

Simulating vegetation change, carbon cycling and fire over the western US using CMIP5 climate projections



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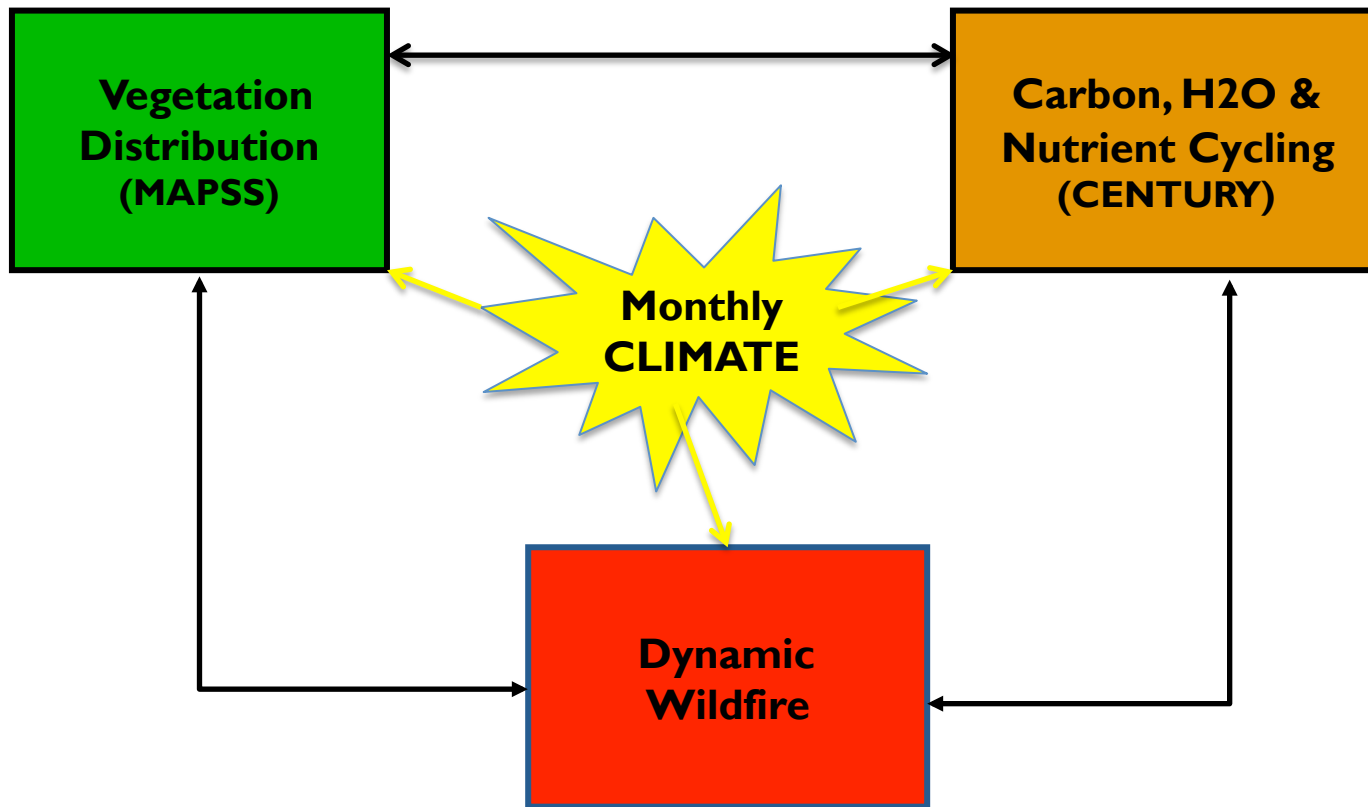


Outline

- Introduction to the vegetation model
 - Inputs
 - Assumptions
 - Protocol: EQ, SPIN, HIST, Futures
- Results
 - Vegetation Distribution
 - Fire frequency
 - Carbon stocks

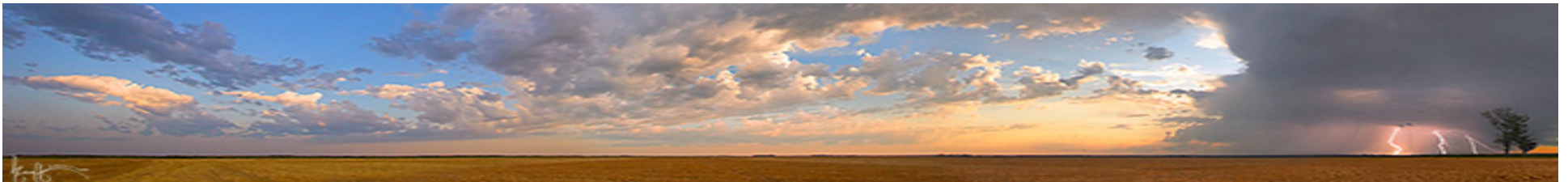


Dynamic Vegetation MC2-CBI



Inputs to the model

- Soil information
 - mineral soil depth
 - % sand and % clay in 3 soil layers
 - % rock fragment in same layers
 - bulk density
- Monthly climate inputs (time series) include:
 - Tmin and Tmax
 - Precipitation
 - Vapor pressure (dew point Temp)



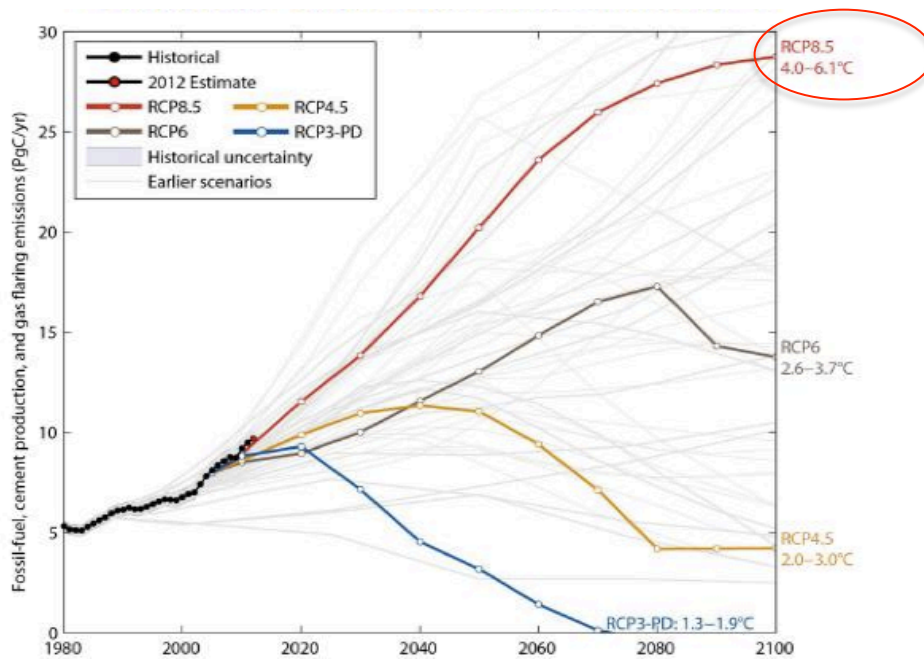
CMIP5 Future Climates

MACA downscaled (U of I) – MC runs

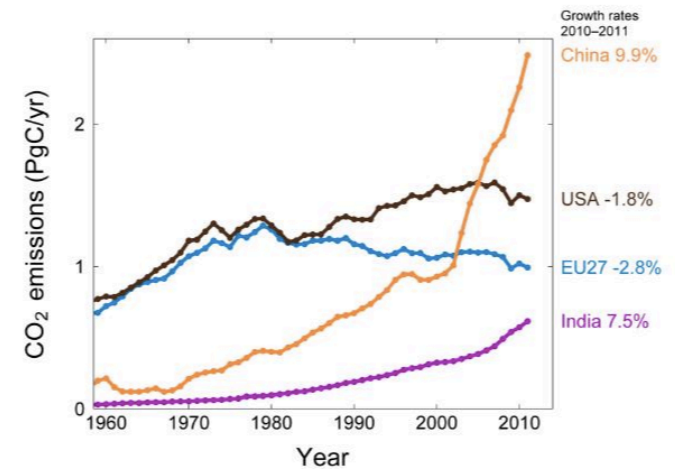
RANK	Climate Models	RCP 8.5	RCP 4.5	
1	CNRM-CM5			1
2	CESM1-FASTCHEM			
3	CESM1-CAM5			
4	CESM1-BGC			
5	IPSL-CM5A-MR			
6	CCSM4			
7	EC-EARTH			
8	GFDL-ESM2M			2
9	CanESM2			3
10	HadCM3			
11	MIROC5			4
12	NorESM1-M			
13	HadGEM2-ES			
14	MPI-ESM-MR			
15	GFDL-ESM2G			5
16	FIO-ESM			
17	GFDL-CM2p1			
18	HadGEM2-AO			
19	NorESM1-M			
20	HadGEM2-CC			
21	IPSL-CM5A-LR			
22	GFDL-CM3			
23	MPI-ESM-LR			
24	bcc-csm1-1-m			
25	CMCC-CM			
26	CSIRO-Mk3-6-0			6
27	CESM1-WACCM			
28	inmcm4			7
29	MIROC-ESM			8
30	MIROC-ESM-CHEM			9
31	bcc-csm1-1			10
32	MRI-CGCM3			11
33	GISS-E2-R			
34	GISS-E2-H			
35	BNU-ESM			12
36	CMCC-CESM			
37	FGOALS-s2			

Climate Models & Emissions

only RCP 8.5 shown today



Source: [Peters et al. 2012](#); [Le Quéré et al. 2012](#); [Global Carbon Project 2012](#); [CDIAC Data](#)



Growing gap between EU27 and USA due to emission decreases in Germany, Poland, and Romania.

Source: [Le Quéré et al. 2012](#); [Global Carbon Project 2012](#); [CDIAC Data](#)

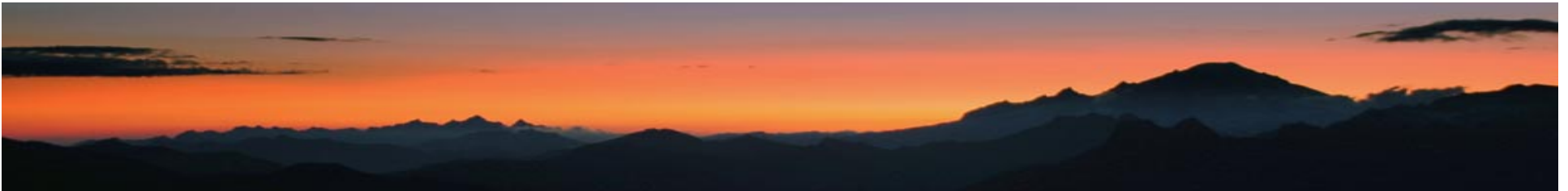
Fire Suppression

- Starts in 1950
- Thresholds of fire line intensity/Energy Release Component/Rate of Spread (900/60/100 = defaults) above which fire routine is run; otherwise not (*B. Rogers' work*)
- Only large “catastrophic fires” occur due to build up of fuel loads and deep drought conditions



Model Assumptions

- . Potential vegetation
- . No species level information
- . “Grasses” include forbs, cactus, mosses, lichens
- . No wetlands/marshes, no rivers
- . Savanna mode – grass & tree competition (unlike century)
- . No shrubs physiology
- . No cell to cell communication (water, fire)
- . Fire ignition not limiting
- . N demand met by N fixation
- . Moderate CO₂ (25% increase production and 25% decrease transpiration when CO₂ reaches 550ppm)



Protocol to run the model

- Run MAPSS equilibrium model on historical average climate (12 months) to initialize vegetation distribution;
- Run biogeochemistry module with fixed vegetation (MAPSS result) and prescribed fire to initialize carbon stocks (reaching stable resistant soil carbon, 3000 years max)
- Run iteratively over several 100s years (detrended climate time series) with dynamic fire module to stabilize fire-sensitive carbon stocks (reaching an NBP near 0.0): 600 year spinup
- Run with monthly historical (1895-) and future (2010-) climate (dynamic vegetation and dynamic fire)































Results

- Vegetation Distribution
- Fire frequency
- Carbon stocks



Potential Vegetation Types

- | | |
|---|---|
|  Cool Needleleaf Forest |  Temperate Shrubland |
|  Barren |  Temperate Grassland |
|  Tundra |  Subtropical Evergreen Broadleaf Forest |
|  Taiga-Tundra |  Subtropical Mixed Forest |
|  Boreal Evergreen Needleleaf Forest |  Subtropical Evergreen Broadleaf Savanna |
|  Boreal Mixed Forest |  Subtropical Mixed Savanna |
|  Subalpine Forest |  Subtropical Shrubland |
|  Maritime Evergreen Needleleaf Forest |  Subtropical Grassland |
|  Temperate Evergreen Needleleaf Forest |  Subtropical Desert |
|  Temperate Deciduous Broadleaf Forest |  Tropical Evergreen Broadleaf Forest |
|  Temperate Cool Mixed Forest |  Tropical Savanna |
|  Temperate Warm Mixed Forest |  Tropical Shrubland |
|  Temperate Evergreen Needleleaf Woodland |  Tropical Grassland |
|  Temperate Deciduous Broadleaf Woodland |  Tropical Desert |
|  Temperate Cool Mixed Woodland | |
|  Temperate Warm Mixed Woodland | |

Potential Vegetation Shifts

Dominant vegetation (mode) – GFDL-ESM-2M (USA) RCP8.5



1971-2000

2036-2065

2071-2100

- Maritime Evergreen Needleleaf Forest
- Temperate Cool Mixed Forest
- Subtropical Mixed Forest

- Subtropical Shrubland
- Temperate Shrubland
- Temperate Grassland

Potential Vegetation Shifts

Dominant vegetation (mode) – INM-CM4 (Russia) RCP8.5



1971-2000



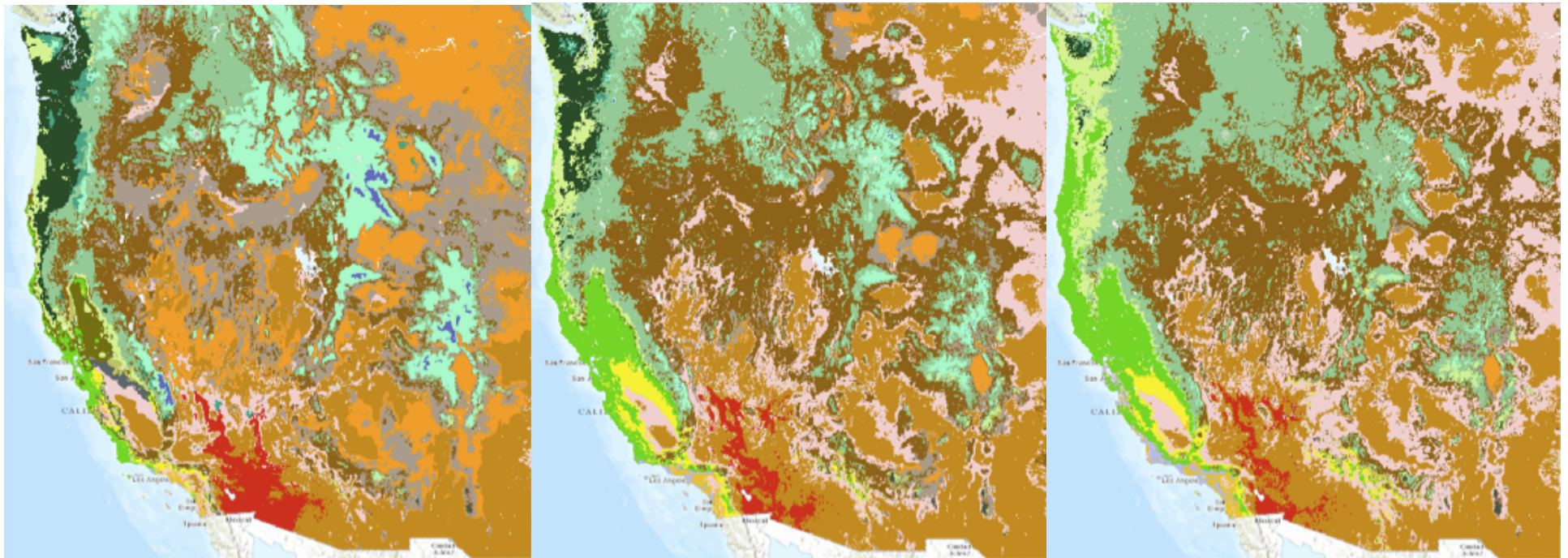
2036-2065



2071-2100

Potential Vegetation Shifts

Dominant vegetation (mode) – CSIRO (Australia) RCP8.5



1971-2000

2036-2065

2071-2100

Potential Vegetation Shifts

Dominant vegetation (mode) – MIROC5 (Japan) RCP8.5



1971-2000



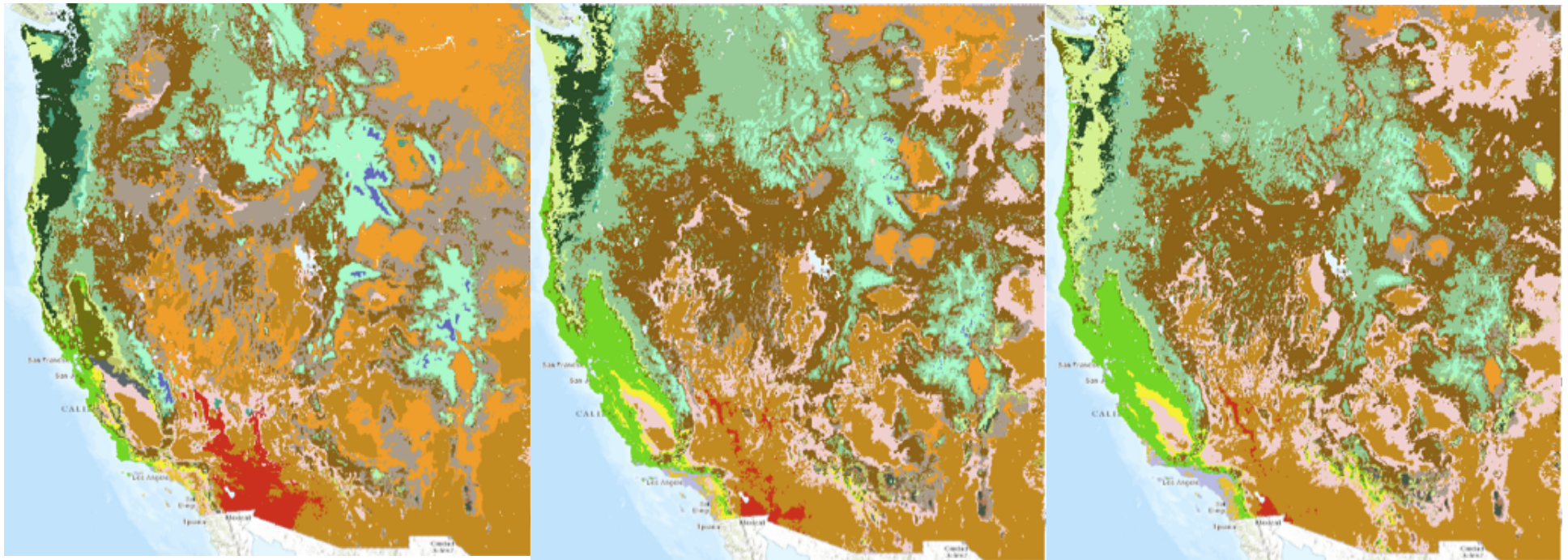
2036-2065



2071-2100

Potential Vegetation Shifts

Dominant vegetation (mode) – MRI-CGCM (Japan) - RCP8.5



1971-2000

2036-2065

2071-2100

Potential Vegetation Shifts

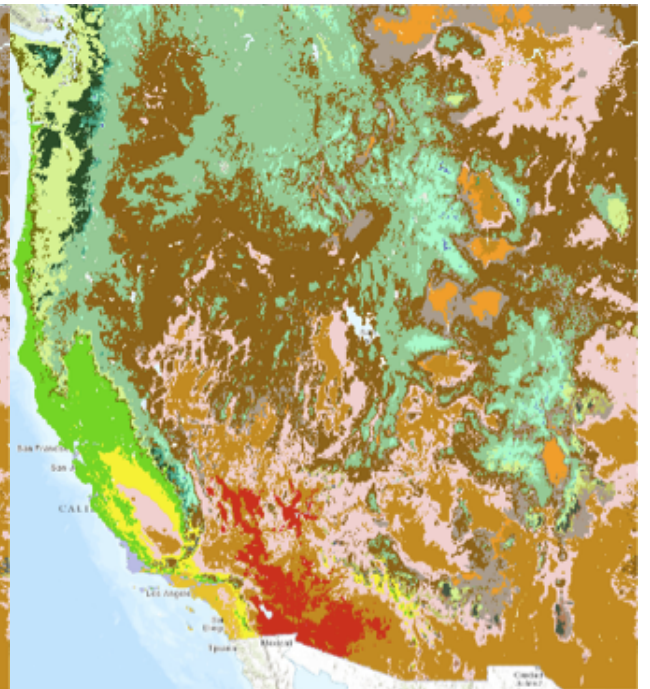
Dominant vegetation (mode) – GFDL-ESM-2G (USA) RCP8.5



1971-2000



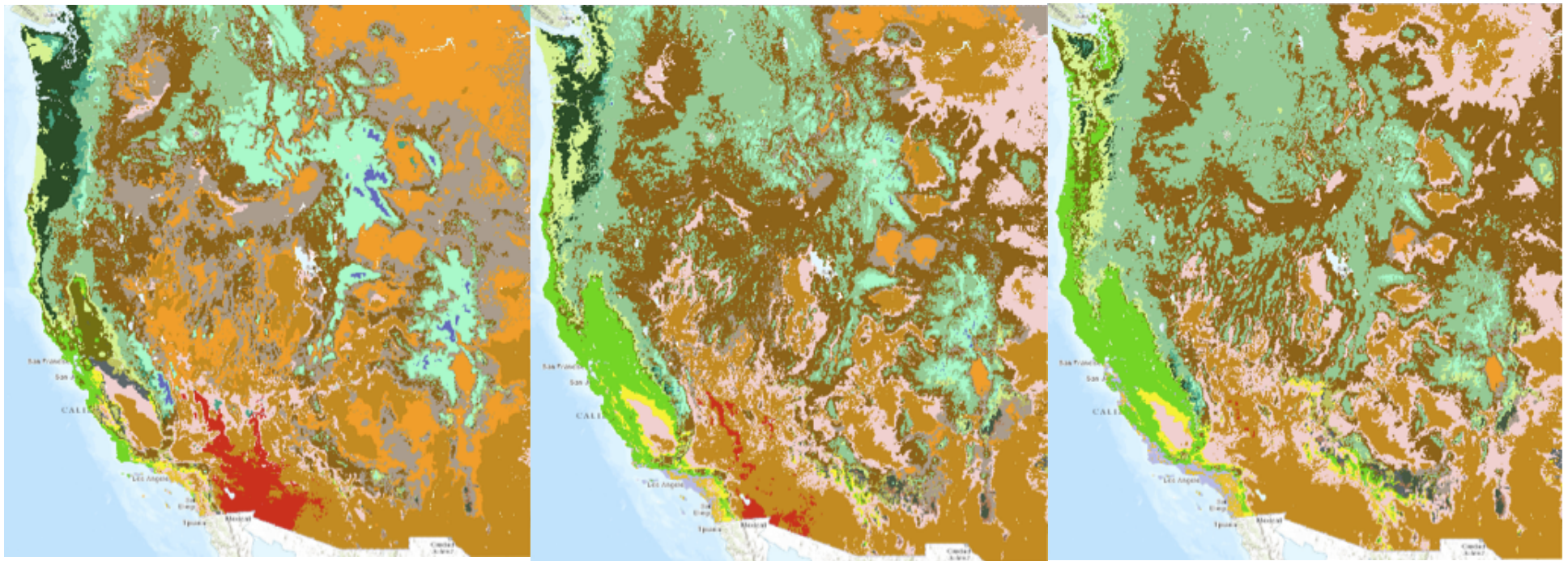
2036-2065



2071-2100

Potential Vegetation Shifts


Dominant vegetation (mode) – CNRM-CM5 (France) RCP8.5



1971-2000

2036-2065

2071-2100

 Subtropical Desert

Potential Vegetation Shifts

Dominant vegetation (mode) – MIROC5-ESM (Japan) RCP8.5



1971-2000



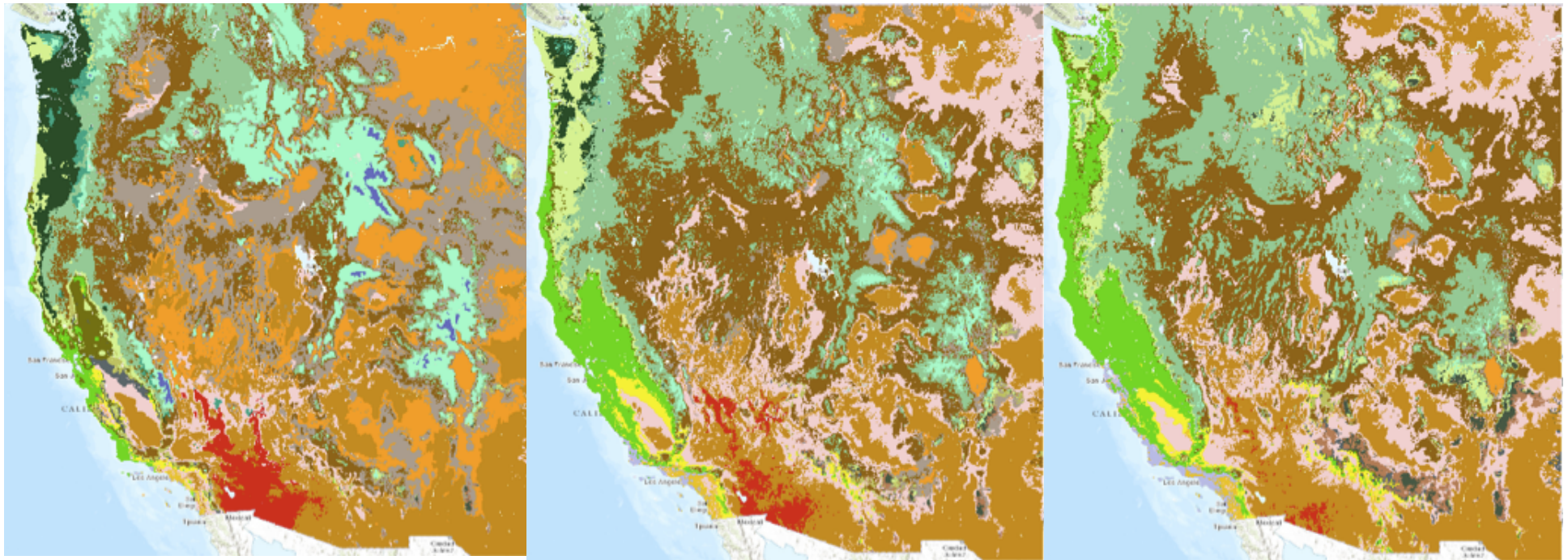
2036-2065



2071-2100

Potential Vegetation Shifts

Dominant vegetation (mode) – CanESM2 (Canada) RCP8.5



1971-2000

2036-2065

2071-2100

Potential Vegetation Shifts

Dominant vegetation (mode) – BCC-CSM-1.1 (Beijing Met Office) RCP8.5



1971-2000



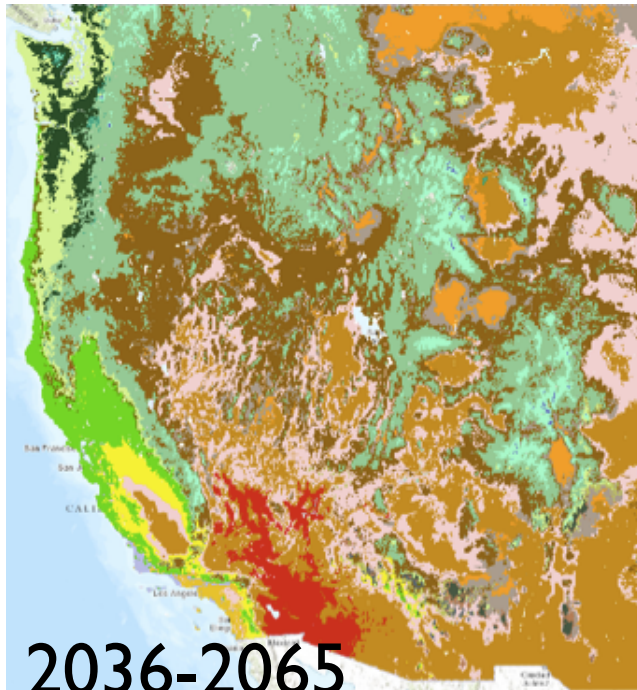
2036-2065



2071-2100

Dominant Vegetation

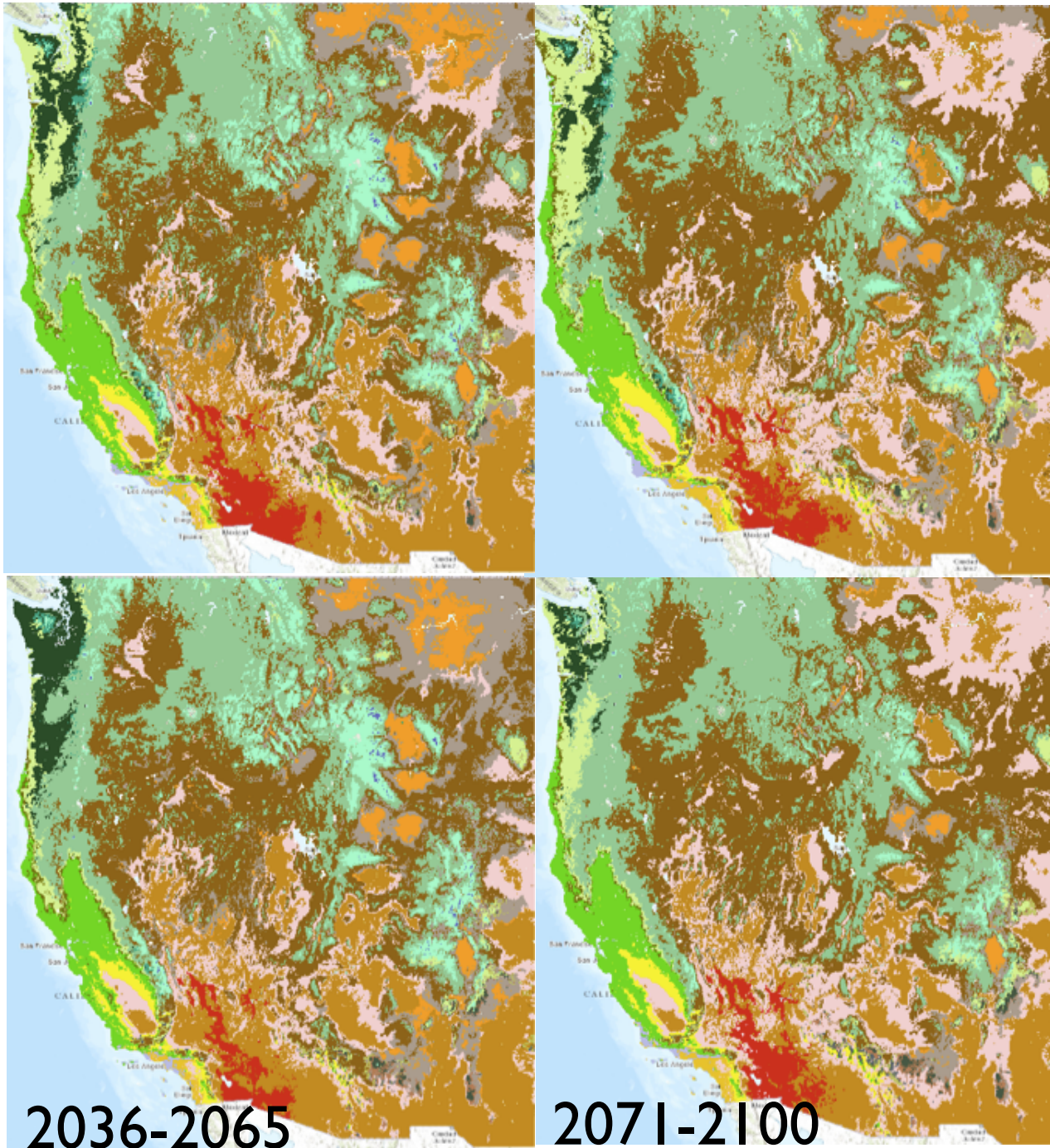
GCM vs ESM



*MIROC5 (top) vs
MIROC5-ESM (bottom)
(Japan) - RCP8.5*

2036-2065

2071-2100



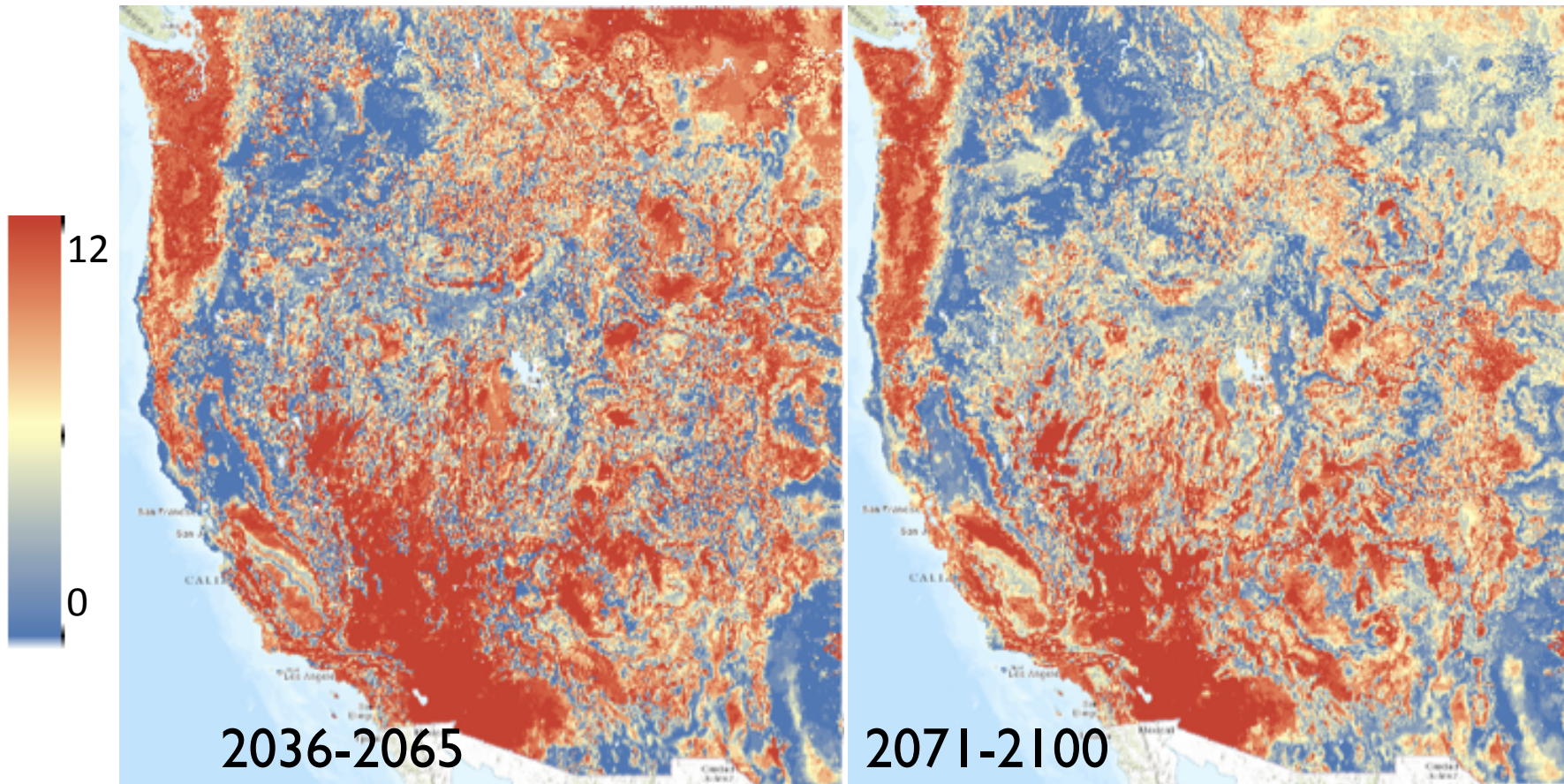
Dominant Vegetation

GFDL
ESM-2G (top)
vs 2M
(bottom)

(USA) RCP8.5

Agreement on Vegetation Instability

*from historical baseline 1971-2000 mode
for 12 CMIP5 models with RCP 8.5*



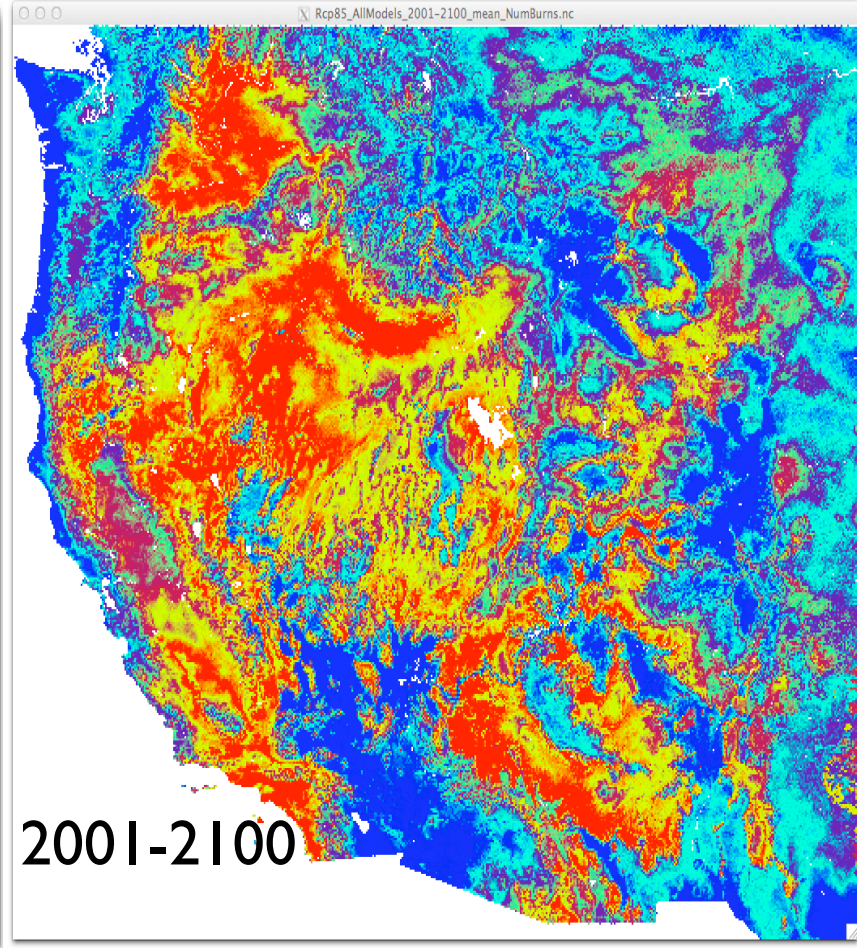
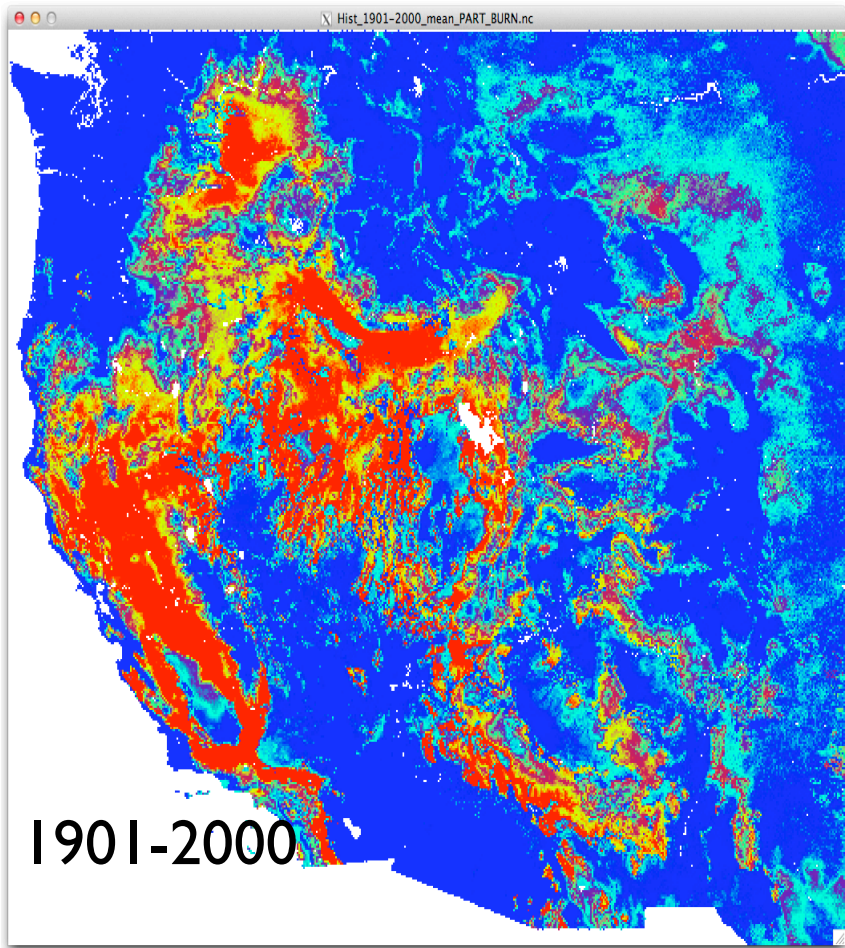
$VI = (\text{number of vegetation type changes}) / (\text{number of years} - 1)$

0 = no change occurs ; 1 = vegetation shifts every year

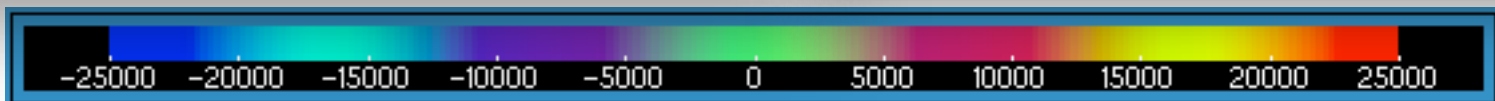
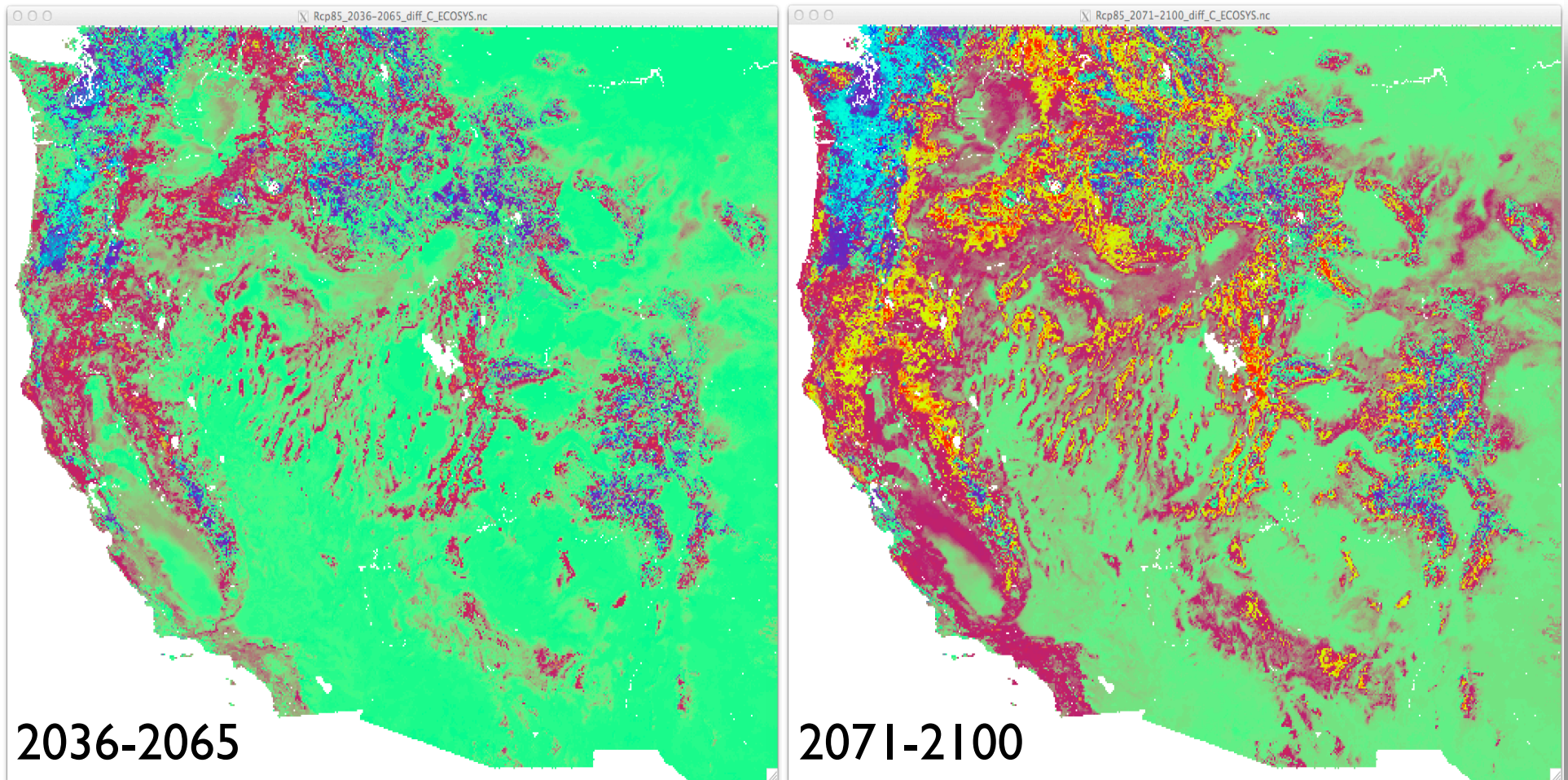
Number of climate futures for which vegetation instability was greater than 0

Fire Frequency

20th century vs 21st century average



Change in Ecosystem Carbon (g C m^{-2}) from historical baseline 1971-2000 ave for 12 CMIP5 models with RCP 8.5

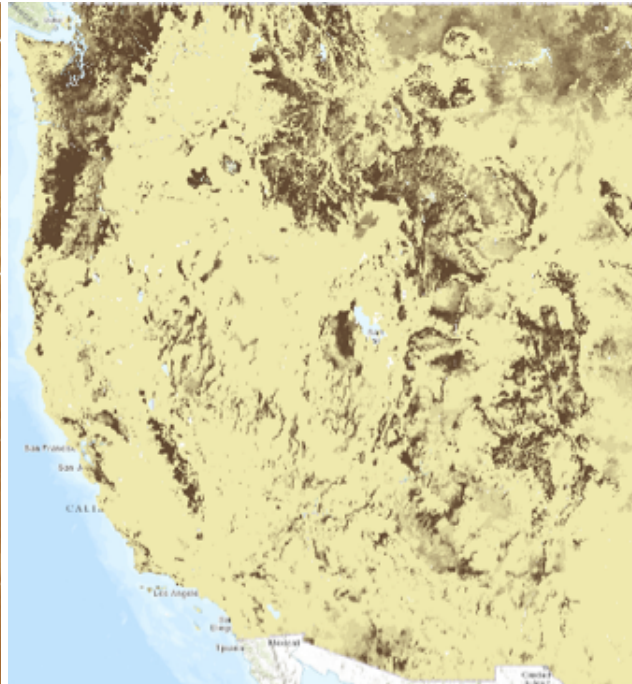


Total Ecosystem Carbon

Historical baseline and Future Losses



1971-2000

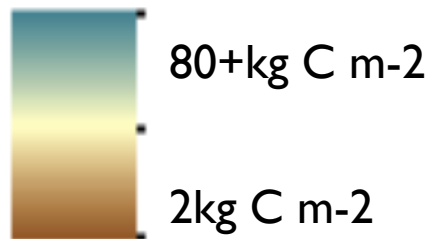


2036-2065



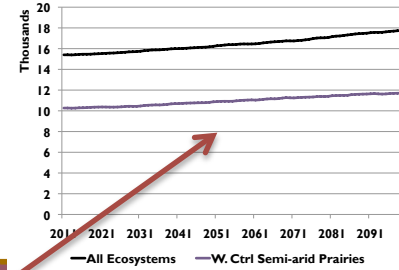
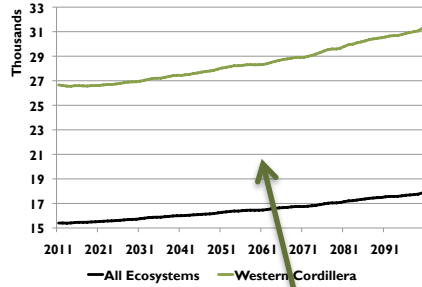
2071-2100

agreement across climate futures

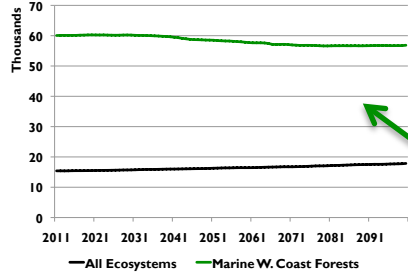


Total Ecosystem Carbon

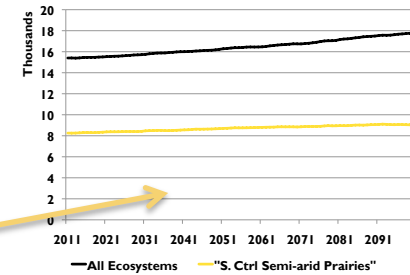
Western Cordillera



Maritime W. Coast Forests

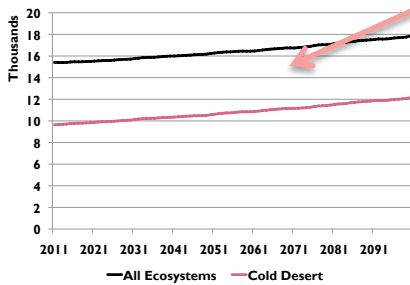


W. Ctrl Semi-arid Prairies

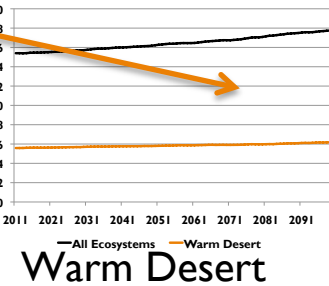
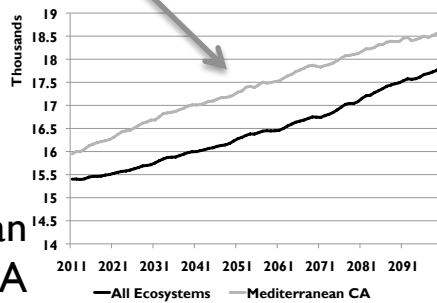


S. Ctrl Semi-arid Prairies

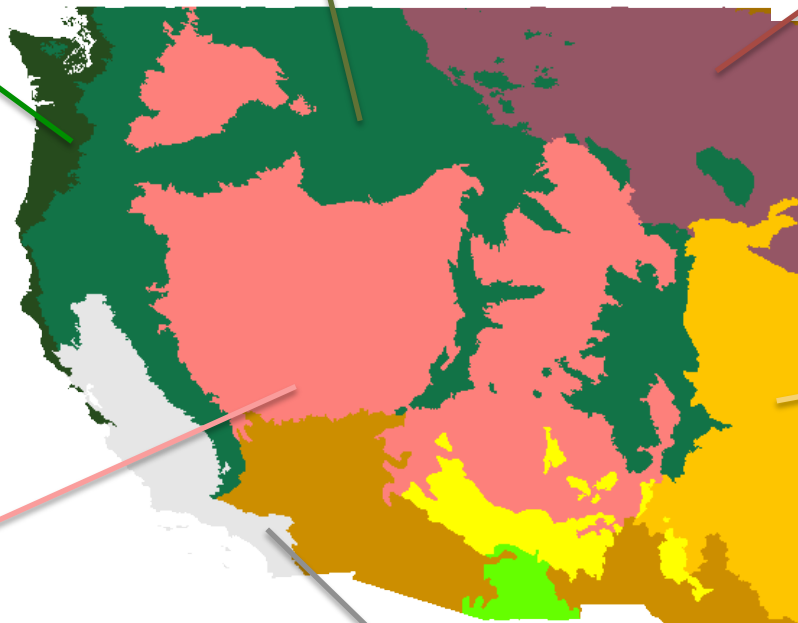
Cold Desert



Mediterranean CA

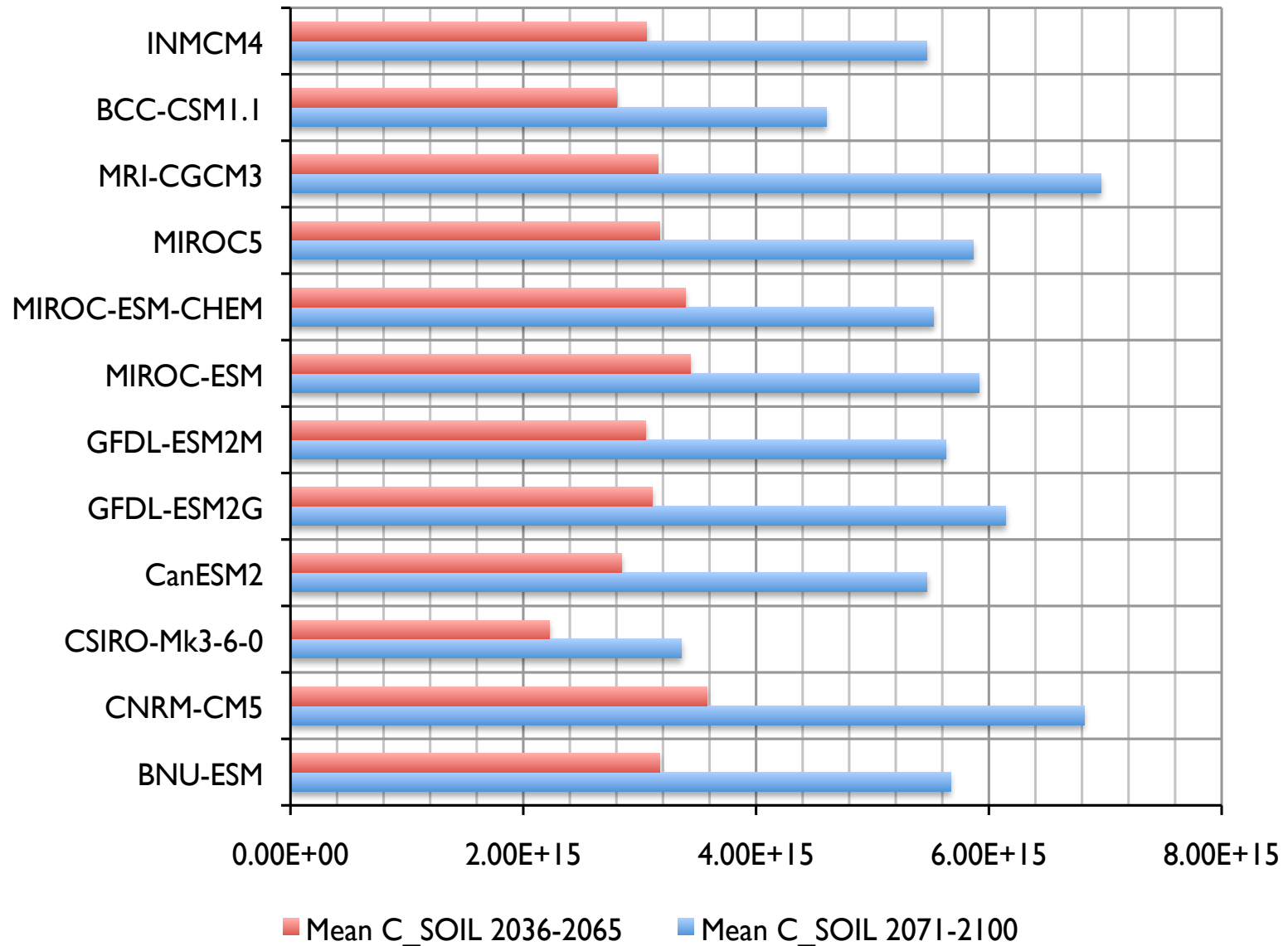


Warm Desert



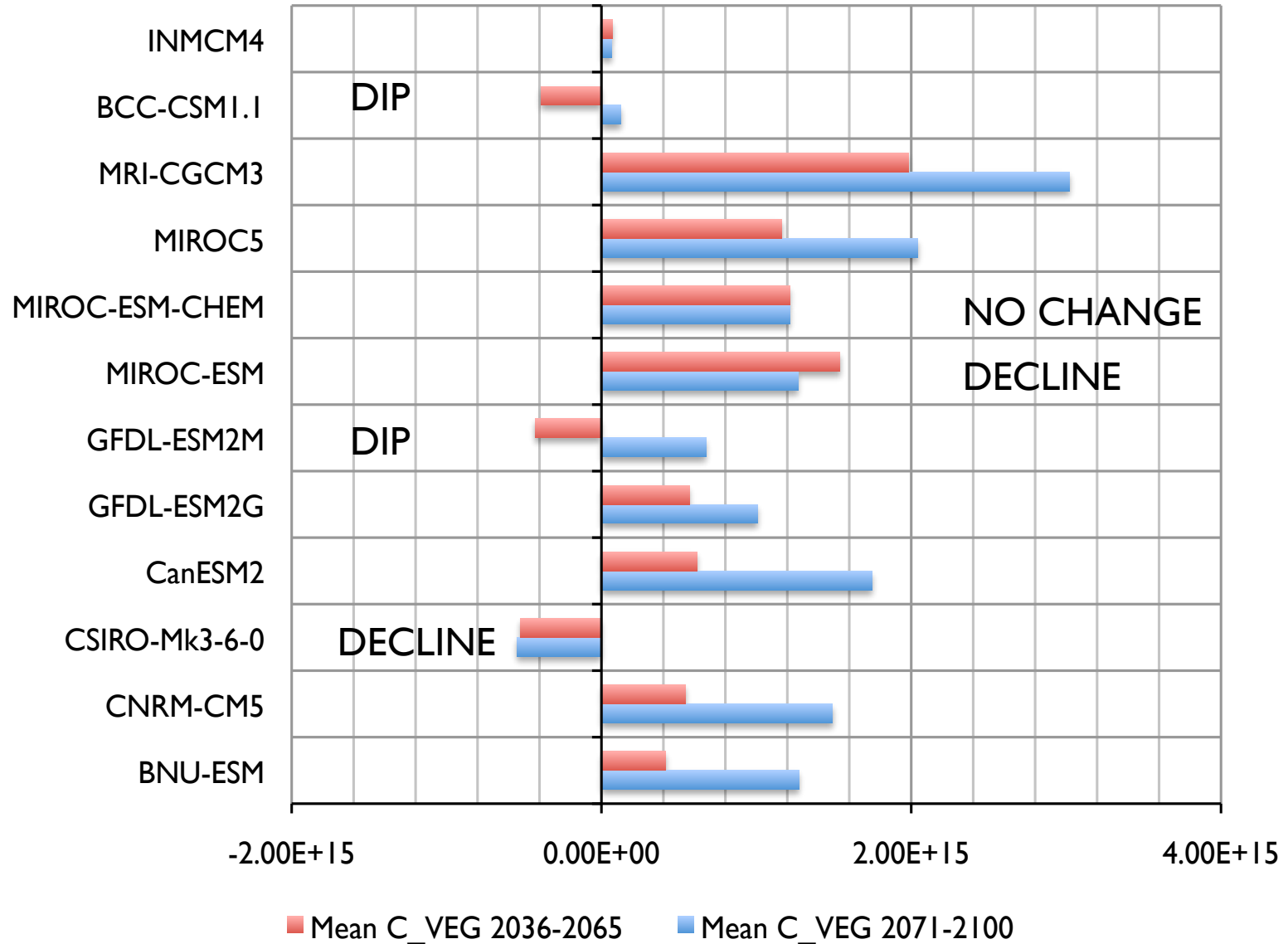
Change in Soil Carbon (g C m⁻²) – RCP 8.5

from historical baseline 1971-2000 ave

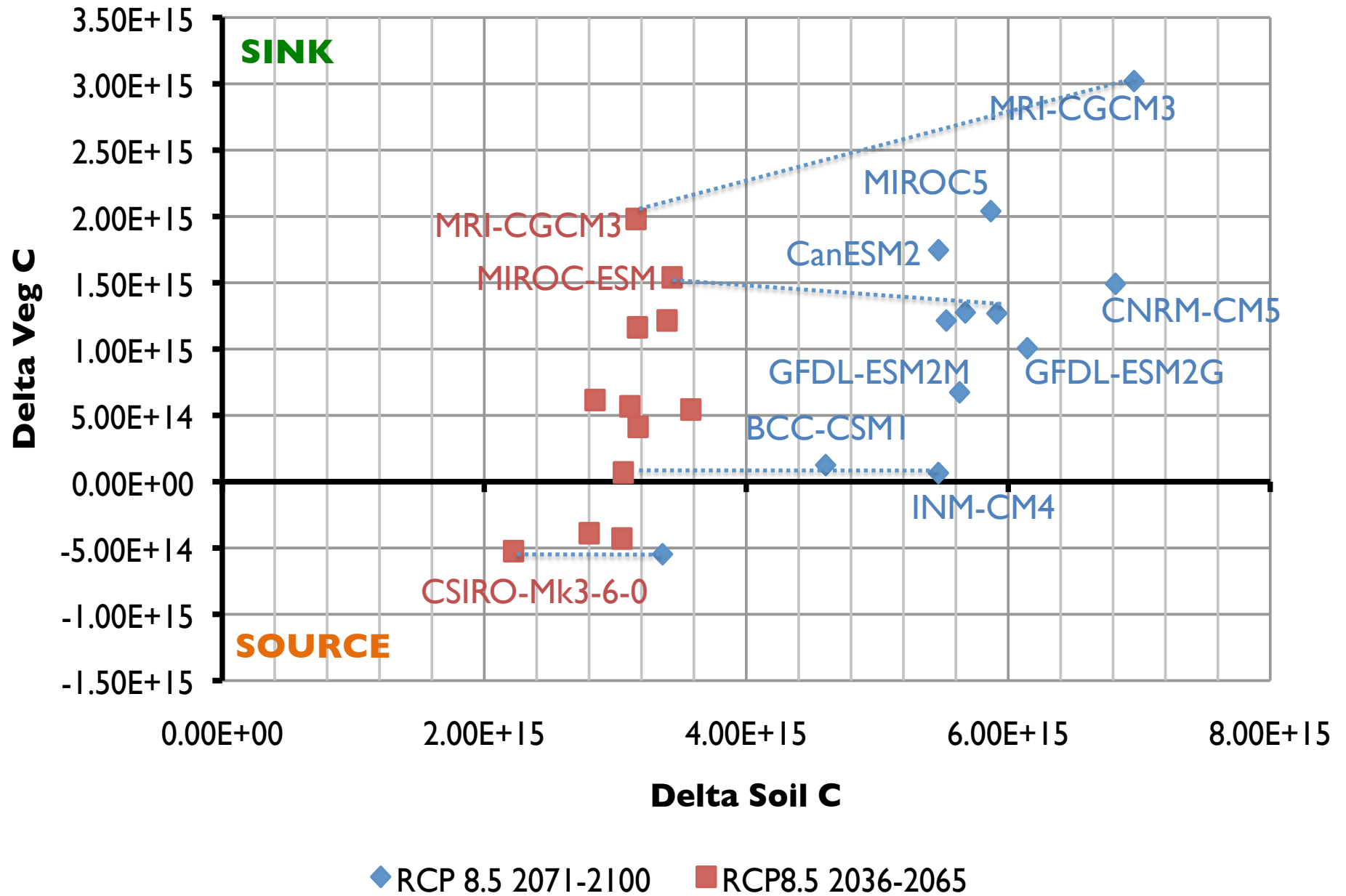


Change in Vegetation Carbon (g C m⁻²) – RCP 8.5

from historical baseline 1971-2000 ave



Change in Carbon Stocks across Futures – RCP 8.5



Conclusions

- Vegetation shifts: to subtropical types, to woodier types;
- Soil C gains, mostly vegetation C gains except in western PNW and Rockies;
- Increased fire frequency;
- Climate futures can be ranked with regard to C sequestration potential and trend (for ex).



All maps available in databasin.org

The screenshot displays the Data Basin website interface. At the top left is the 'DATA BASIN' logo. A search bar is located at the top right with the text 'search by geography'. Below the logo is a navigation bar with tabs: 'Get Started', 'Explore', 'Create', 'Community', 'Services', and 'My Workspace'. A secondary navigation bar contains 'DATA BASIN | GROUPS | INTEGRATED SCENARIOS OF CLIMATE, HYDROLOGY, AND VEGETATION FOR THE WESTERN US'. The main heading is 'Integrated scenarios of climate, hydrology, and vegetation for the western US', created by Dominique Bachelet. A 'Feature Group' button is visible. Below this is a navigation bar with 'Group Home', 'Content', and 'Discussion' tabs. The 'Content' tab is active, showing a large image of a forested mountain. To the right of the image is a welcome message: 'Welcome to Integrated scenarios of climate, hydrology, and vegetation for the western US. To work with datasets, maps, galleries, and this group, click on the content button in the navigation bar above. To work with group discussions, click on the discussion button...'. Below the welcome message is a vertical list of resource categories: Coastal and Marine Resources, Freshwater Resources, Terrestrial Resources, Anadromous Resources, and Climate Change. To the right of these categories is a 'Featured Items' section with a grid of map thumbnails and titles: Pacific Northwest Climate Change Avian Vulnerability, Anadromous Fish, Sea Level Rise, Gifford Pinchot, Tree Species Potential Distribution in the Pacific Northwest (USA), and Soil and Forest Vulnerability to Climate Change in the North Pacific... A 'See More...' link is at the bottom of the grid. Further right is a section titled 'NPLCC Land Cover and Protected Areas' featuring a map of the region and a descriptive paragraph: 'This map represents an overview of the North Pacific LCC geography and some of the habitat and protected areas in the region. Explore the LCC and some of the data layers that the NPLCC has supported.' At the bottom of the page is a footer with links for 'NORTH PACIFIC LCC', 'ABOUT DATA BASIN', 'TERMS OF USE', and 'CONTACT US', along with a copyright notice for '© 2013 Conservation Biology Institute'.



Thank you for your attention

Thank you Phil Mote for including us in the project and NW-CSC for funding