N91-10469

IDENTIFICATION OF CIRRUS OVER WAUSAU DURING THE 1986 FIRE IFO FROM GROUND-BASED RADIOMETER DATA

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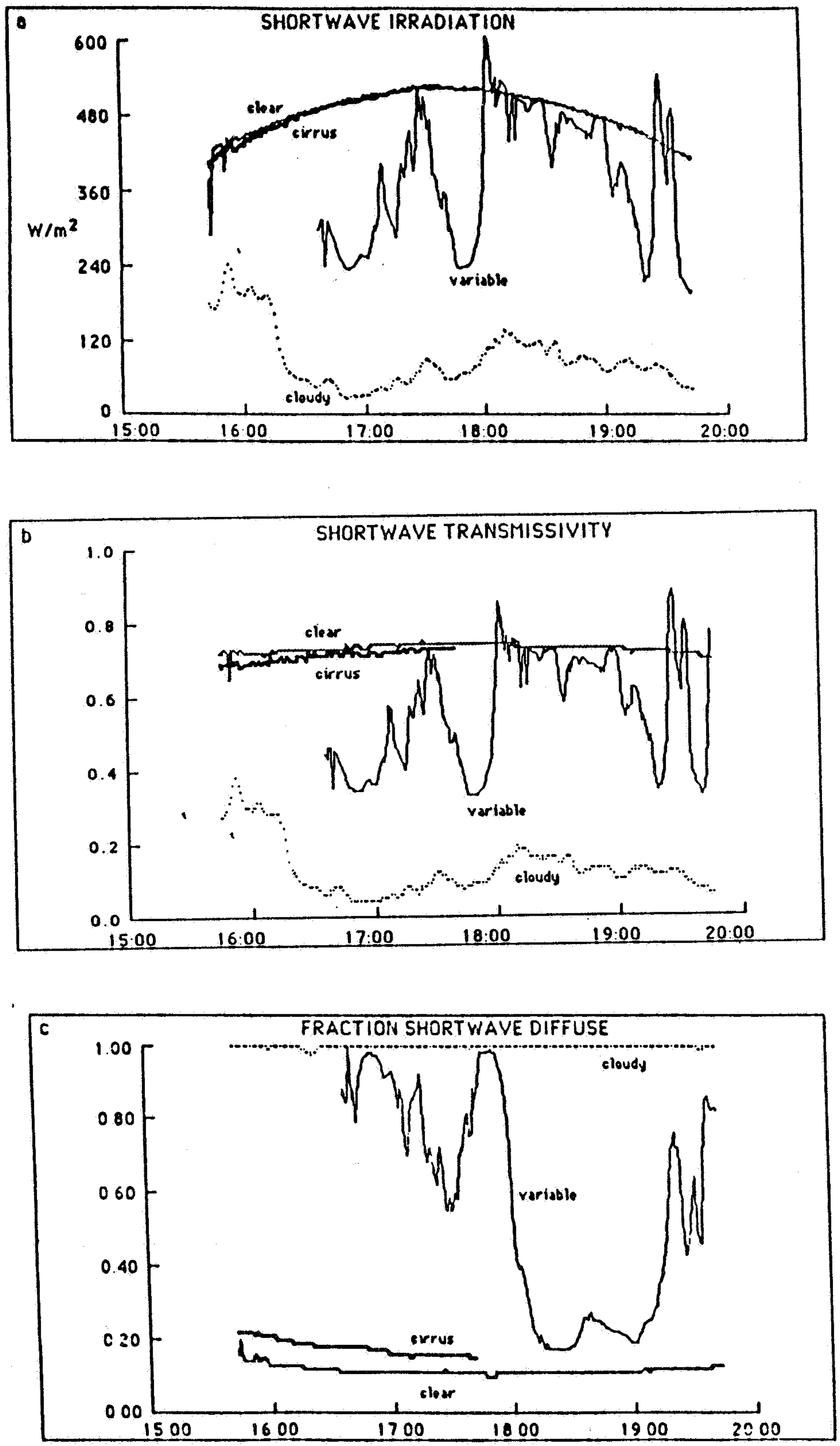
The potential of using irradiation data to indicate episodes of cirrus cloudiness during the day light hours is explored here. Thresholds separating cirrus from other clouds and clear skies are determined using four days of irradiation data, hourly weather observations, sky photographs, sky video and occasional lidar observations. Data were gathered during the First International Satellite Cloud Climatology Program (ISCCP) Regional Experiment (FIRE) Intensive Field Observations (IFO) cirrus project. Thresholds are tested using data from the remaining 17 days of the IFO. Cirrus episodes are defined as intervals when the sky cover is primarily cirrus.

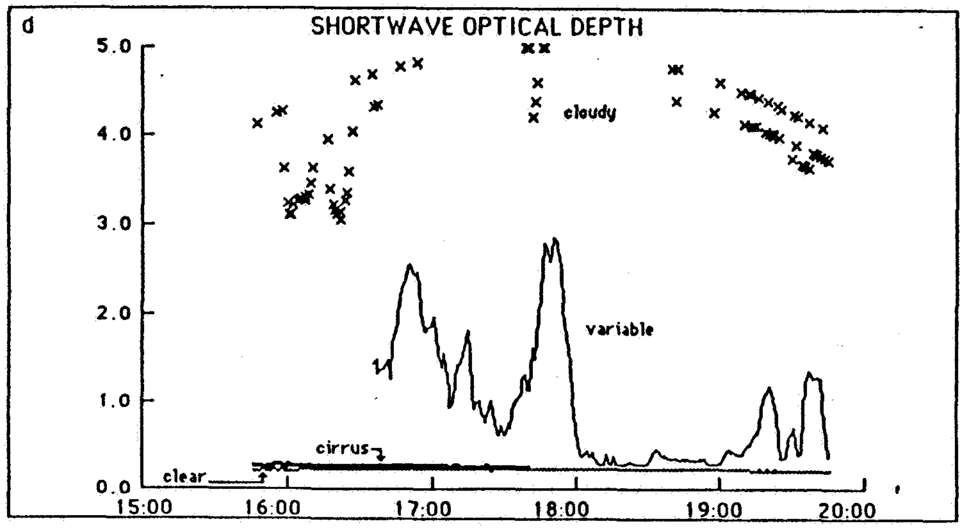
Measurements of incoming shortwave (0.28-2.80μm) and near infrared (0.7-2.80μm) full hemispheric and diffuse irradiation, and atmospheric infrared irradiation (4.0-50.0μm), were made at the Wausau, Wisconsin Municipal Airport. Data were collected between October 13 and November 2, 1986 and are one minute averages of ten second samples. Less than 5% of the data are missing. The Eppley Precision Spectral Pyranometers and the Eppley Pyrgeometer were calibrated with Colorado State University instruments at Madison, WI immediately prior to their installation at Wausau. Pyrgeometer output contains an adjustment for body temperature but not for dome temperature. In addition to the raw irradiances collected, variables derived from these data are analyzed. Ones which proved to be most useful are: shortwave transmissivity, optical depth in the shortwave, fraction of full shortwave which is diffuse, the ratio of near infrared diffuse radiation to visible diffuse radiation, the ratio of full near infrared to full visible, and infrared irradiation.

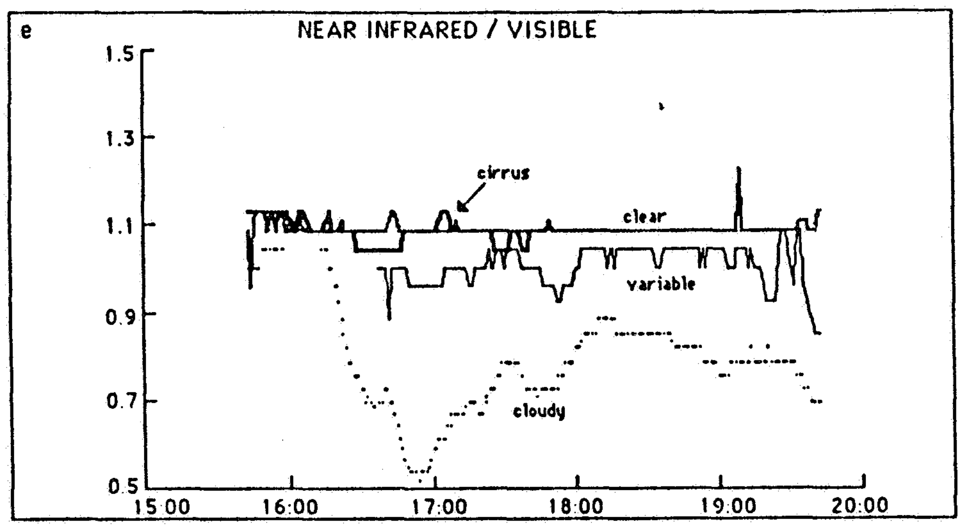
Data from October 23rd and from October 27-29 were used for threshold determination. On the 23rd skies were heavily overcast. Thin cirrus associated with an approaching warm front covered the sky on the 27th. This episode of cirrus continued through the 28th, however throughout most of this day the cirrus were obscured at the observation site by stratus clouds with bases of approximately 3.5km. Skies were primarily clear on the 29th. Figure 1 shows time series of irradiation data and irradiation-derived variables within two hours of solar noon on these dates. At this preliminary stage of the investigation only midday hours are considered in order to minimize the influence of changes in solar zenith angle on the parameter.

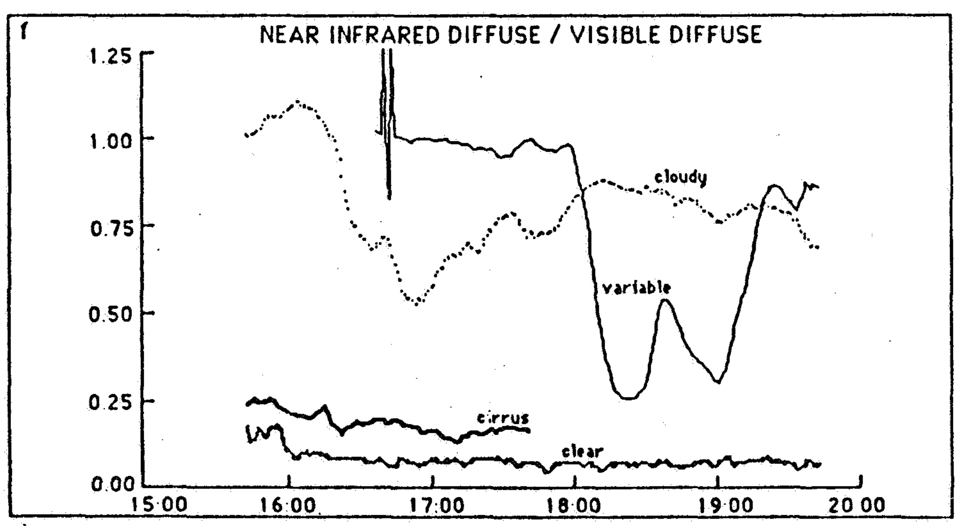
Using weather observations, lidar output, photographs and video, sky conditions were grouped into three categories: non-cirrus cloudy; cirrus and clear. Irradiation data from all periods falling under each of the sky categories were then examined and thresholds denoting a change from one sky category to another were determined. Variables with only a small amount of overlap between sky categories were selected as key indicators. They are listed in Table 1 along with the delimiting thresholds. Variables such as shortwave irradiation, shortwave transmissivity and the ratio of near infrared diffuse to visible diffuse proved inconclusive in terms of distinguishing between cirrus and non-cirrus clouds and/or cirrus and clear conditions. For instance, a shortwave transmissivity threshold of 0.67 separates non cirrus

Figure 1. Mid-day irradiances and associated atmospheric variables at Wausau, WI on October 23 (cloudy), 27 (cirrus), 28 (variable) and 29 (clear), 1986. Time in GMT (local+6). Data are missing after 17:45 on the 27th and before 16:30 on the 28th.




d
SHORTWAVE OPTICAL DEPTH
5.0
4.0
3.0
2.0
1.0
0.0
cloudy
variable
cirrus
clear
15:00
16:00
17:00
18:00
19:00
20:00


e
NEAR INFRARED / VISIBLE
1.5
1.3
1.1
0.9
0.7
0.5
cirrus
clear
variable
cloudy
15:00
16:00
17:00
18:00
19:00
20:00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NEAR INFRARED DIFFUSE / VISIBLE DIFFUSE
1.25
1.00
0.75
0.50
0.25
0.00
cloudy
variable
cirrus
clear
15:00
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17:00
18:00
19:00
20:00

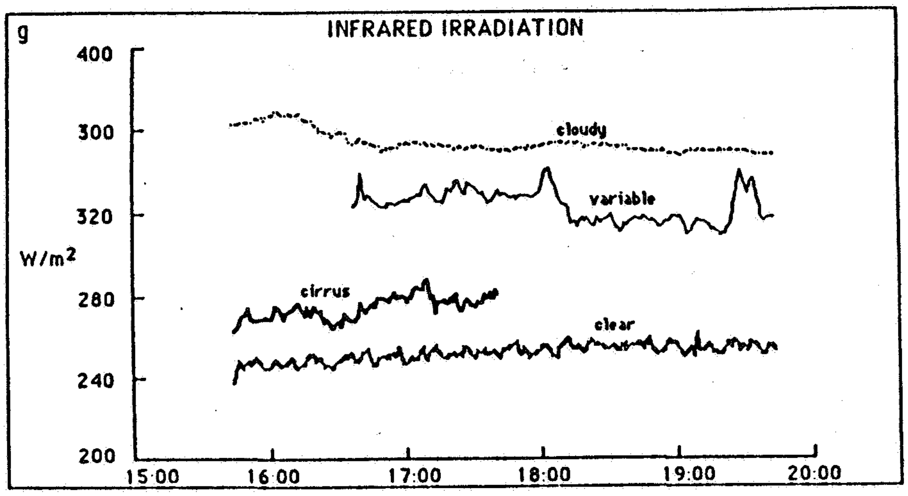


Table 1. Thresholds delimiting non cirrus cloud, cirrus and clear sky conditions.

INDICATOR	CIRRUS / NON-CIRRUS*	CIRRUS/CLEAR*
shortwave transmissivity	$\geq$ 0.67	inconclusive
fraction shortwave diffuse	$\leq$ 0.30	$\geq$ 0.15
shortwave optical depth	$\leq$ 0.30	$\geq$ 0.24
near infrared/visible	$\geq$ 1.00	$\leq$ 1.10
nir diffuse / vis diffuse	inconclusive	$\geq$ 0.12
infrared irradiation	$\leq$ 320 watts/m^2	$\geq$ 260 watts/m^2

*sign refers to what constitutes cirrus

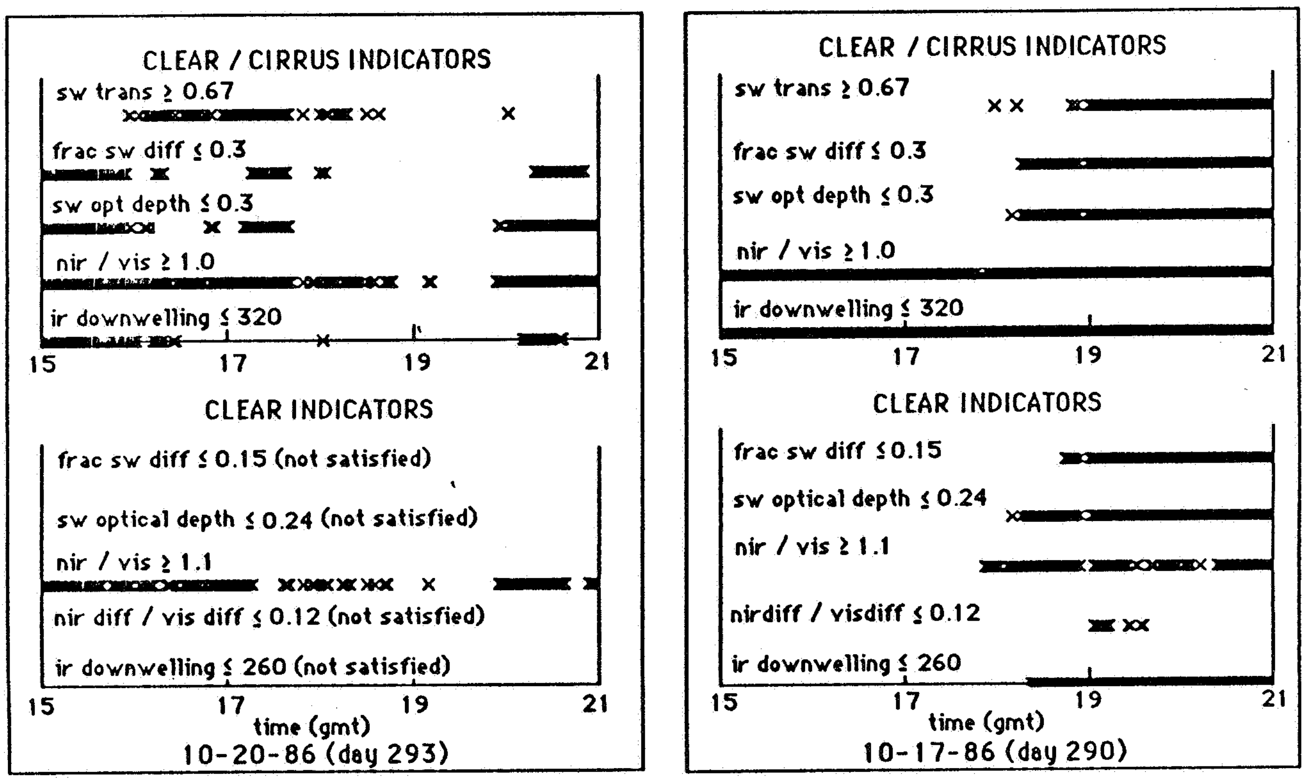
clouds from cirrus quite well, however it is difficult to distinguish cirrus from clear skies using transmissivity. This appears to be due to: difficulties in differentiating between cirrus and clear in the visual observations, photos and video; lack of a specific broad-band shortwave signature which distinguishes cirrus from lower level haze; and to the zenith angle dependance of transmissivity.

Spot checks with other data such as weather service observations, photos, video and lidar indicate that the thresholds listed in Table 1 work quite well on all IFO days. At all times when conclusive evidence from more than one of these sources is available, there is agreement with the threshold-derived results. During the IFO, there were only three or four days with clear episodes, and nine or ten days with at least one short cirrus episode. There were many more hours of overcast conditions than either clear or cirrus. Comparisons of the threshold-derived results with the other types of evidence show that shortwave optical depth, the fraction of shortwave which is diffuse, and shortwave transmissivity seem to be the best indicators for the cloudy/cirrus threshold. The best indicators for the cirrus/clear threshold seem to be the ratio of near-infrared diffuse to visible diffuse radiation, shortwave optical depth, the fraction of shortwave which is diffuse, and infrared irradiation.

The distribution of sky categories as determined by the indicator thresholds is shown for two study days (figure 2). The top graph in each figure shows intervals where clear skies or cirrus were present, the bottom where clear skies occurred. On October 20 there was a non-cirrus cloud episode between approximately 18:00 and 20:00 GMT. Cirrus were prevalent between 15:00 and 18:00 and from 20:00 to 21:00, as suggested by the lack of strong clear indicators throughout these times. The cirrus may occasionally have been thick or obscured by lower-level clouds, as there are breaks in the indicators during the primarily cirrus intervals.

On the 17th skies were cloudy in the morning then cleared up in the afternoon. Most of the indicators in the top portion of the figure (including all of the best ones) show a cloudy morning, with either a cirrus or clear afternoon. The bottom portion of the figure indicates that the afternoon was primarily clear.

Figure 2. Temporal distribution of cirrus or clear skies (top) and clear skies (bottom) at Wausau on October 20 and October 17, 1986 as inferred from key indicators. Intervals when thresholds were exceeded are marked with X's or lines.



Work is continuing on this evaluative approach. This includes the development of multi-indicator thresholds and extending them to early and late day periods. In the future, data gathered at our Extended Time/Limited Area observation site in Palisades, NY will be used to test the algorithms and make necessary adjustments based on potential site and seasonal differences.

Acknowledgment: This work is supported by NASA grant NAG-1-653.