Clouds and Their Impacts in Weather Prediction and Climate Models

Chris Bretherton
University of Washington

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NCEP-GFDL Clouds CPT
NCEP: Jongil Han, Ruiyu Sun
GFDL: Chris Golaz, Ming Zhao
JPL: Joao Teixeira, Marcin Witek
U. Washington: Chris Bretherton, Chris Jones, Peter Blossey
Cloud processes are important in weather and climate

- Precipitation
- Circulation
- Radiation

For radiation, predicting cloud cover and vertical extent are key.
Cloud-radiation interaction - a weather forecast challenge

Puget Sound under low Sc, noon, 20-22 Jul. 2013
Fog weather – warm aloft, weak onshore flow
How’s the Pacific NW 1.3 km WRF doing?  
WRF misses the fog and heats up too early at Sea-Tac 

![Temperature Chart]

- **Observed noon T on 7/20:** 60 F  
- **Forecast noon T:** 73 F
- **Observed noon T on 7/21:** 60 F  
- **Forecast noon T:** 70 F
Cloud-radiation interaction - a climate model challenge

Xiao et al. 2014

Assessment of model accuracy using satellite data for various climate models and forcing scenarios.
Forecast-mode evaluation of clouds in global models

**Goal:** Compare clouds globally in weather and climate models and obs when large-scale dynamics haven’t yet drifted far from reality (‘Transpose-AMIP’ for climate model geeks)

**Use daily-mean TOA radiation as a diagnostic**

- Accurately observed using a combination of polar-orbiting (Aqua/Terra) and geostationary satellites.
- Daily-average maps available within a few months from NASA CERES project.
- Outgoing Longwave (OLR): measure of high cloud
  Reflected shortwave (RSW): measure of total bright cloud
- Together, these can identify key cloud biases and their effect on regional and global radiative fluxes.
Forecast-mode comparison of GFS & GFDL AM clouds

**Period:** July 2013

**GFS:** Daily forecasts with 2013 operational (T574L64), pre-op hi-res (T1534L64) versions (O and P)

**GFDL:** Daily 3-day forecasts from operational GFS analysis using AM3 (2° L48) and AM4a2 (pilot version, ~ 1° L48)

**Obs:** CERES daily-average estimates of OLR and RSW

**Caveat:** Possible spinup issues, esp. for GFDL

Results generated in Clouds CPT by NCEP and GFDL, analyzed at UW.
July 2, 2013  OLR
AM3 and GFS-O

Both models are on the right planet!
July 2, 2013  RSW
AM3 and GFS-O

Both models still on the right planet!
July 2, 2013
ΔOLR vs. CERES
AM3 and GFS-O

AM3: Too much ITCZ high cloud
GFS: Too little warm pool high cloud

Models have different regional bias patterns which don’t vary with forecast lead
July 2, 2013
ΔRSW vs. CERES
AM3 and GFS-O

AM3: Too little coastal Sc

GFS: Too little cloud almost everywhere

Models have different regional bias patterns which don’t vary with forecast lead.
Other days all look rather similar
...summarized with monthly-mean 0-24 hr bias patterns
GFS: 10 W m\(^{-2}\) global radiation imbalance; climate biases similar
Both prototype versions have slightly reduced RSW RMSE
Mean biases also slightly reduced in GFS-P vs. GFS-O
Now comes the hard part: use to target further model improvements!
Implication for cloud-relevant model development

Since clouds respond quickly to local conditions, we should primarily use weather forecasts/hindcasts to test model simulations of clouds. Many years of well-observed weather are a powerful and efficient tool for this.

Climate model ‘tuning’ of cloud-related parameters in models (e.g. critical RH, snow fall speed, autoconversion efficiency) to produce global radiation balance in climate models should be constrained to ‘do no harm’ to hindcast skill in forecasting cloud properties.