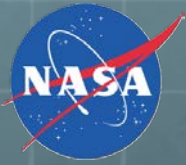


International MODIS/AIRS Processing Package (IMAPP): Polar Orbiter Data is Useful to Operational Weather Forecasters

Kathleen Strabala, Liam Gumley, Allen Huang, Rebecca Cintineo
UW-Madison, Space Science and Engineering Center (SSEC),
Cooperative Institute For Meteorological Satellite Studies (CIMSS)



Focus on IMAPP



International MODIS/AIRS Processing Package

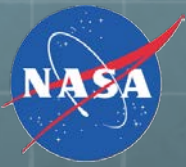
Aqua and Terra support for the Direct Broadcast Community
Funded by NASA since 2000

<http://cimss.ssec.wisc.edu/imapp/>

- 50 software packages released in 13 years
- More than 1700 registrants from 73 different countries
- 11 direct broadcast workshops held on 5 continents
- 16 MODIS related software packages
- 7 AIRS related software packages
- 4 AMSR-E software packages



IMAPP Global Users



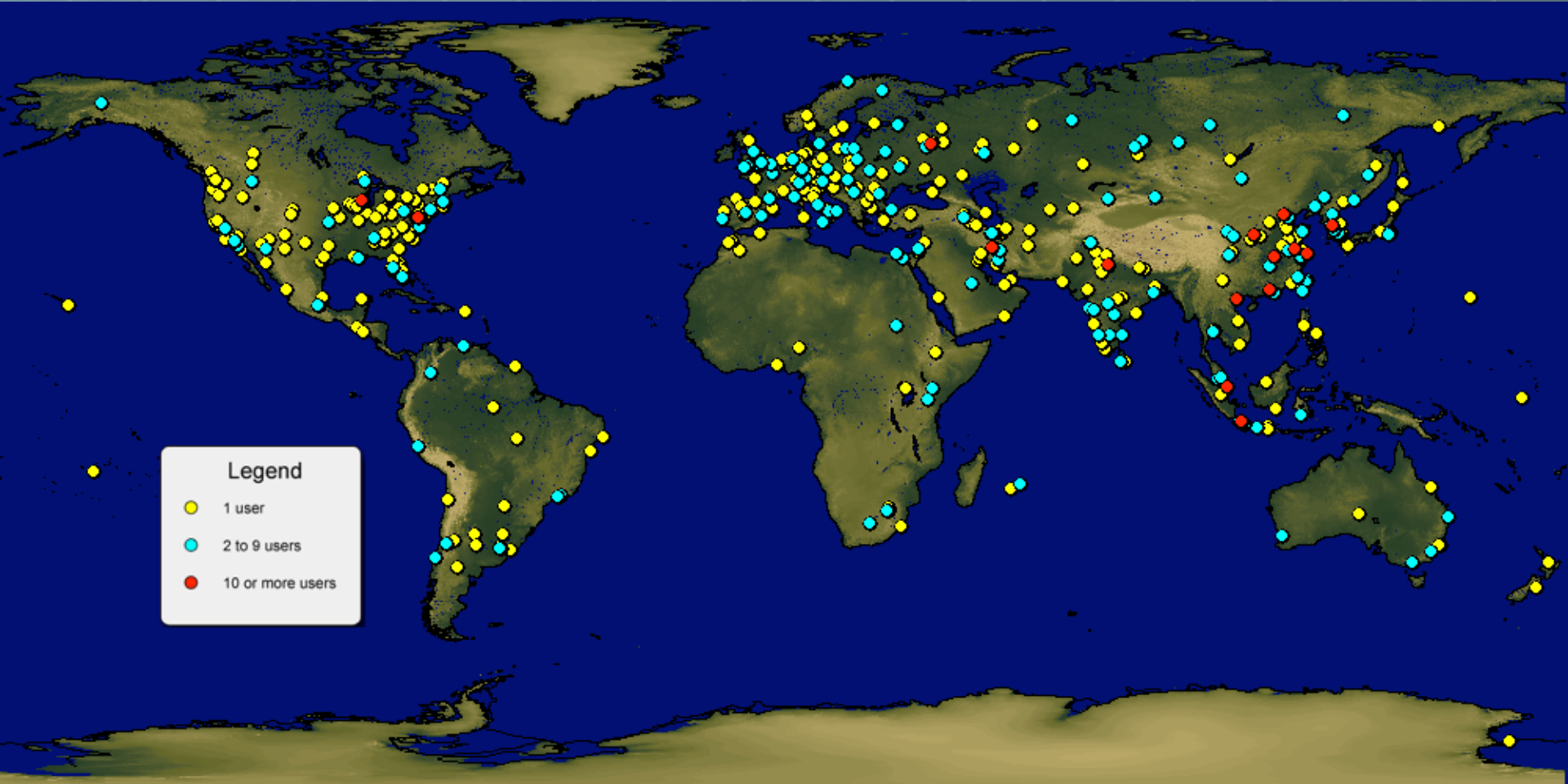
73 Different Countries (> 1/3 of the world total)

Italy
Argentina
Brazil
Kazakhstan
Ukraine
Indonesia
China
Denmark
South Africa
Taiwan
Japan
Morocco
Iran
Singapore
India
Germany
United Kingdom
Iceland
Slovenia

Australia
Czech Republic
Canada
Spain
Chile
Pakistan
Nepal
Portugal
Poland
Saudi Arabia
El Salvador
Colômbia
Serbia
Kenya
Oman
Sweden
Uzbekistan
Switzerland
Peru

Mexico
Hungary
Belgium
Norway
Venezuela
Sri Lanka
France
Russia
Vietnam
Mongolia
Turkey
South Korea
UAE
Lithuania
United States
Thailand
Philippines
Ethiopia
Suriname

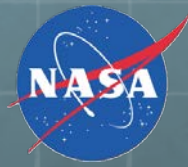
Romania
Malaysia
Algeria
Reunion
Austria
Finland
Czech Republic
New Zealand
Guatemala
Uruguay
Israel
Azerbaijan
Cuba
Kuwait
Syria
Dominican
Republic
Belarus
Laos



More than 1700 people have downloaded some part of the IMAPP suite of products representing 73 different countries and all 7 continents



IMAPP Software Suite



MODIS Atmosphere and Polar Products

- Cloud mask
- Cloud top pressure and temperature
- Cloud optical depth and effective radius
- Temperature and moisture profiles
- Total precipitable water
- Stability indices
- Aerosol optical depth
- Ice Surface Temperature
- Snow Mask
- Ice Cover and Ice Concentration
- Inversion Strength and Inversion Depth

MODIS Land Products

- Land Surface Reflectance
- BRDF

MODIS Image Software

- MODIS in Google Earth (true color)

AIRS Level 1B

- Calibrated and geolocated radiances and brightness temperatures (AIRS)
- Calibrated and geolocated antenna temperatures (AMSU)

AIRS Retrievals

- JPL 3x3 FOV
- Dual Regression Single FOV

AIRS Utilities

- Collocating AIRS/MODIS utility
- AIRS HDF to BUFR utility

AMSR-E Level 1B

- Calibrated and Geolocated Antenna Temperatures

AMSR-E Products

- Rain Rate, Soil Moisture, Snow Water Equivalent

NWP Products

- Globally configurable regional numerical weather prediction model that assimilates MODIS DB products - DBCRAS

Aviation/Severe Weather Products

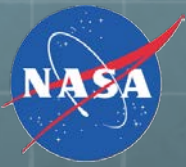
- Overshooting Tops Identification including turbulence and lightning potential

Complete DB Processing System

- VA for Mac, Windows and Linux



IMAPP Software Suite



Air Quality Forecast Product – IDEA-I

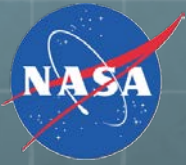
- 48 Hour Aerosol trajectory forecast
- **Beta**- Stratospheric Ozone Intrusions trajectory forecast

Visualization Tools

- Polar2Grid MODIS reprojection software including true color images

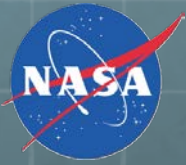
Beta - Web Mapping Service (wms)

- Display and share GeoTIFFs through a web browser
- Can readily display Polar2Grid VIIRS/MODIS Imagery



Polar Orbiter Products and US National Weather Service

- Polar Orbiter Data was not being used in lower 48 states in 2006
- File sizes, delivery and timeliness all issues
- Working with local NWS in Milwaukee Sullivan (MKX), asked to make a presentation that answered this question “Can Research Satellites be Used in Operations”?
- First presentation made on 9 January 2007
- Described how high spatial and spectral MODIS Direct Broadcast data could complement GEO satellite data

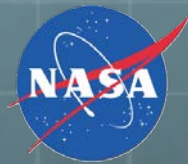


Slowly Built User Base




- Forecasters provided situations that they needed help with
- Especially lacking were nighttime fog detection capability and observations over Lake Michigan
- Made trips to 2 other Forecast Offices in the State (Lacrosse 2008 and Green Bay 2009)
- Set up VisitVIEW TeleTraining called “MODIS Products in AWIPS”
- Started providing MODIS data that could be displayed in AWIPS from DB system in July 2006



Was the Data being Used?

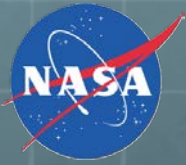


Metrics

-  Forecaster Questionnaire
-  Area Forecast Discussions
-  New Forecast Offices Receiving Data



MODIS Data Forecast

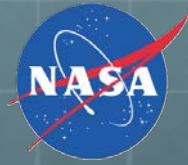


Use

- Snow/Ice Discrimination
- Fog Detection
- Fire Weather
- Post Event Analyses
- Sea State
 - Sea Surface Temperatures
 - Lake Effect Snow Potential

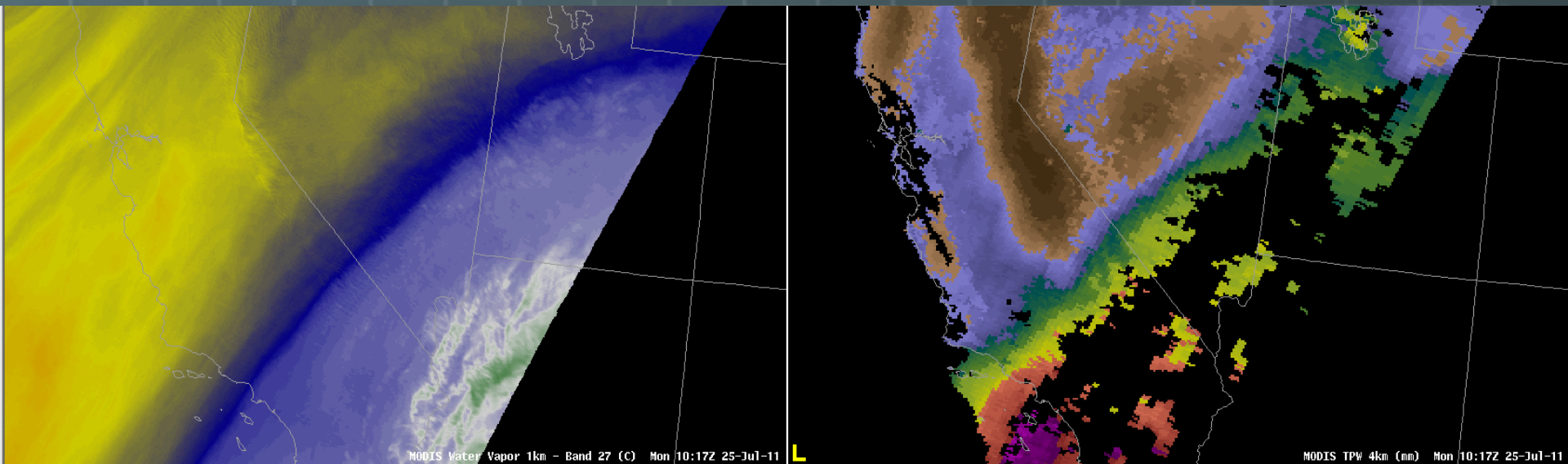


Evaluating Fire Potential



AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE SALT LAKE CITY UT
1024 AM MDT MON JUL 25 2011

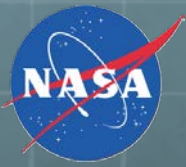
.FIRE WEATHER...MODIS WATER VAPOR IMAGERY INDICATES THAT PRECIPITABLE WATER VALUES APPROACHING ONE INCH HAVE PUSHED AS FAR NORTH AS THE SOUTHERN WASATCH FRONT THIS MORNING. THIS SURGE OF MOISTURE IS ALSO BRINGING EXTENSIVE CLOUD COVER TO CENTRAL AND NORTHERN UTAH THIS MORNING....WITH DEEP MOISTURE MOVING NORTH BELIEVE THAT RISK FOR DRY THUNDERSTORMS IS LIMITED PRIMARILY TO THE LEADING EDGE OF THE MOISTURE SURGE ACROSS NORTHERN UTAH...ALTHOUGH FEEL COVERAGE OF POTENTIAL DRY STORMS WOULD BE LIMITED



MODIS Imagery from UW SSEC Antenna 10:17 UTC 25 July 2011




Fire Detection



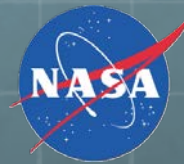
AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE LUBBOCK TX
315 PM CDT MON APR 11 2011

.FIRE WEATHER... ***GOES 3.9 MICRON AND MODIS/POES 3.7 MICRON SATELLITE IMAGES SHOW ONLY ONE FIRE START SO FAR THIS AFTERNOON ALONG THE KENT/SCURRY COUNTY LINE. GOOD NEWS IS THAT THEY ARE NOT SHOWING ANY LARGE FLARE-UPS ON THE SWENSON/STONEWALL AND KING COUNTY FIRE.*** DECREASING WIND SPEEDS WILL ALSO HELP WITH ANY CONTINUED FIREFIGHTING EFFORTS THROUGH TONIGHT. BY LATE TOMORROW MORNING...CONDITIONS CONTINUE TO LOOK MARGINAL TOMORROW FOR MEETING RED FLAG CRITERIA...BUT SOUTH WIND OF 15 TO 25 MPH AND RH VALUES BETWEEN 10 TO 15 PERCENT WILL RESULT IN AT LEAST AN INCREASED FIRE DANGER OVER THE REGION. WILL HOLD ONTO THE FIRE WEATHER WATCH FOR ANOTHER COUPLE OF SHIFTS TO MAKE SURE THE FORECAST REMAINS CONSISTENT IN THE COMPUTER MODELS FOR TOMORROW.

 Due to wildfires, the NWS WFO in Lubbock, Texas, is using the AWIPS alerting system, GUARDIAN, to inform forecasters of each new MODIS and AVHRR shortwave IR image that arrives.

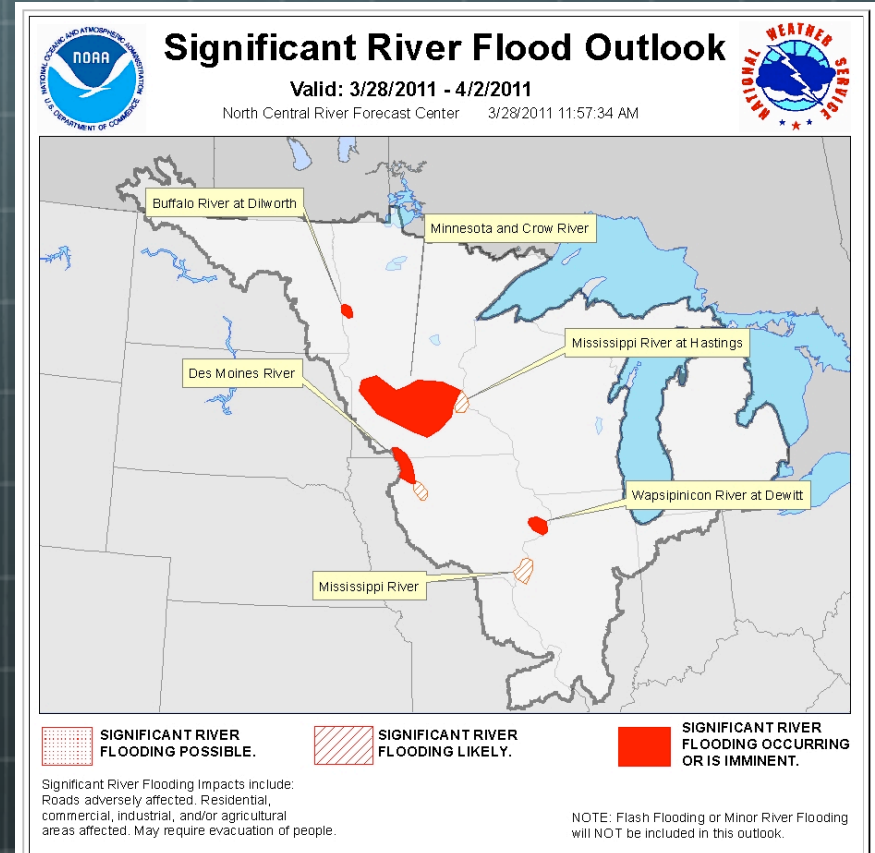
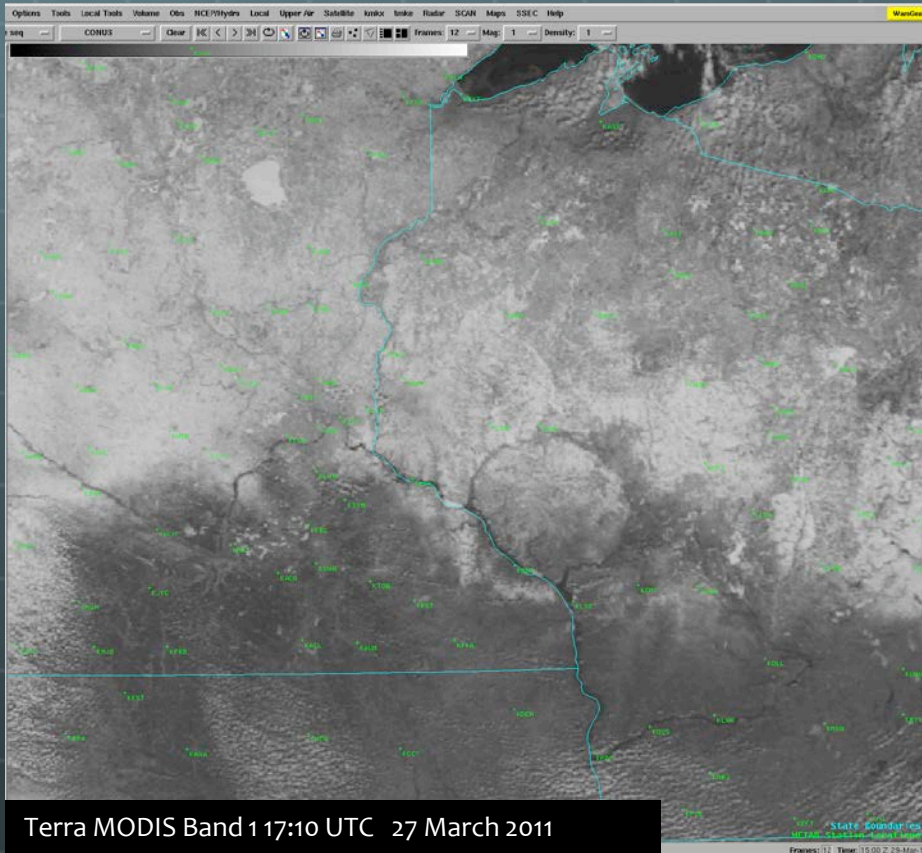


Support for Flood Forecasting



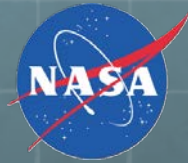
AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE TWIN CITIES/CHANHASSEN MN
422 AM CDT TUE MAR 29 2011

HYDROLOGY...MODIS SATELLITE PASSES OVER THE PAST COUPLE DAYS SHOW LITTLE SNOW COVER IN SOUTHERN MN...SOUTH OF THE MINNESOTA RIVER. THE EXCEPTION IS IN THE MINNESOTA RIVER VALLEY NORTHEAST OF A LINE FROM NEW ULM TO PIPESTONE...WHERE THE EFFECT OF LAST WEEKS SNOWFALL IS STILL QUITE EVIDENT. LATEST NOHRSC 48-HR CHANGE IN SNOW WATER EQUIVALENT SHOWS BETWEEN A TRACE AND 0.20 INCH LOSS SINCE SATURDAY ACROSS ALLOF MN AND WI...DESPITE WELL BELOW NORMAL TEMPERATURES - THE LATE MARCH SUNSHINE IS PLAYING A ROLE IN THIS SLOW MELT...



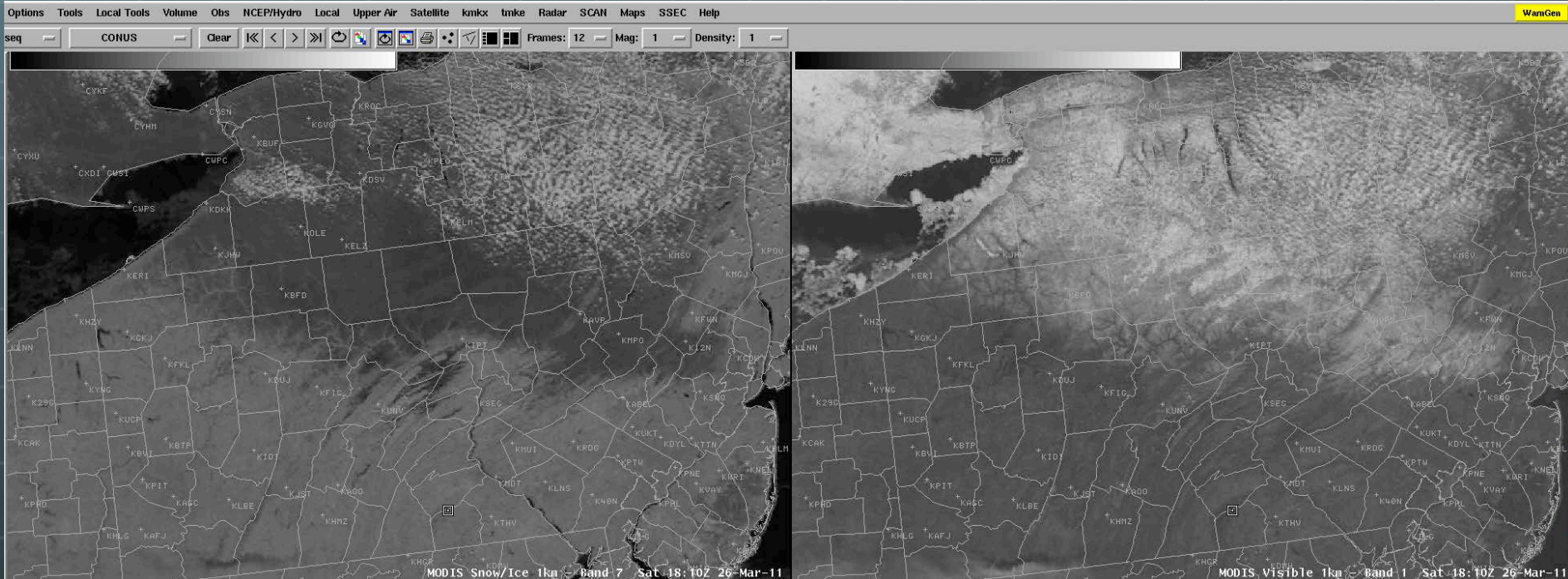


Support for Short Term Forecasts



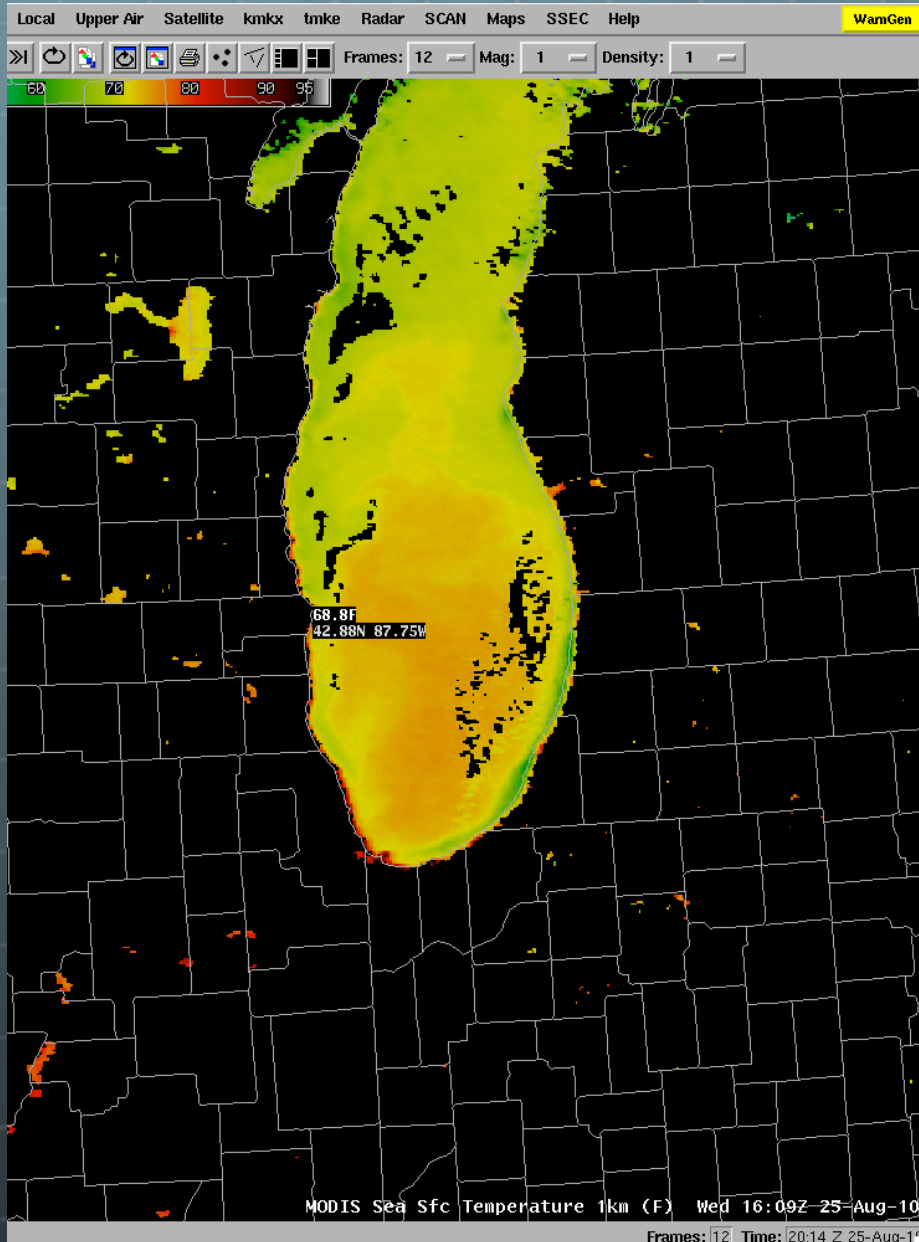
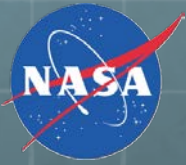
AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE STATE COLLEGE PA
442 AM EDT SUN MAR 27 2011

.SHORT TERM /6 PM THIS EVENING THROUGH 6 PM MONDAY/...ANOTHER VERY CHILLY NIGHT IN STORE FOR THE REGION WITH MINS ARND 15F BLW NORMAL. RIDGE OF HIGH PRESSURE WILL PROVIDE THE CLEARSKIES...**LGT WINDS AND DRY AIR TO ALLOW FOR GOOD RADIATIONAL COOLING. LOWS SHOULD RANGE FROM THE SINGLE DIGITS ACROSS THE SNOW COVERED N MTNS /MODIS BAND 7 IMAGERY SHOWS EXTENT OF SNOW COVER BEAUTIFULLY/...TO ARND 20F IN THE SOUTH.**





Short Term Forecasting



AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE
MILWAUKEE/SULLIVAN WI
228 PM CDT WED AUG 25 2010.

SHORT TERM...TONIGHT THROUGH
FRIDAY...FORECAST CONFIDENCE
HIGH.

...

**TONIGHT...WILL HAVE A CLEAR COOL
NIGHT...WITH UPPER 40S
INLAND...AND N-NE GRADIENT WINDS
OFF THE UPPER 60 LAKE WATER
TEMPERATURES INDICATED BY THE
MODIS SEA SFC TEMPERATURE
IMAGERY HOLDING LAKESHORE
TEMPS UP.** LOWER DEW POINTS
ADVECTING IN OFF-SET BY WARM
GROUND TO KEEP
TEMPERATURE/DEW POINT SPREADS
SUFFICIENT TO LIMIT ANY FOG TO
RIVER VALLEYS AND LAKES.



Local forecast by "City, St" or Zip Code

City, St

XML RSS Feeds
Current Hazards
Watches/Warnings
Outlooks
Submit Report

Current Conditions
Observations
Radar
Satellite
Observed Precip

Forecasts
Forecast Discussion
Activity Planner
Aviation Weather
Fire Weather
Marine Weather
Severe Weather
Hurricane Center

Hydrology
Rivers & Lakes

Climate
Local
National
Drought
More...

Weather Safety
Preparedness
Weather Radio
StormReady
SkyWarn

Additional Info
Other Useful Links
Education Resources
Coop Observer
Top News Archives
Our Office

Contact Us
Contact Info
Feedback

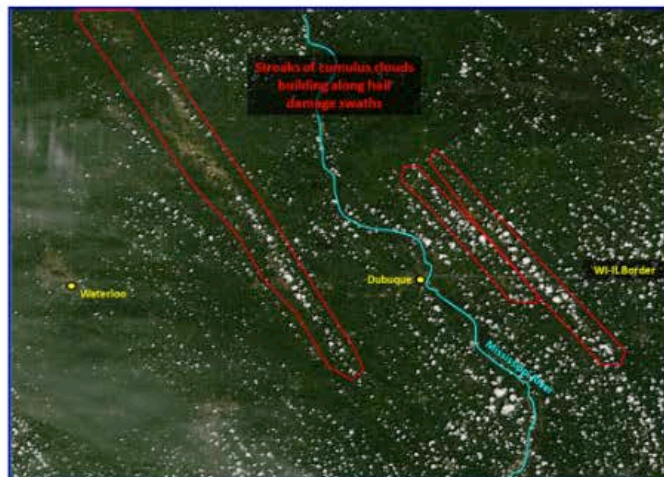
Hail Scars Visible On Satellite Imagery

On Friday July 24, 2009, multiple significant hail storms moved southeastward across northeast Iowa, southwest Wisconsin, and northwest Illinois. These hail storms produced extremely large hail, and copious amounts of hail, which led to some concentrated swaths of damage to vegetation. In some areas, most of the crops were severely damaged or destroyed. For a complete write-up on the situation, [click here](#).

With a relatively clear day today, some of the scarring is visible on satellite images. First, the MODIS Vegetation Index which is a 1km resolution product designed to pick up on areas of greenness in the vegetation:

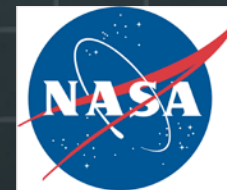
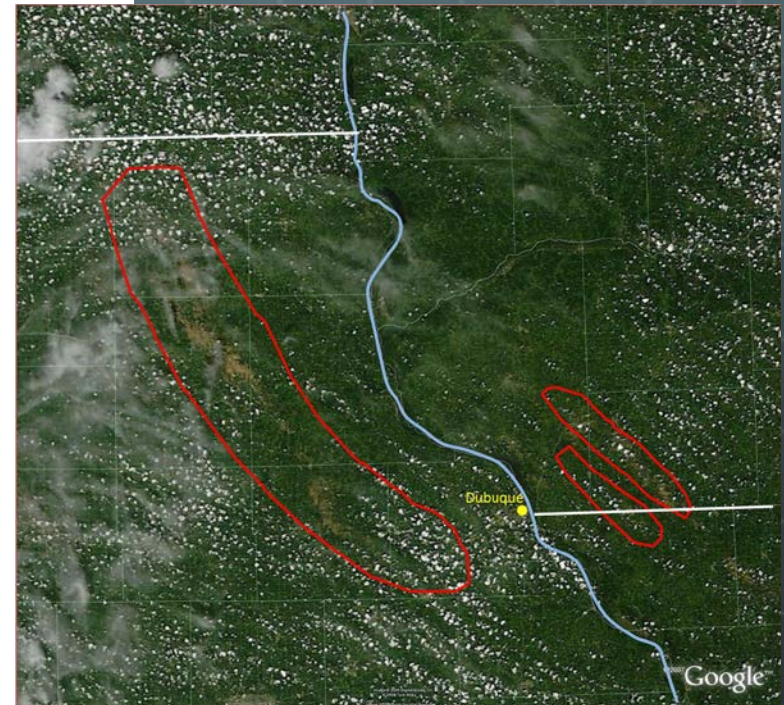


A minimum of about 28% greenness is evident just south-southeast of Belmont, which is not surprising given that is where some of the worst crop damage was observed. Corn stalks were completely stripped and sheared off to a height of less than 2 feet. These damaged areas of vegetation now absorb more radiation from the sun, thereby allowing the surface to heat faster. This phenomenon is evident in the MODIS 250m resolution satellite image from below. Cumulus clouds fired in greater abundance on the Wisconsin hail swaths, which makes them less distinguishable than the Iowa hail swath.



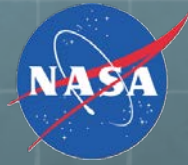
The below image is from a few days later, a little earlier in the day so fewer cumulus clouds. The hail scars are more clearly visible over southwest Wisconsin as well as in northeast Iowa.

MODIS NDVI product used to determine extent of hail damage July 2008



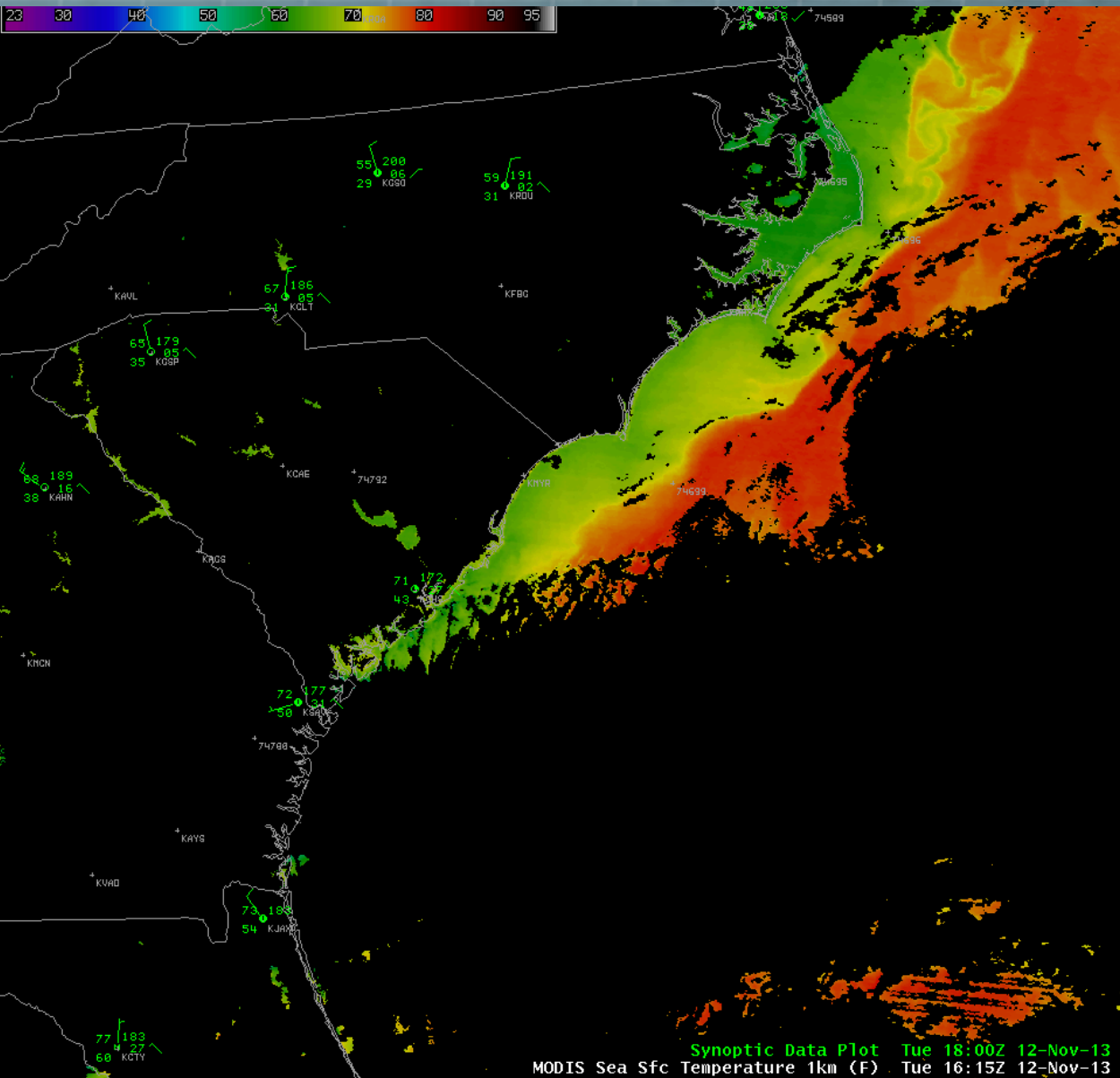


Marine Gale Force Wind Forecasts



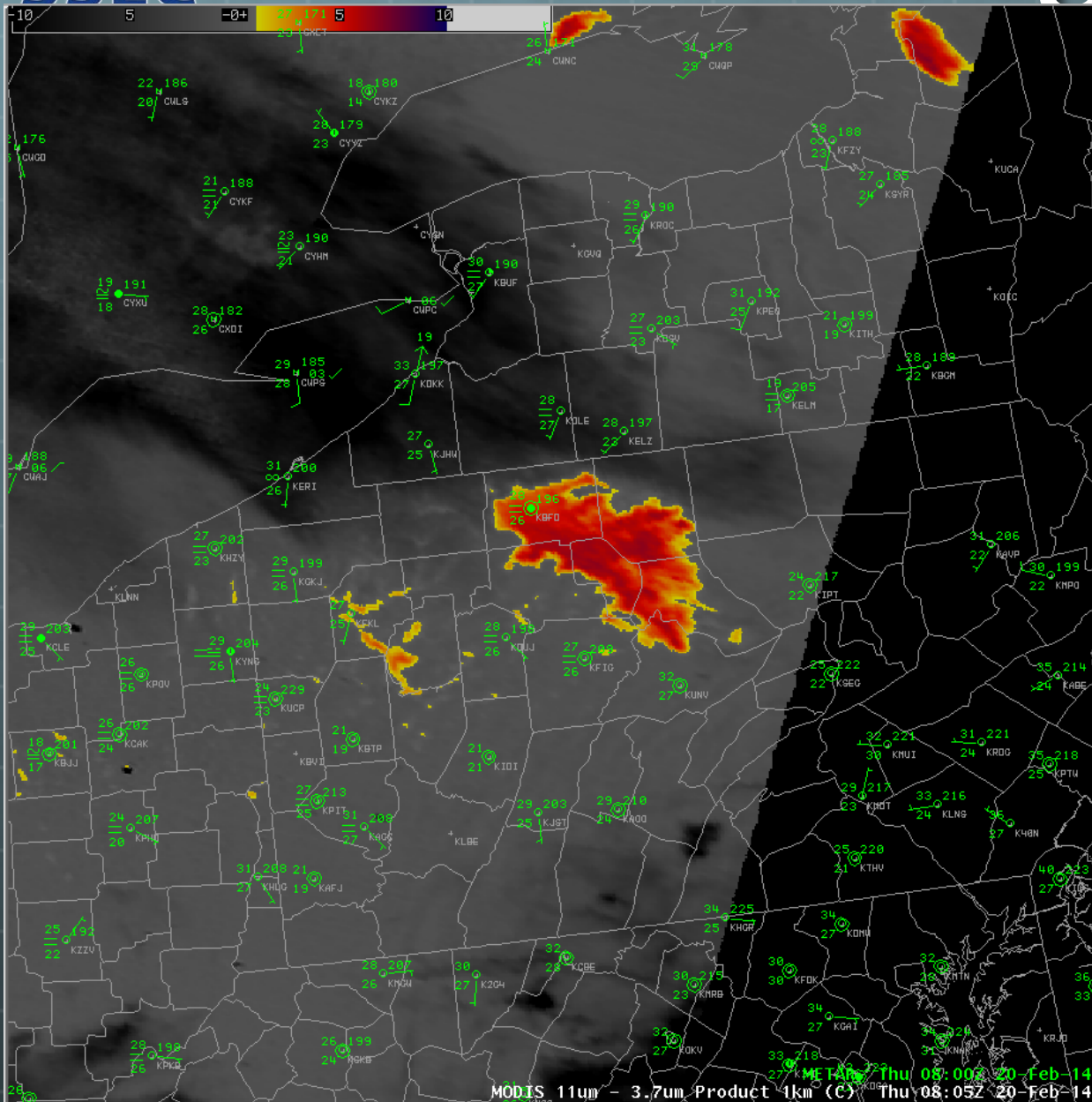
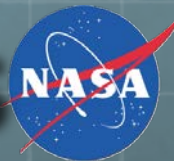
AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE
CHARLESTON SC
632 PM EST TUE NOV 12 2013

MARINE...
TONIGHT...CONDITIONS ARE SET FOR A DANGEROUS AND WIDESPREAD GALE EVENT. WINDS WILL INCREASE QUICKLY THIS EVENING AS THE ARCTIC FRONT PUSHES OFFSHORE AND STRONG COLD AIR ADVECTION ENSUES. SOLID GALES APPEAR LIKELY FOR ALL MARINE LEGS WITH WINDS TOPPING 30-35KT WITH GUSTS 40-45 KT NEARSHORE WATERS AND 35-40 KT WITH GUSTS TO 45 KT OVER THE GEORGIA OFFSHORE LEG. ALREADY SEEING WINDS GUSTING OVER 40 KT OFF THE NORTH CAROLINA OUTER BANKS. GALE WARNINGS ARE IN PLACE FOR ALL WATERS AND WILL BE MAINTAINED. **THERE IS CONCERN THAT FREQUENT GUSTS TO STORM FORCE COULD OCCUR ALONG THE EASTERN PORTIONS OF THE GEORGIA OFFSHORE WATERS WHERE 1KM MODIS SEA SURFACE TEMPERATURE DATA SHOWED THE WESTERN WALL STREAM IS LURKING.**



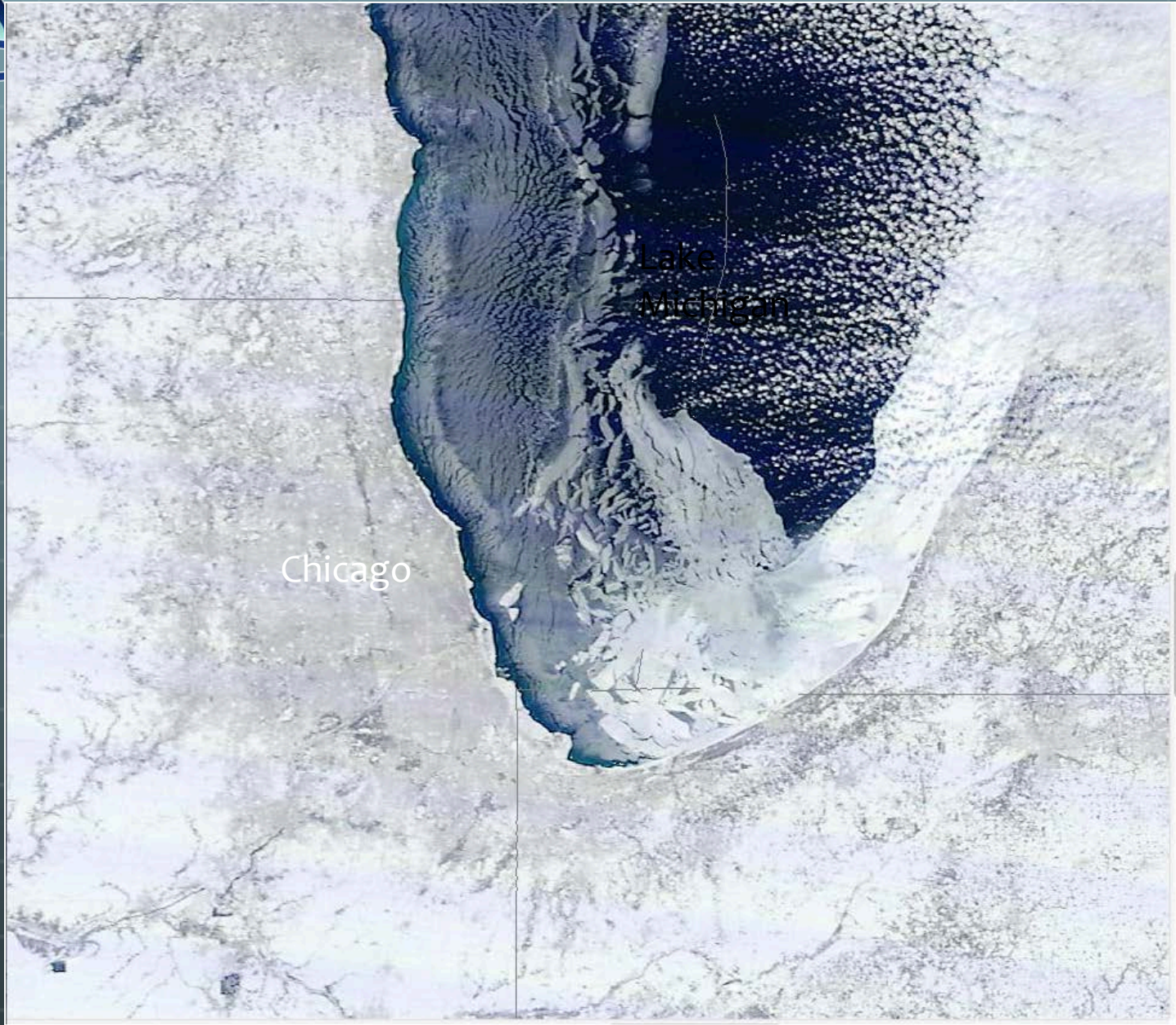


Location of Fog/Status

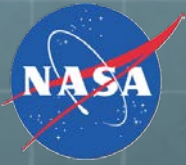


AREA FORECAST DISCUSSION
 NATIONAL WEATHER SERVICE STATE
 COLLEGE PA
 436 AM EST THU FEB 20 2014

**NEAR TERM /UNTIL 6 PM THIS EVENING/...
 EARLY AM MODIS 11-3.7UM IMAGERY
 SHOWING EXTENSIVE VALLEY FOG AND
 STRATUS ACROSS NORTHWEST PA...THE
 RESULT OF CLEAR SKIES AND CALM WIND
 UNDER HIGH PRES SYSTEM. LAMP AND RAP
 DATA BOTH INDICATE AREAS OF FOG WILL
 LIFT BTWN 12Z-14Z. FOCUS WILL THEN BE ON
 BAND OF SHRA LIFTING NORTHEAST FROM
 THE OHIO VALLEY ALONG APPROACHING
 WARM FRONT. REGIONAL RADAR MOSAIC
 ALREADY SHOWING THIS DEVELOPING BAND
 OF RAIN ACROSS ILLINOIS/INDIANA...WHERE
 NOSE OF LL JET INTERSECTS RETREATING 8H
 BAROCLINIC ZONE. ALL NEAR TERM MDL
 DATA TIMES THIS FEATURE THRU CENTRAL
 PA BTWN 17Z-23Z. ENSEMBLE MFLUX VALUES
 AND QPF PROBS SUPPORT NEAR 100 PCT
 CHC OF RAIN ACROSS THE NWMTNS...WITH
 PROGRESSIVELY LOWER CHC OF SHOWERS
 FURTHER SE.**



MODIS Today website: Terra overpass 7 February 2014 18:09 UTC



AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE CHICAGO/ROMEIOVILLE IL
240 AM CST SAT FEB 8 2014

.DISCUSSION...
856 PM CST

FOR OUR ILLINOIS/INDIANA NEARSHORE WATERS...BEAUTIFUL MODIS POLAR ORBITER SATELLITE IMAGERY FROM THE LAST TWO SUNNY DAYS INDICATES MUCH OF THE INDIANA WATERS ARE SOLIDLY ICE-COVERED...WHILE THICKER ICE HAD PUSHED EAST OFF THE ILLINOIS SHORE WITH THE STRONGER WEST WINDS OF THE LAST SEVERAL DAYS. HOWEVER...WEB CAMS SUGGEST THAT OUR SINGLE DIGIT TEMPS HAVE ALLOWED AT LEAST SOME ICE TO CONTINUE TO DEVELOP ALONG THE ILLINOIS SHORE AND THUS WILL OMIT WAVE HEIGHTS IN THE NEARSHORE FORECAST AS LIKELY LITTLE WAVE DEVELOPMENT GIVEN LARGE AMOUNT OF ICE.

RATZER



Isle Royale



Lake Superior

Keweenaw

Caribou Island

Manitou Island

41
26

Houghton County

Alger

Baraga

Marquette

Marquette

28

94

77

Iron

141

Schoolcraft

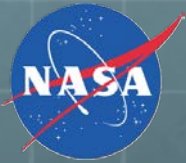
2

© 2013 Google

MODIS – Today Aqua Image in Google Earth, 22 January 2014, 19:10 UTC,

google earth

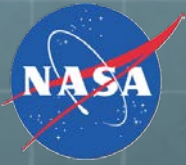
45



AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE MARQUETTE MI
411 PM EST SAT FEB 22 2014

.SHORT TERM...(THIS EVENING THROUGH SUNDAY)
ISSUED AT 410 PM EST SAT FEB 22 2014

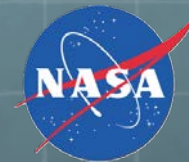
TODAY/S MODIS IMAGE SHOWS SOME OPEN WATER THAT HAS DEVELOPED OFF THE ARROWHEAD OF MINNESOTA AND ALSO TO THE EAST OF THE KEWEENAW. THEREFORE...WITH THE WESTERLY 925MB WINDS EXPECTED TONIGHT...HAVE FOCUSED CLOUD COVER AND SLIGHT TO LOWCHANCE POPS IN THE AREAS DOWNWIND OF THOSE PATCHES OF OPEN WATER. THIS MAINLY AFFECTS THE KEWEENAW PENINSULA. WITH WINDS SHIFTING A LITTLE MORE TO THE NORTHWEST ON SUNDAY AFTERNOON...HAVE SLOWLY TRANSITIONED POPS TOWARDS THAT DIRECTION. DIDN/T PUT MUCH FOR SNOWFALL AMOUNTS (ONLY AROUND AN INCH OR SO) INTO THE FORECAST DUE TO THE STRENGTH OF THE WINDS LIKELY LIMITING FETCH ACROSS THE OPEN WATER.



AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE GRAND RAPIDS MI
1156 AM EST MON FEB 24 2014

ON A SIDE NOTE IT WILL BE INTERESTING TO SEE THE MODIS SAT PIC FROM TODAY AS THERE APPEARS TO BE SOME THIN ICE AGAIN IN PLACE ACROSS THE FAR SOUTH PART OF THE LAKE AND UP THE WESTERN SHORE TOWARDS MILWAUKEE. THIS WILL HAVE SOME AFFECT ON FETCH LENGTH IN A SOUTHWEST FLOW. OBVIOUSLY THE LAKE IS MUCH MORE OPEN THAN IT WAS A WEEK OR SO AGO. THE MODIS PASSES OVER LAKE MICHIGAN AT 1710Z TODAY OR IN ABOUT 15 MINS.

Support National Weather Service Forecasters



Involved Weather Forecast Offices

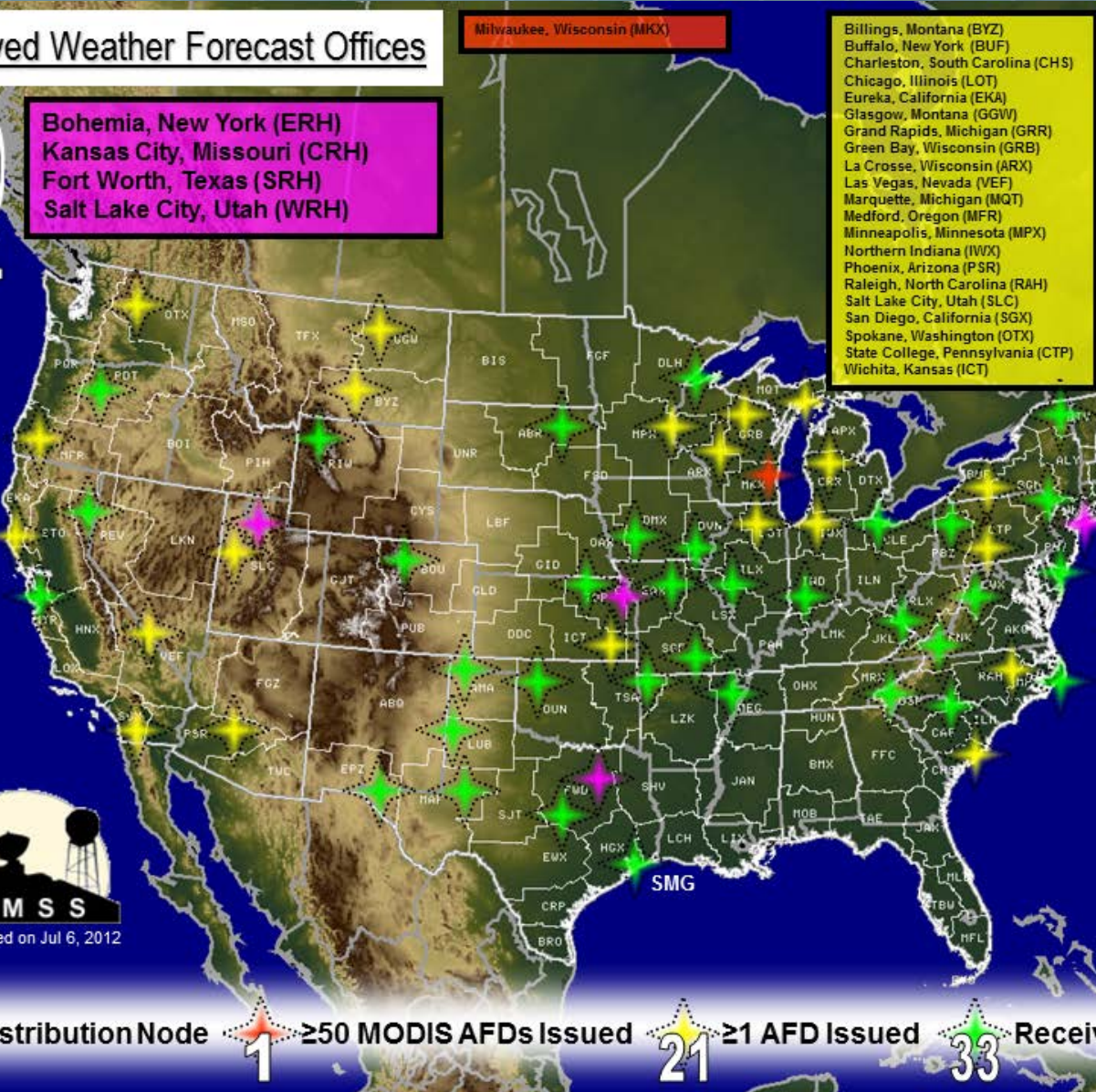
59
TOTAL

Bohemia, New York (ERH)
Kansas City, Missouri (CRH)
Fort Worth, Texas (SRH)
Salt Lake City, Utah (WRH)

Milwaukee, Wisconsin (MKX)

Billings, Montana (BYZ)
Buffalo, New York (BUF)
Charleston, South Carolina (CHS)
Chicago, Illinois (LOT)
Eureka, California (EKA)
Glasgow, Montana (GGW)
Grand Rapids, Michigan (GRR)
Green Bay, Wisconsin (GRB)
La Crosse, Wisconsin (ARX)
Las Vegas, Nevada (VEF)
Marquette, Michigan (MQT)
Medford, Oregon (MFR)
Minneapolis, Minnesota (MPX)
Northern Indiana (IVX)
Phoenix, Arizona (PSR)
Raleigh, North Carolina (RAH)
Salt Lake City, Utah (SLC)
San Diego, California (SGX)
Spokane, Washington (OTX)
State College, Pennsylvania (CTP)
Wichita, Kansas (ICT)

Aberdeen, South Dakota (ABR)
Amarillo, Texas (AMA)
Binghamton, New York (BGM)
Blacksburg, Virginia (RNK)
Boulder, Colorado (BOU)
Burlington, Vermont (BTV)
Cleveland, Ohio (CLE)
Columbia, South Carolina (CAE)
Dallas/Fort Worth, Texas (FWD)
Davenport, Iowa (DVN)
Des Moines, Iowa (DMX)
Duluth, Minnesota (DLH)
El Paso, Texas (EPZ)
Greenville, South Carolina (GSP)
Indianapolis, Indiana (IND)
Kansas City, Missouri (EAX)
Lincoln, Illinois (ILX)
Lubbock, Texas (LUB)
Memphis, Tennessee (MEG)
Midland, Texas (MAF)
Monterey, California (MTR)
Newport, North Carolina (MHX)
Norman, Oklahoma (OUN)
Pendleton, Oregon (PDT)
Philadelphia, Pennsylvania (PHI)
Pittsburgh, Pennsylvania (PBZ)
Reno, Nevada (REV)
Riverton, Wyoming (RIV)
Springfield, Missouri (SGF)
Sterling, Virginia (LWX)
Topeka, Kansas (TOP)
Tulsa, Oklahoma (TSA)
Spaceflight Meteorology Group

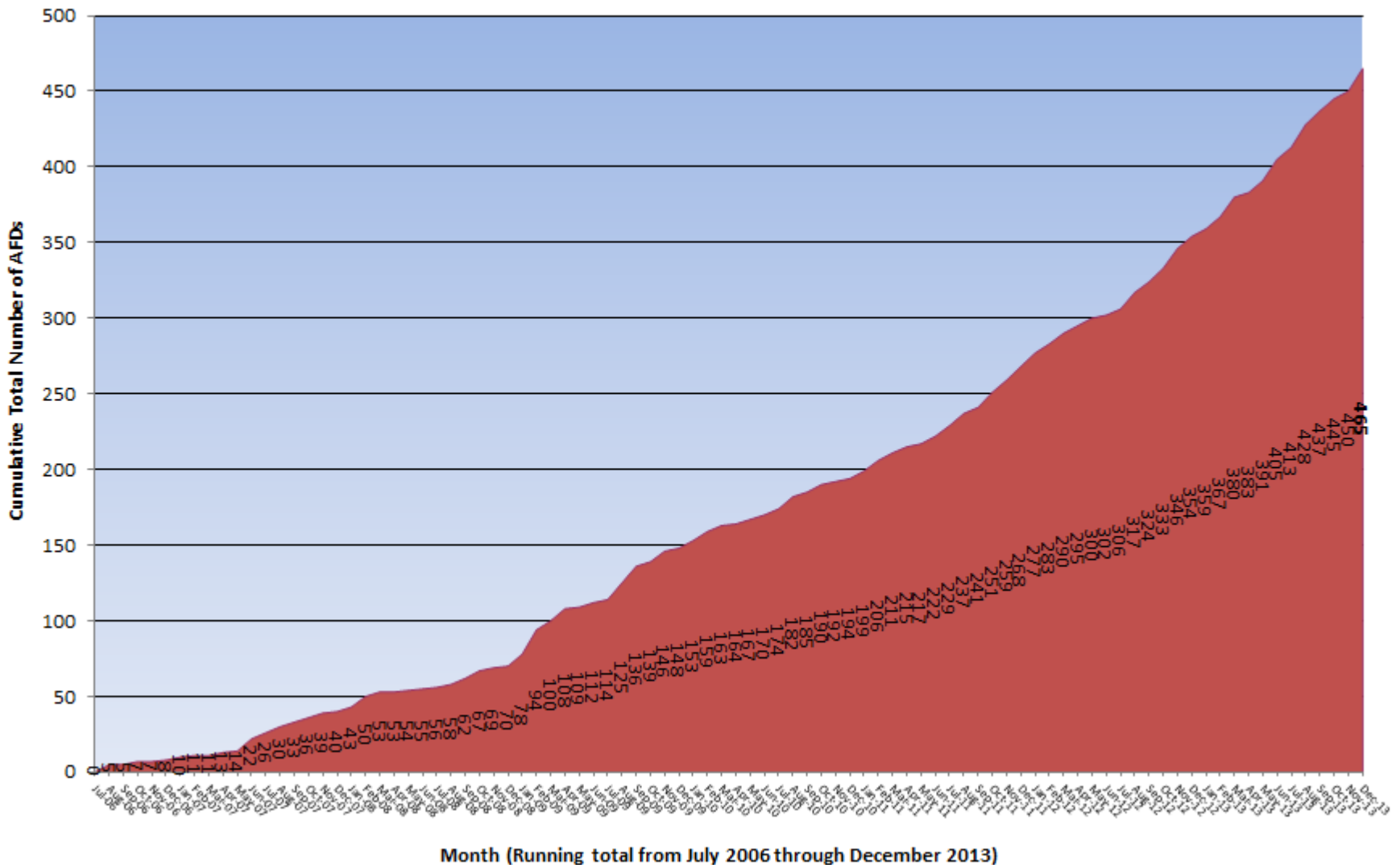


Last updated on Jul 6, 2012



★ 4 Distribution Node
 ★ 1 ≥50 MODIS AFDs Issued
 ★ 21 ≥1 AFD Issued
 ★ 33 Receive MODIS Imagery

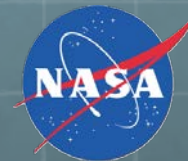
MODIS in Area Forecast Discussions at NWS Forecast Offices through 12/31/2013





Summarizing the First Ten Years of NASA's Aqua Mission

Claire L. Parkinson



Abstract—The Aqua spacecraft was launched on May 4, 2002 with six Earth-observing instruments on board to collect data on a wide variety of Earth system variables. After ten years of on-orbit operations, Aqua has provided data that have contributed to over 2 000 scientific publications, with new results on the Earth's energy budget, trace gases and particulate matter in the atmosphere, vegetation on land and in the oceans, and many aspects of the water cycle, including evaporation and transpiration, water vapor, cloud cover, precipitation, the oceans, sea ice and land ice, snow cover, and soil moisture. Additionally, Aqua data have been used to assist in practical applications ranging from weather forecasting to the deployment of firefighters and the routing of aircraft. Although the six-year design life of the satellite has been successfully completed and exceeded, enough fuel remains on Aqua for approximately another ten years of operations.

Index Terms—Satellite Earth observations, Aqua, global energy budget, water cycle.

I. INTRODUCTION

NASA's Earth-orbiting Aqua spacecraft (Fig. 1) was launched at 2:55 a.m. on May 4, 2002, from Vandenberg Air Force Base in California. It soon was maneuvered to its desired near-polar, sun-synchronous orbit at an altitude of 705 km, crossing the equator going north at 1:30 in the afternoon and south at 1:30 in the morning, local time [32]. At 705 km, Aqua orbits the Earth every 98.8 minutes. Aqua has now exceeded ten years of on-orbit operations, with a wealth of scientific output resulting at least in part from the use of Aqua data.

Aqua was specifically named for the significant amount of information that it collects regarding water in the Earth system, 'Aqua' being Latin for 'water'. Aqua measurements include water in the atmosphere, on land, and in the oceans, and water in each of its three states: gaseous, liquid, and solid. The Aqua measurements, however, include other aspects of the Earth system as well, and this paper highlights a selection of the key results obtained from the extensive Aqua datasets, doing so in sections on: the global energy budget; water vapor, clouds, and precipitation; other atmospheric trace gases; particulate matter in the atmosphere; ice and snow; vegetation and other life forms; and temperature. The science results are followed

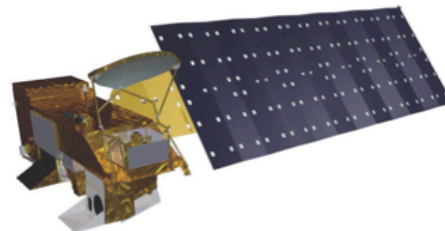


Fig. 1. Artist's rendition of the Aqua spacecraft in orbit. (Rendering by Marit Jentoft-Nilsen, based on an earlier version by TRW/Northrop Grumman.)

by a section on practical applications. First, though, comes a section describing the complement of Aqua's Earth-observing instruments.

II. AQUA'S EARTH-OBSERVING INSTRUMENTS

Aqua has on board six Earth-observing instruments: the Atmospheric Infrared Sounder (AIRS), the Advanced Microwave Sounding Unit (AMSU), the Humidity Sounder for Brazil (HSB), the Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E), the Moderate Resolution Imaging Spectroradiometer (MODIS), and the Clouds and Earth's Radiant Energy System (CERES). HSB was provided by the Brazilian Institute for Space Research, AMSR-E was provided by the Japan Aerospace Exploration Agency (JAXA), and the remaining instruments and the spacecraft were provided by the United States National Aeronautics and Space Administration (NASA).

AIRS, AMSU, and HSB together constitute a sophisticated sounding system centered on AIRS. AIRS makes measurements at 2378 infrared and 4 visible/near-infrared channels and is unique to the Aqua platform. The 2378 infrared channels on AIRS far exceed the number of channels on previous satellite sounders and enable the determination of atmospheric temperature, moisture, and key trace gases in the atmosphere as well as cloud and surface parameters.

In contrast to the uniqueness of AIRS, both AMSU and HSB are near-identical copies of instruments flown also on satellites of the National Oceanic and Atmospheric Administration (NOAA). AMSU is a 15-channel microwave sounder used in the Aqua sounder system to facilitate cloud clearing of the AIRS observations and to provide, for instance, cloud liquid water and vertical temperature profiles in the presence of clouds. HSB is a four-channel microwave sounder that

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IV. PRACTICAL APPLICATIONS

Although the Aqua mission was developed largely for its scientific value, the Aqua data have proven to be of immense practical value as well. This section discusses several of the practical applications of the Aqua data, beginning with one that affects hundreds of millions of people, namely, weather forecasting.

A. Weather Forecasting

When the AIRS instrument was conceived and developed, one of the primary goals for it was to facilitate improved weather forecasts. As anticipated well before launch, the high accuracies of the AIRS/AMSU temperature and water vapor products (Sections III-B and III-G) have led to measurable improvements in forecast skill when these data are incorporated in weather forecast models [4]. As a result, NOAA and other weather forecasting agencies in North America and in Europe, Asia, Africa, Australia, and South America routinely use at least some of the AIRS data in their forecast models. Some of these agencies, however, use only clear-sky radiances; studies have shown that some forecasts could be improved even further with assimilation of more of the AIRS data [36].

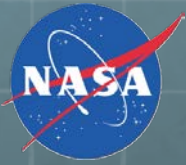
Although less anticipated, MODIS and AMSR-E data have also proven valuable for forecasts. Specifically, incorporation of MODIS-derived polar winds in weather forecast models has resulted in improved forecasts for the polar regions and beyond [24], [37], and AMSR-E sea surface temperature, water vapor, and precipitation data have all been used by hurricane prediction centers. The Japan Meteorological Agency (JMA) has found that assimilation of AMSR-E data has improved the skill of the JMA forecasts of hurricane tracks. Further, the Joint Center for Satellite Data Assimilation has reported that assimilation of AMSR-E radiances over the oceans improves medium-range



Fig. 10. Aqua MODIS image of forest fires in Oregon, in the northwest United States, on August 12, 2002. Such images assist forest services in monitoring forest fires and determining the appropriate deployment of fire fighters.

forecasts in the Southern Hemisphere, although shows neutral impacts for the Northern Hemisphere [30].

The usage of Aqua data in weather forecasts is greatly facilitated by two important services. One is NOAA's National Environmental Satellite, Data, and Information Service (NESDIS), which distributes the AIRS radiance data in near real time. The other is a software package—the International MODIS/AIRS Processing Package (IMAPP)—made available by the University of Wisconsin's Cooperative Institute for Meteorological Satellite Studies (CIMSS). IMAPP converts direct broadcast data from Aqua and Terra into a suite of geophysical data products from the MODIS, AIRS, AMSU, and AMSR-E instruments. This IMAPP software is used not only by weather agencies to support weather forecasting but also for the fog detection and snow/ice/cloud discrimination provided by the MODIS products.



Conclusion

- **Direct broadcast MODIS products are useful to the NWS**
 - **High spatial and high spectral resolution data compliments high temporal GEO data**
 - **Direct Broadcast ensures timely delivery of product**
 - **UW now provides products to 59 forecast offices**
 - **The number of Area Forecast Discussions that mention MODIS as a decision making tool has reach > 450**
- **NASA's support of IMAPP made it possible**
- **Forecasters are starting to use S-NPP VIIRS now as well, supported by CSPP funded by NOAA**