Water resources and climate change

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## Projected Impacts of Climate Change

<table>
<thead>
<tr>
<th>Global temperature change (relative to pre-industrial)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°C</td>
</tr>
<tr>
<td>1°C</td>
</tr>
<tr>
<td>2°C</td>
</tr>
<tr>
<td>3°C</td>
</tr>
<tr>
<td>4°C</td>
</tr>
<tr>
<td>5°C</td>
</tr>
</tbody>
</table>

### Food
- **0°C**: Falling crop yields in many areas, particularly developing regions
- **1°C**: Possible rising yields in some high latitude regions
- **2°C**: Falling yields in many developed regions

### Water
- **0°C**: Small mountain glaciers disappear – water supplies threatened in several areas
- **1°C**: Significant decreases in water availability in many areas, including Mediterranean and Southern Africa
- **2°C**: Sea level rise threatens major cities

### Ecosystems
- **0°C**: Extensive Damage to Coral Reefs
- **1°C**: Rising number of species face extinction

### Extreme Weather Events
- **0°C**: Rising intensity of storms, forest fires, droughts, flooding and heat waves

### Risk of Abrupt and Major Irreversible Changes
- **0°C**: Increasing risk of dangerous feedbacks and abrupt, large-scale shifts in the climate system

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### Extremes - IPCC-AR4, WG1 report (IPCC, 2007)

<table>
<thead>
<tr>
<th>Phenomenon and direction of trend</th>
<th>Likelihood that trend occurred in late 20th century (typically post 1960)</th>
<th>Likelihood of a human contribution to observed trend</th>
<th>Likelihood of future trends based on projections for 21st century using SRES scenarios</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warmer and fewer cold days and nights over most land areas</td>
<td>Very likely</td>
<td>Likely</td>
<td>Virtually certain</td>
</tr>
<tr>
<td>Warmer and more frequent hot days and nights over most land areas</td>
<td>Very likely</td>
<td>Likely (nights)</td>
<td>Virtually certain</td>
</tr>
<tr>
<td>Warm spells/heat waves. Extreme heat events over most land areas</td>
<td>Likely</td>
<td>More likely than not</td>
<td>Likely</td>
</tr>
<tr>
<td>Heavy precipitation events. Frequency (or proportion of total rainfall from heavy falls) increases over most areas</td>
<td>Likely</td>
<td>More likely than not</td>
<td>Very likely</td>
</tr>
<tr>
<td>Area affected by droughts increases</td>
<td>Likely in many regions since 1970s</td>
<td>More likely than not</td>
<td>Likely</td>
</tr>
<tr>
<td>Intense tropical cyclone activity increases</td>
<td>Likely in some regions since 1970</td>
<td>More likely than not</td>
<td>Likely</td>
</tr>
<tr>
<td>Increased frequency of extreme high sea level (excludes tsunamis)</td>
<td>Likely</td>
<td>More likely than not</td>
<td>Likely</td>
</tr>
</tbody>
</table>
FIGURE SPM-6. Relative changes in precipitation (in percent) for the period 2090–2099, relative to 1980–1999. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). White areas are where less than 66% of the models agree in the sign of the change and stippled areas are where more than 90% of the models agree in the sign of the change.
Precipitation
Regions of disproportionate changes in heavy (95th) and very heavy (99th) precipitation

Proportion of heavy rainfalls: increasing in most land areas
Trends in heavy precipitation, see: eca.knmi.nl

(Klein Tank & Können, J.Climate, 2003)
Drought trends in the continental U.S.

- 1925-2003 period selected to account for model initialization effects
- Positive trends dominate (~28% of model domain vs ~1% negative trends)
Precipitation to runoff

Precipitation

Discharge

urbanized area

rural area

Time
Climate change scenarios – impact on flows

Percentage change in flows for the 20-year return period

Areas of increase

Areas of decrease
Box 11.1, Figure 2

Impact on precipitation: means and extremes

IPCC, 2007
Glacier melt in the Himalayas
Drivers of Global Change:

- Increasing population
- Increasing water consumption
- Land cover/use change
- Increasing greenhouse gases
Worldwide Water Use by Region

- Europe
- North America
- Africa
- Asia
- South America
- Australia & Pacific
Human modification of hydrological systems

Figure 1: Mean seasonal hydrographs of the Columbia River prior to (blue) and after the completion of reservoirs at the Dalles, OR.
Cropland expansion (de facto deforestation)


Percentage of global land area:

- 1700: 3
- 1992: 14

**Cropland (fraction)**
Global Reservoir Database
Location (lat./lon.), Storage capacity, Area of water surface,
Purpose of dam, Year of construction, …

Visual courtesy of Kuni Takeuchi
Background: Irrigated areas

- Irrigated areas, globally:
  - $2.8 \times 10^6$ km$^2$
  - 2% of global land area
- Location of irrigated areas:
  - Asia: 68%
  - America: 16%
  - China, India, USA: 47%
- Irrigation: 60-70 % of global water withdrawals (Shiklomanov, 1997)
Change in Water Availability

(Climate Normal – 2050s) Impact of Climate Change

Hot Spots

Change in average annual water availability
2050s, ECHAM4/OPYC3, A2 scenario to climate normal 1961-90

Percentage change
-50 -25 -5 5 25 50 no data
Change in magnitude of 100-year droughts
The times they are a-changin’

We expect an intensification of the hydrological cycle – with increasing intense rainfalls and droughts – generally the dry areas get drier and wet areas get wetter.

We are already seeing an increase in intense rainfalls and droughts

The response of rivers is complicated by the characteristics of the catchments and man’s activities

There has been a huge increase in dams, agricultural areas, irrigation, groundwater extraction etc – these currently dominate the climate change signal on water resources

In the future the increasing exploitation and scarcity of water resources will be exacerbated by climate change
Future priorities

Improved monitoring of the hydrological system

Regional integrated studies – including extremes and feedbacks

Consistent databases and models of the hydrological/biosphere system
Change in runoff

2055

HadCM3 (A2a)

ECHAM4/OPYC

CGCM2

GFDL_R30

Legend:
- < -30
- -30 to -20
- -20 to -10
- -10 to 0
- 0 to 10
- 10 to 20
- 20 to 30
- > 30
Critical regions exhibiting (i) a decrease in the return period of the current 100-year drought to 50 years or less and (ii) a 10% increase in today’s water stress which leads to a future w.t.a. ratio greater than 0.4. Calculated with WaterGAP 2.1 applying the HadCM3 climate model and Baseline-A water use scenario for the 2070s.