Toward Understanding the Characteristics of Mixed-Phase Clouds Simulated in E3SM Atmosphere Model Version 1 (EAMv1)

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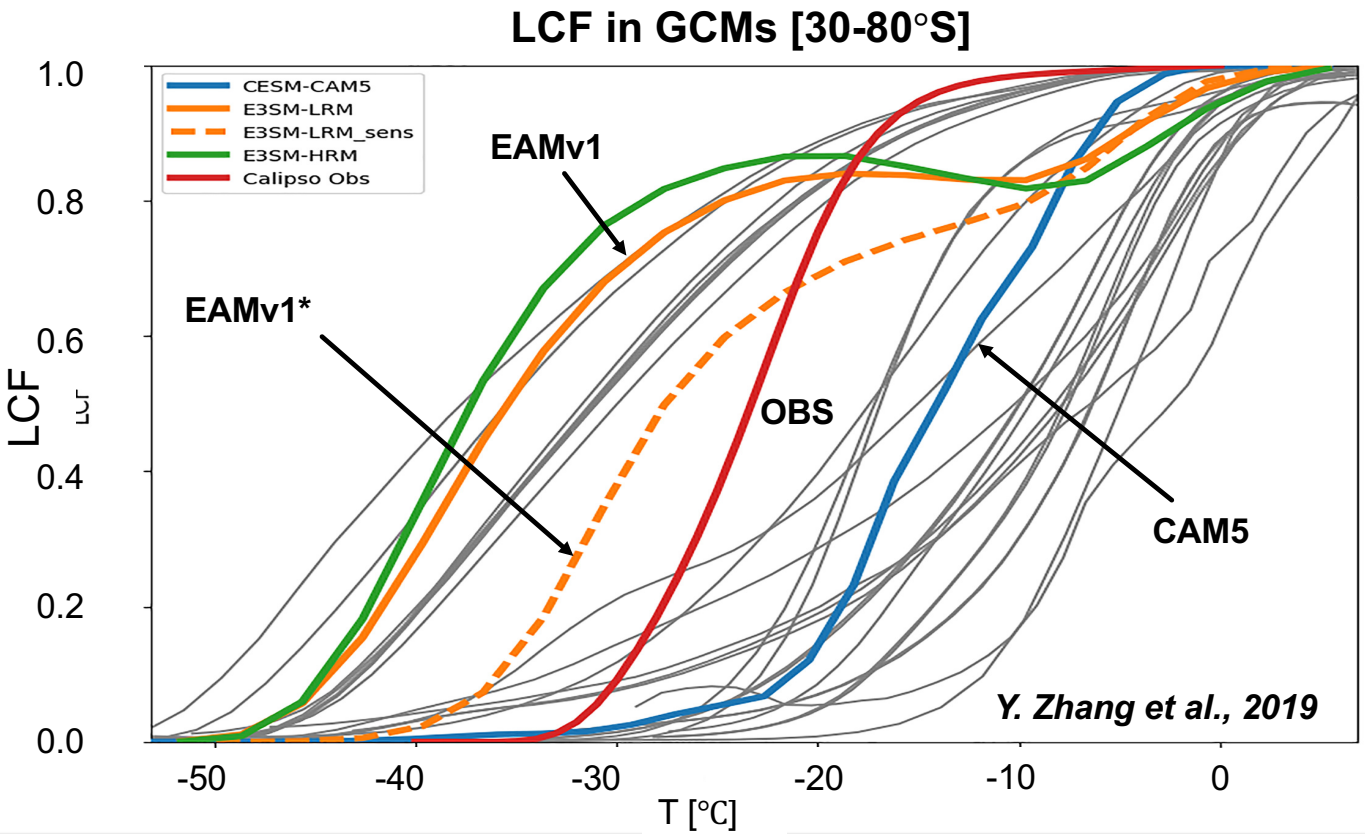
GCM Simulated Liquid Condensate Fraction (LCF) in Mixed-Phase Clouds



- EAMv1 significantly larger LCF than CAM5
  - A tunable parameter that controls the ice deposition growth rate is reduced by a factor of 10 in EAMv1 → significantly slow-down the Bergeron process
  - Relevant parameterizations change in EAMv1 from CAM5:
    - Ice nucleation
    - Cloud microphysics and macrophysics
    - Turbulence
    - Shallow convection
    - …

Changes Made in EAMv1 Relevant to Cloud Parameterizations

- Classical nucleation theory (**CNT**) ice nucleation to replace Meyers et al. (1992)
  - CNT links ice nucleating particles (INPs) to the number concentration of aerosols, → a smaller number of INPs than the Meyers scheme
- **CLUBB** for turbulence, shallow convection, and cloud macrophysics
- **MG2** cloud microphysics
  - Prognostic precipitation

Model sensitivity experiments

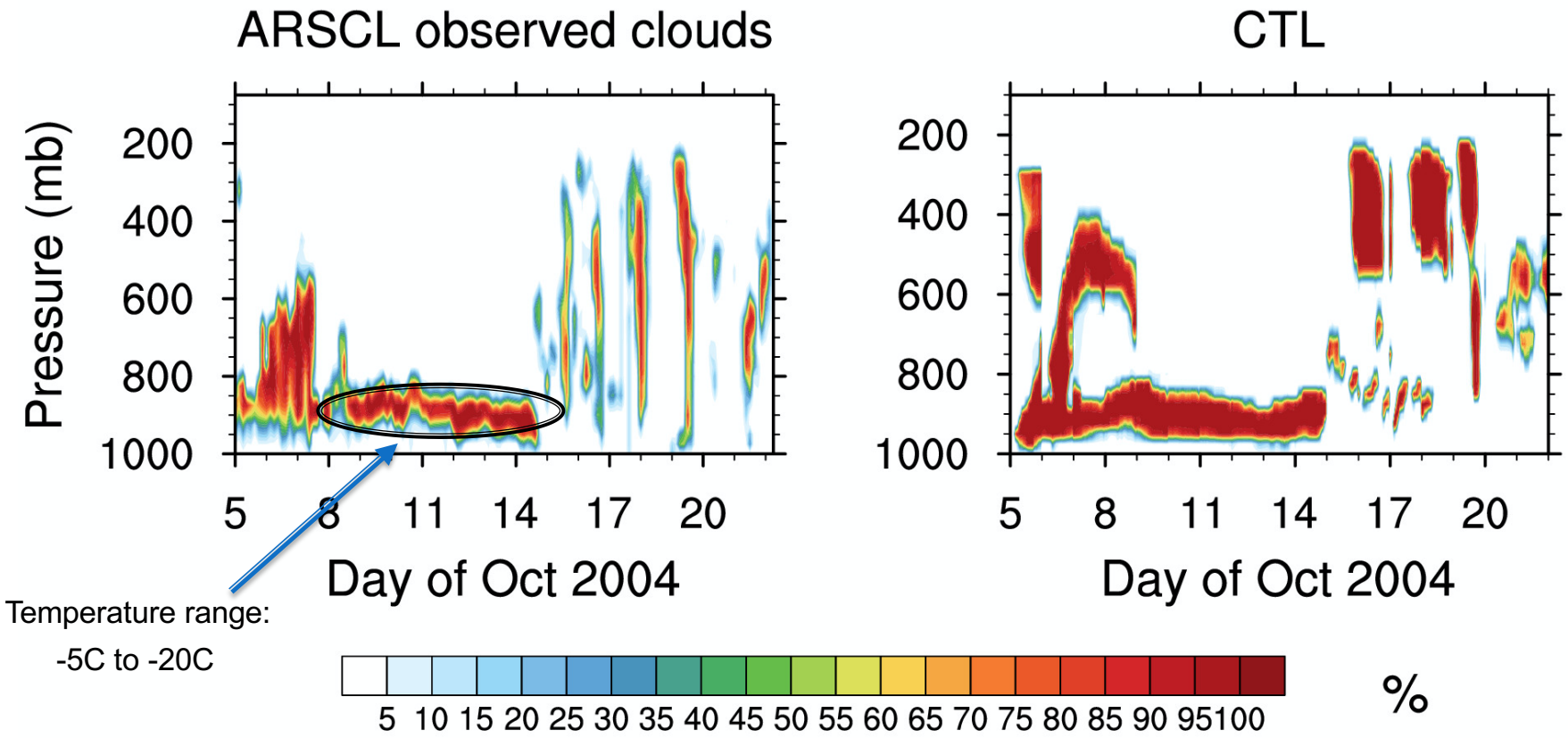
Experiment	Configurations	Note
CTL	E3SM Atmosphere Model version 1 (**EAMv1**) without the artificial reduction of WBF process	Control run
MEYERS	Same as CTL, but replace the **CNT ice nucleation** scheme with the **Meyers scheme**	Examine the effect of heterogeneous ice nucleation
UW	Same as CTL, but replace **CLUBB** by the CAM5 **UW schemes** (shallow convection, turbulence, and cloud macrophysics)	Examine the effect of CLUBB
UW_MG1	Same as UW_MG2, except with the **MG1 microphysics**	Examine the effect of updated cloud microphysics

Modeling approach

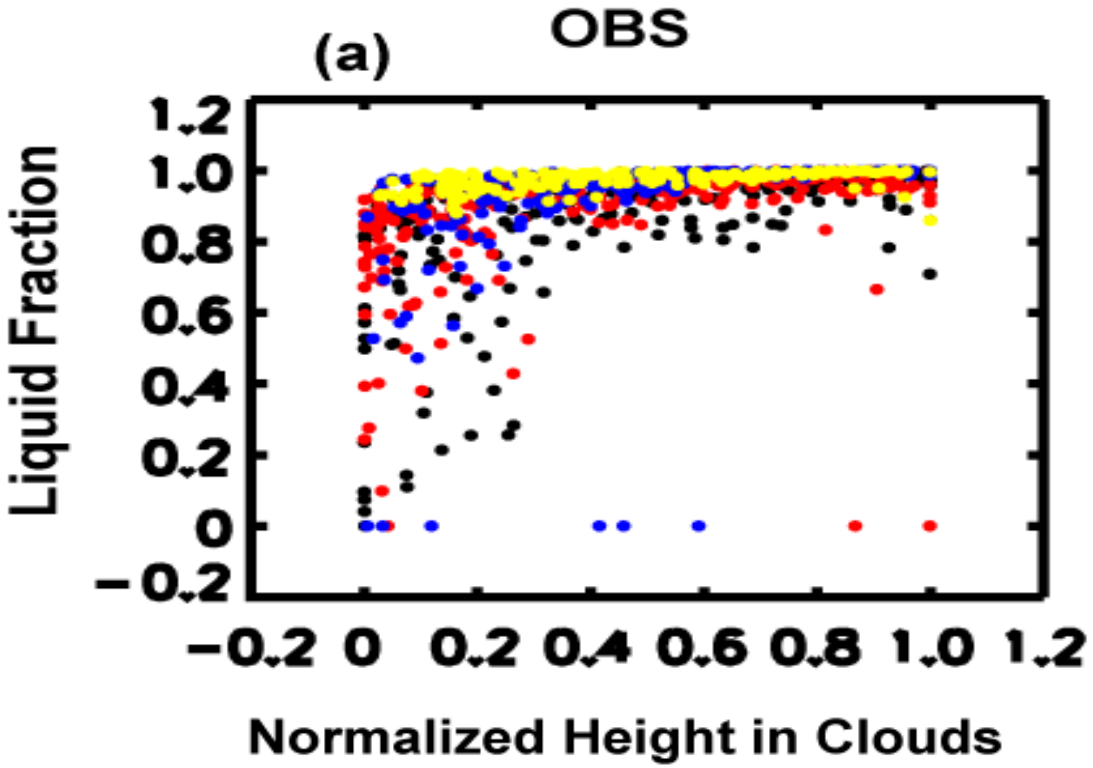
- Cloud-Associated Parameterization Testbed (**CAPT**) Hindcasts
  - Large-scale states remain close to reality in the first few days of hindcasts;
  - Errors in simulated clouds are attributed to model parameterizations.
- Model initialized with ERA-Interim every day for a series of hindcasts from 9/30/2004 to 10/31/2004 to cover the ARM Mixed-Phase Arctic Cloud Experiment (**M-PACE**) field campaign
  - North Slope of Alaska (**NSA**) (71.3 N, 156.5W)
  - 27 September 2004 – 21 October 2004
- Day 2 hindcasts are used in the analysis

M-PACE Experiment Layout

Cloud Fraction

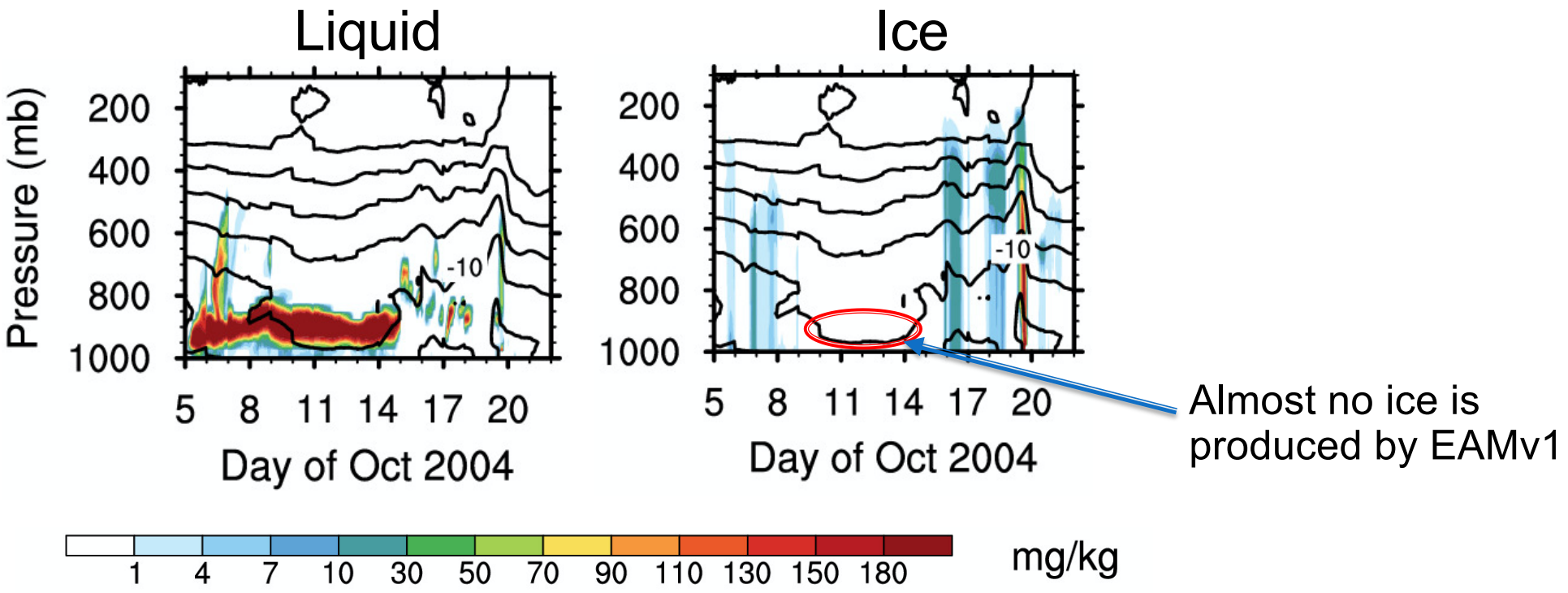


Flights on 9-10 October for the single-layer mixed-phase clouds

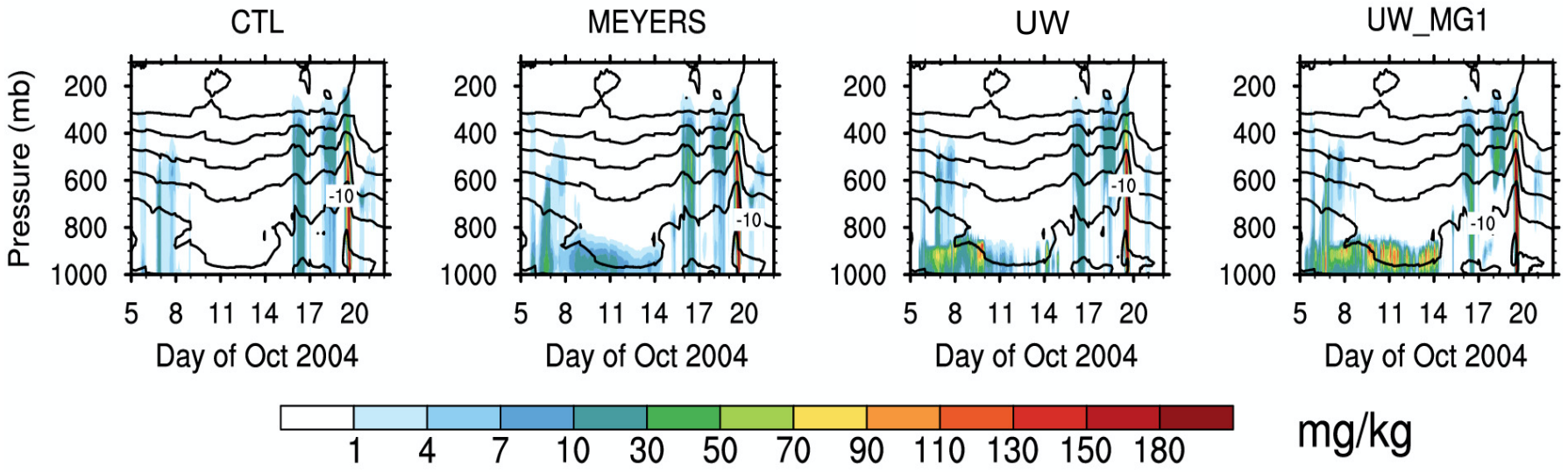


- *liquid dominates the boundary layer clouds, fliq increases with height, ice seen in the lower half of clouds*

CTL modeled cloud water mass mixing ratio



Modeled cloud ice water mass mixing ratio

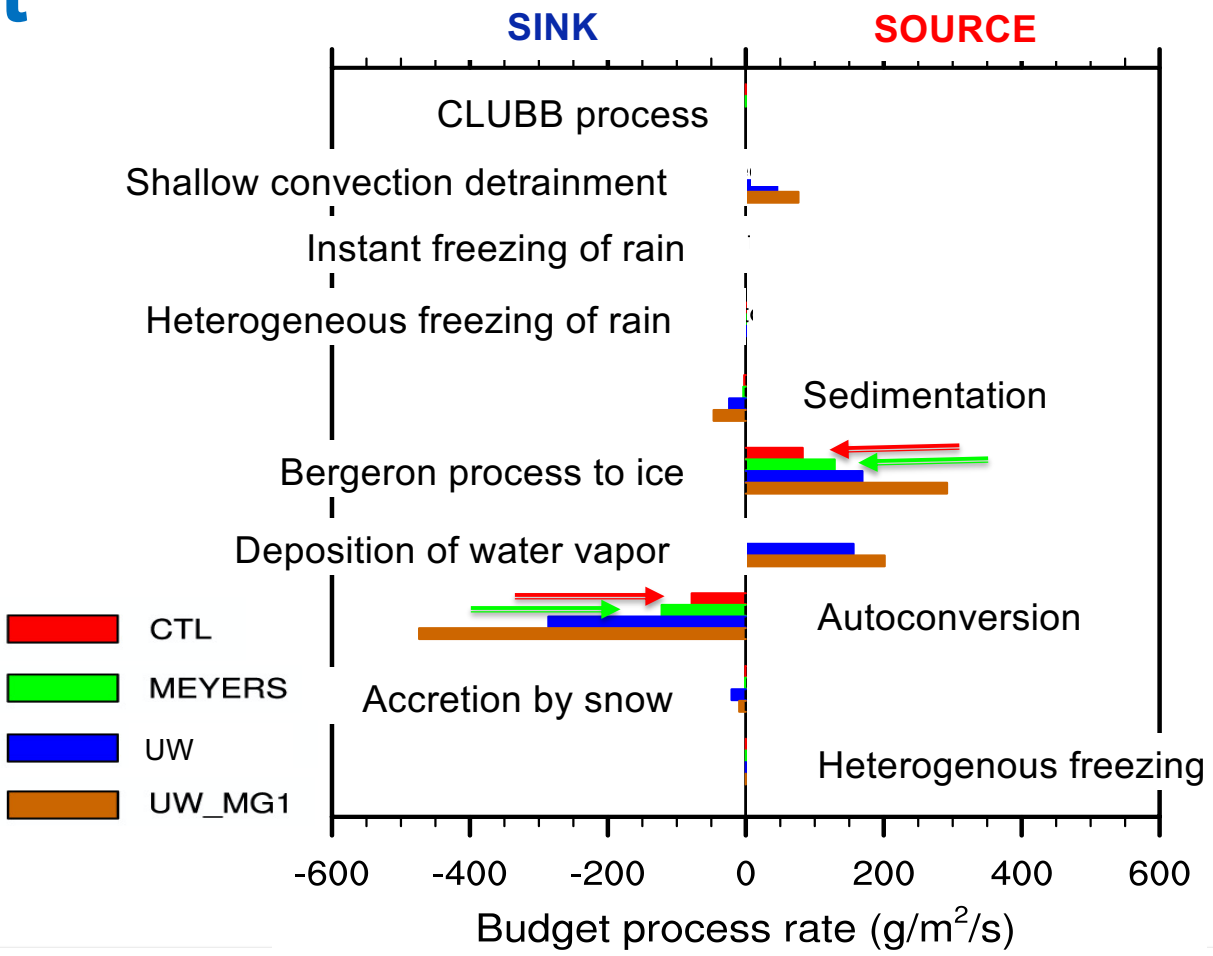


MEYERS → test CNT ice nucleation; UW → test CLUBB; UW_MG1 → test MG2

Ice Budget

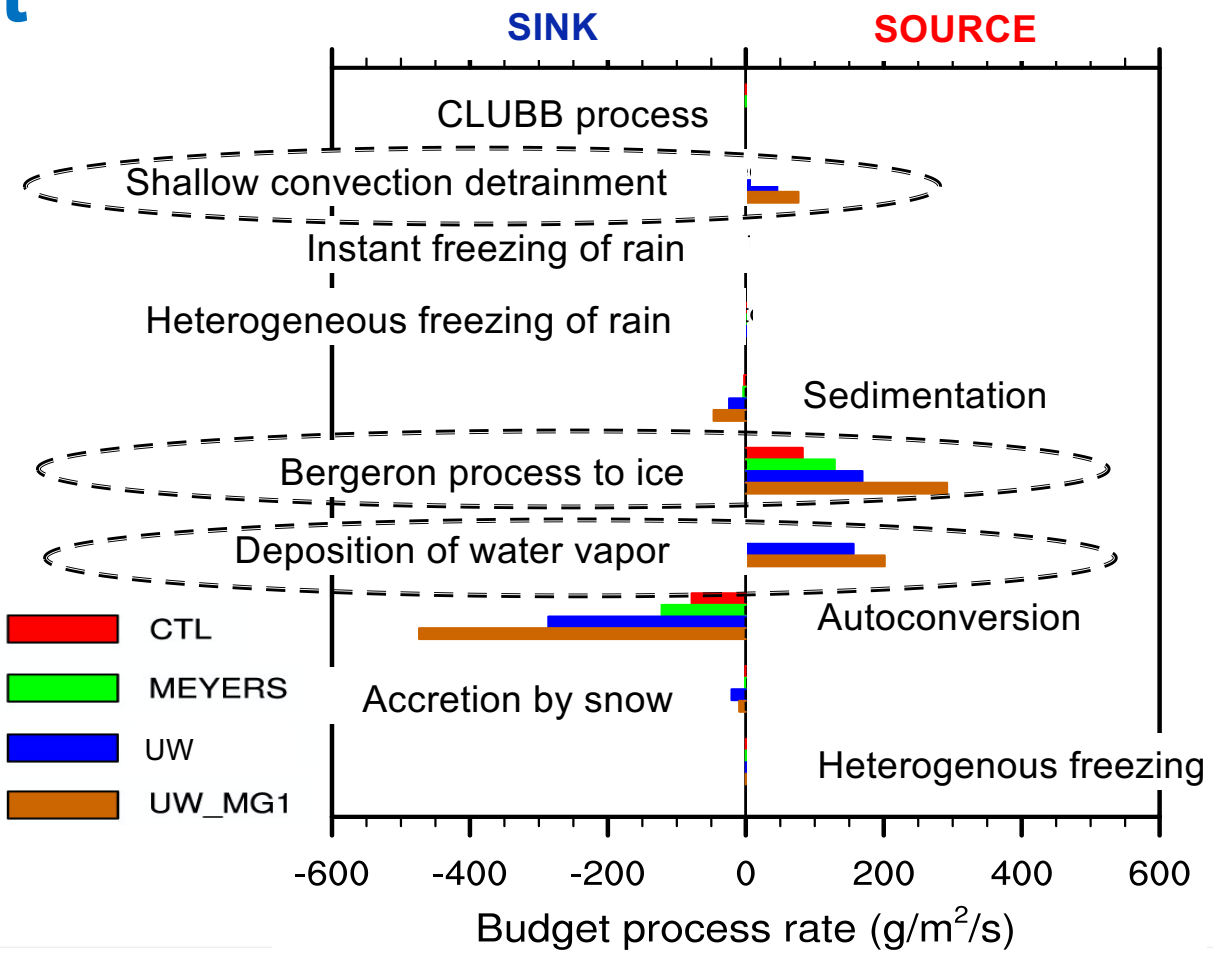
- CTL: the Bergeron process is the only process for ice growth, the formed ice is then converted to snow through auto-conversion

- MEYERS: the Bergeron process is more effective than CTL



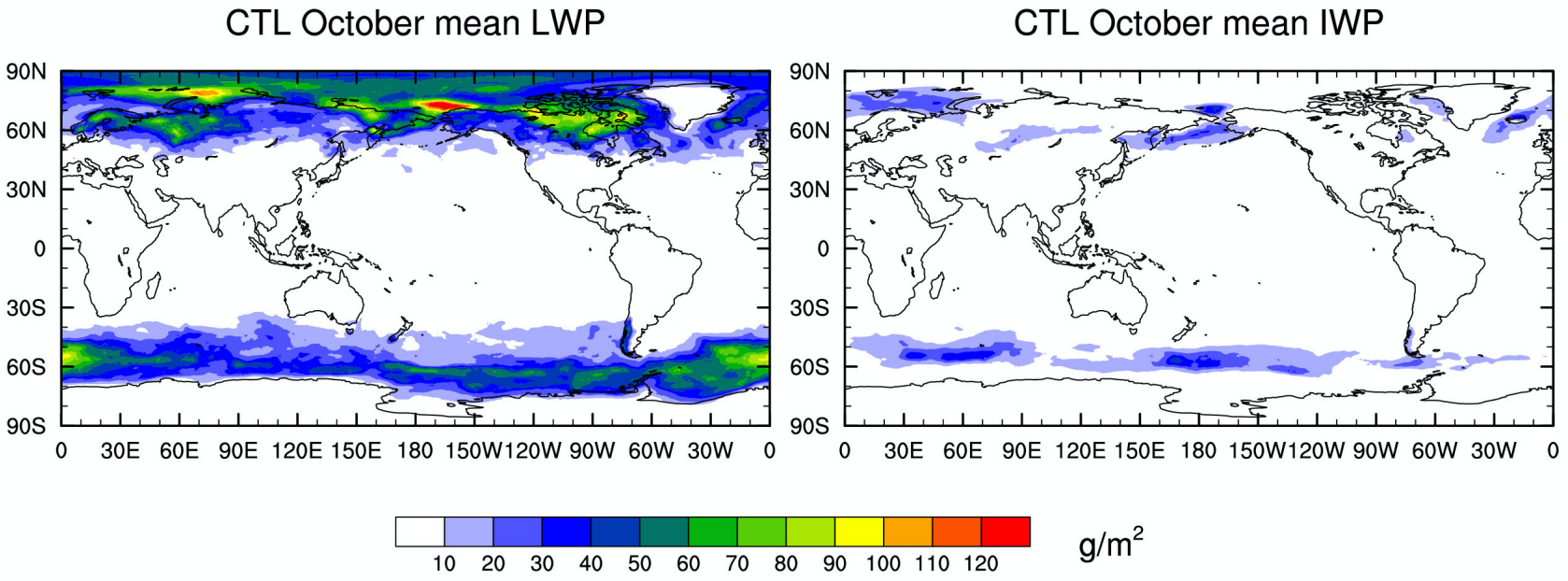
Ice Budget

- UW/UW_MG1: additional resource from detrainment of shallow convection
- UW/UW_MG1: The Bergeron process is more effective
- UW/UW_MG1: Deposition of water vapor provides additional ice growth



Is missing ice only at NSA site?

- Temperature between -40℃ and 0℃
- Cloud liquid and ice coexist
- Cloud top height below 700 hPa



Concluding Remarks

- ✓ Little ice is produced in Arctic single-layer mixed-phase clouds from EAMv1
- ✓ In addition to the artificially reduced ice deposition growth rate, changes in ice nucleation from the Meyers scheme to CNT, updated microphysics, and the use of CLUBB to unified turbulent and shallow convection also play an important role in the dramatically reduced ice phase in mixed-phase clouds
- ✓ Insufficient heterogeneous ice nucleation at warm temperature range in CNT and inactive ice phase process in CLUBB can be the main reasons for underestimated ice
- ✓ Ice phase process in CLUBB and its interaction with cloud microphysics, as well as the heterogeneous ice nucleation require further attention in the future model development

Thank You