Climate Change Impacts on the Green River Basin

Gi-Hyeon Park

Civil & Architectural Engineering
University of Wyoming

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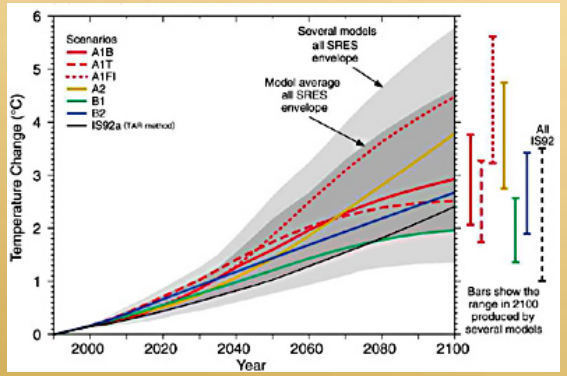
Two Primary Water Resources Challenges

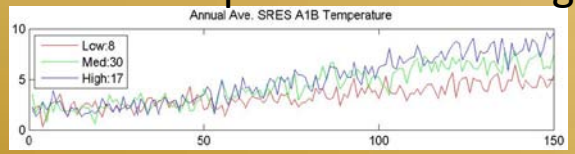
- ***Water Supply Requirements (<u>Quantity</u> and Quality)***

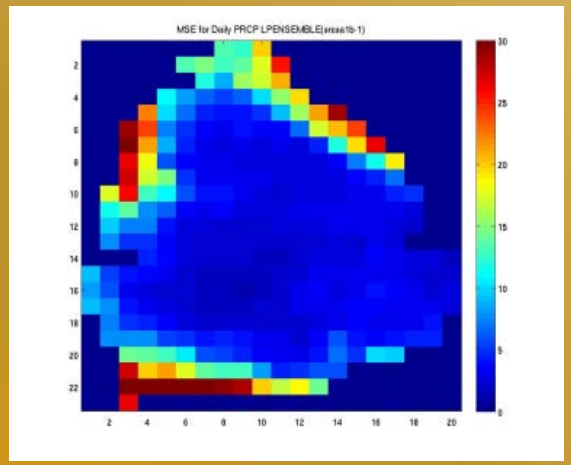
- ***Hydrologic Hazards (<u>Floods</u> and <u>Droughts</u>)***

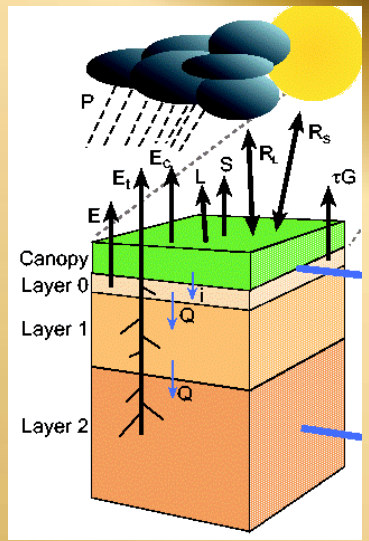
Overview



Spatial &
Temporal downscaling

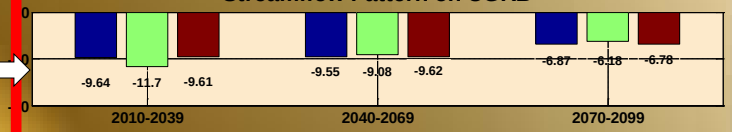




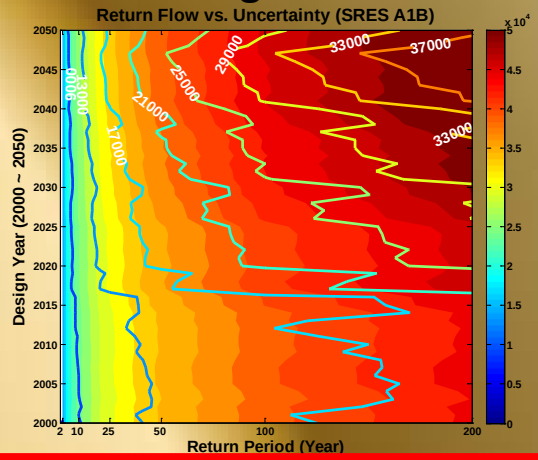


Calibration

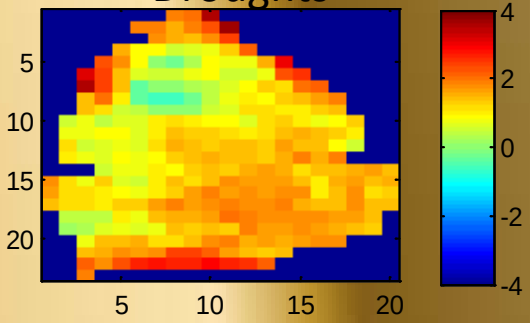
Water Supply Forecast



Design Flow

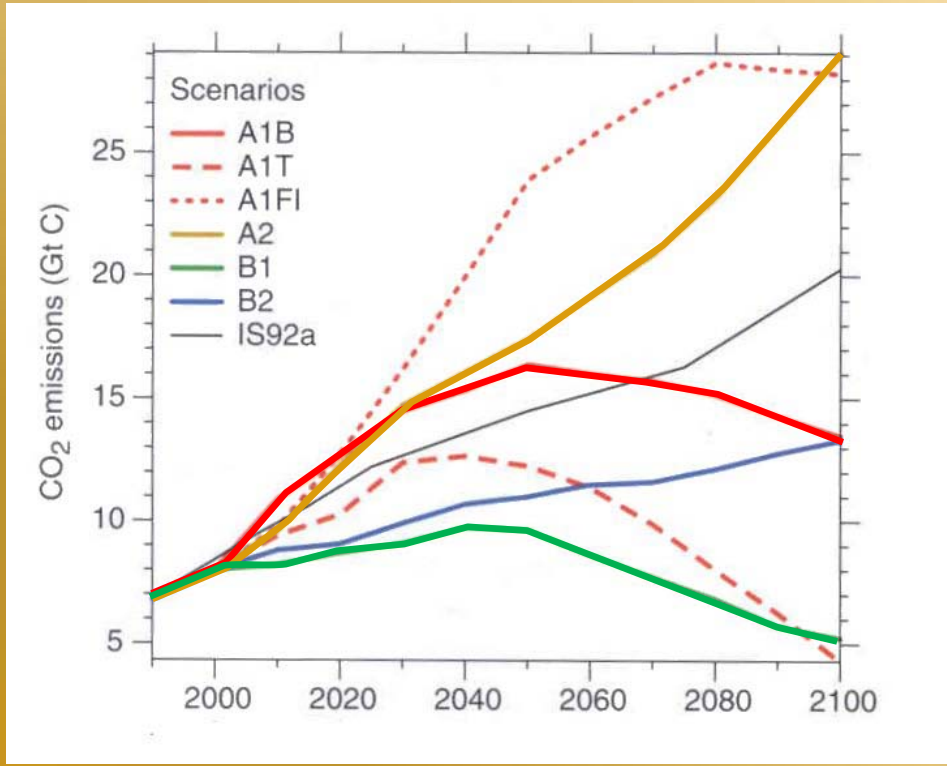


Droughts



IPCC Scenarios

- Emission Scenarios (A2, A1B, and B1)
- 112 BCSD WCRP CMIP3 projections (**B**ias **C**orrected and **S**patially **D**ownscaled **W**orld **C**limate **R**esearch **P**rogramme **C**oupled **M**odel **I**ntercomparison **P**roject Phase **3**) : Monthly 1/8 degree P , max and min T



Scenarios	# of Projections
A2	36
A1B	39
B1	37

Regional Impact of Climate Change

Global average temperature increase of 1–4°C, relative to 1990–2000 (IPCC, 2007)

Increased frequency of extreme events (heatwaves, floods, fires, droughts)

Increase in the areas affected by drought

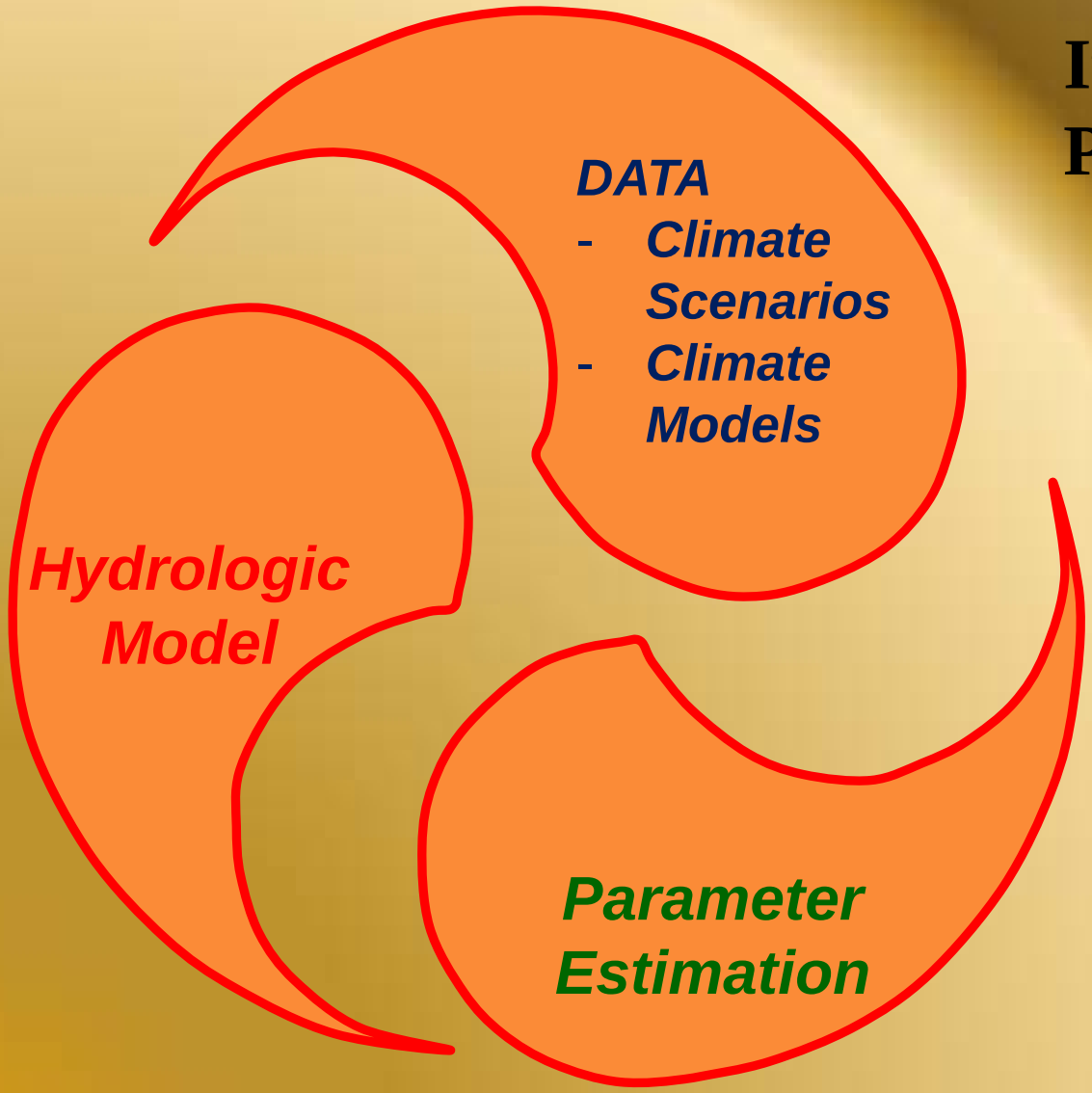
Melting or forming ice, changing the hydrological cycle (evaporation and precipitation)

Net negative impact of climate change on water resources and freshwater ecosystems

Semi-arid and arid areas are particularly exposed to the impacts of climate change on freshwater. With very high confidence, it was judged that many of these areas, e.g., the Mediterranean basin, **western USA**, southern Africa, and north-eastern Brazil, would suffer **a decrease in water resources due to climate change**.

Projections of future climate changes at the regional scale do not hold as high a level of scientific confidence as projections made at the global scale. (Staudt et al, 2008)

Climate Change Impact Modeling

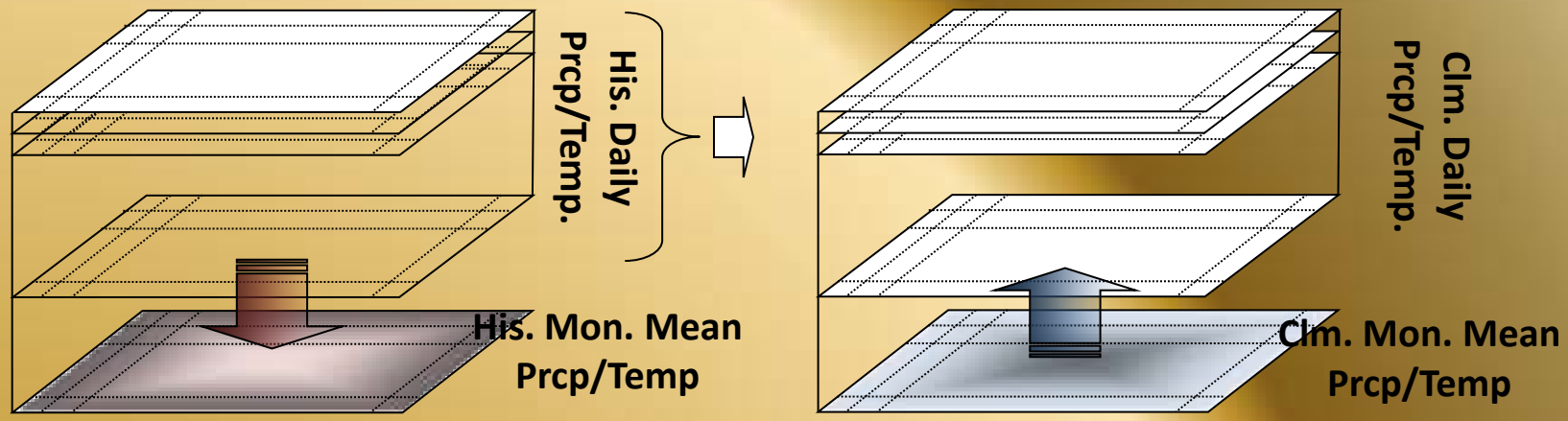


If everything was Perfect!

Uncertainties

- Climate Projection
- Hydrologic Model
- Parameter

Downscaling Climate Projections



Spatial Downscaling

Temporal Downscaling

Daily Climate Scenarios

Spatial Downscaling Limitation

- Hard to Preserve the Statistical Properties among Grid-Cell Data in Space during the temporal downscaling
- Propose an additional **Nearest Neighbor Resampling Method** during the temporal downscaling

Nearest Neighbor Resampling Method

Historical Monthly Mean

o	o	o	o	o	o	o	o	o
o	o	o	o	o	x	o	o	o
o	o	o	o	o	o	o	o	o
o	o	o	o	o	o	o	o	o
o	o	o	o	o	o	o	o	o
o	o	o	o	o	o	o	x	o
o	o	o	o	o	o	o	o	o

Climate Monthly Mean

o	o	o	o	o	o	o	o	o
o	o	o	o	x	x	o	o	o
o	o	o	o	o	o	o	o	o
o	o	o	o	o	o	o	o	o
o	o	o	o	o	o	o	o	o
o	o	o	o	o	o	o	o	o
o	o	o	o	o	o	o	o	o

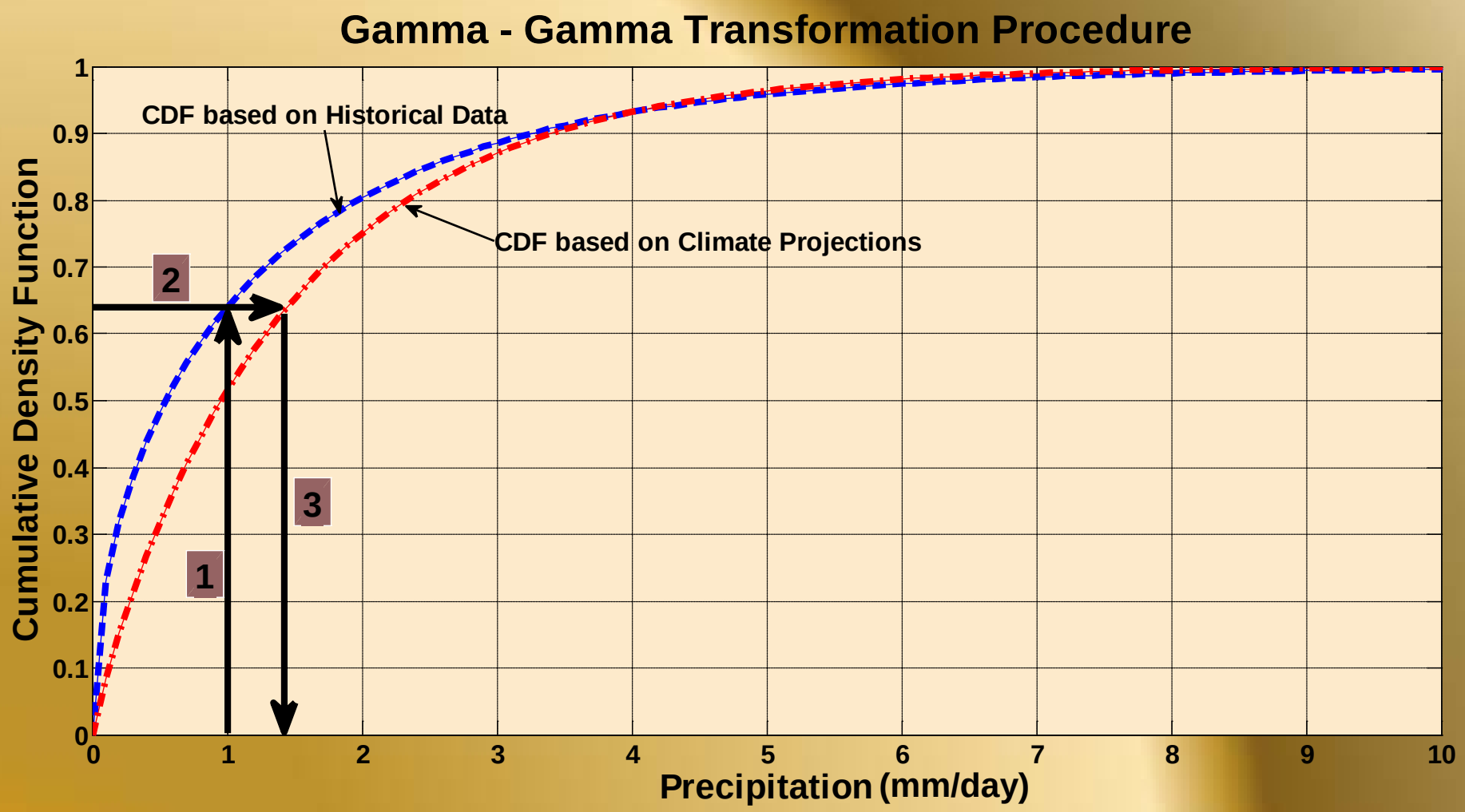
Future Daily climate Scenarios

o	o	o	o	o	o	o	o	o
o	o	o	o	x	x	o	o	o
o	o	o	o	o	o	o	o	o
o	o	o	o	o	o	o	o	o
o	o	o	o	o	o	o	o	o
o	o	o	o	o	o	o	o	o
o	o	o	o	o	o	o	o	o

Temporal Downscaling

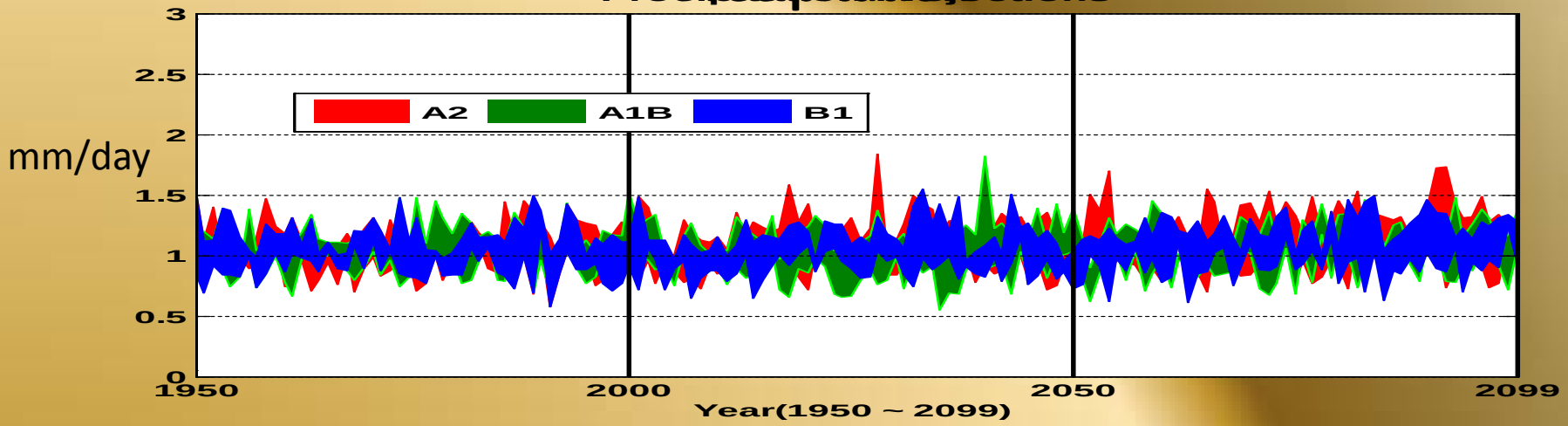
- Ratio Method → Unexpected Extreme Values
- Bias Adjustment -> Frequent Negative values
- **Bias Adjusted Gamma – Gamma Transformation (BAGGT) Method to maintain statistical properties**
  - **Mean**
  - **Variance**
  - **Frequency**

Bias Adjusted Gamma-Gamma Transformation (BAGGT)

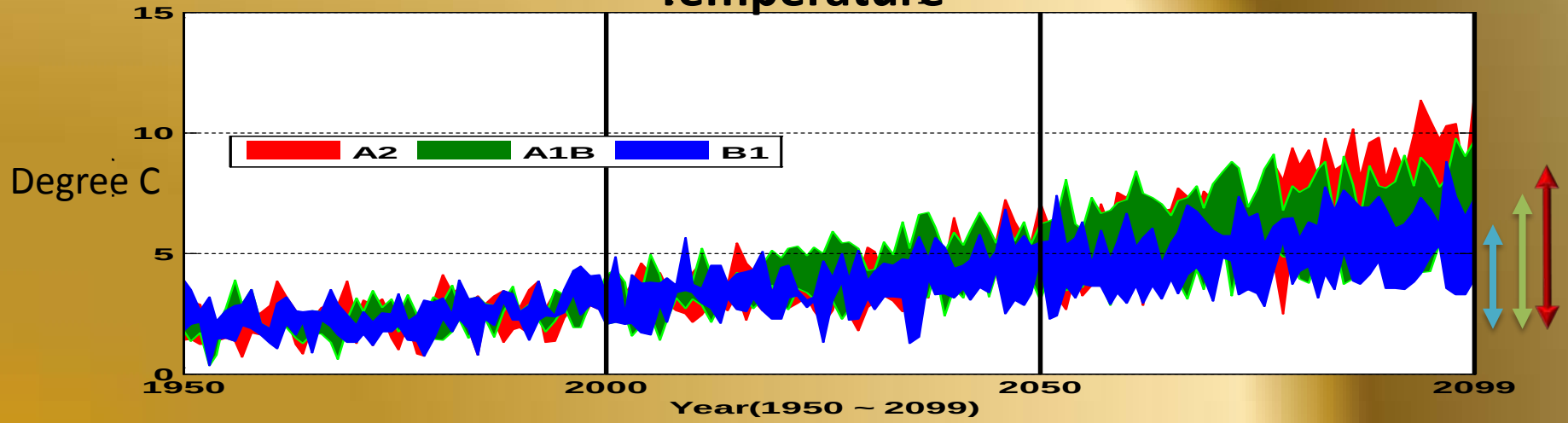


Climate Projections on GRB

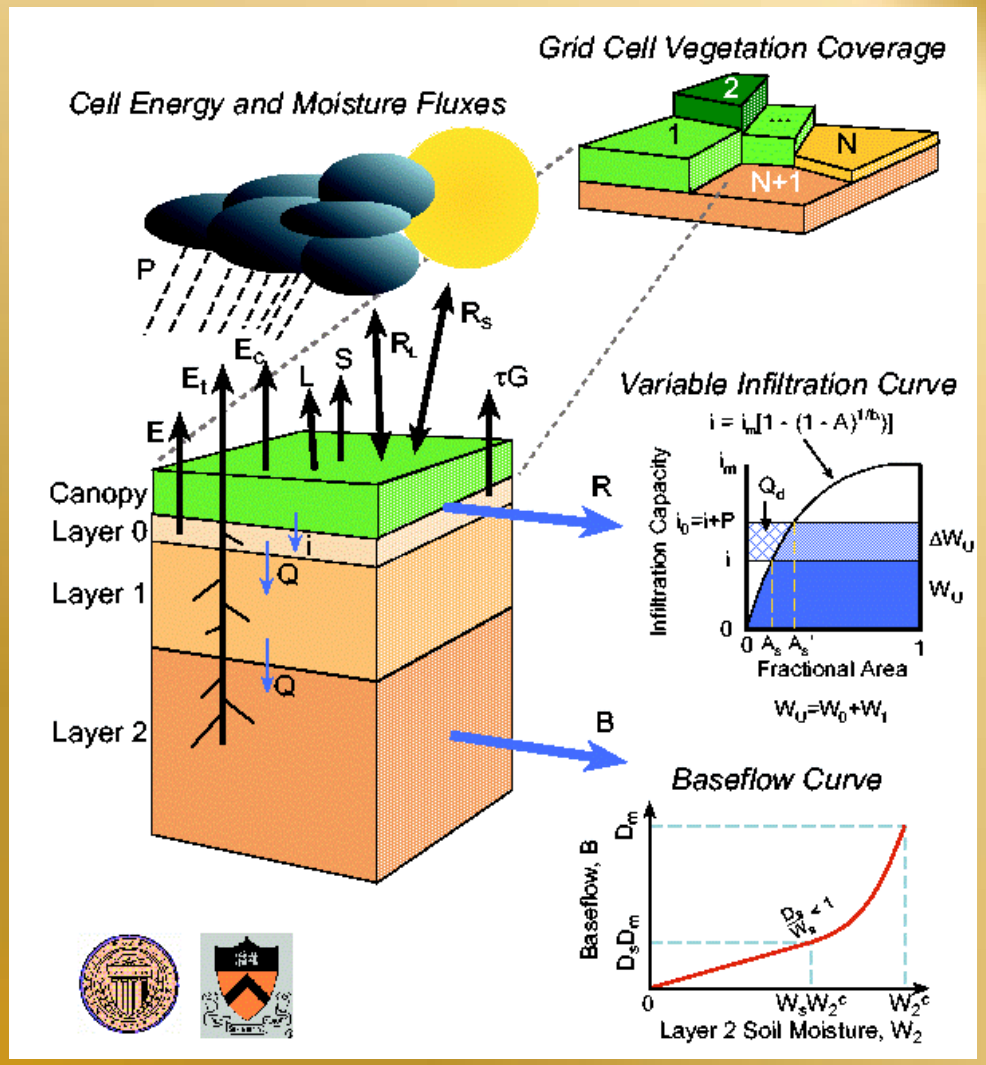
Precipitation



Temperature



Hydrologic Model



Variable Infiltration Capacity (VIC) Model

- Semi-distributed
- Grid-based
- Macro-scale
- Hydrological model

Need to be calibrated for the watershed

Calibration

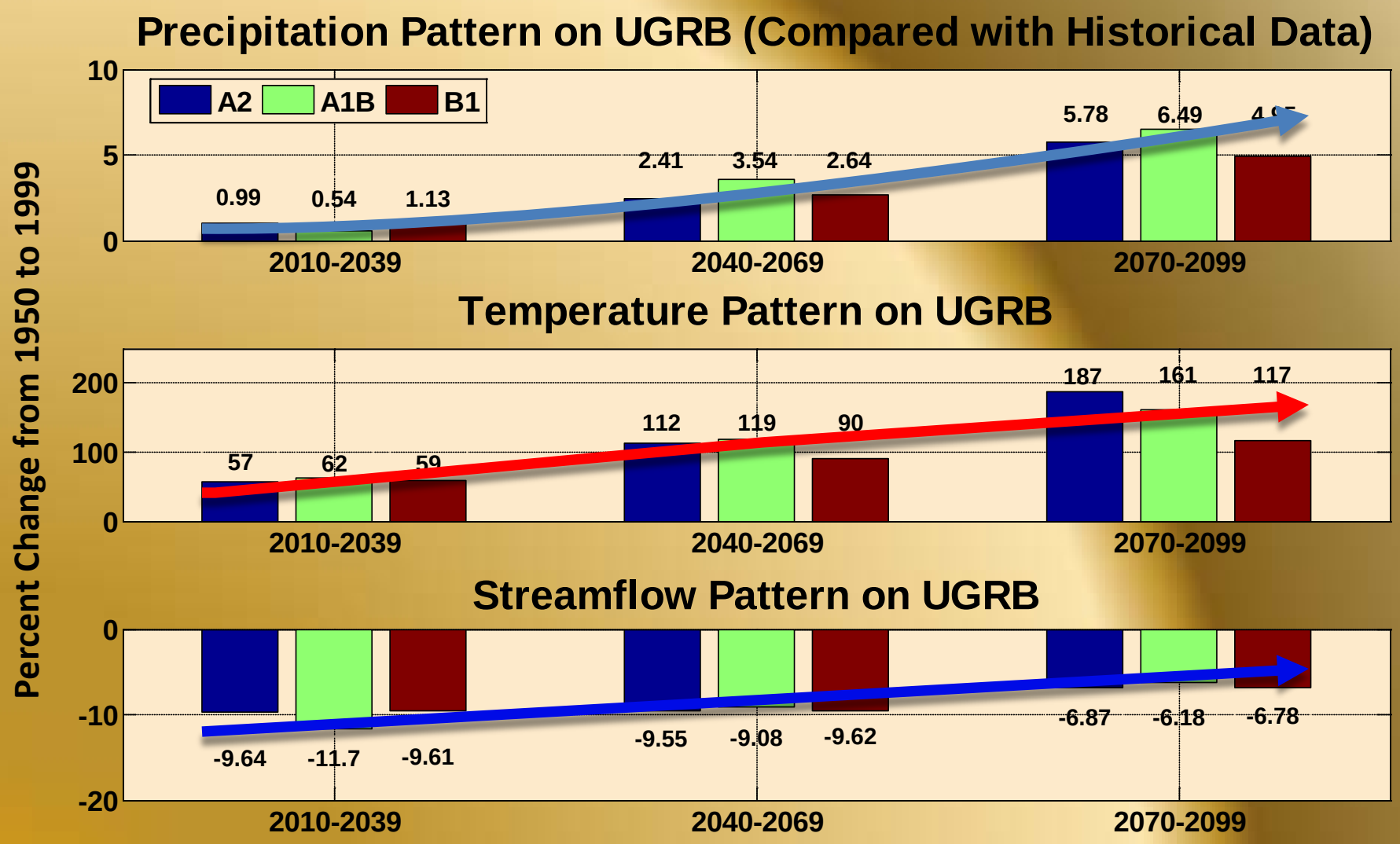
- Calibration Parameters
  - **Ds**: the fraction of the Dsmax parameter at which non-linear base-flow occurs
  - **Dsmax**: the maximum velocity of baseflow for each grid cell
  - **Ws**: the fraction of maximum soil moisture where non-linear baseflow occurs
  - **Binf**: the Variable Infiltration Curve
  - **Soil Depth**: Thickness of each soil moisture layer

- Optimization Method: Shuffled Complex Evolution Model (SCE-UA)

- Calibrated Parameter Values for Green River Basin

Ds	Dsmax	Ws	Binf	Depth1	Depth2	Depth2
0.0145	5.4298	0.4732	0.0961	0.1475	0.4934	1.3869

21st Century Climate Change in UGRB



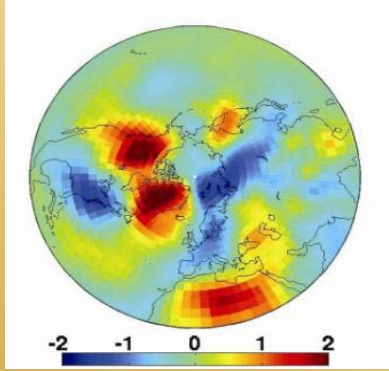
Implications of Design Flow (USGS, 2003: Report 03-4107)

- Engineers
  - The Cost-Effective Design of Bridges, Culverts, and Streamflow Control Structures

- County and City Planners
  - Land Use Zone and Emergency Preparedness
- Government and Private entities
  - Reservoir Management

- Scientists
  - The Studies of the Hydrology, Water-quality, and Ecology of watershed

Past and Future



Climate Projections of Hydrological Data (Precipitation and Temperature)

Variable Infiltration Capacity (VIC) Model

Historical Streamflow Data

Climate Streamflow Projections

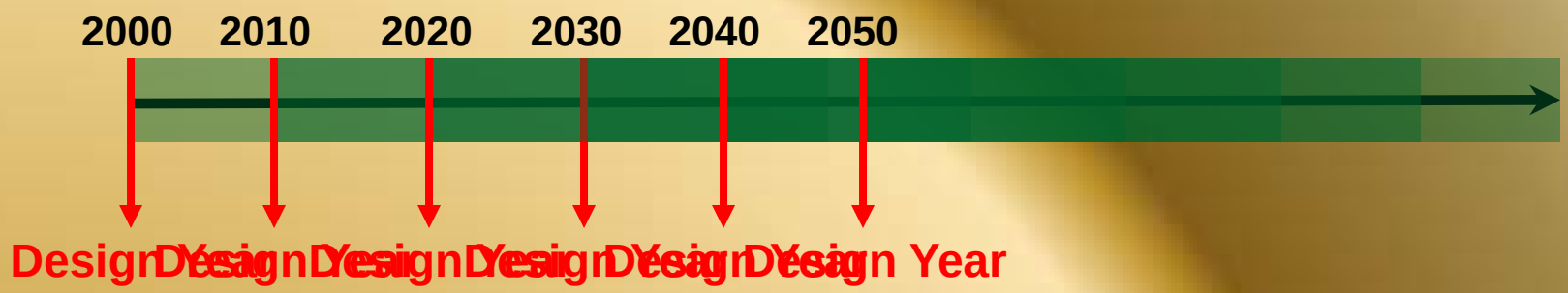
Historical Stationarity Method

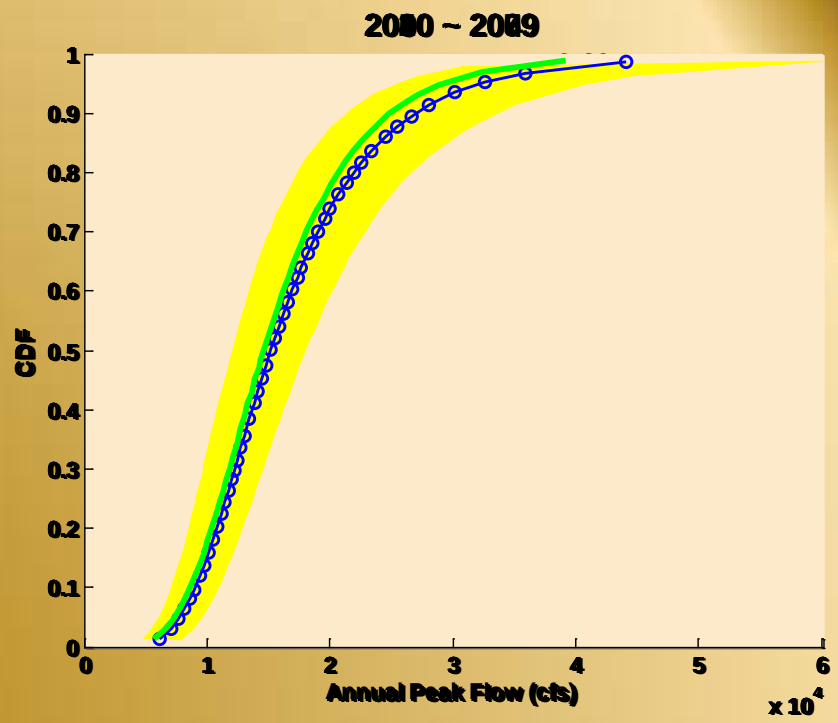
21st Century Stationarity Method

Non-Stationarity Method

Current

Non-stationary Design Flow Method

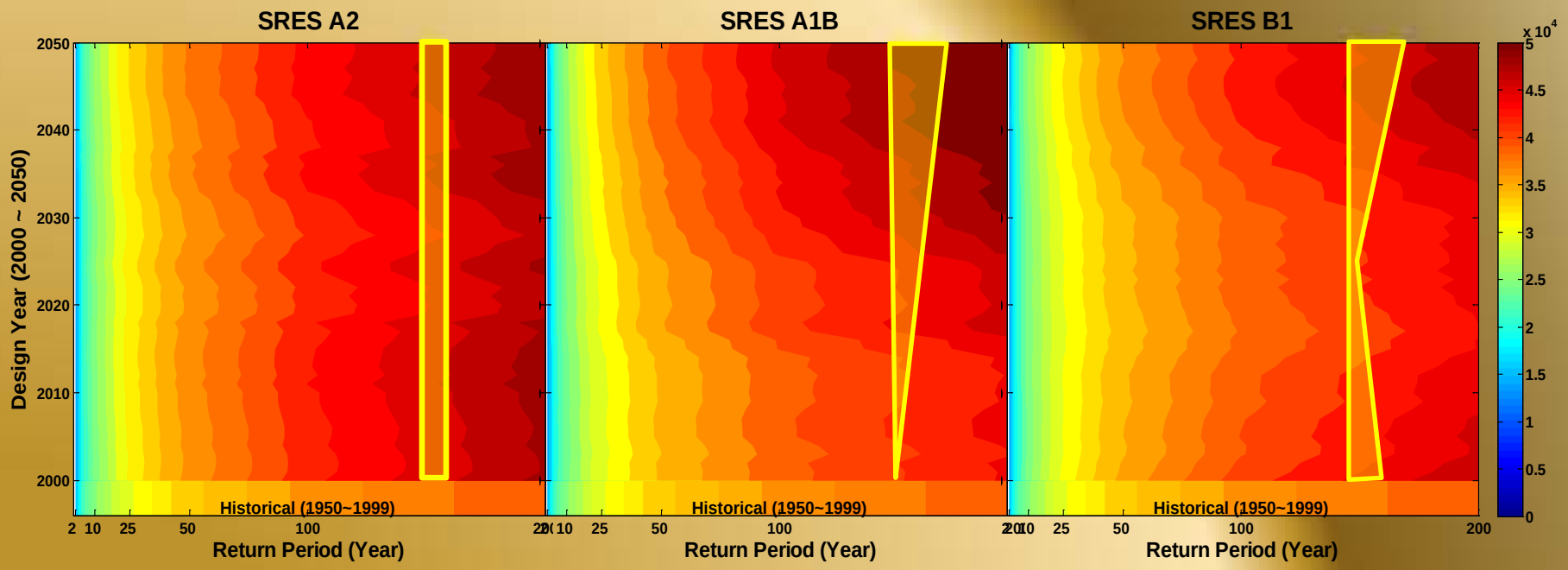




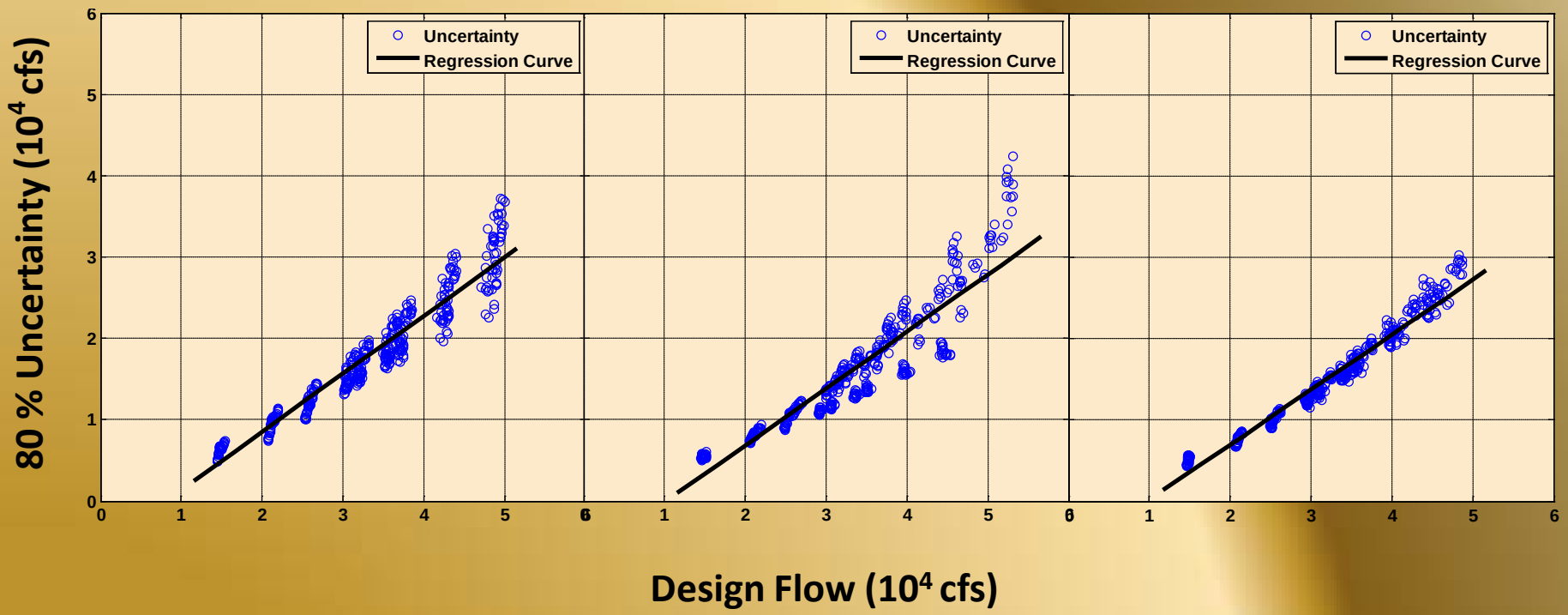
Estimated General Extreme Value

10 – 90 % Uncertainty Boundary

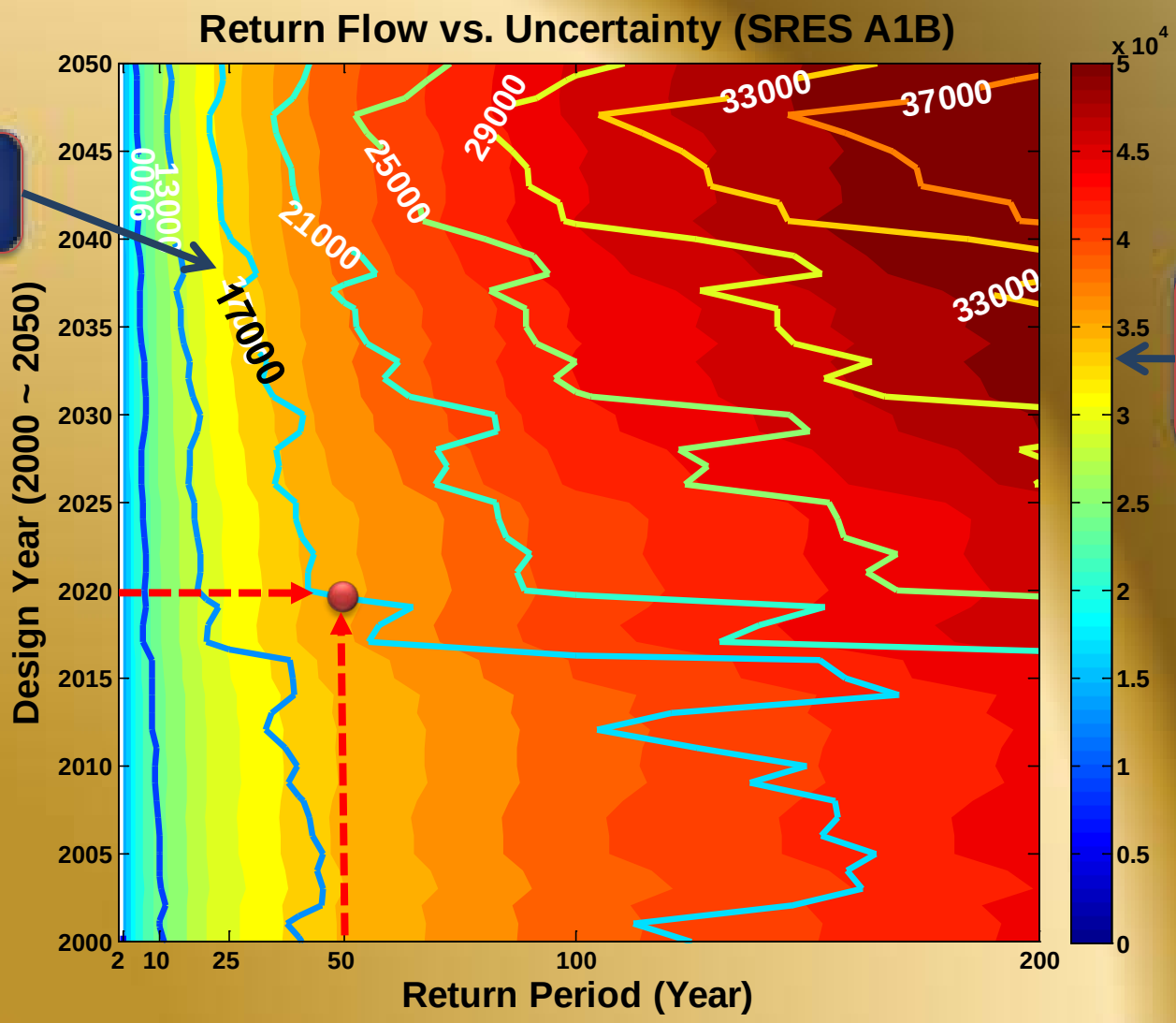
Design Flow from 3 Emission Scenarios



Relationship between Design Flow and Uncertainty



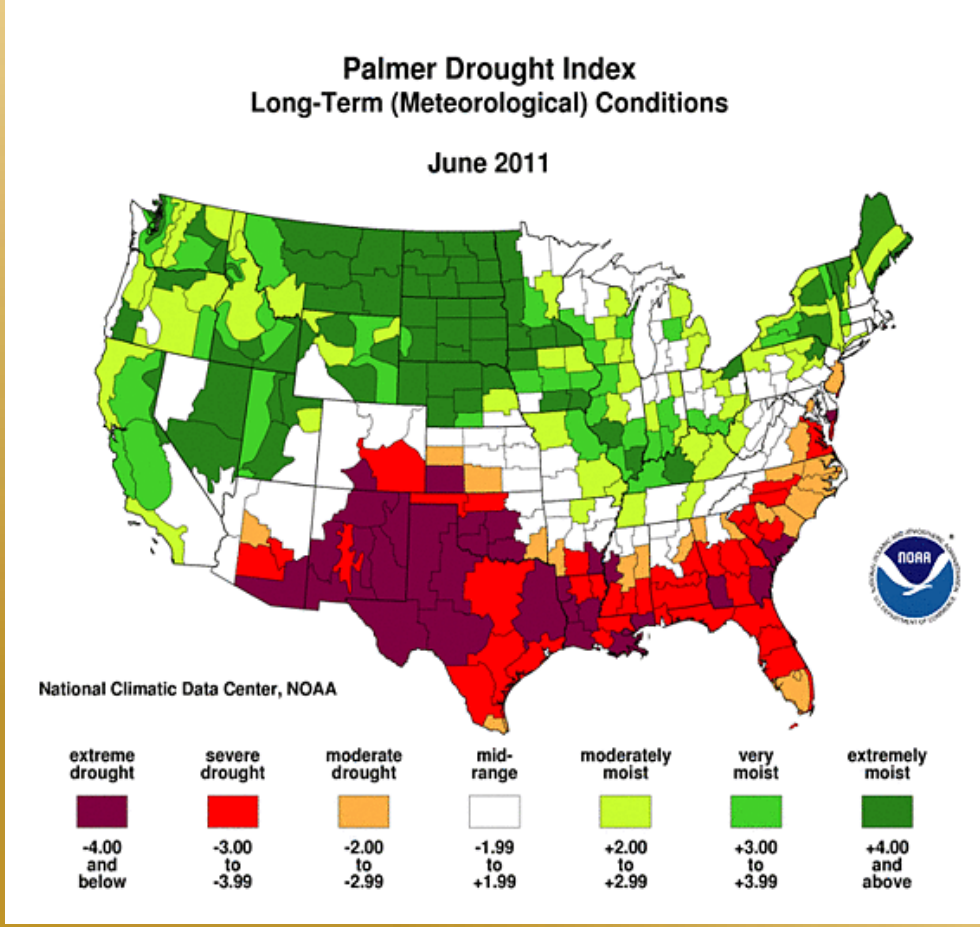
Design Flow and Uncertainty



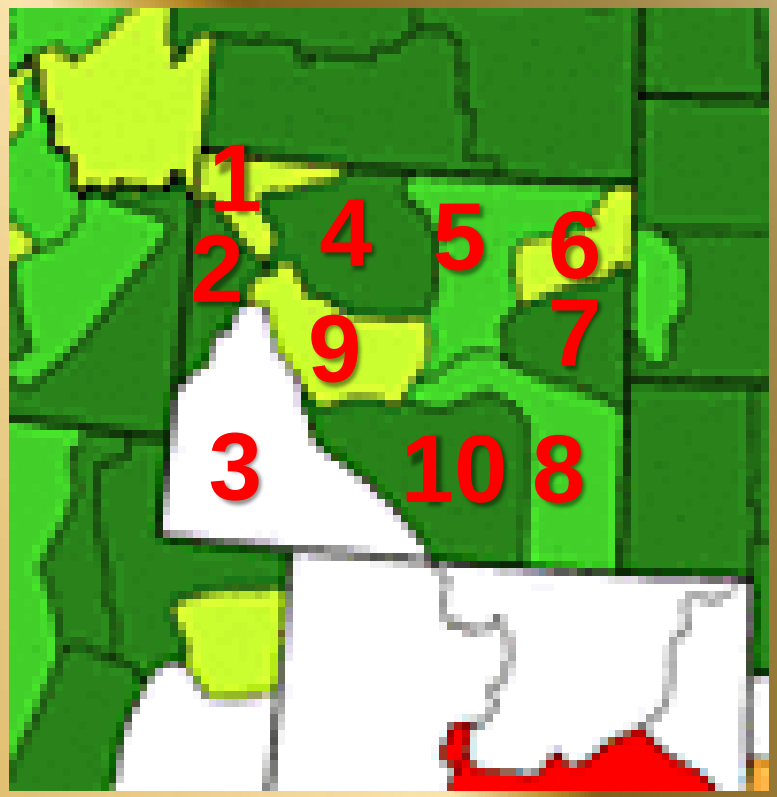
80 % Uncertainty

Mean Design Flow 34,000 (cfs)

Traditional Drought Map

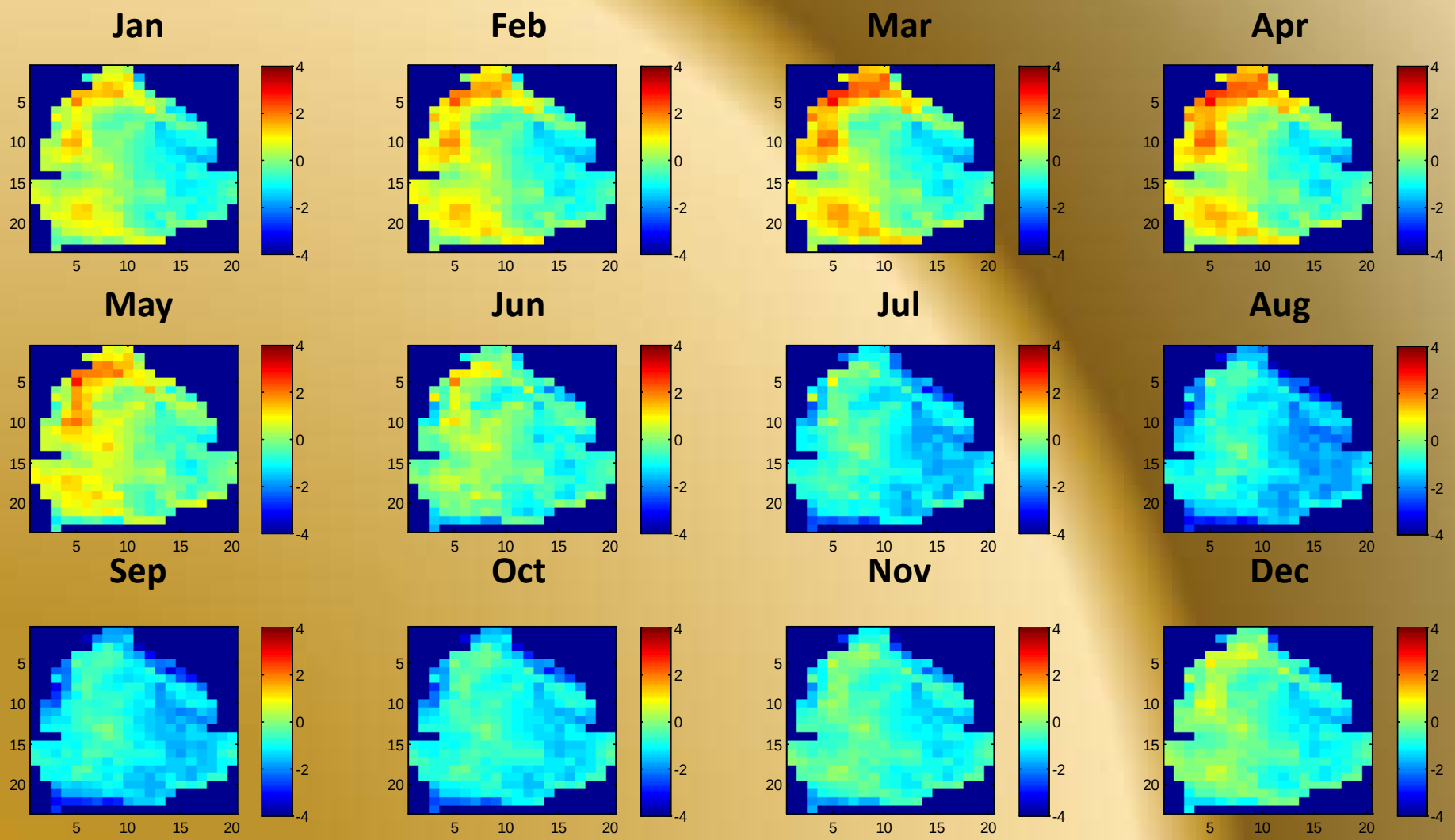


Wyoming Climate Divisions

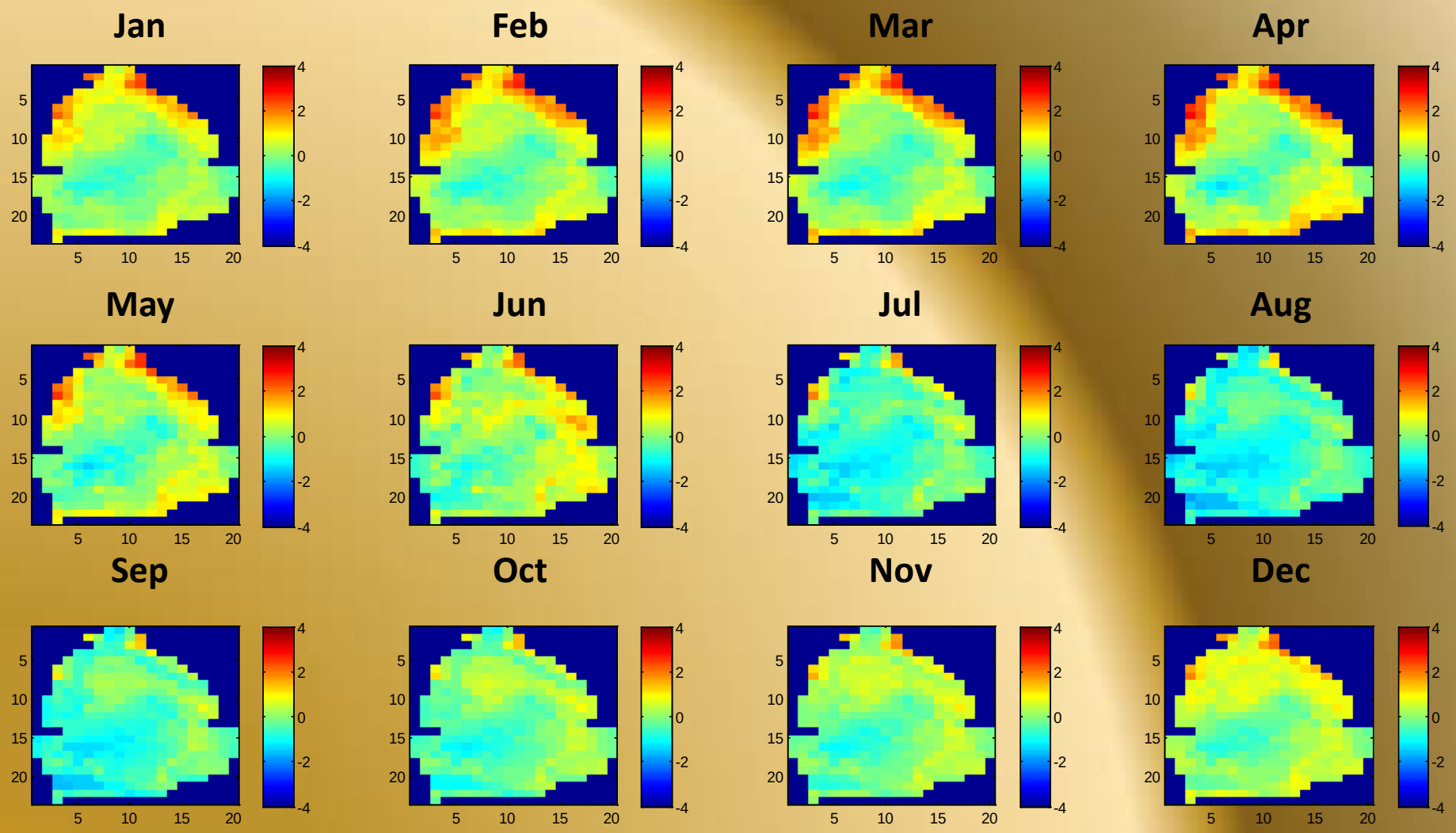


http://www.ncdc.noaa.gov/

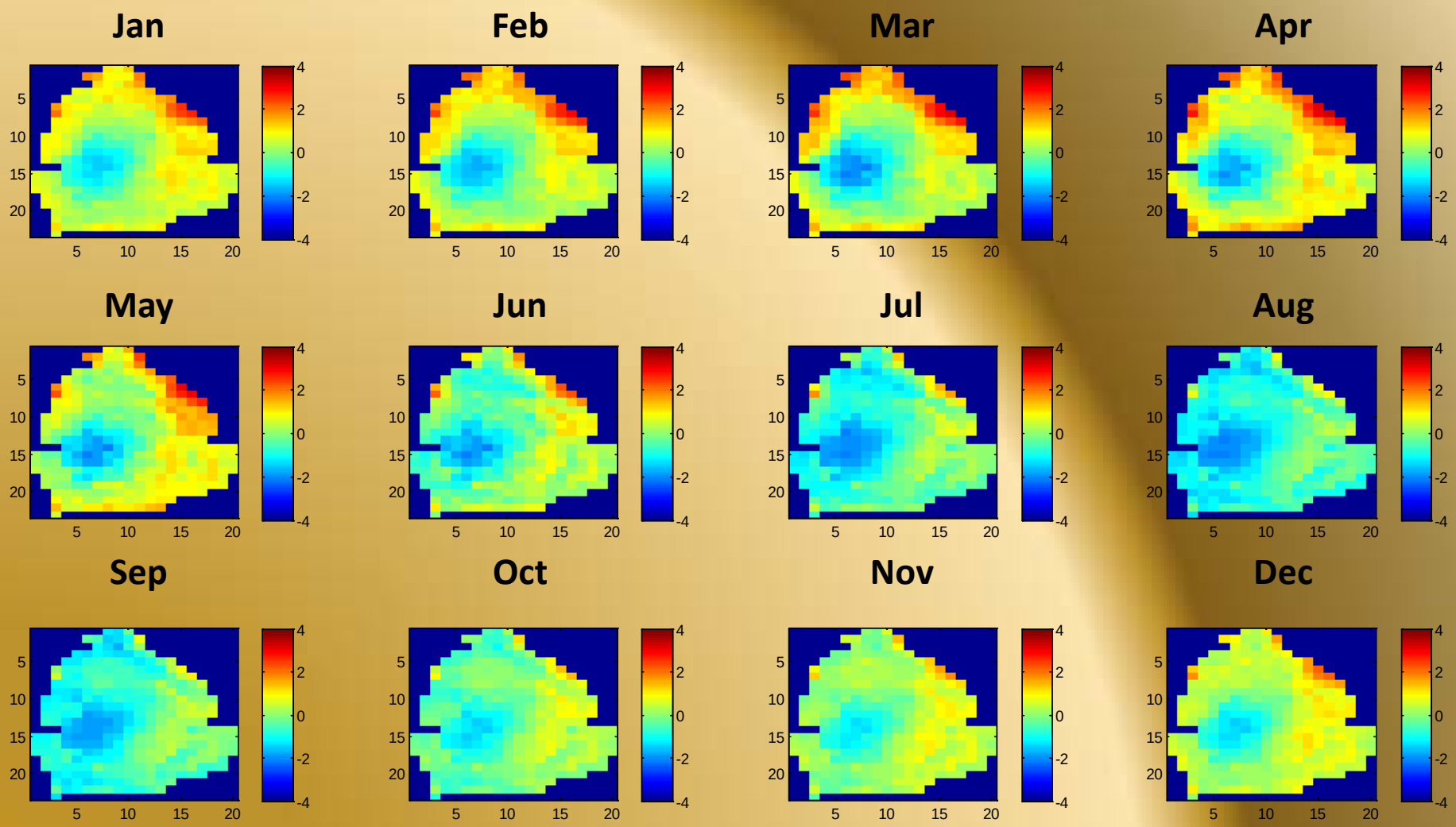
Gridded PDSI (1950 ~ 1959)



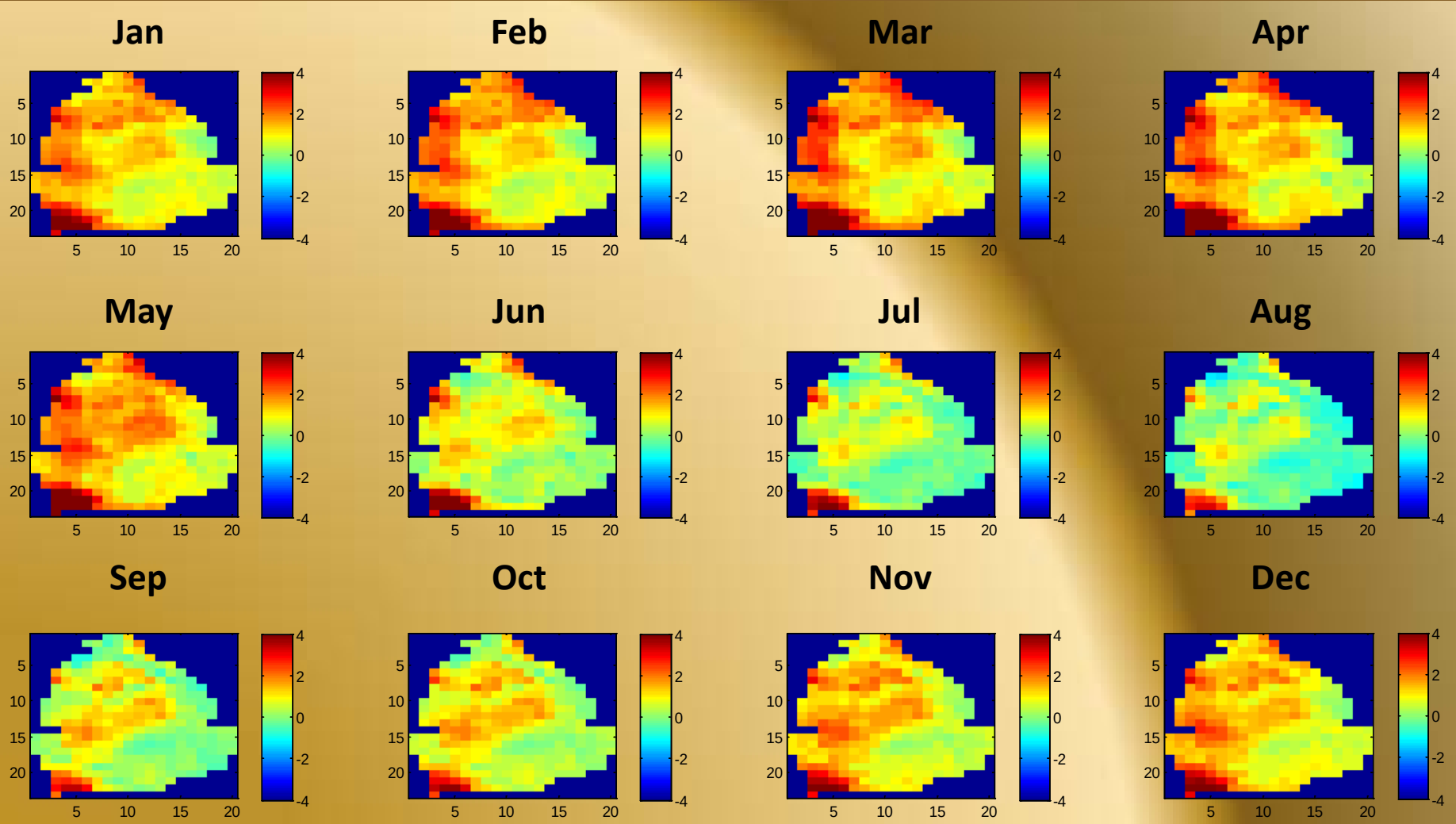
Gridded PDSI (1960 ~ 1969)



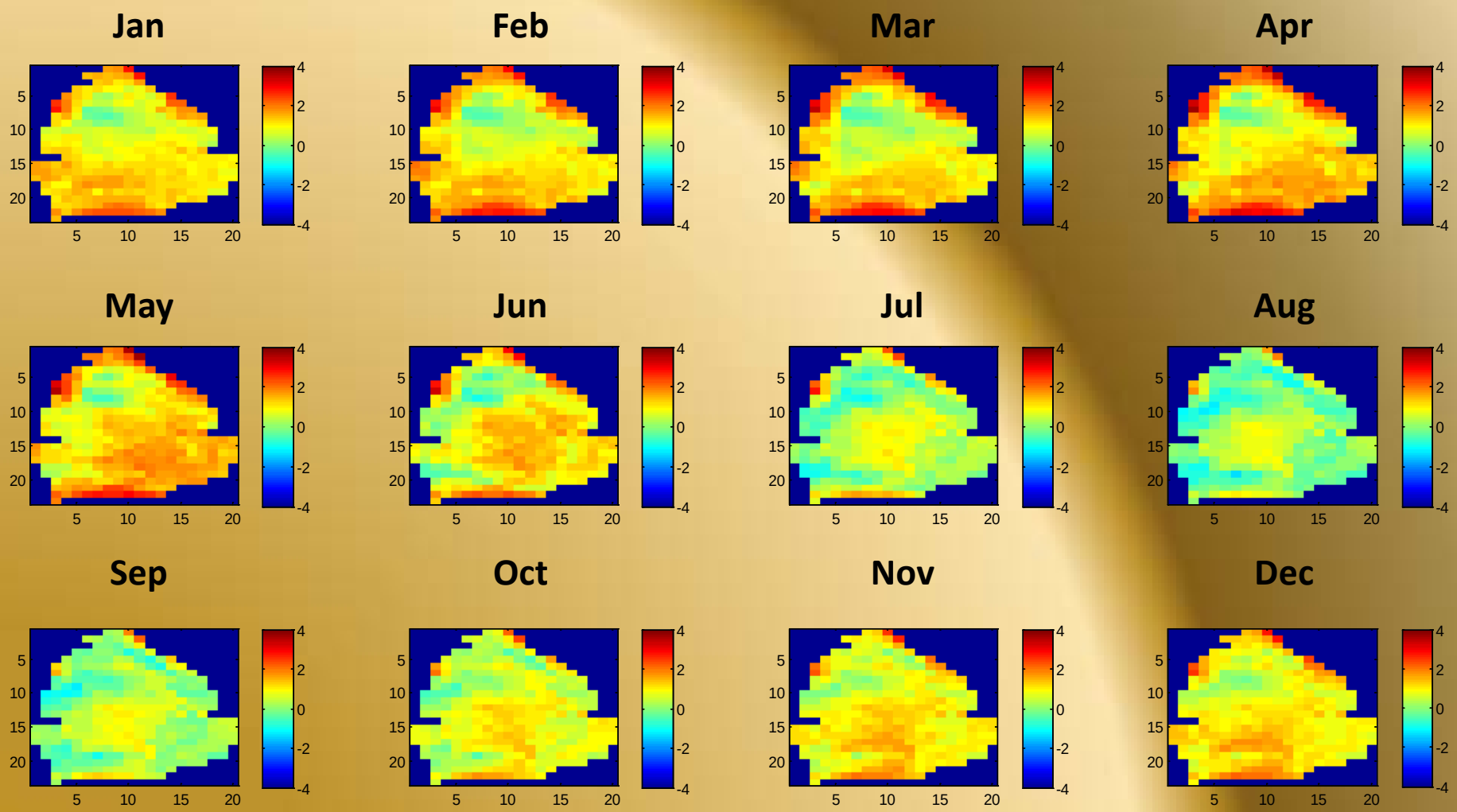
Gridded PDSI (1970 ~ 1979)



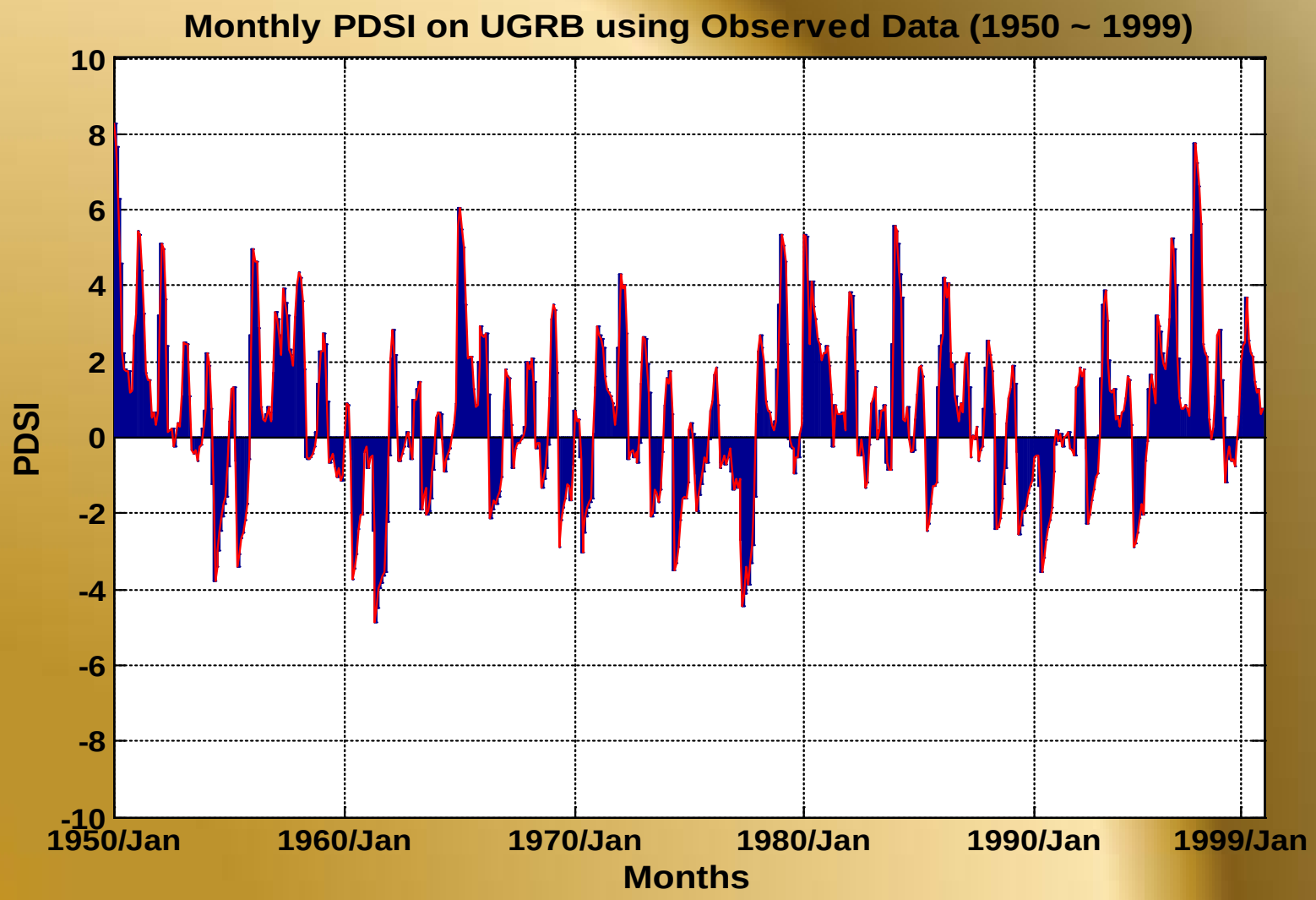
Gridded PDSI (1980 ~ 1989)



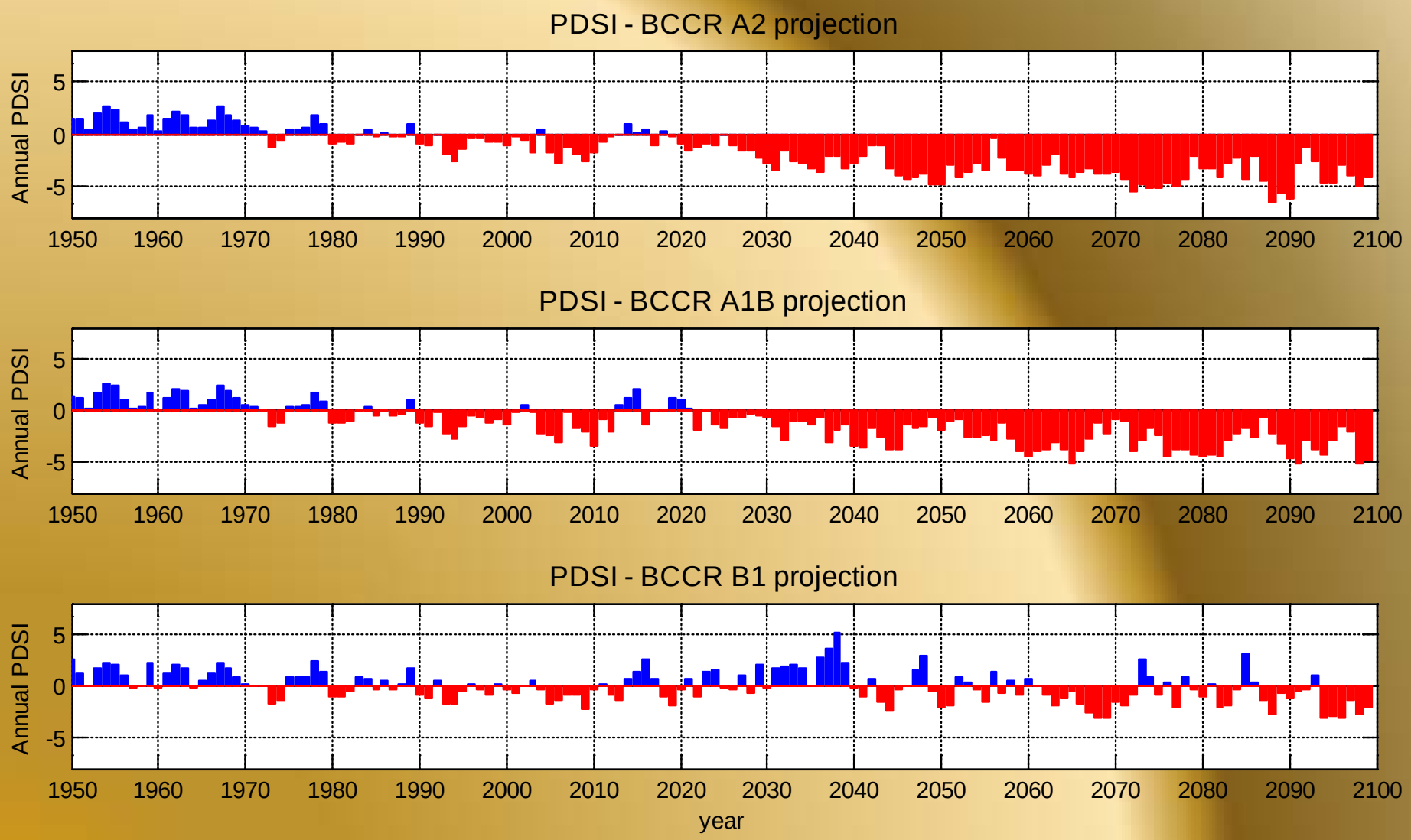
Gridded PDSI (1990 ~ 1999)



Historical PDSI (1950 ~ 1999)



PDSI based on Climate Scenario



Summary

- Both temperature and precipitation increase in the Upper Green River Basin (UGRB) during the 21st century
- Annual streamflow volume of the 21st century is expected to be 5-10 percent lower than that of the 20th century, depending on the climate scenarios. However, it shows an increasing trend during the 21st century.
- Flood frequency analysis suggests that design flow based on climate projections is significantly higher than that from historical streamflow.
- Non-stationarity in design flow is much more evident in the A1B and B1 scenarios than in the A2 scenario.
- Design flow uncertainty increases as the design flow increases.
- Droughts condition will extreme and persist in 10-20 years over Green River Basin. We will reexamine this with 112 climate projections.