# Assessing the impact of recent climate change and rising $CO_2$ on land-atmosphere GHG exchanges in the ABoVE domain

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## I. Introduction

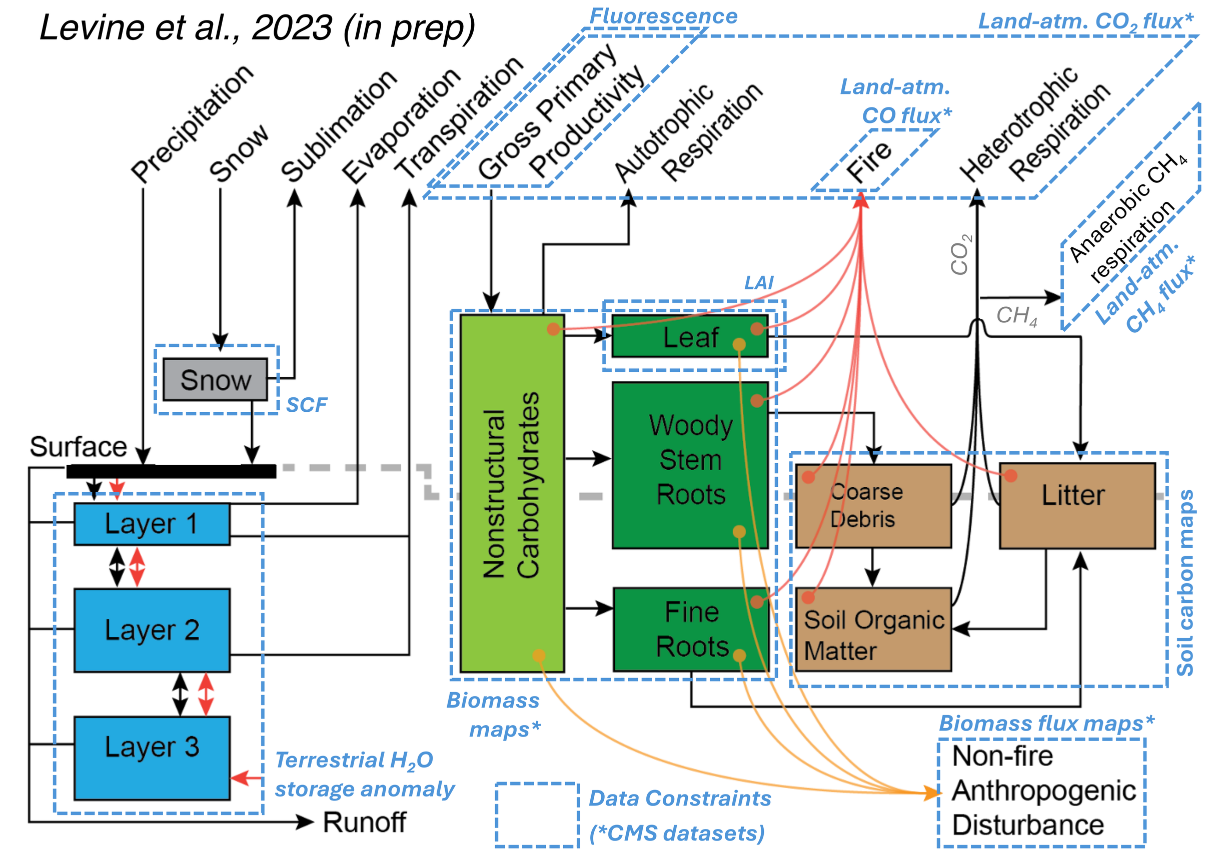
The Arctic has experienced the most rapid change in climate than anywhere else on earth. The wetlands therein are key stores of organic carbon (C), and play a major role in the greenhouse gas balance of high-latitude ecosystems. However, the impact of recent climate change and rising $CO_2$ on Arctic land-atmosphere greenhouse gas exchanges remains poorly understood.

## II. Objectives

To quantitatively assess the carbon feedback to recent climate trends and rising $CO_2$, we use a terrestrial biosphere model (DALEC) and a data-model integration approach (CARbon Data Model fraMework, CARDAMOM) to produce a data-constrained analysis of environmental controls of carbon exchange and its sensitivity to climate and atmospheric $CO_2$ trends at six-teen ABoVE domain high-latitude eddy covariance sites.

## III. Data Model, and data-model fusion

Levine et al., 2023 (in prep)




The CARDAMOM framework uses Bayes' theorem to optimize the posterior probability of initial states and time-invariant process parameters (***y***), given observations ***O***, p(***y***|***O***), as follows: $p(y|O) \propto p(y)p(O|y)$
where p(***y***) is the prior probability distribution of ***y***, and p(***O***|***y***) is proportional to the likelihood of ***y*** given ***O***, L(***y***|***O***). At each tower site, the observation vector ***O*** consists of measurements from *in situ* and satellites.

**Step1.** Optimize biogeochemical process with net $CO_2$, $CH_4$ fluxes and Evapotranspiration (ET) from eddy covariance towers, Above/Below-Ground Biomass, snow cover fraction (SCF), leaf area index (LAI), soil organic carbon, remote sensing using the CARDAMOM Bayesian model-data fusion framework.

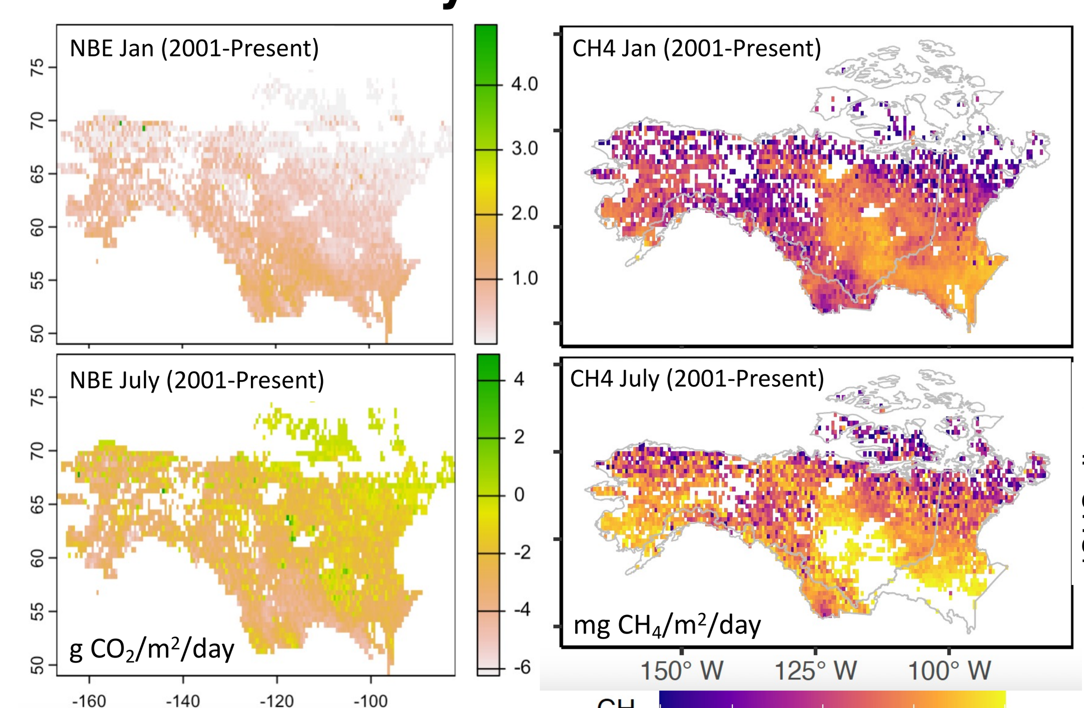
**Step2.** Use the observation-informed CARDAMOM analysis to characterize and quantify the carbon feedback to recent climate trends and rising atm $CO_2$

S2.1 Detrend on month-to-month basis to construct detrended climate drivers ($Met_{detrended}$)
S2.2 Run CARDAMOM_RUN_MODEL with Met and $Met_{detrended}$
S2.3 Impact of 2001-present climate and atm $CO_2$ trend on NBE, $CH_4$, and their combined sustained-flux global warming potential (SGWP):

ΔCH4_Climate = CARDAMOM_RUN_MODEL(x, Met ) - CARDAMOM_RUN_MODEL(x, Met_detrend ) (3.1)
ΔNBE_Climate = CARDAMOM_RUN_MODEL(x, Met ) - CARDAMOM_RUN_MODEL(x, Met_detrend ) (3.2)
ΔCH4_atmCO2 = CARDAMOM_RUN_MODEL(x, Met, atmCO2 ) - CARDAMOM_RUN_MODEL(x, Met, atmCO2_detrend ) (3.3)
ΔNBE_atmCO2 = CARDAMOM_RUN_MODEL(x, Met, atmCO2 ) - CARDAMOM_RUN_MODEL(x, Met, atmCO2_detrend ) (3.4)

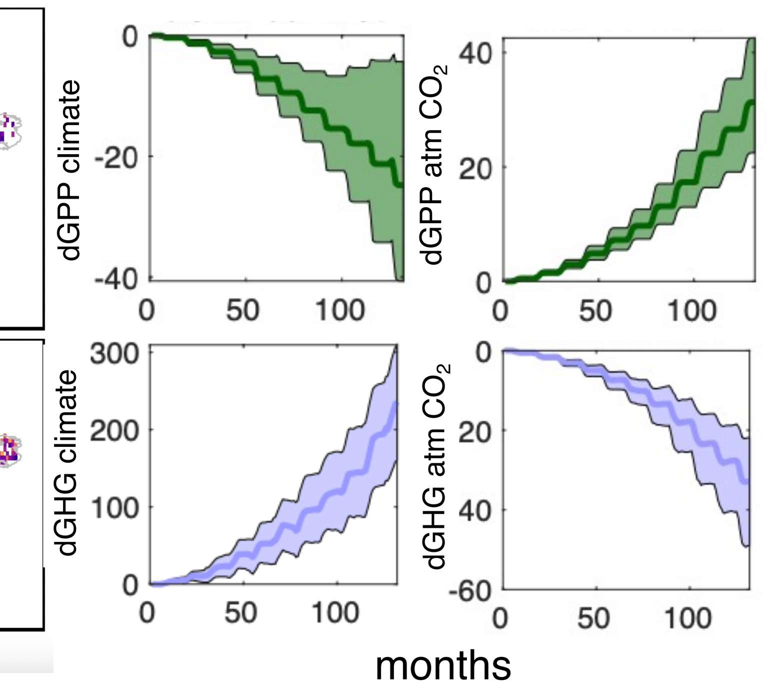
## IV. Results

### ABoVE domain NBE and $CH_4$ map constrained by satellite observations

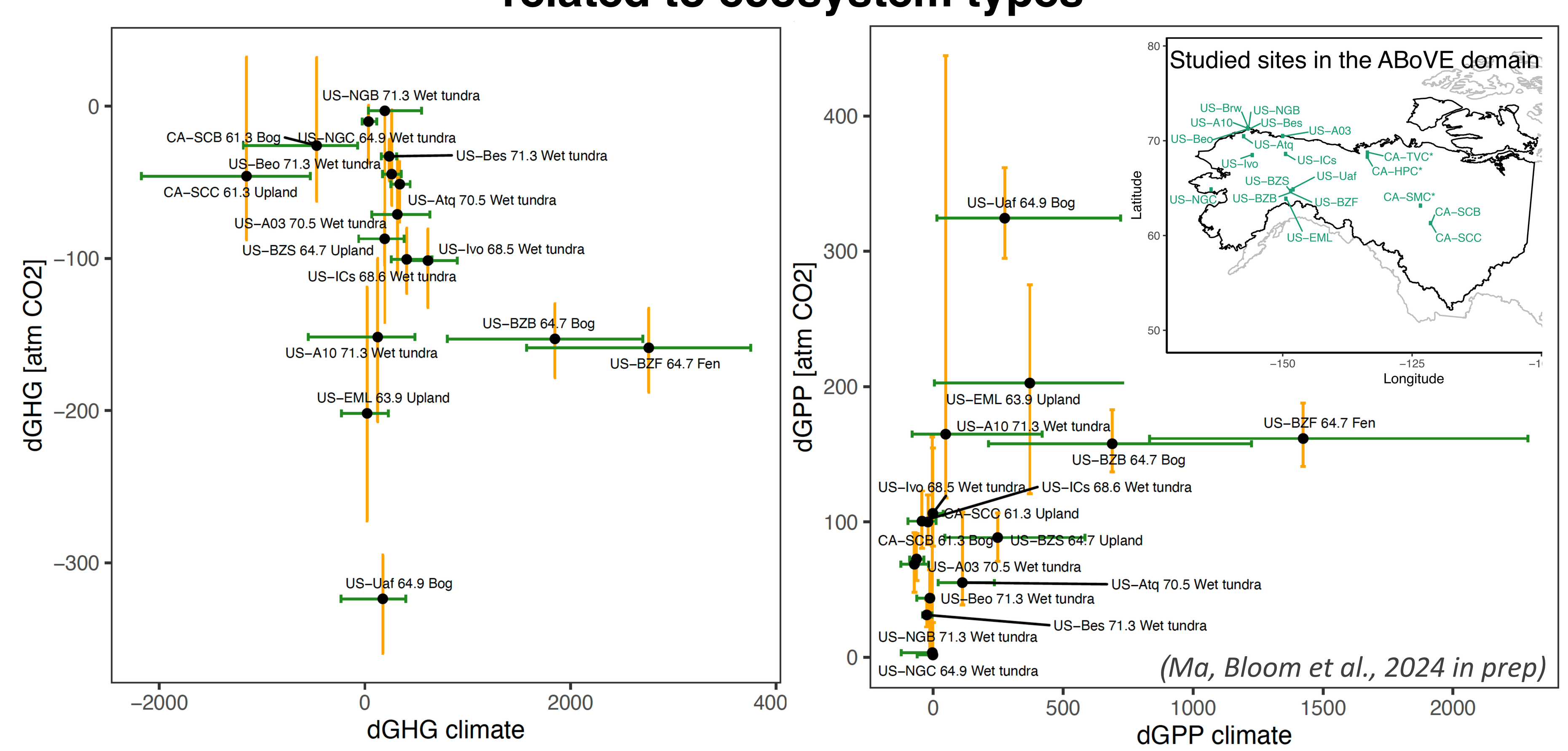



(Ma, Bloom et al., 2024 in prep)

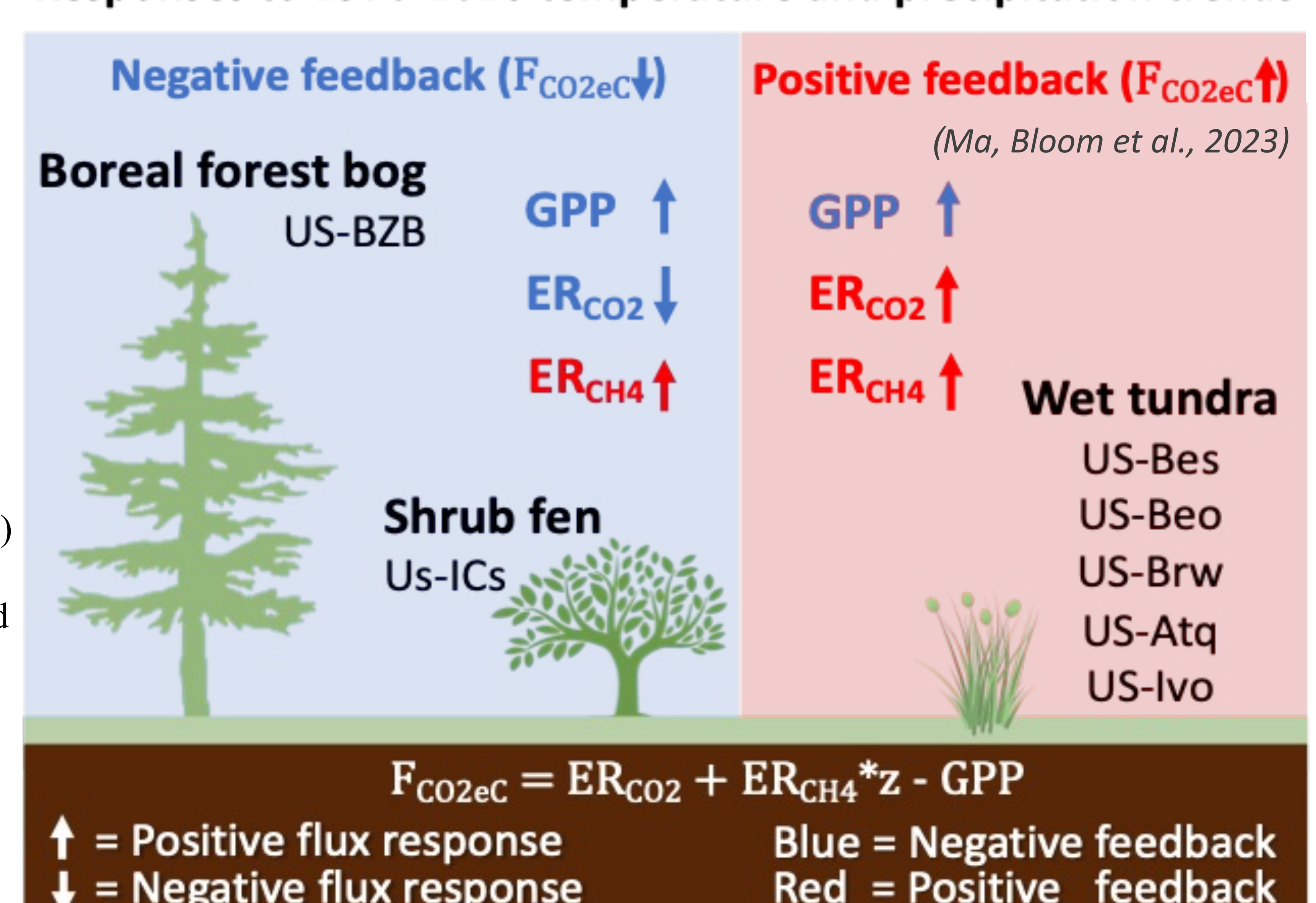
### Accumulated impact of climate and atm$CO_2$ to GHG & GPP




### The impact of 2001-present climate and CO2 trend is strongly related to ecosystem types




### Responses to 1970-2016 temperature and precipitation trends




Biogeochemical insight of carbon fluxes responses to continuation of 1970-2016 trends in temperature and precipitation, comparing three different wetland types investigated in Ma et al 2023.

## V. Conclusions

- We use in-situ measurements to constrain the modeled joint climatic sensitivity of land-atmosphere CH4 and CO2 exchanges.
- Phase I study: A continued 1970-present climate trend leads to positive C-climate feedback in wet tundra sites, but negative feedback in boreal and shrub fen sites.
- Phase II study: The impact of 2001-present climate and $CO_2$ trend is strongly related to ecosystem types.

## VI. Next steps

- Here we presented the phase I and II of the NASA ABOVE funded project "Using CO2, CH4 and land-surface observations to resolve the sign and magnitude of northern high latitude carbon-climate feedbacks"
- The next step is to calibrate domain wise 0.5 degree CARDAMOM fluxes using WRF-Chem and atmospheric $CH_4$ and $CO_2$ measurements. Ultimately it'll answer questions: How do ABoVE domain ecosystem CO2 and CH4 fluxes respond to climatic variability? Will the ABoVE domain CH4 and CO2 flux responses to projected climate changes induce positive or negative carbon-climate feedbacks?

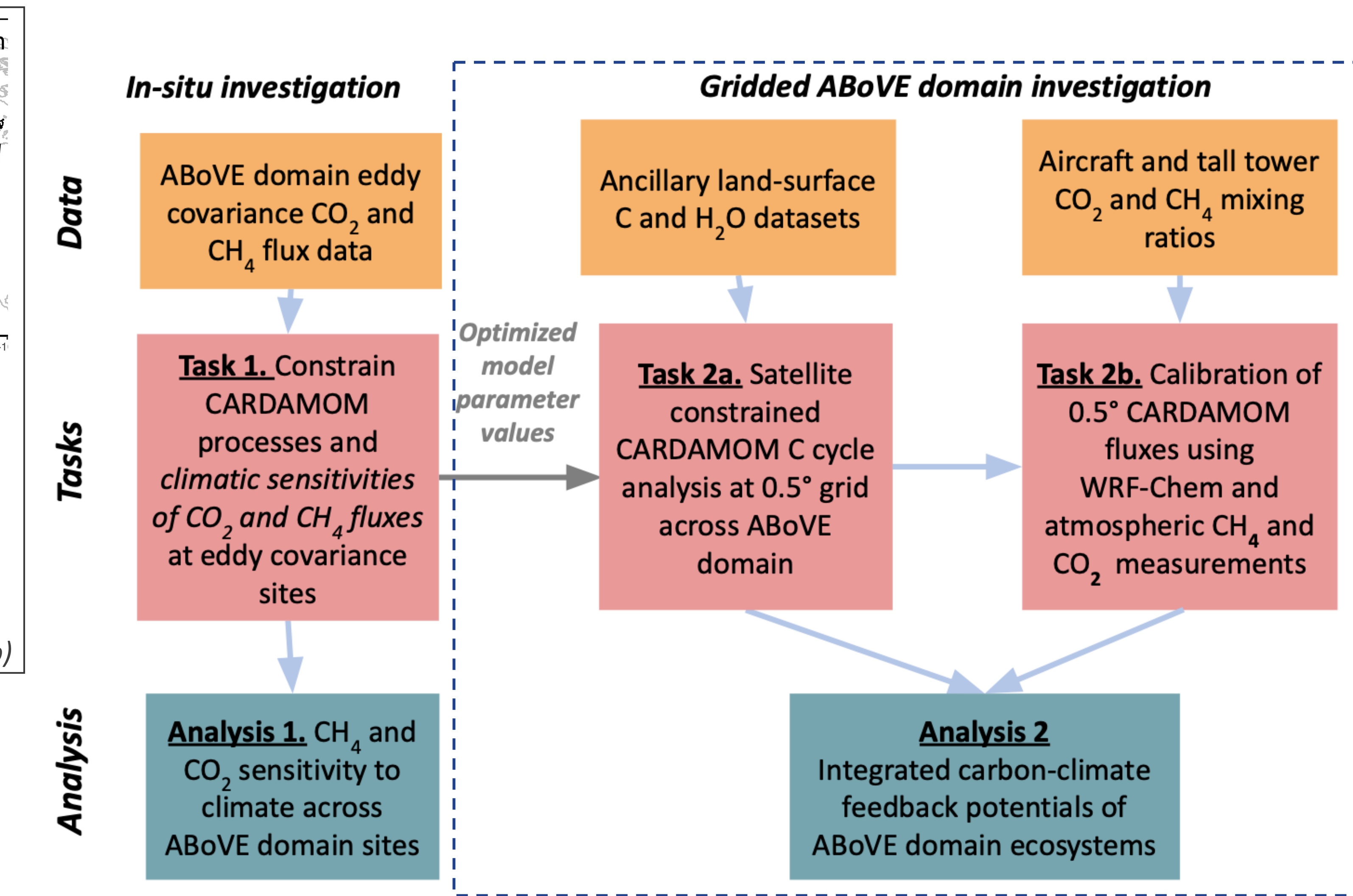



Figure 6. Flowchart for proposed scientific tasks, data, steps and analyses

**Acknowledgements**

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