The Value of CSPP NUCAPS in Real-Time Applications

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

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

Availability
Different pathways to support diverse user base
- CLASS archive
- CSPP direct broadcast
- SBN to AWIPS

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

<table>
<thead>
<tr>
<th>gas</th>
<th>Precision</th>
<th>d.o.f.</th>
<th>Interfering Parameters</th>
<th>Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature Profile, T(p), SST, LST</td>
<td>1.5K/km</td>
<td>6-10</td>
<td>Emissivity, $H_2O$, $O_3$, $N_2O$</td>
<td>surface to ~1 mb</td>
</tr>
<tr>
<td>Water Profile, $H_2O(p)$</td>
<td>15%</td>
<td>4-6</td>
<td>$CH_4$, $HNO_3$</td>
<td>surface to ~300 mb</td>
</tr>
<tr>
<td>Cloud Top Pressure</td>
<td>25 mbar, 1.5K, 5%</td>
<td>2</td>
<td>$CO_2$, $H_2O$</td>
<td>surface to tropopause</td>
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<tr>
<td>Ozone, $O_3$</td>
<td>10%</td>
<td>1+</td>
<td>$H_2O$, emissivity</td>
<td>Lower stratosphere</td>
</tr>
<tr>
<td>Carbon Monoxide, CO</td>
<td>15%</td>
<td>≈ 1</td>
<td>$H_2O$, $N_2O$</td>
<td>Mid-troposphere</td>
</tr>
<tr>
<td>Methane, CH$_4$</td>
<td>1.5%</td>
<td>≈ 1</td>
<td>$H_2O$, $HNO_3$, $N_2O$</td>
<td>Mid-troposphere</td>
</tr>
<tr>
<td>Carbon Dioxide, CO$_2$</td>
<td>0.5%</td>
<td>≈ 1</td>
<td>$H_2O$, $O_3$, T(p)</td>
<td>Mid-troposphere</td>
</tr>
<tr>
<td>Sulfur Dioxide, SO$_2$</td>
<td>≈ 50%</td>
<td>&lt; 1</td>
<td>$H_2O$, $HNO_3$</td>
<td>Volcanic flag</td>
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<tr>
<td>Nitric Acid, HNO$_3$</td>
<td>≈ 50%</td>
<td>&lt; 1</td>
<td>emissivity</td>
<td>Upper troposphere</td>
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<tr>
<td>Nitrous Oxide, N$_2$O</td>
<td>≈ 5%</td>
<td>&lt; 1</td>
<td>$H_2O$, CO</td>
<td>Mid-troposphere</td>
</tr>
</tbody>
</table>
Getting NUCAPS to users HOW, WHEN, WHERE they need it

Weather Forecasting
- AWIPS visualization: plan view, volume browser
- HWT: Norman, OK

New Applications
- Cold Air Aloft
- Smoke Trajectories
- Field campaigns: SongNex + ENRR + FIREX

Algorithm
Can be a test bed for new capability and updates before rollout into Operations
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 Zavodskyy NASA/SPoRT
2D plots of Cold Air Aloft from MiRA and NUCAPS

http://rammb.cira.colostate.edu/ramsdis/online/cold_air_aloft.asp

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?
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**

**AWIPS Vertical Cross Section in “Volume Browser”**
"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
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 interest

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.
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) is critical 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
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”.

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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.
Comparisons between RAQMS and in situ CO measurements during SONGNEX show that RAQMS has a mean high bias of 29 ppbv above 700 mb 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 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
NGGPS will be a multi-scale unified modeling system that will eventually replace the current GFS, GFS ensemble, and Climate Forecast System (CFS).

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<tr>
<th></th>
<th>1 y</th>
<th>2 y</th>
<th>4 y</th>
<th>Update cycle</th>
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<tbody>
<tr>
<td>3 y</td>
<td>1999 - present</td>
<td>1979 - present</td>
<td>Reanalysis</td>
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<td>6h</td>
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NGGPS will include predictions of atmospheric composition and aerosols.
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