Preliminary Exam Questions for **Enter Student Name here**

Questions to be given to **Enter Student Name here** on **enter date here** at 12 noon

Answers due on **enter date here** at 10.a.m.

(Example, Questions due to student at 12 noon on Friday and student emails response on Monday at 10am for a total of 70 hours)

Email your solutions to ADVISOR NAME and **ATS chair (chair@nsstc.uah.edu)**

Requirements and guidelines

1) Unless complex equations are involved, the student MUST type the answers.
2) Make sure that you spell check your answers thoroughly.
3) All answers must be Emailed (or scanned and Emailed) as separate files for each committee member.
4) You cannot copy articles from papers, highlight sections of the articles and attach them to your answers. You must describe answers in your own words.
5) You cannot use "human resources" to answer these questions. This means that you cannot send Emails or discuss these questions with others. However you can use all other "non human resources" (e.g. books, papers and web material). However, note that certain CM's may state that, the use of the Internet is NOT permitted to respond to their questions.
6) When appropriate include references in your answers. However please remember that you are NOT writing a journal paper therefore when you use references you must discuss the issues thoroughly. Do not state phrases such as 'Methodology has been explained in detail by Person et al (2005).
7) While you can seek clarifications for these questions (only if absolutely necessary!), please **do not** Email individual members of the committee and ask questions such as 'This is what I have derived or done so far – Can you tell me if I am on the right path?' – 'Can you tell me what exactly you are looking for' etc…
8) Some if not all questions are purposely "open-ended" to examine the though process. Please make the necessary assumptions and answer the questions.

Questions from Committee member

1: The climate forcing by biomass burning is estimated +0.03 ± 0.12 Wm-2 by IPCC 2007. How would your study relate or contribute to improving this estimation?

2: Explain the approaches, basic assumptions, and possible problems of existing aerosol ADMs.

Questions from Committee member name

Assuming that the global number of biomass burning fires increases by 50% next year, explain how the top of atmosphere (TOA), surface and atmospheric radiative and non radiative energy budget terms will respond to this forcing. You must include both the troposphere and the stratosphere in your discussion.

Be quantitative in your discussion and defend each assumption that you make.

Questions from committee member name

The student may use any books or journal articles they may choose, *but not access to the internet*

Question: Interpretation of basic meteorological features of South America
(Estimates time 2.5 hours)

This will test your basic knowledge of meteorology and meteorology-aerosol coupling in the region of your study. Questions are purposefully open ended to test the extent of knowledge and assumption. Attached you will find a series of gif files taken for a particular day during the middle of the Brazilian burning season. These include:

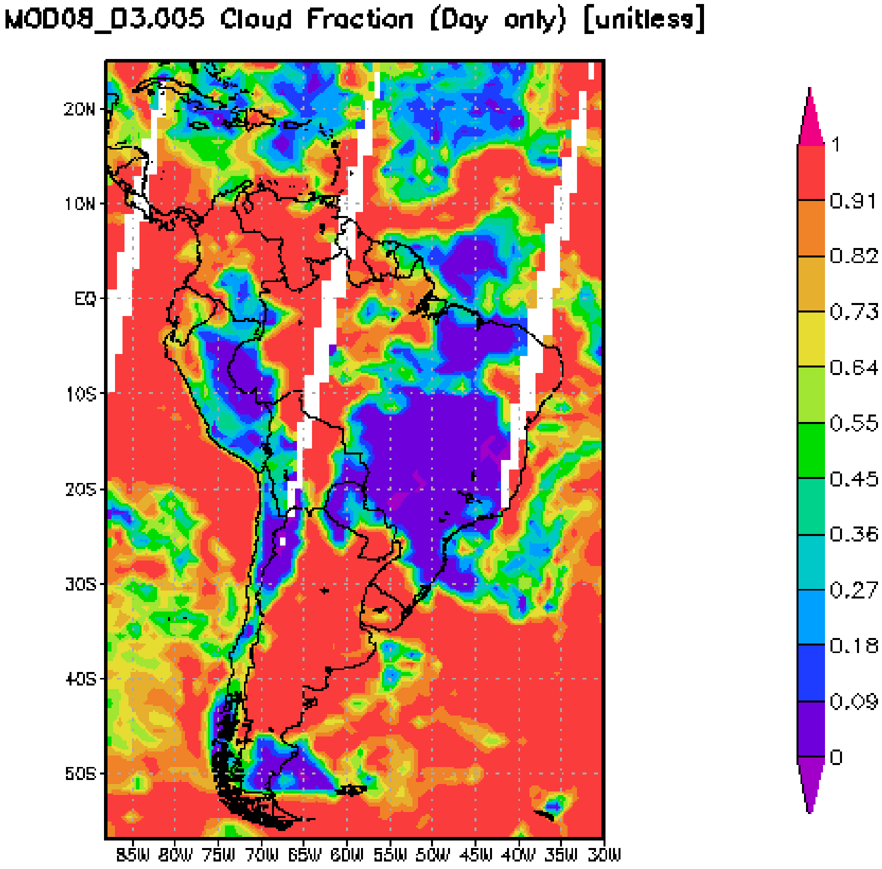
1) MODIS optical depth
2) MODIS cloud cover
3) MODIS cloud top pressures
4) Radiosonde daytime soundings for 3 sites taken over Brazil
5) 1 Radiosonde daytime sounding taken at an Atlantic island site several hundred kilometers off the Southeast coast of Brazil two days after the MODIS data.

a) For each of the 4 Radiosonde sites, give a detailed explanation of the thermodynamic state over the site noting significant levels, layers and stability. Based on the provided MODIS data, give rough latitudinal estimates of the locations of the 3 Radiosonde sites in Brazil.

b) Given all data, give a brief meteorological synopsis of this day labeling important metrological features. Include a description of the state of smoke optical depth over the region and how meteorologically it has the special pattern that it does.

c) For the 4 soundings, what do you expect the vertical distribution of smoke to be?

d) Assume a bulk model for top of atmosphere forcing. How do forcing efficiencies per unit mass change regionally? What is the total top of atmosphere radiative impact of smoke on this day at say, solar noon and 10 degree grids.


MOD08_D3.005 Cloud Fraction (Day only) [unitless]
20N
10N
EQ
10S
20S
30S
40S
50S
85W 80W 75W 70W 65W 60W 55W 50W 45W 40W 35W 30W
1
0.91
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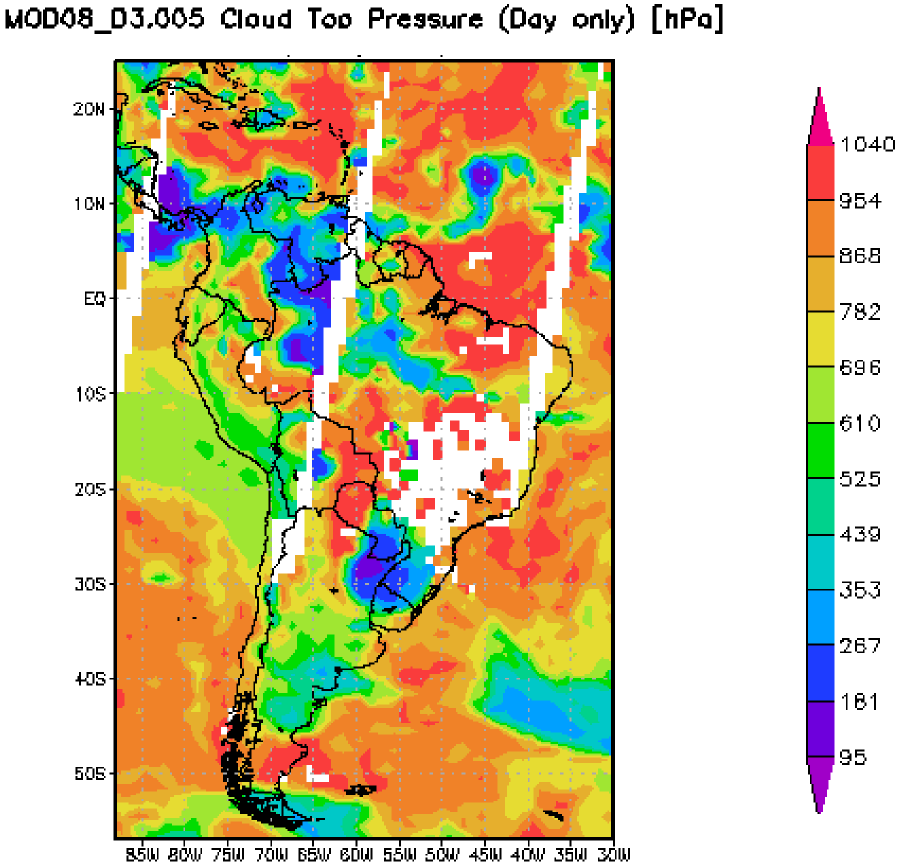
MOD08_D3.005 Cloud Top Pressure (Day only) [hPa]
20N
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85W 80W 75W 70W 65W 60W 55W 50W 45W 40W 35W 30W
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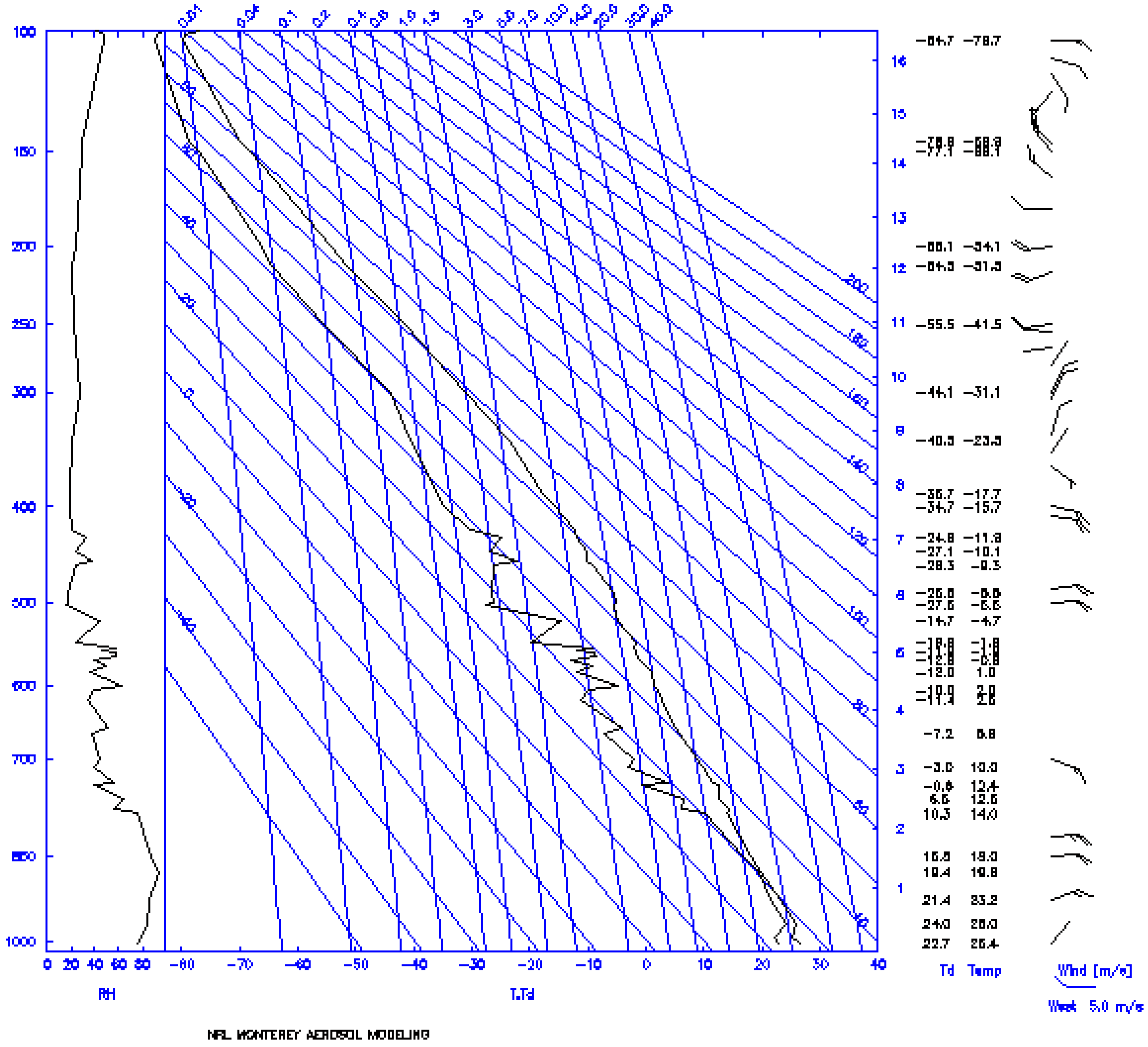
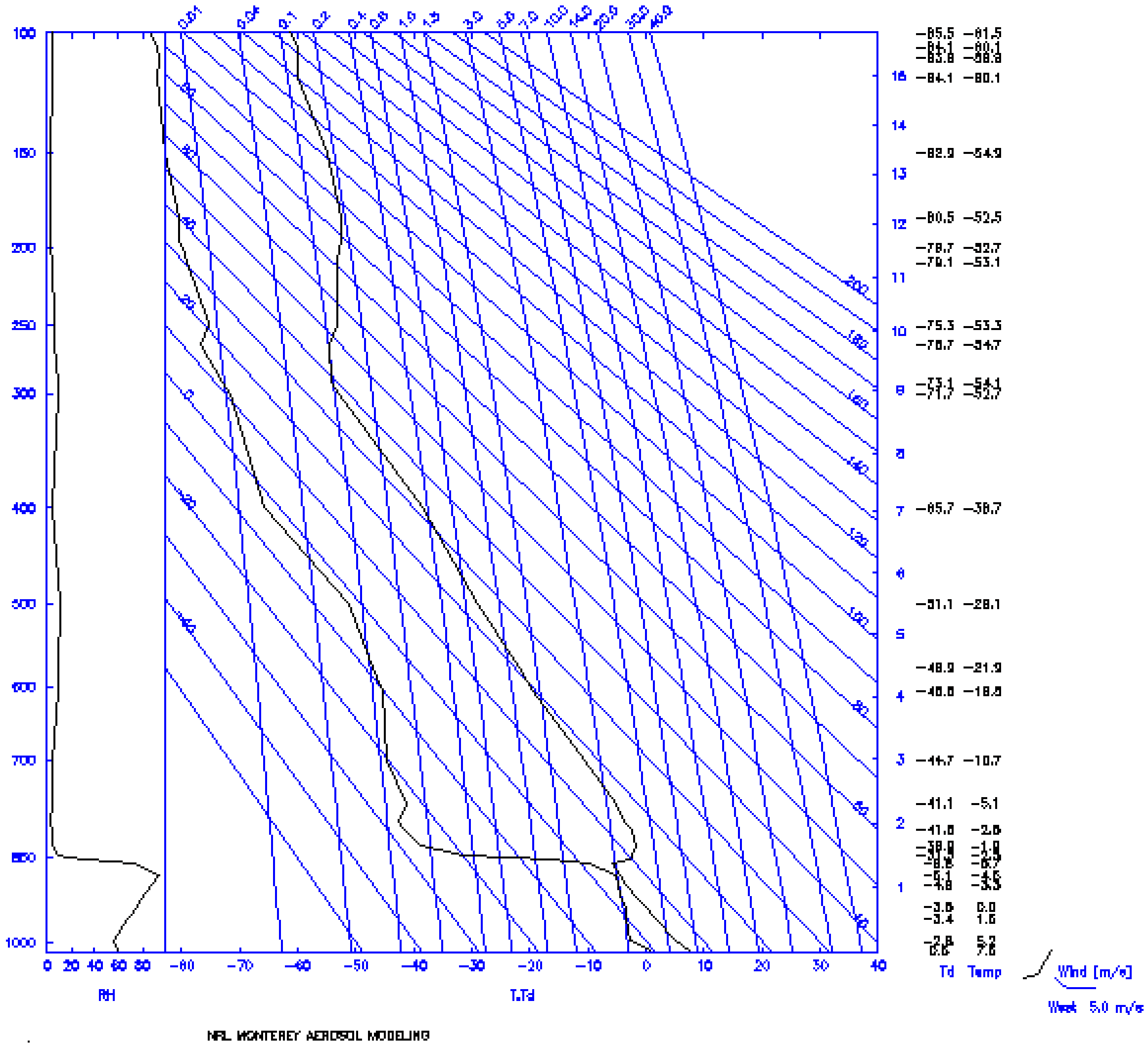
95

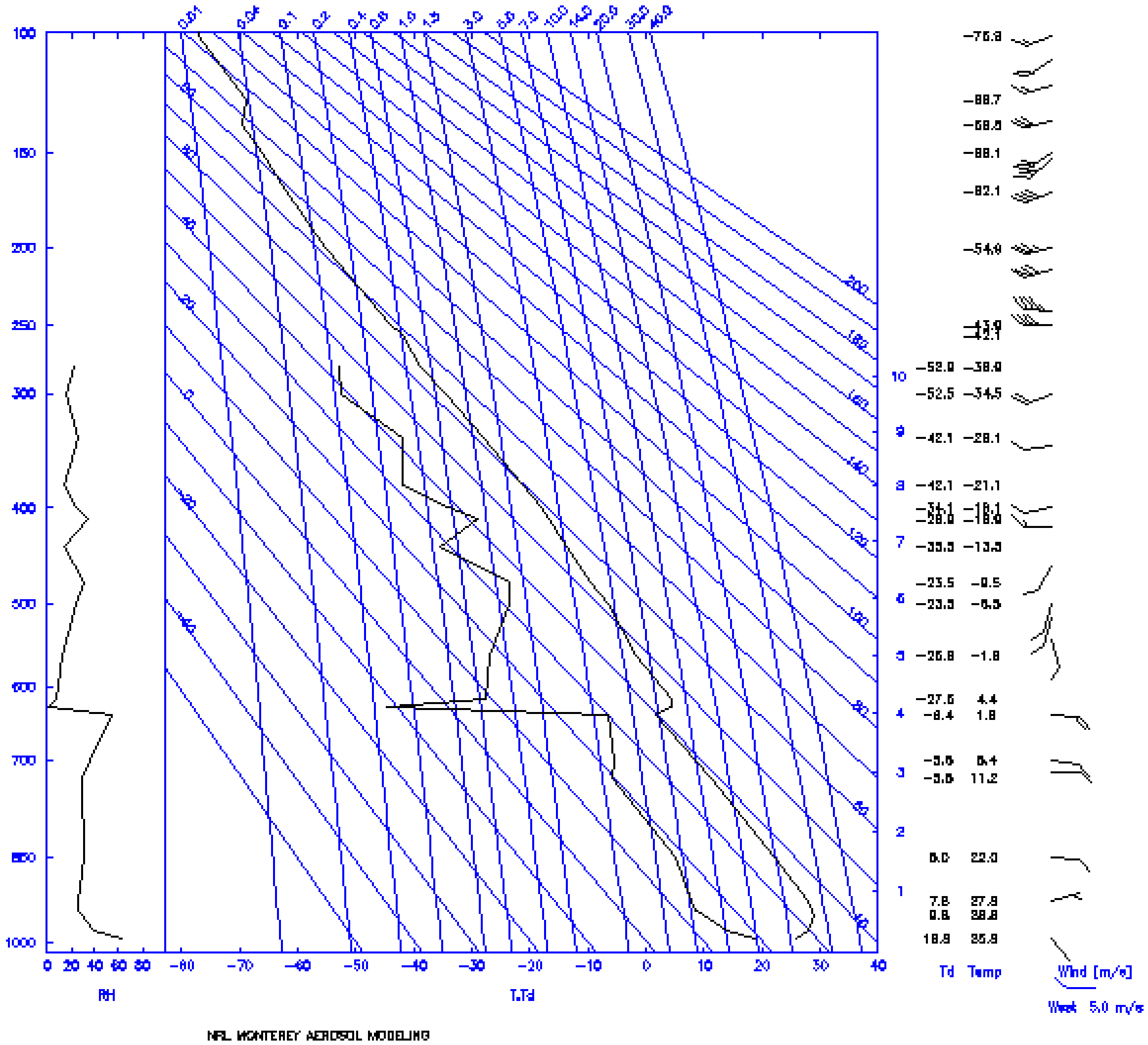


NRL MONTEREY AEROSOL MODELING

SOUNDING A



SOUNDING ATLANTIC


0.01 0.04 0.1 0.2 0.4 0.6 1.0 1.5 3.0 5.0 7.0 10.0 14.0 20.0 30.0 40.0
100
150
200
250
300
400
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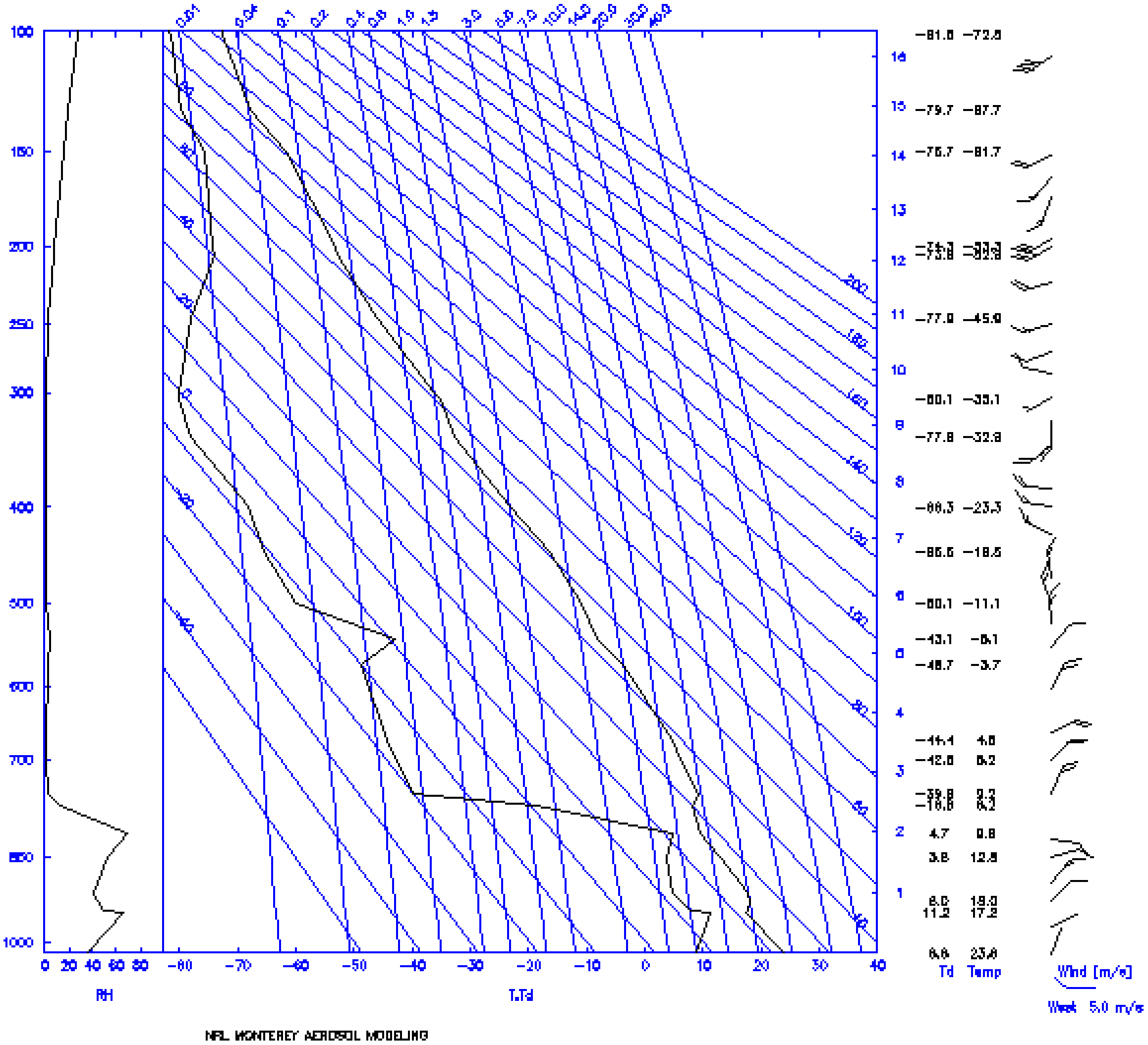
600
700
850
1000
0 20 40 60 80
RH
-80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40
T,Td
10
9
8
7
6
5
4
3
2
1
-76.8
-88.7
-68.5
-88.1
-62.1
-54.9
-43.9
-42.1
-52.9 -38.9
-52.5 -34.5
-42.1 -28.1
-42.1 -21.1
-34.1 -19.1
-28.9 -18.9
-33.3 -13.3
-23.5 -8.5
-23.3 -6.5
-26.8 -1.8
-27.6 4.4
-8.4 1.8
-5.6 8.4
-5.6 11.2
8.0 22.0
7.8 27.9
8.8 28.8
18.9 35.9
Td Temp
Wind [m/s]
West 5.0 m/s
NRL MONTEREY AEROSOL MODELING

SOUDING B


100
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0 20 40 60 80
RH
-80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40
T,Td
0.01 0.04 0.1 0.2 0.4 0.6 1.0 1.5 3.0 5.0 7.0 10.0 14.0 20.0 30.0 40.0
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
−81.8 −72.8
−79.7 −67.7
−76.7 −61.7
−74.3 −53.3
−73.8 −52.8
−77.0 −45.9
−80.1 −35.1
−77.8 −32.8
−66.3 −23.3
−66.5 −18.5
−60.1 −11.1
−43.1 −6.1
−46.7 −3.7
−44.4 4.8
−42.0 6.2
−39.8 9.2
−16.8 6.2
4.7 8.8
3.8 12.8
8.0 19.0
11.2 17.2
6.6 23.8
Td Temp
Wind [m/s]
West 5.0 m/s
NRL MONTEREY AEROSOL MODELING

SOUNDING C

Questions from Committee member name

(1) List major scenarios (e.g. aerosols above clouds) for constructing aerosol ADMs with the presence of clouds. Discuss possible strategies/solutions for each scenario.

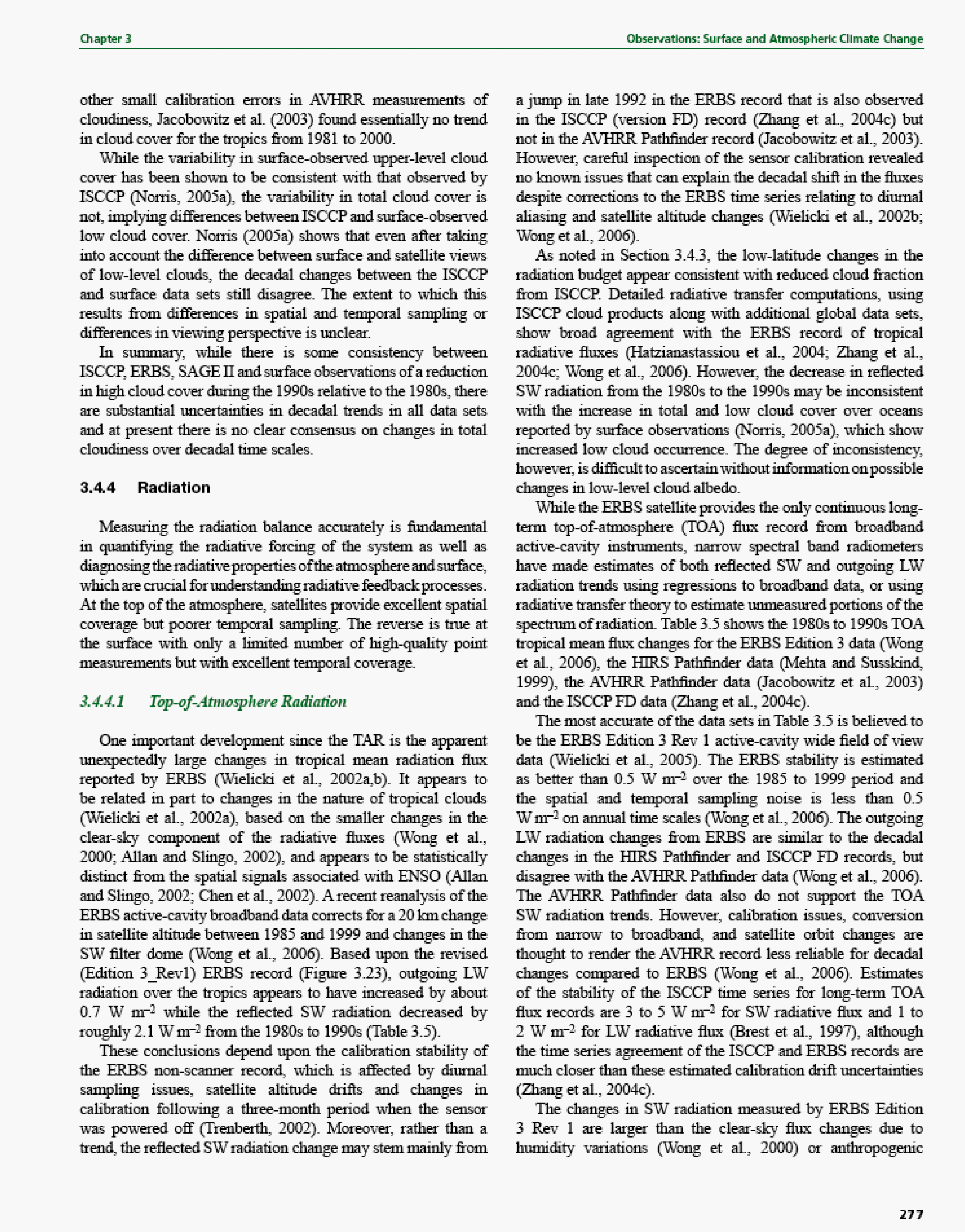
(2) One of the difficulties in constructing ADMs is the data deficiency in certain angular bins. E.g., for angular bins with viewing zenith angles larger than 60 degree. List methods in mitigating this problem, and show pros and cons of each method.

Questions from Committee member name

The proposal focuses on radiative forcing in South American and Africa due to biomass burning.

1. For these two regions, estimate the individual anomalous (i.e.
change over last 100 years) radiative forcing (and their uncertianties) due to all components now studied: Long-lived greenhouse gases (CO2, N2O, CH4, halocarbons), Ozone, Stratospheric water vapor, Surface Albedo, Aerosol (Direct, Cloud Albedo), Contrails, Solar Irradiance.
What is the estimated net forcing and uncertainties for these two regions?

2. In the recent IPCC AR4 Chapter 3, section 3.4.4.1 (SEE BELOW) the idea of Top-of-Atmosphere Radiation is discussed. From this discussion, what do you conclude about our current ability to know the precise radiation balance at TOA and the direction it may be going?



other small calibration errors in AVHRR measurements of cloudiness, Jacobowitz et al. (2003) found essentially no trend in cloud cover for the tropics from 1981 to 2000.

While the variability in surface-observed upper-level cloud cover has been shown to be consistent with that observed by ISCCP (Norris, 2005a), the variability in total cloud cover is not, implying differences between ISCCP and surface-observed low cloud cover. Norris (2005a) shows that even after taking into account the difference between surface and satellite views of low-level clouds, the decadal changes between the ISCCP and surface data sets still disagree. The extent to which this results from differences in spatial and temporal sampling or differences in viewing perspective is unclear.

In summary, while there is some consistency between ISCCP, ERBS, SAGE II and surface observations of a reduction in high cloud cover during the 1990s relative to the 1980s, there are substantial uncertainties in decadal trends in all data sets and at present there is no clear consensus on changes in total cloudiness over decadal time scales.

3.4.4 Radiation

Measuring the radiation balance accurately is fundamental in quantifying the radiative forcing of the system as well as diagnosing the radiative properties of the atmosphere and surface, which are crucial for understanding radiative feedback processes. At the top of the atmosphere, satellites provide excellent spatial coverage but poorer temporal sampling. The reverse is true at the surface with only a limited number of high-quality point measurements but with excellent temporal coverage.

3.4.4.1 Top-of-Atmosphere Radiation

One important development since the TAR is the apparent unexpectedly large changes in tropical mean radiation flux reported by ERBS (Wielicki et al., 2002a,b). It appears to be related in part to changes in the nature of tropical clouds (Wielicki et al., 2002a), based on the smaller changes in the clear-sky component of the radiative fluxes (Wong et al., 2000; Allan and Slingo, 2002), and appears to be statistically distinct from the spatial signals associated with ENSO (Allan and Slingo, 2002; Chen et al., 2002). A recent reanalysis of the ERBS active-cavity broadband data corrects for a 20 km change in satellite altitude between 1985 and 1999 and changes in the SW filter dome (Wong et al., 2006). Based upon the revised (Edition 3_Rev1) ERBS record (Figure 3.23), outgoing LW radiation over the tropics appears to have increased by about 0.7 W m^{-2} while the reflected SW radiation decreased by roughly 2.1 W m^{-2} from the 1980s to 1990s (Table 3.5).

These conclusions depend upon the calibration stability of the ERBS non-scanner record, which is affected by diurnal sampling issues, satellite altitude drifts and changes in calibration following a three-month period when the sensor was powered off (Trenberth, 2002). Moreover, rather than a trend, the reflected SW radiation change may stem mainly from a jump in late 1992 in the ERBS record that is also observed in the ISCCP (version FD) record (Zhang et al., 2004c) but not in the AVHRR Pathfinder record (Jacobowitz et al., 2003). However, careful inspection of the sensor calibration revealed no known issues that can explain the decadal shift in the fluxes despite corrections to the ERBS time series relating to diurnal aliasing and satellite altitude changes (Wielicki et al., 2002b; Wong et al., 2006).

As noted in Section 3.4.3, the low-latitude changes in the radiation budget appear consistent with reduced cloud fraction from ISCCP. Detailed radiative transfer computations, using ISCCP cloud products along with additional global data sets, show broad agreement with the ERBS record of tropical radiative fluxes (Hatzianastassiou et al., 2004; Zhang et al., 2004c; Wong et al., 2006). However, the decrease in reflected SW radiation from the 1980s to the 1990s may be inconsistent with the increase in total and low cloud cover over oceans reported by surface observations (Norris, 2005a), which show increased low cloud occurrence. The degree of inconsistency, however, is difficult to ascertain without information on possible changes in low-level cloud albedo.

While the ERBS satellite provides the only continuous long-term top-of-atmosphere (TOA) flux record from broadband active-cavity instruments, narrow spectral band radiometers have made estimates of both reflected SW and outgoing LW radiation trends using regressions to broadband data, or using radiative transfer theory to estimate unmeasured portions of the spectrum of radiation. Table 3.5 shows the 1980s to 1990s TOA tropical mean flux changes for the ERBS Edition 3 data (Wong et al., 2006), the HIRS Pathfinder data (Mehta and Susskind, 1999), the AVHRR Pathfinder data (Jacobowitz et al., 2003) and the ISCCP FD data (Zhang et al., 2004c).

The most accurate of the data sets in Table 3.5 is believed to be the ERBS Edition 3 Rev 1 active-cavity wide field of view data (Wielicki et al., 2005). The ERBS stability is estimated as better than 0.5 W m^{-2} over the 1985 to 1999 period and the spatial and temporal sampling noise is less than 0.5 W m^{-2} on annual time scales (Wong et al., 2006). The outgoing LW radiation changes from ERBS are similar to the decadal changes in the HIRS Pathfinder and ISCCP FD records, but disagree with the AVHRR Pathfinder data (Wong et al., 2006). The AVHRR Pathfinder data also do not support the TOA SW radiation trends. However, calibration issues, conversion from narrow to broadband, and satellite orbit changes are thought to render the AVHRR record less reliable for decadal changes compared to ERBS (Wong et al., 2006). Estimates of the stability of the ISCCP time series for long-term TOA flux records are 3 to 5 W m^{-2} for SW radiative flux and 1 to 2 W m^{-2} for LW radiative flux (Brest et al., 1997), although the time series agreement of the ISCCP and ERBS records are much closer than these estimated calibration drift uncertainties (Zhang et al., 2004c).

The changes in SW radiation measured by ERBS Edition 3 Rev 1 are larger than the clear-sky flux changes due to humidity variations (Wong et al., 2000) or anthropogenic

radiative forcing (see Chapter 2). If correct, the large decrease in reflected SW radiation with little change in outgoing LW radiation implies a reduction in tropical low cloud cover over this period. However, specific information on cloud radiative forcing is not available from ERBS after 1989 and, as noted in Section 3.4.3, surface data sets suggest an increase in low cloud cover over this period.

Since most of the net tropical heating of 1.4 W m^{-2} is a decrease in reflected SW radiative flux, the change implies a similar increase in solar insolation at the surface that, if unbalanced by other changes in surface fluxes, would increase the amount of ocean heat storage. Wong et al. (2006) showed that the changes in global net radiation are consistent with a new ocean heat-storage data set from Willis et al. (2004; see Chapter 5 and Figure 5.1). Differences between the two data sets are roughly 0.4 W m^{-2}, in agreement with the estimated annual sampling noise in the ocean heat-storage data.

Using astronomical observations of visible wavelength solar photons reflected from parts of the Earth to the moon and then back to the Earth at a surface-based observatory, Pallé et al. (2004) estimated a dramatic increase of Earth-reflected SW radiative flux of 5.5 W m^{-2} over three years. This is unlikely to be real, as over the same time period (2000–2003), the Clouds and the Earth's Radiant Energy System (CERES) broadband data indicate a decrease in SW radiative flux of almost 1 W m^{-2}, which is much smaller and the opposite sign (Wielicki et al., 2005). In addition, changes in ocean heat storage are more consistent with the CERES data than with the Earthshine indirect observation.

The only long-term time series (1979–2001) of energy divergence in the atmosphere (Trenberth and Stepaniak, 2003b) are based on NRA, which, although not reliable for depicting trends, are reliable on interannual times scales for which they show substantial variability associated with ENSO. Analyses by Trenberth and Stepaniak (2003b) reveal more divergence of energy out of the deep tropics in the 1990s compared with the 1980s due to differences in ENSO, which may account for at least some of the changes discussed above.

In summary, although there is independent evidence for decadal changes in TOA radiative fluxes over the last two decades, the evidence is equivocal. Changes in the planetary and tropical TOA radiative fluxes are consistent with independent global ocean heat-storage data, and are expected to be dominated by changes in cloud radiative forcing. To the extent that they are real, they may simply reflect natural low-frequency variability of the climate system.

3.4.4.2 Surface Radiation

The energy balance at the surface requires net radiative heating to be balanced by turbulent energy fluxes and thus determines the evolution of surface temperature and the cycling of water, which are key parameters of climate change (see Box 7.1). In recent years, several studies have focused on observational evidence of changing surface radiative heating.

Figure 3.23. *Tropical mean (20°S to 20°N) TOA flux anomalies from 1985 to 1999 (W m^{-2}) for LW, SW, and NET radiative fluxes [NET = –(LW + SW)]. Coloured lines are observations from ERBS Edition 3_Rev1 data from Wong et al. (2006) updated from Wielicki et al. (2002a), including spacecraft altitude and SW dome transmission corrections.*

Reliable SW radiative measurement networks have existed since the 1957–1958 International Geophysical Year.

A reduction in downward solar radiation ('dimming') of about 1.3% per decade or about 7 W m^{-2} was observed from 1961 to 1990 at land stations around the world (Gilgen et al., 1998; Liepert, 2002). Additional studies also found declines in surface solar radiation in the Arctic and Antarctic (Stanhill and Cohen, 2001) as well as at sites in the former Soviet Union (Russak, 1990; Abakumova et al., 1996), around the Mediterranean Sea (Aksoy, 1997; Omran, 2000), China (Ren et al., 2005), the USA (Liepert, 2002) and southern Africa (Power and Mills, 2005). Stanhill and Cohen (2001) claim an overall globally averaged reduction of 2.7% per decade but used only 30 records. However, the stations where these analyses took place are quite limited in domain and dominated by large urban areas, and the dimming is much less at rural sites (Alpert et al., 2005) or even missing altogether over remote areas, except for

Table 3.5. *Top-of-atmosphere (TOA) radiative flux changes from the 1980s to 1990s (W m^{-2}). Values are given as tropical means (20°S to 20°N) for the 1994 to 1997 period minus the 1985 to 1989 period. Dashes are shown where no data are available. From Wong et al. (2006).*

	Radiative Flux Change (W m^{-2})		
Data Source	TOA LW	TOA SW	TOA Net
ERBS Edition 3 Rev 1	0.7	–2.1	1.4
HIRS Pathfinder	0.2	–	–
AVHRR Pathfinder	–1.4	0.7	0.7
ISCCP FD	0.5	–2.4	1.8