# Climate Change Impact and Adaptation in Water Sector:
# Cases from Asian Countries

Mukand S. Babel

Water Engineering and Management (WEM)

Asian Institute of Technology (AIT), Thailand

# Outlines

- Facing the facts
- Climate change projections
- Case studies
- Key challenges

# Facing the facts
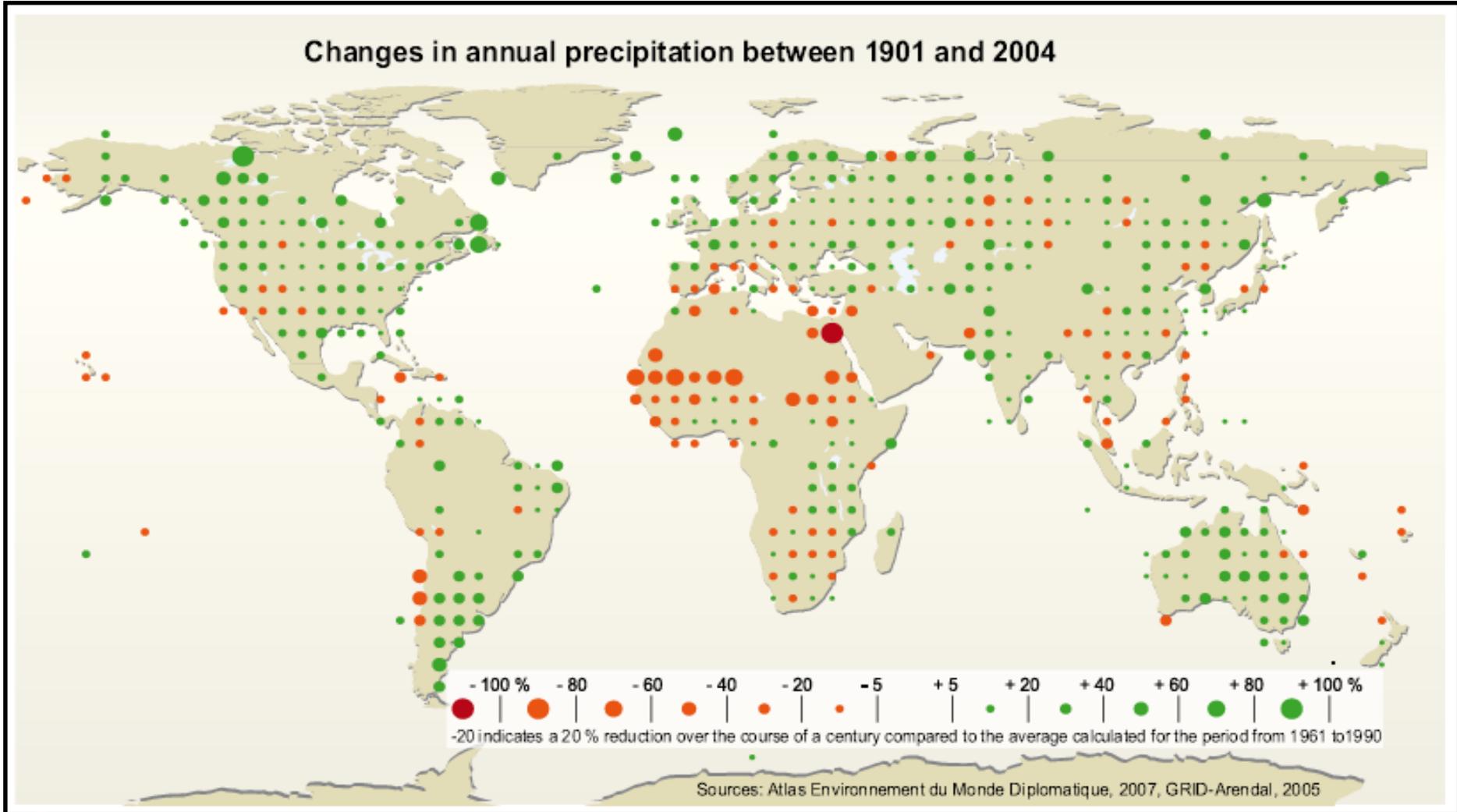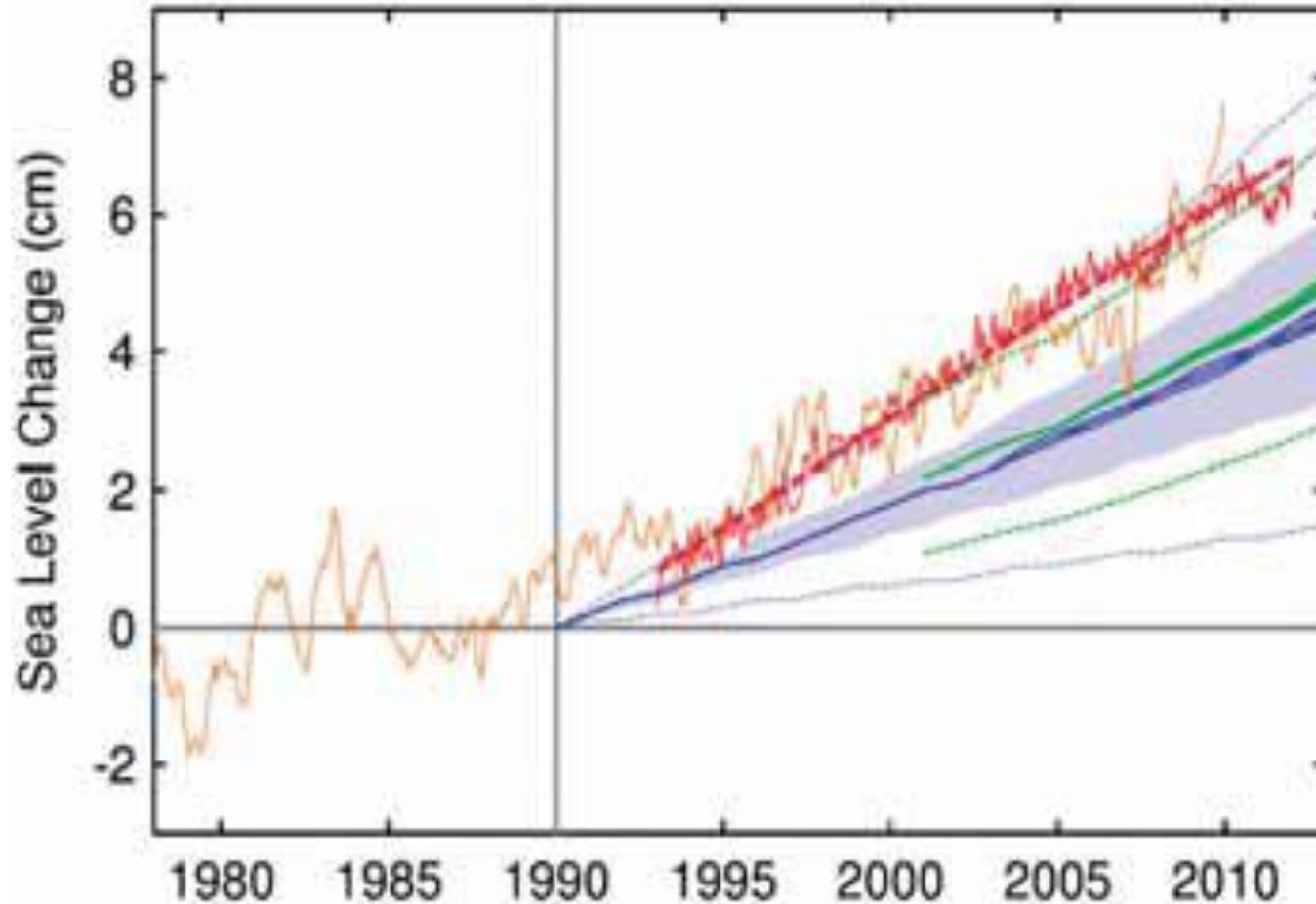
# Facing the facts: Climate change



WMO (2018)

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# Facing the facts

Changes in annual precipitation between 1901 and 2004

-100 %   - 80   - 60   - 40   - 20   - 5   + 5   + 20   + 40   + 60   + 80   + 100 %

-20 indicates a 20 % reduction over the course of a century compared to the average calculated for the period from 1961 to1990

Sources: Atlas Environnement du Monde Diplomatique, 2007, GRID-Arendal, 2005

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# Facing the facts

## Mean Sea Level



Sea levels across the globe have risen in a way consistent with the warming – since 1961 at an average of 1.8 mm per year, and since 1993 at 3.1 mm per year.
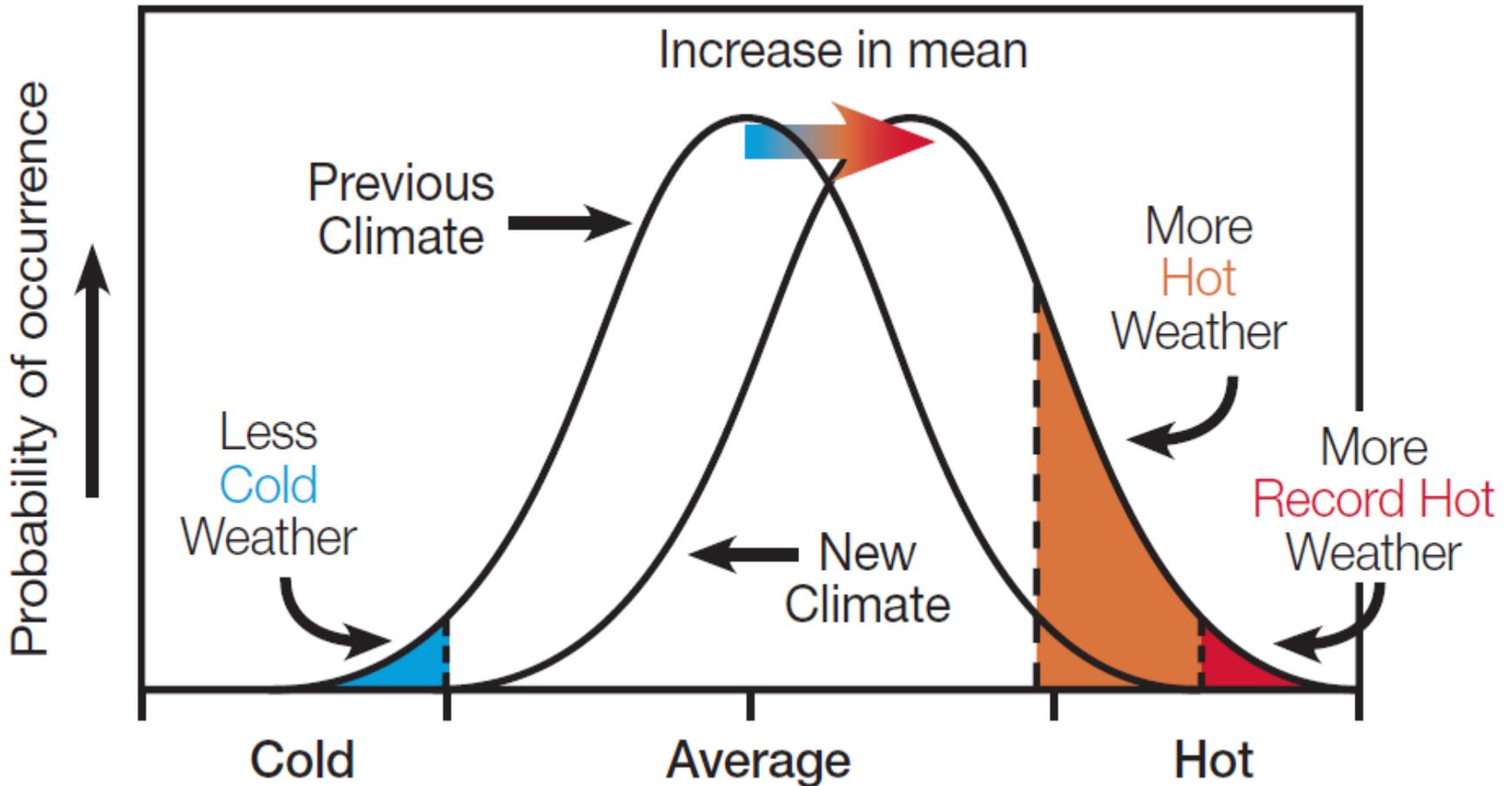
Merrifield et al., 2009:

[1993–2008] $(3.5 \pm 0.4)$ mm/yr

IPCC 2007:

[1993–2003] $(3.1 \pm 0.7)$ mm/yr

Source: World Bank (2013)
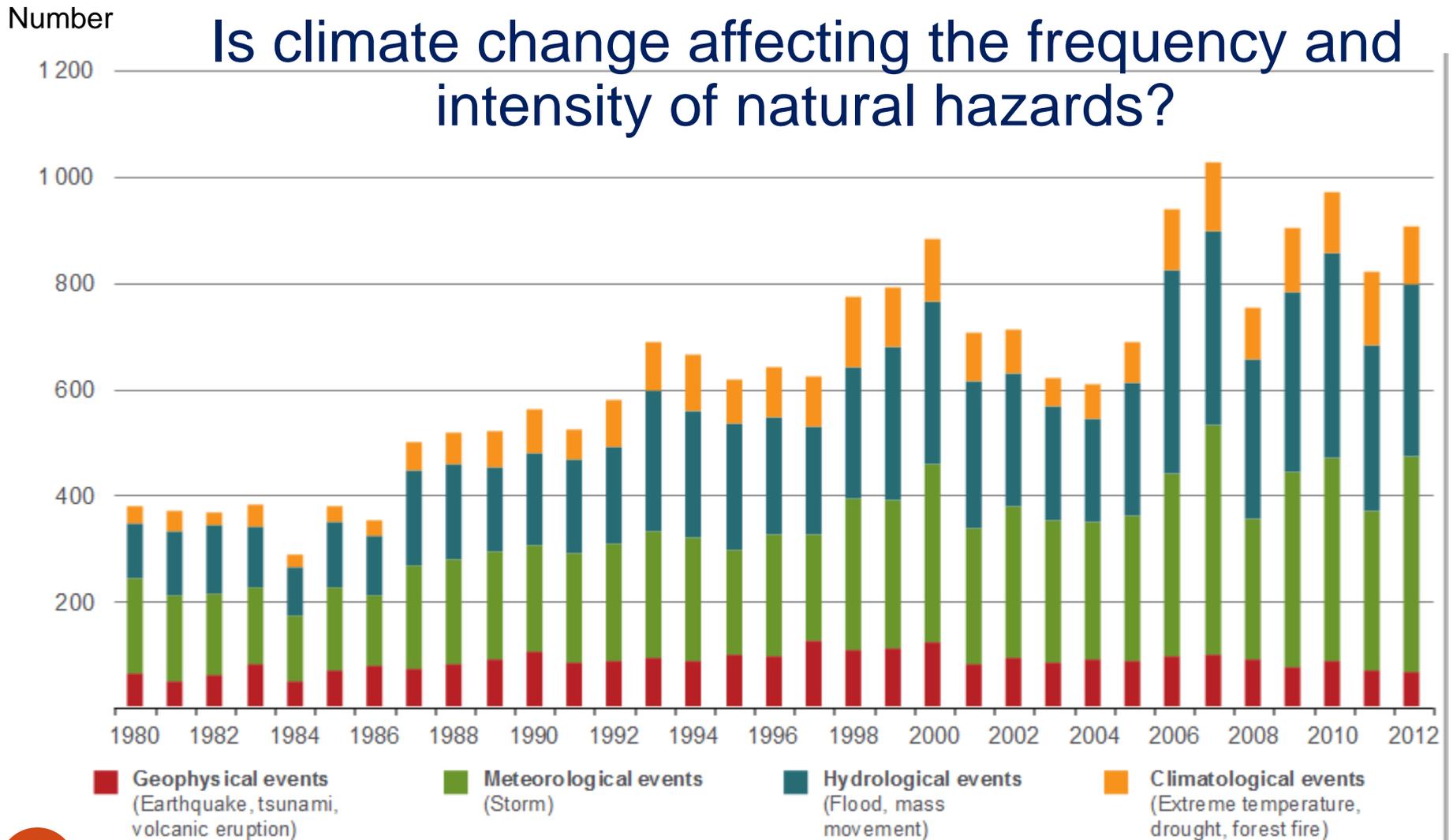
# Facing the facts

Effect of increase in average temperature on extreme temperature



Source: IPCC (2012)

# Facing the facts

## Catastrophes and extreme events

## Is climate change affecting the frequency and intensity of natural hazards?



Source: Munich RE (2012)
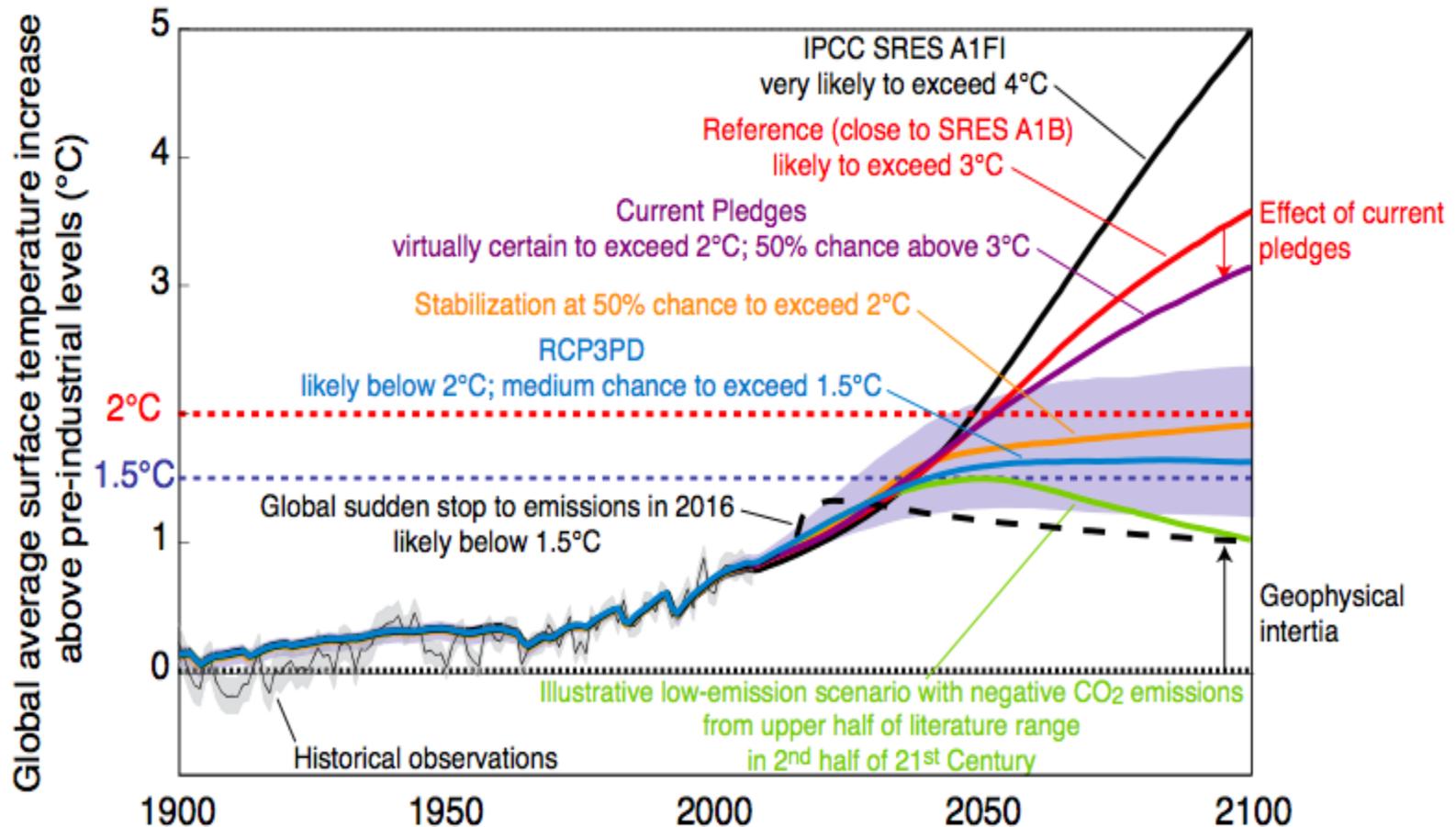
# Facing the facts

## Record breaking meteorological events in the last decade

| Region | Meteorological record breaking event | Confidence in attribution to climate change | Impact costs |
|---|---|---|---|
| England and Wales (2000) | Wettest autumn since 1766 [1] | Medium [2,3] | £ 1.3 Billion [2] |
| Europe (2003) | Hottest summer in 500 years [4] | High [5,6] | Death toll >70,000 [7] |
| Pakistan (2010) | Rainfall records [8] | Low to medium [9,10] | Worst flooding in its history; 3000 deaths; 20M people affected [11] |
| Eastern Mediterranean and Middle East (2008) | Driest winter since 1902 | High [12] | Substantial damage to cereal production [13] |
| 4 US states (TX, OK, NM, LA) (2011) | Summer heat and drought since 1880 [14] | High [14] | Wildfires burning 3 M acres (preliminary impact of $6 to $8 B) [15] |

Source: World Bank (2012)

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[1] Alexander and Jones (2001)  [2] Min et al. (2011)  [3] Kay et al. (2011)  [4] Luterbacher (2004)  [5] Della-Marta et al. (2007); Stott et al. (2004)  [6] Coumou et al. (in review);  Hansen et al. (2012)  [7] Robine et al. (2008)  [8] Webster et al. (2011)  [9] Trenberth et al. (2012);  [10] Lau and Kim (2012);  [11] Hong et al. (2011);  [12] Hoerling et al. (2012);  [13] Ricardo et al. (2010);  [14] Rupp et al. (2012);  [15] NOAA (2011)

# Climate change projections

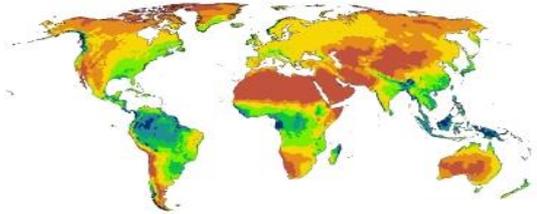# Global projections: Temperature



Even with the current mitigation commitments and pledges fully implemented, there is a 20% likelihood of exceeding 4°C by 2100. 50% chance of temperature rise above 3°C by 2100.

Source: World Bank (2012)

# Global projections: Precipitation

For RCP8.5, global precipitation over land increase in most of the regions during 2070-2099 from period 1971-2000. The relative increase of 99–111%, is also projected in some regions of Africa.

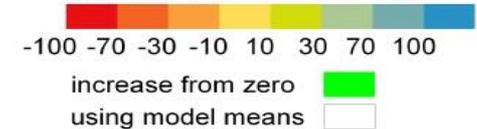Differences exist in GCM projections in direction as well as magnitude of change.
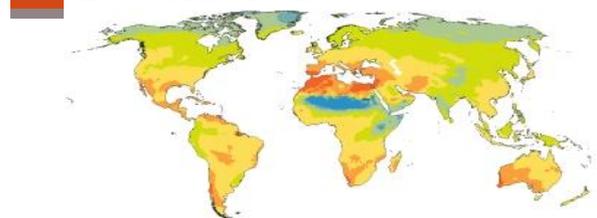


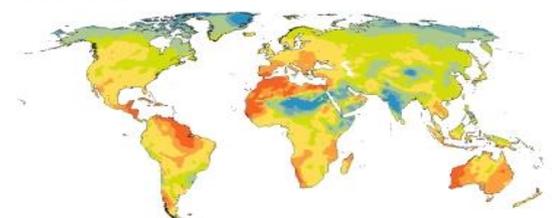(a) GCM mean 1971-2000

(a) Precipitation in mm/yr
250 500 1000 1500 2000 3000 7546

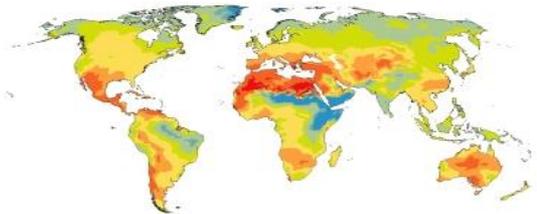(b) Precipitation change in %
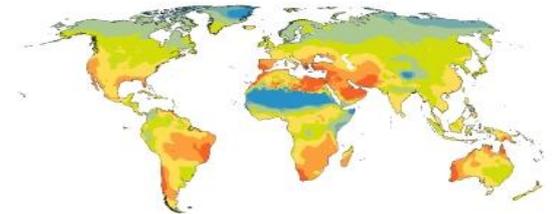-100 -70 -30 -10 10 30 70 100
increase from zero
using model means

(b) GCM mean 2070-2099

HadGEM2-ES

IPSL-CM5A-LR

MIROC-ESM-CHEM

GFDL-ESM2M

NorESM1-M

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Source: Portmann et al. (2013)
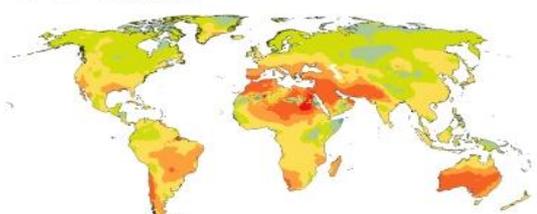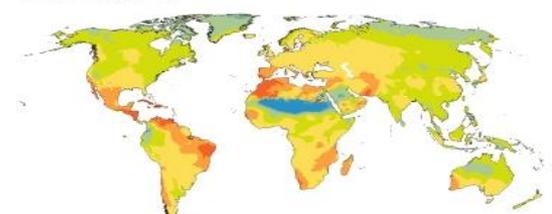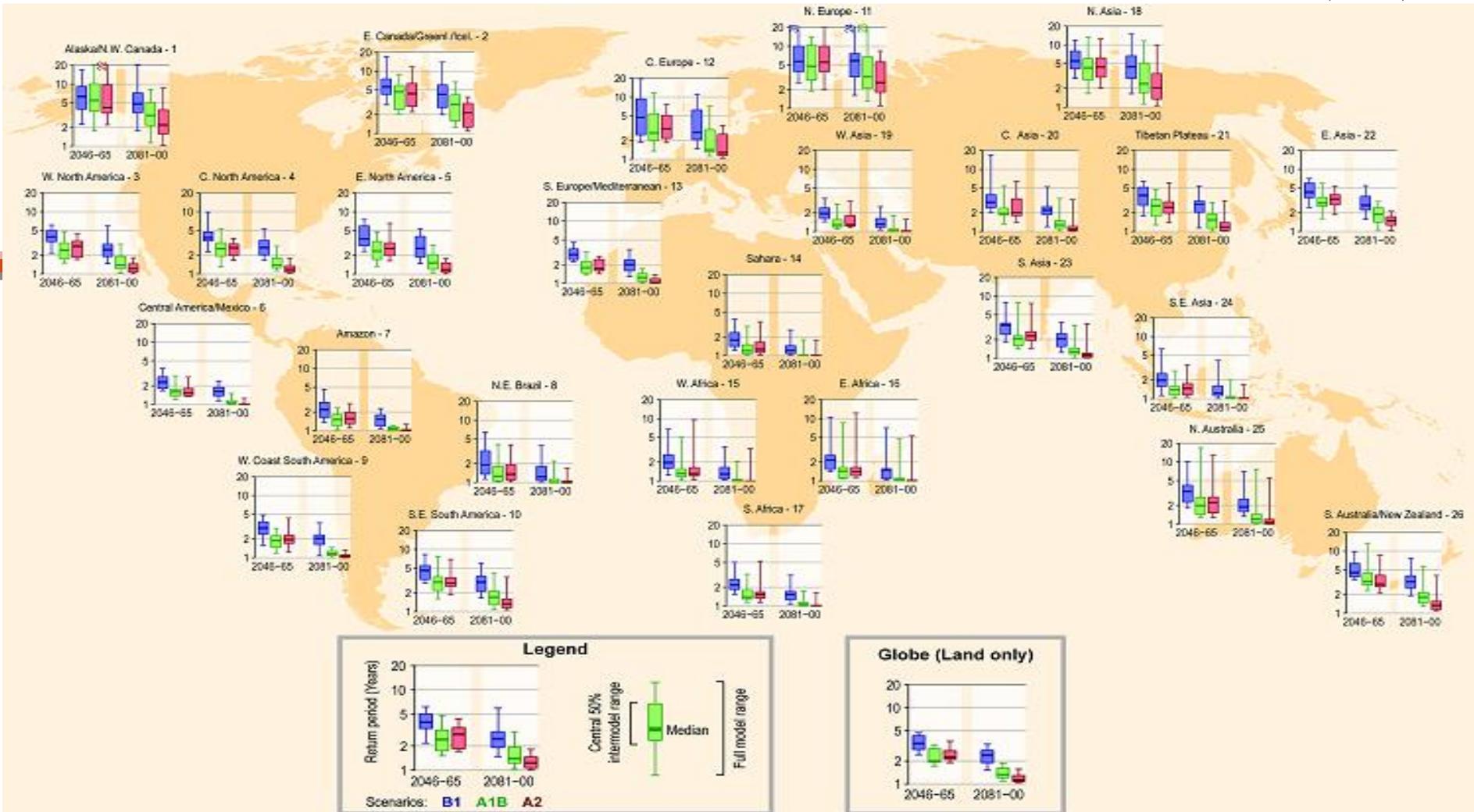
# Global projections: Daily maximum temperature

Source: IPCC (2012)



The frequency of 20-year return period temperature is expected to increase to once in every 2 to 8 years for SA, 1 to 6 years for SEA and 2 to 5 years at Global level during 2046-65.
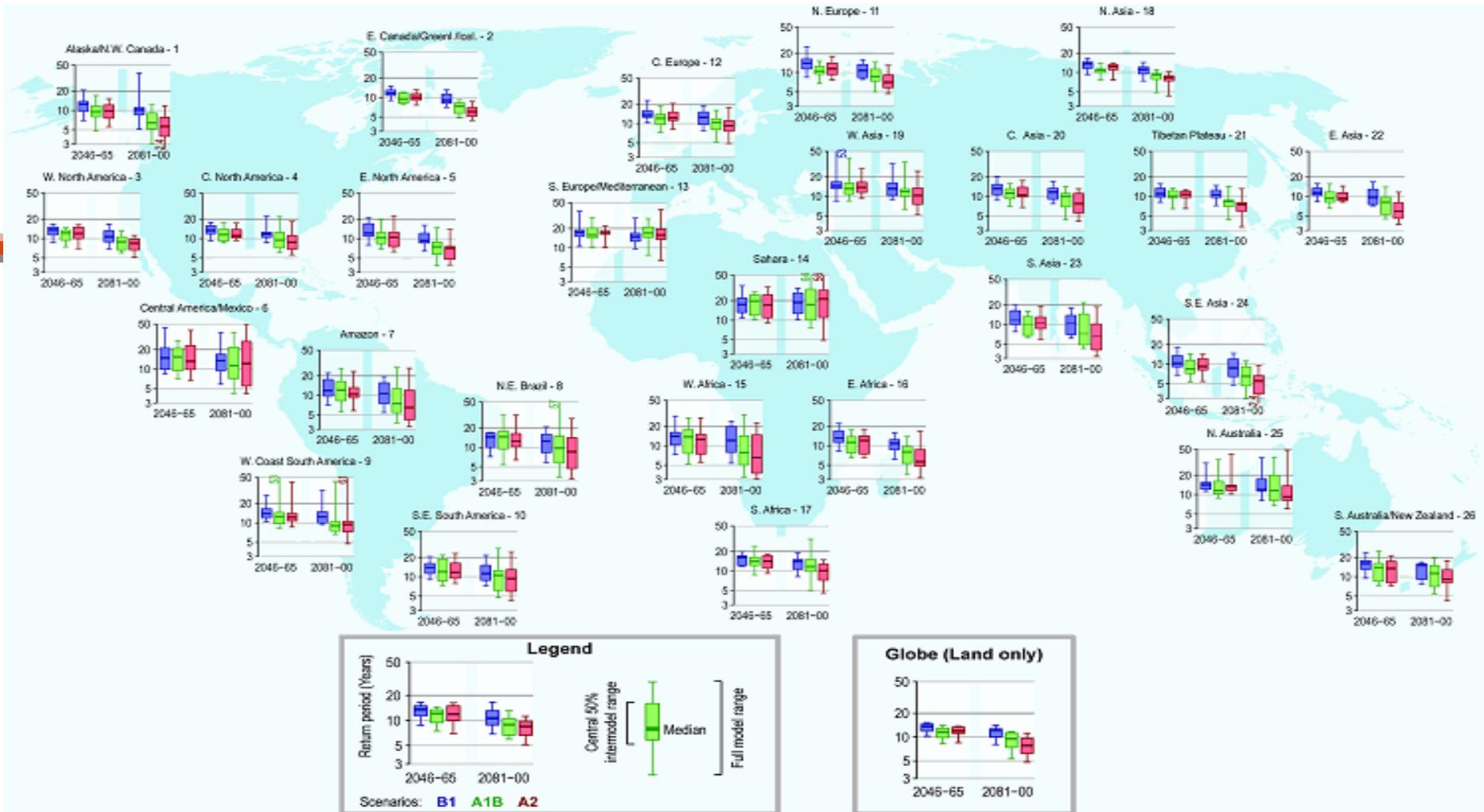
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# Global projections: Extreme precipitation event

Source: IPCC (2012)



The frequency of 20-year return period precipitation event is expected to increase to once in every 8 to 20 years for SA, 5 to 20 years for SE and 9 to 15 years at Global level during 2046-65.

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# Global projections: Change in runoff
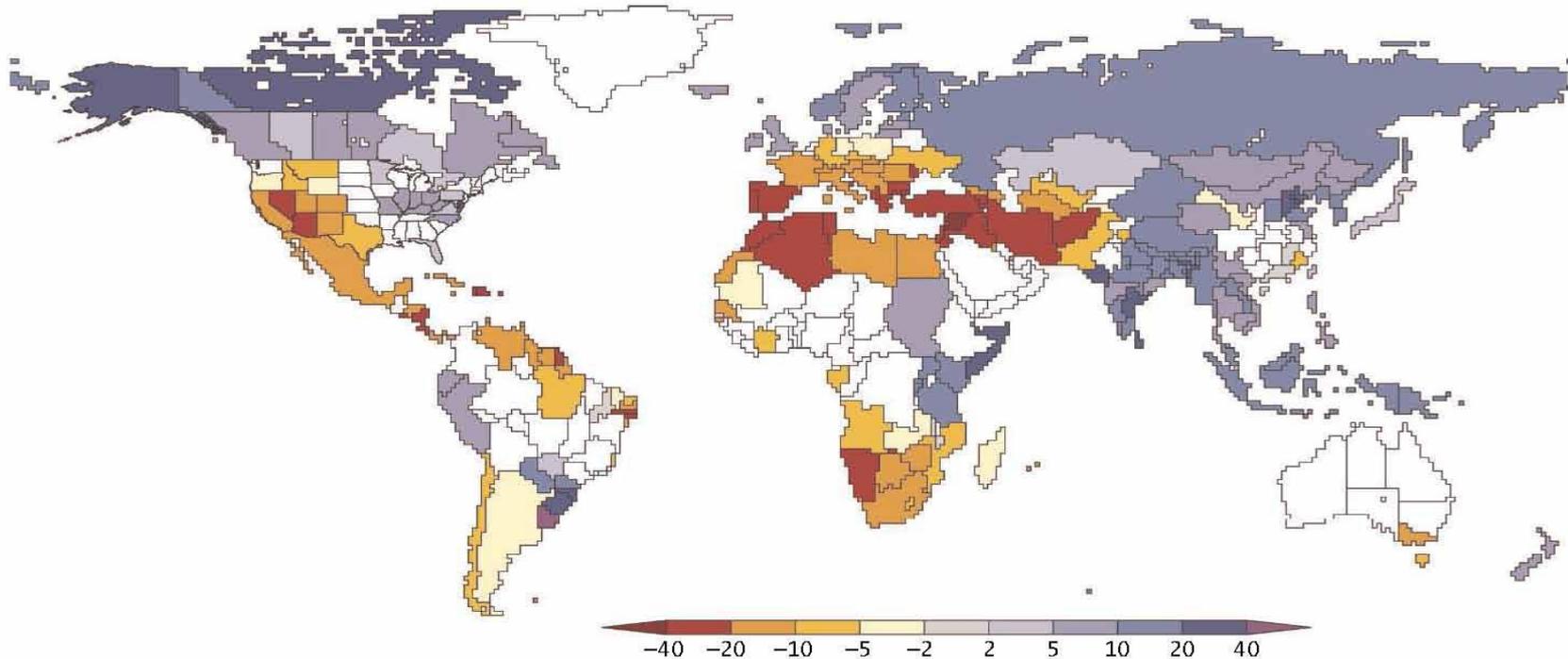


Projected change in annual runoff volume by the middle of the 21st century, relative to the historical period 1900-1970. Colour denotes percentage change (median value from 12 models). Presence of colour indicates that at least 8 of 12 models agreed on the direction (increase or decrease) of runoff change under the IPCC "SRES A1B" emissions scenario.

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Source: Milly et al. (2008)

# Global projections: Flood frequency



Return period (years)
Scale: 2-5, 5-25, 25-50, 50-75, 75-95, 105-125, 125-250, 250-500, 500-1000, >1000
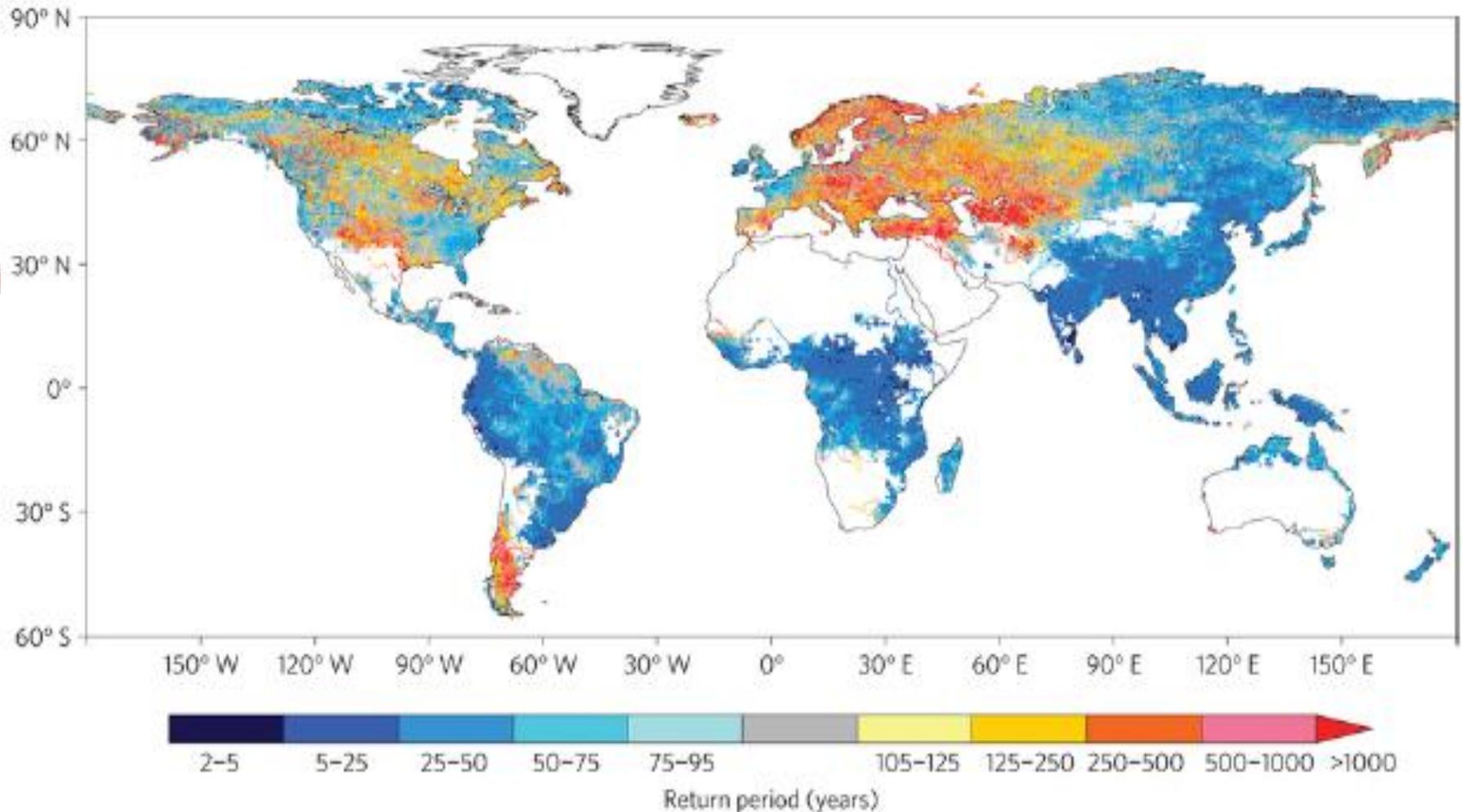
The 100-year return period flood is expected to occur with 5- to 25-year return period in 21st Century in South and SE Asia for RCP8.5

Source: Hirabayashi et al. (2013)

# Global projections: Sea level
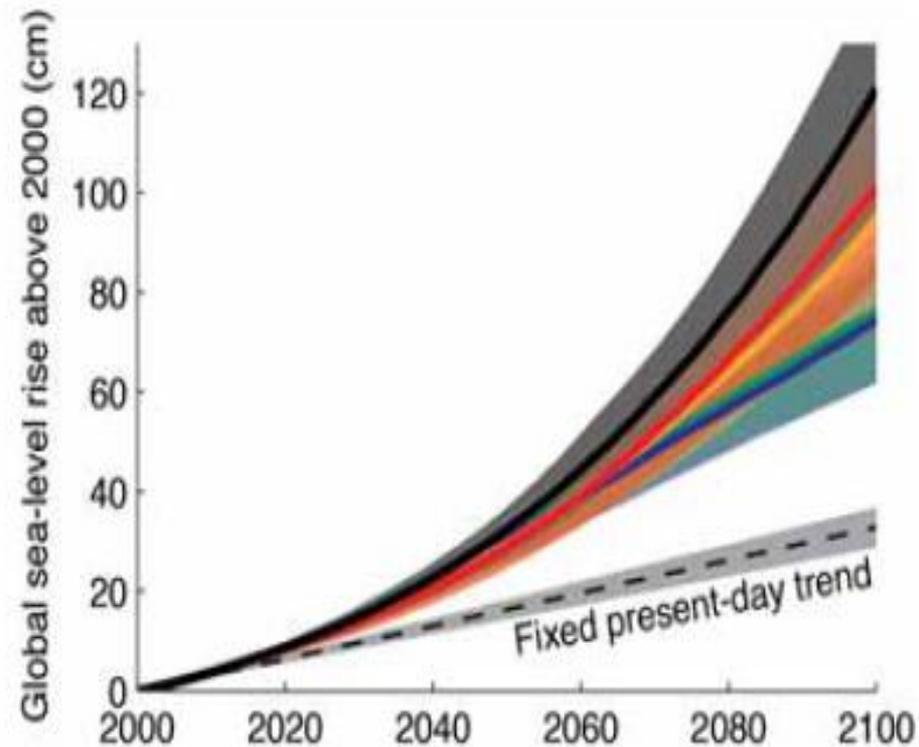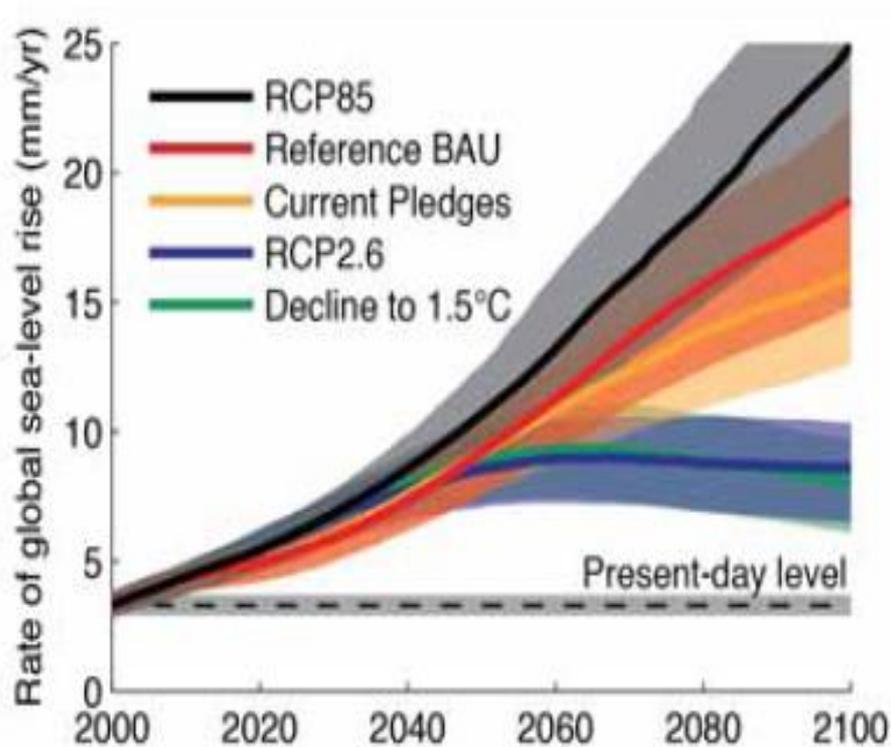


The rate of sea-level rise which is projected **to increase in all scenarios** indicates high risk from climate change, for the long-term resilience of ecosystems and small-island developing states.

Source: World Bank (2013)

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# Global projections: water stress

Between 1900 and 2000, the **population grew by a factor of four**, but **freshwater withdrawal grew by a factor of nine.** If current trends continue, by 2030 two-thirds of the world's population will live in areas of high water stress



1995      2025

Water withdrawal as a percentage of total available water

- more than 40 %
- from 40 % to 20 %
- from 20 % to 10 %
- less than 10 %

Source: UNEP (2008)
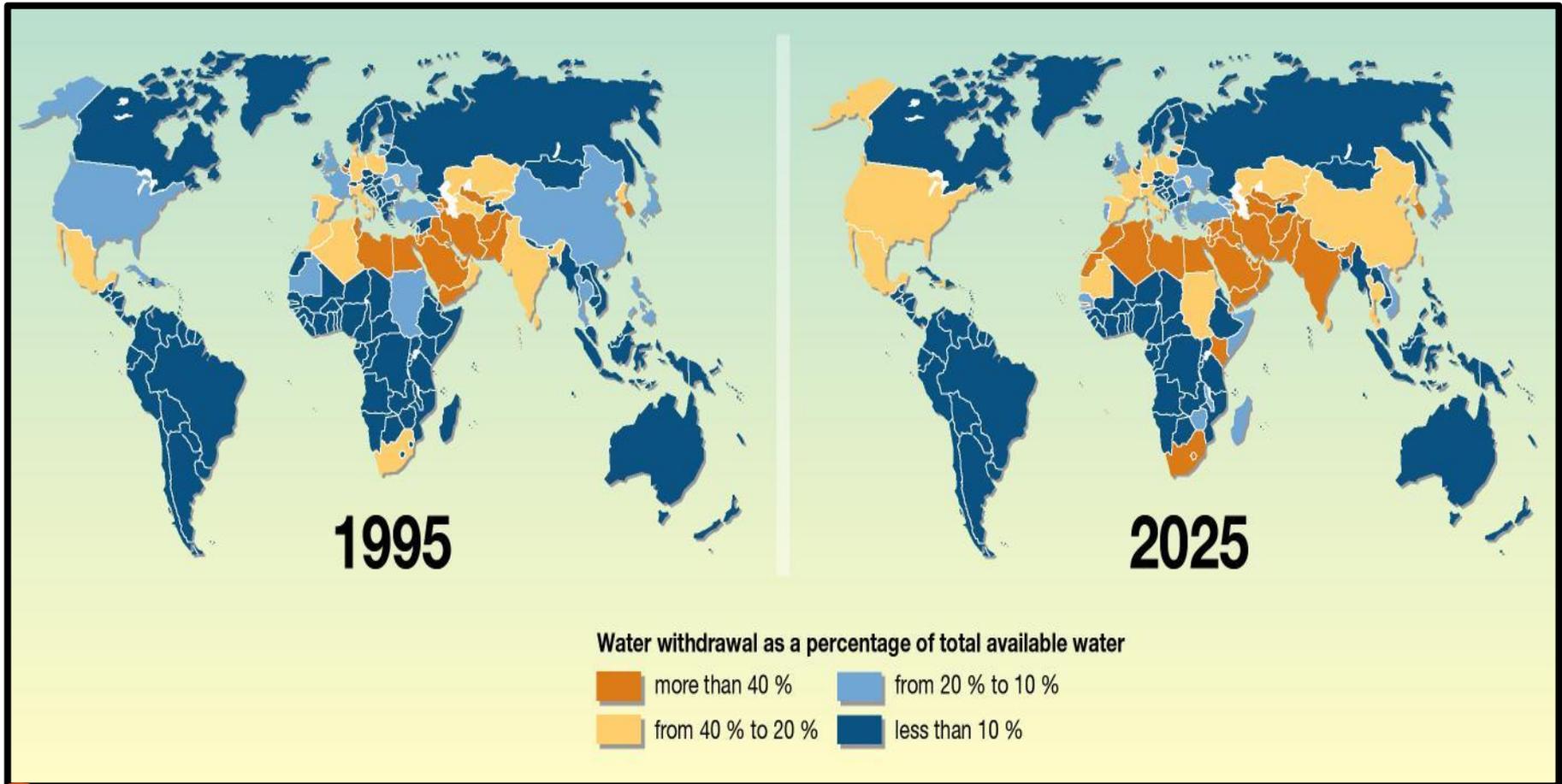
# Case studies

Translating global changes to local information

# Climate Change: Impacts and Adaptation Studies

Assessment of climate change and its impact and adaptation measures on

- Hydrology and water resources
- Extreme events (floods and droughts) and risk management
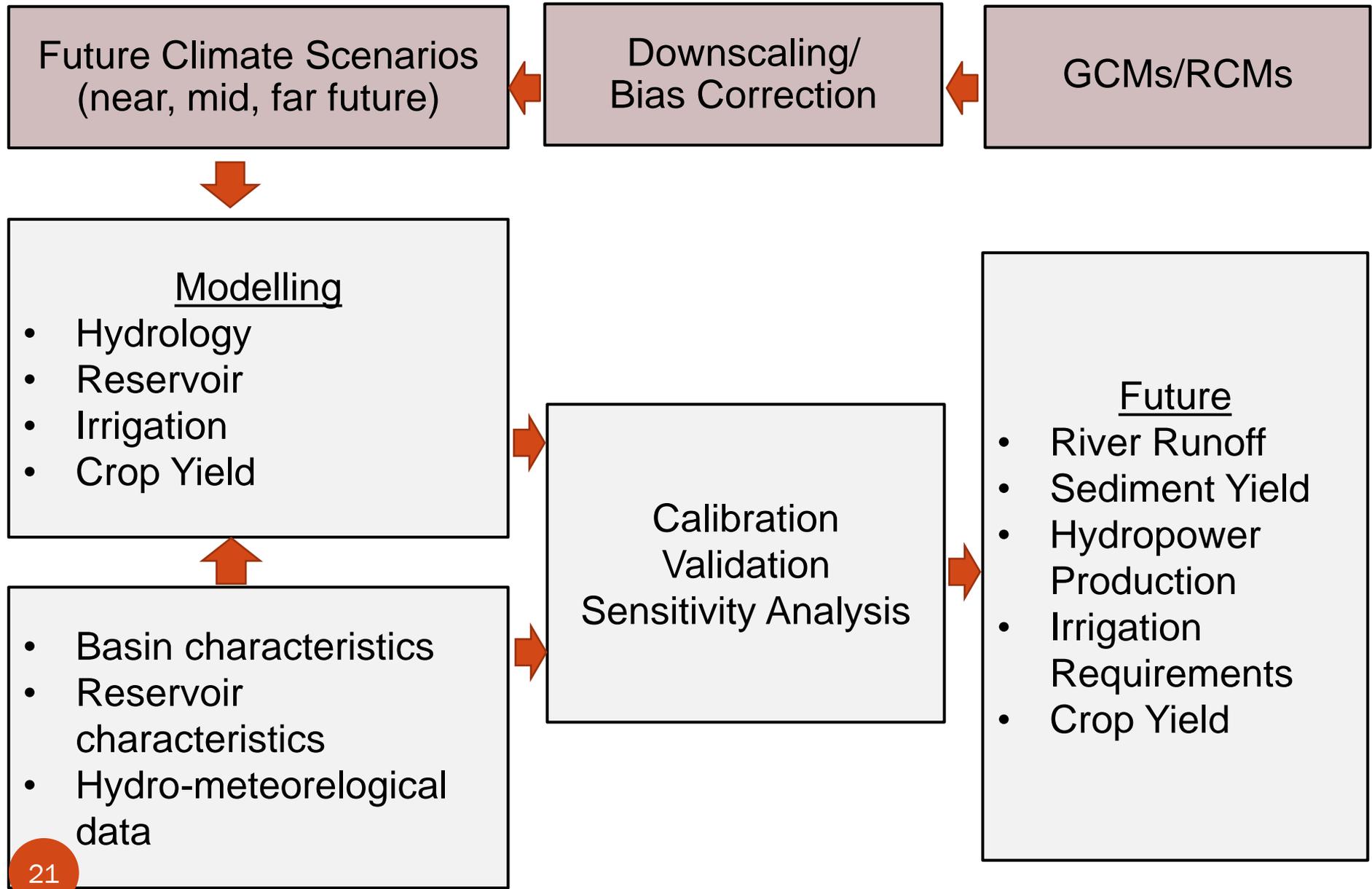- Snow cover in Himalaya
- Urban flooding
- Water quality
- Soil erosion and sediment
- Municipal water demand
- Irrigation water demand
- Crop rice yields
- Hydropower

# Climate change impact assessment framework

| Future Climate Scenarios (near, mid, far future) | ← | Downscaling/ Bias Correction | ← | GCMs/RCMs |
|---|---|---|---|---|

**Modelling**
- Hydrology
- Reservoir
- Irrigation
- Crop Yield

**Basin characteristics**
- Basin characteristics
- Reservoir characteristics
- Hydro-meteorelogical data

**Calibration Validation Sensitivity Analysis**

**Future**
- River Runoff
- Sediment Yield
- Hydropower Production
- Irrigation Requirements
- Crop Yield

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# Assessment of future climate at basin level

# Assessment of future climate at basin/local level

- Afghanistan
  - Kabul basin
- Bhutan
  - Wangchu basin
- India
  - Sikkim
- Indonesia
  - Citarum  basin
- Lao PDR
  - Nam Ou basin
- Myanmar
  - Ngamoeyeik Irrigation Project
  - Myitnge River Basin
- Nepal
  - Bagmati basin
  - Indrawati
  - Tamakoshi basin
  - Dudhkoshi basin
  - Koshi basin

- Pakistan
  - Upper Indus basin
  - Jhelum basin
- Thailand
  - Ping basin
  - Mae Klong basin
  - Pak Phanang basin
  - Mun basin
  - Bangkok
  - Upper Nan basin
  - Yang basin
- Vietnam
  - Ba basin
  - South Central Coast
  - Quang Nam Province
- Uganda
  - Wet agro-ecological zones
  - Dry agro-ecological zones

# Climate Change: Local Insights

## Impact on Maximum Temperature (Change in °C)

| Basin/Area, Country | A2 | | | B2 | | |
|---|---|---|---|---|---|---|
| | Early | Mid | Late | Early | Mid | Late |
| Wangchu, Bhutan | 0.5 | 1.0 | 1.9 | 0.6 | 0.9 | 1.4 |
| Sikkim, India | 0.4 | 0.8 | 1.4 | 0.4 | 0.7 | 1.0 |
| Citarum, Indonesia | 0.1 | 0.7 | 1.5 | 0.2 | 0.5 | 1.0 |
| Nam Ou, Laos | 0.5 | 1.6 | 3.5 | 0.5 | 1.4 | 1.9 |
| Koshi, Nepal | 0.8 | 2.2 | **4.2** | 0.9 | 1.8 | **2.6** |
| Jhelum, Pakistan | 0.2 | 0.6 | **1.0** | 0.3 | 0.5 | **0.8** |
| Mun, Thailand | 1.5 | 1.7 | 3.5 | - | - | - |
| Bangkok, Thailand | 0.3 | 0.7 | 1.2 | 0.3 | 0.5 | 0.9 |
| Pak Phanang, Thailand | 0.7 | 1.7 | 3.0 | 0.8 | 1.6 | 2.2 |

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Maximum temperature is projected to increase in all the basins during three future periods. The range of increase varies from **1.0 to 4.2°C** under A2 scenario and from **0.8 to 2.6°C** under B2 scenario in late century period.

# Climate Change: Local Insights

Impact on Minimum Temperature (Change in °C)

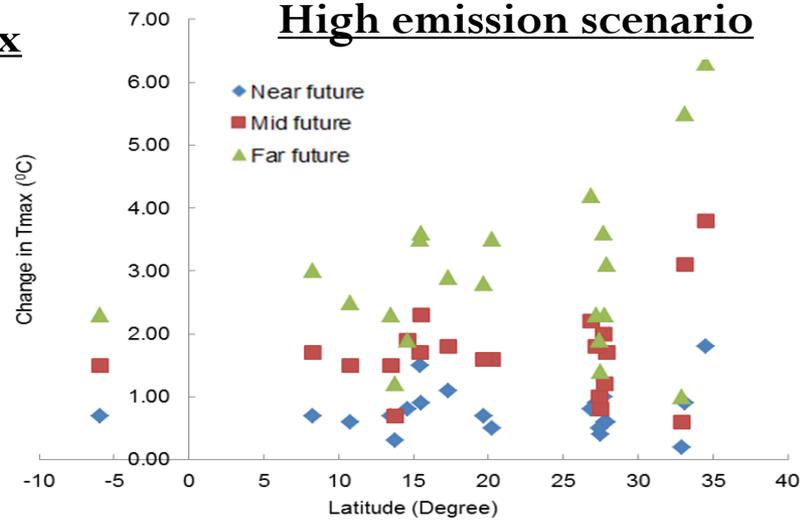| Basin/Area, Country | A2 | | | B2 | | |
|---|---|---|---|---|---|---|
| | Early | Mid | Late | Early | Mid | Late |
| Wangchu, Bhutan | 0.4 | 1.1 | 1.2 | 0.5 | 0.9 | 1.4 |
| Sikkim, India | 0.4 | 0.9 | 1.6 | 0.4 | 0.7 | 1.1 |
| Nam Ou, Laos | 0.5 | 1.6 | 3.5 | 0.5 | 1.3 | 1.9 |
| Bagmati, Nepal | 0.6 | 2.1 | 3.0 | 0.6 | 2.0 | 2.3 |
| Koshi, Nepal | 0.8 | 2.2 | **4.2** | 0.9 | 1.9 | **2.6** |
| Jhelum, Pakistan | 0.1 | 0.4 | **0.7** | 0.1 | 0.3 | **0.4** |
| Mun, Thailand | 0.9 | 2.1 | 3.1 | - | - | - |
| Bangkok, Thailand | 0.3 | 0.8 | 1.6 | 0.4 | 0.6 | 1.1 |
| Pak Phanang, Thailand | 1.3 | 2.5 | 4.2 | 1.3 | 2.3 | 3.2 |

25 The range of increase in Tmin varies from 0.7 to 4.2°C under A2 scenario and from 0.4 to 2.6 °C under B2 scenario in late century period.
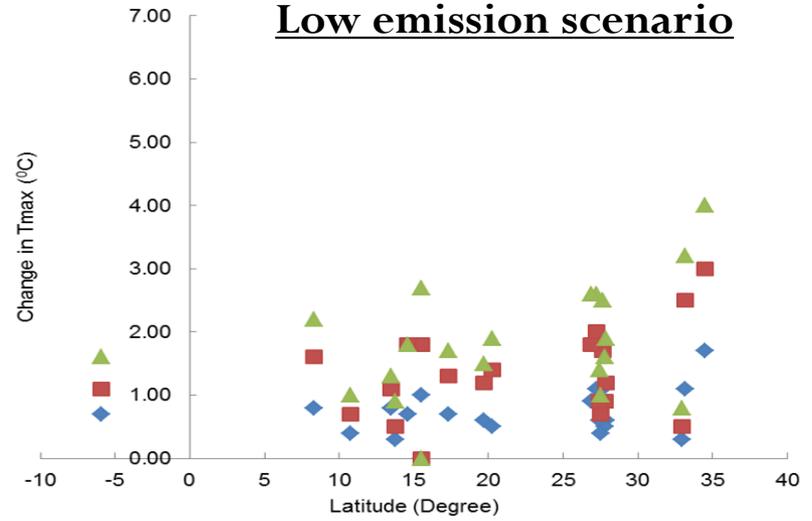
# Climate Change: Local Insights

## Change in average annual maximum and minimum temperature (Change in °C)



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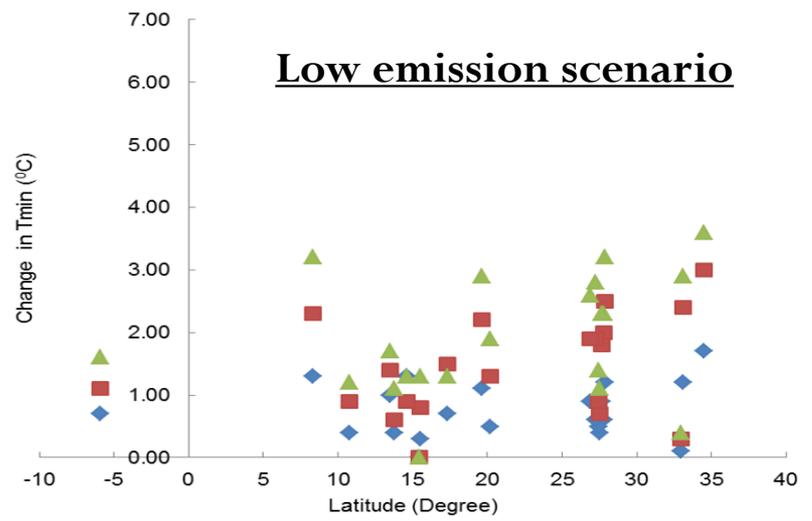
# Climate Change: Local Insights
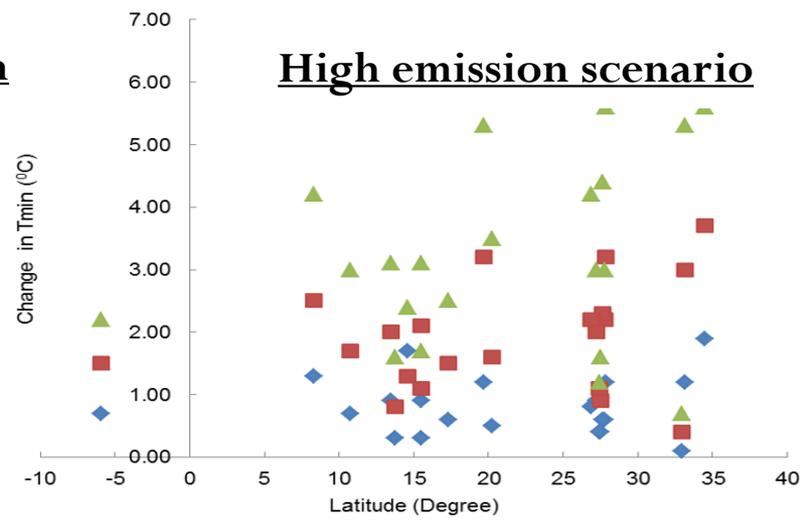
## Impact on Precipitation (% change)

| Basin/Area, Country | A2 | | | B2 | | |
|---|---|---|---|---|---|---|
| | Early | Mid | Late | Early | Mid | Late |
| Wangchu, Bhutan | 3.5 | 9.8 | 18.7 | 1.0 | 1.0 | 6.0 |
| Sikkim, India | -5.9 | -7.4 | -14.6 | -9.2 | -9.1 | -11.4 |
| Citarum, Indonesia | 23.0 | 55.0 | **88.0** | 27.0 | 36.0 | **46.0** |
| Tamakoshi, Nepal | 6.0 | 15.0 | 25.0 | 6.0 | 13.0 | 19.0 |
| Koshi, Nepal | 0.9 | 1.3 | 14.2 | -0.1 | 3.3 | 4.0 |
| Indus, Pakistan | - | 14.0 | 3.0 | - | 37.0 | 8.0 |
| Mun, Thailand | 10.0 | 45.0 | 3.0 | - | - | - |
| Bangkok, Thailand | -2.0 | -0.4 | 3.4 | -0.3 | -1.1 | -1.8 |
| Southern Vietnam | 0.4 | 1.0 | 1.6 | 0.4 | 1.0 | 1.4 |

Precipitation shows different directions of change in various basins. The range varies from -14.6 to 88% change under A2 scenario and from -11.4 to 46% change under B2 scenario for late 21C.
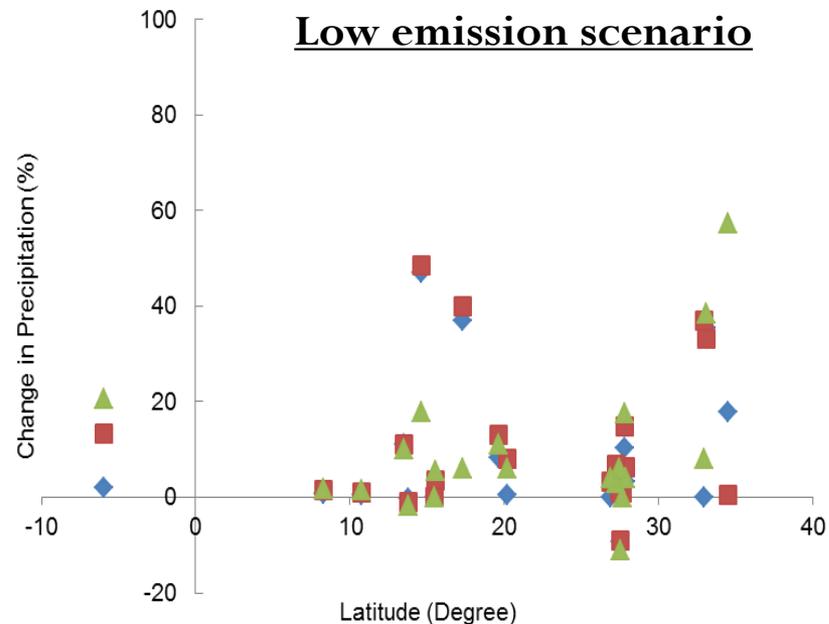
# Climate Change: Local Insights

## Change in precipitation (% Change)
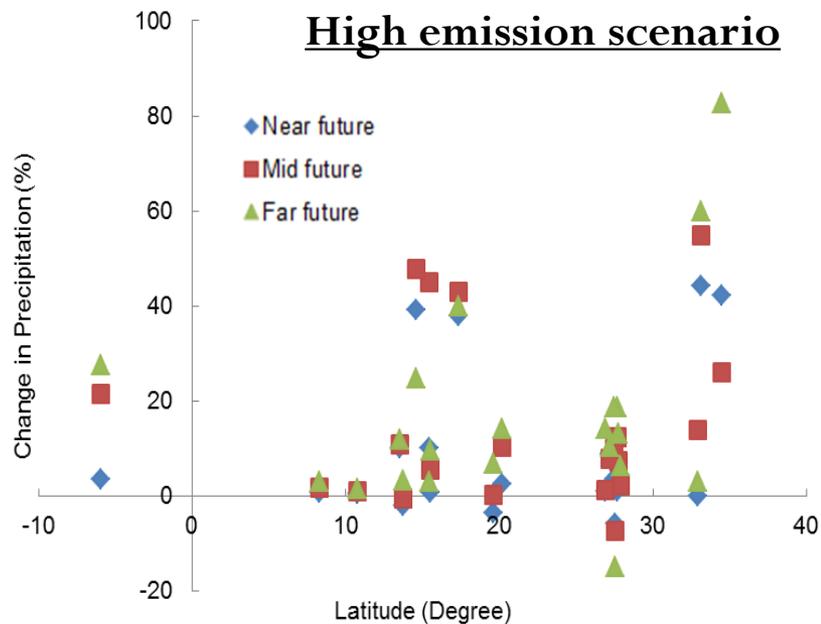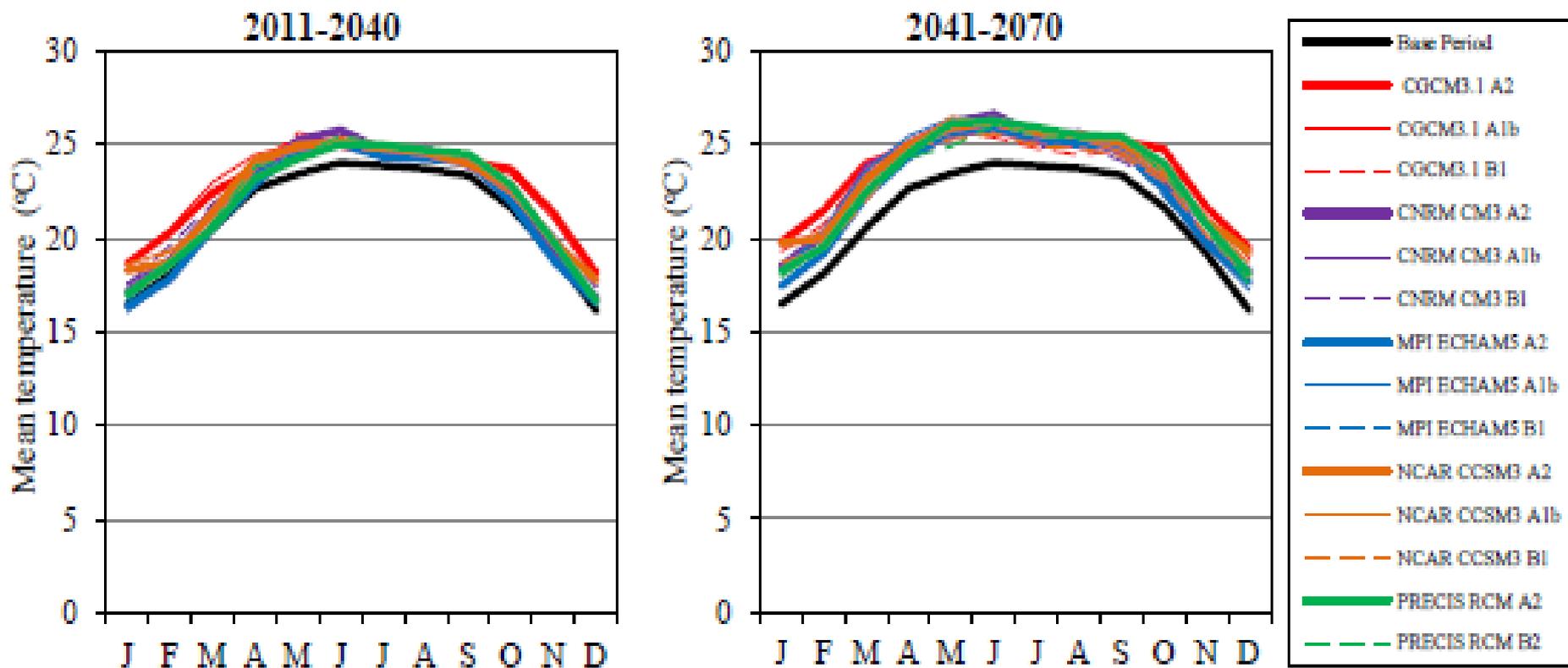
# Climate Change: Local Insights

Change in temperature in the Nam Ou basin, Lao PDR based on multiple GCMs and scenarios



All GCMs for different scenarios indicate an increase in future periods, although difference exists in magnitude of change

Source: Shrestha et al. (2013) HESS

# Climate Change: Local Insights

Change in precipitation in the Nam Ou basin, Lao PDR based on multiple GCMs and scenarios
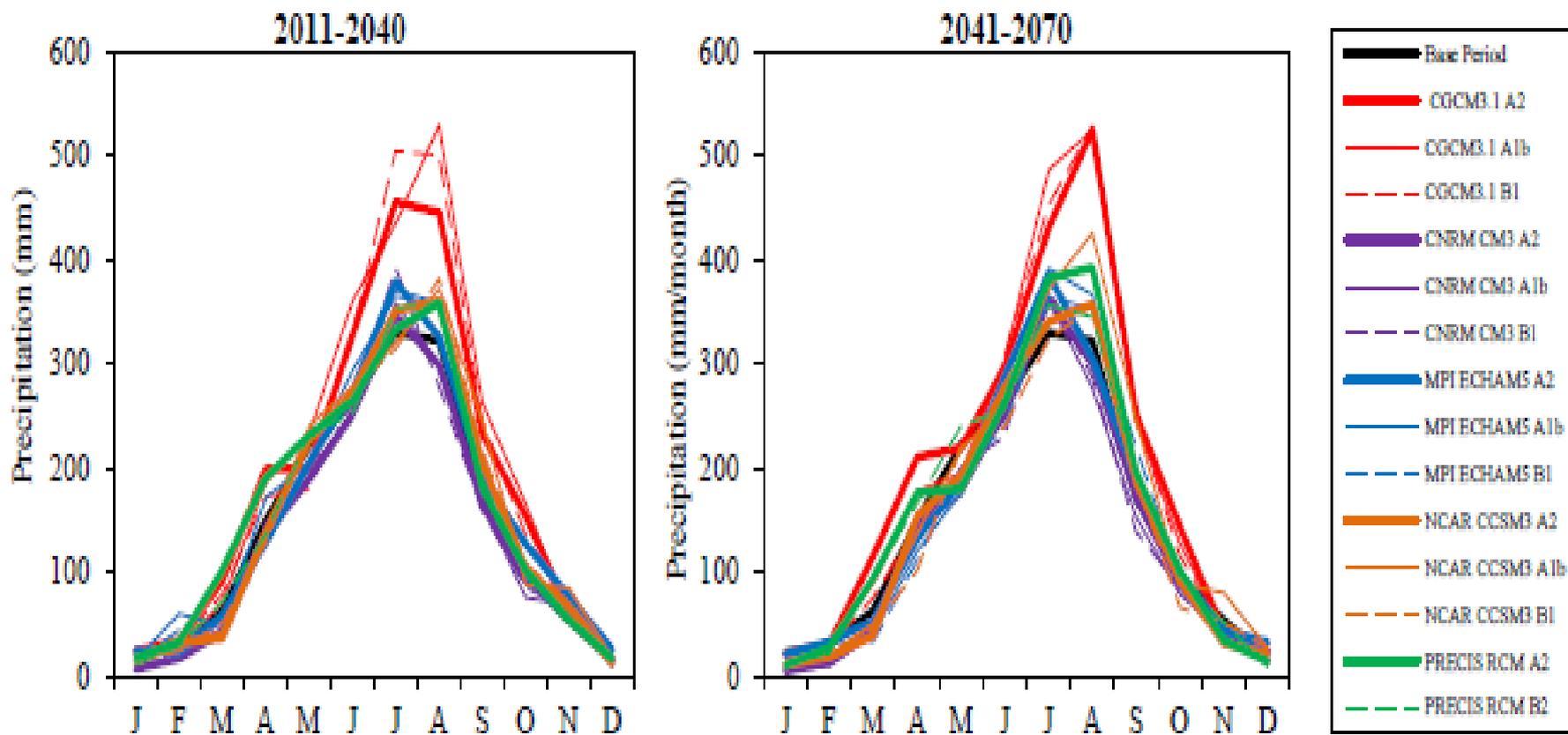


GCMs do not agree for direction as well as magnitude of change in precipitation

Source: Shrestha et al. (2013) HESS

# Hydrology and Water Resources

- Afghanistan
  - Kabul basin
- Nepal
  - Bagmati basin
  - Indrawati
  - Koshi basin
  - Tamakoshi basin
- Thailand
  - Chi basin
  - Ping basin
  - Mae Klong basin
  - Pak Phanang basin
  - Bangkok
  - Yang basin
- Vietnam
  - Ba River basin
  - South Central Coast
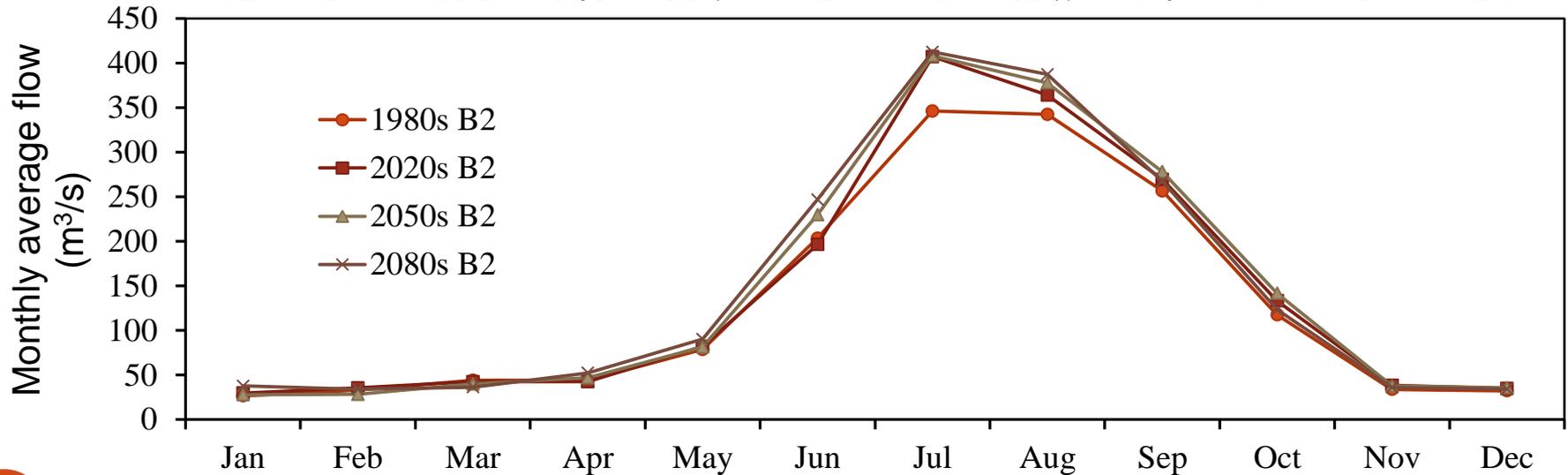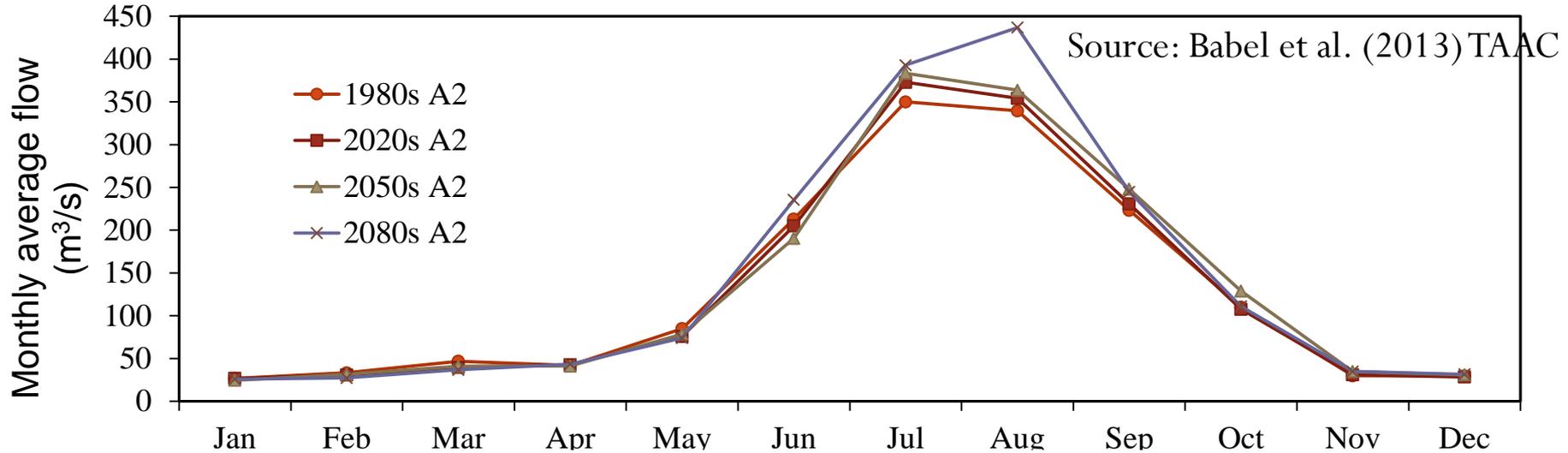
# Climate Change: Local Insights

## Impact on runoff (% change)

| Basin, Country | Baseline | A2 | | | B2 | | |
|---|---|---|---|---|---|---|---|
| | (m³/s) | Early | Mid | Late | Early | Mid | Late |
| Nam Ou, Laos | 543.2 | 0.04 | 0.21 | 9.23 | 4.26 | 0.55 | 5.95 |
| Bagmati, Nepal | 127.4 | -2.1 | 1.7 | 9.3 | 6.4 | 6.9 | 11.4 |
| Koshi, Nepal | 1281.1 | 4.3 | 6.4 | 19.8 | 3.8 | 9.2 | 9.9 |
| Jhelum, Pakistan | 846.6 | 30.9 | 26.5 | 34.3 | 30.5 | 25.6 | 36.5 |

*For Koshi results are presented for B1 scenario instead of B2
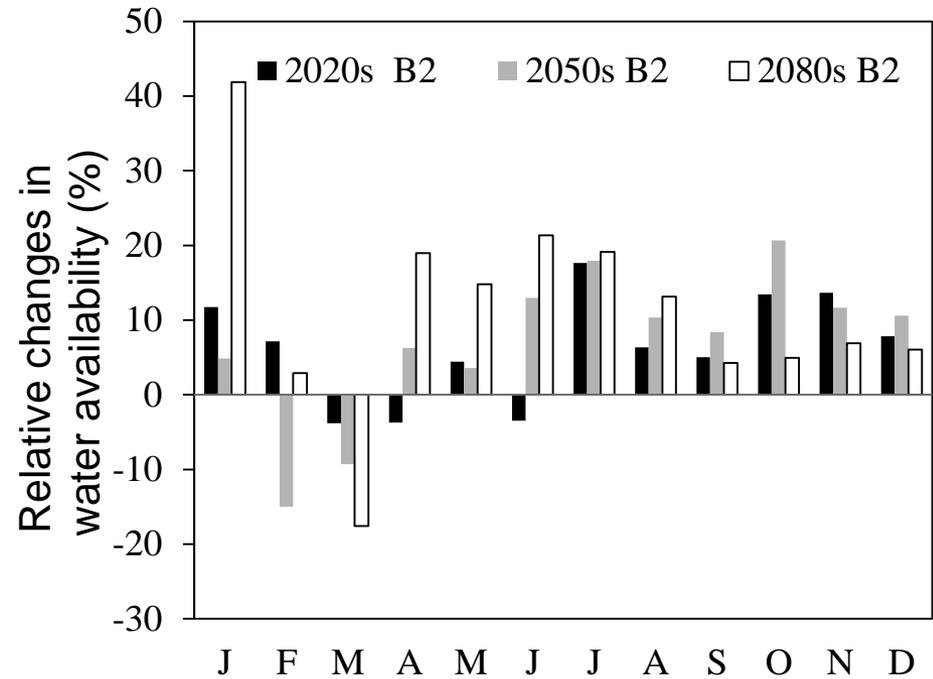
# Climate Change: Local Insights

## Impact on river flow in the Bagmati River Basin, Nepal



Source: Babel et al. (2013) TAAC

Increase in flow is expected to be higher during May-Sept.

# Climate Change: Local Insights

Impact on water availability in the Bagmati River Basin, Nepal
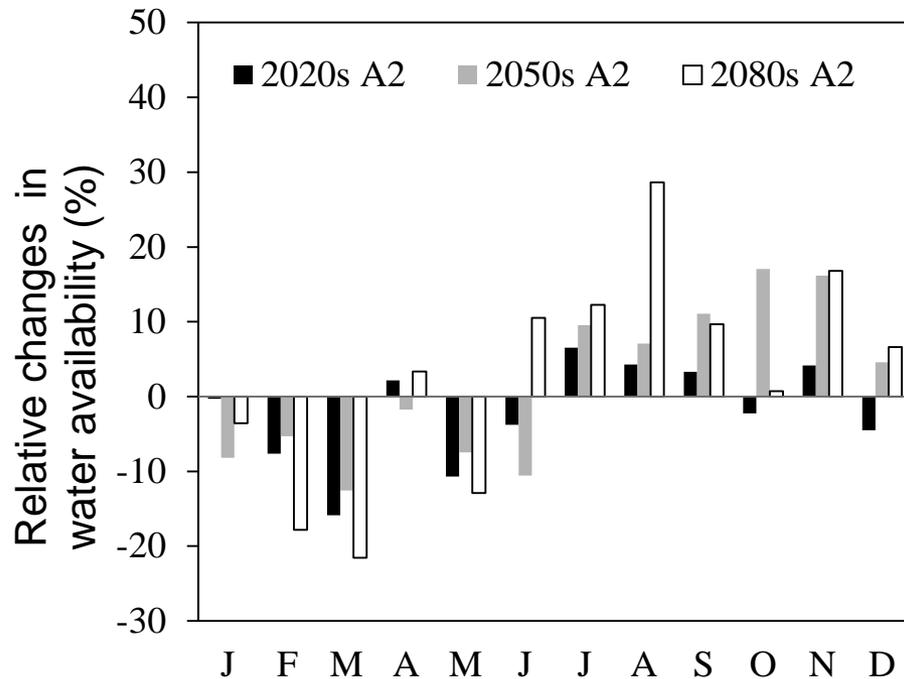


Under A2 scenario, the pre-monsoon water availability may decrease, however, an increase in the post-monsoon water availability is projected. In contrast, under B2 scenario, water availability is expected to increase during both wet and dry seasons.

Source: Babel et al. (2013) TAAC

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# Climate Change: Local Insights

## Impact on streamflow in Jhelum basin, Pakistan

Projected changes (%) in high, low, and median flows relative to 1961-90

| A2 | Naran | G.Habibulla | M.abad | Domel | kohala | Azad Pattan | kotli |
|---|---|---|---|---|---|---|---|
| **Baseline** (1961-1990) | | | | | | | |
| Q5 (high flow) | 170 | 316 | 1078 | 848 | 2142 | **2205** | 359 |
| Q50 (median flow) | 19 | 54 | 194 | 306 | 606 | **687** | 81 |
| Q95 (Low flow) | 8 | 21 | 53 | 64 | 151 | **166** | 19 |
| Changes in **2020s** w. r. to Baseline | | | | | | | |
| Q5 | 40.7 | 16.6 | -4.5 | -16.5 | -5.1 | **-5.5** | 8.5 |
| Q50 | 42.9 | 67.1 | 72.1 | 1.2 | 40.5 | **30.1** | -6.4 |
| Q95 | -98.8 | -25.0 | -34.0 | 0.1 | 6.4 | **6.0** | -42.6 |
| Changes in **2050s** w. r. to Baseline | | | | | | | |
| Q5 | 38.7 | 22.1 | 1.3 | -3.4 | 4.1 | **5.0** | 11.5 |
| Q50 | 43.5 | 54.7 | 65.2 | 1.8 | 32.1 | **20.4** | 17.1 |
| Q95 | -98.8 | -22.2 | -33.3 | 1.2 | -8.6 | **-12.5** | -27.4 |
| Changes in **2080s** w. r. to Baseline | | | | | | | |
| Q5 | 51.6 | 27.5 | -4.6 | -22.9 | -5.5 | **-6.0** | 18.5 |
| Q50 | 60.5 | 75.6 | 66.0 | 5.7 | 39.1 | **29.6** | 14.3 |
| Q95 | -98.8 | -18.3 | -32.3 | 4.0 | 2.1 | **1.7** | -10.5 |

# Climate Change: Local Insights

## Impact on timing and magnitude of peak flows, Jhelum basin Pakistan
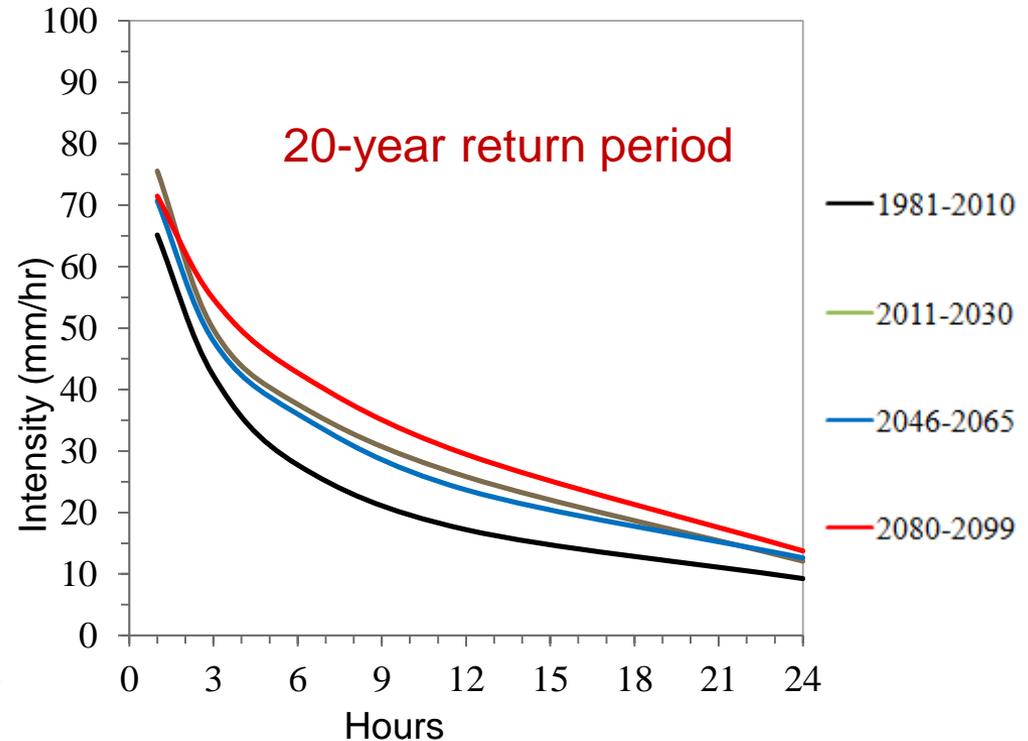
Source: AIT PhD Dissertation (2013)
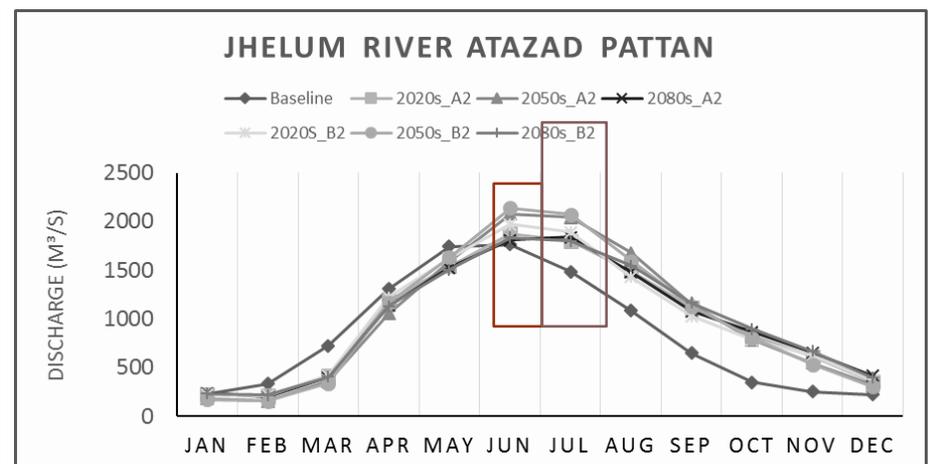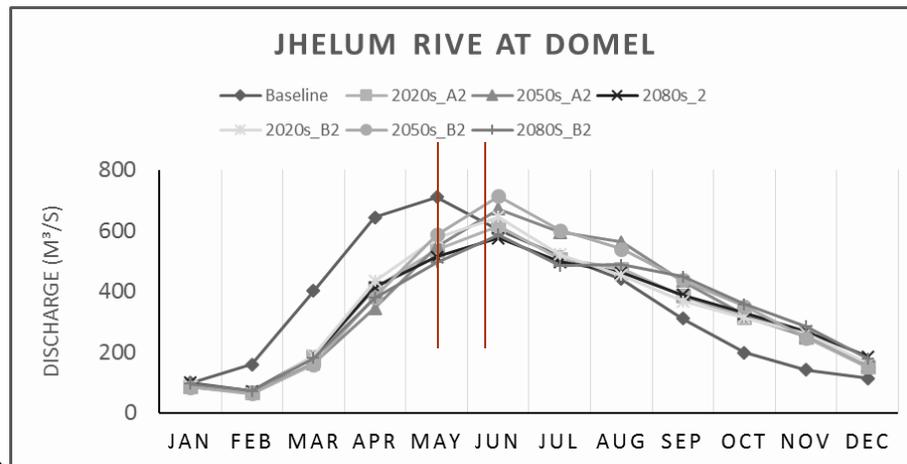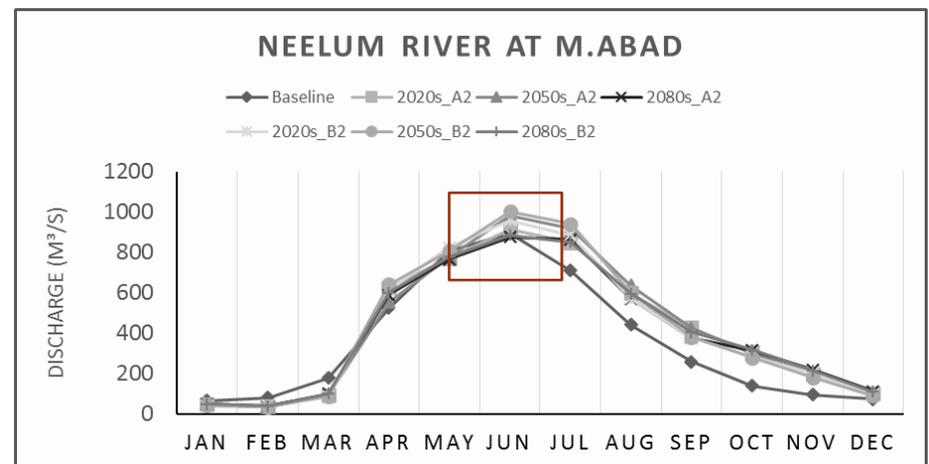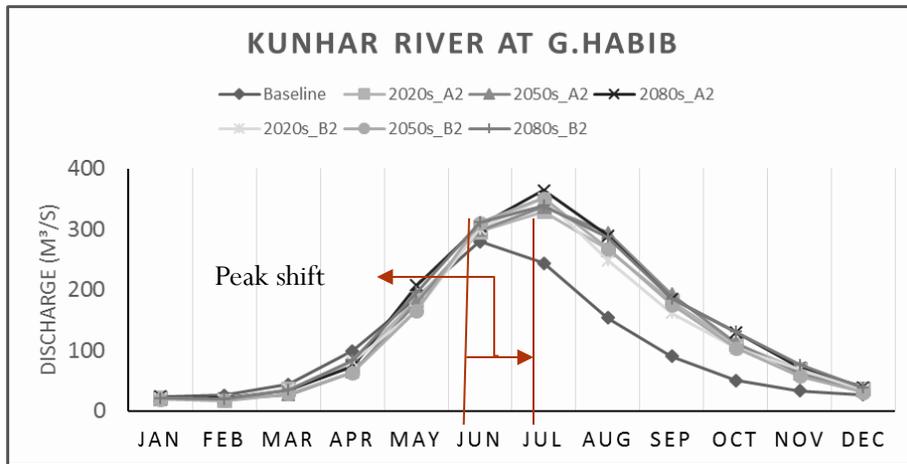
# Climate Change: Local Insights

## Urban drainage

### IDF Curve and Urban Flooding: Sukhumvit (Bangkok)
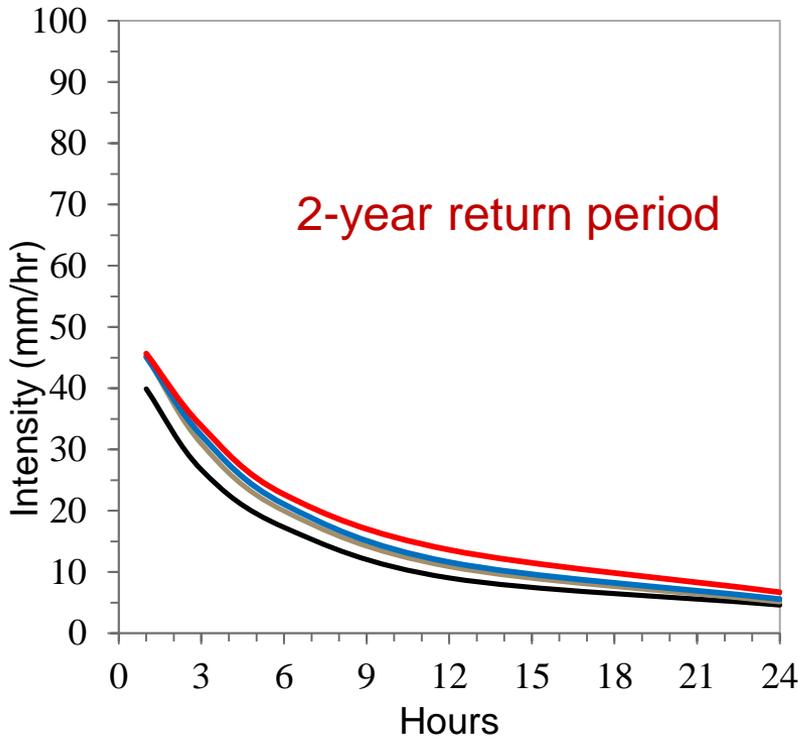


IDF curves for baseline period (1981-2011), and future periods (2011-2030, 2046-2065 and 2080-2099)

Source: AIT Masters Thesis (2013)

# Climate Change: Local Insights

## Urban drainage

### IDF Generation and  Urban Flooding: Sukhumvit, Bangkok

Source: AIT Masters Thesis (2013)
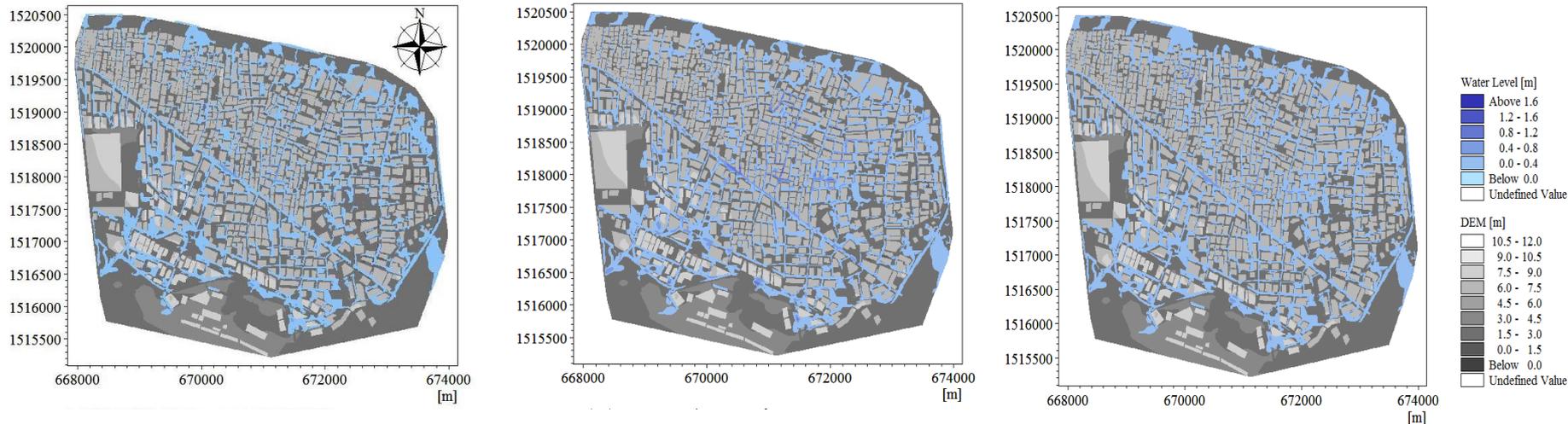


## 20-year return period, 3 h total rainfall

|  | Base condition, BC | 2011-2030 (Change from BC) | 2080-2099 (Change from BC) |
|---|---|---|---|
| Rainfall depth (mm) | 127.0 | 149.0 (+17.3%) | 164.0 (+29.1%) |
| Area flooded (km$^2$) | 5.28 | 6.10 (+15.5%) | 6.60 (+25.0% ) |
| Duration (h) | 5.0 | 5.0 | >5.0 |
| Max depth (m) | 0.60 | 0.66 (+10%) | 0.70 (16.7%) |

# Bangkok Flood Hazard Relationship

**FIGURE 3.4** ■ **Bangkok Flood Hazard Relationship**
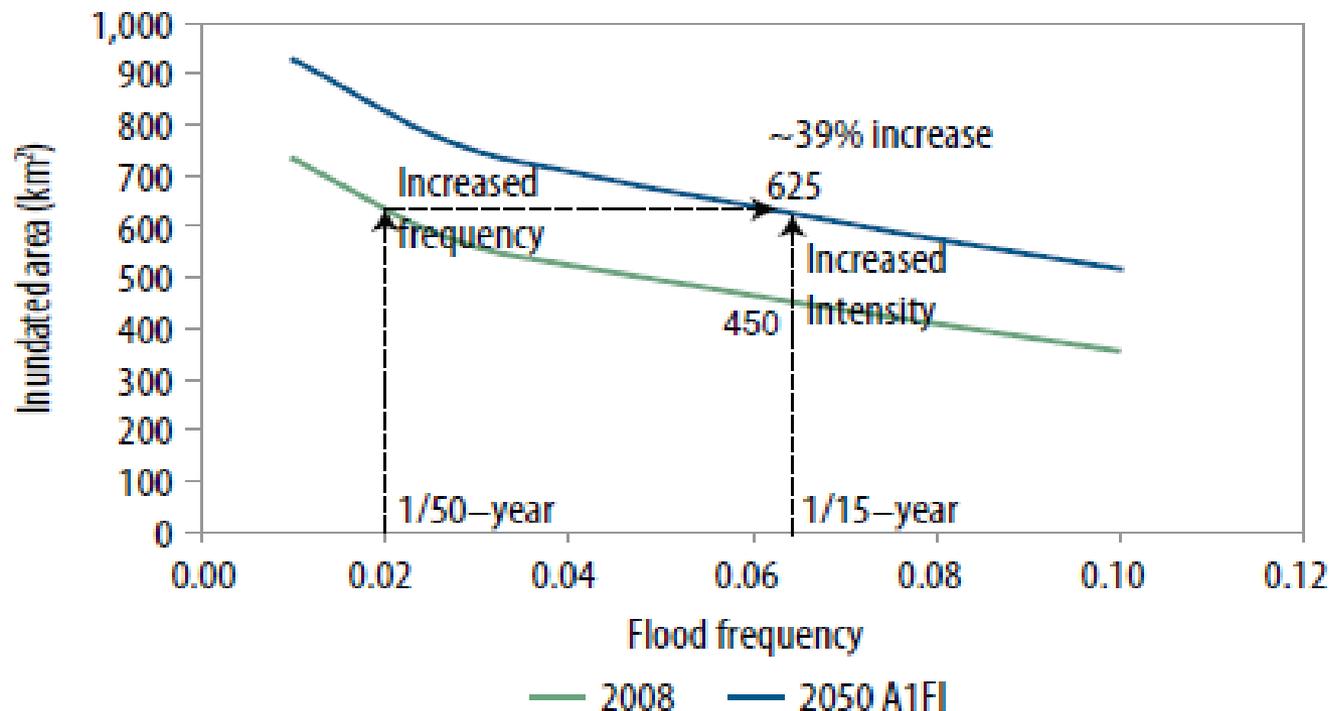


*Source*: Panya Consultants (2009).

# Water Quality and Sediment

- ## Lao PDR
  - ### Nam Ou basin

- ## Thailand
  - ### Upper Nan watershed

- ## Vietnam
  - ### Saigon River system

# Climate Change: Local Insights

## Sediment Yield

### Impact on sediment yield in the Nam Ou basin, Lao PDR

Reservoir impact is much larger than the Impact of climate change

S0: No CC, no reservoir
S1: CC but no reservoir
S2: 1 reservoir
S3: 3 reservoirs
S4: 5 reservoirs
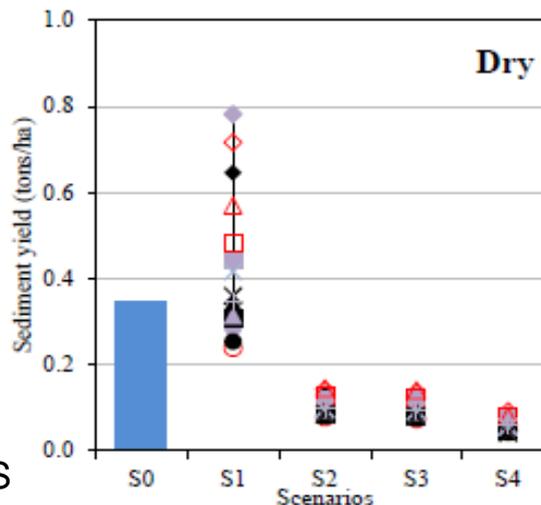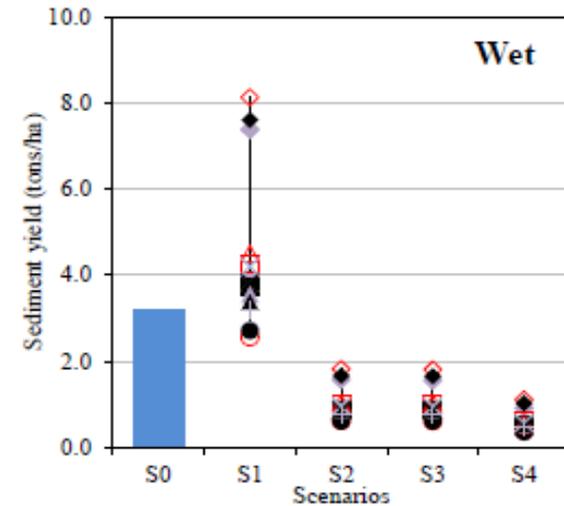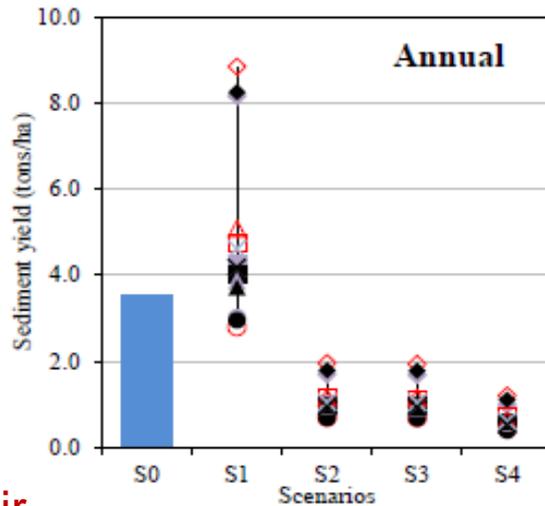
Source: Shreshta et al. (2013) HESS

# Climate Change: Local Insights

## Sediment Yield

Impact on sediment trapping and reservoir capacity in the Nam Ou basin, Lao PDR

Trapping reduces reservoir holding capacity

Source: Shreshta et al. (2013) HESS
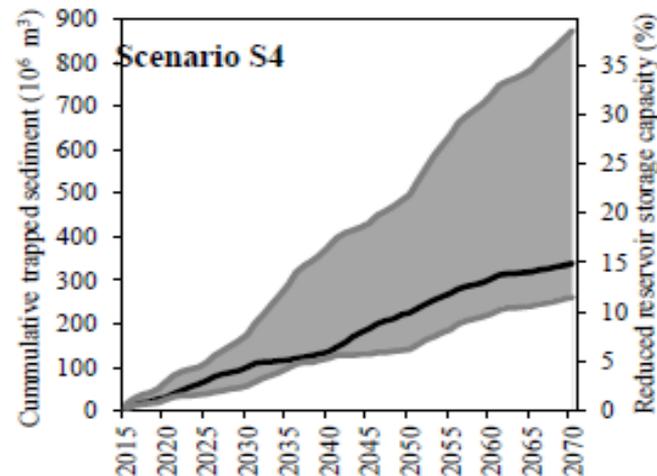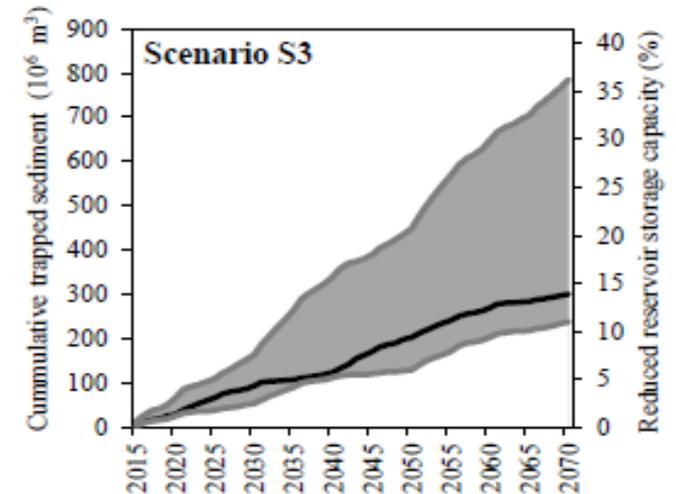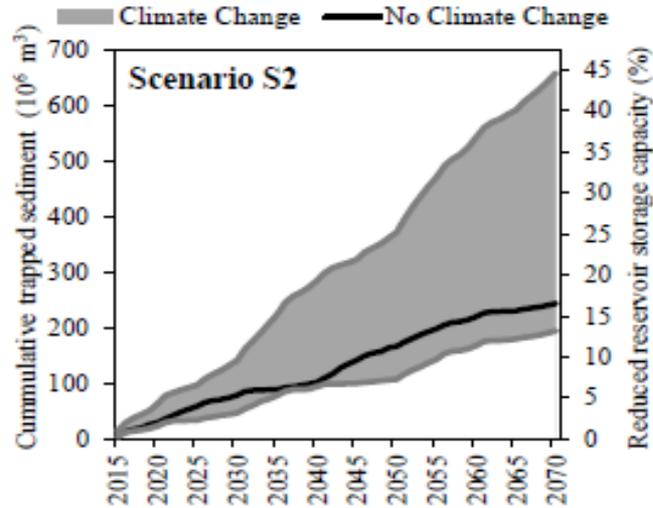
# Climate Change: Local Insights

Reservoir reduces sediment due to trapping and alters deposition

| Scenario | | Erosion (Er) ($10^6$ tons/yr) | Sediment deposition (Sd) ($10^6$ tons/yr) | | Sediment outflux from Nam Ou river (So) ($10^6$ tons/yr) |
|---|---|---|---|---|---|
| | | | Tributary and watershed (Sdt) | Reservoir (Sdr) | |
| S0 | | 18.1 | 11.0 | - | 7.0 |
| S1 | A2 | 25.2 | 16.1 | - | 9.2 |
| | B2 | 22.2 | 13.9 | - | 8.3 |
| S2 | No climate change | 18.1 | 10.0 | 6.4 | 1.7 |
| | A2 | 25.2 | 14.3 | 8.9 | 2.1 |
| | B2 | 22.2 | 12.2 | 8.1 | 1.9 |
| S3 | No climate change | 18.1 | 8.4 | 8.0 | 1.7 |
| | A2 | 25.2 | 12.2 | 11.0 | 2.1 |
| | B2 | 22.2 | 10.3 | 10.0 | 1.8 |
| S4 | No climate change | 18.1 | 7.8 | 9.2 | 1.1 |
| | A2 | 25.2 | 11.4 | 12.6 | 1.2 |
| | B2 | 22.2 | 9.6 | 11.5 | 1.0 |

Source: Shreshta et al. (2013) HESS

# Crop Yield

- ## India
  - ### Sikkim

- ## Thailand
  - ### Chi basin
  - ### Mun basin

- ## Uganda
  - ### Wet agro-ecological zones
  - ### Dry agro-ecological zones

- ## Vietnam
  - ### Quang Nam Province
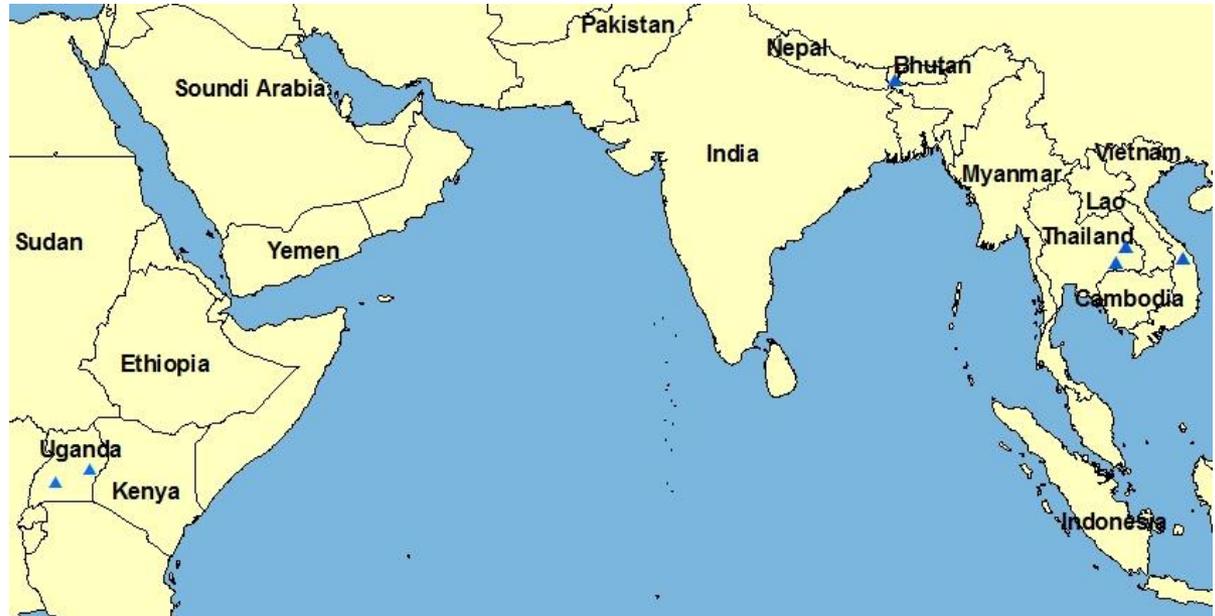
# Climate Change: Local Insights

### Impact on crop production (Change in %)

| | Basin, Country | Baseline | A2 | | | B2 | | |
|---|---|---|---|---|---|---|---|---|
| | | kg/ha | Early | Mid | Late | Early | Mid | Late |
| Rice | Mun, Thailand | 2,732 | -11.2 | -19.5 | -32.1 | - | - | - |
| | Chi, Thailand | 2,807 | -25.2 | -32.9 | -32.3 | - | - | - |
| Maize | Sikkim, India | 3,290 | -21.1 | -32.2 | -44.2 | -15.9 | -26.8 | -37.1 |
| | Uganda (March-May) | 3,010 | -9.6 | -16.4 | -43.3 | -10.5 | -14.5 | -28.4 |
| | Uganda (Sept-Nov) | 3,010 | 8.1 | 10.2 | 9.6 | 8.6 | 12.1 | 10.2 |

Yield is expected to decrease in future periods; In Uganda during Sept-Nov season Maize yield is projected to increase.

# Climate Change: Local Insights

## Impact on Rice Production in Northeast Thailand
### (KDML 105 @ Ubon Ratchathani)

| Period | Yield (kg/ha) | Panicle no. / m$^2$ | No. of grains/m$^2$ | Total Biomass (kg/ha) | Anthesis duration (days) | Maturity duration (days) | Harvest Index |
|--------|-------|---------|---------|---------|------|------|------|
| 1997-06 | 2,732 | 33.4 | 10,613 | 6,353 | 81 | 110 | 0.43 |
| 2020-29 | 2,427 | 31.7 | 8,990 | 6,742 | 87 | 113 | 0.36 |
| 2050-59 | 2,200 | 27.3 | 8,149 | 6,463 | 96 | 120 | 0.30 |
| 2080-89 | 1,855 | 36.2 | 6,869 | 6,625 | 85 | 107 | 0.28 |

Yield is expected to decrease in future periods; No. of panicles and total biomass may decease/increase in future periods

46

Source: Babel et al. (2011) Clim Res

# Climate Change: Local Insights

## Agriculture

Impact on Rice Production in Northeast Thailand
(KDML 105 @ Ubon Ratchathani)

Effect of temperature and $CO_2$ on yield



Source: Babel et al. (2011) Clim Res
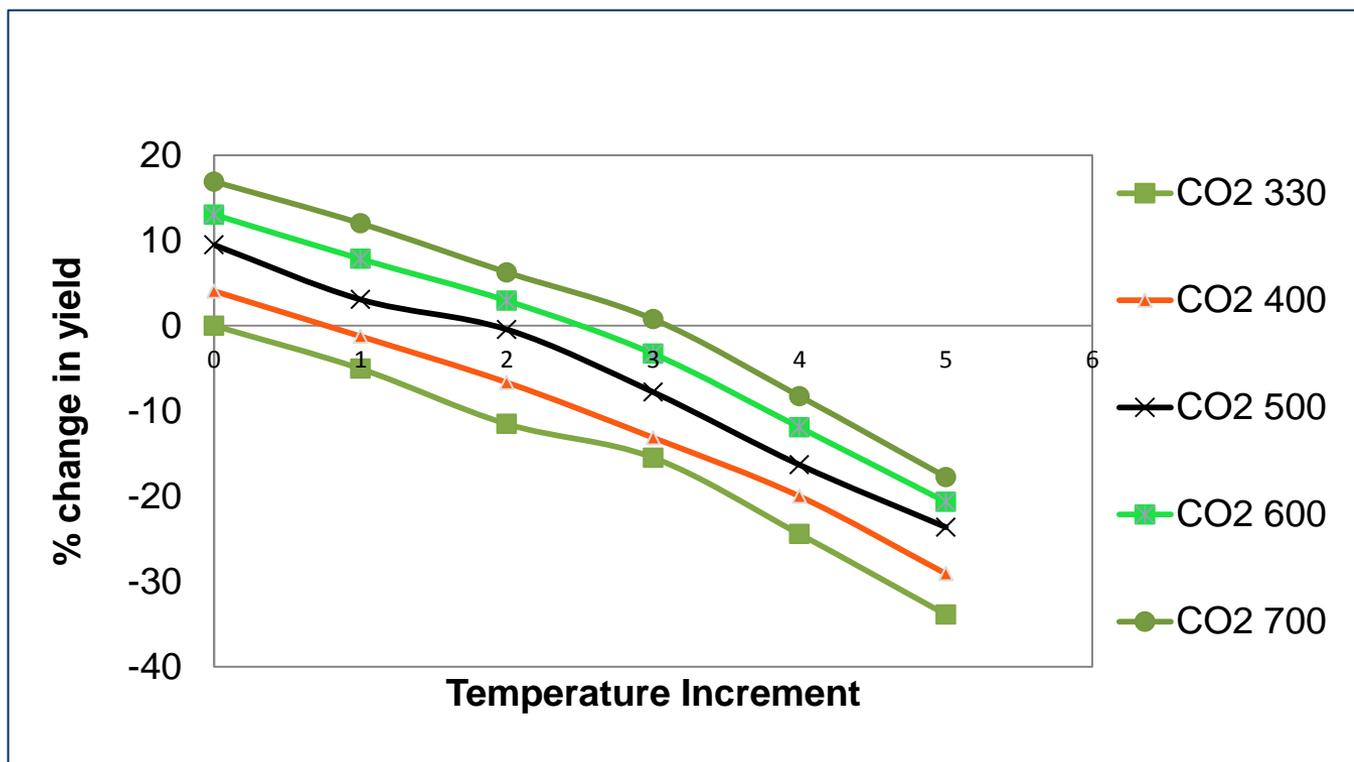
# Climate Change: Local Insights

## Impact on Maize Yield in East Sikkim, India



Aqua Crop

DSSAT
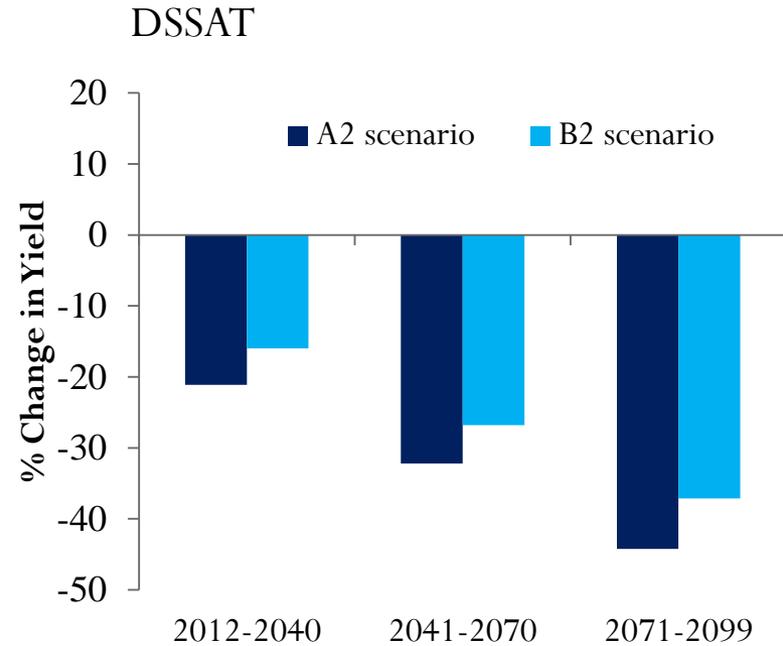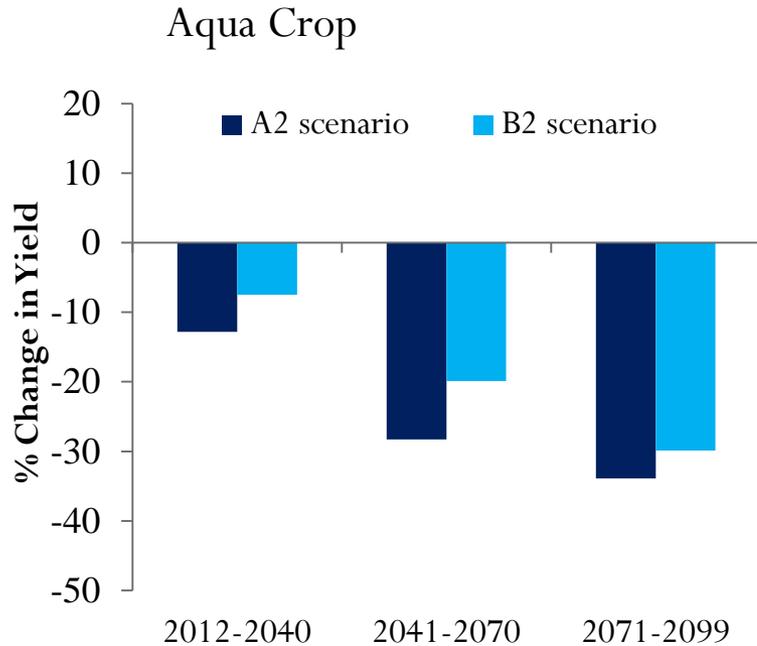
Projected decrease in precipitation and increase in temperature may have negative impact on maize yield

48

Source: Deb et al. (2014) TAAC

# Climate Change: Local Insights

## Agriculture

### Impact on Maize Yield in Uganda

**Mar-May Season**

At 330ppm $CO_2$
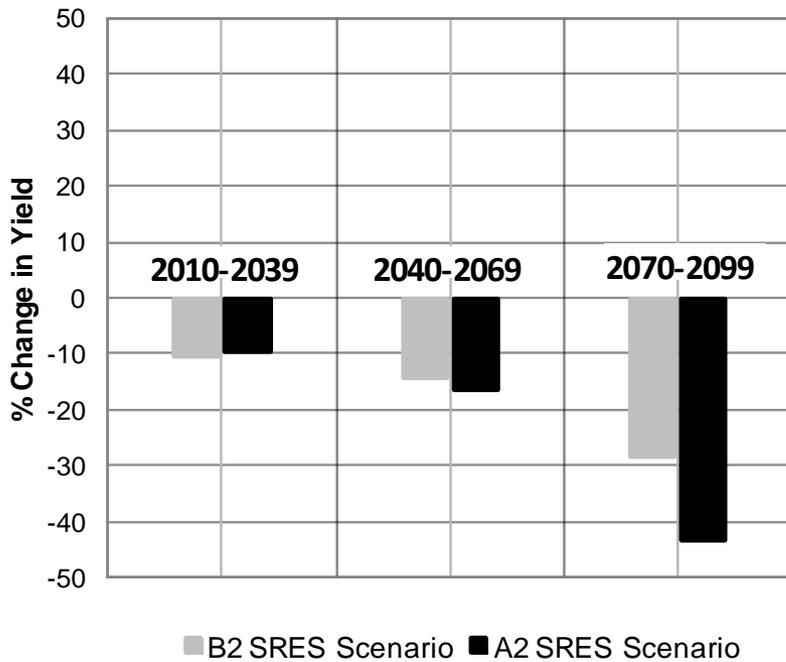
At Scenario $CO_2$

Source: Babel and Turyatunga (2014) TAAC
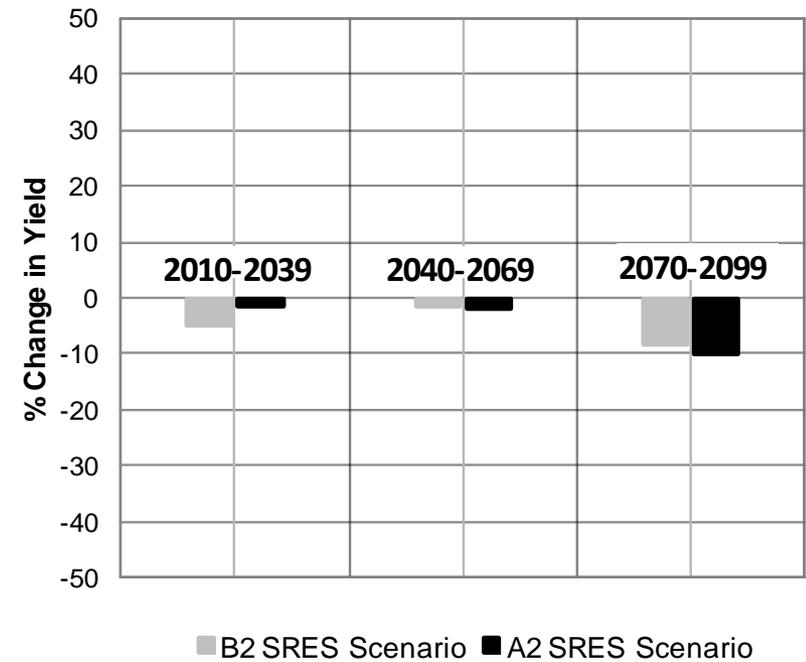
# Climate Change: Local Insights

## Agriculture

### Impact on Maize Yield in Uganda

**Sept-Nov Season**

At 330ppm $CO_2$



At Scenario $CO_2$

Source: Babel and Turyatunga (2014) TAAC
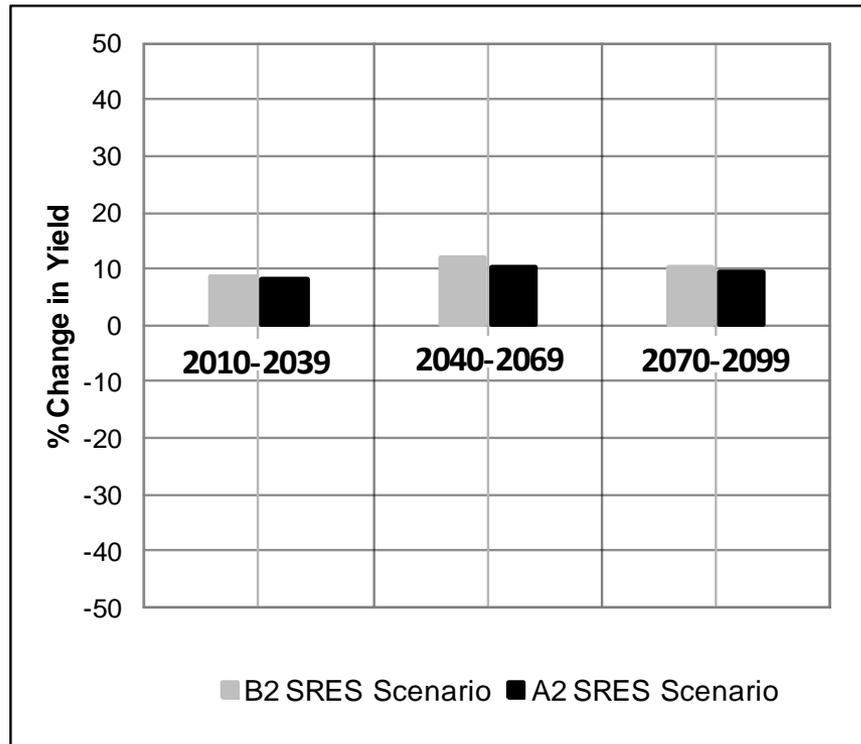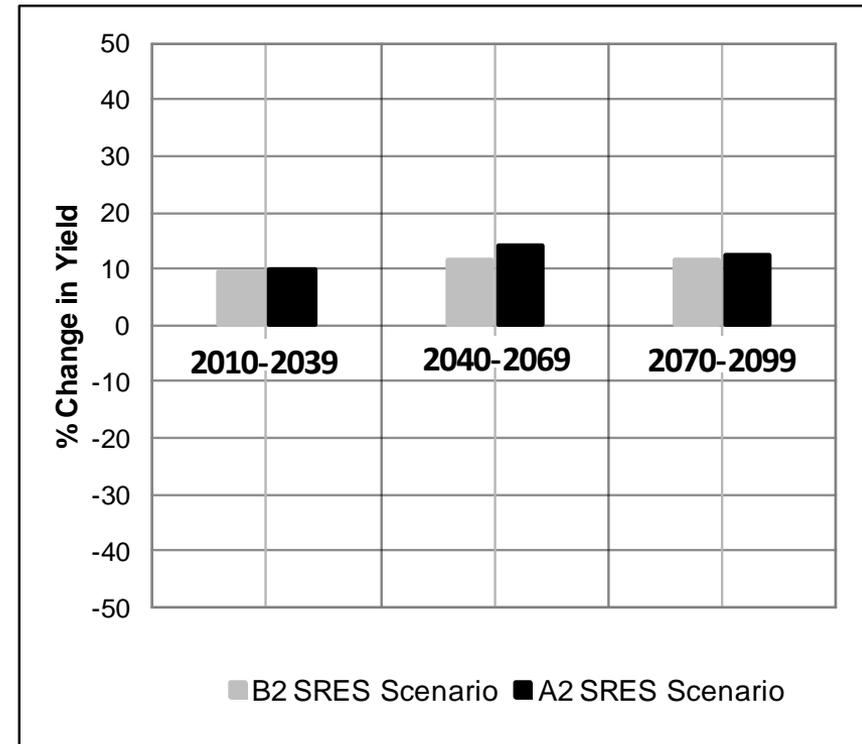
# Climate Change: Local Insights

Agriculture

## Impact on rainfed Rice Yield in Myanmar

Baseline (1961-1990) yield: 2.965 t/ha

| Scenarios | 2020s | 2050s | 2090s |
|-----------|-------|-------|-------|
| | Increase (%) | | |
| A2_ECHAM5 | 21.1 | 32.6 | 40.3 |
| A2_HadCM3 | 21.8 | 34.6 | 35.9 |
| A1B_ECHAM5 | 20.5 | 27.6 | 26.3 |
| B2_HadCM3 | 20.4 | 16.9 | 16.5 |

Rainfed rice yield is projected to increase under all scenarios

51

Source: Shrestha et al. (2014) J Wat Clim Change

# Water Demand

- Indonesia
  - Citarum basin
- Nepal
  - Bagmati basin
- Myanmar
  - Ngamoeyeik Irrigation Project
- Pakistan
  - Upper Indus basin
- Thailand
  - Bangkok

# Climate Change: Local Insights

Irrigation water demand in Bagmati basin, Nepal (Change in %)

| | Physiographic region | Baseline | A2 | | | B2 | | |
|---|---|---|---|---|---|---|---|---|
| | | MCM | Early | Mid | Late | Early | Mid | Late |
| Rice | High Hills | 79.8 | 0.5 | 6.3 | 2.4 | -9.0 | -4.9 | -7.4 |
| | Middle Hills | 83.6 | -4.1 | 1.8 | -4.0 | -8.6 | -2.2 | -9.0 |
| | Terai | 88.2 | 28.6 | 23.9 | 26.9 | 26.9 | 23.2 | 27.4 |
| Wheat | High Hills | 11.7 | -81.4 | -91.3 | -90.1 | -82 | -90.7 | -90.7 |
| | Middle Hills | 8.0 | -28.6 | -28.6 | -24.2 | -29.2 | -28.6 | -24.2 |
| | Terai | 16.1 | 4.4 | 38.5 | 1.3 | 5.6 | 37.3 | 3.1 |

Source: Shrestha et al. (2013) J Wat Clim Change

# Climate change: Local Insights

Impact on Agricultural Water Requirements in Upper Indus River Basin, Pakistan (Change in %)

| Parameter | Baseline | A2 | | | B2 | | |
|---|---|---|---|---|---|---|---|
| | (mm) | Early | Mid | Late | Early | Mid | Late |
| CWR | 635.8 | - | 6.1 | 13.2 | - | 4.2 | 9.7 |
| IWR | 441.5 | | -2.4 | 10.3 | - | -14.0 | 6.1 |

Impact on Domestic water demand in Bangkok, Thailand (Change in %)

Source: Babel et al. (2013) WRM

| Parameter | Baseline | A2 | | | B2 | | |
|---|---|---|---|---|---|---|---|
| | (MCM) | Early | Mid | Late | Early | Mid | Late |
| Domestic water demand | 1240 | 39 | - | - | 39 | - | - |

# Hydropower

- Bhutan
  - Wangchu Basin

- Myanmar
  - Myitnge river basin

- Nepal
  - Dudhkoshi basin
  - Bagmati basin

- Pakistan
  - Jhelum basin

- Thailand
  - Mae Klong basin

# Climate Change: Local Insights

Hydropower (% change)

| Basin, Country | Baseline | A2 | | | B2 | | |
|---|---|---|---|---|---|---|---|
| | (MW) | Early | Mid | Late | Early | Mid | Late |
| Wangchu, Bhutan | 170 | 6.7 | 13.3 | 15.7 | 40.9 | 42.2 | 44.5 |
| Jhelum, Pakistan | 707 | 19.6 | 16.7 | 18.9 | 20.4 | 16.7 | 19.9 |

Hydropower production is projected to increase in all three future periods under both scenarios.

# Climate Change: Local Insights
## Hydropower

Impact on streamflow and hydropower generation, Jhelum basin Pakistan

Future changes (%) in hydropower production, under A2 and B2 from the Mangla plant before raising conditions, relative to 1961-1990

Source: AIT PhD Dissertation (2013)

| Season | 1961-90 | A2 | | | B2 | | |
|---|---|---|---|---|---|---|---|
| | | 2020S | 2050S | 2080S | 2020S | 2050S | 2080S |
| | (MW) | % | % | % | % | % | % |
| Winter | 416 | 39.7 | 35.7 | 41.2 | 39.3 | 34.8 | 41.1 |
| Spring | 799 | 18.0 | 9.6 | 14.8 | 20.7 | 10.2 | 17.2 |
| Summer | 927 | 6.1 | 6.8 | 5.0 | 7.1 | 7.1 | 6.4 |
| Autumn | 688 | 14.6 | 14.7 | 14.6 | 14.3 | 14.7 | 14.7 |
| Annual | 707 | **19.6** | **16.7** | **18.9** | **20.4** | **16.7** | **19.9** |

Future changes (%) in hydropower production under A2 and B2 from the Mangla plant after raising conditions, relative to 1961-1990

| Season | 1961-90 | A2 | | | B2 | | |
|---|---|---|---|---|---|---|---|
| | | 2020S | 2050S | 2080S | 2020S | 2050S | 2080S |
| | MW | % | % | % | % | % | % |
| Winter | 494 | 29.8 | 26.8 | 30.7 | 29.3 | 26.5 | 30.6 |
| Spring | 916 | 11.0 | 7.8 | 9.5 | 11.9 | 8.1 | 10.4 |
| Summer | 989 | 6.1 | 6.7 | 4.8 | 7.3 | 7.3 | 6.0 |
| Autumn | 764 | 13.0 | 13.2 | 12.8 | 12.8 | 13.4 | 13.2 |
| Annual | 791 | **15.0** | **13.6** | **14.5** | **15.3** | **13.8** | **15.1** |

# Key challenges

# Key Challenges

- Interpreting and using climate data at different scales in order to plan the development of water resources more effectively

- Uncertainties in future climate projections

- Forecasting extreme events
  - Past is not a good indicator of future
  - Frequency, location, magnitude, duration of extremes may change
  - Chance of extreme event is not the same from one year to next and is strongly related to large-scale climate drivers like ENSO

- Develop more accurate and reliable early warning systems

- Future local climate information (e.g. atlas)

- Translating the impacts to societal implications (vulnerability and risks)

- Impacts are visible, suitable adaptation and mitigation measures are required

- Science-policy dialogue

# Key Challenges

- Preparing and implementing the adaptation strategies for long term and short term regional and local level impacts:
  - more intensive precipitation events
  - increased drought risk
  - reduced access to water and food
  - ecosystems shift in space and in species composition
  - change in growing season for traditional crops
- Shifting balance because of changed water demand while changed water supplies to simultaneously meet the needs of growing communities, sensitive ecosystems, farmers, energy producers, and manufacturers
- Lack of knowledge and capacity at different levels
- Lack of technology and infrastructure in developing countries
  - Technology transfer
- How global and local communities can more meaningfully be brought together?

msbabel@ait.asia
msbabel@gmail.com