Improving usage of satellite winds in the NCEP data assimilation system

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Abstract

Satellite derived winds have been used in the NCEP global data assimilation and forecast system since 1979. These winds provide valuable information for the numerical forecast model initialization. However it is found that satellite winds have slow tendency. It also has correlated errors, especially for high density satellite wind products. These issues can cause some dropouts in the forecast skills in our system. This study try to dress these issues by applying asymmetric gross check inside data assimilation system and thinning high density satellite winds. Various criteria and schemes were tested and the one with optimal forecast impacts were selected in our data assimilation system.

Introduction

Satellite winds have been assimilated into the National Center for Environmental Prediction (NCEP) data assimilation system since 1979. These winds provide vital information where no conventional data are available. However, there are issues related satellite winds such as correlated errors and slow speed biases compared to collocated rawinsonde observations and the model background (Su, 2000). It is very difficult to explicitly account for correlated errors in a data assimilation system, so thinning is usually adopted to reduce correlated errors (Kelly and Rohn, 2000; Butterworth and Ingby, 2000). In addition, thinning also reduces representative errors in the satellite winds since some satellite winds have a high density which can not be resolved by the current mode resolution. In this study, we are going to address these two issues in our NCEP data assimilation system. First, we are going to do an asymmetric gross check to reduce slow speed bias, and then thin geostationary (GOES) high density winds as described in section 2. Section 3 will show the results and some discussion and the summary will be presented in the final section.

Method

Currently, the NCEP data assimilation system assimilates satellite winds produced by European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), Japanese Meteorological Agency (JMA), and National Environmental Satellite, Data, and Information service (NESDIS). These winds extend from the lowest level at lower boundary layer up to almost 100mb in the vertical and over most ocean areas and polar region in the horizontal. Statistics of the difference between satellite wind observations and the background from the NCEP global model show a slow speed bias (see Figure 1a and 1b, for example). In addition, there is a slow speed bias when compared with rawinsonde wind observations for geostationary (GOES) satellite winds from NESDIS (Su, 2000). The slow speed bias is also found compared the background from other NWP forecast models (see the web site: http://www.metoffice.gov.uk/reserarch/interproj/nwpsaf/satwnd_report/amvinfo.html).

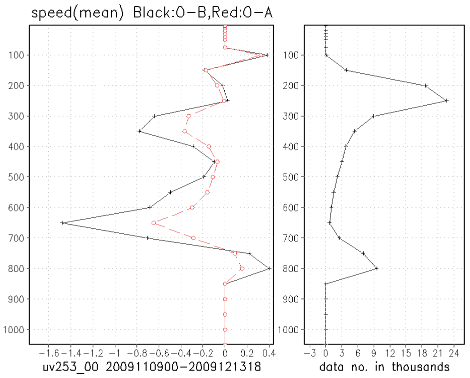

Figure 1a, **The vertical profile of speed differences between the observation and the background(black line) line) averaged over one month from MET-7 IR cloud drift**

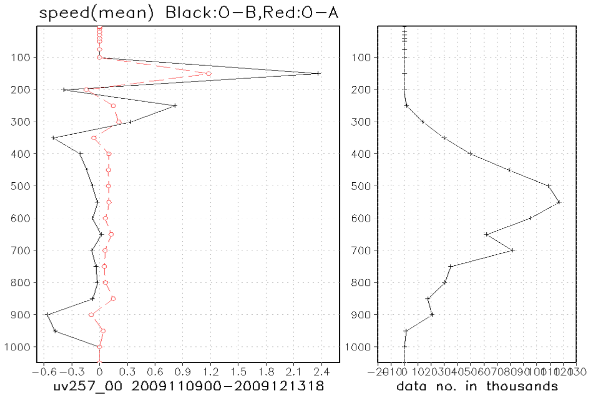

Figure 1b, **The vertical profile of speed differences between the observation and the background (black averaged over one month from MODIS IR cloud drift**

To reduce the slow speed bias in our data assimilation system, the so called Grid Point Statistical Interpretation (GSI), the asymmetric gross check is applied to all satellite winds. Two quality controls are conducted within the GSI: gross check and variational quality control. In the variational quality control, the observation is compared with the background and surrounding observations to determine its analysis weight in the system, a larger weight if it fits more closely to the background and surrounding observations, and a low weight when it fits less well. In the gross check, there is a gross check limit for each observation. The ratio of vector differences between the observation and the background and observation errors was calculated for each wind observation, and the observation is rejected if the ratio is greater than the gross check limit. In the asymmetric gross check for satellite winds, the gross check limit is smaller when the observation speed is slower than the background.

GOES satellite winds produced from NESDIS, IR drift and water vapor cloud tops, have the highest density compared with data from other geostationary satellites produced by other centers. The spatialy correlated errors are inherited in the satellite winds since clusters of winds are derived from similar cloud systems by same tracking techniques. The thinning is simplest way to reduce the correlated error. Another important issue related to thinning is which observation should be chosen, since experimental results show that using different criteria to choose the observation can have very different forecast impacts. The final thinning box and criteria for choosing observation were determined with optimal forecast impacts.

There are three quality indicators provide by data producers: Expected Error (EE), developed by Australia Bureau of Meteorology (Le, Marshall, 2004); Quality Indicator(QI), developed by EUMETSAT (Holmlund, 1998); and the Recursive Filter Flag (RFF), developed by the Cooperative Institute for Meteorological Studies (CIMSS) (Hayden and Purser, 1995). These quality indicators provide valuable information about the data. After a few tests, it was found that combining EE and QI produced the optimal forecast impacts. In this study, the atmosphere is divided into a three dimensional box, 100kmX100 kmX100mb. The observation with the highest EE and QI, closest to the center of the thinning box and closest to the cycle time was selected.

These experiments were conducted for two periods: from June 10, 2009 to July 27, 2009 and from November 1, 2009 to December 13, 2009. The forecast system is the current operational system which was implemented at NCEP in December 2009. It is a T382L64 hybrid spectral model with a horizontal resolution of 42 km at the equator and 64 vertical levels. The term “hybrid” refers here to a sigma-pressure coordinate system in which the near surface model surface layers follows the terrain and smoothly transition to constant pressure levels higher in the atmosphere. The GSI system is the version in use on December 3, 2009.

Results

Forecast Impacts

The forecast impacts of the asymmetric gross check for all satellite winds and GOES satellite wind thinning, expressed as mid-latitude 500mb geopotential height anomaly correlation and tropical wind root mean square error averaged over each experiment period, are shown in Figure 2.

Figure 2 a, b, c, d shows consistent results for both experiment periods (different seasons), with slight positive improvement in 500 geopotential height anomaly correlation scores in both hemisphere, and neutral impacts in tropical regions (Figure 2 e, f, g, h). The consistency of the forecast impacts from both experimental periods, which represent different seasons, demonstrates that the forecast improvements are stable and reliable.

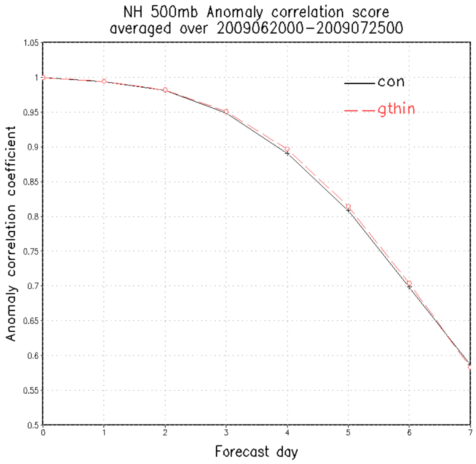

Figure 2a, **Forecast impact in NH in summer**

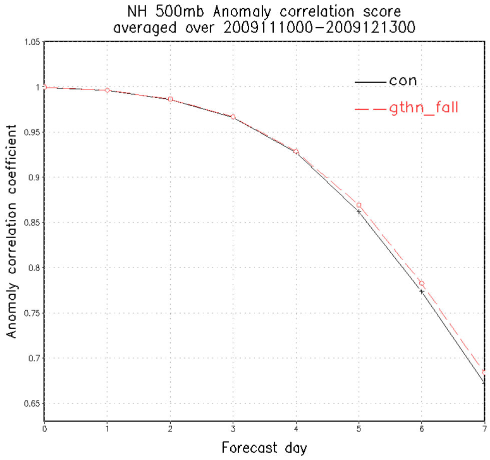

Figure 2b, **Forecast impact in SH in Fall**

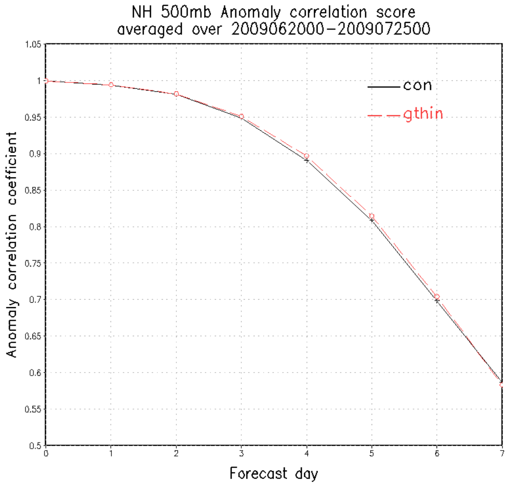

Figure 2c, **Forecast impact in SH in Summer**

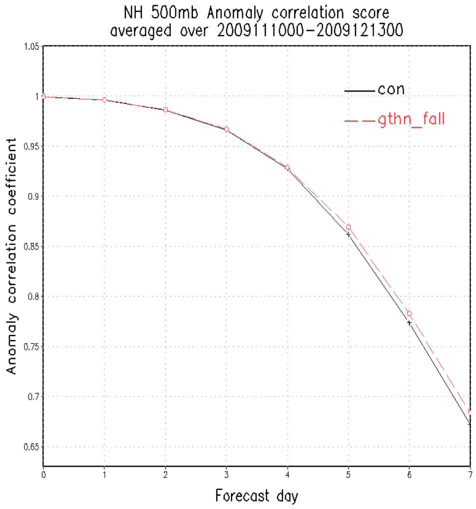

Figure 2d, **Forecast impact in SH in Fall**

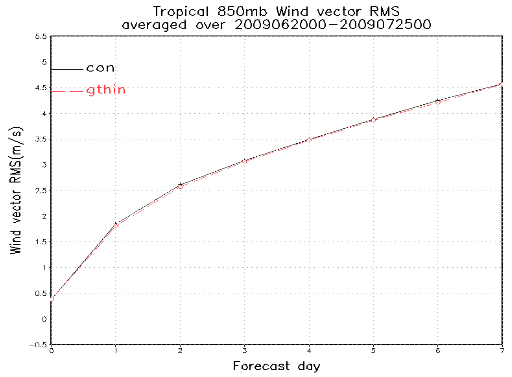

***Figure 2e*, Forecast impact in tropics in Summer**

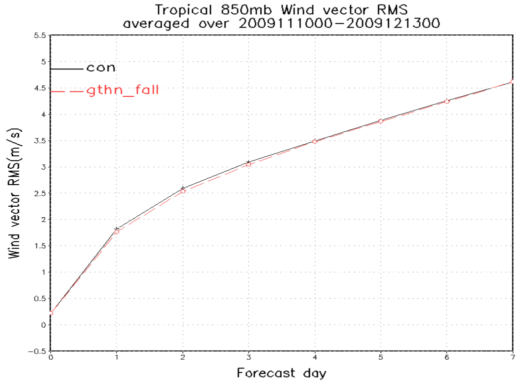

***Figure 2f*, Forecast impact in tropics in Fall**

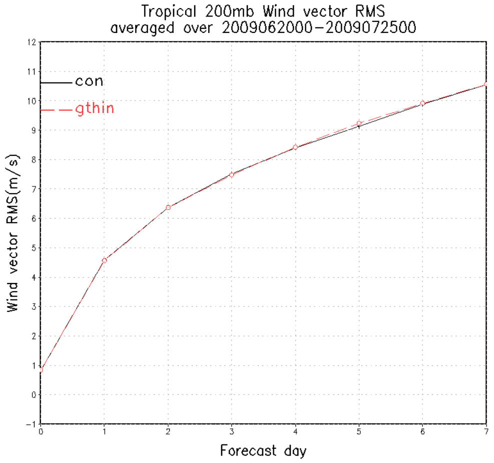

***Figure 2g*, Forecast impact in tropics in Summer**

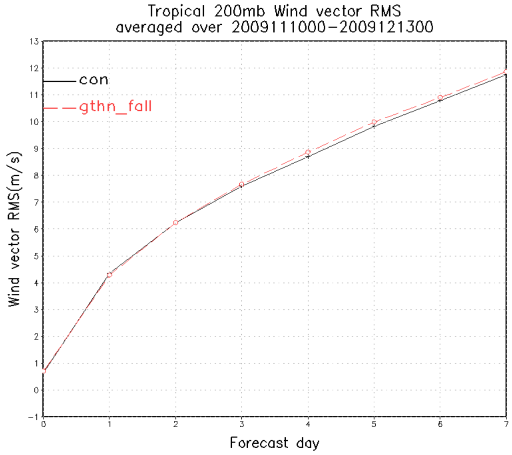

***Figure 2h*, Forecast impact in tropics in Fall**

To further examine the forecast impacts, the time series of 500 geopotential height anomaly correlation over both hemispheres and wind root mean square error over tropical regions is shown in Figure 3. The time series of forecast impacts shows that the impacts are constant throughout the experiment periods, and most improvements or degradations are small, except for some dropout cases (in Figure 3c) where the experiment has large positive impacts. And more improvements than degradations are seen in the cycles. These results further demonstrate that the forecast improvement results are reliable.

Observation and background fit

Examples of observation and background fit before and after asymmetric gross check are shown in Figure 4. The impacts on observation fit for other data types, excluding the satellite winds are very small and negligible, so all discussions on the observation fits will focus on satellite winds. These examples are MET-7 IR cloud drift (Figure 4a) and MODIS IR cloud drift winds (Figure 4b). The negative speed bias (O-B) is shown clearly before the asymmetric gross check (black line), however the O-B (green line) after the asymmetric gross check is positive at most levels. Similar features are shown with other satellite wind types.

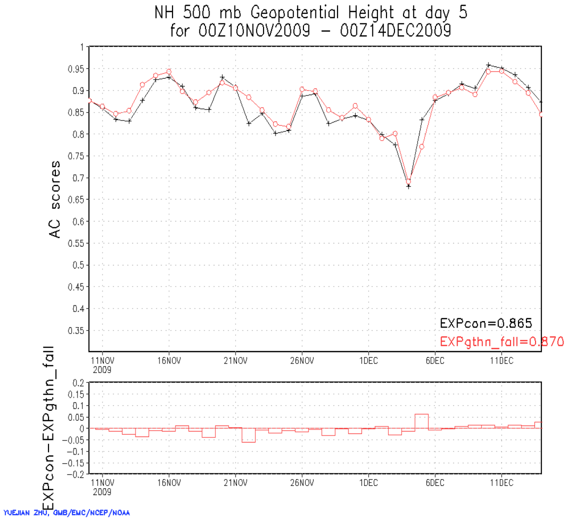

Figure 3a, **Time series of NH 500mb geopotential height anomaly score at day 5**

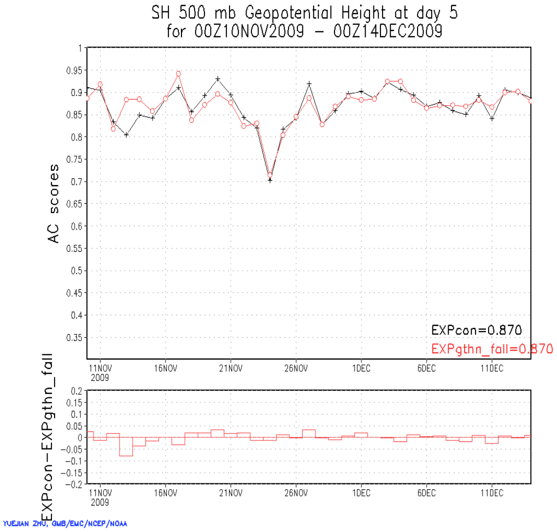

Figure 3b **Time series of SH 500mb geopotential height anomaly score at day 5**

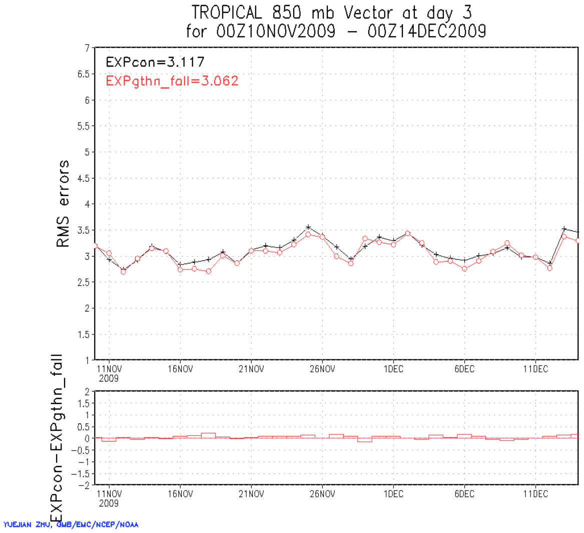

Figure 3c, **Time series of tropical 850mbwind RMS at day 3**

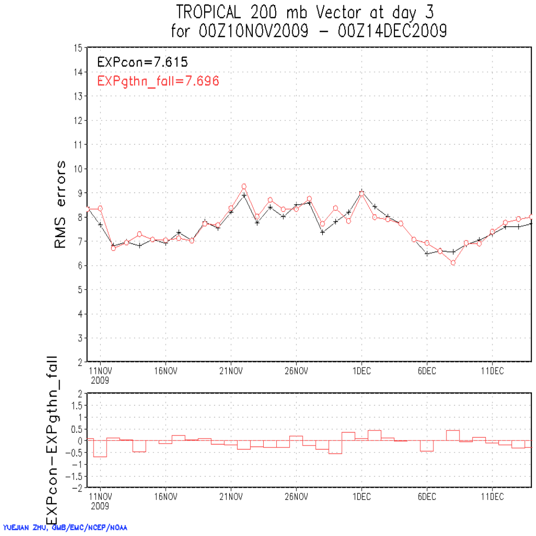

Figure 3d, **Time series of tropical 200mb wind at day 3**

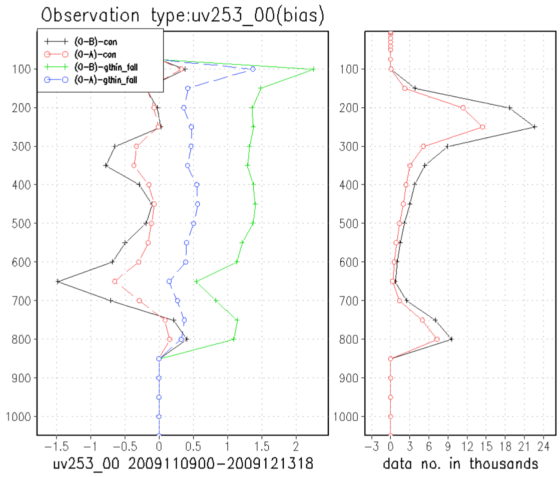

***Figure 4a*, The vertical profile of speed differences between observations and backgrounds from MET-7 (black line is before asymmetric gross check:, green line Is after)**

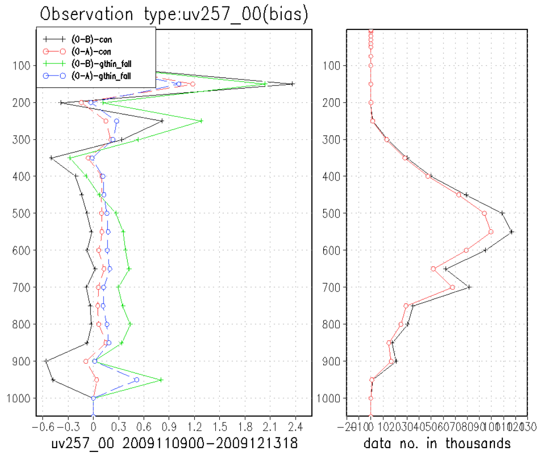

***Figure 4b*, The vertical profile of speed differences between observations and backgrounds form MODIS (black line is before the asymmetric gross check: green line is lafter)**

Satellite wind type	Data Number used and percentage rejected
JMA IR cloud drift and visible low level (242)	389530, 8.1 % rejected
MET-7 IR and visible low level (243_00)	95840, 17.6% rejected
MET-9 IR and visible low level (243_56)	188790, 19.8% rejected
GOES IR cloud drift (245)	1115900, 52.5% rejected
GOES IR Water vapour (246)	584240, 55.1% rejected
JMA IR and visible high level(252)	312920, 20.7% rejected
MET-7 IR and visible all level (253_00)	67073, 36.8% rejected
MET-9 IR and visible all level (253_56)	138470, 36.4% rejected
MODIS IR cloud drift(257)	775160, 13.5% rejected
MODES IR water vapour(258)	452690, 6.3% rejected

***Table 1* Data rejected by asymmetric gross check and thinning for the experiment period of 20091109-20091213**

The number of observations rejected by the asymmetric gross check for each satellite wind type is listed in Table 1. The black number is the number of observations used in the data assimilation, the percentage is the percentage rejected by the asymmetric gross check except for satellite winds from GOES, in which the percentage is the percentage rejected by the asymmetric gross check and thinning. Generally speaking, a higher percentage is rejected by asymmetric gross check for higher level winds in the same satellite. For satellite winds from JMA, for example, the rejection percentage for low level winds is 8.1 percent, about 20% for higher level winds. Satellite winds from NESDIS have a lower rejection percentage since they use the forecast winds as their guidance when tracking winds. The highest percentages rejected by the asymmetric gross check are for satellite winds from EUMETSAT.

Summary

The results of experiments with an asymmetric gross check for satellite winds were evaluated and discussed. The satellite winds show a slow speed bias compared with the background, so an asymmetric gross check was adopted to reduce bias. In addition, thinning was applied to high density satellite winds from GOES to reduce correlated errors. The results show that after an asymmetric gross check the satellite winds at most levels do not have a slow speed bias compared with the background. The forecast impacts are consistent throughout two experiment periods, being slightly positive over both hemispheres and with a neutral impact in tropical regions. The number of observation rejected by the asymmetric gross check varies from one data type to another, and the slow speed bias becomes a fast speed bias, which may suggest that one single factor in the asymmetric gross check for all types of data may be too simple, and that treating each data type differently with the asymmetric gross check may yield more optimal forecast impacts.

Reference

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