Group 1 – anvil cloud evolution

Group 1 - Anvil evolution

- **At what time and spatial scales are the initial conditions of the convection important for anvil evolution?**
- How representative is the point where the switch from SW to LW occurs of the switch where convective dynamics stop controlling? Could be a useful anchor point.
- Will first use a multitool approach using a simple model to build intuition for how sources and sinks set this timescale.
- Using mesoscale updraft velocity from dropsonde aircraft measurements? More sampling of aged anvil cirrus and young anvils. Is there a connection between subsidence rate to lifetime?
- Comparison of these sensitivities in deep convection with interannual variability in both observations and models

\- Large scale tracking of anvils in geostationary sats

Anvil Evolution – Lilli, Emily, Declan, Paula, Adam, Blaž

- Motivation: Understand the controls of anvil optical depth, which depends strongly on how much thin cirrus with $1<OD<2$ there are.
  - Models are only so helpful for this question because they are inconsistent in their amount of thin cirrus.
  - We hypothesize that the large-scale dynamic environment probably effects the amount of thin cirrus.
  - So, we want to look at different regions of the world (TWP, SPCZ, Eastern Pacific ITCZ, Atlantic) to see how anvil evolution and thin cirrus amount vary across these dynamic regimes

- The issue: we want to see thinner cirrus, but geostationary satellites can't see those clouds, and CALIPSO has incomplete time sampling

- Use CALIPSO, MODIS, balloon-borne lidar in the stratosphere, WV reanalysis/remote sensing, and maybe some ML techniques, to figure out where thin clouds are

- Then we'll use this dataset to understand
  - (1) microphysical and (2) large-scale (i.e., circulation regime) sources of optical depth variability
  - How diurnal cycle & anvil life cycle work together to generate the observed distribution of cloudiness and CRE

Group 2 – advantages of high-res modeling

Advantage of high-resolution models

- GSRMs are designed to **resolve convective scales and mesoscale globally** (organized convection is made of different parts connected by a mesoscale circulation). More of the cloud spectrum is resolved from first principles.
- **Big question**: How changes at convective scales, mesoscale and large-scales are reflected in ice clouds. How do sensitivities differ from RCE by moving to realistic boundary conditions?
  - **Changes**: Intensity? (CAPE increase, mesoscale overturning decrease) Organization? Change in vertical structure?
  - **Impacts to revisit**: Radiative properties (optical depth distribution, radiative feedback), Precipitation (convective vs stratiform partitioning, continuity from solid to liquid precipitation), Relative humidity and change thereof with warming (constant RH assumption, clear-sky feedback).
- **Highlight**: What is the bearing of convective dynamics on cloud ice (and other hydrometeors) globally? (High IWP are dependent on strong vertical velocities.) How much the anvil problem is a boundary value problem with boundary conditions in convection vs a local physics problem.
- Frame areas of **disagreement between CMIP6 and GSRMs as the target of future research**. (Example: high cloud feedback)
- GSRMs create **new opportunities for comparison with observations**, which can be performed at similar resolution. (Model validation, interpretation of the satellite record). Can inform new microphysics development.
- **Is km-scale enough**? What is the convergence at sub-km scale model. (km-scale is convection-permitting, not convection-resolving). Do we need to correct for sub-km scale effects?

Day 2 group 2 – high res modelling.

Declan Finney, Adam Sokol, Lilli Freischen, Isabelle Steinke, Rachel Atlas, Aiko Voigt

- Run an LES with a bin microphysics scheme across a sample of world locations and conditions (aerosol and meteorological), and run equivalent pseudo-warming experiments.

- Use the output to train a ML model to predict hydrometeor species (mass and number, liquid and ice). Fine-tune with dardar and existing aircraft data.

- Put the ML-based parameterisation in a global climate model (~5km grid) and run warming scenarios.

- Is present-day high cloud radiative effect more accurately reproduced by our ML-based microphysics model than other NextGems models?

- How do variously defined thin cirrus clouds change with warming?

Group 3 – cirrus cloud formation

Group 3 (Thursday)
Cirrus Cloud Formation

- Most important issue: Full INP characterization
- Activation Spectra
- Number concentrations
- Size Distributions
- Life cycle (scavenging, reservoir, transport, aging)
- Composition
- Morphology

- From field measurements supported by lab characterizations to improvements of models.

Group 3 (Friday)
Cirrus Cloud Formation

- Characterization of INPs

- Dust (INP) life cycle: sources, transport to UTLS
- Characterization (composition, surface)
- Impact of dust on heterogeneous nucleation

- New measurement techniques? Superpressure balloons? UAVs? Online characteristics?

Group 4 - In Situ and Remote Observations

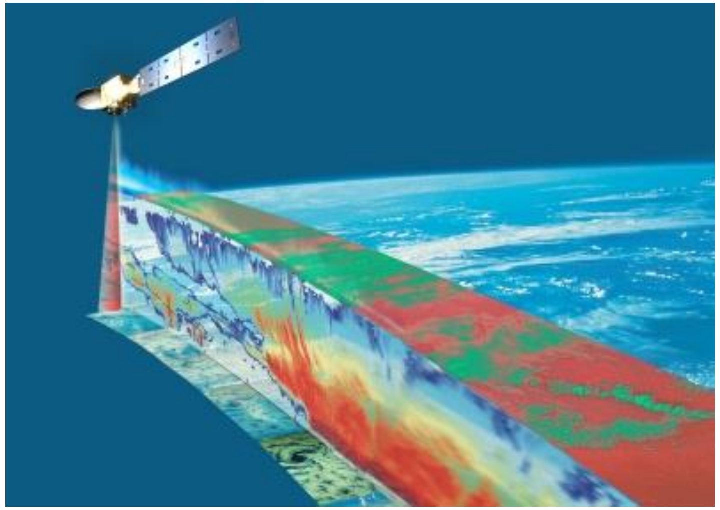
Group 4: *In Situ* and Remote Observations – Day 1

Evaluate remote sensing measurements with *in situ* observations to improve remote sensing algorithms– pass on to modelers for model evaluation and improvement

Problem: In order to evaluate models we need extensive spatial and temporal observations. But we don't necessarily trust the remote observational products.

Solution: Validate remote observational products with *in situ* observations

- Revisit old campaign data sets where we have synergy between *in situ* and remote observations
  - Improved accessibility of data products (review paper on what is available and what are the limitations)
  - More discussions between remote/in situ/modeling communities to improve understanding of observational constraints
- For Earthcare, we should design synergistic *in situ* sampling campaigns to fully quantify uncertainties in remote observations of ice cloud properties



Synergistic combination of in-situ and remote sensing data to improve cirrus cloud process understanding

Why: understand climate feedbacks, validate climate models, assess geoengineering feasibility and risks

1. Extend in situ data base
   a. of cirrus and meteo conditions (vertical velocity, RH, T)
   b. better cloud instruments (current instruments are decades old)
2. Create synergistic remote sensing product by the combination of geostationary, polar orbiting active and passive satellites
3. Evaluation with in situ data and uncertainty quantification

→ Provide observational constraints to modellers

Group 5 – large-scale climate and weather

How do cirrus origins and nucleation mechanisms affect climate sensitivity?

Lab studies

- Huge cloud chamber (Form ice via different formation pathways)
- Processes to properties (Study the processes that lead to the resulting ice properties) (Model cases)

In – situ & remote sensing

- Origin (trajectories or geostationary)
- INP
- IWC, INC, Ice habits, Size distribution, OD
- Macrophysical structures (Vertical and horizontal extent, circulation)

Strategy examples

- North vs South Pole (Polar night and day) (T difference, INP difference)
- Desert, Ice, Ocean
- Pattern effects

Climate models

- Constrain cirrus types and processes from measurements
- Quantify climate feedbacks and sensitivity

Data Synergy – Identify metrics (IWC as function of T) to cross evaluate the ‘process to properties’

The uncertainty in the link from ice cloud process- to climate-scale interactions

Identified main research gaps

- Ice particle formation and growth
- Aerosol-ice cloud interactions (with adjustments)
- Radiative properties

Strategies

- Achieve consistency along scales by e.g. connecting the physics through interconnecting communities

Actions

- Measure observational constraints of research gaps (in situ, RS, lab)
- Evaluate multiscale models with more accurate ice cloud microphysics to assess impacts on radiation budget
- Improve e.g. ice cloud parameterization schemes in global climate models
- Compare to existing climate models