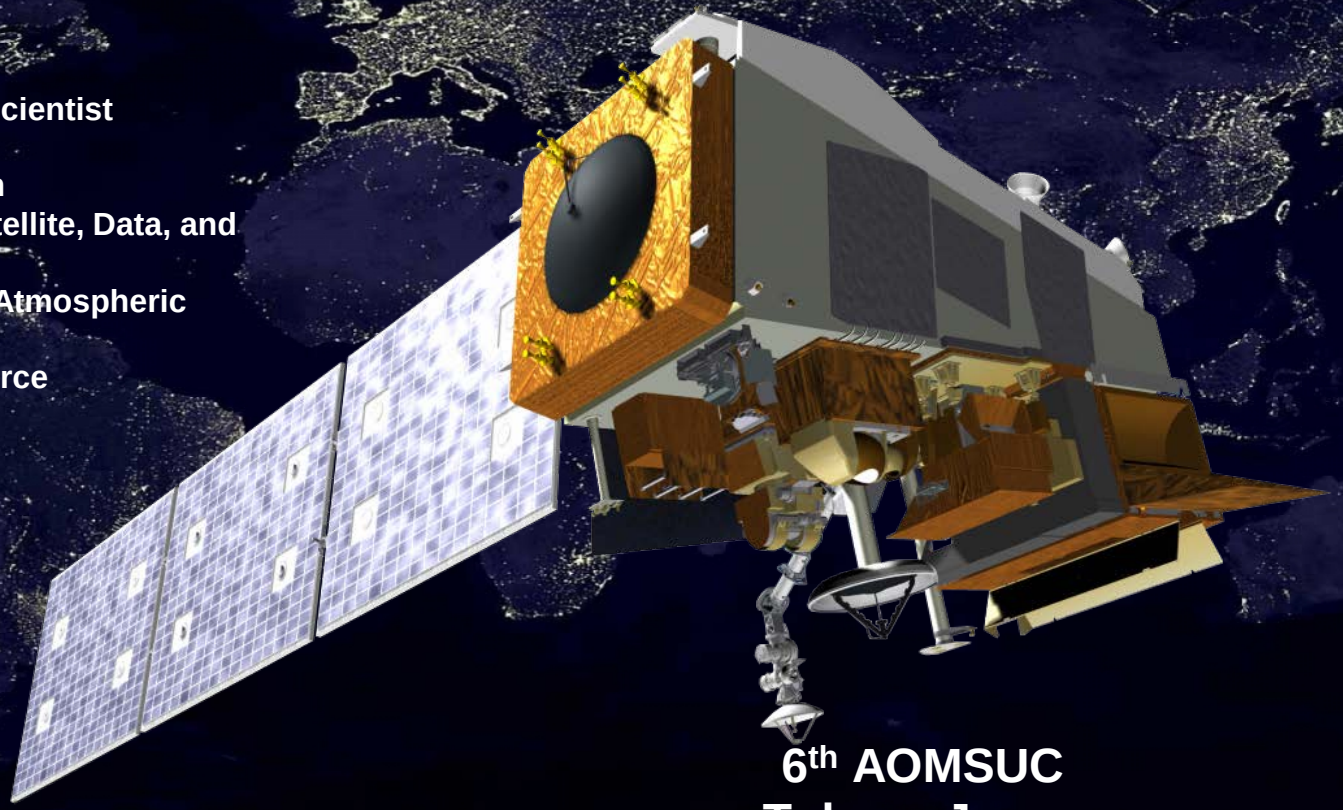
Joint Polar Satellite System (JPSS)

The Contribution of Operational and Research Applications from the Joint Polar Satellite System to Societal Benefits

Mitch Goldberg, Program Scientist

Joint Polar Satellite System
National Environmental Satellite, Data, and Information Service
U.S. National Oceanic and Atmospheric Administration
U.S. Department of Commerce

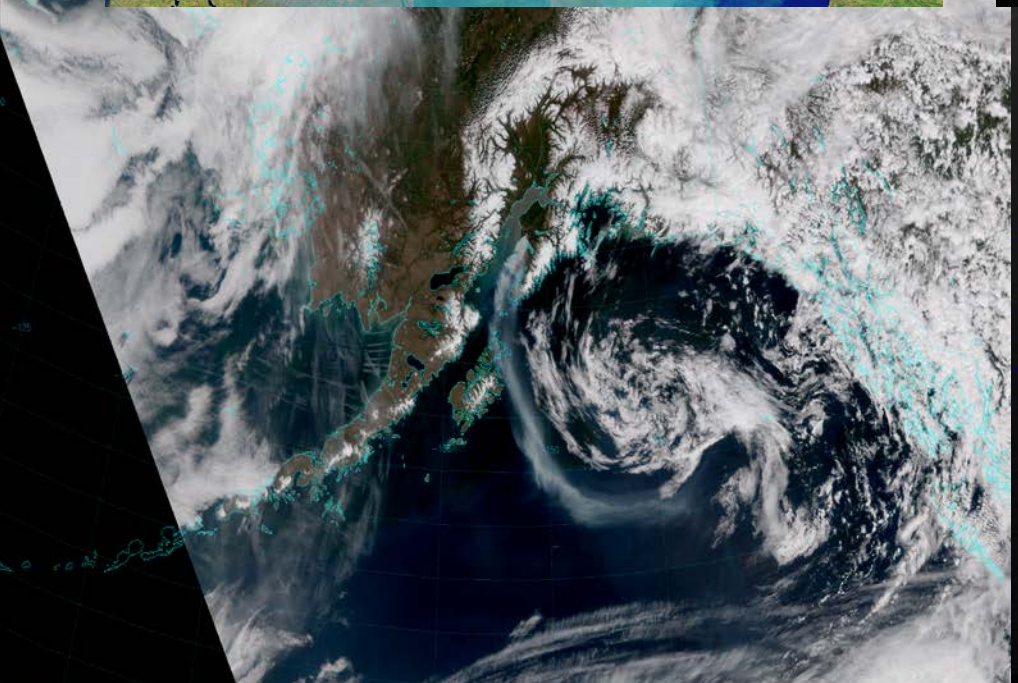


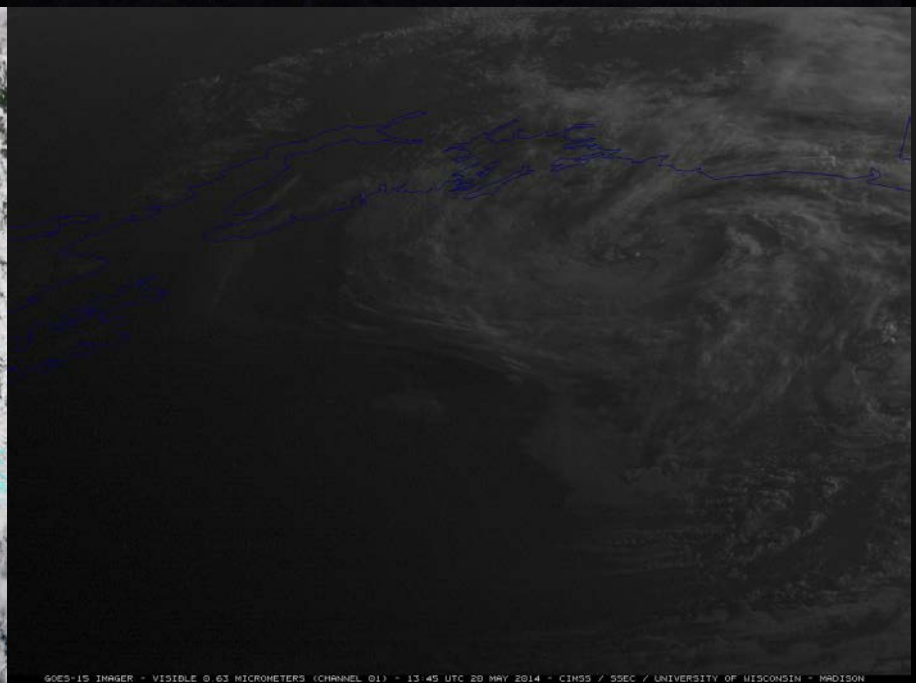
6th AOMSUC
Tokyo , Japan

www.jpss.noaa.gov

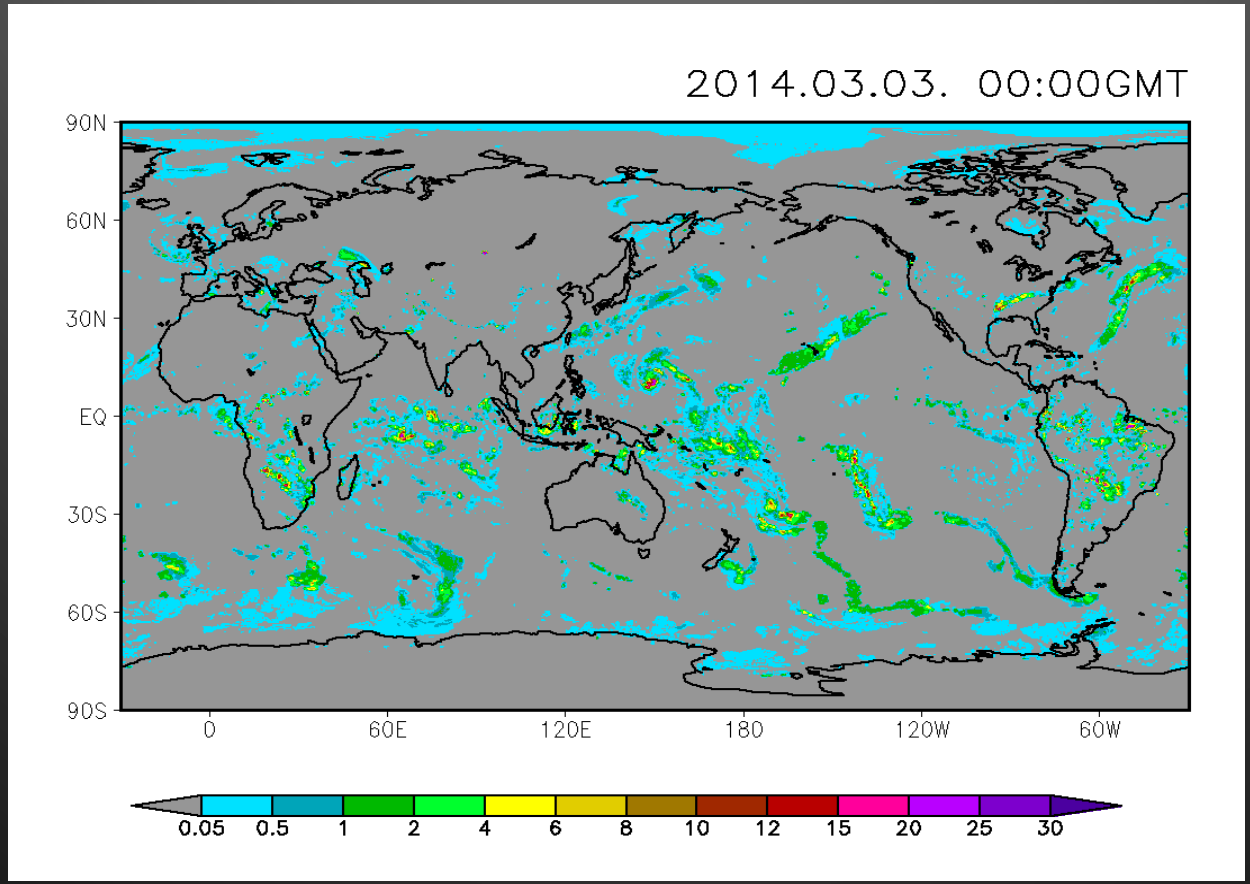
Integrating various satellite data and and other info are critical for decisons

Funny River Fire – Alaska - May 20, 2014





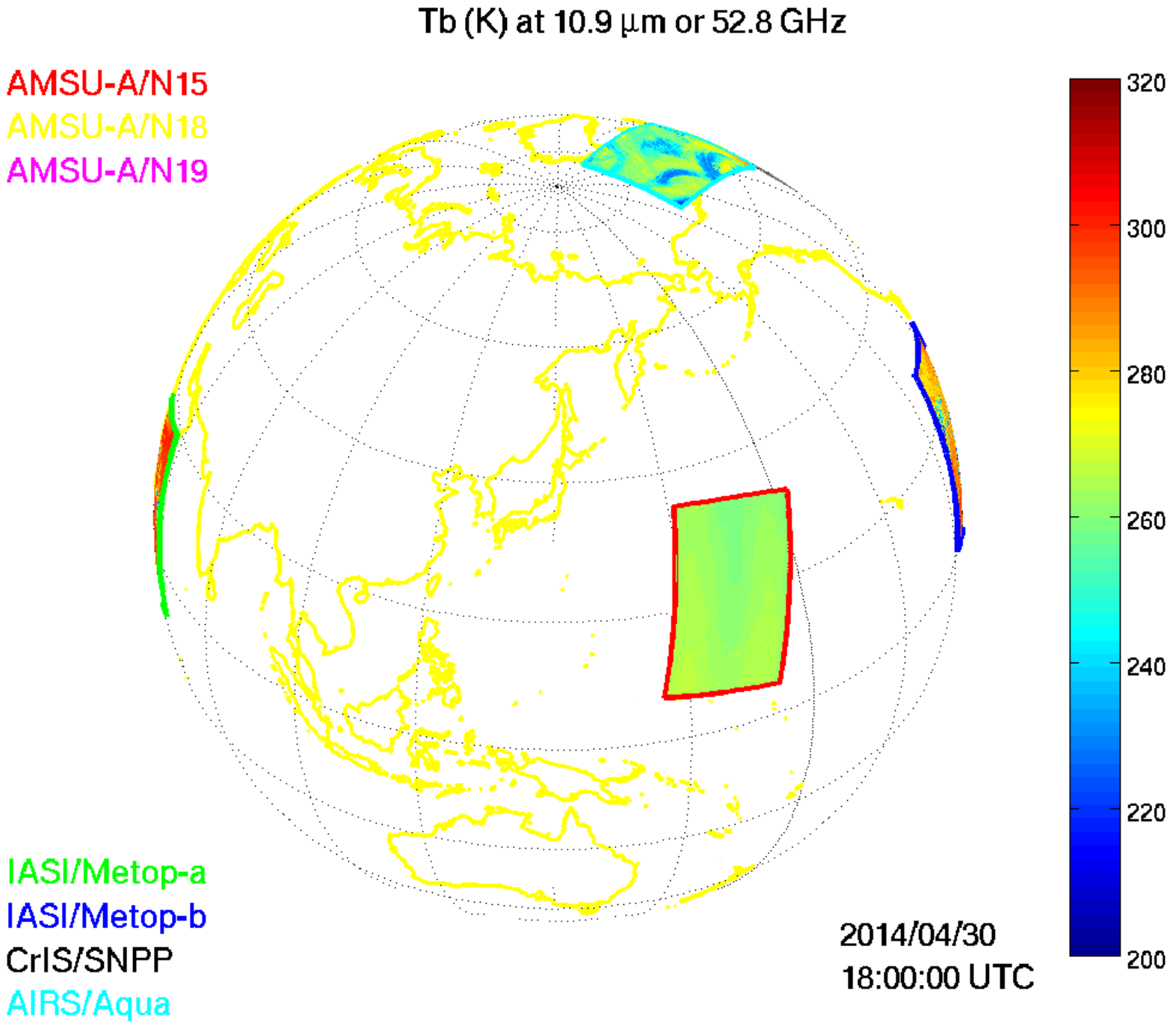
Microwave precipitation transport using cloud motion vectors from geostationary



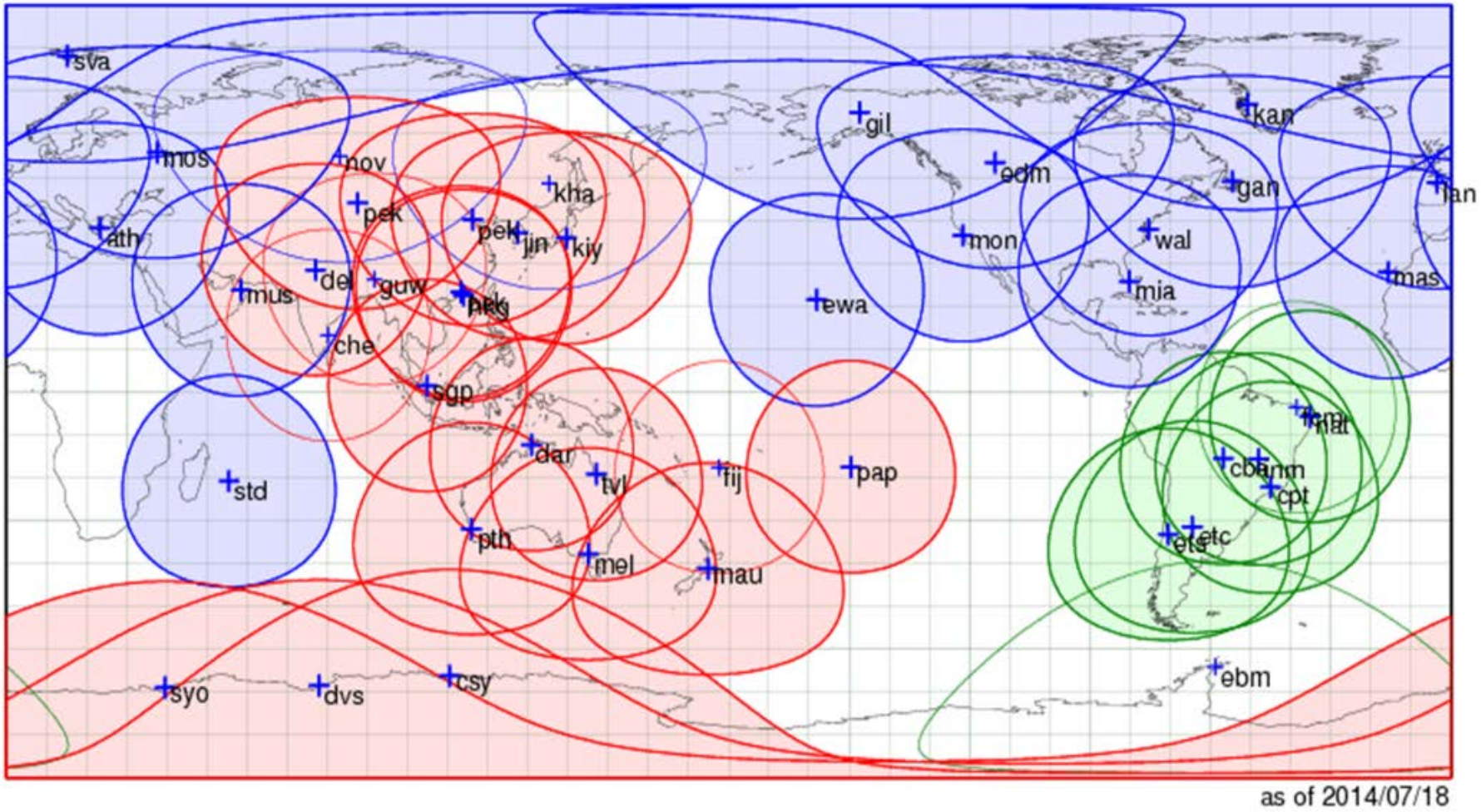
from NOAA Climate Prediction Center (Xie)

Polar orbiting satellites

- Benefits
  - Global coverage from single instruments which are generally well calibrated and stable.
  - Excellent spectral coverage from the UV to Visible to Near Infrared to Infrared to Microwave
  - Relatively high spatial resolution in the visible/infrared imagers
  - Generally good vertical resolving power from Infrared, Microwave and UV.
- Disadvantages:
  - Temporal and latency

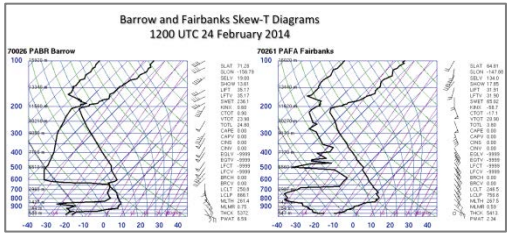

Tb (K) at 10.9 μm or 52.8 GHz
AMSU-A/N15
AMSU-A/N18
AMSU-A/N19
320
300
280
260
240
220
200
IASI/Metop-a
IASI/Metop-b
CrIS/SNPP
AIRS/Aqua
2014/04/30
18:00:00 UTC

Direct Readout Network

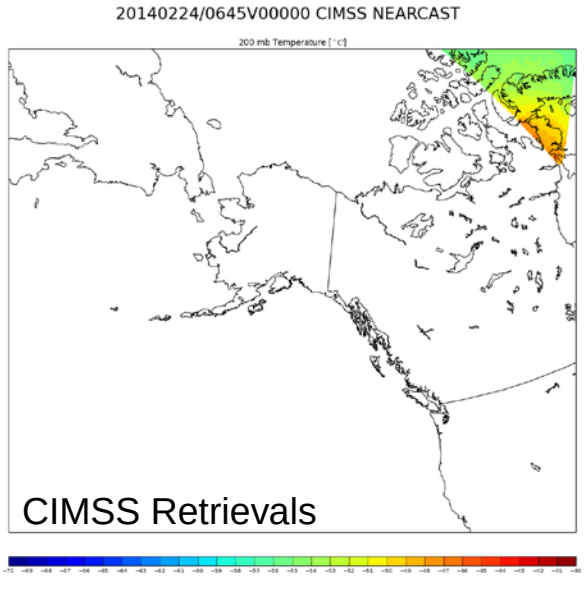


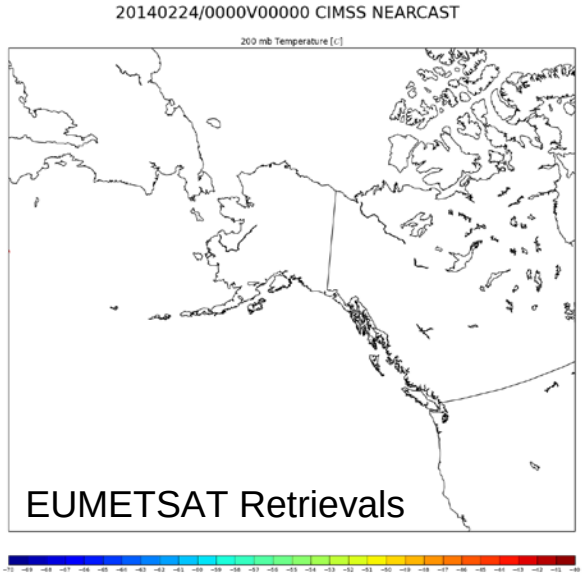
On Demand Weather Forecasting

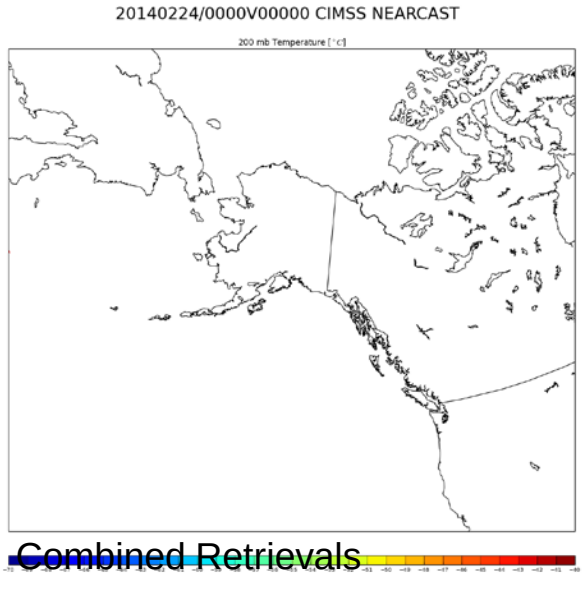
- UW NearCast system ingest LEO retrievals from multiple sources.
- This example is for Extreme Cold Air Aloft application to identify areas of flight risk due to jet fuel gelling.



200 hPa Temperature







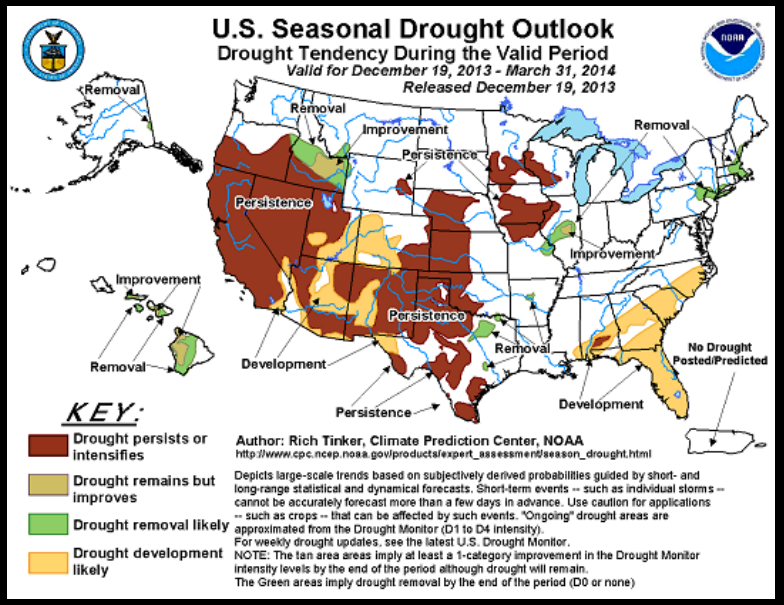
Societal Benefits

- Society benefits from information which enables decisions to improve the quality of life and reduce the impact of extreme events

- Information must flow from government to local - from experts to ordinary citizens.

Information drives decisions

- A bad environmental decision can impact lives, property and segments of the economy for years.
- What if there were no weather warnings or forecasts, tsunami and flood alerts, fire and drought reports and predictions, ice monitoring or harmful algal bloom assessments?
- Better information is usually tied to better observations, modeling and computer resources.
- Decision support tools are essential and information must be easy to comprehend.



From Satellites to Agricultural Decisions

Satellite Products that Support Agricultural Decisions

- Vegetation health products
- Soil moisture, land surface temperature
- Land type
  - arid vs. semi arid
- Snow cover and snow water equivalent
  - water resources
- Precipitation
  - especially important for areas without radar
- Global assessments and historical perspective

Drought affects Global Food Security by reducing agricultural production below consumption. Since 2000, this occurred 8 years out of 13.

Examples of Decisions from Drought Assessments and Predictions

Farmers

- When and what to plant
- Plant density
- Irrigation timing and amount
- Pesticides and fertilization
- Expected yield and harvesting decisions
- Impacts on livestock

Buyers

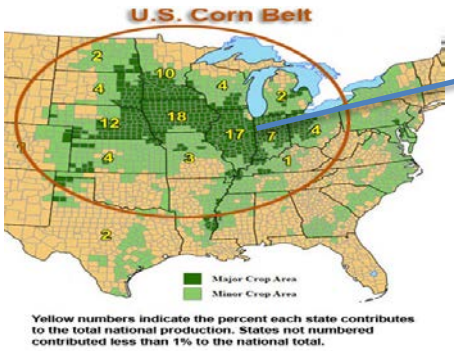
- Anticipate productivity
- Global, Regional vs. local purchasing

Humanitarians

- Anticipated drought regions
- Impact on communities
- Planning relief efforts

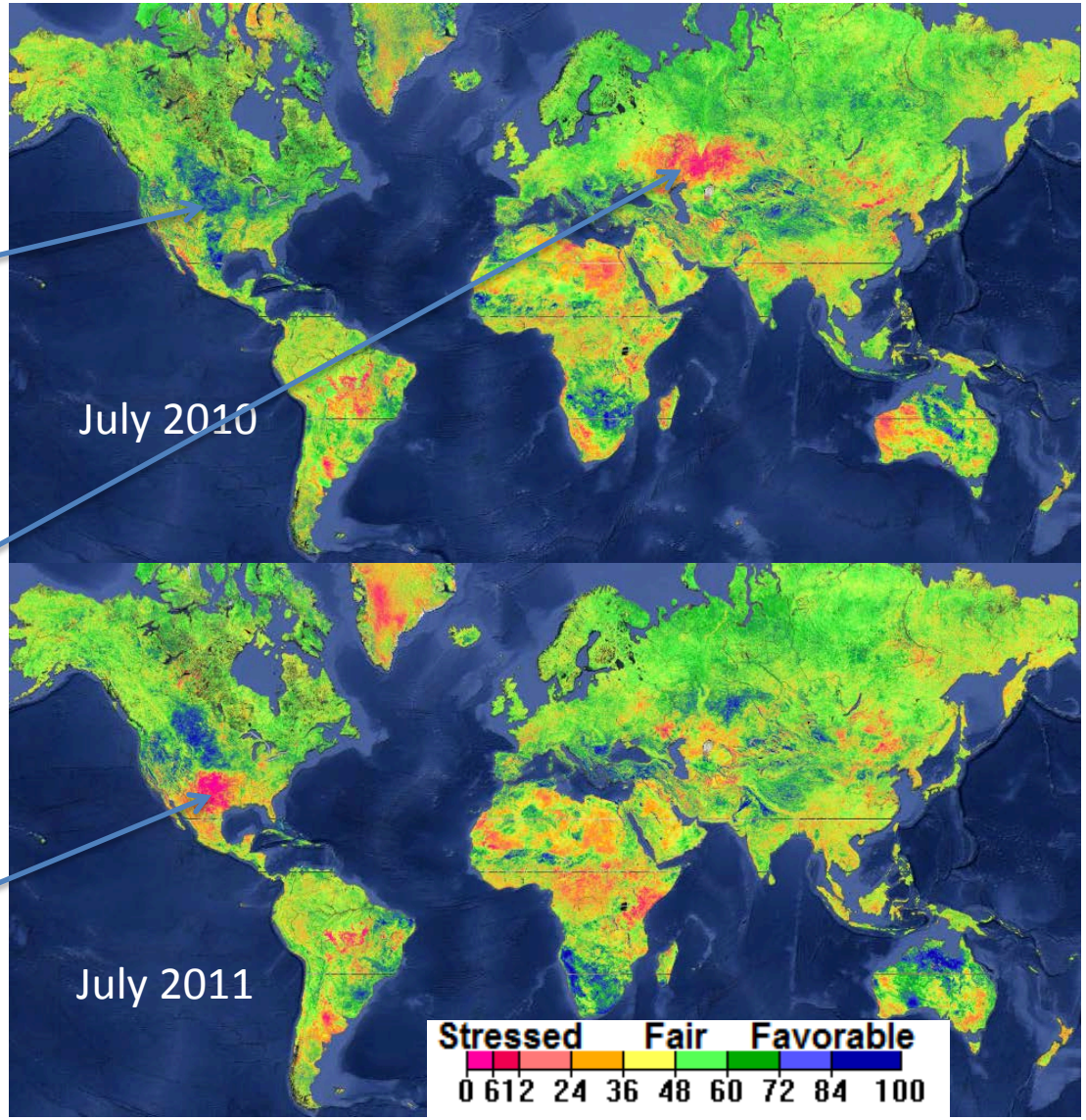
Vegetation Health from AVHRR

IMPACTS:
U.S. corn production in 2010
Hit a record high.



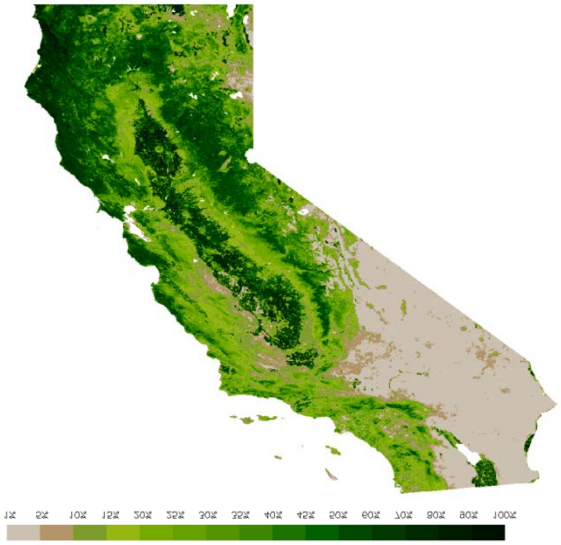
Wheat was down 27% in **Russia**, 32% in **Kazakhstan**, and 19% in the **Ukraine**.

Texas cotton production fell by more than half, from 7.84 million bales in 2010 to 3.5 million in 2011.

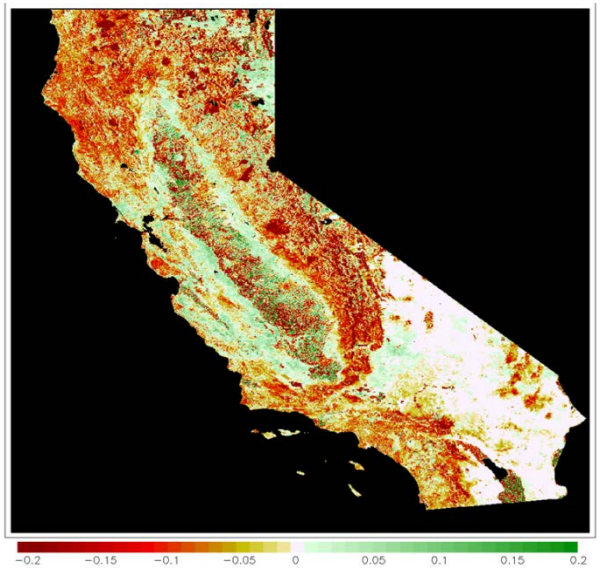


VIIRS 500 meter resolution green vegetation fraction – monitoring the California drought (2015 – 2012)

True Color – 7/24/15



Weekly GVF 7/26/15



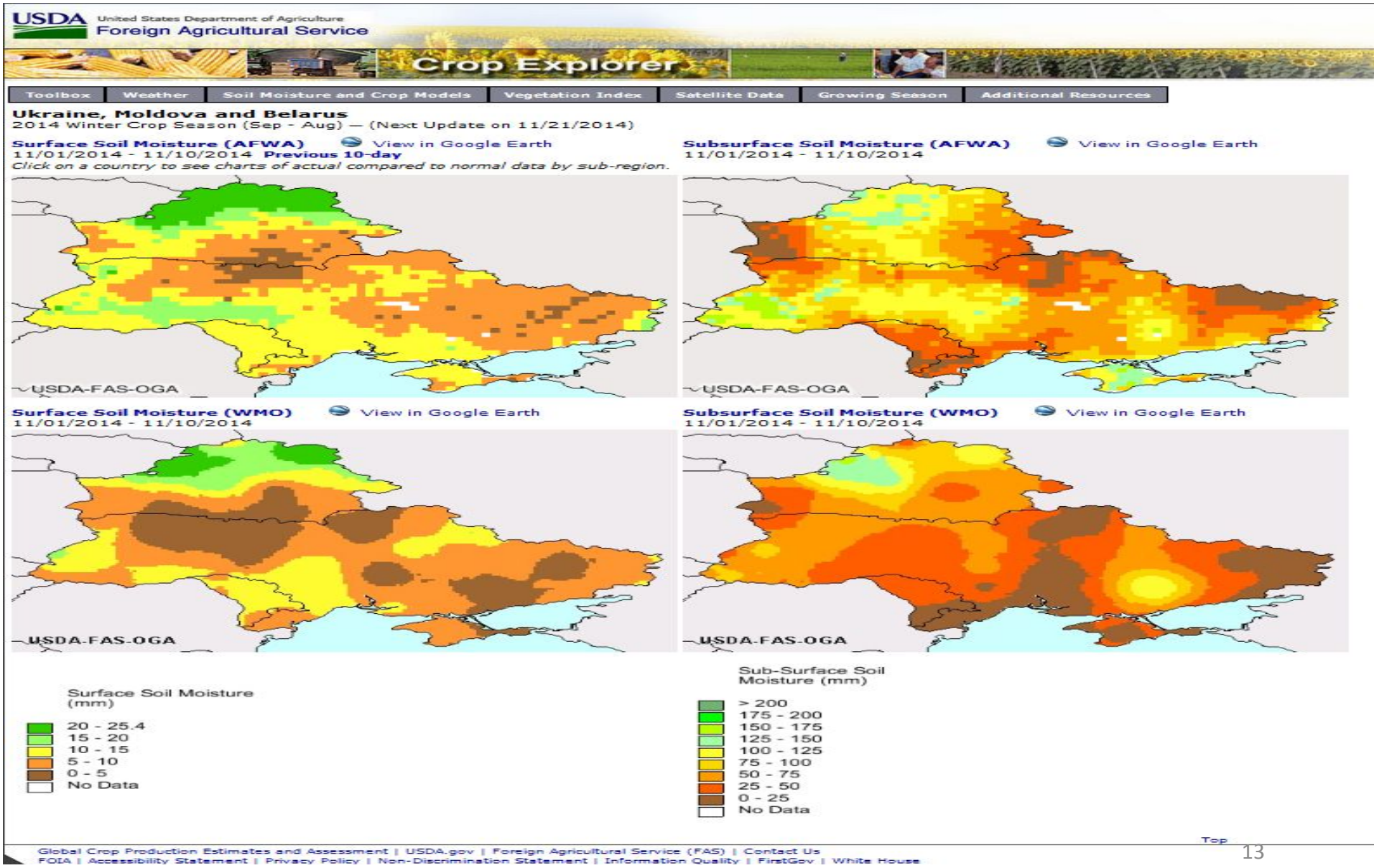
2015-07-26 minus 2012-08-15

NOAA Service Report on the 2014 California Drought included the need to use remote sensing for assessments of temporal changes in the Central Valley configuration, channel shapes, vegetation cover….

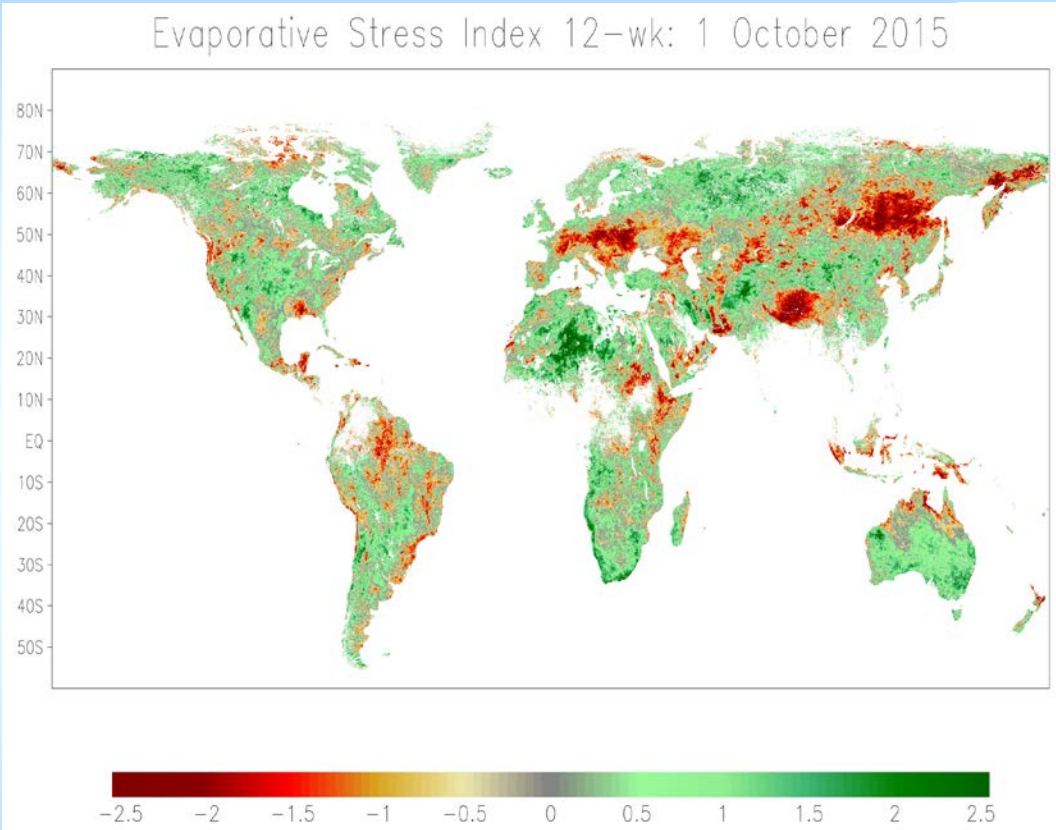
VIIRS Green Vegetation Fraction (GVF) can easily monitor changes in vegetation density. Note higher GVF in irrigated areas in 2015.

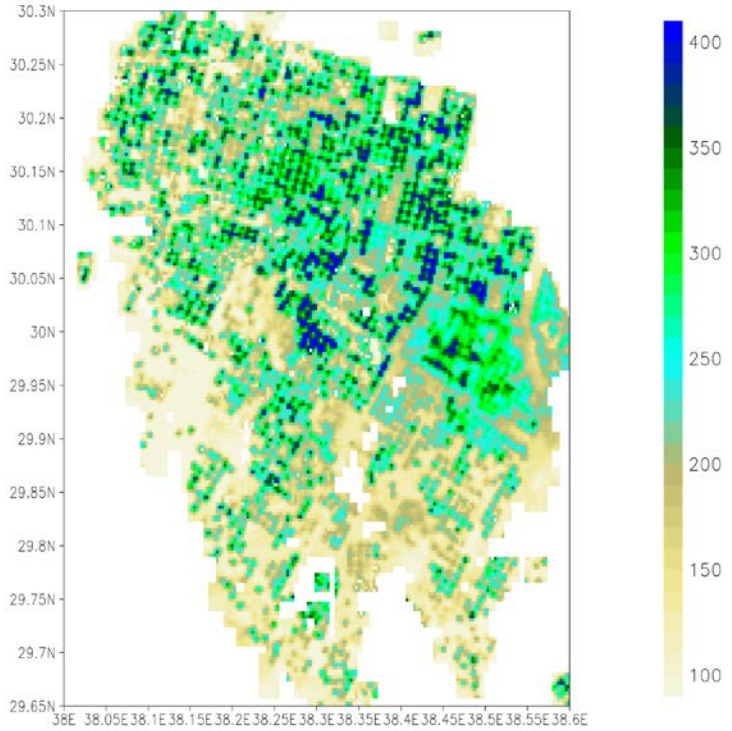
Credit: Marco Vargas (STAR)

Example: AMSR2 Soil Moisture for Crop Forecasts



Application of VIIRS LST in drought monitoring with ESI:



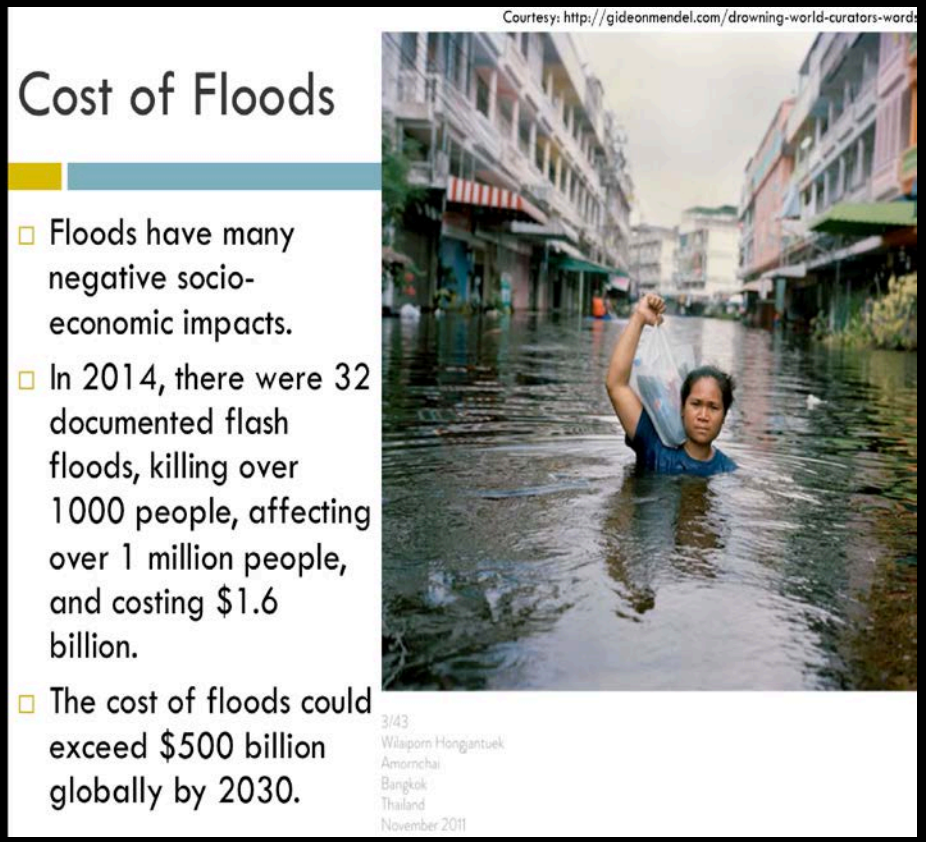


Evapotranspiration (ET) and Evaporative Stress Index (ESI) are computed from VIIRS land surface temperature (LST) using ALEXI model. Dry anomalies of ESI are good indicator of agricultural drought (Hain et al, 2015)

Applications

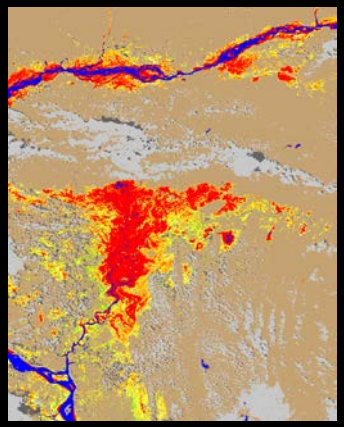
- Applications utilize science and technology to provide products and services.
  - Weather forecasting is the application of science and technology to predict the atmospheric state for a given place and time.

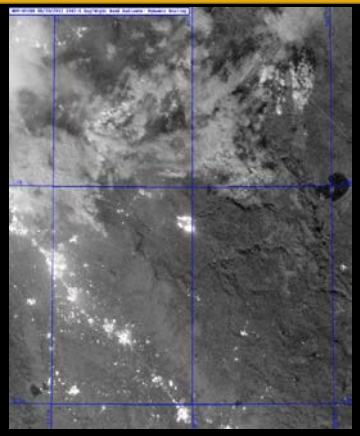
- Application pyramids building upon space and ground-based information and other relevant information including geography, food supply, population, transportation and housing are needed to improve decisions to protect life and property.

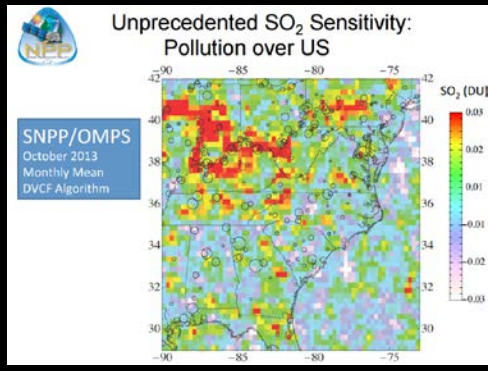


Credit: Jacola Roman (CIMSS)

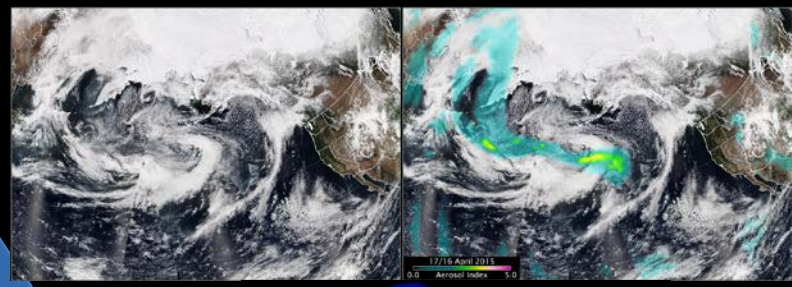
Application Pyramid

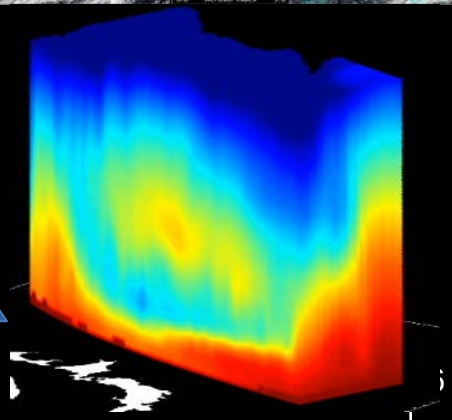


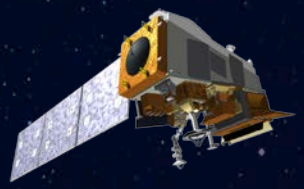




- Decisions
- Warnings
- Impact assessments
- Specialty forecasts - e.g. floods
- Weather forecasts 0- 7 days
- Baseline of robust observations







JPSS User Readiness Program Focused on Application Areas

- Weather Forecasting (Improving Global, Regional forecasts)
  - Tropical Cyclones
  - Severe Weather (Nowcasting)
- Ocean/Coastal (Coral Bleaching, Harmful Algal Bloom alerts)
- Land (Droughts, Agriculture)
- Hazards (Smoke, Fire, Volcanic Ash, Air Quality)
- Hydrological (Precipitation, Floods, Soil Moisture, Snow/Ice, River Ice)
- Climate (integrated products, real-time anomaly products)
- Education and Training
- Infrastructure (Direct Readout and Software (CSPP), Airborne campaigns)

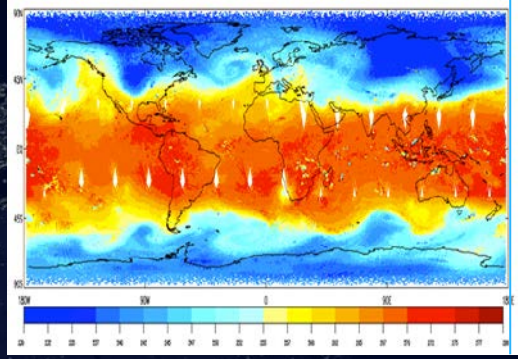
JPSS Proving Ground Partners :
NWS, NOS, NMFS, OAR, NESDIS, NOAA Cooperative Institutes, NASA, and NRL

JPSS Applications Advancements

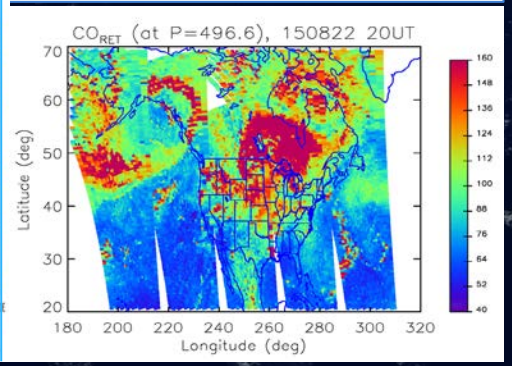
Sounding Products

- Demonstrations with operational forecasters
- Support storm watches and warnings
- CO product for tracking smoke emissions from forest fires

NUCAPS Temperature retrieval @ 500mb
(January 5th 2014 Polar Vortex Anomaly)

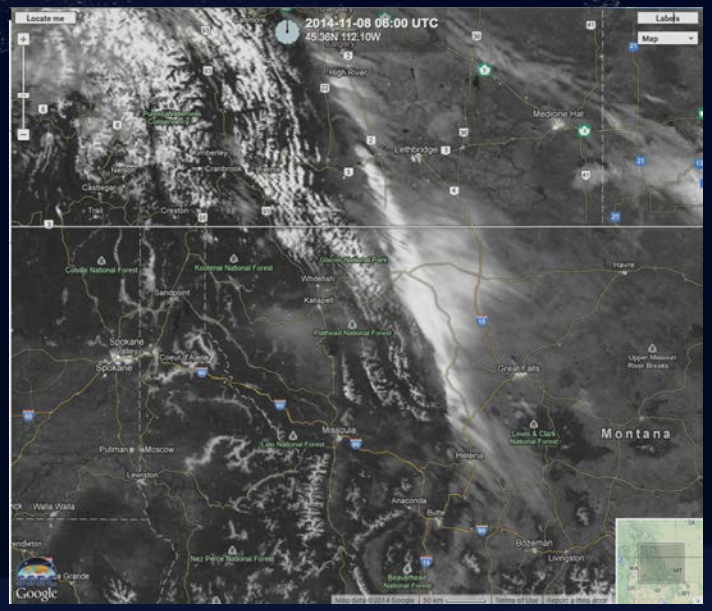


Carbon Monoxide @500mb
August 22, 2015



Day Night Band

- Sea Ice
- Enhanced storm tracking at night
- Ground Fog
- Active fires and smoke



Area Forecast Discussion
National Weather Service
Missoula MT
334 AM MST SAT NOV 8 2014

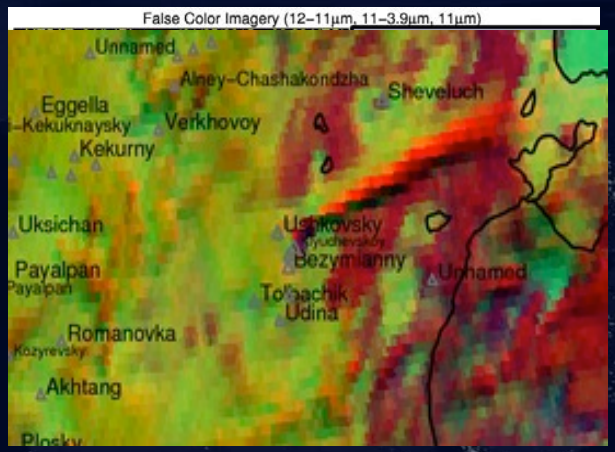
...

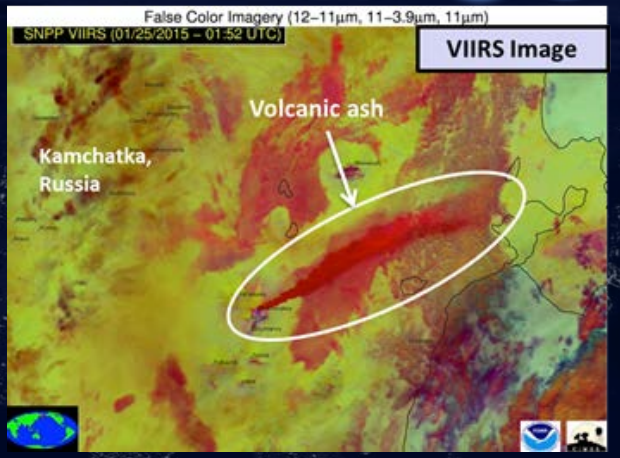
.AVIATION...Moderate high pressure situated over the area will bring a chance for fog to develop at KGPI, KMSO and KSMN. ***The VIIRS night-time visible satellite image at 08/1010z revealed some valley fog across Clearwater County, Idaho and also north across the Idaho Panhandle.*** Any fog that develops near the aforementioned terminals will dissipate by noon. Expect light and variable surface winds at all the terminals.

JPSS Applications Advancements

Volcanic Ash

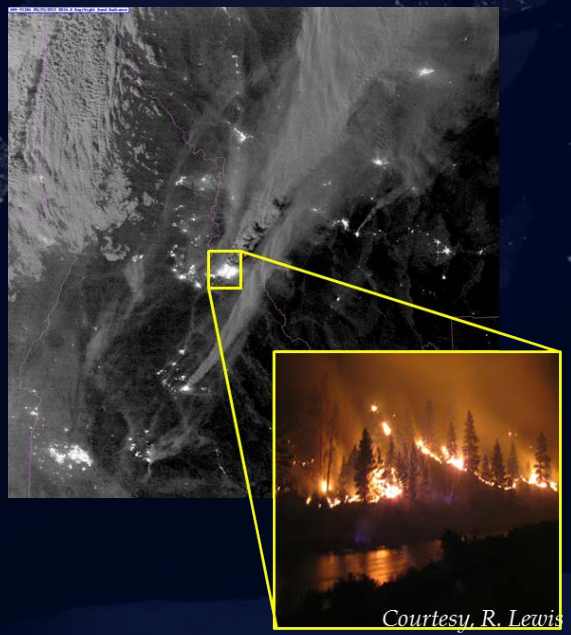
- Wide swath, near constant resolution
- More detections, better plume monitoring / predictions





Active Fires

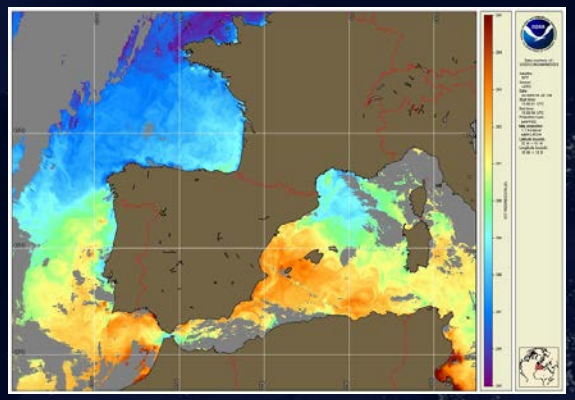
- Fire radiative power
- DNB tracking
- Improved visible resolution/ swath
- Successful field studies

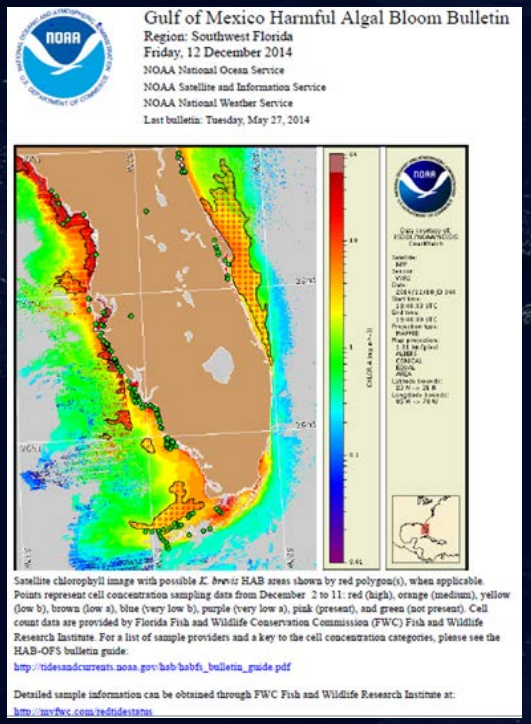


JPSS Applications Advancements

Oceanography

- Improved sea surface temperature
- Highly calibrated global ocean color



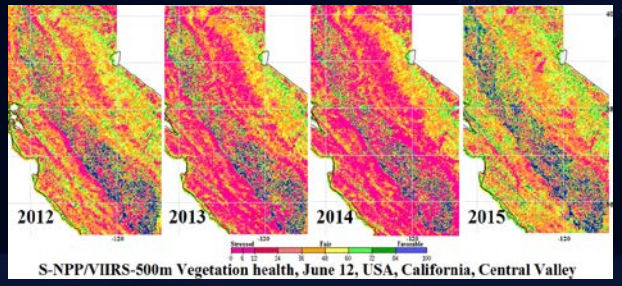


Hydrology

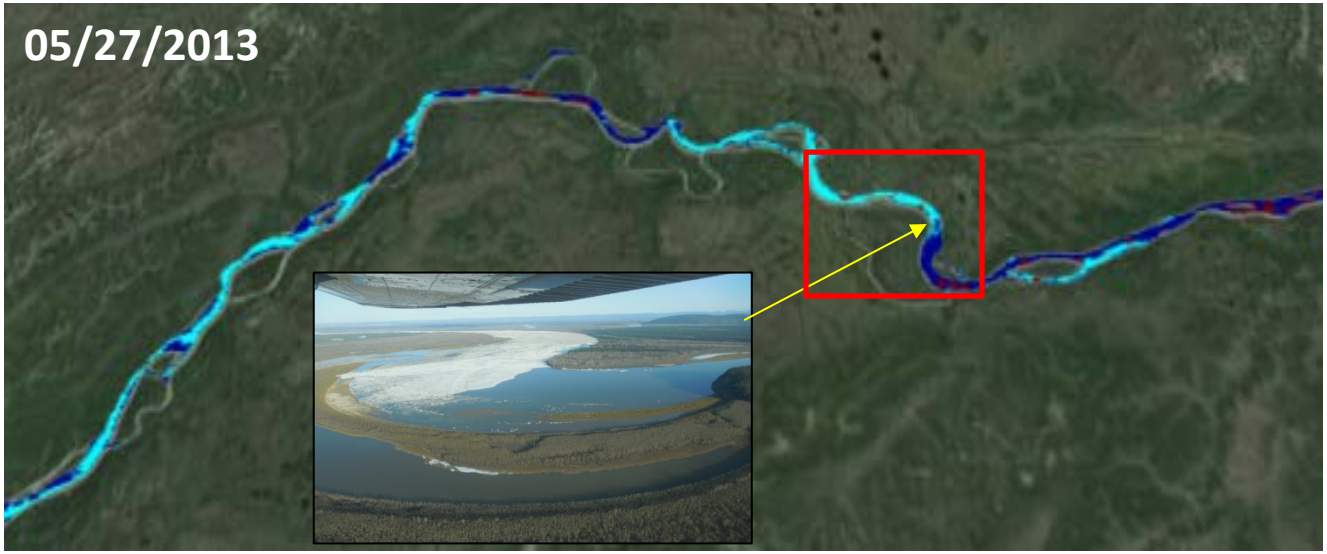
- Ice blockage
- Flood prediction / monitoring

Land

- Green Vegetation Fraction
- Vegetation Stress



VIIRS River Ice and Flood Products

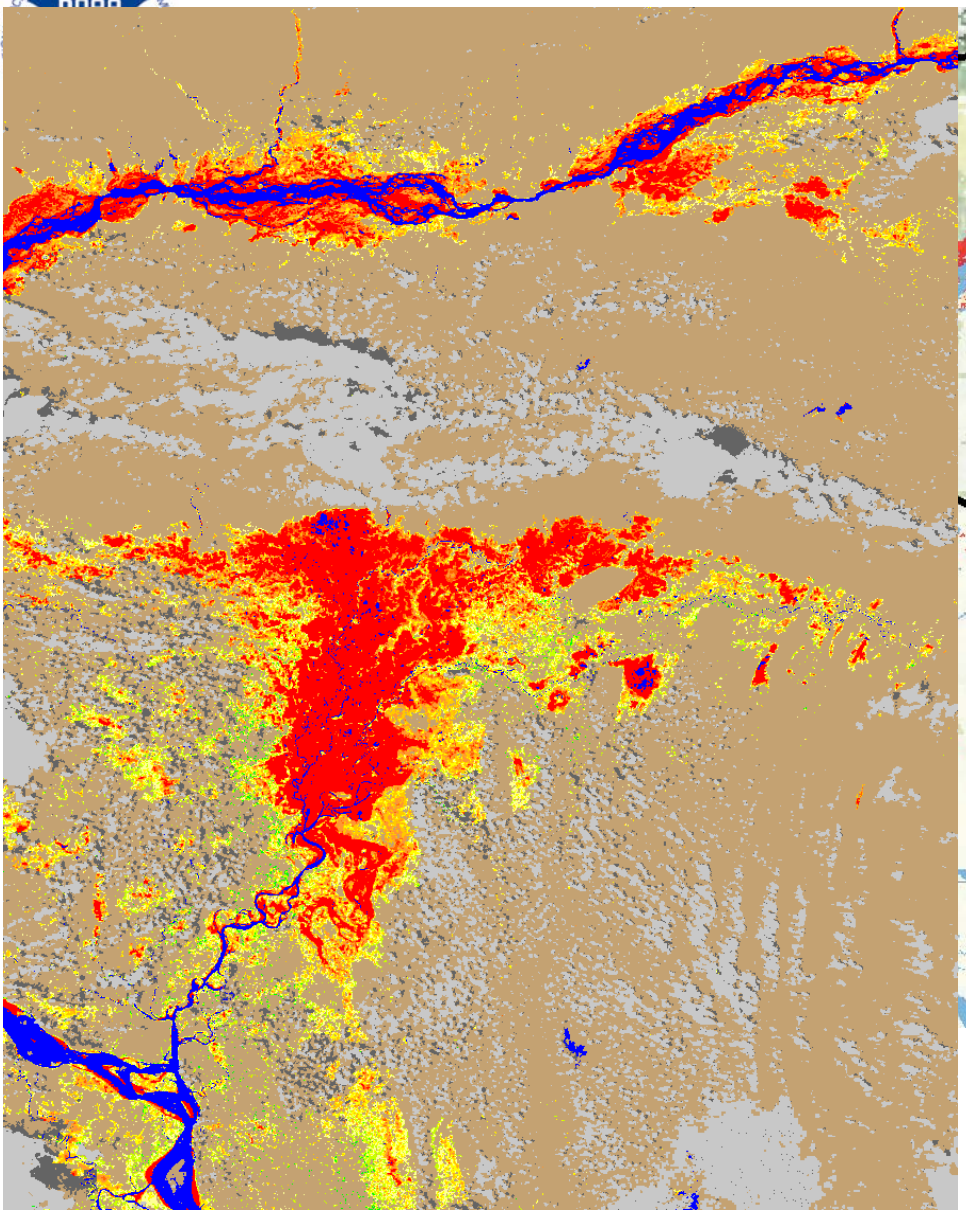


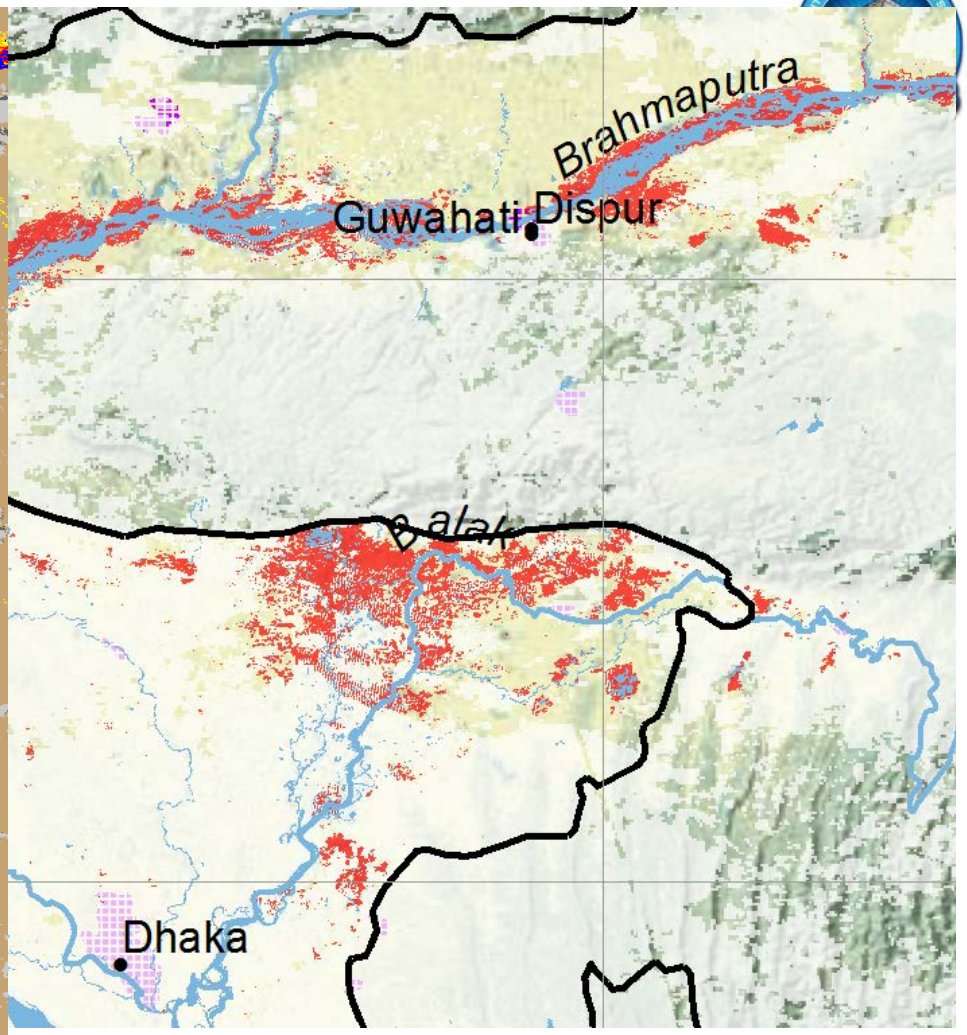
VIIRS can identify river ice jams which can lead to large flood events

- Cyan is mixed ice/water
- Blue is water
- Red is cloud
- Yellow is solid ice

Galena, Alaska on May 28, 2013

Flooding from ice jams can occur in a very short time



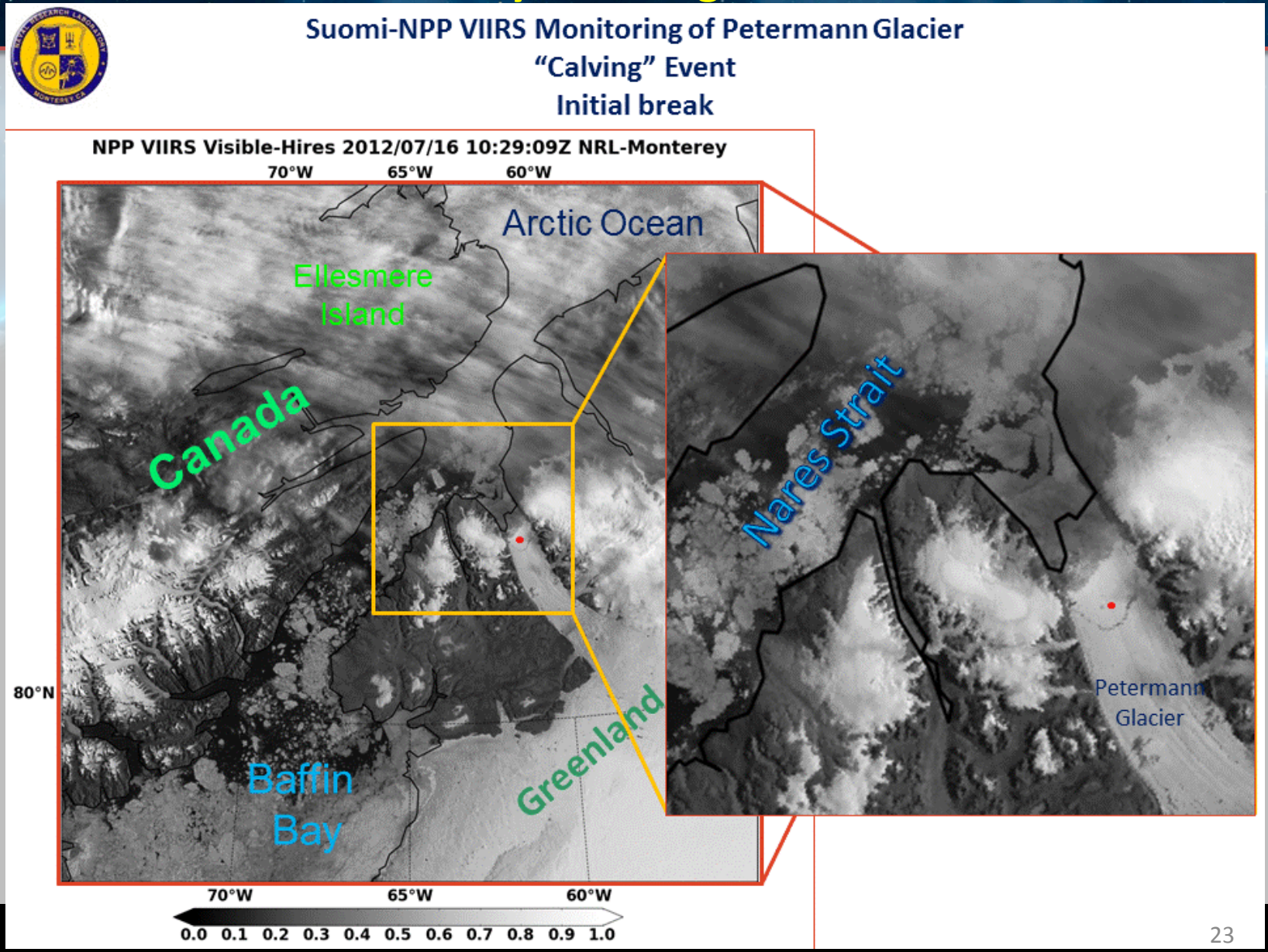


Higher spatial resolution VIIRS and better handling of cloud shadows provides better coverage than MODIS

Bangladesh, August 29, 2014,
Left: VIIRS, right: MODIS

VIIRS Daytime Visible Iceberg Monitoring

16 July – 15 August 2012

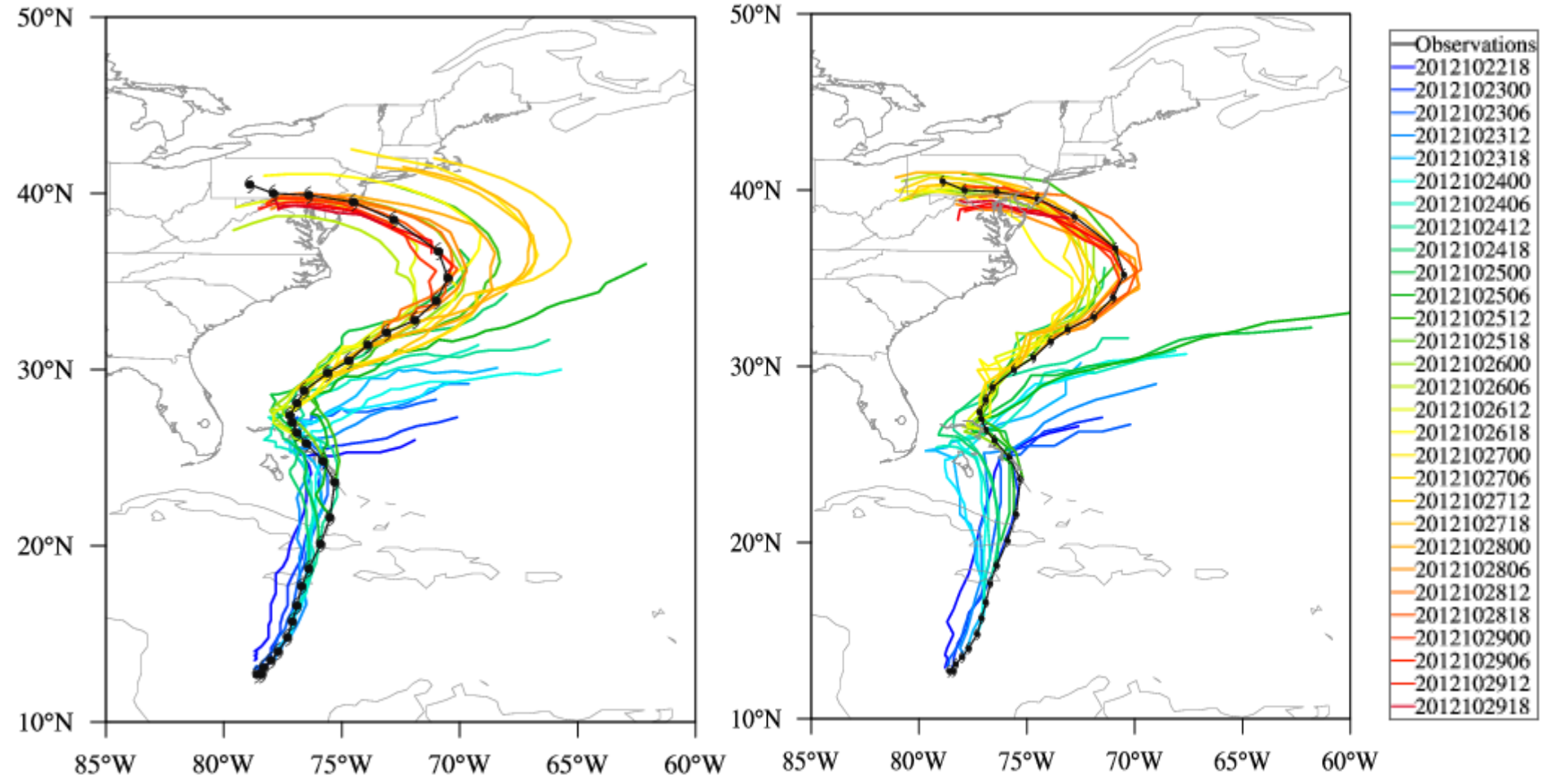


Direct Assimilation of ATMS into Models

Experimental results showing improvements in Sandy track forecasts from Hurricane Weather Research Forecast model with ATMS: NOW OPERATIONAL

HWRF-NCEP Operational

Modified HWRF-NCEP with ATMS



Credit: Fuzhong Weng

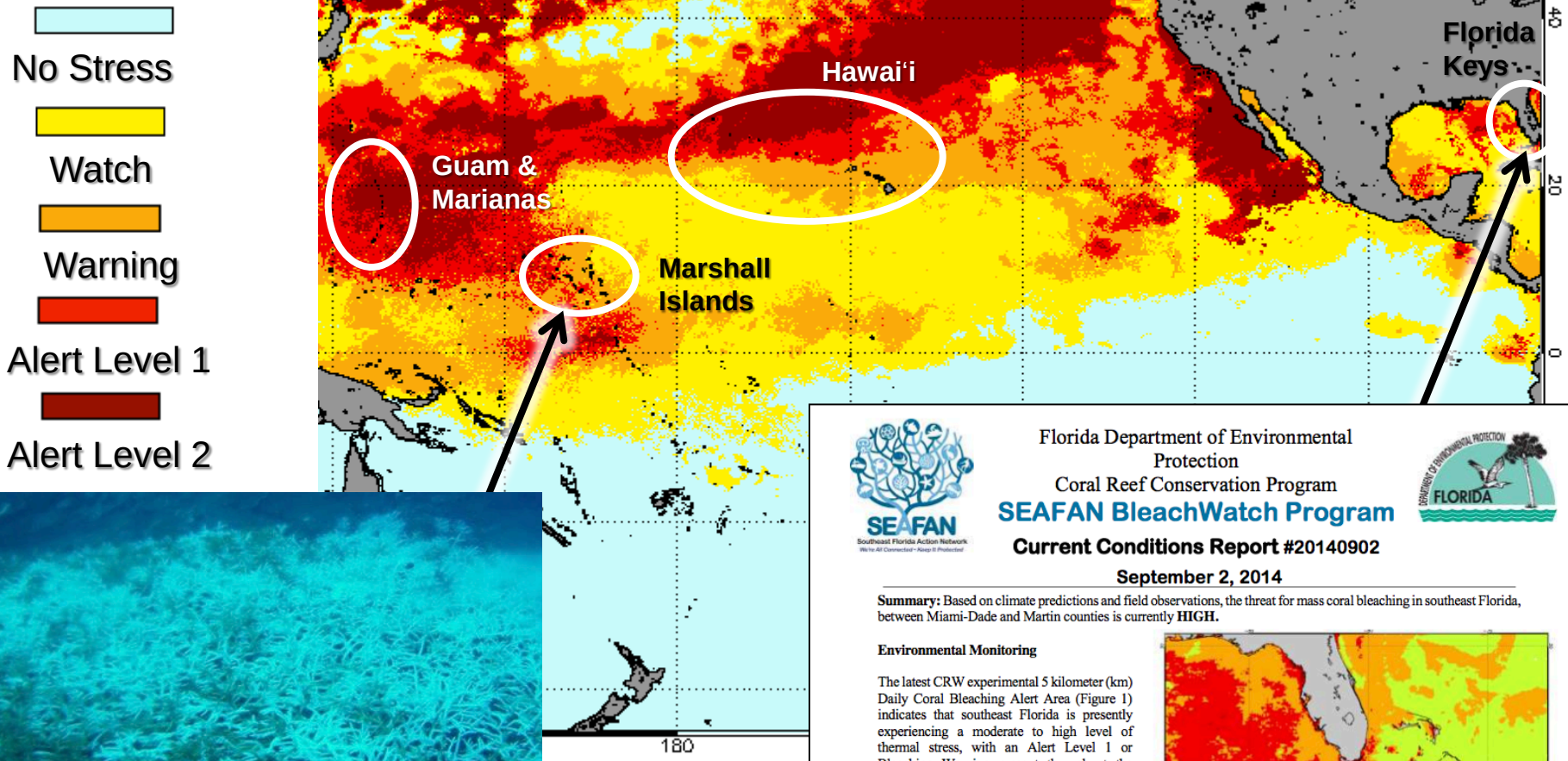
American Samoa:
Dec. 2014 & Feb. 2015

CATLIN SEAVIEW SURVEY

NOAA • NESDIS JPSS Joint Polar Satellite System

2014 Severe Bleaching

NOAA Coral Reef Watch Annual Maximum Satellite Coral Bleaching Alert Area 2014



Florida Department of Environmental Protection
Coral Reef Conservation Program

SEAFAN BleachWatch Program

Current Conditions Report #20140902

September 2, 2014

Summary: Based on climate predictions and field observations, the threat for mass coral bleaching in southeast Florida, between Miami-Dade and Martin counties is currently **HIGH.**

Environmental Monitoring

The latest CRW experimental 5 kilometer (km) Daily Coral Bleaching Alert Area (Figure 1) indicates that southeast Florida is presently experiencing a moderate to high level of thermal stress, with an Alert Level 1 or Bleaching Warning present throughout the region. This indicates that bleaching is likely in southeast Florida and additional alerts are possible if current conditions continue or worsen.

- NOAA's Bleaching Hotspot Map compares current SST to the maximum monthly mean, which is the average temperature during the

Figure 1. NOAA CRW Experimental Daily 5 km Blended Geo-Polar Nighttime Blended Bleaching Alert Area; August 31, 2014
http://coralreefwatch.noaa.gov/satellite/bleaching5km/index.php

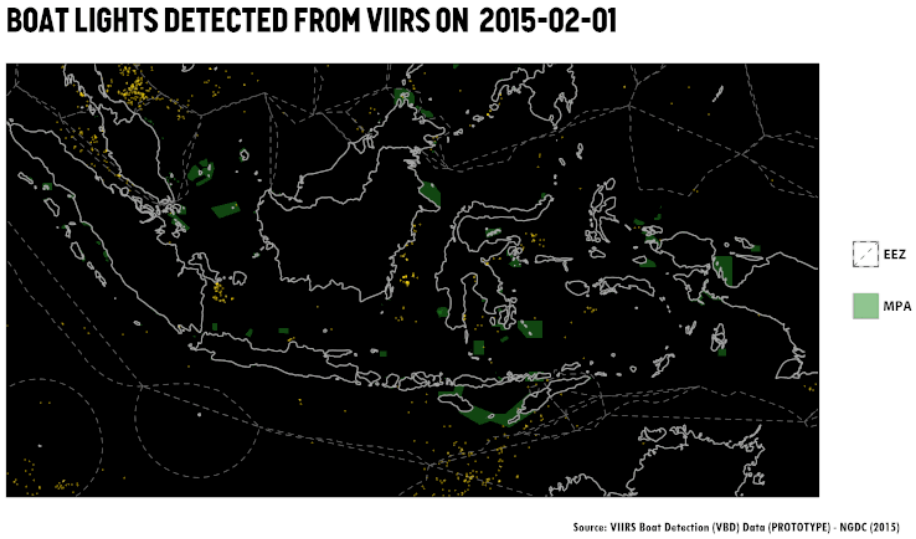
WHITE HOUSE VIIRS ILLEGAL BOAT DETECTION ANNOUNCEMENT AT "OUR OCEAN" CONFERENCE in CHILE

The White House

For Immediate Release October 05, 2015

Fact Sheet: Preserving and Protecting Oceans and America's Waterways for Future Generations

President Obama is committed to protecting the ocean and its marine ecosystems. The Administration has launched landmark initiatives and policies to protect and preserve some of our country's most special places and introduce a new generation of Americans to our national lands and waters.



http://jason-doug-climate.blogspot.com/2015/04/boat-lights-from-viirs-shedding-some.html

Remote Sens. **2015**, *7*(3), 3020-3036; doi:10.3390/rs70303020 Open Access

Article

Automatic Boat Identification System for VIIRS Low Light Imaging Data

Christopher D. Elvidge [1,*], Mikhail Zhizhin [2], Kimberly Baugh [2] and Feng-Chi Hsu [2]

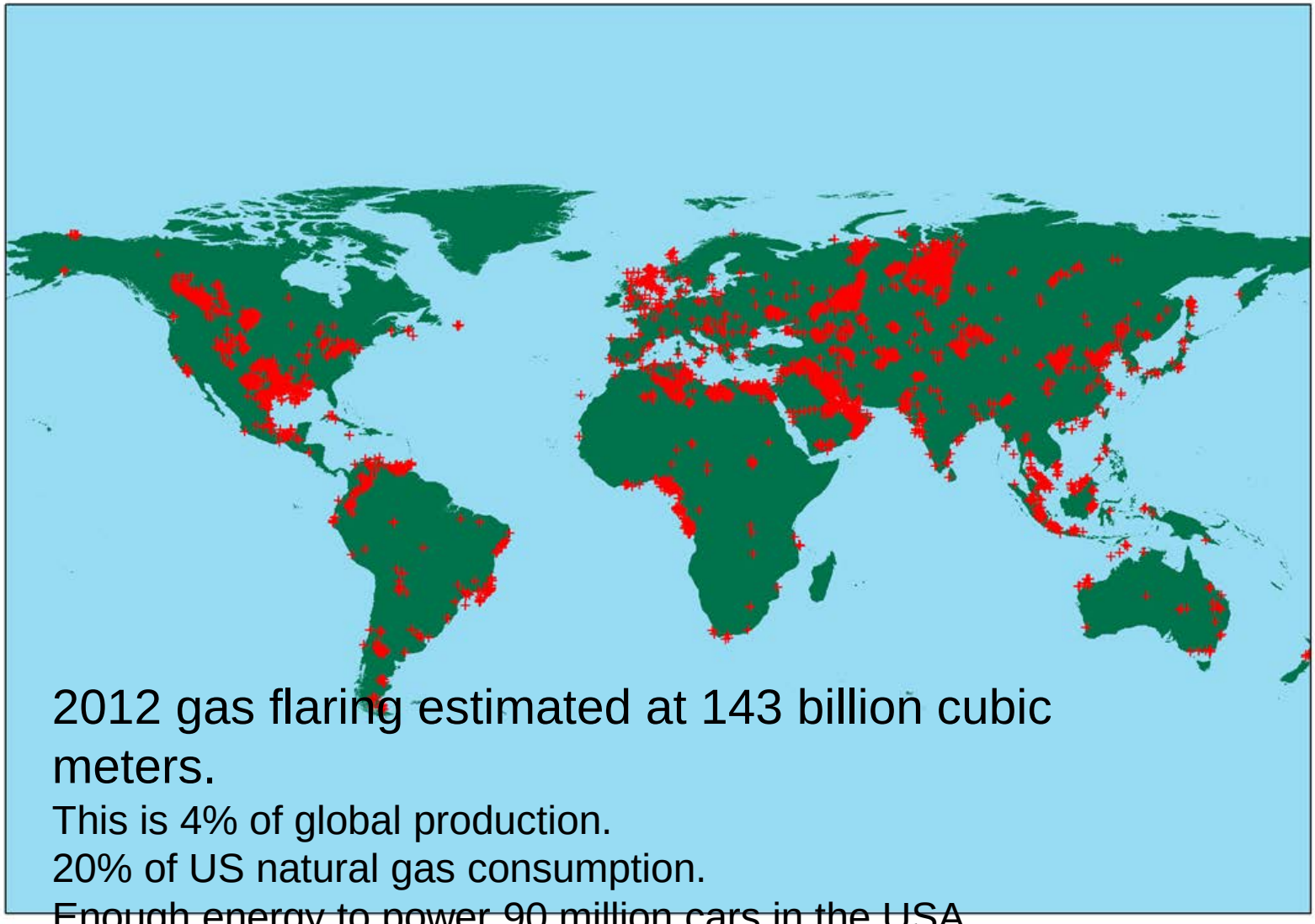
[1] Earth Observation Group, NOAA National Geophysical Data Center, 325 Broadway, Boulder, CO 80305, USA

[2] Cooperative Institute for Research in the Environmental Sciences, University of Colorado, Boulder, CO 80303, USA; E-Mails: mikhail.zhizhin@noaa.gov (M.Z.); kim.baugh@noaa.gov (K.B.); feng.c.hsu@noaa.gov (F.-C.H.)

Key Accomplishment: VIIRS is key to monitoring progress towards “Zero routine flaring by 2030”

“Zero Routine Flaring by 2030” Initiative was officially launched on April 17, 2015 by United Nations Secretary-General Ban Ki-moon and World Bank President Jim Yong Kim with a coalition of governments, oil companies, and development institutions.

Global distribution of gas flaring in 2012. Total is 7,467.



2012 gas flaring estimated at 143 billion cubic meters.

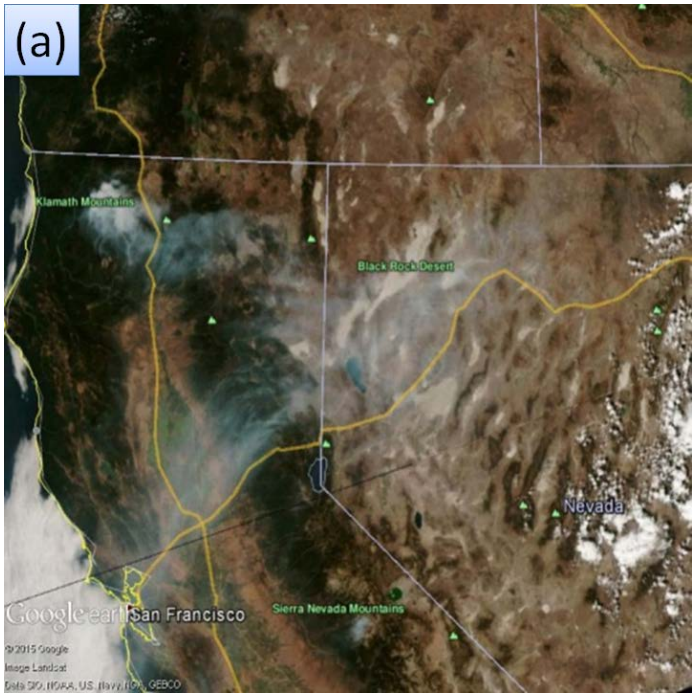
This is 4% of global production.

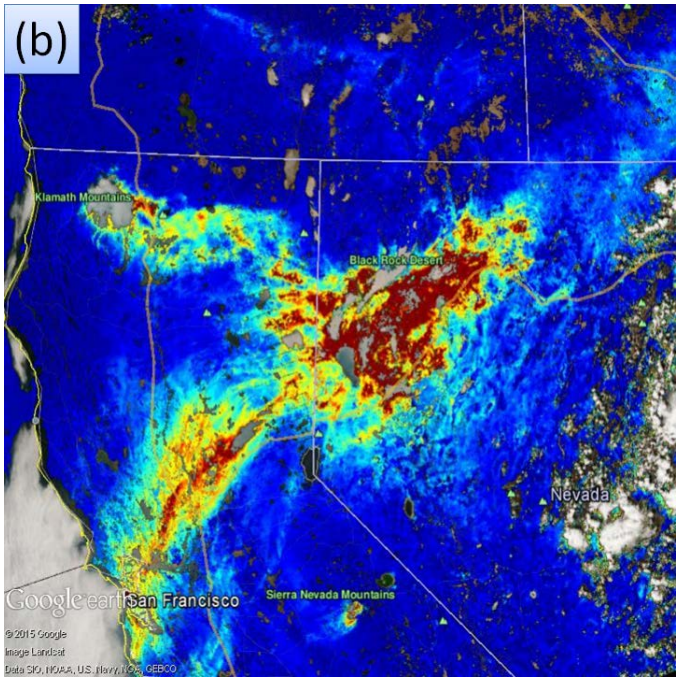
20% of US natural gas consumption.

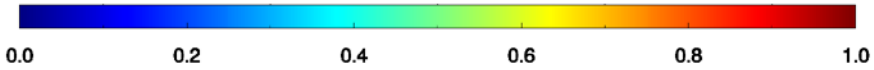
Enough energy to power 90 million cars in the USA.

JPSS Initiatives: Fire and Smoke

- Goal:
  - Makes use of the VIIRS active fire location, fire radiative power and aerosol optical depth, and potentially OMPS derived aerosols to predict fire movement and dispersion of smoke using high spatial resolution and timely forecast models
  - Use CrIS CO products to identify transport during day and night
  - August 15 – September 1, 2015 – our case study since smoke transported from the west to east coast - large OCONUS impacts
- Team:
  - VIIRS Fire Team (STAR, UMD)
  - Satellite Air Quality Team (STAR, UMD, CIMSS)
  - Western Region (NWS)
  - OAR (HRRR Modelling Team)







Smoke over western US 9/9/2014.
(a)VIIRS RGB
(b)VIIRS Aerosol Optical

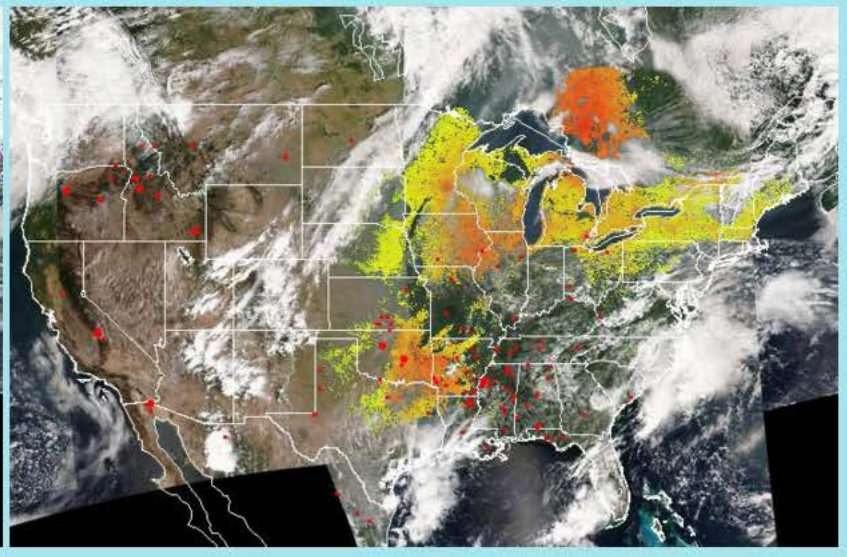
SNPP VIIRS Blended Fire and Smoke Products

- 3-day composite smoke mask
- 3-day smoke mask movie
- 3-day composite smoke AOT
- 3-day smoke AOT movie
- 3-day composite surface smoke concentration
- 3-day surface smoke concentration movie

Select Date 20150831

VIIRS smoke mask and fire hotspots 20150831

VIIRS surface smoke concentration 20150831



FRP (MW)
<100 100-500 500-1000 1000-1500 >1500

$PM_{2.5}$ (ug/m³)
0 20 40 60 80 100

Last updated: November 02 2015 16:01:07 UTC
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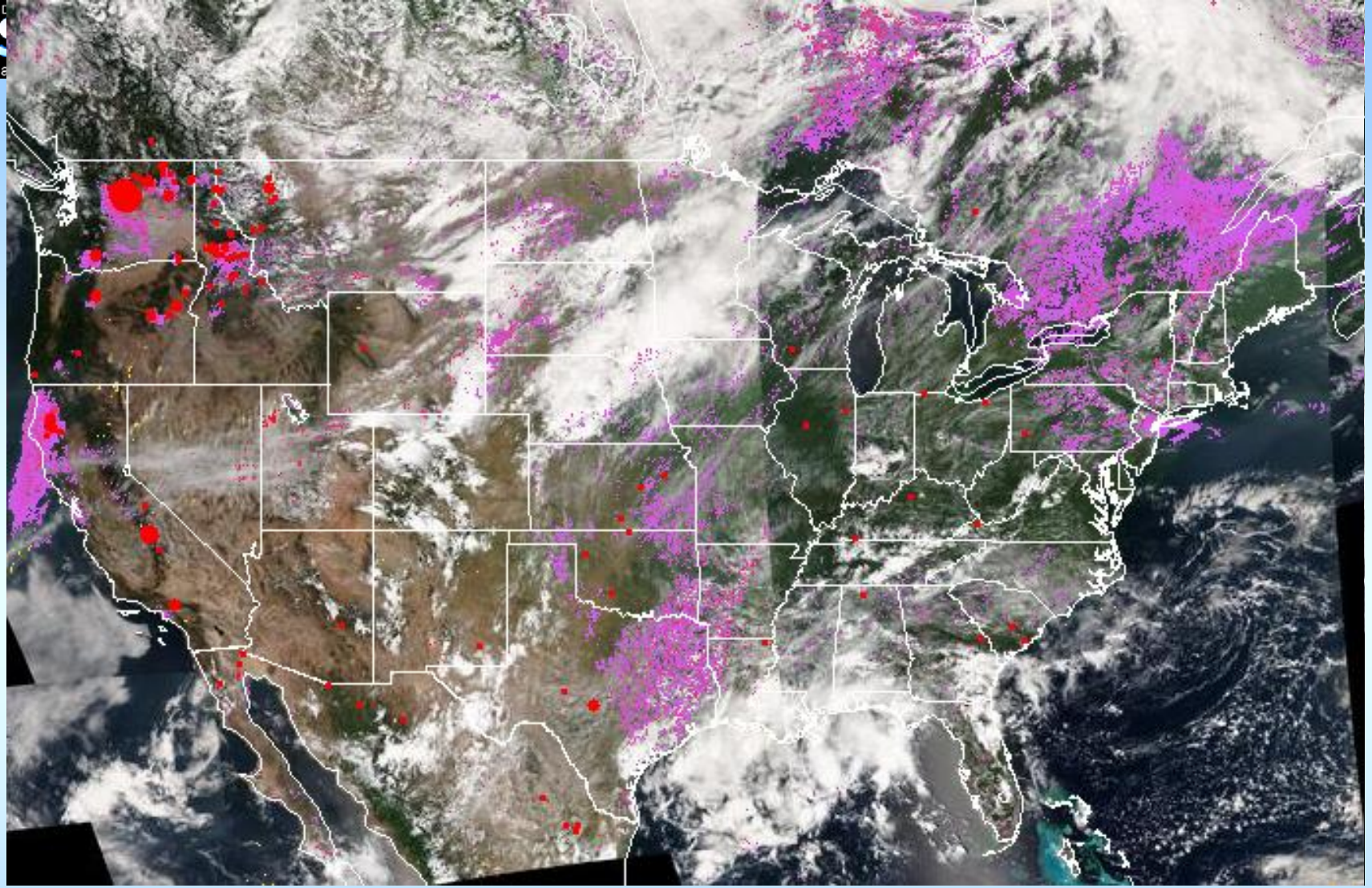
http://www.star.nesdis.noaa.gov/smcd/spb/aq/expr/expr2/



- VIIRS Blended Fire and Smoke Product webpage work underway (eIDEA)
  - In preparation for live demonstration in Spring 2016 in Boise, Idaho
- FRP information added to fire hot spots
- Image gallery for August 15 – August 31, 2015 generated

Plumerise in HRRR: The 1-d in-line cloud model: governing equations

- W equation
- U equation
- 1st law of thermodynamic
- water vapor conservation
- cloud water conservation
- rain/ice conservation
- equation for radius size

$$\frac{\partial w}{\partial t}+w\frac{\partial w}{\partial z}=\gamma gB-\frac{2\alpha}{R}w^2-\delta_{entr}w$$

$$\frac{\partial u}{\partial t}+w\frac{\partial u}{\partial z}=-\frac{2\alpha}{R}|w|(u-u_e)-\delta_{entr}(u-u_e)$$

$$\frac{\partial T}{\partial t}+w\frac{\partial T}{\partial z}=-w\frac{g}{c_p}-\frac{2\alpha}{R}|w|(T-T_e)+\left(\frac{\partial T}{\partial t}\right)_{micro-physics}-\delta_{entr}(T-T_e)$$

$$\frac{\partial r_v}{\partial t}+w\frac{\partial r_v}{\partial z}=-\frac{2\alpha}{R}|w|(r_v-r_{ve})+\left(\frac{\partial r_v}{\partial t}\right)_{micro-physics}-\delta_{entr}(r_v-r_{ve})$$

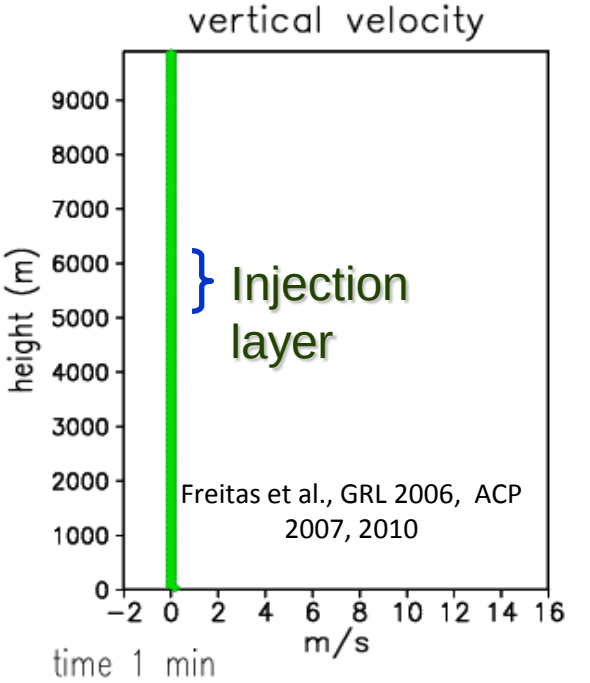
$$\frac{\partial r_c}{\partial t}+w\frac{\partial r_c}{\partial z}=-\frac{2\alpha}{R}|w|r_c+\left(\frac{\partial r_c}{\partial t}\right)_{micro-physics}-\delta_{entr}r_c$$

$$\frac{\partial r_{ice,rain}}{\partial t}+w\frac{\partial r_{ice,rain}}{\partial z}=-\frac{2\alpha}{R}|w|r_{ice,rain}+\left(\frac{\partial r_{ice,rain}}{\partial t}\right)_{micro-physics}+\text{sedim}-\delta_{entr}r_{ice,rain}$$

$$\frac{\partial R}{\partial t}+w\frac{\partial R}{\partial z}=+\frac{6\alpha}{5R}|w|R+\frac{1}{2}\delta_{entr}R$$

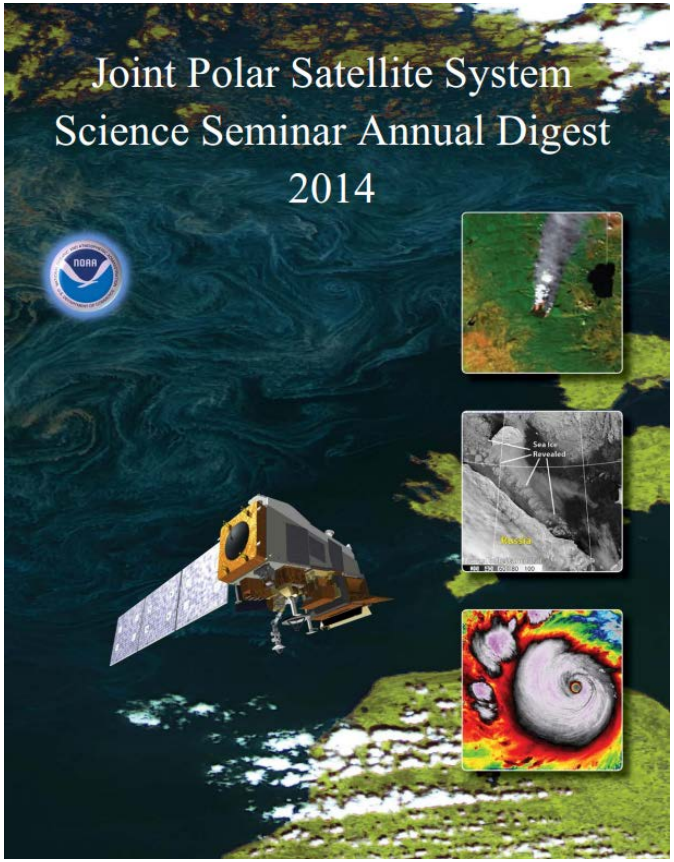
$$\left(\frac{\partial \xi}{\partial t}\right)_{micro-physics}(\xi=T,r_v,r_c,r_{rain},r_{ice}),\ \text{sedim}\begin{cases}\text{bulk microphysics:}\\ \text{Kessler, 1969; Berry,1967}\\ \text{Ogura \& Takahashi,1971}\end{cases}$$

Example of injection height with heat flux of **30** and **80** kW/m^2



Want to learn more?

- 2013 and 2014 Annual Science Digests are available
- 2012-2015, and 2015-2018 Portfolios are available
- Join our monthly JPSS Science Seminars http://www.jpss.noaa.gov/science-seminars.html
- Check out the JPSS Website http://www.jpss.noaa.gov/science.html



Summary

- JPSS is working with NOAA and partner agencies users to further promote the use of JPSS data for operational use and to improve applications.
  - Use of fire location and radiative power in regional fire and smoke models
  - Assimilation of VIIRS aerosols and land products in NCEP global models
  - Assimilation of VIIRS snow fraction and ATMS snow information in hydrological models.
  - Better utilization of CrIS/ATMS soundings by forecasters
  - Improved use of VIIRS, ATMS and AMSR-2 for nowcasting imagery.
  - Better assimilation of CrIS in NCEP models
  - Use of CrIS and ATMS is regional models via direct broadcast

- Internationally we have a powerful tool through direct readout
  - CSPP - test operational and research algorithms and starting including applications (air quality forecasts, flood mapping, fire and smoke forecast, and so on) at a regional level.
  - Need to think integrated satellite data - we need both polar orbiting and geostationary satellites.
  - Need a more robust polar satellite constellation – which together we can easily achieve