A proposal for regime-based LES-GCRM-ESM-observation-forward simulation closure studies

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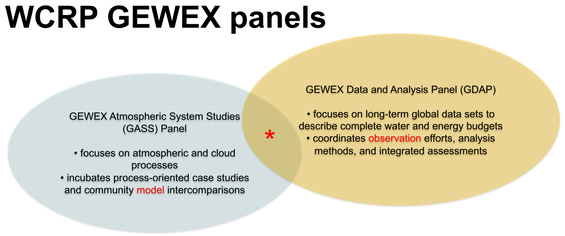
Community context

WCRP GEWEX panels

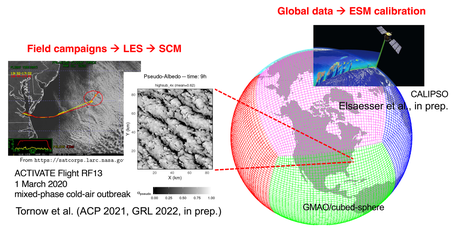


WCRP Lighthouse activities

- Explaining and Predicting Earth System Change activity's Modeling and Monitoring Earth System Change working group
- WG themes
  - observational and modelling requirements to monitor, explain and predict
  - convergence between climate modelling and Earth system data assimilation & reanalysis
- WG identified five relevant gaps/shortcomings
  - persistent model biases
  - underutilization of diverse observational data
  - disconnect between ESM and reanalysis/DA effortssparse observational sampling of parts of the Earth system
  - insufficient approaches to handle model and observational uncertainty

NASA GISS context

ModelE3 development approach



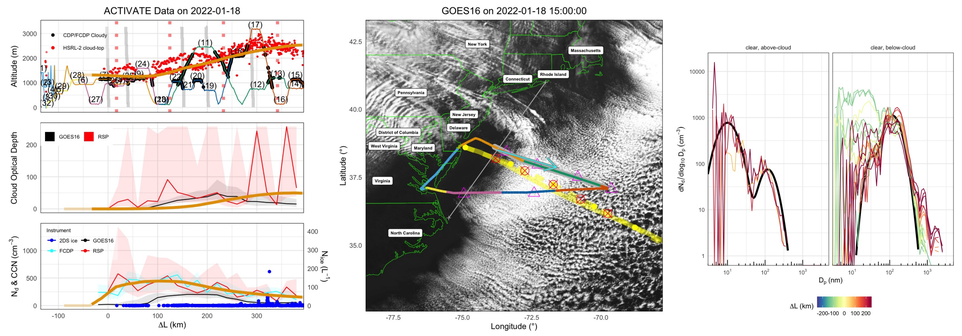
LES/SCM case study library

Conditions	Case study	Aerosol aware?
dry convective boundary layer	idealized [Bretherton and Park 2009]	—
dry stable boundary layer	GABLS1 [Cuxart et al. 2006]	—
marine stratocumulus	DYCOMS-II RF02 [Ackerman et al. 2009]	observed (2 modes)
marine trade cumulus (shallow)	BOMEX [Siebesma et al. 2003]	—
marine trade cumulus (deep, raining)	RICO [van Zanten et al. 2011]	—
marine stratocumulus-to-cumulus *	SCT [Sandu and Stevens 2011]	—
continental cumulus ^	RACORO [Vogelmann et al. 2015]	observed profile (3 modes)
Arctic mixed-phase stratus	M-PACE [Klein et al. 2009]	observed (2 modes)
Antarctic mixed-phase stratus *	AWARE [Silber et al. 2019, 2021, 2022]	estimated (1 mode)
tropical deep convection	TWP-ICE [Fridlind et al. 2012]	observed profile (3 modes)
mid-latitude synoptic cirrus *	SPARTICUS [cf. Mühlbauer et al. 2014]	—
mid-latitude cold-air outbreak *^	ACTIVATE [Tornow et al., 2021, 2022, in prep.]	observed profile (3 modes)
high-latitude cold-air outbreak *^	COMBLE [Juliano, Tornow et al., in prep.]	observed/estimated profiles (3 modes, 1 INP)
marine cumulus and congestus *^	CAMP2Ex [Stanford et al., in review, in prep.]	observed profiles (3 modes)

ACTIVATE example • see Tornow poster

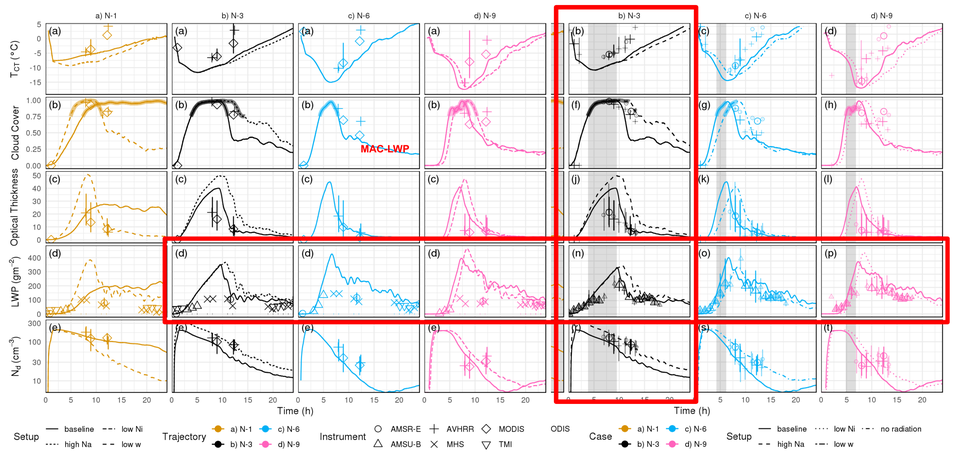
Case study selection

- choose 2020-2022 flights with greatest fetch offshore



Observational constraints

- differing products differ from one another to varying degrees (e.g., liquid water path)



LES case study development ≈ a closure study

- defined as measuring everything that goes into a model and what it predicts, then testing whether a prediction matches the observed results within experiment (and model) uncertainties
  - point and column radiative closure (e.g., Quinn et al. 1996)
  - aerosol–CCN or CCN–droplet closure (e.g., Martin et al. 2011)
  - aerosol–INP closure (Knopf et al. BAMS 2020)
  - foundational framework for more robust handling of observational and model uncertainties? at the same time, a strong development test bed
- LES/SCM case studies also used for retrieval development (e.g., Alexandrov et al. 2020), ground-based simulator development (Silber et al. 2022 GMD; EMC2), satellite simulator refinement (Cesana et al. GRL 2021)

Strawman strategy

Step-by-step

1. select regime-based case studies from a field campaign (e.g., ACTIVATE)
2. collate appropriate satellite data extractions (e.g., MAC-LWP)
3. derive Lagrangian, aerosol-aware set-up for LES/SCM/1D (GASS-type activity; also amenable to extraction of Lagrangians from GCRMs or ESMs)
4. perform closure calculations (e.g., column radiative)
5. if participating models are treated collectively as representative of model uncertainty, then the degree to which individual observational data products are outlying could be quantified (e.g., MAC-LWP on a regime-based basis)

—> foundation for handling model and observational uncertainty regime-wise?

Something for everyone?

- LES, climate model or GSRM participant?
  - regime-based analysis of your model's performance
  - community-based evaluation of diverse observational data
  - LES/SCM/1D development test bed suitable to fix persistent model biases
- retrieval evaluation and development participant?
  - regime-based test beds ready-made to independently estimate model and observational uncertainties
  - multiple LES freely available for retrieval development/testing
  - community results to explain where more funding is needed and why

Summary

Takeaways

- is there a role for regime-based LES-GCRM-ESM-observation-forward simulation closure studies as a community activity to overcome key barriers to progress?
- could such studies by extension help to reduce microphysics process uncertainties by effectively bridging (1) well-observed case studies and global observations, and (2) observation-constrained detailed simulations and climate model physics in SCM mode?

COMBLE-MIP example • see Juliano poster

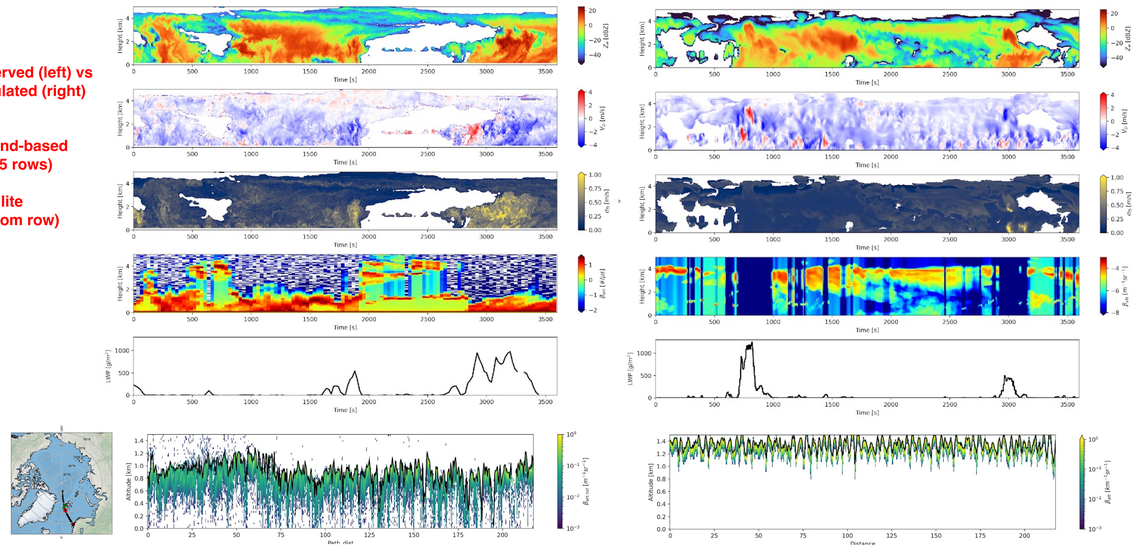
Forward simulation from LES

- use EMC^2 (Silber et al. GMD 2022) to evaluate LES and SCM vs ground-based and satellite observations (e.g., radar and lidar)

observed (left) vs simulated (right)

ground-based (top 5 rows)

satellite (bottom row)

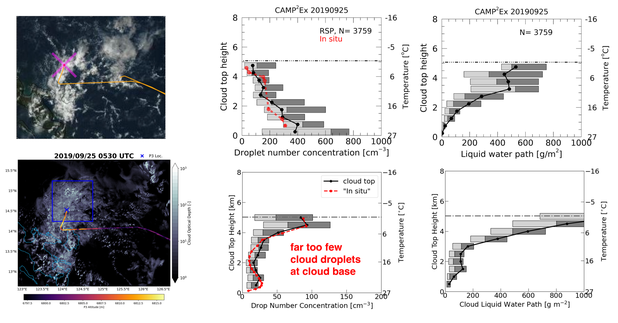


CAMP2Ex example • see Stanford poster

Observational constraint of simulated aerosol-cloud interactions

- robust evaluation can reveal biases in detailed simulations

observed (top) vs simulated (bottom)



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