FULLDISK ATMOSPHERIC PROFILE DATASET DESCRIPTION AND DOCUMENTATION

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1. INTRODUCTION

GOES-R will contain improved spacecraft and instrument technologies capable of observing the earth's atmosphere with greater accuracy and at higher resolutions than current GOES satellites. The Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin-Madison is heavily involved in GOES-R satellite algorithm development, data processing, and measurement capability demonstration activities. To support this work, an end-to-end processing system that utilizes proxy top-of-atmosphere (TOA) radiance datasets has been developed. Since real hyperspectral measurements taken with ground-, air-, or space-based systems are not available with fine temporal resolution across large geographical domains, TOA radiances derived from numerical weather prediction (NWP) model output are a critical component of this system. The availability of model-derived proxy datasets with temporal and spatial resolution comparable to the anticipated GOES-R sensor configuration supports a realistic demonstration of GOES-R measurements and capabilities. Otkin et al (2007) provide a detailed description of the end-to-end processing system.

CIMSS has been tasked with producing high quality proxy datasets that can be used for various GOES-R Risk Reduction and GOES-R Algorithm Working Group research activities. In this paper, we document the first deliverable proxy dataset, which we refer to as the FULLDISK case study. Satellite observations are shown in Section 2 in order to provide a broad overview of the atmospheric conditions during this case study. The Weather Research and Forecasting (WRF) model is described in Section 3. This section also contains a detailed description of the WRF model simulation of this case. The methodology used to generate the proxy atmospheric profile dataset from the WRF model output is presented in Section 4. The proxy dataset is described in Section 5.

2. OBSERVED ATMOSPHERIC CONDITIONS

The FULLDISK case study occurred during 24-25 June 2003 and encompasses most of North and South America, as well as adjacent areas of the Atlantic and Pacific Oceans. As such, the case study contains a wide array of atmospheric conditions, surface characteristics, and cloud types. Fig. 1 shows the infrared and water vapor imagery for 2345 UTC on 24 June 2003. There are many interesting features to note in the satellite imagery. For instance, several large thunderstorm complexes and an extensive area of mid- and upper-level cloud cover were present over central North America. Two cut-off extratropical cyclones and a long, relatively thin cloud band were located over the North Atlantic basin. Generally cloudy conditions prevailed over both ocean basins due to the widespread occurrence of low-level stratus and stratocumulus cloud decks in these regions. A discontinuous band of deep tropical convection was located along the Inter-Tropical Convergence Zone (ITCZ), with locally enhanced convection present in the northwestern Caribbean and to the south of Mexico. Scattered areas of deep convection were also located within the Amazon Basin as well as over portions of the Mexican Plateau. Finally, mostly clear conditions associated with very dry airmasses prevailed over southern Brazil, the southwestern U.S. and along the eastern U.S. coastline.

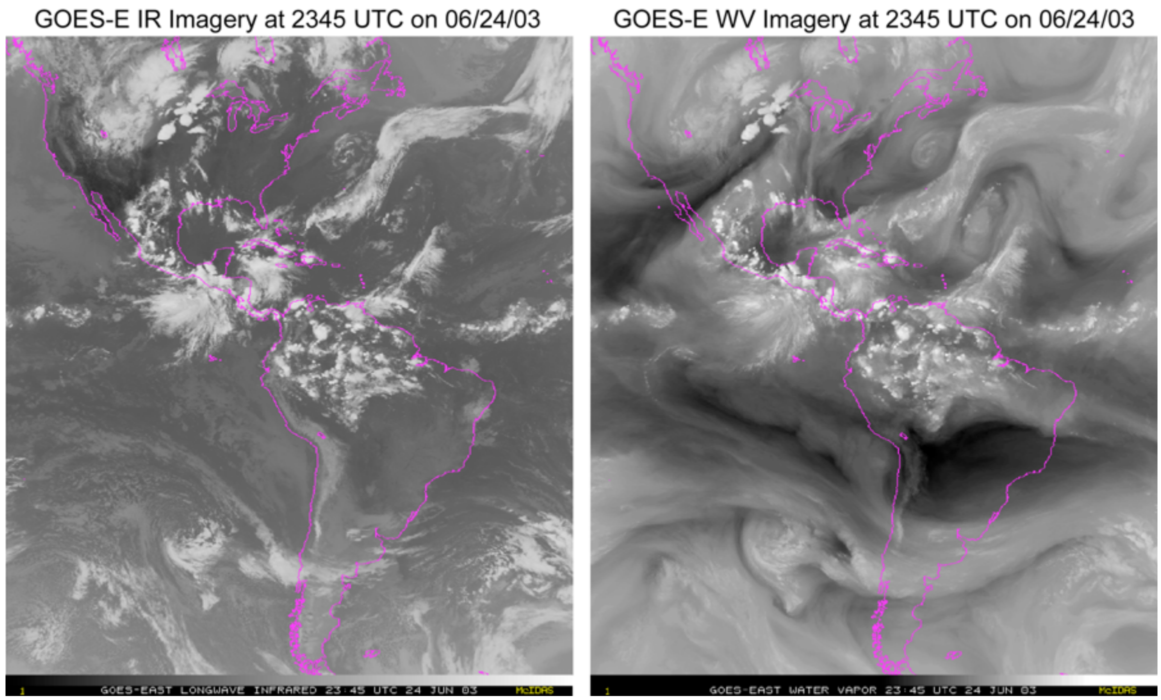

Fig. 1 (left) GOES-E infrared imagery valid at 2345 UTC on 24 June 2003. (right) GOES-E water vapor imagery valid at 2345 UTC on 24 June 2003.

3. MODEL SIMULATION

3.1 WRF MODEL DESCRIPTION

WRF is a sophisticated numerical model that solves the compressible non-hydrostatic Euler equations (cast in flux form) on a mass-based terrain-following vertical coordinate system. The WRF model includes several microphysical, cumulus, and planetary boundary layer schemes. High-resolution global datasets are used to initialize the topography and other static surface fields. Prognostic variables include the horizontal and vertical wind components, several microphysical quantities, and the perturbation potential temperature, geopotential, and surface pressure of dry air. WRF employs the 3rd order Runge-Kutta temporal integration scheme as well as 6th order horizontal and vertical advection schemes. Skamarock et al. (2005) contains a complete description of the WRF model dynamics.

3.2 SIMULATION CONFIGURATION

Version 2.1 of the WRF model was used to simulate the atmospheric conditions during the FULLDISK case study. The simulation was initialized at 00 UTC on 24 June 2003 with 1º GFS data and then run for 30 hours on a single 1580 x 1830 grid point domain with 8-km horizontal grid spacing and 50 vertical levels. The simulation employed the WRF Single-Moment 6-class (WSM6) microphysics scheme (Hong et al. 2004; Hong and Lim 2006), the Yonsei University planetary boundary layer scheme, the Rapid Radiative Transfer Model (RRTM) longwave (Mlawer et al. 1997) and Dudhia

(1989) shortwave radiation schemes, and the Noah land surface model. No cumulus parameterization scheme was used during the simulation.

3.3 SIMULATION RESULTS

The primary goal of this case study was to generate a simulated atmospheric profile dataset that realistically captures the evolution of the large-scale temperature, moisture, and cloud fields during a single 24-hour period across a full disk domain. Fig. 2a shows the simulated 2-m surface temperature at 00 UTC on 25 June 2003. At this time, a very warm airmass was located over the eastern U.S. with a deep trough of cold air over the western U.S. In between, a very sharp temperature gradient helped create a favorable environment for thunderstorm development over the central U.S. The strong influence of the underlying ocean currents on the surface temperature field is also evident. For instance, the cold sea surface temperatures associated with the Labrador, California, Peru, and Antarctic Circumpolar currents are clearly reflected by the cold surface temperatures across these regions.

The simulated precipitable water vapor content for 00 UTC on 25 June 2003 is shown in Fig. 2b. Plentiful moisture is present along the Inter-Tropical Convergence Zone and across the northern third of South America. Several plumes of moist air also extend into the northern mid-latitudes. Very dry air is present across the southern third of the domain as well as portions of the northern third. Substantial fine-scale moisture variability is also present across much of the domain, especially within the various convective regions.

Fig. 3 shows the simulated cloud top pressure and vertically-integrated cloud microphysical content (ICMC) for 00 UTC on 25 June 2003. The ICMC represents the total cloud water, rain water, ice, snow and graupel content within each model column. Together, these data will be used to examine the basic structure of the simulated cloud field. Substantial spatial variability, consistent with the wide array of cloud types evident in Fig. 1, exists across the entire domain. For instance, the stratus and stratocumulus cloud fields over both oceans are generally characterized by low ICMC values and high cloud top pressures. As expected, the highest ICMC values and lowest cloud top pressures are located within the deep convection along the ITCZ and over the north central U.S. There are also extensive areas of thin cirrus clouds within the tropics, with smaller regions to the north and south associated with several extratropical cyclones.

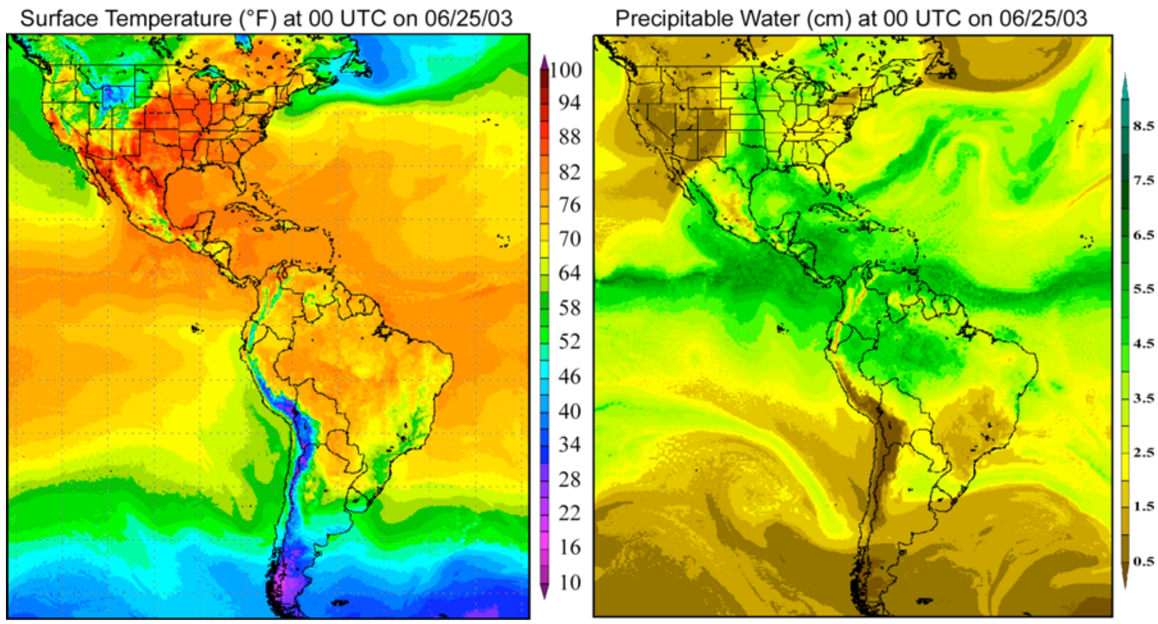

Fig. 2 (left) Simulated 2-m surface temperature (℉) valid at 00 UTC on 25 June 2003. (right) Simulated precipitable water (cm) valid at 00 UTC on 25 June 2003.

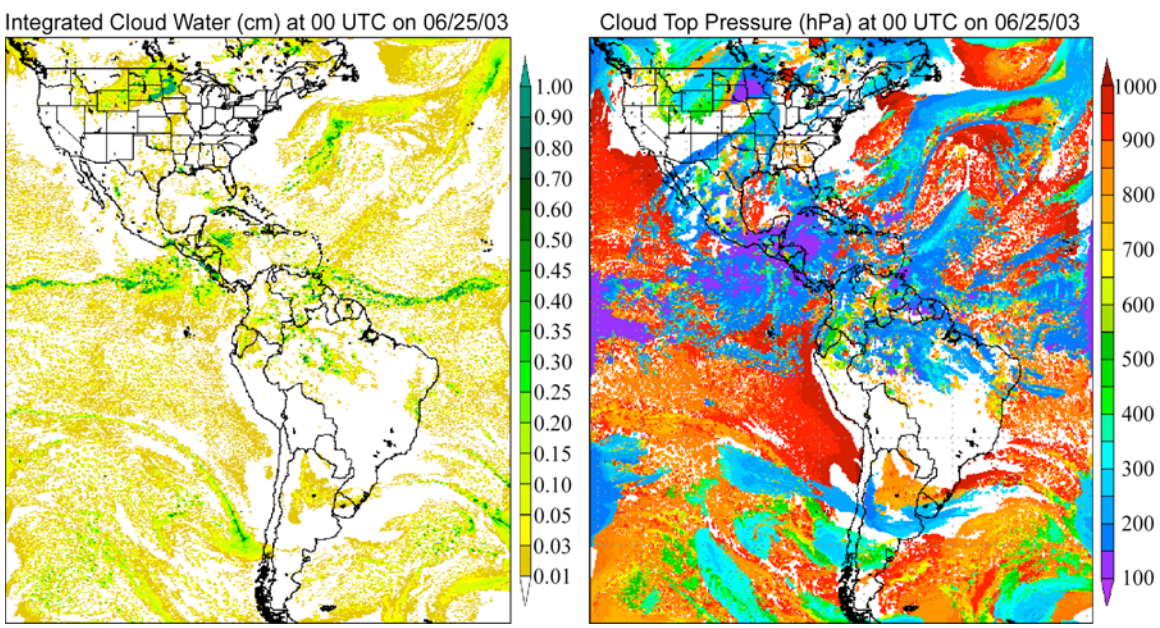

Fig. 3 (left) Simulated vertically-integrated cloud microphysical content (cm) valid at 00 UTC on 25 June 2003. (right) Simulated cloud top pressure (hPa) valid at 00 UTC on 25 June 2003.

4. PROXY DATA SET GENERATION METHODOLOGY

Numerical model output from the high-resolution WRF model simulation serves as the primary component of the proxy atmospheric profile dataset. Simulated fields contained within the dataset include the surface skin temperature, the atmospheric temperature, and the mixing ratios for water vapor, cloud water, rain water, ice, snow, and graupel. Effective particle diameters are calculated for each microphysical species using a method adopted from Mitchell (2002). Total liquid and total ice water paths are calculated using the appropriate mixing ratios. Liquid and ice cloud top pressures are identified by searching downward from the model top until a minimum mixing ratio threshold is exceeded within a given grid cell.

Logarithmic interpolation is used to transfer the simulated 3-dimensional data from the model's sigma coordinate system to an isobaric coordinate system containing 101 unevenly spaced levels extending from 1100 hPa to 0.005 hPa. Temperature and water vapor data on the lowest model sigma level is extrapolated downward to fill all pressure levels located beneath the model topography. Temperature profiles from the NESDIS 1200 dataset are used to fill the pressure levels located above the model top (which was set to 10 hPa), while the water vapor mixing ratio above this level is set to a value representative of dry stratospheric air. Ozone data extracted from 5 different model atmospheres in the line-by-line radiative transfer model (LBLRTM; Clough and Iacono 1995) were used to create representative ozone profiles for each grid point in the model domain.

5. PROXY DATASET DESCRIPTION

The proxy atmospheric profile dataset contains 37 time steps evenly spaced at 40-minute intervals from 06 UTC on 24 June 2003 to 06 UTC on 25 June 2003. The model domain is separated into 168 cubes, each of which contains 128 x 128 horizontal grid points. The data are stored in NetCDF-formatted files, with an individual file size of 83 MB. The total dataset size for each time step is ~14 GB for a grand total of 513 GB for the entire dataset. Appendix A contains a description of the variables and file format for a sample file.

6. REFERENCES

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Appendix A – FILE DESCRIPTION

```
netcdf 8km_0625_2003.0000utc_1_1 {
dimensions:
	time = UNLIMITED ; // (1 currently)
	top_bot = 101 ;
	south_north = 128 ;
	west_east = 128 ;
	number_land_categories = 24 ;
	string_length = 50 ;
variables:
	float T(time, south_north, west_east, top_bot) ;
		T:long_name = "Temperature" ;
		T:units = "K" ;
		T:coordinates = "P lon lat" ;
		T:standard_name = "air_temperature" ;
	float Q(time, south_north, west_east, top_bot) ;
		Q:long_name = "Water vapor mixing ratio" ;
		Q:units = "g/kg" ;
		Q:coordinates = "P lon lat" ;
		Q:standard_name = "humidity_mixing_ratio" ;
	float Ozone(time, south_north, west_east, top_bot) ;
		Ozone:long_name = "Ozone" ;
		Ozone:units = "ppmv" ;
		Ozone:coordinates = "P lon lat" ;
	float Cloud_diam(time, south_north, west_east, top_bot) ;
		Cloud_diam:long_name = "Cloud liquid effective diameter" ;
		Cloud_diam:units = "microns" ;
		Cloud_diam:coordinates = "P lon lat" ;
	float Ice_diam(time, south_north, west_east, top_bot) ;
		Ice_diam:long_name = "Ice effective diameter" ;
		Ice_diam:units = "microns" ;
		Ice_diam:coordinates = "P lon lat" ;
	float Rain_diam(time, south_north, west_east, top_bot) ;
		Rain_diam:long_name = "Rain liquid effective diameter" ;
		Rain_diam:units = "microns" ;
		Rain_diam:coordinates = "P lon lat" ;
	float Snow_diam(time, south_north, west_east, top_bot) ;
		Snow_diam:long_name = "Snow effective diameter" ;
		Snow_diam:units = "microns" ;
		Snow_diam:coordinates = "P lon lat" ;
	float Graupel_diam(time, south_north, west_east, top_bot) ;
		Graupel_diam:long_name = "Graupel effective diameter" ;
		Graupel_diam:units = "microns" ;
		Graupel_diam:coordinates = "P lon lat" ;
	float Cloud(time, south_north, west_east, top_bot) ;
```

```
		Cloud:long_name = "Cloud microphysics mixing ratio" ;
		Cloud:units = "g/kg" ;
		Cloud:coordinates = "P lon lat" ;
	float Ice(time, south_north, west_east, top_bot) ;
		Ice:long_name = "Ice microphysics mixing ratio" ;
		Ice:units = "g/kg" ;
		Ice:coordinates = "P lon lat" ;
	float Rain(time, south_north, west_east, top_bot) ;
		Rain:long_name = "Rain microphysics mixing ratio" ;
		Rain:units = "g/kg" ;
		Rain:coordinates = "P lon lat" ;
	float Snow(time, south_north, west_east, top_bot) ;
		Snow:long_name = "Snow microphysics mixing ratio" ;
		Snow:units = "g/kg" ;
		Snow:coordinates = "P lon lat" ;
	float Graupel(time, south_north, west_east, top_bot) ;
		Graupel:long_name = "Graupel microphysics mixing ratio" ;
		Graupel:units = "g/kg" ;
		Graupel:coordinates = "P lon lat" ;
	float LWP(time, south_north, west_east) ;
		LWP:long_name = "Liquid water path" ;
		LWP:units = "g_m-2" ;
		LWP:coordinates = "lon lat" ;
		LWP:standard_name = "atmosphere_cloud_liquid_water_content" ;
	float IWP(time, south_north, west_east) ;
		IWP:long_name = "Ice water path" ;
		IWP:units = "g_m-2" ;
		IWP:coordinates = "lon lat" ;
		IWP:standard_name = "atmosphere_cloud_ice_content" ;
	float TGRND(time, south_north, west_east) ;
		TGRND:long_name = "Ground temperature" ;
		TGRND:units = "K" ;
		TGRND:coordinates = "lon lat" ;
		TGRND:standard_name = "surface_temperature" ;
	float Altitude(south_north, west_east) ;
		Altitude:long_name = "Terrain" ;
		Altitude:units = "m" ;
		Altitude:coordinates = "lon lat" ;
		Altitude:standard_name = "surface_altitude" ;
	float LANDCLAS(south_north, west_east) ;
		LANDCLAS:long_name = "Land class index" ;
		LANDCLAS:units = "category" ;
		LANDCLAS:coordinates = "lon lat" ;
	float lat(south_north, west_east) ;
		lat:long_name = "Latitude" ;
		lat:units = "degrees_north" ;
```

```
		lat:standard_name = "latitude" ;
	float lon(south_north, west_east) ;
		lon:long_name = "Longitude" ;
		lon:units = "degrees_east" ;
		lon:standard_name = "longitude" ;
	float LTOP(time, south_north, west_east) ;
		LTOP:long_name = "Cloud top with respect to liquid" ;
		LTOP:units = "hPa" ;
		LTOP:coordinates = "lon lat" ;
		LTOP:_FillValue = 9999.f ;
	float ITOP(time, south_north, west_east) ;
		ITOP:long_name = "Cloud top with respect to ice" ;
		ITOP:units = "hPa" ;
		ITOP:coordinates = "lon lat" ;
		ITOP:_FillValue = 9999.f ;
	float PSFC(time, south_north, west_east) ;
		PSFC:long_name = "Surface pressure" ;
		PSFC:units = "hPa" ;
		PSFC:coordinates = "lon lat" ;
		PSFC:standard_name = "surface_air_pressure" ;
	float emiss(time, south_north, west_east) ;
		emiss:long_name = "surface broadband thermal emissivity" ;
		emiss:units = "dimensionless" ;
		emiss:coordinates = "lon lat" ;
	float albedo(time, south_north, west_east) ;
		albedo:long_name = "surface broadband visible albedo" ;
		albedo:units = "dimensionless" ;
		albedo:coordinates = "lon lat" ;
		albedo:standard_name = "surface_albedo" ;
	float P(top_bot) ;
		P:long_name = "pressure" ;
		P:units = "hPa" ;
		P:standard_name = "air_pressure" ;
	char CH_LAND(number_land_categories, string_length) ;
		CH_LAND:long_name = "Land-surface classification" ;
		CH_LAND:units = "" ;
		CH_LAND:standard_name = "surface_cover" ;
	double time(time) ;
		time:long_name = "time" ;
		time:units = "Minutes since 2003-6-24 0:0:0" ;

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		:MODEL = " OUTPUT FROM WRF V2.1 MODEL" ;
		:INSTITUTION = "UNIVERSITY OF WISCONSIN-MADISON
	SSEC/CIMSS" ;
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                :AUTHOR = "JASON OTKIN" ;
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                :DY = 8000.f ;
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                :LAND_SURFACE_CLASSIFICATION_SCHEME = "USGS" ;
}
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