Sensitivity of Thin Tropical Cirrus Clouds to Ice Crystal Shape and Radiative Absorption

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I. OBJECTIVES

Existing cloud-resolving models of thin cirrus in the tropical tropopause layer unrealistically assumed all ice crystals were spherical. We want to know how sensitive these clouds are to ice crystal shape, and to better understand the physics of their life cycle.

II. METHODS

Model: System for Atmospheric Modeling (SAM)

Resolution: Δx = 100 m, Δz = 25 m, Δt = 6 s

Initial ice crystal size: 3.0 μm radius, or equivalent mass for non-spheres

Bin microphysics scheme: *Dinh & Durran* [2012], modified for oblate and prolate spheroids with aspect ratios of 6

Radiation scheme: Plane-parallel radiation solver in SAM; absorption coefficients for spheres, plates and columns parameterized using RRTM radiative transfer model

Table 1: Run Names and Assumptions

Run Name	Fall Speed	Growth Rate	LW Absorption	SW Absorption
Control	Spheres	Spheres	Spheres	Spheres
Oblate Fall Speed	Oblate	Spheres	Spheres	Spheres
Oblate Growth Rate	Spheres	Oblate	Spheres	Spheres
Oblate Microphysics	Oblate	Oblate	Spheres	Spheres
Oblate-Full	Oblate	Oblate	Plates	Spheres
Zero Fall Speed	0	Spheres	Spheres	Spheres
Double LW Absorption	Spheres	Spheres	Spheres x 2.0	Spheres
Half LW Absorption	Spheres	Spheres	Spheres x 0.5	Spheres
Zero SW Absorption	Spheres	Spheres	0	Spheres
Zero Radiative Absorption	Spheres	Spheres	0	0

Results from prolate spheroid runs not included because of similarity to oblate spheroids.

III. RESULTS

Figure 1: Cloud evolution in Control case

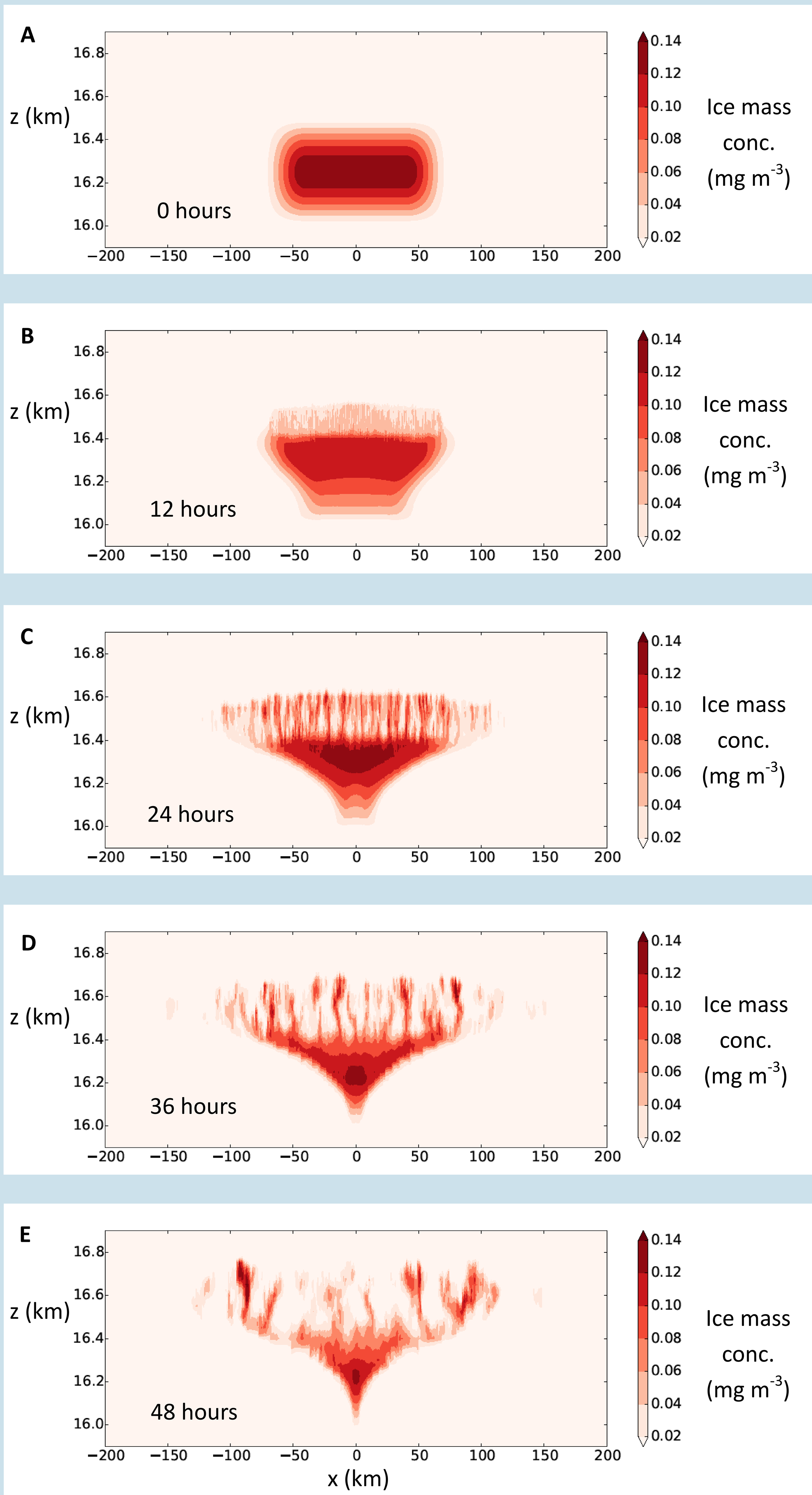


Figure 2: Effects of shape

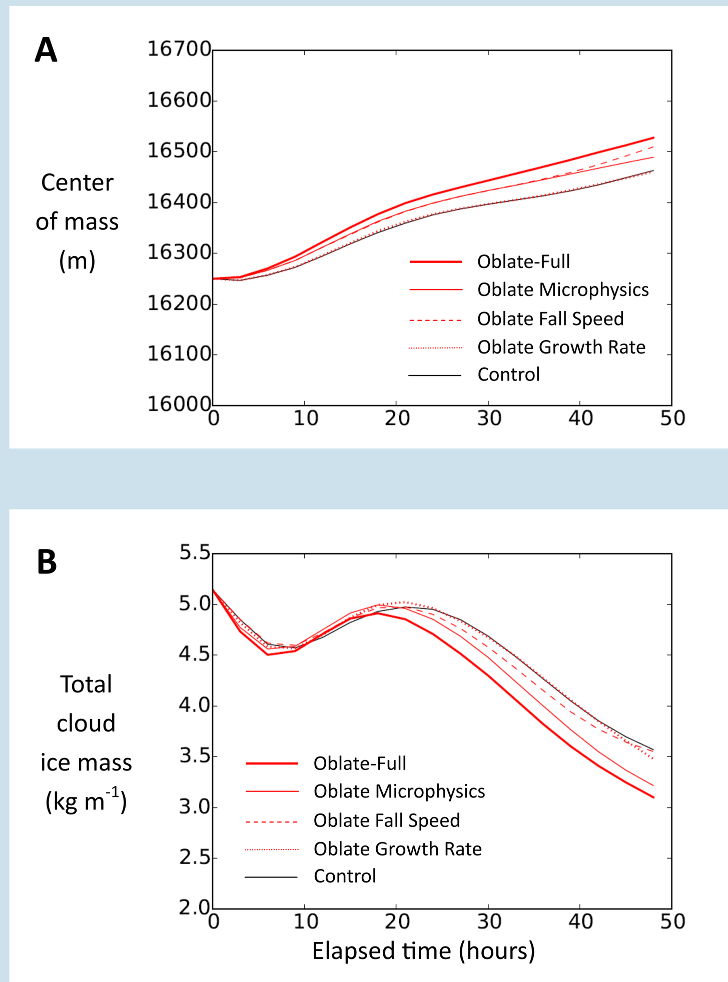


Figure 3: Zero fall speed test

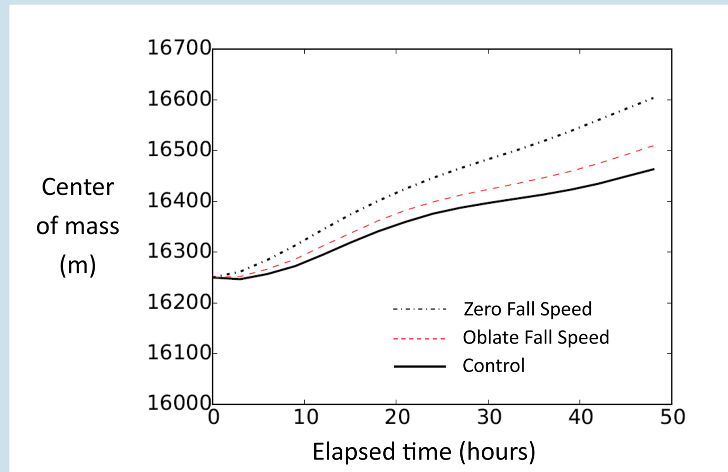
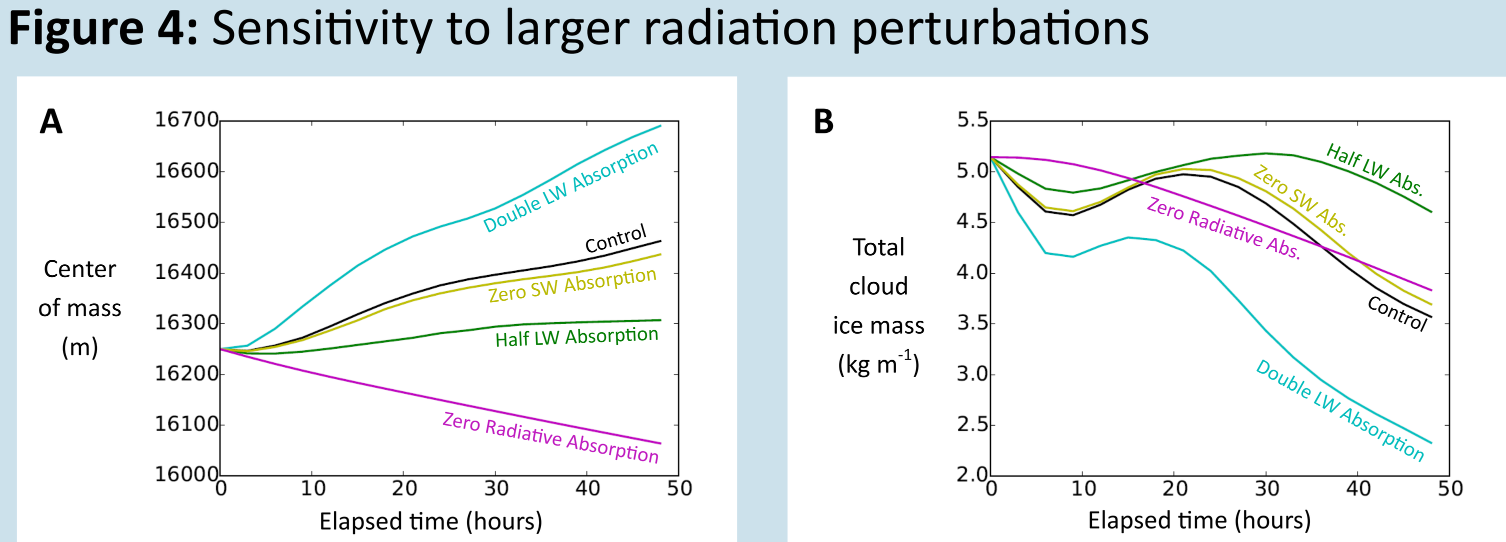


Figure 4: Sensitivity to larger radiation perturbations



IV. DISCUSSION

- Time evolution of the cloud **(Figure 1)** is qualitatively consistent with previous work [*Dinh et al.*, 2010]
- Radiatively induced circulation deforms cloud and maintains it against sedimentation
- Small scale convection develops at the cloud top
- Shape has little effect on center of cloud ice mass **(Figure 2A)** or total ice mass **(Figure 2B)**
- Spheroids have 1/3 lower fall speeds than spheres
- Centers of mass in Control, Oblate Fall Speed and Zero Fall Speed cases are consistent with this **(Figure 3)**
- Stronger radiative absorption versus Control leads to
  - Higher center of mass **(Figure 4A)**
  - A *less* massive cloud **(Figure 4B)**, due to
    - Lower relative humidity in cloud and source air
    - Entrainment of dry air by more vigorous convection

V. CONCLUSIONS

Thin tropical tropopause layer cirrus are sensitive to the amount of LW radiation absorbed, which implies a dependence on underlying clouds, humidity and surface temperature. Sensitivity to ice crystal shape is minimal.

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