Modeling canopy fluxes and optical properties using CliMA Land

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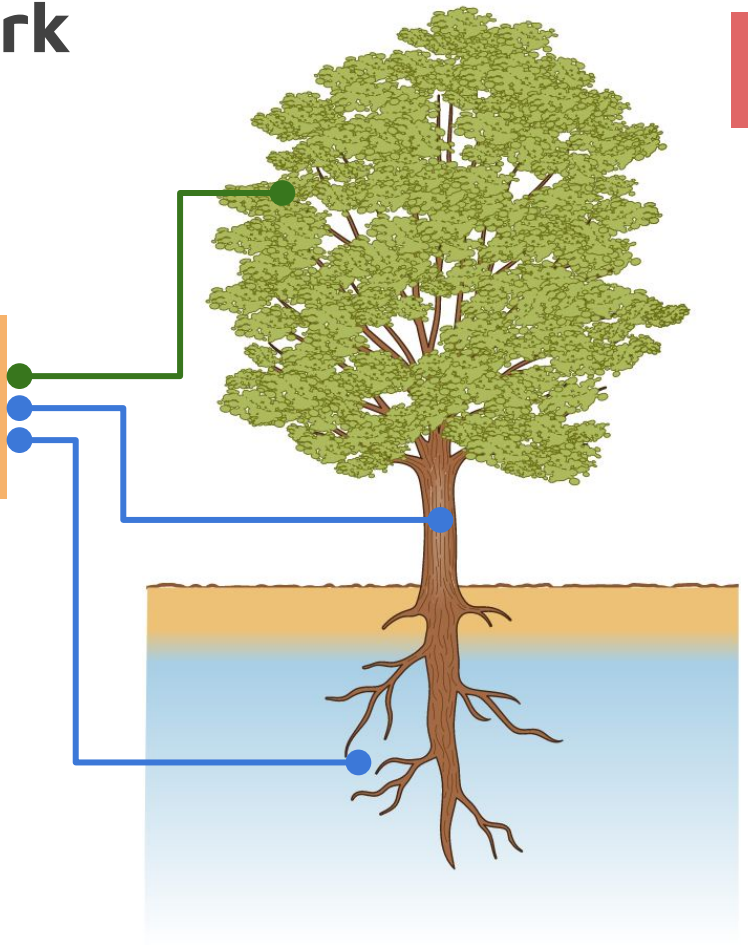
CliMA Land SPAC Module

Key components (sub-modules):

- Canopy radiation
- Photosynthesis
- Plant hydraulics
- Stomatal models
- Soil-Plant-Air Continuum

SPAC Framework



Canopy Radiation

Photosynthesis

Plant Hydraulics

Stomatal Models (decision making)

Image adapted from Wang et al. (2020)

Supported canopy RT models

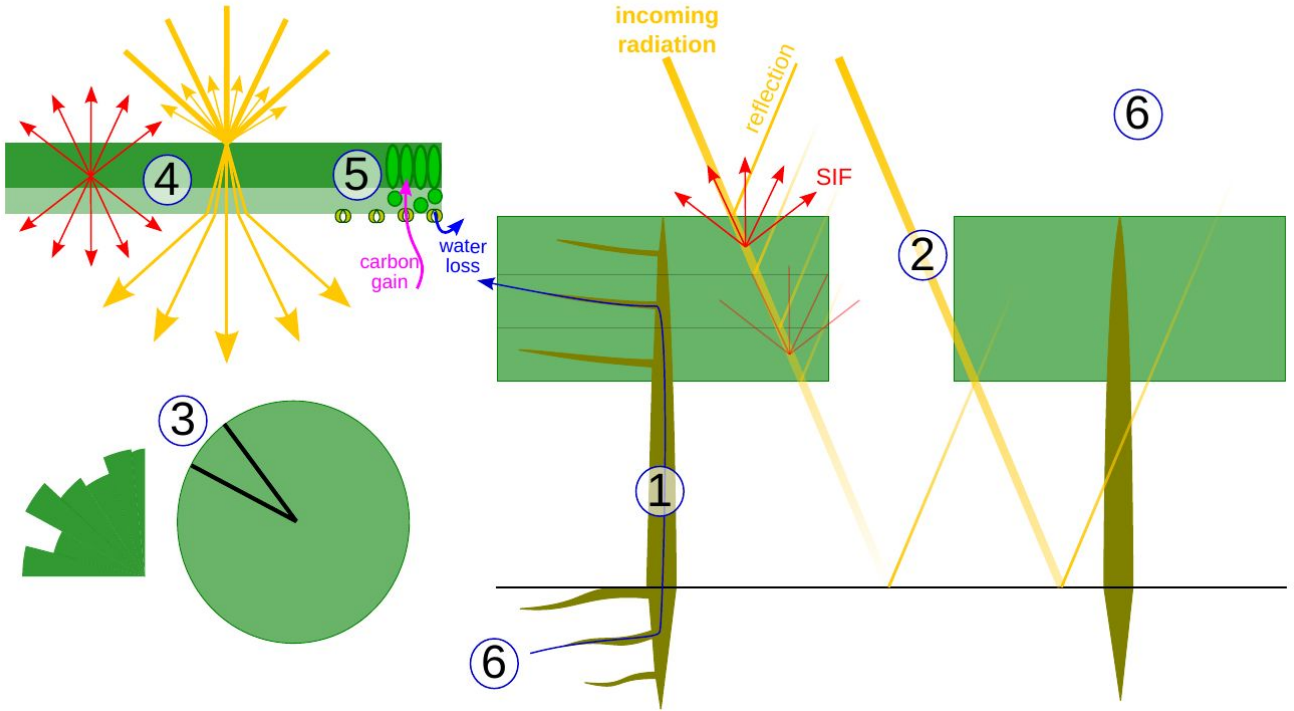
- Broadband two leaf model
  - Sunlit fraction
  - Shaded fraction
- Hyperspectral multilayer model >> canopy optical properties
  - Angular distribution
  - Sunlit fraction
  - Shaded fraction

Supported photosynthesis+fluorescence models

- C3 model (FvCB model)
  - vdT fluorescence model
- C4 model (Collaz model)
  - vdT fluorescence model
- C3 cytochrome model (JB model)
  - JB fluorescence model

Supported plant hydraulics models

- Multiple roots
- Optional trunk
- Multiple branches (matching canopy RT model)
- Drought legacy enabled
- Steady state and non-steady state options



1. **Hydraulic traits** such as vulnerability curve and maximum conductance impact water transport, and thus stomatal behavior.
2. **Canopy traits** such as leaf area index and clumping index impact light penetration to lower canopy, and reflected light and solar-induced chlorophyll fluorescence (SIF) escaping from lower canopy.
3. **Leaf angular distributions** impact light scattering within the canopy.
4. **Leaf biophysical traits** such as chlorophyll and carotenoid contents impact leaf level reflectance, transmittance, and SIF spectra.
5. **Leaf physiological traits** such as maximum carboxylation rate impact leaf gas exchange.
6. **Environmental conditions** such as soil moisture and atmospheric humidity impact plant's physiological responses.

Image from Wang et al. (2021)

Supported stomatal models

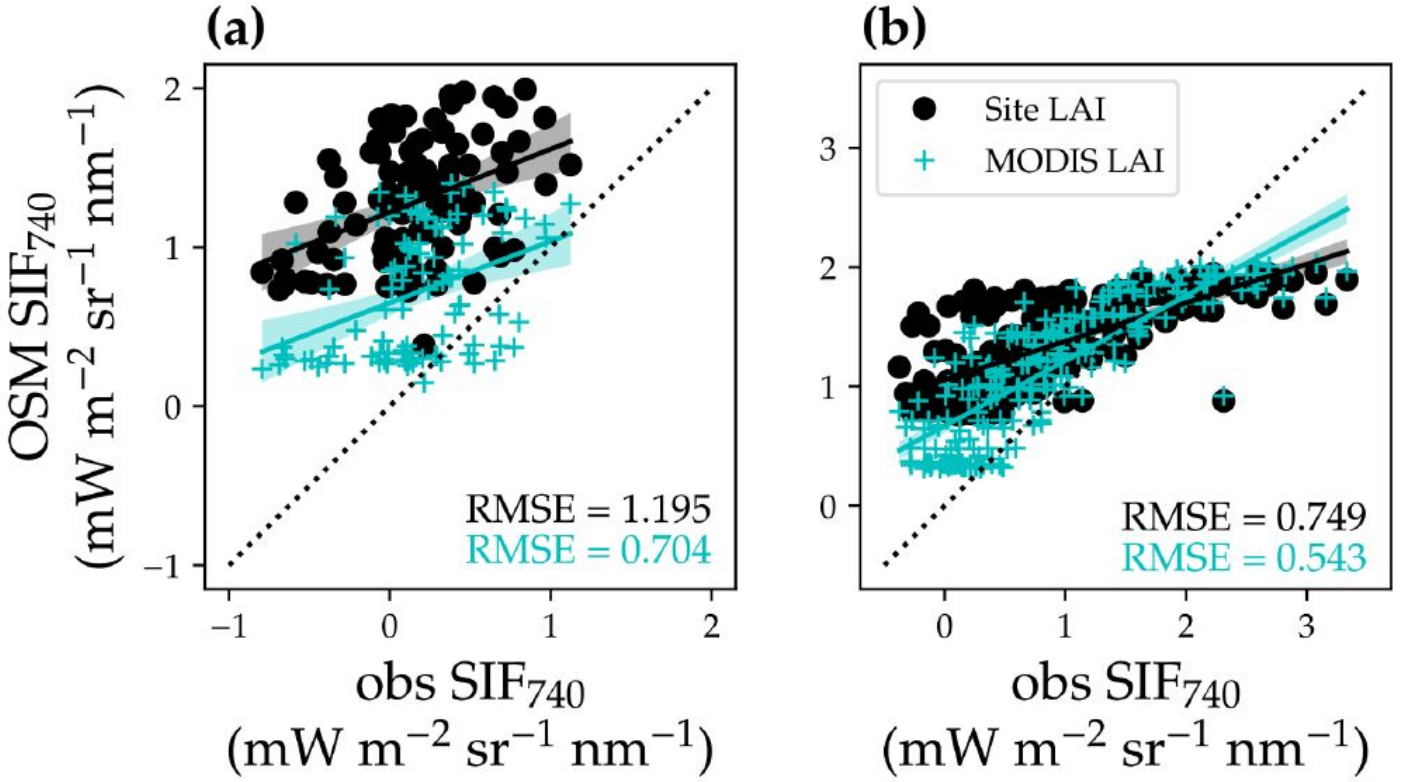
- Empirical models
  - Ball Berry model
  - Leuning model
  - Medlyn model
  - Various BETA functions
- Optimality models
  - Wolf-Anderegg-Pacala model
  - Sperry model
  - Eller model
  - Wang model

Freely customized model

Example 1: SPAC model selection

- Hyperspectral canopy RT model
- C3 FvCB photosynthesis + vdT fluorescence model
- Multiple roots + trunk + multiple branches hydraulics model
- Stomtal models
  - Optimality model (Wang)
  - Empirical models (Ball Berry, Medlyn)

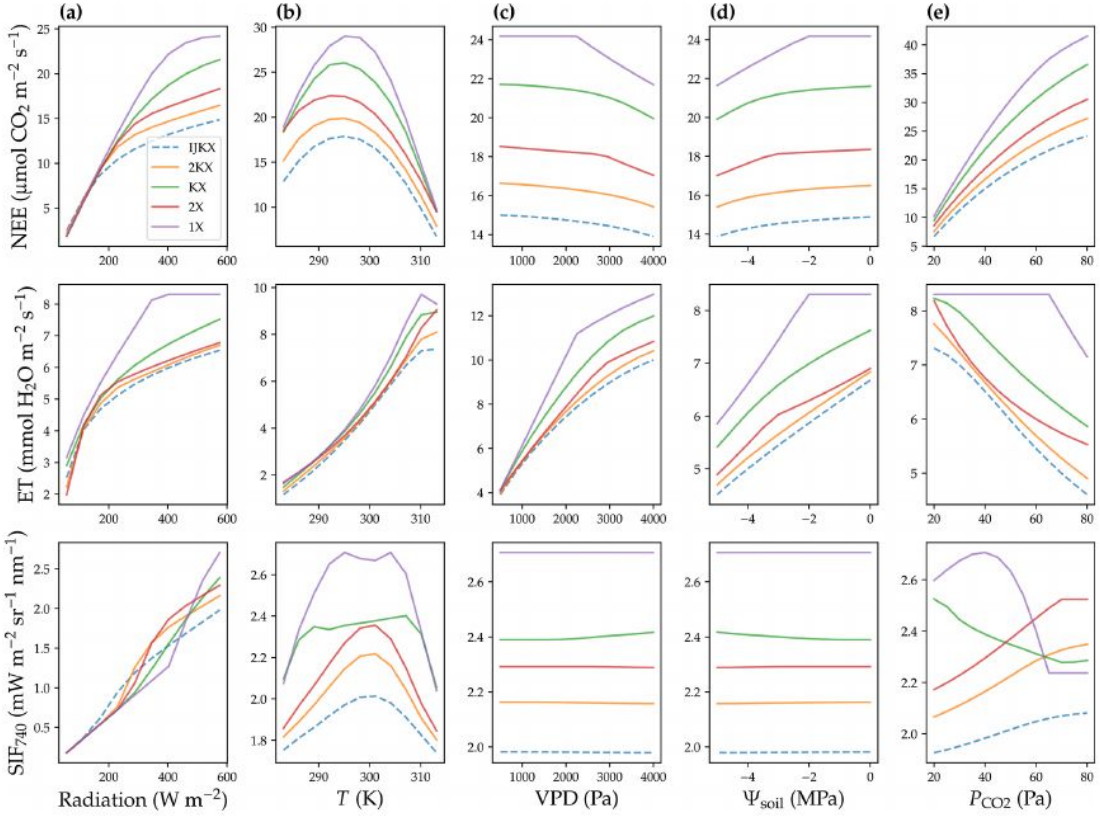
Example 1


(a)
(b)
OSM SIF740 (mW m−2 sr−1 nm−1)
obs SIF740 (mW m−2 sr−1 nm−1)
RMSE = 1.195
RMSE = 0.704
Site LAI
MODIS LAI
RMSE = 0.749
RMSE = 0.543

Example 2: Canopy RT complexity

- N = 1, K = 1
- N = 1, K = 2
- N = X, K = 1
- N = X, K = 2
- N = X, K = I*J + 1

Example 2


(a)
(b)
(c)
(d)
(e)
NEE (μmol CO2 m−2 s−1)
ET (mmol H2O m−2 s−1)
SIF740 (mW m−2 sr−1 nm−1)
IJKX
2KX
KX
2X
1X
Radiation (W m−2)
T (K)
VPD (Pa)
Ψsoil (MPa)
PCO2 (Pa)

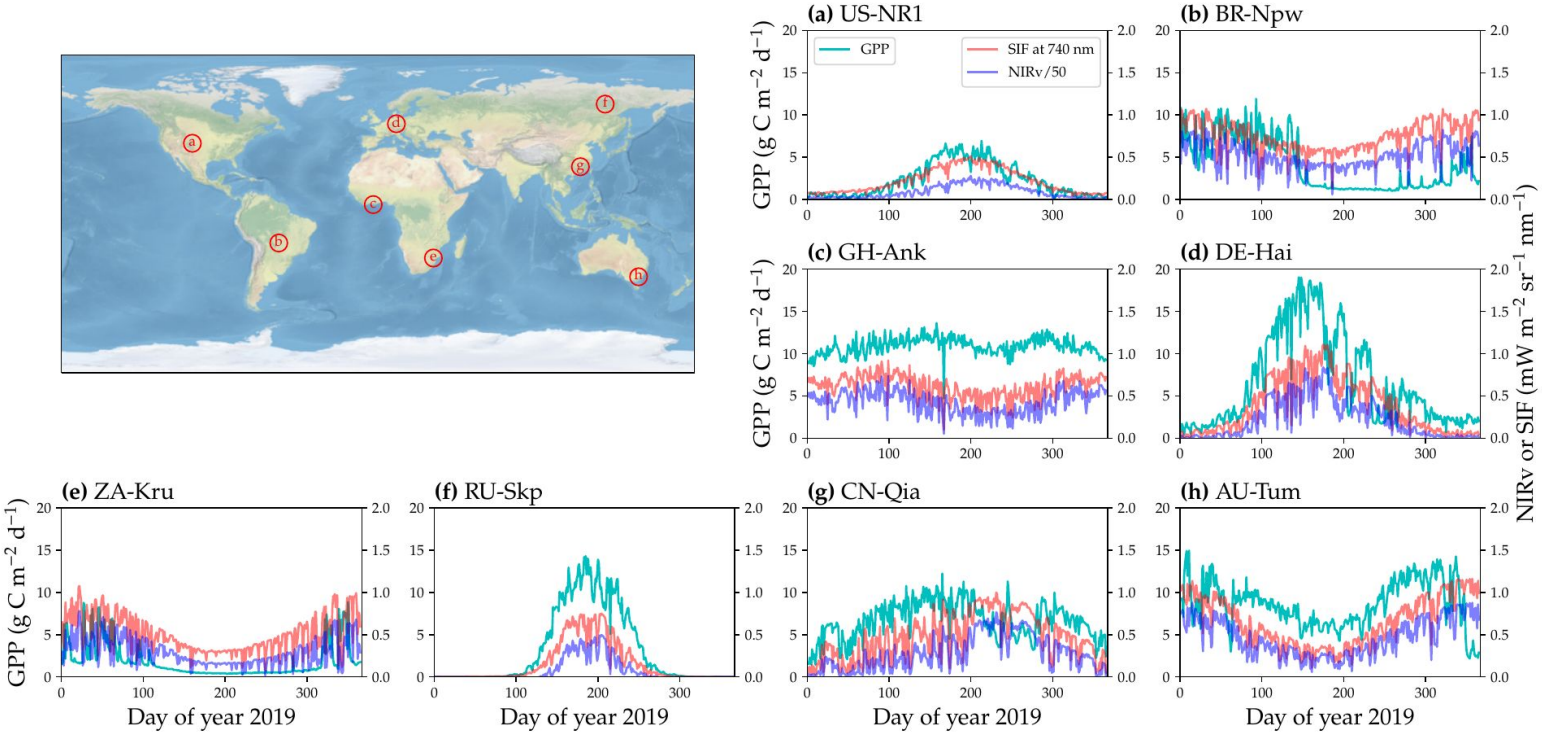
Global simulations

Model selection

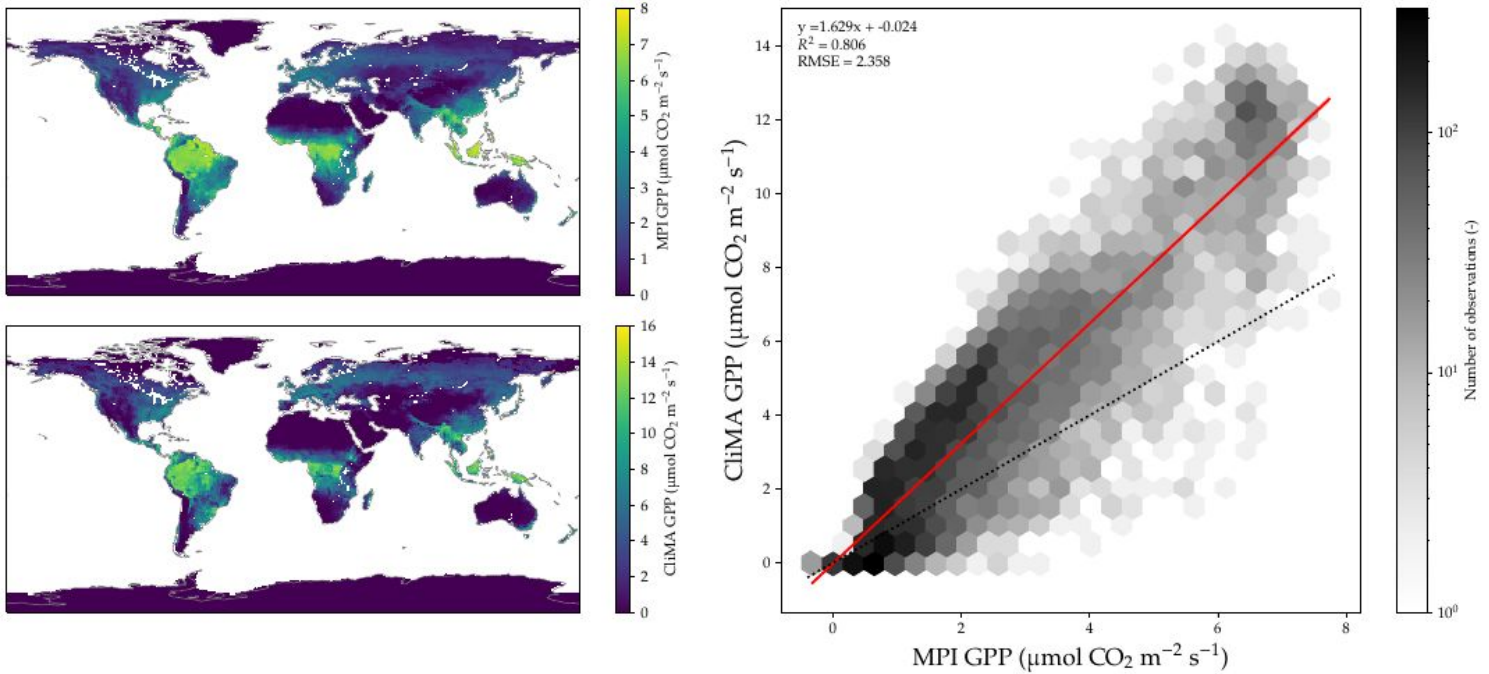
- Hyperspectral canopy RT
- C3 FvCB photosynthesis + vdT fluorescence model
- Multiple roots + trunk + multiple branches hydraulics model
- Medlyn model
- BETA function using soil water content

CliMA Land GPP on a rotating Earth.

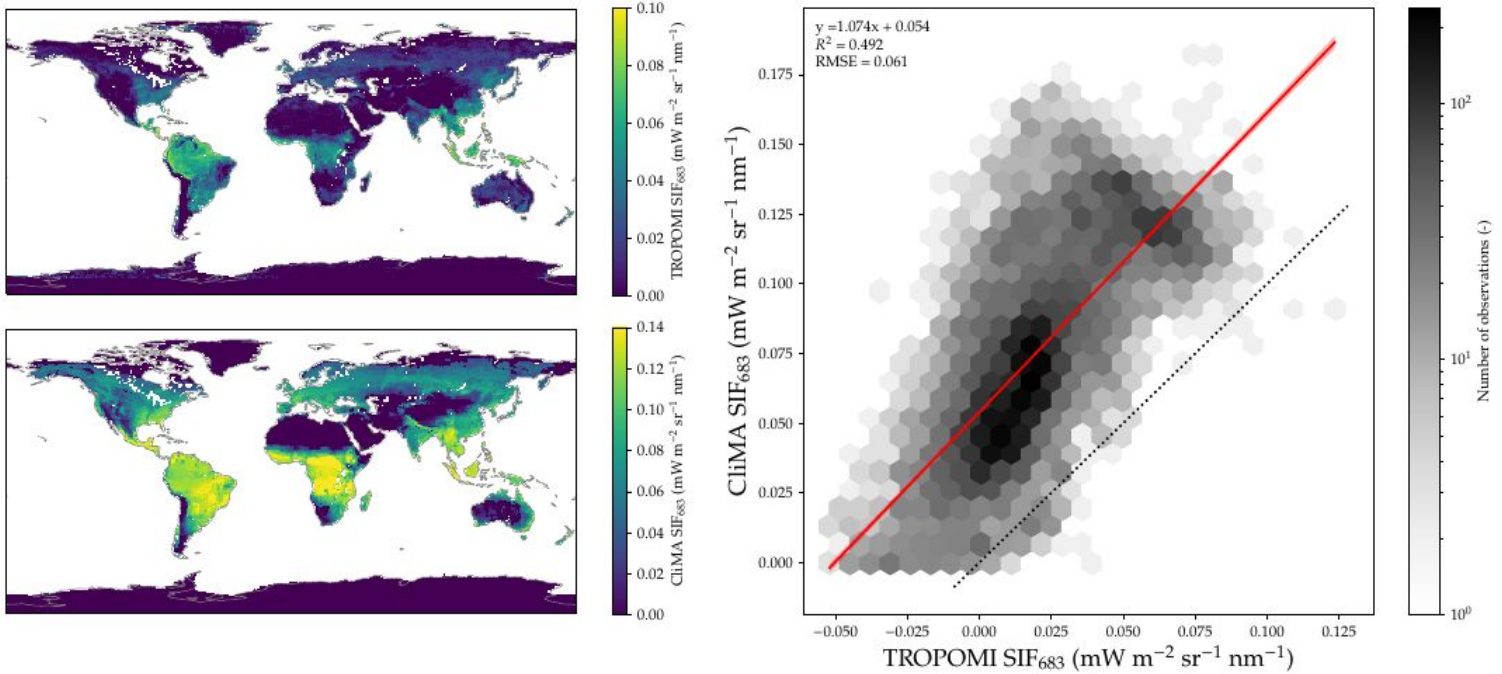
Site level hourly simulation



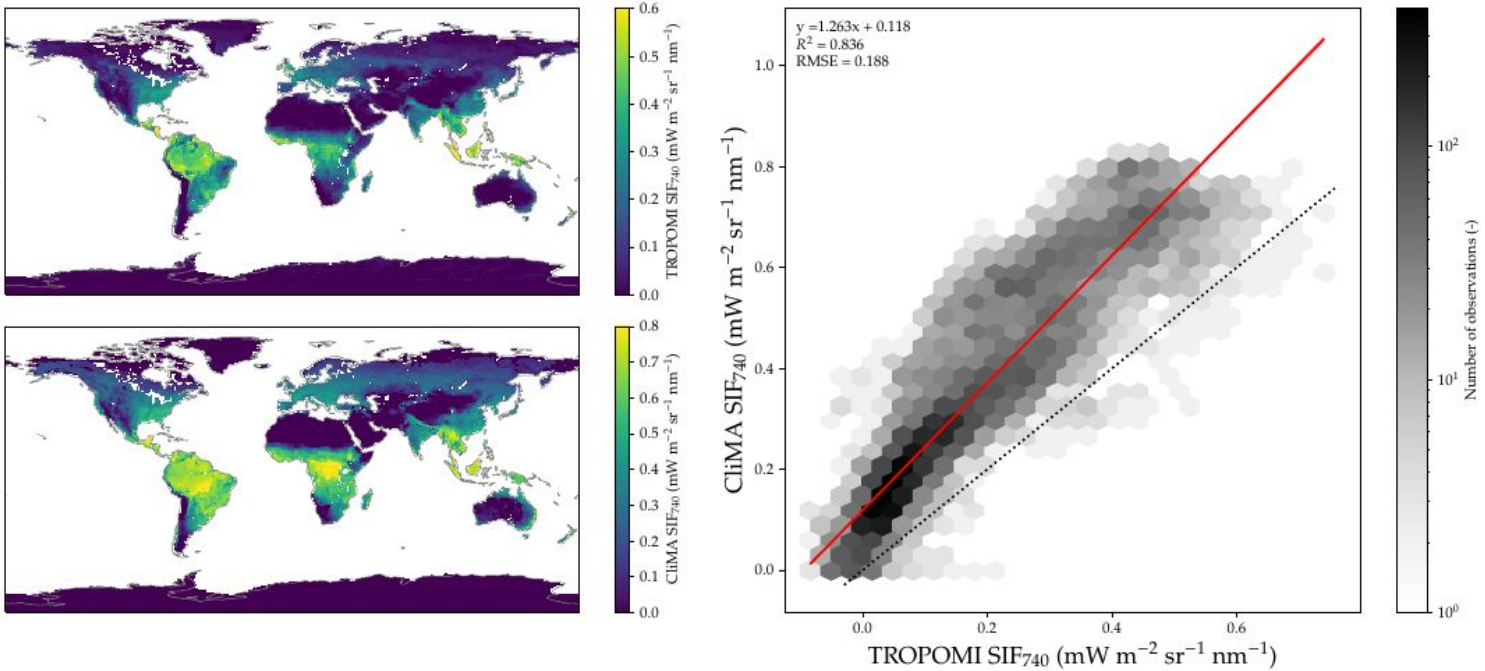
Global scale pattern of GPP



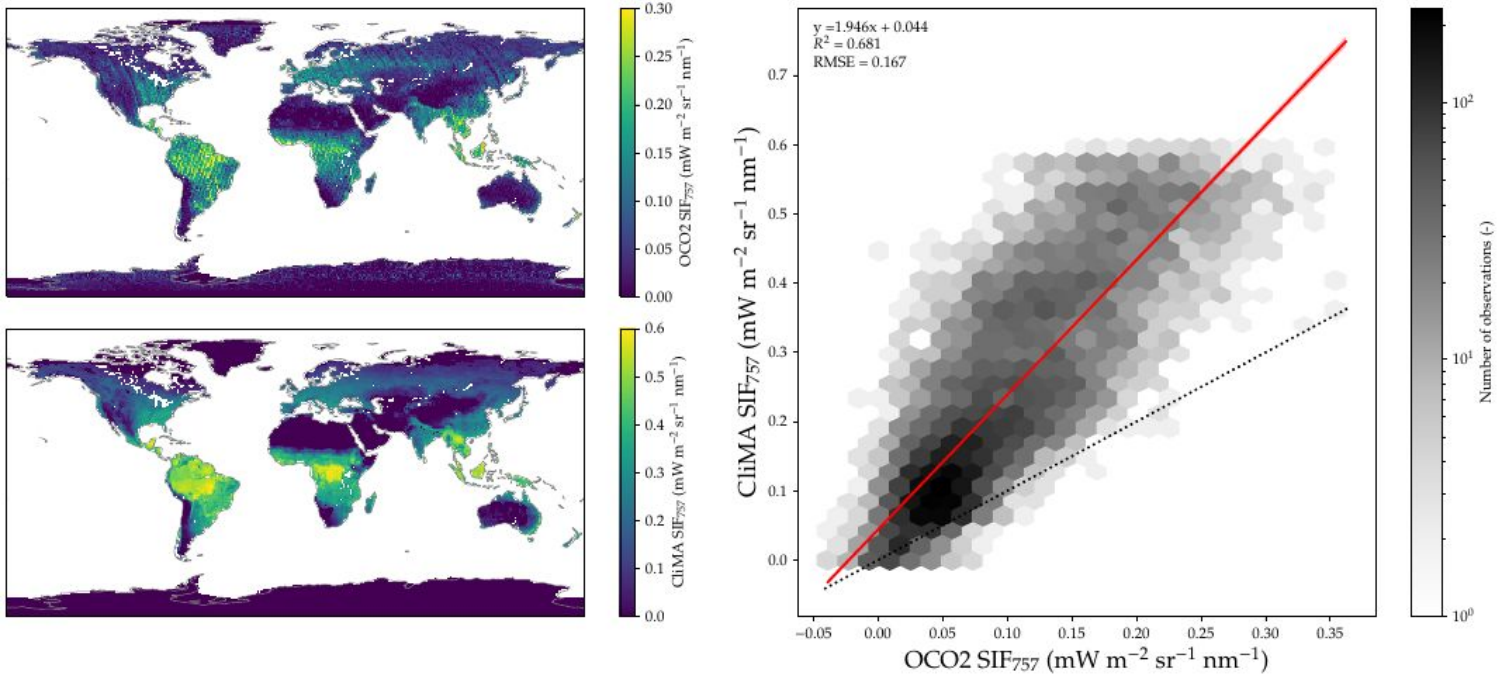
Global scale pattern of SIF_{683}



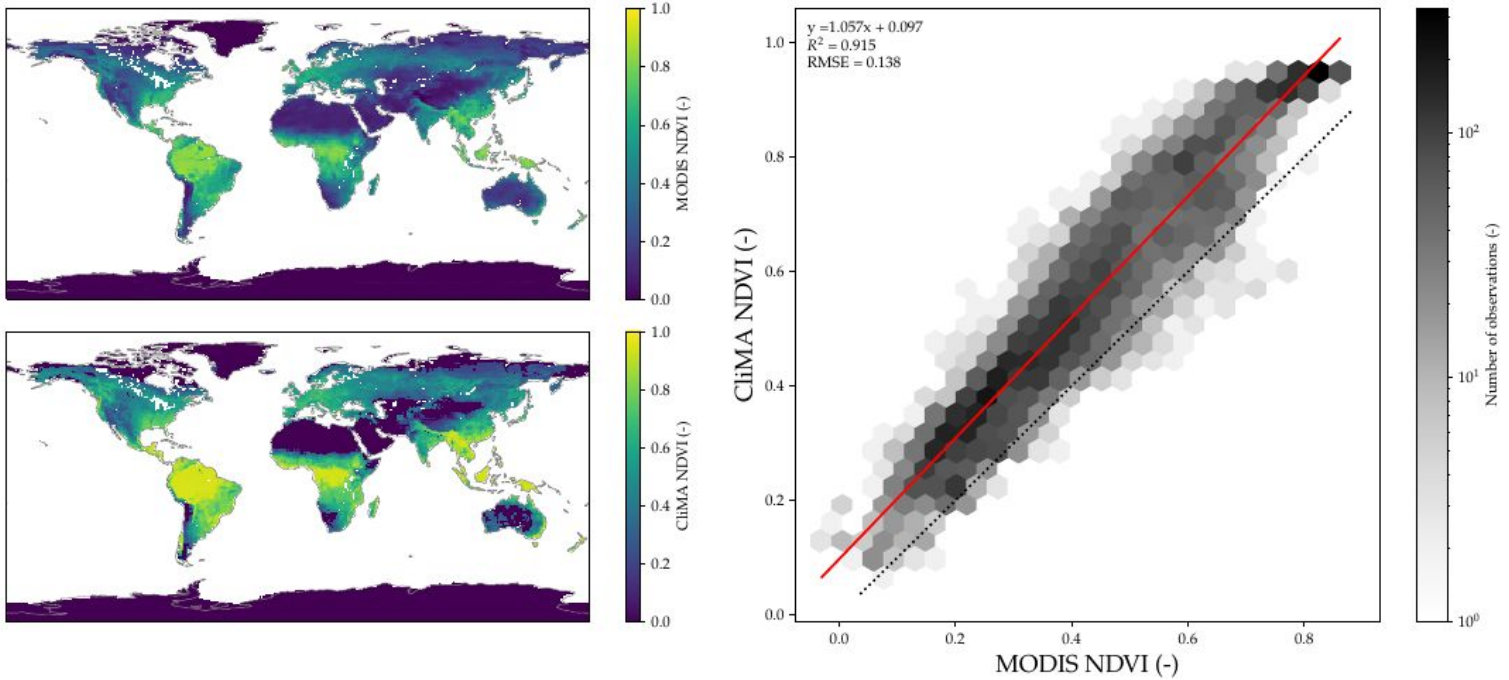
Global scale pattern of SIF_{740}



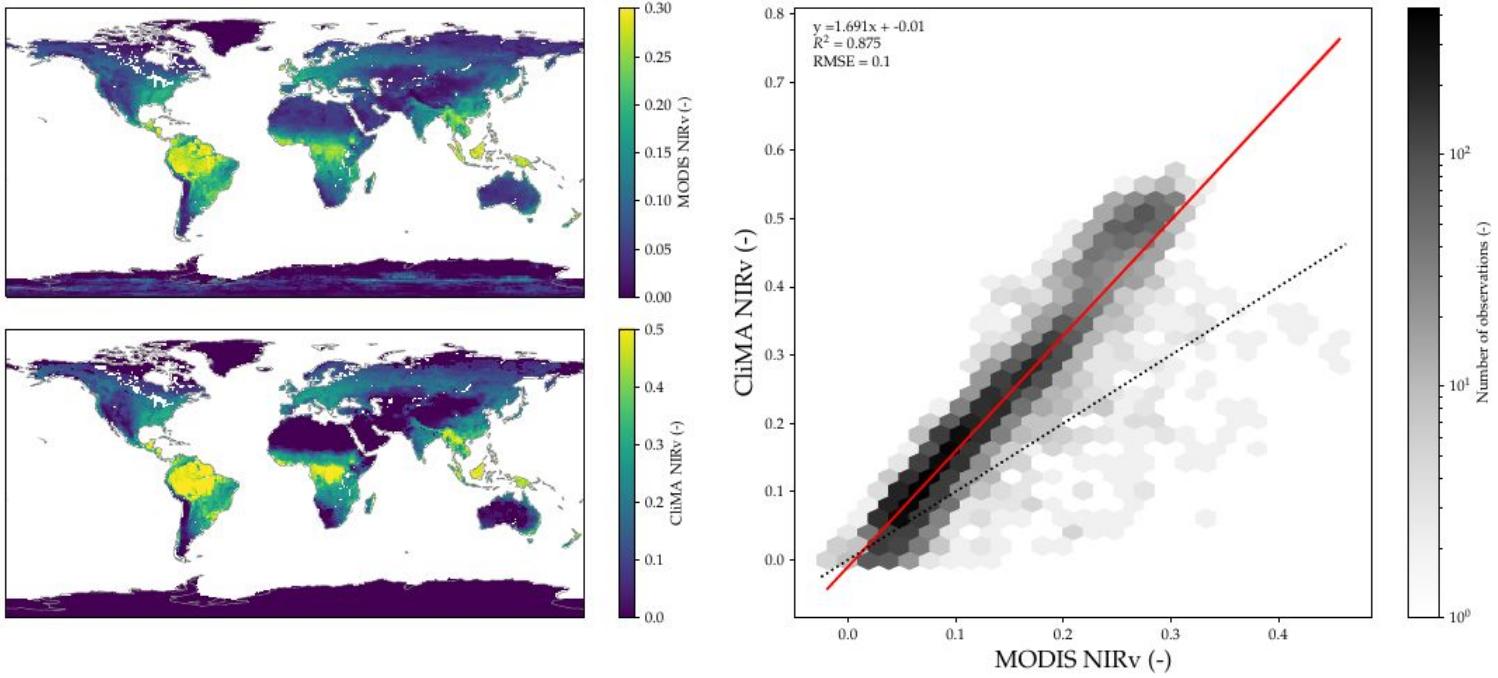
Global scale pattern of SIF_{757}



Global scale pattern of NDVI



Global scale pattern of NIRv



Thanks