Soil C turnover in the real world, CLM5, and other models

C. Koven and many others, including the CLM5 and ILAMB teams and G. Hugelius

CESM LMWG meeting
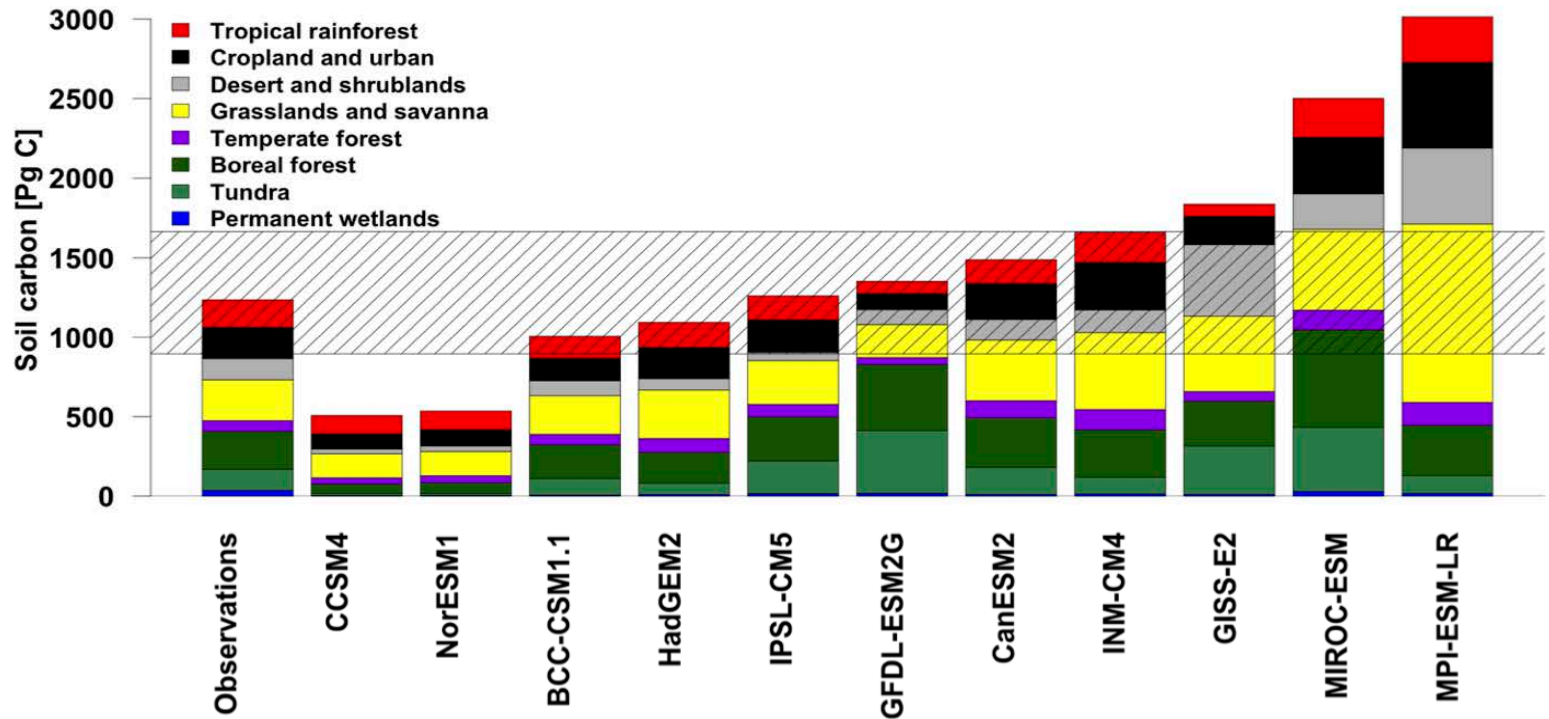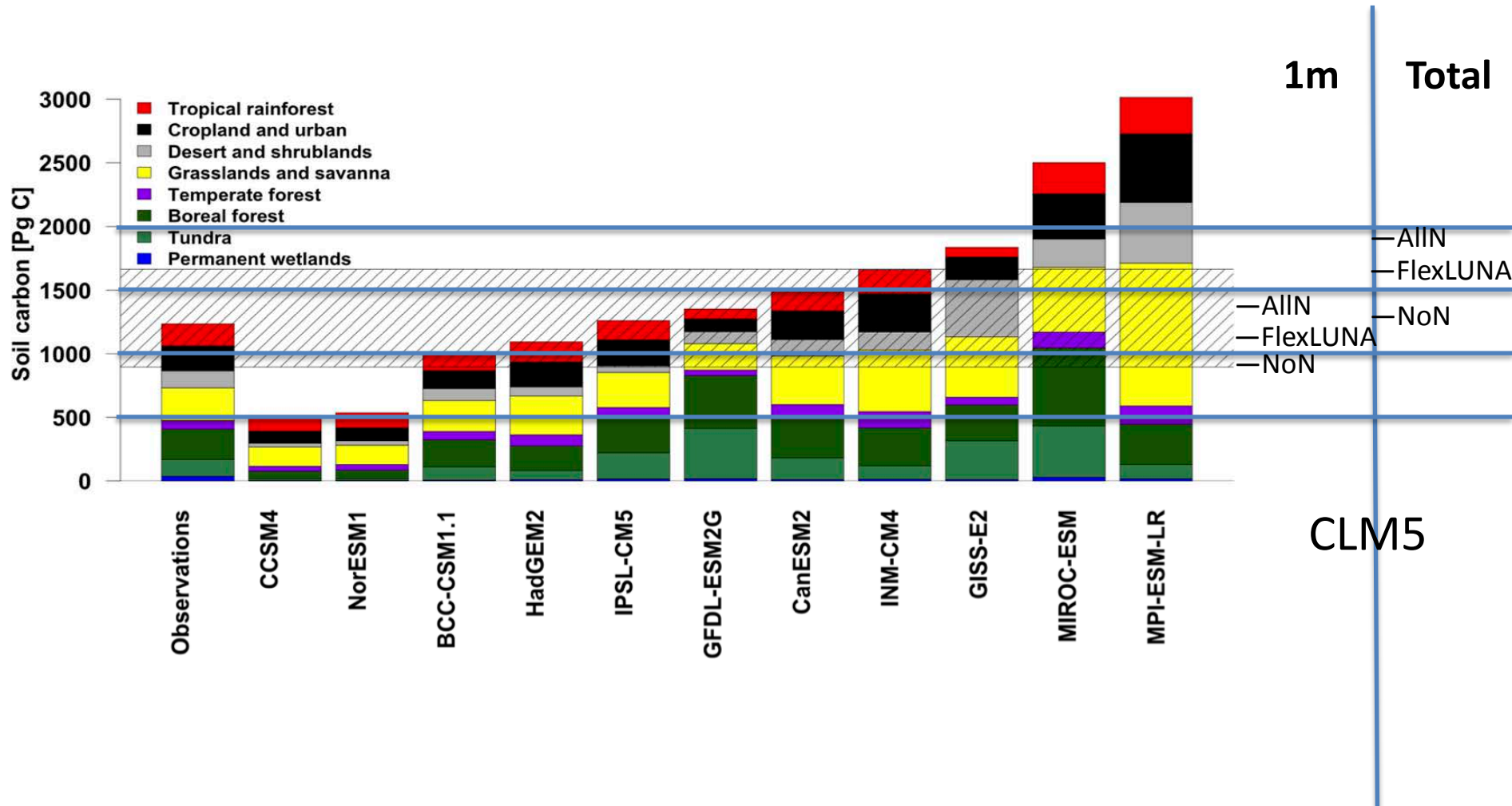
February 9 2016

State of current soil C benchmarking

Compare regional and global observations of C stocks against model predictions

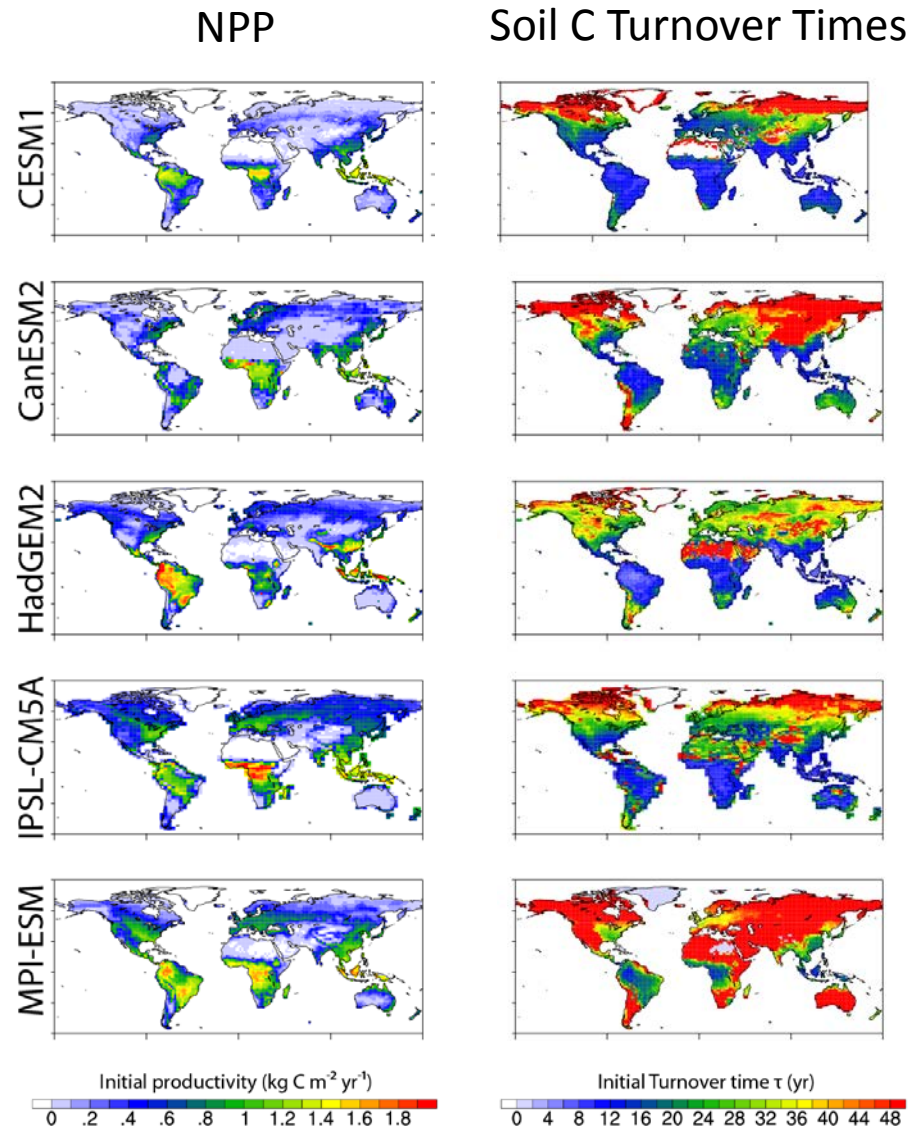Todd-Brown et al., 2013

How does CLM5 stack up here?

# A couple issues with the stock-based benchmarking approach:

1. While total C may be a good indicator of overall ecosystem fidelity, its sensitivity to non-soil processes (here, the representation of plant N cycle) means its not a very useful diagnostic of what's actually going on and how to fix it.

2. Actual target numbers themselves heavily weighted to high-storage ecosystems, some of which the models aren't even trying to capture (e.g. peatlands)

3. Original Todd-Brown et al. 2013 numbers based on HWSD, too small in permafrost

# Proposed alternative: what controls the turnover times?

- Can think of ecosystem C storage as driven by the product of productivity and turnover times; current models have much higher uncertainty in initial conditions of turnover than of productivity

- We also see clear latitudinal variation in turnover times, so makes sense to plot as function of productivity

- We don't actually have observations of turnover time, but we can ask what would be turnover if ecosystem were in equilibrium (which they're not), and use NPP estimate instead from MODIS (which is also highly uncertain and a model, but better than nothing)


NPP   Soil C Turnover Times

Initial productivity (kg C m^{-2} yr^{-1})
0 .2 .4 .6 .8 1 1.2 1.4 1.6 1.8

Initial Turnover time τ (yr)
0 4 8 12 16 20 24 28 32 36 40 44 48

Koven et al., *Biogeosciences* 2015

Proposed alternative benchmark: Log-scaled Inferred Mean Residence Time (= SoilC / NPP) as function of Temperature

observations (CRU, HWSD & NCSCD, MODIS NPP)
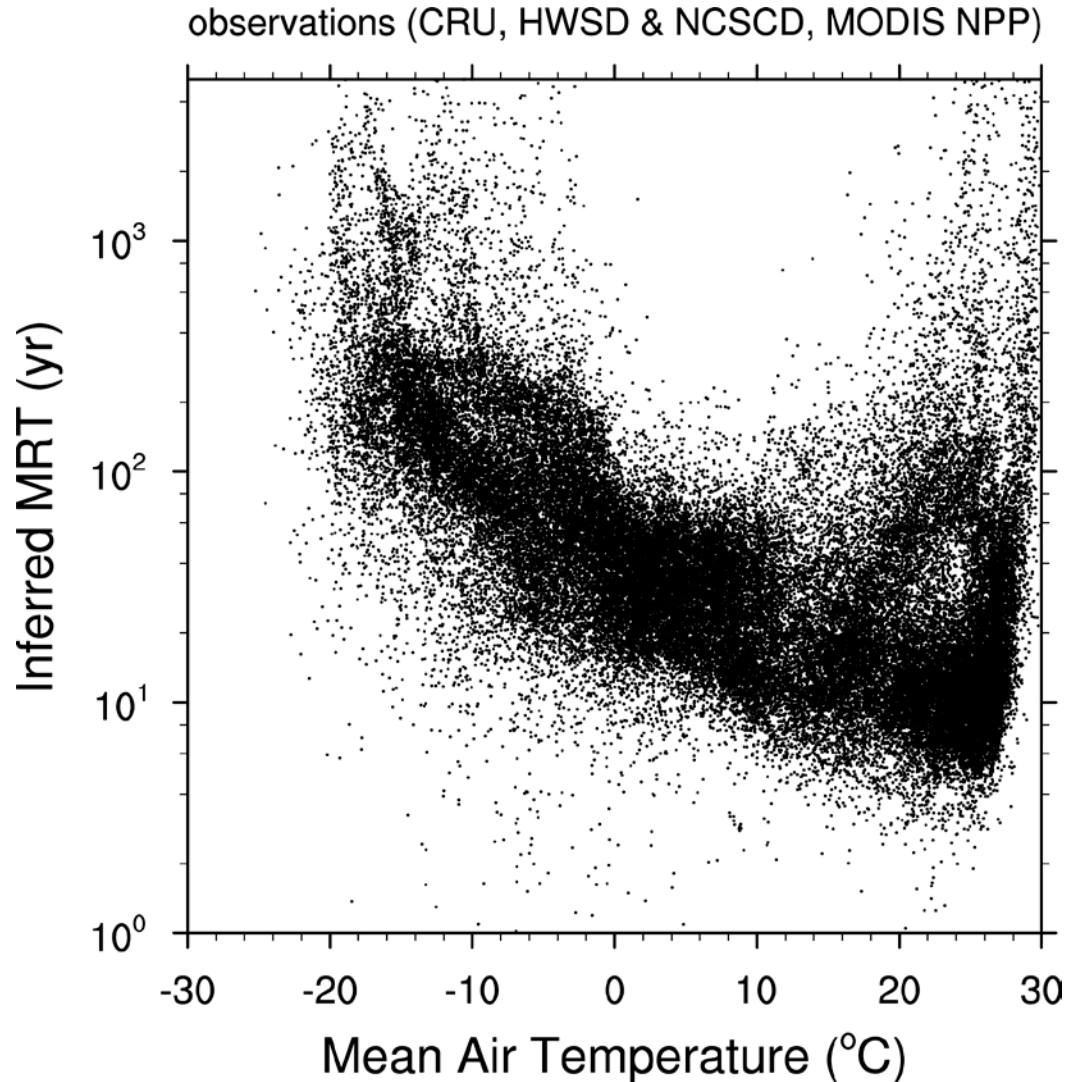
Where are the peatland soils?
(which most models aren't even trying to capture yet)

mineral soils black; peatlands red
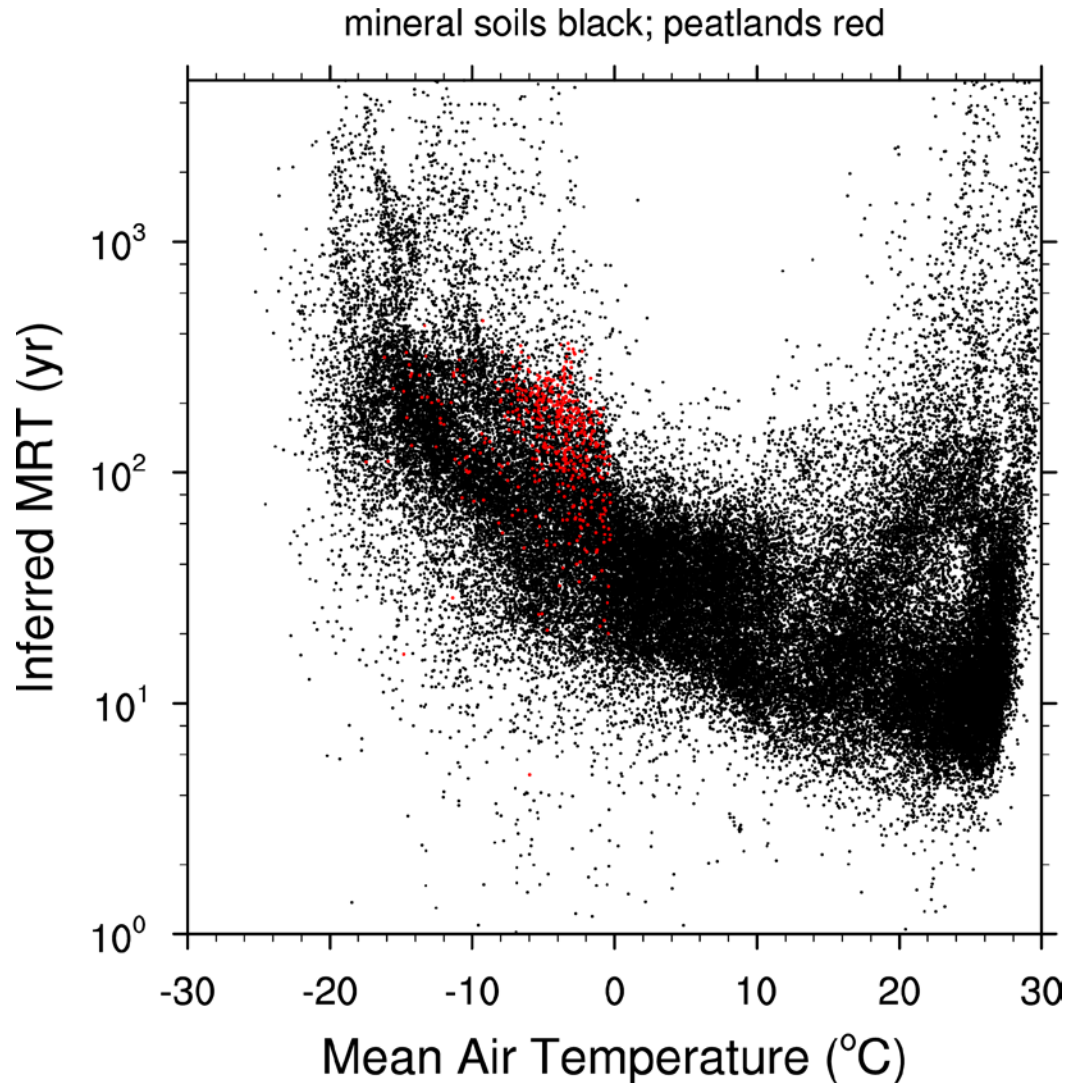
What about moisture controls? Color by Precip...
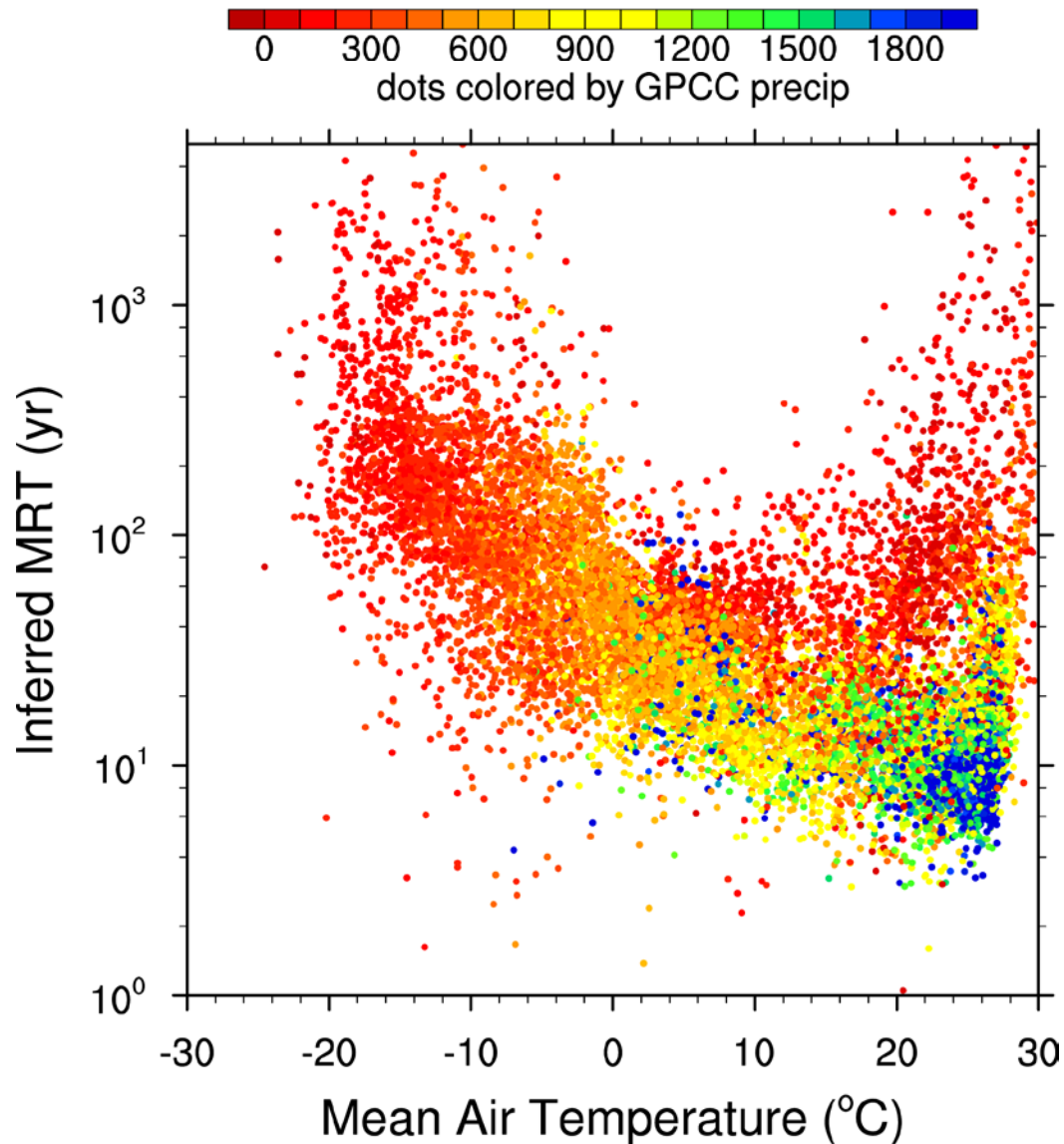
How does this compare with Q10-type model?

Asserted Q_{10}s: Permafrost=5; Temperate=1.5
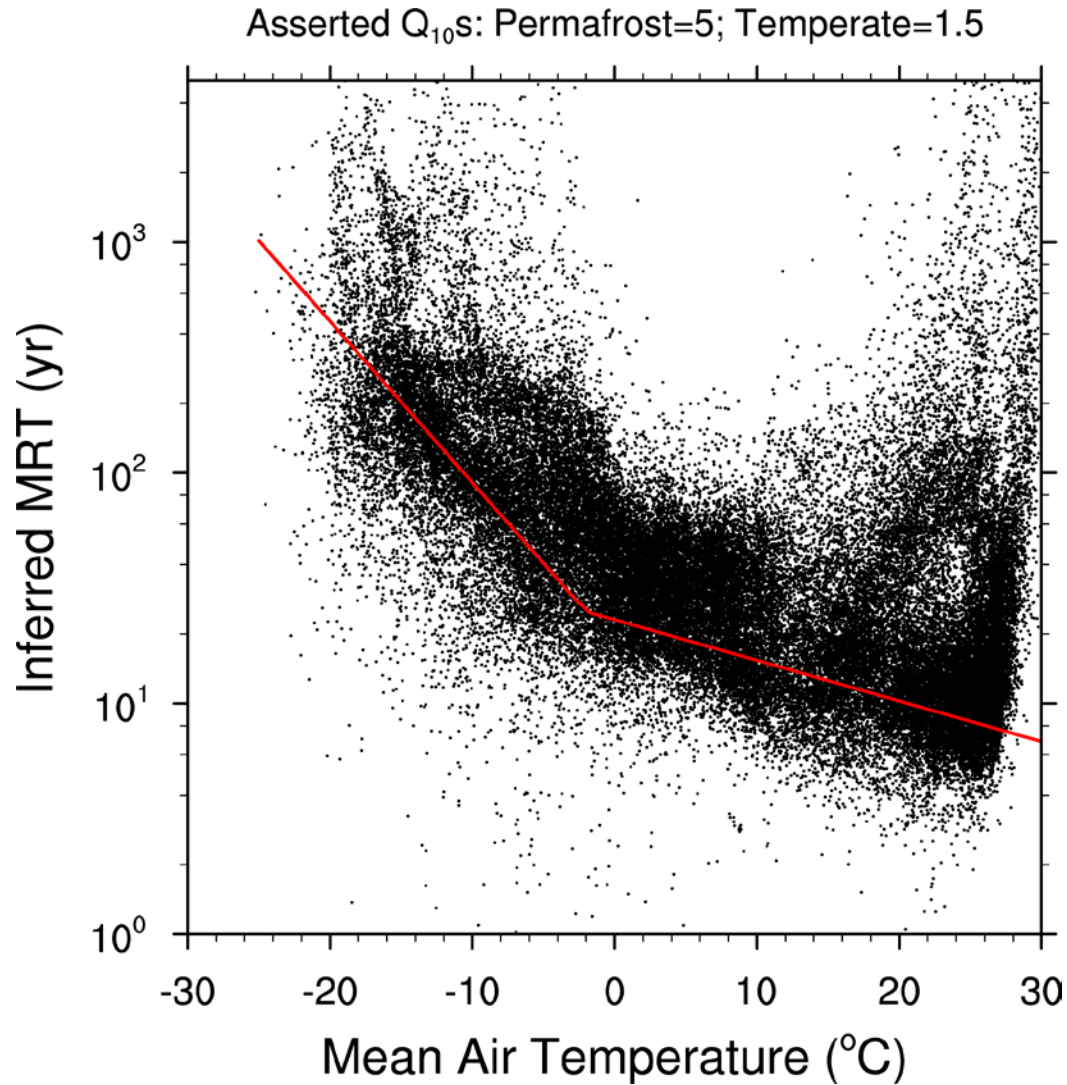
# Main results from observation-based benchmark

- There is a main population of data that follows a temperature trajectory, with secondary populations that have higher inferred MRT due to arid or peat-forming conditions.

- That main trend has a break in slope between cold and warm ecosystems.

- That main warm ecosystem trend is consistent with a CLM-like Q_{10} of around 1.5; this means that long-term and short-term temperature controls on decomposition rates don't disagree, which means no need for emergent behavior to explain this.

  - Note that this argument is modulo that I am literally just drawing lines on a graph and haven't actually done proper multivariate statistics at this point, because need to define aridity using something like P-PET and haven't calculated the PET part yet…

- At the cold end, slope appears consistent with a much higher Q_{10} (~5) which requires some emergent behavior at long timescales since short-term Q_{10}s are either lower when thawed or higher when frozen. Makes sense due to the complex dynamics of permafrost…

Now For CLM5, with same Q10 overlay as before: (1) NoN case

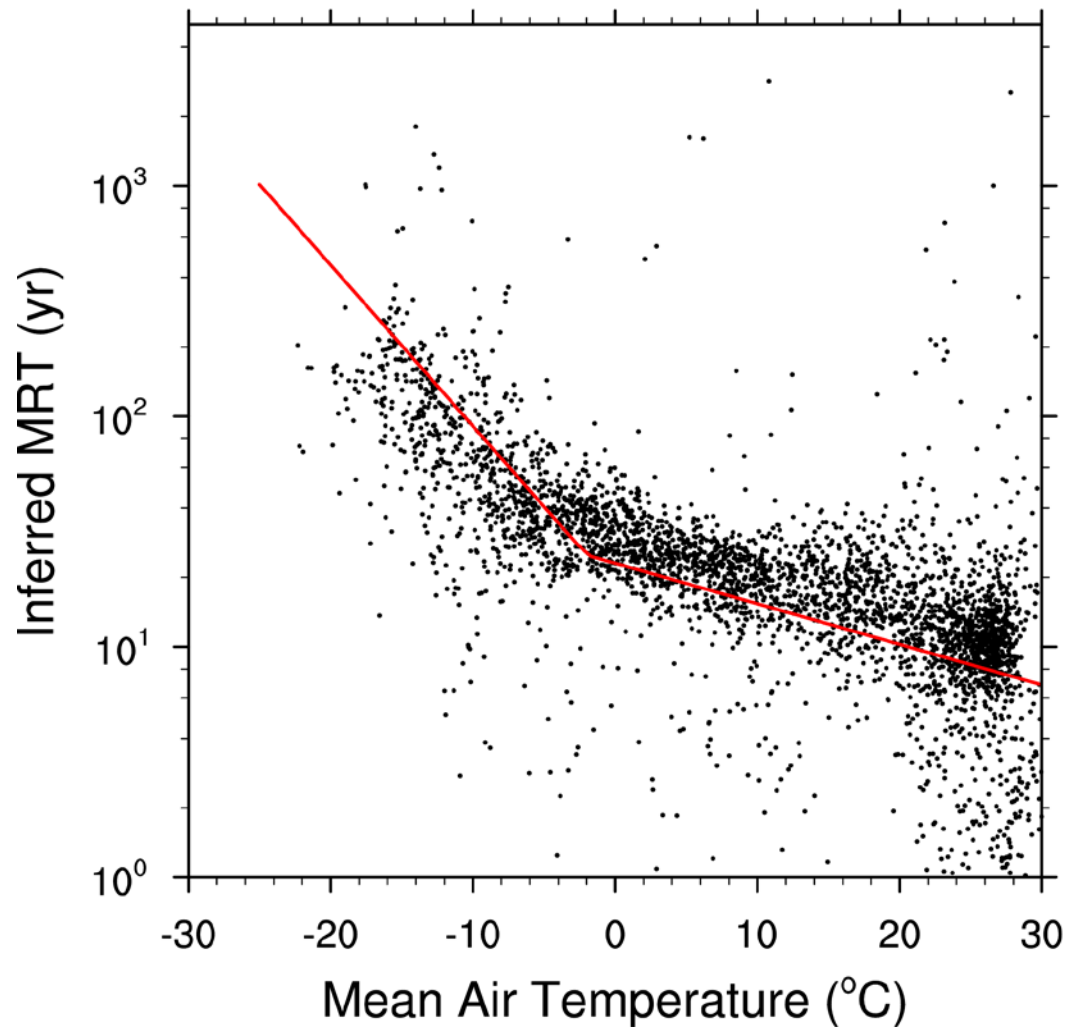CLM5_noN; Asserted Q_{10}s: Permafrost=5; Temperate=1.5
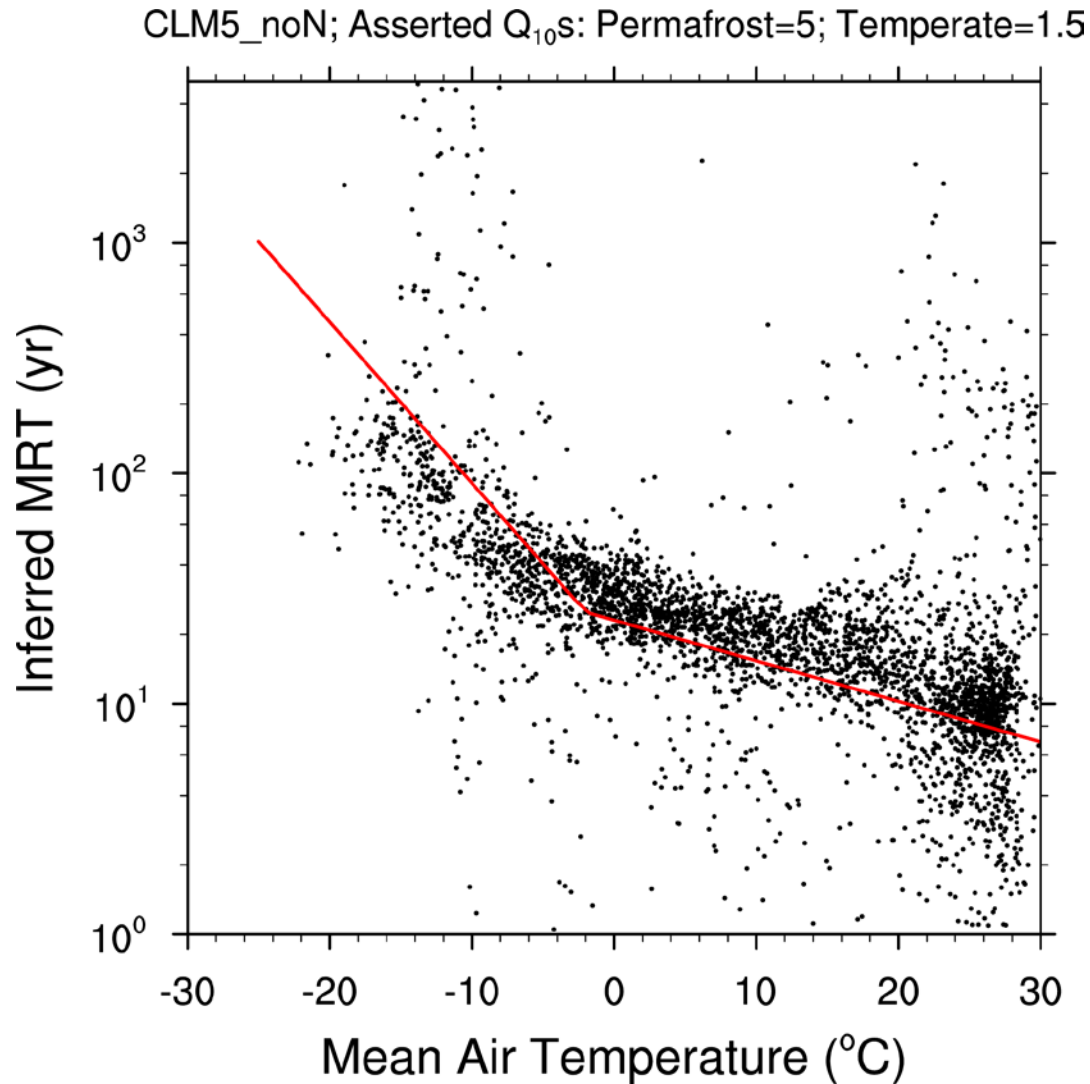
Now For CLM5, with same Q10 overlay as before: (2) FlexLuna case

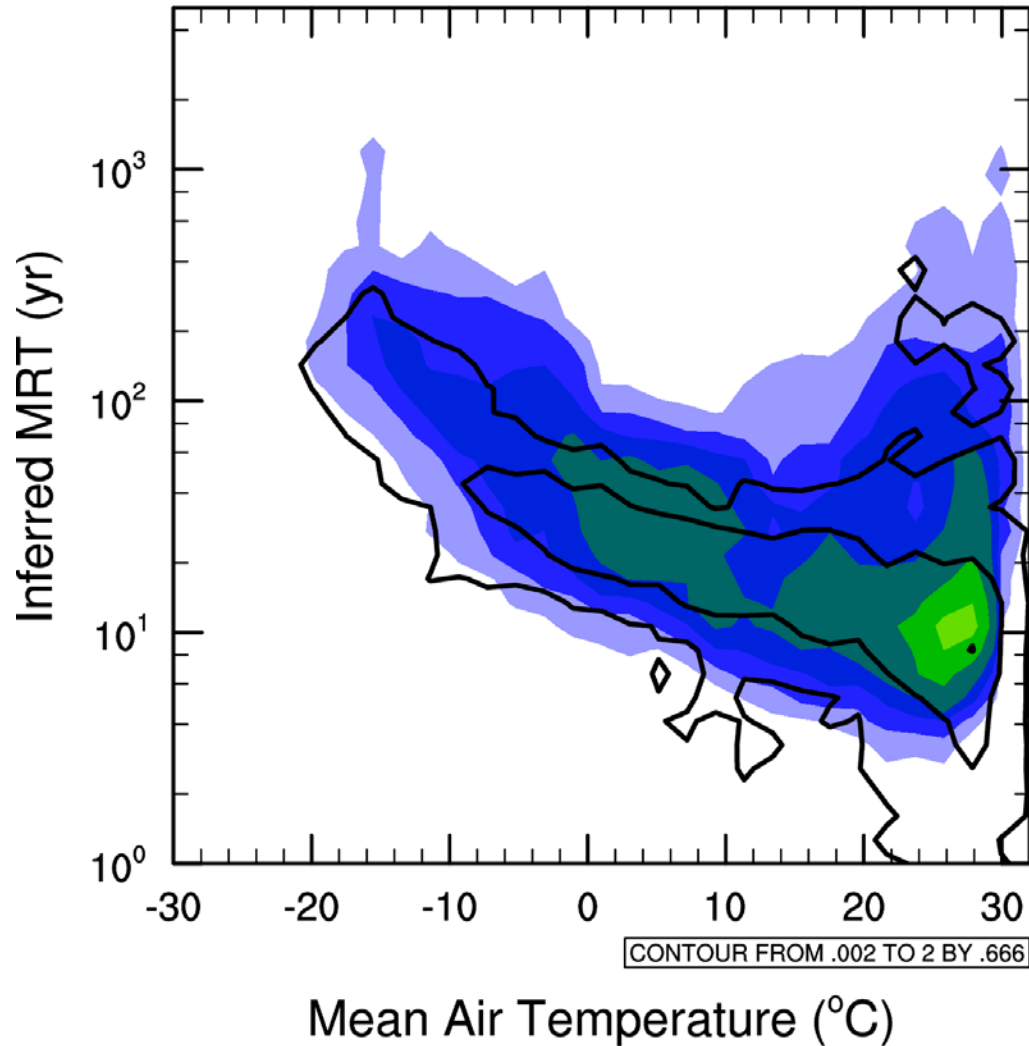CLM5_flexluna; Asserted Q_{10}s: Permafrost=5; Temperate=1.5
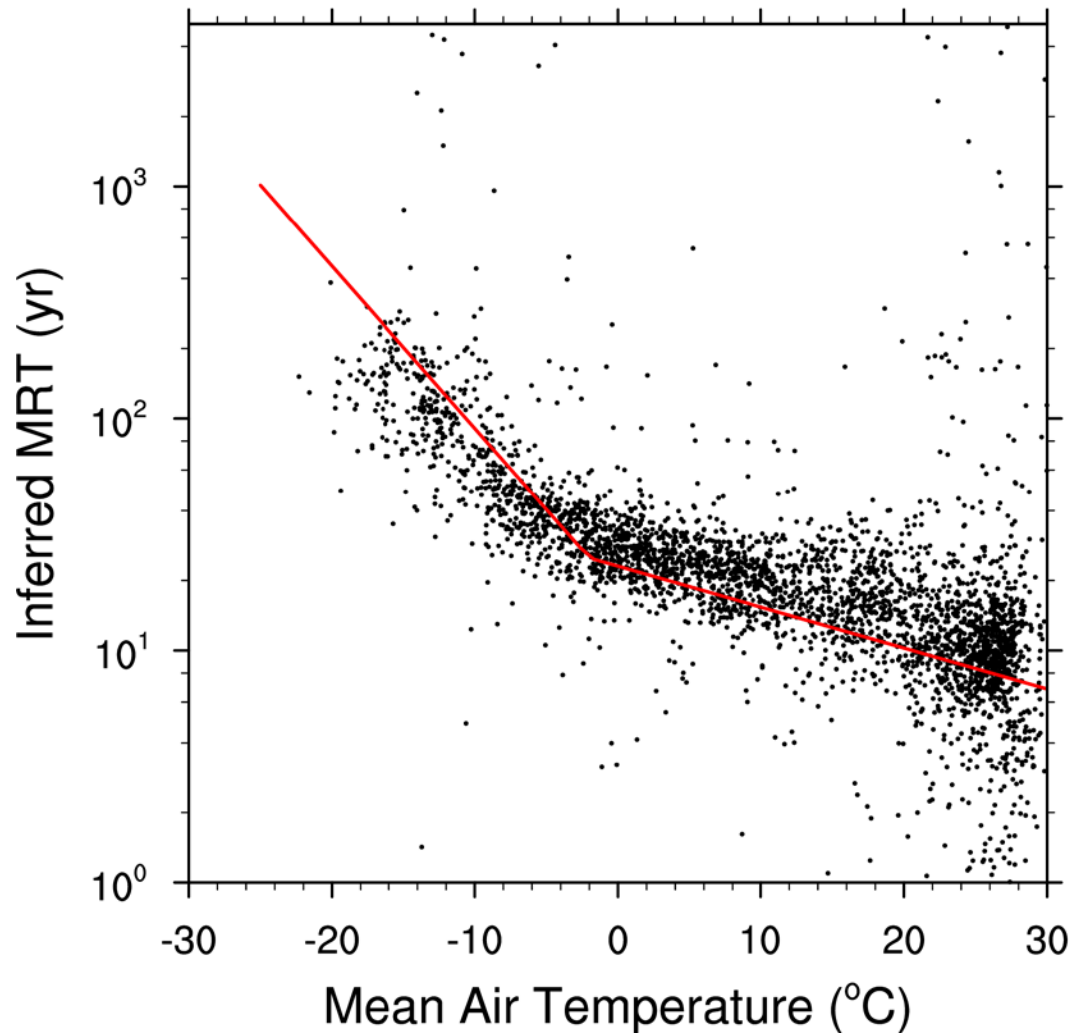
Now For CLM5, with same Q10 overlay as before: (3) AllN Case

CLM5_allN; Asserted Q_{10}s: Permafrost=5; Temperate=1.5

# Compare actual 2D PDF between CLM5 mean model and observations


observations shaded; CLM5 overlay contours

CONTOUR FROM .002 TO 2 BY .666

Inferred MRT (yr)

Mean Air Temperature (°C)

Some first takeaways:

- Pattern reasonably conserved between CLM5 runs
- Overall turnover time not crazy
- Model gets the break in slope between permafrost and non-permafrost soils
- Temperate slope appears reasonable (which it should since we've specified a Q10 of 1.5, which appears to fit the data)
- Permafrost slope possibly too small?
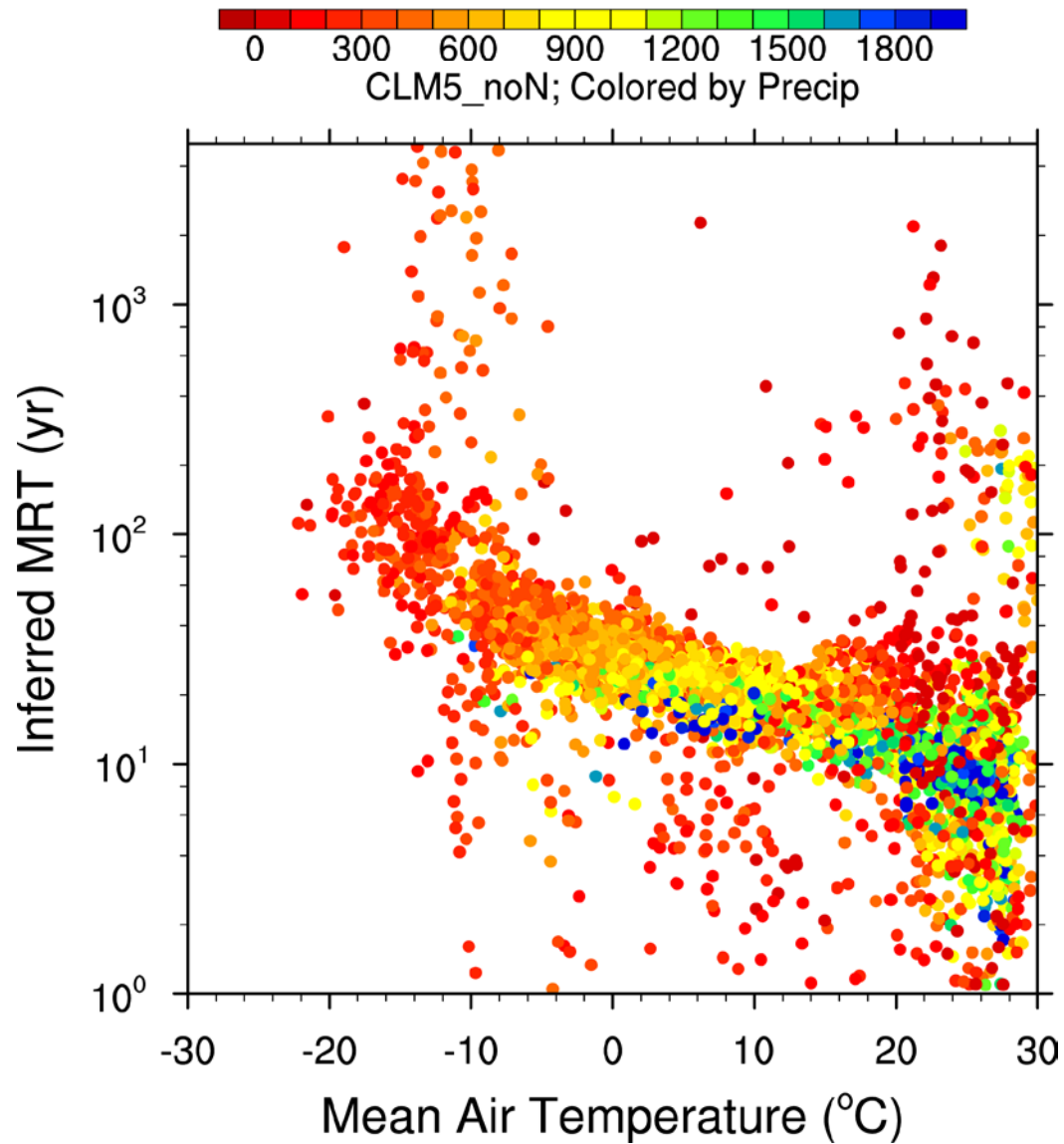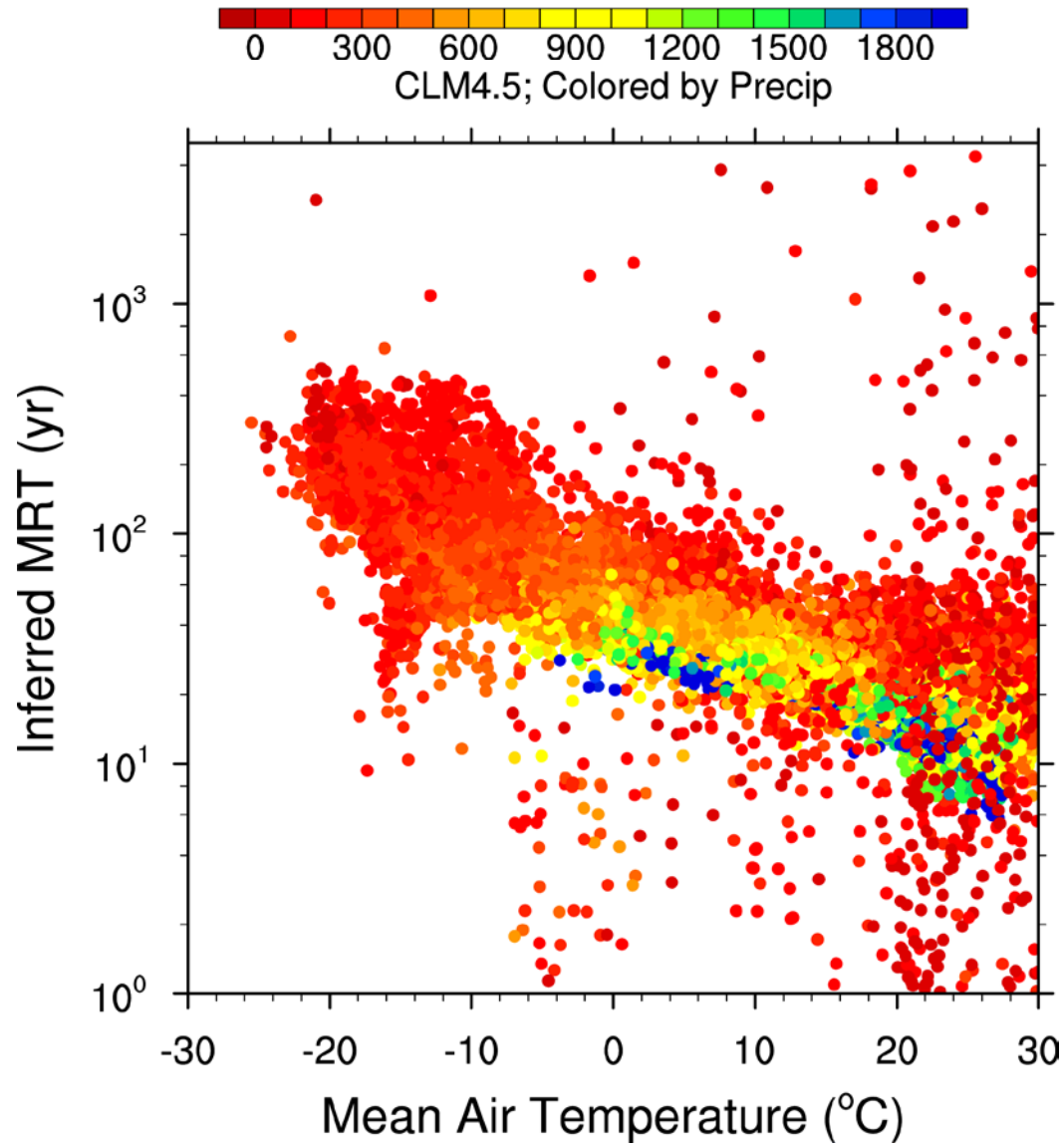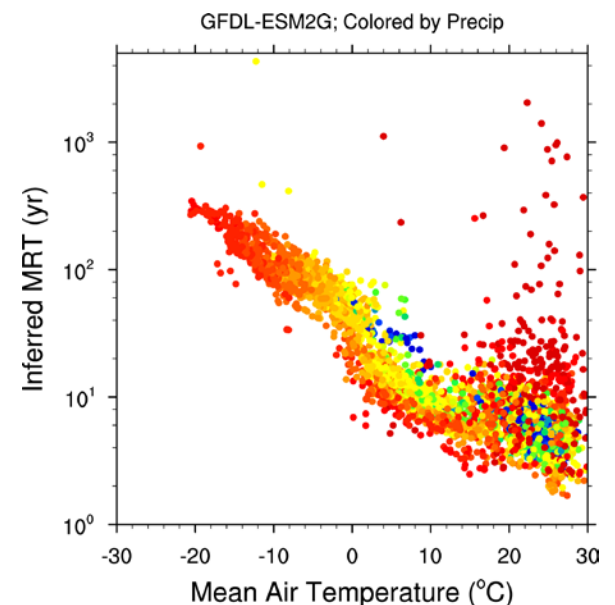
Going back in time, how does CLM4.5 compare?

CLM4.5; Asserted Q_{10}s: Permafrost=5; Temperate=1.5
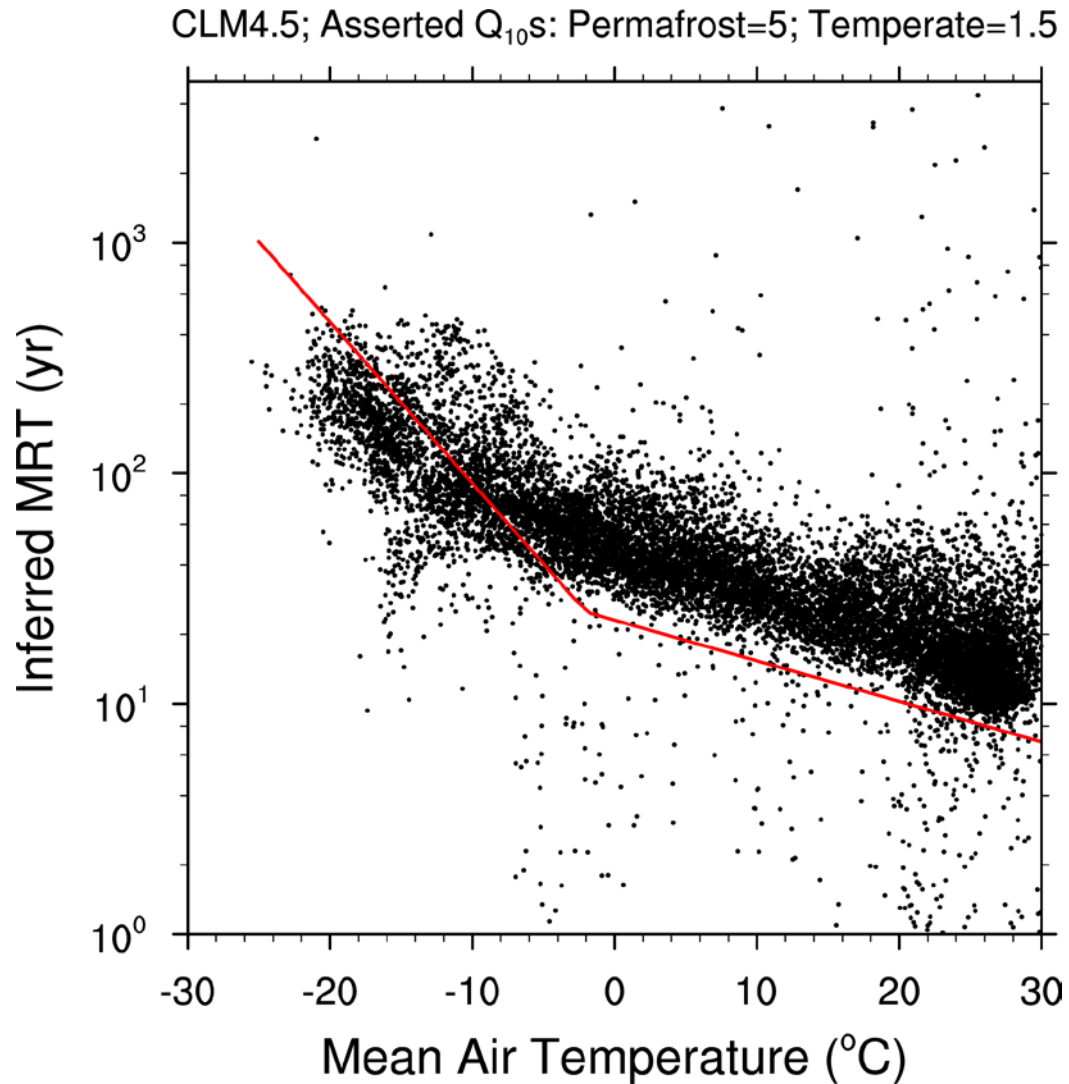
And farther back to CLM4 (in CCSM4)

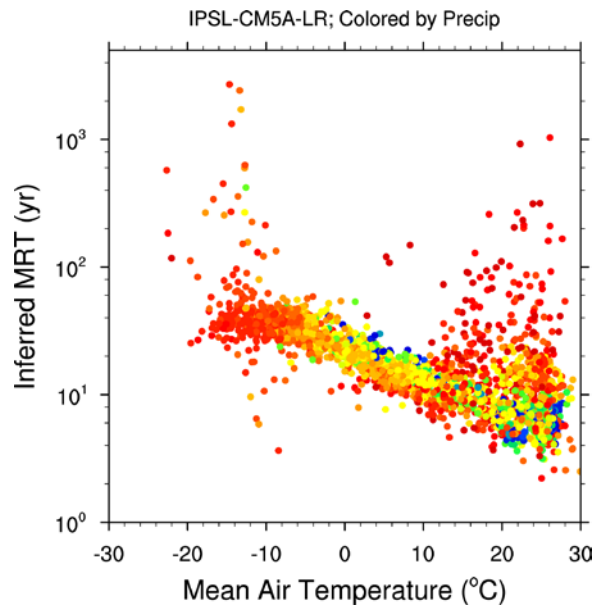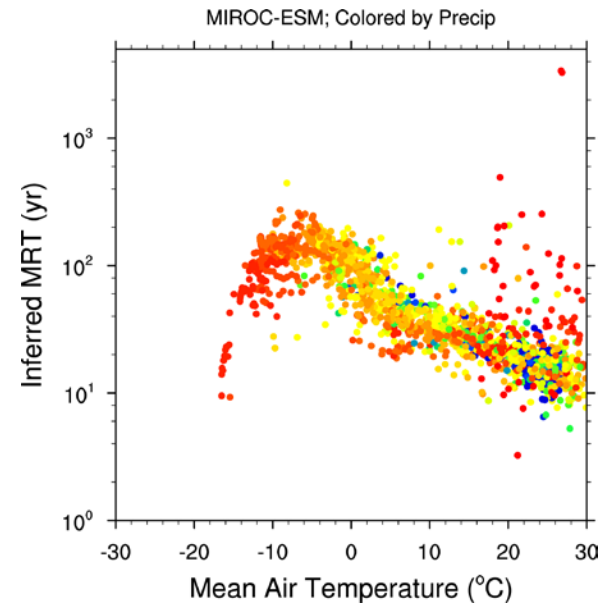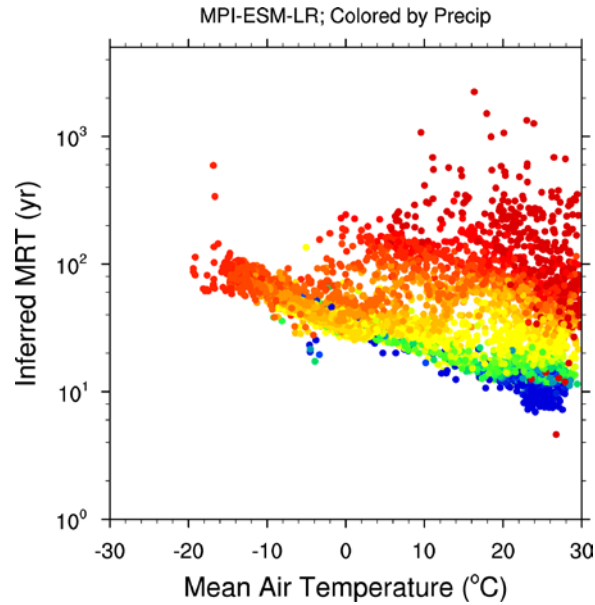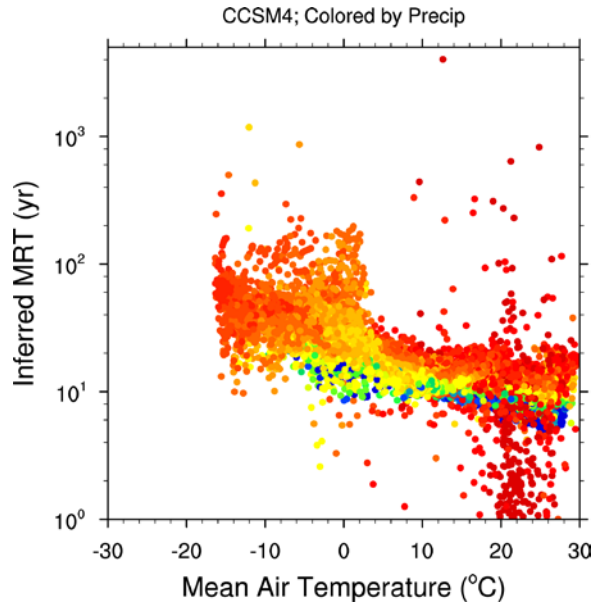CCSM4; Asserted Q_{10}s: Permafrost=5; Temperate=1.5
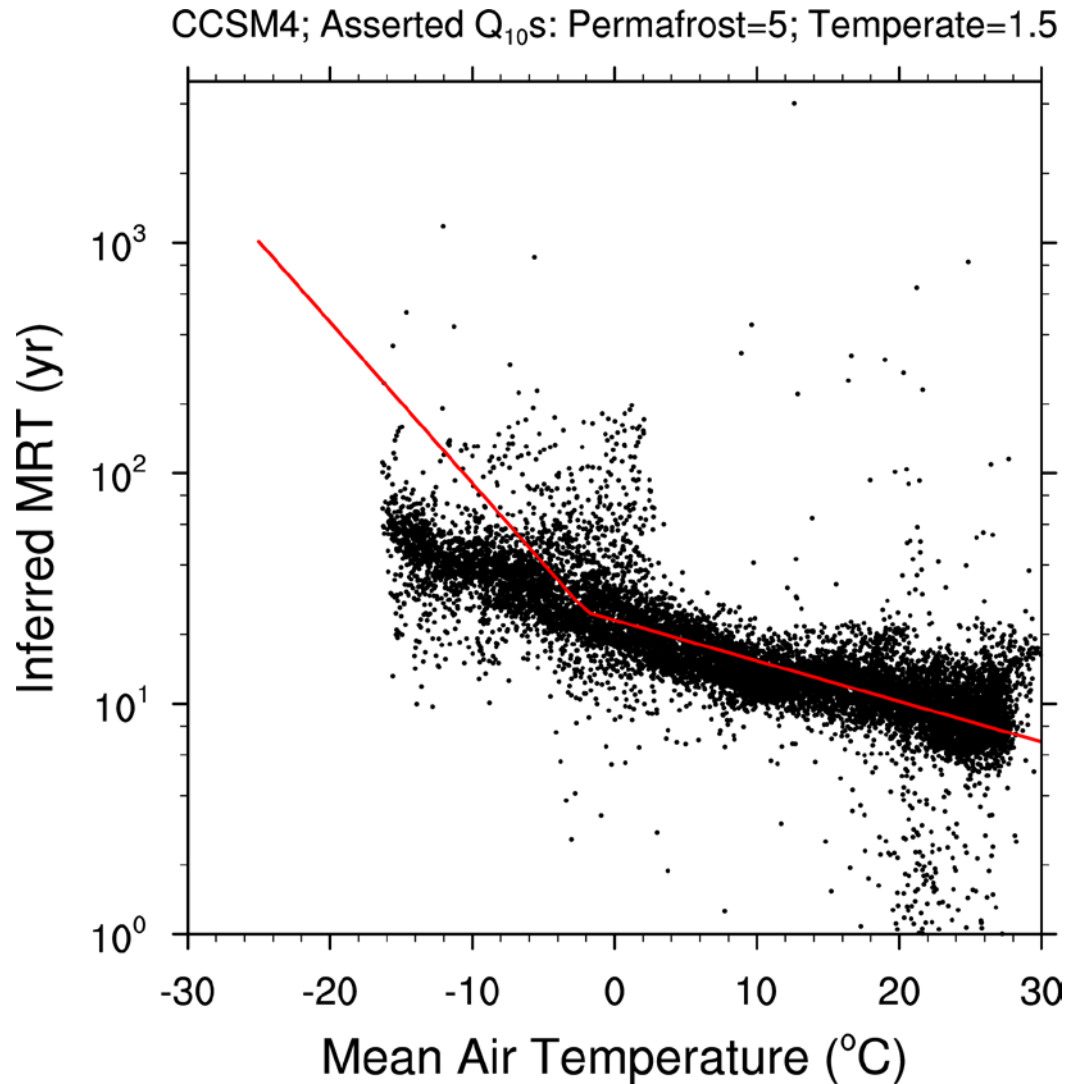
What about moisture controls in CLM5?

Moisture controls were stronger in CLM4.5…

Quick CMIP5 sanity check: is this trivial to get right?
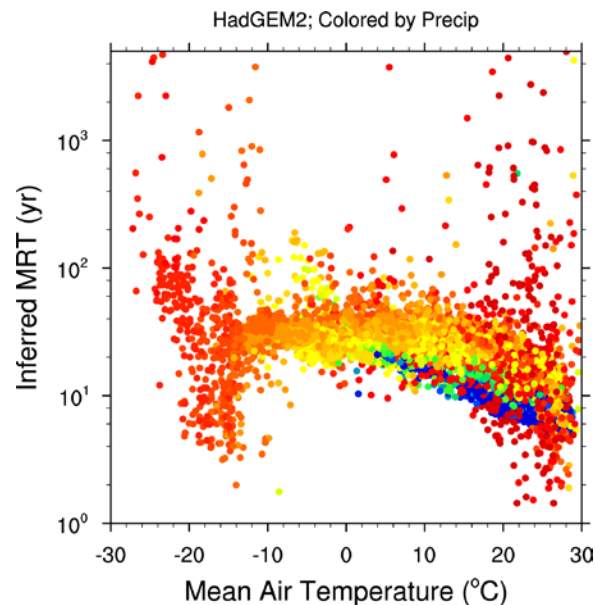
Conclusions:

- Relationship between climate and inferred MRT is a useful diagnostic of model dynamics
- Observations consistent with a pair of global Q10s: non-emergent in tropics/temperate; emergent in permafrost/cold
- CLM5 able to capture break in slope associated with permafrost, which other models do not capture
- Moisture control too weak in CLM5: need to investigate why