Homogeneous versus Heterogeneous SiB3 in a Cloud-Ensemble model

Donald Dazlich
Ian Baker
Colorado State University, Fort Collins CO

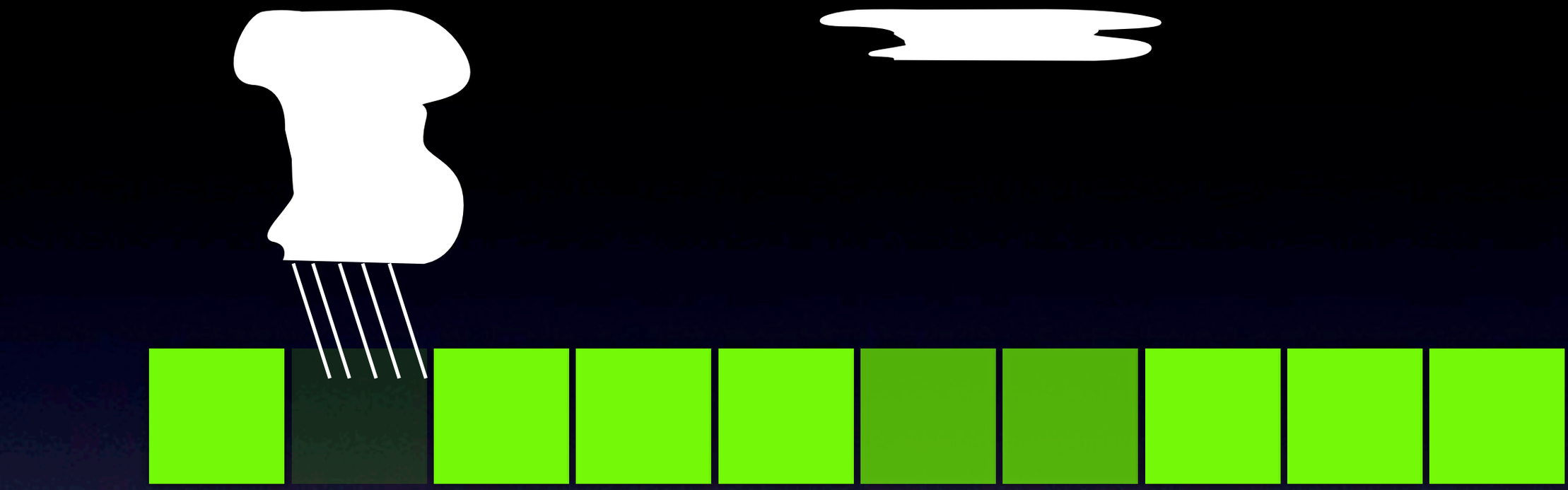
Joe Berry
Carnegie Institution for Science, Stanford CA

CMMAP Team Meeting, Boulder, CO
23 February 2012

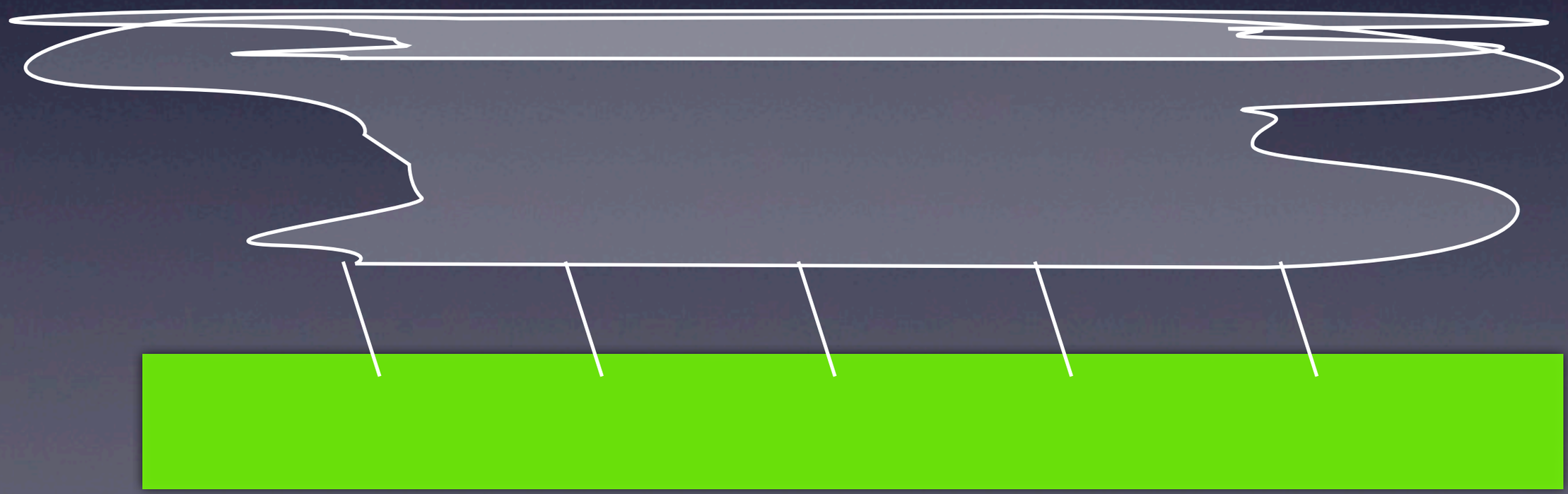
Motivation

- It's always been recognized there is a lot of sub-gridscale heterogeneity in the land surface on the scale of a GCM grid cell.
- Super-parameterization brought multiscale treatment to the atmosphere in the GCM grid cell, but only now is the land-surface getting the same multiscale treatment in a climate system model in terms of forcing from the atmosphere.
- Many land surface processes are highly non-linear. In a climate model the changes in the land surface fluxes interact with the climate as a whole and it can be difficult to isolate the effect of the land surface alone. We do that with the multiscale analog to the Single-Column Model (a Super-SCM).
- But that is just the Cloud-Ensemble Model that was implemented in the climate model atmosphere in the first place!

Multi-point (heterogeneous) land:



One-point (homogeneous) land:



SiB3 Installation in SAM

- SiB3 (Simple Biosphere 3) is a land surface model maintained at CSU. It was installed in an earlier version of SAM a few years ago and reinstalled (in a much more SAM-friendly way) this fall.
- There is an option to run SiB in one-point mode by providing to each land cell the domain average precipitation and radiation rather the the value of the SAM grid column above.
- There are hooks installed to allow prescription of multiple vegetation parameter sets, but all experiments described here have uniform vegetation parameters across the domain.

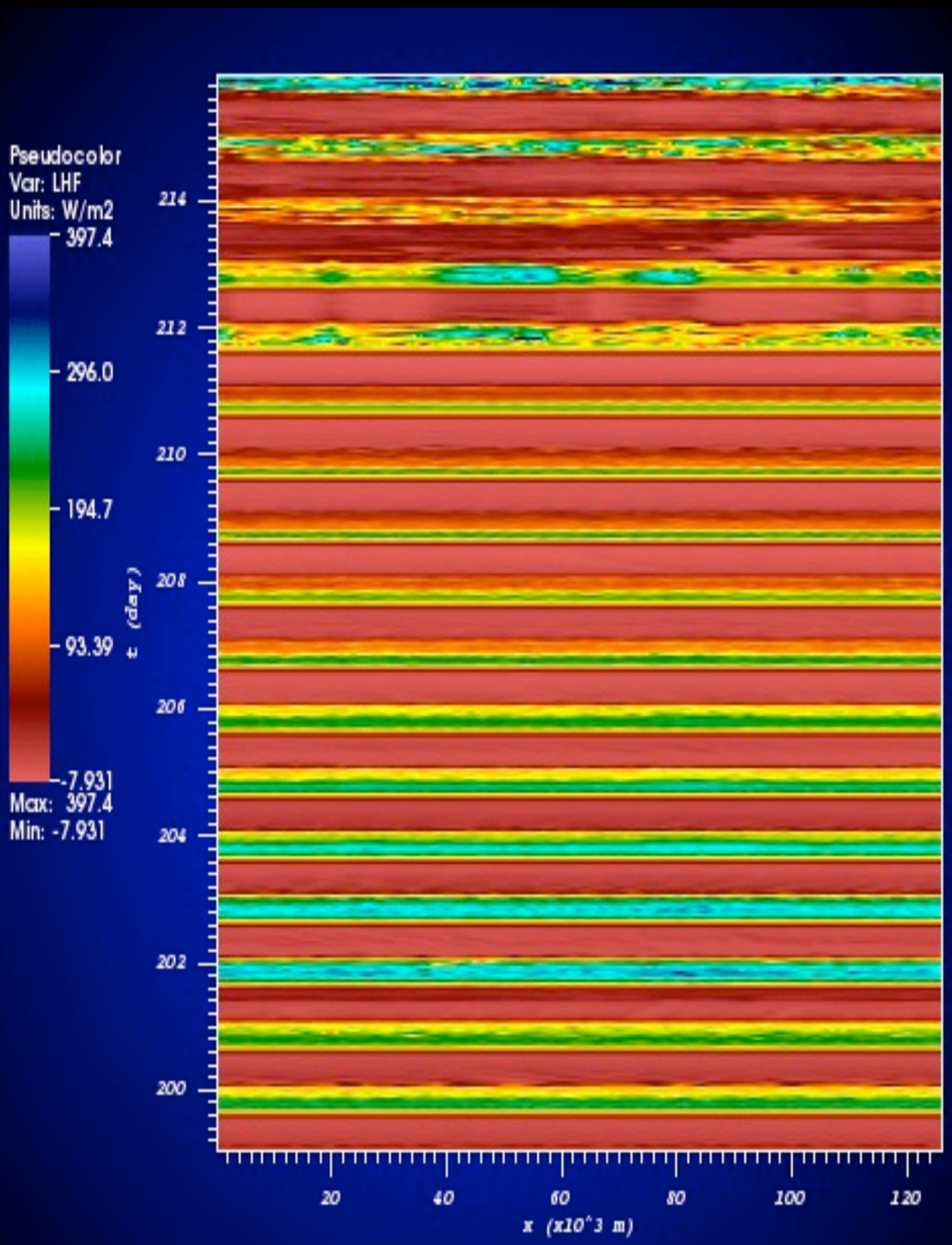
SAM cases for running SiB3

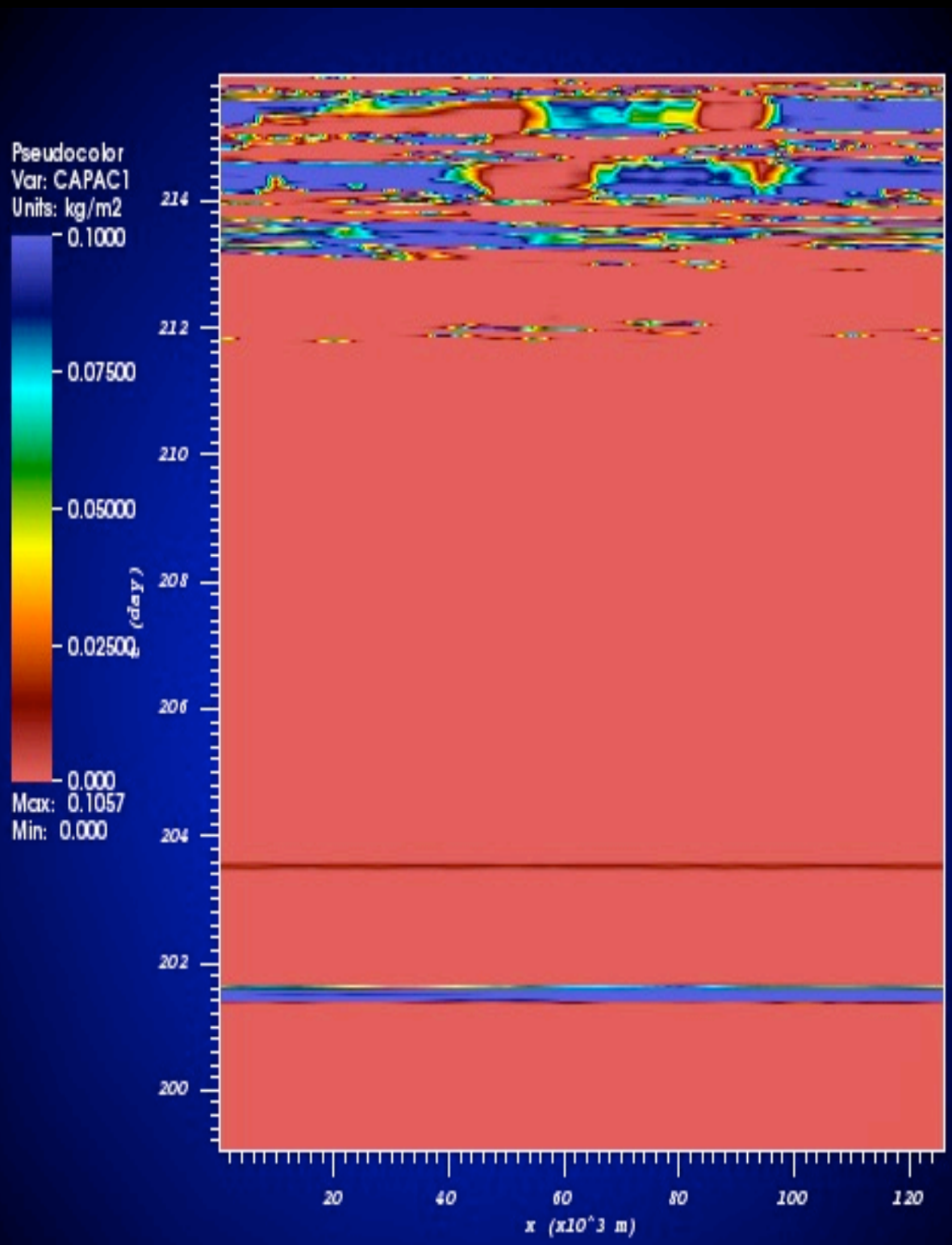
- For a specific IOP an initial condition and time-varying plant physiological parameters must be provided. Ian Baker has extracted these from reanalysis-driven offline SiB runs.
- ARM9507 - 17 days beginning 00z 18 July 1995 at the Southern Great plains site.
- ARM9707 - 30 days beginning 00z 19 June 1997
- TAPAJOS km 83 - 3 years of forcing beginning 00z 2 January 2001; forcing constructed by Anna Harper from reanalysis.

Simulations

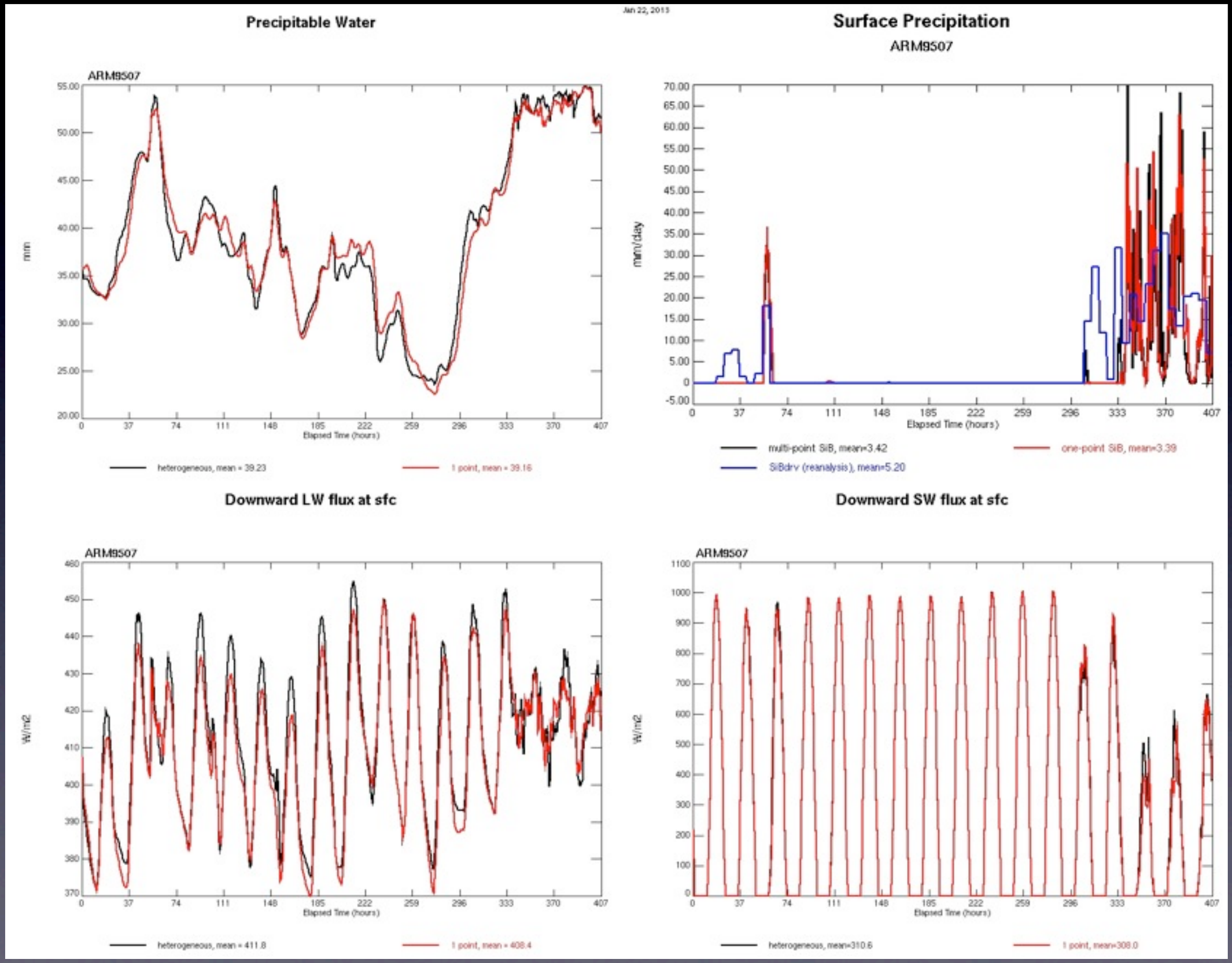
- SAM6.10.3, RRTM radiation, Morrison microphysics, 64x1x64 domain (x-z), dx=2km. U, V, T and Q relaxation. Relaxation minimizes feedback from the atmosphere to the land.
- Homogeneous (1 point) SiB3: SAM precipitation and radiation fluxes, and lowest layer T, Q, Ps, wind speed and CO2 are domain-averaged. The same latent, sensible and carbon fluxes, surface albedo, upward longwave emission and friction velocity are supplied to all SAM columns.
- Heterogeneous (multi-point) SiB3: an independent SiB calculation is done for each SAM gridcell. Physiological parameters are uniform across the domain but the prognostic variables take independent trajectories.
- ARM9507; TAPAJOS

ARM9507 Heterogeneity Examples

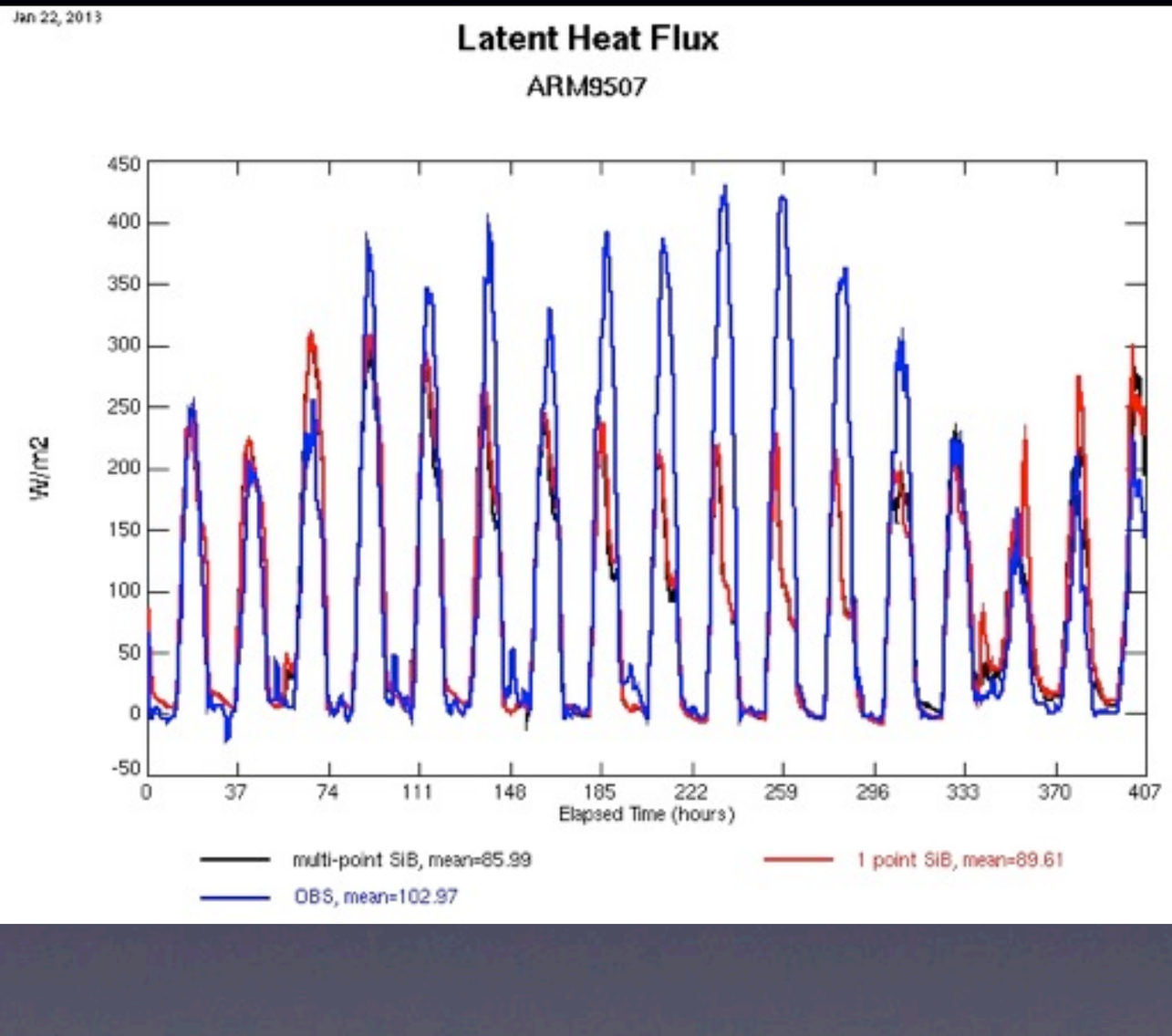


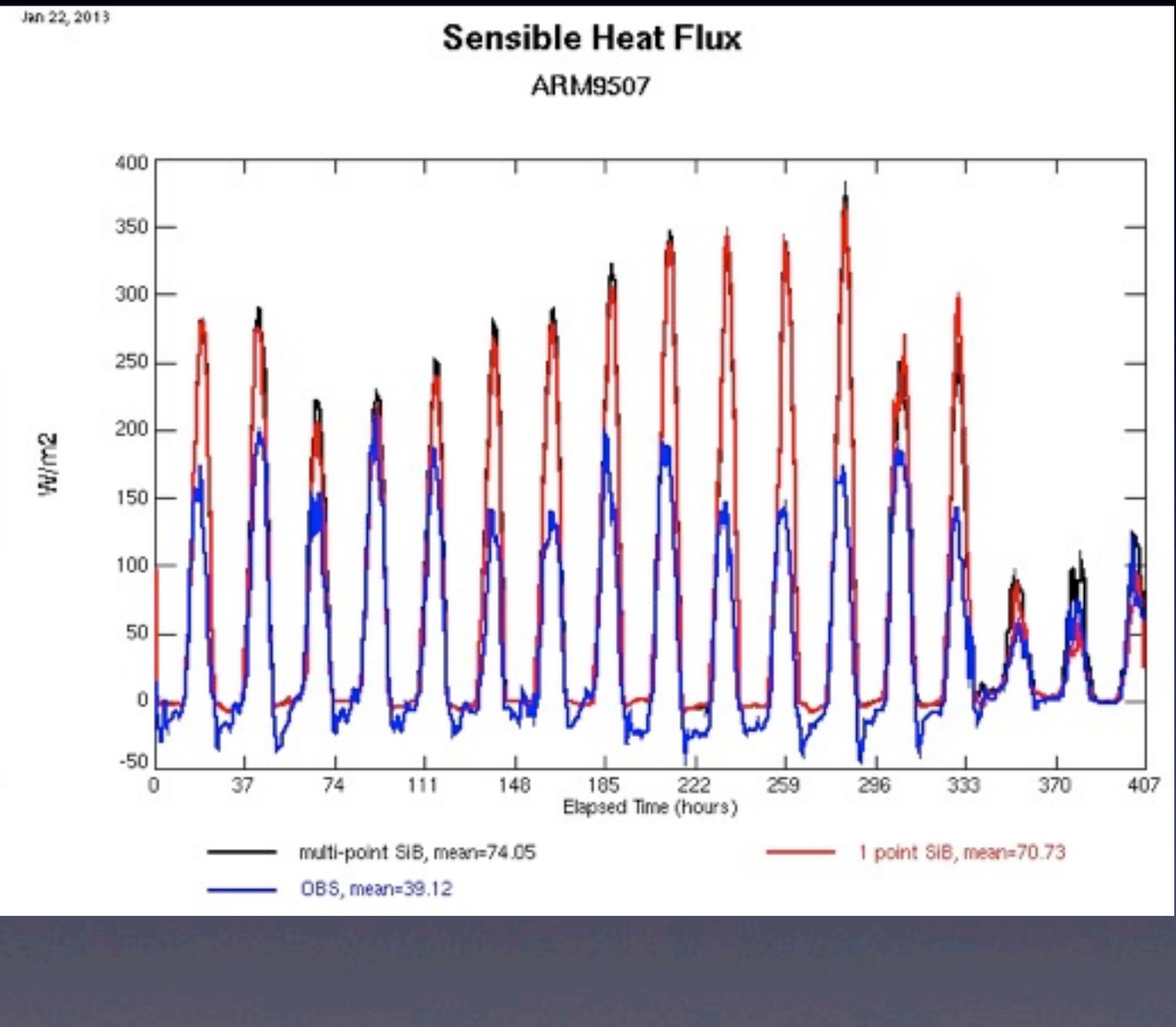


ARM9507: Similar atmospheric forcing in both simulations

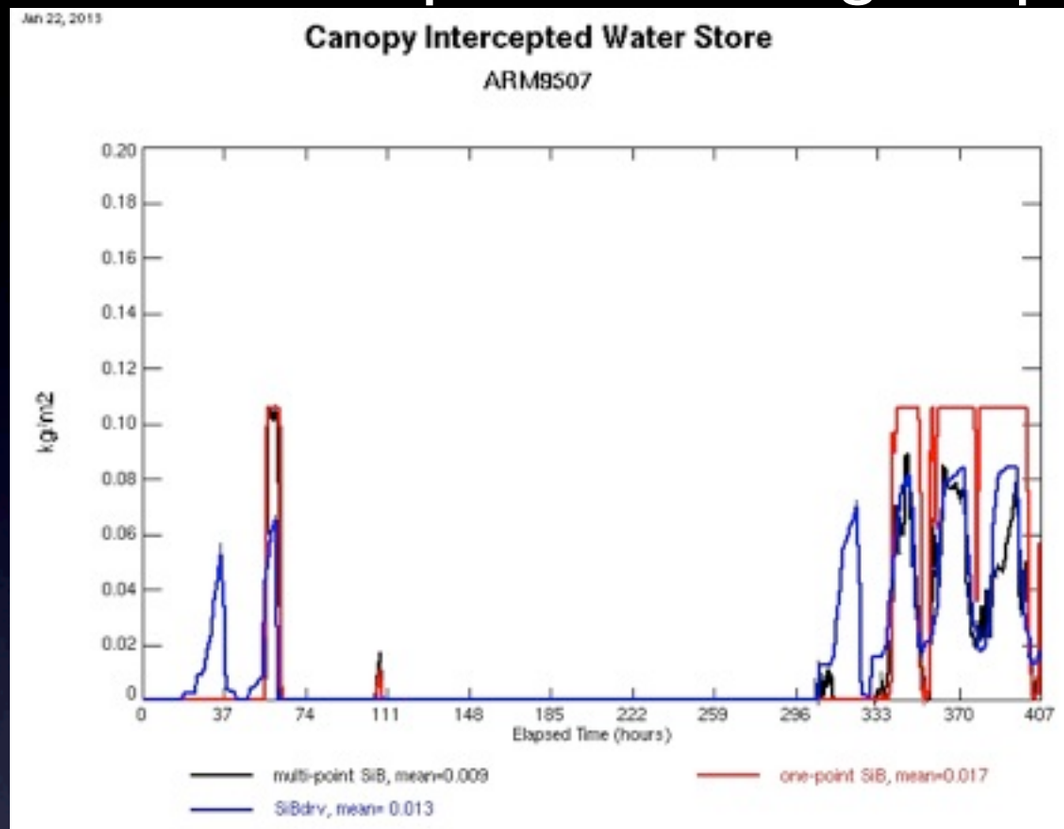


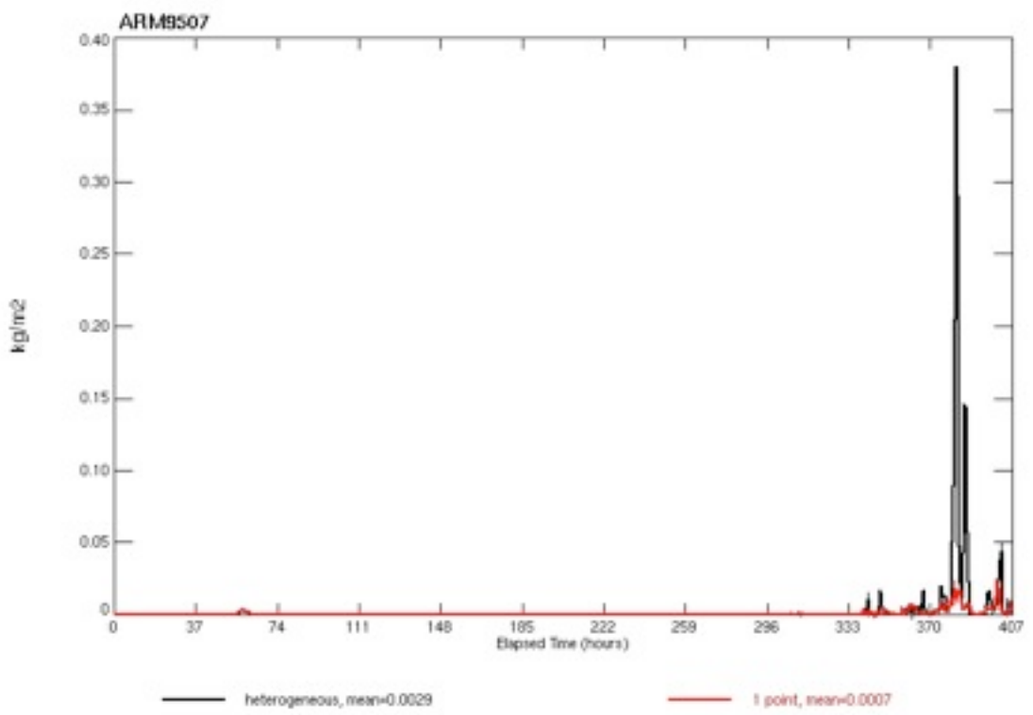
ARM9507: Simulated latent and sensible heat fluxes differ from observed (EBBR) fluxes used to drive a prescribed surface model. However, it is still useful to compare the differences in the two SiB3 runs.

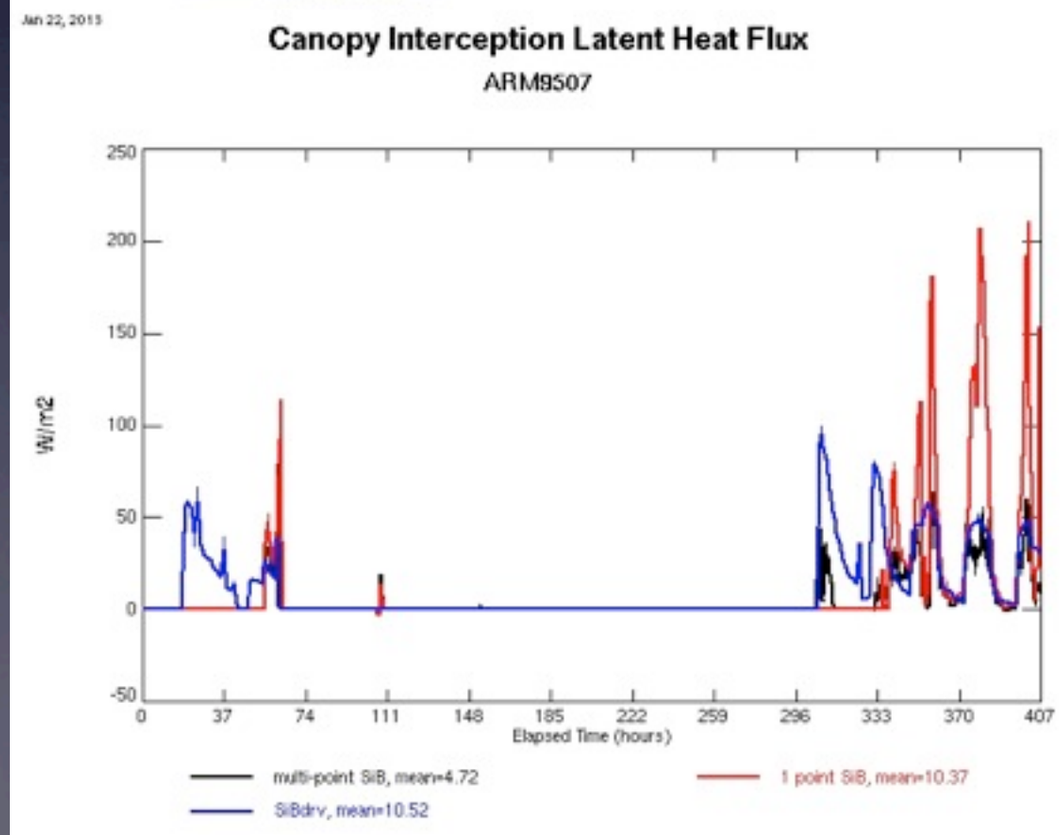


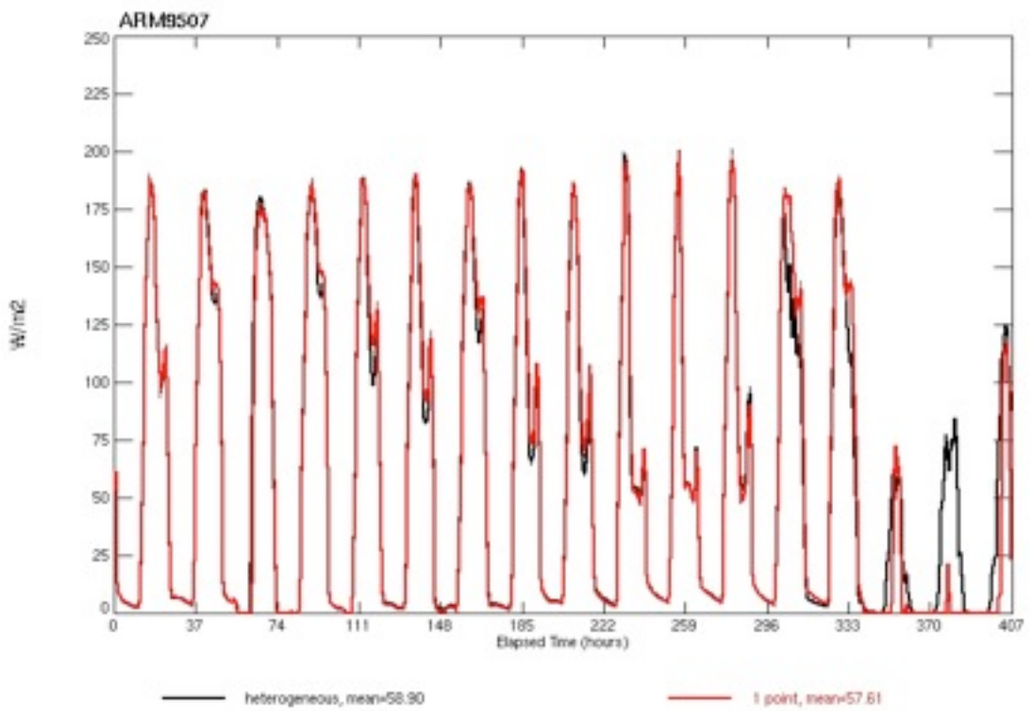


ARM9507: Shift from canopy interception evaporation to evapotranspiration with multipoint SiB3 - multipoint SiB avoids the headache of parameterizing the precipitation-canopy interaction.

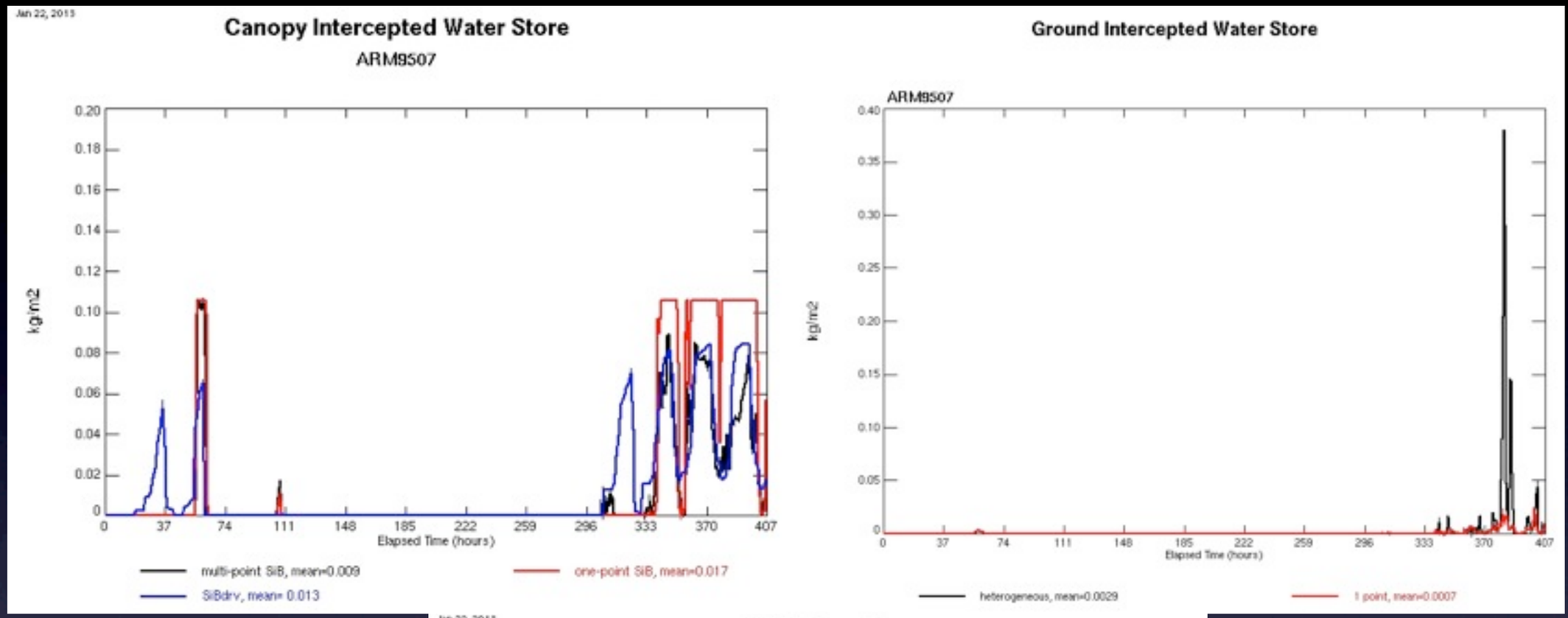


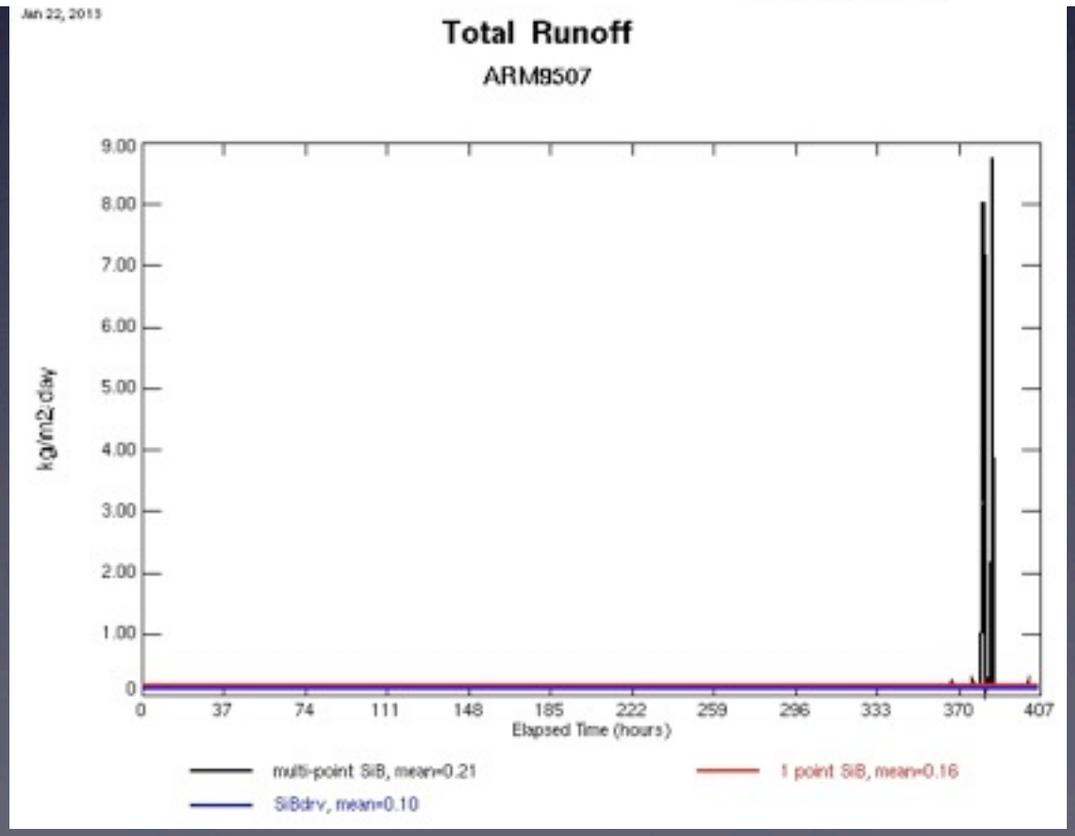




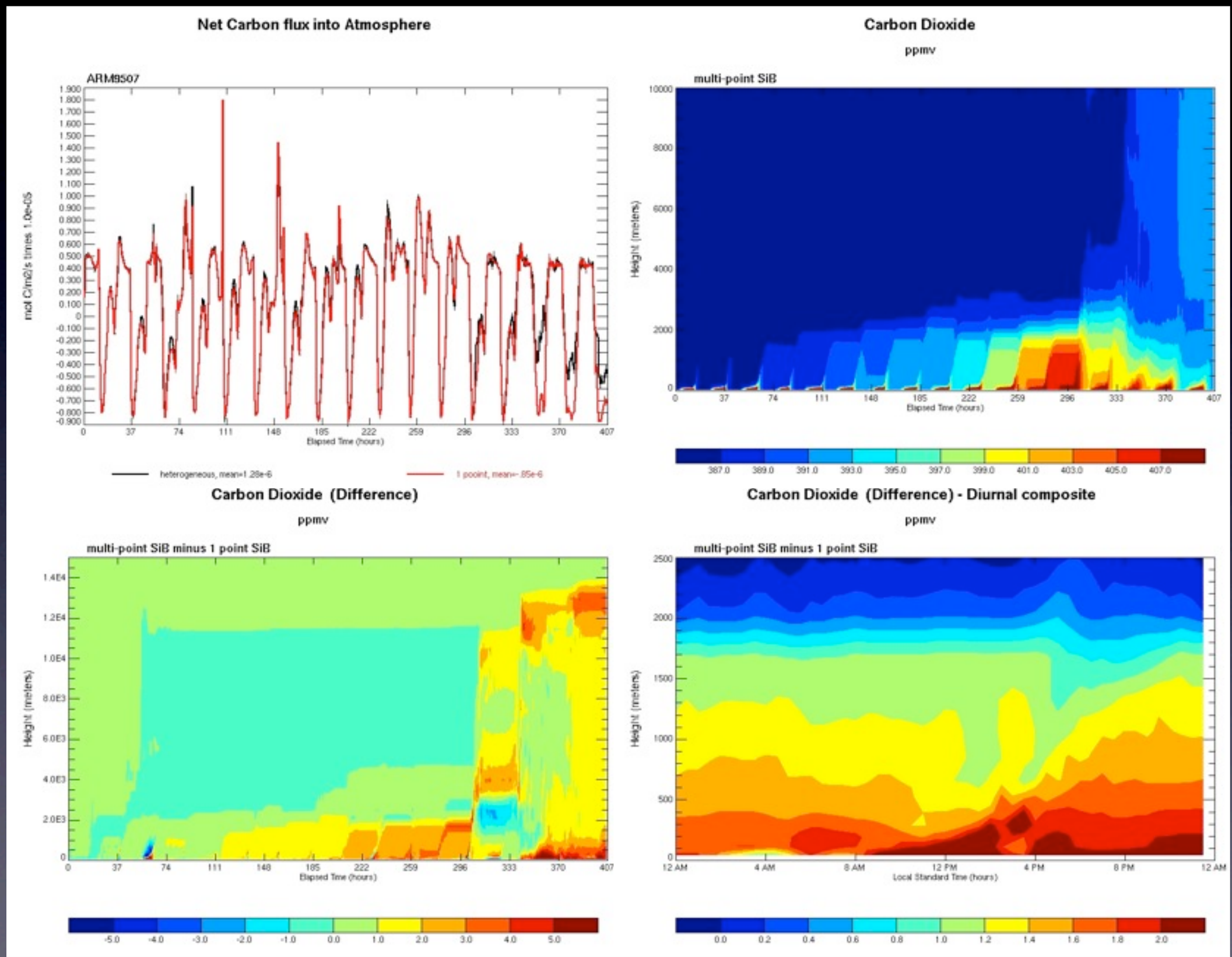


ARM9507: 30% increase in runoff with multi-point SiB3

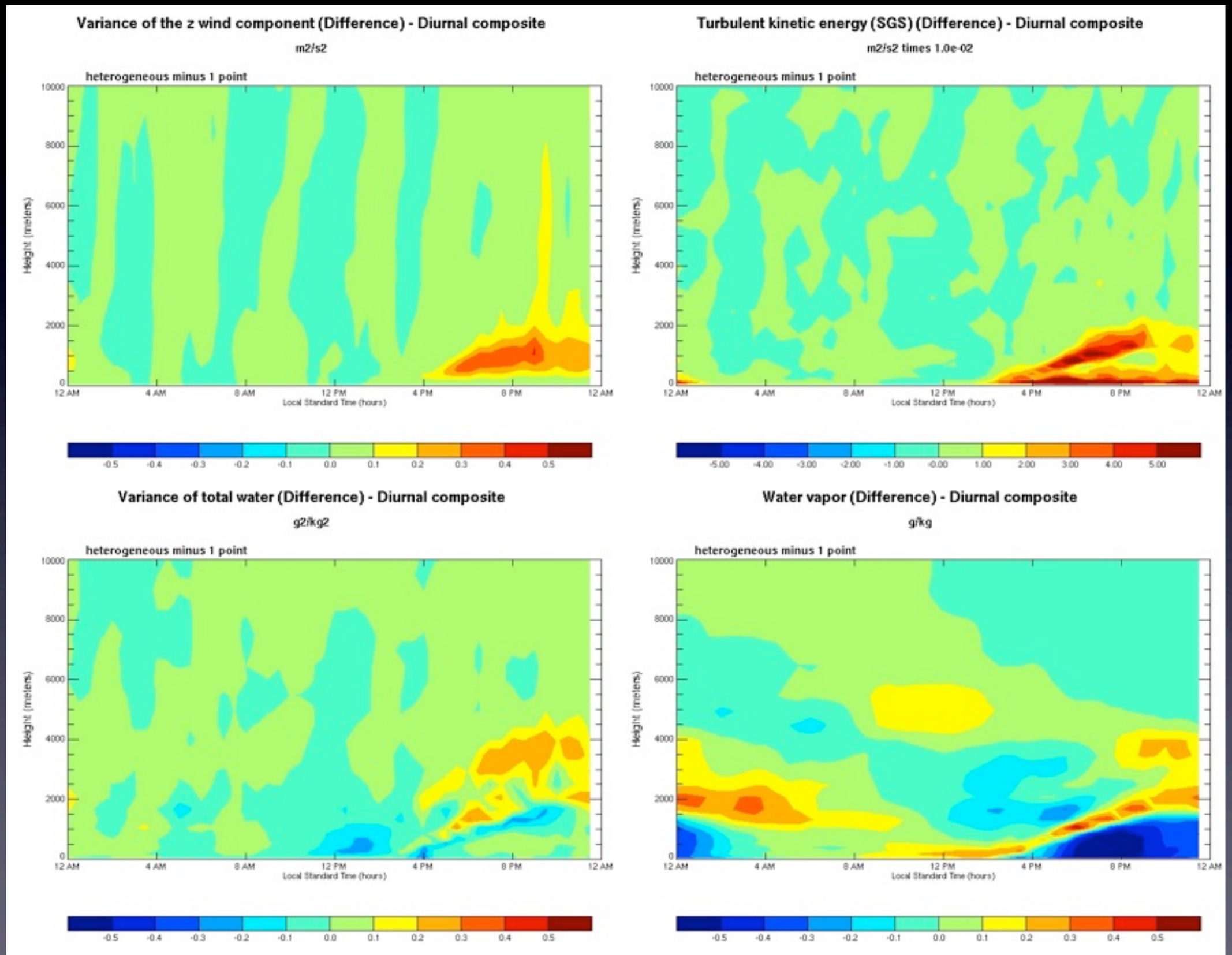




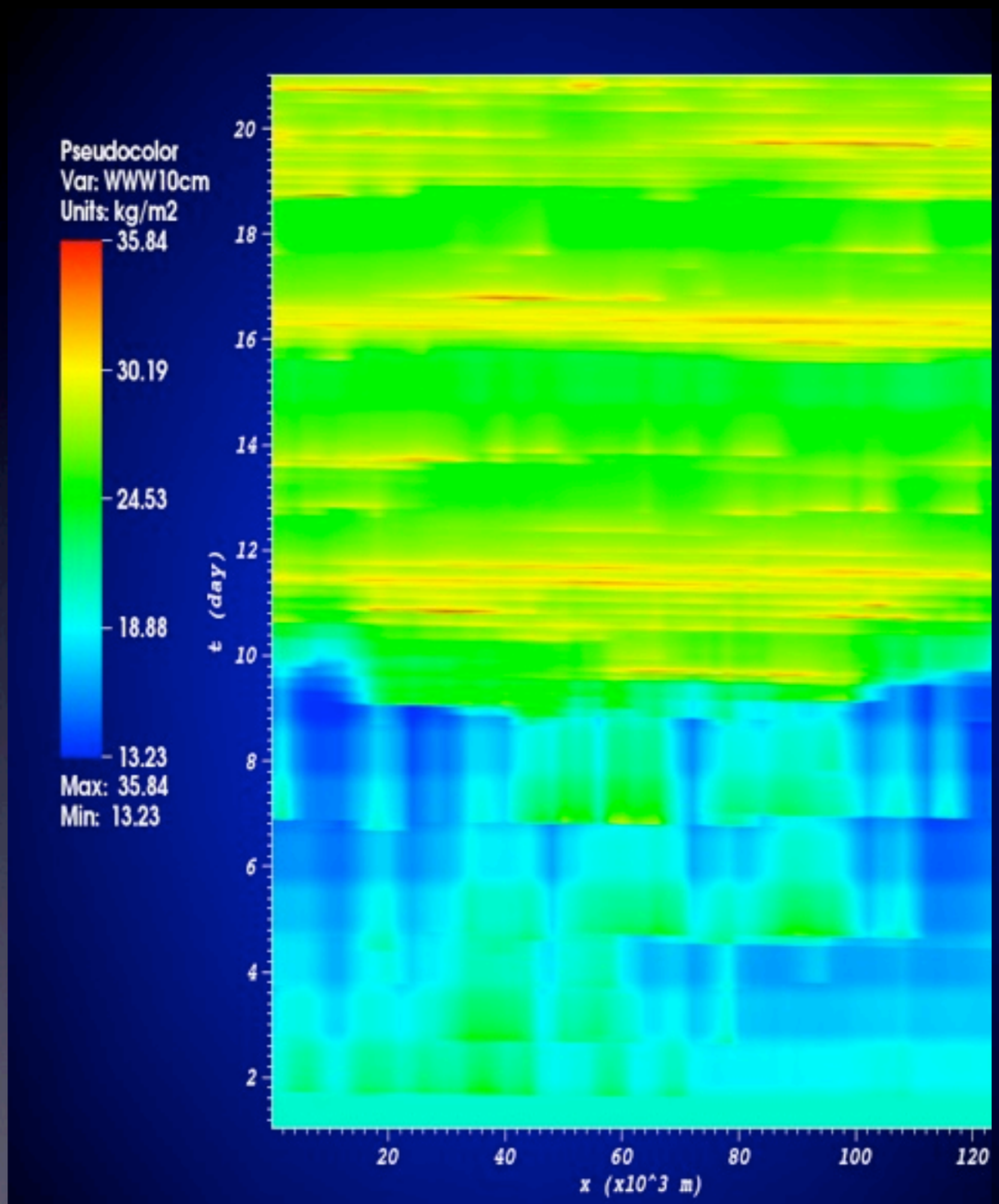
ARM9507: 40% increase in carbon flux to atmosphere with multi-point SiB3 due to decrease in photosynthetic assimilation of C.

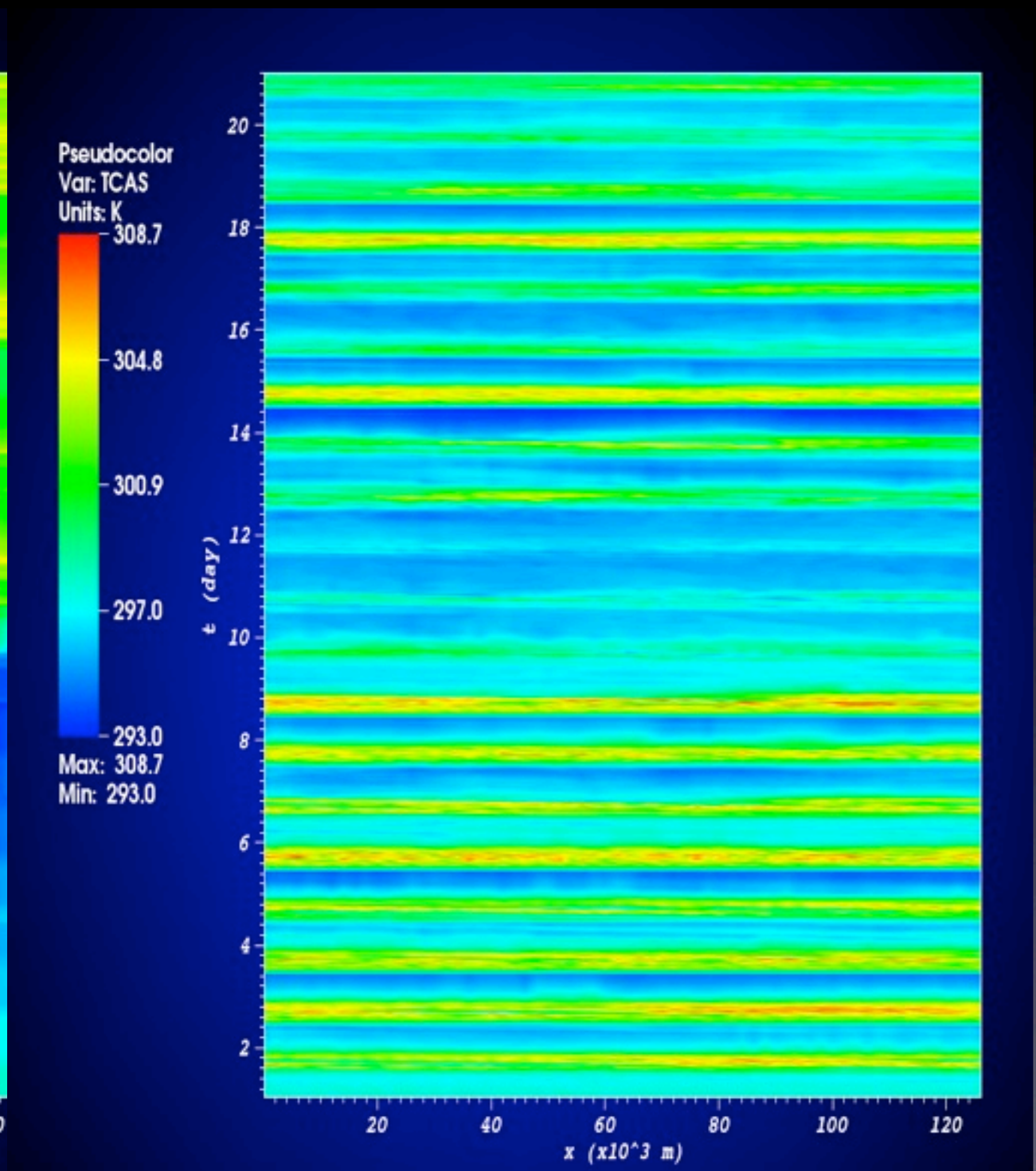


ARM9507: multiple signatures of stronger boundary layer growth with multi-point SiB3

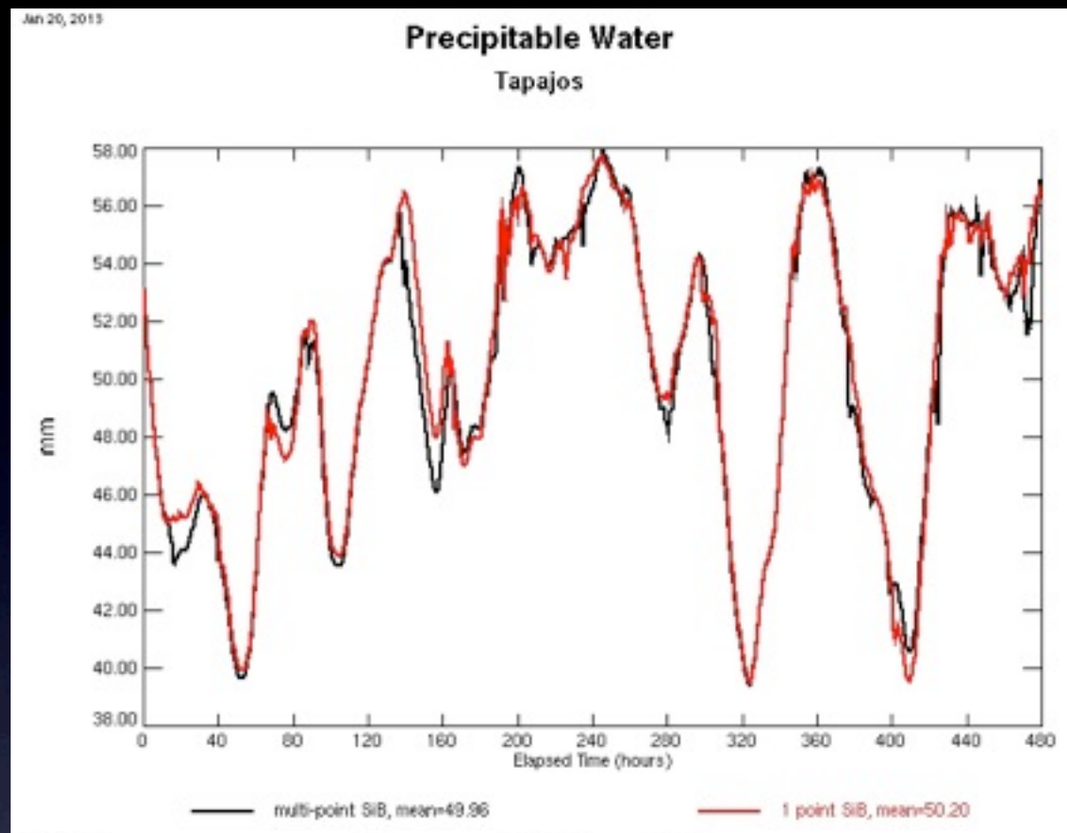


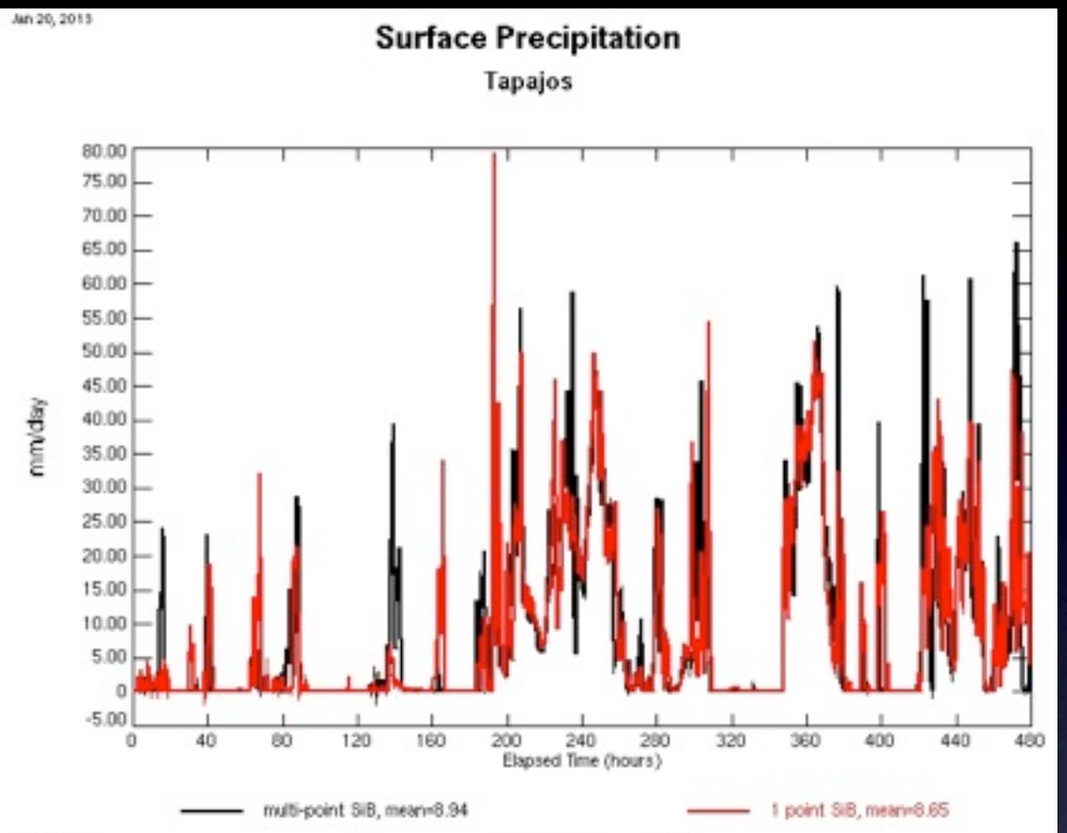
Tapajos Heterogeneity Examples

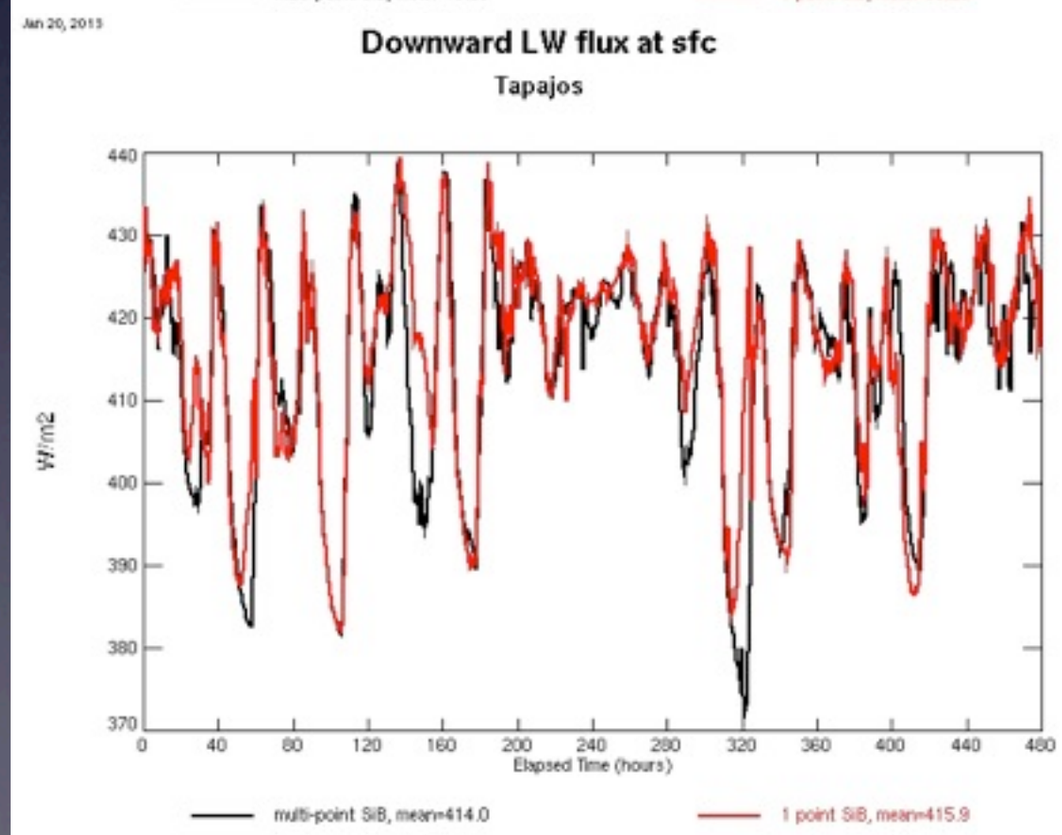


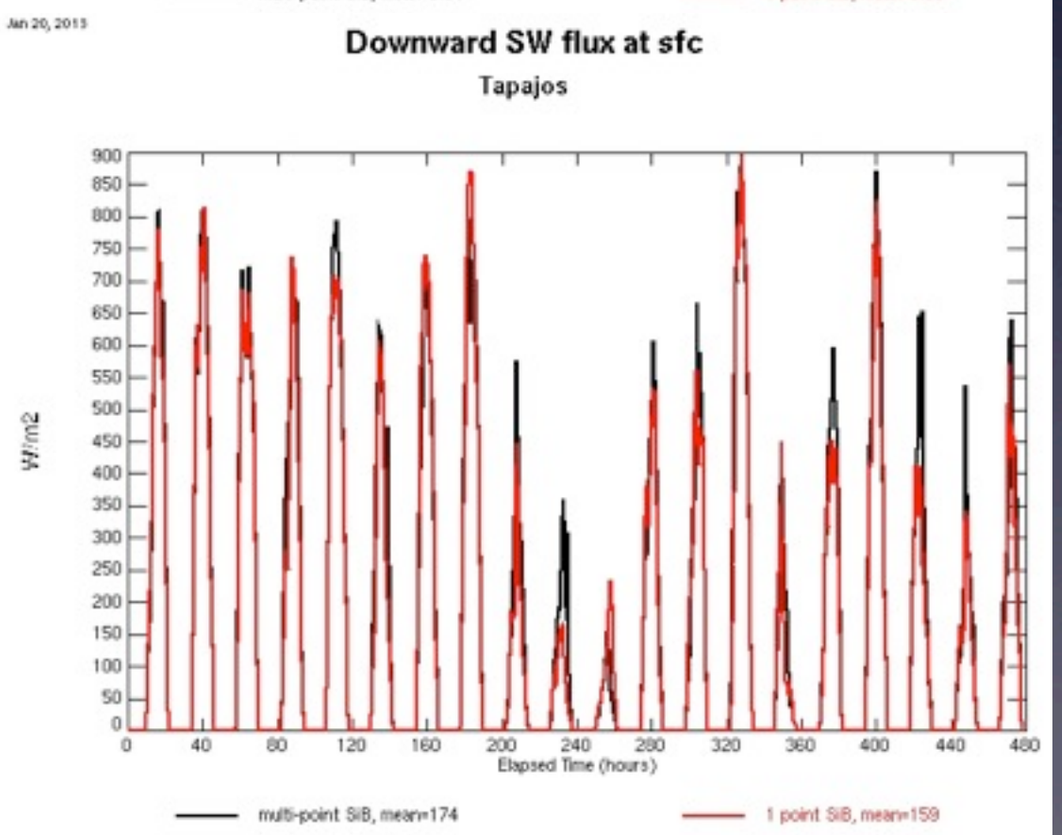


Tapajos: despite relaxation in atmosphere there is noticable feedback in the precipitation and solar forcing at the surface.

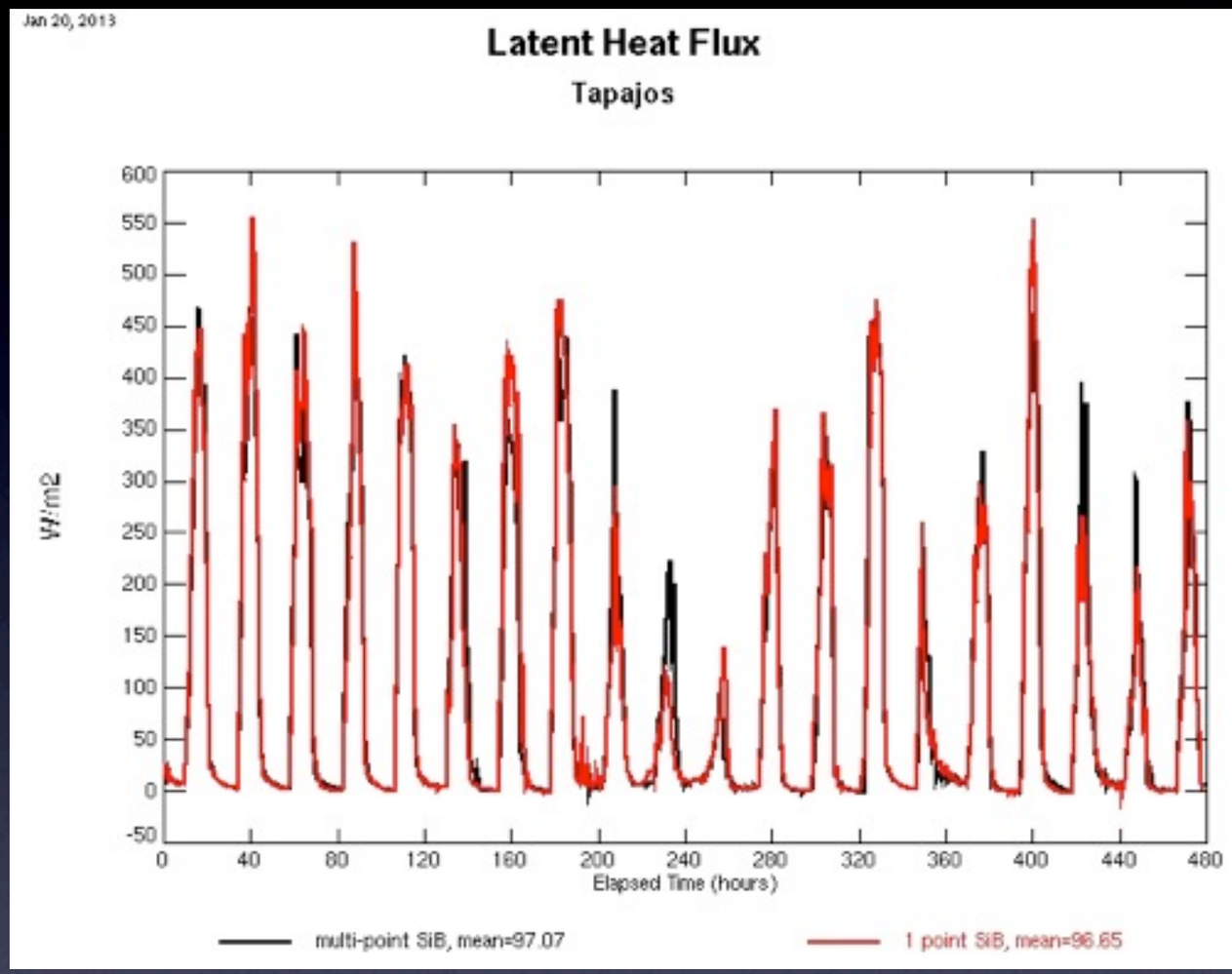


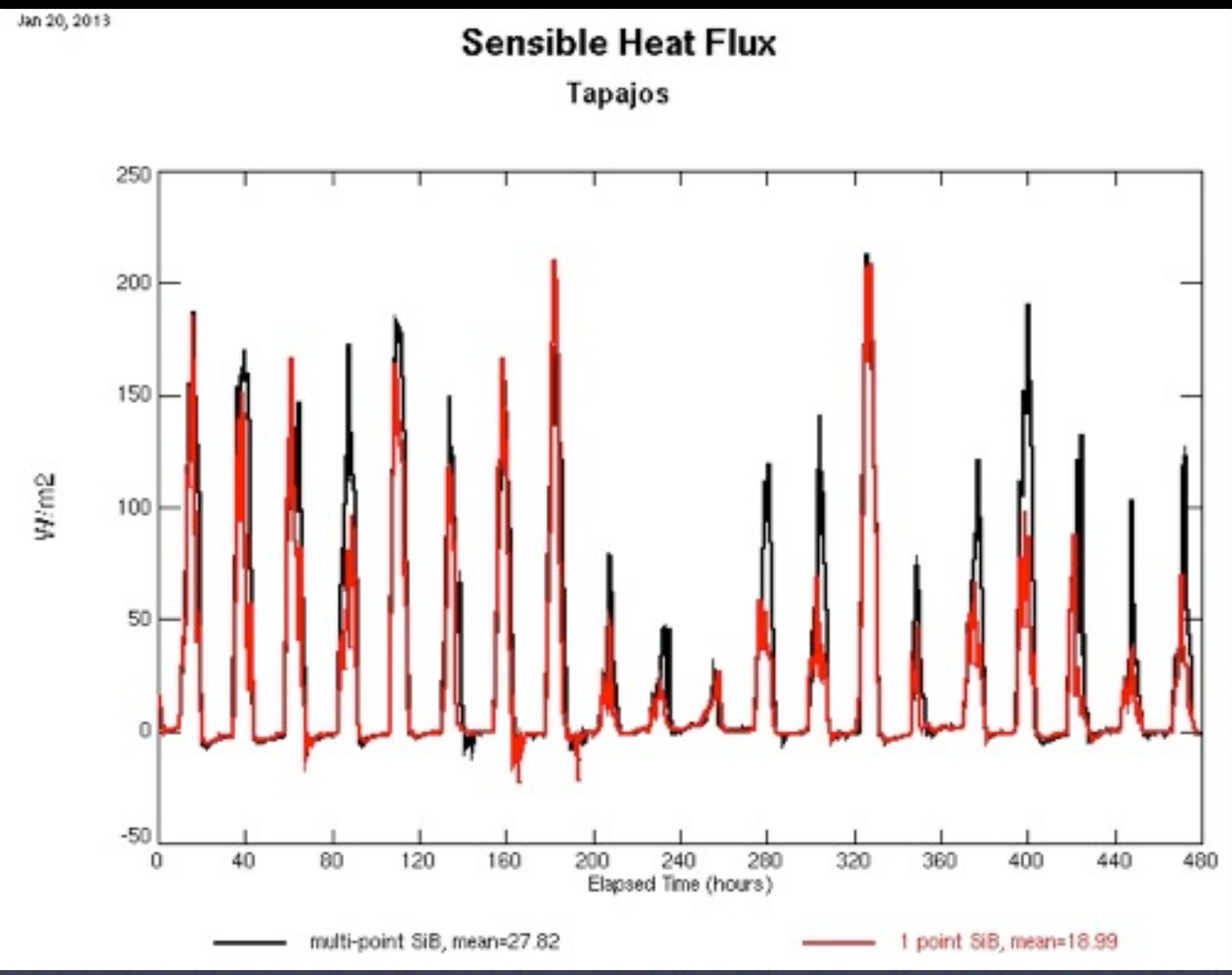




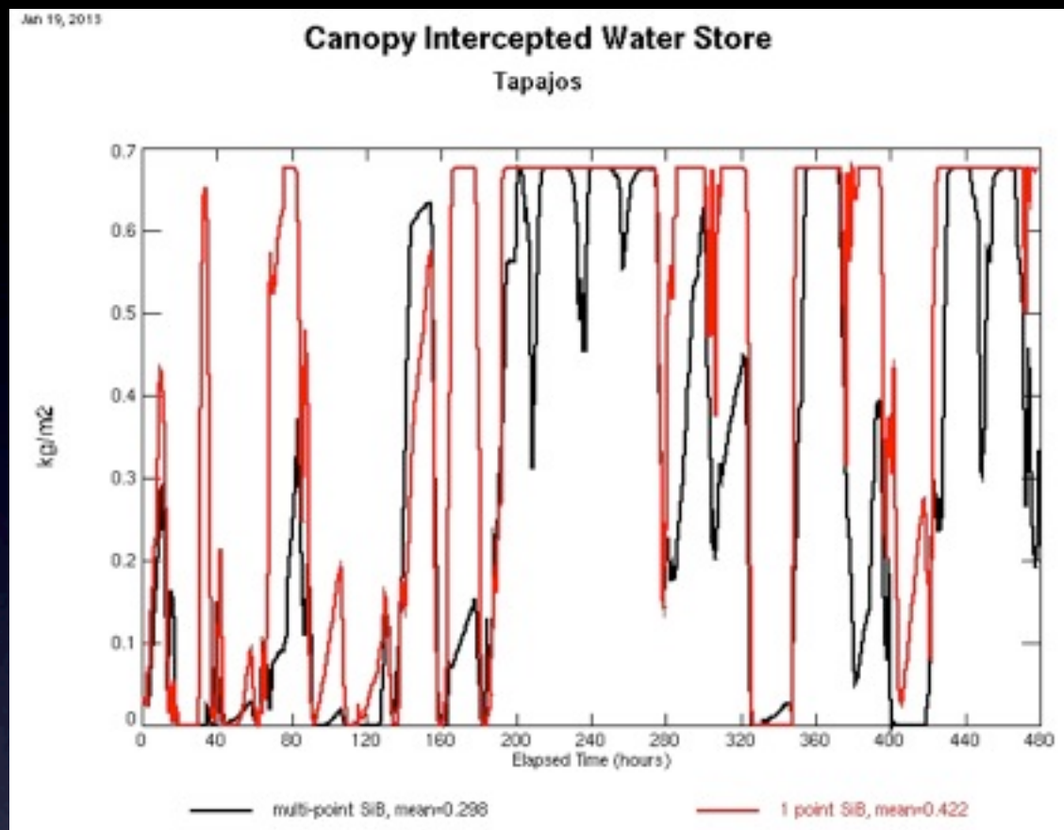


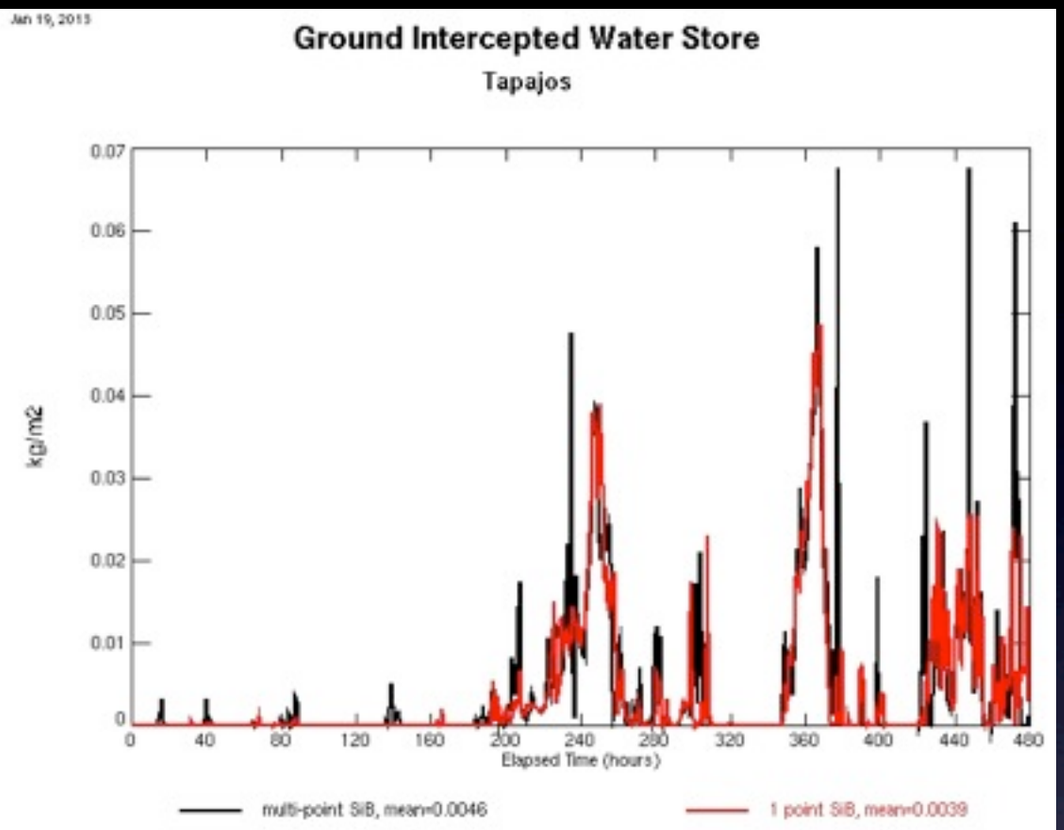
Tapajos: similar latent heat flux, increase of 45% in sensible heat flux for multi-point SiB3.

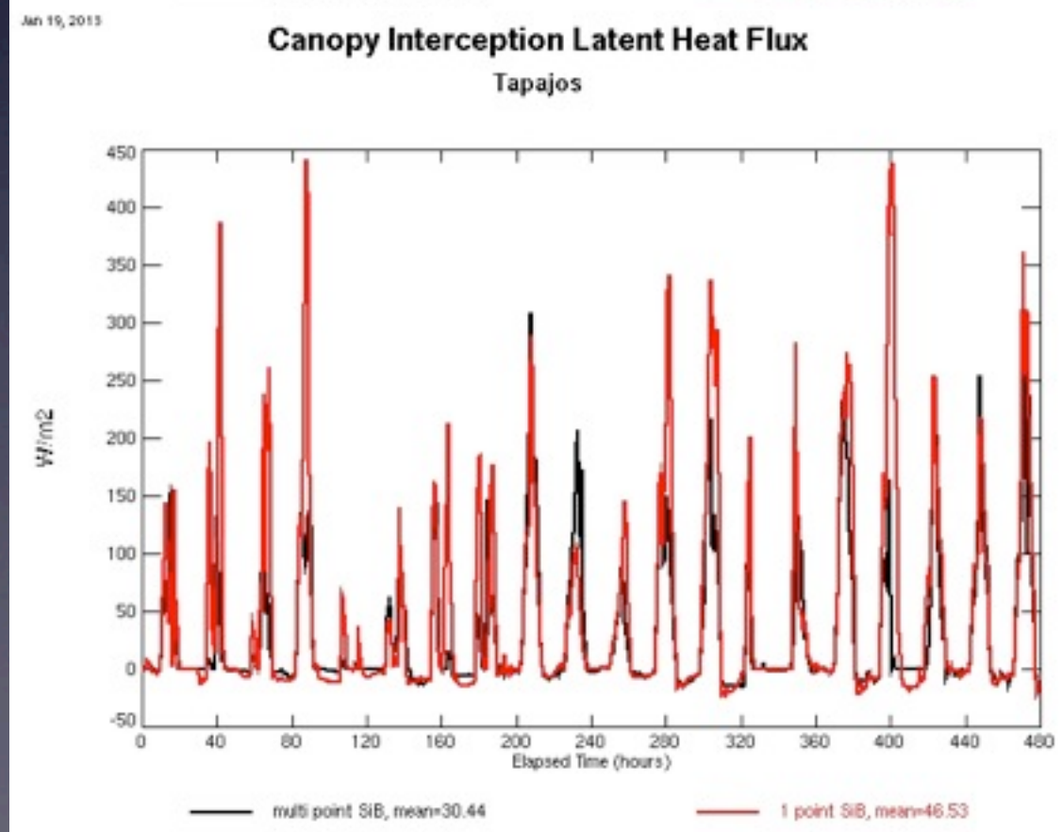


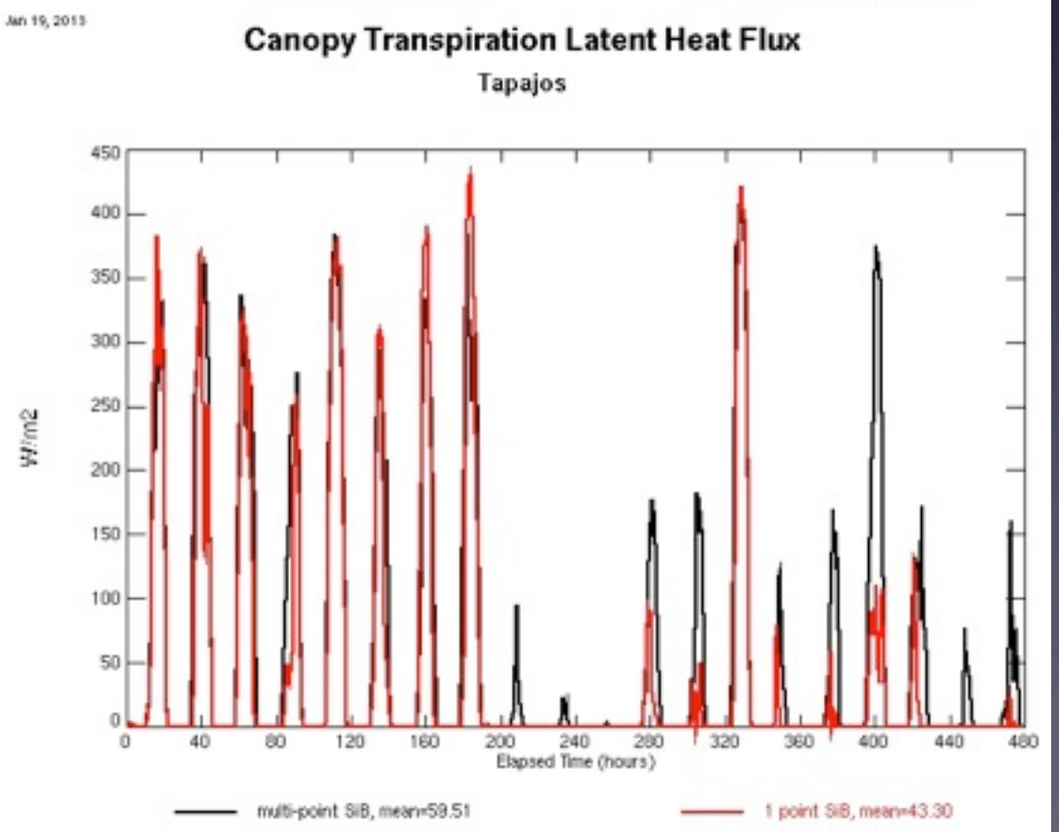


Tapajos: shift in evaporation from canopy interception to transpiration for multi-point SiB3.

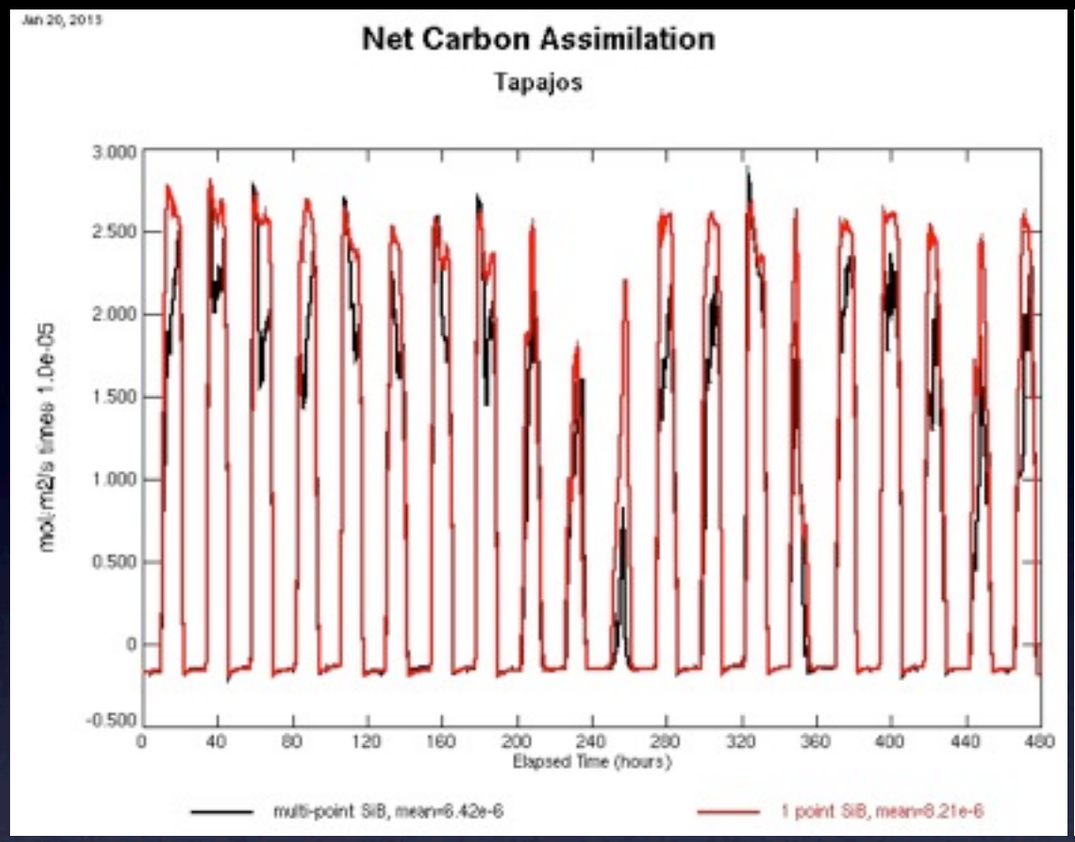


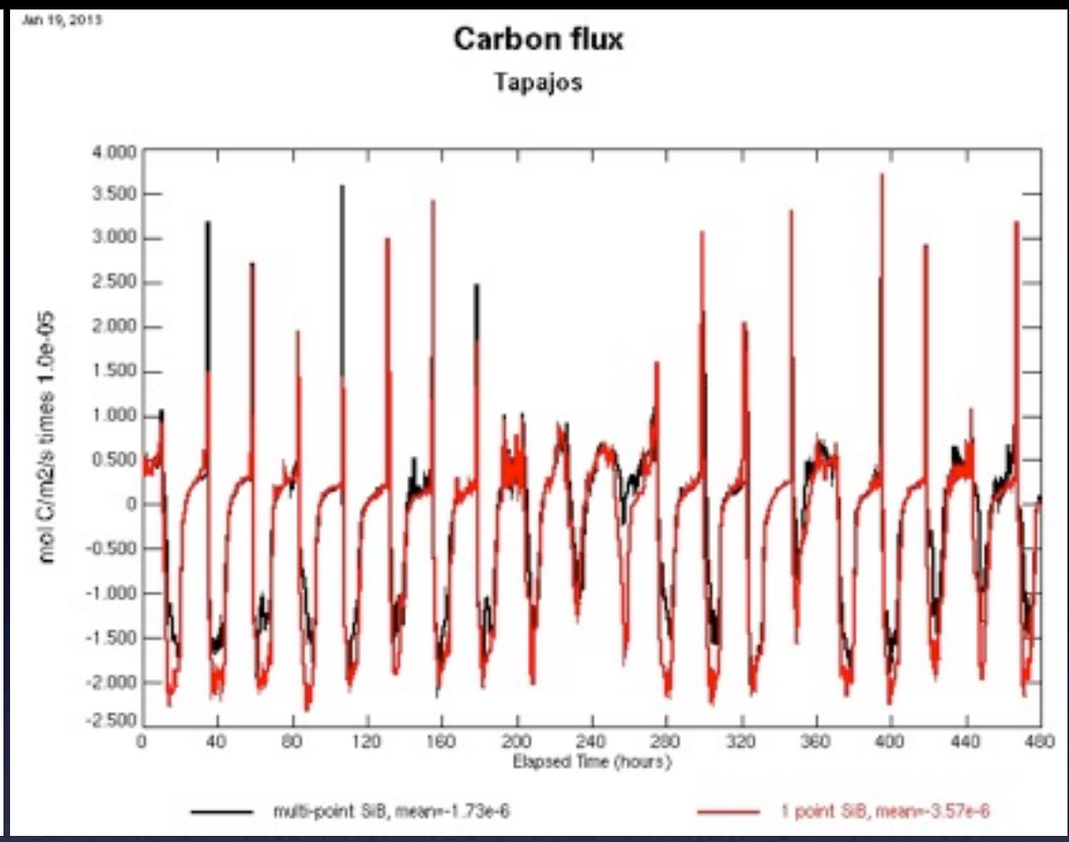




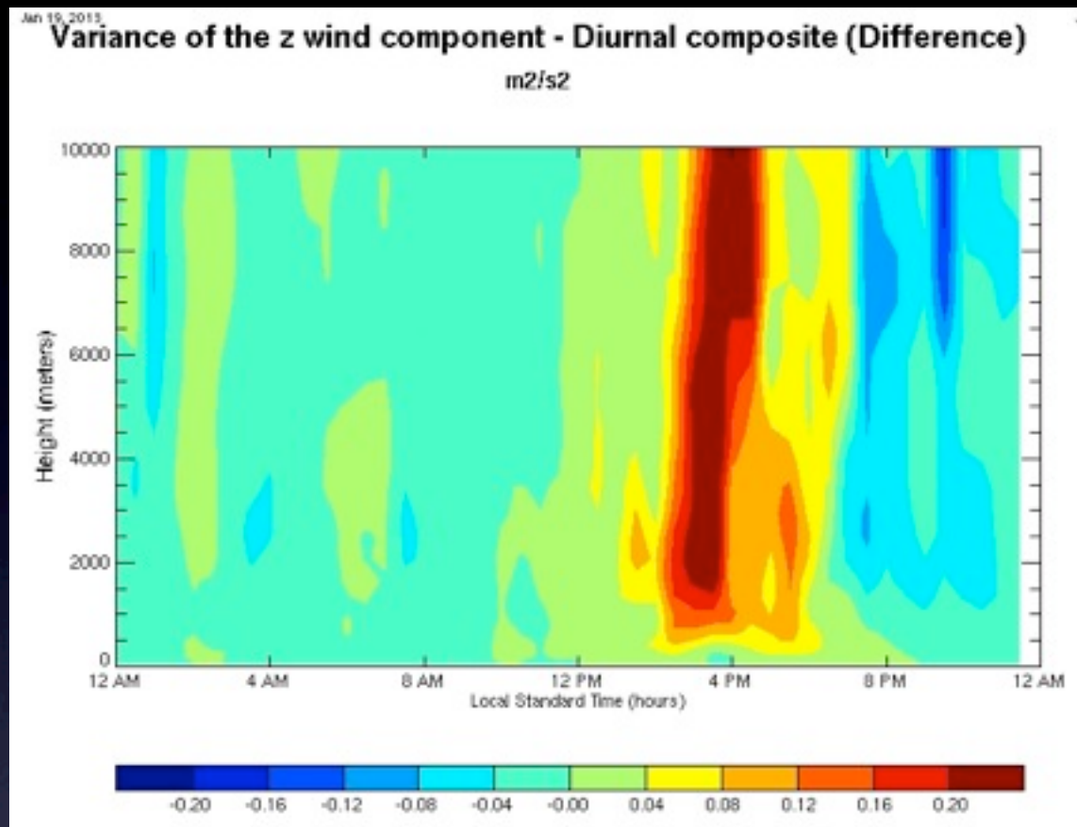


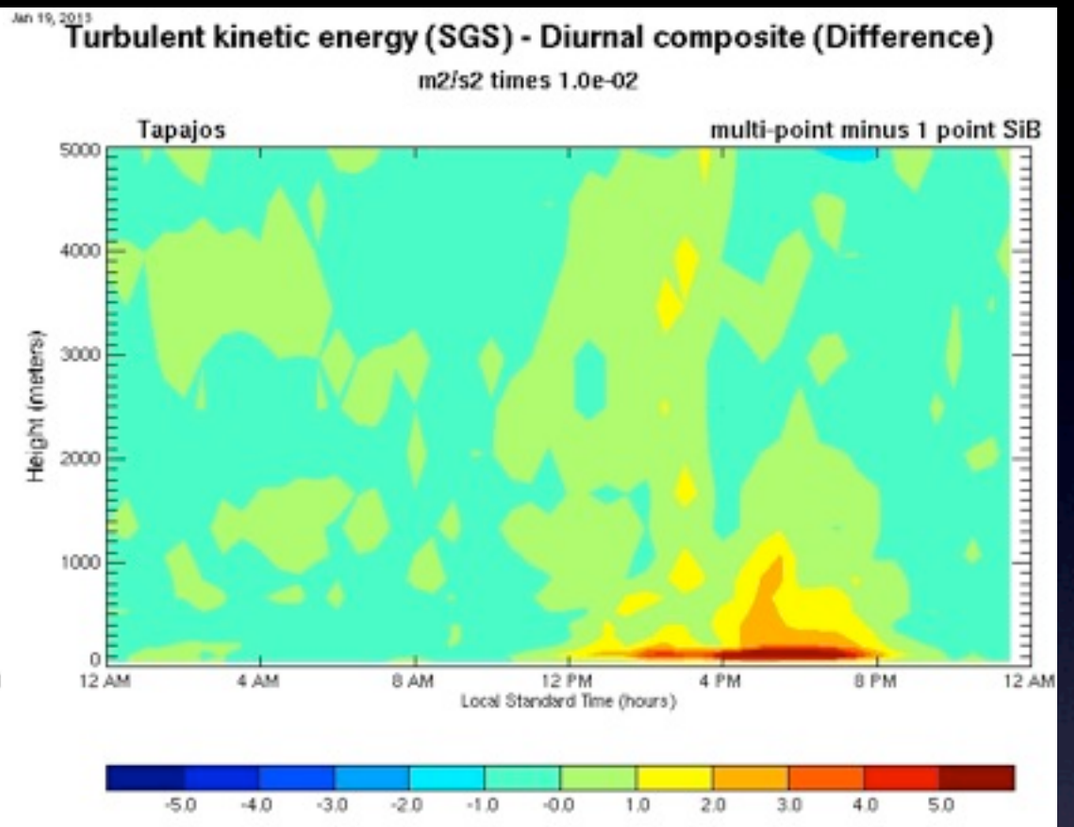
Tapajos: 20% less Carbon assimilation, 50% less net carbon flux into land surface with multi-point SiB3



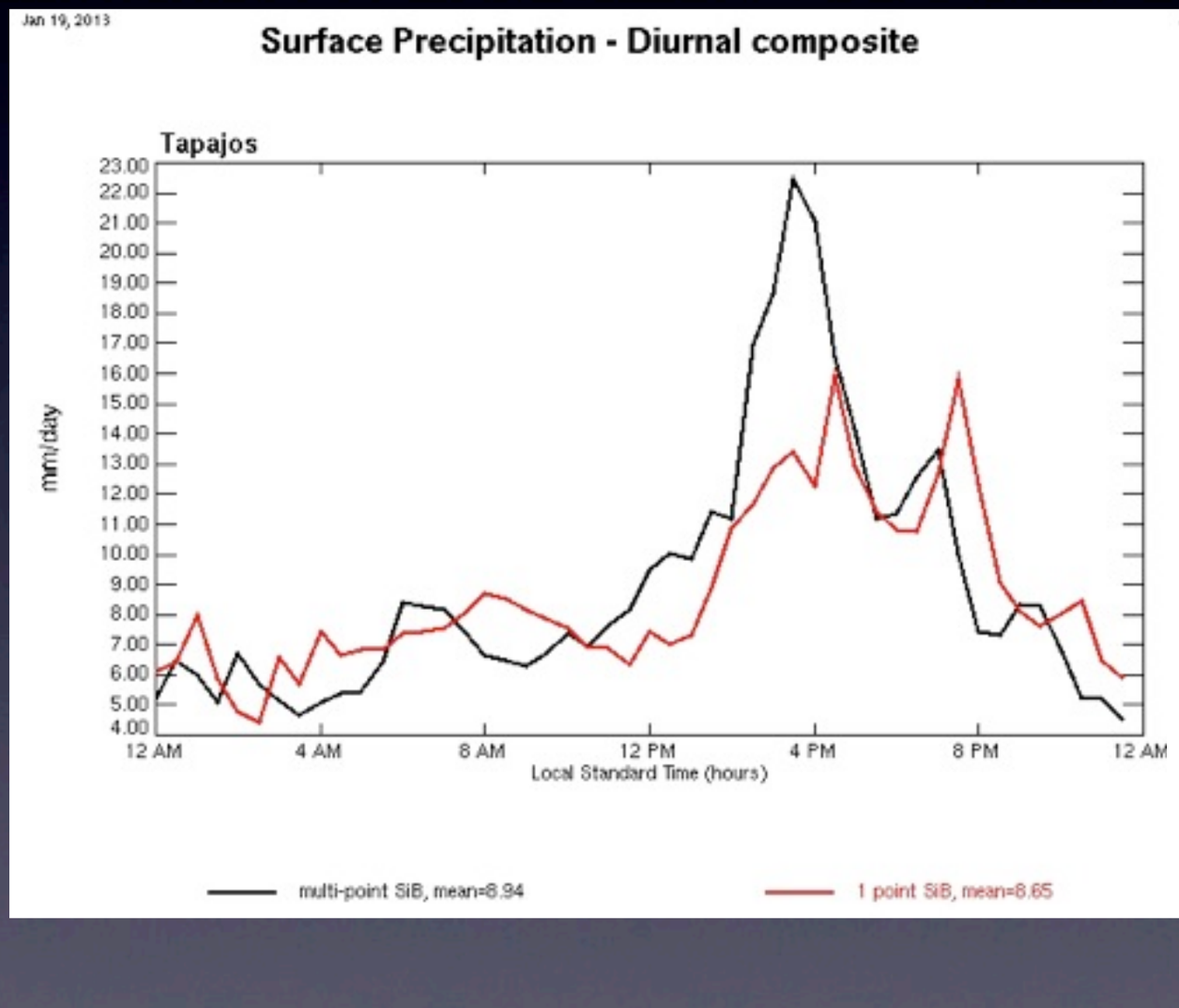


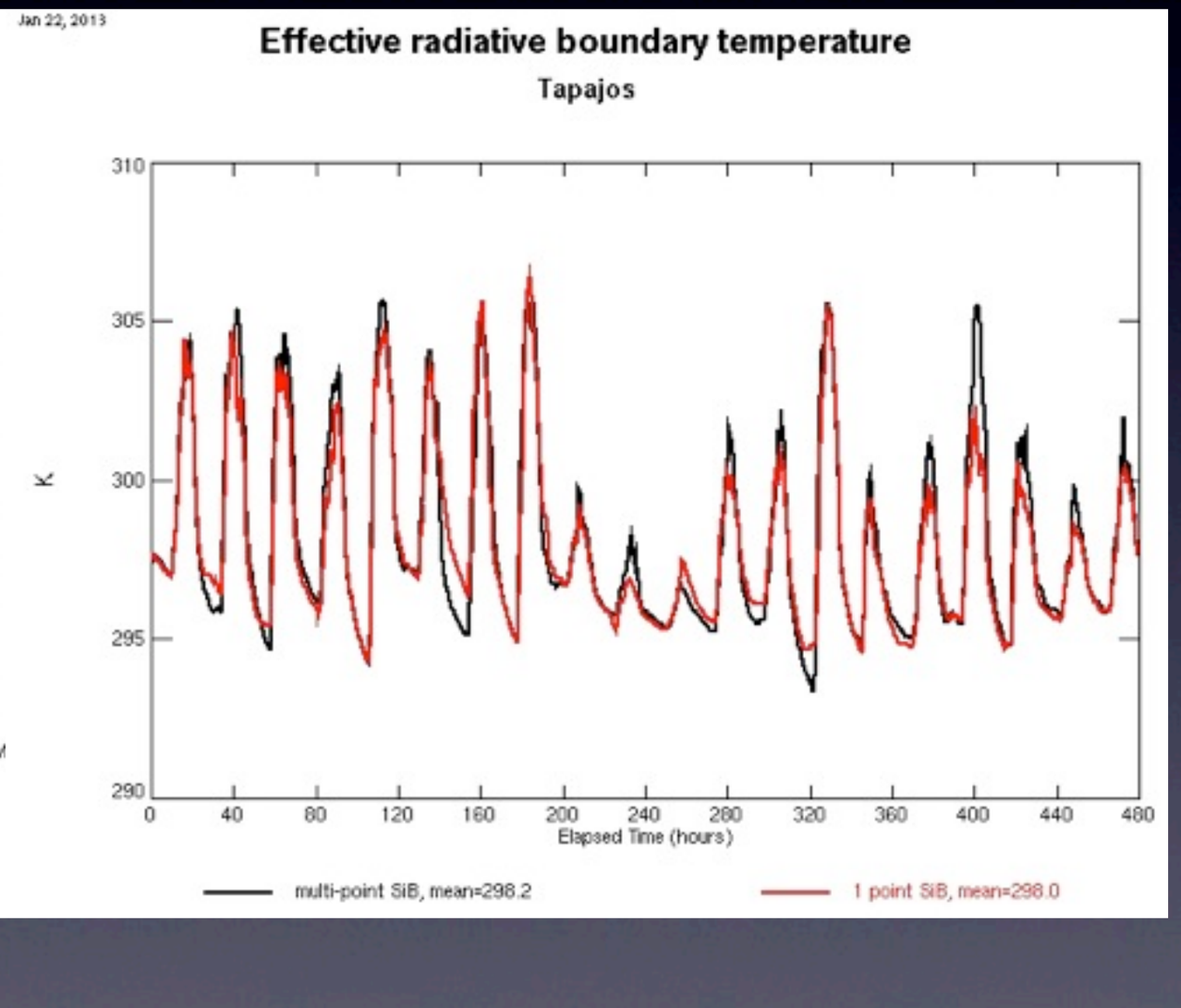
Tapajos: stronger boundary growth plus impact on deep convection with multi-point SiB3.





Tapajos: impact on diurnal cycle with multi-point SiB3, visible in precipitation, and the larger amplitude of the temperature - will these persist with longer run?





Summary

- SiB3 is installed in the latest SAM version (6.10.3) and is planned to be part of future releases.
- SAM/SiB3 has been run as a super-parameterized analog to the SCM as a tool to help investigate the impact of multiple instance land surface.
- A comparison of one-point and multi-point land surface runs show an impact in surface hydrology and carbon fluxes.

Future work:

- Run Tapajos case out at least a full year to see the effects on both the wet and dry seasons.
- Add a boreal forest case to examine effects of heterogeneities in snow on surface albedo.
- CMMAP 2012 intern Leah Lindsey analyzed some of the old SAM/SiB3 runs looking and found they required a higher resolution to converge than did ocean runs. This was mult-point SiB. The convergence of SAM solutions with one-point SiB should be investigated as well.