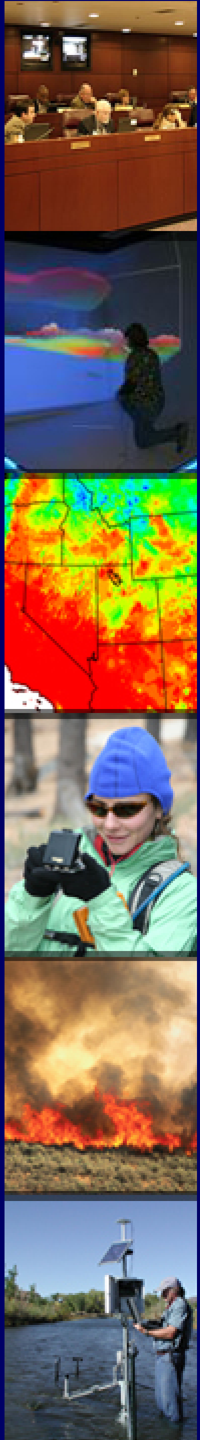


Nevada Infrastructure for Climate Change Science, Education, and Outreach

Component: Climate Modeling

Lead: Darko Koracin, DRI

Steering Committee Members:

Scott Bassett, UNR; Zhongbo Yu, UNLV

Postdoctoral Associate:

John Mejia

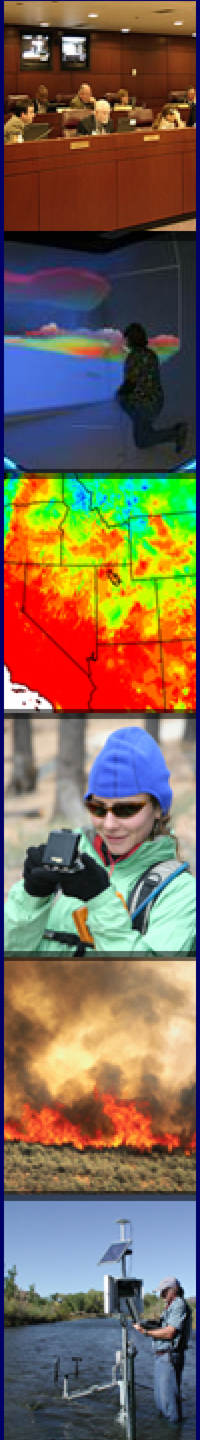
Graduate student:

Benjamin Hatchett, DRI

Computer support:

Travis McCord, Ramesh Vellore, Paul Neeley DRI

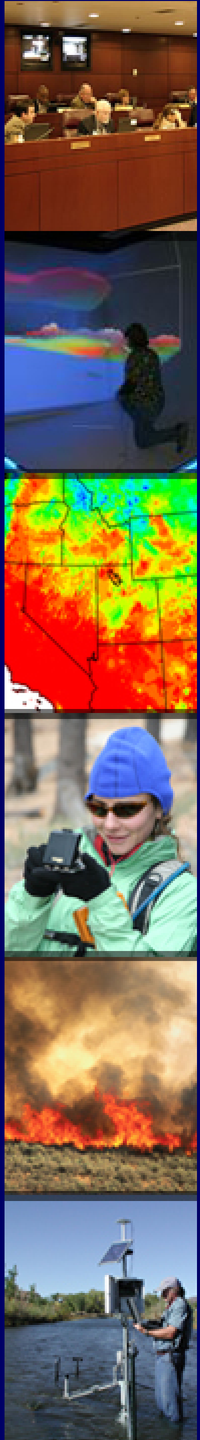
3 February 2010, Las Vegas, NV



Research Goals

- Predict accurate climate trends in Nevada
- Provide inputs to hydrological models and assess future hydrological resources, their variability and uncertainty, and socio-economic impacts
- Test and improve parameterization of land-atmosphere interactions
- Investigate aerosol contribution to climate
- Study feedback interactions among atmosphere, hydrology, and ecological processes
- Link physical and economic models
- Assess impact of climate change on air quality and urbanization
- Provide an integrated GIS system (Geoinformatics) for water, energy, and economic parameters
- Collaborate with partner EPSCoR states: Exchange of information, modeling applications, and workforce development

Overview - Infrastructure



- DRI - Infrastructure
  - Personnel
    - John Mejia – Postdoctoral Associate (Oct 2009)
    --- *Regional climate modeling and dynamical downscaling*

    - Benjamin Hatchett – M.S. graduate student (Jan 2009)
    --- *Statistical regional downscaling*

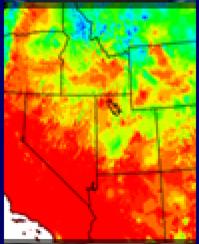
    - Linlin Pan – Postdoctoral Associate (came in Nov 2009 and left in Dec 2009)

    - Eric Wilcox – Climate Modeler – faculty position – offer submitted
    --- Global observational networks and global and regional climate modeling

  - Computer system
    - SUN Fire system (8 chassis; ten blades with 16 GB of memory and 146 GB disk; total of 640 processors)
    - Data storage of 140 TB
    - Rocks (5.2.2) Cluster Management

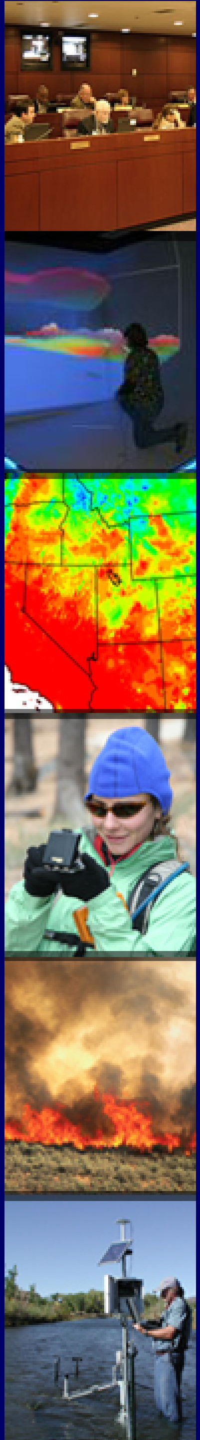
- Scott Bassett – UNR
- Zhongbo Yu - UNLV



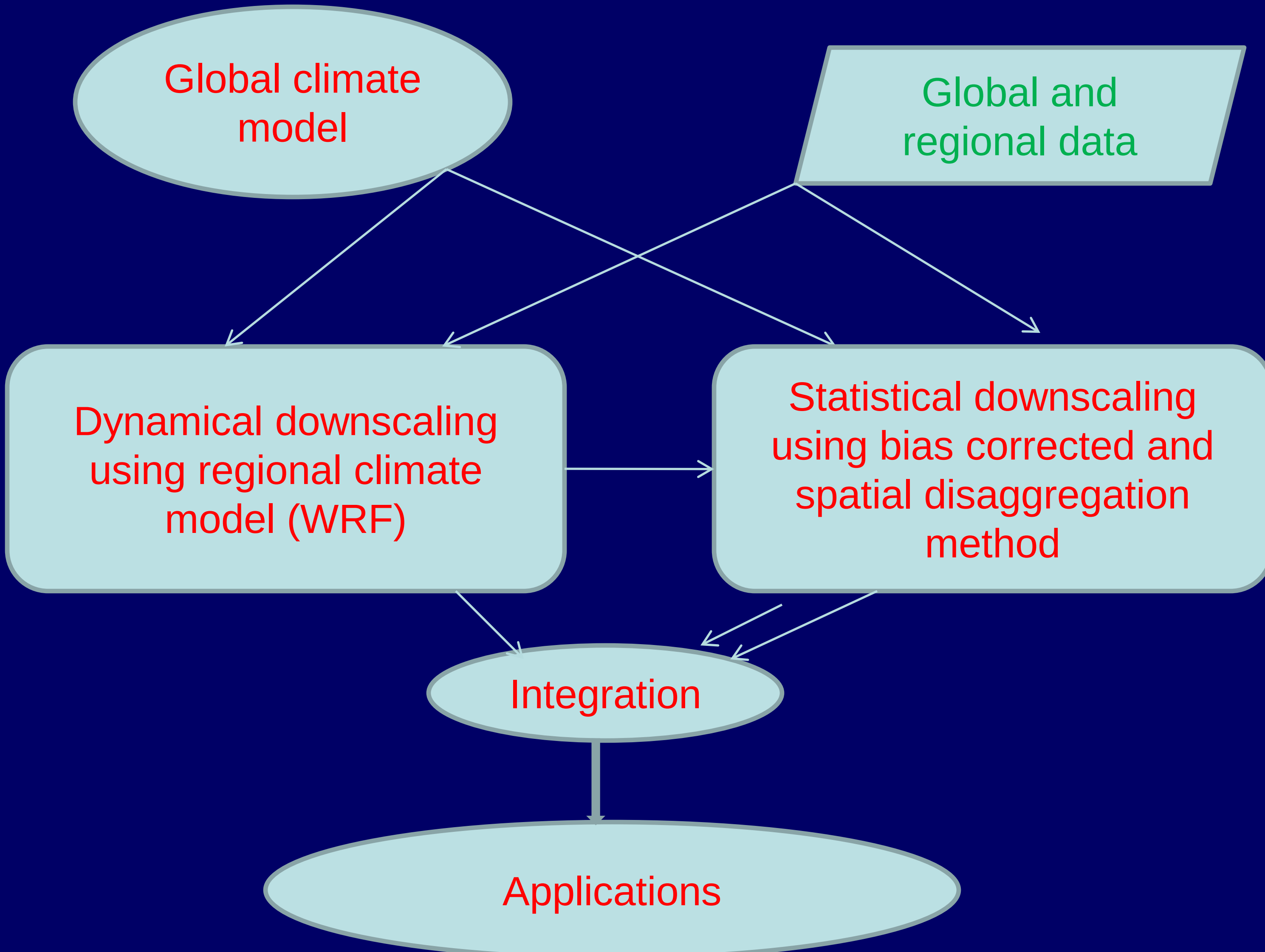



Links with other components

- Cyberinfrastructure
  - Link to data portal and processing software
- Landscape change (land-atmosphere interactions)
  - Paleoclimate modeling
  - Climate modeling
- Water Resources
  - Climate predictions of water resources, their variability, uncertainties, and socio-economic impacts
- Policy
  - *Alternative Future* scenarios (urbanization); socio-economic aspects of future water supply
- Education – Graduate students, post doctoral fellows



Climate modeling

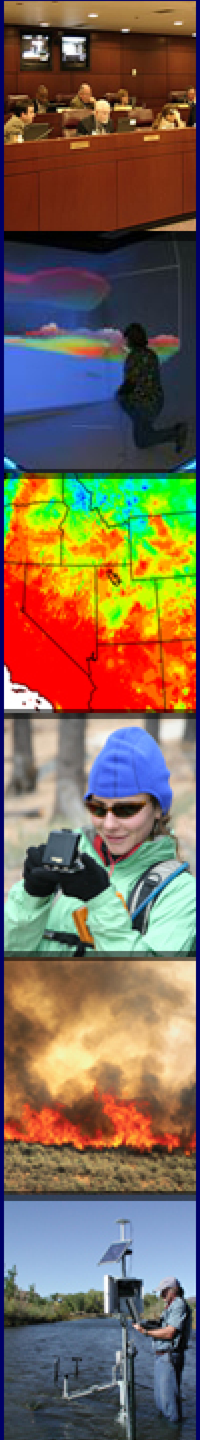


and Outreach

Why Study Climate Change in the Great Basin?

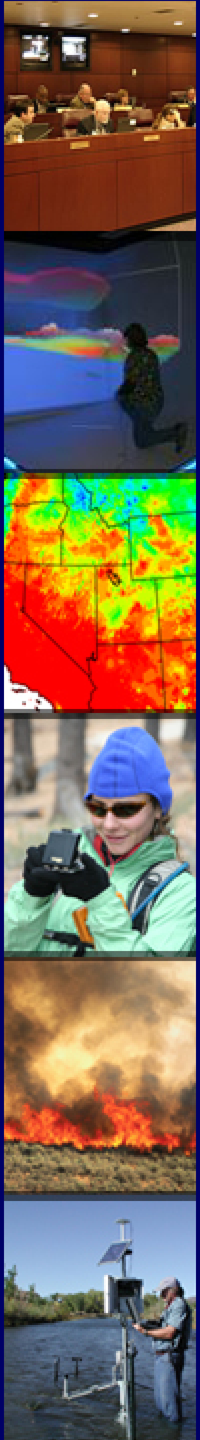
- Great Basin identified as highly sensitive to climate variability
    - Links of climate to regional hydrology (e.g. pluvial lakes)
    - Contemporary water resource planning for urban, agricultural, and industrial use in arid environment
- Excellent record of paleoclimate to help understand/link past with future
- Unique flora and fauna biogeography with changes via ecotonal (transition zones) shifts, invasive species, and fire.

Pluvial lakes in Great Basin (6).



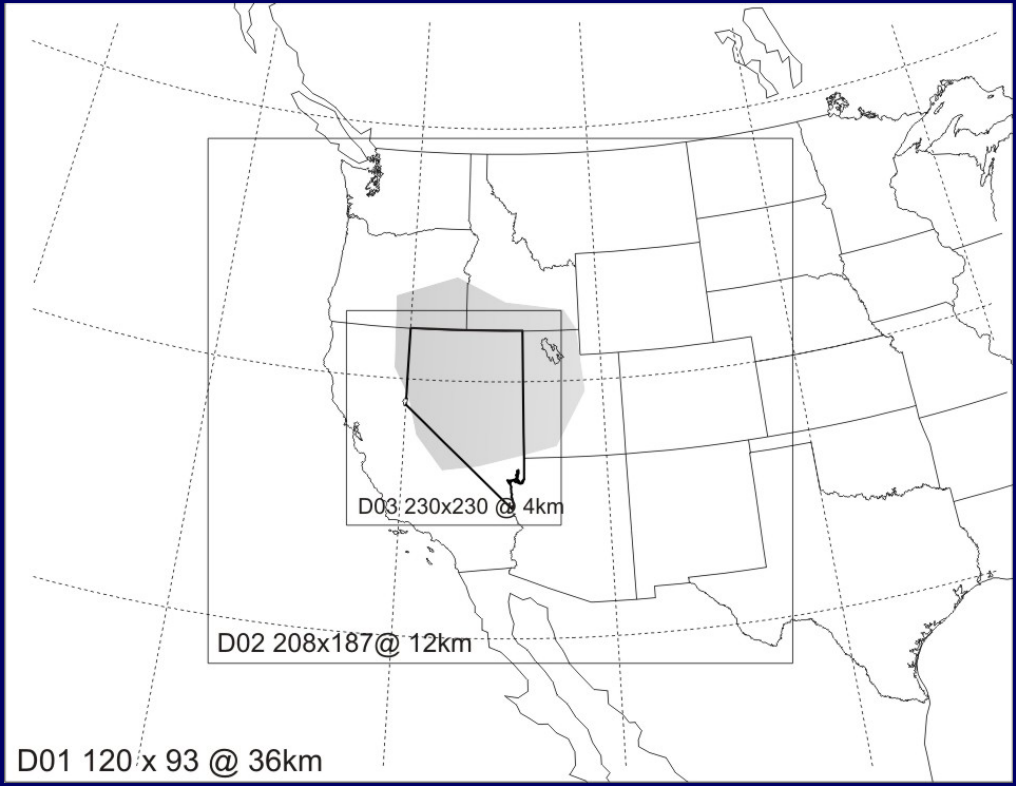
Regional climate modeling
Dynamical downscaling

- Use global climate models with horizontal resolution of 100-200 km to drive regional climate models with resolution of 50 km or better.
- Global climate models provide initial and boundary conditions.
- Regional climate models can have multiple inner-nested domains with increasing horizontal resolutions.



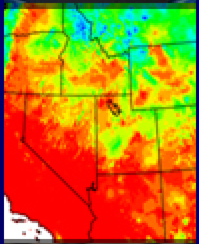
Regional Climate Modeling
Dynamical Downscaling – our study

- This task aims to implement and develop transportable methodologies to improve the applicability of GCMs in climate impact, hydrological, and environmental research.
- Focused on Nevada, but also on a broader region:



RCM-WRF domains (test version) for dynamical downscaling over the SW North America (at 36 km grid size), the Great Basin (at 12km grid size) and Nevada (at 4km grid size). Gray shadings represent approximate location of the Great Basin region.






Dynamical downscaling: Regional climate modeling using Weather and Research Forecasting (WRF) model

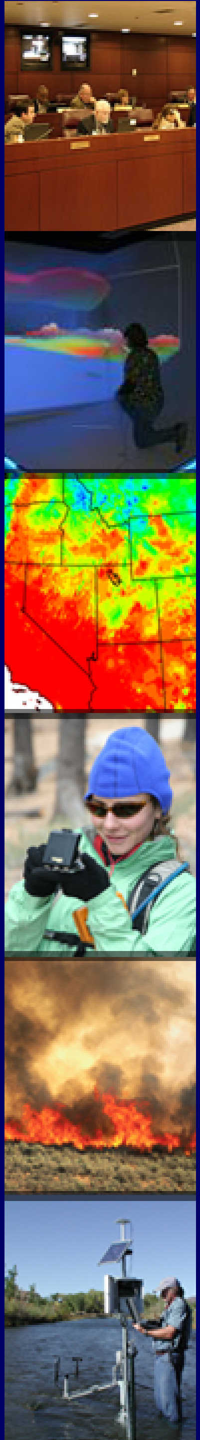
- PLAN:

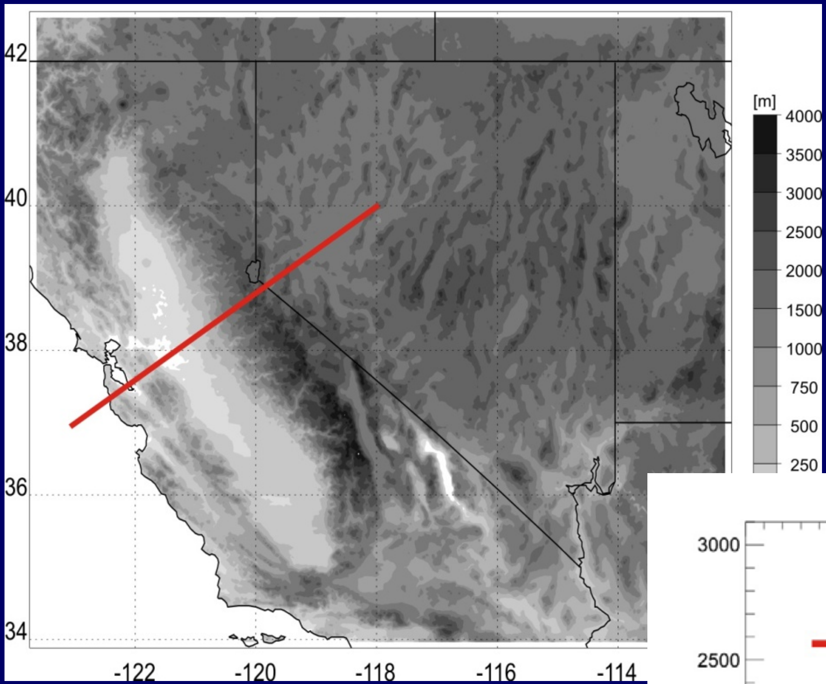
Scenario	1970s	1980s	1990s	2000s	2010s	2020s	2030s	2040s	2050s	2060s	2070s	2080s	2090s
NCEP	■	■	■	■									
CCSM-A1B	■	■	■	■	■			■	■			■	■
CCSM-A2				■	■			■	■			■	■
CCSM-B2				■	■			■	■			■	■

Schematic of the integration periods (shaded boxes) for different scenarios for the RCM downscaling approach. All simulations total 250 years.

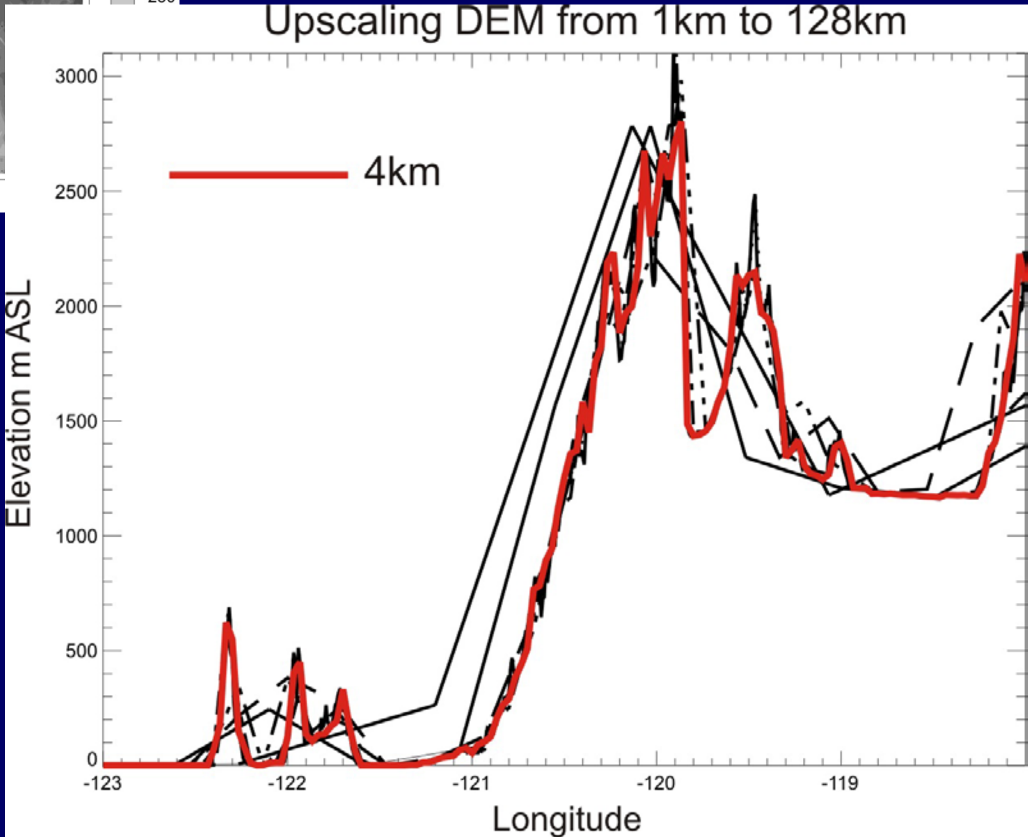
- Bulk of the computation would take about 6 months cpu time
- Hourly and 3 hourly RCM output data.
- Some data archiving issues: Available storage space 150T but need about 300TB.

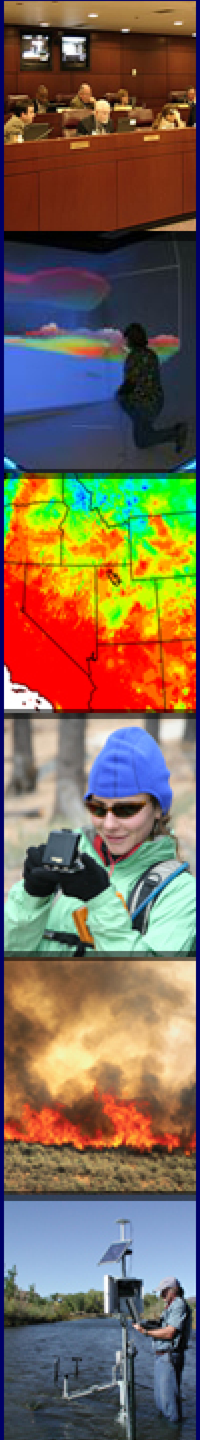
Surface boundary improvement





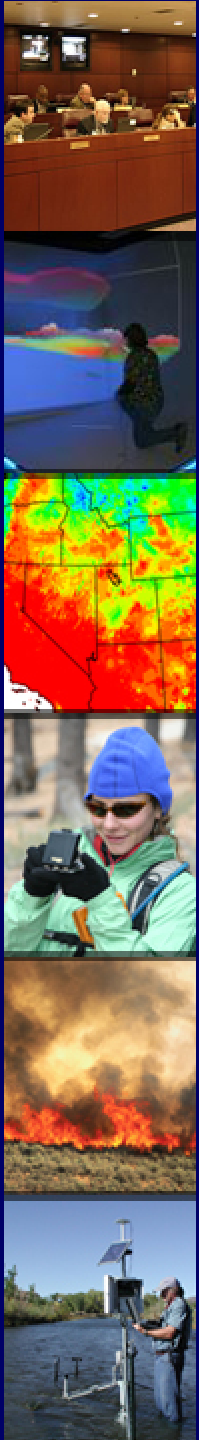
Our inner domain uses 4km resolution....
Is that enough?
Also....Vegetation type, Albedo, Soil type...





Dynamical downscaling: Regional climate modeling using Weather and Research Forecasting (WRF) model

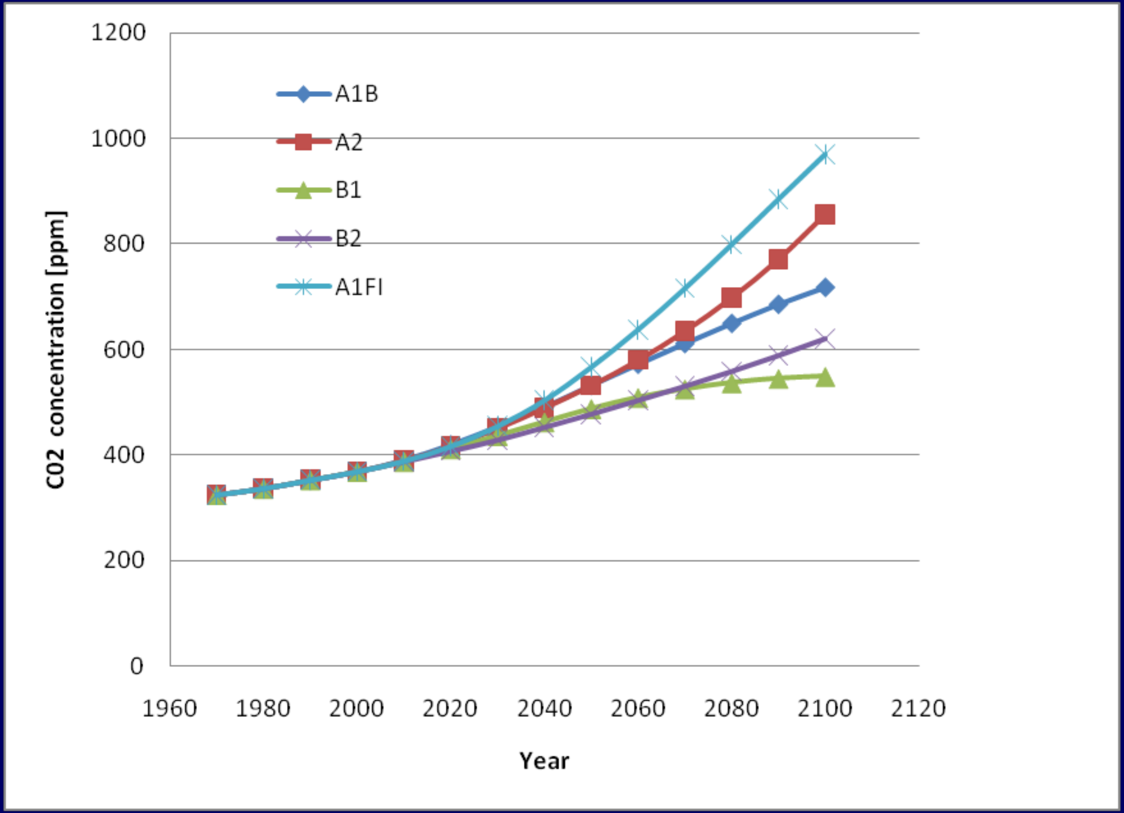
- Forcing data: Initial efforts using CCSM3 (soon V.4) and NCEP/NCAR global reanalysis products (NNRP).
- SST Updates.
- Integration mode: Spectral nudging (k=3) over D01 with relatively weak nudging factors. Only layers above the PBL are nudged.
- Convection: Kain-Fritsch for D01 and D02.
- Microphysics : single-moment 5-class.
- PBL: YSU
- LSM: a modified 4-layer NOAH-distributed (NCAR; Gochis and Chen 2009); water routing routine for surface and underground runoff.
- Radiation (SW and LW): RRTMG and CAM with GHG and aerosols updates.



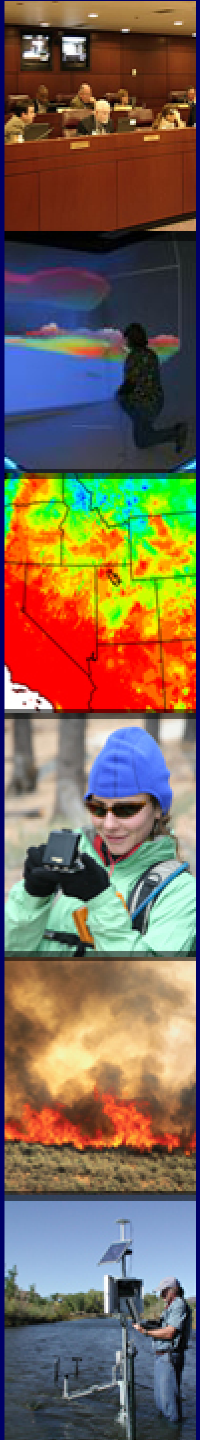
Considered GHC and aerosol emission scenarios

- Selected scenarios for our project:

  B1, A1B and A2 (‘low’, ‘medium’, and ‘high’ scenario, respectively).

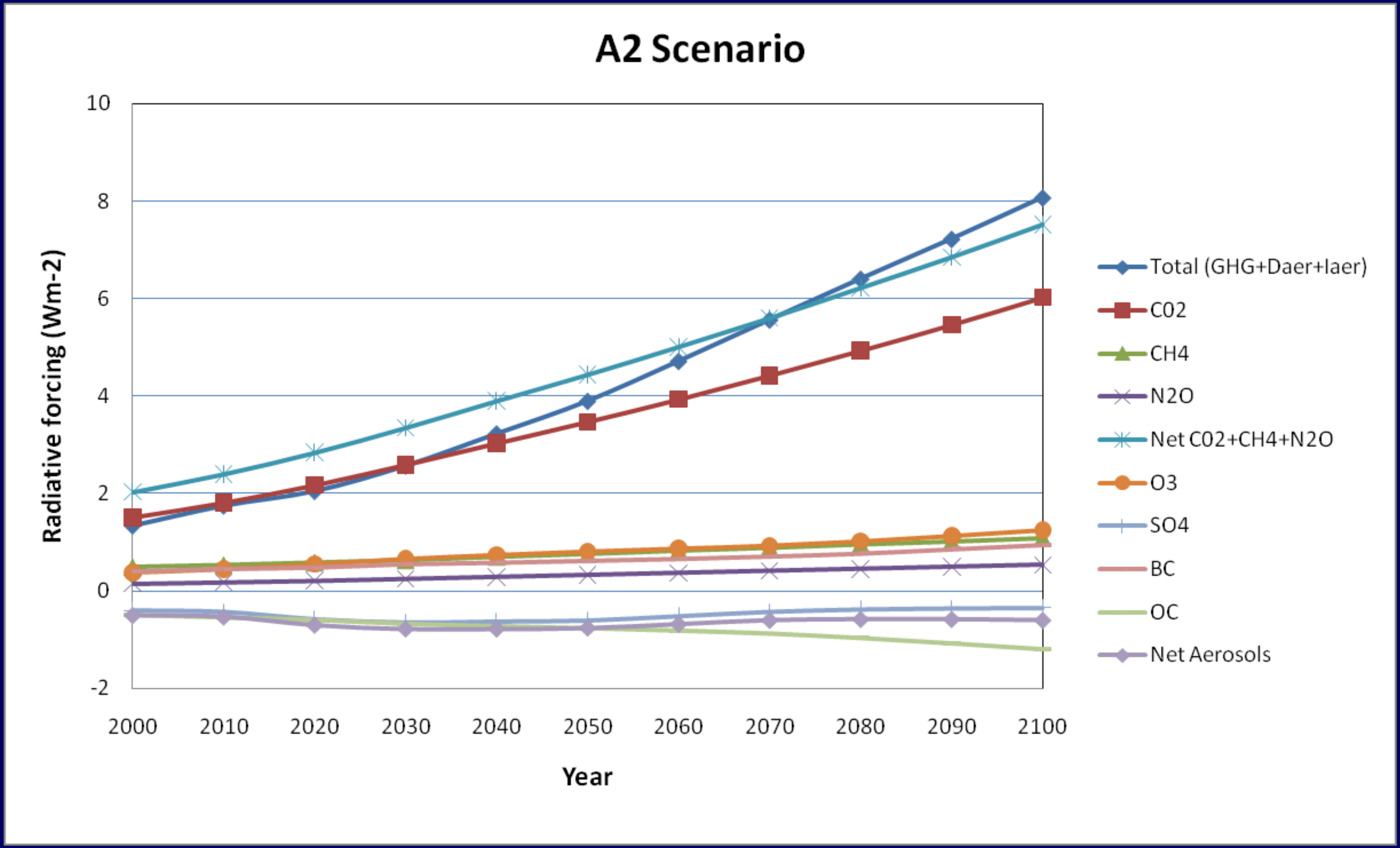


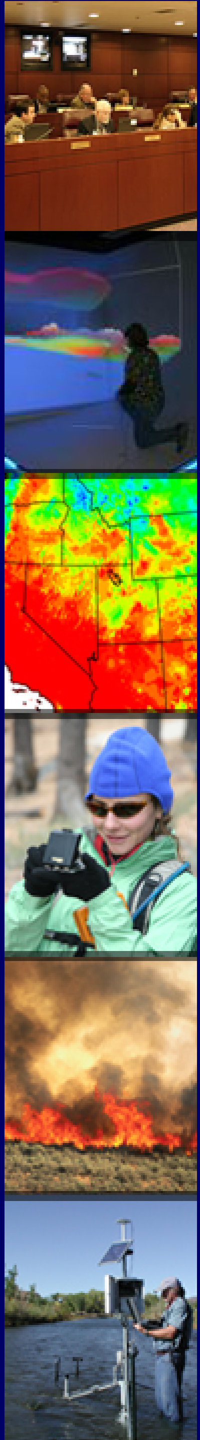
CO2 emissions for different socio-economical and environmental scenarios (IPCC-2007 report: http://www.ipcc-data.org/)



Adaptation of WRF for long-term integration mode

- e.g. Radiative forcings, emissivity, land use, vegetation type…



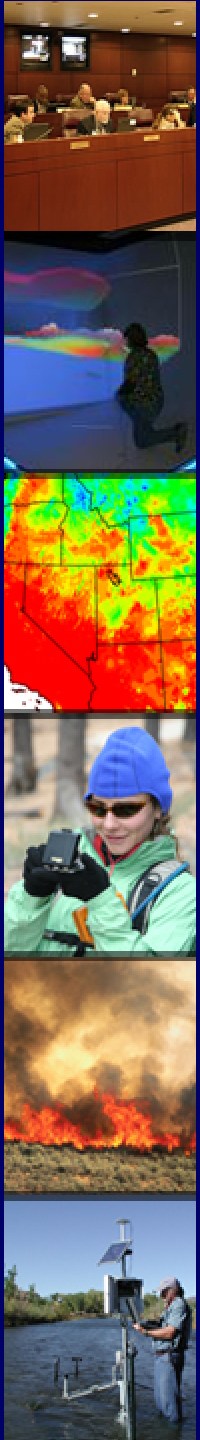


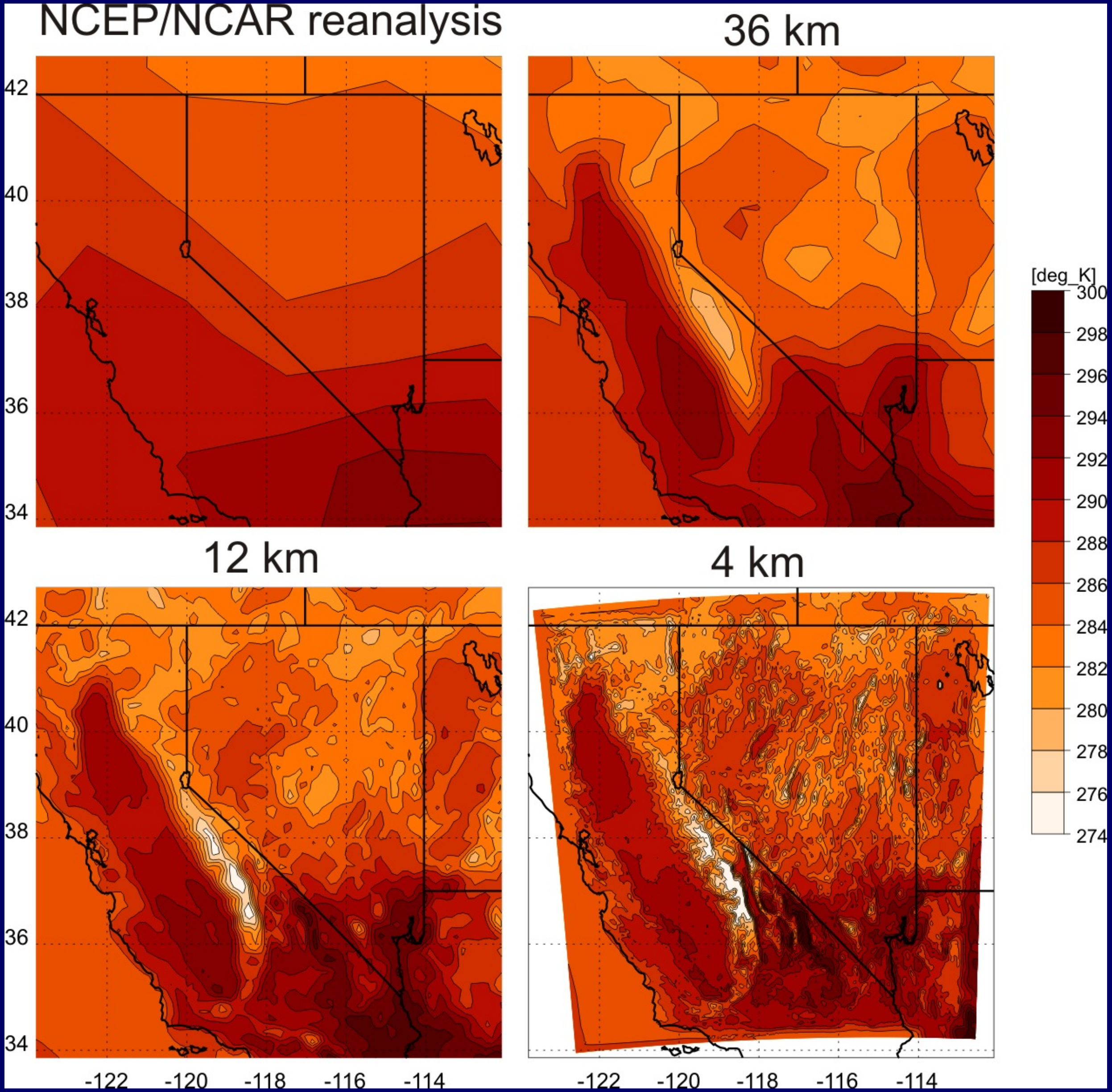
As we speak…

		Year 1				Year 2				Year 3				Year 4				Year 5			
NCEP/NCAR-WRF		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Years	Spinup May 1 to Aug 31																				
70-75																					
75-80																					
80-85																					
85-90																					
90-95																					
95-00																					
00-05																					
2005-2008																					
Total Processors	512																				
Estimated time	45 days																				

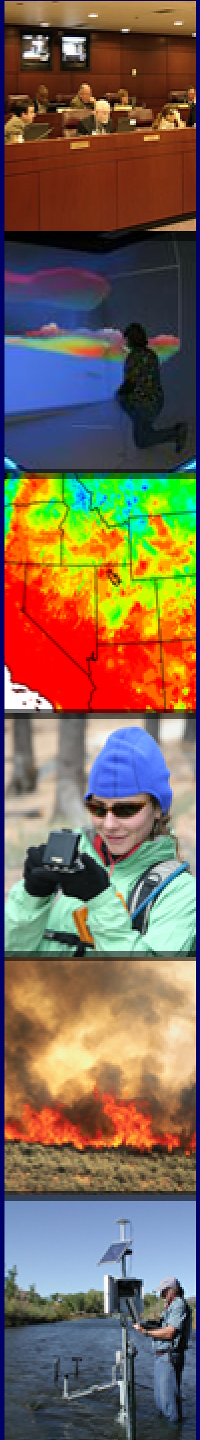
Fall-Winter ,
1970

Downscaling Sfc Temperatures

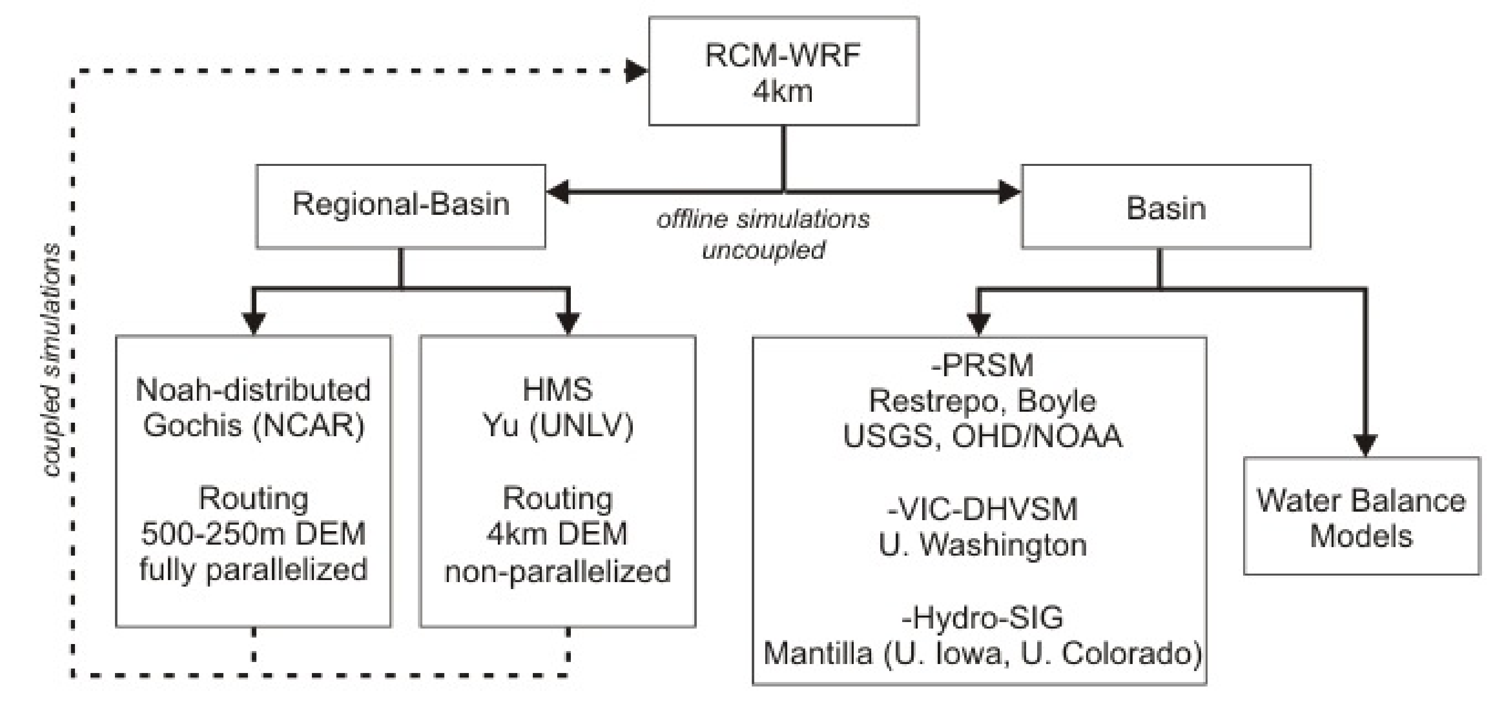




Fall-Winter ,
1970

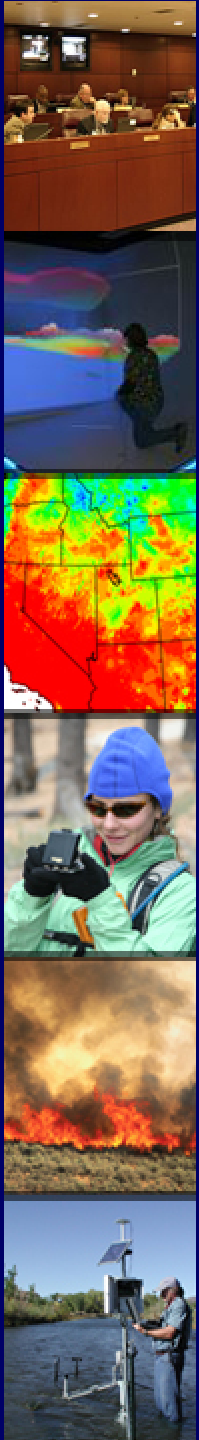


Linkages with Other Components: Hydrological applications



Links with different hydrological modeling teams.

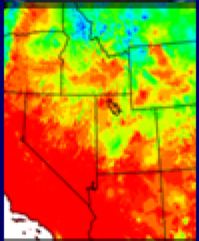
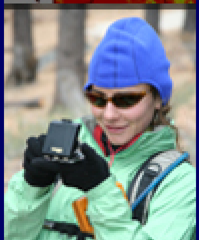
Foster a more formal and dynamical collaboration between different hydrological groups and our Climate Modeling activities
John Mejia – Hydroclimatology focus.



Output Variables

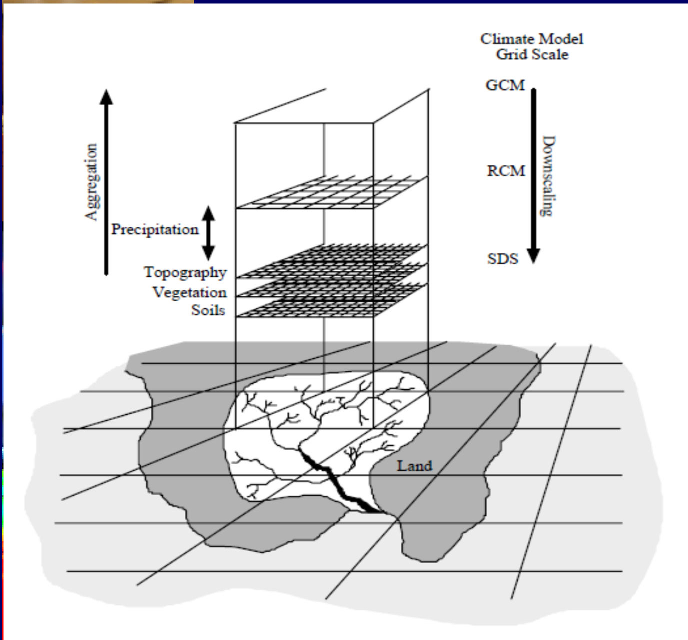
3D fields (3 hourly)	**3D fields (hourly)**
U: x-wind component	TSLB: Soil Temperature
V: y-wind component	SMOIS: Soil Moisture
W: z-wind component	SH2O: Soil Liquid Water
H: Geopotential Height	
T: Potential Temperature	
P: Pressure	
QVAPOR: Water Vapor Mixing Ratio	
QCLOUD: cloud water mixing ratio	
QRAIN: Rain Water Mixing Ratio	
QICE: Ice Mixing Ratio	
QSNOW: Snow Mixing Ratio	
2D fields (3 hourly)	**2D fields (hourly)**
Fraction of Frozen Precipitation	POTEVP: accumulated potential evaporation
SST: Sea Surface Temperature	SNOPCX: snow phase change heat flux
	SOILTB: bottom soil temperature
	Q2: QV at 2 M
	T2: TEMP at 2 M
	TH2: POT TEMP at 2 M
	PSFC: SFC PRESSURE
	U10: U at 10 M
	V10: V at 10 M
	SMSTAV: Moisture Availability
	SMSTOT: Total Soil Moisture
	SFROFF: Surface Runoff
	UDROFF: Underground Runoff
	SFCEVP: Surface Evaporation
	GRDFLX: Ground Heat Flux
	ACGRDFLX: Accumulated Ground Heat Flux
	ACSNOW: Accumulated Snow
	ACSNOM: Accumulated Melted Snow
	SNOW: Snow Water Equivalent
	SNOWH: Physical Snow Depth
	…………



Output Variables

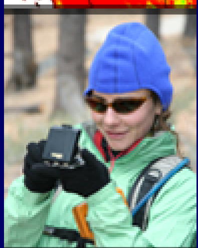
2D fields (hourly)
……..
RHOSN: Snow Density
CANWAT: Canopy Water
TSK: Surface Skin Temperature
RAINC: Accumulated Total Cumulus Precipitation
RAINNC: Accumulated Total Grid Scale Precipitation
SNOWNC: Accumulated Total Grid Scale Snow And Ice
GRAUPELNC: Accumulated Total Grid Scale Graupel
SWDOWN: Downward Short Wave Flux At Ground Surface
GLW: Downward Long Wave Flux At Ground Surface
ACSWUPT: Accumulated Upwelling Shortwave Flux At Top
ACSWUPTC: Accumulated Upwelling Clear Sky SW Flux At Top
ACSWDNT: Accumulated Downwelling Shortwave Flux At Top
ACSWDNTC: Accumulated Downwelling Clear Sky SW Flux At Top
ACSWUPB: Accumulated Upwelling Shortwave Flux At Bottom
ACSWUPBC: Accumulated Upwelling Clear Sky SW Flux At Bottom
ACSWDNB: Accumulated Downwelling Shortwave Flux At Bottom
CSWDNBC: Accumulated Downwelling Clear Sky SW Flux At Bottom
ACLWUPT: Accumulated Upwelling Longwave Flux At Top
ACLWUPTC: Accumulated Upwelling Clear Sky Longwave Flux At Top
ACLWDNT: Accumulated Downwelling Longwave Flux At Top
ACLWDNTC: Accumulated Downwelling Clear Sky Longwave Flux At Top
ACLWUPB: Accumulated Upwelling Longwave Flux At Bottom
ACLWUPBC: Accumulated Upwelling Clear Sky Longwave Flux At Bottom
ACLWDNB: Accumulated Downwelling Longwave Flux At Bottom
ACLWDNBC: Accumulated Downwelling Clear Sky Longwave Flux At Bottom
OLR: TOA Outgoing Long Wave
EMISS: Surface Emissivity
PBLH: PBL Height
HFX: Upward Heat Flux At The Surface
QFX: Upward Moisture Flux At The Surface
LH: Latent Heat Flux At The Surface
ACHFX: Accumulated Upward Heat Flux At The Surface
ACLHF: Accumulated Upward Latent Heat Flux At The Surface



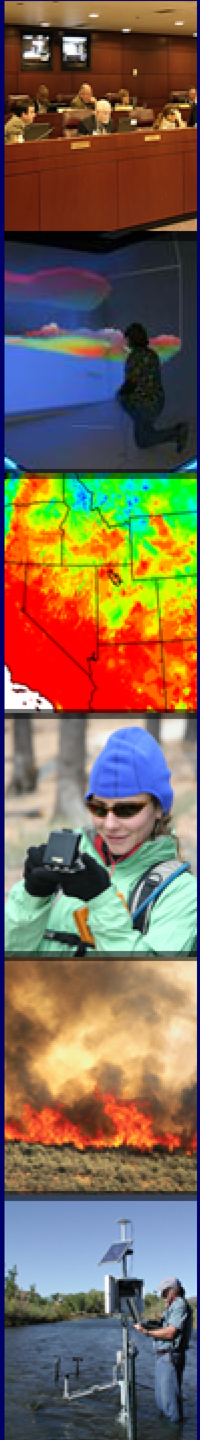
Conceptual GCM to SDS model.

Overview of Statistical Downscaling (SDS)

Statistical downscaling offers a method to ‘bridge the gap’ between GCM and local/regional impacts (e.g. hydrology, growing degree days)

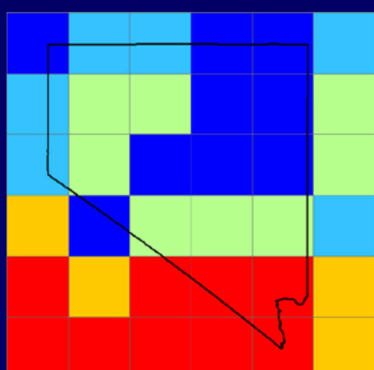


- Resolution of GCMs is 100-500km while regional climate impact studies require resolutions of <50km (e.g. basin-scale) (12)
- SDS seeks to generate statistical relationships between sets of predictors that are well-represented in the GCM (e.g. 1000-500mb thickness, 500mb geopotential) and predictands (often surface temperature and precipitation) (13)
  - Many techniques have been developed and applied in North America, Europe, South America, Asia, and Africa

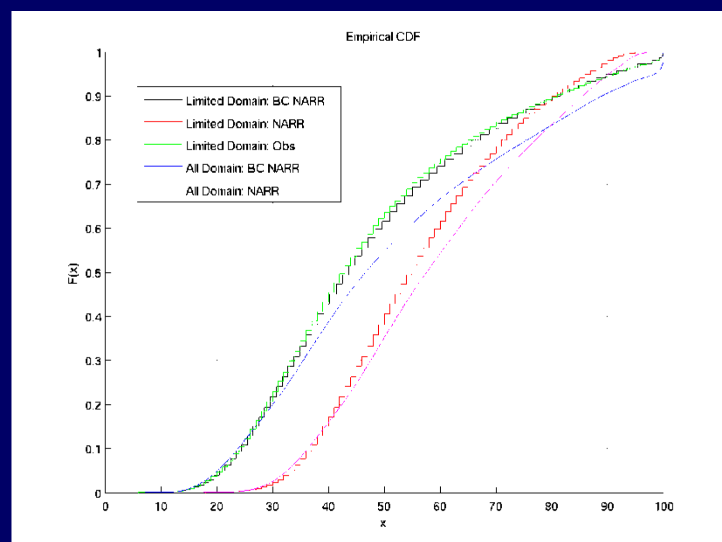


Statistical downscaling:
Bias correction and spatial disaggregation method

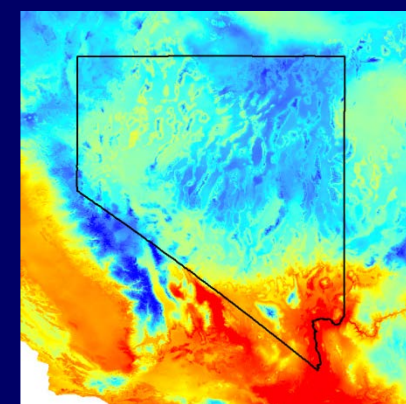
- Large scale GCMs carry inherent bias which will interfere with smaller scale climate signals (magnitude and statistical distribution).
- Correction of GCM bias will yield improved results and will ‘train’ GCM to follow observational distribution
- Method utilizes CDF transform to map distribution of modeled data to observational dataset
- Developed by Climate Impacts Group (CIG) at Univ. Washington, used with success in Pacific Northwest and Eastern U.S.



1. Aggregate 4km PRISM observations (Obs) to model grid size (140km)

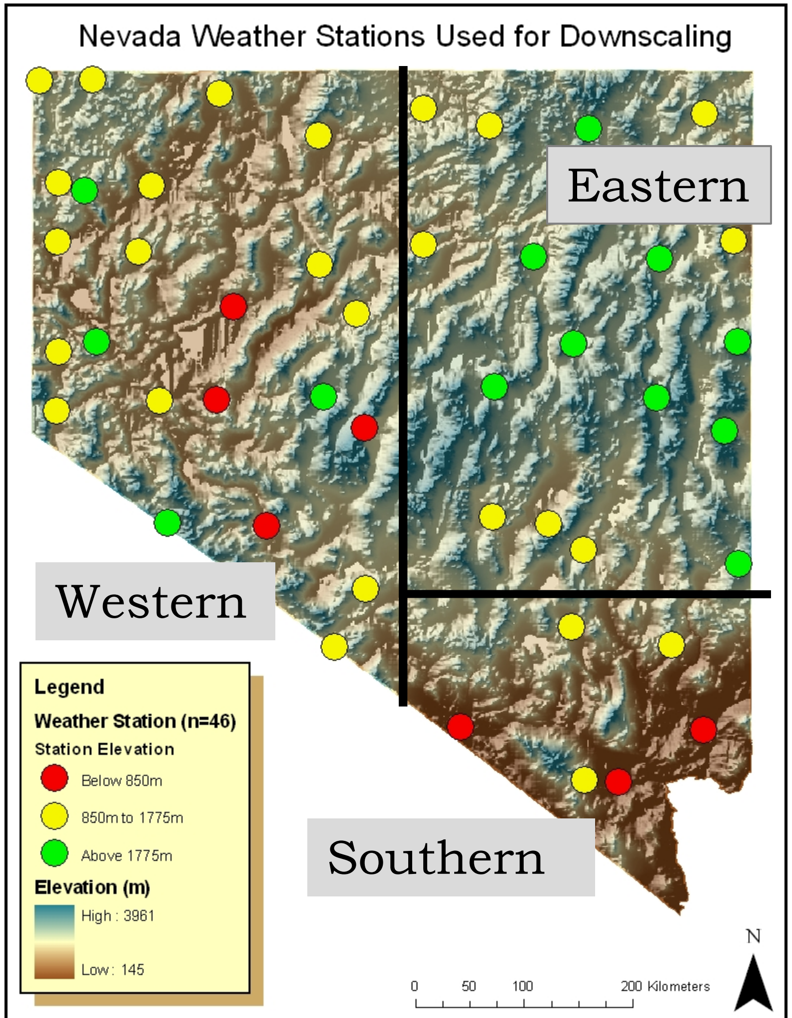


2. Perform CDF transform to correct model bias at model scale (note how BC NARR approaches Obs. (NARR is ‘type’ of GCM))



3. Calculate perturbation factors (Diff. of mean ag. Obs and non ag. Obs) and add to future climate model output). Yields 4km (native PRISM grid) resolution results

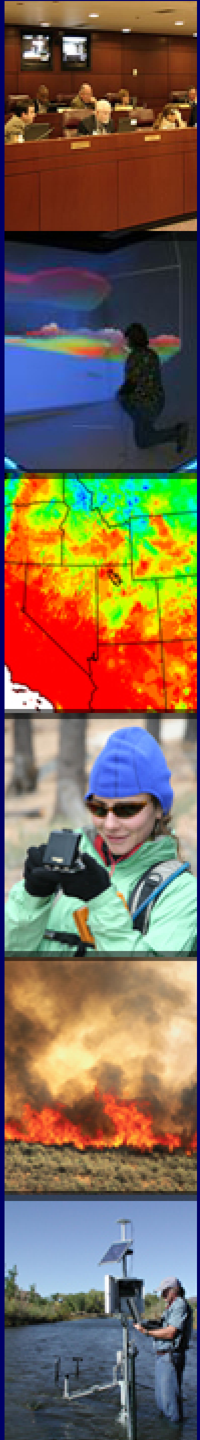
Nevada Downscaling Station Locations



- Note highly complex ‘basin and range’ topography.
- Three sample stations shown, encompassing range of elevation
- Three precipitation regimes in Nevada
  - Western: Landfalling Pacific cyclones, winter max, high orographic influence
  - Eastern: Continental cyclongenesis with advection of Pacific moisture, spring max, less orographic enhancement
  - Southern: North American Monsoon influence, summer max, high precipitation spatial and temporal variability

EPSCoR
Experimental Program to Stimulate Competitive Research

NEVADA SYSTEM OF HIGHER EDUCATION
OMNIA PRO PATRIA
1865

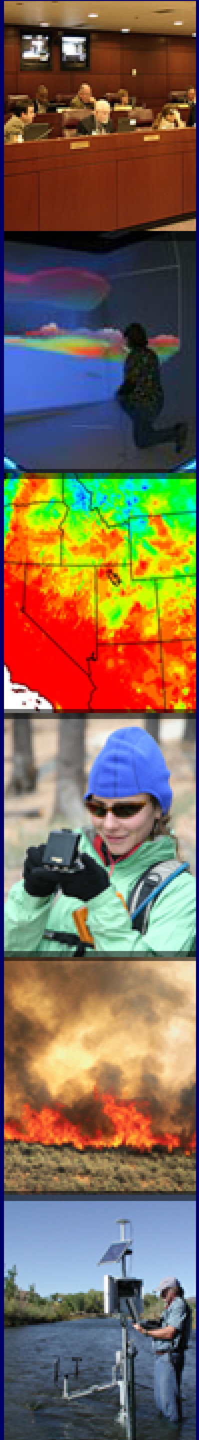


Nevada Infrastructure for Climate Change Science, Education, and Outreach

Downsides of SDS

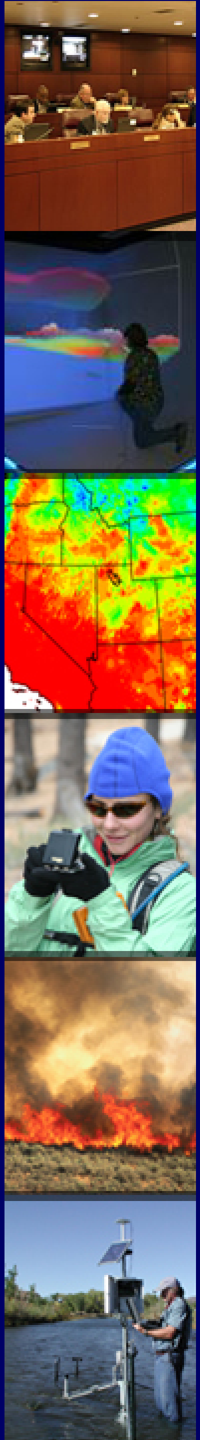
- Ultimate limitation is the assumption that the relationship between local predictands and GCM predictors is stationary; i.e. skillful predictions by SDS under current climate may not hold under future climate conditions
- GCMs susceptible to climatic drift
- GCMs do not completely resolve current climatic variability (e.g. ENSO, PDO)
- Verification of downscaling results for future impossible

NSF
EPSCoR
Experimental Program to Stimulate Competitive Research
Nevada System of Higher Education
Omnia Pro Patria
1865



Benefits of SDS

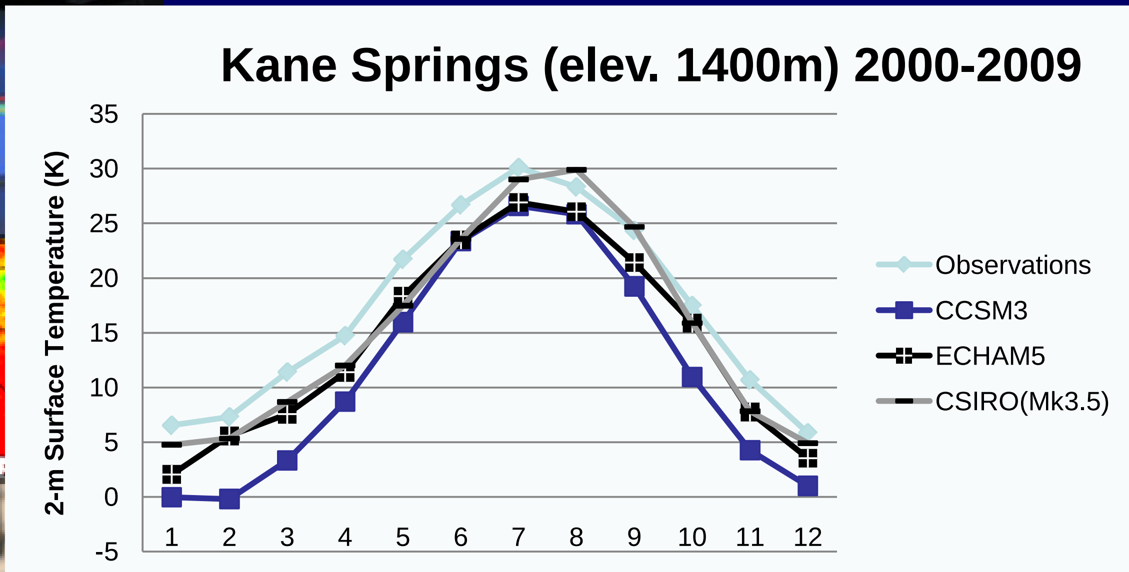
- Can be applied directly to gridded data as well as station data
- Computationally inexpensive
- Once SD method has been established, it can be applied to multiple GCMs and respective IPCC SRES scenarios to generate ensemble forecasts
- Utilizes repeatable, accepted statistical methods
- Allows choice of best predictor variables (often selected via Principal Components Analysis)



Simple Bias Correction Results

- BCM-OM value should approach zero if method is successful.
- The best results for January and July, other months higher than 1.

Monthly Extracted Station Comparisons: CCSM3 to Observations, 2000-2009

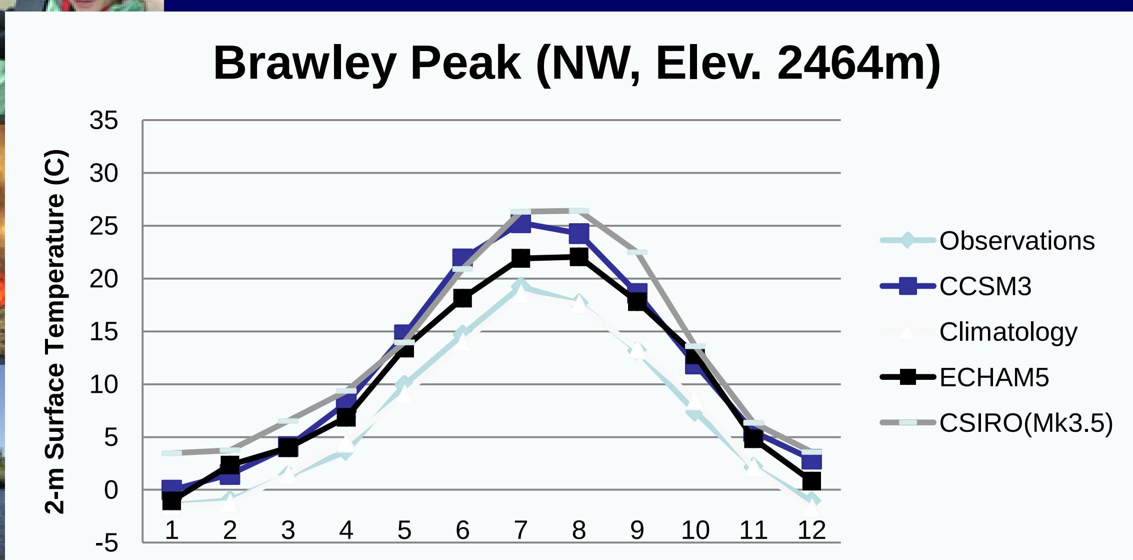


Std. Deviations:

Obs: 8.74

CCSM: 10.3

Absolute Mean Bias: 5.5°C

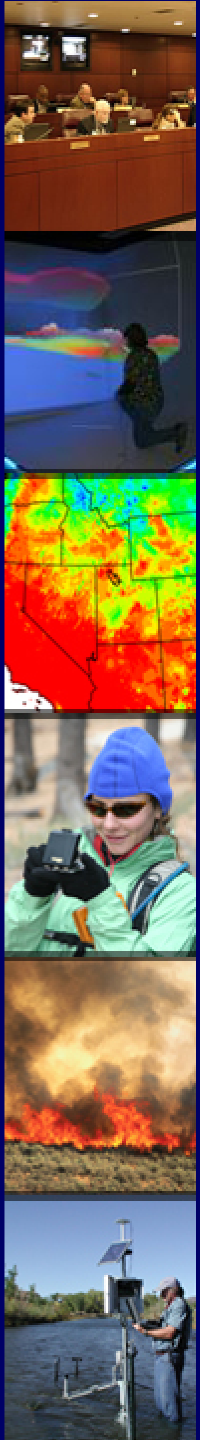


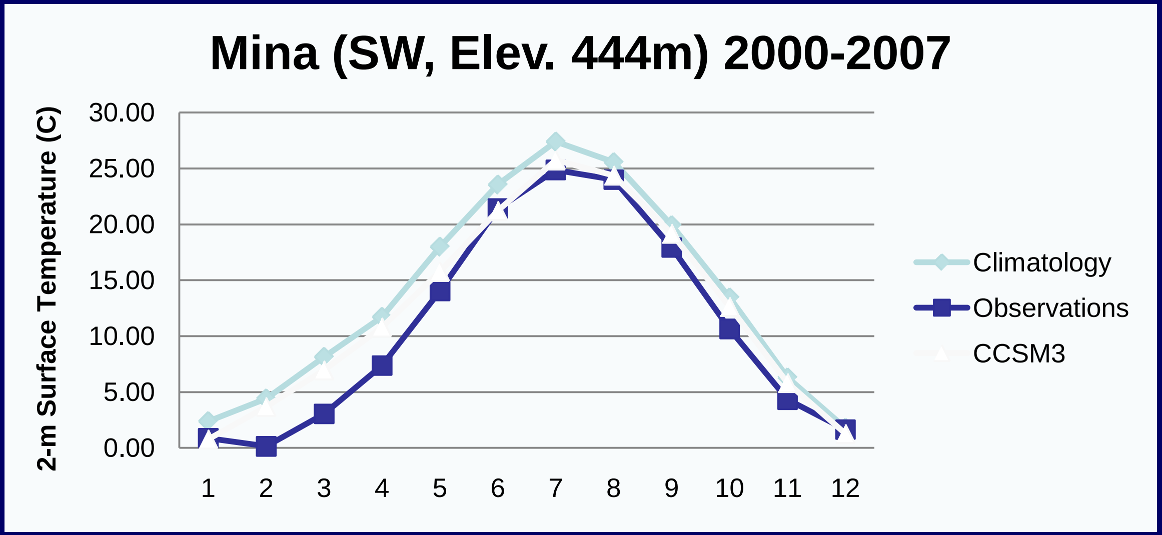
Std. Deviations:

Obs: 7.47

CCSM: 9.19

Absolute Mean Bias: 4.4 C



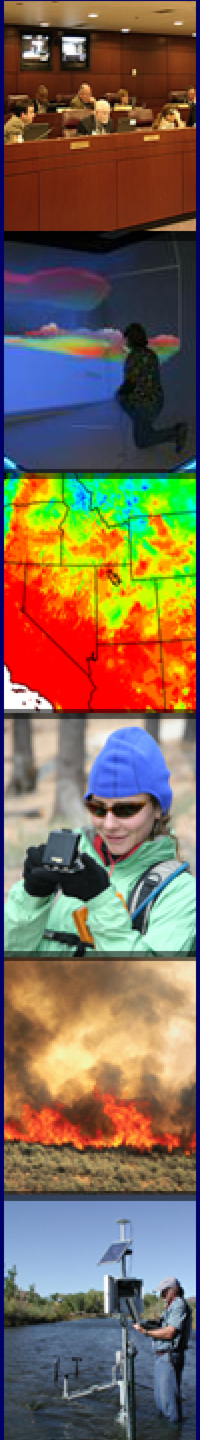


Std. Deviations:

Obs: 8.96

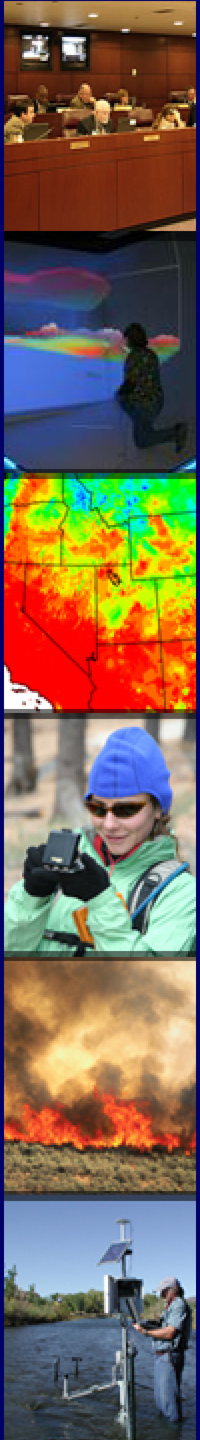
CCSM: 9.32

Absolute Mean Bias: 2.7 C



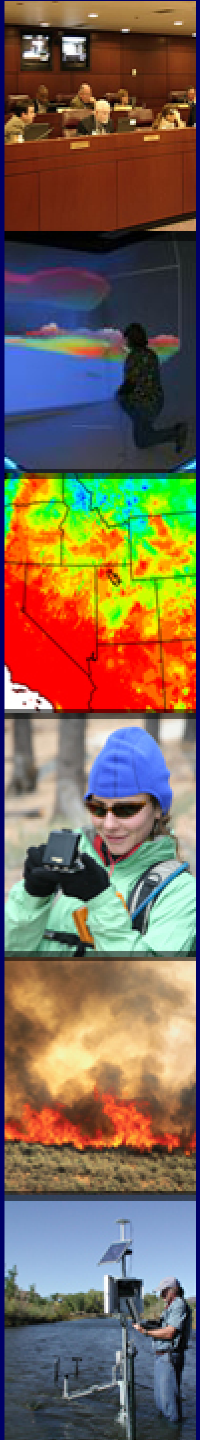
Next Steps… Statistical downscaling

- Complete downscaling of CCSM, CSIRO, ECHAM5 temperature (min and max) and precipitation
- RCM as input to statistical downscaling
- Run downscaled results in hydro model and input results into urban model
- Comparisons of downscaling results
  - Stations to grids (PRISM)
  - Intercomparisons of models (CCSM3, CSIRO, ECHAM5) and scenarios (A1B, A2, B1)



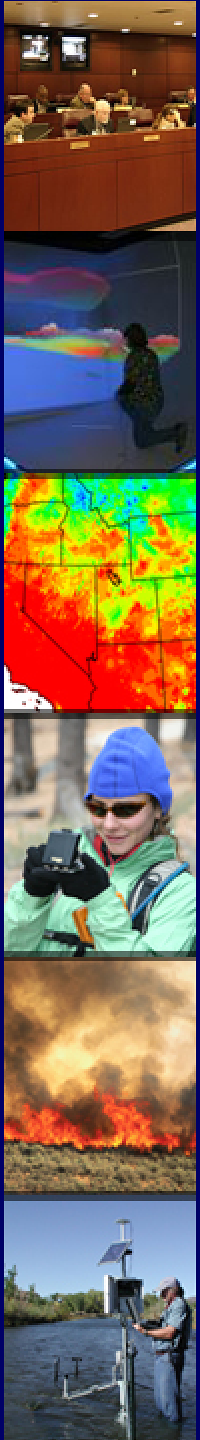
Next steps …
Dynamical downscaling

- 4km Min, Max temperature and Precipitation for 3 GCMs using A1B, A2, and B1 scenarios
- Results will be summarized in 10-year increments (2060-2069, 2090-2099, etc.)
- Data will be available in ASCII format to easily be incorporated into GIS and various other models
- First downscaling results to be submitted Summer 2010, results of climate-hydro-urban modeling project hopefully submitted by Fall 2010



Future steps …

- Climate model results as input to hydrological models including coupling algorithms
- CCSM3 optimum parameterizations
- Use of CCSM4 to be released in April 2010
- Ensemble approach to regional climate predictions
- Extreme weather events
- Statistical downscaling applied to hydrological modeling



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