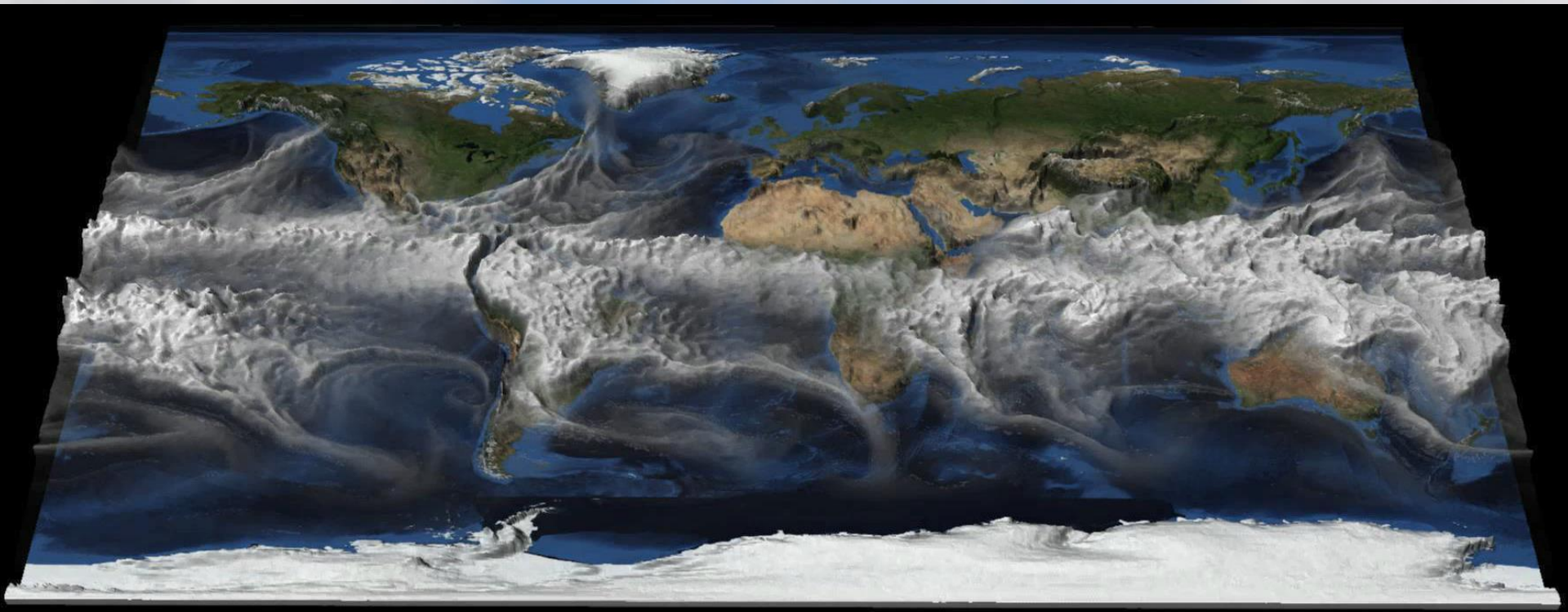
Estimating/Reducing Uncertainty in Precipitation Projections

Lawrence Buja - southern@ucar.edu



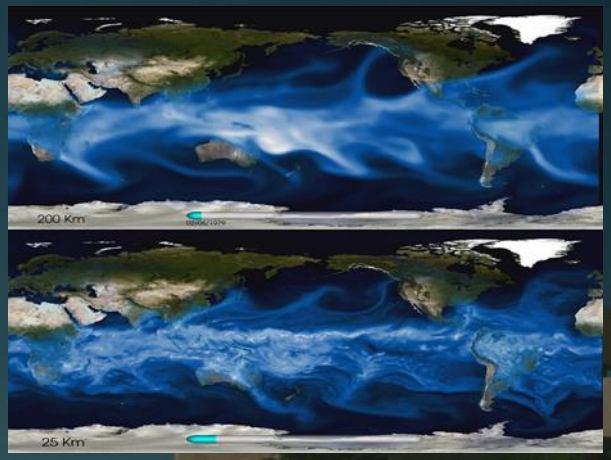
NCAR

NSF

National Center for Atmospheric Research

US National Science Foundation FFRDC 50+ year history
Governed by 100+ U.S. Universities
1000 Scientists, Engineers & Staff, 5 Boulder & Wyoming campuses

EOL, HAO
Earth/Sun Observing Laboratories

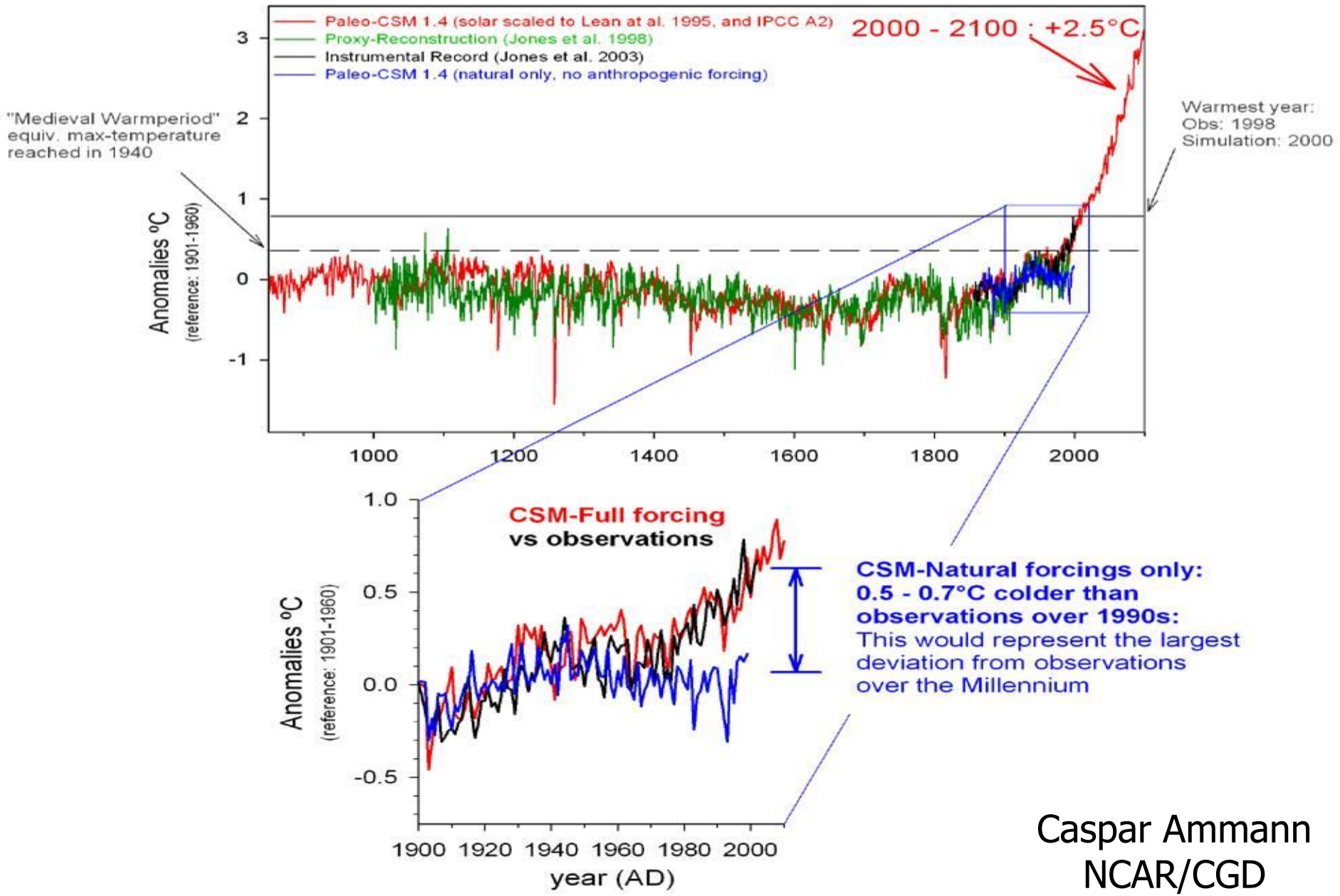


CGD, MMM, ACOM
Earth System Modeling Laboratories

CISL
Computational & Information Systems

RAL
Research Applications Laboratory
Climate Science and Applications Program

Climate of the last Millennium



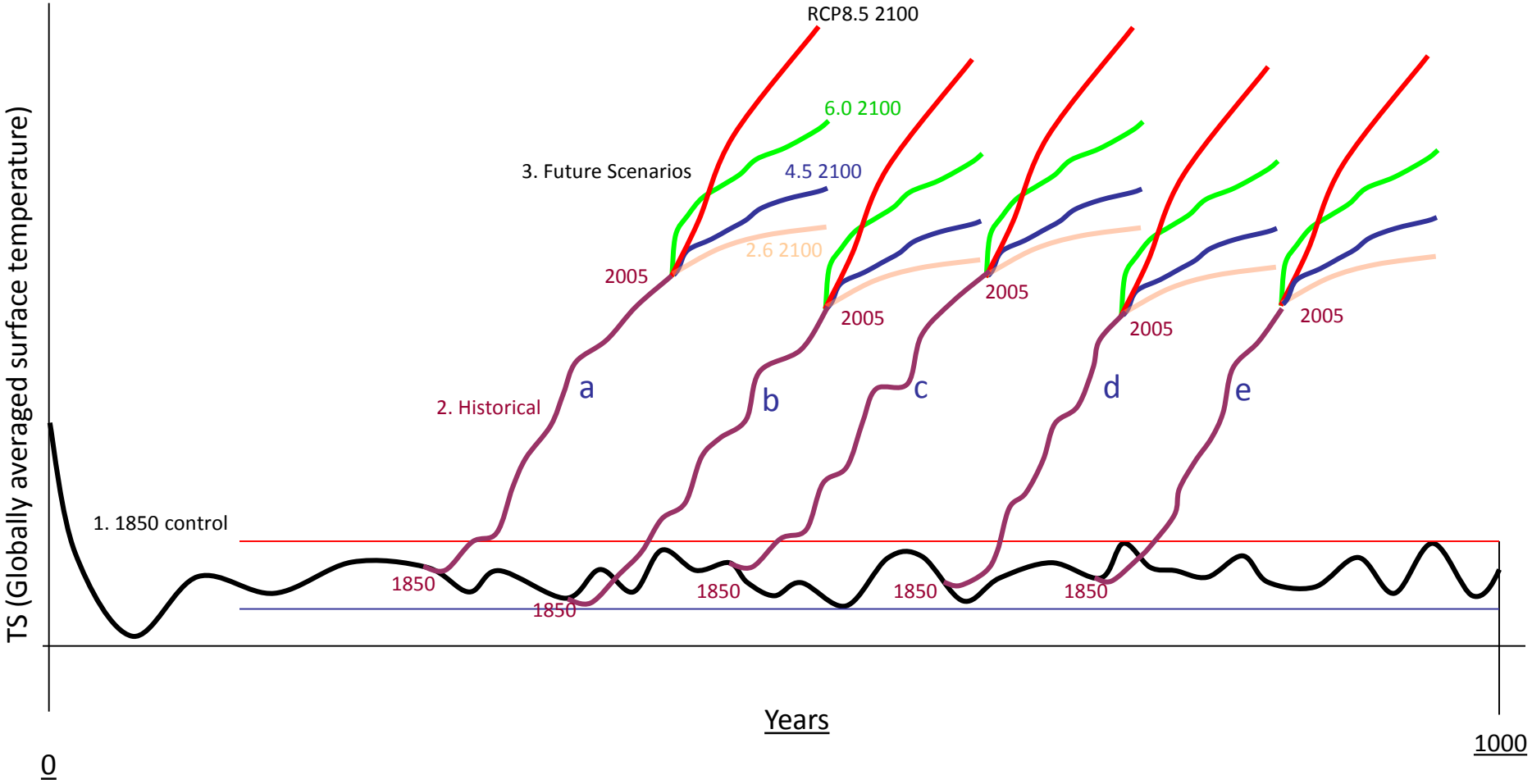
Caspar Ammann
NCAR/CGD

Probablistic Climate Simulations

Stage 1. 1850 control run: 1000 years with constant 1850 forcing: Solar, GHG, Volcanic Sulfate, O3

Stage 2. Historical: 1850-2005 run using time-evolving, observed, Solar, GHG, Volcanoes, O3

Stage 3. Future Scenarios: 4 2005-2100 IPCC RCPs from end of historical run



NSF/DOE IPCC AR5 Project

NCAR, LBL, ORNL, NERSC, ANL, LANL, NCSA

Observations of the Earths Climate System

Simulations Past, Present Future Climate States

6-Year Timeline

2008: Climate Model/Data-systems development

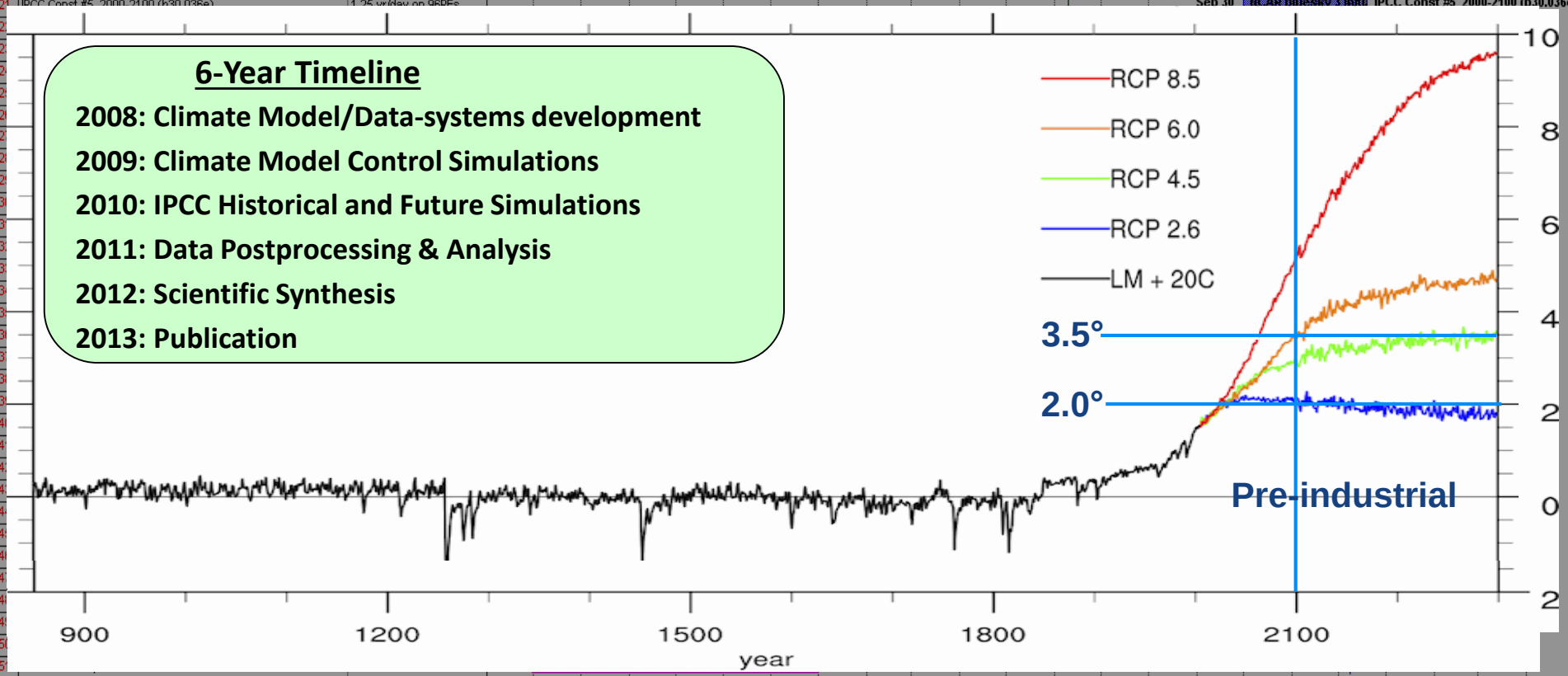
2009: Climate Model Control Simulations

2010: IPCC Historical and Future Simulations

2011: Data Postprocessing & Analysis

2012: Scientific Synthesis

2013: Publication



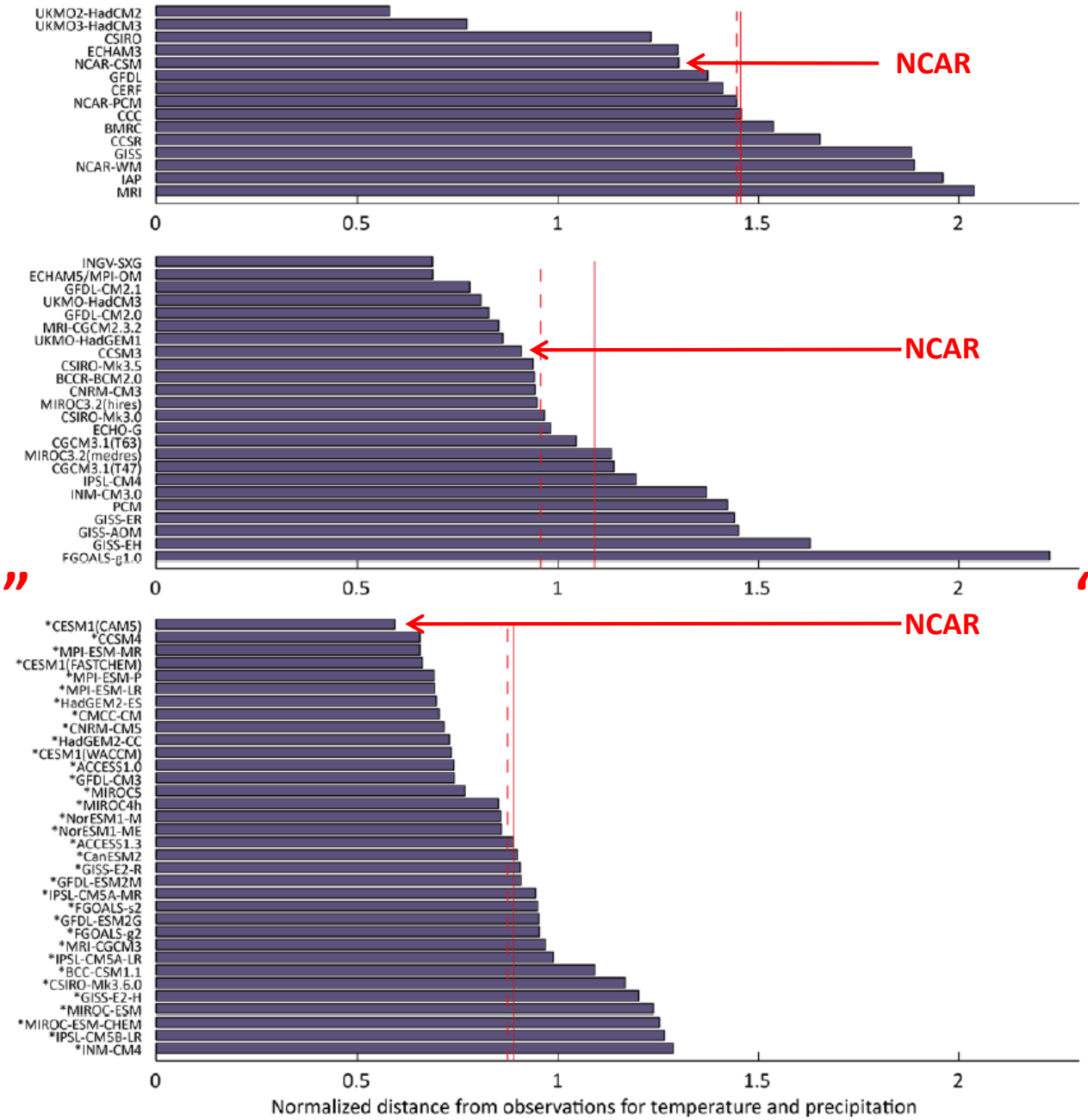
Climate model genealogy: Generation CMIP5 and how we got there

Reto Knutti, David Masson , Andrew Gettelman 2013

CMIP2
1997

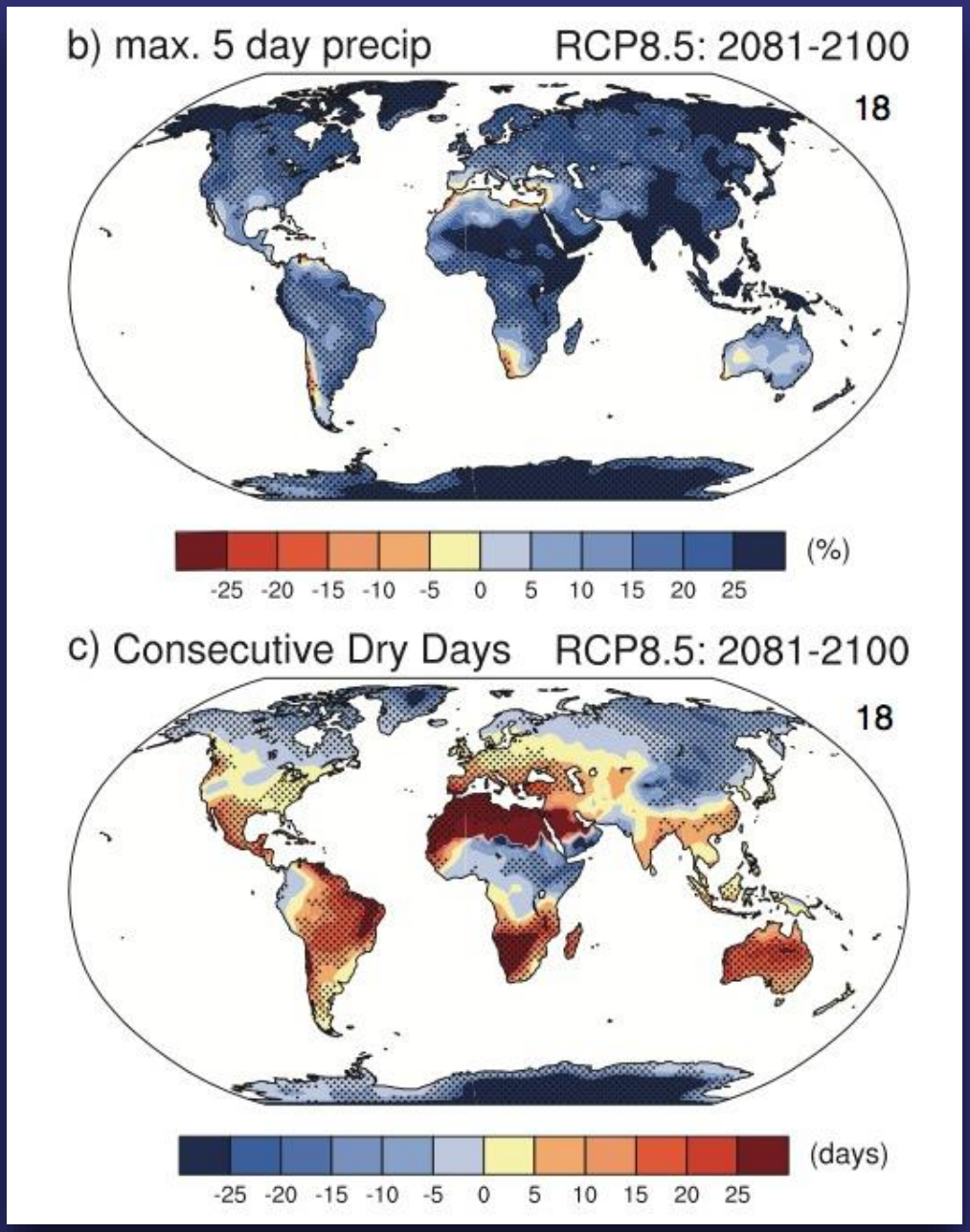
CMIP3
2006

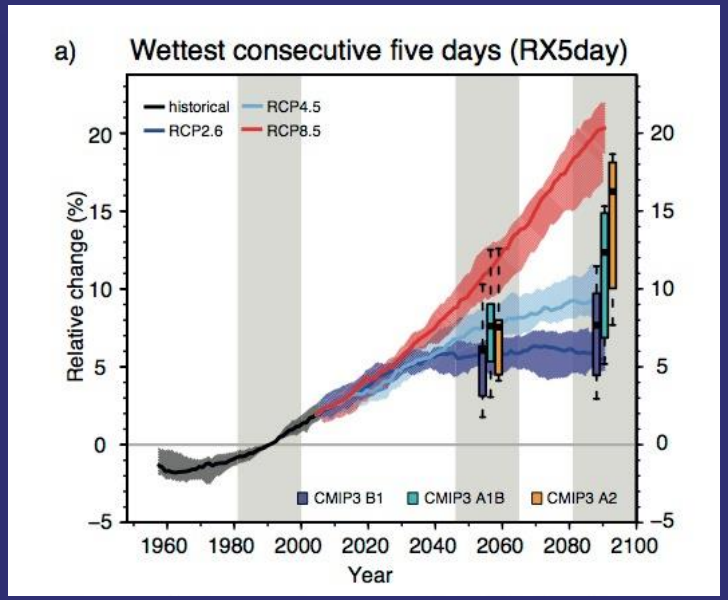
CMIP5
2012



“Better”

“Worse”



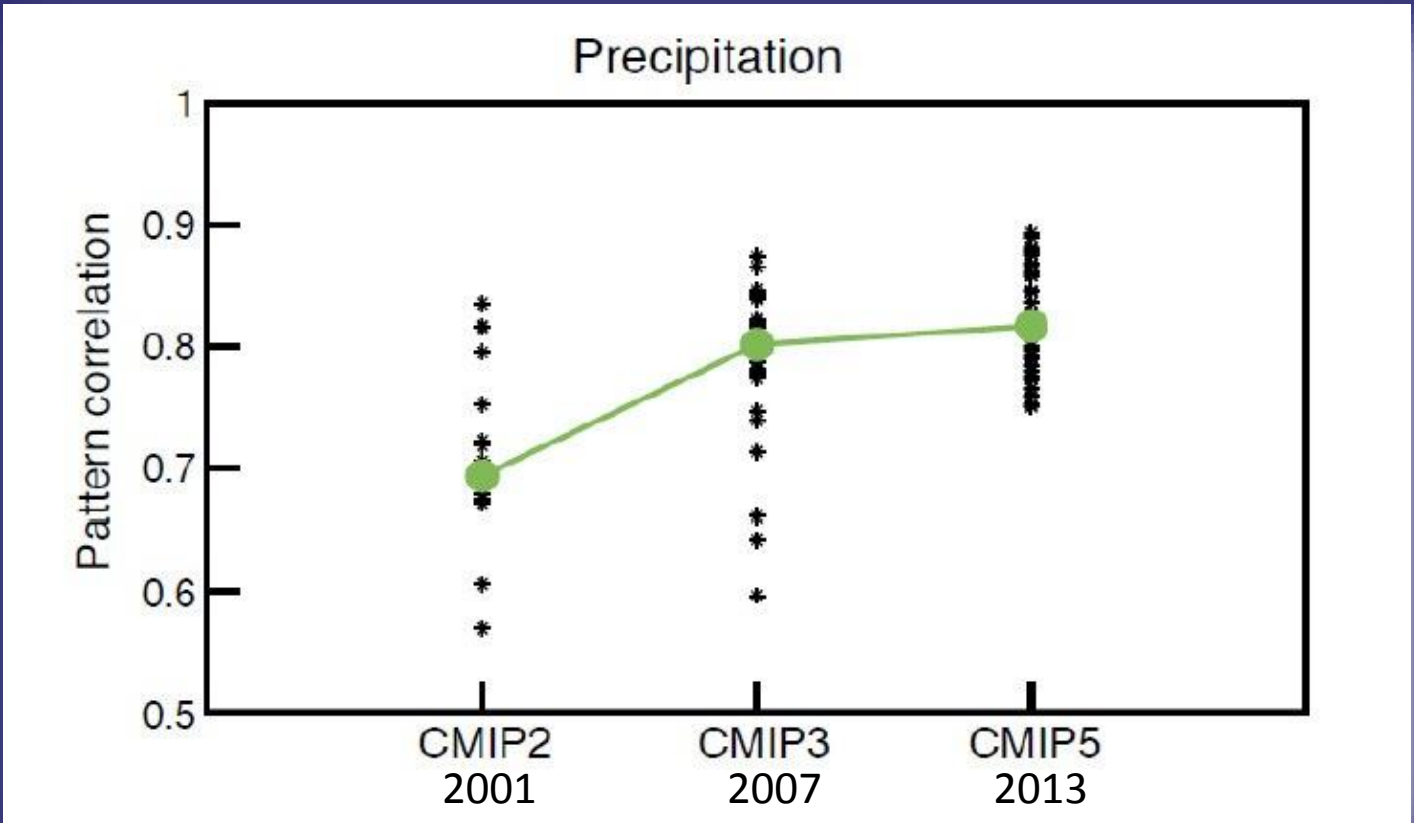


Intra-Seasonal Variability

when wet : wetter..

when dry : drier...

Validation: Skill of Models



IPCC Models: “Spatial Skill”: Pattern Correlations

Climate 3.0 - Usable Science for Society

Climate research is dramatically evolving

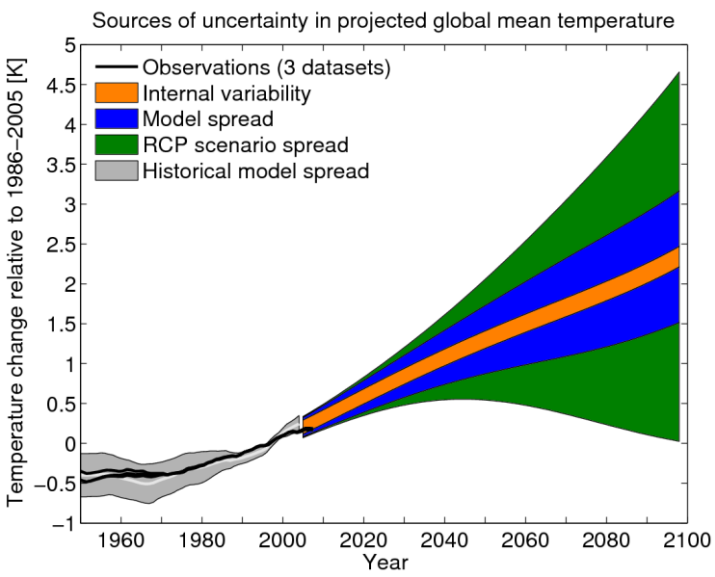
Climate 1.0 Is anthropogenic climate change occurring?

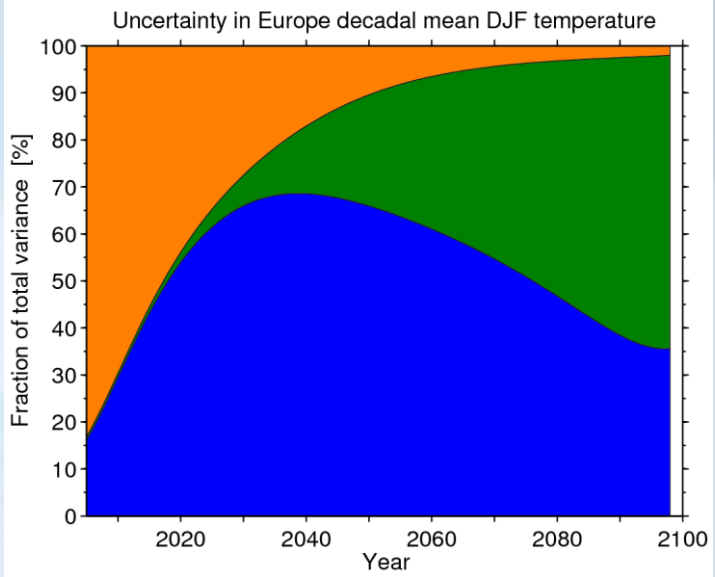
Climate 2.0 What is the impact on human & natural systems?

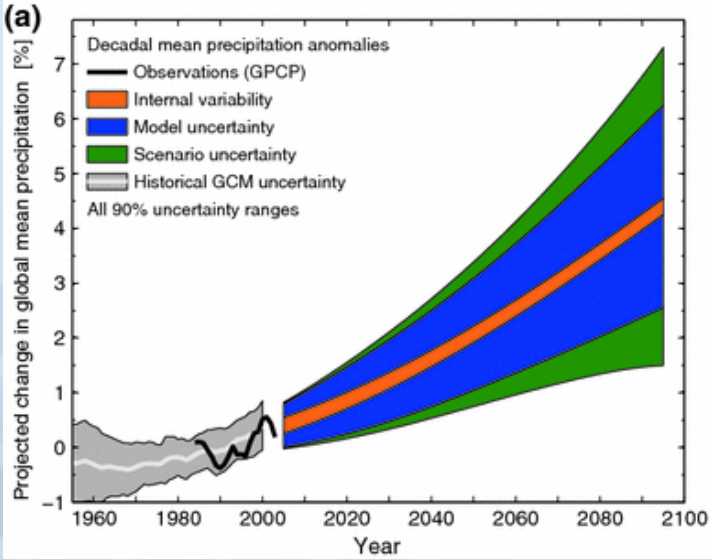
Climate 3.0 How are you partnering with regional/local groups to create usable science for decision making?

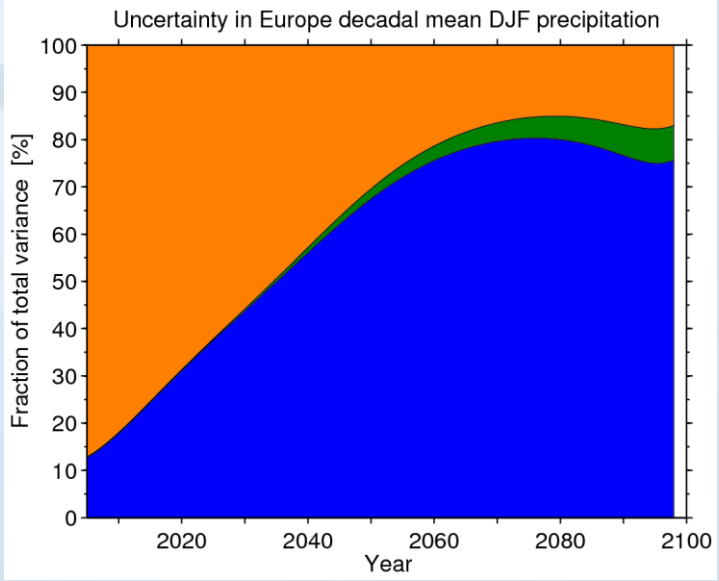
- Regional/Local Seasonal/decadal focus on “actionable” science (now)
- Sustainable Systems:
  Engineering, Energy, Food, Water, Security, Health, Cities
- Societal Impacts: GIS, extremes, climate services
- Co-production: Local dialog and ownership required
- Articulating Uncertainty

Sources of Uncertainty in Climate Projections



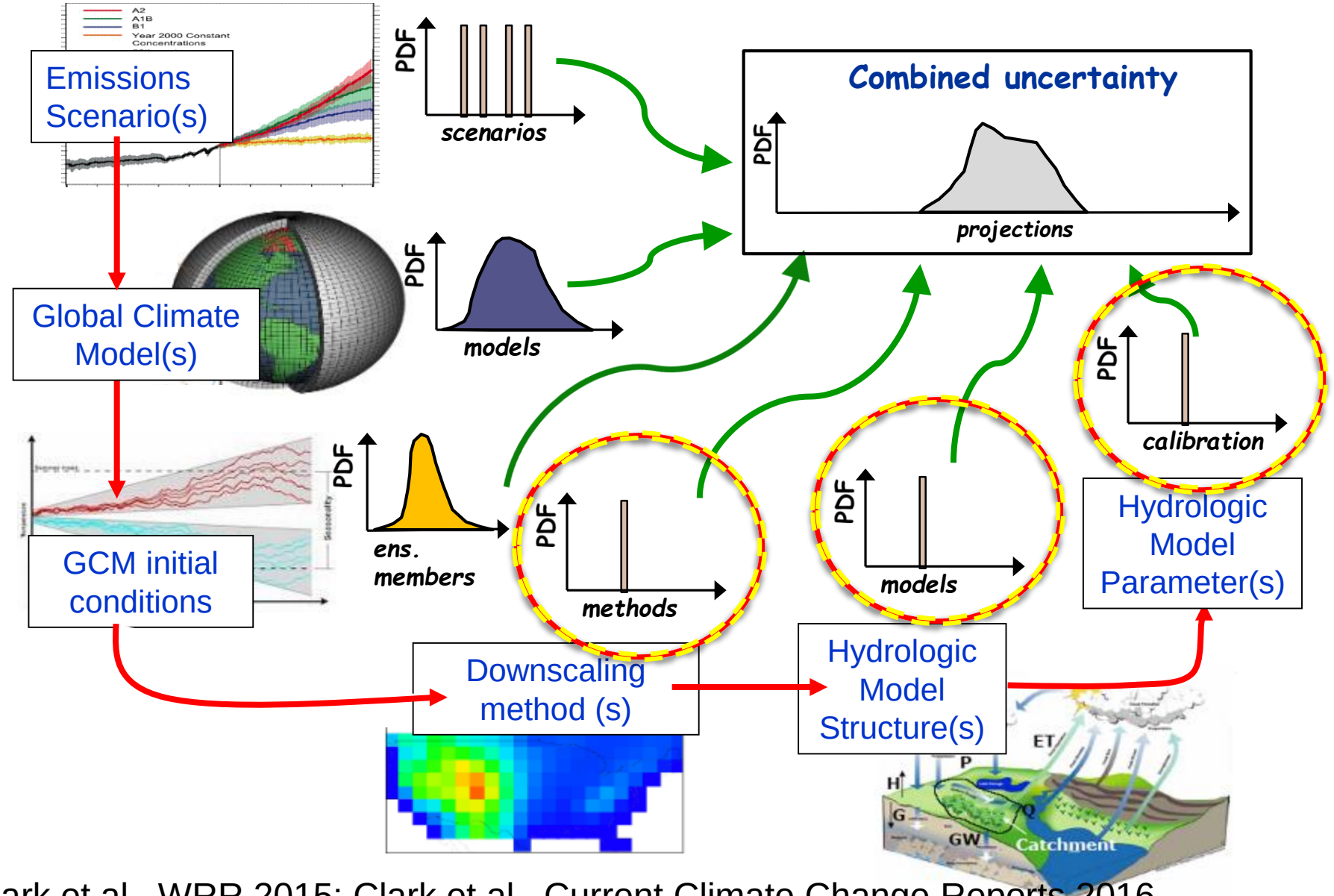






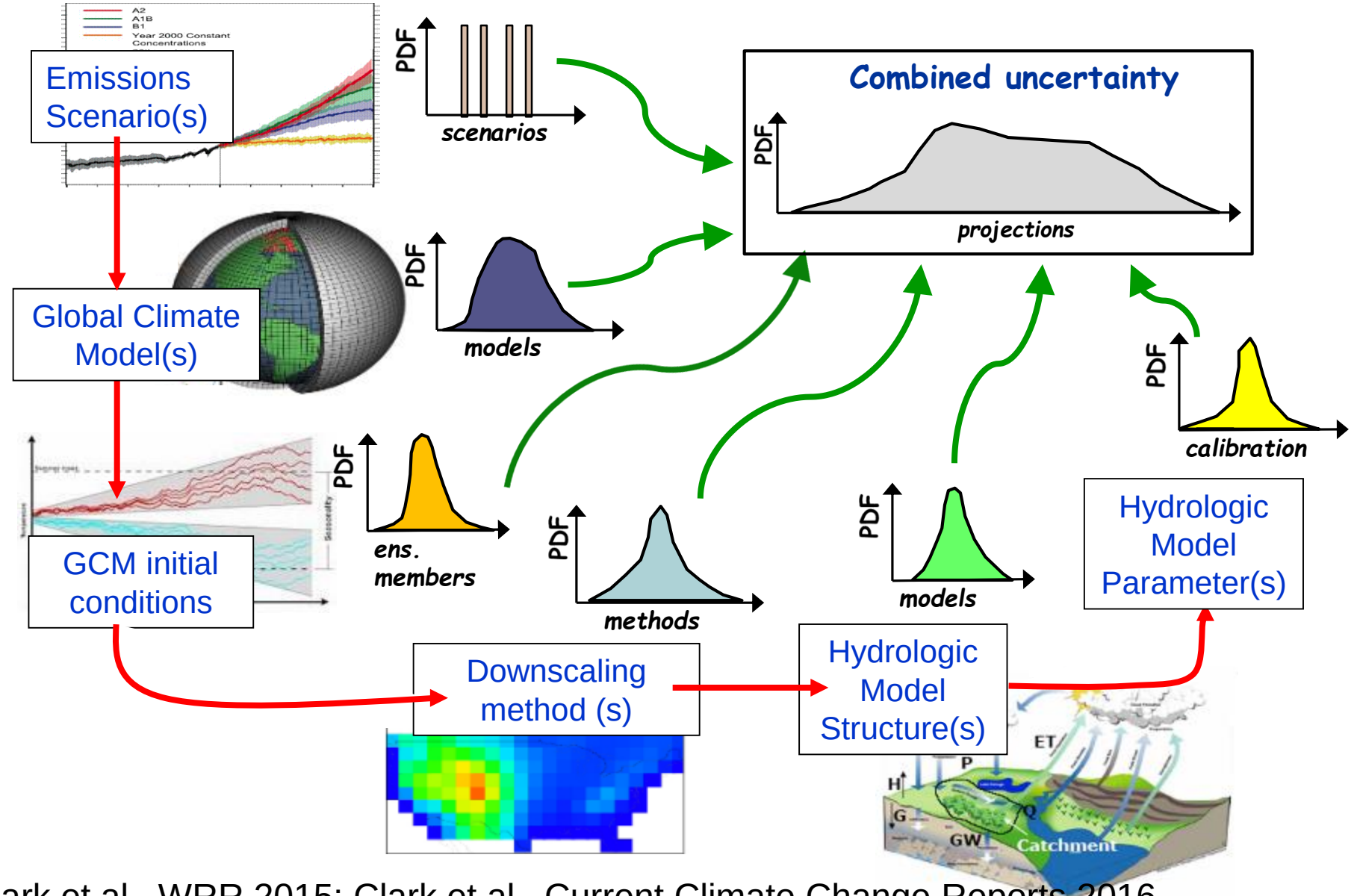
Sources of uncertainty in CMIP5 projections, E Hawkins,

“Revealing” uncertainties



Clark et al., WRR 2015; Clark et al., Current Climate Change Reports 2016

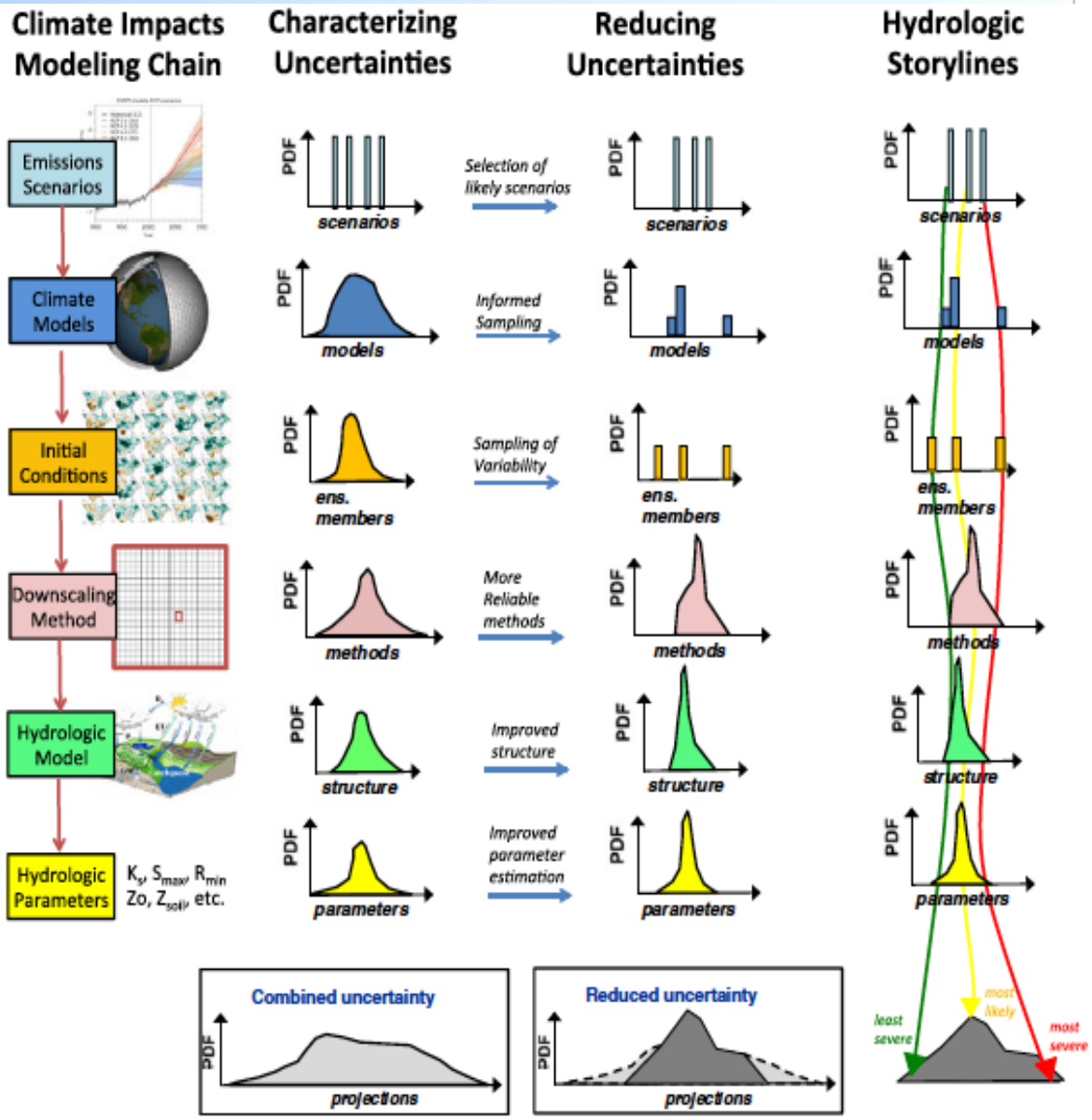
“Revealing” uncertainties



Clark et al., WRR 2015; Clark et al., Current Climate Change Reports 2016

Explicitly characterize uncertainty

- Approach
  - Characterize uncertainty: “full” coverage of model hypothesis space
  - Reduce uncertainty: cull bad models and methods



Clark et al., WRR 2015; Clark et al., Current Climate Change Reports 2016

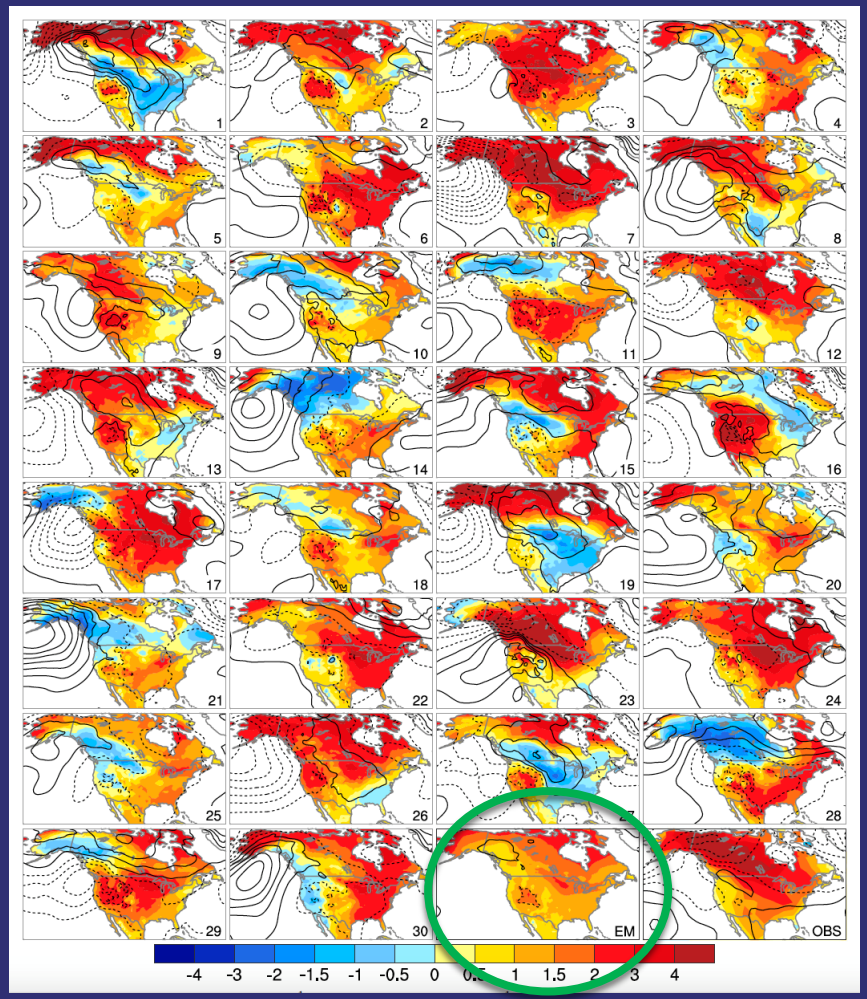
Exposing/Reducing Uncertainty

CESM Large ensemble

Winter temperature trends (in degrees Celsius) for North America between 1963 and 2012

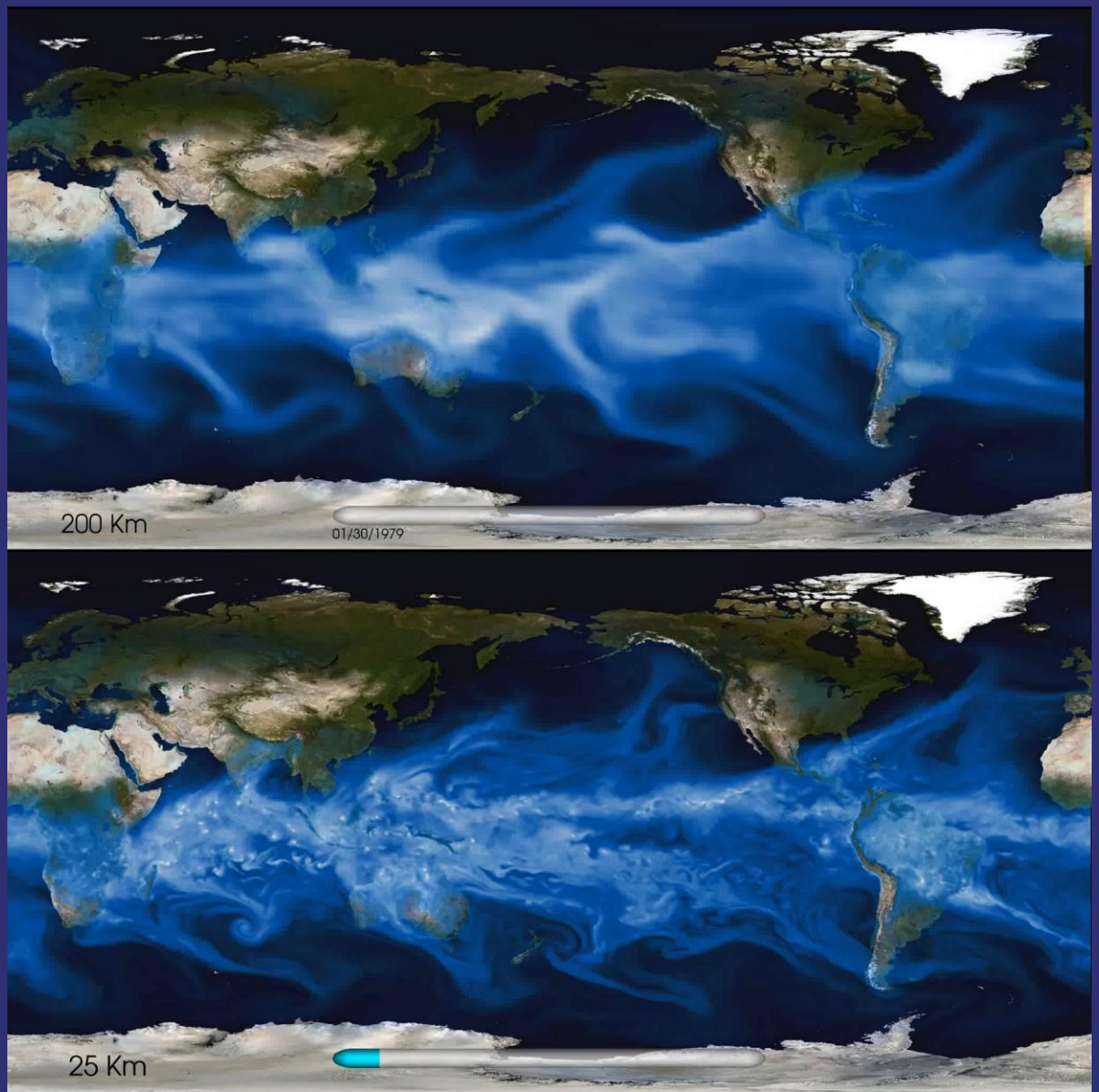
Variations in warming and cooling in the individual members illustrate the far-reaching effects of natural variability superimposed on human-induced climate change.

The ensemble mean (EM; bottom, second image from right) averages out the natural variability, leaving only the warming trend attributed to human-caused climate change.



http://journals.ametsoc.org/doi/abs/10.1175/JCLI-D-15-0304.1
http://journals.ametsoc.org/doi/full/10.1175/BAMS-D-13-00255.1

Exposing/Reducing Uncertainty
Increased Resolution and Processes



High Horizontal Model Resolution needed for Extremes

200km

vs

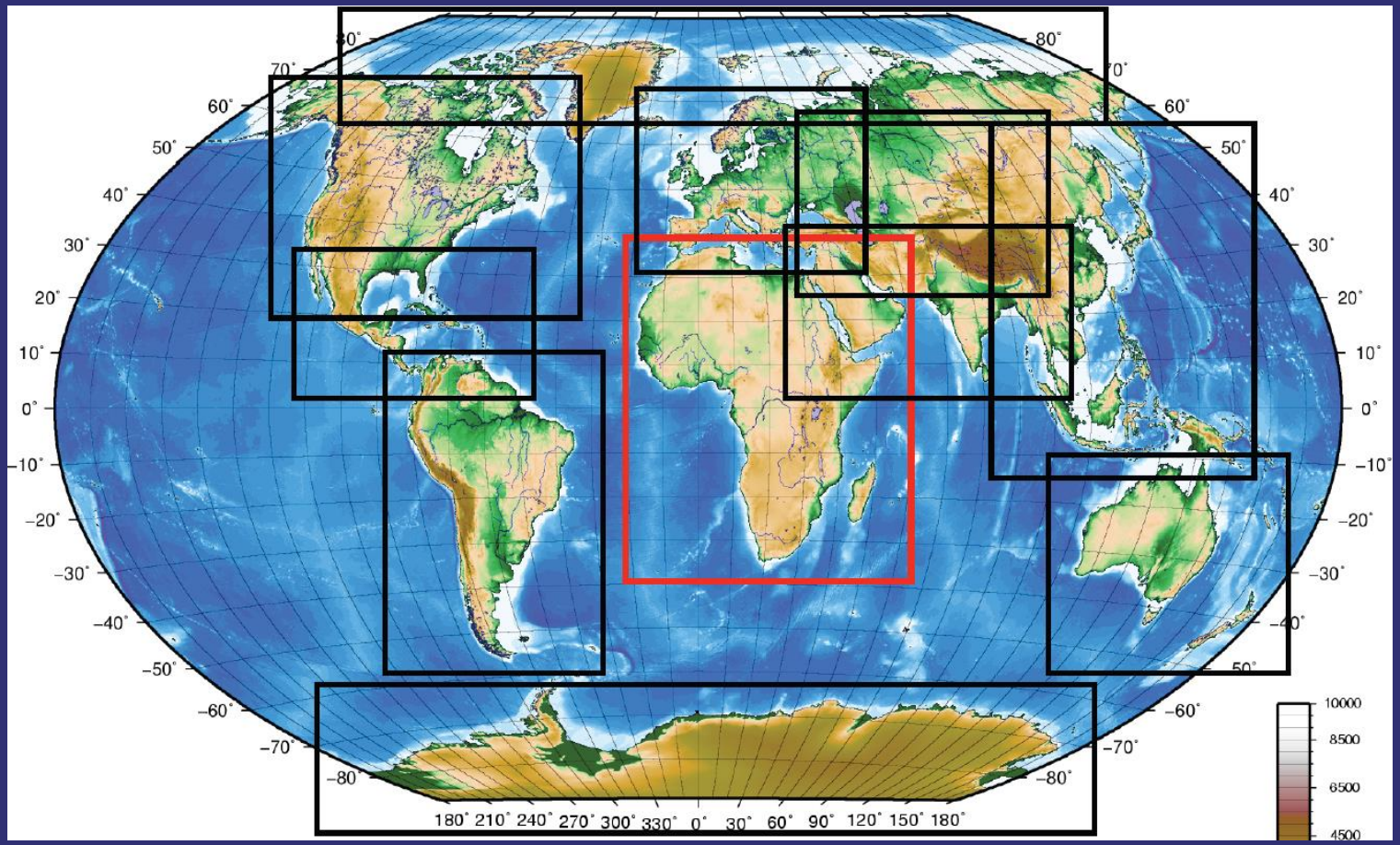
20km

Michael Wehner
Lawrence Berkeley
National Laboratory

Exposing/Reducing Uncertainty

CORDEX: COordinated Regional climate Downscaling EXperiment

WCRP globally coordinated Regional Climate Downscaling experiment for improved regional climate change adaptation and impact assessments



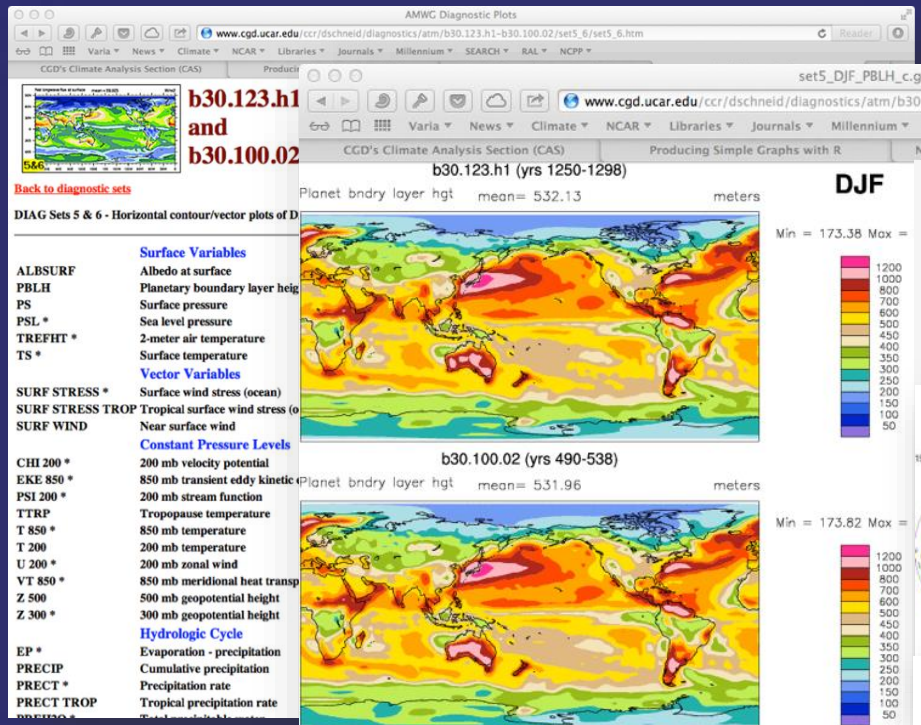
wcrp.ipsl.jussieu.fr/cordex/about.html

Exposing/Reducing Uncertainty

Assess/improve model using sector variables

Standardized CESM Diagnostics

http://www2.cesm.ucar.edu



Water: Precipitation ≠ Precipitation

Application-specific understanding and evaluation needed

Itaipu : Hydropower

Mexico : Drought

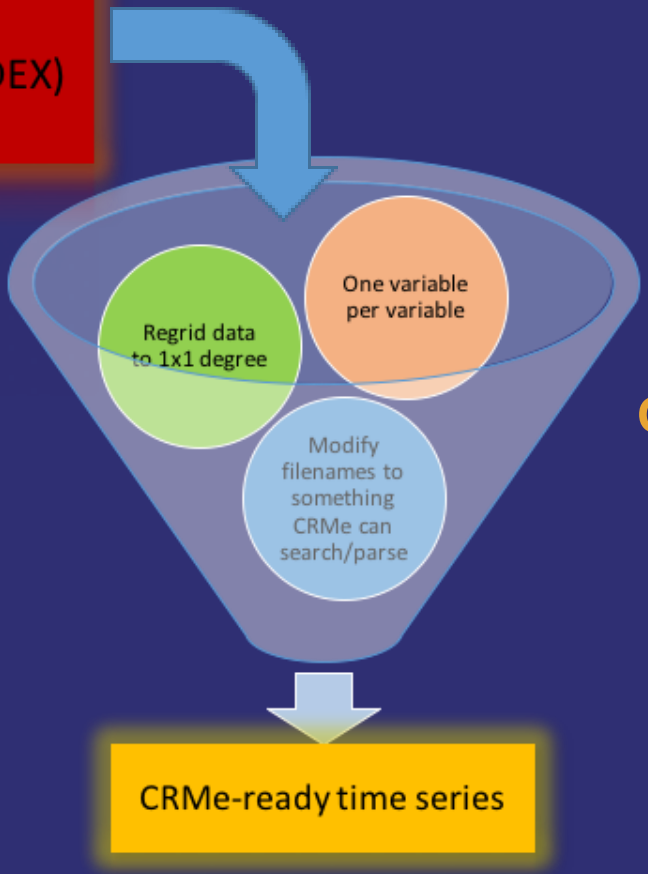
Panama : Flash Flood

Denver Water: Snowpack

CRMe : “Climate Risk Management engine”

efficiency, flexibility, extensibility, …

Broad input data:
- raw models (GCM, RCM),
- compillations (CMIP5, CORDEX)
- observational datasets



Input: Climate variables

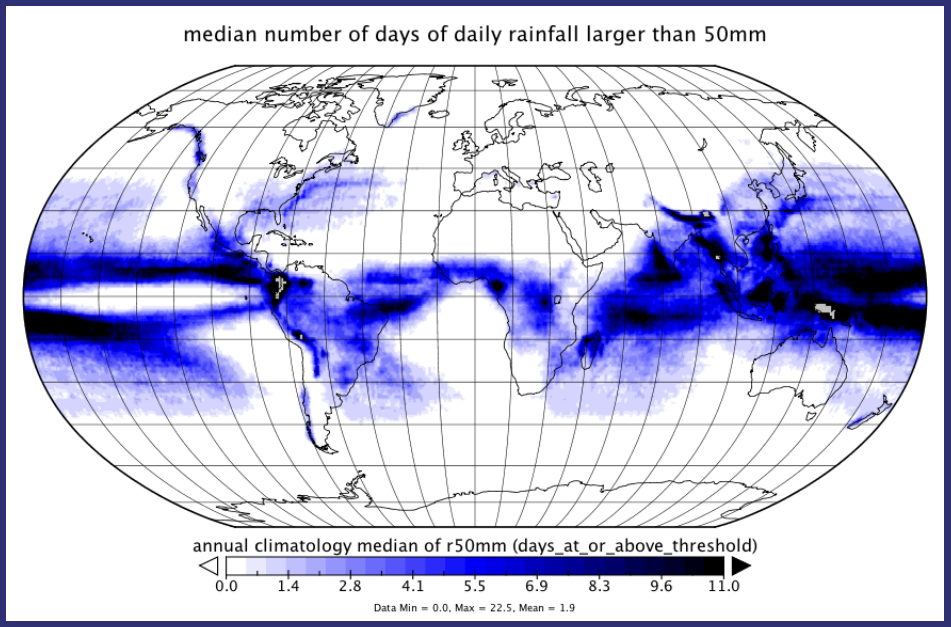
- tas
- tasmin
- tasmax
- pr
- uas
- vas
- rhs
- psl
- huss
- …

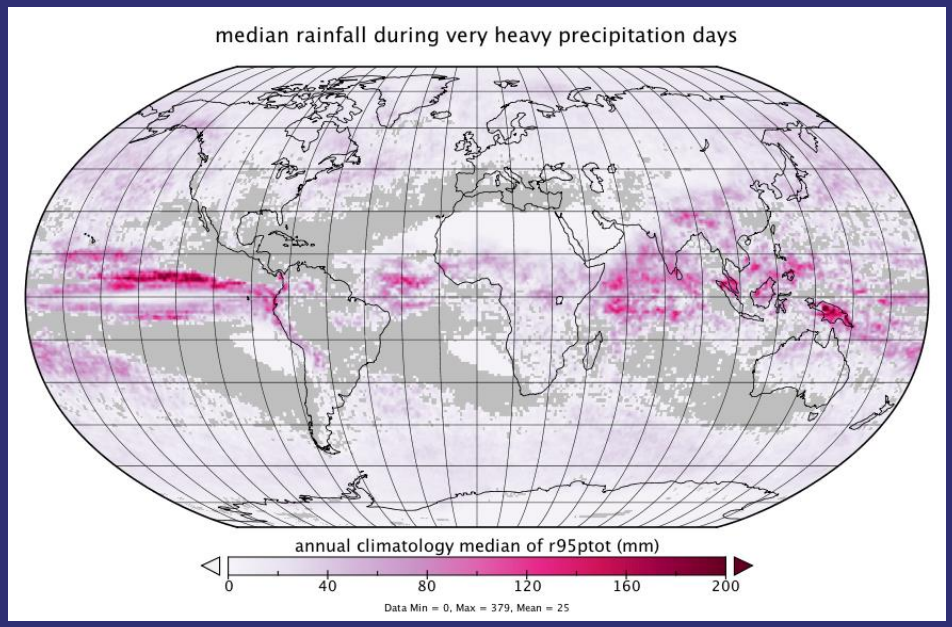
Output: Climate indices

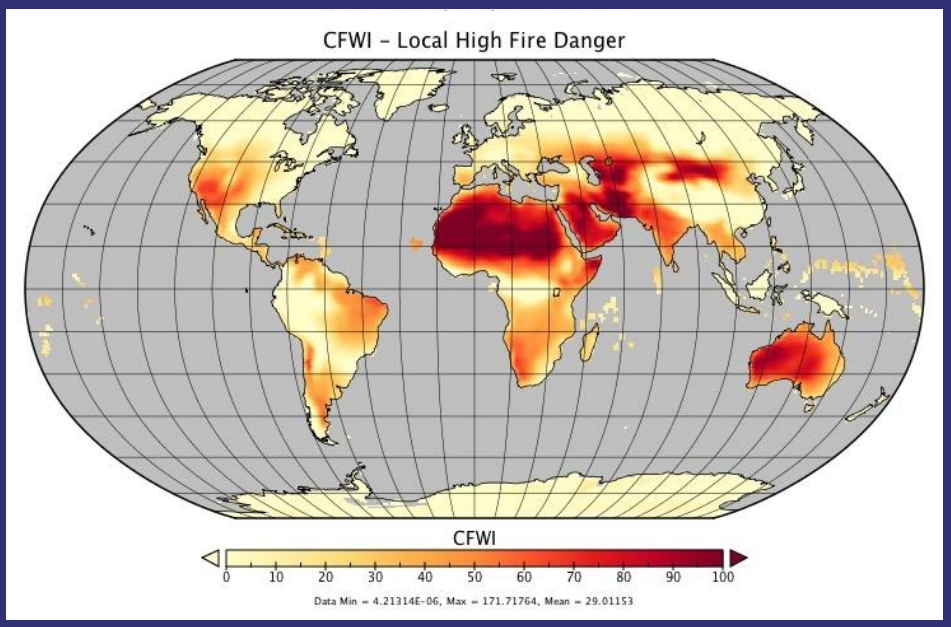
- climatological fields
- sectoral indices
  - health indices
  - agricultural indices
  - water sector indices
  - insurance indices
  - transportation / ports
  - energy
  - …
- diverse climate statistics
- ensemble information
- comparison options

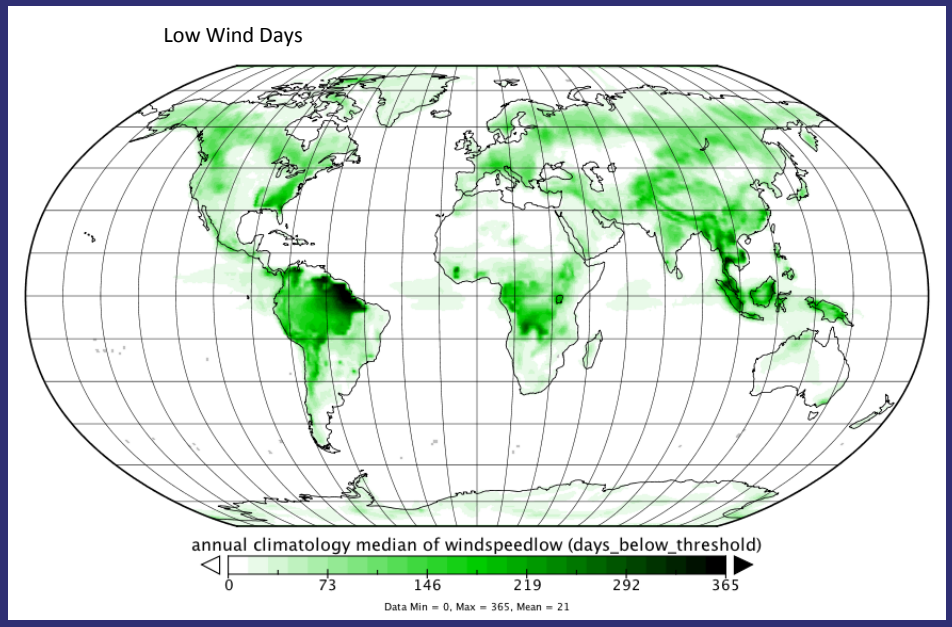
Diversity of Climate Indicators

for analysis platforms, screening tools and dashboards

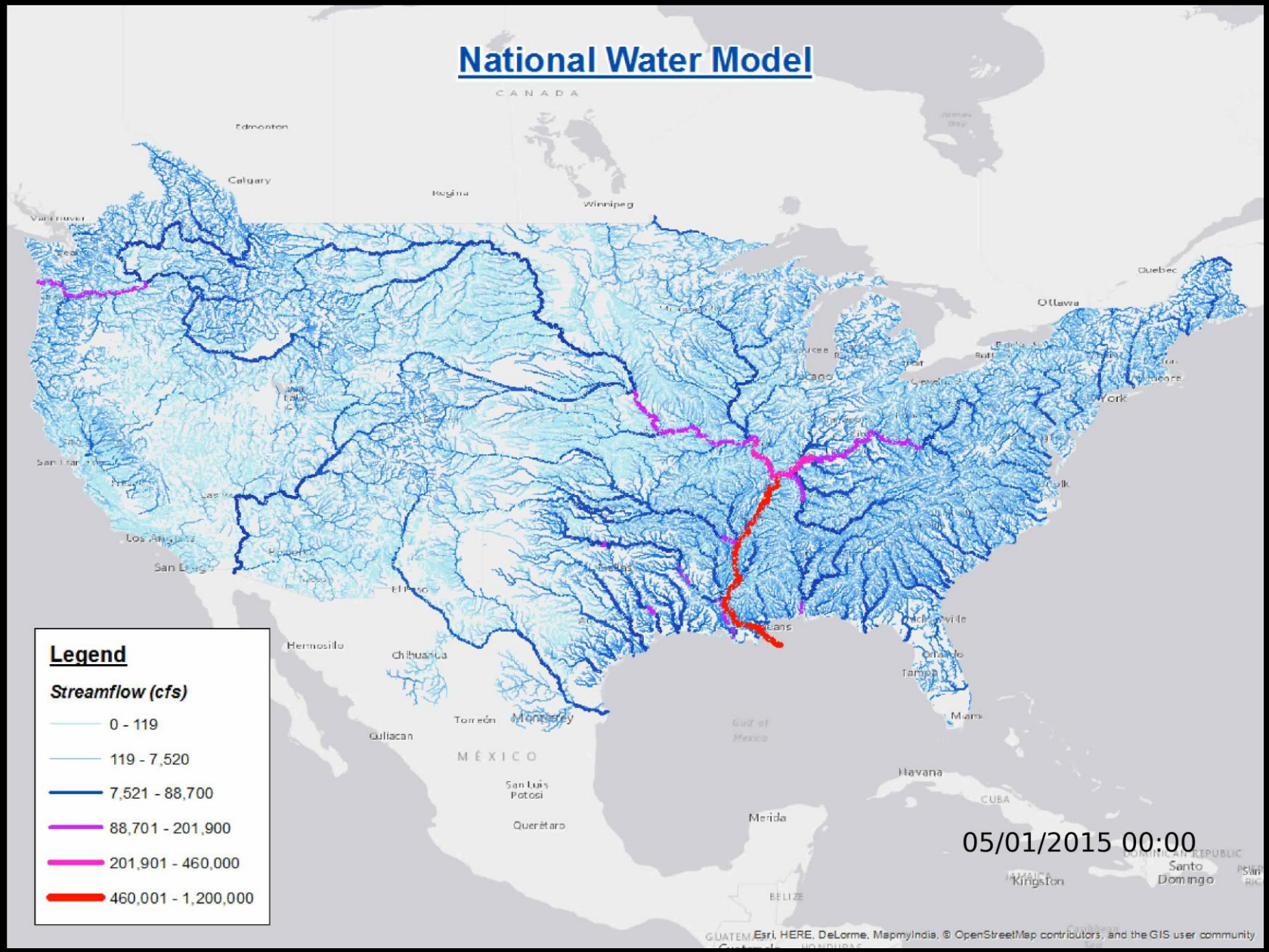




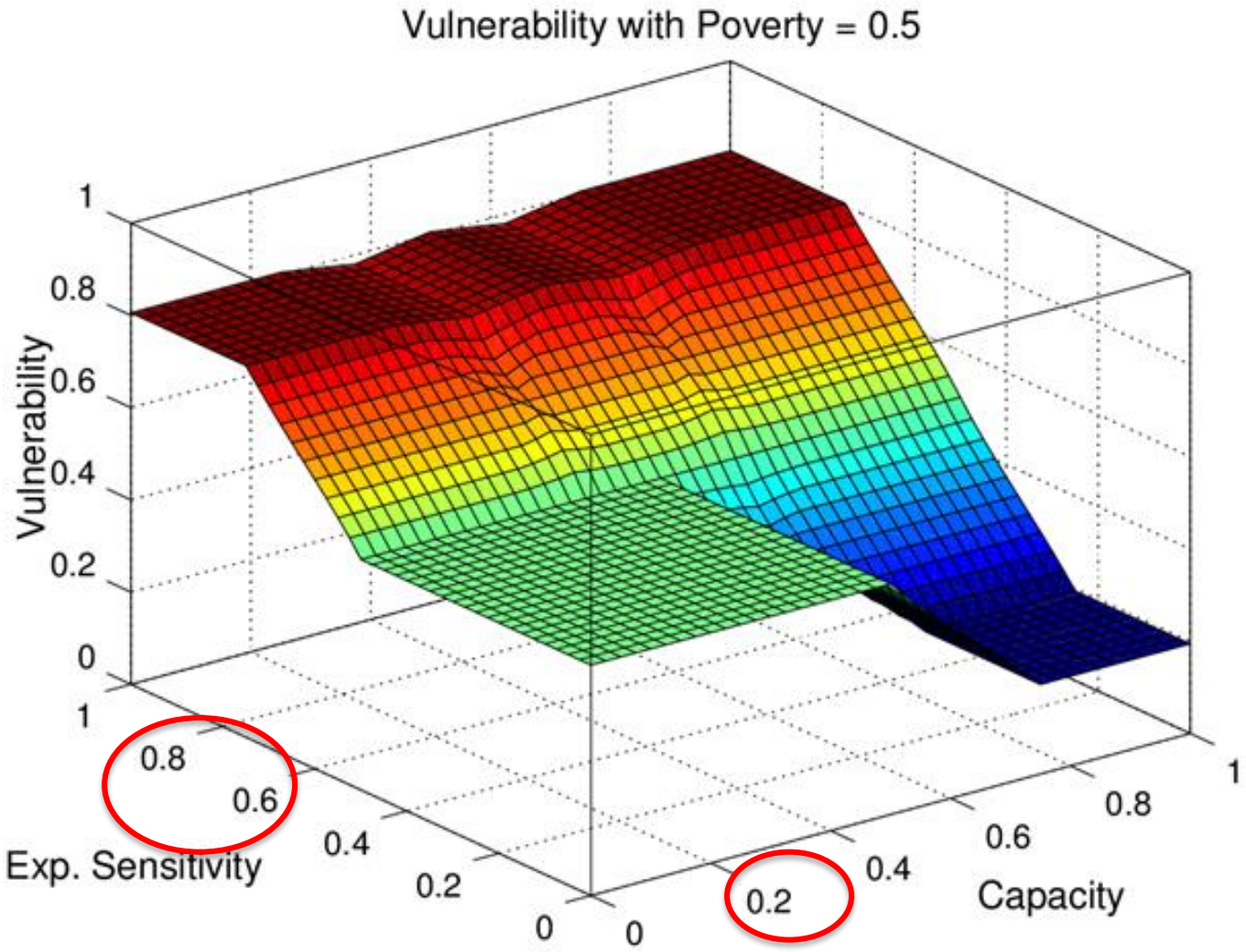




Coupled Models

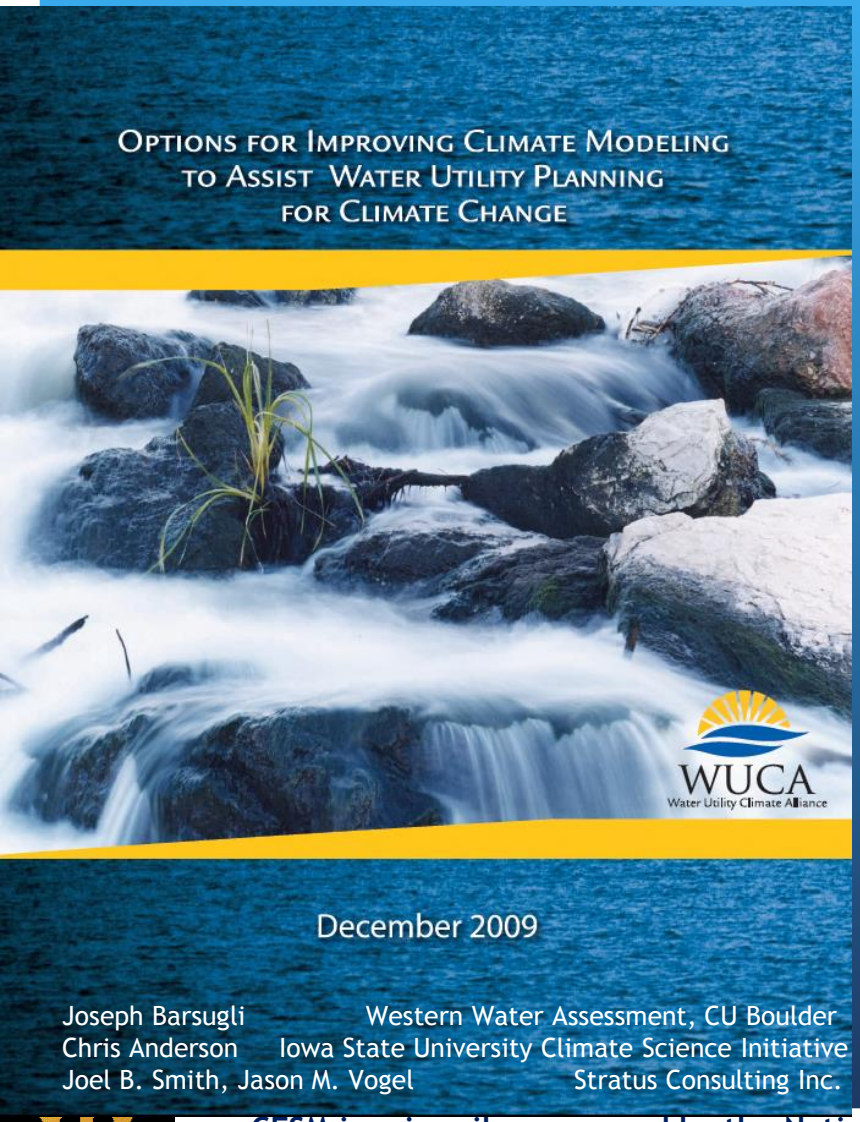


Mumbai: Middle class household vulnerability



P Romero-Lankao – NCAR Urban Futures

Water Utility Climate Alliance



WUCA
Water Utility Climate Alliance

GCM Options

1. Improve the confidence in the range of GCM climate projections better thru understanding of the sources of uncertainty
2. Improve accessibility of GCM data to downscaling groups.
3. Improve the ability to assign credible probabilities to GCM model scenarios based on advanced comparison of the models to obs.
4. Develop the ability to integrate projections of climate variability & decadal variability with projections of climate change.
5. Improve GCM model simulations to increase accuracy at the scale of the GCM and provide better input to downscaling methods.
6. Improve agreement on the sign of change, rate of change, & reduce the range among GCM projections of *global and* regional climate on the timeframes of interest to water managers.

Regional Options:

1. Improve the ability of scientists to express their level of confidence in regional climate projections.
2. Improve the accessibility of local projections.
3. Improve the capacity for water utilities to select scenarios based upon water utilities' management techniques,
4. Reduce the range of climate projections where possible.
5. Address the climate information needed for water utilities planning

CESM is primarily sponsored by the National Science Foundation and the Department of Energy

Advances through Integration / Co-Development

connecting "top-down" with "bottom-up" perspectives

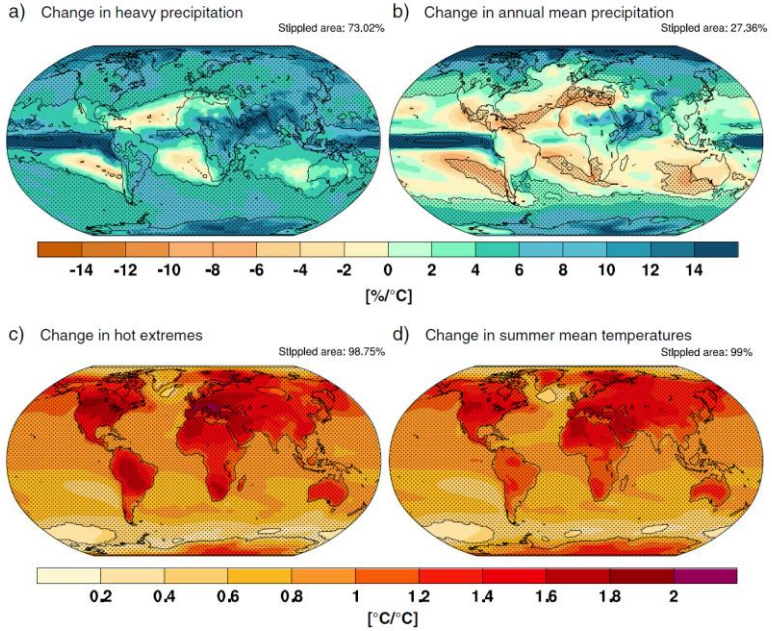


Figure 3. Model robustness in forced signal: Multimodel mean changes in (a) heavy precipitation intensity, (b) annual mean precipitation, (c) hot extremes, and (d) local summer mean temperature (June-July-August in Northern and December-January-February in Southern Hemisphere) per degree global warming in 15 CMIP models. Estimates are based on a linear regression of local changes with respect to global mean temperature change in the respective model simulation in the period 1901–2100 (historical and RCP8.5). Stippling illustrates agreement in sign of changes across at least 12 of the 15 models (80% of models).

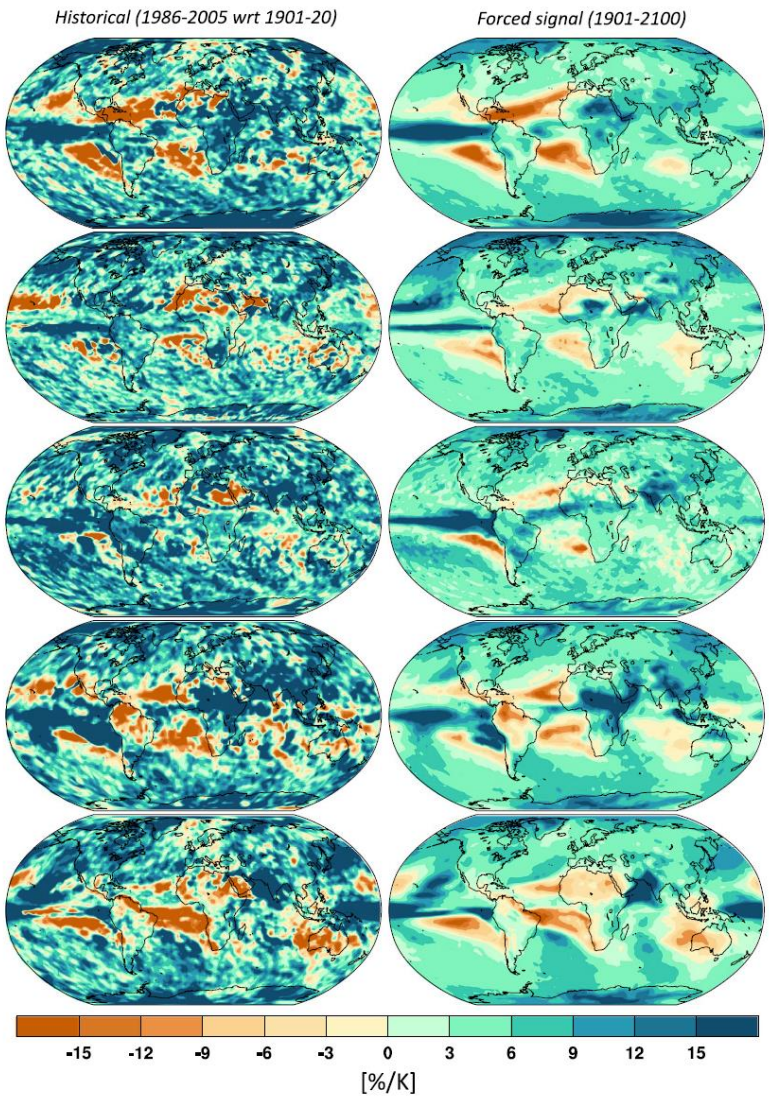


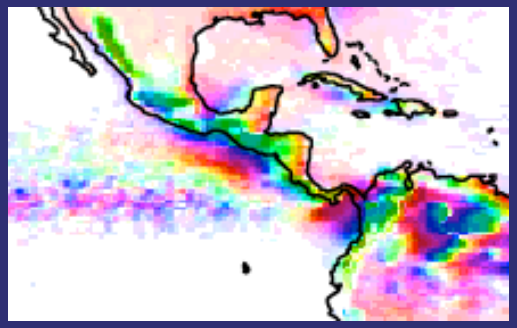
Figure 1. Model agreement on the change in heavy precipitation intensity in individual realizations and forced signal: (left) Change in 20 year means of annual 1 day precipitation maxima (*Rx1day*) in 1986–2005 with respect to 1901–1920 as simulated by the first member of CESM1-CAM4, HadGEM2-ES, EC-EARTH, CanESM2, and CSIRO-Mk3-6-0. Changes are expressed as local percentage changes per degree multimodel mean global warming. (right) Annual *Rx1day* per degree global warming of the respective model derived from a linear regression for the period 1901–2100. Regression slopes are averaged across 4–10 initial condition members of the same models.

Fischer, E. M., J. Sedláček, E. Hawkins, and R. Knutti (2014), Models agree on forced response pattern of precipitation and temperature extremes, Geophys. Res. Lett., 41, 8554–8562, doi:10.1002/2014GL062018.

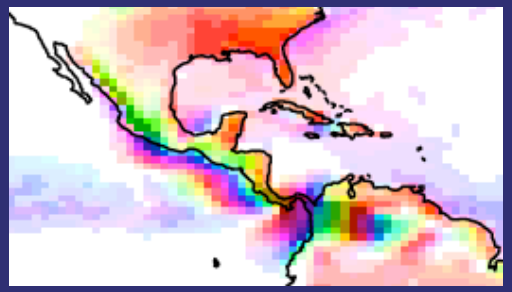
Impact of Model Resolution

JJA Precipitation

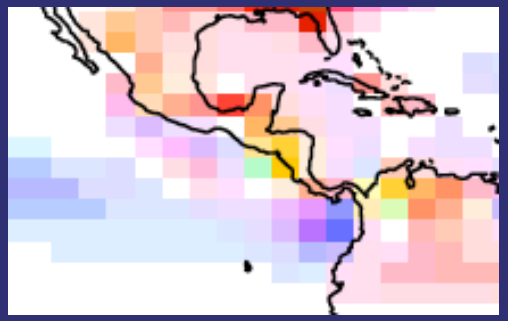
0.25°



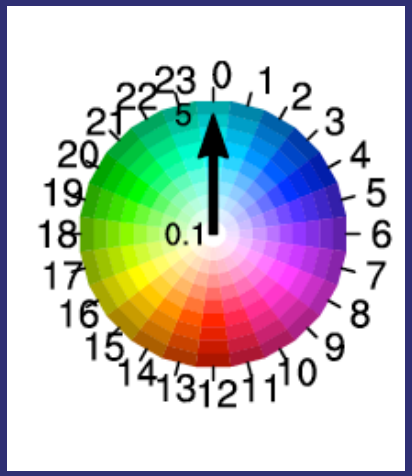
1°



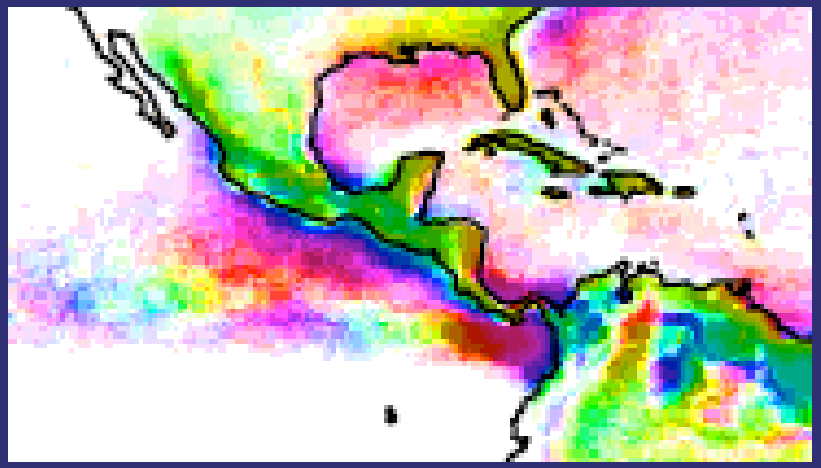
2.5°



Diurnal Cycle
Timing (hour)
Amp. (mm/day)



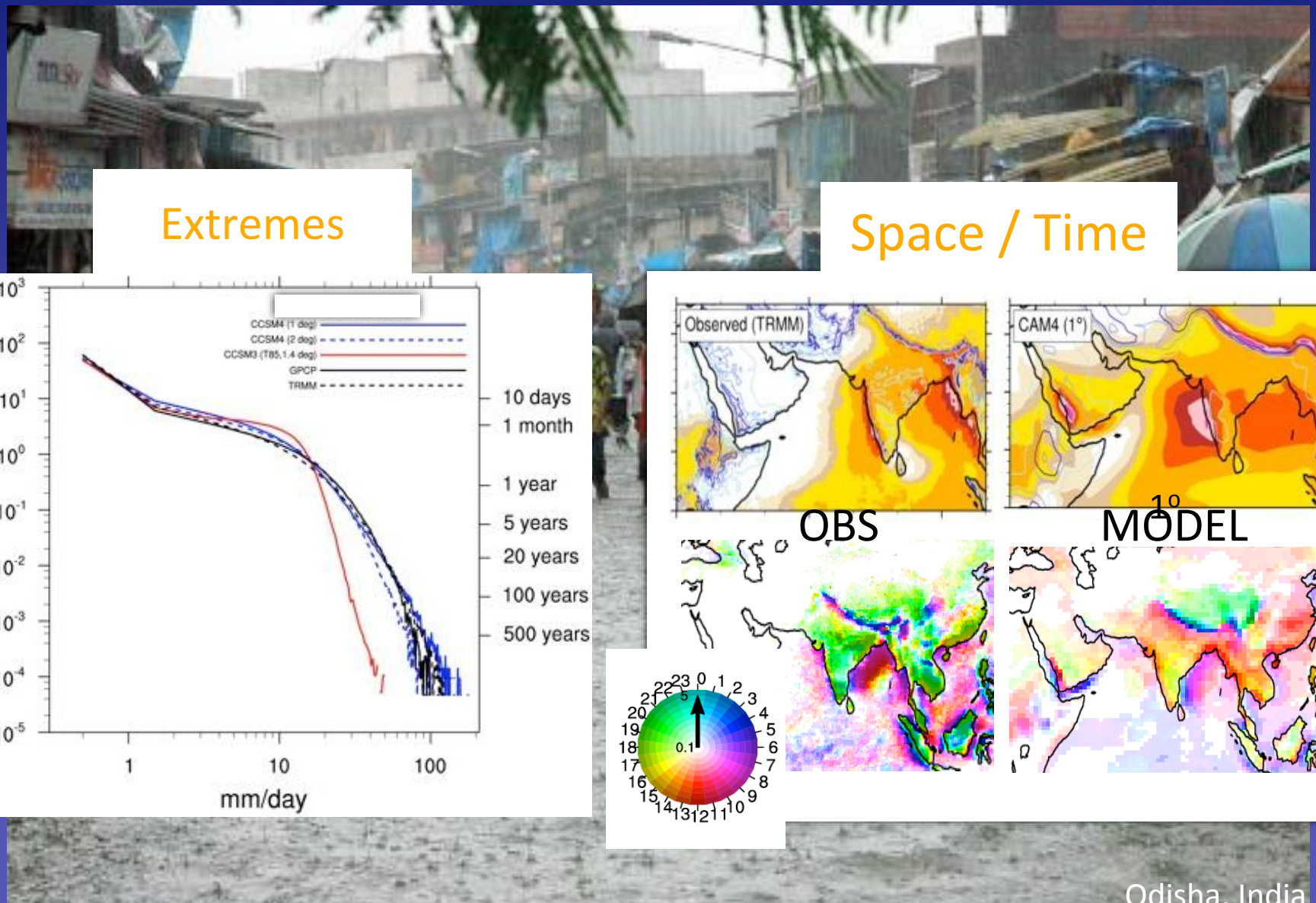
TRMM - Observations



Slide: Rich Neale

Application Context: Precip Biases

Critical Need for Translation and Guidance



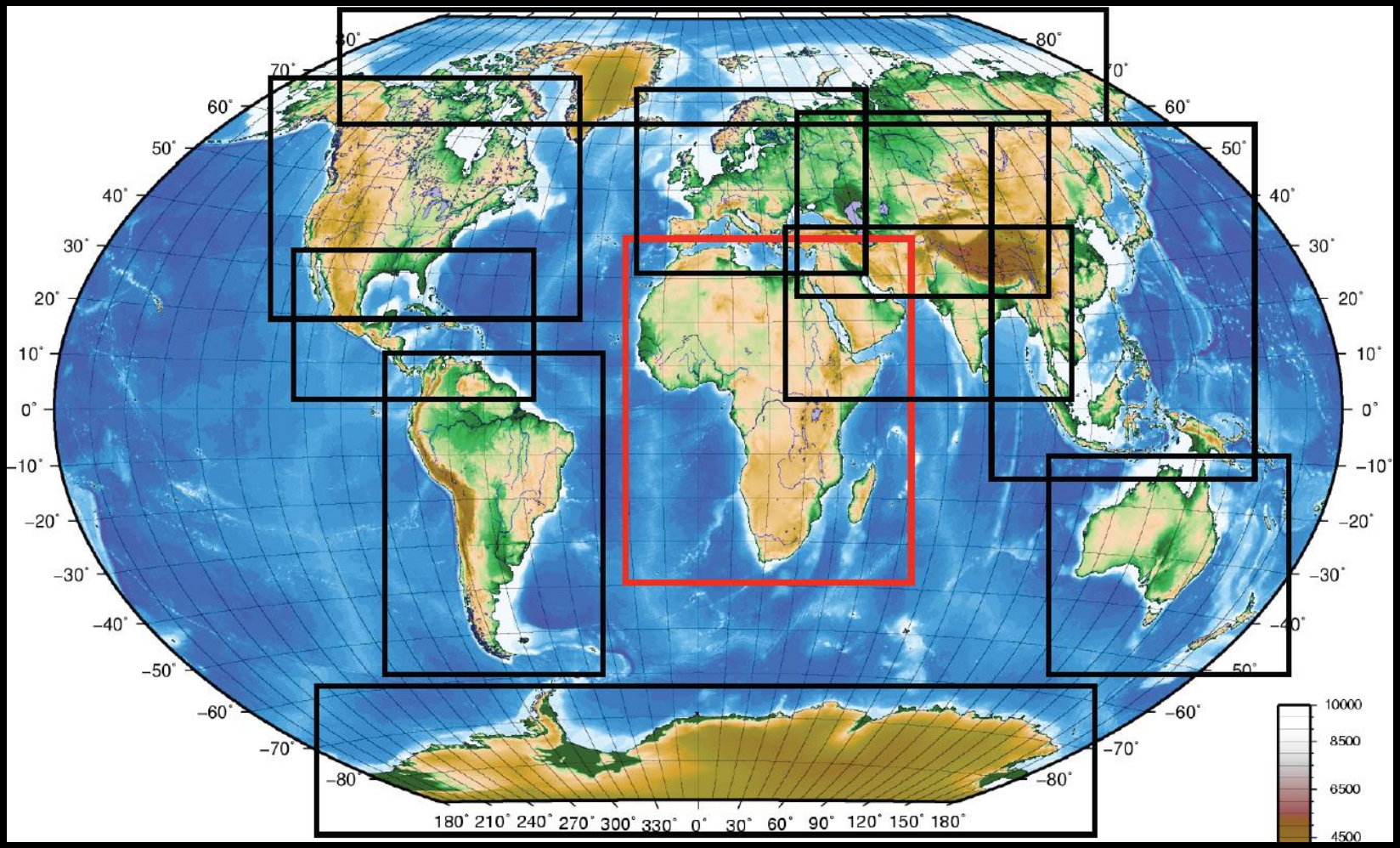
Extremes

Space / Time

Odisha, India

CORDEX: COordinated Regional climate Downscaling EXperiment

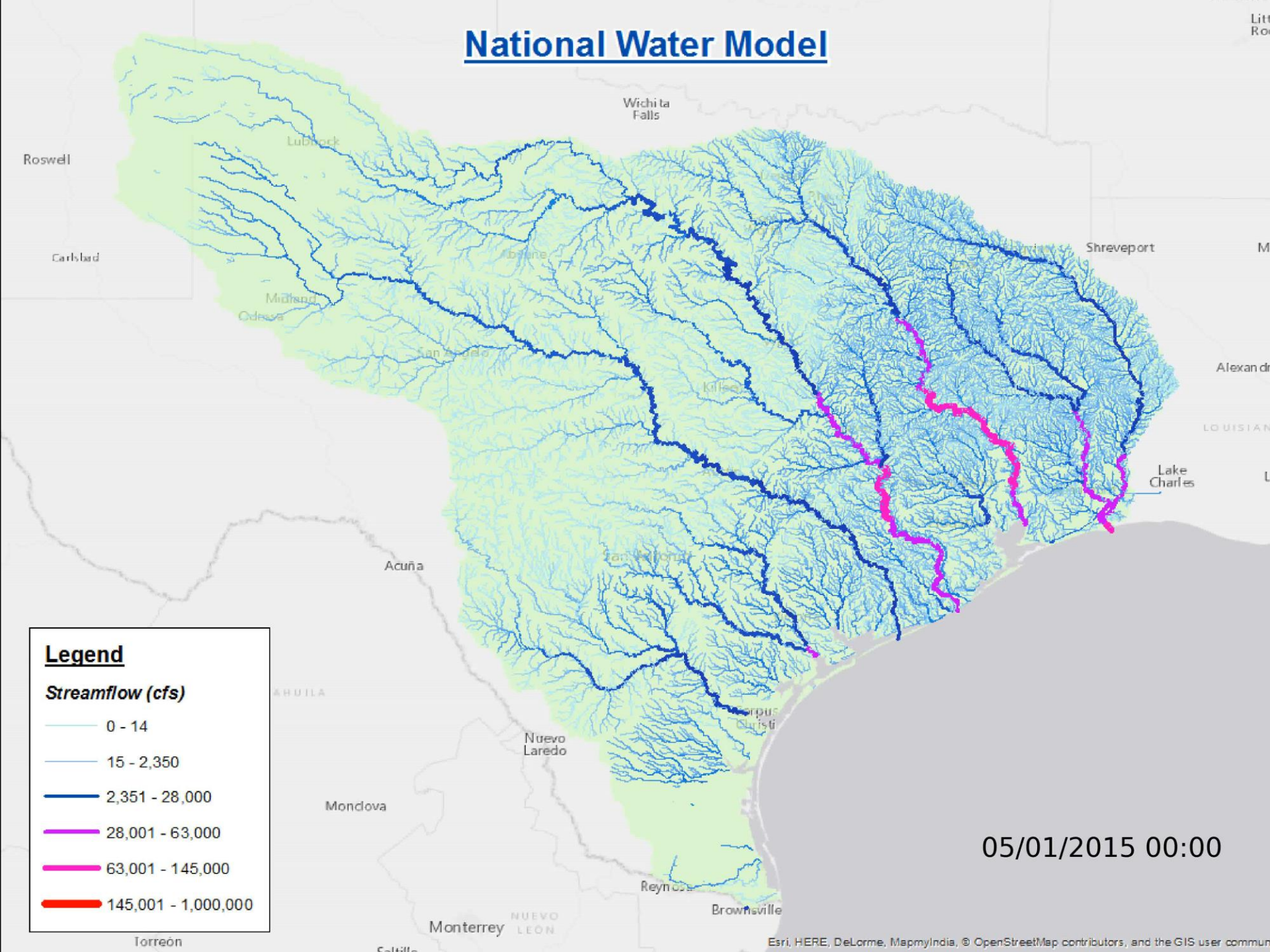
WCRP globally coordinated Regional Climate Downscaling experiment for improved regional climate change adaptation and impact assessments



Lawrence Buja, NCAR

wcrp.ipsl.jussieu.fr/cordex/about.html

National Water Model

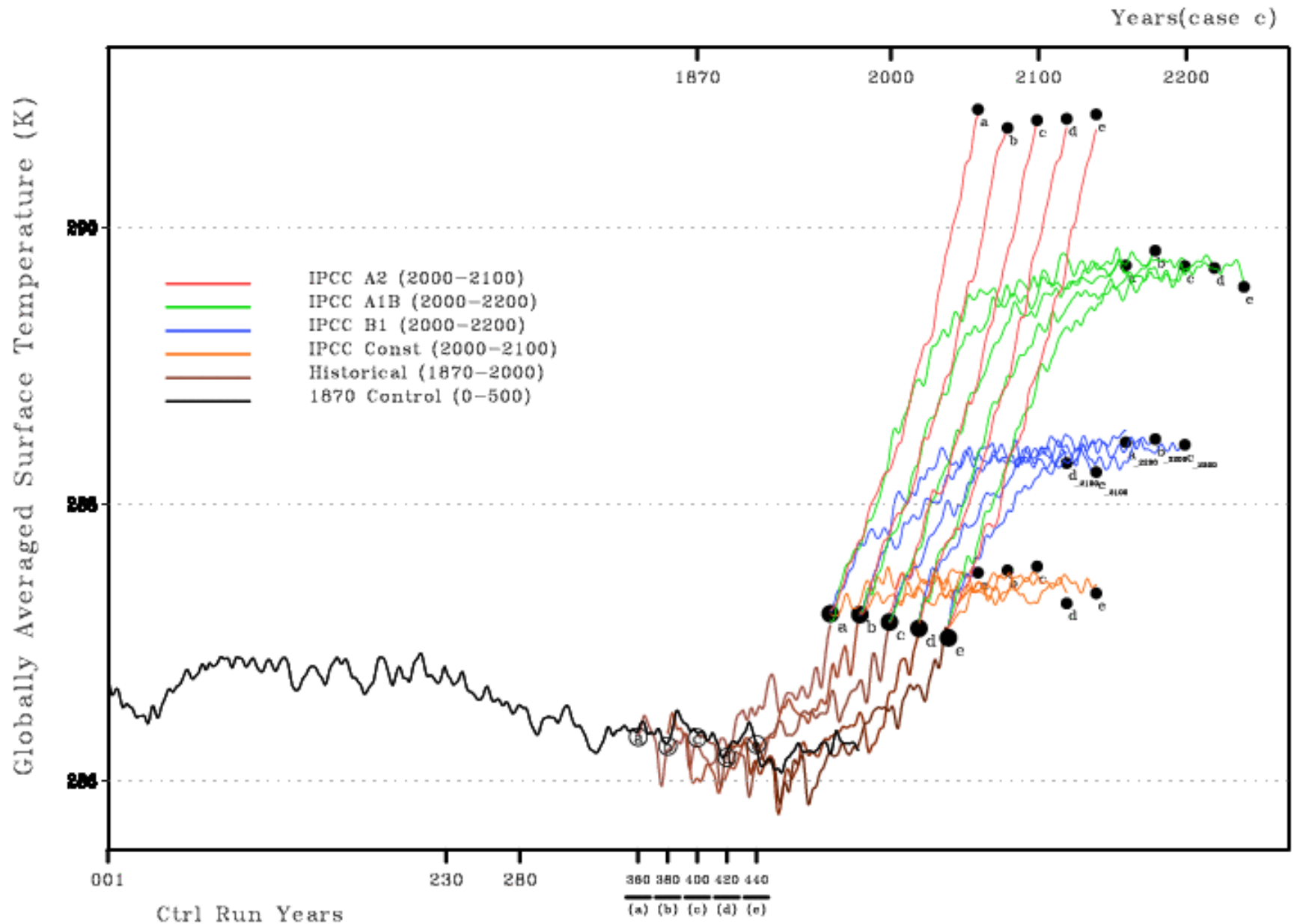


Objectives: Relevant Information

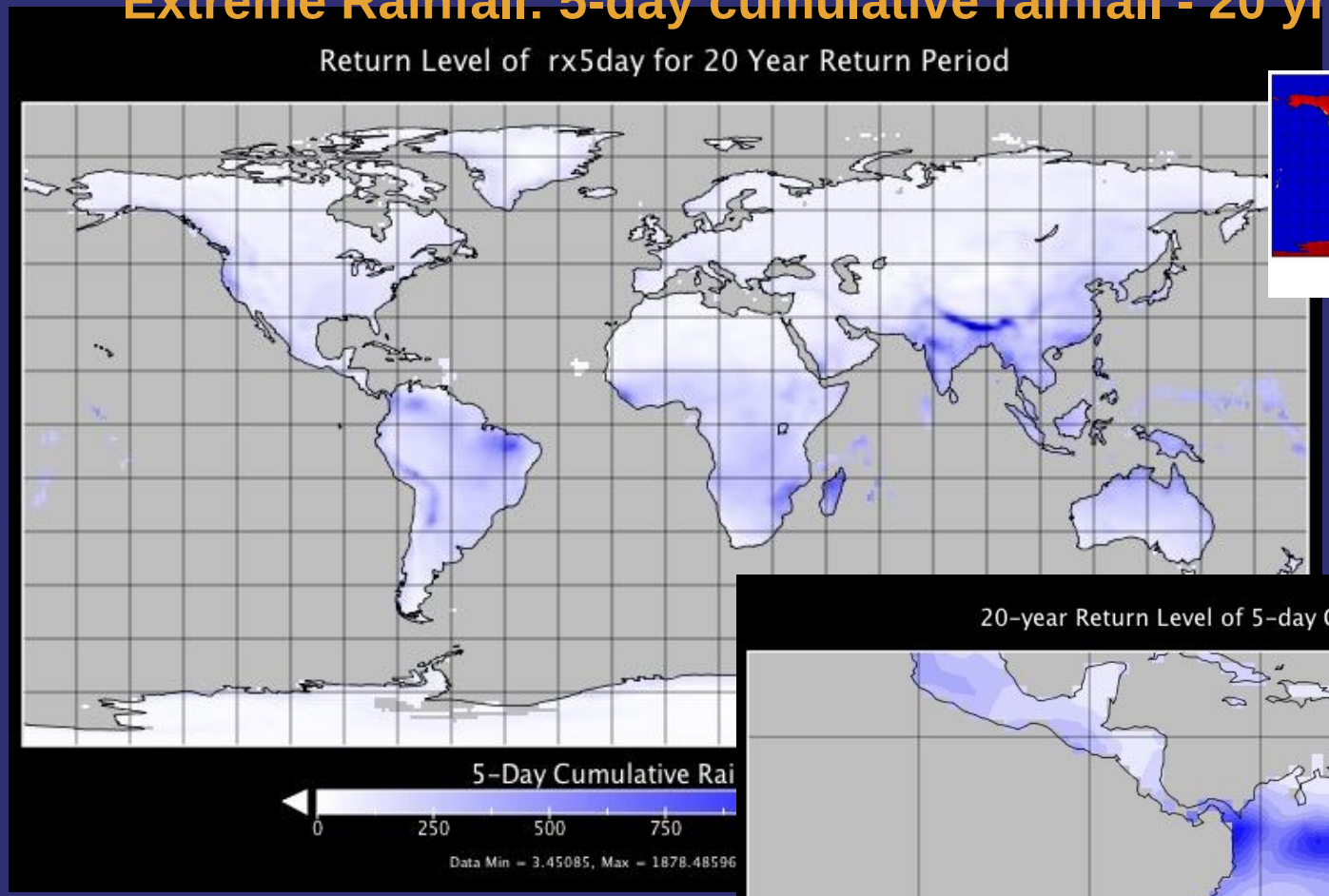
- **Water/Engineering Sector: Inform management and planning decisions with relevant weather & climate information**
  (knowledge chain: access, evaluation, translation, good practice)

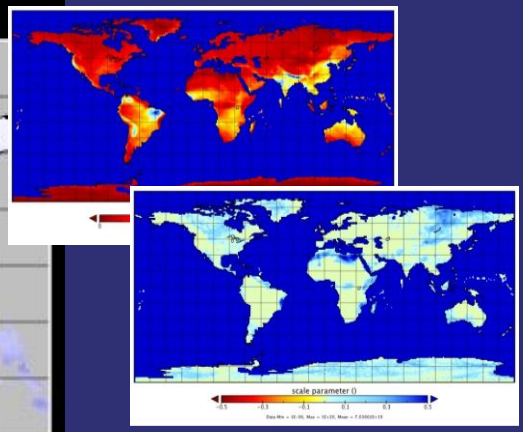
- **Climate Research Community: Understand weather & climate challenges, improve and translate the relevant information**
  (understand challenges at relevant spatial and temporal scales)

- **CoDesign Weather & Climate Products/ actionable information**
  (transparent, tied to observations, translated for understanding and context, probabilistic, …)

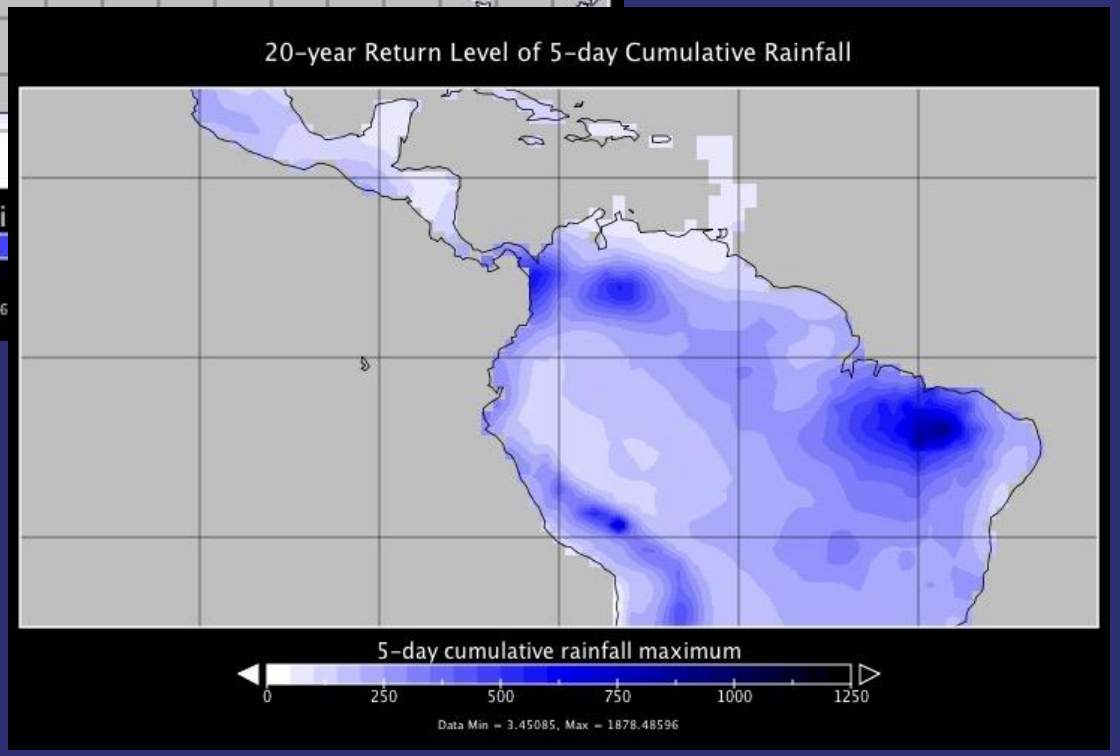

CCSM3 IPCC RUNS
Years(case c)
1870
2000
2100
2200
Globally Averaged Surface Temperature (K)
IPCC A2 (2000–2100)
IPCC A1B (2000–2200)
IPCC B1 (2000–2200)
IPCC Const (2000–2100)
Historical (1870–2000)
1870 Control (0–500)
001
230
280
360 380 400 420 440
(a) (b) (c) (d) (e)
Ctrl Run Years

Extreme Rainfall: 5-day cumulative rainfall - 20 yr return levels





parameters of GEV



Approach:
Naveau et al. 2016, WRR