Evaluation of TAMDAR Data Impact on Forecast Error with WRFDA-FSO System

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About WRFDA FSO:

- Forecast Sensitivity to Observations (FSO) is an adjoint-based diagnostic tool that complements traditional denial experiments (OSEs)
- Capability: measure the observation (used in the data assimilation system) contribution to the forecast
- Constructed with WRF Model V3.3.1, WRF-DA V3.3.1, and WRFPLUS (the adjoint and tangent linear of WRF)

About WRFDA FSO—equations

Forecast Accuracy Norm: $e = (\mathbf{x}^f - \mathbf{x}^t)^T \mathbf{C} (\mathbf{x}^f - \mathbf{x}^t)$

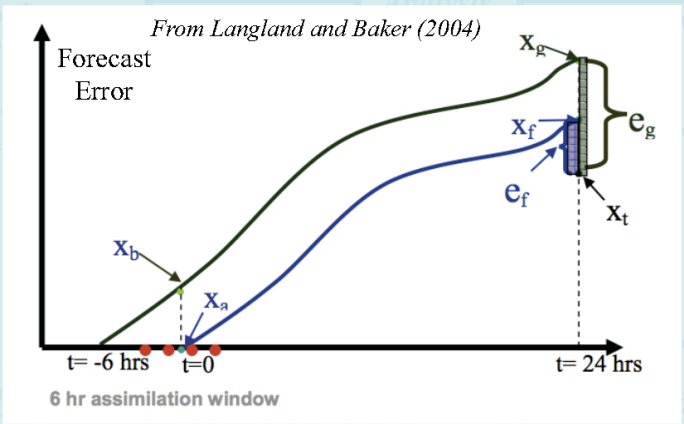
Total dry energy norm: $< \mathbf{x}, \mathbf{x} >= \frac{1}{2} \iint_{\Sigma} \iint [u'^2 + v'^2 + (\frac{g}{\overline{N}\overline{\theta}})\theta'^2 + (\frac{1}{\overline{\rho} c_s}) p'^2] d\Sigma$

Variant of the third order approximation:

$$\delta e_4 = (\mathbf{x}_a - \mathbf{x}_b)^T [\mathbf{M}_a^T C(\mathbf{x}_b^f - \mathbf{x}^t) + \mathbf{M}_a^T C(\mathbf{x}_a^f - \mathbf{x}^t)]$$

Observation Impact:

$$\frac{\partial e}{\partial y} = \frac{\partial e}{\partial \mathbf{x}_a} \frac{\partial \mathbf{x}_a}{\partial y}$$



x^t is the true state, estimated by the analysis at the time of the forecast
x^f is the forecast from analysis x^a
x^g is the forecast from first-guess at the time of the analysis x^a

Impact of analysis: $F = De^{f,g} = e^f - e^g$

Products:
$\delta F / \delta x_a^f = C(x_a^f - x^t)$
$\delta F / \delta x_b^f = C(x_b^f - x^t)$

About WRFDA FSO—flow chart *(from WRFDA tutorial, Auligne, 2011)*

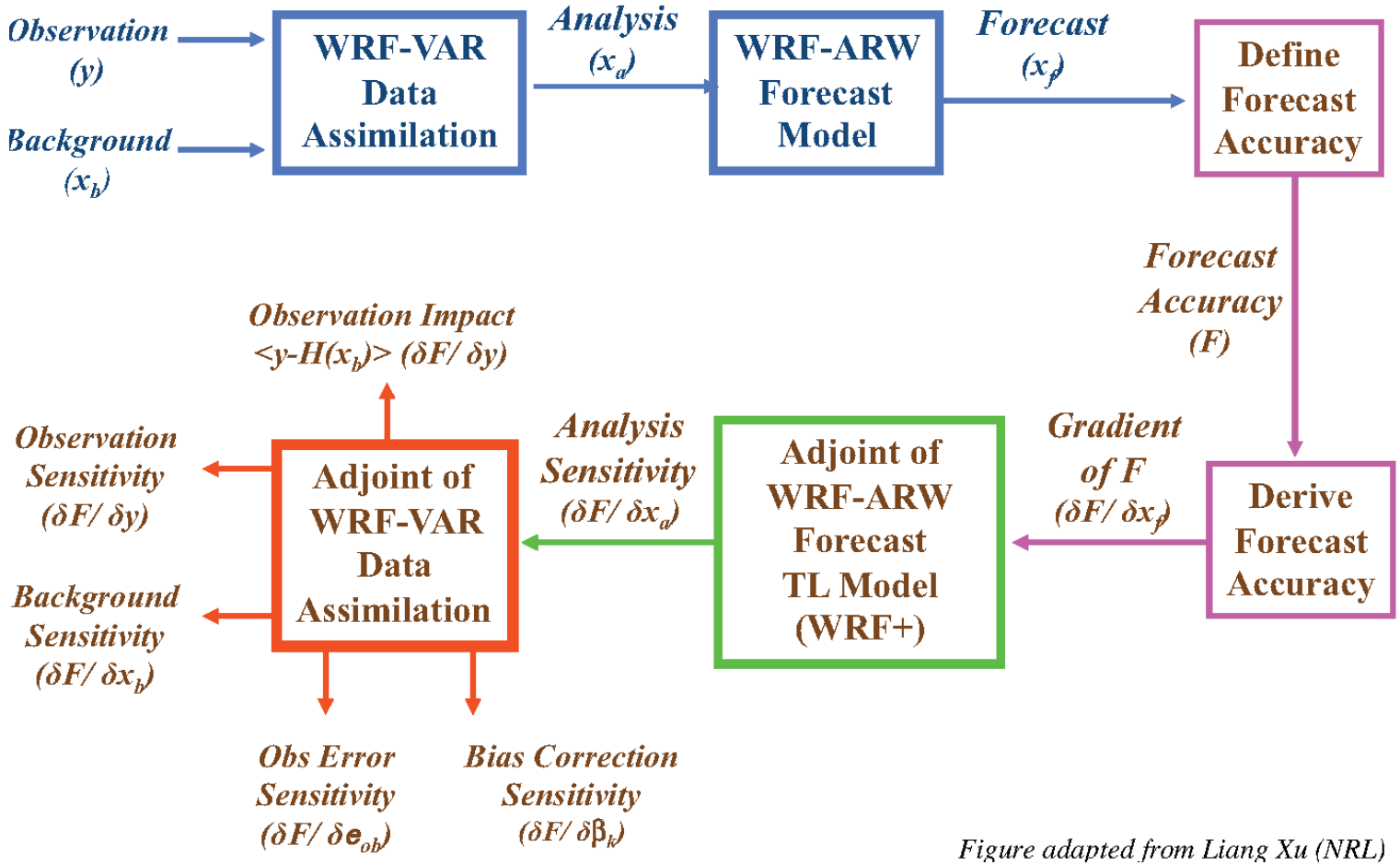
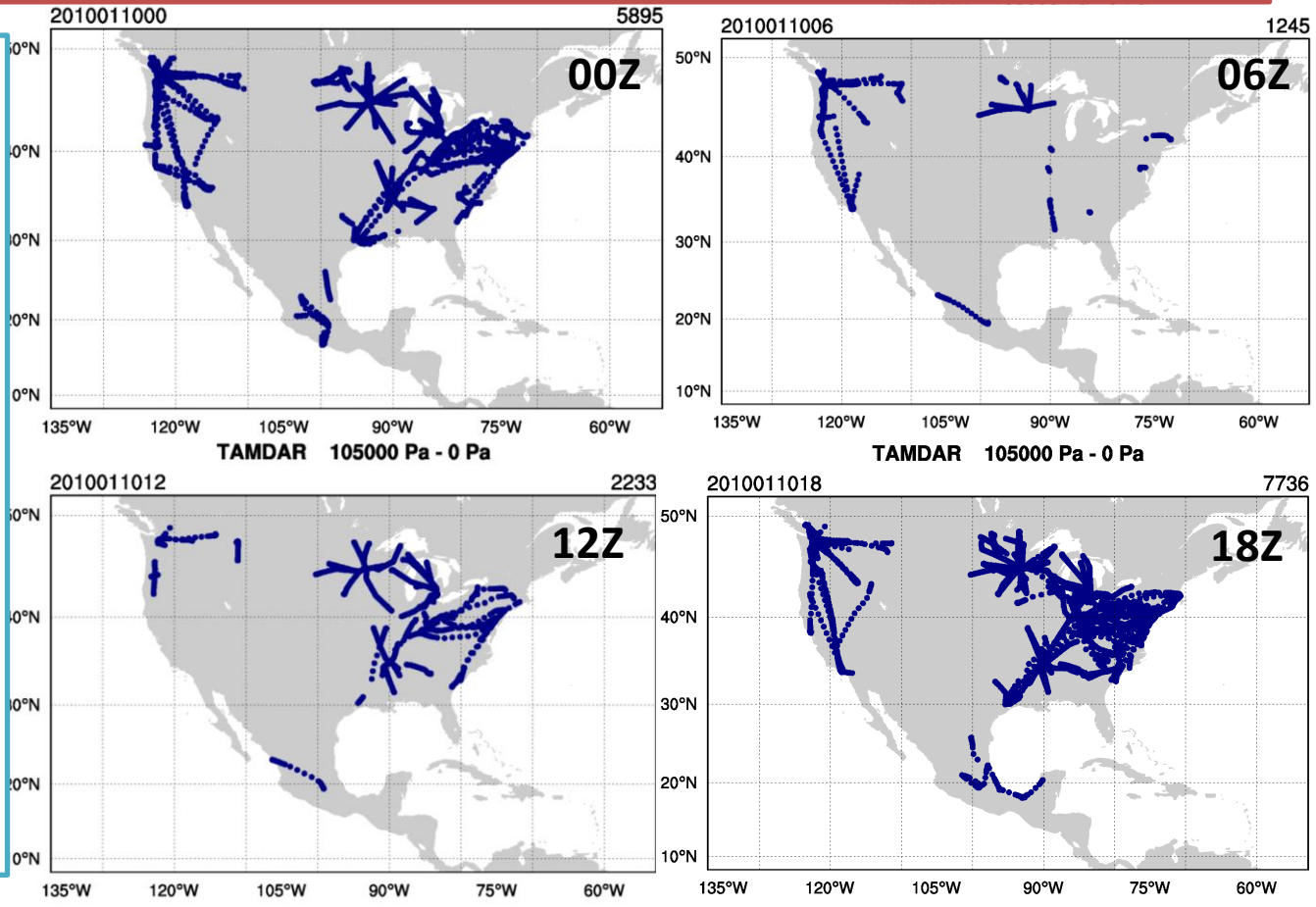


Figure adapted from Liang Xu (NRL)

About TAMDAR:

TAMDAR (Tropospheric Aircraft Meteorological Data Reports) measures not only wind and temperature, but also the humidity, turbulence, and icing which were not available in other most of the aircraft data.

- High spatiotemporal resolution
- Humidity measurements
- Low cruise heights, below the tropopause moisture resides and the convective activity region generally below 25000 feet (Daniels et al. 2006).



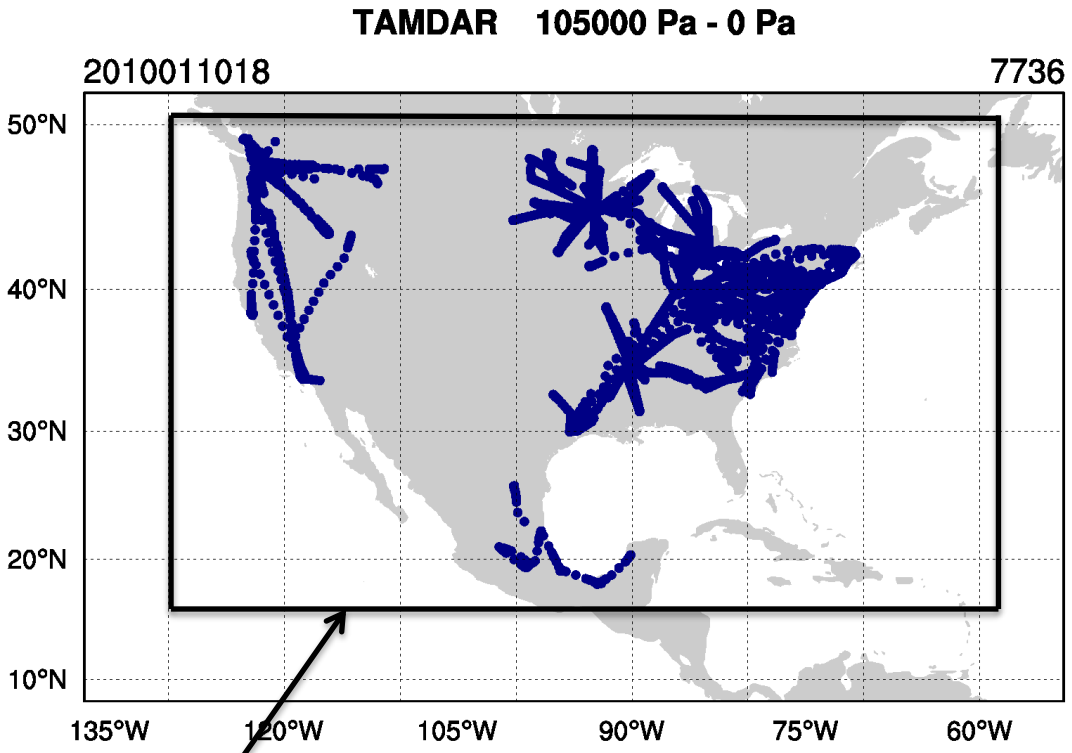
Motivation:

- Recent study showed assimilation of TAMDAR observations improves short-range regional forecast (Moninger, 2010; Gao et al. , 2011)
- FSO calculate the impact of each observation simultaneously
- FSO helps assess the impact of specific sensor and monitor the Data Assimilation
- Aim to assess the impact of TAMDAR observation in 24-h regional forecast with WRFDA-FSO

Experiment Design:

- Experiment period: Winter and summer month
  (January 1 – 30, 2010 & June 1 – 25, 2010)
- WRFDA 3D-Var (6-hour cold-start)
- 24 hours WRF forecast (X_a , X_b)
- 60km resolution CONUS domain
- Variant of third-order approximation (Gelaro et al. (2007))
- Reference state: Own (WRFDA) analysis
- Assimilate observation: raobs, synop, metar, pilot, profiler, airep, ship, buoy, gpsref, gpspw, satellite retrieval wind and TAMDAR

Model Configuration:

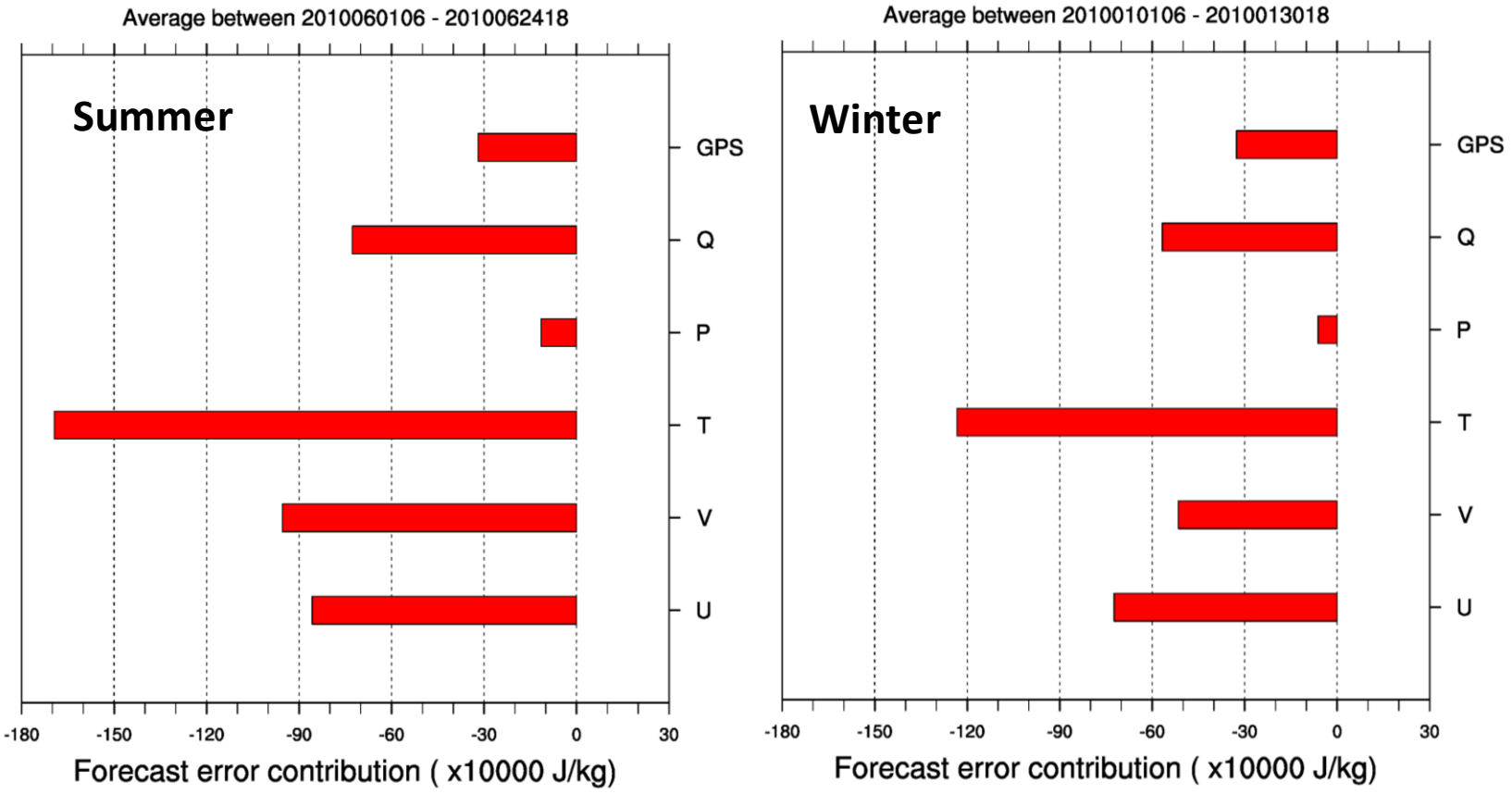


Target Domain

Grids: 134x84x35
DX/DY: 60km

Averaged 24-h forecast error reduction over time

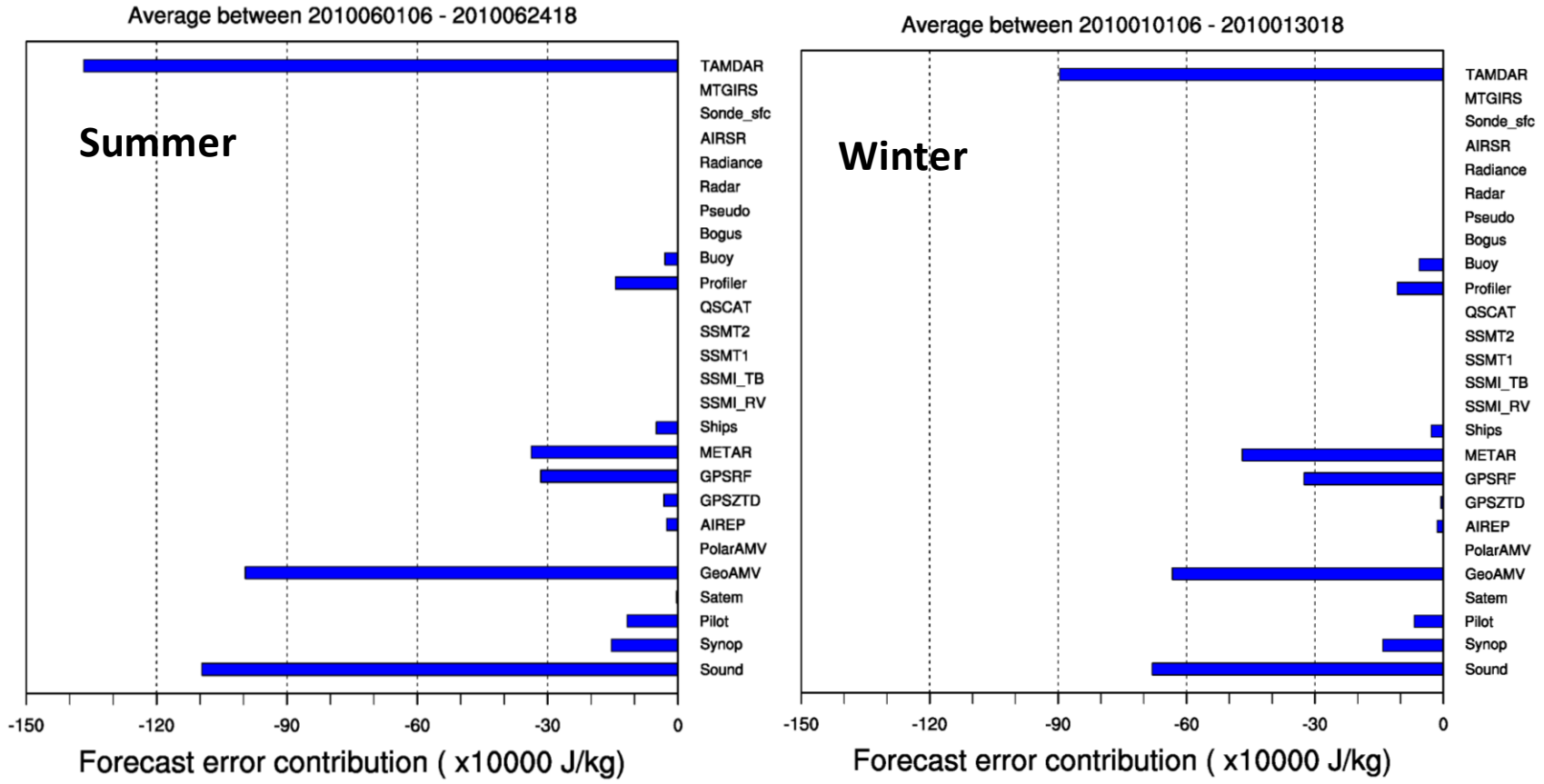
- by the observation variables



Greatest error reduction comes from the temperature and wind observations

Averaged 24-h forecast error reduction over time

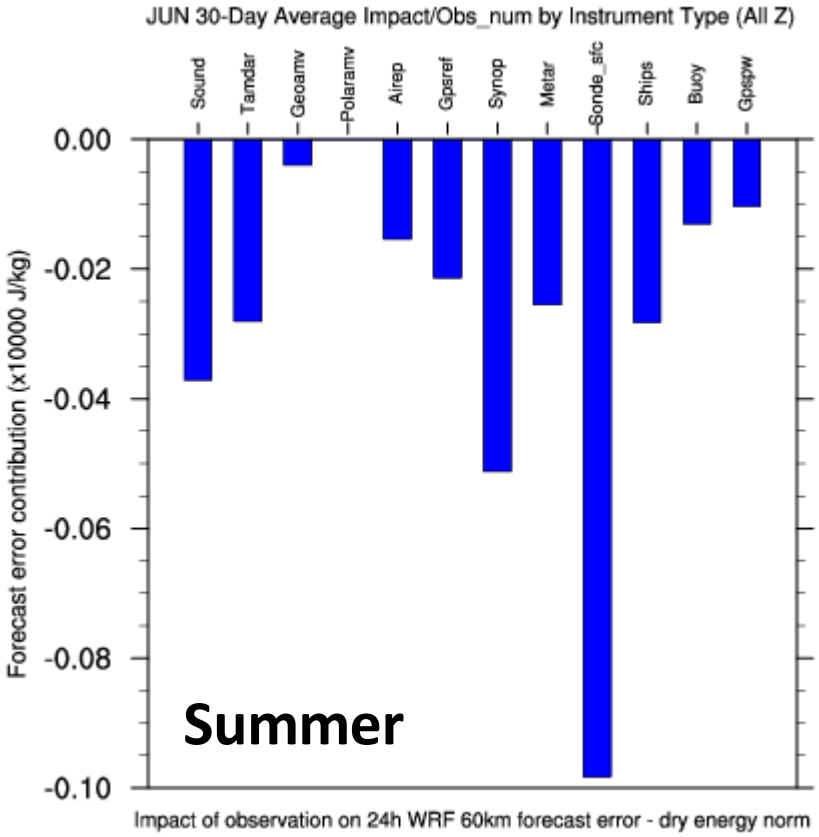
- by the observation instruments

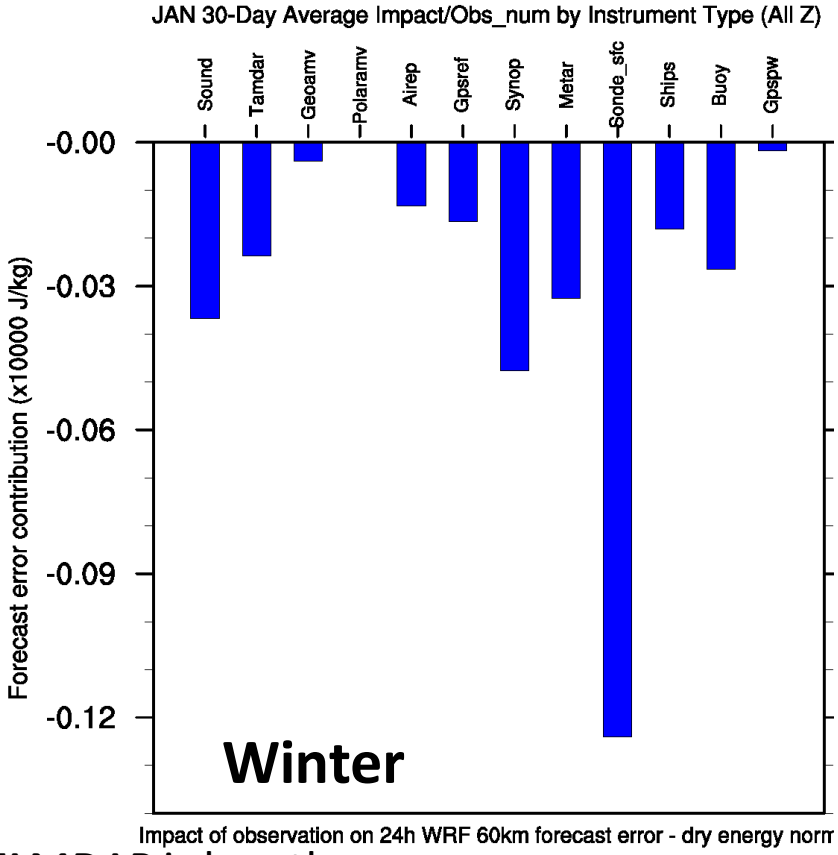


The largest error decrease is due to TAMDAR and Sound
smaller negative value in the winter and bigger errors in summer

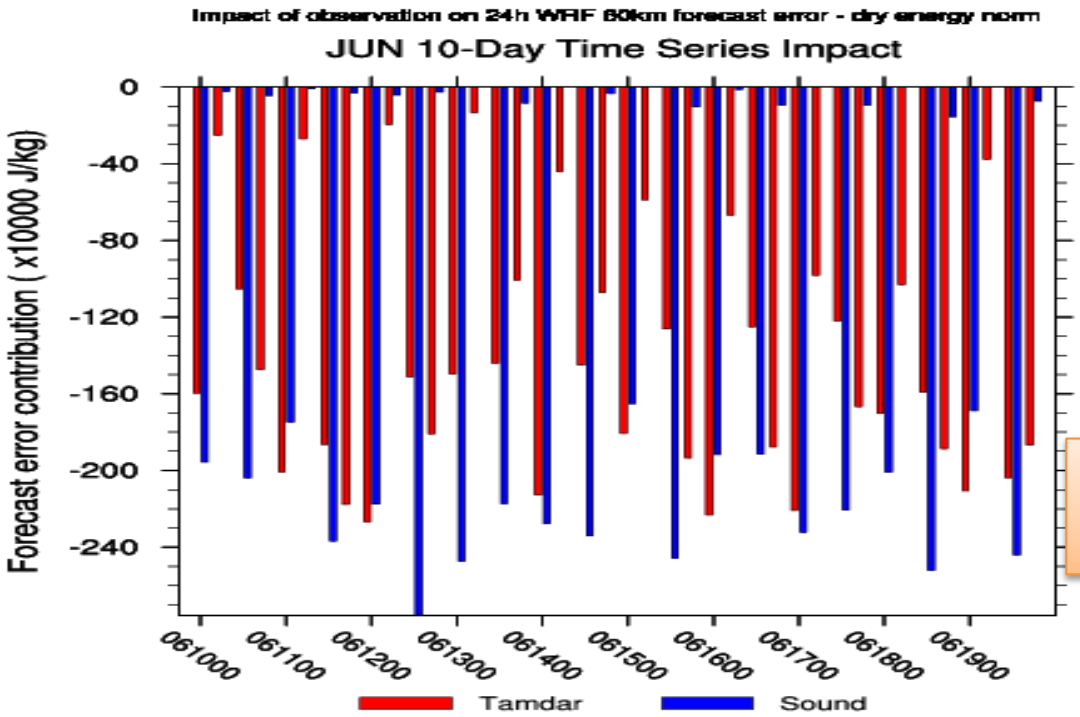
Averaged 24-h forecast error reduction over time

- per observation point





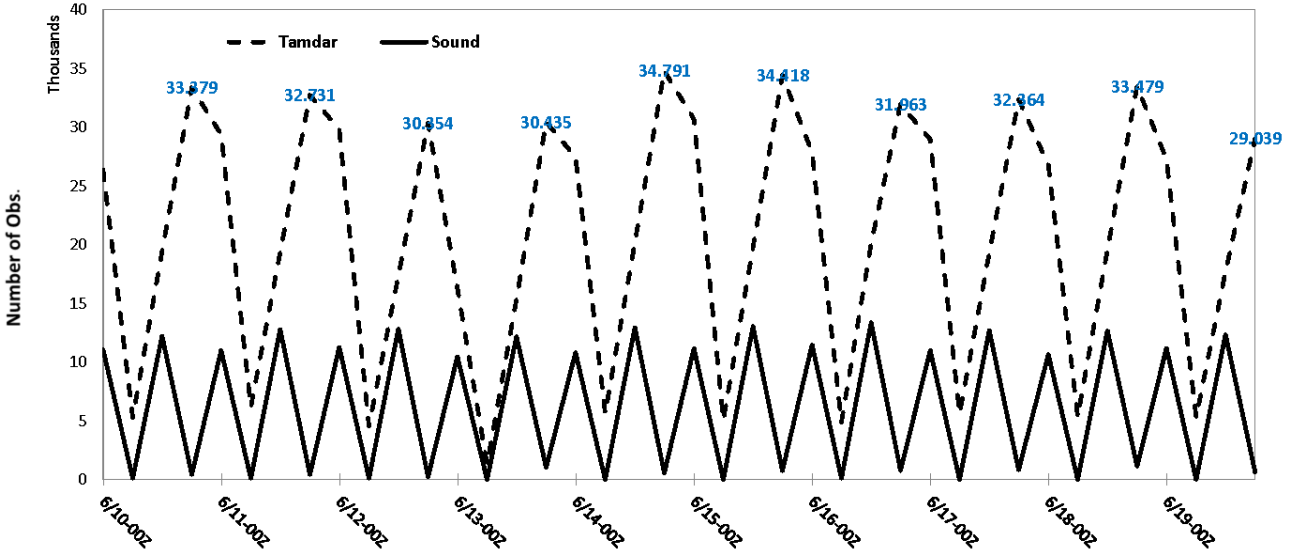
The single contribution from TAMDAR is less than Sound; Surface observation is very important



Time series of 24-h forecast error reduction

TAMDAR has the advantage at 18Z to reduce the forecast error

Time series of observation number assimilated in WRFDA 3D-Var

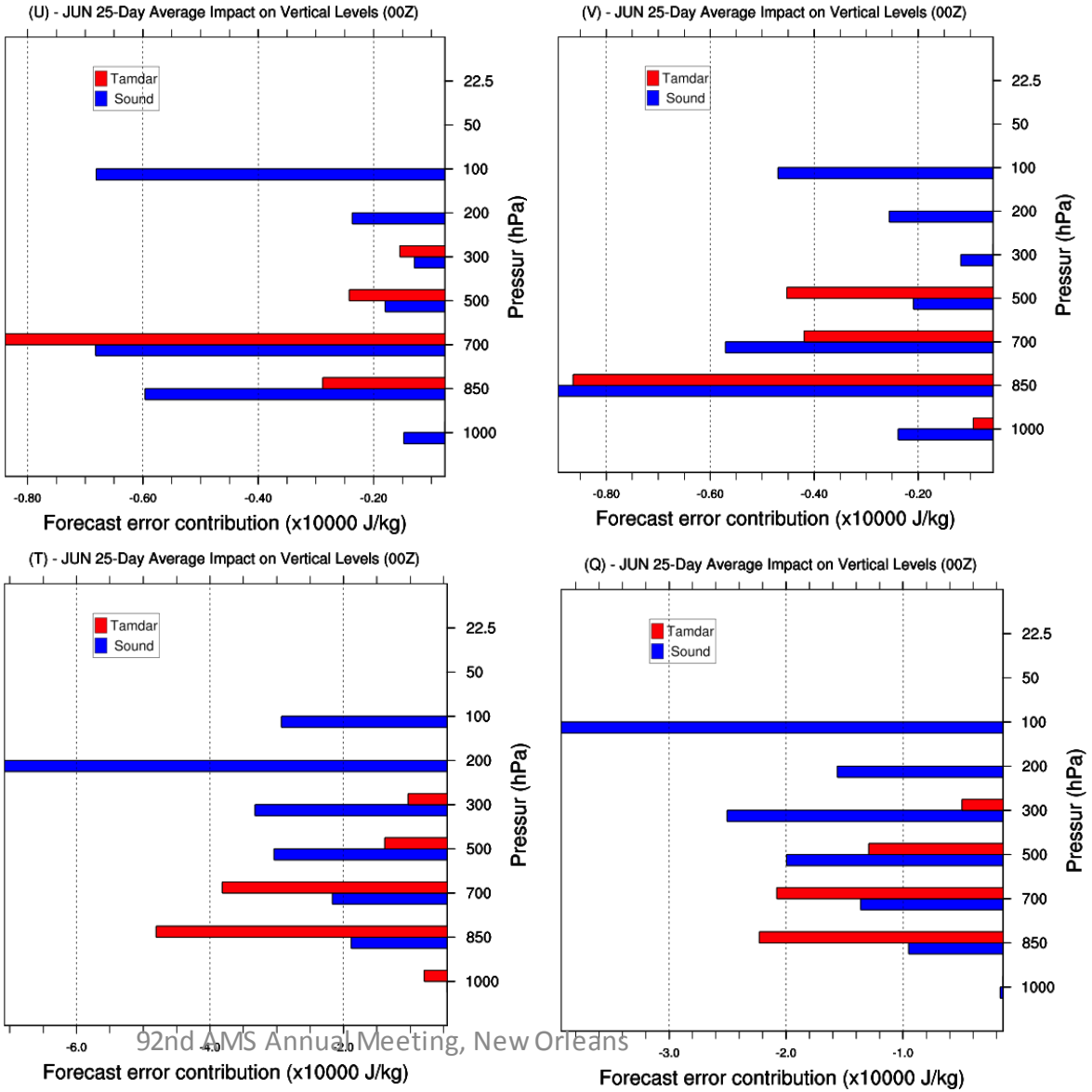


Averaged 00Z forecast error reduction -Vertical

Summer

Equivalent contribution from Wind

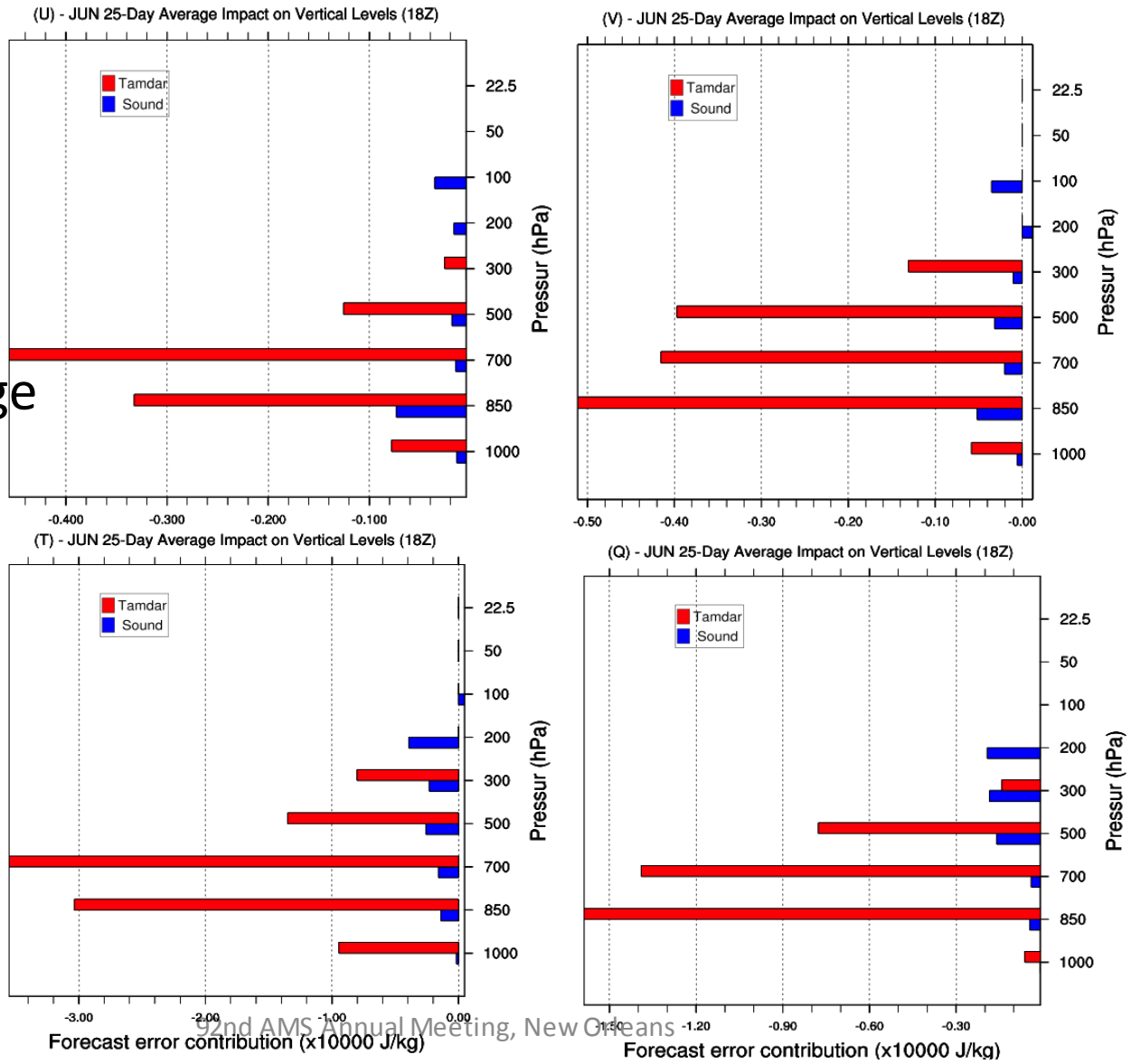
Tamdar has more contribution from T &Q at lower level.



Averaged 18Z forecast error reduction -Vertical

Summer

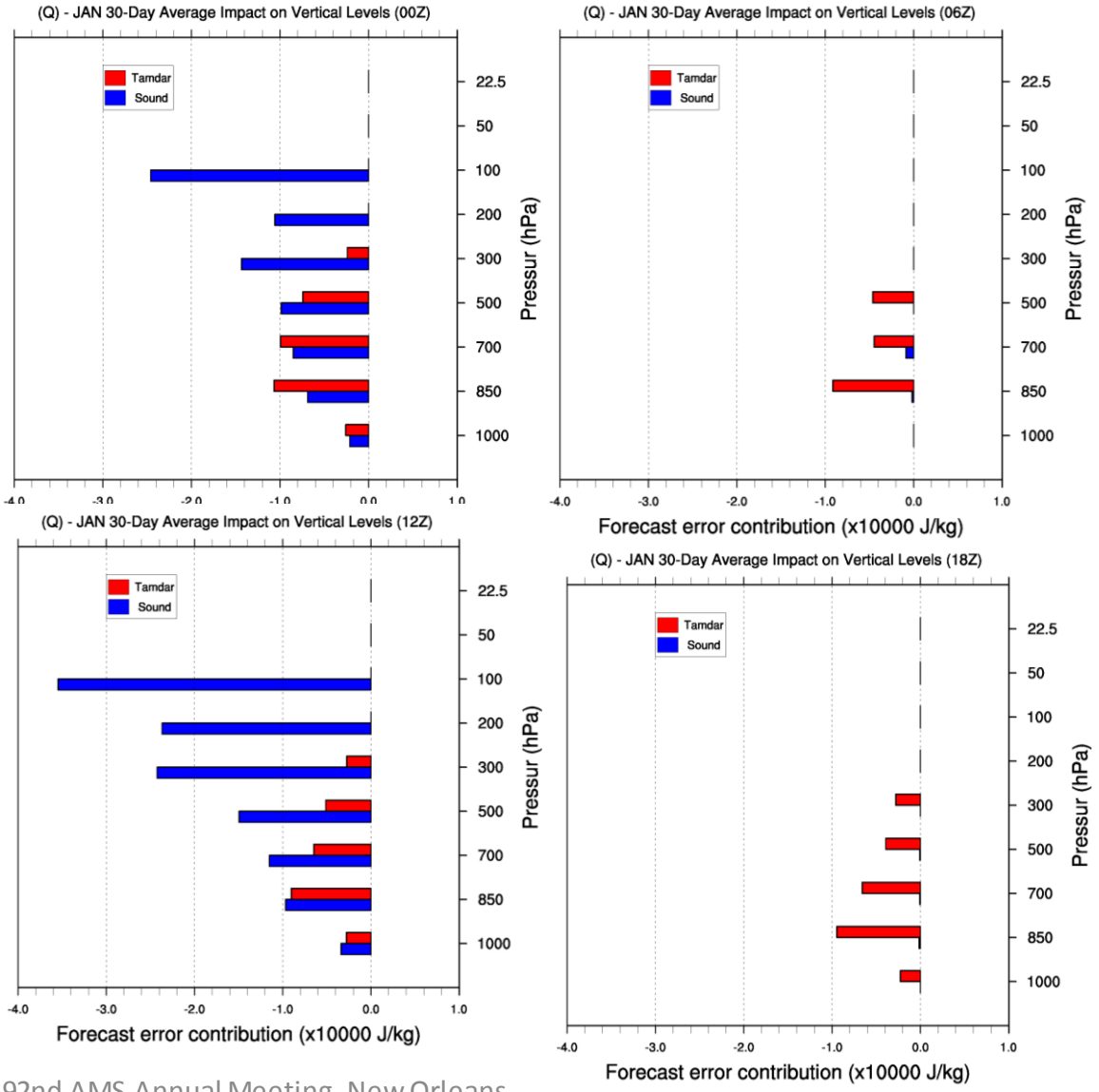
TAMDAR has the absolute advantage at 18Z



Averaged Q forecast error reduction -Vertical

Winter

Better performance from TAMDAR at 18, 06, 00Z



Conclusions:

- Tamdar data has obvious contribution on 1800 UTC to reduce the 24h forecast error;
- Tamdar humidity data is a very important supplementary of sounding data at lower level;
- Dense coverage is the another benefit from Tamdar data;Tamdar has more contribution than Sounding data at 0000 , 0600, especially at 1800 UTC.

Thank You