P2.30 HYPERSPECTRAL DATA STORAGE: PROTOTYPE IMPLEMENTATION USING THE 2003 PACIFIC THORPEX DATASET

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1. INTRODUCTION

Managing the storage and distribution of future hyperspectral satellite data will impose significant demands on scientific computing infrastructure. A prototype system addressing such demands is currently being developed at the University of Wisconsin's Cooperative Institute for Meteorological Satellite Studies. This system employs datasets from the 2003 Pacific THORPEX experiment. THORPEX is an international research program focused on accelerating improvements in accuracy of 1 to 14-day weather forecasts for the benefit of society and the economy. The vast quantity of data available from this field program makes it ideal for preparing to handle the next generation of operational Earth observing systems. In addition to storage of the data, methods by which users can rapidly search the data for weather conditions of interest are being researched.

2. DATASET CONTENTS

The 2003 Pacific THORPEX Observing System Test was the first in a series of Pacific and Atlantic observation campaigns in support of the WWRP/USRP THORPEX Program. The intensive campaign period was between 19 February and 14 March 2003, during which both the NASA ER-2 and the NOAA G4 aircraft were operating out of Honolulu, Hawaii. The NASA ER-2 carried a set of five research instruments while the NOAA G4 released dropsondes along pre-arranged flight paths. Research data from the NASA Terra and Aqua satellite platforms were collected coincident with the ER-2 flight missions. Operational data from the NOAA GOES and POES satellites were also collected during this time period. The list of instruments and products that make up this dataset is given in Table 1. A description of the research instruments is given in Table 2.

Table 1. Contents of the Pacific THORPEX 2003 dataset by instrument and platform.

Platform	Instrument	Products	Volume (Gbytes)
NASA ER2 aircraft	NAV recorder	Aircraft in situ	0.2
	NAST-I	IR Radiance, T/WV Sounding	6.2
	NAST-M	Passive Microwave Temperature	TBD
	S-HIS	IR Radiance, T/WV Sounding	4.7
	MAS	LW/SW Image Products	125
	CPL	Cloud heights, Optical Depth	2.6
NOAA G4 aircraft	NAV recorder	Aircraft in situ	TBD
	Dropsondes	T/WV below aircraft	0.03
NASA AQUA	AIRS	IR Radiance, T/WV retrieval	2.9
	MODIS	LW/SW Image products	7.9
NASA TERRA	MODIS	LW/SW Image products	TBD
NOAA GOES	GOES-10	LW/SW Imagery, Winds	TBD
NOAA POES	AVHRR/TIROS	Imagery, Soundings	TBD

Table 2. Description of the research instruments used to collect data for Pacific THORPEX 2003.

Research Instrument	Spatial Sampling	Number of Spectral Channels	Reference
NPOESS Atmospheric Sounder Testbed – Interferometer (NAST-I)	2.1 km	>8000	Smith et al. 1999
NPOESS Atmospheric Sounder Testbed – Microwave (NAST-M)	2.6 km	54 GHz and 118.75 GHz.	Blackwell et al. 2001
Scanning High-resolution Interferometer Sounder (S-HIS)	2 km	5000	Revercomb et al. 1998
MODIS Airborne Simulator (MAS)	50 meter	50	King et al. 1996
Cloud Physics Lidar	2 km	1064, 532, and 355 nm	McGill et al. 2002
Atmospheric InfraRed Sounder (AIRS)	16 km	2378	Pagano et al. 2002
Moderate Resolution Imaging Spectroradiometer (MODIS)	250m-1km	36	Salomonson et al. 2001

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3. CASE STUDY EXAMPLE: RETRIEVAL VALIDATION

This section includes some selected examples of data and data products included in the Pacific THORPEX 2003 dataset. Two case studies are presented. The first is a "clear air" analysis of the hyperspectral infrared data from the University of Wisconsin Scanning-HIS interferometer (similar results have been obtained from the NAST-I interferometer which was on-board the same aircraft). The ER-2 mission was near the Hawaiian Islands on 03 March 2003. Figure 1 shows the large-scale conditions on this day with a relatively clear region southwest of Hawaii. Figure 1 is an example of the GWINDEX products (http://cimss.ssec.wisc.edu) which derive atmospheric wind motion from the tracking of features in the GOES imagery.

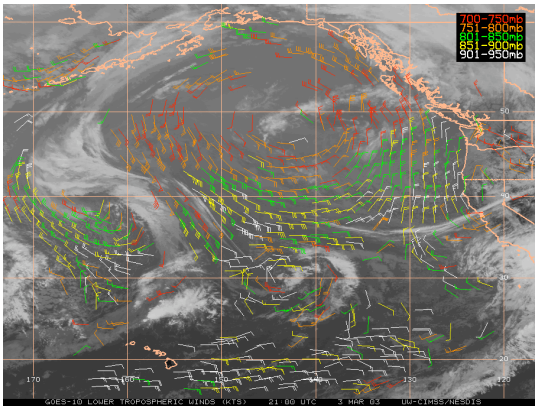

Figure 1. Tropospheric winds over the North Pacific Ocean derived from tracking features in GOES brightness temperature observations. Image is 03 March 2003 during the PTOST experiment. The Hawaiian Islands are indicated in the lower left-hand corner of the image. (Image courtesy of Chris Velden, UW-SSEC).

The Scanning-HIS data is shown in Figure 2. Shown is a brightness temperature spectrum for a single FOV of a window channel and a false color image of the same window channel for a single flight leg. The temperature and water vapor vertical profiles derived from the Scanning-HIS data during this flight leg are shown in Figure 3 compared to a nearly coincident dropsonde profile obtained by the NOAA G4 aircraft. The dropsonde data from the G4 will be used to validate the aircraft derived vertical profiles which will in turn be used to validate measurements from the AIRS instrument on the Aqua platform. The AIRS data can then be used in the analysis of larger scale meteorological processes. The second case study presented here is focused on the interpretation of satellite derived cloud products, an important issue for operational use of satellite data.

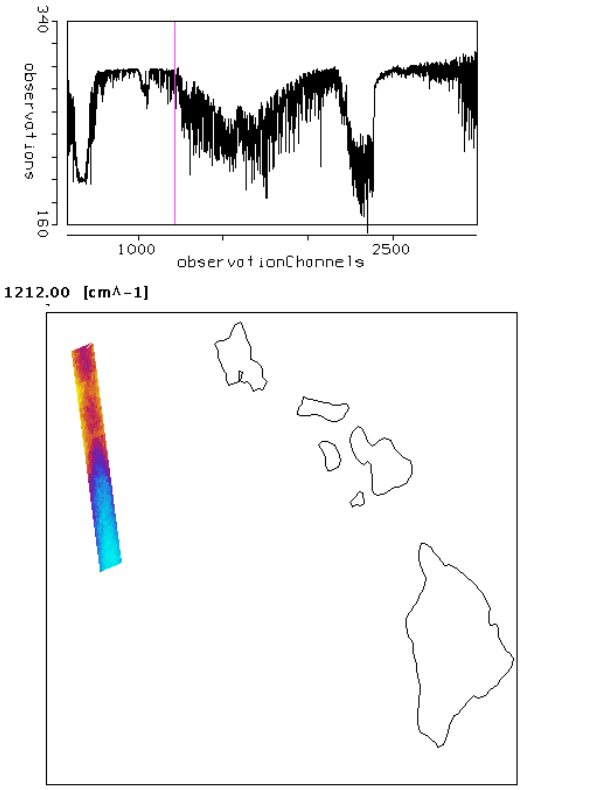

Figure 2. Example S-HIS infrared observation and flight leg west of Oahu, Hawaii. The top image shows one S-HIS Brightness Temperature for a single field of view and the bottom image shows the mapping of a specific wavenumber (1220 cm^{-1}) for one flight leg.

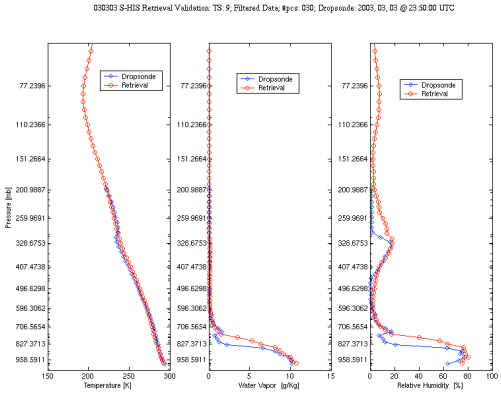

Figure 3. Example S-HIS retrieval product of Air Temperature and Water Vapor vertical profiles compared to a nearly coincident dropsonde profile. Results are preliminary.

4. CASE STUDY EXAMPLE: CLOUD OPTICAL PROPERTIES

Figure 4 is a false color image derived from the MODIS instrument on the Aqua platform from 26 February 2003. The small rectangle indicates the region of interest in this study, which is shown in Figure 5 along with the

flight track of the NASA ER-2 flying at 20-km altitude. Figure 6 shows even greater spatial detail from the MODIS Airborne Simulator (MAS) in a swath below the ER-2 flight path. Coincident observations from the Cloud Physics Lidar (CPL) are shown in Figure 7 which provide “active” sensor measurements of the clouds and aerosol content of the atmosphere directly below the aircraft. It should be noted that in addition to the MODIS, MAS, and CPL data the dataset also includes coincident measurements from AIRS, NAST-I, NAST-M, Scanning-HIS, and GOES. These few examples show the richness of this dataset especially with regard to the synergistic use of high spatial resolution and high spectral resolution observations.

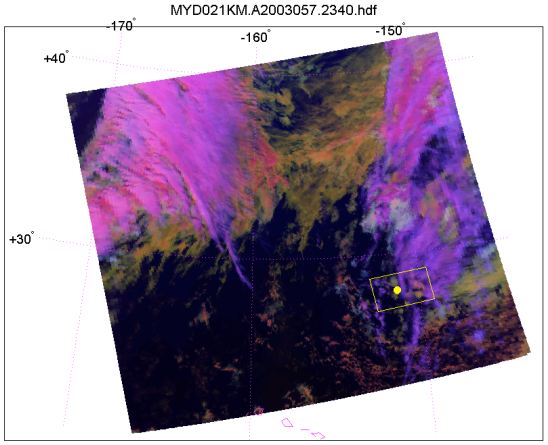

Figure 4. Aqua MODIS granule from 26 February 2003 at 23:40 UTC (5 _ 5 pixel average). False color image to highlight cloud phase. The 0.65 micron reflectance is mapped to red, 2.13 micron reflectance to green, and the 11 micron brightness temperature to blue (scaled so that colder scenes are blue). In this colormap, ice clouds appear purple to pink, water clouds yellow, and open ocean appears black. A 200 _ 200 pixel box is outlined in yellow. The yellow circle marks the ER-2 underflight point (40 degrees off of satellite nadir).

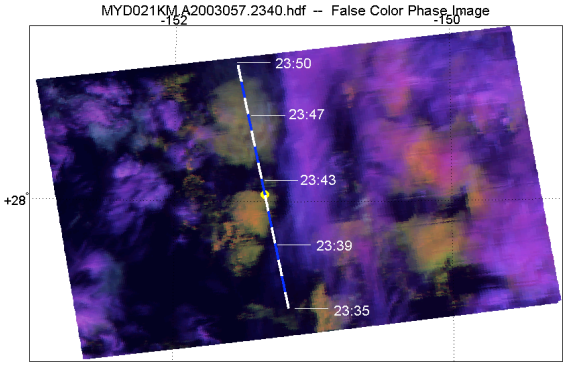

Figure 5. View of the 200 _ 200 pixel box (at 1-km resolution) with the same color mapping. The ER-2 flight track from 23:35 to 23:50 UTC is shown. -

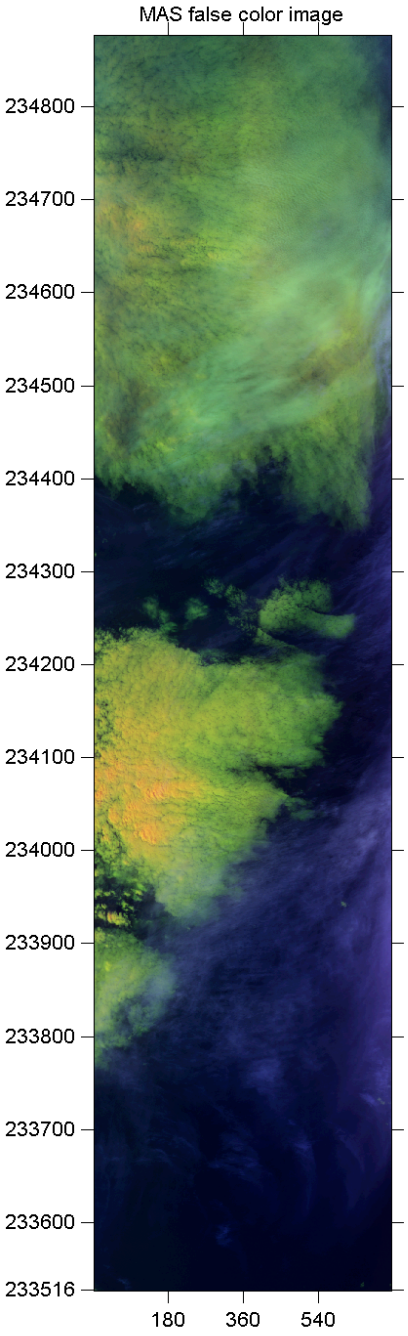

Figure 6. MAS false color imagery from 23:35:16 until about 23:48:50. The 0.65 micron reflectance is mapped to red, 2.13 micron reflectance to green, and the 11 micron brightness temperature to blue (scaled so that colder scenes are blue). At the higher spatial resolution, more cloud features are visible than in the MODIS imagery.

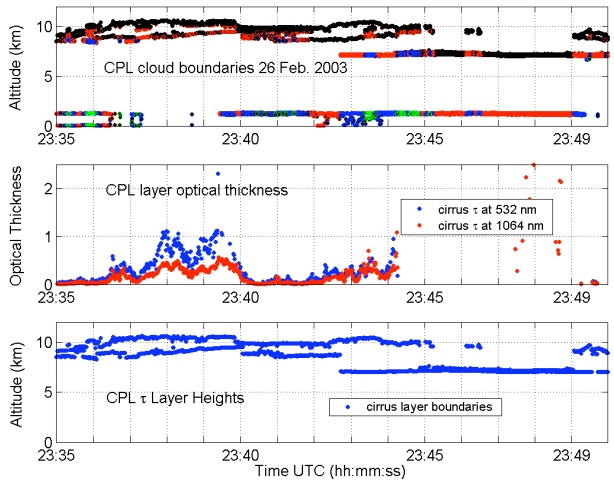

Figure 7. CPL cloud boundaries and optical thickness retrievals from 23:35 to 23:50 UTC. The cirrus observed by the CPL from 23:35 to 23:38 is too thin to be seen in the MODIS imagery. From the lidar depolarization (not shown), we assume that the cloud at 11 km is either super cooled water or mixed ice and water phase.

5. IMPLEMENTATION

This storage system for THORPEX data is the first prototype implementation modeled upon a conceptual design for storing and retrieving hyperspectral data that was also developed at the UW-SSEC (Dedecker et al. 2004).

For the storage of this data we have chosen to use SRB, the Storage Resource Broker. This project is headed at SDSC, the San Diego Supercomputer Center. SRB is a distributed repository allowing data to be stored on multiple servers while having a single point of access. Thus, users no longer need to concern themselves with locating data across multiple server protocols and accounting systems. In addition to providing a single access point to all the data, SRB provides a convenient way to manage your archive, including services for replication, migration and tying metadata and annotations to stored data.

SQL (Structured Query Language) services are being used to search key metadata tables allowing users to rapidly search for groups of data matching commonly-applied criteria. For instance, CPL data could be used to search for flight legs with clear skies. Additionally, users have the ability to co-locate aircraft data with satellite overpasses and dropsondes.

This prototype system also employs an DODS (OPeNDAP) server that has been setup to distribute data to users allowing them to interact with the data without downloading the entire dataset. DODS is a data delivery system developed to work with the Unidata NetCDF project hosted at NCAR. DODS serves up data interactively to applications such as Matlab, IDL, and VisAD applications such as Unidata's IDV.

IDV, the Integrated Data Viewer, is an extremely flexible data viewing program that allows users to connect to DODS servers for direct viewing of subsets of one or more datasets (Rink et al. 2004). DODS with IDV combines dataset description, downloading, format identification, and reading into a network protocol which streamlines the task of interactively analyzing data from distributed instrument datasets. In addition, IDV is built upon the VisAD libraries, allowing for users to map data from different instruments to 2-D and 3-D earth views, to collaborate with remote IDV users, and to integrate mathematical manipulations as short scripts.

6. SUMMARY

The Cooperative Institute for Meteorological Satellite Studies at the University of Wisconsin is compiling a dataset from the Pacific THORPEX Observing System Test 2003 conducted between 19 February and 14 March 2003 over the North Central Pacific basin. The dataset brings together operational satellite data with research-quality observations from both satellite and aircraft platforms. This unique dataset will be used for satellite product validation and the development of new product algorithms. The "hyperspectral" observations of both high spatial and high spectral resolution are also being used to demonstrate and evaluate new methods for the storage, cataloging, interactive data selection, and delivery of this type of data and associated products. This research into storage and archive concepts is a prerequisite for making efficient use of the high data volumes anticipated in the next generation of operational Earth observing systems.

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