Variations of radiation fields with environmental conditions Observed by 10-years of CERES

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Introduction

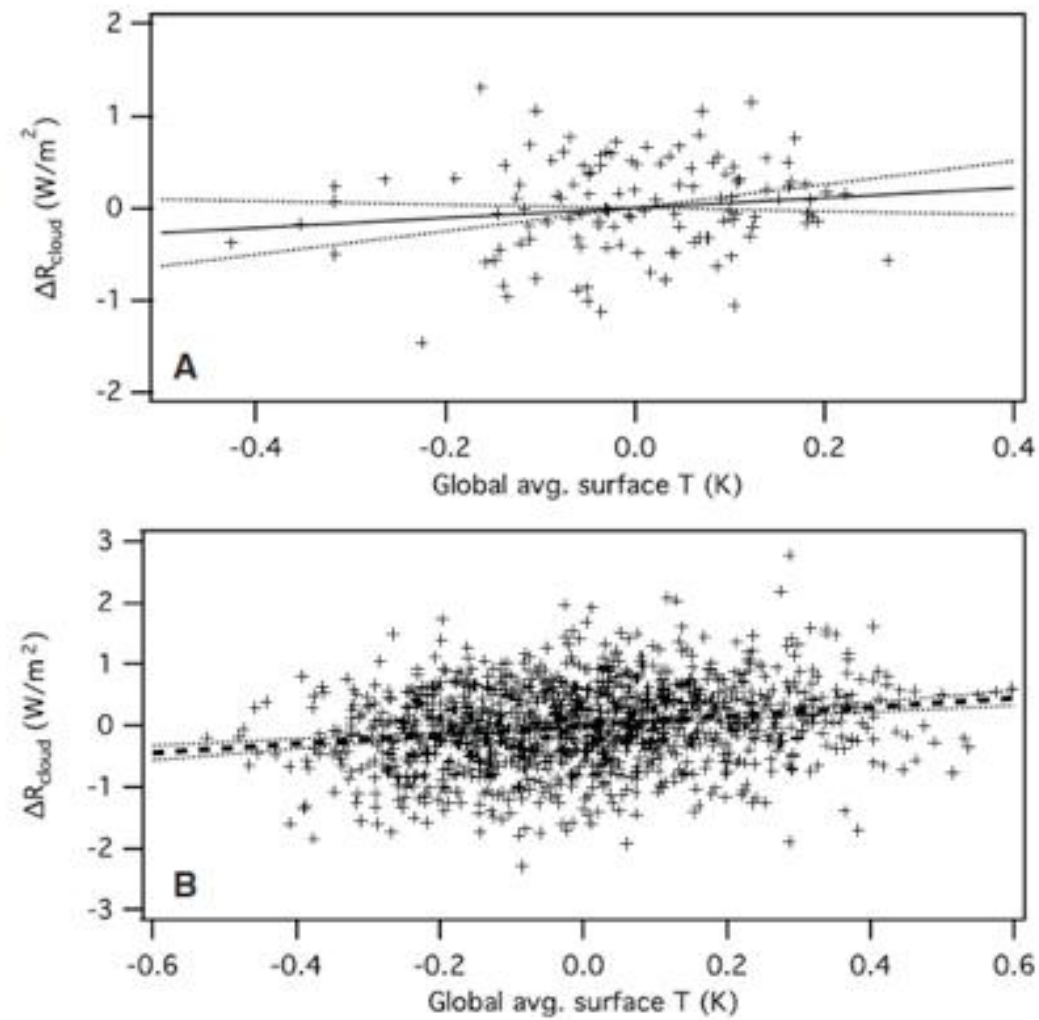
➢ Climate state variations with radiation changes

❖ feedbacks, esp. clouds: model simulations and observations

non-linear, chaotic

variations in different time scales

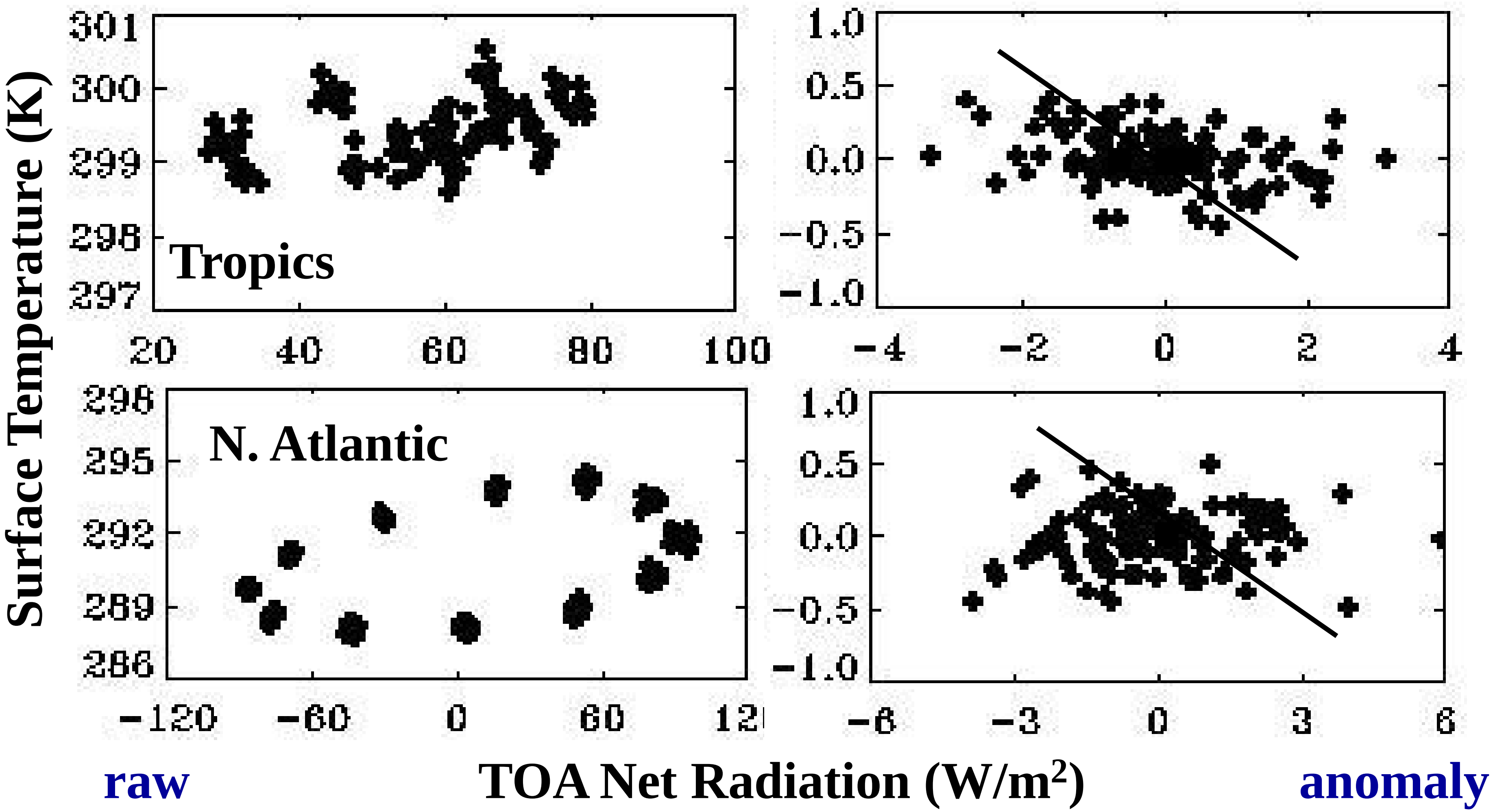
Fig. 2. (**A**) Scatter plot of monthly average values of ΔR_{cloud} versus ΔT_s using CERES and ECMWF interim data. (**B**) Scatter plot of monthly averages of the same quantities from 100 years of a control run of the ECHAM/MPI-OM model. In all plots, the solid line is a linear least-squares fit and the dotted lines are the 2σ confidence interval of the fit.



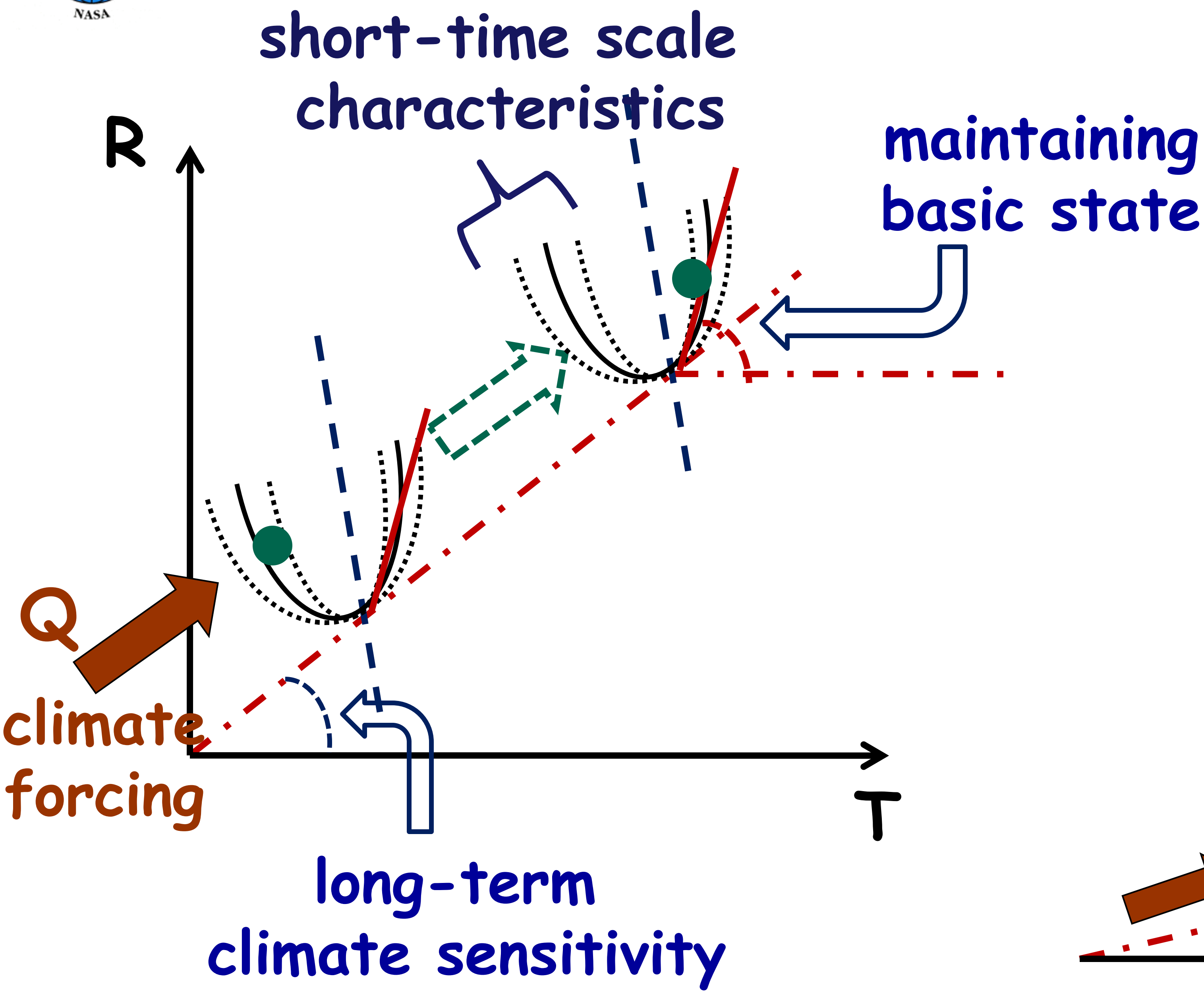
Dessler, 2010

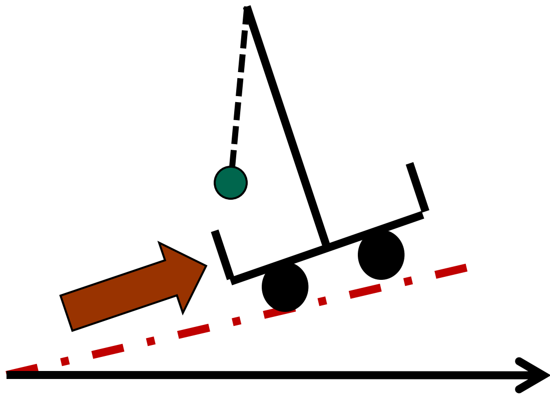
radiation & temp.

- ➢ **Observed radiation variations: not only on T**
  - ❖ climate tendency: maintain its base state
  - ❖ clouds, dynamics/thermodynamics >> T & environmental variables v_i



climate variability





Approaches

- **Radiation measurements**
  - TOA radiation changes: 10 yrs obs.
  - deseasonalized anomalies >>> perturbation/linearization
  - empirically explain the anomalies in radiation fields
- **Basic relationships**
  - dynamic & thermodynamic influences on radiation
  - environmental conditions: T, w, CWV, ∇•w., ∇T, o3
  - ENSO index: representing interannual variability
- **radiation change**

$$R = (1\text{-}c)R_{clr} + cR_{cld}$$

$$\Delta R = -\Delta c\, R_{clr} + (1\text{-}c)\Delta R_{clr} + \Delta c R_{cld} + c\, \Delta R_{cld} + \ldots\ldots$$

$$= \Delta E_T + \Sigma_i\, (\partial R/\partial v_i)\Delta v_i \ + \text{other terms}$$

individual variables' influences on radiation

Blackbody Thermal Emission (climate response function)

$$Cp\frac{dTs}{dt} = (1-\alpha)So - \varepsilon\sigma Ts^4$$

Cp: equivalent heat capacity

non-feedback status: $\Delta\alpha = \Delta\varepsilon = 0$

$$Cp\frac{d\Delta Ts}{dt} = -\frac{4\varepsilon\sigma Ts^4}{Ts}\Delta Ts = E^0\Delta Ts$$

$$= \frac{4LW}{Ts}\Delta Ts \approx -\frac{4\times 237}{288}\Delta Ts = -3.3\Delta Ts$$

$E^0 \approx -3.3\ Wm^{-2}K^{-1}$; $\Delta E_T = E^0\Delta T$

At short time scales,
this feature is mixed with other processes.

Approaches (conti.)

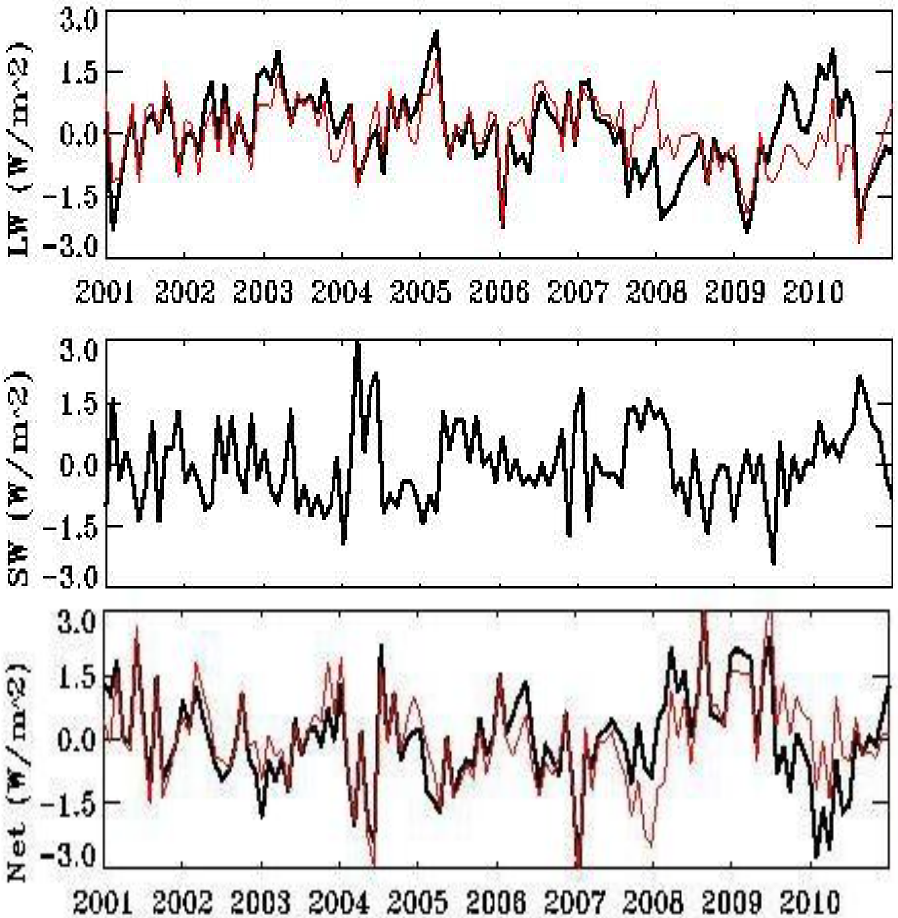
- 10-years CERES data: 2001 ~ 2010
  - TOA radiation changes
  - variations in T and other variables
  - 10 years 'climatologies'

- Statistical analysis
  - SSF1DEG monthly 1°×1° grid boxes
  - Tropics: 23°S to 23°N zonal band
  - Global & other regional or basin results
  - multivariable linear regression (no aerosols considered)

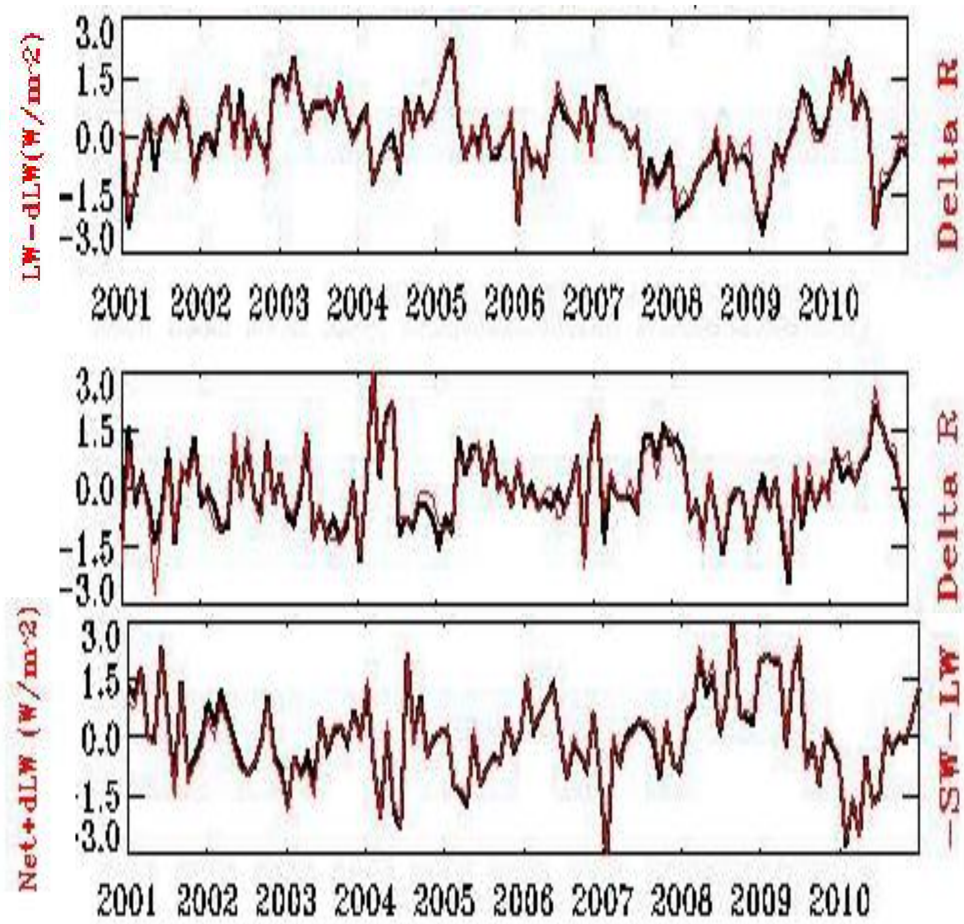
- Residuals
  - uncertainty level
  - remaining unexplained

radiation anomaly

all-sky



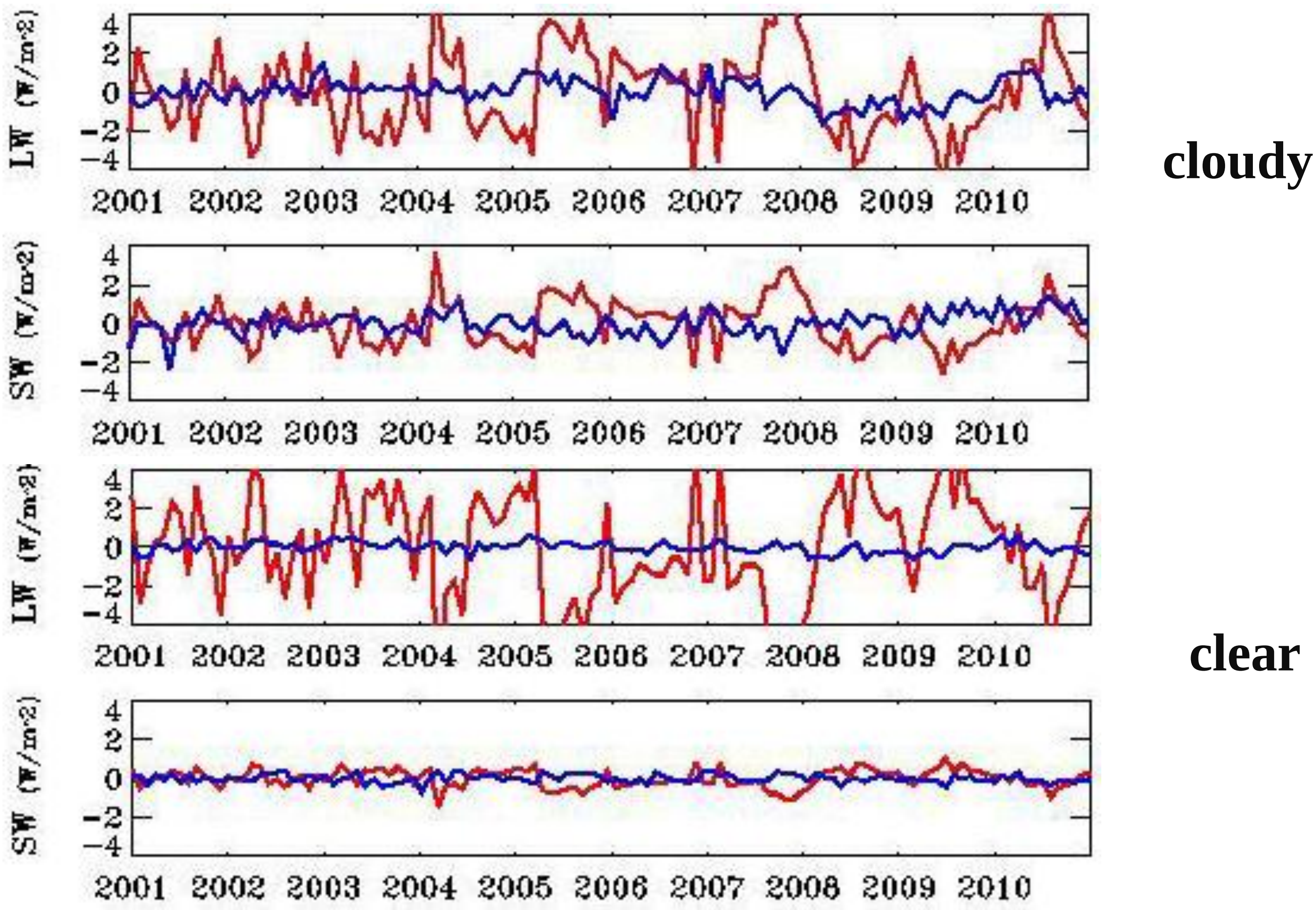
cld+clr combined



Time (yr)

$$\Delta R \approx -\Delta c\, R_{clr} + (1-c)\Delta R_{clr} + \Delta c R_{cld} + c\, \Delta R_{cld}$$

cloud effect

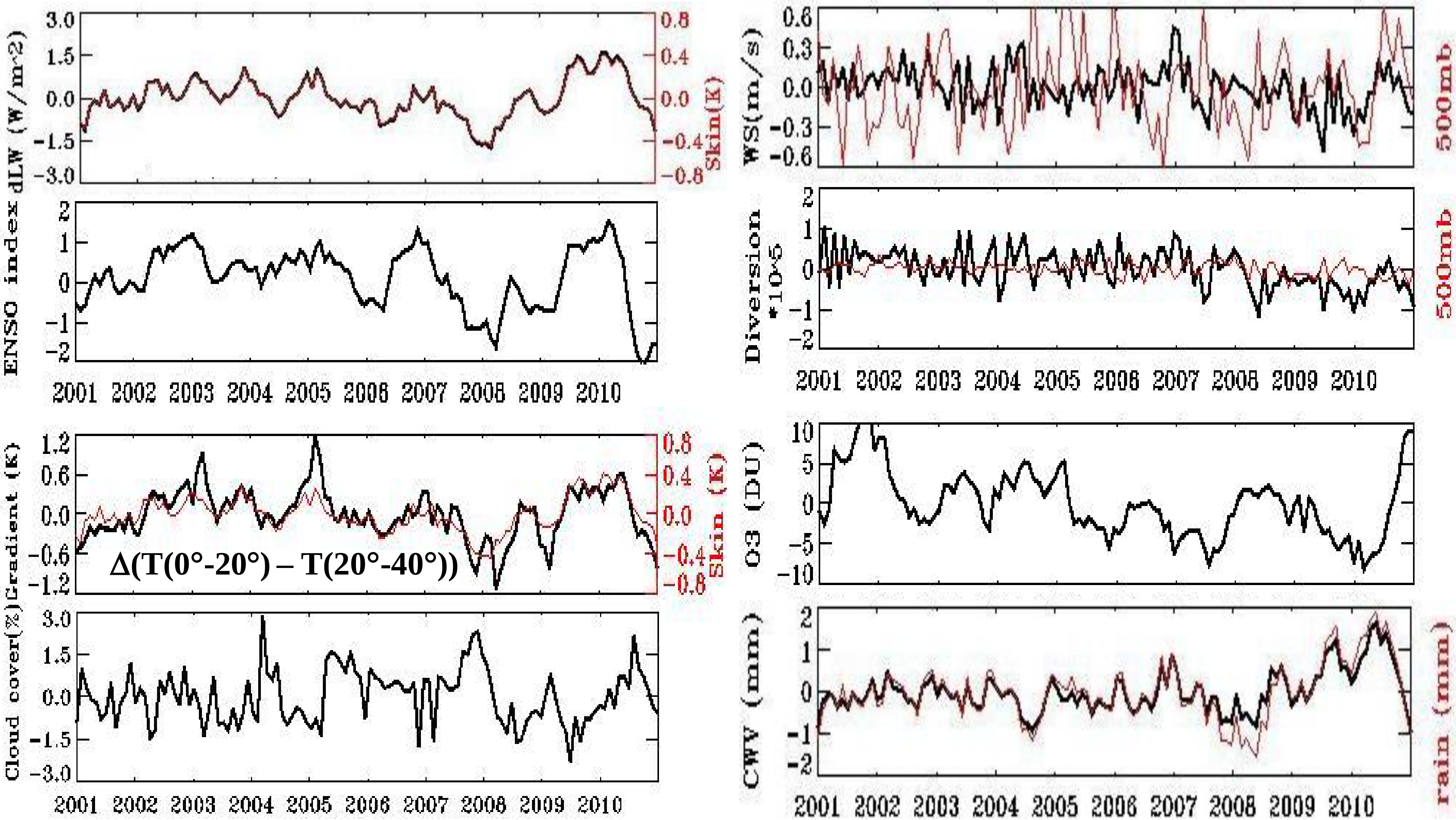


red: ΔC

Time (yr)

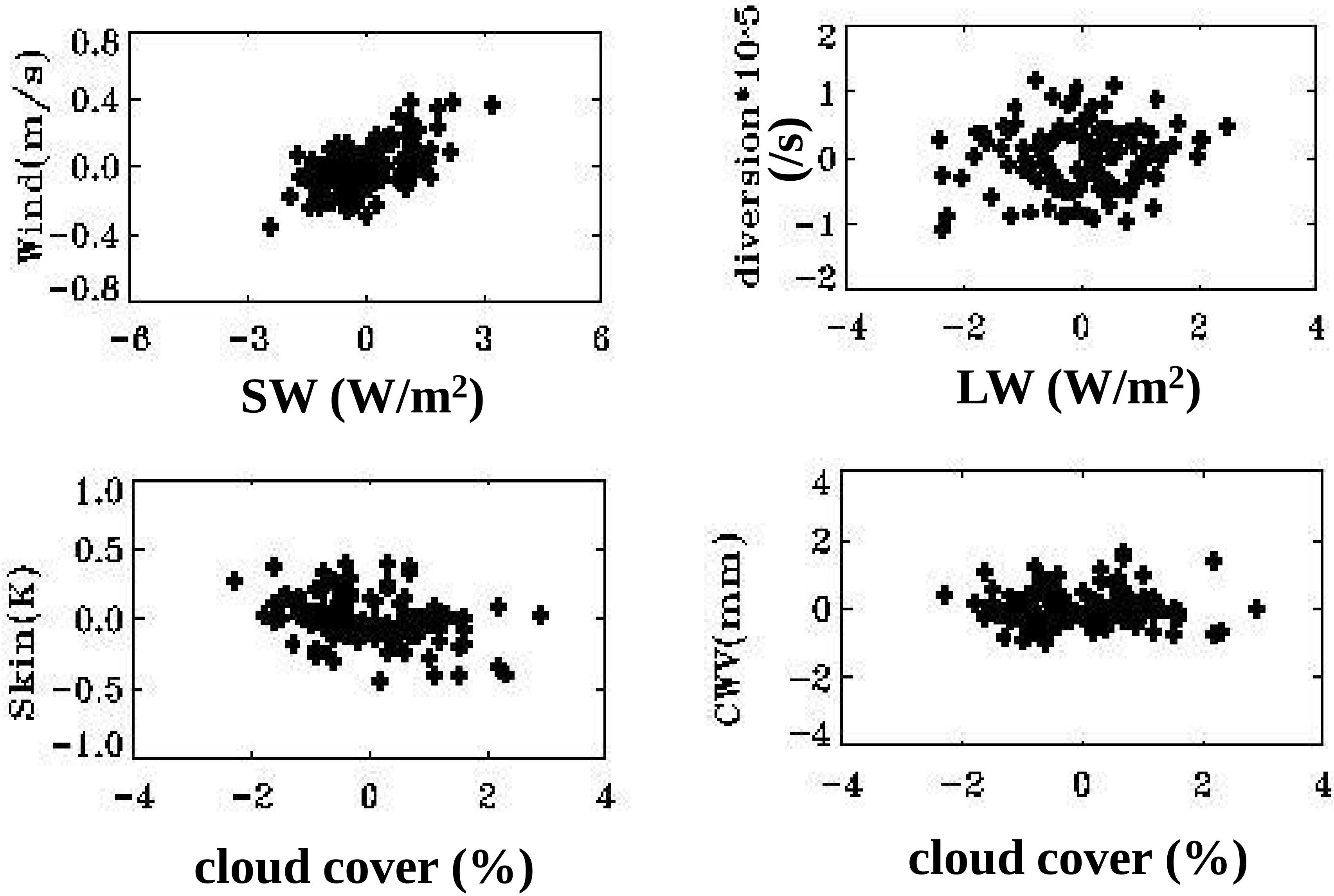
blue: ΔR

environmental variations



Time (yr)

individual relations



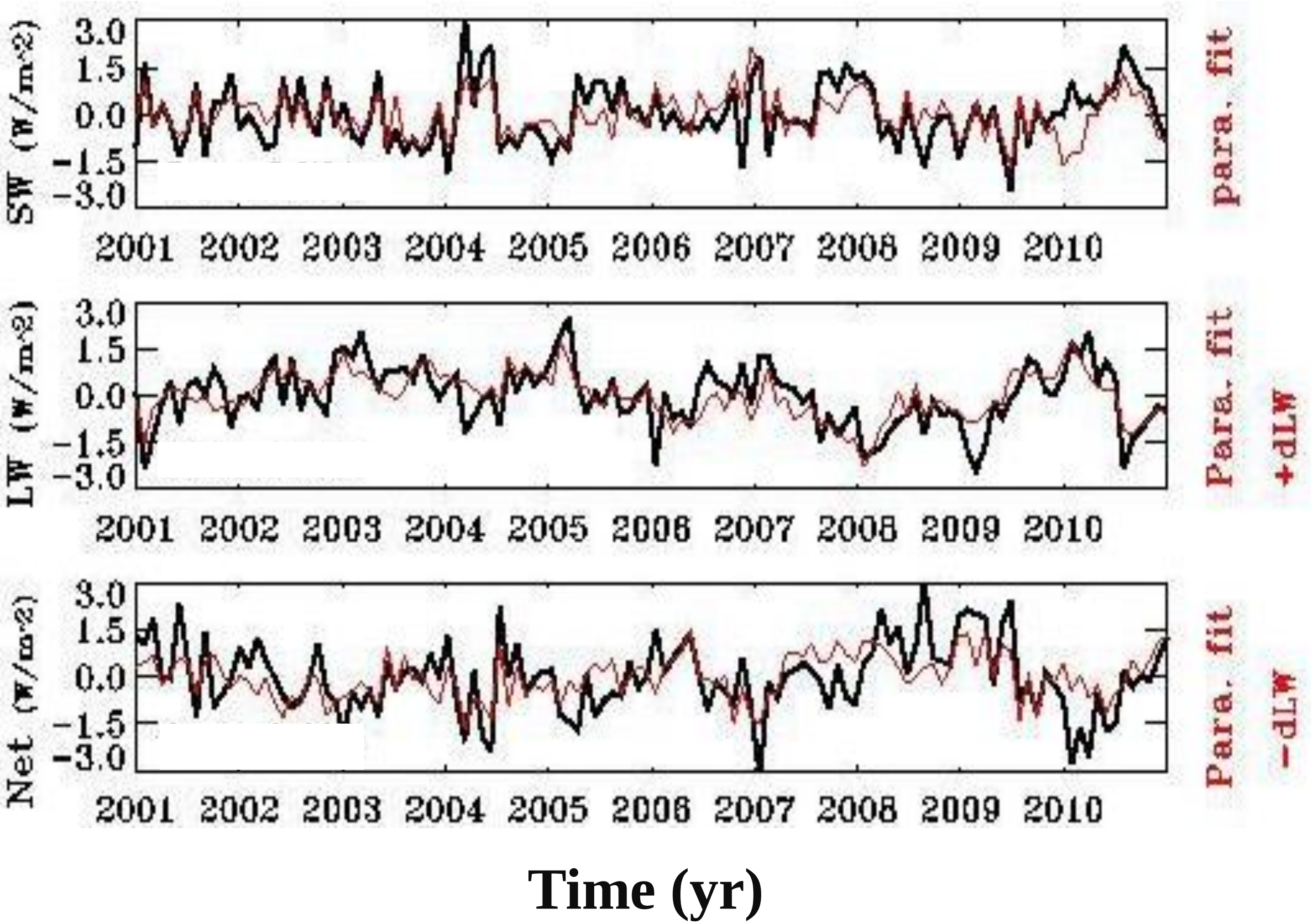
multi-variable relations

$$\Delta R = \Delta E_T + C_0 + \Sigma_i C_i \Delta v_i / \sigma_i$$

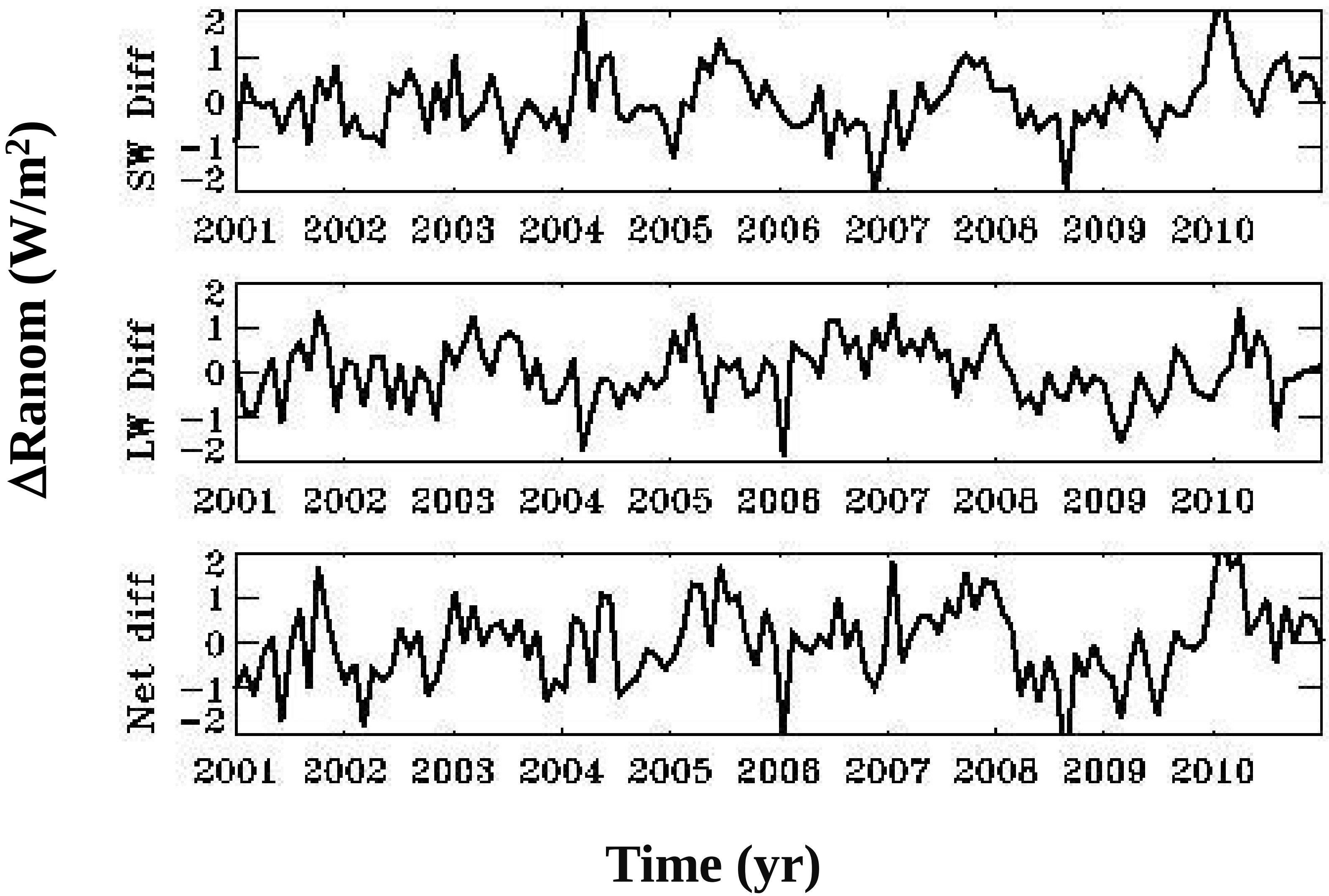
	C_0	Ts	cwv	w	$\nabla \bullet w$	E_{index}
SW	$-6.60e^{-5}$	-0.138	0.243	0.540	-0.107	-0.221
LW	$-1.40e^{-3}$	-0.276	-0.381	0.136	0.187	0.253
net	$1.61e^{-3}$	0.459	0.134	-0.696	-0.132	-0.005

	∇T	O3	r^2	σ_{diff}
SW	-0.122	-0.201	0.73	0.69
LW	0.331	0.105	0.79	0.65
net	-0.223	0.159	0.65	0.89

multi-variable relations

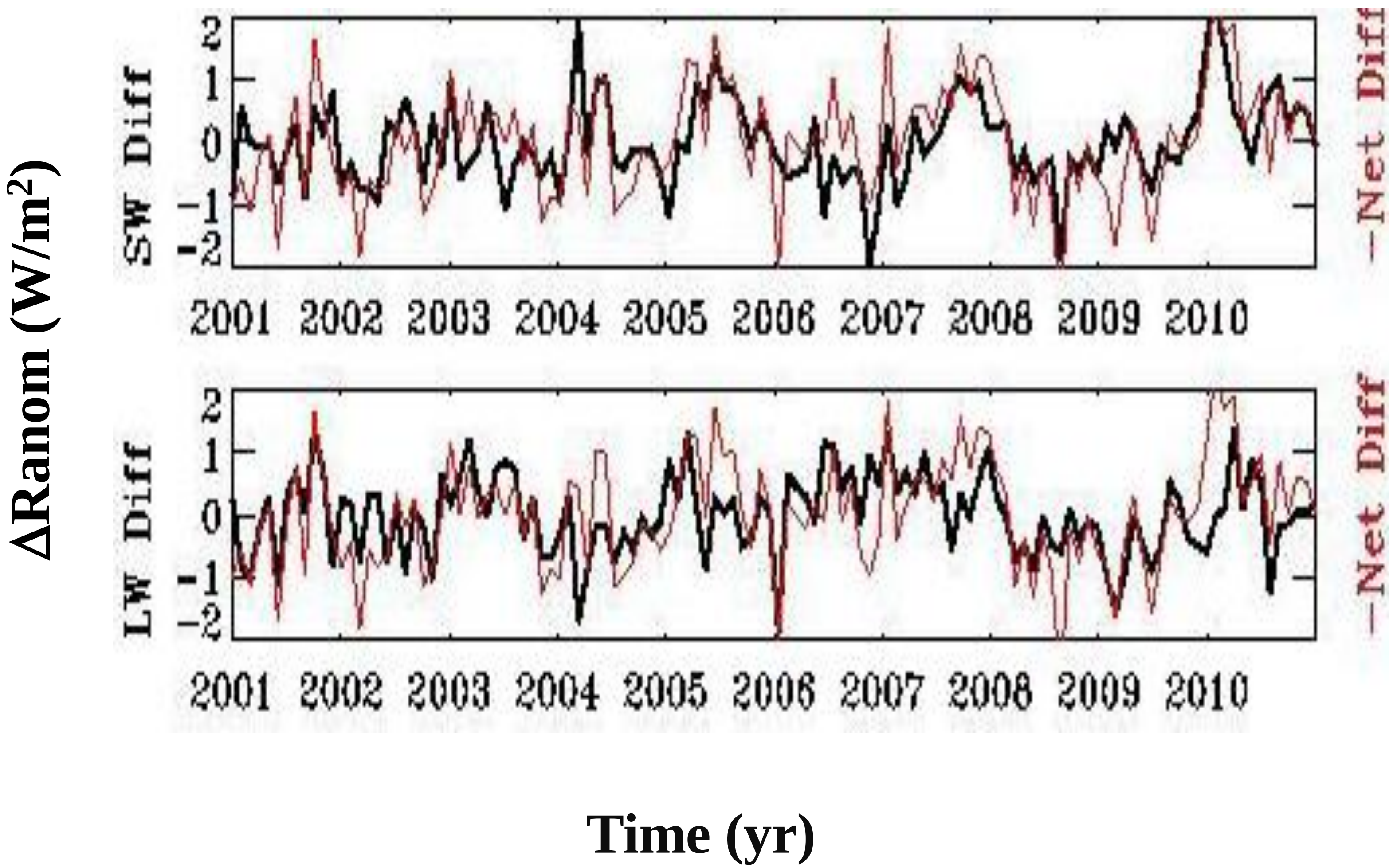


residuals



ΔRanom (W/m²)
SW Diff
LW Diff
Net diff
2
1
0
−1
−2
2001 2002 2003 2004 2005 2006 2007 2008 2009 2010
Time (yr)

residuals (conti.)

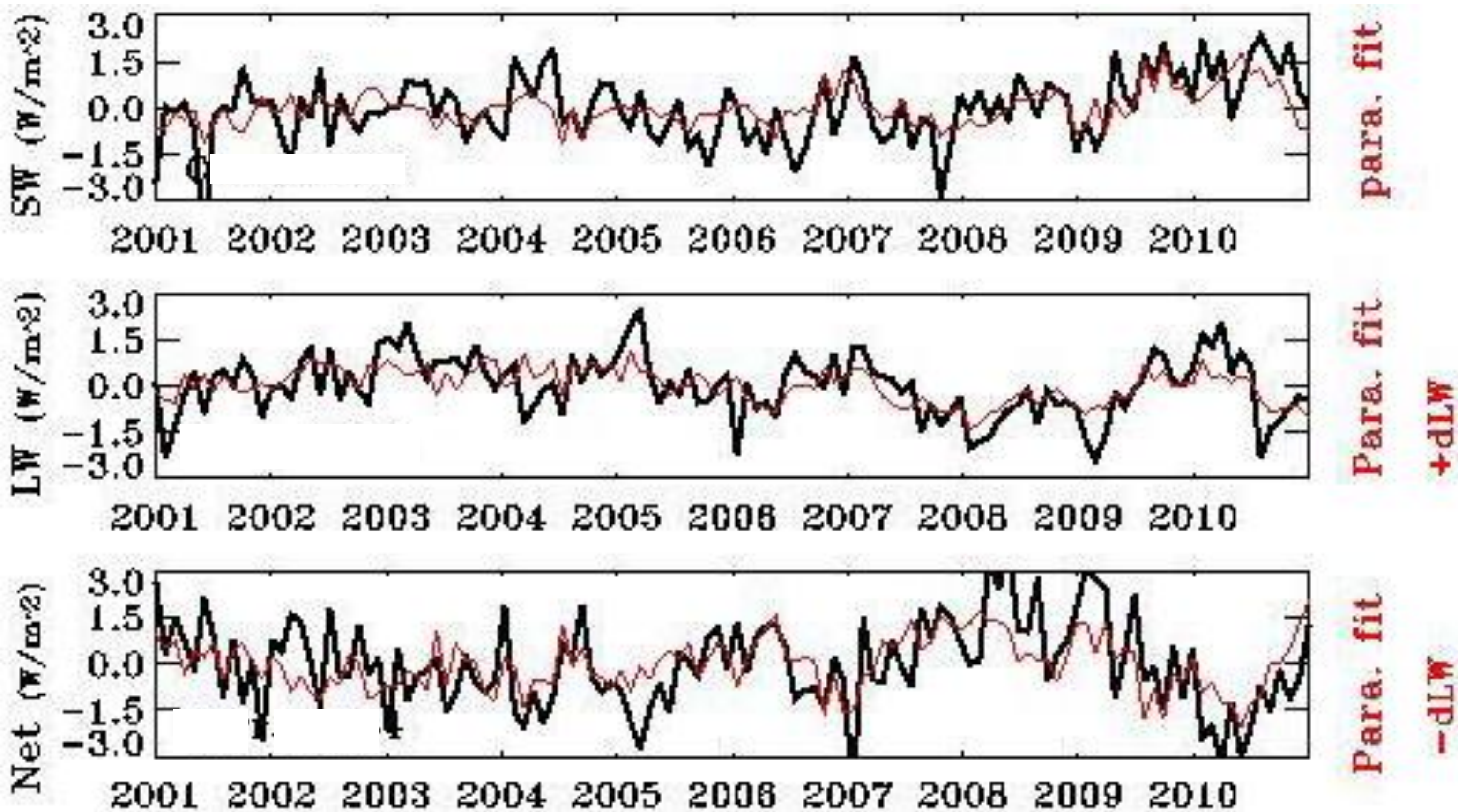


cloudy skies

	C_0	Ts	cwv	w	$\nabla \bullet w$	E_{index}
SW	$2.00e^{-4}$	0.049	0.463	0.491	0.442	-0.151
LW	$-1.04e^{-3}$	-0.559	-0.250	0.185	-0.092	0.173
Net	$9.41e^{-4}$	0.723	-0.331	-0.459	-0.075	-0.046

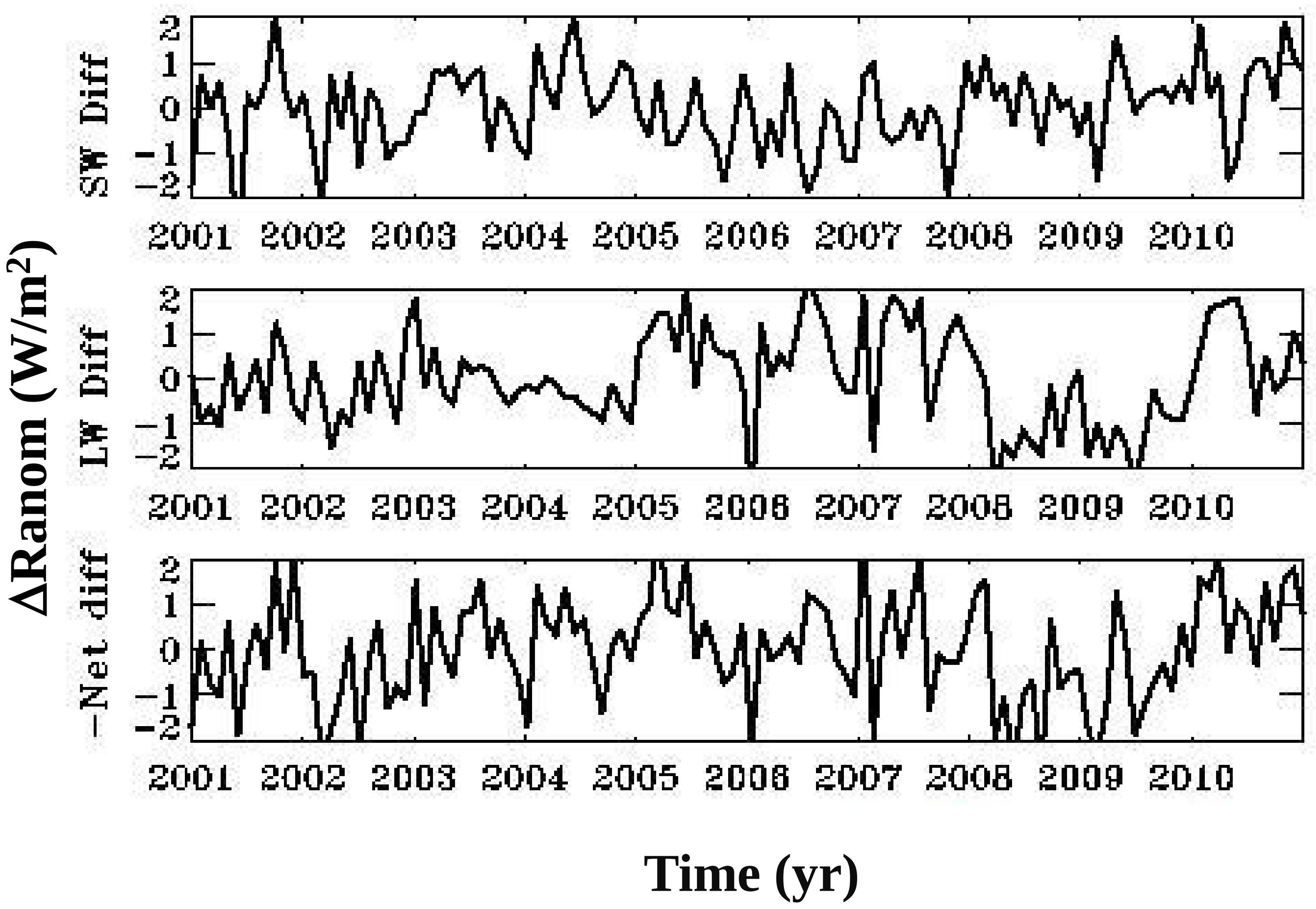
	∇T	O3	r^2	σ_{diff}
SW	0.111	0.261	0.59	0.90
LW	0.424	-0.114	0.54	1.04
net	-0.637	-0.153	0.64	1.16

cloudy skies

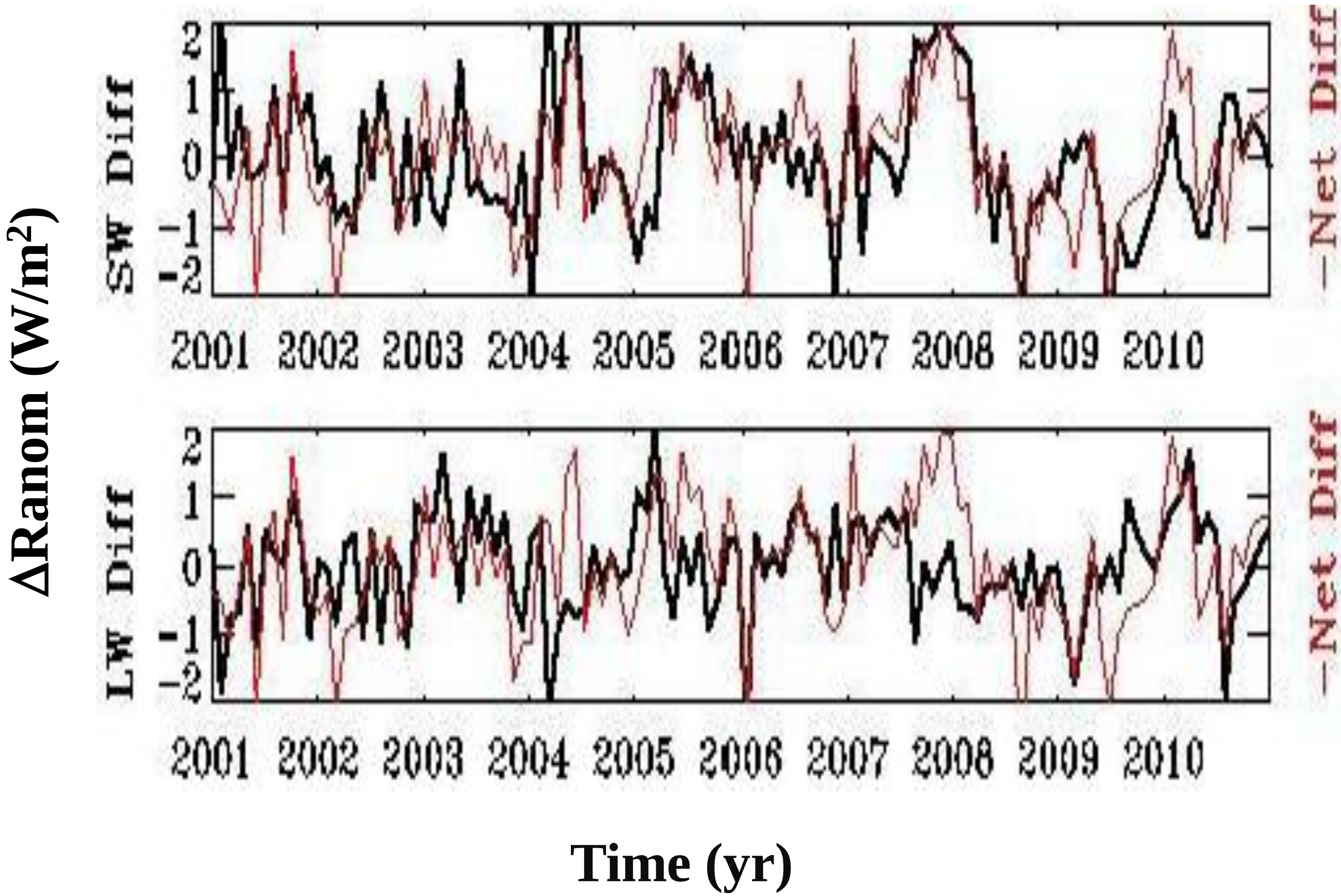


Time (yr)

Residuals: cloudy



Residuals: cloudy



Summary

- Climate system has different characteristics in different time scales. Current analyses focus on short-time scales (within few years).
- Many variables such as clouds, surface temperature, water vapor, wind, divergence, O_3, and temperature gradient have significant influences on the variations of TOA radiation fields in short-time scales
- According to current results, dynamics (e.g. wind) may dominate the SW radiation variations, while for LW, thermodynamics (temperature & water vapor) along with other factors like ∇T and ENSO may be the most important factors in determining its variability.

Summary (conti.)

- Current analysis could explain more than 80% changes in the radiation anomalies observed by CERES for all sky conditions. For cloudy skies, the levels of explained variances are slightly lower.
- Although the variances in the residuals of the radiation anomalies are within the uncertainties of satellite measurements, the differences between empirically analyzed results and CERES observations are still not negligible. Influences of additional variables such as aerosols (indirect effects) on radiation anomalies may still exist.
- Further studies are needed.

Acknowledgement

Many people, especially Norm Loeb, Don Garber, and Gary Gibson, have significant supports for this study.