Supplemental text, tables, and figure captions for "Absorbing aerosols over Asia: A Geophysical Fluid Dynamics Laboratory general circulation model sensitivity study of model response to aerosol optical depth and aerosol absorption"

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Abstract. Supplemental material for doi:10.1029/2008JD010140. Unless noted otherwise, figures and tables described in this document refer to the supplemental figures and tables. Figures depicting the LOD experiment XA are found in the main journal article.

1. LOD Experimental Design

The low extinction optical depth (LOD) regime consists of three simulations: XA, XBa, and XBh. XA uses the MOZART-2 BC, OC, and SO_4 aerosol mass distributions for the year 1990 [*Horowitz*, 2006], and the same sea salt and dust mass distributions as the BASE case as described in the article text. Sulfate aerosols are treated as hygroscopic in XA. For XBa, the BC mass in XA was increased slightly over India and more substantially over China to obtain $\omega_o \leq 0.85$ at 550 nm. Note that the sulfate mass distribution is the same in all LOD experiments. However, in XBa the SO_4 optical properties were fixed at 30% RH in order to maintain $\omega_o \leq 0.85$. This results in a decrease in τ_e for XBa relative to XA. XBh uses the same aerosol mass distributions as XBa; however, SO_4 optical properties are a function of model RH. Thus, XBa and XBh share the same absorption optical thickness (τ_a) though their ω_o and τ_e differ due to the increase in the scattering optical depth (τ_s) associated with sulfate humidification. Because SO_4 dominates τ_e when the aerosol is humidified, and because XA and XBh share the same mass SO_4 mass distributions, their extinction optical depths are similar. Slight differences may, however, result from differences in modeled RH. Note that XBa and XBh were designed to serve as LOD analogs to the HOD experiments XCa and XCh. The optical properties of all LOD and HOD experiments can be found in Table 1 of the journal article.

Figure 1 shows the difference in column-integrated visible extinction optical depth between the experiments (XBa and XBh) and BASE ($\Delta\tau_e$) in summer (JJA). The anthropogenic extinction optical depth increase in XA (Figure 1a; main article text) represents the change in aerosol optical depth determined by 1950 and 1990 aerosol mass distributions from MOZART-2 [*Horowitz*, 2006] and AM2 aerosol optical properties [*Anderson et al.*, 2004]. *Ginoux et al.* [2006] provide a complete evaluation of the strengths and weaknesses of the MOZART-2/AM2-LM2 aerosol optical depths for the years 1996-2000 compared to present-day observations. XBa (Figure 1a) is run without sulfate hygroscopic growth, resulting in a much lower extinction optical depth increase than in XA. The same anthropogenic aerosol masses from XBa are used for XBh (Figure 1b), but SO_4 is hygroscopic. By design, XBh has a $\Delta\tau_e$ similar to XA, though it is slightly more absorbing.

2. LOD Forcing

For XA and XBh, the clear-sky TOA forcings (Table 1) are a factor of 3 to 4 lower than the surface forcing, in agreement with findings from the INDOEX field campaign [*Chung et al.*, 2002]. For XBa, the clear-sky SFC forcing is $\sim$ 13 times TOA clear-sky forcing over India and $\sim$ 7 times TOA clear-sky forcing over China. This is because the high absorption throughout the atmosphere greatly decreases the upward flux at the TOA and the downward flux at the SFC, producing a weak forcing at the TOA relative to a strong negative forcing at the surface [*Erlick*, 2006]. Also, for INDOEX, the absorbing aerosol layer was located within the lowest 3 km of the atmosphere, while in XBa absorbing aerosol extends throughout the troposphere owing to the preservation of the BASE case vertical profile in all the experiments. Table 2 gives the surface, atmospheric, and top of the atmosphere clear-sky radiative efficiencies (β_s, β_a and β_t) for XBa and XBh.

3. LOD Response over India

Table 3 gives the area-average change in surface air temperature relative to the BASE case over India and China for JJA. Changes in surface air temperature with greater than 90% significance calculated using the student's t-test are printed in bold. XBh shows little area-average change in land surface air temperature relative to the BASE case.

Figure 2 gives the change in surface air temperature (ΔT_s) for XBa and XBh. In the LOD regime, Figure 2 indicates surface air cooling throughout most of the Indian peninsula with significant changes occurring only in a small portion of central India. Warming is observed in northwestern India, but this warming is not significant and may be due to internal model variability (it could also be due to the high surface albedo in the region of the Thar desert). Note that the increased surface air temperatures in northwestern India and the smaller decreases over south-central India tend to cancel each other out in the area mean for XBh (Table 3). The pattern of ΔT_s is qualitatively similar for all LOD experiments. Over south-central India, cloud increases (see Table 4) in XBa reduce solar flux to the surface while cloud decreases in XBh over southern and northwestern India increase solar flux to the surface, counteracting the effects of increased aerosol extinction on the flux of radiation to the surface. ΔT_s for these two experiments are

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0148-0227/08/$9.00

qualitatively similar despite large differences in τ_e (and differences in surface forcing; see Table 1), implying that surface aerosol radiative forcing alone does not determine the surface air temperature response and that cloud changes are important.

Strong absorption in XBa over northern India and the snow-covered Tibetan Plateau region (25°N - 40°N, 60°E - 100°E) is accompanied by significant increases in ΔT_s in some small regions in this domain. Absorbing aerosols overlying highly reflective surface albedos exert a radiative warming tendency at the surface due to multiple reflections between the surface and the absorbing aerosol layer [*Chylek and Coakley*, 1974]. Over central India, however, XBa and XBh show little change in surface temperature (a slight cooling), consistent with observations. It should be noted that if GHG increases were considered in this study, the magnitude of the cooling would be reduced, but warming signals would be exacerbated.

Figure 3 shows the zonally averaged JJA air temperature change (ΔT_{atm}) relative to the BASE case over India (averaged over 65°E - 90°E), the increases in BC mixing ratio [μg m^{-3}] between 1950 and 1990, and the change in shortwave all-sky heating rate [K d^{-1}] relative to the BASE case. In the LOD regime, changes in BC mixing ratio were small between XA, XBa, and XBh, and are not apparent in Figure 3. Atmospheric temperature changes over the Indian Ocean (south of 10°N) are generally small for the LOD simulations.

Table 4 shows the area-averaged change in cloud amount relative to the BASE case over land. In the LOD regime, the change in total clouds over India is insignificant (not shown), with the exception of increases in clouds in XA and XBa over the Bay of Bengal (~8°N-20°N, 80°E-100°E). Figure 4 shows the change in vertical velocity (pressure units) relative to the BASE case zonally averaged over India. For the LOD regime, virtually all area-averaged cloud types increase for XA and XBa relative to the BASE case (Table 4) due to increases in vertical velocity around 20°N. Though vertical velocity increases more for XBa relative to XA, mid- and low-level clouds increase less for the more absorbing XBa (Table 1; main paper), consistent with the expectation from the semi-direct aerosol effect [*Hansen et al.*, 1997] in which absorbing aerosol increases local atmospheric heating and low-level stability while decreasing cloudiness. With the exception of mid-level clouds, cloud amount decreases in XBh relative to the BASE case. Mid-level clouds increase less than in XA or XBa as a result of both a weaker increase in vertical pressure velocity at 20°N and the semi-direct effect relative to XA and XBa. Though XBa and XBh have the same τ_a, the scattering optical depth (τ_s) for XBh is much greater than that of XBa since sulfate aerosol is allowed to humidify. Therefore the amount of diffuse and backscattered radiation is increased in XBh relative to XBa [*Stier et al.*, 2006], providing an enhancement of τ_a in XBh over XBa that results in a stronger semi-direct effect and a greater decrease in cloudiness.

Figure 5 shows the change in surface pressure (ΔP_{sfc}) relative to the BASE case overlain with the change in 850 hPa wind vectors relative to the BASE case, with thick contours indicating the 90% significance of ΔP_{sfc}. For most LOD simulations, 850 hPa wind changes are generally southwesterly over the Arabian Sea and then traverse the Indian Peninsula in a westerly direction, again becoming southwesterly along the eastern coast of India and throughout the Bay of Bengal. For XA and XBa, ΔP_{sfc} decreases over the northwestern coast of India (between ~20°N to 25°N). The low-level wind change in XA and XBa flows westerly along the surface-pressure change contours, resulting in strong convergence (not shown) along the south-central western coast of India, enhancing the summer monsoon circulation of the BASE case (not shown). The ΔP_{sfc} changes and wind changes are much weaker and less significant in XBh, which results in weaker convergence along the coast of India relative to the other LOD simulations. Note that the regions of increased convergence (particularly around 20°N) coincide with the increases in vertical velocity from Figure 4.

Evaporation (not shown) decreases over the land and increases slightly over most of the northern Indian Ocean (~8°S-10°N, 55°E-100°E) relative to the BASE case due to increases in wind speed. In the LOD regime, there is generally an increase in column-integrated water vapor over the land in India (not shown). The spatial distribution of the change in precipitation rate relative to the BASE case (ΔP) shown in Figure 6 reveals increases in precipitation corresponding to regions of convergence and increased vertical motion, and decreases in precipitation corresponding to regions of divergence and relative subsidence. In the LOD regime over the Indian land mass, precipitation increases for XA and XBa but primarily decreases for XBh; however, none of these changes are significant above the 90% confidence level.

The surface energy budget reveals the importance of aerosol extinction versus cloud changes in determining the net shortwave flux to the surface. In the global annual mean, the surface energy budget is given by:

$$S + F + LE + H \approx 0 \tag{1}$$

where the net (down minus up) solar (shortwave) heat flux at the surface is denoted by S, the net infrared (longwave) surface heat flux is F, and LE and H are the net latent and sensible heat fluxes at the surface, respectively. The sign convention is such that positive terms warm the surface and negative terms cool the surface. Oceanic transport of heat is not considered since SSTs are prescribed. Note that the fluxes in this equation are taken after equilibrium has been reached; they are not instantaneous fluxes and thus reflect the energy balance at the surface after feedbacks (e.g. clouds) have occured. Equation (1) can be rewritten following *Boer* [1993] and *Chen and Ramaswamy* [1996] as:

$$\begin{aligned}(S_0 - \sigma T_{sfc}^4) \;&+\; (G_{clr} + W_{clr}) \\ &+\; (C_{SW} + C_{LW}) + A_{sfc} + LE + H \approx 0 \end{aligned} \tag{2}$$

S_0 is the global annual-mean solar radiation incident at the top of the atmosphere; σT_{sfc}^4 is the blackbody surface emission; G_{clr} is the downward longwave emission by the clear-sky atmosphere; W_{clr} represents the solar radiation absorbed in the clear-sky atmosphere due to absorption and scattering by gas molecules and aerosols; C_{LW} and C_{SW} are the longwave and shortwave surface cloud forcings; and A_{sfc} is the radiative effect due to the surface albedo.

Table 5 shows the value for each of the terms in Equation (1) for the BASE case and the change in each term in Equation (2) relative to the BASE case for each experiment. XBh has a δC_{SW} warming, but this is due to cloud amount decreases (Table 4). Cloud amounts increase in XA and XBa, but the aerosol extinction optical depth is not high enough to cause a positive δC_{SW} (warming) as in the absorbing HOD simulations. Net downward longwave radiation is increased for XA and XBa due to the combined effects of changes in (1) downward longwave emission from increased water vapor, (2) downward longwave radiation from increased atmospheric temperature (Figure 3), and (3) longwave emission from increased clouds (Table 4) [*Ramaswamy and Kiehl*, 1985]. Decreases in upward longwave emission from the cooler surface imply a lesser cooling effect and contribute to a positive δF for these experiments.

For smaller changes in τ_e, the response of the model's hydrological cycle over India is not as significant for the changes in aerosol optical properties considered in this study. This fact makes it difficult to discriminate between the LOD cases with the same $\Delta\tau_a$ (XBa and XBh). Recall that $\Delta\tau_e$ for XBa is expected to be an underestimate since SO_4 is not humidified

4. LOD Response over China

In the LOD regime, significant (≥90% confidence level) cooling generally occurs in northeastern China and near the Yangtze River Valley (around 30°N - 32°N) with little significant cooling in southern China (Figure 2). ΔT_s increases in central China in XBa and over the Tibetan Plateau region to the west. For the LOD regime, there is little change in atmospheric temperature and shortwave heating rate south of the region of increased BC in China (south of 20°N; Figure 7). In the LOD regime, ΔT_{atm} (Figure 7) is qualitatively similar for all experiments over China. Recall that the BC mixing ratio increases more in XBa and XBh relative to XA over China as compared to India in order to satisfy the optical constraints of the experimental design (Table 1; main paper). North of 40°N in China, all LOD experiments exhibit cooling below 200 hPa.

From Table 4, area-average low- and mid-level clouds generally increase in the model over China for XA and XBh. All cloud types decrease for XChW, and there are small changes in low- and mid-level clouds for XBa. In the LOD regime, low- and mid-level cloud amounts increase in northeastern China for all experiments but decrease in southeastern China (∼25°N) for XBa (not shown). The changes in cloud amount are related to the change in vertical pressure velocity ($\Delta(-w)$) zonally averaged over China in Figure 8. In XBa, note the subsidence near 25°N corresponding to the decrease in low-level cloud amount in southeastern China. Increasing the scattering optical depth while holding the absorption optical depth constant (XBh versus XBa) tends to weaken the magnitude of these changes in vertical motion, indicating the important roles played by both scattering and absorbing components of anthropogenic aerosols,

As was the case over India, changes in vertical velocity (Figure 8) and cloud amount are related to changes in low-level convergence associated with the changes in circulation and surface pressure in Figure 5. In the LOD regime, an increase in ΔP_{sfc} centered over northeastern China leads to a southeasterly flow over southern China and northwesterly flow over northeastern China that advects warm, moist oceanic air into the Yangtze River Valley region. The increase in ΔP_{sfc} in XBa is displaced to the southeast over the East China Sea relative to XA. The resulting change in circulation contributes to increased divergence near 25°N, where subsidence and decreased low-level cloud amounts occur in the model (Table 4). In XBh, significant increases in ΔP_{sfc} are noted over the land in northeastern China.

Evaporation over China (not shown) decreases relative to the BASE case everywhere over land for all experiments. Precipitable water (not shown) increases over northeastern China in the LOD experiments and decreases in southeastern China. In the LOD regime, Figure 6 shows little significant change in precipitation over China relative to the BASE case, though significant decreases in precipitation are found in southeastern China for all LOD simulations except XA, coincident with the subsidence and divergence near 25°N. There is a very slight increase in precipitation near 30°N (the Yangtze River valley), which has experienced a trend of flooding in recent years [*Menon et al.*, 2002; *Cheng et al.*, 2005], for all LOD simulations (particularly XBa); however, this increase is not significant. Relative to the observations (Figure 9), all experiments except XChW capture some increased rainfall in the region of the Yangtze River Basin (∼30°N-32°N, 114°E-120°E) and decreased rainfall in the southeastern drought region, indicating a distinctive regional influence that anthropogenic aerosols have likely exerted over the past few decades.

With the exception of XBa, Equation (2) and Table 5 indicate that $L\delta E$ is the dominant warming term as evaporation decreases over the land surface in China. For XBa, sensible heat flux is the dominant term balancing out the cooling due to surface dimming from aerosols and changes in cloud amount, though the latent and longwave heat flux terms are comparable to δH. An important point is that XBh has the largest decrease in downward shortwave radiation of all the LOD experiments owing to its higher aerosol extinction optical depth and absorption. At low optical depths the changes in sensible heat flux are < 3 W m^{-2}, indicating a slight decrease in stability. δW_{clr} is again the leading cooling term over China in Equation (2). In the LOD regime, this term causes more cooling for XBh versus XA despite having a similar optical depth; this is because XBh is more absorbing.

5. LOD Concluding Remarks

In both regimes, increases (decreases) in cloud amount reinforce (counteract) the aerosol-induced surface solar flux reduction. In the LOD regime, cloud amount generally decreases with increasing absorption (decreasing ω_o) arising in part due to the semi-direct effect. When anthropogenic absorption optical depth (τ_a) is held constant, but anthropogenic scattering optical depth (τ_s) increases (which increases ω_o), increased forward diffuse and backscattered radiation enhance absorption and decrease cloud amount in the LOD regime. This also occurs in the HOD regime; however, circulation changes affect cloud amount more prominently in this regime.

Acknowledgments. This report was prepared by C. A. Randles under award NA17RJ2612 from the National Oceanic and Atmospheric Administration, U.S. Department of Commerce. The statements, findings, conclusion and recommendations are those of the author(s) and do not necessarily reflect the views of the National Oceanic and Atmospheric Administration, or the U.S. Department of Commerce. Randles also acknowledges funding from the DOE Graduate Research Environmental Fellowship. We thank Hiram Levy II and Paul Ginoux for useful comments on the manuscript, M. Shekar Reddy, Dan Schwarzkophf, Yi Ming, and Larry Horowitz for assistance with the GCM, and Surabi Menon for providing AOD measurements over India and China and helpful suggestions. We thank Brent Holben, S. N. Tripathi, Hong-Bin Chen, and Phillipe Goloub for their effort in establishing and maintaining the Kanpur, Kaashidhoo, and Beijing AERONET sites. We also thank three anonymous reviewers for their insights on improvements to the manuscript.

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Figure 1. Column-integrated aerosol optical depth for each experiment differenced with respect to the BASE case ($\Delta\tau_e$): (a) XBa and (b) XBh. Note that this optical depth represents only the anthropogenic (BC, OC and SO_4) aerosol component (increase between 1950 and 1990) since the natural (dust and sea salt) component is shared with the BASE case. The contour interval is 0.2.

Figure 2. JJA change in surface air temperature (ΔT_s) [K] between the BASE case and (a) XBa and (b) XBh. (e) Observed mean ΔT_s between the 1945-1955 and 1985-1995 decades from the CRU database [*Brohan et al.*, 2006]. Thin, solid (dashed) lines and red (blue) shading indicate positive (negative) ΔT_s (contour interval 0.5 K). Thick blue and red contours enclose regions where ΔT_s is at or above the 90% confidence level.

Figure 3. Zonally averaged change in JJA atmospheric temperature (ΔT_{atm}) [K] (shaded) over India (65°E-90°E) between the BASE case and (a) XBa and (b) XBh. Change in BC mixing ratio relative to the BASE case (thick black contours) with contour interval of 0.01 μg m^{-3}. Thin, dotted contours indicate the change in shortwave heating rate [K d^{-1}] relative to the BASE case with contour interval of 0.05 K d^{-1}.

Figure 4. Zonally averaged JJA change in vertical velocity ($\Delta(-w) = \Delta\frac{-dp}{dt}$) between the BASE case and experiments over India (65°E-90°E) for (a) XBa and (b) XBh. Note that the negative of the vertical pressure velocity is taken such that red indicates increased vertical motion and blue indicates relative subsidence. The contour interval is 5×10^{-5} hPa s^{-1}.

Figure 5. Change in JJA surface pressure (ΔP_{sfc}) [hPa] relative to the BASE case (shaded) for (a) XBa and (b) XBh. Thick blue and red contours enclose regions where ΔP_{sfc} is at or above the 90% confidence level. Changes in the 850 hPa winds relative to the BASE case are plotted as vectors.

Figure 6. Change in JJA precipitation rate (ΔP) relative to the BASE case for (a) XBa and (b) XBh. Thin, solid (dotted) contours and red (blue) shading indicate positive (negative) ΔP (contour interval of 0.5 mm d^{-1}). Thick red and blue contours inclose regions where ΔP is at or above the 90% confidence level.

Figure 7. Same as Figure 3 (ΔT_{atm}, BC mixing ratio change, and shortwave heating rate change) except zonally averaged over China (90°E-130°E).

Figure 8. Same as Figure 4 ($\Delta(-w) = \Delta\frac{-dp}{dt}$; contour interval 5×10^{-5} hPa s^{-1}) except zonally averaged over China (90°E-130°E)

Figure 9. Percent change in total precipitation rate relative to the BASE case ((EXP-BASE)/BASE) $\times$ 100 over China for: (a) XBa and (b) XBh. (e) Observed percent change in total precipitation between the 1985-1995 decade and the 1945-1955 decade from the CRU database [*Brohan et al.*, 2006]. Solid (dotted) contours and red (blue) shading indicate increased (decreased) precipitation (5% contour interval). Thick blue and red contours enclose regions where the change in precipitation is at or above the 90% confidence level.

Table 1. JJA All-sky (Clear-sky) DRF[a] [W m^{-2}]

Experiment	TOA	ATM	SFC	SFC/TOA
		India[b]		
BASE	+1.9 (-0.4)	+4.2 (+3.8)	-2.3 (-4.2)	-1.2 (+10.5)
		LOD		
XA	+3.2 (-3.9)	+10.1 (+9.1)	-6.9 (-13.0)	-2.2 (+3.3)
XBa	+4.0 (-0.8)	+10.3 (+9.4)	-6.3 (-10.2)	-1.6 (+12.8)
XBh	+3.3 (-3.8)	+10.2 (+9.3)	-6.9 (-13.1)	-2.1 (+3.4)
		HOD		
XCa	+16.8 (-2.0)	+38.5 (+34.3)	-21.7 (-36.3)	-1.3 (+18.2)
XCh	+14.4 (-12.0)	+38.5 (+34.2)	-24.1 (-46.2)	-1.7 (+3.9)
XChW	-11.3 (-24.6)	≈ 0 (≈ 0)	-11.3 (-24.7)	≈ 1 (≈ 1)
		China[b]		
BASE	+0.5 (-1.5)	+2.9 (+2.7)	-2.4 (-4.2)	-4.8 (+2.8)
		LOD		
XA	+1.0 (-10.8)	+9.1 (+8.3)	-8.1 (-19.1)	-8.1 (+1.8)
XBa	+4.2 (-2.2)	+12.5 (+12.3)	-8.3 (-14.5)	-2.0 (+6.6)
XBh	+2.9 (-9.0)	+12.4 (+11.7)	-9.5 (-20.7)	-3.3 (+2.3)
		HOD		
XCa	+13.6 (-4.8)	+37.7 (+36.5)	-24.1 (-41.3)	-1.8 (+8.6)
XCh	+10.4 (-19.4)	+37.5 (+35.7)	-27.1 (-55.1)	-2.6 (+2.8)
XChW	-13.6 (-34.4)	≈ 0 (≈ 0)	-13.6 (-34.4)	≈ 1 (≈ 1)

[a] All-sky anthropogenic (OC + BC + SO_4) DRF with clear-sky DRF in parenthesis.

[b] Land-area average only.

Table 2. JJA Clear-sky SW Aerosol Radiative Efficiency[a] [W m^{-2} τ_e^{-1}]

Experiment	β_s (SFC/τ_e)	β_t (TOA/τ_e)	$\frac{\beta_s}{\beta_t}$	β_a (ATM/τ_e)
	India[b]			
	LOD			
XA	-48.3	-21.4	+2.3	+26.9
XBa	-56.5	-16.9	+3.3	+39.6
XBh	-48.5	-20.8	+2.3	+27.7
	HOD			
XCa	-71.4	-20.3	+3.5	+51.1
XCh	-49.4	-20.3	+2.4	+29.1
XChW	-28.0	-29.8	+0.9	≈ 0
	Observations			
Ramanathan et al. [2001a, b]	-70 to -75	-22	+3	+48 to +58
Satheesh and Ramanathan [2000]				
	China[c]			
	LOD			
XA	-39.0	-20.2	+1.9	+18.8
XBa	-58.5	-11.7	+5.0	+46.8
XBh	-41.1	-18.8	+2.2	+22.3
	HOD			
XCa	-67.2	-10.7	+6.3	+56.5
XCh	-39.1	-15.2	+2.6	+23.9
XChW	-24.0	-24.2	+1.0	≈ 0
	Observations			
Bush and Valero [2003]	-74	–	–	–
Markowicz et al. [2003]	-60	–	–	–
Conant et al. [2003]	-55	–	–	–
Nakajima et al. [2003]	-50 to -80	-25 to -26	+2 to +3	+25 to +67
Kim et al. [2005]	–	–	–	+39 to +67
Takamura et al. [2007]	-81.6	-32.5	+2.5	+49.4

[a] All aerosol species (natural + anthropogenic) included in radiative efficiencies.

[b] DJF values calculated over ocean only to match the time and spatial coverage of INDOEX more closely.

[c] MAM values calculated over land and ocean to match the time and spatial coverage of ACE-Asia more closely.

Table 3. JJA Surface Air Temperature (ΔT_s) and Lapse Rate Change over Land

Experiment	ΔT_s[a] **[K]**	Δ **Lapse Rate**[b] **[K]**
	India BASE (T_s **= 297.42 K)**	
XA	-0.17	-0.3
XBa	-0.06	-0.3
XBh	+0.03	-0.1
XCa	**-0.60**	-1.2
XCh	**-0.67**	-1.3
XChW	-0.16	+0.6
	China BASE (T_s **= 290.26 K)**	
XA	-0.42	-0.5
XBa	-0.19	-0.5
XBh	-0.38	-0.5
XCa	**-0.56**	-1.4
XCh	**-0.91**	-1.5
XChW	**-1.14**	0.0

[a] Land-area average ΔT_s with $\geq$ 95% confidence from student's t-test are indicated in bold.

[b] Lapse rate is calculated as the difference between the surface air temperature and the layer-average tropospheric temperature (T_{TT}), where T_{TT} is calculated following *Fu and Johanson* [2005]. Δ Lapse Rate is the difference between the lapse rate of the given experiment and the lapse rate of the BASE case. Positive numbers indicate decreased stability while negative numbers indicate increased stability relative to the BASE case.

Table 4. JJA Cloud Amount Change [%] over Land[a,b]

Experiment		TOT	LOW	MID	HIGH
		India			
BASE[c]		69.9	35.0	28.6	46.3
LOD[d]	**XA**	0.8	1.5	1.8	*-0.02*
	XBa	1.0	1.1	1.4	0.8
	XBh	*-0.5*	*-0.2*	0.7	*-0.4*
HOD[d]	**XCa**	2.4	3.4	5.2	1.7
	XCh	2.0	4.0	5.6	0.2
	XChW	*-6.4*	*-4.4*	*-1.6*	*-4.8*
		China			
BASE[c]		66.0	28.3	35.0	44.3
LOD[d]	**XA**	0.4	1.4	0.7	*-0.7*
	XBa	*-0.4*	0.4	*-0.1*	*-0.9*
	XBh	*-0.01*	1.1	0.7	*-1.0*
HOD[d]	**XCa**	*-0.2*	2.5	0.8	*-0.7*
	XCh	0.2	3.1	0.9	*-1.1*
	XChW	*-1.7*	*-1.2*	*-0.6*	*-2.5*

[a] Cloud amount refers to the change in the spatially averaged frequency of occurrence of clouds [*Wetherald and Manabe*, 1988; *Erlick et al.*, 2006].

[b] Total (TOT), low-level (LOW), mid-level (MID), and high (HIGH) cloud regimes defined in text.

[c] Absolute cloud amount [%] given for BASE case.

[d] Change relative to BASE case. Decreased cloud amount relative to BASE given in italics for clarity.

Table 5. JJA Land Surface Energy Balance[a,b] [W m^{-2}]

	Shortwave (S)[c]			**Longwave (F)**[d]			**Latent (LE)**	**Sensible (H)**
	W_{clr}	C_{SW}	A_{SFC}	G_{clr}	C_{LW}	$-\sigma T^4$		
				India				
BASE		167.6			*-47.1*		*-79.5*	*-36.6*
				LOD Change				
XA	*-9.6*	*-0.5*	1.9	0.2	0.4	1.6	2.8	3.1
XBa	*-6.4*	*-1.7*	1.7	0.1	0.2	0.8	3.5	1.8
XBh	*-9.2*	3.4	0.8	0.2	*-0.4*	*-0.1*	5.1	0.4
				HOD Change				
XCa	*-38.9*	0.1	7.3	*-1.0*	1.3	5.9	16.0	9.7
XCh	*-50.6*	8.3	7.9	*-0.8*	0.9	6.4	18.0	10.4
XChW	*-25.2*	27.2	*-1.0*	*-3.7*	*-2.2*	*-0.7*	7.4	*-3.5*
				China				
BASE		187.1			*-58.4*		*-85.4*	*-35.8*
				LOD Change				
XA	*-14.6*	4.6	1.8	*-1.6*	0.2	3.1	3.6	2.9
XBa	*-10.6*	3.0	1.4	*-0.5*	*-0.1*	1.7	2.5	2.7
XBh	*-16.8*	5.3	2.1	*-1.0*	0.1	2.9	4.3	3.2
				HOD Change				
XCa	*-44.0*	10.3	6.1	*-0.7*	0.3	5.7	12.7	10.1
XCh	*-59.4*	20.7	7.0	*-1.3*	*-0.6*	7.8	16.0	10.3
XChW	*-34.5*	24.9	1.3	*-5.1*	*-1.8*	7.1	4.4	1.9

[a] Negative values (cooling or less warming) given in italics for clarity.

[b] BASE follows Equation (1) and are absolute values; experiments are change in parameters from Equation (2) relative to BASE case. Note that energy balance closure is not obtained for JJA but is obtained in the annual mean (not shown).

[c] $S = S_0 + W_{clr} + C_{SW} + A_{SFC}$; see text for definitions of S_0, W_{clr}, C_{SW}, and A_{SFC}. Note S_0 does not change between the BASE case and experiments.

[d] $F = G_{clr} + C_{LW}$ - σT^4; see text for definitions of G_{clr}, C_{LW}, and σT^4.