JPSS STAR (J-STAR)

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NUCAPS TRACE GAS PRODUCTS SUMMARY FOR NOV. 18TH MEETING

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NUCAPS Trace Gas products

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Outline

- NUCAPS Current Operational Trace Gas Products
- JPSS Specification Performance Requirements
- Current NUCAPS trace gas JPSS funded initiatives
- Trace gas users needs
- Definition of operational trace gas products
- Hyper spectral trace gas sounding capabilities
- Maintaining and developing an operational trace gas product: the need for a user request
- Summary

NUCAPS Current Operational Trace Gas Products

species	Range (cm^{-1})	Precision	d.o.f.	Interfering Species
T	650-800 2375-2395	1K/km	6-10	H2O,O3,N2O emissivity
H_2O	1200-1600	15%	4-6	CH4, HNO3
O_3	1025-1050	10%	1+	H2O,emissivity
CO	2080-2200	15%	≈ 1	H2O,N2O
CH_4	1250-1370	1.5%	≈ 1	H2O,HNO3,N2O
CO_2	680-795 2375-2395	0.5%	≈ 1	H2O,O3 T(p)
Volcanic SO_2	1340-1380	50% ??	< 1	H2O,HNO3
HNO_3	860-920 1320-1330	50% ??	< 1	emissivity H2O,CH4,N2O
N_2O	1250-1315 2180-2250	5% ??	< 1	H2O H2O,CO

JPSS Specification Performance Requirements
CrIS Trace Gas EDR Uncertainty (O_3, CO, CO_2, CH_4)

CrIS Infrared Trace Gases Specification Performance Requirements		
PARAMETER	**THRESHOLD**	**OBJECTIVE**
O_3 (Ozone) Profile Precision, 4–260 hPa (6 statistic layers)	20%	10%
O_3 (Ozone) Profile Precision, 260 hPa to sfc (1 statistic layer)	20%	10%
O_3 (Ozone) Profile Accuracy, 4–260 hPa (6 statistic layers)	±10%	±5%
O_3 (Ozone) Profile Accuracy, 260 hPa to sfc (1 statistic layer)	±10%	±5%
O_3 (Ozone) Profile Uncertainty, 4–260 hPa (6 statistic layers)	25%	15%
O_3 (Ozone) Profile Uncertainty, 260 hPa to sfc (1 statistic layer)	25%	15%
CO (Carbon Monoxide) Total Column Precision	35%, or full res mode 15%	3%
CO (Carbon Monoxide) Total Column Accuracy	±25%, or full res mode ±5%	±5%
CO_2 (Carbon Dioxide) Total Column Precision	0.5% (2 ppmv)	1.05 to 1.4 ppmv
CO_2 (Carbon Dioxide) Total Column Accuracy	±1% (4 ppmv)	NS
CH_4 (Methane) Total Column Precision	1% (≈20 ppbv)	NS
CH_4 (Methane) Total Column Accuracy	±4% (≈80 ppmv)	NS

(Table courtesy of Nick Nalli)

Source:
(L1RD, 2014, pp. 45-49)

Current NUCAPS trace gas JPSS funded initiatives

1. **Carbon Monoxide and Methane product evaluation** (NESDIS/STAR & OAR/ESRL/CSD).

Scope: Models are used to interpolate the sparse aircraft observations to the satellite temporal, spatial, and vertical sampling characteristics for detailed validation. NUCAPS (and AOD from VIIRS) will be used within IDEA (Infusing Satellite Data into Environmental Air Quality Applications)

I. PI Greg Frost: "Understanding emissions and tropospheric chemistry using NUCAPS and VIIRS"

II. PI Brad Pierce: "High Resolution Trajectory-Based Smoke Forecasts using VIIRS Aerosol Optical Depth and NUCAPS Carbon Monoxide Retrievals. "

- References:
  - Songnex: http://esrl.noaa.gov/csd/projects/songnex/
  - SENEX: http://www.esrl.noaa.gov/csd/projects/senex/
  - IDEA: http://www.star.nesdis.noaa.gov/smcd/spb/aq/

2. Use of NUCAPS Ozone in hurricane extra-tropical transition applications (SPoRT)

Scope: Migrate AIRS/SEVIRI product to NUCAPS O_3 with VIIRS RGB. To conduct a product demonstration and assessment with the NHC, WPC and OPC forecasters

I. PI Emily Berndt: "investigation of NUCAPS T(p), q(p), and O3(p) to study extra-tropical transition of hurricanes"

- Reference:
  - https://nasasport.wordpress.com/2016/10/05/nucaps-soundings-and-hurricane-matthew/

Few lessons learned on users needs in preparation for the next field campaigns

- This is not validation in the traditional sense, it is developing new users applications.

- Users need to know spatial and vertical error covariance
  - Many of the signals we see have seasonal or spatial variability in the information content.
  - Trace gas retrievals are sensitive to stratospheric-tropospheric exchange. Broad vertical weighting functions tend to mix stratospheric and upper tropospheric contributions together. Averaging kernels should become an integral part of the operationally distributed products.

- Users need reprocessing capability to study long-term stability of an algorithm.
  - All archived data ("granule" processing)
  - Global "gridded" data sub-sets (for rapid evaluation of algorithm modifications)
  - All validation datasets (including radio-sonde, aircraft match up datasets)

- Users need user-friendly data formats (netcdf4 is generally preferred)

- Users need more sophisticated QCs than what is used in current operations
  - Original QC was developed to demonstrate that we meet requirements
  - Some "green" scenes are bad, some "red" scenes are good
  - We need to develop QCs specifically tailored for trace gas applications

- Users need near real time access to NUCAPS high resolution operational products (essential for applications involving CO). A plan to run NUCAPS using CrIS in full resolution mode in the NOAA DB at CSPP is lacking. This poses a risk for the future NOAA FIREX 2018 campaign (http://www.esrl.noaa.gov/csd/projects/firex/).

What defines the need for a trace gas operational product?

- What defines the need for a trace gas operational product?
  - Just because we can retrieve a product, it does not mean that we should do it.
  - We need a real time, vetted, institutional user: EPA, National Forest Service, DOA, etc.
  - We need users that need archived consistent products: NUCAPS CO2 might serve as forecast climatology for the National Weather Service.

- We would like to support any project supported by the NOAA AC4 Program to engage new potential users and gain insights on the applicability of our products. **This will ultimately lead to a <u>user requirement</u> to justify the effort of**
  - **maintaining current and**
  - **developing new**

  trace gas operational products.

- What additional trace gas product could we develop in within NUCAPS? Next slide

HYPER SPECTRAL SOUNDING CAPABILITY (1/2)

chemical symbol	chemical name	atmospheric lifetime	spectral range (cm-1)	primary applications	region of best sounding	comments and caveats	interfering species	precision	AIRS	IASI	CrIS	references
O_3	Ozone	22 day	1025-1050	Montreal Protocol, STE, (maybe Wind)	UT/LS (day or ngt)	very little mid- to lower-trop sensitivity	H2O, surface	10%	2003	2009	2012	Haskins 1993, Divakarla 2008
CH_4	Methane	~12 y	1250-1370 2900-2940	Climate, Emissions	mid-troposphere	Accuracy of 2% (40 ppb) and only in mid-trop	H2O, HNO3, N2O	1.5%	2003	2009	2012	Haskins 1993, Xiong 2012
CO	Carbon Monoxide	few months	2080-2200	Fires, Pollution, (maybe Wind)	mid-troposphere	accuracy of ~10%	H2O, N2O	15%	2003	2009	2016	Haskins 1993, McMillan 2011
CO_2	Carbon Dioxide	~1000 y	650-750 2250-2400	Climate, Emissions	mid-troposphere	no PBL sensitivity, band used for T(p) sounding	H2O, HNO3, T(p) T(p)	0.5%	2003	2009	2012	Haskins 1993, Maddy 2008
HNO_3	Nitric Acid	2-4 weeks	860-900 (n5, 2n9) 1320-1330 (n3)	Polar clouds	lower-stratosphere (day or ngt)	not aware of any users for this product	surface, CFC-12 H2O, CH4, N2O	20%	yes (LW)	2009	2012	Haskins 1993, Wespes 2009
N_2O	Nitrous Oxide	110 y	1200-1350(n1) 2150-2250(n3)	Climate (0.5%/y)	300-400 mbar	Accuracy of ~2% not good enough for climate work	H2O H2O, CO	5%	yes (SW)	2009	2012	Haskins 1993, Xiong 2014
SO_2	Sulfur Dioxide		1100-1200 (n1) 1340-1380 (n3)	Volcanic Detection	mid-troposphere	Tends to see polar volcanic eruptions	surface H2O, HNO3	volcanic detection	e-mail	e-mail	yes yes	Clarisse 2011
NH_3	Ammonia		800-1150	Agriculture, Fire	lower-troposphere (750-900 mbar)	Is an experimental AIRS product	surface		yes	yes	yes	Warner, 2016 Van Damme 2014 Clarisse 2009
									GREEN =	operational product from AIRS, IASI, CrIS		
									YELLOW =	science product from AIRS, IASI, CrIS		
Selected Organic Molecules												
$C_2H_3NO_5$	peroxyacetyl nitrate (PAN)	few days	780-810 (n16) 1153-1172 (n10)	Smog, Nox chemistry	mid-troposphere	global and seasonal, frequency of elevated amounts	surface, CO2 surface, H2O,O3,N2O	30-50% (TES)	yes NO	yes yes	yes NO	Payne 2014
C_2H_2	Acetylene	2-4 weeks	730 (n5)	fires	8-11 km	seasonal and regional	CO2,H2O,O3	5% (IASI)	yes	yes	yes	Duflot 2015
C_2H_4	Ethylene	14-32 hours	949 (n7)	fires , oil refining, ocean and biogenic	mid-troposphere	detection when > 2-3 ppt	surface		yes	yes	yes	Dolan 2016
C_2H_6	Ethane		820 (n9)			typical amounts are too low to detect			yes	yes	yes	
CH_3OH	methanol (wood alcohol)		950-1050	fires	700-900 mbar	global, seasonal			yes	yes	yes	Cady-Pereira 2012
HCOOH	Formic Acid	1 week	1105 (n6)	Emissions from vegetation		detection, ~ 1 ppb			partial	yes	partial	Clerbaux 2013 Atmos. Sci
OCS	Carbonyl Sulfide	2-6 y (trop) 64 y (strat)	2000-2100	tracer of photosynthesis	mid-troposphere	detection	H2O, CO2, CO, O3		NO	yes	NO	Barkley 2008 GRL Vincent 2016 ACPD

HYPER SPECTRAL SOUNDING CAPABILITY (2/2)

chemical symbol	chemical name	atmospheric lifetime	spectral range (cm-1)	primary applications	region of best sounding	comments and caveats	interfering species	precision	AIRS	IASI	CrIS	references
Chlorofluorcarbons												
$CFC1_3$	F11, CFC-11	35-70 y	814-866 1060-1107	Montreal Protocol	mid-troposphere	global annual averages			yes yes	yes yes	yes partial	Haskins 1993
CF_2Cl_2	F12, CFC-12	102 y	855-952 1067-1135	Montreal Protocol	mid-troposphere	global annual averages			yes yes	yes yes	yes partial	Haskins 1993
CCl_4	Carbon Tetrachloride	25 y	776	Montreal Protocol	mid-troposphere	global annual averages			yes	yes	yes	Haskins 1993
Perfluorcarbons												
C_3F_8	Perfluoropropane	2600 y	1265	Montreal Protocol		typical amounts are too low to detect			yes	yes	yes	
C_2F_6	Hexafluoroethane	10,000 y	1250	Montreal Protocol		typical amounts are too low to detect			yes	yes	yes	
CF_4	Carbon Tetrafluoride	50,000 y	1280	Montreal Protocol		typical amounts are too low to detect			NO	yes	yes	
Other												
CH_3-CO-CH_3	Acetone	15 days	1200-1205	95 Tg/y emissions	0.3 to 3 ppb	source of PAN			yes	yes	yes	
CH3-COOH	Acetic Acid	hours to days	1145-1220 (n8)			source of Formic Acid			yes	yes	yes	Clarisse 2011
HCN	Hydrogen Cyanide	5-6 months	713	biomass burning	9-14 km	seasonal, regional	CO2, O3, HNO3	IASI: 10% tropics, 25% mid-lat	yes	yes	yes	Clarisse 2011
C_3H_6	Propylene		912 (n19)	biomass burning			surface					Clarisse 2011
C_4H_4O	Furan		744 (n20)									Duflot 2015
N_2	Nitrogen	1 billion y	2180-2290	Surface Pressure		not as good as GFS (~4 mbar) accuracy			yes	yes	yes	
HDO	Heavy Water		2600-2750	Water transport		1:3200 as strong as H2O			yes	yes	no	Haskins 1993
NF_3	Nitrogen Trifluoride	500 y	840-960	semiconductor industry pollutant		GWP=17000						
SF_6	Sulfur Hexafluoride	800-3200 y	947.9 n3 Q-branch	Anthropogenic tracer		unable to detect in typical Earth abundances (~4 ppt)			yes	yes	yes	

Summary and the path forward

- NOAA is funding an unprecedented list of Proving Ground and Risk Reduction (PGRR) initiatives to demonstrate the operational need of NUCAPS trace gas products.

- This is not validation in the traditional sense, it is developing new users applications.

- Users needs:
  - spatial error covariance and averaging kernels.
  - Reprocessing and re-gridding capability, user friendly formats, trace gas tailored QCs, near real time access to NUCAPS high res data.

- What defines the need for a trace gas operational product?
  - Just because we can retrieve a product, it does not mean that we should do it.
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