Sharpening the IPCC conclusions into New Climate Change Scenarios for The Netherlands

Bart van den Hurk, Albert Klein Tank, Geert Lenderink, Aad van Ulden, Geert Jan van Oldenborgh, Caroline Katsman, Henk van den Brink, Franziska Keller, Janette Bessembinder, Gerrit Burgers, Gerbrand Komen, Wilco Hazeleger and Sybren Drijfhout

Introduction

The recently presented Fourth Assessment Report (AR4) from Working Group I of the Intergovernmental Panel on Climate Change (IPCC) has been received with great interest by stakeholders in many sectors of modern society where climate change may have serious consequences. One means of dealing with the inevitable uncertainty of future climate is by constructing a suite of different discrete climate change scenarios. The present paper describes how a new set of four scenarios for The Netherlands has recently been developed, representative for the local climate conditions around the years 2050 and 2100. The method combines a range of global and regional climate model simulations and local observations in order to optimally span the major sources of climate variability and uncertainty in the region of interest. Although no explicit likelihood is assigned to any of the scenarios, the set of four enables a meaningful assessment of the impact of climate change on many sectors of society. They provide considerable additional detail to the general IPCC conclusions for the region of interest.

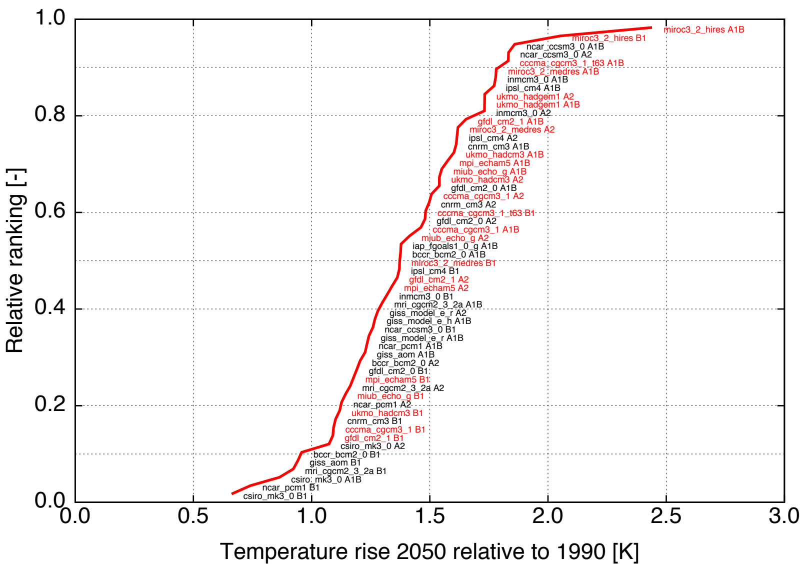


Figure 1. Cumulative frequency distribution of the model-predicted global temperature rise between 1990 and 2050 of all available GCM projections used for AR4, driven by the SRES B1, A1B and A2 emission scenarios.

A modelling chain to construct regional scenarios

In most cases regional climate scenarios are constructed from projections from a limited set of Global Climate Models (GCMS), driven by a few greenhouse gas emission scenarios, and statistically or dynamically downscaled to increase the information content at the regional scale[1,2].

The climate change scenarios for The Netherlands are constructed differently from this general approach[3]. A combination of GCM projections, Regional Climate Model (RCM) results and local observations is used, and a sophisticated set of external scaling factors is derived to cover a major portion of climate variability in the region of interest. Apart from the global mean temperature rise (ΔT_g) the (uncertain) response of the regional atmospheric circulation to global temperature change appeared to be an important external indicator.

A large number of GCM projections has been made available by the Program for Climate Model Diagnosis and Intercomparison (PCMDI) during the preparation of AR4. The (political and socio-economical) relevance of scenarios covering the full range of global temperature rise (+1.1 to +6.4°C in 2100, according to the Summary for Policy Makers (SPM)[4]) is not uniform across this range. Limitation in available adaptation resources, political will and persistence of existing policy generally exclude a serious consideration of very extreme scenarios with a relatively low probability. Scenarios are developed for two values of ΔT_g in 2050 relative to 1990 (being +1 and +2 °C), which optimizes a sufficiently wide range with only a few outlying GCM projections (see Figure 1) and is consistent with previous scenarios[5]. Up to 2050, differences in GCM projections of ΔT_g are mainly associated with uncertainty about the climate sensitivity, and less with variations between greenhouse gas (GHG) emission scenarios.

In West Central Europe, variations in the frequency distribution of the seasonal mean atmospheric circulation patterns explain a major part of the variability of the seasonal mean temperature[6]. Systematic

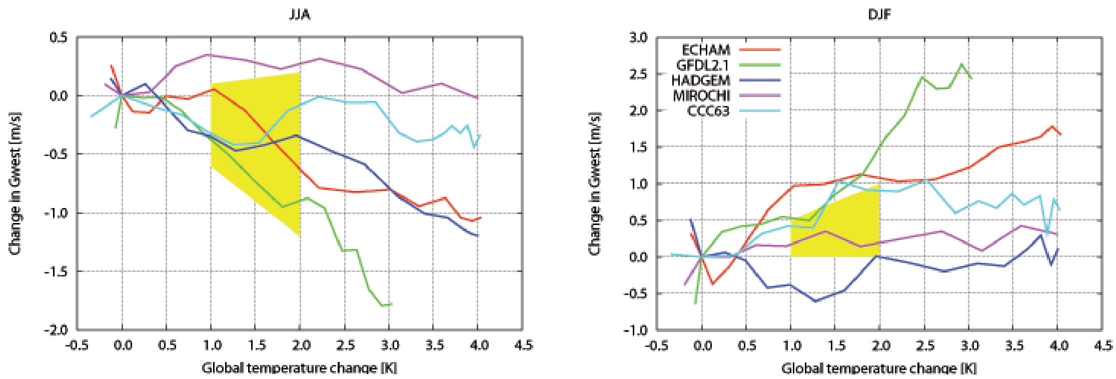


Figure 2. Change in mean westward geostrophic flow Gw as function of the simultaneous change in global temperature (ΔT_g) for the five GCMs considered for (left) JJA and (right) DJF. Shown are transient A1b emission scenario simulations between 2000 and 2100. The coloured shapes span the scenario values of ΔG_W and ΔT_g.

Systematic changes in circulation, for instance, impact strongly on the likelihood of extreme dry summer conditions

changes in circulation, for instance, impact strongly on the likelihood of extreme dry summer conditions[7]. Many state-of-the-art GCMS have systematic biases in the frequency distribution of the seasonal mean westward geostrophic flow (G_W)[8]. It is highly questionable whether GCMS with a strong circulation bias over West Central Europe are able to adequately represent the circulation response to global warming. Therefore, the climate change scenarios for The Netherlands are based on a selection of GCMS that most accurately represent the present day circulation on the Northern Hemisphere. Five models passed the selection criteria (ECHAM5, HadGEM1, CGCM3.1, MIROCHI, and GFDL2.1).

The response of the regional circulation to global warming varies widely across the five selected GCMS. MIROCHI forms an example of the GCMS that show only a marginal change of the circulation statistics in both summer and winter, whereas GFDL2.1 represents a regime with a strong increase in the seasonal mean westward geostrophic flow G_W in winter and a decrease in summer (Figure 2). The local effects on precipitation and temperature induced by gradients in land-sea, topography, clouds, snow, soil moisture and vegetation are not represented well in GCMS. Also extreme events are generally not reproduced in the course resolution GCM grid size. In an ensemble of 10 selected RCM runs from the EU 5th Framework Programme PRUDENCE project[9] the desired scenario range (ΔT_g of +1 and +2°C in 2050, small or large change of ΔG_W) was not well covered[10]. In particular, projections with a small change in circulation over Western Europe were not at all present in the collection of simulations due to the limited number of driving GCMS. To extrapolate the results from the available RCM integrations to the global temperature and circulation conditions covered by the scenarios, a two-variable scaling equation was designed by Van Ulden and Van Oldenborgh[8] and Lenderink et al.[11]. The values of ΔG_W in each scenario and season (shown by the coloured shapes in Figure 2) are chosen such that the range of seasonal mean precipitation projected by the GCM ensemble is well covered by the scenarios (Figure 3). The same set of ΔT_g and ΔG_W values are used to generate all temperature and precipitation variables.

Sea level rise projections

In the SPM sea level rise (SLR) projections for 2100 are composed of a quantified contribution from thermal expansion and decreased land ice storage (in a range between 0.18 and 0.59 m), and an extra SLR associated with changes in ice cap dynamics which are too uncertain to be quantified. Like the IPCC assessment, the SLR scenarios for The Netherlands are based on the AR4 GCM archive[12]. The global mean SLR contribution from thermal expansion is derived from the AR4 GCM ensemble using a linear regression plus uncertainty bands on projected ΔT_g. However, a number of additional SLR terms are quantified.

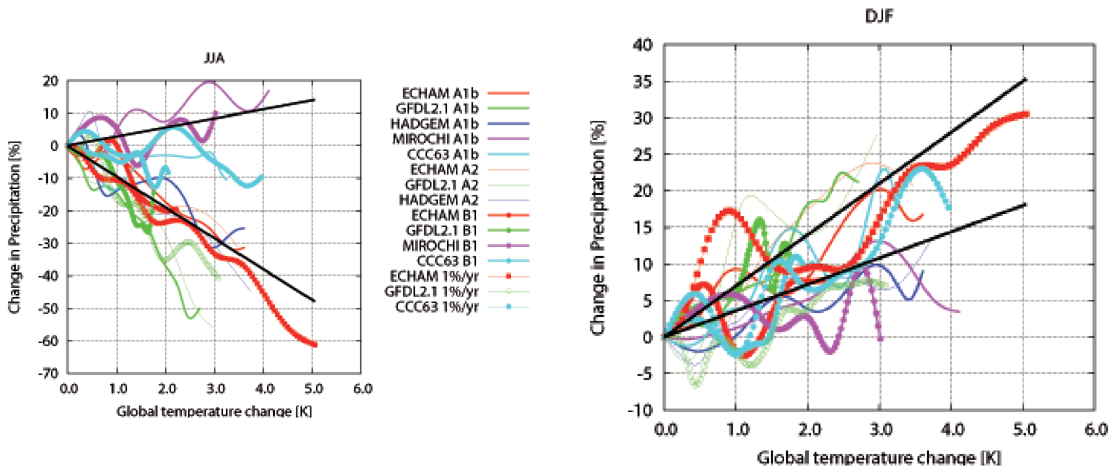


Figure 3. Smoothed projected change of seasonal mean precipitation for (left) JJA and (right) DJF in The Netherlands as function of global mean temperature rise, as simulated for the period 1990-2200 by a selection of AR4 GCM simulations. The black solid lines indicate the scaling relationships used for the two circulation regimes in the scenarios.

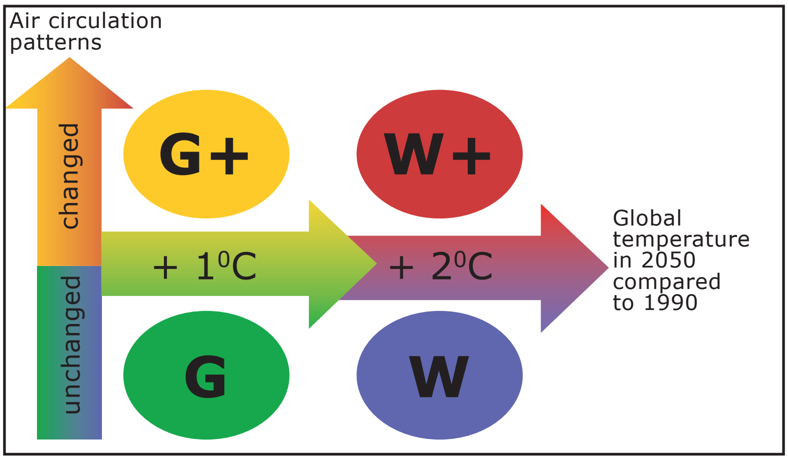
The impact of a relatively fast response of ice sheets to large rises in atmospheric temperature is used to determine the upper bound of the contribution to sea level rise

First, SLR in the eastern North Atlantic basin is projected to be larger than the global mean by most model simulations, which probably is a response to a weakening of the thermohaline circulation[13]. This difference and its uncertainty are assessed by assuming a linear dependence on ΔT_g, based on 25 quality-checked GCM simulations for which local data were available.

Second, a contribution of the Greenland and Antarctic ice sheets (including small glaciers and ice caps around their edges) to SLR is quantified using both model results and recent observations. Estimates of the observed present-day melt rate[14] are combined with observed and modelled dependence of the mass loss on global mean atmospheric temperature. For Antarctica, modelled[15] and observed[16] trends in mass losses are of opposite sign. Therefore the climate sensitivity of this ice sheet is assumed to be zero. For Greenland a positive relation between net mass loss and temperature is adopted. In addition, the impact of a relatively fast response of ice sheets to large rises in atmospheric temperature[17] is used to determine the upper bound of the contribution to sea level rise. As a result, the upper uncertainty band is about 4 times larger than the lower uncertainty band.

Scenarios of the wind regime

In line with the IPCC assessment, projected changes in the wind regime in the region of interest are very uncertain. Although many model projections agree in some aspects (such as the poleward shift of the storm track[18]), they differ with respect to changes of the strength and number of extra-tropical cyclones[19 vs 20]. In The Netherlands there is a need for scenarios for wind speed extremes with a very long return period (10,000 yrs), for coastal defence strategic planning. These extremes cannot be derived from the available GCM results without considerable statistical extrapolation. Instead, changes in 'moderate' wind extremes (daily mean wind exceeded once per year) are derived from the AR4 GCM archive. As for the temperature and precipitation scenarios, two regimes of circulation change are discerned, but additional downscaling with RCMs did not prove to add significant information on the variable of interest. The projected changes are small in comparison with the natural variability of the extreme wind speed.



G	Moderate*	1°C temperature rise on earth in 2050 compared to 1990 no change in air circulation patterns in Western Europe
G+	Moderate +	1°C temperature rise on earth in 2050 compared to 1990 + milder and wetter winters due to more westerly winds + warmer and drier summers due to more easterly winds
W	Warm	2°C temperature rise on earth in 2050 compared to 1990 no change in air circulation patterns in Western Europe
W+	Warm +	2°C temperature rise on earth in 2050 compared to 1990 + milder and wetter winters due to more westerly winds + warmer and drier summers due to more easterly winds

Figure 4. Schematic overview of the four KNMI'06 climate scenarios. For explanation see the legend below.

		G	G+	W	W+
Global temperature rise		+1°C	+1°C	+2°C	+2°C
Change in air circulation patterns		no	yes	no	yes
Winter [3]	average temperature	+0.9°C	+1.1°C	+1.8°C	+2.3°C
	coldest winter day per year	+1.0°C	+1.5°C	+2.1°C	+2.9°C
	average precipitation amount	+4%	+7%	+7%	+14%
	number of wet days (≥ 0.1 mm)	0%	+1%	0%	+2%
	10-day precipitation sum exceeded once in 10 years	+4%	+6%	+8%	+12%
	maximum average daily wind speed per year	0%	+2%	-1%	+4%
Summer [3]	average temperature	+0.9°C	+1.4°C	+1.7°C	+2.8°C
	warmest summer day per year	+1.0°C	+1.9°C	+2.1°C	+3.8°C
	average precipitation amount	+3%	-10%	+6%	-19%
	number of wet days (≥ 0.1 mm)	-2%	-10%	-3%	-19%
	daily precipitation sum exceeded once in 10 years	+13%	+5%	+27%	+10%
	potential evaporation	+3%	+8%	+7%	+15%

Table 1. KNMI'06 scenarios for 2050.
See www.knmi.nl/climatescenarios for more details.

Conclusion

The results of the 4 scenarios are presented in Table 1. An overview of the scenario structure is given in Figure 4.
The construction of the scenarios is carried out by a considerable selection, weighing, scaling and grouping of GCM results to sharpen the broad IPCC assessment into a set of relevant, plausible and internally consistent climate change scenarios for The Netherlands. Uncertainties regarding emission scenarios, lack of understanding of the climate system, internal climate variability, and regional detail all have been included in the scenarios. Yet, a future generation of climate change scenarios may possibly be very different from the present set, since a great deal of known and (yet) unknown uncertainties (like major feedback processes involving the carbon cycle, dynamic vegetation and ice cap dynamics) are still not fully captured in the GCM results.

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