GOES-R AWG Sounding Team: ABI Legacy Atmospheric Temperature Profile, Legacy Atmospheric Moisture Profile, Total Precipitable Water and Atmospheric Stability Indices Algorithm

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Executive Summary

- This ABI Legacy Atmospheric Profile (LAP) algorithm generates the Option 1 products of clear sky temperature/moisture profiles and derived product imagers (DPI) for total precipitable water and atmospheric stability.
- Version 5 was delivered in May 2010. ATBD (100%) is on schedule for a July delivery.
- Regressed temperature/moisture and surface skin temperature are used as first guess; multiple solutions (for land and ocean) are provided to determine surface emissivity; physical retrieval over different surfaces (land/ocean/desert) are optimized; algorithm is modulated for plugging in cRTM.
- Collocated ECMWF analysis and radiosonde dataset are prepared and applied to 18-month of SEVIRI data.
- Radiosonde and surface measurement in AEROSE are used to evaluate the algorithm over ocean.
- Completed TIM (Technical Interchange Meeting)

Requirements

Product	*Accuracy*	*Precision*	*Latency (mesoscale)*	*horizontal resolution*
Temperature profile (K)	1K below 400 hPa and above boundary	2K below 400 hPa and above boundary	4.4 min	10 km
Moisture profile (RH)	Sfc-500 mb: 18% relative humidity; 500-300 mb: 18% relative humidity; 300-100 mb: 20% relative humidity	Sfc-500 mb: 18% relative humidity 500-300 mb: 18% relative humidity 300-100 mb: 20% relative humidity	4.4 min	10 km
Derived stability indices	LI: 2 K CAPE: 1000 J/ kg SI: 2 K TT: 1 KI: 2	Lifted Index: 6.5 K CAPE: 2500 J/ kg Showalter index:6.5 K Total totals Index:4 K index: 5	**2.7 min**	10 km
TPW	1 mm	3 mm	4.4 min	10 km

Qualifiers

Theses are made with the following qualifiers.

- Day and Night
- LZA less than 67 degrees
- Clear sky

Algorithm Description

Algorithm Summary

- This ABI LAP sounding generates the Option 1 products of clear sky temperature/moisture profile, total precipitable water vapor and water vapor at low/mid/high levels, along with the derived atmospheric stability indices (LI, CAPE, KI, TOTO, and SI) .
- Two methods (simple averaging the clear brightness temperatures, or taking warmest clear pixel at 11.0-um band) are provided to mitigate the instrumental noise or possible cloud contamination.
- A non-linear regression method is used to generate the first guess of temperature/moisture profile as well as the surface skin temperature. ABI IR radiances along with the numerical weather prediction (NWP) forecast are used as predictors.
- 1DVAR approach with discrepancy principal is used to update the first guess. PFAAST is used as RTM for inverse (easy to change to cRTM/RTTOV). EOF representation for profile is used in 1DVAR.
- UW baseline fit emissivity database is used over land, the emissivity model is used over ocean in 1DVAR.
- For oceanic cases, we find that the forecast sea surface temperature is better than the regressed surface skin temperature. Therefore the forecast sea surface temperature is used as first guess in the physical retrieval.
- Multiple quality indices are provided for quality check, including the number of iterations, the RMSE of average BT difference between the calculations and observations after retrieval and the BT difference of the 11.0-µm window channel between calculation and observation.

Motivation for Algorithm Channel Selection

- The 3.9-um near IR channel is not used in the algorithm due to the large difference between observation and calculation using PFAAST as RTM. Including this channel in the physical iteration is optional if the new RTM can reduce the difference to 0.2 K or lower.

- The 8.5-um window channel is not used in regression and is optional in physical retrieval. Simulating BT of this channel over land strongly depends on the quality of surface emissivity. It should be avoided over ocean if the pixel is contaminated by dust aerosol.

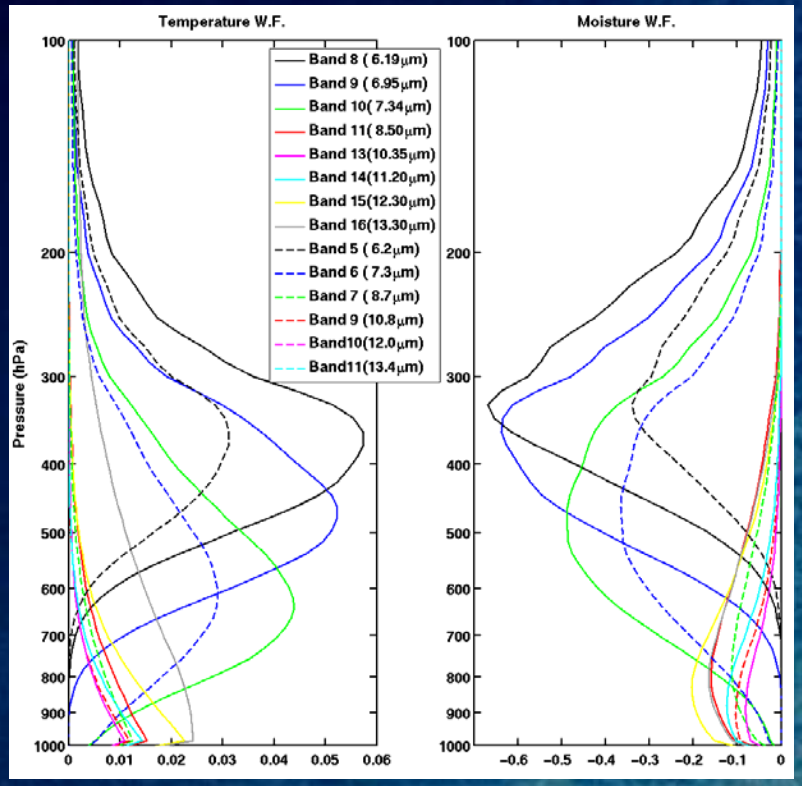
- The 9.7-um ozone absorbing band is used in regression only and not used in physical retrieval.

- The 13.3-um CO_2 absorbing band is included in both regression and physical retrieval but it must be noticed that the current RTM (PFAAST) has obvious bias for this corresponding SEVIRI band.

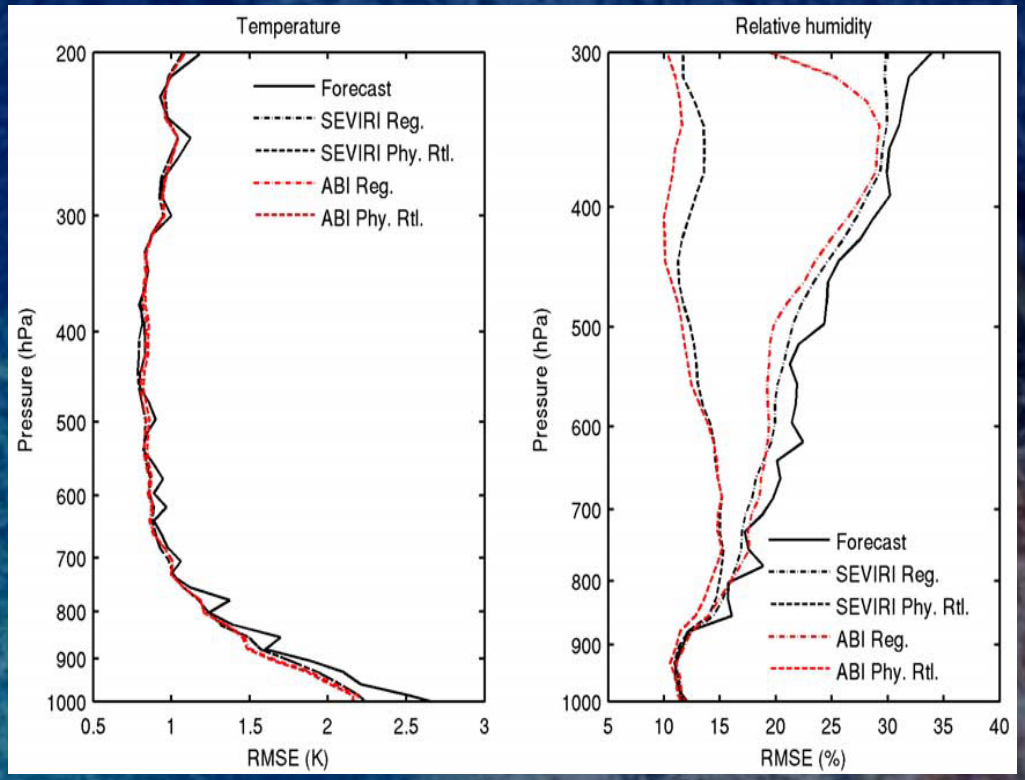
Expected ABI Performance Relative to Other Sensors

- Compared with SEVIRI, they both have only one CO_2 band for temperature retrieval; however, ABI has one more water vapor absorbing band (6.9-um), making it possible to retrieval better mid-level water vapor information. It has one more window channel (10.3-um) to provide more low-level moisture information.

Weighting function profiles of ABI (solid) and SEVIRI (dash)



Simulation of (left) temperature and (right) moisture profile retrieval with ABI (red) and SEVIRI (black)



LAP Sounding Processing Schematic

BT: Channel 7 to 16 IR Brightness Temperature

T(p) = Temperature profile

W(p) = Moisture profile

P_{sfc} = Surface air pressure

T_{skin} = Surface skin temperature

E_{sfc} = Surface IR emissivity

$Flag_{lw}$ = Land/water flag

LZA = Local zenith angle

Lat = Latitude

Mon = numerical month ID (1 to 12)

WS_{sfc} = Near surface wind speed

T_{sfc} = Near surface air temperature

W_{sfc} = Near surface air moisture

INPUT: (Required) BT, forecast T(p)/W(p)/P_{sfc}/T_{skin}, E_{sfc}, $Flag_{lw}$, LZA, Lat, Mon; (Optional) WS_{sfc}, T_{sfc}, W_{sfc}

↓

Retrieval Algorithm
(Regression followed by physical iteration)

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OUTPUT: Retrieved T(p)/W(P)/Ts

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Calculate derived products

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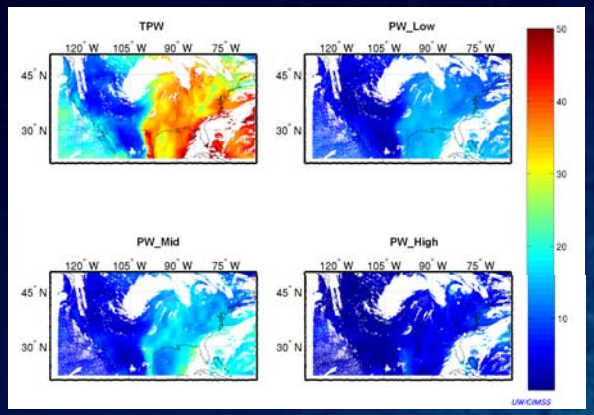
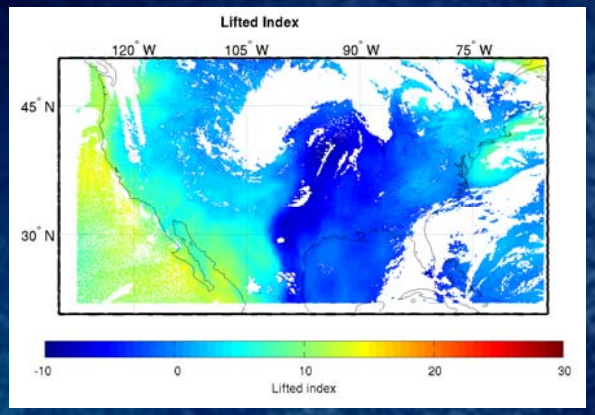
OUTPUT: TPW, layered PW, LI, CAPE, KI, TT, SI

Example LAP Output using Simulated ABI data

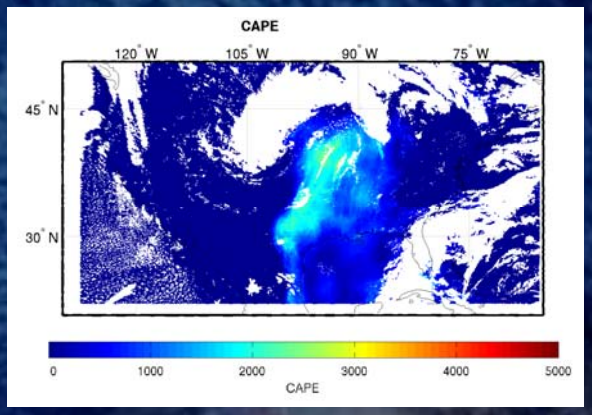
TPW and layered PW



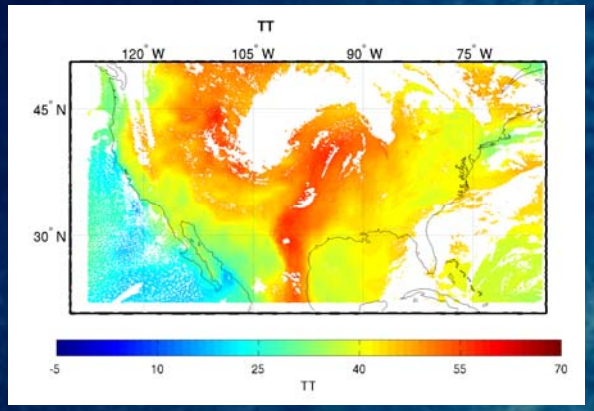
Lifted Index



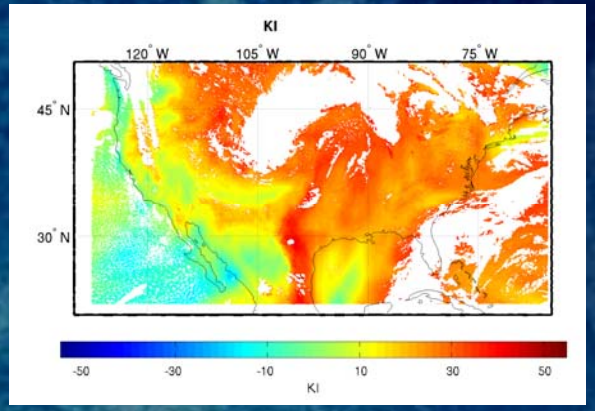
Convective Available Potential Energy



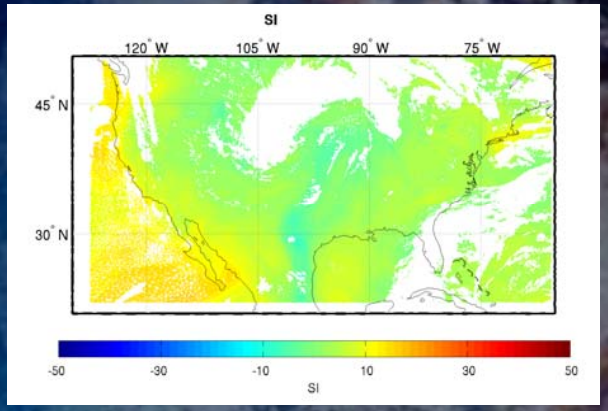
Total Totals



K Index



Showalter Index



Algorithm Changes from 80% to 100%

- Adjustable block size of the field of regard (FOR), initialized in the namelist file.
- Adjustable BT manipulation method (simple average or maximal value) within FOR, claimed in the namelist file.
- Interpolated surface wind speed for each FOR to calculate emissivity over water with the look-up-table method.
- Built-in subroutines for TPW, layered PW and stability calculation.
- Error status added for each subroutine
- Metadata output added.
- Quality flags standardized.

ADEB and IV&V Response Summary

- All ATBD errors and clarification requests have been addressed.
- No feedback required substantive modifications to the approach.

Validation Approach

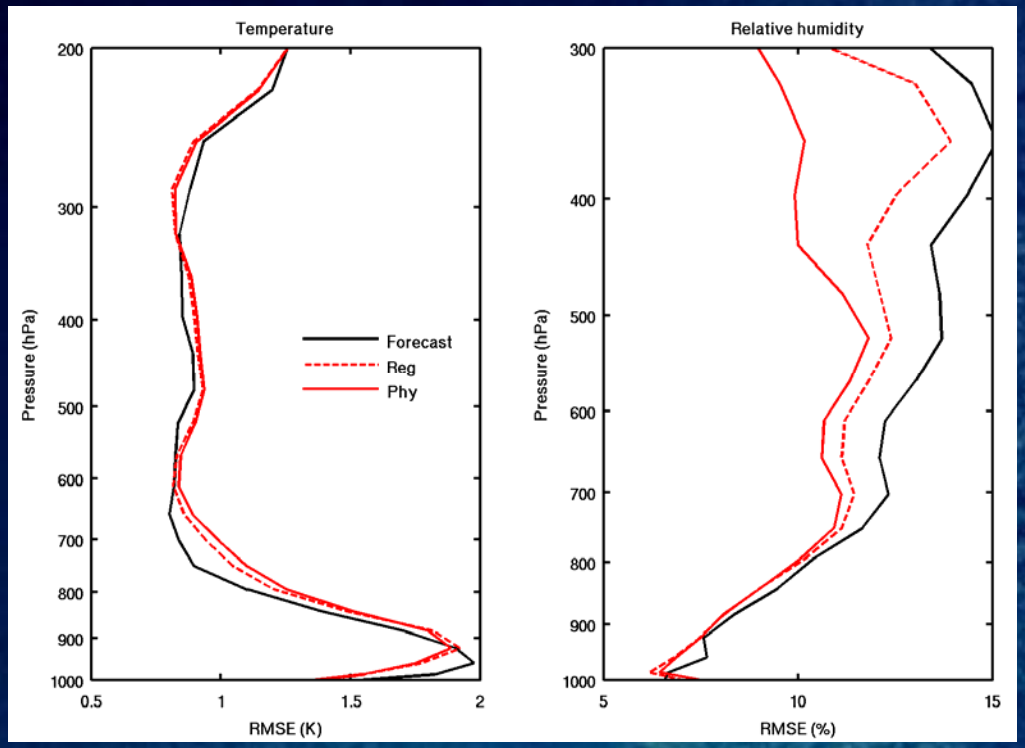
Validation Approach

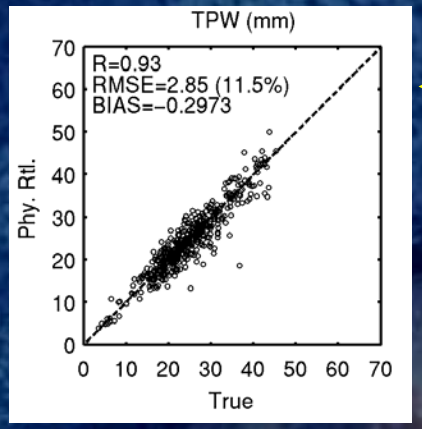
- SEVIRI onboard MSG is the best proxy for ABI LAP sounding validation.
- ECMWF 12-hr analysis profile products are good for full disk evaluation.
- Radiosonde profiles collected in AEROSE is the best for validation over ocean.
- AMSR-E TPW product is useful over ocean too.
- Operational radiosonde dataset collected twice a day at WMO weather stations is the best for validation over land.
- An 18-month SEVIRI database with collocated ECMWF analysis profiles, as well as operational radiosonde profiles are ready for a comprehensive validation.
- The long-term dataset makes it possible to validate the algorithm's seasonal, diurnal, and latitudinal performance, or the performance over different surfaces (land, water and desert)

Validation Results

Temperature/Moisture Profile Validation over Land

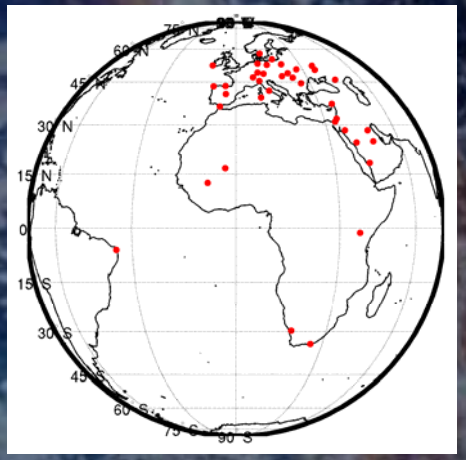
The following images illustrate the temperature/moisture/TPW retrieval by SEVIRI against 475 radiosonde measurements over land for August 2006





← **TPW**

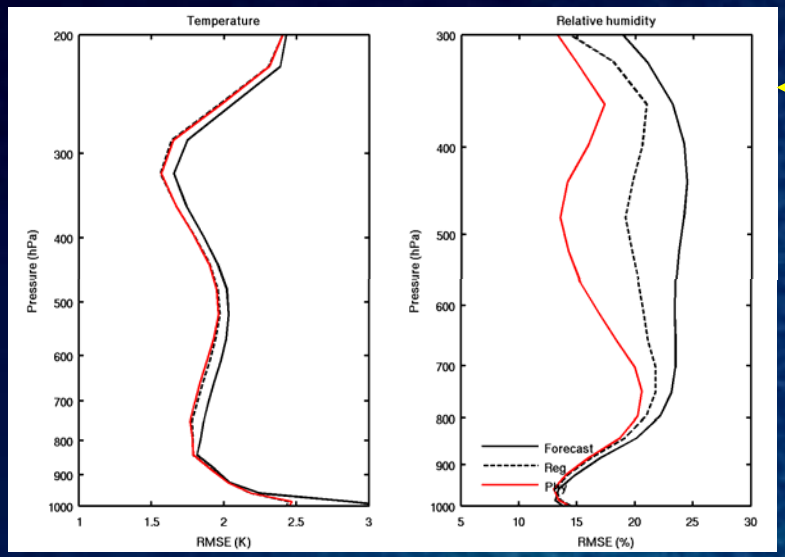
Sample sites



Accuracy = -0.3 mm and Precision = 2.85 for TPW
Improvement for temperature profile is trivial

Temperature/Moisture Profile Validation over Land (con'd)

The following images illustrate the temperature/moisture/TPW retrieval by SEVIRI against 203491 ECMWF analysis profiles over land for January 2008

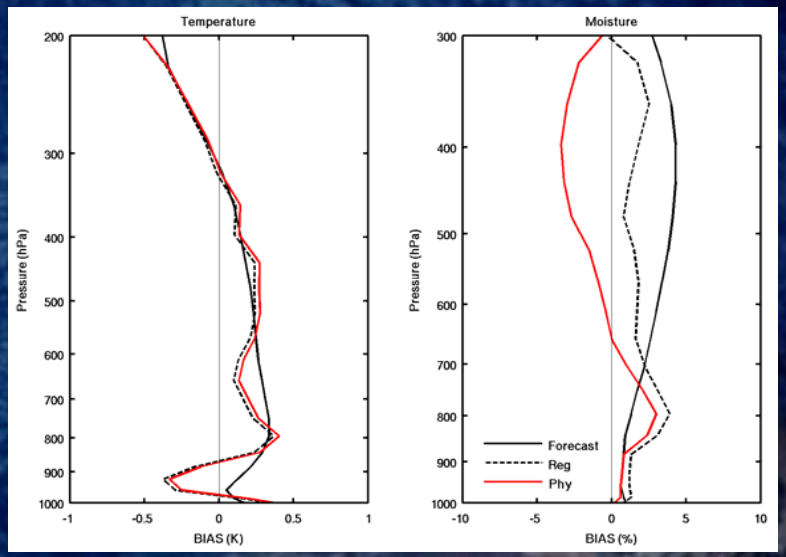


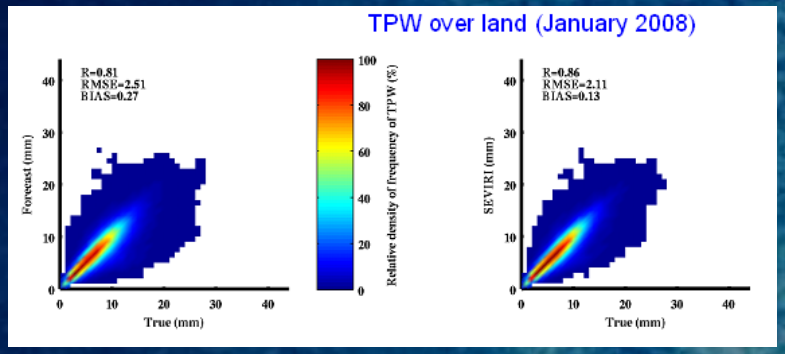
RMSE

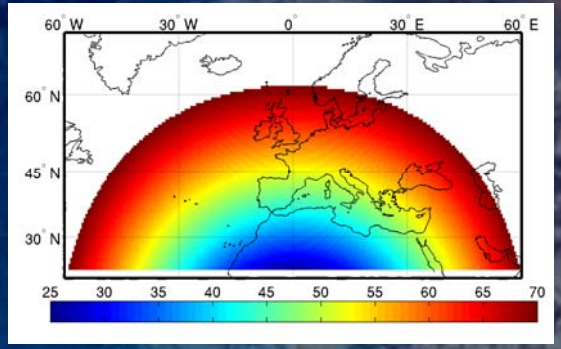
(Precision)

BIAS

(Accuracy)



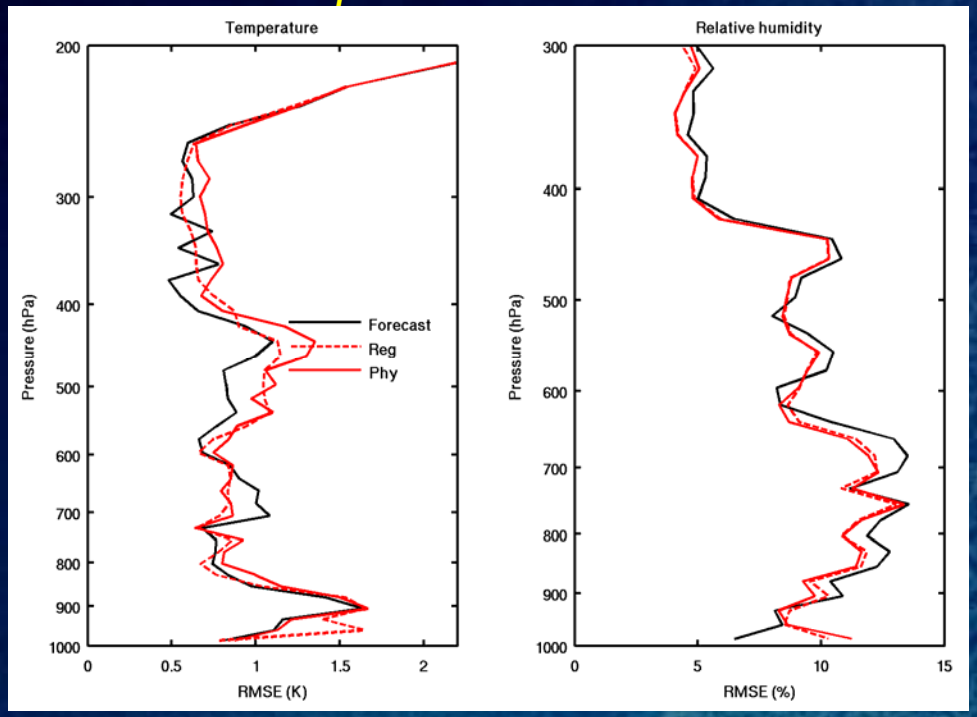


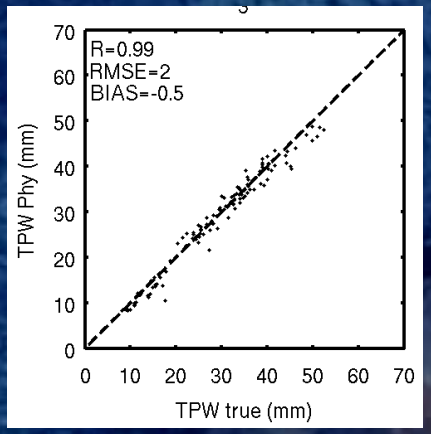


Sample area

Temperature/Moisture Profile Validation over Ocean

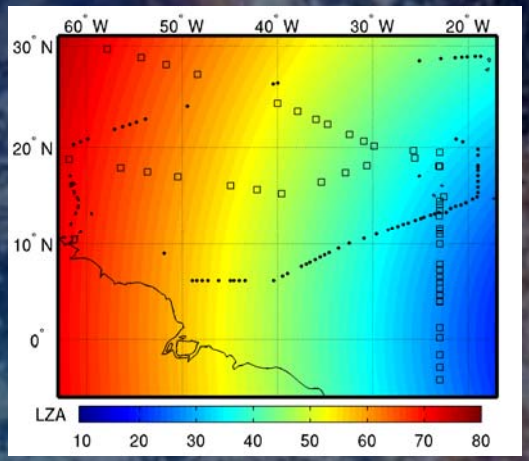
The following images illustrate the temperature/moisture/TPW retrieval by SEVIRI against 121 radiosonde measurements over ocean for summer of 2004 and 2006 as part of AEROSE





← **TPW**

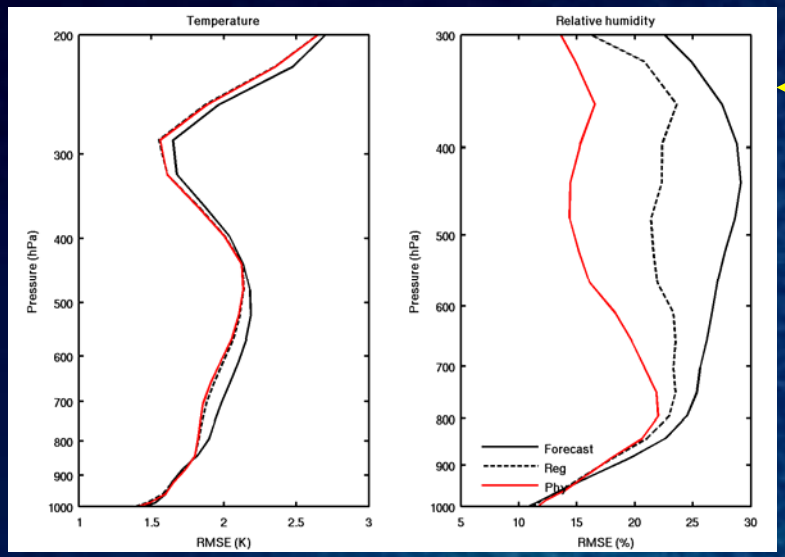
Sample sites



Accuracy = -0.5 mm and Precision = 2 mm for TPW
Improvement for T/W profiles over tropical ocean is trivial

Temperature/Moisture Profile Validation over Ocean (con'd)

The following images illustrate the temperature/moisture/TPW retrieval by SEVIRI against 149721 ECMWF analysis profiles over ocean for January 2008

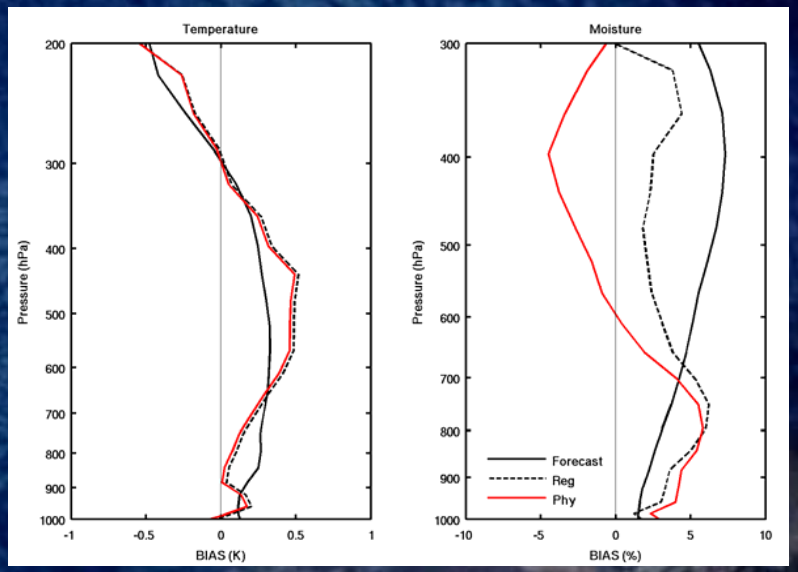


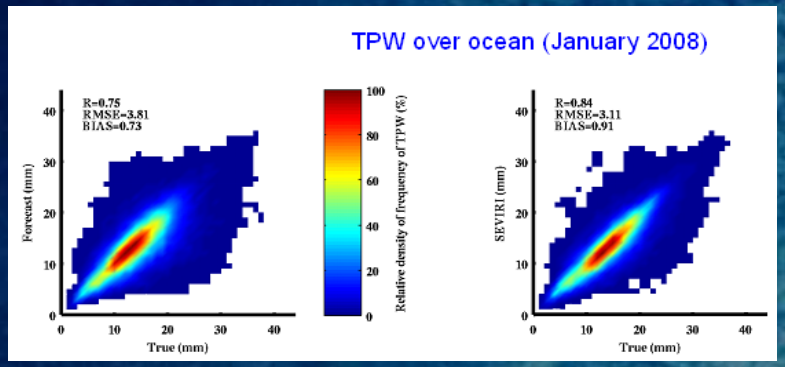
RMSE

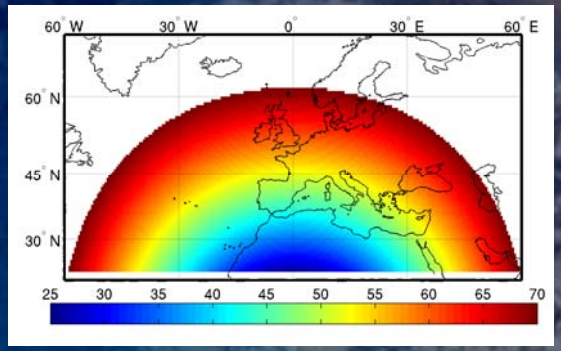
(Precision)

BIAS

(Accuracy)



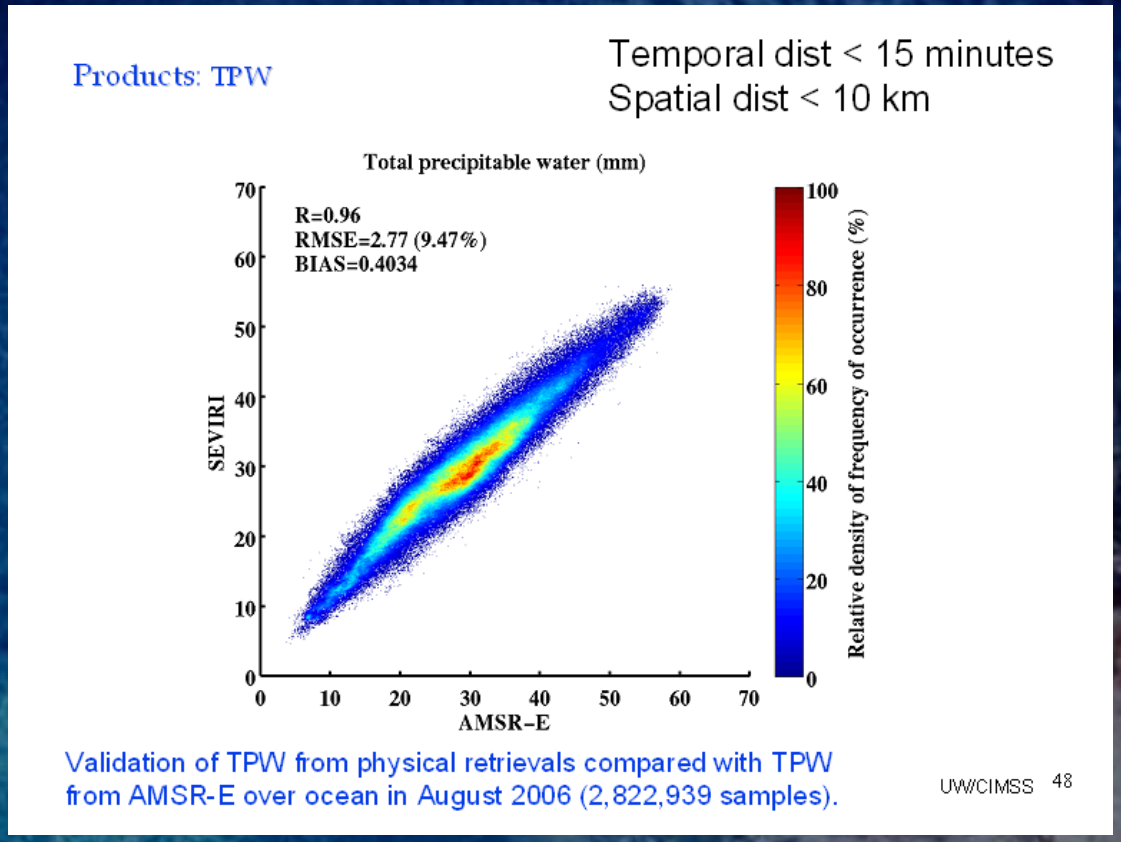




Sample area

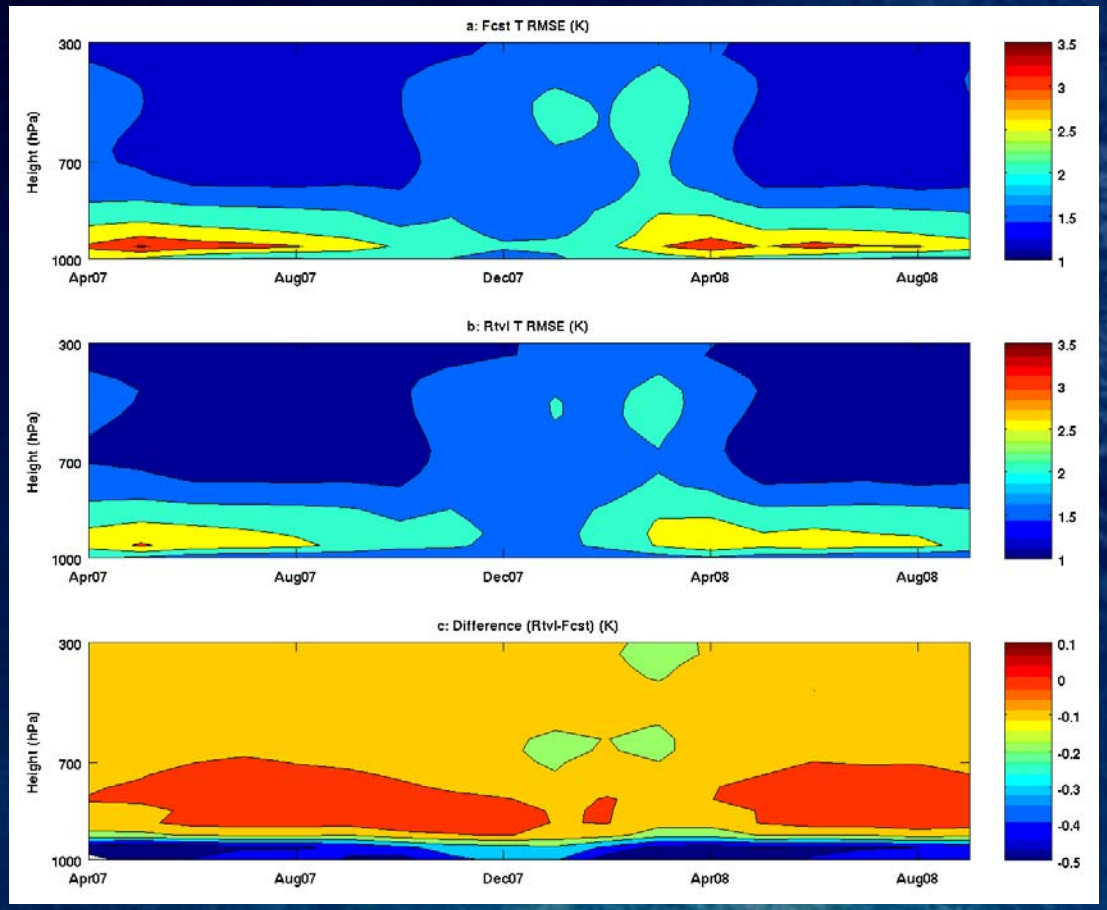
AMSR-E-based TPW Validation over Ocean

- AMSR-E level-2 provides TPW over ocean.
- Accuracy = 0.4 mm
- Precision = 2.77 mm



Temperature Profile Validation over long term

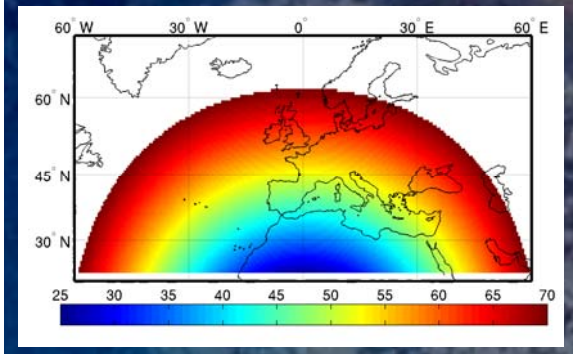
The following images illustrate the temperature profile retrieval by SEVIRI against ECMWF forecast and analysis profiles over all surfaces between April 2007 and September 2008



Improvement is trivial (0 to 0.1 K) at upper levels;

Precision improves about 0.5 K at near surface layer;

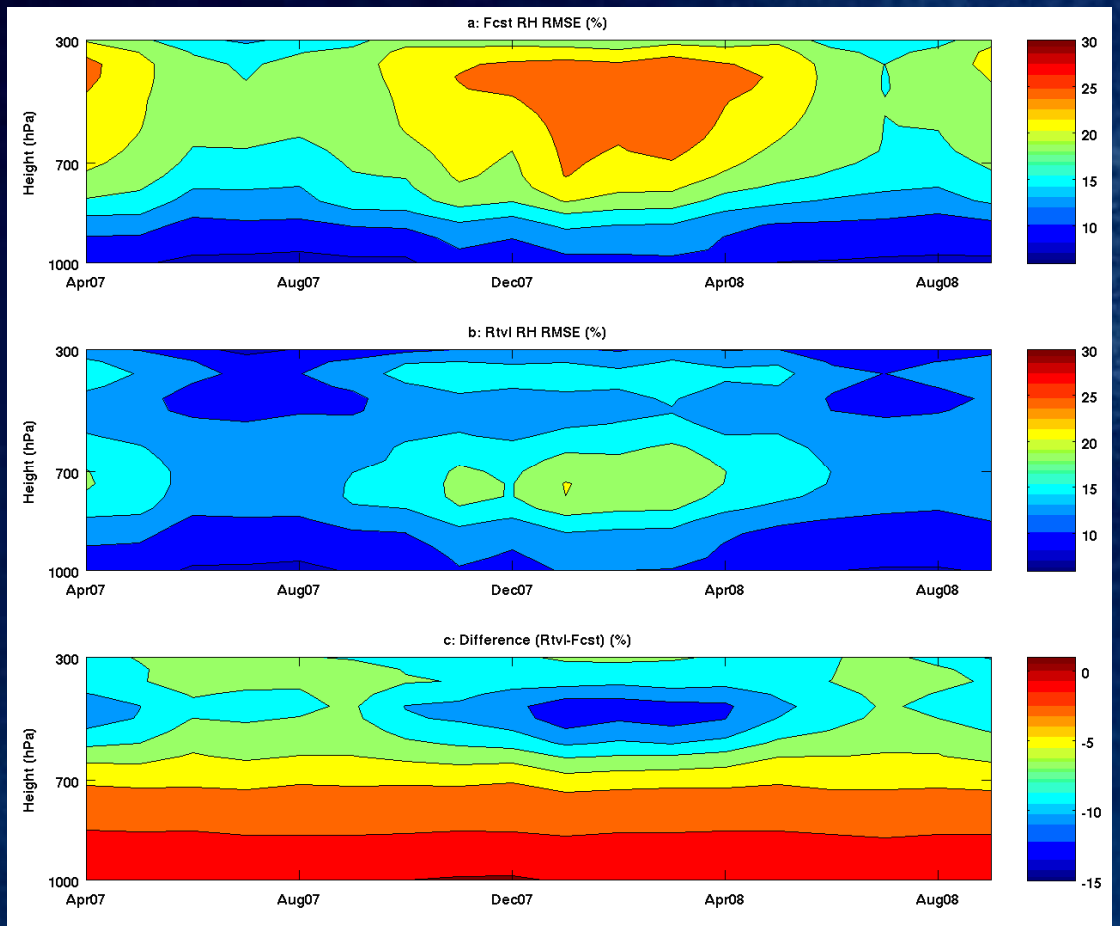
Algorithm performances better in summer than in winter



Sample area

Moisture Profile Validation over long term (con'd)

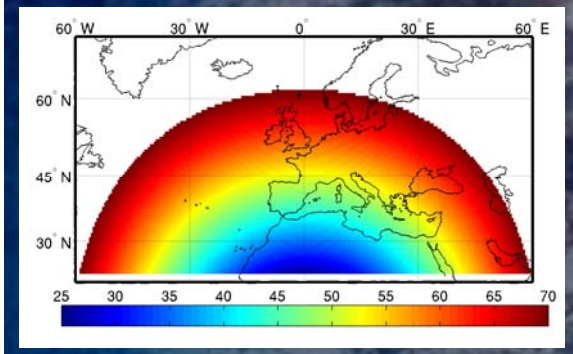
The following images illustrate the moisture profile retrieval by SEVIRI against ECMWF forecast and analysis profiles over all surfaces between April 2007 and September 2008



Improvement is trivial (0 to 3%) at low levels (below 700 hpa);

Precision improves more than 5% at high levels (above 700 hPa);

Algorithm performances better in winter than in summer



Sample area

Preliminary results from LAP algorithm with SEVIRI

Comparison with requirements

Product	*Accuracy (Req.)*	*Precision (Req.)*	*Accuracy (SEVIRI)*	*Precision (SEVIRI)*
Temperature profile (K)	1K below 400 hPa and above boundary	2K below 400 hPa and above boundary	0.5K below 400 hPa and above boundary	<1.9K below 400 hPa and above boundary
Moisture profile (RH)	Sfc-500 mb: 18% relative humidity; 500-300 mb: 18% relative humidity; 300-100 mb: 20% relative humidity	Sfc-500 mb: 18% relative humidity 500-300 mb: 18% relative humidity 300-100 mb: 20% relative humidity	5%	Sfc-900 hPa: 12% 900-600 hPa: 18% 600-300 hPa: 15%
Derived stability indices	LI: 2 K CAPE: 1000 J/ kg SI: 2 K TT: 1 KI: 2	Lifted Index: 6.5 K CAPE: 2500 J/ kg Showalter index: 6.5 K Total totals Index: 4 K index: 5	LI: 0.7 K CAPE: 50 J/KG SI: 0.5 K TT: 0.5 K KI: 1.5 K	LI: 2 K CAPE: 200 J/ kg SI: 2 K TT: 3.5 K KI: **6 K**
TPW	1 mm	3 mm	0.3 mm	< 3 mm

Summary

- The ABI LAP Sounding Algorithm provides improved mid and upper-tropospheric moisture information over the forecast.
- Version 5 is delivered and the 100% ATBD is coming.
- These products meet the specifications (with the exception of KI, from SEVIRI, over land) and are proving useful to downstream applications.
- Retrievals from the ABI should be improved compared to SEVIRI.