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Top-of-atmosphere Radiation Budget and Global Mean Sea Surface Temperature

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1. Objectives

Amount of atmospheric major components such as nitrogen, oxygen, argon depends on the sea water temperature through solubility and biogenic activity . Depth, extent and cause of temperature change related to interannual variations of the climate system are not known well.

An attempt was made to estimate ocean depth using top-of-atmosphere radiation imbalance and sea surface temperature without using ocean interior data.

ACRONIMS:
RT: Top-of-atmosphere net downward radiation
SST: Sea surface temperature
GMST: Global mean sea surface temperature
ASR: Absorbed solar radiation
OLR: Outgoing longwave radiation

2. Data and Method

Top-of-atmosphere radiation fields:
The Cloud and the Earth's radiant energy system; CERES_EBAF_2.8 (Loeb et al., 2009). ASR-OLR=RT
Sea surface temperature of Hadley Centre; HadISST(Rayner et al.,2003)
Monthly mean: Analysis period: 2000. March – 2013. December
3-1. Decomposition in frequency bands.
FFT, Mean, SD: Inter-annual, annual, semi-annual, sub-semi-annual
3-2. Decompositions in seasonal cycle and anomaly
Lag-correlation RT vs GMST
3-3. Month to month variations of SST and RT
Lag-correlation RT and d(SST)/dm
3-4. Inter-annual variations
Lag-correlation RT and d(SST)/dm, 12 month running mean
4-1. GMST next year may be predicted with RT this year
Liner regression RT and d(SST)/dY
4-2. Why GMST does not contribute to RT ?
Correlations and regression coefficients of OLR and ASR

3. Results

3.1 Decomposition in frequency bands

Fig.1 Mean (up) and standard deviations (SD: down) of RT (left) SST (right). Note that high mean RT is observed on the high SST indicating ASR overwhelms high OLR due to high SST. Also note that RT has less variances in the Tropics compared to extratropics.

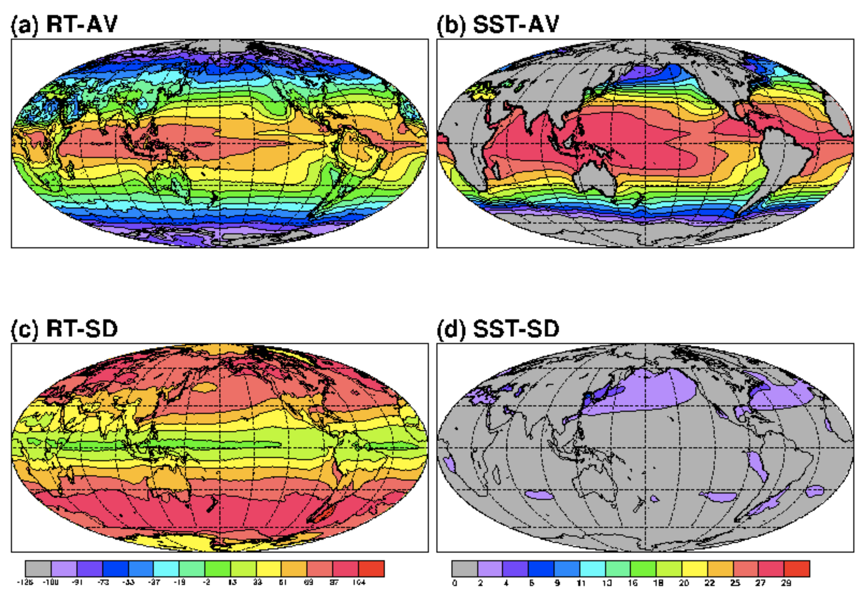


Fig.2 Power spectra of SST in inter-annual, annual, semi-annual and sub-semi-annual. El-Niño is a major component in the Tropics.

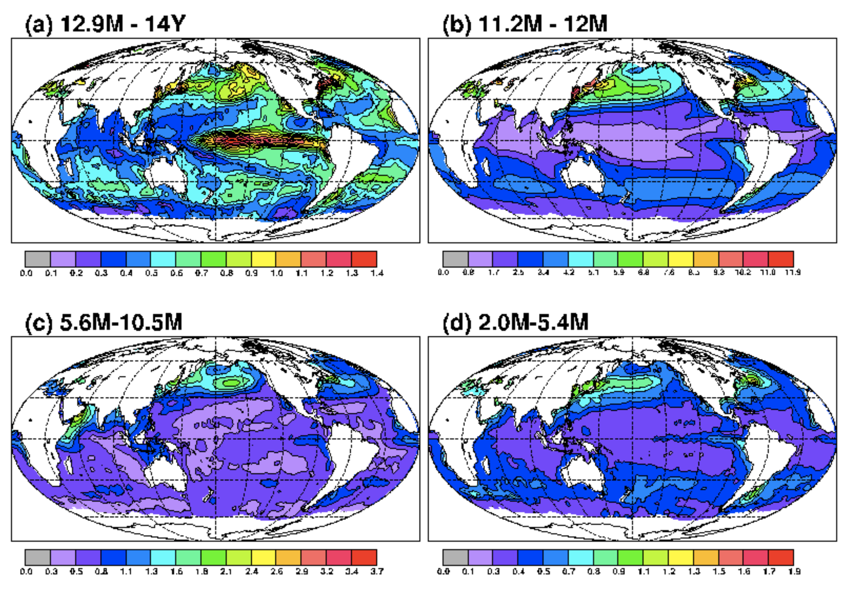
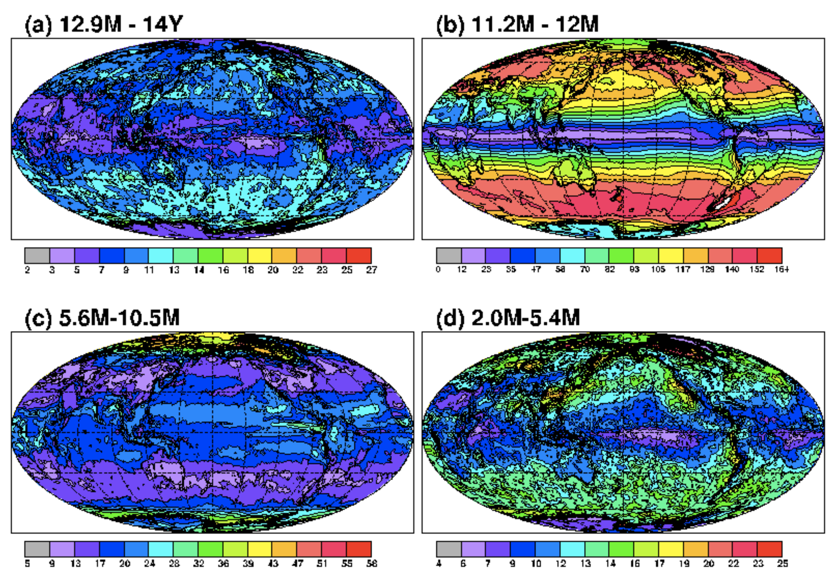


Fig.3 Same as Fig.2, except for RT. Note less powers in the Tropics as compared to extratropics for all frequency bands, except for semi-annual frequency.



3.2 Decomposition in Seasonal cycle and Anomaly

Fig.4 Monthly mean of GMST (black) and RT (heating in orange and cooling in blue). Error bar shows one standard deviations. Month to month variations of GMST are shown in red.
Seasonal cycle of RT is created from the seasonal cycle of Sun-Earth distance, the minimum in January and the maximum in July, with seasonal cycle of cloud distributions.
RT and tendency of GMST have same sign, except in April, July, September and October.

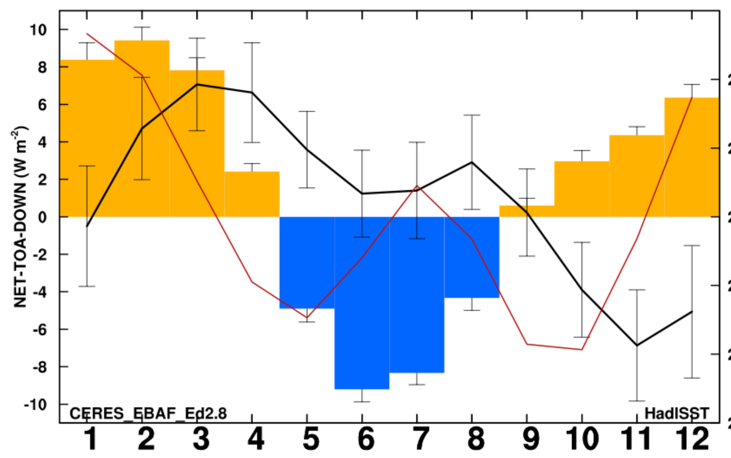
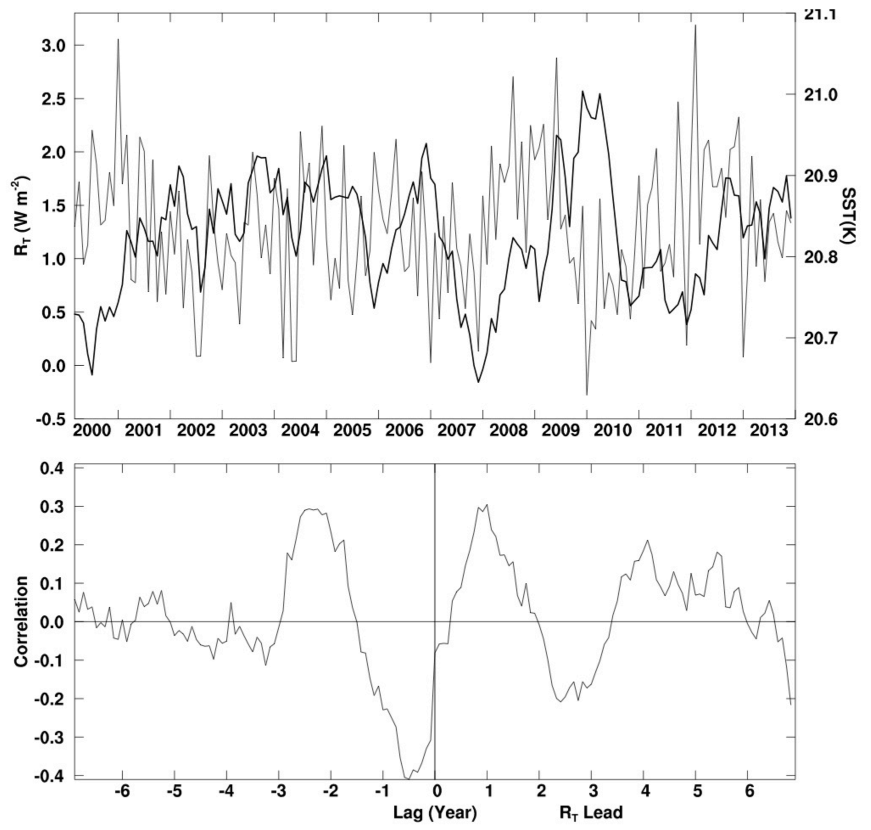


Fig.5 Time series of global mean RT and GMST (upper) and lag correlations (below). Note that zero-lag correlation is negative but smaller than some lag-correlations. Negative lag, GMST leads case, are well studied as El Niño related phenomena but positive correlation in positive lag case is not known well.



3.3 Month to month variations of SST and RT

Fig.6 Lag-correlations between month to month difference of GMST and RT. Note that one month lag of RT has a sharp positive peak.
Eitzen et al. (2008) studied cloud optical properties and SST using contemporary correlations. OLR is increased with SST.

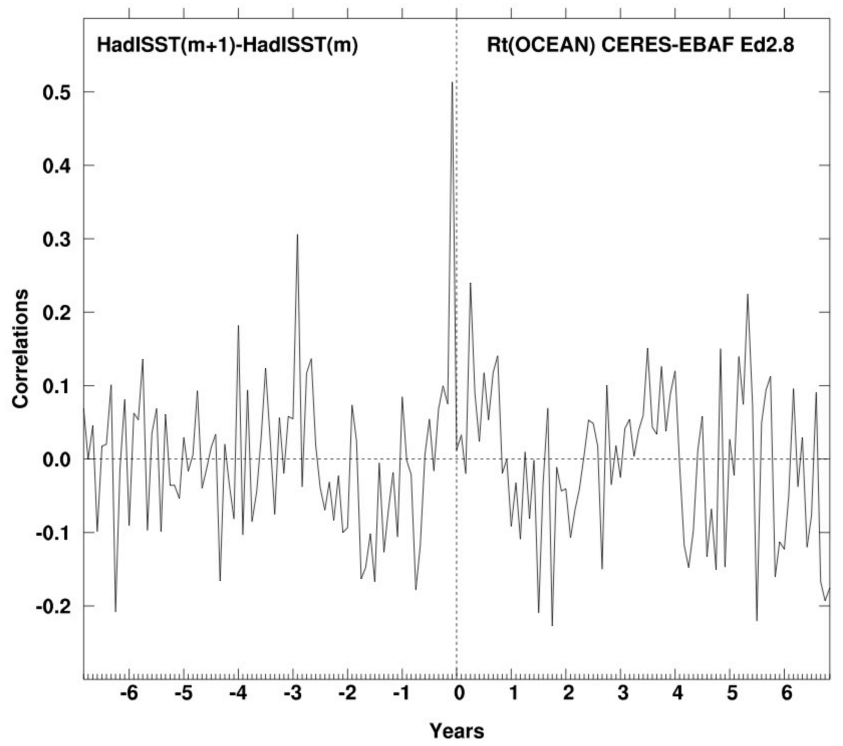


Fig.7 Local correlations between RT and the difference of SST of this month from SST last month. Note positive correlations are observed in the middle latitudes. If cloud does not change, increase of SST must increase of OLR and decrease of RT anomaly.

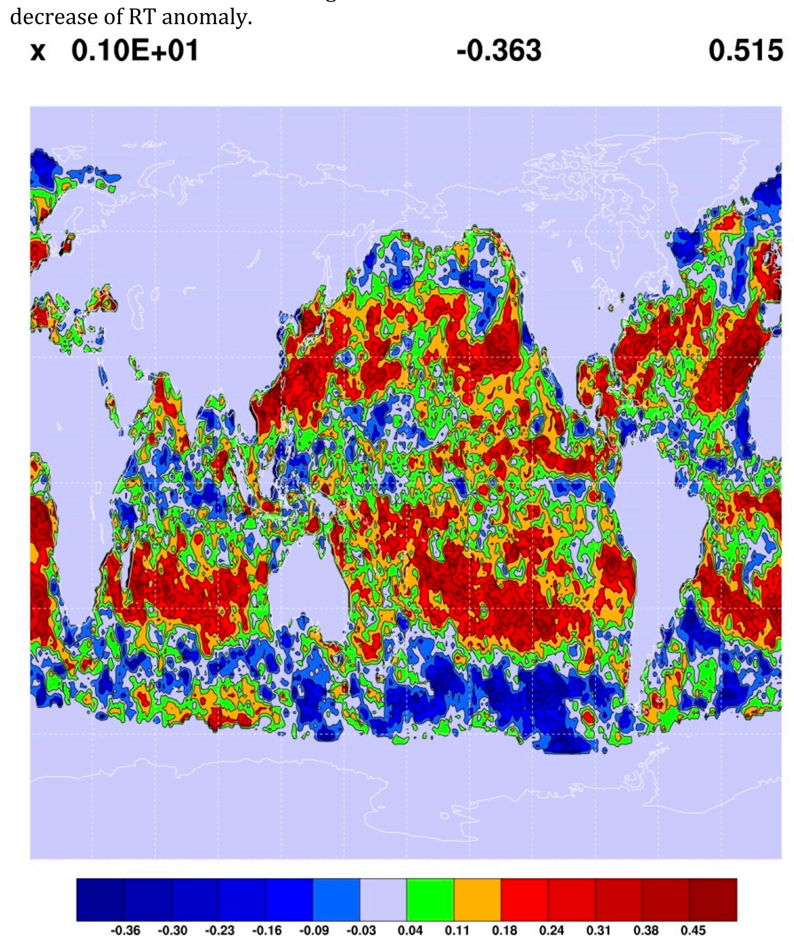
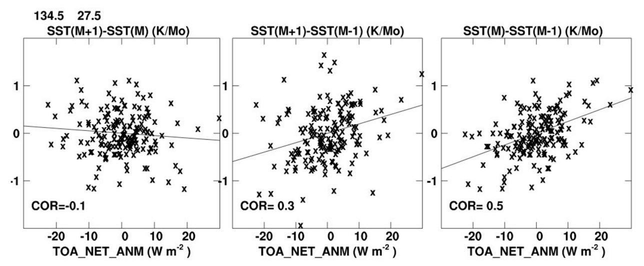
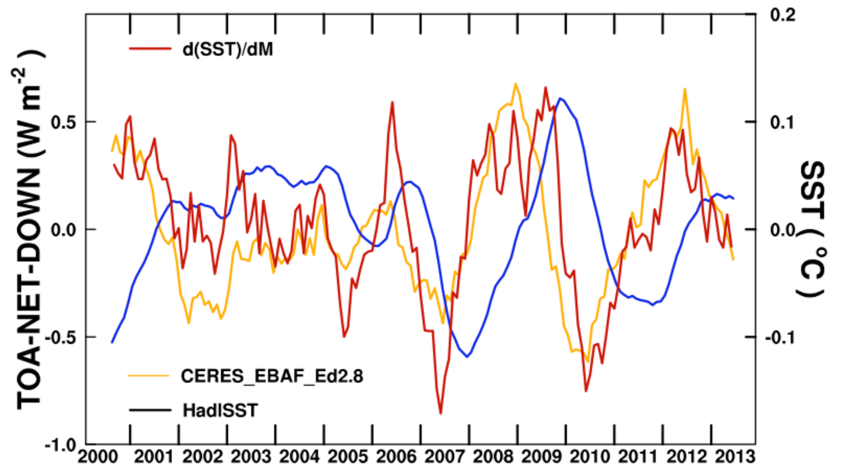


Fig.8 Scatter diagram between RT and month to month difference of SST at a middle latitude point (134.5E, 27.5N).
One month lead of RT (left), contemporary (middle) and lag (left).
Note that correlation is highest when SST leads RT half months.



3.4 Interannual variations

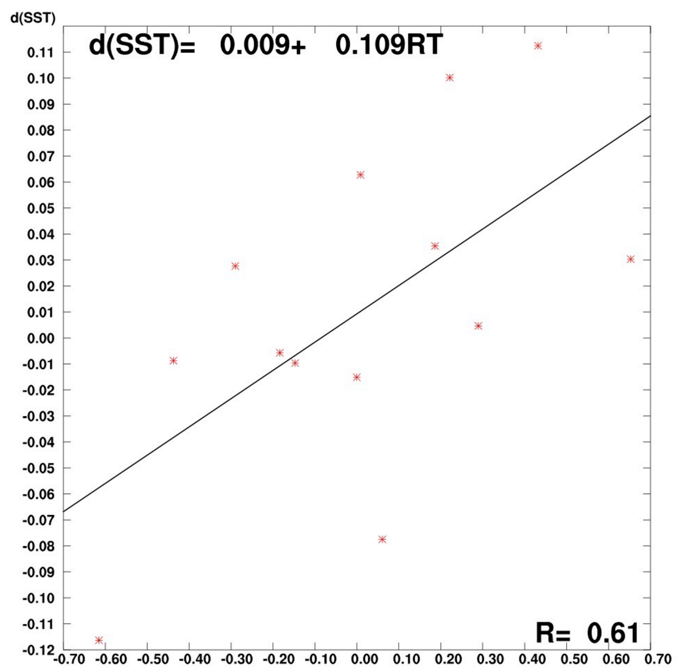
Fig.9 GMST(blue) and RT (orange) after 12 month running mean of those given in Fig.5. Also shown is the month to month differences of GMST. Note that warming and cooling of GMST are coincident with heating and cooling of RT. Warm and cool SST are not coincident with RT.



4. Discussions

4.1 GMST next year may be predicted with RT this year

Fig.10 Scatter diagram between RT and time derivative of GMST. RT is annual average of this year. D(SST) is the difference between annual mean GMST of next year minus annual mean of GMST this year.



In slab ocean approximation.

$$A_g\int_0^t (RT-B)dt = A_o \rho C_p T(t)\delta z + others$$

Ag=$5.09\times10^{14}m^2$
Ao=$3.39\times10^{14}m^2$
ρ =$1025 kgm^{-3}$
Cp=$3990 Jkg^{-1}K^{-1}$
t =365.25x24x60x60 sec
B=0
Others=0
For 1 Wm^{-2} heating of one year, GMST increases 0.109K then
δz=107m

Numbers from Trenberth et al. (2002)

(50m for decade, Donohoe, et al. 2014)

4.2 Why GMST does not contribute to RT ?

Fig.11 Time series of RT(top), time derivative of SST (middle), and SST(bottom). Extratropical values were damped with the map factor of latitude.
Temporal variations of SST are dominated in the Tropics (middle and bottom) while variations of RT are dominated in extratropics (top). 12 month running mean.

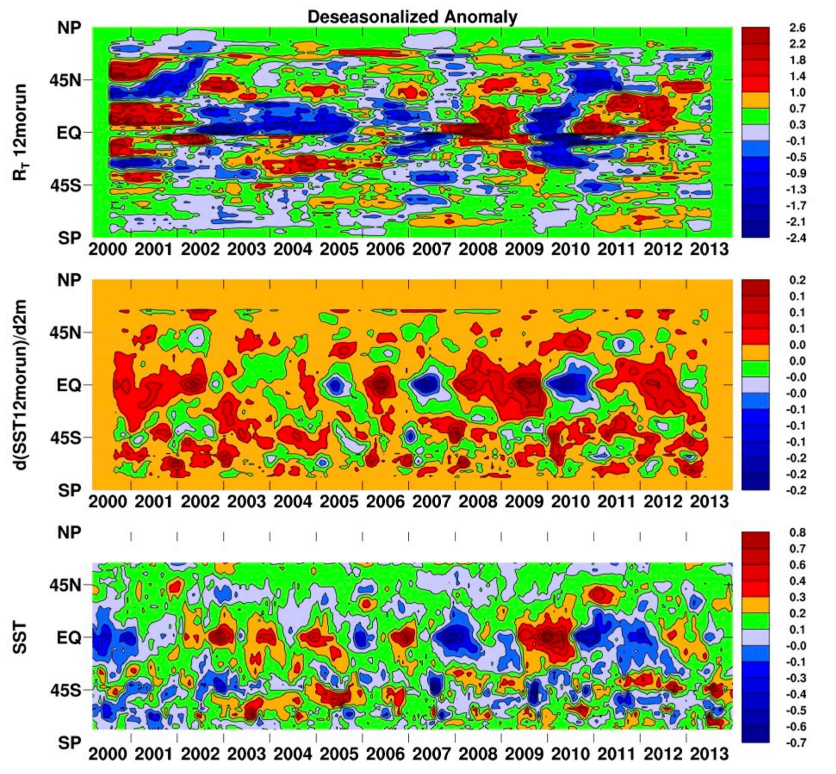
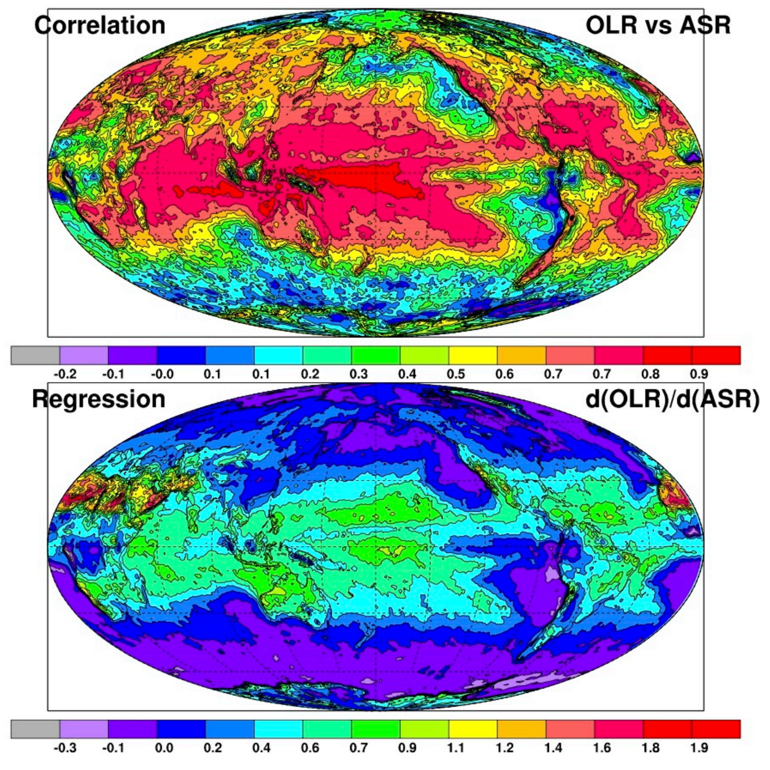


Fig.12 Correlation (top) and regression coefficient (bottom) between OLR and ASR. Correlation indicates that OLR and ASR are well correlated over Tropical ocean , except over Eastern Pacific. Regression coefficient (down) is about one over the positive correlations, indicating canceling between OLR and ASR.



5. Conclusions

1) Clouds may be less than climatology when SST is increased this month from last month, and vice versa.
2) SST in the Tropics is increased if RT in the extratropics is increased in time scale longer than a year.
3) Equivalent slab ocean depth corresponding to year-to-year variations of GMST is about 107 m.
4) Tropical ocean may be a storage of Earth's energy due to canceling of longwave and shortwave (Kiehl, 1994) in the Tropics.

6. References

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