Pacific Northwest
NATIONAL LABORATORY

Notes from NASA–GISS workshop on designing observations for climate applications

Johannes Mülmenstädt (opinions are the speaker's own)

July 9, 2024

U.S. DEPARTMENT OF ENERGY BATTELLE

PNNL is operated by Battelle for the U.S. Department of Energy

Slides excerpted from Ann Fridlind's NASA workshop intro

A Strategy for Improved Planning of Earth Observations from Space: Earth System Model Development Observational Constraint (OC) Studies

Ann Fridlind, Natassa Romanou, George Tselioudis, Clara Orbe,
Alex Ruane, Gavin Schmidt

NASA Goddard Institute for Space Studies

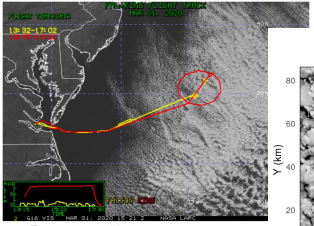
as presented to David Considine, Tsengdar Lee, Hongbin Yu, and Qing Liang on 2/17/23

What future satellite data could better constrain climate models?

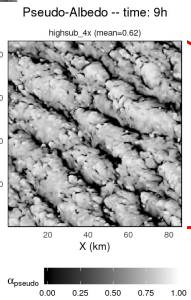
?

Global data → ESM tuning

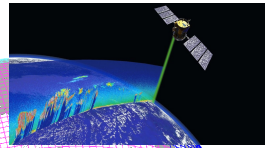
Field campaigns → LES → SCM



From https://satcorps.larc.nasa.gov



ACTIVATE Flight RF13
1 March 2020
mixed-phase cold-air outbreak
(*Tornow et al., in prep*)



CALIPSO

GMAO/cubed-sphere

Workshop on the Use of Climate Models in Satellite Mission Design
Meeting Agenda

Monday, June 10 / 9–5:30ET

Session 1 — Introductions
Gavin Schmidt — Welcome to GISS and Institute Orientation
Ann Fridlind and George Tseldioudis — Workshop Motivation, Strategy, Goals
Everyone — Round Table Self-Introductions

Session 2 — NASA Decadal Survey Mission Incubation
Amber Emory — Road Map to Decadal Survey Mission Development
Ann Fridlind — A GISS Modeler's-Eye View of the DS, TRL, ESTO, SATM, Value Framework and Costing Practices, and Community Support

Session 3 — OSSE Applications
Fanglin Yang — OSSE Applications at NOAA: A Data Assimilation Modeling Framework
Derek Posselt — OSSE Applications at JPL: Testing Sampling and Retrievals in a Bayesian Framework
Greg Elsaesser — GISS ModelE3's Calibrated Physics Ensemble (CPE) as an OSSE Foundation
Marcus van Lier-Walqui — First Results of a Proof-of-Concept Climate OSSE for PBL Target Observables
Discussion — Q&A, Other Climate OSSE Approaches?

Tuesday, June 11 / 9–5:30ET

Session 4 — OSSE Considerations
Greg Cesana — Relationship of CPE Members to Cloud Feedback and Climate Sensitivity
Johannes Mülmenstädt — Relationship of Climate Model Processes to Cloud Feedbacks
Lazaros Oreopoulos — Observation-Model Sample Matching in GEOS5
George Tselioudis — Metrics for Operational Climate Modeling
Discussion — OSSE Capabilities and Limitations

Session 5 — Earth Observation Planning Context
Matt Lebsock — NASA PBL Incubation Mission Report
Dan Miller — NASA AOS Mission Report
Brian Cairns — NASA PACE Mission Report
Ryan Kramer — KISS Study Report
Betsy Weatherhead — WMO-BIPM Report and Designing the Earth Observing System of the Future
Discussion — Designing Observations for Climate Applications

Wednesday, June 12 / 9–12ET

Session 6 — Summary and Outlook
Workshop Outcomes
Publication Planning: Strawman Outline
Town Hall and Other Follow-On Possibilities

What kind of questions would ESM OCs answer?

- Mission design process
  - what coverage and dynamic range is optimal for climate model constraint?
  - what are optimal temporal, spatial, or spectral resolution?
  - how are observational data streams related to capabilities to answer leading mission science questions?
  - enable evaluation of added value of mission design investments
  - quantify and demonstrate observation-to-parameter constraint pipeline
- How to implement
  - use more than one US climate model for each study
  - studies must be embedded with each Decadal Survey mission lifetime

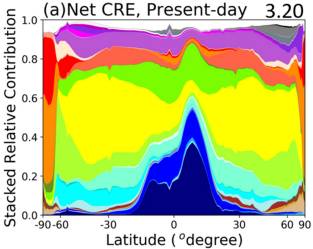
Things I took away from the discussion

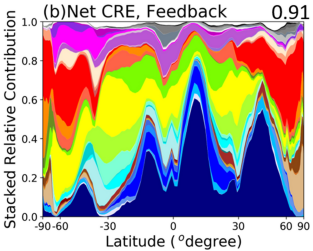
Main message: To constrain climate response with observations, we need to systematically identify which observations provide a constraint.

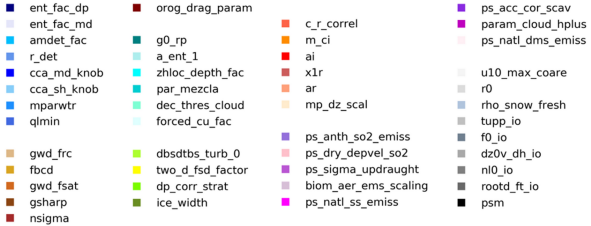
State and sensitivity

Tsushima et al. (2020); Regayre et al. (2018); Lee et al. (2016); von Bertalanffy (1950)

State and sensitivity

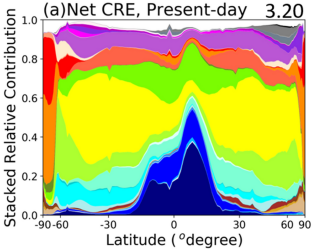


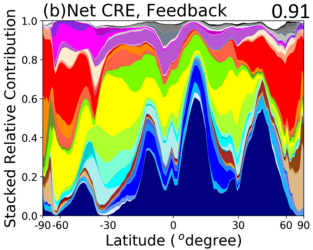


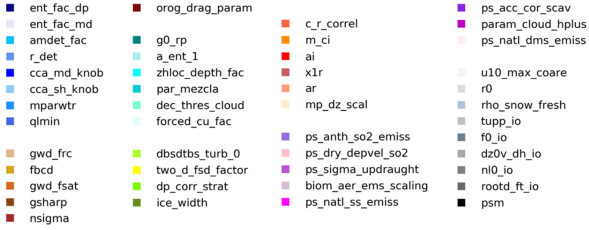


Tsushima et al. (2020); Regayre et al. (2018); Lee et al. (2016); von Bertalanffy (1950)

State and sensitivity



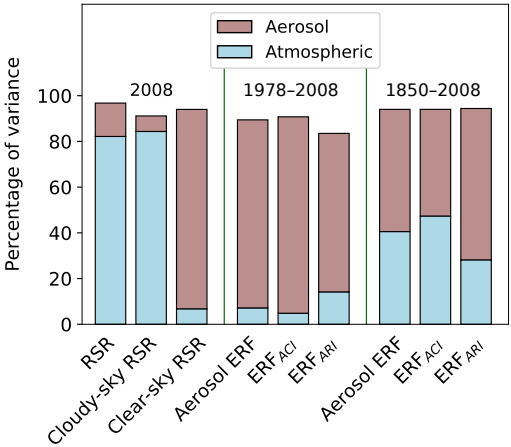




1. Cloud state and cloud feedbacks are fundamentally controlled by different model parameters
2. Models are a tangle of compensating process errors can be combined in different ways to give a similar state, but all have different sensitivities to perturbations – equifinality
3. Constraining cloud state (e.g., CRE, SLF) is likely not enough to constrain the feedback

Tsushima et al. (2020); Regayre et al. (2018); Lee et al. (2016); von Bertalanffy (1950)

State and sensitivity, clouds and aerosols



- Both cloud and aerosol parameters contribute to clear-sky and cloudy-sky radiative fluxes
- . . . differently for base state and for anthropogenic forcing!

Tsushima et al. (2020); Regayre et al. (2018); Lee et al. (2016); von Bertalanffy (1950)

Corollary: constraining base climate may require different observations than constraining perturbed climate

What does this mean for AMSG?

- Global modeling community can provide essential input into design of observations (where, when, what?)
- Climate OSSEs as an objective and quantitative way to evaluate AMF proposals?

What does this mean for AMSG?

- Global modeling community can provide essential input into design of observations (where, when, what?)
- Climate OSSEs as an objective and quantitative way to evaluate AMF proposals?
- Can't ask every proposal to design and execute a global model PPE!

What does this mean for AMSG?

- Global modeling community can provide essential input into design of observations (where, when, what?)
- Climate OSSEs as an objective and quantitative way to evaluate AMF proposals?
- Can't ask every proposal to design and execute a global model PPE!

- But can the global modeling, process modeling, and observations communities come together to provide this capability?

Lee, L. A., C. L. Reddington, and K. S. Carslaw, 2016: On the relationship between aerosol model uncertainty and radiative forcing uncertainty. *Proc. Nat. Acad. Sci. USA*, **113 (21)**, 5820–5827. doi:10.1073/pnas.1507050113.

Regayre, L. A., J. S. Johnson, M. Yoshioka, K. J. Pringle, D. M. H. Sexton, B. B. B. Booth, L. A. Lee, N. Bellouin, and K. S. Carslaw, 2018: Aerosol and physical atmosphere model parameters are both important sources of uncertainty in aerosol erf. *Atmos. Chem. Phys.*, **18 (13)**, 9975–10 006. doi:10.5194/acp-18-9975-2018.

Tsushima, Y., M. A. Ringer, G. M. Martin, J. W. Rostron, and D. M. H. Sexton, 2020: Investigating physical constraints on climate feedbacks using a perturbed parameter ensemble. *Clim. Dynam.*, **55 (5-6)**, 1159–1185. doi:10.1007/s00382-020-05318-y.

von Bertalanffy, L., 1950: The theory of open systems in physics and biology. *Science*, **111 (2872)**, 23–29. doi:10.1126/science.111.2872.23.