Variational Retrieval of Eastern Pacific Marine Atmospheric Boundary Layer Parameters using ATOVS with the COAMPS™ Mesoscale Forecast System

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Motivation

To investigate the ability of an operational IR and MW atmospheric sounding system to contribute information to a mesoscale NWP system within the summertime eastern Pacific (EPAC) environment.

- Advanced TIROS Operational Vertical Sounder (ATOVS)
- Coupled Ocean – Atmosphere Mesoscale Prediction System (COAMPS™) and the Naval Research Laboratory (NRL) Atmospheric Variational Data Assimilation System (NAVDAS)

Approach

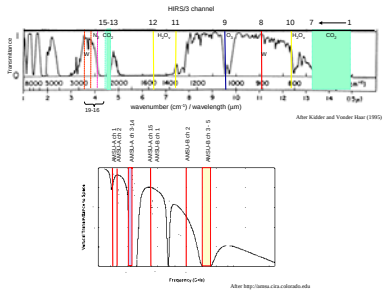
Information content and retrieval error sensitivity analyses based upon representative EPAC background state vectors

- Quantify total profile temperature and humidity information
- Establish the *a priori* elements critical for successful 1DVAR retrievals within the clear and cloudy sky EPAC environment

1DVAR profile temperature and humidity retrievals using both simulated and actual ATOVS observations constrained by the COAMPS™ short-term forecasts and synoptically relevant background errors.

The time period of interest coincided with the Dynamics and Chemistry of Marine Stratocumulus (DYCOMS) Phase II field study (July 2001).

ATOVS Channels



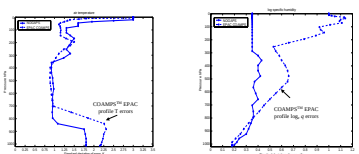
ATOVS Instrument and RTTOV-6 Forward Model Errors (R = O + F)

CH	$(R_{ii})^{1/2}$ K HIRS/3	AMSU-A	AMSU-B
1	2.78	2.13	1.96
2	0.77	2.43	1.29
3	0.58	1.24	1.15
4	0.37	0.31	0.78
5	0.27	0.32	0.98
6	0.27	0.32	
7	0.24	0.31	
8	0.21	0.31	
9	0.24	0.37	
10	0.26	0.40	
11	0.48	0.40	
12	0.98	0.49	
13	0.22	0.58	
14	0.22	0.95	
15	0.31	1.93	

Background Error Covariance Matrix (B)

$\mathbf{B}_N$ - Globally averaged NOGAPS errors
- First-order approximation
- No surface-atmosphere error correlations

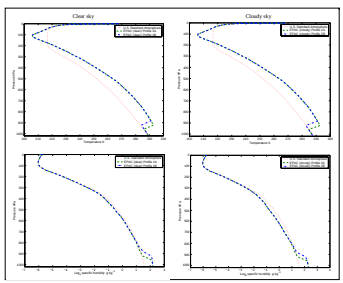
$\mathbf{B}_C$ - COAMPS™ EPAC 6-hr forecast errors
- Correlated surface-atmosphere temperature errors



Background error $(B_{ii})^{1/2}$

	NOGAPS	COAMPS™	Unit
T_{2m}	1.80	2.15	K
$\log_e q_{2m}$	0.18	0.18	g kg^{-1}
P_s	3.38	3.38	hPa
u_{2m}	0.00	2.00	ms^{-1}
v_{2m}	0.00	2.00	ms^{-1}
T_{skin}	1.57	1.57	K
P_{CT}	N/A	Various	hPa
C_{FC}	N/A	Various	0-1
ε_{ii}	0.00	0.02	0-1

Representative EPAC Background State Vectors ($\mathbf{x}^b$)



Summertime conditions
Clear and cloudy sky

- **Profile O_3**: RTTOV-6 reference profile
- **Profile LWP**: 2A1 90 g m^{-2}
  2B2 285 g m^{-2}
- **Surface elements**: T_{2m} , $\log_e q_{2m}$, P_s , u_{2m} , v_{2m} , T_{skin}
- **Cloud elements**: P_{CT} 2A1 957.44 hPa
  2B2 922.46 hPa
  C_{FC} 1.00
- **Emissivity**: IR ISEM-6
  MW FASTEM

Part I: Information Content and Retrieval Error Sensitivity

Information matrix = Hessian of cost function **J(x)**

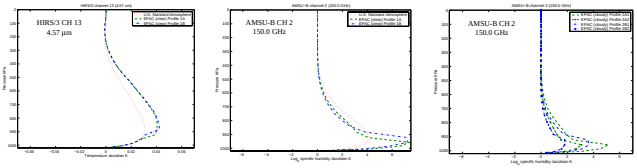
$$0.5\nabla^2_x J(\mathbf{x}) = \mathbf{S}(\mathbf{x})^{-1} = \mathbf{B}^{-1} + \mathbf{H}^T \mathbf{R}^{-1} \mathbf{H}$$

Alternate form of retrieval error covariance

$$\mathbf{S} = \mathbf{B} - \mathbf{B}\,\mathbf{H}^T [\mathbf{H}\mathbf{B}\mathbf{H}^T + \mathbf{R}]^{-1}\,\mathbf{H}\,\mathbf{B}$$

Profile T and Log$_e$ q Jacobians

(Column elements of **H** calculated using RTTOV-6)



Singular Value Decomposition ($\mathbf{H}' = \mathbf{R}^{-½}\,\mathbf{H}\,\mathbf{B}_N^{½}$)

The effective rank = number of singular values > ~ 1

Elements outside effective row space cannot be measured.

$$ds_i = \sum_i \frac{\lambda_i^2}{(1+\lambda_i^2)} = tr(\mathbf{A})$$

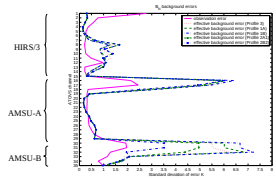
Total degrees of freedom for signal			
EPAC (clear) Profile 1B		U.S. Standard Atmosphere	
Full **B**	Diagonal **B**	Full **B**	Diagonal **B**
7.4	6.9	7.2	6.7

Effective Background Error ($\mathbf{H}\,\mathbf{B}_N\,\mathbf{H}^T$)

Projects **B** into radiance space and allows for direct comparison with **R**.

For channels with large effective background error, the retrieval is nearly insensitive to the background and the solution is determined primarily by the satellite observation.

Larger effective background error for AMSU window channels

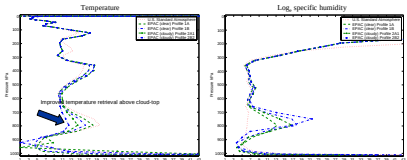


Vertical Resolution

Number of RTTOV-6 model levels per degree of freedom for signal

Reciprocal of the diagonal elements of $\mathbf{A} = \mathbf{K}\mathbf{H} = \mathbf{B}_N\mathbf{H}^T[\mathbf{H}\mathbf{B}_N\,\mathbf{H}^T + \mathbf{R}]^{-1}\,\mathbf{H}$

Vertical resolution ~ 100 hPa near clear sky MABL



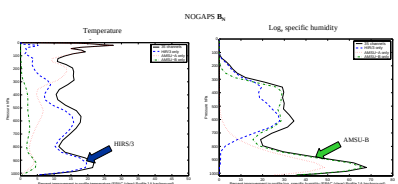
Theoretical Retrieval Performance (*P*)

$P = 100[1 - (S_{ii} / B_{ii})]$

As $S_{ii} / B_{ii} \rightarrow 0$ $P \rightarrow 100\%$

NOGAPS $\mathbf{B}_N$

As a function of ATOVS instrument



As a function of ATOVS "window channel"