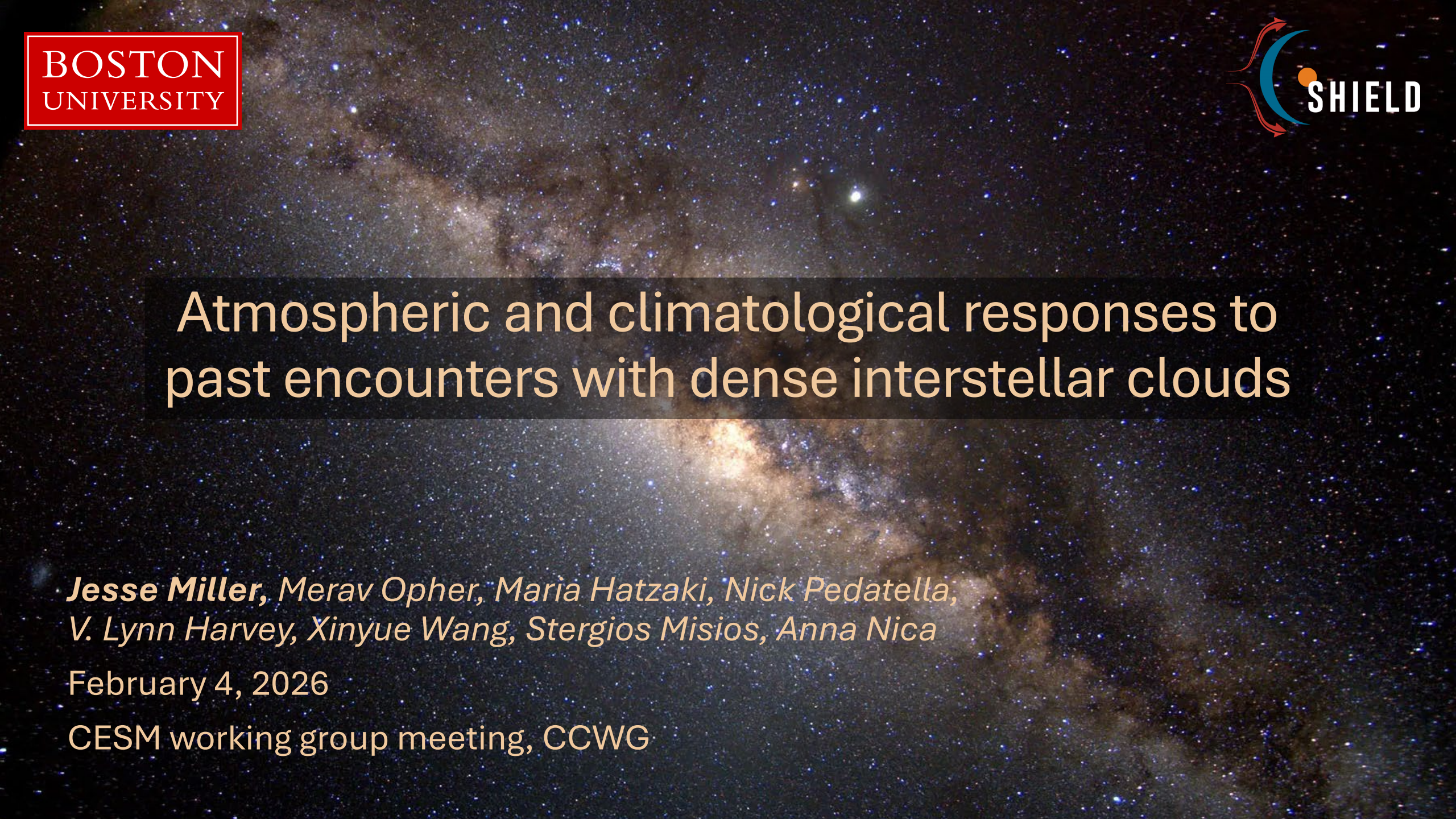

Atmospheric and climatological responses to past encounters with dense interstellar clouds

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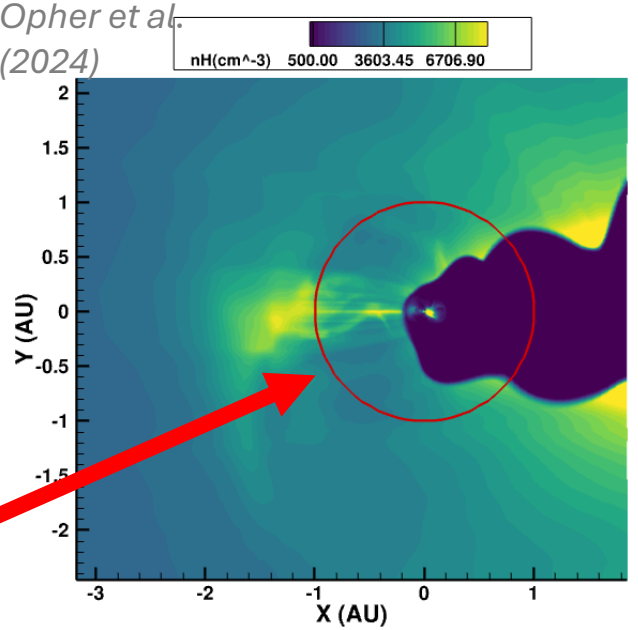
The heliosphere in a cold cloud

- Crossed dense (3000 cm^{-3}) interstellar clouds in the recent past
  - 2 Myr ago *(Local Lynx of Cold Clouds, Opher et al. 2024 Nature Astr)*
  - 7 Myr ago *(Edge of the Local Bubble, Opher et al., 2024 ApJ)*

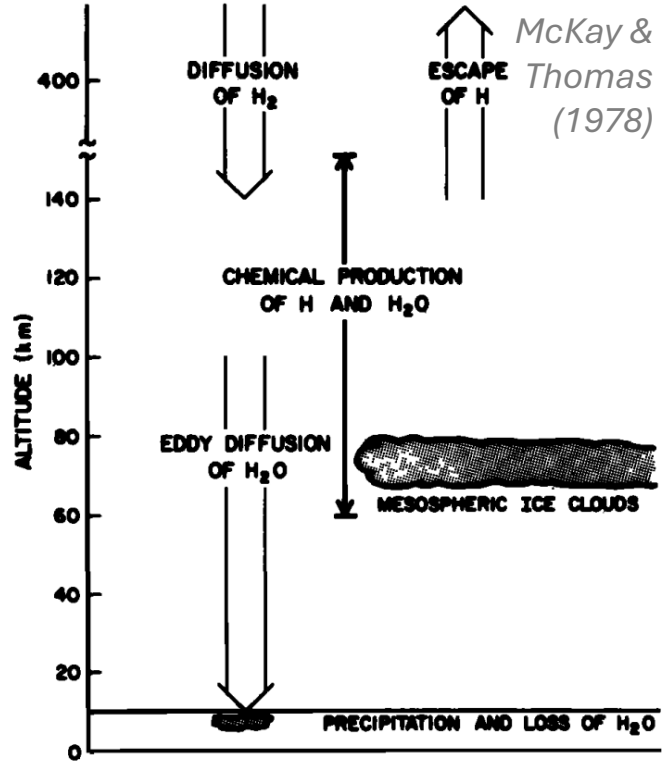
Earth was likely exposed to interstellar clouds 2 & 7 Myr ago!

- H diffuses down through thermosphere
  - Generates high-altitude H_2O and HO_x
  - JAM+ (2024) suggests PMC enhancement is neither global nor permanent
- How can a steady source of high-altitude water alter the climate?

Opher et al. (2024)



McKay & Thomas (1978)



Simulation setup

- CESM v2.1.5 with WACCM
  - Atmosphere only, not coupled to ocean
  - Middle atmosphere chemistry
  - Pre-industrial boundary conditions
  - 2º resolution

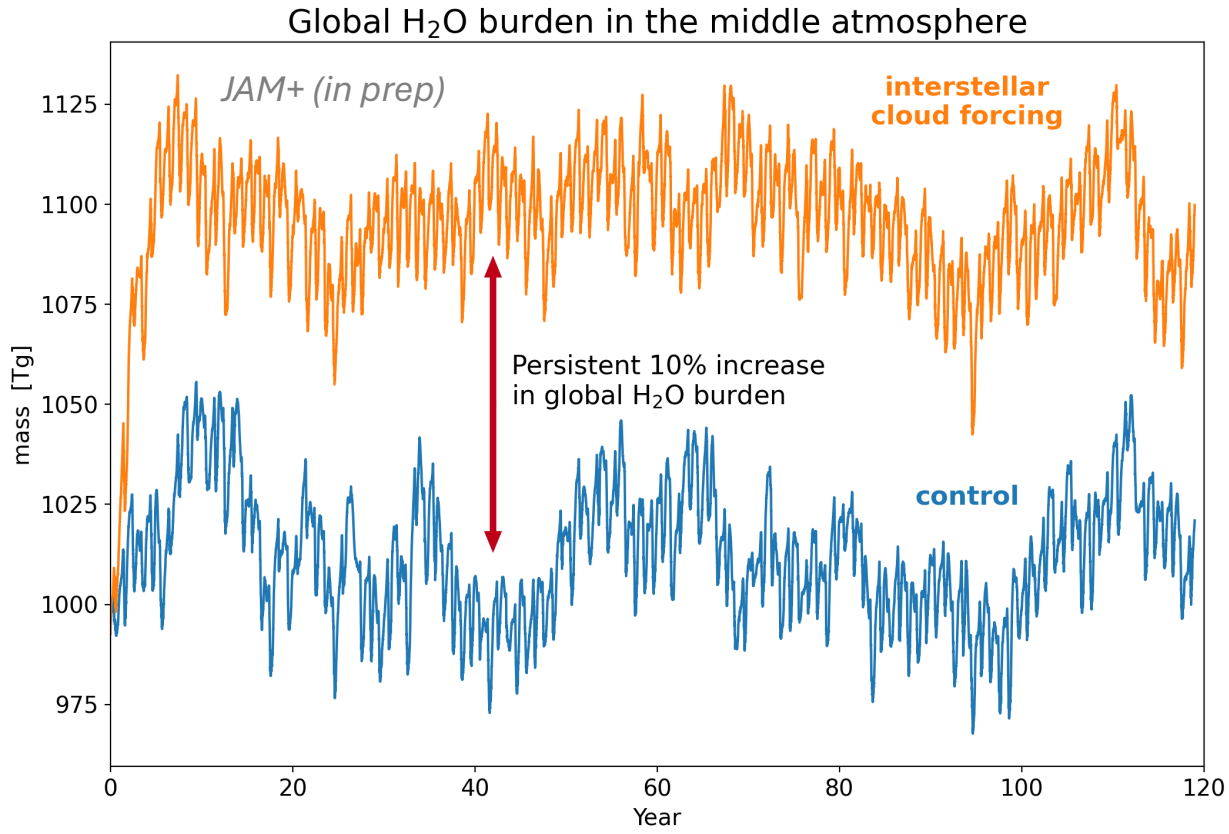
} FWma1850 compset

- Interstellar cloud forcing
  - Added source term for H_2O at 70-80 km, global
  - Constant source based on density and velocity of interstellar cloud
    - 6000 molec cm^{-3} s^{-1} ~ 30 Tg/year

Total water burden in middle atmosphere

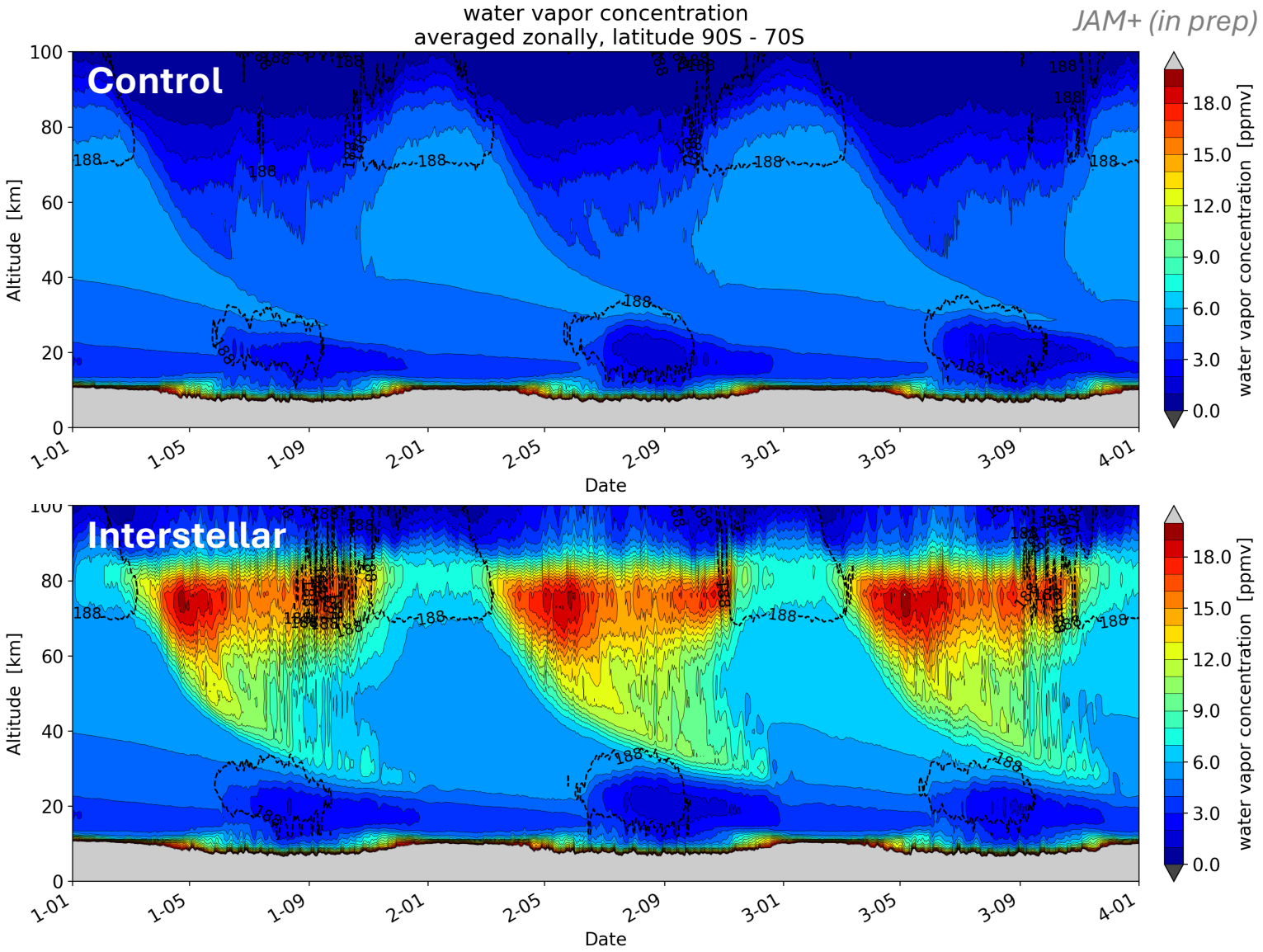
- How much water builds up?
  - Total burden from 50-0.01 hPa (stratosphere + mesosphere)
  - Control and interstellar cases
  - Takes ~5 years to reach equilibrium
  - Maintains an extra ~100 Tg

For comparison:
Hunga-Tonga injected ~150 Tg of water into the stratosphere



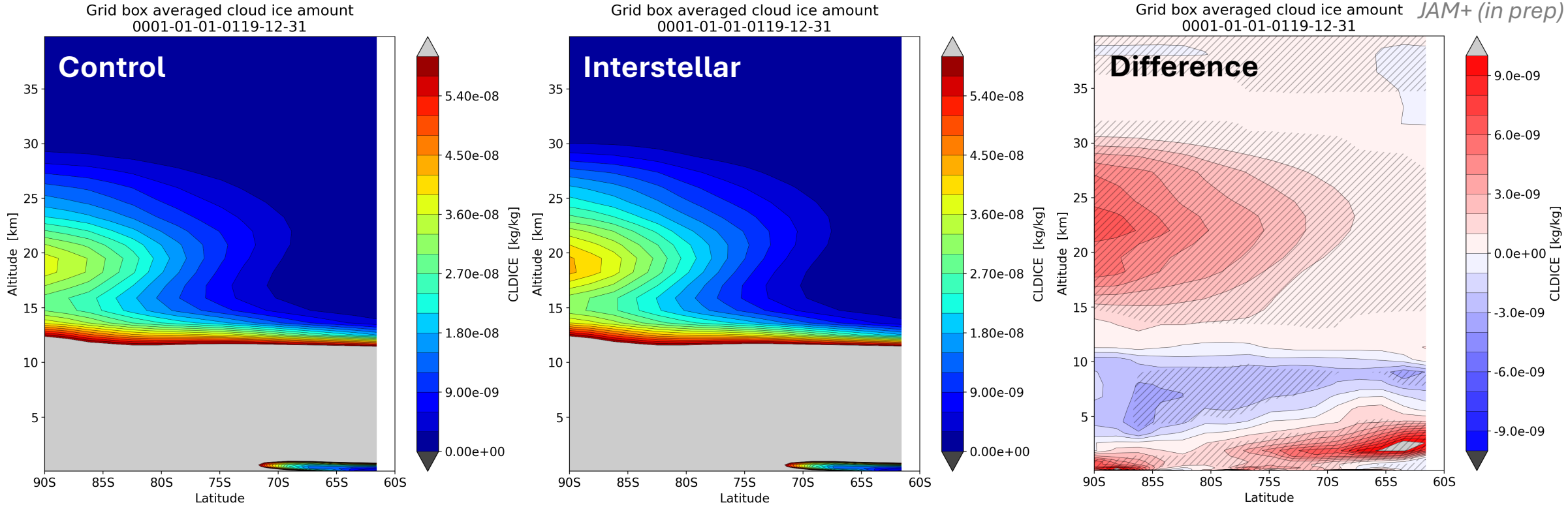
Water descends during polar vortex

- Top: control
- Bottom: interstellar
- Normally, dry air descends in the vortex
- With so much water, now moist air descends
- H_2O is increased even below 30 km



Enhancement of PSCs

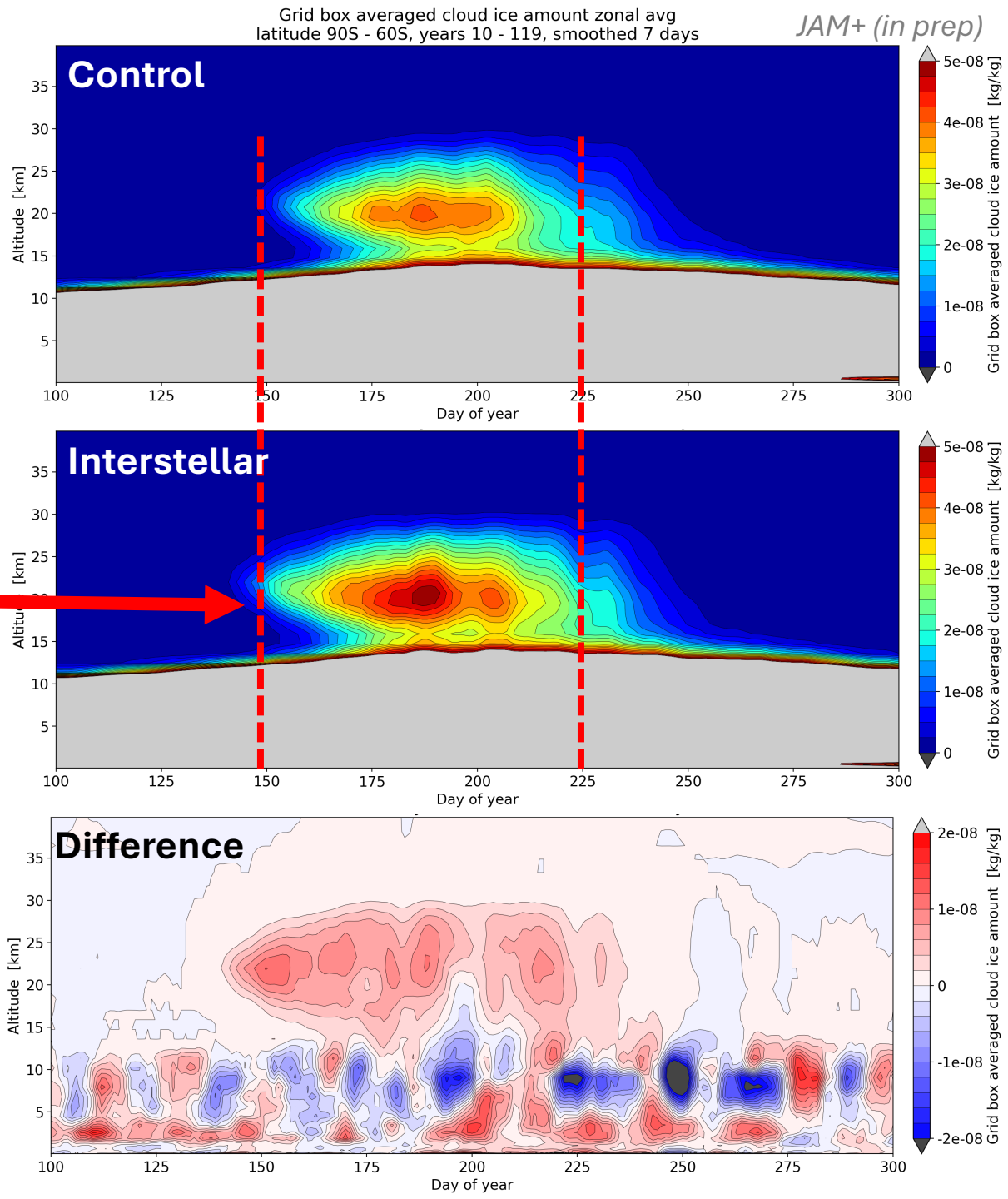
- Polar stratospheric clouds (seen in CLDICE)
- More PSCs seen at higher altitude and lower latitude



Enhancement of PSCs

- Over the course of a year
- Same altitude increase as previous
- Now we see a seasonal extent as well

- Takeaway: PSCs extend to greater altitudes, latitudes, and durations



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Summary

Passage through interstellar clouds (last 10 Myr) CAN alter the atmosphere

- Interstellar clouds generate high-altitude water
  - Brought downwards by the polar vortex
  - Enhances polar stratospheric clouds
  - PSCs are known to have radiative effects on the surface
  - How can a steady source of high-altitude water alter the climate?
- Several other ways interstellar clouds can affect atmosphere
  - E.g., increased cosmic rays (Opher+ 2026, Nica+ in prep)
  - Pliocene/Pleistocene atmosphere instead of pre-industrial