Overview of S-NPP Sounding Discipline Team activities

Monday, Oct. 1, 2018

Session.1: 8:50 EDT

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S-NPP ROSES Cycle #2: 2012-2014

- Primary activity was to evaluate the NOAA NPOESS algorithms for NASA applications
- The NPP Sounding Group Evaluation Report (Strow, L.L., W. Blackwell, E. Fishbein, B. Lambrigtsen and H. Revercomb. 2013) recommended a viable system should be:
  - Capable of processing CrIS full-resolution resolution (FSR) spectra;
  - Produce a satellite climatology for temperature, water vapor, and trace gases from Aqua AIRS/AMSU, Suomi-NPP and JPSS CrIS/ATMS, and potentially Metop IASI/AMSU/MHS;
  - Retrieval approach that elucidates climate signals without bias;
  - Provide surface, cloud, O3, CO, CH4, CO2, SO2, HNO3, N2O, and NH3 products in addition to cloud cleared radiances, temperature and moisture;
  - Be product-centric rather than sensor-centric;
  - Output the full geophysical state such that radiances can be computed;
- The report is available at http://asl.umbc.edu/pub/reports/npp_nasa_hq_report.pdf

S-NPP ROSES Cycle #3: 2015-2017

- Review panel selected 3 “core” algorithm types (PI’s: Susskind, Moncet, Barnet), a microwave-only algorithm (Lambrigtsen), and one trace gas algorithm (Cady-Pereira/Worden).
  - In addition, the Terra-Aqua ROSES Panel selected a experiment single-FOV algorithm (PI: Irion) for Aqua sounding.
- The Sounder SIPS has implemented all the S-NPP selected algorithms and are producing eight months ([2013,2015]*[Jan, Apr, July, Oct]) for inter-comparison and evaluation.
  - Our intent was too use this evaluation to down-select or merge algorithm components

Summary of the Algorithms Selected by the ROSES S-NPP Panel in 2013

	Table 1: Summary of Level.2 Algorithms to be studied as part of NPP Science Team Activities (update: Nov.2017)					
PI	Lambrigtsen	Susskind (CHART)	Barnet (CLIMCAPS)	Moncet	Cady-Pereira	Irion
Affiliation	JPL	GSFC	STC	AER	AER	JPL
Funding	NPP	NPP	NPP	NPP	NPP	Terra-Aqua
ATMS	ATMS FOV	CrIS FOR	CrIS FOR	CrIS FOR	n/a	n/a
CrIS	n/a	CrIS FOR	CrIS FOR	CrIS FOR	CrIS FOV	CrIS FOV
Regularization	O-E	SVD	O-E	O-E	O-E	O-E
Alg. Type	Sequential	Sequential	Sequential	Simultaneous	Sequential	Simultaneous
Alg. Heritage	AIRS ST	AIRS ST	AIRS ST v5.9, NUCAPS-IASI, -CrIS	CrIMSS EDR	TES	TES
Cloud Clearing	n/a	Yes	Yes	Yes	No	No
T/q a-priori	NCEP Climatology	Neural Net	Merra-2	Climatology	AER Product	ECMWF
Trace Gases	n/a	O_3, CO, CH_4	O_3, CO, CH_4, CO_2, HNO_3, N_2O, SO_2	O_3	NH_3, CO (single FOV)	O_3
Trace gas a-priori	n/a	Climatology	Climatology	Climatology	Climatology	Climatology
Error estimate	O-E	ECMWF regression	O-E	O-E	O-E	O-E
Averaging Kernels	No	No	Yes	No	Yes	Yes
Execution Time (per FOR)	?	~1.3 sec/FOR	~200 ms/FOR	?	?	~15 sec/FOV (will improve)
To be installed	11/2017	7/2017 (installed) Running 8 months	11/2017 (T,q,ε) 2/2018 (trace gas)	1/2018 6/2018 (final)	NH3: 11/2017 CO: 3/2018 (need OSS)	?
	Abbreviations: SVD=Singular Value Decomposition, O-E=Optimal Estimation, FOV=field of view, FOR=field of regard (CrIS set of 3x3 FOVs)					

S-NPP ROSES Cycle #4: 2018-2021

- The ROSES solicitation primary focus is on the continuity of the EOS mission. In addition, the solicitation cited
  - Improvements to estimates of information content (e.g. error covariance matrix and averaging kernels).
  - Improvements in the boundary layer.
  - *"All data products must be focused on an application that can be justified as meeting NASA's applied science goals or a unique unmet operational data need that fits within the NASA program objectives and mission. For Suomi NPP, to* ***prevent duplication of efforts pursued by NOAA****, NASA will only support the upgrade, refresh and operation and maintenance of EOS Continuity algorithms and supporting systems*." ROSES A.37 solicitation p.9-10.
- The Panel Review selected CLIMCAPS as the one "core" algorithm.
  - Microwave-only product was retained
  - Trace gas retrievals (NH3 and CO) were maintained with an additional PAN product.
  - Numerous science applications that will be dependent on the upstream level-1 or level-2 products were selected.

Summary of the Algorithms Selected by the ROSES S-NPP Panel in 2018

PI, last name	PI, first name	affil.	instruments	summary of topic	Intro talk / NSTM ?
Barnet	Chris	STC	Aqua AIRS/AMSU S-NPP and NOAA-20 CrIS/ATMS	CLIMCAPS algorithm for T, q, trace gas, surface and cloud	Sep. 19, Yes (M-F)
Cady-Pereira	Karen	AER	CrIS Level-1	CrIS single-FOV NH3 Product	Oct. 17, Yes (W-F)
Elsaesser	Gregory	Columbia	AIRS Level-2 T/q at high spatial resolution	Deep Conv. Clouds	Sep. 19, Yes (M-F)
Henze	Daven	U.Colo.	CrIS Level.1 and CrIS NH3 product	NH3 Inv. Model	Oct. 17, NO
Huang	Xianglei	U.Mich.	AIRS, + CrIS (L-1), CERES, Merra(T,q)	cloud radiative effect	Sep. 19, Yes (Tu-Th)
Lambrigtsen	Bjorn	JPL	AMSU, ATMS Level.1	ATMS Level-1 and Level-2 T, q	Sep. 19, Yes (M-F)
Liu	Xu	LaRC	AIRS/AMSU Level.1 CrIS/ATMS Level.1	CLARREO Climate Fingerprinting	TBD, Yes (M-F)
Milstein	Adam	MIT/LL	AIRS, CrIS, Level.1	NN L2 alg for boundary layer	TBD, ?
Payne	Vivienne	JPL	CrIS Level.1	PAN	Sep. 19, Yes (M-F)
Reale	Oreste	USRA	AIRS, CrIS Level.1 and CCR's	Test use of data thinning in DA	Sep. 19, Yes (M-W)
Ruston	Benjamin	NRL	AIRS, CrIS, CALIOP, MODIS, MISR	dust correction within radiance DA	Sep. 19, NO
Santek	David	U.Wisc	AIRS, CrIS Level.2 q, O3	H2O,O3 winds	TBD, Yes
Soden	Brian	U.Miami	AIRS, CrIS T/q, CERES, MODIS	radiative kernels to quantify CMIP6 fluxes	Sep. 19, NO
Strow	Larrabee	UMBC	AIRS, CrIS, IASI level-1	Climate trend products, compare w/ Merra and ECMWF	Sep. 19, NO?
Tan	Ivy	UMBC	MODIS, AIRS, CERES, AMSR	cloud feedback	TBD, maybe
Tian	Baijun	JPL	AIRS/AMSU (v.6)	CMIP5/6, compare w/ Merra	Sep. 19, Yes (Tu-F)
Wilcox	Eric	DRI	MODIS, AMSE-R, CloudSat, CALIPSO, OMI, AIRS, IASI	study of radiative heating by black carbon	TBD, ?
Worden	Helen	UCAR	MOPITT, CrIS level-1	Single FOV Carbon Monoxide retrieval product	Oct. 17, NO

How we plan to organize the sounding community

- Aqua/AIRS/AMSU is a project.
- S-NPP/NOAA-20 is a ROSES competed SIPS.
- With the Terra-Aqua-Suomi-NPP (TASNPP) selection these two worlds have been intertwined
  - Joao Teixeira is the AIRS Project Lead
  - Bryan Baum is the S-NPP Science Team Lead
  - Chris Barnet is the S-NPP Sounder Discipline Lead
- We are working towards a common goal of producing a EOS/S-NPP/JPSS continuity product
  - We have a brief opportunity to build a continuity baseline product for future generations.

We should *<u>commit</u>* to having a GLOBAL baseline (CLIMCAPS) sounding product begin production at GES-DSIC by Oct. 2019 for Aqua, S-NPP, NOAA-20

Creating a hyperspectral sounding continuity product

- We have 5 operational thermal sounder suites at this time

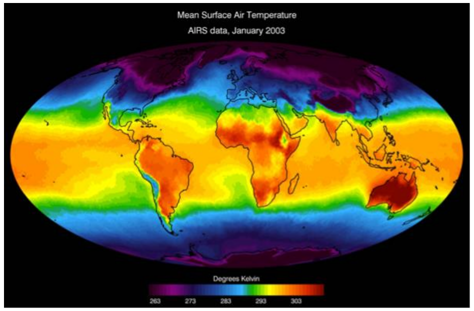
Satellite	Instruments	Overpass	Launch dates
Aqua	AIRS, AMSU	1:30	2002
Metop	IASI, AMSU, MHS	9:30	2008, 2012, …
S-NPP, JPSS	CrIS, ATMS	1:30	2011, 2017, …

- There are numerous differences in these sounding suites
  - Instruments are different
    - Spectra resolution, sampling and noise
    - Spatial sampling
    - Degradation over time
  - Algorithm differences
    - NOAA algorithms became operational ~1 year after launch and have asynchronous maintenance schedules (e.g., training datasets are different)
    - 9:30/1:30 orbits co-location w/ insitu is different (affects regression training and makes validation more difficult)
  - Sensitivity to a-priori assumptions
    - Sensitivity to meteorology (e.g., clouds at 9:30 vs 1:30 am/pm)
    - Sensitivity to seasonal and climate changes (e.g., 8% increase in CO_2, 2002-2017)

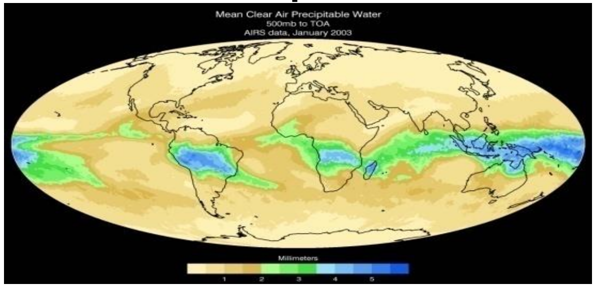
Continuity was not the primary design criteria of the modern satellite sounding suite

Example of retrieval products (AIRS v.5 & 6 products are shown)

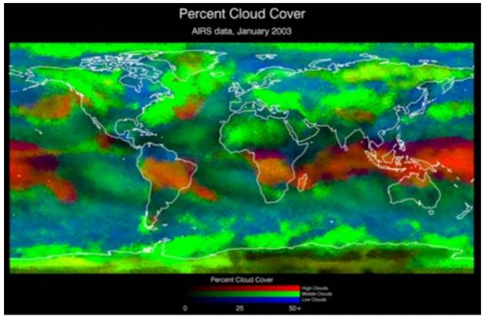
Temperature Profiles



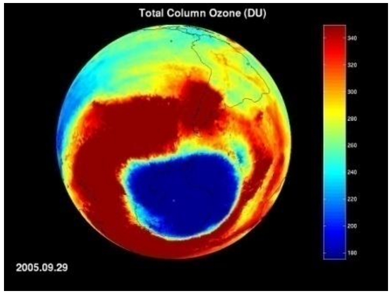
Water Vapor Profiles



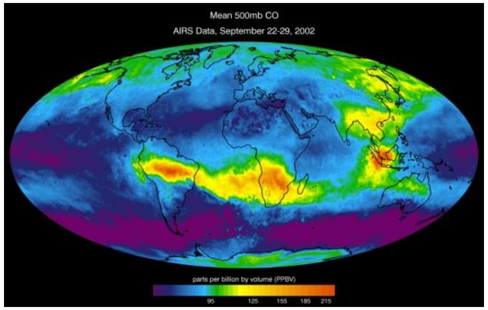
Clouds



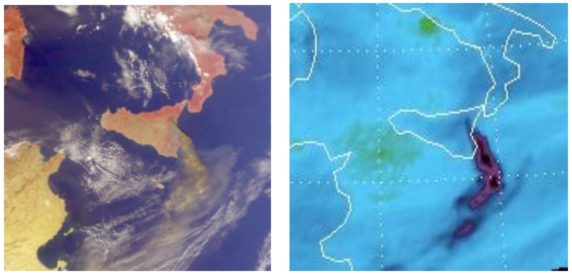
Ozone



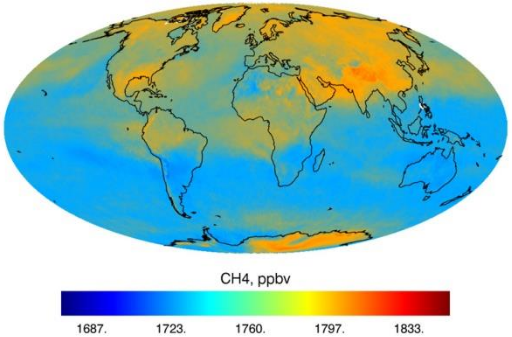
CO



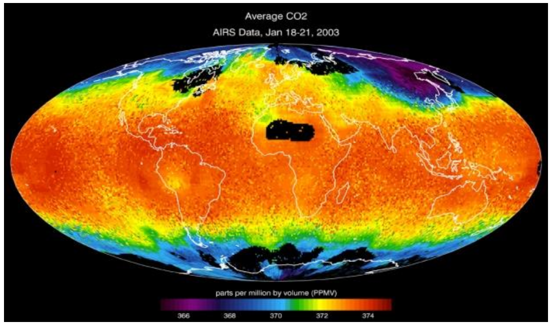
SO2



Methane

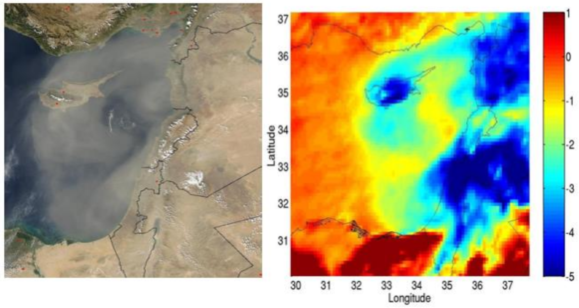


CO2



Dust

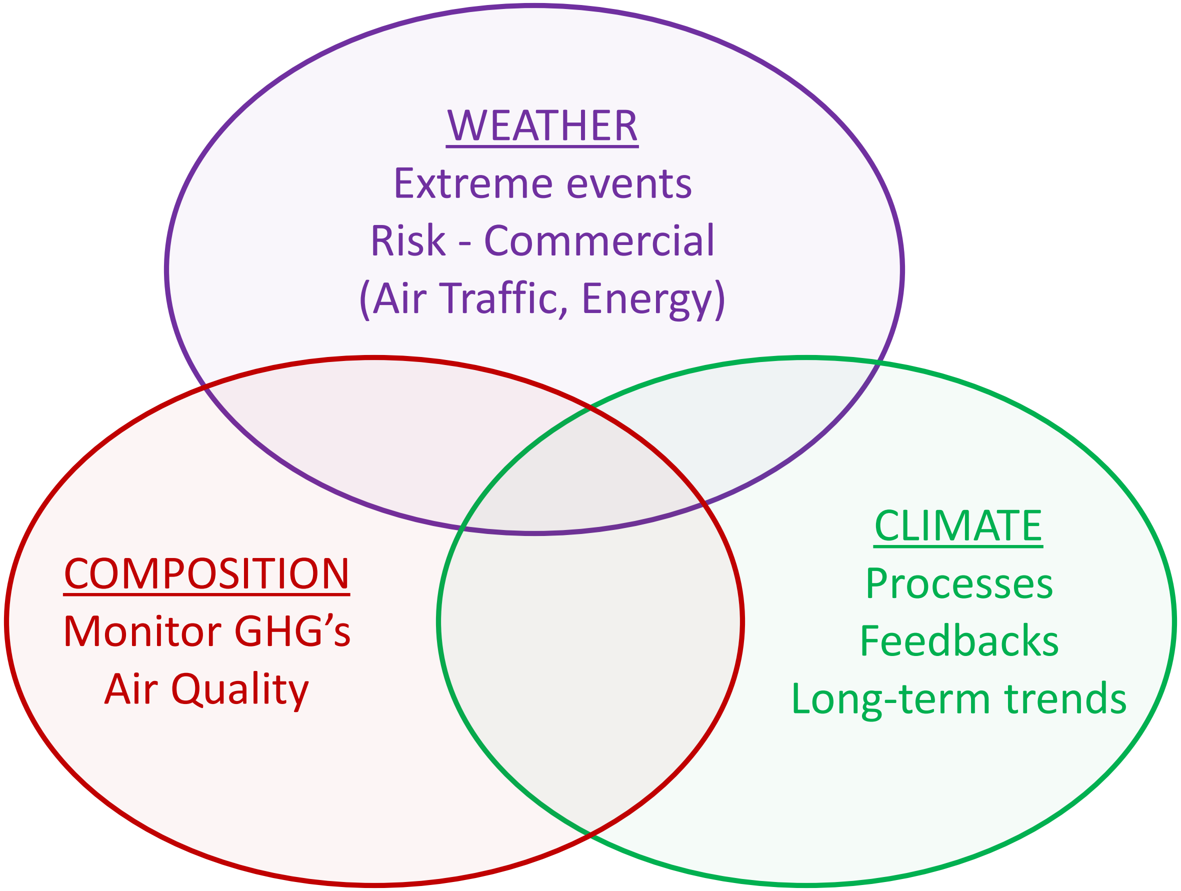
AIRS vs MODIS AEROSOLS
Eastern Mediterranean Dust Storm



What are the areas of our current sounding research?

- NOAA-Unique Combined Atmospheric Processing System (NUCAPS) can handle the real-time weather and air quality applications (Metop 9:30 and S-NPP/JPSS 1:30 orbits).
  - Air traffic safety.
  - Pre-convective forecasting
  - Wildfire management and air quality.
  - Hurricane forecasting.
  - Ozone recovery and use of ozone at STE indicator.
- The NASA Continuity product should focus on developing a long-term (2002-2040's and beyond) record for Aqua/AIRS and S-NPP/JPSS CrIS
  - Study how to build <u>*and document*</u> continuity records.
    - Transparent, instrument agnostic approaches.
    - Choose the appropriate a-priori for NASA applications.
  - Communicate the strengths and caveats of the product

We are attempting to meet the needs of 3 communities



Applications we should target for the NASA continuity product.

Topic	Potential applications for thermal sounding products
Fingerprinting (e.g., Santer 2018 Science, Pierrehumbert 2011 Phys. Today)	Improved stratosphere/troposphere allows better separate of O3 hole from GHG's, N.H./S.H. gradients, polar amplification (downwelling thermal), Arctic moisture budget (Boisvert 2015 JGR)
PBL (Fetzer 2004 GRL, Hoogewind 2017 J.Clim)	Capping layer inversions, convection and stability. Most important for a thermal sounder is knowledge of when we have skill (i.e., averaging kernels).
UTH, double ITCZ (Tian 2015 GRL), ENSO, MJO	Stable and seasonally consistent T(p) will stabilize cloud clearing and q(p). Departures from Merra-2 will be more valuable than a derived state.
Ozone	Ozone hole; Intrusions and mid-trop O3 (Langford 2018 Atmos. Env); LS O3 trends (Ball 2018 ACP, Wargan 2018 GRL); CO/O3 ratio (Anderson 2016 Nat.Comm)
Carbon Dioxide (CO2)	Contribute to discussion of seasonal cycle amplitude (Barnes 2016 JGR), clear bias of OCO (Corbin 2008 JGR)., and stratospheric/troposphere CO2 gradient. (Separability of T/CO2 is improved with use of Merra-2 and AMSU/ATMS.
Carbon Monoxide	Long-term trends of CO (Worden 2013 ACP). Impact on OH (Gaubert 2017 GRL), Seasonal cycle (Park 2015 JGR) and CO/CO2 emission factors (Wang 2009 ACP)
Methane (CH4)	Monitoring of Amazon CH4 (Bloom 2016 ACP), Changes to Arctic emissions (Shakhova 2010 Science, Thornton 2016 GRL)
Other trace gases	Nitric Acid, Nitrous Oxide, Sulfur Dioxide, Isoprene, PAN, Acetylene, Methanol, etc – all benefit from stable cloud clearing and upstream derived T(p), q(p), etc.

Which a-priori is best for these applications?

Concern	Statistical Model	Re-analysis model
Satellite data is used twice	YES: All channels are used in NN and regressions. Subset of the same exact channels are re-used.	$\rightarrow$zero Weight of obs is extremely small w.r.t. 6 hour window and all other instruments.
Vertical sub-structure	Derived from ECMWF statistics and only our obs. The a-priori contribution in the solution cannot be quantified.	Derived from ensemble of many instruments and model dynamics. Contribution is partitioned via error propagation, $dXdX^T$
Latency	Zero – it is a static training	Re-analysis: ~1 month GMAO FP: ~4 to 7 hours
Spatial consistency	Clouds and other signals cause “spatial speckle” that can induce large gradients at 100 km scale.	Constrained by model dynamics (including thermal wind) and is spatially consistent.
Temporal consistency (NOTE NN and regressions are “trained” from specific instruments within specific year(s).)	Non-graceful response to instrument changes (e.g. , degradation, AIRS/CrIS transition) and state changes (climate, volcanoes, or anything outside the domain of its training)	Stated goal is to mitigate obs. discontinuities. Can have artifacts due to instrument changes: O3: MLS in 10/2004; T/q: Metop 2009, 2013, S-NPP 2012, etc.

Choosing the cross-over point for Aqua to S-NPP

- Nominal or Full spectral resolution (NSR or FSR)
  - Dec. 2014 S-NPP/CrIS was put into FSR mode
  - Dec. 2015 a correct to the bit-trim mask improved FSR mode
- Transition from AMSU+HSB to ATMS
  - Aqua/AMSU Chl.7 has never been used
  - HSB was lost on Feb. 5, 2003
  - Aqua/AMSU Chl.5 noise degraded from 2009-2011, then removed
  - Aqua/AMSU Chl.4 noise degraded in 2007, removed 10/2007.
  - Aqua/AMSU Chl.1 and 2 lost in 10/2016
- ***Recommendation*** (based on discussions w/ L. Strow):
  - Use AIRS+AMSU from 9/1/2002 to 8/31/2016
    - Use "pristine" AIRS channels that were well behaved
    - Use AMSU 1, 2, 3, 6, 8, 9, 10, 11, 12, 13, 14, 15
  - Use S-NPP CrIS.FSR+ATMS from 9/1/2016 to 8/31/2018
    - 12/10/2015-9/31/2016 overlap periods of Aqua/S-NPP should be adequate
  - Use NOAA-20 CrIS.FSR+ATMS from 9/1/2018 to …
    - Adequate overlap periods of S-NPP and NOAA-20 exist

CLIMCAPS supports building a continuity dataset *NOW*

- Provide the best archive of these measurements as a baseline for the future.
  - Reasonable mitigation of instrument artifacts.
  - Full suite of trace gases, error propagation.
- Build a long-term record so that TASNPP researchers can
  - Use the record for understanding climate processes and change
  - Document our best understanding of the information content of these measurements
  - 9/2002-8/2016 AIRS + AMSU → 9/2016-8/2035 CrIS-FSR + ATMS
    - 5 satellites and 2 instrument types at 1:30 am/pm
    - With sufficient overlap period of 2012-present
- Future work (next ROSES cycle?)
  - 2007-2020’s IASI/AMSU/MHS → 2021-2040 IASI-NG
    - Metop-A, -B, -C at 9:30 am/pm with IASI, AMSU, MHS
    - Follow-on (EPS-SG/IASI-NG) has been approved for 2021-2040
  - Reprocessing using a Common Hyperspectral InfraRed Product (CHIRP) dataset (AIRS, IASI, CrIS to common spectrum).

QUESTIONS?