Simulated **aerosol radiative forcing** by overlying and entrained **smoke aerosol**: Importance of background conditions and longwave impacts

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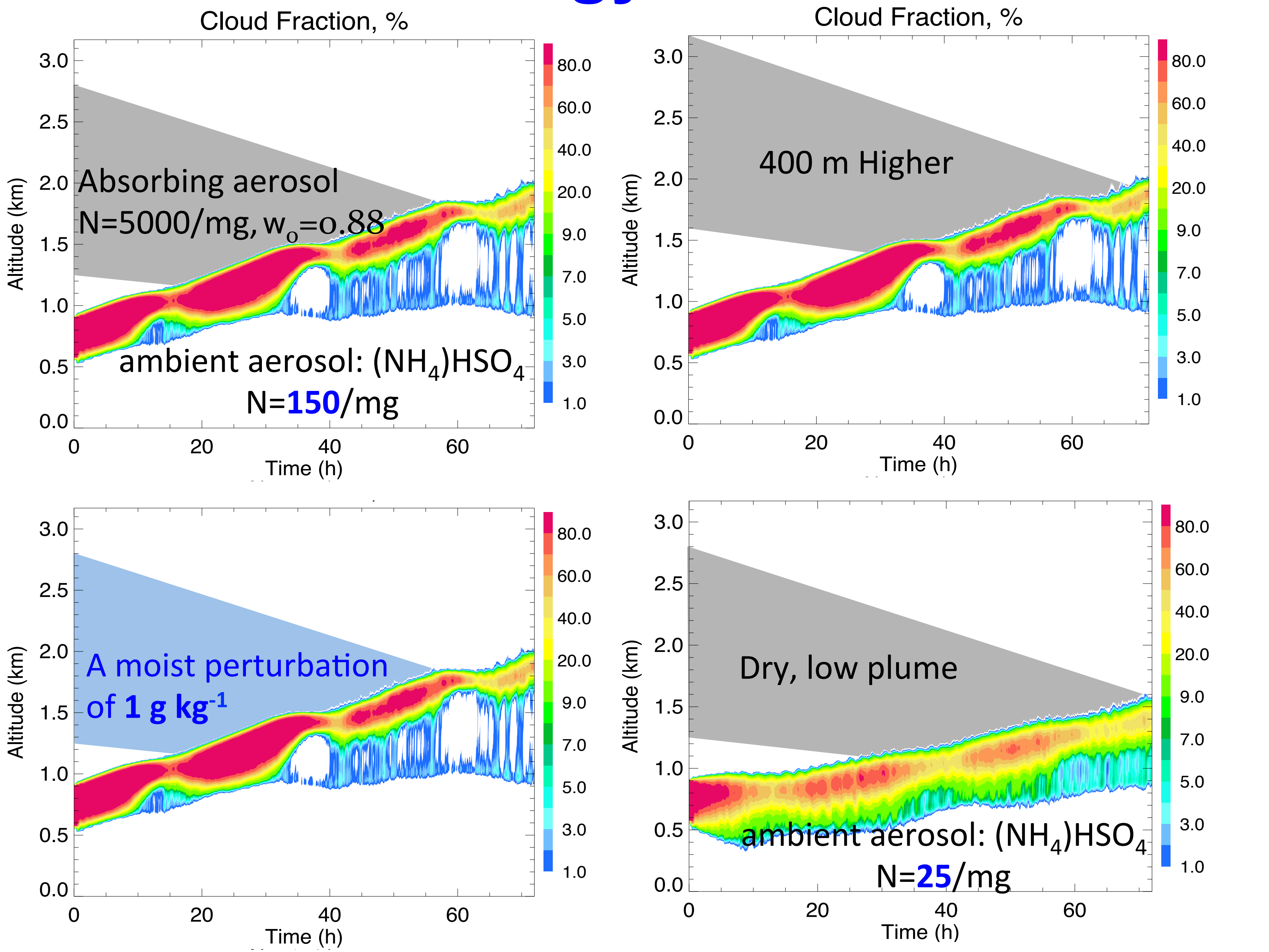
Background

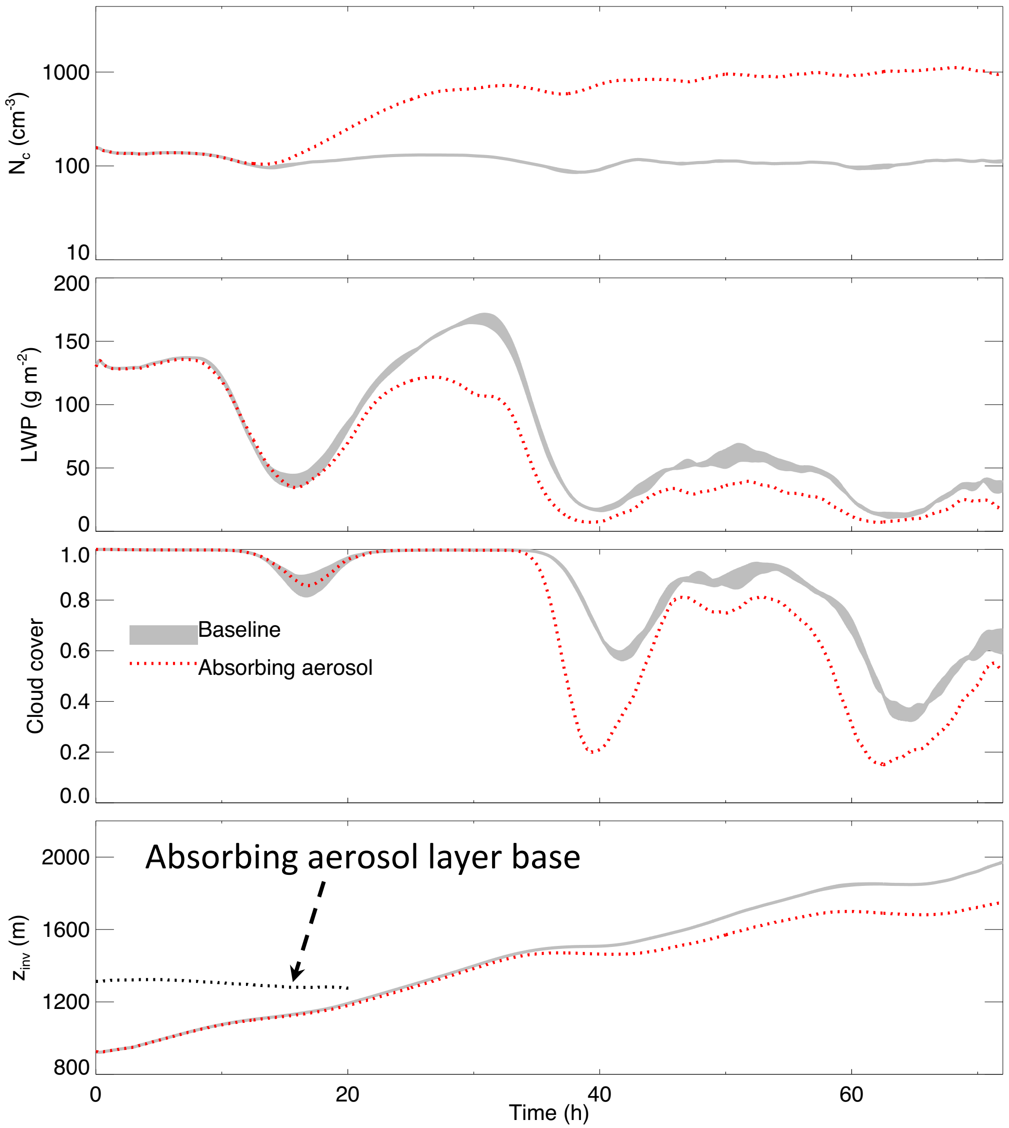
- Semi-direct effect (Hansen et al. 1997): aerosol solar absorption evaporates embedded clouds, **+ive shortwave (SW) radiative forcing at TOA (DF)**
- Johnson et al. (2003): heating *immediately above* Sc strengthens inversion, reduces entrainment drying, thickens clouds, **–ive SW DF**
- Here: consider effect of overlying absorbing aerosol (active as CCN) on transition of Sc → TrCu, **+ive SW RF? –ive SW DF?**
- Unperturbed: advection across warmer SSTs drives progressive entrainment, cloud-top LW cooling cannot maintain well-mixed PBL → buildup of heat and moisture in surface layer drive shallow Cu (Wyant et al. 1997)
- Yamaguchi et al. (2015): absorbing aerosol *delays* transition via slower entrainment, less drizzle, **–ive change in SW cloud radiative forcing, 👎CRF = 👎F – 👎F(clear sky)**
- **What about longwave (LW) 👎F?**

Simulation strategy

- 10.8 x 10.8 x 3.2 km grid
- 2-moment microphysics
- meteorology: base case used in de Roode et al. (2016) LES intercomparison (from NE Pacific trajectories)
- ambient aerosol: k=0.55, r_g=0.05 μm, σ_g=1.2
- absorbing layer: k=0.2, r_g=0.12 μm, σ_g=1.3



Indirect plus semi-direct forcings



- Transition hastened and strengthened (Y15: transition delayed instead)
- Net **negative** radiative forcing D*F* (but positive ΔCRF, opposite of Y15)
    - SW: Twomey overcomes reduction in CF and LWP
    - LW: shallower PBL, reduced CF both increase upwelling LW

	D*F* (W m^{-2})		
	SW	LW	TOTAL
Day 2	-0.5	**-2.6**	**-3.1**
Day 3	**-1.2**	**-6.0**	**-7.2**

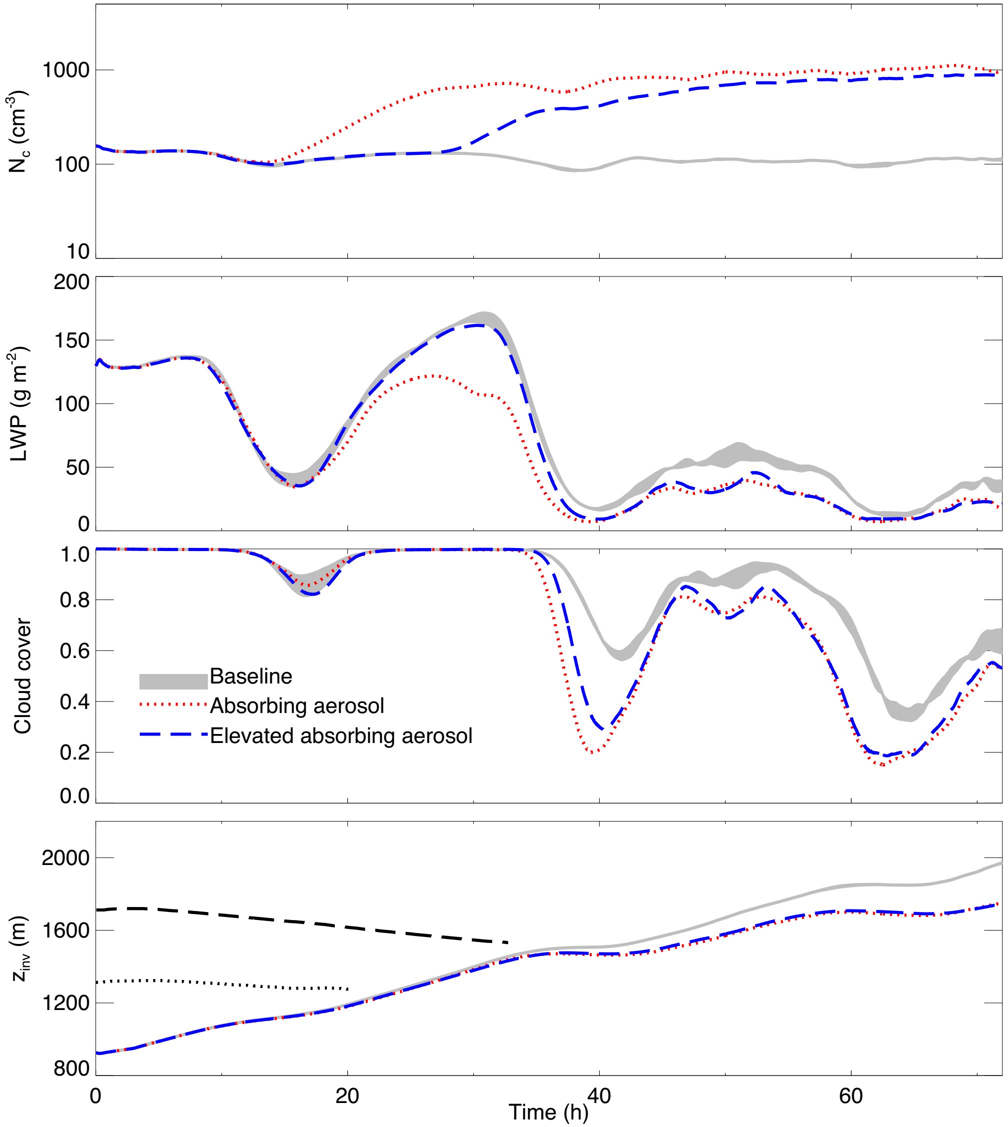
Indirect forcings

		SW	LW
Cloud layer			
Twomey effect	N_c↑	−	
Sedimentation↓	LWP↓	+	
	CF↓	+	−

Semi-direct forcings

		SW	LW
FT heating			
Inversion strength ↑	CF↑	−	+
	Z_i↓		−
PBL heating			
RH ↓ stabilization ↑	CF↓	+	−
	Z_i↓		−

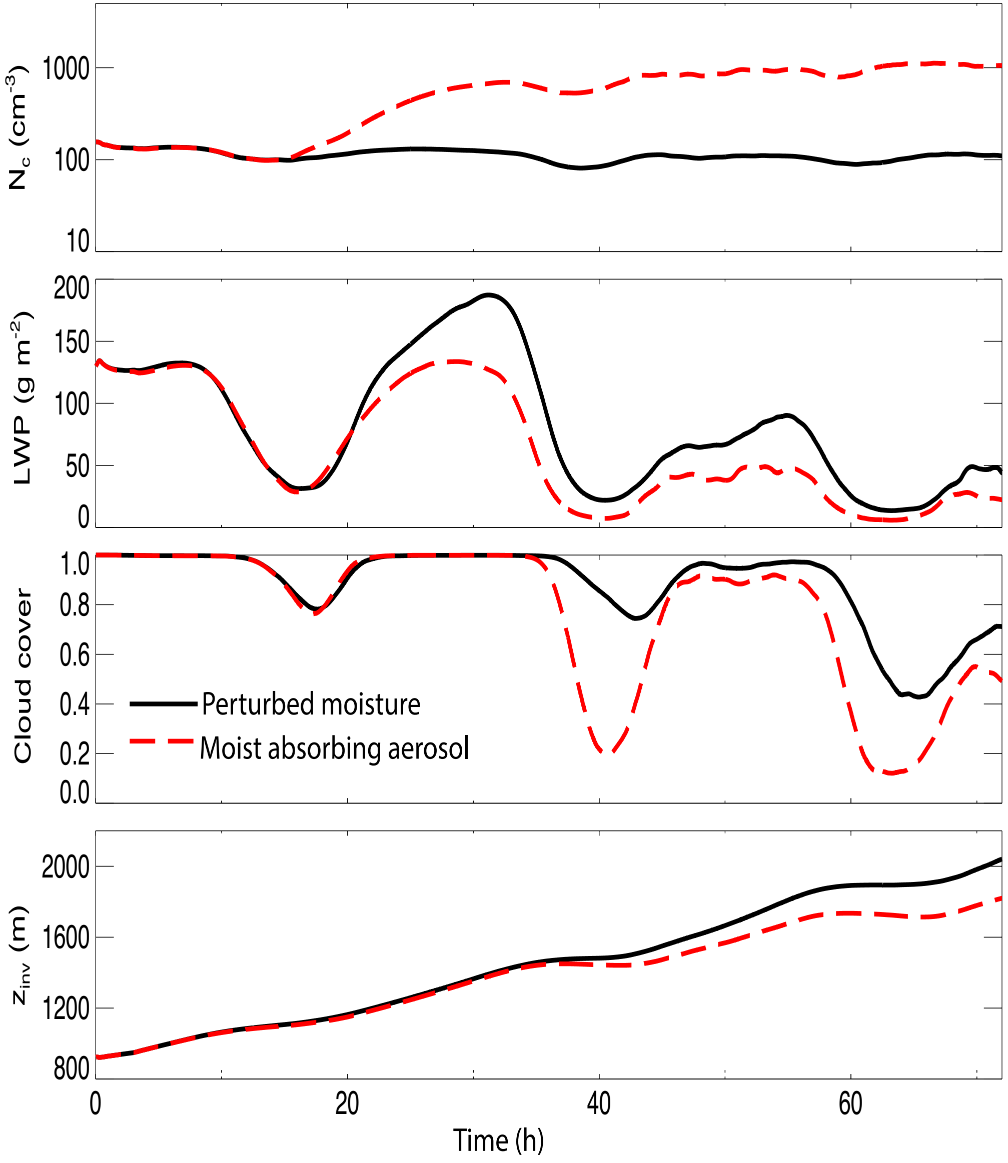
Higher initial absorbing aerosol layer



- Still, transition hastened
- **Stronger** net **negative** forcing
  - SW: Twomey more dominant (greater CF)
  - LW: forcing reduced (greater CF), yet not to be ignored

	D*F* (W m^{-2})		
	SW	LW	TOTAL
Day 2	**-11.2**	**-1.9**	**-13.1**
Day 3	**-5.0**	**-4.7**	**-9.7**

A moisture perturbation aloft

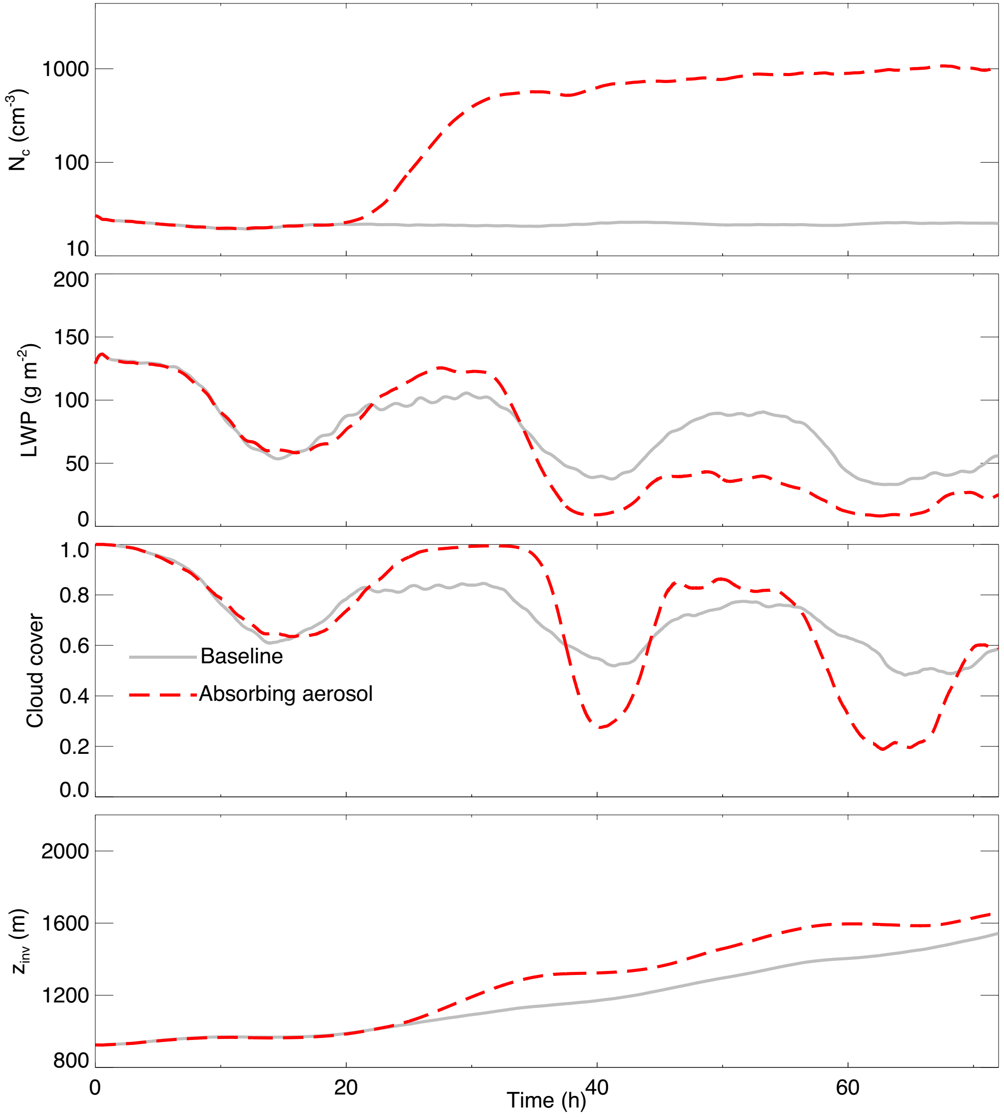


- Adebiyi et al. (2015) report plume moister than environment by ~ 1 g/kg
- Relative to dry baseline: less entrainment drying → greater LWP and CF
- A thicker cloud layer has more to lose → greater reduction in LWP and CF
- SW: positive forcing (-ΔCF overcomes Twomey)
- LW: forcing slightly increased (greater -ΔCF)

→ **weaker** net **negative** forcing

	DF (W m^{-2})		
	SW	LW	TOTAL
Day 2	**3.0**	**-2.2**	**0.8**
Day 3	**2.8**	**-6.8**	**-4.0**

Heavily drizzling baseline, dry aerosol plume



- Background sulfate: 150 → 25/mg
- Baseline: drizzle reduces diurnal cycle of LWP, CF and reduces entrainment
- Entrainment of aerosol inhibits drizzle, reversing those changes
- SW: stronger Twomey effect (much lower baseline)
- LW forcing *reversed* (deeper PBL)
- Transition still not delayed

	D*F* ($W\ m^{-2}$)		
	SW	LW	TOTAL
Day 2	**-52.0**	**6.3**	**-45.7**
Day 3	**-9.4**	**3.4**	**-6.0**

Summary

- TOA indirect and semi-direct radiative forcings consistently **–ive** (greater than or comparable to +ive direct forcing)
- LW forcings not to be ignored (subtropical troposphere is dry): substantial and –ive, induced by reduction in CF and PBL height, reversed in drizzling case
- Higher aerosol layer **enhances**
- Presence of additional moisture **reduces**
- Presence of drizzle **enhances**

} total aerosol radiative forcing

- Unlike Y15, here Sc → TrCu transition never delayed: *why*?

Differences with Y15

- **Possible differences in microphysics treatment**:
  Omit cloud droplet sedimentation and fix relaxation time for diffusional growth in DHARMA
  → Transition *delayed*

- **Differences in set-up**:
  Y15 used prognostic aerosol
  → Feedback of aerosol consumption and drizzle leads to catastrophic cloud breakup at end of control run

- **Differences in the LES dynamics**:
  Sc breakup much greater for DHARMA than SAM (used in Y15) in intercomparison of same SCT case (de Roode et al. 2016)