Climate Change and Flood Risks: Understanding the Uncertainty Range of Hydrologic Response

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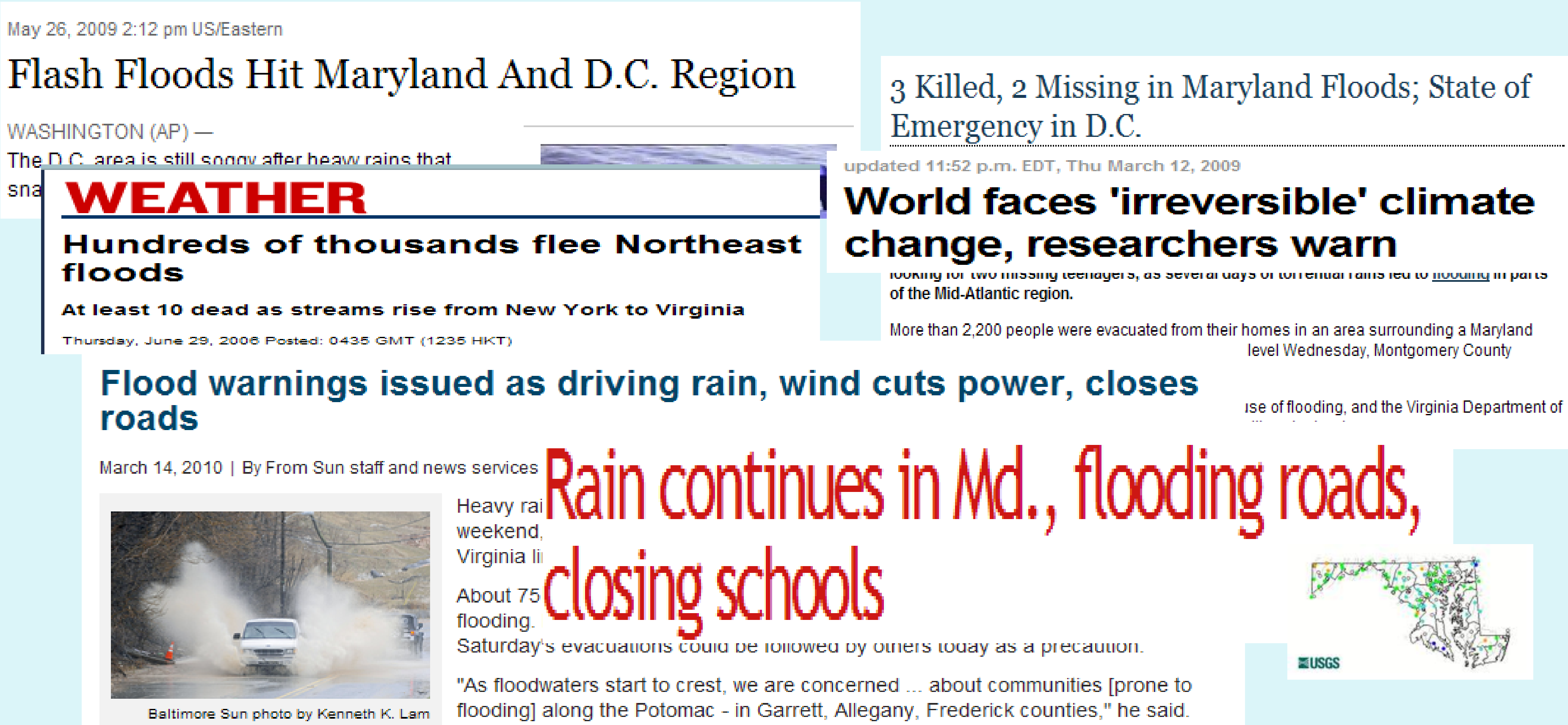
Outline

- **Introduction: Observational Records**
- **Maryland's Vulnerability to Climate Change**
- **Adaptive Measures: Missing Information and Knowledge Gaps**
- **Uncertainty in Climate Change Projections**
- **Climate Change Scenarios**
- **Uncertainty Range of Hydrologic Response**
- **Summary and Conclusions**

Introduction: Observational Records


May 26, 2009 2:12 pm US/Eastern

Flash Floods Hit Maryland And D.C. Region

WASHINGTON (AP) —

3 Killed, 2 Missing in Maryland Floods; State of Emergency in D.C.

of the Mid-Atlantic region.

More than 2,200 people were evacuated from their homes in an area surrounding a Maryland

level Wednesday, Montgomery County

WEATHER

Hundreds of thousands flee Northeast floods

At least 10 dead as streams rise from New York to Virginia

Thursday, June 29, 2006 Posted: 0435 GMT (1235 HKT)

updated 11:52 p.m. EDT, Thu March 12, 2009

World faces 'irreversible' climate change, researchers warn

Flood warnings issued as driving rain, wind cuts power, closes roads

March 14, 2010 | By From Sun staff and news services

Baltimore Sun photo by Kenneth K. Lam

"As floodwaters start to crest, we are concerned ... about communities [prone to flooding] along the Potomac - in Garrett, Allegany, Frederick counties," he said.

Rain continues in Md., flooding roads, closing schools

USGS

In recent years, hurricanes, tropical storms and heavy rains have inundated Maryland residents with extensive flooding problems.

Introduction: Observational Records

- Why "historic" floods are occurring more often than calculations suggest they should?

- Why are we seeing “more” floods and “worse” floods than ever before?

We need a broader view to develop progressive strategies for reducing flood risks.

Introduction: Observational Records

- **Observational evidence indicates an ongoing acceleration of the water cycle and consistent with both warming and increase of atmospheric water vapor, the frequency of heavy precipitation events has increased** *(IPCC WGI).*

- **Globally, the number of great inland flood catastrophes over the last 10 years (1996-2005) is twice as large, per decade, as between 1950 and 1980, while related economic losses have increased by a factor of five** *(Kron and Bertz, 2007).*

- **Human encroachment into flood plains and lack of flood response plans increase the damage potential** *(IPCC WG II).*

Maryland's Vulnerability to Climate Change

Maryland's people, property, and natural resources face new challenges under climate change conditions.

Maryland's Vulnerability to Climate Change

What does climate change imply for flooding in the future?

- **Maryland can expect temperatures to be warmer during every season, with the largest deviations from average temperature occurring during the summer months.**
- **Annual precipitation will increase and more winter precipitation will fall as rain; there will also be more frequent and intense storms.**
- **Sea level rise will inundate and alter much of the Maryland coastline.**

Maryland Commission on Climate Change

Adaptive Measures: Missing Information and Knowledge Gaps

- Structural flood protection schemes should take into account the possible increase in the magnitude of the design flood.

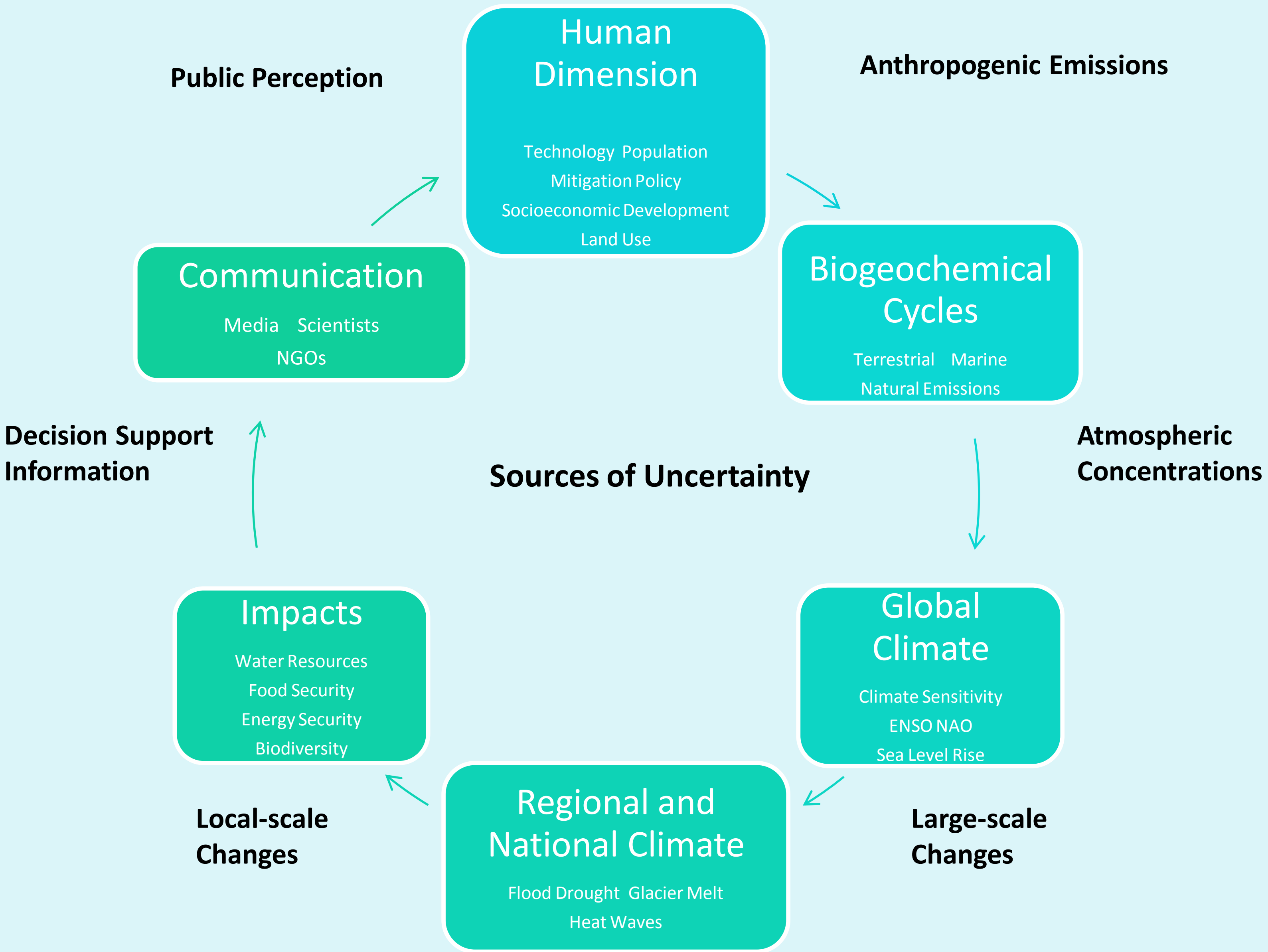
- What are the potential effects of climate change on flood frequencies and the extent of the floodplains?

- The biggest challenge in developing adaptive measures is the inherent uncertainty in climate change projections

- What are the most appropriate protection strategies given climate change uncertainty?

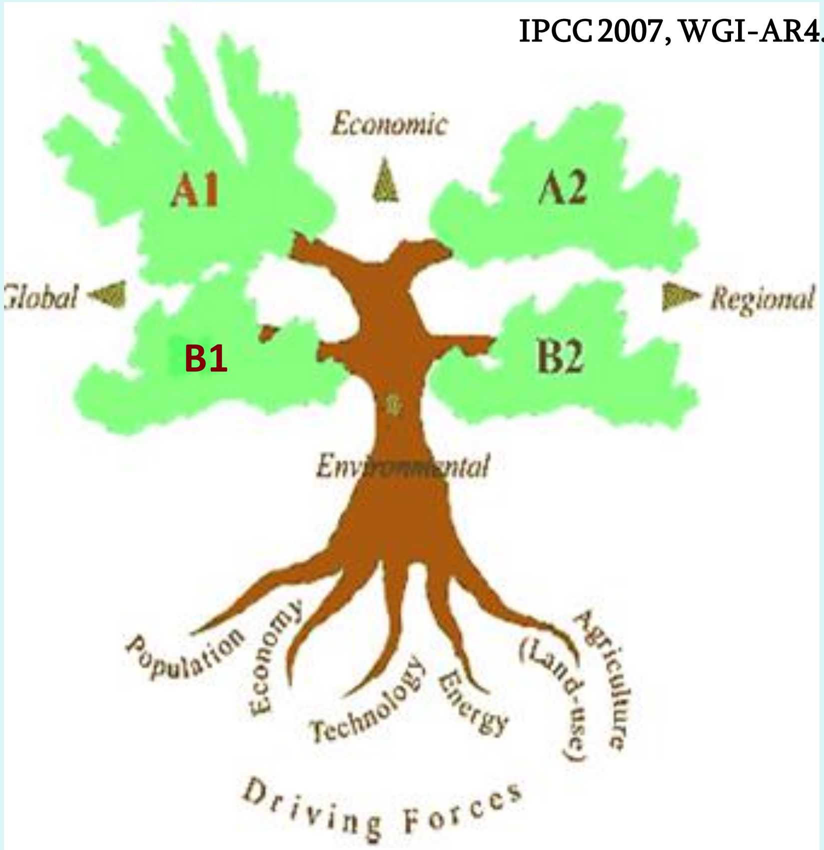
- Structural designs should allow the possibility of future incremental adaptation.

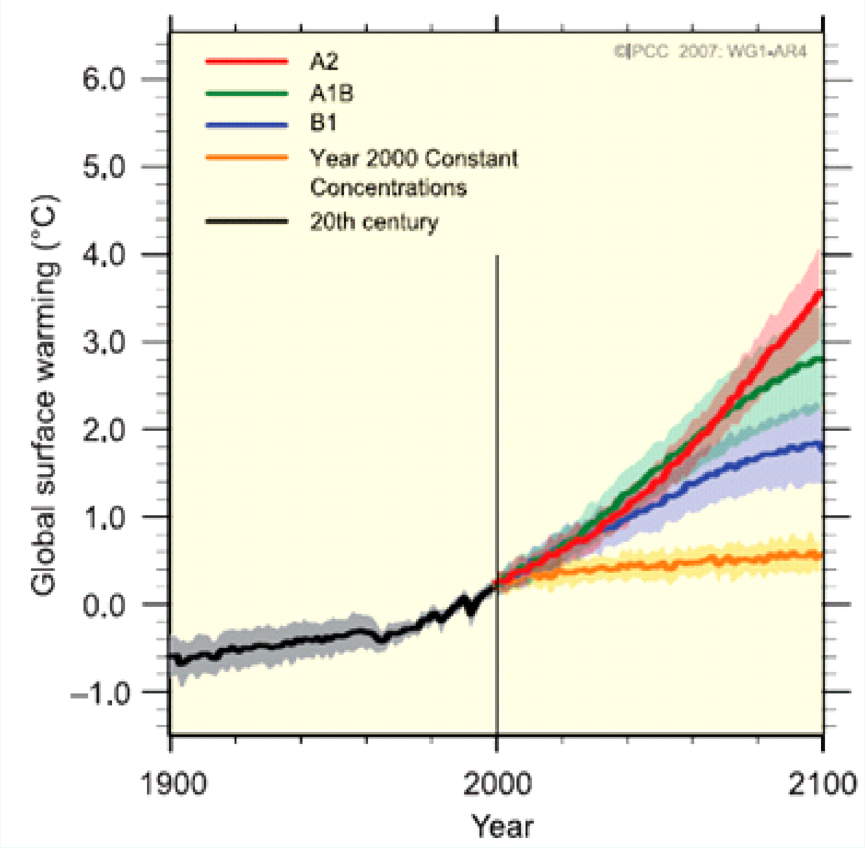
Uncertainty in Climate Change Projections



EOS, Transactions, AGU – Nov08

An Overview of Climate Change Scenarios





Summary characteristics of the four IPCC SRES storylines (based on Nakićenović and Swart, 2000).

Economic emphasis

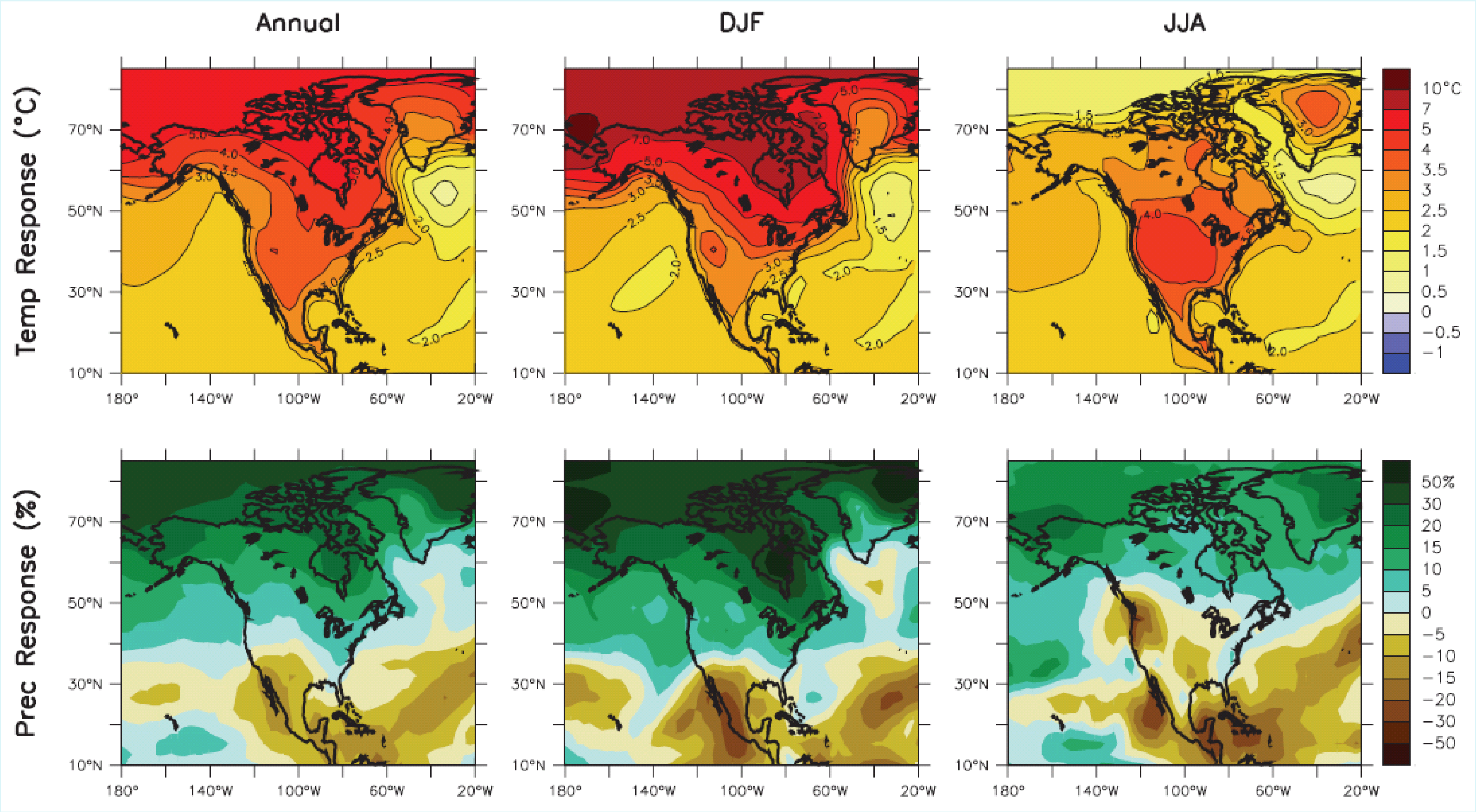
Global Integration (left) / **Regional emphasis** (right)

A1 storyline: World: market-oriented Economy: fastest per capita growth Population: 2050 peak, then decline Governance: strong regional inter-actions; income convergence Technology: three scenario groups: • **A1FI**: fossil intensive • **A1T**:non-fossil energy sources • **A1B**: balanced across all sources	**A2 storyline** World: differentiated Economy: regionally oriented; low-est per capita growth Population: continuously increasing Governance: Self-reliance with preservation of local identities Technology: slowest and most fragmented development
B1 storyline World: convergent Economy: service and information based; lower growth than A1 Population: same as A1 Governance: global solutions to economic, social and environmental sustainability Technology: clean and resource-efficient	**B2 storyline** World: local solutions Economy: intermediate growth Population: continuously increasing at lower rate than A2 Governance: local and regional solutions to environmental protec-tion and social equity Technology: More rapid than A2; less rapid, more diverse than A1/B1

Environmental emphasis

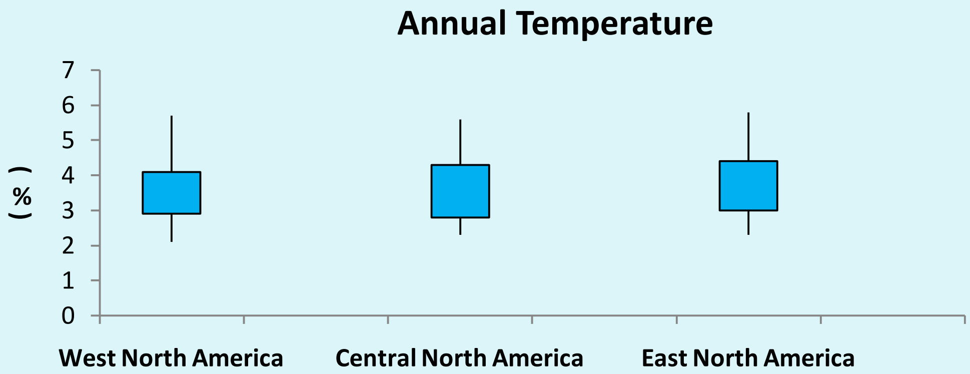
Summary characteristics of the four SRES storylines (based on Nakićenović and Swart, 2000).

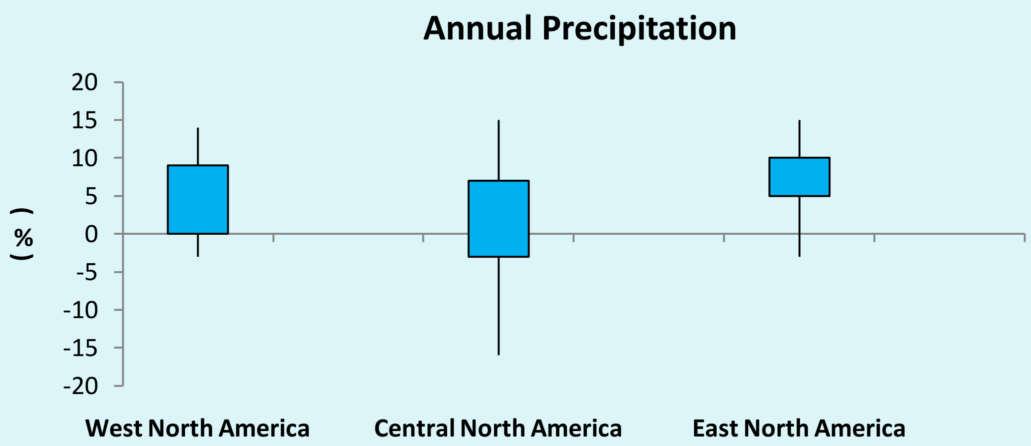
Climate Change Projections

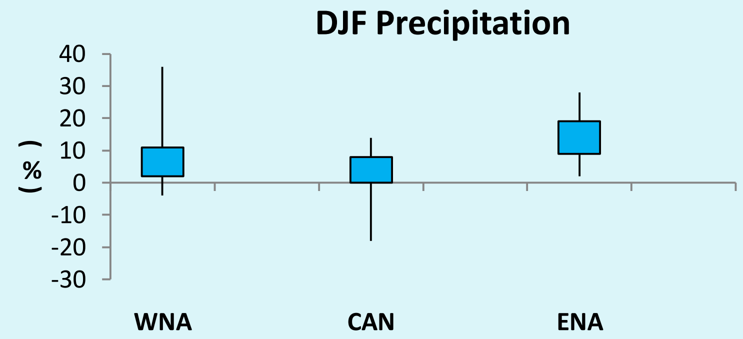


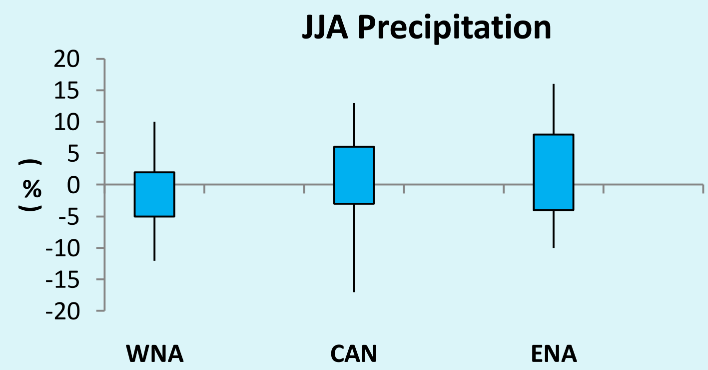
Annual, Winter (DJF) and Summer (JJA) Temperature and Precipitation change between 1980 to 1999 and 2080 to 2099, averaged over 21 models from the MMD-A1B Simulations (IPCC AR4, Climate Change 2007:Physical Science Basis)**.**

Climate Change Projections



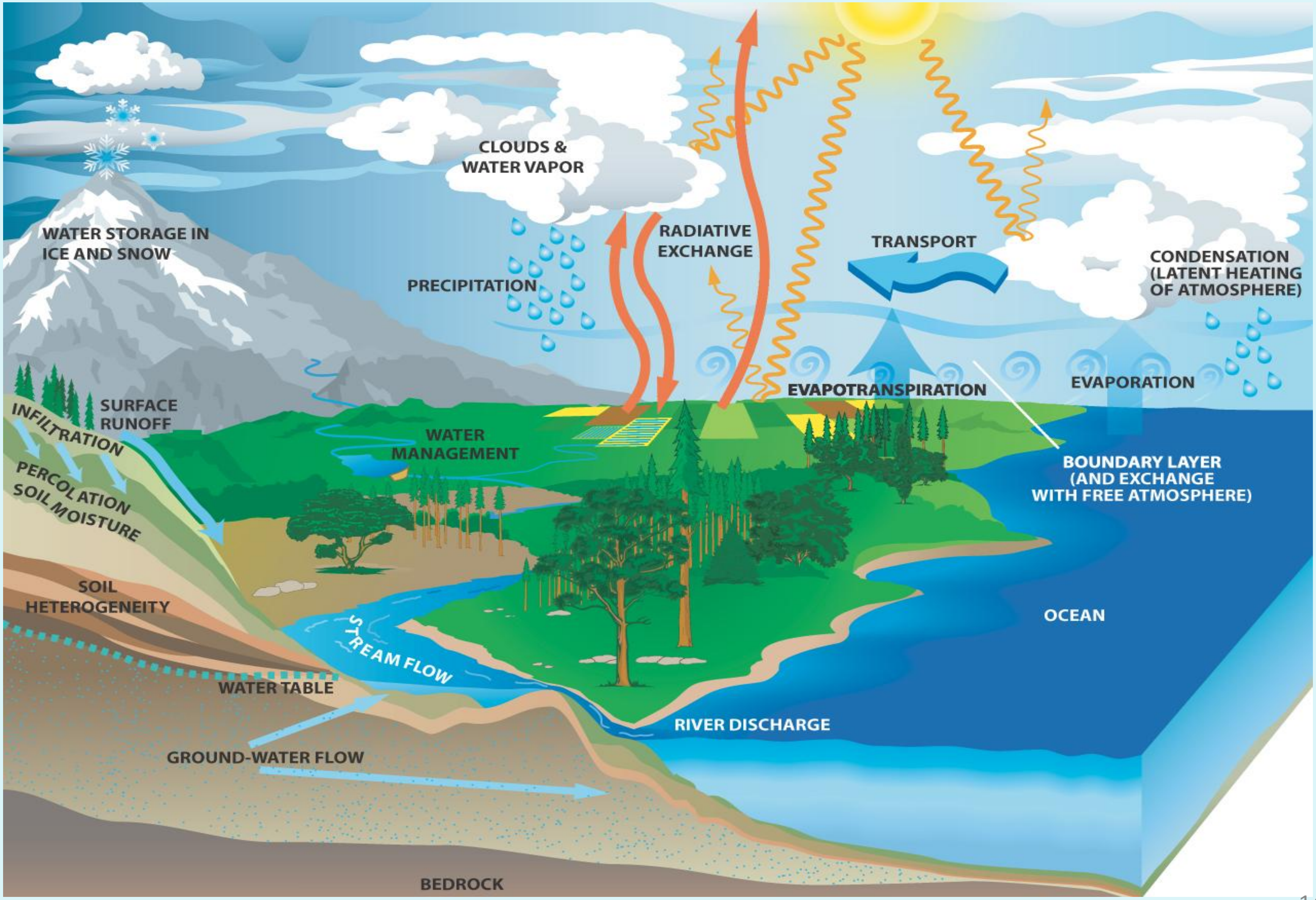






The distribution of the annual mean temperature and precipitation change is described by the median, the 25 and 75% values and the maximum and minimum values in the model ensemble of 21 General Circulation Models (IPCC AR4, Climate Change 2007:Physical Science Basis).

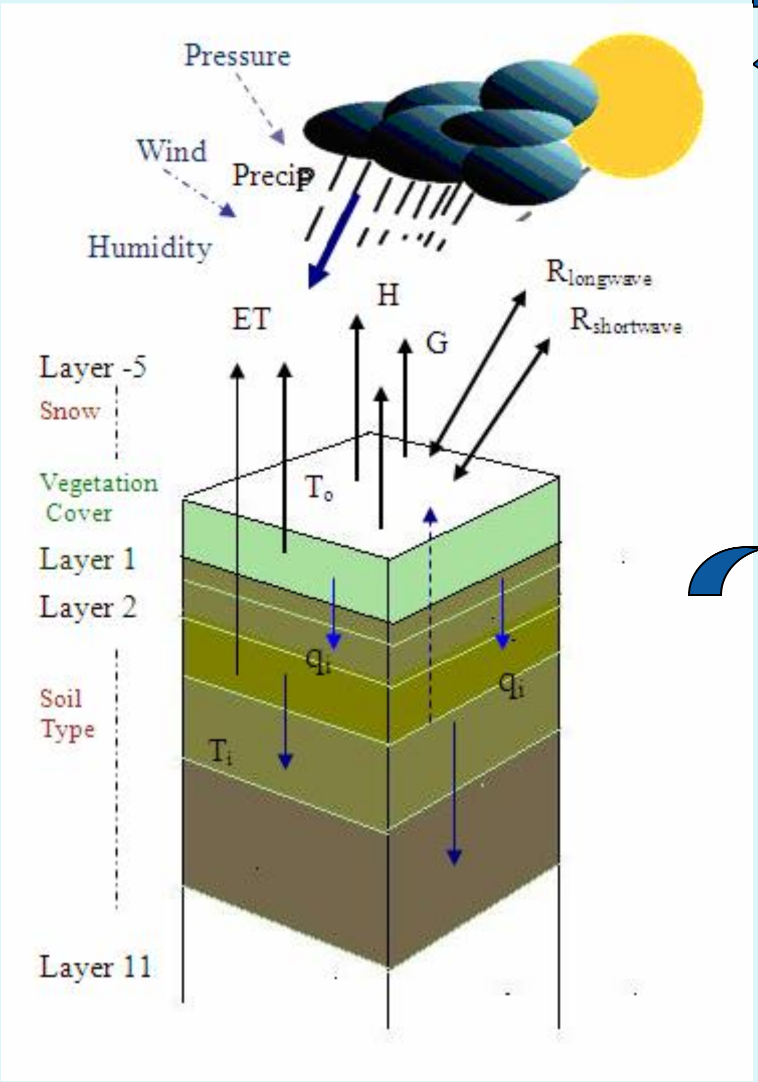
Understanding the Uncertainty Range of Hydrologic Response



Understanding the Uncertainty Range of Hydrologic Response

Hydrologic Modeling Framework

Physically based distributed model



Input: Meteorological Forcing

- Incoming Shortwave Radiation
- Incoming Longwave Radiation
- Total Precipitation
- Convective Precipitation
- Total Snowfall
- Air Temperature
- Pressure
- Wind Components
- Specific humidity

Input: Surface Boundary Conditions

- Surface elevation (DEM) and related variables
- Land cover category (LCC)
- Fractional vegetation cover
- Sand & Clay fraction profiles
- Bedrock depth

Output:

- Energy fluxes
- Water fluxes

Perfect energy and water balance within every time step

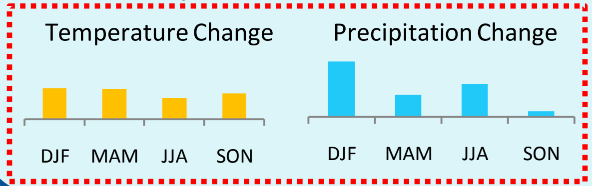
Understanding the Uncertainty Range of Hydrologic Response

Surface Boundary Conditions

Topography, Vegetation Cover,
Bedrock Depth,
Sand and Clay % Profiles
Land Use-Land Cover

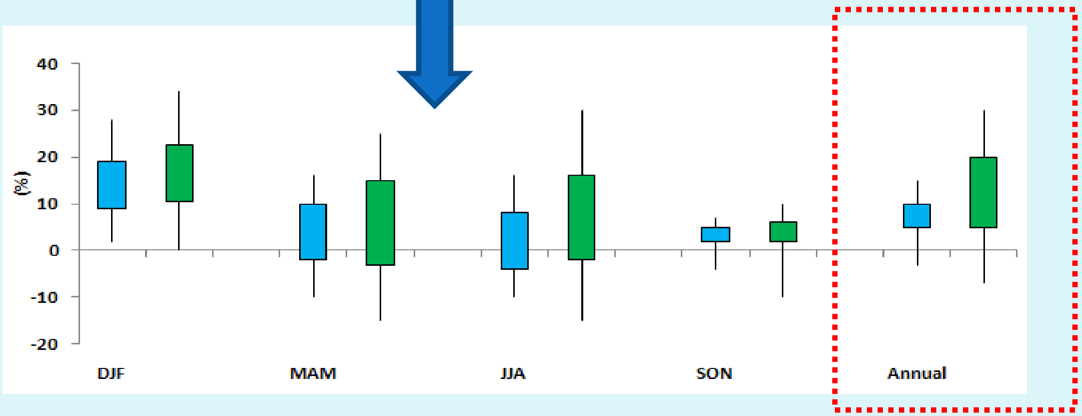
Meteorological Forcing

Temperature, Precipitation,
Radiation, Humidity, Pressure,
Wind Components



Hydrologic Model

Hydrologic cycle is changing, how can we predict it?



A Non-linear Increase in the Runoff Response (shown in green) adjacent to the % Precipitation Change

Understanding the Uncertainty Range of Hydrologic Response

- **The accuracy of the 100-year floodplain boundary is influenced most strongly by the quality of the 100-year discharge estimates. The next most significant factor is the quality of the topographic mapping.**

- **Uncertainties in projected changes in the hydrological system arise from internal variability of the climate system and model uncertainty.**

- **A large number of simulations are now available from a broader range of climate models, run for various emission scenarios.**

- **Despite uncertainties, robust results are available for climate change projections in the fourth assessment report of IPCC.**

Understanding the Uncertainty Range of Hydrologic Response

- **Projections become less consistent between climate models with regionalization as the spatial scale decreases.**

- **The resolution of current climate models limits the proper representation of tropical cyclones and heavy rainfall events.**

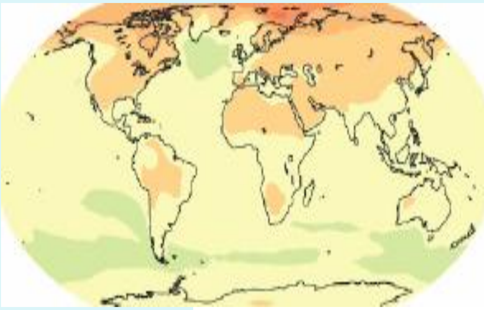
- **Changes in inter-annual or day-to-day variability of climate parameters are not taken into account in most hydrological impact studies. This leads to underestimation of future floods.**

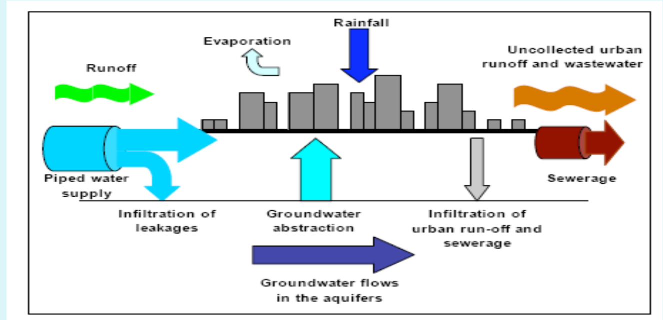
Conclusions

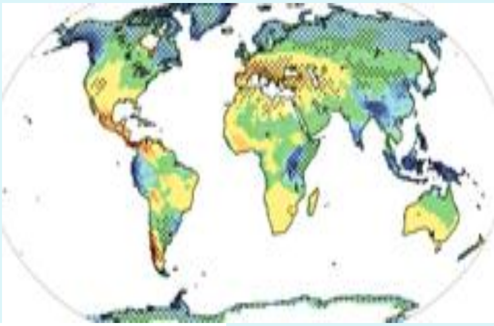
- **Climate models and impact assessments are becoming increasingly refined, generating information at higher spatial and temporal resolutions than previously possible.**

- **Although, there is an inherent uncertainty in measuring climate change and its impacts; scenarios and ranges of confidence enable us to take actions now to reduce severe economic losses.**

- **We need to acknowledge higher flood risks than 100-year-flood for flood control structures and regulations. More up-to-date flood studies are required.**





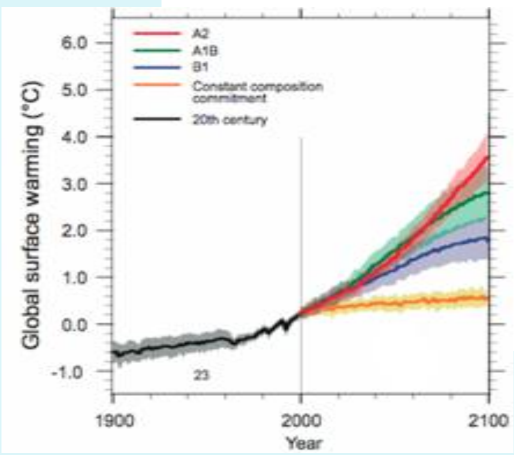


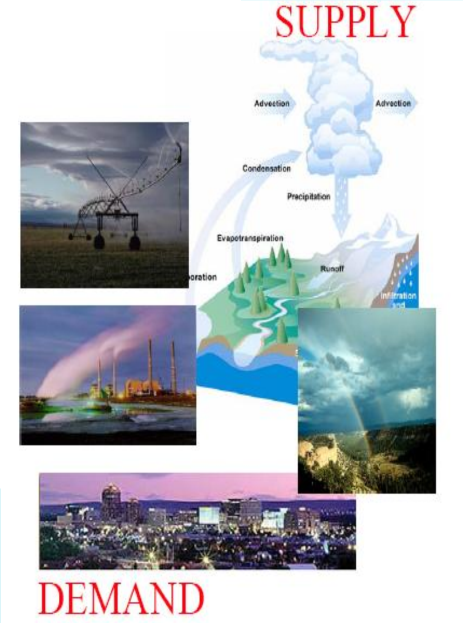
Climate Change

Hydrologic Response

Integrated Approach

Climate Policy





Mitigation

Adaptation