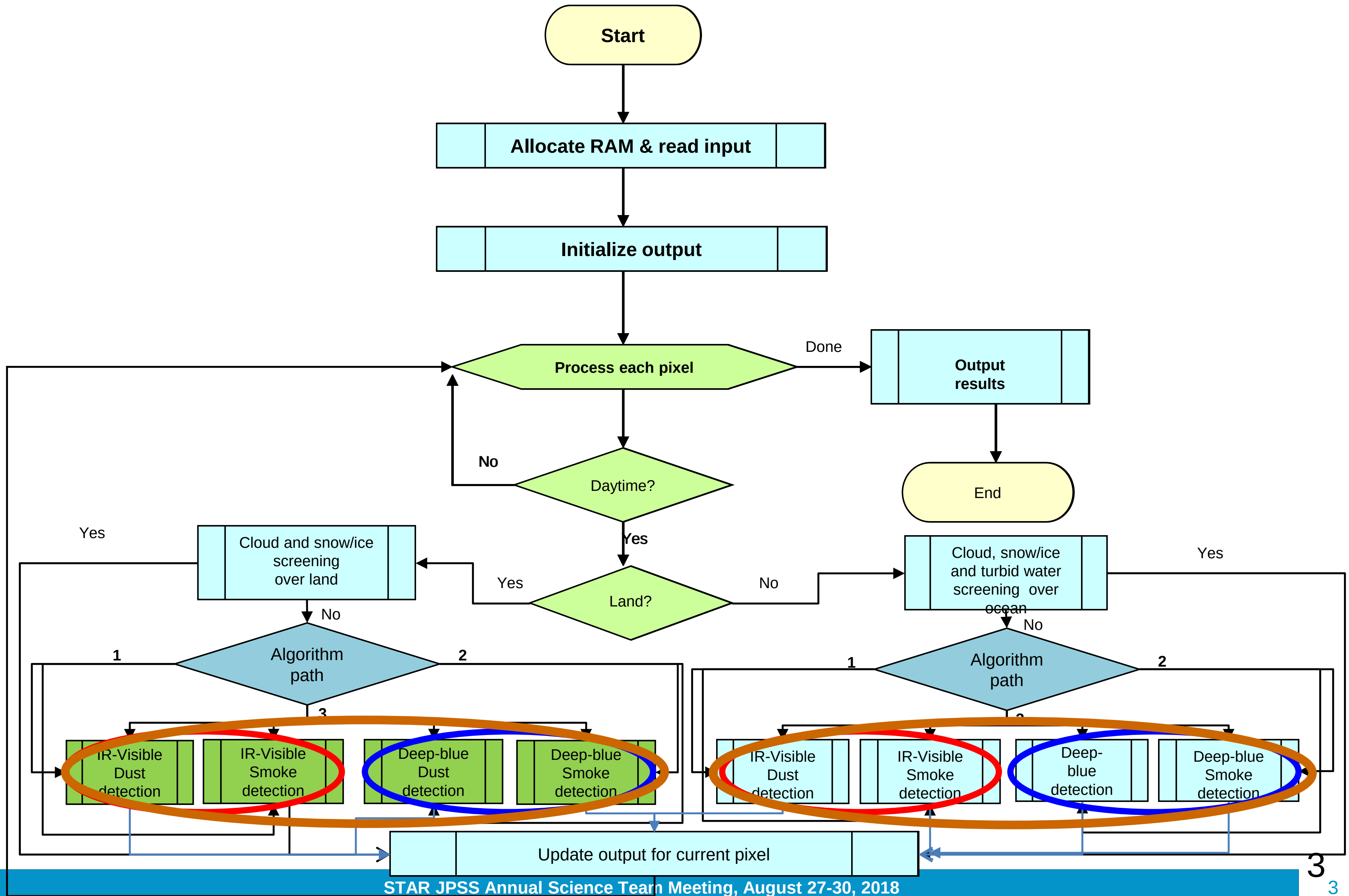
JPSS AEROSOL DETECTION PRODUCT

Shobha Kondragunta
NESDIS/STAR
Shobha.Kondragunta@noaa.gov

Cal/Val Team Members

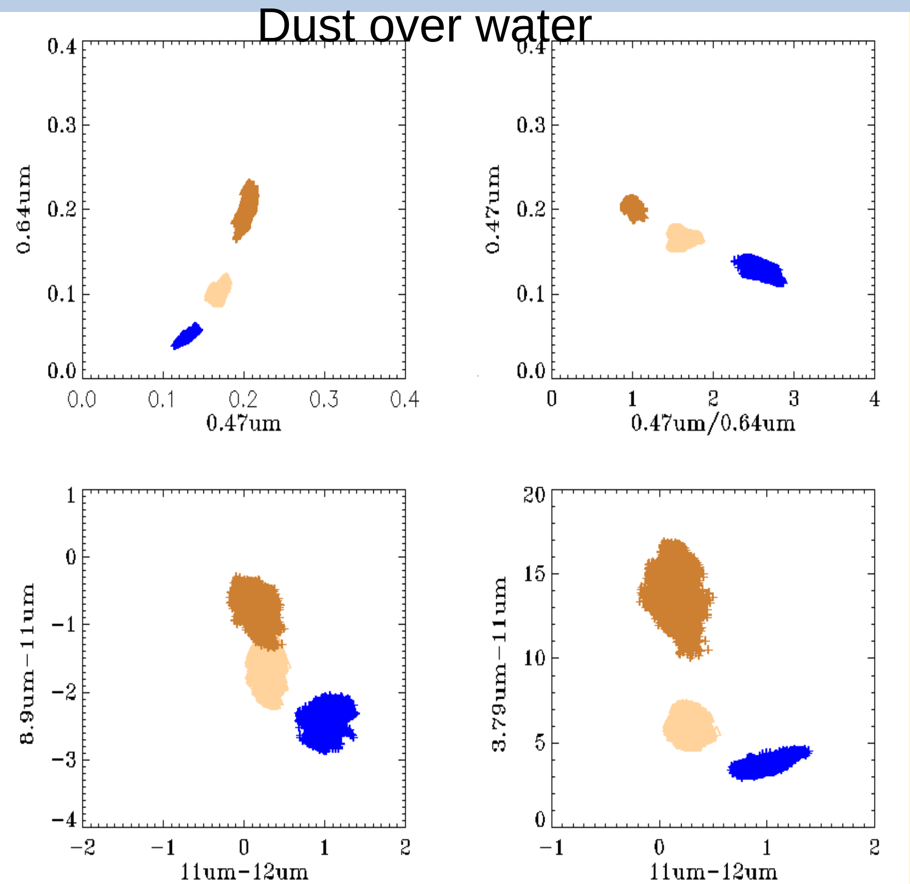
Name	Organization	Major Task
Pubu Ciren	IMSG/NOAA	Aerosol Detection Product development/validation
Brent Holben	NASA/GSFC	AERONET observations for validation work
Amy Huff	PSU	User outreach and product assessment
Edward J. Hyer	NRL	Product validation, assimilation activities
Shobha Kondragunta	NOAA/NESDIS	Co-lead
Istvan Laszlo	NOAA/NESDIS	Co-lead
Hongqing Liu	IMSG/NOAA	Visualization, algorithm development, validation
Lorraine A. Remer	UMBC	Documentation and validation
Hai Zhang	IMSG/NOAA	Algorithm coding, validation within IDEA
Arthur Russakof	IMSG/NOAA	Algorithm integration
Ivan Valerio	IMSG/NOAA	Data management and user outreach

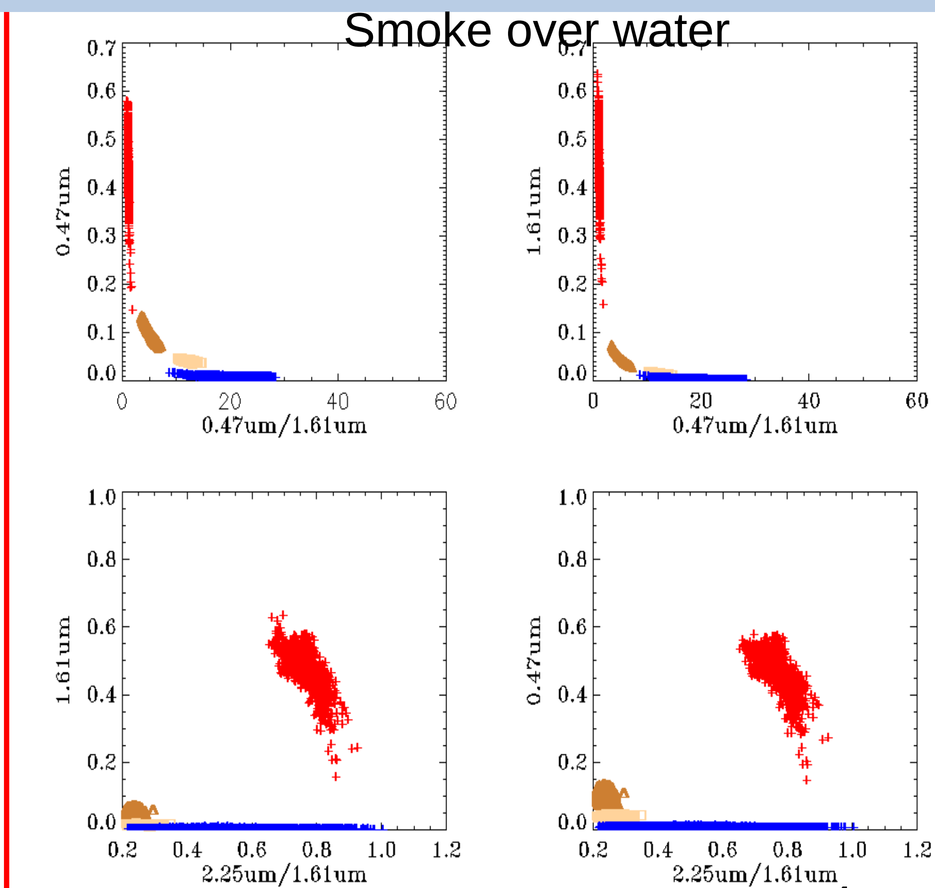
EPS Aerosol Detection Algorithm



JPSS EPS Aerosol Detection Algorithm-IR-Visible path

- **In IR region, dust decreases the brightness temperature difference between 11 and 12 µm, compared to clear sky. In visible region, dust reduces the contrast between two neighboring wavelengths , such as 0.47 µm/0.64 µm.**
- **Weak spectral dependence of reflection from clouds and strong wavelength dependent reflection from smoke allows us to use spectral contrast between two visible wavelengths to separate smoke from clouds; and further separate thick smoke from thin smoke .**



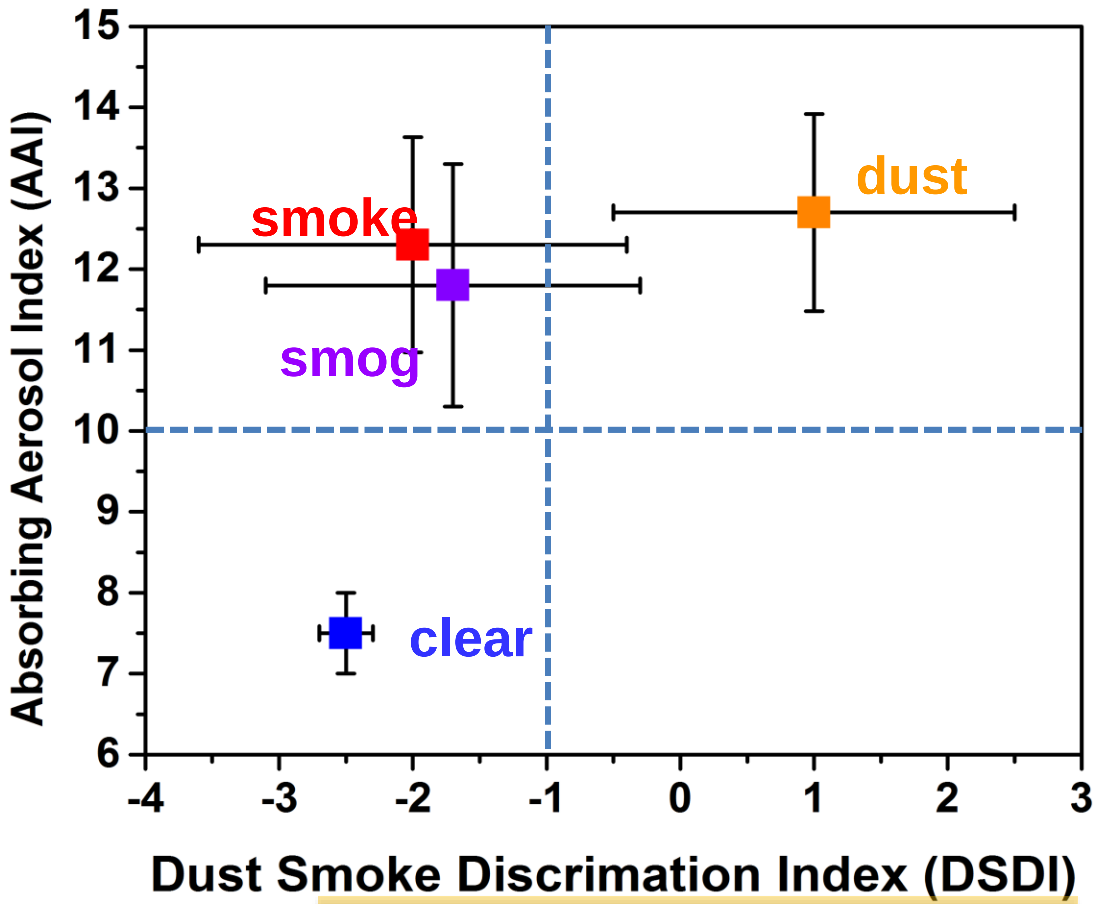


Clear Thin Dust Thick Dust **Clouds** Thin Smoke Thick smoke **Clear**

JPSS EPS Aerosol Detection Algorithm-Deep Blue Path

- Smoke/Dust reduces the contrast between 412 nm and 440 nm as absorption increases with decreasing wavelength.
- Difference in particle size enables us to pick-out the smoke by introducing short-wave IR channel (2.25 µm)

Absorbing Aerosol Index
$AAI = -100[1og_{10}(R_{412}/R_{440}) - \log_{10}(R'_{412}/R'_{440})]$



Aerosol indices shown here for schematic purpose only. Indices depend on view geometry

Dust Smoke Discrimination Index
$DSDI = -10[1og_{10}(R_{412}/R_{2250})]$

VIIRS Aerosol Detection Product Performance

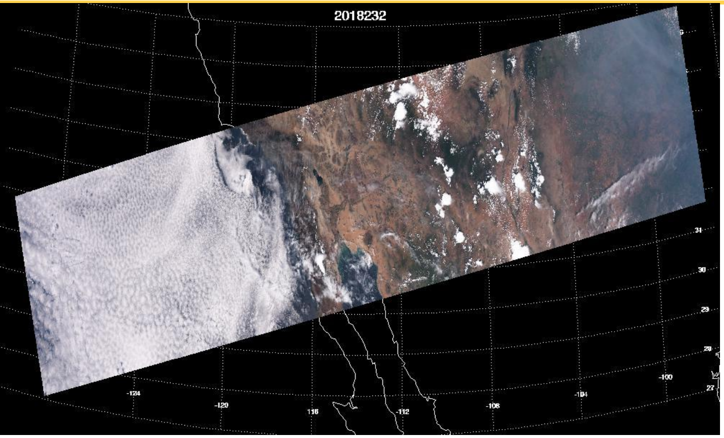
January 9 – March 31, 2018

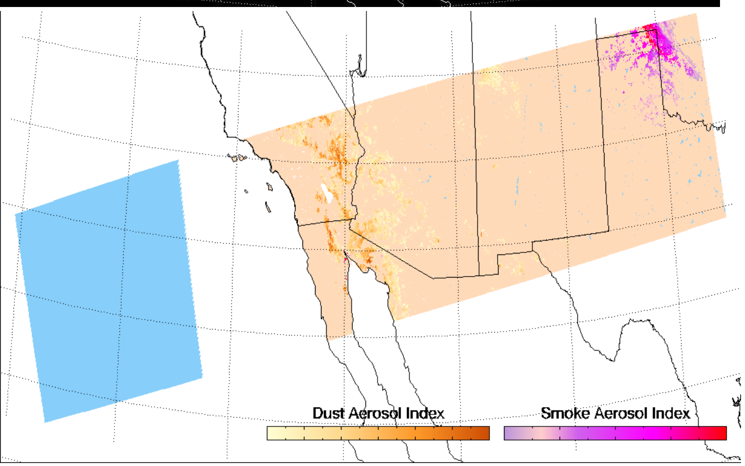
Product	L1RD APU (%)	S-NPP Performance (%)	NOAA-20 Performance (%)
Smoke	80 (land) 70 (ocean)	84.7	83.1
Dust	80 (land) 80 (ocean)	92.6	92.6

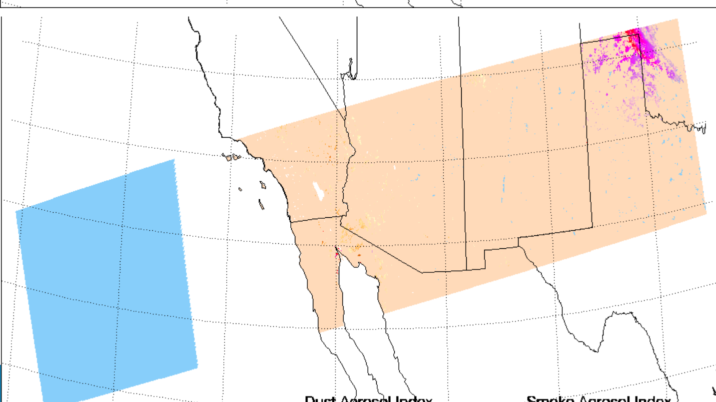
Major Risks/Issues and Mitigation

Risk/Issue	Description	Impact	Action/Mitigation
False dust detections over bright surface	Over bright surfaces such as desert, there are many false detections especially in nadir view	Product reliability issues	Developed a patch for the algorithm to revert to IR-visible path during nadir views
Missed dust detections	The full range of dust plume extent is sometimes missed due to conservative thresholds	Product reliability issues	Adjusted (relaxed) thresholds to detect dust on plume edges and so forth
Enterprise Cloud Mask	ECM assigns cloud mask to dust plumes	Product reliability issues	Not using ECM bits anymore. Using internal methods to detect clouds

ADP Improvements due to Algorithm Updates







NOAA-20 ADP Example

Relying on IR-Visible path over Deep Blue path of the algorithm minimizes false dust detections over bright surfaces when there is no dust event

FY19 Milestones and Deliverables

Task	Description	Deliverables	Scheduled Date
ADP algorithm updates	Minor adjustments to thresholds	Updated code	December 2018
Test using surface reflectance database	Test using a surface reflectance database to compute surface reflectance and remove it from reflectances before computing absorbing aerosol index and dust smoke discrimination index	Updated code	March 2019
Update STAR VIIRS aerosol website	ADP component will be added to VIIRS aerosol website	Updated website deployment	December 2018
Webinars/tutorials	Educate users about VIIRS ADP	Webinars	August 2019
NOAA-20 validated maturity review	Conduct NOAA-20 ADP validation work to demonstrate validated maturity	Review	March 2019

Future Plans/Improvements

- Algorithm Improvements
  - Maintenance
- J2 and Beyond
  - Subject to any instrument issues
- Reprocessing Plans/Status
  - Subject to availability of computing resources and SDR information
- Long Term Monitoring/Website links
  - ongoing

User Feedback & Summary

- **Smoke/Dust Mask**
  - *Group of nine air quality forecasters and others: Too many things are colored red; can't have red for high density smoke and FRP hotspots and high AOD. Suggestion to keep hot spots red but change AOD and smoke mask colors.*
  - Particulate transport
  - Good to identify what the AOD will be and help distinguish "cloud-like" features
  - Will be **very** useful when forecasting or determining smoke/fire locations
  - Much of smoke mask looks accurate, but not believable over Great Lakes on Aug 2nd. Should smoke mask more closely follow AOD?
  - The smoke and dust masks only begin to pick up smoke or dust about 45 minutes after local sunrise. The smoke and dust masks also pick up on some known bright areas, such as the Bonneville Salt Flats and urban areas like Los Angeles.
  - Needs more work
  - Looks good!
  - Still learning how this works based on western fires
  - Seems to work ok

AEROSOL OPTICAL DEPTH

Istvan Laszlo
NESDIS/STAR
Istvan.Laszlo@noaa.gov

JPSS Aerosol Cal/Val Team

Name	Organization	Major Task
Pubu Ciren	IMSG	Aerosol detection product development and validation
Amy Huff	PSU	User (forecasters) feedback, outreach
Edward J. Hyer	NRL	Product validation, assimilation activities
Shobha Kondragunta	NOAA	Co-lead (detection)
Istvan Laszlo	NOAA	Co-lead (optical depth)
Hongqing Liu	IMSG	Algorithm development, validation, visualization
Lorraine A. Remer	UMBC	Documentation, liaison to Cloud Team
Arthur Russakoff	IMSG	Algorithm integration
Ivan Valerio	IMSG	Data management and monitoring
Hai Zhang	IMSG	Algorithm coding for and maintenance of eIDEA, AerosolWatch websites

AOD/APS Algorithm Overview

- Compares selected VIS and NIR VIIRS reflectances with reflectances calculated for a set of **AOD** and aerosol models. Selects AOD and aerosol model for which calculated reflectances best match observed ones over *dark* and *bright* surfaces.
- Calculates **APS** over water as the negative slope of AODs in log-space at two pairs of wavelengths.

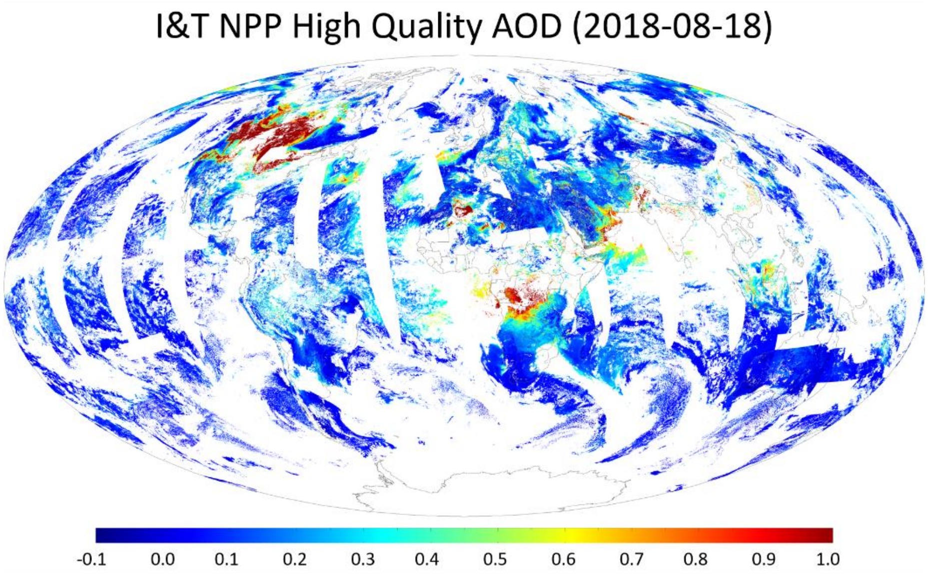
Band	Central Wavelength (µm)	Retrieval		Internal Test	
		Land	Water	Land	Water
M1	0.412	X		X	X
M2	0.445	X		X	X
M3	0.488	X		X	X
M4	0.555		X	X	X
M5	0.672	X	X	X	X
M6	0.746		X		
M7	0.865		X	X	X
M8	1.240		X	X	
M9	1.378			X	X
M10	1.610		X		X
M11	2.250	X	X	X	X
M15	10.763			X	X
M16	12.013			X	

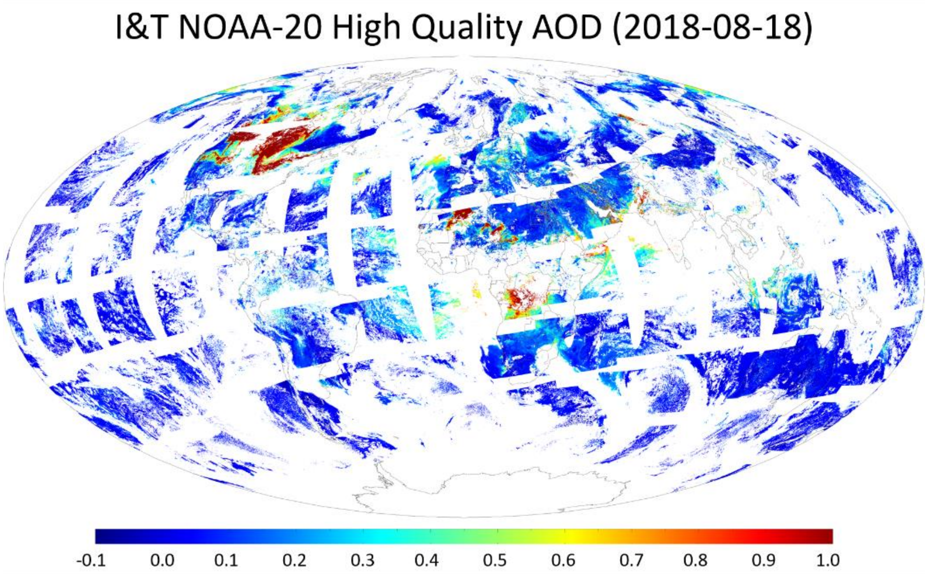
- **Input**: Reflectances in selected VIIRS bands.
- **Ancillary data**: Cloud, cloud-shadow, heavy-aerosol, land/water, snow/ice, fire and glint masks; total precipitable water and ozone amount, surface pressure, wind speed and direction; land cover type; atmospheric and sun-glint LUTs.
- **Output**: AOD at 550 nm, APS at 550-860 and 860-1610 nm; aerosol model(s), fine mode weight over water; AODs in M1-M11 VIIRS bands, diagnostic data.

S-NPP/N-20 Product(s) Overview

- **Status of AOD in NDE:**
  - **OPS**: S-NPP, JPSSRRv1.2 since 8/13/2018) (for AOD, same as v1.1)
  - **I&T**: S-NPP and NOAA-20 (with S-NPP LUT), JPSSRR v1.2
  - **DEV**: S-NPP and NOAA-20 (NOAA-20 LUT), JPSSRR v2.0; moves to I&T in Sep 2018
  - **NOAA-20 AOD is provisional pending LUT update**

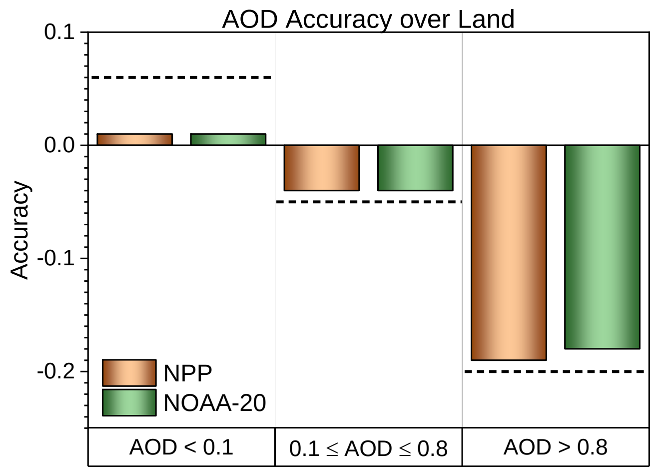
- **AOD Example** (08/18/2018)
  - S-NPP AOD in NDE OPS (still) has missing granules.
  - S-NPP AOD in OPS and in I&T are identical, but I&T has a few more granules missing.
  - NOAA-20 AOD in I&T has a lot more missing granules

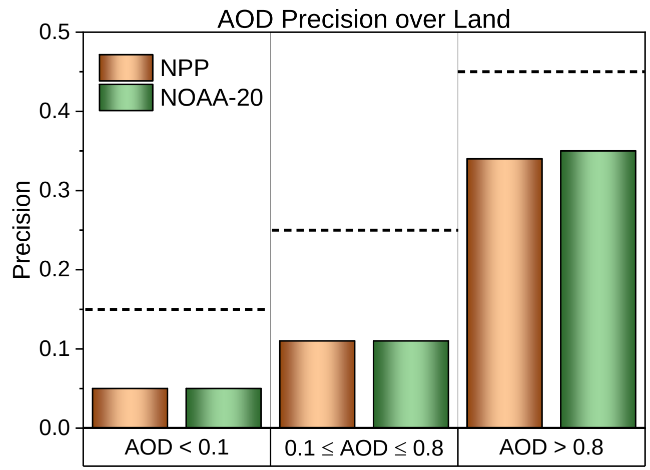




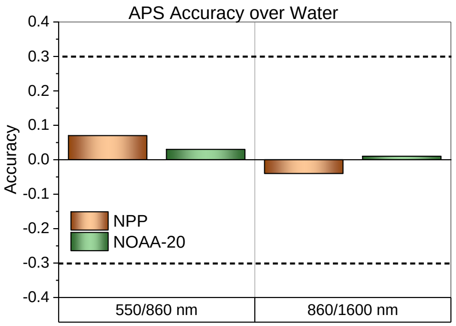
S-NPP/N-20 Product(s) Overview

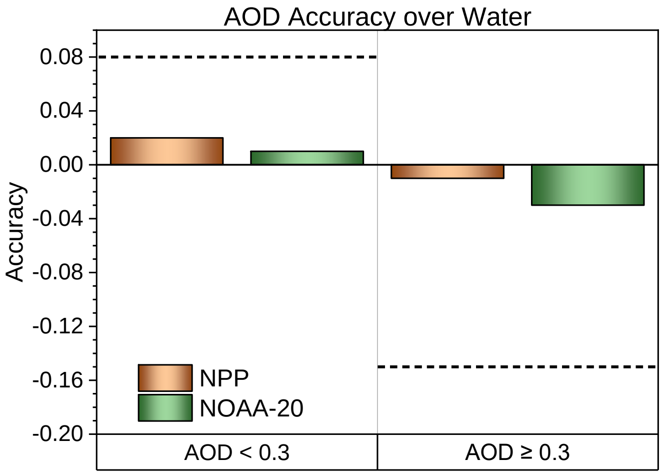
- Product(s) Performance Summary (1/7/2018 - 8/4/2018)

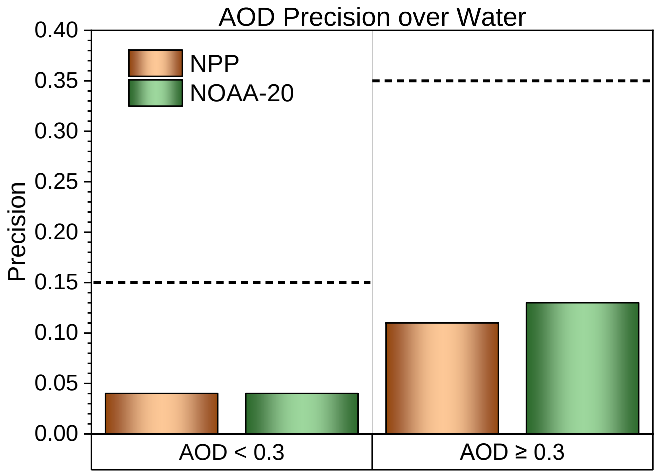


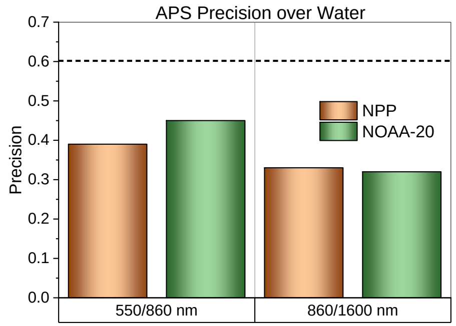


NOAA-20 results are from offline runs with NOAA-20 LUT.









S-NPP/N-20 Product(s) Overview

- Product(s) Performance Summary (1/7/2018 - 8/4/2018)

AOD	L1RDS A(P)	S-NPP	N-20
LAND			
AOD < 0.1	0.06 (0.15)	0.01 (0.05)	0.01 (0.05)
0.1 ≤ AOD ≤ 0.8	0.05 (0.25)	-0.04 (0.11)	-0.04 (0.11)
AOD > 0.8	0.20 (0.45)	-0.19 (0.34)	-0.18 (0.35)
WATER			
AOD < 0.3	0.08 (0.15)	0.02 (0.04)	0.01 (0.04)
AOD >= 0.3	0.15 (0.35)	-0.01 (0.11)	-0.03 (0.13)

APS	L1RDS A(P)	S-NPP	N-20
WATER			
550-860 nm	0.3 (0.6)	0.07 (0.39)	0.03 (0.45)
860-1610 nm	0.4 (0.6)	-0.04 (0.33)	0.01 (0.32)

Only High quality AOD and APS were used

Major Risks/Issues and Mitigation

- Provide updates for the status of the risks/actions identified

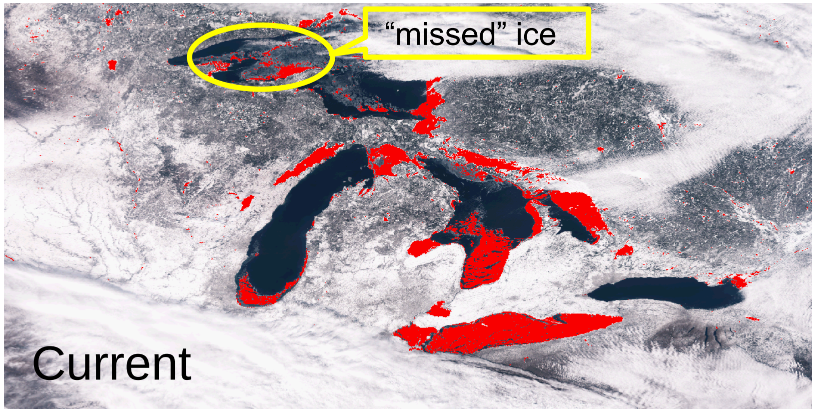
Risk/Issue	Description	Impact	Action/Mitigation
NOAA-20 LUT	Algorithm currently running in NDE I&T uses S-NPP LUTs for NOAA-20	Degraded quality AOD	Implement LUT for NOAA-20 in AOD algorithm. NOAA-20 LUT for AOD was received by NDE on 8/4/2018 and updated algorithm is currently running in DEV

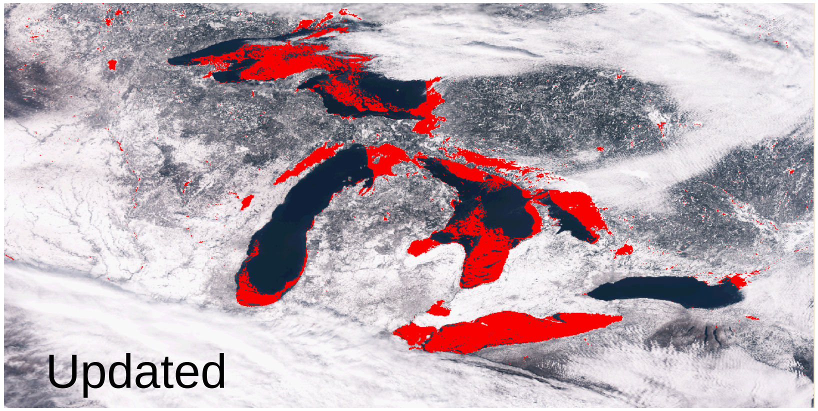
FY19 Milestones and Deliverables

Task	Description	Deliverables	Scheduled Date
Improve tracking of algorithm version	Add to the output as metadata detailed version information on algorithm and production system, internal/external data files, date and time of modifications	Updated code to ASSISTT	Oct 2018
Product maturity review	Complete NOAA-20 AOD validated maturity review	Review material	TBD
Website update	Add NOAA-20 AOD to and update the LTM site maintained by the STAR aerosol team	Updated aerosol LTM website	Dec 2018
Revise QFs	Group output quality flags based on the retrieval quality; will make interpretation easier for users	Updated code to ASSISTT	Dec 2018
Internal tests update	Sea/ice mask does not always indicate presence of ice. Revise thresholds of M4 and M7 reflectances. Cloud mask may miss heavy aerosol; update threshold.	Updated thresholds to ASSISTT	Mar 2019
AOD algorithm update	Update the bright surface reflectance database for AOD retrieval over bright surface	Updated database to ASSISTT	Jul 2019

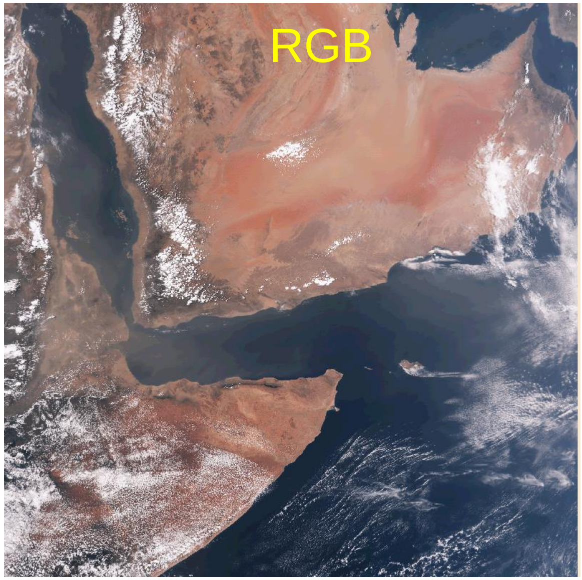
FY19 Milestones and Deliverables

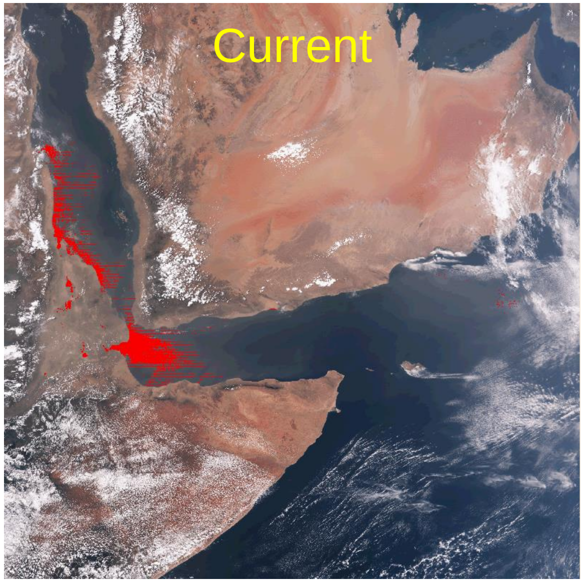
- Threshold update to better detect **ice**

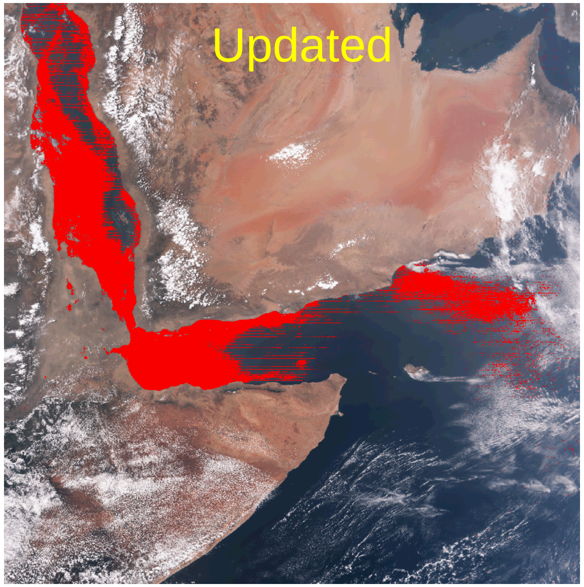




- Threshold update to better detect **heavy aerosol** over water

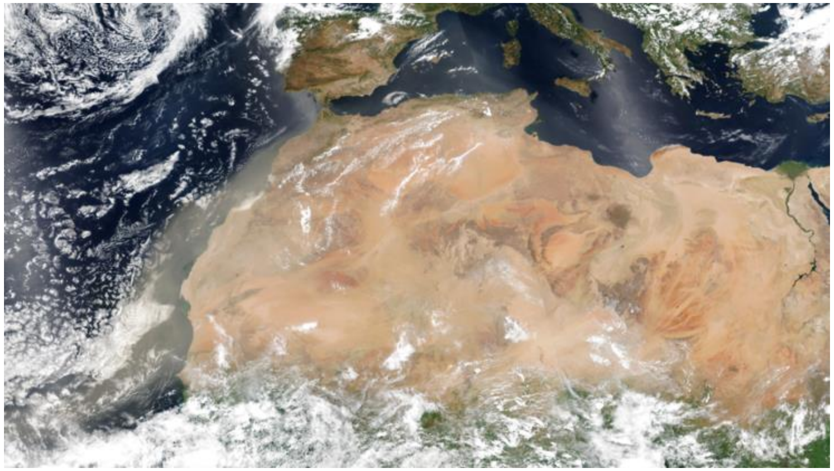


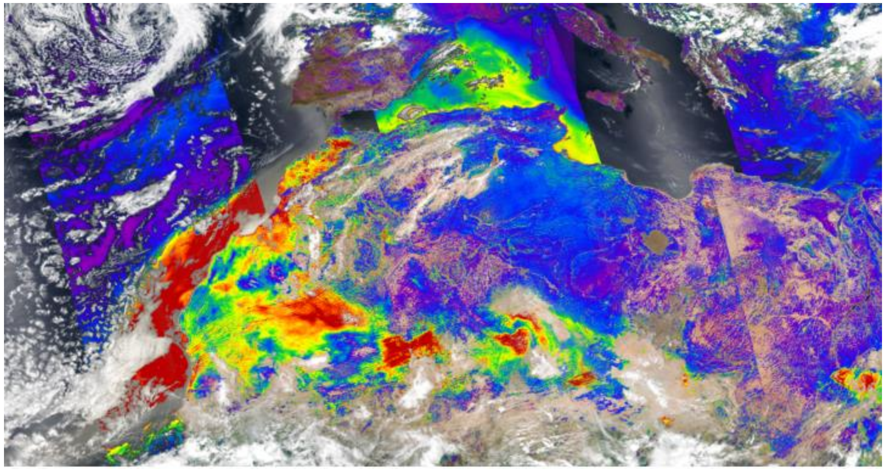




Future Plans/Improvements

- **Algorithm Improvements**
  - Add more aerosol models for over-land retrieval.
  - Update retrieval over bright surface to avoid discontinuity between ocean and land.

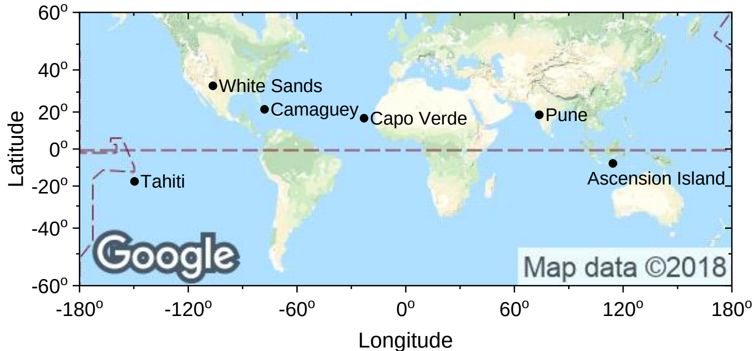


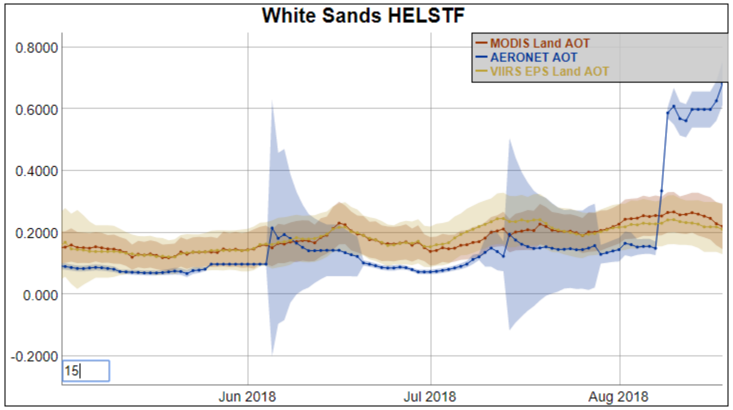


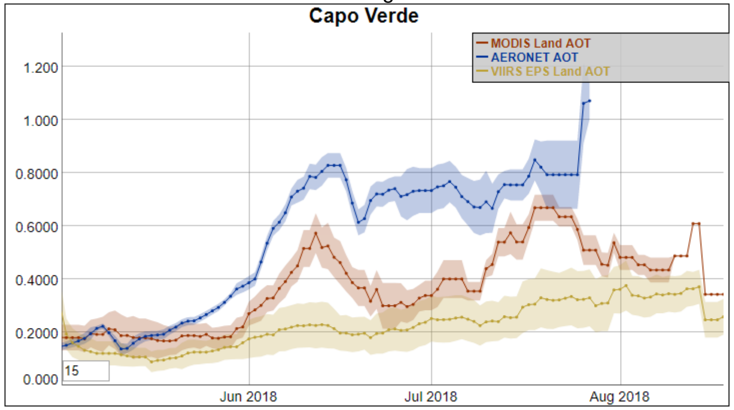
- **Reprocessing Plans/Status**
  - Reprocessed S-NPP VIIRS AOD with EPS algorithm for 2015 as a demonstration.
  - EPS AOD algorithm is mature and ready for re-processing more years once dedicated hardware resources are in place. Will use code with updates to record expanded version information.

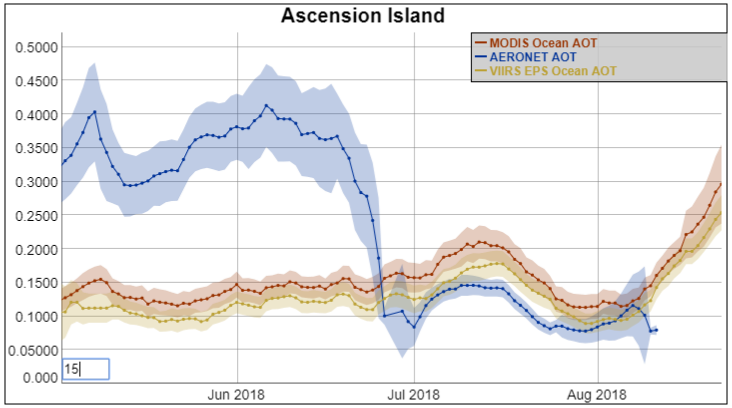
Future Plans/Improvements

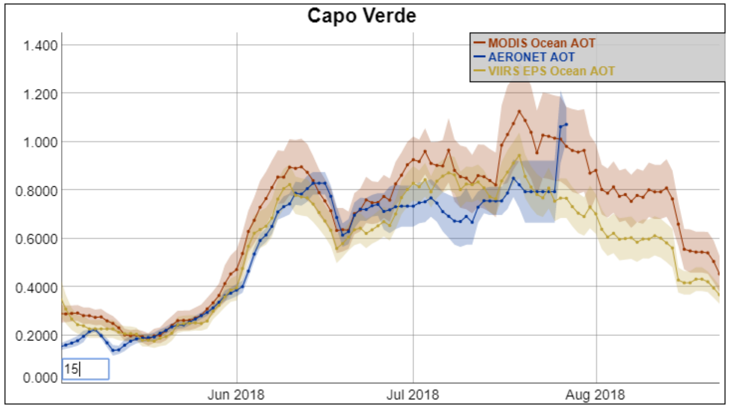
- **Long Term Monitoring**
  - Website: https://www.star.nesdis.noaa.gov/smcd/emb/viirs_aerosol/evaluation_ltm.php











AOD Summary

- Evaluation of S-NPP and NOAA-20 AOD with AERONET data shows the products meet requirements.
- NOAA-20 AOD is provisional pending LUT update.
- No significant risks have been identified once NOAA-20 LUT is implemented.
- Several algorithm updates are planned in FY19, including revised internal tests of ice and heavy aerosol.

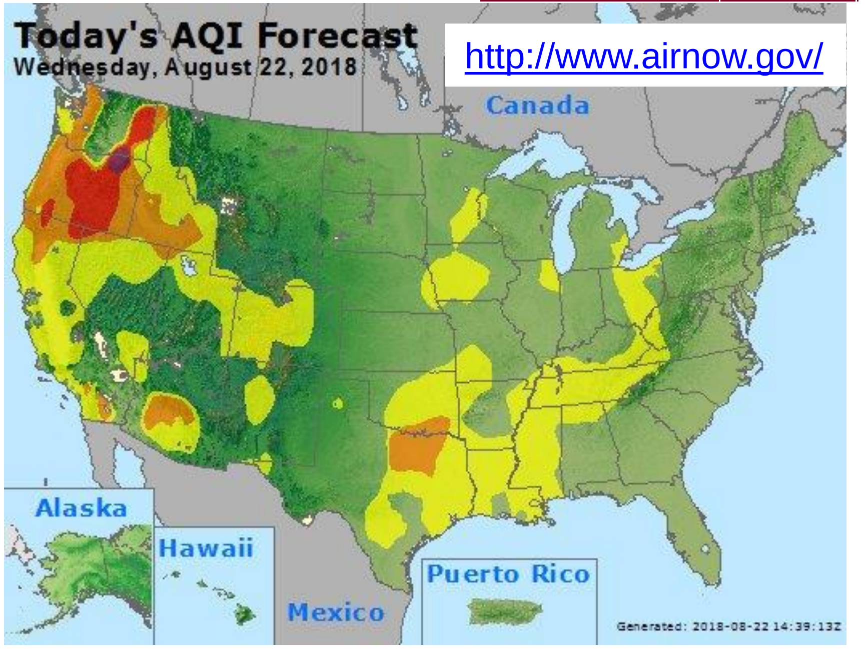
APPLICATION OF VIIRS AOD FOR AIR QUALITY

Amy K. Huff
Department of Meteorology, Penn State University
akh157@psu.edu

Ambient Air Quality Forecasting in the U.S.

- **State, local, and tribal government agencies** issue air quality forecasts to protect the public from the adverse health effects of **criteria pollutants**
  - O_3, $PM_{2.5}$, PM_{10} most commonly forecasted pollutants in the U.S.
- Forecasts typically issued by mid-afternoon (~3:00 PM), valid for the **next day**
  - Allows for lead time to communicate with public, local governments, businesses, schools in case of poor air quality forecast
- Forecasts communicated using the color-coded **Air Quality Index (AQI)**
  - Forecasts available on the **AirNow** national website, also state/local websites

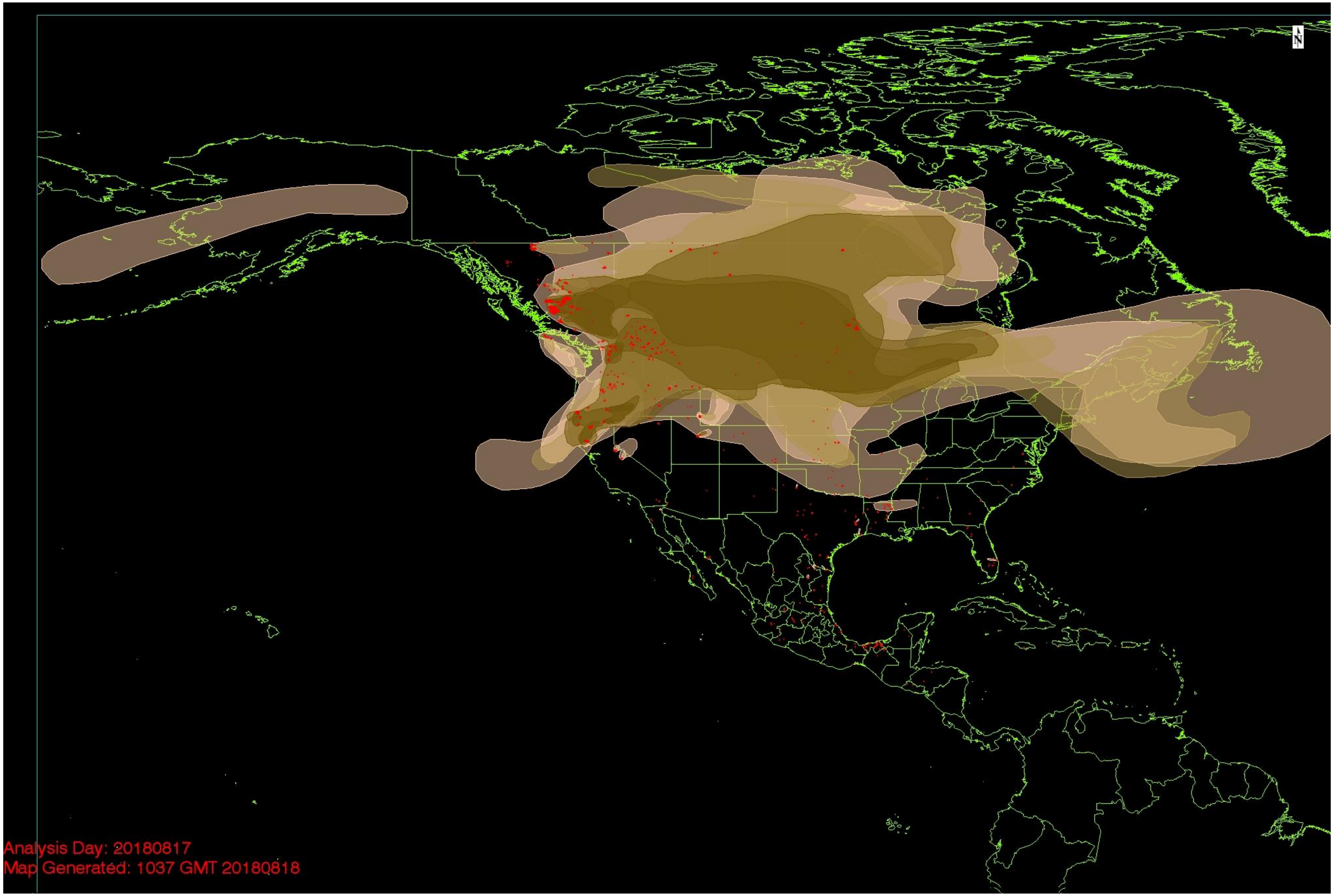
Good	0 to 50
Moderate	51 to 100
Unhealthy for Sensitive Groups	101 to 150
Unhealthy	151 to 200
Very Unhealthy	201 to 300
Hazardous	301 to 500



Wildfires are a Threat to Air Quality

- Emissions plumes from large wildfires contain:
  - Primary $PM_{2.5}$ and PM_{10} (smoke aerosols)
  - Nitrogen oxides (NO_x) and volatile organic compounds (VOCs): precursors for secondary formation of O_3 and $PM_{2.5}$
- Wildfires are becoming larger, more intense, and more frequent
  - Impact air quality **locally**, in vicinity of the fire
- Wildfire emissions plumes can be lofted above the boundary layer and remain relatively intact while traveling long distances, often hundreds of km
  - If the wildfire plume mixes to the surface **downwind**, it can substantially increase ambient O_3 and $PM_{2.5}$
- **Huge wildfires in western U.S. and Canada have been deteriorating local and downwind air quality across the CONUS in August 2018!**
  - **Example: week of Aug 13-17, 2018**

NOAA HMS Analysis: Aug 14-17, 2018



Smoke Transport in the News, Aug 16-17 *Washington Post* newspaper

Capital Weather Gang

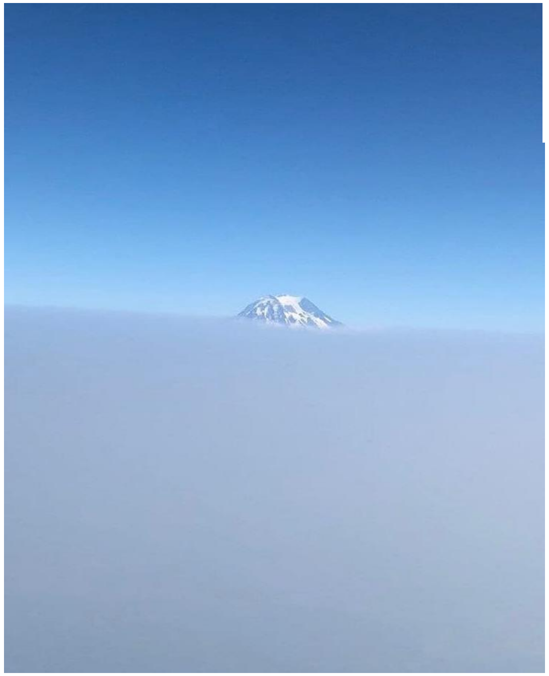
Smoke from California's wildfires is reaching Washington and Baltimore

By Jason Samenow, Weather editor
August 16

Lest anyone living in the D.C. area think Western wildfires are a problem 3,000 miles away, they might take a whiff of the air in their own backyard. Yes, high-altitude winds have carried the smoke across the country into the Mid-Atlantic region.

"I walked outside earlier and definitely smelled wildfire smoke," tweeted @annikaep from downtown Washington on Wednesday.

Capital Weather Gang readers queried on Twitter reported smelling smoke all over the region.



Capital Weather Gang

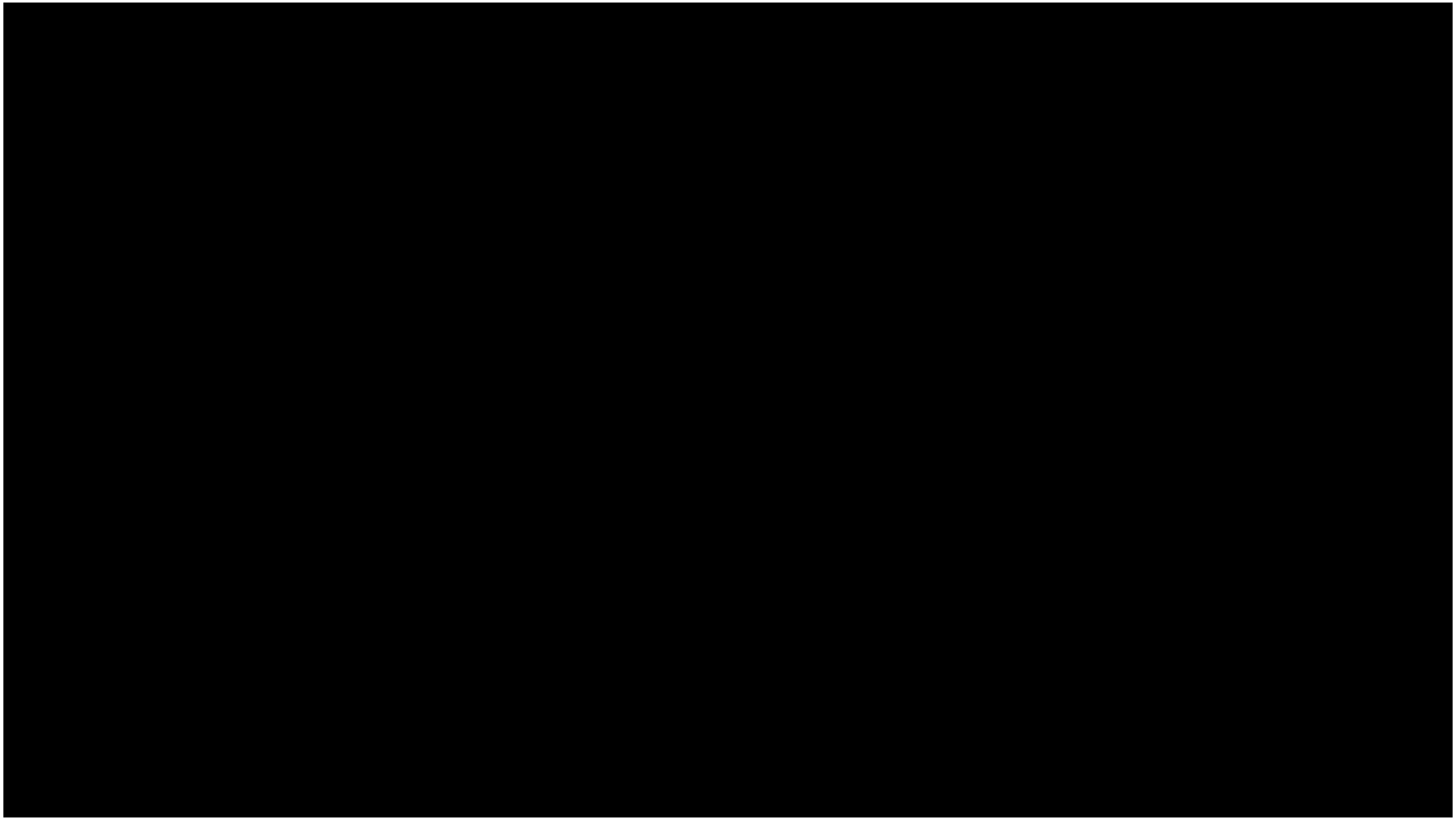
Mount Rainier looked like an iceberg floating in a sea of smoke earlier this week

By Kathryn Prociv
August 17

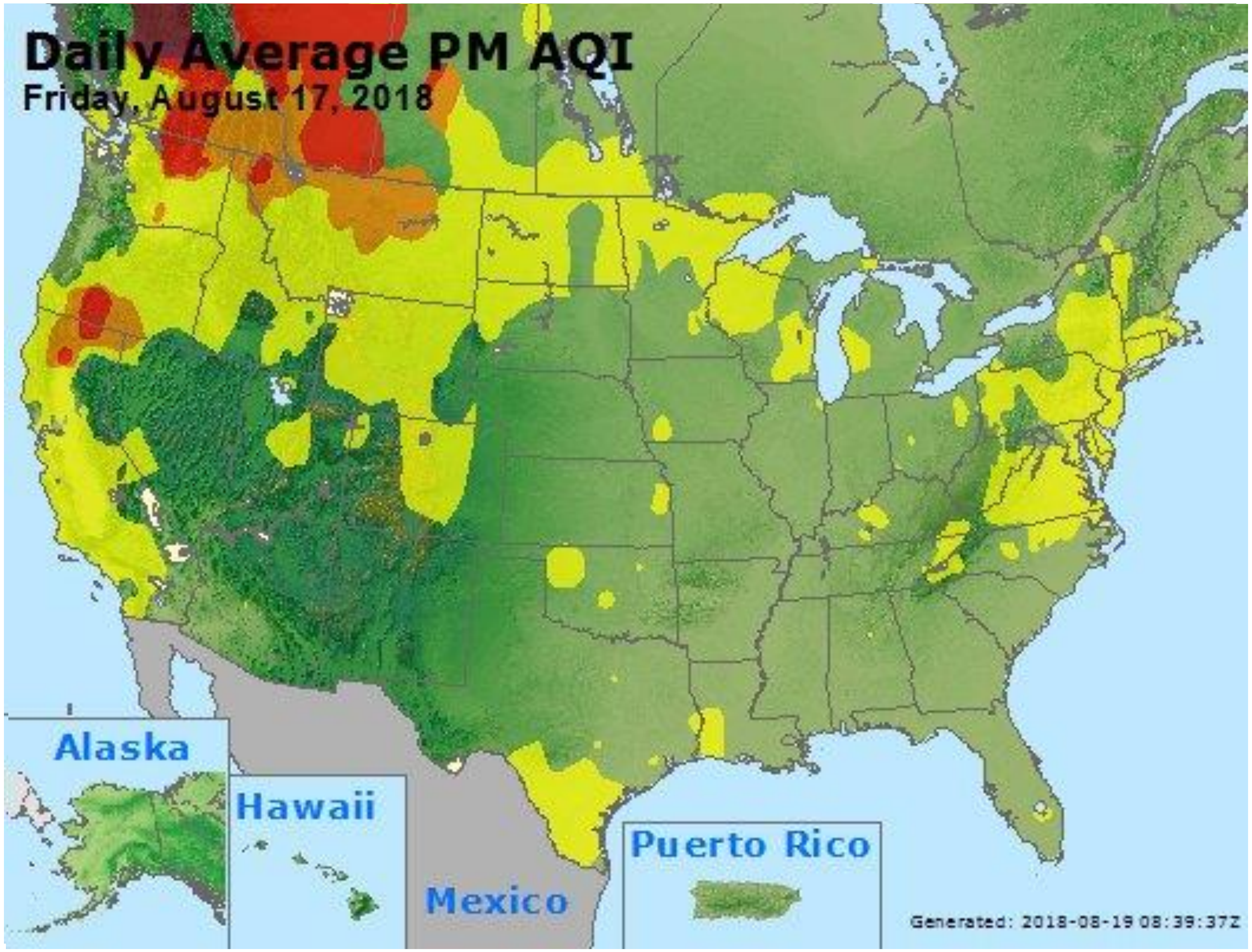
Capital Weather Gang

Wildfire smoke is choking Seattle, obscuring the view and blocking out the sun

Video of Thick Smoke on the Ground in British Columbia, Aug 17

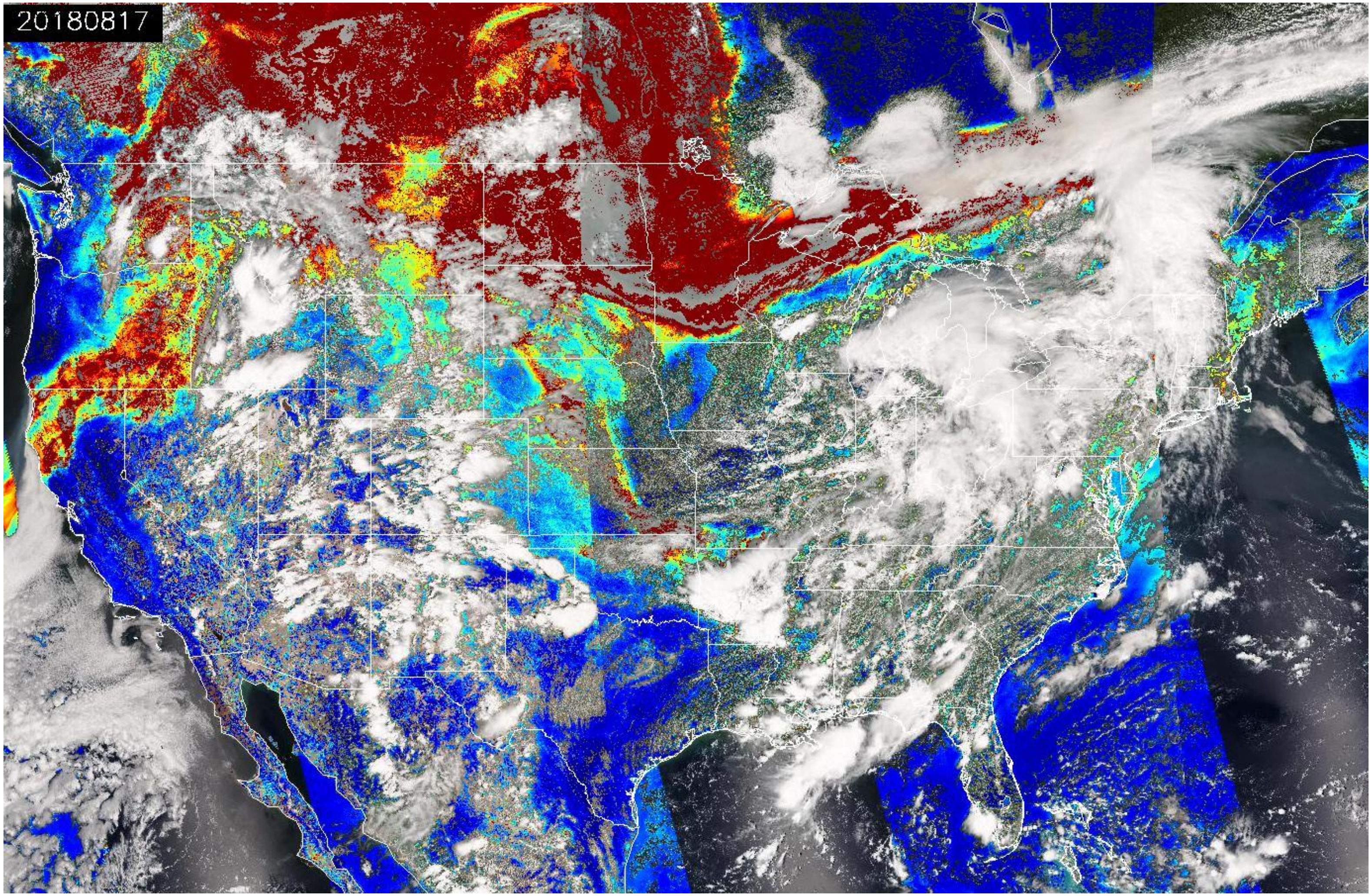


Observed Daily $PM_{2.5}$ Air Quality: Aug 14-17

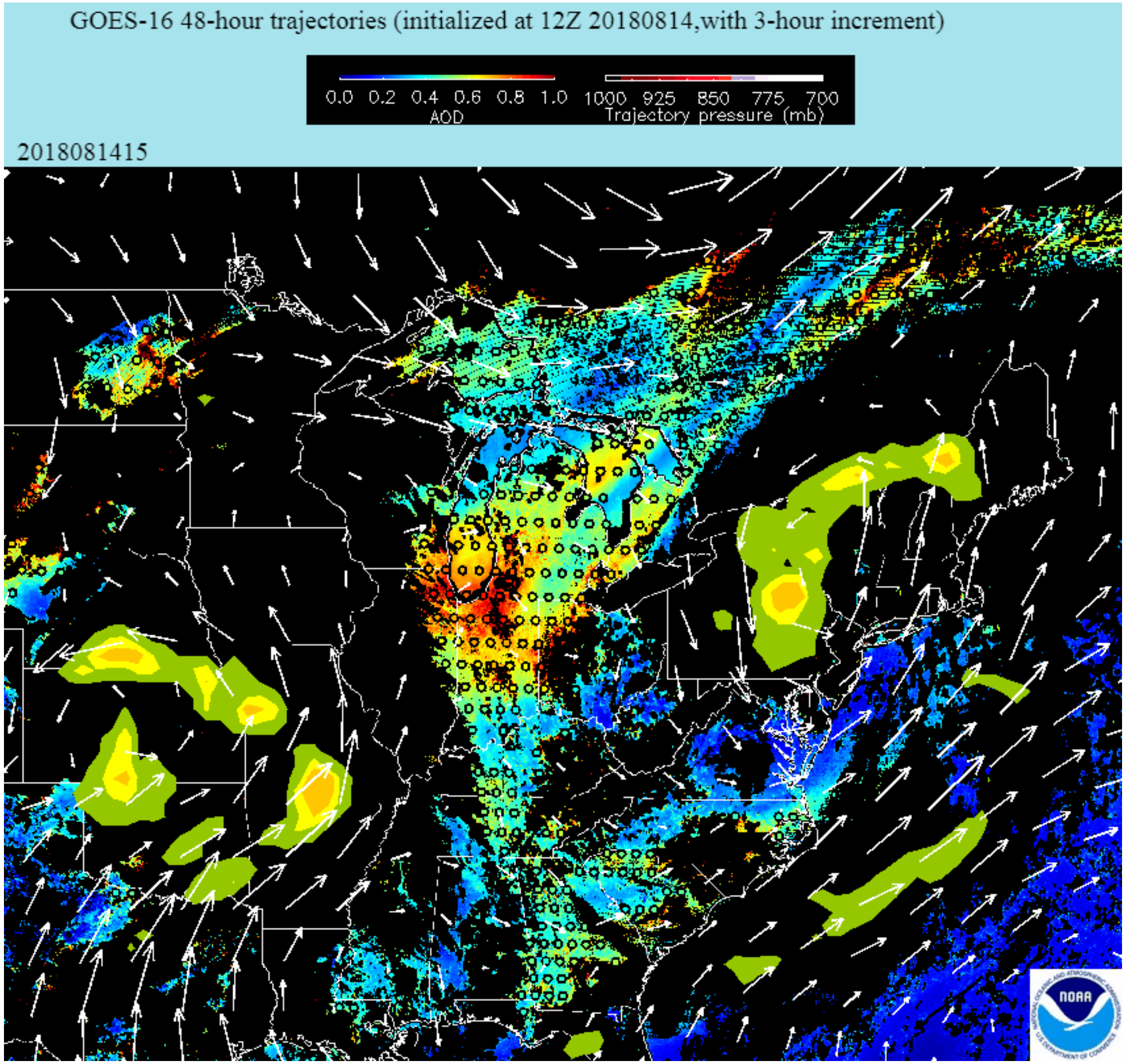


Good	0 to 50
Moderate	51 to 100
Unhealthy for Sensitive Groups	101 to 150
Unhealthy	151 to 200
Very Unhealthy	201 to 300
Hazardous	301 to 500

VIIRS SNPP RGB/AOT Captures Smoke Plumes: Aug 14-17



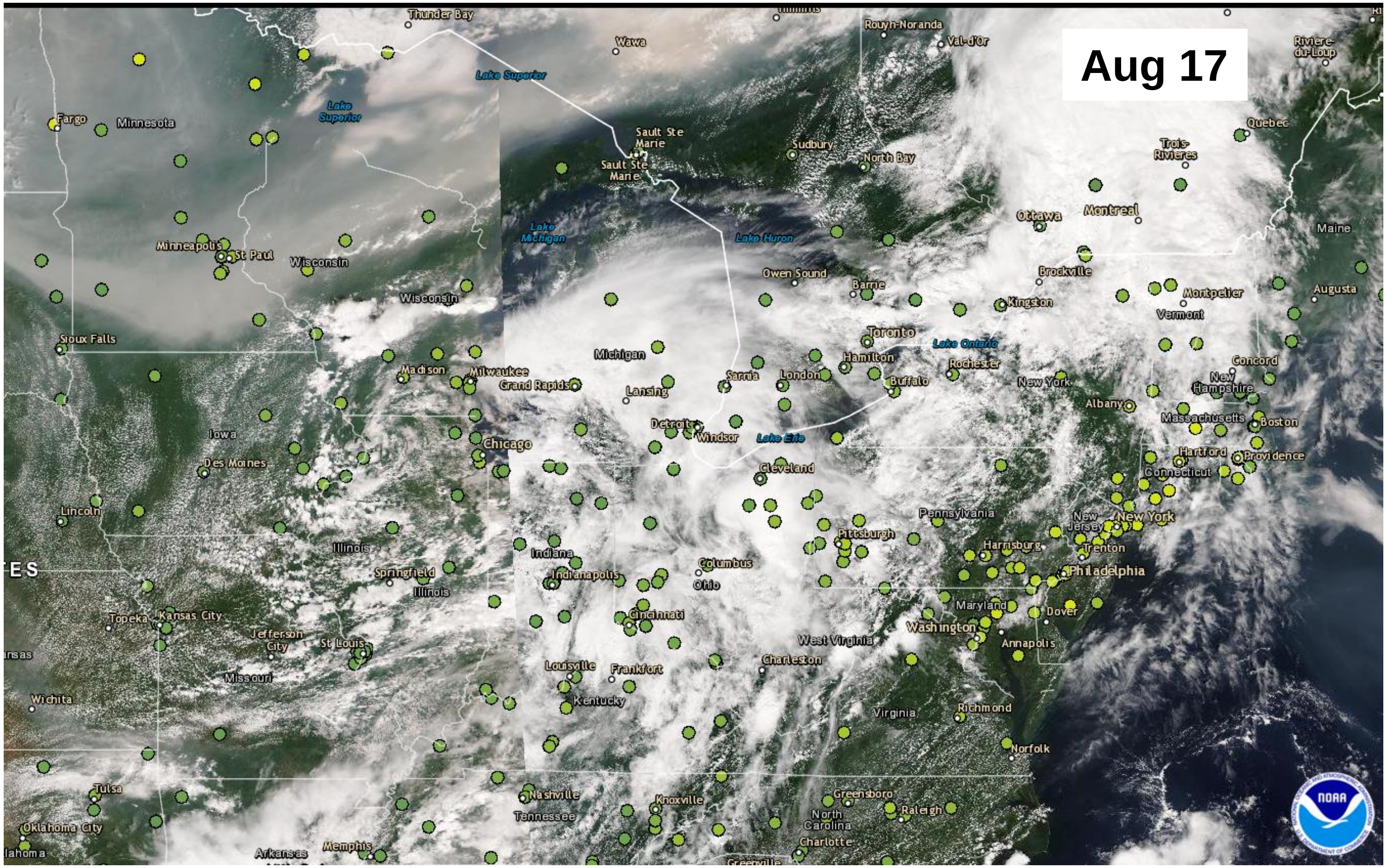
Where is the Smoke in the Great Lakes on Aug 14 Going to be on Aug 15?



Forecasting $PM_{2.5}$ in Mid-Atlantic

- Trajectories indicate 48-hr forward motion of aerosol plumes, vertically and horizontally
- Areas of high ABI AOD (>0.4) used as starting locations
- Trajectories initialized at 50, 100, 150, and 200 mb above surface
- Trajectories initialized with NAM 12Z run, plotted in 3-hr increments:
  - Pink: near surface
  - White: away from surface
- 850 mb wind vectors (white)
- 3-hr accumulated precipitation (yellow)

Smoke Moves into Mid-Atlantic: Aug 15-17



Good	0 to 50
Moderate	51 to 100
Unhealthy for Sensitive Groups	101 to 150
Unhealthy	151 to 200
Very Unhealthy	201 to 300
Hazardous	301 to 500

VIIRS NOAA-20 RGB and daily $PM_{2.5}$ observed ground-level concentrations from *AerosolWatch* website

VIIRS Data Supports Forecasting and Post-Analysis

- Satellite AOD essential for identifying smoke plume transport
  - Gives forecasters a heads-up when smoke may be heading toward forecast area
  - Use in conjunction with surface $PM_{2.5}$ measurements to determine when smoke is impacting surface air quality
- 48-hour aerosol trajectories critical tool for identifying when smoke will reach surface in forecast area (affecting local ambient $PM_{2.5}$ and O_3)
- New *AerosolWatch* website designed for operational users
  - Includes VIIRS aerosol imagery from **SNPP and NOAA-20**
- VIIRS AOD, smoke/dust mask, and aerosol trajectories critical for post-analysis, including Exceptional Event demonstrations
  - Petitions by states to U.S. EPA, showing exceedance of NAAQS was not due to local conditions, rather caused by “exceptional event”
  - Example: May 25-26 O_3 exceedances in CT, NJ, PA due to smoke transport from Ft McMurray wildfire in Alberta, Canada

VIIRS Cloud Product Status

Andrew Heidinger - NOAA/NESDIS/STAR
JPSS Cloud Team (STAR, CIRA, CIMSS and Aerospace)

Outline

1. NDE Status

1. Performance

1. User Feedback

1. Cloud Team’s Role in Alaska Cloud Demo

1. New Activities

NDE Status and Algorithm Maturity

NDE/STAR Cloud Production Status & Delivery

Algorithm	Suomi NPP	NOAA-20
February 2018 DAP August 2017 Science Code delivery **(v1r2)**	**NDE** **Currently in Operations since 1200UTC on 13 August 2018**	**NDE** **Currently in I&T since 28 March, 2018** (Ops after NOAA-20 provisional)
August 2018 DAP February 2018 Science Code delivery (**v2r0**)	**STAR** Systematic production since June, 2018 **NDE** Delivered in Aug 2018 (I&T after NOAA-20 provisional)	**STAR** Systematic production since June, 2018 **NDE** Delivered in Aug 2018 (I&T after NOAA-20 provisional)
Jan/Feb 2019 DAP August 2018 Science Code delivery (**v2r1**)	**Delivery and development in progress** Delivery schedule provided by ASSISTT	**Delivery and development in progress** Delivery schedule provided by ASSISTT

NOAA Enterprise Cloud Maturity

Algorithm	Suomi NPP	NOAA-20
Mask	Prov	Beta
Phase/Type	Prov	
Height	Prov	Beta
Day Opt Prop	Prov	Beta
Night Opt Prop	Prov	
Base	Prov	Beta
CCL	Prov	

NOAA-20 Provisional Reviews to be held in October 2018.

NOAA Enterprise Major Issue Status

- Missing Granules
  - Will be resolved after Aug 2018 DAP is integrated to NDE I&T and Ops string (see previous slides for implementation dates)

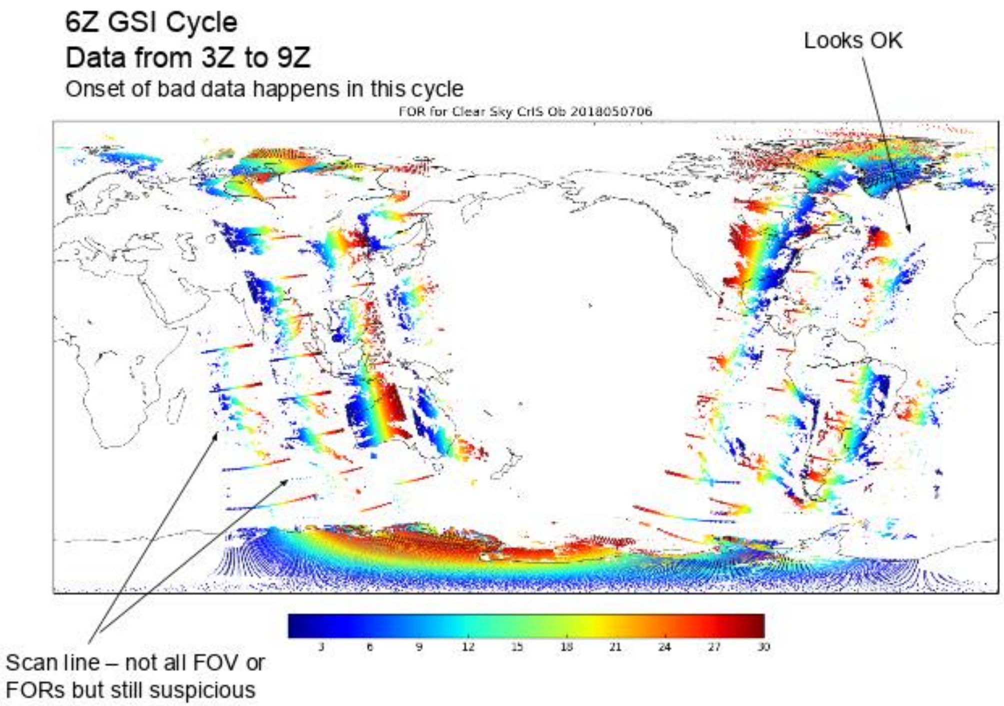
- Corrupted ECM Table
  - Solved.
  - Implemented to I&T string in June 2018 for NOAA-20 and NPP.
  - Implemented in operations for NPP at 12:00 UTC on 13 August 2018.

- M5 Calibration on SNPP

User Feedback

Use of VIIRS Cloud Products by NCEP

- NCEP uses the VIIRS cloud products to detect and characterize clear CrIS FOVs.
- Error detected due to the timeliness of an input file which could be missing. A fix has been identified and OSPO has received the required changes. Currently waiting for implementation for NPP & N20.
- Once data is corrected, NCEP will evaluate the CrIS radiance quality for data assimilation using the VIIRS cloud information.
- Potential to use CrIS/VIIRS information in CrIS radiance bias correction and/or assimilation of cloud information.



Missing files are being interpreted as clear data - NCEP won't use until this fixed.

Other External Users

- ESRL is pulling VIIRS Cloud Products from PDA. Won’t go forward in testing until missing granule issue resolved. Goal is assimilation at high latitudes.

- Alaska NWS will receive VIIRS products from CSPP LEO for the Alaska Cloud Demonstration (This Fall/Winter)

- NCEP is also exploring using VIIRS cloud products to improve high-latitude ATMS assimilation.

- NCEP has also expressed interest in VIIRS All-sky Radiance (ASR) similar to the GOES-16 ASR product which uses cloud mask and cloud height.

- Cloud Mask (led by Tom Kopp) continue to poll mask users and response to feedback. Thanks to those that attended breakout on Monday.

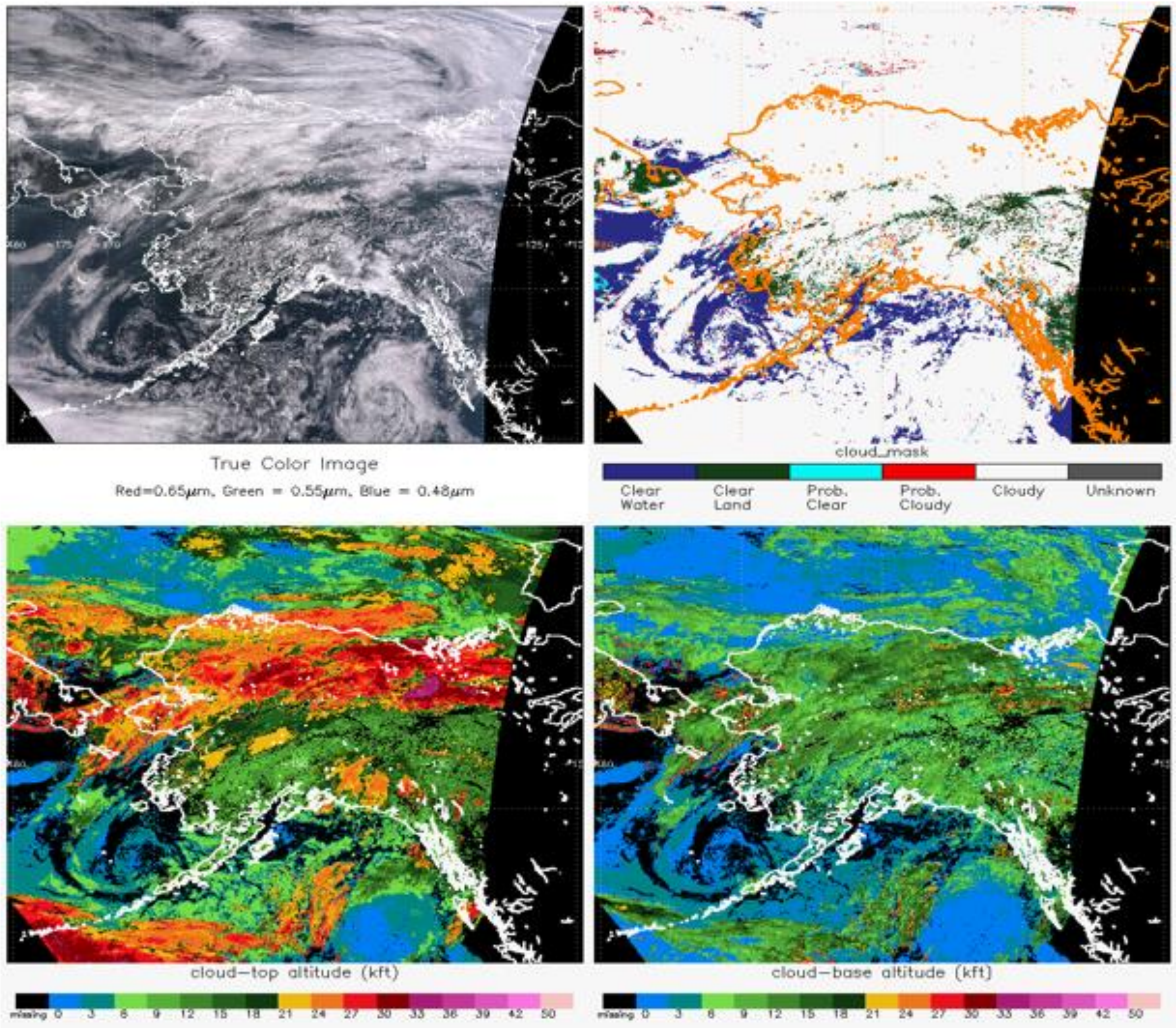
Alaska Cloud Product Demo

- Starting in the Fall 2018, the Cloud Team will support the generation of NOAA Enterprise Cloud Products from VIIRS DB Data from UA Fairbanks / GINA.
- Focus is on Aviation Support and participants will include the Alaska Aviation Weather Unit (AAWU).
- Products distributed into AWIPS and the Web via Polar2Grid.
- Product list will include
  - Cloud Top Altitude
  - Cloud Base Altitude
  - Cloud Cover Layers
  - Supercooled Water Probability
  - Precipitation (maybe)
- Key questions will be
  - Can VIIRS add anything to the model/in-situ existing capabilities?
  - How can we infuse satellite information into existing capabilities?

Cloud Demo Example: Cloud Top and Base Altitude

A day time scene from SNPP between 2248 and 2300 UTC on August 16, 2018 shows

- true color image (top left)
- cloud mask (top right)
- cloud top altitude (bottom left)
- cloud base altitude (bottom right)



Improved VIIRS Cloud Base over High Latitudes using ATMS funded by JPSS-RR (YJ Noh - CIRA)

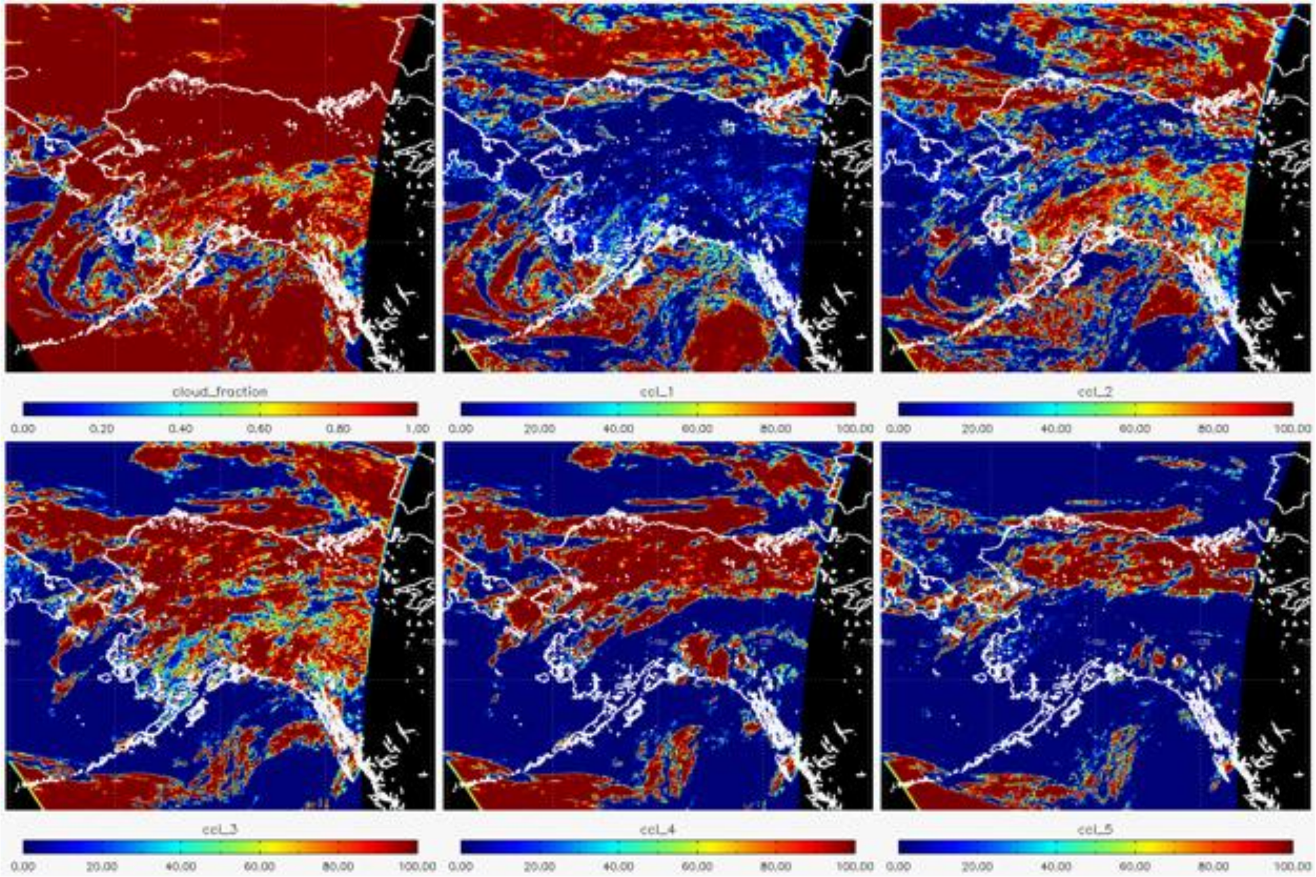
Cloud Demo Example: CCL Cloud Fraction

- Total cloud fraction (top left) and 5 layer cloud fractions indicate clouds are well distributed vertically

- The layer definitions are consistent with NOAT requirement (pressure levels are also supported)

- Layer 1 is the lowest layer and layer 5 is the highest

- Both cloud top and cloud base altitudes are used to identify clouds in different layers; other options (top only, top+base+lower level top) are also supported

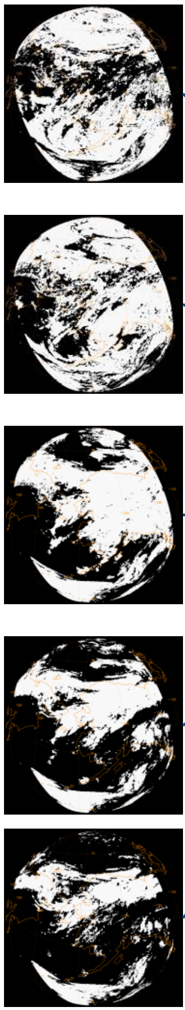


Cloud Demo Example: CCL Cloud Fraction

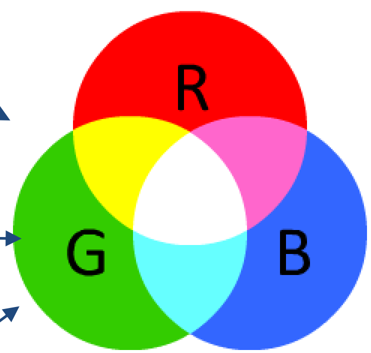
We will “demo” an RGB made from the 5 Cloud Layers defined by Flight Levels in addition to display each layer independently.

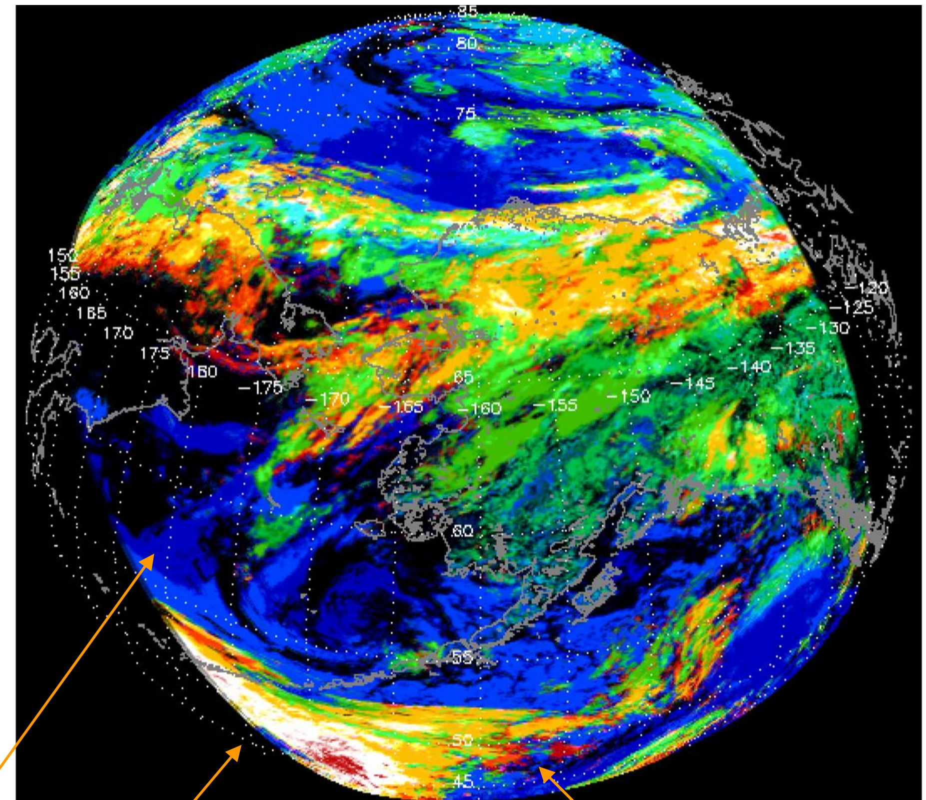
Cloud Layer

1
2
3
4
5



*R = 0.75*FL5 + 0.25 *FL4*
*G = 0.25*FL4 + 0.5*FL3 + 0.25*Fl2*
*B = 0.25*FL2 + 0.75*FL1*





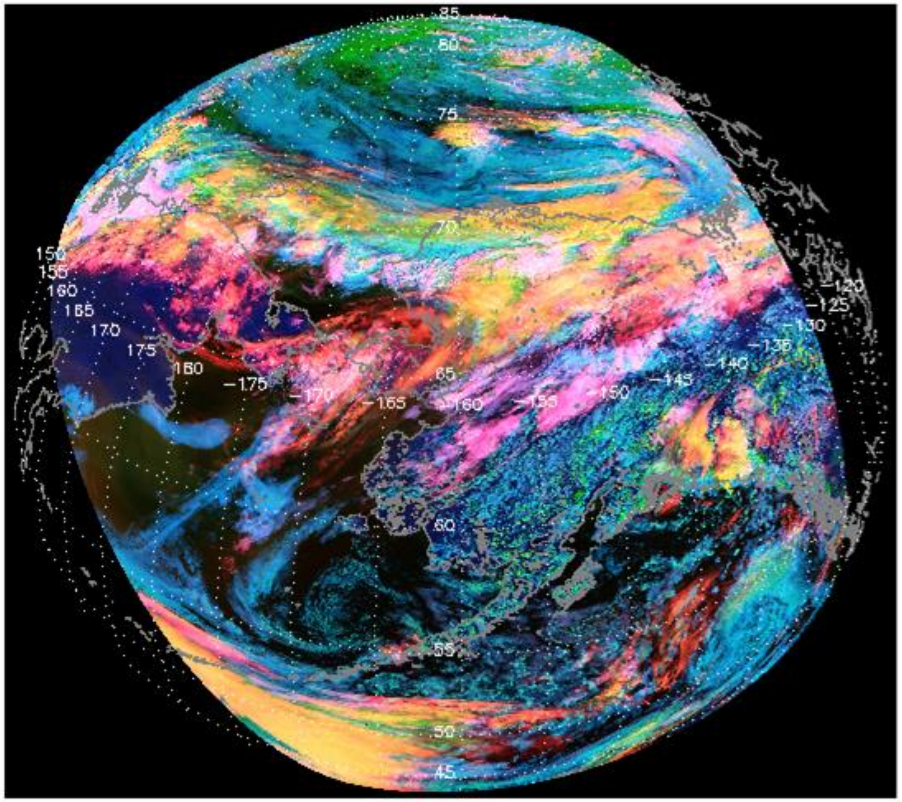
blue = unobscured low cloud

white = cloud in all layers

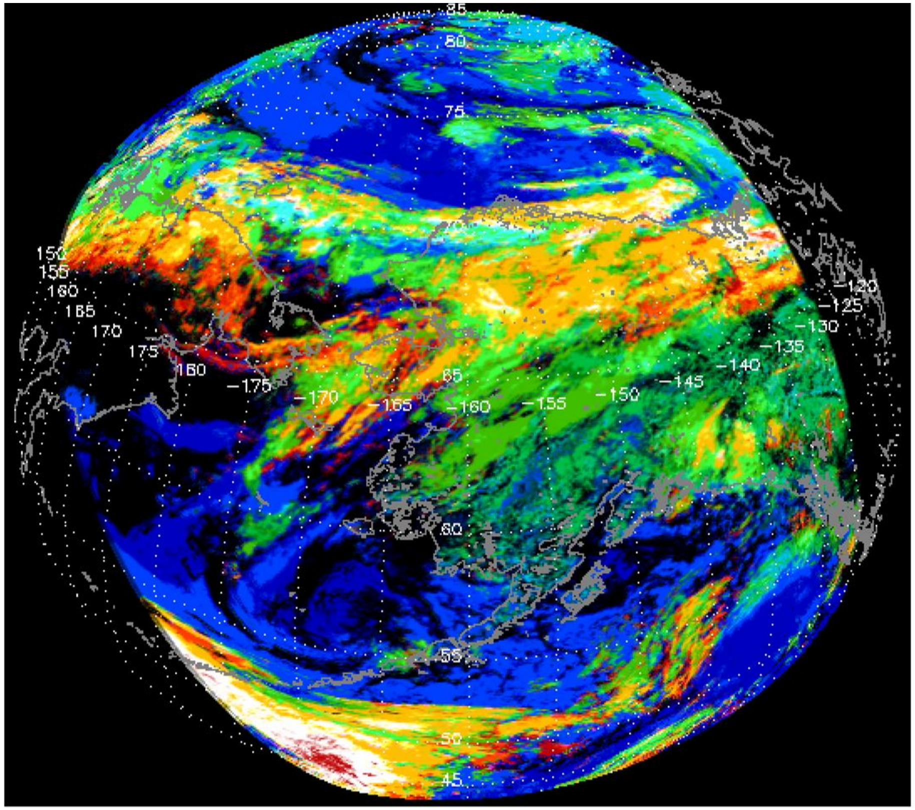
yellow = cloud in high and mid layers

Cloud Demo Example: CCL Cloud Fraction

We can compare this "cloud cover layer" RGB to an RGB using cloud height/phase sensitive channels. We'll provide both in the Cloud Demo



RGB from Red = 1.38 micron, Green = 0.65 micron and Blue = 1.6 micron

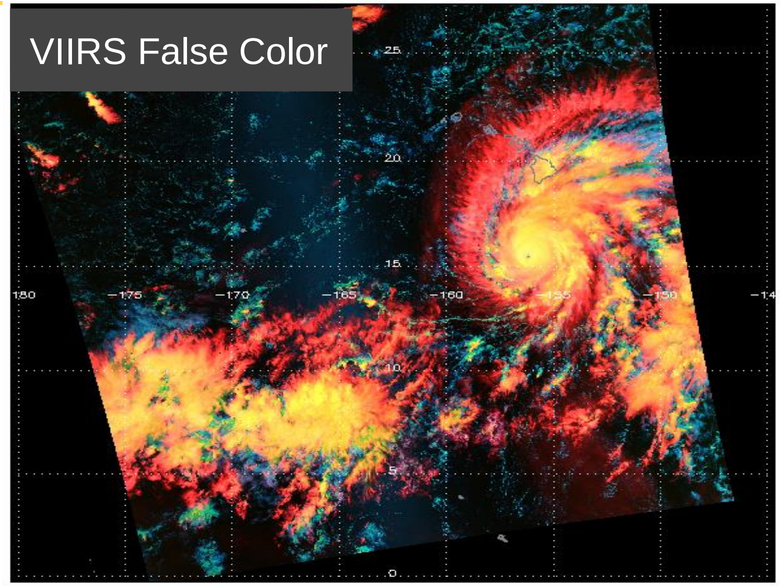


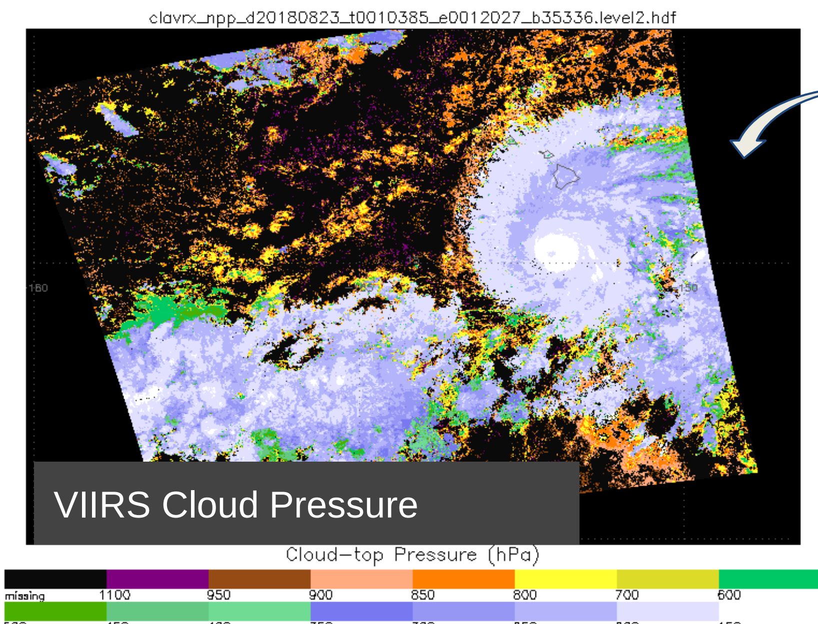
RGB from from the 5 Cloud Layer values.

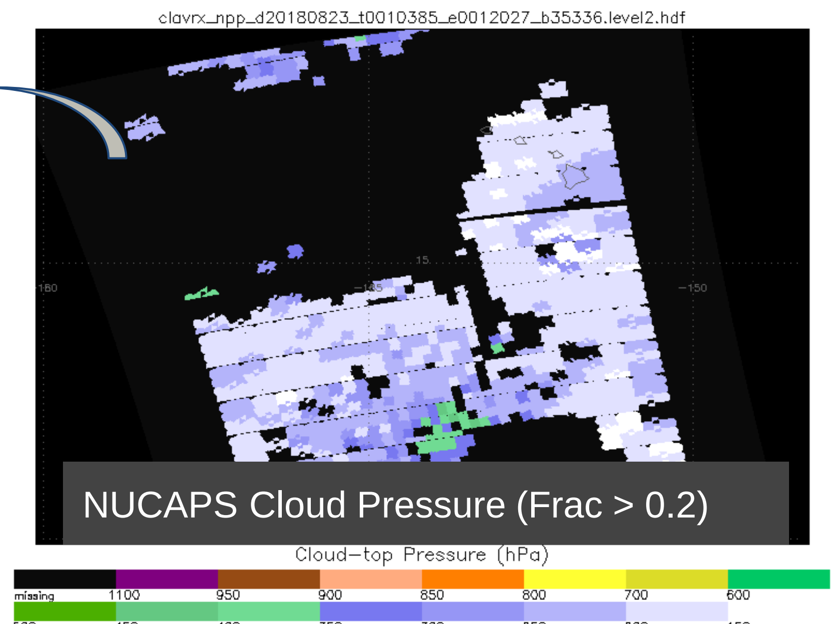
New Activities / Risk Reduction

JPSS RR: Using NUCAPS to Improve VIIRS Cloud Heights

- VIIRS Heights are used in Polar Winds, Aviation Decisions and in Assimilation.
- VIIRS has excellent spatial resolution but poor spectral resolution in the IR.
- CrIS is opposite (low spatial, fine spectral).
- JPSS RR is funding us to use the NUCAPS cloud product to improve the VIIRS products.
- ***Exploit Spectral, Preserve Spatial***

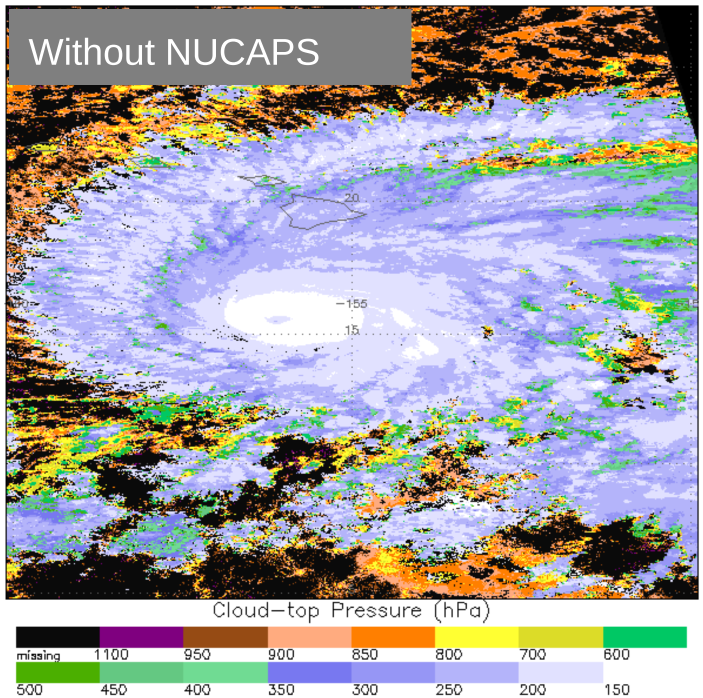






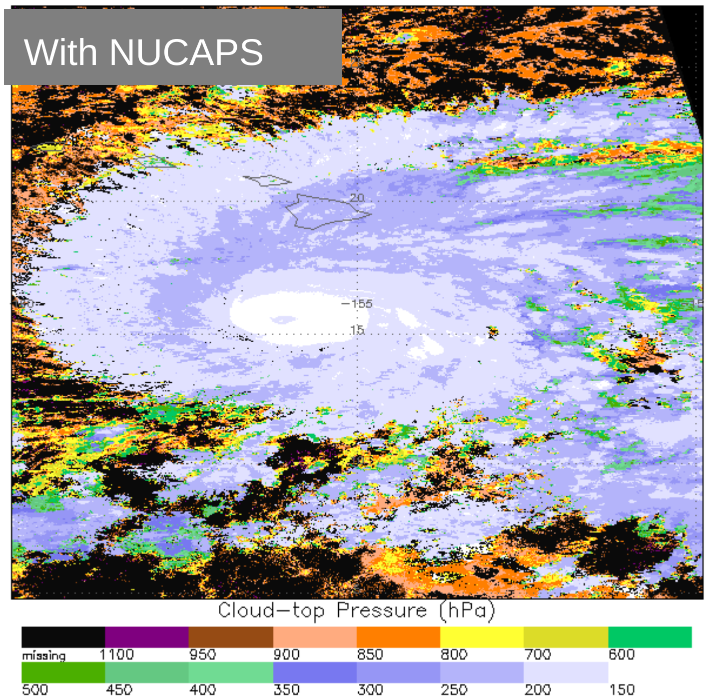
JPSS RR: Using NUCAPS to Improve VIIRS Cloud Heights

- NOAA Enterprise AWG Cloud Height Algorithm (ACHA) uses multiple imager IR bands and an optimal estimation (OE).
- OE can accept constraints from climatology or NWP.
- Here we use the NUCAPS cloud pressures and fractions as a new constraint.
- We colocate NUCAPS Edrs to the VIIRS M-bands using tools from SSEC.
- ***Initial results are promising. Just started.***



Impact is to

- ***Improve Cirrus Detection***
- ***Raise Cirrus Heights***
- ***Improve performance at cloud edges***



Impact of DNB on ECM

In the cloud mask images, red and cyan pixels are uncertain results.

Example of impact of lunar reflectance on cloud detection.

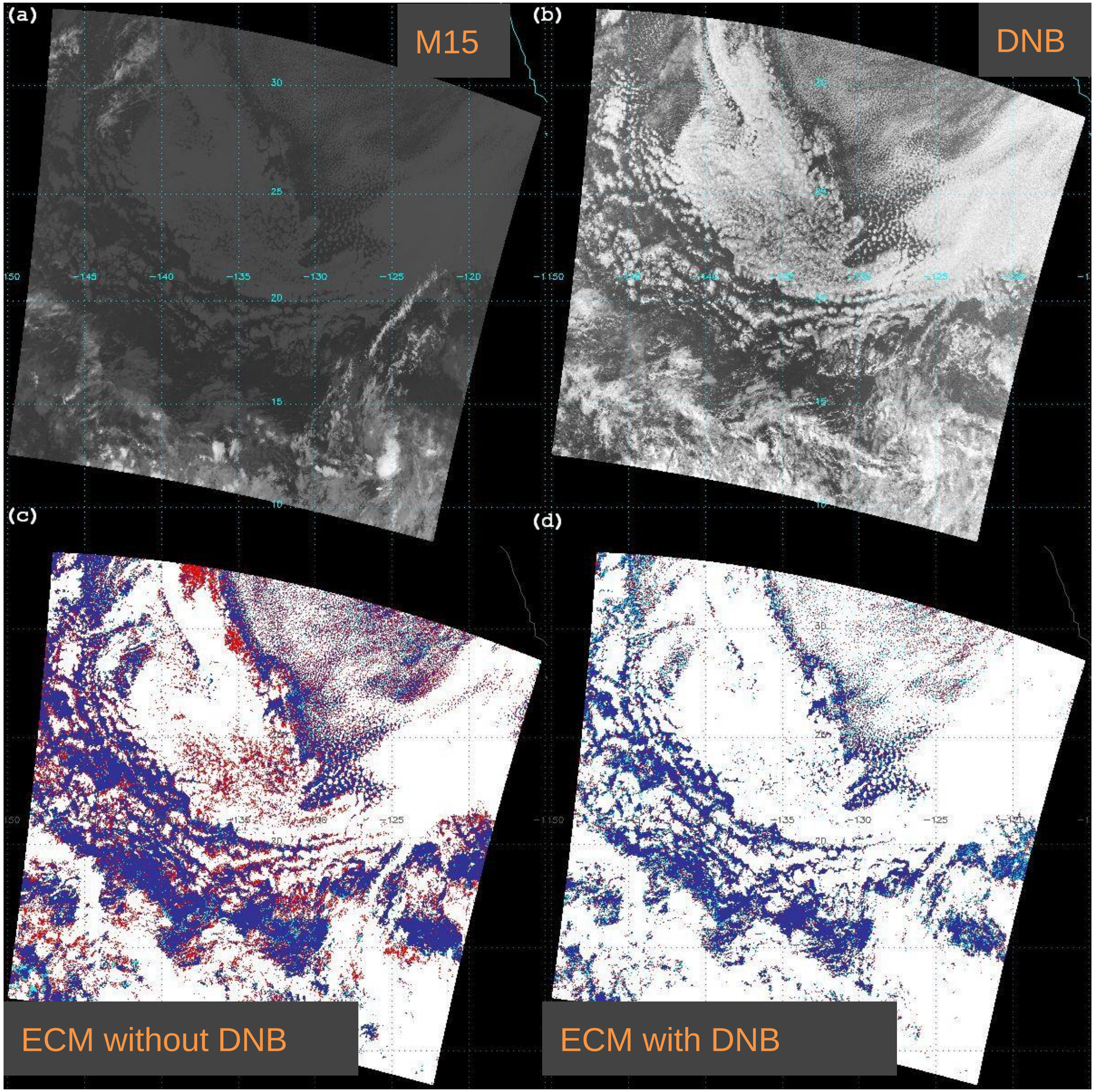
(a) shows an 11 micron brightness temperature from SNPP over the Pacific Ocean near the USA West Coast.

(b) shows the lunar reflectance for the VIIRS DNB.

(c) shows the NOAA Enterprise 4-level cloud mask without the use of the lunar reflectance.

(d) shows the NOAA Enterprise mask that uses the lunar reflectance.

Use of the lunar reflectance greatly reduces the number of uncertain cloud detection results especially in areas of low thin clouds with fine spatial features.

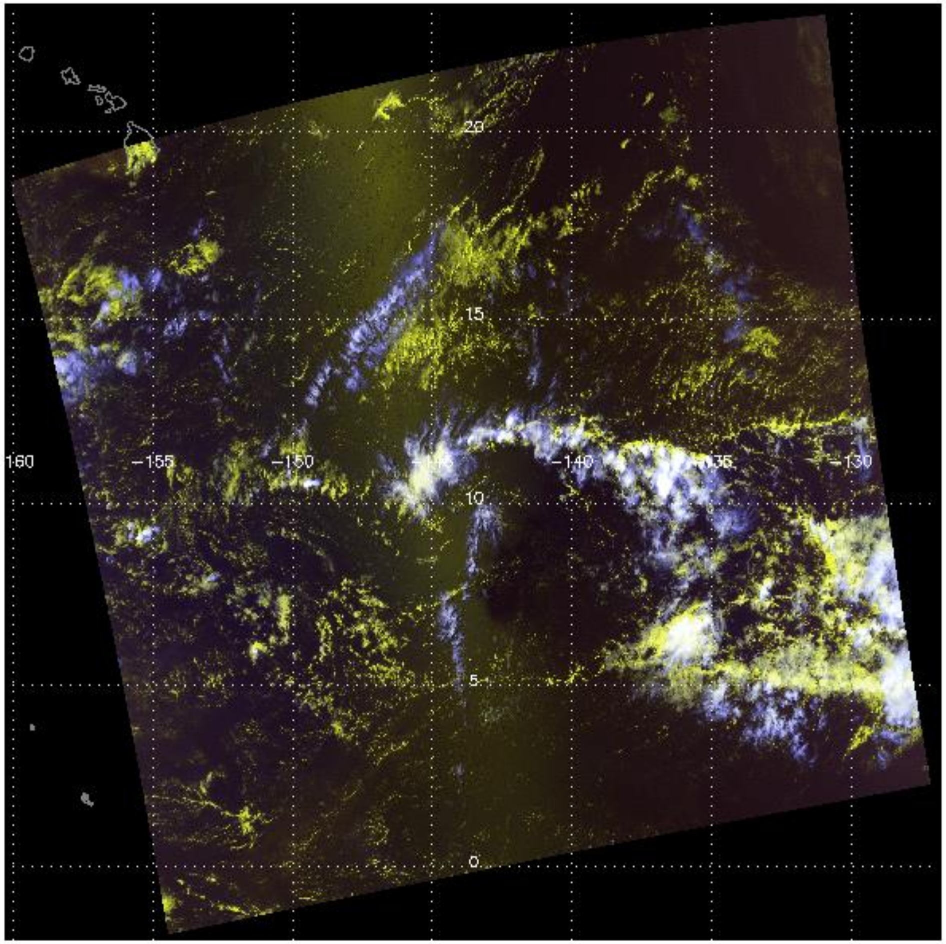


Use of I-Bands in ECM

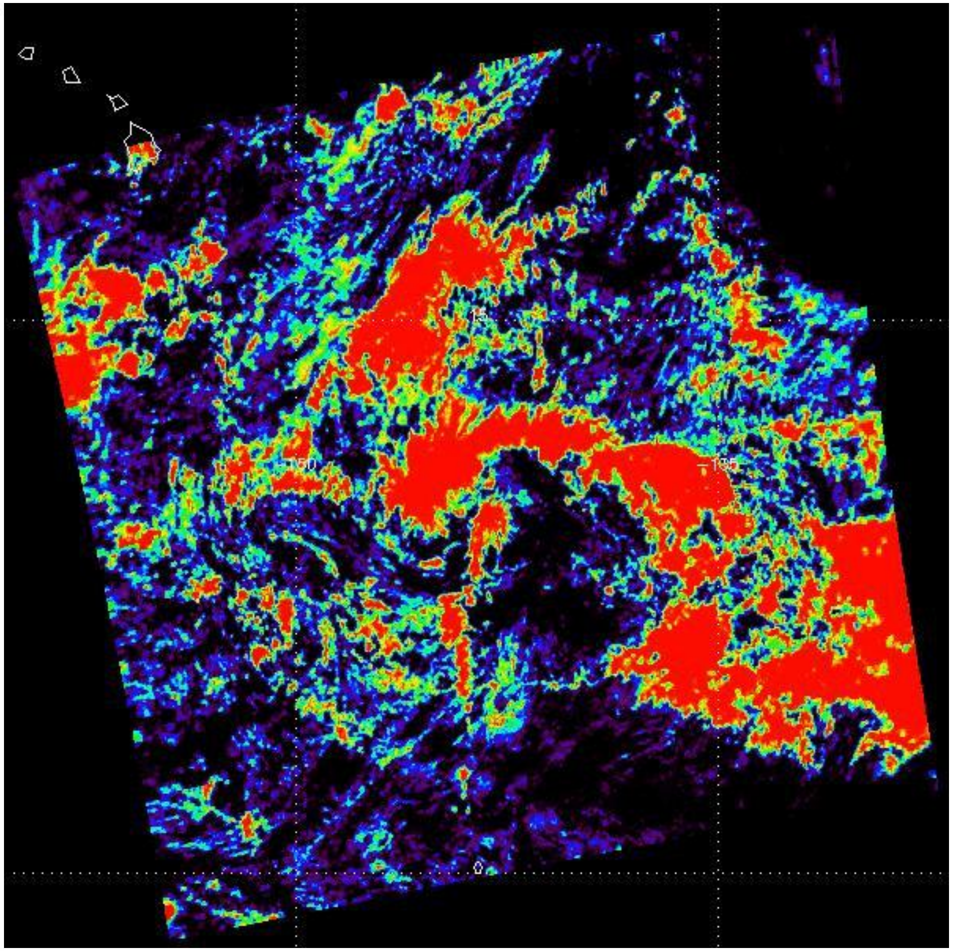
We can run the ECM using the min and max values of the analogous I-bands for relevant channels. This can greatly impact the yield of the cloud detection and benefit users.

The images show animations of 3 images. The first uses the darkest/warmest I-band, the second uses the nominal M-band s and the third uses brightest/coldest I-bands..

False Color from 0.65, 0.86 and 11 micron

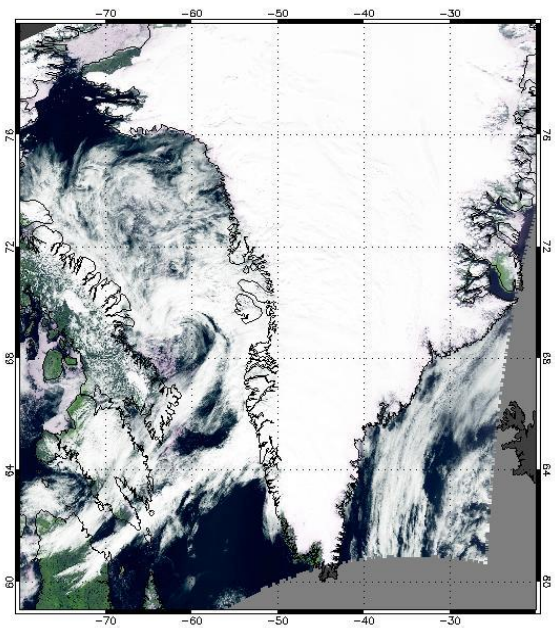


Total Cloud Fraction from CCL

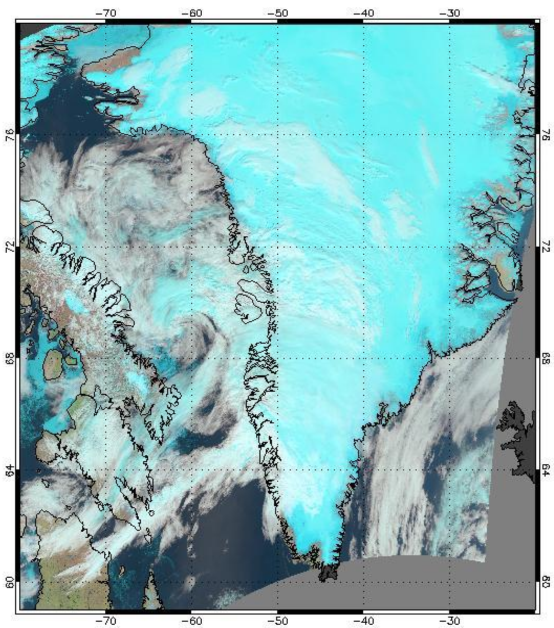


Improvements over snow and sea-ice surfaces

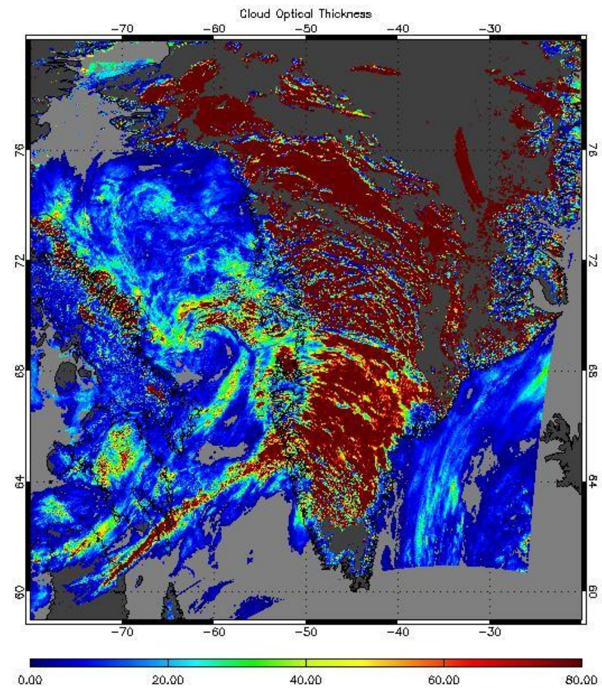
- Standard all-surface DCOMP runs on 0.6/2.2 micron channel combination.
- Bright snow surface made COD retrieval impossible for thin and medium thin clouds. The information depth of the algorithm is very low.



RGB [M5,M6,M11,M12] Clouds and snow surface are not distinguishable



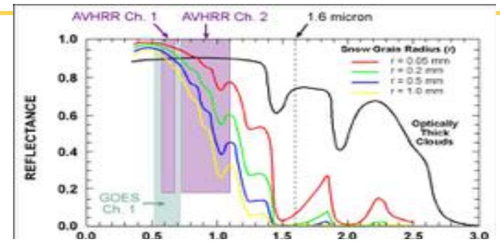
Enhanced RGB [M10,M6,M5]. illustrates how 1.6 micron channel [M10] helps separating clouds and surface.

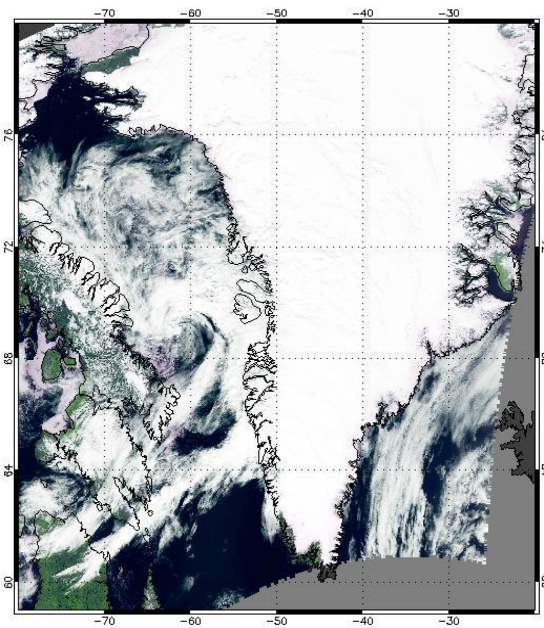


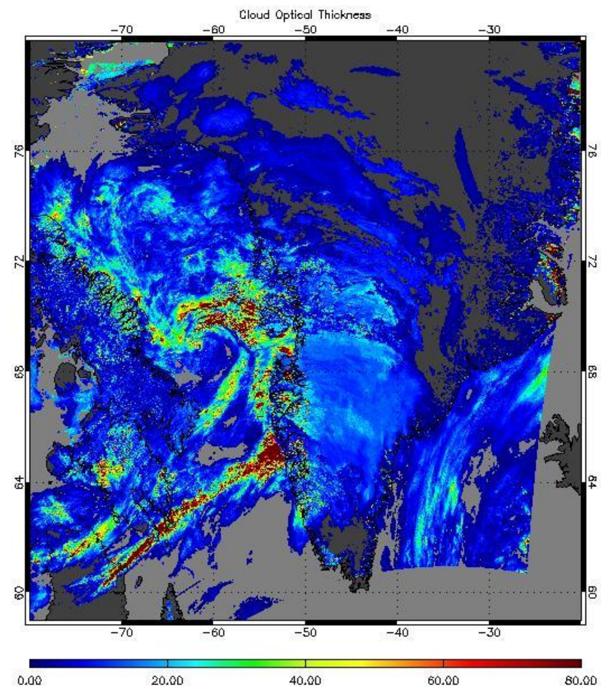
Cloud Optical Thickness from M5/M11 (0.6/2.2 microns) approach over snow has shown unrealistic high values.

Improvements over snow and sea-ice surfaces

- Recently included approach in CLAVR-x applies 1.6/3.75 channel combination [M10/M12]. [Platnick 2001]
- Advantage: 1.6 micron channel snow reflectivity is very low
- Figure right shows typical reflectance functions for clouds(black) and different snow types







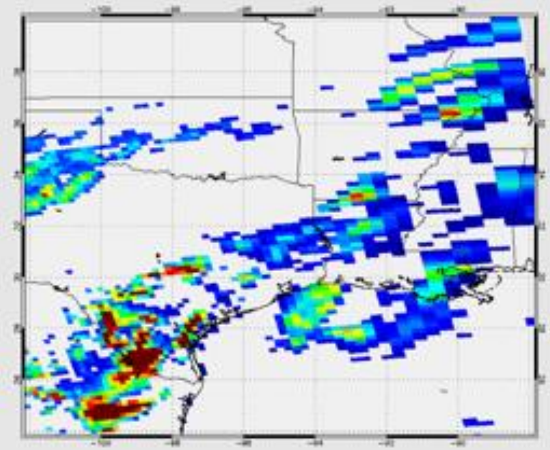
RGB [M5,M6,M15,M16]. Clouds and snow surface are indistinguishable if using only visible channels.

A “Snow” RGB employs channels M6(r),M10(g) M12(b)]. Snow surface appears red, clouds are white/yellish

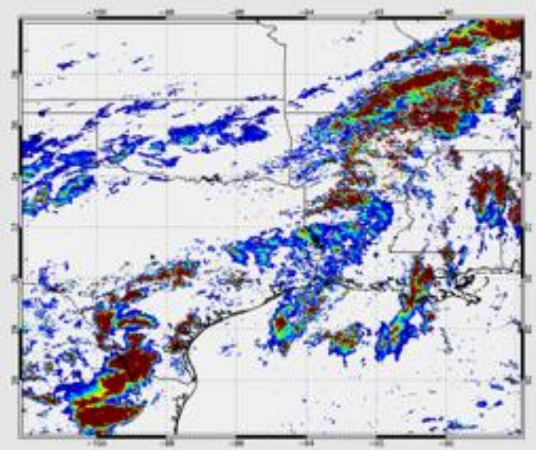
Cloud Optical Thickness images over snow show more realistic values if retrieved with 1.6 channel

Hybrid Cloud and Precipitation from VIIRS and ATMS

- **Microwave-based** (MW) rain rate retrievals such as MIRS retrieval applied to ATMS, are based on a physical approach.
- Spatial resolution is low, as well as accuracy over land.
- DCOMP and NLCOMP includes rain detection and rain rate retrieval from a **VIS/NIR approach** from VIIRS based on trained coefficients. Training linked cloud parameters COD, REF and Cloud Water path with truth data from NEXRAD.
- A **hybrid approach** uses MIRS/ATMS rain rate to adjust quantitative rain rates during processing. The method uses a factor to weight MW rain rates from ATMS, preserves the sub-pixel texture, corrects COD saturation effects for thick clouds.
- This effort enables us to analyze ATMS **sub-pixel precipitation** on a VIIRS grid.
- Advantages: Combining physically-based MW rain rates with high (VIIRS) **spatial resolution from VIIRS** cloud products. It retrieves rain detection and rate also **over land**.



ATMS Rain Rate



VIIRS Rain Rate after ATMS adjustment

Conclusions

- Usage of VIIRS Cloud Products by NCEP/ESRL is hindered by data production artifacts.

- Performance of these algorithms is good and we expect the resolution of these issues will allow NCEP/ESRL to begin using VIIRS.

- Blending or fusion with other sensors (CrIS and ATMS) offers opportunities for improved JPSS cloud products and some of this work is actively funded by JPSS-RR.

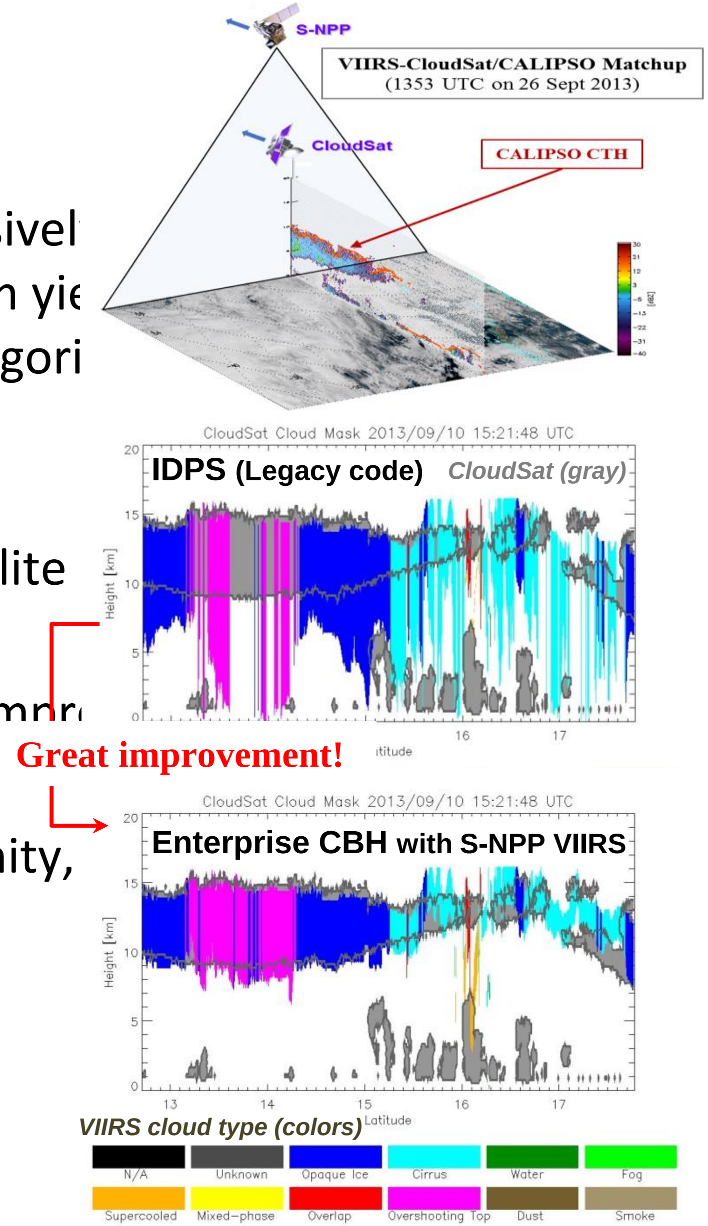
- NOAA Enterprise Cloud algorithms have been developed to benefit from the DNB and I-bands and these offer additional opportunities for improvements.

Thank You

Extra Material Follows

Enterprise Cloud Base Height

- Has been applied to S-NPP VIIRS and intensivel
CloudSat/CALIPSO, the Enterprise algorithm yie
performance over the original VIIRS IDPS algori
reqs
  - *Seaman et al. & Noh et al. (2017 JTECH)*
- Support both polar and geostationary satellite
NOAA Enterprise Cloud Algorithm Suite
- The CBH information is made available to impr
Layers product (not in the current DAP)
- Practical relevance to the aviation community,
feedbacks in numerical models

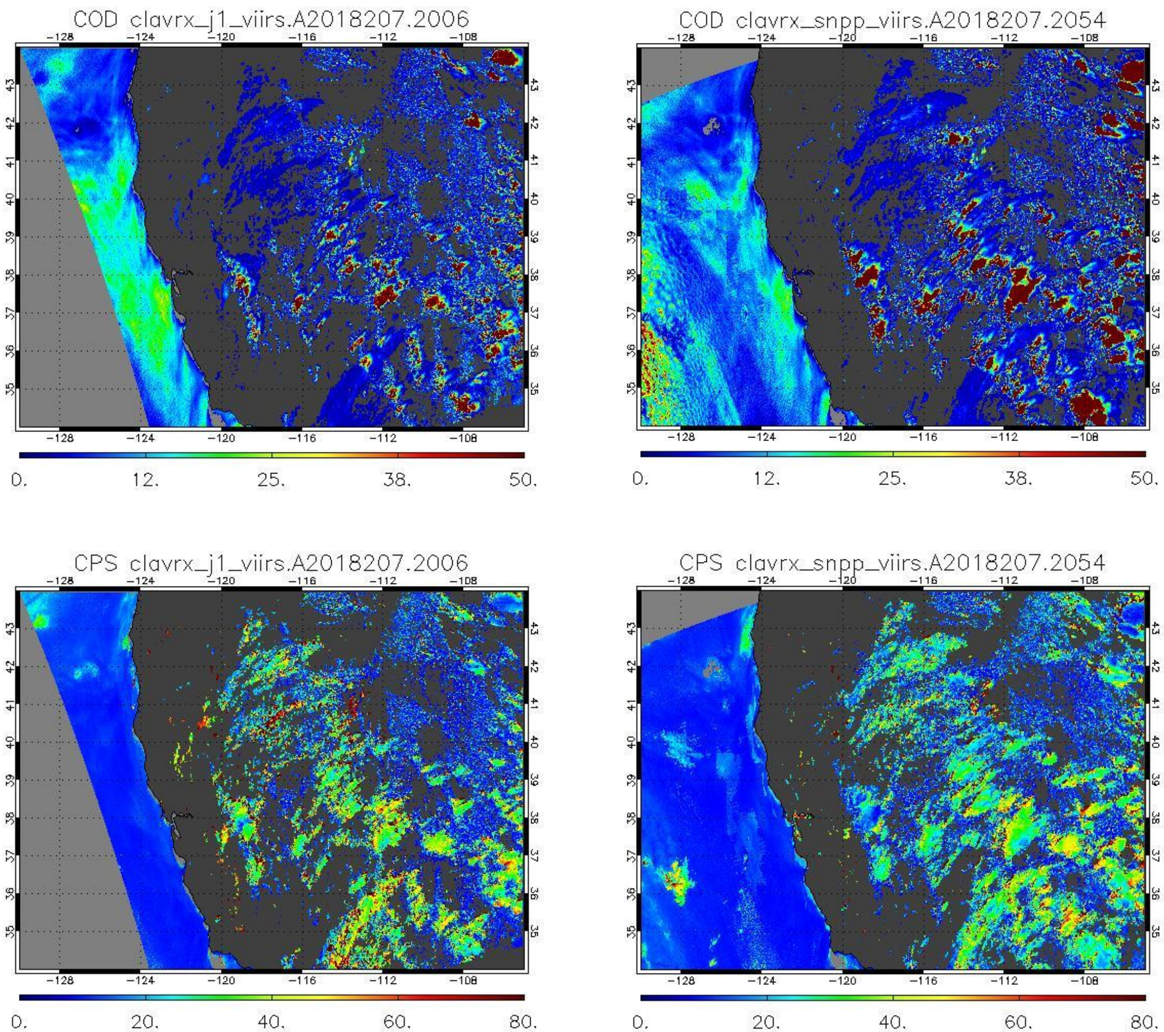


Cloud Optical Properties from SNPP and NOAA-20

NOAA-20 (aka JPSS-1) operates about 50 minutes ahead of Suomi NPP.

This constellation allows more studies of cloud diurnal developments from polar-orbiting satellites.

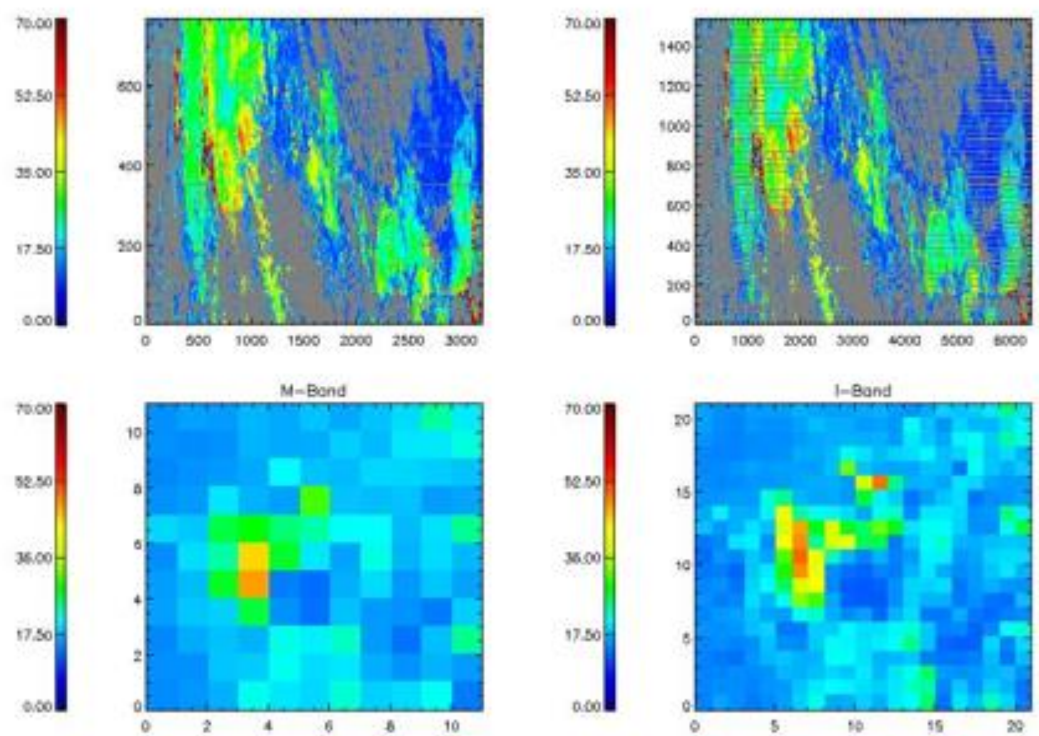
Images show an example of California coast from 26 July 2018 20:06 UTC (NOAA-20) and 20:54 UTC (S-NPP) for Cloud Optical Thickness and Cloud Particle Size.



DCOMP on I-band

Official NOAA Cloud Optical Products are retrieved on M-Band grid on a 2km x 2km grid.
We currently include an I-band DCOMP version to CLAVR-x.
Advantages: Higher spatial resolution allows us to use sub-pixel information, and to detect extreme values.
Potential use cases: Detecting convective cores and small-scale cloud particle size dynamics to predict the genesis of severe convective events.

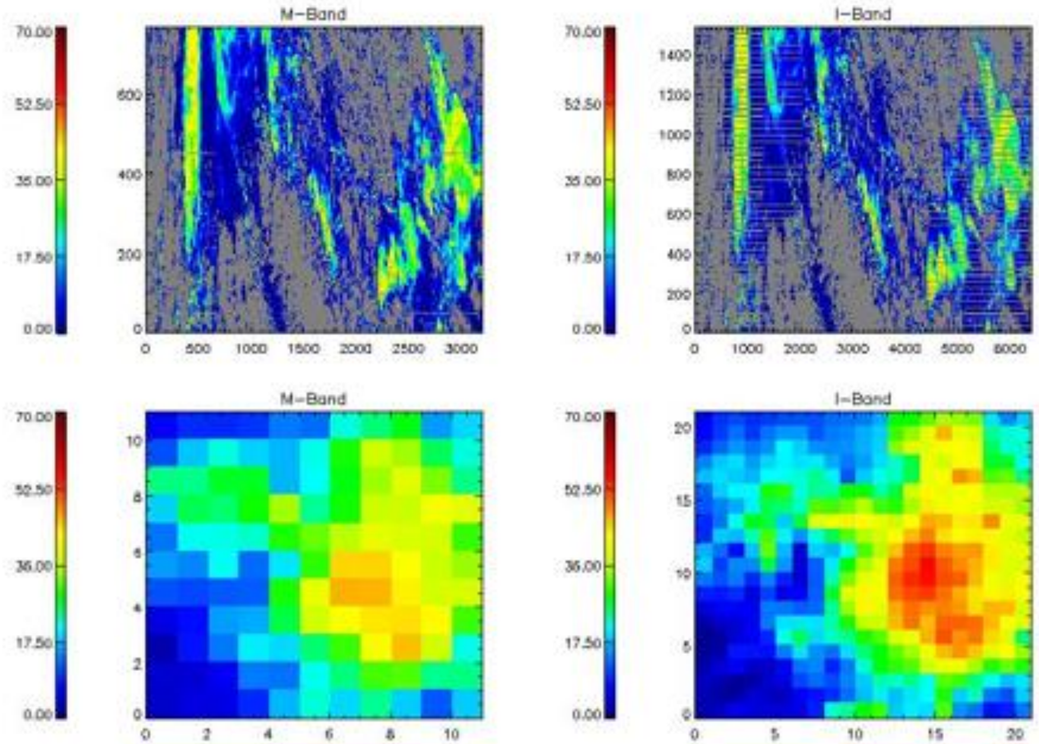
Cloud Effective Radius



DCOMP on I-band

Official NOAA Cloud Optical Products are retrieved on M-Band grid on a 2km x 2km grid.
We currently include an I-band DCOMP version to CLAVR-x from I1/I3 channel combination.
Advantages: Higher spatial resolution allows us to use sub-pixel information, and to detect extreme values.
Potential use cases: **Detecting convective cores** and small-scale cloud particle size dynamics to predict the **genesis of severe convective events**.

Cloud Optical Thickness



VOLCANIC ASH EDR

NOAA/NESDIS/STAR
608-263-9597; Mike.Pavolonis@noaa.gov
Mike Pavolonis (STAR)
Justin Sieglaff (UW-CIMSS)
Jason Brunner (UW-CIMSS)

Outline

- Cal/Val Team Members
- Algorithm Overview
- S-NPP/N-20 Product(s) Performance
- Major Risks/Issues and Mitigation
- Milestones and Deliverables
- Future Plans/Improvements
- Summary

Cal/Val Team Members

PI	Organization	Team Members	Roles and Responsibilities
Mike Pavolonis	NOAA/NESDIS/ STAR	Justin Sieglaff (UW-CIMSS), Jason Brunner (UW-CIMSS)	EDR algorithm development, refinement, validation, product review and delivery

Algorithm Overview

Instrument: VIIRS

Channels: 8.5 (M14), 11 (M15), and 12 μm (M16)

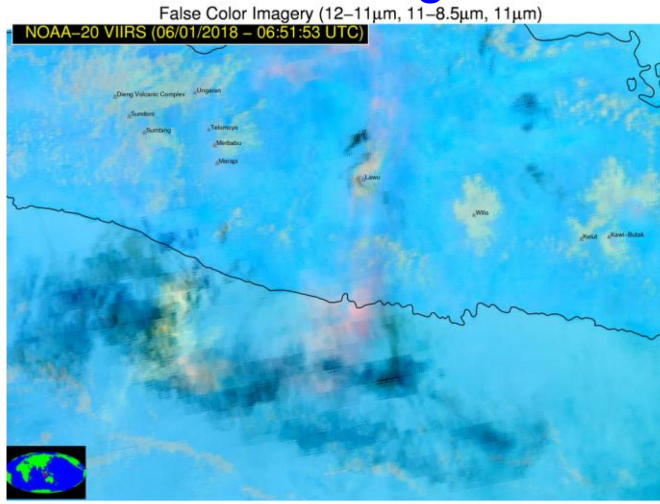
Ancillary data: GFS and OISST

Ash detection: differential absorption (Pavolonis 2010)

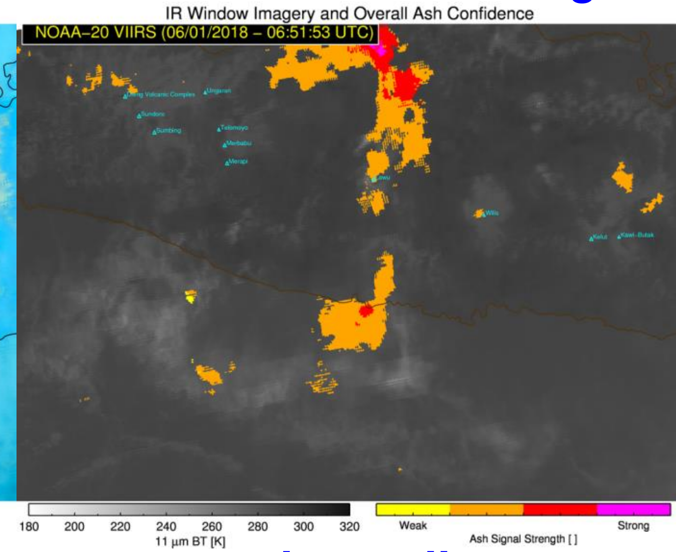
Ash properties: optimal estimation (Pavolonis et al., 2011)

Algorithm is the same as the baseline GOES-R algorithm except it does not utilize IR absorption channels

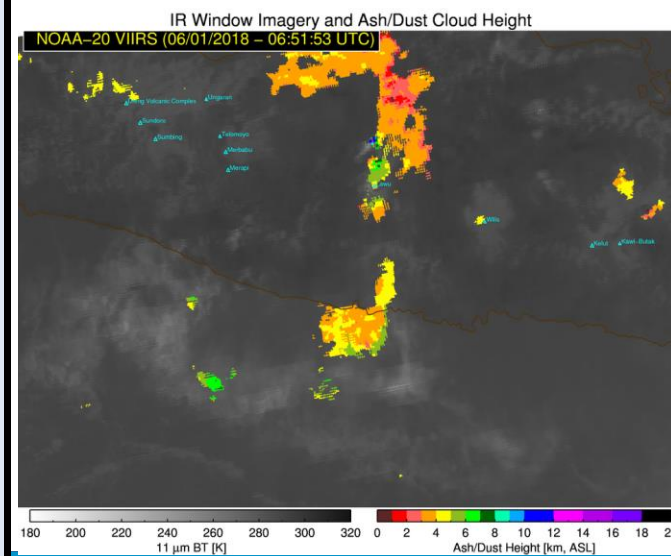
RGB Image



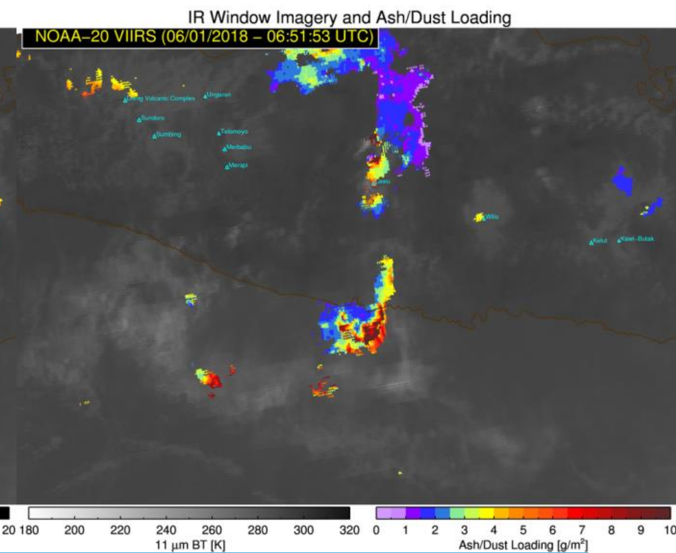
Ash Detection Flag



Ash Height



Ash Loading



S-NPP/N-20 Product(s) Overview

- Product(s) Performance Summary

Product	L1RDS APU Thresholds	S-NPP Performance	N-20 Performance
Ash Top Height	3 km	-1.9 km	~ 2 km (preliminary)
Ash Mass Loading	2 tons/km^2	1.1 tons/km^2	~1.5 tons/km^2

Wind correlation, comparisons to space-based lidar, and comparisons to other well characterized satellite products are the primary validation techniques

Major Risks/Issues and Mitigation

Risk/Issue	Description	Impact	Action/Mitigation
N20 Product Availability	NOAA-20 products are currently generated in the Integration and Testing string of NDE and are often unavailable (high impact on volcanic ash since this significantly reduces the number of validation opportunities).	High	Possible delay of provisional review until enough volcanic ash cases, sufficient for validation analysis, are collected
Underutilization of JPSS	The JPSS NDE algorithm only exploits a fraction of the JPSS capabilities. More sophisticated multi-sensor approaches have been, and continue to be, developed	Medium	A new PGRR initiative will develop, test, and evaluate a multi-sensor approach

Milestones and Deliverables

- FY19 Milestones/Deliverables

Task	Description	Deliverables	Scheduled Date
Development	Pursue algorithm enhancements	Cost benefit analysis	Sep 2019
Integration & Testing	Prepare for NOAA-21 and S-NPP and NOAA-20 updates	Updated algorithm code, NOAA-21 LUT	Sep 2019
Calibration & Validation	Comparison of volcanic ash products with validation data	Accuracy statistics	Sep 2019
Maintenance	Refine thresholds and LUTs for S-NPP and NOAA-20 as needed	Updated code and ATBD	Sep 2019
Long-term monitoring	Develop long-term monitoring tools	A tool for alerting when product anomalies are detected	Sep 2019

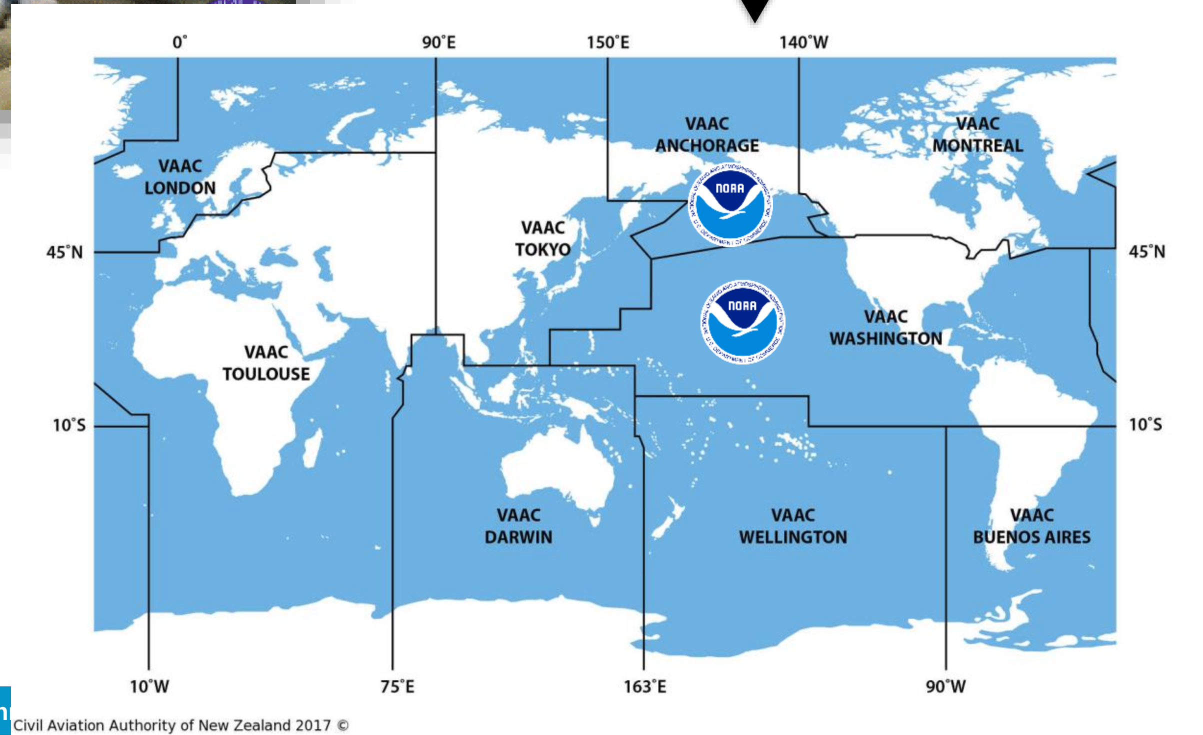
Future Plans/Improvements

- Volcanic ash products should be generated using a holistic approach that integrates all relevant components of the volcanic hazard problem, using all relevant measurements (JPSS and non-JPSS).

User Needs

Major Aviation Hazard

Operational Mandate



Key Operational Questions:

1). Has an eruption occurred?

2). Where is the ash/SO_2 now?

3). How much ash/SO_2 is present?

4). Where will the ash/SO_2 be in the future?

Volcanic Hazards Initiative

Core Research Team: Mike Pavolonis (PI, NOAA/STAR), Simon Carn (Michigan Tech), Alice Crawford (NOAA/ARL), Christoph Kern (USGS), Taryn Lopez (University of Alaska - Fairbanks), Dave Schneider (USGS), Ariel Stein (NOAA/ARL)

Core User Team: Jamie Kibler (NOAA – Washington VAAC), Christina Neal (USGS), Jeff Osiensky (NWS – Anchorage VAAC), Dave Schneider (USGS), Bill Ward (NWS PRH)

Key Operational Questions:

1). Has an eruption occurred?

- **Volcanic eruption alerts for ash and SO_2 emissions**

2). Where is the ash/SO_2 now?

- **Highly skilled automated volcanic ash and SO_2 detection and tracking**

3). How much ash/SO_2 is present?

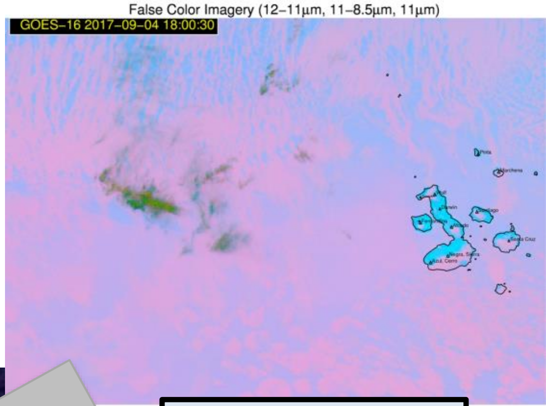
- **Retrievals of ash height, ash loading, ash effective radius, dominant mineral composition, SO_2 height, and SO_2 loading**

4). Where will the ash/SO_2 be in the future?

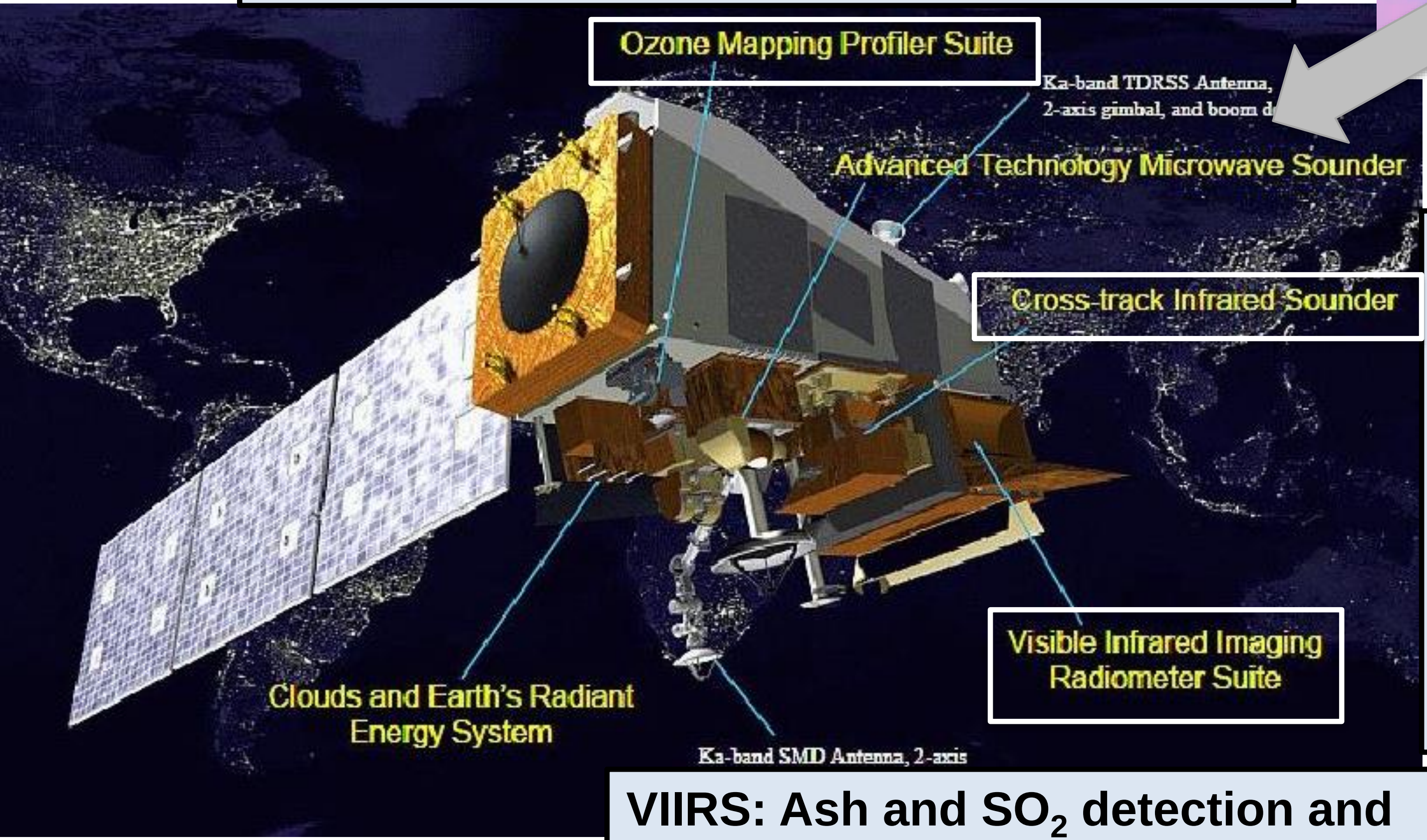
- **Integration of satellite products and HYSPLIT (dispersion model)**

Volcanic Hazards Initiative

OMPS: SO_2 detection and characterization, ash in optically thick clouds (SZA limited and course spatial resolution)



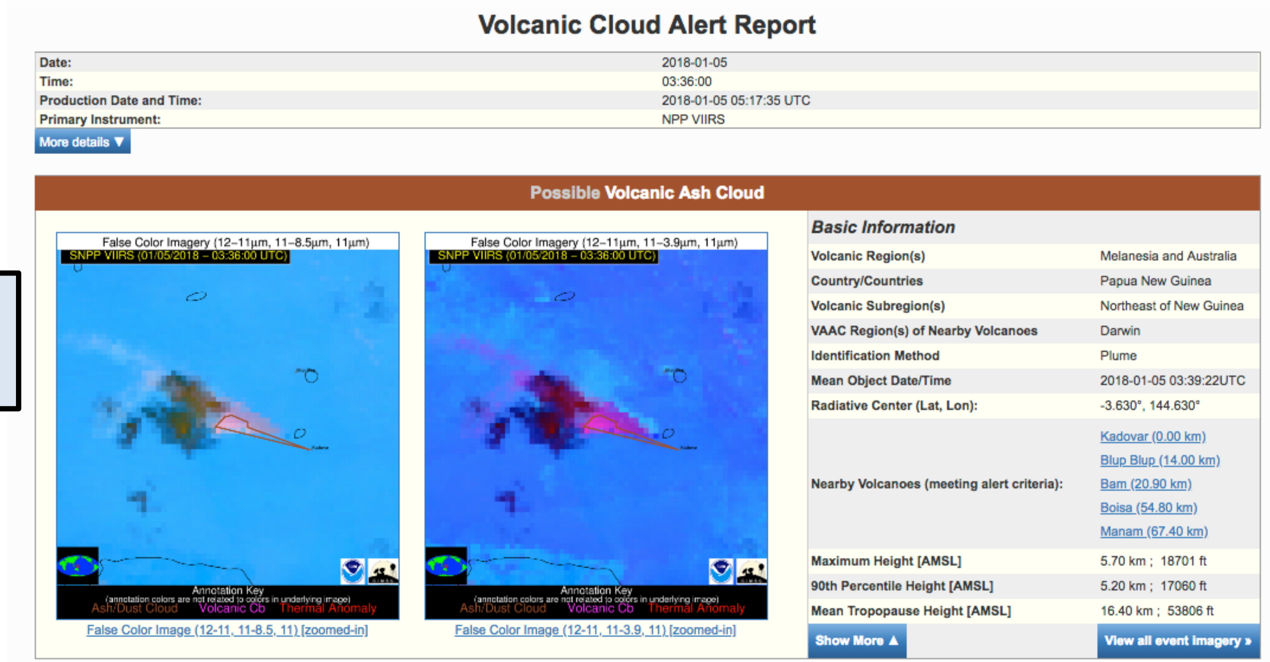
GEO



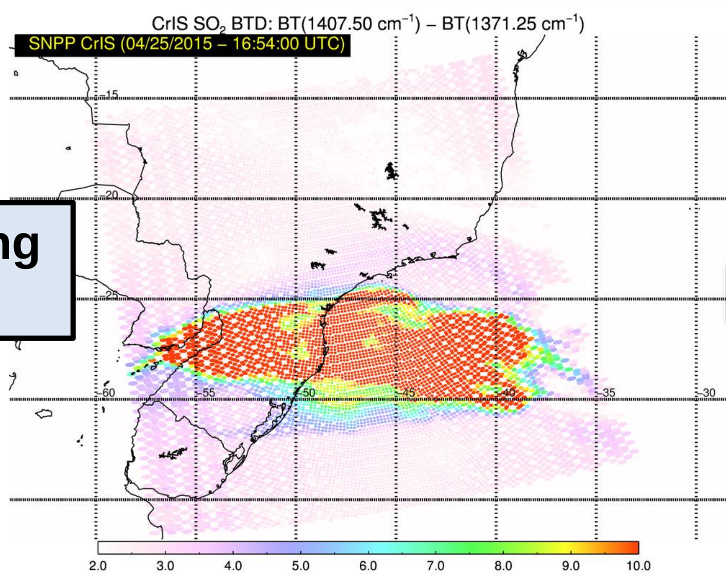
CrIS: Ash detection and characterization (including mineral composition), SO_2 detection and characterization (course spatial resolution)

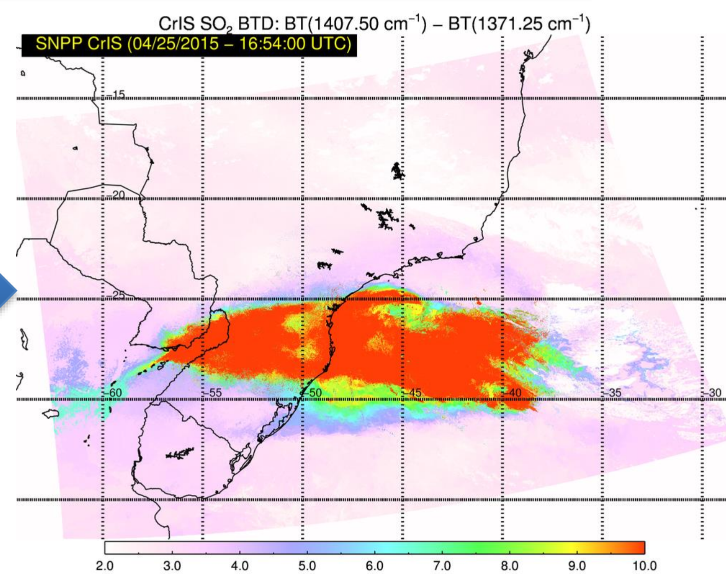
VIIRS: Ash and SO_2 detection and characterization, source of imagery (limited accuracy for ash and SO_2 properties)

Volcanic Hazards Initiative



Eruption Alerting

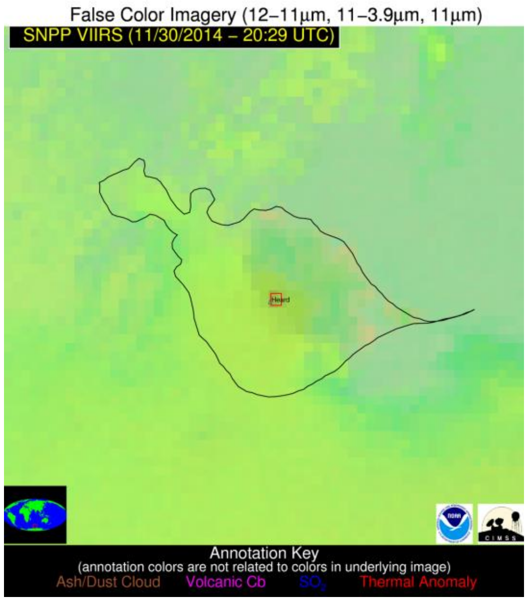




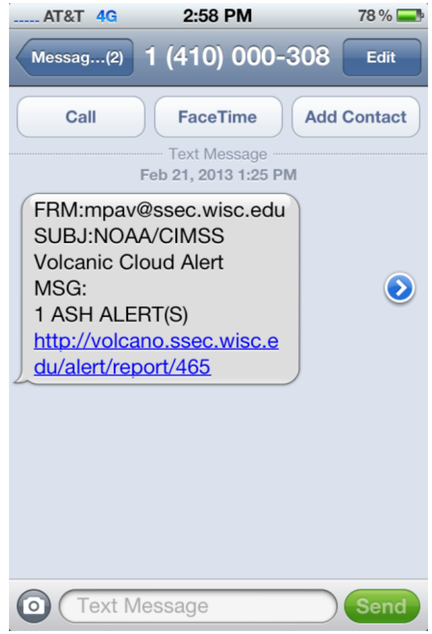
Downscaling of CrIS

VOLcanic Cloud Analysis Toolkit (VOLCAT)

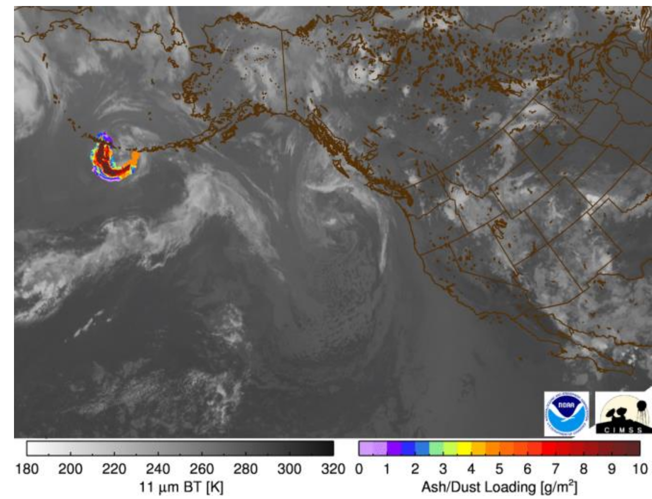
1). Unrest Alerts



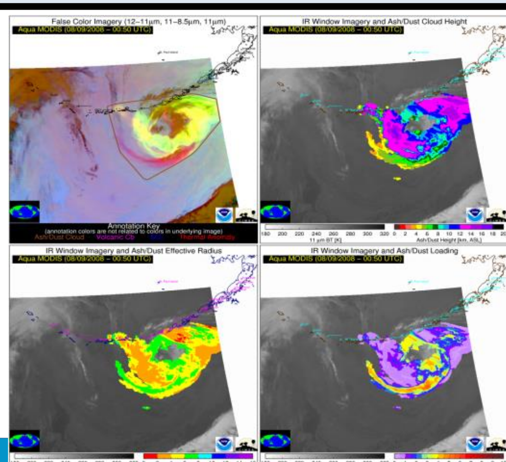
2). Eruption Alerts



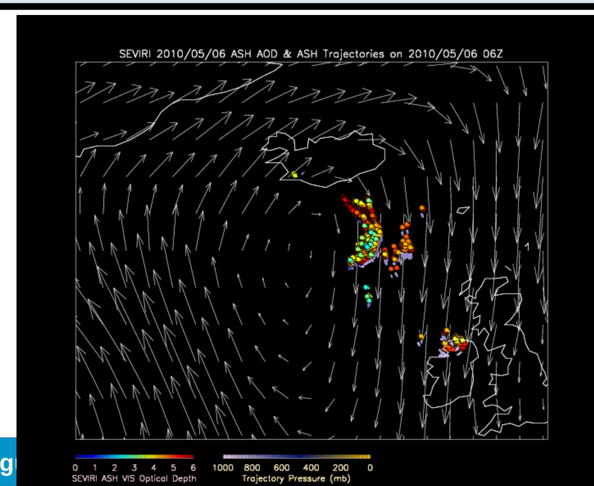
3). Volcanic Cloud Tracking



4). Volcanic Cloud Characterization

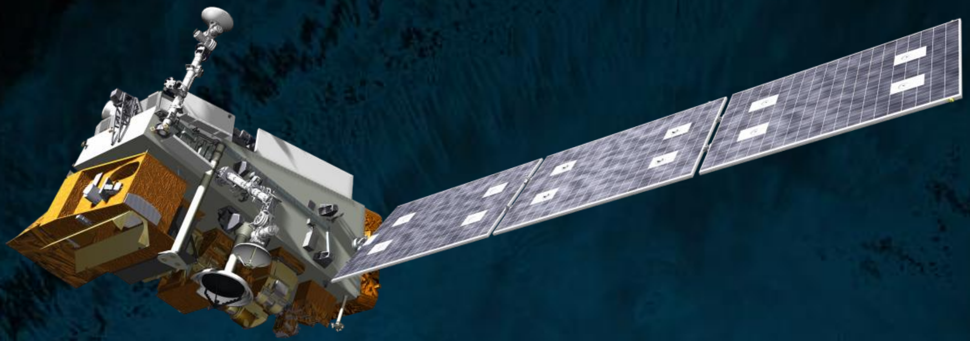


5). Dispersion Forecasting



User Feedback & Summary

- No two volcanic clouds are alike and non-volcanic features can mimic the spectral signature of ash and SO_2
- Thus, volcanic cloud detection and characterization is extremely challenging
- Present day satellite measurements (LEO and GEO combined) are capable of addressing the volcanic cloud problem, but only with highly sophisticated multi-sensor algorithms
- Users have found significantly greater value in the VOLCAT products
- The NDE products will continue to be validated and maintained while the integrated solution is developed



Joint Polar Satellite System

NOAA's Next-Generation Polar Orbiting Environmental Satellite System

Aviation Initiative

Jeff Weinrich, Science and Technology Corporation (STC)

GLOBAL DATA.
LOCAL WEATHER.

Agenda

- Aviation Initiative
- Users
- Demonstration planning
- Conclusion/Summary

Aviation Initiative

- Focus on polar data needs for aviation users.
- Alaska aviation users will be our initial focus.
- Subject areas include clouds, icing, turbulence, Cold Air Aloft (CAA)
- New Volcanic Ash Initiative will work closely with Aviation Initiative due to similar objectives.
- Plan to partner with FAA, NWS, pilots and other users.

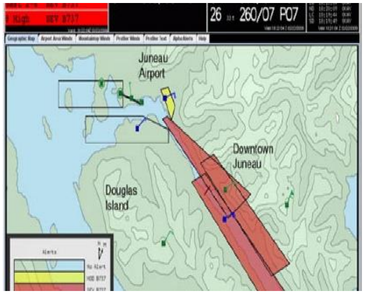
NWS Aviation Initiative Users

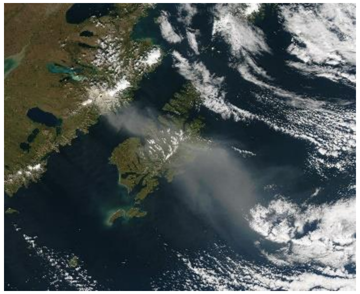
Alaska Aviation Weather Unit (AAWU)

National Weather Service Forecast Offices

National Weather Service Center Weather Service Units

WORLD METEOROLOGICAL ORGANIZATION



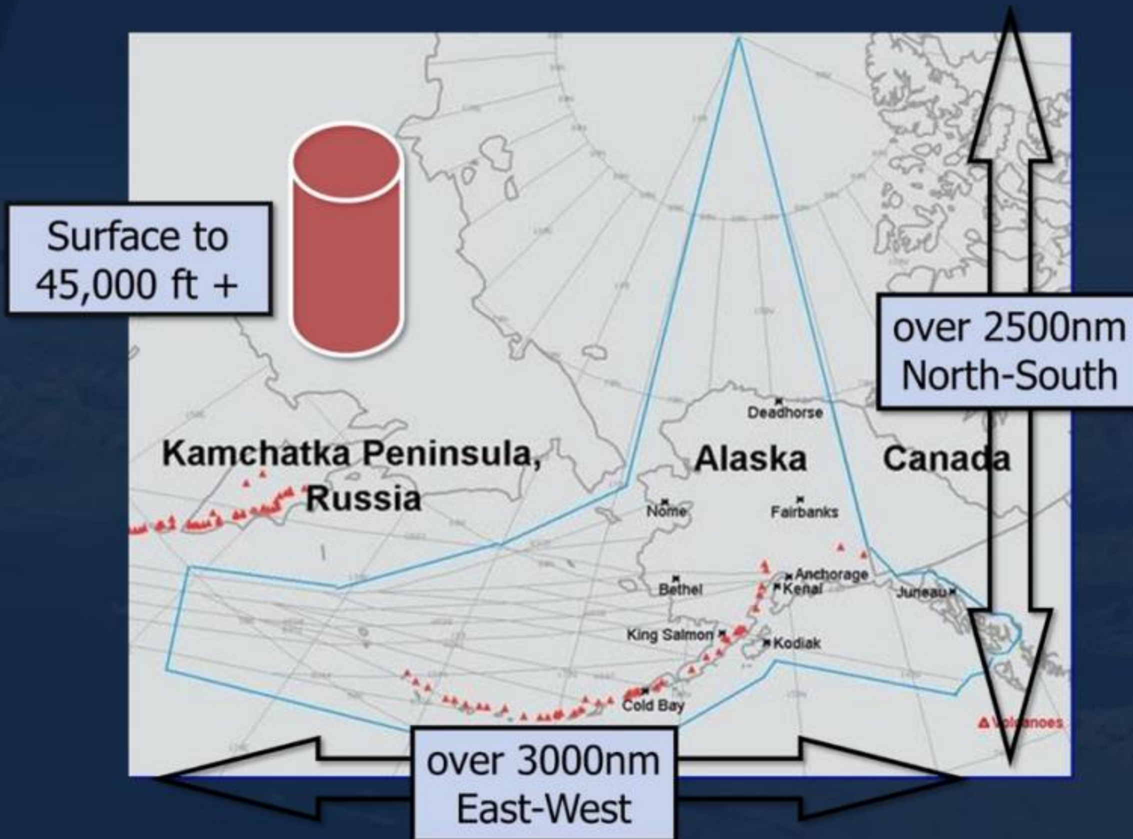


NWS Alaska Region Overview

Alaska Aviation Weather Unit (AAWU)

Alaska Aviation Weather Unit (AAWU)

- Forecasts for over 2.4 million sq. miles of airspace
  - Graphics, Area Forecasts, AIRMETs, and SIGMETs
  - Flight Category, Icing, Turbulence, Convection, Surface Analyses, and Volcanic Ash
- Need for a strong internal collaborative forecast process
- Close partnerships with FAA, industry, and formal associations to help guide services



AAWU Forecast Responsibility

Alaska Aviation Weather Unit (AAWU)

North Desk:
- 12 Area Forecasts
- Freezing Levels
- Icing
- Convection
- Flight Category

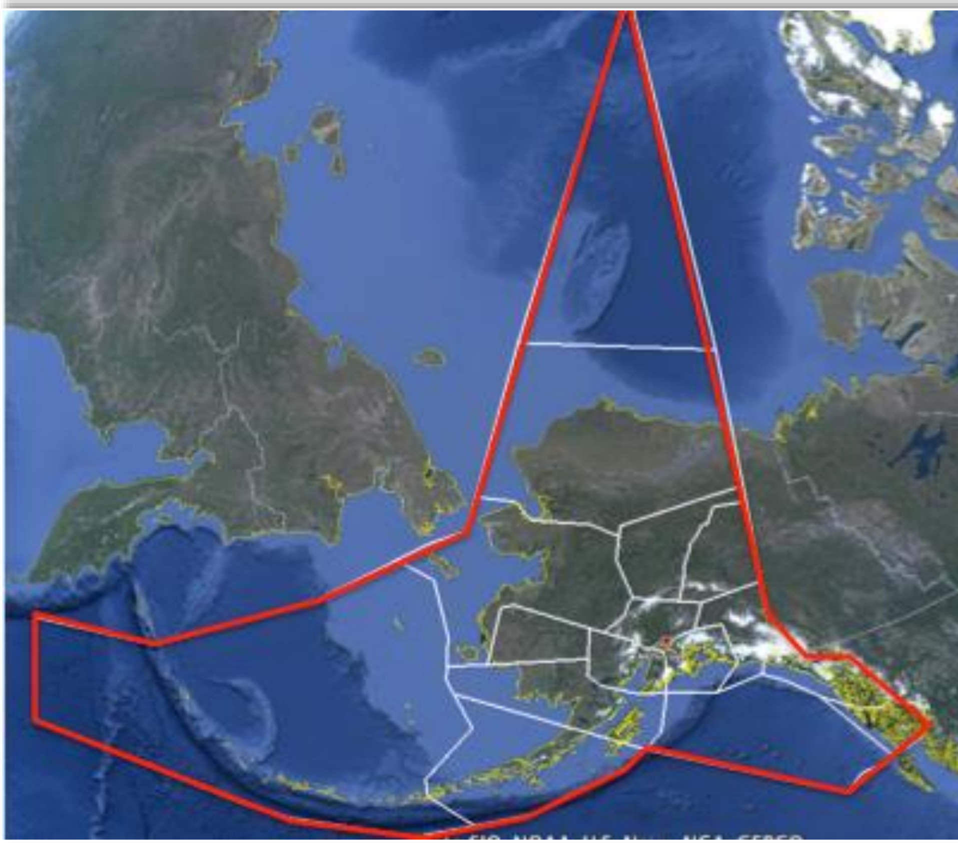
South Desk:
- 13 Area Forecasts
- Surface wind
- Low-level Turbulence
- High-level Turbulence
- Surface Analysis

Anchorage Center Weather Service Unit

ZAN CWSU Area of Responsibility

- ZAN Flight Information Region covers 2.4 million square miles
  - = Approximately the area covered by 13 of the 20 Lower 48 CWSUs

- Borders Russian, Japanese, Canadian, and U.S. (Oakland) FIRs

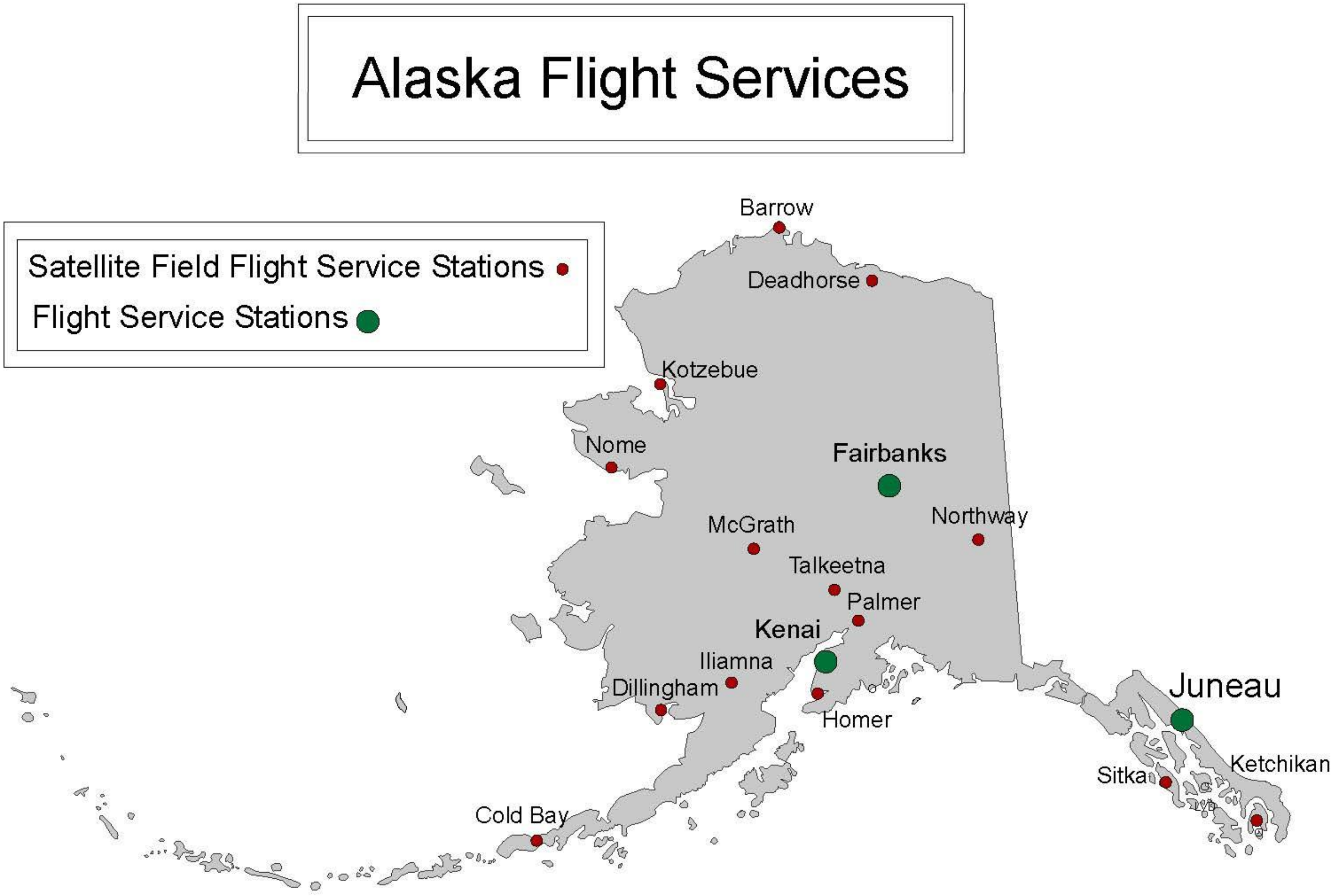


Federal Aviation Administration

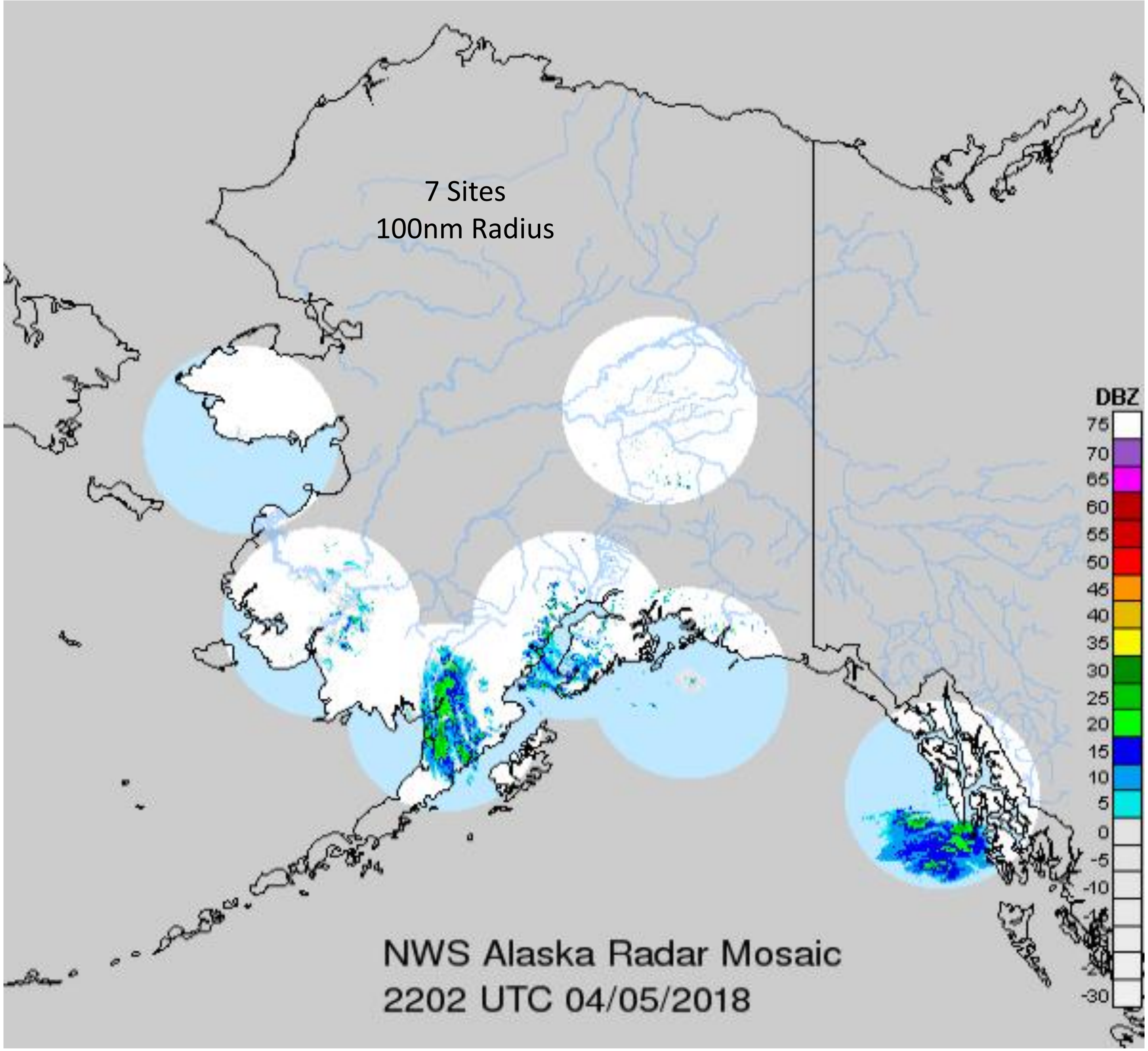
FAA Flight Service Briefing Tools

- Surface Charts
- Weather Prognostic Charts
- Satellite Imagery
- NEXRAD Radar
- Weather Cameras
- Pilot Reports

Alaska Flight Service Station Facilities



NEXRAD Weather Radar



Private Pilots

- Tom George
  - FAA ratings and certificates: Commercial Pilot, Single Engine Land, Single Engine Sea, Multi Engine Land, Instrument Airplane. Also Flight Instructor, Airplane Single Engine
  - Over 4,300 hours flight time, almost exclusively in Alaska. Fly a single engine aircraft, VFR In the past have flown supercubs in off-field operations, today fly a Cessna 185 for business travel, and to collect aerial photography and other data. Mostly operate in Interior, north slope, south central parts of the state.
  - Work for the Aircraft Owners and Pilots Association, a national organization advocating on behalf of pilots and aircraft owners who fly for non-commercial purposes such as private business, government or recreational activities.

Private Pilots

- Adam White
  - Has the following FAA ratings and certifications: Commercial Pilot
    - Single Engine Land
    - Single Engine Sea
    - Multiengine Land
    - Instrument Airplane
    - Flight Instructor
    - Airplane Single Engine
    - Instrument Airplane
    - Mechanic
    - Airframe and Power plant

  - I have 4500+ hours flight time in the past 28 years, 95% of it in Alaska. I primarily fly VFR, single engine, below 10K' and just about every flight involves off-airport operations. I fly floats and wheels in the summer season and skis and wheels in the winter with a Maule M7 and a Cessna 206. While I do fly IFR occasionally, the infrastructure in Alaska doesn't really support IFR operations in remote, off-airport situations. Most of my flights are in the Interior and Northwest Arctic regions of the Alaska. Because I fly in remote, off-airport situations I find it difficult to get an accurate and complete weather picture for flight planning.

NOAA Arctic Test Bed and Proving Ground

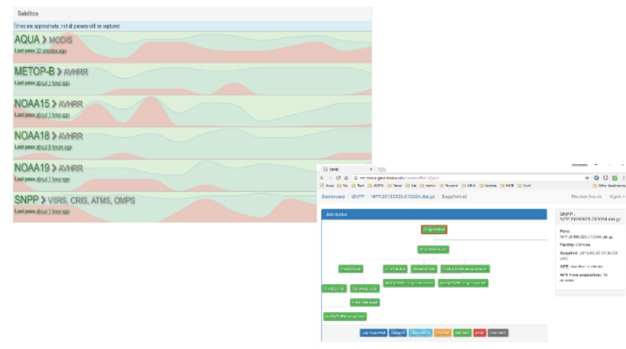
Test Bed Specifics

- Purpose
  - Located at NWS Alaska Region HQ, Anchorage. Part of Environmental and Scientific Services Division (ESSD) & the NWS Science and Technology Integration (S&TI) Portfolio
  - Focus NWS Alaska Region development efforts to maximize service delivery effectiveness in Alaska
  - Facilitate and improve (R2O, O2R, and O2O) of new and improved products and services that fulfill current and emerging decision-support requirements
- Capabilities:
  - Integration with NWS forecast systems & data streams, and research data streams
  - Ability to simulate operations with archived data in AWIPS
  - Test generate new products or services in real-time or during simulation
- Synergistic Opportunities
  - Connecting the research community with NWS operations in Alaska
  - Potential to evaluate new datasets directly in operations or in a simulated environment
- Expectations
  - Model and data assimilation improvements to operational models for sea ice forecasting
  - Working with satellite partners to bring new capabilities to the Alaska Sea Ice Program and all of our forecast programs (Marine, Hydro, Aviation, Public, Fire Weather)
  - Evaluate and assimilate new forecast data, methods and procedures into operations

Geographic Information Network of Alaska (GINA)

University of Alaska Fairbanks

NESDIS/FCDAS
Gilmore Creek, AK



The Geographic Information Network of Alaska (GINA) located on the University of Alaska Fairbanks campus receives polar satellite data from several downlink resources via Direct Broadcast. Using redundant systems GINA is able to processes and deliver polar satellite data in Near Real Time (NRT) to the National Weather Service and other government agencies in Alaska.

Direct Broadcast satellite processing is made possible by CSPP software provided by CIMSS
http://cimss.ssec.wisc.edu/cspp/

Aviation Initiative Goals

- Establish an Alaskan User for the cloud macrophysical (vertical structure) products included in the new CCL formulation.
- Build relationships for perhaps extending into other products where people expressed interest:
- Develop a sense of the utility of JPSS products compared to the current AAWU product suite (IPA, CIP, FIP) from NCAR and FAA. Use feedback to motivate collaboration with those groups.

JPSS Cloud Products Demonstration Motivation

- Alaska region has expressed a renewed interest in JPSS / VIIRS cloud products.
- The recent JPSS Arctic Demo was successful and we plan to leverage off of that experience.

.

The Participants

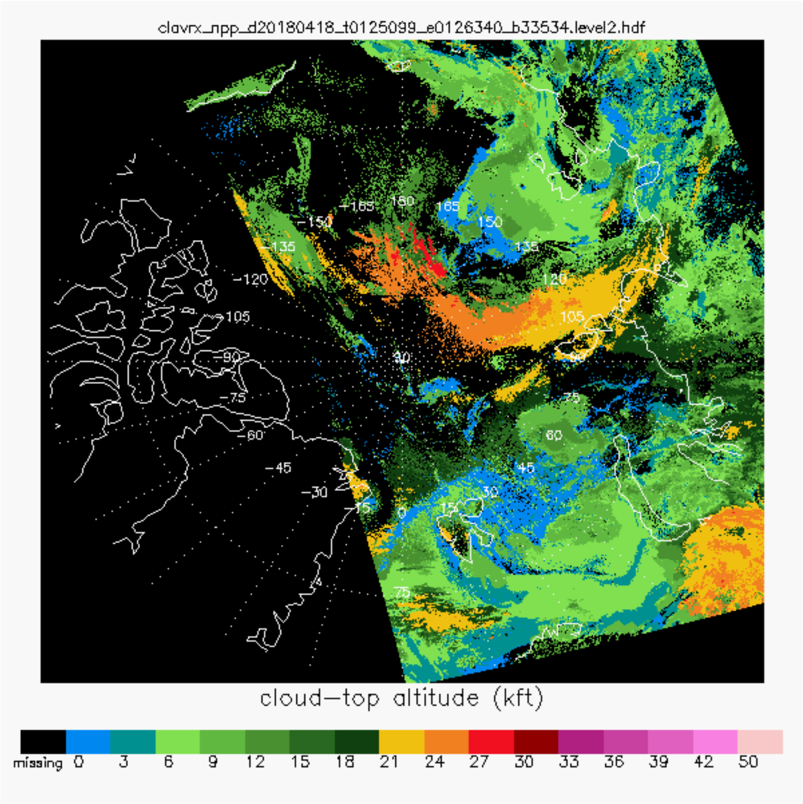
- CIMSS: Deliver CLAVR-x and algs to CSPP-LEO. Support GINA’s processing and support cloud height and detection demo.
- CIRA: Work with CIMSS to ensure cloud base and CCL are functioning as planned. Support base and CCL in demo.
- CSPP: Generate JPSS data products from DB data stream.
- GINA: Implement new CSPP-LEO on their DB stream and run POLAR2GRID to inject products into AWIPS.
- Particpants just mentioned above: provide feedback
- JPSS Program: Oversight and coordination.
- Arctic Test Bed: Technical Expertise and Feedback Coordination

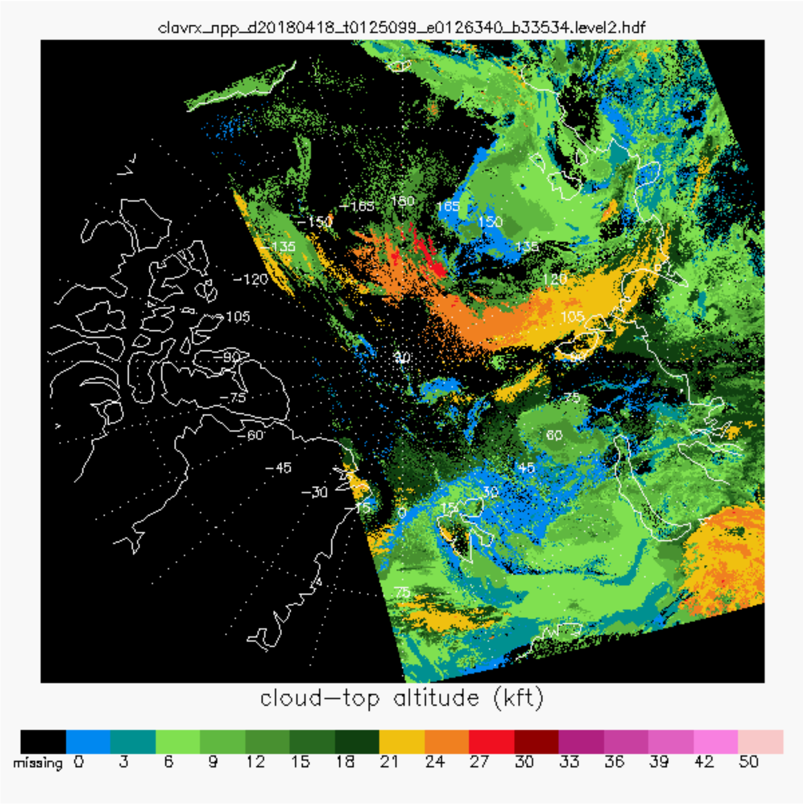
The Products

- Users expressed an interest in the cloud macrophysical products:
  - Cloud top altitude
  - Cloud base altitude
  - Cloud geometrical thickness
  - Cloud cover at flight levels
- Would like to provide these other aviation centric products
  - Supercooled water probability at cloud top
  - Supercooled water probability on flight levels

Cloud-top Altitude (kft)

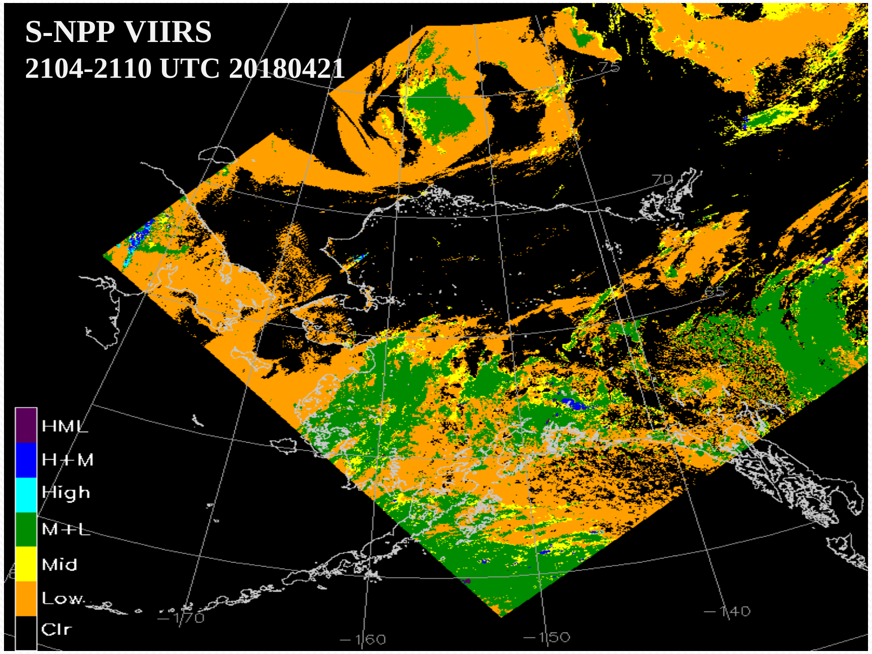
We currently provided this to AWC using global geo data..



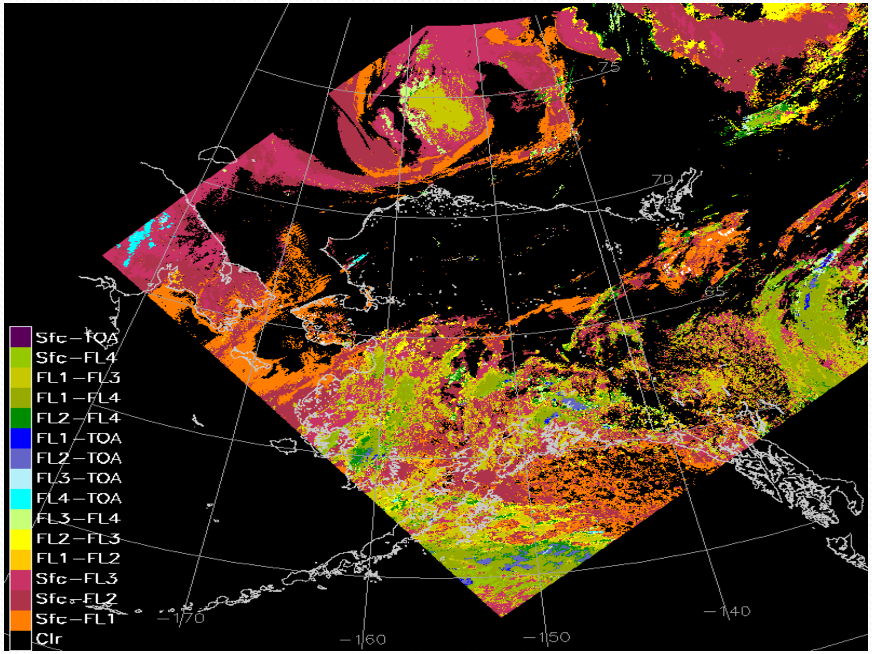


JPSS VIIRS CBH and CCL over Alaska

- Cloud Cover/Layers from S-NPP and NOAA-20 (JPSS-1) over Alaska in near real time
- Flight level-based CCL: Sfc -5 kft - 10 kft - 18 kft - 24 kft – TOA (currently 20 km for CTH)



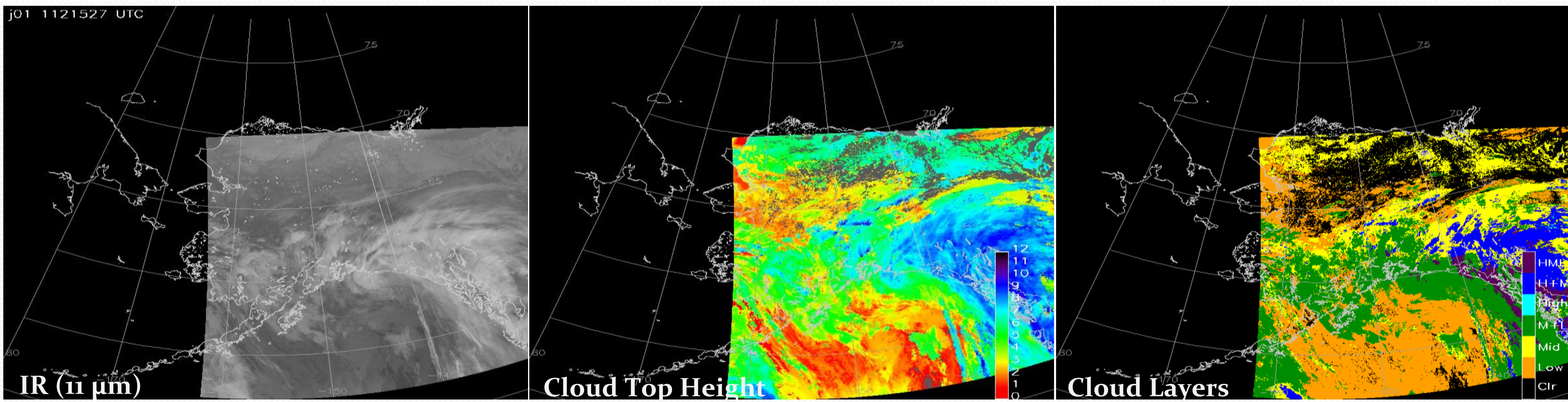
High/Mid/Low CCL
based CCL



Flight level

JPSS VIIRS CBH and CCL over Alaska

- Cloud Cover/Layers from S-NPP and NOAA-20 (JPSS-1) over Alaska in near real time
- Work in progress
  - ✓ Validation against surface-based measurements from the ARM Northern Slope of Alaska (NSA) site: Nighttime performance utilizing VIIRS DNB lunar reflectance
  - ✓ Leveraging research from CIRA's GOES-R Risk Reduction project for multi-layer clouds combining a multi-spectral approach (0.6 & 1.38 µm) and NWP humidity data



Public release in CIRA's Arctic website (http://rammb.cira.colostate.edu/ramsdis/online/npp_viirs_arctic.asp)

Summary

- An Alaskan Cloud Demo builds on the successful JPSS Arctic Summit.
- First phase will focus on cloud vertical structure for AAWU.
- Will discuss timeframe with JPSS, GINA and AAWU.
- Next steps will be to get JPSS Imagery and products to users.
- How can polar data improve diagnosis and forecast of aviation hazards?

Thank you!

Acknowledge Andy Heidinger, Bonnie Reed and all the users in the initiative

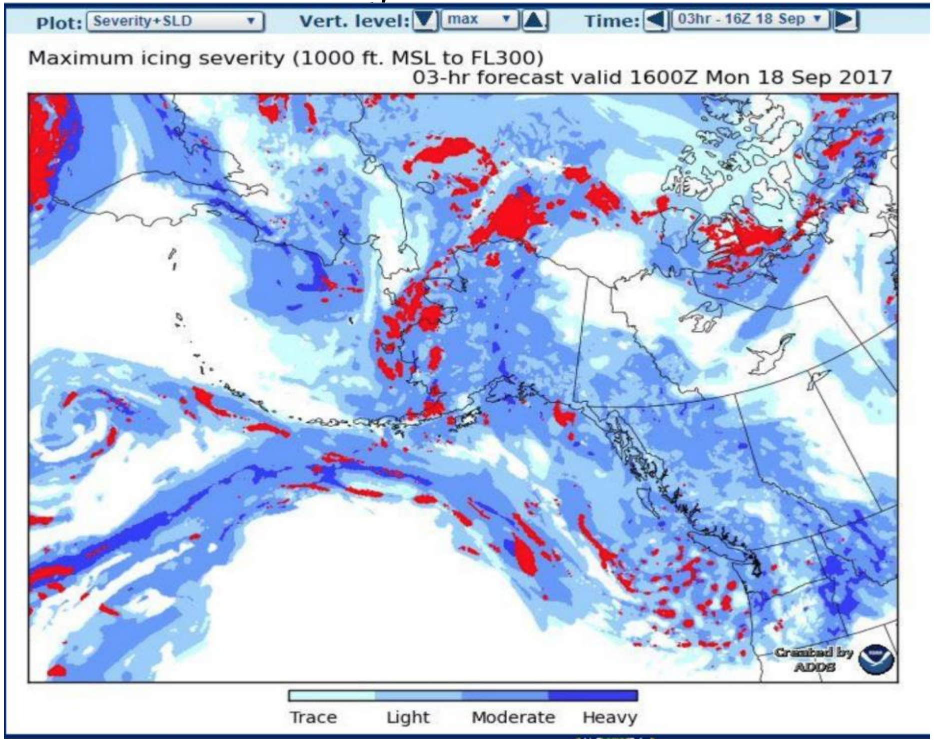
Jeff Weinrich
Jeffrey.weinrich@noaa.gov

Backup Slides

Role of JPSS Cloud Products in Aviation

- AAWU is evaluating the FAA IPA.
- In CONUS, NCAR's CIP is a dominant source of Icing Information to the NOAA Aviation community.
- Is it relevant to the AAWU?
- CIP uses an NCAR cloud-top temperature but no other satellite products. (Not NOAA or NASA LaRC)
- Should our goal be to integrate with the IPA and the CIP?
- Should JPSS try to present its satellite products in a similar format?

FAA Icing Product Alaska

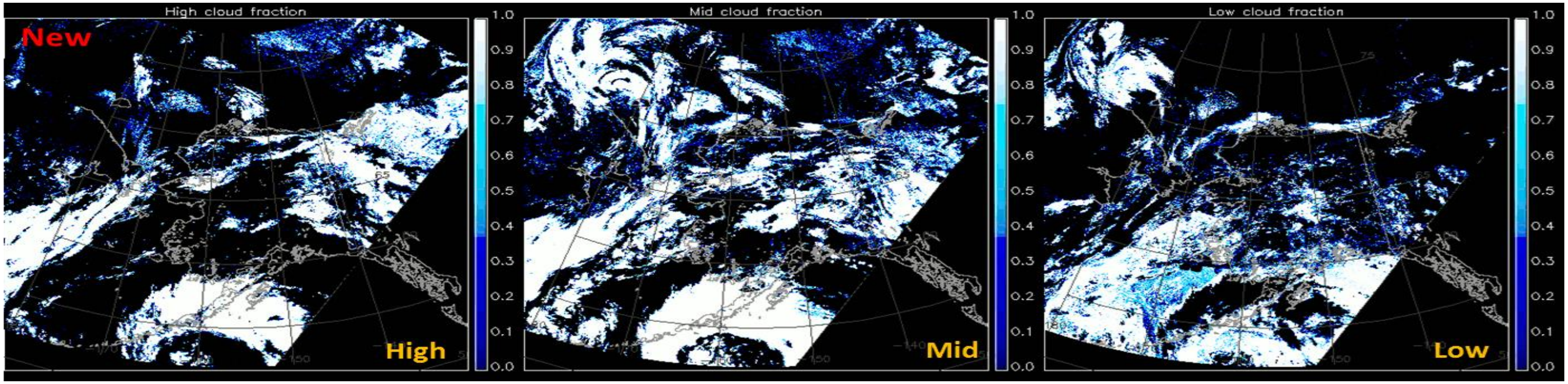


This is a product that is straightforward to make from JPSS suite. Is there value in a JPSS SLD product / image?

JPSS VIIRS CBH and CCL over Alaska

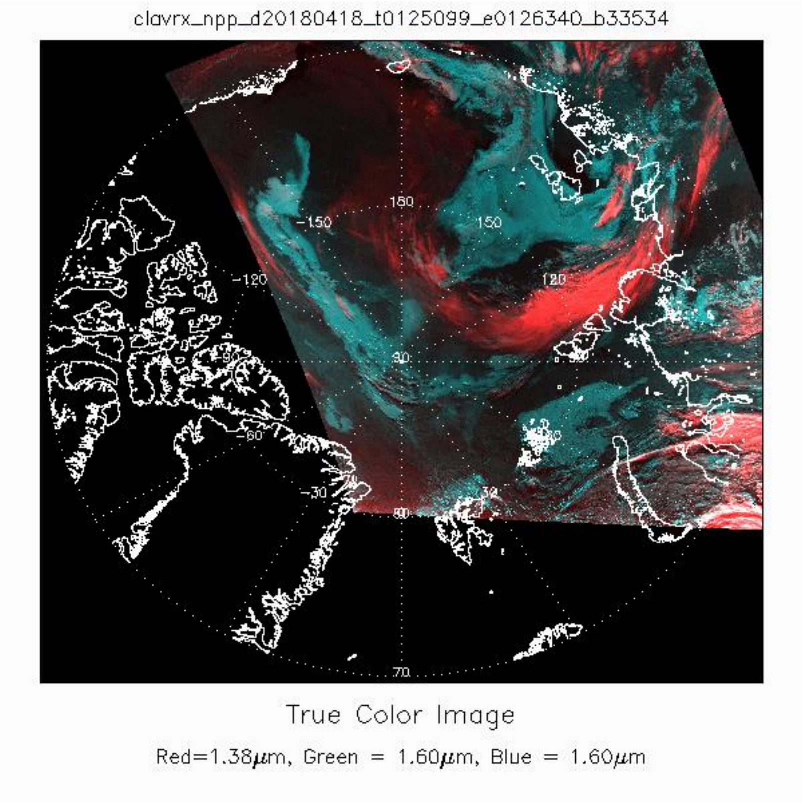
- A statistical Cloud Base Height (CBH) algorithm has been developed by using A-Train satellite data and was intensively evaluated against CloudSat/CALIPSO data
- The algorithm is now operational as part of the NOAA Enterprise Cloud Algorithms
- The CBH information can improve Cloud Cover/Layers products by introducing additional cloud coverage at lower levels of the profile (unobserved via satellite)

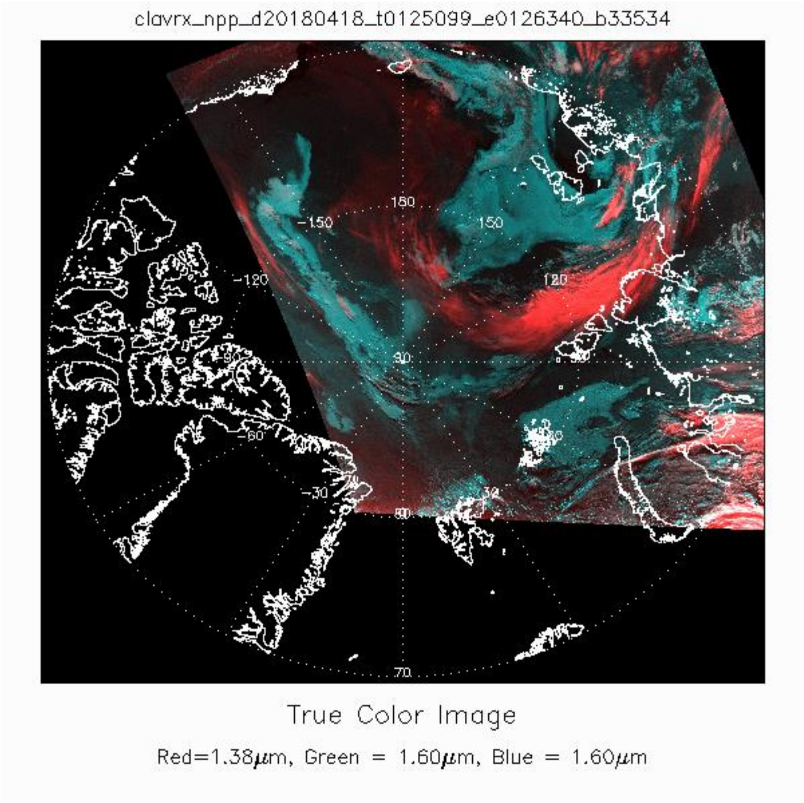
Increases of Middle and Low Cloud Fractions by using the CBH information (S-NPP VIIRS 1355 UTC 2016-02-29 **Alaska**)



Working on expansion from 3 layers ->5 flight level-based layers at request of NOAT & AWC partners

Impact of NOAA-20 on VIIRS Samping of the Arctic





Red = 1.38 micron = cirrus / high cloud
Cyan = Green + Blue = 1.6 = water phase cloud
Black = surface ice or open water

Imager Cloud Products Explained

Fundamental Cloud Products (these are products in the JPSS documentation that we have to make and meet spec)

- Cloud Presence
- Cloud Phase
- Cloud Vertical Extent
- Cloud Mass
- Cloud Particle Size

Derived Cloud Products (These are the products based on the fundamental products to estimate products of more meteorological relevance.

- Skycover
- Icing Threat
- Supercooled Water Prob.
- Cloud Cover at Flight Levels
- Cloud Base/Ceiling
- Cloud Types
- Precipitation (not IR)
- Fog
- Convective Cloud Prob.
- ASOS
- LWP/ IWP

Many of these use multiple sensors and/or new information or techniques not used in the fundamental product generation

Even though no forecaster may want to see cloud particle size in AWIPS, our ability to make accurate estimates of particle size is necessary for the derived products. For example, both Icing and Precipitation use cloud phase, optical depth, cloud-top temperature and cloud particle size.

Current and Planned Use of JPSS Cloud Products by NWS

- VIIRS cloud detection and cloud-top pressure are used in creation of the CrIS Radiance fields for NCEP Radiance Assimilation.
- VIIRS Cloud-top pressure are used in the NESDIS Polar Winds which is assimilated by NWP centers.
- NOAA/OAR/ESRL has requested cloud-top temperature (primary) and other fields from SNPP and NOAA-20 over the Arctic for assimilation into the HRRR.
- Fog / Low Stratus (M. Pavolonis) and SkyCover (J. Gerth) are widely used by NWS.
- Other cloud products are available in AWIPS but use is unclear.
- CSPP does (CLAVR-x) and will (SAPF) provide these level2 products to the DB community.

Aerosol Products for Atmospheric Transport Modeling Applications; A path forward

Ariel Stein, PhD
OAR/Air Resources Laboratory
August 27, 2018

Barbara Stunder, Glenn Rolph, Mark Cohen, Christopher Loughner, Fantine Ngan, Tianfeng Chai, Hyun Kim, Alice Crawford, and Roland Draxler.

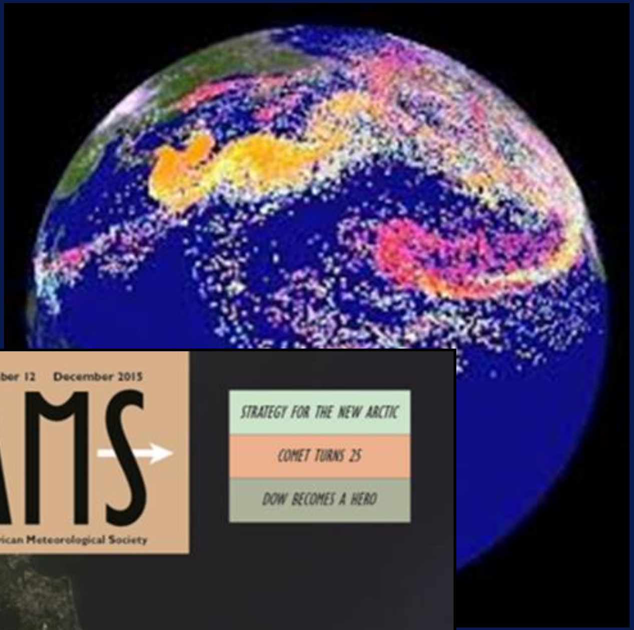
The accidental or intentional release of hazardous materials to the atmosphere (chemical, biological, nuclear agents, volcanic ash, smoke, dust) can have significant health, safety, national security, economic, and ecological implications.

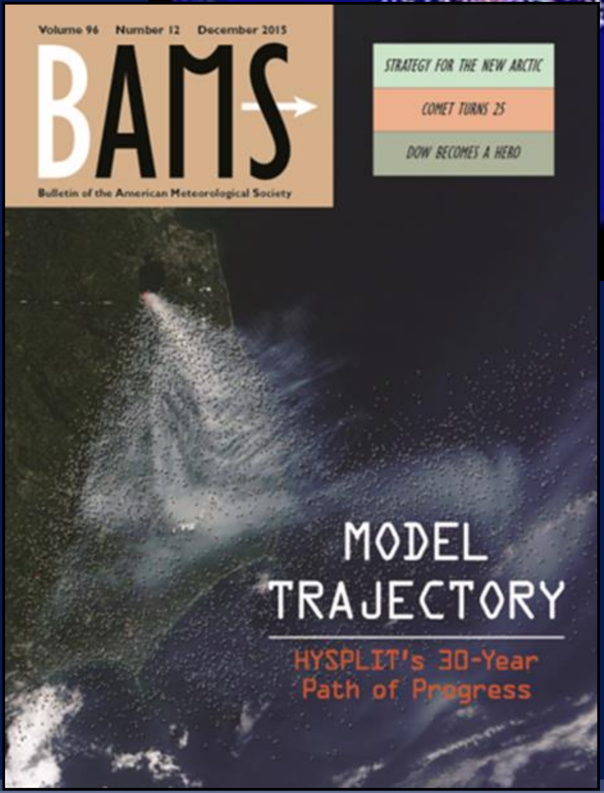
Goals

- Understand atmospheric transport and dispersion processes to improve the model quality.
- Assess the simulation uncertainties and applicability.
- Transition dispersion model products (Research to operations/applications/services) to NOAA and other agencies and organizations.

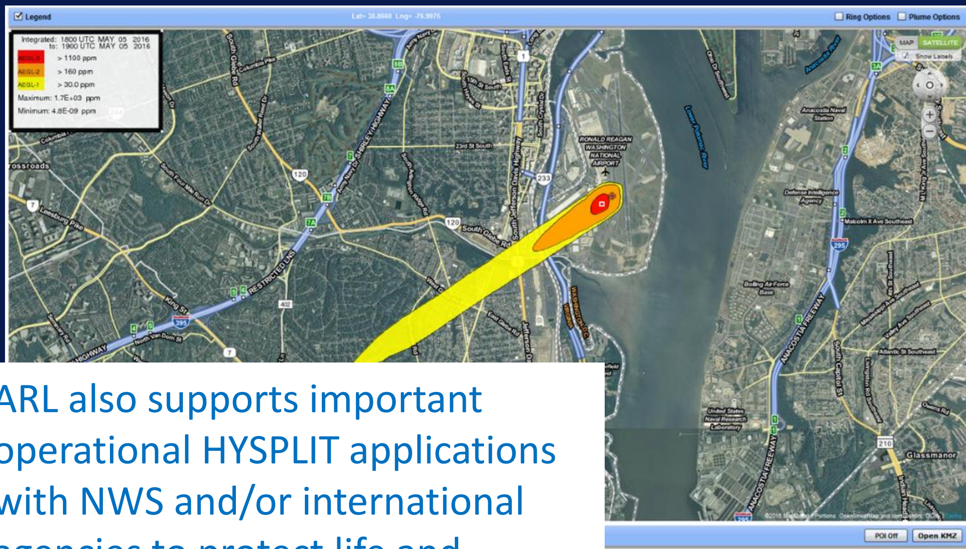
HYSPLIT

- We are the developers of the state-of-the-art HYSPLIT atmospheric transport and dispersion model.
- Operational and research grade dispersion products
- 4,100+ formally registered users from US and overseas (government, private sector, and academia) who require ability to use forecast data and/or the source code
- Extensive additional use by others
- *READY* HYSPLIT web site usage:
  - Average 70,000+ simulations/month
  - 1,200,000+ in 2017
  - Meteograms in READY: ~10,000/day
- *HYSPLIT peer literature reference*:
  - 800+ references to Draxler and Hess, 1998. Source: Web of Science
  - 650+ references to HYSPLIT BAMS Stein et al, 2015 (published in December, 2015)





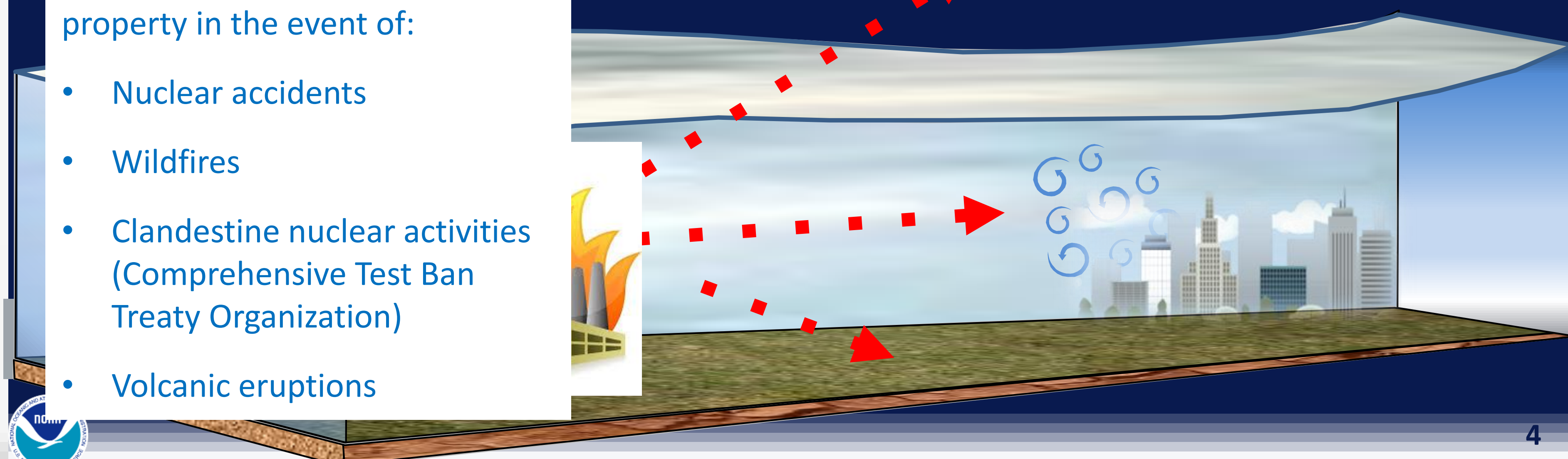
Operational uses



- HYSPLIT used operationally by the Weather Forecast Offices to forecast transport and dispersion of **hazardous materials from industrial accidents**, to protect life and property

ARL also supports important operational HYSPLIT applications with NWS and/or international agencies to protect life and property in the event of:

- Nuclear accidents
- Wildfires
- Clandestine nuclear activities (Comprehensive Test Ban Treaty Organization)
- Volcanic eruptions



MODELS NEED DATA

Emissions Data

Initialization

Output from NPW Model (WRF, NARR, GDAS, ECMW, SREF, HRRR)

For verification we look for cases with good emissions data and good observations.

HYSPLIT

For many applications, HYSPLIT model output is more sensitive to uncertainties in the initialization and the NWP model inputs than to uncertainties in the dispersion calculation.

Output

Observation Data

Evaluate

Evaluation results drive model development.

Volcanic Clouds (ash and SO_2)

- Utilize new sources of information
  - Satellite data

- Reduce uncertainty in initialization (source term)
  - Data insertion
  - Inversion algorithms

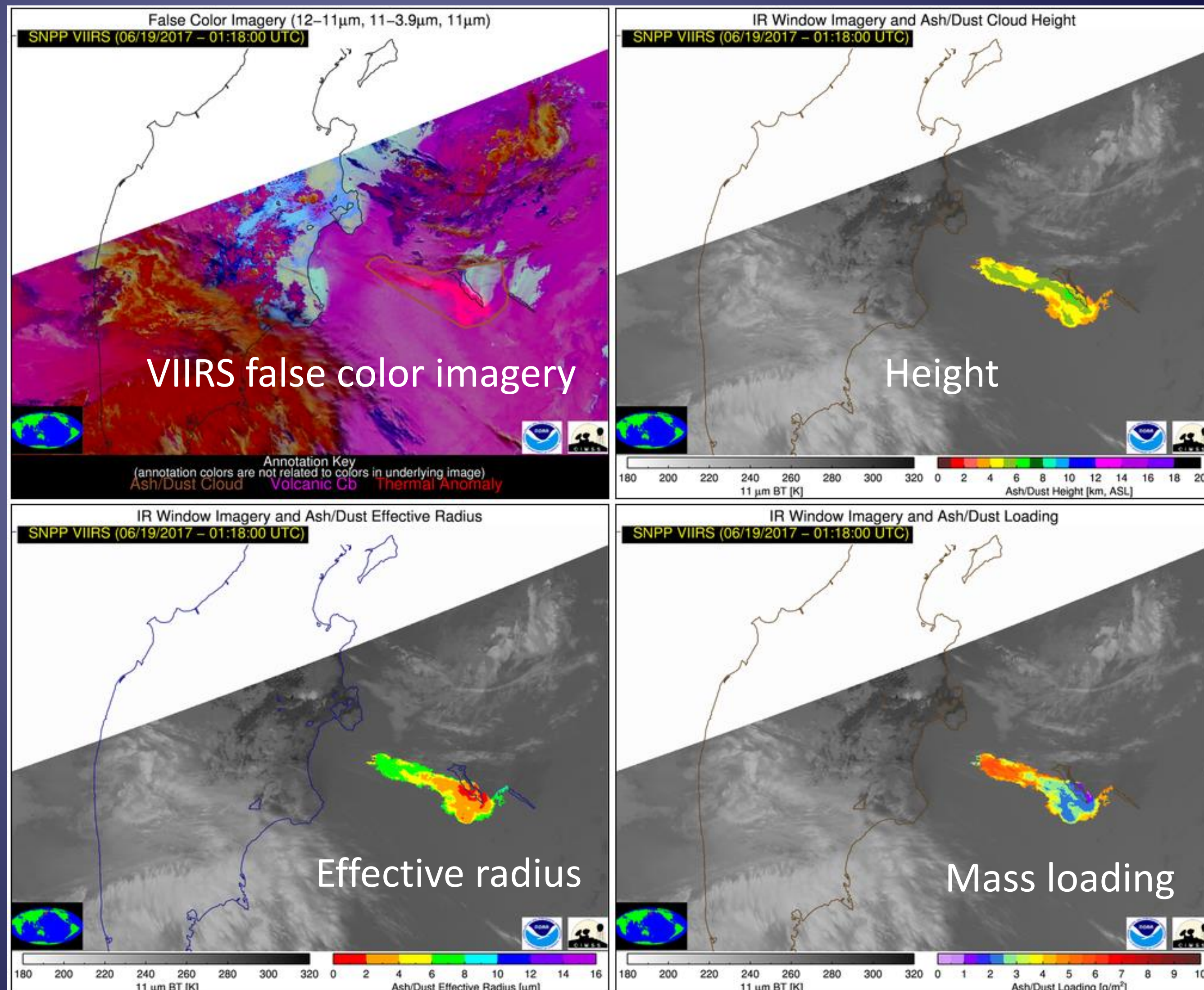
- produce probabilistic output

- Quantitative verification metrics

- Automate

VOLcanic Cloud Analysis Tookit (VOLCAT): An “enterprise information system” is a scientific software package that transforms large volumes of satellite (using all relevant GEO and LEO satellites, *including S-NPP*) and non-satellite data into, application specific, actionable information.

VOLCAT volcanic eruption products derived from a SNPP overpass on June 19, 2017 at 01:18 UTC shows the volcanic ash cloud generated by a short but powerful eruption of Shiveluch in Kamchatka.



Steps to using satellite products in HYSPLIT

Identify product which is potentially useful.

Transfer the product from where it lives to where we can work with it.

Transform the satellite product into a format which can be ingested into HYSPLIT or compared to HYSPLIT model output.

Understand satellite product data limitations and uncertainties.

Less time on this

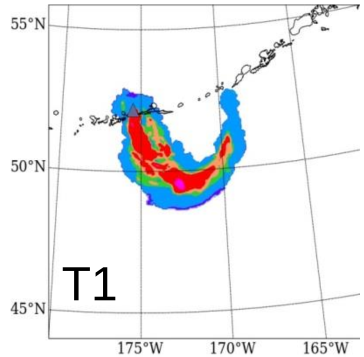
Devise, revise, and evaluate methods for using the data.

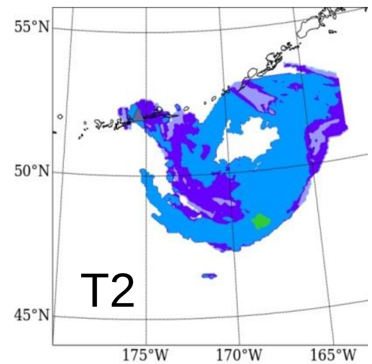
More time on this!

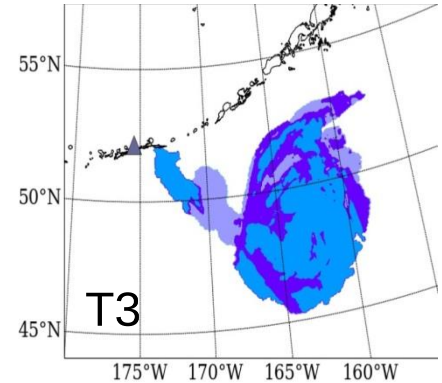
An enterprise information system allows users to spend more time using the data.

Data Insertion

Passive IR satellite retrievals of column mass loading of ash





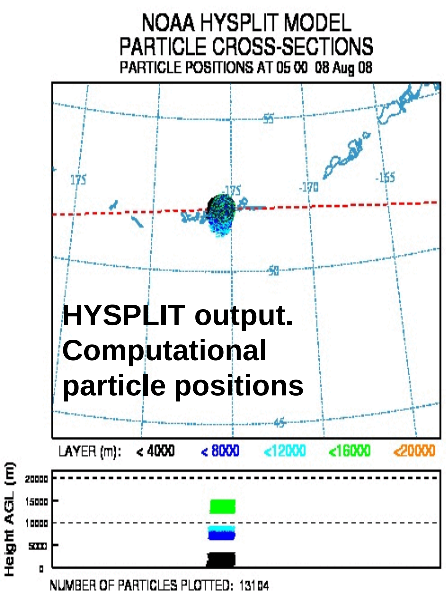


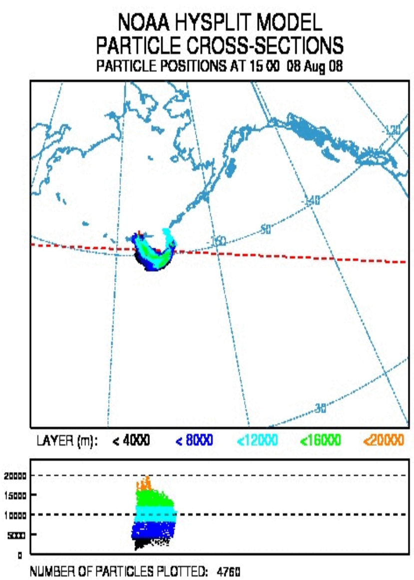
Cylindrical Source Term
08/08 04:00 UTC

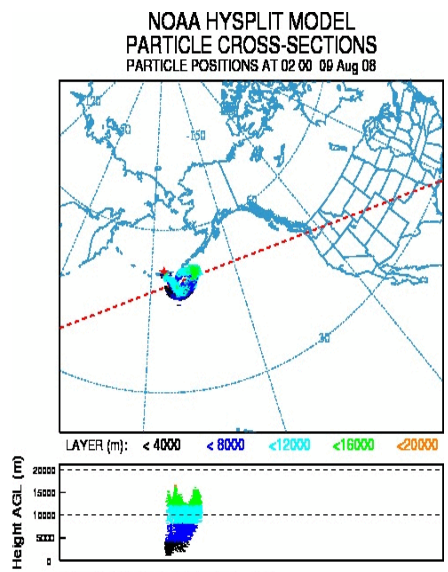
Source term RT1
08/08 14:00 UTC

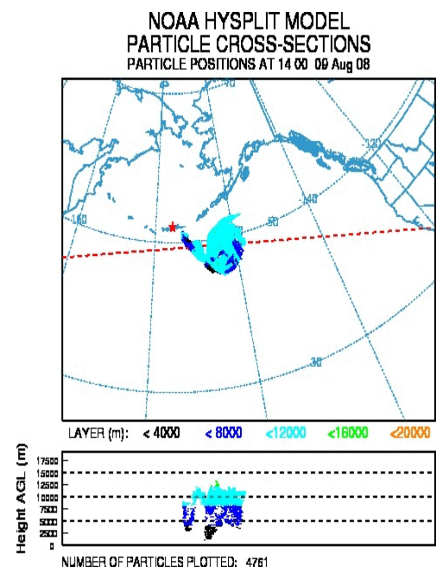
Source term RT2
08/09 01:00 UTC

Source term RT3
08/09 13:00 UTC









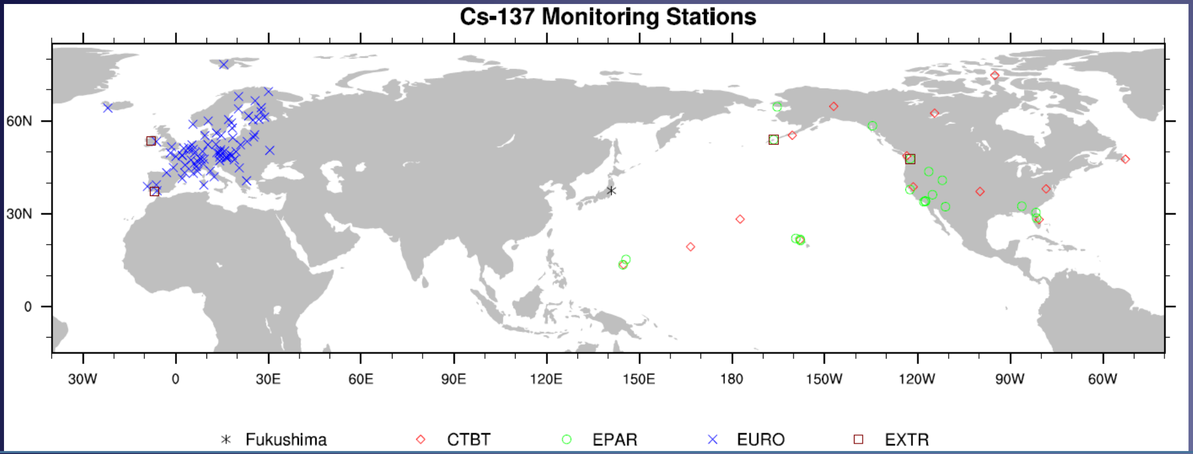
Crawford, et al., (2016) Initializing HYSPLIT with satellite observations of volcanic ash: A case study of the 2008 Kasatochi eruption *J. of Geophysical Research: Atmospheres,* 121, p 10,786, doi:10.1002/2016D024779

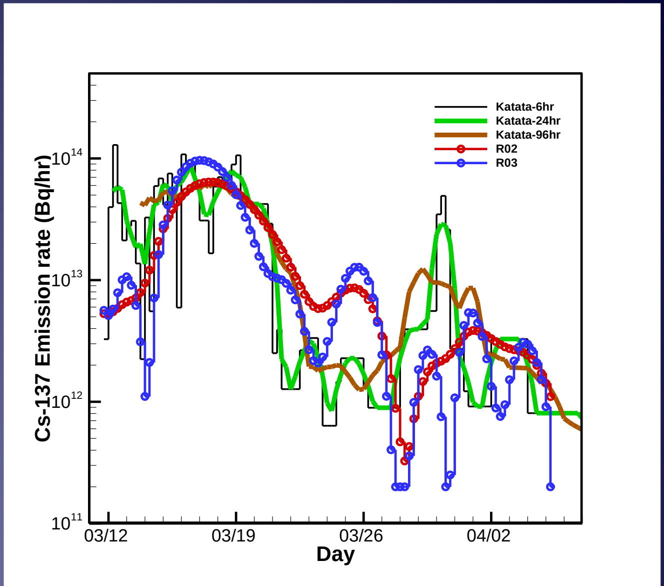
Inverse modeling

- Infer information about sources (strength, location, temporal variation/trends, vertical distribution)
- Applications:
  - Comprehensive Test Ban Treaty Organization
  - Greenhouse gas sources monitoring and verification
  - Volcanoes
  - Nuclear accidents

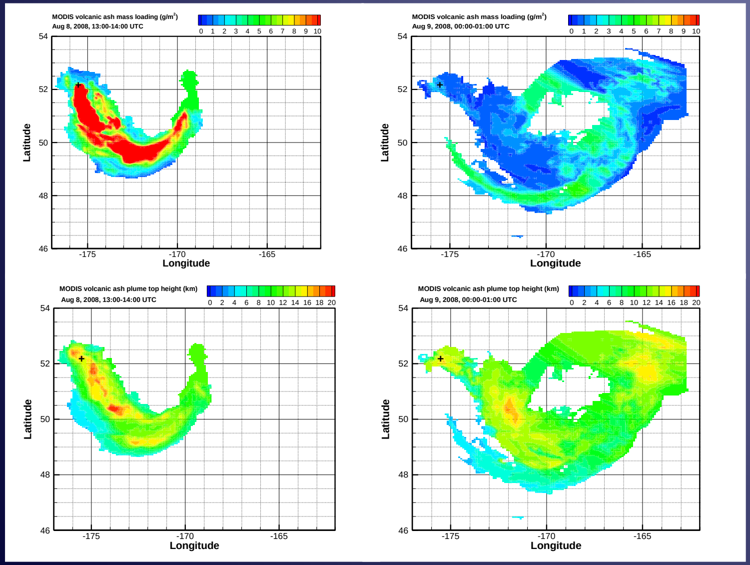
HYSPLIT inverse modeling

1. Fukushima source term estimation

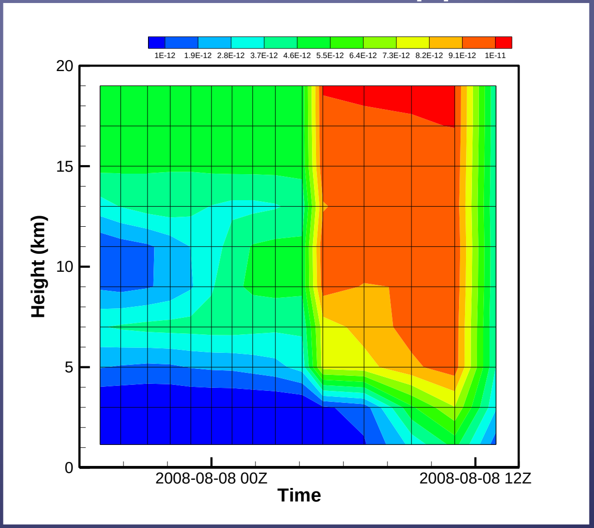




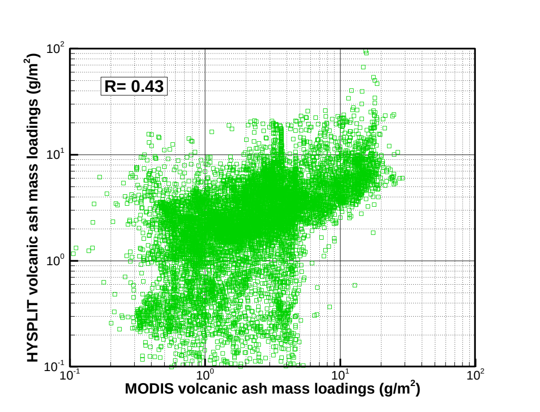
Ref: Source term estimation using air concentration measurements and a Lagrangian dispersion model– Experiments with pseudo and real cesium-137, T Chai, R Draxler, A Stein – Atmos. Environ., 2015



2. Volcanic ash application - Kasatochi eruption



Chai, et al., (2017) Improving volcanic ash predictions with the HYSPLIT dispersion model by assimilating MODIS satellite retrievals Atmos. Chem. Phys., 17, p1-15 doi:10.5194/acp-17-1-2017



Searching for emission terms.

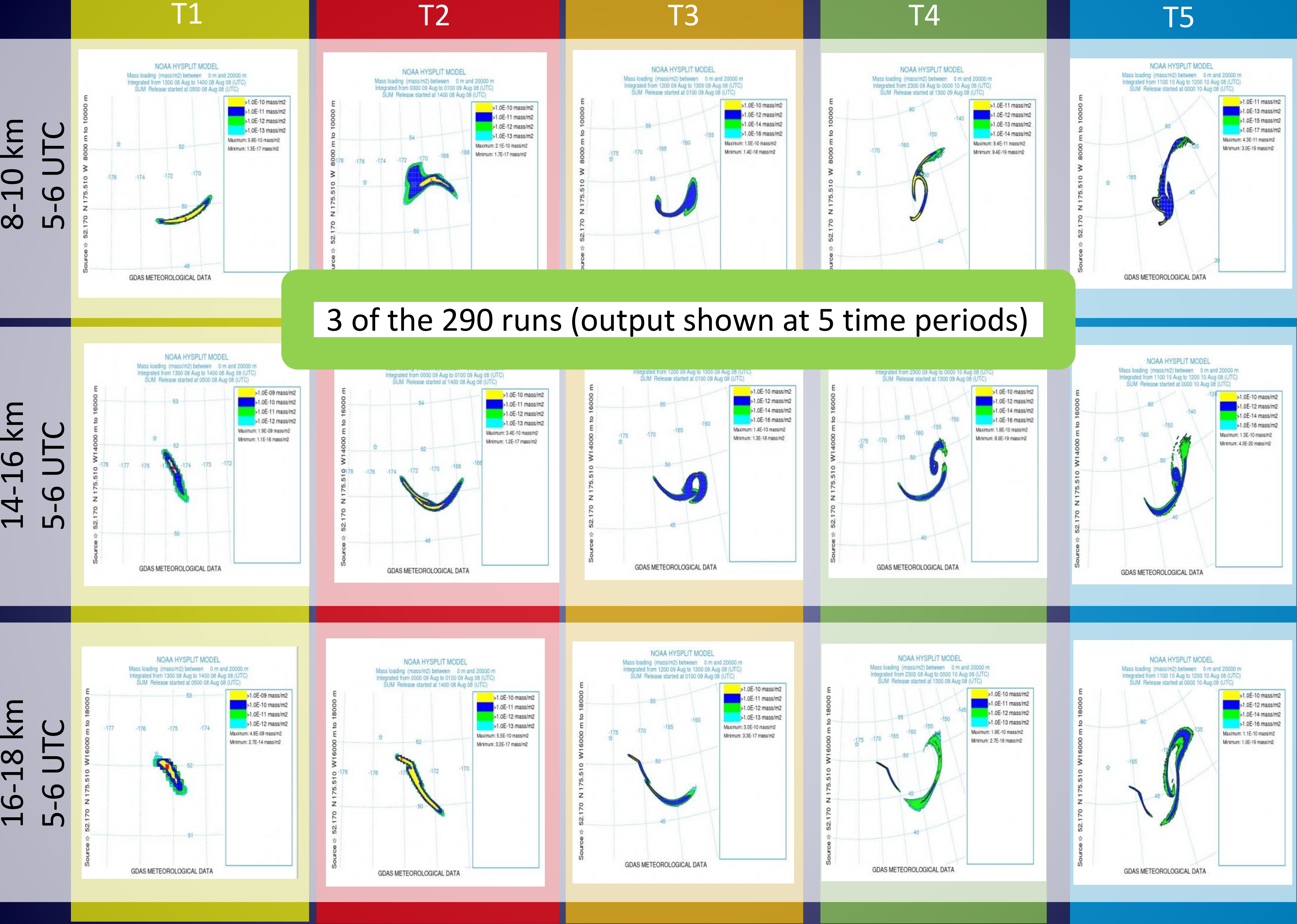
1 – determine positions and times of likely emissions.

HYSPLIT RUNS For Inversion Algorithm

290 HYSPLIT Simulations

Unit emission for every hour

Particles released over 2 km increments from vent to 20 km.
(10 runs per time period)


T1
T2
T3
T4
T5
8-10 km
5-6 UTC
14-16 km
5-6 UTC
16-18 km
5-6 UTC
NOAA HYSPLIT MODEL
GDAS METEOROLOGICAL DATA
3 of the 290 runs (output shown at 5 time periods)

2 – Decide on observations
3 – Create TCM

Transfer Coefficient Matrix

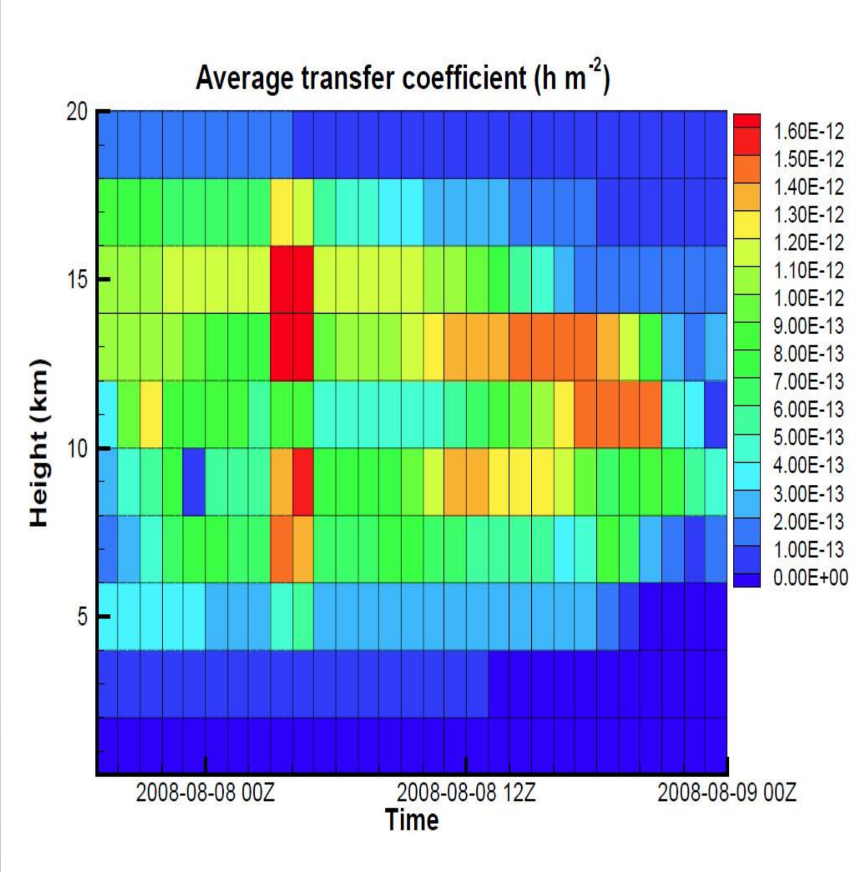
Which HYSPLIT runs produce ash which coincides with observed ash?

Average over all observations containing ash. (shows 290 squares).

290 columns for each HYSPLIT run

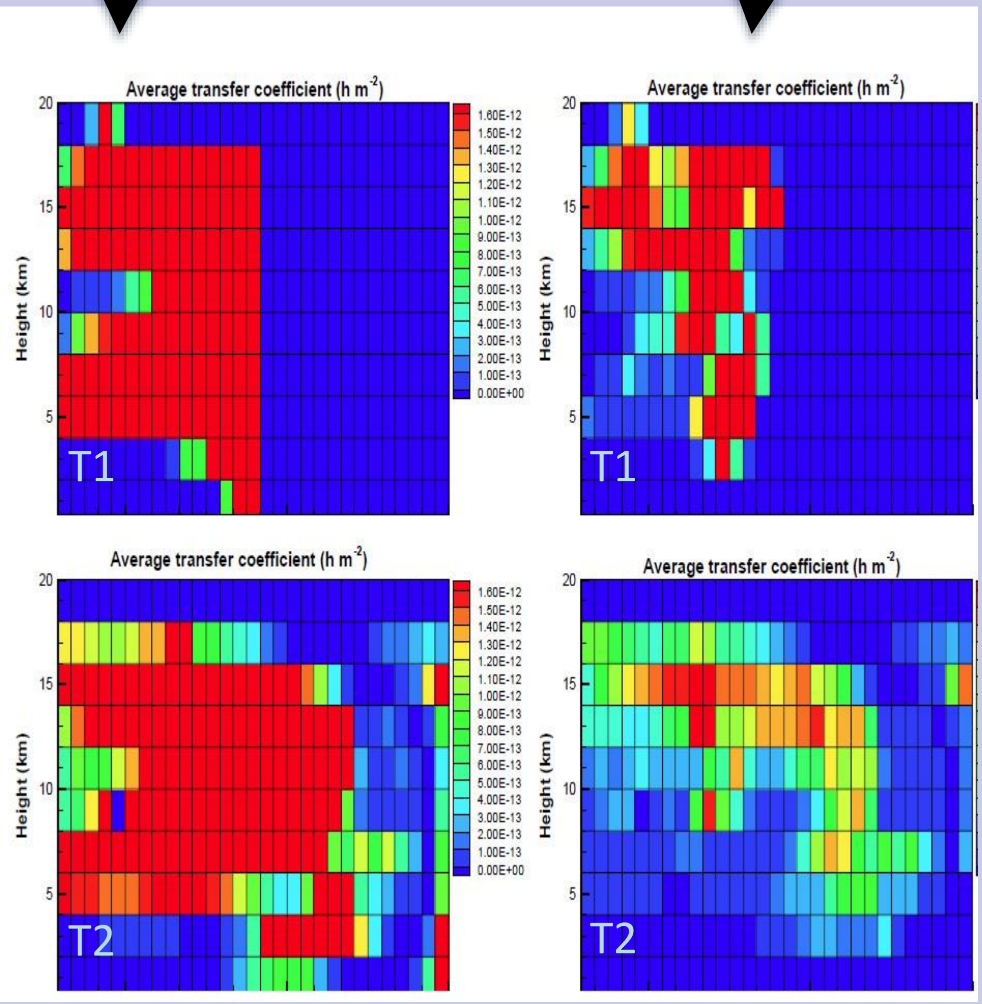
Y number of observation points / times

Mass/m² from HYSPLIT run at observation point / time.



Model results at
An observation point $C^h{}_1 = M_{1\,1}x_1 + M_{1\,2}x_2 + M_{1\,3}x_3 + \ldots\ M_{1\,290}x_{290}$ Where x_N are the unknown emissions

Which observations to use?



Assumptions about vertical structure of observations?

- Ash present from surface to observed cloud top
- Ash present only in layer of observed cloud top
- Ash present in layer of observed cloud top and also layer above and layer below

Observations at how many times should be used?

As newer observations become available should older observations be discarded?

Should clear sky observations be taken into account?

Areas where no ash is observed

Area above the observed cloud top

How to Search for emissions?

Create cost function

Measure how well observations agree with model output.
Take into account errors in observations
May take into account other restrictions (e.g. smoothness of emissions)

C^0_n – observations
x^b_i - first guess emission rates.

Cost Function

$$F = \frac{1}{2}\sum_i^{290}\frac{(x_i - x^b_i)^2}{\sigma_i^2} + \frac{1}{2}\sum_n^{Y}\frac{(c^h_n - c^o_n)^2}{\epsilon_n}$$

Since emissions are not well known, make this large so penalty for diverging from first guess emission is small.

$$C^h_n = M_{n1}x_1 + M_{n2}x_2 + M_{n3}x_3 + \ldots.. M_{n\,290}x_{290}$$

Minimize cost function to find emission terms $x_1 \ldots. x_{290}$.

Some conclusions

Different assumptions about vertical structure of ash cloud result in quite different emissions estimates.

However predictions made with the different emissions estimates all show decent skill.

Enforcing zero mass loading in ash-free regions does not create emission estimates which improve model skill.

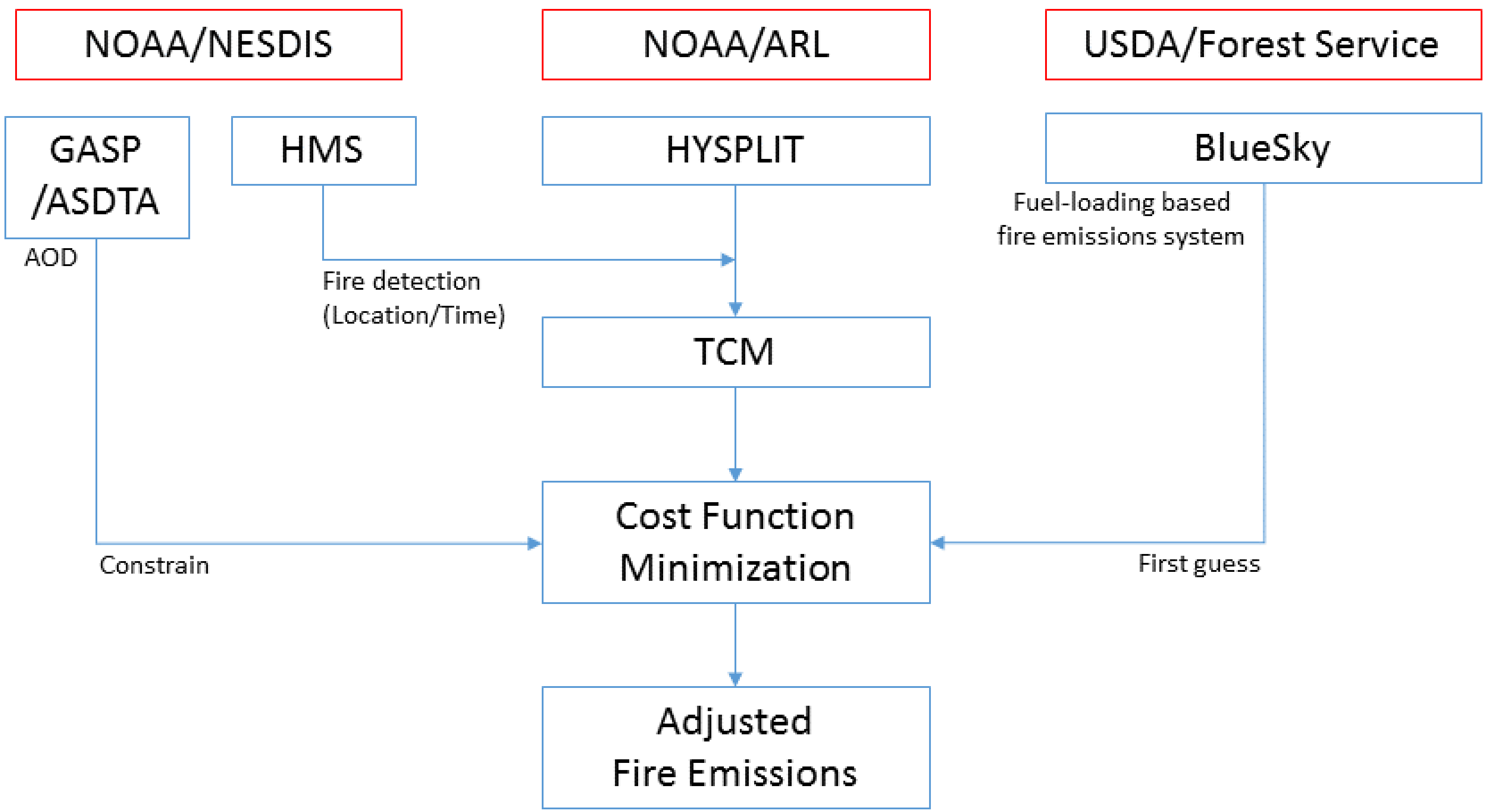
Assimilating observations from multiple time periods is beneficial.

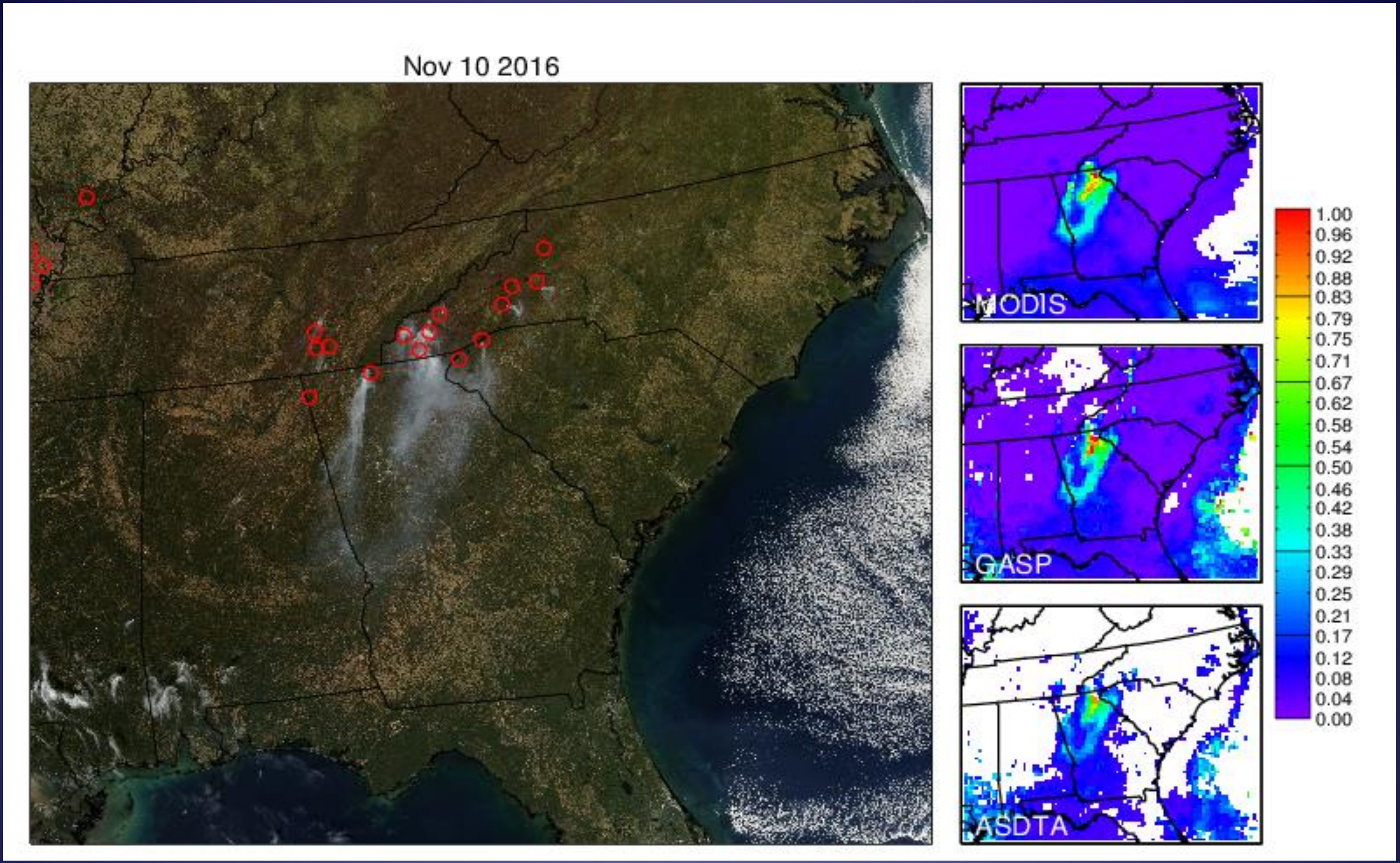
Planned work

- VOLCAT will offer volcanic SO_2 products. Extend the volcanic ash work to SO_2 and refine the proto-typed methods.
- Develop model evaluation toolkit for HYSPLIT which utilizes VOLCAT products. This toolkit will be used for
  - new HYSPLIT ensemble products
  - Evaluating HYSPLIT driven by new NWP (numerical weather prediction model) data such as FV3.

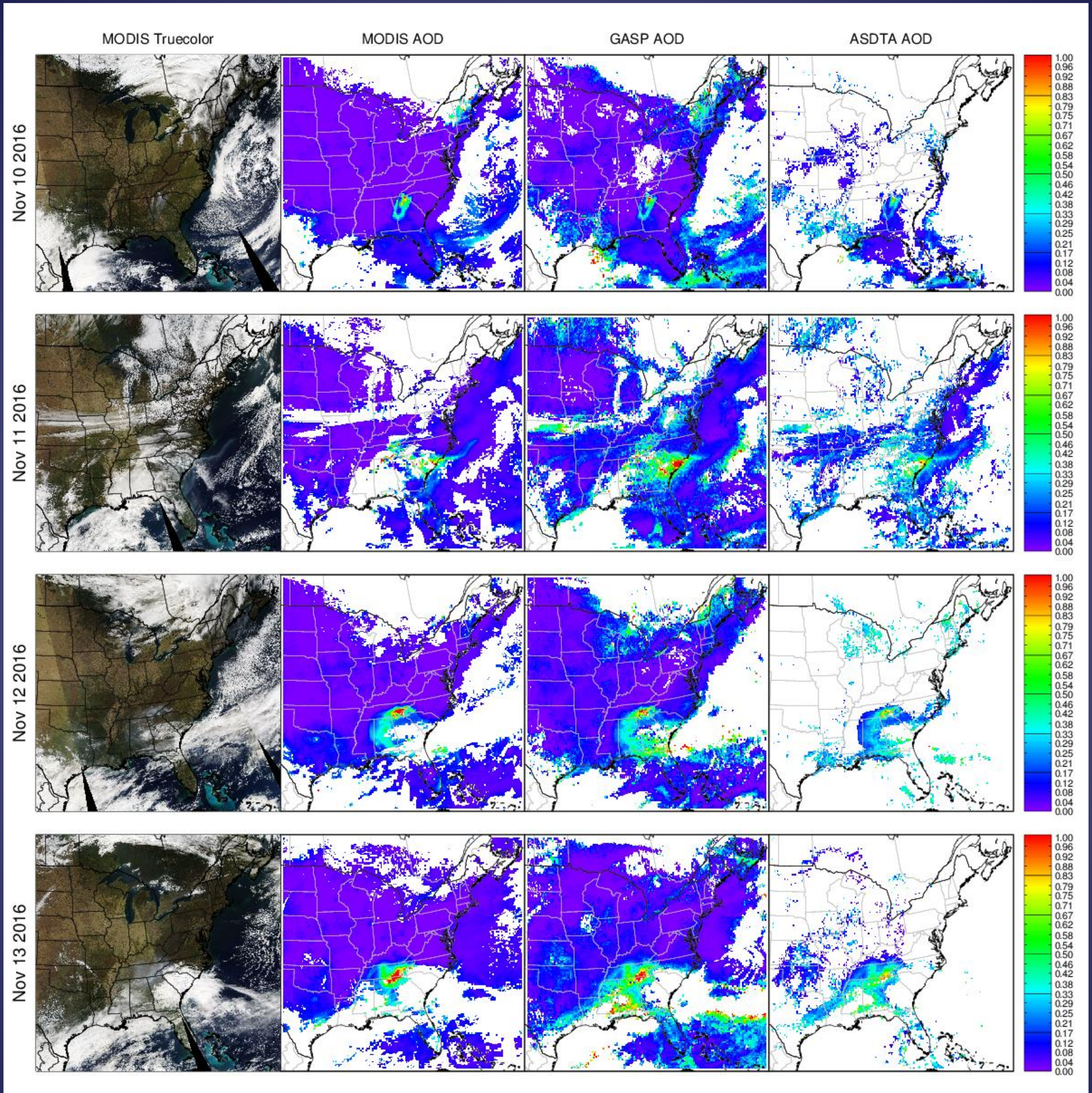
Thanks!!

HYSPLIT-based Emissions Inverse Modeling System (HEIMS-fire)

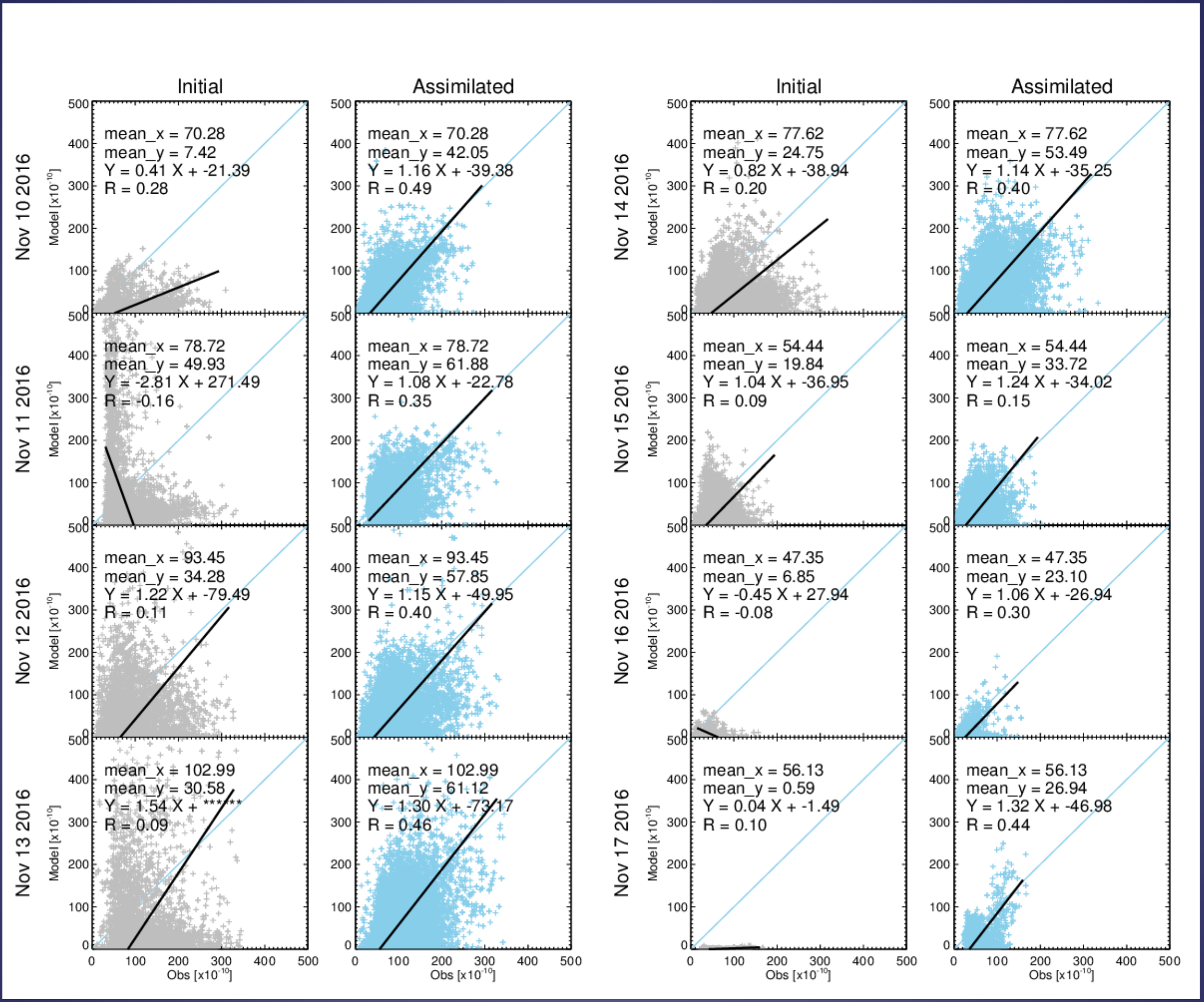




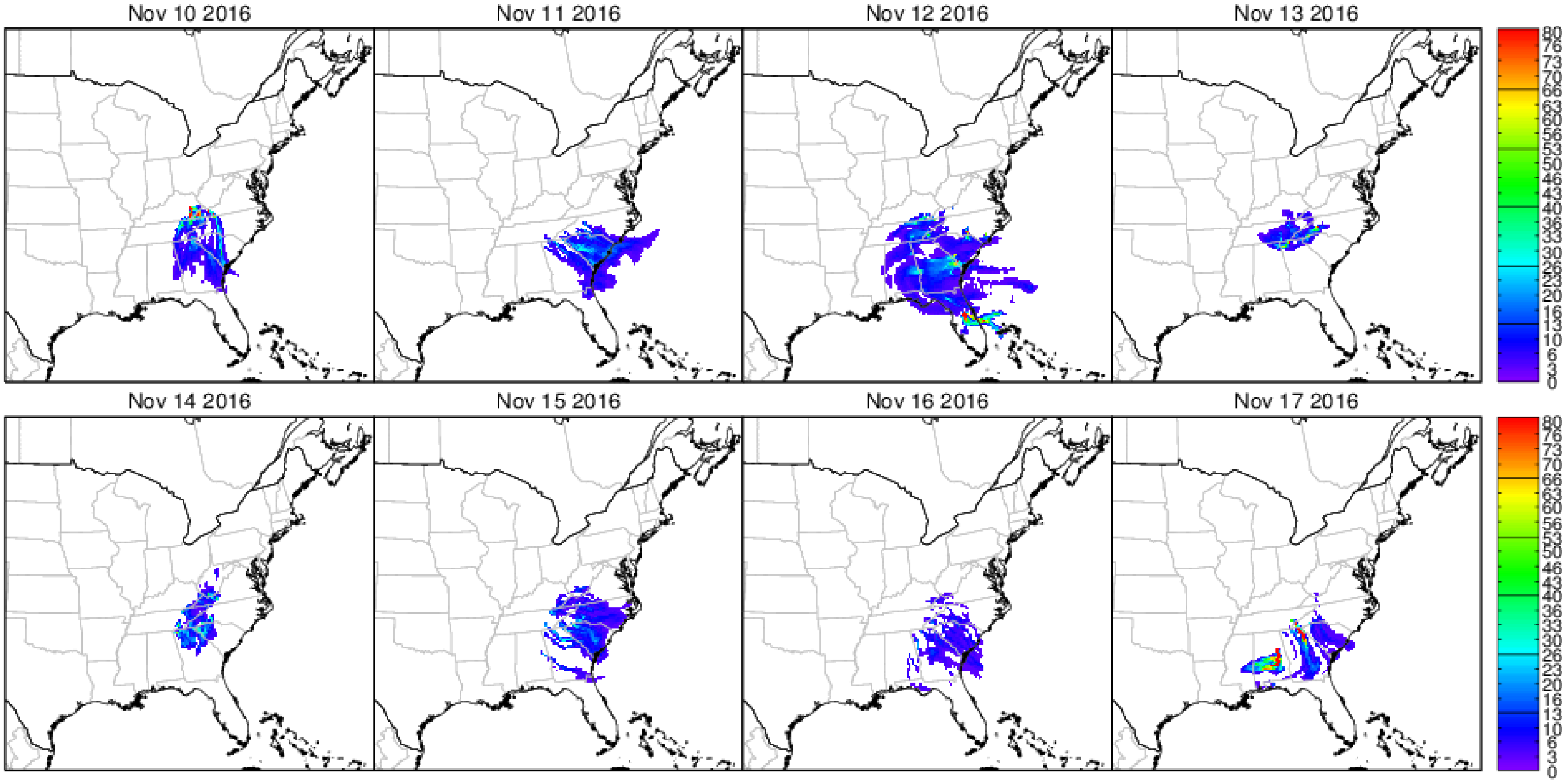
Observed fire events in southeastern US on November 10, 2016. MODIS truecolor image is shown in left panel, and MODIS, GASP, ASDTA aerosol optical depths are shown in right panel. Red circles indicate locations of wildfires detected by HMS.



Observed wildfire events for the study during November 10-17, 2016. MODIS truecolor images, MODIS AOD, GASP AOD, and ASDTA AOD are shown.



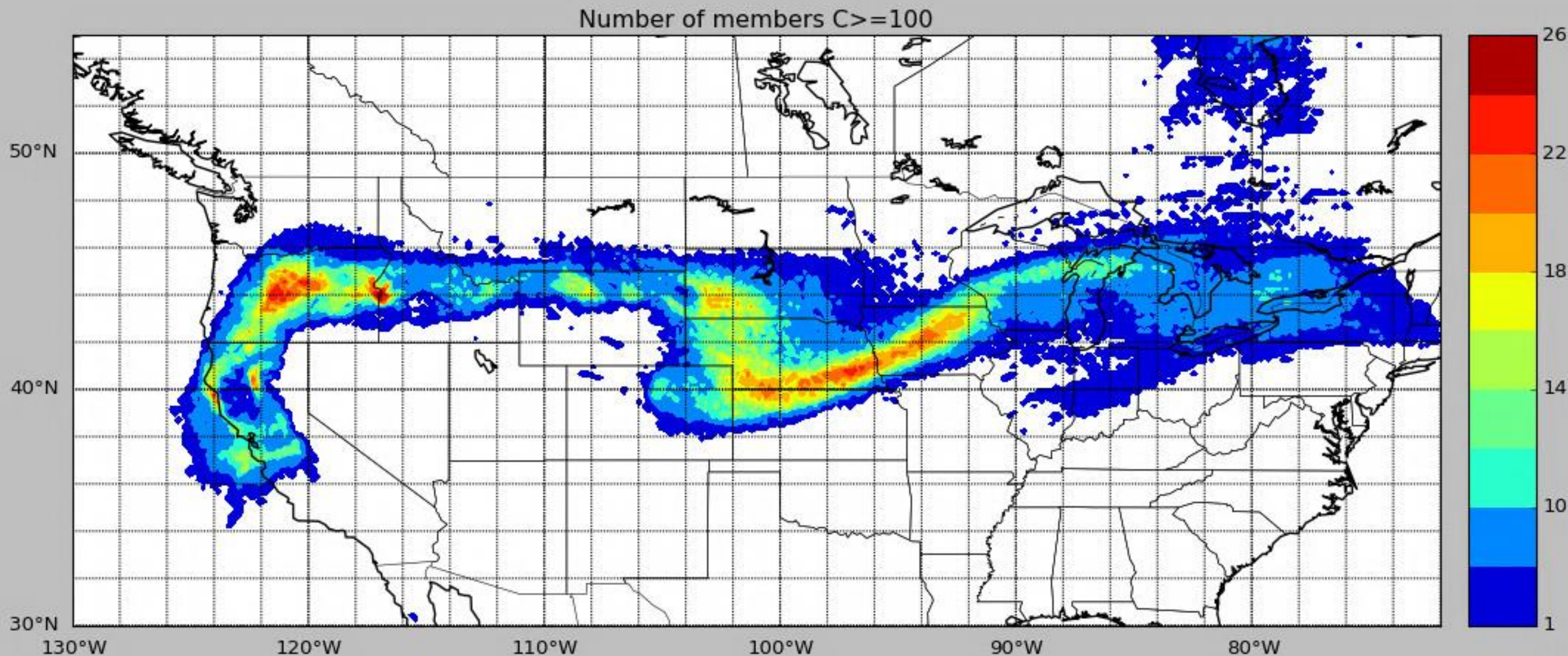
Scatter plot comparison between initial and assimilated particulate matter column concentrations using adjusted fire emissions during November 10-17, 2016

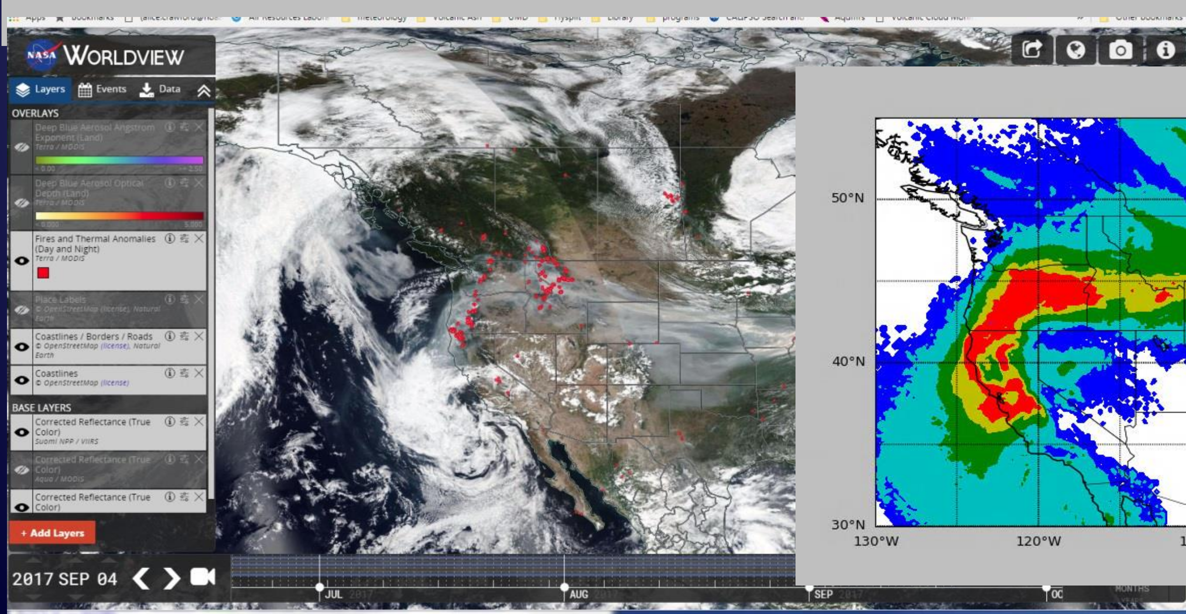


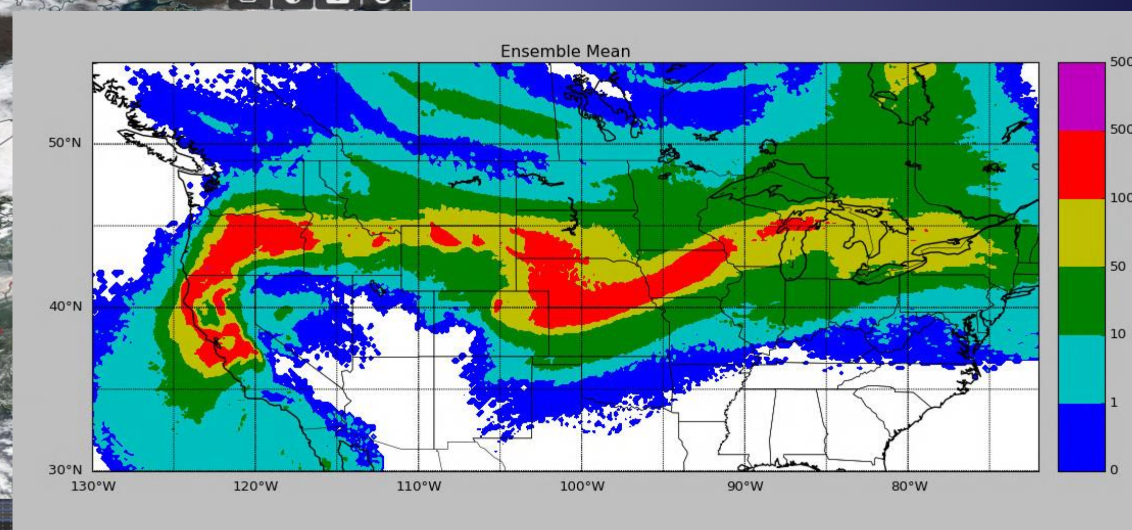
Spatial distributions of reconstructed fire particulate matter column concentrations using assimilated wildfire emissions.

		Nov. 10	Nov. 11	Nov. 12	Nov. 13	Nov. 14	Nov. 15	Nov. 16	Nov. 17
	Observation	70.28	78.72	93.45	102.99	77.62	54.44	47.35	56.13
mean	Initial	7.42	49.93	34.28	30.58	24.75	19.84	6.85	0.59
	Assimilated	42.05	61.88	57.85	61.12	53.49	33.72	23.10	26.94
RMSE	Initial	73.34	118.20	93.68	11.53	69.63	46.56	50.49	61.22
	Assimilated	51.43	46.50	68.14	72.44	51.87	39.28	40.61	43.69
Slope	Initial	0.41	-2.81	1.22	1.54	0.82	1.04	-0.45	0.04
	Assimilated	1.16	1.08	1.15	1.30	1.14	1.24	1.06	1.32
R	Initial	0.28	-0.16	0.11	0.09	0.2	0.09	-0.08	0.1
	Assimilated	0.49	0.35	0.40	0.46	0.4	0.15	0.3	0.44

Statistics of modeled smoke particulate column air masses using initial and assimilated fire emissions (unit: x10^{-10} kg)


Number of members C>=100
50°N
40°N
30°N
130°W
120°W
110°W
100°W
90°W
80°W
26
22
18
14
10
1

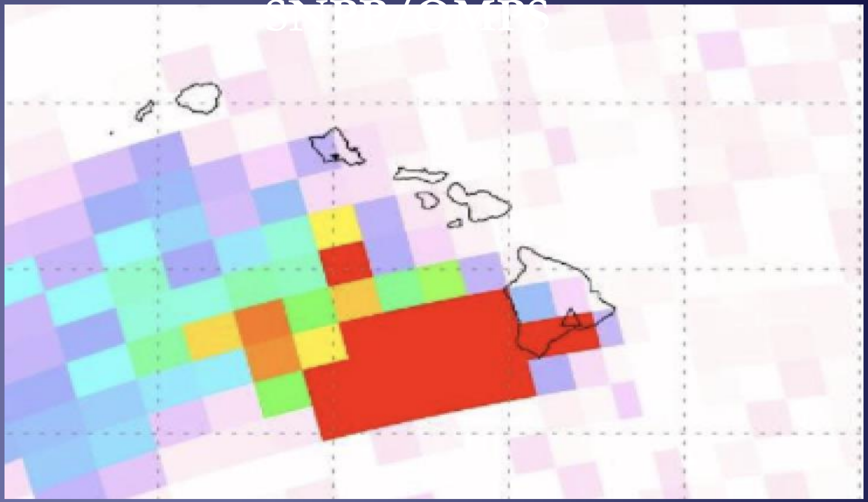

WORLDVIEW
Layers
Events
Data
OVERLAYS
Fires and Thermal Anomalies (Day and Night)
Terra / MODIS
Coastlines / Borders / Roads
Coastlines
BASE LAYERS
Corrected Reflectance (True Color)
Suomi NPP / VIIRS
+ Add Layers
2017 SEP 04
JUL
AUG
SEP


Ensemble Mean
50°N
40°N
30°N
130°W
120°W
110°W
100°W
90°W
80°W
50
10
1
0

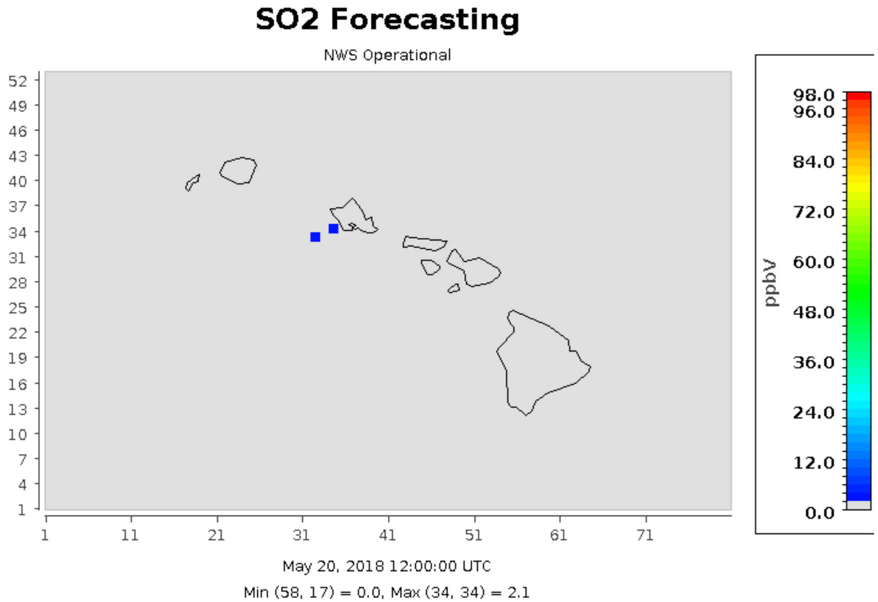
SO_2 Forecasting from Kilauea Eruption

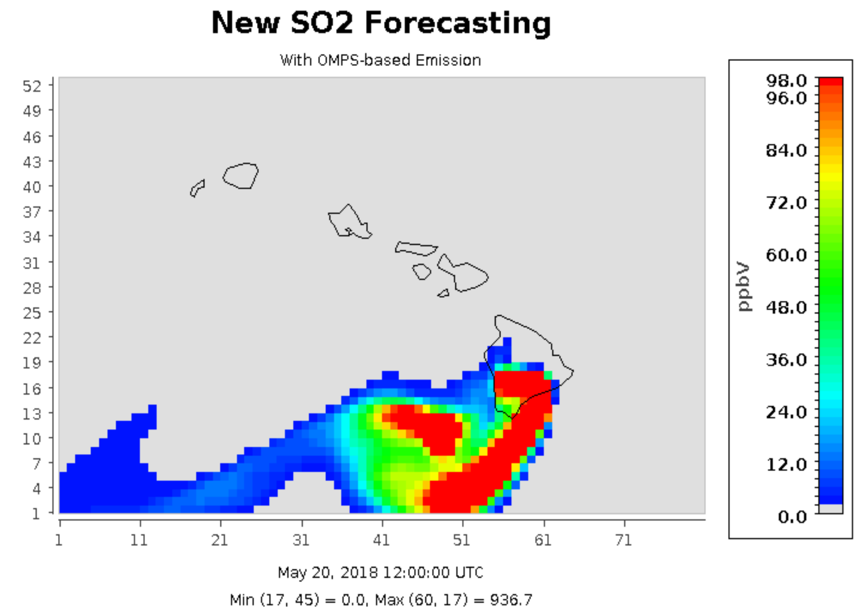
(Daniel Tong, OAR/ARL)

(REUTERS/Terray Sylvester)



(Li Can and Nickolay Krotkov, NASA GSFC)





QUESTIONS