CLIMATE SCENARIOS IRMA AND PERSPECTIVES

G.P. Können

Royal Netherlands Meteorological Institute (KNMI),

De Bilt, Netherlands

EXPLANATION CLIMATE SCENARIOS IRMA

1. The scenarios are the same as those of WB21, NW4 and previous greenhouse scenarios formulated by KNMI [1-3]. These scenarios are augmented by a scenario for a sudden climate change induced by a change in ocean circulation [4].
2. The precipitation scenarios are based on the empirical relation between precipitation (on wet days) and daily mean temperature, as observed at the Dutch station De Bilt [5,6]. Temperature and precipitation change are uniquely related in these scenarios. The scenarios are assumed to be valid for the entire Rhine/Meuse catchment. GCM results do not contradict this assumption. Under the assumption that the probability density function of atmospheric circulation is insensitive for climate change, estimates about the changes in recurrence periods of extreme events can also be obtained.
3. The classical estimates consist of a low estimate, a central estimate and a high estimate. The range between the low and high estimates is supposed to cover the model- and emission uncertainty. As working hypothesis it is assumed that for Europe the range between the low and high temperature estimate represents an 80% confidence interval [1]. In WB21 [2] the low, central and high estimates are referred too as trend, worse and extreme, respectively.
4. As central estimate for Europe a temperature change of +2 °C for 2100 with respect to 1990 is adopted; the lower and high estimates being +1 °C and + 4 °C, respectively (Tables 1-3). The estimates for Europe are the same as the rounded IPCC SAR estimates [7] of global warming.
5. The high IPCC TAR [8] 2100-estimate of global warming of 5.8 °C is 1.2 °C higher than the high SAR (constant aerosols) [7] estimate of 4.6 °C (reference year 1990). About half of this difference can be attributed to differences in the high emission scenario's between SAR and TAR, and half to differences in the modeling of the carbon cycle [9]. GCM improvements have only a minor effect on the TAR-SAR difference. Note that the central estimate of TAR of about 2.5 °C remained virtually unchanged with respect to the SAR constant-aerosol estimate.
6. Although the TAR widened the range of global warming, there are no reasons to change the range for Europe accordingly. This holds in particular for precipitation. There are four reasons for this:
   i. The inherent larger uncertainty of regional climate projections combined with the fact that the temperature response of region Europe (region NEU of TAR [8]) to global warming is small with respects to other TAR-regions.
   ii. Downscaling of the output of extreme GCMs to precipitation may produce less realistic results than those of moderate GCMs.
   iii. Downscaling using the empirical temperature-precipitation relation requires an extrapolation far outside the domain of this relation. This means a lack viz. absence of temporal analogue situations. Similarly, a spatial analogue of a ≈6 °C temperature increase would be located in Spain, which is too far south and too far outside the jet stream to serve as a plausible analogue for our region.
   iv. An extrapolation of the precipitation scenario based on the temperature-precipitation relation (Tables 1-2) to a 5.8 °C temperature rise would lead to an increase in precipitation that is outside the range in the regional TAR [8] projections for Europe.
7. If one, despite of points 6 i-iv, regards the increase from 4.6 to 5.8 °C in the upper estimate of global temperature as a relevant factor for the European region, then there are two ways to incorporate its effect on temperature and precipitation on Europe:
   i. The first and preferred method is to incorporate its effect on Europe as a lowering of the confidence interval from 80% (point 3) to e.g. 70%, while maintaining the +1 °C, +2 °C, and +4 °C temperature estimates and their associated precipitation estimates in the wet scenarios for 2100 (Tables 1-3).
   ii. The second though less attractive (see point 6 i) strategy is to adopt new high temperature estimates of +3 °C and +6 °C for 2050 and 2100, respectively. In this new high estimate scenario, the +4 °C level is reached in about 2070.

      In the 0-4 °C range (2000-2070), precipitation in the wet scenarios can be linked to temperature according to Tables 1-3. In the perspective of point 6 iii-iv above, it is recommended to keep precipitation constant from the point where the temperature rises exceeds +4 °C (hence no change from 2070 onward).

Evaporation can be assumed to remain linear with temperature [10], hence increasing to 24% for a 6 °C temperature rise.

iii. In any case we advise against extrapolating directly the temperature-based precipitation estimates from of Tables 1-3 into the range +4 °C to +5.8 °C viz. +6 °C (see points 6 ii-iv).

iv. Given the consistency between the SAR and TAR central estimates of global warming (point 5, above), we recommend to maintain the central and lower estimates for 2050 and 2100 in Tables 1-3.

8. For WB21 [2] a dry scenario is presented, where temperature and precipitation change are uncoupled. It is assumed in that scenario that the frontal precipitation amount decreases by 10%. In Tables 1 and 2, the dry scenario is presented in combination with the high estimate of the temperature. In this combination it is plausible (but unproved) to assume that the convective precipitation amounts for 2100 remain unchanged and that the probability for high wind speeds decreases.
9. The return periods of extreme events (Table 3) for the wet and dry scenario's are estimated under the (unproven) assumption that the number of wet days remains the same. Without such an assumption the return periods cannot be determined.
10. Evaporation: these numbers appeared for the first time in WB21 [2] and are based on a study by Riza [11].
11. Gales: As in NW4 [1] and WB21 [2] a margin of ±5% is advised in wind speed and gale intensities. This because of lack of signal in wind speed in the GCMs and lack of signal in extreme gale intensity and frequency in long KNMI GCM ECBilt simulations. This recommended margin equals the observed decadal variability in the past century [3].
12. Sea level rise: these are the IPCC estimates, supplemented with the natural trend and subsidence of the Netherlands.
13. The Tables are completed by a scenario forced by a change in the Atlantic thermohaline circulation. This 'sudden surprise' scenario is not bound to a predictable moment and will not evolve linearly in time. According to a KNMI study [4] an ocean cooling of X °C results in first order in an atmospheric cooling of about 0.5X °C. This result is obtained under the assumption of unchanged atmospheric circulation. The cooling is with respect of the climate of that moment. The transition in the oceanic circulation is estimated to be completed in 5-10 year.
14. Details thermohaline circulation scenario:
    i. Temperature: Assuming a worst-case cooling of 4 °C of the ocean and an unchanged atmospheric circulation results in a season-independent cooling of 2 °C of the Netherlands. Extreme hot days in the summer and extreme cold days in the winter maintain their probability of occurrence. Hence the day-to-day variability increases in summer but decreases in winter.
    ii. Precipitation: unclear what will happen. The best is to base an estimate on the temperature-precipitation relation. This means that, if the event would occur now, the change in precipitation is equal to that of the +2° C/wet scenario but with reversed sign. The possibility remains open to uncouple precipitation from temperature and to postulate an increase of e.g. 5% in precipitation.
    iii. Time scale of the transition: it is reasonable to relate a time scale of the 5-10 year to the transition.
    iv. Timing: it could happen at any moment. Its effect should be superposed on the climate at the moment of the event. So: suppose it happens in 2050 and the (greenhouse-forced) climate has evolved according to the high estimate (+2 °C), then the mean temperature will be as present. But the annual course in extremes will be different, see above.
    v. Sea level rise: this is unaffected by this (regional) effect.
    vi. Gales: within this scenario they are not a subject of change (given the assumption of an unchanged atmospheric circulation).

vii. Return periods extreme precipitation: these should be calculated from the Gumbel statistics adopting the total climate change of that moment (greenhouse and thermohaline). If the change in thermohaline circulation would occur now and would be instantly, the return periods t can be obtained from the +2 °C scenario: $t(-2°C)/t(0°C) = t(0°C)/t(+2°C)$

Climate scenarios and the Perspectives:

The climate scenarios have been related to so-called ‘Perspectives’. The Perspectives method developed by the TARGETS research group at RIVM [12], forms the basis of the integrated scenarios established for the present NRP and IRMA-SPONGE studies. A perspective is a consistent description of the perceptual screen through which people interpret the world, and which guides them in acting. A perspective can be focusing on environment (Egalitarian), control (Controllist/Hierarchist), or economy (Individualist). The interpretation of these perspectives in the context of water management in the Rhine and Meuse basins is given in [13].

1. Egalitarian (perspective focusing on environment): considers the largest bandwidth of the climate change, in which temperature (T) and precipitation (P) are uncoupled. In the warm/wet and the warm/dry greenhouse scenarios this leads to dT between 1 and 4°C, and to dP between –10 and +40% for 2100. These numbers represent the largest (absolute) numbers in Table 2, columns 4 and 6. The bandwidths are enhanced by considering an imminent change in thermohaline circulation. This scenario results in dT of –2 to 0°C and dP of –20%-0% in the near future. For 2100 it results in a full range of dT between –1 and +4°C and for dP between –10 and +40%.
2. Controllist/Hierarchist (perspective focusing on control): one would expect the Controllist to count with the worst-case = high estimate and to apply this on the long-term plans. Here no-regret strategies take a 50-year time horizon into account. Nevertheless we assume that the Controllist adopts the central estimate rather than the high estimate. The reason is that RWS, being a typical example of a Controllist, yet adopts a 60-cm sea level rise for 2100 in accordance with the +2 degree scenario. Typical for the attitude of the Controllist is his tendency to investigate everything over and over again, which makes it difficult to come to a real decision. This is another indication that the extreme scenario does not fit always the Controllist.
3. Individualist (perspective focusing on economy): estimates potential losses, but takes usually the depreciation and investments into account. In most cases his time horizon is only of order 10 year. Within that time horizon, a temperature rate of 1°C in 50 year is not relevant and the Individualist will not incorporate climate change. Only for planning of a big investment with a long depreciation, climate change effects will be taken into account according to the central estimate. Perhaps augmented with a calculation of the risk of a sudden surprise, i.e. a climate change induced by a change in thermohaline circulation.

Table 1: Scenarios for 2050

	present	low estimate wet	central wet	high est. wet	change N-Atl circ*	high est. dry
temperature		+ 0.5 ^{0}C	+ 1 ^{0}C	+ 2 ^{0}C	- 2 ^{0}C	+ 2 ^{0}C
yearly precipitation, Netherlands	700 à 900 mm	+ 1.5 %	+ 3 %	+ 6 %	- 6 %	- 10 %
total summer precipitation , Netherlands	350 à 475 mm	+ 0.5 %	+ 1 %	+ 2 %	- 2 %	- 10 %
total winter precipitation, Netherlands	350 a 425 mm	+ 3 %	+ 6 %	+ 12 %	- 12 %	- 10 %
precipitation intensities in showers		+ 5 %	+ 10 %	+ 20 %	- 20 %	- 10 %
10-day precipitation sum winter Netherlands	amount depends on return period, see table 3	+ 5 %	+ 10 %	+ 20 %	- 20 %	- 10 %
10-day precipitation sum winter Belgium	amount depends on return period, see table 3	+ 5 %	+ 10 %	+ 20 %	- 20 %	- 10 %
evaporation summer, Netherlands	540 à 600 mm	+ 2 %	+ 4 %	+ 8 %	- 8 %	+ 8 %
evaporation winter, Netherlands	(ca. 100 mm)	+ 2 %	+ 4 %	+ 8 %	- 8 %	+ 8 %
evaporation year, Netherlands	620 à 720 mm	+ 2 %	+ 4 %	+ 8 %	- 8 %	+ 8 %
absolute sea level rise, NL		+ 10 cm	+ 25 cm	+ 45 cm	-	+ 45 cm
absolute rise high tide, NL		+ 12.5 cm	+ 27.5 cm	+ 47.5 cm	-	+ 47.5 cm
absolute rise low tide, NL		+ 7.5 cm	+ 22.5 cm	+ 42.5 cm	-	+ 42.5 cm
wind speed and gales, NL		+/- 5 %	+/- 5 %	+/- 5 %	-	0 to - 10%

Table 2: Scenario's for 2100

	present	low estimate wet	central wet	high est. wet	change N-Atl circ*	high est. dry
temperature		+ 1 ^{0}C	+ 2 ^{0}C	+ 4 ^{0}C	- 2 ^{0}C	+ 4 ^{0}C
yearly precipitation, Netherlands	700 à 900 mm	+ 3 %	+ 6 %	+ 12 %	- 6 %	- 10 %
total summer precipitation, Netherlands	350 à 475 mm	+ 1 %	+ 2 %	+ 4 %	- 2 %	- 10 %
total winter precipitation, Netherlands	350 a 425 mm	+ 6 %	+ 12 %	+ 25 %	- 12 %	- 10 %
precipitation intensities in showers		+ 10 %	+ 20 %	+ 40 %	- 20 %	0 %
10-day precipitation sum winter Netherlands	amount depends on return period, see table 3	+ 10 %	+ 20 %	+ 40 %	- 20 %	- 10 %
10 day precipitation sum winter Belgium	amount depends on return period, see table 3	+ 10 %	+ 20 %	+ 40 %	- 20 %	- 10 %
evaporation summer, NL	540 à 600 mm	+ 4 %	+ 8 %	+ 16 %	- 8 %	+ 16 %
evaporation winter, NL	(ca. 100 mm)	+ 4 %	+ 8 %	+ 16 %	- 8 %	+ 16 %
evaporation year, NL	620 à 720 mm	+ 4 %	+ 8 %	+ 16 %	- 8 %	+ 16 %
absolute sea level rise, NL		+ 20 cm	+ 60 cm	+ 110 cm	-	+ 110 cm
absolute rise high tide, NL		+ 25 cm	+ 65 cm	+ 115 cm	-	+ 115 cm
absolute rise low tide, NL		+ 15 cm	+ 55 cm	+ 105 cm	-	+ 105 cm
wind speed and gales, NL		+/- 5 %	+/- 5 %	+/- 5 %	-	0 to - 10%

*** Climate changes due to change in the thermohaline circulation of the N-Atlantic are presented with respect to the climate when the change occurs. This type of change becomes mature in 5-10 yr.**

Table 3: Heavy precipitation

	2050 low est. wet	2050 central 2100 low est. wet	2050 high est. 2100 central wet	2100 high est. wet	change N-Atl circ. *	2050 high est. dry	2100 high est. dry
Temperature	0.5°	1^0	2^0	4^0	-2^0	2^0	4^0
24 -hour precipitation, Netherlands	+ 1.5 % assuming unchanged wet-day frequency	+ 3 % assuming unchanged wet-day frequency	+ 6 % assuming unchanged wet-day frequency	+ 12 %	- 6 % with respect to the climate at that time.	- 10 %	- 10%
return period 1 yr (34mm) return period 10 yr (53 mm) return period 100 yr (73 mm)	0.95 yr 9 yr 90 yr	0.9 yr 8 yr 78 yr	0.8 yr 7 yr 62 yr	0.65yr 5 yr 40 yr		1.6yr 17 yr 200 yr	1.6 yr 17 yr 200 yr
10-day precipitation sum, winter Netherlands	+ 5 % assuming unchanged wet-day frequency	+ 10 % assuming unchanged wet-day frequency	+ 20 % assuming unchanged wet-day frequency	+ 40 %	-20 % with respect to the climate at that time.	-10 %	- 10%
return period 1 yr (62 mm) return period 10 yr (98 mm) return period 100 yr (136 mm)	0.85 yr 8 yr 75 yr	0.7 yr 6 yr 47 yr	0.5 yr 5 yr 25 yr	0.3 yr 2 yr 9 yr		1.5 yr 17 yr 200 yr	1.5 yr 17 yr 200 yr
10-day precipitation sum, winter Belgium (Visé)	+ 5% assuming unchanged wet-day frequency	+ 10 % assuming unchanged wet-day frequency	+ 20 % assuming unchanged wet-day frequency	+ 40 %	-20 % with respect to the climate at that time.	- 10%	- 10%
return period 1 yr (79 mm) return period 10 yr (117 mm) return period 100 yr (147 mm)	0.85 yr 8 yr 75 yr	0.7 yr 5 yr 32 yr	0.5 yr 3 yr 14 yr	0.35yr 2 yr 5 yr		1.5 yr 20 yr 300 yr	1.5 yr 20 yr 300 yr

*** In case of climate changes due to a change in the thermohaline circulation of the N-Atlantic within 10-20 years from now, an estimate of the return periods *t* can be obtained from the formula *t*(-2°C)/t(0°C)=*t*(0°C)/*t*(+2°C). If the change occurs later in the 21st century, the return periods *t* should be estimated from the total temperature change with respect to present (greenhouse + NA circ.)**

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