Changes in Surface Radiation Flux Associated with Cloud Variability over Land During the Past 40+ Years

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Fundamental Question

How has surface radiation flux changed in recent decades?

<u>Challenges</u>

- Few direct measurements at surface
- Flux datasets derived from satellite observations suffer from artifacts
- Only visual observations of clouds prior to 1980s

<u>Solutions</u>

- Empirically correct the satellite data (accepted paper in *JAOTech*)
- Estimate radiation anomalies due to visual cloud cover anomalies

1971-2009 Trends in Total Cloud Cover



Mediterranean Total Cloud Cover



Cloud Cover Radiative Effect (CCRE)

Rad flux: R_{ALL} = all conditions R_{CLR} = clear sky R_{OVC} = overcast R_{CRE} = cloud radiative effect R_{CCRE} = "cloud cover" radiative effectf = cloud fractioná ñ = climatology¢= anomaly

$$R_{\rm ALL} = R_{\rm CLR} + f(R_{\rm OVC} - R_{\rm CLR}) = R_{\rm CLR} - R_{\rm CRE}$$

$$\begin{aligned} R_{\text{ALL}} & \phi &= -f \phi \acute{a} R_{\text{CRE}} \, \widetilde{n} / \, \acute{a} f \, \widetilde{n} \\ & + \, \acute{a} f \, \widetilde{n} R_{\text{OVC}} \phi + \, (1 - \acute{a} f \, \widetilde{n}) R_{\text{CLR}} \phi \\ & + \, f \phi R_{\text{OVC}} \phi - \, f \phi R_{\text{CLR}} \phi \end{aligned}$$

 $R_{\rm CCRE}$ ¢= f¢á $R_{\rm CRE}$ ñ/áfñ

Mediterranean CCRE from CERES



Mediterranean CCRE from CERES



Mediterranean Downward SW







Northern Europe Downward SW



Detection of Aerosol Radiative Effect





Eastern Asia Downward SW





Central America Downward SW





South America Downward SW



Summary

- Cloud cover anomalies produce most of the variability in downward SW flux at the surface ("cloud cover" radiative effect)
- Visual cloud observations can be used to estimate long-term changes in downward SW flux at the surface
- Correction of artifacts improves satellite-derived surface radiation flux record (method not discussed)
- With SW CCRE and direct measurements of SW flux at surface, can estimate long-term variations in aerosol radiative effects
- Cloud cover has decreased and estimated downward SW radiation
 has increased over most subtropical land regions since 1971