GEWEX Global Atmospheric System Studies (GASS)

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California, USA

Co-Chair: Sandrine Bony (LMD/IPSL) and Shaocheng Xie (LLNL)

Panel members: Ann Fridlind, Daniel Klocke, Louise Nuijens, Felix Pithan, Pier Siebesma, Martin Singh, Philip Stier, Claudia Stubenrauch, Yongkang Xue

https://www.gewex.org/panels/global-atmospheric-system-studies-panel/

WGNE40 Annual Meeting (3-7 November, 2025)

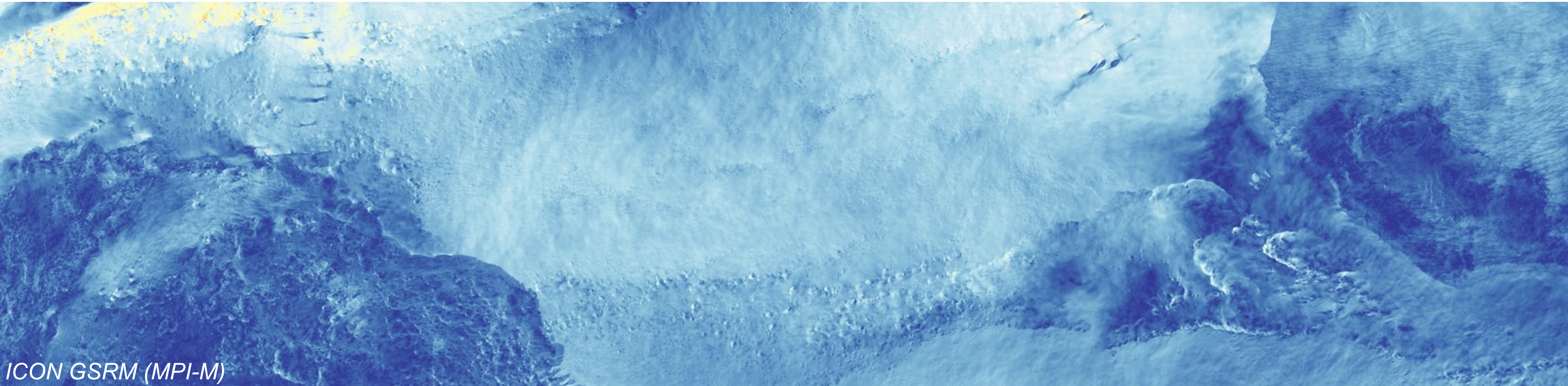
Work from LLNL is performed under the auspices of the US DOE by LLNL under Contract DE-AC52-07NA27344. LLNL-PRES-2202579

GASS objective and activities

GASS Global Atmospheric System Studies

Scientific Objective:
To improve the understanding of physical processes in the atmosphere, and their coupling to the surface and atmospheric dynamics, with the goal of advancing the understanding and prediction of weather and climate.

Activities:
To promote and facilitate the coordination of projects addressing this goal through the development and use of observations, process studies and a hierarchy of numerical models.



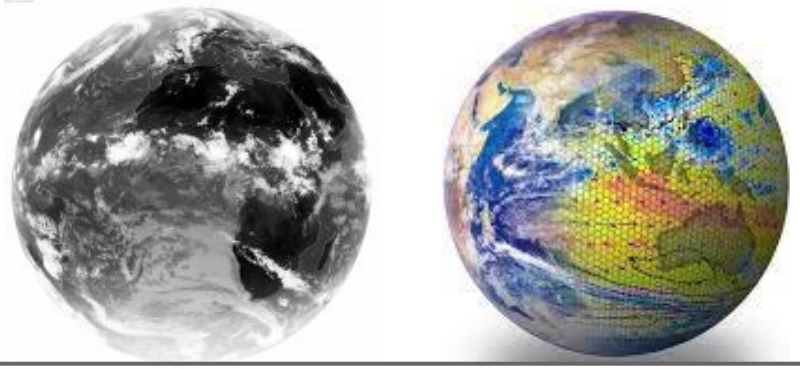
ICON GSRM (MPI-M)

Outline

- GASS overarching questions
- Opportunities
- Ongoing GASS projects and major results
- Cross-WGNE synergies

GASS: Overarching questions

How do micro to meso scale atmos processes control global water and energy exchanges?



→ radiation budget
→ hydrological cycle
→ atmospheric circulations

Opportunities

- Legacy of the WCRP Grand Challenge on *Clouds, Circulation and Climate Sensitivity*
→ role of cloud processes in extreme events, large scale circulation, climate sensitivity ?
→ convective organization/aggregation: physical mechanisms and role in climate ?

- New observations
→ exploit past and future field campaigns, e.g. COMBLES, EUREC^{4}A, MOSAIC, ORCESTRA
→ exploit past and new satellite dataset, e.g. long time series precip/rad/clouds, high-res geo, EarthCARE

- New models
→ LES and CRMs running over increasingly large domains, in idealized or realistic configurations
→ new, emerging generation of climate models

- New technologies
→ apply AI/ML techniques to explore model sensitivity to parameter choices, gaining deeper insights into the underlying physical processes.
→ utilize AI/ML techniques in helping bridge gaps between observations and models to support process studies.

ORCESTRA (Organized Convection ExperimentS in the tropical Atlantic)

ORCESTRA

- Took place in in Aug-Sep 2024 over the tropical Atlantic from Cape Verde to Barbados.
- collected obs over a wide range of scales (microphysical scale, turbulence scale, cloud-scale, meso-scale, large-scale).
- Part of ORCESTRA operations were coordinated with EarthCARE., which was launched in May 2024.
- Data are being analyzed and global km-scale simuations will be made for ORCESTRA as part of DYAMOND.

Objectives:

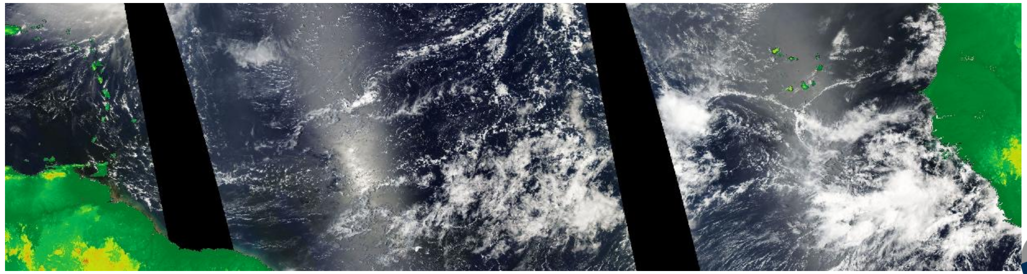
- Test our understanding of the physical processes controlling the mesoscale organisation of convection
- Understand the structure of the ITCZ
- Evaluate EarthCARE products (satellite launched in May 2024)
- Provide the observations needed to assess organisation and its processes in the new generation of climate models

ORCESTRA will feed several GASS projects: DYAMOND, EUREC4A-MIP, Deep convective orga, UTCC-PROES, GAP And potentially GDAP (EarthCARE, SAR, IASI, MTG)

BOWTIE ORCESTRA

MAESTRO ORCESTRA

PERCUSION ORCESTRA

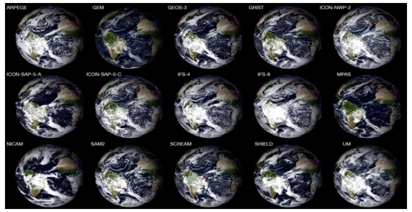


GASS Global Atmospheric System Studies

Ongoing GASS projects

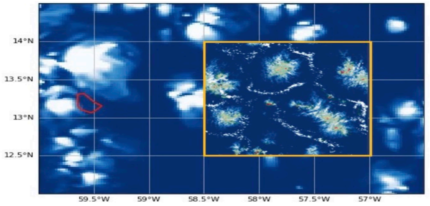
GASS Global Atmospheric System Studies

DYAMOND III

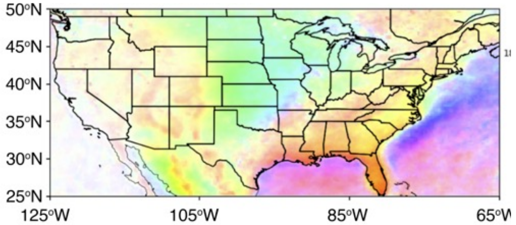


MesoDeep

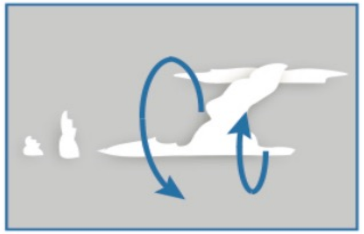
EUREC^{4}A-MIP



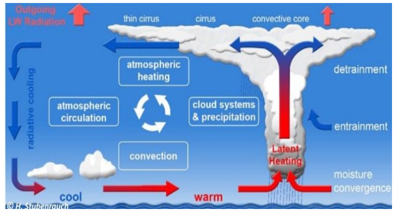
Diurnal Cyc of Precip



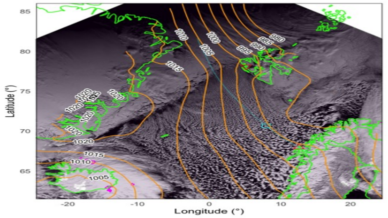
Cumulus Friction



UTCC-PROES

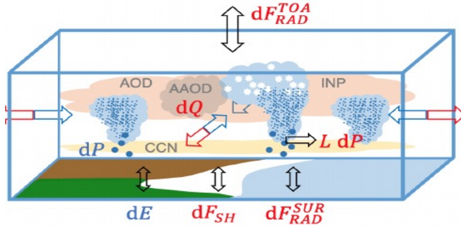


COMBLE-MIP

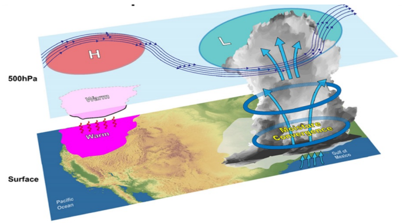


MOSAIC-MIP

GAP



LS4P



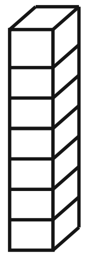
1. **DYAMOND III**: Global Storm-Resolving MIP (Daniel Klocke)
2. **MesoDeep**: Convection Organization (Martin Singh)
3. **EUREC^{4}A-MIP**: Mesoscale Organization of Shallow Cumulus Clouds in Present and Future Climate (Pier Siebesma)
4. **DCP**: Diurnal cycle of precipitation (Shaocheng Xie)
5. **Cumulus Friction**: Shallow Cumulus Friction (Louis Nuijens)
6. **UTCC-PROES**: Upper Troposphere Clouds and Convective Process Evaluation Study (Claudia Stubenrauch)

7. **COMBLE-MIP**: Modeling Convective Clouds during Arctic Cold-Air Outbreaks (Ann Fridlind)
8. **MOSAIC-MIP**: Nudged climate model runs for MOSIC (Felix Pithan)
9. **GAP**: GEWEX Aerosol Precipitation Initiate (Philip Stier)
10. **LS4P:** Impact of land T and snowpack Initial Conditions on S2S (Yongkang Xue)

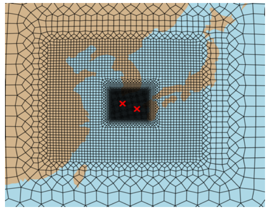
Multi-scale Modeling and Comprehensive Observations

GASS Global Atmospheric System Studies

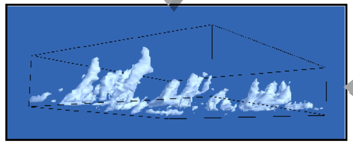
Process Models



Single Column Model (SCM)



Regional Refined Mesh (RRM)



Cloud-resolving Model (CRM) Large-Eddy Simulations (LES)

CAPT Cloud-Associated Parameterizations Testbed

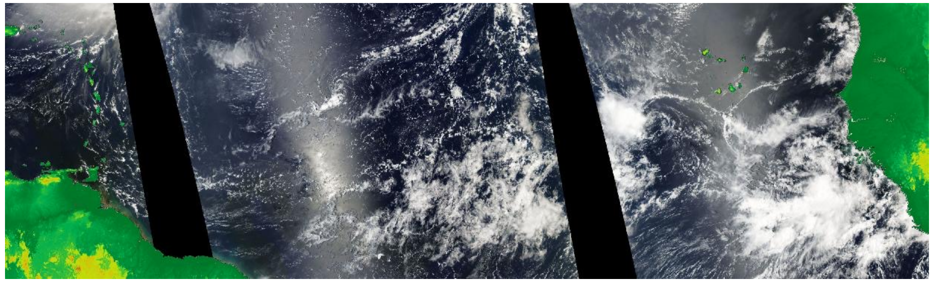
Cloud-Associated Parameterization Testbed (CAPT) - Hindcast Approach

Earth System Models

Globa Storm-Resolving Model

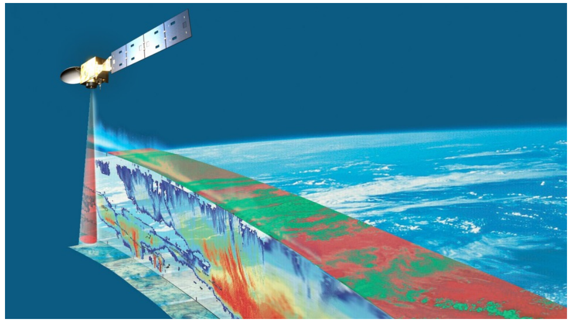
Global Climate Model

ORCESTRA



EUREC^{4}A

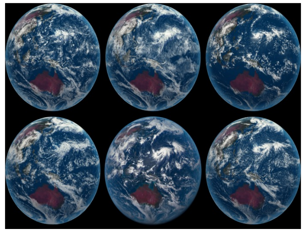
ARM



EarthCARE

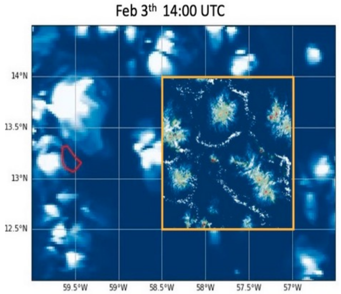
Status

Global Atmospheric System Studies



Daniel Klocke (MPI)

DYAMOND-3: Promote the comparison and analysis of simulations from GSRMs. Participating models having grid spacing of 5km or less; Making best use of ORCESTRA and EarthCARE (Takasuka et al. 2025: A protocol and analysis of year-long DYAMOND-3 simulations). Coordinated global k-scale model hackathon.



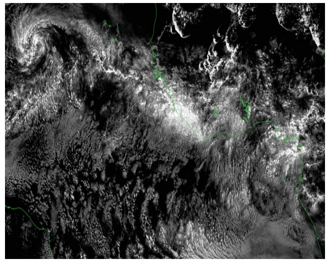
Pier Siebesma (TU Delft)

EUREC^{4}A-MIP: Study mesoscale organization of shallow cumulus convection with:

1)Storm Resolving Model simulations with res of 0.5 – 2.5km over a domain of ~3000x4000 kmr for EUREC4A period of Jan-Feb 2020;

2) LES simulations with res of 50-250m over a domain of 500x300km for Feb 1-11, 2020

Current effort is to analyze initial results from participating models, understanding the underlying dynamical processes that lead to the mesoscale cloud patters of shallow cumulus convection



Martin Singh (Manish U)

MesoConv: Focus on deep conv organization using a hierarchy of models including SRMs; No many collaborative activities, the project is being reorganized.

Status Diurnal Cycle of Precipitation

Shaocheng Xie (LLNL)
Hsi-Yen Ma (LLNL)

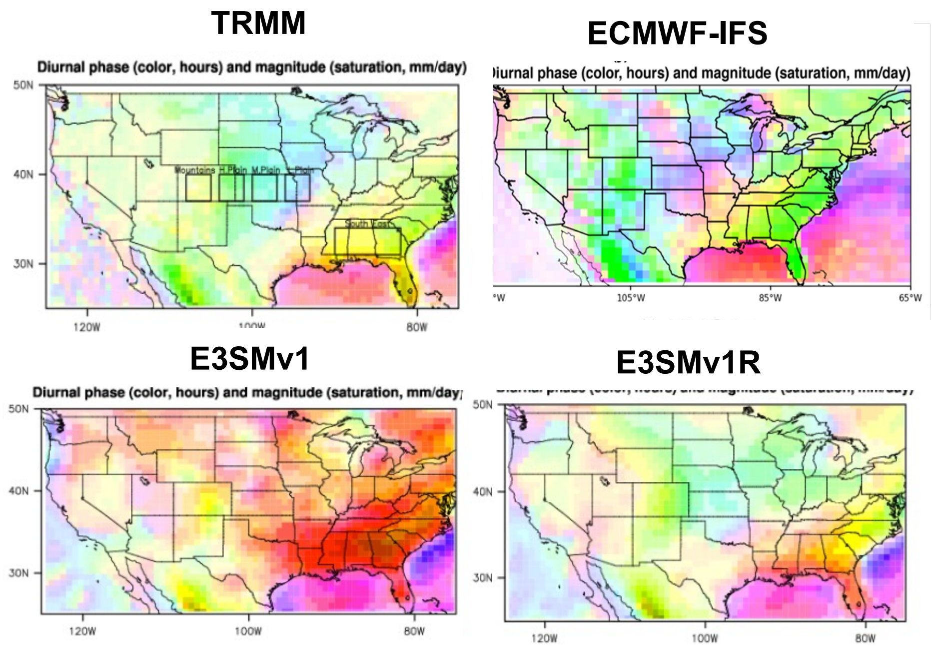
Global Atmospheric System Studies

DCP: Understand what processes control the diurnal cycle of precipitation

Phase 1 focused on diurnal cycle of precip over lands (completed) - Tang et al. 2022 and Tao et al. 2024

Key Results

- **Failure in capturing late afternoon precipitation over land:**
  - Unrealistically strong coupling of convection to surface heating → need large-scale and physical controls
  - Lack of transition from shallow to deep convection → need a unified treatment of turbulent, shallow, and deep convective processes
- **Failure in capturing nocturnal precipitation**
  - Lack of mechanisms to detect instability above a stable PBL at night → need the capability to capture convective instability above BL
- **Convective memory**
  - Acts to suppress light-to-moderate rain and promote intense rainfall; however, it also weakens the diurnal variability → won't help improve diurnal cycle, but improve propagation.



Xie et al. 2019, Tao et al. 2024

Phase 2 will focus on assessment of the diurnal cycle of precipitation simulated by GSRMs

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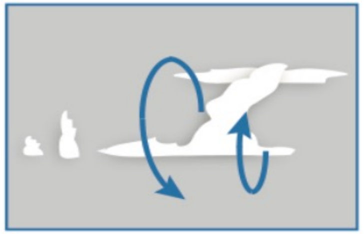


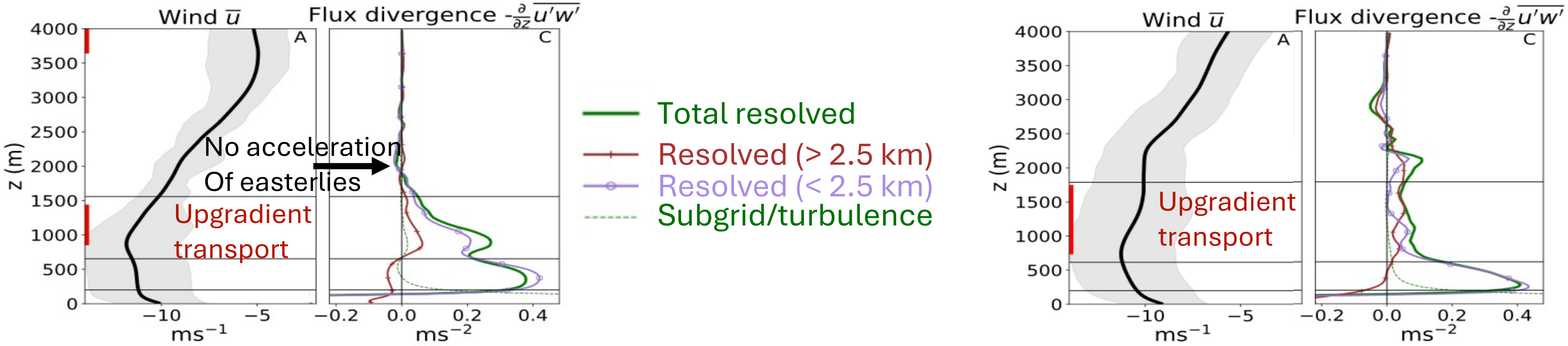
Cumulus Friction: The goal is to understand what shallow CMT does to the larger-scale circulations in global models. Started to examine the EUREC4A-MIP simulations for that. The main results emerging is that shallow CMT is far less efficient in vertical mixing in real nature than in modes, at least throughout the boundary layer.

Louise Nuijens (TU Delft)

Cumulus friction: resolved in large eddy simulation (EUREC4A-MIP)

Unorganized cloud field

Organized / precipitating cloud field



Main finding: <u>shallow convection is much less efficient in vertical momentum mixing</u> (especially in cloud layer) with a minimum in friction near cloud base and no (large) acceleration of easterlies near inversion

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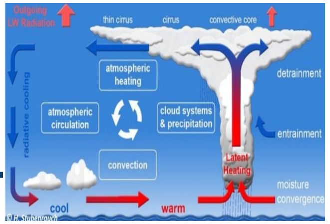
UTCC-PROES

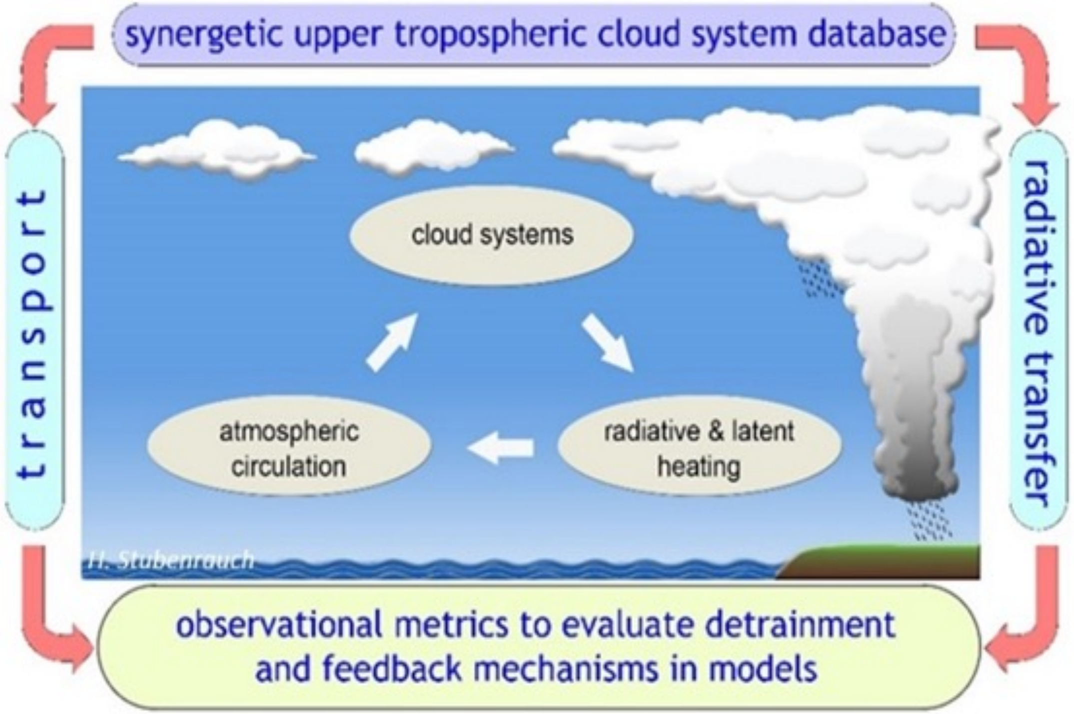


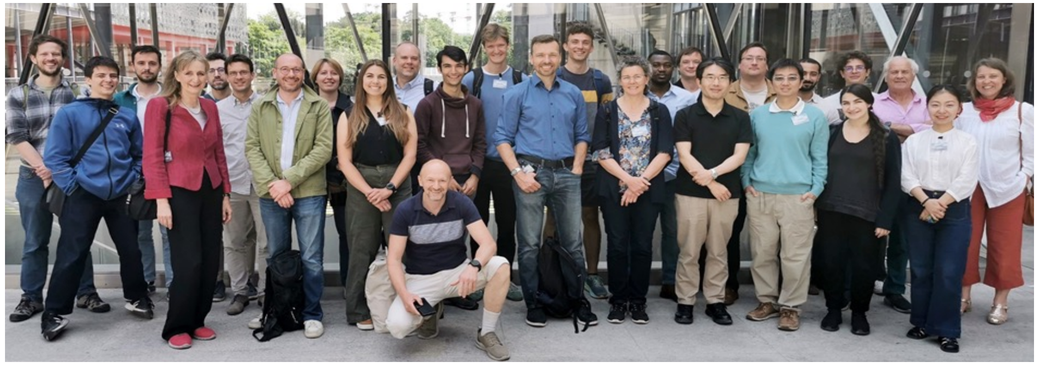
Claudia Stubenrauch
(LMD/IPSL)

UTCC-PROES: Assess convection-cloud-precipitation-diabatic heating datasets and synergy with GASS Mesoscale organization of Deep Convection and DYAMOND projects for process studies and model evaluation:

Results of the year:

- Analysis of relation between latent & radiative heating in MCSs:
- Evaluation of MCS identification in DYAMOND simulations:





UTCC-PROES meeting, in conjunction with GDAP meeting held in May 21-23, 2025, in Paris.

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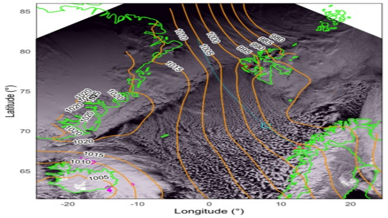
COMBLE-MIP



Ann Fridlind, Florian Tornow (GISS)
Tim Juliano (NCAR)

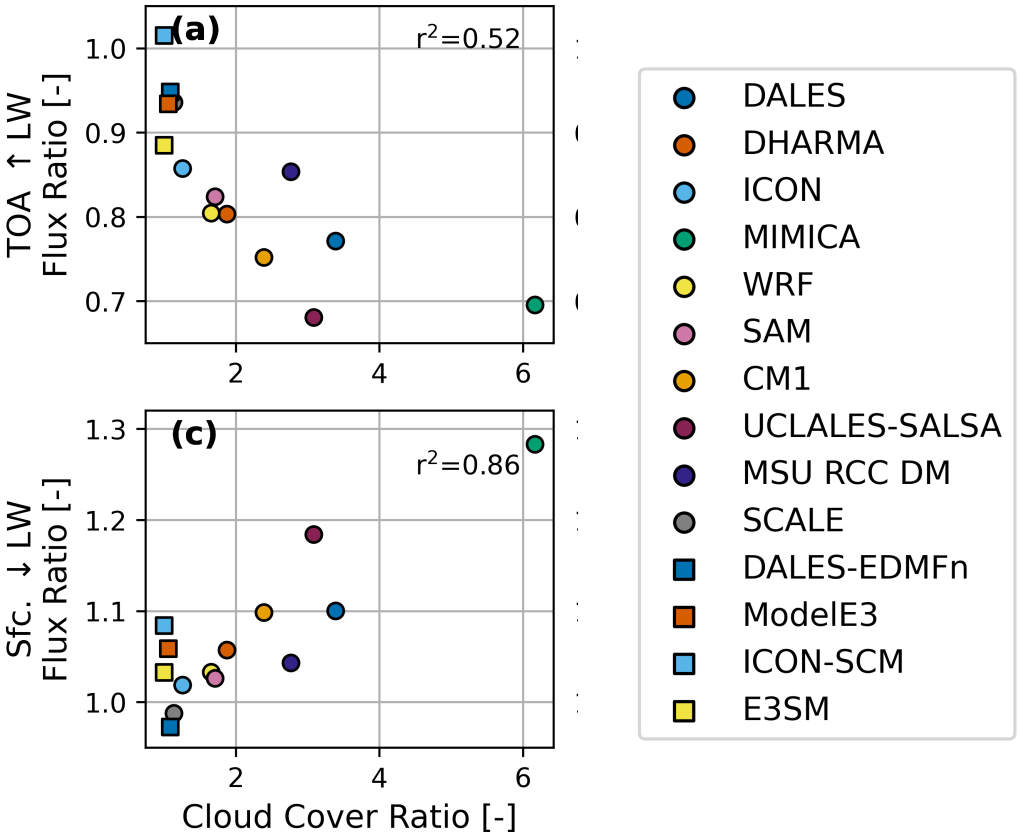
Global Atmospheric System Studies

COMBLE-MIP: Evaluate simulated convective clouds during Arctic cold-air outbreaks. Focus on mesoscale cloud organization, PBL structure and turbulence, and supercooled clouds simulated by LES and SCM models.

Finalizing a manuscript for submission to GMD.

- Ice processes control cloud properties and corresponding LW radiative fluxes (comparing liquid-only and mixed-phase simulations)
- SCM models tend to deviate from LES models (e.g., far less decrease in cloud cover and increase in outgoing top-of-atmosphere longwave fluxes)

SCM models (squares) tend remain overcast and emit less outgoing LW at TOA when including ice processes



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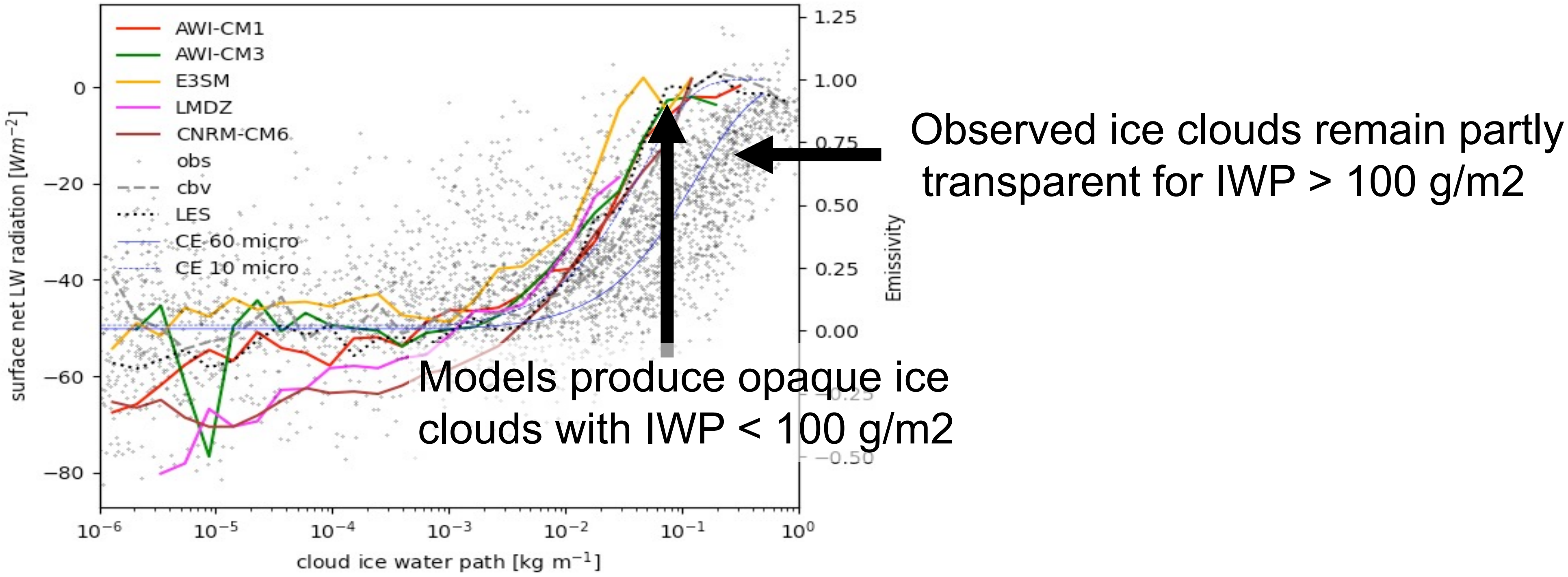
MOSAIC-MIP: Evaluate CMIP6 model with MOSAIC using nudged model runs.

Felix Pithan (AWI)

Climate models overestimate the longwave radiative effect of thin Arctic ice clouds



Ongoing work: sensitivity experiments to understand implications for Arctic climate and cloud feedback

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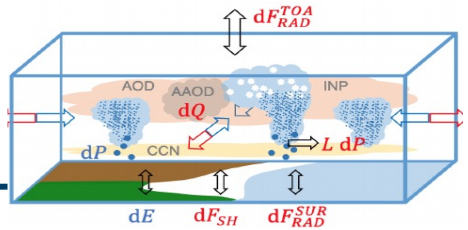
GEWEX Aerosol Precipitation Initiate (GAP)



Philip Stier
(U of Oxford)

GAP: Understand the multiple ways in which aerosols interact with precipitation and their implications for climate at regional and global scales

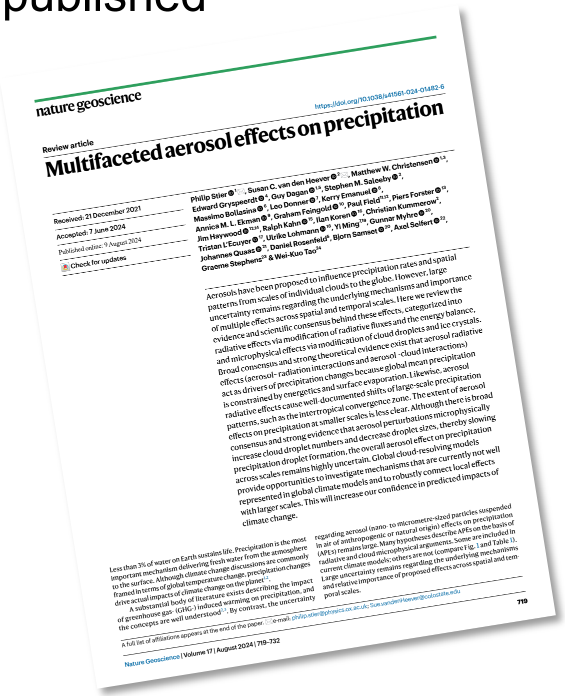
GAP Radiative Convective Equilibrium (RCE) model intercomparison project (RCEMIP) with aerosol perturbation (completed and an overview paper accepted)

- RCE setup is ideal for comparing the response of clouds to aerosol perturbation under wide environmental (SST) conditions, focusing on the equilibrium state
- will examine the sensitivity of the RCE climate, cloud feedback, precipitation efficiency and convective aggregation to the based state of assumed aerosol/cloud droplet concentration

GAP global km-scale model intercomparison of aerosol effects on precipitation (simulation protocol aligned with DYAMOND3) (planning/ ongoing)

- Can be easily and consistently implemented in all participating km-scale atmospheric models

The GAP review paper published


nature geoscience

https://doi.org/10.1038/s41561-024-01482-6

Review article

Multifaceted aerosol effects on precipitation

Received: 21 December 2021

Accepted: 7 June 2024

Published online: 9 August 2024

Check for updates

Philip Stier, Susan C. van den Heever, Matthew W. Christensen, Edward Gryspeerdt, Guy Dagan, Stephen M. Saleeby, Massimo Bollasina, Leo Donner, Kerry Emanuel, Annica M. L. Ekman, Graham Feingold, Paul Field, Piers Forster, Jim Haywood, Ralph Kahn, Ilan Koren, Christian Kummerow, Tristan L'Ecuyer, Ulrike Lohmann, Yi Ming, Gunnar Myhre, Johannes Quaas, Daniel Rosenfeld, Bjorn Samset, Axel Seifert, Graeme Stephens & Wei-Kuo Tao

Aerosols have been proposed to influence precipitation rates and spatial patterns from scales of individual clouds to the globe. However, large uncertainty remains regarding the underlying mechanisms and importance of multiple effects across spatial and temporal scales. Here we review the evidence and scientific consensus behind these effects, categorized into radiative effects via modification of radiative fluxes and the energy balance, and microphysical effects via modification of cloud droplets and ice crystals. Broad consensus and strong theoretical evidence exist that aerosol radiative effects (aerosol–radiation interactions and aerosol–cloud interactions) act as drivers of precipitation changes because global mean precipitation is constrained by energetics and surface evaporation. Likewise, aerosol radiative effects cause well-documented shifts of large-scale precipitation patterns, such as the intertropical convergence zone. The extent of aerosol effects on precipitation at smaller scales is less clear. Although there is broad consensus and strong evidence that aerosol perturbations microphysically increase cloud droplet numbers and decrease droplet sizes, thereby slowing precipitation droplet formation, the overall aerosol effect on precipitation across scales remains highly uncertain. Global cloud-resolving models provide opportunities to investigate mechanisms that are currently not well represented in global climate models and to robustly connect local effects with larger scales. This will increase our confidence in predicted impacts of climate change.

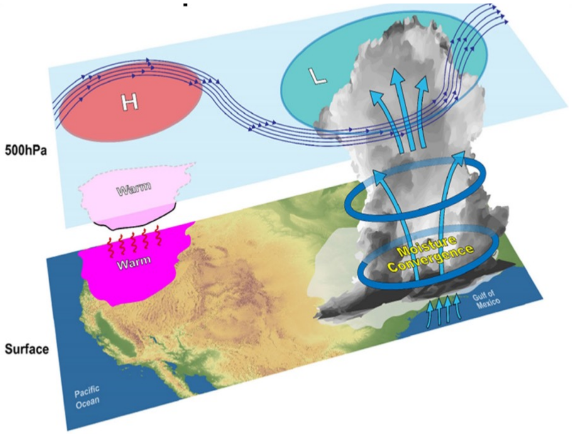
Nature Geoscience | Volume 17 | August 2024 | 719–732

719

Stier et al., Nat. Geosci, (2024)

Status

Yongkang Xue
(UCLA)



LS4P: Impact of land temperature and snowpack initialization on S2S.

Experiments run by 20 ESM models and 10 RCM models, from 40 institutions worldwide

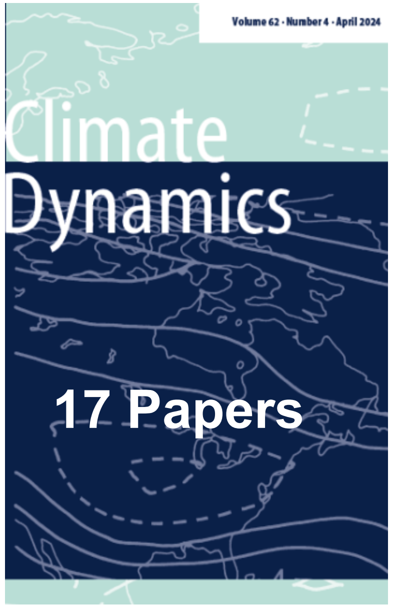
Developed two new methods of soil initialization:

- adjusting soil temperature and moisture while ensuring enthalpy conservation
- nudging of initial LST anomalies and circumglobal wave train

Main Findings

- Remote effect of Tibetan Plateau (TP) spring land T anomaly affecting downstream summer precipitation (Xue et al. 2024)
- NCEP reanalysis shows a Tibetan-Rocky Mountain Circuglobal (TRC) wave train due to TP May T2m anomaly (Xue et al. 2022)
- 8 hotspots are identified in June 2003 precipitation anomalies due to cold TP land source and subsurface T anomaly.
- Nudging improves initialization of TRC wave train and prediction

Climate Dynamics LS4P Special Issue in 2024



GASS-WGNE synergies and complementarities

- **GASS-WGNE collaboration on model development**
  - Long history of collaboration (parameterization development, drag project, grey zone project)
  - Topics of common interest:
    - all GASS projects, especially convective organization (EUREC4A-MIP, Deep orga, COMBLE), air-sea coupling, drag (Friction), global SRMs (DYAMOND)
    - GASS-Digital Earth collaboration on global SRMs
  - Systematic error workshops (every 4 years) of interest for both WGNE and GASS

    - Pan-GASS meeting anticipated in 2026 or 2027 in Germany

Global Atmospheric System Studies

Thank you