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

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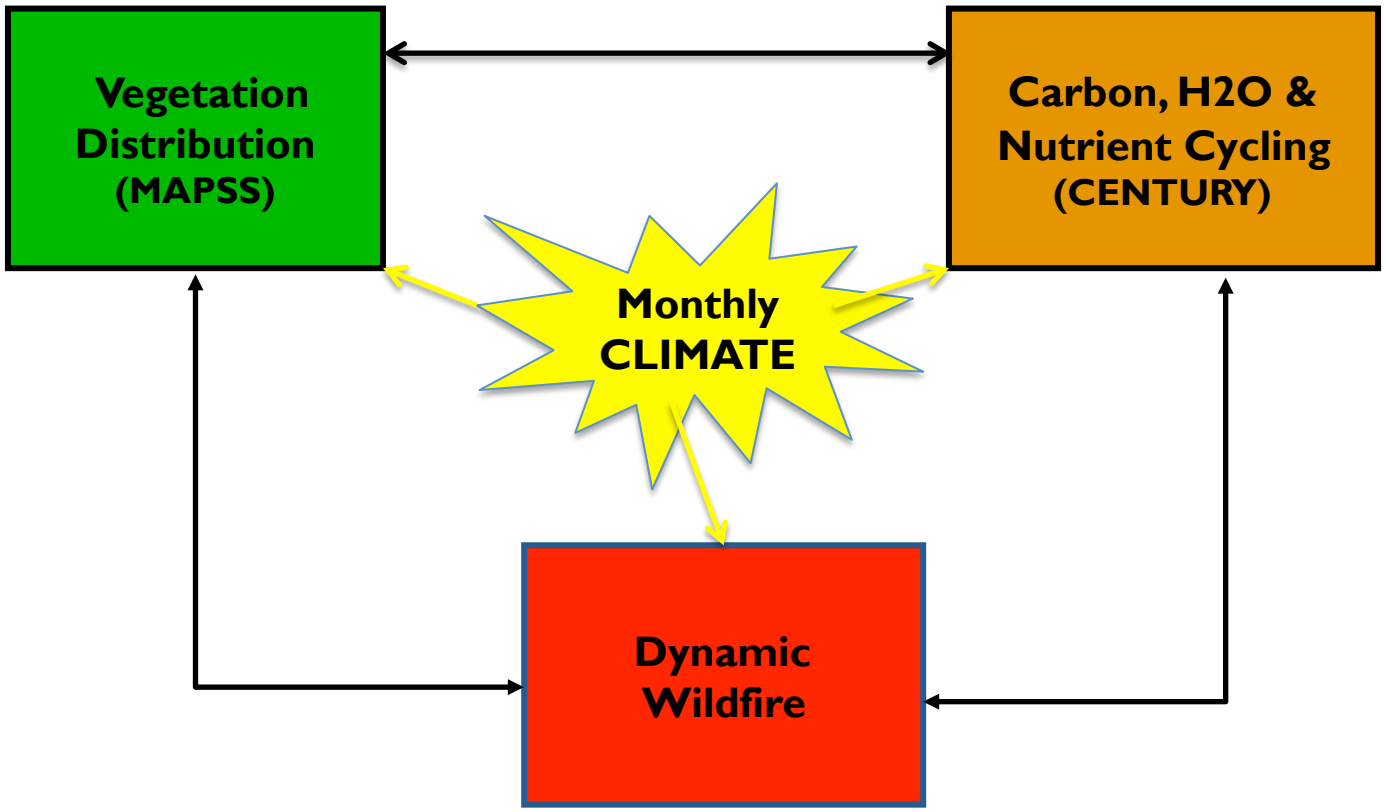
Outline

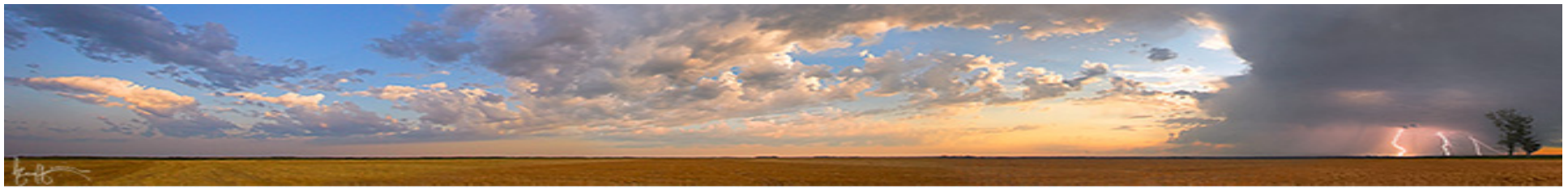
- Introduction to the vegetation model
  - Inputs
  - Assumptions
  - Protocol: EQ, SPIN, HIST, Futures
- Results
  - Vegetation Distribution
  - Fire frequency
  - Carbon stocks

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)



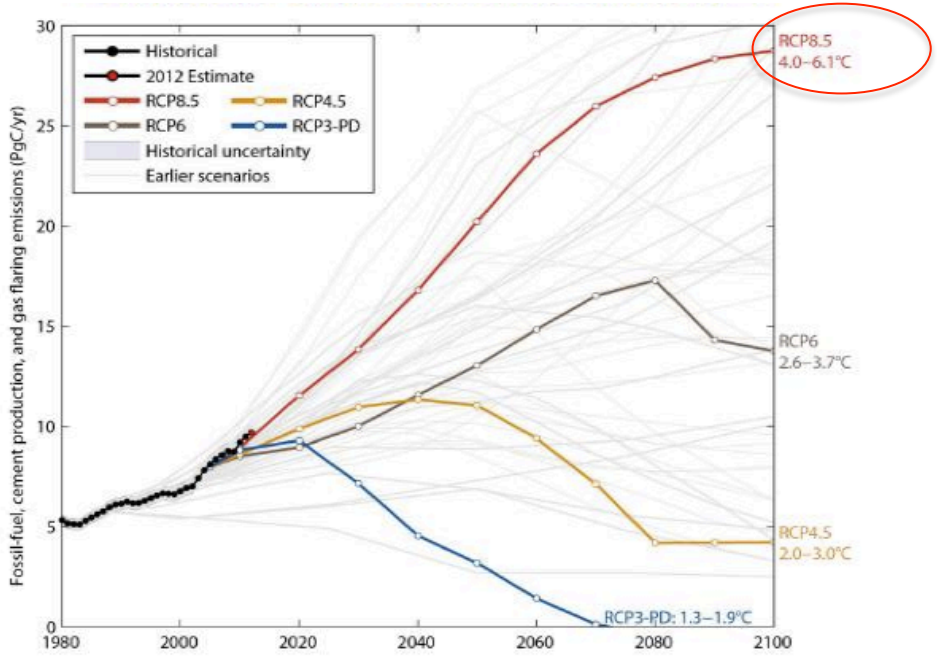
CMIP5 Future Climates

MACA downscaled (U of I) – MC runs

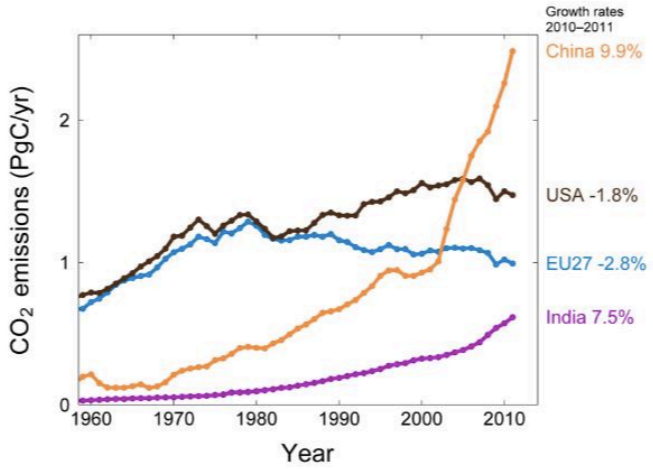
RANK	Climate Models	RCP 8.5	RCP 4.5	
1	CNRM-CM5			1
2	CESM1-FASTCHEM			
3	CESM1-CAM5			
4	CESM1-BGC			
5	IPSL-CM5A-MR			
6	CCSM4			
7	EC-EARTH			
8	GFDL-ESM2M			2
9	CanESM2			3
10	HadCM3			
11	MIROC5			4
12	NorESM1-M			
13	HadGEM2-ES			
14	MPI-ESM-MR			
15	GFDL-ESM2G			5
16	FIO-ESM			
17	GFDL-CM2p1			
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 CO_2 (25% increase production and 25% decrease transpiration when CO_2 reaches 550ppm)

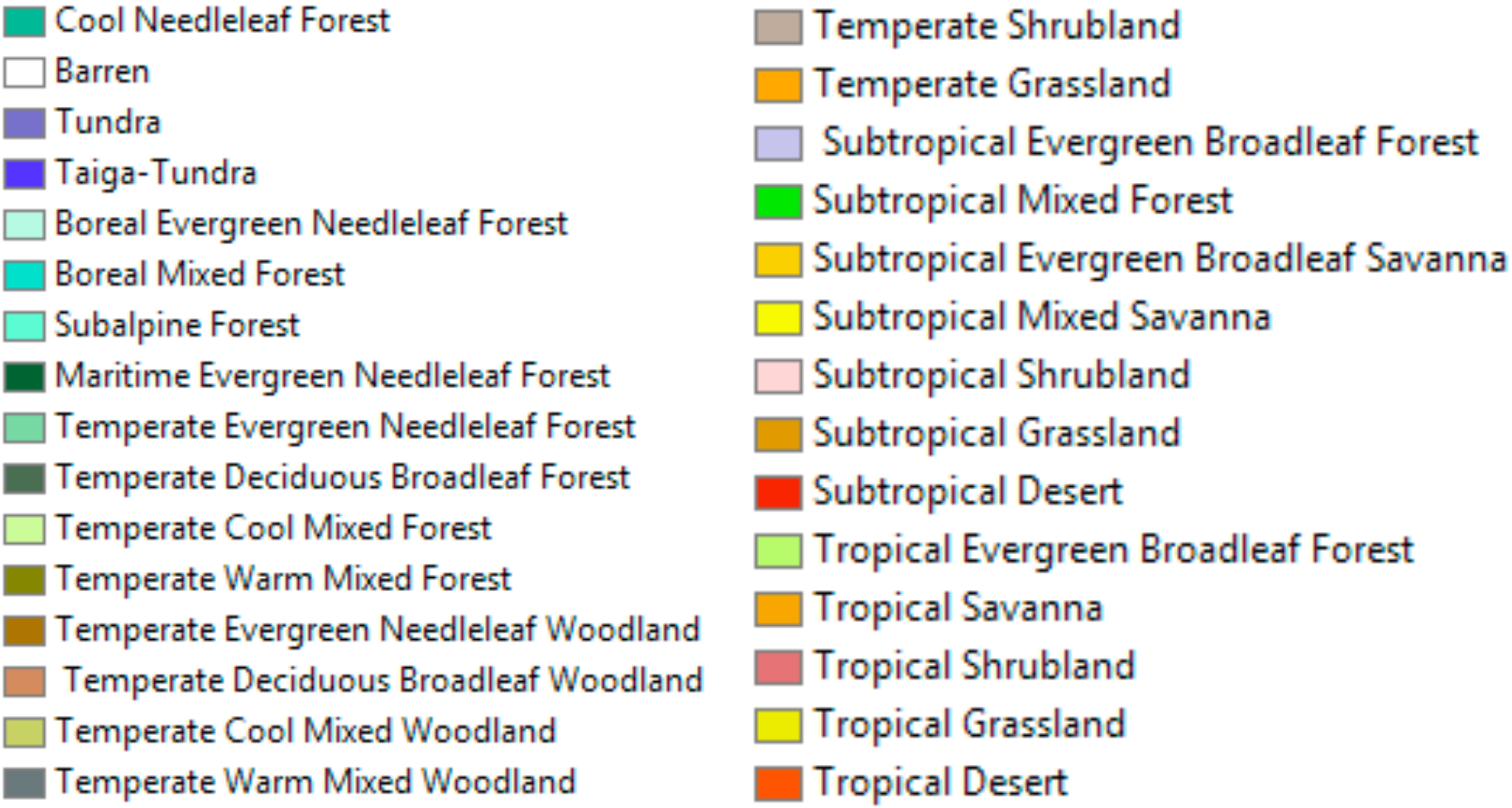
Protocol to run the model

- 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

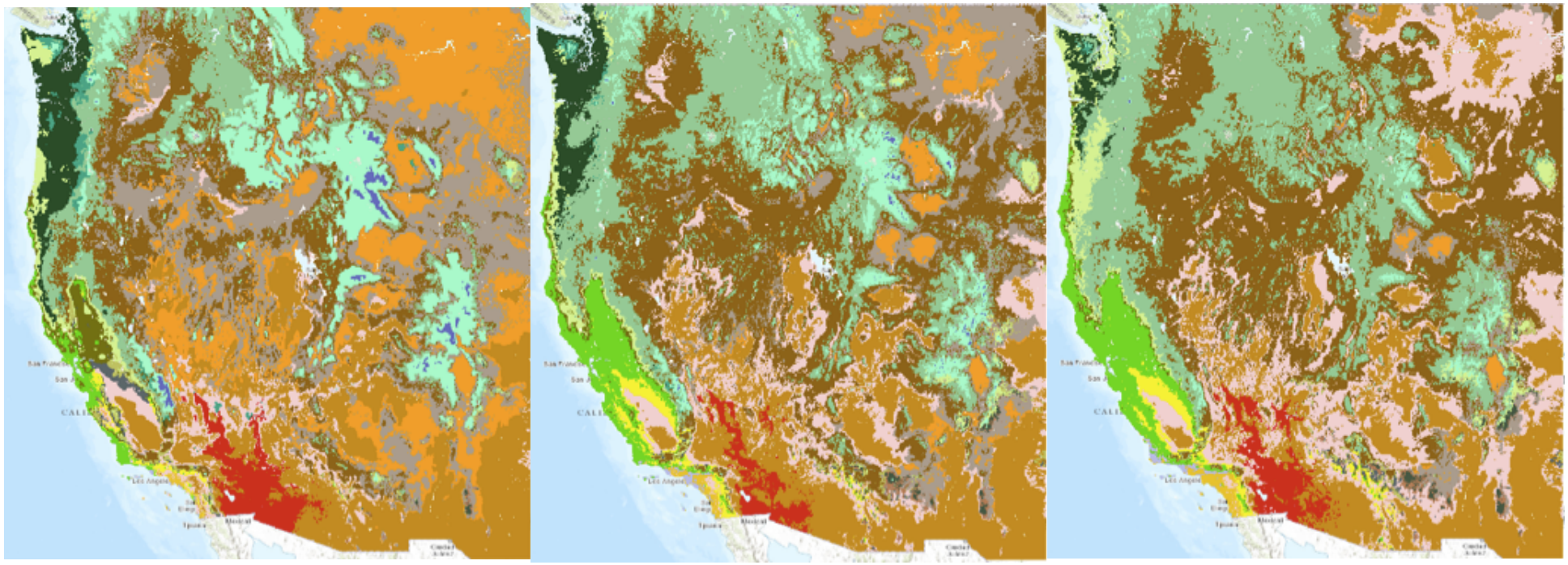
– Vegetation Distribution
– Fire frequency
– Carbon stocks

Potential Vegetation Types



Potential Vegetation Shifts

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

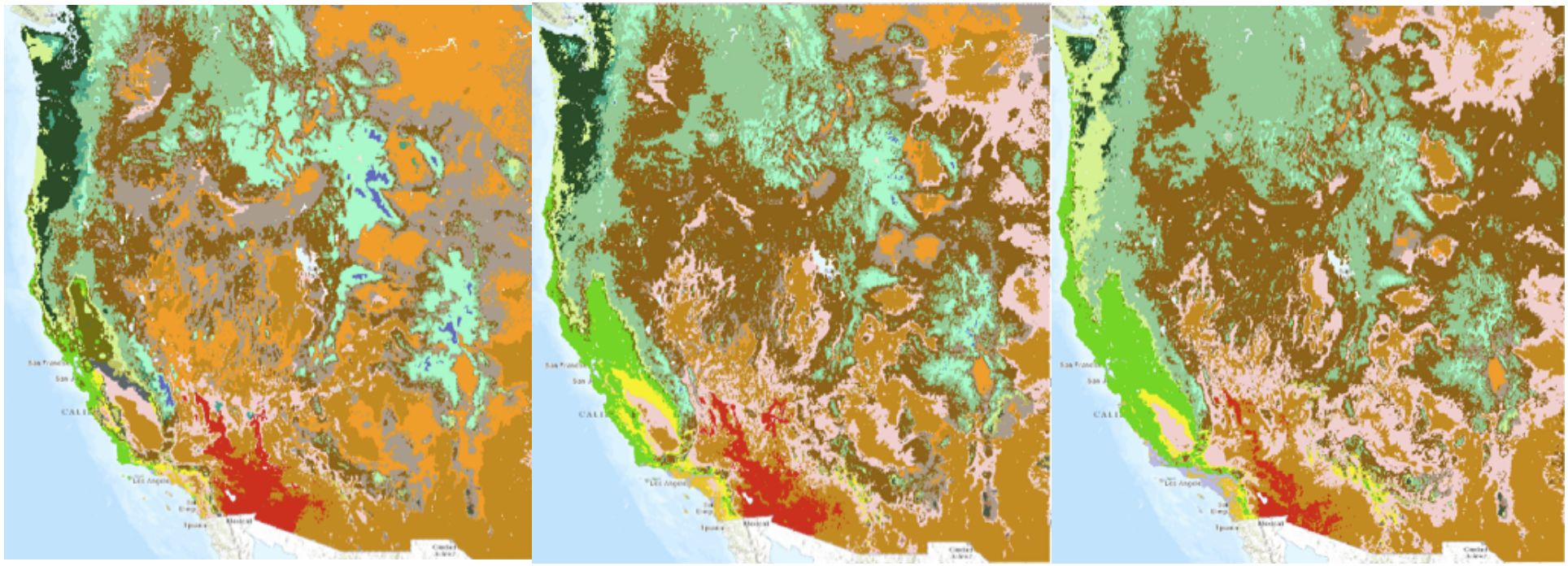


1971-2000 2036-2065 2071-2100

Maritime Evergreen Needleleaf Forest
Temperate Cool Mixed Forest
Subtropical Mixed Forest
Subtropical Shrubland
Temperate Shrubland
Temperate Grassland

Potential Vegetation Shifts

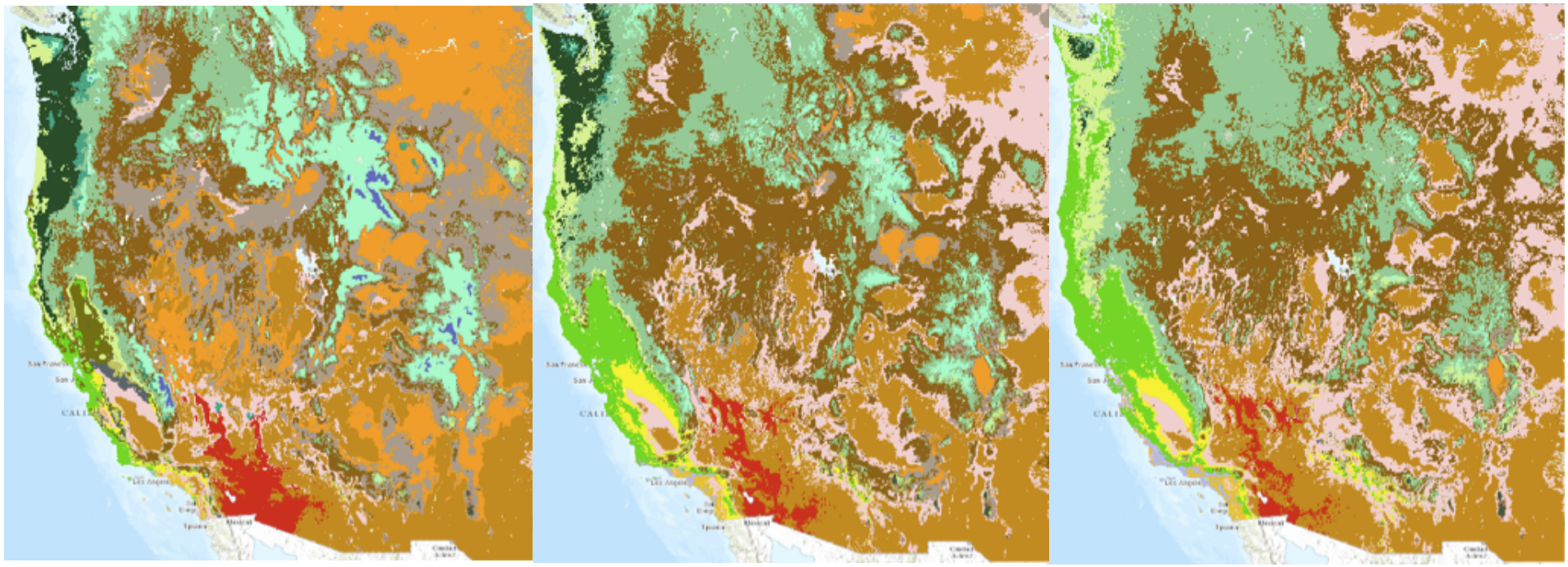
Dominant vegetation (mode) – INM-CM4 (Russia) RCP8.5



1971-2000 2036-2065 2071-2100

Potential Vegetation Shifts

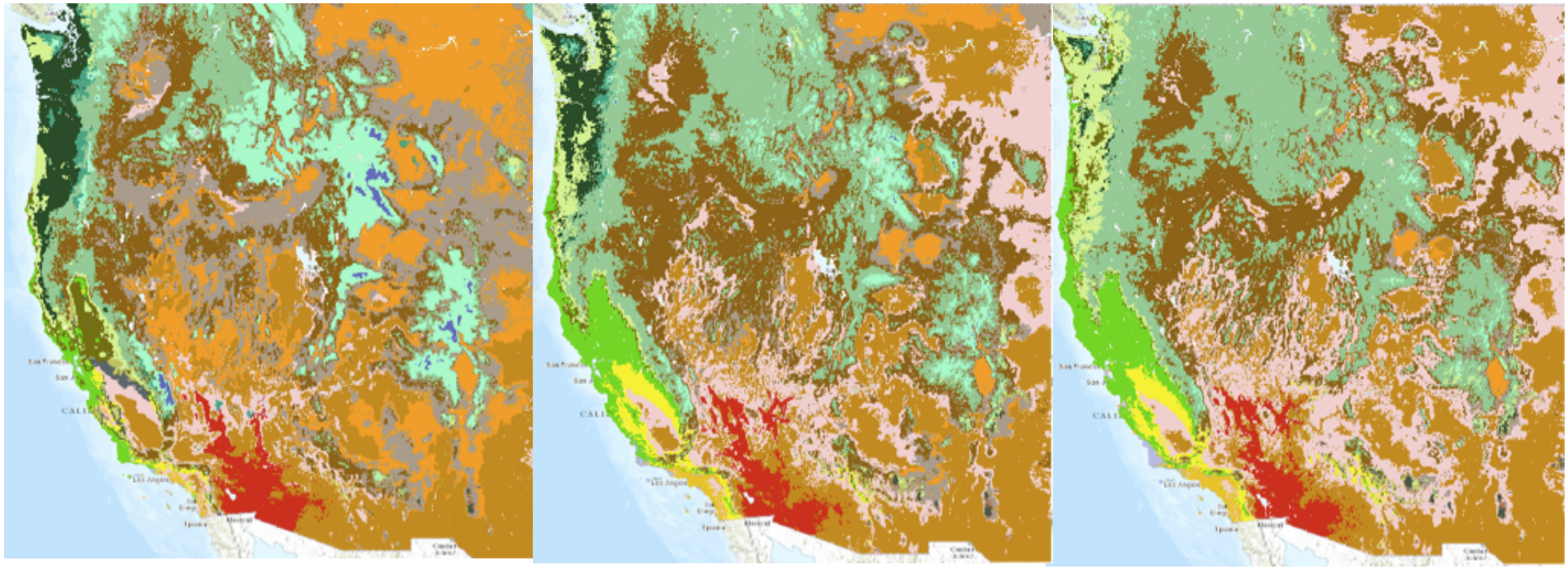
Dominant vegetation (mode) – CSIRO (Australia) RCP8.5



1971-2000 2036-2065 2071-2100

Potential Vegetation Shifts

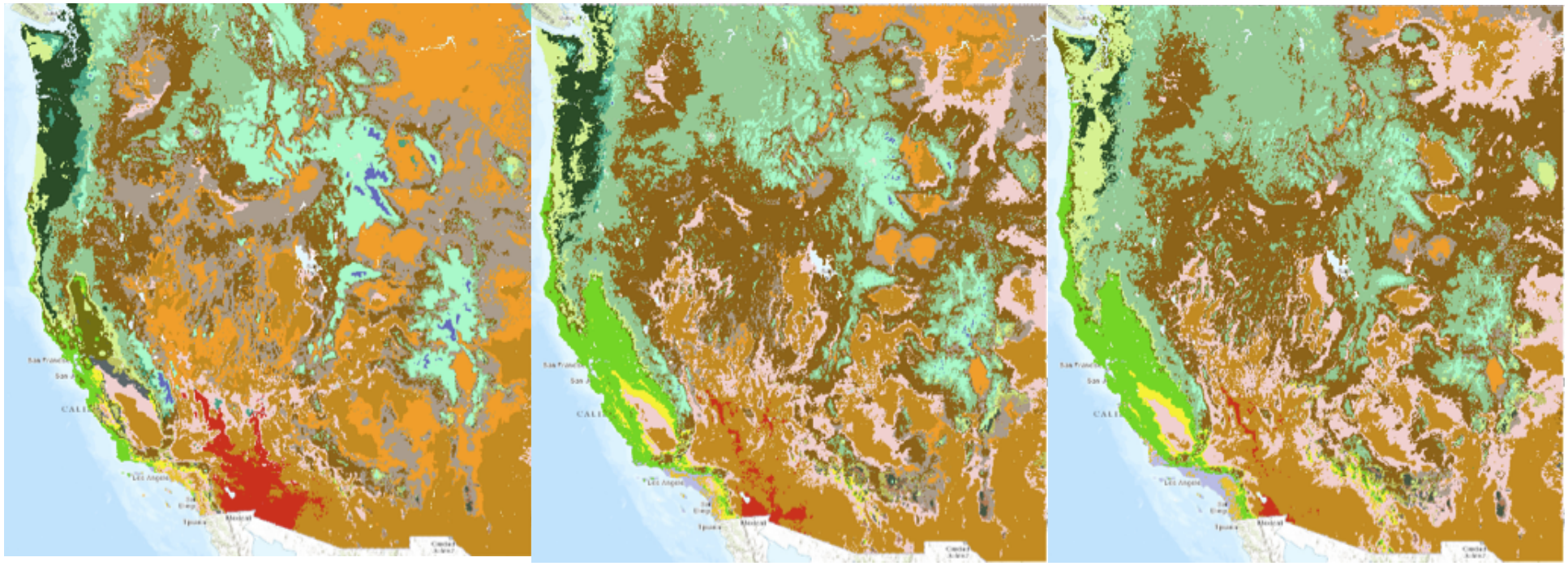
Dominant vegetation (mode) – MIROC5 (Japan) RCP8.5



1971-2000 2036-2065 2071-2100

Potential Vegetation Shifts

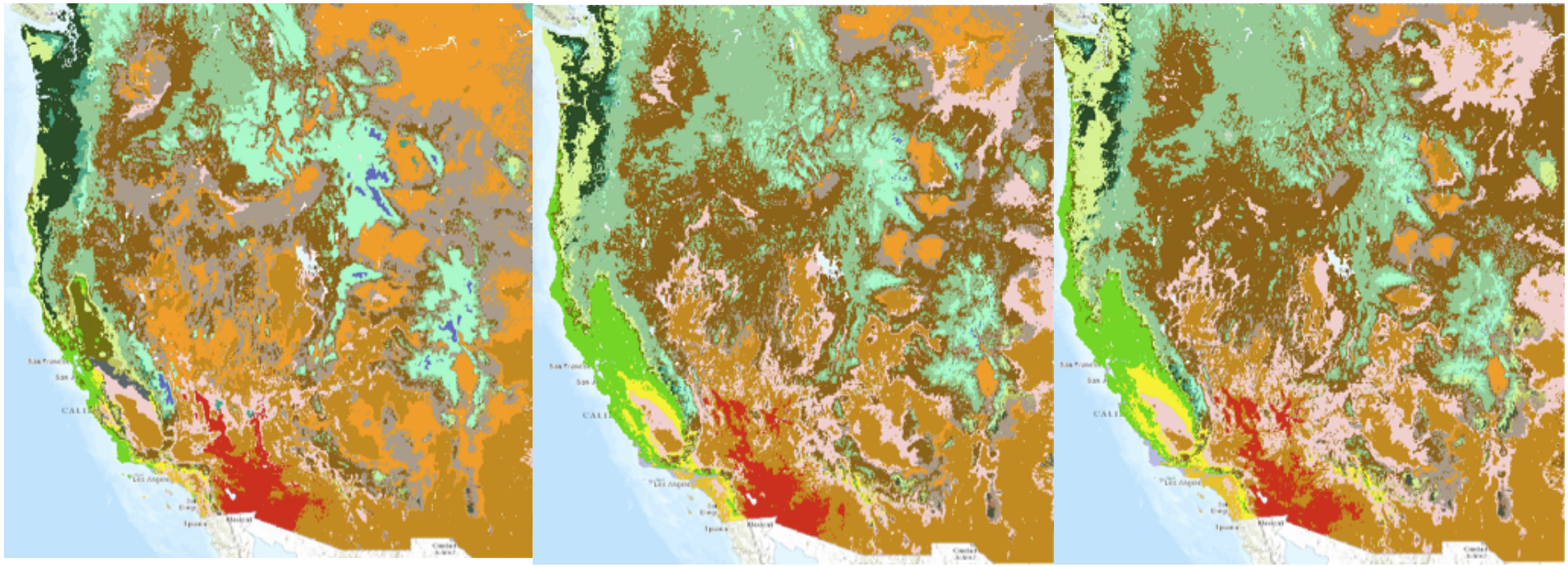
Dominant vegetation (mode) – MRI-CGCM (Japan) - RCP8.5



1971-2000 2036-2065 2071-2100

Potential Vegetation Shifts

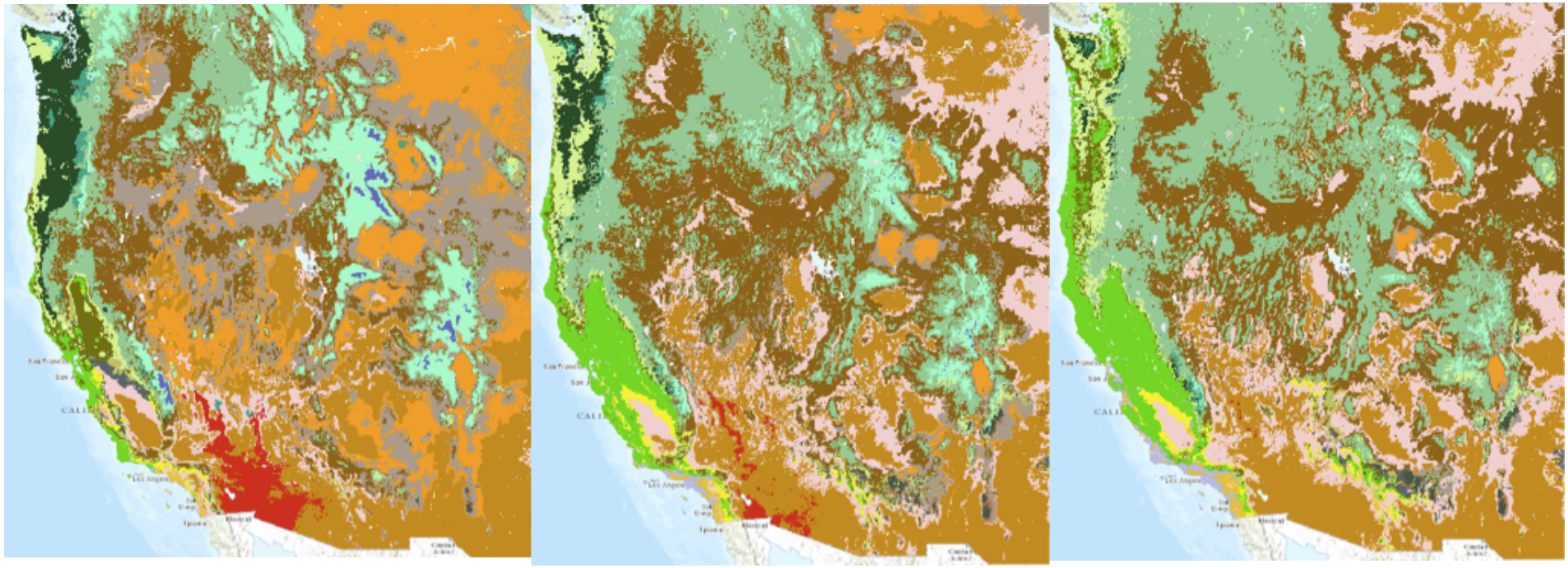
Dominant vegetation (mode) – GFDL-ESM-2G (USA) RCP8.5



1971-2000 2036-2065 2071-2100

Potential Vegetation Shifts

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

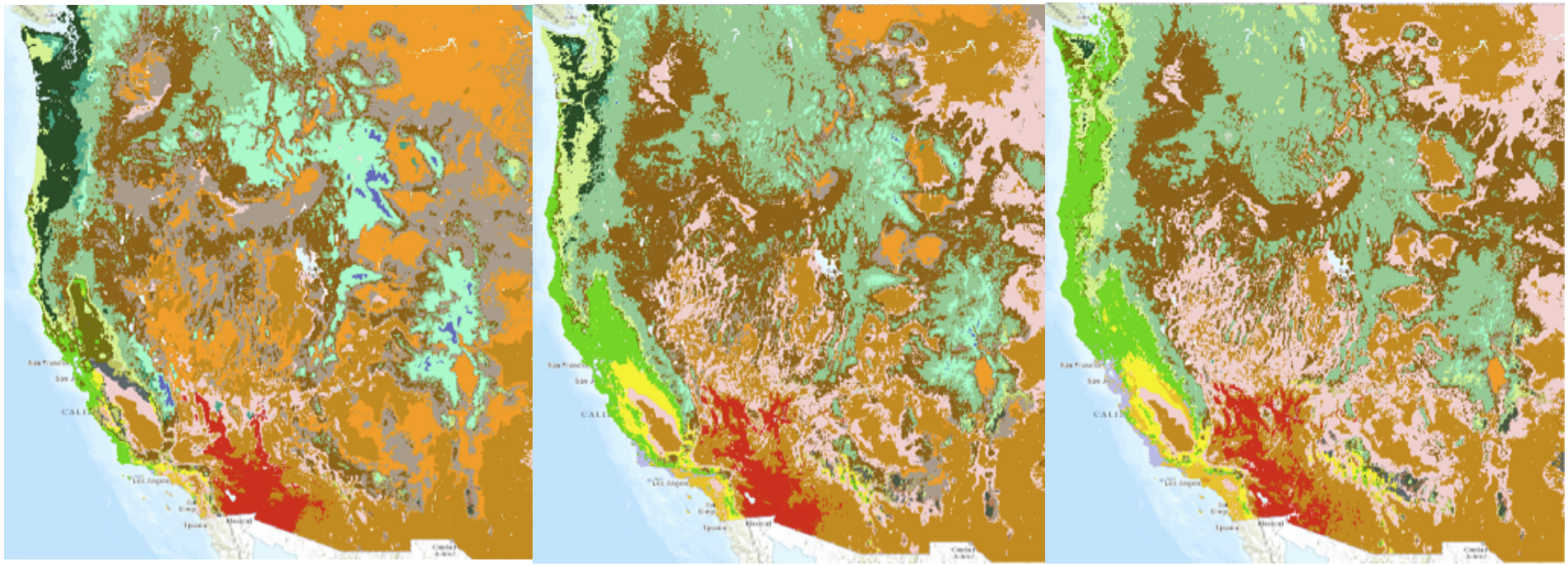


1971-2000 2036-2065 2071-2100

Subtropical Desert

Potential Vegetation Shifts

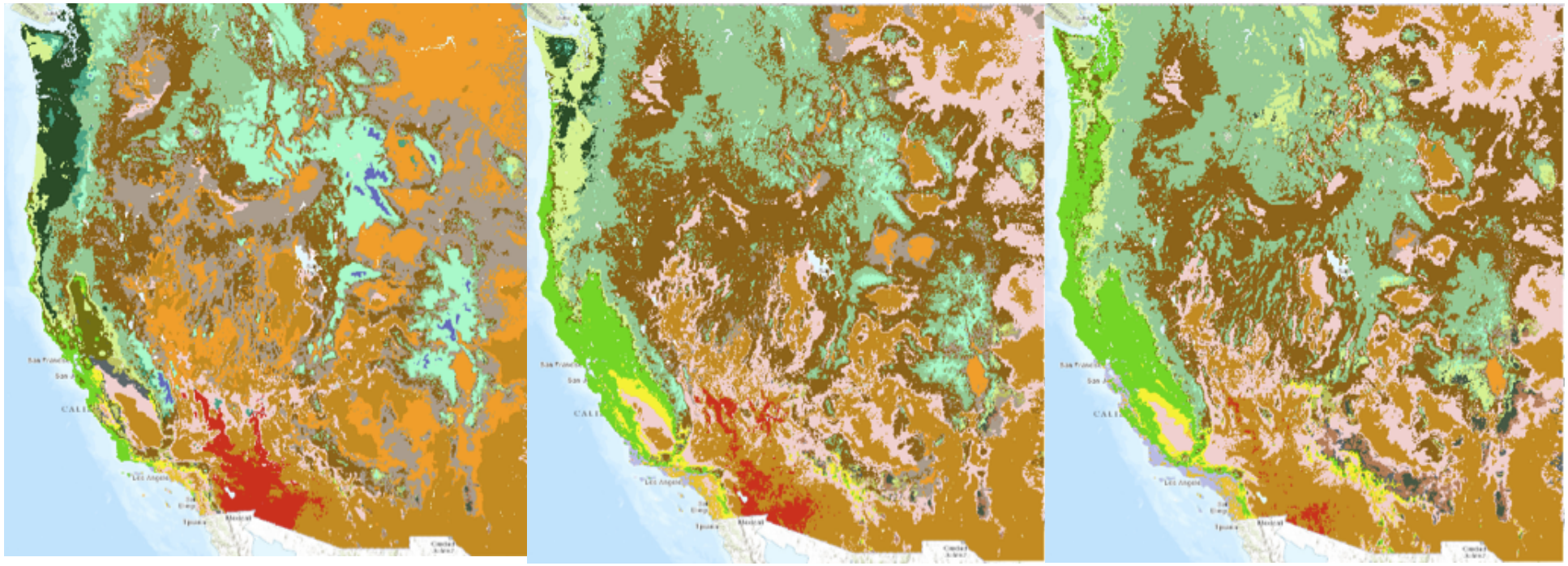
Dominant vegetation (mode) – MIROC5-ESM (Japan) RCP8.5



1971-2000 2036-2065 2071-2100

Potential Vegetation Shifts

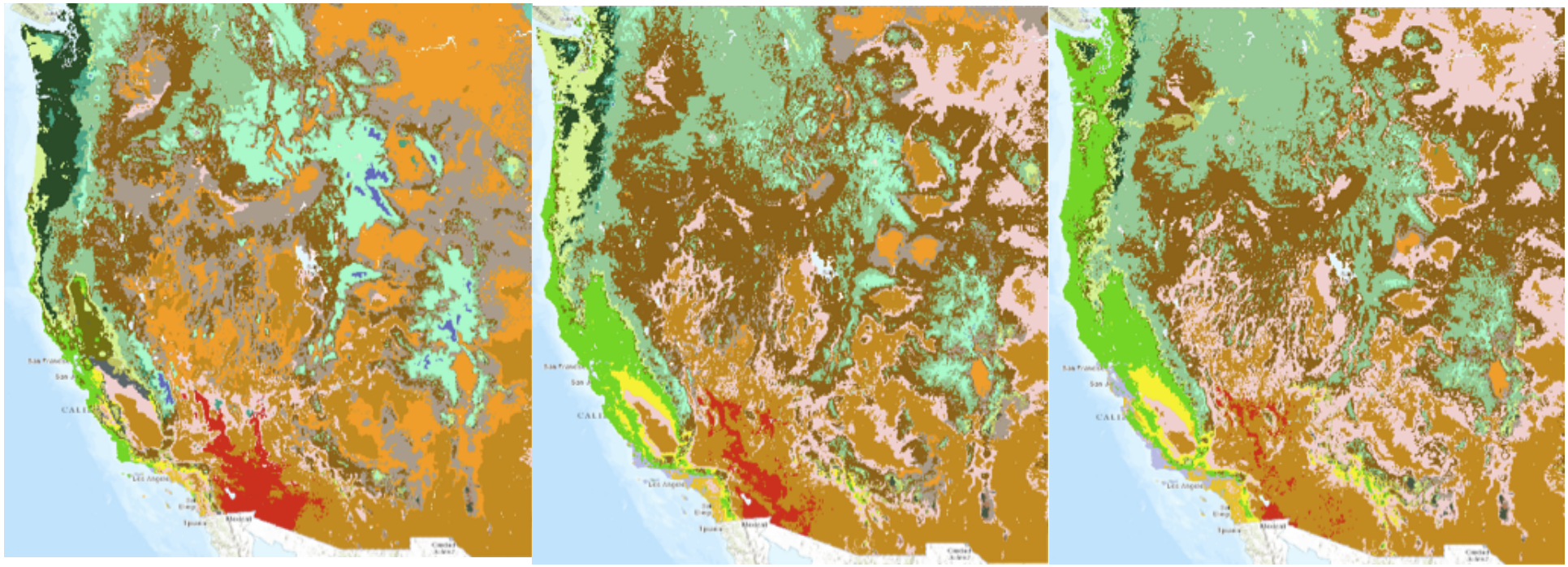
Dominant vegetation (mode) – CanESM2 (Canada) RCP8.5



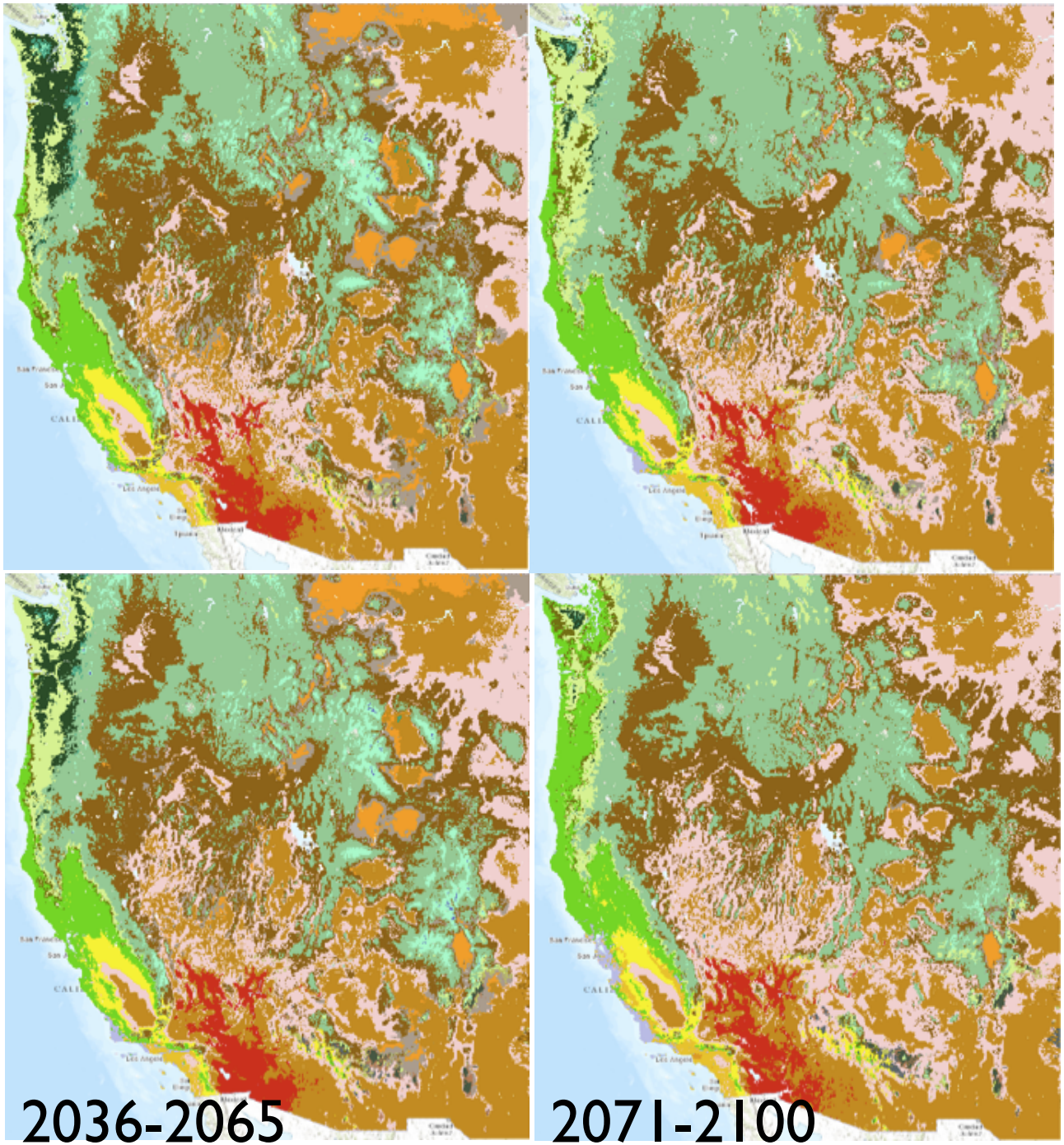
1971-2000 2036-2065 2071-2100

Potential Vegetation Shifts

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



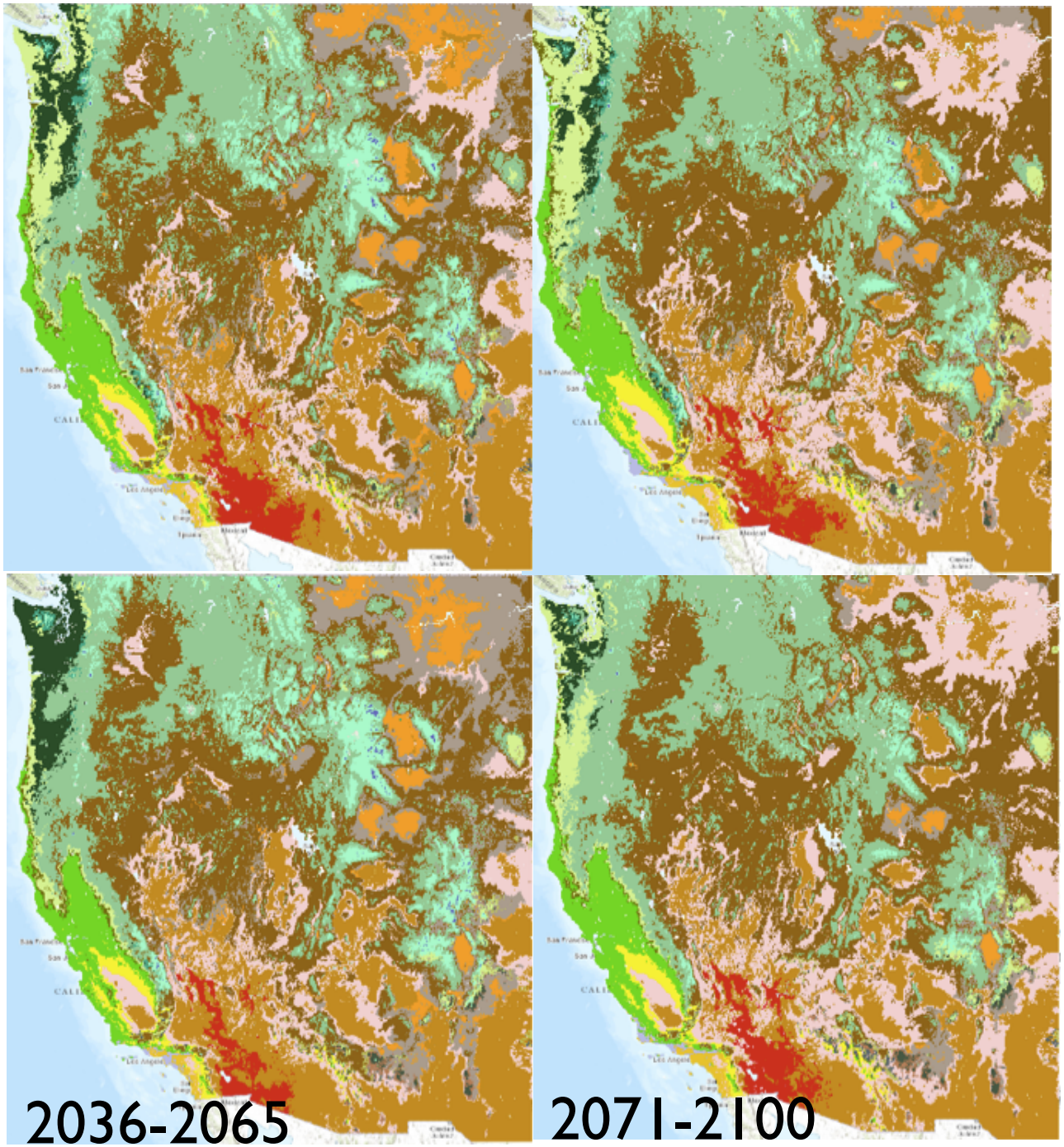
1971-2000 2036-2065 2071-2100



Dominant Vegetation

GCM vs ESM

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



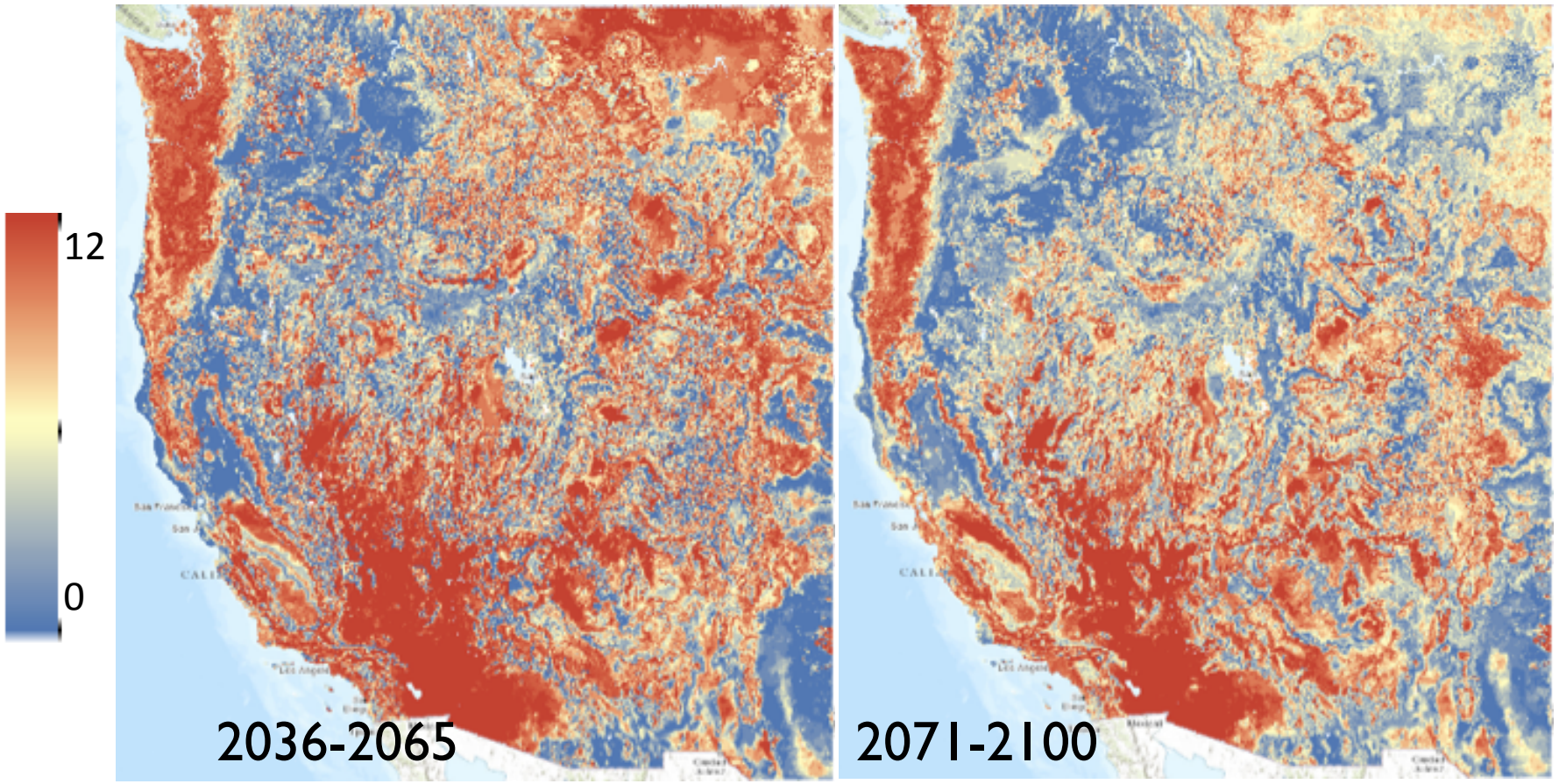
Dominant Vegetation

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



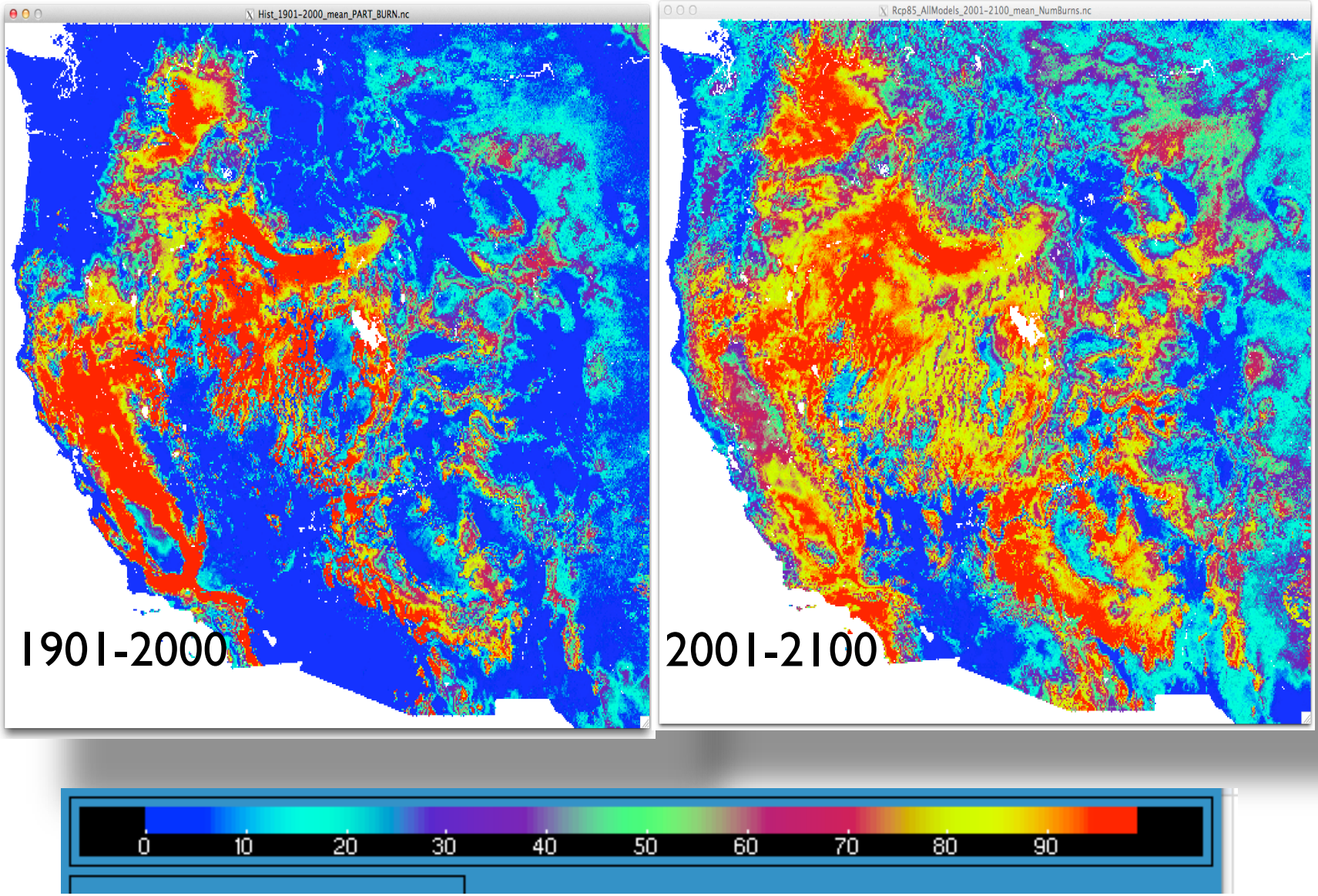
VI=(number of vegetation type changes)/(number of years -1)

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

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

Fire Frequency

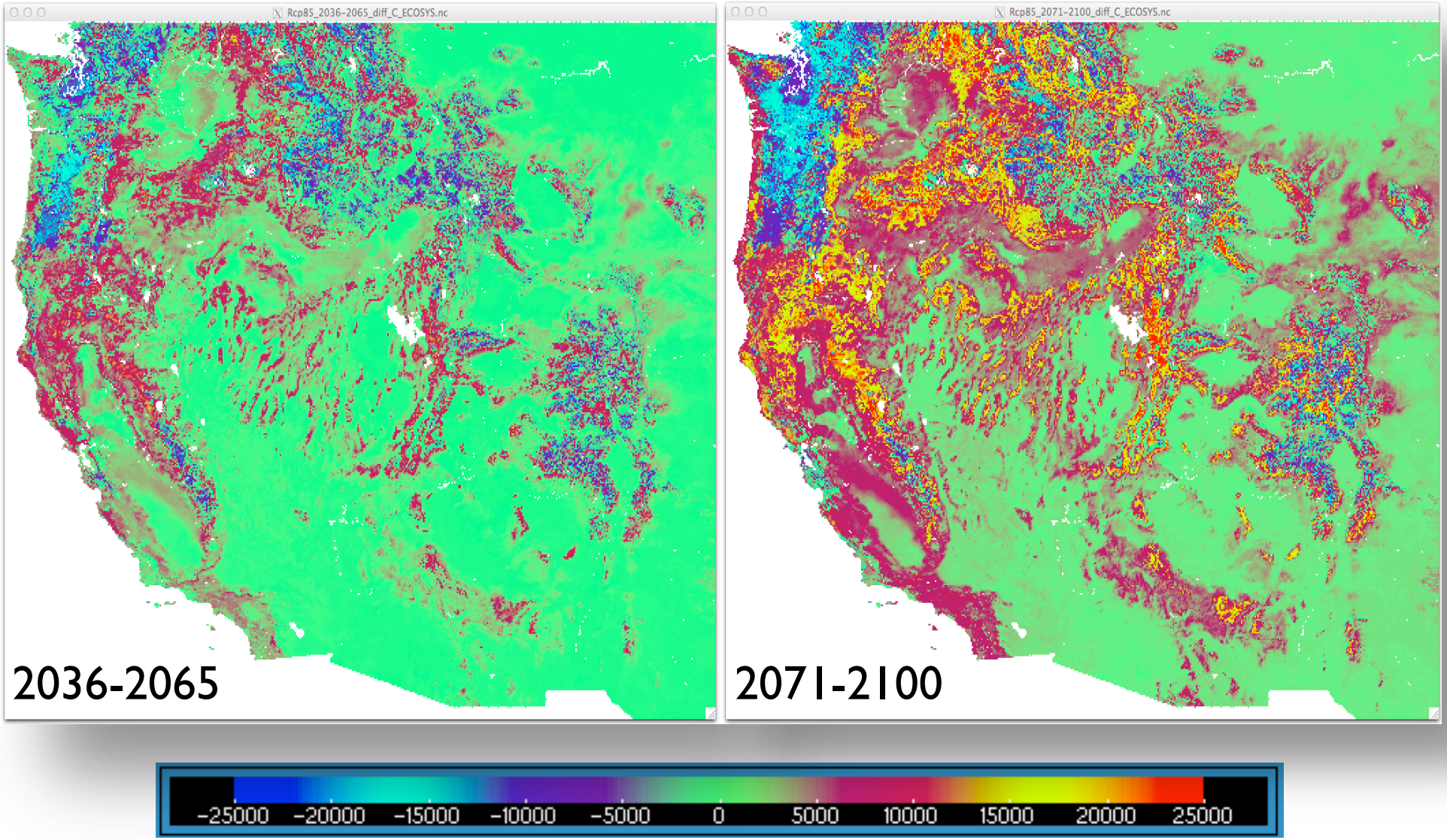
20th century vs 21st century average



Change in Ecosystem Carbon (g C m-2)

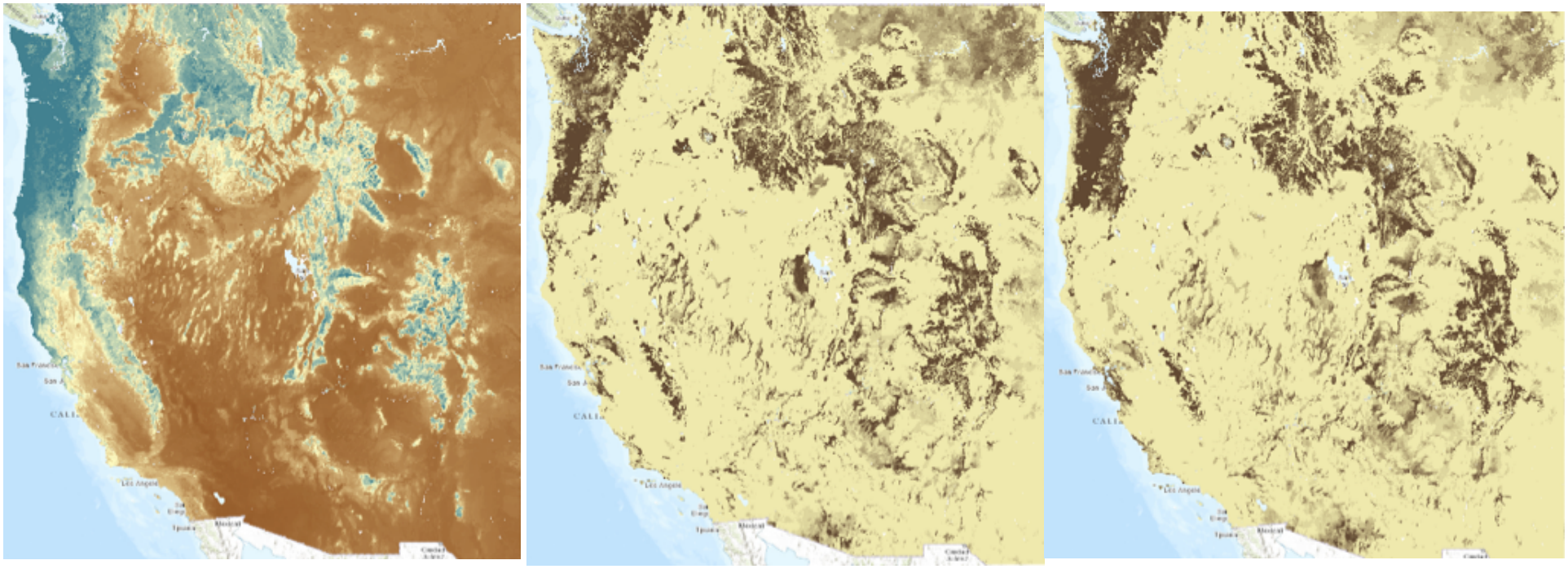
from historical baseline 1971-2000 ave

for 12 CMIP5 models with RCP 8.5



Total Ecosystem Carbon

Historical baseline and Future Losses



1971-2000 2036-2065 2071-2100

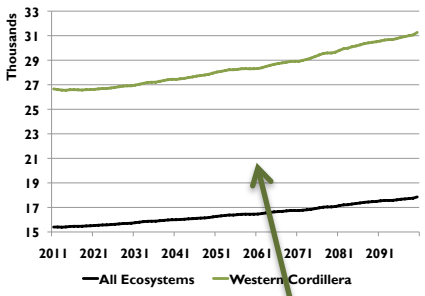
agreement across climate futures

80+kg C m-2

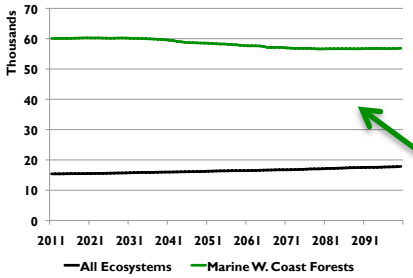
2kg C m-2

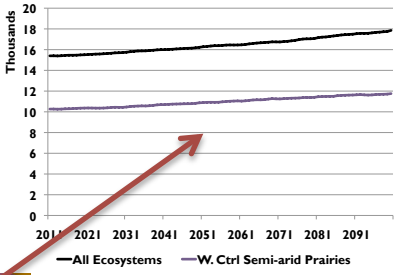
Total Ecosystem Carbon

Western Cordillera

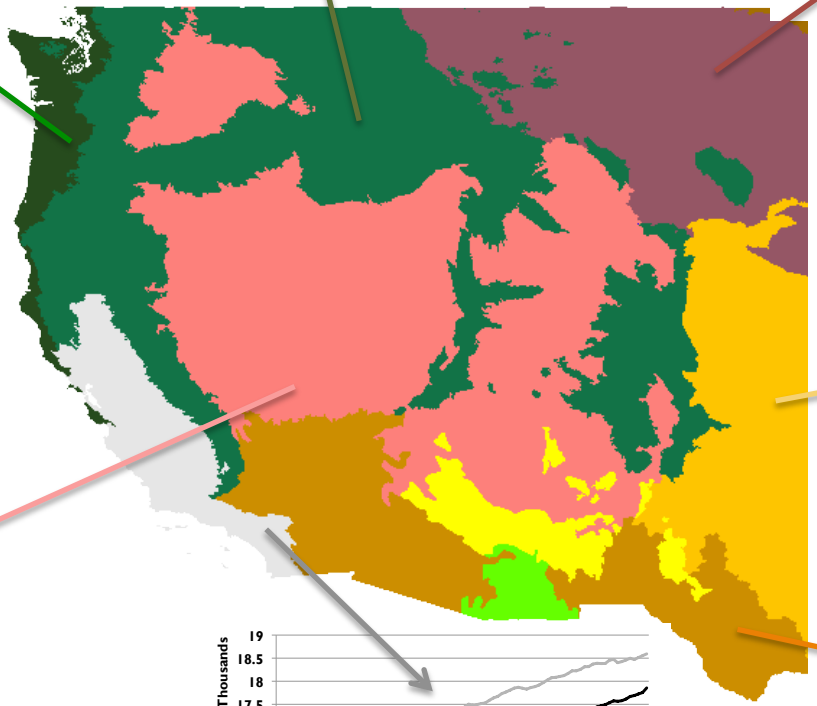


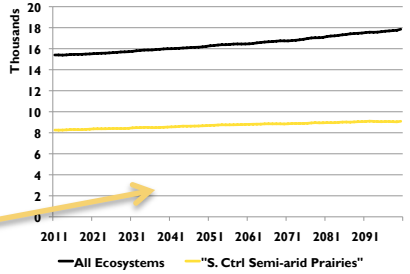
Maritime W. Coast Forests





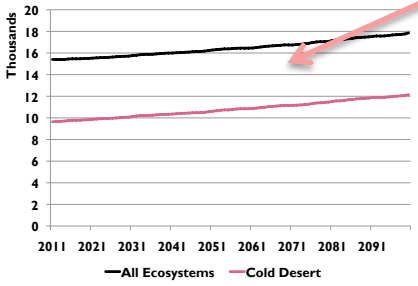
W. Ctrl Semi-arid Prairies

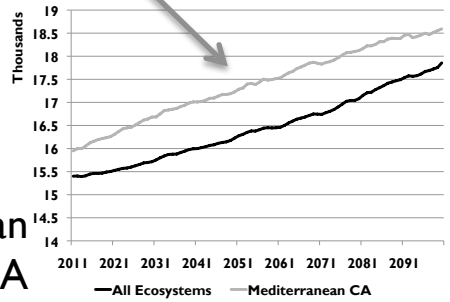




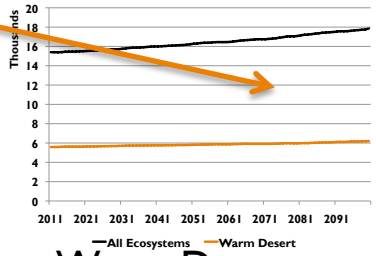
S. Ctrl Semi-arid Prairies

Cold Desert





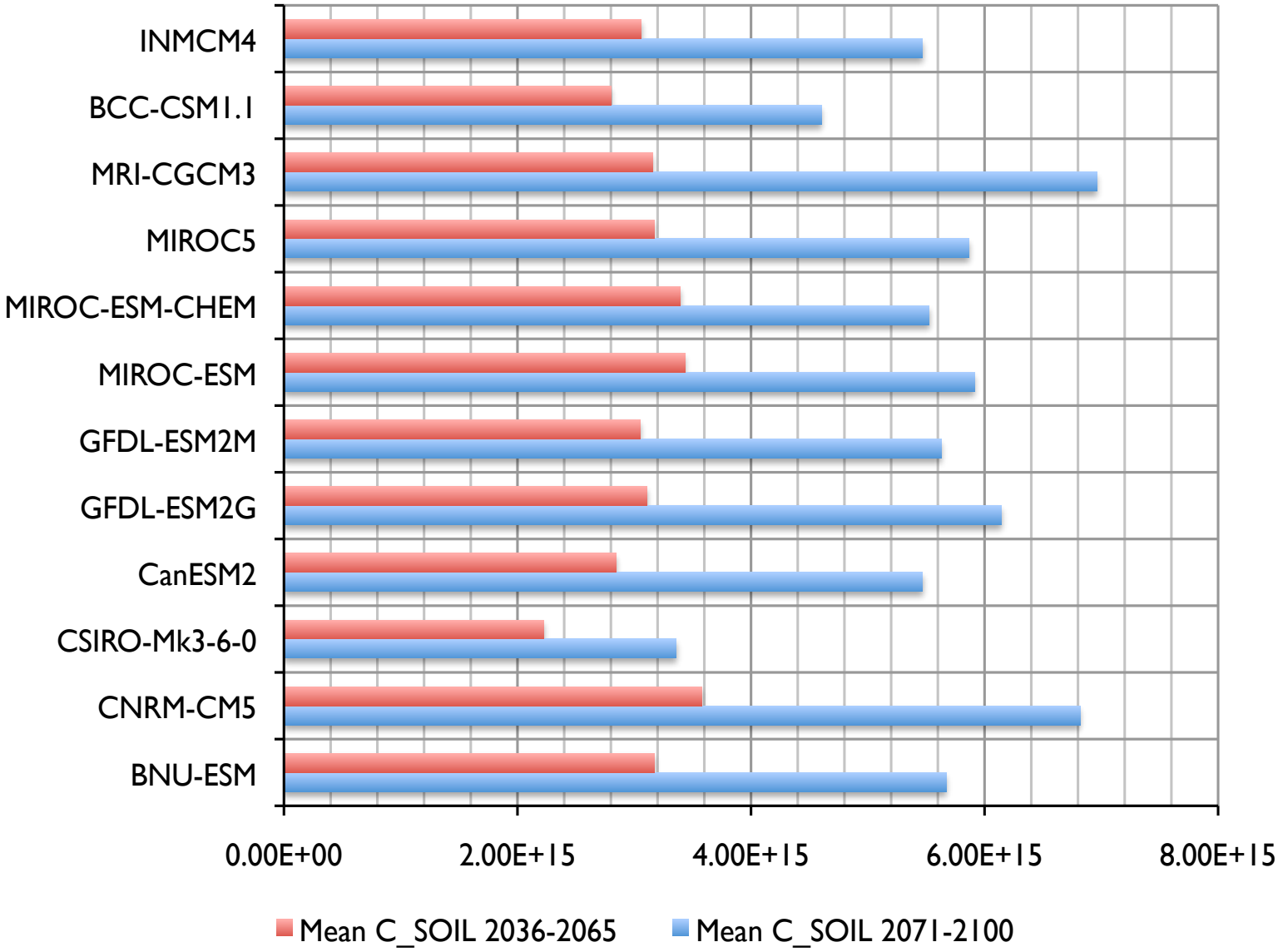
Mediterranean CA



Warm Desert

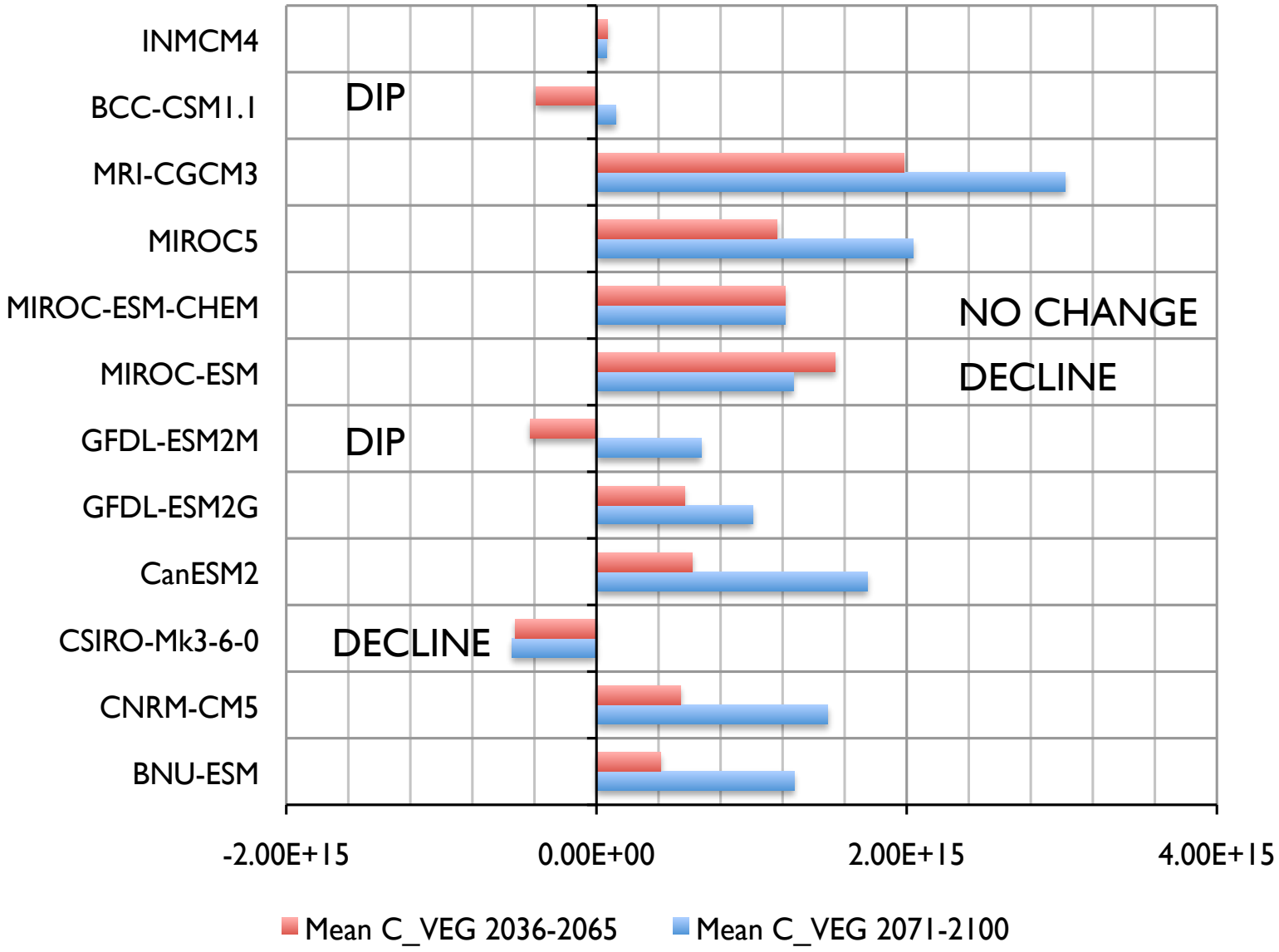
Change in Soil Carbon (g C m-2) – RCP 8.5

from historical baseline 1971-2000 ave

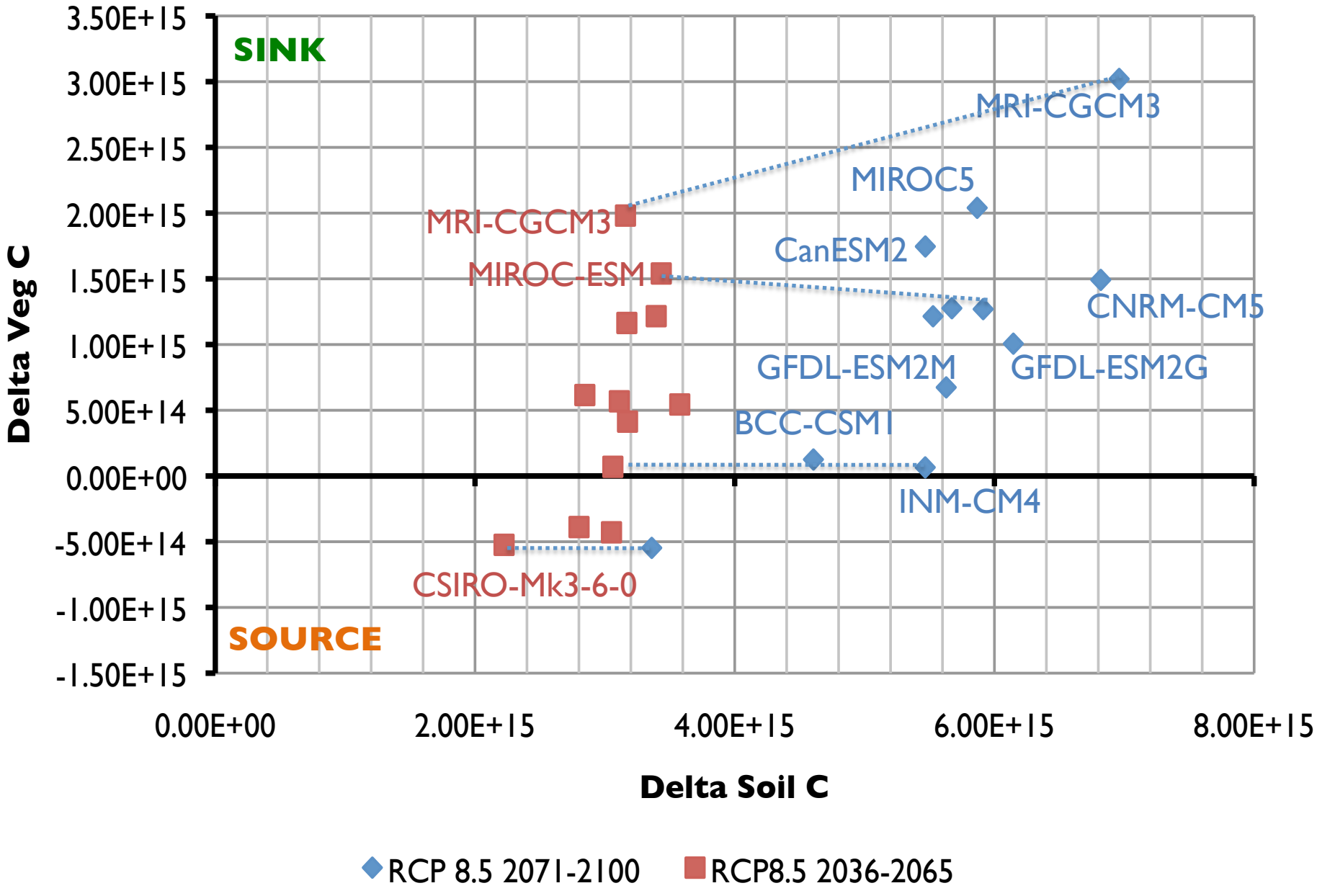


Change in Vegetation Carbon (g C m-2) – RCP 8.5

from historical baseline 1971-2000 ave



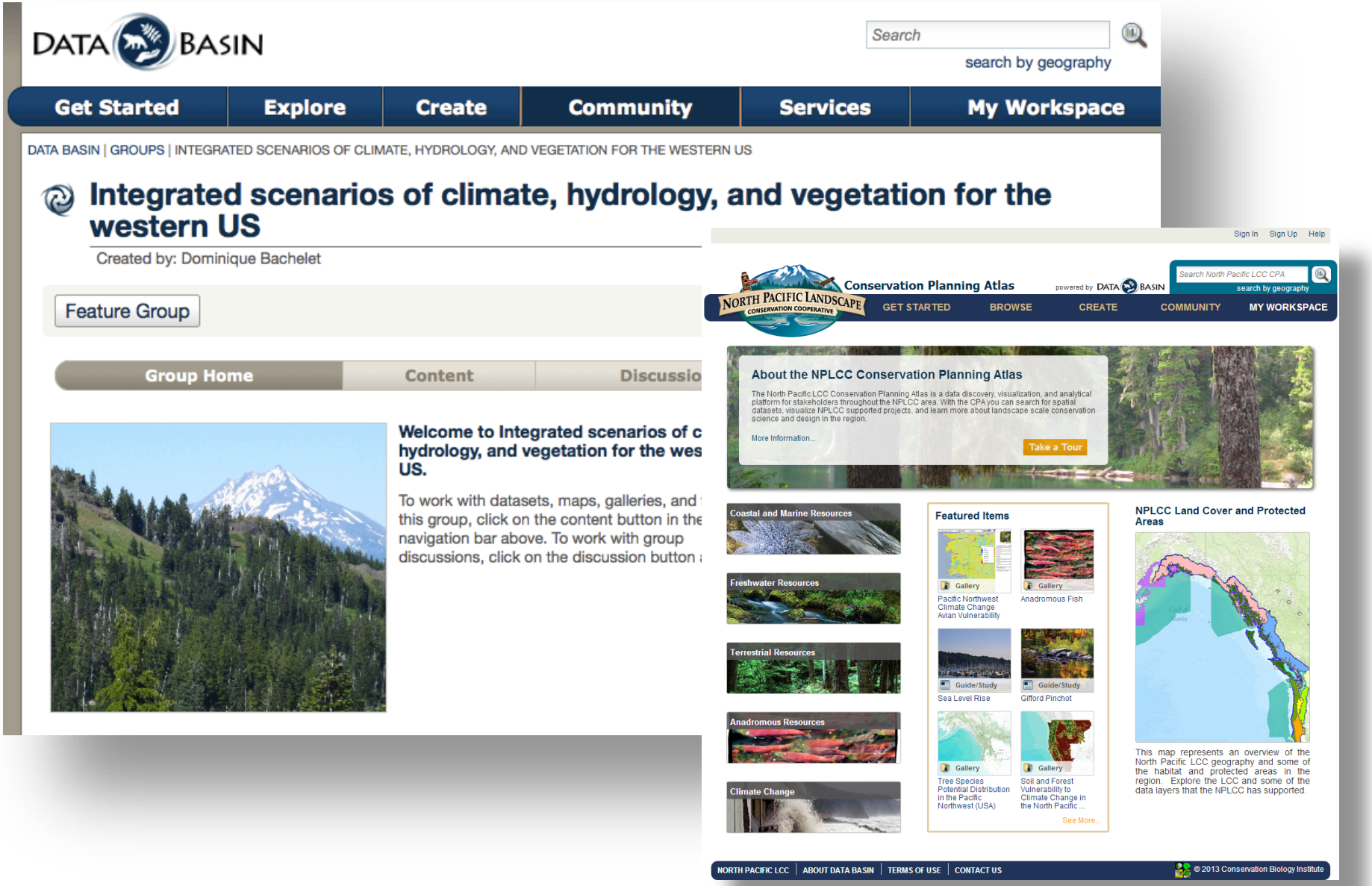
Change in Carbon Stocks across Futures – RCP 8.5



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




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