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Estimating soil organic carbon stocks with ensemble Kalman Filter methods

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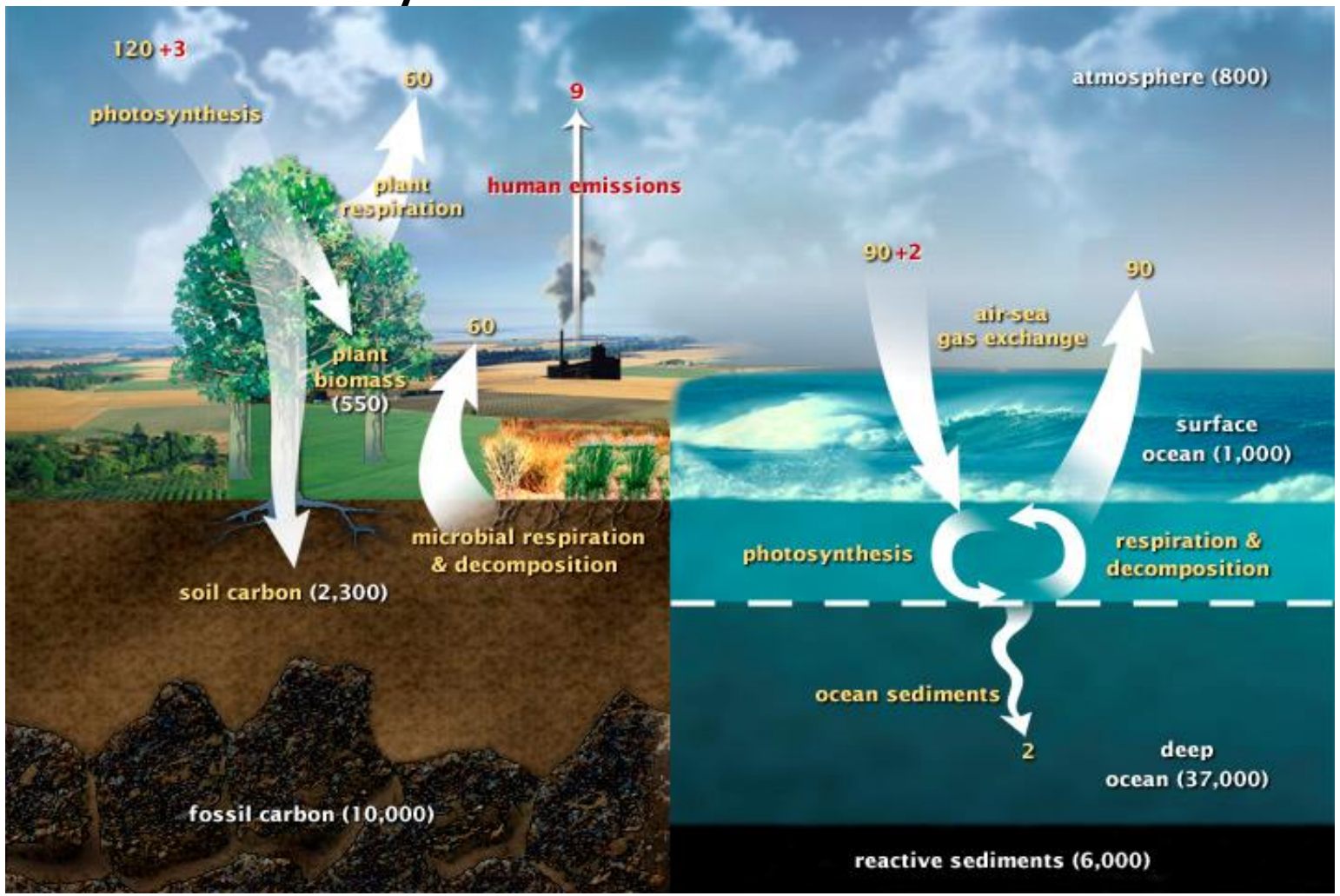
Presentation structure

1. Background and context on the system
   - What are the constraints on our efforts to project soil organic carbon stocks?
2. What have we done so far?
   - Not much
3. What are our plans to tackle the multitude of challenges?
   - Preliminary stages at the moment, but already started with the setup

Vegetation is a critical component in the global carbon cycle



Picture: https://earthobservatory.nasa.gov/features/CarbonCycle

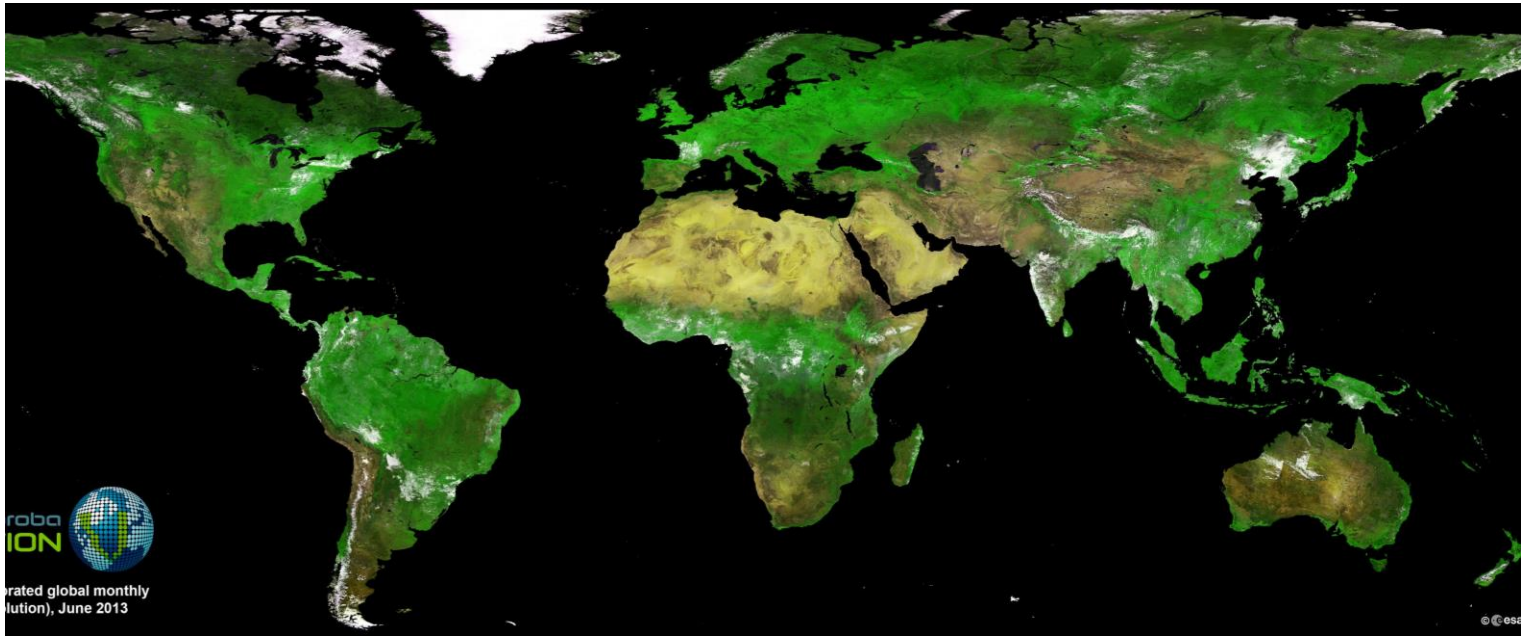
Vegetation decomposition deposits carbon into the soil which is the largest terrestrial carbon pool

There are numerous projects at the moment focusing on estimating/improving global soil organic carbon (SOC) stocks

- National Greenhouse inventories must include SOC approximations
- The international “4 per 1000” initiative aims to increase the SOC allocation in agricultural lands by 4 promilles
- There are numerous projects across the world focusing on how different management approaches affect SOC stocks
- This is one of the potential components in the carbon credit markets

When it comes to approximating SOC stocks, there are three central challenges

- Difficulty to measure
- Spatial heterogeneity
- Challenges in both assessing model dynamics as well as initialization

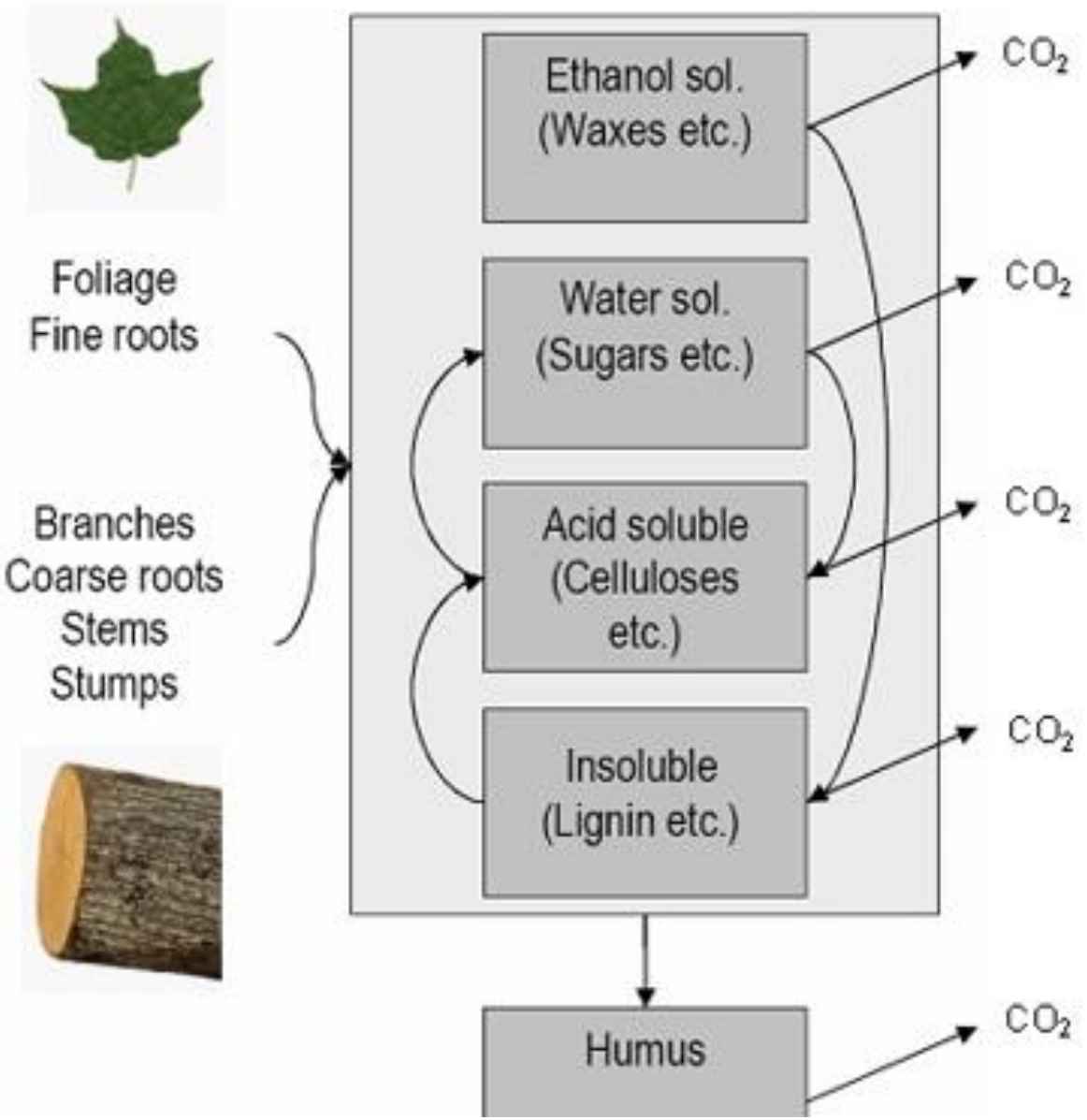


There are multiple possible observations of surface vegetation, but all have their own limitations

With SOC measurements, the options are very limited

Even in a small area, there can be large changes in state

Additionally, vast majority of the SOC measurements are total SOC while models need a more nuanced state for their dynamics



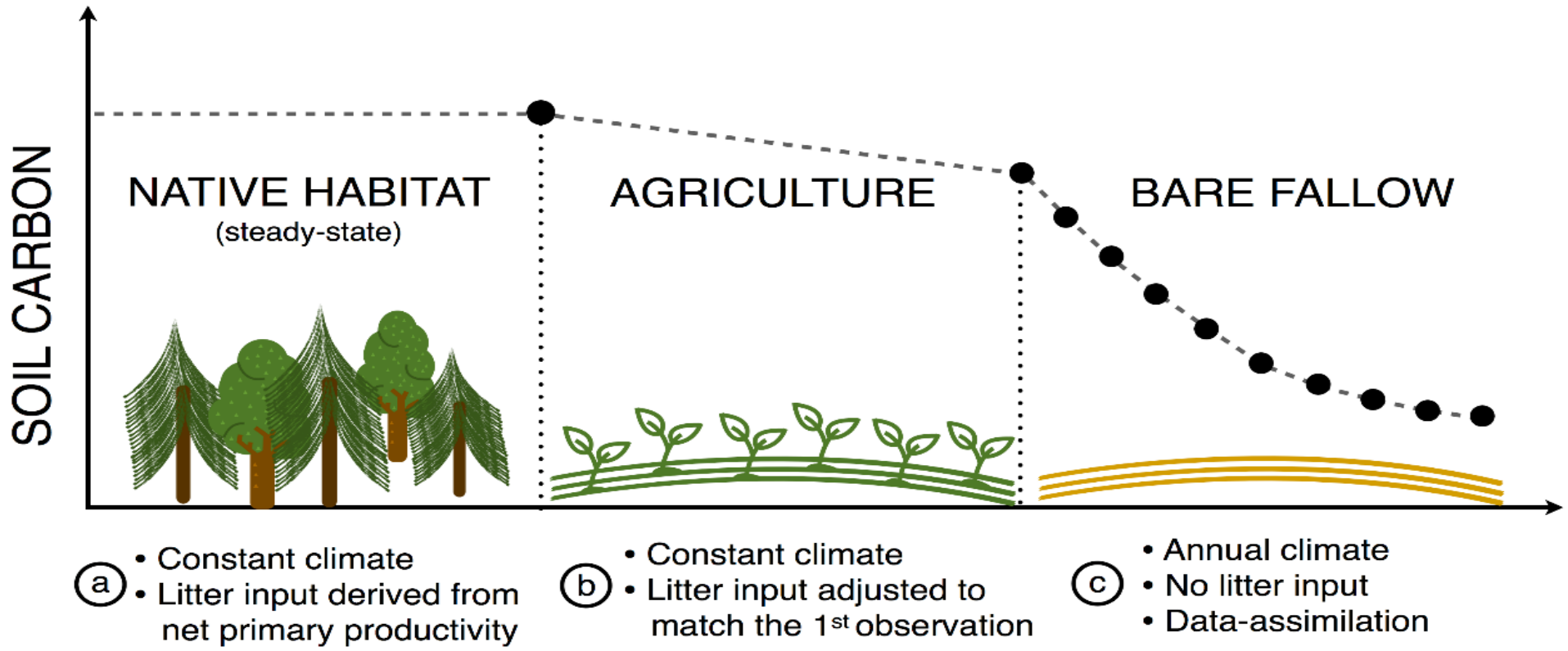
There’s a lot of noise in SOC observations and the system dynamics are slow

- Initial states have to be determined often be modeled from assumed driver conditions
- As a consequence, it is difficult to even assess when we should expect to see the changes from different soil treatments or changing environments while the projection uncertainties themselves are huge
- This is a fundamental challenge when weighing different farm management options or when calculating carbon credits

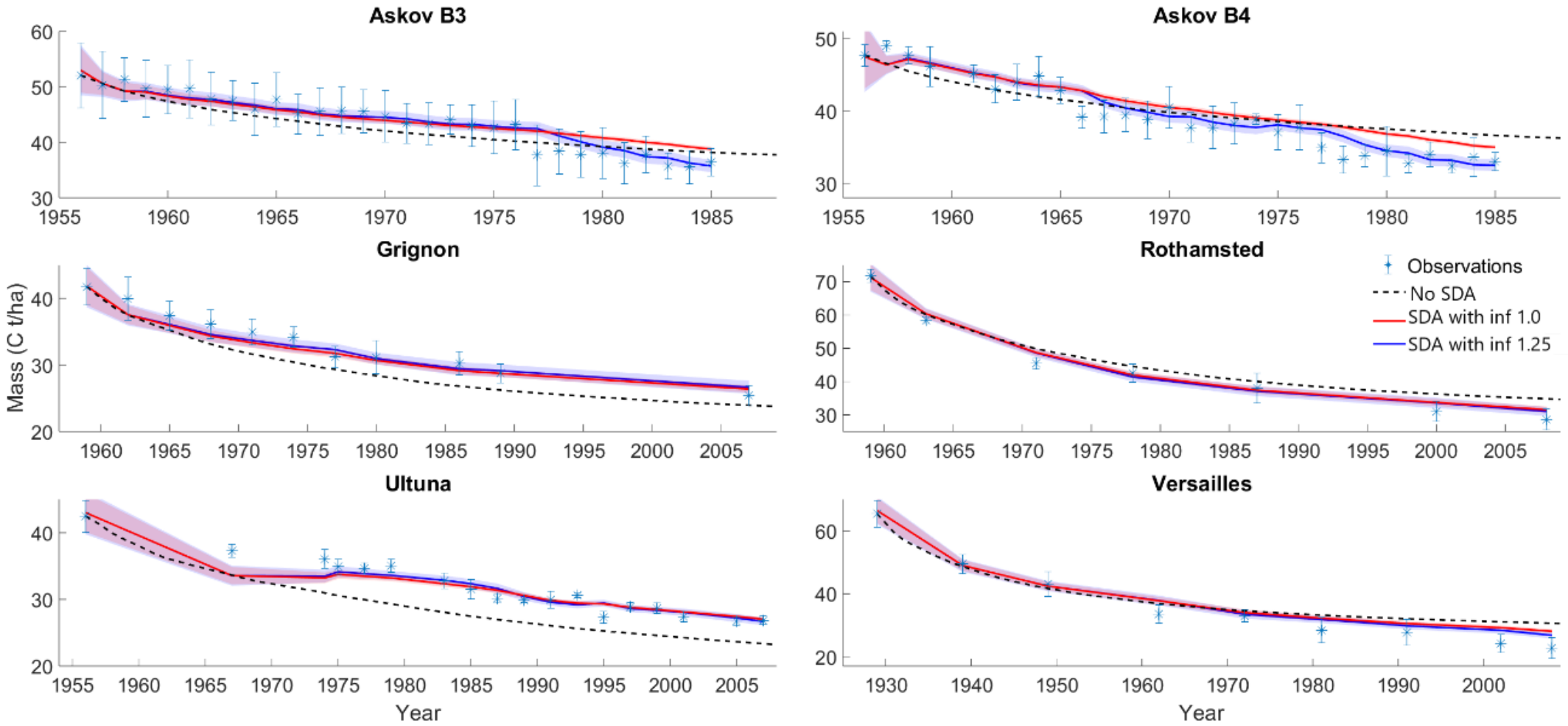
We did a preliminary study on how state data assimilation can improve future SOC projections

- Six fallow sites from across Europe were chosen for the experiments
  - Farm plots where all the vegetation is removed and total SOC measured at various points over 20-50 years at different time intervals
  - No litter input, experiment to see how the SOC decomposes
- Our own Yasso SOC model was used as the model
  - First order dynamics model where the SOC decomposition is driven by the climate conditions
- Ensemble Adjustment Kalman Filter (EAKF) was used as the SDA method

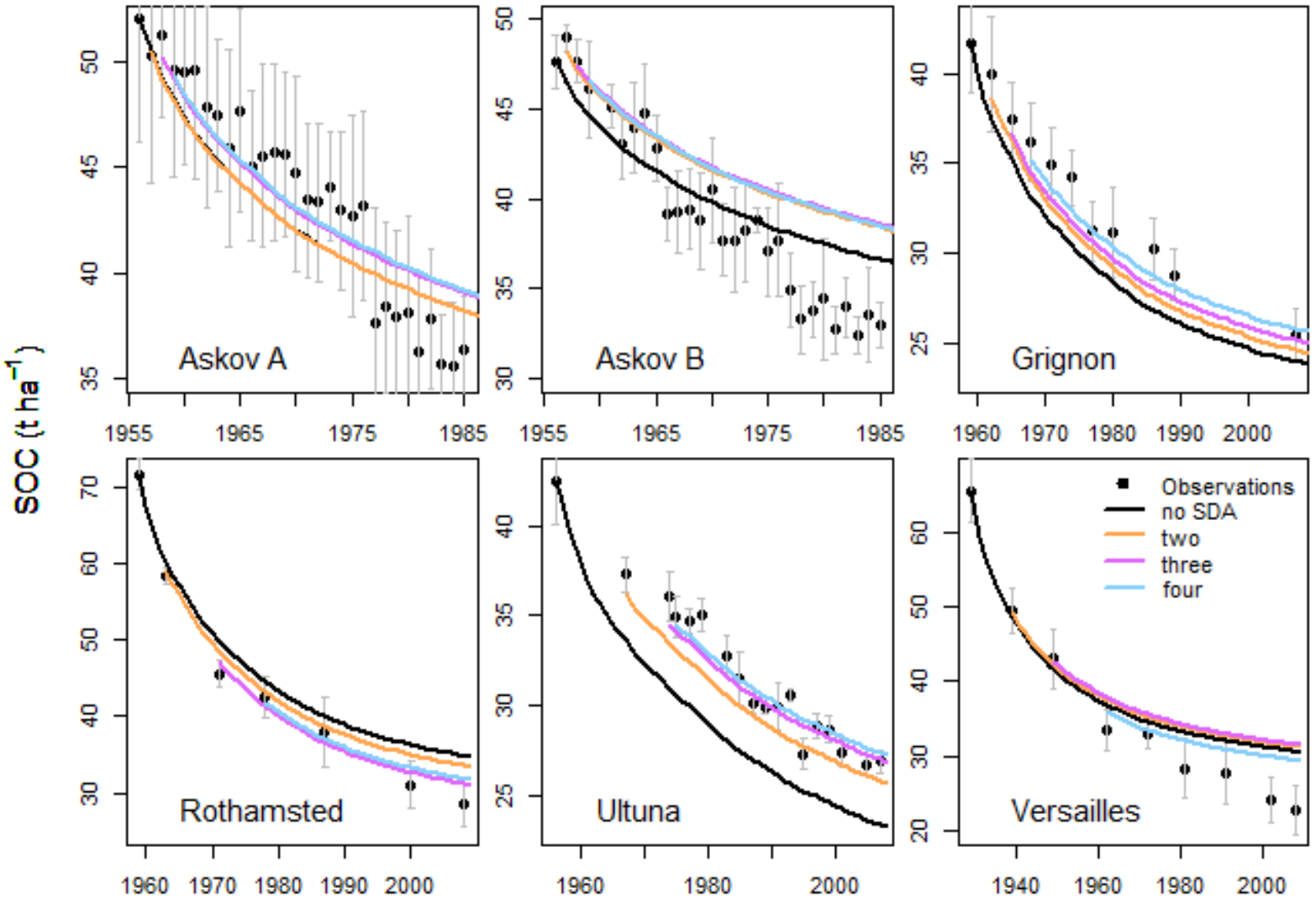
The initialization of the agricultural SOC requires multiple assumptions



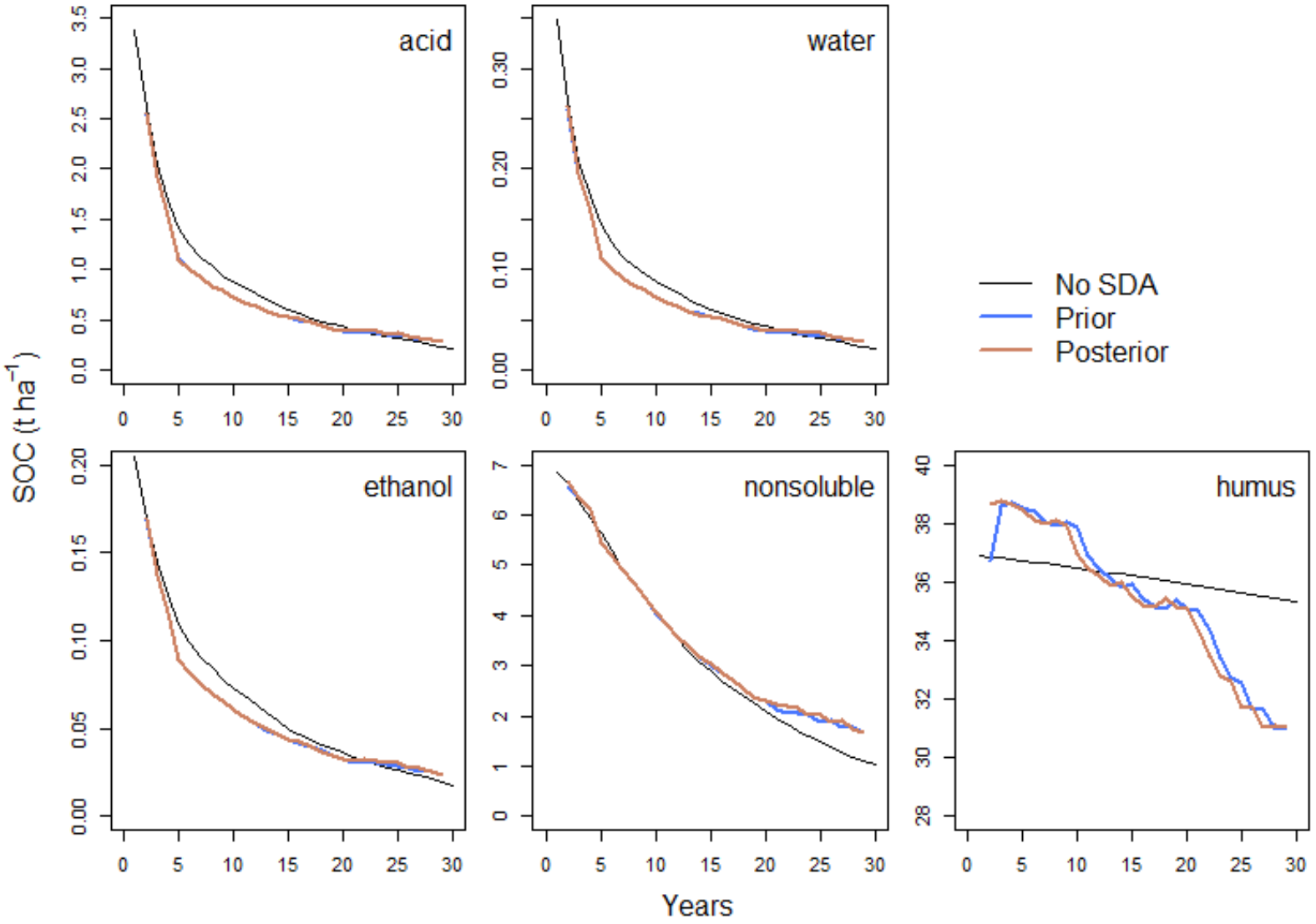
System dynamics are so slow that with frequent observations inflation was necessary



Even the assimilation of the first few measurements showed meaningful improvement at the non-Askov sites



Closer examination of Askov results did show that assimilating the rough measurements can produce unrealistic states



This was naturally a very limited initial test with numerous aspects to be added

- No litterfall
- Sites independent of each other and only one observation assimilated at each analysis
- Far more observations we will have in practical applications
- Currently planning on running 4DEnKF, but will need to evaluate how uneven observation time series will affect the unobserved state

Carbon allocation in agriculture is inherently not a spatially continuous system

This, combined with the resources required for measurements, raises several challenges

- How many farms within a region need to be measured?
- At what distance, be it spatial or variable, does measurements from one farm benefit estimates of another?
- With limited resources available, how often should SOC at one location be measured? How does the times when measured affect projection accuracy?

We are setting up an OSSE system to at least get approximations of what should be done

- Straight-forward to set up for a single farm, but need to be really careful how to implement for multiple farms
- Allows us to at least provide best information available for partners to plan different measurement campaigns as well as provide uncertainty ranges for carbon credit markets
- Nothing beats real data, though

Two positions related to these kinds of studies are opening at FMI

- One more focused on vegetation model aspects, other on soil carbon allocation
- Post doc or PhD student level
- More information can be found at FMI open positions page or just contact me at toni.viskari@fmi.fi
- If you know anyone who might be interested, please share
- Application deadline on June 13