TWO STAGE ARTIFICIAL INTELLIGENCE ALGORITHM FOR CALCULATING MOISTURE-TRACKING ATMOSPHERIC MOTION VECTORS

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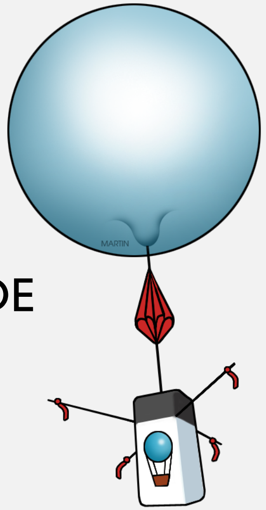
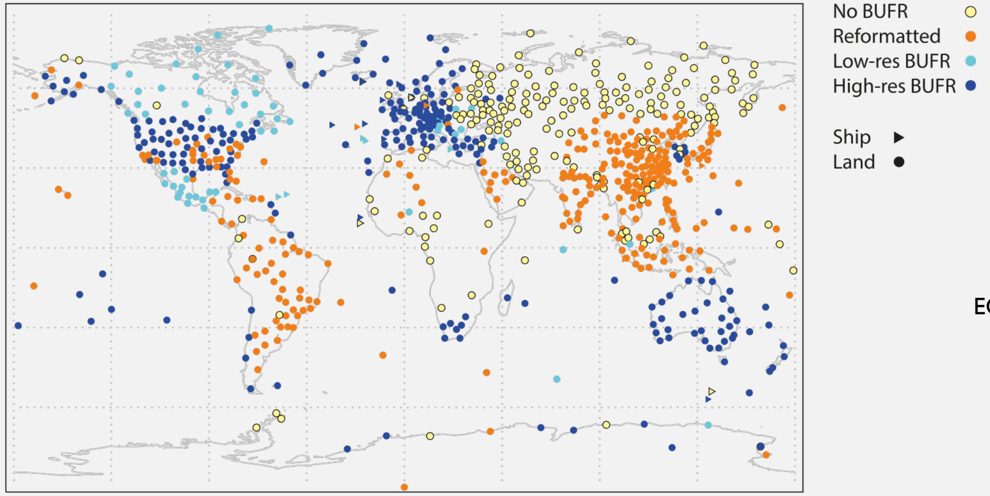
Many sources of wind velocity observations, but all have problems.

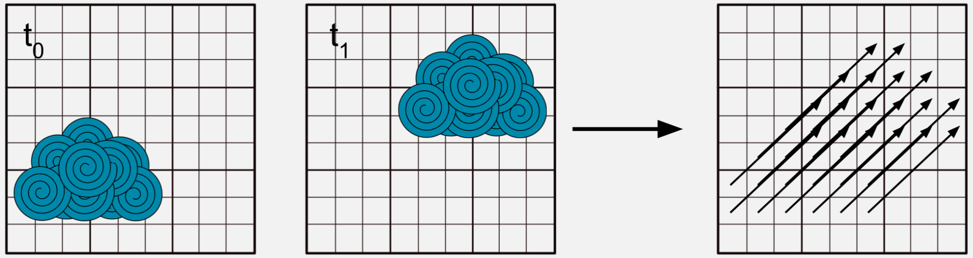
RADIOSONDE

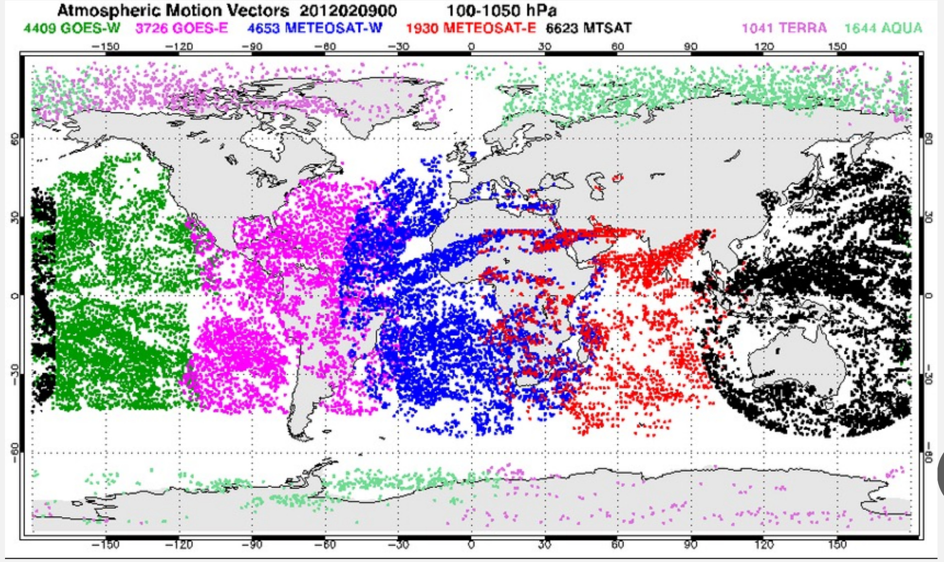




ECMWF

FEATURE TRACKING + SATELLITE IMAGING



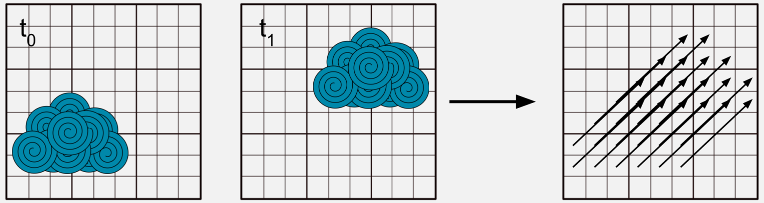


Warning: sparse vertically!

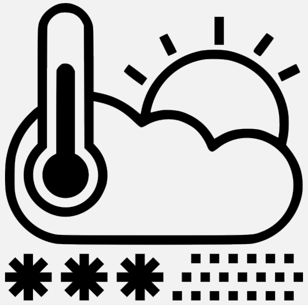
Garand, Louis, et al. "OSSE to infer the impact of Arctic AMVs extracted from highly elliptical orbit imagery."

Method: Reduce noise of multiscale moisture tracking by combining it with a machine learning algorithm that "learns" from short-term forecasting:

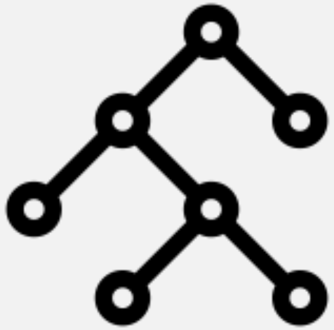
Moisture Tracking



Numerical Weather Prediction



Machine Learning (Random Forest)



Two stage algorithm: Process satellite images with feature tracking and correct it with short-term forecast data at same timestep.

fsUA $$\mathbf{V}^*(t) = f_{\text{variational}}(\mathbf{q}(t - \Delta t), \mathbf{q}(t), \mathbf{q}(t + \Delta t))$$

UA $$\mathbf{V}(t) = f_{\text{RF}}(\mathbf{V}^*(t), \mathbf{V}_{\text{NWP}}(t))$$

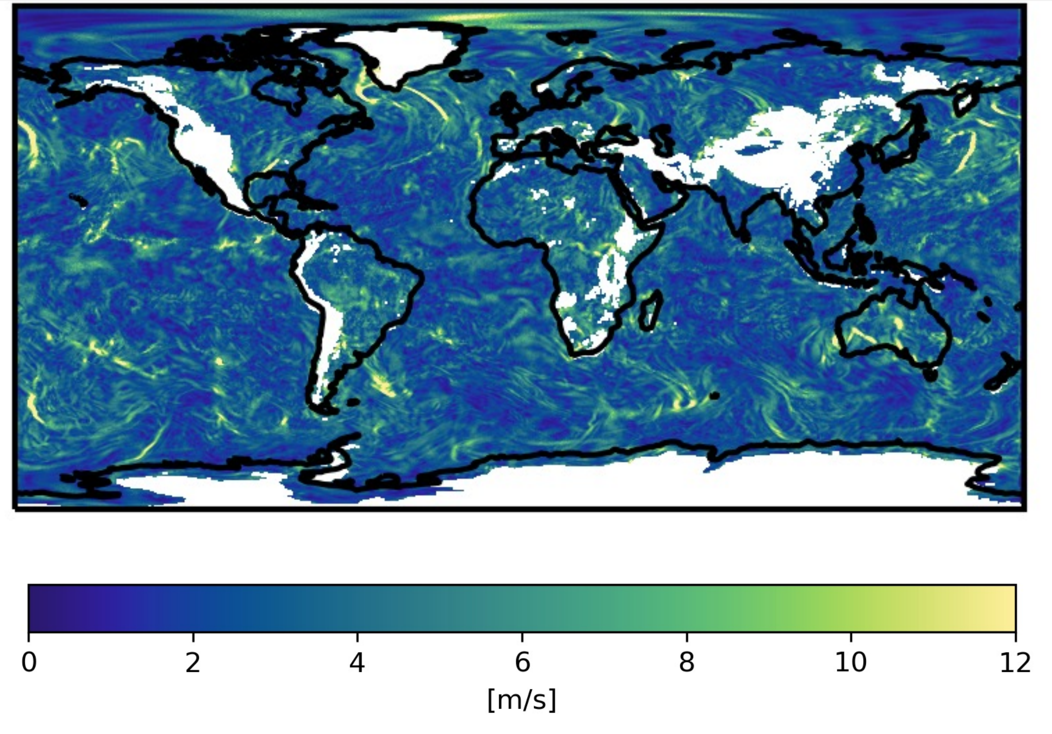
Ouyed et al. 2021, submitted

v_{NWP} (t): forecasted horizontal wind field at time t from operational model.

Forecast error is calculated from reanalysis differences. Ground truth is GOES-5 Nature Run wind velocities fields.

$$||\varepsilon_{forecast}|| \sim ||v_{ERA5}(t) - v_{CFSR}(t)||$$
$$v_{NWP}(t) = v_{G5NR}(t) + \varepsilon_{forecast}$$
$$v_{ground\ truth}(t) = v_{G5NR}(t)$$

Forecast Error

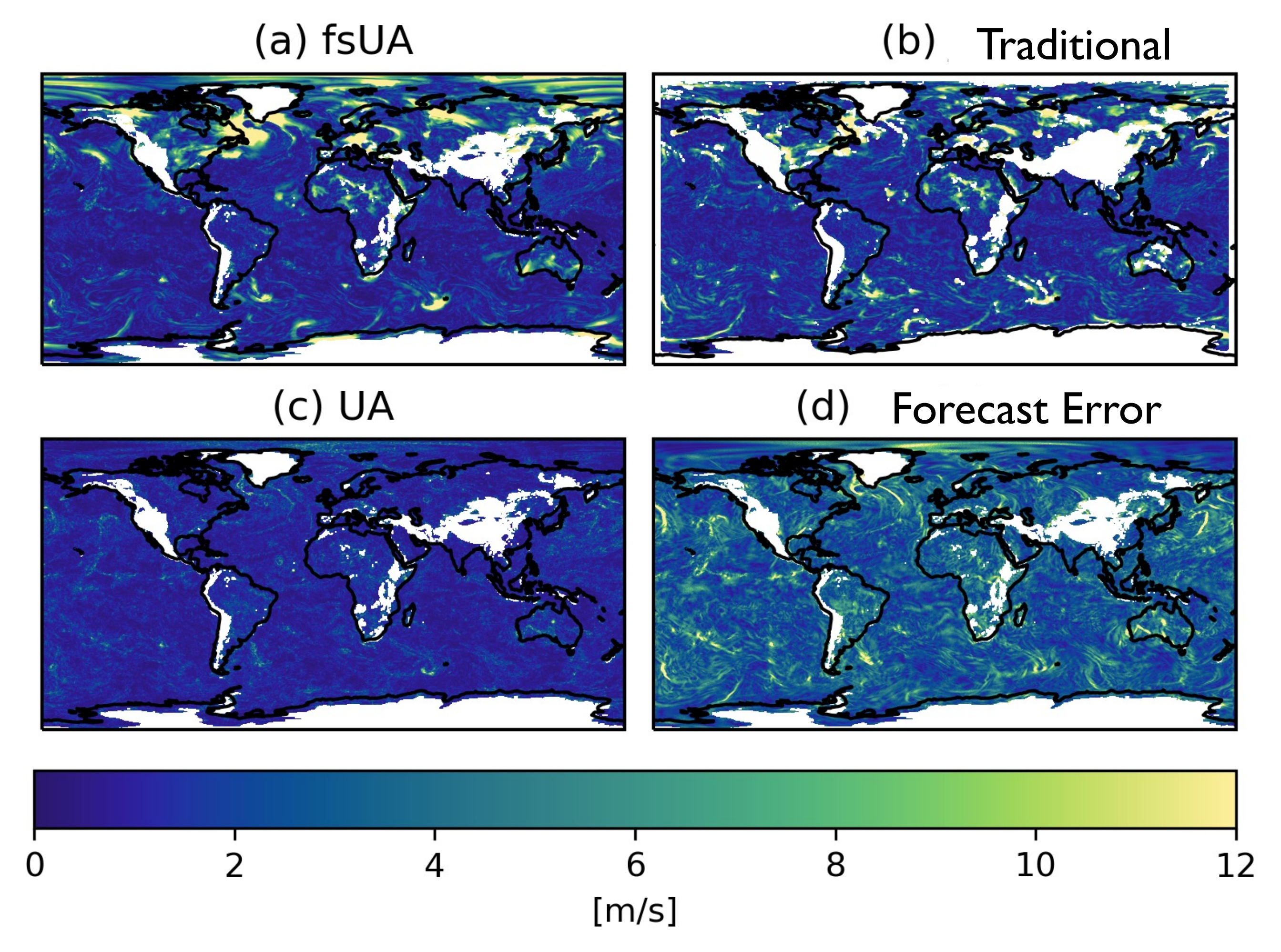


January 1, 2006, 0:00 (UT)

Ouyed et al. 2021, submitted

UA performs much better than other algorithms.

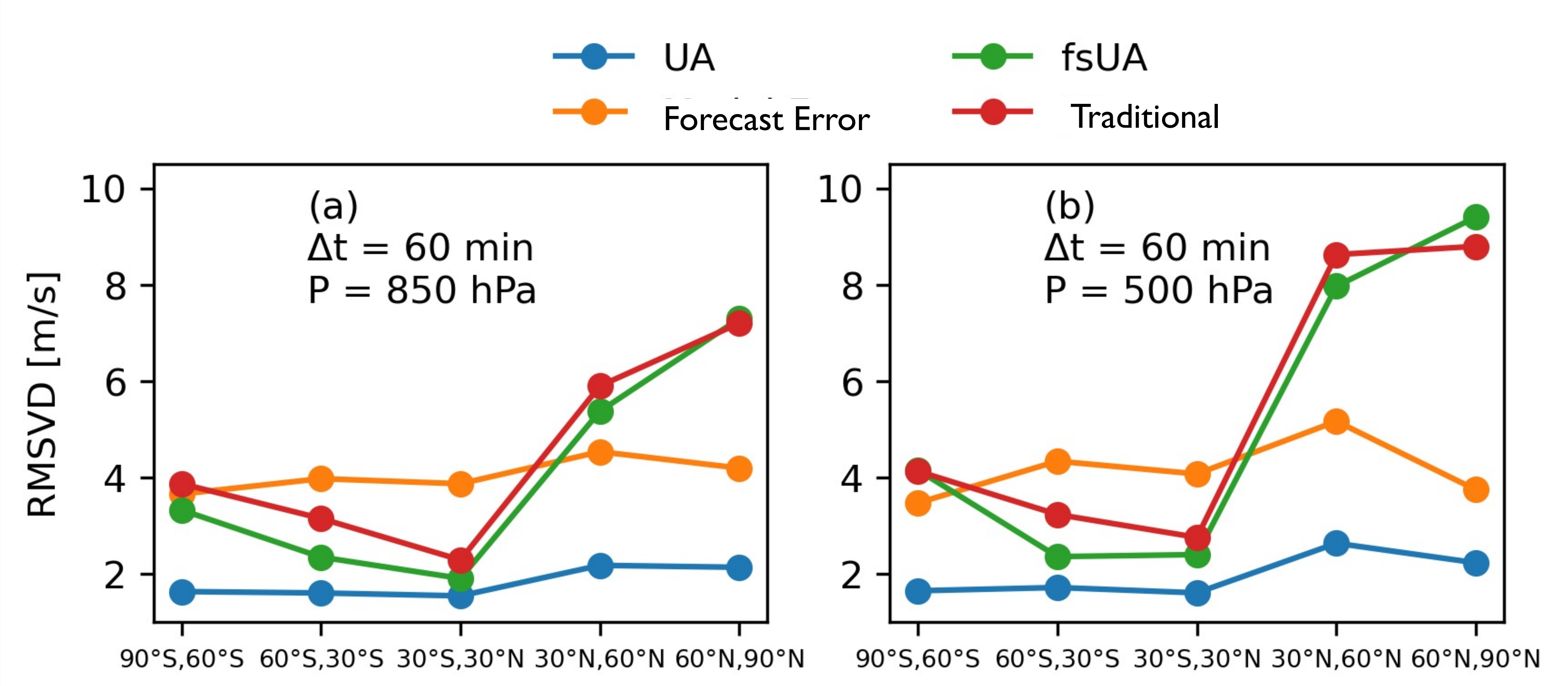
850 hPa, dt=1 hour,
January 1, 2006,
0:00 (UT)



Ouyed et al. 2021, submitted

Results: UA performs much better than forecast error and traditional algorithm.

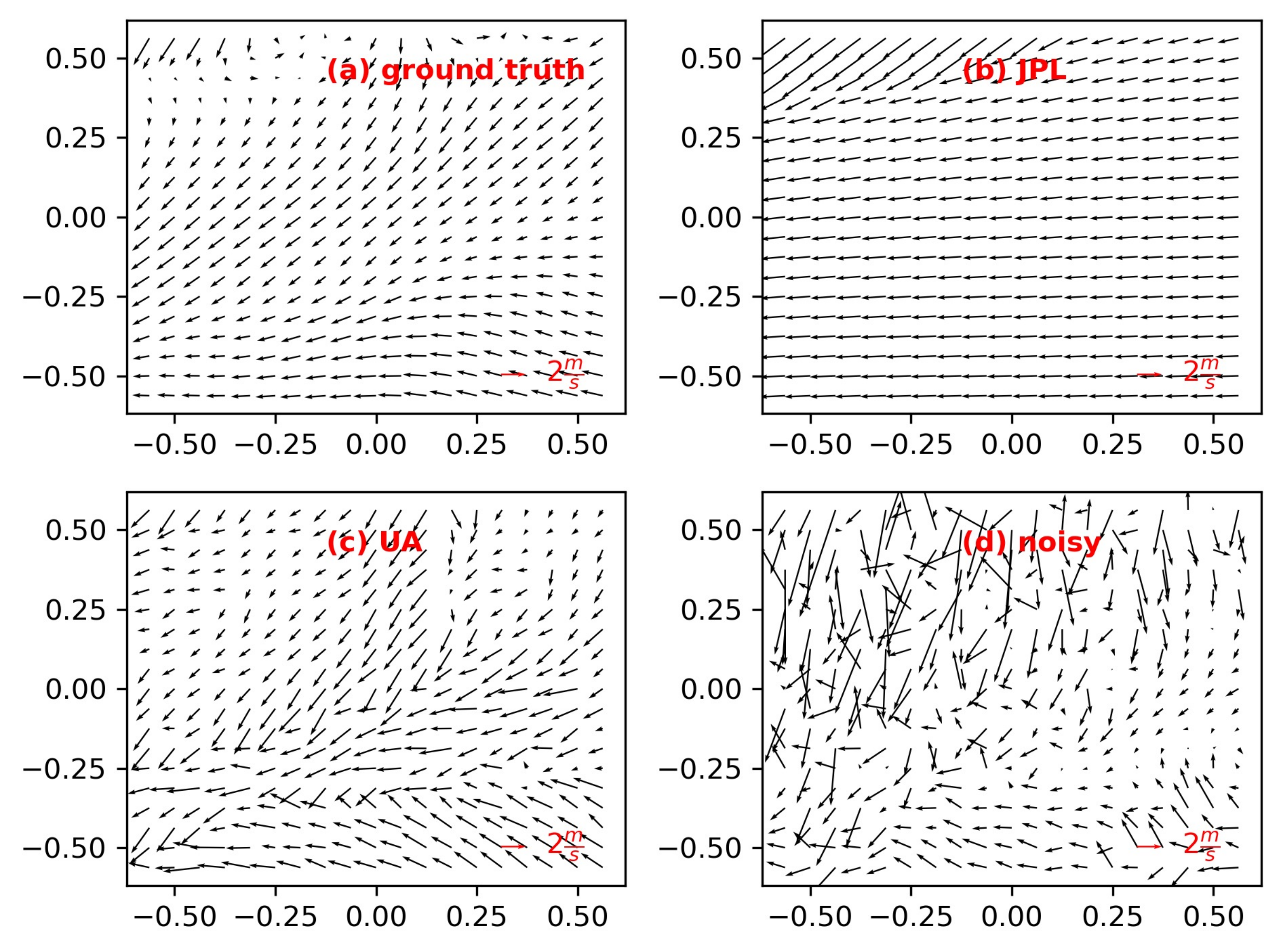
Ouyed et al. 2021, submitted



January 1-3, 2006

UA produces high resolution AMVs.

850 hPa, dt=1 hour, January 1, 2006, 0:00 (UT)

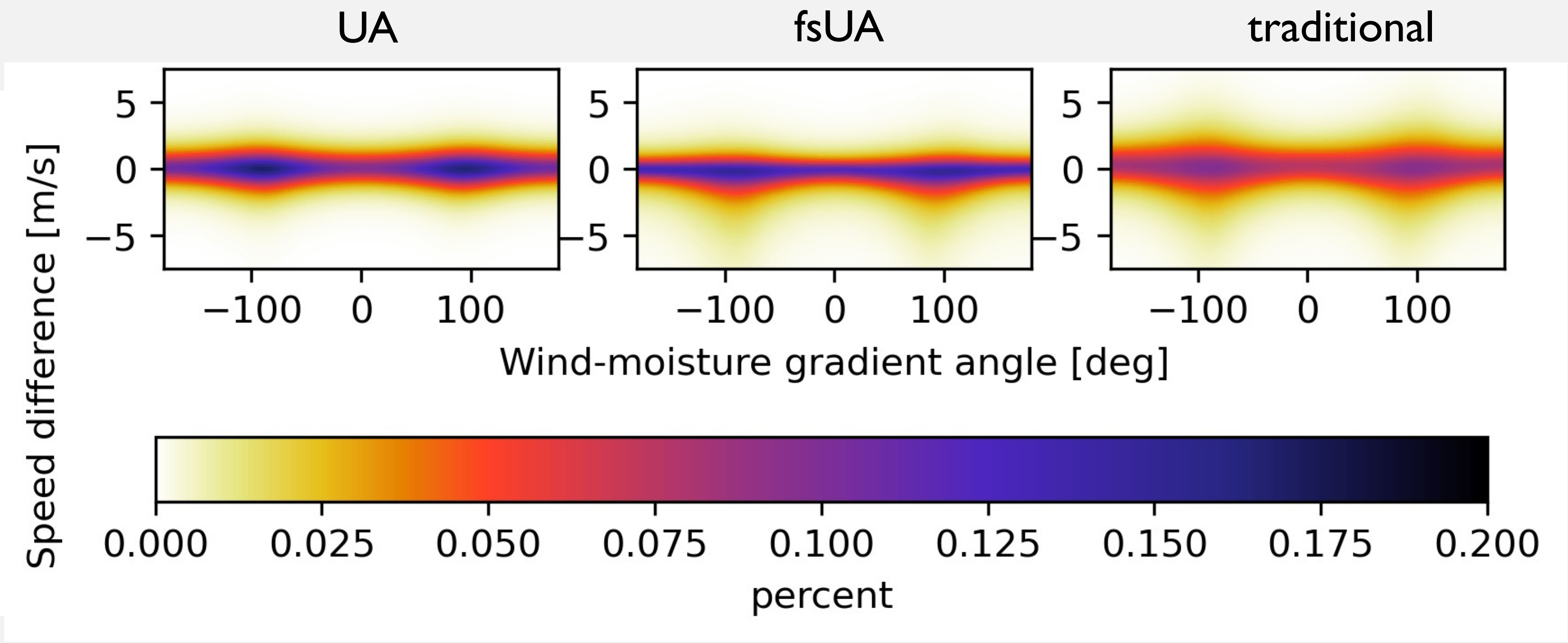


Ouyed et al. 2021, submitted

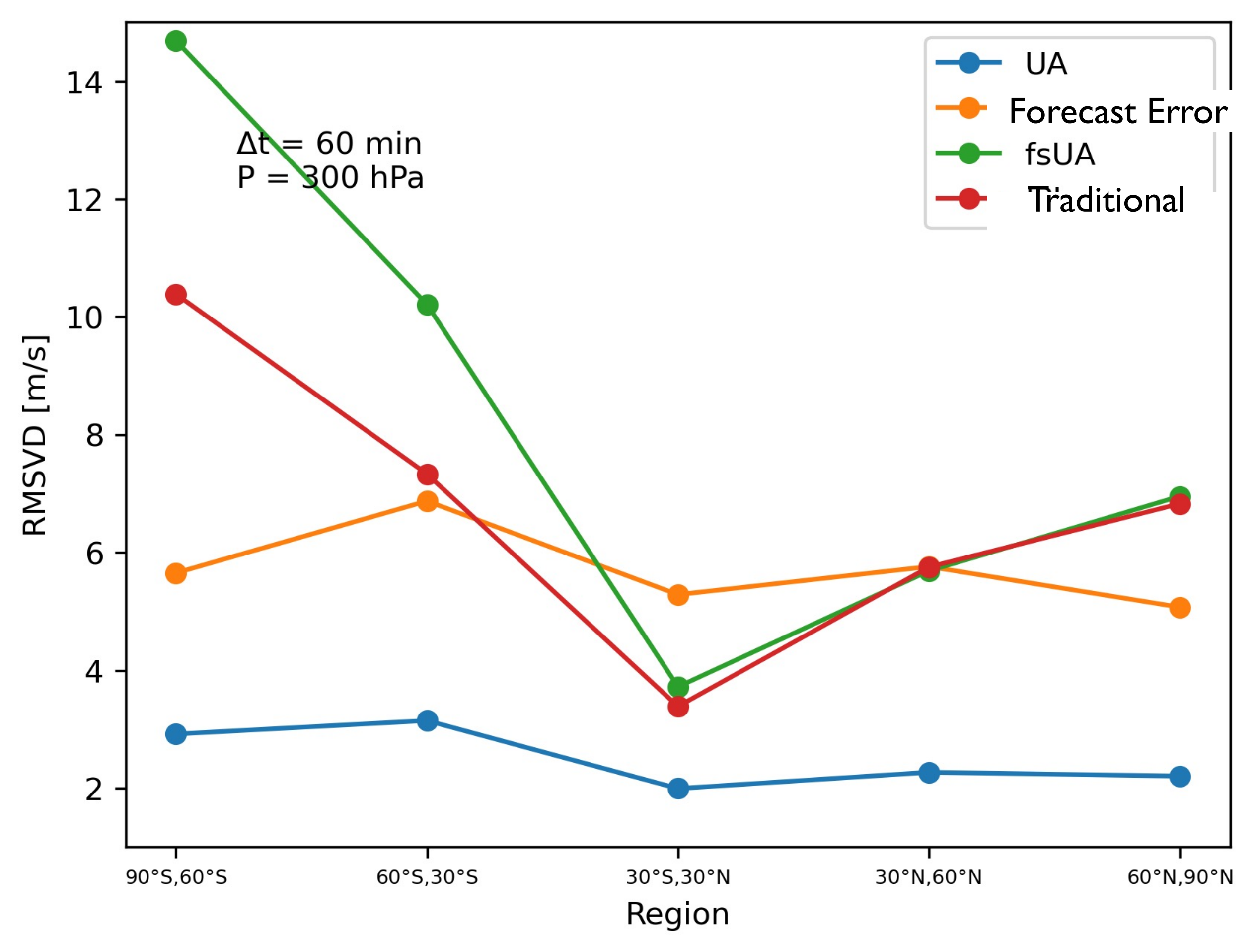
UA corrects even error prone regions like points where water vapor isolines are parallel to motion.

Ouyed et al. 2021, submitted

January 1-3, 2006, 850 hPa, dt = 1 hour



UA handles the upper troposphere well.



Ouyed et al. 2021, submitted

UA passed various robustness tests, with error within 3 m/s in all of them.

- UA robust to random sampling of training data (standard deviation <0.2 m/s).
- UA robust to collocation error.
- UA robust to simulated satellite retrieval error

Conclusion

- UA performs much better than the traditional algorithm.
- UA excels under difficult conditions such as low moisture or when moisture isolines are parallel to velocity.
- This results act as a lower bound of error for UA, since they are based on model data, rather than satellite imaging.