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Perturbation Analysis of TOA and Surface Fluxes using Fu-Liou model with CERES, MODIS, GEOS 5.4.1, and MATCH data

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Introduction

Radiative kernels have been used to estimate feedbacks due to water vapor, lapse rate, surface albedo and cloud property changes (e.g. Soden et al. 2008). The approach uses pre-computed top-of-atmosphere (TOA) broadband irradiance changes by the perturbation of these properties. Once atmospheric changes are known from climate model outputs, the contribution to the TOA irradiance by these properties can be computed. A similar approach can be used to estimate contribution of surface, atmospheric and cloud properties to observed TOA (Loeb et al. 2012) and surface irradiance monthly anomalies in order to understand how these properties contribute month-to-month variability of TOA and surface irradiances.

•In this study, we use a framework of CERES data production and perturb surface, atmospheric and cloud properties to determine the contribution to the TOA and surface irradiance monthly anomalies.

Objectives

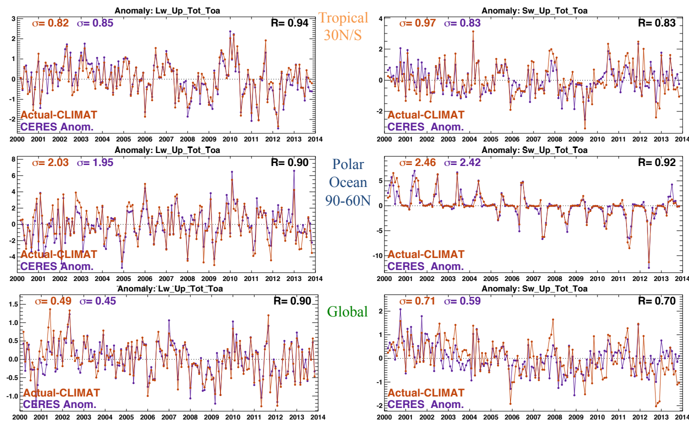
Plots and tables displaying the monthly variability of TOA and surface irradiances as caused by individual inputs and input groups are shown. In particular, how the contribution of surface, atmospheric and cloud property variability to TOA and surface irradiance variability changes depend on ENSO phase are investigated. In addition, the contribution to TOA and surface irradiance variability over the Arctic ocean region is investigated.

Method

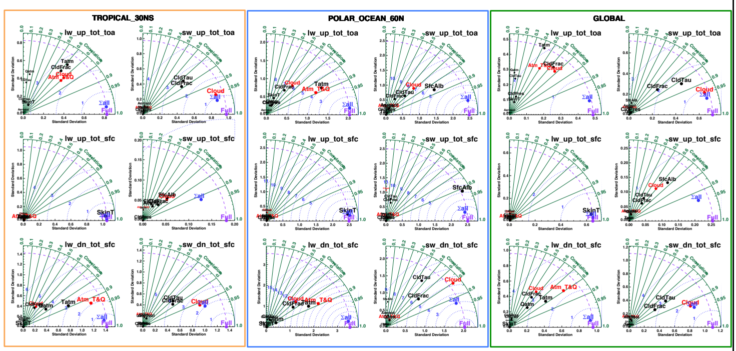
We use fourteen years (2000-2013) of gridded CERES, MODIS, and MATCH data. Canonical monthly means are formed from CERES SW, LW irradiances, GEOS 5.4.1 temperature and humidity and ozone profiles, MODIS based cloud properties, MATCH aerosol optical depth, as well as surface albedo and surface skin temperature. The LaRC modified version of the Fu-Liou broadband radiative transfer code is run using A) Canonical climotological means of all inputs B) Selecting individually inputs as climotological values keeping all others as actual monthly means. C) Actual monthly mean values for all inputs. The inputs that are perturbed in this study are 1) Profile of Temperature,2) Profile of Humidity,3) Skin temperature, 4) Cloud Fraction, 5) Cloud Top Pressure, 6) Cloud Optical Depth, 7) Surface Albedo, 8) Aerosol Optical depth. Individual perturbations are further grouped into 9) All cloud properties, 10) Temperature and Humidity profile. Note that radiative kernels used in this analysis changes depending on monthly gridded atmospheric states, as opposed to pre-computed, i.e. fixed, kernels throughout the time period of the analysis. Global and Tropical 30N/S and Polar Ocean 90-60N mean of the monthly gridded runs are formed. The sum of computed perturbations of TOA irradiances are evaluated by comparing the standard deviation of anomalies with CERES-derived TOA irradiance anomalies, as well as using the correlation coefficient. Individual perturbations are further grouped into cloud, atmosphere and surface property contributions for the analysis. The sum of surface irradiances perturbations are evaluated by comparing against the modeled irradiances with observed inputs. Shortwave monthly mean computations are run at the mean of the 50% highest and 50% lowest solar zenith angles over the course of the daytime month. Breaking the computation up into two mean SZAs increases the accuracy of the shortwave computation.

Results

•Monthly anomaly time series plots for tropical domain showing CERES observed (blue) and model monthly mean computations (red) for longwave emitted (left) and shortwave reflected (right) top-of-atmosphere irradiance (Wm^{-2}). Length of record is from March 2000 to November 2013. Similar standard deviations and large correlation are a metric of the fidelity of the monthly mean Fu-Liou computations.



•Standard deviations and absolute values of cross-correlations for 6 Fu-Liou Model output parameters (LW TOA UP, SW TOA UP, LW SFC UP, SW TOA DN, LW SFC DN, SW SFC UP) as deseasonalized anomalies for individual variable perturbations and grouped variable perturbations for domains of Left) Tropical 30NS, Center) Polar Ocean 60N-90N, Right) Global are shown as Taylor diagrams.



• Table: Domain Tropics 30NS. showing correlation of ENSO index with CERES TOA observed SW and LW irradiances as well a Fu-Liou monthly mean anomalies correlations for 6 Fu-Liou Model output parameters (LW TOA UP, SW TOA UP, LW SFC UP, SW TOA DN, LW SFC DN, SW SFC UP) for individual variable perturbations and grouped variable perturbations runs.

Correlation(ObsxENSO):

lw_up_tot_toa	0.53
sw_up_tot_toa	-0.19

Correlation(ModelxENSO):	Full	Atm_T&Q	Cloud	Tatm	Qatm	SkinT	CldPres	CldFrac	CldTau	SfcAlb	Aerosol
lw_up_tot_toa	0.48	0.32	0.23	0.58	-0.51	0.68	-0.15	0.26	0.04	0	0
sw_up_tot_toa	-0.20	-0.34	-0.24	-0.44	-0.33	0	-0.09	-0.2	-0.15	0.28	-0.05
lw_dn_tot_sfc	0.63	0.68	0.05	0.76	0.36	0.69	-0.13	0.08	-0.09	0	0
lw_up_tot_sfc	0.77	0.45	-0.05	0.60	0.14	0.77	-0.07	0.08	-0.05	0	-0.09
sw_dn_tot_sfc	0.06	-0.45	0.22	-0.50	-0.44	0	0.28	0.17	0.16	0.15	-0.12
sw_up_tot_sfc	0.12	-0.17	0.26	-0.43	-0.16	0	0.32	0.18	0.21	0.26	-0.05

Conclusions

•Monthly mean radiation transfer computations using the Langley Fu-Liou code with GMAO assimilation products and CERES/MODIS cloud properties and Match aerosols can with reasonable fidelity reproduce the regional and global **variability** seen from CERES TOA broadband flux observations.

•Biases compared to CERES observations are present in the Model monthly mean computations of a few percent (not shown)

• The radiative perturbation method is useful to isolate the physical properties that are responsible for variability of TOA and surface irradiances.

•The variability and secular decrease in sea ice over the past 14 years is evident in TOA and Surface Shortwave via the effect on surface albedo.

•ENSO index is well correlated with Sfc Lw Dn primarily through variability in atmospheric temperature.

References

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See talk by Norman Loeb: **LJ7.3 Observing Recent Cloud and Radiation Budget Changes over the Arctic** Tuesday, 8 July 2014: 9:15 AM