Day 1 Session 2
How to Use the Climate Toolbox

North Central
Climate Adaptation
Science Center

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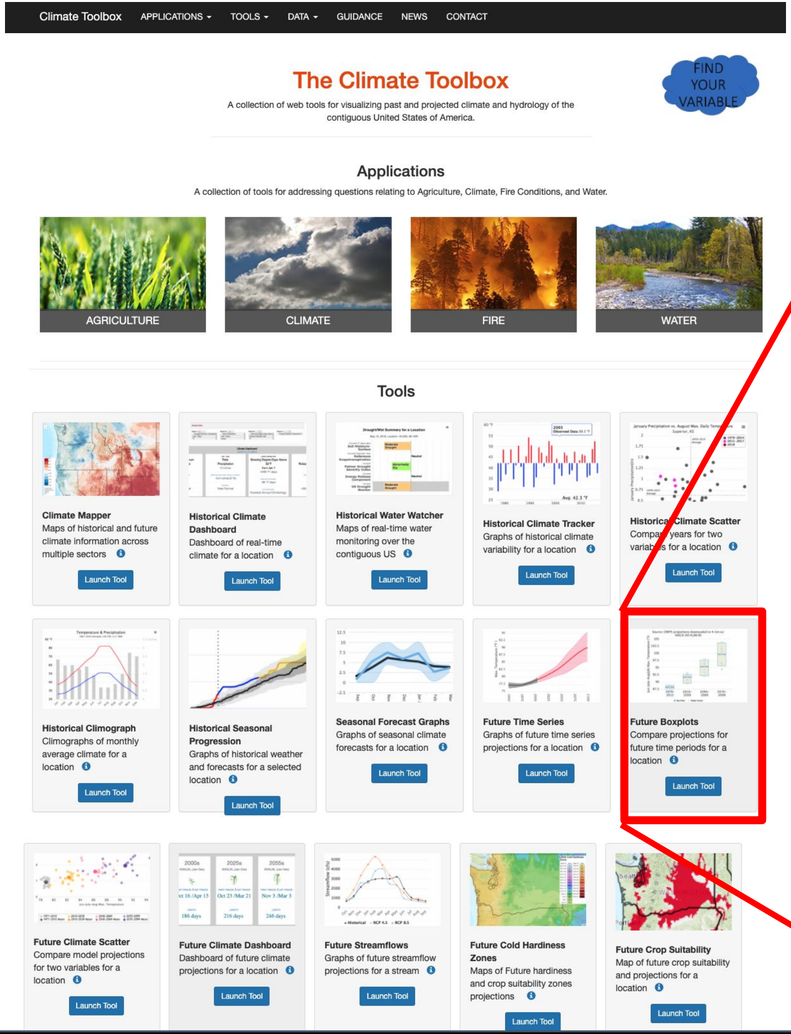
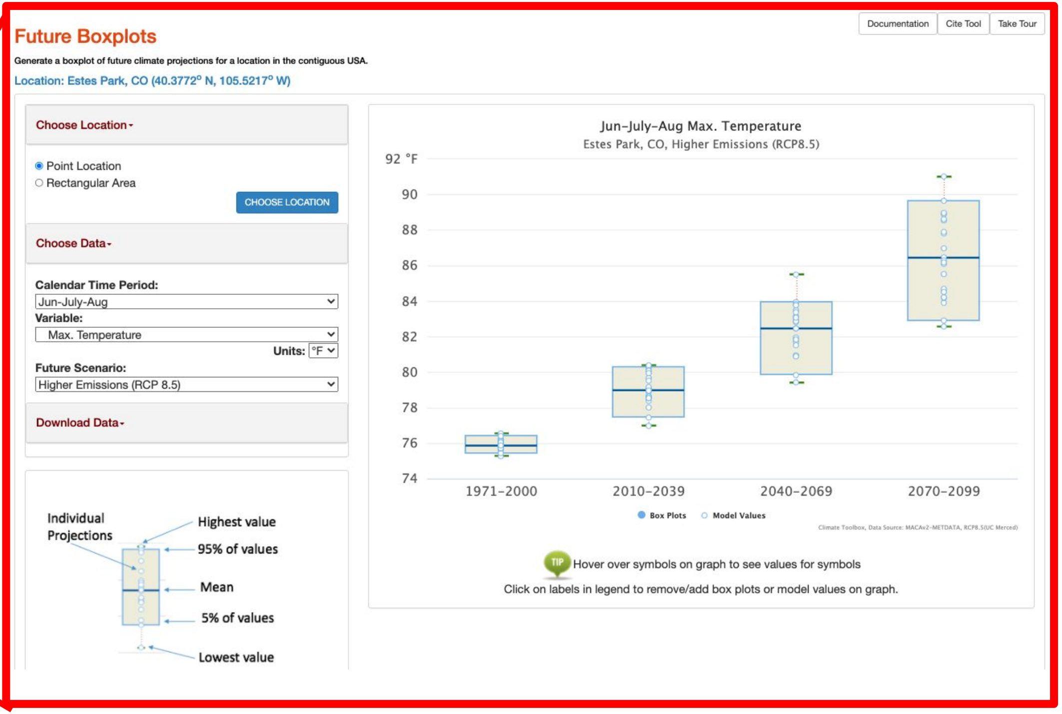
OUTLINE

- Climate Toolbox: Datasets, Metrics and Tools
- Incorporating Future Climate and Uncertainty in Impacts Assessment
- Application: Using Scenario Climate Information for SSAs
- Hands-On Activity

The Climate Toolbox

The Climate Toolbox



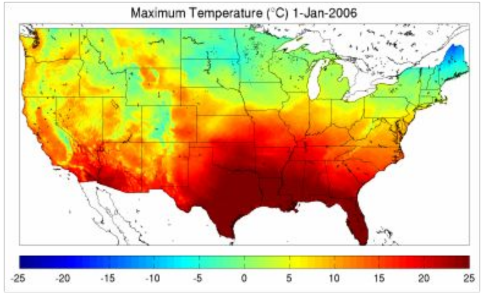


Historical Data in
The Climate Toolbox

Toolbox - Historical Data

Climate Dataset

gridMET - a blend of satellite & ground station data
(1979-Yesterday)



Surface Weather:

- Temperature
- Precipitation
- Humidity
- Wind
- Solar Radiation

- Daily data from:
- Continental USA (4-km, 2.5 mi grids, 1/24-deg)

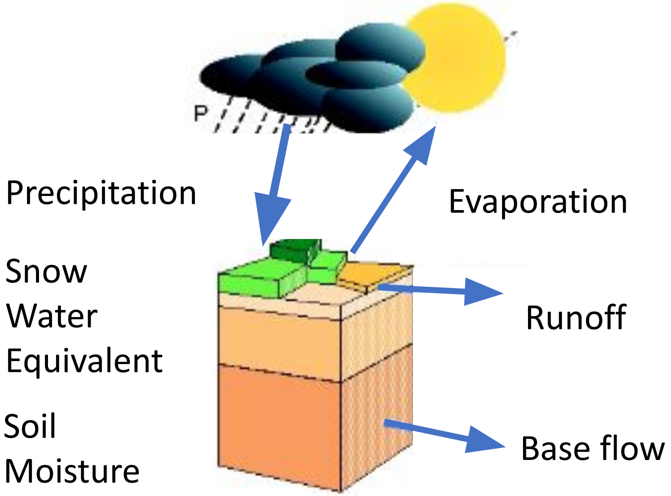
2.5 mile

Grid cell

2.5 mile

Hydrology Modeling

Variable Infiltration Capacity (VIC) Model
(1920-Yesterday)



UCLA Surface Hydrology Group

Toolbox - Historical Data

Climate Metrics

- Temperature
- Precipitation
- Humidity
- Wind
- Radiation

Ecology Metrics

- Day of First Fall Freeze
- Day of Last Spring Freeze
- Growing Season
- Palmer Drought Severity Index
- Standardized Precipitation Index

Water Metrics

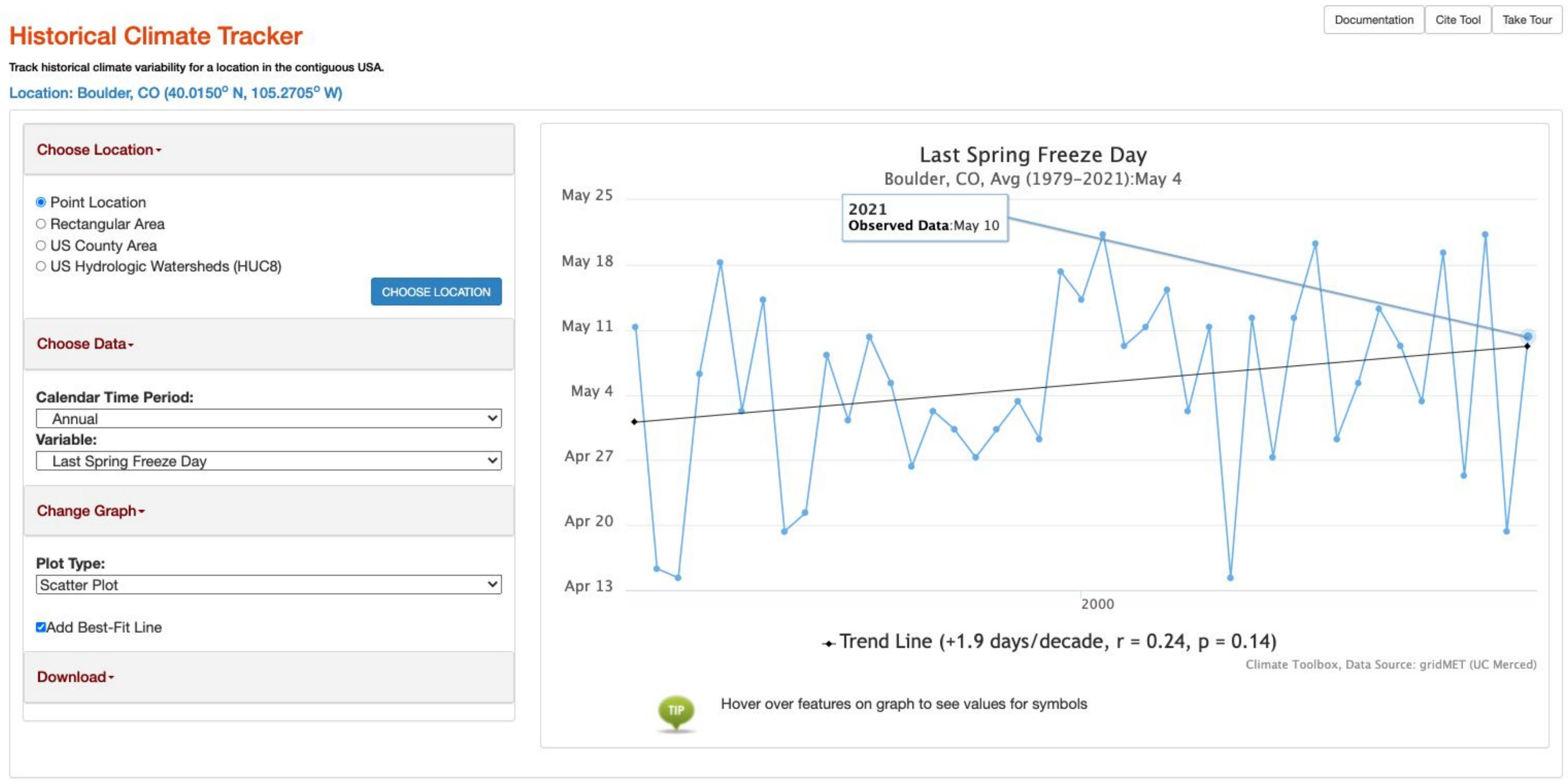
- Soil moisture
- Total moisture
- Snow water equivalent
- Runoff

Fire Danger Metrics

- Days since 0.1” precipitation
- 100-hour fuel moisture
- Vapor Pressure Deficit

Historical Data Tools in The Climate Toolbox

Toolbox- Climate Tracker Tool



Toolbox - Climate Scatter Tool

Future Projection Data in The Climate Toolbox

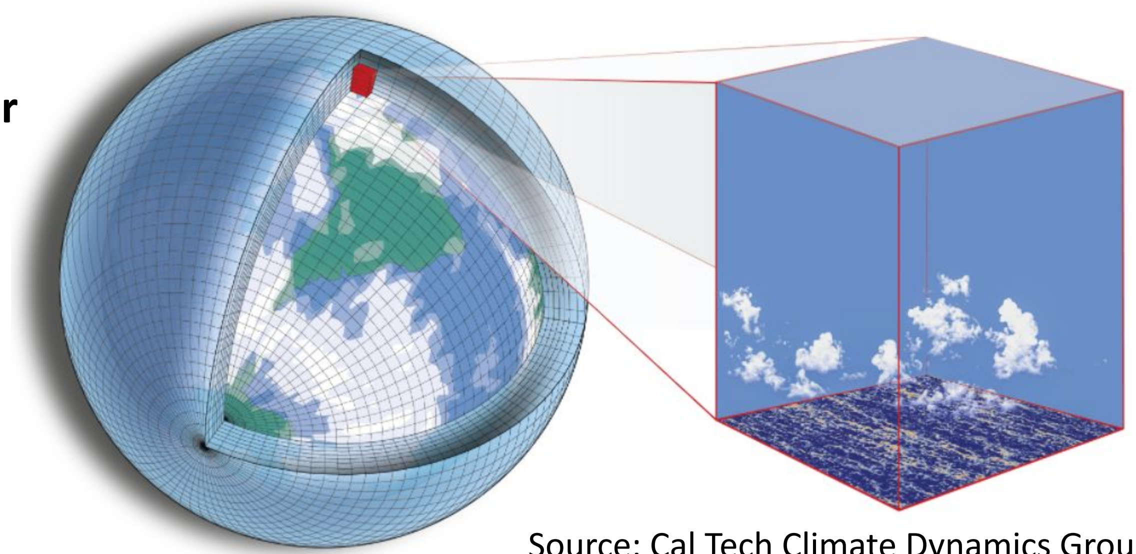
Toolbox - Future Projection Data

Global Climate Simulations

Scientists use computer simulations to conduct experiments and test hypotheses about our changing climate.

Simulations of global weather

- Atmosphere
- Ocean
- Land surface
- Cryosphere



Source: Cal Tech Climate Dynamics Group

Toolbox - Future Projection Data

Future Climate Projections

The Intergovernmental Panel on Climate Change (IPCC) created the Coupled Model Inter-Comparison Project (CMIP) to create an ensemble of future climate projections.

- phase 5 (CMIP5) completed in 2011
- phase 6 (CMIP6) completed in 2021

Global Climate Models

Over 20 climate modeling centers contribute outputs to CMIP.

Climate Outputs

Models provide daily outputs of temperature, precipitation, humidity, wind, radiation.

Model	Country	Model	Country
ACCESS1-0	Australia	CCSM4	U.S.A.
CSIRO-Mk3-6-0	Australia	CESM1-BGC	U.S.A.
CanESM2	Canada	CESM1-CAM5	U.S.A.
bcc-csm1-1	China	GFDL-CM3	U.S.A.
BNU-ESM	China	GFDL-ESM2G	U.S.A.
FGOALS-g2	China	GFDL-ESM2M	U.S.A.
FIO-ESM	China	GISS-E2-R	U.S.A.
CNRM-CM5	France	MIROC5	Japan
IPSL-CM5A-LR	France	MIROC-ESM	Japan
IPSL-CM5A-MR	France	MIROC-ESM-CHEM	Japan
MPI-ESM-LR	Germany	MRI-CGCM3	Japan
CMCC-CM	Italy	HadGEM2-CC	U.K.
NorESM1-M	Norway	HadGEM2-ES	U.K.
inmcm4	Russia	HadGEM2-AO	Korea

Toolbox - Future Projection Data

Future Climate Experiments

Each model runs simulations of global weather for historical and future time periods.

Historical Simulations

1950 - 2005

Historical simulations are initialized with pre-industrial conditions.

Historical -
Pre-industrial greenhouse gas concentrations

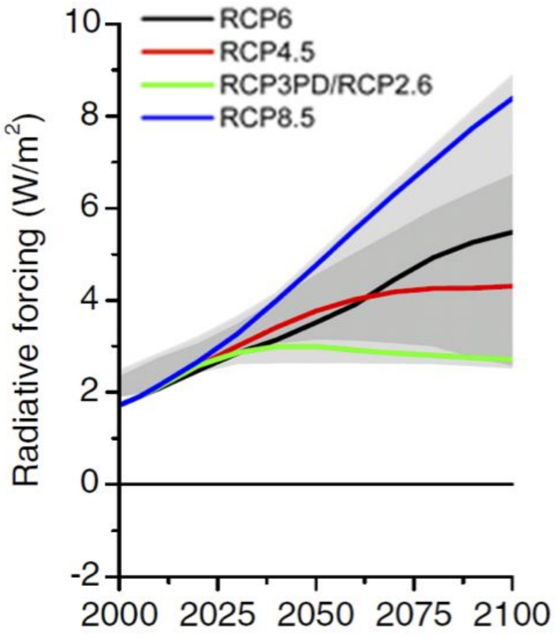
Future Simulations

2006 - 2100

Future simulations assume an emission pathway to 2100.

RCP8.5 – "High emissions"
is the highest baseline emissions scenario in which emissions continue to rise throughout the twenty-first century

RCP4.5 – "Intermediate emissions"
a moderate emissions scenario in which emissions peak around 2040 and then decline

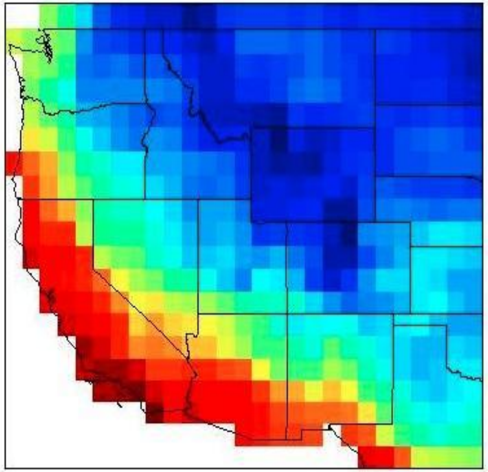


Toolbox - Future Projection Data

Statistical Downscaling

In downscaling, biases are removed using statistics from a training dataset and the resolution of the gridded data is increased.

Coarse Model Outputs

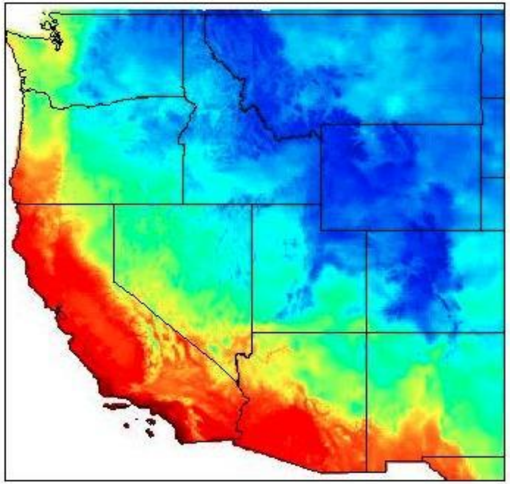


~200 mile x ~200 mile grid cells

Downscaling

- Increase resolution of data
- Remove or reduce biases

Finer Resolution Data



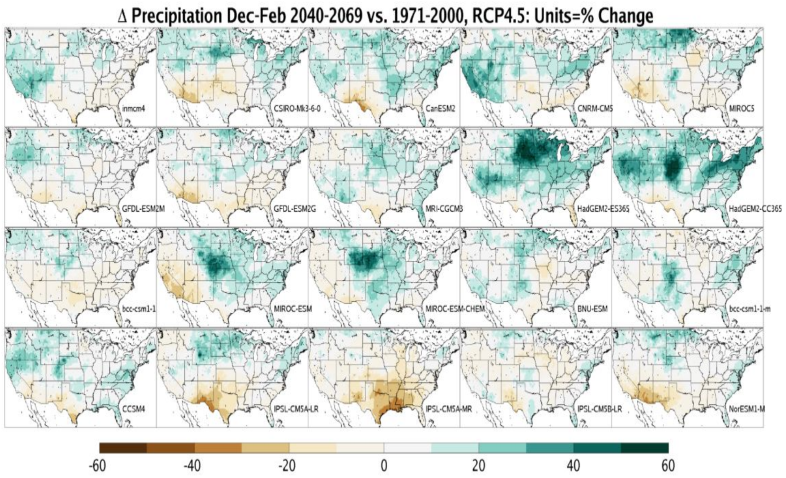
~2.5 mile x ~2.5 mile grid cells

MACA (Multi-Variate Adaptive Constructed Analogs) downscaled CMIP5 outputs using gridMET as training dataset. (Abatzoglou, 2011)

Toolbox - Future Projection Data

Future Climate Projections

- **Global climate models:** 20 GCMS from CMIP5
- **Scenarios:** Historical, RCP 4.5, RCP 8.5
- **Downscaling:** MACA (Abatzoglou, 2011)
- **Training data:** gridMET (1979-2012)
- **Spatial coverage:** continental USA (4-km, 2.5 mi)
- **Daily projections** (2020-2099)



Toolbox - Future Projection Data

Climate Metrics

- Temperature
- Precipitation
- Humidity
- Wind
- Radiation

Ecology Metrics

- Coldest Winter Day
- Hottest Summer Day
- Day of First Fall Freeze
- Day of Last Spring Freeze
- Growing Season
- Days of Max Temperature>86F

Water Metrics

- Soil moisture
- Total moisture
- Snow water equivalent
- Runoff
- Streamflow

Fire Danger Metrics

- Days of Extreme Fire Danger
- 100-hour fuel moisture
- Vapor Pressure Deficit

Toolbox - Find Your Variable Tool

Climate Toolbox APPLICATIONS TOOLS DATA VIDEOS CASE STUDIES TOOL SUMMARIES GUIDANCE NEWS CONTACT

Documentation | Cite Tool

Variable Lookup

Find which tools in the Climate Toolbox have information on your variable of interest.

Choose A Variable of Interest

Variable of Interest:

Last Spring Freeze

Definition:

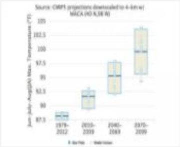
The last day of the year before August 1st in which daily minimum temperature drops below 32 deg F.

Special Notes:

In the Future Climate Dashboard tool, this variable is available under the Growing Season Dashboard.

In the Climate Mapper, this metric can be found under Time Scale: Future Projections, Impact: Agriculture.

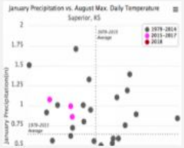
List of Tools providing "Last Spring Freeze"



Future Boxplots

Compare projections for future time periods for a location

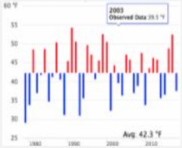
Launch Tool



Historical Climate Scatter

Compare two historical climate variables for a location

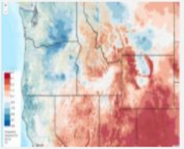
Launch Tool



Historical Climate Tracker

Graphs of historical climate variability for a location

Launch Tool



Climate Mapper

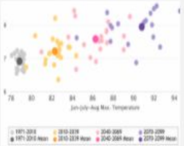
Maps of historical and future climate information across multiple sectors

Launch Tool

Future Climate Dashboard

Dashboard of future climate projections for a location

Launch Tool



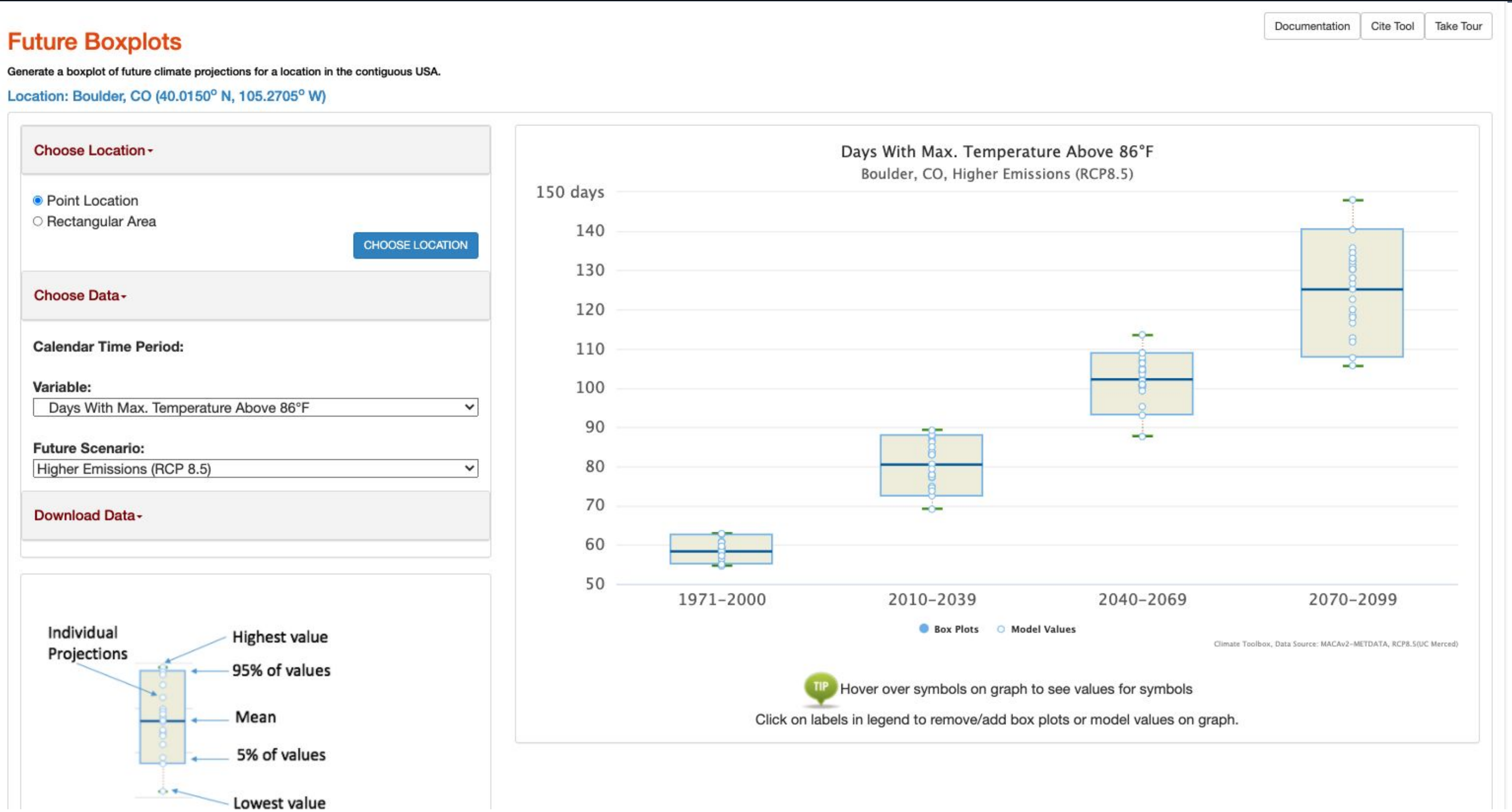
Future Climate Scatter

Compare model projections for two variables for a location

Launch Tool

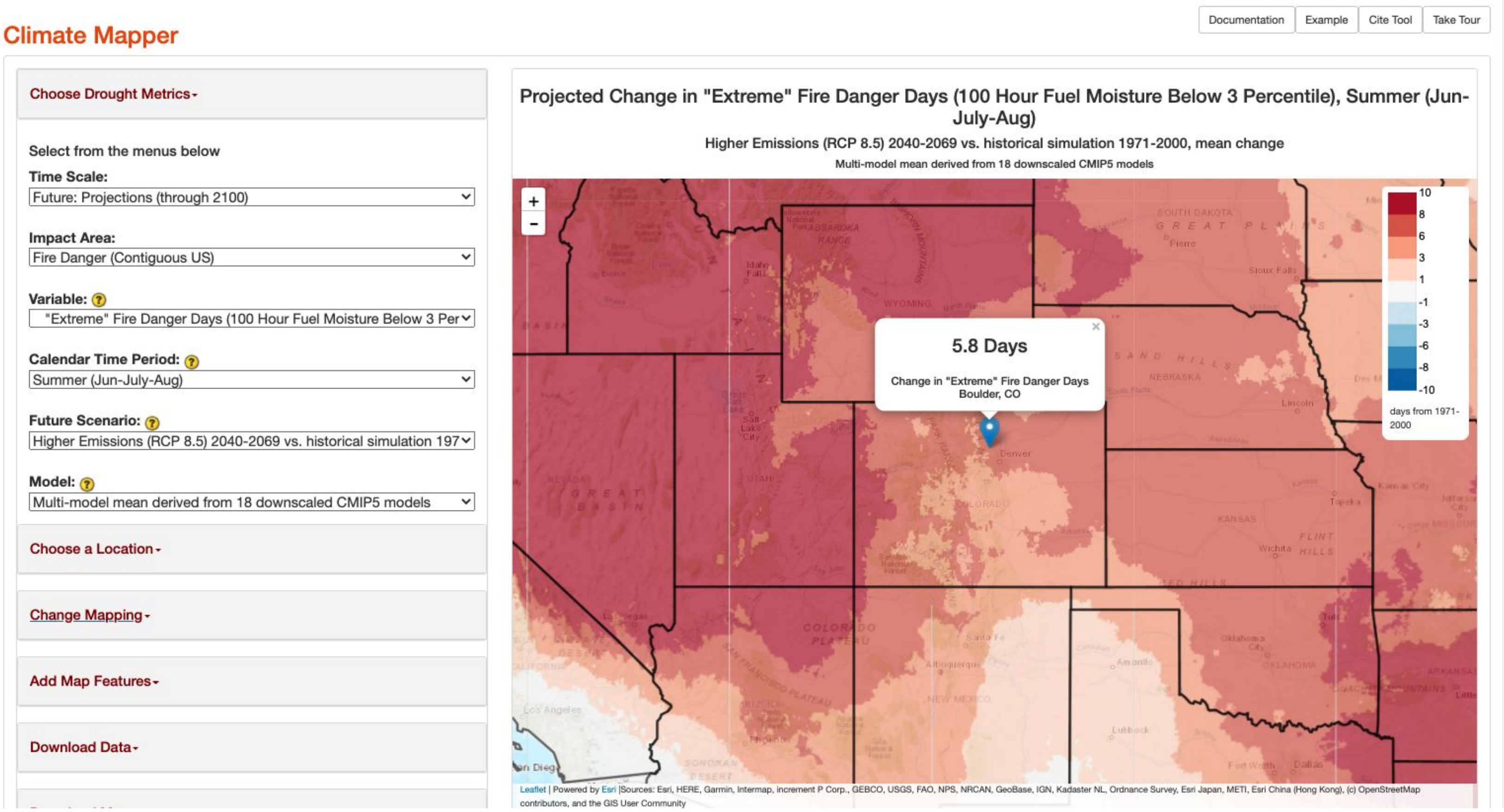
Future Data Tools in The Climate Toolbox

Toolbox - Future Boxplots Tool



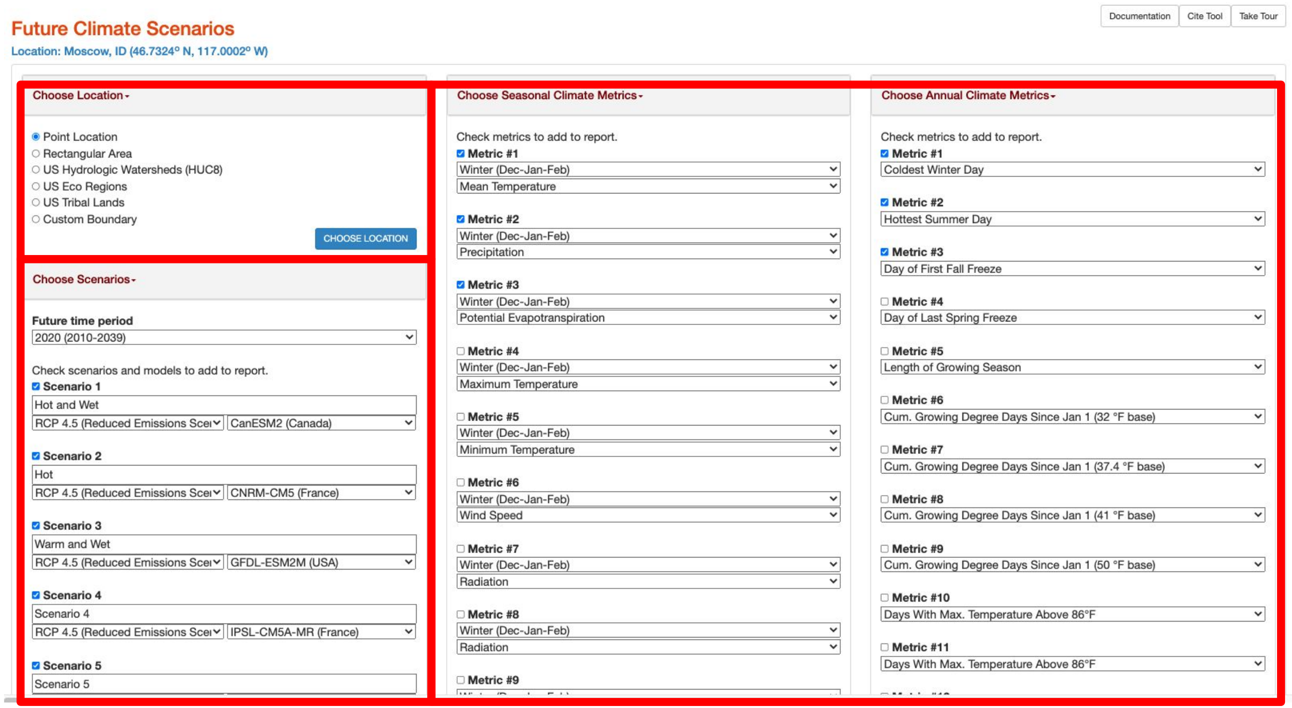
Toolbox - Future Climate Scatter Tool

Toolbox - Climate Mapper Tool



Toolbox - Future Scenarios Tool

- Select location of habitat.
- Select future climate scenarios from GCMs, RCPs.
- Select summary climate metrics.



Toolbox - Future Scenarios Tool

Climate Scenarios

The summary table below describes changes in the future climate by 2020 (2010-2039) relative to the 1971-2000 period under climate scenarios: **Hot and Wet** (CanESM2.rcp45), **Hot** (CNRM-CM5.rcp45), **Warm and Wet** (GFDL-ESM2M.rcp45)

Climate Metric	Hot and Wet	Hot	Warm and Wet	Historical Value
Winter Mean Temperature (°F) (change relative to historical by °F)	**35.71 (3.01)**	**34.43 (1.73)**	**33.54 (0.84)**	**32.70**
Winter Precipitation (% change relative to historical)	**2.35 (12.98)**	**2.51 (20.67)**	**2.19 (5.29)**	**2.08**
Winter Potential Evapotranspiration (% change relative to historical)	**4.66 (21.35)**	**4.20 (9.38)**	**3.96 (3.13)**	**3.84**
Winter Maximum Temperature (°F) (change relative to historical by °F)	**47.89 (2.26)**	**46.82 (1.19)**	**45.97 (0.34)**	**45.63**
Coldest Winter Day (relative to historical by °F)	**-3.59** (3.09)	**-5.19** (1.49)	**-4.37** (2.31)	**-6.68**
Hottest Summer Day (relative to historical by °F)	**100.27** (3.46)	**98.03** (1.22)	**96.36** (-0.45)	**96.81**
Day of First Fall Freeze (relative to historical by days)	**Oct. 10** (9.30)	**Oct. 10** (9.30)	**Sept. 25** (-5.70)	**Sept. 30**
Day of Last Spring Freeze (relative to historical by days)	**May 1** (-4.50)	**Apr. 24** (-11.50)	**May 4** (-1.50)	**May 5**
Length of Growing Season (relative to historical by days)	**162.00** (13.80)	**169.00** (20.80)	**144.00** (-4.20)	**148.20**

Quantities and projected changes described above are for the location at 40.015°N; 105.2705°W and a mean elevation of ?? ft.. Winter is Dec, Jan, Feb; Spring is Mar, Apr, May; Summer is Jun, Jul, Aug and Fall is Sep, Oct, Nov.

Dataset: MACA-METDATA v2 (4-km downscaled climate projections), VIC (v4.1.2) forced by MACAv2-LIVNEH (6-km hydrology projections) and gridMET (4-km historical).

Geospatial Layer Downloads

×

Climate Scenarios by 2020 (2010-2039) for the {Name of Region} {Name of Species}

The table below provides links to download the geospatial raster data (all of the contiguous US) of the future climate projections by 2020 (2010-2039) relative to the 1971-2000 period under climate scenarios: **Hot and Wet** (CanESM2.rcp45), **Hot** (CNRM-CM5.rcp45), **Warm and Wet** (GFDL-ESM2M.rcp45), **Scenario 4** (IPSL-CM5A-MR.rcp45), **Scenario 5** (20CMIP5ModelMean.rcp45)

Climate Metric	Hot and Wet	Hot	Warm and Wet	Scenario 4	Scenario 5	Historical Value
Winter Mean Temperature	Link	Link	Link	Link	Link	Link
Winter Precipitation	Link	Link	Link	Link	Link	Link
Winter Potential Evapotranspiration	Link	Link	Link	Link	Link	Link
Coldest Winter Day (relative to historical by °F)	Link	Link	Link	Link	Link	Link
Hottest Summer Day (relative to historical by °F)	Link	Link	Link	Link	Link	Link
Day of First Fall Freeze (relative to historical by days)	Link	Link	Link	Link	Link	Link

Quantities and projected changes described above are for the location at 46.7324°N; 117.0002°W and a mean elevation of ?? ft.. Winter is Dec, Jan, Feb; Spring is Mar, Apr, May; Summer is Jun, Jul, Aug and Fall is Sep, Oct, Nov.

Dataset: MACA-METDATA v2 (4-km downscaled climate projections), VIC (v4.1.2) forced by MACAv2-LIVNEH (6-km hydrology projections) and gridMET (4-km historical).

Incorporating Future Climate and Uncertainty in Impacts Assessment

Current State of Practice

Build Partnerships!

It's a tricky business…but one which we must carry out with the best available information and understanding

Challenges

1. **Uncertainty:** *Arising from differences across climate models, emission scenarios, and choice and structure of ecological methods*

2. **Complexity:** *Complex interactions between climate and ecological process and their relevant spatiotemporal scales (known unknowns and unknown unknowns)*

3. **Constraints:** *Availability of suitable observed and modeled data at appropriate spatiotemporal scales*

climate MDPI

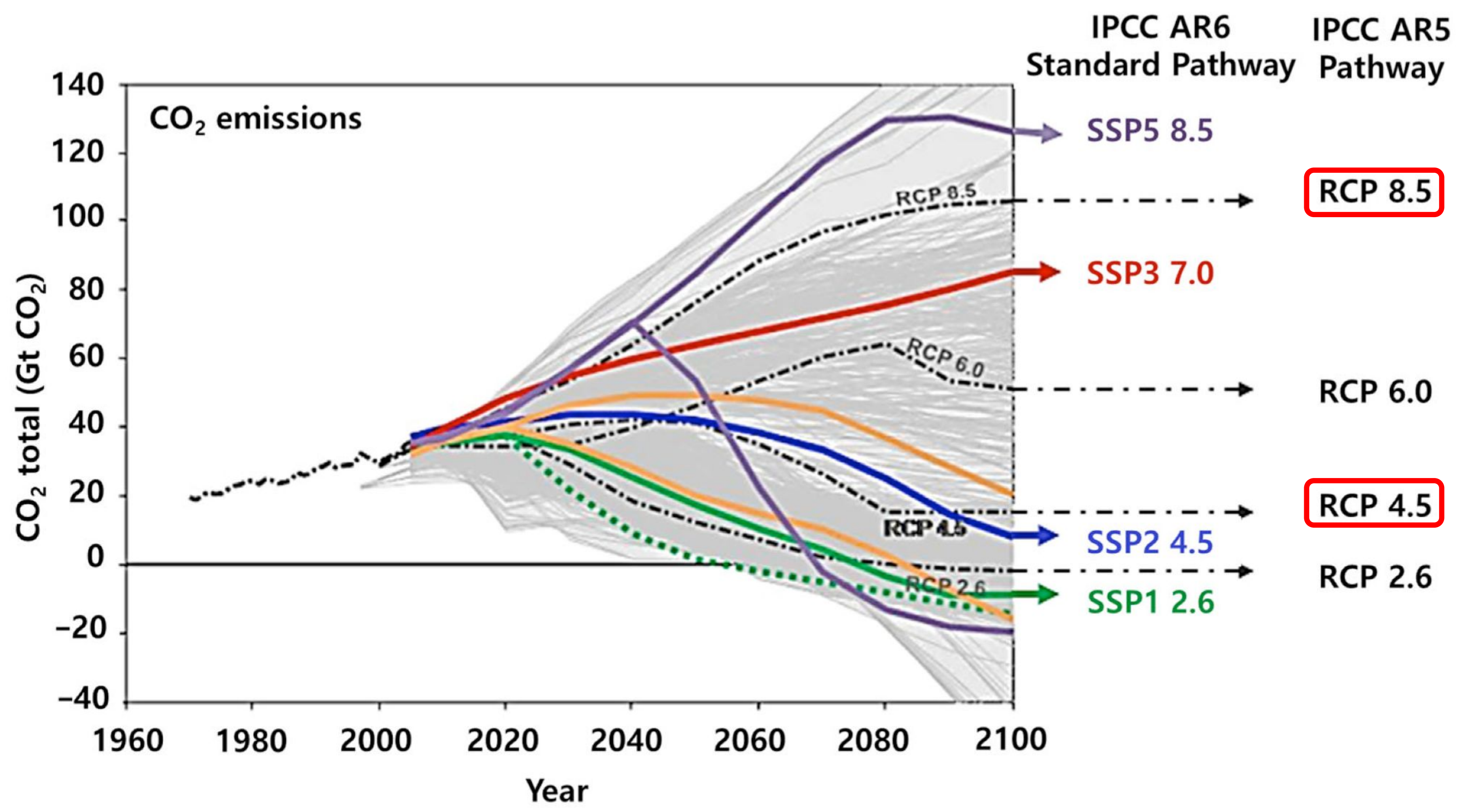
Article

Uncertainty, Complexity and Constraints: How Do We Robustly Assess Biological Responses under a Rapidly Changing Climate?

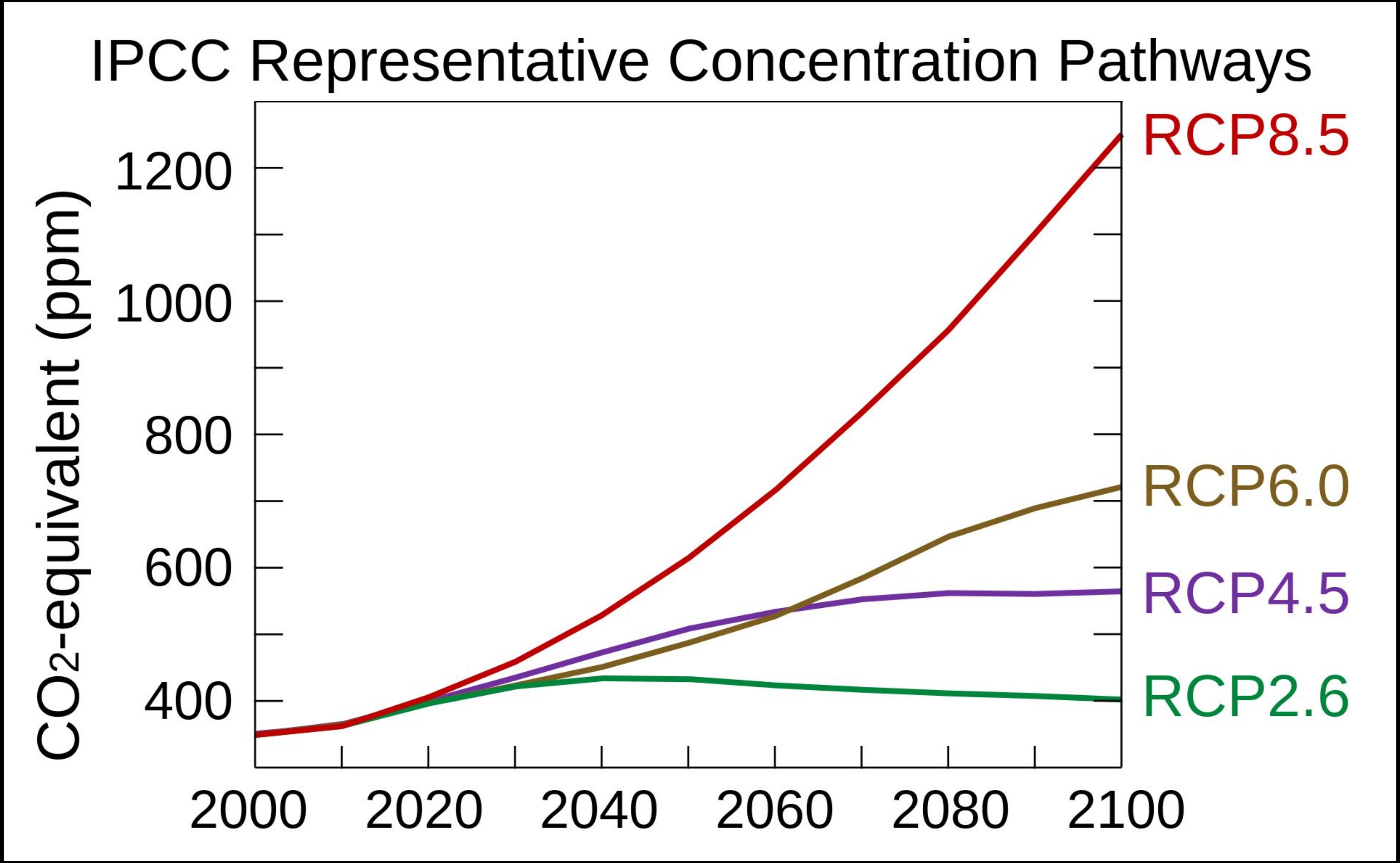
Imtiaz Rangwala [1,*], Wynne Moss [1,2], Jane Wolken [1], Renee Rondeau [3], Karen Newlon [4], John Guinotte [4] and William Riebsame Travis [1,5]

Uncertainty from emission scenarios and inter-model differences

Different Emissions Scenarios

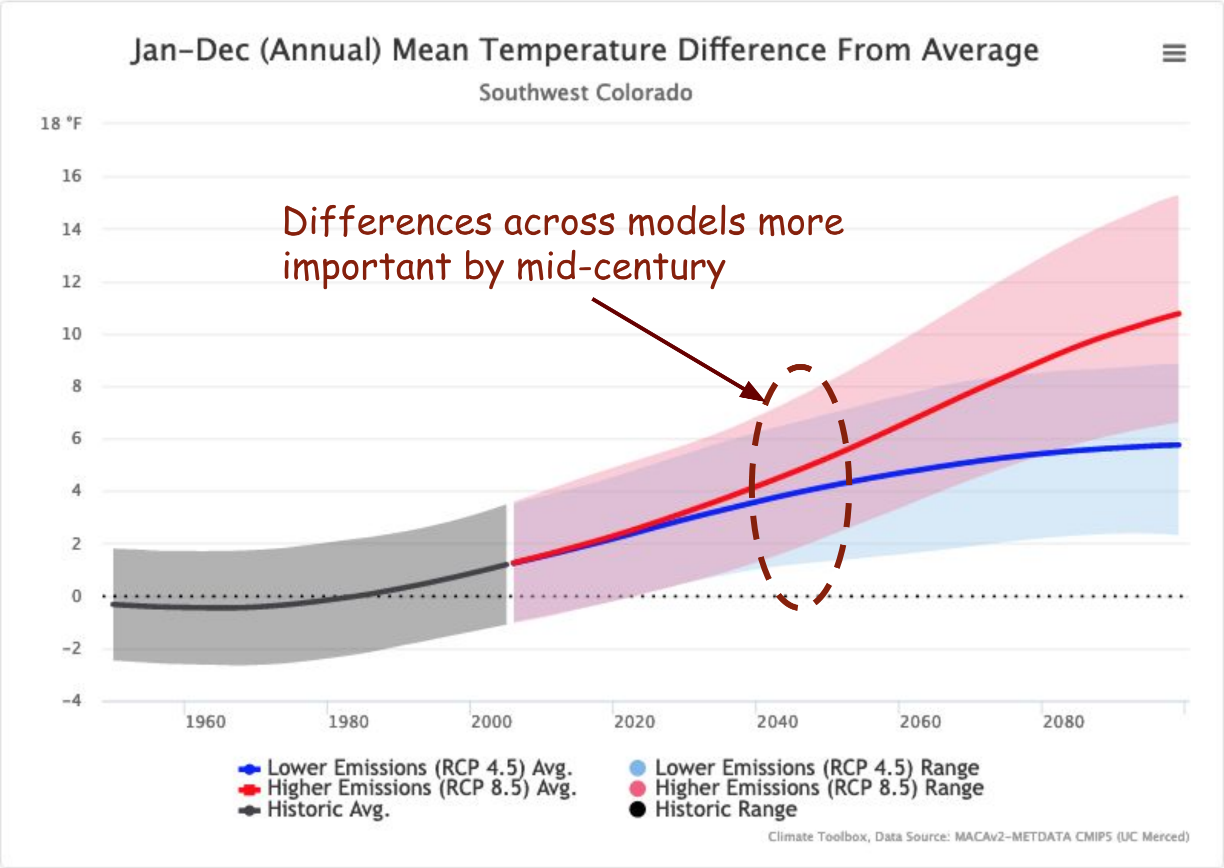


Sustainability **2022**, *14*(7), 4252; https://doi.org/10.3390/su14074252

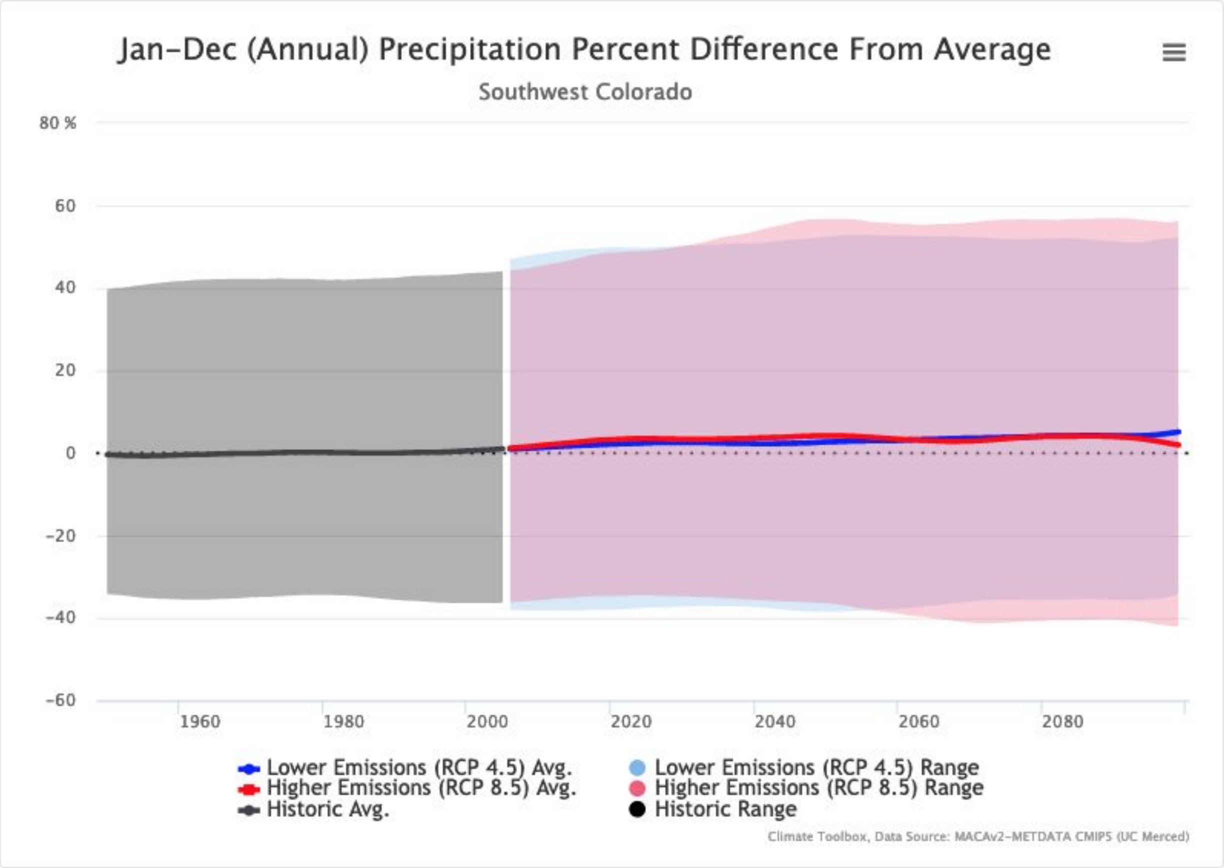


https://commons.wikimedia.org/wiki/File:All_forcing_agents_CO2_equivalent_concentration.svg

Differences in temperature projections across emission scenarios become important after 2050

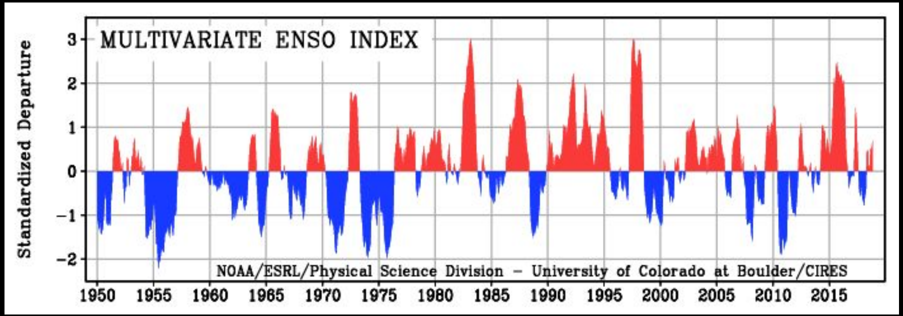


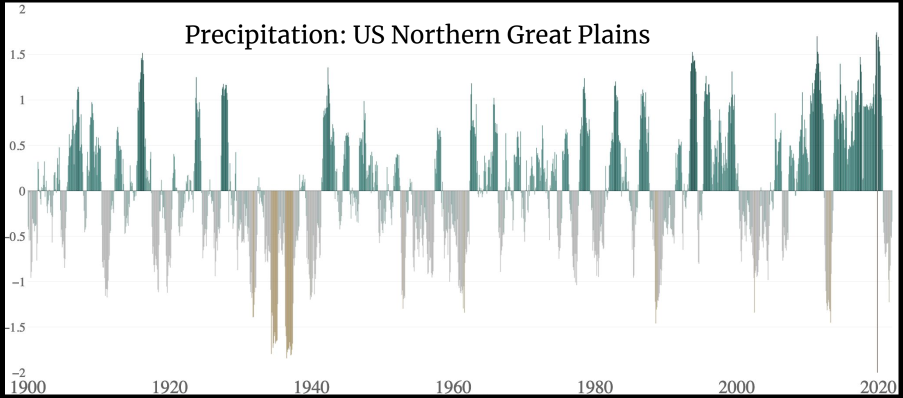
Emission scenarios have no significant impact on total precipitation projections; natural climate variability has a large influence

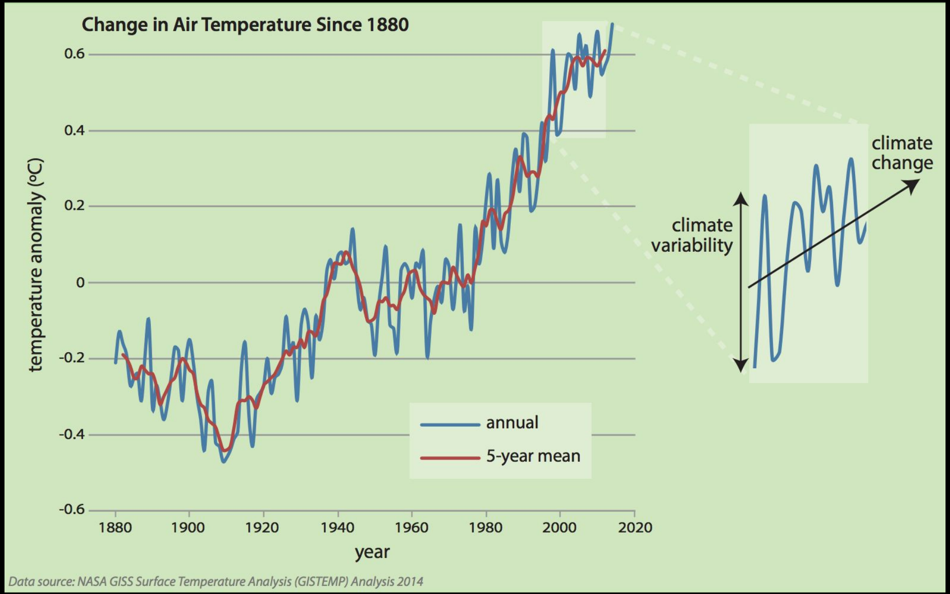


Climate Variability/Stochasticity

- ➔ Fluctuations (ups and downs around a long-term mean) in climatic conditions on time scales of months, years, decades, centuries and beyond

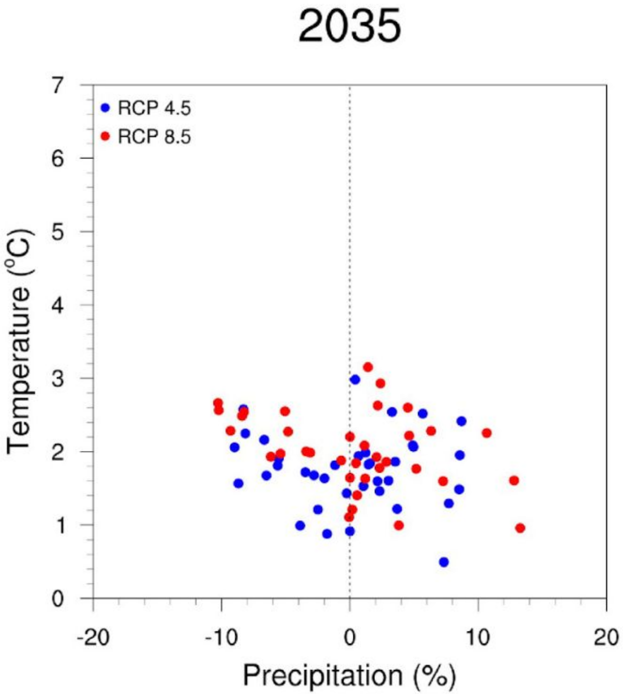






Climate and Weather Extremes!

Changes in Annual Temperature and Precipitation in southwestern Colorado



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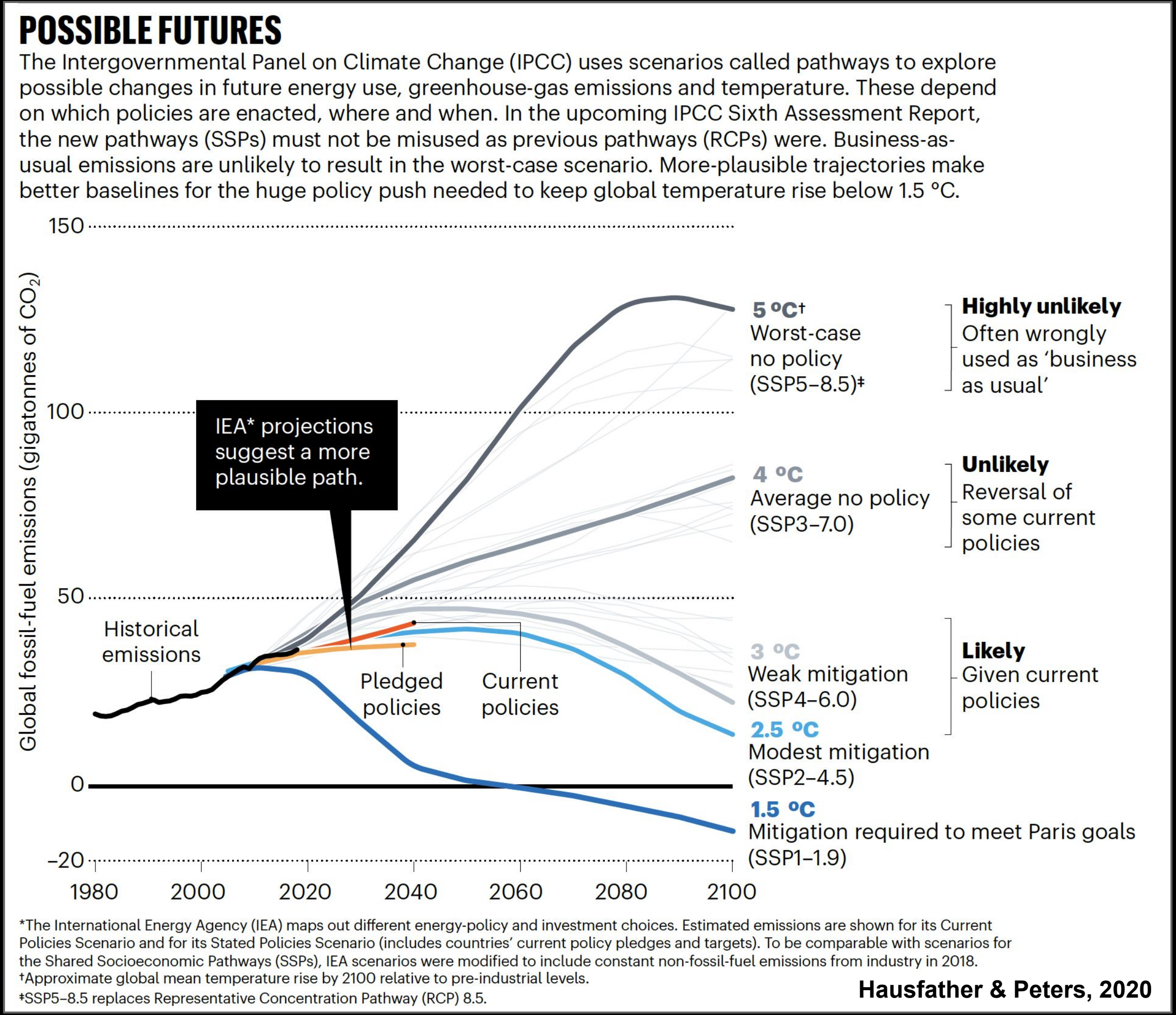


On the likelihood of emission scenarios

“high-end [emission] scenarios have become considerably less likely since AR5 but cannot be ruled out. It is important to realise that RCP8.5 and SSP5-8.5 do not represent a typical ‘business-as-usual’ projection but are only useful as high-end, high-risk scenarios”

IPCC AR6 WGIII Report

Scenario Planning to incorporate future climate uncertainty into impact assessment

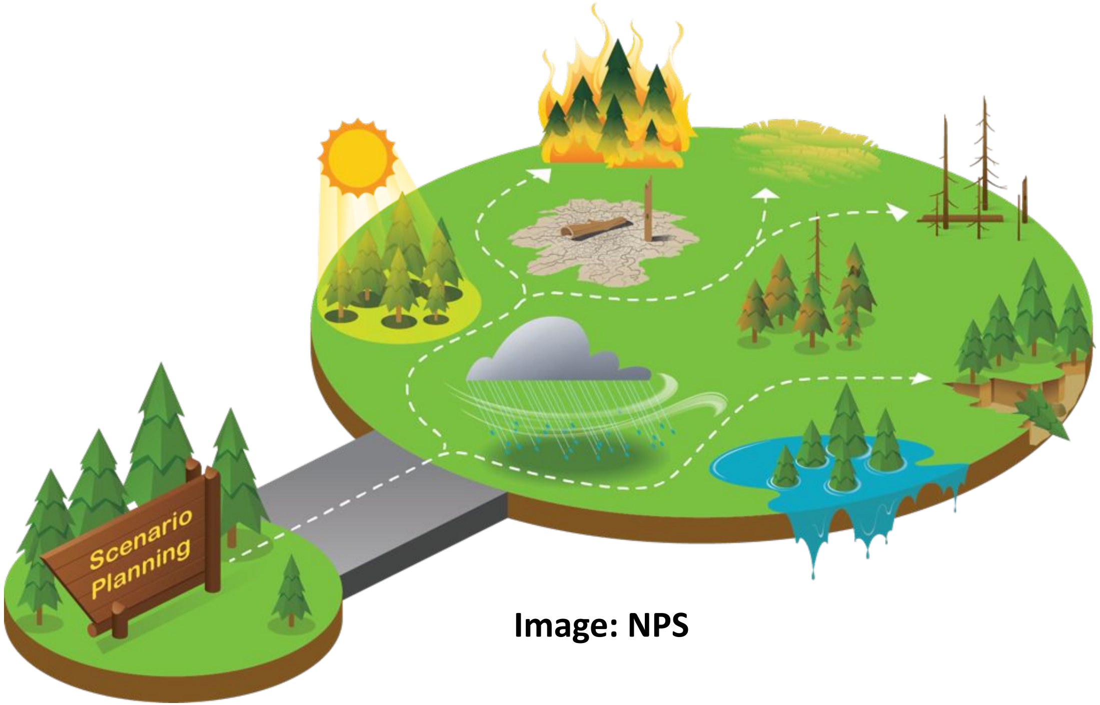
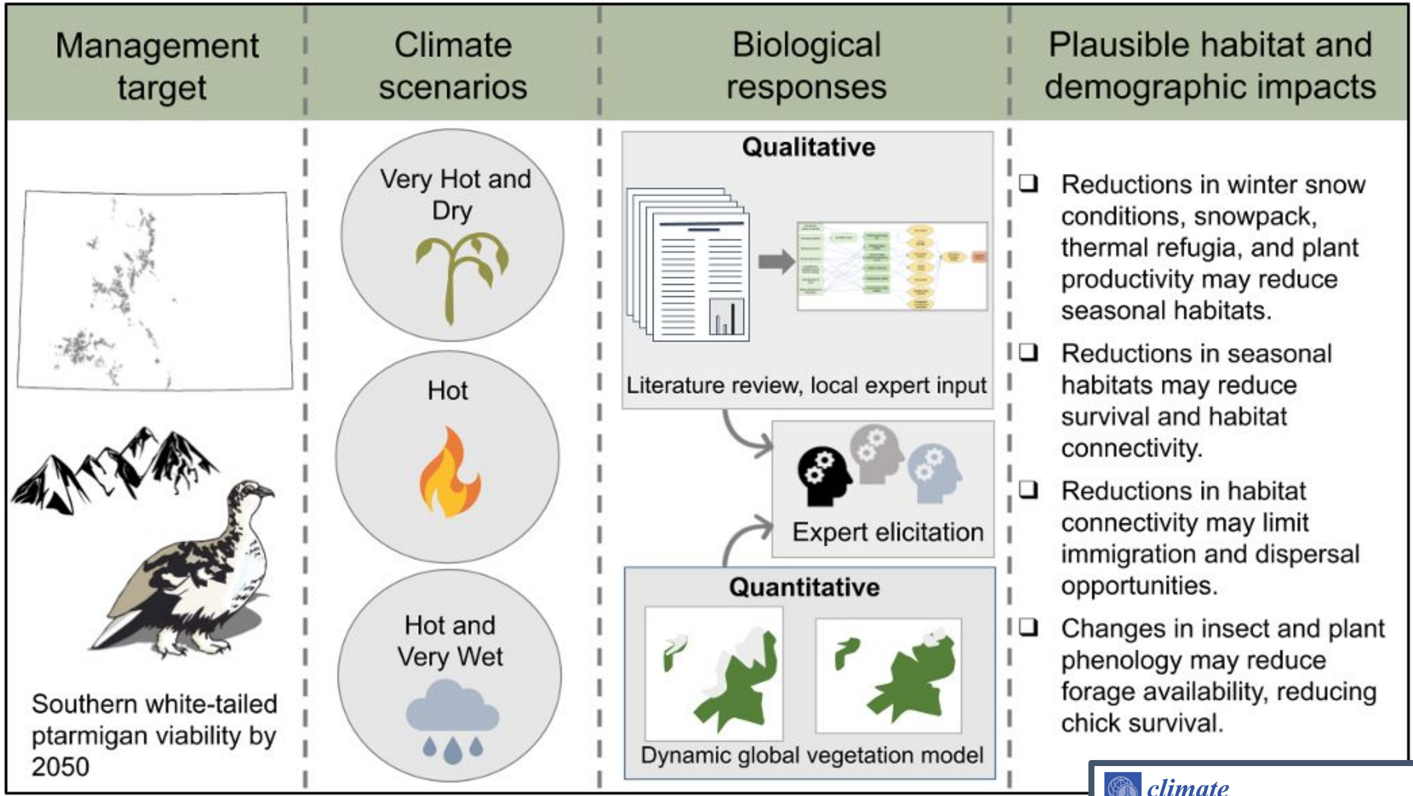


Image: NPS



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Scenario-Based Climate Change Impact Assessment

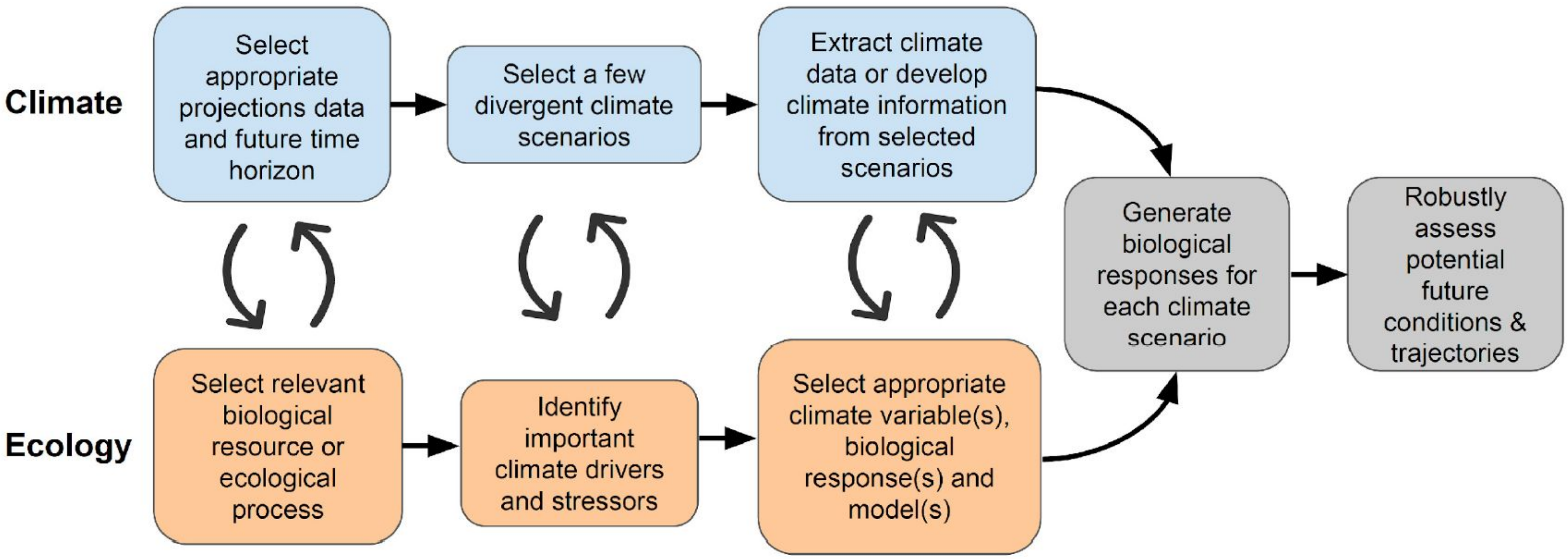
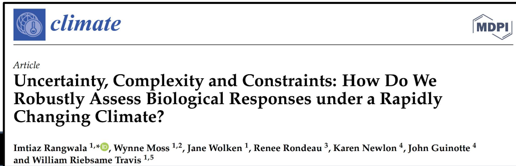


Figure 1. Process flow diagram of a typical approach for conducting biological impact assessments under different future climate scenarios. The curved arrows demonstrate the iterative (i.e., non-linear) process of integrating climate and ecology methods in conservation projects (e.g., Case Study 1 and 2 in Appendix A).



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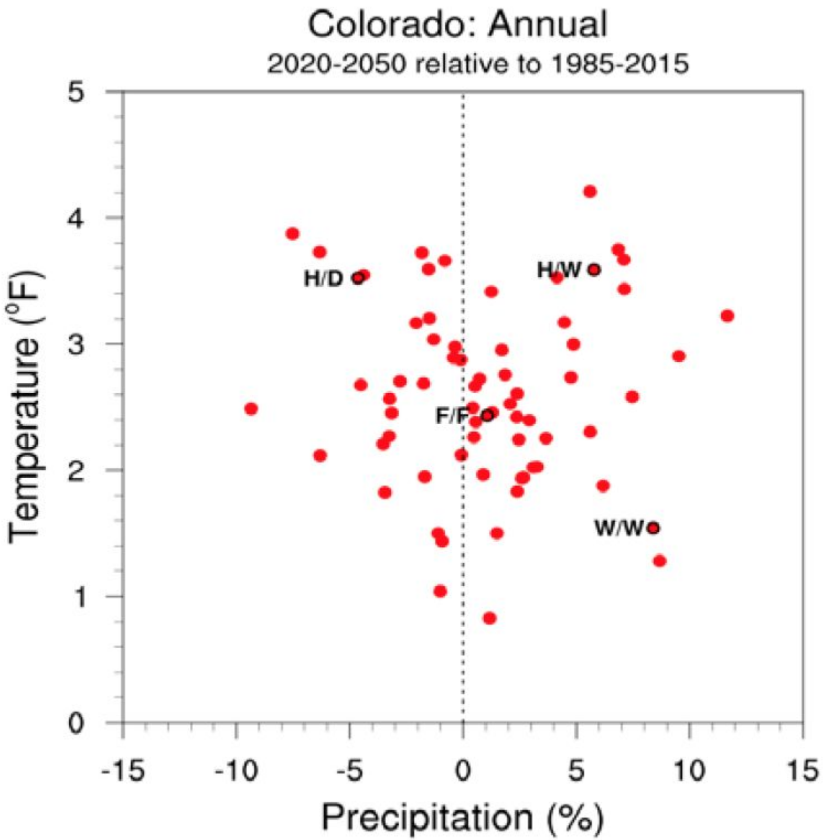
- Selecting and working with specific future climate scenarios (or climate futures)
- Use of bivariate scatter plot to select future climate scenarios



Climate Toolbox can help you do these kinds of scenario selections!

H/W	Hot & Wet	W/W	Warm & Wet
F/F	Feast & Famine	H/D	Hot & Dry

USFWS - Climate Information for Species Status Assessments

SSA climate metric table

Climate Scenarios by 2050 for the White-tailed Ptarmigan Range in Southern Colorado

The summary table below describes changes in the future climate by 2050 (2030-2069) relative to the 1971-2000 period under three climate scenarios: **Very Hot and Dry** (IPSL-CM5A-MR.rcp85), **Hot** (CCSM4.rcp45), and **Hot and Very Wet** (MIROC5.rcp45)

Climate Metric	Time Period	Very Hot and Dry	Hot	Hot and Very Wet	*Historical Value*
Mean Temperature (°F)	Annual	8	4	6	*33°F*
	Winter	7	4	6	*19°F*
	Spring	7	4	10	*31°F*
	Summer	8	4	4	*49°F*
	Fall	8	5	5	*34°F*
Precipitation (%)	Annual	-18	0	6	*38 inches*
	Winter	-10	5	-6	*11 inches*
	Spring	-22	-1	41	*10 inches*
	Summer	-27	-2	28	*7 inches*
	Fall	-16	-3	-9	*10 inches*
Daytime Maximum Temperature (°F)	Annual	8	4	6	*47°F*
	Winter	7	3	6	*32°F*
	Spring	8	4	10	*45°F*
	Summer	8	5	3	*63°F*
	Fall	9	5	5	*47°F*
Daytime Minimum Temperature (°F)	Annual	7	3	6	*20°F*
	Winter	7	4	7	*5°F*
	Spring	6	3	9	*17°F*
	Summer	8	3	4	*36°F*
	Fall	8	3	4	*22°F*
Snow Water Equivalent (%)	January 1	-27	-13	-28	*9 inches*
	April 1	-17	-7	-17	*21 inches*
	May 1	-37	-14	-37	*24 inches*
Soil Moisture (%)	Spring	-9	-1	4	*22 inches*
	Summer	-19	-8	-10	*24 inches*
	Fall	-25	-8	-6	*21 inches*
Potential Evapotranspiration (%)	Summer	20	11	7	*16 inches*
	Fall	54	28	28	*6 inches*

Climate Metric	Very Hot and Dry	Hot	Hot and Very Wet	*Historical Value*
Coldest Winter Day (°F) **(warmer relative to historical by °F)**	-9 (9)	-15 (3)	-10 (8)	*-18*
Hottest Summer Day (°F) **(warmer relative to historical by °F)**	80 (8)	77 (5)	75 (3)	*72*
#Days with daytime low above 32°F **(increases in #days)**	147 (52)	118 (23)	133 (38)	*95*
First Fall Freeze **(later relative to historical by #days)**	Sep 21 (42)	Sep 10 (31)	Sep 14 (35)	*Aug 10*
Last Spring Freeze **(earlier relative to historical by #days)**	Jun 4 (17)	Jun 17 (4)	Jun 13 (8)	*Jun 21*
Growing Season Length (#days) **(higher relative to historical by #days)**	109 (45)	90 (26)	93 (29)	*64*
Growing Degree Days (°F; 32°F base)	4098	3276	3517	*2381*
Frequency of Severe Drought like 2002	Almost every year	Every 3-4 years	Every 6 years	-
Duration of Severe Drought like 2002	1-6 years	1-2 years	1-2 years	1 year
"High" Fire Danger Days **(higher relative to historical by #days)**	128 (55)	86 (13)	82 (11)	*73*
"Very High" Fire Danger Days **(higher relative to historical by #days)**	84 (47)	48 (11)	44 (7)	*37*
"Extreme" Fire Danger Days **(higher relative to historical by #days)**	47 (36)	19 (9)	14 (3)	*11*

Very Hot and Dry	• Very large increase in annual and summer temperatures (8°F) with substantial reduction in annual (-20%) and summer (-30%) precipitation • Hottest summer daytime high increases by 8°F; severe drought almost every year with extreme drought conditions lasting up to 6 years • Large reduction in spring snowpack (May 1 SWE is 40% lower) • Growing season and "High" fire danger days increase by ~50 days • Monsoonal precipitation decreases significantly, but 20% more intense rainfall events when they occur
Hot	• Moderate increase in annual temperature (4°F) but no change in precipitation amounts • Hottest summer daytime high increases by 5°F; severe drought every 6 years with extreme drought conditions lasting up to 2 years • Moderate reduction in spring snowpack (May 1 SWE is 15% lower) • Growing season increases by > 3 weeks and "High" fire danger days increase by 2 weeks • Monsoonal precipitation decreases very slightly, but 10% more intense rainfall events
Hot and Very Wet	• Least increase in summer daytime high temperature (3°F) but extremely warm springs (10°F) • 40% increase in spring precipitation and a high proportion of that falling as rain • Spring runoff increases by 50%, but decline in summer flows; severe drought every 3-4 years with extreme drought conditions lasting up to 2 years • Growing season increases by 4 weeks and "High" fire danger days increase by > 1 week • Monsoonal precipitation increases very substantially (+30%) with 10% greater intensity

Values and projected changes described above are for the location at **37.8125°N; 107.7819°W** and a mean elevation of **10,750 ft**. Winter is Dec, Jan, Feb; Spring is Mar, Apr, May; Summer is Jun, Jul, Aug and Fall is Sep, Oct, Nov. Dataset: MACA metdata v2 (4-km downscaled climate projections), VIC (v4.1.2) forced by MACAv2-LIVNEH (6-km hydrology projections) and gridMET (4-km historical).

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CIRES, University of Colorado, Boulder; North Central Climate Adaptation Science Center

USFWS - Climate Information for Species Status Assessments

SSAs where the climate toolbox has been used

#	SSA	Year	FWS contacts
1	Wolverine (CO, MT)	2017	Steve Torbit, John Guinotte
2	Skiff milkvetch (CO)	2018	Dara Taylor, Sarah Backsen, John Guinotte
3	Southern White-tailed Ptarmigan (WY, CO, NM)	2018-19	Karen Newlon, John Guinotte
4	Rocky Mountain Monkey Flower	2018-19	Dara Suich
5	Colorado North Park Phacelia	2020	Kurt Broderdorp, Creed Clayton
6	Silverspot butterfly (CO)	2020	Terry Ireland, Creed Clayton
7	Several listed species in Mojave Desert UT	2020	Hilary Whitcomb, John Guinotte, Kimberly Smith
8	DeBeque Phacelia and CO Hookless Cactus	2020	Alexandra Kasdin, Aimee Crittendon, Creed Clayton, John Guinotte
9	Brandegee's Buckwheat (CO)	2021	Alexandra Kasdin, Laura Archuleta, John Guinotte
10	Cisco and Isely's milkvetch (UT)	2021	Karen Newlon, John Guinotte
11	Regal Fritillary Butterfly (central US, PA)	2021	Craig Hansen, Kim Daniel, Natalie Gates, Pamela Shellenberger, Sarah Furtak, Steven Choy, Brooke Stansberry, John Guinotte
12	Western Bumble Bee	2021	Tabitha Graves, William Janousek
13	Narrow Foot Hygrotus Diving Beetle	2022	Julie Reeves, Alex Kasdin, John Guinotte
14	Canada Lynx	2022 (?)	Jim Zelenak, John Guinotte


Wolverine (CO, MT)

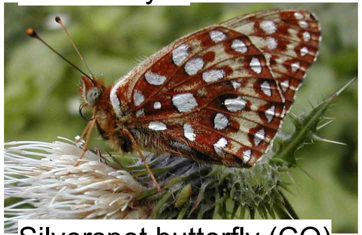

Southern White-tailed Ptarmigan


Western Bumble Bee


Canada Lynx


Hookless Cactus


Monkey Flower


Silverspot butterfly (CO)


Cisco and Isely's milkvetch


Phacelia

USFWS - Climate Information for Species Status Assessments

Recent publication outlining the process and tools

climate MDPI

Article

Uncertainty, Complexity and Constraints: How Do We Robustly Assess Biological Responses under a Rapidly Changing Climate?

Imtiaz Rangwala [1,*], Wynne Moss [1,2], Jane Wolken [1], Renee Rondeau [3], Karen Newlon [4], John Guinotte [4] and William Riebsame Travis [1,5]

1 North Central Climate Adaptation Science Center & Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder, Boulder, CO 80309, USA; wynne@csp-inc.org (W.M.); Jane.Wolken@colorado.edu (J.W.); william.travis@colorado.edu (W.R.T.)
2 Conservation Science Partners, Truckee, CA 96161, USA
3 Colorado Natural Heritage Program, Colorado State University, Ft. Collins, CO 80523, USA; renee.rondeau@colostate.edu
4 U.S. Fish and Wildlife Service, Lakewood, CO 80228, USA; karen_newlon@fws.gov (K.N.); john_guinotte@fws.gov (J.G.)
5 Department of Geography, University of Colorado Boulder, Boulder, CO 80309, USA
* Correspondence: imtiaz.rangwala@colorado.edu

Abstract: How robust is our assessment of impacts to ecosystems and species from a rapidly changing climate during the 21st century? We examine the challenges of *uncertainty, complexity* and *constraints* associated with applying climate projections to understanding future biological responses. This includes an evaluation of how to incorporate the uncertainty associated with different greenhouse gas emissions scenarios and climate models, and constraints of spatiotemporal scales and resolution of climate data into impact assessments. We describe the challenges of identifying relevant climate metrics for biological impact assessments and evaluate the usefulness and limitations of different methodologies of applying climate change to both quantitative and qualitative assessments. We discuss the importance of incorporating extreme climate events and their stochastic tendencies in assessing ecological impacts and transformation, and provide recommendations for better integration of complex climate–ecological interactions at relevant spatiotemporal scales. We further recognize the compounding nature of uncertainty when accounting for our limited understanding of the interactions between climate and biological processes. Given the inherent complexity in ecological processes and their interactions with climate, we recommend integrating quantitative modeling with expert elicitation from diverse disciplines and experiential understanding of recent climate-driven ecological processes to develop a more robust understanding of ecological responses under different scenarios of future climate change. Inherently complex interactions between climate and biological systems also provide an opportunity to develop wide-ranging strategies that resource managers can employ to prepare for the future.

Keywords: natural resource management; conservation; climate adaptation; climate change; ecological transformation; biodiversity; ecosystems; regional projections; uncertainty; complexity; scenario planning; ecological impact assessment; wildlife; expert elicitation

check for updates

Citation: Rangwala, I.; Moss, W.; Wolken, J.; Rondeau, R.; Newlon, K.; Guinotte, J.; Travis, W.R. Uncertainty, Complexity and Constraints: How Do We Robustly Assess Biological Responses under a Rapidly Changing Climate? *Climate* **2021**, *9*, 177. https://doi.org/10.3390/cli9120177

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Published: 7 December 2021

1. Introduction

The Earth's climate is experiencing rapid heating caused by an increasing accumulation of human-induced greenhouse gases in the atmosphere. The resulting climatic changes, which are unprecedented in at least the last 2000 years, are expected to continue and further intensify in coming decades as the concentrations of atmospheric greenhouse gases rise [1]. Shifts in large-scale climate regimes and their influence on climate and weather extremes experienced at local-to-regional scales are expected to drive significant

Uncertainty, Complexity and Constraints: How Do We Robustly Assess Biological Responses under a Rapidly Changing Climate?
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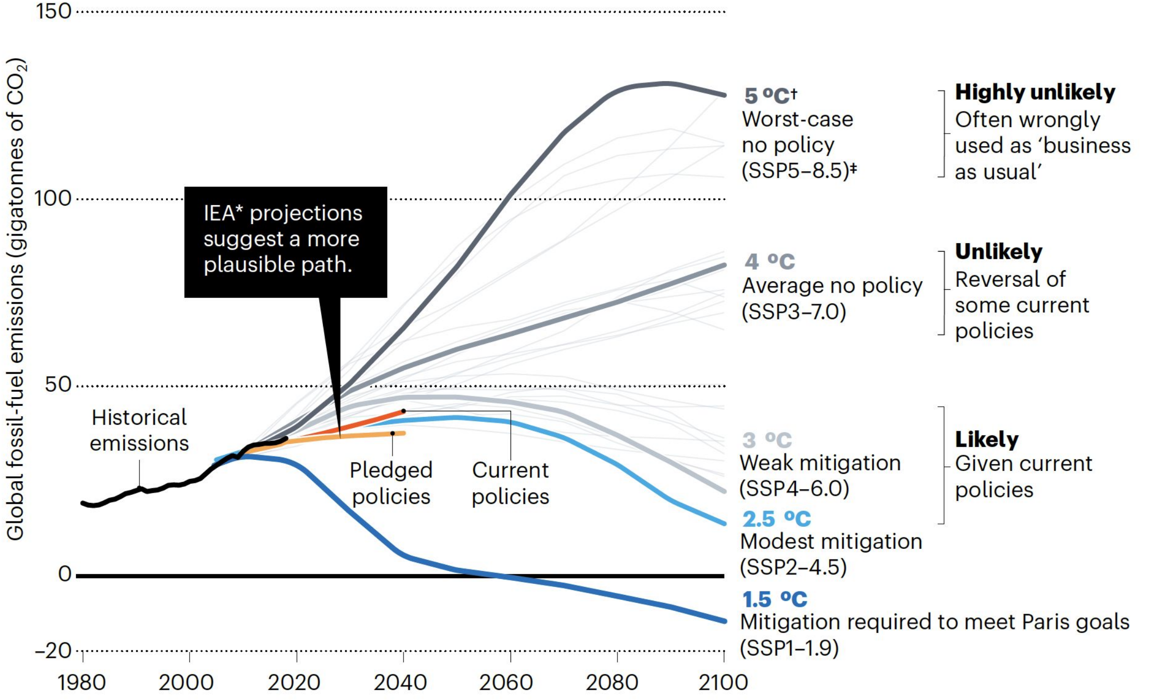
2021, Climate

POSSIBLE FUTURES

The Intergovernmental Panel on Climate Change (IPCC) uses scenarios called pathways to explore possible changes in future energy use, greenhouse-gas emissions and temperature. These depend on which policies are enacted, where and when. In the upcoming IPCC Sixth Assessment Report, the new pathways (SSPs) must not be misused as previous pathways (RCPs) were. Business-as-usual emissions are unlikely to result in the worst-case scenario. More-plausible trajectories make better baselines for the huge policy push needed to keep global temperature rise below 1.5 °C.



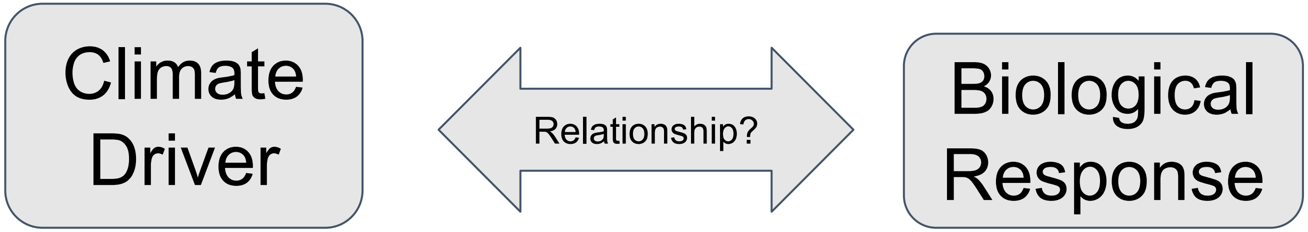
*The International Energy Agency (IEA) maps out different energy-policy and investment choices. Estimated emissions are shown for its Current Policies Scenario and for its Stated Policies Scenario (includes countries' current policy pledges and targets). To be comparable with scenarios for the Shared Socioeconomic Pathways (SSPs), IEA scenarios were modified to include constant non-fossil-fuel emissions from industry in 2018.
†Approximate global mean temperature rise by 2100 relative to pre-industrial levels.
‡SSP5–8.5 replaces Representative Concentration Pathway (RCP) 8.5.

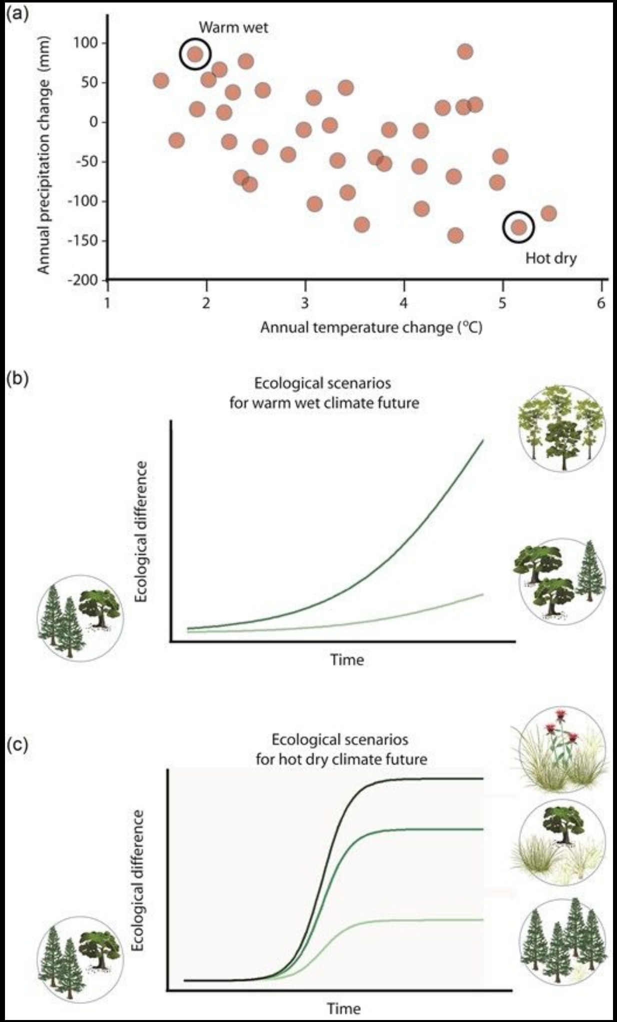
Hausfather & Peters, 2020

FWS definition of foreseeable future

"foreseeable future" to extend "only so far into the future as the Service can reasonably determine that both the future threats and the species' responses to those threats are likely."

Next Big Challenge to Impact Assessment

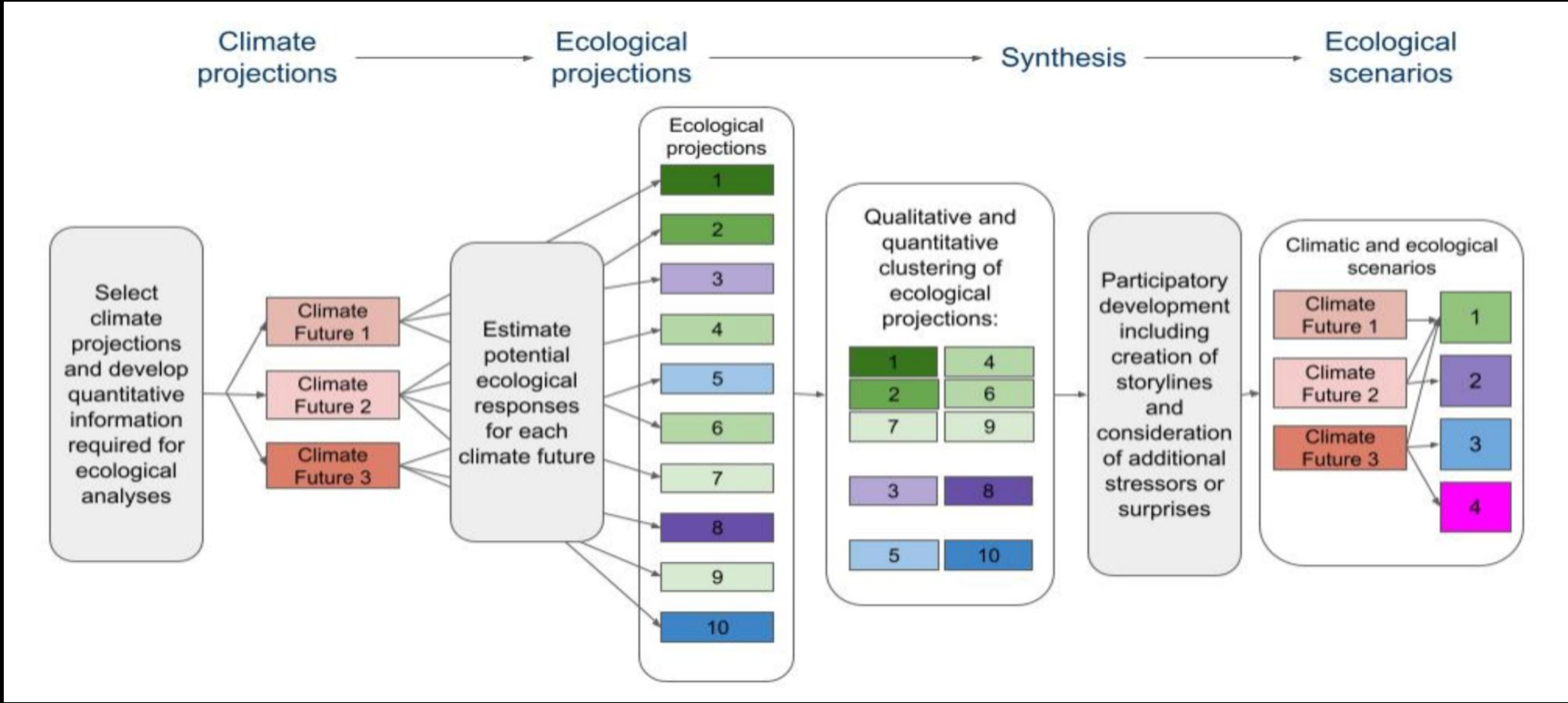




Multiple ecological/biological response scenarios are plausible for a given climate scenario!!!

A Science Agenda to Inform Natural Resource Management Decisions in an Era of Ecological Transformation

SHELLEY D. CRAUSBAY, HELEN R. SOFAER, AMANDA E. CRAVENS, BRIAN C. CHAFFIN, KATHERINE R. CLIFFORD, JOHN E. GROSS, CORRINE N. KNAPP, DAVID J. LAWRENCE, DAWN R. MAGNESS, ABRAHAM J. MILLER-RUSHING, GREGOR W. SCHUURMAN, AND CAMILLE S. STEVENS-RUMANN



Hypothetical workflow for developing ecological scenarios

Climate Toolbox Activity: Retrieving Scenario Data

Regal Fritillary

Location of Interest:

Prairie Coteau

(45.8766 N Lat , 98.2591 W Long)

Climate Variables of Interest:

- Days with heat index > 105F and
- Jun-Aug precipitation

Futures of Interest:

- RCP 4.5
- Mid-Century (2040-2069)

Climate Toolbox Activity

1. ClimateToolbox.org

2. Future Scatter Tool
   - Select location
   - Select variables of interest
   - Select future emission scenario
   - Look at the spread of the model results
     - Choose 2 divergent models in the scatter of results
     - Record the model names & data in Scenario Table
     - Save the Scenario Table

3. Future Climate Scenario Tool
   - Select location
   - Select future emission scenario
   - Select the model names from previous
   - Select different variables
   - Generate and save a report

Regal Fritillary (Prairie Coteau)

Documentation | Cite Tool | Take Tour

Future Climate Scatter

View a scatterplot of future projections for a location in the contiguous USA.

Location: 45.8766° N, 98.2591° W

Make Request

To update the graph, make all of your selections and then click this button.

MAKE REQUEST

Choose Location

- Point Location
- Rectangular Area
- US County Area
- US Hydrologic Watersheds (HUC8)

CHOOSE LOCATION

Choose Data

Show changes

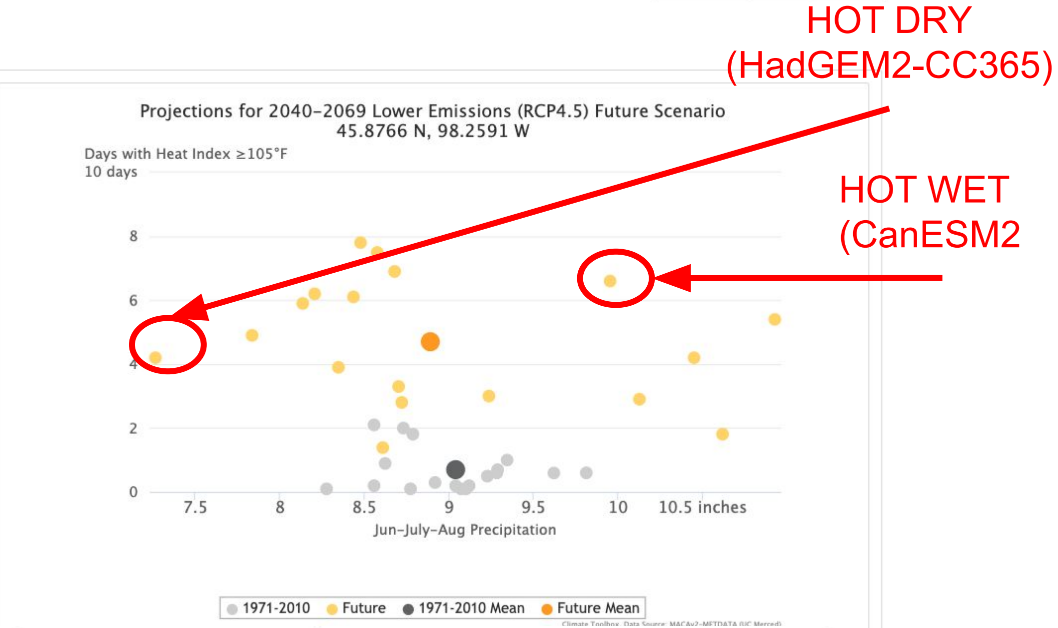
Vertical(Y)-Axis:

Days with Heat Index ≥105°F

Horizontal(X)-Axis:

Jun-July-Aug

Precipitation



Scenario Table Results

SCENARIO	TIME PERIOD	MODEL	X-VALUE	Y-VALUE
Scenario	Time Period	Model	Jun-July-Aug Precipitation(inches)	Dec-Jan-Feb Days with Heat Index ≥105°F(days)
RCP 4.5	2040-2069	CanESM2	10	6.6
RCP 4.5	2040-2069	HadGEM2-CC365	7.3	4.2
HISTORICAL	1971-2010	20CMIP5ModelMean	9	0.7

Regal Fritillary (Prairie Coteau)

Documentation | Cite Tool | Take Tour

Future Climate Scenarios

Location: 45.8766° N, 98.2591° W

Choose Location▾

- (•) Point Location
- ( ) Rectangular Area

CHOOSE LOCATION

Choose Scenarios▾

Future time period
2050 (2040-2069)

Check scenarios and models to add to report.

☑ **Scenario 1**
Hot and Wet
RCP 4.5 (Reduced Emissions Scenario)
CanESM2 (Canada)

☑ **Scenario 2**
Hot and Dry
RCP 4.5 (Reduced Emissions Scenario)
HadGEM2-CC365 (United Kingdom)

☐ **Scenario 3**
Warm and Wet
RCP 4.5 (Reduced Emissions Scenario)

Choose Seasonal Climate Metrics▾

Check metrics to add to report.

☑ **Metric #1**
Winter (Dec-Jan-Feb)
Mean Temperature

☑ **Metric #2**
Winter (Dec-Jan-Feb)
Precipitation

☑ **Metric #3**
Winter (Dec-Jan-Feb)
Potential Evapotranspiration

☑ **Metric #4**
Winter (Dec-Jan-Feb)
Maximum Temperature

☑ **Metric #5**
Winter (Dec-Jan-Feb)
Minimum Temperature

☑ **Metric #6**
Winter (Dec-Jan-Feb)
Wind Speed

Choose Annual Climate Metrics▾

Check metrics to add to report.

☑ **Metric #1**
Coldest Winter Day

☑ **Metric #2**
Hottest Summer Day

☑ **Metric #3**
Day of First Fall Freeze

☑ **Metric #4**
Day of Last Spring Freeze

☑ **Metric #5**
Length of Growing Season

☐ **Metric #6**
Cum. Growing Degree Days Since Jan 1 (32 °F ba

☐ **Metric #7**
Cum. Growing Degree Days Since Jan 1 (37.4 °F b

☐ **Metric #8**
Cum. Growing Degree Days Since Jan 1 (41 °F ba

Climate Scenarios

The summary table below describes changes in the future climate by 2050 (2040-2069) relative to the 1971-2000 period under climate scenarios: **Hot and Wet** (CanESM2.rcp45), **Hot and Dry** (HadGEM2-CC365.rcp45)

Climate Metric	Hot and Wet	Hot and Dry	Historical Value
Winter Mean Temperature (°F) (change relative to historical by °F)	**23.24** **(8.42)**	**23.67** **(8.85)**	**14.82**
Winter Precipitation (% change relative to historical)	**2.13** **(39.22)**	**1.89** **(23.53)**	**1.53**
Winter Potential Evapotranspiration (% change relative to historical)	**0.66** **(230.00)**	**0.70** **(250.00)**	**0.20**
Winter Maximum Temperature (°F) (change relative to historical by °F)	**31.93** **(7.08)**	**32.85** **(8.00)**	**24.85**
Winter Minimum Temperature (°F) (change relative to historical by °F)	**14.56** **(9.76)**	**14.48** **(9.68)**	**4.80**
Winter Wind Speed (% change relative to historical)	**9.47** **(-3.86)**	**10.01** **(1.62)**	**9.85**
Coldest Winter Day (relative to historical by °F)	**-10.50** (13.67)	**-12.31** (11.86)	**-24.17**
Hottest Summer Day (relative to historical by °F)	**106.08** (5.91)	**106.78** (6.61)	**100.17**
Day of First Fall Freeze (relative to historical by days)	**Oct. 6** (5.05)	**Oct. 11** (10.05)	**Sept. 30**
Day of Last Spring Freeze (relative to historical by days)	**Apr. 25** (-7.75)	**Apr. 20** (-12.75)	**May 2**
Length of Growing Season (relative to historical by days)	**164.00** (12.80)	**174.00** (22.80)	**151.20**
Days With Max. Temperature Above 86°F (relative to historical by days)	**74.53** (38.33)	**70.00** (33.80)	**36.20**

Quantities and projected changes described above are for the location at 45.8766°N; 98.2591°W and a mean elevation of ?? ft.. Winter is Dec, Jan, Feb; Spring is Mar, Apr, May; Summer is Jun, Jul, Aug and Fall is Sep, Oct, Nov.

Dataset: MACA-METDATA v2 (4-km downscaled climate projections), VIC (v4.1.2) forced by MACAv2-LIVNEH (6-km hydrology projections) and gridMET (4-km historical).

Conclusions/Wrap Up

Wrap Up

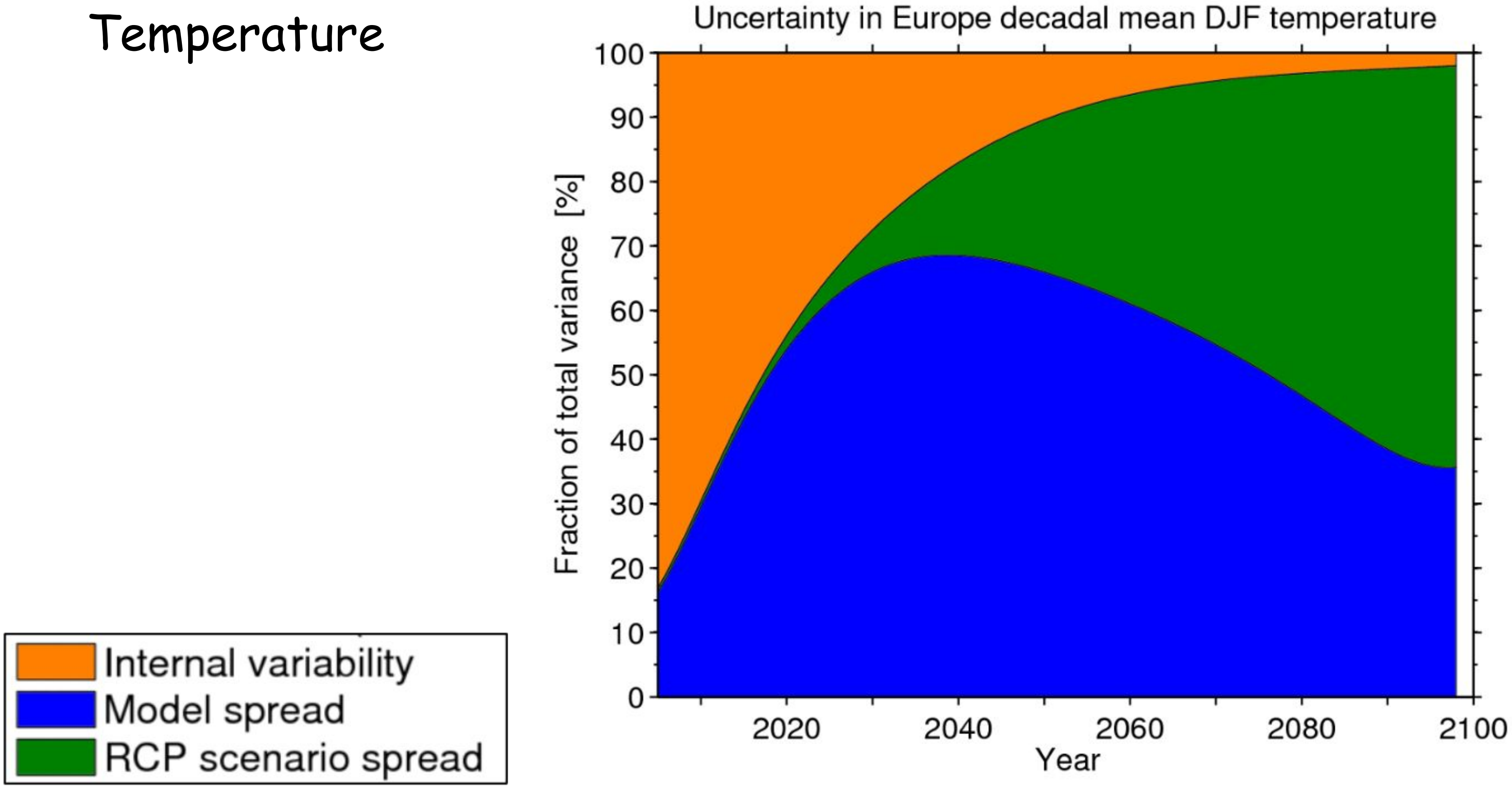
Extra Slides

Session 2: **How to Use the Climate Toolbox** 75 min 8:50-10:05 Moderator: Christy Miller Hesed	**Presenters:** Data/Analysis Tools: Imtiaz Rangwala (UC Boulder) John Guinotte (FWS) Katherine Hegewisch (UC Merced) **Resources:** Climate Toolbox: https://climatetoolbox.org/ NC CASC Tools and Data: https://nccasc.colorado.edu/index.php/resources/tools	**Goals:** Increased proficiency in accessing and using climate data and summaries to help your decision making. **Learn:** Participate in a demonstration of climate science tools and how they apply the tools to your work **Do:** Hands on use of a set of tools in the toolbox **Reflect:** Do you want to discover more tools and how to use them? Are there tools you need but don't have?

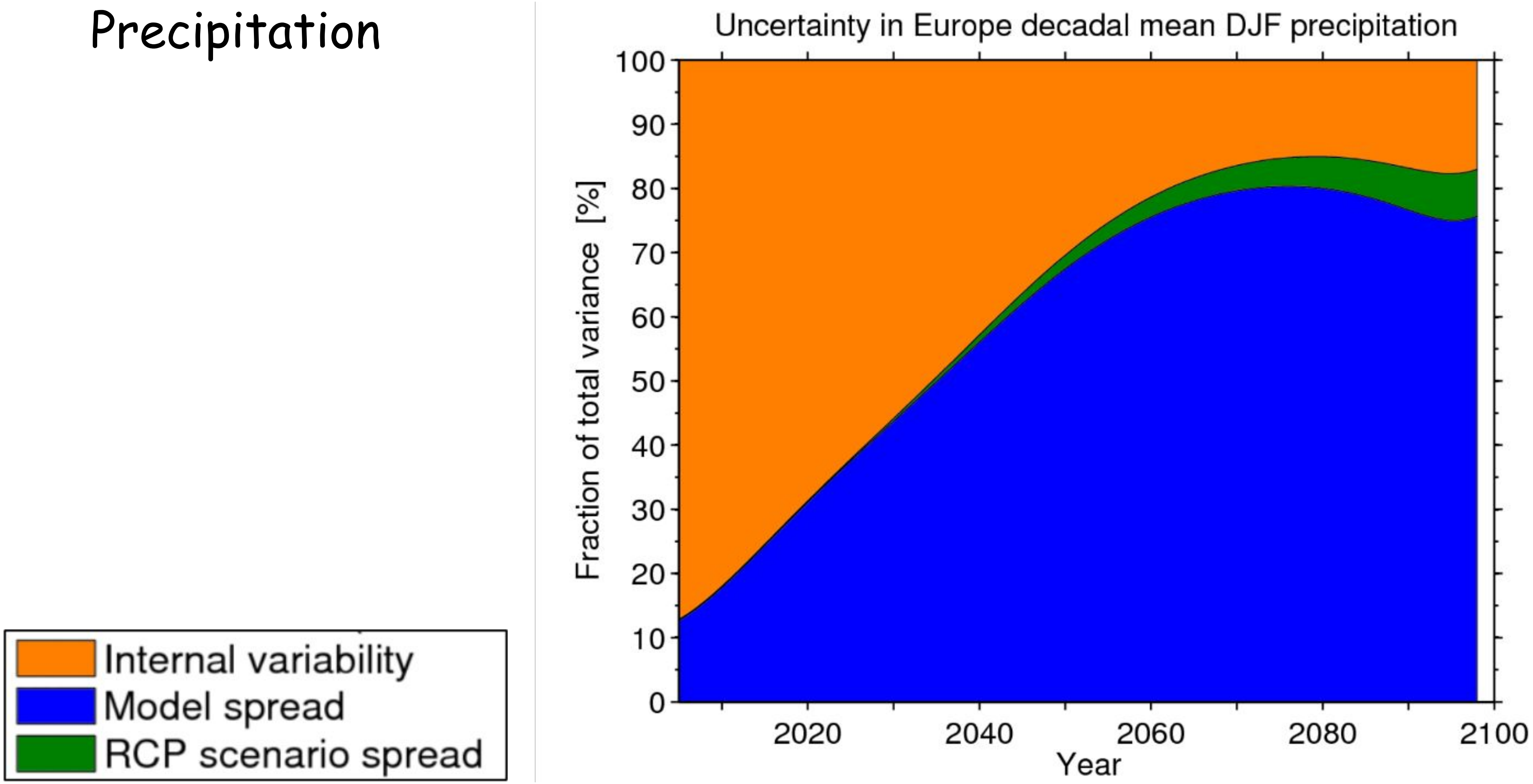
Past Presentations to Pull Slides from

- February, 2022 FWS - Slides
- April 2022 Climate 101 - Slides
- December 2022 Stakeholder meeting - Slides

Temperature

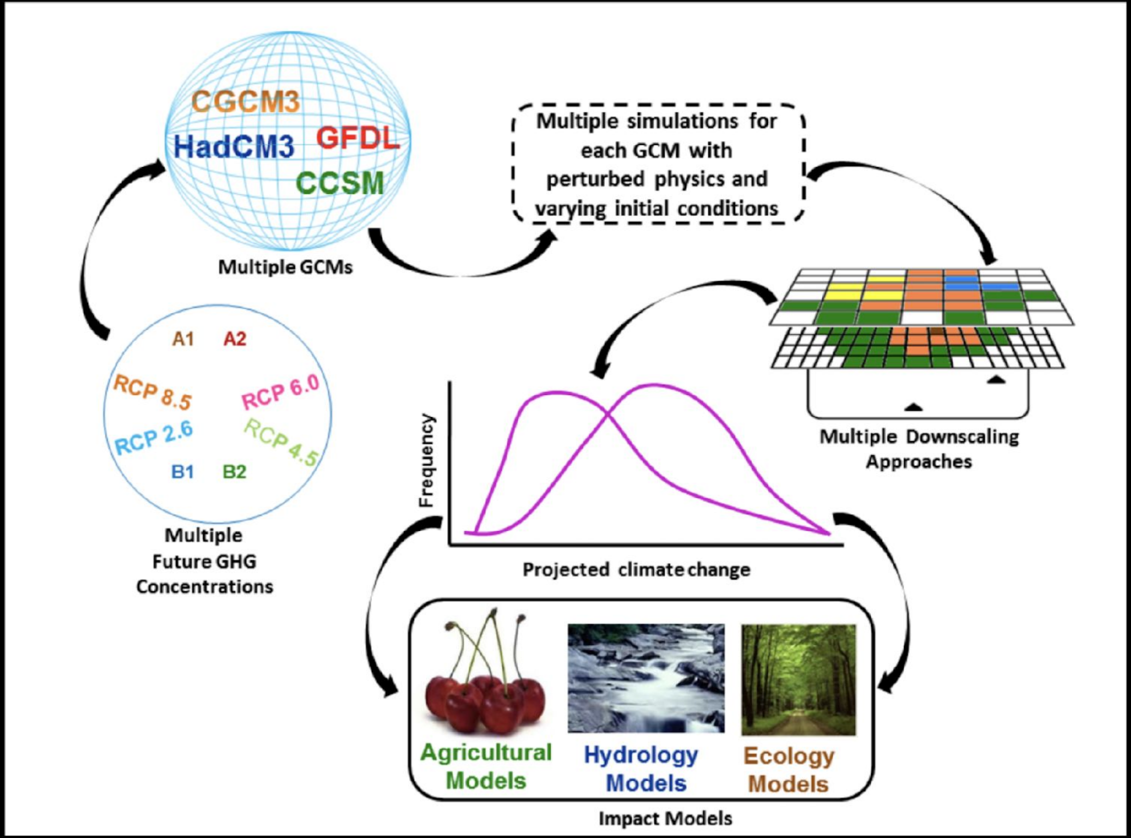


Precipitation



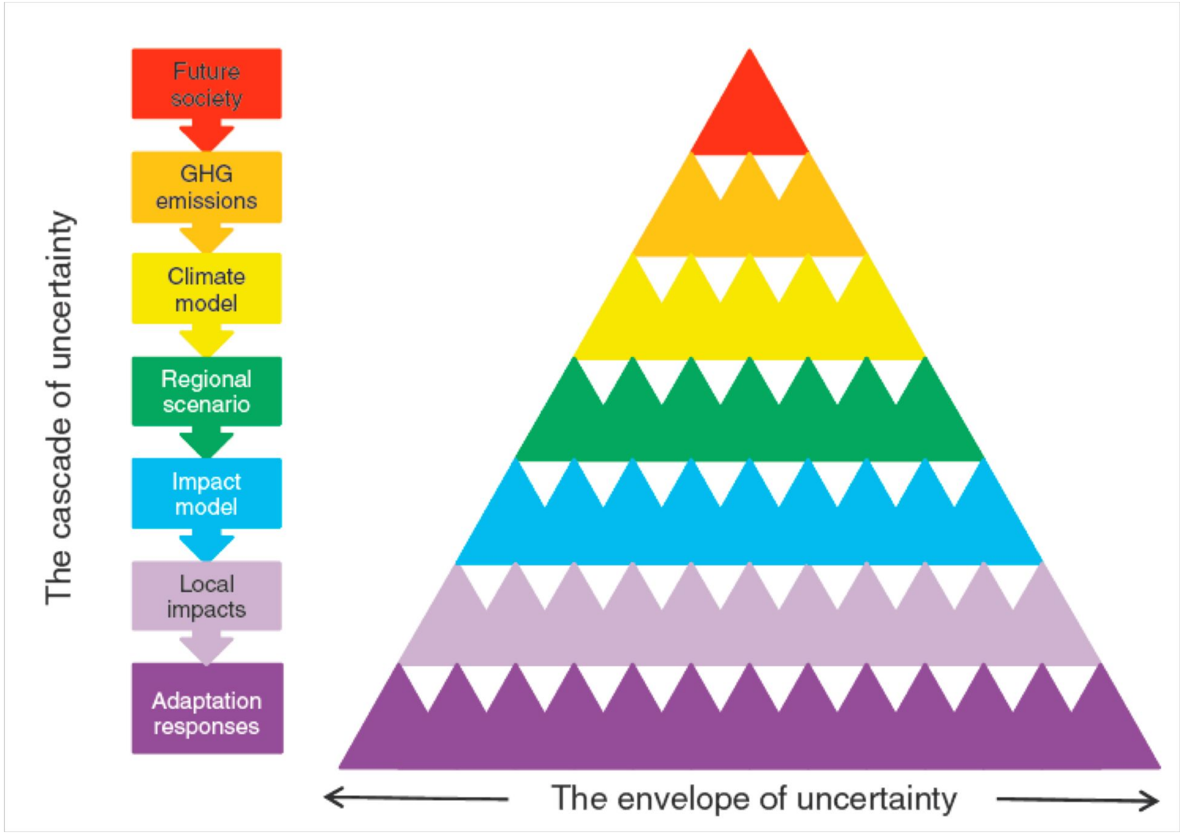
Climate Projections to Regional Impacts

Often require use of multiple tools and data processing steps



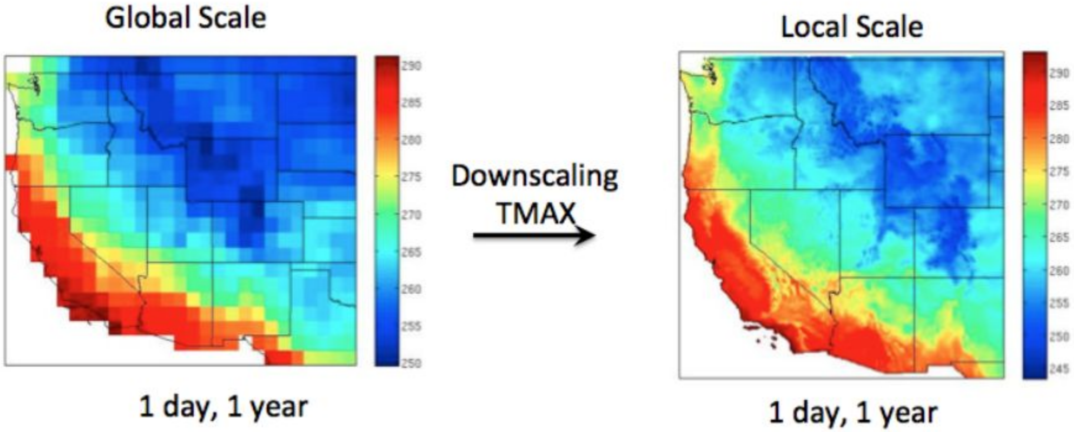
http://glisa.umich.edu/media/files/NCA/MTIT_Future.pdf

Climate Projections to Impacts: Compounding of Uncertainty



Downscaling of GCM Climate Projections

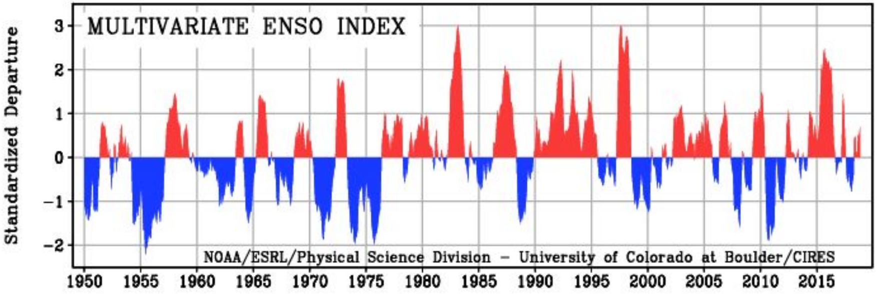
- One main reason to do downscaling is to have data at the right scale to run an impacts model
- Bias correction + Increasing spatial resolution
- Different downscaled datasets could be appropriate for a particular assessment — <u>consult a climate scientist!</u>

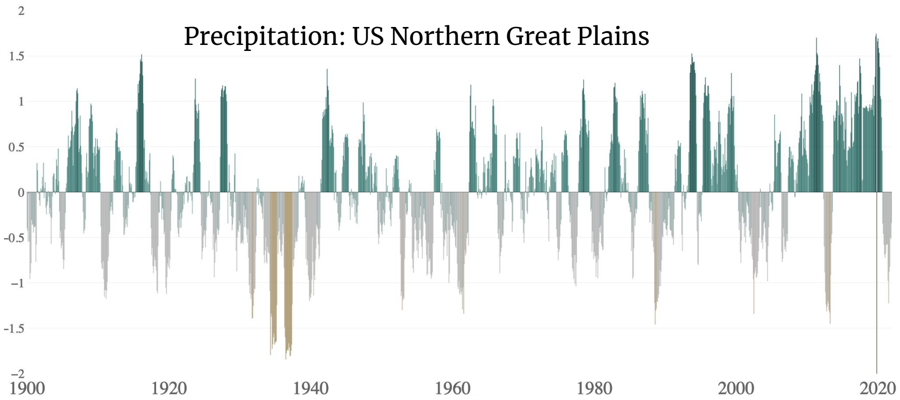


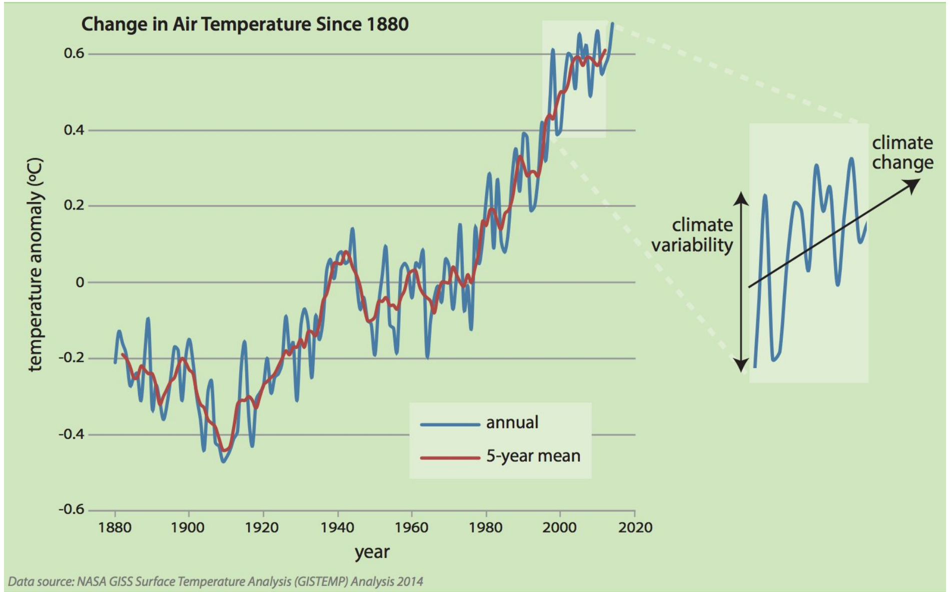
An example of the downscaling process, converting coarse data to a higher resolution. Source: Databasin.org.

Sources of uncertainty in climate projections

Climate Variability

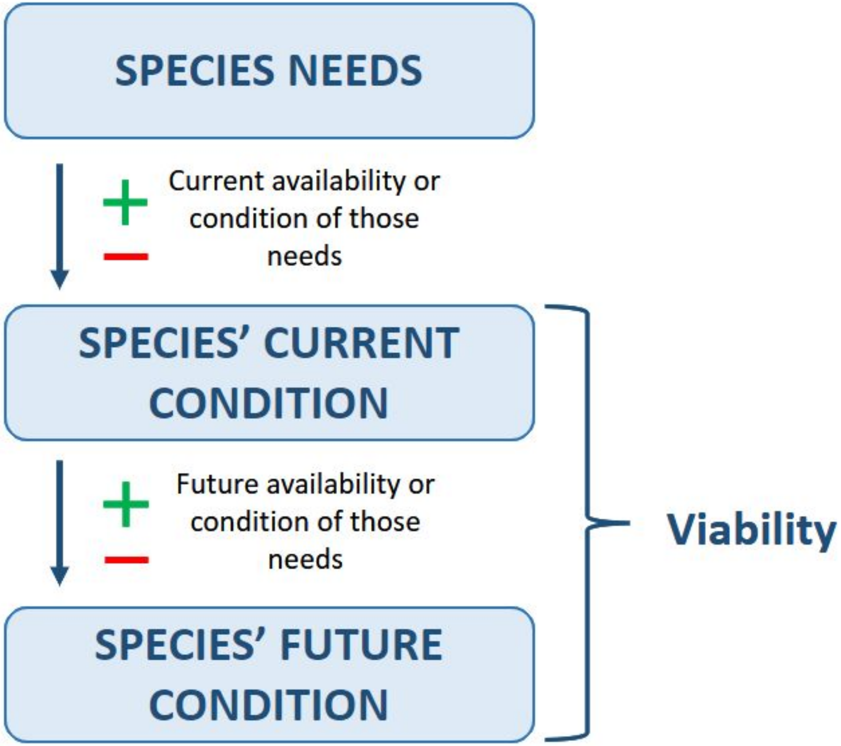






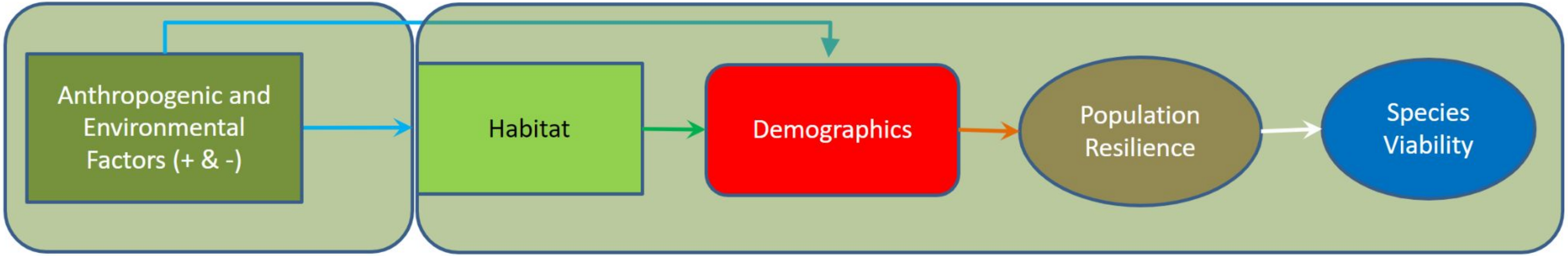
Climate and Weather Extremes!

Species Status Assessment Framework



- The SSA Framework is a different way of thinking about biological status assessments under the ESA.
- Its purpose is to describe the **viability** of a species in a way that supports our ESA decisions.
- Viability is the ability of a species to sustain populations in the wild over a biologically meaningful timeframe.

Species Status Assessment Framework



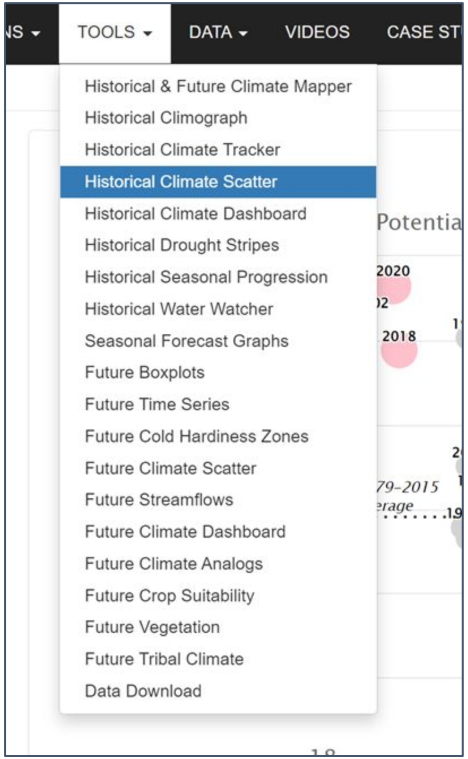
USFWS - Climate Information for Species Status Assessments

SSA Condition Category Table

Analytical Unit Resiliency	Habitat Needs	Demographic/Distribution Factors		Climate	Analytical Unit Resiliency Score
	Habitat Condition Index	Survivorship	Minimum Population Size Estimates (90% LCL)	Summer Water Deficit	
High (Healthy)	1.41 – 1.8	80% - 100%	> 10,000 Plants / AU	within 1 standard deviation of historic mean	2.34 - 3
Moderate	1.01 – 1.4	50% -80%	500-10,000 Plants / AU	within 2 standard deviations of historic mean	1.67 – 2.33
Low	0.6 – 1.00	0-50%	< 500 Plants / AU	2+ standard deviations of historic mean	1 – 1.66

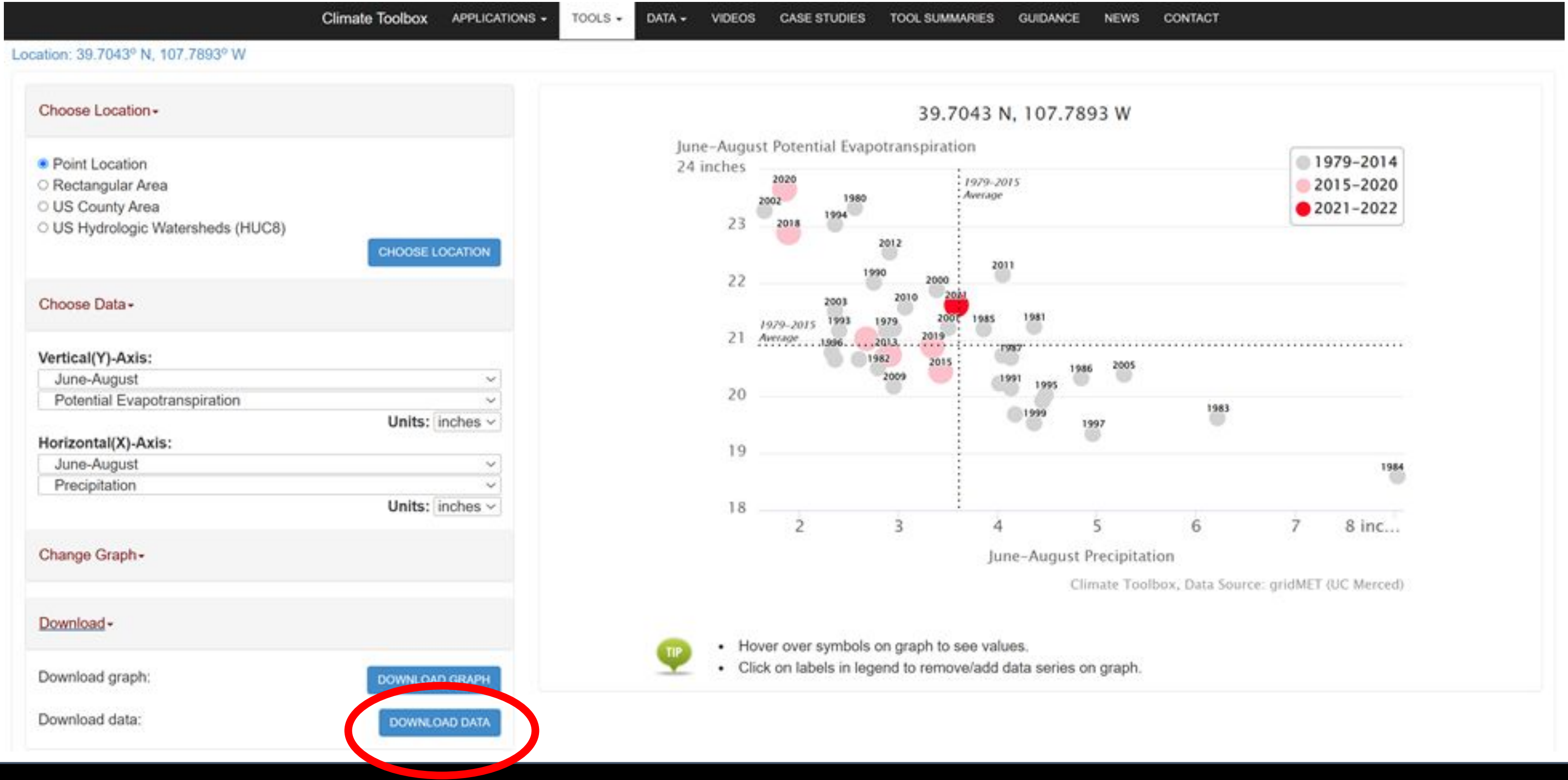
USFWS - Climate Information for Species Status Assessments

Climate Toolbox Tools



USFWS - Climate Information for Species Status Assessments

Climate Toolbox Tools



USFWS - Climate Information for Species Status Assessments

Climate Analysis

Month	(Multiple Items)
Row Lab	**Sum of Water Deficit (PET-ppt)(in)**
1979	1[illegible].49
1980	[illegible].83
1981	[illegible].46
1982	1[illegible].07
1983	15.[illegible]
1984	13.03
1985	19.22
1986	17.32
1987	17.47
1988	18.41
1989	18.44
1990	19.62
1991	17.81
1992	17.4
1993	19.01
1994	21.61
1995	16.2
1996	19.12
1997	16
1998	17.57
1999	13.92
2000	19.16
2001	17.38
2002	21.82
2003	19.97
2004	19.6
2005	16.84
2006	16.71
2007	18.24
2008	18.53
2009	18.42
2010	17.5
2011	18.44
2012	19.39
2013	16.62
2014	15.64
2015	15.44
2016	17.9
2017	18.09
2018	21.84
2019	19.32
2020	22.43
Grand Total	**763.37**

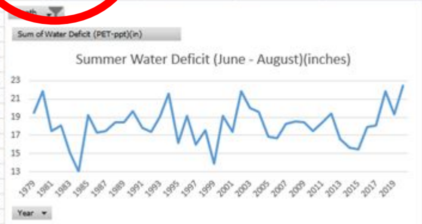
	1979-2000	1979-2020	2011-2020	Imtiaz's historic summer water deficit
Max	21.83	22.43	22.43	
Min	13.03	13.03	15.44	
Mean	17.88	18.18	18.51	
STDEV	2.093	2.029	2.229	

Condition Category Table Values

	1979-2000		1979-2020		2011-2020	
	Lower	Upper	Lower	Upper	Lower	Upper
High (w/in 1 SD)	15.782	19.968	[illegible]6.147	20.204	16.282	20.740
Moderate (w/in 2 SD)	13.690	22.060	[illegible]4.118	22.233	14.054	22.968
Low (2+ SD)						

OR: 1/2 SD

	19[illegible]-2000	
	Lower	Upper
High (w/in 1 SD lower; 1/	15.782	18.921
Moderate (w/in 2 SD low	13.690	19.968
Low (2+ SD)		



		Using 1 SD	Using 1/2 SD
SCGL "bad" years	% Change	Rank	Rank
2012	8%	High	Moderate

			Using 1 SD	Using 1/2 SD
Climate Models	Value	% Change	Rank	Rank
1 (pessimistic)	20.764	16%	Moderate	Low
2 (not used)	19.318	8%	High	Moderate
3 (optimistic)	17.576	-2%	High	High
4 (continuation)	18.62	4%	High	High

			Using 1 SD	Using 1/2 SD
	Value	% Change	Rank	Rank
Current Condition	18.51	4%	High	High

USFWS - Climate Information for Species Status Assessments

SSA Condition Category Table

	Habitat Needs	Demographic/Distribution Factors		Climate	
Analytical Unit Resiliency	Habitat Condition Index	Survivorship	Minimum Population Size Estimates (90% LCL)	Summer Water Deficit	Analytical Unit Resiliency Score
High (Healthy)	1.41 – 1.8	80% - 100%	> 10,000 Plants / AU	within 1 standard deviation of historic mean	2.34 - 3
Moderate	1.01 – 1.4	50% -80%	500-10,000 Plants / AU	within 2 standard deviations of historic mean	1.67 – 2.33
Low	0.6 – 1.00	0-50%	< 500 Plants / AU	2+ standard deviations of historic mean	1 – 1.66

USFWS - Climate Information for Species Status Assessments

Climate Analysis

Month	(Multiple Items)
Water Deficit Feb-Apr	
Row Labels	**Sum of Water Deficit (PET-ppt)(in)**
1979	4.63
1980	2.76
1981	7.41
1982	6.36
1983	2.2
1984	3.46
1985	3.23
1986	5.19
1987	4.85
1988	6.35
1989	7.34
1990	4.73
1991	4.83
1992	5.46
1993	2.65
1994	4.71
1995	3.43
1996	5.45
1997	4.74
1998	3.11
1999	5.79
2000	6.19
2001	5.43
2002	8.36
2003	5.99
2004	5.08
2005	4.88
2006	6.78
2007	6.43
2008	6.21
2009	6.77
2010	4.17
2011	4.75
2012	7.87
2013	4.85
2014	6.11
2015	7.02
2016	5.94
2017	8.3
2018	6.4
2019	1.86
2020	6.94
Grand Total	**225.01**

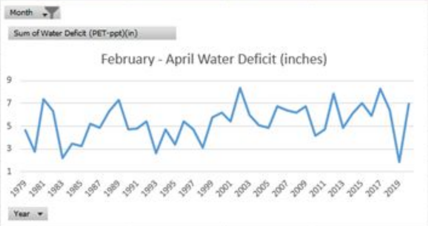
	1979-2000	1979-2020	2011-2020	Imtiaz's historic spring water deficit (Mar-May; different months)
Max	7.41	8.36	8.3	
Min	2.2	1.86	1.86	
Mean	4.77	5.36	6.00	N/A
STDEV	1.455	1.592	1.758	

Condition Category Table Values

	1979-2000		1979-2020		2011-2020	
	Lower	Upper	Lower	Upper	Lower	Upper
High (w/in 1 SD)	3.312	6.222	3.766	6.949	4.246	7.762
Moderate (w/in 2 SD)	1.857	7.677	2.174	8.540	2.488	9.520
Low (2+ SD)						

OR: 1/2 SD

	1979-2000	
	Lower	Upper
High (w/in 1 SD lower	3.312	5.494
Moderate (w/in 2 SD	1.857	6.222
Low (2+ SD)		



		Using 1 SD	Using 1/2 SD
PHSU "good" years	% Change	Rank	Rank
1984	-27%	High	High
1986	9%	High	High
1995	-28%	High	High
2010	-13%	High	High
2011	0%	High	High
2013	2%	High	High

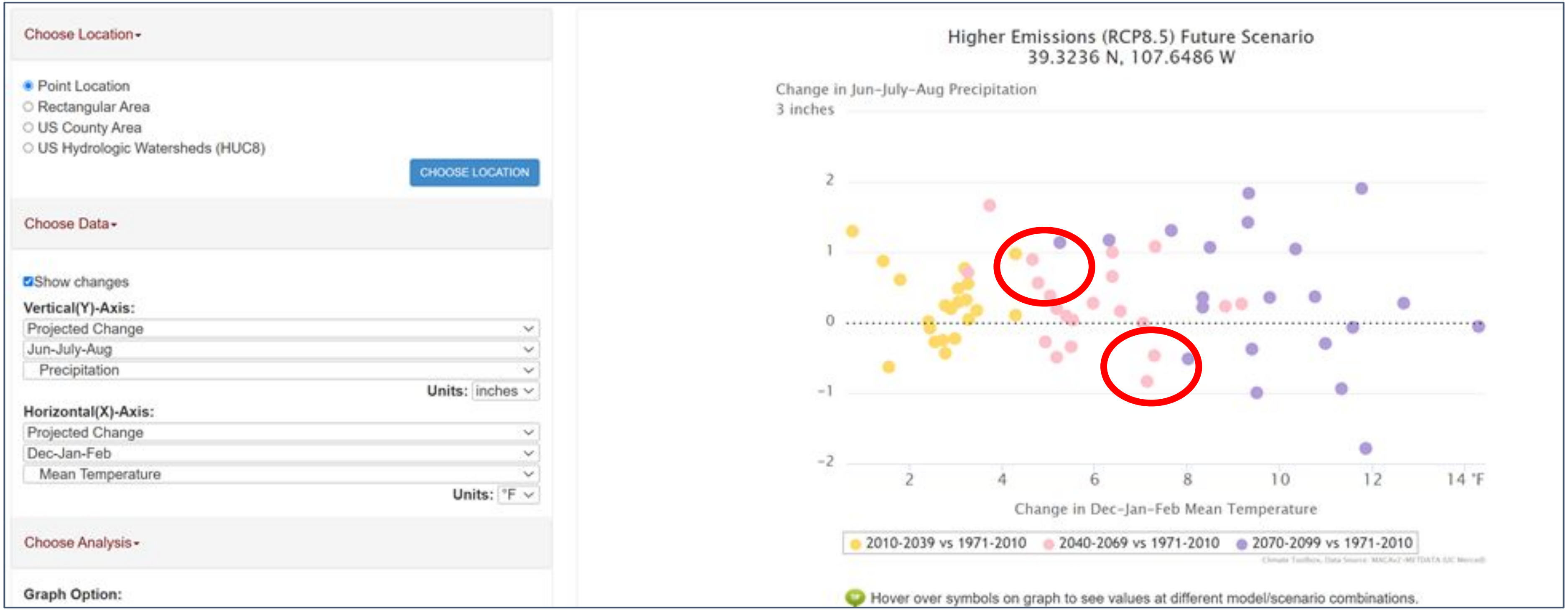
		Using 1 SD	Using 1/2 SD
PHSU "bad" years	% Change	Rank	Rank
2008	30%	High	Moderate
2012	65%	Low	Low

			Using 1 SD	Using 1/2 SD
Climate Models	Value	% Change	Rank	Rank
1 (continuation)	6.61	39%	Moderate	Low
2 (not used)	5.09	7%	High	High
3 (pessimistic)	6.811	43%	Moderate	[illegible]
4 (optimistic)	5.437	14%	High	High

			Using 1 SD	Using 1/2 SD
	Value	% Change	Rank	Rank
Current Condition	6.00	26%	High	Moderate

USFWS - Climate Information for Species Status Assessments

Climate Analysis



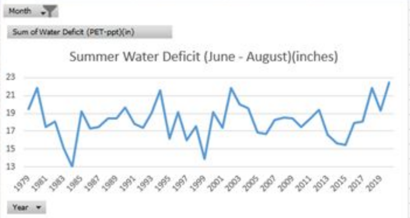
Climate Analysis

Month	(Multiple Items)
Row Lab	Sum of Water Deficit (PET-ppt)(in)
1979	19.49
1980	21.83
1981	17.46
1982	18.07
1983	15.09
1984	13.03
1985	19.22
1986	17.32
1987	17.47
1988	18.41
1989	18.44
1990	19.62
1991	17.81
1992	17.4
1993	19.01
1994	21.61
1995	16.2
1996	19.12
1997	16
1998	17.57
1999	13.92
2000	19.16
2001	17.38
2002	21.82
2003	19.97
2004	19.6
2005	16.84
2006	16.71
2007	18.24
2008	18.53
2009	18.42
2010	17.5
2011	18.44
2012	19.39
2013	16.62
2014	15.64
2015	15.44
2016	17.9
2017	18.09
2018	21.84
2019	19.32
2020	22.43
Grand Total	763.37

	1979-2000	1979-2020	2011-2020	Imtiaz's historic summer water deficit
Max	21.83	22.43	22.43	
Min	13.03	13.03	15.44	
Mean	17.88	18.18	18.51	
STDEV	2.093	2.029	2.229	

Condition Category Table Values						
	1979-2000		1979-2020		2011-2020	
	Lower	Upper	Lower	Upper	Lower	Upper
High (w/in 1 SD)	15.782	19.968	16.147	20.204	16.282	20.740
Moderate (w/in 2 SD)	13.690	22.060	14.118	22.233	14.054	22.968
Low (2+ SD)						

OR: 1/2 SD		
	1979-2000	
	Lower	Upper
High (w/in 1 SD lower; 1/2	15.782	18.921
Moderate (w/in 2 SD lowe	13.690	19.968
Low (2+ SD)		



		Using 1 SD	Using 1/2 SD
SCGL "bad" years	% Change	Rank	Rank
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			Using 1 SD	Using 1/2 SD
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4 (continuation)	18.62	4%	High	High

				Using 1/2 SD
	Value	% Change	Rank	Rank
Current Condition	18.51	4%	High	High

USFWS - Climate Information for Species Status Assessments

Climate Analysis

Optimistic Scenario						
Analytical Units		Habitat Needs	Demographic / Distribution Factors		Climate	Analytical Unit Resiliency
		Habitat Condition Index	Species-level Survival	Minimum Population Size (90% LCL)	Summer Water Deficit*	
S. glaucus	Whitewater	High	High	High	High	High
	Palisade	Moderate		Low	High	Moderate
	Dominguez-Escalante	High		High	High	High
	North Fruita Desert	Moderate		Moderate	High	High
	Devil's Thumb	High		High	High	High
	Cactus Park	High		High	High	High
	Gunnison Gorge	Moderate		Moderate	High	High
	Gunnison River East	High		High	High	High
S. dawsonii	Plateau Creek	High	High	Moderate	High	High
	Roan Creek	High		High	High	High

Pessimistic Scenario						
Analytical Units		Habitat Needs	Demographic / Distribution Factors		Climate	Analytical Unit Resiliency
		Habitat Condition Index	Species-level Survival	Minimum Population Size (90% LCL)	Summer Water Deficit	
S. glaucus	Whitewater	Moderate	Moderate	High	Moderate	Moderate
	Palisade	Low		Low	Moderate	Low
	Dominguez-Escalante	High		High	Moderate	High
	North Fruita Desert	Low		Moderate	Moderate	Moderate
	Devil's Thumb	High		Moderate	Moderate	Moderate
	Cactus Park	Moderate		Moderate	Moderate	Moderate
	Gunnison Gorge	Low		Moderate	Moderate	Moderate
	Gunnison River East	High		Moderate	Moderate	Moderate
S. dawsonii	Plateau Creek	Moderate	High	Moderate	Moderate	Moderate
	Roan Creek	High		High	Moderate	High