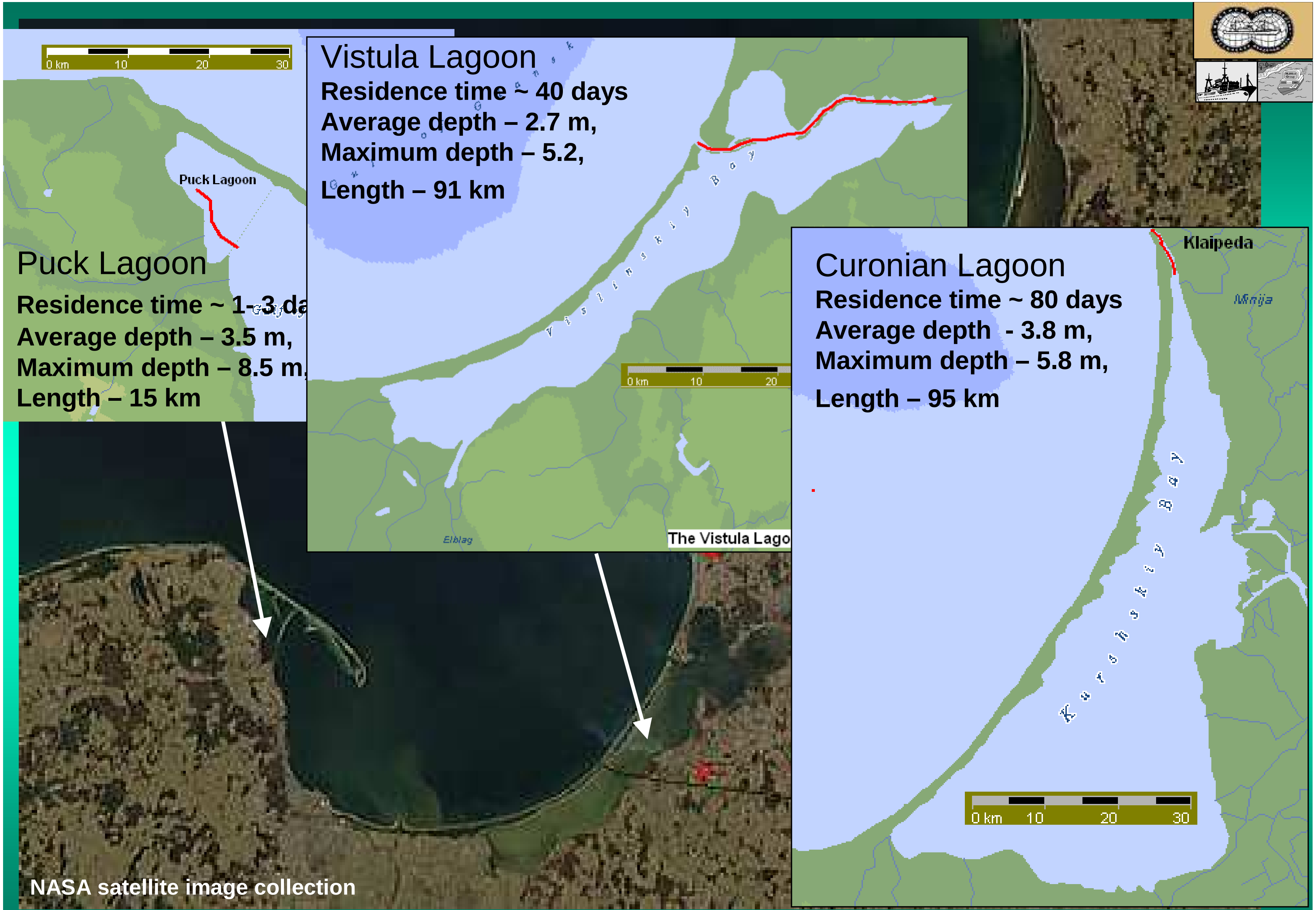
Laboratory for Coastal Systems Study
Atlantic Branch of P.P.Shirshov Institute of Oceanology,
Russian Academy of Sciences

Preliminary assessment of climate change related variations in hydrological forcing factors for South-East Baltic (literature overview)

Boris Chubarenko

Scopes

- South-East Baltic
- Some examples of existed changes of the climate characteristics
- Future possible climate changes and consequences
- Conclusions



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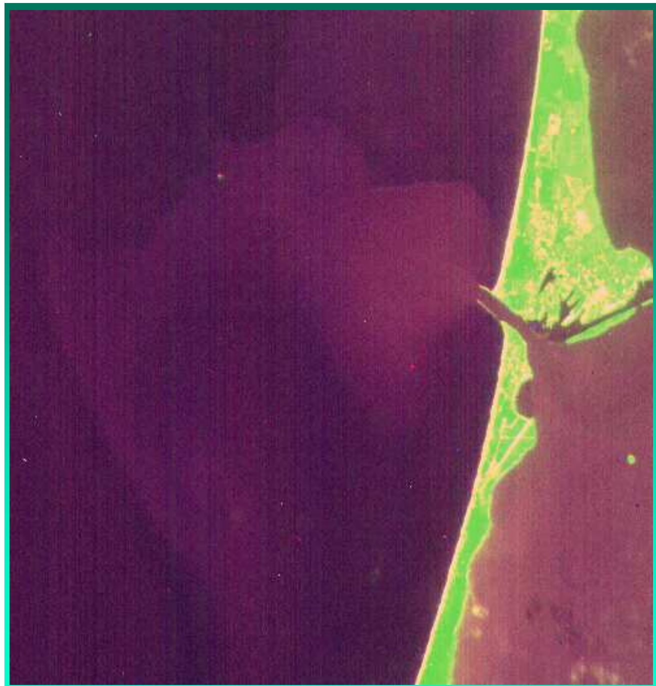
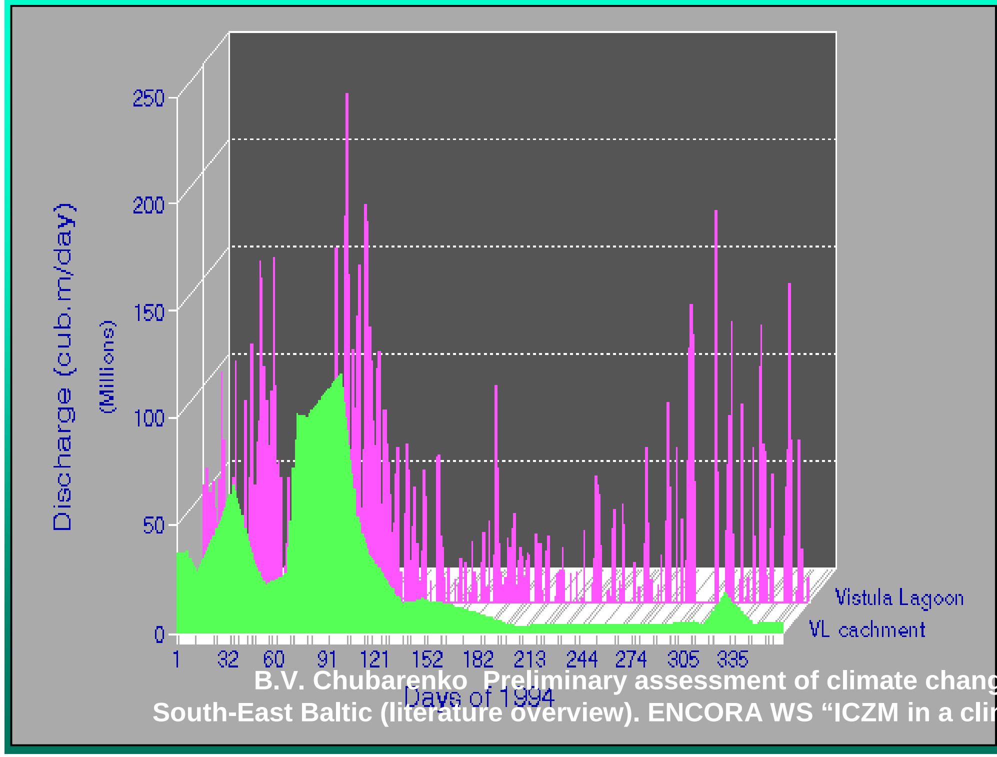


Importance for the Baltic:

Lagoons accept seaward flow from the main part of the South and East Baltic catchment and keep the water inside the lagoon pool during a residence time of 1-3 months

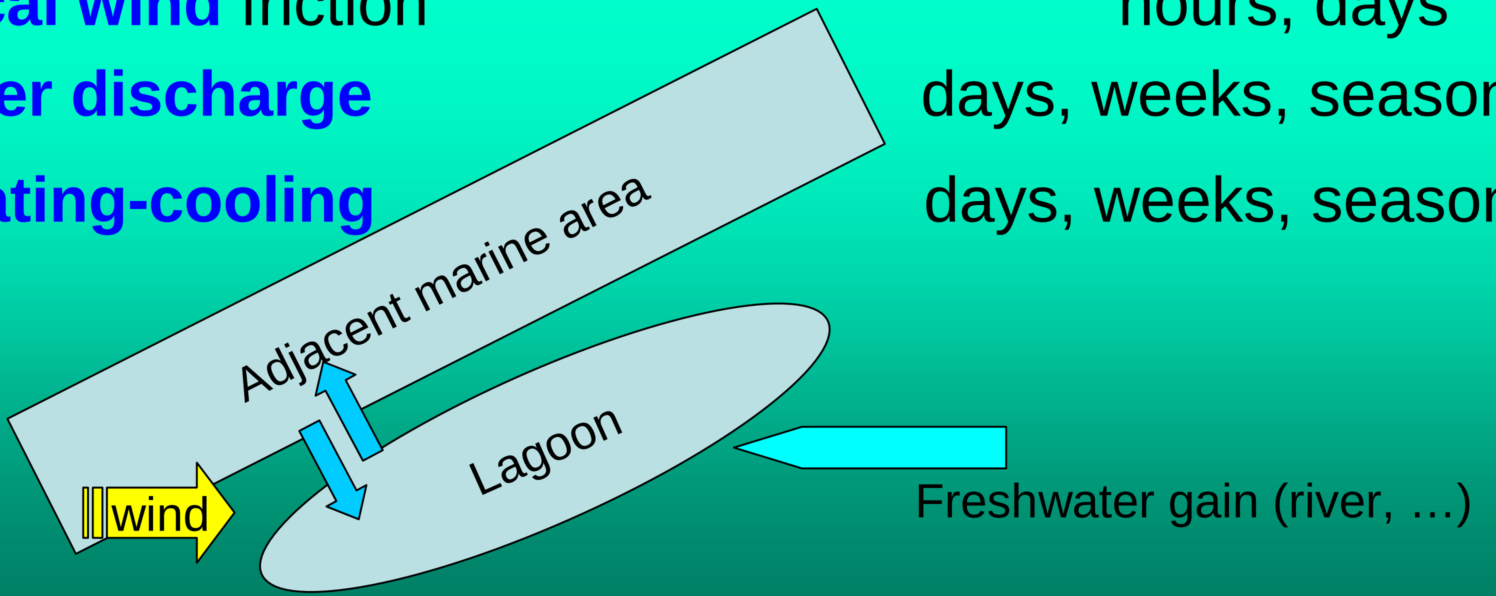


Lagoons modify a temporal variations of the water discharge, sediment, nutrient and pollution load from the land part towards the Baltic Sea

Chubarenko, B.V., Chubarenko, I.P. **(2001) New way of natural geomorphological evolution of the Vistula Lagoon due to crucial artificial influence. In: Emeliayanov E.M. (Ed.), 2001, Geology of the Gdansk Basin, Baltic Sea. Yantarny Skaz, Kaliningrad, p. 372-375**

Main external forcing factors:

- **Water level variations** in adjacent marine area causes intensive water exchange through the lagoon outlet:
  … no tides, but water level oscillations in the Baltic of different origin:
  - local and "global" wind action
  - seiches and long coast trapped waves — hours, days
- **Local wind** friction — hours, days
- **River discharge** — days, weeks, seasons
- **Heating-cooling** — days, weeks, seasons



Current changes in forcing factors

Water temperature
Wind
Level variations

Daily measurements of water temperature at 6:00 hr GMT, at a depth of 0.4 m

Mean daily air temperature, height 2 m above surface

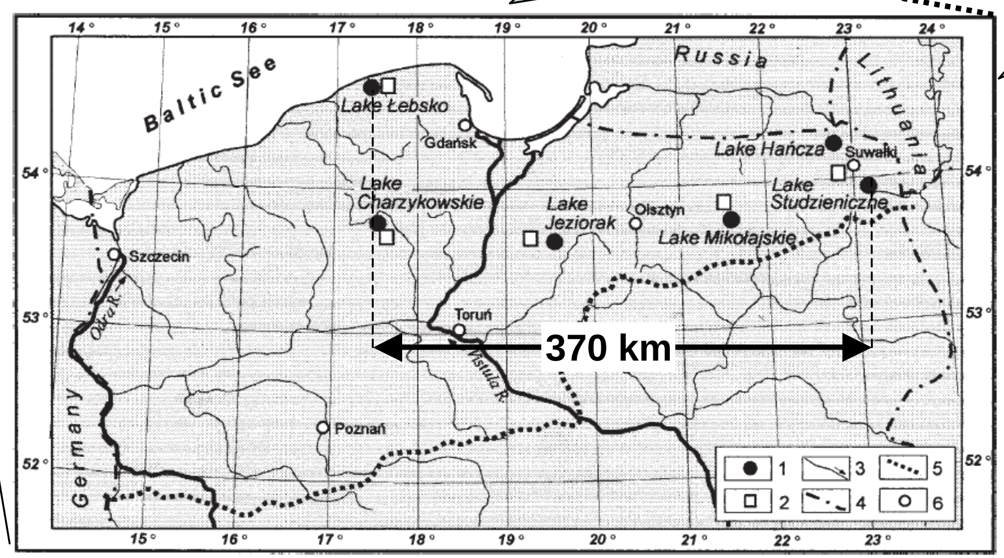


Fig. 1. *Location of the lakes: 1–lakes (numbered according to Table 1); 2–meteorological stations; 3–rivers; 4–country borders; 5–maximum extent of the Weichselian Glaciation; 6–towns.*

40 years period: 1961 – 2000

6 lakes

Area: 2.4÷71.4 km^2

Men depth: 1.6 ÷ 39 m

Max depth: 6.3 ÷ 106 m

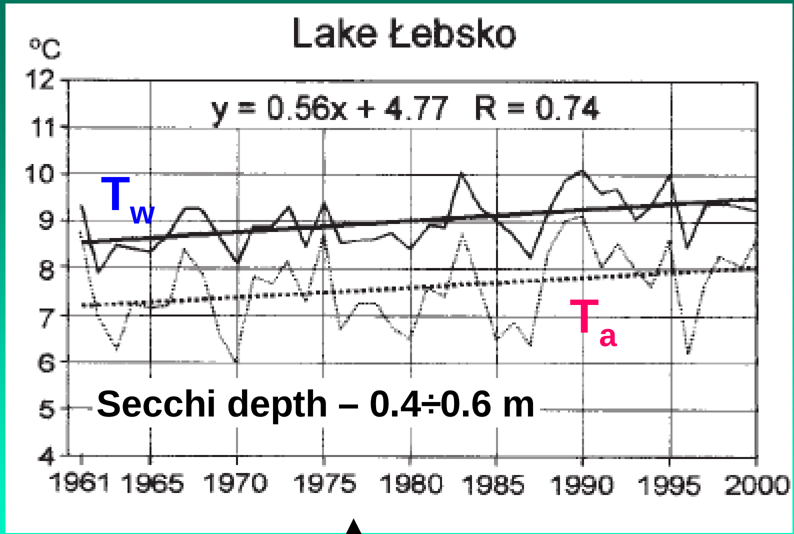
Volume: (22÷141)10^6 m^3

The trends and dependencies between air and water temperatures in lakes in northern Poland from 1961–2000

Mieczyslaw Dabrowski[1], Wlodzimierz Marszelewski[2] and Rajmund Skowron[2]

Hydrology and Earth System Sciences, 8(1), 79–87 (2004) © EGU

Hydrology & Earth System Sciences



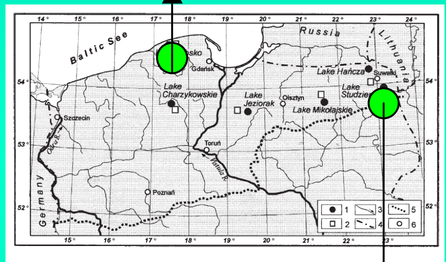
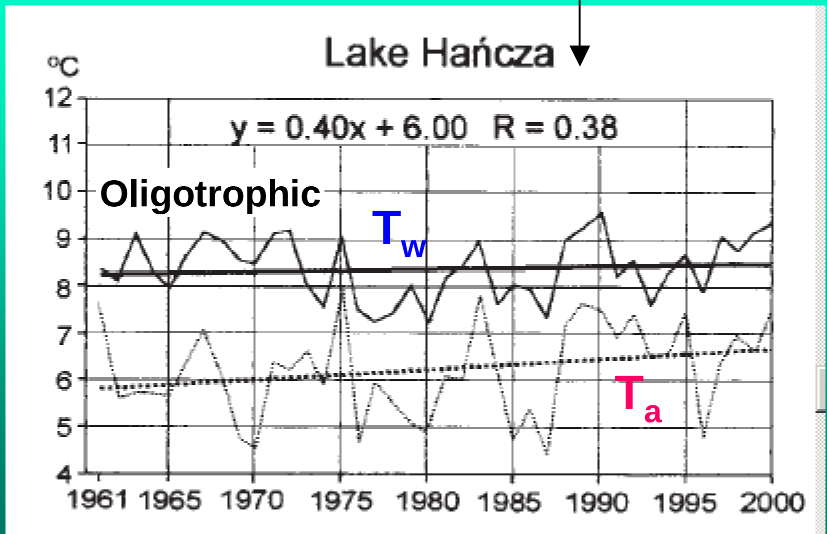


Fig. 1. Location of the lakes: 1–lakes (numbered according to Table 1); 2–meteorological stations; 3–rivers; 4–country borders; 5–maximum extent of the Weichselian Glaciation; 6–towns.



Water and air temperature changes for the period 1961 – 2000 (40 years)

Lake:	ΔTw, ℃	ΔTa, ℃	Trend Tw, ℃ yr^{-1}	Trend Ta , ℃ yr^{-1}
Lebsko	+0.9	+0.8	+0.023	+0.021
Hancza	+0.2	+1.0	+0.006	+0.025

The trends and dependencies between air and water temperatures in lakes in northern Poland from 1961–2000
Mieczyslaw Dabrowski[1], Wlodzimierz Marszelewski[2] and Rajmund Skowron[2]
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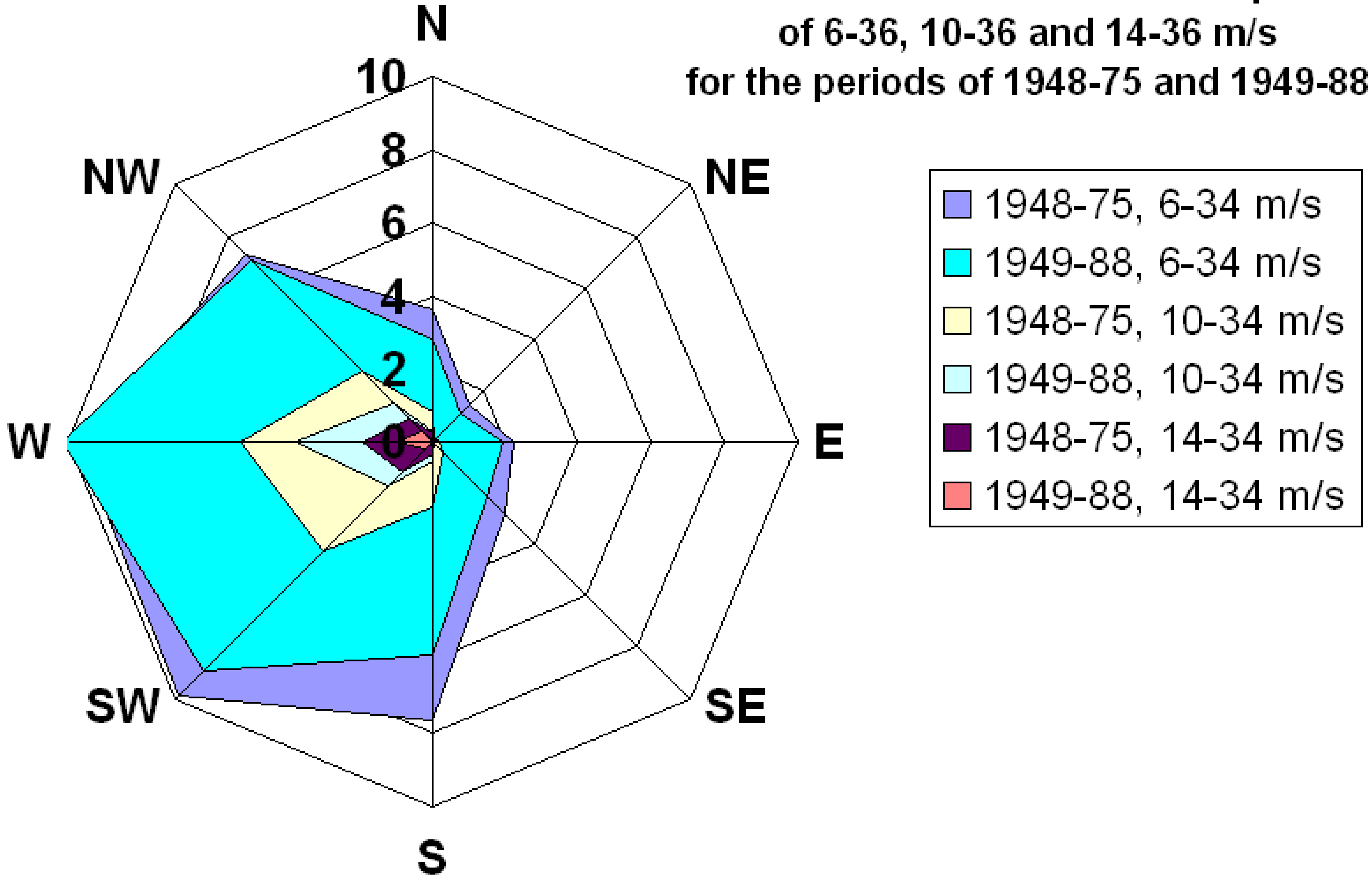
Hydrology & Earth System Sciences

Frequency (%) of occurrence of negative mean period air temperatures in January and February for the years 1961-2000 (40 years)

Station (lake)	1961-1970	1971 – 1980	1981-1990	1991-2000
Leba (Lebsko)	70.0	53.3	56.7	38.3
Suwalki (Hancha)	93.3	85	68.3	71.7

Average yearly probability of occurrence of wind direction for the wind speeds of 6-36, 10-36 and 14-36 m/s for the periods of 1948-75 and 1949-88



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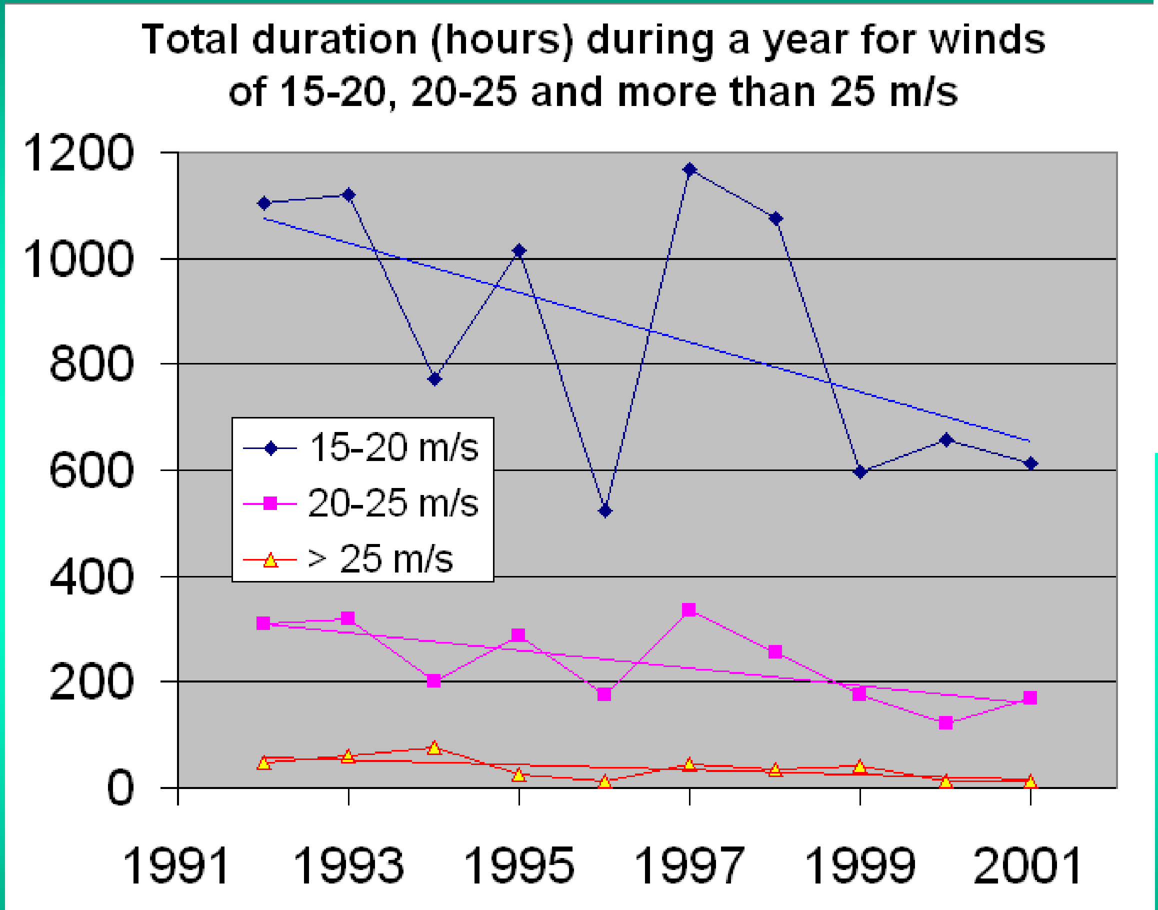

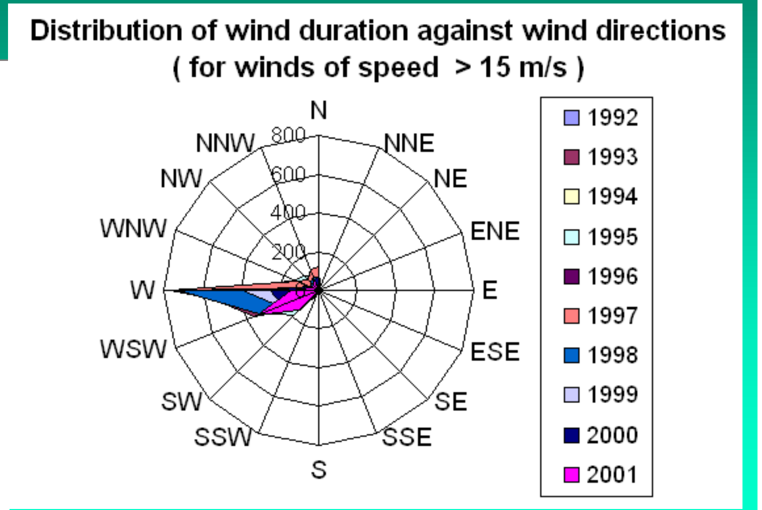

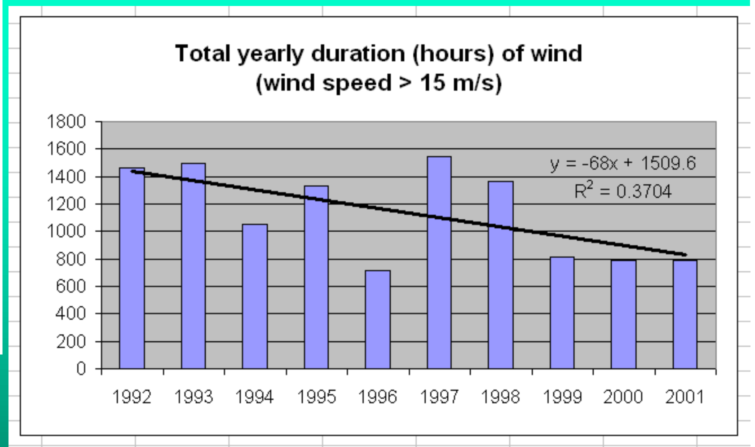

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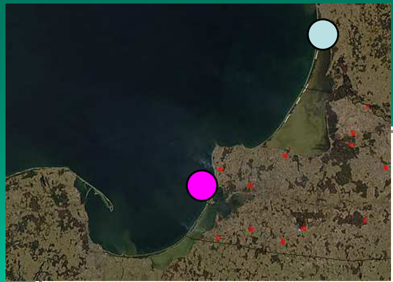
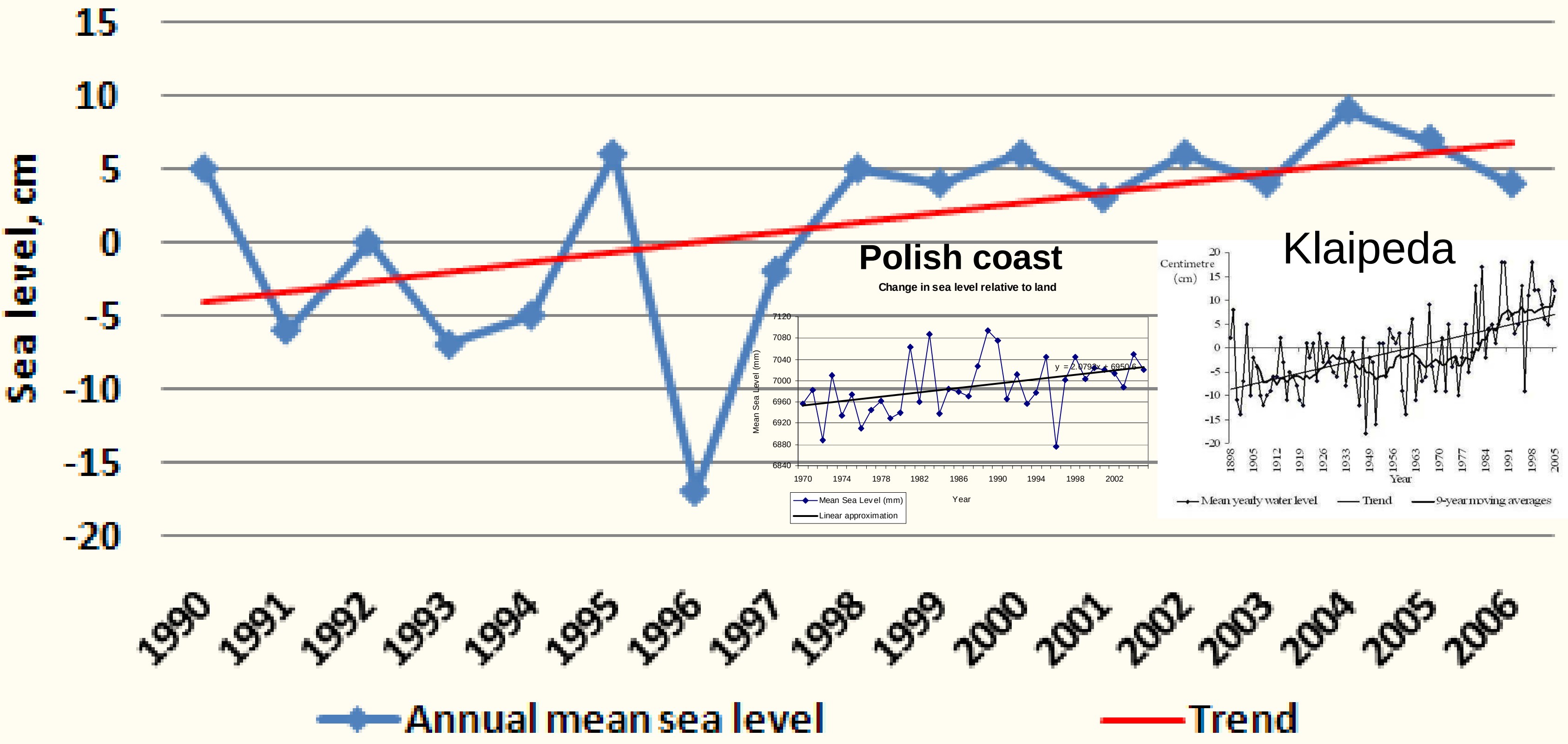


Annual mean sea level in the Baltiysk (Kaliningrad oblast)



Materials of the INTERREG-Tacis (2006/131-758) Project "Sustainable Development Indicators for ICZM in the South-Eastern Baltic (SDI-4-SEB) http://www.corpi.ku.lt/SDI-4-SEB/

Future:
Air temperature, Precipitation, Evaporation and River Runoff

Model of General Atmospheric Circulation [GGO]
1981 – 2100 (20 years – present, 80 years – scenario B2),
Monthly SST and ice for B2 – results of ocean-atmosphere general circulation model (www.dkrz.de),
Δx=250÷300 km, Δt = 6 hours

Regional Climate Model [GGO]
Δx=50 km, 1991-2000, 2041-2050, 2091-2100

Scenario B2 (moderate):

CO_2 ↑ x 1.76
CH_4 ↑ x 1.75
N_2O ↑ x 1.18

IPCC – 2000: Emissions scenarios

Shkolnik I.M., Meleshko V.P., Katcov V.M. (2006)
Probable climate change on both the European part of Russian Federation and adjacent territory up to the end of XXI century: simulation by regional model of 'Voejeikov's GGO'. Russian Meteorology and Hydrology (Meteorologiya I Gidrologiya). No 3, 2006. Pp. 5-16.

Climatic changes for the Baltic Region in a whole up to 2100

	Winter	Spring	Summer	Autumn	Year
ΔT, C° **(temperature)**	4.4	3.1	2.2	3.1	3.2
ΔP, % **(precipitation)**	24	23	8	28	20
ΔR, % **(river runoff)**	65	19	12	57	38

Shkolnik I.M., Meleshko V.P., Katcov V.M. (2006) Probable climate change on both the European part of Russian Federation and adjacent territory up to the end of XXI century: simulation by regional model of 'Voejeikov's GGO'. Russian Meteorology and Hydrology (Meteorologiya I Gidrologiya). No 3, 2006. Pp. 5-16.

General Circulation Models
(HadAM3H, Hadley Centre, UK;
ECHAM4/OPYC3 (Max Plank Inst for Meteorology)
1961 – 1990 (control), 2071 – 2100 (forecast), Scenario B2,
2 times per 30 years

Rossby Centre Atmosphere Ocean Model
(Regional Climate Model)
Δx=49 km, 1961 – 1990, 2071 – 2100
2 times per 30 years

Scenario B2
(moderate):

Equivalent CO_2:
353 ppm – 1990
822 ppm - scenario
↑ x 2.32

IPCC – 2000:
Emissions scenarios

Graham, L.P. (2004) Climate Change Effects on River Flow to the Baltic Sea. Ambio, Vol. 33, No4-5, Pp. 235-241.

Mean annual RCAO modeled changes for 2071 – 2100

	RCAO-H/B2		RCAO-E/B2		GGO
	Baltic Proper	Total Baltic	Baltic Proper	Total Baltic	
ΔT, C° (temperature, at 2 m)	2.5	2.6	4.0	3.9	**3.2℃**
ΔE, % (evaporation)	6	10	13	15	
ΔP, % (precipitation)	3	7	8	16	**20%**

Graham, L.P. (2004) Climate Change Effects on River Flow to the Baltic Sea. Ambio, Vol. 33, No4-5, Pp. 235-241.

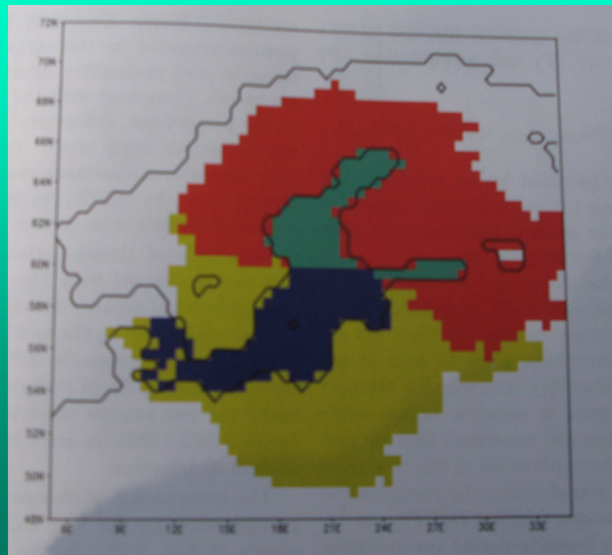
Assessment of Climate Change for the Baltic Basin. 2008. Springer-Verlag: Berlin, Heidelberg. P.24-25.:

Global warming during 1990 - 2100: + (1.4 ÷ 5.8ºC) [Cubasch et.al., 2001]

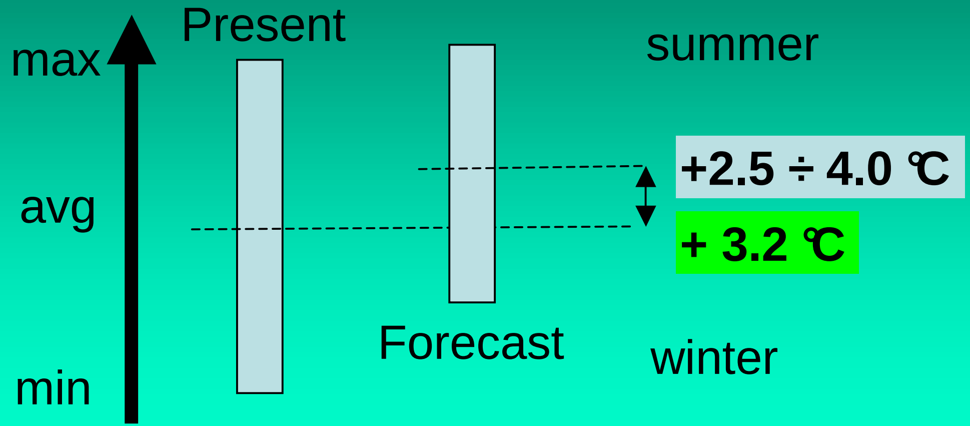
Baltic Region warming:
mean annual, whole basin - +(3÷5) ºC,
higher than for global warming

Relative uncertainty is high than for global prognosis:
e.g. warming in northern part of the Baltic Sea Region (late 20th – late 21th):
+1ºC ÷ … (in summer) and +(... ÷ 10 ºC) in winter

	Summer	Winter
Northern areas:		+(4÷6)**ºC**
Southern areas	+(3÷5)**ºC**	



Air temperature changes

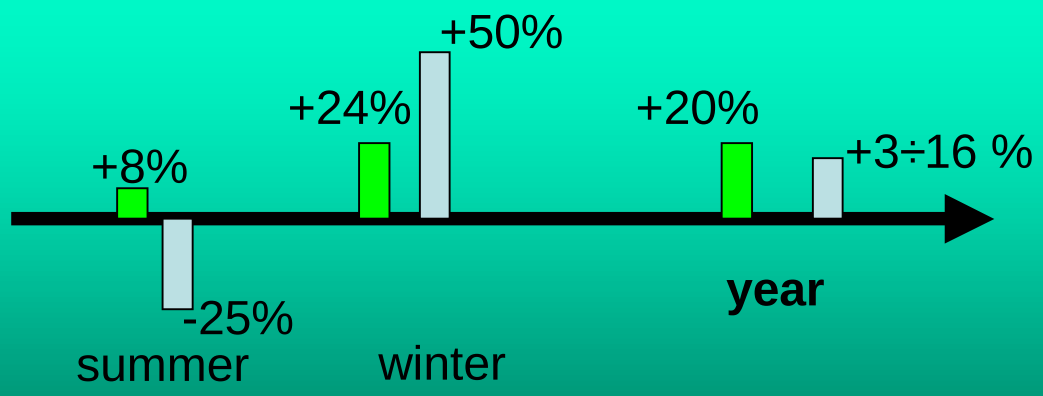


Air temperature will increase !!!

GGO model, Total Baltic basin

RCAO model, the Baltic Proper

Precipitation



Precepitation will increase in total, but … temporal and spatial variations will be strong !!!

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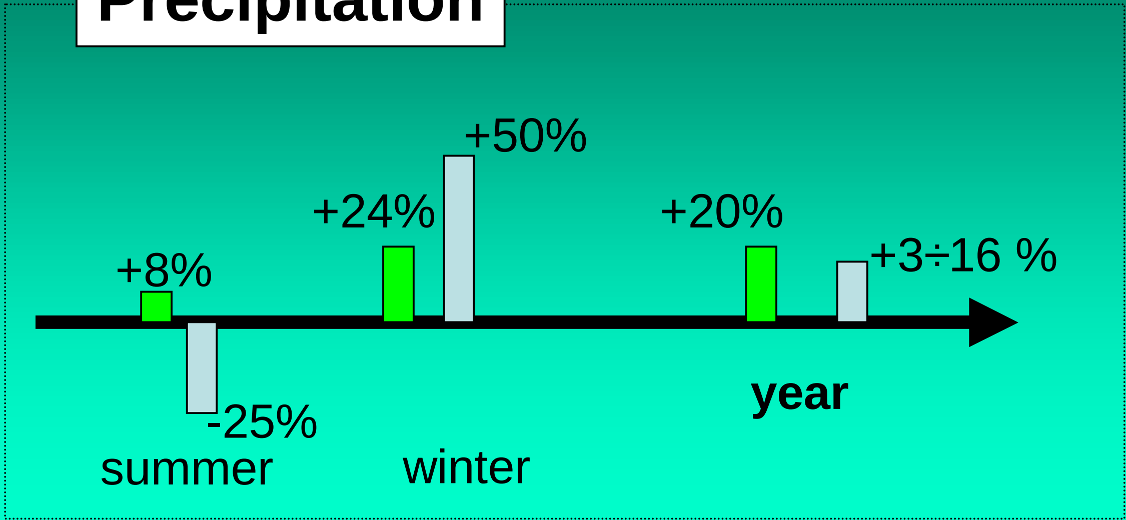
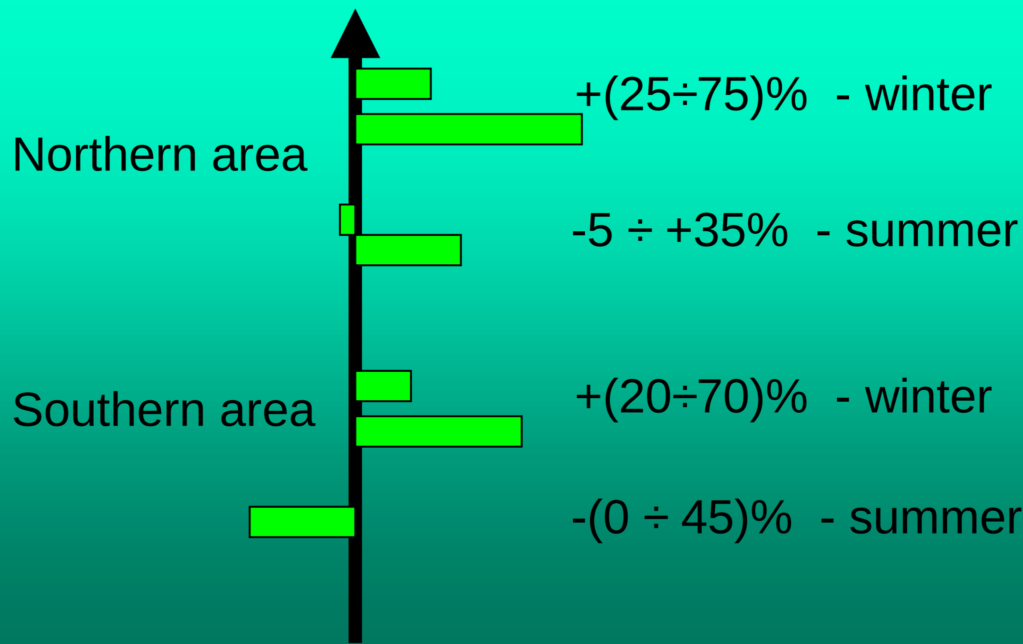
Precipitation



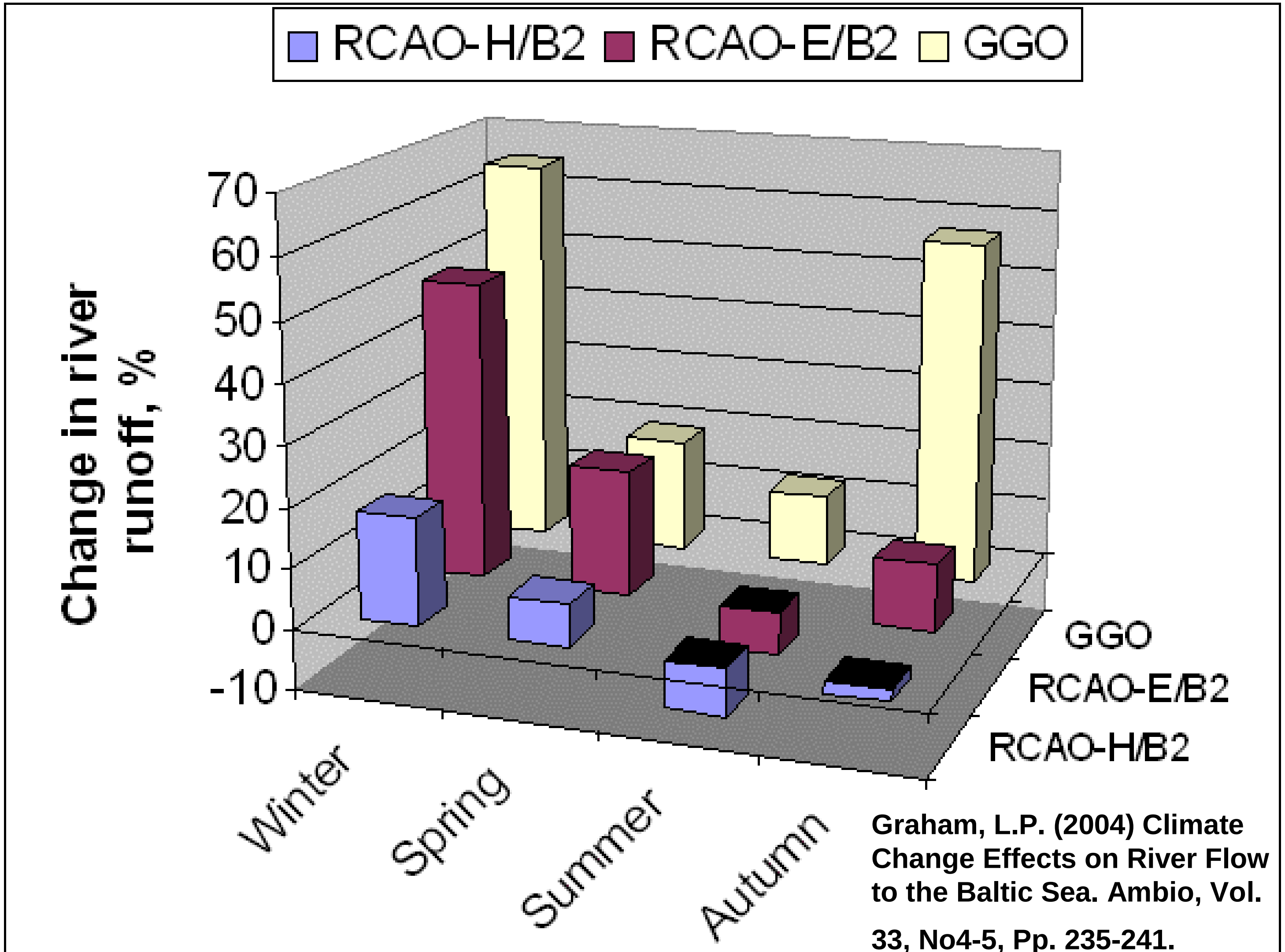
GGO model, Total Baltic basin

RCAO model, the Baltic Proper

Precipitation

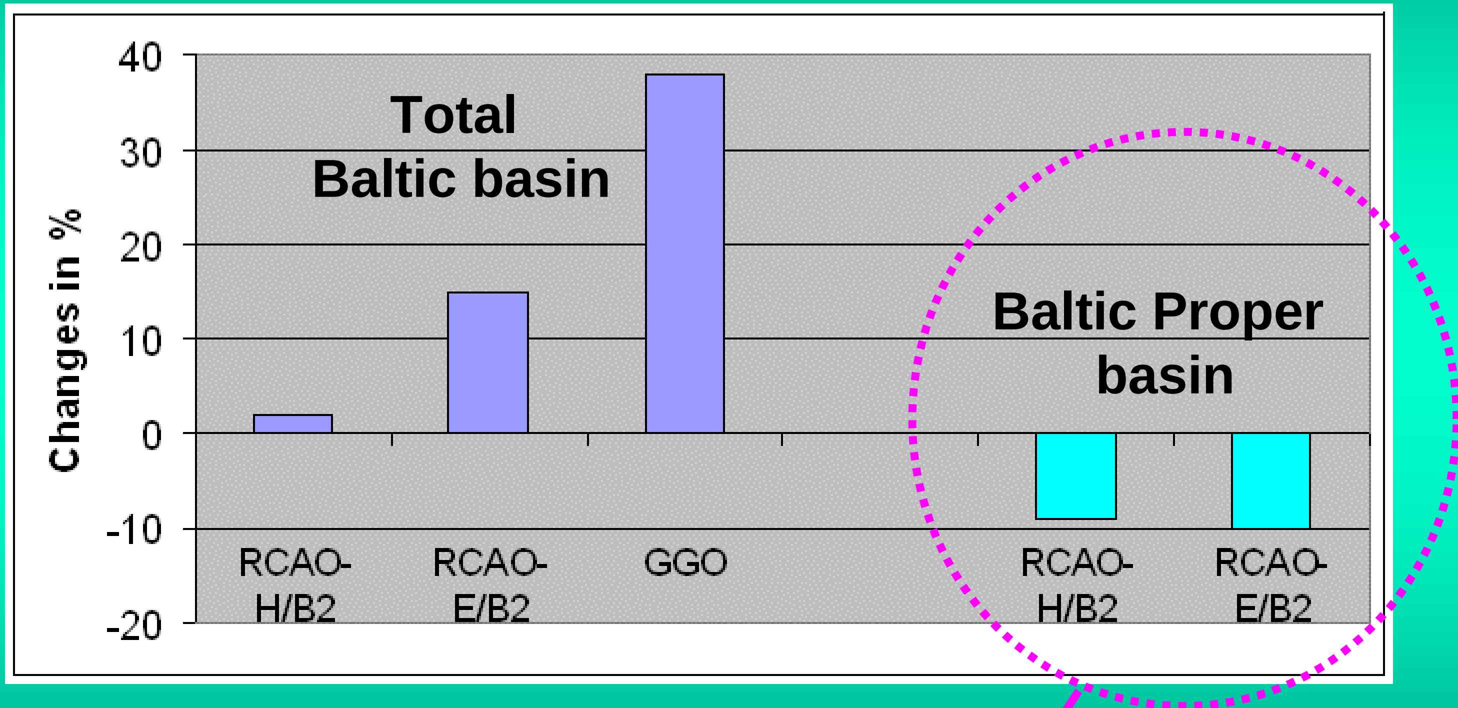


Changes in river run-off for the total Baltic



Graham, L.P. (2004) Climate Change Effects on River Flow to the Baltic Sea. Ambio, Vol. 33, No4-5, Pp. 235-241.

Climatic changes in runoff for the total Baltic and the Baltic Proper



Net river runoff will decrease !!!

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Changes in river runoff for the Baltic (Graham, 2004):

Graham, L.P. (2004) Climate Change Effects on River Flow to the Baltic Sea. Ambio, Vol. 33, No4-5, Pp. 235-241.

Increase in winter flows

More frequent medium to high flow events

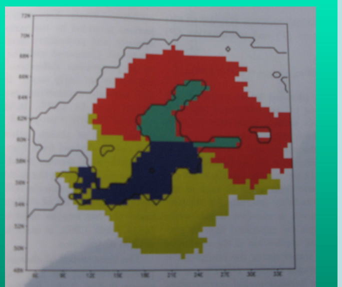
Reduction in summer flows

(Graham, 2004)

Increase in flows from northern basins

No pronounced increase in magnitude of high flow events

Decrease in flows from southern basins



The Baltic Proper:

- Decrease in total runoff is expected
- Typical spring snowmelt peaks will change to earlier peaks covering a wider range of occurrence
- Spring flood will occur earlier and autumn/winter floods will generally become more frequent

Consequences (Graham, 2004):

- Changes to hydropower operations (changes in timing of flows especially at the northern basins)

- Agriculture sector at the southern basins has to adapt to future shorteges, irrigation will be needed

- Municipal water supply in the south can be potentially affected as well both as surface supply diminish and as ground water recharge will be reduced during part of a year

- Some rehabilitation for the Baltic as more flow will originate in northern areas with relatively little agriculture and level of fertilization

- Cultivated areas will move to north

Increased winter runoff (from September to March) seems to reduce the probability of major Baltic inflows (Schinke and Matthäus (*1998*) and Matthäus and Schinke (*1999*))

Wind

Assessment of Climate Change for the Baltic Basin. 2008. Springer-Verlag: Berlin, Heidelberg. P.24-25.:

- Projected changes in wind differ widely between various climate models

-An increase in windiness for the Baltic Sea Basin would be somewhat more likely than a decrease (??? + 8-12%)

Sea surface temperature and salinity

Assessment of Climate Change for the Baltic Basin. 2008. Springer-Verlag: Berlin, Heidelberg. P.24-25.:

… Oceanographic studies show that the mean annual sea surface temperature could increase by some 2 to 4ºC by the end of 21th century

… Ice extent in the sea would than decrease by some 50 to 80%.

… The average salinity in the Baltic Sea is projected to decrease between 8 and 50%.

Water level

Meier, M.H.E., Broman, B.,Kjellstrom, E. Simulated sea level in past and future climates of the Baltic Sea, Rossby Centre, SMHI

General Circulation Model (Atmosphere)	HadAM3 (Hadley Centre) **HC**	ECHAM4/OPYC3 (Max Planck Ins 4 Meteorology) MPI

X

SRES Scenarios for greenhouse gases	**A2** **(larger increase)**	**B2** **(moderate increase)**

Global ocean sea level rise, **cm** — **88 "worst"** **48 "average"** **9 "best"**

RCAO, **fully coupled atmosphere-ice-ocean model (Doscher et.al., 2002)**

RCO, **regional coupled ice-ocean model**

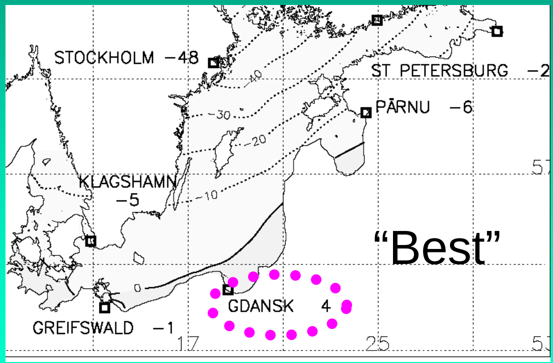
(Meier et.al., 1999, 2003; Meier, 2001; Meier&Faxen, 2002)

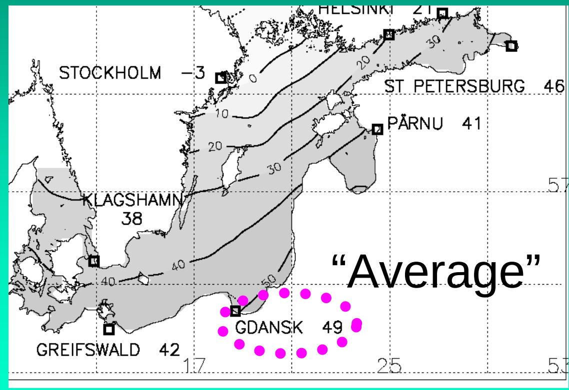
41 levels with layer thicknesses from 3 m close to the surface to 12 m near the bottom; the horizontal resolution is 6 nautical miles corresponding to $\Delta\varphi$ = 6'(latitude) and $\Delta\lambda$ = 12' (longitude)

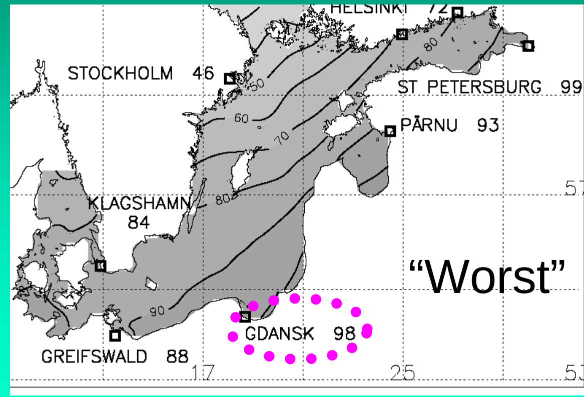
Hindcast (1903-1998), Control (1961-1990), Scenario (2071-2100)

Meier, M.H.E., Broman, B.,Kjellstrom, E. Simulated sea level in past and future climates of the Baltic Sea, Rossby Centre, SMHI

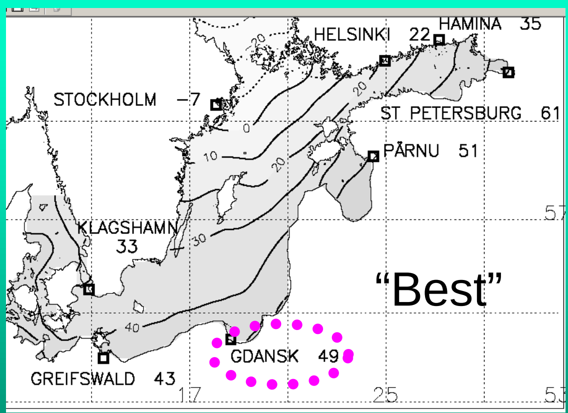
Seasonal mean SSH (2071-2100) relative to the annual mean SSH for 1960-1990, climatological winter (Dec – Feb)

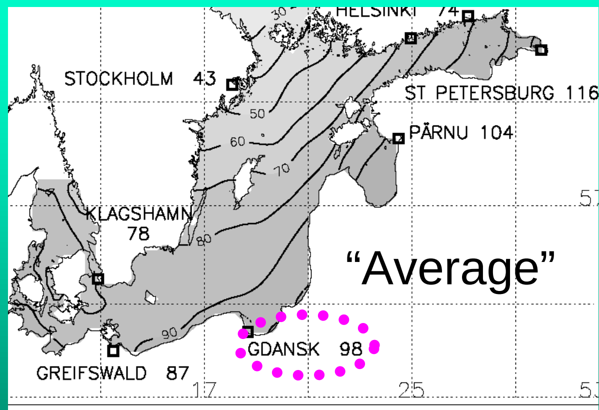


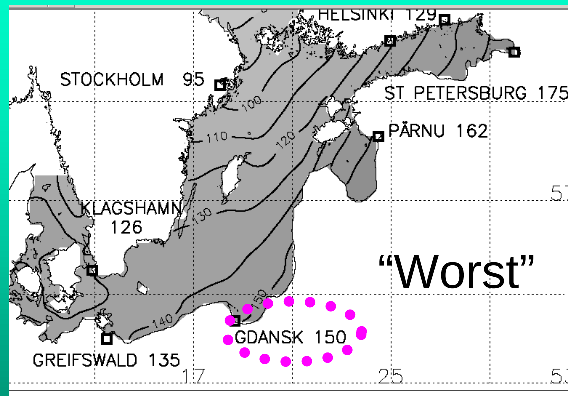


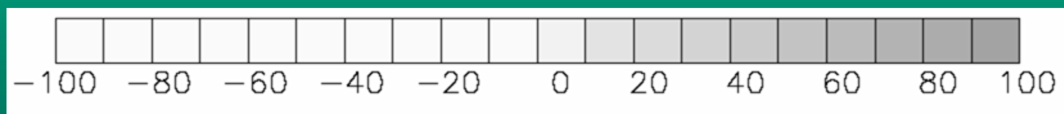


Seasonal mean 99% quantiles (per 33 yr) of the sea level (cm) (2071-2100) relative to the mean SSH for 1960-1990, climatological winter (Dec – Feb)









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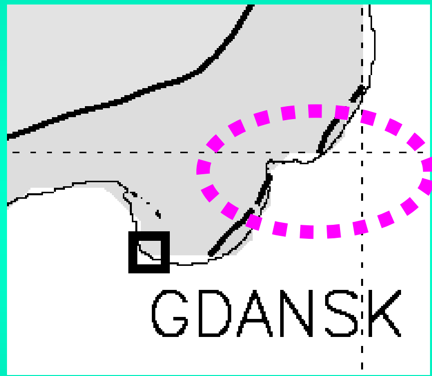
Probability (in %) for sea level (in cm) exceeding certain levels and sea level maxima (relative to the mean sea level 1961-1990), Gdansk

SSH, cm	Hindcast	"Best"	"Average"	"Worst"
100	0.01	0.02	1.41	27.5
120	0	0	0.21	8.00
140	0	0	0.03	2.37
160	0	0	0.003	0.43
Max, cm	118	123	168	219



Water level will rise both in terms of average and extreme values!

Conclusions

Increase in average temperature, winters will be more warmer, less spring picks in freshwater discharge

- ice-coverage on lagoons will not be usual as it is now

Net river runoff will decrease, especially summer runoff will decrease

- the Vistula and Curonian lagoons will be more salty

- for Kaliningrad it will bring problematic situation with drink water supply, as saltwater upstream intrusion will be intensified

Salinity in the adjacent Baltic area will decrease

Water level will rise both in terms of average and extreme values! – it will influence on constructing reference standards,

Wind – it is uncertain now, but coastal erosion will increase

Society preparedness is an insurance for sustainable human activity

Great thanks for Your attention!