Uncertainties and some observed climate change

Hst 9

UN climate body admits 'mistake' on Himalayan glaciers

Monday's lecture

- Climate is what you affect, weather is what gets you
- Climate/weather systems are non-linear, chaotic
  - Attractors to certain states
  - Prediction possible
- But what do we know about current climate change?
- How to deal with uncertainties

Modern climate models

- Perform well at continental scales (global)
- Perform well at inter-annual scales (climate)
- Perform less well at regional scales (local)
- Perform less well at short time scales (weather)
- We continuously need to make decisions about future actions for
  - At what spatial and temporal scales do we need predictions of climate change to make these decisions?

De drie grote problemen in modellen

- Onzekerheid in correctheid fysische procesbeschrijving
- Onzekerheid sub grid schaal processen (wolken, landoppervlak)
- Hoe om te gaan met onzekerheid, chaotisch gedrag
- Oplossingen:
  - Denk meer na
  - Ga met kleiner grids werken
  - Doe multiple ensembles (is eigenlijk al standaard procedure)

Some technical problems…

Climate simulations are quite sensitive to the uncertainties in formulating subgrid-scale processes.

The use of higher resolutions often makes the results worse.

Improving a part of the model usually requires retuning of other parts.

Optimum tuning is, however, model-dependent and experience at a particular modeling center is not necessarily shared with other centers.

Thus verification against observations has not been as constructive as they should be.

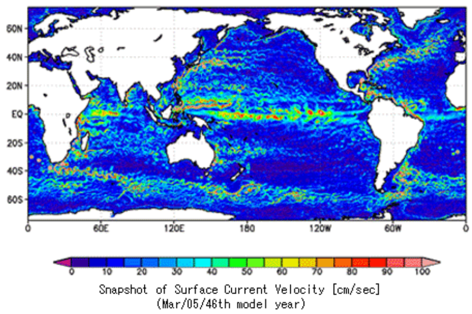
FRUSTRATIONS !

Arakawa, 2005

Working with smaller grids

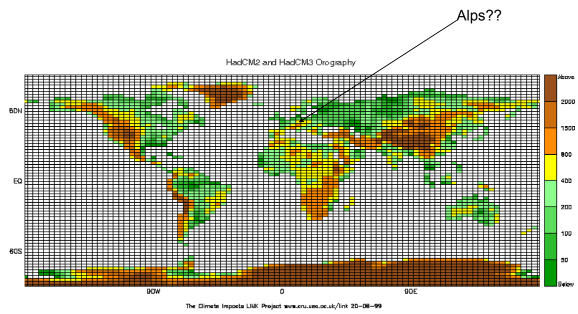
- Computing power – Earth simulator, Japan
  - Mission: To build a harmonious relationship between the Earth and human beings, the Earth Simulator Center will endeavor to achieve the maximum benefit of the Earth Simulator's capabilities, and will pursue challenges in various areas of research and development.
    - Environment: Solution for environmental problem like the global warming, and prediction of various natural disasters
    - Industry: Development Simulation of Nuclear power plant, ecological engine, nano technology and etc.
  - NEC SX-6 architecture. 640 nodes with eight vector processors and 16 gigabytes of computer memory at each node, for a total of 5120 processors and 10 terabytes of memory.
  - At 3.5 km grid cell size global ocean covered Earth: simulates 10 days in 1 day on half power
- New supercomputer to be build

Earth Sim' s Ocean Eddy resolving model



Source: http://www.jamstec.go.jp/esc/research

Topography in a GCM

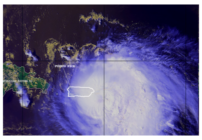


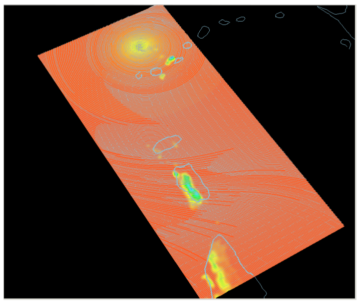
Global versus regional modelling

- GCMs are used to model climate, land and ocean processes for the whole world
  - Coarse grid (100 x 100 km) to limit computation times
- GCMs not suitable for regional modelling
  - Fine grid required (< 10 x 10 km)
  - Topography included
  - Small-scale variations in land surface/cover important
  - Atmospheric model: Regional Atmospheric Modelling System (RAMS)
- Use regional climate models (RCMs)

Hurricane George by RAMS

- 5 x 5 km grid
- 230 E-W, 105 N-S points
- 26 atmospheric layers (1 km resolution)
- Generated on a 64 processor computer

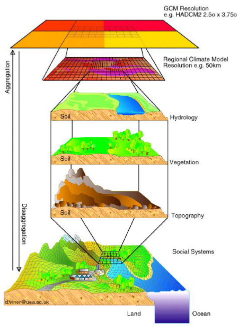




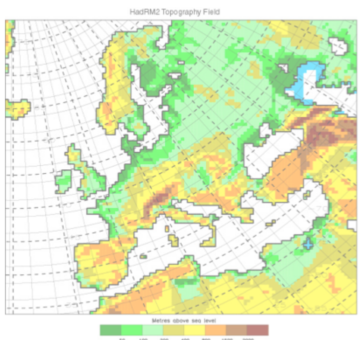
Regional climate model structure

- Small grid
- Data files for soil, vegetation, topography, hydrology and perhaps socio-economic systems

- Question: How good are these sub-models and are these equal in quality and complexity?



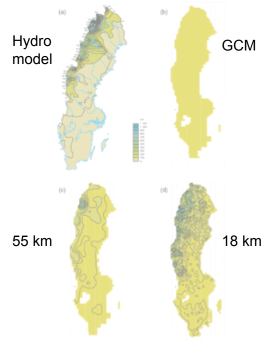
Topography Regional Climate Model



- Rainfall is very sensitive to topography, so improvement in rainfall prediction can be expected

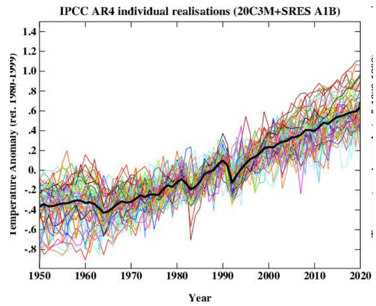
RCM: impact on hydrology

- Resolution ~2 times grid size
- Note the improved detail
- Compare RCM/GCM simulations with hydrological model simulations



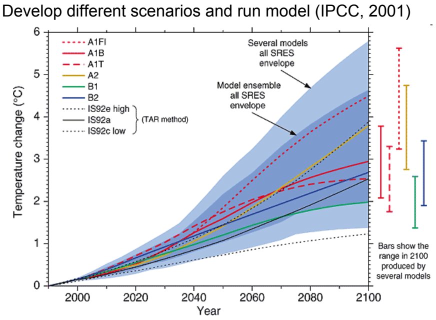
Ensembles

- Uncertainty in your model:
  - Make runs with same conditions using different models

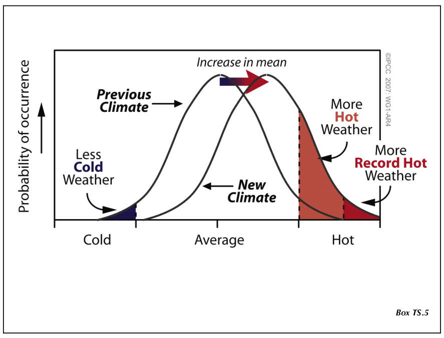


Uncertainties in boundary conditions

- Uncertainty in future developments (GHG emissions, land use, economy, etc.)
  - Develop different scenarios and run model (IPCC, 2001)



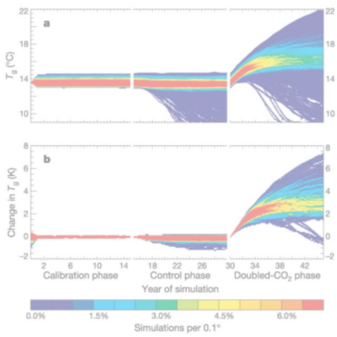
Impacts of climate change



Multiple ensembles

climate*prediction*.net

- Assessing probabilities
- Thousands of runs made on distributed home PC network show:
  - Trouble is in the extremes of the predictions
  - You can use statistics on ensemble runs!

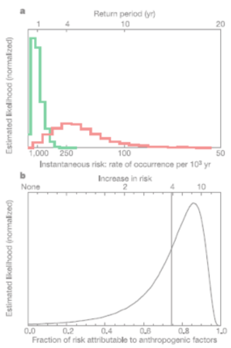


Nature 2005

Impacts of drought

Changes in extremes

- Statistics
  - Return period changes from 1 in 1000 years to 1 in 250 years?
- Consequences?
  - Temperature
  - Rainfall
  - Wind
  - Sea level



Stott et al, Nature 2004

Changes in extremes

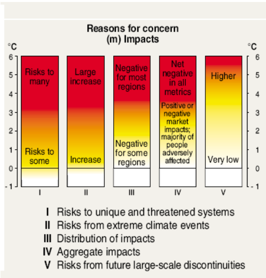
Table 9.6: Estimates of confidence in observed and projected changes in extreme weather and climate events.

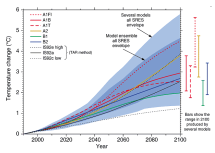
Confidence in observed changes (latter half of the 20th century)	Changes in Phenomenon	Confidence in projected changes (during the 21st century)
Likely	**Higher maximum temperatures and more hot days[a] over nearly all land areas**	Very likely
Very likely	**Higher minimum temperatures, fewer cold days and frost days over nearly all land areas**	Very likely
Very likely	**Reduced diurnal temperature range over most land areas**	Very likely
Likely, over many areas	**Increase of heat index[b] over land areas**	Very likely, over most areas
Likely, over many Northern Hemisphere mid- to high latitude land areas	**More intense precipitation events[c]**	Very likely, over many areas
Likely, in a few areas	**Increased summer continental drying and associated risk of drought**	Likely, over most mid-latitude continental interiors. (Lack of consistent projections in other areas)
Not observed in the few analyses available	**Increase in tropical cyclone peak wind intensities[d]**	Likely, over some areas
Insufficient data for assessment	**Increase in tropical cyclone mean and peak precipitation intensities[d]**	Likely, over some areas

[a] Hot days refers to a day whose maximum temperature reaches or exceeds some temperature that is considered a critical threshold for impacts on human and natural systems. Actual thresholds vary regionally, but typical values include 32°C, 35°C or 40°C.
[b] Heat index refers to a combination of temperature and humidity that measures effects on human comfort.
[c] For other areas, there are either insufficient data or conflicting analyses.
[d] Past and future changes in tropical cyclone location and frequency are uncertain.

Concerns and abrupt change

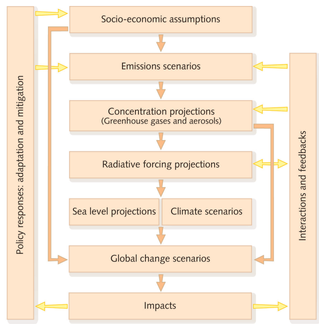
- Temperature rise above 3 °C cause high risks to many systems
- Abrupt change: very difficult to predict (timing and occurrence)
  - Low probability
  - High to very high risk
  - One of the growing fields of climate research



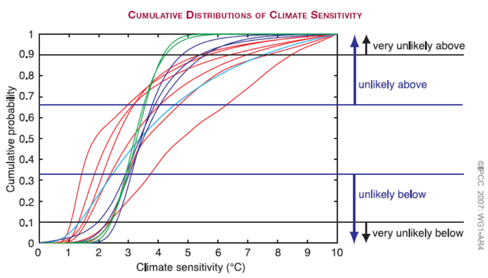


Onzekerheden

- Onzekerheden in klimaat-waarnemingen
- Onzekerheden in modellen
- Onzekerheden over beleid



Uncertainty in Climate sensitivity (550 ppm)



Key uncertainties Climate

- Climate data coverage remains limited in some regions and there is a notable lack of geographic balance in data and literature on observed changes in natural and managed systems, with marked scarcity in developing countries.
- Analysing and monitoring changes in extreme events, including drought, tropical cyclones, extreme temperatures, and the frequency and intensity of precipitation, is more difficult than for climatic averages as longer data time-series of higher spatial and temporal resolutions are required.
- Effects of climate changes on human and some natural systems are difficult to detect due to adaptation and non-climatic drivers. Difficulties remain in reliably simulating and attributing observed temperature changes to natural or human causes at smaller than continental scales. At these smaller scales, factors such as land-use change and pollution also complicate the detection of anthropogenic warming influence on physical and biological systems.
- The magnitude of CO2 emissions from land-use change, and CH4 emissions from individual sources remain as key uncertainties.

Uncertainties in drivers of climate change

- Uncertainty in equilibrium climate sensitivity creates uncertainty in the expected warming for a given CO2-eq stabilisation scenario. Uncertainty in the carbon cycle feedback creates uncertainty in the emission trajectory required to achieve a particular stabilisation level.
- Models differ considerably in their estimates of the strength of different feedbacks in the climate system, particularly cloud feedbacks, oceanic heat uptake, and carbon cycle feedbacks, although progress has been made in these areas. Also, the confidence in projections is higher for some variables (e.g. temperature) than for others (e.g. precipitation), and is higher for larger spatial scales and longer time averaging periods.
- Aerosol impacts on the magnitude of the temperature response, clouds and precipitation remain uncertain.
- Future changes in the Greenland and Antarctic ice sheet mass, particularly due to changes in ice flow, are a major source of uncertainty that could increase sea level rise projections. The uncertainty in the penetration of the heat into the oceans also contributes to the future sea level rise uncertainty.

Uncertainties in drivers of climate change

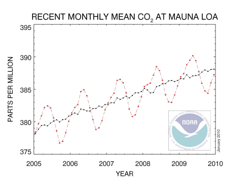
- Projections of climate change and its impacts beyond about 2050 are strongly scenario- and model dependent, and improved projections would require improved understanding of sources of uncertainty and enhancements in systematic observation networks.
- Impacts research is hampered by uncertainties surrounding regional projections of climate change, particularly precipitation.
- Understanding of low-probability/high-impact events, and the cumulative impacts of sequences of smaller events, which is required for risk-based approaches to decision-making, is generally limited.

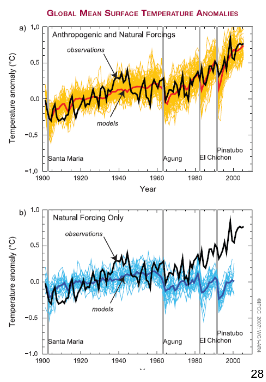
Onzekerheid in beleid, respons

- Understanding of how development planners incorporate information about climate variability and change into their decisions is limited. This limits the integrated assessment of vulnerability.
- The evolution and utilisation of adaptive and mitigative capacity depend on underlying socioeconomic development pathways.
- Barriers, limits and costs of adaptation are not fully understood, partly because effective adaptation measures are highly dependent on specific geographical and climate risk factors as well as institutional, political and financial constraints.
- Estimates of mitigation costs and potentials depend on assumptions about future socio-economic growth, technological change and consumption patterns. Uncertainty arises in particular from assumptions regarding the drivers of technology diffusion and the potential of long-term technology performance and cost improvements. Also little is known about the effects of changes in behaviour and lifestyles.
- The effects of non-climate policies on emissions are poorly quantified

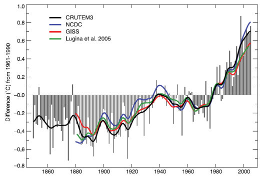
Waarnemingen

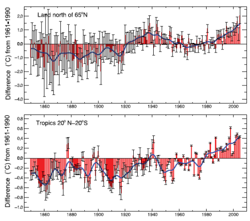
- Essentieel om vinger aan de pols te houden
- Cruciaal voor model validatie





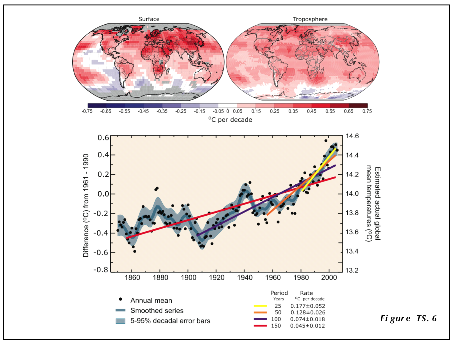
Waarnemingen: temperatuur verloop



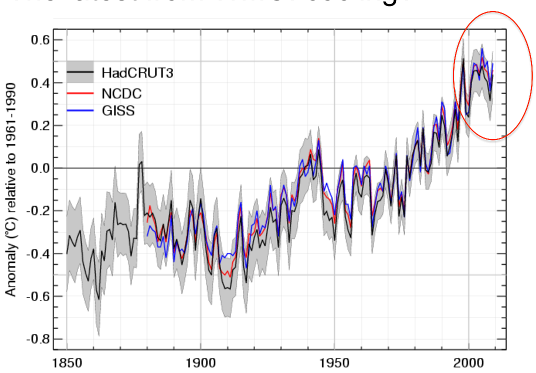


De aarde warmt op, maar niet overal even snel. Vooral in de noordelijke regio's gaat het veel sneller….

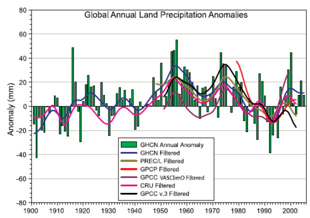
Trends in opwarming aarde en troposphere



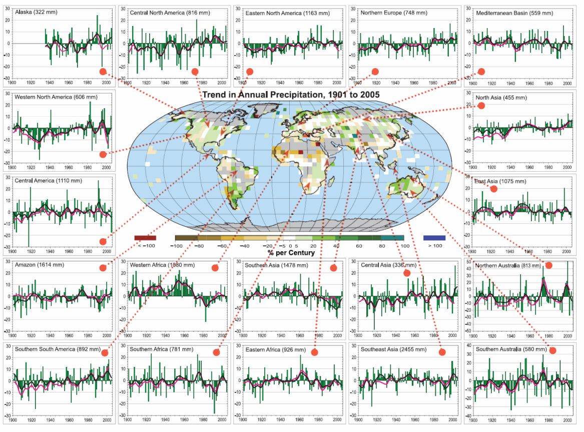
The latest from WMO: cooling?



Waarnemingen: veranderingen neerslag

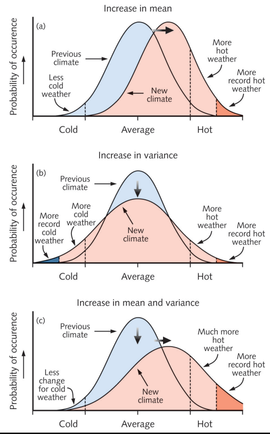


Grote verschillen
In data sets, trend globaal omhoog, maar weer grote regionale verschillen



Extremen

- Geleidelijke verandering kunnen wellicht met aanpassingen worden verwerkt (adaptatie)
- Maar liggen die in het gemiddelde of the extremen (variantie)?
- Hoe waarschijnlijk zijn die echter?



Contributie extra natte dagen

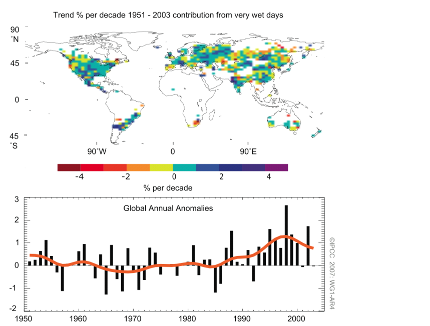
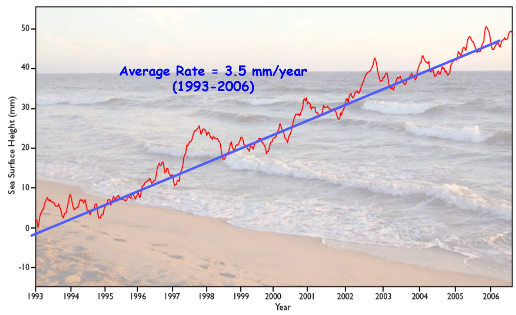


Figure TS. 10

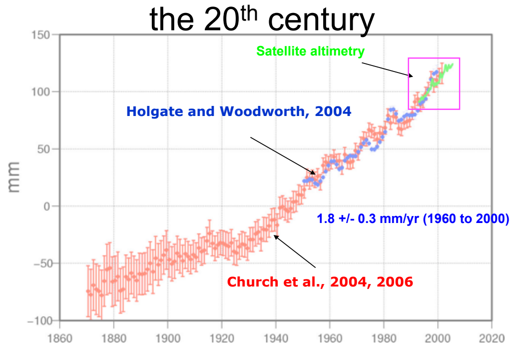
Stijgt de zeespiegel?



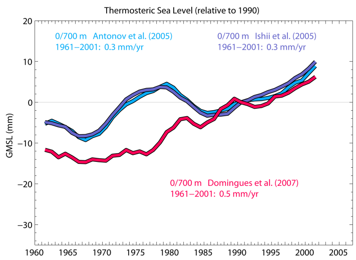
Key Impacts in the Coastal Zone

- Sea-level rise
  - inundation
  - storm surges, waves

Sea-level rise accelerated during the 20th century

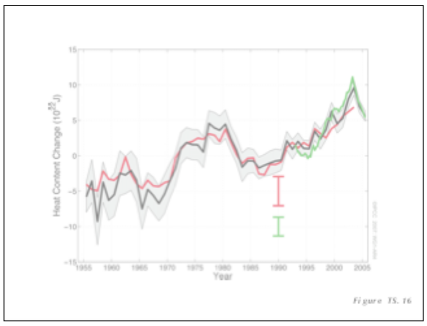


Ocean thermal expansion the largest contribution to sea-level rise

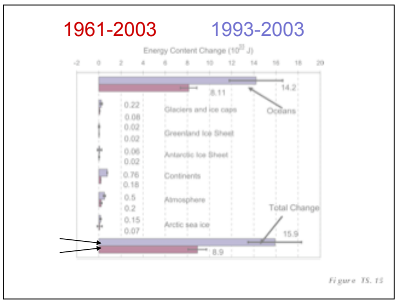


Higher rate of rise during 1961-2001.
Magnitude of decadal variability less than previous estimates.

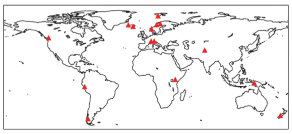
Warmte inhoud oceanen

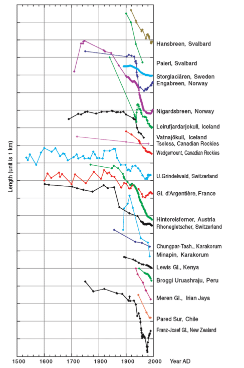


Verandering in energie inhoud



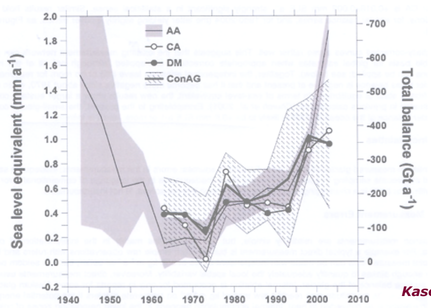
Glacier retreat





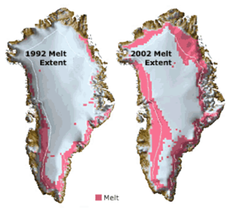
Complex balance between input (snow) and output (melt); most , but not all are declining

Glacier melting contributes to sea level

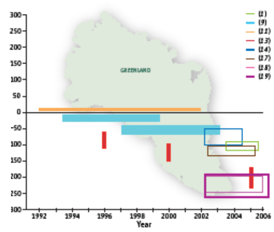


Kaser et al. 2005)

Ice mass loss of the Greenland ice sheet since 1992

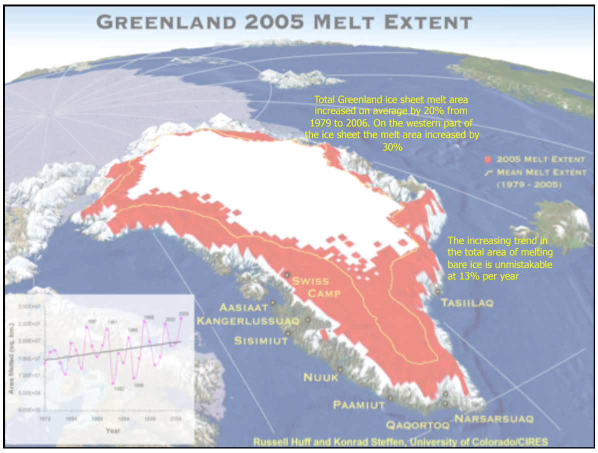


Greenland contribution
to present-day sea level rise
(1992-2006) :
~ 0.3 mm/year

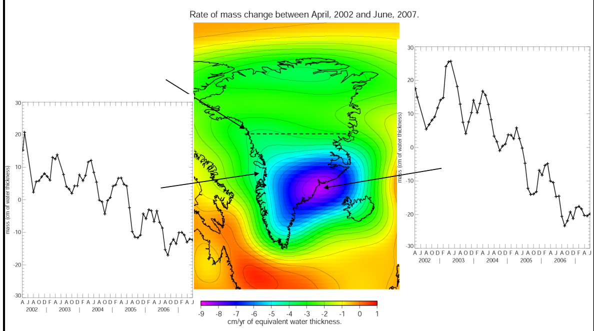


Ice mass loss measured by remote sensing techniques

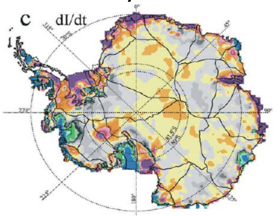
Steffen et al.
Cazenave, 2006



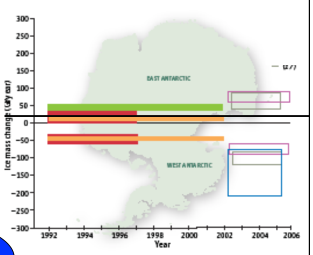
Greenland Ice Mass Loss from GRACE



The Antarctica ice sheet is nearly in balance



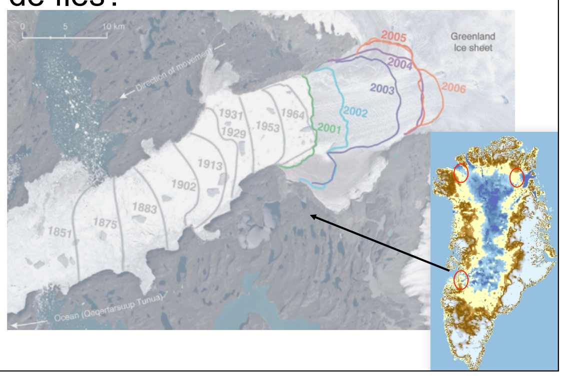
Contribution to present-day sea level rise (1992-2006): ~0.1 mm/an



Remote sensing measurements

(Cazenave, 2006)

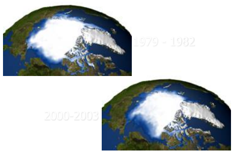
Jacobshavn gletscher, de kurk op de fles?

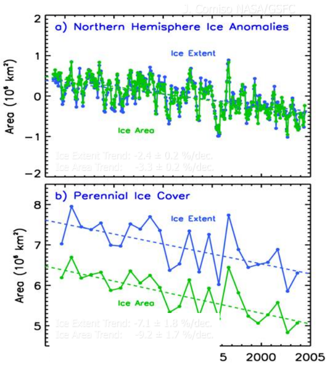


Melt Induced Ice Flow and Moulins

Changes in Arctic Sea Ice Cover

Changes in Arctic Sea Ice Cover

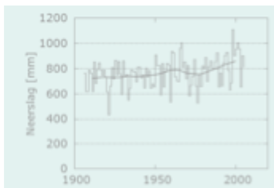




- Trends in decline of perennial ice cover 3x that of total NH ice cover
- Disappearing thick perennial ice cover replaced by thinner younger ice (if at all).
- What volume of ice???
  - Submarine obs. Suggest 40+% thinning since 1950s

Waarnemingen neerslag in NL

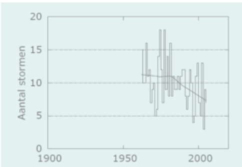
- In Nederland is de jaarlijkse neerslag vanaf 1906 toegenomen met 18% Dit komt vooral voor rekening van de winter (+26%), het voorjaar (+21%) en de herfst (+26%). In de zomer is de neerslaghoeveelheid nauwelijks veranderd (+3%).
- In de winter nam ook de neerslaghoeveelheid in lange periodes met veel regen toe. De hoogste 10-daagse neerslagsom per winter is sinds 1906 met 29% gestegen. In de zomer is geen duidelijke trend in extreme neerslag vastgesteld.



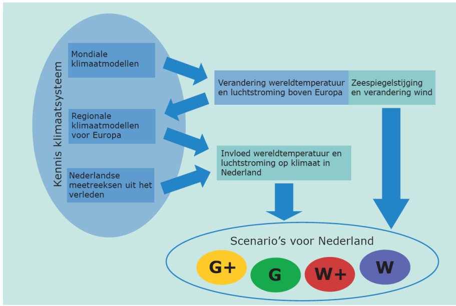
Bron KNMI, 2006

Wind en stormen

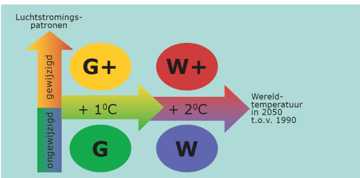
- Het aantal waargenomen stormen neemt af



Wat gaat er gebeuren?



Vier scenario's



G	Gematigd	1°C temperatuurstijging op aarde in 2050 ten opzichte van 1990 geen verandering in luchtstromingspatronen in West Europa
G+	Gematigd +	1°C temperatuurstijging op aarde in 2050 ten opzichte van 1990 + winters zachter en natter door meer westenwind + zomers warmer en droger door meer oostenwind
W	Warm	2°C temperatuurstijging op aarde in 2050 ten opzichte van 1990 geen verandering in luchtstromingspatronen in West Europa
W+	Warm +	2°C temperatuurstijging op aarde in 2050 ten opzichte van 1990 + winters zachter en natter door meer westenwind + zomers warmer en droger door meer oostenwind

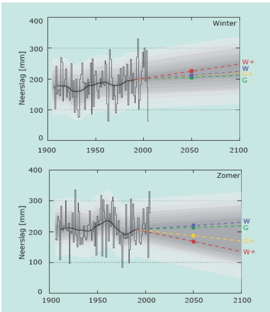
Legenda voor de KNMI'06 klimaatscenario's

Uitwerking vier scenario's

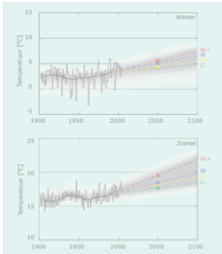
		G	G+	W	W+
Wereldwijde temperatuurstijging		+1°C	+1°C	+2°C	+2°C
Verandering in luchtstromingspatronen		nee	ja	nee	ja
Winter [3]	gemiddelde temperatuur	+0,9°C	+1,1°C	+1,8°C	+2,3°C
	koudste winterdag per jaar	+1,0°C	+1,5°C	+2,1°C	+2,9°C
	gemiddelde neerslaghoeveelheid	+4%	+7%	+7%	+14%
	aantal natte dagen (≥ 0,1 mm)	0%	+1%	0%	+2%
	10-daagse neerslagsom die eens in de 10 jaar wordt overschreden	+4%	+6%	+8%	+12%
	hoogste daggemiddelde windsnelheid per jaar	0%	+2%	-1%	+4%
Zomer [3]	gemiddelde temperatuur	+0,9°C	+1,4°C	+1,7°C	+2,8°C
	warmste zomerdag per jaar	+1,0°C	+1,9°C	+2,1°C	+3,8°C
	gemiddelde neerslaghoeveelheid	+3%	-10%	+6%	-19%
	aantal natte dagen (≥ 0,1 mm)	-2%	-10%	-3%	-19%
	dagsom van de neerslag die eens in de 10 jaar wordt overschreden	+13%	+5%	+27%	+10%
	potentiële verdamping	+3%	+8%	+7%	+15%
Zeespiegel	absolute stijging	15-25 cm	15-25 cm	20-35 cm	20-35 cm

Scenario neerslag in NL

- In alle scenario's neemt in de zomer de gemiddelde neerslaghoeveelheid op dagen met veel regen juist toe door de zwaardere buien (het meest in het W scenario).
- Voor de winter geldt in alle scenario's dat de hoeveelheden in langere periodes met veel neerslag (extreme 10-daagse winterneerslag) ongeveer evenveel veranderen als de gemiddelde neerslagsom.



Wordt Nederland warmer?



- De vier scenario's laten een opwarming zien rond 2050 variërend van 0,9°C tot 2,3°C in de winter en van 0,9°C tot 2,8°C in de zomer
- Doordat natuurlijke schommelingen zullen blijven voorkomen, is het goed mogelijk dat er in de komende decennia tijdelijk een periode van relatief koel weer zal volgen

Projecties voor NL

- de opwarming zet door, hierdoor komen zachte winters en warme zomers vaker voor
- de winters worden gemiddeld natter en ook de extreme neerslaghoeveelheden nemen toe
- de hevigheid van extreme regenbuien in de zomer neemt toe, maar het aantal zomerse regendagen wordt juist minder
- de berekende veranderingen in het windklimaat zijn klein ten opzichte van de natuurlijke grilligheid
- de zeespiegel blijft stijgen

Klimaatverandering, wat nu?

- Het klimaat verandert (dat deed het vroeger ook)
- De huidige veranderingen zijn zeer waarschijnlijk toe te schrijven aan menselijke invloeden
- Er zijn nog vele verrassingen mogelijk in het systeem die moeilijk voorspelbaar zijn
- Voor Nederland is aanpassing mogelijk als die abrupte veranderingen zich niet snel voordoen
- Er zijn grote naijl effecten waardoor emissiereductie slechts langzaam merkbaar is
- Een andere mogelijkheid is er echter niet…