P3.16 Surface Radiation Budget Over Pacific and Atlantic: Interannual Variability

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1. INTRODUCTION

A 21.5-year (July 1983 to December 2004) global dataset of surface shortwave (SW) and longwave (LW) radiative parameters on a 1°x1° grid was recently completed under the NASA/GEWEX Surface Radiation Budget (SRB) Project at the NASA Langley Research Center (LaRC; Stackhouse et al. 2004). Both SW and LW surface fluxes were derived with two sets of radiation algorithms: one set designated as primary and the other as quality-check. Several top-of-atmosphere (TOA) radiation budget parameters were also derived with the primary algorithms. Surface fluxes from all algorithms were extensively validated with ground-based measurements obtained from the Baseline Surface Radiation Network (BSRN), the SURFace RADiation (SURFRAD) network, and the Global Energy Balance Archive (GEBA). This dataset is identified as SRB Release-2.5 and will be shortly made available to the science community. A predecessor dataset covering the period July 1983 to October 1995 and designated as Release-2.0 is already available to the science community at – http://eosweb.larc.nasa.gov/PRODOCS/srb/table_srb.html.

Detailed analysis and validation of this dataset is being presented in accompanying papers at this conference. The purpose of the present study is to advance the validation objective by determining if the dataset was able to capture the variability associated with global and regional interannual phenomena, such as the El Nino/La Nina episodes and North Atlantic Oscillation (NAO) phases that occurred during its period. The predecessor dataset was used to examine interannual phenomena of 1980s and early 1990s. The primary focus here was to extend that study to late 1990s and beyond and examine anomalies of surface radiative fluxes and certain meteorological inputs corresponding to the strong 1997-98 El Nino, the following La Nina, and strong NAO phases of mid and late 1990s. The 1997-98 El Nino peaked around January 1998 and the following La Nina peaked around December 1999. Strong positive and negative phases of NAO occurred in 1995 and 1996 respectively. Surface and corresponding TOA flux anomalies associated with Mt. Pinatubo eruption were also examined.

2. RADIATION MODELS AND INPUT DATA

The NASA/GEWEX SRB (hereafter GEWEX/SRB) project makes use of two sets of algorithms. One set of SW and LW algorithms is designated as primary, and the other set designated quality-check as follows: the primary SW algorithm is Pinker and Laszlo (1992); the primary LW algorithm is an adaptation of Fu et al. (1997) by P. Stackhouse; the quality-check SW algorithm is known as the Langley Parameterized Shortwave Algorithm (LPSA; Gupta et al. 2001); and the quality-check LW algorithm is Gupta et al. (1992). For detailed descriptions of these algorithms, the reader is referred to the references cited above. Meteorological inputs for this project were obtained from many satellite data archives and data assimilation products. Cloud properties were derived on a 1°x1° resolution using International Satellite Cloud Climatology Project (ISCCP; Rossow and Schiffer 1999) pixel-level (DX) datasets. Other meteorological input, namely, the temperature and humidity profiles were taken from GEOS-4 reanalysis product (Bloom et al. 2005) of the Global Modeling and Assimilation Office (GMAO) at NASA Goddard Space Flight Center (GSFC). Ozone data were

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taken primarily from the Total Ozone Mapping Spectrometer (TOMS) archive. Gaps in TOMS ozone fields, including those over unlit polar areas, were filled with data from the TIROS Operational Vertical Sounder (TOVS) archive.

3. RESULTS AND DISCUSSION

Figure 1 shows the anomalies of downward SW flux (DSF) and downward LW flux (DLF) for the January 1998 El Nino over western Pacific (120E-180; 20S-20N) and eastern Pacific (180-120W; 20S-20N) regions. Corresponding anomalies in surface temperature (Ts), column water vapor (WV in kgm^{-2}), and total cloud amount are shown in Fig.2. These anomalies were

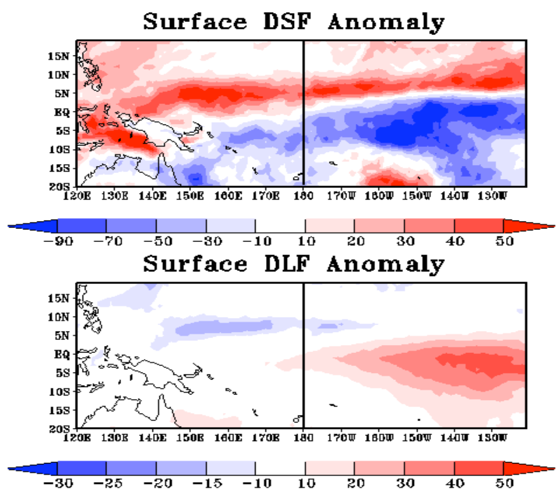

Fig. 1. Surface flux anomalies for January 1998.

computed relative to 21-year averages for the month of January (1984-2004). The distributions show that SW anomalies are driven primarily by cloud amount anomalies even though water vapor anomalies also have a smaller effect. The anomalies indicate a movement of convective activity from western to eastern Pacific during the El Nino. The patterns of LW anomalies are only weakly similar to those for SW. Increased cloud amounts in E. Pacific give rise to a strong positive anomaly, but decreased cloud amounts and even lower WV in the W. Pacific have only a small effect of LW fluxes. LW anomalies are also affected by increased T_s in the E. Pacific. The DSF and DLF anomalies have opposite signs though DSF magnitudes are much larger. The flux anomalies for the December 1999 La Nina

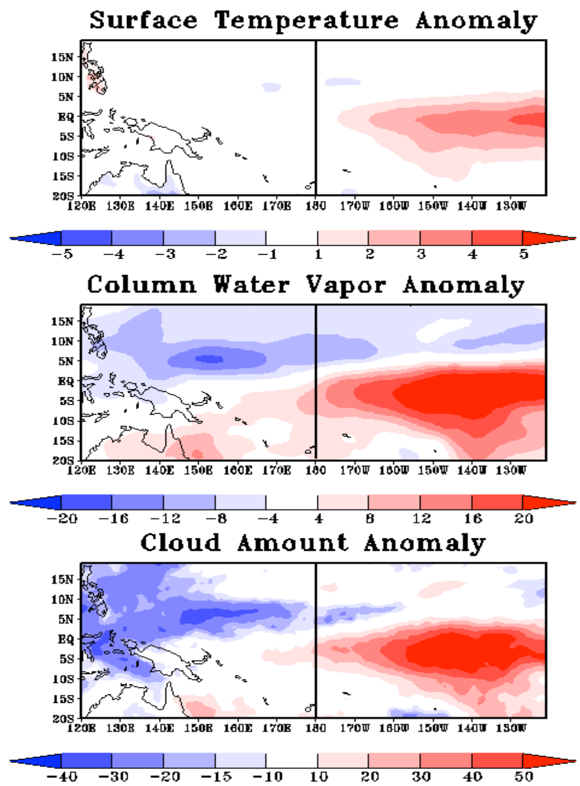

Fig. 2. Anomalies of meteorological variables corresponding to the January 1998 El Nino.

shown in Fig. 3 present a picture largely opposite of that in Fig. 1. The strong positive anomaly in DSF and negative anomaly in DLF are driven mainly by cloud amount anomalies with smaller

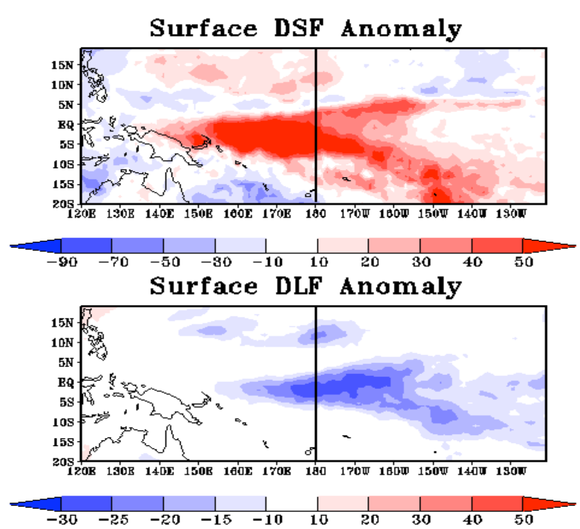

Fig. 3. Surface flux anomalies for Dec. 1999.

contributions from changes in WV and T_s. Corresponding anomalies of meteorological variables for December 1999 are not shown here but follow the same relationship between flux and meteorology anomalies.

Surface flux anomalies derived for the May 1987 El Nino and July 1988 La Nina episodes from the predecessor (Release-2.0) dataset, similar to those shown in Figs. 1 and 3, were compared with corresponding TOA anomalies derived from Earth Radiation Budget Experiment (ERBE) scanner measurements (Gupta et al. 2005). Strong correspondence in SW and moderate correspondence in LW between TOA and surface anomalies, as was to be expected from theoretical considerations, was observed. This constituted a strong test of the verity of surface flux datasets. Similar comparisons will be undertaken with the present (Release-2.5) dataset in the near future.

Figure 4 shows the deseasonalized anomalies of DSF (top) and DLF (middle), relative to multivariate ENSO index (bottom) for 1983 to 2004. The flux anomalies show curves for global averages and those for western and eastern Pacific regions separately. Both DSF and DLF time series show strong correlation with the ENSO

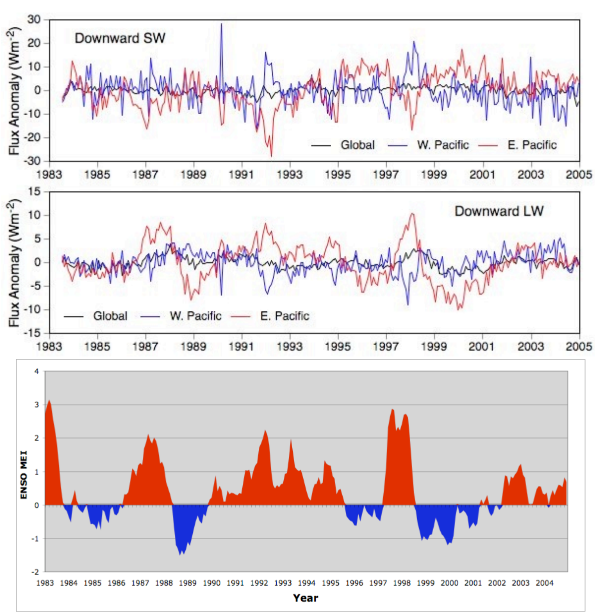

Fig. 4. Time series of deseasonalized anomalies of DSF and DLF averaged over the globe, and western and eastern Pacific regions. Multivariate ENSO index is also shown.

index, though the DLF signal is stronger in relative terms. The SW curves show positive anomalies in W. Pacific and negative anomalies in E. Pacific for all El Nino episodes related to the movement of convective activity from west to the east. The La Nina episodes have the opposite effect. The LW effects have the opposite sign but are smaller in magnitude. Among the two regions of the Pacific, the signal for the eastern Pacific is stronger than for the western Pacific.

Figure 5 shows surface DLF anomalies over north Atlantic region for a positive phase of NAO in 1995 and the following negative phase in 1996. During positive phase of NAO, the subtropical highs get stronger and the Icelandic lows get deeper forcing the north Atlantic storms on a more northerly track. This results in colder and drier winters in northern Canada and Greenland, and warmer and wetter winters over central and northern Europe. The opposite happens during

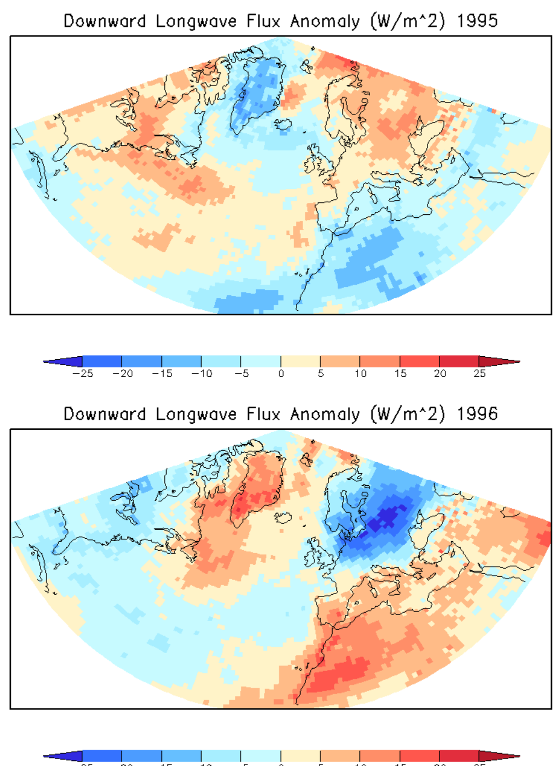

Fig. 5. Surface DLF anomalies over North Atlantic region for a positive NAO phase during winter of 1995 (top) and for a negative phase during winter of 1996 (bottom). Winter season for NAO is considered from December of the previous year to March of the current year.

the negative NAO phase. The top panel shows a positive DLF anomaly over Europe and a negative anomaly over Greenland. Both panels show that LW flux anomalies respond as expected to the environmental changes.

Figure 6 shows the time-series of deseasonalized anomalies for DSF (top) and TOA reflected SW flux (bottom) averages over the globe and the tropical region (20S-20N). These anomalies clearly indicate the effect of Mt. Pinatubo eruption which built up after the June 1991 eruption and slowly decayed over the next 18 months. As expected, the signals indicating the increase of reflected SW flux and the decrease of DSF are relatively stronger for the tropical averages than for the global averages.

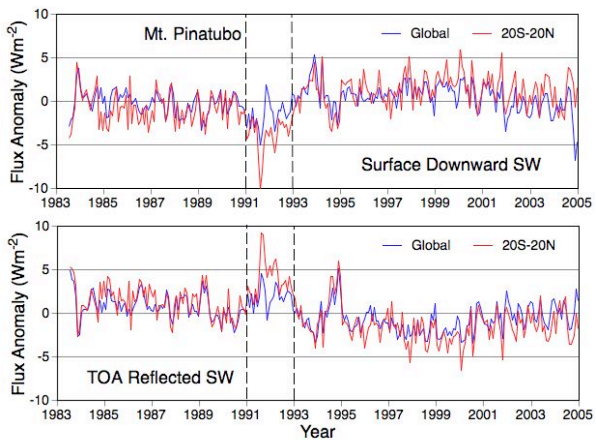

Fig. 6. Time series of deseasonalized anomalies of DSF and TOA reflected SW flux averaged over the globe and the tropics (20N-20S) showing the effect of Mt. Pinatubo eruption.

4. CONCLUDING REMARKS

A 21.5 (July 1983-December 2004) dataset of SRB parameters on a 1°x1° grid has been developed recently at LaRC under the NASA/GEWEX Surface Radiation Budget project. This dataset was used to examine the anomalies of SW and LW fluxes associated with the interannual phenomena which occurred during the period of the dataset. The DSF and DLF anomalies over the western and eastern Pacific regions clearly showed signals to the January 1998 El Nino and the December 1999 La Nina. This also confirms studies on El Nino and La Nina episodes of 1980s and early 1990s performed with the predecessor dataset. Anomalies also responded well to the positive and negative phases of NAO over north Atlantic and to the Mt. Pinatubo eruption of 1991.

REFERENCES

Bloom, S., A. da Silva, D. Dee, M. Bosilovich, J-D. Chern, S. Pawson, S. Schubert, M. Sienkiewicz, I. Stanjer, W-W. Tan, and M-L. Wu, 2005: Documentation and validation of the Goddard Earth Observing System (GEOS) Data Assimilation System – Version 4. *NASA/TM-2005-104606*, Vol. 26, 187 pp.

Fu, Q., K. N. Liou, and A. Grossman, 1997: Multiple scattering parameterization in thermal infrared radiative transfer. *J. Atmos. Sci.*, **54**, 2799-2814.

Gupta, S. K., W. L. Darnell, and A. C. Wilber, 1992: A parameterization for longwave surface radiation from satellite data: Recent improvements. *J. Appl. Meteor.,* **31**, 1361-1367.

_____, D. P. Kratz, P. W. Stackhouse Jr., and A. C. Wilber, 2001: The Langley Parameterized Shortwave Algorithm (LPSA) for surface radiation budget studies (Version 1.0). *NASA/TP-2001-211272*, 31 pp. Available on-line at: http://techreports.larc.nasa.gov/ltrs/ltrs.html

_____, P.W. Stackhouse Jr., S. J. Cox, J. C. Mikovitz, M. Chiacchio, and Taiping Zhang, 2005: Interannual variability of surface radiation budget.. Proceedings of the16th Conference on Climate Variability and Change, San Diego, California, 9-13 January 2005.

Pinker, R., and I. Laszlo, 1992: Modeling surface solar irradiance for satellite applications on a global scale. *J. Appl. Meteor.*, **31**, 194-211.

Rossow, W. B., and R. A. Schiffer, 1999: Advances in understanding clouds from ISCCP. *Bull. Amer. Meteor. Soc.*, **80**, 2261-2287.

Stackhouse, P. W., S. K. Gupta, S. J. Cox, J. C. Mikovitz, T. Zhang, and M. Chiacchio, 2004: 12-Year Surface Radiation Budget Data Set. *GEWEX News*, Vol. 14, 10-12, November 2004.