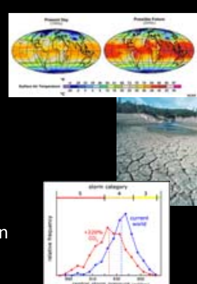
Elements of a Vulnerability Assessment: **Exposure**

Exposure

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

- Primary factors
  - Shifts in temperature, precipitation
- Secondary factors, e.g.
  - Sea-level rise
  - Hydrologic changes
  - Relative humidity/evapotranspiration
  - Shifting sea ice dynamics



Exposure in action: an NPS example

Common uses for climate data in the National Park Service

- **Planning**: Foundation Document, General Management Plans, Resource Strategies, CC scenario and other workshops
- **Assessments**: CC vulnerability, coastal & watershed assessments
- **Specific resource projects**: weed management, species of concern, hydrology, visitor services, infrastructure, visitor safety, revegetation (fire, construction, etc.)
- **Education**: Interpretation and outreach

Needs range from very general trends to somewhat sophisticated.
One size fits nobody.

Climate Variable	Trend	Relative Change by 2050	Projections for 2050s	Confidence	Source / Comments
Temperature (change from 1960-1990: ± SD)	↑	Large	2.7 ± 0.7 C (4.9 ± 1.3 F) Warming greater in summer	Very likely	CMIP3 ensemble for 1 degree cell including RMNP*
Extreme high temperatures	↑	Large	1-in-20 year mean maximum temperature Likely to increases by 2-3 C (3.6 -5.4 F). 1-in-20 year maximum temperature events Likely to occur 1-in-2 to 1-in-4 years.	Likely	IPCC 2012
Mean precipitation (% change from 1960-1990: + 1 sd)	↔	Small	1 ± 7.2 %	About as likely as not	CMIP3 ensemble for 1 degree cell including RMNP*
Evaporation	↑	Moderate	Increase due to temperature; difficult to quantify	Likely	Evapotranspiration may increase 20-30% at higher elevations (BOR 2012)
Intense precipitation events	↑	Moderate	"Marked" increase in 24-hr precipitaton for 2040-2070 period. 50-70% increase in event maxima.	Likely	IPCC 2012; Mahoney et al. 2012
Snowfall (April 1 SWE)	↓	Moderate	2050: -15 to -30%	Likely	Christensen & Lettenmaier 2006; BOR 2012; Gangopadhyay & Pruitt. 2011
Streamflow (total quantity)	↔	Small	No change to slight decrease.	About as likely as not	BOR 2012; Evapotranspiration may increase 20-30% at higher elevations (BOR 2012: B57ff)
Streamflow (timing)	↓	Moderate to large	Peak flows earlier; summer base flows lower	Very likely	Clow 2010; BOR 2012; Christensen & Lettmaier 2006
Drought	↑	Moderate	Difficult to quantify. Likely result of higher temperatures, increased evaporation, and increased variation in precipitation.	Likely	IPCC 2012
Hail	↓	Large	Almost complete elimination of surface hail	Likely	Mahoney et al. 2012

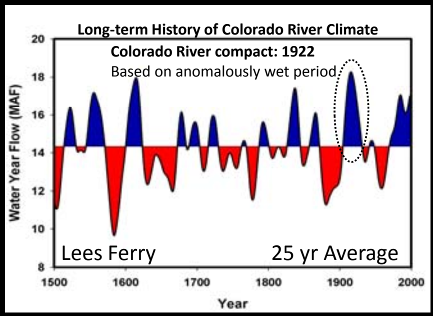
* The CMIP3 ensemble includes 15 Bias-Corrected and Spatially Downscaled (BCSD) GCMs, at 1/8 degree resolution.

Past and present climate

- Long term (paleo-climate) and historical
- Observations from weather stations
  - NOAA's NCDC
- Gridded "observations"
  - PRISM, DayMet
- Topoclimate models

“Stationarity is Dead”

(But was it every really alive?)

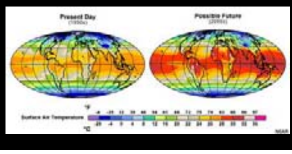


Future climate

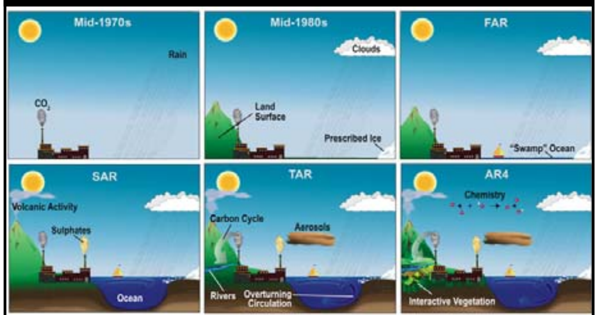
- Projections include
  - Global Climate Models
    - basis for all projections
  - Downscaled Global Climate Models
  - Regional Climate Models
  - Decadal projections

Global Climate Models (GCMs)

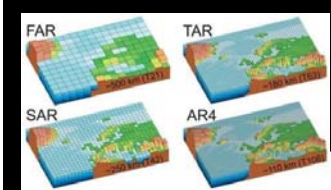
- Global climate models
  - Based on principles of thermodynamics and fluid dynamics
  - Describe complex interaction between atmosphere, cryosphere, oceans, land, and biosphere
  - Large-scale (~100 km^2 but constantly decreasing)

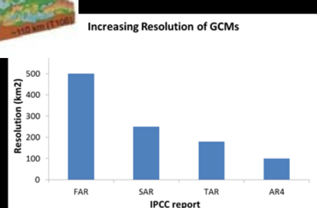


GCM evolution: complexity

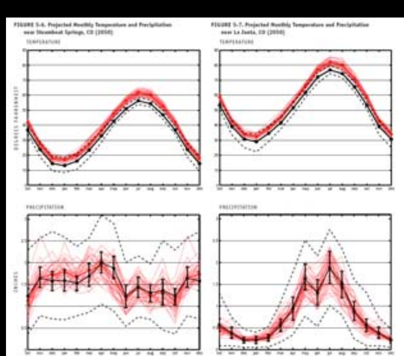


GCM evolution: scale



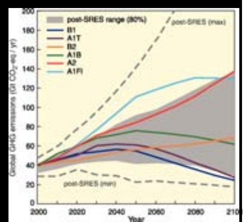


GCM skill: temp vs. precip



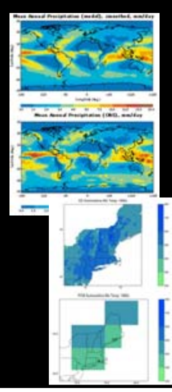
Which Projections to Use?

- Factors to consider
  - Length of planning horizon
  - Sensitivity of key species or processes
  - Relationship to current trends
  - Level of acceptable risk
  - Needed specificity
  - Region of interest



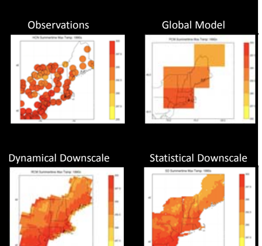
Downscaling GCMs

- Using models or observations to convert GCM data to smaller grid sizes (50 – 1 km^2)
- Multiple techniques available
  - Dynamic
  - Statistical
  - Change-factor (Delta method)



Is Downscaled Information Necessary?

- Factors to consider
  - Management question
  - Scale of area being managed
  - Climatic complexity of area being managed
  - Available data quality
- Benefits and limitations
  - Data often more relevant for management scale
  - Not necessarily more "accurate"



Questions to Ask About Downscaled Data

- Based on *good GCM(s)* for your region?
- *Suitable downscaling method* for purpose/region?
- *Adequate data* to build and calibrate model?
- *Grid cell size* supportive of relative input uncertainty?

Recommendation from recent meeting with climate modelers*

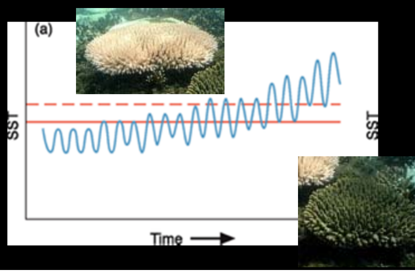
1. Include at least 12 models
2. don't pick "the best;" work with modelers to cull available model output based on intended use.
3. Consider both downscaled GCM and RCM.
4. Use multiple projections to do multiple impacts models, then ensemble.

Some Options for Determining Exposure

- Simple overlay model
- Climate analogues
- Cumulative effects assessment

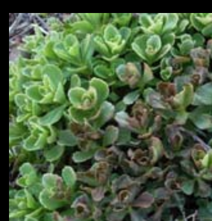
Exposure of What to What?

- Most species and habitats don't care about temporal averages



Exposure of What to What?

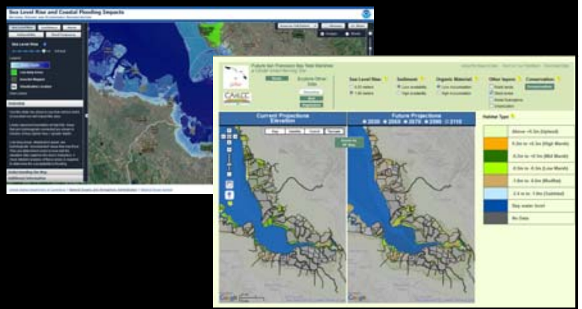
- Most species don't experience spatial averages



Exposure: secondary factors

- Response Models
  - Conceptual (qualitative)
  - Qantitative (wide range of complexity)
- Examples of secondary factors
  - Sea level rise
  - Hydrology
  - Fire regime
  - Vegetation changes
  - Snow pack
  - Sea ice

Secondary factors: sea level rise



San Francisco Bay - areas at risk for inundation

Secondary factors: hydrology

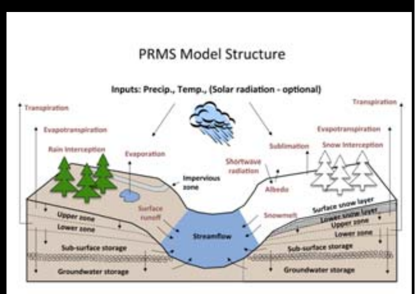
Climate change

↓

Hydrological changes

↓

Species and locations most affected?



Secondary factors: fire regime

- Reduced snow pack, earlier snow melt → bigger, more frequent fires
- Fuel production decline → lower fire frequency

CSIRO PUBLISHING

Future climate affects management strategies for maintaining forest restoration treatments

Corinne Diggins[A], Peter Z. Fulé[A,C], Jason P. Kaye[B] and W. Wallace Covington[A]

Break-out: Assessing Exposure

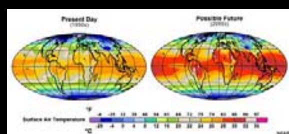
EXTRA SLIDES

Class exercise

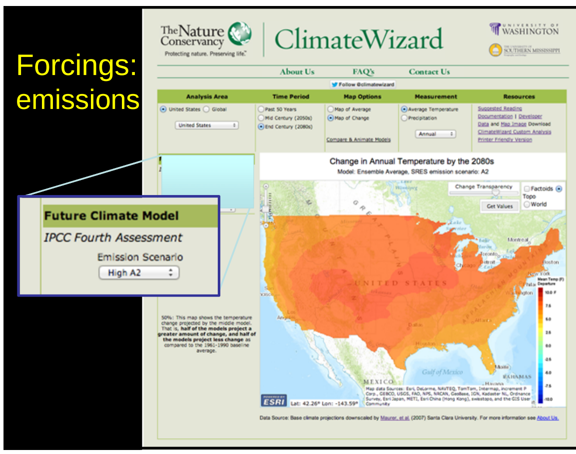
What do you think of when someone says “climate data”?

For every climate change vulnerability assessment you want to recognize the choice for:

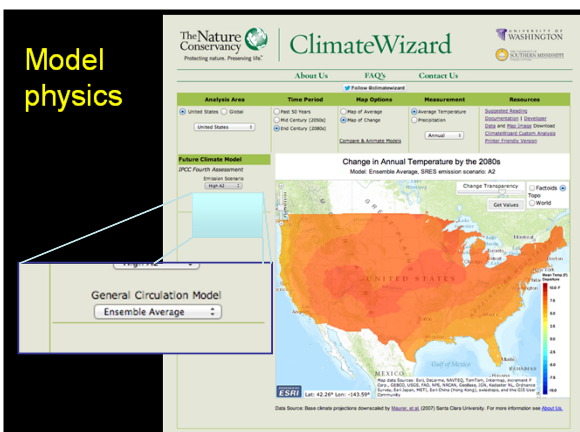
- Forcings
- Model physics
- Output
- Scale: in time and space



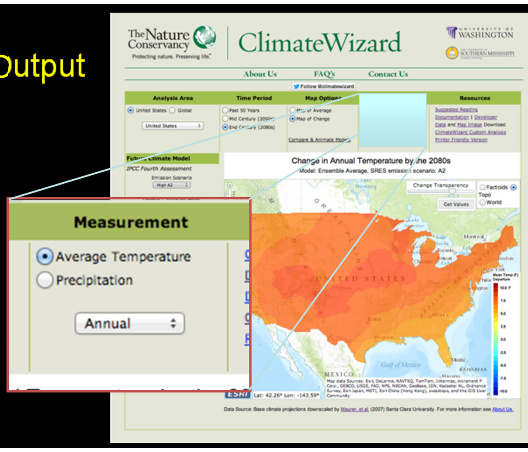
Forcings: emissions



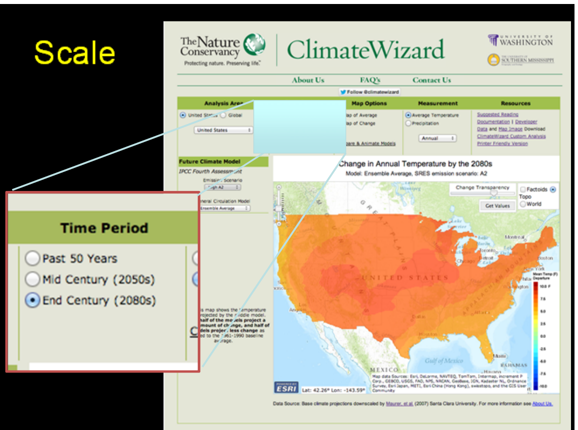
Model physics



Output

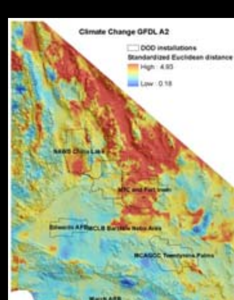


Scale

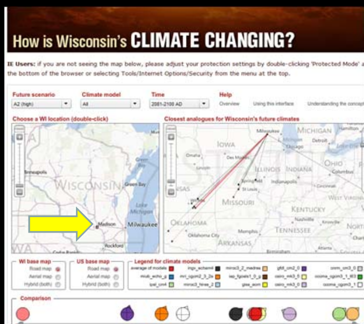


Simple Overlay Example

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



Climate Analogues

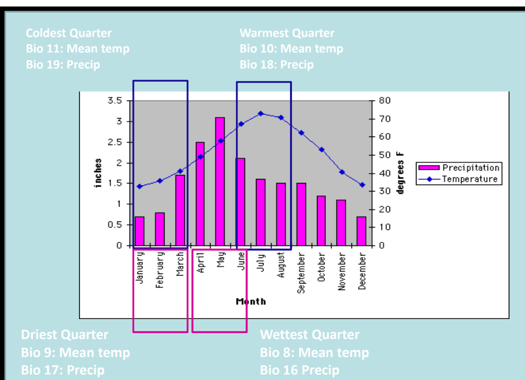


http://www.wicci.wisc.edu/climate-map.php

Example: BioClim summaries

BIO1 = Annual Mean Temperature
BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))
BIO3 = Isothermality (BIO2/BIO7) (* 100)
BIO4 = Temperature Seasonality (standard deviation *100)
BIO5 = Max Temperature of Warmest Month
BIO6 = Min Temperature of Coldest Month
BIO7 = Temperature Annual Range (BIO5-BIO6)
BIO8 = Mean Temperature of Wettest Quarter
BIO9 = Mean Temperature of Driest Quarter
BIO10 = Mean Temperature of Warmest Quarter
BIO11 = Mean Temperature of Coldest Quarter
BIO12 = Annual Precipitation
BIO13 = Precipitation of Wettest Month
BIO14 = Precipitation of Driest Month
BIO15 = Precipitation Seasonality (Coefficient of Variation)
BIO16 = Precipitation of Wettest Quarter
BIO17 = Precipitation of Driest Quarter
BIO18 = Precipitation of Warmest Quarter
BIO19 = Precipitation of Coldest Quarter

Nix, H. 1986. A biogeographic analysis of Australian elapid snakes. Pages 4 - 15 in R. Longmore, editor. Atlas of Elapid snakes of Australia. Australian Government Publishing Service, Canberra.



8 Temperature/Precipitation Interaction layers

Secondary factors: hydrology

USGS generating hydrological models for the Bay Area

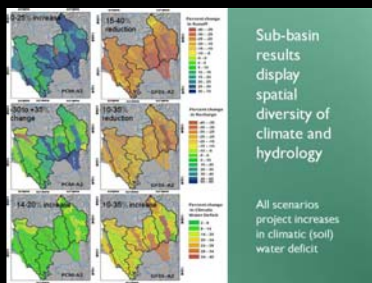
Climate change

↓

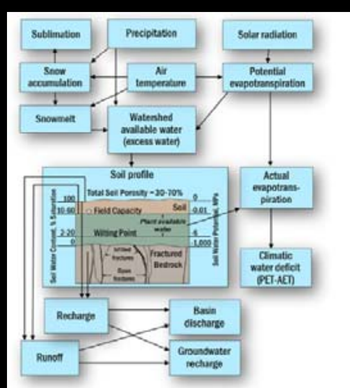
Hydrology & Water temp

↓

Species and locations most affected?



Micheli et al. 2010



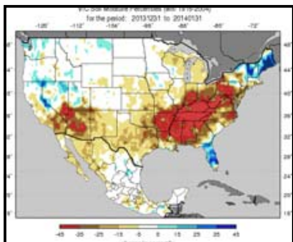
Tools/Resources for Relevant Information

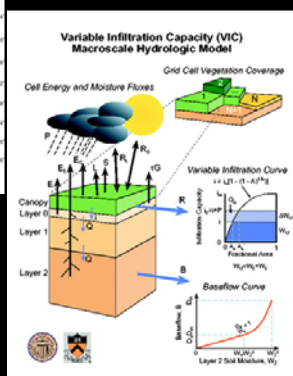
- DOI Climate Science Centers (CSCs) and Landscape Conservation Cooperatives (LCCs)
  - CSCs will deliver basic climate impact science to LCCs
  - LCCs will link science with conservation delivery

- 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/

Some important acronyms

- Intergovernmental Panel on Climate Change (IPCC)
- Assessment Reports (AR)
  - TAR (first AR), second (SAR), third (TAR), AR4, AR5,…
- CMIP5 - Coupled Model Intercomparison Project (most current)
- GCM: Global Climate Models
- RCM: Regional Climate Models
- Represenative Concentration Pathways (RCP) (which is the CMIP5 term for emissions scenarios)





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

- Climate tools, e.g. ClimateWizard
- Secondary factor tools, e.g. SLAMM, SWAT
- Regional portals, e.g.
  - SNAP (Scenarios Network for AK Planning)
  - California Climate Commons