How to spin-up the slow components of JULES

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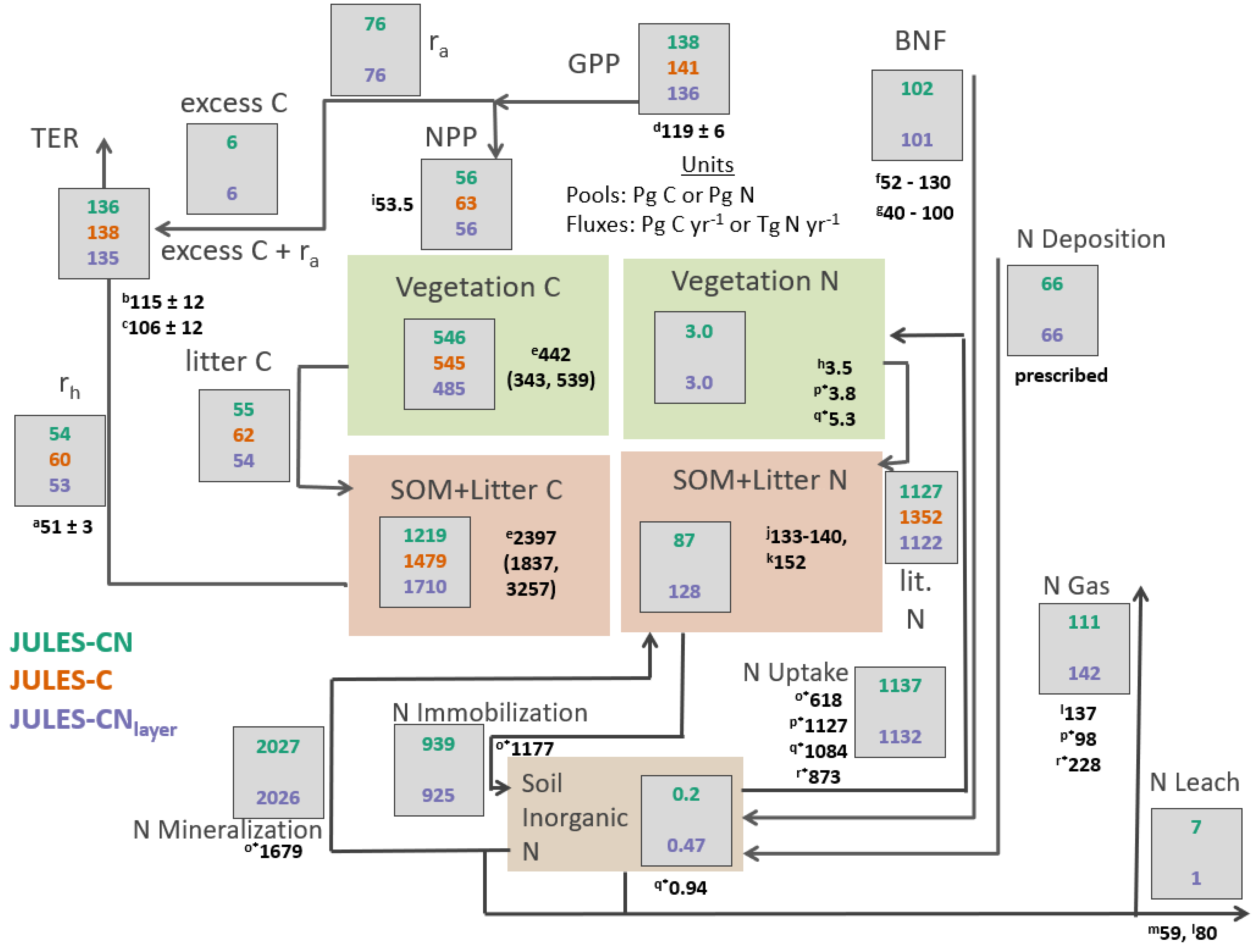
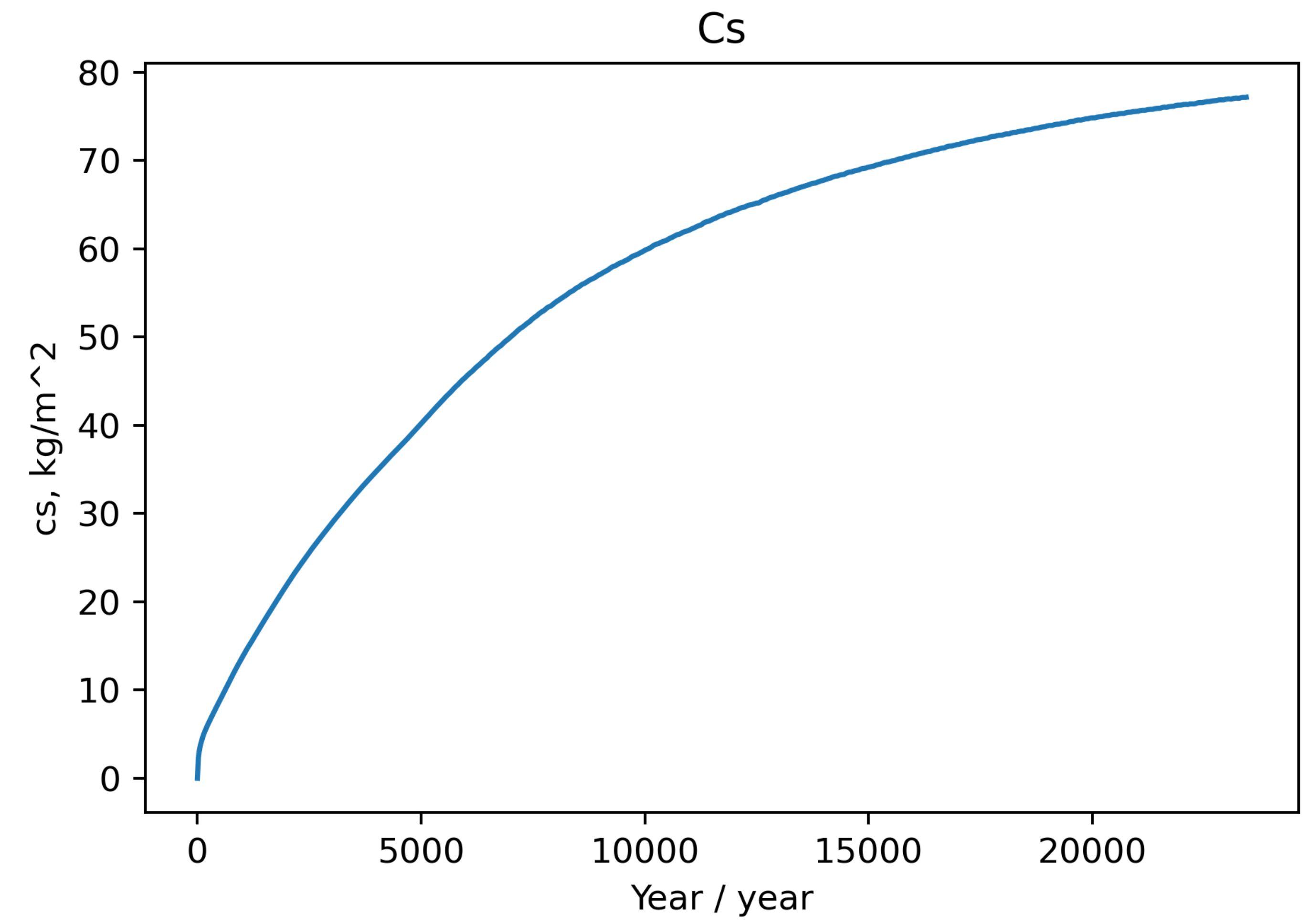
JULES set-up

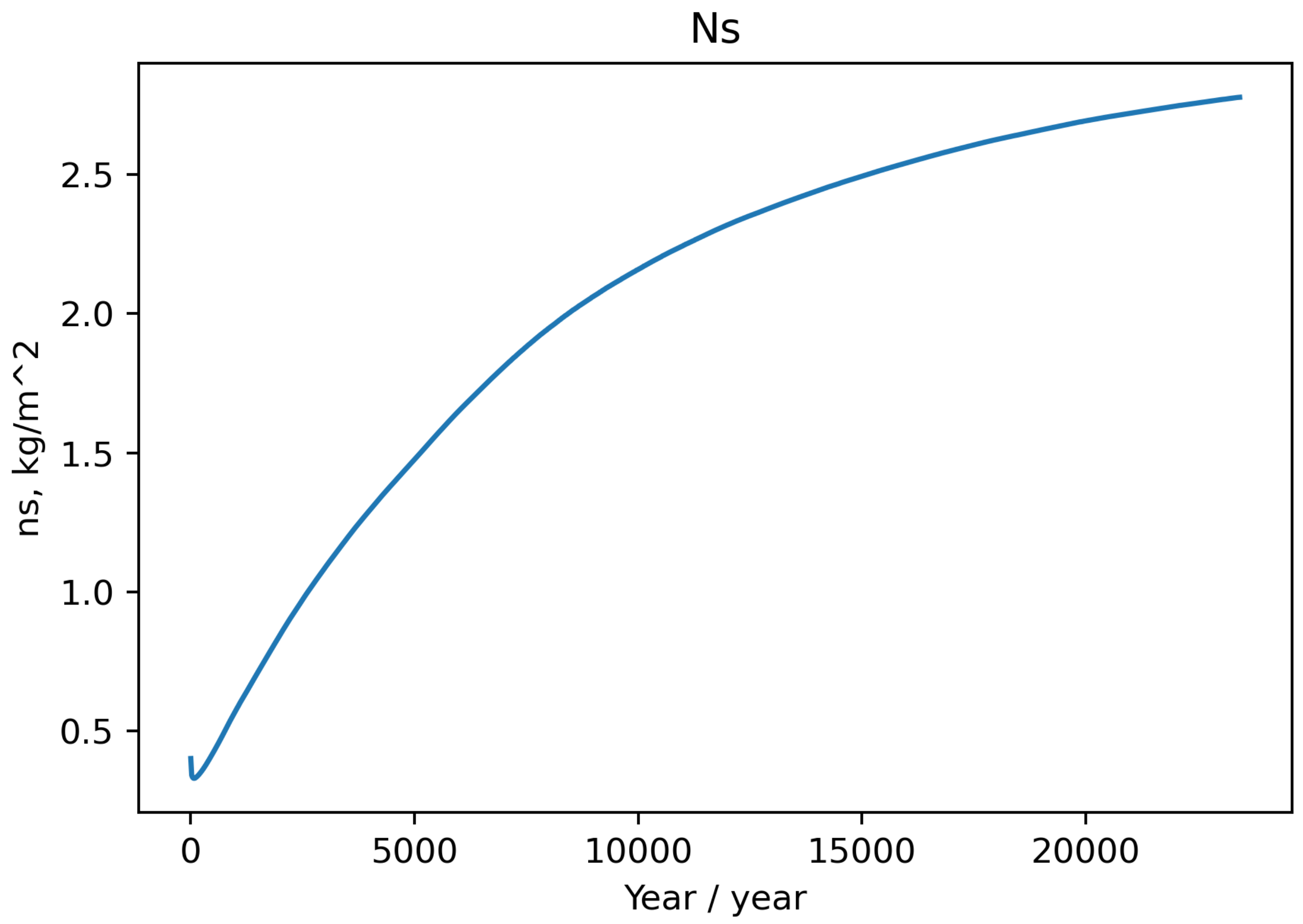
- JULES-ES based:
  - includes nitrogen cycle
  - no fire
- 20 soil levels
- Depth-varying soil carbon and nitrogen
- Bedrock heat sink

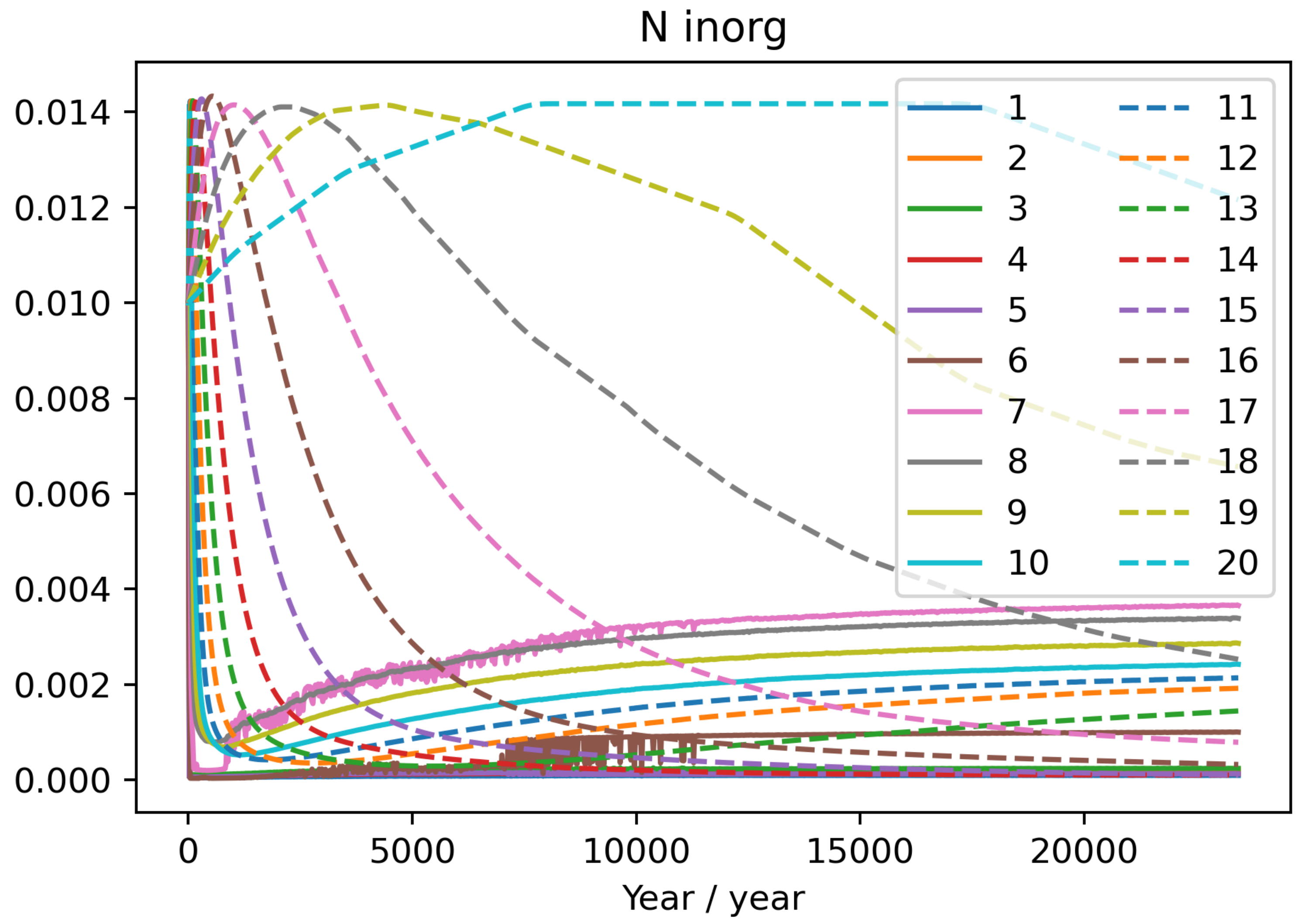


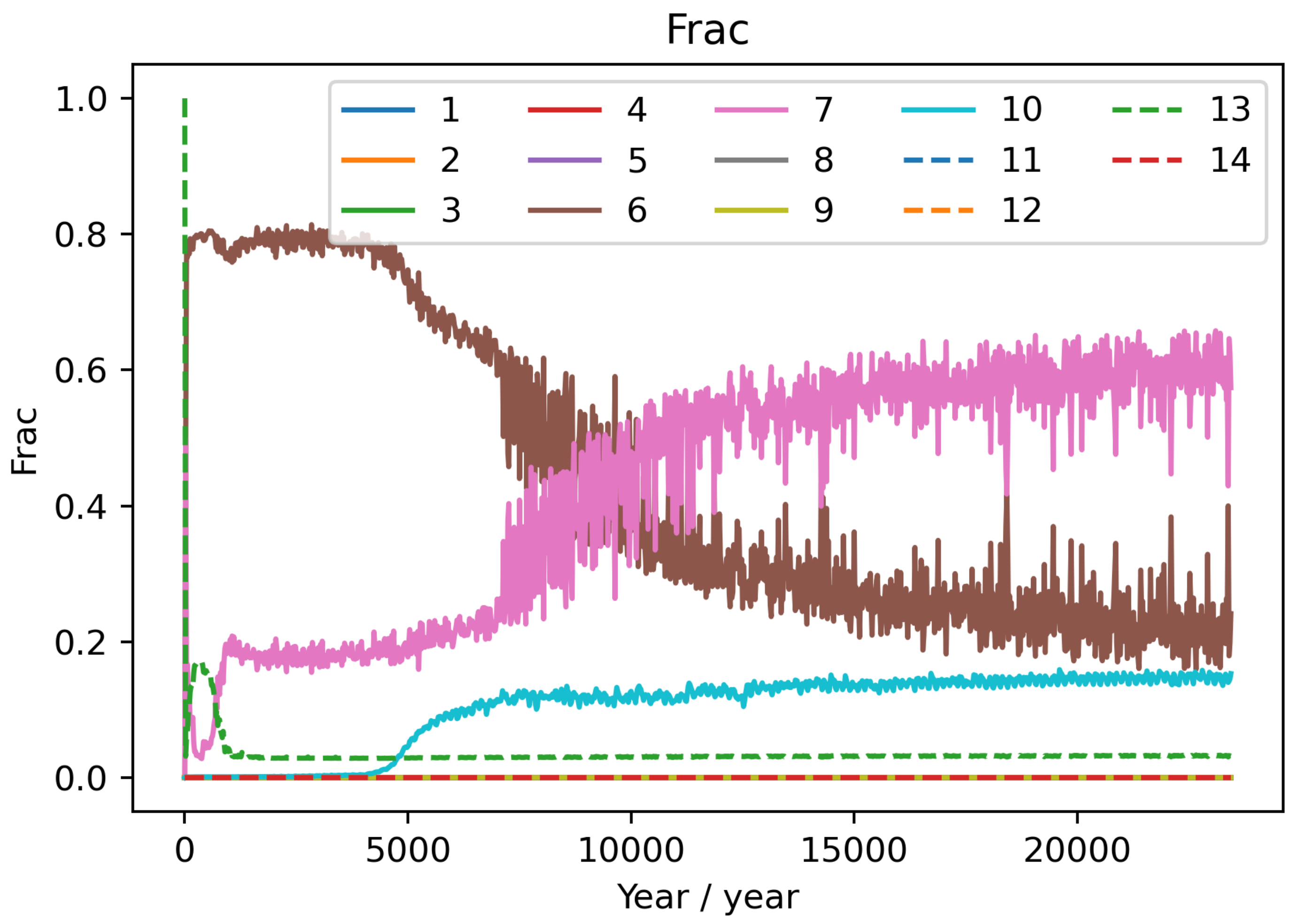
Slow spin-up

Permafrost site









Slow spin-up

Gridded run

Gridpoints are spun-up if rate of change of soil carbon is small

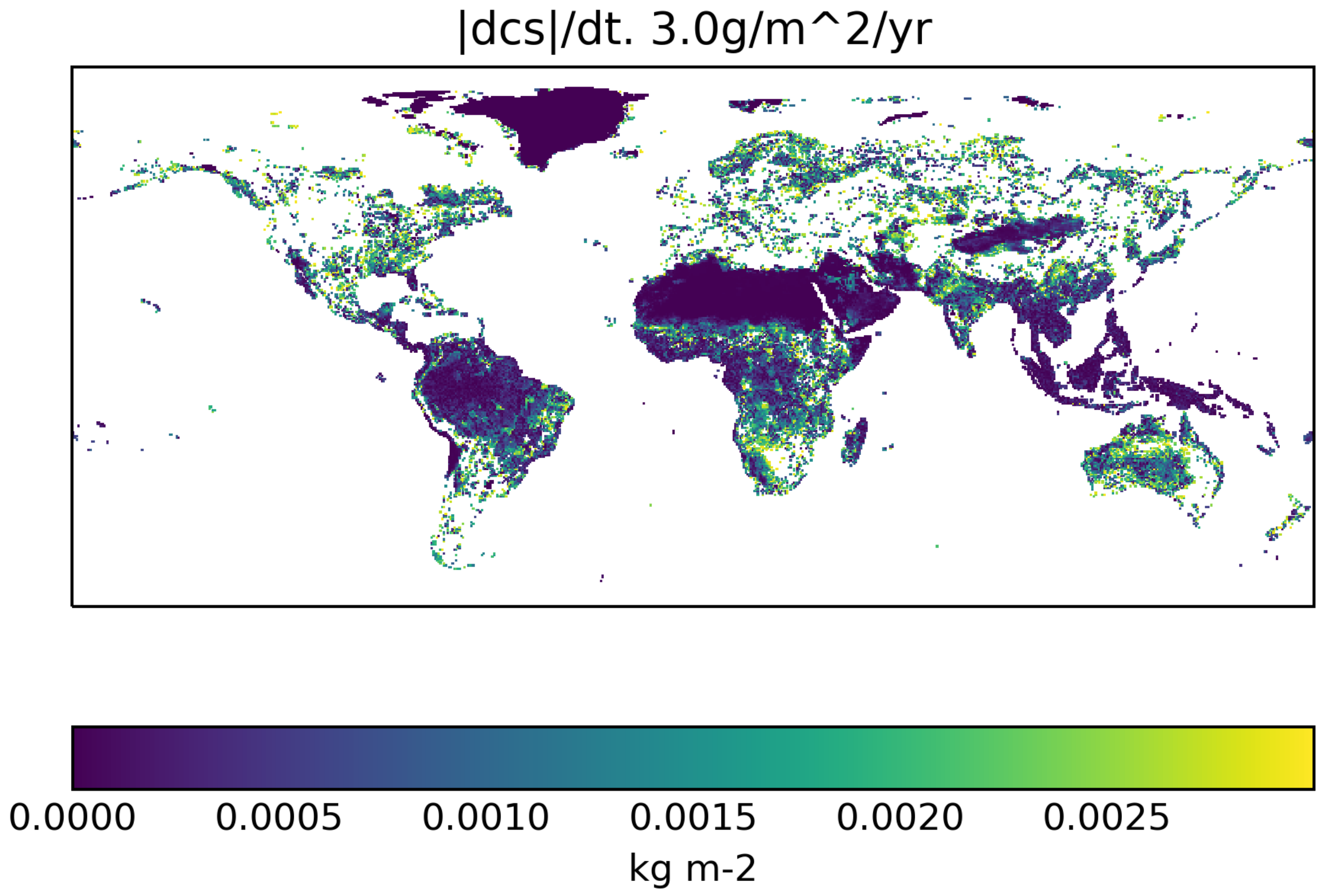
The gridpoint is spun-up if the following is true [Thornton and Rosenbloom (2005)]

$$\frac{|cs(t_{47}) - cs(t_{46})|}{\Delta t} \leq \tau \times 10^{-3},$$

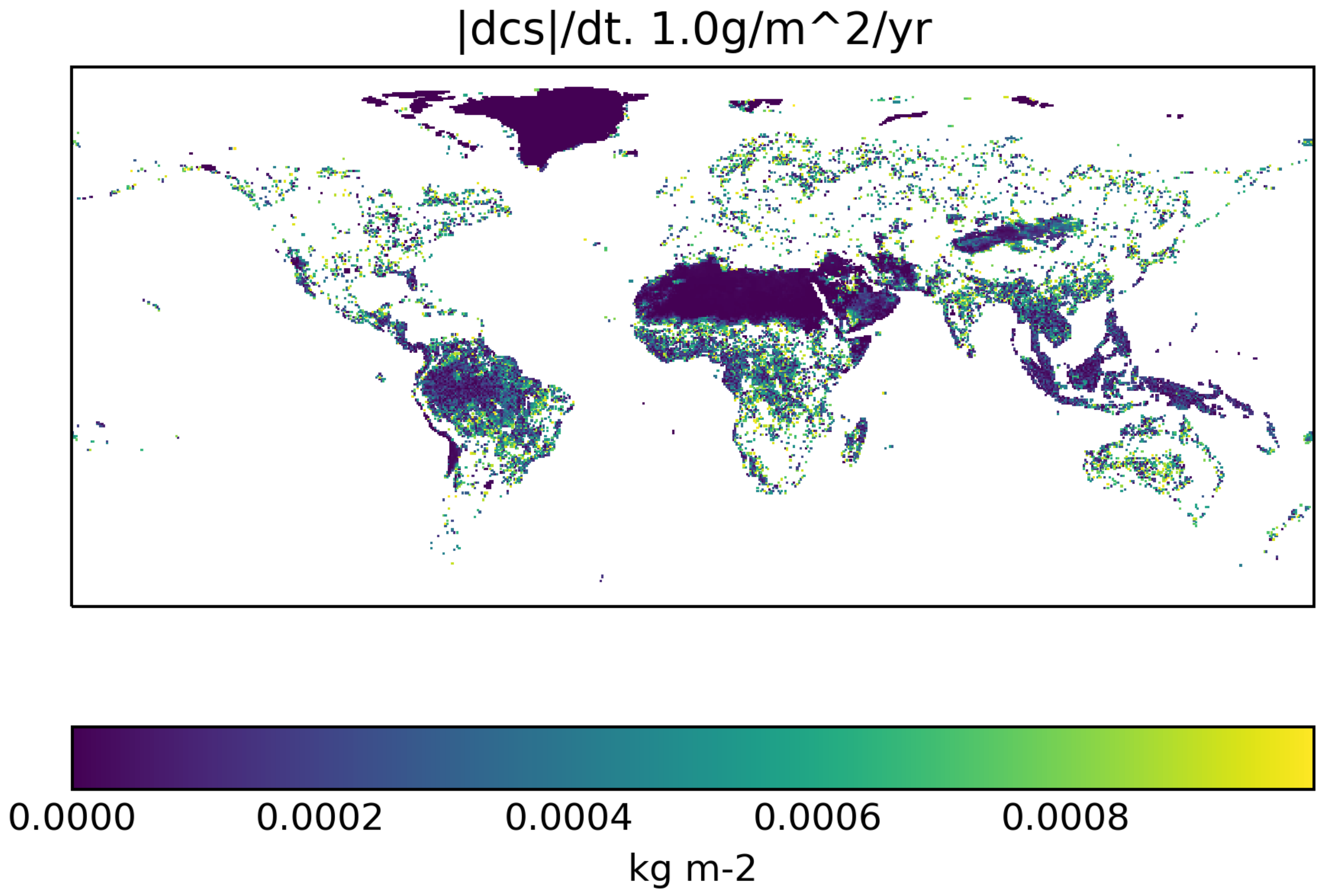
where Δt=10 is the forcing cycle length, $cs(t_{47})$ and $cs(t_{46})$ are average cs values throughout cycles 47 and 46, respectively,

τ is set to [Shi et al (2013)]:

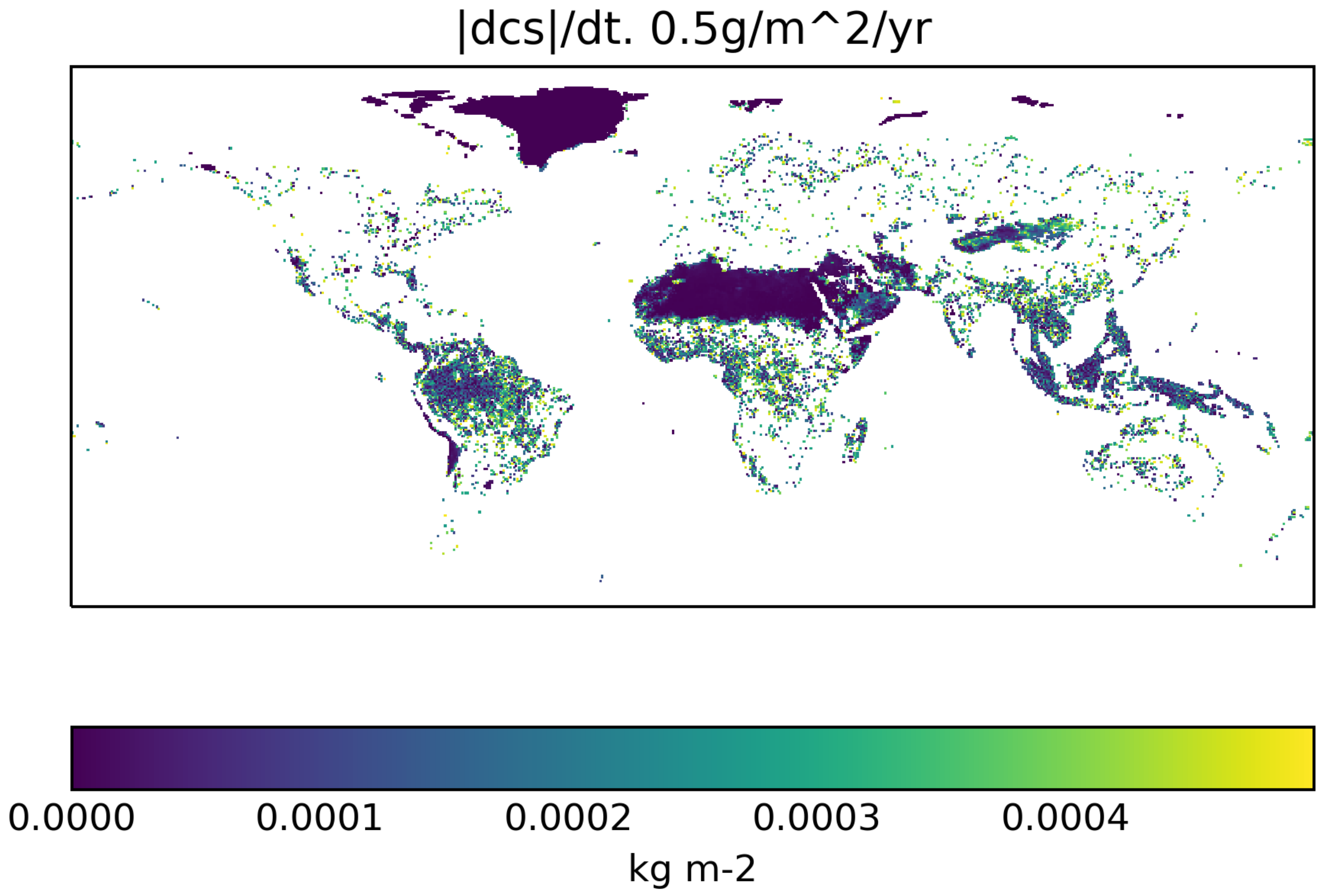
- 3g/m^2/yr
- 1g/m^2/yr
- 0.5g/m^2/yr



36,389 gridpoints



24,650 gridpoints



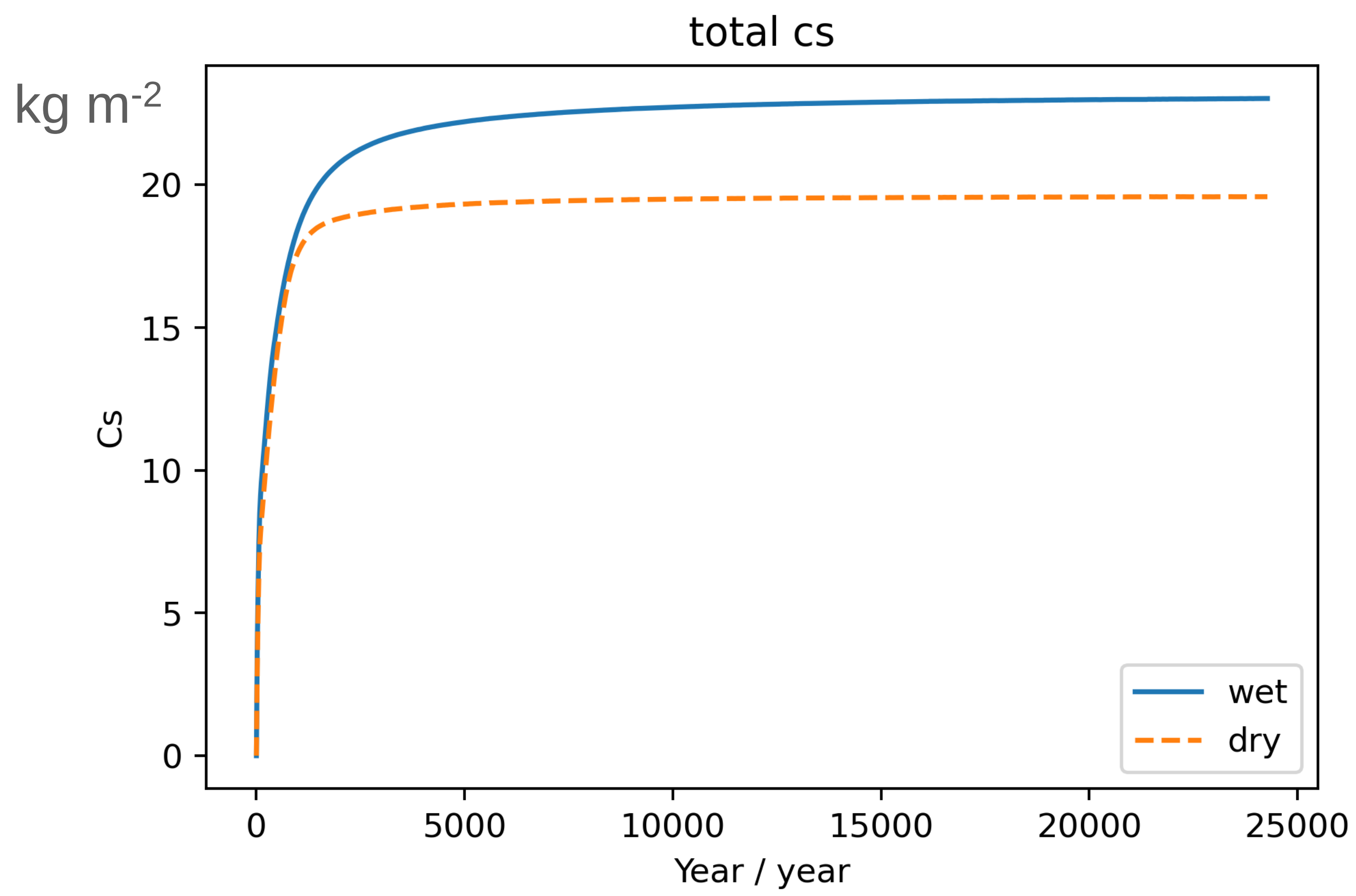
19,209 gridpoints

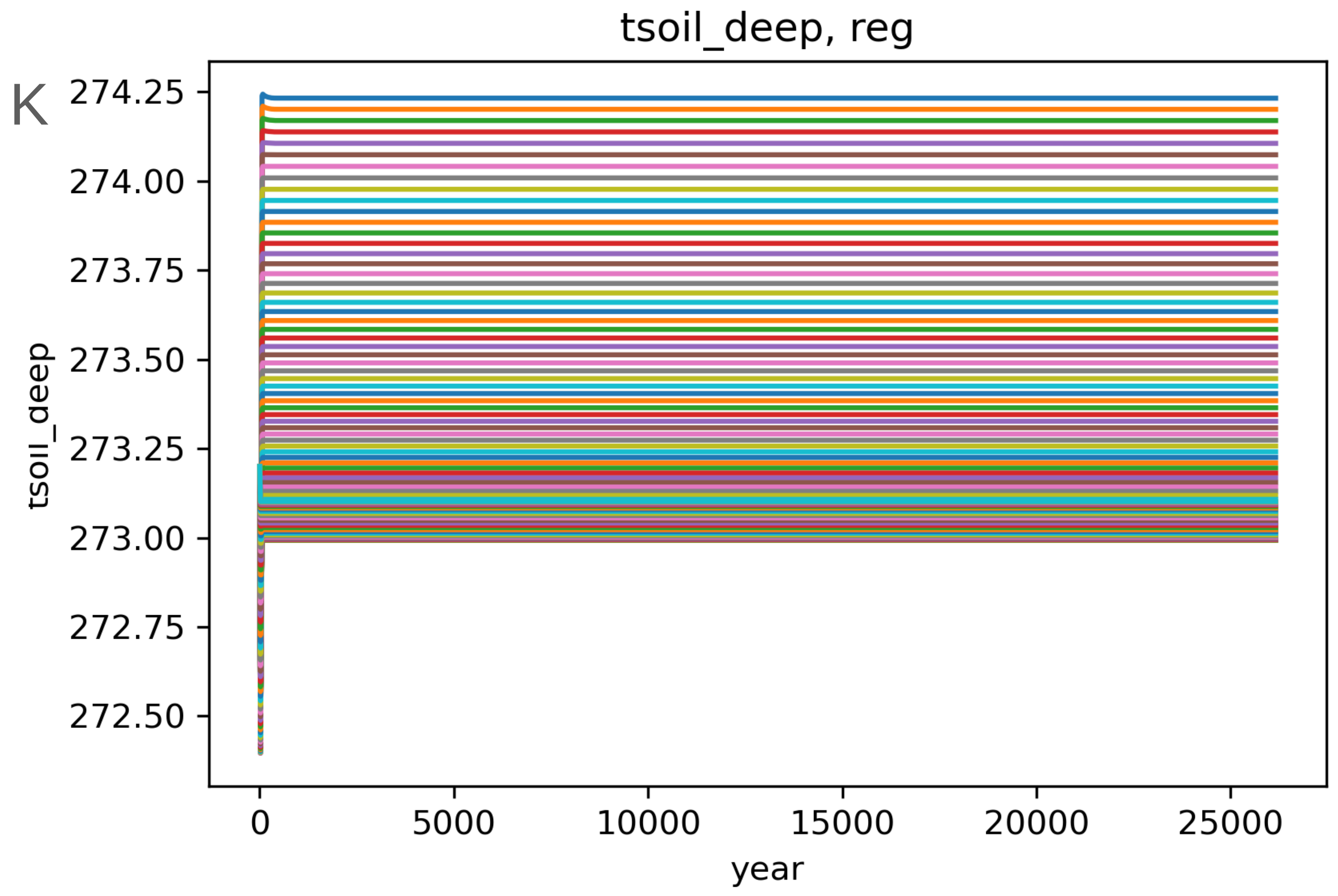
Dry initialisation

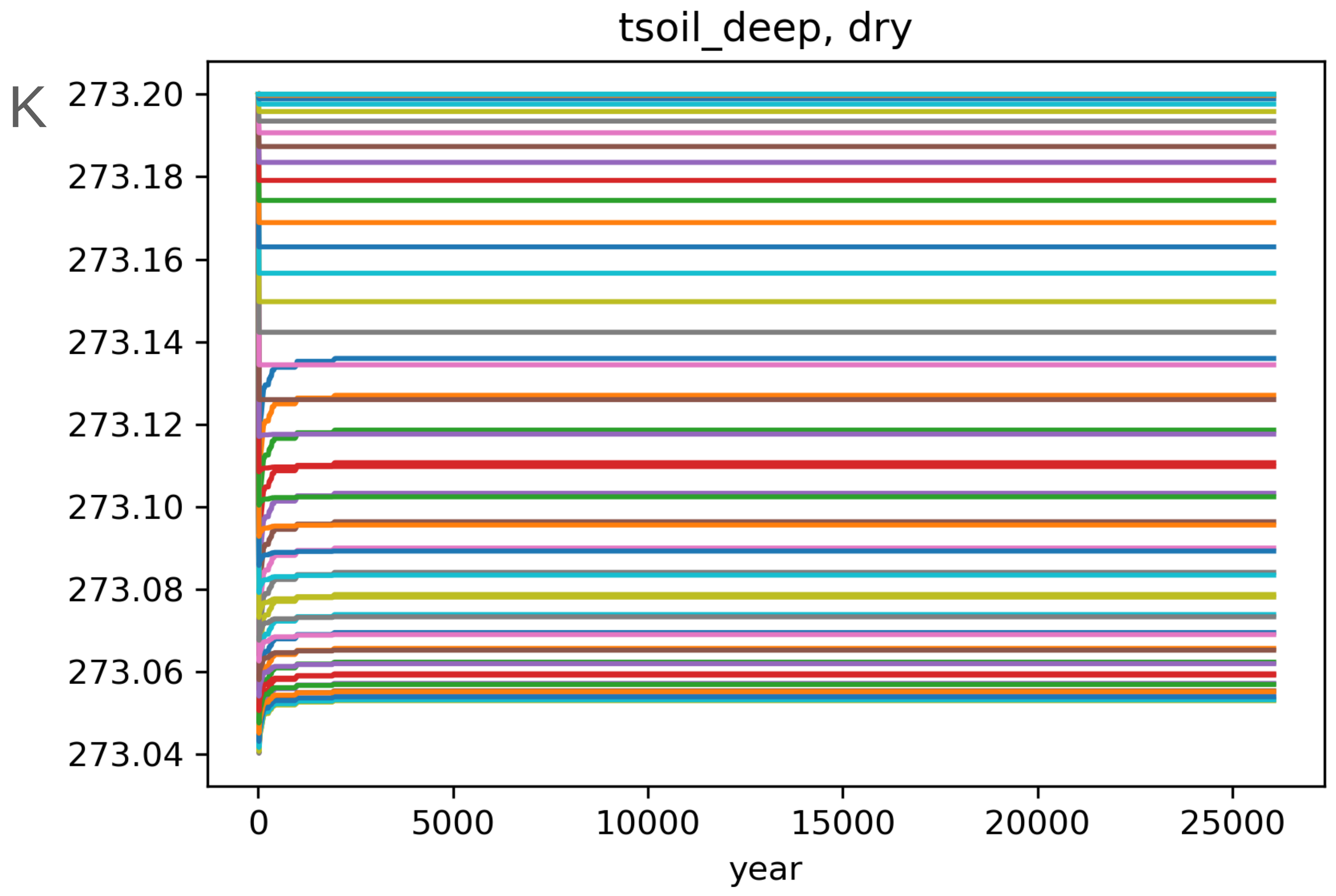
Temperate site

Wet and dry initializations give different steady states

Recommendations for initialization:
- wet soil column
- climatological mean for bedrock

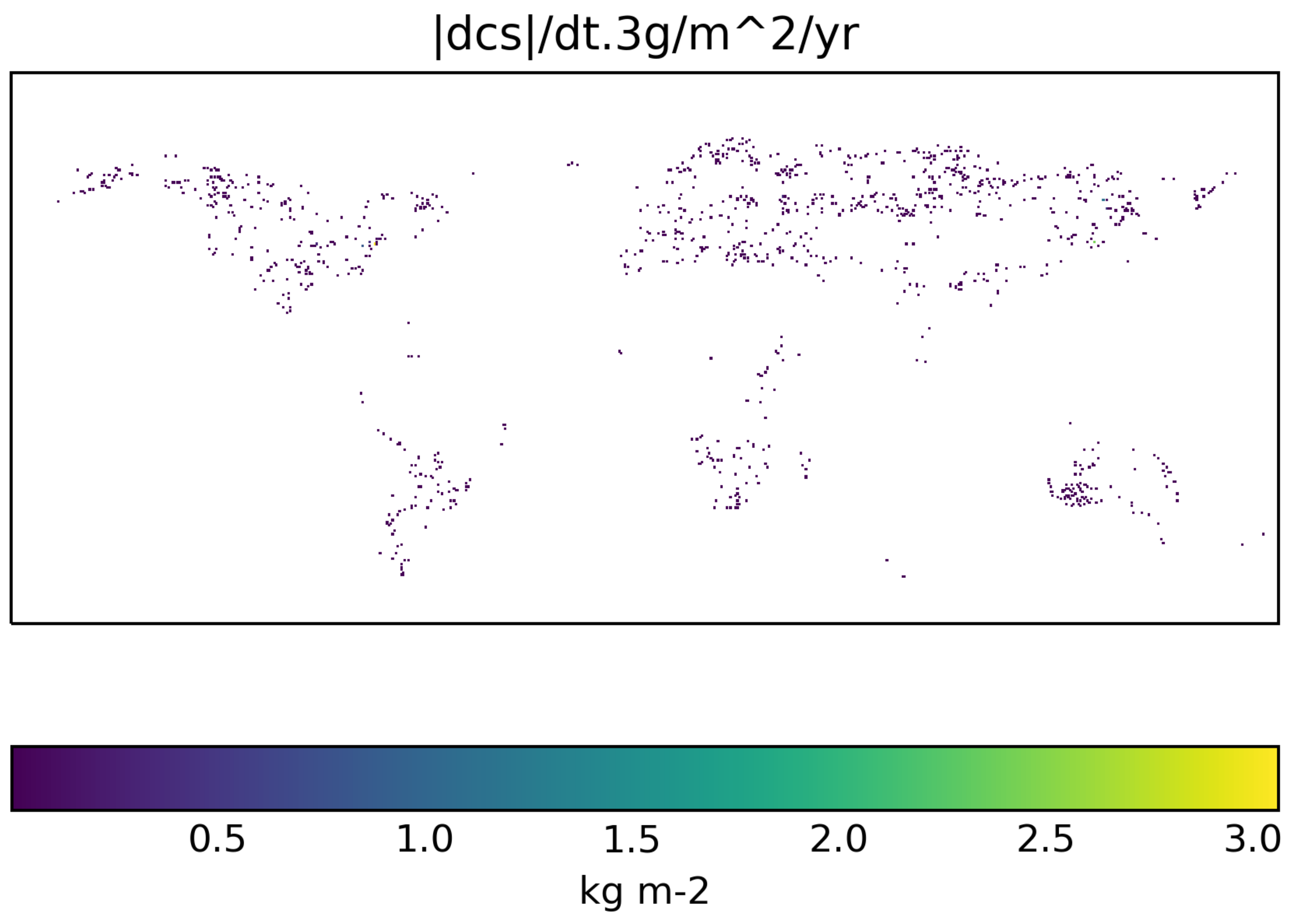




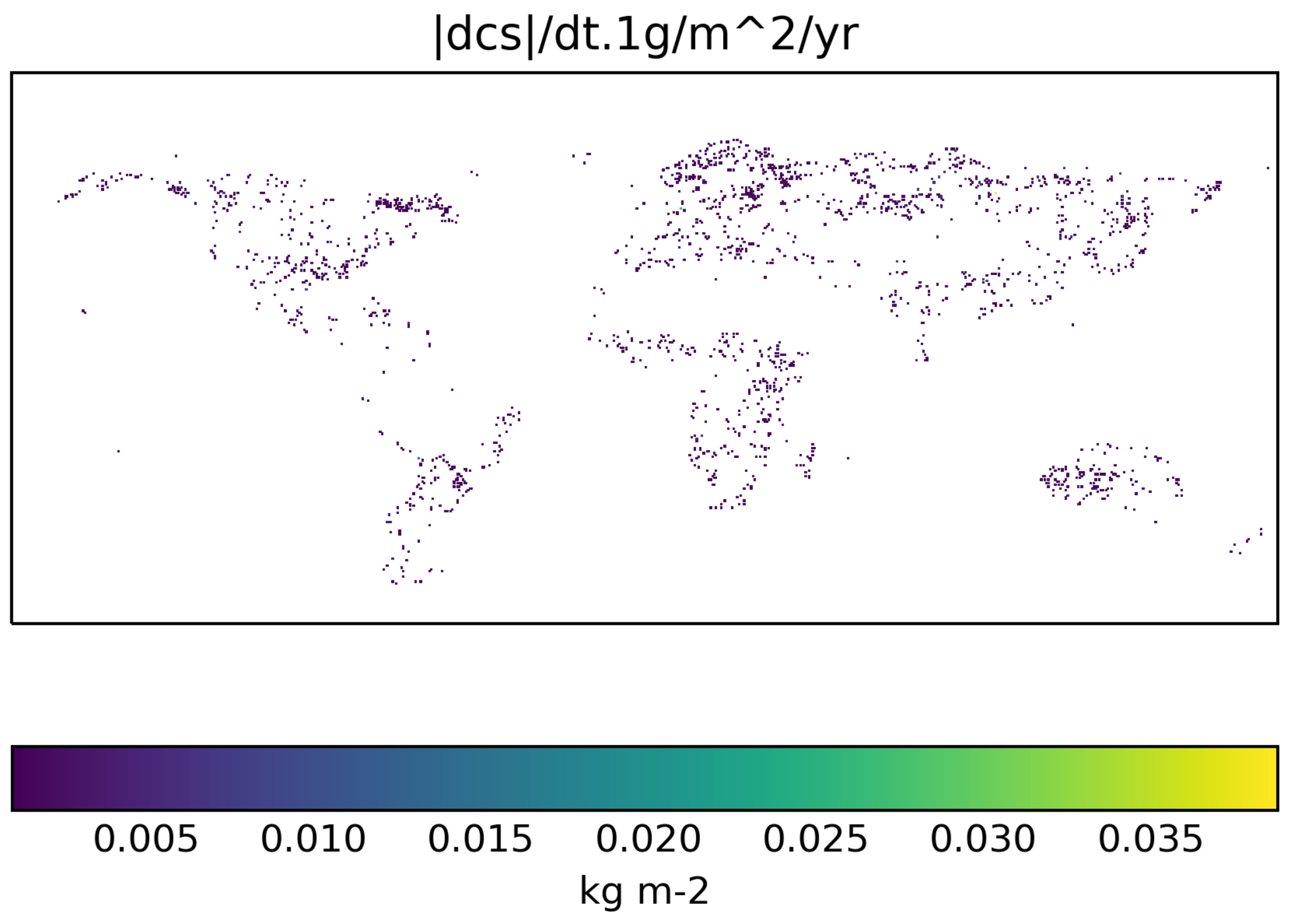


Checking for spin-up

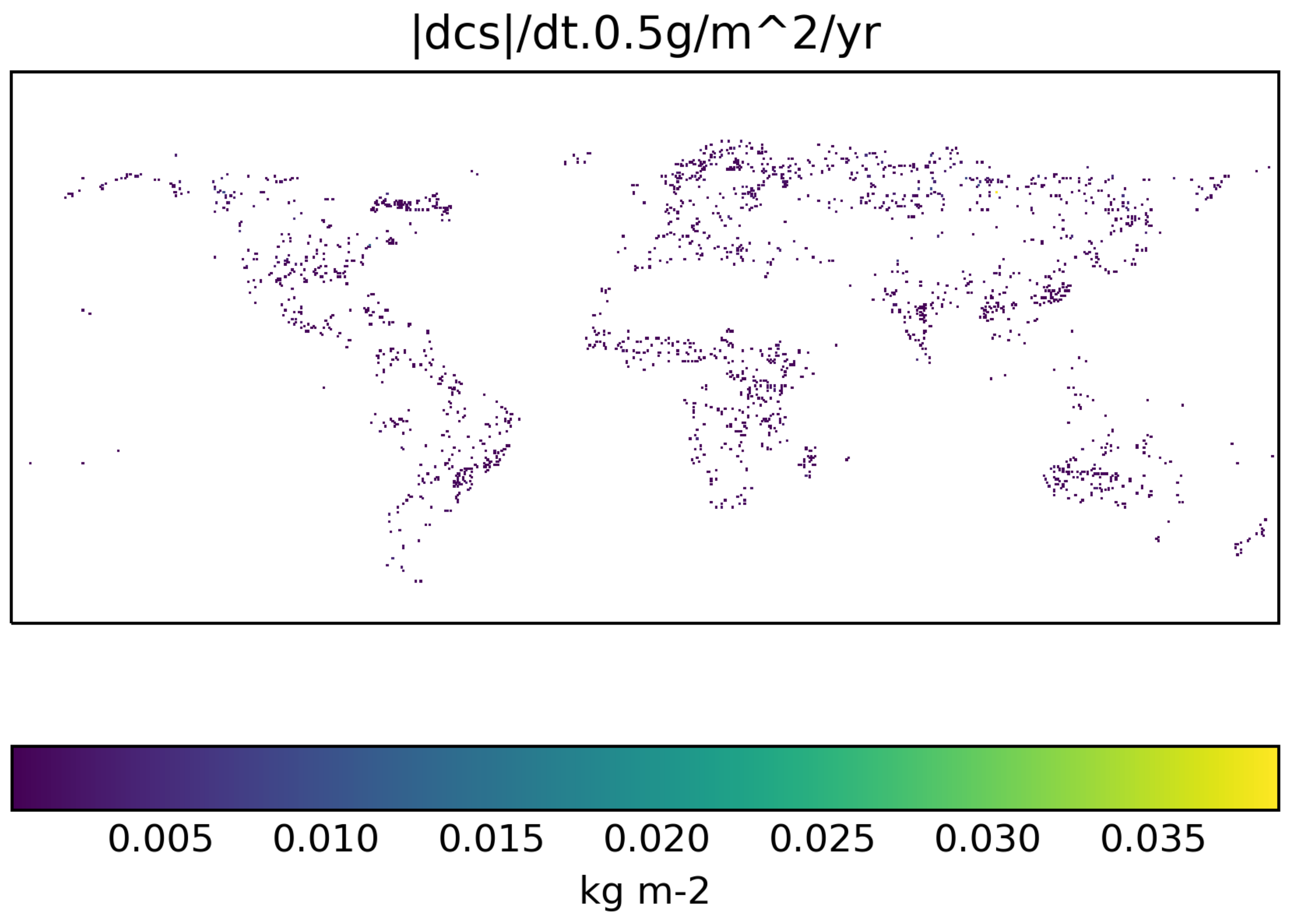
Gridpoints can pass the threshold at one time, but not later



1,170 gridpoints



1,967 gridpoints

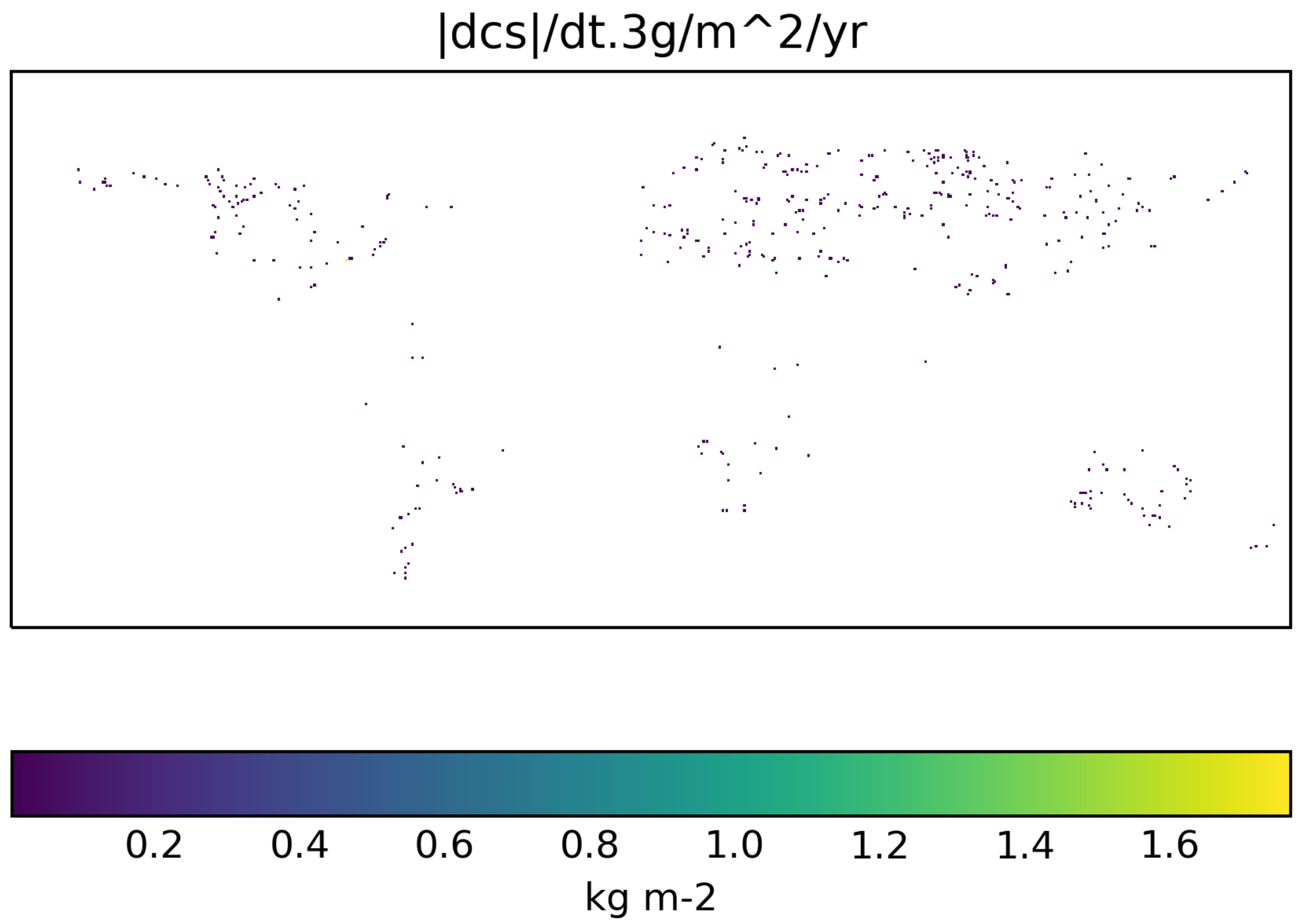


2,047 gridpoints

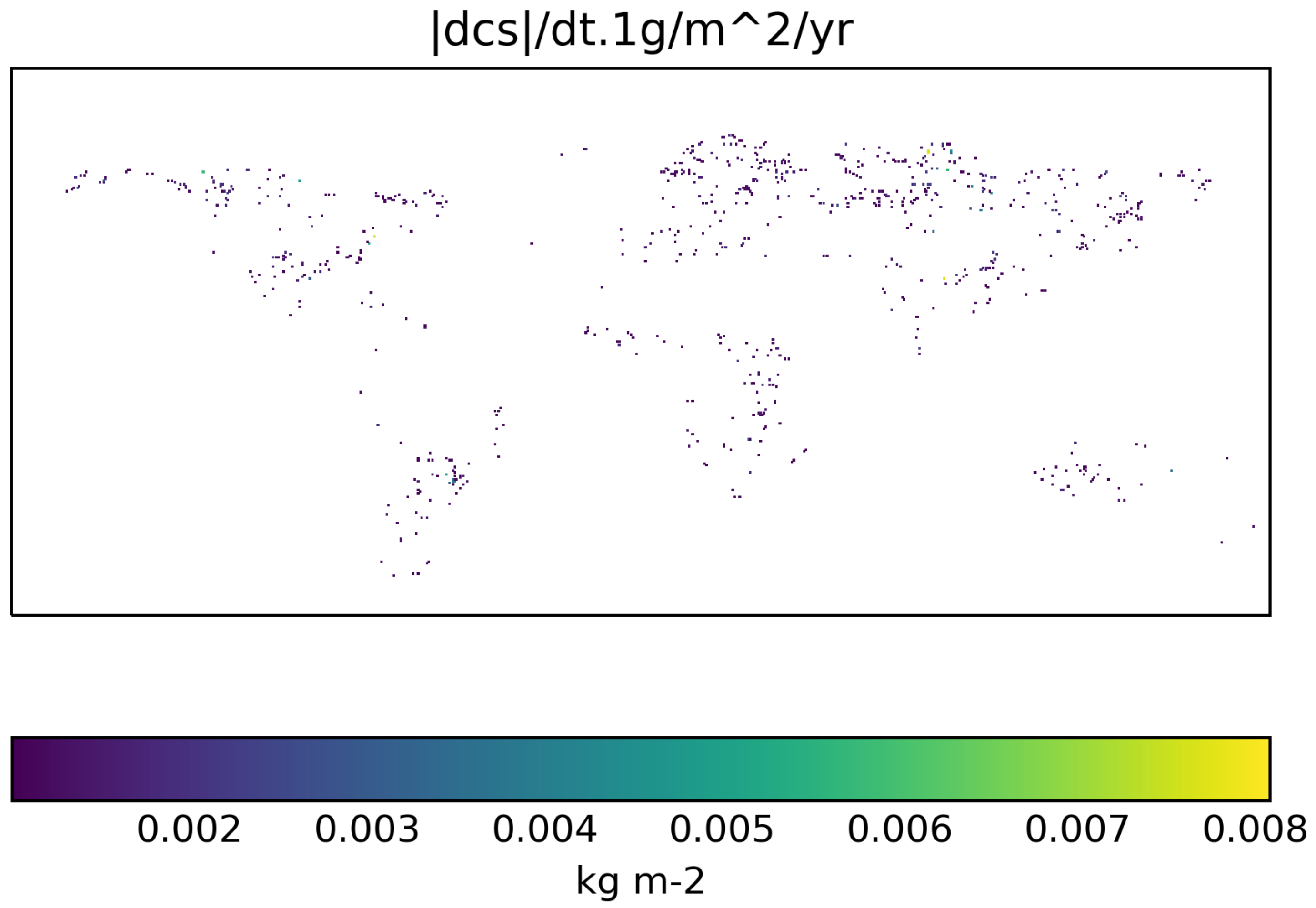
Checking for spin-up

Taking averages over a few cycles (more data points) reduces the noise impact

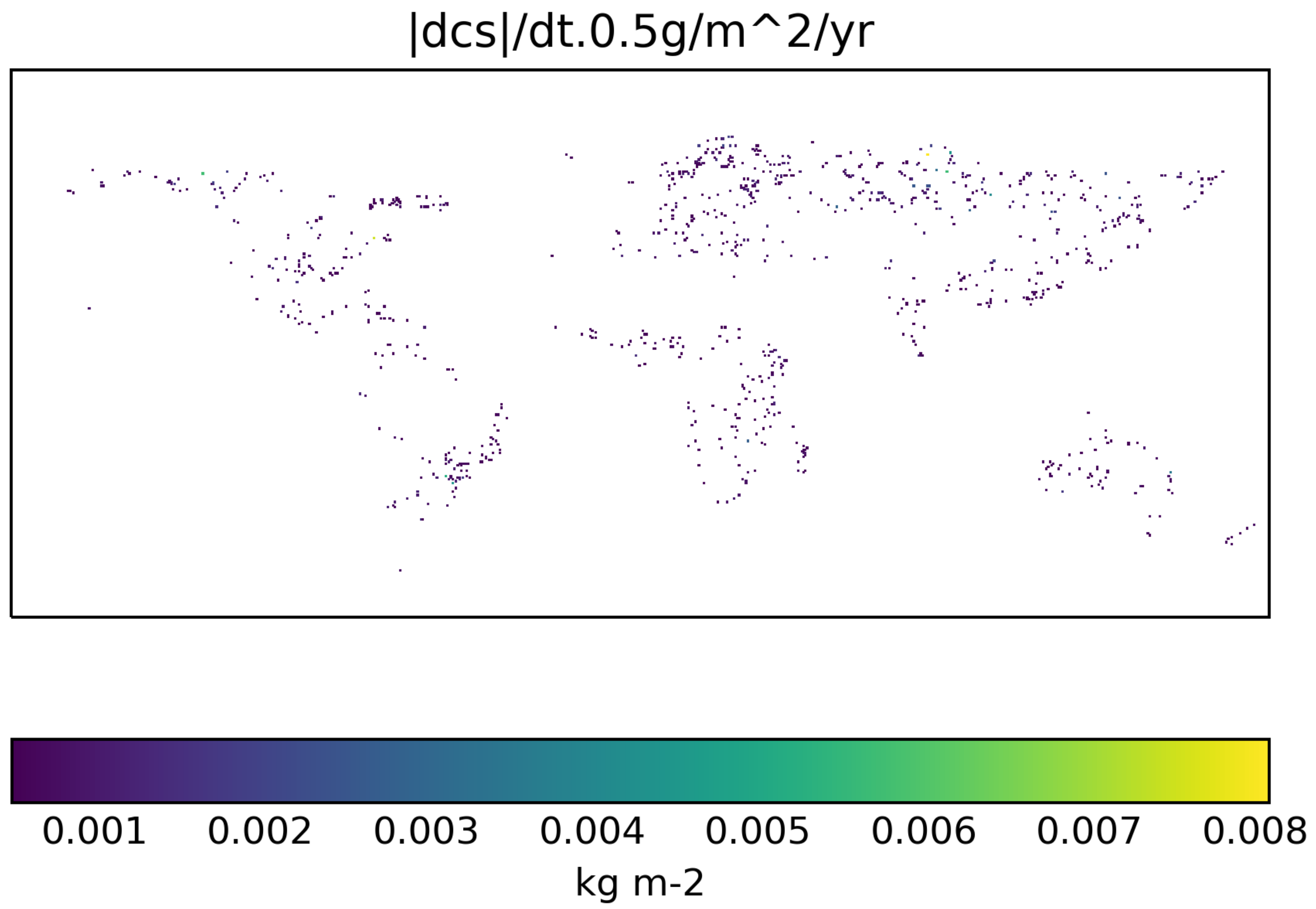
Larger thresholds are less sensitive to the noise



435 gridpoints



787 gridpoints



988 gridpoints

Spatially varying spin-up length

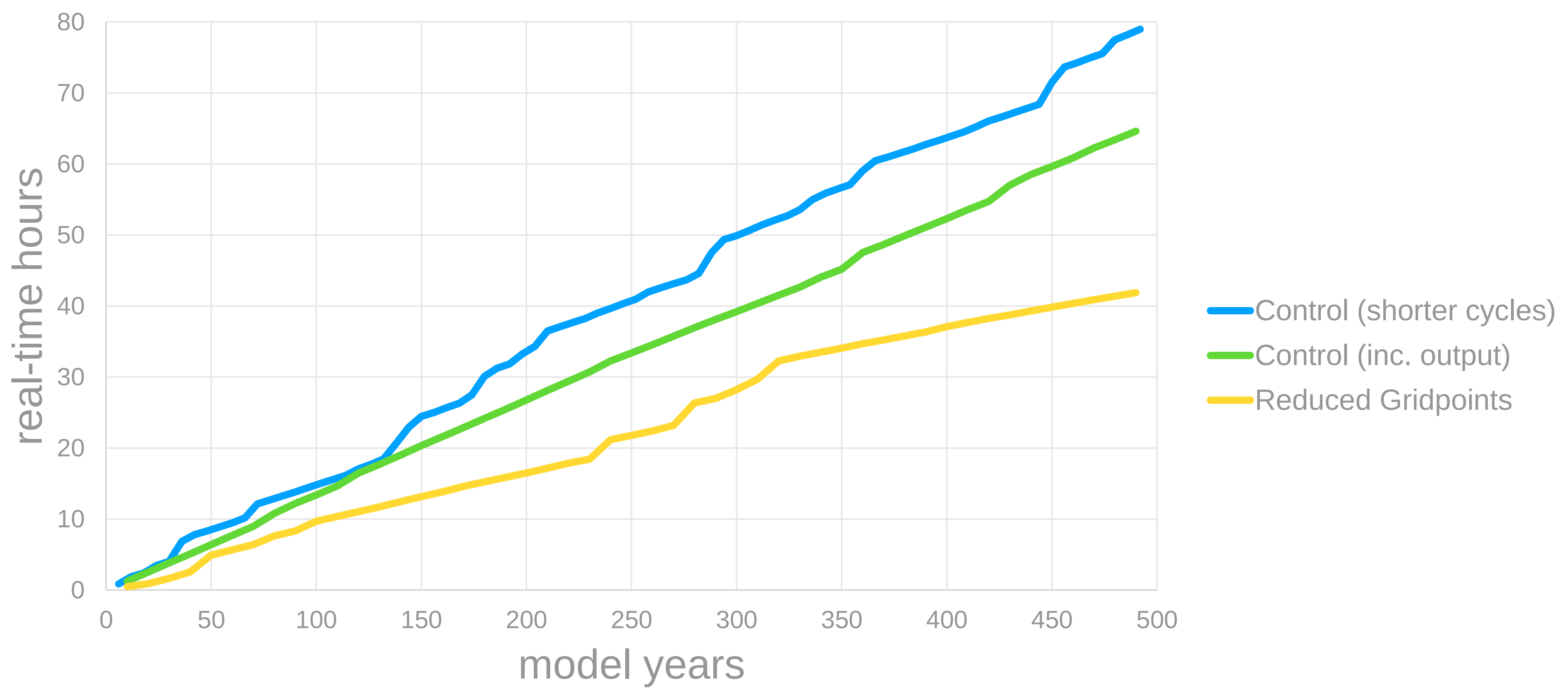
Stop the spin-up for gridpoints that satisfy the criteria

When tested approximately 30% time saving

3g/m^2/yr

1g/m^2/yr

0.5g/m^2/yr



Gradient projection

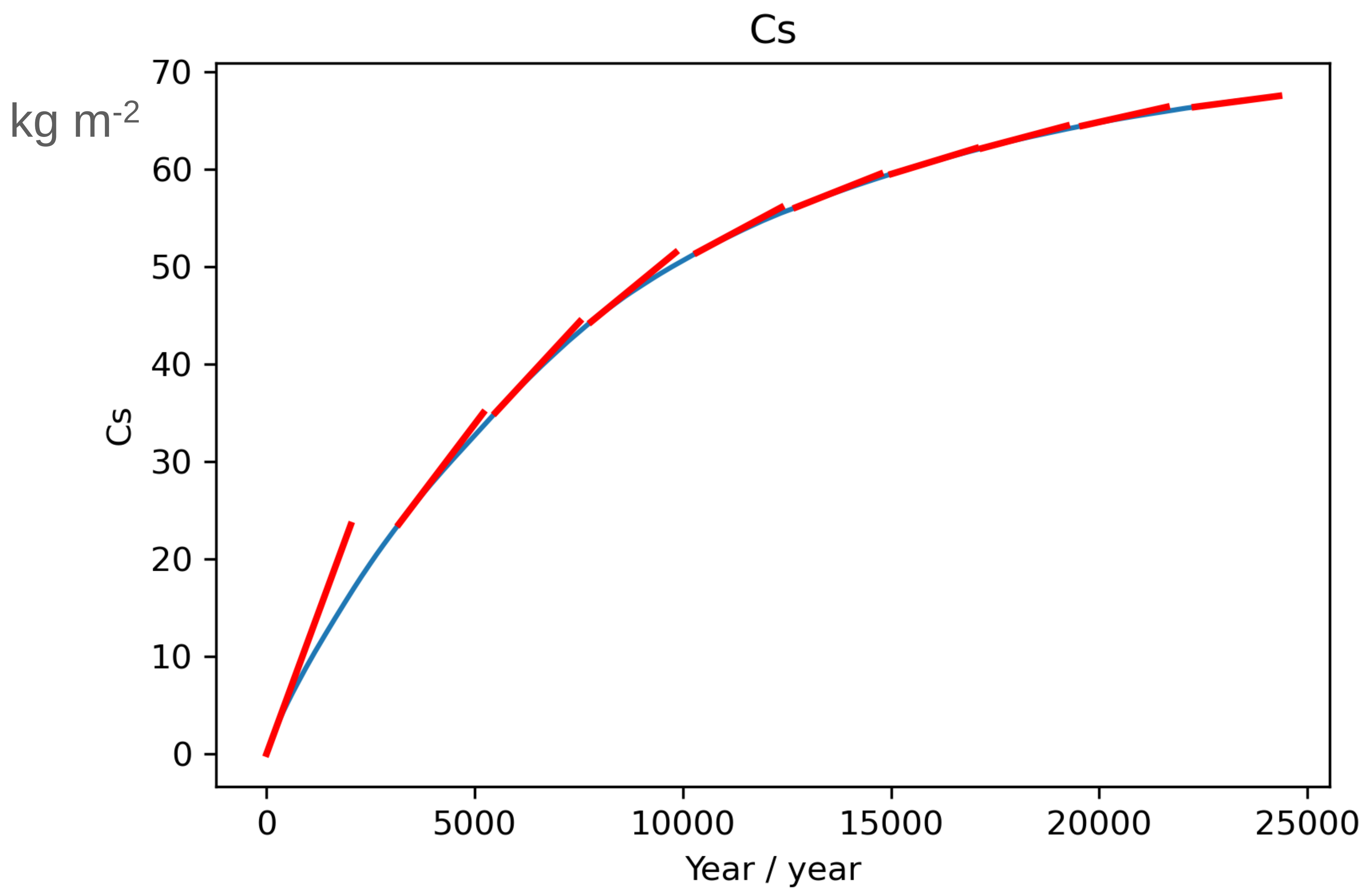
Idea

- Use the cs values at the beginning of two consecutive cycles (cs(t_0) and cs(t_1)) to find the gradient and use it to approximate the future value cs(t_n):

$$cs(t_n) = cs(t_1) + \frac{cs(t_1) - cs(t_0)}{m_c}(t_n - t_1),$$

  where m_c is the length of the forcing cycle in years,
  (t_n - t_1) is a multiple of m_c

- Run the model for a few cycles to stabilise the fast components
- Evaluate *dcs/dt:* stop or project again
- Run a short final spin-up
- [Fang, Liu, and Leung (2015)]



Permafrost site. Each gradient projection is 2,000 years

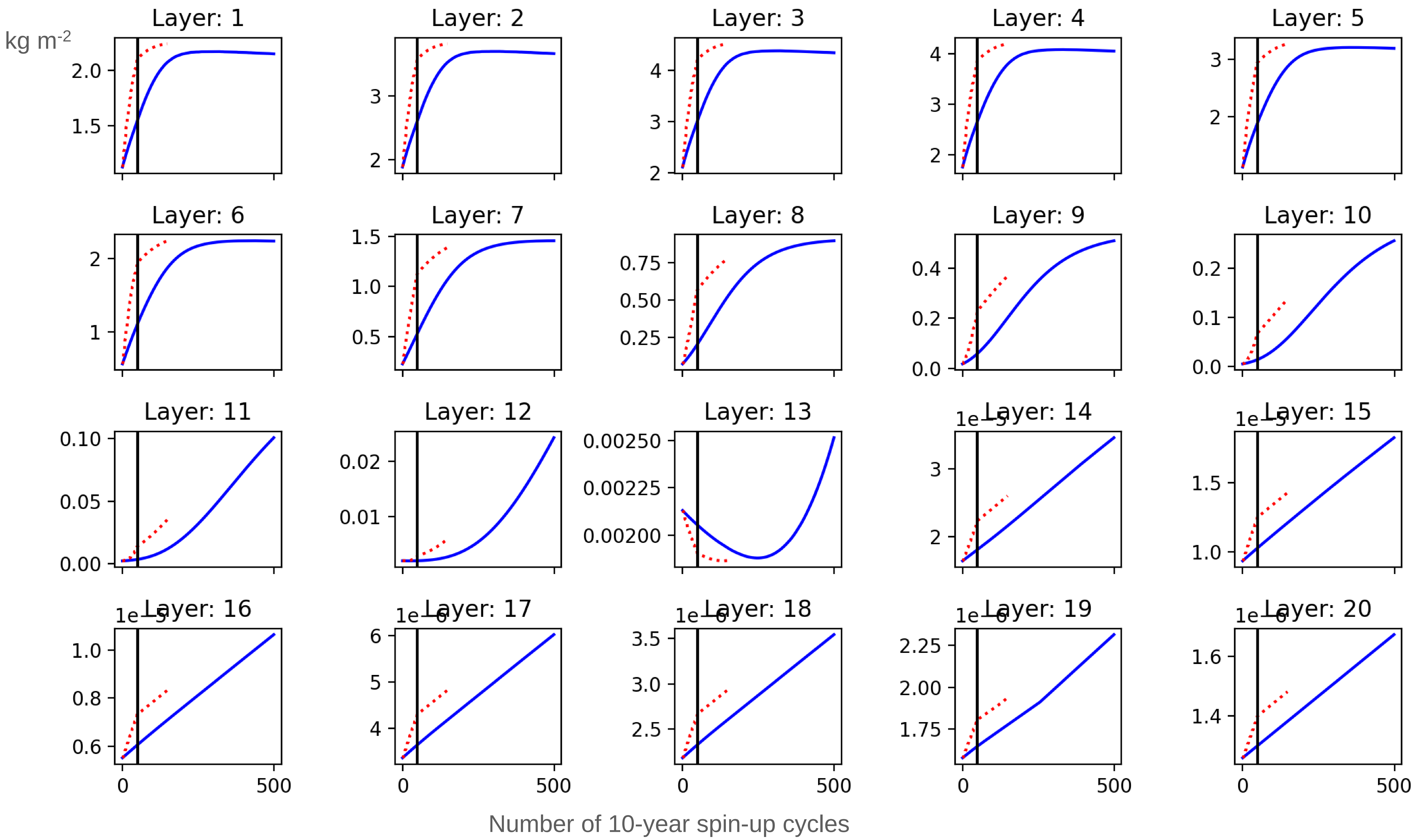
Gradient projection

Results

lat: 30.75; long: -98.25
(Texas)

Pool 4
Other pools very similar

Blue: control run
Red dotted: gradient projection for 50 cycles before the black line + regular run after the black line



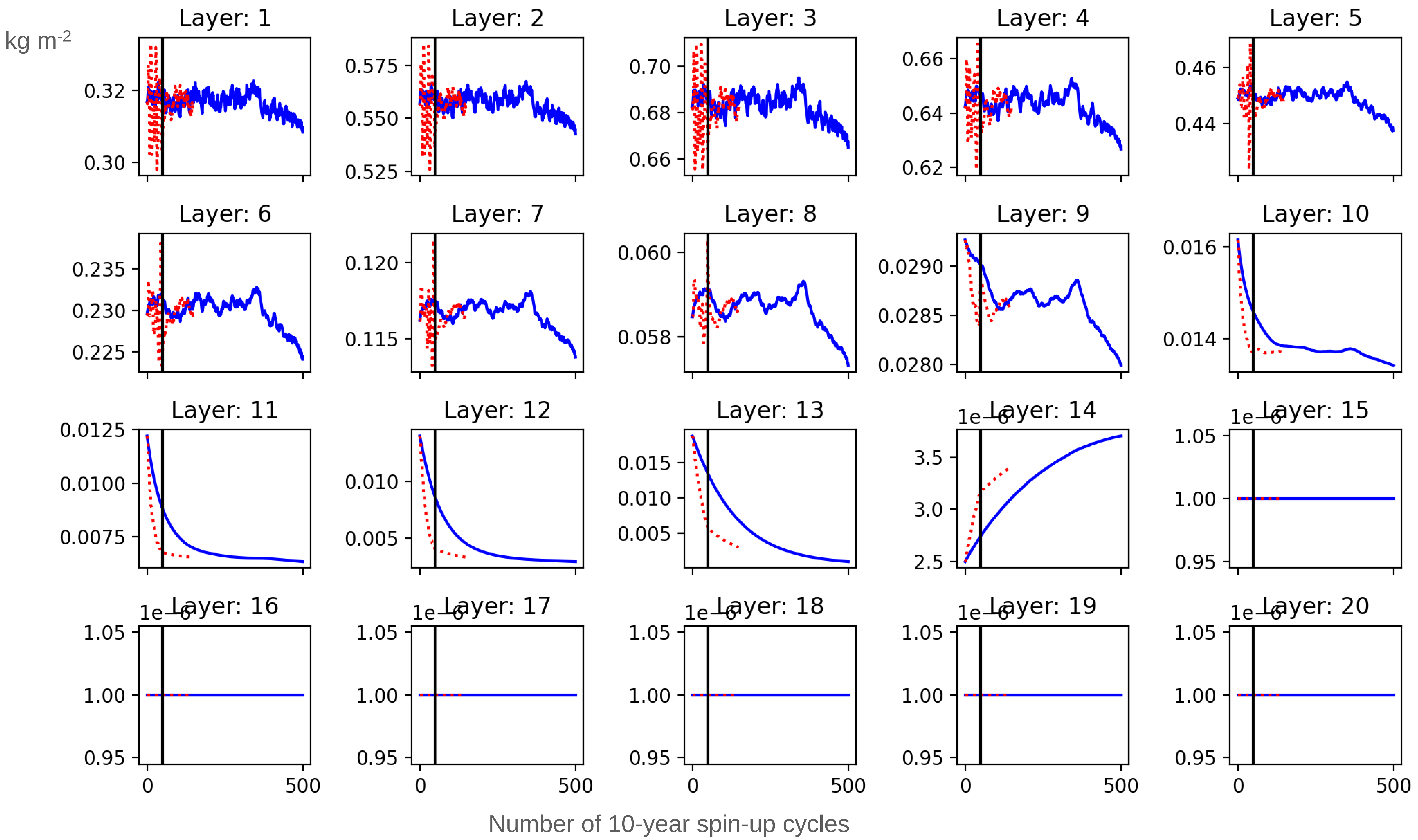
Gradient projection

Results

lat: 71.75; long: 142.25
(permafrost)

Pool 2
GP increases the noise in pools 1 and 2
Evolution of pools 3 and 4 is similar to the case in the previous slide

Blue: control run
Red dotted: gradient projection for 50 cycles before the black line + regular run after the black line



Summary

- Wet soil column and climatological bedrock initialization
- Check for spin-up using long averages
- Turn off gridpoints during the spin-up
- Gradient projection can accelerate the soil carbon spin-up

References

Fang, Y., Liu, C., and Leung, L. R.: Accelerating the spin-up of the coupled carbon and nitrogen cycle model in CLM4, Geosci. Model Dev., 8, 781–789, https://doi.org/10.5194/gmd-8-781-2015, 2015.

Shi, M., Yang, Z.-L., Lawrence, D.M., Dickinson, R. E., and Subin, Z. M.: Spin-up processes in the Community Land Model version 4 with explicit carbon and nitrogen components, Ecological Modelling, 263, 308-325, https://doi.org/10.1016/j.ecolmodel.2013.04.008, 2013.

Thornton, P. E., and Rosenbloom, N. A.: Ecosystem model spin-up: Estimating steady state conditions in a coupled terrestrial carbon and nitrogen cycle model, Ecological Modelling,189, 25-48, https://doi.org/10.1016/j.ecolmodel.2005.04.008, 2005.