Can assimilating satellite observations of clouds improve model forecast skill?

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To state the obvious:
This is a weather forecasting project

Context: weather forecasts made with global models

- Grid sizes of order 200 km
- Cloud processes are parameterized

Weather forecasts rely on initial conditions

- Better ICs can increase forecast skill

Initial conditions are created using data assimilation

Assimilation minimizes the global difference between

- the model state (e.g. $T(x, y, z)$) and
- a set of observations

Assimilating cloud observations

Assimilation schemes typically focus on temp., humidity, winds

Model state vectors include cloud variables

Profiles of cloud fraction (q_a) and cloud condensate (q_c)

Can we increase forecast skill by assimilating observations of clouds?

Forecasts of clouds (and precipitation?)

Forecasts of e.g. temperature

Cloud variables and model state

Cloud parameterizations couple cloud variable more or less tightly to other elements in the state vector (temperature, humidity)

Impact of cloud observations will likely depend on cloud scheme

Diagnostic relationships = tight coupling: cloud variables are redundant information

Implication: better to attempt assimilation using a range of schemes

We'll use four models

two built for weather (NASA GEOS-5; NCEP GFS)

two built for climate (NCAR CAM3; GFDL AM2)

Four models!?!

We're doing our data assimilation with ensemble Kalman filters

- No adjoint model like variational methods
- Good (if not always best) performance - OK for proof of concept

CDC has our own system but for flexibility we're using

- NCAR Data Assimilation Research Testbed (DART)
- from Jeff Anderson's group at NCAR
- ESMF compliant (possible computational advantages)

What kinds of observations might we assimilate?

Forecasts will show the most routine improvement from global obs.

Satellite observations are desirable

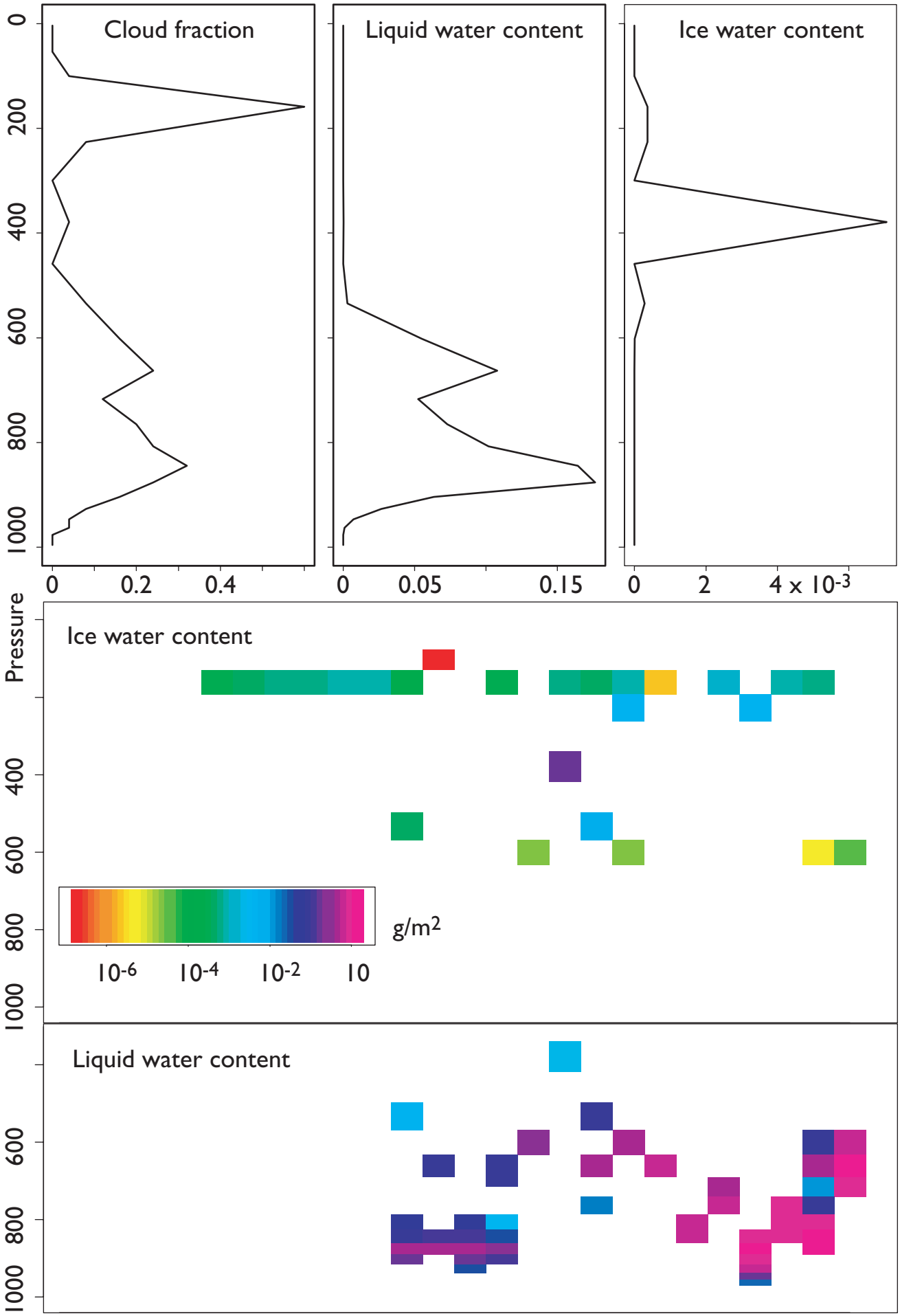
We'll focus on MODIS joint histograms of optical thickness $\boldsymbol{\tau}$

and cloud top pressure p_c

We need a "forward operator" to map $q_a(z)$, $q_c(z)$ to $P(\boldsymbol{\tau}, p_c)$

We'll create randomly-sampled subcolumns

(like the SCOPS part of the ISCCP simulator)


Cloud fraction
Liquid water content
Ice water content
Pressure
0
200
400
600
800
1000
0
0.2
0.4
0
0.05
0.15
0
2
4 x 10-3
Ice water content
g/m2
10-6
10-4
10-2
10
Liquid water content

Step by step…

Perfect model assimilating perfect observations

e.g. profiles of cloud fraction and condensate

Perfect model assimilating synthetic observations

τ-p_c histograms made with forward operator

Assimilating real observations (imperfect model)

Single grid cells

Global MODIS observations

We repeat each experiment with each forecast model

What can we offer other investigators?

For short-term forecasts:

- two-ish months of initial conditions and verifying analyses
- GEOS-5, AM2, CAM3, GFS

Help with ensemble data assimilation, esp. using DART

- Would this be useful for Model E?