The Value of CSPP NUCAPS in Real-Time Applications

Nadia Smith[1*], Emily Berndt[2], Brad Zavodsky[2], Brad Pierce[4], Jim Davies[3], Dave Hoese[3], Kris White[2,5], Greg Frost[6], Stuart McKeen[6], Antonia Gambacorta[1], Ashley Wheeler[1], Chris Barnet[1], etc.

[1]STC, [2]NASA/SPoRT, [3]UW/SSEC/CIMSS, [4]NOAA/NESDIS, [5]NWS, [6]NOAA/ESRL
*nadias@stcnet.com

CSPP/IMAPP Users Group Meeting; 27–29 June 2017; Madison, WI

History of NOAA operational Satellite Soundings

NUCAPS – NOAA Unique Combined Atmospheric Processing System

Prior to 2014: NUCAPS branches off from NASA AIRS v.5 algorithm and becomes operational system for Metop IASI/AMSU sounders at NOAA

April 2014: NUCAPS went operational for the SNPP CrIS/ATMS sounders

July 2014: NOAA Proving Ground initiative was launched to promote sounding applications

Sep 2014: NUCAPS available in AWIPS for the first time as skew-T plots

March 2016: NUCAPS available in AWIPS as gridded layer maps – thanks to CSPP tools

June 2017: NUCAPS upgrade to full-spectral resolution CrIS to allow CO retrieval applications

2017–: NUCAPS will become operational system for JPSS1 CrIS/ATMS sounders

Data Product

- Satellite Sounding (~50km at nadir)
- Vertical resolution; 1-2km in troposphere
- Thermodynamic and trace gas parameters
- Global coverage, ~75% yield
- Meets NOAA operational requirements

Availability

Different pathways to support diverse user base

- **CLASS archive**
- **CSPP direct broadcast**
- **SBN to AWIPS**

NUCAPS

Algorithm

- Platform-agnostic; runs on measurements from Metop-A/Metop-B, Suomi NPP and JPSS (future)
- Combining MW and IR to retrieve profiles of cloud-cleared atmosphere
- AIRS v5.9 heritage

Operational Weather Forecasting

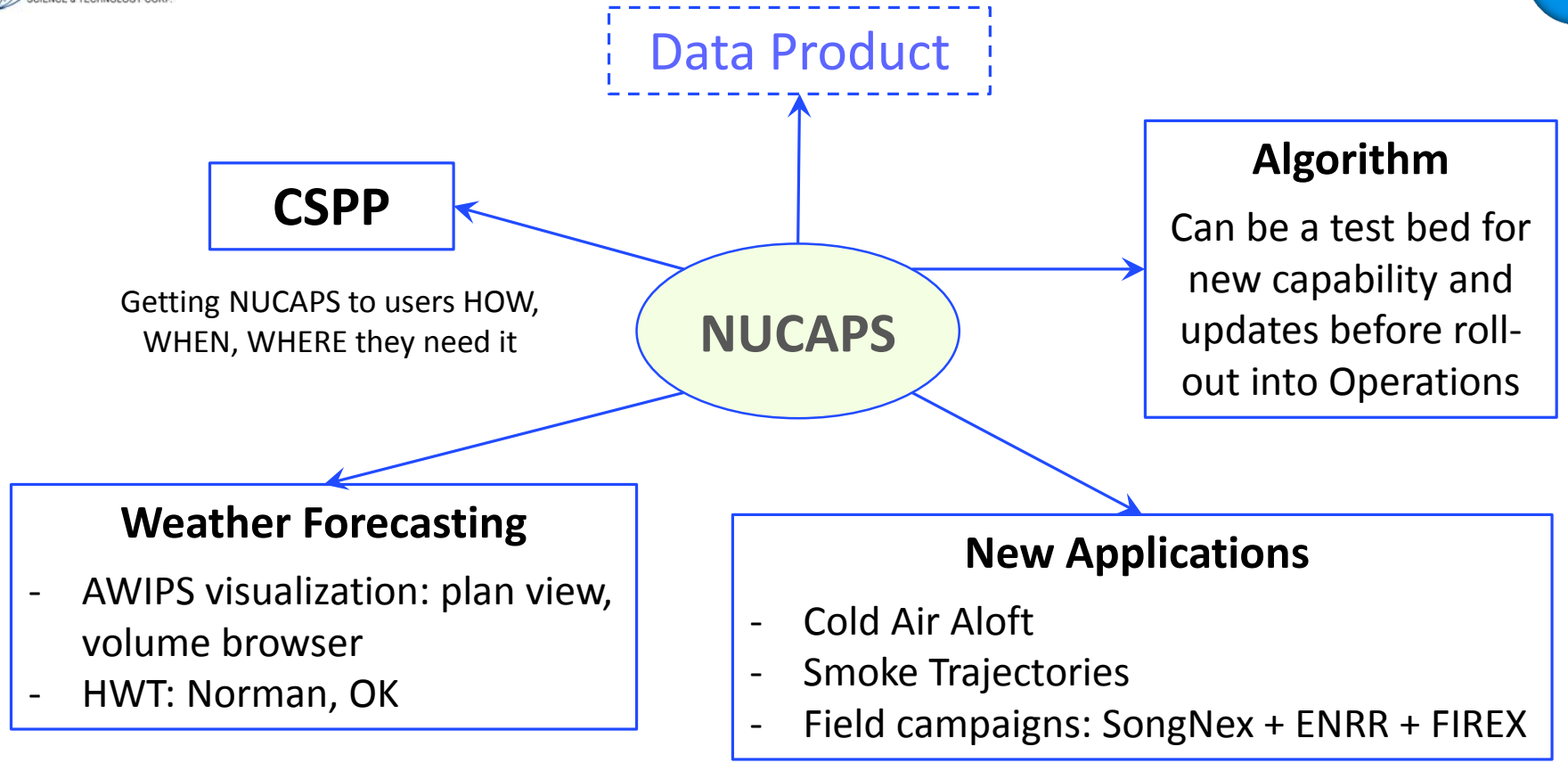
- Visualization in AWIPS: Profiles
- Severe weather indices to understand pre-convective environment
- Independent verification of models

Proving Ground and Risk Reduction

- Deep dive evaluation
- Dialogue between user and developer
- Illustrate capability; Visualization
- Supports product/algorithm improvement
- Develop training modules

NUCAPS Product – Vertical Atmospheric Measurements of thermodynamic parameters and trace gas species

gas	Precision	d.o.f.	Interfering Parameters	Sensitivity
Temperature Profile, T(p), SST, LST	1.5K/km	6-10	Emissivity, H_2O, O_3, N_2O	surface to ~1 mb
Water Profile, H_2O(p)	15%	4-6	CH_4, HNO_3	surface to ~300 mb
Cloud Top Pressure Cloud fraction	25 mbar, 1.5K, 5%	2 18	CO_2, H_2O	surface to tropopause
Ozone, O_3	10%	1+	H_2O, emissivity	Lower stratosphere
Carbon Monoxide, CO	15%	≈ 1	H_2O, N_2O	Mid-troposphere
Methane, CH_4	1.5%	≈ 1	H_2O, HNO_3, N_2O	Mid-troposphere
Carbon Dioxide, CO_2	0.5%	≈ 1	H_2O, O_3, T(p)	Mid-troposphere
Sulfur Dioxide, SO_2	≈ 50%	< 1	H_2O, HNO_3	Volcanic flag
Nitric Acid, HNO_3	≈ 50%	< 1	emissivity H_2O, CH_4, N_2O	Upper troposphere
Nitrous Oxide, N_2O	≈ 5%	< 1	H_2O, CO	Mid-troposphere


Data Product
CSPP
Getting NUCAPS to users HOW, WHEN, WHERE they need it
NUCAPS
Algorithm
Can be a test bed for new capability and updates before roll-out into Operations
Weather Forecasting
- AWIPS visualization: plan view, volume browser
- HWT: Norman, OK
New Applications
- Cold Air Aloft
- Smoke Trajectories
- Field campaigns: SongNex + ENRR + FIREX

NUCAPS has evolving capability driven by User Requirements

- **Are Soundings being effectively used**? What are your data needs?
- Can NUCAPS products be improved to be more useful?
- What does this product measure? How should we use it?
- Does this work?

CSPP + PGRR allows Developers and User Community to form productive partnerships

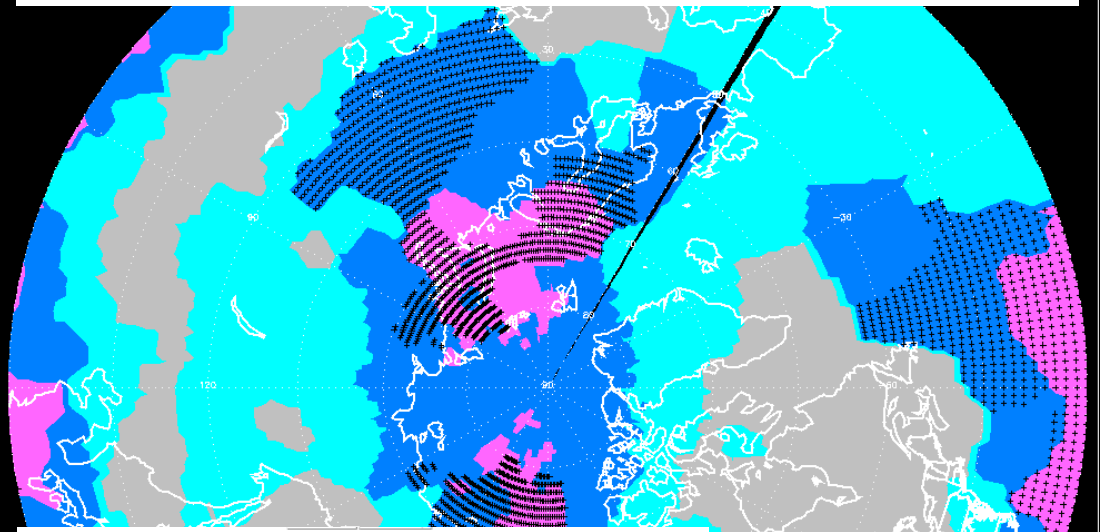
PGRR – Proving Ground and Risk Reduction

Novel Applications

NOAA Proving Ground and Risk Reduction

Cold Air Aloft: PI Brad Zavodsky NASA/SPoRT

Figure by Jack Dostalek (CIRA)
2D plots of Cold Air Aloft from MiRA and NUCAPS
http://rammb.cira.colostate.edu/ramsdis/online/cold_air_aloft.asp



FAAK20 KZAN 040358 ZAN MIS COR 01 VALID 040355-041555 ...FOR ATC PLANNING PURPOSES ONLY... FROM 320 NW BRW-980N BRW-360NE BRW-320NW NRW COLD AIR ALOFT TEMPS -65C OR LESS FM FL310-500 STNR. NC. NO UPDATES AFT 0500Z...REFER TO HTTP://AAWU.ARH.NOAA.GOV KAN DEC 15

Kristine Nelson

Alaskan forecaster (CWSU) with a vision to improve information service to aviation community

Cold Air Aloft (-65˚C and below) can freeze airliner fuel. The Center Weather Service Units (CWSU) provides Meteorological impact statements (MIS) to Air Traffic Controllers to direct flights around 3D air features.

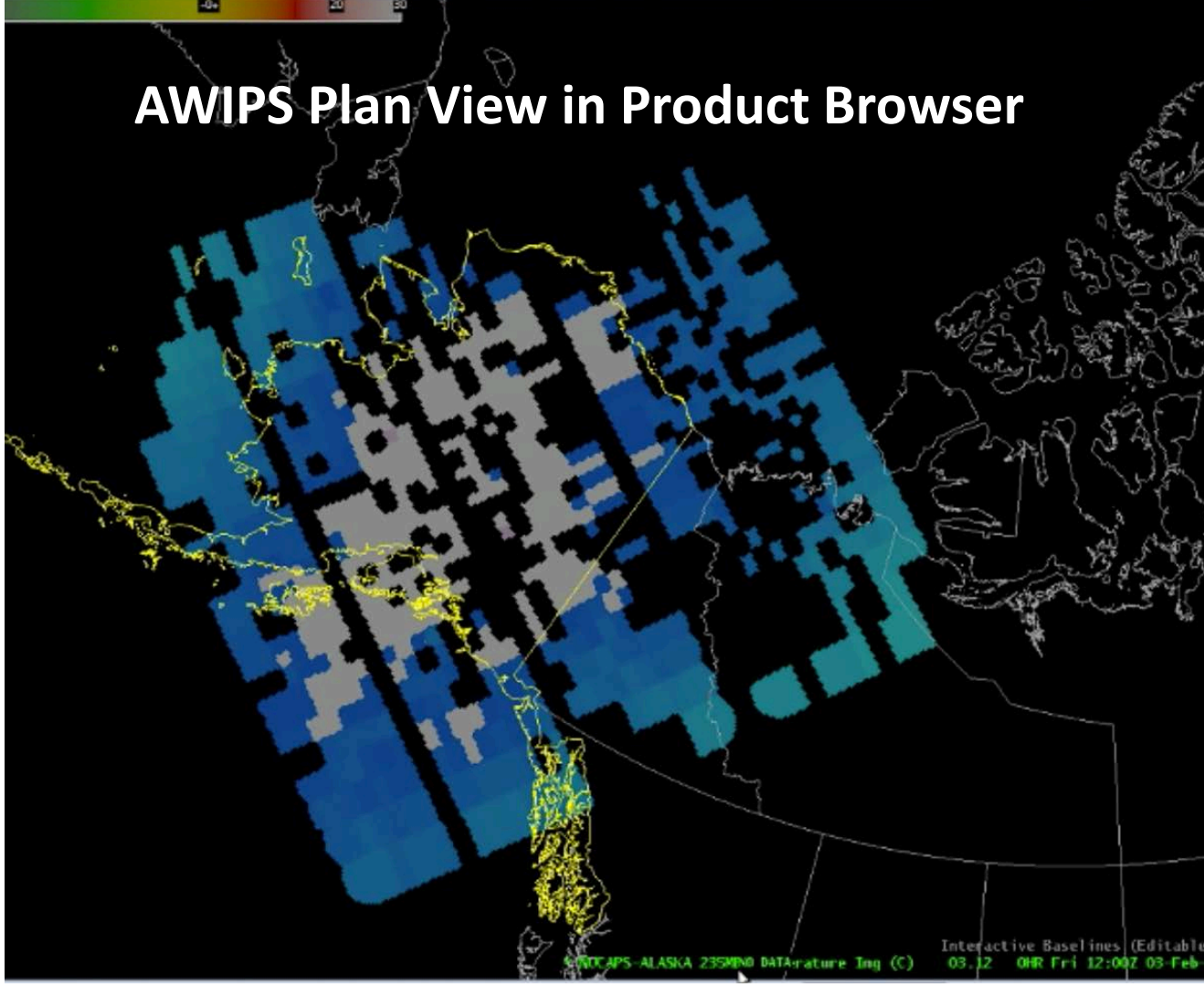
NUCAPS has high vertical resolution and provide 3D information about extent of CAA

Challenge: How to visualize 3D features?

AWIPS Plan View in Product Browser

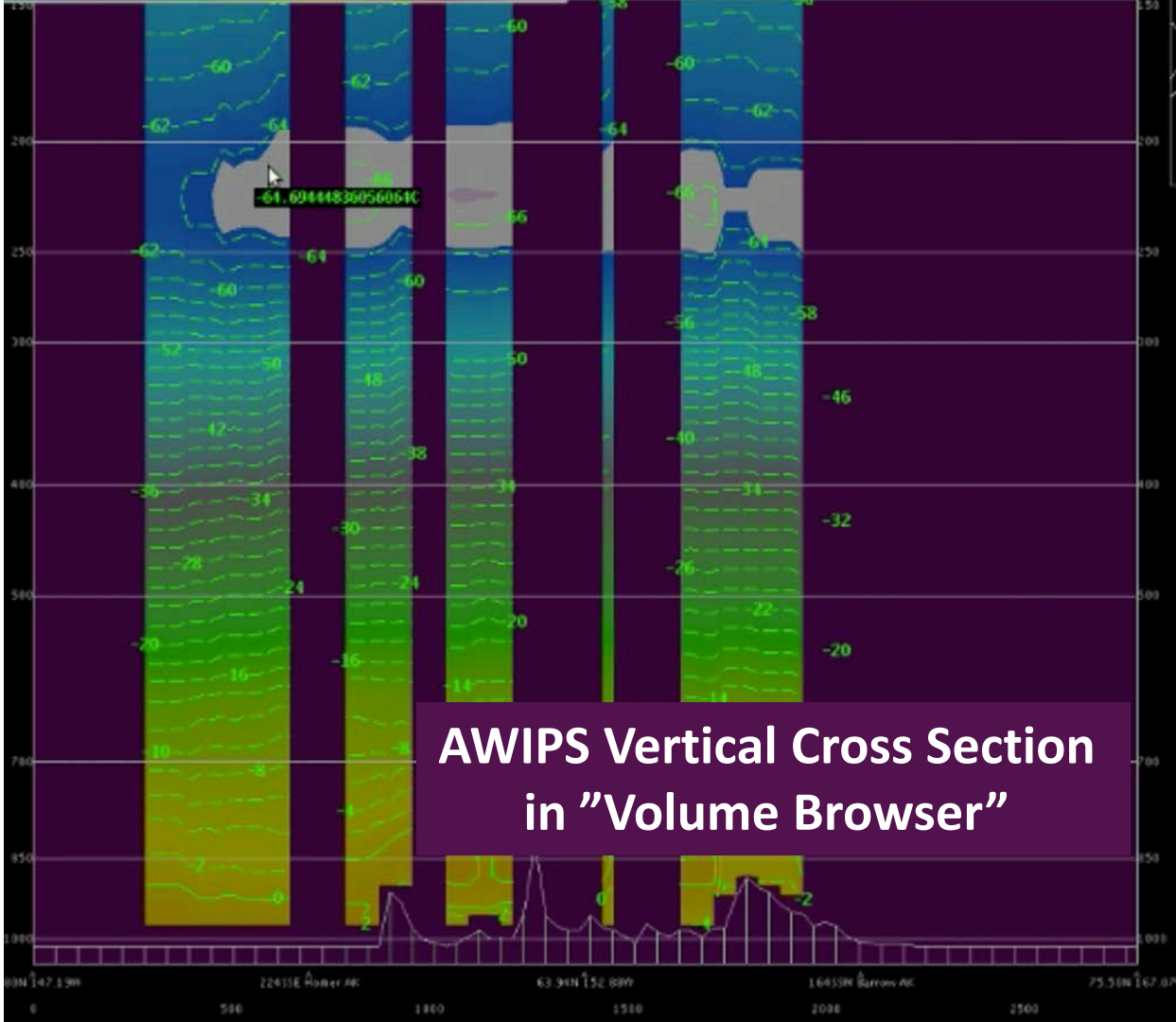
Develop, Demonstrate and Test novel NUCAPS visualization in AWIPS using CSPP Algorithms (polar2grid + NUCAPS) and Direct Broadcast data stream

CSPP allows Algorithm Developers and User Community to work together



Data products and applications can be tested and vetted by users before transition into Operations

Cost Effective solution
User-Centric design
Ownership of products
Training through collaboration



Cold Air Aloft Winter Demonstration Debrief

20 March 2017 – Forecasters + Developers – PI Brad Zavodsky, NASA/SPoRT

- "**We use NUCAPS to help decide between GFS or NAM**" (Carrie Haisley). Evidence that NUCAPS, as independent measurement, has real-time value in evaluating model accuracy.
- Direct Broadcast latency at GINA is sufficient for CAA forecasting
- NUCAPS at flight levels will be more valuable in CAA application than NUCAPS at pressure levels (a future product enhancement).
- JPSS-1 NUCAPS will be a welcome addition to S-NPP NUCAPS since it will help
  - → Fill orbital data gaps in AWIPS plan views
  - → Help monitor the evolution of CAA event
- Suggestions for future applications: Identifying **icing layers** will help air traffic controllers to avoid icing hazards.

Supporting Operations

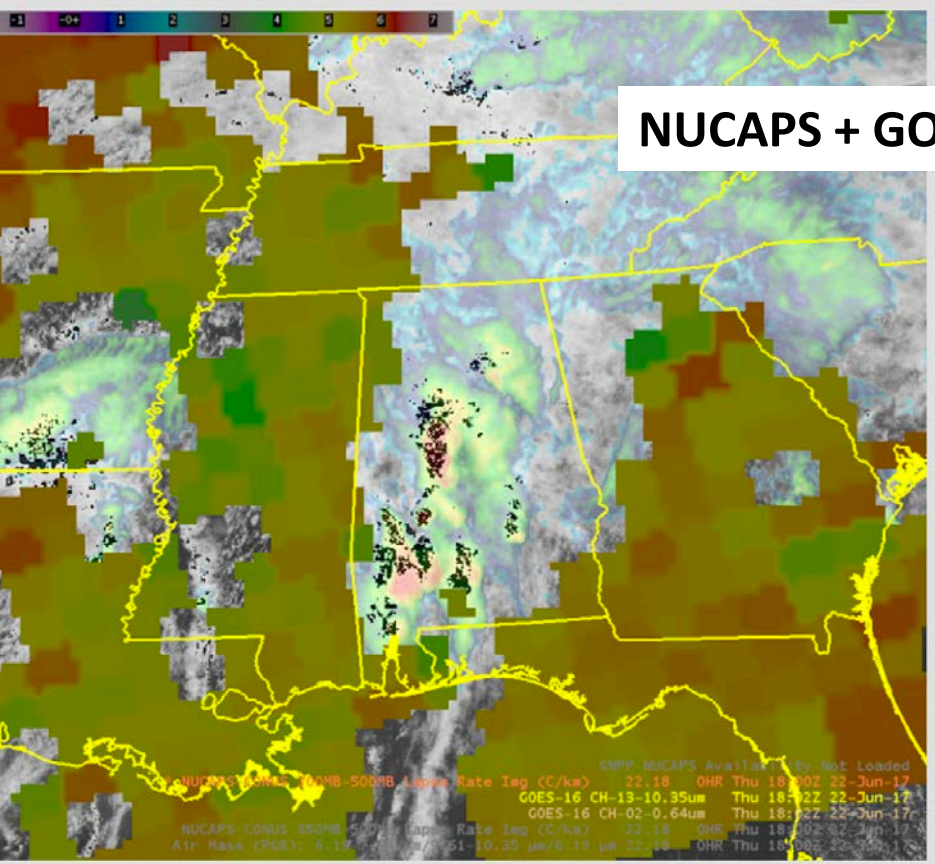
Hazardous Weather Testbed, Norman OK

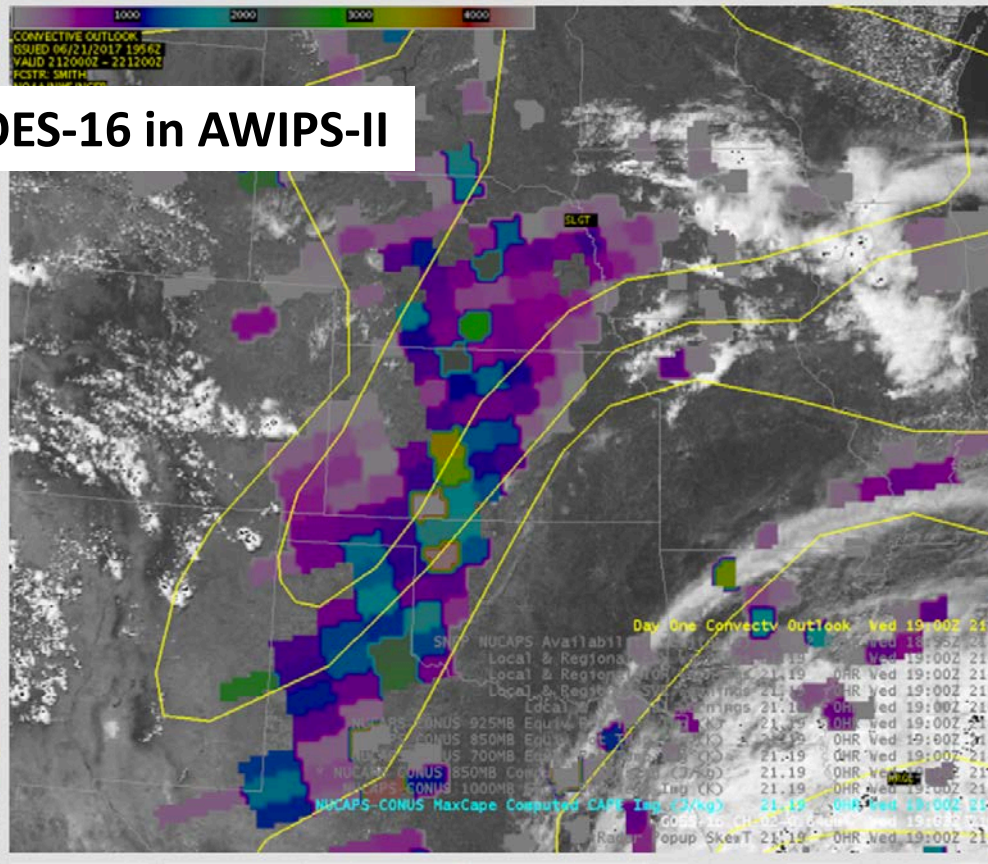
NUCAPS in Pre-convective Environment

View NUCAPS Training modules: http://hwt.nssl.noaa.gov/ewp/

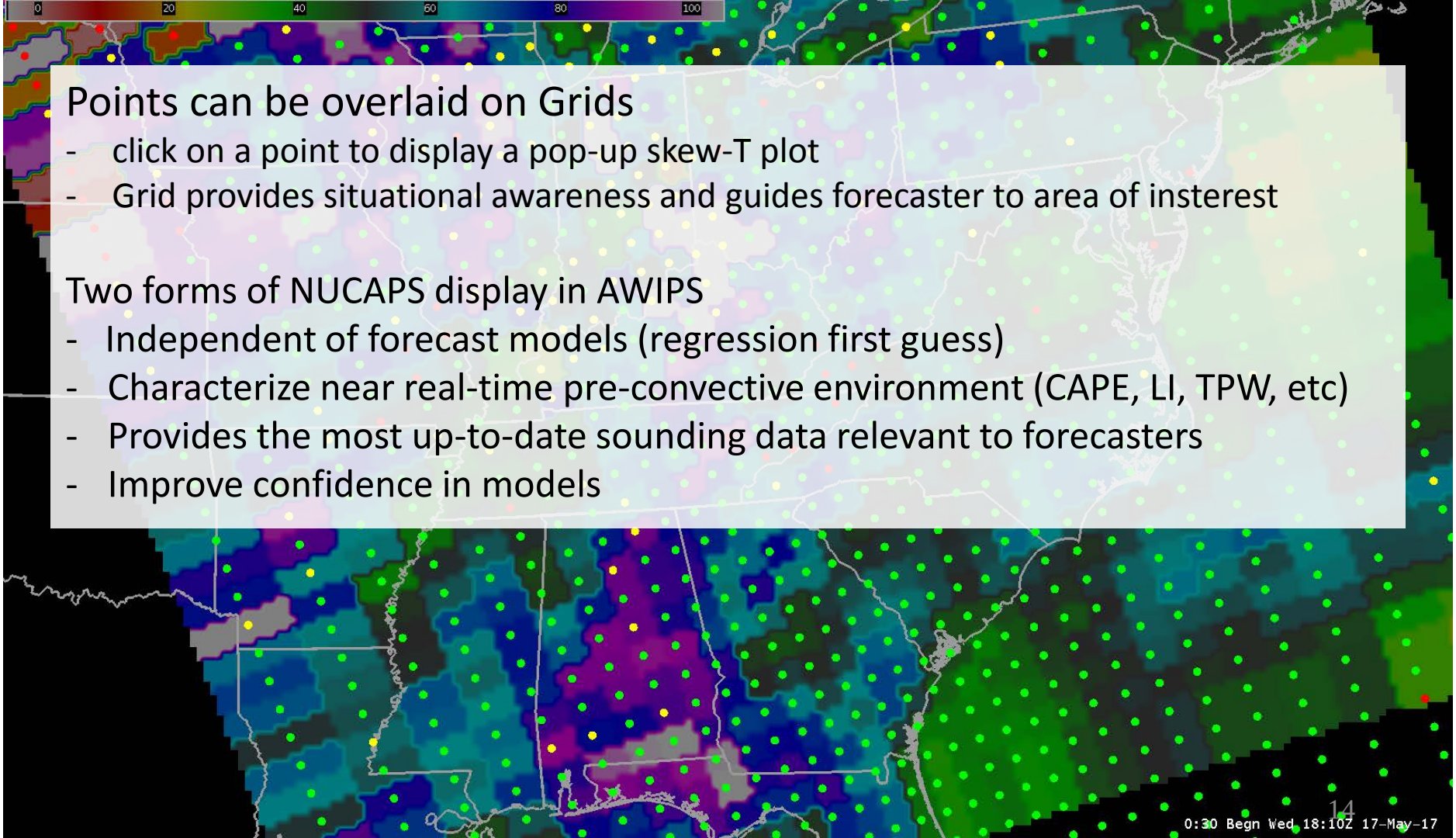
View Forecaster feedback:
http://goesrhwt.blogspot.com/search/label/NUCAPS

NUCAPS + GOES-16 in AWIPS-II





Test new forms of visualization in AWIPS and determine if it has value before committing operational resources



Points can be overlaid on Grids

- click on a point to display a pop-up skew-T plot
- Grid provides situational awareness and guides forecaster to area of insterest

Two forms of NUCAPS display in AWIPS

- Independent of forecast models (regression first guess)
- Characterize near real-time pre-convective environment (CAPE, LI, TPW, etc)
- Provides the most up-to-date sounding data relevant to forecasters
- Improve confidence in models

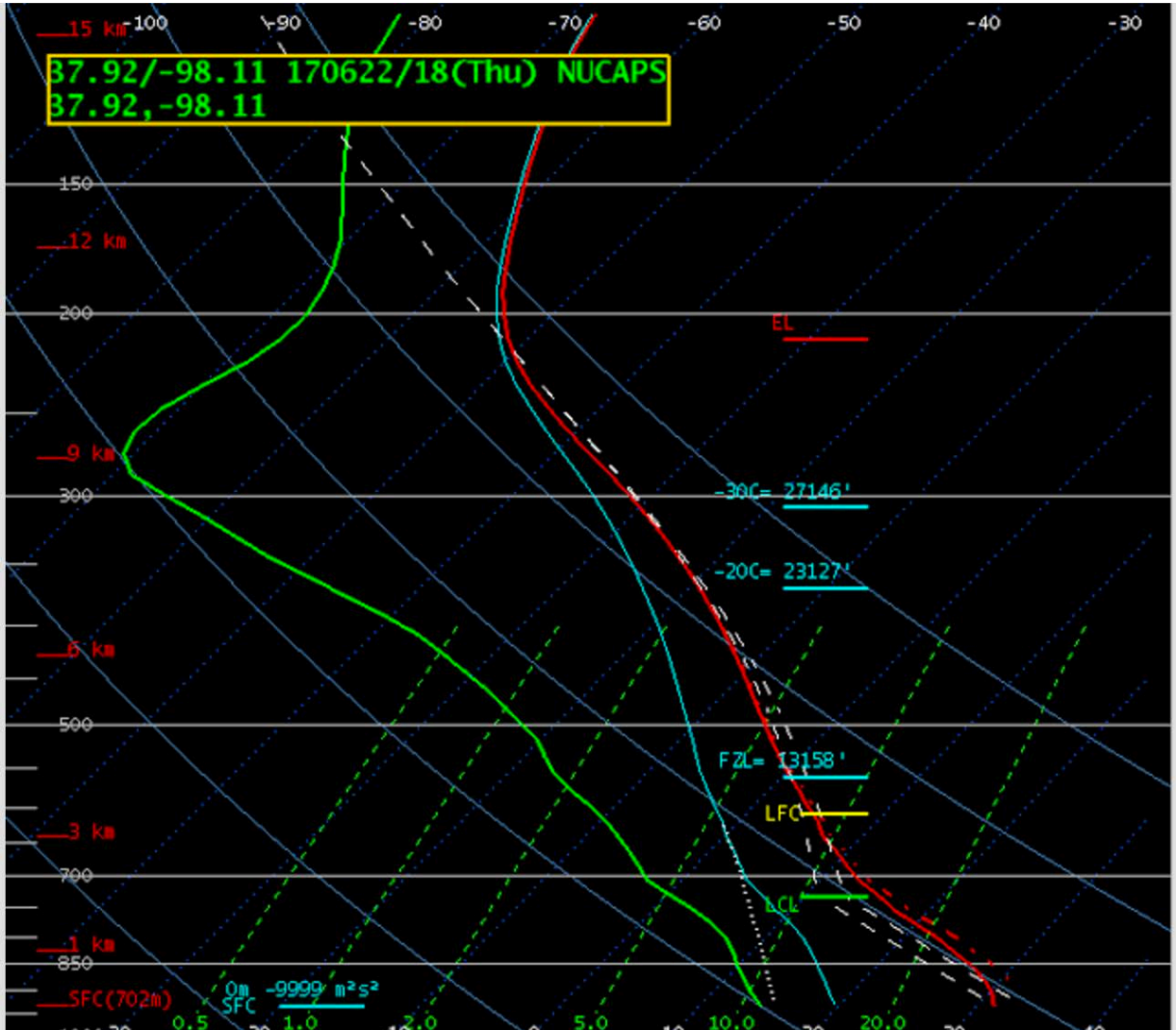
NUCAPS skew-T plot in AWIPS

It is valuable, but shortcomings are:

- Surface conditions – differences with surface networks
- Only one sounding is displayed at a time. Need to plot multiple soundings from different sources.
- Need cloud top pressure information
- Need height of 0C and -20C isotherms

Thanks to the pathways of collaboration established with SPoRT, we were able to get NUCAPS (Metop) into AWIPS for HWT 2017 despite operational setbacks.

Make progress and reach forecaster community by cultivating culture of collaboration.



Forecaster Debrief

19–23 June 2017 – Forecasters + Developers – Coordinator Bill Line, NWS

How is NUCAPS soundings valuable to you?

- NWP independence – can be used to evaluate different regional models
- Consistent quality – no regional dependence
- High vertical resolution

Will they use it again? YES

"*Monitoring mixed layer depth evolution which are quite important in regards to fire weather/explosive wildfire growth (Haines Index) and smoke dispersion*. "

"*Monitoring inversion (stable layers) iscritical for downslope wind storms, air quality, convective suppression or cap breaking*."

"*Stability evolution (assuming better temporal resolution) for aviation*"

Deep Dive Evaluation of New Products

Full Spectral Resolution (FSR) CrIS SDRs

NUCAPS CO, O_3 and CH_4 Retrievals

PI: Brad Pierce NOAA/NESDIS
PI: Greg Frost NOAA/ESRL

NOAA PGRR – Sounding and Fire+Smoke Initiatives

JPSS Proving Ground/Risk Reduction (PGRR) project is a collaborative effort combining expertise in satellite retrieval development (STC), airborne trace gas measurements (ESRL/CIRES), and satellite trace gas validation (STAR/CIMSS/) to characterize NUCAPS retrieval quality, with the goal of improving the accuracy of the NUCAPS daily global measurements of methane (CH4) and carbon monoxide (CO).

2014 NOAA CrIS Atmospheric Chemistry Data User's Workshop Report (http://docs.lib.noaa.gov/noaa_documents/OAR/CPO/AC4/CrIS_workshop_2014.pdf) which concluded "*that the current state of validation of the NUCAPS trace gas retrievals is insufficient for the use of these retrievals in most atmospheric chemistry applications*" and recommended that the "*CrIS retrieval development community should closely coordinate with the project teams of upcoming field campaigns (aircraft, surface, balloon, etc.) on trace gas validation activities*".

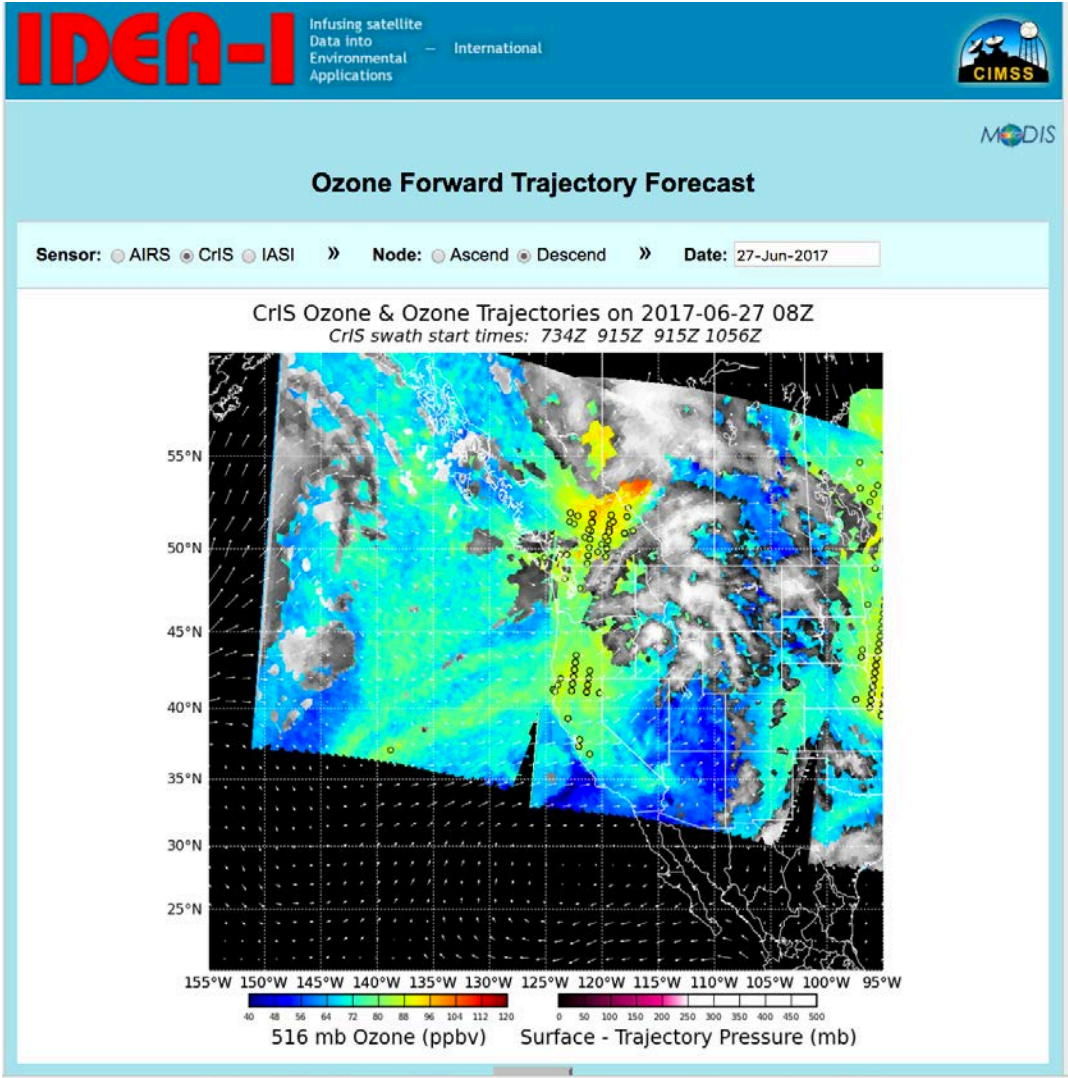
CSPP NUCAPS in IMAPP application

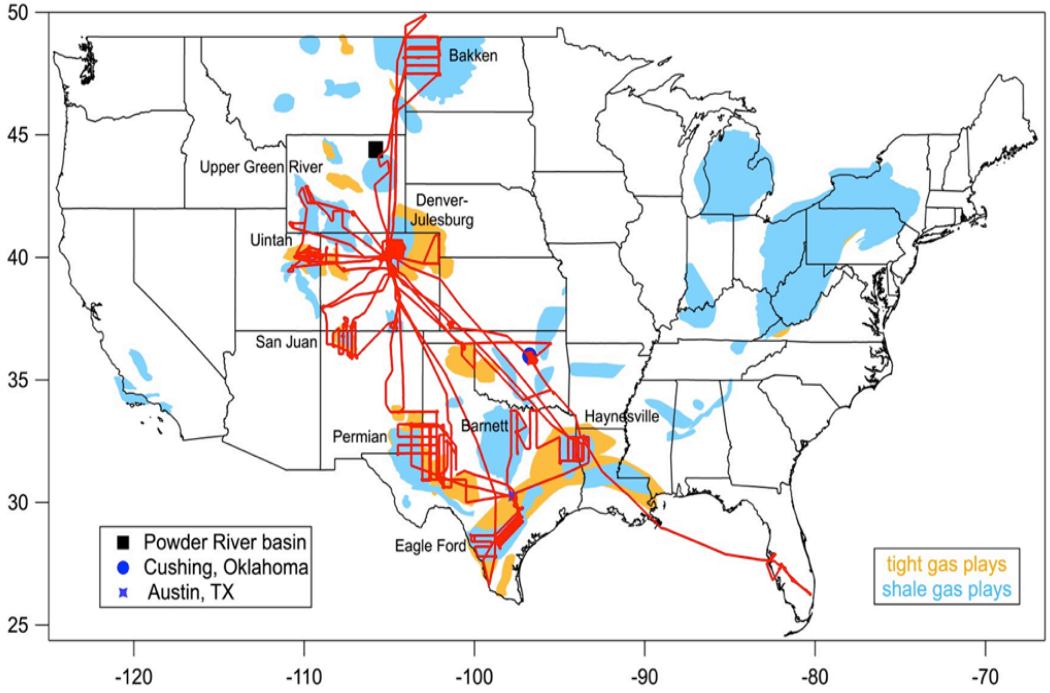
http://cimss.ssec.wisc.edu/idea-i/USozone/

Real-time stratospheric intrusion forecasts

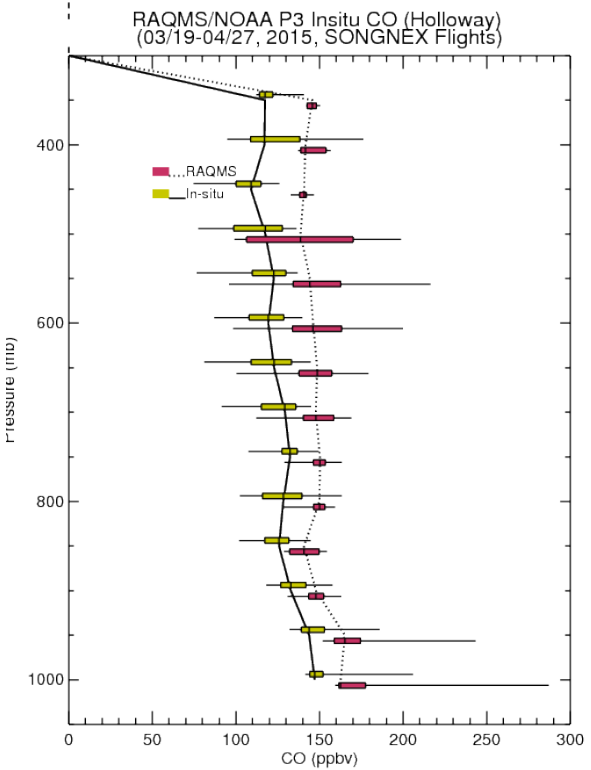
The background basemap is the daily AIRS, IASI, or CrIS Dual Regression (CSPP HSRTV) Ozone retrievals at 516mb, which is used in conjunction with Dual Regression dewpoint temperature retrievals to initialize trajectories which show where the stratospheric intrusion (high ozone/dry air) is expected to move in the next ~48 hours. The products are derived from AIRS, IASI and CrIS data acquired and processed directly from the Terra, METEOP-A, and SNPP satellites, respectively

As soon as CrIS FSR SDR is available in CSPP we will ingest NUCAPS CO retrieval in IDEA-I to initialize smoke dispersion forecasts





NOAA P-3 aircraft flight paths over the western US during the **SONGNEX field campaign**, March-April, **2015**.

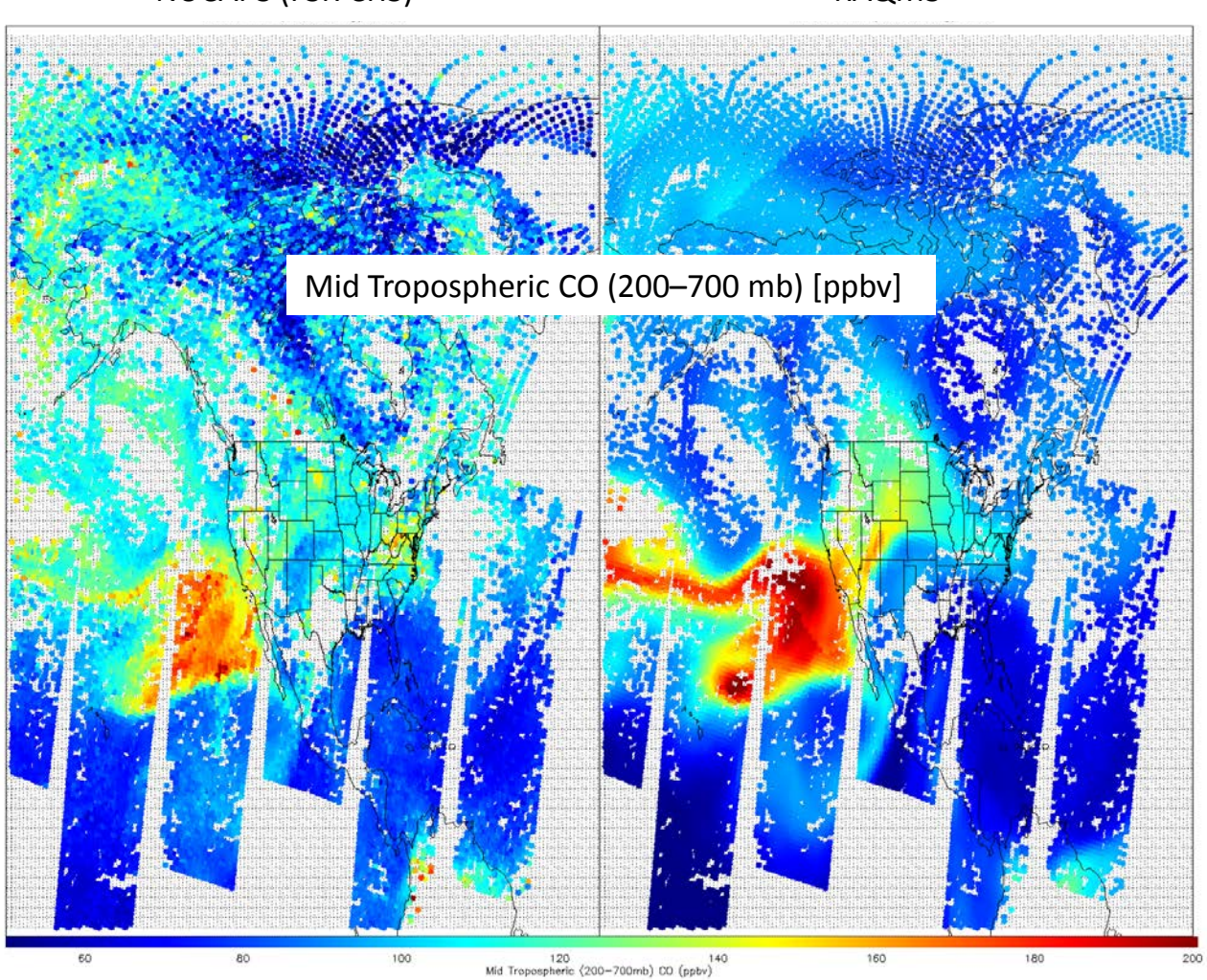


Comparisons between RAQMS and in situ CO measurements during SONGNEX show that RAQMS has a mean high bias of 29ppbv above 700mb and tends to overestimate the observed mid tropospheric variability

Comparisons between bias corrected RAQMS and NUCAPS mid tropospheric CO suggests that NUCAPS has a 6.8 ppbv high bias relative to the in situ aircraft measurements

In **2016** CSPP NUCAPS supported a field campaign in real-time (**ENRR**) for the first time

Building on lessons learned, CSPP NUCAPS will support **FIREX** in **2018/2019**



Contact with NUCAPS users across the world 2016-2017

- Katja Hungershöfer – **German Weather Service (DWD)**
- Dmitry Gorski – **Belarussian Center of Hydrometeorology**
- Junhyung Heo – **National Metrological Satellite Center of KMA**
- Ronald Goodson – **Environment Canada**
- Meteorological Satellite Center, **Central Weather Bureau of Taiwan**
- Bozena Lapeta, **National Research Institute of Poland**

NUCAPS from Metop + SNPP + JPSS (temporal resolution)

Sounding Visualization Tools (web-based + desktop)

Data format conversion tools (easy ingest into applications)

Training modules (what is this product good for?)

Looking to the future

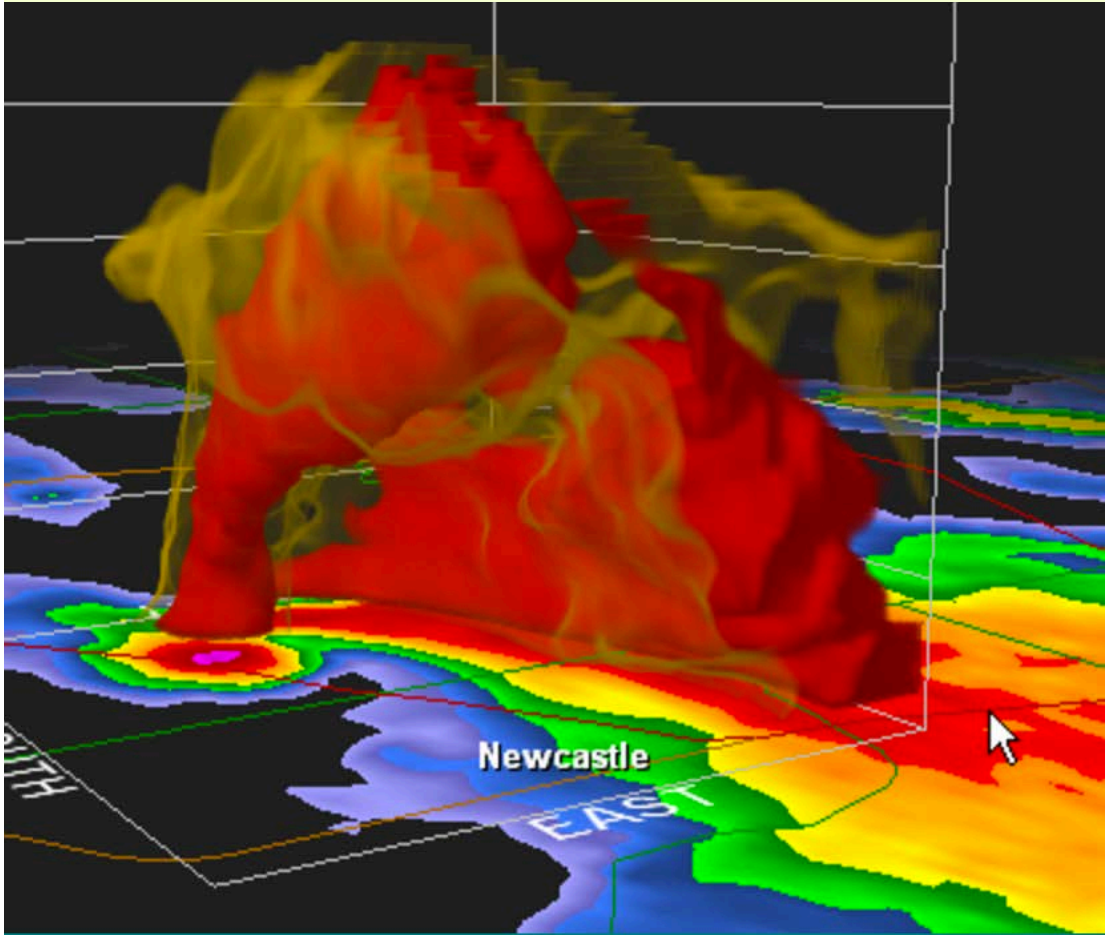
NUCAPS trace gas product data assimilation into next generation forecast models (NGGPS)…

Weather forecasting beyond the the pre-convective environment…

High temporal resolution with multiple platforms...

Multi-platform, multi-product data fusion in applications...

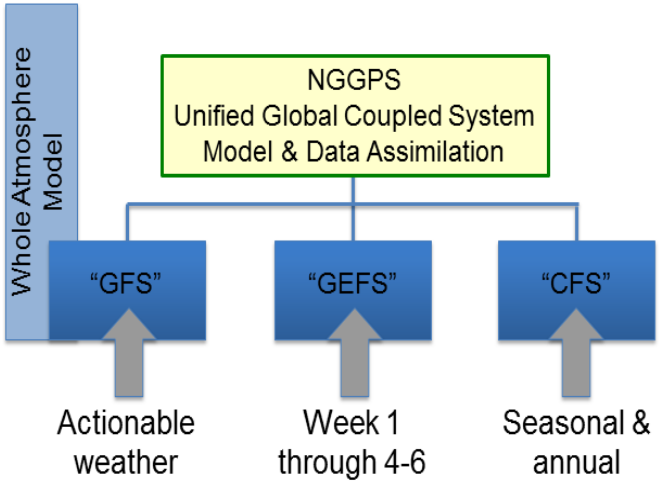
True 3D visualization...?



We sincerely thank the JPSS program and CSPP (specifically Mitch Goldberg, Allen Huang, Liam Gumley, Kathy Strabala) for their vision to create this unique opportunity to advance the value of satellite products

- Develop new pathways towards applications
- Build strong networks of data dissemination and collaboration
- Design information products based on consensus and user support

[EXTRA slide]: NOAA Next Generation Global Prediction System (NGGPS) Finite Volume (FV3)-based Unified Modeling System

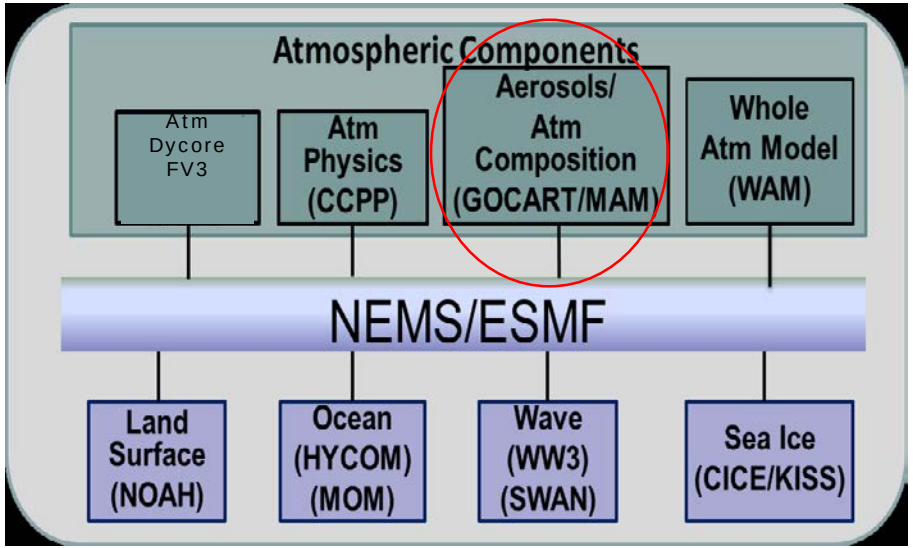


Application = Ensemble + Reanalysis + Reforecast

1 y	2 y	4 y	Update cycle
3 y	1999 - present	1979 - present	Reanalysis
6h	6h	6h	cycling
WCOSS	WCOSS	WCOSS	where

NGGPS will include predictions of atmospheric composition and aerosols

NGGPS will be a multi-scale unified modeling system that will eventually replace the current GFS, GFS ensemble, and Climate Forecast System (CFS)



Ongoing NUCAPS Research Activities

- *Pre-convective environment* (Dan Nietfield, Brad Zavodsky): building forecaster confidence in NUCAPS to characterize pre-convective conditions. Combine with surface measurements and GOES-16 products.
- *Winter Weather* (Emily Berndt, Kris White, Rob Rabin): heavy banded snow
- *Stratospheric Ozone intrusions* (Emily Berndt, Amanda Terborg): potentially affecting small/medium aircraft without adequate air quality filters
- *Fire emissions and Fire weather* (Brad Pierce, Greg Frost, Eric Stevens): Carbon Monoxide convective updrafts and transport, plume forecasts, fire weather.
- *Evolving Features*: Adopting a multi-instrument approach to characterize evolving features/weather with S-NPP, Metop-A/B, JPSS-1, GOES-16. Fill gaps, improve temporal resolution