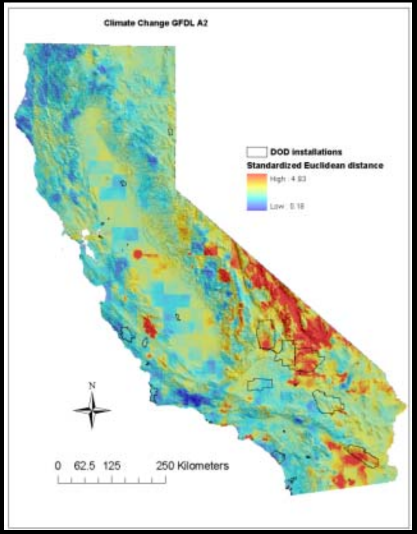
Unit 2: Elements of a Vulnerability Assessment: Exposure

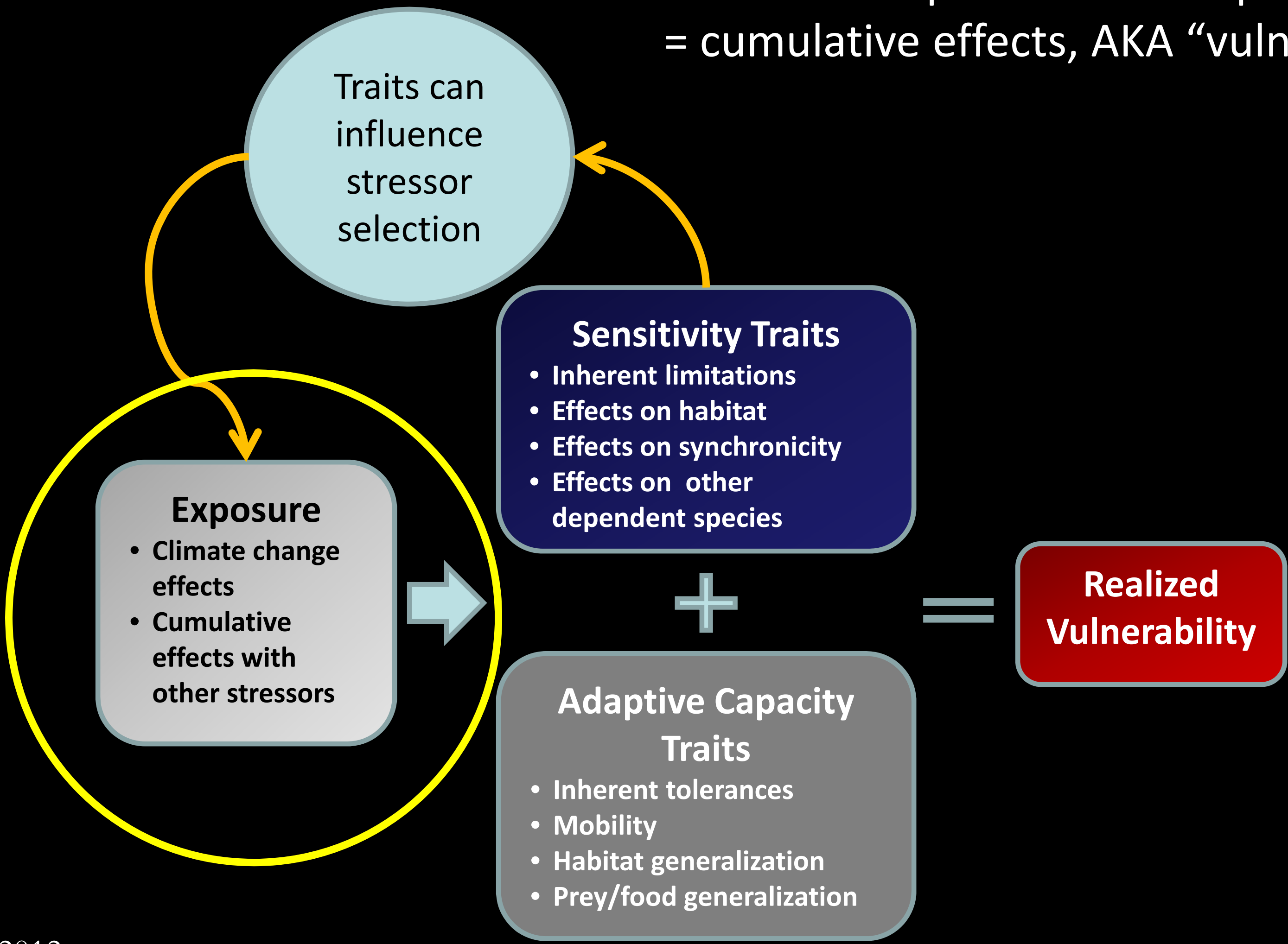


Exposure to What?

- Climate change direct and indirect effects
- Other current, planned, forecast stressors

Vulnerability Model

Combined exposure less adaptive capacity = cumulative effects, AKA “vulnerability”



Crist et al. 2012

Where Do I Start?

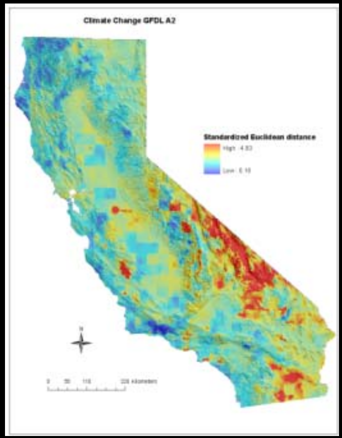
- Useful to have a conceptual model to think through all stressors to be assessed and how they can affect resources
  - Precursor to "response models" covered in the assessment section
- Can also be greatly informed by scenario-based planning approaches to identify potential future stressors

What do you care about?

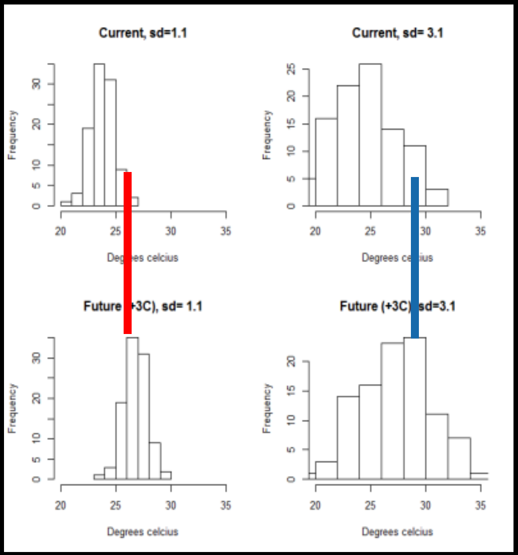
- Max temp
- Min temp
- # of days below freezing
- Degree days
- Amount of precipitation
- Timing of precipitation
- Form of precipitation
- Persistence of precipitation

Climate Change Exposure

Measure of how much of a change in climate or other secondary factors a species or system is likely to experience



- Primary factors
  - Shifts in temperature, precipitation
  - Seasonality and extremes more important than averages
  - Historical inter-annual variation
- Secondary factors, e.g.
  - Sea-level rise
  - Soil moisture
  - Hydrologic & chemical changes
  - Shifting sea ice dynamics

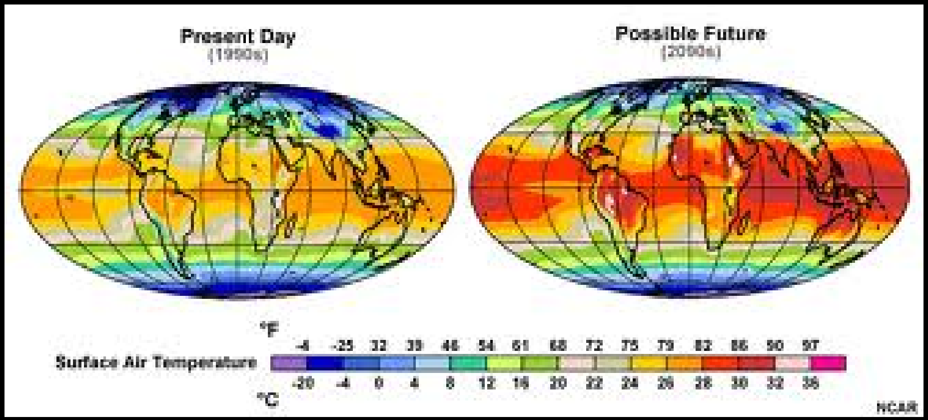


Sources & Differences in Climate Change Data

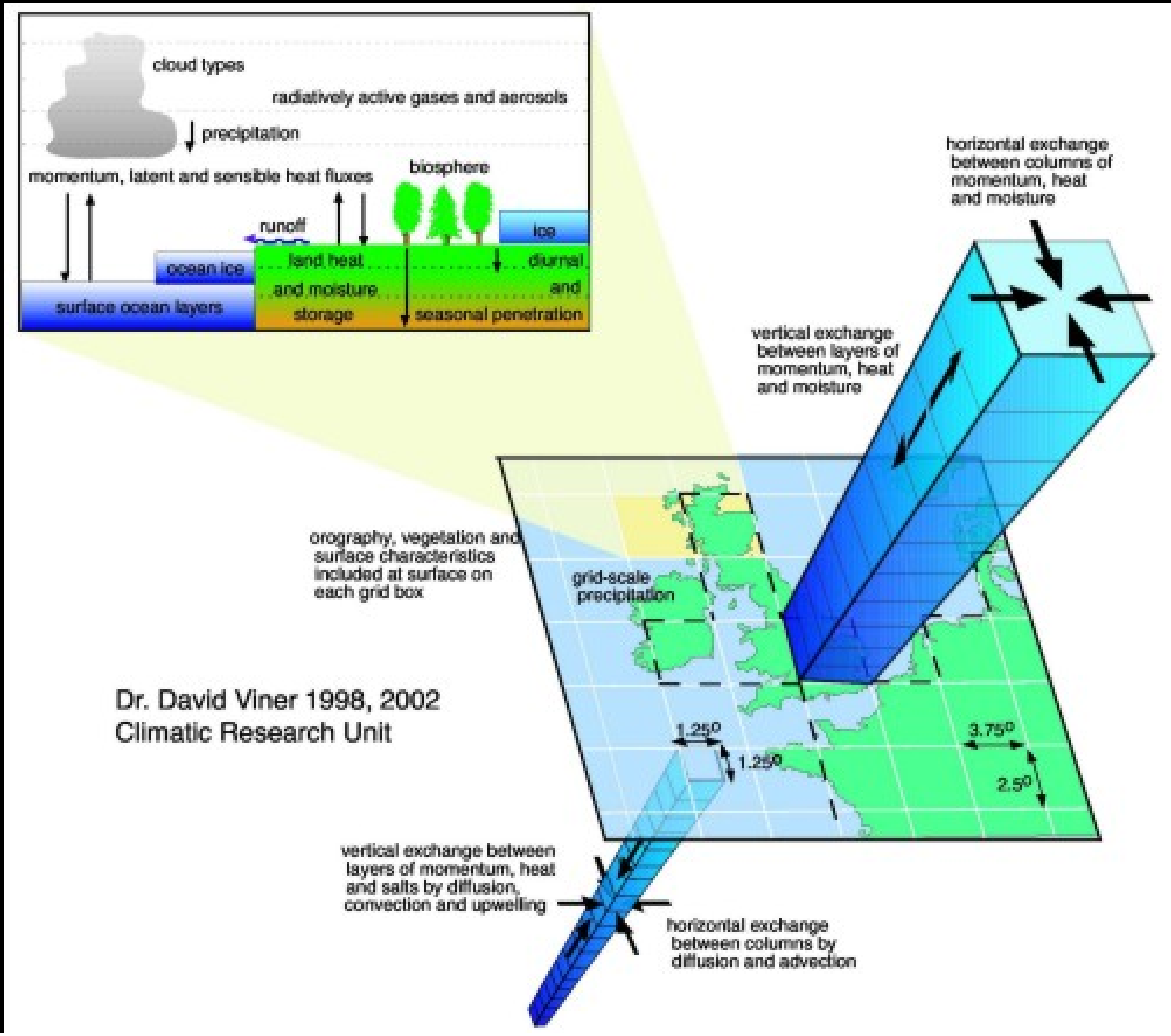
- All climate change data come from Global Climate Models (GCMs)
- Downscaled CC data are now ubiquitous but not standardized, use different methods and produce different variables
- Future forecasts don’t come with probabilities
  - Ensembles
  - Scenario planning

Global Climate Models (GCMs)

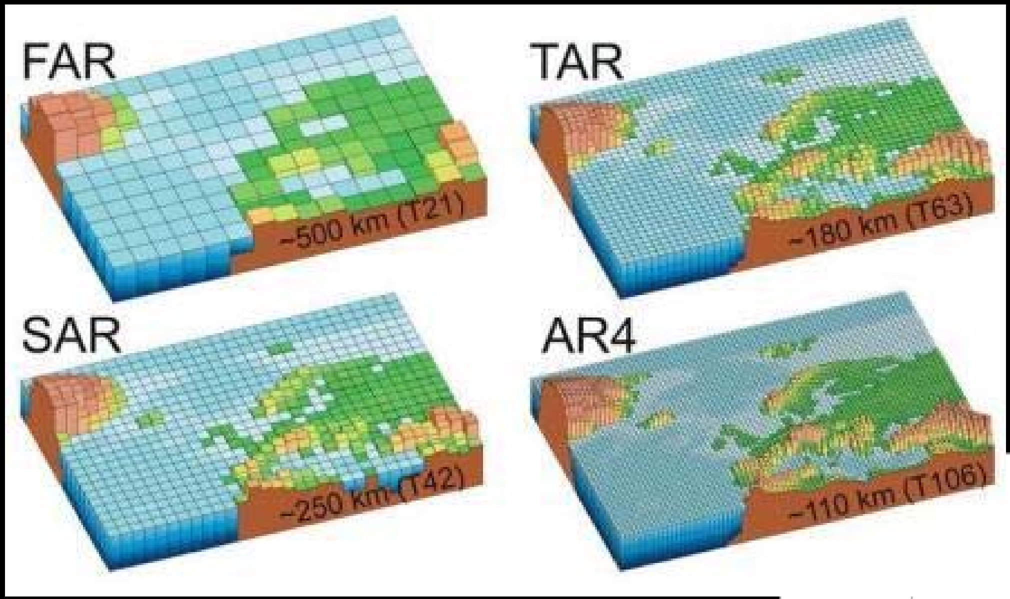
- Global climate models
  - Based on principles of thermodynamics and fluid dynamics
  - Describe complex interaction between atmosphere, cryosphere, oceans, land, and biosphere
  - Large-scale (~100 km^2 but constantly decreasing)

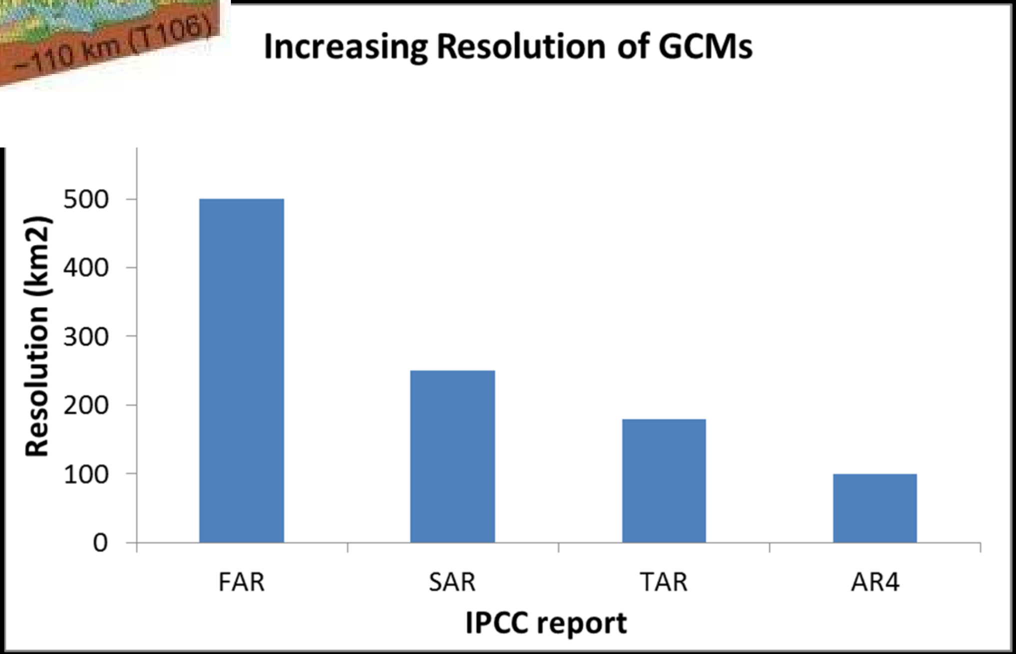


Global Climate Models (GCMs)



Modeling climate: scale





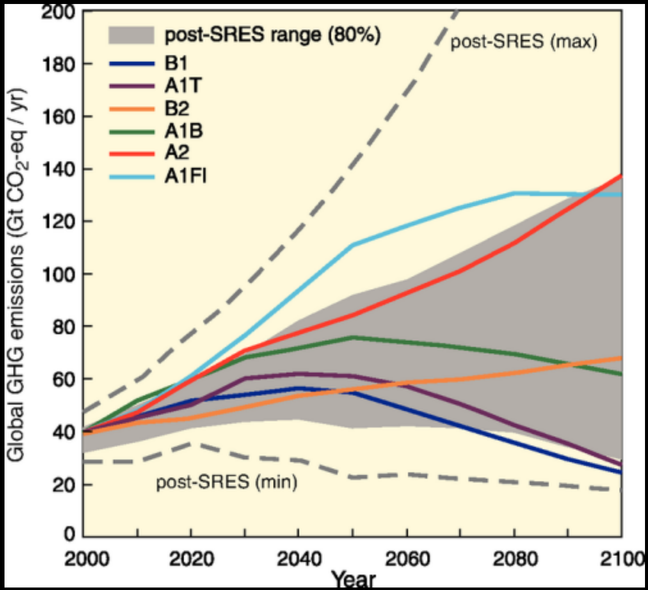
Projecting Global Climate Models

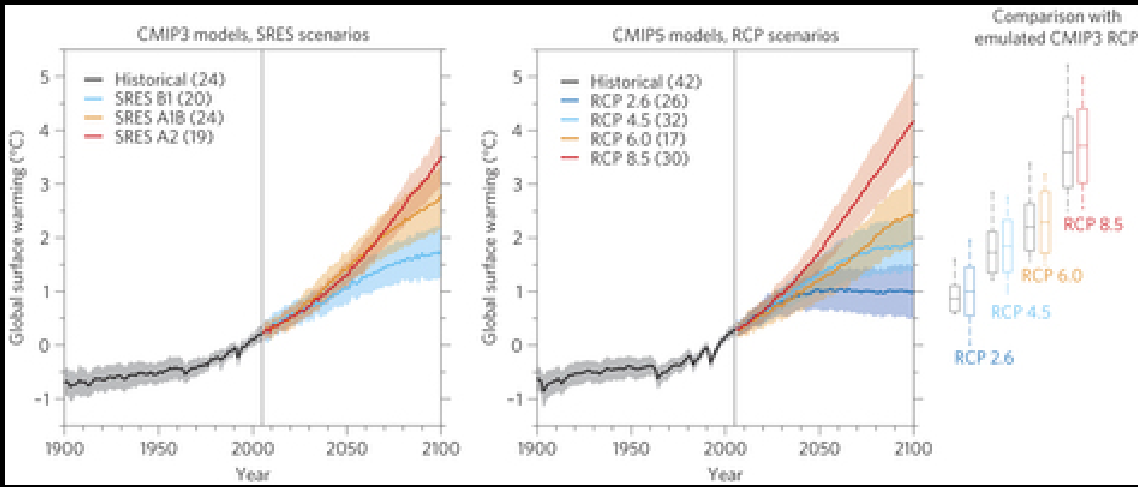
Projections for changes in climatic variables (e.g., average temperatures, precipitation) based on one or more scenarios for emissions of greenhouse gases, particulates, other factors

- Factors to consider in applying GCMs
  - Uncertainties in scenarios (depend on policy, economics, population, etc.)
  - Variation among output from different modeling teams
  - Confidence in results often higher in nearer term, also higher for temperatures than precipitation

Which Scenarios to Use?

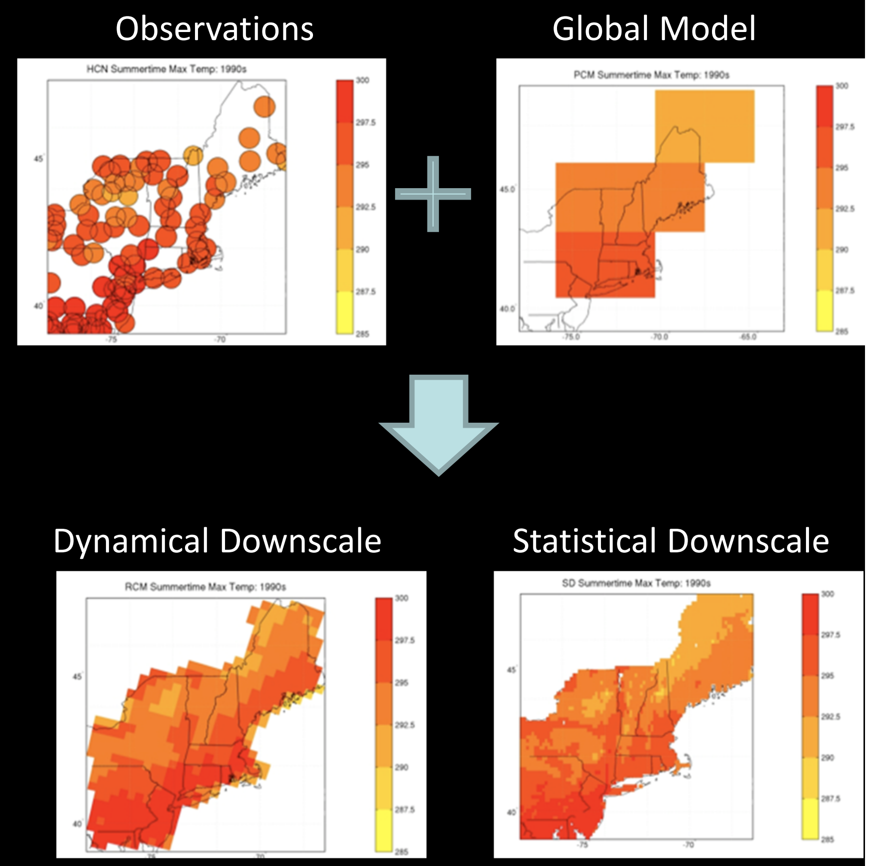
- Factors to consider
  - Length of your planning horizon
  - Sensitivity of key species or processes (helps ID variables to consider)
  - Relationship to current trends
  - Level of acceptable risk
- Level of detail
  - Specific numbers
  - A range of numbers
  - Directionality





Is Downscaled Information Necessary?

- Factors to consider
  - Scale of area being managed
  - Complexity of area being managed
- Benefits and limitations
  - Data often more relevant for management scale
  - Not necessarily more “accurate”
  - Better for modeling of secondary factors



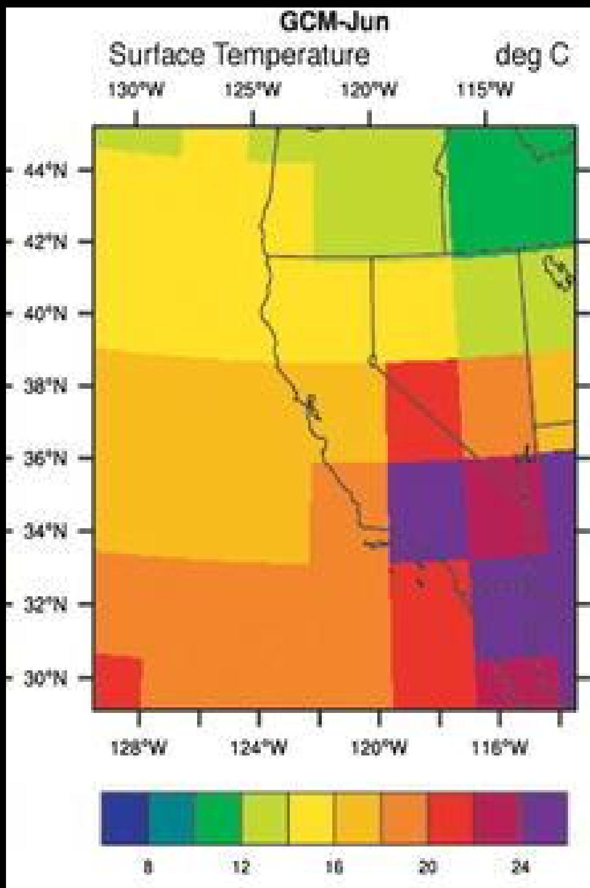
What's the rationale for downscaling?

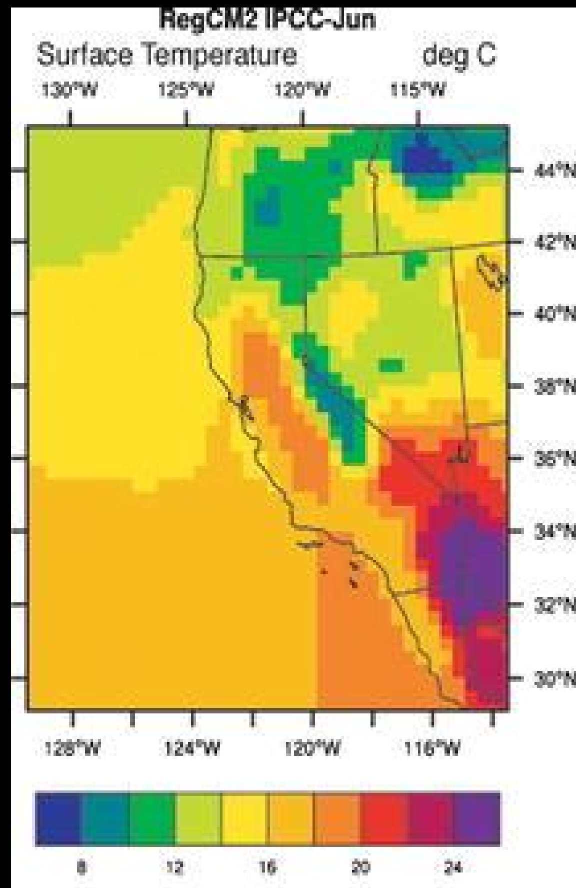
- *...studies of the impacts of projected global warming on a regional scale...necessitates the development and application of scenarios to specific problems... Cohen (1990)*
- *...Even if global climate models in the future are run at high resolution there will remain the need to 'downscale' the results from such models to individual sites or localities for impact studies... DOE (1996)*
- *...'downscaling' techniques, [are] commonly used to address the scale mismatch between coarse resolution global climate model (GCM) output and the regional or local catchment scales required for climate change impact assessment and hydrological modeling... Fowler & Wilby (2007)*

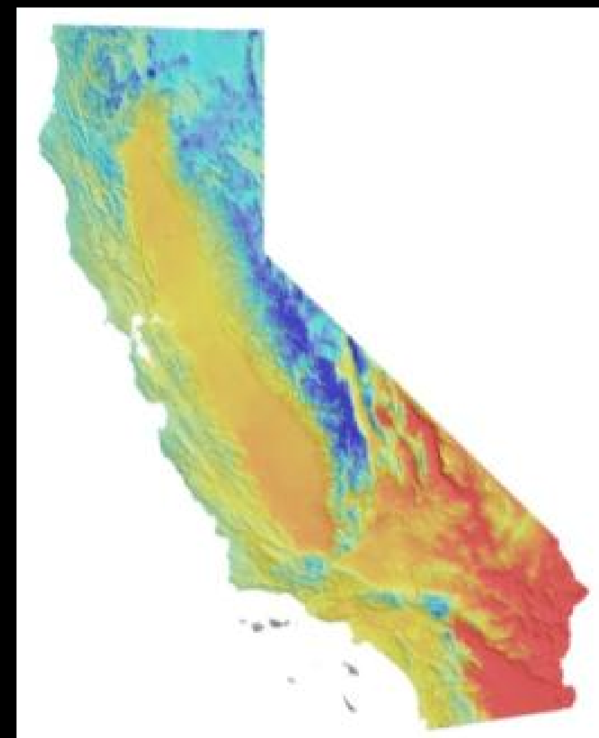
Downscaling GCMs

General Circulation Model (GCM): 2-3°

Regional Climate Model (RCM): 30 km

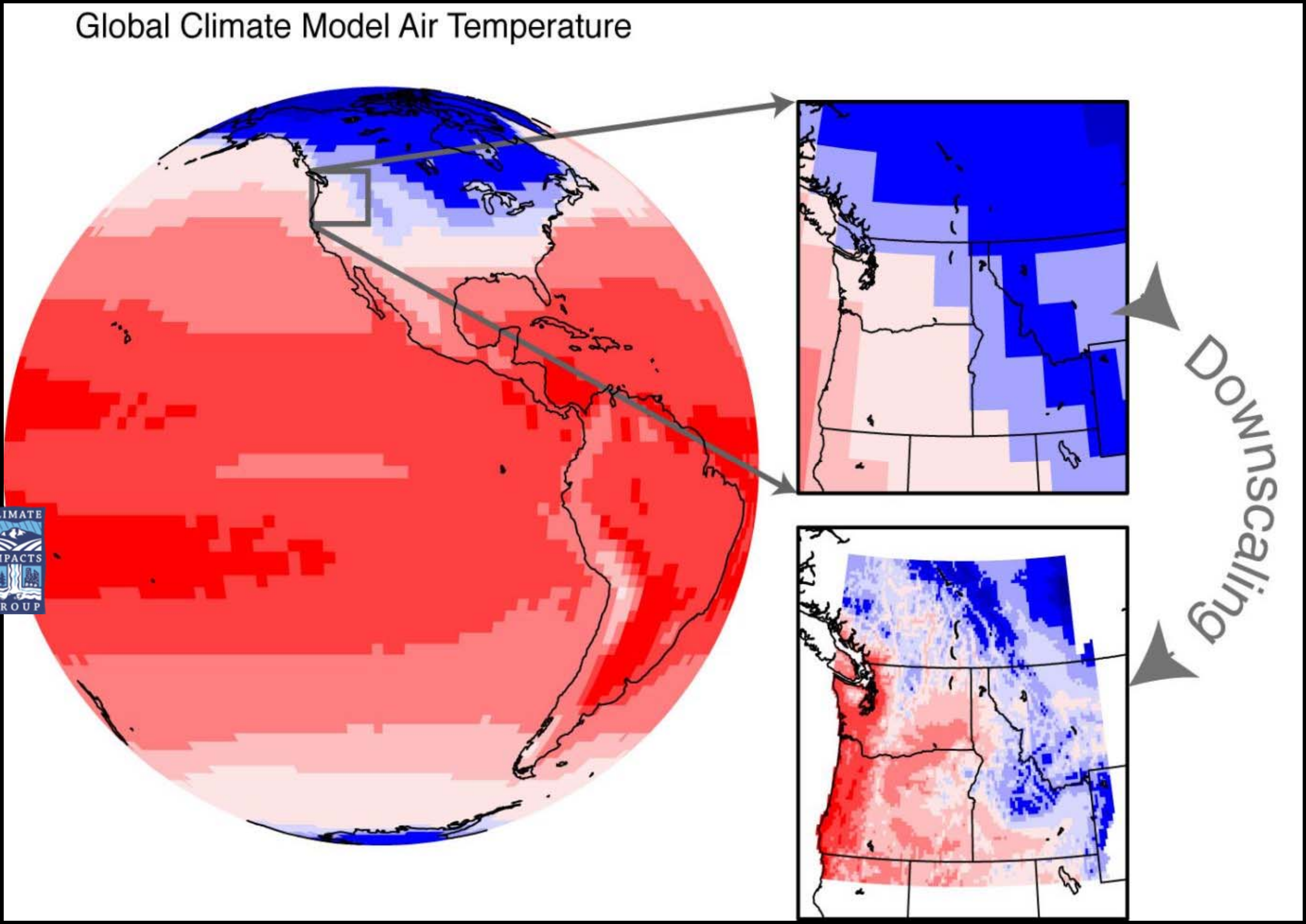




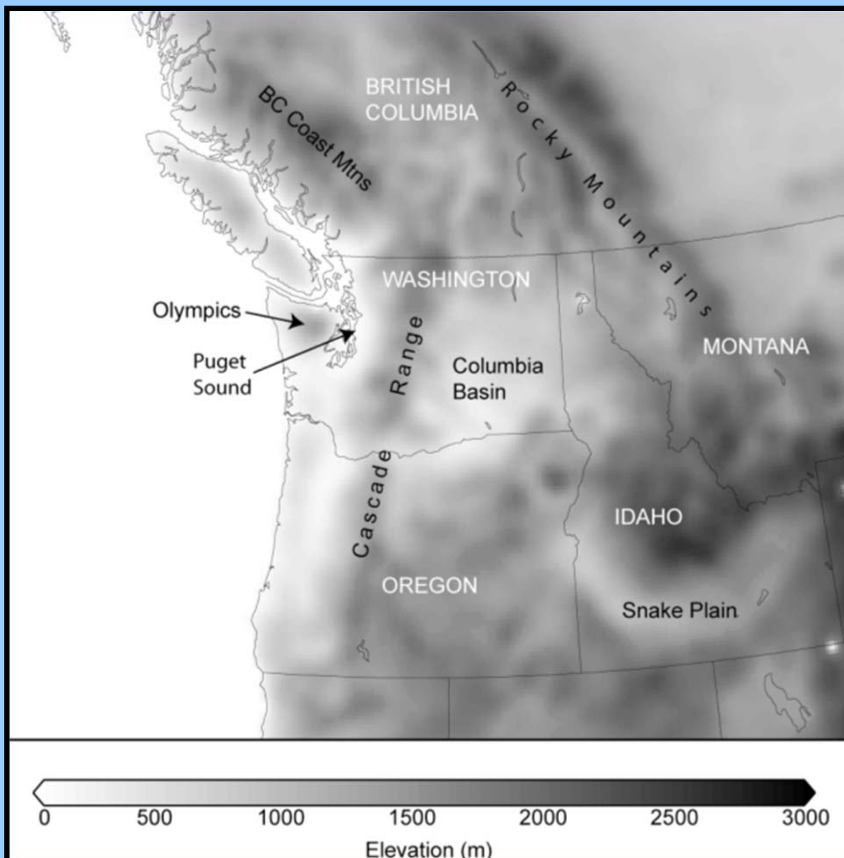


Regional Climate Models from M. Snyder (UCSC)
RegCM3 (inputs from GFDL CM2.1, NCAR CCSM3.0
800m

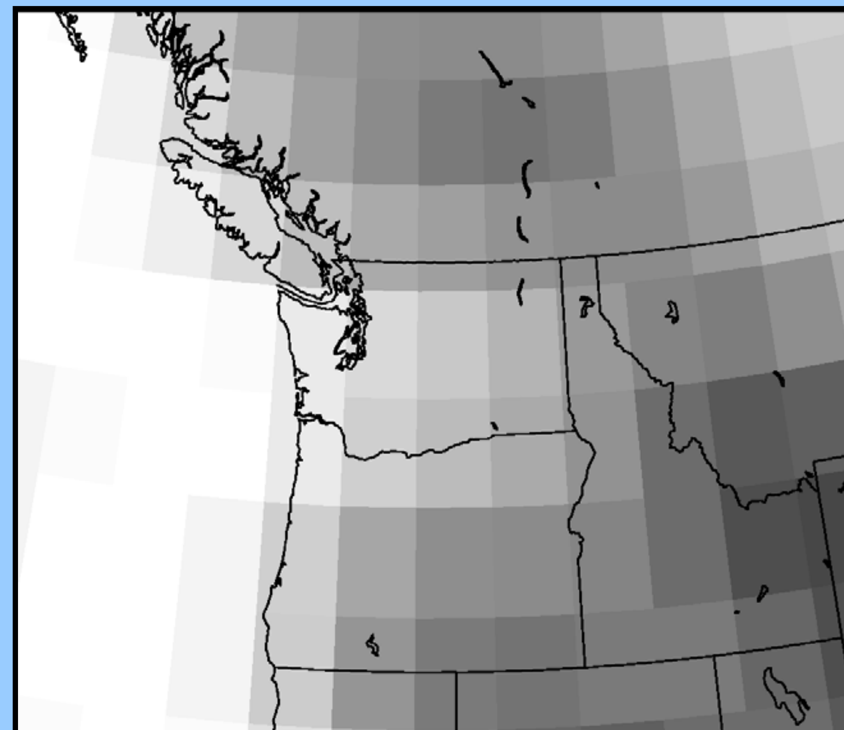
Regionalizing Effects from Global Model Predictions



Tortured Topography with Sparse Data Requires Dynamical Downscaling

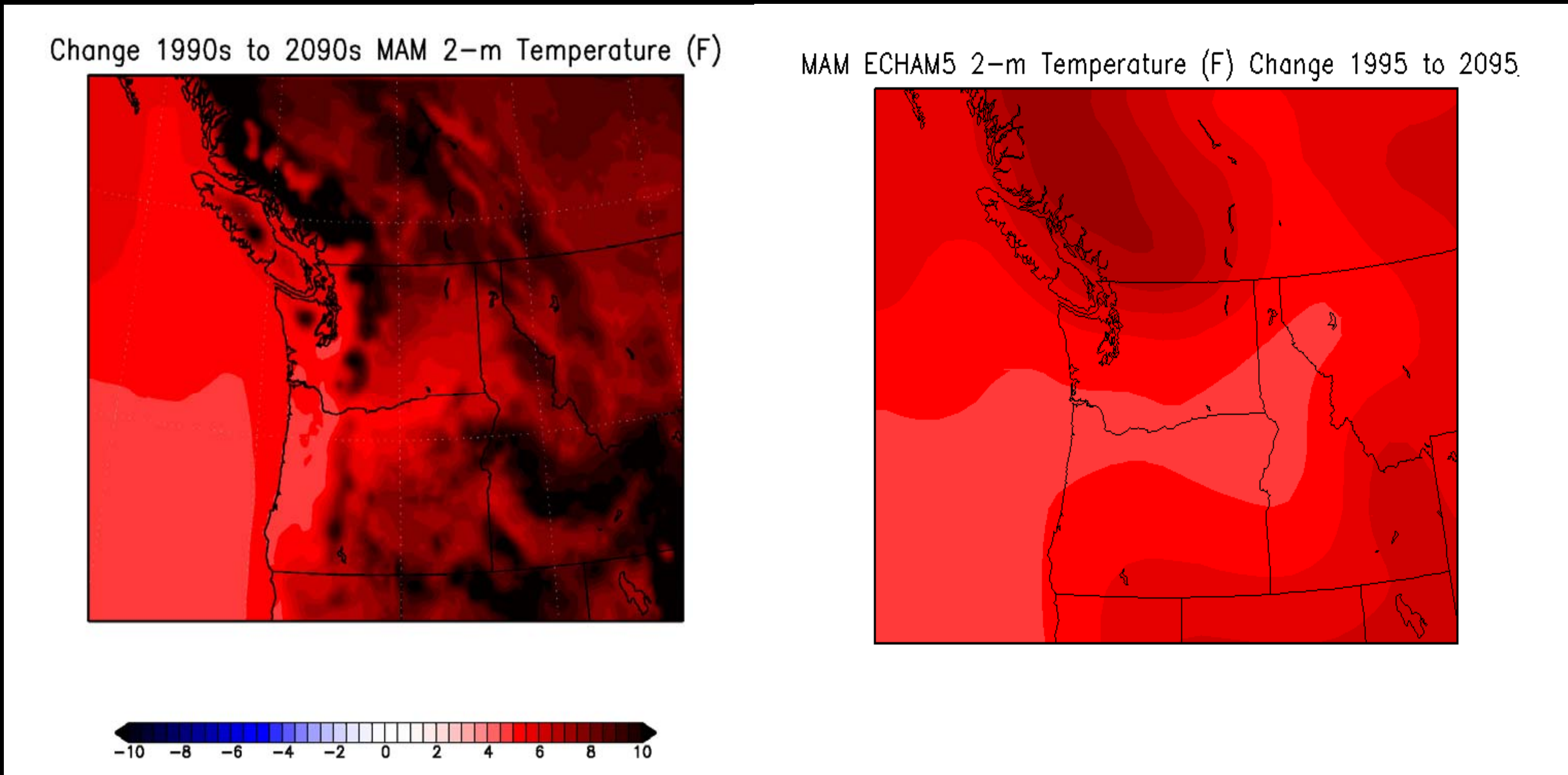


15 km MM5 Topography



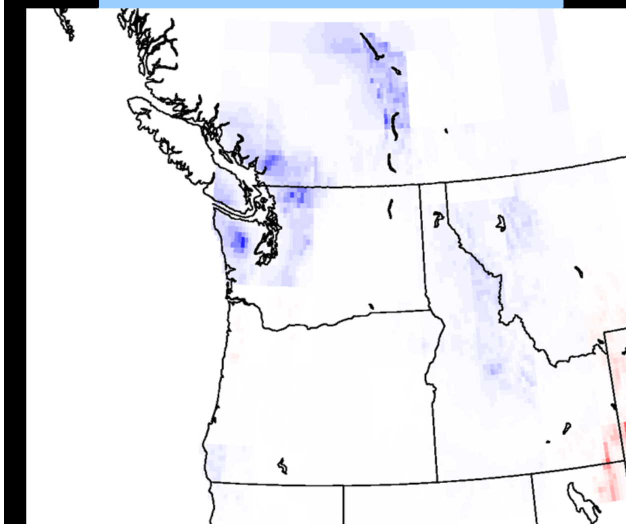
150 km ECHAM5 Topography

Downscaled Solution from A2 Scenario Differs at Regional Scale

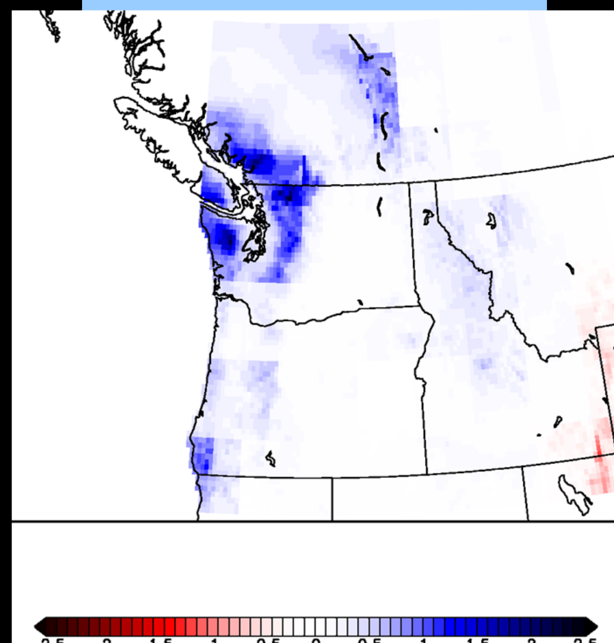


Change in Precipitation (mm day^{-1})
Sep-Oct-Nov
1990s to 2050s

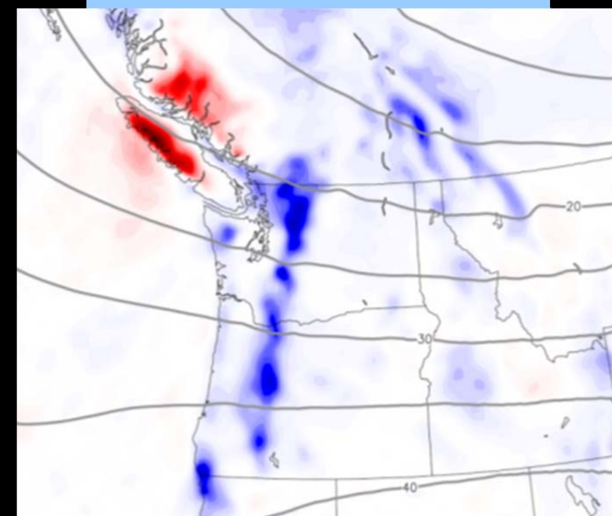
Statistically Downscaled Precipitation Only



Statistically Downscaled Precipitation + Winds



Dynamically Downscaled with MM5



CLIMATE IMPACTS GROUP

Downscaling Projected GCMs: techniques

- Multiple techniques available to convert GCM data to smaller grid sizes (50 – 1 km^2)
  - Dynamic: modeling embeds regional climate model w/in GCM (RCM can account for local surface-rainfall interactions, cloud formation, etc)
  - Statistical: statistical relationship identified between GCM and local variables (ex: GCM atmospheric pressure forecasts and local rainfall) – relationships used to downscale GCM for specific areas
  - Change-factor (Delta method): historical values from observations subtracted from GCM values – differences are used to correct modeled values at smaller scale

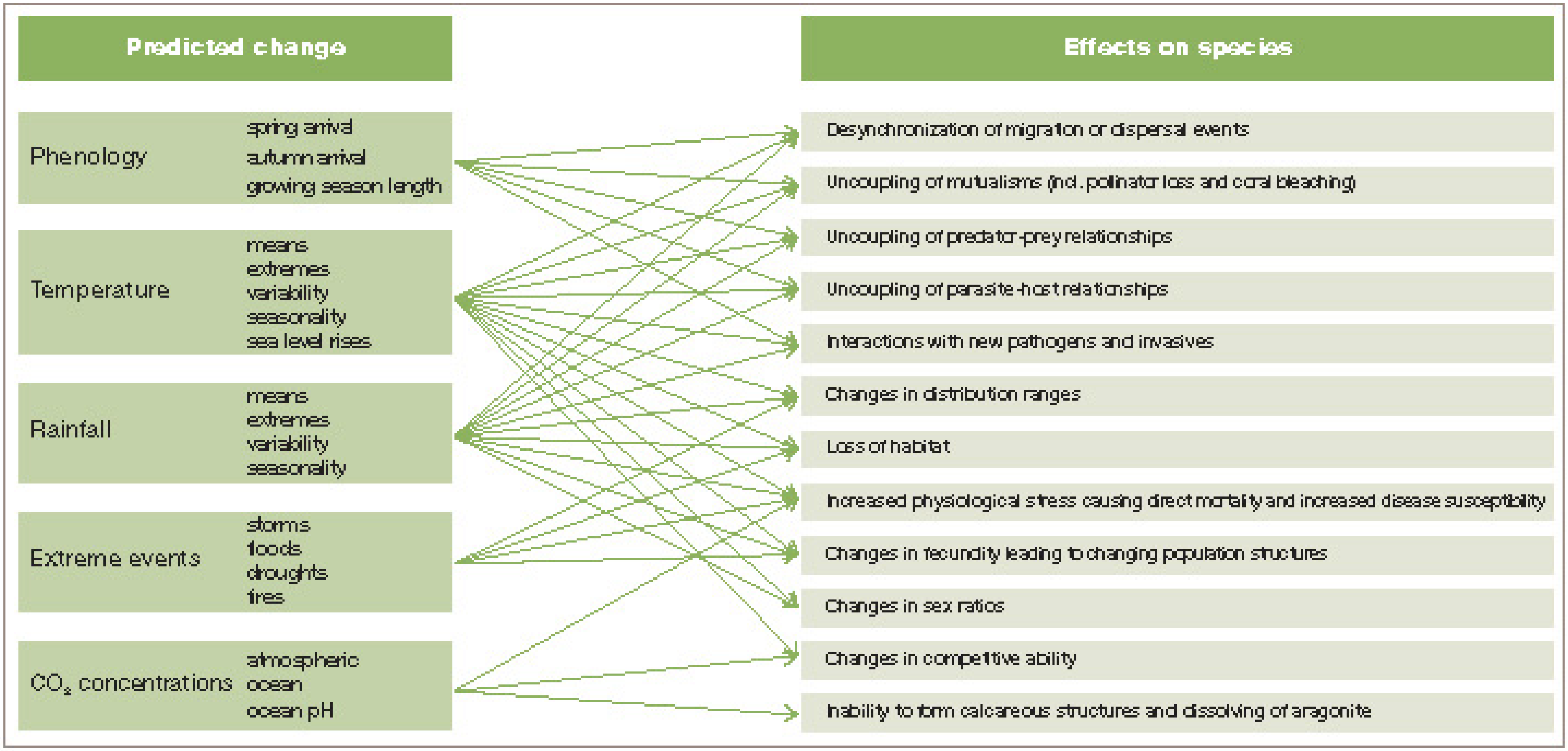
Questions to Ask About Downscaled Data

- What GCM(s) is it based on, and how well do they perform for this particular region?
- Downscaling method used and suitability for the purpose and region?
- Adequacy (density) of weather stations to calibrate the downscale model
- Is the grid cell size supportive of the relative uncertainty in the inputs?

Secondary Factors

- All resources will be exposed to direct climate changes
- Not all resources will be exposed to all secondary climate change effects or may be irrelevant for any particular resource
- Conceptual model/expert involvement can assist in determining what effects are necessary to assess, based on e.g.,
  - Location, e.g., proximity to coast, landscape position
  - Dependence on regimes, e.g., hydro, precip, fire
  - Sensitivity to gradients, e.g., soil moisture, water temperature or salinity

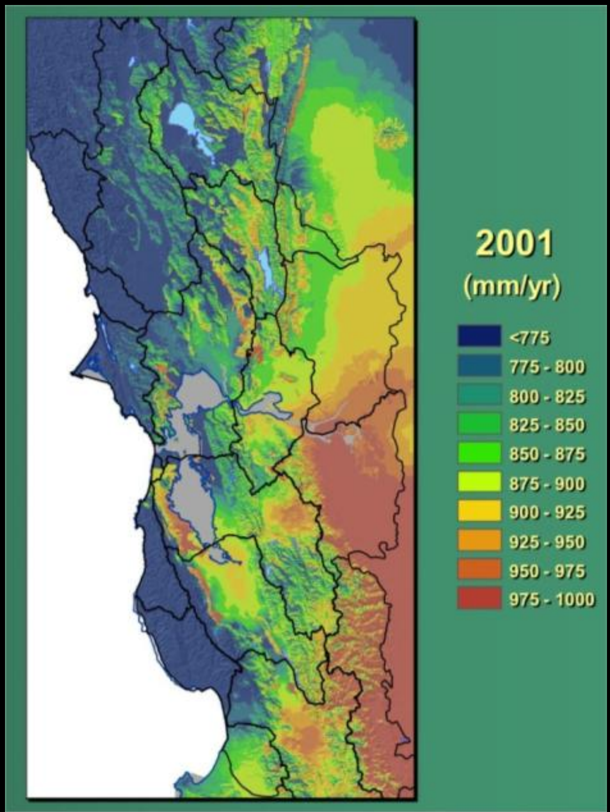
Some complications



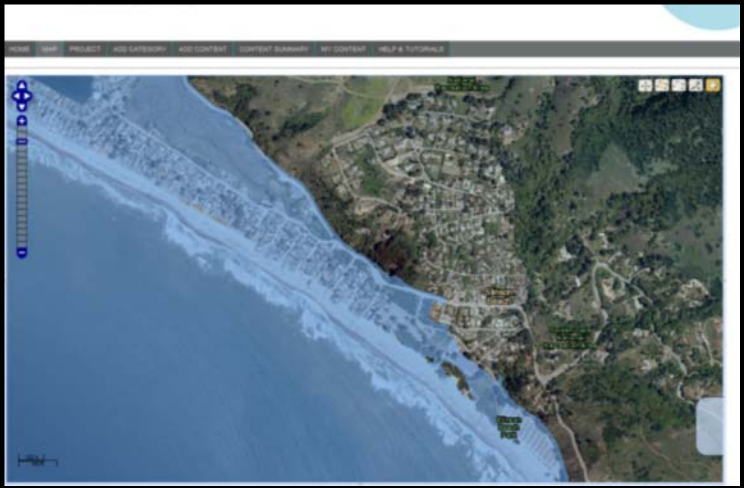
CC Exposure: secondary factors

- Examples of secondary factors
  - Sea level rise
  - Hydrologic regime
  - Soil moisture
  - Fire regime
  - Snow pack vs rainfall
  - Sea ice

http://data.calcommons.org



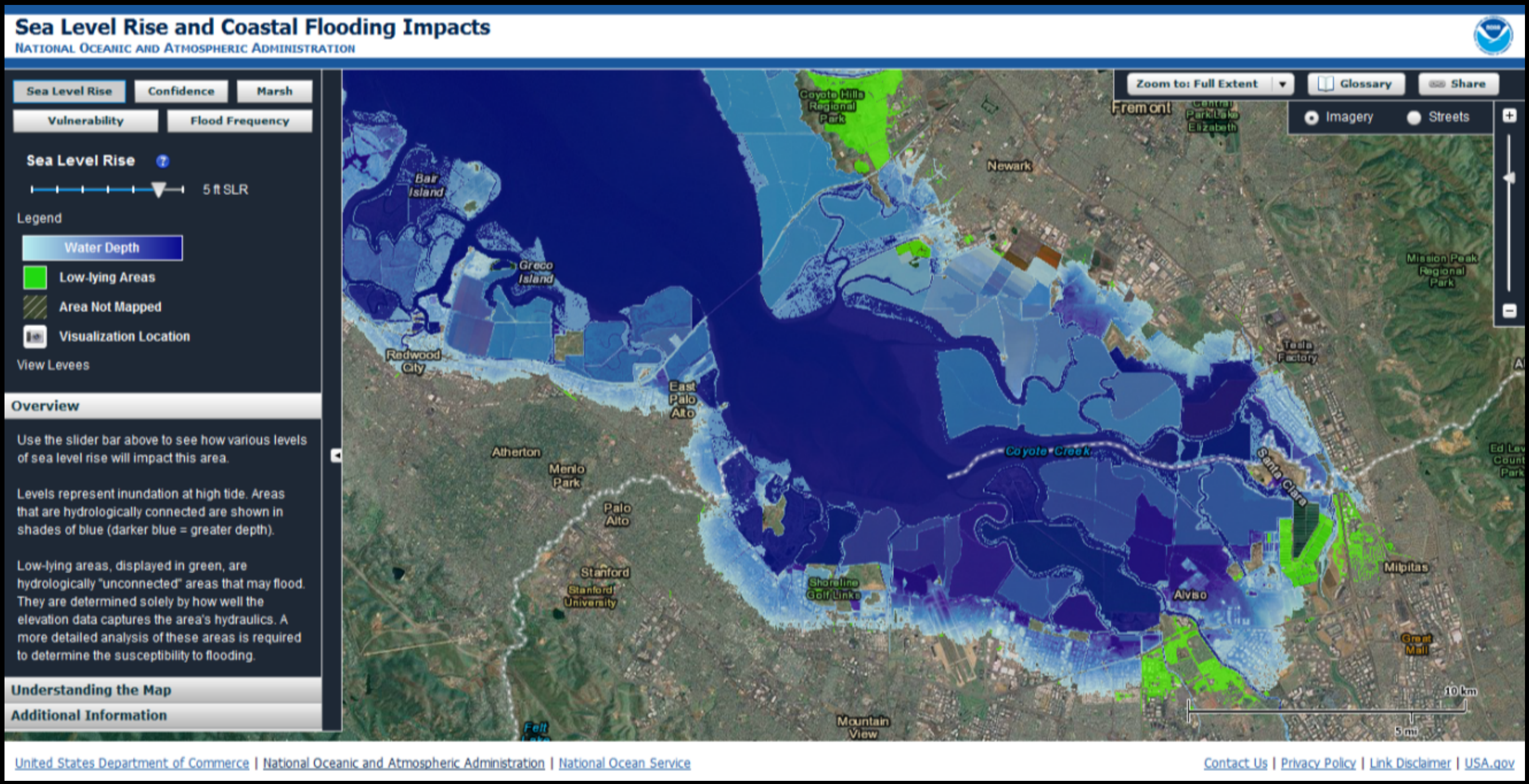
courtesy: Al and Lorrie Flint, USGS
see Stephenson 1998 J. Biogeog.



http://data.prbo.org/apps/ocof/

Secondary factors: sea level rise bathtub model

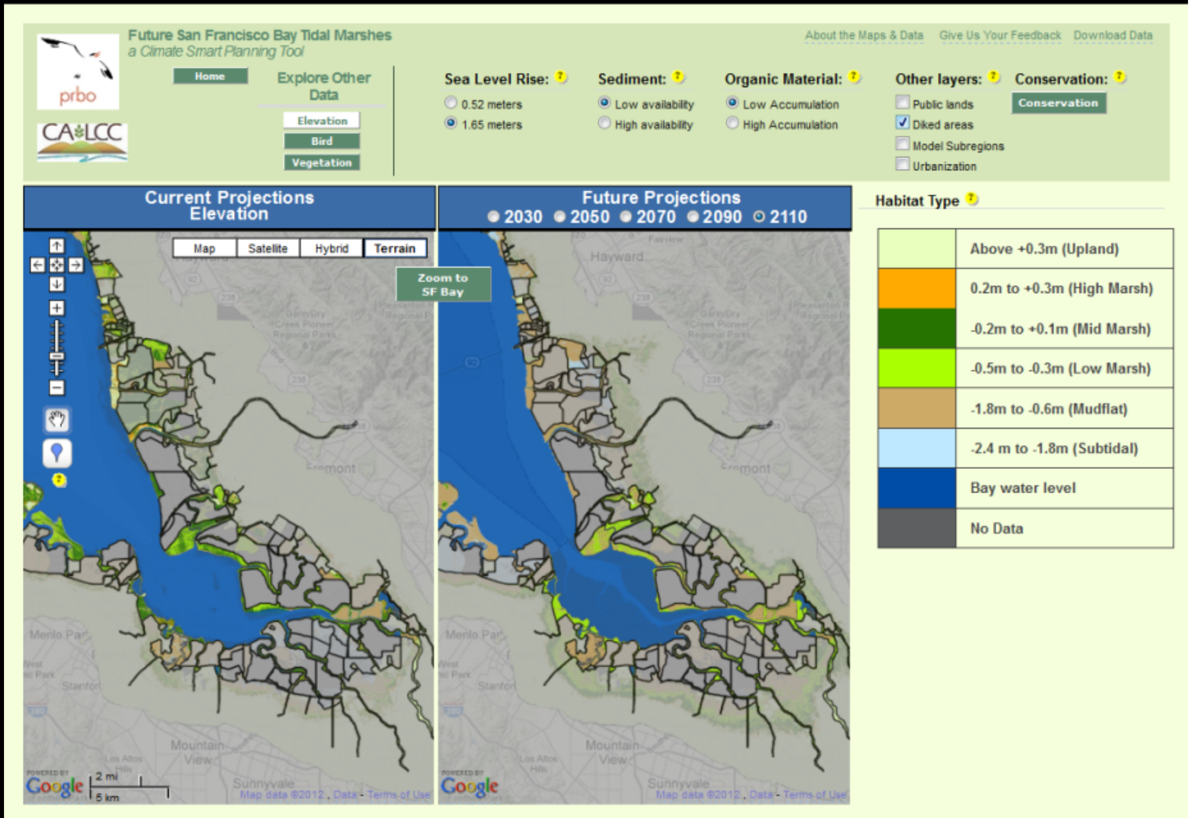
San Francisco Bay - areas at risk for inundation



Secondary factors: sea level rise
Complex responses modeled

Exposure analysis for assessing vulnerability of coastal wetlands to sea-level rise (wetlands are sensitive to tides/elevation)

- 2010 - 2110
- Diked areas



http://data.prbo.org/apps/sfbslr/

Secondary factors: hydrology

USGS generating hydrological models for the Bay Area

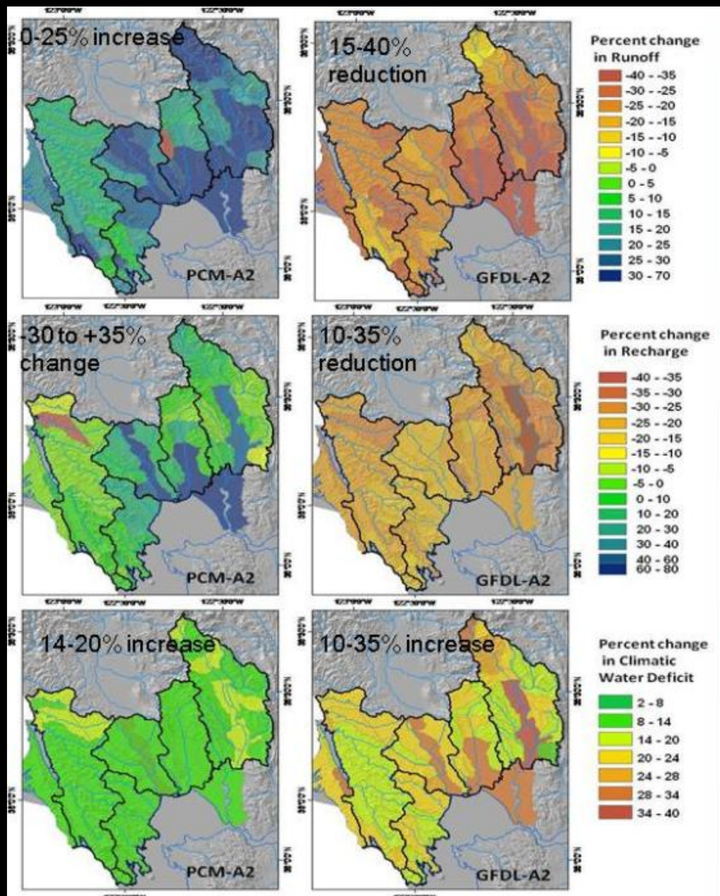
Climate change

↓

Hydrology & Water temp

↓

Species and locations most affected?



Sub-basin results display spatial diversity of climate and hydrology

All scenarios project increases in climatic (soil) water deficit

Flint et al. (USGS)

Secondary factors: hydrology

- Used downscaled projections to examine potential hydrological shifts

- With increasing temperature, found increases in climatic water deficit regardless of changes in precipitation

Secondar

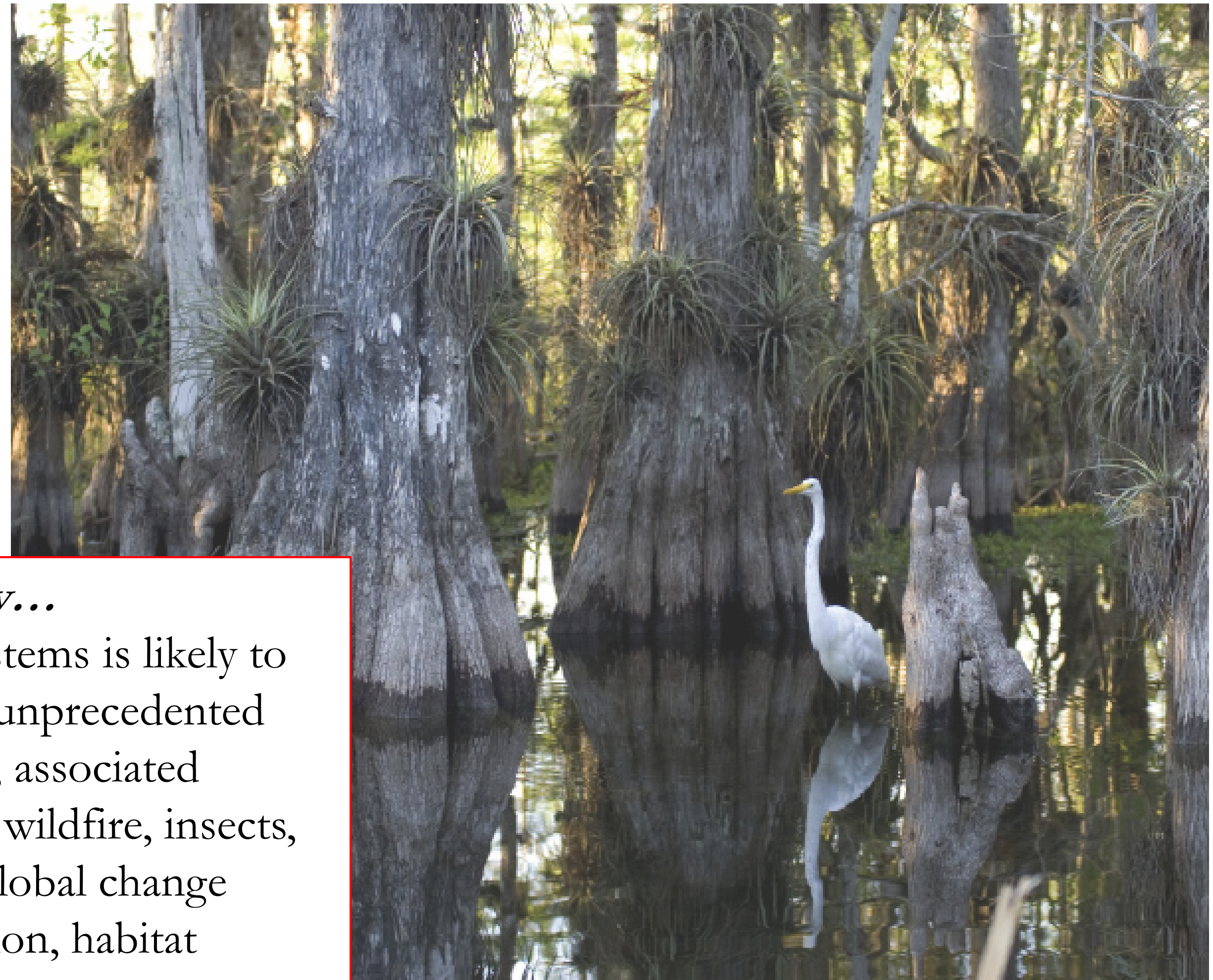
- Decreased soil
  precip) can lea

And/or

Understanding the Science of Climate Change

Talking Points – Impacts to the Gulf Coast

Natural Resource Report NPS/NRPC/NRR—2010/210

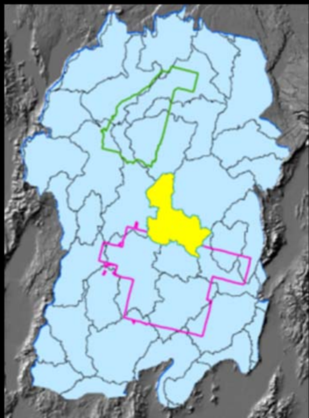


What scientists think is likely…

• The resilience of many ecosystems is likely to be exceeded this century by an unprecedented combination of climate change, associated disturbance (flooding, drought, wildfire, insects, ocean acidification) and other global change drivers (land use change, pollution, habitat fragmentation, invasive species, resource over-exploitation) (Figure 6).

Secondary: dynamic veg models

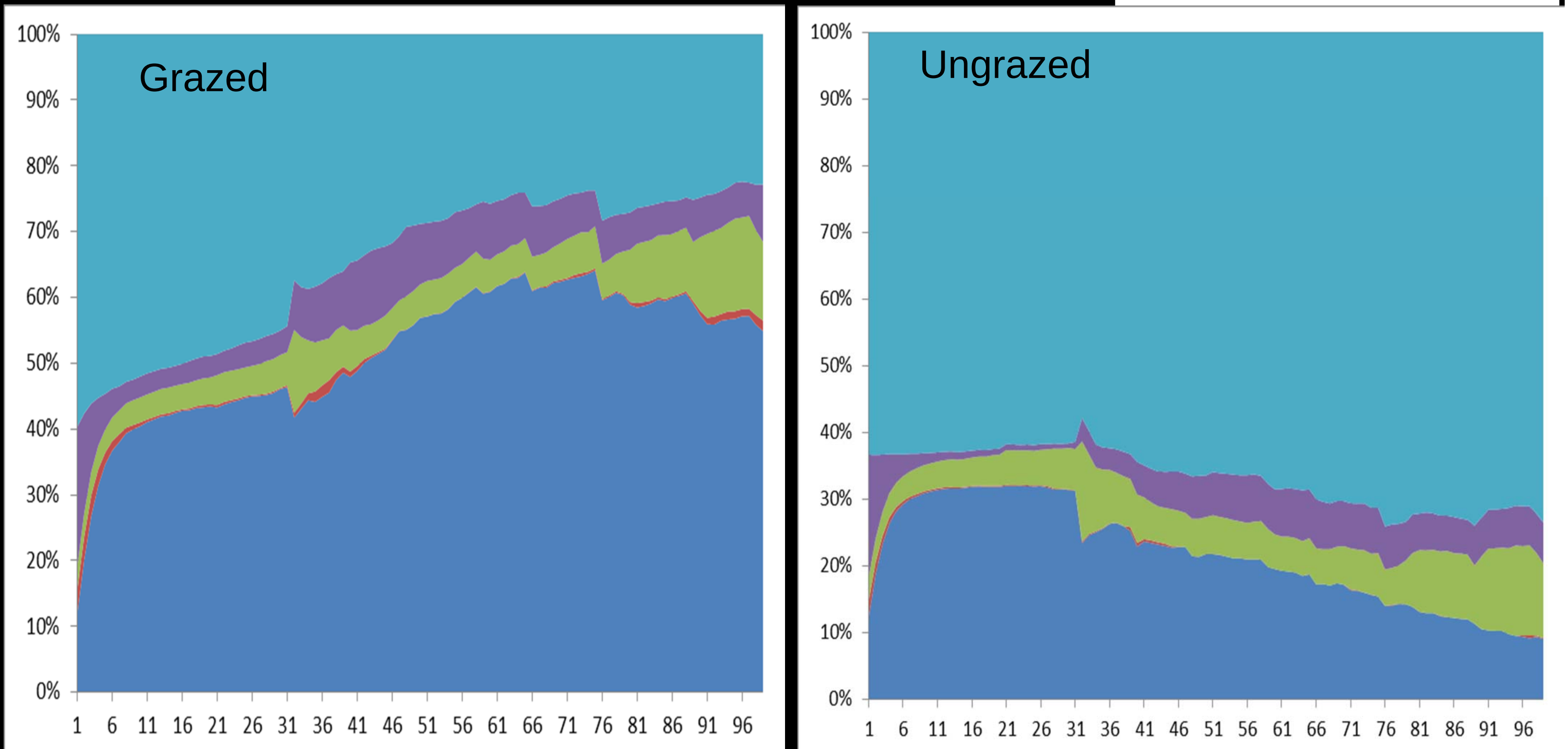
- Niche-based modeling to understand vegetation response to changing climate
  - Uses empirical physiological characteristics to model
  - Can link to GCMs (but with caution)
  - Excludes some ecosystem types (e.g., wetlands)
- Exposure or sensitivity?



Climate Analysis Results

Results for Wyoming Big Sage in Sage Hen Creek watershed with grazing (left) and without grazing (right) under MIROC over 100 years

- ShrubSteppe-Native
- ShrubSteppe_SemiDegraded
- ShrubSteppe_Seeded
- ShrubSteppe_Exotic
- ExoticMonoculture



Non-climate Stressors Exposure

Important because they decrease integrity making resources less resilient to climate change (along with traditional conservation concerns)

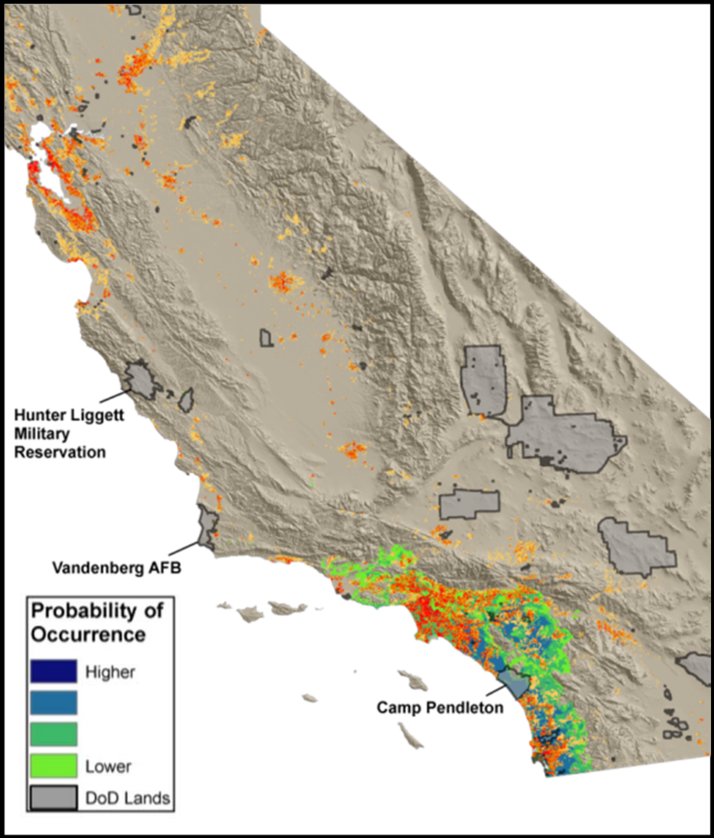
Examples

- All types of development (some resource dependent, e.g., power lines)
- Management practices (resource dependent)
- “Tertiary CC effects” e.g., invasive spp spread

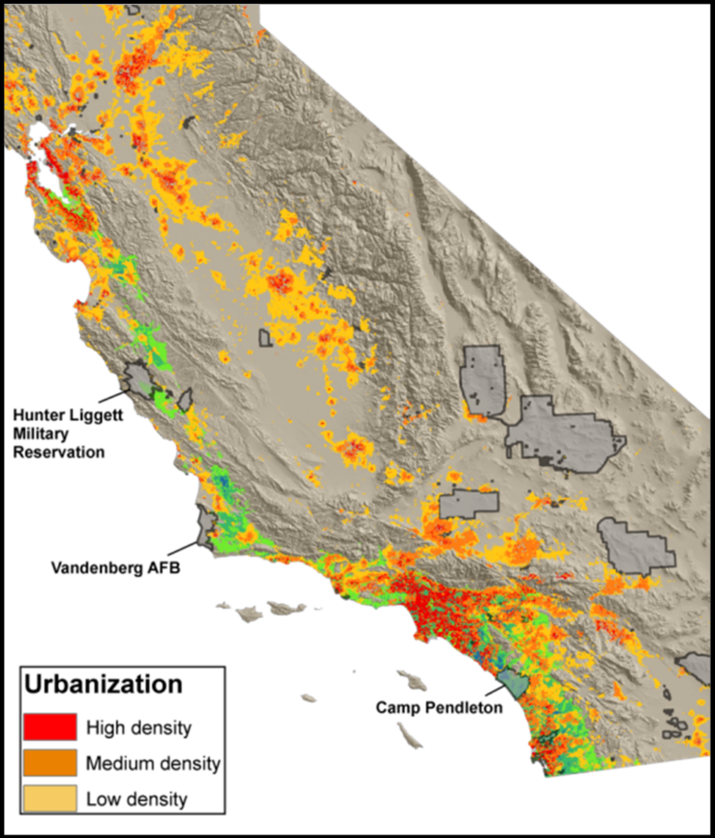
Non-climate Stressors Exposure

California Gnatcatcher

2010



2070

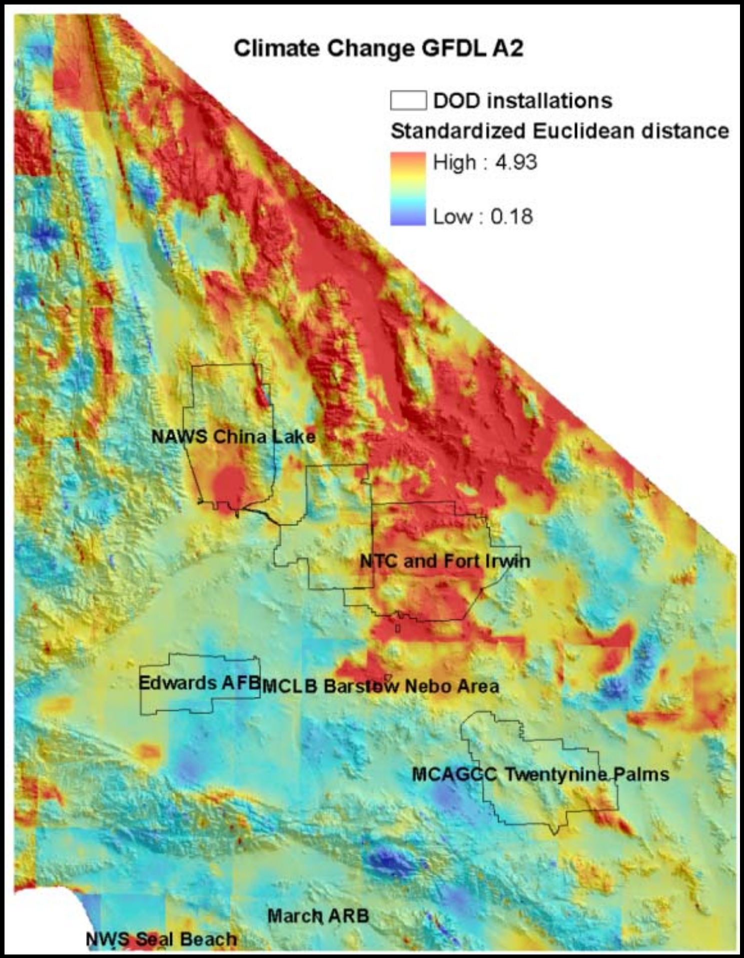


Some Options for Determining Exposure

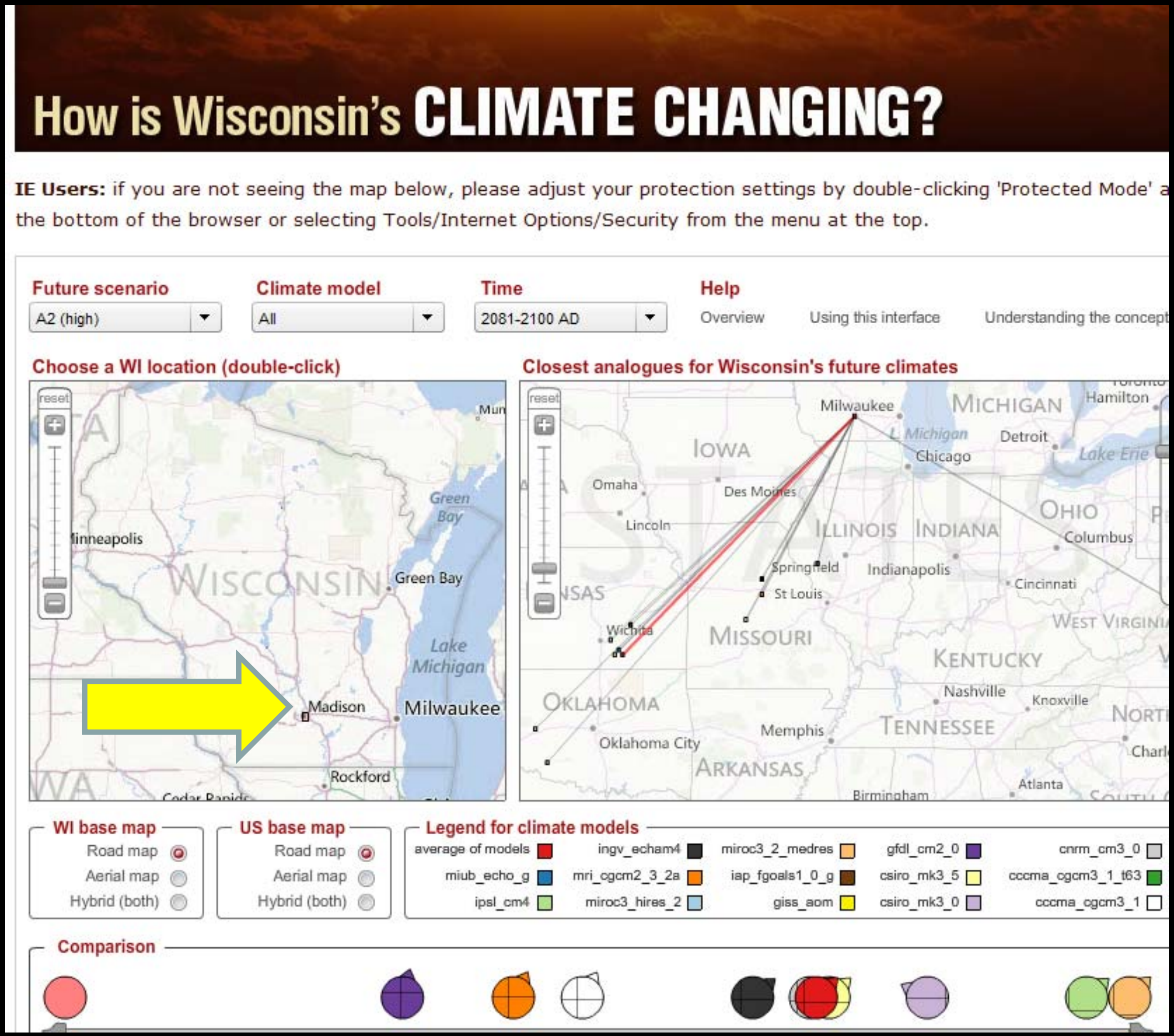
- Simple overlay model (what effects may this resource be subject to) – visual or quantitative
- Climate analoguess: Where is current climate the closest match for future climate?
- Cumulative effects assessment (what parts of the resource's distribution will be subject to what combinations of stressors)

Simple Overlay Example

- For each pixel, distance in climate space between current and future (standardized by inter-annual variation)



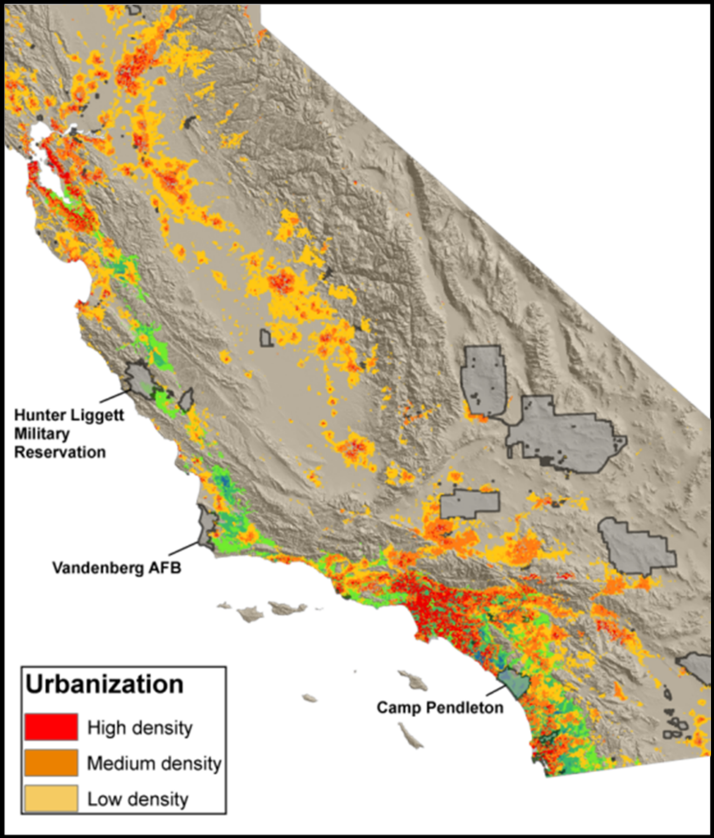
Climate Analogues



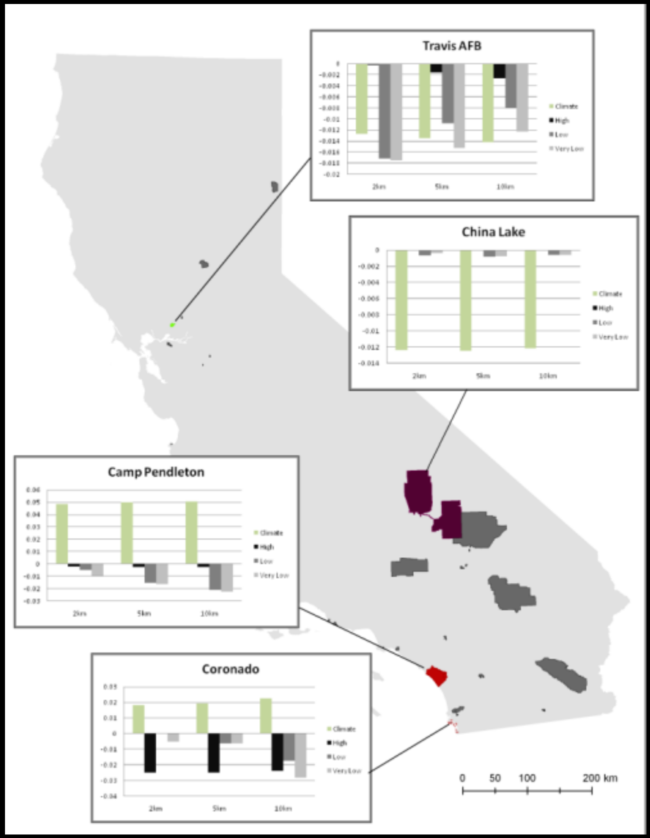
http://www.wicci.wisc.edu/climate-map.php

Cumulative effects

Climate and urbanization



Cumulative effects



Characterize Degree of Exposure

- Qualitative: Visual examination of overlay—typical when using online “viewers” where you can’t get quantification.
  - Tend to use “degree” or “relative proportion.”
- Quantification through GIS intersect, provides more, but maybe not necessary or true, precision

Considerations for Ecological Response Models

- Choice of models
  - Depends on the species, habitats, ecosystems of concern (including scale)
  - Depends on the types of questions being asked
  - Depends on end-user's needs
- Limitations of response models
  - Overly-simplified (e.g., may ignore factors such as interactions between species; nonlinear, complex responses; other factors)
  - Data availability varies
  - Transferability across regions and scales

Tools/Resources for Relevant Information

- DOI Climate Science Centers (CSCs) and Landscape Conservation Cooperatives (LCCs)
  - CSCs will deliver basic climate impact science to LCCs
  - LCCs will link science with conservation delivery

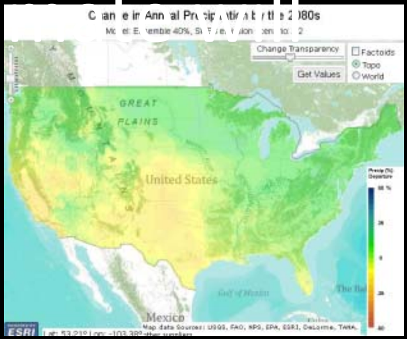
- California Climate Commons (view & obtain data) http://climate.calcommons.org
  Southern Regional Climate Center http://www.srcc.lsu.edu/
- Sea Level Rise Viewer http://www.csc.noaa.gov/slr/viewer/#
- Our Coast Our Future (view & obtain data) http://data.prbo.org/apps/ocof/
- Future San Francisco Bay Tidal Marshes (view & obtain data) http://www.prbo.org/sfbayslr
- California Environmental Change Network http://data.prbo.org/apps/ecn/

DOWNSCALING METHODS

- **Dynamical Downscaling:**
  - Uses physically based models with finer spatial resolution than the original global model
- **Statistical Downscaling :**
  - Uses statistical relationships (usually some form of regression equation) where a fine-scale prediction is related to a set of course-resolution predictors

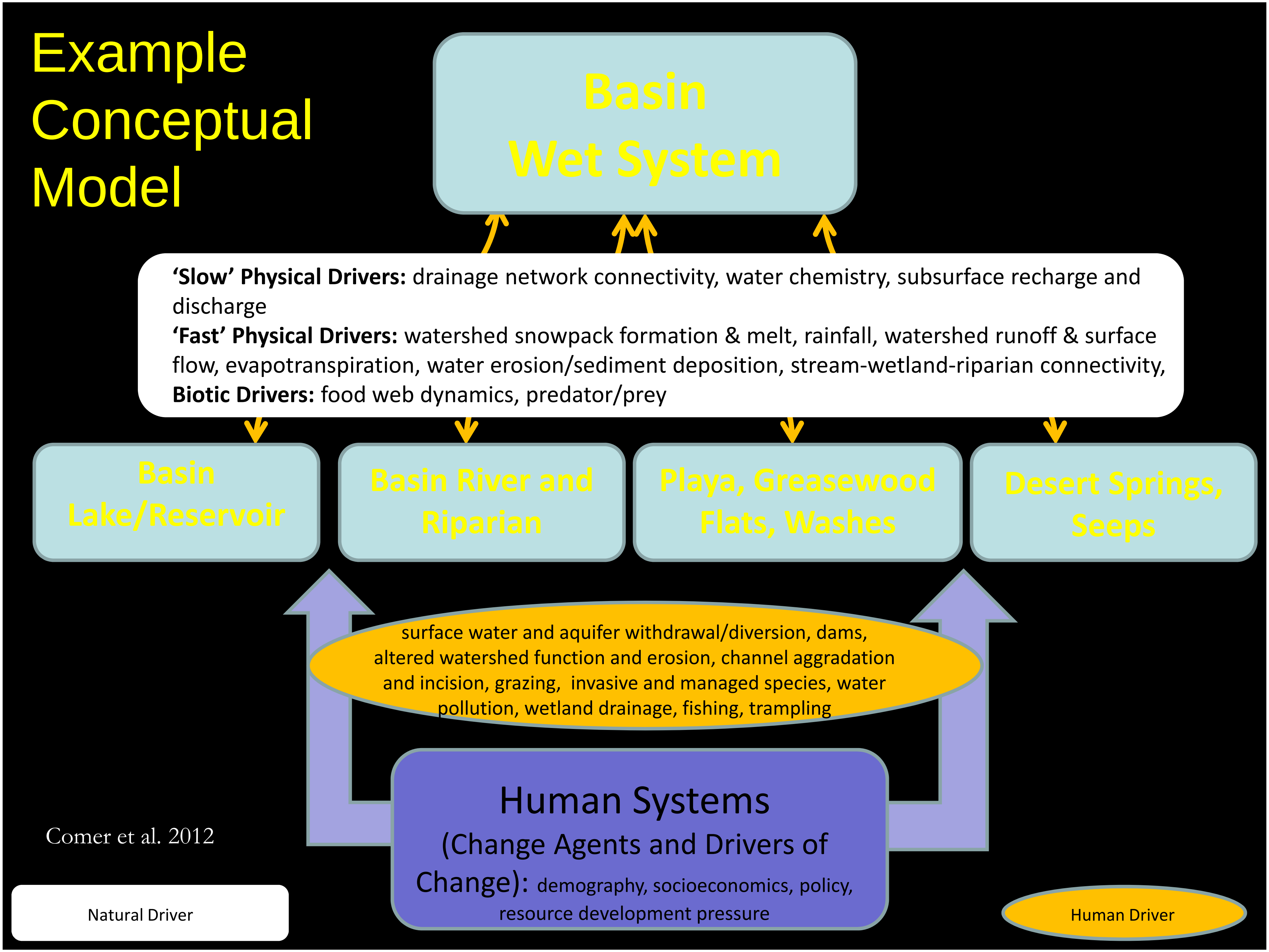
What is Climate Wizard?

- Web-based application that provides:
  - Climate data analyses
  - Climate data visualizations
  - Data subsets for download --for import into e.g. ArcGIS
- uses high resolution climate data sets created using downscaling techniques that use information from finer resolution data sets of past observed climate to inform how climate will change at finer spatial scales



Why use it?

- Easy to use
- Access to most commonly requested analyses:
  - Emission scenarios for low (B1), med (A1B), high (A2)
  - Temperature, precipitation
  - Quantiles(e.g., 20%, 40%, etc)
  - Absolute temperature or precipitation or changes from base
  - Past 50 years observations (1951-2001) PRISM
- Good graphical output –maps and plots
- Broad geographical range –states, countries, global
- Widely used by conservation organizations (i.e., credible within appropriate limits)
- Single model or ensemble of GCMs


Example Conceptual Model
Basin Wet System
'Slow' Physical Drivers: drainage network connectivity, water chemistry, subsurface recharge and discharge
'Fast' Physical Drivers: watershed snowpack formation & melt, rainfall, watershed runoff & surface flow, evapotranspiration, water erosion/sediment deposition, stream-wetland-riparian connectivity,
Biotic Drivers: food web dynamics, predator/prey
Basin Lake/Reservoir
Basin River and Riparian
Playa, Greasewood Flats, Washes
Desert Springs, Seeps
surface water and aquifer withdrawal/diversion, dams, altered watershed function and erosion, channel aggradation and incision, grazing, invasive and managed species, water pollution, wetland drainage, fishing, trampling
Human Systems
(Change Agents and Drivers of Change): demography, socioeconomics, policy, resource development pressure
Comer et al. 2012
Natural Driver
Human Driver

Break-out: Assessing Exposure