Validated Maturity Science Review for NUCAPS IR Ozone Profile and CrIS Outgoing Longwave Radiation EDRs

Presented by

Nicholas R. Nalli (IR ozone profile)
and
Kexin Zhang (CrIS OLR)

With contributions from Mark Liu, Changyi Tan, Flavio Iturbide-Sanchez, Antonia Gambacorta, A. K. Sharma, Chris Barnet, Jonathan Smith

Date: 2016/10/18

Outline

- Algorithm Cal/Val Team Members
- Product Requirements
- Evaluation of algorithm performance to specification requirements
  - EDR product analysis/validation
  - Error Budget
- Identification of Processing Environment
- Users & User Feedback
- Documentation (Science Maturity Check List)
- Conclusion
- Path Forward

Sounding EDR Cal/Val Team

Algorithm Cal/Val Team Members

Name	Organization	Major Task
Q. Liu, T. Reale, W.Wolf	NOAA/STAR	Management leads
A. Gambacorta, C. Barnet	STC	NUCAPS algorithm development leads
N. Nalli	IMSG at STAR	NUCAPS product validation lead (AVTP, AVMP, O_3, trace gases)
C. Tan, K. Zhang, M. Wilson, F. Iturbide-Sanchez, X. Xiong	IMSG at STAR	NUCAPS algorithm team members
B. Sun, M. Pettey, Frank Tilley, Charlie Brown	IMSG at STAR	NPROVS/NPROVS+
A. K. Sharma	NOAA/OSPO	Operational implementation
X. Liu	NASA/LaRC	NUCAPS independent assessment
P. J. Mather	DOE	support validation of EDRs
L. Borg	UW/SSEC	ARM-RAOBS at SGP, NSA, ENA

Special thanks to T. King and ASSISTT team. NUCAPS codes are under version control in ClearCase.

JPSS Data Products Maturity Definition

JPSS/GOES-R Data Product Validation Maturity Stages – COMMON DEFINITIONS (Nominal Mission)

1. Beta

- Product is minimally validated, and may still contain significant identified and unidentified errors.
- Information/data from validation efforts can be used to make initial qualitative or very limited quantitative assessments regarding product fitness-for-purpose.
- Documentation of product performance and identified product performance anomalies, including recommended remediation strategies, exists.

2. Provisional

- Product performance has been demonstrated through analysis of a large, but still limited (i.e., not necessarily globally or seasonally representative) number of independent measurements obtained from selected locations, time periods, or field campaign efforts.
- Product analyses are sufficient for qualitative, and limited quantitative, determination of product fitness-for-purpose.
- Documentation of product performance, testing involving product fixes, identified product performance anomalies, including recommended remediation strategies, exists.
- Product is recommended for potential operational use (user decision) and in scientific publications after consulting product status documents.

3. Validated

- Product performance has been demonstrated over a large and wide range of representative conditions (i.e., global, seasonal).
- Comprehensive documentation of product performance exists that includes all known product anomalies and their recommended remediation strategies for a full range of retrieval conditions and severity level.
- Product analyses are sufficient for full qualitative and quantitative determination of product fitness-for-purpose.
- Product is ready for operational use based on documented validation findings and user feedback.
- Product validation, quality assurance, and algorithm stewardship continue through the lifetime of the instrument.

CrIS OLR Validation

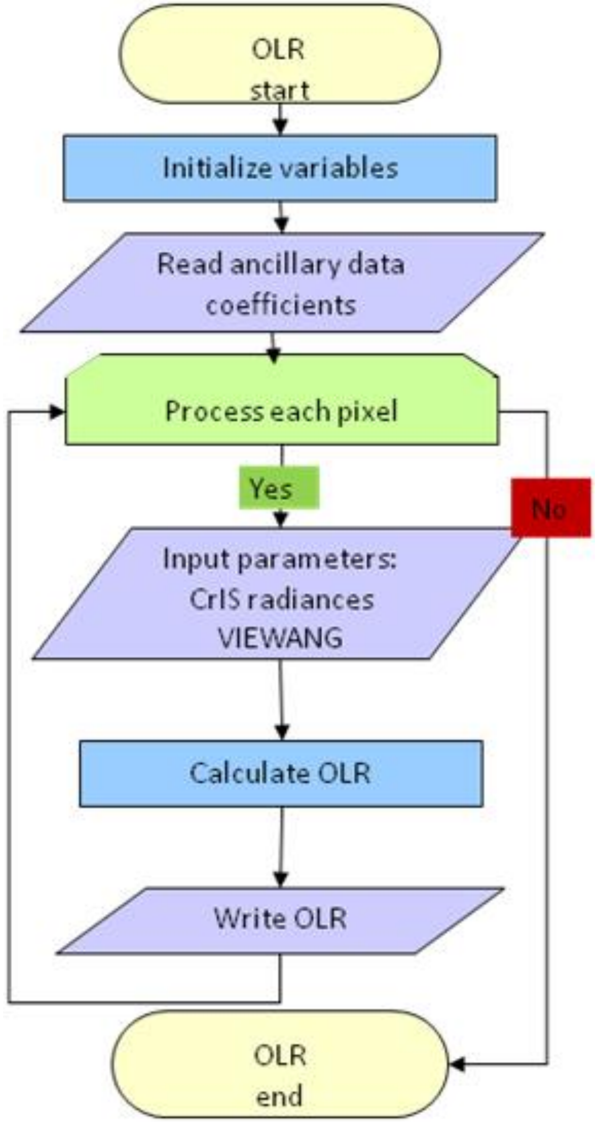
Presented by Kexin Zhang

Required Algorithm Inputs

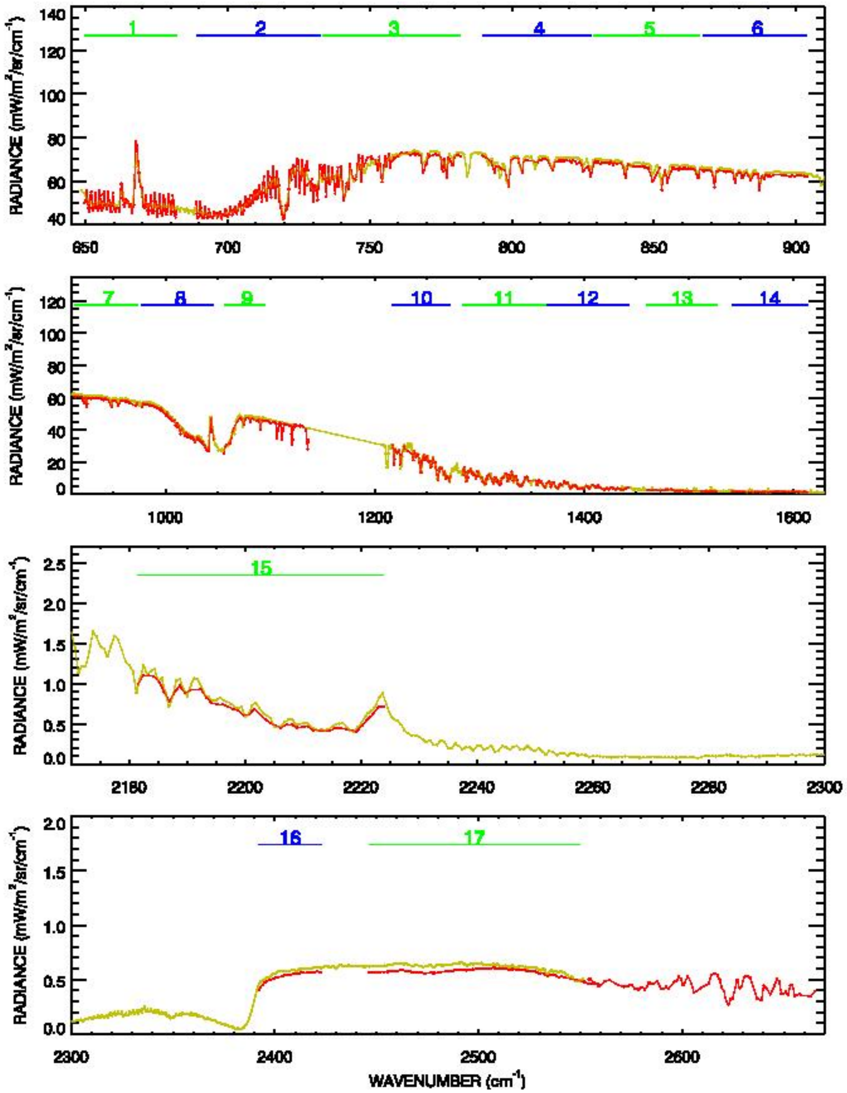
CrIS Outgoing Longwave Radiation (OLR)

- Required Algorithm Inputs
  - Primary Sensor Data
    - CrIS apodized radiances of 1305 channels
    - View angles
  - Ancillary Data
    - Parameters of 17 pseudo channels, OLR regression Coefficients, radiance correction coefficients.
- Evaluation of the effect of required algorithm inputs
  - CrIS SDR quality flag

CrIS Outgoing Longwave Radiation (OLR) Algorithm



CrIS OLR Pseudo-Channels



Pseudo channel range within simulated CrIS (yellow) AIRS (red) radiance spectra.

Quality flag analysis/validation

CrIS Outgoing Longwave Radiation (OLR)

- Defined Quality Flags
  - Variable: Quality_Flag
  - Description
  - Values
    - 0 = *good*
    - 1 = *rejected*
    - −9999 = *missing*
- OLR quality flag is based on the SDR quality flags for each CrIS band
  - QF3_CRISSDR
  - QF4_CRISSDR
- If the calculated OLR < 0 and > 500 W/m^2, then Quality_Flag is also set to 1

CrIS Outgoing Longwave Radiation (OLR)

- Improvements since Algorithm Readiness Review (ARR, Provisional)
  - Updated correction regression coefficients
- Cal/Val Activities for evaluating algorithm performance:
  - Compared estimated CrIS OLR with CERES SSF products on Aqua and SNPP
  - Daily and monthly mean comparison
  - Interannual difference comparison

Requirements – CrIS OLR

- Product performance requirements from JPSS L1RD supplement (threshold) versus observed/validated

Attribute	Threshold	Observed/validated
Geographic coverage	At least 90% coverage of the globe every 12 hours (monthly average) (once/daytime; once/nighttime)	Meets threshold
Vertical Coverage	N/A	
Horizontal Cell Size	25 km at nadir	14 km (CrIS nadir FOV)
Mapping Uncertainty (3σ)	5 km at nadir	
Measurement Range	0 – 500 W/m^2	0 – 500 W/m^2
Measurement Accuracy	5 W/m^2	< 2 W/m^2
Measurement Precision	12 W/m^2	5 W/m^2

CrIS OLR Validation Methodology

- **Daily OLR validation**
  - Compared with simultaneous S-NPP CERES OLR
  - Compared over 1deg lat/lon global grids
- **Monthly OLR validation**
  - Compared with CERES OLR monthly mean on Aqua and S-NPP CERES
  - Compared over 1deg lat/lon global grids
- **Inter-annual variability validation**
  - Compared with CERES OLR inter-annual variability on Aqua and S-NPP CERES
  - Compared over 1deg lat/lon global grids

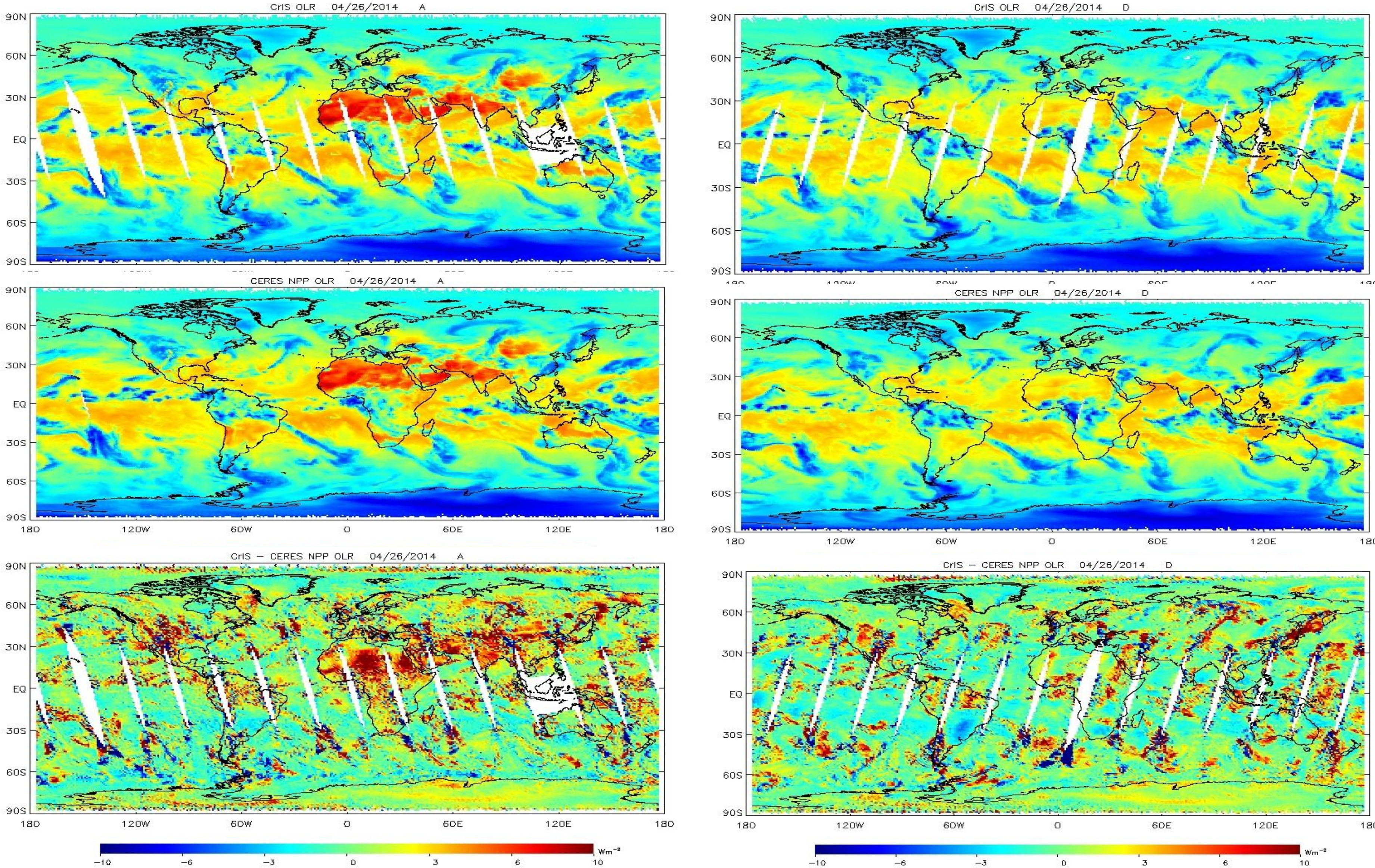
CrIS OLR Validation – Test data description

- **CERES SSF archived data products**
  - Single Scanner Footprint TOA/Surface Fluxes and Clouds (SSF) product files each contain one hour of instantaneous CERES data obtained from the Atmospheric Science Data Center (ASDC) at NASA Langley Research Center. https://eosweb.larc.nasa.gov/HORDERBIN/HTML_Start.cgi
    - The latency of the CERES OLR is typically 6 months or more
  - CERES Aqua FM3 Edition3A SSF products
  - CERES SNPP FM5 Edition1A SSF products
  - Merge the 24 hour boxes into 2 bins for ascending and descending orbits, respectively.
  - Averaged CERES OLR at 1deg lat/lon grids.

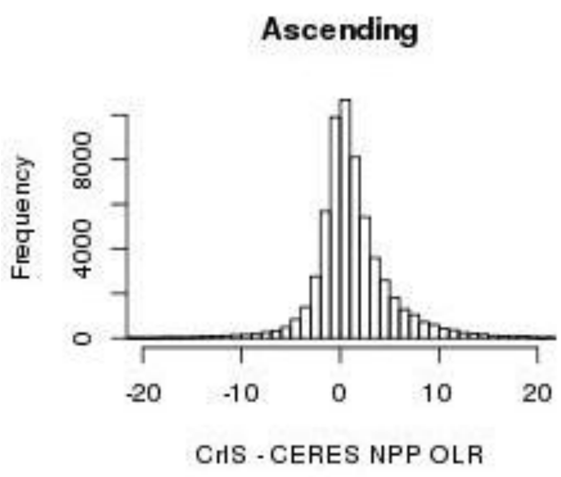
CrIS OLR Validation – Test data description

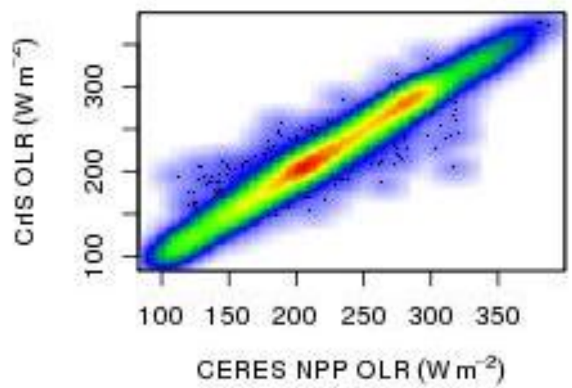
- **CrIS SDR data**
  - Hamming apodization performed by NUCAPS preprocessor.
  - Applied CrIS OLR algorithm to calculate CrIS OLR for each FOV.
  - Merged CrIS OLR into 2 bins per day, one for all of the ascending orbits and the other for all of the descending orbits.
  - Averaged CrIS OLR at 1deg lat/lon grids.

CrIS OLR Validation – Daily OLR

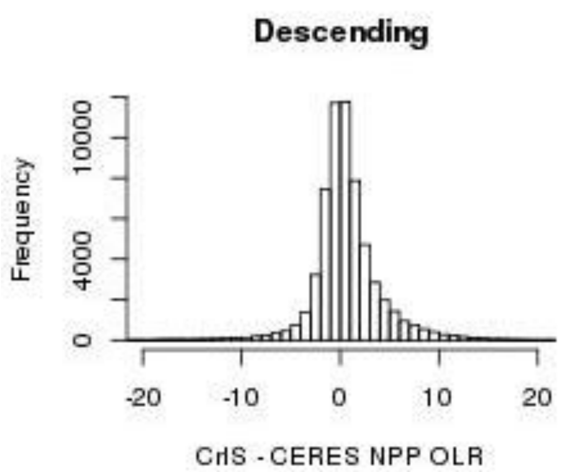


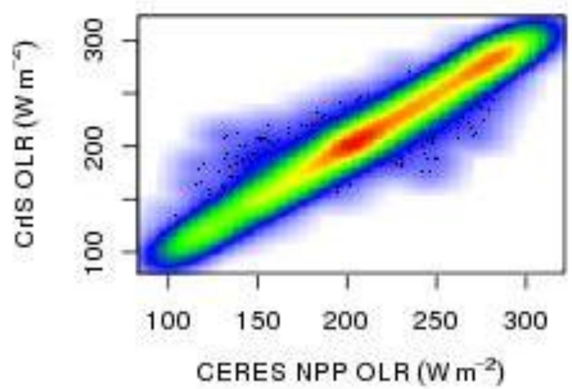
CrIS OLR Validation – Daily OLR





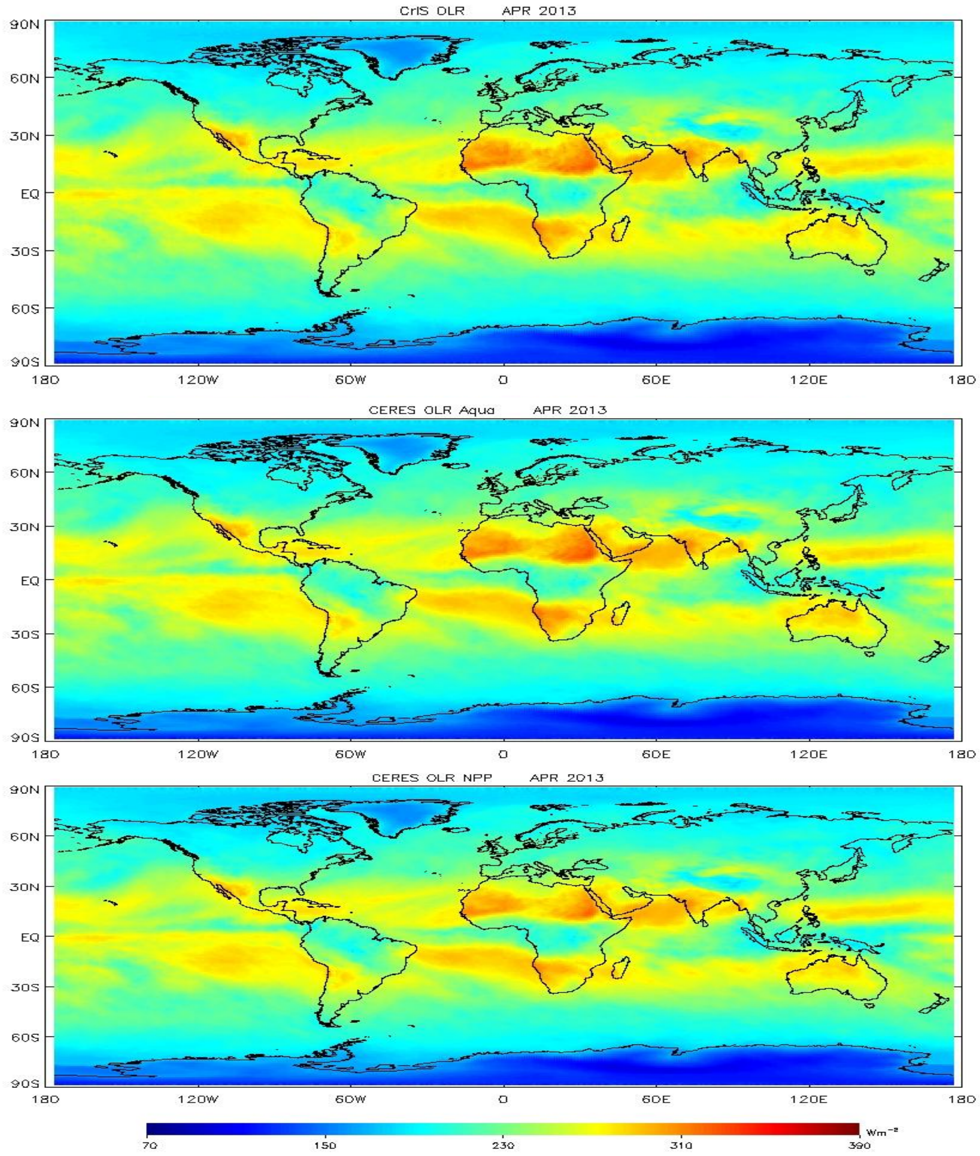
Mean = 1.138 Wm^{-2}
SD = 4.957 Wm^{-2}



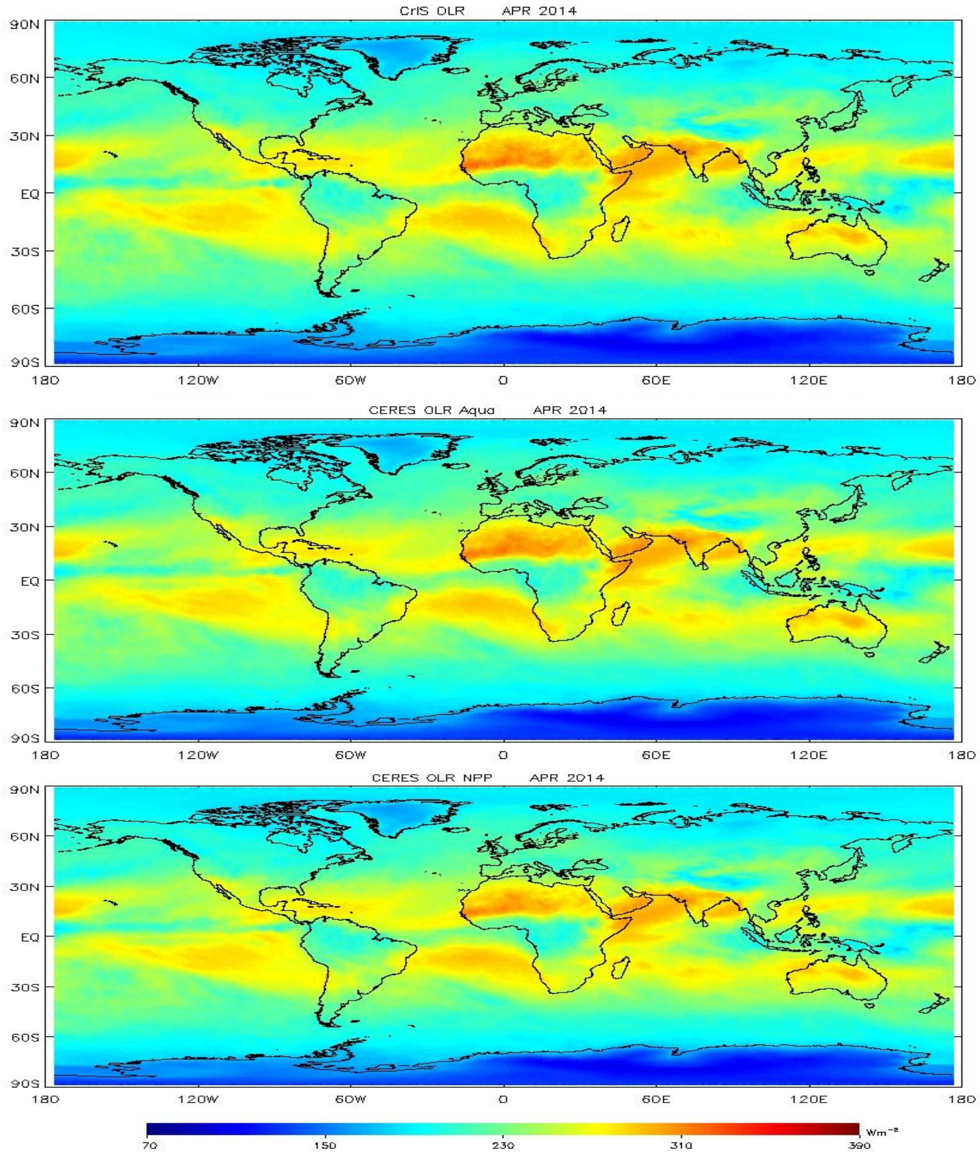


Mean = 0.624 Wm^{-2}
SD = 4.484 Wm^{-2}

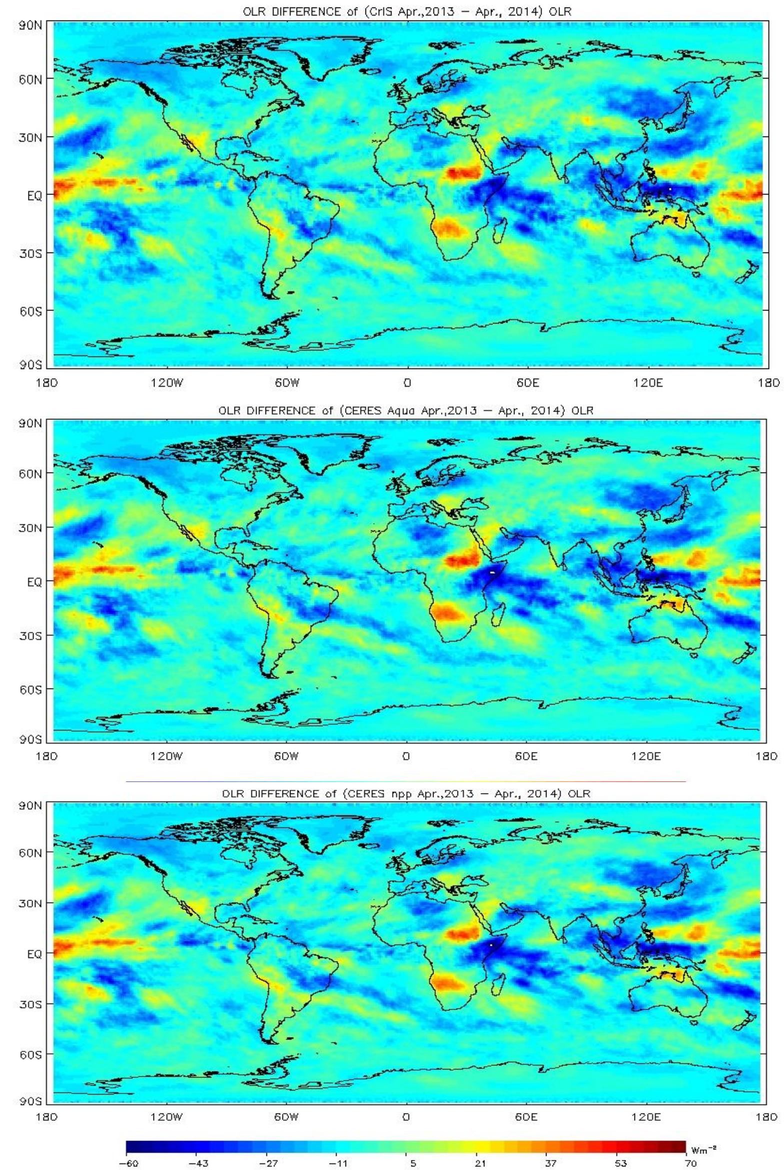
CrIS OLR Validation – Monthly mean (April 2013)



CrIS OLR Validation – Monthly mean (April 2014)



CrIS OLR Validation – Interannual difference



CrIS OLR Validation – Statistical Results

Monthly mean	(CrIS – CERES Aqua) OLR (W/m²)			(CrIS – CERES SNPP) OLR (W/m²)			(CERES Aqua – SNPP) OLR (W/m²)		
	mean	SD	ρ	mean	SD	ρ	mean	SD	ρ
April 2013	−0.15	2.47	0.998	+1.24	2.27	0.998	+1.39	1.97	0.999
April 2014	−0.14	2.32	0.998	+0.99	2.01	0.999	+1.13	1.90	0.999
Interannual	−0.004	3.07	0.943	+0.25	2.71	0.955	+0.25	1.88	0.975

CrIS OLR Error Budget

Attribute Analyzed	L1RD Threshold accuracy / precision	Analysis / Validation Result	Error Summary	Support Artifacts
Daily	5 W/m^2 12 W/m^2	1.5 W/m^2 5 W/m^2	Meets threshold and objective requirements	See documentation slide

Identification of Processing Environment

CrIS Outgoing Longwave Radiation (OLR)

- Latest update is 12 September 2016
- Algorithm version
  - OLR v1.0
- Version of LUTs used
  - OLR coefficient file v1.0
- Version of PCTs used
  - N/A
- Description of environment used to achieve validated maturity stage
  - NDE 1.0

CrIS Outgoing Longwave Radiation (OLR)

- User list
  - NOAA CPC
  - Precipitation and OLR Teams
- Feedback from users
  - None
- Downstream product list
  - CPC gridded daily OLR analysis (for improved climate monitoring and analysis)
- Reports from downstream product teams on the dependencies and impacts
  - In progress

Documentation – CrIS OLR

Science Maturity Check List	Yes ?
ReadMe for Data Product Users	Yes
Algorithm Theoretical Basis Document (ATBD)	Yes (draft)
Algorithm Calibration/Validation Plan	Yes
(External/Internal) Users Manual	Yes (draft)
System Maintenance Manual (for ESPC products)	OSPO website
Peer Reviewed Publications (Demonstrates algorithm is independently reviewed)	Submitted, under review
Regular Validation Reports (at least. annually) (Demonstrates long-term performance of the algorithm)	Yes

Documentation for OLR:
http://www.ospo.noaa.gov/Products/atmosphere/soundings/nucaps/NUCAPS_OLR.html

Conclusion

CrIS Outgoing Longwave Radiation (OLR)

- Cal/Val results summary:
  - Near real-time (2 hour latency)
  - Meets threshold requirements
  - Achieved objective requirements
  - Team recommends algorithm validated maturity
  - Caveats
    - Bias between Aqua and SNPP CERES OLR

Path Forward

CrIS Outgoing Longwave Radiation (OLR)

- Planned further improvements
  - Re-generate regression coefficients using new version CERES SSF OLR, like CERES Aqua FM3 Edition4A SSF products
  - Use SNPP full resolution radiances for OLR estimation
  - J-1 full resolution OLR estimation

- Planned Cal/Val activities / milestones
  - SNO OLR analysis
  - Regional OLR analysis
  - Seasonal OLR analysis
  - Time series of OLR analysis

IR Ozone Profile Validation

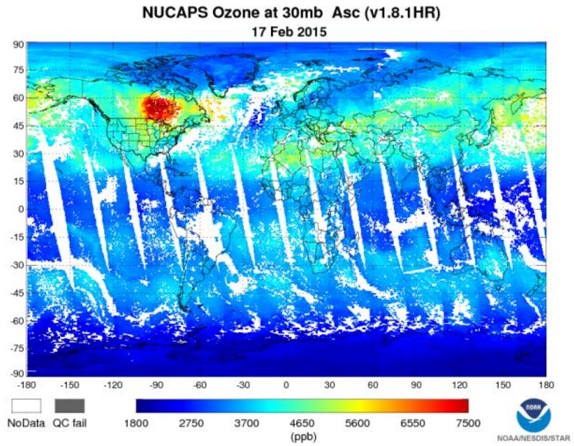
Presented by Nick Nalli

NOAA Unique Combined Atmospheric Processing System (NUCAPS) Algorithm

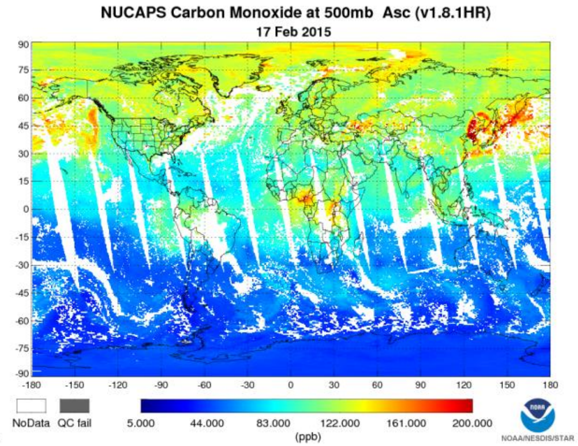
- **Operational algorithm**
  - Unified Sounder Science Team (AIRS/IASI/CrIS) retrieval algorithm (*Susskind, Barnet and Blaisdell,* IEEE 2003; *Gambacorta et al.,* 2014)
  - Global non-precipitating conditions
  - Atmospheric Vertical Temperature, Moisture Profiles (AVTP, AVMP)
  - **Trace gas profiles** (O_3**, CO,** CO_2**,** CH_4)
  - Validated Maturity for AVTP/AVMP, Sep 2014

- **Users**
  - **Weather Forecast Offices (AWIPS)**
    - Nowcasting / severe weather
    - Alaska (cold core)
  - **NOAA/CPC (OLR)**
  - **TOAST (IR ozone)**
  - NOAA/ARL (IR ozone, trace gases)
  - Basic and applied science research (e.g., *Pagano et al.,* 2014)
    - Via NOAA Data Centers (e.g., CLASS)
    - Atmospheric chemistry research
    - Universities, peer-reviewed pubs

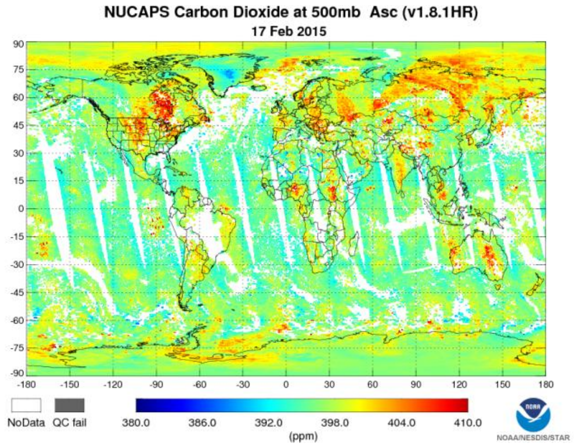
NUCAPS IR O_3



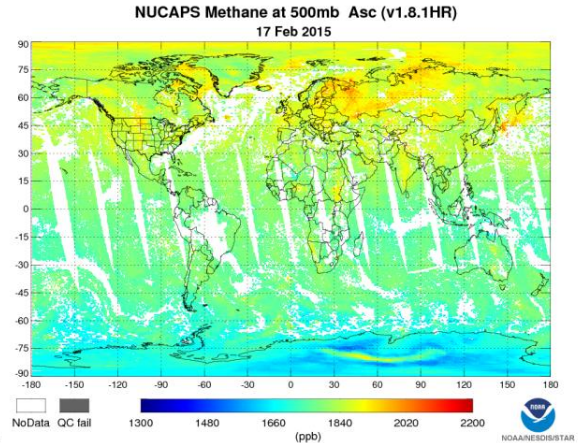
NUCAPS CO



NUCAPS CO_2

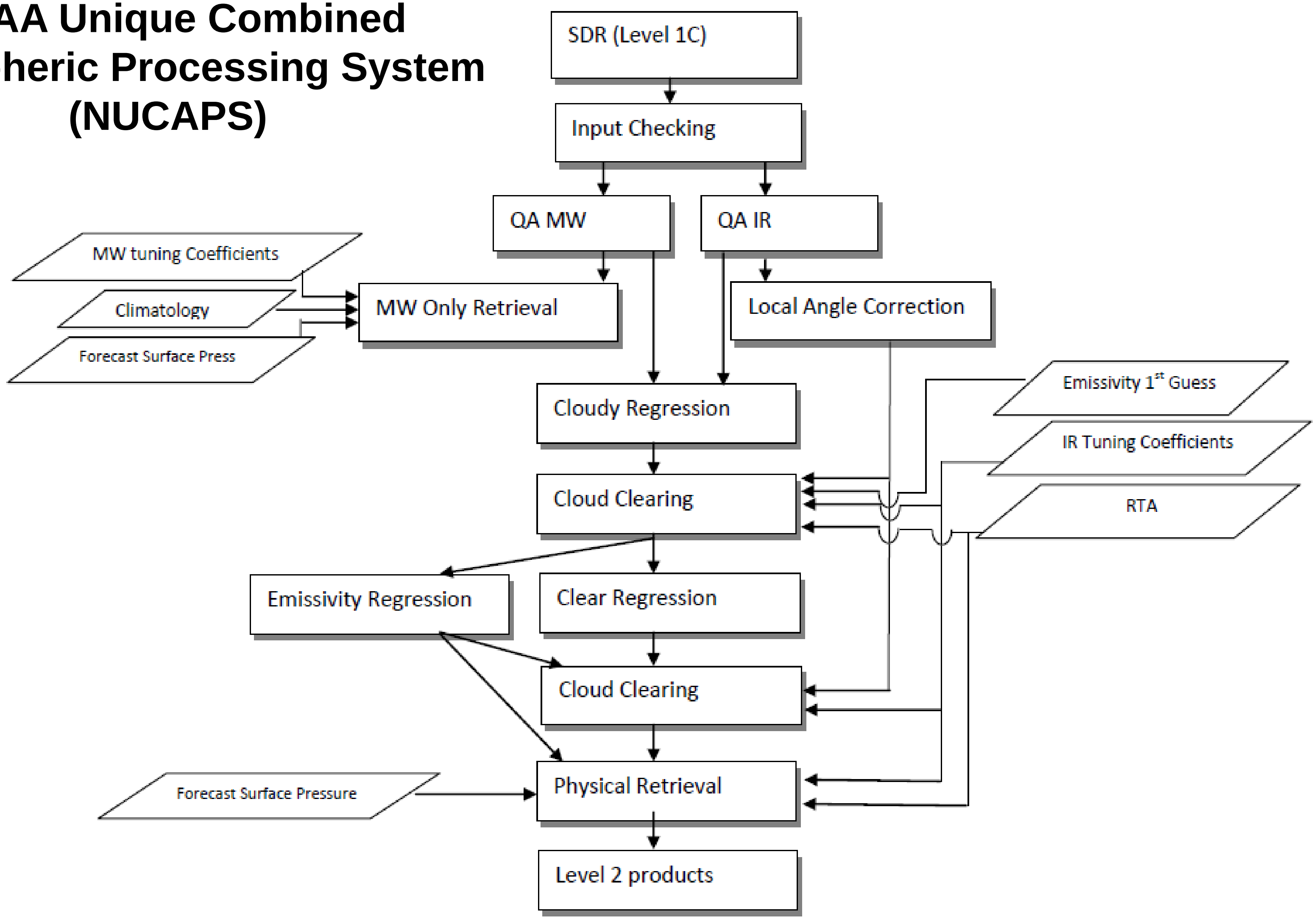


NUCAPS CH_4



NUCAPS Algorithm I/O Flowchart

NOAA Unique Combined Atmospheric Processing System (NUCAPS)

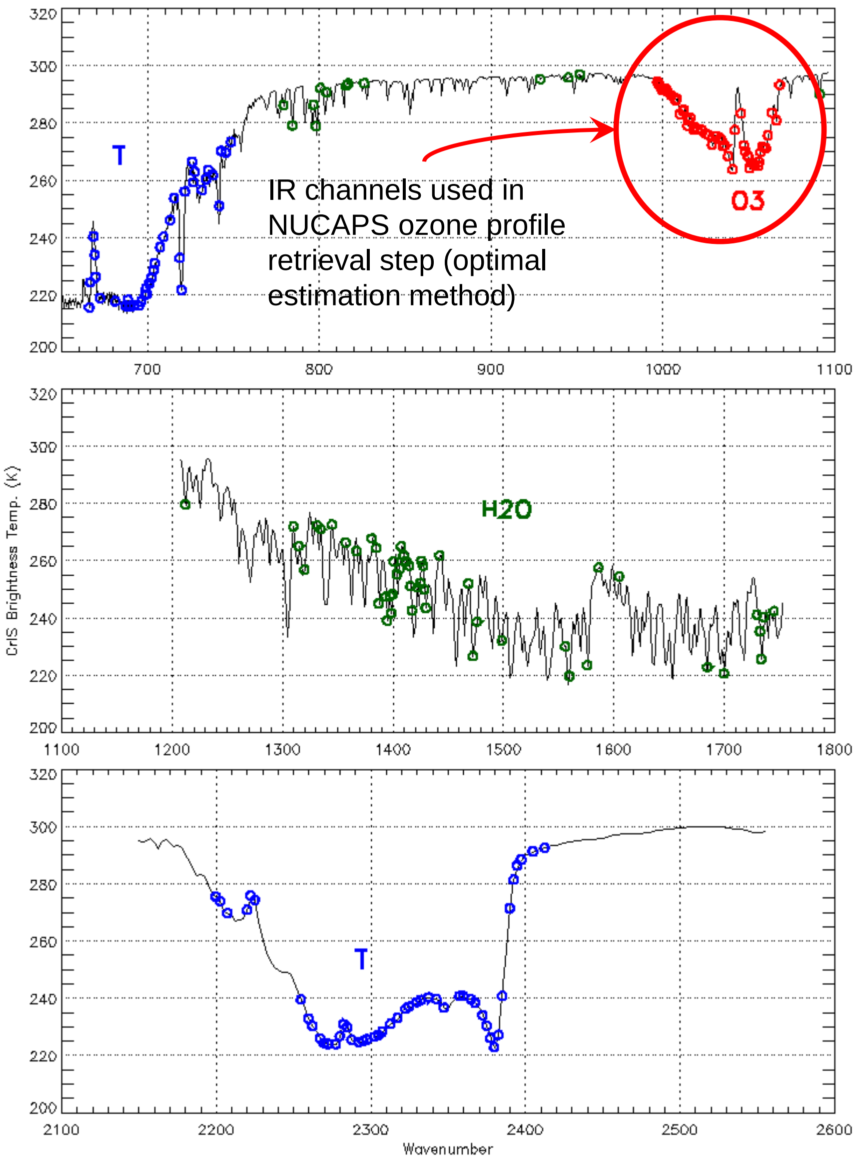


A. Gambacorta and C Barnet (2012), 10.1109/TGRS.2012.2220369

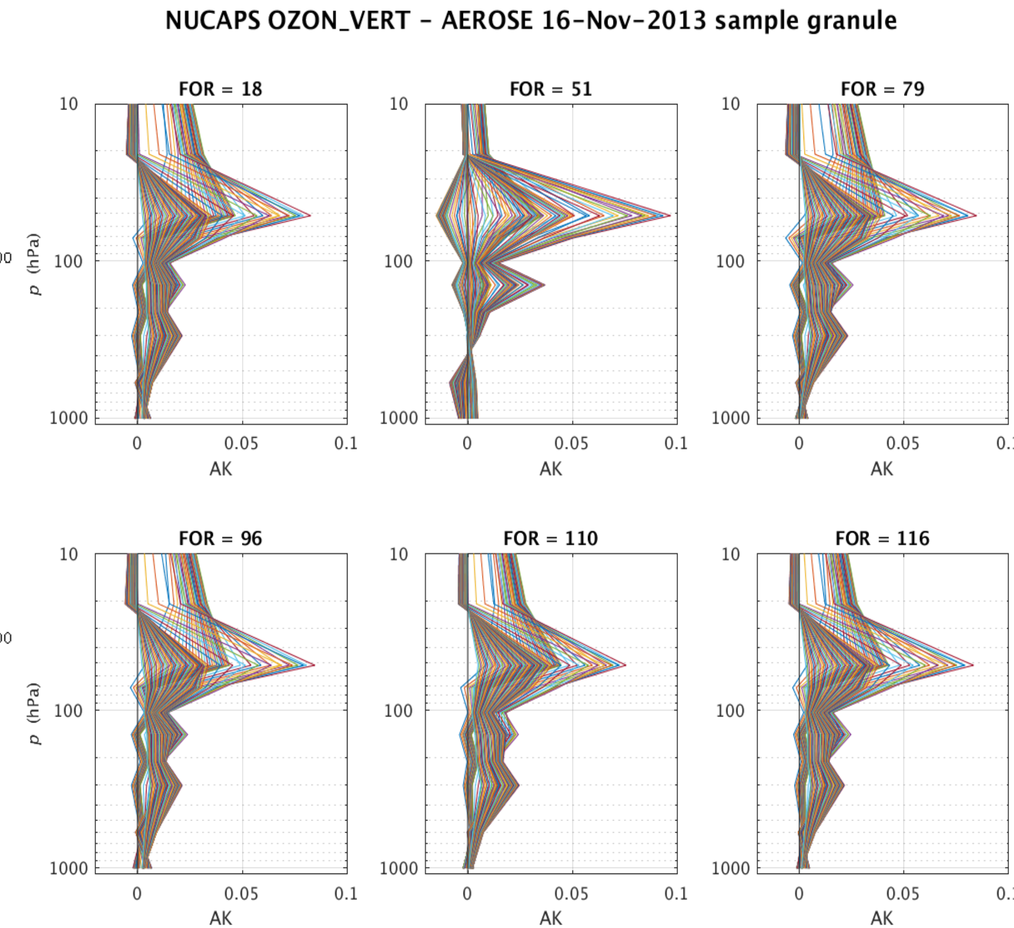
NUCAPS Required Algorithm Inputs

- **Primary Sensor Data**
  - CrIS SDR (full or nominal resolution unapodized spectra)
  - ATMS TDR (contingency “IR-only” algorithm undergoing development)
- **Ancillary Data**
  - Background Climatologies
    - Temperature and water vapor profiles for MW-only retrieval step
    - Trace gas profiles for first guess in the IR physical retrieval step
  - GFS Forecast
    - Surface pressure is calculated from the 3-,6-, and 9-hour forecasts, and interpolated in space and time to match observed location
    - Surface temperature (if ATMS not-present)
  - Surface Emissivity First Guess
    - Over ocean – Masuda emissivity model
    - Over land – Regression based
- **Coefficients**
  - Local Angle Adjustment
  - Infrared and Microwave BT Tuning Coefficients
- Evaluation of the effect of required algorithm inputs
  - CrIS SDR quality flag

NUCAPS *T*, H_2O and O_3 Channels



Ozone Effective Averaging Kernels



NUCAPS channels plots courtesy of C. Tan

Quality flag analysis/validation (1/2)

- **Defined Quality Flags**
  - **Variable:** Quality_Flag
  - **Description:** This flag is used to determine the final quality checks of the MIT microwave (MW) regression, the infrared (IR) regression, and the combined IR+MW retrieval of the NUCAPS algorithm.

Quality flag analysis/validation (2/2)

- **Defined Quality Flags**
  - **Values:**

Values	Definition	Notes
0	*accepted*	
1	*IR+MW final physical retrieval failed at least one quality check*	
2	*MW regression failed at least one quality check*	removed
4	*rejected by NOAA (IR regression) file*	removed
8 → 9	*rejected by internal MIT (MW) file*	becomes 9
16 → 17	*IR regression failed at least one quality check*	becomes 17 ⇒ Quality_Flag = 1
24→25	*MW and IR+MW both failed at least one quality check*	becomes 25 ⇒ Quality_Flag = 1
−9999	*missing*	

Outline

- Improvements since Algorithm Readiness Review (ARR, Provisional)
  – Algorithm Improvements
  – LUT updates
- Cal/Val Activities for evaluating algorithm performance:
  – Test/Ground truth data sets
  – Validation strategy / method
  – Validation results

Offline Algorithm Improvements

NUCAPS IR Ozone Profile EDR

- **Version 1.5**
  - For testing, we run an **offline emulation of current v1.5 operational algorithm**
  - Runs on **nominal CrIS spectral resolution** data
  - v1.5.1
    - Used a new rtaerr file: cris_rtaerr_v10b.asc
  - v1.5.2
    - Uses earlier v1.5 rtaerr file, but with the ascending/descending flag added
    - All versions from here forward have the ascending/descending flag
- **Version 1.8.x**
  - Experimental offline version
  - Runs on **CrIS full spectral resolution** data

Requirements – IR Ozone Profile EDR

- Product performance requirements from JPSS L1RD (June 2013) Supplement (threshold) versus observed/validated

Attribute	Threshold	Observed/validated
Geographic coverage	At least 90% coverage of the globe every 16 days (monthly average, both day and night)	Global
Vertical Coverage	TOA to surface	0.005 hPa to surface
Vertical Cell Size	4 hPa to 260 hPa (6 statistic layers) 260 hPa to surface (1 statistic layer)	0.005 hPa to sfc (100 RTA layers) Validation performed on: 4 hPa to 260 hPa (6 statistic layers) 260 hPa to surface (1 statistic layer)
Horizontal Cell Size	50 km at nadir	50 km at nadir (CrIS/ATMS FOR)
Mapping Uncertainty	10 km	SDR 10 km
Measurement Accuracy	±10%	−1.8% (4–260 hPa) –9.4% (260 hPa to sfc)
Measurement Precision	20%	14.3% (4–260 hPa) 21.2% (260 hPa to sfc)
Measurement Uncertainty	25%	18.9% (4–260 hPa) 23.2% (260 hPa to sfc)

IR Ozone Profile Validation Strategy/Method

(cf. *Nalli et al., JGR Special Section on SNPP Cal/Val,* 2013)

1. **Numerical Model (e.g., ECMWF, NCEP/GFS) Global *Comparisons***
   – Large, truly global samples acquired from Focus Days
   – Useful for sanity checks, bias tuning and regression
   – Limitation: *Not* independent truth data

2. **Satellite Sounder EDR (e.g., AIRS, ATOVS, COSMIC) *Intercomparisons***
   – Global samples acquired from Focus Days (e.g., AIRS)

3. **Conventional RAOB (Ozonesonde) Matchup *Assessments***
   – SHADOZ and WOUDC network sites that collocate with SNPP overpasses
   – Representation of global zones, long-term monitoring
   – Large samples accumulated over several months
   – Limitations:
     - Skewed distribution toward NH-continents
     - Mismatch errors, potentially systematic at individual sites

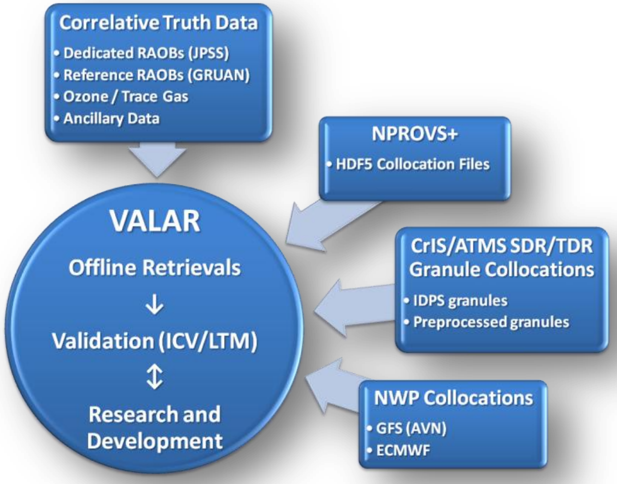
4. **Dedicated/Reference RAOB (Ozonesonde) Matchup *Assessments***
   – *Dedicated* for the purpose of satellite validation
     - Known measurement uncertainty and optimal accuracy
     - Minimal mismatch errors

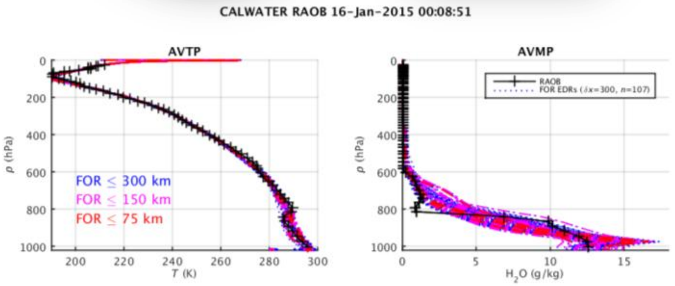
5. **Intensive Field Campaign *Dissections***
   – Include dedicated RAOBs, some *not* assimilated into NWP models
   – Include ancillary datasets
   – Ideally include funded aircraft campaign using IR sounder (e.g., NAST-I, S-HIS)
   – Detailed performance specification; state specification; SDR cal/val; case studies
   – E.g., **SNAP, SNPP-1,-2, AEROSE, CalWater/ACAPEX**, JAIVEX, WAVES, AWEX-G, EAQUATE

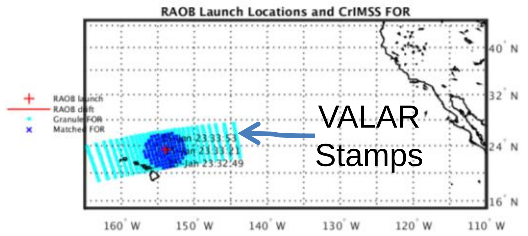
IR Ozone Profile Validation Datasets and Tools

- **STAR Validation Archive (VALAR)**
  - Low-level research data archive designed to meet needs of Cal/Val Plan
  - Dedicated/reference and intensive campaign RAOBs and ozonesondes
  - SDR/TDR granule-based collocations (“stamps”) within 500 km radius acquired off SCDR (past 90 days) or CLASS (older than 90 days)
  - Trace Gas EDR validation
  - Offline retrievals / retrospective reprocessing
  - MATLAB and IDL statistical codes and visualization software tools for monitoring
  - Rigorous coarse-layer (1-km, 2-km) product performance measures based on statistical metrics corresponding to Level 1 Requirements detailed in *Nalli et al.* (2013)

VALAR Concept and Objectives





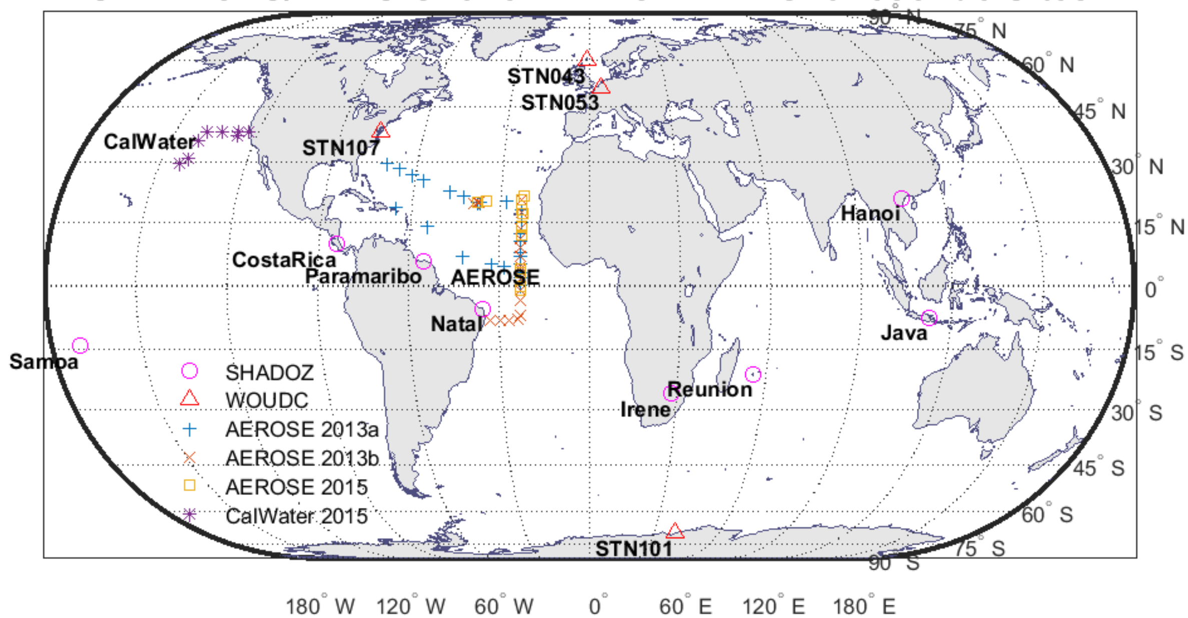


Test / Ground Truth Data Sets

NUCAPS IR Ozone Profile EDR

- **Collocated Ozonesondes**
  - **Dedicated Ozonesondes**
    - **NOAA AEROSE** (*Nalli et al.* 2011)
    - **CalWater/ACAPEX 2015**
  - **Sites of Opportunity**
    - **SHADOZ** (*Thompson et al.* 2007)
      - Costa Rica
      - Hanoi
      - Irene
      - Java
      - Natal
      - Paramaribo
      - Reunion
      - American Samoa
    - **WOUDC**
      - STN043
      - STN053
      - STN107
      - STN101

S-NPP CrIS/ATMS Ozone EDR ICV-LTM Ozonesonde Sites



Assessment Methodology: Reducing Truth to Correlative Layers

- The **measurement equation** (e.g., *Taylor and Kuyatt,* 1994) for retrieval includes forward and inverse operators (*Rodgers*, 1990) to estimate the measurand, $\mathbf{x}$, on forward model layers:

$$\hat{\mathbf{x}} = I\left[F(\mathbf{x},\mathbf{b}),\mathbf{b},\mathbf{c}\right]$$

- **Rigorous validation** therefore requires high-resolution truth measurements (e.g., ozonesonde) be **reduced to correlative RTA layers** (*Nalli et al.*, 2013, *JGR Special Section on SNPP Cal/Val*)
- **Radiative transfer (“klayers”) approach** is to integrate quantities over the atmospheric path (e.g., number densities $\rightarrow$ column abundances), interpolate to RTA (arbitrary) levels, then compute RTA layer quantities, e.g.,

$$\sum\nolimits_{x}(z) = \int_{z_t}^{z} N_x(z')\,dz'$$

Assessment Methodology: Statistical Metrics

- Level 1 IR ozone profile accuracy requirements are defined over **7 coarse layers**, 6 for UT/LS and 1 for troposphere (Table, Slide 35).

Method and Formulas for Gas Abundances

- W2 weighting was originally used in determining Level 1 Requirements
- To allow compatible STD calculation, W2 weighting is consistently used for both RMS and BIAS

$$\Delta q_{\mathfrak{L},j} \equiv \frac{\hat{q}_{\mathfrak{L},j} - q_{\mathfrak{L},j}}{q_{\mathfrak{L},j}}$$

$$\mathrm{RMS}(\Delta q_{\mathfrak{L}}) = \sqrt{\frac{\sum_{j=1}^{n_j} W_{\mathfrak{L},j}(\Delta q_{\mathfrak{L},j})^2}{\sum_{j=1}^{n_j} W_{\mathfrak{L},j}}},$$

weighting factor, $W_{\mathfrak{L},j}$,

$$\mathrm{BIAS}(\Delta q_{\mathfrak{L}}) = \frac{\sum_{j=1}^{n_j} W_{\mathfrak{L},j}\, \Delta q_{\mathfrak{L},j}}{\sum_{j=1}^{n_j} W_{\mathfrak{L},j}},$$

$$W_{\mathfrak{L},j} = \begin{cases} 1 & , \mathrm{W}^0 \\ q_{\mathfrak{L},j} & , \mathrm{W}^1 \\ (q_{\mathfrak{L},j})^2 & , \mathrm{W}^2 \end{cases}$$

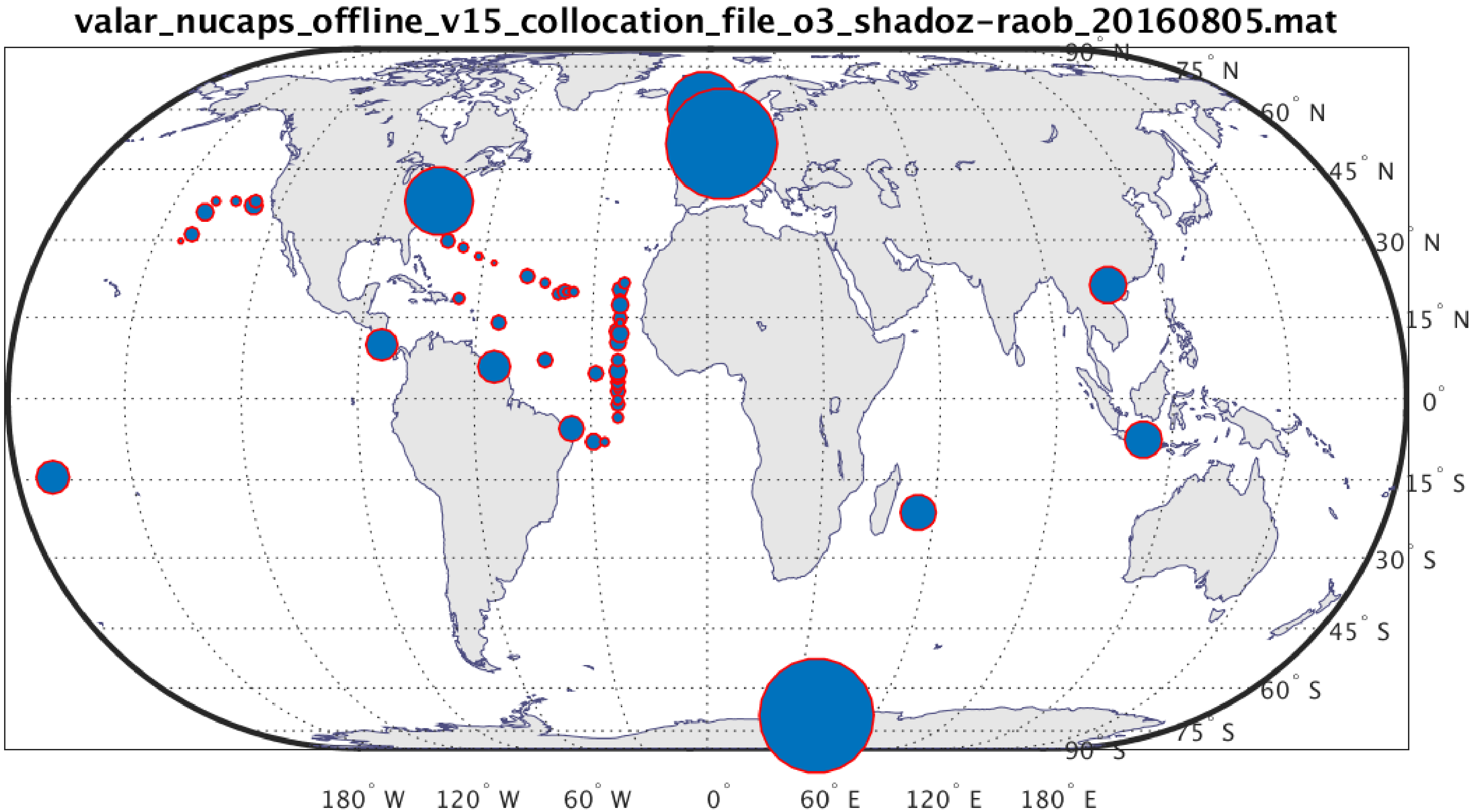
$$\mathrm{STD}(\Delta q_{\mathfrak{L}}) = \sqrt{[\mathrm{RMS}(\Delta q_{\mathfrak{L}})]^2 - [\mathrm{BIAS}(\Delta q_{\mathfrak{L}})]^2}$$

IR Ozone Profile EDR Validation Results (1/7)

VALAR Ozonesonde-FOR Collocation Sample (n = 6024)

Geographic Histogram (Equal Area)

FOR Collocation Criteria: $\delta x \leq 125$ km, $-240 < \delta t < +120$ min



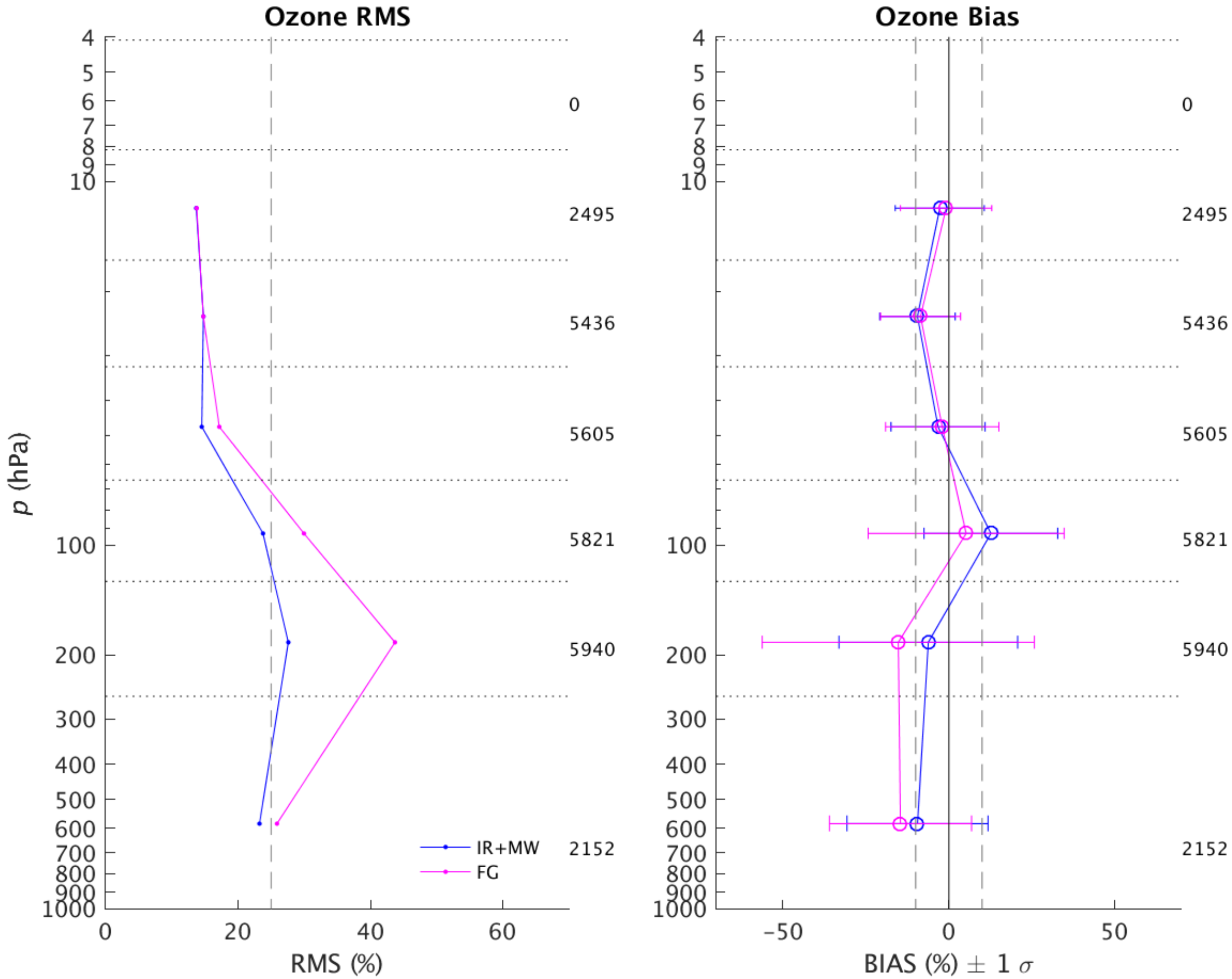
IR Ozone Profile EDR Validation Results (2/7)

NUCAPS Offline (v1.5) versus Global Ozonesondes

Retrieval and *A Priori* First Guess

IR+MW
First Guess

IR+MW Yield = 62.2%



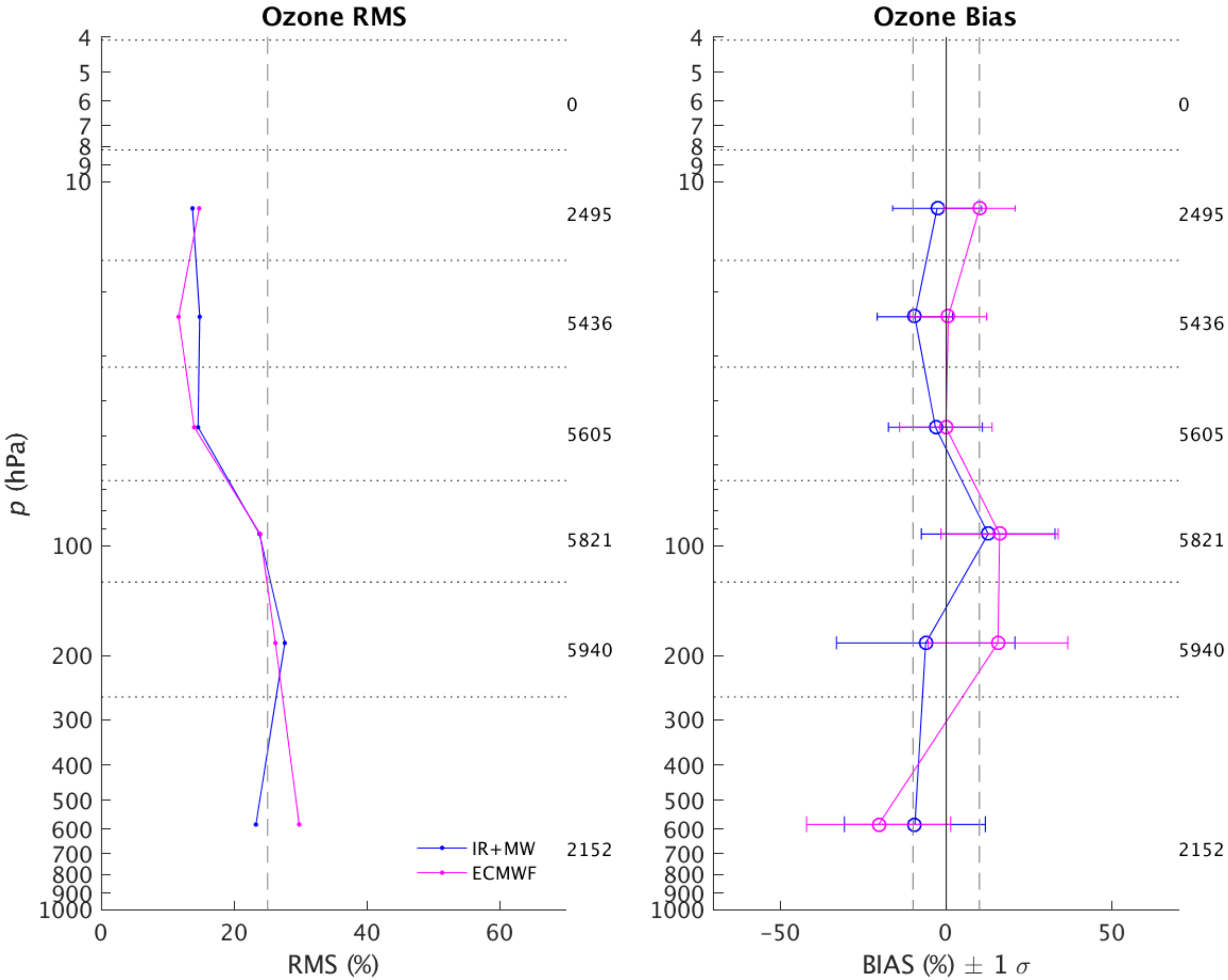
IR Ozone Profile EDR Validation Results (3/7)

NUCAPS Offline (v1.5) versus Global Ozonesondes

Retrieval and ECMWF

IR+MW
ECMWF

IR+MW Yield = 62.2%



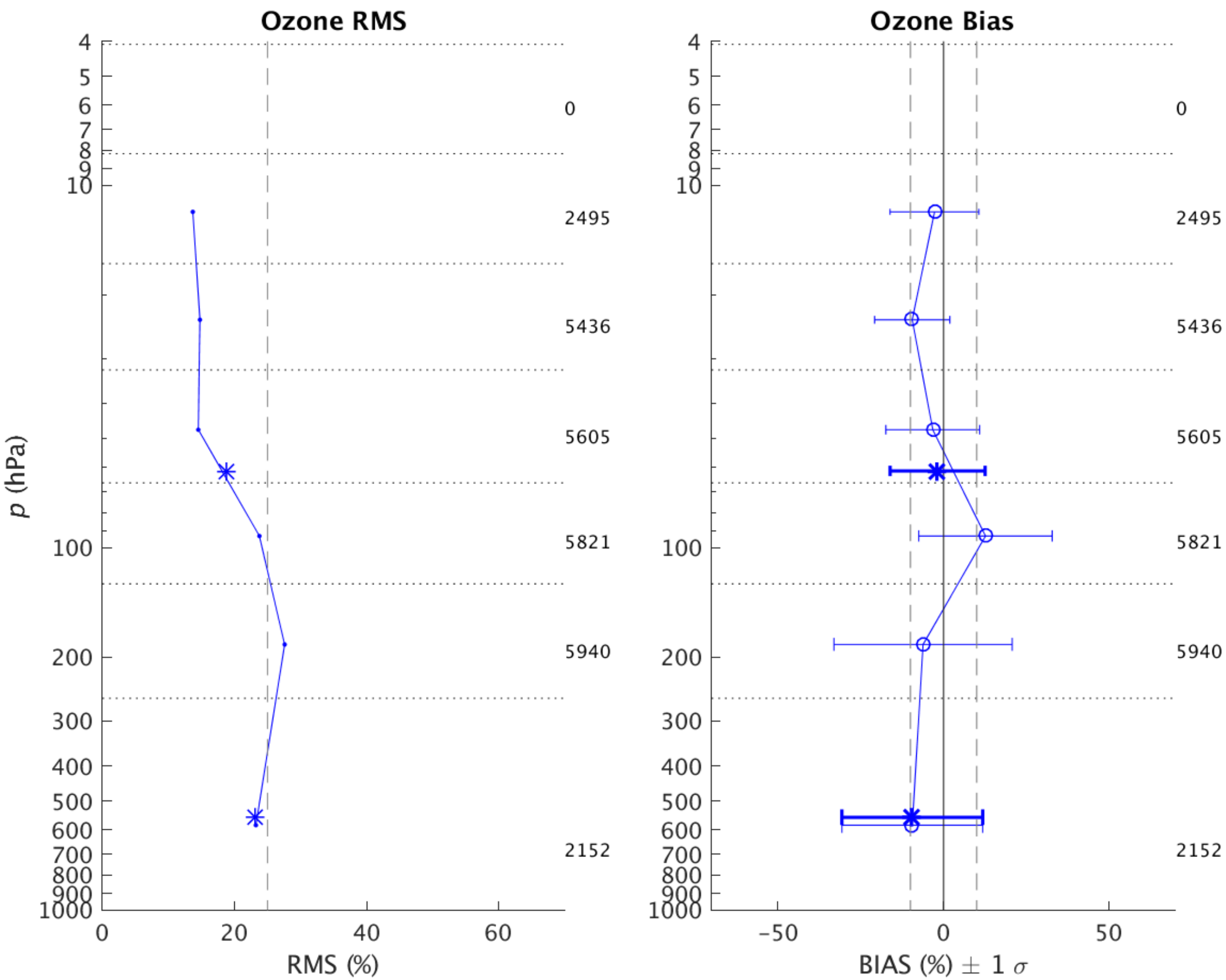
IR Ozone Profile EDR Validation Results (4/7)

NUCAPS Offline (v1.5) versus Global Ozonesondes

*** Broad-Layer Statistics**

(Per JPSS Level 1 Requirements)

IR+MW Yield = 62.2%



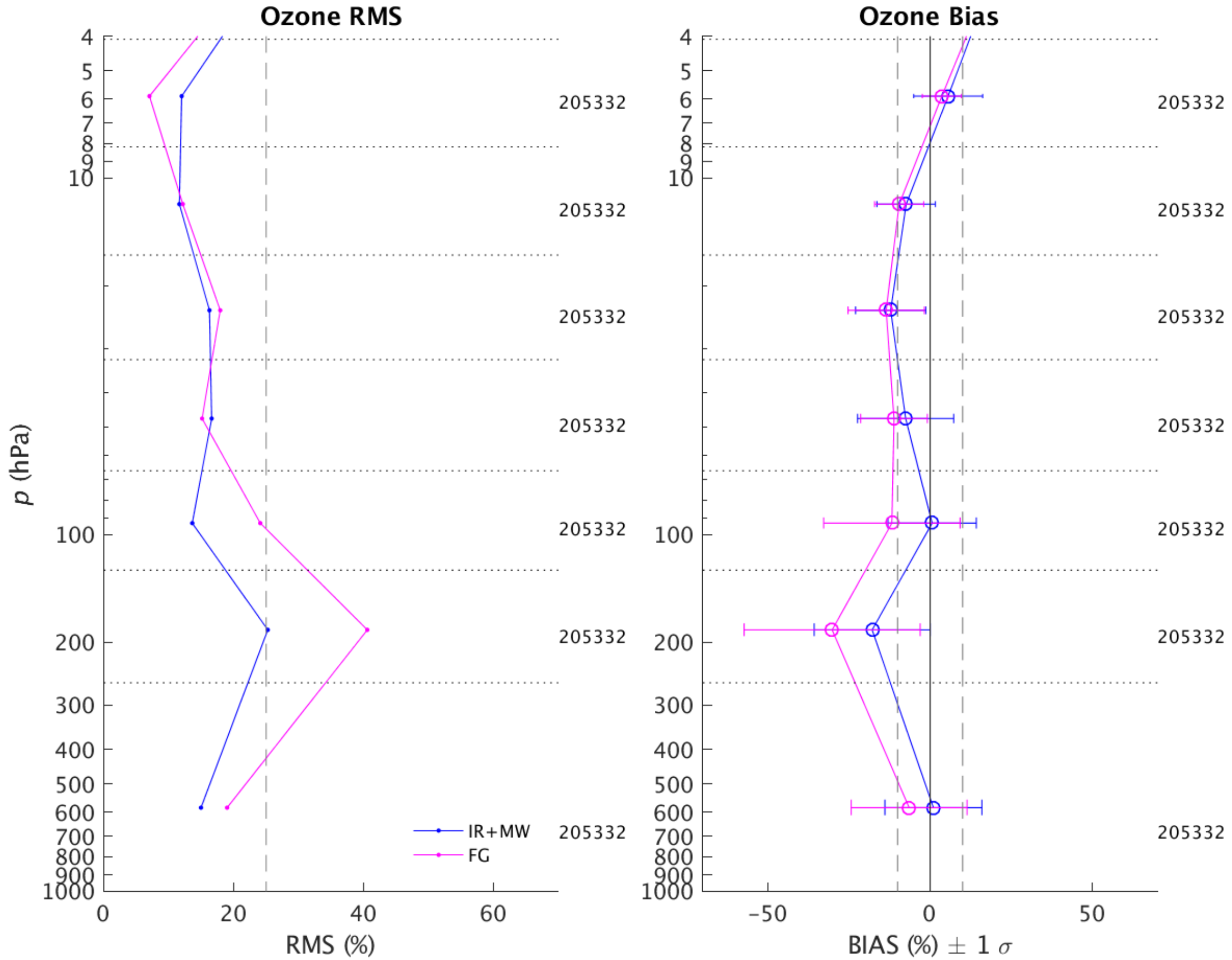
IR Ozone Profile EDR Validation Results (5/7)

NUCAPS Offline (v1.5) versus Global Focus Day 17-Feb-2015

O_3 Versus ECMWF

IR+MW
First Guess

NUCAPS v1.5
Yield = 63.4%



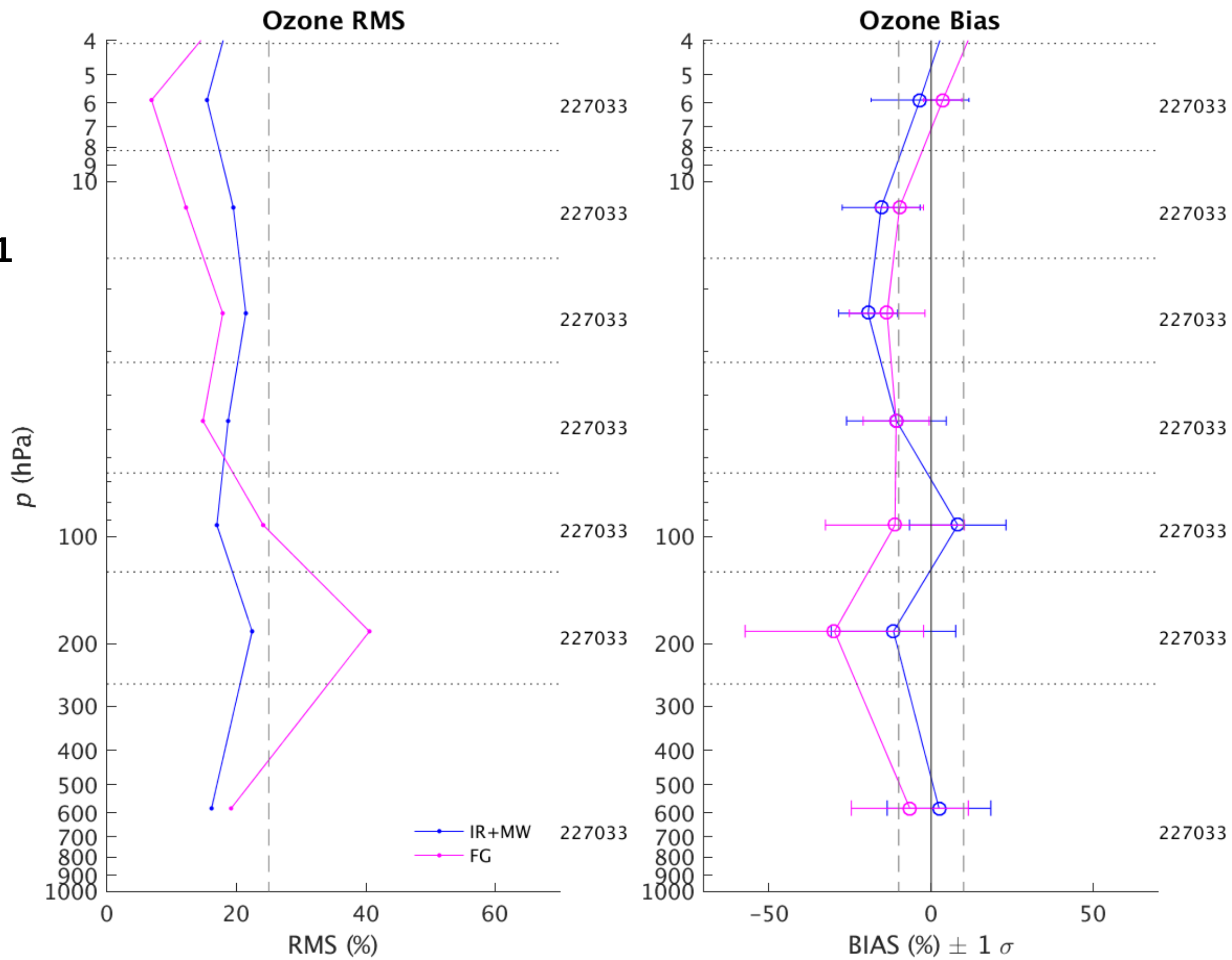
IR Ozone Profile EDR Validation Results (6/7)

NUCAPS Offline (v1.8.1) versus Global Focus Day 17-Feb-2015

O_3 Versus ECMWF

IR+MW
First Guess

NUCAPS v1.8.1
Yield = 70.1%



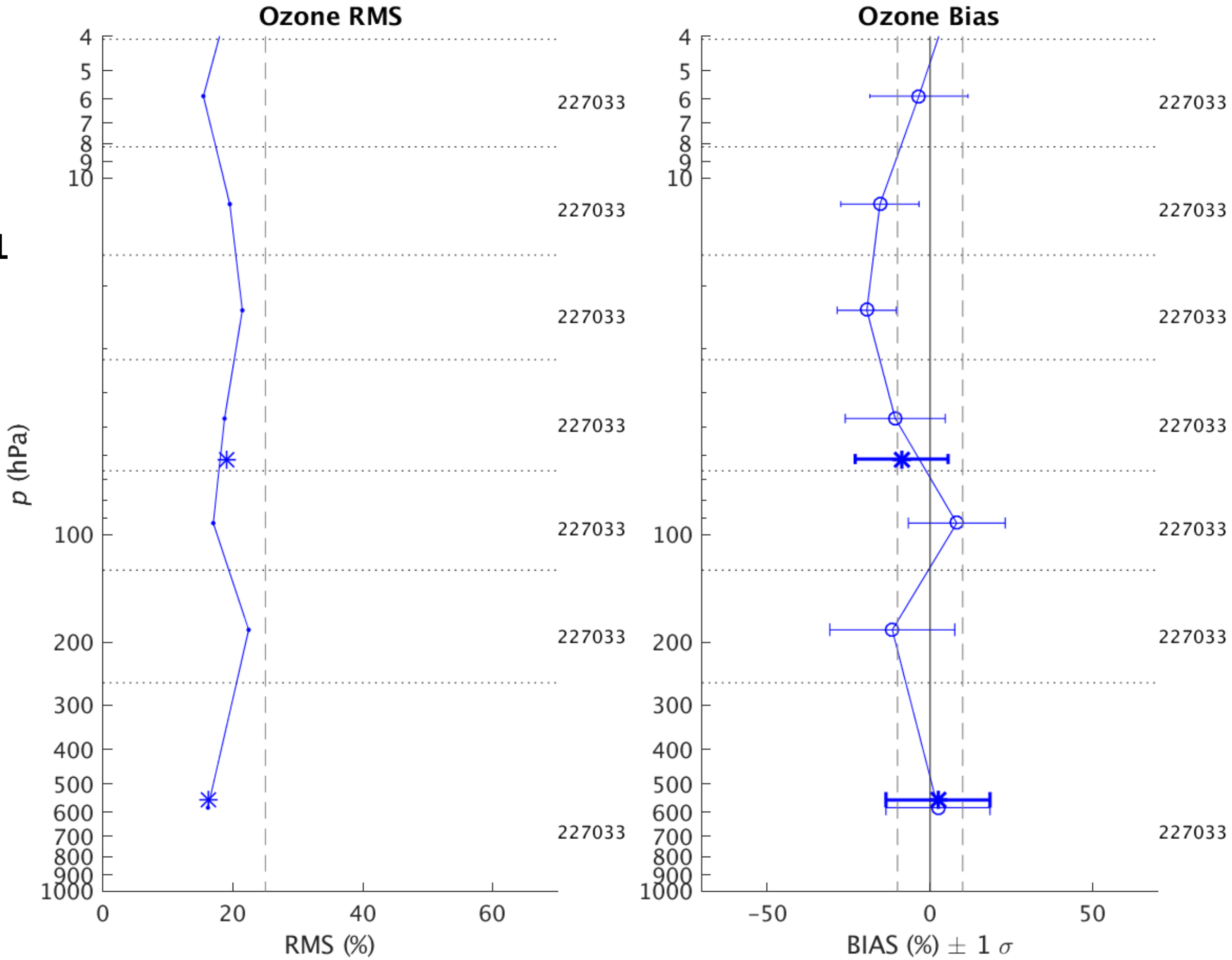
IR Ozone Profile EDR Validation Results (7/7)

NUCAPS Offline (v1.8.1) versus Global Focus Day 17-Feb-2015

*** Broad-Layer Statistics**

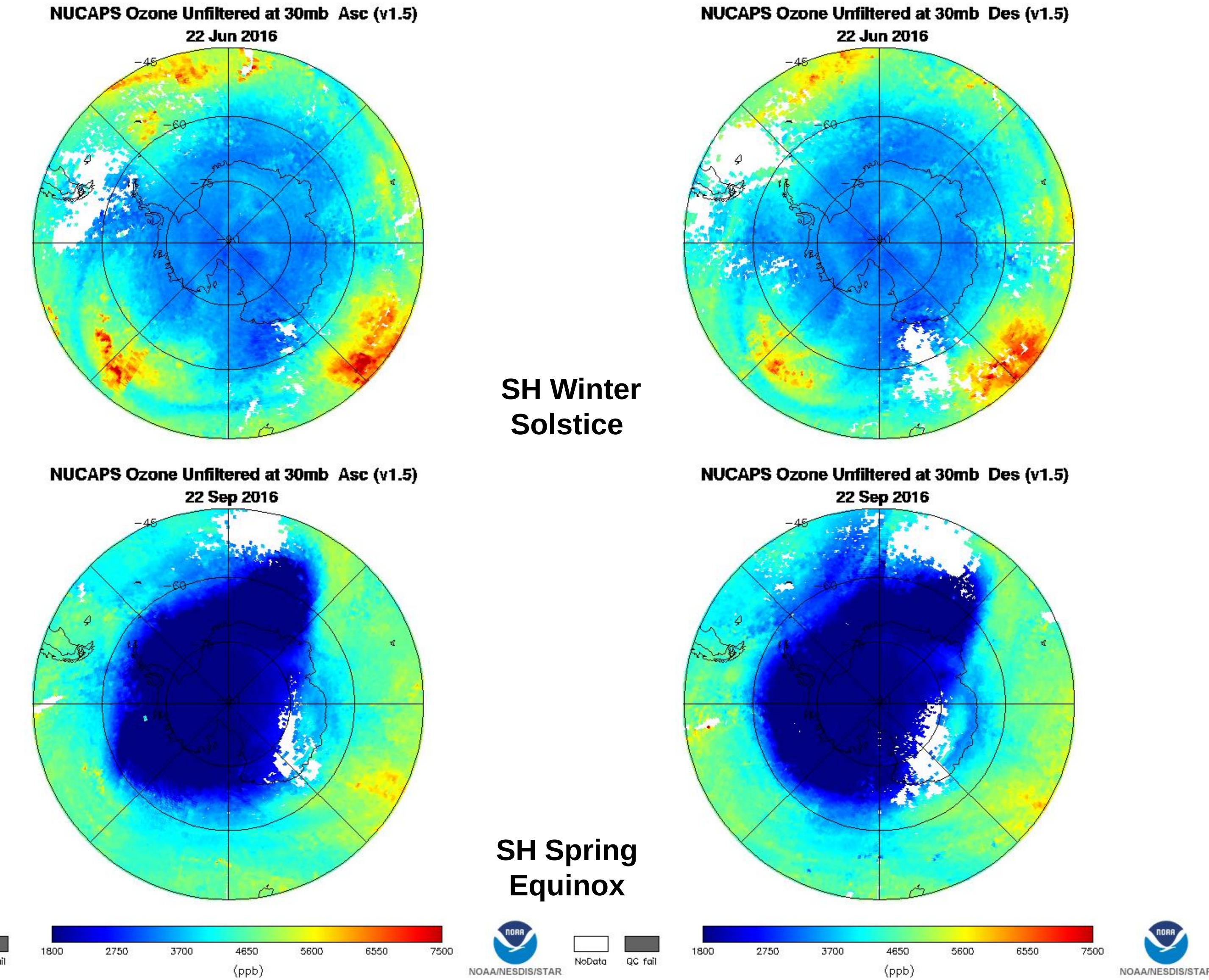
(Per JPSS Level 1 Requirements)

NUCAPS v1.8.1
Yield = 70.1%



Ozone Hole Over Antarctica from NUCAPS Operational v1.5

NUCAPS observed ozone depletion during SH springtime



NUCAPS maps courtesy of F. Iturbide-Sanchez

Error Budget – NUCAPS IR Ozone Profile EDR

Attribute Analyzed	L1RD Threshold	Analysis / Validation Result	Error Summary	Support Artifacts
Measurement Accuracy	±10%	−1.8% (4–260 hPa) −9.4% (260 hPa to sfc)	Meets threshold	See documentation slide
Measurement Precision	20%	14.3% (4–260 hPa) 21.2% (260 hPa to sfc)	• UT/LS layer meets threshold • Trop layer is close to meeting threshold	See documentation slide
Measurement Uncertainty	25%	18.9% (4–260 hPa) 23.2% (260 hPa to sfc)	Meets threshold	See documentation slide

Identification of Processing Environment

NUCAPS IR Ozone Profile EDR

- NDE Build
  - v1.1.10, 8 September 2016
- Algorithm Version
  - NUCAPS v1.5
- Version of LUTs used
  - NUCAPS v1.5
- Version of PCTs used
  - N/A
- Description of environment used to achieve validated maturity stage
  - NDE 1.0

NUCAPS IR Ozone Profile EDR

- **User list**
  - **TOAST** (IR ozone profile)
  - AWIPS (AVTP/AVMP)
  - NOAA CPC (CrIS OLR)
  - Science research users (all NUCAPS EDRs)

- Feedback from users
  - Monthly NUCAPS Initiative Telecons
  - Blog post by Kris White at the Huntsville NWS Forecast Office on the use of NUCAPS for a summertime convection event in North Alabama on 24 July 2016.
    - https://nasasport.wordpress.com/2016/07/24/observations-of-nucaps-soundings-in-the-tn-valley-20-july-2016/
    - Huntsville's version of AWIPS is confirming that the new QC flags for NUCAPS are indeed in some offices. This is a good development that directly came out of guidance from this group.

- Downstream product list
  - Enhanced TOAST ozone product
  - The TOAST product is dependent on NUCAPS ozone product

Documentation – NUCAPS IR Ozone Profile EDR (1/2)

Science Maturity Check List	Yes ?
ReadMe for Data Product Users	Yes
Algorithm Theoretical Basis Document (ATBD)	Yes
Algorithm Calibration/Validation Plan	Yes
(External/Internal) Users Manual	Yes
System Maintenance Manual (for ESPC products)	Yes
Peer Reviewed Publications (Demonstrates algorithm is independently reviewed)	Yes; O_3 validation paper in prep
Regular Validation Reports (at least. annually) (Demonstrates long-term performance of the algorithm)	Yes

Documentation – CrIS OLR and NUCAPS IR Ozone Profile EDR (2/2)

- NUCAPS EDRs (including ozone) and OLR available from NOAA CLASS
  - http://www.class.ncdc.noaa.gov/saa/products/search?datatype_family=NDE_L2
- NOAA OSPO NUCAPS EDRs and OLR gridded images, retrieval statistics
  - http://www.ospo.noaa.gov/Products/atmosphere/soundings/nucaps/index.html
  - http://www.ospo.noaa.gov/Products/atmosphere/soundings/nucaps/NUCAPS_OLR.html
  - Documentation: NUCAPS External user manual; ATBD; System maintenance manual
- NUCAPS EDRs and OLR Long-term monitoring site at NOAA/STAR
  - http://www.star.nesdis.noaa.gov/jpss/soundings.php
  - Click “NUCAPS Soundings” in the middle box on the right
- Other documentation:
  - NUCAPS EDR and OLR Cal/Val Plan – 31 Dec 2015
  - README for NUCAPS ozone data users
  - OLR ATBD
  - README for OLR data users
  - Peer reviewed publications
    - Sounder EDR Cal/Val – Nalli et al. (2013), *JGR Special Section on SNPP Cal/Val*
    - CrIS OLR product – Zhang et al. (2016), in review for *JTECH*
    - IR Ozone Profile Validation – Nalli et al. (2017), manuscript in preparation for *JGR*

NUCAPS IR Ozone Profile EDR

- Cal/Val results summary:
  - V1.5 (CrIS nominal resolution, offline emulation of operational algorithm) meets threshold requirements versus global ozonesondes
  - V1.8.1 (CrIS full resolution, experimental version) meets threshold requirements versus ECMWF
  - Team recommends algorithm validated maturity
  - Caveats
    - Contingency “IR-only” algorithm (in the event of ATMS failure) currently undergoing development and testing
    - The CrIS IR ozone channels provide very little sensitivity to ozone in the troposphere as evidenced by the retrieval averaging kernels – therefore, we expect that the tropospheric layer ozone retrieval relaxes to the *a priori* and thus should be used with caution.

NUCAPS IR Ozone Profile EDR

- Planned further improvements
  - Implement CrIS full-resolution SARTA model (to be delivered by STC)
  - Optimize full-res algorithm
  - Develop and test “IR-only” algorithm
  - Prepare for J-1
- Planned Cal/Val activities / milestones
  - Apply averaging kernels, degrees-of-freedom, etc.
  - Publish peer-reviewed publication on SNPP NUCAPS IR ozone profile validation
  - Prepare for J-1
    - Global Focus Day numerical model comparisons
    - Support intensive campaigns featuring dedicated ozonesondes
    - Acquire and collect global ozonesonde datasets, including dedicated ozonesondes if available

Thank You!

Questions?