The Impact of Background Error Statistics and MODIS Winds for AMPS

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Main objectives:

- Evaluation of the impact of Background Error (BE) statistics, using new analysis control variables.

- Impact of MODIS wind data in AMPS

Domain configuration:

AMPS Domain-1:

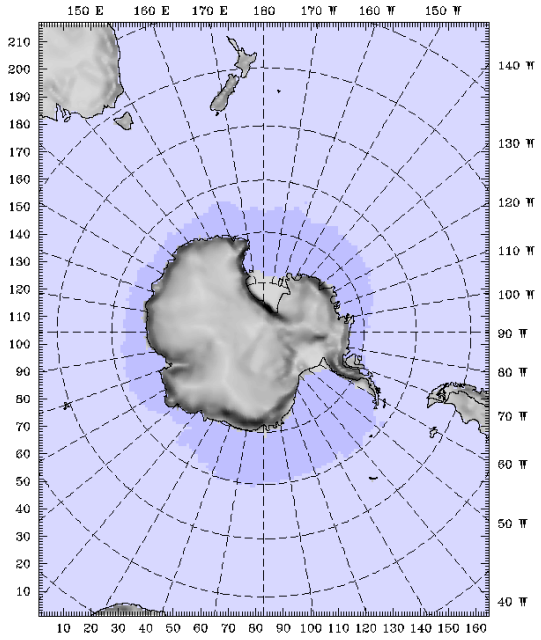
- Grid size: 60 Km.
- Grid numbers: 165 x 217 x 30
- Projection: Polar stereographic

AMPS Domain-2:

- Grid size: 20 Km.
- Grid numbers: 331 x 313 x 30
- Projection: Polar stereographic

Domain-1

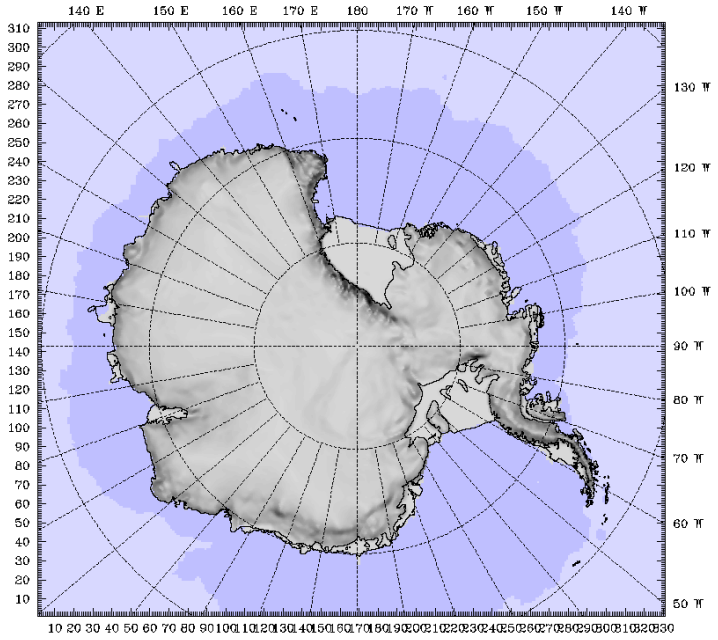
Dataset: d1 RIP: nest
Fcst: 0.00 h
Init: 1200 UTC Mon 05 Jun 06
Valid: 1200 UTC Mon 05 Jun 06 (0600 MDT Mon 05 Jun 06)



Model info: V3.4.0 Grell Eta PBL Reisner 1 60 km, 31 levels, 120 sec

Domain-2

Dataset: d2 RIP: nest
Fcst: 0.00 h
Init: 1200 UTC Mon 05 Jun 06
Valid: 1200 UTC Mon 05 Jun 06 (0600 MDT Mon 05 Jun 06)



Model info: V3.4.0 Grell Eta PBL Reisner 1 20 km, 31 levels, 40 sec

Analysis Algorithm:

The cost function **J** is defined as,

$$J(X') = 1/2\ [X'^{T}\ B^{-1}X' + \{H'(X') - d\}^{T}\ (O + F)^{-1}\ \{H'(X') - d\}\ ]$$

Where,

- X Analysis state vector
- X_b First Guess or the background state vector
- X' Analysis increments $= (X - X_b)$
- d Innovation vector $= (Y_o - H(X_b))$
- Y_o Observation vector
- H Forward Observation Operator (FOO)
- H' Tangent linear operator of the forward operator, H
- B Background (previous forecast) errors
- O Observation (instrumental) errors
- F Representivity (observation operator) errors
- ^{T} Adjoint operator

Analysis algorithm:

In terms of control variable (V), defined as $X' = UV$,
where $B = UU^T$, the cost function (J) can be written as

$$J(V) = 1/2\ [VV^T + \{H'(UV) - d\}^T (O + F)^{-1} \{H'(UV) - d\}\ ]$$

Thus minimization ($\partial J/\partial v = 0$) of cost function (J) leads to,

$$V - U^T H'^T (O + F)^{-1} (d - H'UV) = 0, \quad \text{or}$$

$AV = R$ ⟶ Analysis equation

Where,

$$A = [\ I + U^T H'^T (O + F)^{-1} H'U\ ], \quad \text{and}$$
$$R = U^T H'^T (O + F)^{-1} d$$

Analysis equation is solved for V and thus X' is determined

Analysis control Variables:

CV_Option = 2:

Control variables are defined in terms of the amplitudes of EOF's of the following variables:

- **Stream Function (ψ)**
- **Velocity potential (χ)**
- **Unbalanced pressure (p_u)**
- **Specific humidity (q)**

Balance part of pressure is determined by using balance equation:

$$\nabla^2 p_b = -\nabla \cdot \overline{\rho}[\overline{\mathbf{v}} \cdot \nabla \mathbf{v} + \mathbf{v} \cdot \nabla \overline{\mathbf{v}} + f\mathbf{k} \times \mathbf{v}]$$

Unbalanced pressure:

$$p_u = p - Cp_b$$

Analysis control Variable

CV_Option = 5:

Control variables are defined in terms of amplitudes of EOF's of the following variables:

- **Stream Function (ψ)**
- **Unbalanced velocity potential (χ_u)**
- **Unbalanced temperature (T_u)**
- **Unbalanced surface pressure (P_u)**
- **Pseudo relative humidity (q)**

Unbalanced part of χ, T & P is determined correspondingly in terms of its regression coefficient with the stream function. These regression coefficients (C_χ, C_T & C_P) are determined statistically.

$$X = X_u + C_\chi * \psi$$
$$T = T_u + C_T * \psi$$
$$P = P_u + C_P * \psi$$

Experiments details:

Exp A: Six hourly cycling with all QC'd obs (cv_options=2)

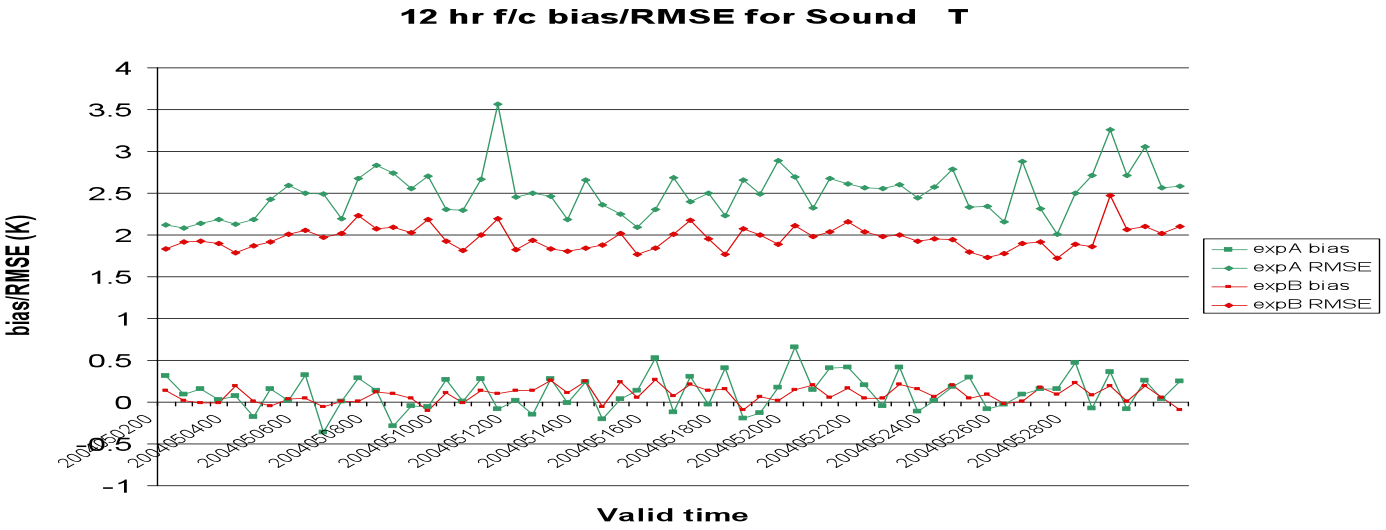
Exp B: Six hourly cycling with all QC'd obs (cv_options=5)

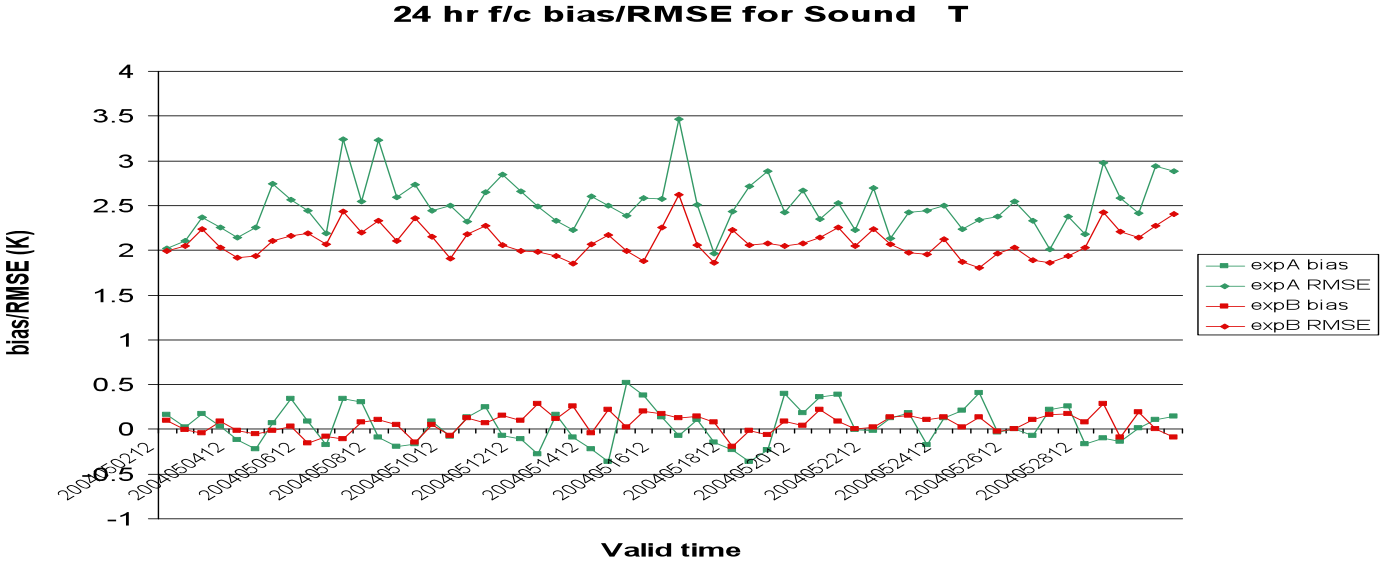
Cycling period : 01-31 May, 2004

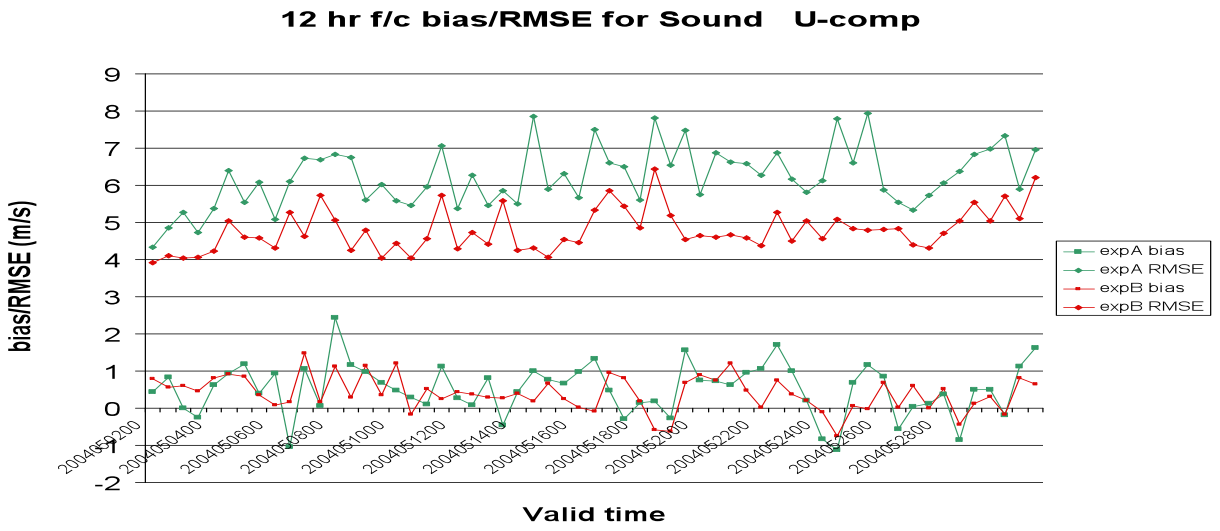
QC'd obs : Generated using WRF-Var with AVN analysis as FG

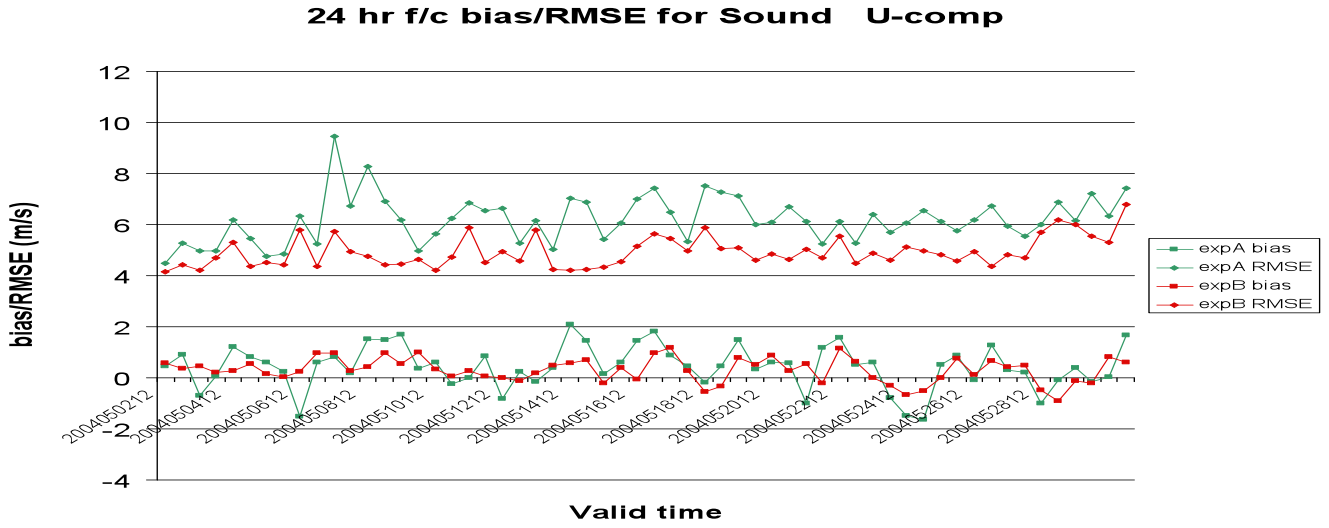
Both experiments are run with "check_max_iv = .FALSE" to ensure that same observations are assimilated in both the experiments.

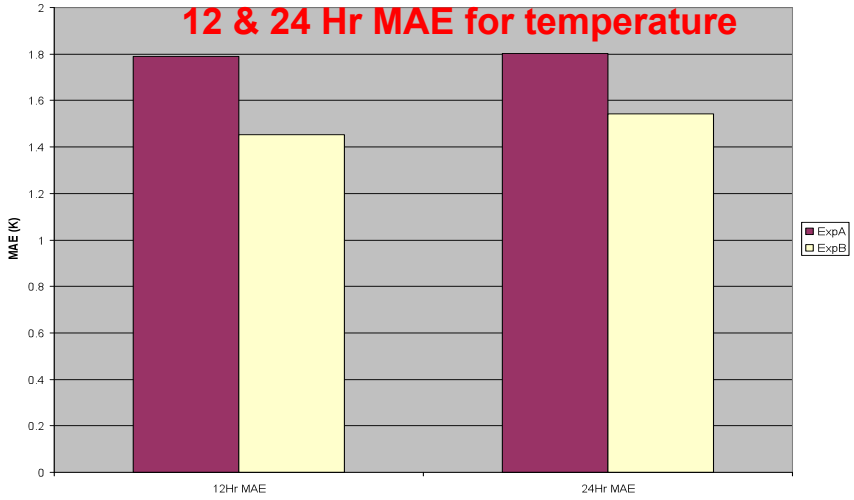
Verification criteria: 12 & 24 hour forecasts for each experiments are verified against "sound" wind & temperature observations. Scores for BIAS, RMSE & MAE are compared.

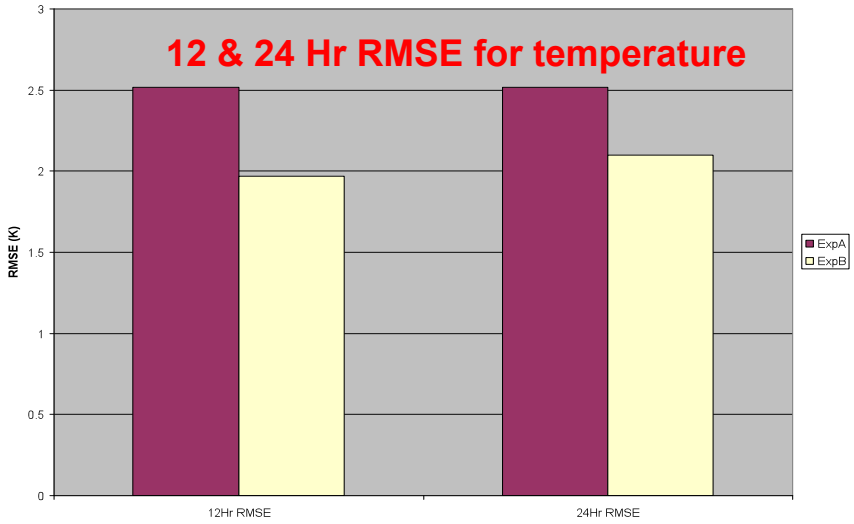

12 hr f/c bias/RMSE for Sound T
bias/RMSE (K)
Valid time
expA bias
expA RMSE
expB bias
expB RMSE

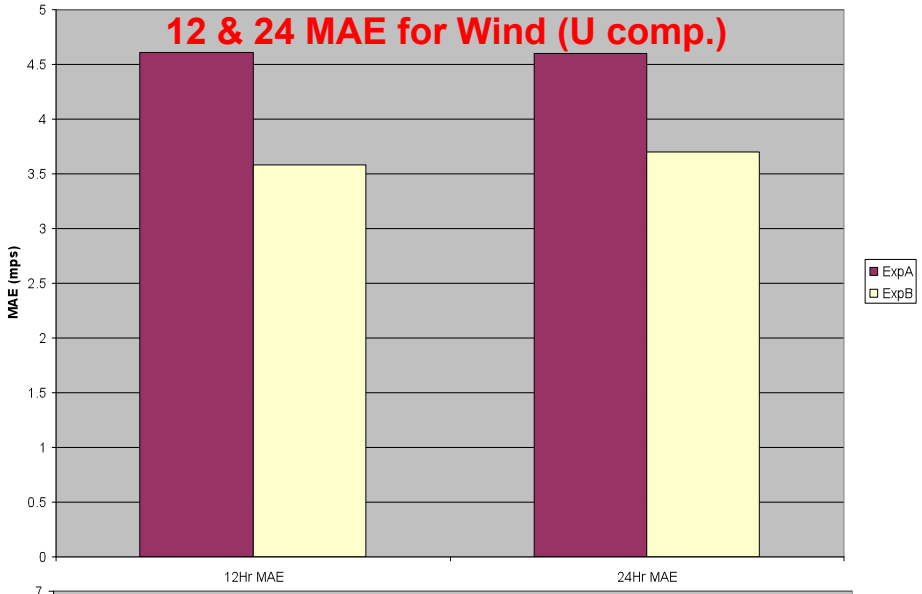

24 hr f/c bias/RMSE for Sound T
bias/RMSE (K)
Valid time
expA bias
expA RMSE
expB bias
expB RMSE

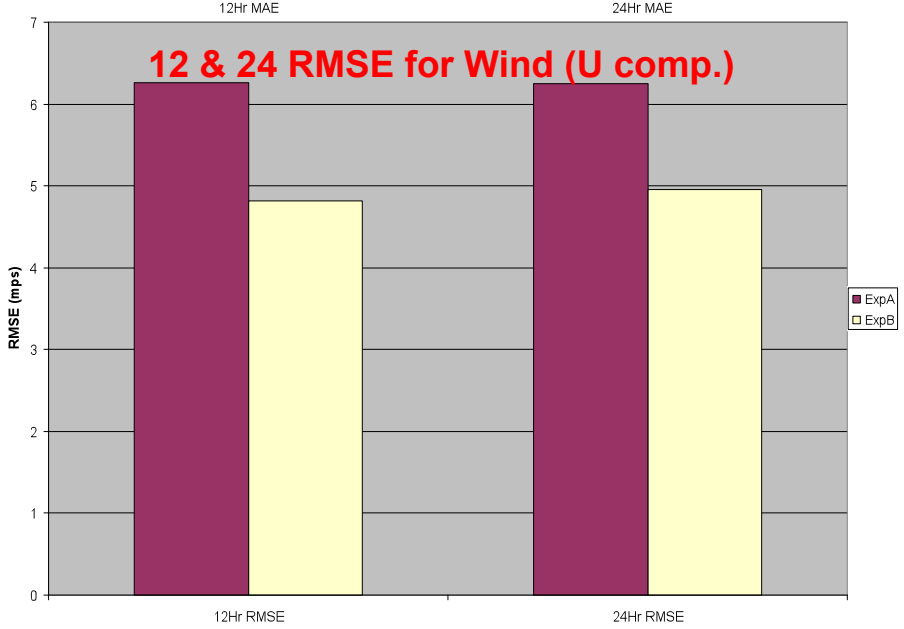

12 hr f/c bias/RMSE for Sound U-comp
bias/RMSE (m/s)
9
8
7
6
5
4
3
2
1
0
-1
-2
20040502200
20040503000
20040503400
20040503800
20040504200
20040504600
20040505000
20040505400
20040505800
20040510200
20040510600
20040511000
20040511400
20040511800
20040512200
20040512600
20040513000
20040513400
20040513800
20040514200
20040514600
20040515000
20040515400
20040515800
20040520200
20040520600
20040521000
20040521400
20040521800
20040522200
20040522600
20040523000
20040523400
20040523800
20040524200
20040524600
20040525000
20040525400
20040525800
20040526200
20040526600
20040527000
20040527400
20040527800
Valid time
expA bias
expA RMSE
expB bias
expB RMSE


24 hr f/c bias/RMSE for Sound U-comp
bias/RMSE (m/s)
12
10
8
6
4
2
0
-2
-4
20040502212
20040503012
20040503412
20040503812
20040504212
20040504612
20040505012
20040505412
20040505812
20040510212
20040510612
20040511012
20040511412
20040511812
20040512212
20040512612
20040513012
20040513412
20040513812
20040514212
20040514612
20040515012
20040515412
20040515812
20040520212
20040520612
20040521012
20040521412
20040521812
20040522212
20040522612
20040523012
20040523412
20040523812
20040524212
20040524612
20040525012
20040525412
20040525812
20040526212
20040526612
20040527012
20040527412
20040527812
Valid time
expA bias
expA RMSE
expB bias
expB RMSE


12 & 24 Hr MAE for temperature
MAE (K)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
12Hr MAE
24Hr MAE
ExpA
ExpB


12 & 24 Hr RMSE for temperature
RMSE (K)
3
2.5
2
1.5
1
0.5
0
12Hr RMSE
24Hr RMSE
ExpA
ExpB


12 & 24 MAE for Wind (U comp.)
MAE (mps)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
12Hr MAE
24Hr MAE
ExpA
ExpB


12 & 24 RMSE for Wind (U comp.)
RMSE (mps)
0
1
2
3
4
5
6
7
12Hr RMSE
24Hr RMSE
ExpA
ExpB

Conclusions:

- Both BIAS & RMSE corresponding to cv_options = 5 (ExpB) are less as compared to cv_options=2 (ExpA)
- Improvements for cv_options=5 compared to cv_options=2 is as follows:

	wind		Temperature	
Forecast	AME	RMSE	AME	RMSE
12 Hr.	25%	27%	22%	24%
24 Hr.	22%	20%	18%	17%