A Statistical Cloud Scheme for CAM

Peter Caldwell, Steve Klein, & Sungsu Park
(with Bretherton, Teixeira, and more)

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Background: The Concept

Define the saturation excess $s = q_w - q_s(T,p)$.

liquid + vapor mixing ratio ↑

↑ saturation mixing ratio at temperature *T* and pressure *p.*

If condensation/evaporation are instantaneous and the shape and moments of the s PDF are known,

$$\text{Cloud Fraction} = \int_0^\infty PDF(s)\,ds$$

$$\text{Cloud Mass} = \int_0^\infty s \cdot PDF(s)\,ds$$

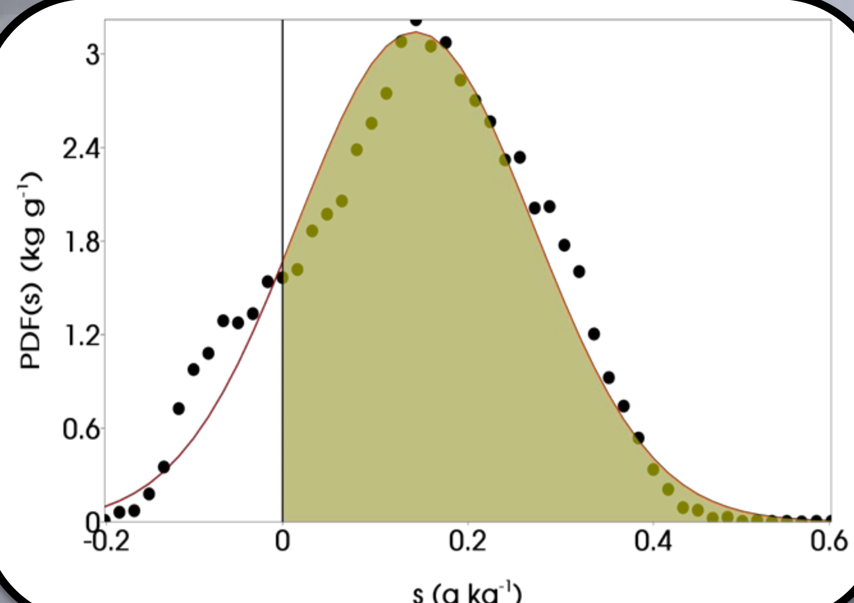


Fig: Example PDF from ASTEX (dots) with Gaussian fit (line) and cloud fraction (shaded area).

History

- Statistical schemes aren’t new – were/are used in many GCMs (ECHAM, CCMA, HadGEM, etc).
- Tried in CAM (Ben Johnson ’05, Sungsu Park ‘08)

Problems:

- Ice supersaturation
- variance, skewness computation

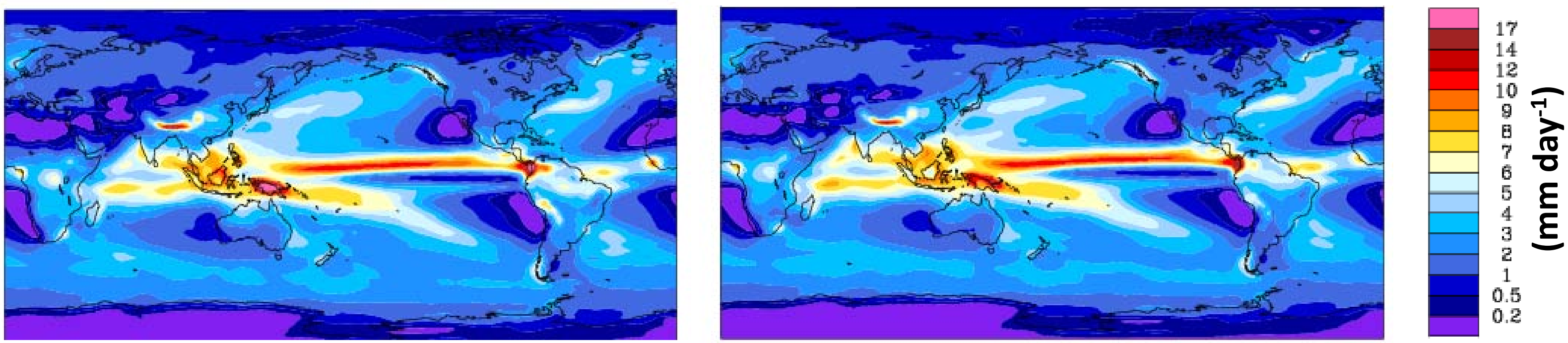
Phase 1 (to finish this year)

1. ✓ Implement a bivariate Gaussian PDF in q_w and θ_l
2. ✓ Use q_w = total water minus ice mixing ratio

   ⇒ ice handled as in CAM5

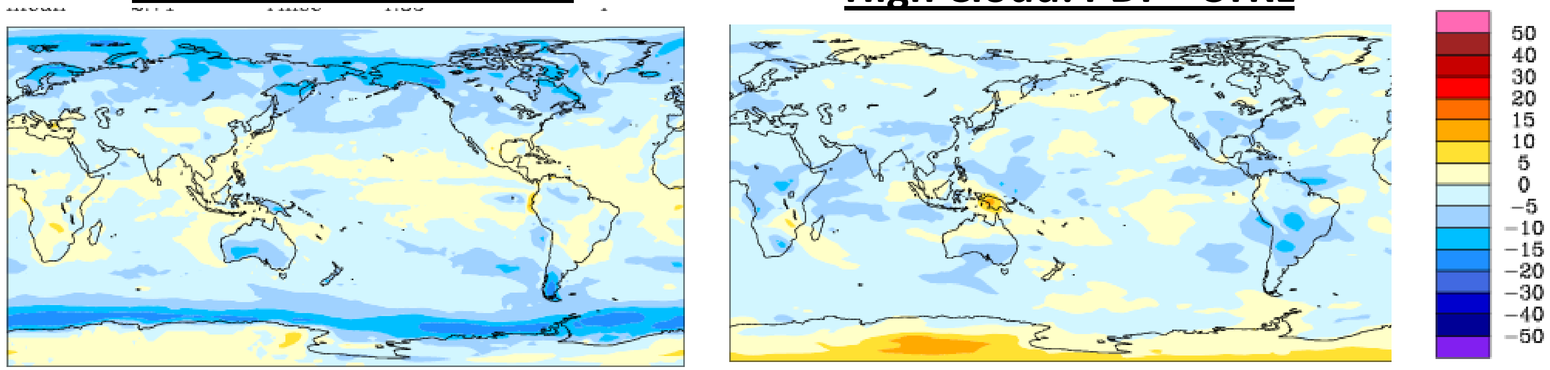
3. ✓ Use PDF variance set to match CAM5
4. ✓ Make microphysical process rates consistent with our Gaussian PDF
5. Set up consistent Monte-Carlo subcolumn generator for radiation

Precipitation: PDF **Precipitation: CTRL**



Annual-average precipitation from 5 yr climatological SST runs.

Low Cloud: PDF - CTRL **High Cloud: PDF - CTRL**



- **Precipitation, thermodynamic variables not affected by change.**
- **Cloudiness largely decreases**

*** Results are still very preliminary and model is completely untuned. ***

*** The main point is that the model *runs*. ***

Phase 2 (next several years)

1. Use process-based variance (and predict $\overline{w'^2}$ for aerosols/chemistry use)
   - Include turbulence, microphysics, mesoscale, topography, convective detrainment
2. Include ice-phase PDF
   - Kärcher-Burkhardt (2008) style cirrus scheme in collaboration with Minghuai Wang, Xiaohong Liu
   - and/or ??? (how to handle mixed-phase?)