On a Derivable Formula for Long-Wave Radiation from Clear Skies: A Theoretical and Practical Contribution

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Brutsaert, W. 1975. On a Derivable Formula for Long-Wave Radiation from Clear Skies. Water Resources Research 11:742-744.

Overview

- Downward Long-wave Radiation
  - Theoretical Basis
  - Validation
  - Importance in Net Radiation
- Practical Value
  - Remote Sensing
  - Evapotranspiration
- The Next Generation

It is not easy to measure long-wave radiation in nature …

In many practical situations… it is still expeditious to calculate it on the basis of measurements of more easily-measured variables.

Brutsaert (1982)

On a Derivable Formula for Long-Wave Radiation from Clear Skies

Downward longwave radiation under clear skies (R_{ldc}) typically uses an equation of the form

$$R_{ldc} = \varepsilon_{ac}\sigma T_a^4$$

where ε_{ac} is the atmospheric emissivity under clear skies, σ is the Stefan - Boltzmann constant, and T_a is the air temperature near the ground.

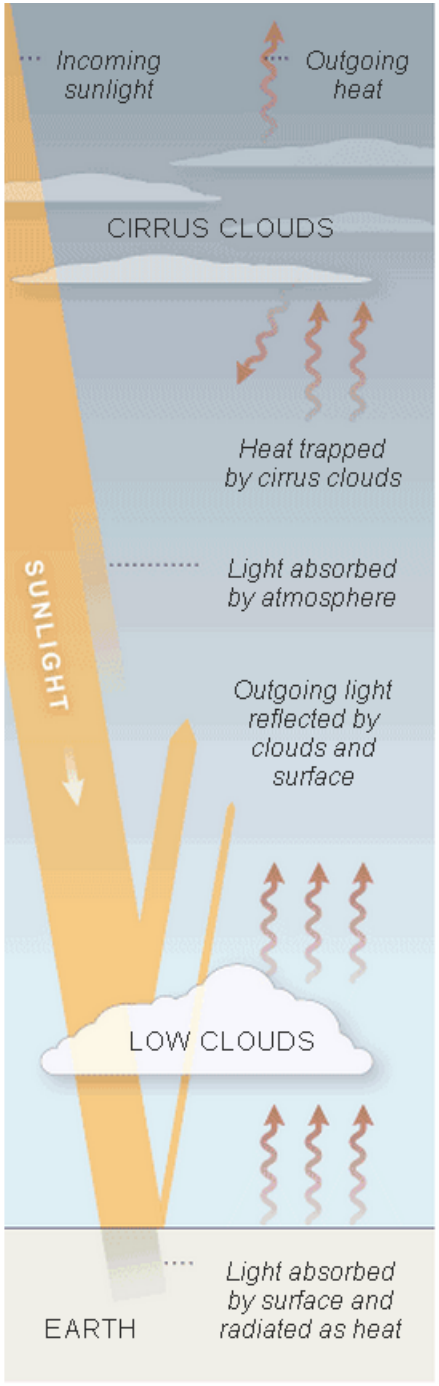
Brutsaert (1975) derived ε_{ac} to be

$$\varepsilon_{ac} = a\left(e_a / T_a\right)^b$$

where a and b are constants $a = 1.24$ and $b = 1/7$ when the vapor pressure e_a is in mb and T_a is in K.

To be useful, a parameterization must be valid.

Brutsaert (2005)



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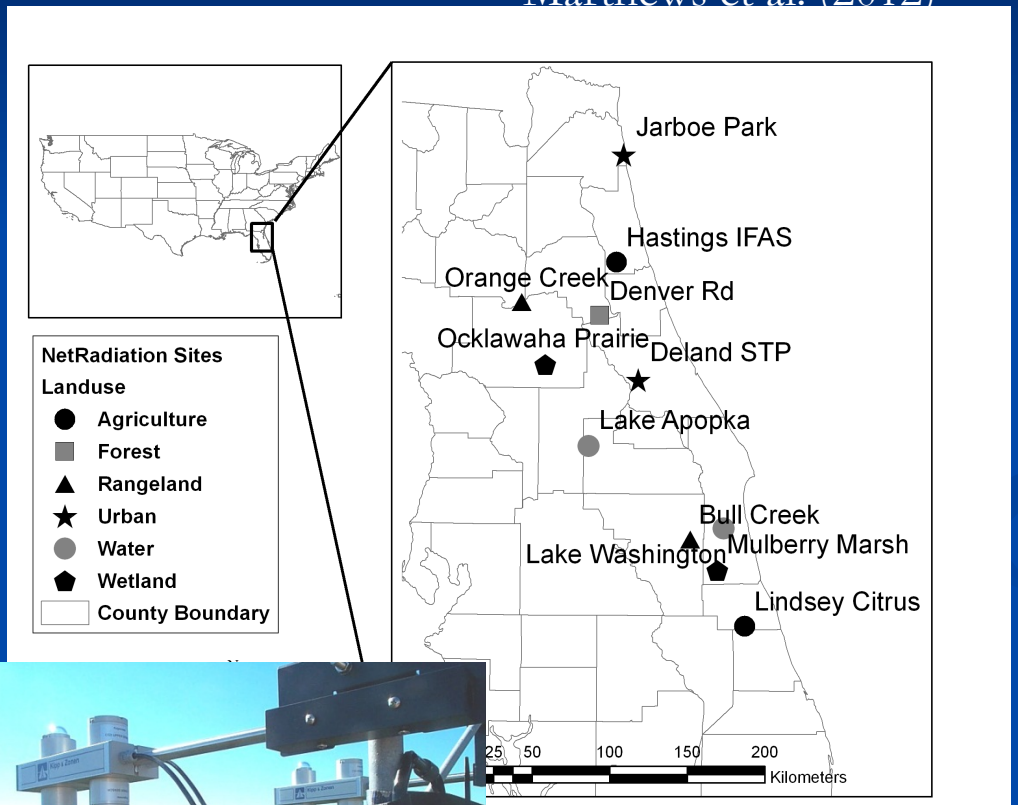
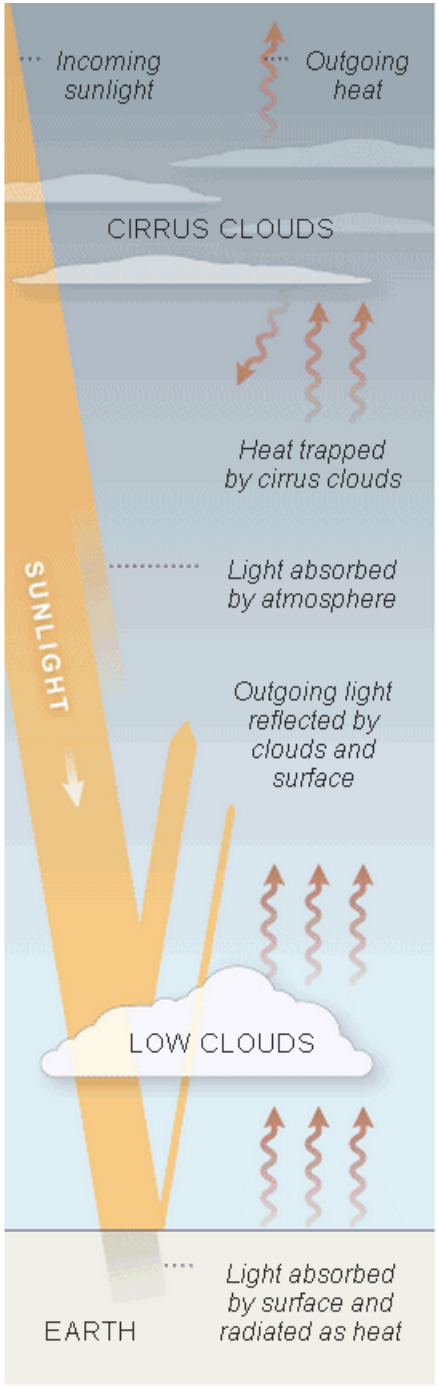
Field measurements of radiation fluxes-notably downwelling longwave radiation flux (LW flux)-are as yet rare or nonexistent…

Marthews et al. (2012)



R_{ld} constitutes a major component of the radiation budget at the surface; a better estimation of the net radiation will in turn contribute to a more accurate estimation of the surface energy budget

Sugita and Brutsaert (1993)



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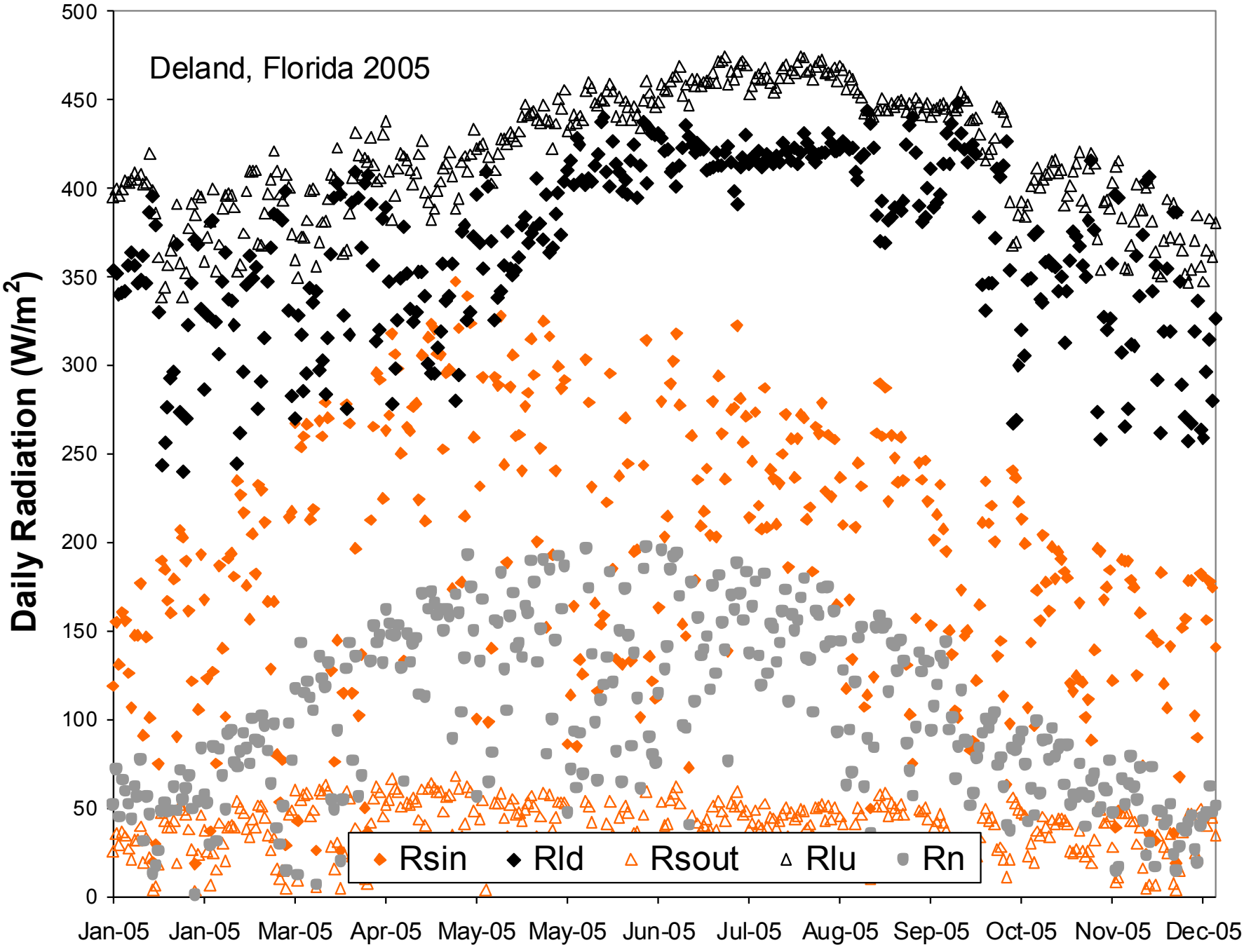
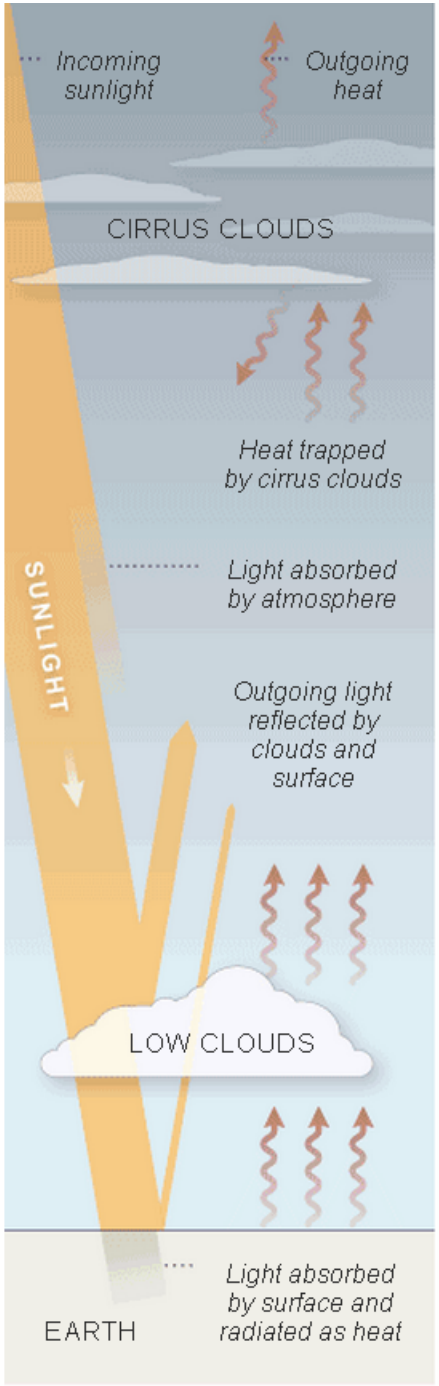
$$R_n = R_s(1-\alpha_s) + \varepsilon_s R_{ld} - R_{lu}$$

Net radiation can be broken down into several components


Deland, Florida 2005
Daily Radiation (W/m2)
500
450
400
350
300
250
200
150
100
50
0
Jan-05
Jan-05
Mar-05
Apr-05
May-05
May-05
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05
Nov-05
Dec-05
Rsin
Rld
Rsout
Rlu
Rn

Besides being valid, a useful parameterization must satisfy the dual requirements of parsimony and robustness.

Brutsaert (2005)



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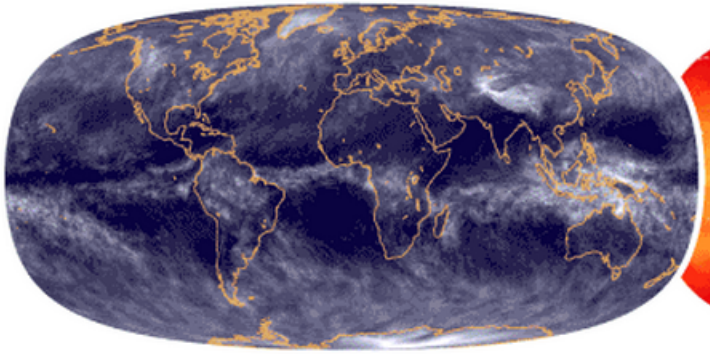
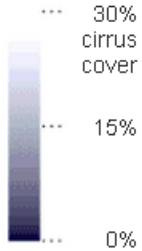
Global Energy Balance

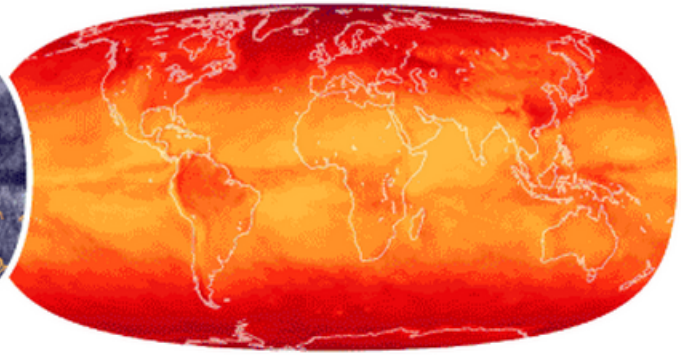
March 2012

NASA Earth Observations
NY Times 2012

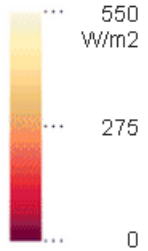


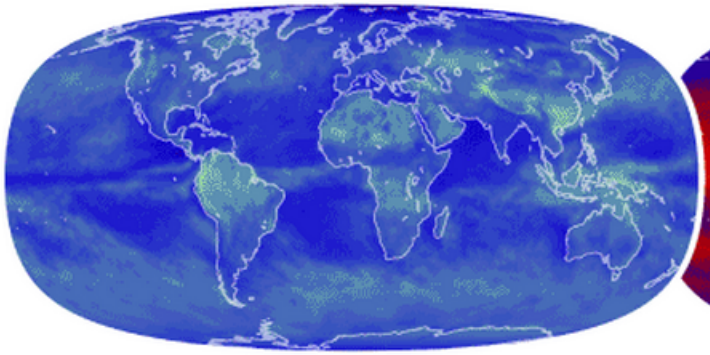
Cirrus clouds are high, thin and cold. Many of these wispy clouds allow sunlight to pass through easily, but they tend to trap rising heat. A future increase in cirrus clouds would probably warm the planet, while a decrease would most likely cool it.



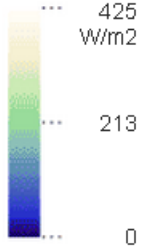


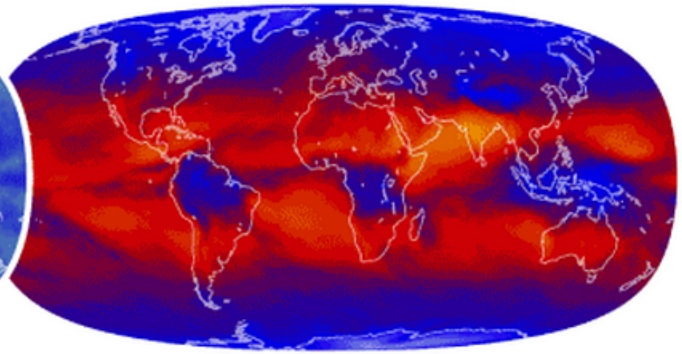
Incoming sunlight varies with location and with the seasons. The above map shows the average sunlight falling on the earth's surface in March, as measured in watts per square meter.



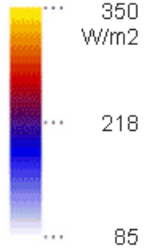


Reflected sunlight from low clouds, ice and other bright surfaces returns some of the sun's energy back into space. The oceans and other dark surfaces reflect less light and are warmed by absorbing sunlight.





Radiated heat from land, oceans and low clouds is held near the earth's surface by greenhouse gases but must eventually escape to space, as shown above. Areas with more cirrus cloud cover tend to emit less heat to space.



Author	Year	Title
Trigo	2010	Estimation of downward long-wave radiation at the surface combining remotely sensed data and NWP data
Yang	2010	Estimation of evapotranspiration using a remote sensing model over agricultural land in the North China Plai
Choi	2009	An intercomparison of three remote sensing-based surface energy balance algorithms over a corn and soyl
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Gao	2008	Estimation of daily actual evapotranspiration from remotely sensed data under complex terrain over the upp
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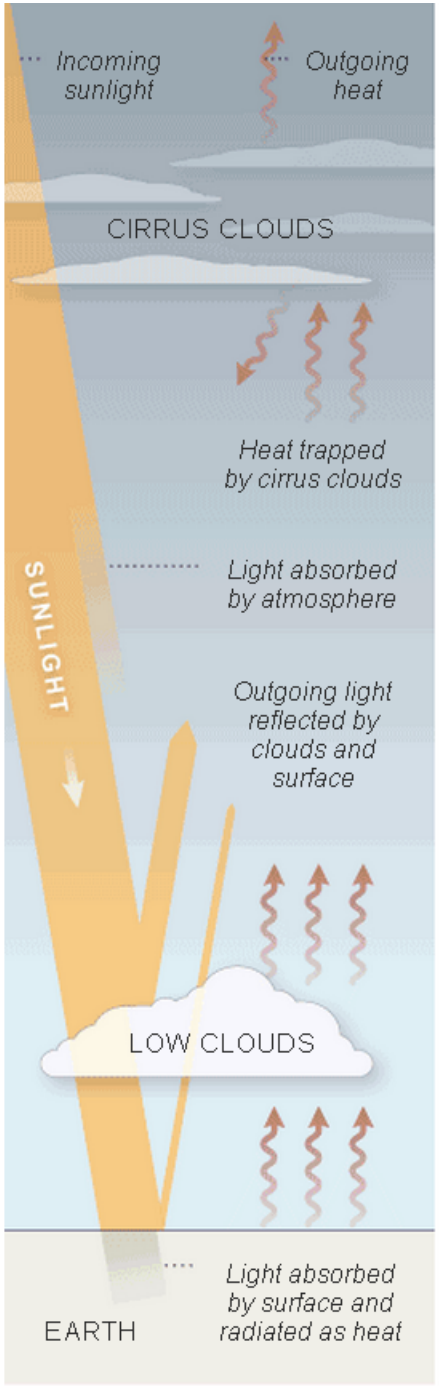
Kustas	1994	Using Satellite Remote-Sensing to Extrapolate Evapotranspiration Estimates in Time and Space over a Ser
Kustas	1994	Surface-Energy Balance Estimates at Local and Regional Scales Using Optical Remote-Sensing from an A
Moran	1994	Use of Ground-Based Remotely-Sensed Data for Surface-Energy Balance Evaluation of a Semiarid Range
Vidal	1991	Atmospheric and Emissivity Correction of Land Surface Temperature Measured from Satellite Using Groun

Evaporation and sensible heat flux into the atmosphere require the availability of some form of energy at the earth-atmosphere interface

Brutsaert (1982)



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Yang	2012	Climatic factors influencing changing pan evaporation across China from 1961 to 2001
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Choi	2011	Evapotranspiration estimation using the Landsat-5 Thematic Mapper image over the Gyungan watershed in
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Chavez	2009	Radiometric surface temperature calibration effects on satellite based evapotranspiration estimation
Gao	2008	Intercomparison of remote sensing-based models for estimation of evapotranspiration and accuracy assess
Gao	2008	Estimation of daily actual evapotranspiration from remotely sensed data under complex terrain over the upp
Liu	2007	Estimation of regional evapotranspiration by TM/ETM plus data over heterogeneous surfaces
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Patel	2006	Mapping of regional evapotranspiration in wheat using Terra/MODIS satellite data
Martinez	2006	A simulation model for predicting hourly pan evaporation from meteorological data
Zhang	2006	An integrated algorithm for estimating regional latent heat flux and daily evapotranspiration
Verstraeten	2005	Estimating evapotranspiration of European forests from NOAA-imagery at satellite overpass time: Towards
Wu	2005	Estimating evaporation coefficient during two-stage evaporation from soil surfaces
Jacobs	2002	GOES surface insolation to estimate wetlands evapotranspiration
Li	2002	Remote estimation of regional evapotranspiration
Farah	2001	Impact of spatial variations of land surface parameters on regional evaporation: a case study with remote s
El Garouani	2000	Use of the Geographic Information System and remote sensing data for the estimation of real evapotranspir
Ibanez	2000	Simplifying daily evapotranspiration estimates over short full-canopy crops
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dos Reis	1998	Multi with limited meteoro
Llasat	1998	Data
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Kim	1997	Exar layer and land surfac
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Courault	1996	Evap information and airbo
Courault	1996	Airborne thermal data for evaluating the spatial distribution of actual evapotranspiration over a watershed in
Zhang	1995	A One-Layer Resistance Model for Estimating Regional Evapotranspiration Using Remote-Sensing Data
Mirschel	1995	Simulation of Soil Water and Evapotranspiration Using the Model Rowet and Data Sets from Krummbach ar

$$LE + H = R_n - G$$

R_{ld} and Climate

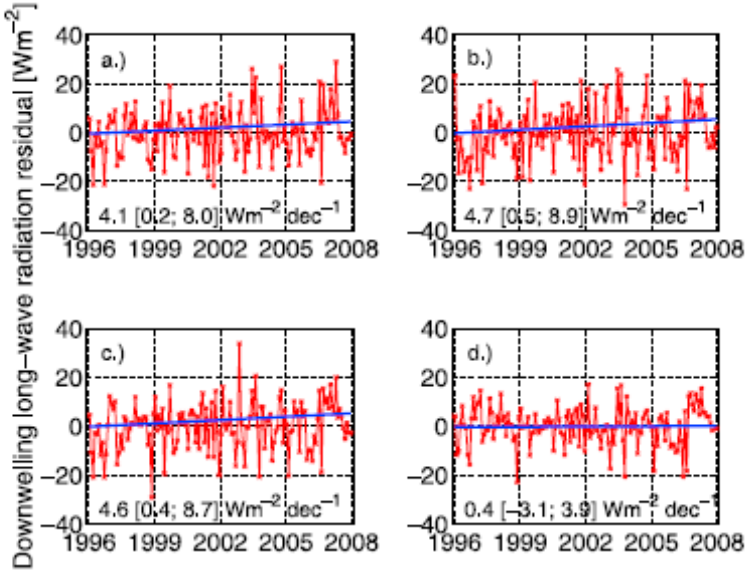

Figure 3. Time series and linear trends (blue) of the deseasonalized monthly mean cloud-free downwelling longwave radiation at (a) Locarno, (b) Payerne, (c) Davos, and (d) Jungfraujoch. Shown are the residuals of the deseasonalized data with the least squares slope estimate and the corresponding lower and upper bounds of the 90% confidence interval.

Wacker et al. (2011)

"Longwave cloud feedback is systematically positive and nearly the same magnitude across all global climate models…" Zelinka and Hartmann (2010)

You're next

Brutsaert (1996)

DoE ARM CART Central Facility, 1995

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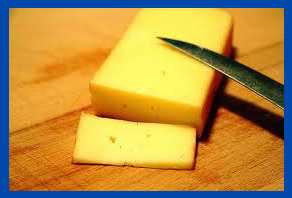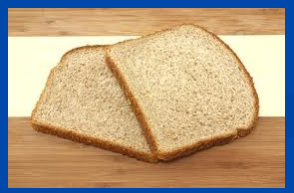
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