Notes from the clouds and aerosols breakout

Notetaker: Brian Medeiros (sorry!)

Brief Notes During Live Oral Presentations

(intro to the whitepaper; Klein & Fan)
Important exercise to communicate to program mgrs what are the important topics on the horizon.
3-6 pgs -- high level, not many details -- thematic view of where research should go.
Input is needed for Grand Challenge / Questions / Research Goals
During discussion, we also want to hit upon: use of machine learning, metrics (CMEC), role of high-resolution model experiments, future intercomparisons

Clouds feedbacks in the WCRP Assessment -- Klein

In area of feedbacks, a subgroup of co-authors looked at all evidence to assess value of cloud feedback (radiation per degree warming). Looked at all avail literature. Satellites / LES / theory / GCMs. Broken down by cloud types. Mostly positive feedback, tropical anvil provides a negative feedback; total feedback of ~0.4 W/m2/K but still large uncertainty from 0.15 to 0.8 W/m2/K. No single cloud type dominates the uncertainty.

Validation of CMIP5 Tropical Fast Feedback Processes and Comparison to Temperature trends -- Spencer

Partly related to global temperature dataset (starts in 1979 for model validation). Also relating to diagnosing feedbacks, dating back to a series of papers. Correlations between radiative flux and temperature tend to be weak, but there’s hope because we have confidence there is a relationship. Tropospheric temperatures work better than surface temperature (related to recent work by Dessler). Compare satellite to climate models. Slope of regression compared to temperature trend, get a noisy signal in models. Relation to longterm climate sensitivity is still open question, but short term variability is a way to test the models.

Cloud feedbacks cause higher climate sensitivity in CMIP6. What do observations say? -- Zelinka

Update on status of CMIP5 vs CMIP6 climate sensitivity. 45 CMIP6 models with abrupt4xCO2 simulation. Mean sensitivity is up. 16 are above the CMIP5 maximum (2 below the CMIP5 mean). Reason is primarily due to stronger positive cloud feedback, particularly higher latitudes (southern ocean) (equally from amount and optical depth). May be associated with improved cloud phase in current models. Cloud feedbacks broken into pieces as in the WCRP assessment. Uses ISCCP simulator (subset of models). E3SM example of very strong positive cloud feedback. Comes from 3 main terms: high cloud altitude feedback, tropical anvil area, unassessed feedbacks (extratropical high cloud optical depth). Highlights utility of this framework to diagnose the feedbacks.

Observational constraints on decadal low cloud feedbacks associated with varying sea surface temperature patterns -- Myers

Obs. of energy budget over 40yrs suggest low climate sensitivity tied to negative decadal low-cloud feedback in 80s-2000s. Climate models link decadal feedbacks to SST variability (pattern effect). Key to finding is that climate models respond correctly to the SST variability. Use satellites to assess sensitivity of marine low clouds; multiple regression of annual anomalies; Scott et al JCLIM; Combine estimates with changes in meteorology in piForcing and abrupt4xCO2 experiments. Produce observational estimates of feedbacks. Time series of 30yr AMIP Feedback, dots show 4x feedbacks; recently negative feedbacks because of increase in EIS, in contrast the 4x feedbacks is positive for both obs and models. Provides observational evidence for pattern effect that is largely consistent with models. Highlights varying feedback estimates, especially related to EIS. Corrobrates that satellite-based estimates of sensitivity are biased low.

Spurious Late Historical-Era Warming in CESM2 and Other CMIP6 Simulations -- Fasullo

Recent work looking at CESM2; based on switch from CMIP5 to CMIP6 forcings. 11-members of historical era. Biomass burning focus. Emissions based on different records (GFED era spliced to previous homogenized emissions). Strong temperature response to the variability in biomass burning. Global mean shows accelerated warming, almost all from northern hemisphere. Shortwave radiation absorbed is sensitive to biomass burning; northern boreal regions; thins the clouds through a set of processes that warm lower troposphere and reduce RH. Results in more radiation absorbed by system that leads to warming. A number of models besides CESM2 show a cooling after the GFED emissions era.

Cloud feedbacks in E3SM: Do atmosphere-only experiments reproduce fully-coupled results? -- Qin

E3SM has high climate sensitivity due to cloud feedback. Prev studies suggest AMIP capture the cloud feedbacks. Here compare E3SM simulations in AMIP and coupled. Use ISCCP dicop into net, sw, all, high, all, low clouds. E3SM has stronger feedback than other models. 4xCO2 feedback is stronger than AMIP4k feedback. Differs from other models. Comes from 2 contributions. Stronger decrease of high cloud amount and optical depth. Stronger decrease of low cloud optical depth. Look at zonal average of feedbacks. High cloud feedback spread over midlats. Low cloud over southern ocean. Caution when looking at AMIP runs b/c different patterns fo feedback.

The impact of cloud radiative effects on the distribution of tropical precipitation -- Medeiros

Revisiting a potential relationship between global-mean precipitation change and climate sensitivity with CMIP6 -- Pendergrass

Paper in GRL. This is just one of the sections. See also ECS virtual seminar series. Starts with Watanabe study: link between ECS and hydrologic sensitivity. CMIP5 and PPE to show process-level link between TOA SW and surface CRE via low clouds. CMIP6 can be treated as a different sample of simulations to test hypotheses based on previous ensembles. SW sfc CRE sensitivity negative correlation with sfc dLWCRE/dT -> process level relationship works. Hydrologic sensitivity not correlated with ECS in CMIP6 though, also in CMIP5. ECS vs TOASWCRE are related, as we know. Hydrologic sensitivity NOT correlated with surface dLWCRE/dT. Surface LWCRE not a dominant factor driving spread across the CMIP6 simulations.

Precipitation-radiation-circulation feedback processes associated with structural changes of the ITCZ in a warming climate during 1980-2014 -- Lau

Deep-tropical-squeeze hypothesis. Wet get wetter, dry get drier. Used a superparameterized model to do experiment where CRE and circulation are decoupled somehow that keeps the mean climate about the same. They found a change in largescale circulation. Tightening of ITCZ; deepening hadley circ; stronger sinking in subtropics and drying/widening. Main idea is that CRE leads to squeezing tropics. Reduction in RH related to drying in western USA (fire weather). This is detectable in observed record (Lau and Tao 2020).

Impact of atmospheric processes on mechanisms of Southern Ocean heat uptake -- Morrison

Motivated by fact that peak OHuptake happens around 60S, but role of clouds is less clear. LongRunMIP absorbed SW radiation. 4 reanalyses looking over past 40 years. ERA5/JRA55 representative. Southern ocean heat uptake index as a zonal average. Regress on cloud cover. When index is large, more cloud cover. Cloud increase ocean heat uptake by changing surface fluxes (related to stability changes). Strongest increase in stability when clouds lead stability by 2 hours (ERA5). Increase in cloud cover leads to heat uptake increase of 5Wm2 in same regions as where relationship between index and cloud cover is strongest. Highlight of interaction in atmospheric and surface processes that are important for polar climate.

Roles of aerosol, cloud and associated radiative feedbacks in the recent Arctic warming -- Wang

Two recent studies. Comparison of global mean radiative feedabcks between AMIP and abrupt4xCO2 (radiative kernels). Some differences between feedbacks between AMIP and abrupt4x. Then look at Arctic feedback vs tropical feedback; models mostly agree on contribution of LR, WV, Albedo contribution to arctic amplification. Look at contributions of sulfate and black carbon; local cloud-aerosol interactions matters (ari&aci) in Arctic.

A modeling examination of cloud seeding conditions under the warmer climate in Utah, USA -- Pokharel

Idaho and Wyoming field programs to look at cloud seeding. Orographic clouds with abundant supercoold liquid water is suitable for seeding (hypothesis). Lidar shows layer of supercooled cloud downwind of Medicine Bow Mts. Ask what will happen with future warming climate. Used WRF simulation (PGW). Figure shows cloud seeding potential decreases widely except over a small region in northern Utah. Paper available.

Anthropogenic aerosol impacts on deep convective clouds and precipitation over Houston -- Zhang

How athro. Aero. effect is influenced by parameterization and how aerosol works with urban land effect to modify convection. WRF-Chem-SBM experiments. Change microphysics. Spectral bin gets better convective storm. Latent heating profiles show that aerosol changes convective intensity. Subsequent modified morrison scheme (explicit supersaturation) shows similar aerosol effect as spectral bin, so saturation adjustment makes a difference for convection strength. Joint urban land and athro aerosol effects strengthen convection; upper levels are mostly the aerosol effect because urban land effect enhances sea breeze to affect transition to mixed phase clouds. See pre-recorded video for more.

The tug-of-war between regional warming and anthropogenic aerosol effects -- Wang

Case study of tropical cyclone last year. Developed with a lot of sulfate aerosol. Was record setting TC. Two opposing effects: strengthening due to warming SST, weakening by sulfate aerosol. Warming wins.

Using CESM-RESFire to Understand Climate-Fire-Ecosystem Interactions and the Implications for Decadal Climate Variability -- Zou

CESM-ResFire model. Improved treatment for atmosphere processes for fire weather. Feedbacks between climate variability and fire severity. Impacts of fires on radiative, hydrologic, chemical, biogeochemical processes. Net cooling effect overall; would strengthen in 2050s because of more burning in warmer climate (also provides additional carbon emissions). Need complete biogeochemical cycles to evaluate.

Discussion of Talks

(copy of chat transcript)

From Host to Everyone (in Waiting Room): (11:26 AM)
Hello and welcome to the Cloud and Cloud-Aerosol Interactions and Feedbacks Breakout. We will be admitting attendees into the meeting shortly. Thank you. Hello and welcome to the Cloud and Cloud-Aerosol Interactions and Feedbacks Breakout. We will be admitting attendees into the meeting shortly. Thank you.
From Timothy Myers to Everyone: (12:43 PM)
@Ariel did you examine surface fluxes (including surface cloud radiative effect) from the CERES-EBAF surface product? I wonder if it could provide additional information beyond total cloud cover.
From Mark Zelinka to Everyone: (12:51 PM)
@Roy: What do the gray dashed lines represent in your 3rd figure?
From Ariel Morrison to Everyone: (12:56 PM)

@Timothy Yes, we’ve looked at radiative fluxes from CERES and cloud data from CALIPSO-GOCCP (plus low/opaque cloud cover) to compare against the reanalyses, but I’m still looking for reasonable observational heat flux data. Any suggestions on data sources or other processes I could look at are appreciated!
From Roy Spencer to Everyone: (12:59 PM)
@mark, the dashed lines just represent what kind of functional relationship we might expect between Net feedbank and warming trend, that is, an inverse relationship (power law).
From Jiwen Fan to Everyone: (1:02 PM)
Feel free to raise your hand in Q/A section
From John Fasullo to Everyone: (1:02 PM)
@Yufei: Thanks for the interesting summary of CESM-RESFire. I’m curious how the model validates versus observations (e.g. GFED or other) and whether you find the model to be reliable/stable enough to run in fully coupled mode in its present state?
From Timothy Myers to Everyone: (1:05 PM)
@Ariel got it, thanks. Very interesting findings. My understanding is that CERES-EBAF surface fluxes are considered the best quality because they are constrained by measured TOA fluxes.
From Timothy Myers to Everyone: (1:15 PM)
*CERES-EBAF surface radiative fluxes
… (following was later, after initial discussion) ...
From Phil Rasch to Everyone: (2:22 PM)
John Fasullo, I am interested in whether you think that the warming associated with heterogeneous forcing is really spurious, or whether it is just “different” from homogeneous forcing. If we had heterogeneous forcing for the last couple of centuries there would not necessarily be an unrealistic recent warming since the GFED emission updates. I worry that the word “spurious” is delivering a message that the recent emission characterizations is wrong. Rather it is the use of one type of emissions for past estimates and another for more recent estimates
From John Fasullo to Everyone: (2:24 PM)
@Phil: Good point. It is the temporal evolution of forcing that is spurious rather than the GFED record itself. Given what we show for the GFED era, the “true” correction would be a net warming of the eras without variability (before and after GFED) rather than during GFED itself.
From Phil Rasch to Everyone: (2:25 PM)
Thanks John
From Phil Rasch to Everyone: (2:53 PM)
have to sign off, bye all

Yufei & JohnFasullo: In general the model is stable and reliable. Used GFED to calibrate in terms of global burned area and emissions. Only have run in Atm/Lnd, not coupled run.
Jiwen asks John about GFED uncertainty. John thinks the uncertainties are small compared to the effect. John relates back to challenges through better understanding the forcing.
Hailong asks Steve about the WCRP assessment. Steve relates the feedbacks being established through interannual variability. Question is that in stronger warming scenarios shows net global mean cloud feedback is strong, but observations don't support such strong feedback, does cloud feedback depend on warming? Steve: evolution of SST in last 40 years has driven increase in inversion which is DIFFERENT from expected change with longterm warming. Longterm observed cloud feedback inferred may be different than what we expect in the future because of pattern effect.

Steve: Related to Ariel's talk. When you do the regression, how to determine the causality? What about confounding factors like winds? Ariel: They do look at a lot of factors, still working on causation. One thing is to use highest temporal resolution possible. Observations of turb heat fluxes aren't great in southern ocean; they don't have much except ships.
Jiwen followup: results shown from winter season, wondering if in winter LW is dominant, is the story different in summer?
Ariel: they looked at annual mean global ocean heat uptake first. Winter was bigger effect overall, which is why they are focused on it. Relationship is much weaker in summer.

Steve: related to Bill's and Brian's talks. Curious about how this plays into improving models.
Bill: tough question because best you can do with parameterization is limited, and if radiation is wrong, you never get correct answer.
Roy: mentions the implication for water vapor feedback strength based on Bill's results. Notes that all this is very tightly connected to precipitation efficiency.
Brian: Notes that the connection between extremes and organized convection provides one way to try to improve models with either resolution or parameterization development focused on organized convection.
Jiwen wonders about microphysics impact. Brian says hard to say from these results. Hui adds that PPE with CESM shows convection and microphysical parameters both important, but convective parameters make spread more like multimodal spread.
Jiwen asking about CMIP5 vs CMIP6. John says CMIP6 in past 20 years is maybe not very reliable.

Jiwen asks Hailong about his figure and strength of cloud feedback compared to Mark's. Hailong says might be partly because of model sample. In general ensemble mean is close between CMIP5 and CMIP6; Mark agrees that the difference is subtle. Need to look at joint distribution of forcing and feedback to understand why ECS is so much higher in CMIP6.

Discussion of whitepaper

Input on questions:

Soden: Pattern effect aspects and how that affects cloud feedbacks, one question is how much of the pattern over past 40 years is forced (or not)?

How do other components of Earth System force clouds, and how does that tell us about how they function in the climate system? (generalized version)

How much of the pattern effect is forced? (specific version)

Su: Important to put cloud feedback in the context of aerosol effects.

These research communities have often been pretty separate in the past, but they seem to be coming together in past few years to better understand how aerosols play into cloud feedbacks.

Fan: Specific question focusing on tropical anvil clouds?

Fan: Uncertainty in forcing is also not represented in current questions.

Steve: Where is the uncertainty in the aerosol-cloud interaction understanding?
Fan: Deep convection / cumulus parameterization is a very large uncertainty. Detrainment from cumulus plays a big role, but we don't have good understanding of aerosol effects in these clouds. As we are going to convection-permitting scale, we should be able to get better idea of how much high cloud dCRE can offset low-cloud dCRE.

Collins: Have we discussed the challenges associated with D&A in this group?

- Right now we have not addressed it. Any particular issue to be raised?
- Decomposing precipitation signal between aerosol and GHG is very hard in regions (like USA) because they are nearly equal and opposite.

- Spencer: large uncertainties in precipitation retrieval. Don’t trust trends. (Bill Collins: right, use rain gauge data. Still faced with problem of not being able to disentangle signal because we don’t know the aci and have to rely on models that we don’t necessarily trust)
- Klein: How do we interpret changes observed in cloud and aerosol and put in context of understanding of climate change?
- Hailong Wang: aerosol parameterizations vary across models (a lot); a lot of models don’t have aerosol effects on deep convection at all; findings about “semi-direct effects” are very reliant on models.
- Collins: A different take on that. A challenge in observing these effects. If we assert they are active in the climate system but they are at the limit of our ability to detect them, it raises a question of how we do process evaluation in models.

Moving toward goals section:

Long term (10 years):

Quantitatively reduce uncertainty in cloud feedback and aci.
- Curious to ask group whether it is worth trying to improve parameterizations, or do we need to jump to ultra high resolution models?
- Soden: (might fit under earlier comment about cloud types) Is it worth including the combined lapse rate + water vapor in the group of feedbacks because it is about half as much uncertainty as the total cloud feedback.
- Rasch: Still seems to be lot of disagreement in community about aci that are sufficiently diverse set of model responses to indicate that we can resolve anything by going to high-res / convection-permitting models.
- Fan / Medeiros / Hailon: All agreeing with Phil that high resolution is not a panacea even though some aspects of the clouds do improve. Might be useful to focus on difference between model deficiency versus uncertainty.
- Our goal is to reduce uncertainty. Can’t rely on model resolution to solve the problem.
- Myers: Distinguish between inter-model uncertainty and “real” uncertainty. WCRP assessment indicates reduced uncertainty in real cloud feedbacks, but Zelinka work shows increased inter-model spread.
- Neale: Pay attention to vertical resolution because a lot of the processes are acting on small vertical scales.

Additional specific topic discussion

ML

- Training on high-resolution models to “learn” parameterization.
- Transport in filamentary features that are not resolved in coarse models. Train to characterize those transports.
- Some projects are trying to do ML for autoconversion, scavenging and activation; replacing traditional parameterizations.
- How much can ML do? Particular processes or all moist physics? How will that affect feedbacks? Can ML-based models deal with climate change, and can we understand the feedbacks?

Metrics

- Do we have important diagnostic capabilities that developers should always be using? Or things coming in our own research that would be useful for repeated applications?
- Are we measuring the right things in models, or are there diagnostics that need to be added?
- One thing is “natural aerosol experiments” that seem to be very useful/revealing (e.g., Icelandic volcanoes; Hawaii).
- Do model developers need anything that isn’t available right now?
    - Tendency diagnostics -- process oriented diagnostics
    - Aci - want co-located measurements for evaluation
    - Simulators are better than model diagnostic output
    - PDFs are very useful.

High-resolution

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Future MIPs

- Forcing ensembles might be a good idea
- Coordinate with aerocom community
- WCRP has cloud modeling workshop to help coordinate intercomparison (usually process models / field-campaign-oriented)
-