P1.1 INDICATIONS OF BIASES IN REPORTING CLOUD COVER AT MAJOR AIRPORTS

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1. INTRODUCTION

Cloud cover has traditionally been an important quantity for solar energy applications. Irradiance data and data sets have been generated all or in part from cloud cover data, Davis & McKay (1982), IEA (1988). This paper presents evidence that cloud cover, as currently reported in the US by the NCDC exhibits systematic biases depending on the observing location. As a consequence, irradiances generated from that data exhibit the same systematic biases.

Today, satellite-derived irradiances can provide wider coverage, higher ground resolution and better accuracy than cloud cover-derived data. However, many existing products rely, at least in part, on cloud cover reports from weather services; e.g., Maxwell et al., (1995). Cloud cover reports are also useful as an ancillary input to current satellite models. In particular, it has been shown that satellite-models' accuracy can be improved if an external check on cloud cover is available during conditions of rapidly changing ground albedo such as caused by ground snow cover variations; Ineichen et al., (2000).

We noted unexpected cloud cover-induced biases while conducting a validation of our satellite model against data from the Southern Great Plains' ARM site; Stokes & Schwartz, (1994), Perez et al., (2001). As an ancillary input to the model, we used cloud cover reports from the US National Weather Service (NWS) for sites in the vicinity of the ARM network – a 160,000-km2 area spanning central Oklahoma and southern Kansas. Unexplained distortions in satellite-derived maps were traced to the cloud cover input: out of 21 selected sites, the 3 corresponding to major airport locations showed a consistent reporting trend toward higher cloud cover. In an attempt to further investigate this observation, we decided to analyze NWS cloud cover data at, and around major airport locations throughout the US.

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2. CLOUD COVER REPORTS

Traditional cloud cover observations have been made by human observers by dividing the sky vault into 8 regions (4 azimuthal quadrants and 2 zenithal elevations). Using this framework, the human observer decides whether each sky region contains clouds, and reports cloud cover in octas (0 = clear, 8 = overcast). In the US, octas are converted in tenths before reporting; Steuer & Bodosky, (2000). In addition, cloud cover is reported for three cloud altitudes (low, middle and high clouds).

Beginning in the mid 1990s, the US National Weather Service has been switching an increasing number of stations to an automated cloud cover measurement system as part of its ASOS program; ASOS (2000). At automated sites, cloud measurements are made using a ceilometer (fig. 1) that detects the presence and altitude of clouds directly overhead. This instrument sees only a narrow region at the sky's zenith. On the other hand, it provides a time-continuous stream of data. Therefore, the 8-region spatial discriminator is replaced by a temporal discriminator, and the reported cloud cover octas for a given hour are a function of the fraction of time cloud presence is detected over a 30 minute window; Steuer & Bodosky, (2000). The cloud cover data made available by the NCDC and used in this study – NCDC (2000) - are further extrapolated from fractional readings and reported as "clear", "few", "scattered", "broken clouds" and "overcast", using the equivalence function presented in Table 1. The National Weather Service also distributes the same cloud cover data, reported in tenths, as part of their DATSAV2 data sets; NCDC-a (2000).

TABLE 1

Reported cloud cover	Sky octas
Clear	0/8
Few	1/8 - 2/8
Scattered	3/8 - 4/8
Broken	5/8 -7/8
Overcast	8/8

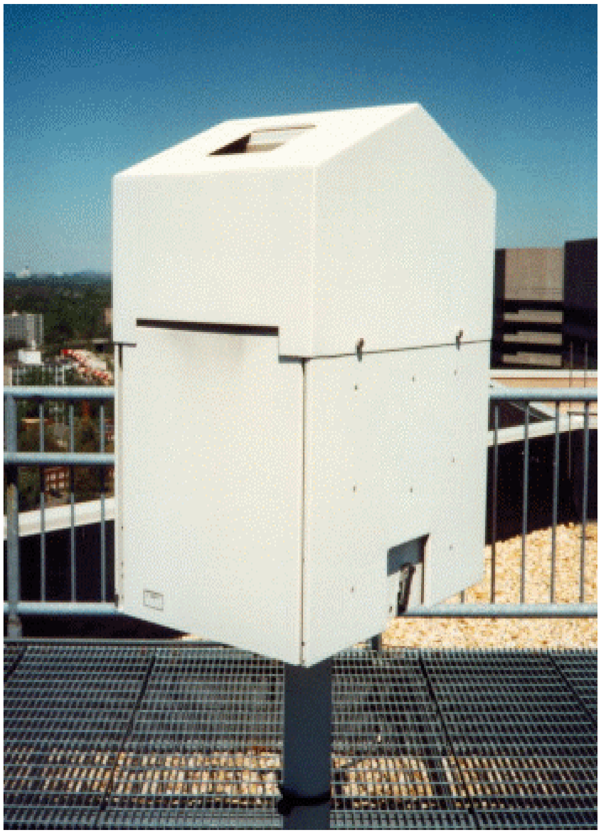

Fig. 1: Ceilometer used at ASOS stations

3. SELECTED CLOUD COVER REPORTING SITES

We selected seven climatically distinct regions in the US. For each region we picked one or two NWS stations at major airports and the others at minor airports or other non-airport locations. We selected the month of June 1999 as a basis for our analysis. We also took a limited look at January 2000 data in order to detect the trace of any possible seasonal trend in reporting bias.

These stations are listed in Table 2, along with their ASOS status. Note that only one station was not using the automated measurement system as of June 1999.

4. RESULTS

In Figure 2, we have plotted the respective occurrence of clear and overcast reports for each station within each considered region.

TABLE 2

Sites	Type of Site	ASOS
New York City area		
Central Park	Other	Yes
Caldwell Essex County Air	Small Airport	Yes
Long Is. McAuthur Air-ISLIP	Large Airport	No
JFK International	Large Airport	Yes
Pittsburgh area		
Ohio County Air	Small Airport	Yes
Allegany County Air	Small Airport	Yes
Pittsburgh International	Large Airport	Yes
Chicago area		
Chicago/Wheeling	Small Airport	Yes
Dupage Air	Small Airport	Yes
Midway Air	Large Airport	Yes
Ohare International	Large Airport	Yes
Phoenix area		
Deer Valley Muni Air	Small Airport	Yes
Prescott Love Field	Small Airport	Yes
Tucson International	Large Airport	Yes
Phoenix International	Large Airport	Yes
Atlanta area		
Dekalb-Peachtree Air	Small Airport	Yes
Fulton County Air	Small Airport	Yes
Peachtree City Falcon Field	Small Airport	Yes
Hartfield International	Large Airport	Yes
Orlando area		
Sanford Air	Small Airport	Yes
Orlando Executive Air	Large Airport	Yes
Orlando International	Large Airport	Yes
Los Angeles		
Palmdale Air	Small Airport	Yes
Sandberg	other	Yes
Long Beach Daugherty Field	Small Airport	Yes
Hawthorne Muni Air	Large Airport	Yes
LA International	Large Airport	Yes

Figure 2 provides evidence that large airport stations report less clear skies and more overcast skies than non-airport or small airport sites. This observation is verified for all selected regions. The magnitude of the differences is most important for clear sky reporting (reaching a factor 10 in Chicago, New York and Orlando). Differences for overcast reporting are not nearly as strong, but nevertheless significant.

A limited test at two sites (Chicago and Los Angeles) for January 2000 led to similar observations, suggesting that seasonal cloud types are not the cause of the differences.

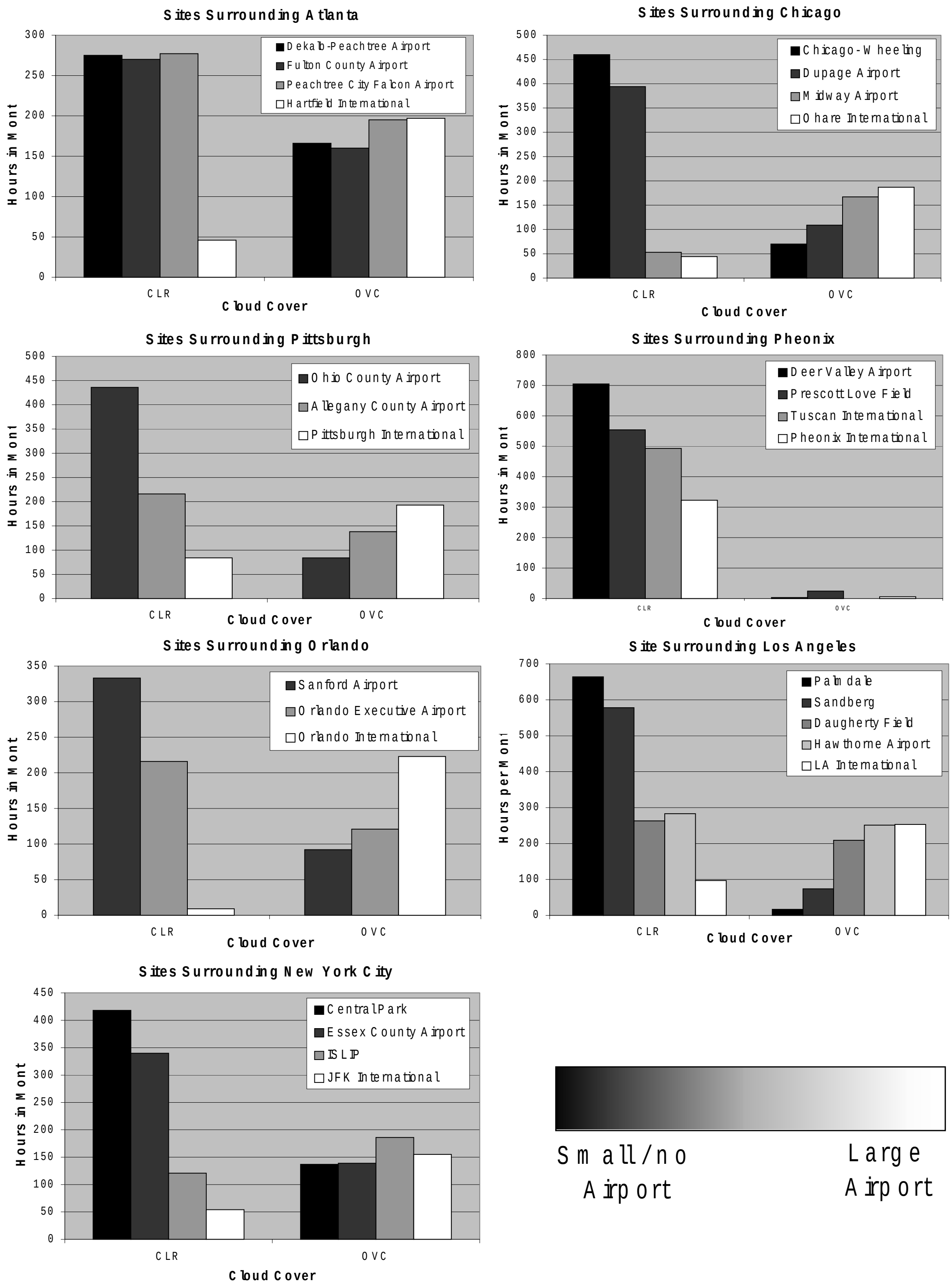

Fig2: Reported clear sky (CLR) and overcast (OVC) hours for each selected site in June 1999

5. DISCUSSION

We observe major differences in cloud cover reported at climatically similar sites, with major airport sites reporting many less clear hours and appreciably more overcast hours.

Since only one station is non-ASOS, the cause of the bias is not the station's ASOS status as we had initially expected.

Another possible source of the discrepancy that we had initially advanced was the nature of the web-based NWS reports that we used – NCDC (2000) -- and the post-processing of the original cloud observations. However, we verified that the same systematic differences also exist in the DATSAV2 data sets where cloud cover is reported in tenths.

Based on discussions with weather observers we suspect that the likely cause of the discrepancy is that not all ASOS stations are operating alike. Several ASOS stations are "augmented" with human observations. These augmented stations are generally located at major airports where a precise knowledge of cloud cover is crucial for air traffic concerns. Human-augmented observations tend to be biased towards higher cloud amount for several possible reasons: (1) observers have access to numerous plane-based observations around their station; (2) observers report any cloud in their field of view that are not directly overhead and not sensed by ceilometers: sometimes distant clouds seen by observers may lead to "few" or "scattered" reports, whereas the highly local ceilometers report "clear" conditions; (3) air traffic safety concerns may lead to more conservative reports.

This explanation will have to be further investigated.

Implications for cloud-cover-derived irradiances are not negligible. An example of these implications is shown in Figure 3. In a separate study -- Perez et al. (2001) -- we conducted a detailed validation of a satellite algorithm in the ARM site region in northern Oklahoma. For this investigation, we had access to an irradiance network consisting of 19 high accuracy/high maintenance stations. We had also assembled cloud cover data for 21 NWS stations spanning the same area. Out of these stations, three were major airports (Wichita Airport, Tulsa International Airport, and Oklahoma International Airport).

Figure 3 includes for maps generated respectively:

(a) from satellite data;
(b) via interpolation of the ARM irradiance measurements;
(c) via interpolation of all the cloud cover measurement sites – using a very basic cloud-cover-to irradiance model and;
(d) via interpolation of the same sites minus the three large airports.

All maps are normalized to produce the same average irradiance throughout the area.

The satellite, ground and the non-airport cloud cover maps are consistent with one another. Understandably, there is much more microclimatic detail with the satellite map, but overall features are comparable. On the other hand, the all-inclusive cloud cover map exhibits marked cloudy singularities around each airport location.

6. CONCLUSIONS

We have shown that National Weather Service sites located at large airports systematically report more cloud cover than other sites. This trend is consistent throughout the US.

We suspect that the cause of this discrepancy is the special "augmented" status of several NWS stations where ceilometer cloud observations are augmented by human observations. Such stations tend to be located at large airports.

Implications for irradiance are not negligible. As this study is based on recent observations, linked with the deployment of ASOS stations, we are confident that irradiance data sets derived from earlier cloud cover observations -- e.g., Maxwell et al. (1995) -- are not affected. However any use of current US cloud observations for irradiance data generation should be handled with great care. We suggest that unbiased cloud observations (e.g., as derived from satellite observations) be used to verify/correct/complement such data products.

7. ACKNOWLEDGEMENT

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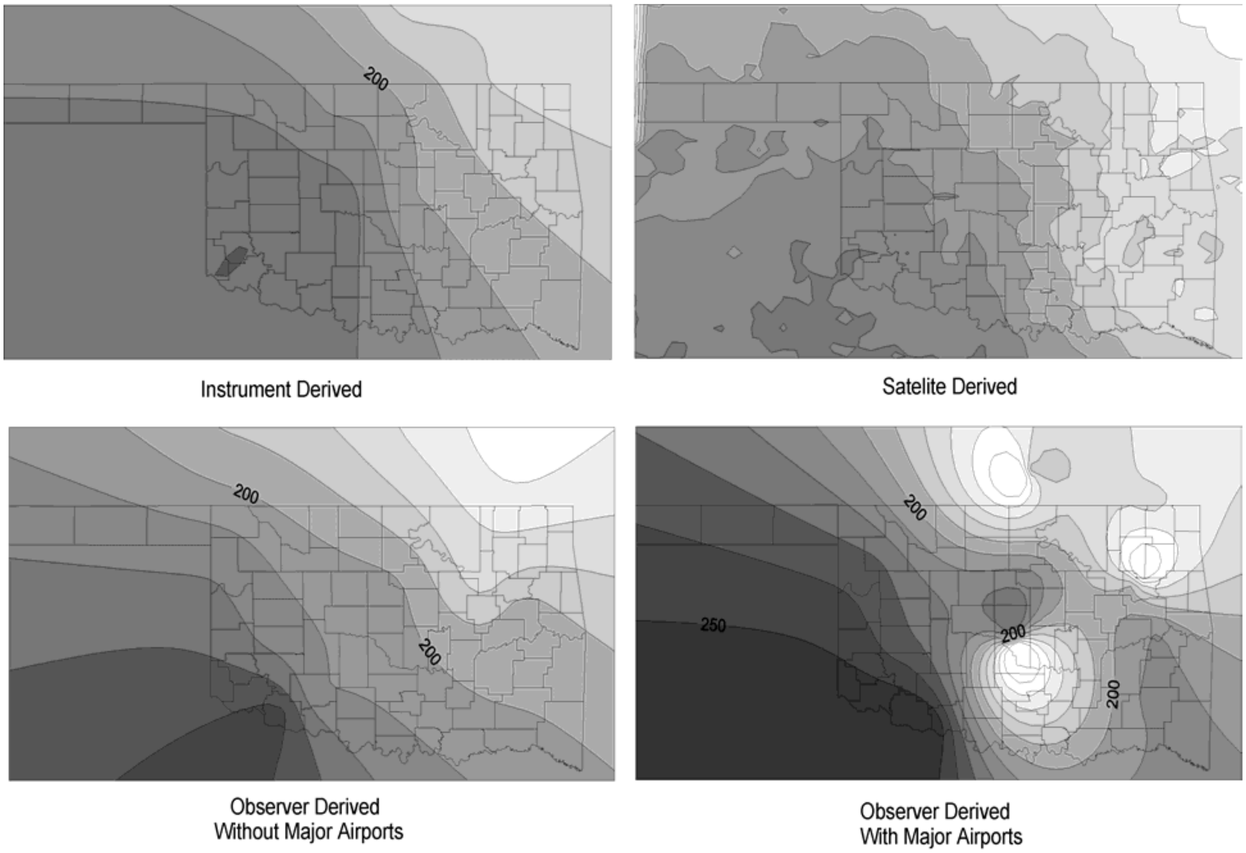

Fig. 3: Irradiance maps for Oklahoma for the month of April 1999, derived from (a) the 19 station ARM irradiance network, (b) geostationary satellite data, (c) cloud cover reports from 21 stations, (d) same as c, but minus three large airport stations

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