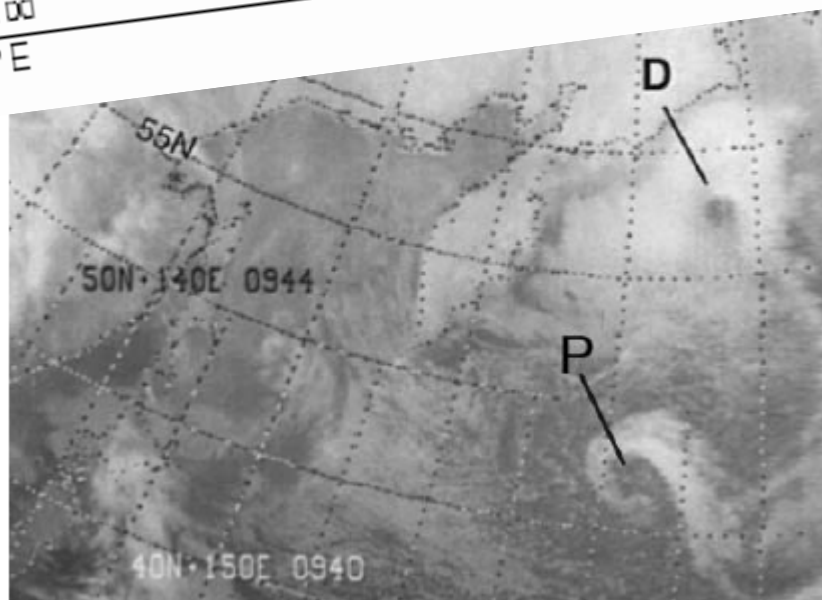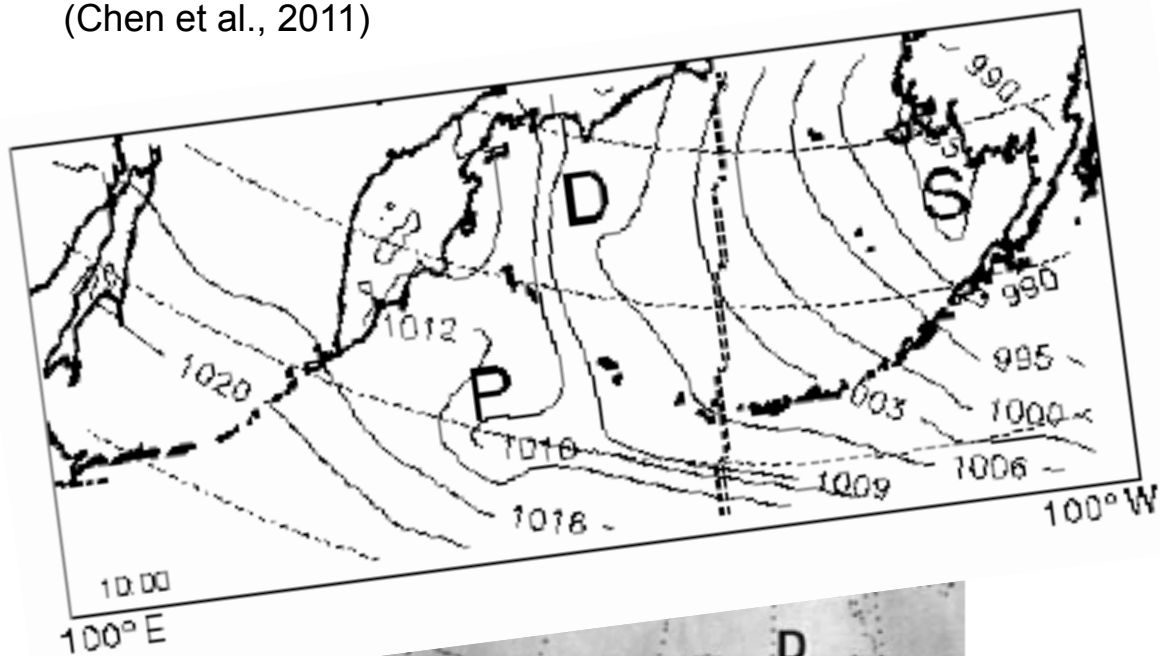
Genesis in RCM simulation constrained by NCEP reanalsysis

Zahn, M., and H. von Storch, 2008

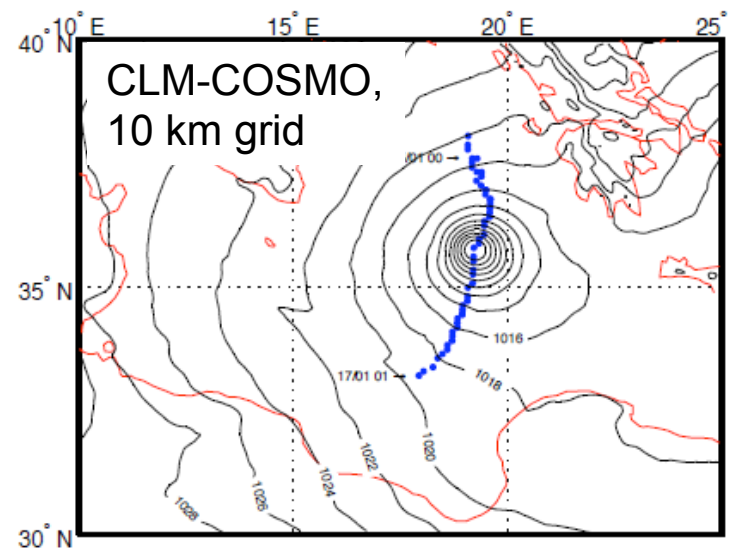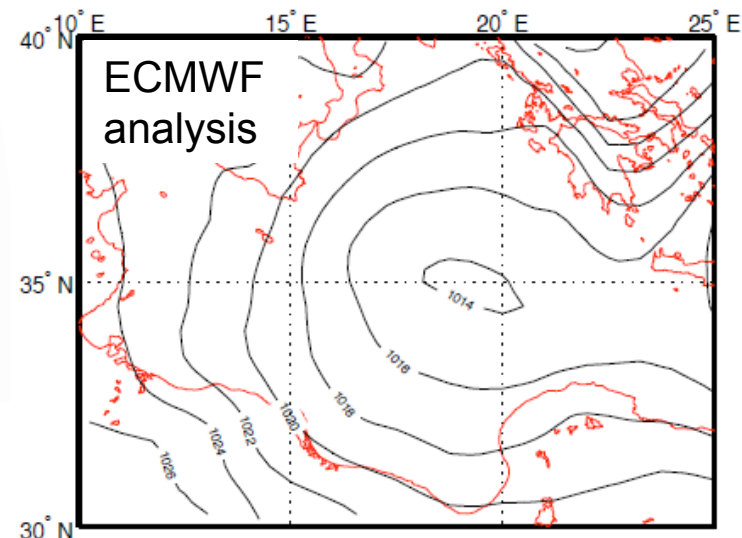Bracegirdle, T. J. and S. L. Gray, 2008

North Pacific Polar Low on 7 March 1977

(Chen et al., 2011)

Medicane of January 16, 1995

*NOAA-5 infrared satellite image at 09:58UTC 7th March 1977*

Cavicchia and von Storch, 2011

Improved representation of forcing fields for impact models

- NCEP-driven multidecadal simulation with RCM REMO
- Employing spectral nudging (wind above 850 hPa, for scales > 800 km)
- 1948-2010 simulation
- Wind and air pressure used to drive models of sea level and circulation of marginal seas (not shown) for describing currents and sea level (North Sea "CoastDat"; not shown)
- Wind used to drive models of the statistics of surface waves (ocean waves) in coastal seas (North Sea).

Wave Parameters at Helgoland

significant wave height
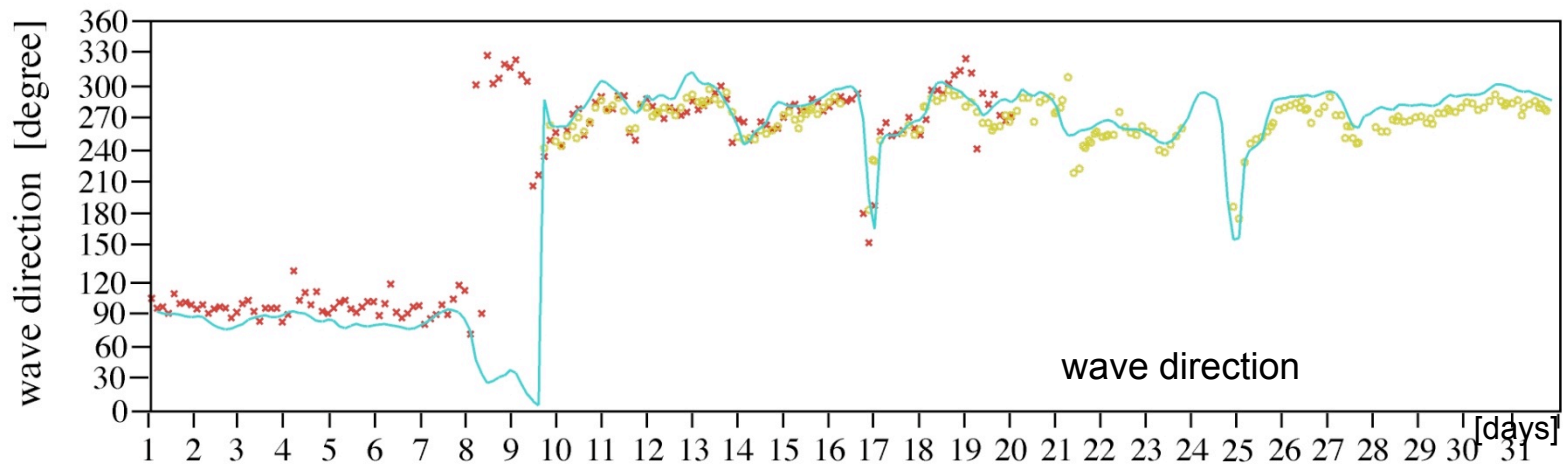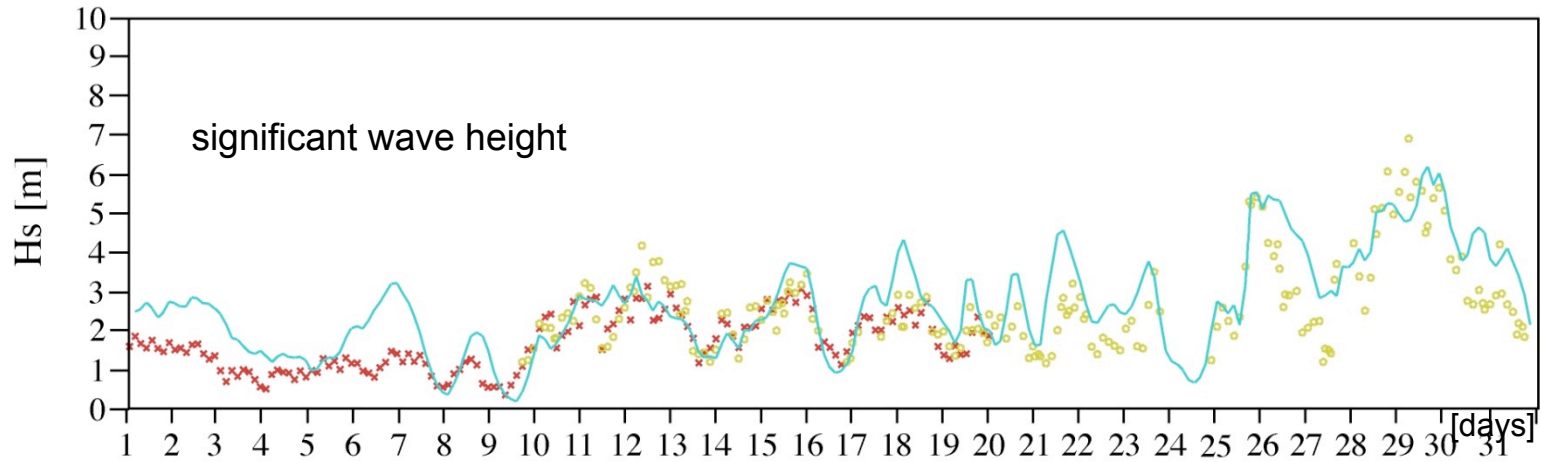
wave direction

October 1998

directions coming from and related to true north

Red: buoy, yellow: radar, blue: wave model run with REMO winds

Gerd Gayer, pers. comm., 2001

Added value …

- … in medium scales. Medium scales are determined by both the large scale dynamics and the regional physiographic details ($C_s = f(C_l, \Phi_s)$)

- More added value with large-scale constraint (spectral nudging)

- Little improvement over driving large-scale fields for SLP, which is a large-scale variable, but significant improvement for structured fields like 2 m temp or coastal wind.

- Dynamical downscaling works … - Large scales are hardly affected but smaller scales respond to regional physiographic detail.

- Present analysis refers to reconstructions, where we can compare the results with a "truth". For scenario simulations other approaches are needed (e.g., big brother-type)