ClimateToolbox.ORG: *A Discussion of Climate Applications to Support Quantitative Climate Change Impact Assessment and Scenario Planning*

Katherine Hegewisch, University of California Merced

John Guinotte, US Fish & Wildlife Service (Region 6)

Imtiaz Rangwala, NC CASC, University of Colorado Boulder

North Central Climate Adaptation Science Center

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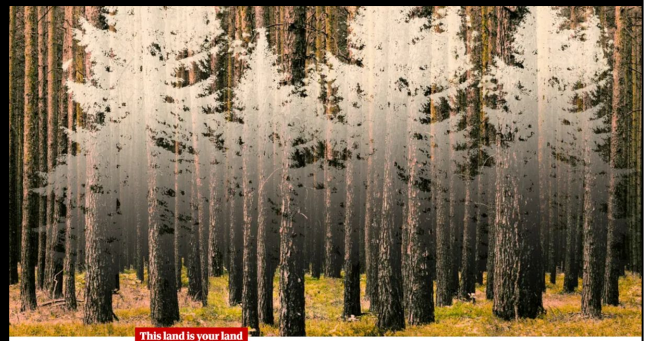
DEPARTMENT OF THE INTERIOR

Outline

- Integrating Future Climate Uncertainty
- Climate Applications for USFWS Species Status Assessments
- Climate Toolbox
  - Introduction
  - Data
  - Discussion of two specific tools for *quantitative scenario planning* applications, including Live Demos

Integrating Future Climate *Uncertainty*

Climate change is rapidly altering environmental processes, reshaping and transforming ecosystems, at times in surprising ways. These are expected to intensify in coming decades. Land managers are asked to better anticipate these impacts and develop science-informed adaptation strategies.



This land is your land

Is this the end of forests as we've known them?

If the Hardiest Species Are Boiled Alive, What Happens to Humans?

The June heat wave caused billions of deaths.

By Stephen Leahy

Invasive grasses are taking over the American West's sea of sagebrush

Highly flammable cheatgrass and similar nonnative plants dominate one-fifth of the Great Basin

Nebraska on pace for second-worst wildfire year ever; 2023 outlook is dim

Drought and strong winds spawned large, fast-moving fires in spring, summer and fall

BY: **PAUL HAMMEL** - NOVEMBER 7, 2022 5:00 AM

The lack of interoperable radios among volunteer firefighters came into focus in 2022, the second-worst year for wildfires in state history. The fires included this one sparked in late July by lightning south of Gering. (Courtesy of Nebraska State Patrol)

Floods, park closure contribute to decrease in Yellowstone National Park visitors

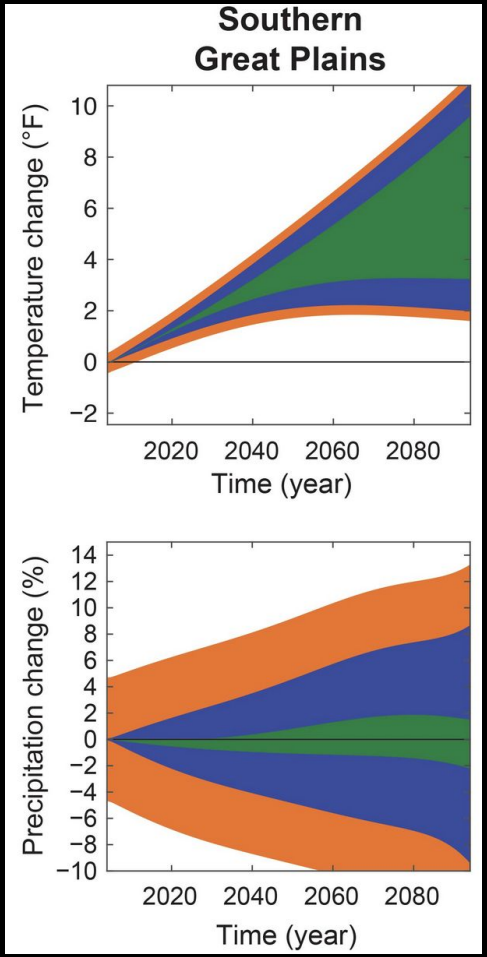
Park officials expect to open roads to North Entrance and Northeast Entrance by mid-October

BY: **CLARK CORBIN** - AUGUST 12, 2022 4:30 AM

Yellowstone National Park's North Entrance Road was damaged by flooding in June 2022. The Old Gardiner Road is expected to be open by Nov. 1. (Courtesy of National Park Service)

Eastern red cedar trees spread out of control

Future Climate Uncertainty



Magnitude and Direction of Change

- How much hotter?
- Will there be more or less water?
- How will the severity of extreme weather/climate events change?

Emission Scenario & Future Time Horizon

Integrate this uncertainty into assessments

Figure Source: Fig. 3.6, NCA 2023
https://nca2023.globalchange.gov/all-figures/

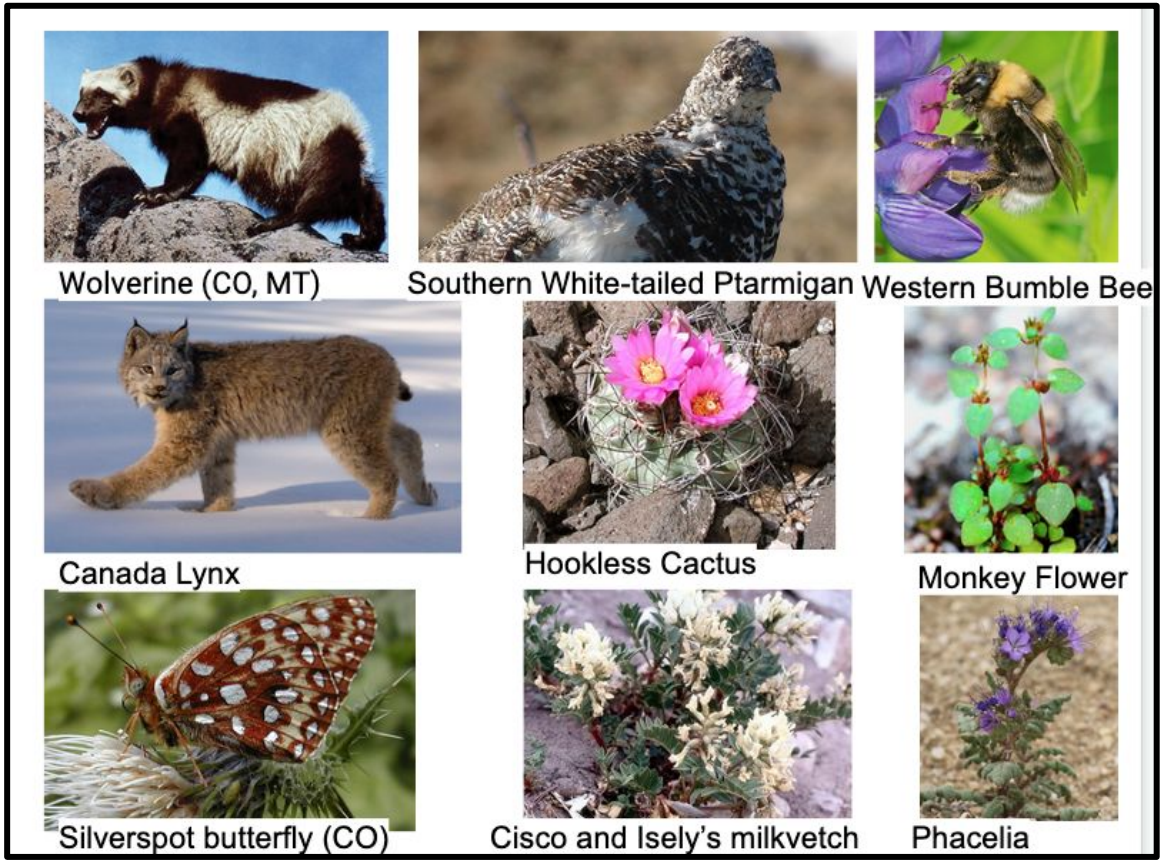
Scenario Planning: A functional and effective approach to consider in the face of significant & irreducible uncertainties

Scenario-based approaches are increasingly being used to do climate change impact assessments by practitioners

Image: National Park Service

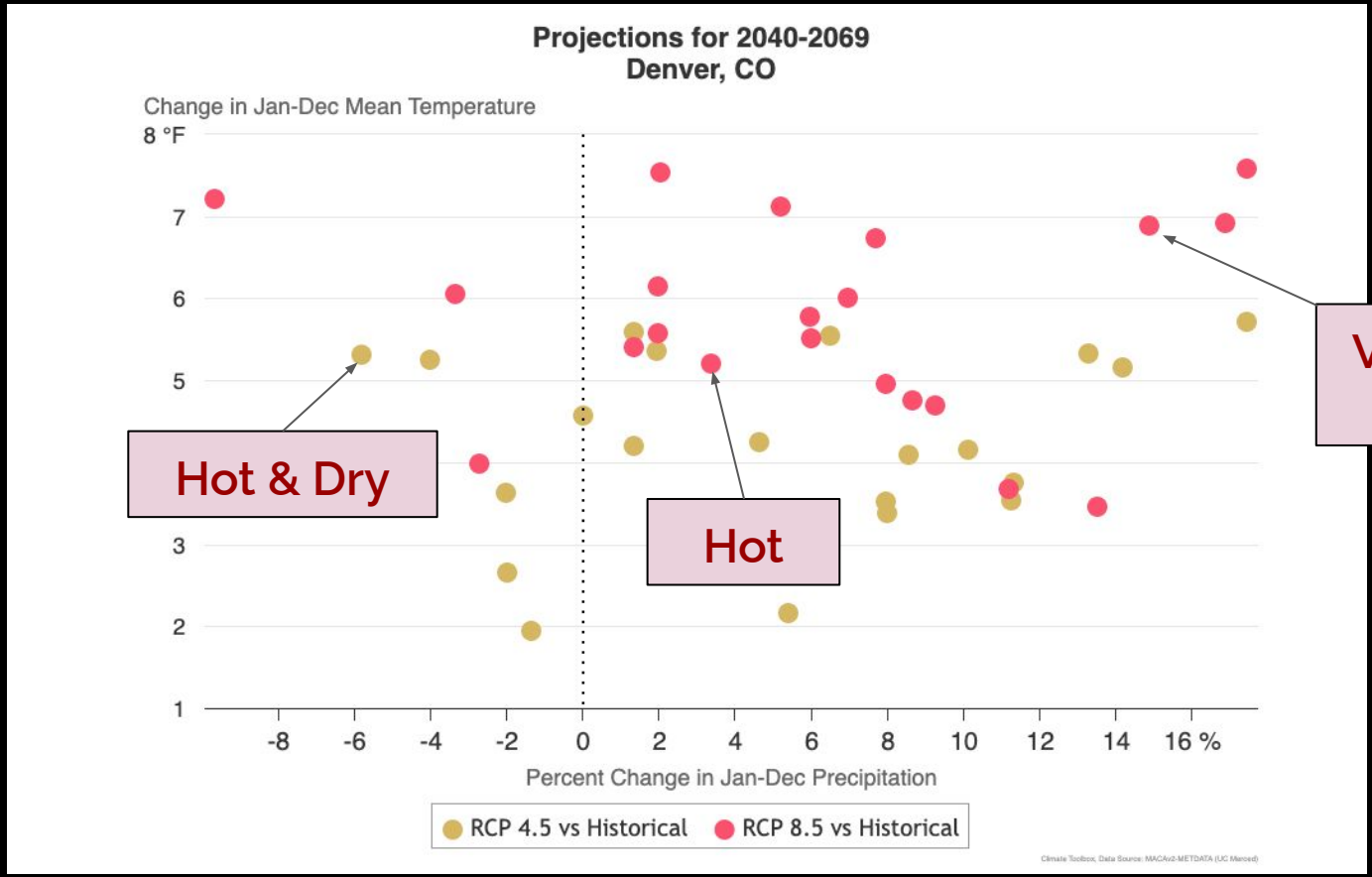
Science Support and Applications Development for USFWS Species Status Assessments

#	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
15	Ute Lady Tress	2022	Willey Lark, Karen Newlon, John Guinotte
16	Rio Grand Cutthroat Trout	2022	Nathan Allan, Jonathan Cummings
17	Topeka Shiner	2023	Laura Mendenhall
18	Sturgeon and Sicklefin Chubs	2023	Jim Boyd
19	Canada Lynx	2023	John Guinotte
20	Wolverine	2023	John Guinotte
19	Heliotrope Milkvetch	2024	Karen Newlon
20	Greenback Cutthroat Trout	2024	Karen Newlon



Images: FWS (John Guinotte)

Integrating Climate Uncertainty: Working with divergent climate futures



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).

Imtiaz Rangwala (Imtiaz.Rangwala@colorado.edu)
CIRES, University of Colorado, Boulder; North Central Climate Adaptation Science Center

Climate Applications for USFWS Species Status Assessments

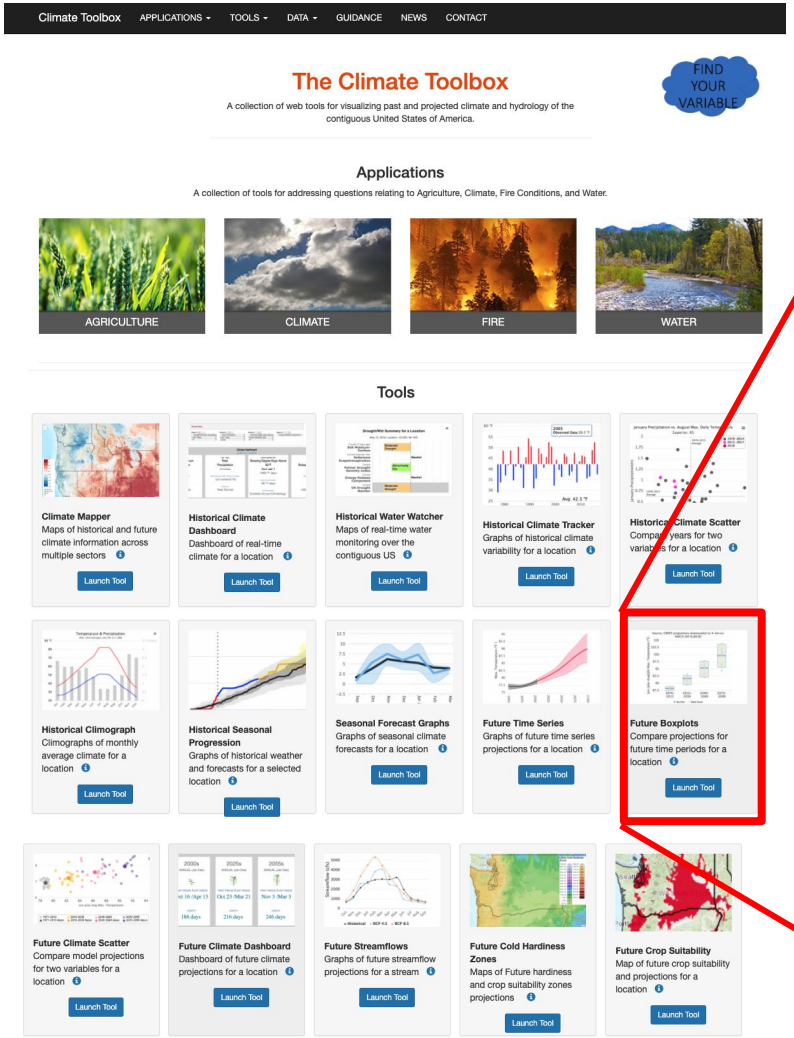
- Close working relationship with Imtiaz and Katherine has created efficiencies for FWS when dealing with SSA future condition.
  - Future condition (large climate component) is one of the most difficult issues for FWS biologists working on SSAs
    - Uncertainty in climate scenarios and species response.

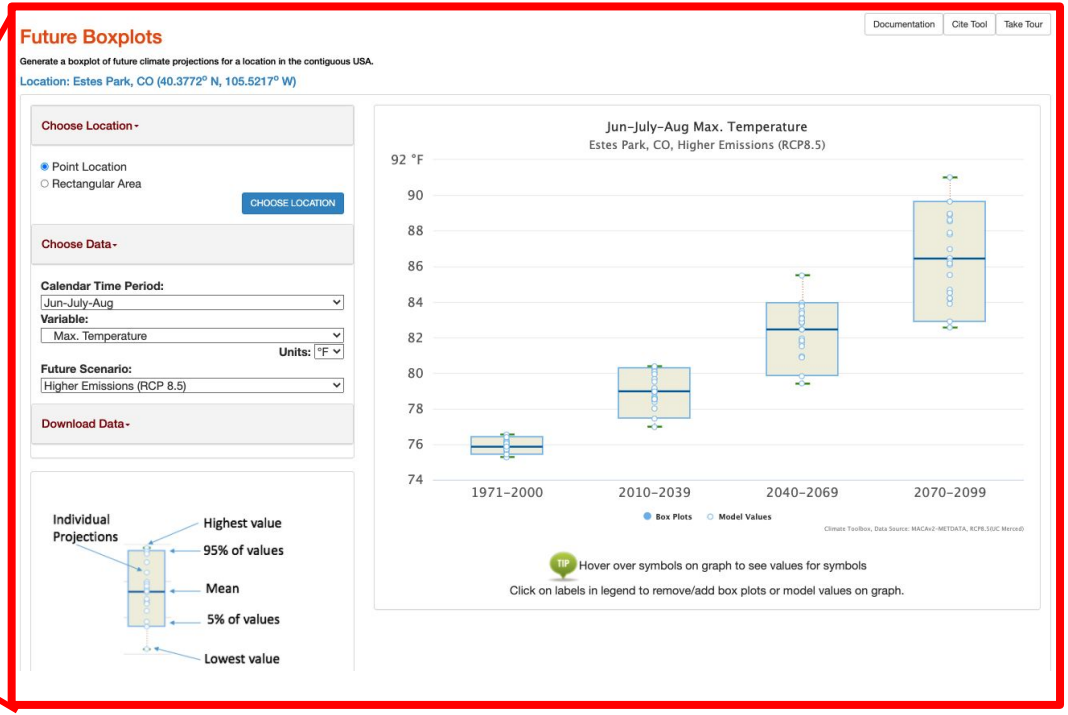
- Iterative approach to toolbox development has enabled FWS to provide input for tool improvement to suit our needs
  - Climate Metric Table automated
  - GIS shapefile upload option has streamlined table generation for separate sp. populations (big time saver)
  - Visualization tools to help guide biologists in making choices (Climate Scatter tool).

Climate Toolbox

The Climate Toolbox

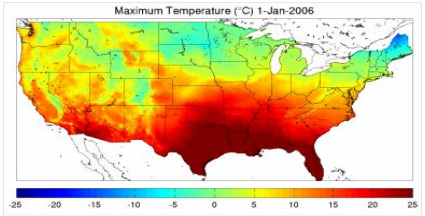
climateToolbox.org





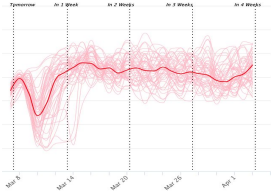
Toolbox - The Data

Past/Real-Time



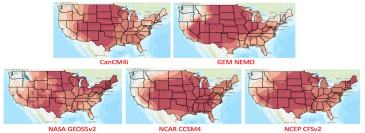
- Blend of ground station/satellite daily data from PRISM & NLDAS2
- Jan 1, 1979- Yesterday
- 2.5 mile grid cells
- Contiguous USA

Forecasts



CFSv2 - gridMET forecast data

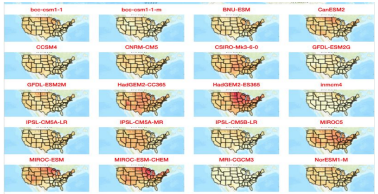
- Daily forecasts from NOAA's CFSv2
- Forecasts for next 28 days
- 48 ensemble members



NMME - gridMET forecast data

- Monthly forecasts from NOAA's NMME
- Forecasts for next 7 months
- 5 climate models

Future Projections



- Daily projections from IPCC's CMIP5
- Projections to 2100
- 20 climate models
- 2 future scenarios (RCP4.5/8.5)

All data has been bias corrected to gridMET (2.5 mile grid cells, contiguous USA)

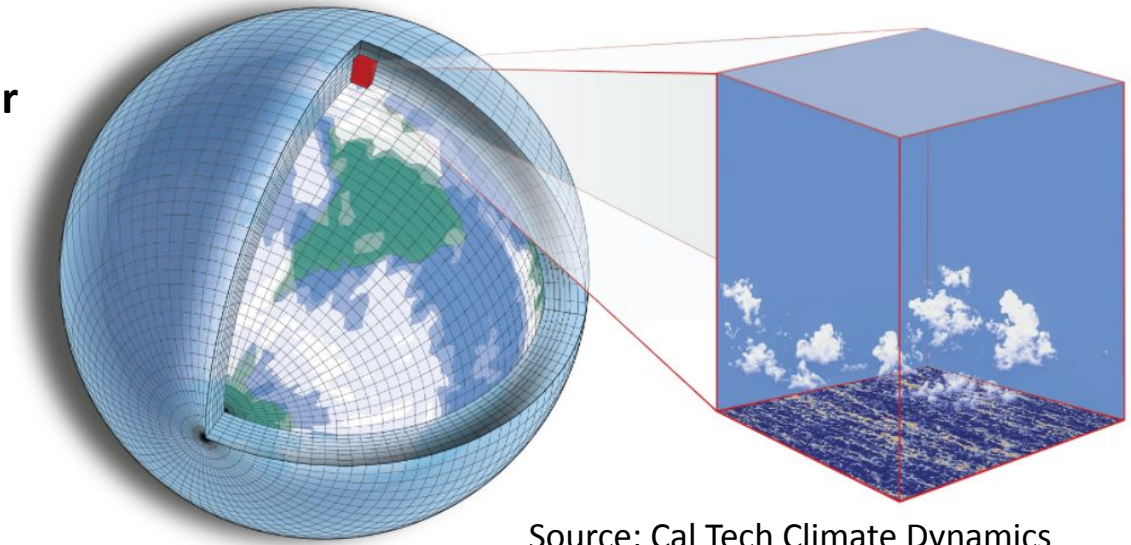
Toolbox - Future Projection Data

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) was completed in 2011

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 emissions

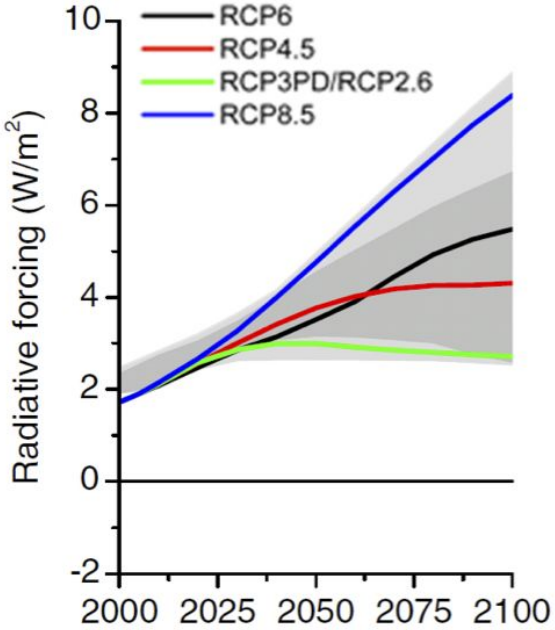
Future Simulations

2006 - 2100

Future simulations assume an emission pathway to 2100.

RCP8.5 – "High emissions"
A 'business as usual' extension of our current emissions pathway where there is 8.5 W/m2 by 2100.

RCP4.5 –"Low emissions"
a reduced emissions pathway from global mitigation of emissions. 4.5 W/m2 by 2100.

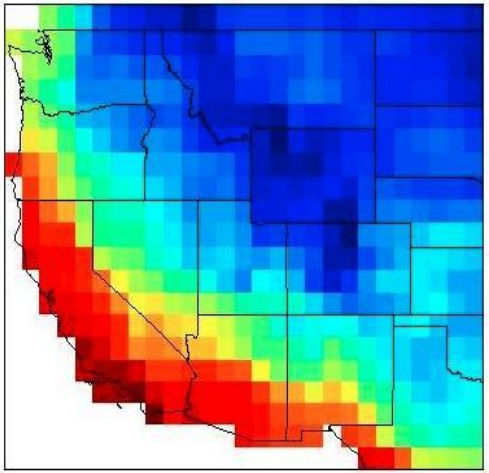


Toolbox - Future Projection Data

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

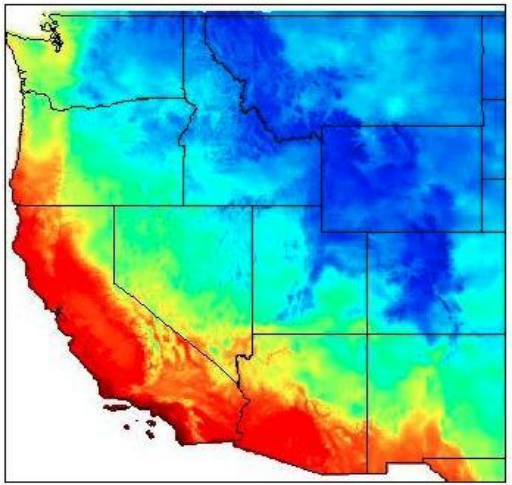


~200 mile x ~200 mile grid cells

Downscaling

- Increase resolution of data
- Correct errors in modeling

Finer Resolution Data



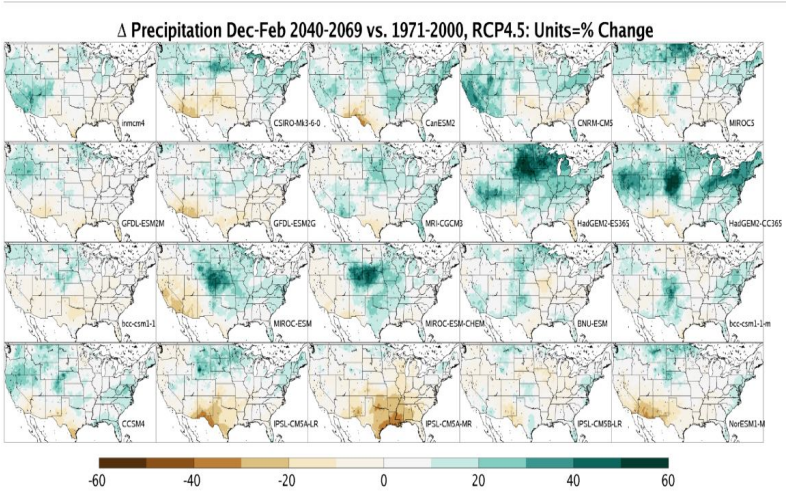
~2.5 mile x ~2.5 mile grid cells

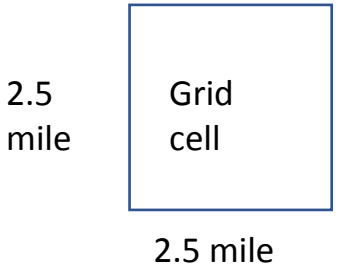
MACA (Multi-Variate Adaptive Constructed Analogs) downscaled CMIP5 outputs using gridMET as training dataset. (Abatzoglou, 2011)

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** (1950-2099)





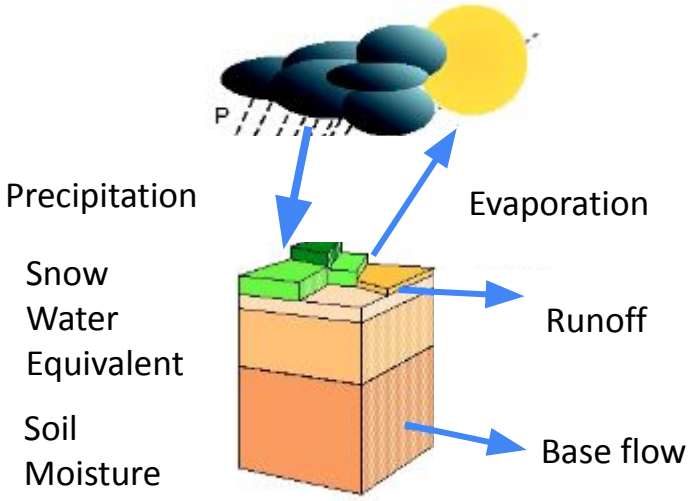
Toolbox - Future Projection Data

Climate Data

Surface Weather:

- Temperature
- Precipitation
- Humidity
- Wind
- Solar Radiation

Hydrology Data



- VIC Model - UW Lettenmaier/Nijssen
- Monthly Water Balance Model - Hostetler, Alder

Fire Danger Data

National Fire Danger Rating System

- fuel model G (dense conifer forests)

Metrics:

- Energy release component
- Burning index
- 100-hr fuel moisture

Toolbox - The Metrics

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

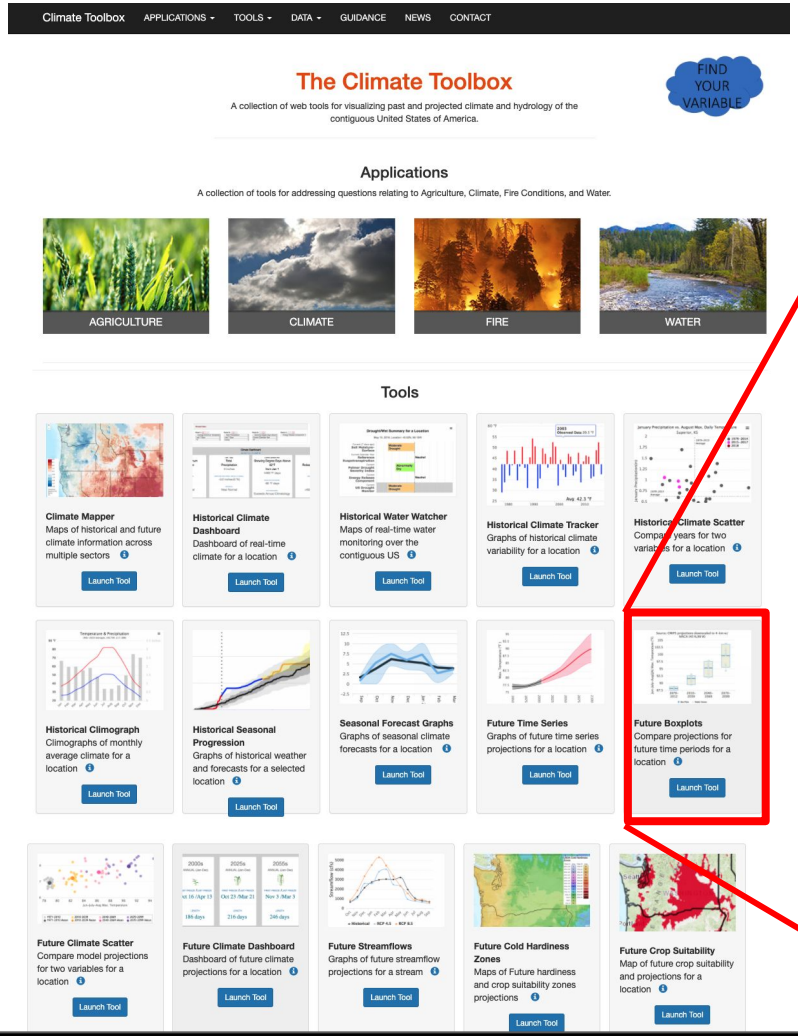
Water Metrics

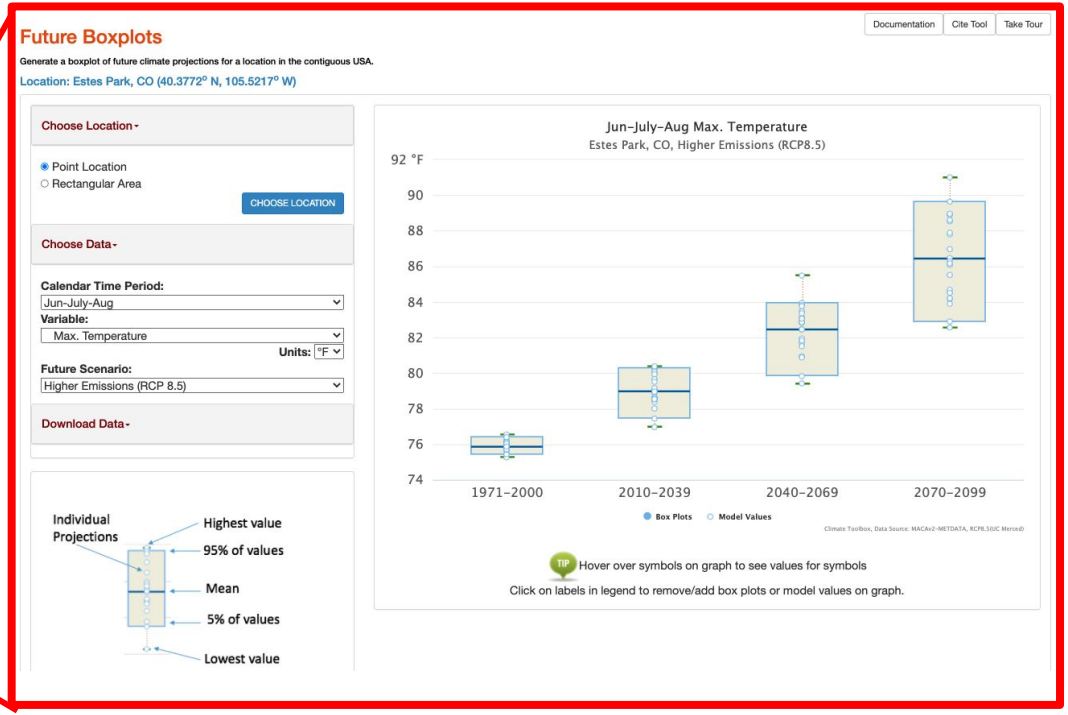
- Soil moisture
- Total moisture
- Snow water equivalent
- Runoff

Fire Danger Metrics

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

The Climate Toolbox





Toolbox - Future Climate Scatter Tool

Documentation | Cite Tool | Take Tour

Future Climate Scatter

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

Location: 39.7708° N, 105.9069° W

Make Request

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

Choose Location

Point Location

CHOOSE LOCATION

Choose Data

Show changes

Vertical(Y)-Axis:

Projected Change
Jan-Dec
Mean Temperature

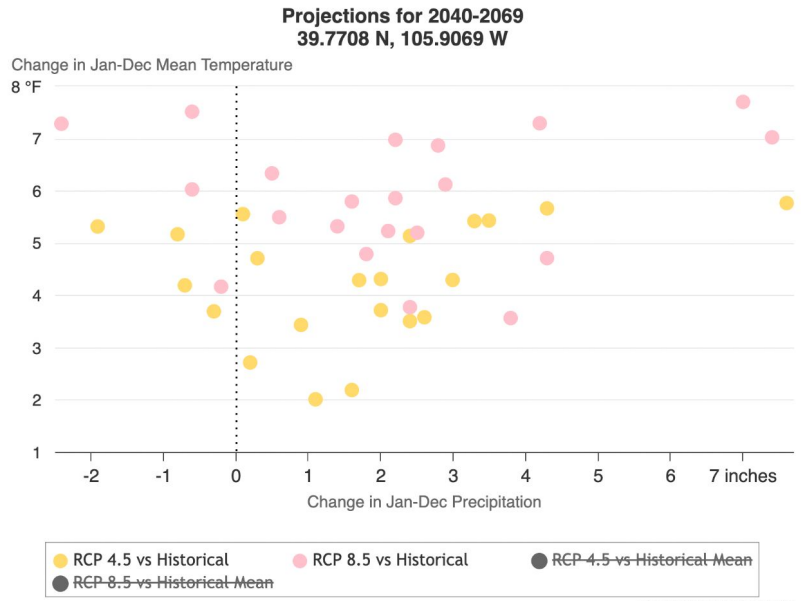
Units: °F

Horizontal(X)-Axis:

Projected Change
Jan-Dec
Precipitation

Units: inches

Choose Analysis

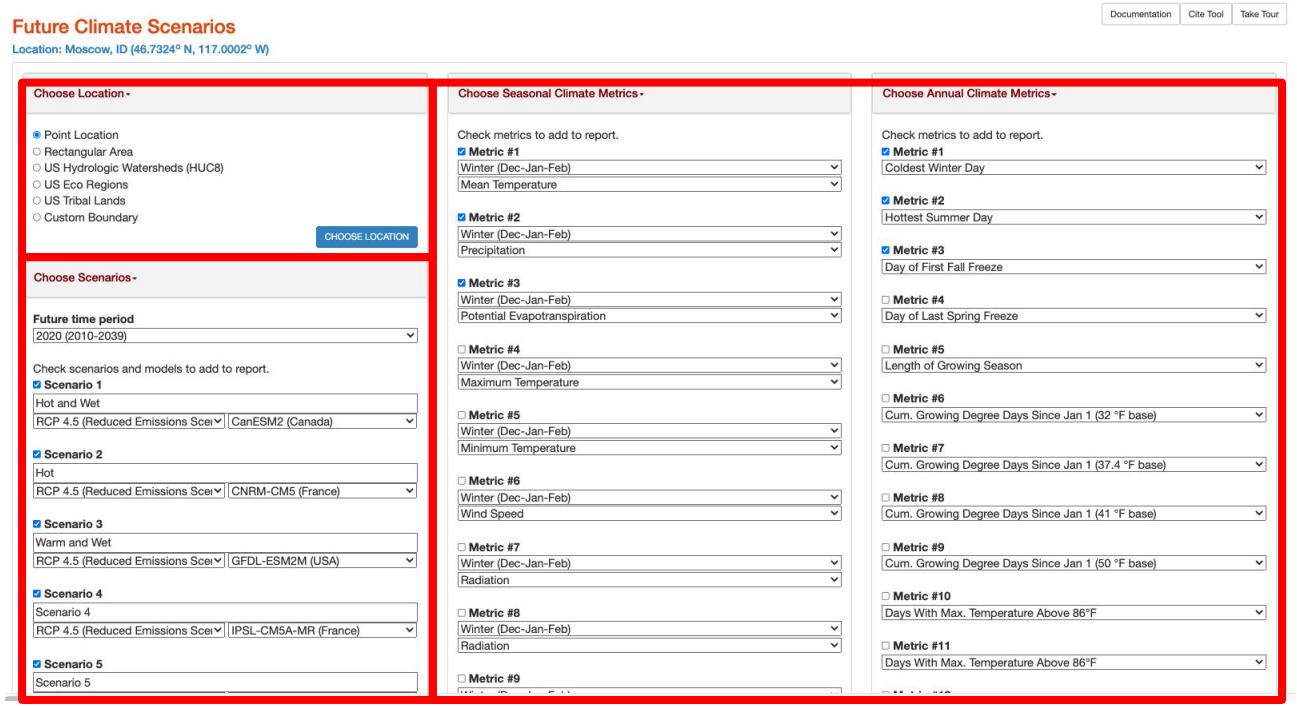


Interact with the Graph

- Hover over symbols on graph to see values at different model/scenario combinations.
- Click legend label to remove/add series on graph
- Drag the legend to any location inside the graph

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).

Thank You!

Katherine Hegewisch: khegewisch@ucmerced.edu
John Guinotte: john_guinotte@fws.gov
Imtiaz Rangwala: imtiaz.rangwala@colorado.edu