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Special Session 3: Choosing Models for Resilient Water Resources Management
Water Partnership Program (WPP)/TWIWA-The World Bank

Sampling Variability vs. Climate Change: How Does it Affect Hydrologic Design?

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Hydrologic Uncertainties in Design

- **Sampling uncertainty:** how accurate are the flood estimates using the historical streamflows available?
- **Model and parameter uncertainty:** which extreme value distribution should be used in this case? Even if the model is known, parameters have sampling uncertainty; in addition there are several parameter estimation methods, e.g. MoM, ML and LM.
- **Climate change and long term persistence (LTP) uncertainty**: are there non-stationarity signals in the historic and/or reconstructed record?.

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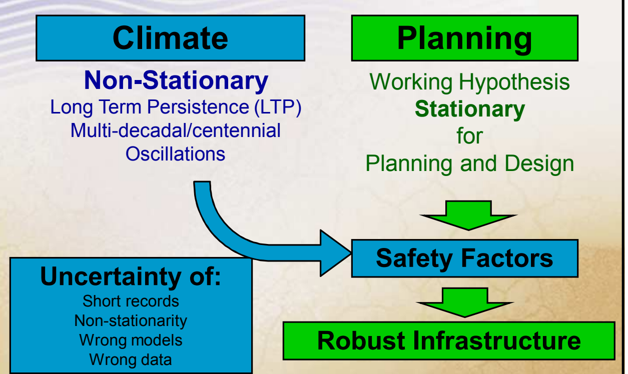

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Reconciling climate change projections with traditional planning methods

- How to include the additional uncertainty due to climate change (from GCM results and observations) into traditional hydrologic planning and design?
- In particular, how will Q_{100} change and which is the uncertainty associated?

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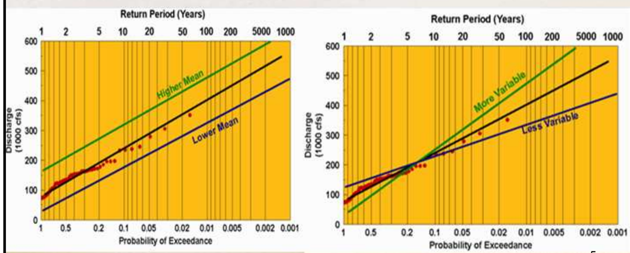
IPCC: *"Climate change will intensify the hydrologic cycle"*

changes in averages/ trends

changes in variability (magnitude, severity, duration)



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Challenges to quantify new flood magnitude and frequency

- Global Circulation Model (GCMs) runs coupled with downscaling models (statistical and dynamic): spatial resolution, and in some instances inaccurate representation of current climate (Kundzewicz & Stakhiv, 2010; Anagnostopoulos et al. 2010; Koutsoyiannis et al. 2008)
- Analysis of historic/paleo/proxy streamflow records: signal not clear, particularly in streamflow extremes

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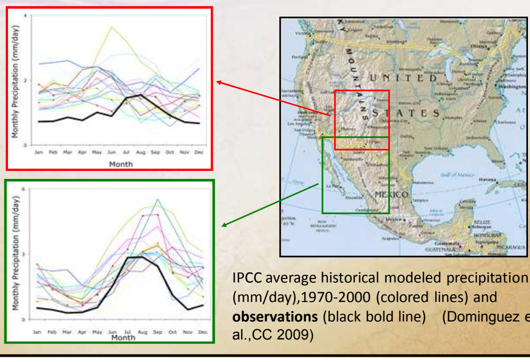
GCMs still have problems capturing the seasonal cycle of precipitation, in many parts of the world



IPCC average historical modeled precipitation (mm/day),1970-2000 (colored lines) and **observations** (black bold line) (Dominguez et al.,CC 2009)

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Climate Change Impact: Observations

Clearly Detected: [Hirsch, 2011;]

- Higher temperatures [IPCC, 2007]
- Less snow storage [Barnett et al. 2005, 2008]
- Early spring-melt. [Stewart et al. 2005; Maurer et al. 2007; Hidalgo et al. 2009]

No clear and consistent signal on streamflows:

- **Decreasing** [Krug, 1996]
- **Increasing** [Changnon and Demissie, 1996; Olsen et al., 1999; Novotny and Stefan, 2007; Pinter et al., 2008; Hejazi and Markus, 2009]
- **Mixed Results** [Changnon and Kunkel, 1995; Gebert and Krug, 1996; Rasmussen and Perry, 2001; Lins and Slack, 2005]
- **No Overall Trends** [Lins and Slack, 1999; Douglas et al., 2000; Schilling and Libra, 2003; Zhang and Schilling, 2006; Villarini et al., 2009a].

Explanation: rainfall and streamflows are highly non-linear with asymmetric probability distributions, while temperature are more linear and Gaussian (Bloschl and Montanari, 2010)

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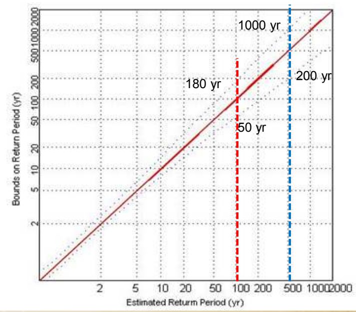
Suggested Approach

Considering sampling uncertainty provides us with a way to represent climate change in the near future (next 30 years) in planning and design since sampling variability masks the expected values of climate change-induced hydrologic variables

Example Extremes Sampling Uncertainty



French Broad, North Carolina (n=69 yrs)

Evaluation of Sampling and Climate Change Uncertainty

Three examples:

1. Annual Maximum Flows at Verde basin (Arizona, USA)
2. Annual Maximum Flows at Faleme sub-basin (Senegal River, Africa)
3. Intensity-Duration-Frequency Curves at Wet Creek sub-basin (Verde basin)

Input Data

- **Verde**: GCM results (HadCM3) were statistically and dynamically downscaled (using WRF RCM model) for the basin to estimate the precipitation and temperature used as inputs to a rainfall-runoff model (VIC)
- **Senegal:** Two GCMs (HadCM3 and MPI) results statistically downscaled to estimate the precipitation and temperature used as inputs to a rainfall-runoff model (PRMS)

Approach

- **Precipitation**: a Bartlett-Lewis point process precipitation model was calibrated and used to estimate the IDF. A Monte Carlo analysis was used to estimate the uncertainty intervals for the 100-yr intensity
- **Streamflows**: standard Bulletin 17B approach was used to estimate the expected maxima and their corresponding uncertainty at 5% and 95% intervals

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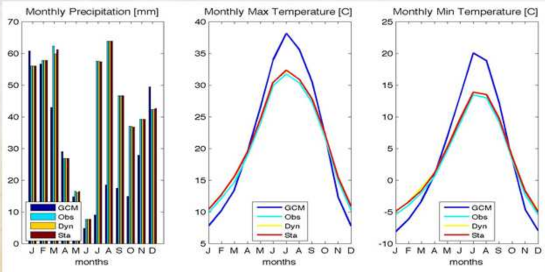
Verde Basin



HadCM3 Raw and Bias-corrected Precipitation [mm], Maximum and Minimum Temperature [° C] Verde River Basin. Period 1970-99.

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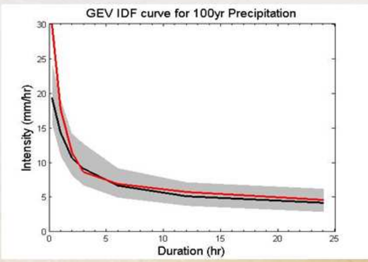
Wet Creek (Verde Basin) IDF Curve 100-yr Precipitation



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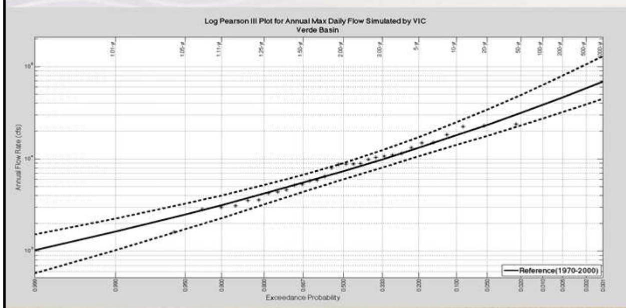
Verde Basin Annual Maxima



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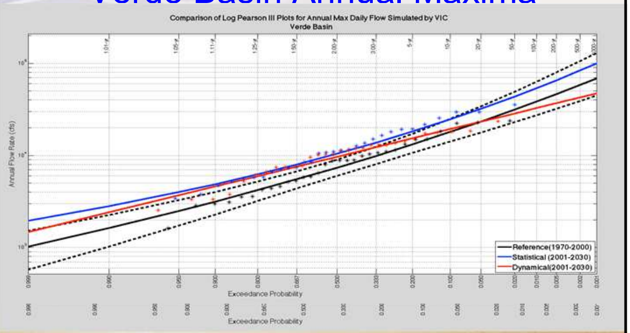
Verde Basin Annual Maxima



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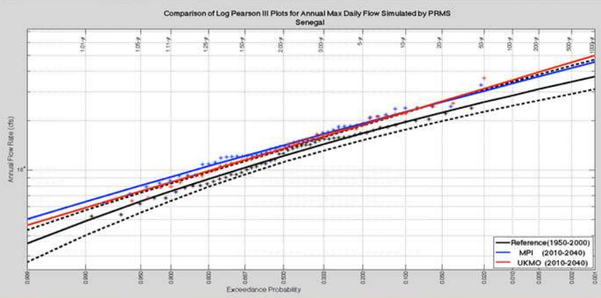
Senegal Basin Example



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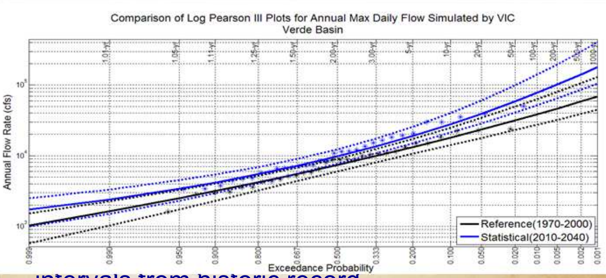
Comments



intervals from historic record.

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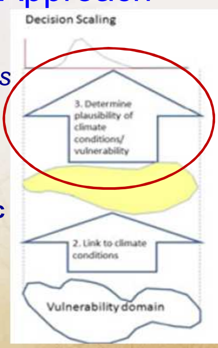
Input for No-Regrets Approach

- Once the decision analysis identifies *important uncertainties from a decision-making viewpoint*:
- Our approach can quantify:
  - **The expected value of a climatic event and**
  - **Its sampling uncertainty**

that is critical to a planning decision.



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(Figure from Brown et al, 2011)

Final Comments: Benefits for Planning

Including the sampling uncertainty of streamflows extremes in the planning and design of projects provides a solution to the design until:

- The accuracy and resolution of GCMs improves
- Probabilities can be assigned to climate emission scenarios (A1B, A2, B1, etc)

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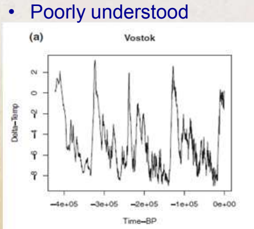
One remaining challenge:

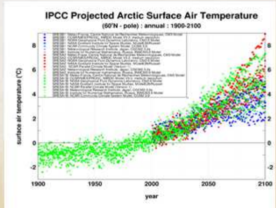
How do we reconcile these two?

Planetary Climate Records:
- Observations
- Poorly understood

CO2 driven climate projections:
- Recent or no records
- Betterl understood



Reconstructed temperature record Vostok ice core (East Antarctica)



IPCC model projections for the Arctic

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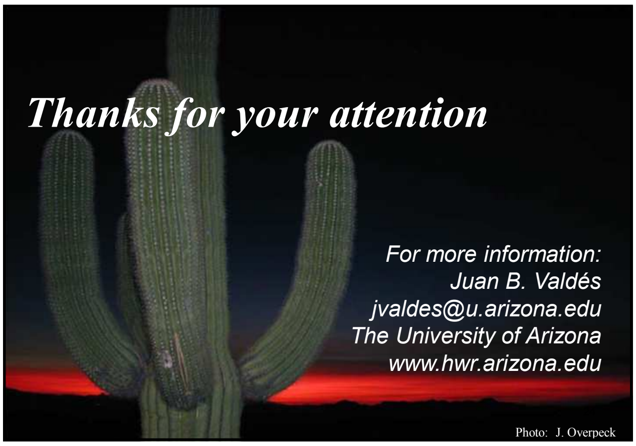
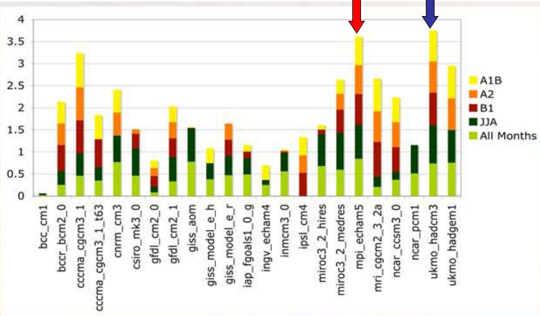


The Max Plank Institute and the UK. Met. Office models perform the best in the U.S. Southwest.



Dominguez et al, 2010

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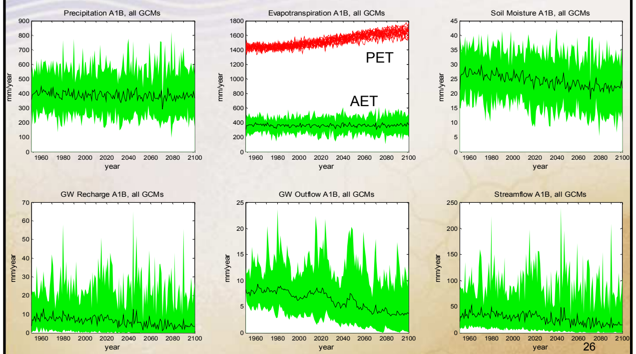
Verde River Basin: Climate Change Impacts



Serrat-Capdevila et al, 2010

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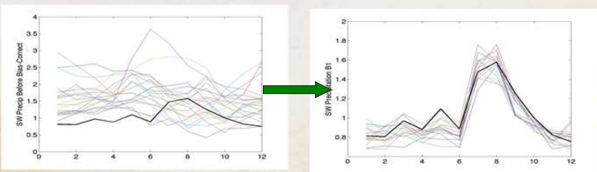
We used a bias-correction technique to obtain a realistic seasonal cycle of the climate variables.

Historical (20c3m) runs before bias-correction

Future (B1) runs after bias-correction



Dominguez et al, CC 2009

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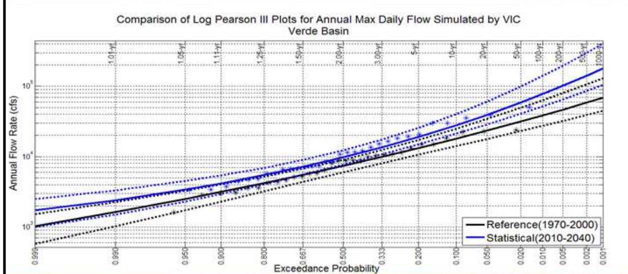

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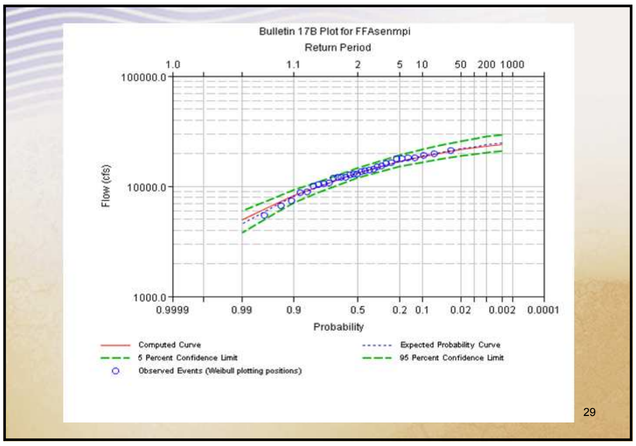
Bulletin 17B Plot for FFAsenmpi
Return Period
1.0
1.1
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5
10
50
200
1000
100000.0
10000.0
1000.0
Flow (cfs)
0.9999
0.99
0.9
0.5
0.2
0.1
0.02
0.002
0.0001
Probability
Computed Curve
5 Percent Confidence Limit
Observed Events (Weibull plotting positions)
Expected Probability Curve
95 Percent Confidence Limit
29