NESDIS ADVANCED-TOVS (ATOVS) SOUNDING PRODUCTS: SYSTEM-2005

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Measurement and Product Status

On May 13, 1998, the Advanced TIROS Operational Vertical Sounder (ATOVS) radiometer configuration onboard NOAA-15 was successfully deployed into an evening orbit (1930 ascending). This was followed by NOAA-16 into an afternoon orbit (1330 ascending) on September 21, 2000, and NOAA-17 into a mid morning orbit (1030 ascending) on June 22, 2002.

The ATOVS instrument configuration features:

15 - channel …	Advanced Microwave Sounding Unit -A	**AMSU-A**
5 - channel …	Advanced Microwave Sounding Unit -B	**AMSU-B**
20 - channel …	High resolution Infrared Radiation Sounder	**HIRS/3**
6 - channel ...	Advanced Very High Resolution Radiometer	**AVHRR/3**

AMSU-A and B provide "all-weather" surface and atmospheric temperature / moisture data, respectively. The HIRS provides cloud and clear-sky temperature and moisture data, and the AVHRR provides surface temperature and cloud information.

ATOVS operational temperature and moisture sounding product systems as currently operated by NESDIS use AMSU-A, HIRS and AVHRR data. Separate operational moisture sounding products are also produced using AMSU-B.

ATOVS sounding products from NOAA-17 were discontinued during October, 2003 due to the failure of AMSU-A. ATOVS products from NOAA-15 and 16 currently do not use HIRS, which completely failed onboard NOAA-15 during April, 2005, and began experiencing marginal noise for NOAA-16 during December, 2004.

AMSU-B moisture sounding products are available for NOAA-15, NOAA-16 and NOAA-17.

NOAA-18, containing an operational configuration of HIRS, AMSU-A, Microwave Humidity Sounder (MHS), which is very similar to AMSU-B, and AVHRR instruments was tentatively scheduled for launch into an afternoon orbit (1330 ascending) on May 20, 2005. ATOVS and AMSU-B product systems are currently in an operational check-out phase with operational implementation of product systems expected within 30 to 90 days from launch.

Science Algorithm

Several components of the current operational science algorithm for deriving ATOVS science product are scheduled for replacement. The revised operational system is referred to as ***ATOVS System 2005***. The motivation for these changes is to achieve a scientific re-alignment that is more consistent with existing NWP and Climate applications and requirements for utilizing satellite data, and planned next generation (NPP, METOP and NPOESS) satellite product systems.

Support and interest for such work beckons the question *" Why Soundings*?", and ITSC to address:
- importance of maintaining *"heritage"* systems,
- utility in weather/climate analyses,
- data compression,
- global, regional and local (including direct readout) scales

A summary of current ATOVS operational system "Components" **(Black)** and pending "Changes" **(Red-yes or Yellow-maybe)** in System-2005 are listed below.

COMPONENTS	CHANGES
• Earth-location/Calibration	
• Append SST, Terrain, Ice/Snow, NWP	complete NWP, 100km, 3-hr forecast
• Limb Adjustment	5-day vs 30-day sample for coefficients
• Interpolate to HIRS	
AMSU-A	
AMSU-B	append "closest" to HIRS
• MW Products (CLW, TPW, Em ..)	include AMSU srfc emissivity f / MSPPS
• Contamination Detection	
Precipitation	
Cloud	
• First Guess T, H20	AMSU regression replaces Library Search
• First Guess BTemp	Calculated f/guess (OPTRAN-CRTM)
• RT-Bias Adjustment	Observations adjusted for RT-bias
AMSU-A	Yes
AMSU-B	Maybe
HIRS	Not likely
• Retrieval	Analytic solution (+AMSU-B) from Guess (OPTRAN-CRTM) replaces Pre-computed

Science Algorithm - discussion

NWP: Mainly used for validation. Previous method only stored 6-hour forecasts at 250km grid over two tropospheric layers (1000 to 700) and (500 to 300) mb; now stores 3-hr forecast at 100km grid for all available levels. Surface pressure to serve as input for retrieval.

Limb Adjustment: Same approach except measurement sample (1b-level) expanded from 5-days to 30(+) days

AMSU-B: Measurements (calibrated and limb adjusted) at full density with fov closest to HIRS fov identified.

Microwave Products: Consistent with products from NESDIS operational Microwave Surface and Precipitation Products System (http://www.orbit.nesdis.noaa.gov/corp/scsb/mspps/main.html see Fuzhong Weng) including microwave surface emissivity (for possible use in guess and retrieval steps).

First Guess Temp and H20: Library Search technique replaced with AMSU based statistical regression:

$$FGCOEF_{i,j} = (Syx)\,(Sxx + q*I)\text{-}1$$

where:
I is identity matrix; -1 is matrix inversion; i- levels, j- channels
q is stabilization factor; -0.5 for Temp., -0.0005 for H20
Syx is predictand/predictor covariance matrix
Sxx is predictor/predictor covariance matrix

$$FG_i(y) = FGCOEF_{i,0} + FGCOEF_{i,j}\ M(x)_j$$

4 Sets of Coefficients:

Sea temperature predictors (M) :	AMSU-A 4 -14
Sea temperature predictands (FG):	@ 40 TOVS 1000 to .1 mb
sea moisture predictors:	AMSU-A 1, 4 – 8; AMSU-B 3 - 5
sea moisture predictands:	ln (H20) g/kg @ 17 TOVS 1000 to 200mb
land temperature predictors:	AMSU-A 5 - 14
land temperature predictands:	@ 40 TOVS 1000 to .1 mb
land moisture predictors:	AMSU-A 5 - 8; AMSU-B 3 - 5
land moisture predictands:	ln (H20) g/kg @ 17 TOVS 1000 to 200 mb

Regression coefficients and covariance matrices updated weekly using daily updated samples of collocated radiosonde (Y) and satellite observations (X) as stored on dedicated Matchup Data Bases (MDB) that are routinely compiled in support of NESDIS operational products tuning and validation, and archived (NCDC-SAA)

First Guess BTemp: Calculated from First Guess temperature and H20 using OPTRAN-CRTM

Radiative Transfer (RT) Bias Adjustment: Applied to sensor measurements to compensate for possible RT model bias in calculated first guess Btemp.

$$R^T = E\,(EM^T ME^T + \alpha I)^{-1}\,(EM^T CD + \alpha J)\,D^{-1}$$

where
for "k" channels, "p" predictors, "n" collocations:
C is the "n x k" matrix of calculated btemps (centered),
M is the "n x p" matrix of (measured btemps) predictors (centered),
I the p x p identity matrix; J the p x k matrix ("k" upper rows I, "p – k" rows zero),
E and D are scaling (sd-1) matrices for additional predictors, and
α is the stabilizing (shrinker) parameter (Gamma)

$$c_k = C_k\,bar + R_{p,k}\,(m - Mbar)_p$$

6 Sets of Coefficients:

Sea AMSU-A predictors (m):	AMSU-A 4-14; Lat, Long, Solar Z
Sea AMSU-A predictands (c):	AMSU-A 4-14
Land AMSU-A predictors:	AMSU-A 5-14; Lat, Long, Solar Z
Land AMSU-A predictands:	AMSU-A 5-14
Sea AMSU-B predictors:	AMSU-B 1-5; Lat, Long, Solar Z
Sea AMSU-B predictands:	AMSU-B 4-14
Land AMSU-B predictors:	AMSU-B 3-5; Lat, Long, Solar Z
Land-AMSU-B predictands:	AMSU-B 3-5
Sea HIRS predictors:	HIRS 2-7, 10-16; Lat, Long, Solar Z
Sea HIRS predictands:	HIRS 2-7, 10-16
Land HIRS predictors:	HIRS 2-7, 10-16; Lat, Long, Solar Z
Land HIRS predictands:	HIRS 2-7, 10-16

Regression coefficients and matrix R updated weekly using daily updated samples of collocated radiosonde (C)and satellite observations (M) as stored on dedicated Matchup Data Bases (MDB) that are routinely compiled in support of NESDIS operational products tuning and validation, and archived (NCDC-SAA)

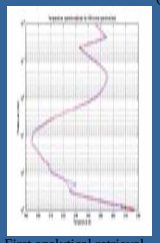
Science Algorithm - discussion

Retrieval: The **retrieval** is still done using a Minimum Variance Simultaneous (MVS) solution (*Rodgers 1976 and Fleming 1986*):

$$T - T_g = S\,A^t\,(A\,S\,A^t + N)^{-1}\,(R - R_g)$$

where "*t*" indicates the matrix transpose, -1 the inverse, and:

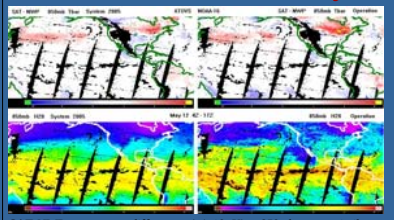
T : final soundings products vector, (151),
T_g : first guess products vector, (151), from AMSU regression,
S : first guess error covariance matrix, (151 x 151),
A : sounder channel weighting matrix, (40 x 151), computed (analytic) online from first guess and OPTRAN- CRTM (see T. Kleespies)
N : measurement uncertainty matrix, (40 x 40), computed (analytic) online
R : observed radiance temperature vector, RT bias adjusted for **AMSU-A**, **AMSU-B** and HIRS
Rg : first guess radiance temperature vector, calculated (OPTRAN-CRTM) from T_g



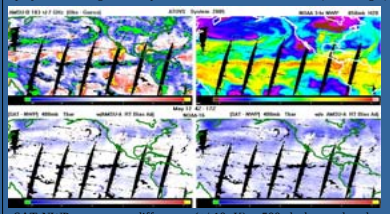
First analytical retrieval (red) vs Oper (blue)

Covariance S-matrices (background error) are updated weekly using daily updated samples of collocated "Radiosonde minus Satellite First Guess Temperature and H20" differences computed from the dedicated Matchup Data Bases (MDB) that are routinely compiled in support of NESDIS operational products tuning and validation, and archived (NCDC-SAA)

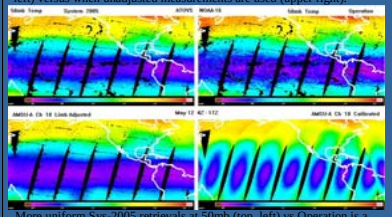
Preliminary Validation / Results



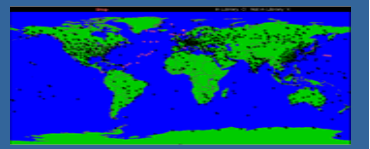
SAT-NWP temperature differences (+/- 10° K) at 850mb appear similar but more uniform for Sys-2005 (top, left) vs Operation (top, right). 850mb H2O (g/kg) appears more structured but also more noisy than for Operation (right) vs Sys-2005. However, the "observed minus first guess" Btemp (+/-7°K) for lower peaking AMSU-B channel (below, left) "projects" convergence of Sys-2005 H20 retrieval with NWP (below, right).



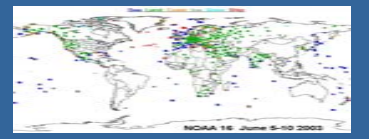
SAT-NWP temperature differences (+/-10° K) at 500mb show reduced cold bias when RT-adjusted AMSU-A are used in SAT retrieval (upper, left) versus when unadjusted measurements are used (upper right).



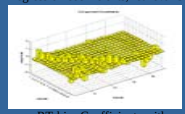
More uniform Sys-2005 retrievals at 50mb (top, left) vs Operation is a manifestation of the improved first guess method, but the impact of increased noise in associated AMSU-A (shown for limb corrected (left) and calibrated channel 10 (right) for NOAA-16 is evident.



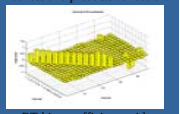
Daily radiosondes (above) and satellite collocations (below) are stored on operationally supported Matchup Data Bases (MDB)



MDB's per satellite are basis for generating First Guess and RT-bias regression coefficients, retrieval S-matrices and products validation.

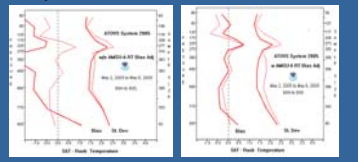


RT-bias Coefficients with Gamma = 0



RT-bias coefficients with Gamma = 0.05

(Calculated - Observed) Btemps over various terrain types are computed from the MDB and the basis for RT-bias coefficients.



Soundings derived with RT-bias adjusted Btemps (left) show better agreement with collocated radiosondes (MDB) than those retrieved with unadjusted Btemp measurements (right).