THEME 3
Interdisciplinary Processes

Co-chairs: Sandy Lucas (NOAA/CPO)
Sally McFarlane (DOE/EESSD)

Description:

This session covers key processes and interactions that are important in the transition zones on either side of an interface such as, ocean-atmosphere, land-atmosphere, aerosol-cloud-precipitation transitions, and troposphere-stratosphere connections.

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Session Speakers:

Elizabeth Thompson
NOAA Physical Sciences Laboratory

Andrew Gettelman
National Center for Atmospheric Research

Ana Barros
Duke University

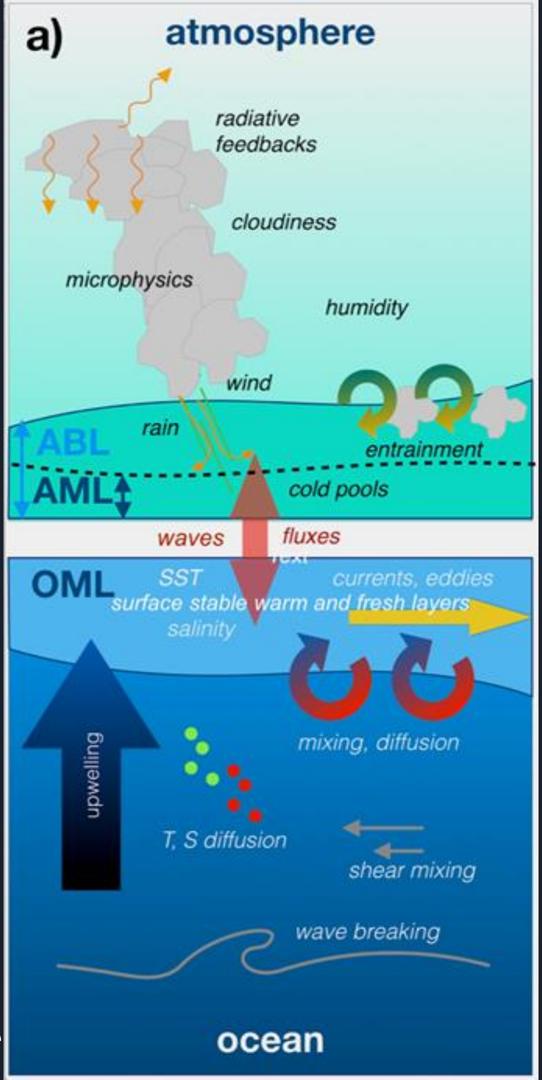
Abigail Swann
University of Washington

Yaga Richter
National Center for Atmospheric Research

Ocean-atmosphere interactions Related to Precipitation - Elizabeth Thompson

- **Ocean-atmosphere processes are complex, multi-scale, and are a combination of local and remote forcing in a coupled environment.**
  - Exchanges are dependent on: SST, air-sea fluxes, marine atmospheric boundary, convection – surrounding environment, convective organization and upscale growth, teleconnections, on-shore flow -- we need to better understand these
- O-A affect CONUS precipitation thru 1) moisture transport, and 2) general circulation
  - Predictions can fail are by getting the tropical convection wrong and/or not representing realistic teleconnection to CONUS
- Outstanding issues - ocean is poorly predicted/large biases
  - Ocean mean state issues like Tropical Pacific ENSO, atmospheric NAO
  - Flavors of tropical mean state and variability poorly predicted (types of MJO, ENSO)
  - Synoptic scale weather events over ocean can also teleconnect and affect US precip
- CONUS precipitation prediction requires accurate multi-scale, multi-location air-sea interaction to be captured in fully-coupled global models

c/o Charlotte DeMott



How NOT to represent aerosol-cloud-precipitation interactions - Andrew Gettelman

- Aerosols are critical for the coupled hydrologic cycle - and for getting precip right for the right reasons
- Aerosols also alter radiation, directly (dust, smoke, etc.) and indirectly (cloud drop conc., reflectivity of clouds)
- We have many models of the individual processes (radiation transfer, deep and shallow convection). Coupling all these pieces in global model is hard and large uncertainty is involved

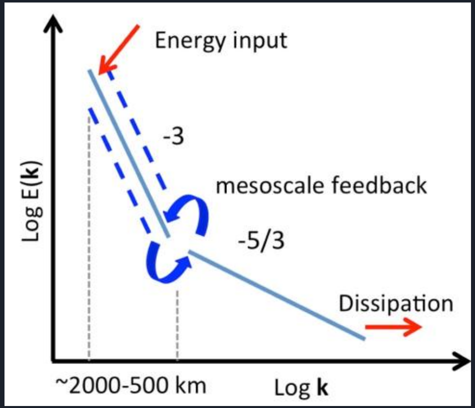
Key issues

- Aerosol radiation interaction are not done on short timescales - dust and smoke are new to weather-scale models
- Don't know freezing process well; important for cloud lifetime of shallow clouds in Arctic, Southern Ocean regions
- Warm rain, we understand well small-scale, but need to make assumptions about covariance, thresholds, non-linear process rates when we scale-up from sub-grid scales.
- Need to couple scales better - seconds to minutes. Not so good for climate scale.

We need

- Unified approach to cloud processes that can go from the local to the global scales including complexity
- Linking the microphysics with the aerosols
- Getting a correct aerosol budget
- Work on the key issues

Precipitation Prediction vs Predictability - Ana Barros



Nastrom and Gage (1985)

Assessment of prediction vs predictability - Confronting models with theory, and with observations, to assess consistency across scales.

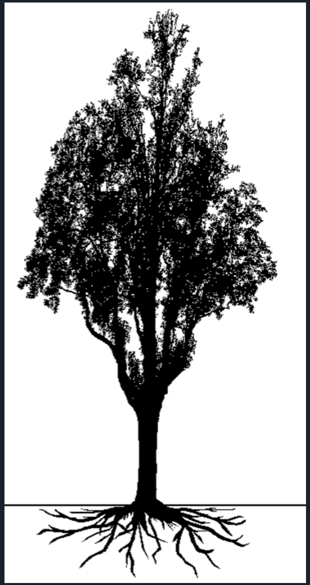
Cascade of energy between larger scale (2,000 to 500km) and smaller scale (<500km). We need to understand the energy sources at different scales and models need to capture the mesoscale feedback connecting those scales.

Instability Dynamics - Obs of the diurnal cycle - daytime heating/convection contributes to dissipation and erodes the stability. Night creates stability. Look at models to see if they capture this behavior well - they don't.

Persistence and intermittency - Satellite data of clouds - look at instability. Models are very rigid. If we have those rigid dynamics, how can we get the persistence correct? Places where there is persistence of low clouds and fog - which produce season precipitation of 50% - summer and winter may have different day/night behavior.

The big challenge, in the case of the land-atmosphere interactions, is how to put the intermittency into the persistence across scales. How do we get that right, seamlessly across scales?

Quantifying the role that terrestrial ecosystems play in Earth's climate - Abigail Swann

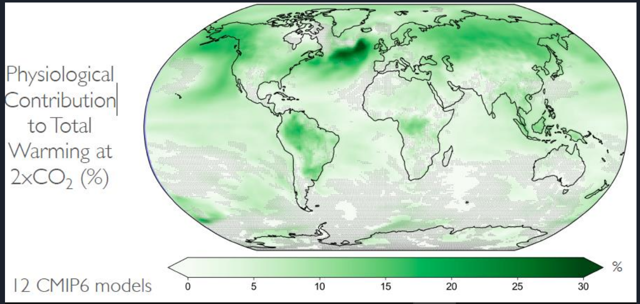


Ecosystems respond to changing environments. Leaves on trees will close stomata in response changing conditions (gas exchange, CO2 and H2O)

Biological functioning will affect how the energy and land surface behave. How the surface energy budget will balance.

Plant responses to climate can have a big impact on surface climate but are highly uncertain. Uncertainty is typically not accounted for in estimates.

Plants affect many aspects of physical surface climate such as relative humidity over land with impacts on total precipitation -- Tropics -up to half of the rainfall. It’s all local to each continent, not due to circulation.



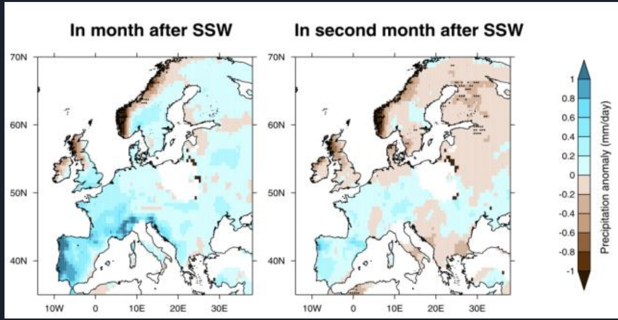
Biases in land surface properties (either prescribed or varying) can impact surface climate both directly and through atm feedbacks. Plants can change albedo, land surface - atm temp response is large and is a coupled process.

Stratosphere-Troposphere Interactions and Precipitation - Yaga Richter

The Sudden stratospheric warmings (SSWs) occur about every other year and they cause a huge change in the circulation in the stratosphere. The precipitation extremes are associate with the SSWs.

How to capture precipitation predictability from SSWs? --Model needs to well-resolve stratosphere. Get the polar vortex climatology right (and coupling with the surface). Spend time on the Gravity Wave parameterization

N Europe: Wetter SW Europe: Drier



King et al. (2019)

The Quasi-Biennial Oscillation - Madden-Julian Oscillation (QBO-MJO). QBO is an oscillation of the zonal mean winds in the tropical stratosphere region. Climate models start to get QBO, but no CMIP6 model reproduces the observed QBO-MJO relationship.

How to capture QBO-MJO teleconnection? -- Adequate vertical resolution in the stratosphere and troposphere to represent QBO. Need to get the right downward vertical motion, which needs high vertical resolution in the models. Improve the GW parametrization to get the deep convection. Improve representation of deep convection.

What are the most important processes?

Depends on what you are trying to predict … And, at what timescale! Here are some important ones ...

- SST predictions are limited by limitations in modeling the ocean mixed layer
  - Understand important factors air-sea fluxes, turbulence, mixing; Modeling with higher vertical, horizontal resolution.
- For aerosol-cloud interactions
  - Freezing processes/cold cloud processes still not well understood
  - Need more unified treatments of aerosol/cloud processes
- Land-atmosphere interactions
  - Understanding how energy is dissipated across scales
  - Intermittency and instability at small scales
  - Plant physical processes and feedbacks with atmosphere
- Stratosphere-Troposphere
  - Model needs a well-resolved stratosphere. Get the polar vortex climatology right (and coupling with the surface). Gravity waves and coupling with deep convection are important.

Do models reproduce seasonal to multidecadal precipitation patterns well (i.e., simulation of precipitation variability and trends)? Spatially, Temporally?

- Ocean models and reanalysis lack realistic mixing/turbulence => major limitation for modeling SST
- Coupled atmosphere-wave-ocean models are successful in research models, and are needed operationally
- Increasing ocean horizontal resolution improves model skill in SST and precipitation (upwelling, coastlines, eddies)
- Identify opportunities for model and observation teams to work together in order to make future progress
- Some models starting to produce a QBO - but still need improvement
- Sudden Stratospheric Warmings influence precip patterns, need well-resolved stratosphere, and processes.
- For aerosol-clouds (and others), there are issues with non-linear process rates when we scale-up (sub-grid scale to grid scale). Couple the scales and processes better. We want consistent treatment of complexity across scales.
- Models often do not get the mean state/persistence right - this causes problems in trying to understand predict the variability/regimes

Do we have existing observations, data, and understanding of these processes to parametrize them? How can we most effectively take advantage?

- In-situ observations of SST or ocean mixed layer depth to validate or initialize models are sparse. Several new plans for sustained ocean observations are being proposed.
- Need coupled ocean-atm observations and coupled data assimilation for improvement of predictions
- Uncrewed vehicles for obs of ocean and atmosphere are useful for testing coupled ocean-atm modeling but need more key observations near the Maritime continent (a critical area for driving CONSUS precip)
- Models have just now evolved to a level where we can examine observation data from turbulence/mixing field campaigns (CBLAST, HIWINGS)
- For land-atm field studies, observations can be used to confront models and test for areas of improvement
- Getting a correct aerosol budget is important
- Currently, there is a lack data to constrain the dynamics of plant responses to future climate
- Shallow boundary layer clouds are not well-resolved from satellite. They move moisture, momentum, and heat between ocean and free troposphere -- important in the hydrologic cycle.

What are the gaps in research that would make advancement over the next 2 to 5 years?

- Ocean-atmosphere interactions
  - Tropical oceans: Western Pacific and Maritime Continent influence precip/drought
  - Arctic: disappearance of ice and changing seasons of spring and fall, storm tracks
  - On-shore coastal flow: warm season US precip is analogous to MC convection
  - Target new innovations and investments in modeling and observations in these regions. Use information from new/existing field campaigns.

- Coupling-interfaces
  - New approaches for thinking about coupling model components
  - Moving from treating linear series of processes to more integrated/coupled approach - covariances
  - Increased resolution could be very important for some processes/regions, but won't solve all the problems - other ideas like advanced methods for representing heterogeneity

- Aerosols-Clouds
  - Understanding the subgrid treatments, subgrid co-variance, and how to go across scale linking the vertical velocity and humidity, precipitation, and the aerosols.

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Thank you!

Workshop Participants