Some Radiometer Sonde Results w/ Comments and Suggestions

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Outline

- Purpose of presentation
- Asano et al., 2004 EKO IR/Solar sonde
- Suomi-Kuhn IR sonde - Wisconsin
- R. Stone analysis of S-K sonde – S. Pole
- Ideas/ Possibilities
- NOAA UAS program

Purpose of This Presentation

- Response to request from Warren W. to examine Asano et al 2004 and advise (1st presented at ARM ST '06 IRF session)
- Discuss some other radiometer sonde results
- Offer some suggestions
- Raise the question of the merit of future broadband profile obs.
- Mention NOAA/UAS (ROA) activities

This is not a proposal

Typical Merits of Small-Balloon Platform

- High-altitudes are achievable
- Mostly all-weather
- Minimal air-traffic/safety regulation
- Expendable or recoverable (cost issue)

Negatives

- Minimal control
- Sensor motion
- …

Journal of the Meteorological Society of Japan, Vol. 82, No. 2, pp. 623--637, 2004

Development of a Radiometer-Sonde for Simultaneously Measuring the Downward and Upward Broadband Fluxes of Shortwave and Longwave Radiation

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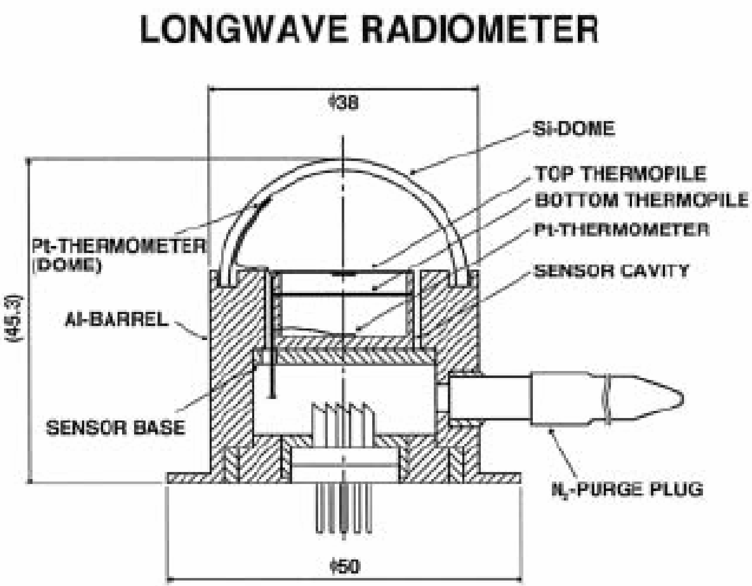
(Manuscript received 6 May 2003, in final form 19 November 2003)

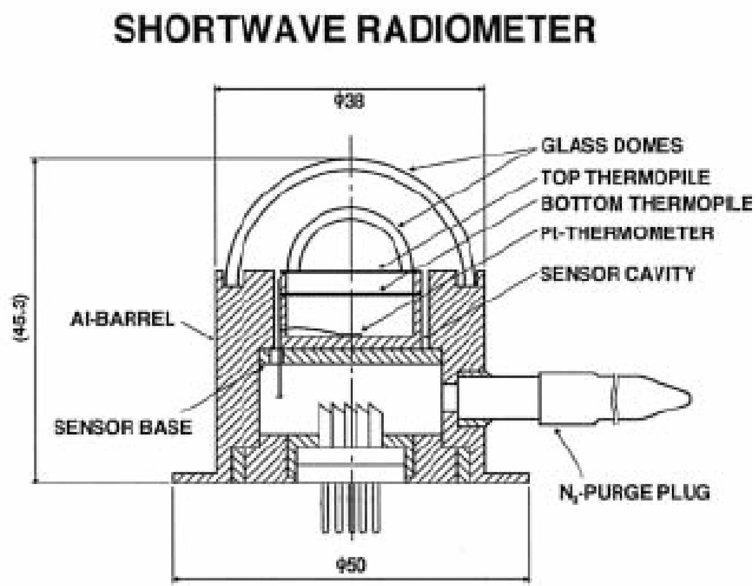
Abstract

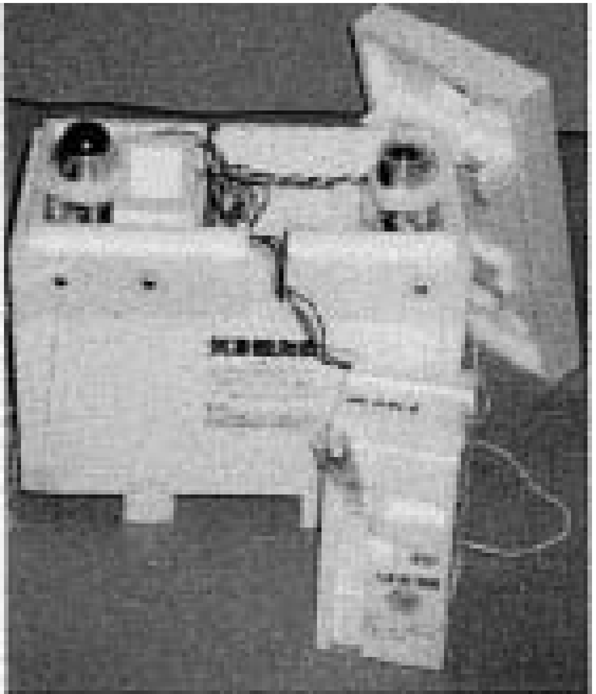
We have developed a disposable type of radiometer-sonde for independently measuring the downward and upward broadband fluxes of solar and terrestrial radiation with a pair of up-looking and downlooking shortwave (SW) and longwave (LW) radiometers. The radiometer-sonde contains a built-in rawinsonde for simultaneously measuring air-temperature, humidity and wind profiles. The paper outlines the state-of-the-art of the radiometer-sonde, and discusses its performance. We have investigated such characteristics as temperature dependence, linearity, and transitional thermal effects of the SW radiometers, as well as transitional thermal effects of the LW radiometers through laboratory experiments and sonde-launching tests. Further, we have tested the practical performance of the radiometer-sonde for several cases of clear skies. The measured flux profiles were compared with those computed for modeled atmospheres. The developed radiometer-sondes have proved their adequate performance to simultaneously measure the radiative flux profiles and the atmospheric profiles with enough accuracy to detect radiative effects of aerosols (SW radiometers) and water vapor (LW radiometers) in the lower troposphere. It is also suggested that the SL radiometer-sondes will be also effective for measuring the radiative flux profiles in high-level ice-clouds with stronger radiative effects.`

EKO Sonde Features

- Four sensors, up and down, solar and IR
- "Disposable"
- Thermopile sensors with internal cavity reference
- Nitrogen purged and sealed
- 3- and 6-second time response, S and L respectively
- Characterized for cosine, T, and delta-T responses
- 8-second (40-m) resolution
- Error ~ ±35 W m^{-2}, but some cancellation in net & reflect
- Std met variables
- Not in production but "lives"


LONGWAVE RADIOMETER
φ38
Si-DOME
TOP THERMOPILE
BOTTOM THERMOPILE
Pt-THERMOMETER
SENSOR CAVITY
Pt-THERMOMETER (DOME)
(45.3)
Al-BARREL
SENSOR BASE
N_2-PURGE PLUG
φ50


SHORTWAVE RADIOMETER
φ38
GLASS DOMES
TOP THERMOPILE
BOTTOM THERMOPILE
Pt-THERMOMETER
SENSOR CAVITY
(45.3)
Al-BARREL
SENSOR BASE
N_2-PURGE PLUG
φ50



Sensor Characterization
Asano et al

Dynamic T response

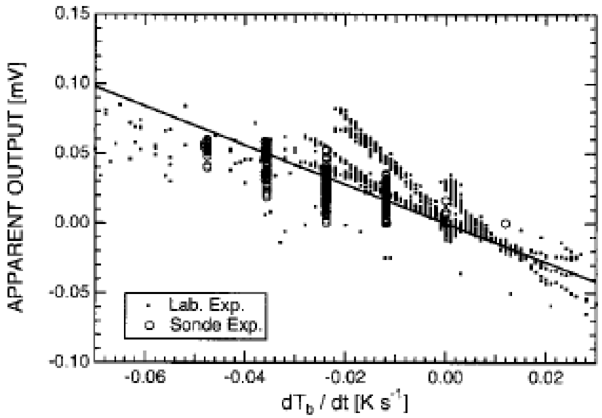


Fig. 2. Apparent outputs ΔV_S, as a function of the changing rates of radiometer temperature, dT_b/dt, for three SW radiometers tested in the laboratory ex-

Capped pyrgeometer

Lab

Flight test

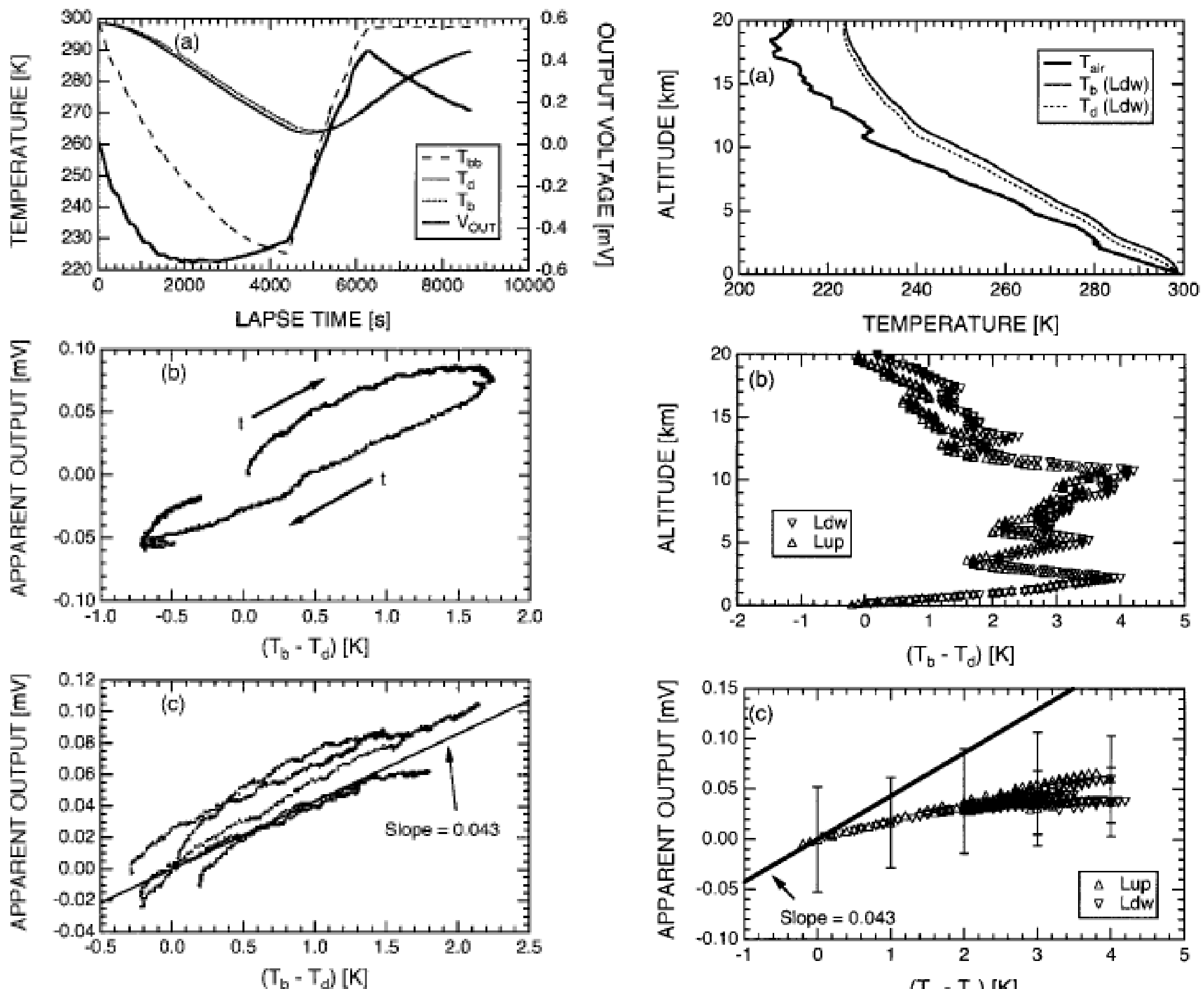


Fig. 4. Results of the blackbody-imitated radiometer-sonde launched on 19 June 1996 (see Text). (a) Height distribu-

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Fig 6 - clear

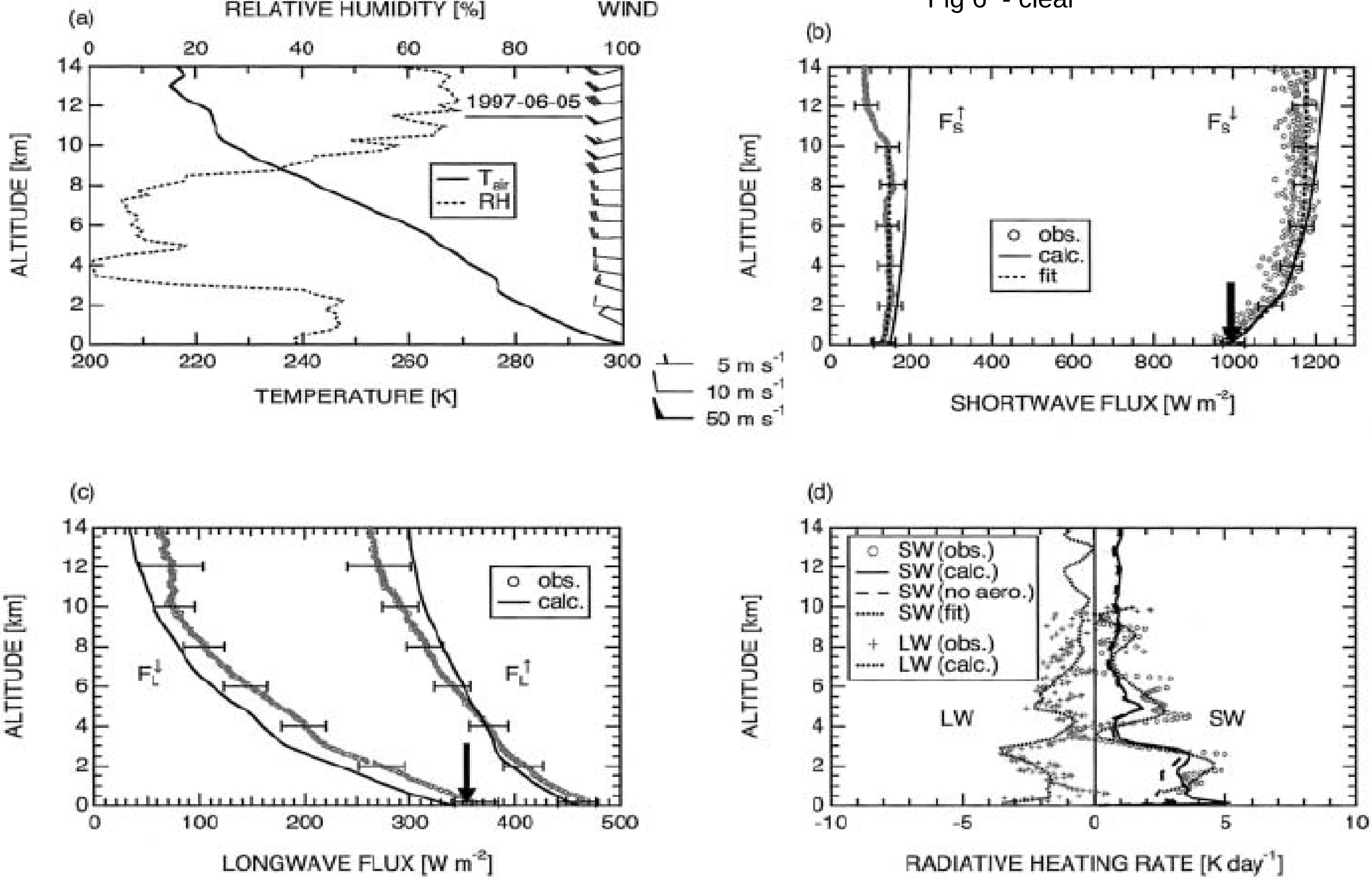

Fig. 6. The height profiles of (a) air-temperature, humidity and wind measured by the built-in rawinsonde, and the shortwave (b) and longwave (c) radiative fluxes measured by the radiometersonde as well as the (d) radiative heating rates estimated from the fluxes profiles for the cloudless case observed on 5 June 1997. For the downward SW fluxes in the upper atmosphere shown in (b), we have omitted the scattered data points that were deviated more than $\pm 10\%$ from the mean value. The horizontal error bars in (b) and (c) represent the range of measurement uncertainties caused by the radiometer characteristics discussed in the text. The thick dotted lines in (b) and (d) represent the smoothed (fitted) SW flux and heating rate profiles.

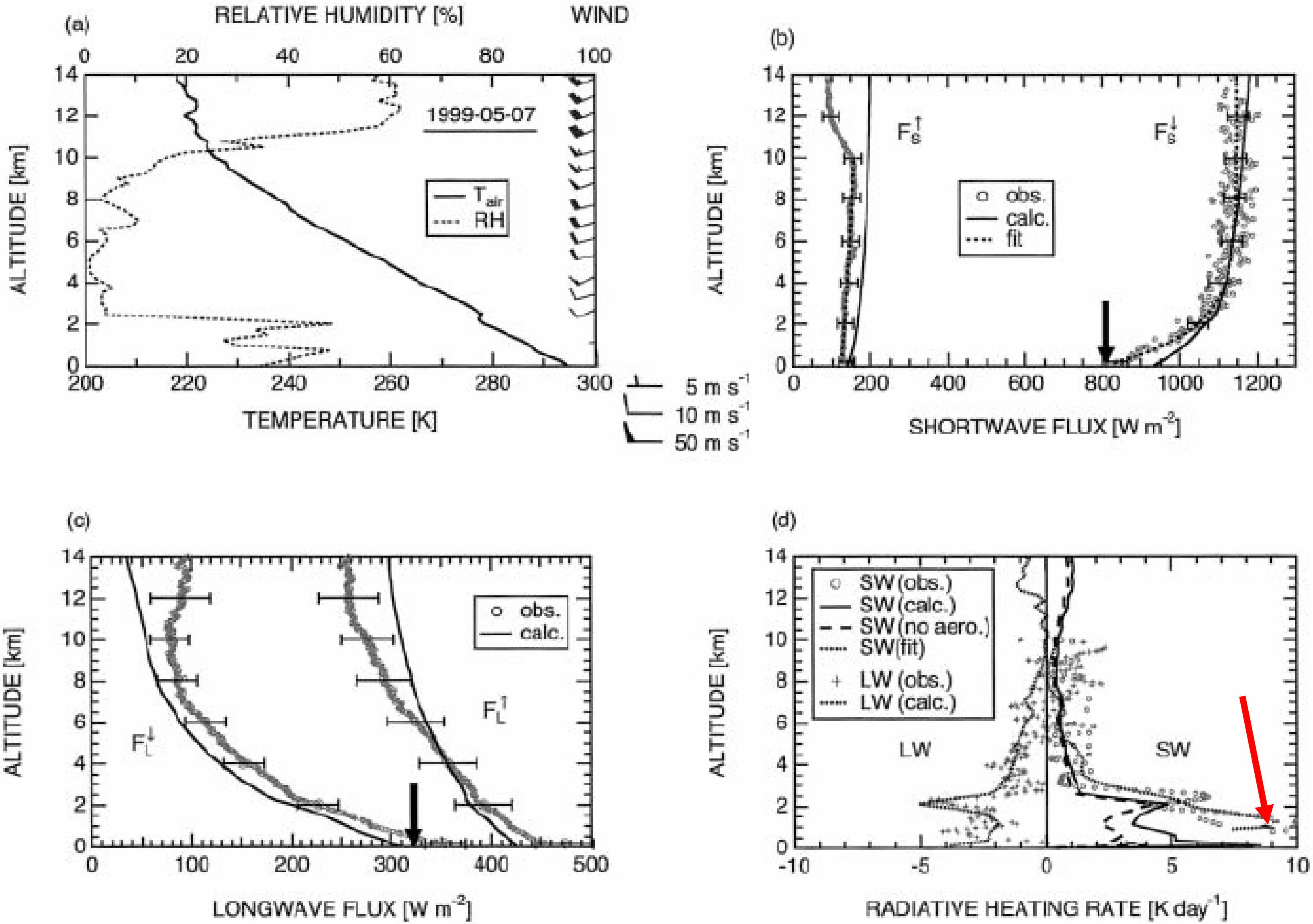

Fig. 7. Same as Fig. 6, but for a cloudless, hazy case on 7 May 1999. The SL radiometer-sonde was launched at 10:40 (LST).

SOUNDINGS OF TERRESTRIAL RADIATION FLUX OVER WISCONSIN[1]

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V. E. SUOMI and G. L. DARKOW, Department of Meteorology, The University of Wisconsin

[Manuscript received January 6, 1959; revised April 7, 1959]

ABSTRACT

Results and conclusions drawn from 50 radiometer-sonde ascents over Wisconsin are presented. Atmospheric infrared radiation flux is separated into upward, downward, and net components. Radiation divergence and resulting cooling are computed. Seasonal averages of these direct observations are compared.

MWR 1959

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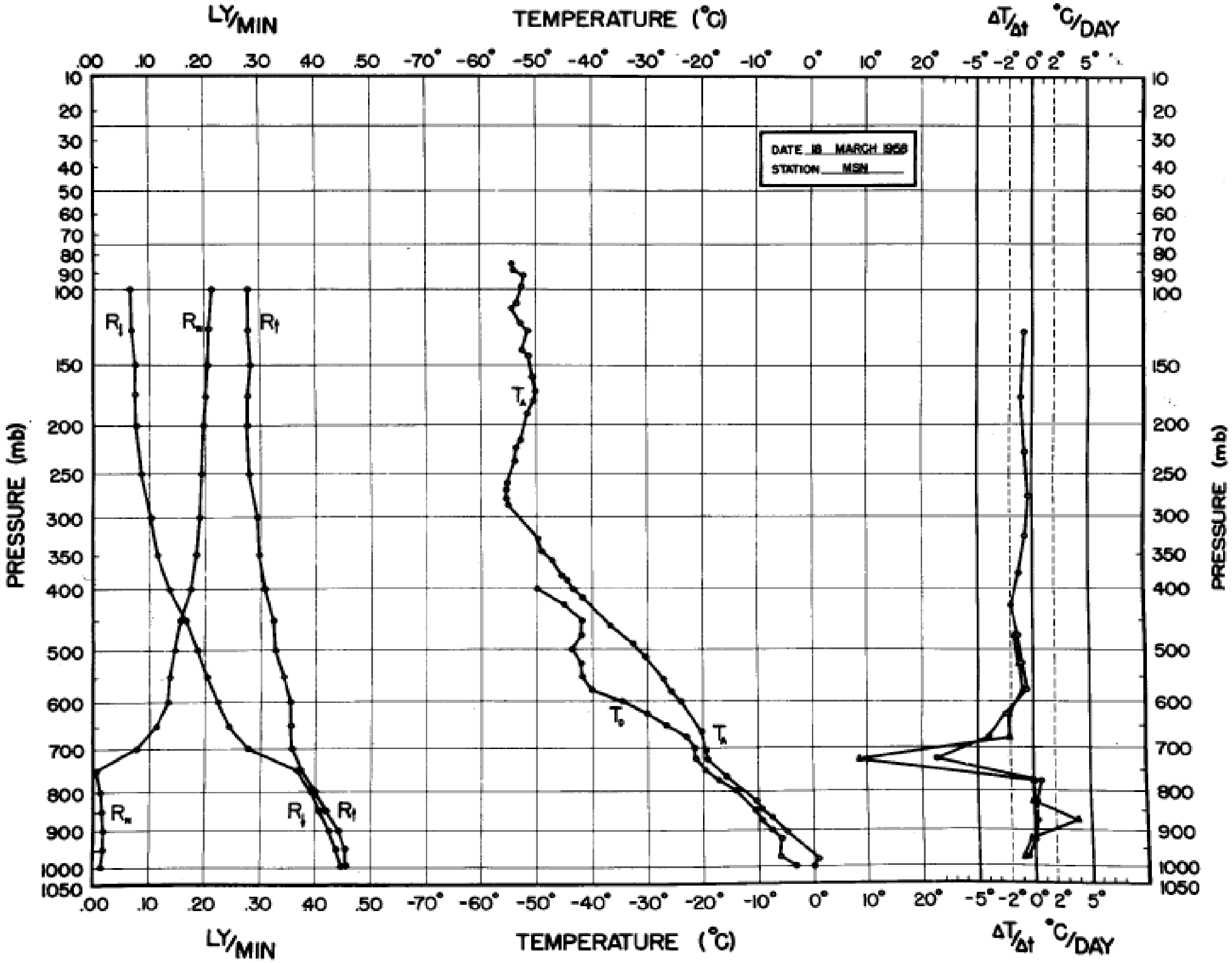

FIGURE 3.—Cloudy winter radiometer-sonde ascent. March 18, 1958, 2033 CST, Madison, Wis. Triangles represent Elsasser cooling evaluation. Circles indicate direct evaluation of radiative cooling.

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JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 98, NO. D7, PAGES 12,961–12,971, JULY 20, 1993

(Nighttime)

Properties of Austral Winter Clouds Derived From Radiometric Profiles at the South Pole

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Although clouds are known to radiatively modulate the energy budget of Antarctica, particularly during the polar night, very little is known about their physical, radiative, or microphysical properties. A unique set of measurements consisting of infrared flux profiles (radiometersonde data) collected at the south pole is analyzed in conjunction with ancillary meteorological observations to gain a better understanding of austral winter clouds. Distinct radiometric features associated with cloud boundaries are used to estimate the heights, thicknesses, and temperatures of selected cloud systems. The physical cloud properties are combined with infrared flux measurements to formulate the thermal energy budgets of the cloud layers and to derive their bulk radiative properties. By comparing these derived radiative properties with theoretically computed values for model clouds varying in microphysical characteristics the clouds' ice contents and effective particle sizes are also inferred. Austral winter clouds are found to be moderately thick and on average extend to heights greater than 3 km above the top of the surface-based inversion layer. They are optically thin, however, and nonblack, having mean effective emissivities of about 0.6. Because they are cold (≤ -40°C) these clouds are composed of small ice particles, have low total ice contents, and contain little or no liquid water. Overall, they are similar to high-level cirrus clouds observed in the mid-latitudes. The characteristic radiometric features that distinguish overcast from clear sky conditions at south pole are discussed; mean profiles of infrared fluxes, temperatures, vector winds, and heating rates are presented; and a summary is provided of cloud properties that may be of use to climate modelers.

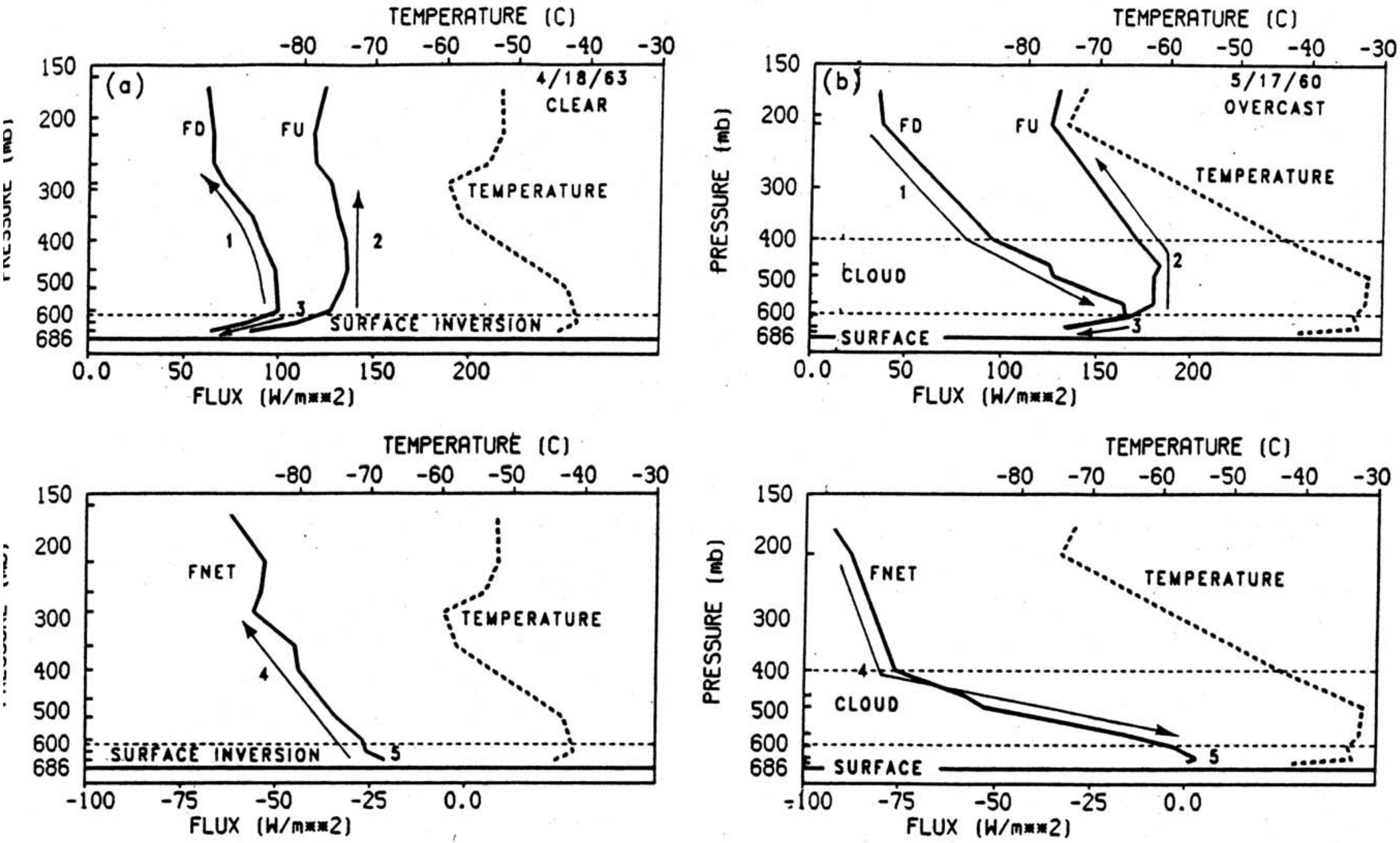

Fig. 1. IR flux profiles showing typical features that distinguish (*a*) clear-sky from (*b*) overcast conditions at the south pole during winter. The top of the surface-based temperature inversion is shown in (*a*) and the estimated cloud boundaries are indicated in (*b*). Coincident temperature soundings are plotted as dashed curves referenced to the upper scales. Features of each profile are numbered as discussed in the text. FD is downward flux; FU, upward flux; and FNET, net flux.

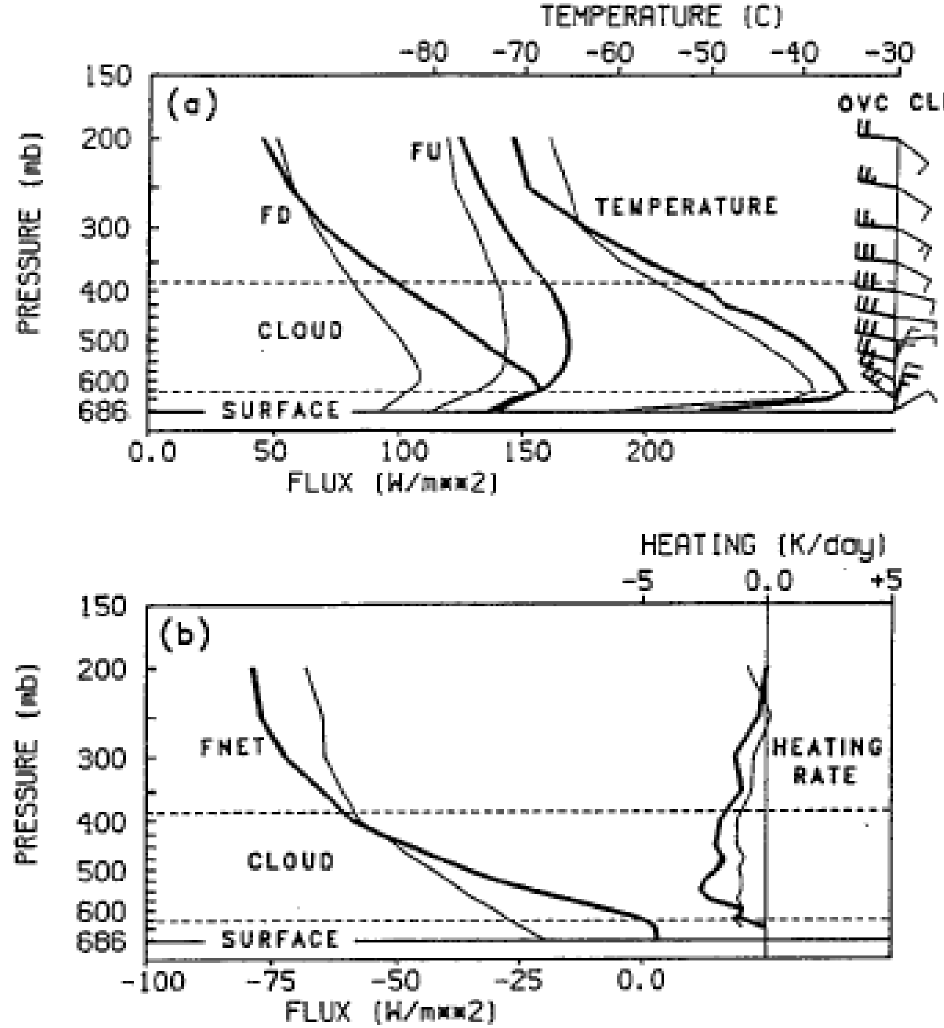

Fig. 2. Mean profiles of (*a*) upward (FU) and downward (FD) longwave fluxes (lower scale), temperatures (upper scale) and vector winds (barbs at right with 1 full barb equal to 5 knots), and (*b*) net fluxes (FNET referenced to lower scale) and associated heating rates (upper scale) for eight overcast cases (bold curves/wind barbs) and 10 clear-sky cases (thin curves/wind barbs). The mean cloud extent is indicated by dashed lines.

R. Stone 1993, JGR

TABLE 1. Sensitivity of Cloud Radiative Properties to Errors in Cloud Top Determination

Property	P_T, mbar 400	350	450
ε^*	0.444	0.580 (+31%)	0.250 (-44%)
τ_{eff}	0.587	0.868 (+48%)	0.288 (-51%)
κ_{eff}, km^{-1}	0.175	0.207 (+18%)	0.112 (-36%)

P_T is cloud top pressure; ε^* is effective broadband longwave emissivity; τ_{eff} is effective broadband IR optical depth; and κ_{eff} is effective broadband volume extinction coefficient. Relative percent differences from the assumed true cloud top pressure level at 400 mbar are given in parentheses.

TABLE 2. Derived or Inferred Properties of Austral Winter Clouds at the South Pole

P_B, mbar	P_T, mbar	Z_B, m	ΔZ, m	T_B, °C	T_T, °C	ε^*	τ_{eff}	κ_{eff} km^{-1}	r_e, µm	IWC, $g\ m^{-3}$
635	380	465	3350	-36.6	-52.8	0.62	1.03	0.35	*	*
(25)	(90)	(240)	(1335)	(4.8)	(9.7)	(0.06)	(0.16)	(0.12)	*	*
600	280	140	1785	-45.1	-66.7	0.54	0.77	0.21	4	0.0003
665	500	840	5625	-30.8	-39.6	0.71	1.25	0.53	16	0.006

: standard deviation; P_B, P_T, T_B, and T_T are the respective cloud base (B) and cloud top (T) pressures (P) and temperatures l Z_B is the cloud base height above ground level; ε^* is effective broadband longwave emissivity; τ_{eff} is effective broadband IR depth; κ_{eff} is effective broadband volume extinction coefficient; r_e is effective radius; and IWC is ice water content. Asterisks: e estimated ranges for these microphysical quantities are given, inferred by comparing derived quantities for the observed with properties of model clouds, as described in the text.

R. Stone, 1993

Desirable improvements for profiling radiometers

Sonde sensors:

- Aerodynamic or spin stabilization
- Gimbal mounting
- Electronic compass and tilt meter
- Pendulum damping
- Measurement during descent, more stable

All radiometric profiling sensors:

- Dynamic temperature characterization
- Duplicate, blanked or capped, instruments
- Mechanical stabilization
- …

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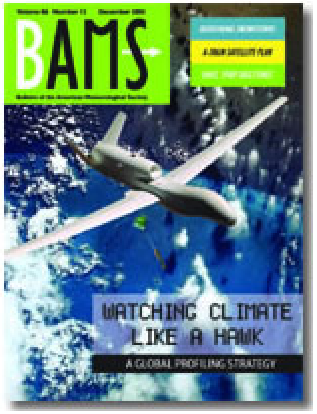
Some Key Issues for Broadband Profile Obs. Regardless of Sensor or Platform

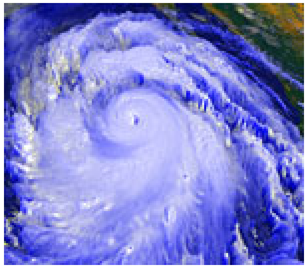
- Scientific utility
- Desired and achievable accuracy
- Radiometer characterization - all the usual + dynamic thermal conditions
- Sensor orientation
- Altitude range of greatest interest
- Condensation & other obstructions

NOAA UAS (ROA) Initiatives

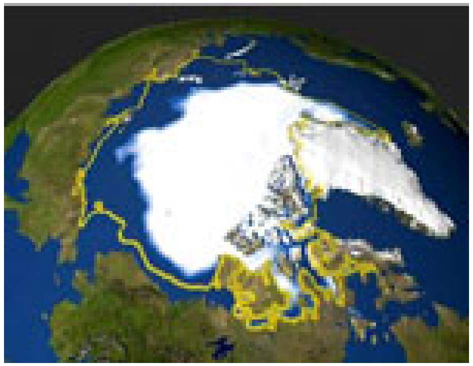


Global Observing Network

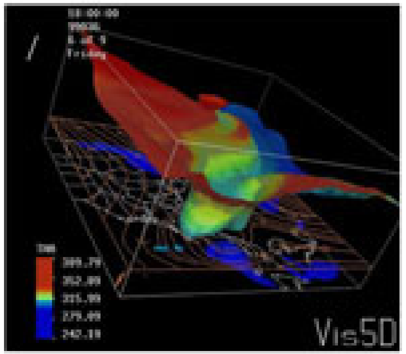
Instrumentation



Hurricanes



Polar Research



Stratosphere-Troposphere Exchange

http://uas.noaa.gov/index.html

Text from:

NOAA Report to Congress on the Potential Use of Unmanned Aircraft Systems (UAS) for NOAA missions

NOAA's Office of Marine and Aviation Operations and NOAA's Office of Oceanic and Atmospheric Research 2006

Radiation and aerosol instrumentation on a routinely or expeditionary operated UAS platforms could provide a valuable bridge closing the gap between the two major sources of information for climate applications, ground- and space-based observing platforms. For the scientific goals of addressing aerosol radiative forcing and understanding climate radiative processes and feedbacks, there is the need for greater vertical and geographic coverage. UAS could permit extended coverage over oceanic areas and remote land regions where either surface observations are unavailable or by providing temporal and vertical resolution that satellites do not. Both types of extended coverage will provide more information about the climatic state of the planet and in many cases be more advantages if carried out over long-term to help define climate variability.

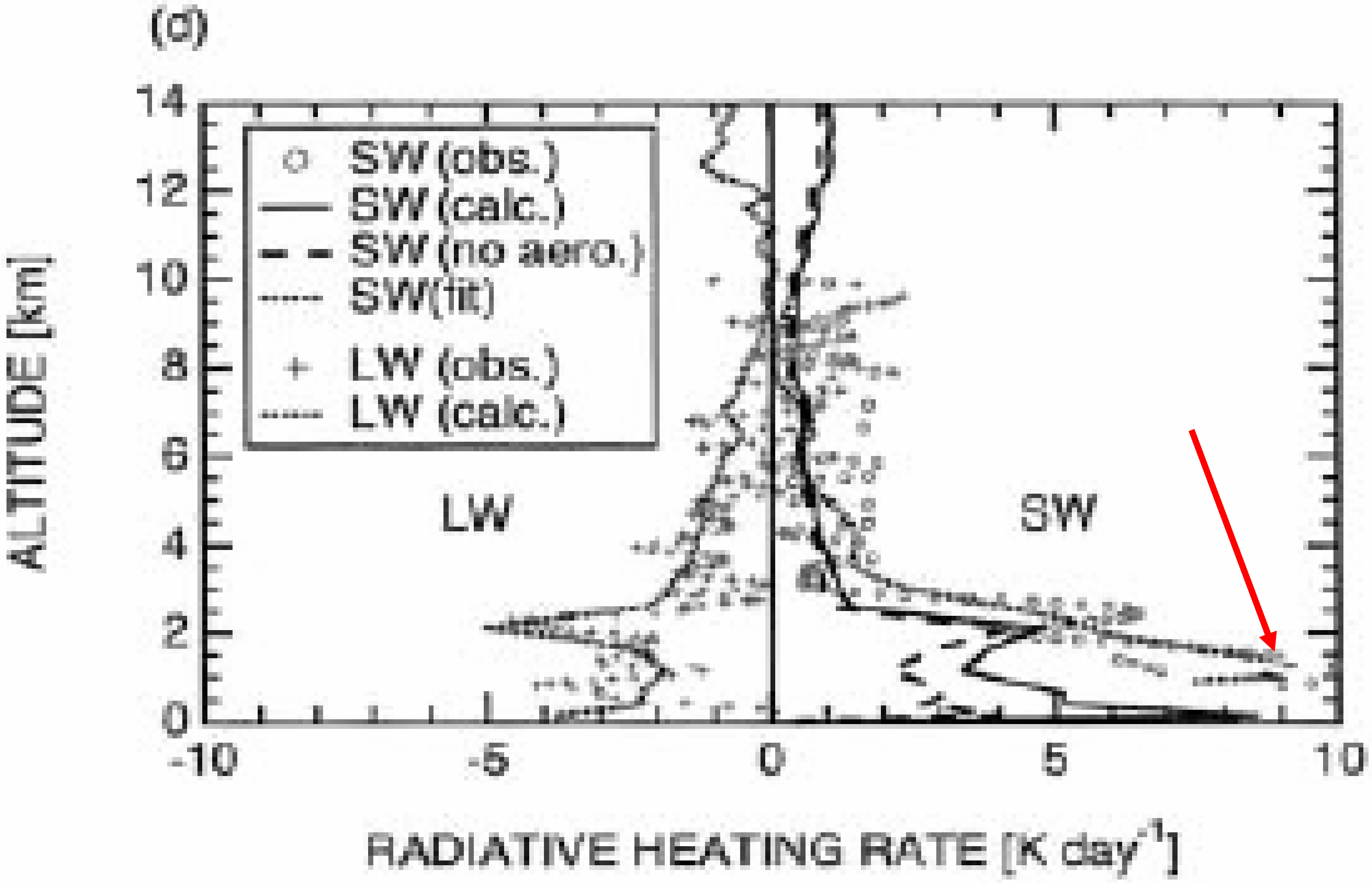
Specific radiation measurements that could be made from a UAS platform, with adequate development and adaptation, fall into four main categories; 1) in-situ radiative energetics, 2) remote sensing total column atmospheric constituents, particularly aerosol optical depth but including other gases, 3) remote sensing of the earth's surface radiative features such as albedo, and 4) ancillary and supporting observations to aid in data interpretation. The first set of measurements could include upward and downward looking broadband radiometers that could determine not only the radiation budget portion of the local energy budget but could also provide the radiative heating rate profiles. These instruments would require a continually level-stabilized mounting platform. The second set of instruments would require an active solar tracking capability for best results. Measurements of aerosol optical depth could be combined with onboard observations of in-situ aerosol properties for the most complete understanding of those aerosols. The third type of measurements would require downward looking spectral sensors preferably with scanning and variable field of view capability. The fourth set of instruments would be for typical environmental conditions plus upward and downward full hemispheric digital imagery.

Conclusions

- EKO sonde may be better than concluded in Asano et al.
- Small balloonborne sondes have provided useful info.
- A number of improvements in balloon and profiling radiometers are desirable and a few suggestions were given.
- UAS are becoming more available

NSF SBIR, let Jan 06

- Phase I - Proprietary
- Combine radiosonde and 4-component radiometers, SW & LW, up and down
- Expendable
- Error analysis included, but…
- Phase II proposal due Jul 2006
- Phase II testing ~Dec 2008
- Testing at SGP is anticipated


(d)
SW (obs.)
SW (calc.)
SW (no aero.)
SW(fit)
LW (obs.)
LW (calc.)
LW
SW
ALTITUDE [km]
RADIATIVE HEATING RATE [K day^-1]
14
12
10
8
6
4
2
0
-10
-5
0
5
10