Validated Stage 1 Science Maturity Review for Soundings

Presented by

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September 3, 2014

Outline

- Algorithm Cal/Val Team Members
- Product Requirements
- Evaluation of algorithm performance to specification requirements
  - Evaluation of the effect of required algorithm inputs
  - Quality flag analysis/validation
  - Error Budget
- Documentation
- Identification of Processing Environment
- Users & User Feedback
- Conclusion
- Path Forward

Sounding EDR Cal/Val Team

Name	Organization	Major Task
M. Liu, T. Reale, W.Wolf	NOAA/STAR	Management leads
A. Gambacorta	IMSG@STAR	NUCAPS algorithm lead, X. Xiong, C. Tan, F. Iturbide-Sanchez, K. Zhang:NUCAPS algorithm team member AVTP, AVMP, O_3, OLR, trace gases
N. Nalli	IMSG@STAR	NUCAPS product validation lead
C. Barnet	STC	NOAA CrIS/ATMS EDRs in complex weather regimes
B. Sun, M. Pettey, Frank Tilley, Charlie Brown	IMSG@STAR	NPROVS/NPROVS+
X. Liu	NASA/LaRC	NUCAPS independent assessment
P. J. Mather	DOE	support validation of EDRs
D. Tobin	UW	ARM-RAOBS at NWP, SGP, NSA

Special thanks to T. King, M. Wilson, and Y. Zhou. NUCAPS codes are now under version control in ClearCase.

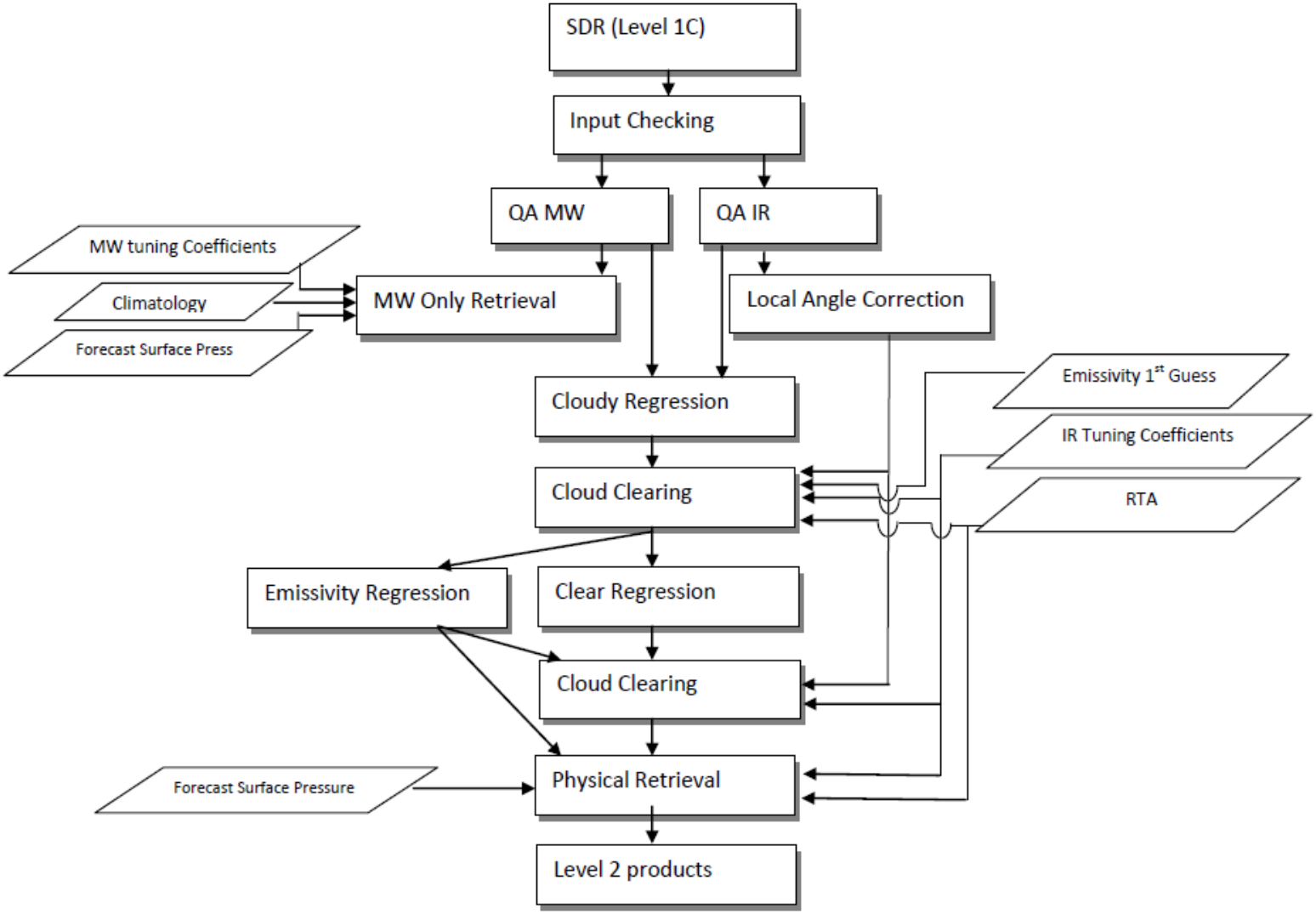
Temperature Profile Requirements

	Attribute	Threshold	Objective
	Geographic coverage	90% every 18 hours	> 90%
L1RD p43	Vertical Coverage	Surface to 0.5 mb	Surface to 0.5 mb
	Vertical Cell Size	0.2 ~50 mb	0.1 ~ 10 mb
	Horizontal Cell Size	50 km at nadir	1 km at nadir
	Mapping Uncertainty	5 km	0.5 km
	Measurement Range	Propose 150 ~ 400 K	Propose 100 ~ 500 K
	Measurement Uncertainty		
	Cloud < 50%: Surface to 300 mb	1.6 K per km layer	0.5 K per km layer
IR + MW	300 to 30 mb	1.5 K per 3 km layer	0.5 K per 3 km layer
	30 to 1 mb	1.5 K per 5 km layer	0.5 K per 5 km layer
	1 to 0.5 mb	3.5 K per 5 km layer	0.5 K per 5 km layer
	Cloud >= 50%: Surface to 700mb	2.5 K per km layer	0.5 K per km layer
	700 to 300 mb	1.5 K per km layer	0.5 K per km layer
MW only	300 to 30 mb	1.5 K per 3 km layer	0.5 K per 3 km layer
	30 to 1 mb	1.5 K per 5 km layer	0.5 K per 5 km layer
	1 to 0.5 mb	3.5 K per 5 km layer	0.5 K per 5 km layer

Moisture Profile Requirements

	Attribute	Threshold	Objective
L1RD p41	Geographic coverage	90% every 18 hours	3 hrs
	Vertical Coverage	Surface to 0.5 mb	Surface to 0.5 mb
	Vertical Cell Size	20 ~50 mb	5 ~ 10 mb
	Horizontal Cell Size	50 km at nadir	1 km at nadir
	Mapping Uncertainty	5 km	0.5 km
	Measurement Range	Propose 0.001 ~ 100 g/kg	Propose 0.001 ~ 100 g/kg
	Measurement Uncertainty	Expressed as a percent of average ratio in 2 km layers	
IR + MW	Cloud < 50%: Surface to 600 mb	Greater of 20% or 0.2 g/kg	10%
	600 to 300 mb	Greater of 35% or 0.1 g/kg	10%
	300 to 100 mb	Greater of 35% or 0.1 g/kg	10%
	Cloud >= 50%: Surface to 600mb	Greater of 20% or 0.2 g/kg	10%
MW only	600 to 300 mb	Greater of 40% or 0.1 g/kg	10%
	300 to 100 mb	Greater of 40% or 0.1 g/kg	10%

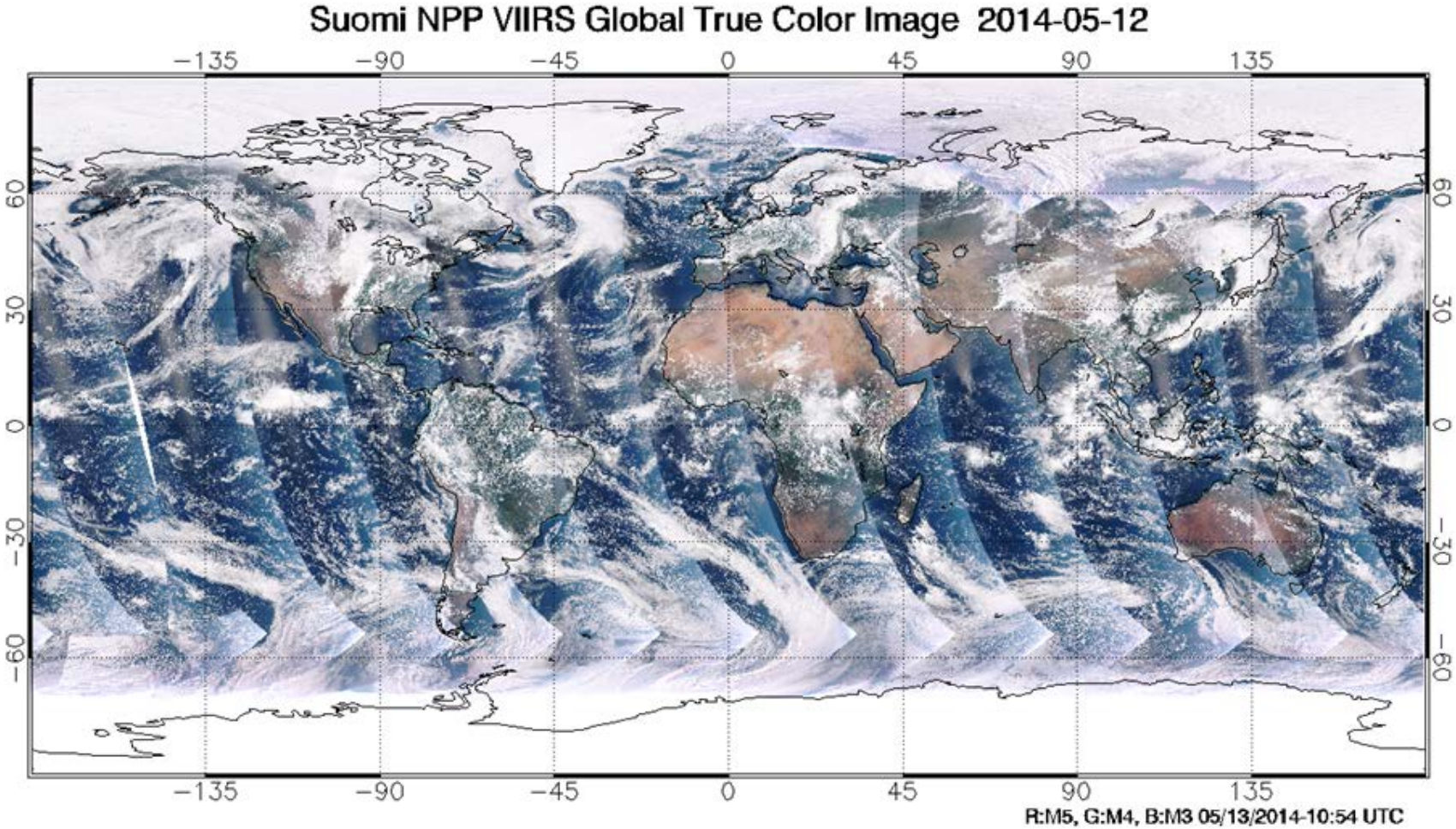
NOAA Unique CrIS/ATMS Processing System (NUCAPS) Retrieval System



Antonia Gambacorta and Chris Barnet, 2012: 10.1109/TGRS.2012.2220369.

Cloud Coverage, May 12, 2014

from STAR ICVS



Clear	1-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-99	100%
8.61	13.92	6.16	5.67	4.52	3.94	3.68	3.80	4.32	8.66	18.28	18.44

Cloud coverage = 57%

Data from Haibing Sun

CCR (CF< 80%)

Using cloud-clearing radiance, IR retrieval data increases from 8.6% to 55%.

Validation Methodology, NPROVS and VALAR

Numerical Model (e.g., ECMWF, NCEP/GFS)
Global *Comparisons*
Large, global samples acquired from Focus Days
Useful for early sanity checks, bias tuning and regression
However, not independent truth data

Satellite EDR (e.g., CrIS, AIRS, ATOVS, COSMIC)
Intercomparisons
Global samples acquired from Focus Days (e.g., CrIS/ATMS)
Consistency checks; merits of different retrieval algorithms
However, IR sounders have similar error characteristics; must take rigorous account of averaging kernels of both systems (e.g., *Rodgers and Connor,* 2003)

Conventional RAOB Matchup *Assessments*
Conventional WMO/GTS operational sondes launched ~2/day for NWP (e.g., NPROVS)
Useful for representation of global zones and long-term monitoring
Large statistical samples acquired after a couple months' accumulation
Limitations:

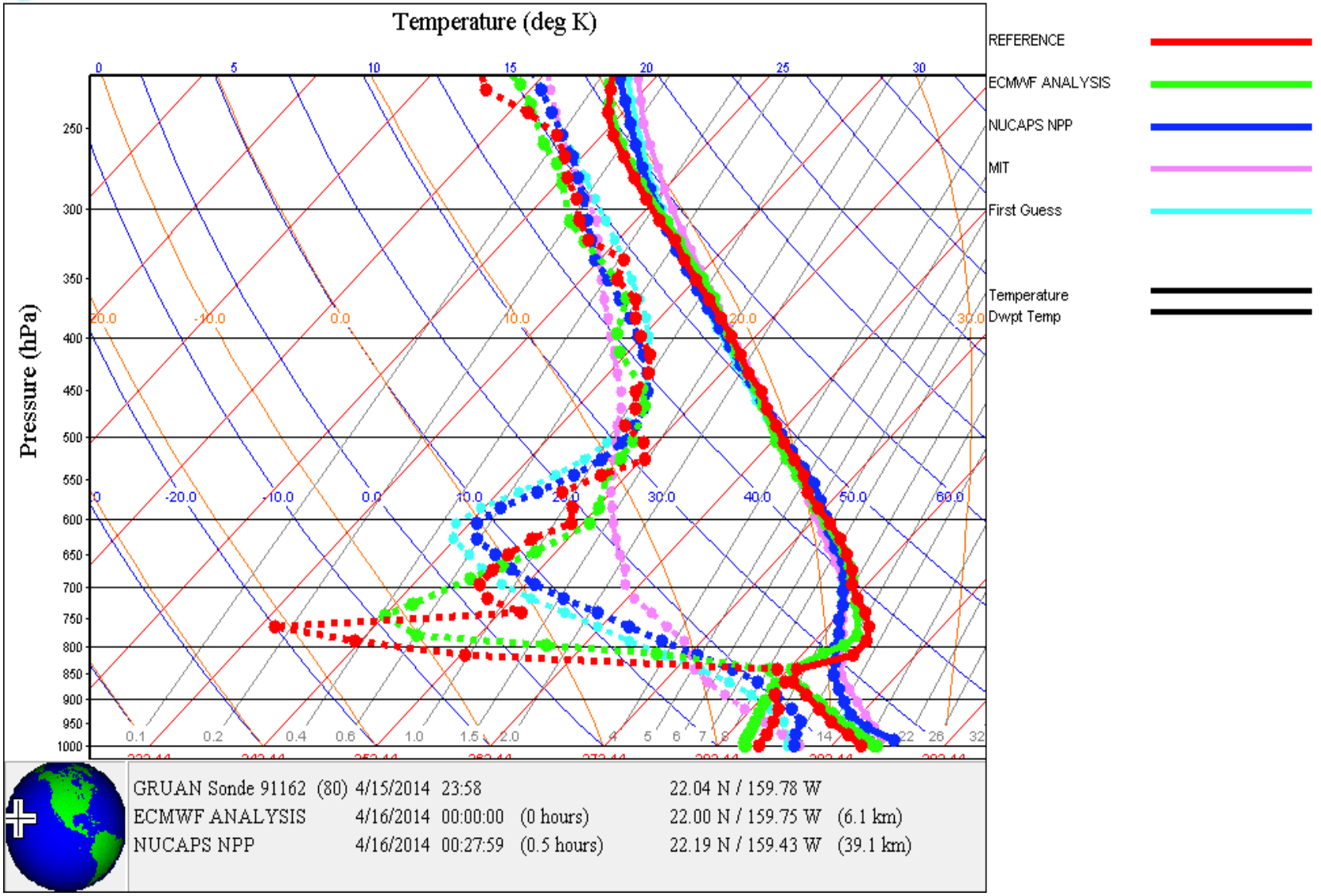
- Skewed distribution toward NH-continental sites
- Significant mismatch errors, potentially systematic at individual sites
- Non-uniform, less-accurate and poorly characterized
- radiosonde types used in data sample

Dedicated/Reference RAOB Matchup *Assessments*
Dedicated for the purpose of satellite validation
Well-specified error characteristics and optimal accuracy
Minimal mismatch errors
Include atmospheric state "best estimates" or "merged soundings"
Reference sondes: CFH, corrected RS92, Vaisala RR01 under Development
Traceable measurement
Detailed performance specification and regional Characterization
Limitation: Small sample sizes and geographic coverage
E.g., ARM sites (e.g., *Tobin et al.,* 2006), GRUAN sites, NOAA AEROSE

Intensive Field Campaign *Dissections*
Include dedicated RAOBs, especially those *not* assimilated nto NWP models
Include ancillary datasets (e.g., ozonesondes, lidar, M-AERI, MWR, sunphotometer, etc.)
Ideally include funded aircraft campaign using aircraft IR sounder (e.g., NAST-I, S-HIS) underflights
Detailed performance specification; state specification; SDR cal/val; EDR "dissections"
E.g., AEROSE, JAIVEX, WAVES, AWEX-G, EAQUATE, CalWater-2

Nalli et al., 2013: JGR; Divakarla, et al., 2014: JGR-Atmosphere.

NOAA Products Validation System (NPROVS)



Data Product Maturity Definition

Validated Stage 1:

Using a limited set of samples, the algorithm output is shown to meet the threshold performance attributes identified in the JPSS Level 1 Requirements Supplement with the exception of the S-NPP Performance Exclusions.

Validation Data Set

Qualitative Analysis

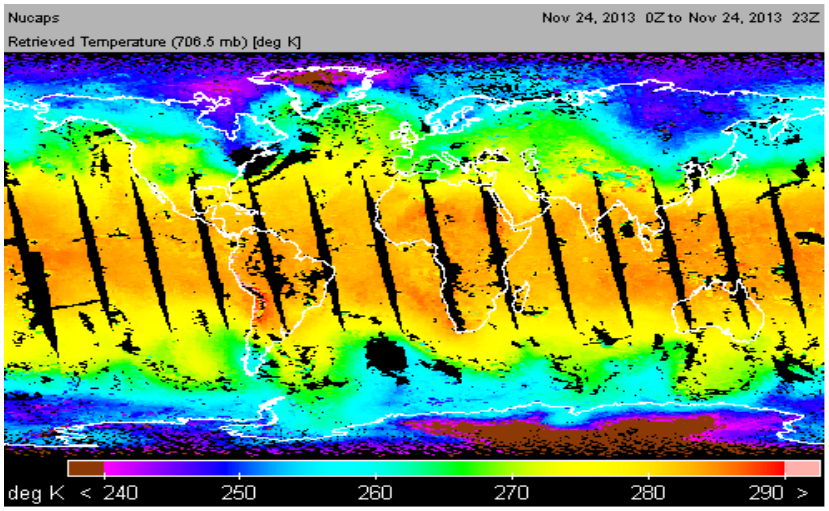
Product global distribution

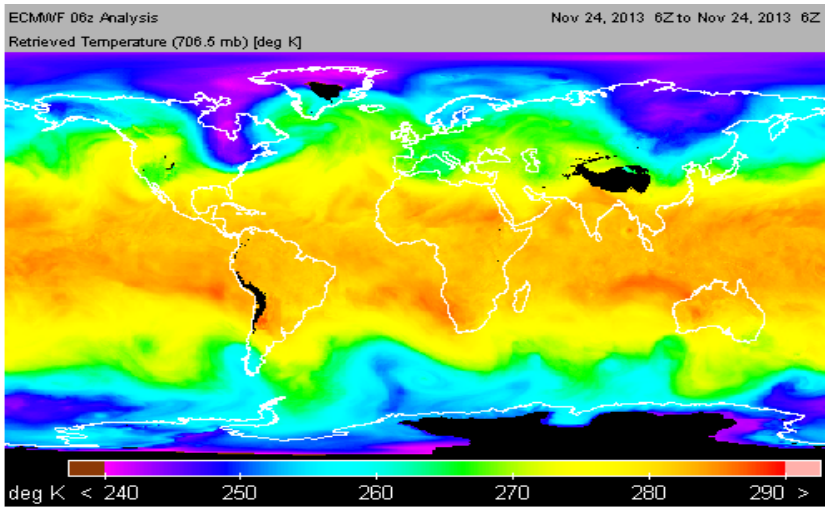
Quantitative Analysis

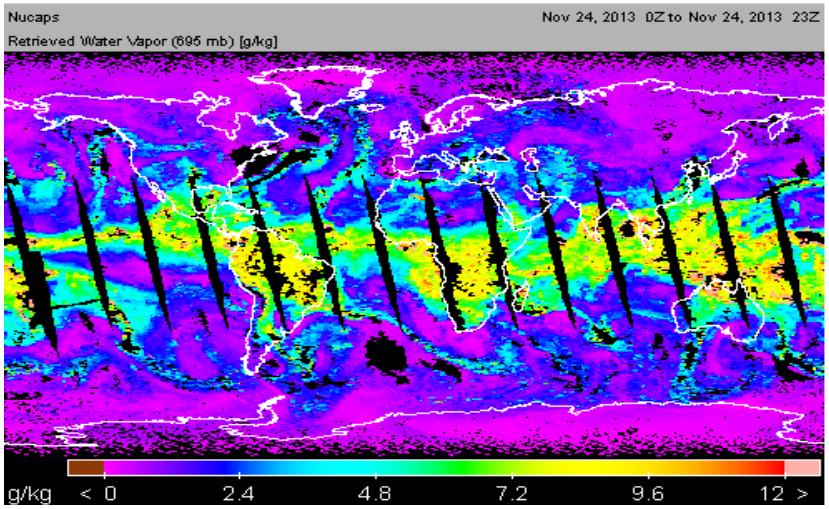
a. Aerosols and Ocean Science Expeditions (AEROSE)
b. ECMWF Global Analysis
c. Dedicated radiosondes
    ARM-SGP : Mid-latitude land
    ARM-TWP: Tropical western pacific
    ARM-NSA: Polar area

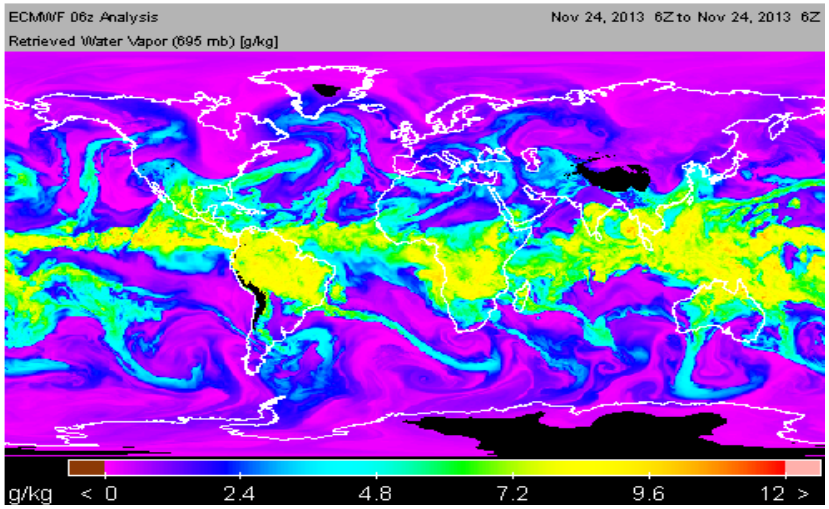
NUCAPS Products

NUCAPS vs ECMWF, T and H_2O







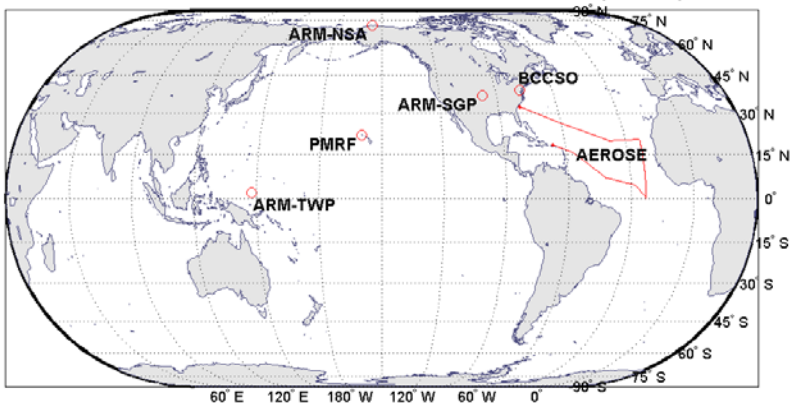


Black indicate where IR+MW and MW-only failed qc …

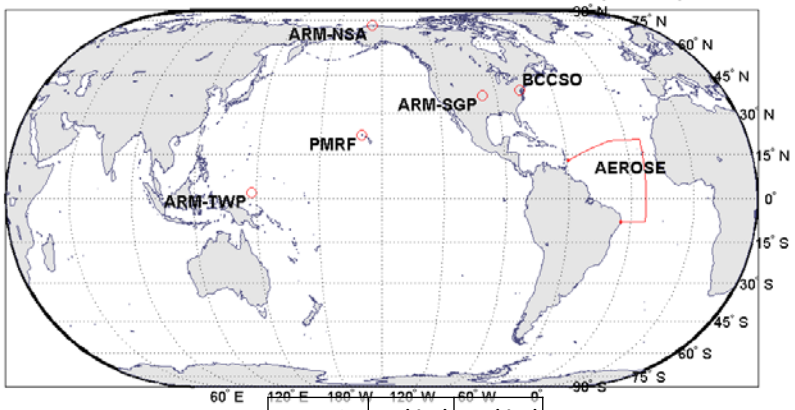
Dedicated and GRUAN Reference RAOB

JPSS S-NPP Dedicated

S-NPP CrIMSS EDR ICV Dedicated RAOB Sites (Year 1)



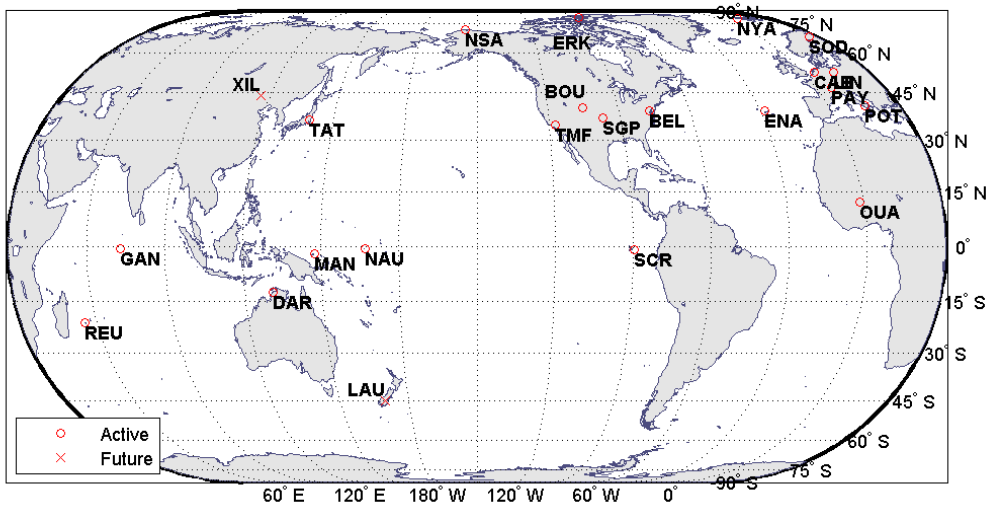
S-NPP CrIMSS EDR ICV Dedicated RAOB Sites (Year 2)



RAOB Site	Lat (deg)	Lon (deg)
ARM-SGP	36.6	-97.5
ARM-NSA	71.3	-156.6
ARM-TWP	2.06	147.43
PMRF	22.05	-159.78
BCCS	39.05	-76.88
AEROSE	Tropical Ocean	

GRUAN Reference Sites (NPROVS+ Collocation)

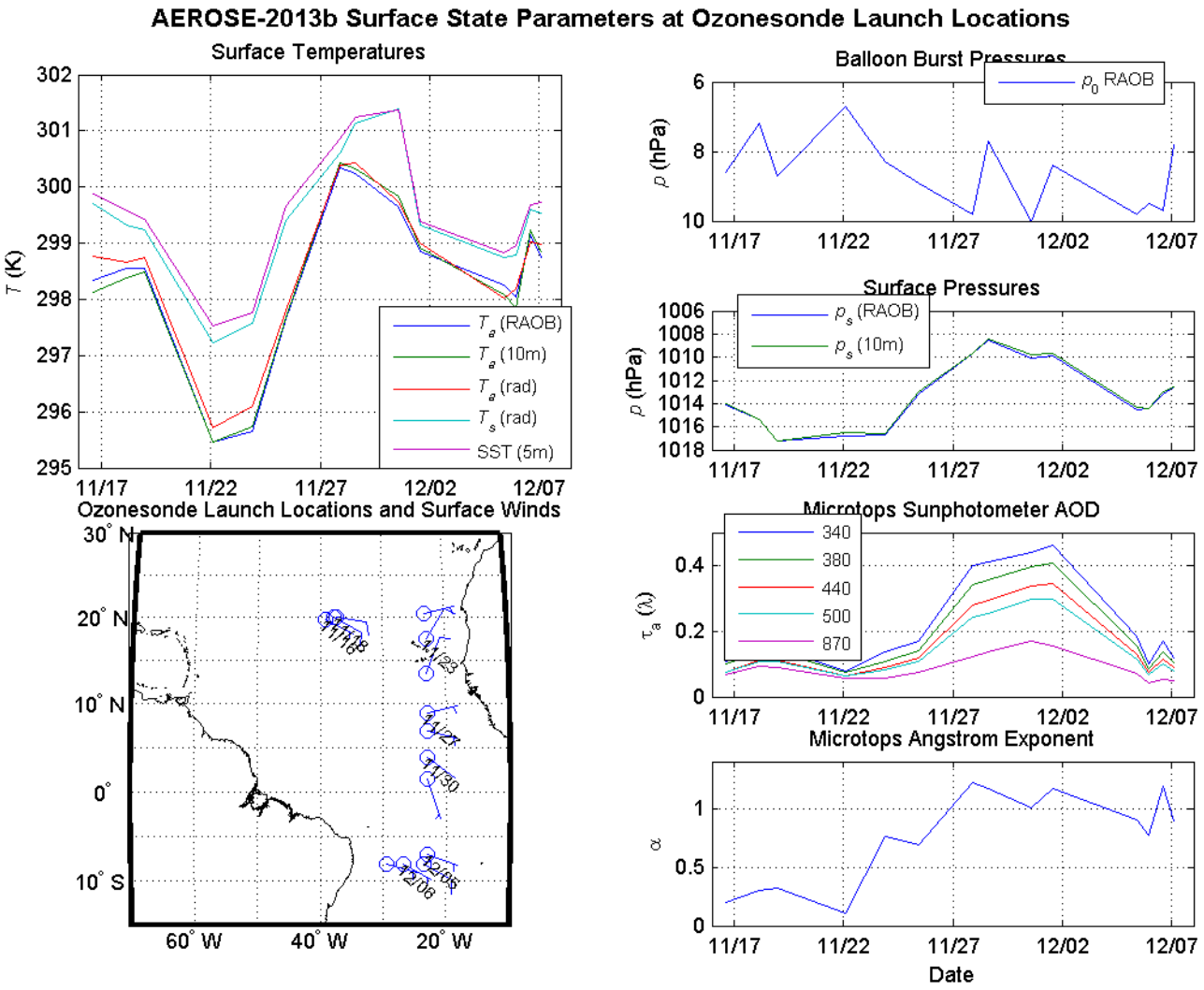
GRUAN RAOB Sites for Sounder EDR ICV



Location	BEL	BOU	CAB	DAR	ENA	ERK	GAN	HIH	LAU	LIN	MAN	NAU
Lat (deg)	39.05	39.95	52.1	-12.475	39.05	79.98	-0.69	19.72	-45.04	52.22	-2.06	-0.52
Lon(deg)	-76.88	-105.2	5.18	130.83	-28.03	-85.93	73.15	-155.05	169.68	14.12	147.43	166.92

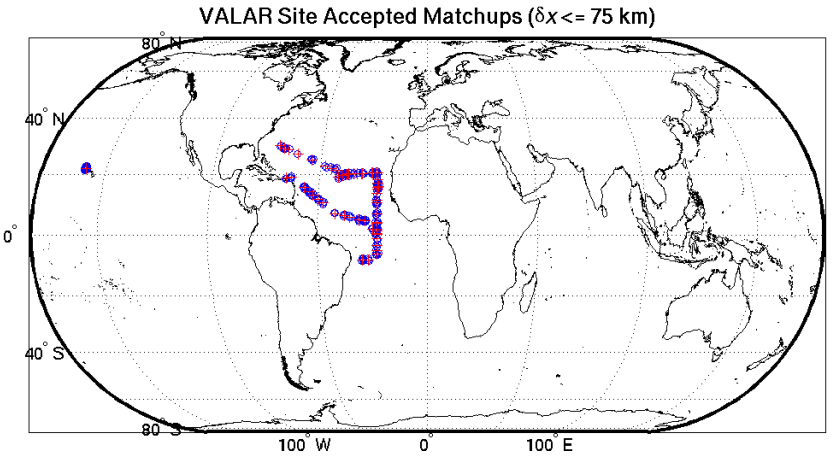
Location	NSA	NYA	OUA	PAY	POT	REU	SRC	SGP	SOD	TAT	TMF	XIL
Lat (deg)	71.32	78.92	12.4	46.81	40.6	-21.08	-0.9	36.61	67.37	36.06	34.39	43.95
Lon(deg)	-156.6	11.92	-1.5	6.95	15.72	55.38	-89.6	-97.49	26.63	140.1	-117.7	116.12

2013 AEROSE State Parameters
$P(z)$, $T(p)$, $U(p)$, $O_3(p)$, T_s, u_s, v_s, AOD

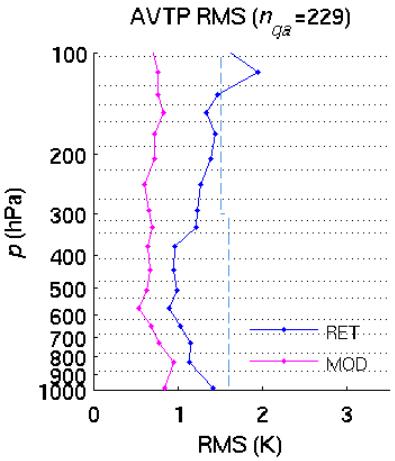


NDE-OPS IR + MW

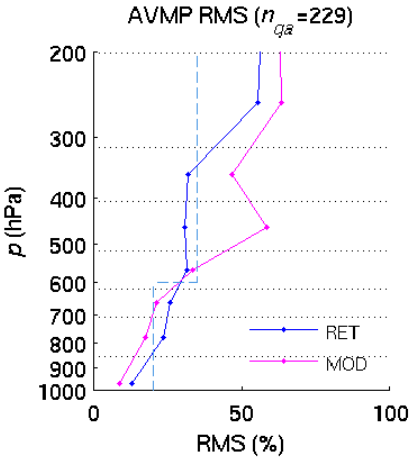
MOD=ECMWF



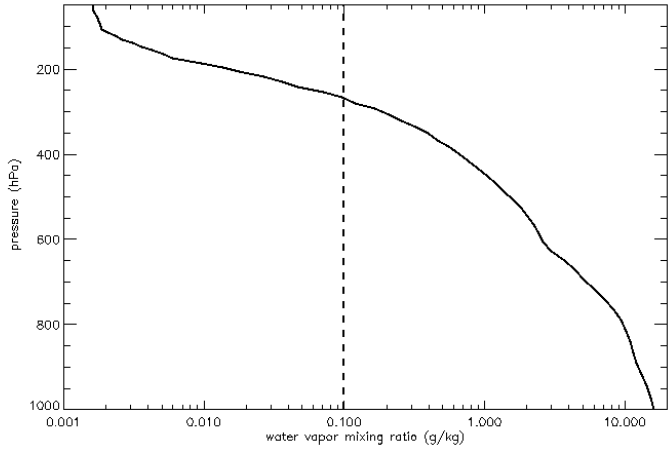
Temperature

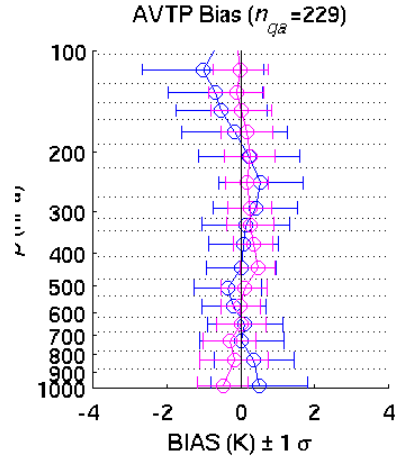


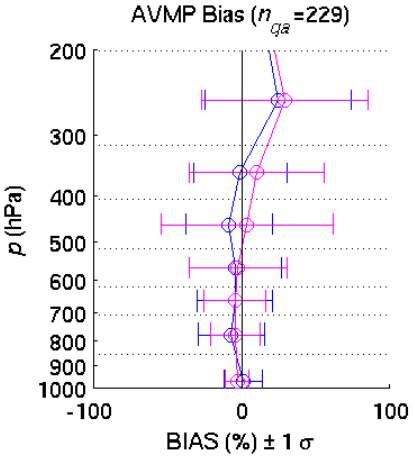
Moisture



Standard tropical water vapor profile

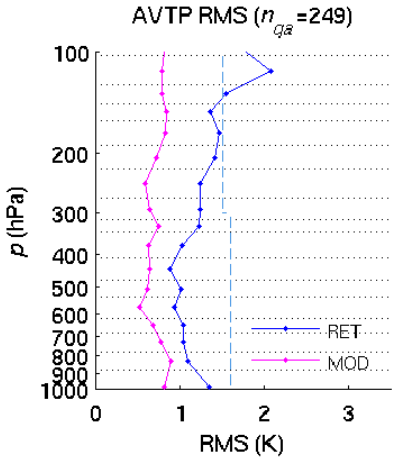


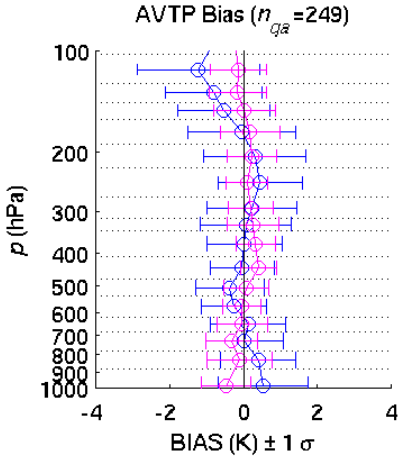




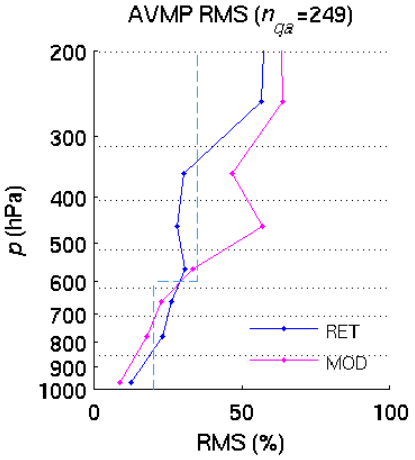
Offline IR + MW

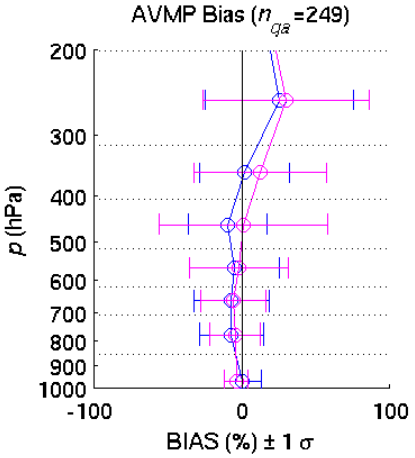
Temperature





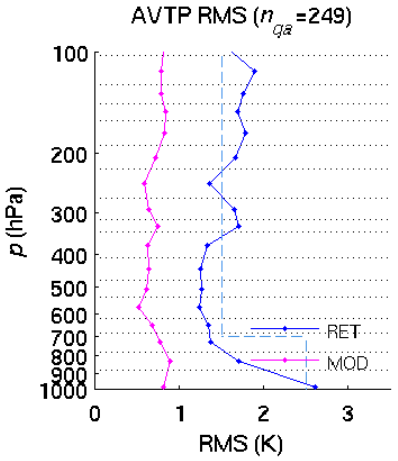
Moisture

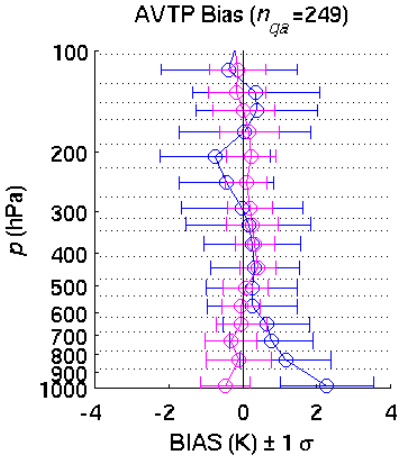




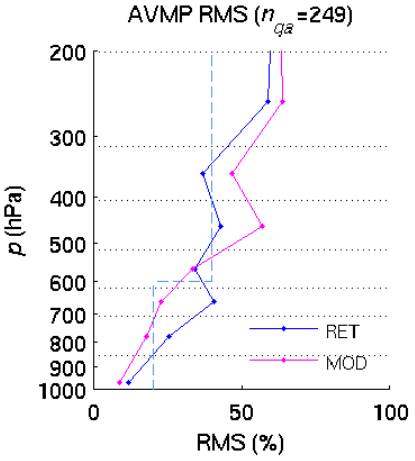
Offline MW-Only (MIT)

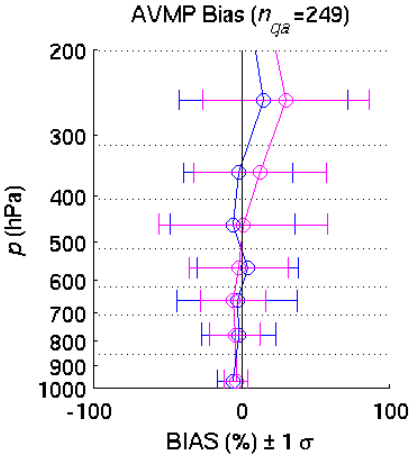
Temperature





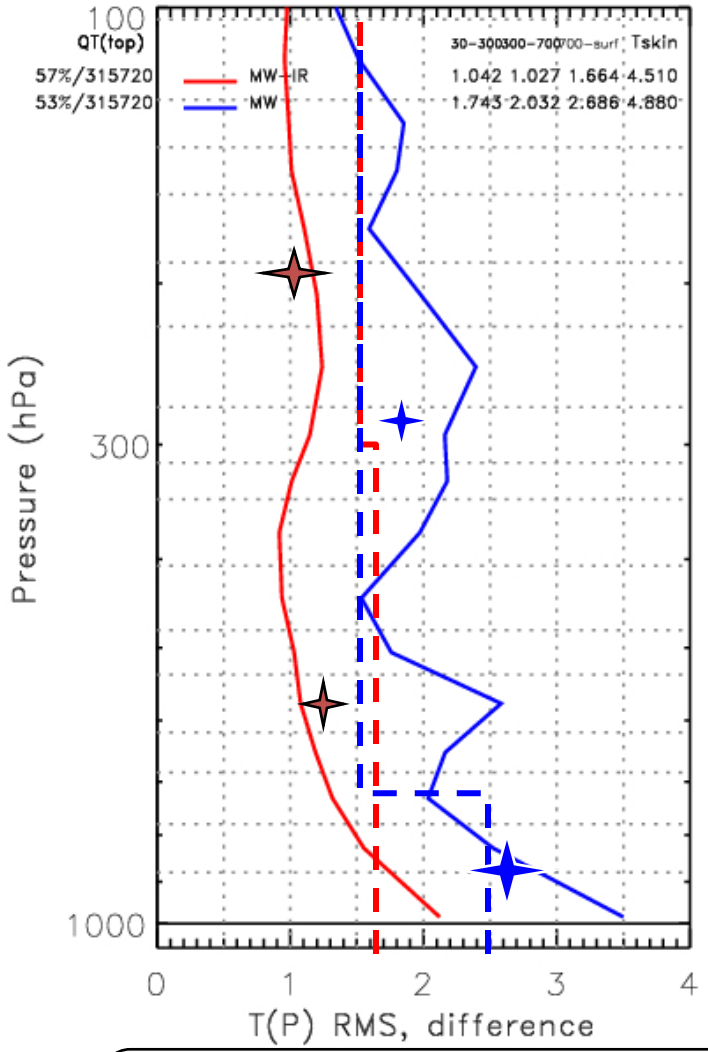
Moisture

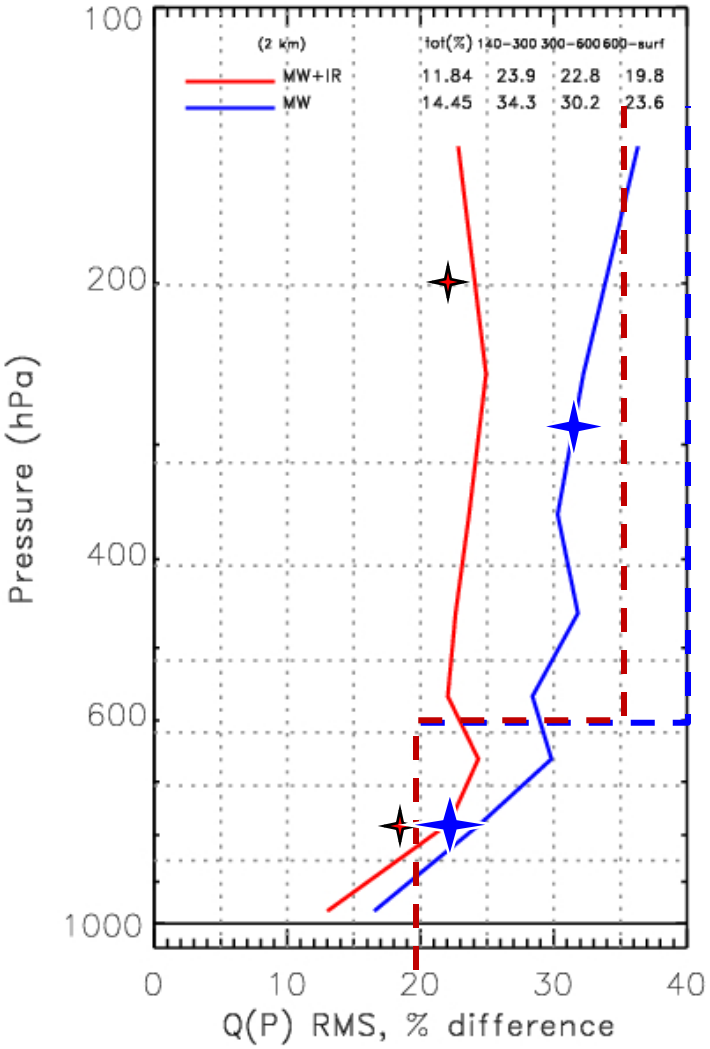




NUCAPS MW+IR & MW Only

Global (land+ocean) vs ECMWF Analysis (focus day 2012-05-15)





JPSS L1RD:
(see next slide)

30 – 300mb	300-SURF
1.042K (Req:1.5K)	1.34K (Req:1.6K)
TOA – 700mb	700-SURF
1.88K (Req:1.5K)	2.68K (Req:2.5K)

100 – 600mb	600-SURF
23.3% (Req:35%)	19.8% (Req:20%)
32.2% (Req:40%)	23.6% (Req:20%)

Summary on GLOBAL validation vs ECMWF

green = passed yellow = close red = failed

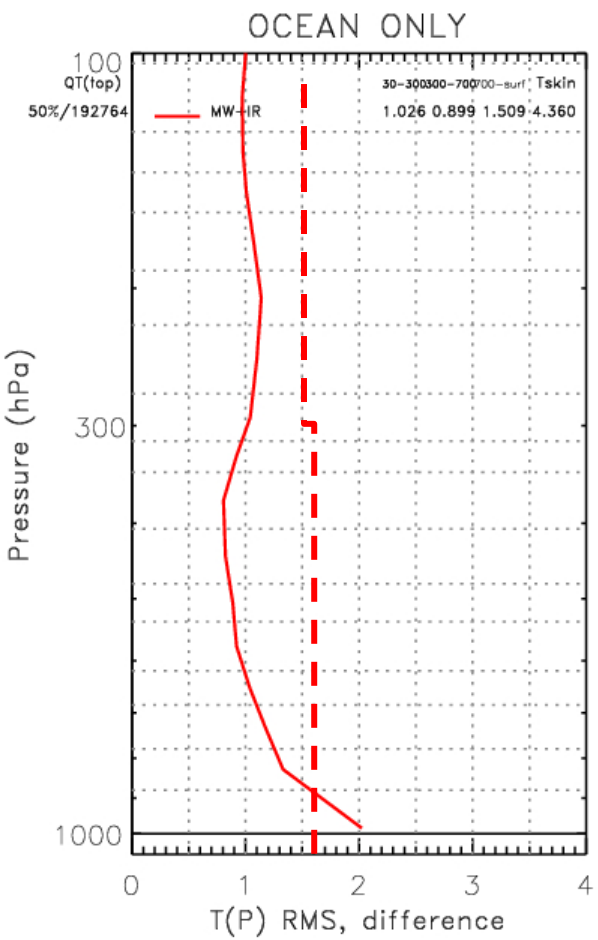
SUMMARY ON MW+IR RESULTS vs JPSS L1RD REQUIREMENTS					
MW+IR TEMPERATURE	RESULTS	JPSS L1RD	MW+IR WATER VAPOR	RESULTS	JPSS L1RD
30 – 300mb	1.04K	1.5K	100 - 600mb	23.3%	35%
300mb - SURF	1.34K	1.6K	600mb -SURF	19.8%	20%

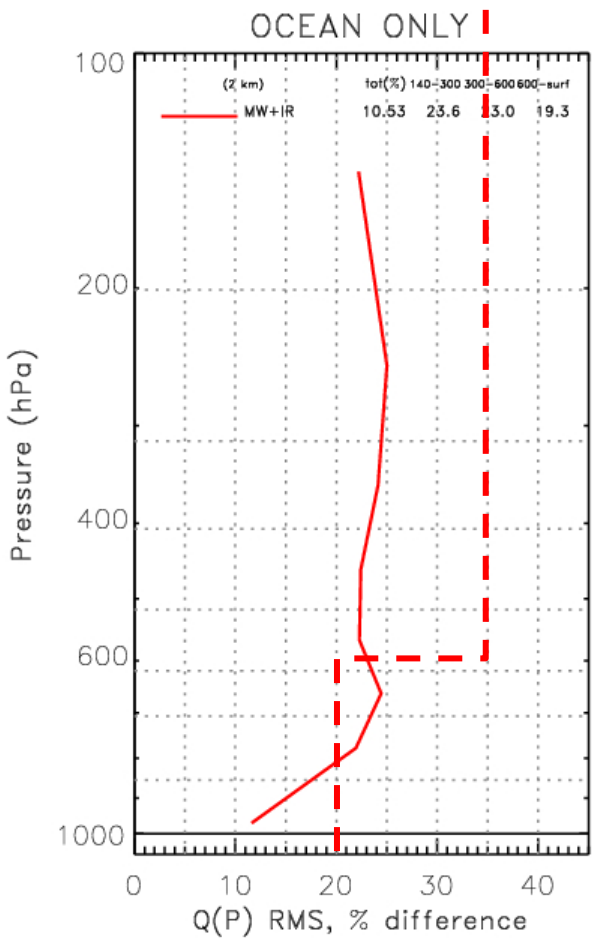
SUMMARY ON MW-ONLY RESULTS vs JPSS L1RD REQUIREMENTS					
MW-ONLY TEMPERATURE	RESULTS	JPSS L1RD	MW-ONLY WATER VAPOR	RESULTS	JPSS L1RD
30 – 700mb	1.88K	1.5K	100 - 600mb	32.2%	40%
700mb - SURF	2.68K	2.5K	600mb -SURF	23.6%	20%

- **NUCAPS MW+IR fully meets requirements globally**
- **NUCAPS MW-Only is close to fully meets spec.**
  - **Possible isues are**:
    - Residual temporal and spatial mismatch between retrievals and model: ECMWF mismatch is +/- 1.5 hour and +/- 0.25 deg and we use both forecast and analysis depending on UT time.
    - Uncertainty in the model
    - Uncertainty in the retrievals
  - **Ongoing NUCAPS improvement activity:**
    - Improve NUCAPS look up tables (RTA tuning and first guess)
    - Improve validation methodology by using dedicated RAOBs: **see ahead**

GLOBAL OCEAN VALIDATION

NUCAPS MW+IR vs ECMWF Analysis (focus day 2012-05-15)

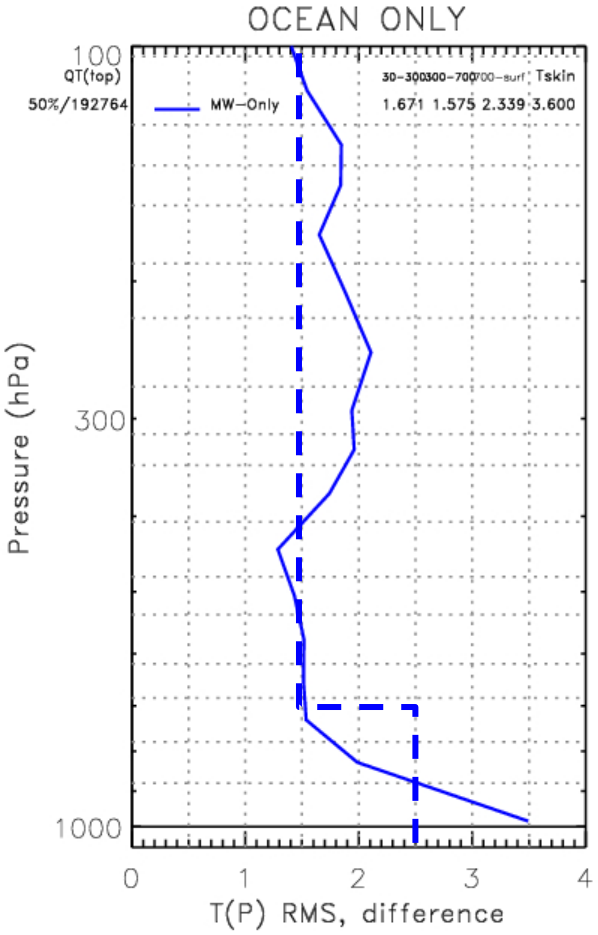


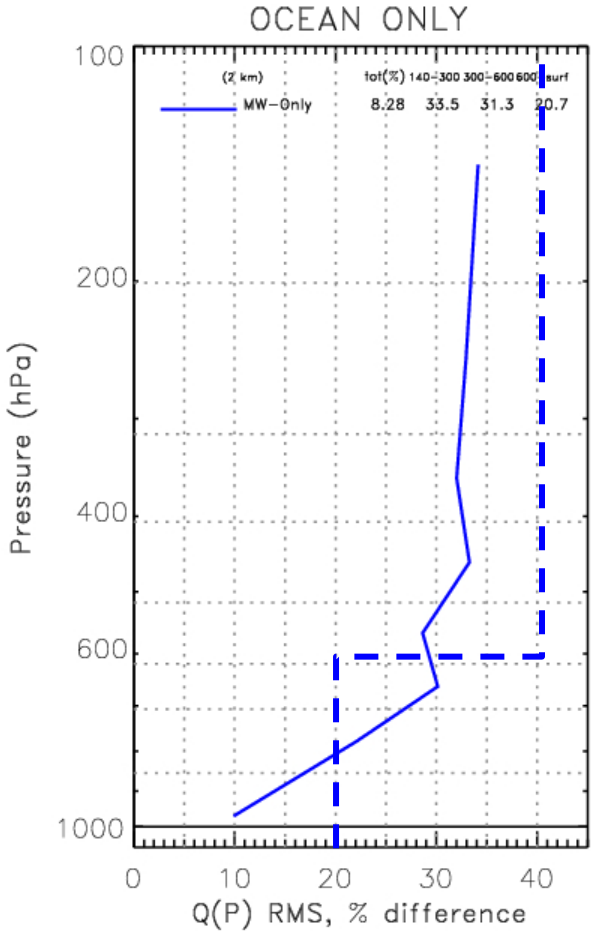


SUMMARY ON OCEAN MW+IR RESULTS vs JPSS L1RD REQUIREMENTS					
MW+IR TEMPERATURE	RESULTS	JPSS L1RD	MW+IR WATER VAPOR	RESULTS	JPSS L1RD
30 – 300mb	1.02K	1.5K	100 - 600mb	23.3%	35%
300mb - SURF	1.20K	1.6K	600mb -SURF	19.3%	20%

GLOBAL OCEAN VALIDATION

NUCAPS MW Only vs ECMWF Analysis (focus day 2012-05-15)





SUMMARY ON OCEAN MW-ONLY RESULTS vs JPSS L1RD REQUIREMENTS					
MW-ONLY TEMPERATURE	RESULTS	JPSS L1RD	MW-ONLY WATER VAPOR	RESULTS	JPSS L1RD
30 – 700mb	1.55K	1.5K	100 - 600mb	32.4%	40%
700mb - SURF	2.33K	2.5K	600mb -SURF	20.7%	20%

Summary on OCEAN validation vs ECMWF

green = passed yellow = close red = failed

SUMMARY ON OCEAN MW+IR RESULTS vs JPSS L1RD REQUIREMENTS					
MW+IR TEMPERATURE	RESULTS	JPSS L1RD	MW+IR WATER VAPOR	RESULTS	JPSS L1RD
30 – 300mb	1.02K	1.5K	100 - 600mb	23.3%	35%
300mb - SURF	1.20K	1.6K	600mb -SURF	19.3%	20%

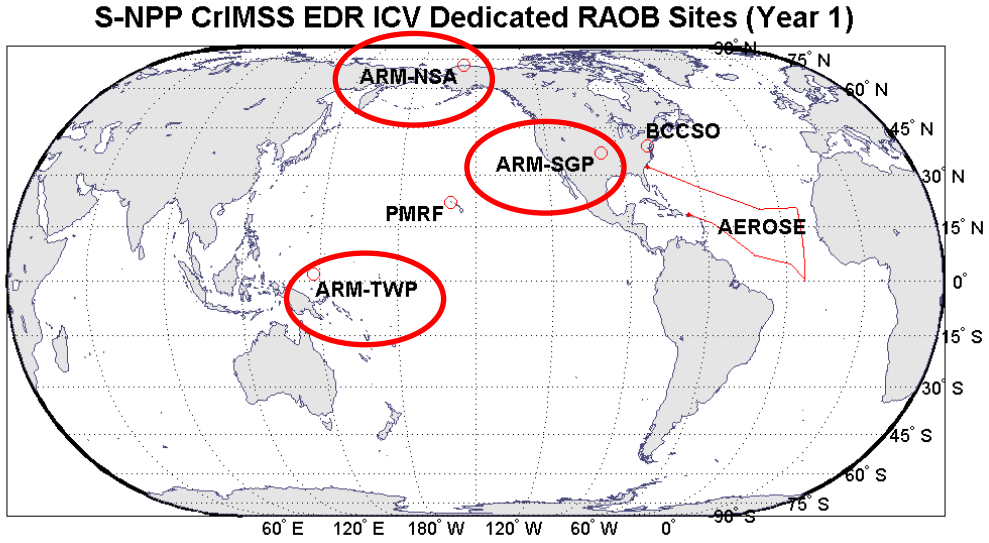
SUMMARY ON OCEAN MW-ONLY RESULTS vs JPSS L1RD REQUIREMENTS					
MW-ONLY TEMPERATURE	RESULTS	JPSS L1RD	MW-ONLY WATER VAPOR	RESULTS	JPSS L1RD
30 – 700mb	1.55K	1.5K	100 - 600mb	32.4%	40%
700mb - SURF	2.33K	2.5K	600mb -SURF	20.7%	20%

- **NUCAPS MW+IR fully meets requirements over ocean**
- **NUCAPS MW-Only is close to fully meet spec.**
  - **Possible issues are:**
    - Residual temporal and spatial mismatch between retrievals and model: ECMWF mismatch is +/- 1.5 hour and +/- 0.25 deg and we use both forecast and analysis depending on UT time.
    - Uncertainty in the ECMWF model
    - Uncertainty in the retrievals
  - **Ongoing NUCAPS improvement activity:**
    - Improve NUCAPS look up tables (RTA tuning and first guess)
    - Improve validation methodology by using dedicated RAOBs: **see ahead**

NUCAPS validation vs ARM

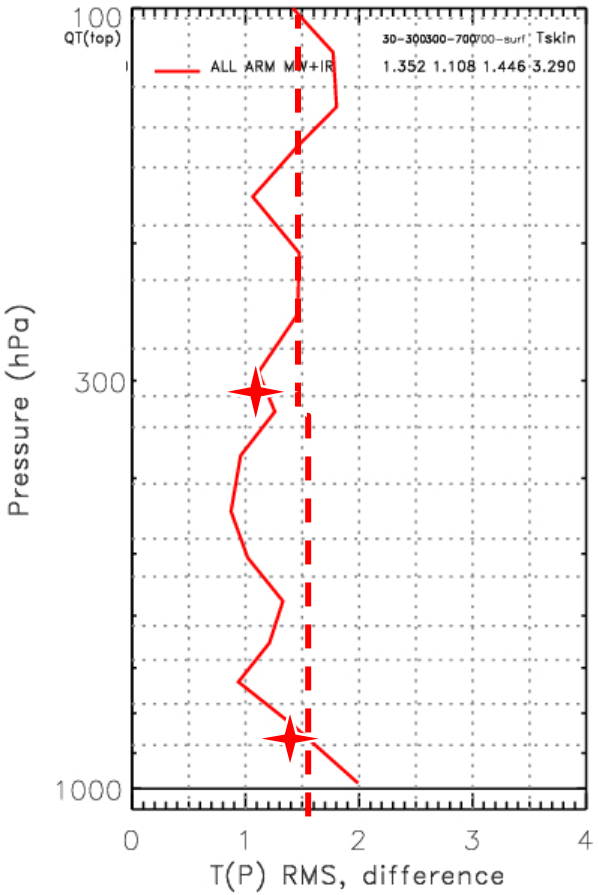
- JPSS funded dedicated (time and location) wrt NPP
- **Global** ensemble, ~ 3 month field campaign (2012):
  - Tropical Western Pacific (TWP)
  - Southern Great Plans (SGP)
  - North Slope of Alaska (NSA)

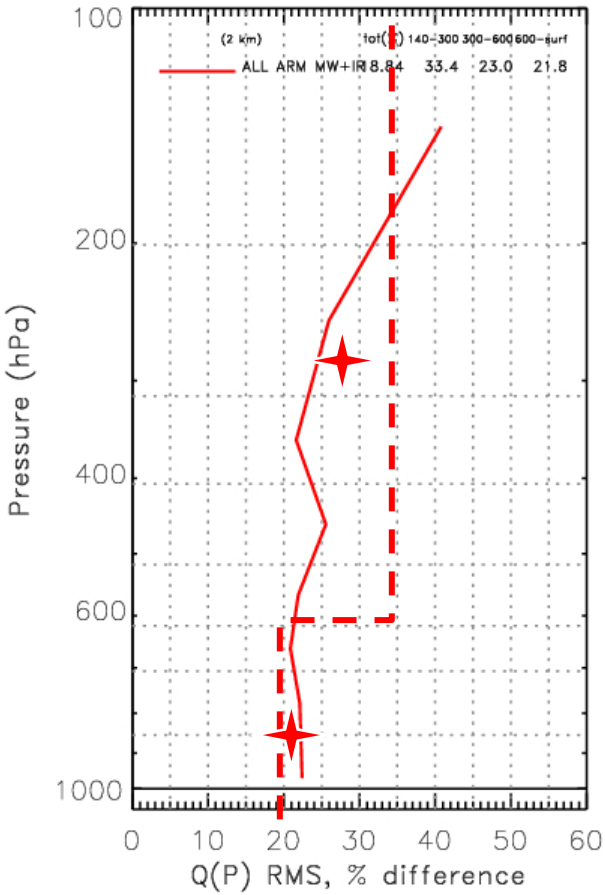
RAOB Site	Lat (deg)	Lon (deg)
ARM-SGP	36.6	-97.5
ARM-NSA	71.3	-156.6
ARM-TWP	2.06	147.43



NUCAPS MW+IR

RMS Statistics vs ARM TWP, SGP, NSA Dedicated RAOBs

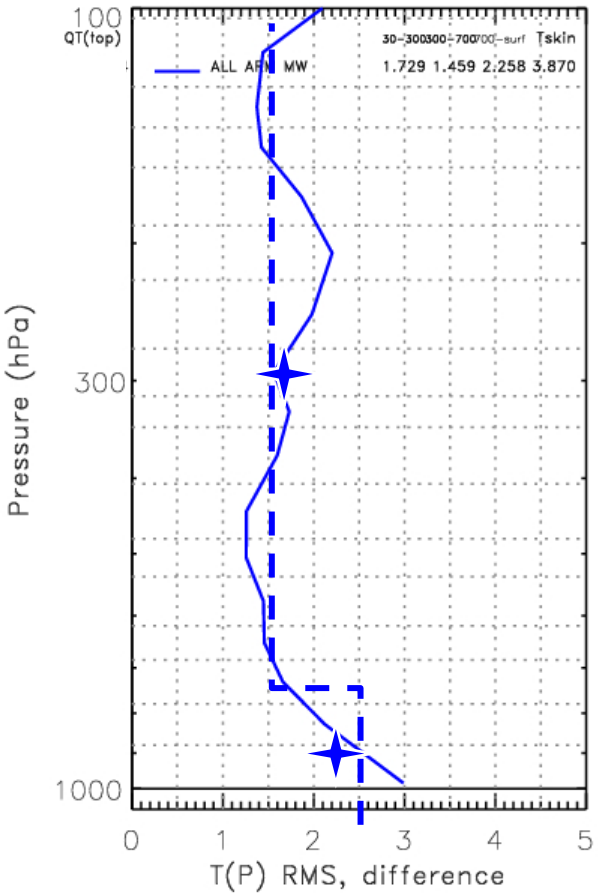


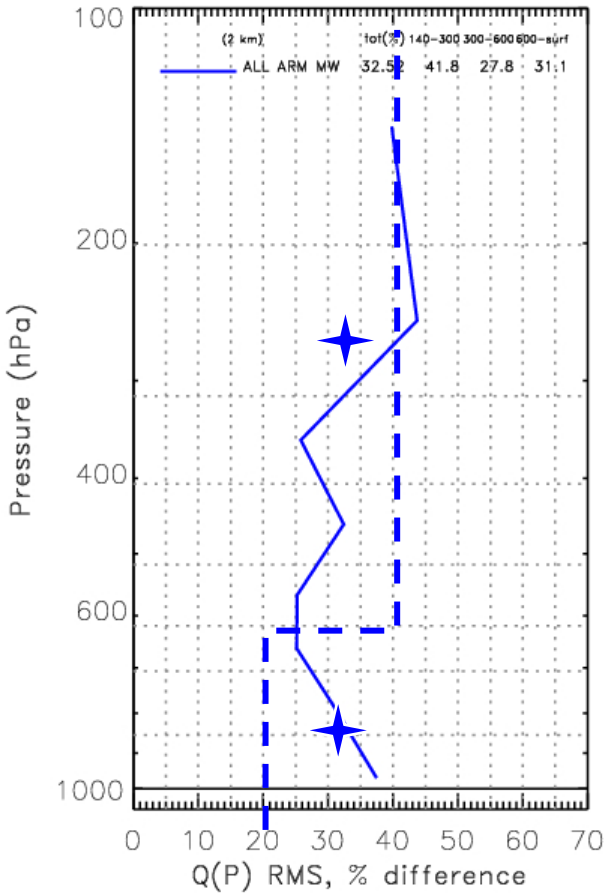


SUMMARY ON MW+IR RESULTS vs JPSS L1RD REQUIREMENTS					
MW+IR TEMPERATURE	**RESULTS**	**JPSS L1RD**	**MW+IR WATER VAPOR**	**RESULTS**	**JPSS L1RD**
30 – 300mb	**1.35K**	**1.5K**	**100 - 600mb**	**28.2%**	**35%**
300mb - SURF	**1.25K**	**1.6K**	**600mb -SURF**	**21.8%**	**20%**

NUCAPS MW Only

RMS Statistics vs ARM TWP, SGP, NSA Dedicated RAOBs





SUMMARY ON MW-ONLY RESULTS vs JPSS L1RD REQUIREMENTS					
MW-ONLY TEMPERATURE	RESULTS	JPSS L1RD	MW-ONLY WATER VAPOR	RESULTS	JPSS L1RD
30 – 700mb	1.59K	1.5K	100 - 600mb	34.8%	40%
700mb - SURF	2.25K	2.5K	600mb -SURF	31.1%	20%

Summary on global validation vs ARM dedicated RAOBs

green = passed yellow = close red = failed

SUMMARY ON MW+IR RESULTS vs JPSS L1RD REQUIREMENTS					
MW+IR TEMPERATURE	RESULTS	JPSS L1RD	MW+IR WATER VAPOR	RESULTS	JPSS L1RD
30 – 300mb	1.35K	1.5K	100 - 600mb	28.2%	35%
300mb - SURF	1.25K	1.6K	600mb -SURF	21.8%	20%

SUMMARY ON MW-ONLY RESULTS vs JPSS L1RD REQUIREMENTS					
MW-ONLY TEMPERATURE	RESULTS	JPSS L1RD	MW-ONLY WATER VAPOR	RESULTS	JPSS L1RD
30 – 700mb	1.59K	1.5K	100 - 600mb	34.8%	40%
700mb - SURF	2.25K	2.5K	600mb -SURF	31.1%	20%

- **The NUCAPS system meets requirements globally** except for water vapor MW-only (31.1% vs 20%) in the layer 600mb – surface and the water vapor MW+IR (21.8% vs 20%) in the layer 600mb - surface .
- **Possible issues are:**
  - Residual temporal and spatial mismatch (75km) between retrievals and RAOBs considerably affects water vapor statistics (up to 10% due to 50km mismatch, especially in the UTH due to RAOB drift)
  - Uncertainty in the RAOBs (supersaturation, calibration uncertainty)
  - Uncertainty in the retrievals: we are aware that there is a need for updating the look up tables and a possible bug in the MW-only retrieval module but just did not have enough time to fix it (ongoing NUCAPS improvement activity)

VALIDATION SUMMARY

- **NUCAPS MW+IR**
  - **meets requirements globally vs ECMWF**
  - **meets requirements over ocean vs ECMWF**
  - **Close to meet requirements globally and over selected areas vs Dedicated RAOBs**

- **NUCAPS MW – Only**
  - **NUCAPS MW Only close to meet requirements globally vs ECMWF**
  - **NUCAPS MW only close to meet requirements over ocean vs ECMWF**
  - **meets requirements over tropical western pacific dedicated RAOBs**

- **Present issues in the validation truth:**
  - Residual temporal and spatial mismatch between retrievals and model: ECMWF mismatch is +/- 1.5 hour and +/- 0.25 deg and we use both forecast and analysis depending on UT time.
  - Uncertainty in the ECMWF model
  - Residual temporal and spatial mismatch (75km) between retrievals and RAOBs considerably affects water vapor statistics (up to 10% due to 50km mismatch, especially in the UTH due to RAOB drift)
  - Uncertainty in the RAOBs (supersaturation, calibration uncertainty)
- **Ongoing activity:**
  - We are aware that there is a need for updating the look up tables for both the MW-Only and MW+IR retrieval:
    - A priori, First guess, radiance bias correction

Evaluation of the effect of required algorithm inputs (1)

- Required Algorithm Inputs
  - Primary Sensor Data: CrIS, ATMS
  - Ancillary Data: GFS surface pressure
  - Upstream algorithms: UV O_3
  - LUTs:

  ATMS bias correction

  CrIS bias correction

  Regression Coefficients for the first guess

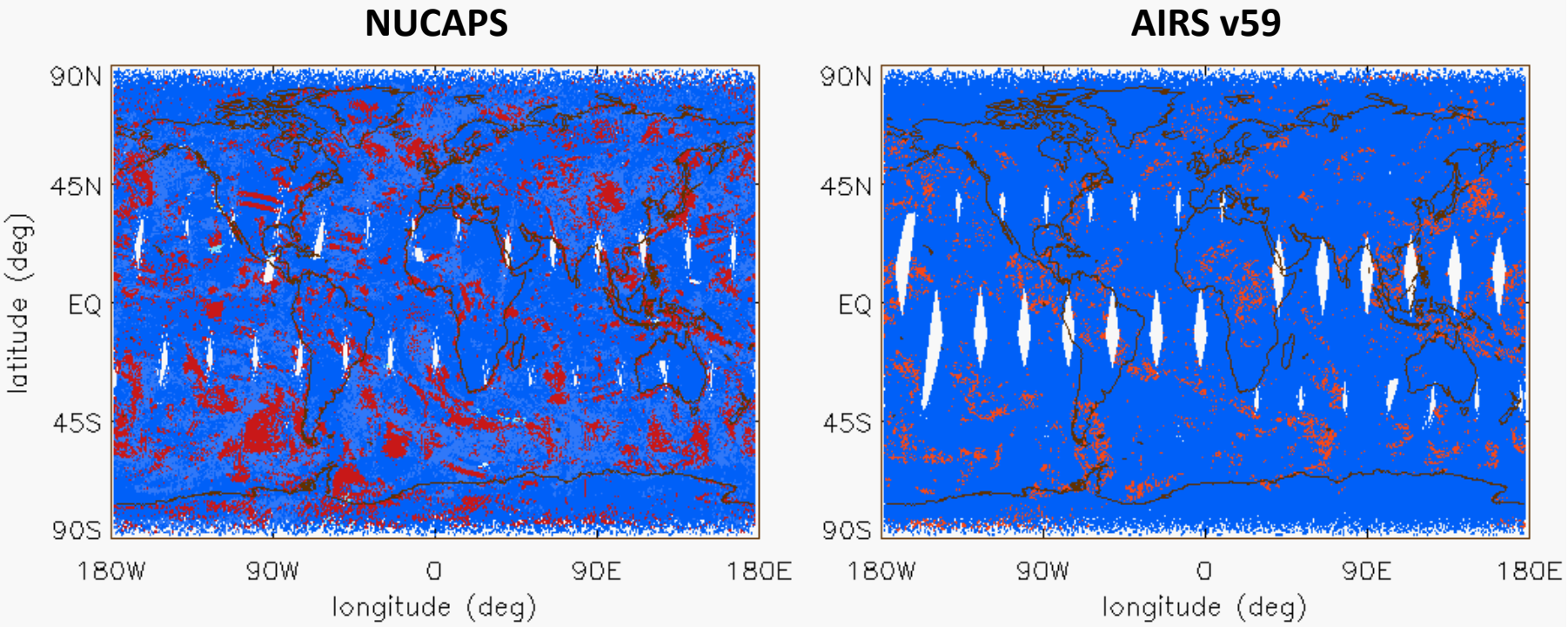
  tuning parameters

  CRTM cloud and aerosol optical properties, surface emissivity, transmittance coefficients

Evaluation of the effect of required algorithm inputs (2)

- Evaluation of the effect of required algorithm inputs
  - Study / test cases
  1. CrIS/ATMS, IASI/AMSU/MHS
  2. ECMWF global analysis and 6h forecast
  3. Conventional radiosondes
  4. Trace gases from various sources
  5. GFS surface pressure
  - Results
  1. CrIS/ATMS
  2. GFS global analysis
  3. Dedicated radiosondes
  4. Aerosols and Ocean Science Expeditions (AEROSE)
  5. ECMWF global analysis

NUCAPS vs AIRS v59 acceptance yield (blue = accepted red = rejected)



- **NUCAPS global acceptance yield is ~60% (focus day 2012/05/15)**
- **AIRS v59 global acceptance yield is ~75% (focus day 2012/05/15)**
- **Ongoing activity: QA optimization reflecting instrument properties**

Error Budget for Temperature Profile

	Attribute Analyzed	L1RD Threshold	Analysis/Validation Result	Error Summary
	Geographic coverage	90% every 18 hours	> 90%	
	Vertical Coverage	Surface to 0.5 mb	Surface to 0.016 mb	
	Vertical Cell Size	0.2 ~50 mb	0.2 ~ 30 mb	
	Horizontal Cell Size	50 km at nadir	50 km at nadir	
	Mapping Uncertainty	5 km	5 km	
	Measurement Range	Propose 150 ~ 400 K	200 ~ 310 K	
	Cloud < 50%: Surface to 300 mb	1.6 K per km layer	1.34 K per km layer	
IR + MW	300 to 30 mb	1.5 K per 3 km layer	1.04 K per 3 km layer	
IR + MW	30 to 1 mb	1.5 K per 5 km layer	1.04 K per 5 km layer	
IR + MW	1 to 0.5 mb	3.5 K per 5 km layer	1.04 K per 5 km layer	
	Cloud >= 50%: Surface to 700mb	2.5 K per km layer	2.68 K per km layer	NUCAPS MW only has tougher requirement than MiRS. MiRS 3 K (sea clear), 5.5 K (land)
MW only	700 to 300 mb	1.5 K per km layer	1.88 K per km layer	MiRS 2 K (sea clear), 2.5 K (land)
MW only	300 to 30 mb	1.5 K per 3 km layer	1.88 K per 3 km layer	MiRS 2 K
MW only	30 to 1 mb	1.5 K per 5 km layer	1.88 K per 5 km layer	
MW only	1 to 0.5 mb	3.5 K per 5 km layer	1.88 K per 5 km layer	

MiRS Precision L1RD p44

Error Budget for Moisture Profile

	Attribute Analyzed	L1RD Threshold	Analysis/Validation Result	Error Summary
	Geographic coverage	90% every 18 hours	> 90%	
	Vertical Coverage	Surface to 0.5 mb	Surface to 0.016 mb	
	Vertical Cell Size	0.2 ~50 mb	0.2 ~ 30 mb	
	Horizontal Cell Size	50 km at nadir	50 km at nadir	
	Mapping Uncertainty	5 km	5 km	
	Cloud < 50%: Surface to 600 mb	Greater of 20% or 0.2 g/kg	19.8%	
IR + MW	600 to 300 mb	Greater of 35% or 0.1 g/kg	23.3%	
IR + MW	300 to 100 mb	Greater of 35% or 0.1 g/kg	23.3%	
	Cloud >= 50%: Surface to 600mb	Greater of 20% or 0.2 g/kg	23.6%	MiRS 36% (sea clear), 53% (land)*
MW only	600 to 400 mb	Greater of 40% or 0.1 g/kg	32.2%	MiRS 63% (sea ocean), 61% (land)*
MW only	400 to 100 mb	Greater of 40% or 0.1 g/kg	32.2%	MiRS 67% (see clear), 67% (land)*

* MiRS uncertainty is calculated from its precision and accuracy (see L1RD p42).

Documentation

- The following documents will be updated and provided to the EDR Review Board before AERB approval:
  - Current or updated ATBD

  YES
  - Current or updated OAD

  No, different documentation requirements specifically for SPSRB to support OSPO
  - README file for CLASS

  http://gis.ncdc.noaa.gov/geoportal/catalog/search/resource/details.page?id=gov.noaa.ncdc:C00868

  http://www.ospo.noaa.gov/Products/atmosphere/soundings/nucaps/index.html

  - Product User's Guide (Recommended)

  NUCAPS External User Manual (Jan. 2013)

Identification of Processing Environment

- IDPS or NDE build (version) number and effective date
  NDE, version 1. NOAA CLASS publicly released since April 8, 2014.
- Algorithm version
  NUCAPS Version 1
- Version of LUTs used
  NUCAPS LUT version 1
- Version of PCTs used
  NA
- Description of environment used to achieve validated stage 1
  IBM at NOAA/OSPO
  Linux at NOAA/STAR

Users & User Feedback

- **User list**
  - NOAA CLASS
  - AWIPS-II
  - FNMOC – Fleet Numerical Meteorology and Oceanography Center
  - Nowcasting
  - Direct broadcast
  - Support SDR data monitoring, retrieval products and SDR have the same time, the same location, and the same footprint.
  - Timely temperature and moisture profiles for the warning of severe weather (Mark DeMaria) , e.g. atmospheric stability condition for tropical storm. For tornado warning, retrieval products of higher spatial resolution (~ 10 km) is needed.
  - Basic and applied geophysical science research/investigation
    - E.g., over 590 AIRS peer reviewed publications have appeared in the literature since launch of Aqua (*Pagano et al.,* 2013)

- **Feedback from users**
  - Two meetings with forecasters, color-coded flags to be done for AWIPS II

- **Downstream product list**

  No

- **Reports from downstream product teams on the dependencies and impacts**

  No

Support CrIS SDR

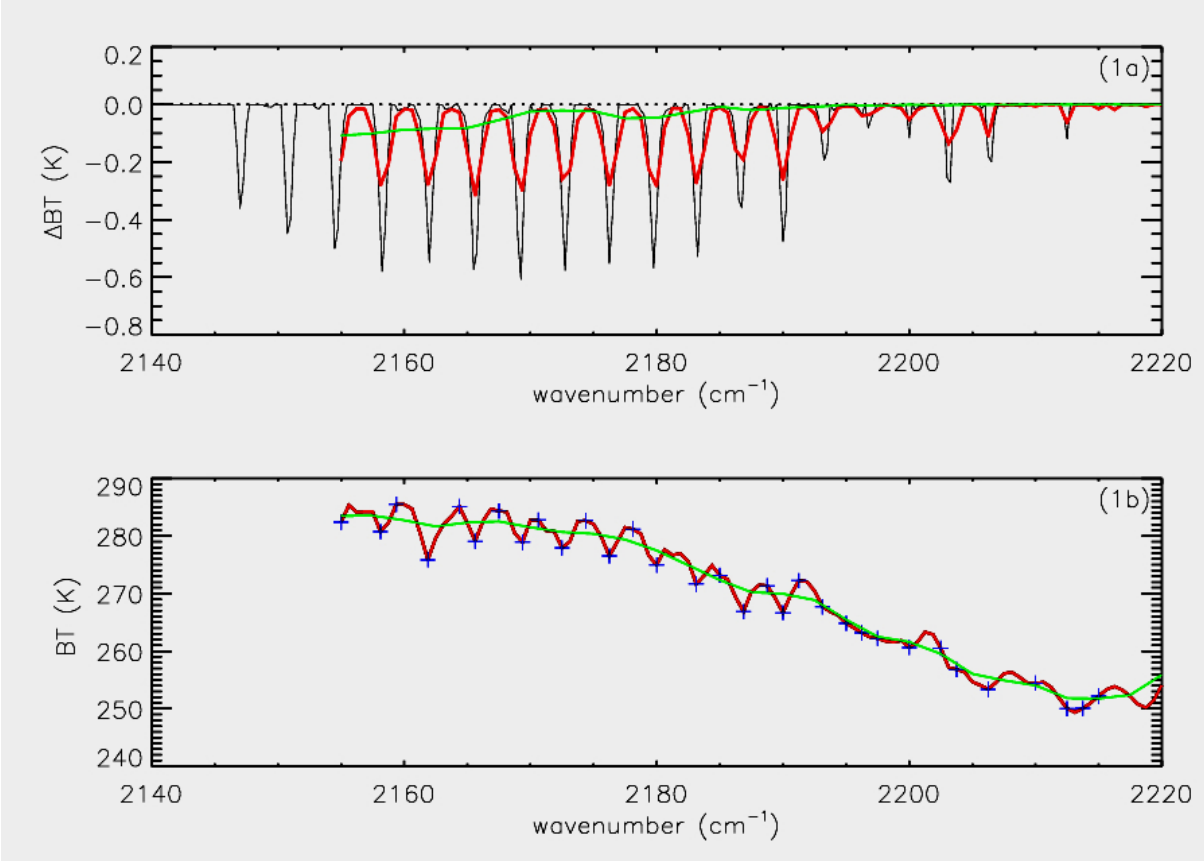
- Full Spectral Requirement
  - CrIS full spectral data are required for trace gas retrievals.

- ILS
  - Inhomogeneity effect on CrIS spectral shift is < 3 ppm, smaller than noise.

- Discard one FOV for direct full-spectral CrIS broadcast
  - The corner FOV 7 should provide a slight better contrast, but the large noise of FOV 7 degrades the use. Our recommendation is to discard FOV 7 instead of FOV 4 for NPP CrIS full spectral data direct broadcast.

Sensitivity Analysis to 1% CO perturbation

2.5cm^-1 0.625 cm^-1 0.25cm ^-1

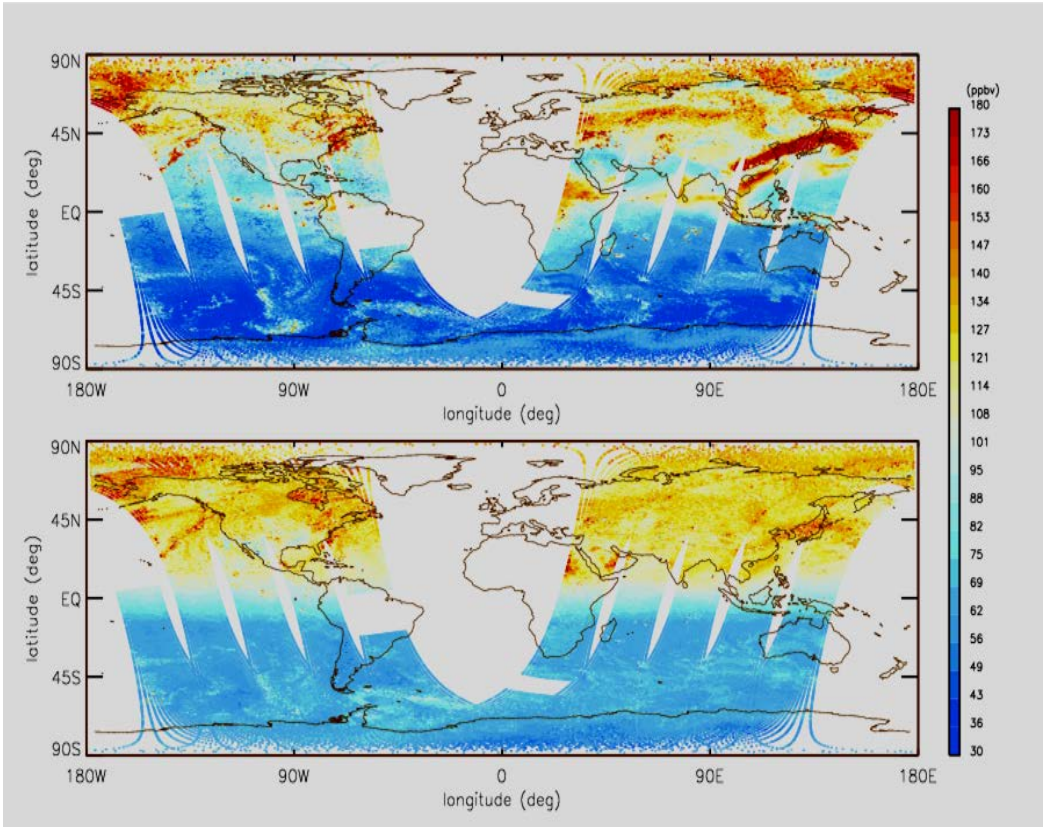


Ref: ***Gambacorta et al., IEEE Geoph. And Rem. Sen. Letters, 2014.***

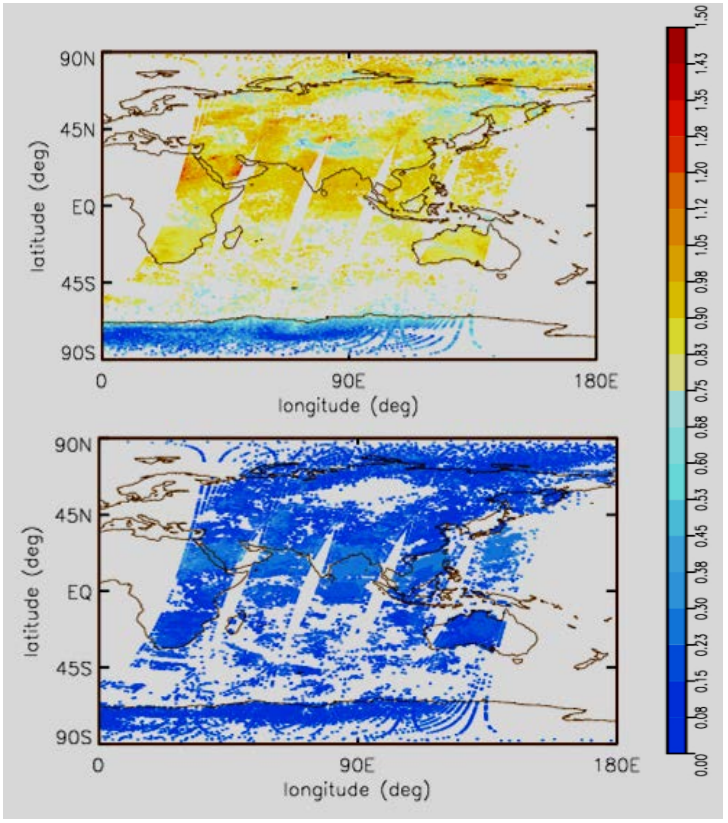
- Only when switched to high spectral resolution, CrIS spectrum (red curve, bottom part) shows the distinctive signature of CO absorption (red and black curve, top figure).
- Blue cross symbols: CO high resolution channel selection.

CO high resolution (top) vs operational low resolution results (bottom)

NUCAPS CO retrieval (~450mb)



CO DOF

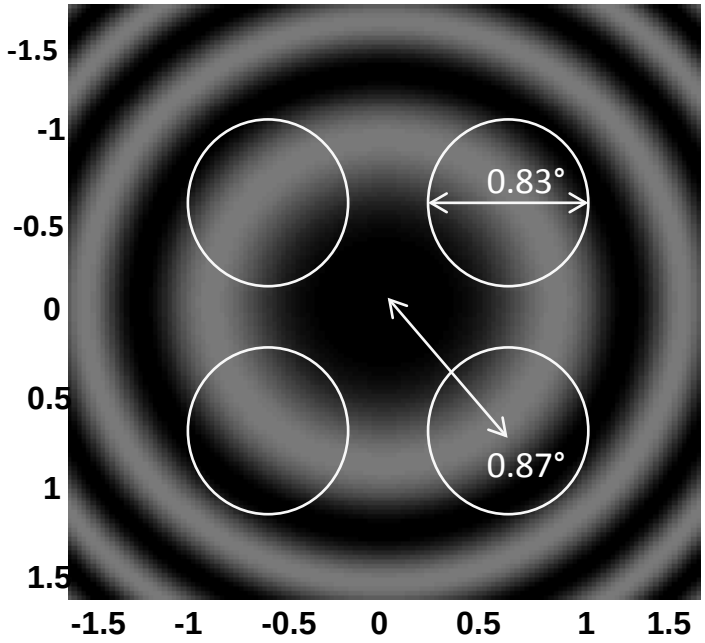


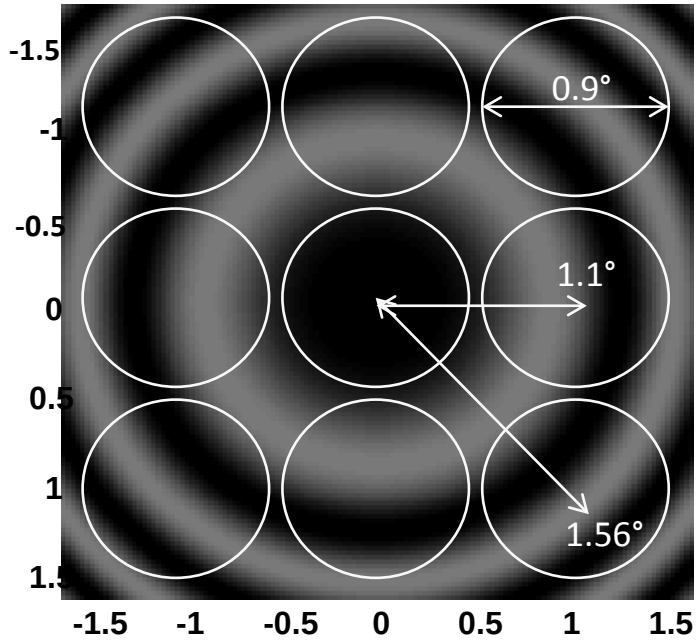
Ref: ***Gambacorta et al., IEEE Geoph. And Rem. Sen. Letters, 2014.***

- The higher information content enables a larger departure from the a priori, hence the increased spatial variability observed in the high spectral resolution map (top left) compared to the low resolution (bottom left).
- A demonstration experiment in support for the need of high spectral resolution CrIS measurements.
- NUCAPS modular architecture has proven that there is no risk of disruption to the operational processing upon switching to high spectral sampling.

IASI vs CrIS FOV geometry

IASI





CrIS

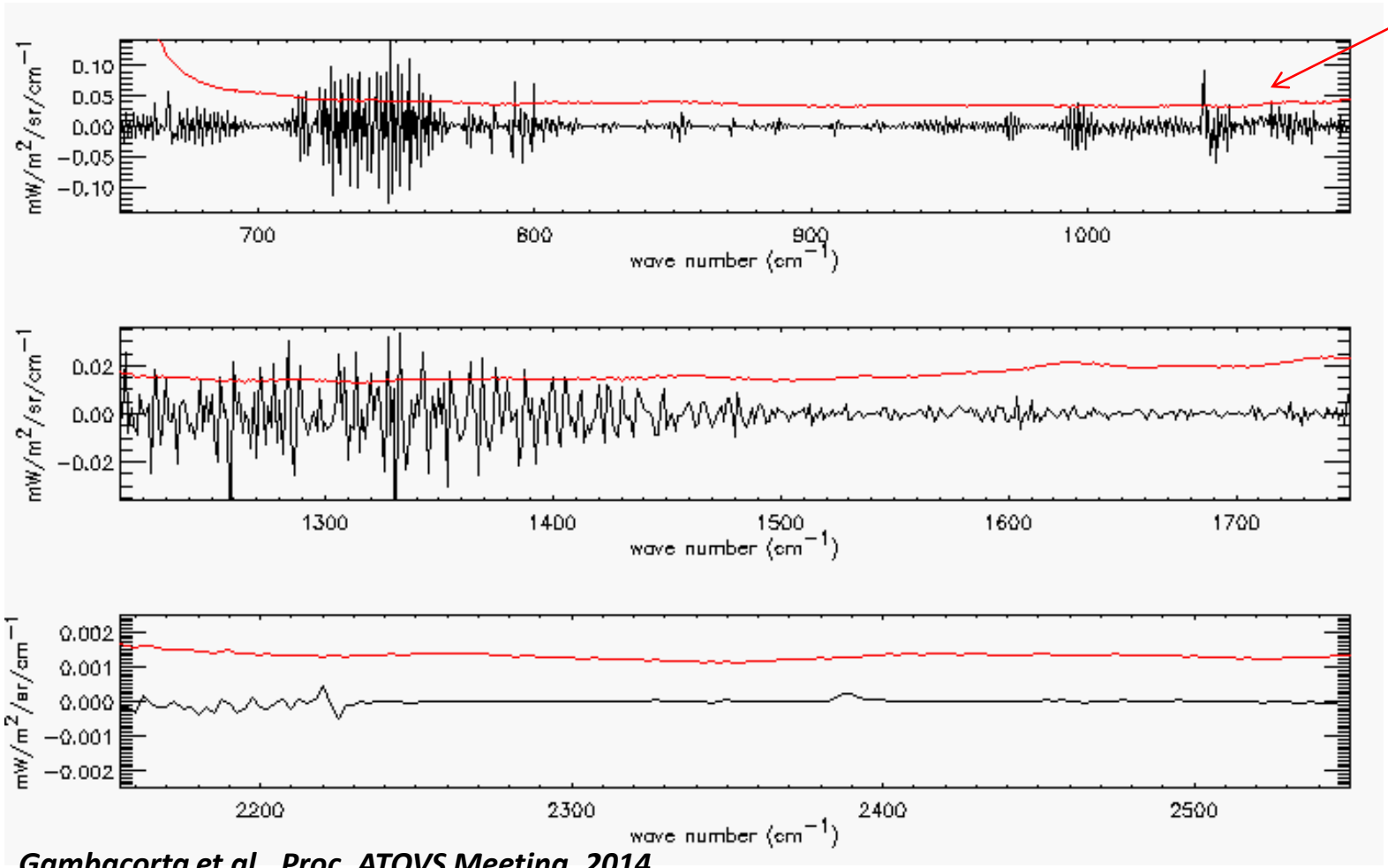
Gambacorta et al., Proc. ATOVS Meeting, 2014.

•Applying IASI's δα results to CrIS (assuming surface inhomogeneity and interference ringing are close enough between the two instruments):

- •CrIS Side Cube (α=1.1°=0.019rad): δν/ν ~ αδα = **1.91e-6**
- •CrIS Corner Cube (α=1.56°=0.027rad): δν/ν ~ αδα = **2.72e-6**

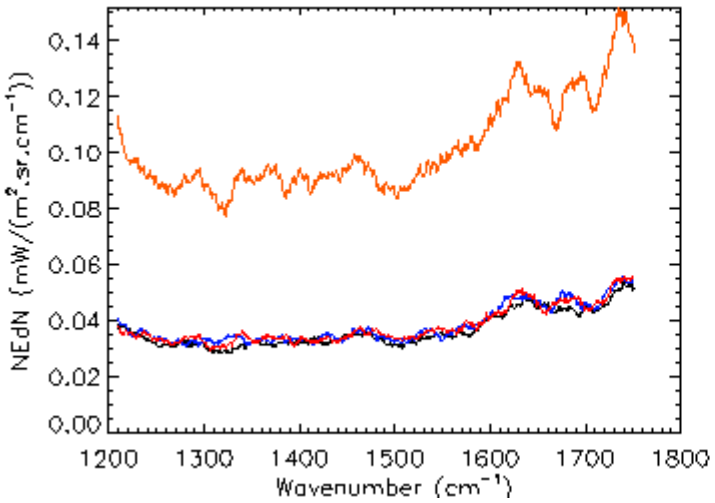
< 3ppm

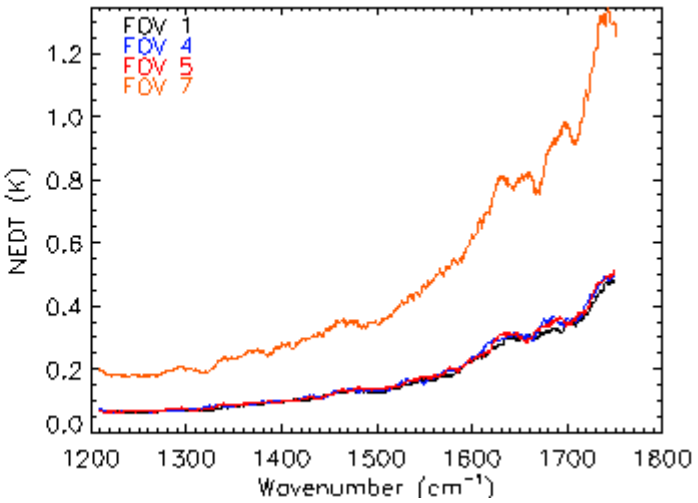
Radiance error induced by ILS shift
- corner cube -



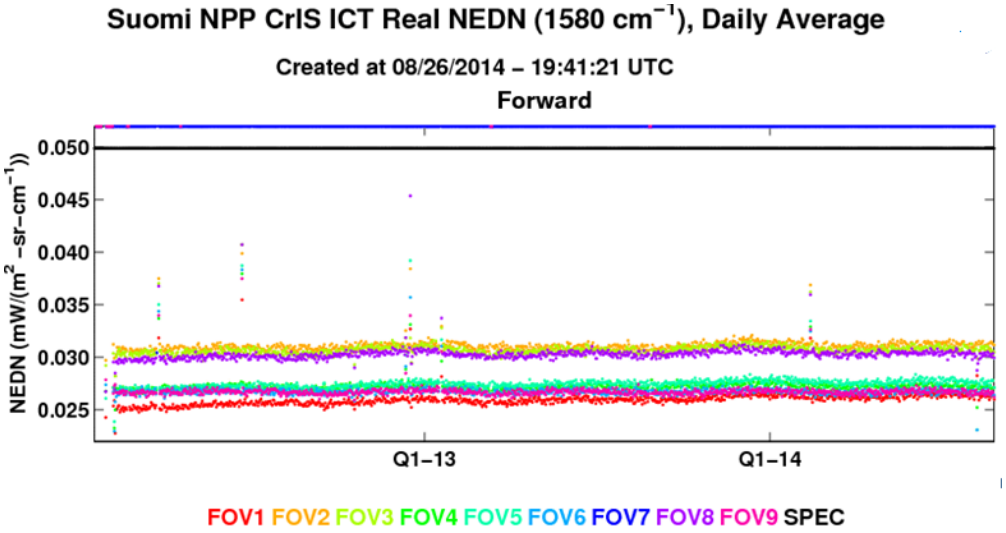
Gambacorta et al., Proc. ATOVS Meeting, 2014.

Discard FOV 7 in CrIS full spectral data

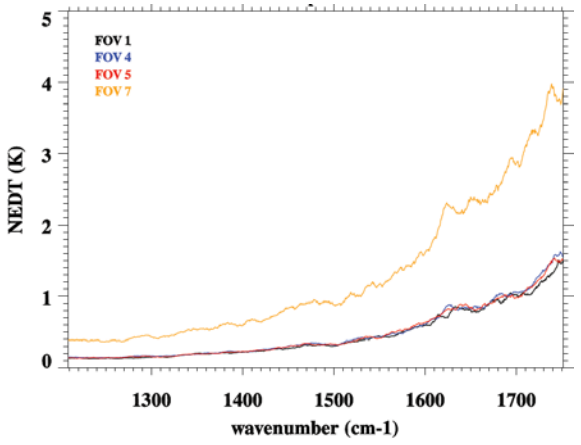




Tref=250K



Tref=220K



NeDT depends strongly on scene temperature.

Courtesy of X. Jin, Y. Chen, L. Wang

Conclusion

- **NUCAPS Validation Results Summary**
  - NUCAPS IR+MW AVTP and AVMP EDRs are demonstrated to meet the threshold requirements (on the coarse coarse-layers) as follows:
    - Ocean and land versus global ECWMF model
    - Tropical marine regions (ship and island) versus high-quality dedicated RAOBs (e.g., AEROSE, TWP and PMRF)
  - NUCAPS MW-only (MIT algorithm) EDRs are demonstrated to be close to meeting the threshold requirements for the same data samples.
  - NUCAPS AVTP and AVMP EDRs are publicly available on the NOAA CLASS. NUCAPS products are available from AWIPS II and forecasters have started to use the product.
  - The Sounding Team therefore recommends that the NUCAPS AVTP and AVMP achieve the maturity of the Stage 1 validation.
- Caveats:
  - Color-code quality flag needed for forecasters.
  - MW retrieval algorithm needs to be further investigated.
  - Updates IR and MW surface emissivity tables

Path Forward (1)

- Planned further improvements

1) Make quality flag simple
2) Improve MW only performance
3) Update IR+MW surface emissivity tables
4) Standardize retrieval code
5) Improve trace gas retrieval algorithm
6) Investigate the impact by using radiance and NEDN directly

Path Forward (2)

- Planned Cal/Val activities / milestones

- NUCAPS Phase 3 Algorithm Readiness Review – Sep 2014
- NUCAPS Phase 3 DAP Delivery – Sep 2014
- Improvement of MW only Retrieval – Nov. 2014
- MW+IR QC Flag –- Nov. 2014
- CrIS OLR Algorithm Tuning, Validation, and Verification – Nov. 2014
- SPSRB Phase 3 briefing – Nov. 2014
- NUCAPS Phase 3 Operations Commence – Nov. 2014
- Unified Hyperspectral Sensors' Sounding System – Dec. 2014
- CrIS full spectral channel selection for NWP and NUCAPS – Mar. 2015
- CrIS Full Spectral Data in Sounding System – Sep. 2015
- Trace Gas (CO, CO_2, and CH_4) Algorithm Tuning, Validation, and Verification –June 2016
- AIRS, IASI, CrIS Full Data Record Reprocessing for Science Application – Dec. 2016.

BACK UP SLIDES

Dedicated Soundings

- Soundings for specific weather events

  - High spatial resolution (single FOV ~ 12 km at nadir):
    - needed for monitoring atmospheric stability;
    - needed for hurricane studies;
    - high accuracy needed under cloudy conditions;
  - Integration of satellite product information:
    - Cloud EDRs
    - UV total ozone and stratospheric ozone profile
    - Surface temperatures
    - Aerosol EDRs
  - Precise radiative transfer calculations for the given small area

NUCAPS-AWIPS meeting

1	Name	Organization and address
2	bill sjoberg	JPSS Office, Greenbelt, MD
3	bonnie reed	JPSS Ground System Division
4	brian motta	NWS/Forecast Decision Training
5	anthony mostek	NWS/FORECAST DECISION TRAINING BRANCH
6	dan nietfeld	NWS/CR/WFO/VALLEY NE
7	antonia gambacorta	NESDIS/STAR
8	thomas king	NESDIS/STAR
9	murty divakarla	NESDIS/STAR
10	lihang zhou	NESDIS/STAR JPSS manager
11	Quanhua (Mark) Liu	NESDIS/STAR
12	scottl Lindstrom	Space Science and Engineering Center
13	james heil	NWS/OBSERVING SERVICES DIVISION
14	walter wolf	NESDIS/STAR
15	nick nalli	NESDIS/STAR
16	tony reale	NESDIS/STAR
17	bill line	NWS/SCIENCE SUPPORT BRANCH
18	kevin schrab	NWS, Observing Services Division
19	Bomin Sun	NOAA/STAR
20	chris barnet	TECHNOLOGY, PLANNING, AND INTEGRATION I

NUCAPS Products (1)

Mean CO2
Surface Pressure
Skin Temperature
MIT Skin Temperature
First Guess Skin Temperature
Microwave Surface Class
Microwave Surface Emissivity
Number of Cloud Layers
Retrieval Quality Flag
Cloud Top Pressure
Cloud Top Fraction
Pressure (at 100 levels)
Effective Pressure (at 100 levels)
Temperature (at 100 levels)
MIT Temperature (at 100 levels)
First Guess Temperature (at 100 levels)
H2O layer column density (at 100 levels)
H2O mixing ratio (at 100 levels)
First Guess H2O layer column density (at 100 levels)
First Guess H2O mixing ratio (at 100 levels)
MIT H2O layer column density (at 100 levels)
MIT H2O mixing ratio (at 100 levels)

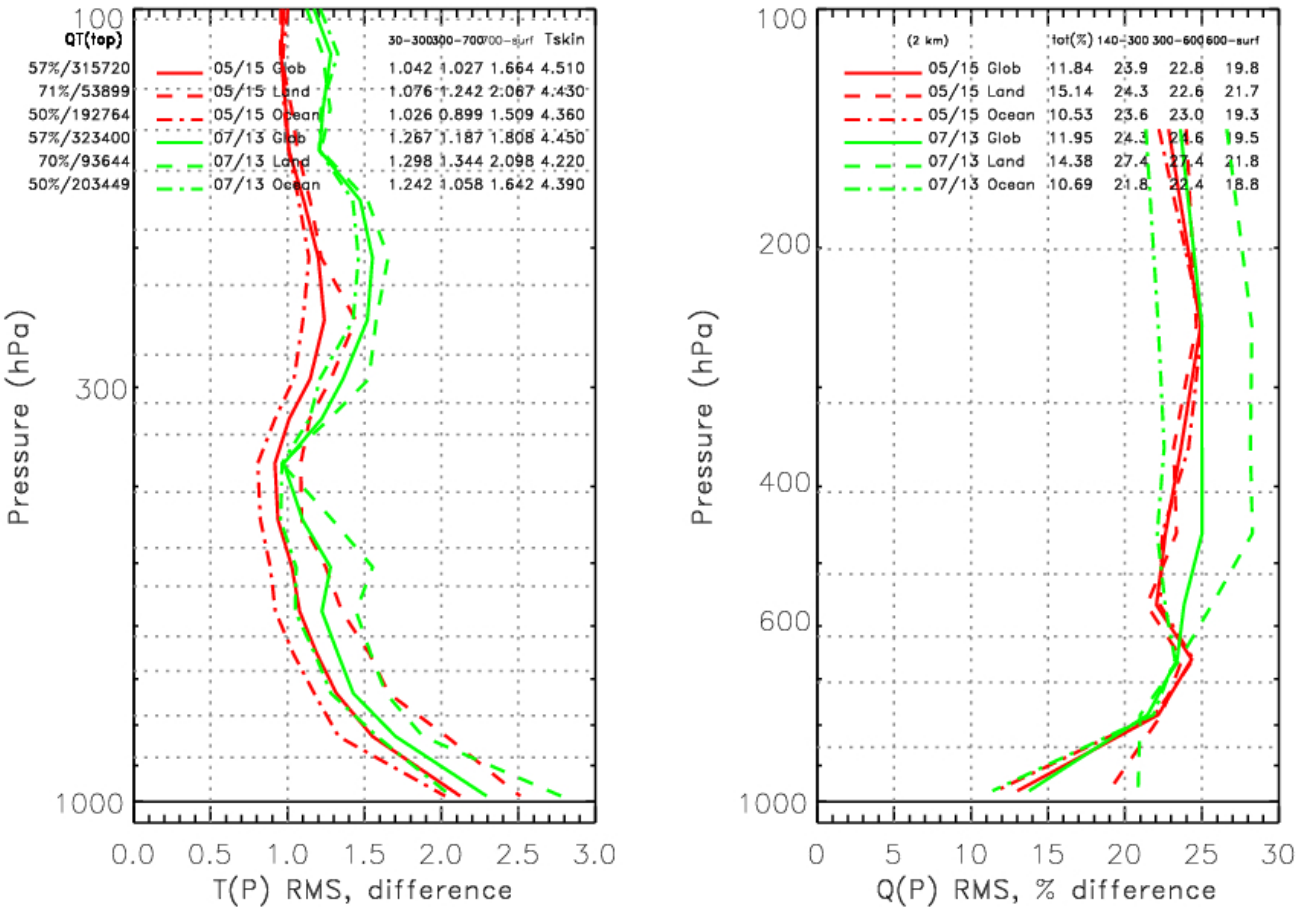
NUCAPS Products (2)

O3 layer column density (at 100 levels)
O3 mixing ratio (at 100 levels)
First Guess O3 layer column density (at 100 levels)
First Guess O3 mixing ratio (at 100 levels)
Liquid H2O layer column density (at 100 levels)
Liquid H2O mixing ratio (at 100 levels)
Ice/liquid flag (at 100 levels)
CH4 layer column density (at 100 levels)
CH4 mixing ratio (at 100 levels)
CO2 mixing ratio (at 100 levels)
HNO3 layer column density (at 100 levels)
HNO3 mixing ratio (at 100 levels)
N2O layer column density (at 100 levels)
N2O mixing ratio (at 100 levels)
SO2 layer column density (at 100 levels)
SO2 mixing ratio (at 100 levels)
Microwave emissivity
MIT microwave emissivity
Infrared emissivity
MIT infrared emissivity
Infrared surface emissivity

NUCAPS Products (3)

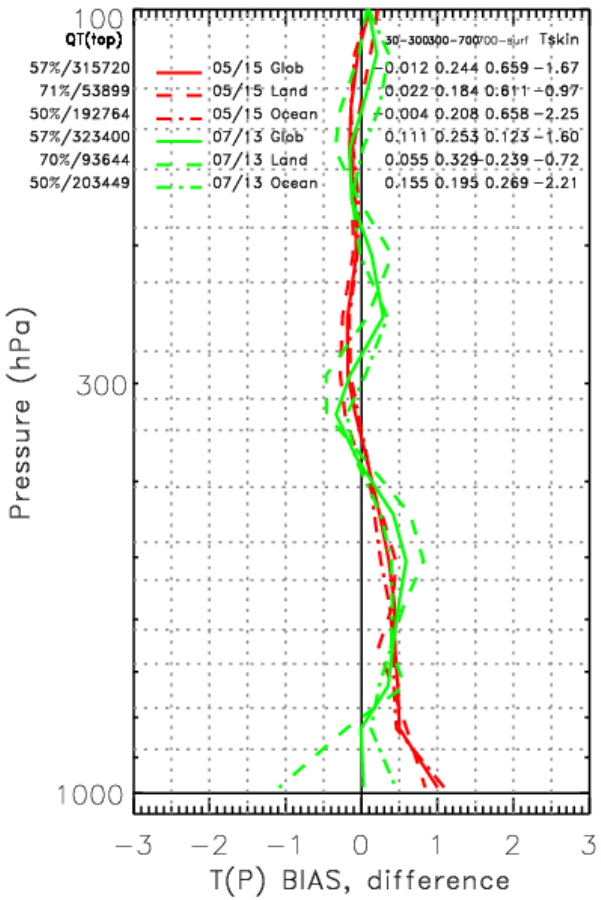
First Guess infrared surface emissivity
Infrared surface reflectance
Atmospheric Stability
Cloud infrared emissivity
Cloud reflectivity
Stability

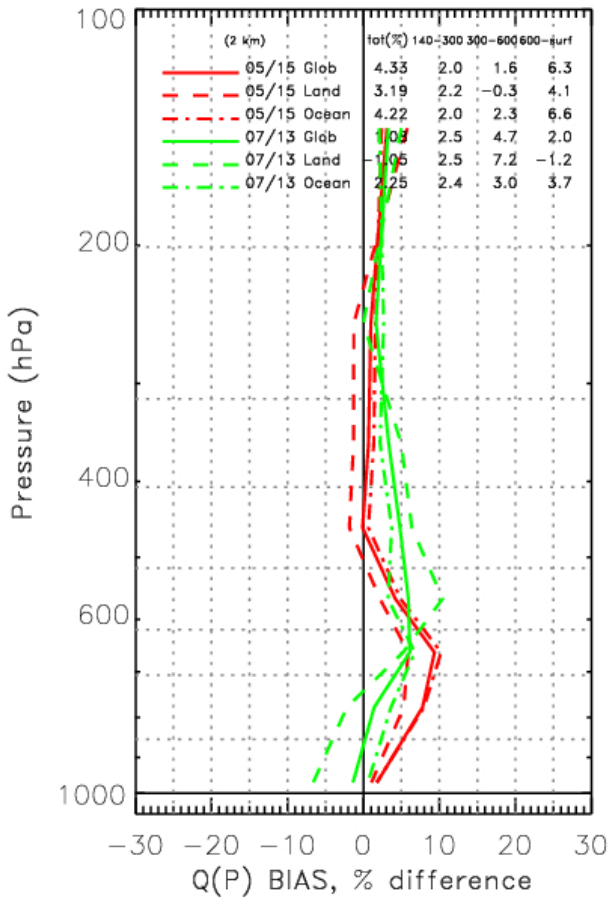
05/15 vs 07/13 focus day RMS statistics



Significance: NUCAPS performance is stable and robust over multiple focus days, including those not used for tuning and regression training :05/15 focus day (red curves) was used for training, 07/13 (green curves) was not.

05/15 vs 07/13 focus day BIAS statistics





Significance: NUCAPS performance is stable and robust over multiple focus days, including those not used for tuning and regression training :05/15 focus day was used for training, 07/13 was not.