Climate Observations, Models and Diagnostics needs for California
A Discussion Paper for the CEC PIER Climate Program 8/25/2008

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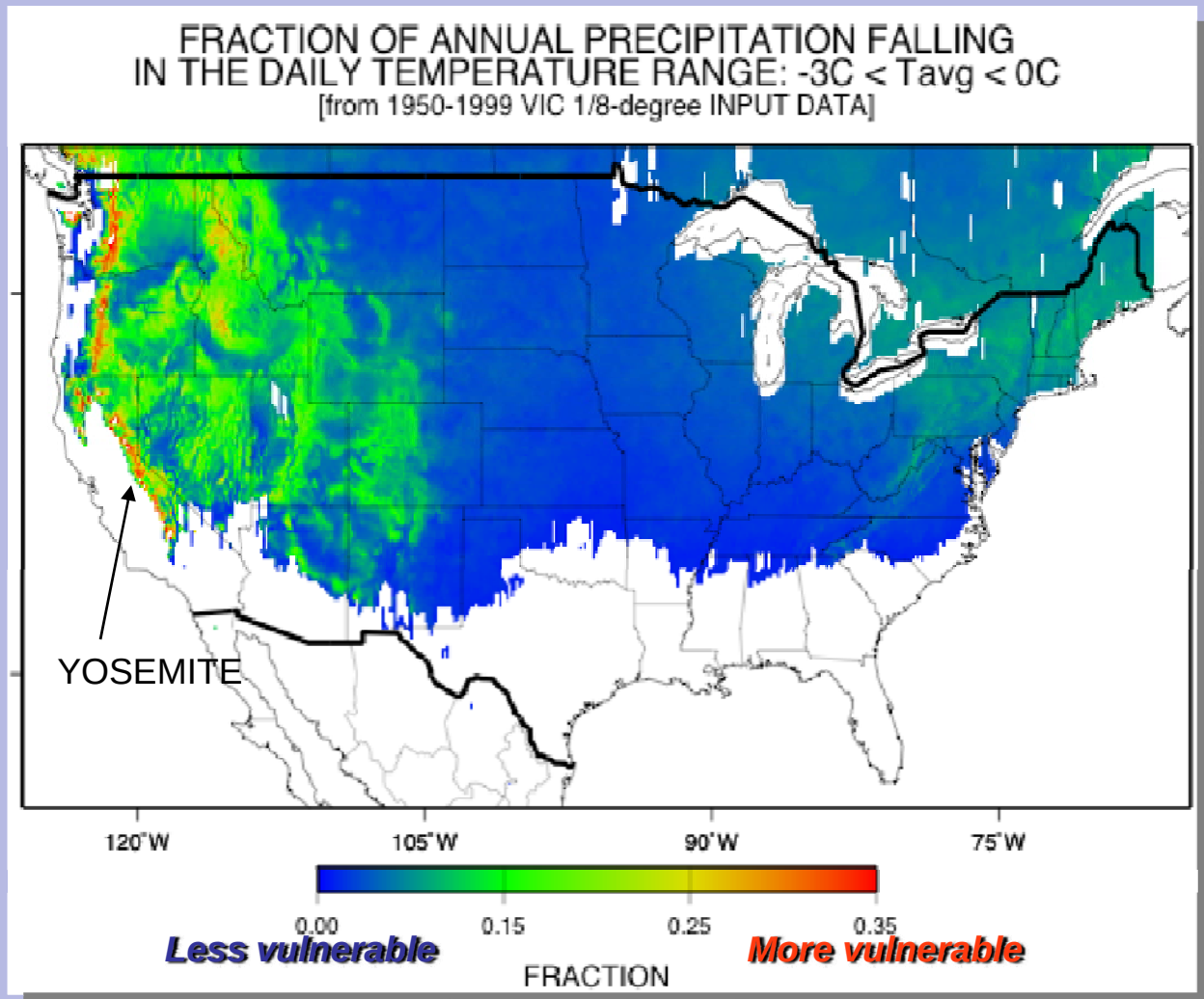
to provide high quality information will require
improved observations, models
and considerable work to diagnose and understand them.

Motives

- *what is the current status of California's climate?*
- *how has climate changed in California's past?*
- *how is California's climate changing now and why is it changing?*
- *how will California's climate change in future decades? how certain can we be?*
- *what locations and systems are most vulnerable?*
- *are models used to simulate climate changes and impacts working realistically?*
- *what are the interconnections and impacts?*

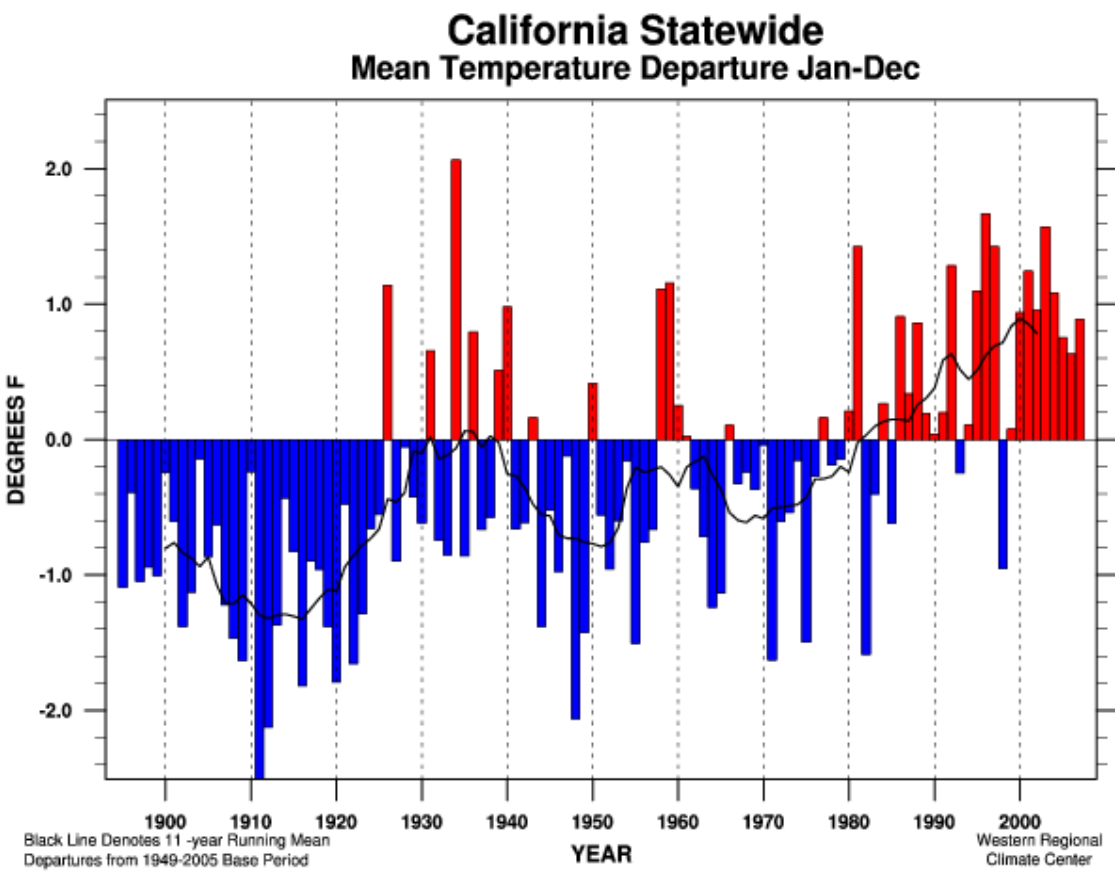
SENSITIVITY TO A +3ºC WARMING…

What fraction of each year's precipitation historically fell on days with average temperatures just below freezing?



"Rain vs Snow"

Computed by Mike Dettinger from gridded historical US weather data (from Bates et al, in rev)

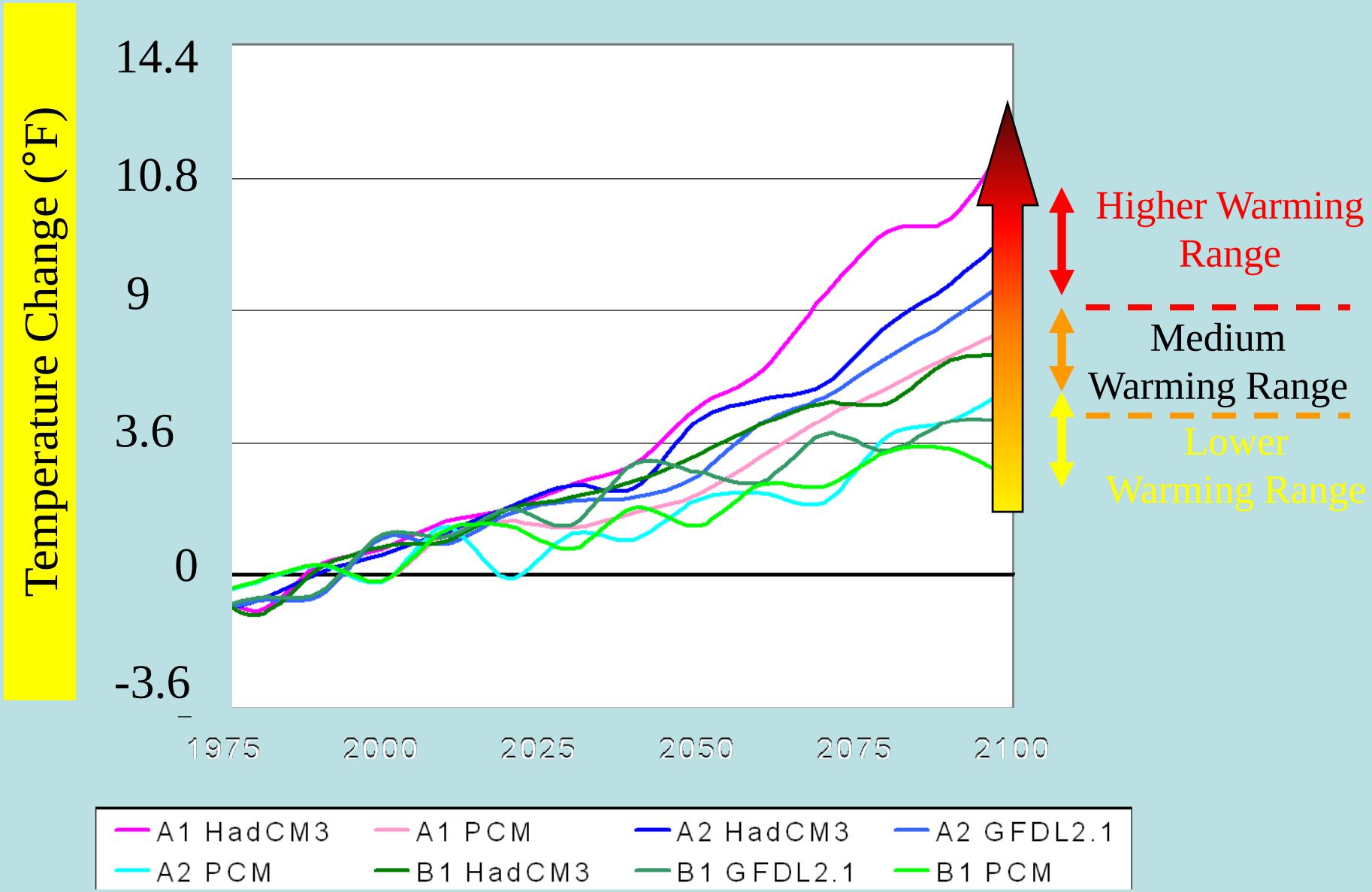


observed temperature records suggest that California has warmed 1.5°F over last 100yr

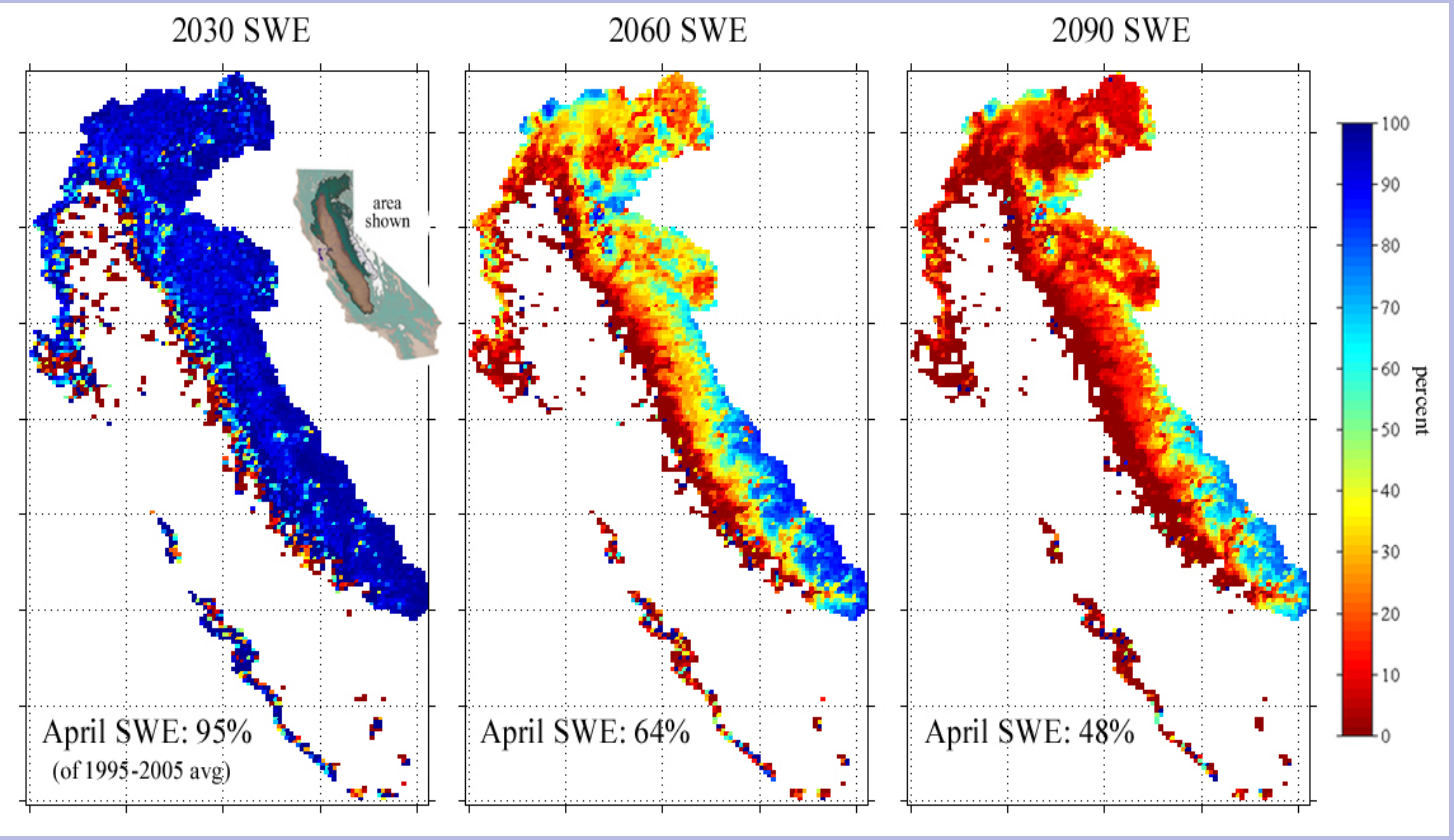
Linear Trend 1895-present	+ 1.55 ± 0.44 °F/100yr		
Linear Trend 1949-present	+ 2.80 ± 1.11°F/100yr		
Linear Trend 1975-present	+ 4.63 ± 2.64 °F/100yr		
Warmest Year	59.5 °F (+ 2.1°F) in 1934	MEAN	57.5 °F
Coldest Year	54.9 °F (- 2.5 °F) in 1911	STDEV	0.87 °F
Jan-Dec 2007	58.3 °F (+ 0.9 °F)	RANK	97 of 113

California Climate Tracker
Western Regional Climate Center DRI

Uncertainty: Projected Warming Ranges
Statewide annual average (°F)



We face significant losses of spring snowpack



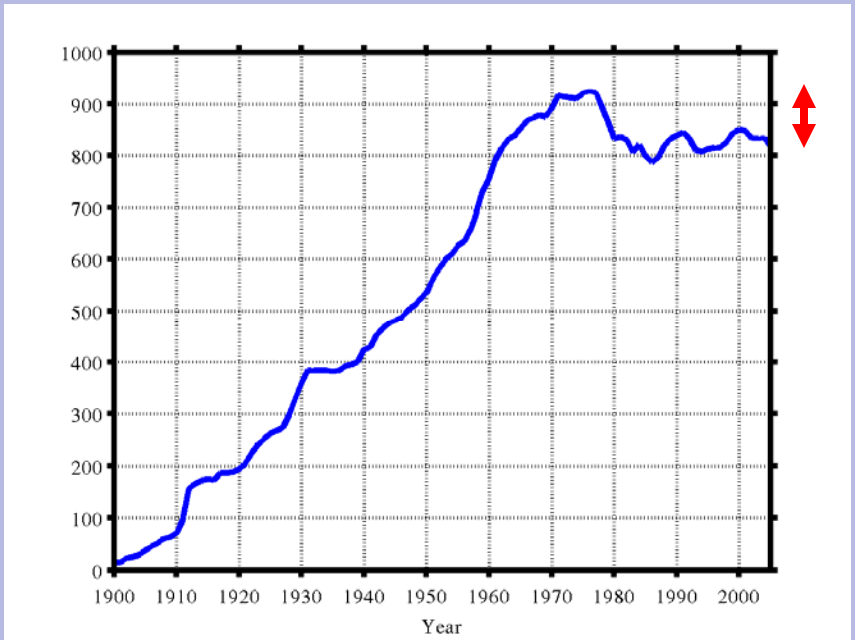
- Less snow, more rain
- Particularly at lower elevations
- Earlier run-off
- More floods
- Less stored water

By the end of the century California could lose half of its late spring snow pack due to climate warming. This simulation by Noah Knowles is guided by temperature changes from PCM's Business-as-usual climate simulation. (a middle of the road emissions scenario)

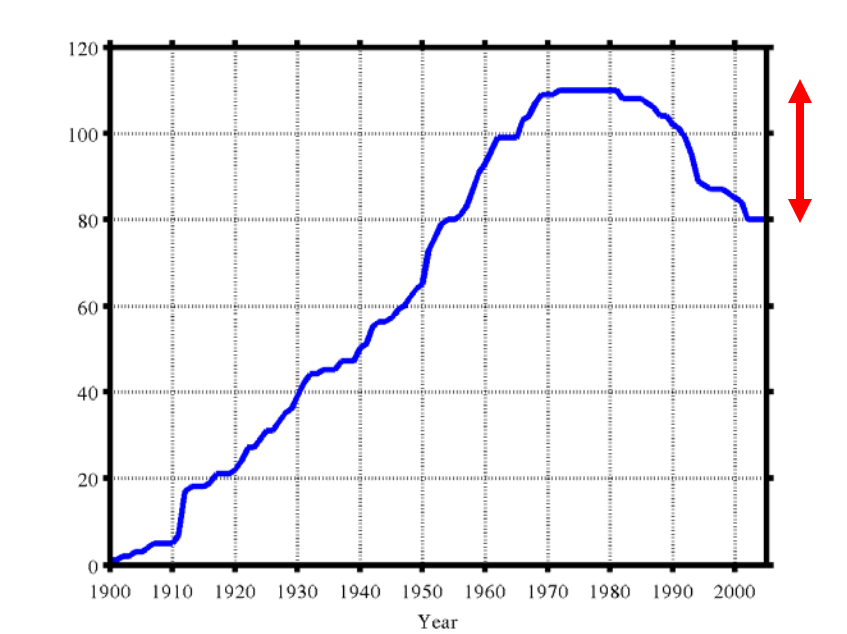
Knowles and Cayan 2001

Total number of streamflow gages since 1900

Stream gage network In California has declined



11% discontinued since peak



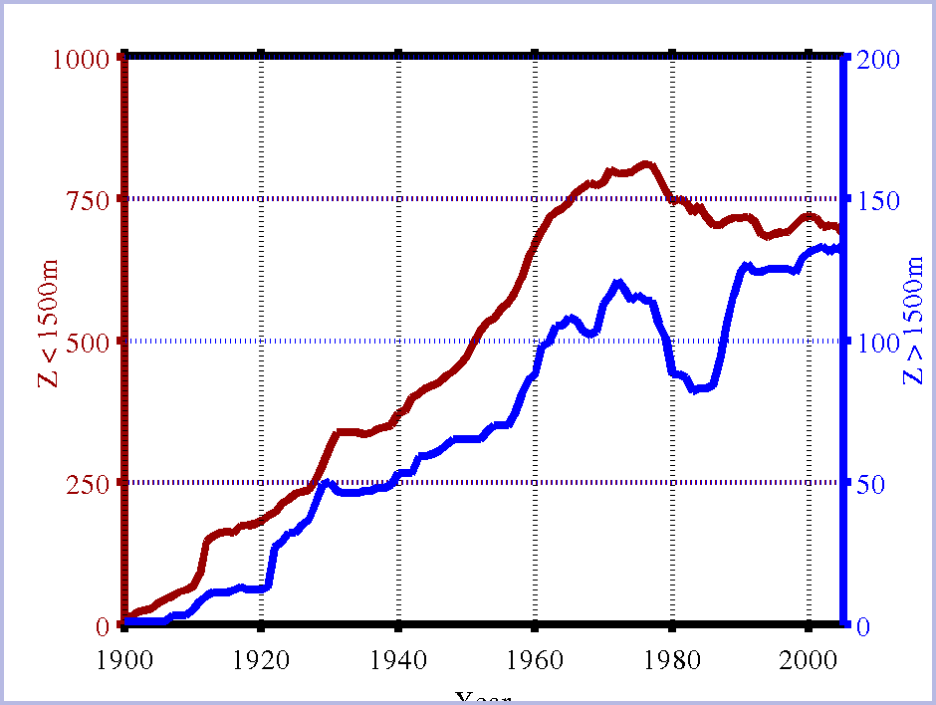
27% discontinued since peak

Total number of HCDN gages since 1900

Noah Knowles

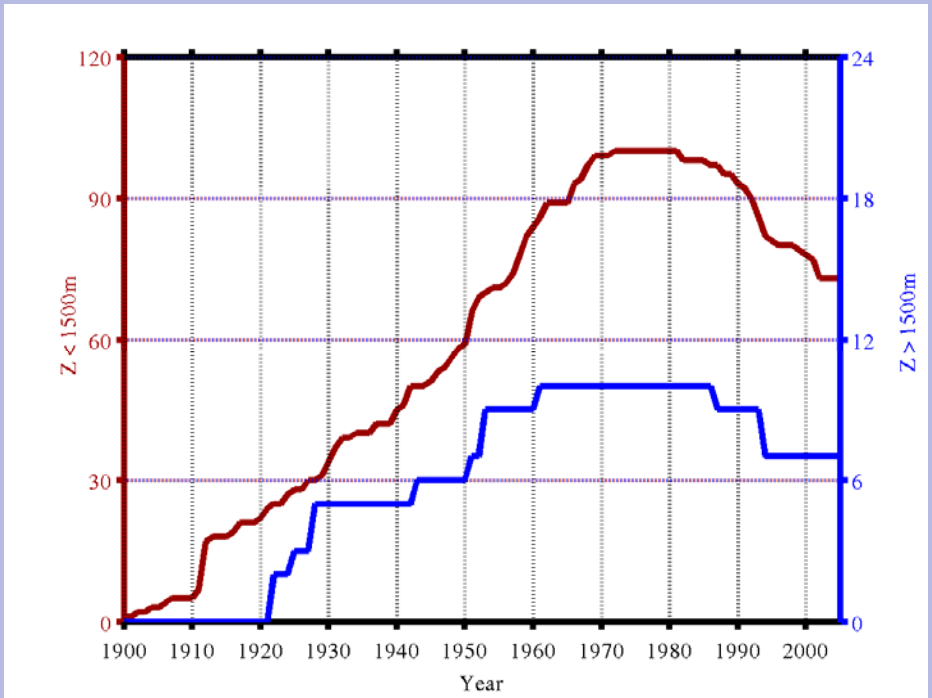
Total number of streamflow below 1500m (red)

in
lower and higher elevations
HCDN
stream gages
have diminished
in number



Total number of streamflow above 1500m (blue)

Total number of HCDN gages below 1500m (red)



Total number of HCDN gages above 1500m (blue)

Noah Knowles

Suggestions for Observational Program

o Develop climate observations in California's sensitive, vulnerable and sparsely observed areas.

Ex: coast-inland transition zones, valley-mountain gradients, and rain-snow transitions.

o Augment traditional measurements with new observations to track multivariate climate changes :

Ex: soil moisture, aerosols, radiation, GPS water vapor, water temp

o Place greater emphasis on remote sensing of surface, snow, vegetation, and atmosphere; develop operational monitoring products describing variations of snow cover, snow albedo, vegetation greenness and vigor, seasonal wetlands and inundation, etc, at State and watershed scales

o Develop more pervasive real time observation capacity—communications are a key technology that enables more effective use, analyses and maintenance of the observing system.

Suggestions for Observational Program, con'd-1

o Build hierarchical observation networks, to include selected numbers of highest quality sensors and stations, and denser numbers of lesser quality stations.

o Monitor the vertical structure of the atmosphere (e.g., profilers and radar)

o Increase observations of urban climate (e.g. temperature, humidity, radiation, winds, precipitation).

o Access pertinent paleoclimate records, particularly high resolution records that provide proxy records of recent Holocene climate in California; support integration of paleoclimatic records across and between California's critical climate gradients, linking paleoclimates of the mountains with valleys, the coast with the inland areas, more fully than has been the case to date

o Integrate efforts with the coastal ocean monitoring community.

Suggestions for Observational Program, con'd-2

o Fund climate data managers to organize climate observing system, including climate archive.

o Work to develop "Citizen Science" observing programs.
e.g. cooperative weather observers, phenological observers.

o Work with climate impact and other communities to develop non-traditional retrospective and ongoing datasets needed to evaluate climate impacts.

o Collaborate across agencies (federal, local, private, ..) to collect observations

o Conduct a California climate-observation-system summit: work with the State Climatologist and other to communally assess and identify future monitoring needs and opportunities

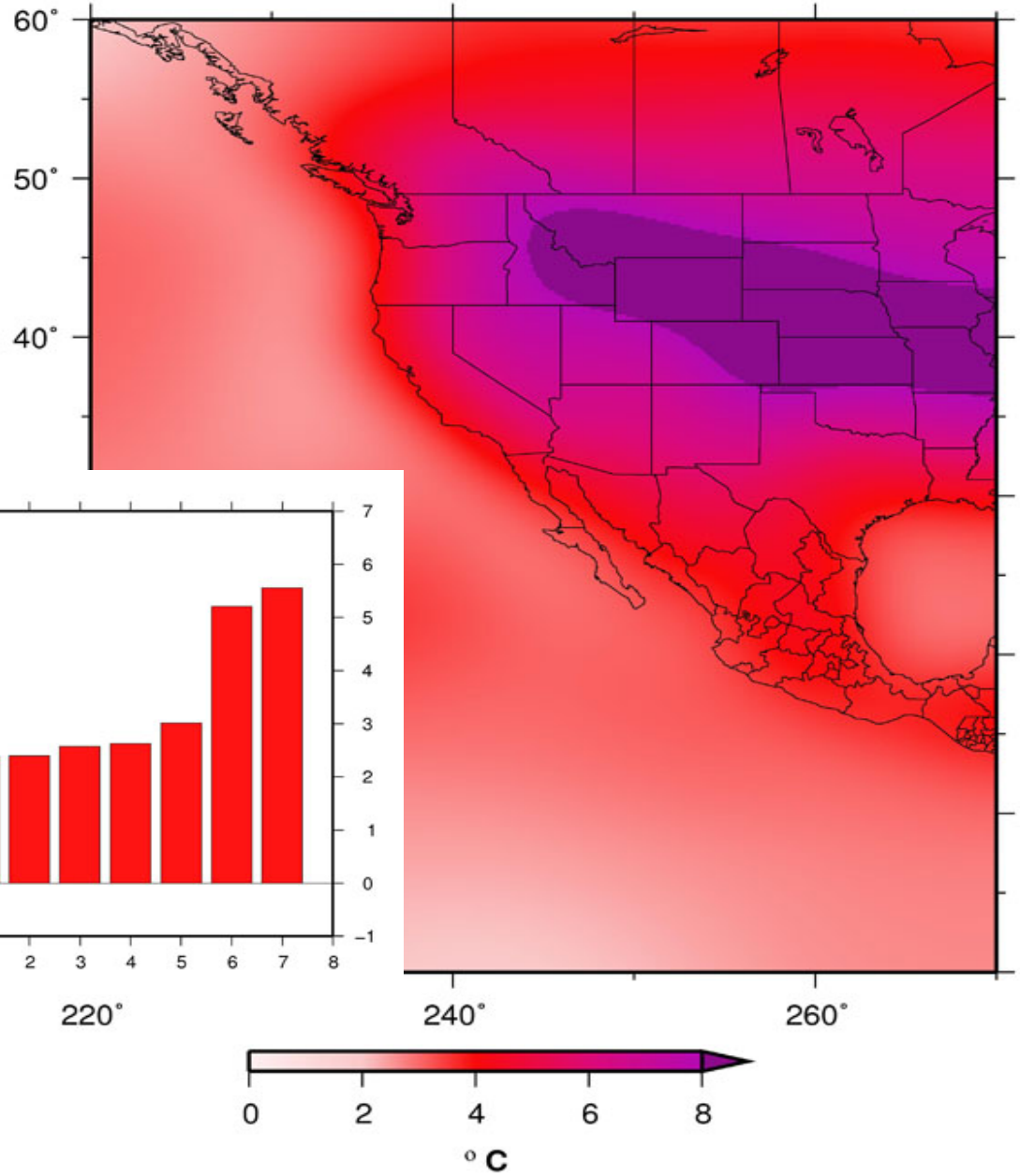
o Periodically (*e.g*. every 5 years), evaluate and publish an Assessment of state of the State's climate observation system, perhaps in concert with an assessment of the State's recent climate.

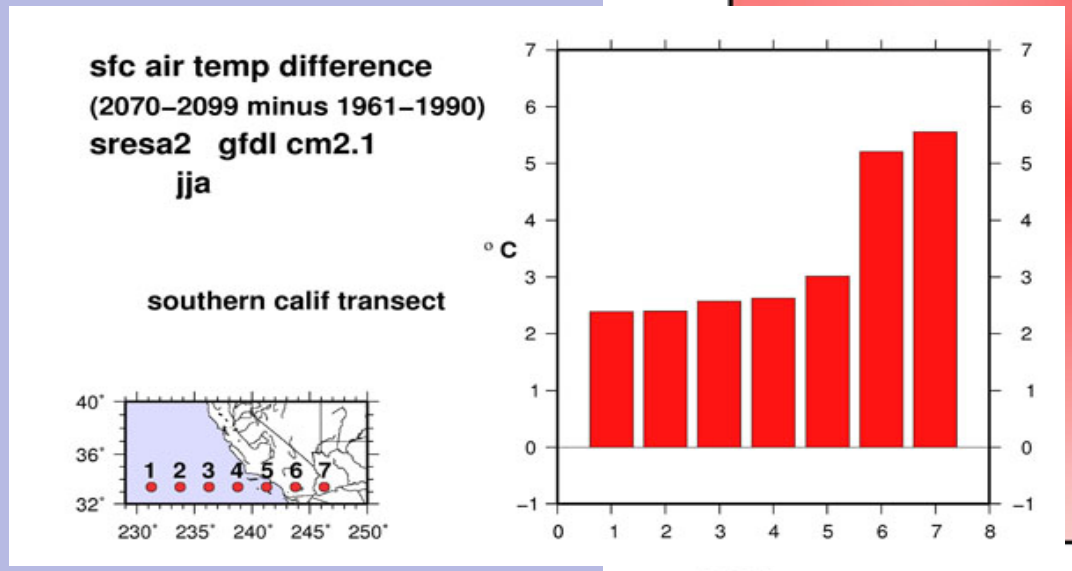
Climate models project 1.5-2.C ocean surface warming by end–of-century.

Greater warming on land than oceans would amplify California coast-interior thermal gradient.

Summer land warming is accentuated

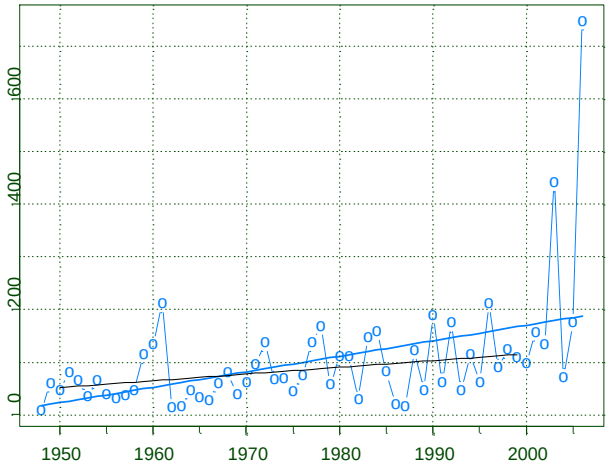
GFDL CM2.1 Jun-Aug air temp change
2070-2099 *minus* 1961-1990



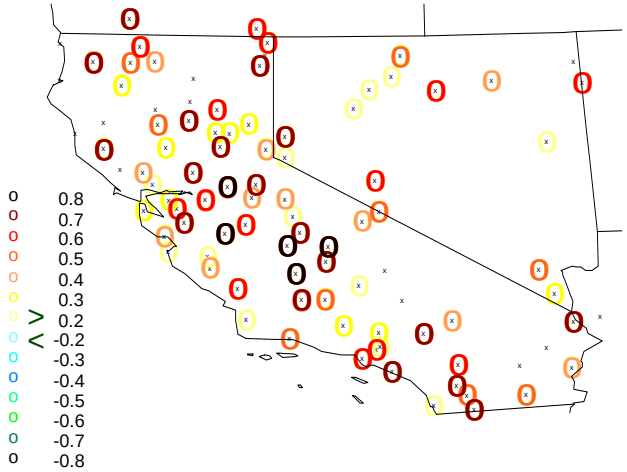


GFDL CM2.1 is a medium-high sensitivity model. Other models produce less (or more) warming

b) DN_{99}

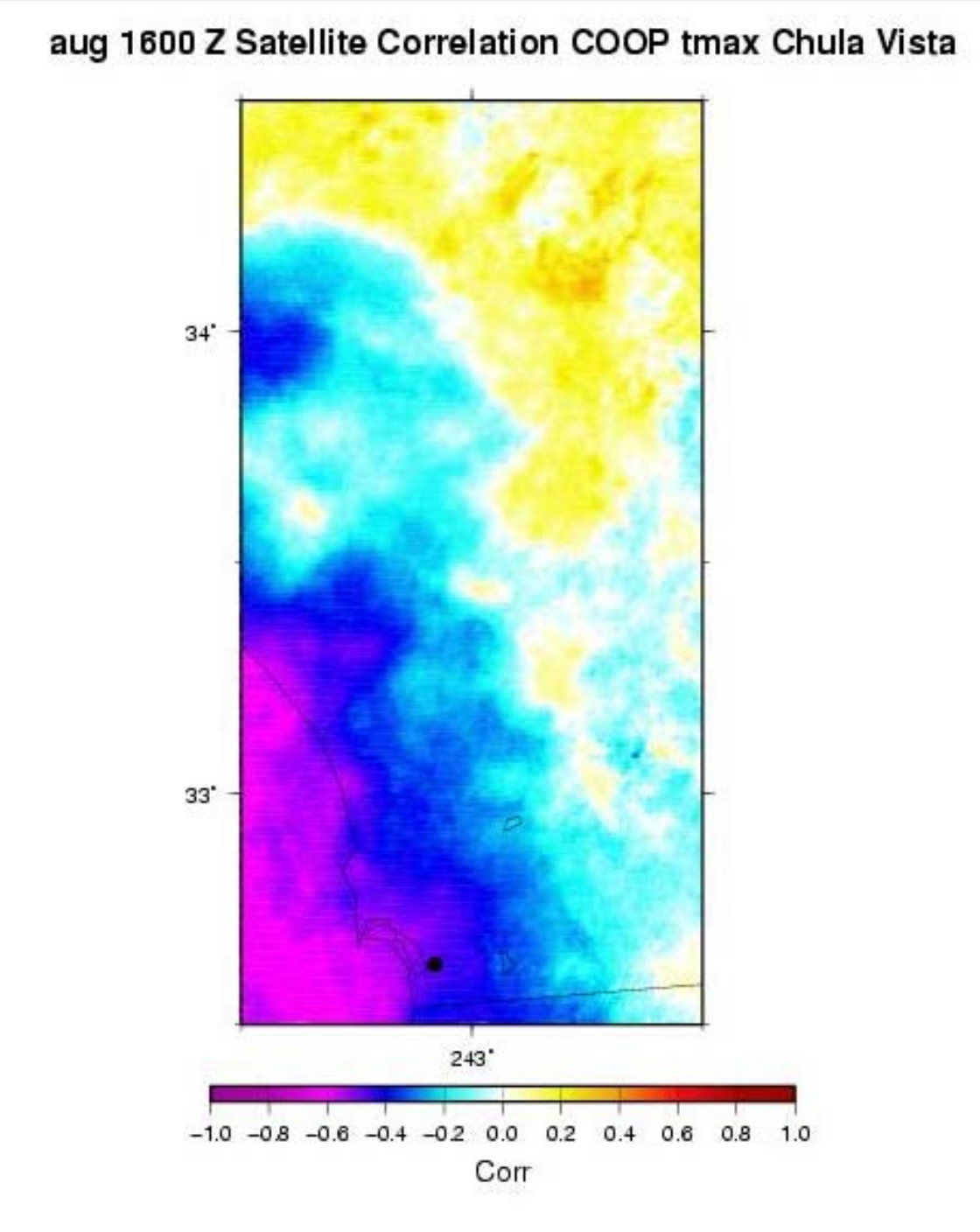


d) Spatial expression (cor) of DN_{99}



across California
over last six decades
daytime heat waves have
been roughly unchanging
but *nighttime* heat waves
have shown strong increase

Alexander Gershunov 2008
In review, J. Climate

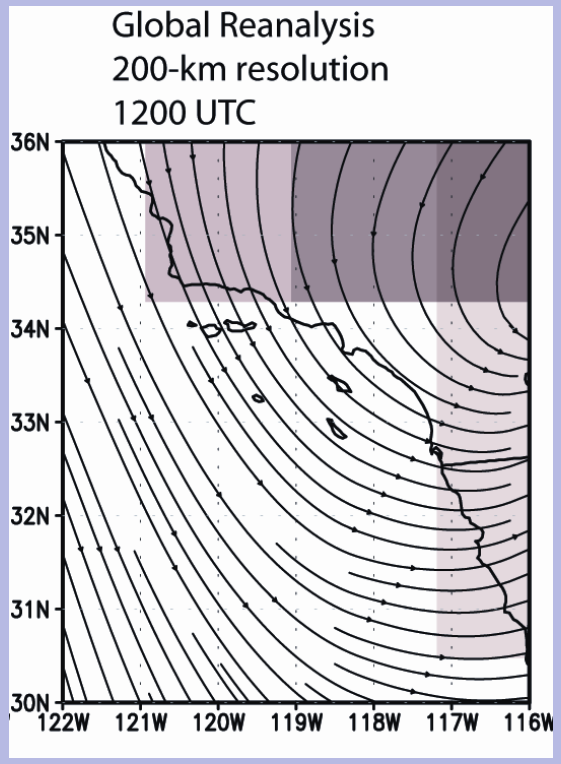


morning cloud cover
Is a key factor
determining
afternoon temp

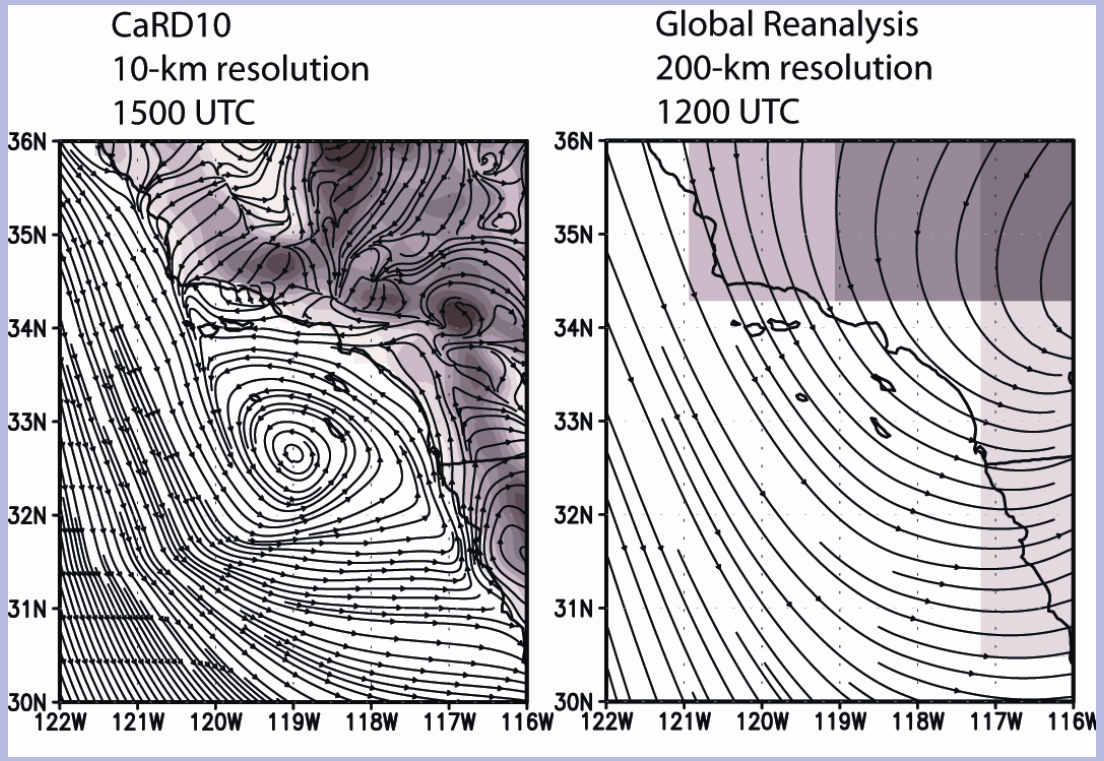
This map shows
9am cloud albedo
vs. daily Tmax

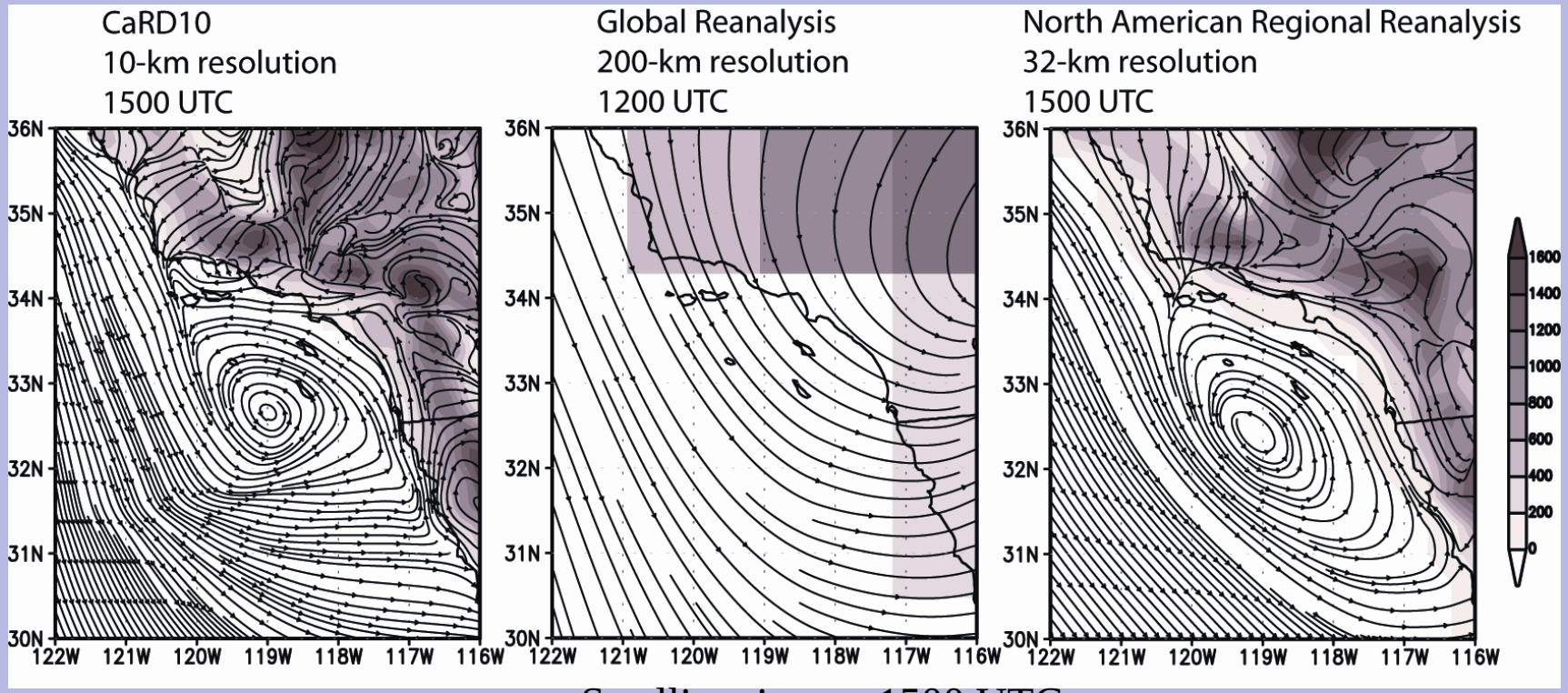
August days 2001-2005
San Diego County region

CaRD10 provides small scale features not in the global reanalysis

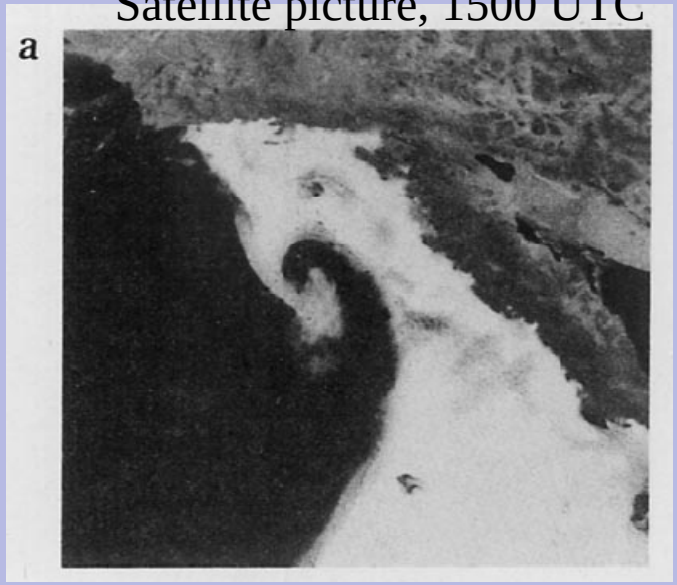


CaRD10 provides small scale features not in the global reanalysis



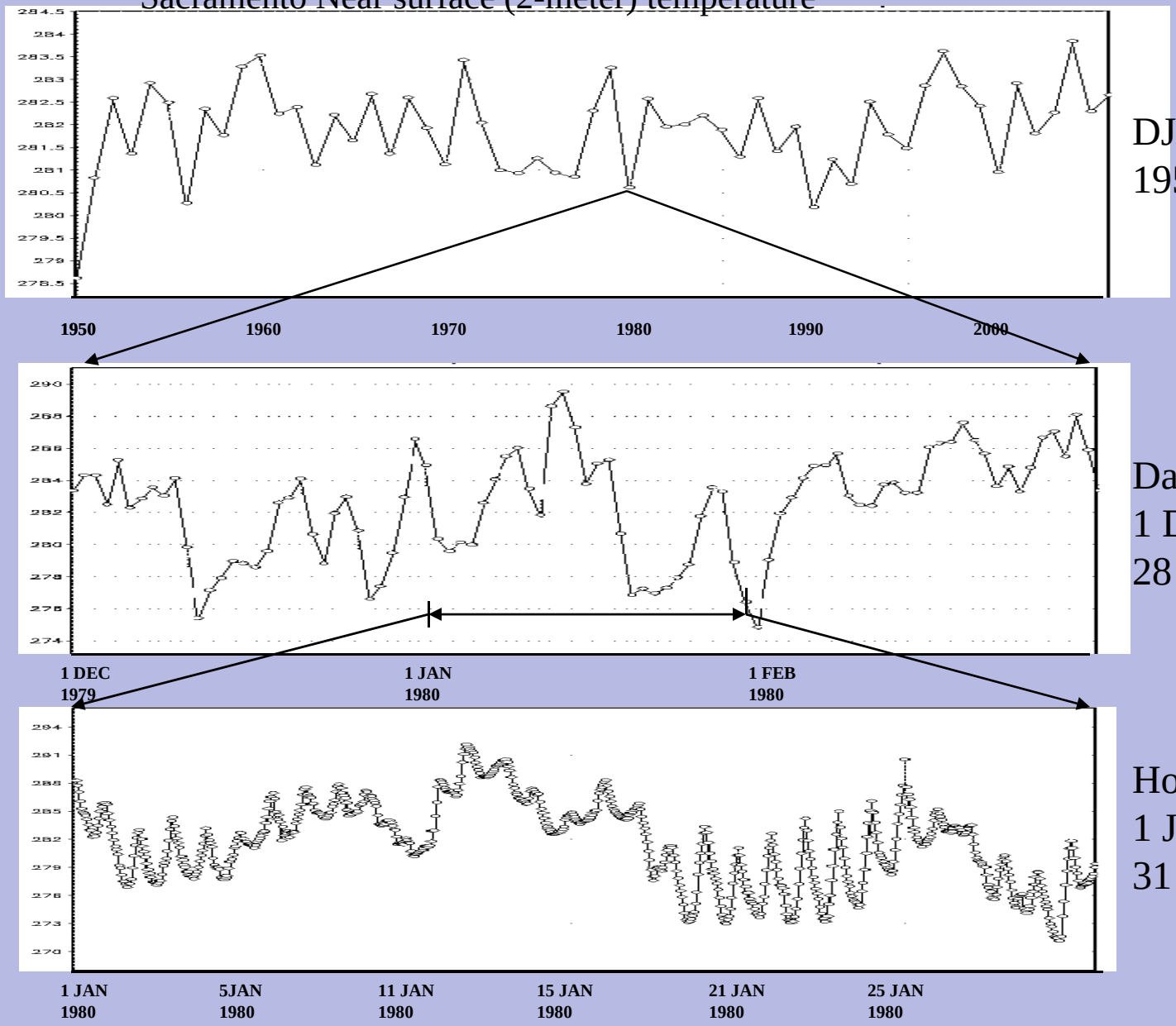


Satellite picture, 1500 UTC



CaRD10 provides analysis of different time scales

Sacramento Near surface (2-meter) temperature



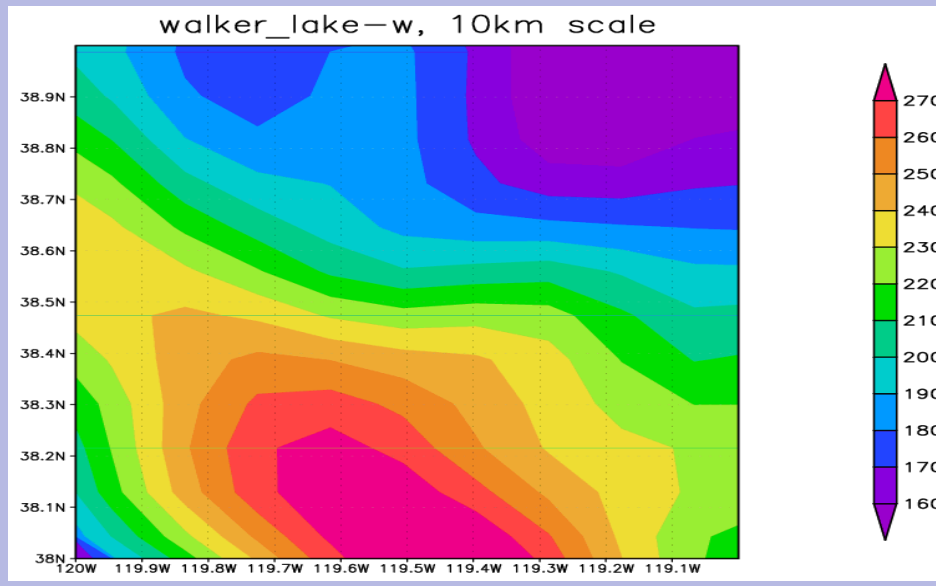
DJF mean
1950-2005

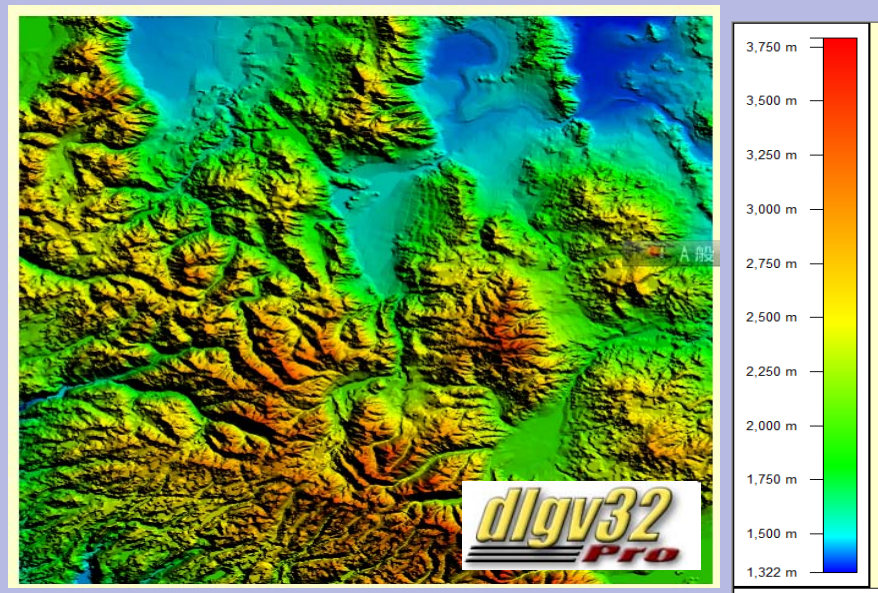
Daily mean
1 Dec 1979 -
28 Feb 1980

Hourly
1 Jan 1980 -
31 Jan 1980

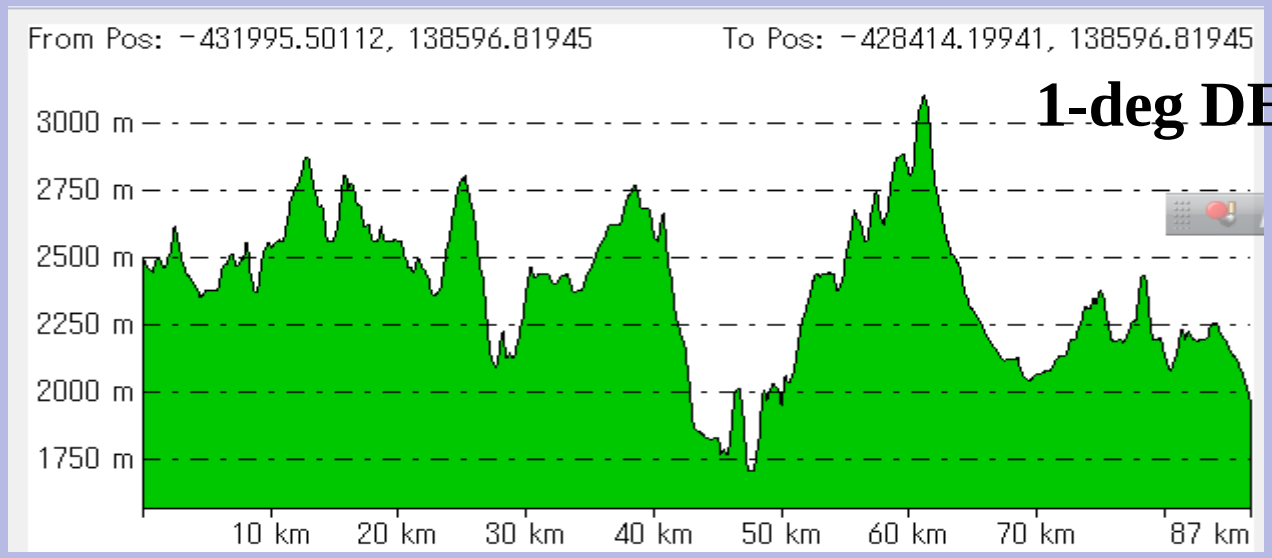
Need for even higher resolution model

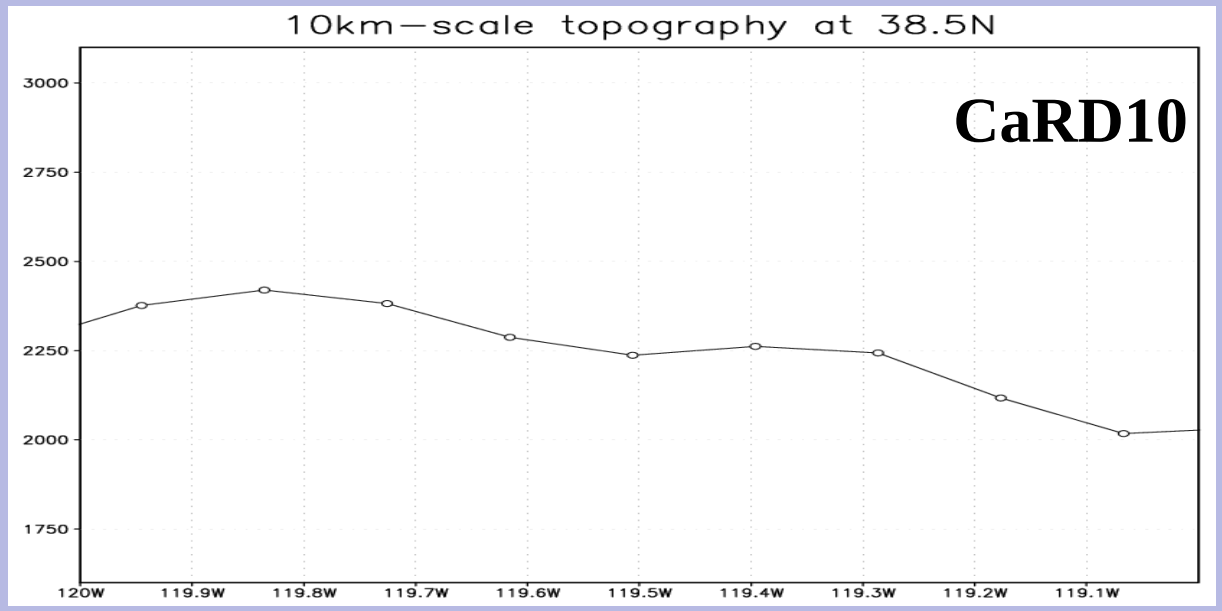
CaRD10 vs. USGS 1-deg
DEM 3-sec (100m) topo





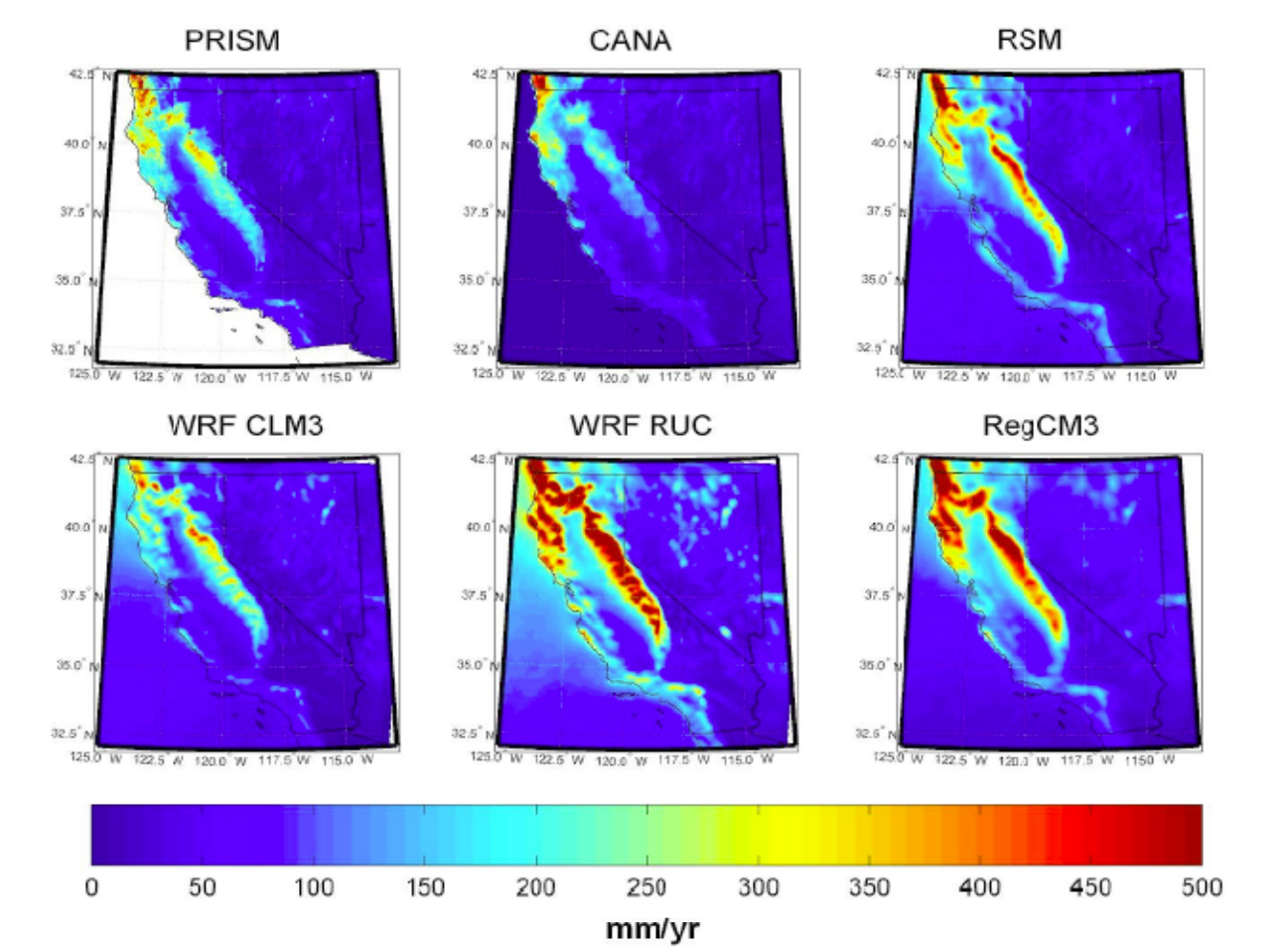
Need for even higher resolution model





Precipitation Bias

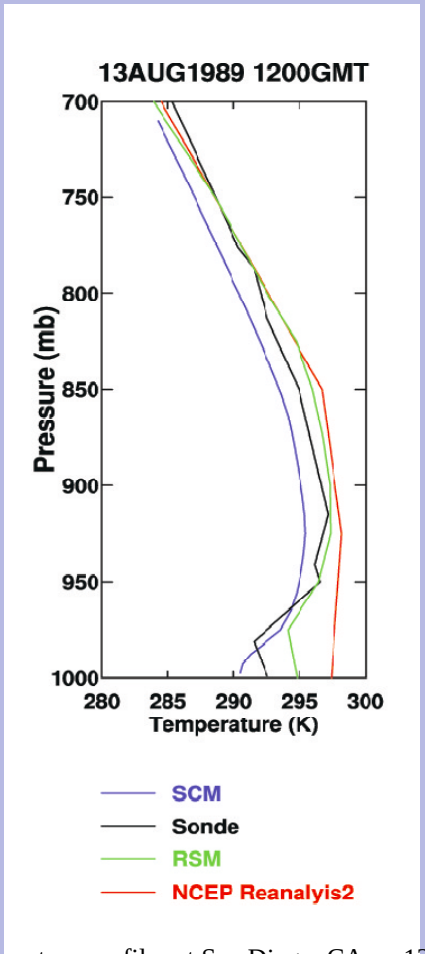
Cumulative November-March precipitation climatological mean for 1980-1989.



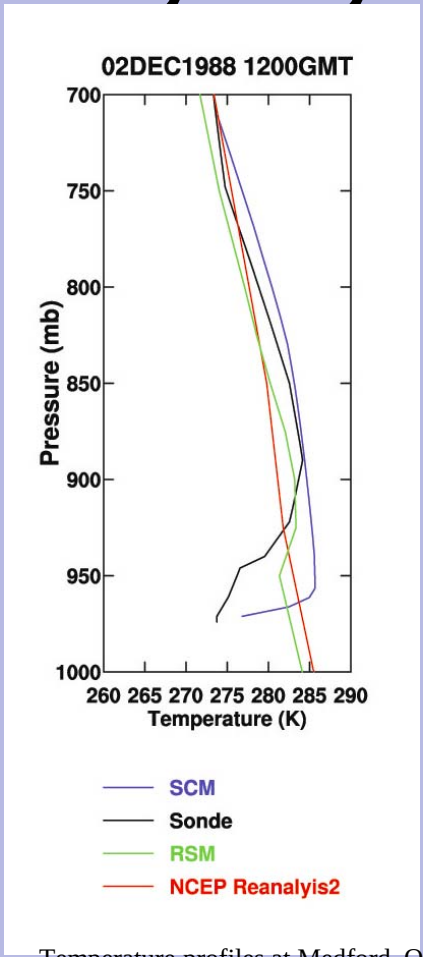
PRISM: obs.
CANA:Statistical
RSM : model
WRF : model
Reg : model

(From Miller et al 2008)

Boundary layer



Temperature profiles at San Diego, CA on 13 Aug 1989 12Z from radiosonde (black), SCM (blue), RSM (green), and NCEP Reanalysis 2 (red).



Temperature profiles at Medford, OR on 02 Dec 1988 12Z from radiosonde (black), SCM (blue), RSM (green), and NCEP Reanalysis 2 (red).

The two models, **RSM** and **SCM** do reasonable job in resolving marine boundary layer but still Display significant errors.

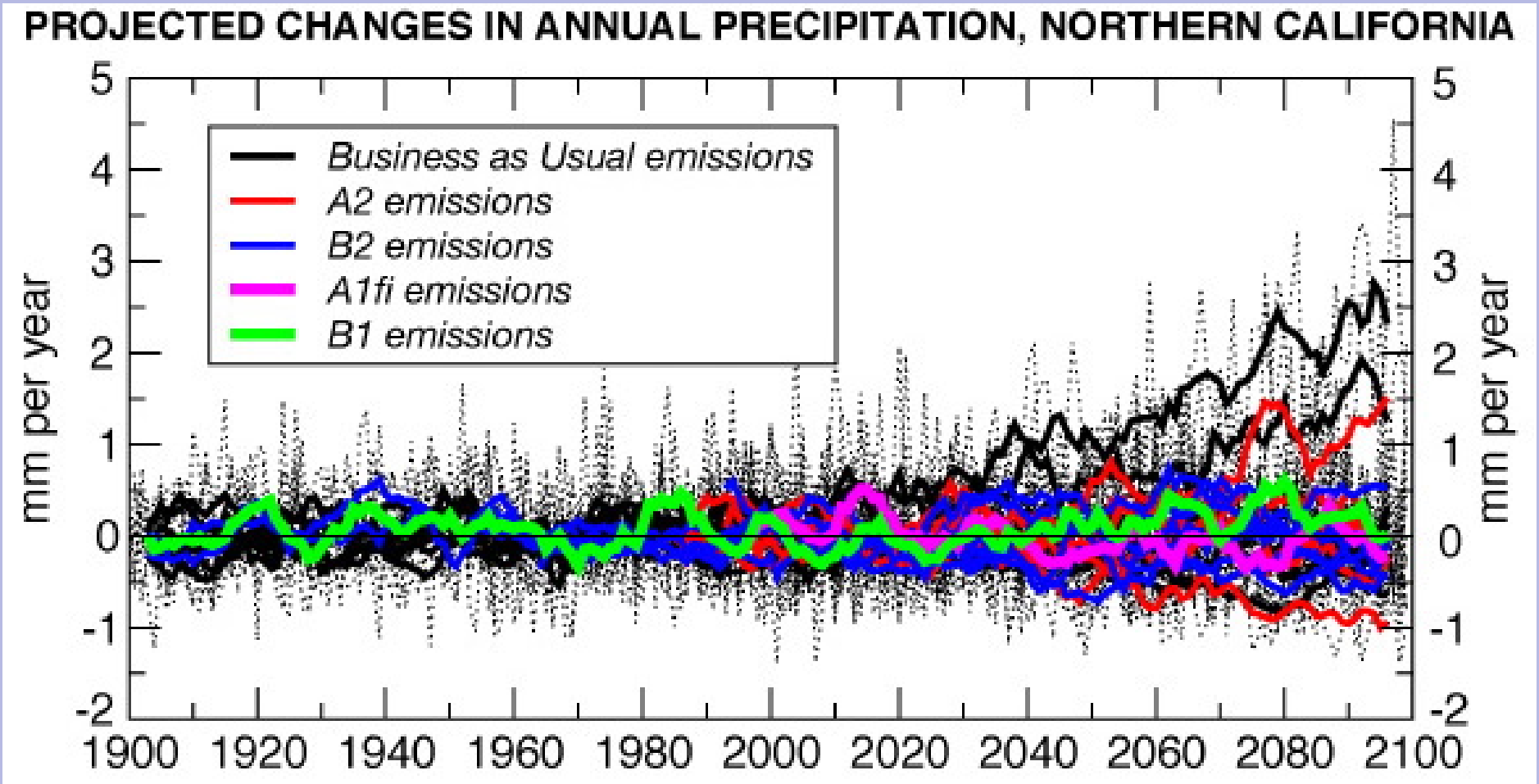
Note that the two models are much better than the coarse resolution global Reanalysis standard pressure level Fields (in red).

Recommendations for California Regional Model Development

- Continue the model development and intercomparisons, such as the REBI Expand this effort to perform an intercomparison of the downscaling of global warming simulations. This project should be accompanied by more detailed analysis than was possible during the first REBI project, providing skill mask, model systematic errors and ensemble averaging.
- Conduct dynamical downscaling of multiple-global model simulations to identify uncertainties in results due to global model simulations. Compare the uncertainties due to the global model and the uncertainties coming from interannual variability. Compare dynamical downscaling results with (limited variables) statistical downscaling results.
- Continue improving regional model physics. Particular emphasize snow model and marine stratocumulus parameterizations, and focus upon processes that are most crucial to California results. Continued attention should be given to determining which aspects of the physics result in the largest intermodel differences over California.

California Regional Model Development, con'd

- Develop and evaluate coupled regional atmosphere/ocean/land model(s) for the California region.
- Conduct modeling experiments with offline models, but linked to the forcing of atmosphere and coupled atmosphere/ocean/land models, regional and global. e.g., California's physical hydrology, water resources, coastal waves, air quality, and ecosystems.
- Work to obtain computer resources for modeling activities.
- Continue to collaborate across modeling, analysis, prediction and diagnostics for the California region. Move towards a comprehensive data assimilation model that incorporates multivariate environmental processes.



Although models unanimously indicate a warmer climate, they are undecided if it will get wetter or dry out

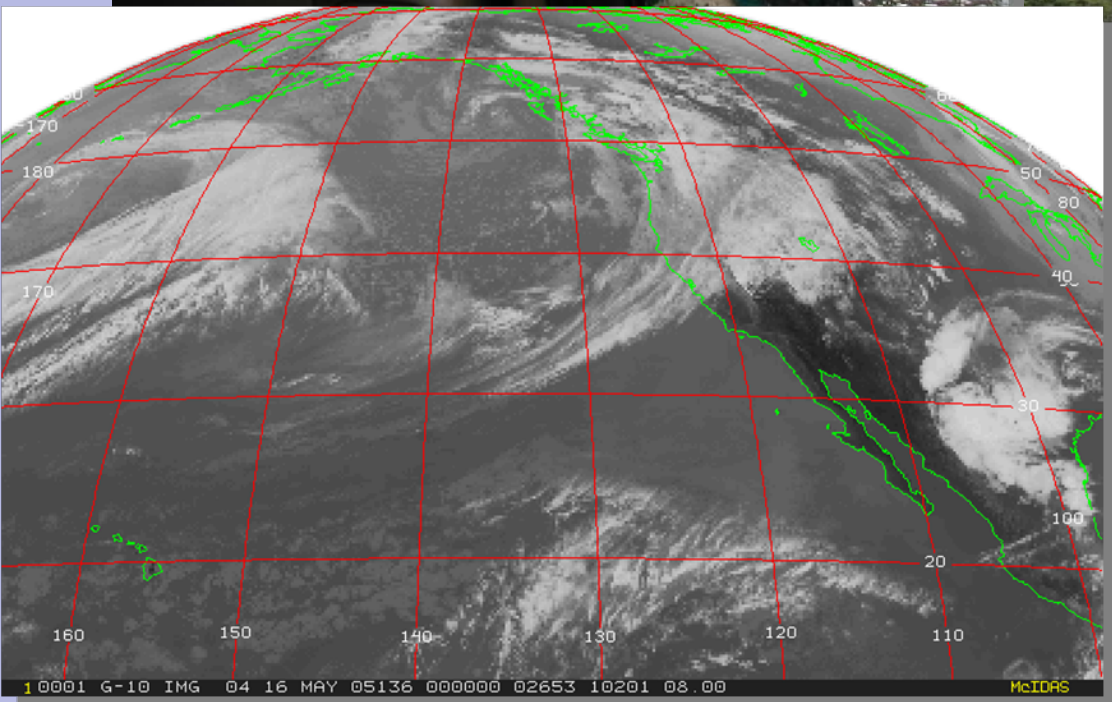
6 different climate models
5 emission scenarios,
IPCC SRES runs

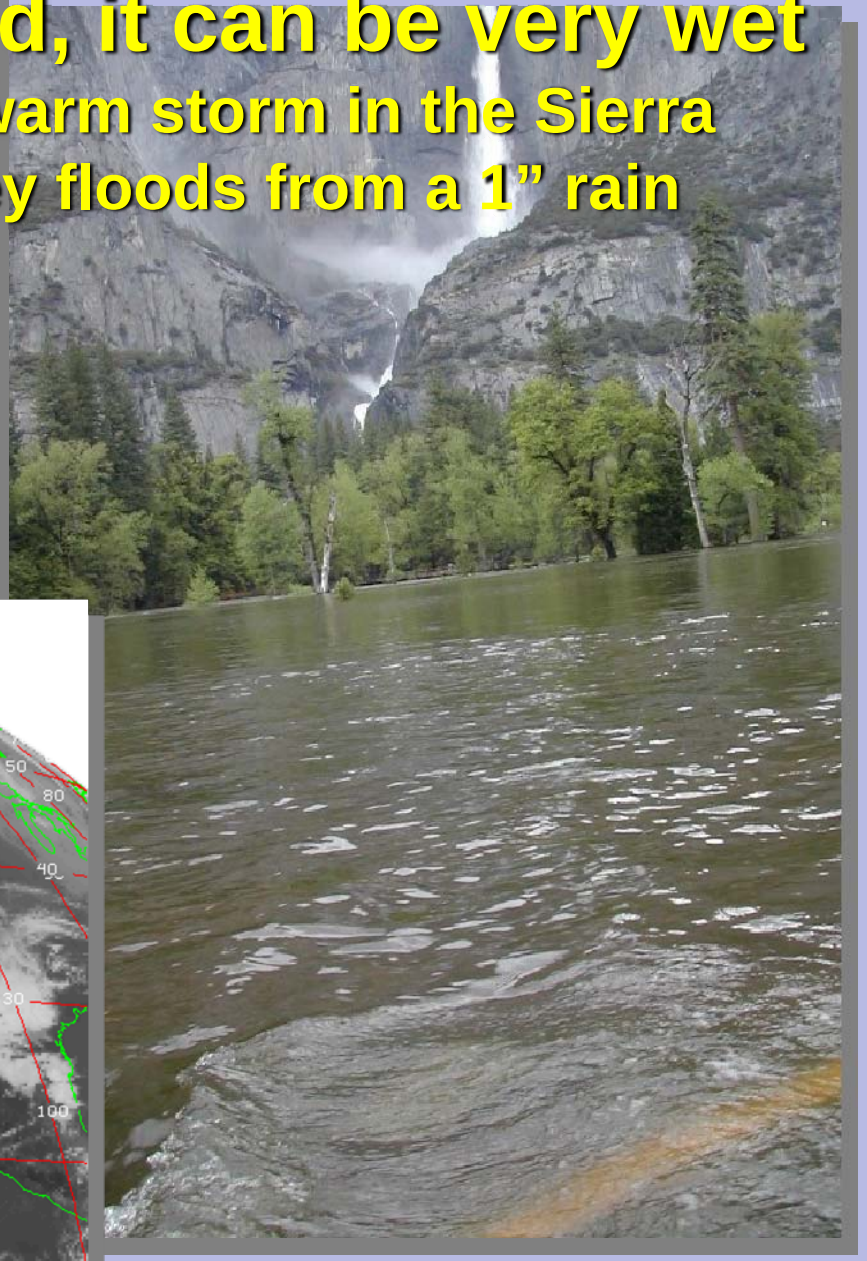
Mike Dettinger, 2005
San Fran. Estuary and Watershed Science

…on the other hand, it can be very wet

May 16th 2005 A warm storm in the Sierra

Yosemite Valley floods from a 1” rain





Ocean Beach, California , February 1983

storm-forced sea levels during an extreme tide, massive El Nino

Climate Diagnostics of Importance to California

- Climate Change Detection in California region—where, when, how much?

- Climate Change Attribution in California region—natural variability or related to anthropogenic forcings?

- Understanding and quantifying uncertainties within and among climate change projections and expected impacts

- Understanding Climate linkages within the climate and hydrologic system

- Understanding climate impacts, along with other factors in present-day and future changes

Diagnostics, con'd-1

- Understanding Climate linkages within the climate and hydrologic system

- What are the best predictors of long-term climate variability in California and are these also the best predictors of long-term climate change influences?

- What is the role and future of Pacific (and global) climate modes like ENSO, as affects California?

- How much of projected California climate change reflect local radiative changes and how much will be advected into the region from global responses?

Diagnostics, con'd-2

- How does the 3-dimensional structure of winds, humidity and other air mass characteristics affect precipitation, e.g. in high precipitation storm events?

- Will major storms change in frequency or strength?

- How do ocean and land feedbacks affect weather and climate? What is the role and future of coastal upwelling and coastal clouds and their effects on coastal and inland climates?

- What is the aerosol budget ? How do aerosols affect precipitation and snowmelt?

- How/why has vegetation changed over the last century, how will vegetation change as climate changes and how will that affect climate and hydrology?

Diagnostics, con'd-3

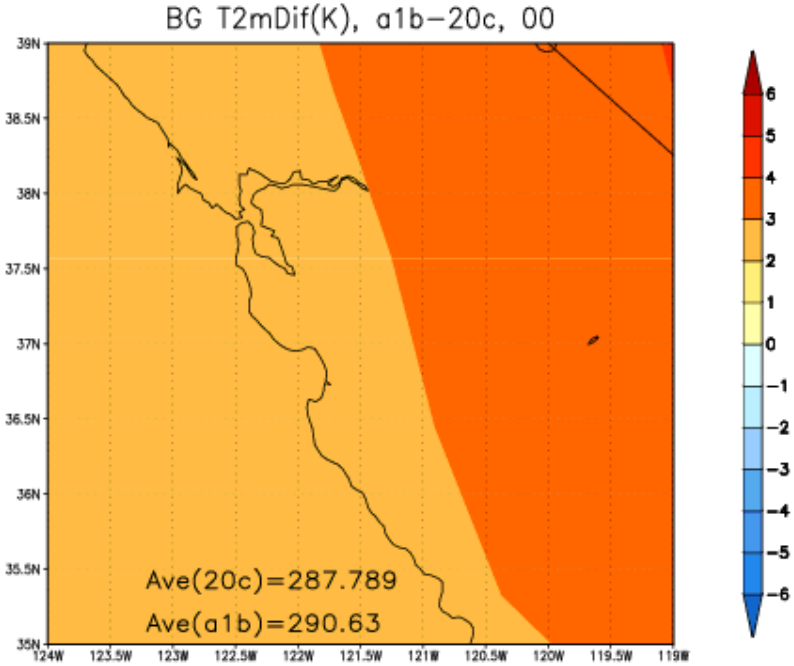
- How will urban climates change as climate changes? Which urban centers are likely to be most impacted by warming and other climate changes?

- How will climate warming and other climate change effects vary from the coast to the interior and from low to high altitude settings in California?

- Which critical micro-climates will respond adversely to climate change?

- Will droughts increase in frequency, intensity or duration? How will atmospheric demands for evaporation and transpiration change?

- How will the impacts of climate change cut across multiple sectors? factors in present-day and future changes?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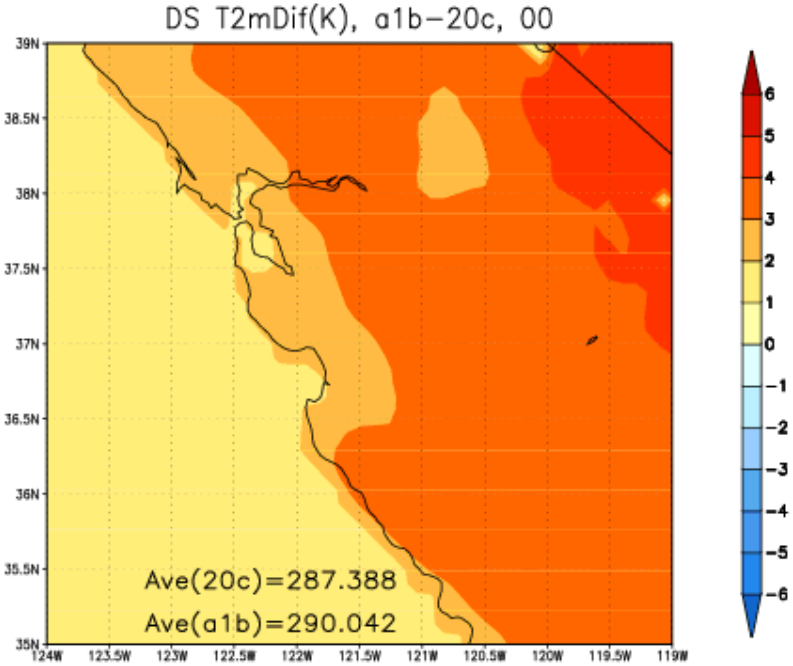
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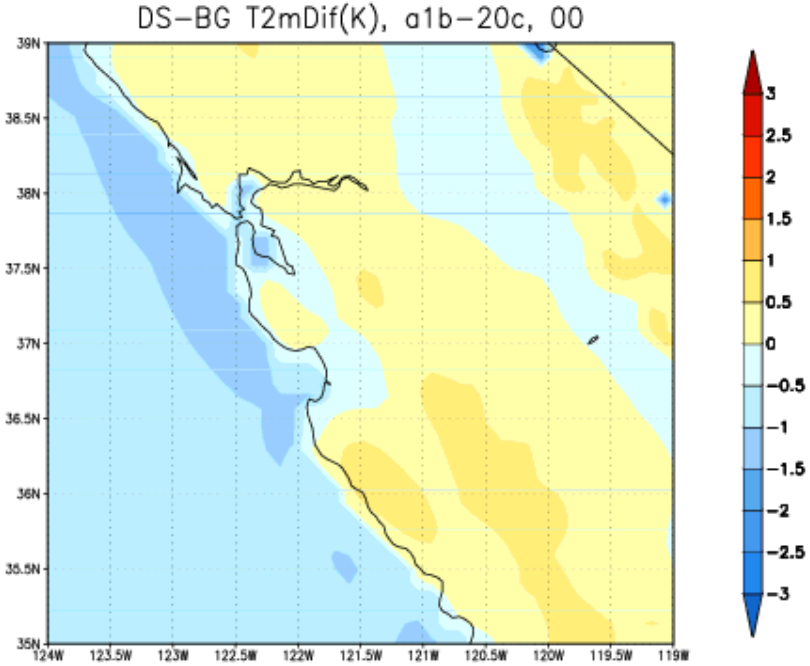
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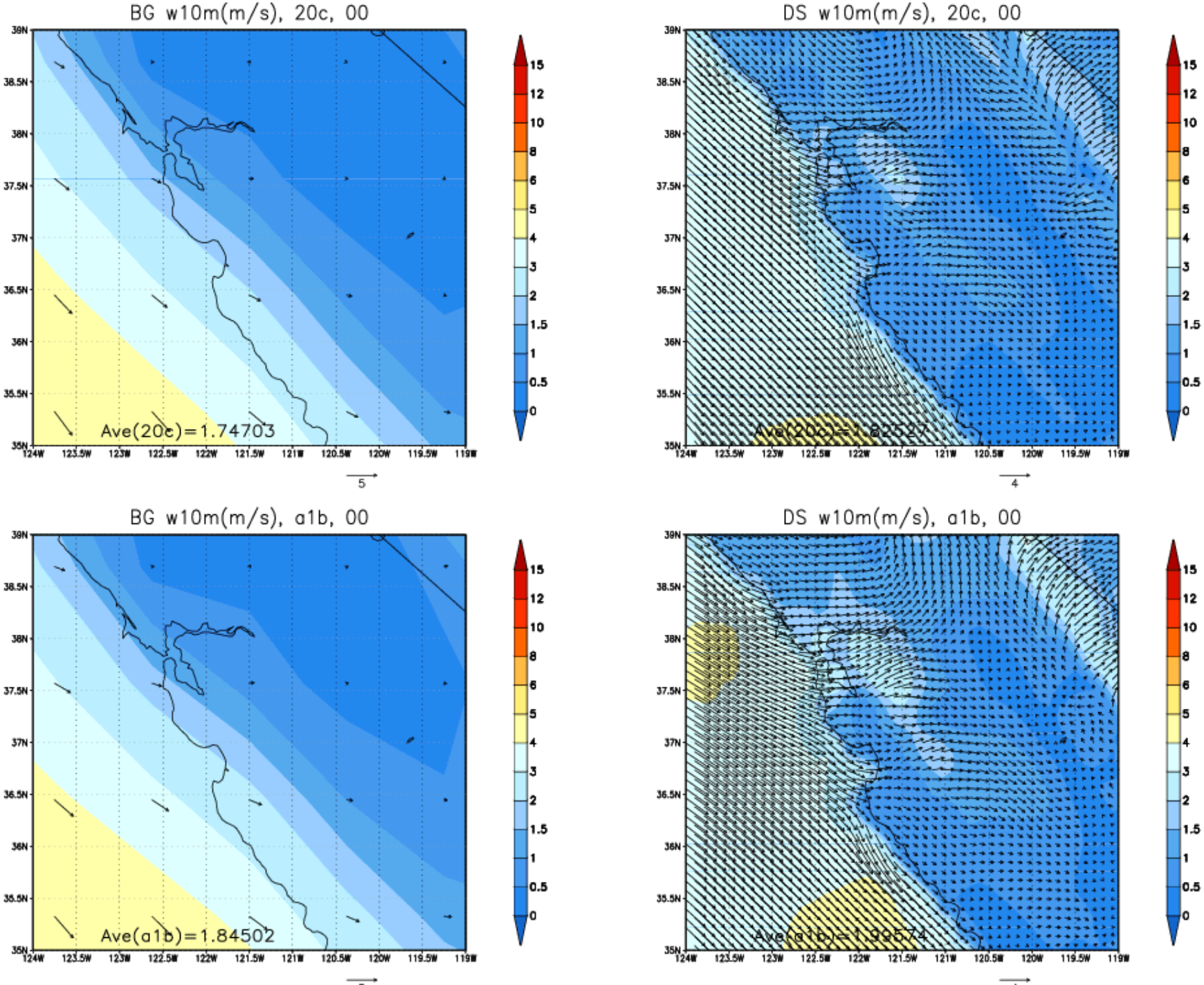
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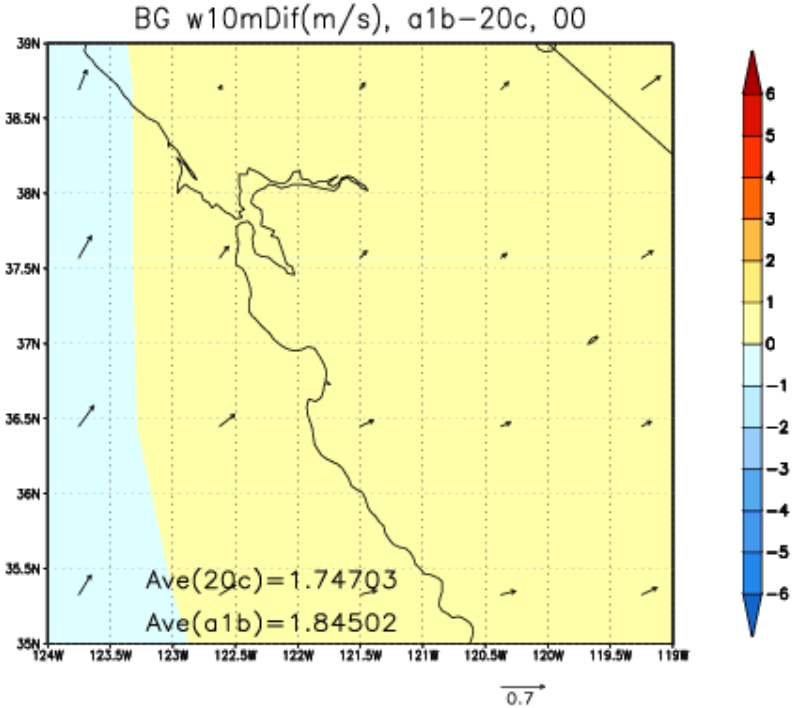
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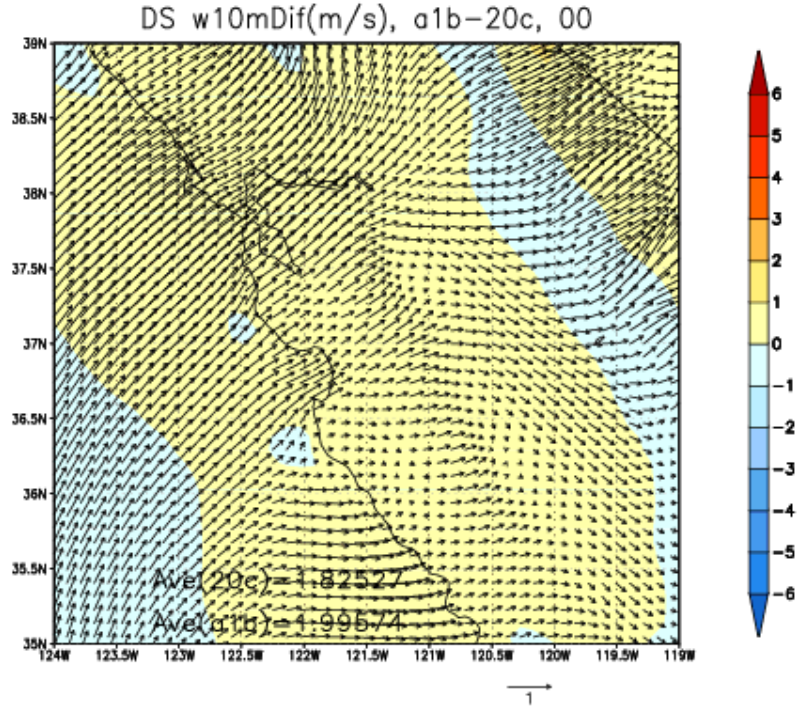
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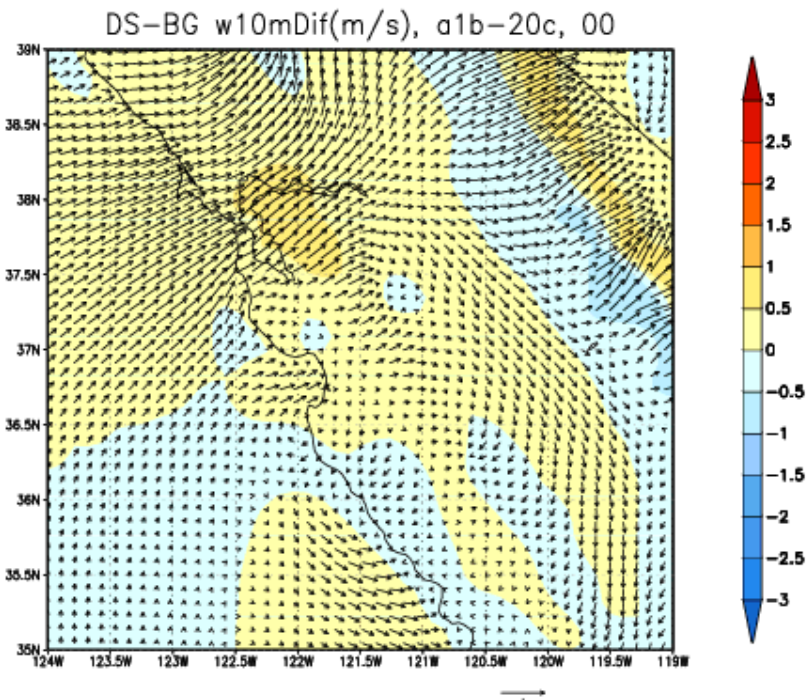
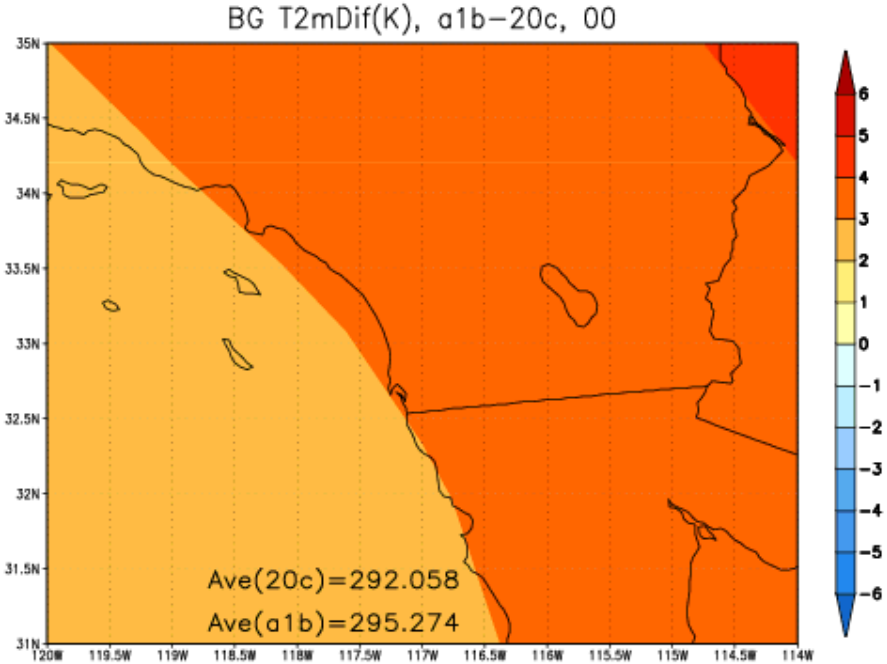
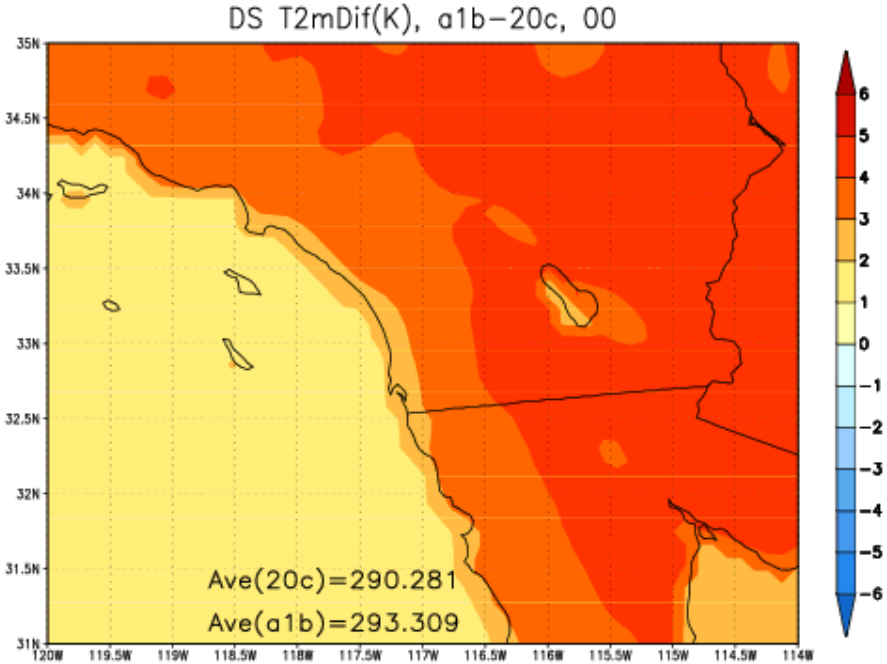
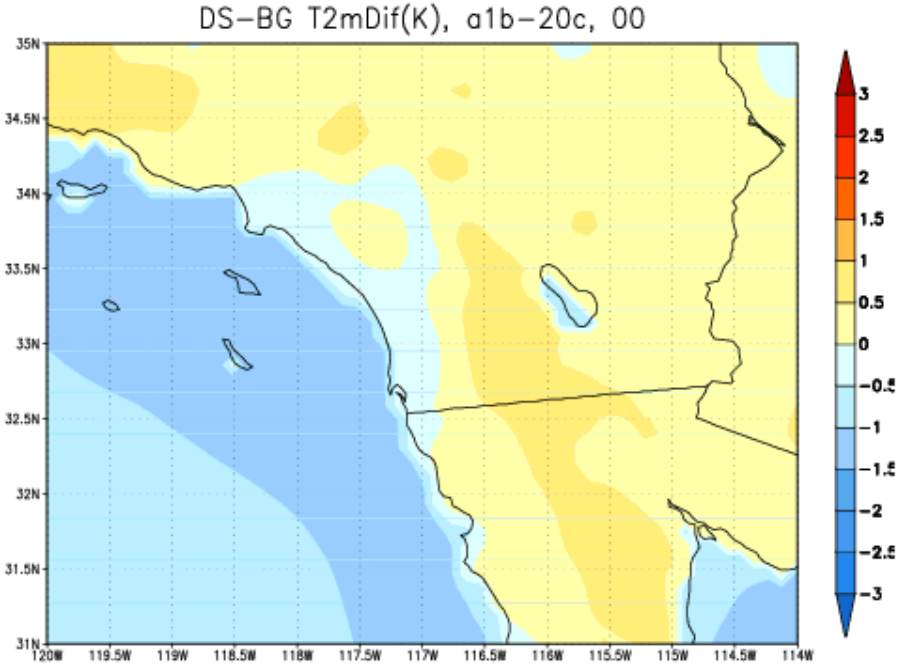
Ave(a1b)=1.99574
1


DS−BG w10mDif(m/s), a1b−20c, 00


BG T2mDif(K), a1b−20c, 00
Ave(20c)=292.058
Ave(a1b)=295.274


DS T2mDif(K), a1b−20c, 00
Ave(20c)=290.281
Ave(a1b)=293.309


DS−BG T2mDif(K), a1b−20c, 00

8/25/2008

Comments Welcome

please send comments to

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