Comparing LES output to cloud parameterizations

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Why are LESs useful for parameterization development?

Observations are helpful for detecting errors.

But LESs are helpful for diagnosing the *source* of *parameterization* errors.

A discrepancy between a model and observations may arise from an error in initialization, forcing, or a model error within a parameterization

For example, if a single-column model mispredicts shallow cloud fraction over the ARM site, is that because, e.g., the

- initial variational analysis is inaccurate?,
- the horizontal advection of cloud droplets is omitted?, or
- the turbulence parameterization is erroneous?

Tuning the turbulence parameterization to observations might merely compensate for errors in initialization or advective forcings, making the model *worse*!

LES can help separate errors in initialization/forcing from errors in a single-column model (SCM) itself.

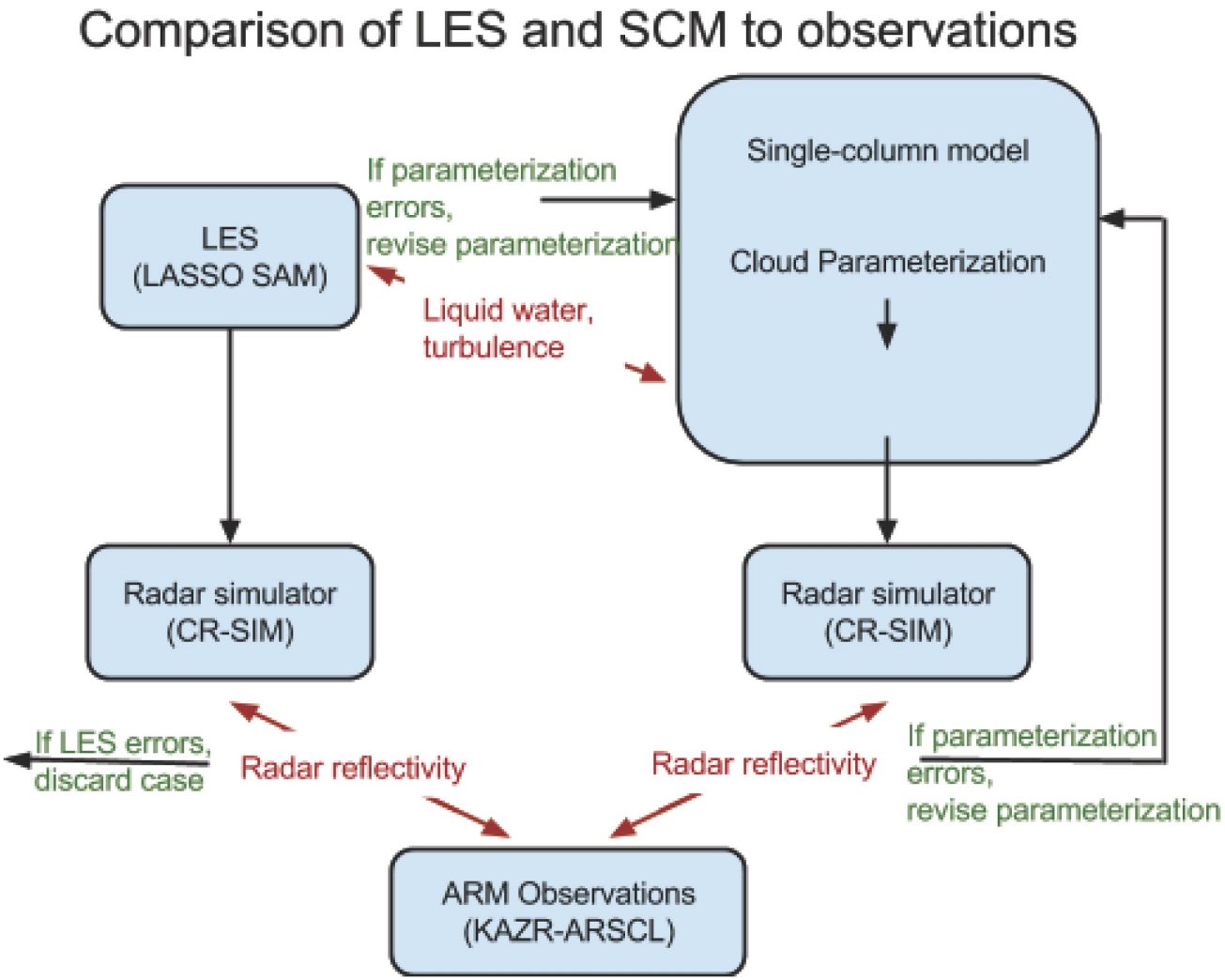
Given that:

- A SCM can be set up with identical initial conditions, boundary conditions, and microphysics as a LES, and
- SCMs can be treated as LES emulators,

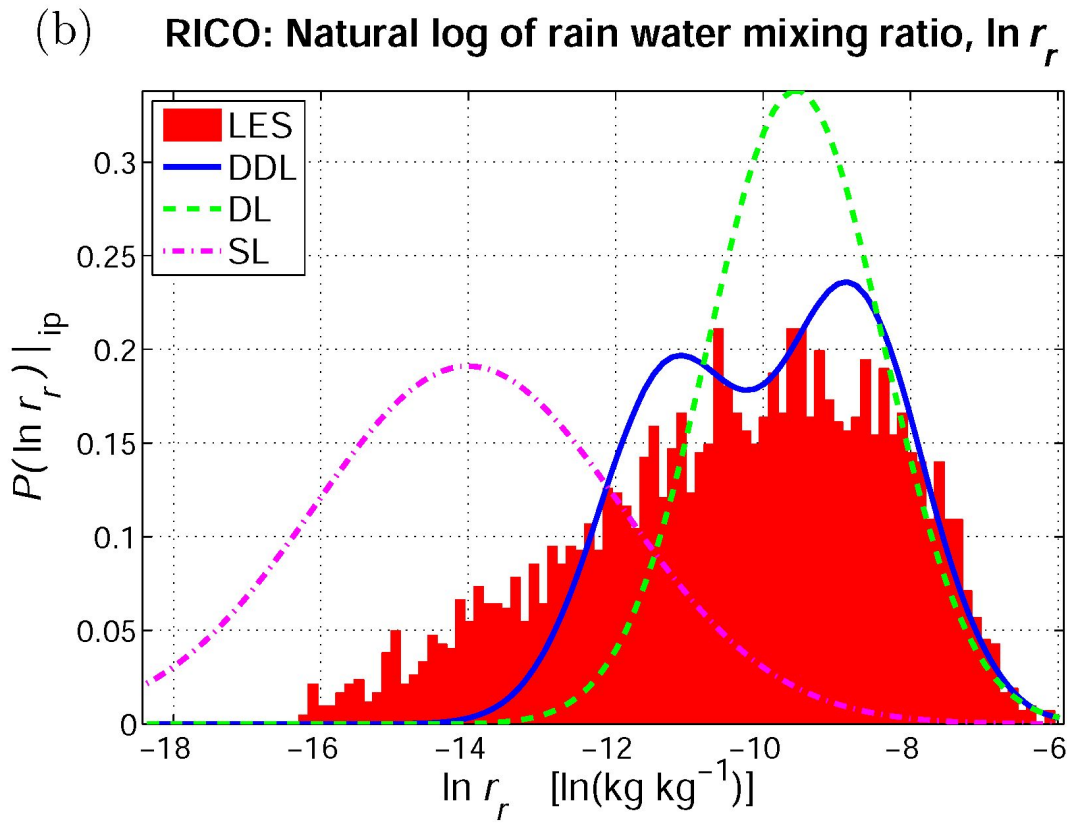
then we can argue:

- If the SCM fails to replicate the LES, then the SCM has an error.

LES and obs can be used in concert to isolate errors in initializations or forcings

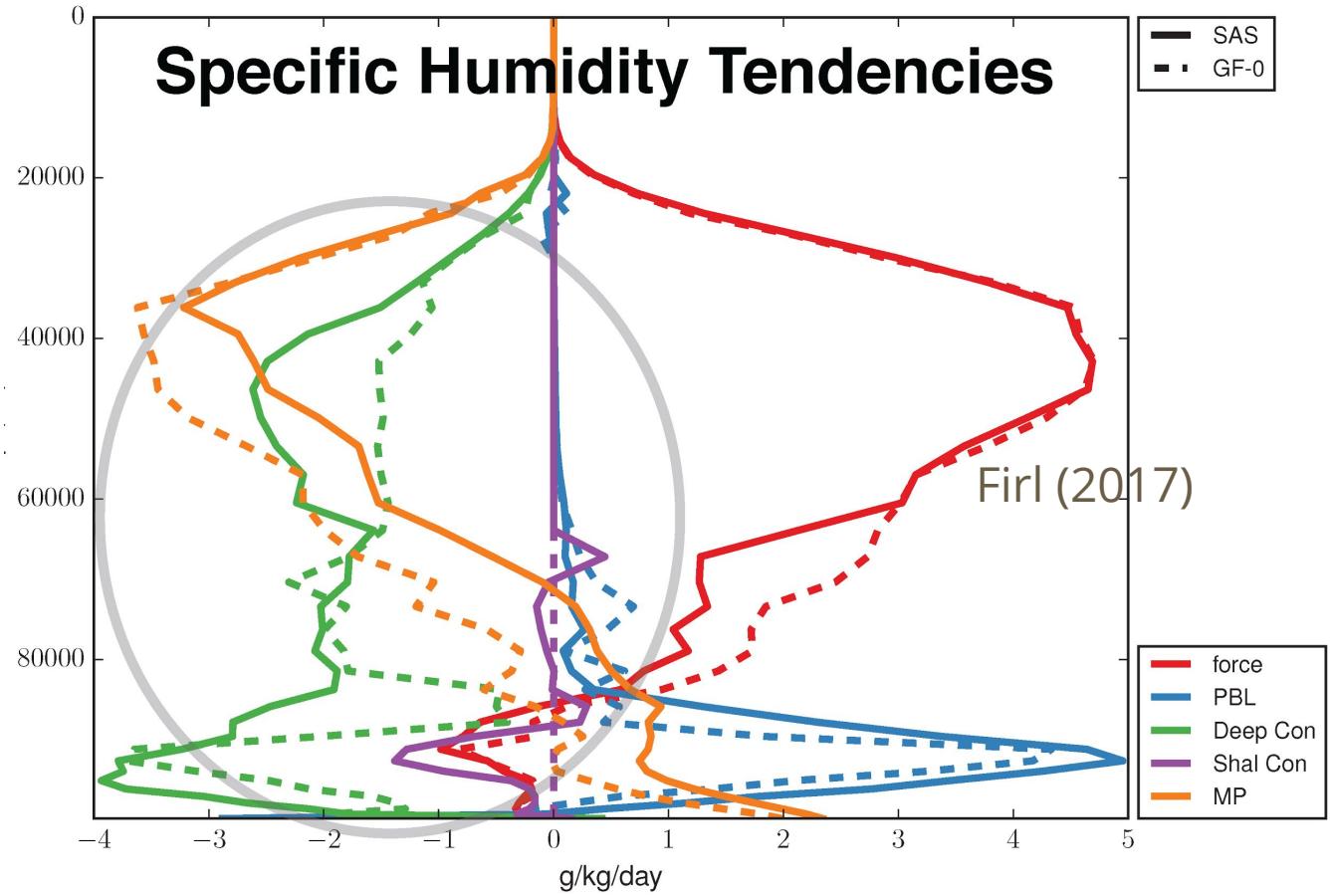


LES can also help isolate errors within a parameterization



Griffin and Larson (2016a)

A LES and a SCM can even be compared term by term



Firl (2017)

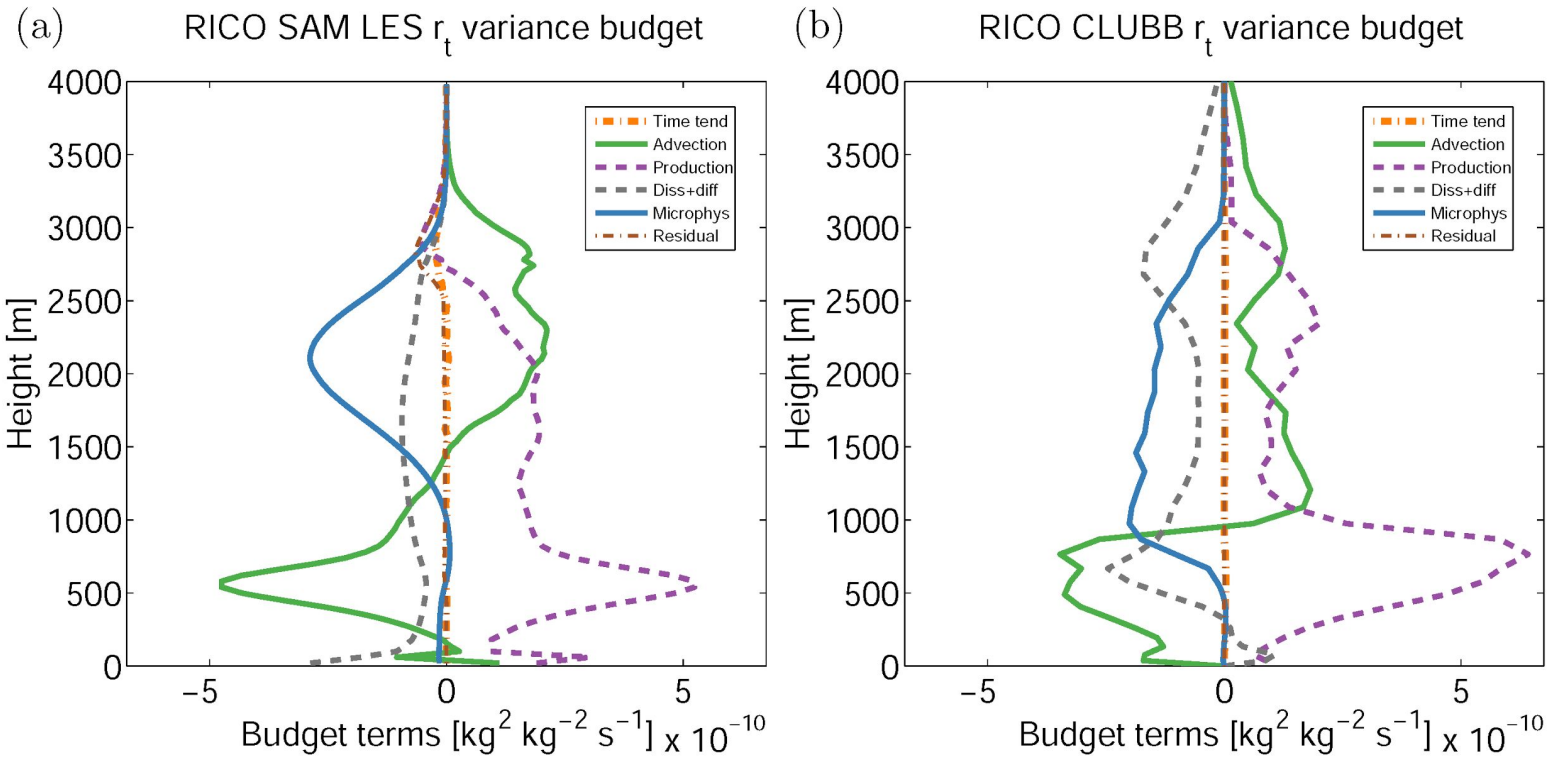
Well, not in some cases . . .

But one can compare term by term for a higher-order closure model like CLUBB. Consider the total water variance budget:

$$\frac{\partial \overline{r_t'^2}}{\partial t} = \underbrace{-\frac{1}{\rho_s}\frac{\partial \rho_s \overline{w}\,\overline{r_t'^2}}{\partial z} - \frac{1}{\rho_s}\frac{\partial \rho_s \overline{w' r_t'^2}}{\partial z}}_{\text{advection}} \underbrace{-2\,\overline{w' r_t'}\,\frac{\partial \overline{r_t}}{\partial z}}_{\text{production}}$$

$$\underbrace{+\varepsilon_{r_t} r_t}_{\text{diss+diff}} \underbrace{+2\,\overline{r_t'\left.\frac{\partial r_t}{\partial t}\right|_{mc}'}}_{\text{microphysics}},$$

Total water variance: Term-by-term comparison between LES and CLUBB



Griffin and Larson (2016b)

Conclusions

- Use of LES can help separate errors in initializations/forcings from errors in a parameterization.

- LES has good statistics and lots of detail.

- For higher-order closure parameterizations, LES can be used to compare with SCM simulations *term by term*.