

Practical 1 – Radiation

(GE2219 – Climate, Water and Environment)

January 20, 2004

Due date: 27 January 2004, 5 pm. Drop hardcopy of your typed answers in mailbox marked “GE2219 – Practical 1 Reports” located near the Department of Geography main office (AS2/0306). Please make sure to provide concise, self-explanatory answers. Don’t forget to indicate the units where appropriate. The report should not exceed 3 pages (don’t include this question sheet). You may submit the report in groups of up to 3 students if you wish. 2 points will be deducted for each day the report is submitted late!

This Practical is designed to acquaint you with the transfer of radiation through our atmosphere (Part A) and the component fluxes of the radiation budget at the planetary scale (Part B) and for individual surfaces (Part C).

Remember the radiation budget given by:

$$Q^* = K \downarrow - K \uparrow + L \downarrow - L \uparrow \quad [\text{W m}^{-2}]$$

where Q^* – net all-wave radiative flux density

$K \downarrow$ – incoming short-wave radiative flux density

$K \uparrow$ – short-wave radiation reflected by the surface, *i.e.* $K \uparrow = K \downarrow \alpha$, where α is the surface albedo

$L \downarrow$ – long-wave radiation reaching the surface from the atmosphere or other objects

$L \uparrow$ – long-wave radiation emitted by the surface to the atmosphere. For a blackbody the emission is given by the Stefan-Boltzmann law: $L \uparrow = \sigma T_0^4$ where σ is the Stefan-Boltzmann constant and T_0 is the surface temperature in Kelvins. For a grey body, it is necessary to add the surface emissivity (ϵ): $L \uparrow = \epsilon \sigma T_0^4$.

The all-wave budget can also be considered to consist of a net short-wave budget, $K^* = K \downarrow - K \uparrow$ and a net long-wave budget, $L^* = L \downarrow - L \uparrow$, *i.e.* $Q^* = K^* + L^*$. The sign convention adopted here is that individual fluxes have no sign but net fluxes (those with an asterisk) are positive if they are a net energy gain for the surface and negative if they are a net energy loss.

A. RADIATIVE TRANSFER

Question 1

The issue of ozone depletion in the stratosphere has become a major environmental concern recently. Use the website on the Ozone hole tour given below (and others you may want to explore on your own) plus section 1-2 ("Focus on the Environment: Depletion of the Ozone Layer") from your textbook to answer the following questions: [6 points]

- (i) Why is the ozone in the upper atmosphere so important to life on earth?
 - (ii) Why is ozone destruction greatest above Antarctica, rather than, say, the tropics?
 - (iii) At what time of year is the loss most severe and why?
 - (iv) What are the four key processes by which ozone loss occurs (*i.e.* "The Recipe for Ozone Loss")?
 - (v) How long ago did ozone concentration begin to fall rapidly?
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- (vi) Do you think that the ozone layer will recover? Why might it take some time, even if production of all CFC's disappeared overnight?

The Ozone hole tour: <http://www.atm.ch.cam.ac.uk/tour/>

Note: Don't simply quote from the sources but write in your own words.

B. PLANETARY-SCALE RADIATION COMPONENTS

Question 2

Using your understanding of the concept of radiation balance, complete the missing values in the following table of the annual radiation balance of the Earth (E), the Atmosphere (A) and the Earth-Atmosphere (E-A) system. Explain how you arrived at your results. [4 points]

You are given: (1) the average annual solar radiation to the E-A system $K_{Ex} = 338 \text{ Wm}^{-2}$, (2) the planetary albedo, $\alpha_{E-A} = 0.30$ and (3) the two values inserted into the matrix (table) below. Remember: Albedo is defined as the ratio of reflected to incoming shortwave radiation:

System	Net short-wave (K^*)	Net long-wave (L^*)	Net all-wave (Q^*)
A			-95.8
E		-67.2	
E-A			

Note: Sign convention has all radiative gains for the system as positive, losses as negative!

Hints: Determine K^*_{E-A} first. You don't need the numbers given in the lecture notes on the K, L and Q balances.

Question 3

Describe (!) and discuss (!) the main features of the satellite image (LW_out.gif - appended below and available on the course website) which shows outgoing long-wave radiation (in W m^{-2}) averaged over the entire month of April 1985. This image represents average (*i.e.* for April) conditions and includes effects of clouds.

Hint: remember which climate variable the long-wave radiation is related to. [3 points]

C. SITE-SPECIFIC RADIATION COMPONENTS

Question 4

Consider a very dry and scrub landscape at midday where: $K_{\downarrow} = 900 \text{ Wm}^{-2}$, $L_{\downarrow} = 325 \text{ Wm}^{-2}$, α (albedo) = 0.30 and $T_0 = 37 \text{ }^{\circ}\text{C}$ (T_0 = surface temperature). At midday on the following day the incoming radiation terms are identical with the previous day but the lawn was irrigated over night and new $\alpha = 0.19$ and $T_0 = 25 \text{ }^{\circ}\text{C}$.

- Calculate Q^* at midday for both days and the change in Q^* between the two occasions (you may assume the surface to act as a blackbody for long-wave radiation). [3 points]
 - If the surface emissivity also dropped from the first to the second day, would this augment or diminish the change in Q^* ? Explain your reasoning. [1 point]
 - How would a strong increase of CO_2 concentration (*e.g.* doubling) in the atmosphere qualitatively affect K_{\downarrow} , K_{\uparrow} , L_{\downarrow} , L_{\uparrow} , and Q^* ? Explain your answer. [2 points]
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LW_out.gif:

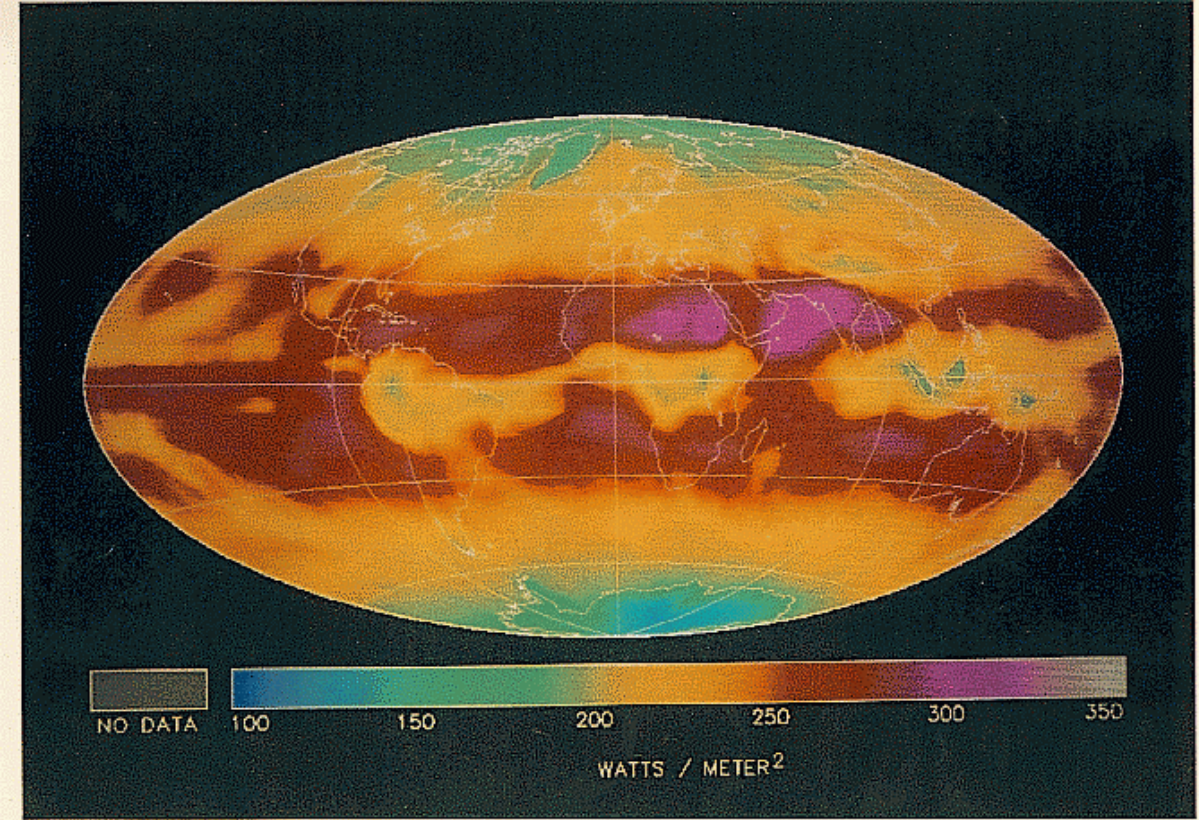


FIG. 5. ERBE monthly mean LWRE for April 1985.