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POTENTIAL CLIMATE APPLICATIONS FROM A GLOBAL GEOSTATIONARY SATELLITE DATA SET

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1. INTRODUCTION

The International Satellite Cloud Climatology Project (ISCCP) has provided data for numerous studies of the Earth's climate. ISCCP cloud and radiance information are derived from geostationary and polar-orbiting satellites for the time period of 1983 through the present. However, one ISCCP data set – level B1 – has seen little research despite its 20 year record at the National Climatic Data Center (NCDC). At first this was due to the volume of the B1 data, in the context of computing capabilities of the 1980's. But by the time computing power caught up with the B1 volume, data had already languished for years with little documentation, and no support software or quality control. Thus, in light of the capability to process the entire B1 data set (merely 1.2 Tb at present) for climate research, it becomes necessary to assess and correct these deficiencies.

There are many benefits in using the B1 data, since they have:

- near global coverage,
- 3-hour temporal sampling,
- approximately 10 km spatial sampling, and
- the only visible GMS data from 1983-1987.

So work at NCDC is ongoing to compile B1 data documentation, develop input and output software, test data quality and make them accessible. Up to date information on the ISCCP B1 data rescue can be obtained from:
http://www.ncdc.noaa.gov/oa/rsad/isccpb1/isccpproject.html.

3. B1 DATA COVERAGE

3.1 *Spectral Coverage*

The primary channels for ISCCP cloud analysis are the visible channel (a broad channel centered near 0.6 µm) and an infrared channel in the IR window region (near 11 µm) which have been on every meteorological geostationary satellite since 1983. The relative similarity of the channels has allowed cross-calibration and has been used to estimate cloud properties including optical depth and cloud top.

Observations at other wavelengths are also available from the ISCCP B1 data. For instance, the Meteosat-series of satellites has provided water vapor imagery (near 6.7 µm) since its inception. Also, the newer GOES-series (beginning with GOES-8) provide similar water vapor imagery along with near IR (~3.9 µm) and IR split-window (~12µm) channels. In the future, new satellite sensors will provide more spectral channels (such as Meteosat Second Generation).

3.2 *Spatial Coverage*

The spatial coverage of the B1 data set includes most of the world. The primary deficiency is lack of observations of the poles (which is made up for in ISCCP data by incorporating AVHRR observations). Otherwise, coverage is continuous when satellite data are available. Times when data are unavailable include random missing observations (i.e., files never delivered by the SPC) and systematic gaps in the data coverage. In particular, the lack of geostationary observations over the Indian Ocean is prominent. Until recently, these data were not made available, so a gap exists in the merged imagery. This was overcome when EUMETSAT moved the Meteosat-5 to 63º East in 1997 to support the Indian Ocean Experiment (INDOEX), where it remains to present.

The spatial resolution of the B1 data is roughly 8 km at the Equator. Sub-sampling for most of the sensors constituted taking every other observation in the IR which generally had 4 km resolution. The exception to this is the Meteosat series which had an IR resolution of 5 km, so the B1 resolution is 10 km. Also, the visible channels tend to have finer resolutions than their IR counterpart. In such cases, the visible pixels were averaged to the IR resolution (4 or 5 km, depending on the sensor), then subsampled to the B1 resolution.

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3.3 *Temporal Coverage*

The temporal span of ISCCP B1 data is July 1983 to present. During this time, more than 18 satellites have contributed to the data record. Observations are made from each satellite full disk observation nearest the synoptic time (00, 03, 06, …, 21 UTC), IR imagery is provided each time period while visible imagery is generally dropped for times near the satellite local midnight. Work is ongoing to extend this record into the past from the archives. In particular, data from 1977 is available for GOES while the Japanese have GMMS IR data beginning in 1981. This will allow the expansion of climate records a few more years.

4. B1 CLIMATE APPLICATIONS

Climate applications that would benefit from B1 data abound. For example, once the data set undergoes some basic stewardship, the data set could be used to extend the current data coverage for the Global Precipitation Climatology Project (GPCP). Other applications are possible, some of which are described below.

4.1 *Scientific Data Stewardship*

The process of developing climate data records is founded in stewardship of the raw data. In this case, before one retrieve geophysical parameters from the ISCCP B1 data we should perform some simple data analyses which will determine data quality. In this case, stewardship includes: navigation, quality control, and calibration.

Image navigation is crucial to satellite applications because it provides the geolocation of image pixels, determining such things as land or water pixel classification and viewing/illumination geometry. Initially the satellites were spin-stabilized, but the newer GOES-8 series is 3-axis stabilized, each providing different navigation algorithms. Among the spin-stabilized satellites, a variety of navigation styles were employed. Among them were: Keplerian orbital elements, Chebyshev polynomials of the orbit, satellite position and velocity components, and rectification of the satellite image to a fixed view (as done for Meteosat). Navigation accuracy can be tested through comparisons with coincident imagery from other geostationary and polar satellites. Tests show that navigation corrections are possible. This work is ongoing.

Another step in data stewardship is determining and monitoring the data quality. Initially, the B1 data were provided with no information on data quality. We have developed a simple scan line-by-scan line quality check which flags scans with missing, faint, repeated or corrupt values. This allows further processing to remove corrupt data from the analysis.

Calibration is perhaps the most important step of the ISCCP B1 stewardship. ISCCP processing includes a thorough cross-calibration between geostationary sensors as well as with AVHRR (performed by the ISCCP Satellite Calibration Center). Our results have shown some problems with the ISCCP calibration of the IR window channel (Knapp, 2007a) as well as the IR water vapor channel (Knapp, 2007b). Further analysis of the visible channels is needed.

4.2 *Clouds*

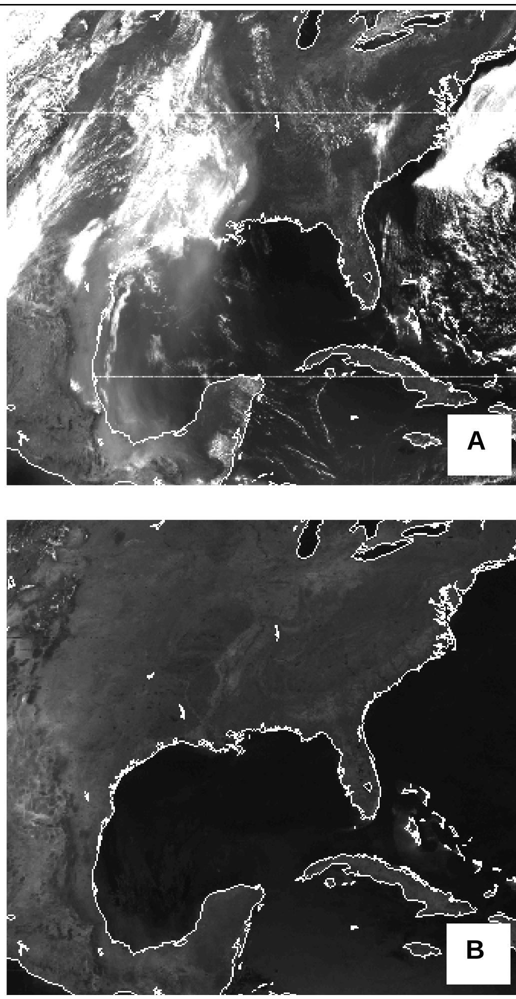
Cloud detection is generally the precursor to many satellite applications which use either the cloud pixels (e.g., precipitation analysis) or the clear-sky observations (e.g., albedo and aerosol retrievals). The ISCCP cloud detection algorithm (Rossow and Garder 1993) uses spatial and temporal tests to mask for clouds. The increased resolution provided by B1 data should provide a more accurate cloud detection algorithm (since the spatial tests will be better resolved). The increased resolution also will provide a cloud climatology at a higher spatial resolution than before, which will be beneficial to such industries as solar power.

4.3 *Tropical Cyclones*

Another example of the use of ISCCP B1 data for climate studies is the recent reanalysis of tropical cyclone intensity. Brightness temperature observations from the IR window are used by meteorologists to estimate storm intensity. Thus, the 20+ years of ISCCP B1 data provides a homogeneous record for reanalysis. The data were subset to 8km fixed grids centered over each storm around the world from 1983 through 2005. This data set is detailed by Knapp and Kossin (2007). Kossin et al (2007) radially-averaged the data about the storm center, from which they estimated storm intensity. Reconstructing the intensity for each storm, they then were able to analyze trends in tropical cyclone activity in all basins.

4.4 *Aerosol*

The B1 data set has the opportunity to provide the first visible observations of aerosol over land for the 20-year record. While polar-orbit observations exist, they are either limited to ocean observations (e.g., AVHRR, (Jacobowitz *et al.*, 2003)) or inferred optical depths from ultraviolet wavelengths (e.g., TOMS, (Torres *et al.*, 2002)). Techniques which allow aerosol optical depth retrievals from current sensors like the GOES Aerosol/Smoke Product (GASP), (Knapp *et al.*, 2002) can be used to retrieve aerosol information for the B1 record.



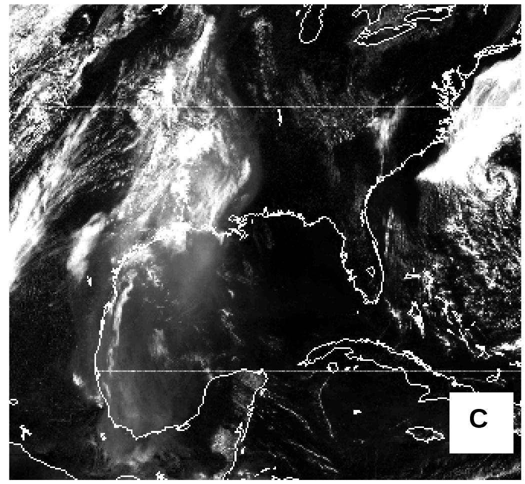


Figure 1 – a) GOES-8 B1 image from May 14, 1998, b) Composite image for May 1998, c) Difference between the image (in A) and the composite (in B).

The example in **Figure 1** demonstrates this concept. In general, a visible image (**Figure 1**a) is composed of atmospheric and surface components. The surface component can be derived by compiling the darkest observation from a time series of observations from the same time of day (**Figure 1**b), and then the atmospheric component can be estimated using the difference (**Figure 1**c). In this example, the atmospheric component shows clouds, but also vast amounts of aerosol transported to the U.S. during the Central American forest fires of May 1998. When this qualitative analysis is replaced by a quantitative one (using radiative transfer) the outcome is retrieved optical depth. From B1 data, this would be possible for most of the Earth's land masses (exceptions are deserts and snow covered land).

4.5 *Surface Heating*

Solar heating of the Earth's surface during forenoon hours (e.g., from 9:00 to 12:00 local time) primarily depends on the surface moisture and evapotranspiration (Tarpley, 1988). As such, the heating rate is a primary candidate for assimilation into weather forecast models, since it provides valuable surface measurements where there are none. For example, an IR image from GOES-8 for May 18, 1998 at 17:45 is provided in **Figure 2**a. The change in temperature (K) from 14:45 UTC is provided in **Figure 2**b (no cloud mask has been applied, so clouds cause large changes in temperature, generally saturating the scale at either black or white). In general, the changes over the ocean are less then ±1 K, while over land, there is strong heating (in cloud-free regions). Also, some variation in the heating is apparent over land. While this is a simple example, using more sophisticated assumptions (e.g., water vapor correction) and ancillary data can yield a climatology of heating rate for most of the world's land mass.

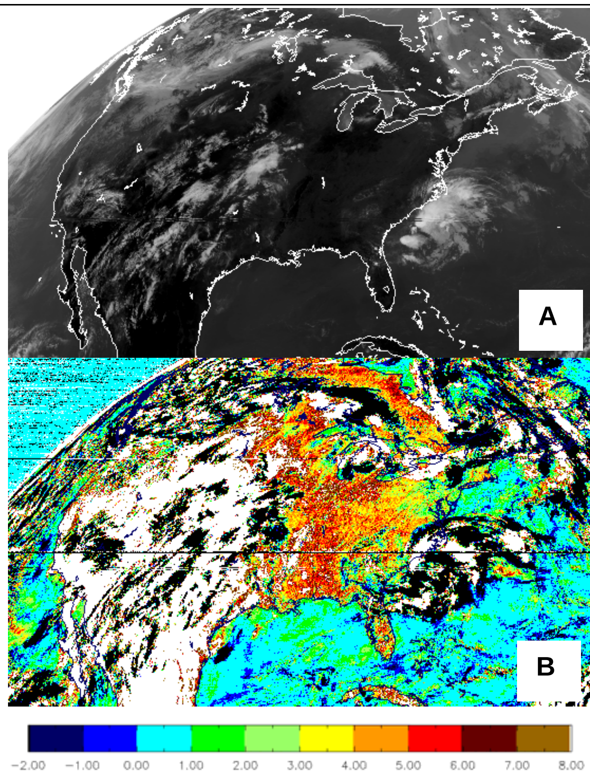


Figure 2 – a) Infrared image (11 pm) from GOES-8 B1 on 18 May 1998, 17:45 UTC, b) 3-hour temperature change between part A and 14:45 UTC, demonstrating the ability to observe surface heating.

5. SUMMARY & FUTURE WORK

In summary, the B1 data set provides a unique view of the earth, rich with climate information covering the past twenty years. From the work to document the formats and to test the quality and calibration, the B1 data can now be used to develop long-term data sets for many atmospheric, land and ocean variables.

6. ACKNOWLEDGMENTS

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7. REFERENCES

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