ASL761 - Class Presentation

Understanding Model Evaluation and Validation

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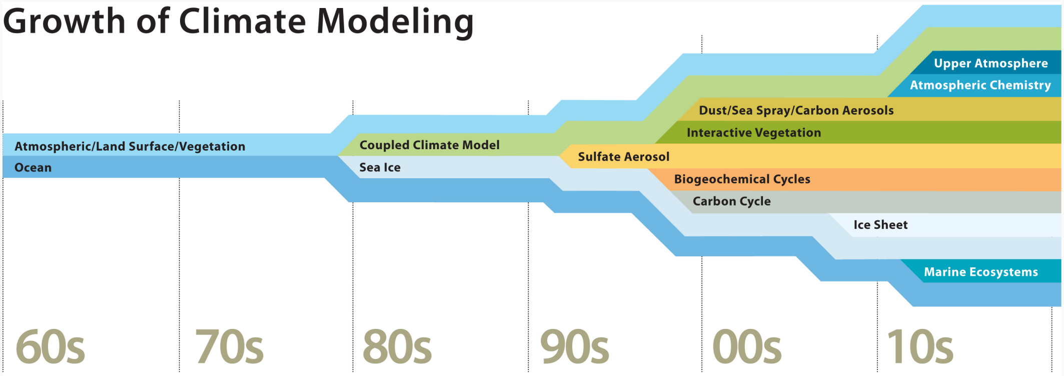
Introduction

Why evaluate climate models



https://news.ucar.edu/sites/default/files/news/2011/predictFlow2.jpg

Why evaluate climate models

- Evaluation
  - Process of understanding a model and how well it works.
  - Key objective is to quantify statistically how good or bad the model is against the observations by comparing distributions.
  - Depends on the purpose and experimental design of the simulations.
  - We evaluate models to have a better understanding of different aspects of climate model.
- Validation
  - Process of ascertaining or testing the truth of a model.
  - Generally done through recreating known past climate and comparing with past observed data.
  - Not the perfect truth — models are incomplete representations of reality.

Evaluation using observations

Issues with observations

- Observations are not absolute truth.
- Observations can have missing/inaccurate information — depends on
  - Duration of records.
  - Errors arising due to
    * Systematic error — Calibration and instrument issues thus leads to consistent departures from true value.
    * Random error — Unpredictable disturbances thus leads to outliers in the observations.
  - Erroneous retrieval algorithms.
  - Artifacts in satellite retrievals.

Issues with observations

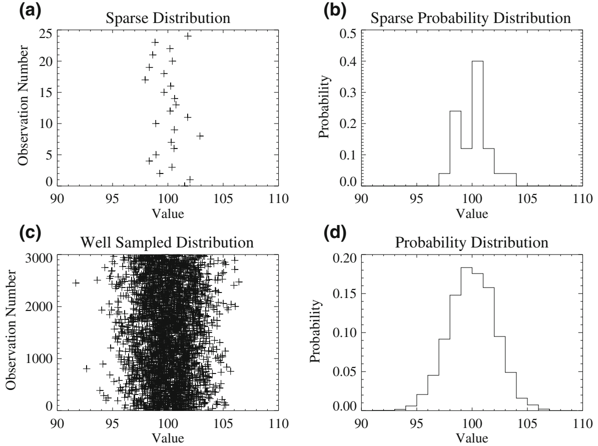


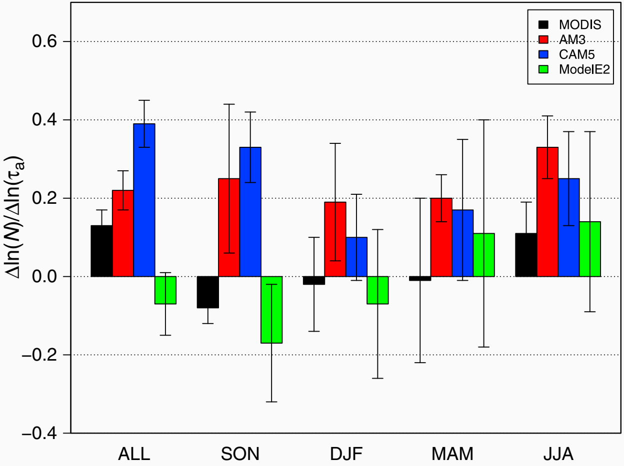
Fig. 9.1 Sampled distributions. Points representing individual observations are randomly sampled from a distribution with a mean of 100 and a standard deviation of 2. **a** Sample with 25 points. **b** The probability distribution function (PDF) of these points. **c** Same distribution with a sample of 3000 points. **d** The PDF of these points

Andrew Gettelman (2016) :

Demystifying Climate Models: A Users Guide to Earth System Models

Uncertainty in observations

- Evaluation of climate models also depends on how well do we understand the uncertainty in observations.



Ban-Weiss et al. (2014) :
Evaluating clouds, aerosols, and their interactions in three global climate models using satellite simulators and observations

Understanding the uncertainty in the observations, including the retrieval algorithms that are used for observations, and the difference between what the observations and the model represent is critical for evaluation.

Next step: Identifying model errors

Identifying model errors

- Majority of errors in model come from the modeled physics — parameterized processes.
- Model errors (model uncertainty) can arise due to reasons such as
  - Internal variability
  - Simplistic model physics
  - Errors in land-sea coupling in the model.
  - Compensating errors
- Once the source of model error pertaining to a specific process is known, the next step is model improvement.

Model-Observations comparison — Apple-Orange problem

Conceptualizing satellite simulator

- Large uncertainty persists in simulation of cloud cover and cloud properties (Bony and Dufresne, 2005).
- Satellites are the first source of global observations.
- Direct comparison between model and observations inconsistent (Apple-Orange comparison !) since
  - Satellite derives the observations through processing radiance values and model calculates atmospheric variables through prognostic and diagnostic equations.
  - The assumptions inherent in the retrieval algorithms of satellite (viewing geometry, sensors' sensitivity, vertical overlap of cloud layers etc.) are absent in climate models
- To overcome this problem, satellite simulator was devised

What is COSP ??

- World Climate Research Programme (WCRP) came up with Cloud Feedback Model Intercomparison Project (CFMIP) whose objective was to improve the understanding and evaluation of clouds, cloud feedbacks and changes in regional-scale circulation and precipitation.
- CFMIP community has developed an integrated satellite simulator, the CFMIP Observation Simulator Package (COSP) (Bodas-Salcedo et al., 2011).
- COSP is a software tool that enables the simulation of data from several satelliteborne active and passive sensors from model variables.
- It facilitates the use of satellite data to evaluate models in a consistent way (Apple-Apple comparison !).

Apple-Apple comparison

- COSP diagnoses from model outputs some quantities (e.g. infrared and visible radiances, radar reflectivities, lidar backscattered signals) that would be observed from space if satellites were flying above an atmosphere similar to that predicted by the model.
- Diagnostics about the presence and the properties of clouds can then be applied consistently to observations and to simulator outputs, ensuring a consistent model-data comparison.
- COSP includes several simulators under the same interface and facilitates the implementation of a range of simulators in models (ISCCP, MODIS, MISR, CALIPSO etc.).
- Facilitates model intercomparison, not only model–satellite comparison (e.g., comparisons of cloud properties simulated by GCMs and CRMs).

What is COSP ??

So COSP is basically what satellites would see if they were inside the climate model !!

COSP use case

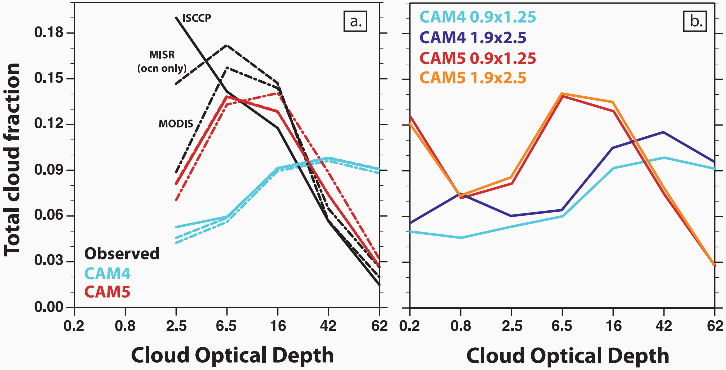


FIG. 3. Global column-integrated cloud optical depth (τ) distributions: (a) MISR, MODIS, and ISCCP from satellite observations, CAM4, and CAM5, (b) ISCCP from CAM4 and CAM5 at both 0.9° × 1.25° and 1.9° × 2.5° horizontal grid resolutions. Below τ= 3.6 there are large intersatellite differences in cloud fraction due to the difference in detection and treatment of cloud edges and subpixel clouds. Observational agreement below τ= 1.3 is especially poor (see P12, Fig. 4) and is therefore not plotted in (a). CAM τ distributions are accumulated over model columns and include the subgrid-scale variability implied by partly cloudy layers.

Kay et al. (2012) :

Exposing Global Cloud Biases in the Community Atmosphere Model (CAM) Using Satellite Observations and Their Corresponding Instrument Simulators

COSP use case

Evolutions of CAM-CESM1

Model	CCSM3 (2004)	CCSM3.5 (2007)	CCSM4 (Apr 2010)	CESM1 (Jun 2010)
Atmosphere	**CAM3 (L26)**	**CAM3.5 (L26)**	**CAM4 (L26)**	**CAM5 (L30)**
Boundary Layer Turbulence	Holtslag-Boville (93) Dry Turbulence	Holtslag-Boville	Holtslag-Boville	Bretherton-Park (09) UW Moist Turbulence
Shallow Convection	Hack (94)	Hack	Hack	Park-Bretherton (09) UW Shallow Convection
Deep Convection	Zhang-McFarlane (95)	Zhang-McFarlane Neale et al.(08) Richter-Rasch (08)	Zhang-McFarlane Neale et al.(08) Richter-Rasch (08)	Zhang-McFarlane Neale et al.(08) Richter-Rasch (08)
Cloud Macrophysics	Zhang et al. (03)	Zhang et al. with Park & Vavrus' mods.	Zhang et al. with Park & Vavrus' mods.	Park-Bretherton-Rasch (14) Revised Cloud Macrophysics
Stratiform Microphysics	Rasch-Kristjansson (98) *Single Moment*	Rasch-Kristian. *Single Moment*	Rasch-Kristian. *Single Moment*	Morrison and Gettelman (08) *Double Moment*
Radiation / Optics	CAMRT (01)	CAMRT	CAMRT	RRTMG Iacono et al.(08) / Mitchell (08)
Aerosols	Bulk Aerosol Model (BAM)	BAM	BAM	Modal Aerosol Model (MAM) Liu & Ghan (2009)
Dynamics	Spectral	Finite Volume (96,04)	Finite Volume	Finite Volume
Ocean	POP2 (L40)	POP2.1 (L60)	POP2.2 - *BGC*	POP2.2
Land	CLM3	CLM3.5	CLM4 - *CN*	CLM4
Sea Ice	CSIM4	CSIM4	CICE	CICE

http://www.cesm.ucar.edu/events/wg-meetings/2015/presentations/amwg/park2.pdf

Conclusion

Summary

- Evaluation and validation of climate models is important in order to improve the capabilities of weather forecasting and climate projections.
- Evaluating climate models is a task specific exercise i.e. specific aspects of climate model are evaluated against specific observations.
- While evaluating the model, the uncertainty, errors and assumptions inherent in the observations must be taken into account.
- Since a climate model is a stochastic system, it can only be analyzed statistically and thus requires large number of samples in observations for it’s validation.

Questions?

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