

ARSET

Applied Remote Sensing Training

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Introducción a la Teledetección para Pronósticos Ecológicos con Base en Escenarios

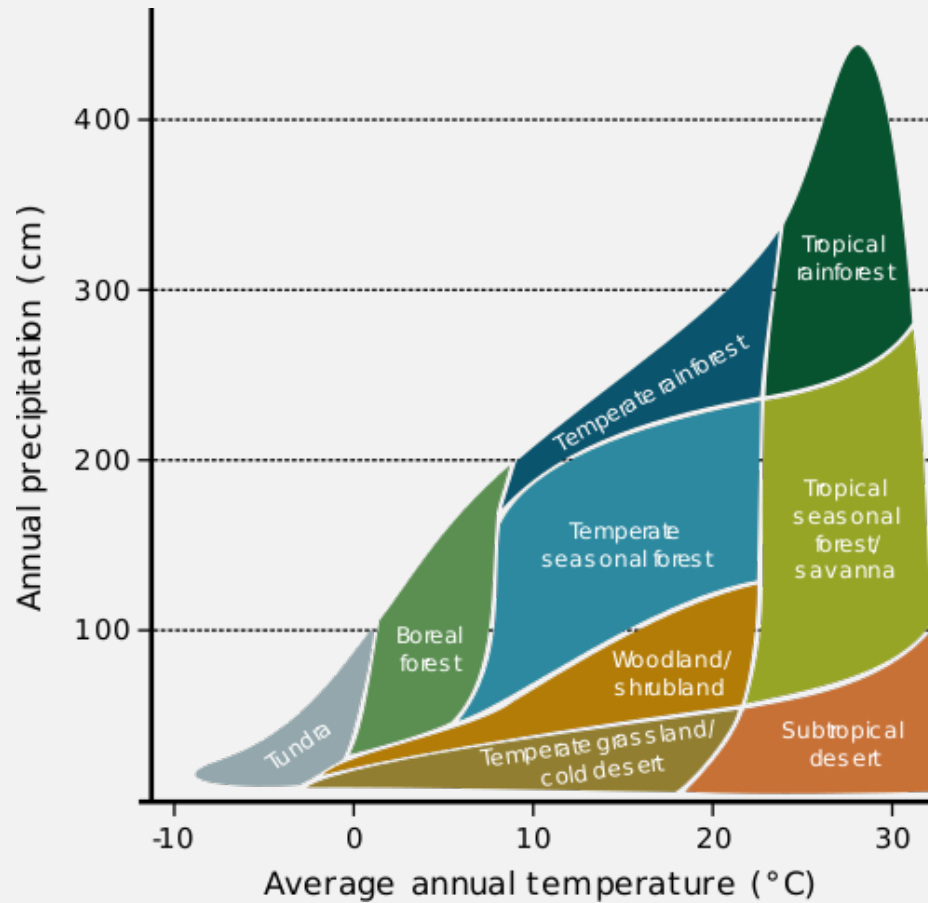
Semana 2: Vistazo General de la Ciencia Climática y Sus Datos
Helen Sofaer, U.S. Geological Survey, Fort Collins Science Center



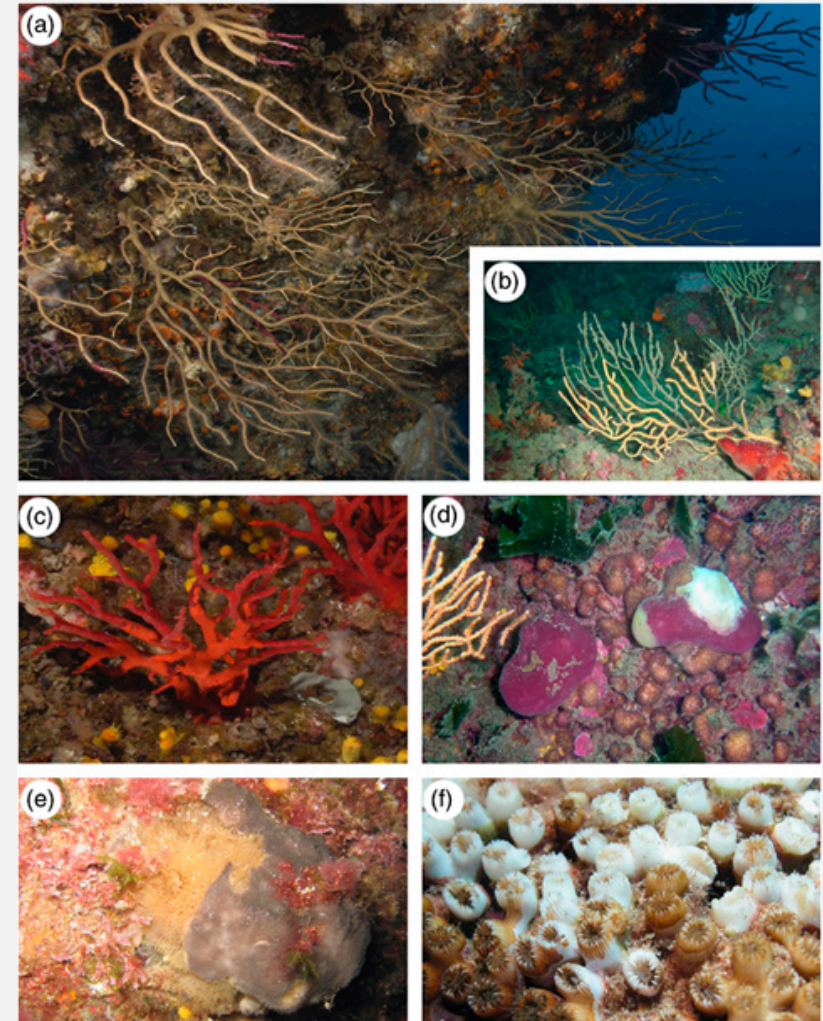
Gombe
National Park

Datos Climáticos Históricos en Cuadrícula

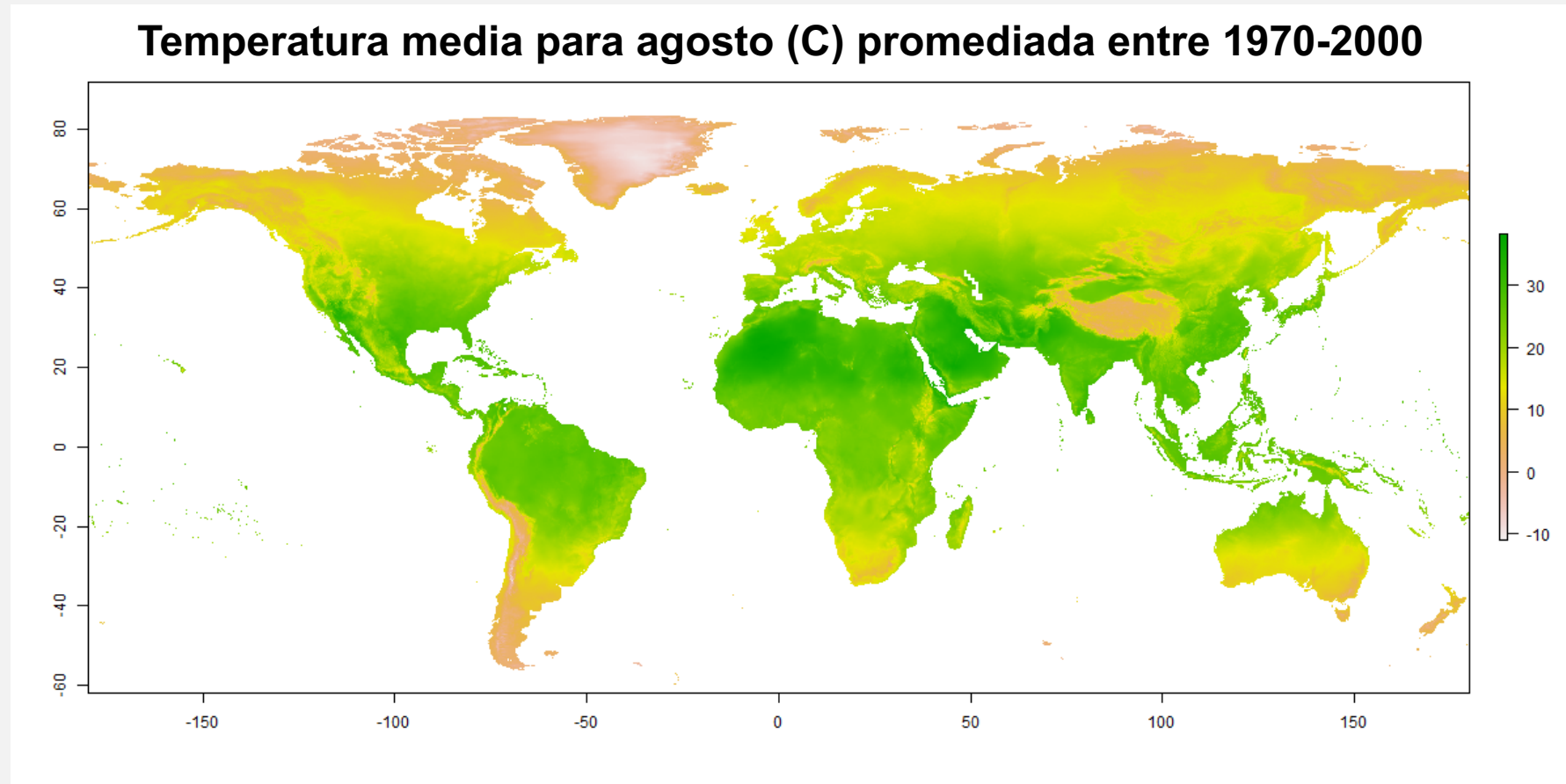
El Clima y la Meteorología Impulsan los Procesos Ecológicos Claves



Clasificación de biomas según Whittaker; imagen de Wikipedia, Garrabou et al. 2009 Global Change Biology



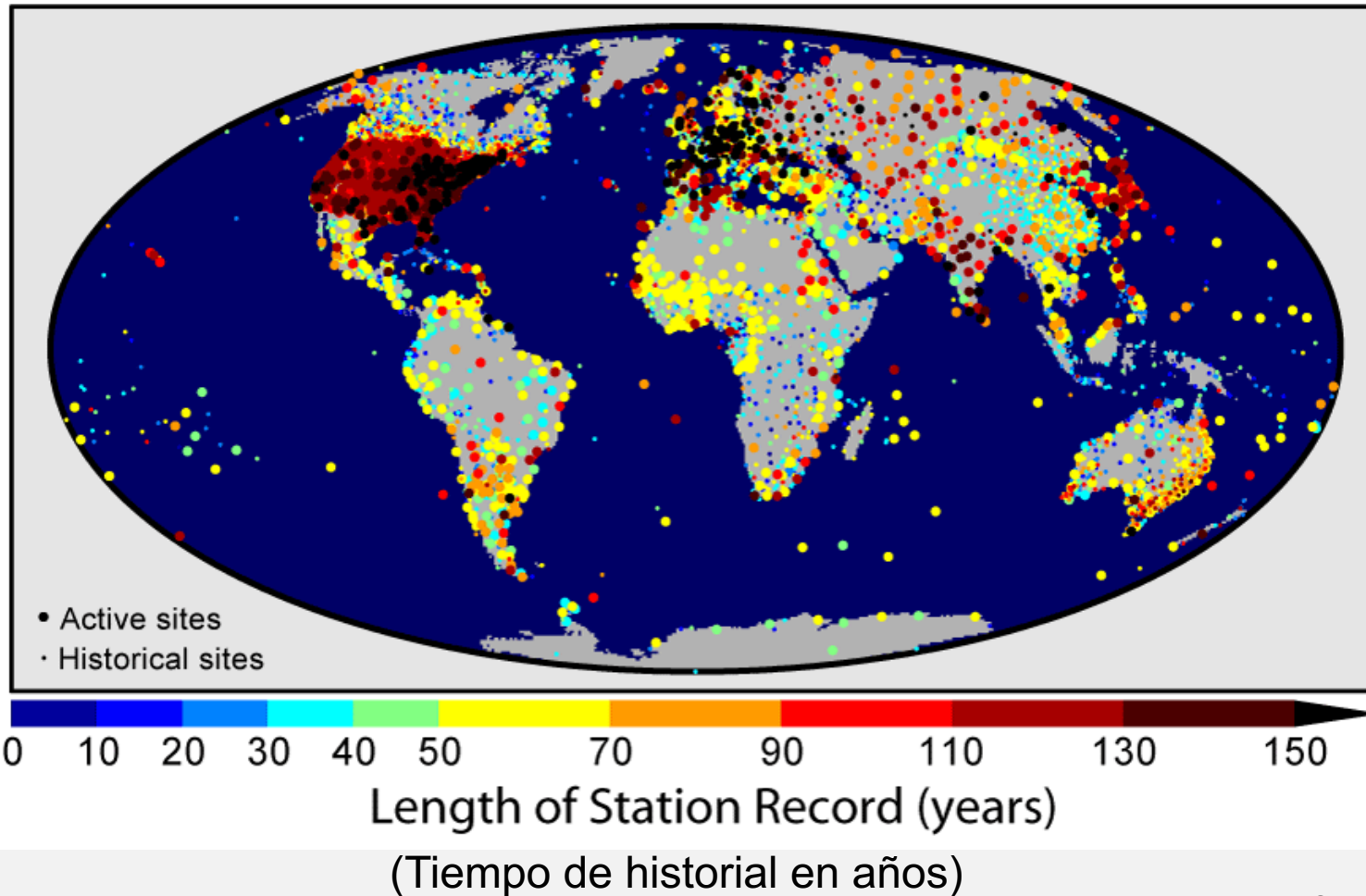
Los Estudios a Gran Escala Vinculan los Datos Ecológicos a los Datos Climáticos en Cuadrícula



Fick, S.E. and R.J. Hijmans, 2017. Worldclim 2: New 1-km spatial resolution climate surfaces for global land areas. International Journal of Climatology

Los Datos en Cuadrícula se Estimán Usando las Estaciones Climáticas

Global Climate Network Temperature Stations

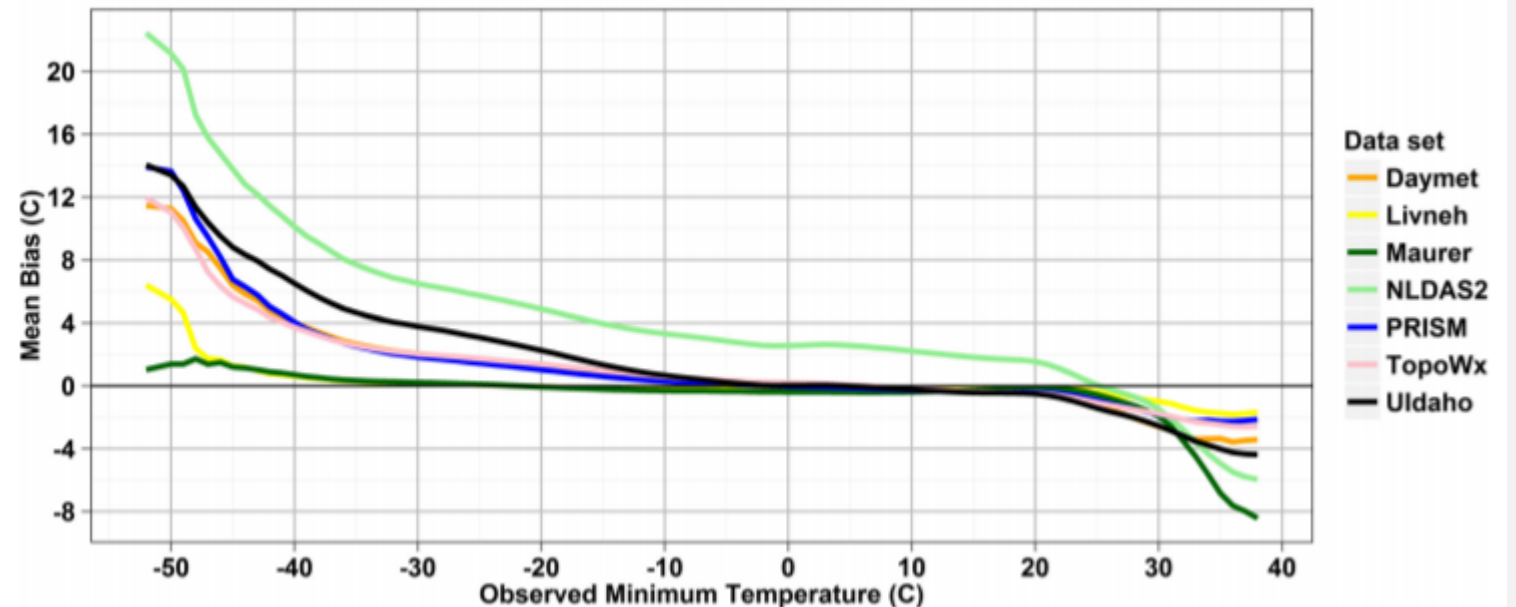


Fuente: Robert Rohde/Global Warming Art

Las 'Observaciones' en Cuadrícula Aún Son Estimaciones

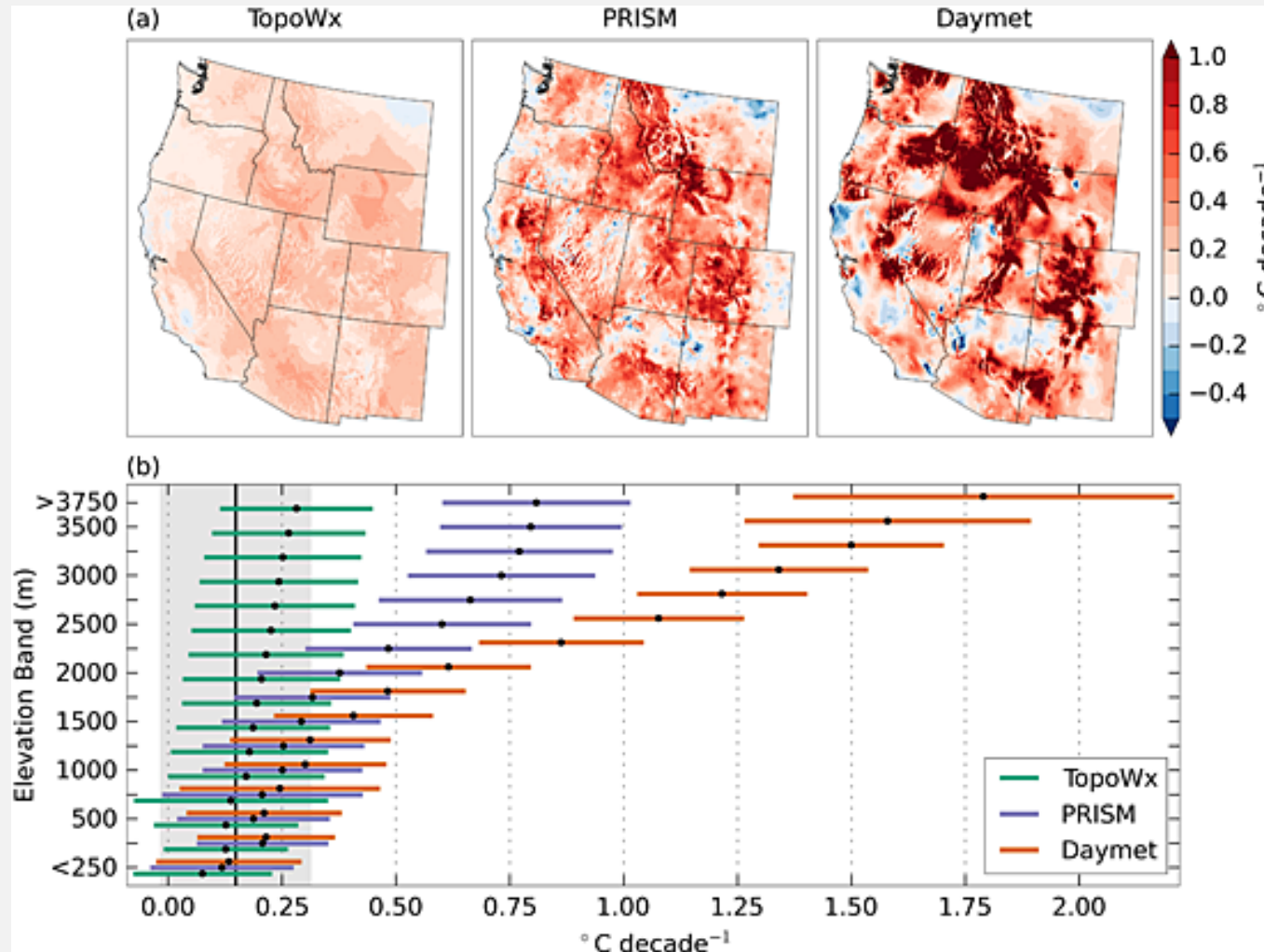
TABLE 1. Information on the eight gridded data products used in this study.

Data set	Variables used	Time span	Resolution (km)
Climate prediction center unified gauge-based analysis of daily precipitation (CPC)	prcp	1948–	28 × 21
Daymet	prcp, tmax, tmin	1980–2014	1 × 1
Livneh			
Maurer			
National land data assimilation system, version 2 (NLDAS2)			
Parameter-elevation regressions on independent slopes model (PRISM (AN81d))			
Topographical (TopoClimatic) weather (TopoWx)			
Utah			



Behnke et al. 2016 Ecological Applications

Más Incertidumbre en el Clima 'Observado' en las Montañas



Oyler et al. 2015 Geophysical Research Letters

Los conjuntos de datos difieren en cuanto a resolución espacial, años disponibles y variables

WorldClim Version2

WorldClim version 2 has average monthly climate data for minimum, mean, and maximum temperature and for precipitation for 1970-2000.

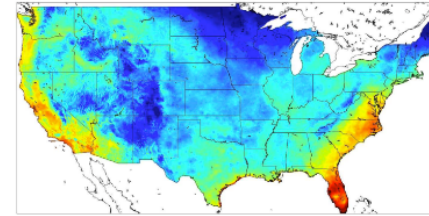
You can download the variables for different spatial resolutions, from 30 seconds (~1 km²) to 10 minutes (~340 km²). Each download is a "zip" file containing 12 GeoTiff (.tif) files, one for each month of the year (January is 1; December is 12).

variable	10 minutes	5 minutes	2.5 minutes	30 seconds
minimum temperature (°C)	tmin 10m	tmin 5m	tmin 2.5m	tmin 30s
maximum temperature (°C)	tmax 10m	tmax 5m	tmax 2.5m	tmax 30s
average temperature (°C)	tavg 10m	tavg 5m	tavg 2.5m	tavg 30s
precipitation (mm)	prec 10m	prec 5m	prec 2.5m	prec 30s
solar radiation (kJ m ⁻² day ⁻¹)	srad 10m	srad 5m	srad 2.5m	srad 30s
wind speed (m s ⁻¹)	wind 10m	wind 5m	wind 2.5m	wind 30s
water vapor pressure (kPa)	vapr 10m	vapr 5m	vapr 2.5m	vapr 30s

Below you can download the standard (19) WorldClim [Bioclimatic variables](#) for WorldClim version 2. They are the average for the years 1970-2000. Each download is a "zip" file containing 19 GeoTiff (.tif) files, one for each month of the [variables](#).

variable	10 minutes	5 minutes	2.5 minutes	30 seconds
Bioclimatic variables	bio 10m	bio 5m	bio 2.5m	bio 30s

Worldclim.org; <http://metdata.northwestknowledge.net/>



University of Idaho Gridded Surface Meteorological Data (UofI METDATA)

[HOME](#) [EXAMPLE FIELDS](#) [DERIVED FIELDS](#) [DOWNLOAD DATA](#) [UPDATES](#) [REFERENCES](#) [CONTACT](#)

UofI Gridded Surface Meteorological Dataset

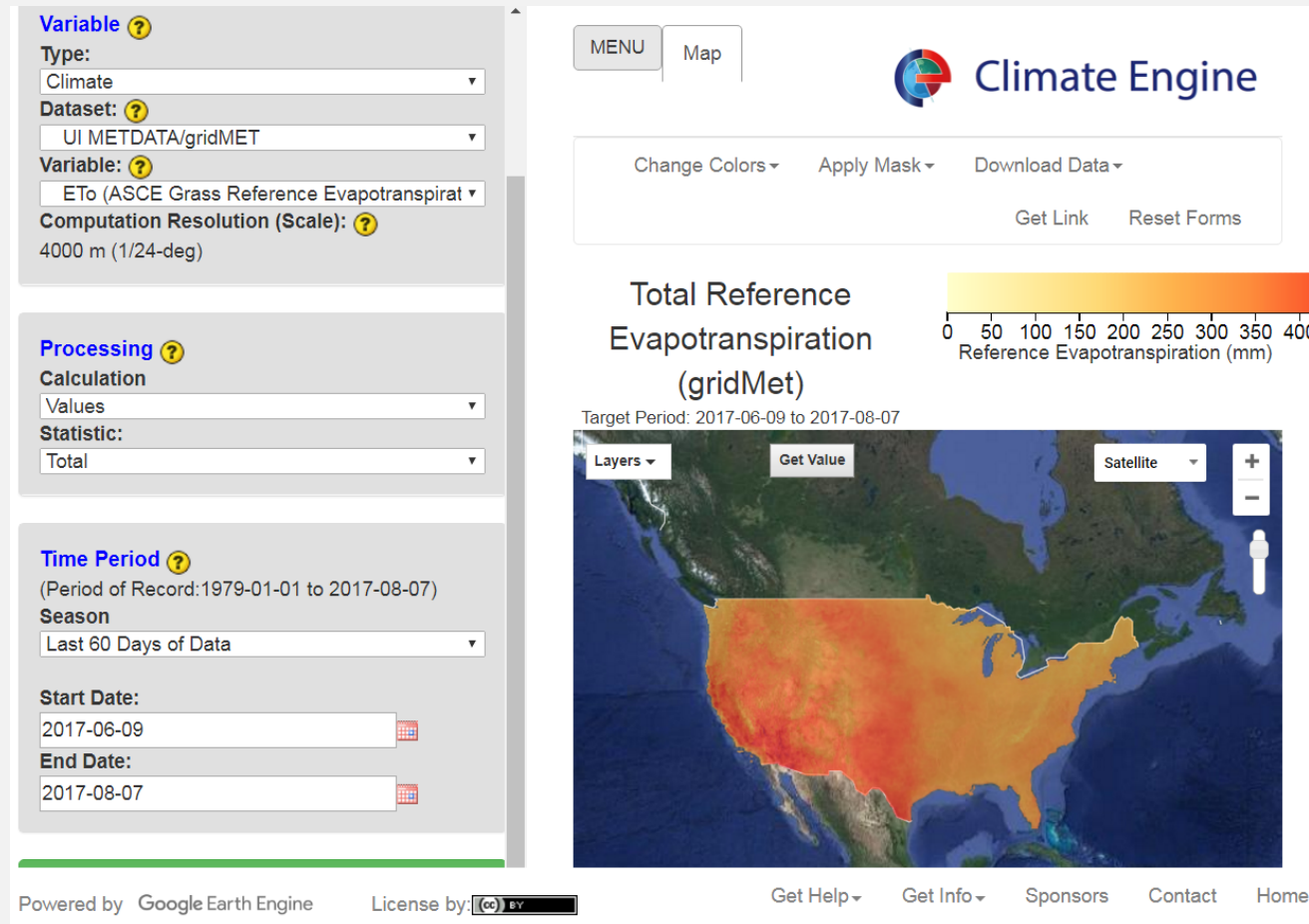
Landscape-scale modeling has been hindered by suitable high-resolution surface meteorological datasets that include temperature, precipitation, downward shortwave radiation, humidity and winds. To overcome these limitations, desirable spatial attributes of gridded climate data from [PRISM](#) are combined with desirable temporal attributes of regional-scale reanalysis and daily gauge-based precipitation from [NLDAS-2](#) to derive a spatially and temporally complete, high-resolution (1/24th degree ~4-km) gridded dataset of surface meteorological variables required in modeling for the coterminous United States from 1979-present.

Validation of the resulting gridded surface meteorological data was conducted against an extensive network of weather stations including [RAWS](#), [AgriMet](#), [AgWeatherNet](#) and [USHCN-2](#). For more information on validation measures see [Abatzoglou \(2011\)](#).

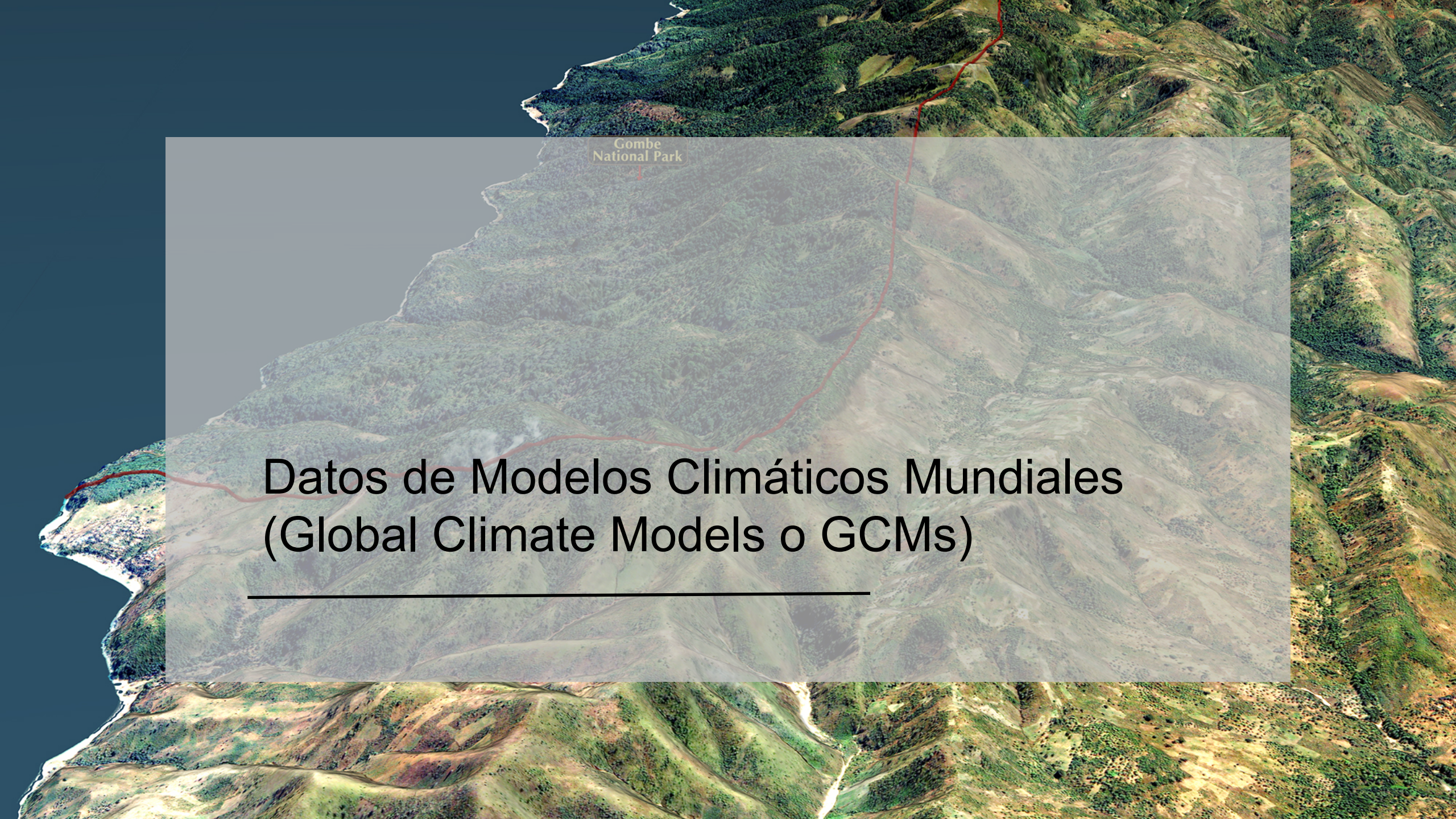
This Dataset has the following features:

- Spatial Resolution: 4-km (1/24-degree) grid
- Spatial Extent: Coterminous United States
- Temporal Resolution: Daily (some sub-daily)
- Temporal Extent: 1979-present (1-2 day lag)
- Variables: (all variables are daily extrema/sums/means over a given calendar day)
 - Precipitation
 - Temperature (maximum and minimum)
 - Humidity (maximum and minimum relative humidity and specific humidity)
 - Surface downward shortwave radiation (daily mean)
 - 10-meter Wind velocity (daily mean)
 - Reference evapotranspiration
 - NFDRS fire danger indices
- Definition of day: ie. Jan 21 is 6Z Jan 21 to 6Z Jan 22
- Format: netCDF adhering to Climate and Forecasting Metadata standards

Las Variables Derivadas Se Están Volviendo Más Accesibles



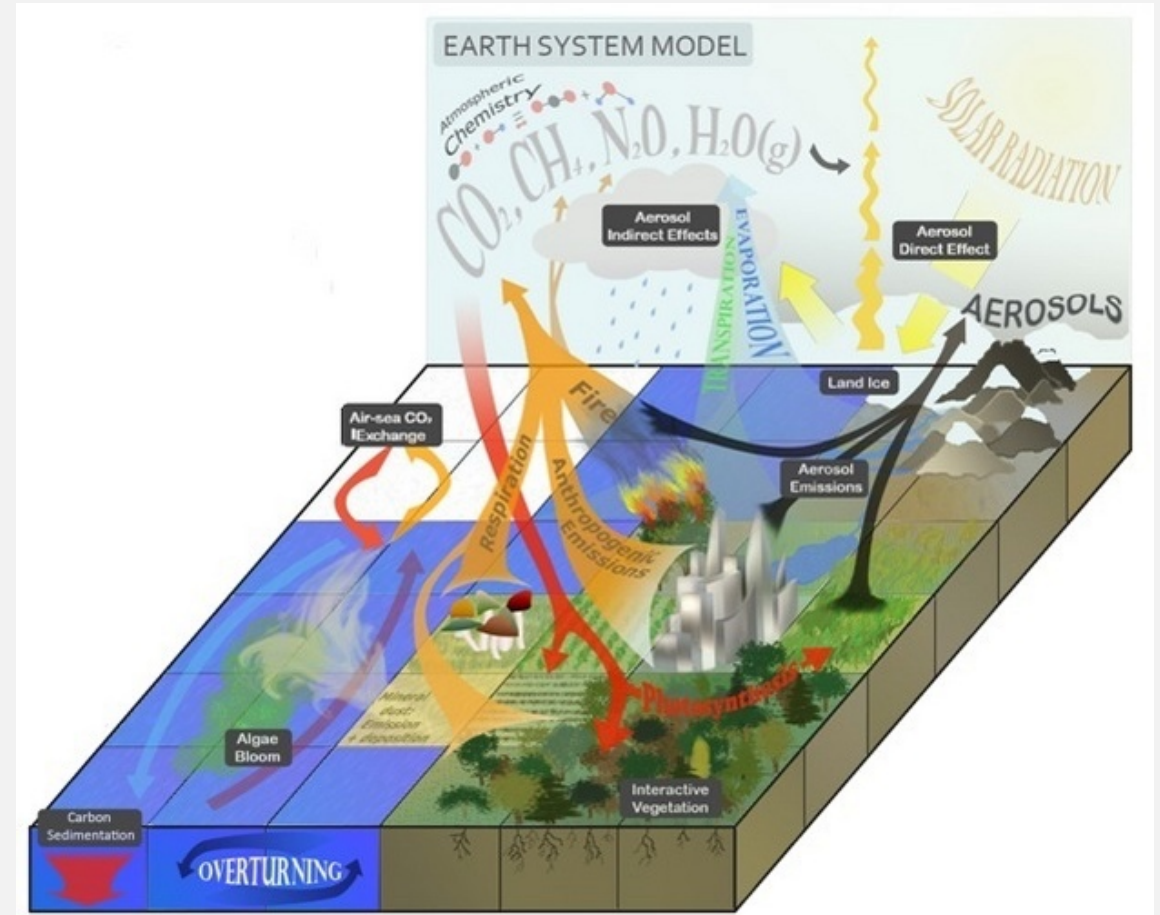
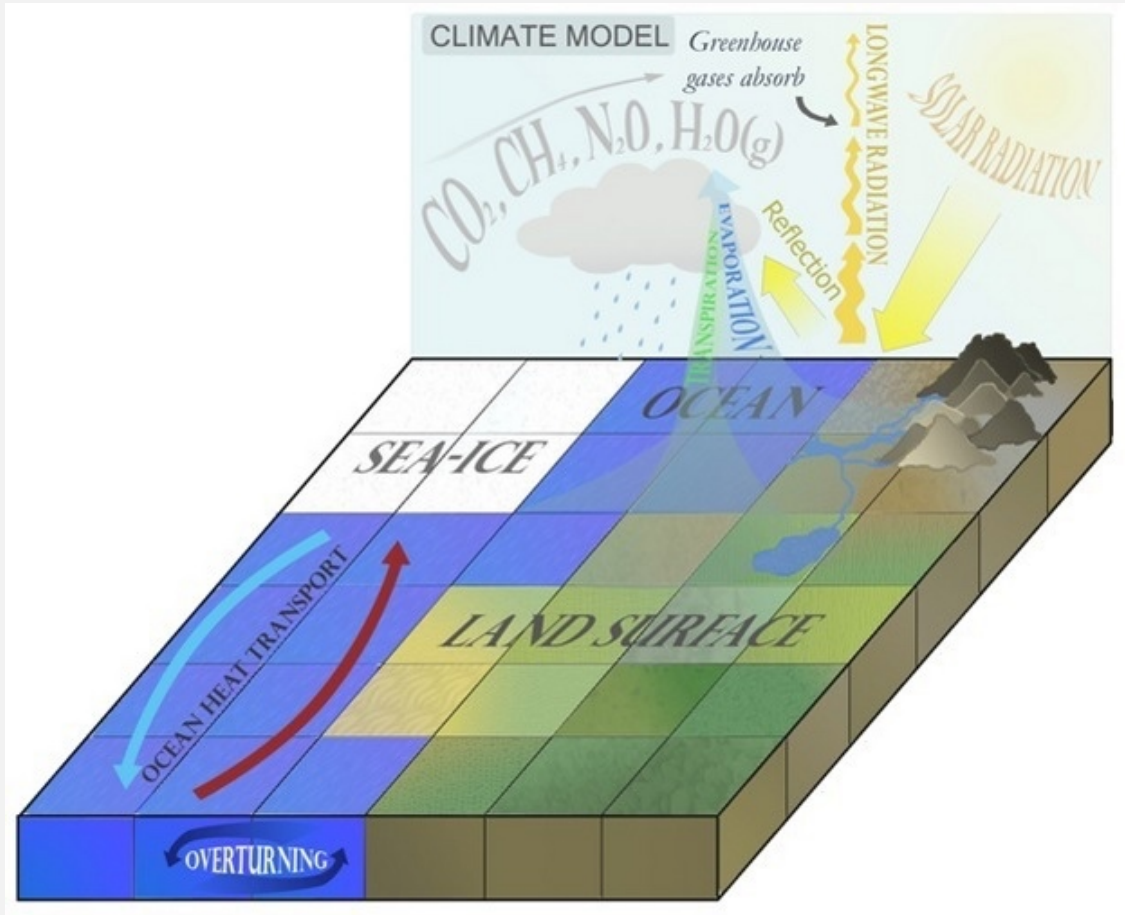
Climate Engine: <http://clim-engine.appspot.com/>; Huntington et al. 2017 Bulletin of the American Meteorological Society



Gombe
National Park

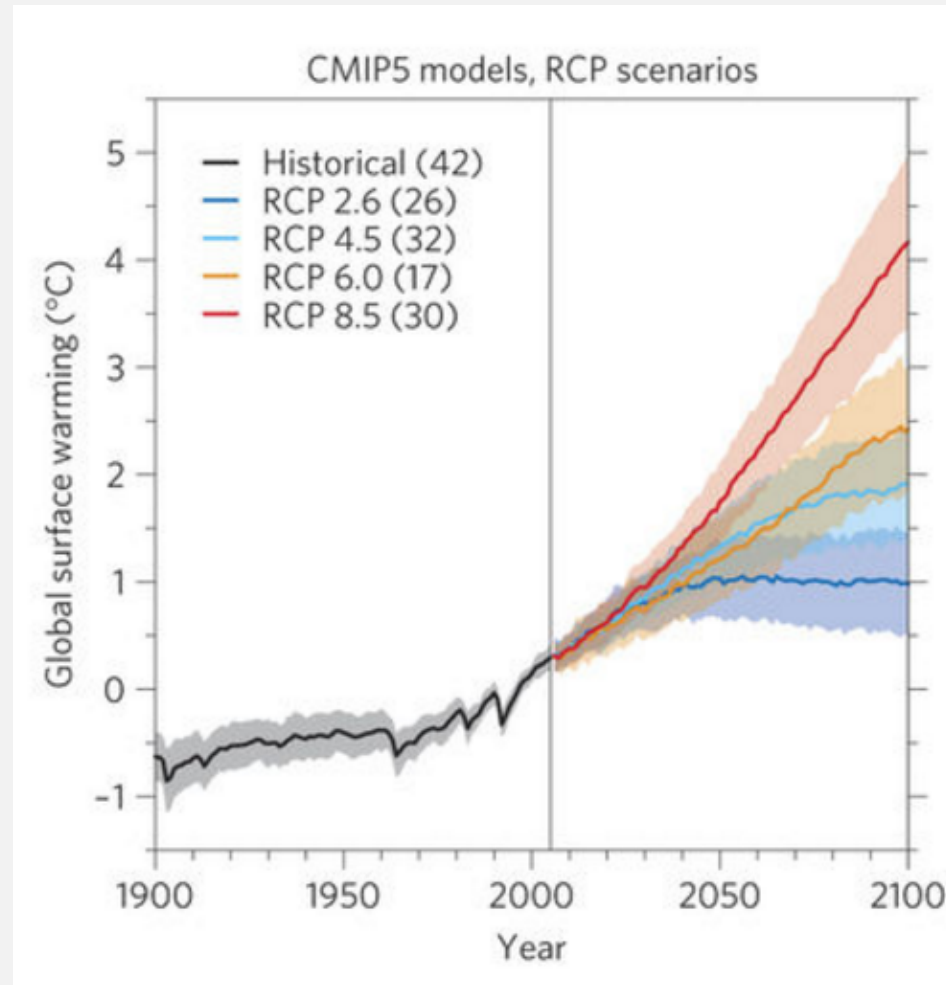
Datos de Modelos Climáticos Mundiales (Global Climate Models o GCMs)

Modelos Climáticos Mundiales



Heavens et al. 2013 Nature Education Knowledge

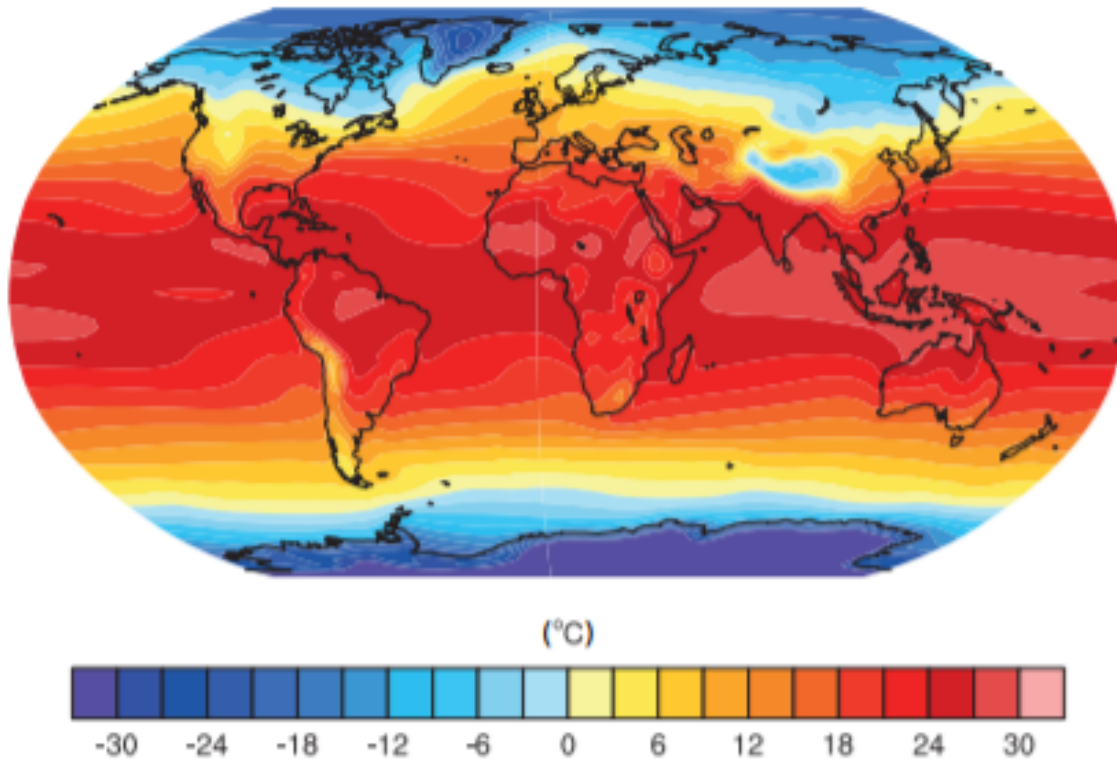
Representative Concentration Pathways (Patrones de Conexiones Representativas)



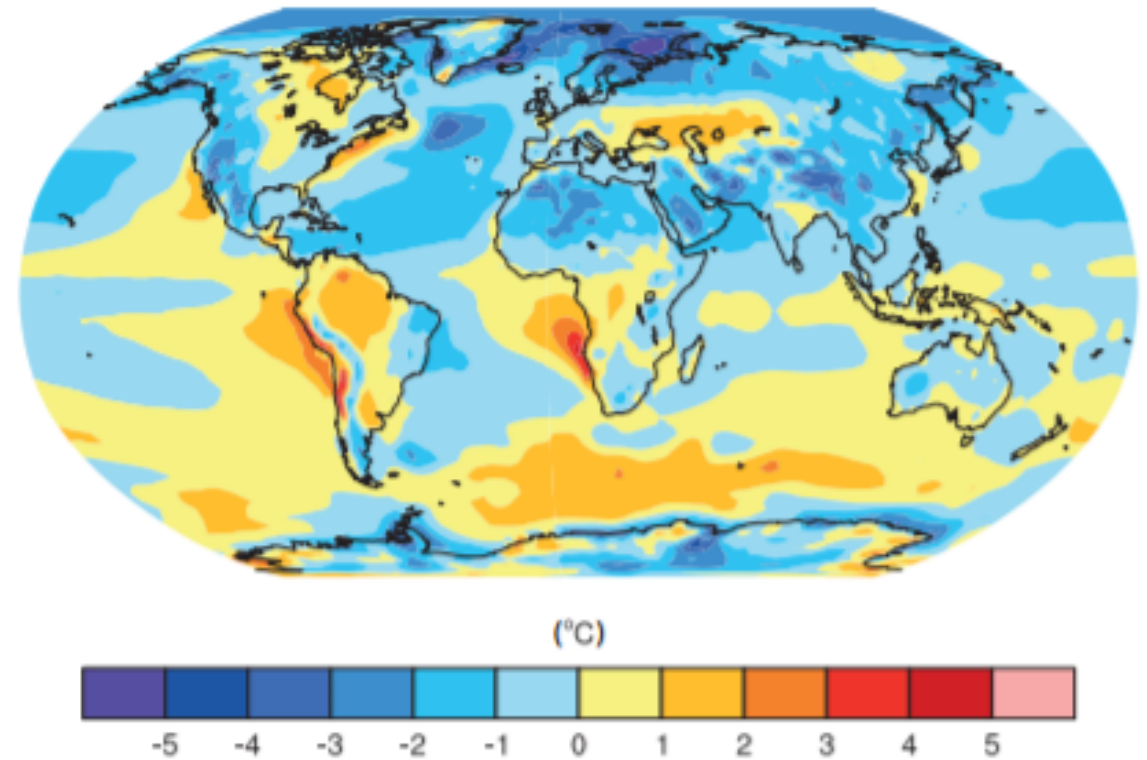
Knutti y Sedlacek 2013 Nature Climate Change

Los Modelos Climáticos Reproducen los Patrones Espaciales a Gran Escala Bien

(a) Temperatura Superficial Media Multi-Modelo

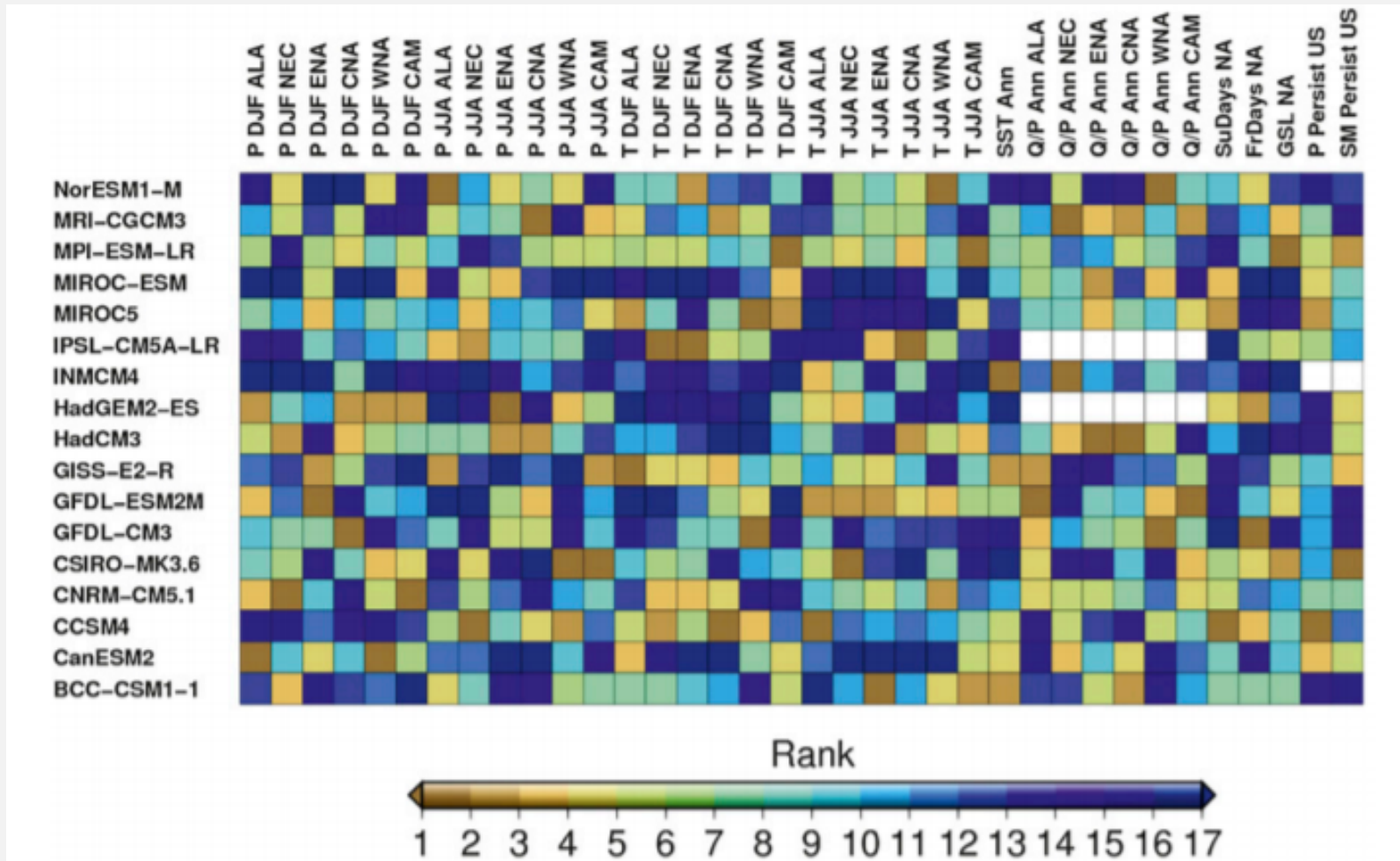


(b) Sesgo Medio Multi-Modelo



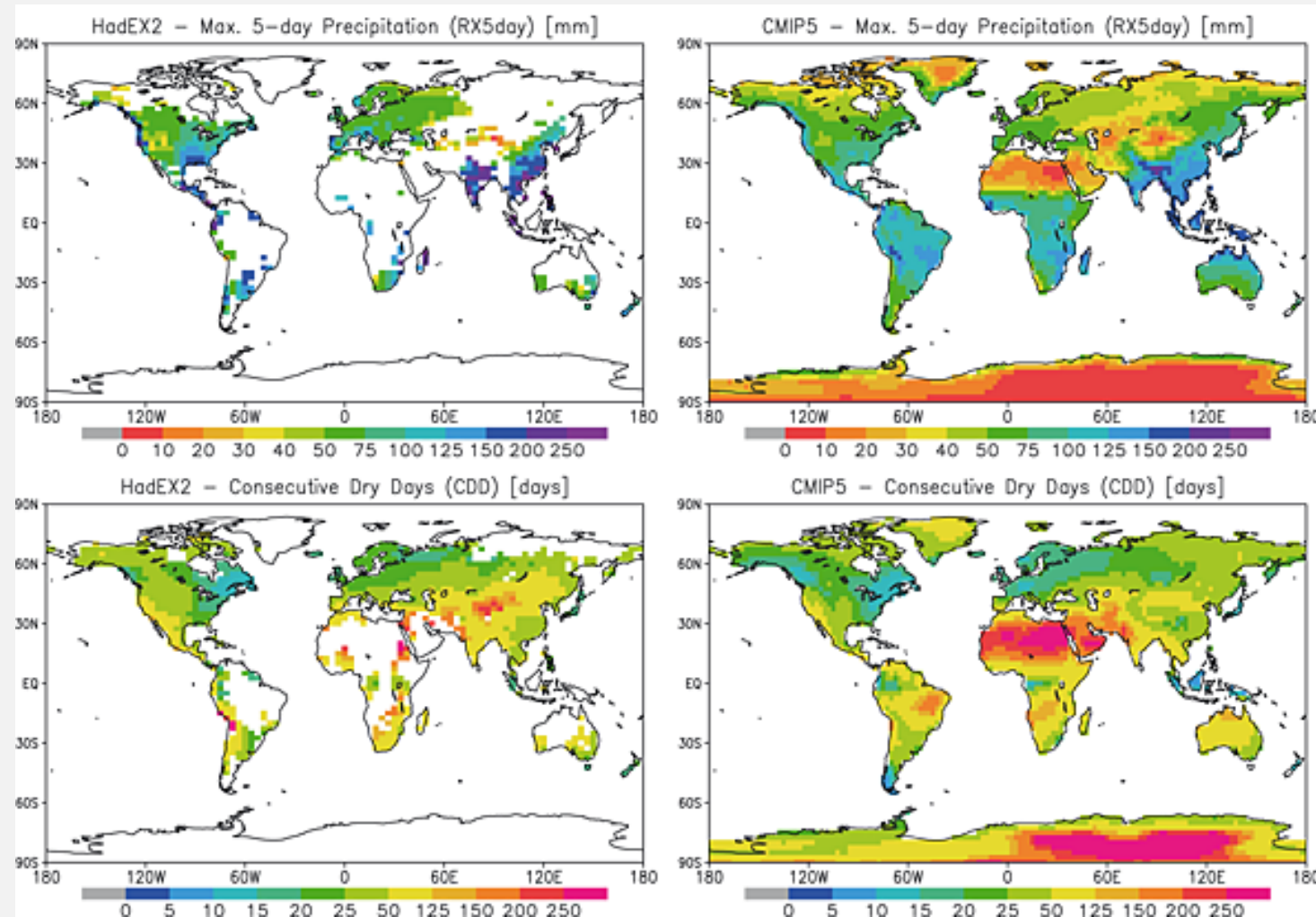
Flato et al. 2013. Evaluation of climate models. Ch. 9 of IPCC Physical Science Basis

El Rendimiento de los Modelos Varía Entre Regiones y Métricas



Sheffield et al. 2013
Journal of Climate

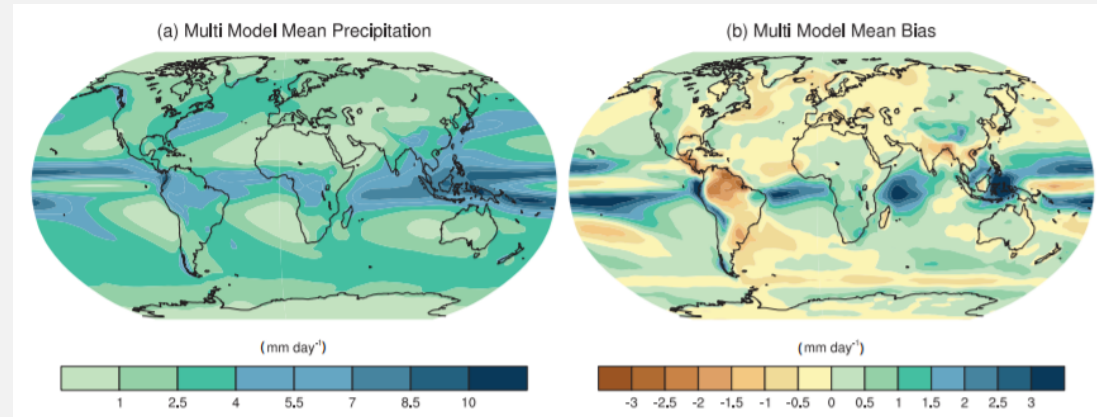
La Falta de Observaciones Puede Dificultar La Evaluación de Modelos



Sillmann et al. 2013 Journal of Geophysical Research: Atmospheres

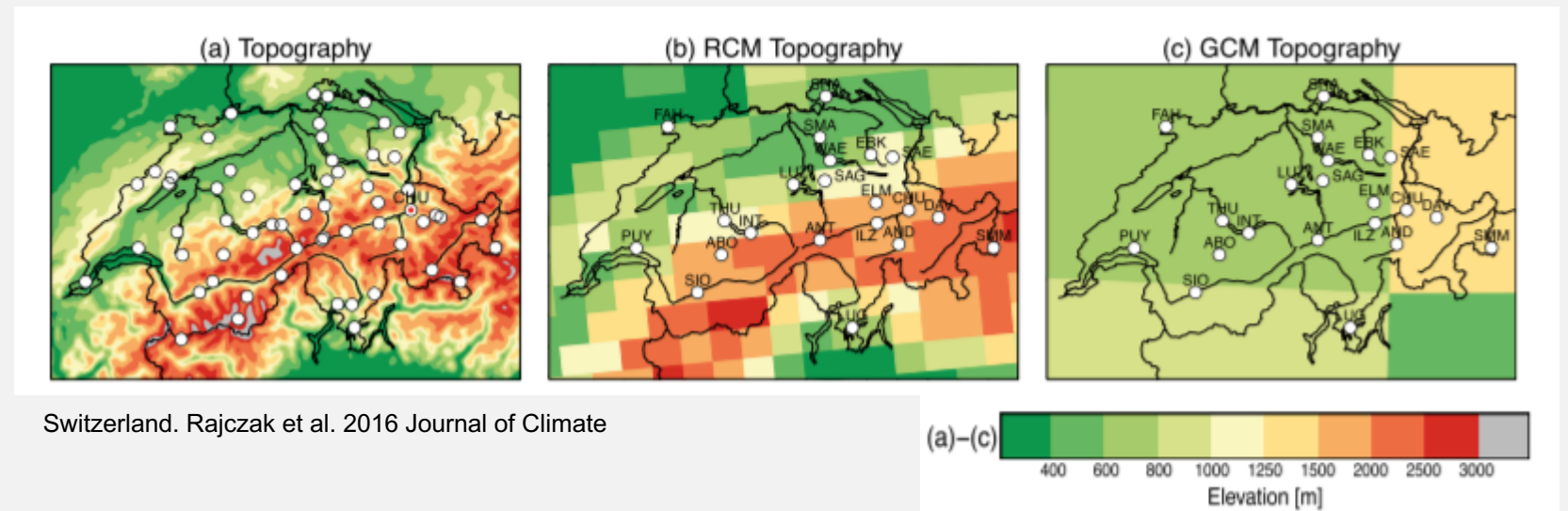
El Rendimiento de los Modelos Climáticos Rara Vez se Usa Directamente en los Estudios Ecológicos

- Sesgo

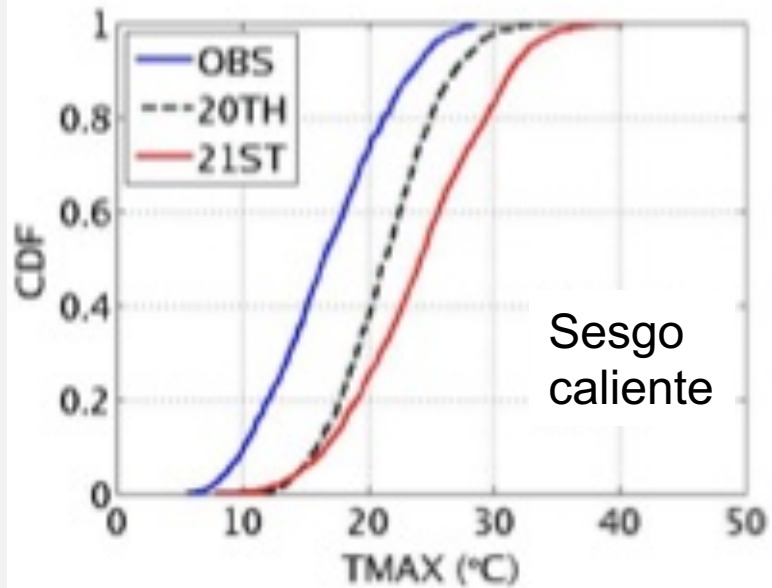


Flato et al. 2013. Evaluation of climate models. Ch. 9 of IPCC Physical Science Basis

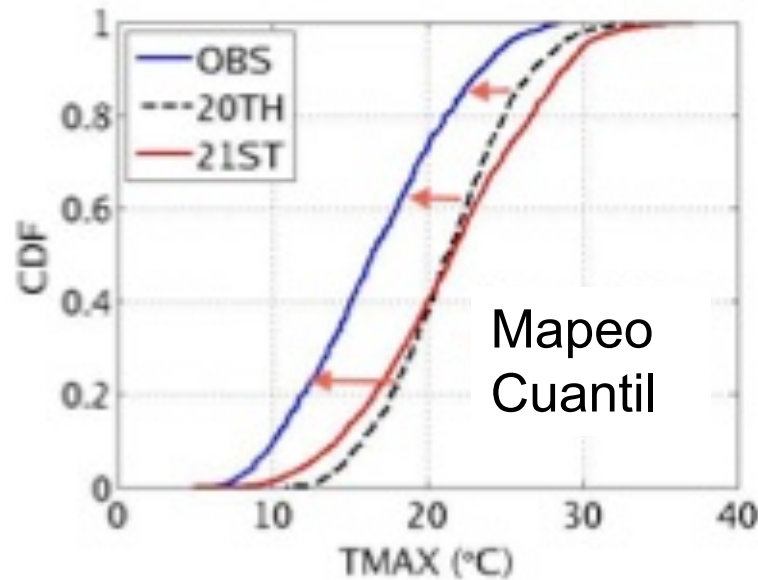
- Escala Espacial Bruta



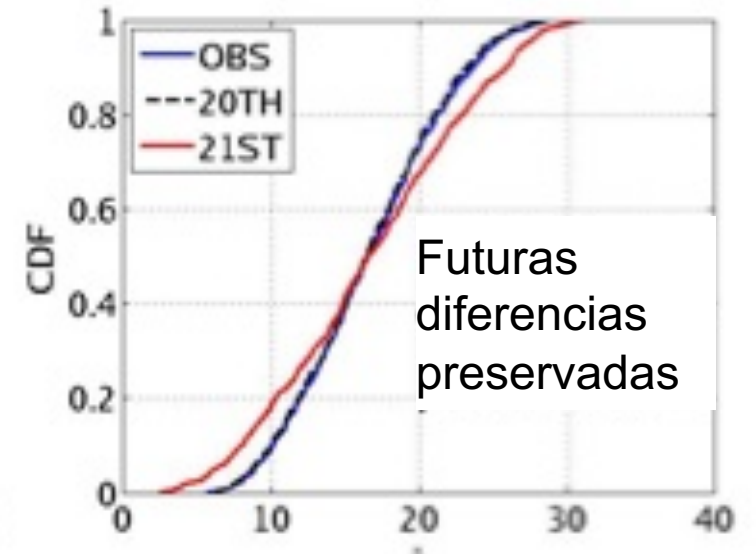
La Corrección por Sesgo a Menudo Se Basa en el Mapeo Cuantil



Datos de GCM brutos



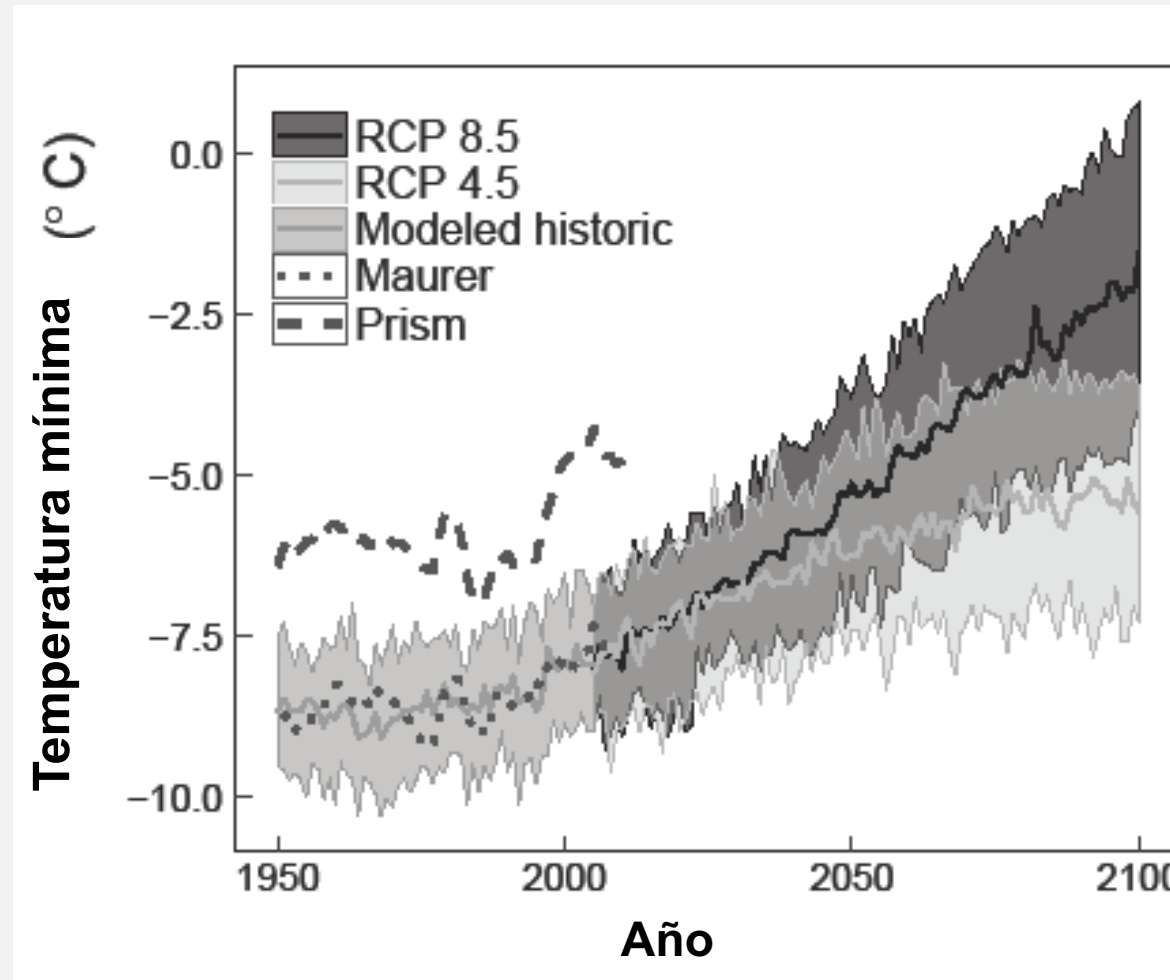
Después de ajustar por época



Después de corregir por sesgo

From MACA Website: <http://maca.northwestknowledge.net/MACAMethod.php>; Abatzoglou and Brown 2012 International Journal of Climatology

Los Datos Climáticos se Corrigen por Sesgo Según Un Conjunto de Datos Observacionales Particular

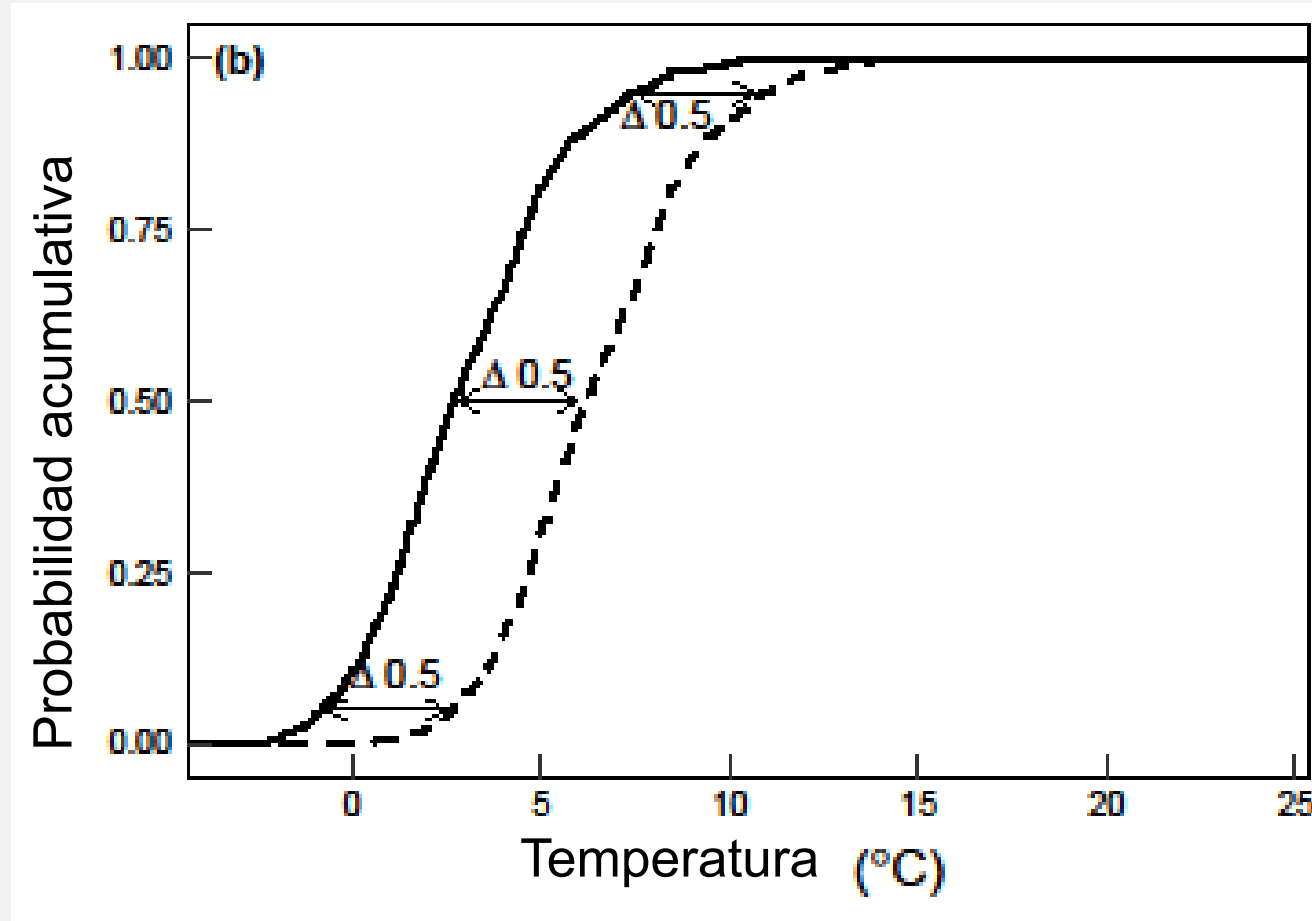


Sofaer et al. 2017 Global Change Biology

Proyecciones a Resoluciones Espaciales Más Finas: Método de Reducción de Escala

- Método Delta
 - Aplica cambios en los GCM a los datos climáticos históricos
- Reducción de escala estadística
 - Modela la relación entre el clima a gran escala y a fina escala
 - Varios diferentes métodos para descargar
- Reducción de escala dinámica
 - Basado en un Modelo Climático Regional

Método Delta: Aplica el Cambio del Medio en el GCM al Clima Histórico



Sofaer et al. 2017 Global Change Biology

Hay Conjuntos de Uso Difundido Basados en el Método Delta

Historical and projected climate data for North America (ClimateNA)

WorldClim Version2

WorldClim version 2 has average monthly climate data for minimum, mean, and maximum temperature and for precipitation for 1970-2000.


You can download the variables for different spatial resolutions, from 30 seconds (0.5 minutes) (~340 km²). Each download is a "zip" file containing 12 GeoTiff (.tif) files of the year (January is 1; December is 12).

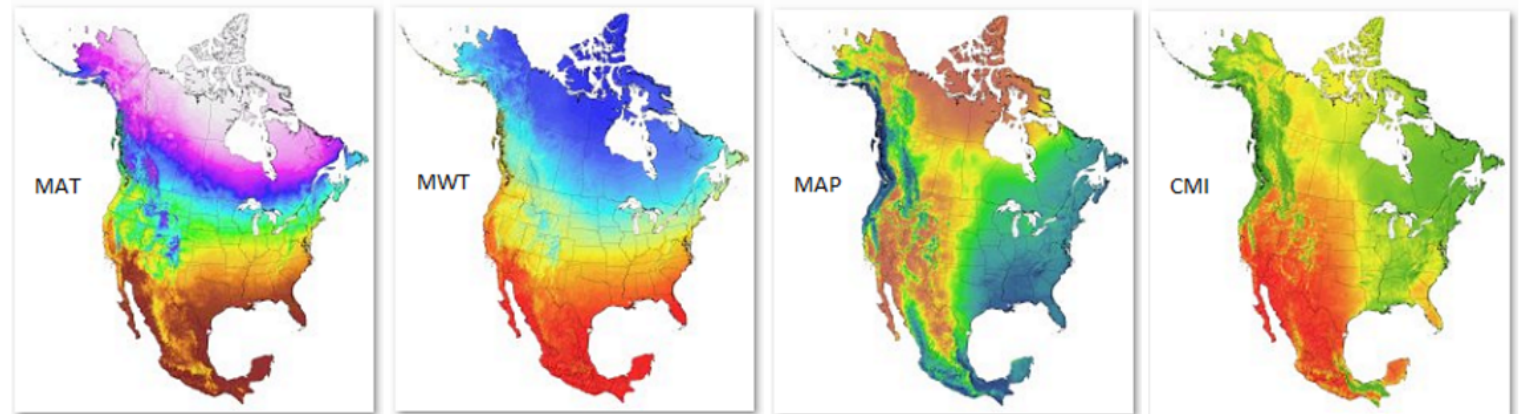
variable	10 minutes	5 minutes	2.5 minutes
minimum temperature (°C)	tmin 10m	tmin 5m	tmin 2.5m
maximum temperature (°C)	tmax 10m	tmax 5m	tmax 2.5m
average temperature (°C)	tavg 10m	tavg 5m	tavg 2.5m
precipitation (mm)	prec 10m	prec 5m	prec 2.5m
solar radiation (kJ m ⁻² day ⁻¹)	srad 10m	srad 5m	srad 2.5m
wind speed (m s ⁻¹)	wind 10m	wind 5m	wind 2.5m
water vapor pressure (kPa)	vapr 10m	vapr 5m	vapr 2.5m

Below you can download the standard (19) WorldClim Bioclimatic variables for WorldClim. They are the average for the years 1970-2000. Each download is a "zip" file containing files, one for each month of the variables.

variable	10 minutes	5 minutes	2.5 minutes	30 seconds
Bioclimatic variables	bio 10m	bio 5m	bio 2.5m	bio 30s

The software, downloadable from this web page, can be used to estimate more than 50 monthly, seasonal, and annual variables, including many economically or biologically relevant variables such as growing and chilling degree days, heating and cooling degree days, Hargrave's moisture deficit and reference evaporation, beginning and end of the frost-free period, etc.

Click on the thumbnails below and use the zoom tool  to see high resolution images of mean annual temperature (MAT), mean winter temperature with inversions in northern mountain valleys (MWT), mean annual precipitation with leeward rainshadows (MAP), and a climate moisture index (CMI):

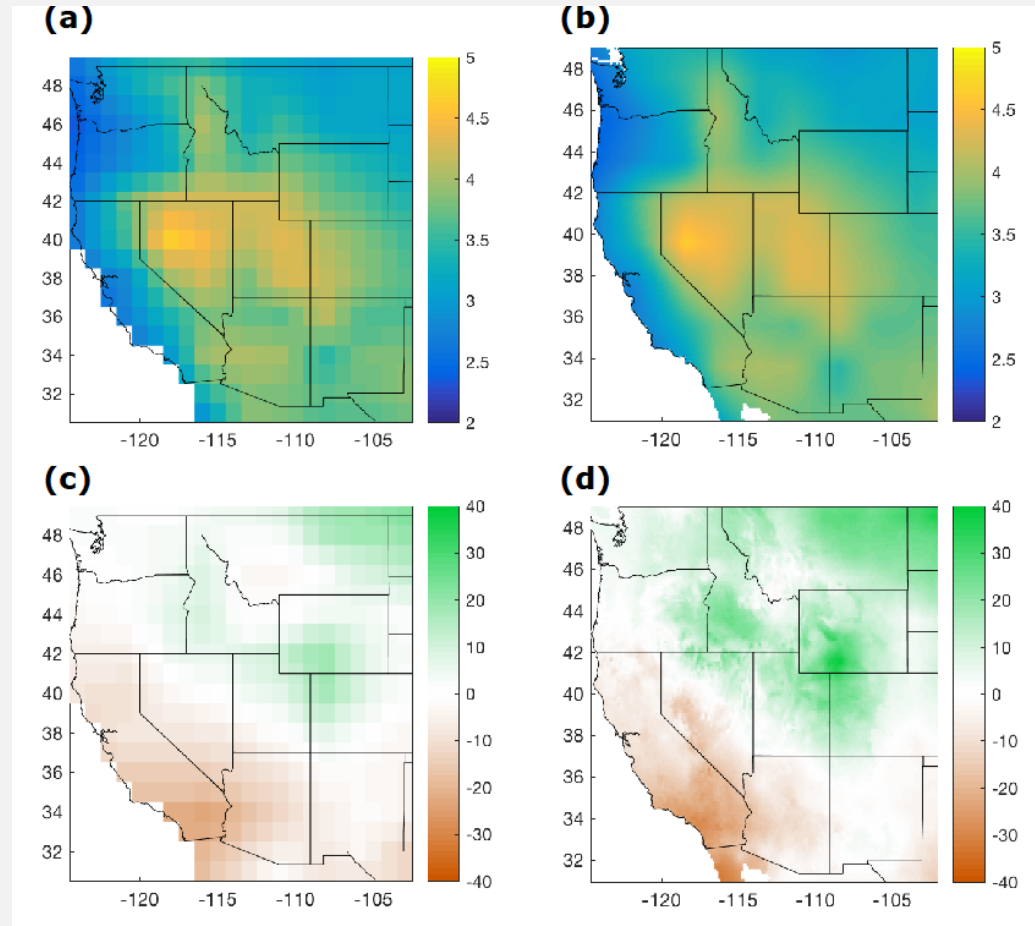


Worldclim.org; ClimateNA: <http://tinyurl.com/ClimateNA>

Reducción de Escala Estadística

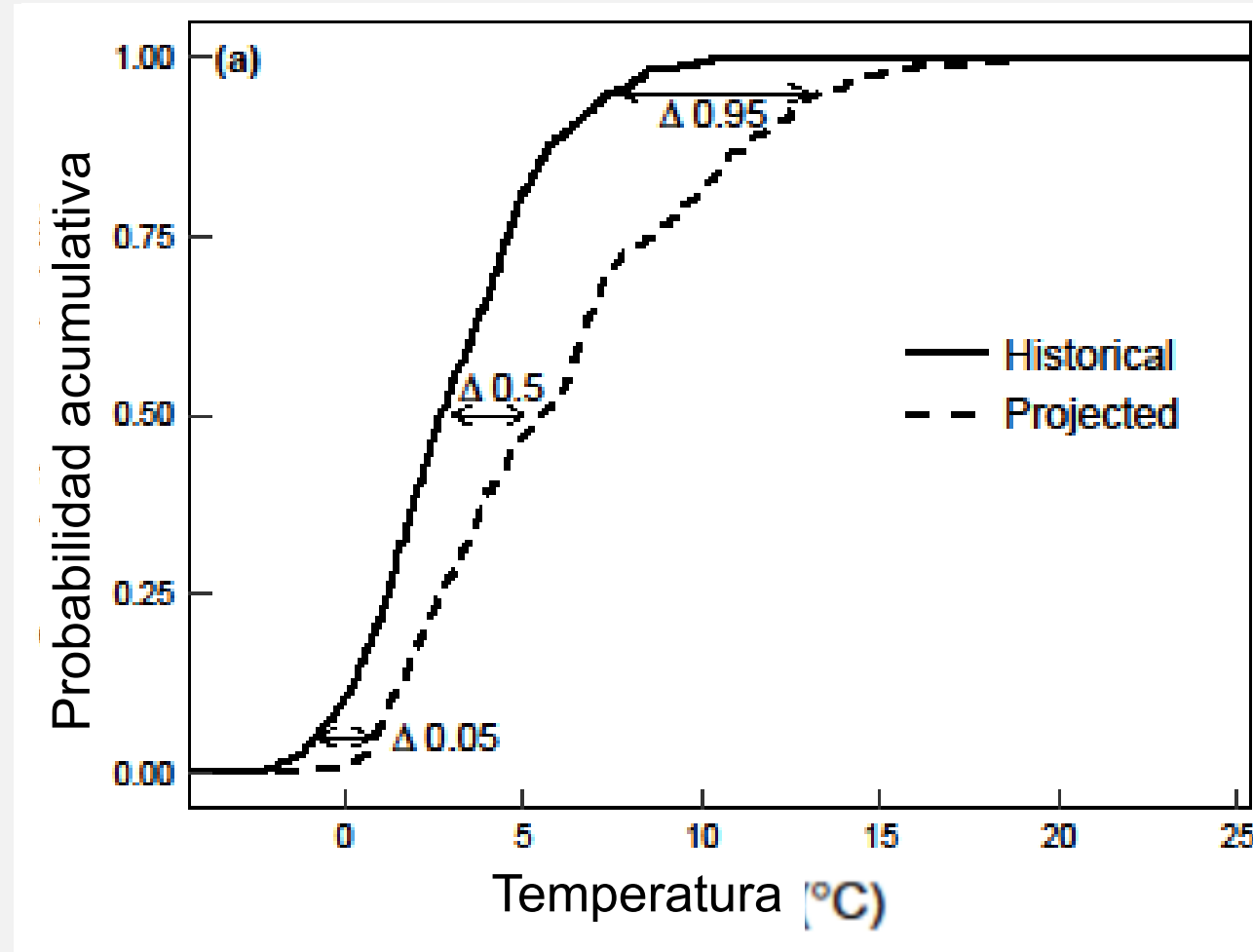
GCM: cambio proyectado en la temperatura ($^{\circ}\text{C}$)

GCM: cambio proyectado en la precipitación (mm)



Sofaer et al. 2017 Global Change Biology

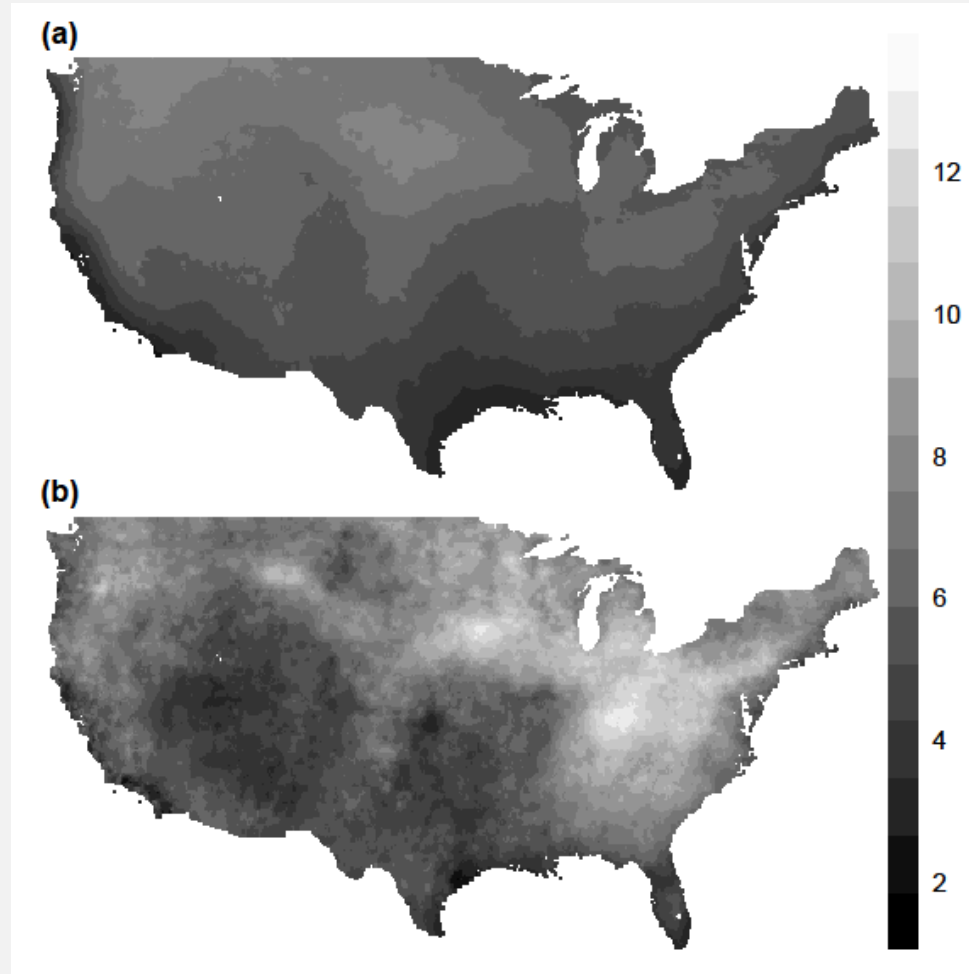
Preserva las Diferencias Proyectadas en los Medios y los Extremos



Los Medios y los Extremos Pueden Cambiar a Diferentes Pasos

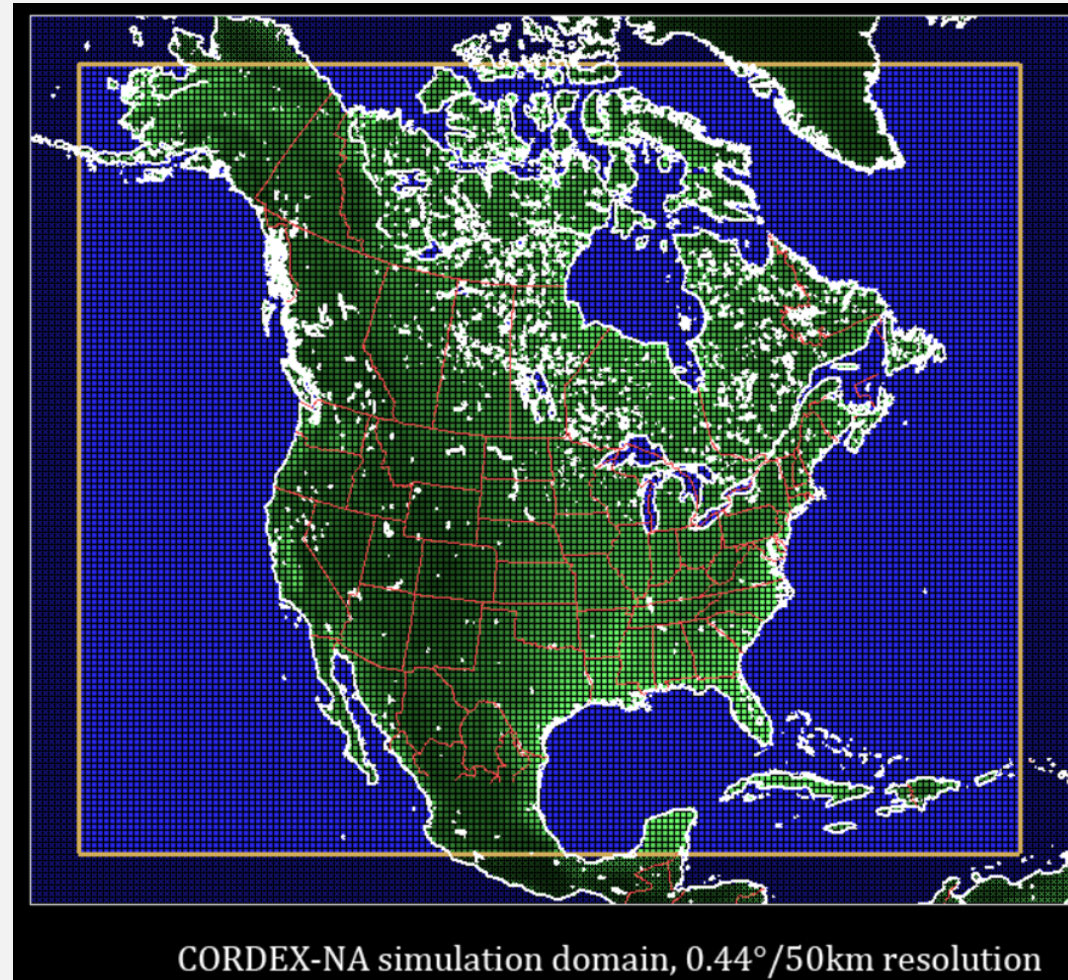
Cambio proyectado en la temperatura media de julio ($^{\circ}\text{C}$)

Cambio proyectado en el día más caliente pronosticado en julio para un período de 10 años ($^{\circ}\text{C}$)



Sofaer et al. 2017 Global Change Biology

La Reducción Dinámica de Escala Puede Capturar Procesos que los GCMs Pasan por Alto



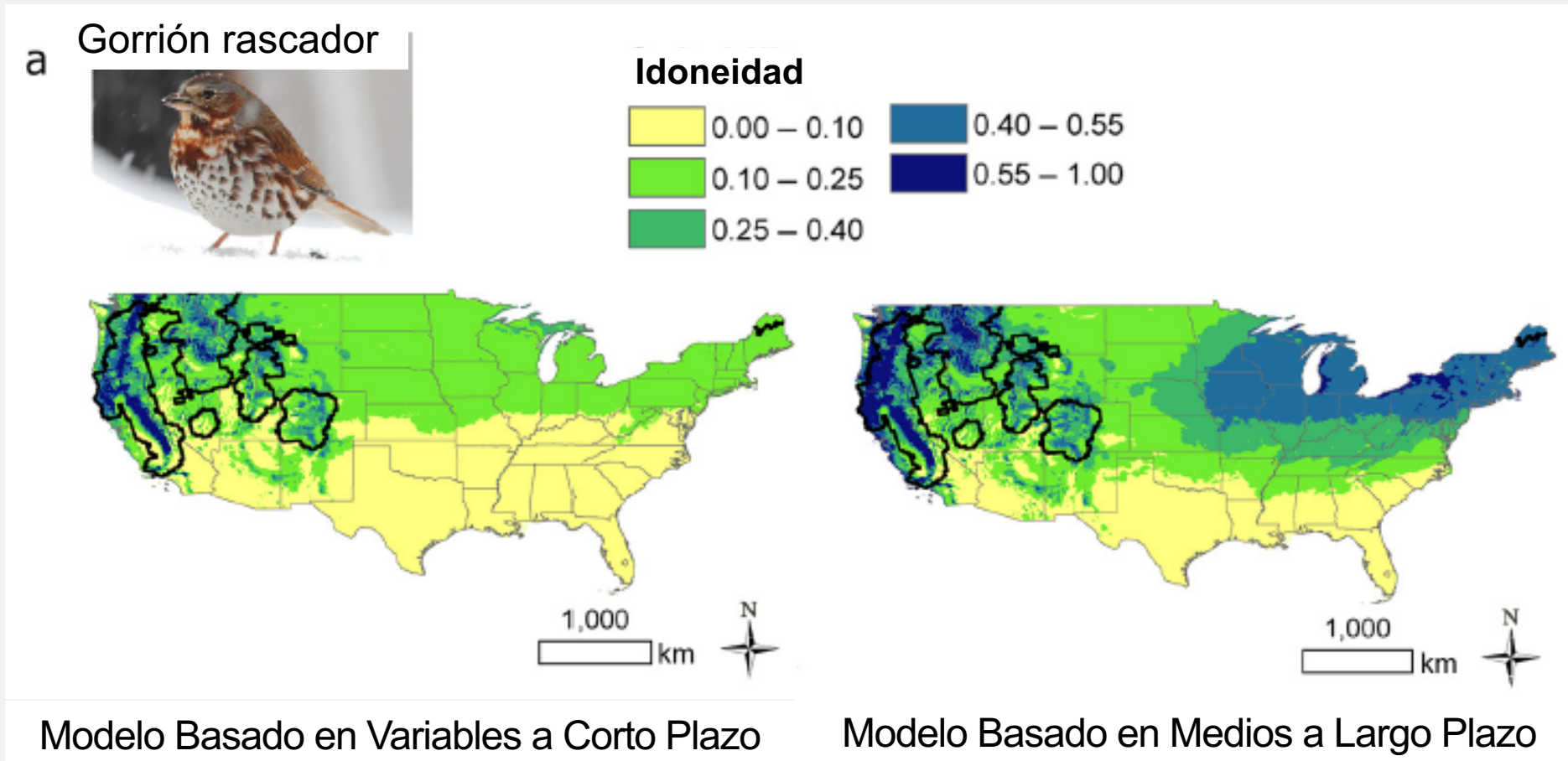
<https://na-cordex.org/>



Gombe National Park

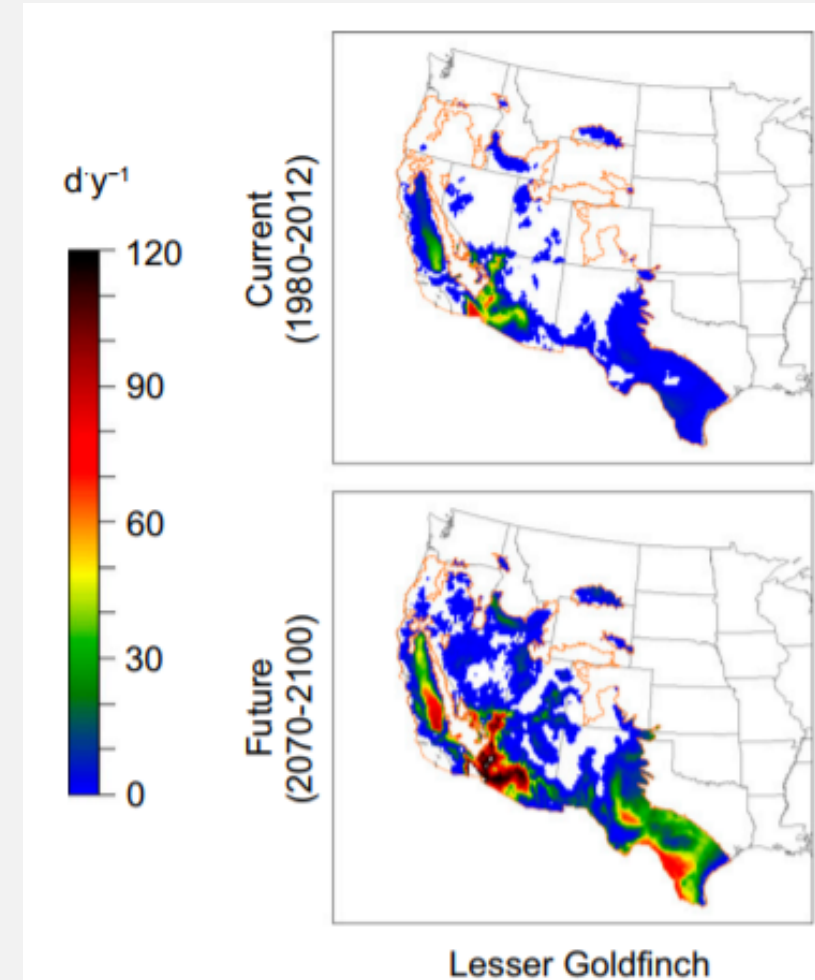
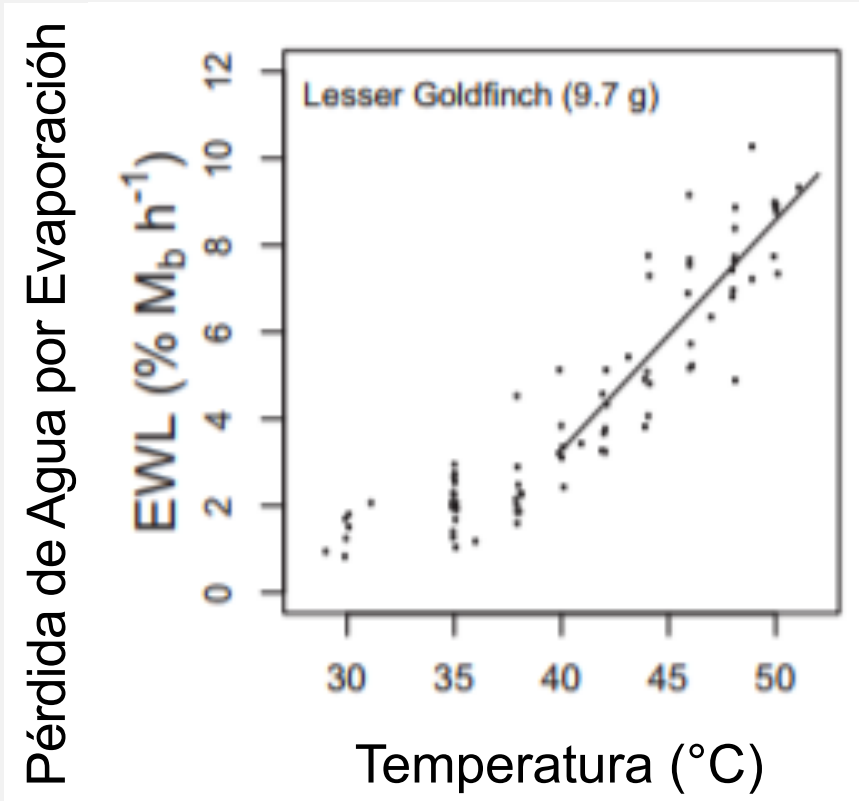
Cómo Utilizar las Proyecciones Climáticas

Primero, identifique los factores climáticos de su sistema



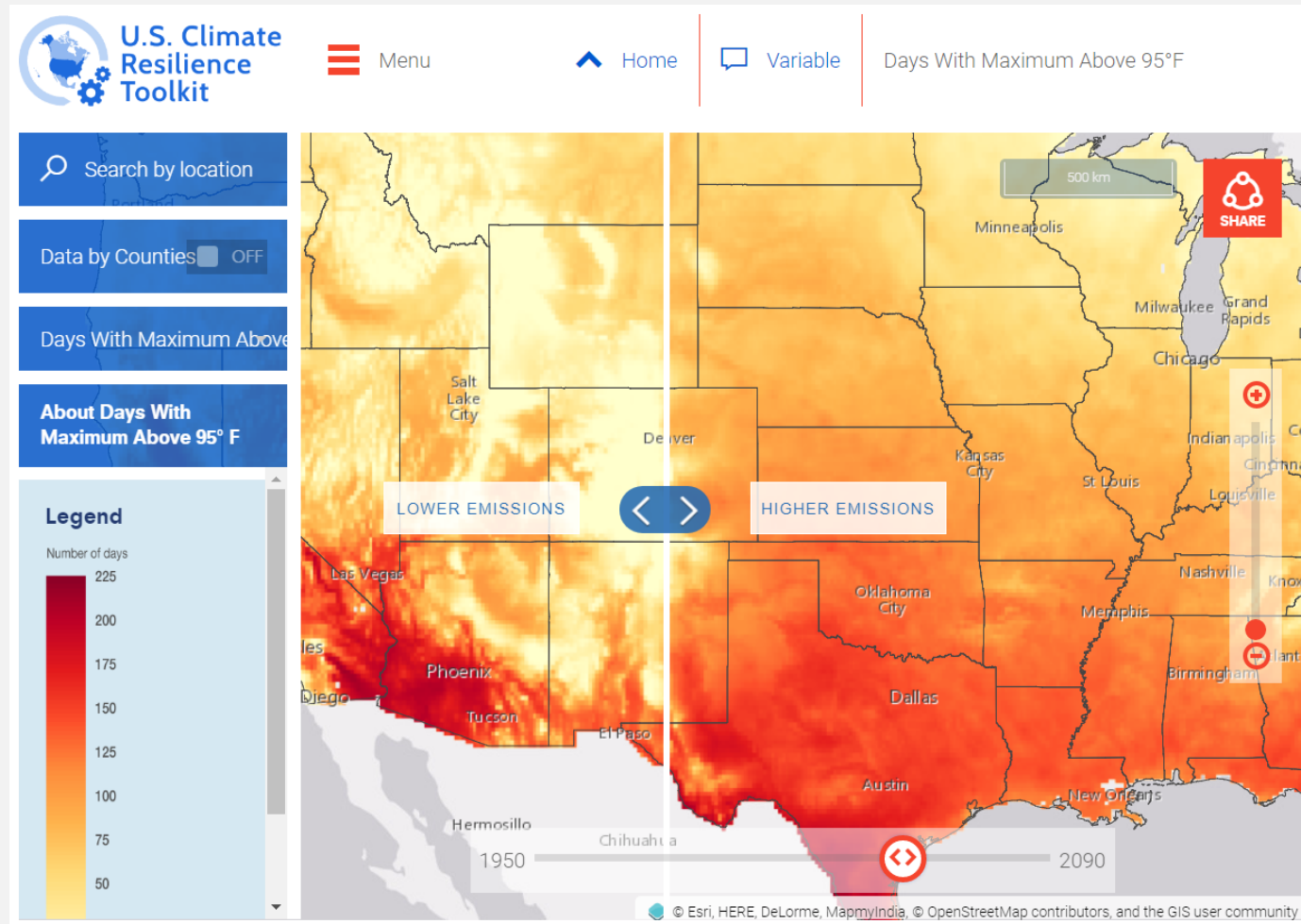
Bateman et al. 2016 Ecological Applications

Considere los Análisis de Sensibilidad Sencillos (e.g. + 4°C)



Albright et al. 2017 PNAS

Escala Espacial: ¡No interprete célula por célula!



U.S. Climate Resilience Toolkit:
Climate Explorer:
<https://toolkit.climate.gov/#climate-explorer>

¿Cuántos y Cuáles Modelos y Patrones Elegir?

- Patrones de Concentración Representativa (Representative Concentration Pathways o RCPs):
 - Enfóquese en una RCP si las proyecciones son hasta mediados del siglo o antes
 - Es común usar 4.5 y 8.5 para finales del siglo
- Modelos climáticos:
 - Elimine modelos que no son satisfactorios en regiones o variables de su interés
 - Use productos “en bruto”
 - Estrategias:
 - Use cuantos GCMs le sea factible o estén disponibles
 - Averigüe la gama de cambios proyectados por los GCMs

Considere la Cantidad de Cambio Proyectada por Diferentes Modelos

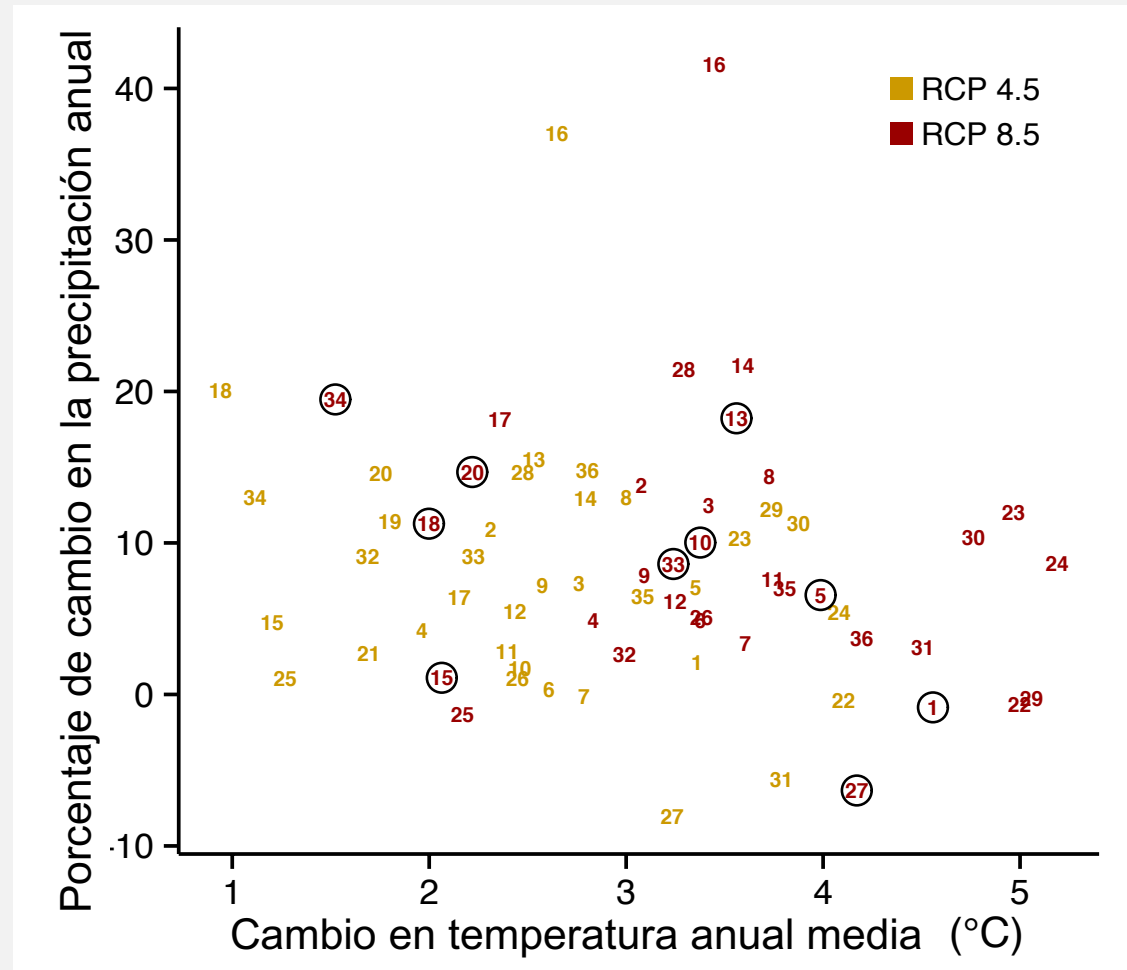
Mean annual temperature change for states and provinces of North America projected for the 2050s under the RCP4.5 scenario. States and provinces are alphabetically sorted from left to right, AOGCMs are sorted by magnitude of projection for North America from top to bottom.

AOGCM	AB	AK	AL	AR	AZ	BC	CA	CO	CT	DC	DE	FL	GA	IA	ID	IL	IN	KS	KY	LA	MA	MB	MD	ME	MI	MN	MO	MS	MT	NB	NC	ND	NE	NH		
INM-CM4	1.9	2.3	1	1.2	1.1	1.7	1.1	1.2	1.1	1.2	1	0.8	0.9	1.7	1.4	1.5	1.4	1.4	1.2	0.9	1.1	2	1.1	1.4	1.7	1.8	1.4	1	1.4	1.4	0.9	1.7	1.4	1.3		
CNRM-CM5	2.3	3.1	1.7	1.9	2.3	2.1	1.9	2.4	2.2	2.1	2	1.3	1.7	2.2	2.3	2.1	2.2	2.1	2	1.7	2.3	3	2	2.4	2.6	2.5	1.9	1.7	2.4	2.5	1.8	2.6	2.3	2.4		
CCSM4	2.8	3.6	2.1	2.2	2.2	2.7	1.9	2.3	2.2	2.2	2.1	1.7	2	2.7	2.7	2.3	2.3	2.3	2.3	1.9	2.3	3	2.2	2.4	2.6	2.9	2.3	2.1	2.6	2.4	2.1	2.9	2.4	2.5		
MPI-ESM-LR	3	3.7	1.7	1.9	2.3	2.8	2	2.3	2.3	2.1	2	1.5	1.7	2.6	2.4	2.3	2.2	2.3	2	1.6	2.4	3.4	2.1	2.5	2.7	2.9	2.2	1.7	2.3	2.6	1.8	3	2.5	2.5		
IPSL-CM5A-LR	3.2	3.6	2.5	2.7	2.9	3.2	2.7	3.1	2.9	2.8	2.7	2.1	2.4	3.3	3.3	3	2.9	2.8	2.7	2.5	2.9	3.3	2.7	3.2	3.1	3.4	2.9	2.6	3.2	3.3	2.5	3.4	3	3.2		
HadGEM2-ES	3.6	4.7	2.9	3.2	2.9	3	2.6	3	3.2	3.3	2.9	2.3	2.8	3.3	3.1	3.4	3.5	3.2	3.4	2.9	3.3	4.2	3.2	3.4	3.6	3.5	3.3	3.1	3.1	3.5	2.8	3.7	3.2	3.4		
GFDL-CM3	3.2	5.5	2.7	2.8	3.1	3.6	2.8	3.6	3.4	3.3	3.1	2.4	2.6	3.2	3.7	3.1	3.2	3.1	3.2	2.5	3.4	4.2	3.2	3.9	3.6	3.5	3.1	2.6	3.2	4	2.9	3.2	3.1	3.8		
AOGCM	NJ	NL	NM	NS	NT	NV	NY	OH	OK	ON	OR	PA	PE	QC	RI	SC	SD	SK	TN	TX	UT	VA	VT	WA	WI	WV	WY	YT	Can	USA	ContUSA	NorAm				
INM-CM4	1.1	1.2	1.1	1.1	2	1.2	1.4	1.3	1.2	1.8	1.1	1.3	1.3	1.4	1	0.8	1.5	2	1.2	1.1	1.3	1.1	1.4	1.1	1.8	1.2	1.3	2.1	1.9	1.5	1.3	1.7				
CNRM-CM5	2.1	2.3	2.4	2.3	3.3	2.5	2.3	2.2	2	2.8	2.1	2.2	2.5	2.8	2.2	1.7	2.4	2.6	1.8	2	2.6	1.9	2.4	2	2.4	2.1	2.3	2.6	2.9	2.4	2.2	2.7				
CCSM4	2.2	2.5	2.1	2.1	3.7	2.5	2.5	2.3	2.1	2.7	2.2	2.4	2.3	2.9	2.1	2	2.7	2.9	2.3	1.9	2.7	2.2	2.5	2.3	2.8	2.3	2.6	3.2	3.3	2.7	2.3	3				
MPI-ESM-LR	2.1	3	2.2	2.4	3.8	2.2	2.4	2.2	2.1	3	2.1	2.3	2.6	3.2	2.3	1.7	2.6	3.2	1.9	2	2.4	2	2.5	2.2	2.7	2.1	2.3	3.3	3.4	2.6	2.2	3.1				
IPSL-CM5A-LR	2.8	3.3	3	2.9	3.5	3.3	3.2	2.9	2.8	3.2	2.9	2.9	3.3	3.4	2.8	2.4	3.2	3.3	2.6	2.7	3.4	2.7	3.3	2.9	3.3	2.8	3.1	3.2	3.4	3.1	3	3.3				
HadGEM2-ES	3.1	3.6	2.9	3.3	5.5	3	3.6	3.6	3	3.9	2.7	3.5	3.8	4.1	3.1	2.8	3.4	3.8	3.2	2.9	3.2	3.1	3.6	2.9	3.5	3.4	3.1	4.1	4.6	3.5	3.1	4.2				
GFDL-CM3	3.3	5	3.2	3.5	7.3	3.5	3.8	3.4	3	4.3	2.9	3.5	3.8	5.6	3.2	2.7	3.1	3.6	3	2.8	3.9	3.2	3.9	2.9	3.5	3.4	3.4	4.7	5.7	3.8	3.2	5				

ClimateNA: <http://tinyurl.com/ClimateNA>



Considere la Cantidad de Cambio Proyectada por Diferentes Modelos

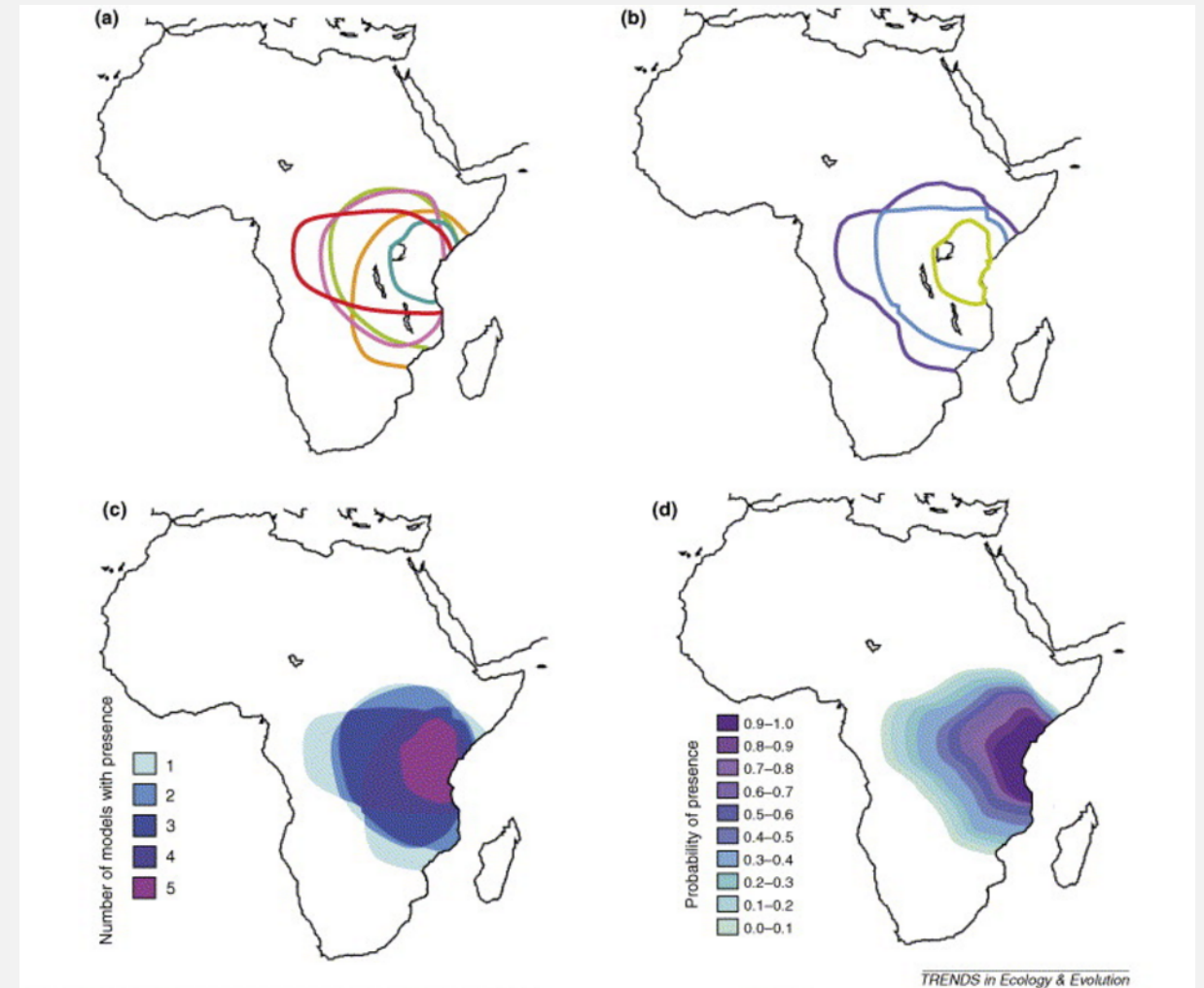


Cambio proyectado entre 1971-2000 y 2041-2070

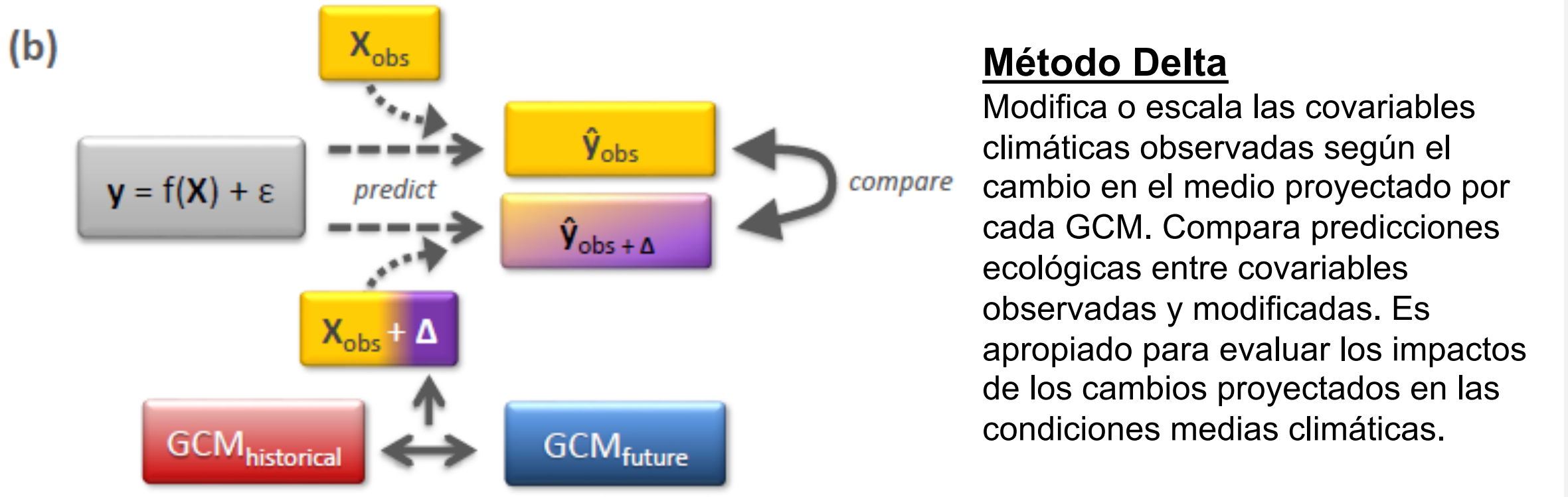
Sofaer et al. 2016 Ecological Applications

Cómo Desarrollar y Resumir Proyecciones Ecológicas

- Pronostique según cada modelo climático / RCP por separado
 - Se pueden promediar los resultados ecológicos, pero no los insumos climáticos
 - ¡Muestre la variabilidad!



Si los Medios a Largo Plazo son Factores Claves: Use el Método Delta

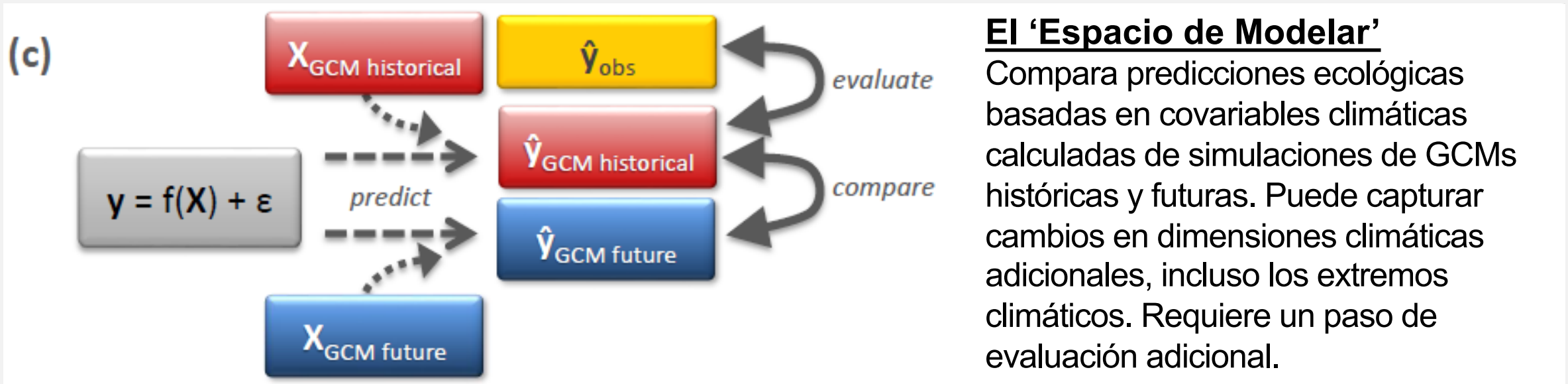


Método Delta

Modifica o escala las covariables climáticas observadas según el cambio en el medio proyectado por cada GCM. Compara predicciones ecológicas entre covariables observadas y modificadas. Es apropiado para evaluar los impactos de los cambios proyectados en las condiciones medias climáticas.

Sofaer et al. 2017 Global Change Biology

Si los Extremos Son los Factores Claves: Considere el “Espacio de Modelar”



Sofaer et al. 2017 Global Change Biology

A satellite-style map of a mountainous region, likely in the Andes. A red line traces a path across the terrain. A semi-transparent grey box is overlaid on the center of the image, containing text. A small label 'Gombe National Park' is visible near the top center.

Gombe
National Park

¿Preguntas?

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