Validation of the SNPP CrIS Full-Resolution NUCAPS Carbon Trace Gases

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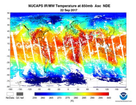
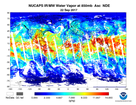
NOAA Unique Combined Atmospheric Processing System (NUCAPS)

- **Operational algorithm**
  - **NOAA Enterprise Algorithm** for CrIS/IASI/AIRS (*Susskind, Barnet and Blaisdell,* IEEE 2003; *Gambacorta et al.,* 2014)
  - Multi-step physical retrieval
  - Global non-precipitating conditions (clear to partly cloudy)
  - **Atmospheric Vertical Temperature** and **Moisture Profile** (**AVTP, AVMP**) **Environmental Data Records (EDRs)**
  - **Trace gas EDRs (O_3, CO, CO_2, CH_4)**
  - **Version 1.5** CrIS Nominal Spectral Resolution AVTP/AVMP/O3 are fully validated (*Nalli et al.* 2018a,b; *Sun et al.* 2017)
  - **Version 2.0 (Phase 4), CrIS Full Spectral Resolution (FSR)**
    - Includes **IR-only version** (risk-mitigation for ATMS loss)
    - **Phase 4 Algorithm Readiness Review (ARR)** delivered in July 2017

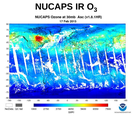
NUCAPS AVTP



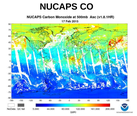
NUCAPS AVMP (H_2O)



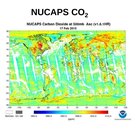
NUCAPS IR O_3



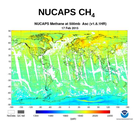
NUCAPS CO



NUCAPS CO_2



NUCAPS CH_4



Long Term Monitoring

http://www.star.nesdis.noaa.gov/jpss/EDRs/products_Soundings.php

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

- **Users**
  - **Weather Forecast Offices (AWIPS)**
    - Nowcasting / severe weather
    - Cold air aloft, stability indices, etc.
  - NOAA/CPC (OLR)
  - NOAA/ARL (IR ozone, trace gases)
  - NOAA TOAST product (IR ozone)
  - Basic and applied science research (e.g., *Pagano et al.,* 2014)

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

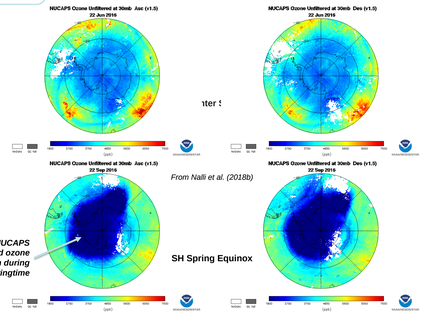
CrIS Infrared Trace Gases Specification Performance Requirements		
PARAMETER	**THRESHOLD**	**OBJECTIVE**
O_3 (Ozone) Profile Precision, 4–260 hPa (6 statistic layers)	20%	10%
O_3 (Ozone) Profile Precision, 260 hPa to sfc (1 statistic layer)	20%	10%
O_3 (Ozone) Profile Accuracy, 4–260 hPa (6 statistic 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 rs 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

CEOS AC-VC-14 2018 Poster

NUCAPS IR Ozone Profile EDR

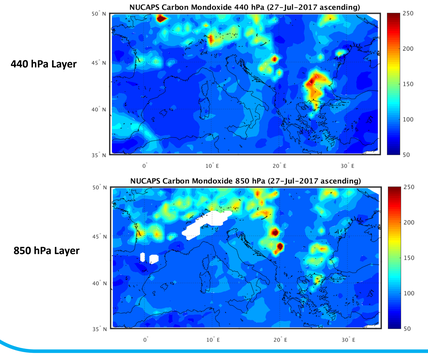
See *Nalli et al.* (2018b) for details of NUCAPS IR ozone profile validation

Ozone Hole Over Antarctica

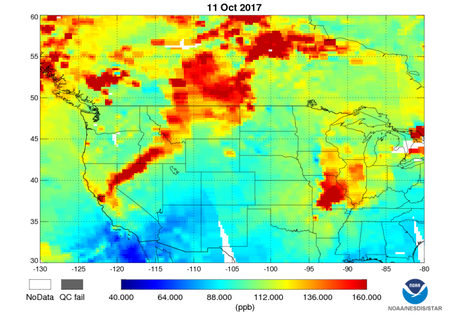


NUCAPS Carbon Monoxide EDR

Elevated CO Observations of European Fires, 27 July 2017



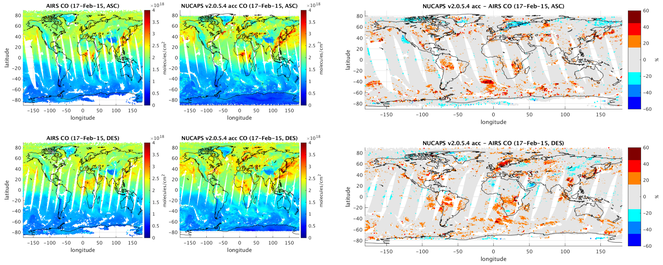
JPSS NUCAPS CO Observations of Santa Rosa Fire, 11 Oct 2017



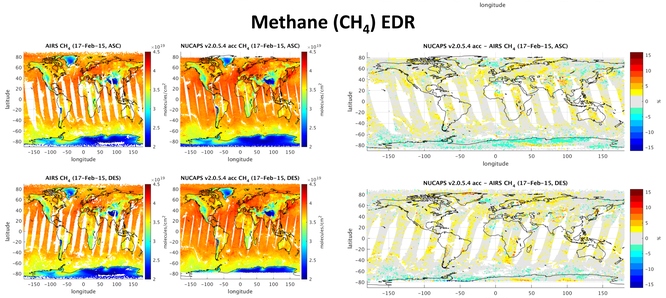
Preliminary SNPP NUCAPS Carbon Trace Gas Validation Results

NUCAPS Versus AIRS v6

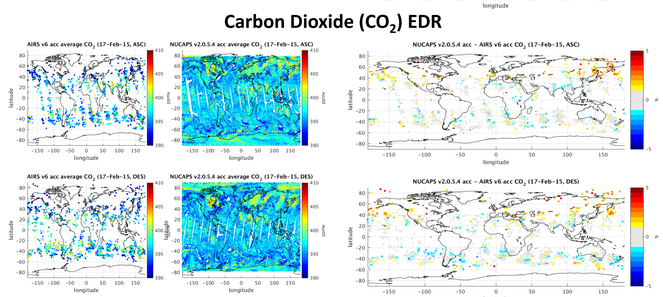
Carbon Monoxide (CO) EDR



Methane (CH_4) EDR



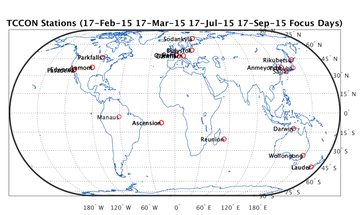
Carbon Dioxide (CO_2) EDR



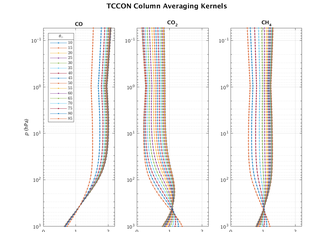
NUCAPS Versus Total Carbon Column Observing Network (TCCON)

17 Feb, Mar, Jul, Sep 2015 Focus Days

TCCON Stations (17-Feb-15 17-Mar-15 17-Jul-15 17-Sep-15 Focus Days)

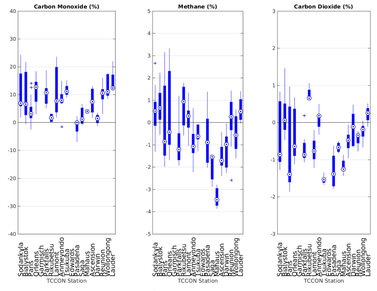


TCCON Column Averaging Kernels



TCCON (*Wunch et al.* 2011)

NUCAPS v2.1.4 acc+qa (17-Feb-15 17-Mar-15 17-Jul-15 17-Sep-15)



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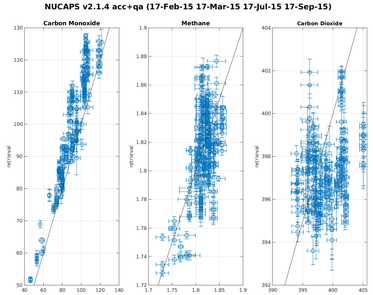
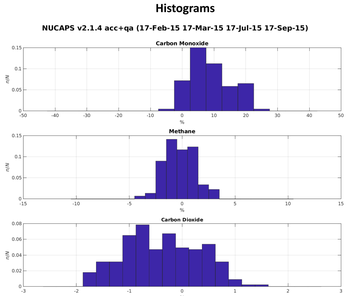


Histograms

NUCAPS v2.1.4 acc+qa (17-Feb-15 17-Mar-15 17-Jul-15 17-Sep-15)



Summary Table

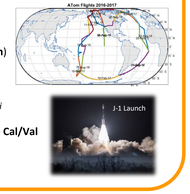
Trace Gas EDR	TCCON Baseline V2.1.4 Full Res *Trace Gas QA* BIAS (%)	STD (%)	RMS (%)	TCCON Baseline V2.1.5 Full Res *Trace Gas QA* BIAS (%)	STD (%)	RMS (%)	TCCON Baseline V2.1.6 Full Res *Trace Gas QA* BIAS (%)	STD (%)	RMS (%)
CO	**+8.9** **+7.6** (±5.0)	**6.5** **6.4** (15.0)	11.1 9.9	**+4.0** **+2.3** (±5.0)	**6.9** **5.5** (15.0)	8.0 5.9	**+3.6** **+1.4** (±5.0)	**7.7** **7.4** (15.0)	8.5 7.5
CO_2	**-0.4** **-0.3** (±1.0)	**0.7** **0.7** (0.5)	0.8 0.8	**-0.4** **-0.3** (±1.0)	**0.7** **0.7** (0.5)	0.8 0.8	**-0.4** **-0.3** (±1.0)	**0.7** **0.7** (0.5)	0.8 0.8
CH_4	**-0.2** **-0.3** (±4.0)	**1.4** **1.4** (1.0)	1.4 1.4	**-0.2** **-0.3** (±4.0)	**1.4** **1.4** (1.0)	1.4 1.4	**-0.2** **-0.3** (±4.0)	**1.4** **1.4** (1.0)	1.4 1.4

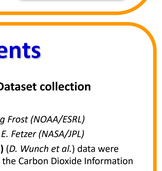
Carbon Trace Gas Validation Methodology

1. **Numerical Model Global *Comparisons***
   - Examples: **NOAA CarbonTracker** (*Lan et al.* 2017)**, ECMWF, NCEP/GFS**
   - Large, truly global samples acquired from Focus Days
2. **Satellite Sounder EDR *Intercomparisons***
   - Examples: **AIRS, OCO-2, MLS**
   - Global samples acquired from Focus Days (e.g., AIRS)
   - Limitation: Similar error characteristics
3. **Surface-Based Network Matchup *Assessments***
   - **Total Carbon Column Observing Network (TCCON)** spectrometers (*Wunch et al.* 2010, 2011)
   - **AirCore balloon-borne *in situ* profile observations** (*Membrive et al.* 2017)
   - Provide routine independent measurements representing global zones akin to RAOBs
   - Limitations: Small sample sizes, uncertainties in unit conversions, different sensitivities to atmospheric layers
4. **Intensive Field Campaign *In Situ* Data *Assessments***
   - Include ancillary datasets, ideally funded aircraft campaign(s)
   - E.g., **ATom**, **ACT-America**, FIREX, HIPPO

Discussion and Future Work

- **Discussion**
  - **Carbon trace gas EDR validation** versus program-established uncertainty specifications was a **new task** beginning with the transition to the FSR CrIS NUCAPS
  - Despite this, our **preliminary validation** versus AIRS and TCCON truth datasets in this presentation show the products are reasonably close to meeting JPSS Level 1 requirements
- **Future Work**
  - Investigate TCCON "outlier sites"
  - Utilize field campaign datasets (viz., **ATom**)
  - Utilize **NOAA CarbonTracker** model
  - Utilize **AirCore** datasets where available
  - **Trace Gas EDR Upgrades**
    - Optimization of NUCAPS trace gas *a priori*
    - Develop Trace Gas EDR quality flags
  - **JPSS-1 (NOAA-20) NUCAPS EDR Intensive Cal/Val**





Acknowledgements

- **SNPP Sounder Trace Gas EDR Validation Truth Dataset collection**
  - **Carbon Trace Gases**
    - *Monika Kopacz (NOAA/UCAR), Colm Sweeney, Greg Frost (NOAA/ESRL)*
    - NASA Sounder Science Team: *E. Olsen, T. Pagano, E. Fetzer (NASA/JPL)*
    - **Total Carbon Column Observing Network (TCCON)** (*D. Wunch et al.*) data were obtained from the TCCON Data Archive, hosted by the Carbon Dioxide Information Analysis Center (CDIAC), tccon.ornl.gov
- The **NOAA Joint Polar Satellite System (JPSS-STAR) Office** (*M. D. Goldberg, et al.*) and the NOAA/STAR Satellite Meteorology and Climatology Division.
- **STAR soundings team:** *A.K. Sharma, Q. Liu, T. King, W. W. Wolf* (STAR)

The views, opinions and findings contained in this report are those of the authors and should not be construed as an official NOAA or U.S. Government position, policy or decision.

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