

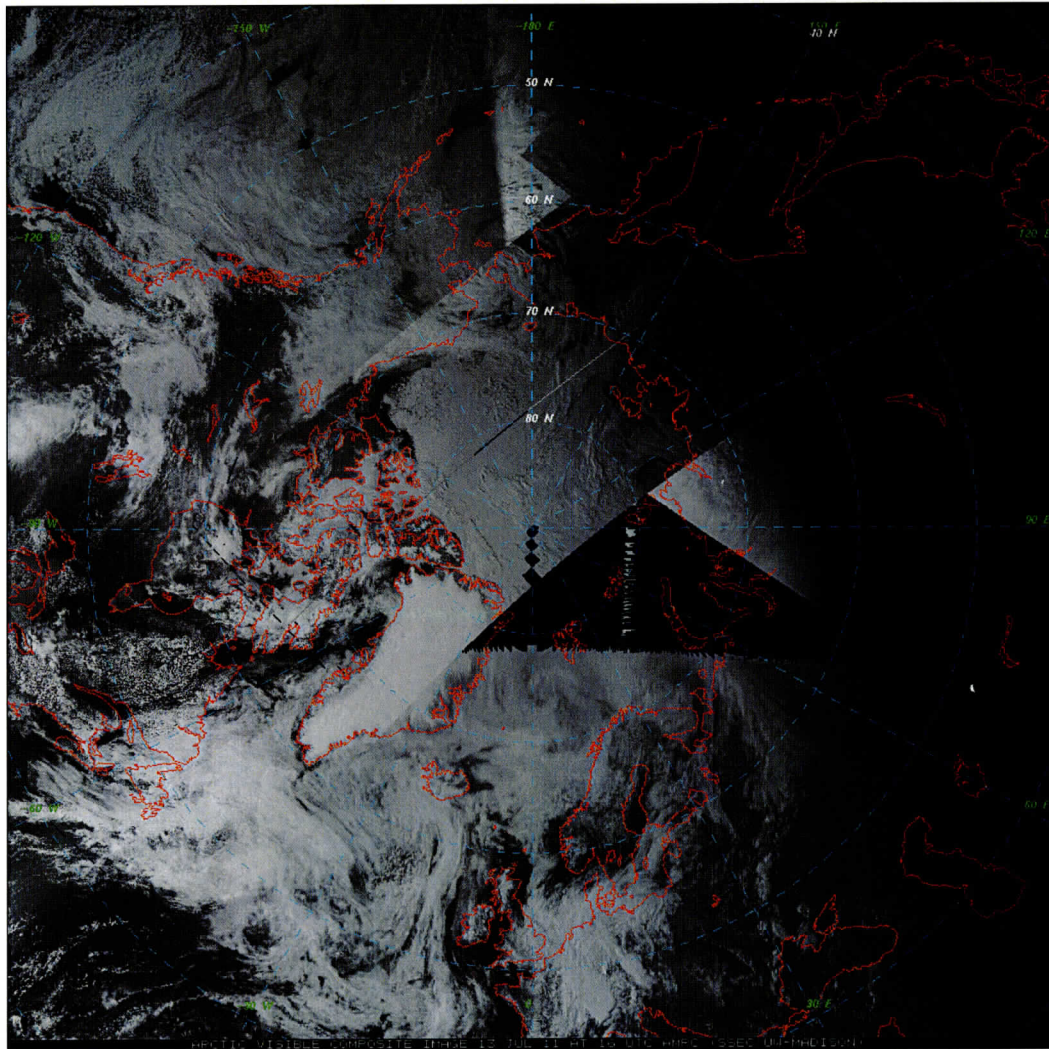
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*Arctic Composite Final Project Report: NSF-OPP Grant #ARC-0713843, September 1, 2007 to October 31, 2011*

## Arctic Satellite Composite Project

*An Final Report to the Office of Polar Programs, National Science Foundation*



Dr. Matthew A. Lazzara, Principal Investigator  
Shelley L. Knuth, co-Principal Investigator

Space Science and Engineering Center  
University of Wisconsin-Madison

Submitted on November 15, 2011



**Final Report for Period:** 09/2010 - 08/2011

**Submitted on:** 11/10/2011

**Principal Investigator:** Lazzara, Matthew A.

**Award ID:** 0713843

**Organization:** U of Wisconsin Madison

**Submitted By:**

Lazzara, Matthew - Principal Investigator

**Title:**

Arctic Satellite Composite Project

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Madison, WI 53706

### Project Participants

#### Senior Personnel

**Name:** Lazzara, Matthew

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Dr. Matthew Lazzara, Principal Investigator, oversees the Arctic satellite composite project. He developed the method that creates the Arctic Satellite Composites, specifically working on the infrared composites. He has also given presentations on the project at science meetings, and conducted educational outreach on the project.

**Name:** Knuth, Shelley

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Shelley Knuth has worked on the initial development of the Arctic Water Vapor Composite Satellite imagery, and has followed with developing shortwave and longwave infrared composite imagery. She has also given presentations on the effort at science meetings.

st-doc

#### Graduate Student

##### Undergraduate Student

**Name:** Schroeder, Nicole

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Nicole has worked on generating time series of composite imagery for community use, animation creation, etc.

**Name:** Willmot, Kathleen

**Worked for more than 160 Hours:** No

**Contribution to Project:**

K. Elena Willmot has assisted with requests from the community using the composite and other minor tasks.

##### Technician, Programmer

**Name:** Bellon, Willard (Bill)

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Bill Bellon has provided assistance with the creation of the Arctic composite web site.

**Name:** Dworak, Richard

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Rich has worked on the exploration of generating atmospheric motion vectors derived from the Arctic composites.

**Name:** Kohrs, Richard

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Rick has worked on developing improved satellite composite methods which has lead to the development of the visible composites as well as creating tools for a multi-banded file structure for holding the various composites into one file.

**Other Participant**

**Research Experience for Undergraduates**

**Organizational Partners**

**Other Collaborators or Contacts**

Owen Cooper, NOAA CIRES/ESRL

Tom Yoksas, Unidata UCAR

**Activities and Findings**

**Research and Education Activities: (See PDF version submitted by PI at the end of the report)**

Project Activities (September 2010 to October 2011):

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- \* Worked on generating a formal visible composite imagery
- \* Continued to generated Atmospheric Motion Vectors
- \* Improved the Web page for the project and data portal

Presentation/Conference:

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Lazzara, M.A., R. Dworak, D.A. Santek, N.A. Bearson, J.R. Key, and C.S. Velden, 2011: Polar Satellite Composite Atmospheric Motion Vectors. 11th Conference on Polar Meteorology and Oceanography, Boston, MA.

Project Activities (September 2009 to August 2010):

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- \* Worked on generating hourly infrared composite imagery
- \* Tested the generation of atmospheric motion vectors (AMV)
- \* Setup a validation data sets for verification of the derived AMV

Presentations/Conferences:

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Lazzara, M.A., R. Dworak, D.A. Santek, C.S. Velden, and J.R. Key, 2010: High latitude atmospheric motion vectors: Application of Antarctic and Arctic composite satellite imagery. 10th International Winds Workshop, Tokyo, Japan.

Lazzara M.A., R. Dworak, D.A. Santek, N. Bearson, C.S. Velden, and J.R. Key, 2010: Composite satellite atmospheric motion vectors, 5th Antarctic Meteorological Observation, Modeling and Forecasting Workshop in Columbus, OH

Lazzara, M.A., 2010: The polar meteorologist's dream machine: Artificial LaGrange orbit satellite applications via Arctic and Antarctic composite satellite imagery. 2nd International Symposium on Solar Sailing. New York City College of Technology, City University of New York, NY

Lazzara, M.A., 2010: Observing Antarctic Weather from Space and the surface -at US Army Cold Regions Research and Engineering Laboratory, Hanover, NH

Lazzara, M.A., 2010: Observing Antarctic Weather from Space and the surface -at 109th New York Air National Guard, Scotia, NY

Project Development/Activities (September 2008 to August 2009):

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Completed development of water vapor composite

\* Development of long wave infrared composite

Development of short wave infrared composite

Presentations/Conference:

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Presentation at the American Meteorological Society's 10th Conference on Polar Meteorology and Oceanography:

M.A. Lazzara, and S.L. Knuth, 2009: Arctic Satellite Composite Observations: A New Perspective. Tenth Conference on Polar Meteorology and Oceanography, 18-21 May, Madison, WI.

Project Development/Activities (September 2007 to August 2008):

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\* Development of IR composite

Initial Development of WV composite

\* Initial Development of the Arctic composite web site/portal

Presentations and Conferences:

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 Colloquium at U. Toronto Department of Atmospheric Physics (Lazzara)

Presentation at IASC-SCAR in St. Petersburg (Knuth)

Poster at First Workshop on Satellite Imaging of the Arctic (in absentia)

**Findings: (See PDF version submitted by PI at the end of the report)**

Findings (2011)  
 -----

This past year saw the goals of this project reached, in some areas superseded, and a future plan for the key results of this project outlined.

First and foremost, a visible satellite composites now have been created over the Arctic. Thus, this project now sees the routine generation of the 5 most common spectral channels available on most meteorological satellites: Visible (~0.65 microns), Infrared, (~11.0 microns), Longwave infrared (~12.0 microns), Shortwave infrared (~3.8 microns), and Water Vapor (~6.7 microns).

Second, the generation of atmospheric motion vectors (AMVs) from the composites generated under this project was attempted. The demonstration showed that composite AMVs could be generated. However, validation of the generated winds showed large root mean square errors (RMSE), when comparing composite AMVs with AMVs generated by single satellites (either geostationary or polar orbiting). The composites AMVs demonstrated in this project spurred on a follow-on project. Funded by the GOES-R Risk Reduction program, this project builds a slightly different composite, with some additional improved methodologies, and is now successfully making a composite AMV data set with RMSE now on par with geostationary and polar-orbiting AMVs.

A future for the Arctic composite project has now recently been outlined. With a formal request from the Ocean Prediction Center (and companion requests from the Hydrometeorological Prediction Center, National Ice Center, and National Weather Service Alaska), the National Oceanic and Atmospheric Administration (NOAA) will fund the effort to have the Arctic composites demonstrated by this project routinely generated by NOAA's Office of Satellite and Product Operations (OSPO). This effort, joint between UW-Madison and OSPO, will begin next calendar year (2012) with operations expected by 2013. During this evolution, composites will continue to be created here at UW-Madison, and this effort will allow the composite to be improved, with the inclusion of newer satellite platforms as they are launched and available and continuing to generate the composites with improved methodology.

Findings (2010)  
 -----

Two prime activities were accomplished this year; the generation of hourly infrared composites were successful. This allowed the second accomplishment - the generation of atmospheric motion vectors, which was also successful. Efforts are underway to validate these winds generated from satellite. Hourly composites in the other spectral channels and the addition of visible channel (~0.65 microns) are in progress.

Findings (2009):  
 -----

In the past year, the Arctic composite project has seen growth in the development of composites in two additional spectral channels, the shortwave infrared (~3.8 microns) and long wave infrared (~12.0 microns) in addition to the completion of the water vapor channel (~6.7 microns). All of these composite and the infrared window channel (~11.0 micron) composite continue to be produced in real-time.

The first year of this project had the composite trailed by two Arctic field programs, DLARCAT and ARCTAS. The second year of the project has seen not only the development of additional composites, but the initiation of having the composites made available to the Unidata community for broader use by the university and college servers. Future years will be a more complete availability of the composites from the server systems at the University of Wisconsin, as well as testing out an application of the composites, following in the foot-steps of the AMRC sister Antarctic composite project. Additionally, avenues of longer-term operational adoption of this project will be explored the coming year.

**Findings (2008):**

-----  
 See attached brief report on the project (2008).

**Training and Development:**

The project has given Ms. Knuth the opportunity to understand at a greater depth the satellite compositing process.

In addition, we have included undergraduate students. Ms. Schroeder and Ms. Willmot, where they have learned about the satellite composites as they work on building time series of composites for community use.

The project has also permitted the exploration of improved composite satellite imagery methodologies. It has enabled the development of an improved visible composite, and may well influence compositing techniques for other spectral channels.

**Outreach Activities:**

The Arctic composite project's sister projects, the Antarctic Automatic Weather Station (AWS) Program, and Antarctic Meteorological Research Center (AMRC) have an established grassroots education outreach effort, of which this project is benefiting from. Presentations to schools, the general public, and beyond have been a part of the activities over the past few years. A sample includes:

**General Public:**

- 
- \* SEC Public Tours, UW-Madison, Madison, WI (multiple tours, including University of Wisconsin Science Expeditions/Open House)
  - \* Deerfield Cub Scouts, Deerfield, WI
  - \* Madison West Rotary Club, Madison, WI
  - \* Waunakee Public Library, Waunakee, WI

**University/College:**

- 
- \* Madison Area Technical College, Madison, WI
  - \* CIMSS/WSGC workshop, UW-Madison, Madison, WI

Middle School:  
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\* Lodi Middle School, Lodi, WI

Elementary School:  
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\* Deerfield Elementary School, Deerfield, WI (Multiple visits)

### Journal Publications

Lazzara, M.A. and S.L. Knuth, "Arctic and Antarctic Satellite Composite Imagery", Polar Research, p. , vol. , (2011). Submitted,

Roiger, A., H. Schlager, A. Schafler, H. Scheibe, H. Aufmhoff, O.R. Cooper, H. Sodemann, A. Stohl, J. Burkhart, M. Lazzara, C. Schiller, K.S. Law, and F. Arnold, "In-situ Observation of Asian Pollution Transported into the Arctic Lowermost Stratosphere", Atmospheric Chemistry and Physics, p. 10975, vol. 11, (2011). Published, 10.5194/acp-11-10975-2011

M.A. Lazzara, A. Coletti, B.L. Diedrich, "The possibilities of polar meteorology, environmental remote sensing, communications and space weather applications from Artificial Lagrange Orbit", Advances in Space Research, p. 1880, vol. 48, (2011). Published, 10.1016/j.asr.2011.04.026

### Books or Other One-time Publications

### Web/Internet Site

**URL(s):**

<http://arctic.ssec.wisc.edu/>

**Description:**

This web site hosts real-time Arctic composite imagery. Multiple sizes of the imagery are offered, as well as animations of the imagery. This site has been revised in the last year of the project, and will continue to host project Arctic composite imagery into the foreseeable future.

### Other Specific Products

**Product Type:**

**Data or databases**

**Product Description:**

Arctic composite satellite imagery: Multi-channel satellite imagery from both geostationary and polar orbiting satellites are combined into a single view centered on the Arctic. Composite are made in the following spectral channels:

Longwave Infrared: ~12.0 microns

Infrared Window: ~11.0 microns

Water Vapor: ~6.7 microns

Shortwave Infrared: ~3.8 microns

Visible: ~0.65 microns

**Sharing Information:**

This data is or will be made available via the following avenues:

- Web Site
- FTP Site
- McIDAS ADDE Server
- LDM/IDD
- E-mail distribution (upon requests)

### Contributions

#### **Contributions within Discipline:**

tial early contributions of this project included aiding in the field efforts by the  
DLARCAT and ARCTAS projects.

At the end of the second year, the composites are began to be the distribution to the  
data community for utilization in university and college classrooms.

In the third year, the Ocean Prediction Center/NOAA has expressed interest in the use of  
composites, and they are experimenting with them.

At the close of the project, the composite is now being made available directly to the  
University of Alaska Geographic Information Network of Alaska (GINA)/National Weather  
Service Alaska.

#### **Contributions to Other Disciplines:**

#### **Contributions to Human Resource Development:**

This project partially supported undergraduate students (Ms. Nicole  
Schroeder and Ms. K. Elena Willmot) in the Department of Atmospheric and Ocean Sciences at  
the University of Wisconsin-Madison. Their work on the project included assisting with  
generating time series of composites for community use, animations, etc.

#### **Contributions to Resources for Research and Education:**

#### **Contributions Beyond Science and Engineering:**

### Conference Proceedings

#### Categories for which nothing is reported:

Organizational Partners

Any Book

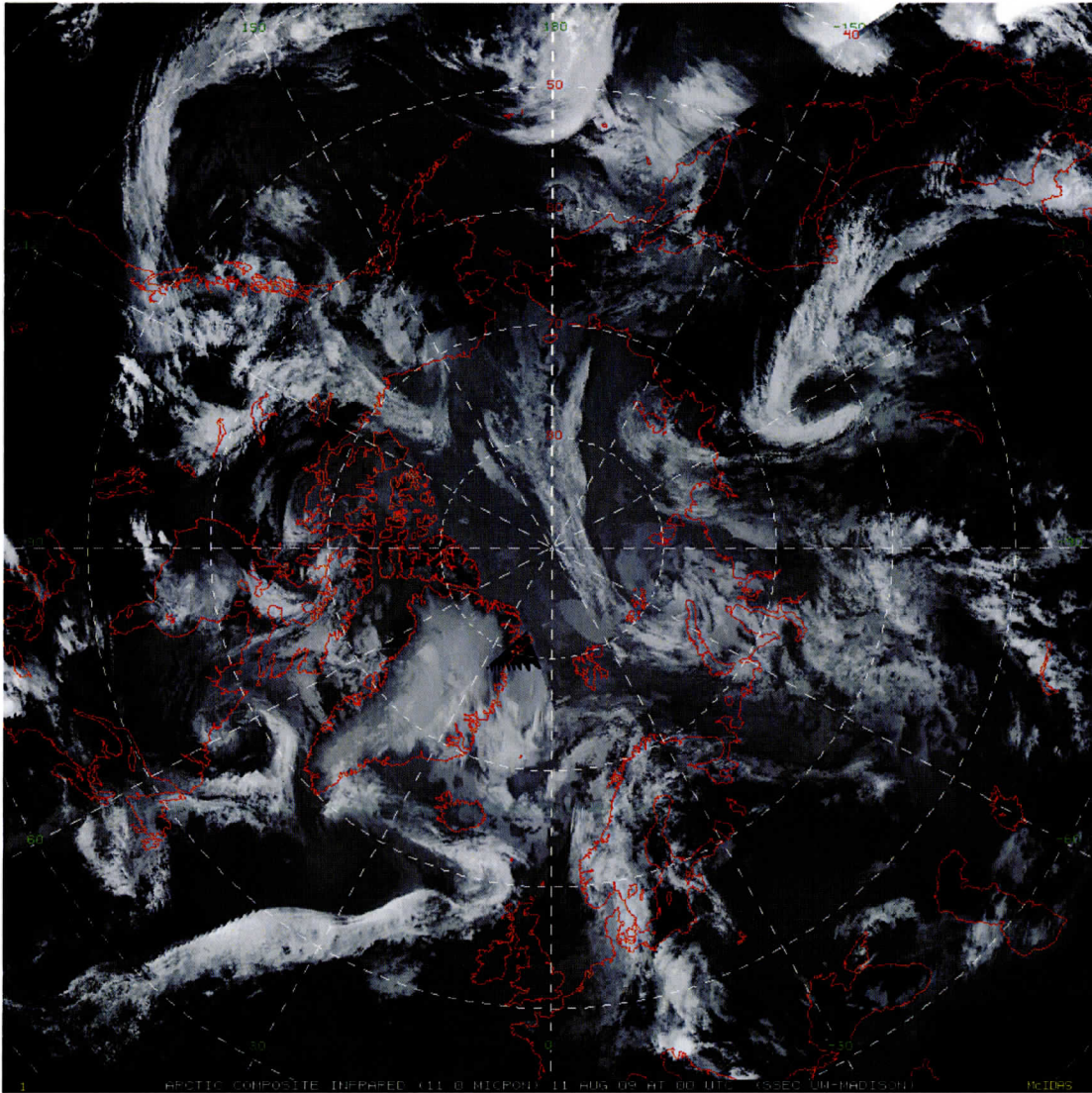
Contributions: To Any Other Disciplines

Contributions: To Any Resources for Research and Education

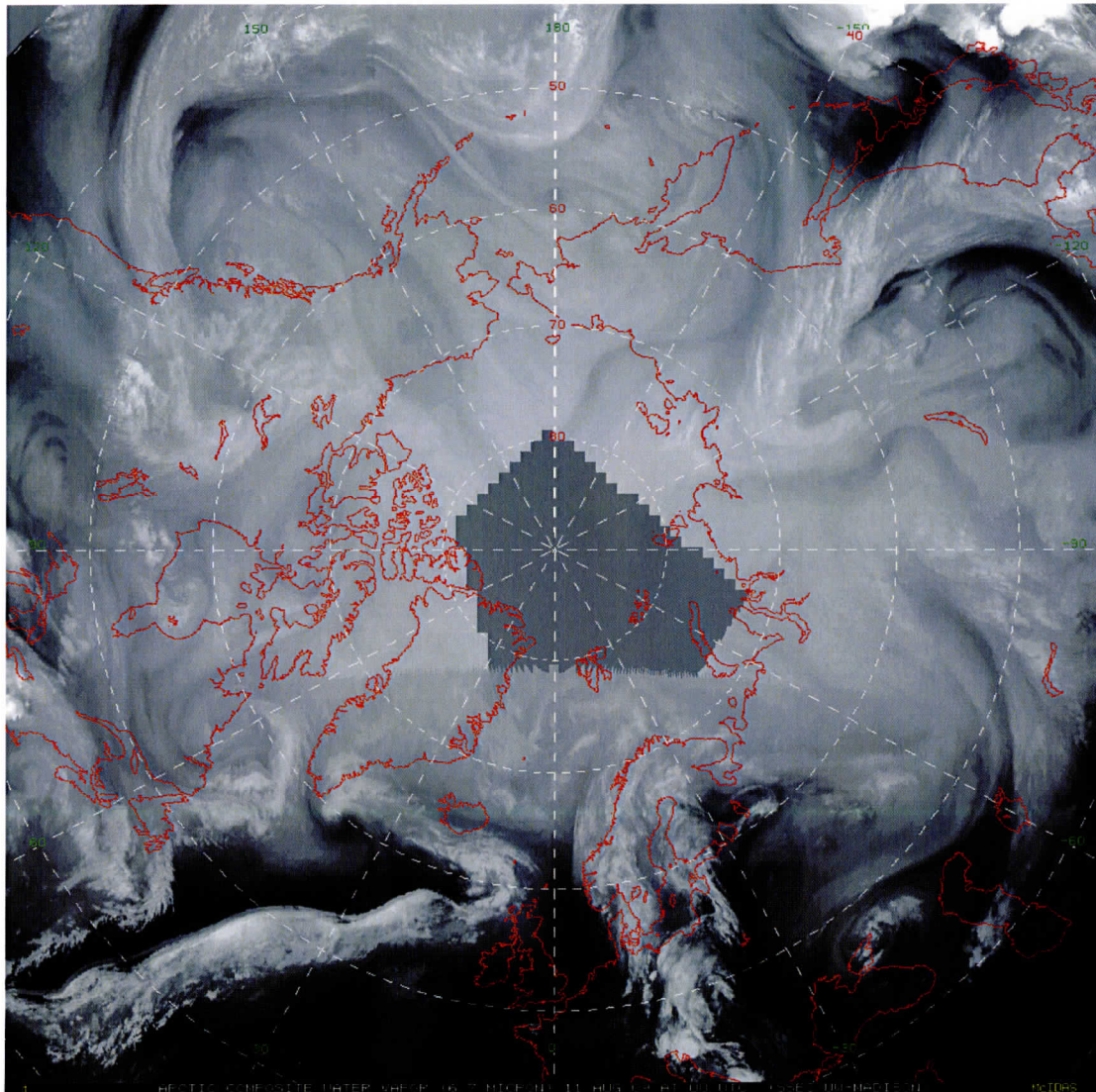
Contributions: To Any Beyond Science and Engineering

Any Conference

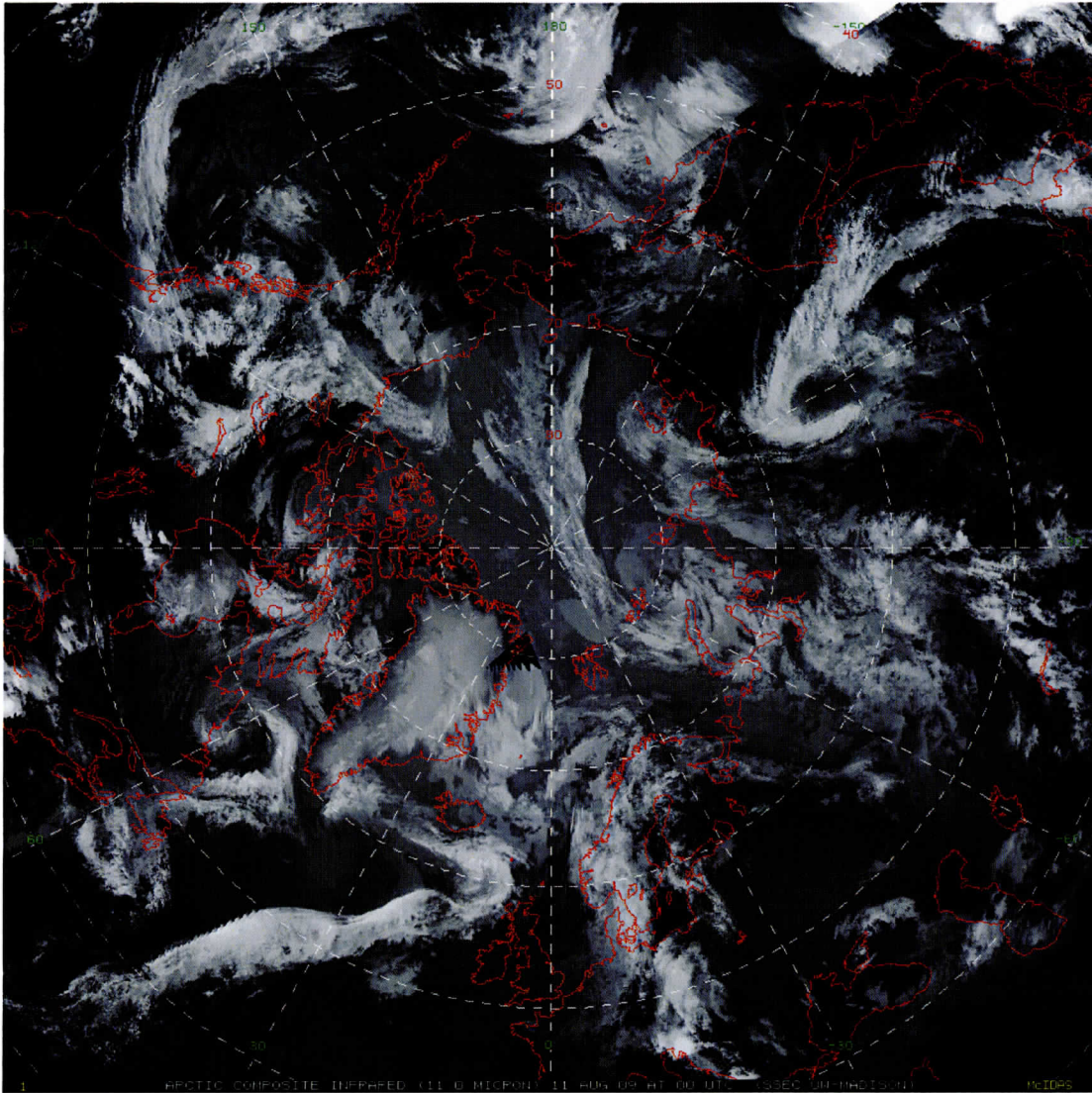




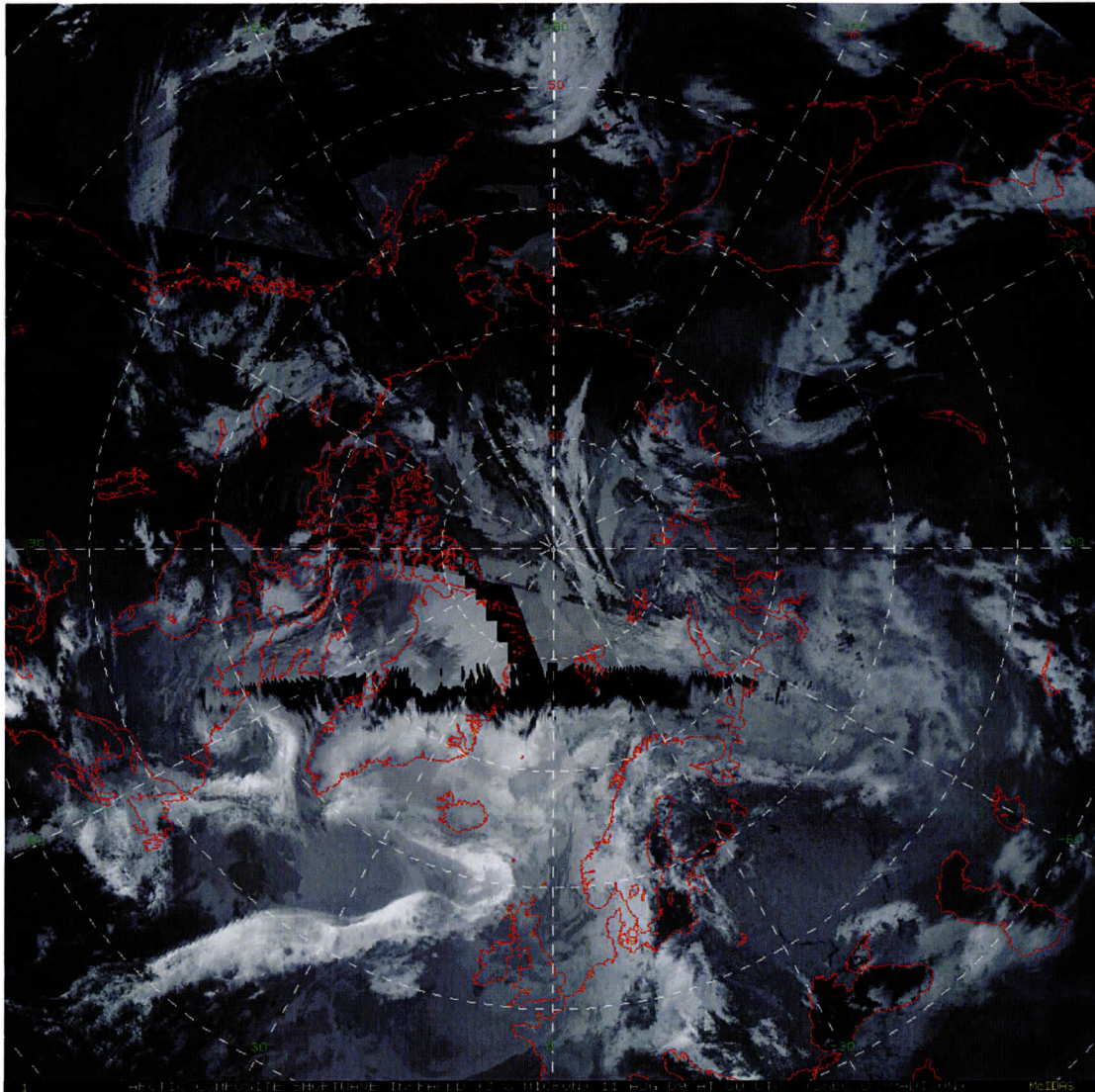
**Figure 1. A sample Arctic infrared (~11.0 micron) satellite composite from 11 August 2009 at 0 UTC shows good satellite coverage over the Arctic basin and adjacent mid-latitude regions. Note the colder, white cloud masses and storm systems in the westerly wind belt distinct from the warmer, darker summertime landmasses.**



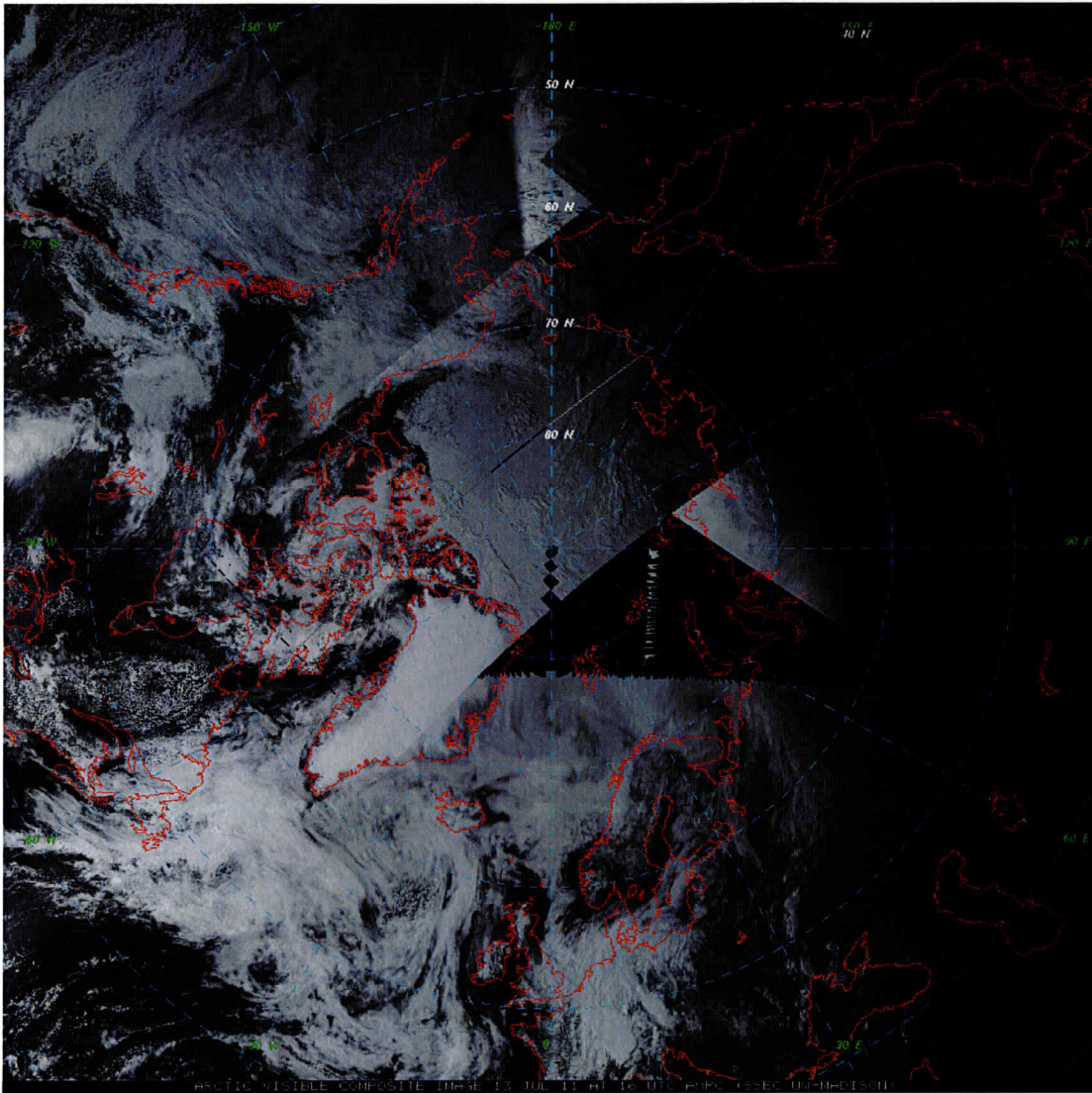
**Figure 2. A water vapor channel (~6.7 micron) satellite composite over the Arctic from 11 August 2009 at 0 UTC shows traces of mid-tropospheric water vapor as well as cloud masses. The gray area over a portion of the Arctic basin is an area of missing satellite coverage where no satellite observations met the criteria for inclusion into the composite.**



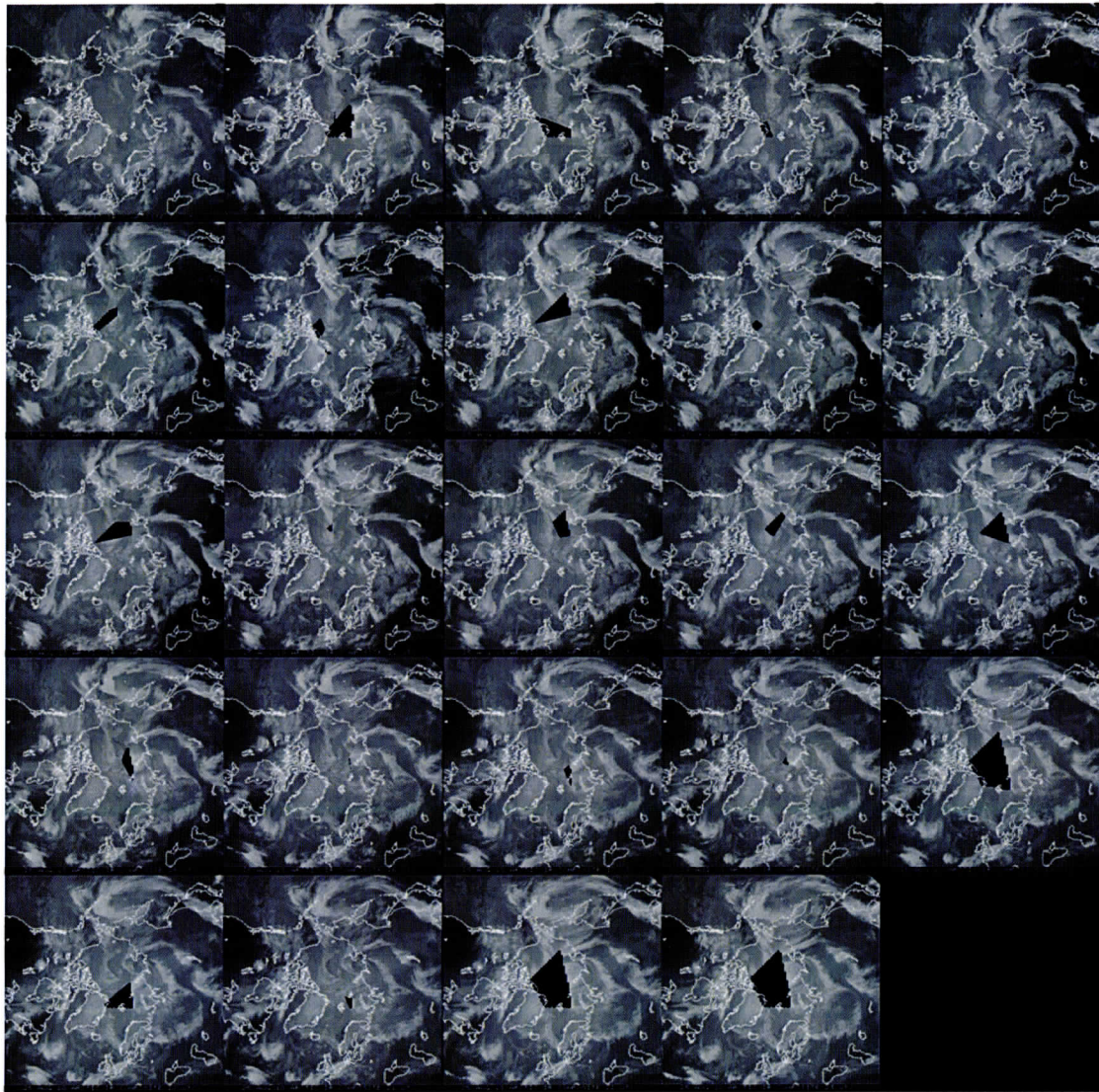
**Figure 3.** A long-wave infrared (~12.0 micron) Arctic composite satellite image from 11 August 2009 at 0 UTC depicts a coverage much the same as the infrared composite.



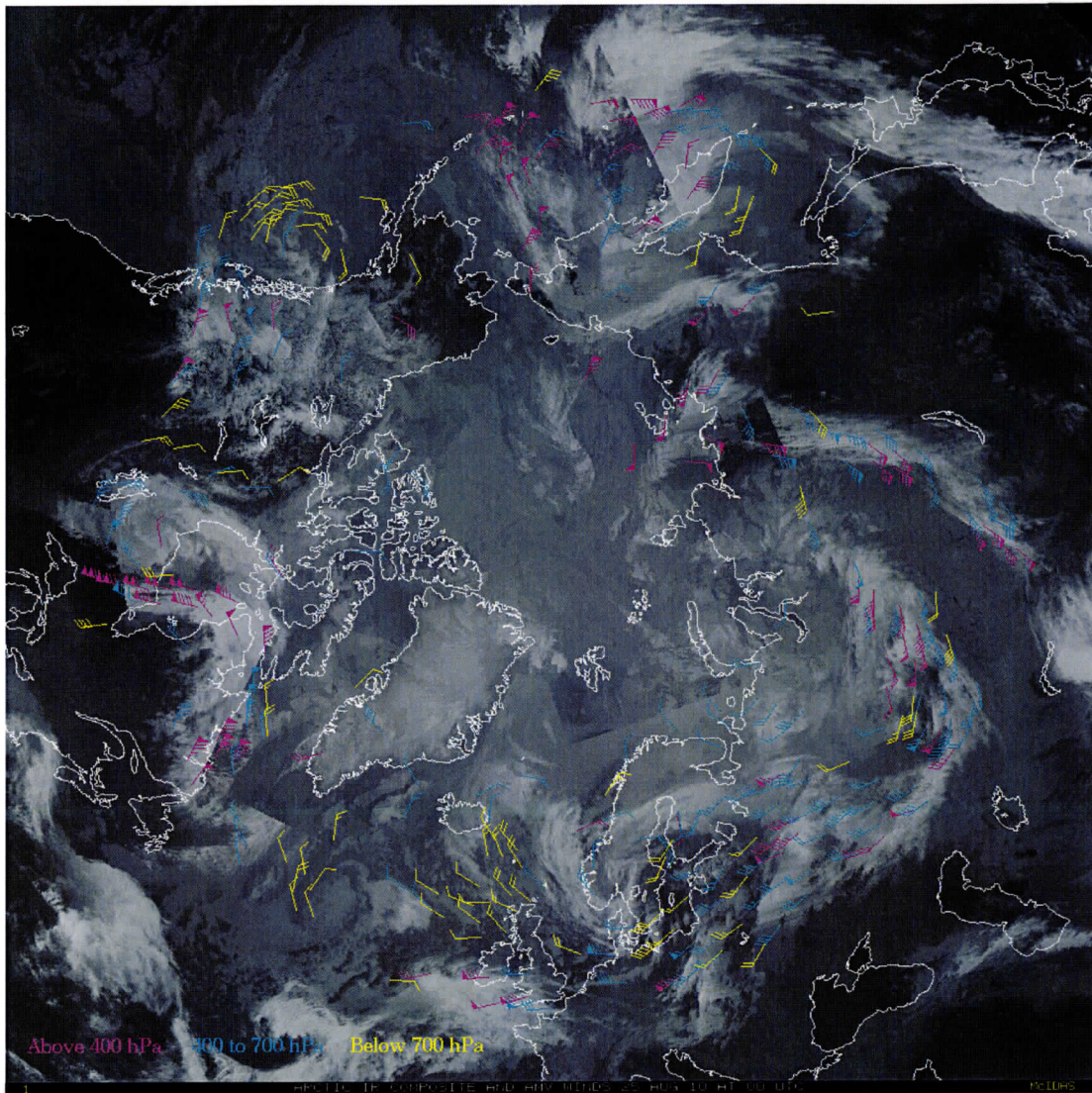
**Figure 4. A short-wave infrared (~3.8 microns) Arctic composite from 11 August 2009 at 0 UTC shows the issues in compositing in this only semi-uniform spectral channel. Not all of the contributing satellites have the same peak wavelength as some have 3.7 microns and others have 3.9 microns. Hence, the radiometric returns are slightly different between satellites (e.g. the polar orbiting passes are distinctive from the rest of the composite). Also, some of the geostationary satellites do have some quality challenges in this spectral band (as seen through Greenland and the North Sea).**



**Figure 5. A visible (~0.65 microns) Arctic composite image from 13 July 2011 at 16 UTC shows the sunlight side of the Earth, with storms/clouds, polar ice cap on Greenland, and sea ice depicted.**



**Figure 6. 24 hours of 1-hourly Arctic infrared composites for 25 August 2010.**



**Figure 7. A sample infrared Arctic composite satellite image from 25 August 2010 at 00 UTC with atmospheric motion vectors (AMV) overlaid shows winds at three atmospheric layers: Below 700 hPa, 400 to 700 hPa and above 400 hPa.**

# Arctic Satellite Composite Observations: *A New Perspective*

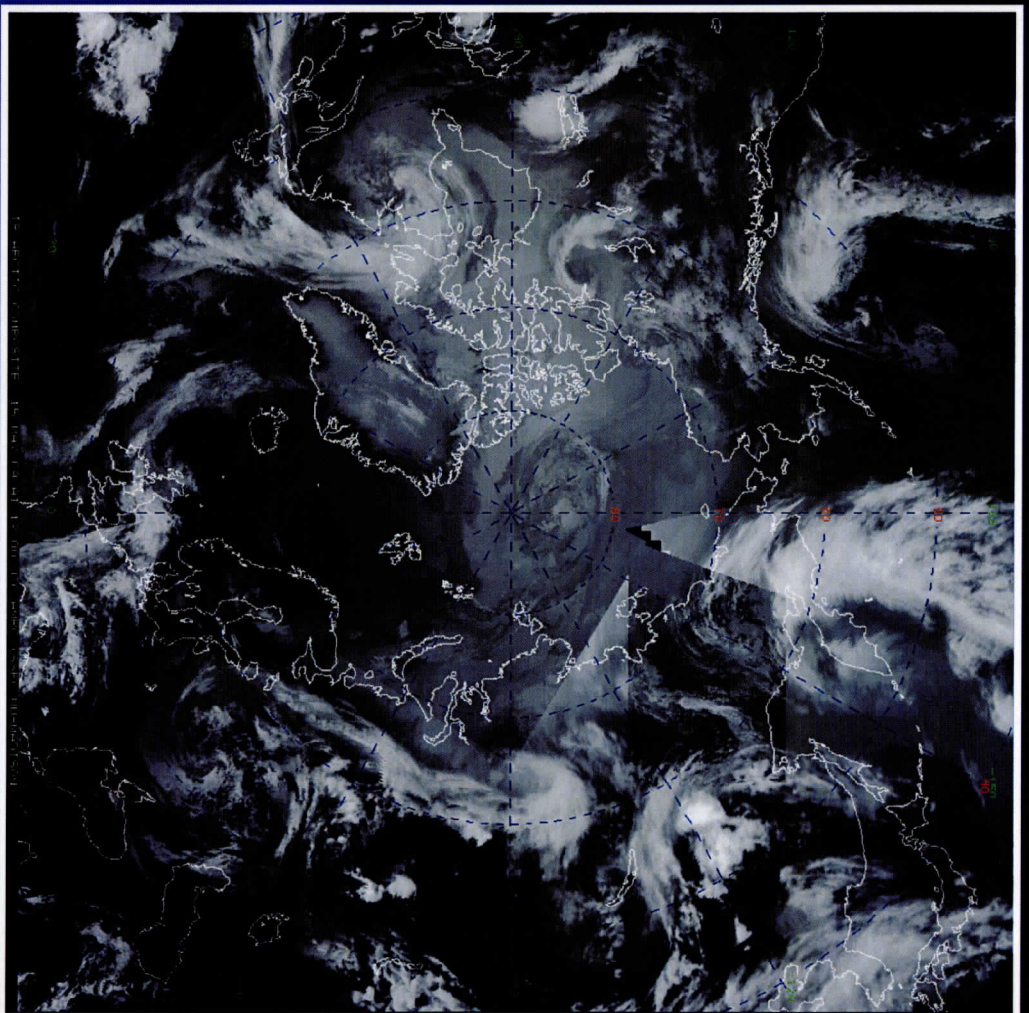


WISCONSIN



**Matthew A. Lazzara**  
**Shelley L. Knuth**

**Antarctic Meteorological Research Center**  
**Space Science and Engineering Center**  
**University of Wisconsin-Madison**





# The Road to Arctic Composites (aka going bi-polar!)

- \* Antarctic composites (inspired from one-time composites, Dr. Charles Stearns)
  - \* First(?) to use both geostationary and polar orbiting
- \* Multiple attempts with multiple agencies to fund an Arctic cousin
  - \* No luck for over 10 years to over 4 agencies!
- \* Success – National Science Foundation, Arctic Natural Science program at the start of the International Polar Year!
  - \* Learning lessons from Antarctic effort
  - \* New opportunities...

# Composite Generation

- \* Satellite acquisition at SSEC Data Center
- \* “Clean up” of bad lines
- \* Remapping imagery
- \* Removal of “space” background
- \* Merge imagery
  - \* Geostationary first
  - \* Polar orbiting last
- \* Post processing and distribution

# Arctic Composite

## Satellite Sources

- \* Geostationary:
  - \* GOES-10, -11, -12
  - \* KALPANA-1
  - \* Meteosat-7, -9
  - \* FY-2C
  - \* MTSAT-1R
- \* Polar orbiting
  - \* NOAA-15, -16, -17, -18
  - \* Aqua and Terra
- \* Spectral Bands:
  - \* Infrared Window (~11.0 microns)
  - \* Water Vapor (~6.7 microns)
  - \* Shortwave Infrared (~3.9 microns)
  - \* Longwave Infrared (~12.0 microns)

## Specifications

- \* 3 hourly data (at synoptic hours 0, 3, 6, 9, 12, 15, 18, 21 UTC)
- \* +/- 50 minutes to the top of the hour
  - \* Most +/- 15 minutes
  - \* Otherwise its left missing...
- \* 5 kilometer nominal resolution
- \* Polar stereographic
  - \* Centered at North Pole 90°
  - \* Standard/True at 60° North
  - \* "Dateline up/Greenwich down" Standard at 0°

# Distribution & Formats

Web:

<http://arctic.ssec.wisc.edu>

FTP:

<ftp://arctic.ssec.wisc.edu/arctic>

ADDE:

Group: ARCTIC

Machine: arctic.ssec.wisc.edu

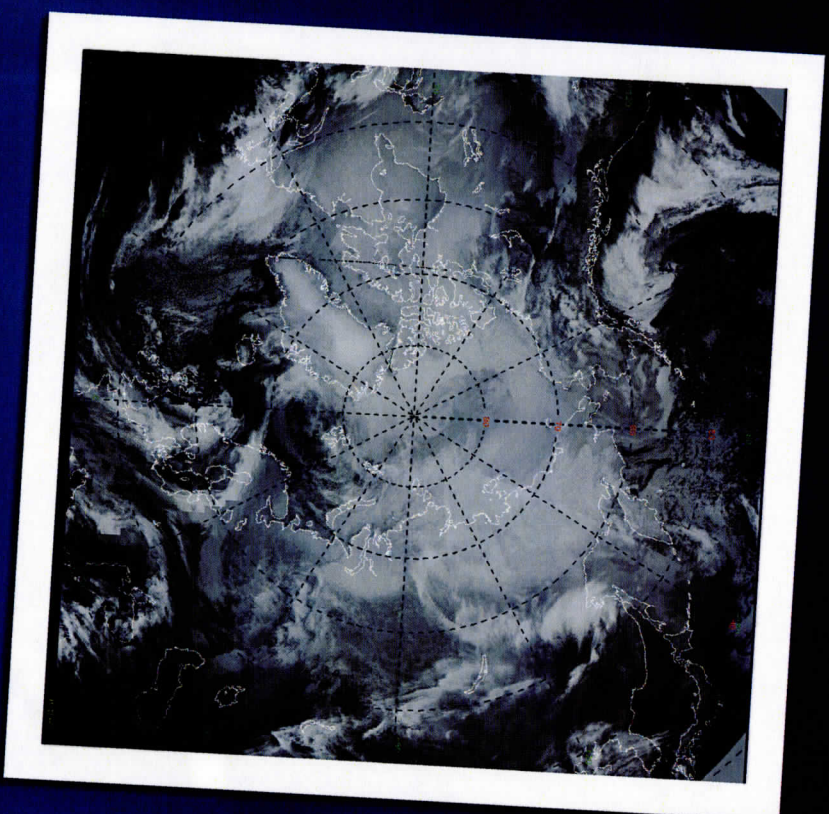
LDM (Antarctic-IDD):

ANSP.AMRC.Composite.<band>.<date>.<time>

ANSP.AMRC.Composite.<band>.<date>.<time>.jpg

Formats:

McIDAS AREA, netCDF, GIF/JPEG/etc., "flat" file (ASCII, binary), etc.

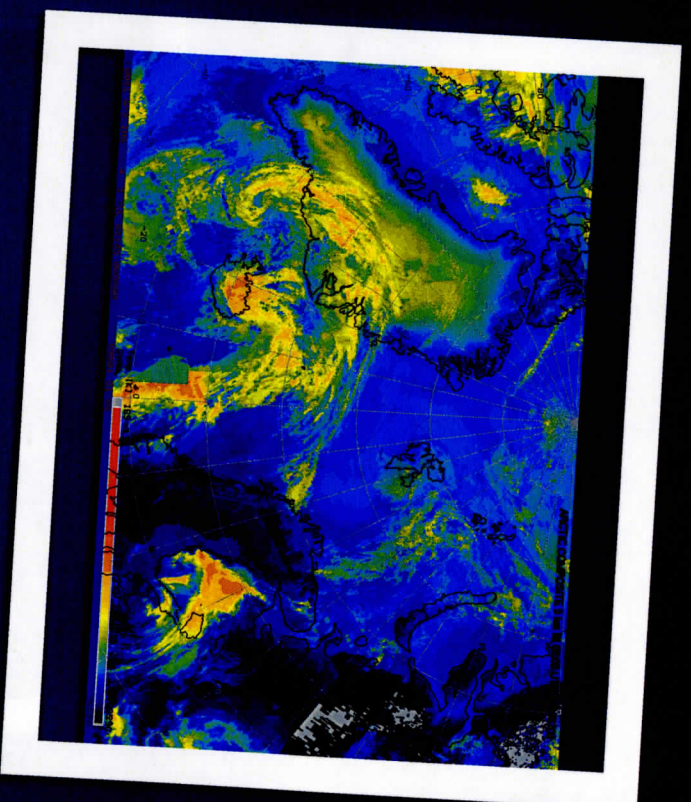


# Applications

## ARCTAS

Arctic Research of the  
Composition of the  
Troposphere Aircraft and  
Satellite program

<http://www.nasa.gov/arctas/>

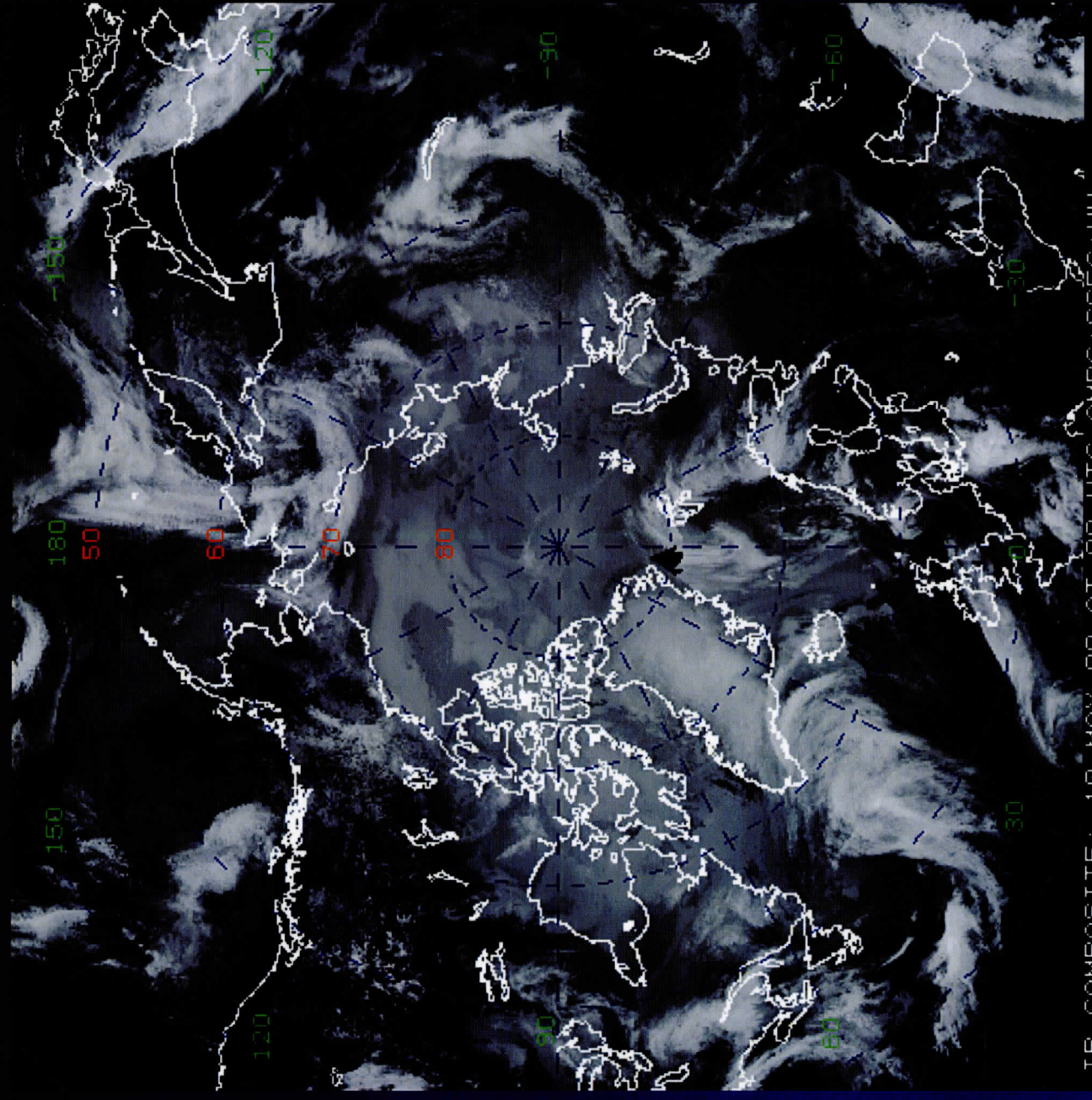


## POLARCAT

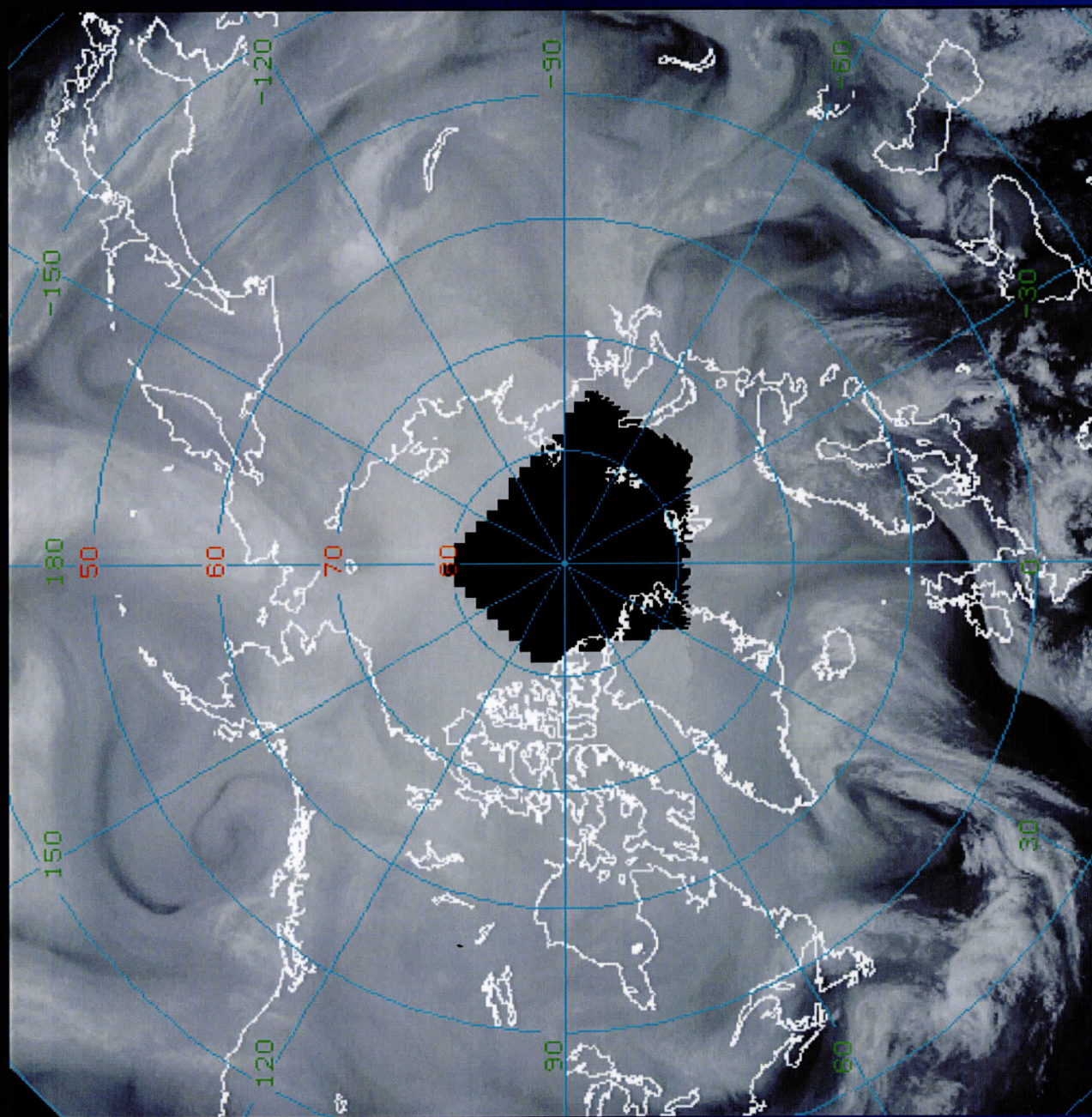
Polar study using aircraft, remote sensing, surface  
measurements and modeling.

Exploring climate, chemistry, aerosols, and transport

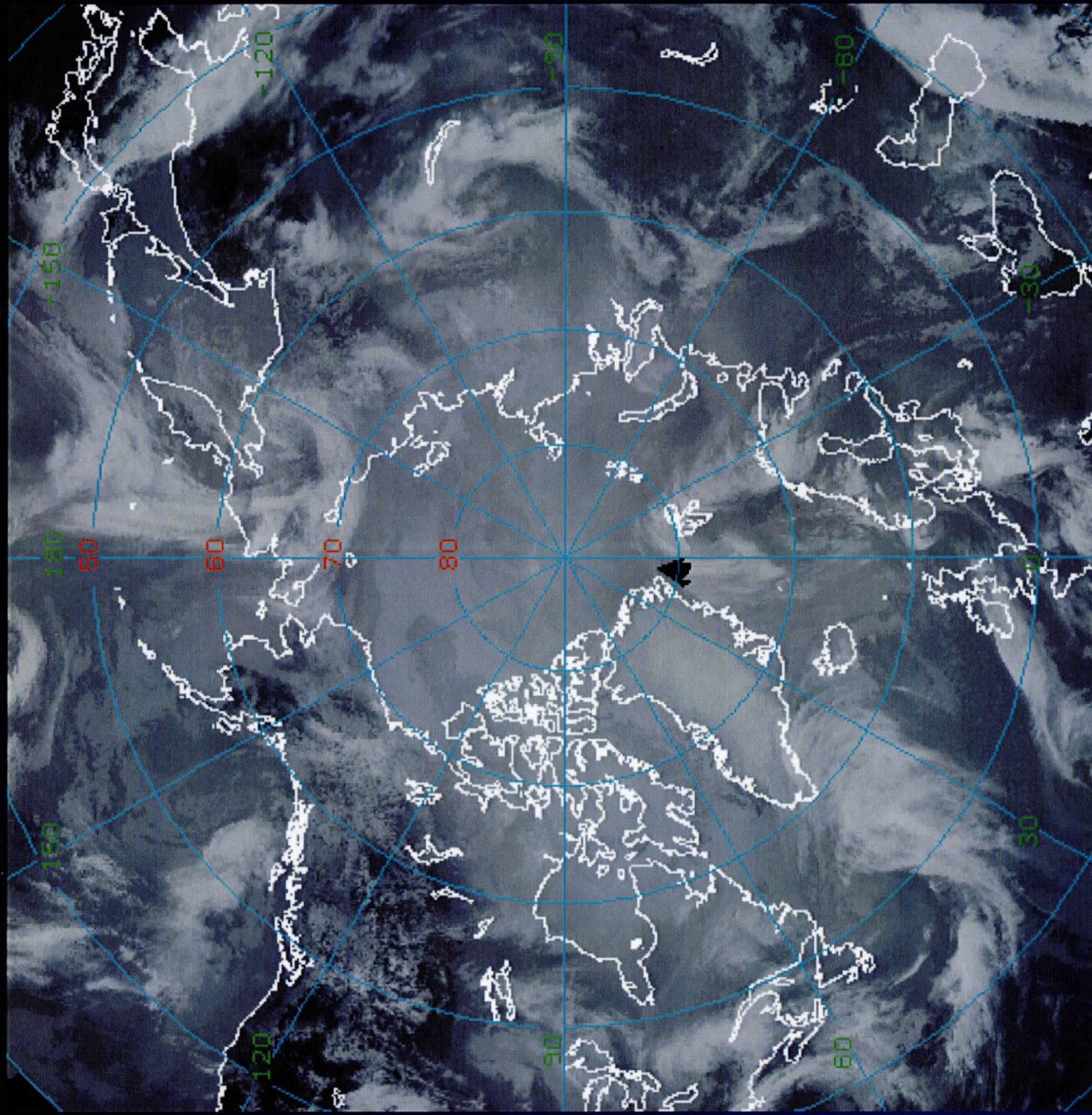
<http://www.esrl.noaa.gov/csd/metproducts/polarcat/>



IR COMPOSITE: 10 MAY 09 AT 00 UTC AMRC:SSFC:UM



ARCTIC VAPOR COMPOSITE: 10 MAY 09 AT 15 UTC AMRC: SSEC: UJ



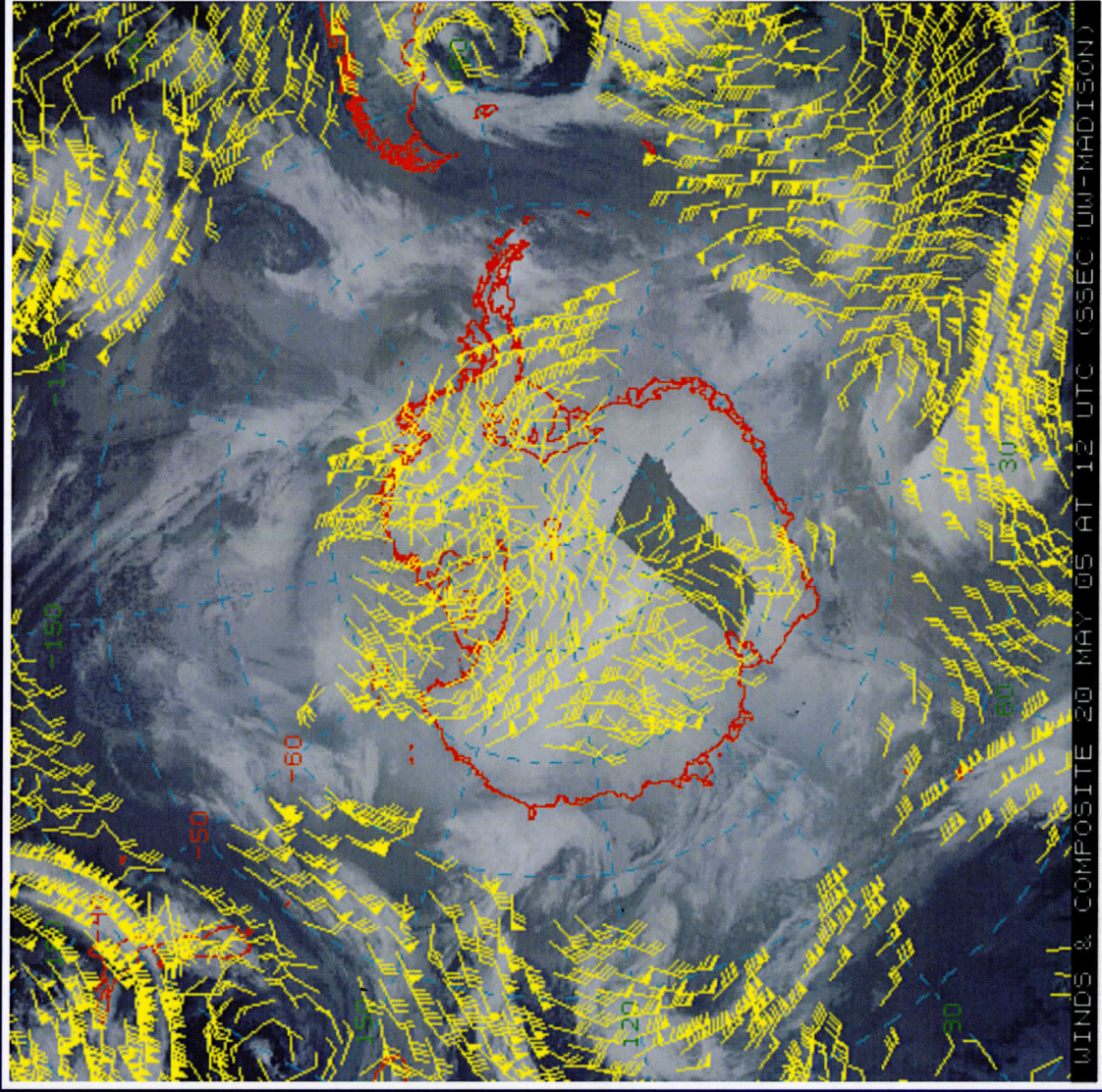
ARCTIC LONG WAVE COMPOSITE: 10 MAY 09 AT 00 UTC AMRC: SSE

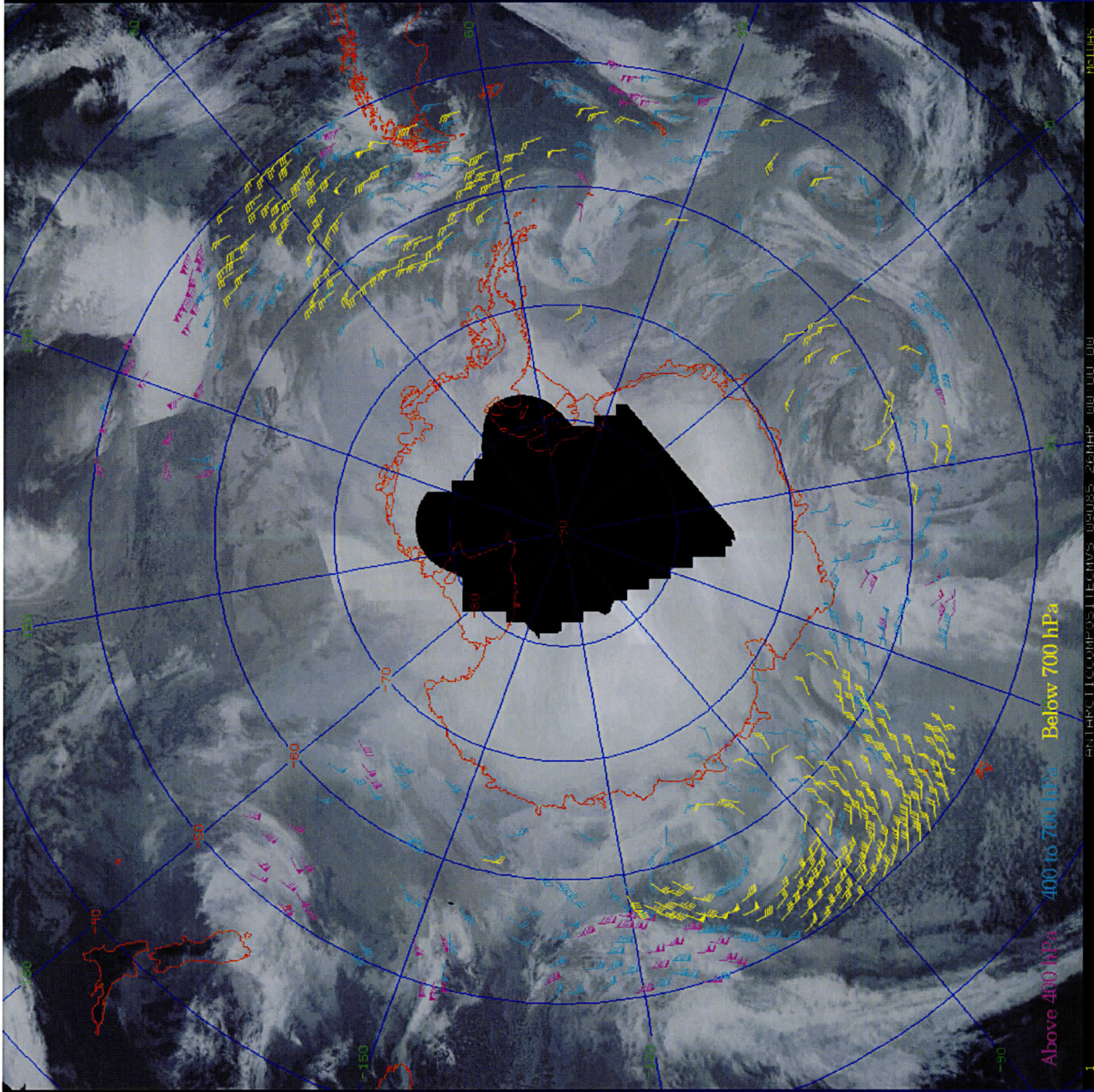


# Future Work

- \* Adding satellites
  - \* FY-2D
  - \* NOAA-19
  - \* MetOp-A
  - \* Aqua/Terra (water vapor composites)
- \* Visible channel composites
- \* Hourly composites
- \* Archive/rsync server/Web site
- \* Unidata Internet Data Distribution (IDD)
- \* Application: Atmospheric Motion Vectors (AMV) ?

# Atmospheric Motion Vectors

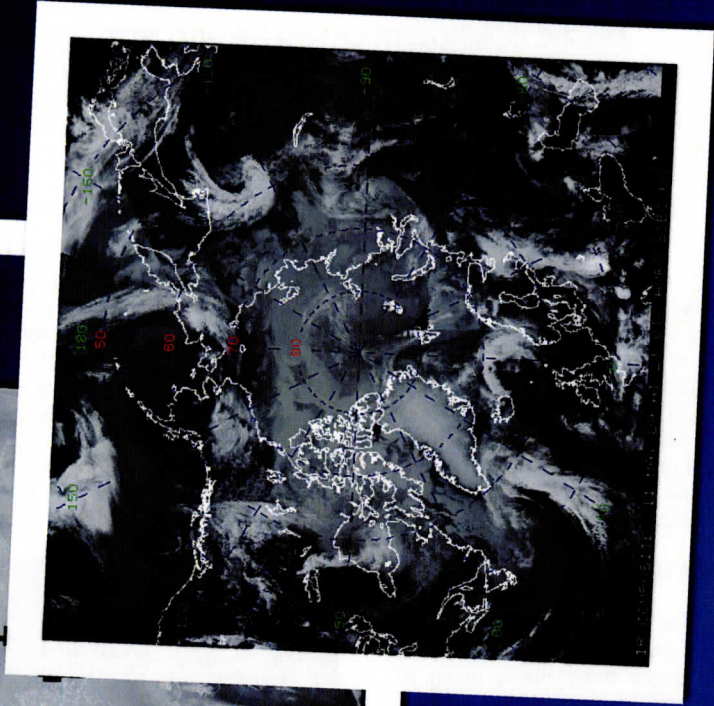
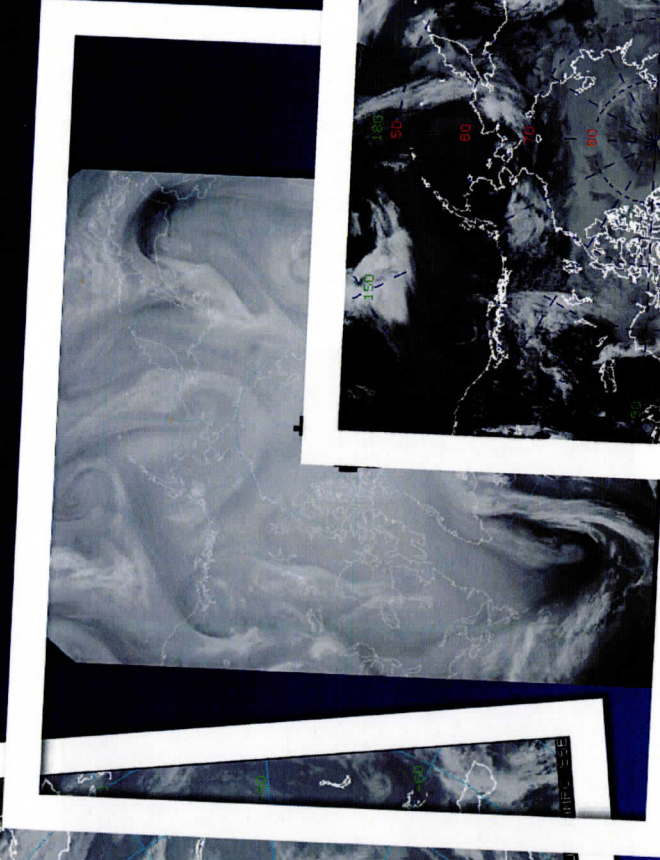
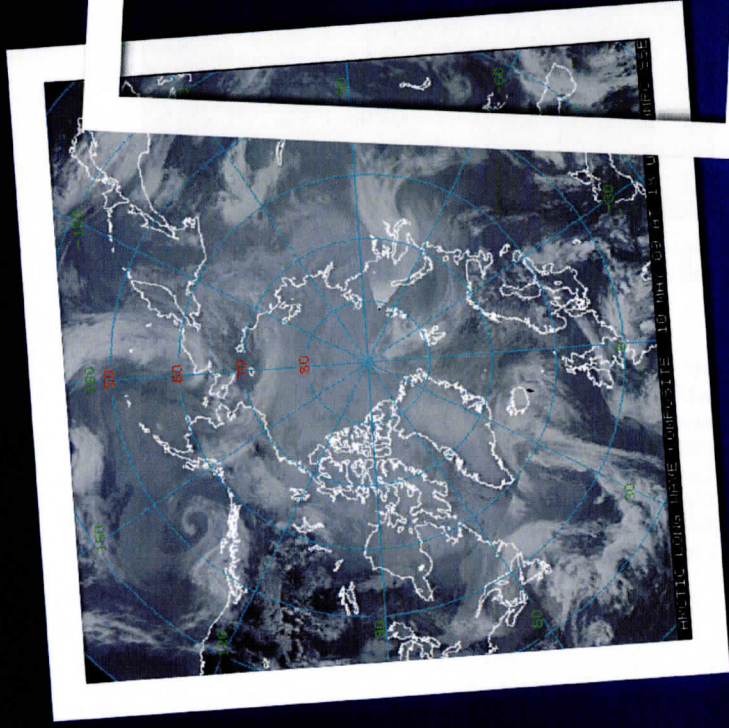




ANTARCTIC COMPOSITE USING 2EMHF 00 100 00

Above 400 hPa 400 to 700 hPa Below 700 hPa

1



Thank you!

<http://arctic.ssec.wisc.edu/>

[arctic@ssec.wisc.edu](mailto:arctic@ssec.wisc.edu)

This effort is funded by National Science Foundation  
Office of Polar Programs Grant #ARC-0713843

## ARCTIC COMPOSITE SATELLITE PROJECT

Matthew A. Lazzara and Shelley L. Knuth  
Antarctic Meteorological Research Center, Space Science and Engineering Center,  
University of Wisconsin-Madison, Madison, Wisconsin

<http://amrc.ssec.wisc.edu/arctic/>

### 1. INTRODUCTION

The University of Wisconsin has made Antarctic satellite composite imagery for over 15 years in support of forecasting, research and education. Unfortunately efforts to offer the same product for the Arctic have not been possible until now. The Arctic Natural Science program at the Office of Polar Programs of the National Science Foundation has funded an Arctic composite satellite project. This unique project is timely as it is available during the International Polar Year.

### 2. COMPOSITE GENERATION

The composite imagery for the Arctic currently follows the same process as the Antarctic (Lazzara, 2003): imagery is made every three hours using all available geostationary and polar-orbiting satellite imagery (see Table 1). Data used in each composite includes data primarily within plus or minus 15 minutes to the top of the synoptic hour, and then failing that uses data plus or minus 50 minutes to the top of the synoptic hour. The resulting image resolution is a nominal 5 kilometers making the final image size over 4 megabytes in raw format. The composite are assembled using the Man computer Interactive Data Access System (McIDAS) interactive processing system (Lazzara et al. 1999).

Table 1. Satellites used in generating the Arctic composite imagery.

Platform	Satellites
Geostationary	GOES-10 GOES-11 GOES-12 KALPANA-1 Meteosat-7 Meteosat-9 FY-2C MTSAT-1R
Polar-orbiting	NOAA-15, -16, -17, -18 Aqua Terra

As a part of the process of making the composite, any bad lines of satellite imagery are cleaned up along with any bad buffer flakes removed to improve the resulting image. To allow for proper merging of the satellites, the space background it removed as well. The final composite, which is made in both the infrared (~11.0 micron) and water vapor (~6.7 micron) bands, do retain some temperature information, in addition to brightness information. However, the accuracy of the information is not as good as the original 2-byte data, as the final product is 1-byte deep.

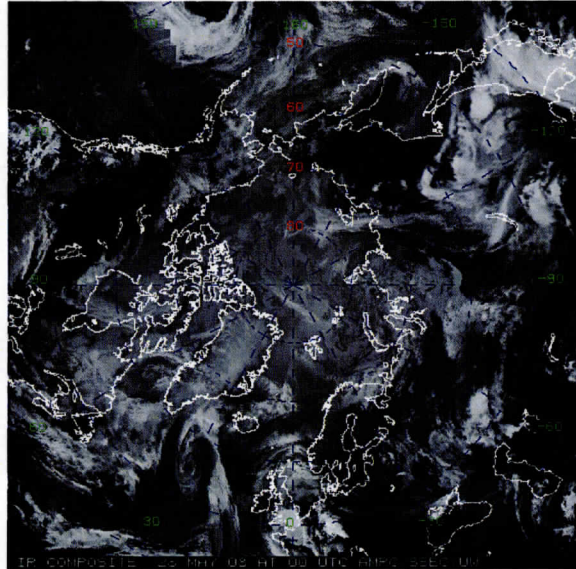


Figure 1. A display of an example Arctic composite infrared image created on 00 UTC on 26 May 2008.

The final composite image is navigated in a polar stereographic projection centered at the North Pole, with standard latitude of 60 degrees South and standard longitude of 0 degrees. This orientation was selected to match the most common view of the Arctic basin. The process for generating the composites is completely automated and experiences only a few failures other than those due to missing satellite imagery, power outages, etc.

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Email: [mattl@ssec.wisc.edu](mailto:mattl@ssec.wisc.edu)

### 3. APPLICATIONS

One of the first uses of the composite is in support of the Polar study using Aircraft, Remote sensing, surface measurements and modeling of the Climate, chemistry, Aerosols and Transport (POLARCAT) and Arctic Research of the Composition of the Troposphere Aircraft and Satellites (ARCTAS) programs. These IPY efforts are important applications of the composite in both an operational setting with the data used in briefing/determining logistics for the airborne portion of the field campaigns as well as for research as a part of the diagnostics involved in the analysis. More applications and users are expected in the upcoming year as word of the availability of these composites spreads to the community.

### 4. DISTRIBUTION AND FORMAT

The distribution of the composites takes several available routes, including:

- File Transmission Protocol (FTP)
- World Wide Web (WWW)
- Unidata Internet Data Distribution (IDD)
- Abstract Data Distribution Environment (ADDE)
- Various computer media
- Printed form or hard copy

Currently, real-time composites can be viewed on the web servers as still images and animations.

The archived data format for the composite is McIDAS AREA format. However, it can be made available into netCDF format, "flat" binary or ASCII formats along with imagery formats such as JPG, GIF, etc.

### 5. FUTURE DIRECTIONS

With regards to the future, Arctic composite project has several unmet goals. First will be to continue to create composites in other commonly available spectral channels found on board both geostationary and polar orbiting satellite platforms. This includes visible channel, shortwave and longwave infrared channels as well. A second activity will be to continue to inform the community of the composites availability. A third activity will be the utilization of the composite in educational settings and public outreach events.

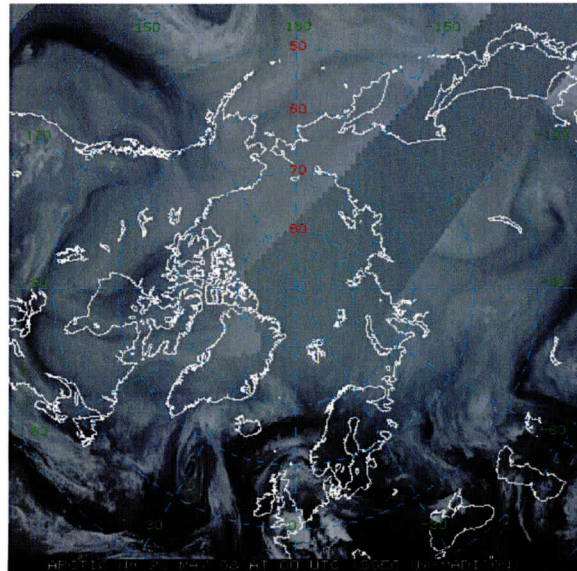


Figure 2. A sample water vapor Arctic composite satellite imagery taken at 00 UTC on 28 May 2008.

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