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)]

 $|cs(t_{47}) - cs(t_{46})| \le \tau \times 10^{-3},$ Δt

where $\Delta t = 10$ 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





|dcs|/dt. 3.0g/m^2/yr



0.0015	0.0020	0.0025	
kg m-2			



24,650 gridpoints

36,389 gridpoints

|dcs|/dt. 0.5g/m^2/yr





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







|dcs|/dt.1g/m^2/yr



1,170 gridpoints

1,967 gridpoints |dcs|/dt.0.5g/m^2/yr



0.005 0.010 0.015 0.020 0.025 0.030 0.035 kg m-2

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







988 gridpoints

Spatially varying spin-up length

Stop the spin-up for gridpoints that satisfy the criteria

3g/m^2/yr

When tested approximately 30% time saving



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):

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

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 *d*cs/*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



Number of 10-year spin-up cycles

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.