P3.6: CERES SYNOPTIC GRIDDED DIURNALY RESOLVED RADIATIVE TRANSFER

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1. Introduction

Each satellite with CERES instruments typically provides a single daylight and a single nighttime observation (TERRA 1030L and 2230L, AQUA 0130L and 1330L) of TOA (top of atmosphere) longwave and shortwave flux per day. Diurnal and synoptic variability in clouds make it desirable to bring in geostationary satellite data to provide, daily and monthly cloud and flux products of sufficient accuracy. Here we will briefly describe: 1) Method used to calibrate, provide narrowband to broadband conversion and normalization to CERES fluxes. 2) Geostationary satellite derived cloud products. 3) Radiative transfer used to diurnally model the TOA, surface and in atmosphere broadband fluxes.

2.Synoptic Diurnal Simulation

The sun-snychronous TERRA satellite, with CERES accurate TOA flux measurements and MODIS multi-wavelength cloud properties, observes most of the globe twice a day. To provide an accurate diurnal cycle and capture synoptic changes in clouds, three hourly geostationary data data from multiple satellites (which lack CERES and MODIS) are used when TERRA is not available. Near the poles, where there is no geostationary coverage, TERRA data alone give multiple observations daily. We introduce a preliminary version of the of the CERES SYNI (**SYN**optic **I**nterpolated) Edition2 product, which includes consistent top-of-the atmosphere (TOA) to surface (SFC) radiative transfer, as in the sun-synchronous-only CRS product (Charlock et al. in this volume), but which also spans the diurnal cycle. Broadband radiative transfer computations are made hourly on a ~1 degree equal area grid containing 44012 grid boxes. Simple interpolation of cloud properties and observed TOA flux is done in between TERRA and geostationary measurements to give hourly input data. A completely independent SYNI product will combine AQUA and geostationary data with similar calculations.

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2.1 Geostationary Data

Multiple geostationary satellites (GOES, METEOSAT, GMS) are used to provide global coverage at 3hrly intervals. The CERES satellites have multiple observations per day near the poles, because of orbital inclination. Each geostationary satellite is calibrated monthly against matched angle observation of MODIS shortwave 0.63µ over oceans. Here spectral differences between MODIS and each of the SW GEO satellites are expected to be minimal. Geostationary thermal-IR ~11µ channels have their own on-board calibration.

Cloud properties of fraction, optical depth, height are determined using a method described by Minnis (1995), but particle size and phase are not retrieved in this geostationary visible & thermal infrared two channel scheme. The geostationary retrieval method is much simpler than the multi-channel retrieval used with MODIS data at times of CERES/MODIS overpass, where phase and particle size retrievals are possible.

Next conversion of calibrated narrowband radiances to broadband radiances is done. This is accomplished using a DISORT model based LUT on angles (solar, view, azimuth), surface type, ozone, cloud (fraction, phase, optical depth). Once broadband radiances are obtained, Angular Directional Models (ADM's) based on CERES TRMM are applied to give a broadband flux estimate.

It is acknowledged that this process will not give the same flux as a CERES observation so normalization is done based on all cloudy sky matches within a *five*-degree region having the same surface type. The normalization is in the form of a 2nd order polynomial fit to CERES fluxes over a month against the geostationary broadband flux obtained from the DISORT based narrowband to broadband conversion.

Clear sky TOA fluxes from geostationary satellites were found to be susceptible to the spectral nature of the surface, so monthly average CERES clear sky values moved to the appropriate sun angle by a diurnal model were used instead.

2.2 Radiative Transfer Method

One goal of the CERES project is to provide surface and in atmosphere fluxes consistent with the satellite observations made at TOA. To accomplish this we use the LaRC Fu-Liou radiative transfer model and constrain to observed TOA fluxes.

The LaRC Fu-Liou model (Rose and Charlock, 2002) consists of a gamma weighted two-stream shortwave and a 2/4 stream longwave using correlated-k's based on HITRAN 2000. The new Gamma Weighted Two Stream Algorithm (GWTSA) solver for shortwave, allows for horizontal inhomogeniety of the cloud optical depth to be modeled (Kato 2005).

Inputs of GMAO GEOS 4.0.3 skin temperature and vertical profiles of temperature and humidity, SMOBA ozone, MODIS (MOD04) aerosol optical depths and MATCH (Collins 2001) aerosol vertical profiles and constituents types tied to OPAC aerosol optical properties.

Surface spectral emissivity in the non-window is tied to IGBP type. Window (8-12μ) emissivities are a gridded monthly climatology from MODIS clear sky data (Minnis). The spectral albedo of the ice-free ocean is based on a lookup table to the well-validated Coupled Ocean Atmosphere Radiative Transfer Code (COART), using solar zenith angle, surface wind speed, and and the optical depth of clouds/aerosols (Jin et al., 2004). Surface spectral albedo *shape* for ice and snow are based on lookup tables to a similar code (Jin 1994), and they also use simple estimates of snow grain size from the ratio of .63μ/1.6μ TOA clear sky overhead sun albedo maps stored by the the CERES cloud algorithm.

Broadband surface albedo for non-ocean is derived from clear-sky TOA broadband albedo, corrected for atmosphere. The correction method uses a LaRC Fu-Liou look-up-table considering sun angle, aerosol optical depth and type, ozone, surface pressure and spectral albedo shape. Land (ie. non-snow, non-ocean) cloudy sky surface albedo is derived from the monthly minimum clear sky value moved to the diffuse angle using directional models. Cloudy snow/ice surface albedo for clouds that have optical depths less than ~20 use a TOA albedo based retrieval attempt, so that surface albedo will be consistent with cloud properties. In the case of cloud optical depth greater than 20, snow/ice albedo is taken from a COART look-up-table. Scene ID determinations of snow/ice are from NSIDC microwave maps, and secondarily by thresholds applied MODIS 0.63μ clear sky TOA overhead sun albedo maps.

There are four modes of fluxes output from model computations:

1) Pristine Sky (Clear, NO Aerosol)
2) Clear Sky (Clear, with Aerosol)
3) Total Sky (Clouds, with Aerosols)
4) "CNA" Sky (Clouds, NO Aerosols)

By differencing these calculations, estimates of the ***direct*** effect of aerosols on cloud forcing can be made. A problem with this approach is cloud retrievals using MODIS only account for a mean aerosol condition while geostationary cloud retrievals do not account for the presence of aerosols at all. To the extent that aerosols are not being retrieved as cloud, this method provides an estimate of the direct aerosol effect.

3. Preliminary Results

The data presented here is **preliminary** and has not undergone validation. Official release ("Editions") of the CERES SYN and AVG products are expected within a year. The month July 2002 was used for algorithm testing.

Two primary outputs are the untuned TOA shortwave and longwave fluxes. These parameters give a check on how well model computations using all inputs match observations. For TOA shortwave the global monthly bias untuned minus obs is +2.4 Wm^{-2} with a regional standard deviation of 6.0 Wm^{-2}. Longwave bias is +0.73 Wm^{-2} with a regional standard deviation of 4.1 Wm^{-2}

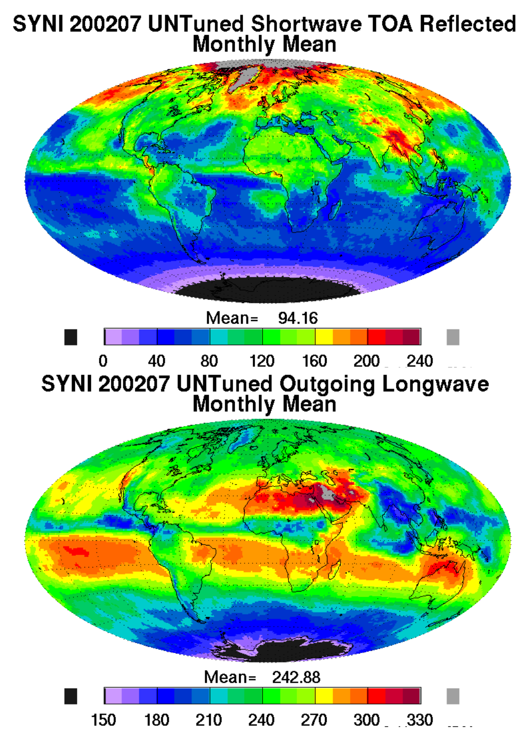

Fig 1: Plots of monthly mean LaRC Fu-Liou untuned computation a) TOA shortwave reflected[Wm^{-2}] b) TOA outgoing longwave[Wm^{-2}], using CERES/MODIS and multiple geostationary satellite cloud and flux observations.

Surface flux plots of shortwave and longwave downwelling are shown in (fig 2). At this point validation over sites with surface radiometry has not been done. Plans are to use CERES ARM Validation Experiment (CAVE) data, a collection of several groups radiometry, aerosol and cloud observations

Global maps of shortwave cloud forcing at the top of atmosphere and at the surface are shown for the no aerosol case “CNA”. Here the global mean TOA value is 44.9 Wm^{-2}. For the case of including aerosol the shortwave TOA cloud forcing is 42.6 Wm^{-2}, giving a difference in TOA shortwave cloud forcing due to aerosol of -2.3 Wm^{-2}. At the surface the shortwave cloud forcing without aerosol is -53.6 Wm^{-2} while with aerosol it is –50.8 Wm^{-2}, a difference of +2.8 Wm^{-2}. An interpretation of this (i.e., of direct aerosol forcing in cloudy sky) is that aerosols are reflecting some of the radiation that otherwise would have been reflected by clouds, and preventing it from reaching the surface by aerosol reflection or absorption. Some interpretations of the effects of aerosols with this data can be confounded by the retrieved values for cloud properties, which (unlike the flux calculations) do not explicitly account for geograhical and temporal variations in aerosol scattering and absorption.

Fig 2, Global plots of monthly mean LaRC Fu-Liou computation of untuned a) Surface shortwave downwelling[Wm^{-2}] b) Surface longwave downwelling[Wm^{-2}], using CERES/MODIS and Geostationary cloud and flux observations.

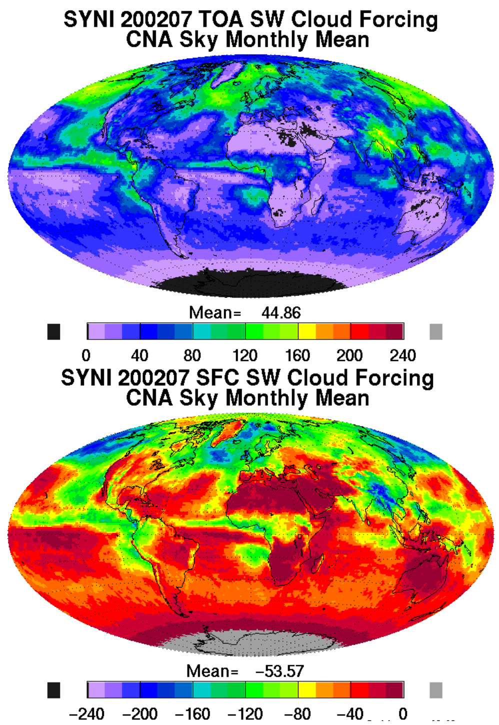

Fig 3, Global monthly mean plots of a)Top of Atmosphere (TOA) shortwave cloud forcing [Wm^{-2}] without aerosols included in model computations. b)Surface shortwave cloud forcing[Wm^{-2}] without aerosols.

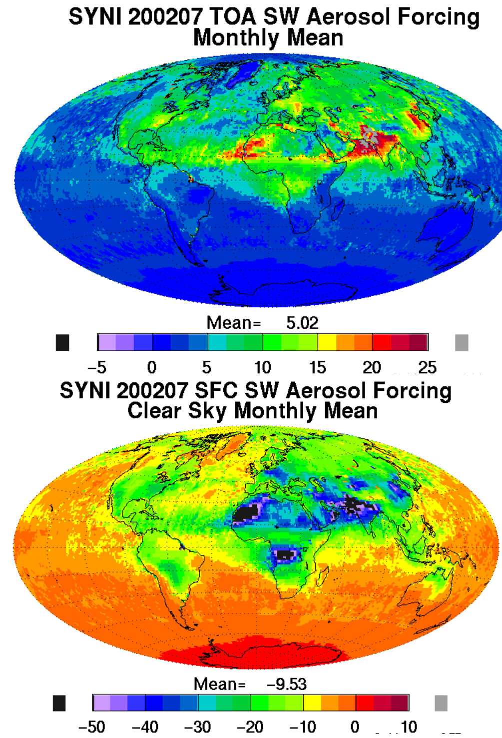

Fig 4, Global monthly mean plots of a)Top of Atmosphere (TOA) shortwave b) Surface shortwave: aerosol forcing[Wm^{-2}] without clouds included in model computations. (Method II clear sky)

Another way to look at aerosol forcing from model computations is a method II differencing of model clear sky (with aerosol) minus pristine sky (no aerosol) regardless of the occurrence of clouds. Here positive TOA SW forcing occurs in regions of large aerosol optical depth, especially over regions with low surface albedo. Over the high surface albedo of Greenland, the absorbing nature of the aerosol, cause TOA SW forcing to go slightly negative.

In figure 5, longwave flux profiles over 744 hours of the month of July 2002 a for a single ocean grid box, are shown. The effects of clouds can be seen reducing OLR and increasing DLF. In the middle of the time series (near hour 186), a clear period having reduced mid-troposphere humidity results in increased OLR, decreased DLF in the 200-700hpa region, with increased DLF near the surface.

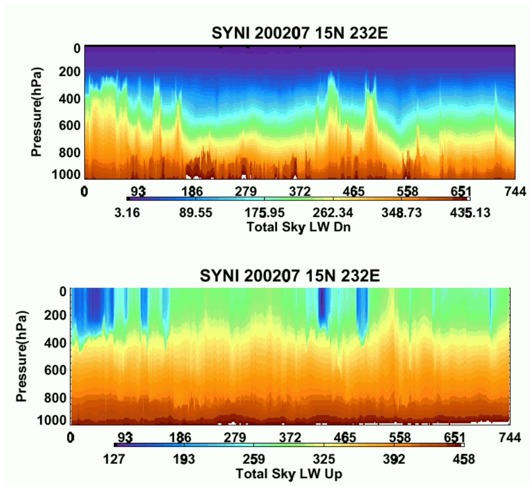

Fig. 5 Example time (hr) vs. height (hPa) plot of total sky longwave upwelling[Wm^{-2}] (top) and total sky longwave downwelling[Wm^{-2}] for July 2002 for grid box in pacific ocean (15N,232E)

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