Downscaled Climate Data: What is Available and How to Use it

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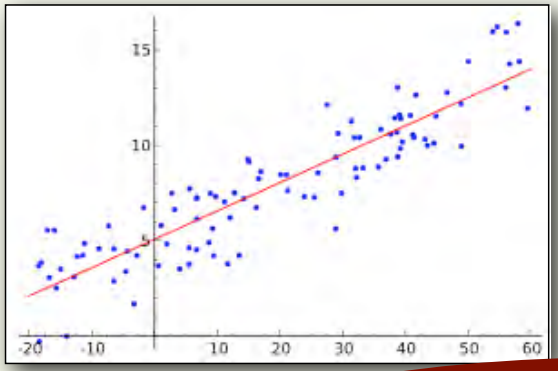
University of Oklahoma

What's a Global Climate Model?

Physical Model

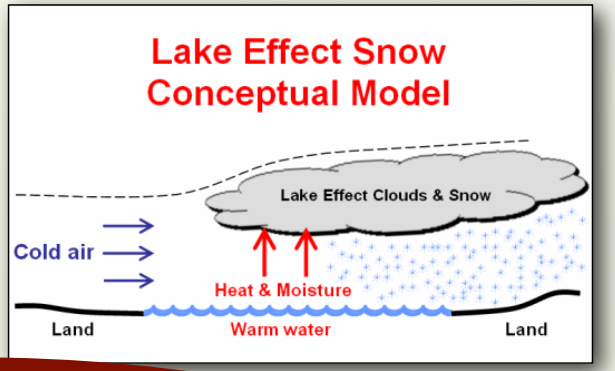
Sean Gallup/Getty Images

Statistical Model



Wikimedi

Conceptual Model



NOAA

Analytical Model

$$\frac{\mathrm{d}P}{\mathrm{d}t} = kP$$

Numerical Model

$$Population\ growth\ rate = \frac{P(t_2) - P(t_1)}{P(t_1)(t_2 - t_1)}$$

What's a Global Climate Model?

Conservation of momentum, energy, mass and moisture:

$$\frac{\partial \vec{V}}{\partial t} = -(\vec{V}\cdot\nabla)\vec{V} - \frac{1}{\rho}\nabla p - \vec{g} - 2\vec{\Omega}\times\vec{V} + \nabla\cdot(k_\omega\nabla\vec{V}) - \vec{F}_d$$

$$\rho c_p\frac{\partial T}{\partial t} = -\rho c_p(\vec{V}\cdot\nabla)T - \nabla\cdot\vec{R} + \nabla\cdot(k_\tau\nabla T) + C + S$$

$$\frac{\partial \rho}{\partial t} = -(\vec{V}\cdot\nabla)\rho - \rho(\nabla\cdot\vec{V})$$

$$\frac{\partial q}{\partial t} = -(\vec{V}\cdot\nabla)q + \nabla\cdot(k_q\nabla q) + S_q + E$$

Equation of state:

$$p = \rho R_d T$$

$V = velocity$

$T = temperature$

$p = pressure$

$\rho = density$

$q = specific\ humidity$

$g = gravity$

$\Omega = rotation\ of\ Earth$

$F_d = drag\ force\ of\ Earth$

$R = radiation\ vector$

$C = conductive\ heating$

$c_p = heat\ capacity, constant\ p$

$E = evaporation$

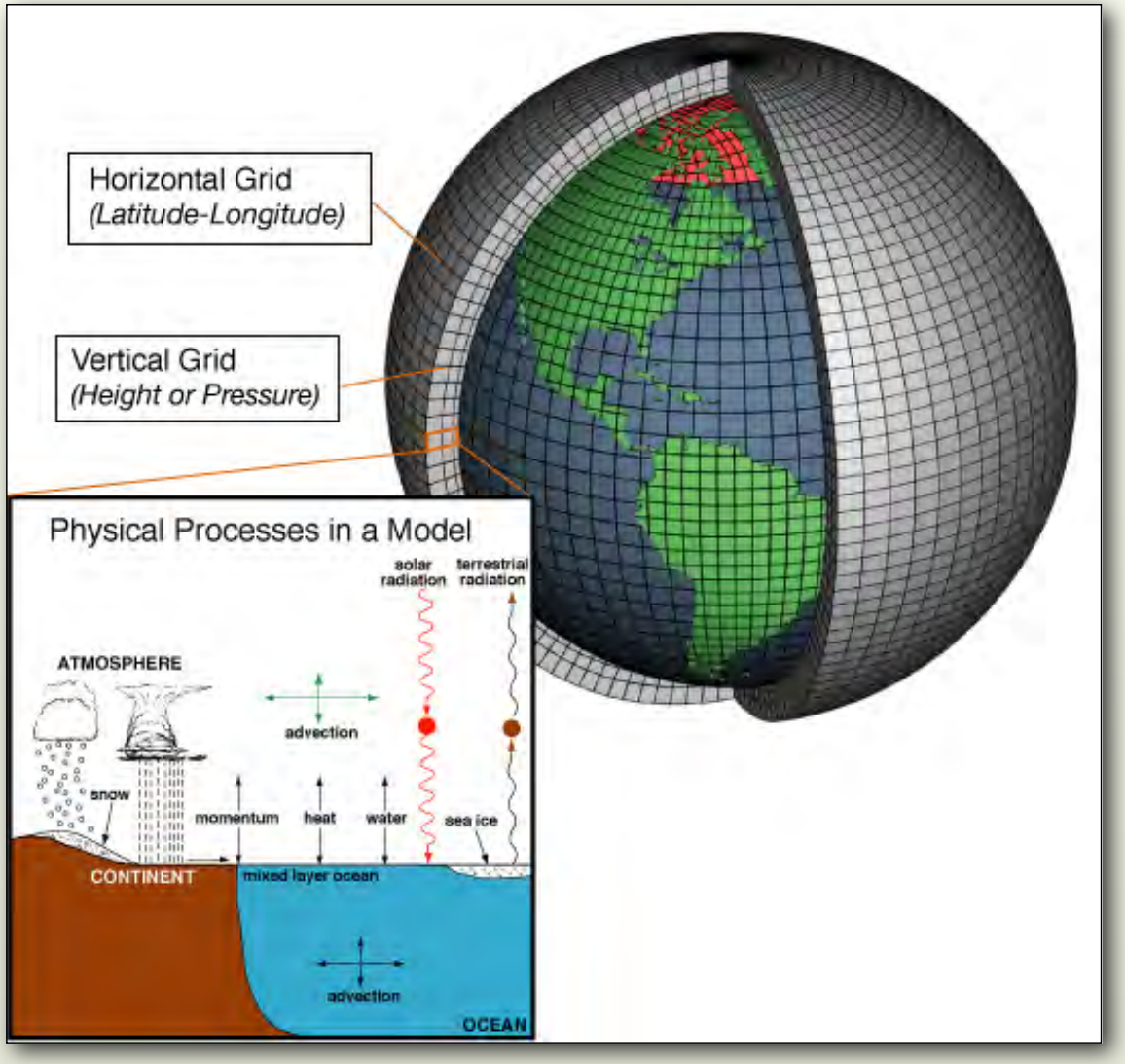
$S = latent\ heating$

$S_q = phase\ change\ source$

$k = diffusion\ coefficients$

$R_d = dry\ air\ gas\ constant$

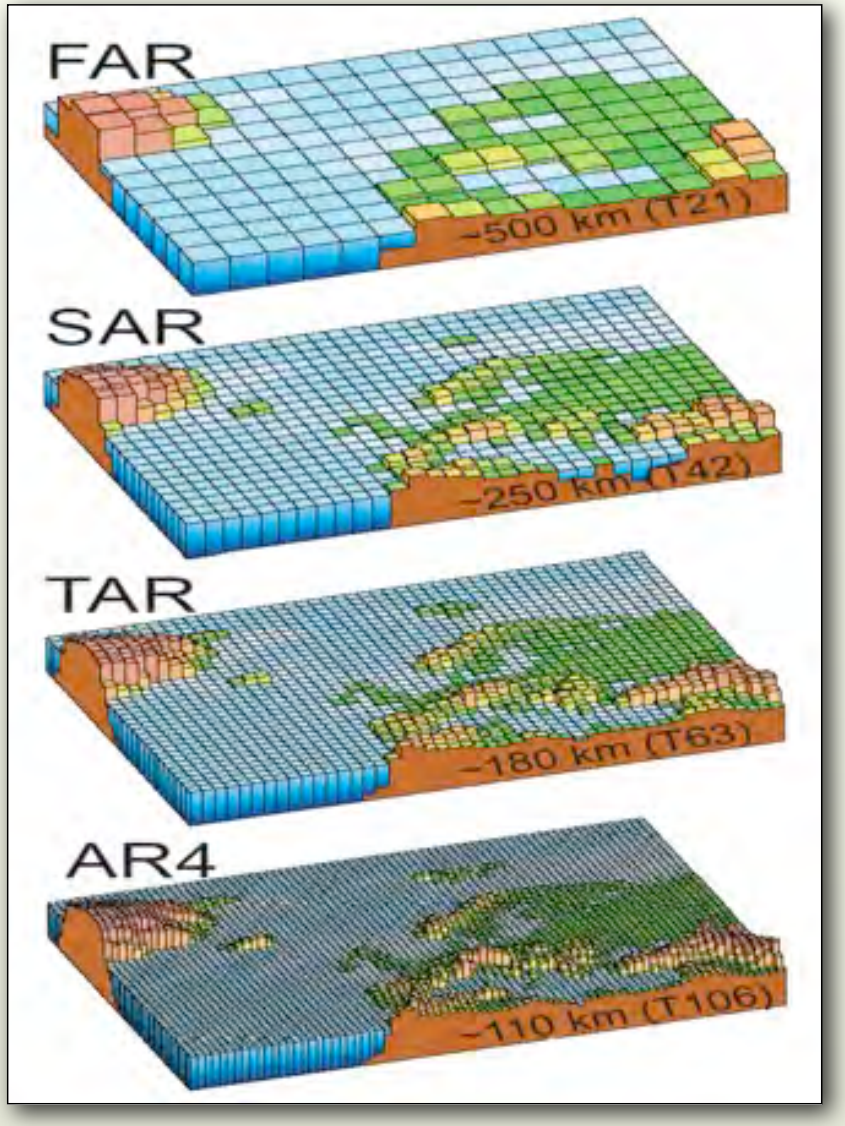
What's a Global Climate Model?



"Essentially, all models are wrong, but some are useful"
– George E.P. Box

What's a Global Climate Model?

- FAR = First Assessment Report (IPCC; 1990)
- SAR = Second Assessment Report (1996)
- TAR = Third Assessment Report (2001)
- AR4 = Fourth Assessment Report (2007)
- AR5 = Fifth Assessment Report (2014)



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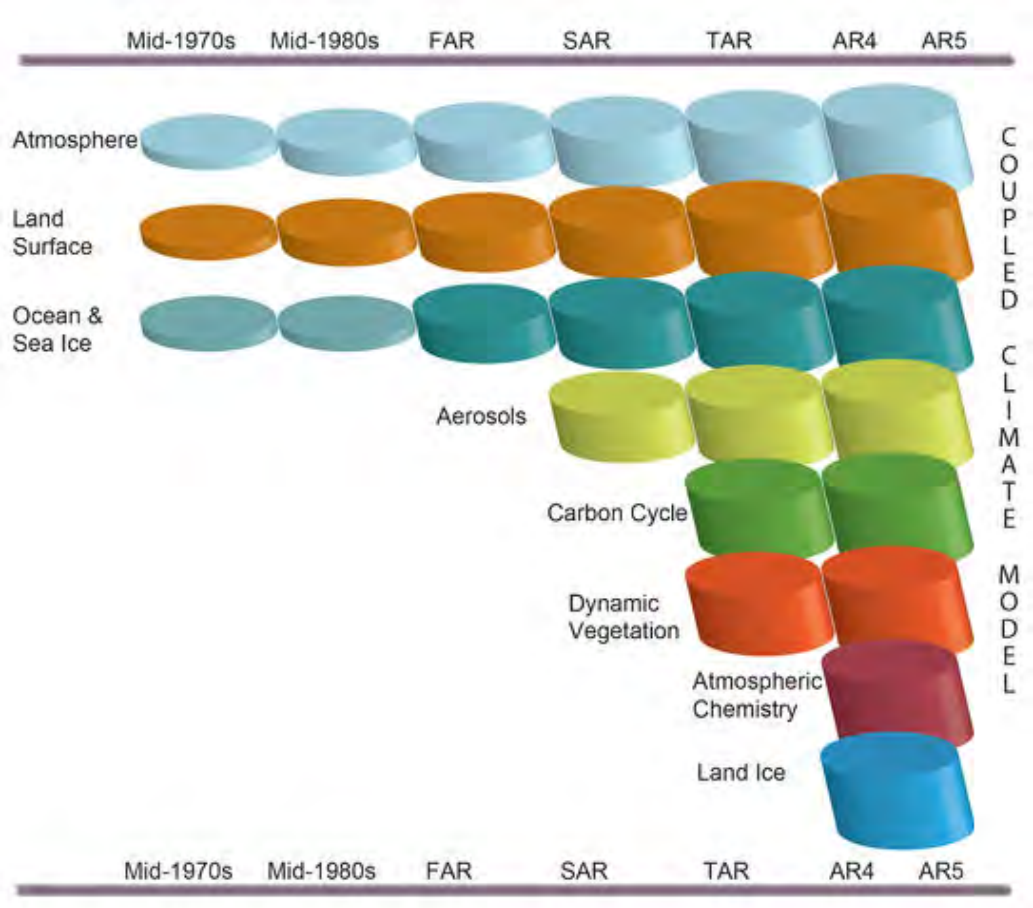

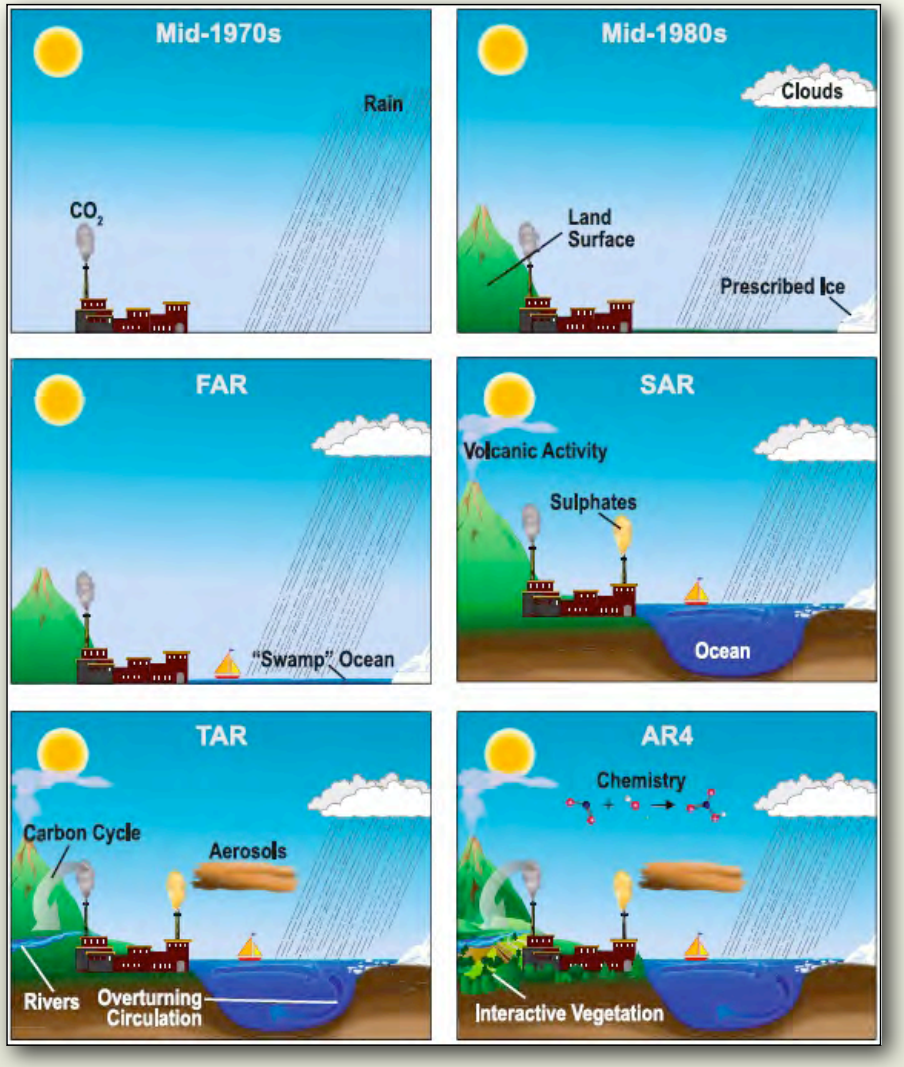

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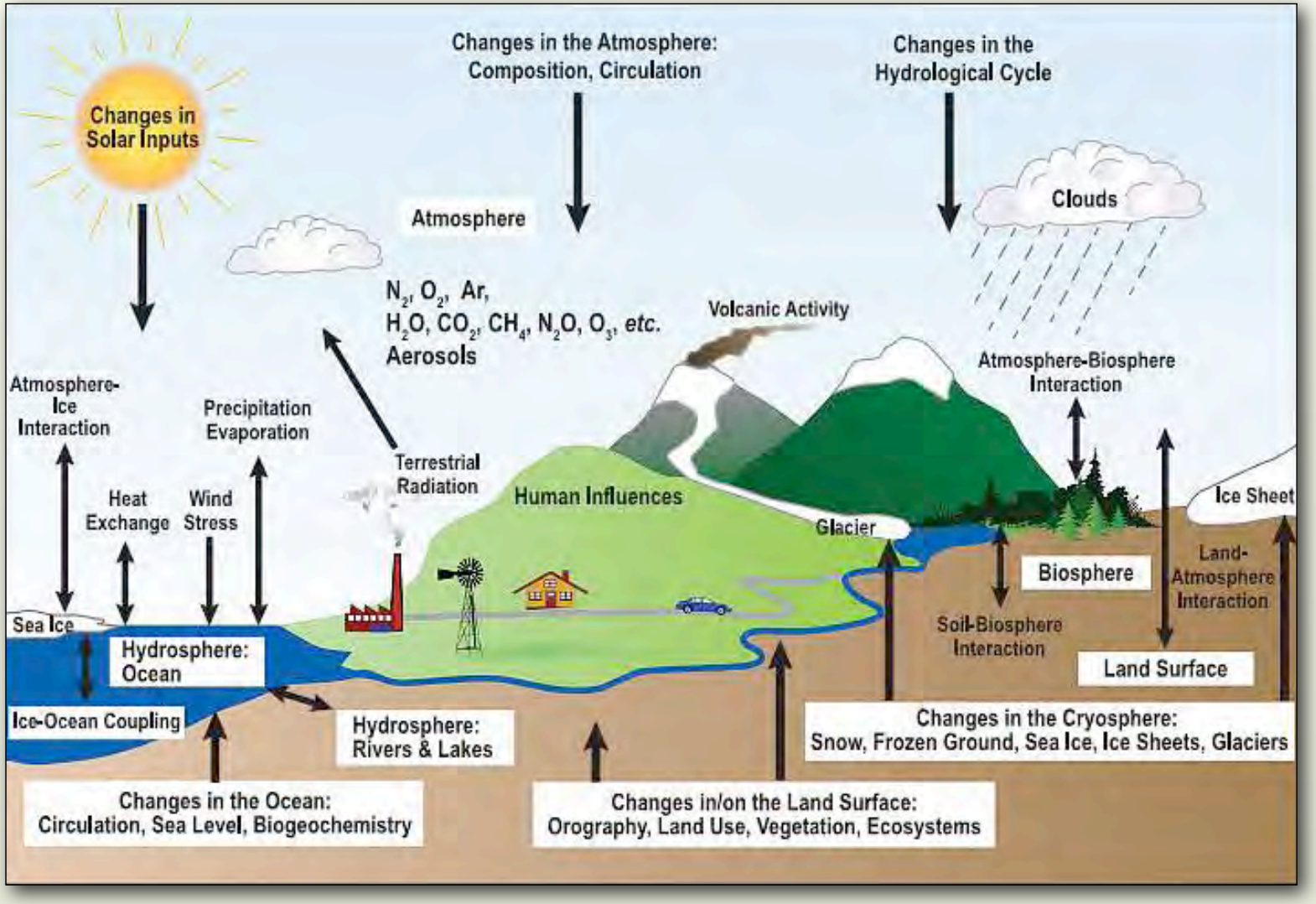

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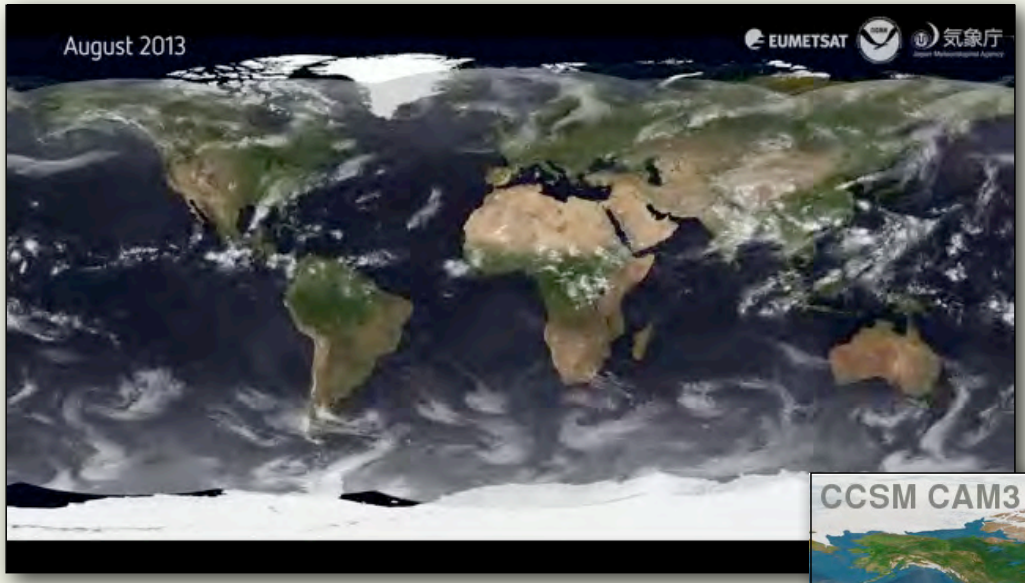


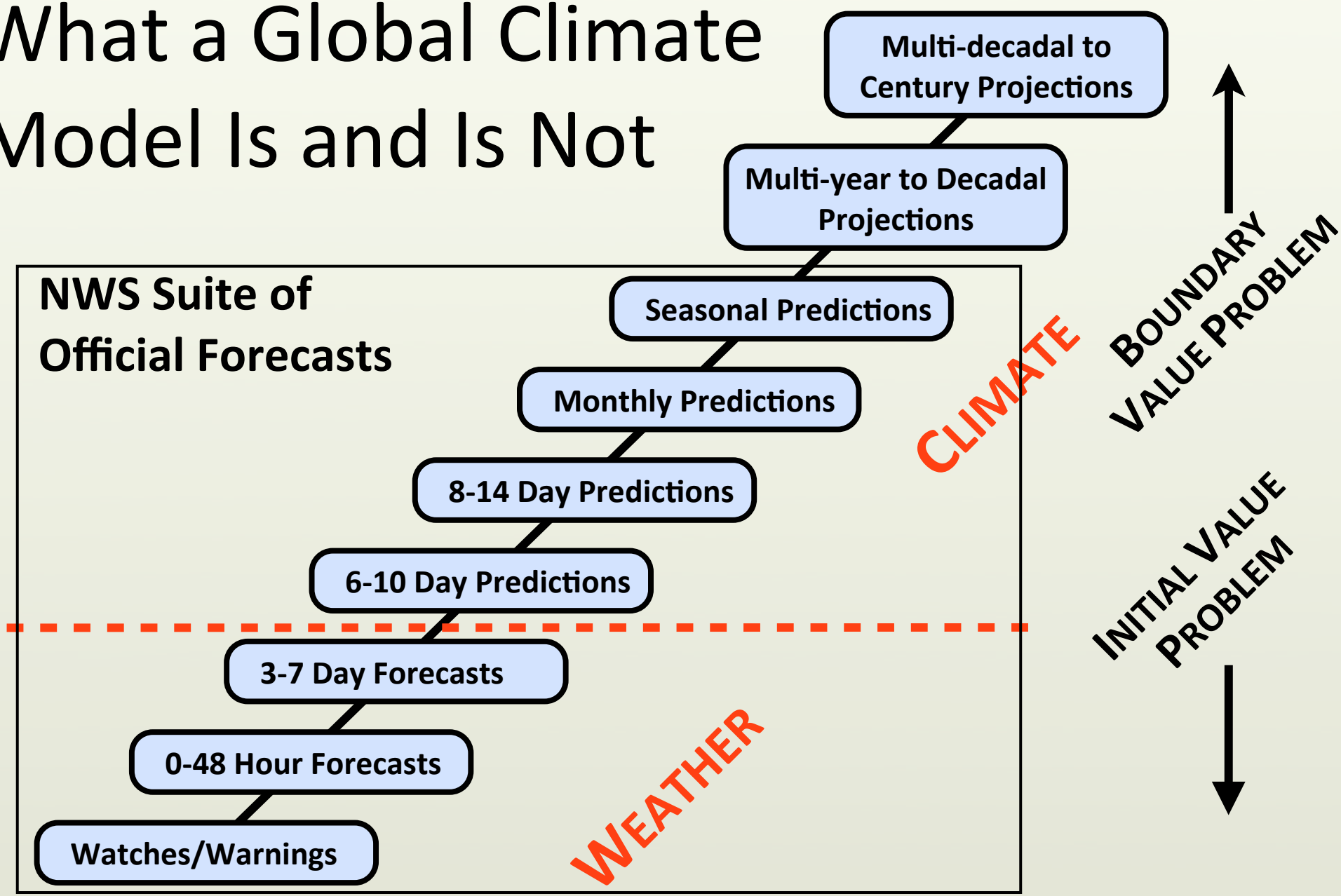
Multi-Satellite Image Animation

https://www.youtube.com/watch?v=m2Gy8V0Dv78

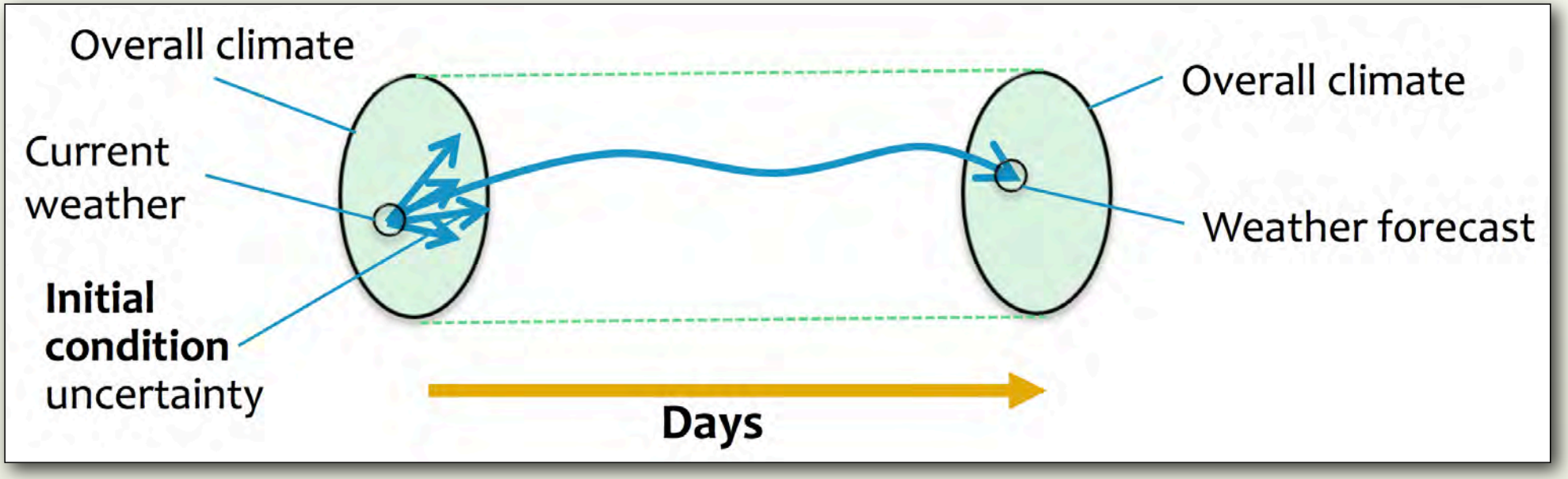
Global Climate Model Simulation

http://www.vets.ucar.edu/vg/T341/index.shtml

What a Global Climate Model Is and Is Not



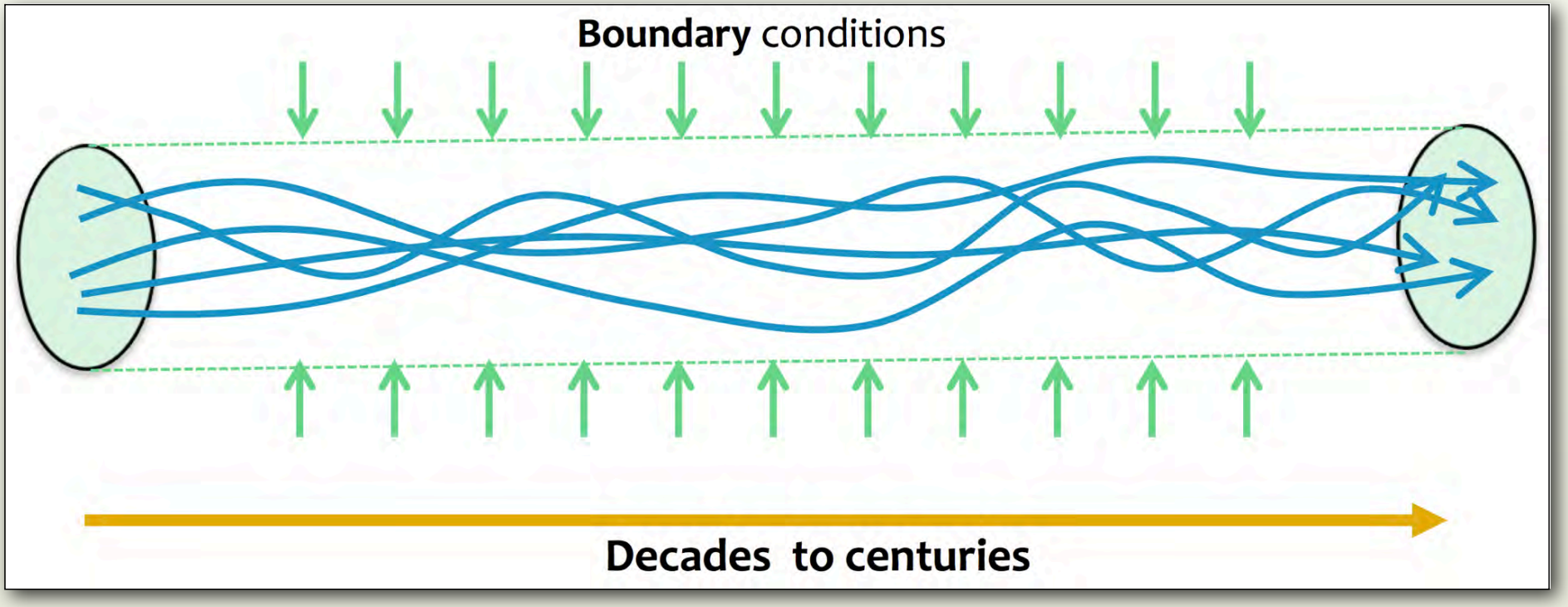
What a Global Climate Model is Not



Steve Easterbrook

Chaos theory: Does the flap of a butterfly's wings in Brazil set off a tornado in Texas? – Ed Lorenz

What a Global Climate Model Is



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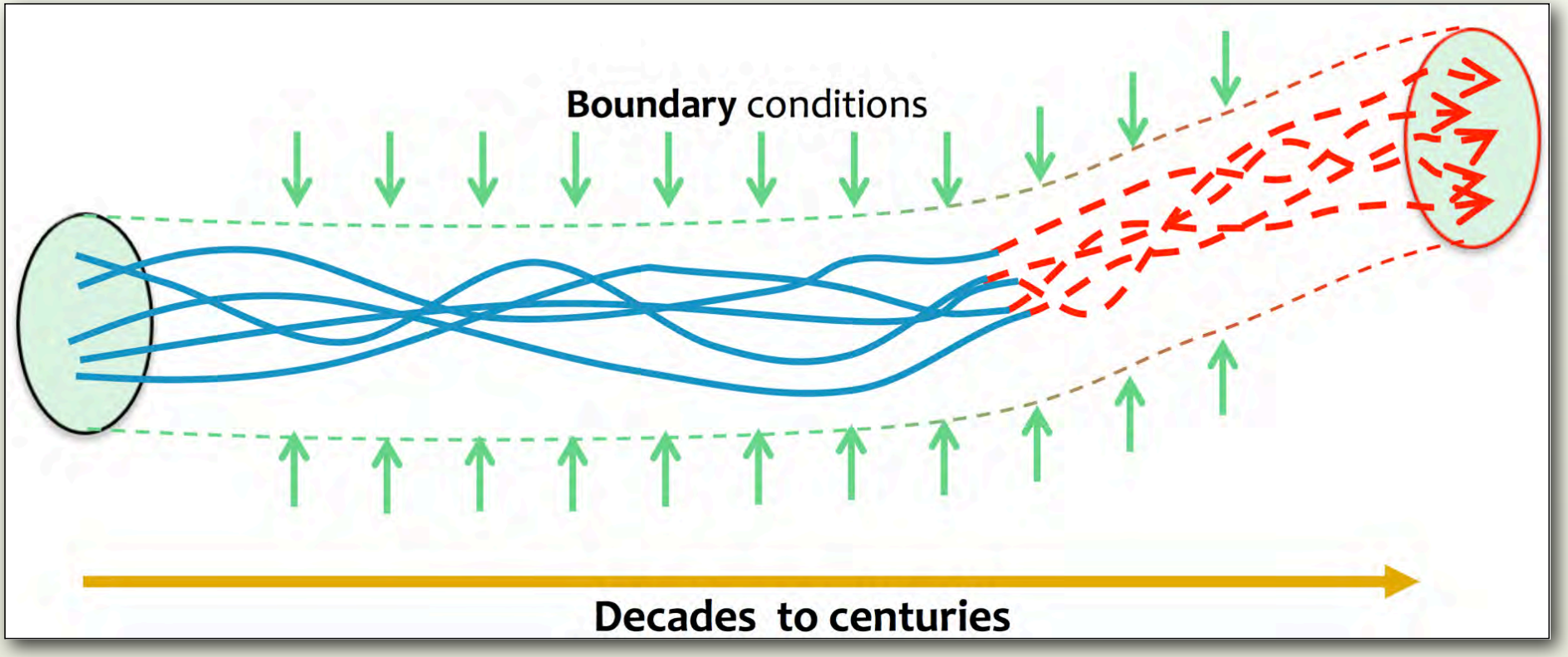
What a Global Climate Model Is



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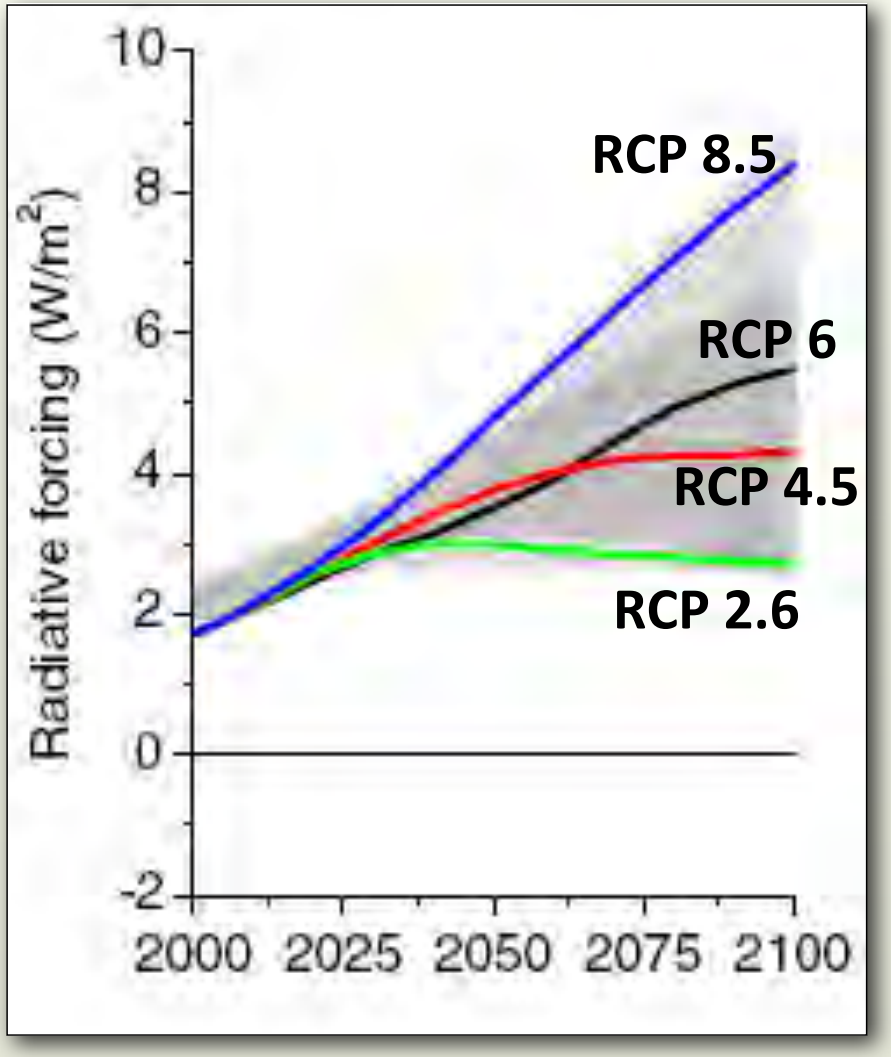
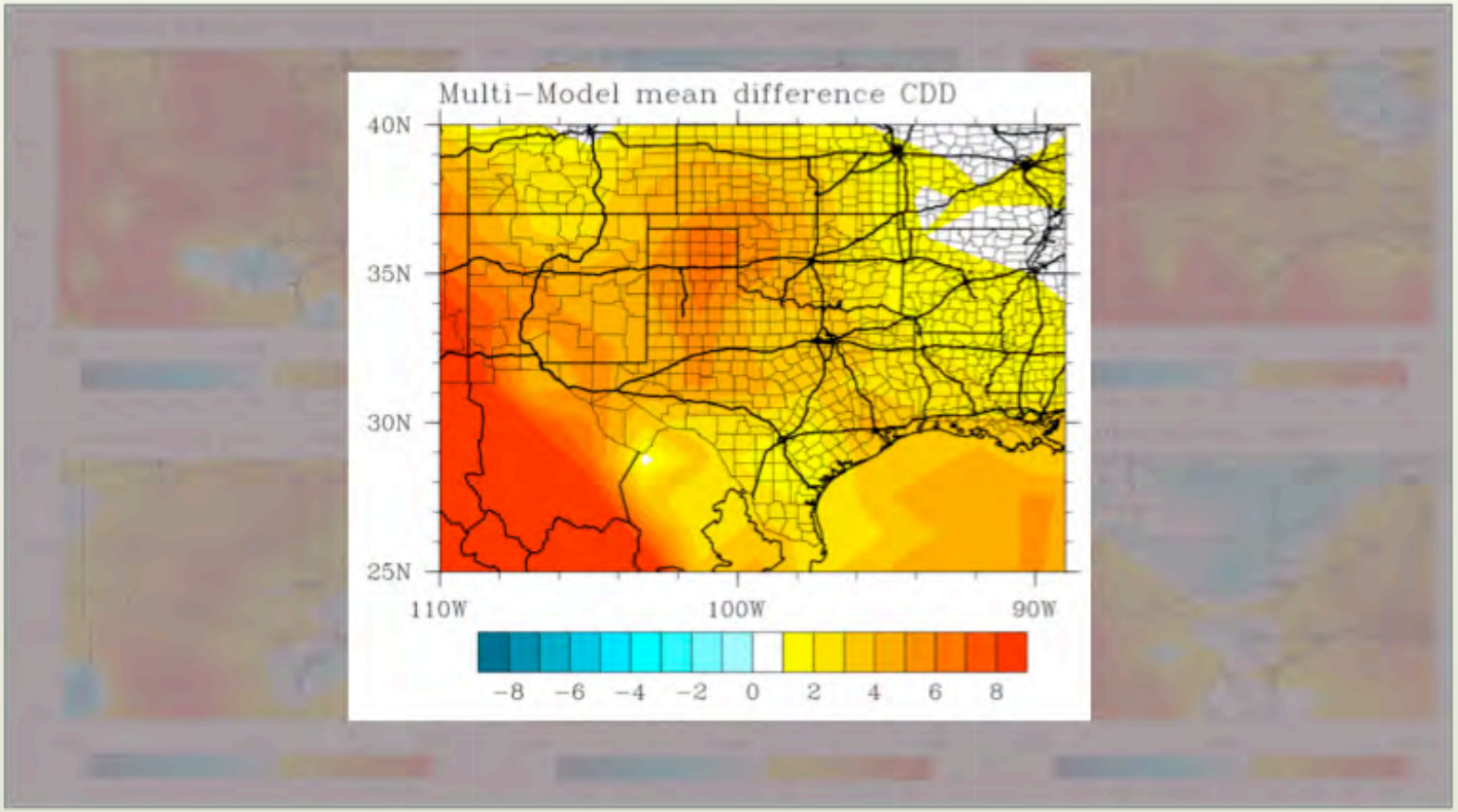
What GCMs Produce



- **RCP 8.5** – Greenhouse gas (GHG) emissions increase until forcing difference reaches 8.5 Watts per square meter
- **RCP 4.5** – radiative forcing stabilized around 2100 using a variety of technologies & strategies to reduce GHGs
- **RCP 2.6** – a "peak-and-decline" scenario where GHG emissions are reduced significantly over time

What GCMs Produce

Multi-Model Mean

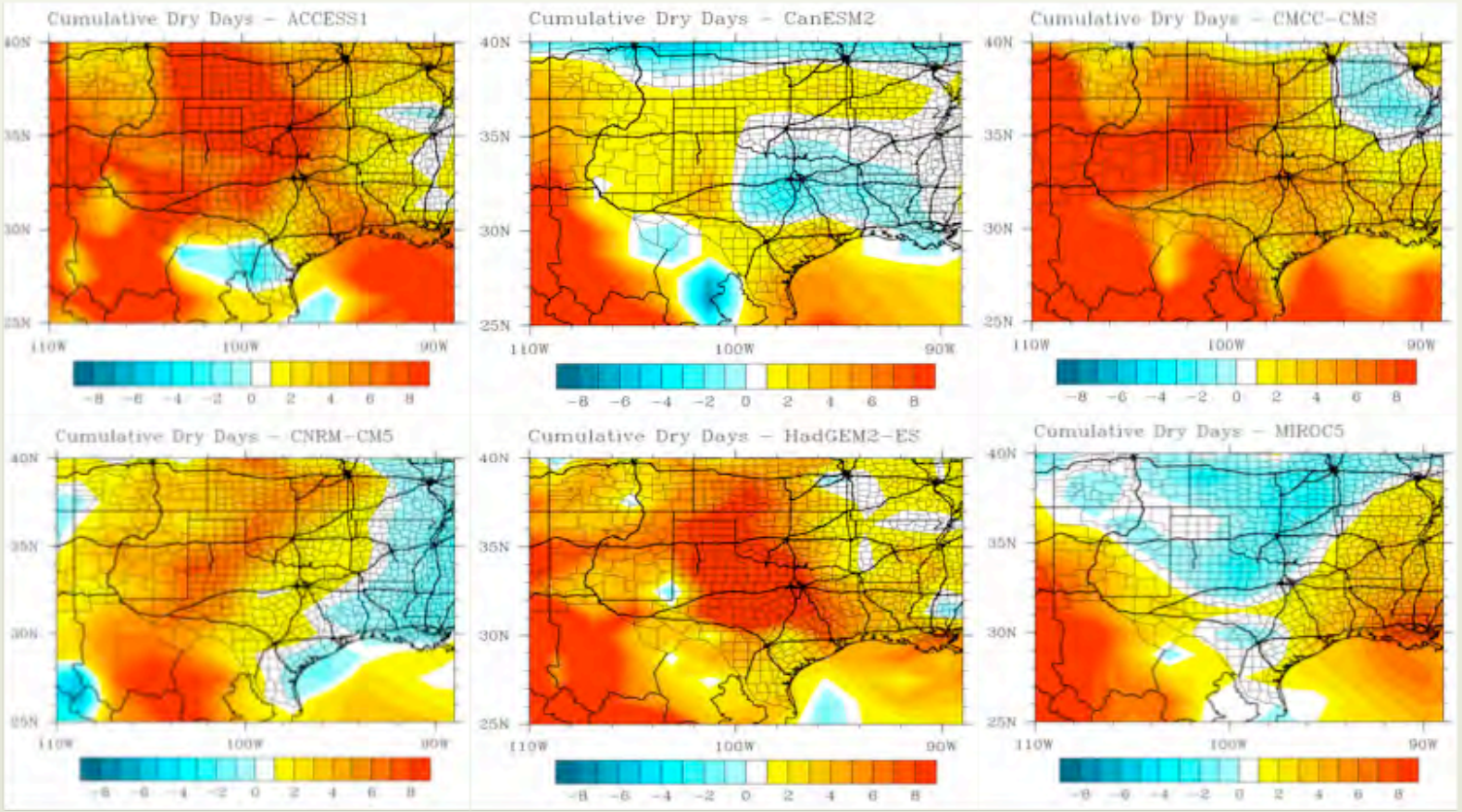


Consecutive dry days, difference 2050-70 relative to 1980-2000

CLIMDEX Climate Extremes Indices, obtained from Environment Canada

What GCMs Produce

Individual GCMs with Same Forcings

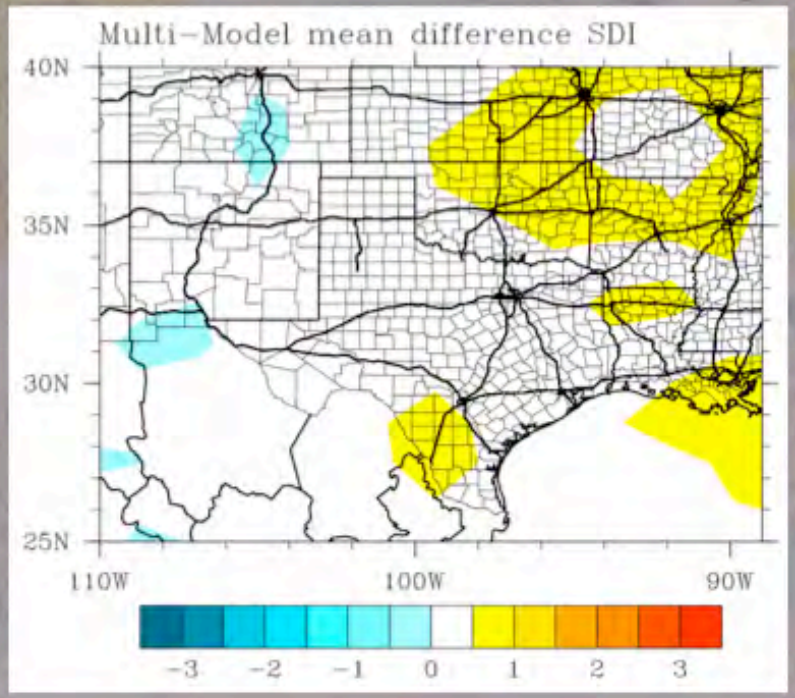


Consecutive dry days, difference 2050-70 relative to 1980-2000 (RCP8.5)

CLIMDEX Climate Extremes Indices, obtained from Environment Canada

What GCMs Produce

Multi-Model Mean

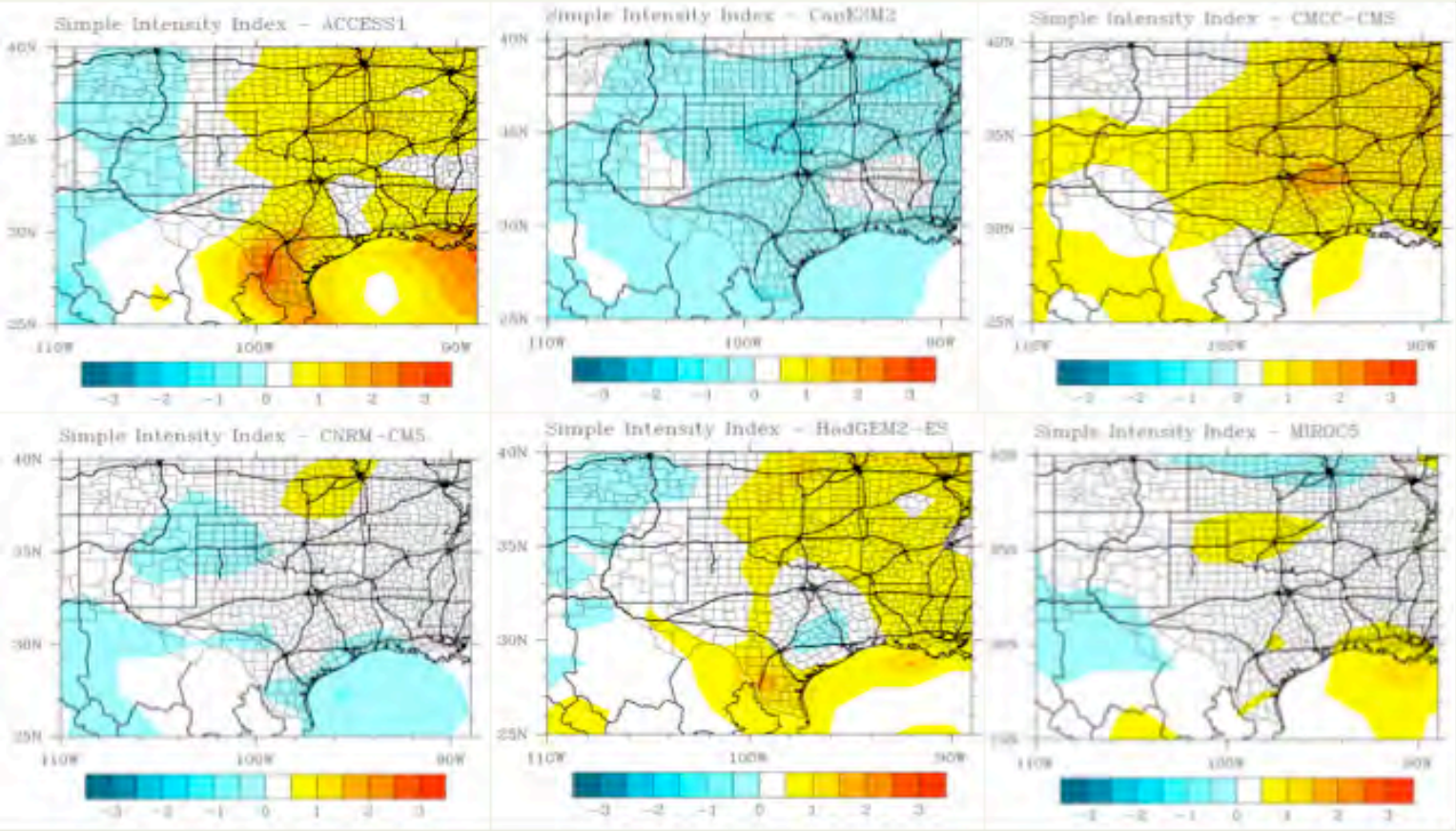


'Simple intensity index' for precipitation

CLIMDEX Climate Extremes Indices, obtained from Environment Canada

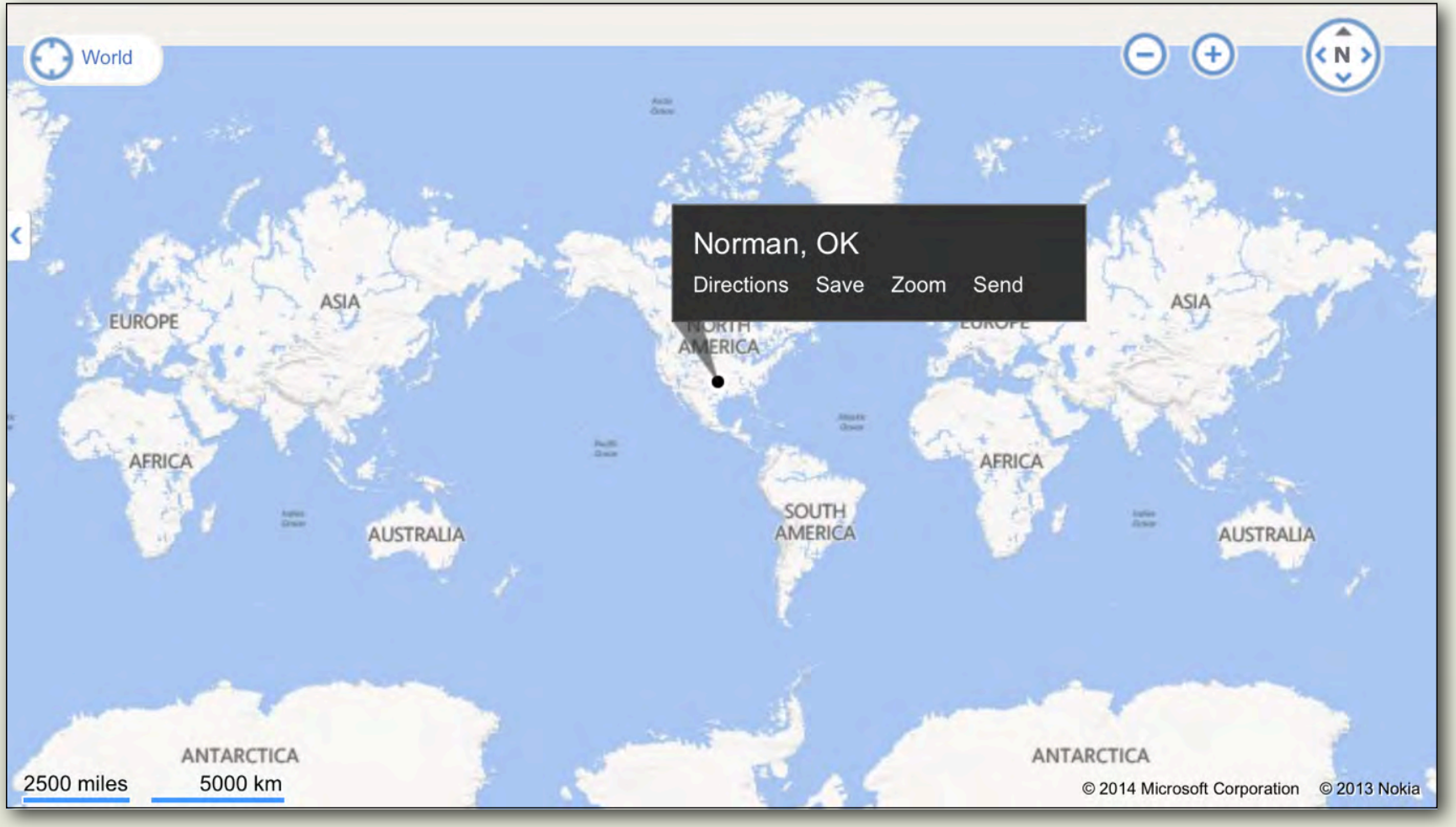
What GCMs Produce

Individual GCMs with Same Forcings



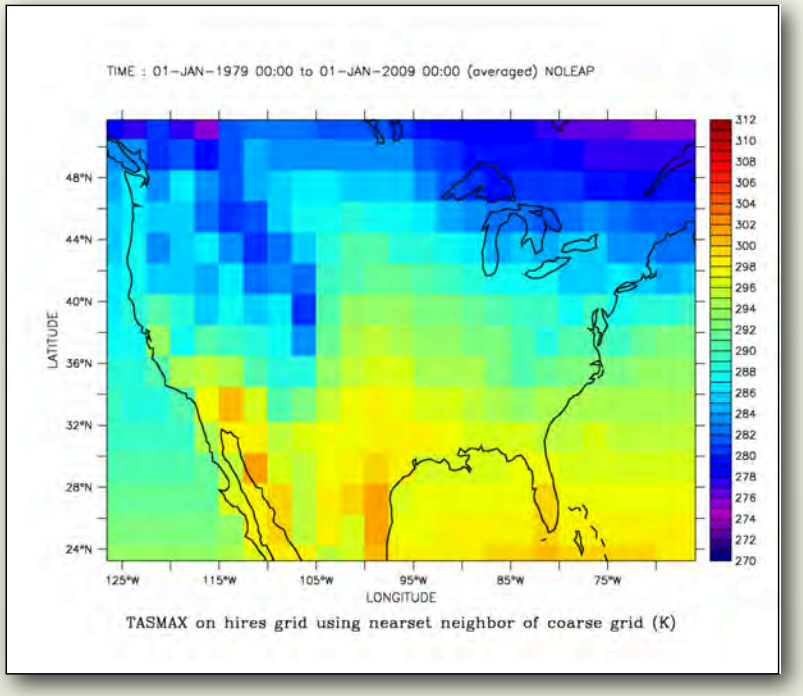
'Simple intensity index' for precipitation (2050-70 difference from 1980-2000, RCP8.5)

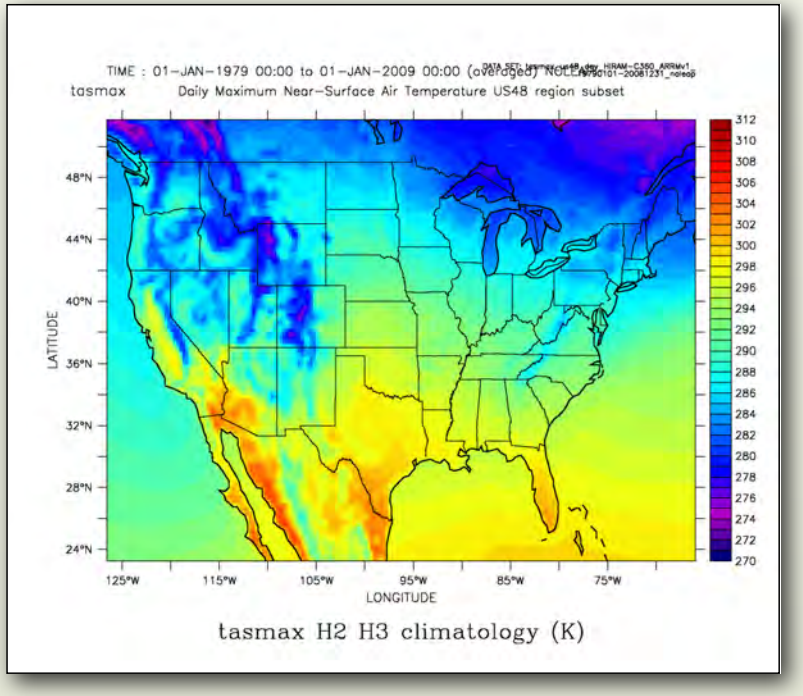
But What About Me? Downscaling to Regions



What is Downscaling?

- Method to use coarse (low) resolution output (e.g., 100-500 km grid) from global climate models and obtain fine (high) resolution datasets (e.g., 10-50 km grid) for regional to local decision making



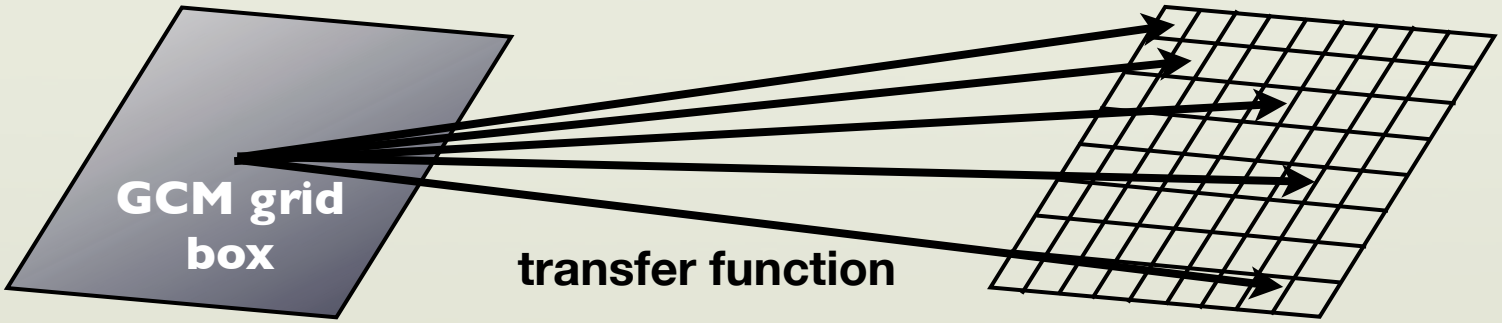


What is Downscaling?

- **Dynamical downscaling** – uses high-resolution numerical models (i.e., regional climate models) to produce high-resolution, three-dimensional fields
- **Statistical downscaling** – uses statistical relationships to relate the value of the large-scale grid box to site-specific values at the surface (two-dimensional fields); different methods include: (1) scaling/delta, (2) transfer functions, (3) weather typing, and (4) weather generators

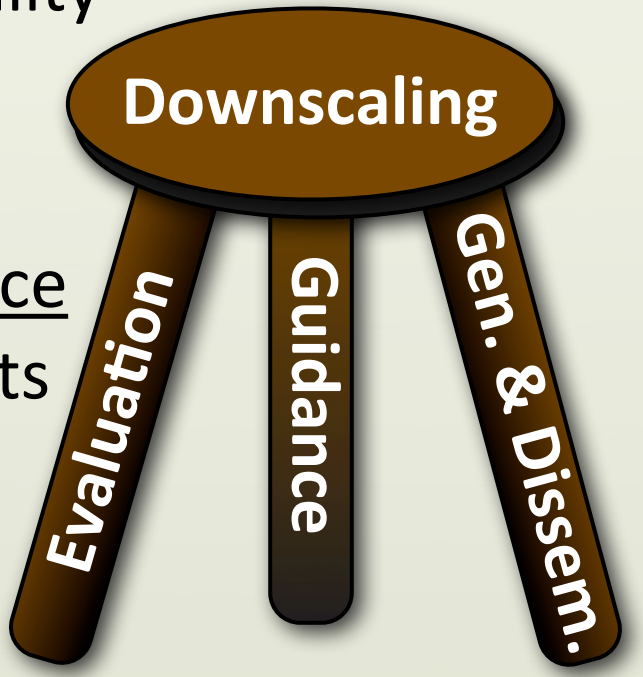
What is Downscaling?

- **Predictor** – values of a climate variable (e.g., air temperature, precipitation) at the GCM grid box
- **Predictand** – site-specific variable (e.g., max. temperature at the surface) that is predicted, usually on a daily time scale, from the predictors
- **Transfer function** – a statistical model that relates predictor to predictand using an appropriate technique & actual observations for calibration & validation

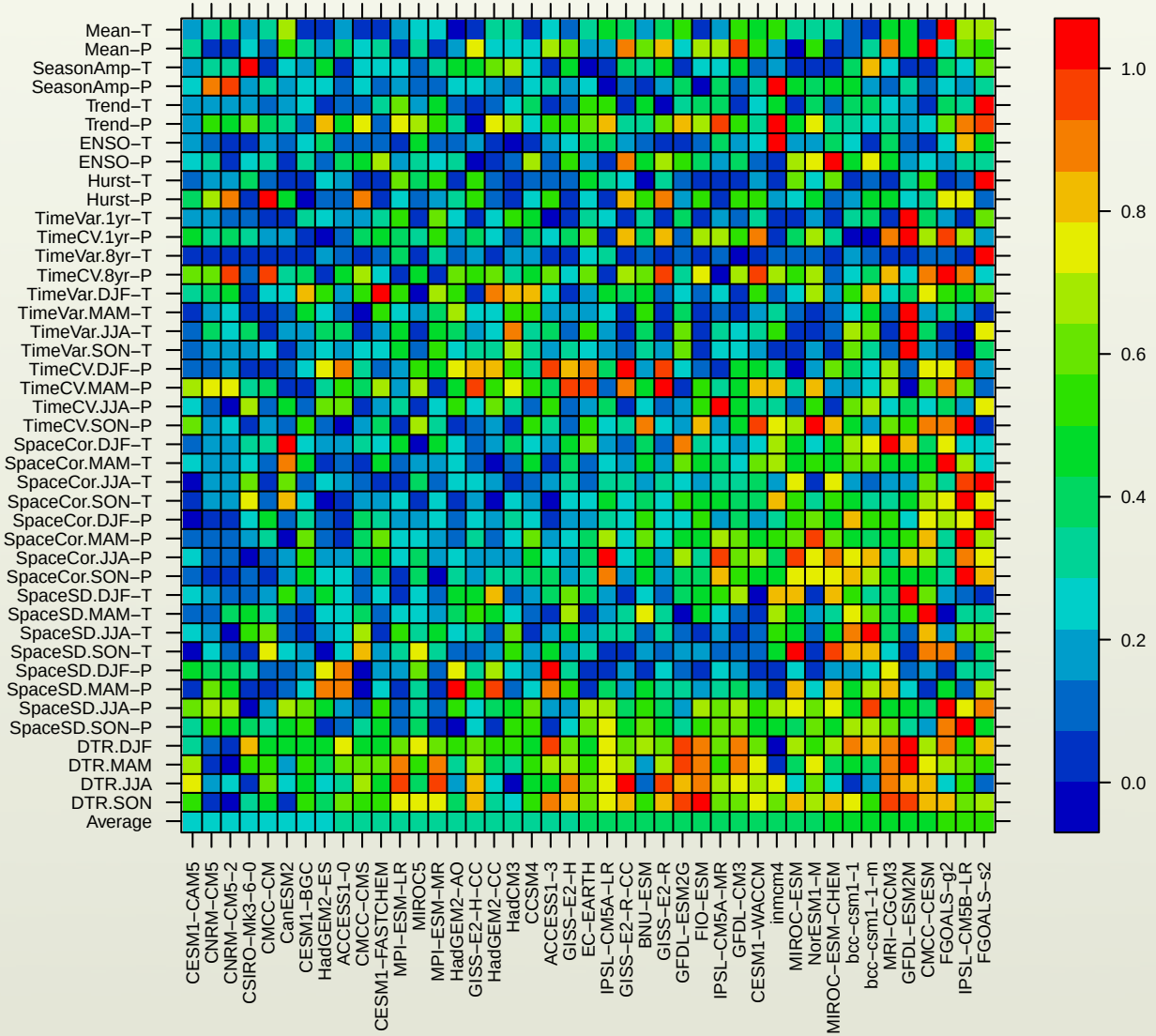


How "Good" Are Downscaled Data?

- Needs a robust & quantitative evaluation of the strengths & limitations of both global climate models and downscaling methods
- Generation & dissemination of high quality downscaled datasets for use within the greater climate science community
- Developing & communication of guidance on the suitability of downscaled products for different classes of applications



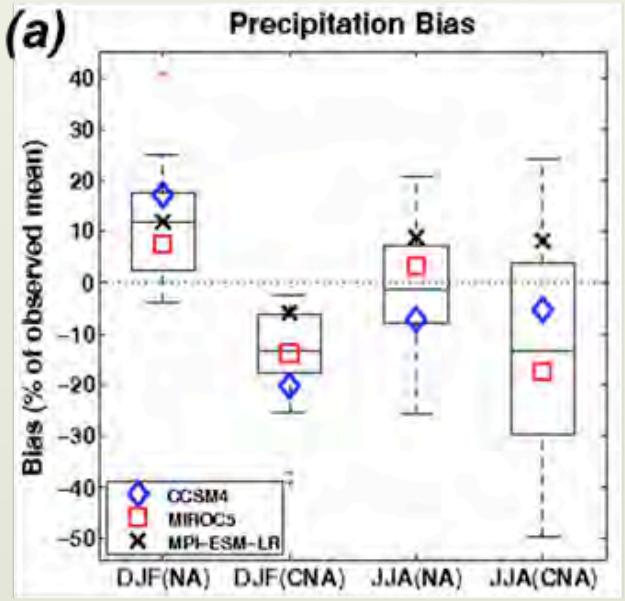
GCM Evaluation

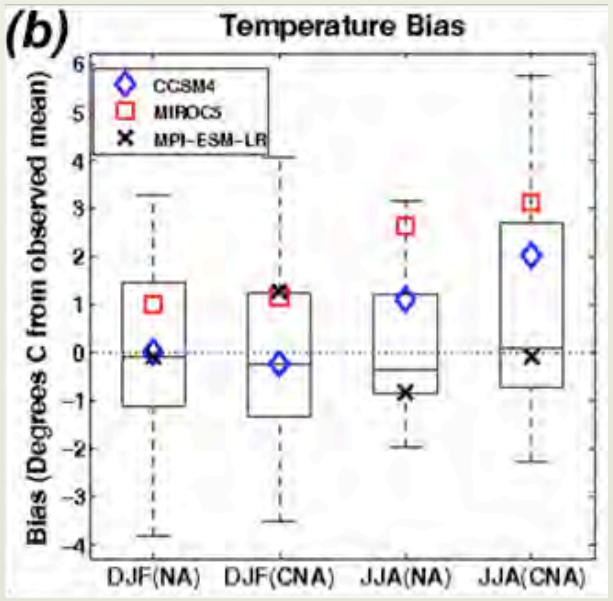


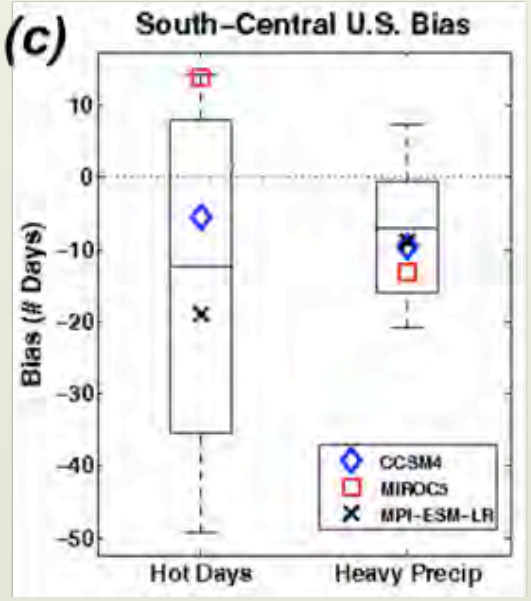
Derek Rosendahl

GCM Evaluation

Model		Resolution	Scenarios
CCSM4	U.S. National Center for Atmospheric Research (NCAR) Community Climate System Model, version 4	0.90° x 1.25°	hist, RCP 2.6, RCP 4.5, RCP 8.5
MIROC5	Japanese Model for Interdisciplinary Research on Climate, version 5	1.41° × 1.41°	hist, RCP 2.6, RCP 4.5, RCP 8.5
MPI-ESM-LR	Max Planck Institute Earth System Model, low resolution	1.80° x 1.80°	hist, RCP 2.6, RCP 4.5, RCP 8.5







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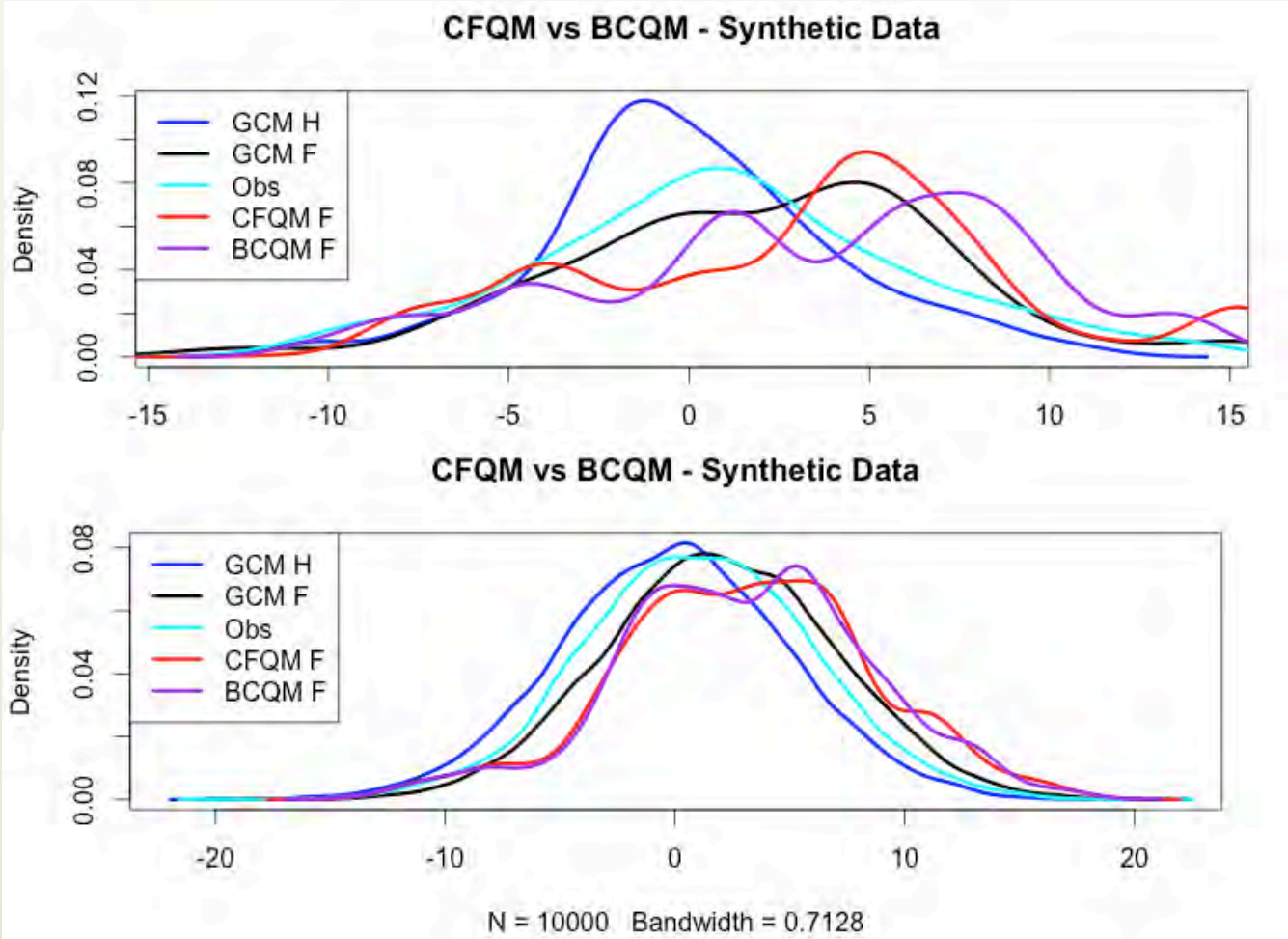
Downscaling Evaluation

- **Variables** – daily maximum and minimum surface temperature, and daily precipitation
- **Period** – historical (1961-2005) & future (2010-2039, 2040-2069, and 2070-2099)
- **Validation** – Livneh et al., 2013 (from Climate Downscaling Group), based on methods of Maurer et al. (2002)

Quantile Mapping Method		GCM Forcing	Scenarios
CDFt	Cumulative Density Function Transform; Vrac and Michelangeli (2009)	CCSM4, MIROC5, MPI-ESM-LR	hist, RCP 2.6, RCP 4.5, RCP 8.5
EDQM	Equi-Distant Quantile Mapping Li et al. (2010)	CCSM4, MIROC5, MPI-ESM-LR	hist, RCP 2.6, RCP 4.5, RCP 8.5
BCQM	Bias Correction Quantile Mapping Ho et al. (2012) – **deemed inappropriate to use**	CCSM4, MIROC5, MPI-ESM-LR	hist, RCP 2.6, RCP 4.5, RCP 8.5

Downscaling Evaluation



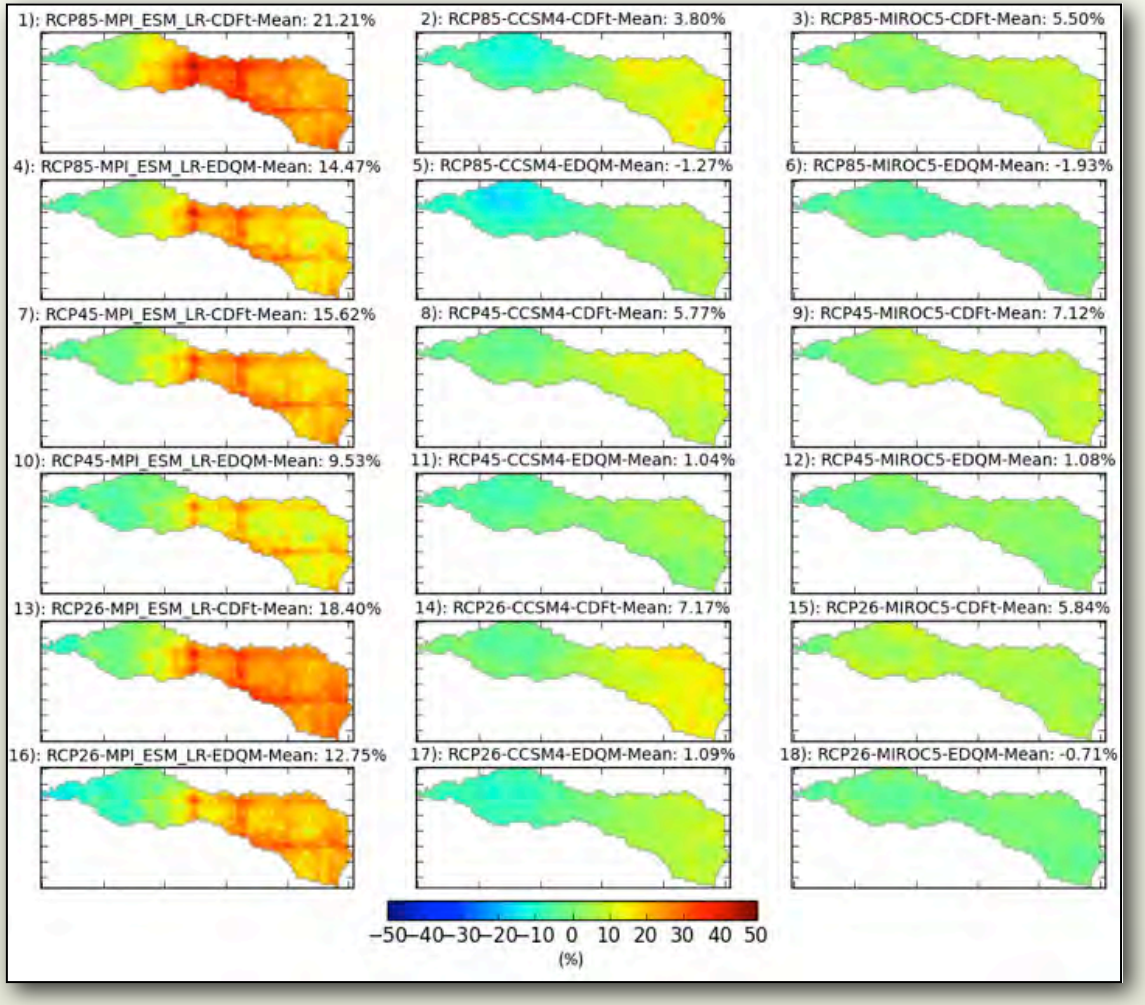
John Lanzante

Example Downscaling Results

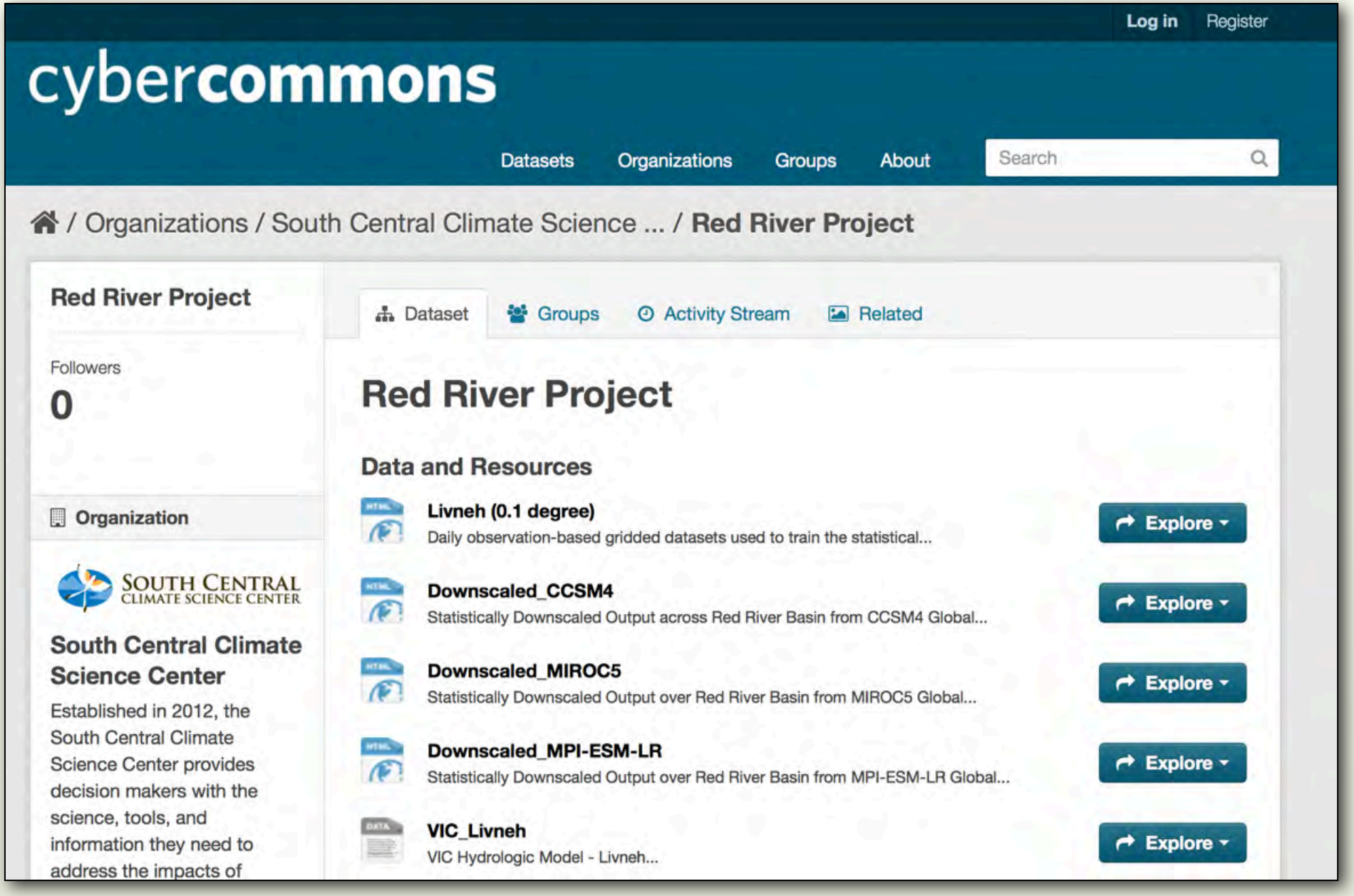
- Experimental evaluation design conducted for all reaches of the Red River Basin, in partnership with Chickasaw Nation (lead) and Aqua Strategies, Inc.

Example Downscaling Results

Precipitation Change for End of Century vs. 1976–2005



Carlos Gaitán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Explore
Downscaled_MIROC5
Statistically Downscaled Output over Red River Basin from MIROC5 Global...
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Downscaled_MPI-ESM-LR
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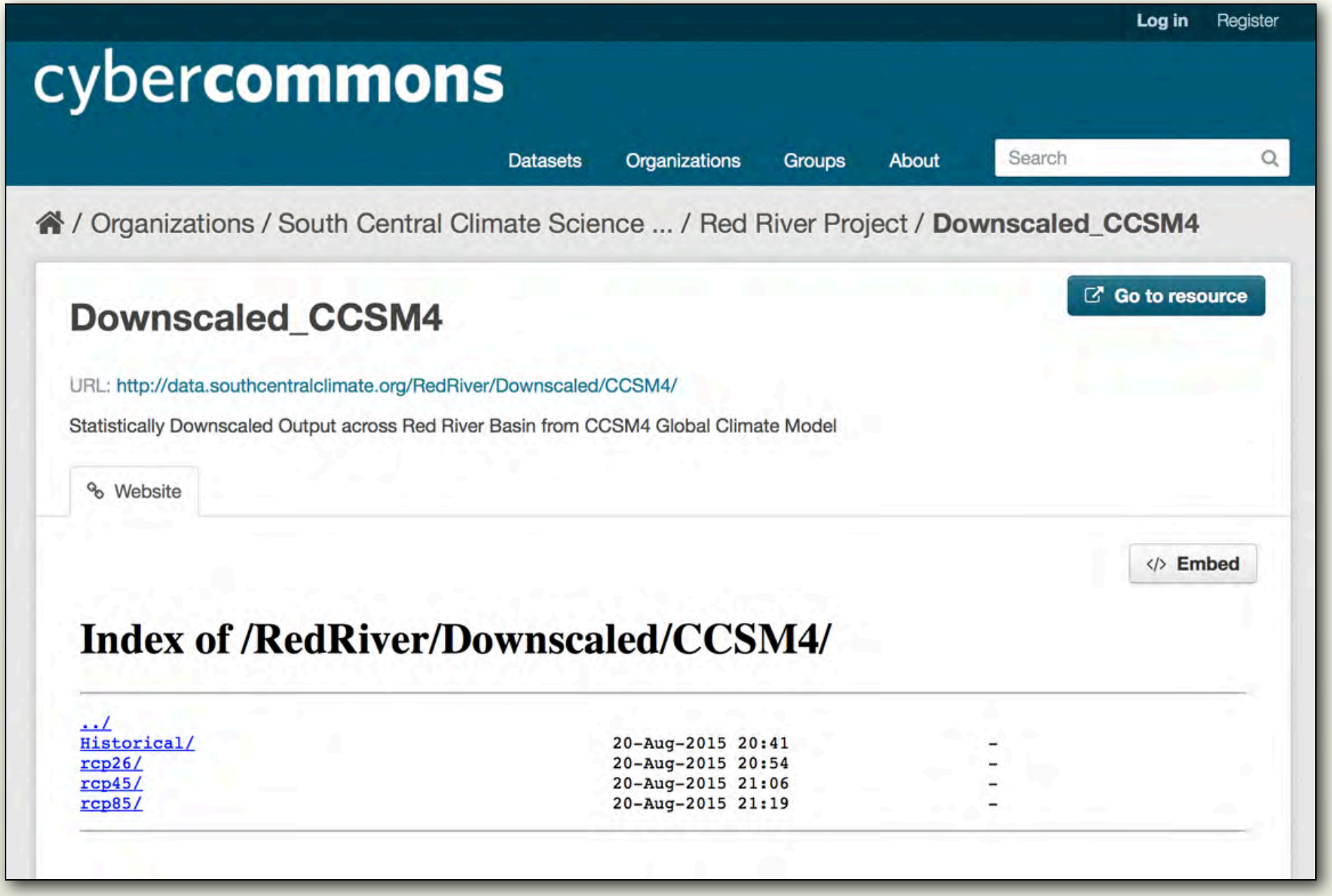
Explore
VIC_Livneh
VIC Hydrologic Model - Livneh...
Explore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Statistically Downscaled Output across Red River Basin from CCSM4 Global Climate Model
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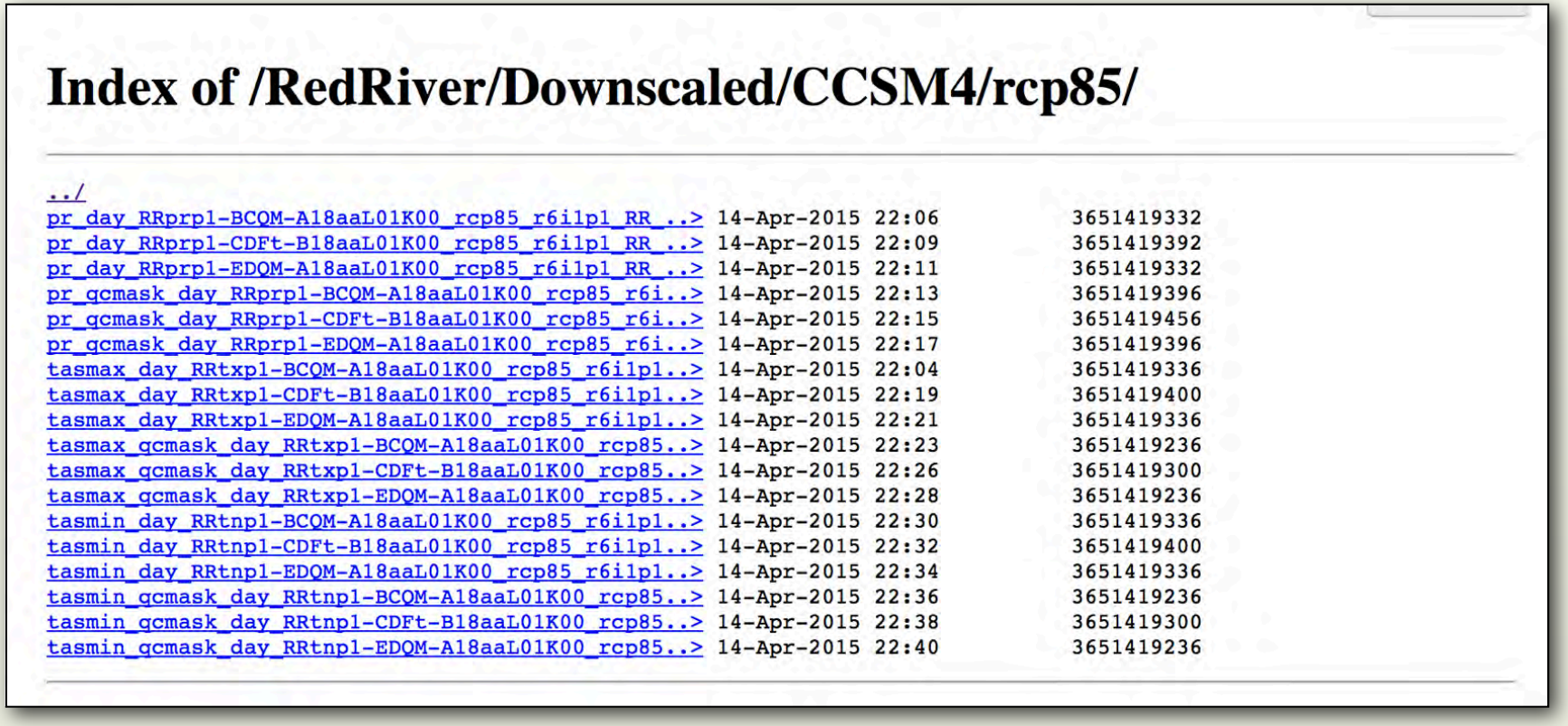
rcp45/ 20-Aug-2015 21:06 -
rcp85/ 20-Aug-2015 21:19 -

Getting the Data



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Questions?

This material is based on work supported by the U.S. Geological Survey under Grant Nos. G12AC00002 & G13AC00386 and by the National Science Foundation under Grant No. IIA-1301789.

Dr. Renee A. McPherson

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