ATM 265, Spring 2019
Lecture 11
Assessing Parameterizations
Tuning Models
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Assessing the Parameterization

Source: Cecile Hannay

The Straightforward Path

- Climate Runs

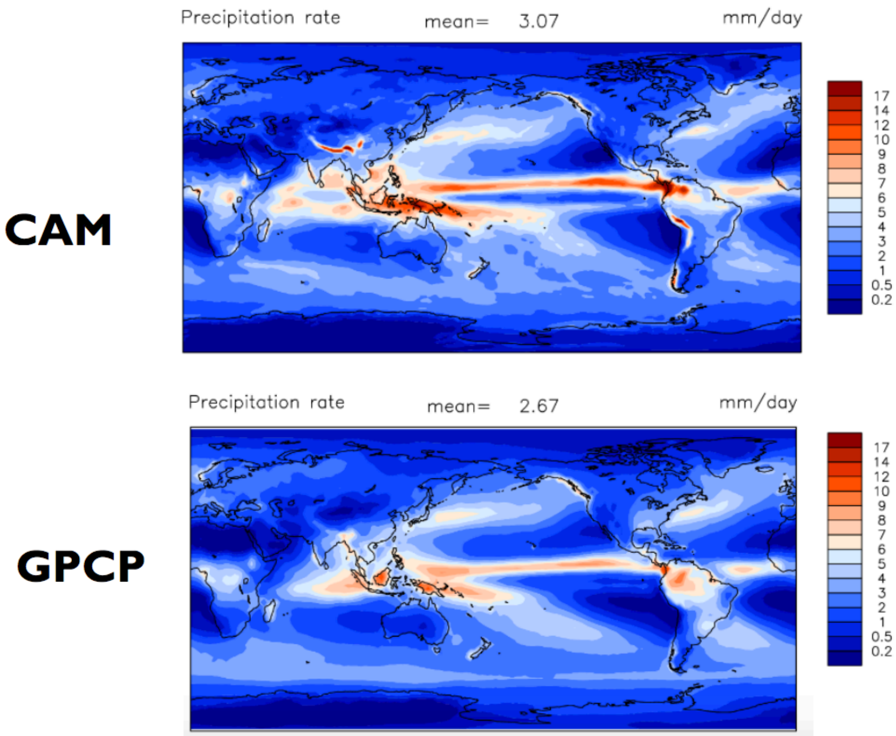
Alternate Approaches

- Forecast Runs
- Single Column Model

Climate Runs

Source: Cecile Hannay

Precipitation (ANN, 10-year)



Strategy
- Make multiple-year run
- Compare the climatology with observations
- Probabilistic approach

Advantages
- Tests the parameterization as it is intended to be used

Limitations
- Very expensive
- Results are complicated and depend on all aspects of the model (physics, dynamics, feedback)

How many years do we need ?
- 1-year can be enough to have a quick look at global means
- 5-year is needed to look at the tropics
- 10-year is needed to capture variability in the Arctic

Climate Runs

Source: Cecile Hannay

Typical climate runs to assess parameterizations

CAM Standalone (no active ocean)

- **AMIP runs:** Standard protocol for testing GCMs. GCM is constrained by realistic sea surface temperatures and sea ice from 1979-2005
- **Climo SSTs:** Variant of AMIP. Use 12-month climatologies for boundary datasets. Repeat year 2000 to produce present-day climate.

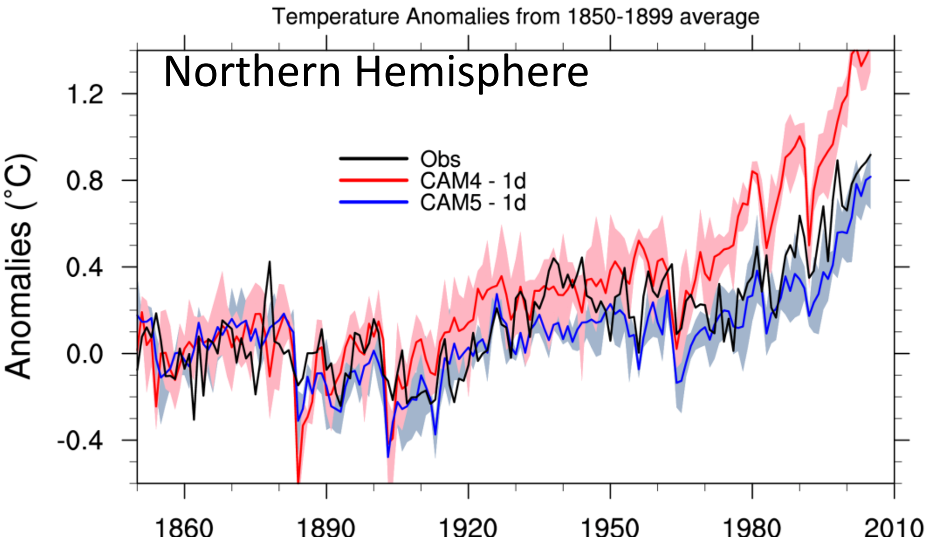
Fully Coupled model (atm+lnd+ocn+ice)

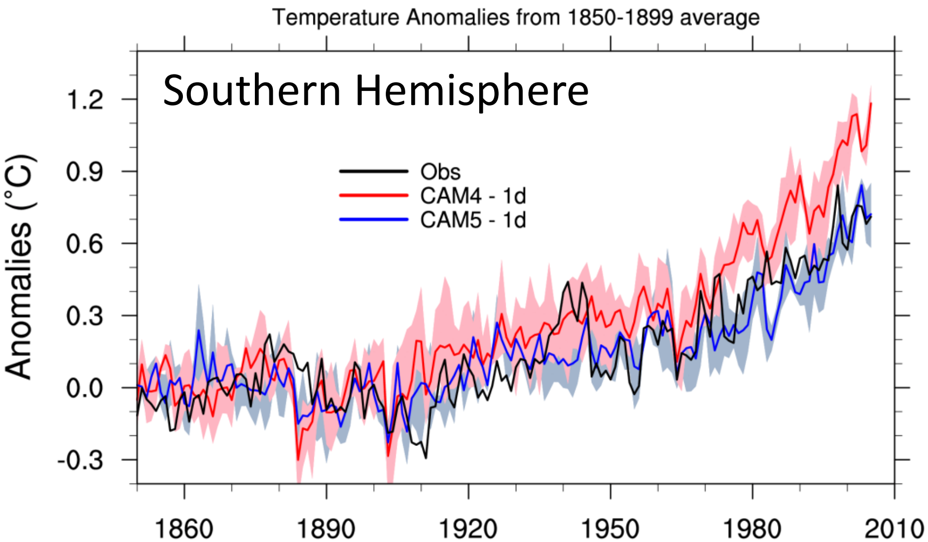
- **1850 control:** Control simulations for pre-industrial time. Repeat year 1850 to produce pre-industrial climate.
- **20th century:** Simulation of the 20th century.

Climate Runs

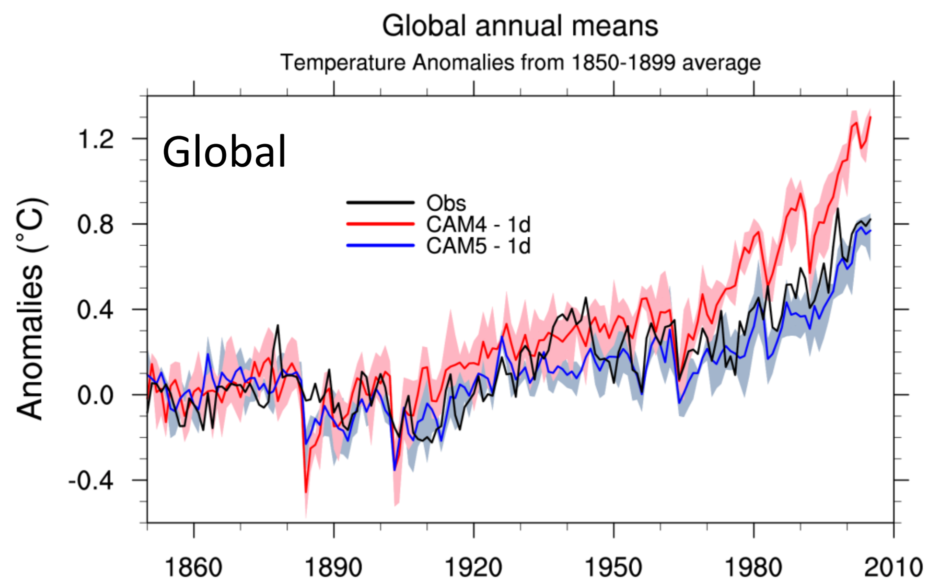
Source: Richard Neale

CESM1(CAM5) CMIP5 version vs. CCSM4(CAM4)





- Climate Sensitivity
  -Feedbacks (clouds, albedo, ocean heat uptake etc.)
- Direct and Indirect (cloud) aerosol effects



Climate Runs

Source: Cecile Hannay

Typical climate runs to assess parameterizations

Aerosol effect

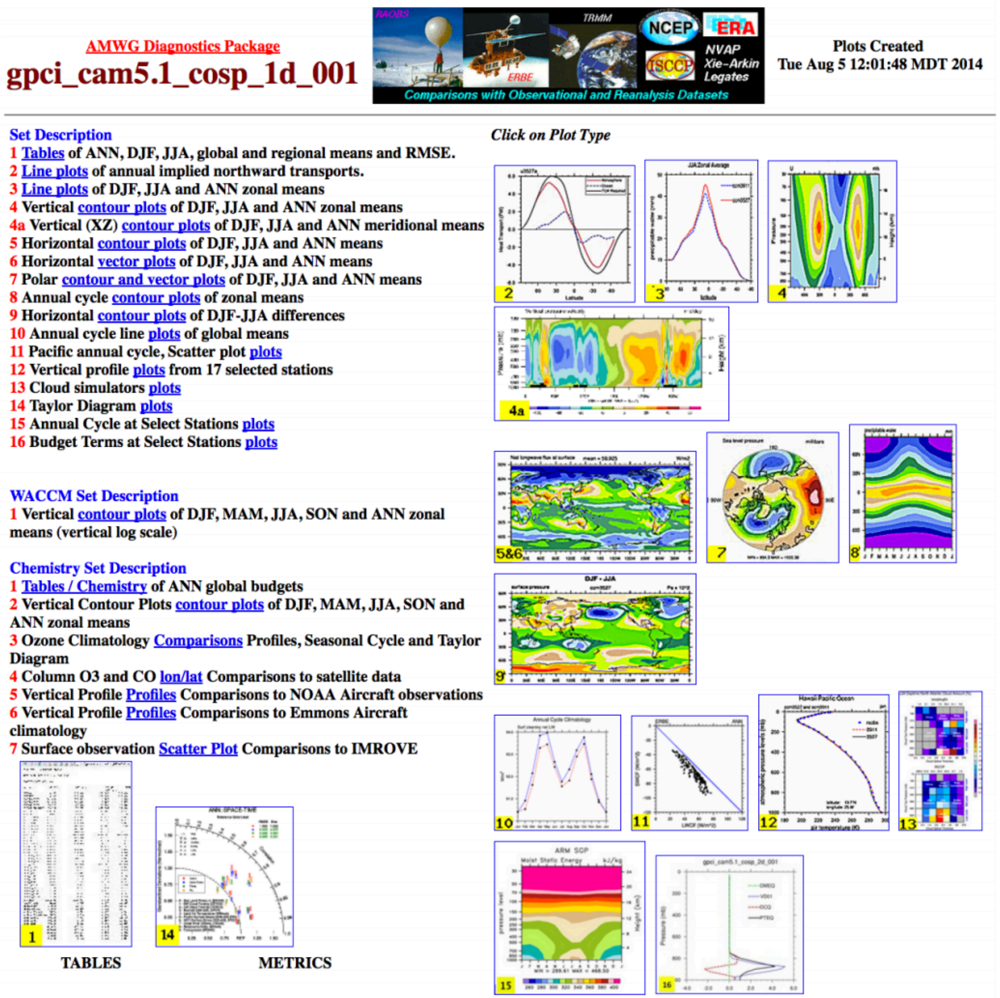
- **Amplitude of cooling (direct and indirect effect):** Two climo SSTs runs with everything kept the same except aerosols (pre-industrial versus present-day).

Climate Sensitivity

- **Equilibrium change in surface temperatures due to a doubling in CO_2:** Slab ocean model runs with $1xCO_2$ and $2xCO_2$

AMWG Diagnostics

Source: Cecile Hannay


AMWG Diagnostics Package

gpci_cam5.1_cosp_1d_001

Comparisons with Observational and Reanalysis Datasets

Plots Created
Tue Aug 5 12:01:48 MDT 2014

Set Description
1 Tables of ANN, DJF, JJA, global and regional means and RMSE.
2 Line plots of annual implied northward transports.
3 Line plots of DJF, JJA and ANN zonal means
4 Vertical contour plots of DJF, JJA and ANN zonal means
4a Vertical (XZ) contour plots of DJF, JJA and ANN meridional means
5 Horizontal contour plots of DJF, JJA and ANN means
6 Horizontal vector plots of DJF, JJA and ANN means
7 Polar contour and vector plots of DJF, JJA and ANN means
8 Annual cycle contour plots of zonal means
9 Horizontal contour plots of DJF-JJA differences
10 Annual cycle line plots of global means
11 Pacific annual cycle, Scatter plot plots
12 Vertical profile plots from 17 selected stations
13 Cloud simulators plots
14 Taylor Diagram plots
15 Annual Cycle at Select Stations plots
16 Budget Terms at Select Stations plots

WACCM Set Description
1 Vertical contour plots of DJF, MAM, JJA, SON and ANN zonal means (vertical log scale)

Chemistry Set Description
1 Tables / Chemistry of ANN global budgets
2 Vertical Contour Plots contour plots of DJF, MAM, JJA, SON and ANN zonal means
3 Ozone Climatology Comparisons Profiles, Seasonal Cycle and Taylor Diagram
4 Column O3 and CO lon/lat Comparisons to satellite data
5 Vertical Profile Profiles Comparisons to NOAA Aircraft observations
6 Vertical Profile Profiles Comparisons to Emmons Aircraft climatology
7 Surface observation Scatter Plot Comparisons to IMROVE

TABLES METRICS

Click on Plot Type

A quick way to look at a climate run: The AMWG diagnostics package

Compute climos

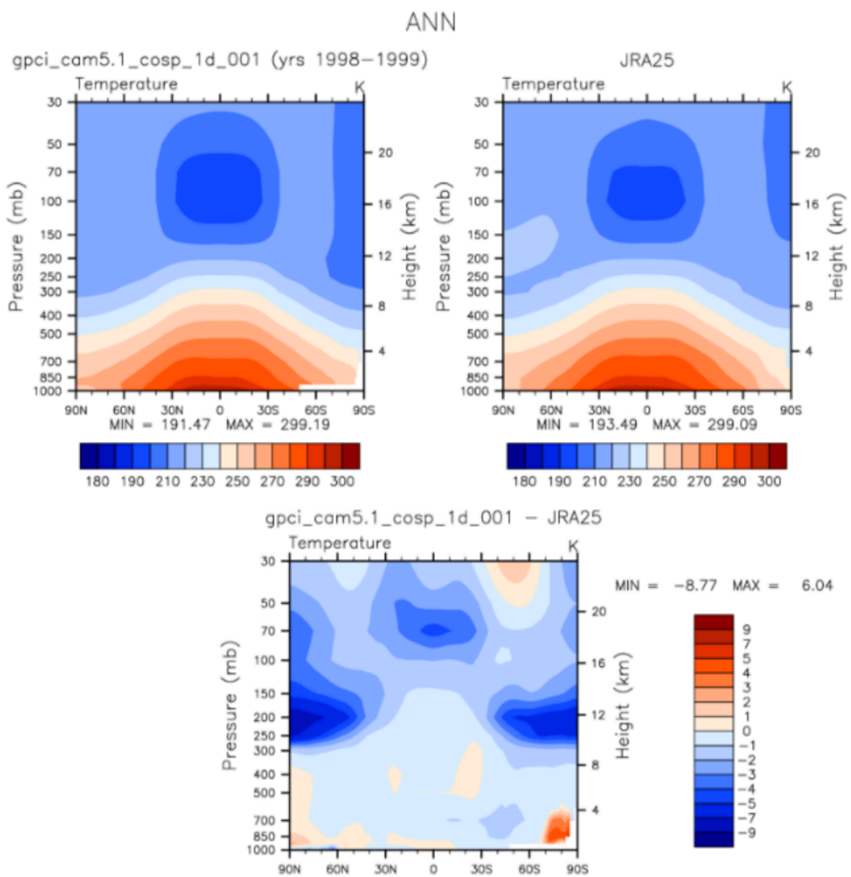
Create a webpage with 100s of tables and plots:

- Global means
- Zonal means
- Lat/lon plots
- Annual cycle
- Cloud simulator
- Taylor diagrams
- and many more…
- Comparison Model to observations & Model to model

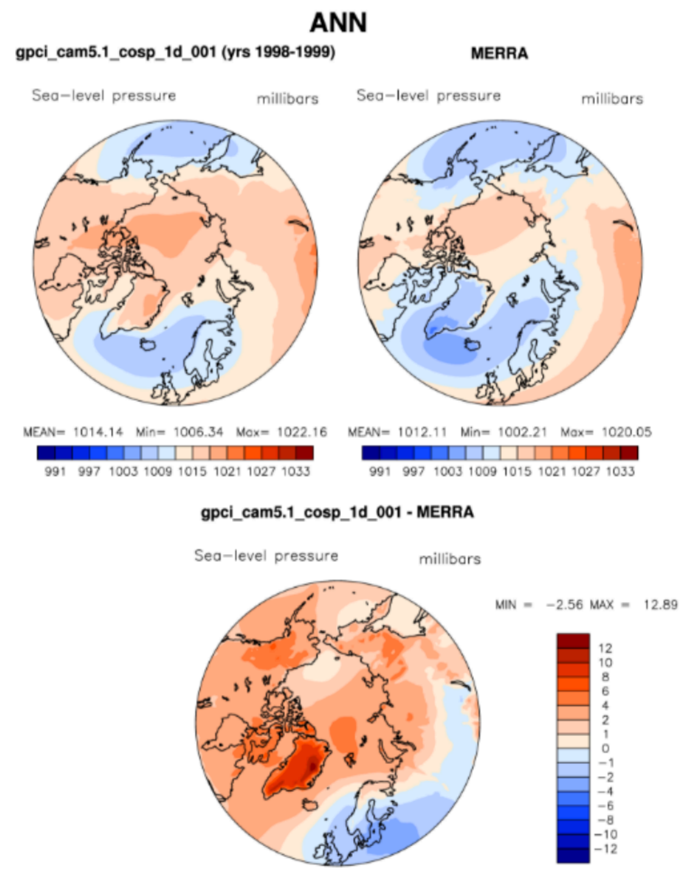
AMWG Diagnostics

Source: Cecile Hannay

Zonal mean temperature



Polar plots: Sea level pressure



Taylor Diagrams

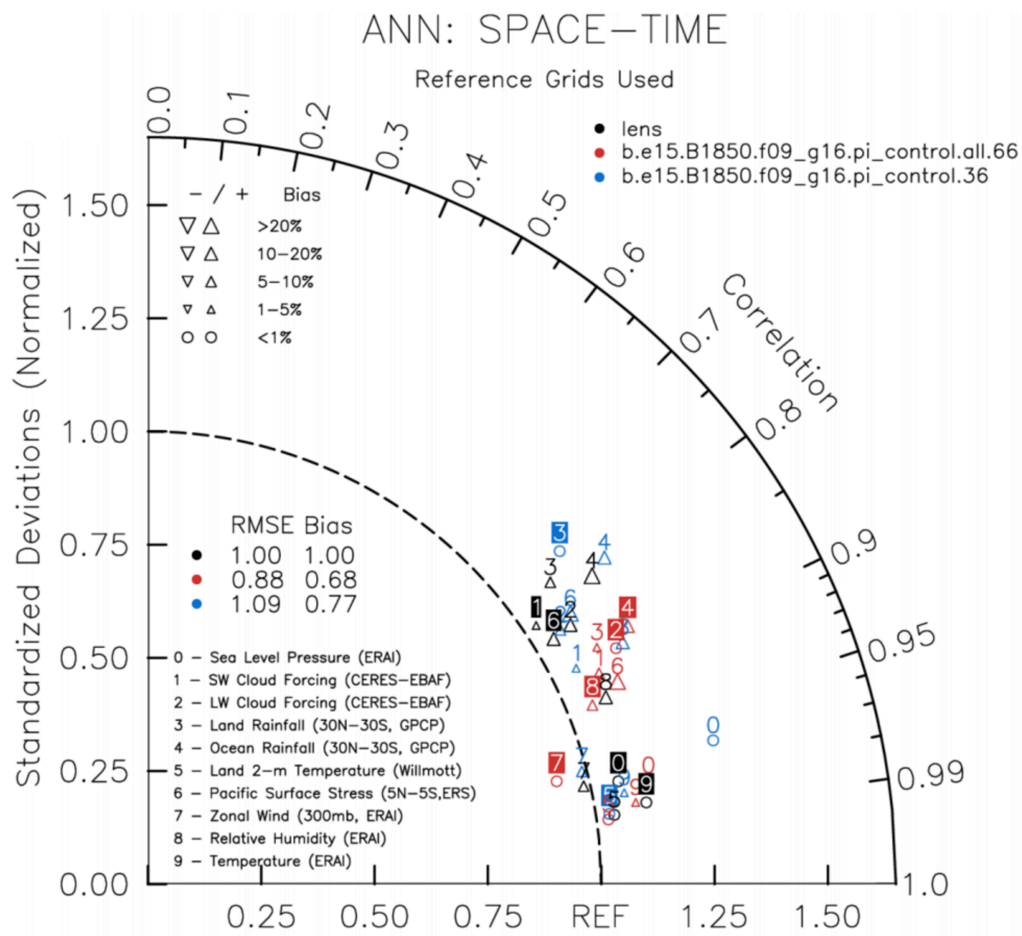
Source: Cecile Hannay

Polar plots: Sea level pressure

Metrics: condense information about variance and RMSE of 10 variables we consider important, when compared with observations

Reference:
Large-ensemble (LENS)

	RMSE	Bias
LENS	1.00	1.00
CESM2	0.88	0.68
CESM1.5	1.09	0.77



ILAMB Diagnostics

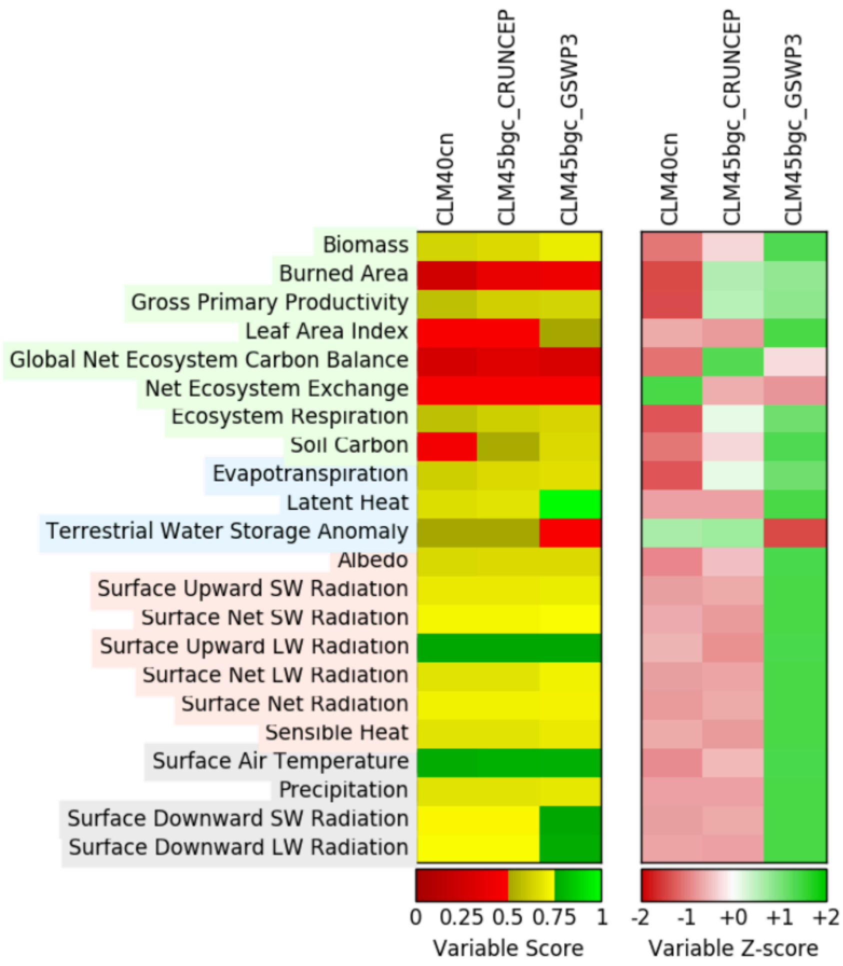
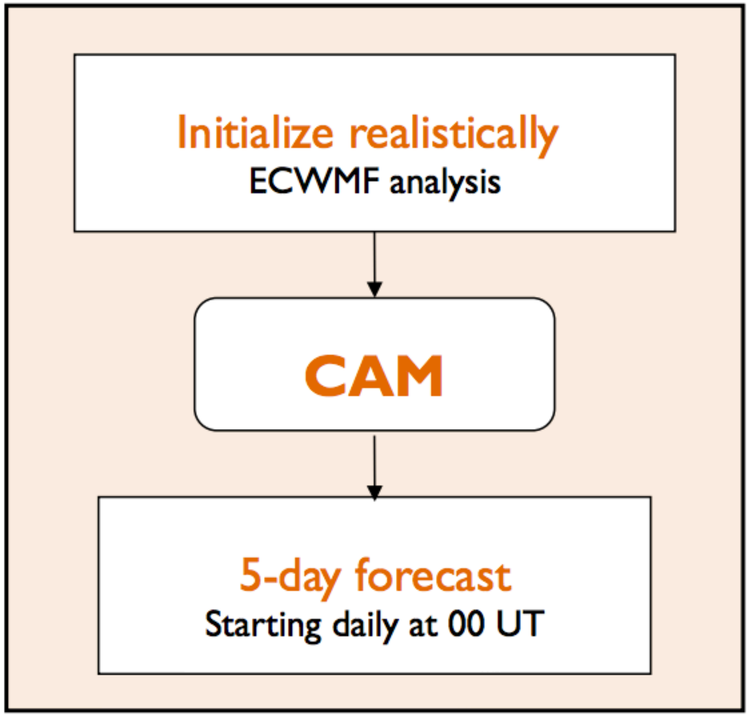


Figure: An example "stoplight diagram" from the ILAMB benchmarking software. The left plot shows how well the quantity is represented, and the right plot shows how the result compares with other modeling systems.

Forecast Runs

Source: Cecile Hannay



Strategy

- If the atmosphere is initialized realistically, the error comes from the parameterizations deficiencies.

Advantages

- Evaluate the forecast against observations on a particular day and location
- Evaluate the nature of moist processes parameterization errors before longer time scale feedbacks develop.

Limitations

- Accuracy of the atmospheric state?

Single Column Runs

Source: Cecile Hannay

Strategy

- Take a column in insolation from the rest of the model
- Use observations to define what is happening in neighboring columns

$$\frac{\partial\theta}{\partial t} = \left(\frac{\partial\theta}{\partial t}\right)_{phys} - \left(\vec{V}.\nabla\theta\right)_{obs} - \left(\omega_{obs}\frac{\partial\theta}{\partial p}\right)$$

$$\frac{\partial q}{\partial t} = \left(\frac{\partial q}{\partial t}\right)_{phys} - \left(\vec{V}.\nabla q\right)_{obs} - \left(\omega_{obs}\frac{\partial q}{\partial p}\right)$$

Observations for:

- Horizontal advective tendencies
- Vertical velocity
- Surface boundary conditions

Advantages

- Inexpensive (1 column instead of 1000s)
- Remove complications from feedback between physics and dynamics

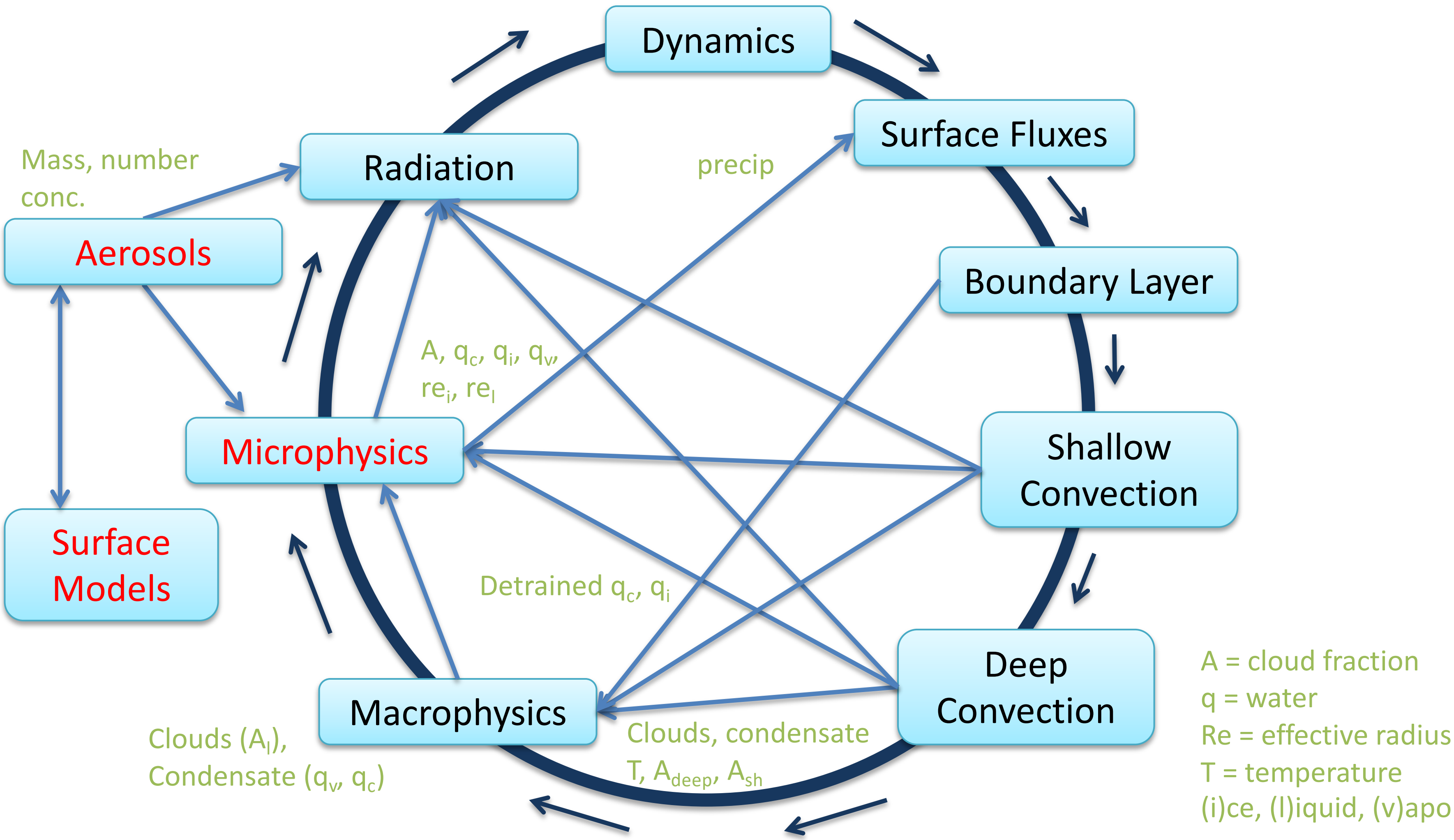
Limitations

- Data requirements (tendencies needs to be accurate to avoid growing error)
- Cannot detect problem in feedback

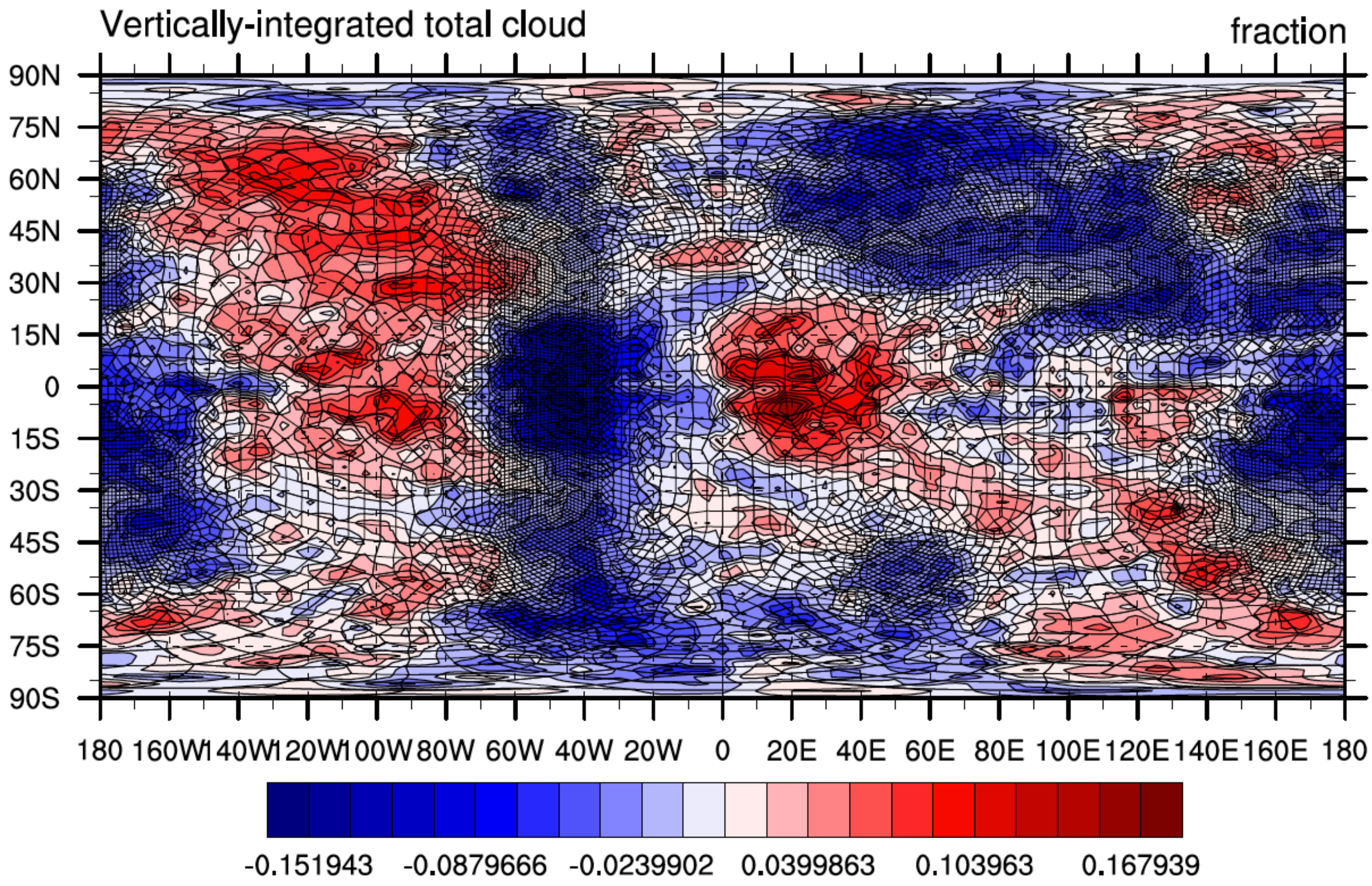
Model Tuning

CAM Time Step

Source: Rich Neale, Julio Bacmeister



Resolution Dependence in CAM4



Tuning

Source: James Hack

Tuning is a fundamental element of all discrete approximations

Parameterized processes must be tuned

- Historical constraints used as guidance (measurement uncertainty?)
- Other constraints relate to behavior of individual processes

Parameterized physics behavior varies with resolution

- Changes with horizontal resolution (difficult challenge)
- Scale-aware parameterizations
- Changes with vertical resolution (extremely difficult challenge)

Resolution Dependent Parameters

Resolution and dynamical-core dependent parameters

The following adjustable parameters differ between various finite volume resolutions in the CAM 4.0. Refer to the model code for parameters relevant to alternative dynamical cores.

Table C.1: Resolution-dependent parameters

Parameter	FV 1 deg	FV 2 deg	Description
$q_{ic,warm}$	2.e-4	2.e-4	threshold for autoconversion of warm ice
$q_{ic,cold}$	18.e-6	9.5e-6	threshold for autoconversion of cold ice
$k_{e,strat}$	5.e-6	5.e-6	stratiform precipitation evaporation efficiency parameter
RH_{min}^{low}	.92	.91	minimum RH threshold for low stable clouds
RH_{min}^{high}	.77	.80	minimum RH threshold for high stable clouds
$k_{1,shallow}$	0.04	0.04	parameter for shallow convection cloud fraction
$k_{1,deep}$	0.10	0.10	parameter for deep convection cloud fraction
p_{mid}	750.e2	750.e2	top of area defined to be mid-level cloud
$c_{0,shallow}$	1.0e-4	1.0e-4	shallow convection precip production efficiency parameter
$c_{0,deep}$	3.5E-3	3.5E-3	deep convection precipitation production efficiency parameter
$k_{e,conv}$	1.0E-6	1.0E-6	convective precipitation evaporation efficiency parameter
v_i	1.0	0.5	Stokes ice sedimentation fall speed (m/s)

In CAM5: 20+ tuning knobs

Tuning

Source: Cecile Hannay

Focus on our favorite variables:

- **TOA radiative balance**
- **SWCF:** SW cloud forcing (= Net SWall sky - Net SWclear sky)
- **LWCF:** LW cloud forcing (= Net LWall sky - Net LWclear sky)
- **PREH2O:** precipitable water
- **Precipitation**

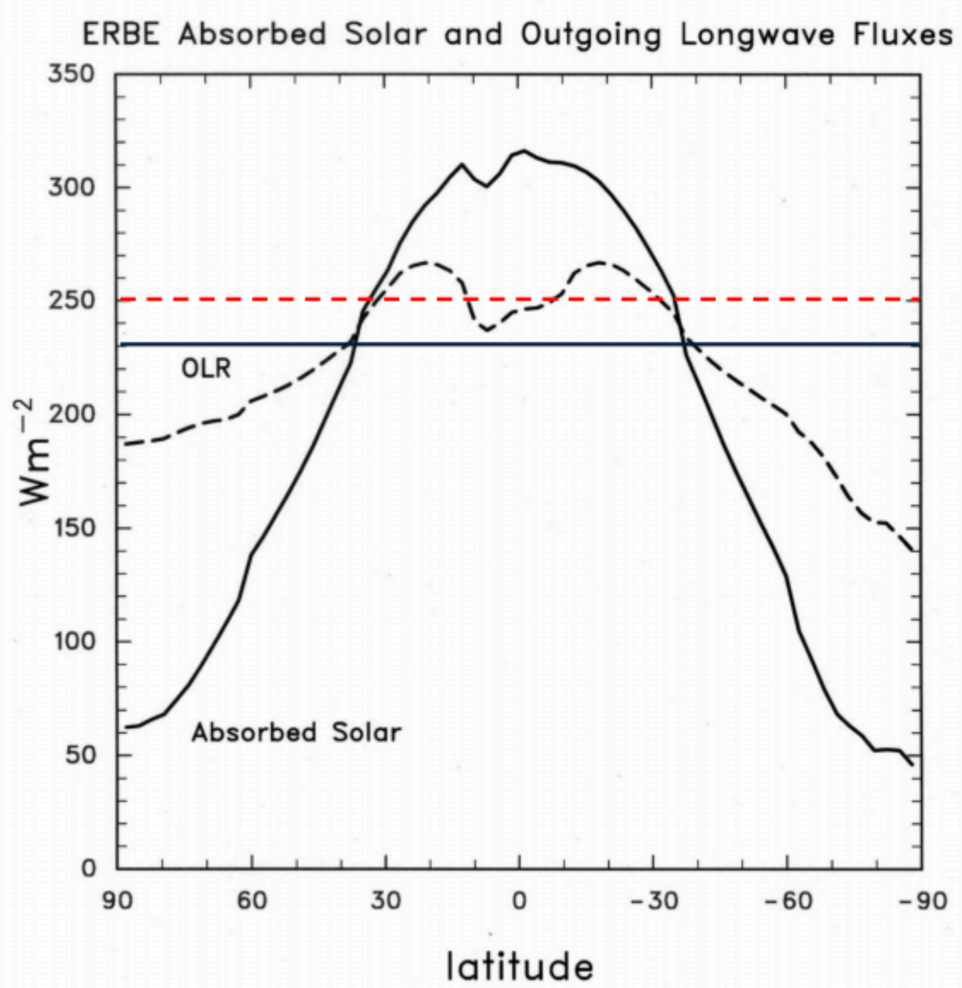
For each diagnostics, we have our favorite observation/reanalysis dataset

Goal: <our favorite variables> = <our favorite datasets>

Characterizing the Tuning Process

Source: James Hack

- Outgoing Longwave Radiation = Absorbed Solar Radiation (temperature balance)



- Meridional structure of the component fluxes is strongly modulated by cloud processes

- One requirement is to accurately reproduce this structure as observed by Earth Radiation Budget observations by exploring sensitivities in the parameterizations of moist physical processes.

Tuning

Source: Cecile Hannay

Suite of runs:

- **5-10 year standalone CAM simulations** (guidance)
- **10+ yr coupled runs** (tuning)

Evaluation of favorite variables versus favorite datasets using AMWG diagnostic package:

- Global averages
- Zonal means
- Lat-lon plots
- Taylor diagrams
- Time series of radiative balance
  and surface temperature

Tuning

Why tune in coupled mode?

Source: Cecile Hannay

CAM standalone misses the feedback atm ⇔ ocn

- Simulation that can look acceptable in standalone can produce runaway coupled simulation