A Fresh Look at Hyperspectral Sounders:

How 3-D Quantitative Information about the Atmosphere can Enhance Real-Time Applications and Decision Making

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High-spectral resolution IR spectra contain signatures of

- Surface properties (type, temperature, emissivity, inversion...)
- Temperature and humidity profiles
- Cloud properties (altitude, temperature, optical thickness, ice/liquid content...)
- Trace gases ($O_3$, $CO$, $N_2O$, $CH_4$...)
- Dust and volcanic ash (see image on the left)
28 Jan 2013

Sea ice

CrIS FOV 86/40

Brightness Temperature

Surface Emissivity Retrieval

T and RH Profile Retrieval

CrIS 20130128 124337
BT [K] at 910.0 cm$^{-1}$

CrIS 2013-01-28
T Cloud Top Pressure [hPa]
The dual-regression retrieval technique is used to retrieve the following single FOV products under clear and cloudy conditions from input direct broadcast or archived AIRS, IASI and CrIS L1 radiance files:

- atmospheric temperature [K] at 101 pressure levels
- atmospheric moisture [g/kg] at 101 pressure levels
- atmospheric ozone [ppmv] at 101 pressure levels
- atmospheric relative humidity [%] at 101 pressure levels
- atmospheric dew point temperature [K] at 101 pressure levels
- surface skin temperature [K]
- surface emissivity (at full spectrum)
- total precipitable water [cm]
- precipitable water 1 (900 hPa to surface) [cm]
- precipitable water 2 (700 to 900 hPa) [cm]
- precipitable water 3 (300 to 700 hPa) [cm]
- total ozone amount (vertically integrated) [dobson units]
- lifted index [°C]
- convective available potential energy [J/kg]
- CO2 concentration [ppmv]
- cloud top pressure [hPa]
- cloud top temperature [K]
- cloud optical thickness
- effective cloud emissivity
- cloud mask (values: 0 clear, 1 cloud)

Available at http://cimss.ssec.wisc.edu/cspp/
**Direct Broadcast “Dual-Regression” Retrieval Algorithm Overview**

- **Ultra-spectral sounder measurements**
  - AIRS
  - IASI
  - CrIS

**Theoretical Statistics**

- Global clear soundings
  - Radiances (clear FM)
  - Clear-trained regression coefficients
- Theoretical Statistics
- Radiance Observations
- Cloud-trained EOF regression retrieval

**Cloud Top Altitude**

- Level where $T_{\text{cloudy}} > T_{\text{clear}}$ for $p > p_{\text{cl}}$

**Final Profile**

- from cloudy and/or clear retrievals

**Temperature, Humidity and Ozone profiles, Surface and Cloud parameter at single FOV (15-km) resolution**

- Weisz, E., W. L. Smith, N. Smith (2013), Advances in simultaneous atmospheric profile and cloud parameter regression based retrieval from high-spectral resolution radiance measurements, Submitted to *JGR-Atmospheres.*

**0.02s / FOV**
A look at the vertical nature of sounder retrievals

CrIS RTV Temperature [K] at 986.1 hPa

Lat/Lon: 64.7/-147.7
CrIS and IASI

Metop-B IASI Brightness Temperature [K] at 910 cm\(^{-1}\)
00:43, 02:18, 03:59 UTC

Metop-B IASI Cloud Top Pressure [hPa]
00:43, 02:18, 03:59 UTC

CrIS Brightness Temperature [K] at 910 cm\(^{-1}\)
06:34, 08:14, 09:56 UTC

CrIS Cloud Top Pressure [hPa]
06:34, 08:14, 09:56 UTC
VIIRS Day/Night band

Suomi NPP VIIRS 0.7 µm Day/Night Band and 11.45 µm IR channel

From: http://cimss.ssec.wisc.edu/goes/blog/archives/date/2012/09/26

Low Pressure System Gulf of Alaska (26 Sep 2012)
Low Pressure System Gulf of Alaska (26 Sep 2012)

VIIRS 11.45 um

CrIS Relative Humidity

CrIS Cloud Top Pressure

CrIS Optical Thickness
Transect of vertical information through granule

CrIS Relative Humidity

Scanline 168: CrIS RTV Relative Humidity [%]
Severe Weather Support: Hurricane Sandy (29 Oct 2012)
Severe Weather Support: Hurricane Sandy (29 Oct 2012)
Severe Weather Support: Hurricane Sandy (29 Oct 2012)

CALIOPI (2012-10-29T17-41-08ZD) Total Attenuated Backscatter 532 nm
CrIS 17:19-17:43 UTC, AIRS 18:05-18:23 UTC (granules 181-184)
Imager–Sounder pairing

05 May 2013, 07:22 UTC

VIIRS M-band 15

CrIS Cloud Top Pressure

CrIS Cloud Optical Thickness

Suomi NPP SVM15 Brightness Temperature 20130505.0722005-0734462
Imager–Sounder pairing

05 May 2013, 20:32 UTC

VIIRS M-band 15

CrIS Cloud Top Pressure

CrIS Cloud Optical Thickness
Making use of the high frequency of satellite overpasses at high latitudes

AQUA, Metop-A, SNPP passing over Alaska on 28 Jan 2013
Relative Humidity [%] at 300 hPa (27 - 29 Jan 2013)

Time-series of three instruments: AIRS + CrIS + IASI

IASI 2013-01-27 06:05 UTC
Time Tendencies (CTOP change per hour) Examples
Tornado Outbreak in U.S. Midwest (Feb 2012)

EF4 tornado hit at 10:51 UTC

AIRS Lifted Index [°C]

CrIS Lifted Index [°C]

CrIS Retrieval at 07:11 UTC

AIRS Retrieval at 08:23 UTC

Temperature [K]  Relative Humidity [%]

Temperature [K]  Relative Humidity [%]
CrIS Stability Indices
20 May 2013 ~07:43 UTC (02:43am)

Lifted Index

Total Totals
Cloud Top Pressure

Cloud Optical Depth
AIRS cloud parameter retrievals
20 May 2013 ~08:23 UTC (03:23am)

Cloud Top Pressure

Cloud Optical Depth

Gap between overpasses
IASI Metop-A cloud parameter retrievals
20 May 2013 ~15:56 UTC (10:56am)
IASI Metop-B cloud parameter retrievals
20 May 2013 ~16:51 UTC (11:51am)

Cloud Top Pressure

Cloud Optical Depth
CrIS cloud parameter retrievals
20 May 2013 ~19:07 UTC (2:07pm)

Cloud Top Pressure

Cloud Optical Depth
AIRS cloud parameter retrievals
20 May 2013 ~19:35 UTC (2:35pm)

Cloud Top Pressure

Cloud Optical Depth
The Dual-Regression (DR) algorithm\textsuperscript{1,2} available as part of CSPP on http://cimss.ssec.wisc.edu/cspp/, provides single field-of-view products (temperature, humidity and ozone profiles, surface and cloud parameters, stability indices) under \textbf{clear and cloudy conditions} from input Direct Broadcast (DB) or archived Aqua-\textit{AIRS} (Atmospheric Infrared Sounder), Metop-\textit{IASI} (Infrared Atmospheric Sounding Interferometer) and NPP-\textit{CrIS} (Cross-Track Infrared Sunnder) radiance measurements.

These parameters are used to

\begin{itemize}
  \item measure temperature \textbf{trends}, water cycle, cloud properties, and trace gases (regional and global)
  \item study \textbf{time tendencies} of atmospheric parameters (e.g. lifted index) from consecutive overpasses
  \item add \textbf{quantitative information} to MODIS/AVHRR/VIIRS imagery
  \item improve weather prediction, \textbf{forecasting} and climate models
\end{itemize}


\textsuperscript{2} Weisz, E., W. L. Smith, N. Smith (2013), Advances in simultaneous atmospheric profile and cloud parameter regression based retrieval from high-spectral resolution radiance measurements, Submitted to \textit{JGR-Atmospheres}. 
Current and Future work

- **Time tendencies** (multi-instrument time-series analysis, quantifying change)
- In close collaboration with GINA and forecasters in Alaska: include sounder retrievals in **regional forecast systems** (AWIPS)
- **Climatologies** from archive data (EUMETSAT conference): climate data records
- Adding additional **trace gases** to retrieval product suite: CO, CH4
- Develop readily interpretative products (classification), **indicators**, value-added information/data products
- Regionalize algorithm and products: **monitoring** and quick response
- Improve **access** to quick looks and data products
- Investigate adding microwave retrievals to profiles below clouds

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2. Weisz, E., W. L. Smith, N. Smith (2013), Advances in simultaneous atmospheric profile and cloud parameter regression based retrieval from high-spectral resolution radiance measurements, Submitted to *JGR-Atmospheres*. 
- Classifying cloud heights into three nominal classes; high, medium low.

- Average vertical soundings into broader layers. At the moment they are defined along 101 levels from surface to top of atmosphere.

- Calculate additional indices of atmospheric stability that forecasters are used to or find particularly useful in certain cases.

- Derive compound products that can serve as indicators of weather features or onset of change, e.g. combining low level moisture and surface temperature.

- Derive geostrophic winds and moisture fluxes

- Calculate and archive regional statistics that can be used to calculate trends over time

- Include profile retrievals for use in regional data assimilation models
Available at http://cimss.ssec.wisc.edu/cspp/

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2 Weisz, E., W. L. Smith, N. Smith (2013), Advances in simultaneous atmospheric profile and cloud parameter regression based retrieval from high-spectral resolution radiance measurements, Submitted to *JGR-Atmospheres*. 