# How Can Biosphere Models Grow Enough Vegetation Biomass in the Mountains of Western United States? Implications of Meteorological Forcing

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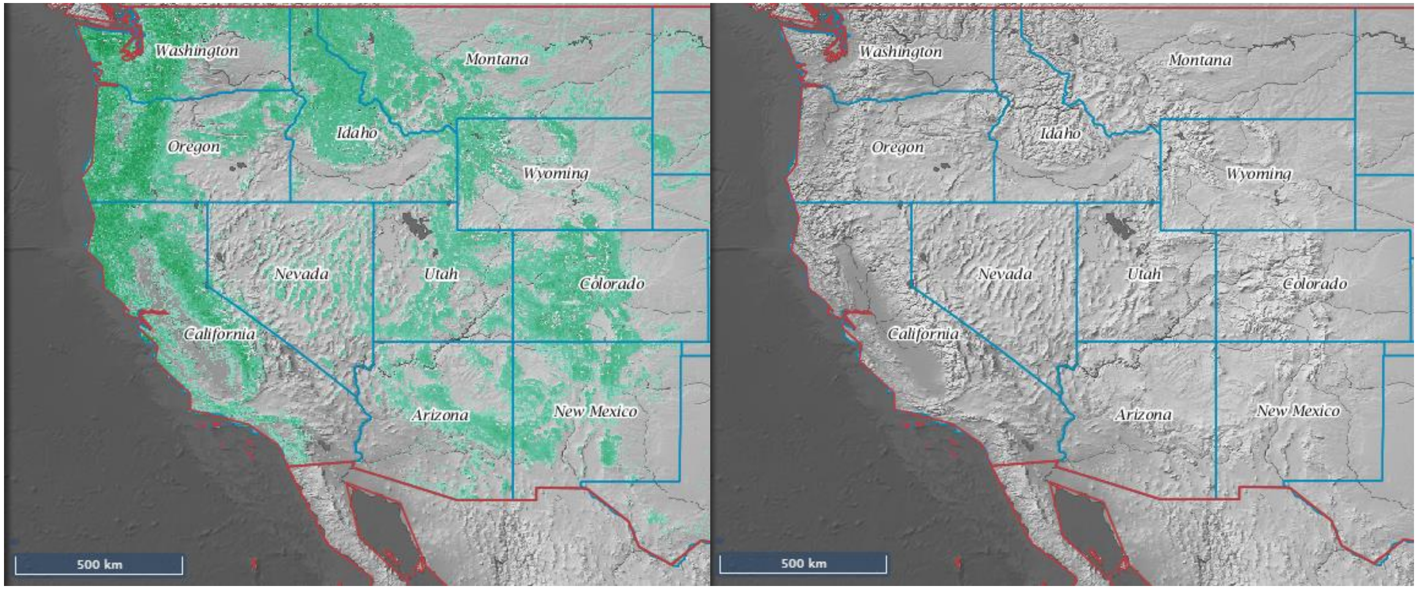
2019 CESM Land Model and Biogeochemistry Working Group Meetings

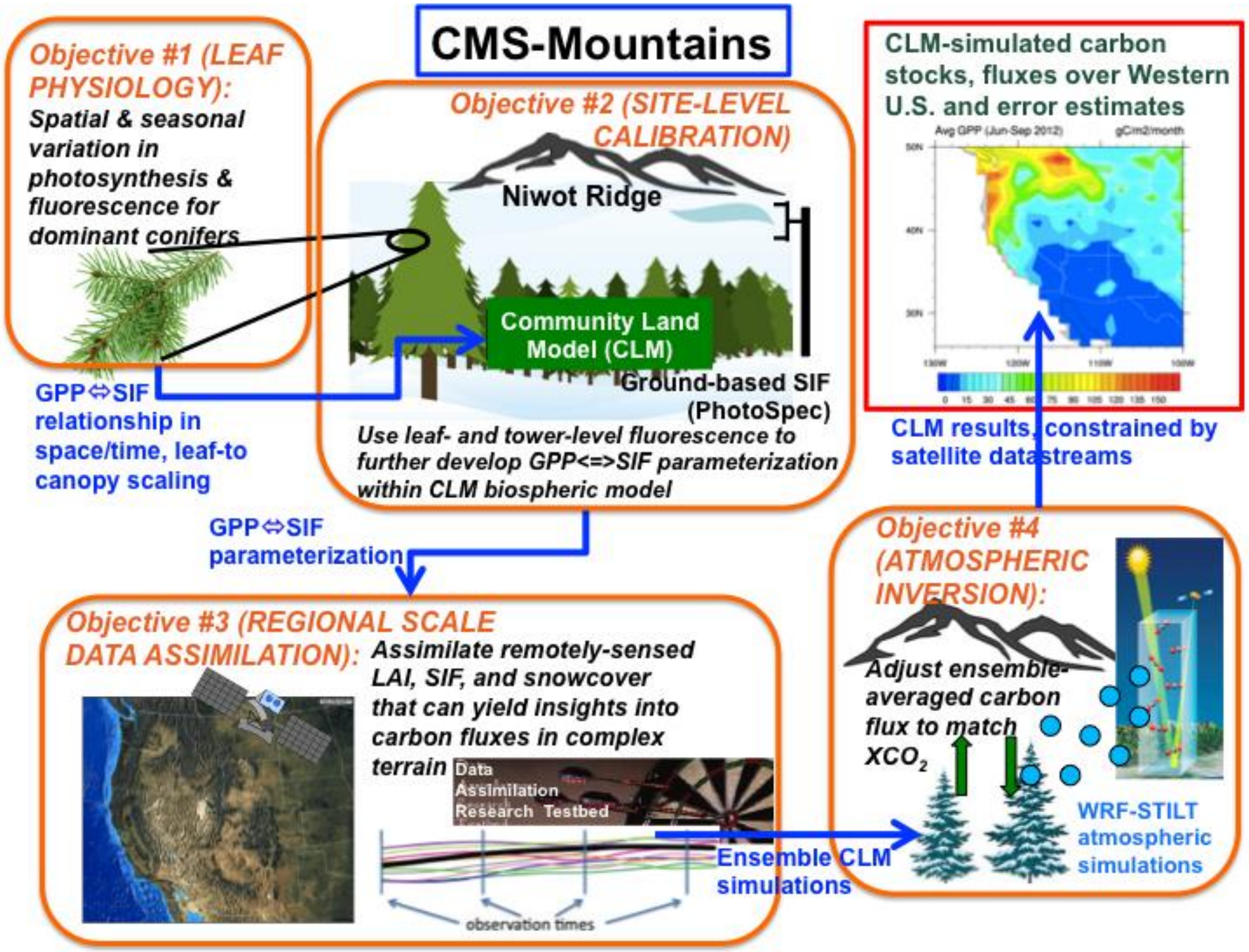
# MOTIVATION: High-elevation forests represent a major fraction of the potential carbon sink in the Western U.S.




*Total vegetation carbon (from NASA's Carbon Mapper webpage: https://cmsun.jpl.nasa.gov)*

- At the same time, these ecosystems are vulnerable to drought, wildfires, and insect outbreaks (more to come with climate change)
- Despite their relevance, these ecosystems are typically "neglected" (complex terrain issues)

# NASA Carbon Monitoring System (CMS) Project



# Problem

- **CLM4.5 and many other LSMs heavily underestimate carbon stocks and fluxes in the western U.S.**
- Big disparity between model state and observations complicates data assimilation efforts

- In general, model errors may arise from numerous sources, including model structure and parameterization, initial and boundary conditions, and external forcing
- In this study we focus on **meteorological forcing**

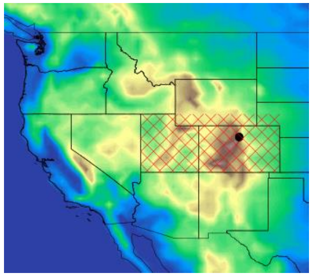
# Questions

- To what extent is the biomass underestimation in the western U.S. related to meteorological forcing?
- Can we improve the simulation of biomass in the western U.S. by using more accurate meteorological forcing datasets?

- We ran CLM4.5 with CRU-NCEP and 4 alternative meteorological datasets to investigate these questions

# Methods

- Model configuration
  - CLM4.5-CN
  - Inactive fire
  - Original PFT parameters
  - Customized 0.2ºx0.2º surface map, UT+CO domain

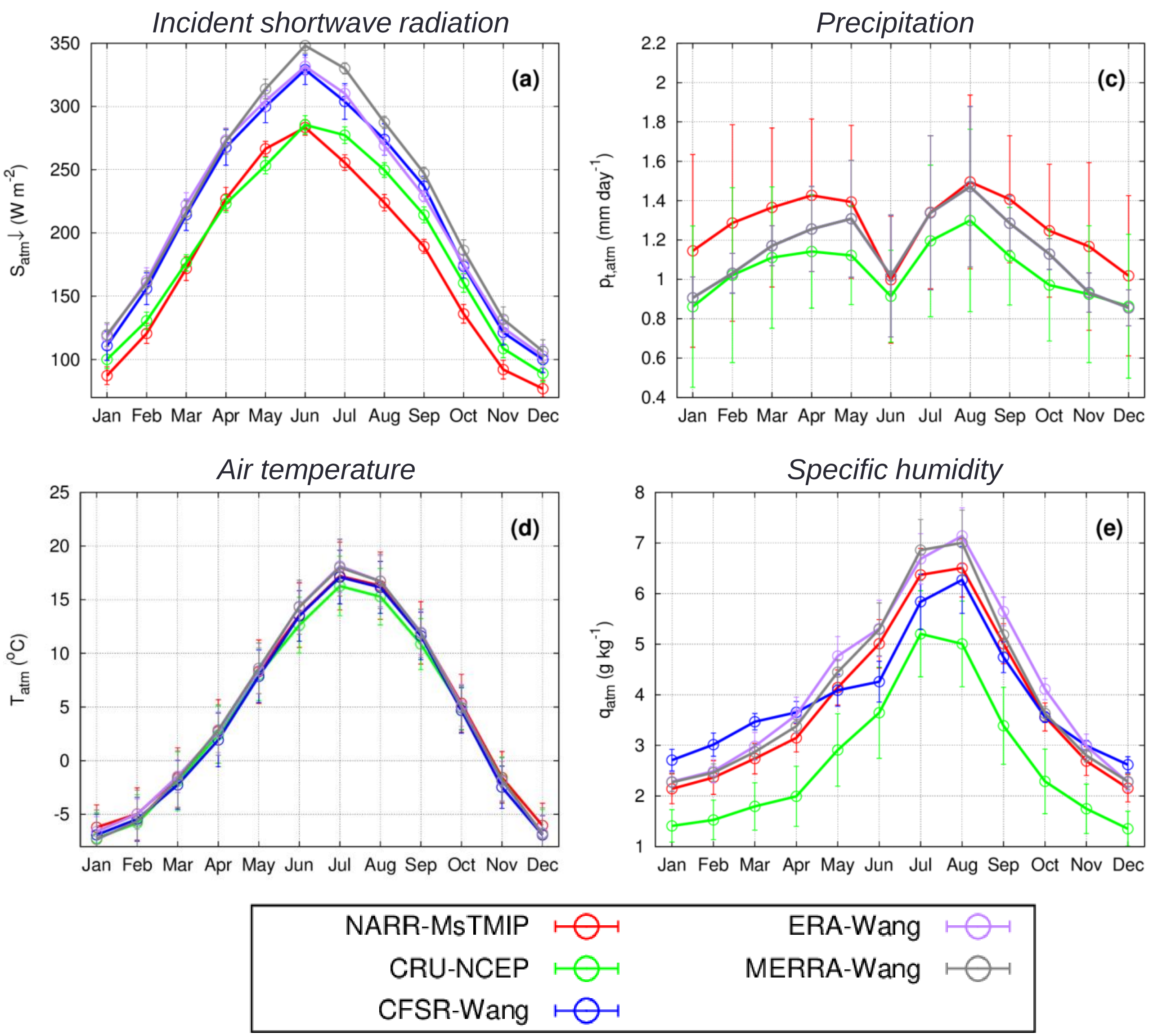


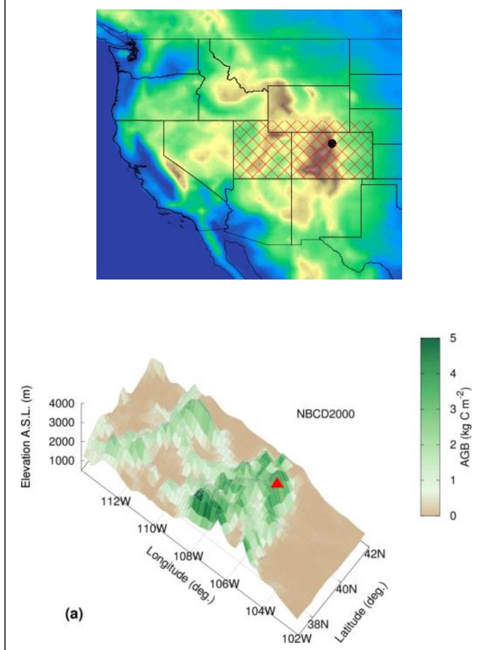
- Simulations
  - Pre-industrial spin-up & 1850--2009 transient run, cycling 1980-2009 meteorology
  - 5 complete simulations (spin-up+TR), one for each meteorological forcing product
  - CLM4.5-SP runs also conducted (fixed vegetation state) to assess the impact of meteorological forcing on potential GPP

# Global and regional meteorological datasets used as drivers

| Dataset | Grid | Frequency | Coverage | Notes |
|---|---|---|---|---|
| **CRU-NCEP** (default forcing) | 0.5°x0.5° | 6 hourly | 1901--2010, global | CRU TS3.2 climatology (monthly, 0.5°x0.5°) + NCEP/NCAR Reanalysis 1 (6 hourly, 2.5°x2.5°) |
| **MERRA-Wang** (Wang et al. 2016) | 0.5°x0.5° | hourly | 1979—2009, global | Based on NASA GMAO MERRA (hourly, 0.5°x0.33°); **Precipitation is bias-corrected based on GPCP 2.2** (monthly, 2.5°x2.5°; Adler et al. 2003) |
| **ERA-Wang** (Wang et al. 2016) | 0.5°x0.5° | 3 hourly | 1979—2009, global | Based on ECMWF ERA-Interim (3 hourly, ~0.75°x0.75°); **Precipitation is bias-corrected based on GPCP 2.2** (monthly, 2.5°x2.5°; Adler et al. 2003) |
| **CFSR-Wang** (Wang et al. 2016) | 0.5°x0.5° | 6 hourly | 1979—2009, global | Based on NCEP CFSR (6 hourly, 0.5°x0.5°); **Precipitation is bias-corrected based on GPCP 2.2** (monthly, 2.5°x2.5°; Adler et al. 2003) |
| **NARR-MsTMIP** (Wei et al. 2014) | 0.25°x0.25° | 3 hourly | 1979—2010, North America | Based on NCEP NARR (3 hourly, 32 km); **Precipitation is bias-corrected based on GPCP 2.1** (monthly, 2.5°x2.5°; Adler et al. 2003); **Incident shortwave radiation is bias-corrected based on MT-CLIM 4.3 (Thornton & Running 1999) estimates** using daily max and min air temperature and daily precipitation (bias-corrected). Product created for the Multi-Scale Synthesis and Terrestrial Model Intercomparison Project (MsTMIP; Huntzinger et al. 2013) |

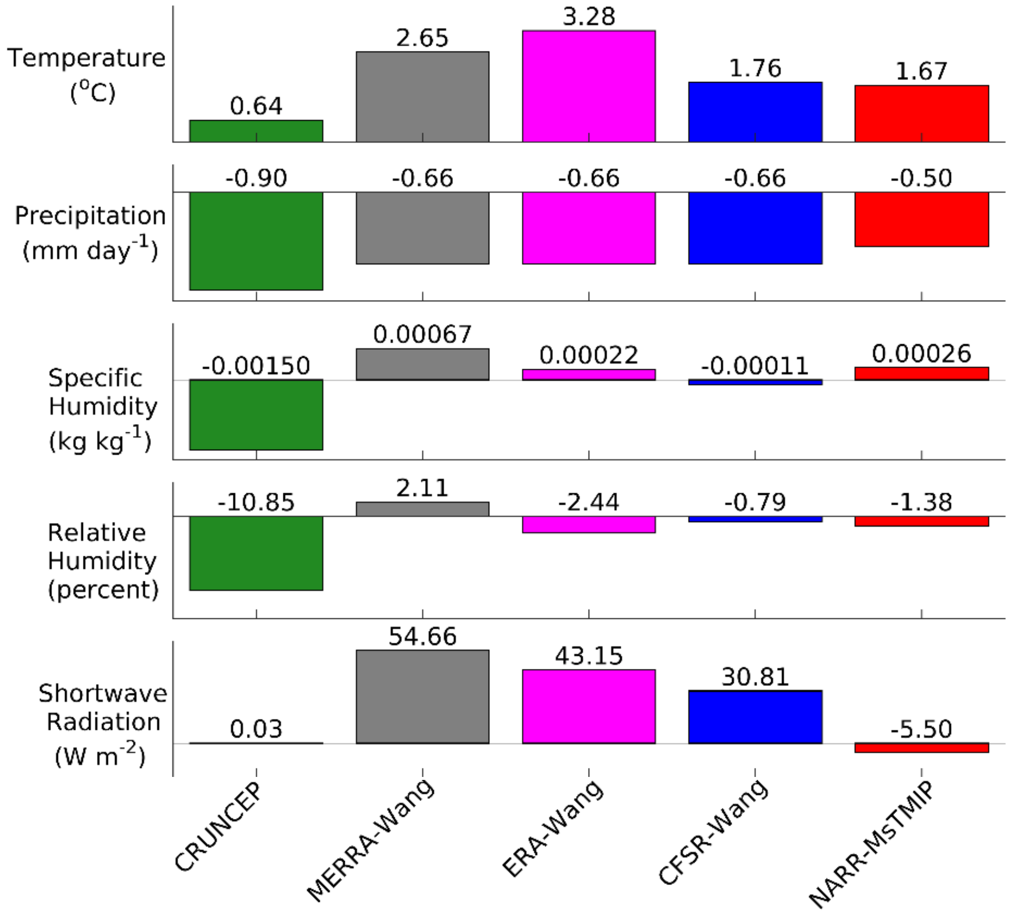
# Met data (1980-2009) averaged over high-elevation grid cells*

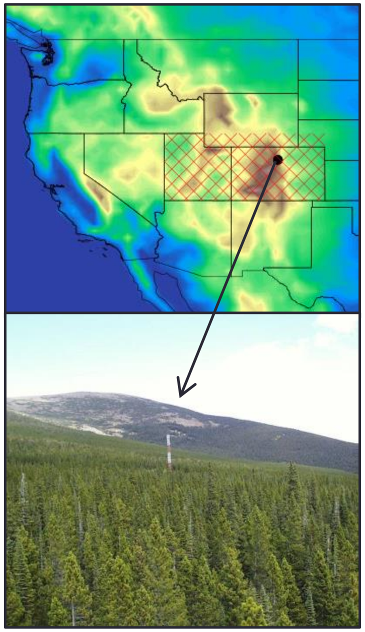



* z > 2235 m
75% of total AGB
(NBCD2000 product, Kellndorfer et al., 2013)

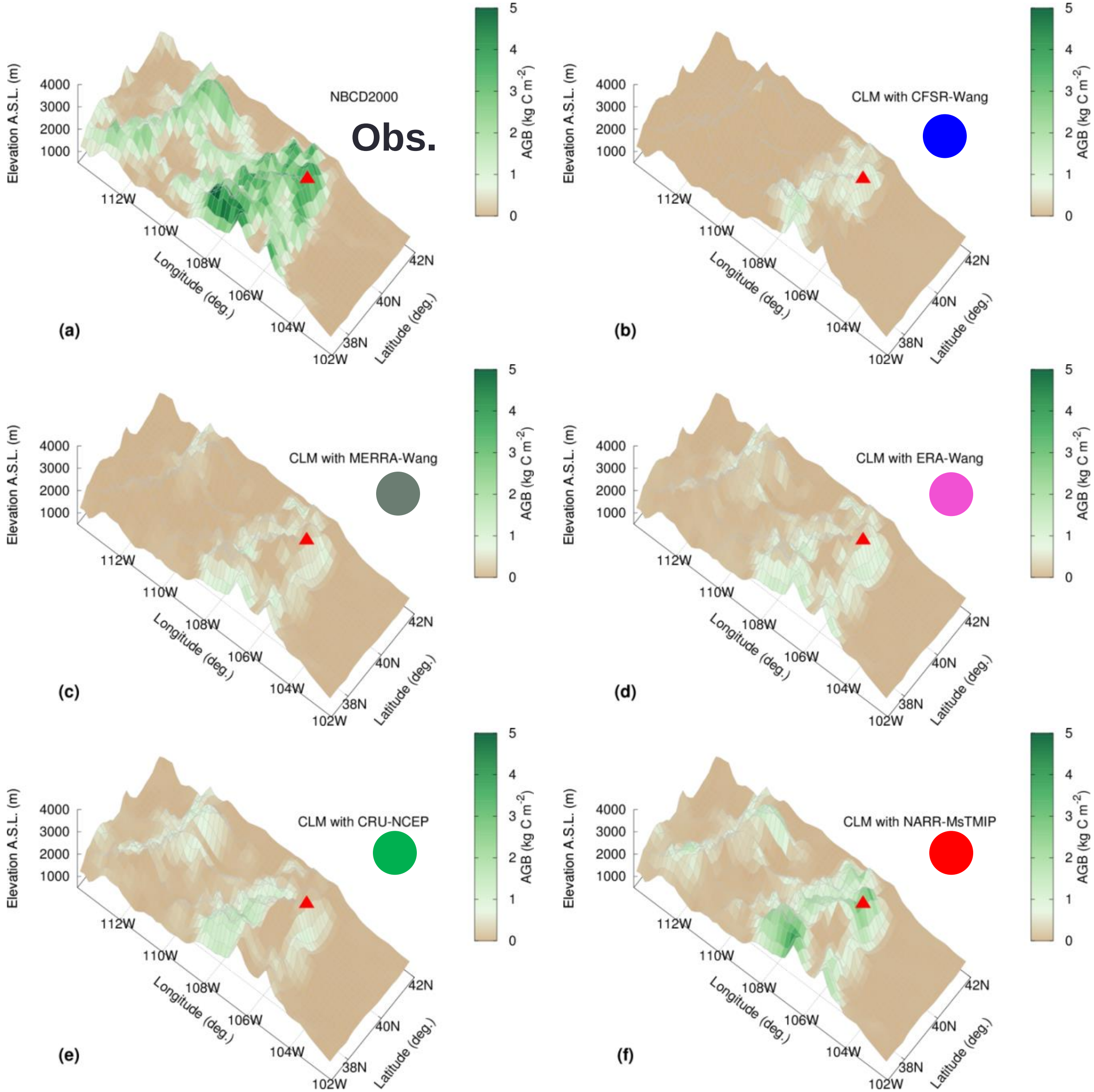
# Mean bias errors (1998-2007) at the Niwot Ridge site

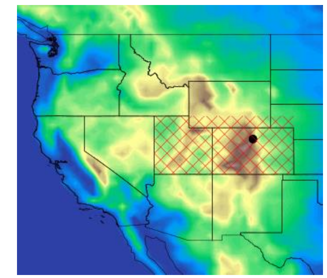


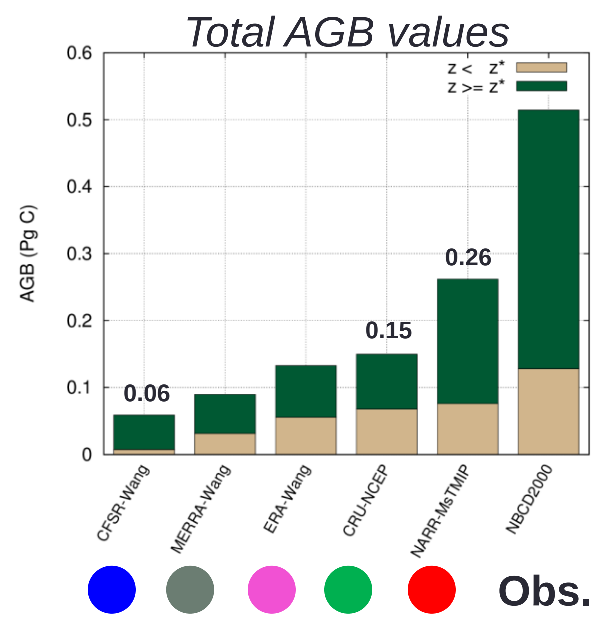



*Niwot Ridge AmeriFlux Tower*

# Simulated above-ground biomass (AGB), year 2000

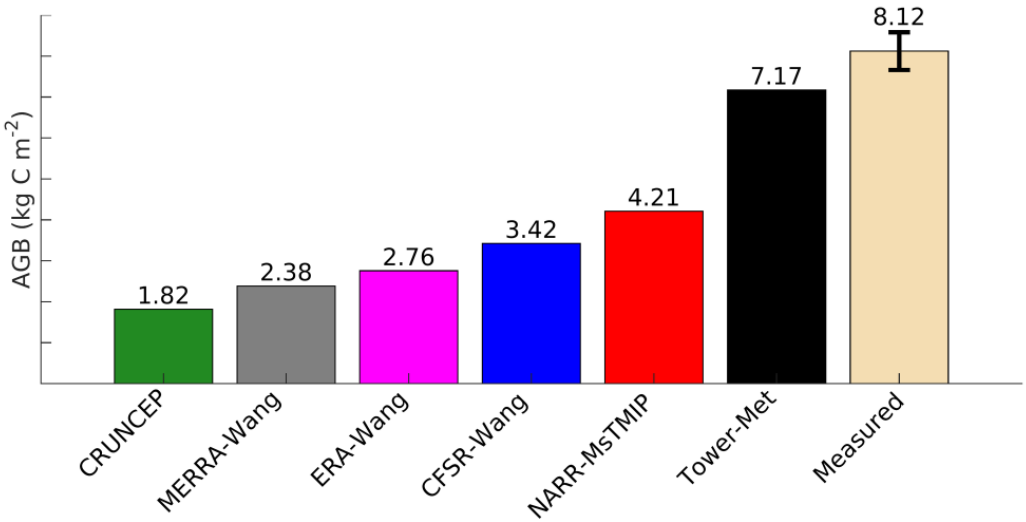


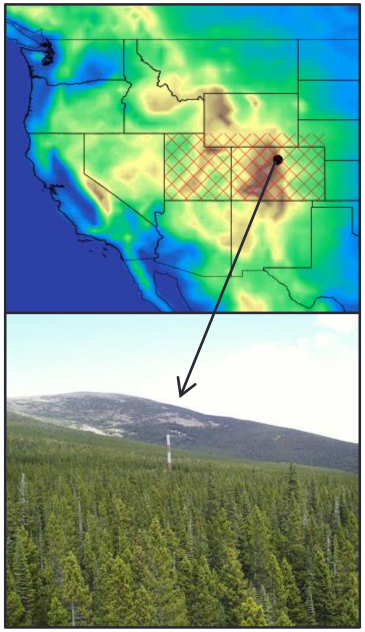






z* = 2235 m

# Simulated above-ground biomass (AGB), year 2005
# Niwot Ridge site

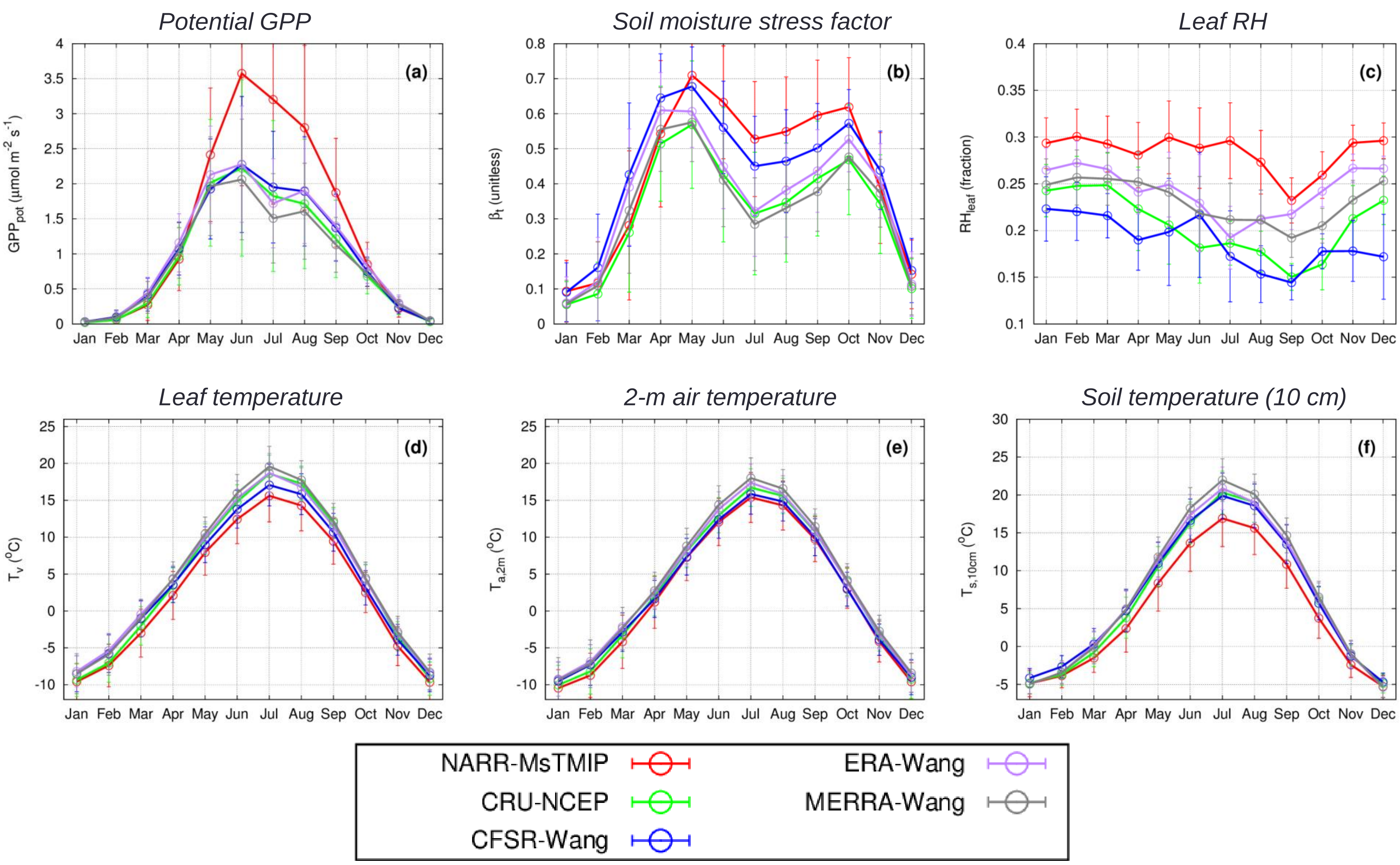


*Niwot Ridge AmeriFlux Tower*

Point-level CLM4.5-CN simulations
based on Raczka et al. (2016)

# CLM4.5-SP results (1980-2009), averaged over high-elevation grid cells



# Conclusions

- Simulation of AGB in UT+CO is highly sensitive to the met forcing product used (0.06—0.26 Pg C)
- Fundamental restriction on plant growth in UT+CO is linked to summer water stress, exacerbated by positive biases in SW↓ and negative biases in Precip
- CLM performance greatly improves with NARR-MsTMIP forcing (both biases are minimized)
  - At high elevations, AGB more than doubled in comparison with CRU-NCEP simulation

*Using more accurate met datasets with smaller biases is a direct, effective, and justifiable way to improve model performance.*

# Recent developments & future work

Received: 28 July 2018 | Revised: 8 October 2018 | Accepted: 10 October 2018
DOI: 10.1111/gcb.14490

PRIMARY RESEARCH ARTICLE

WILEY Global Change Biology

**Near-future forest vulnerability to drought and fire varies across the western United States**

Polly C. Buotte[1] | Samuel Levis[2] | Beverly E. Law[1] | Tara W. Hudiburg[3] | David E. Rupp[4] | Jeffery J. Kent[3]

- Significant boost in AGB in the western U.S. after using high-resolution (4x4km) met forcing and surface maps and species-specific PFTs with unique parameters (and other CLM4.5 mods)
  - Contribution from met forcing alone is yet to be determined
- We plan to build upon this work to improve our prior simulations before DA

# Acknowledgements

This research was supported by the U.S. Dept. of Energy's Office of Science, Terrestrial Ecosystem Science Program (awards DE-SC0010624 and DE-SC0010625), and by the NASA Carbon Monitoring System Project (award NNX16AP33G).

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# References


- **Adler et al. (2003):** The version-2 Global Precipitation Climatology Project (GPCP) monthly precipitation analysis (1979–present). Journal of Hydrometeorology, 4, 1147–1167.
- **Huntzinger et al. (2013):** The North American Carbon Program Multi-Scale Synthesis and Terrestrial Model Intercomparison Project – part 1: Overview and experimental design. *Geoscientific Model Development*, 6, 2121–2133.
- **Kellndorfer et al. (2013):** *NACP Aboveground Biomass and Carbon Baseline Data, V. 2 (NBCD 2000), U.S.A., 2000* [Dataset]. Oak Ridge, TN: ORNL DAAC.
- **Raczka et al. (2016):** An observational constraint on stomatal function in forests: evaluating coupled carbon and water vapor exchange with carbon isotopes in the Community Land Model (CLM4.5). Biogeosciences, 13, 5183–5204.
- **Thornton & Running (1999):** An improved algorithm for estimating incident daily solar radiation from measurements of temperature, humidity, and precipitation. *Agricultural and Forest Meteorology*, 93, 211–228.
- **Wang et al. (2016):** Estimates of global surface hydrology and heat fluxes from the Community Land Model (CLM4.5) with four atmospheric forcing datasets. *Journal of Hydrometeorology*, 17, 2493–2510.
- **Wei et al. (2014):** The North American Carbon Program Multi-scale Synthesis and Terrestrial Model Intercomparison Project – part 2: Environmental driver data. *Geoscientific Model Development*, 7, 2875–2893.

# CLM4.5-CN results at Niwot Ridge
# (average over first five simulation years after initialization)