An Aeolus-AMV Collocation Study Using a Feature Track Correction (FTC) Observation Operator

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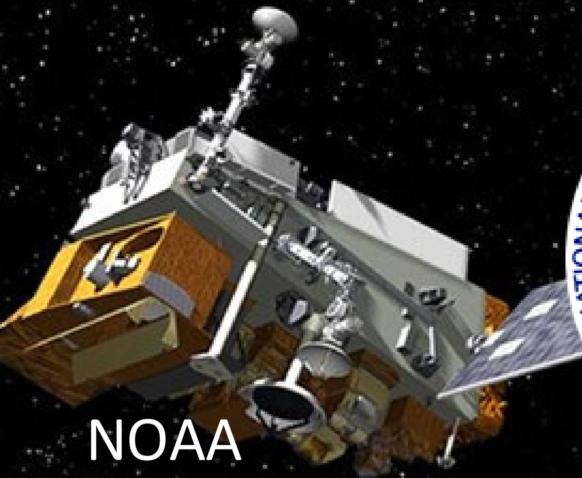

NOAA
National Satellite and Information Service

14 April 2021
15IWWG Workshop

Introduction

- If Aeolus DWL line of sight (LOS) winds are sufficiently accurate they may enhance the use of AMVs.
- In the same way that GNSS/RO observations have provided the highly accurate observations necessary to make VarBC of radiances successfully, it is anticipated that Aeolus winds will do the same for the variational feature track correction (VarFTC) of AMVs.
  - GNSS/RO and Aeolus DWL observations have global but sparse coverage, should be extremely accurate, and have high vertical resolution.
  - Radiances and AMVs are imperfectly calibrated and have horizontally correlated errors based on geophysical factors not properly accounted for.

AMV feature track correction (FTC) obs operator

- There are notable differences in the obs operator and form of the bias correction for radiances and AMVs.
- The FTC obs operator must correct for three factors,
  - First, it is thought that the most critical bias of AMVs is due to height assignment errors.
  - Second, AMVs may have additional wind speed biases once height assignments are corrected.
  - Third, AMVs are representative of a layer, not a level, and the estimate of the layer depth may be estimated or bias corrected.

The FTC obs operator

The estimate of the AMV is given by a weighted integral in the vertical plus a correction. Thus, the FTC observation operator in general is

$$\widehat{\mathbf{V}} = \int w(z)\mathbf{V}(z)dz + \delta\mathbf{V} \quad (1)$$

- $\widehat{\mathbf{V}}$ is the FTC estimate of the observed vector wind
- z is the vertical coordinate
- $\mathbf{V}(z)$ is the background vector wind profile
- $w(z)$ is the profile of weights to be determined
- $\delta\mathbf{V}$ is the additive correction to be determined

In discrete form, if we assume constant weights

$$\widehat{\mathbf{V}} = \gamma\overline{\mathbf{V}} + \delta\mathbf{V} \quad (8)$$

$$\overline{\mathbf{V}} = \frac{1}{T}\sum_{S}^{S+T-1}\mathbf{V}_k \quad (9)$$

- $\overline{\mathbf{V}}$ is the average of the background vector wind profile
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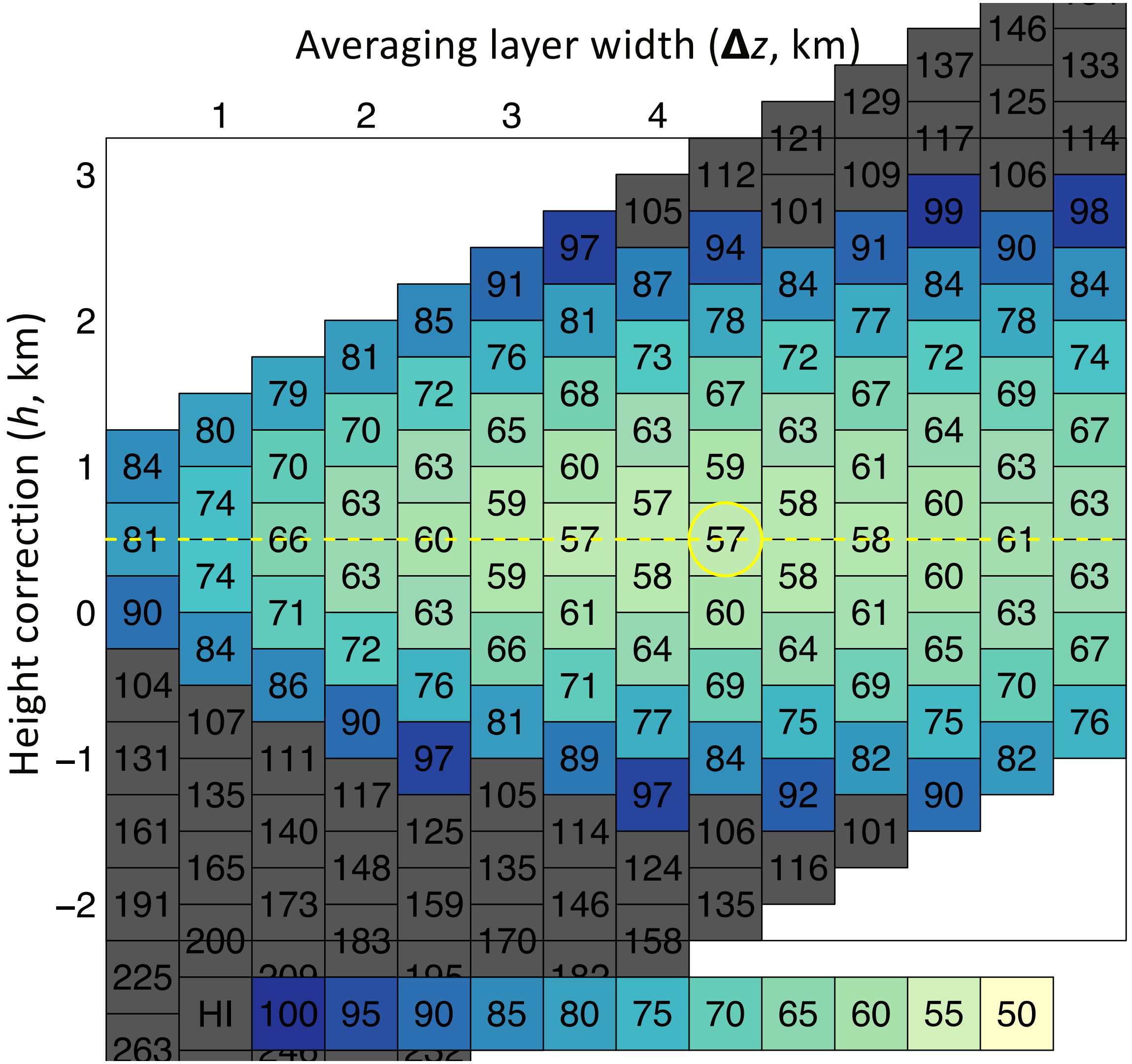
- δz is the thickness of one layer (km)
- $\Delta z = T\delta z$ is the layer thickness
- $h = (S + (T-1)/2)\delta z$ is the height correction

Now we only need to determine S, T, γ, and $\delta\mathbf{V}$

The FTC obs operator in practice

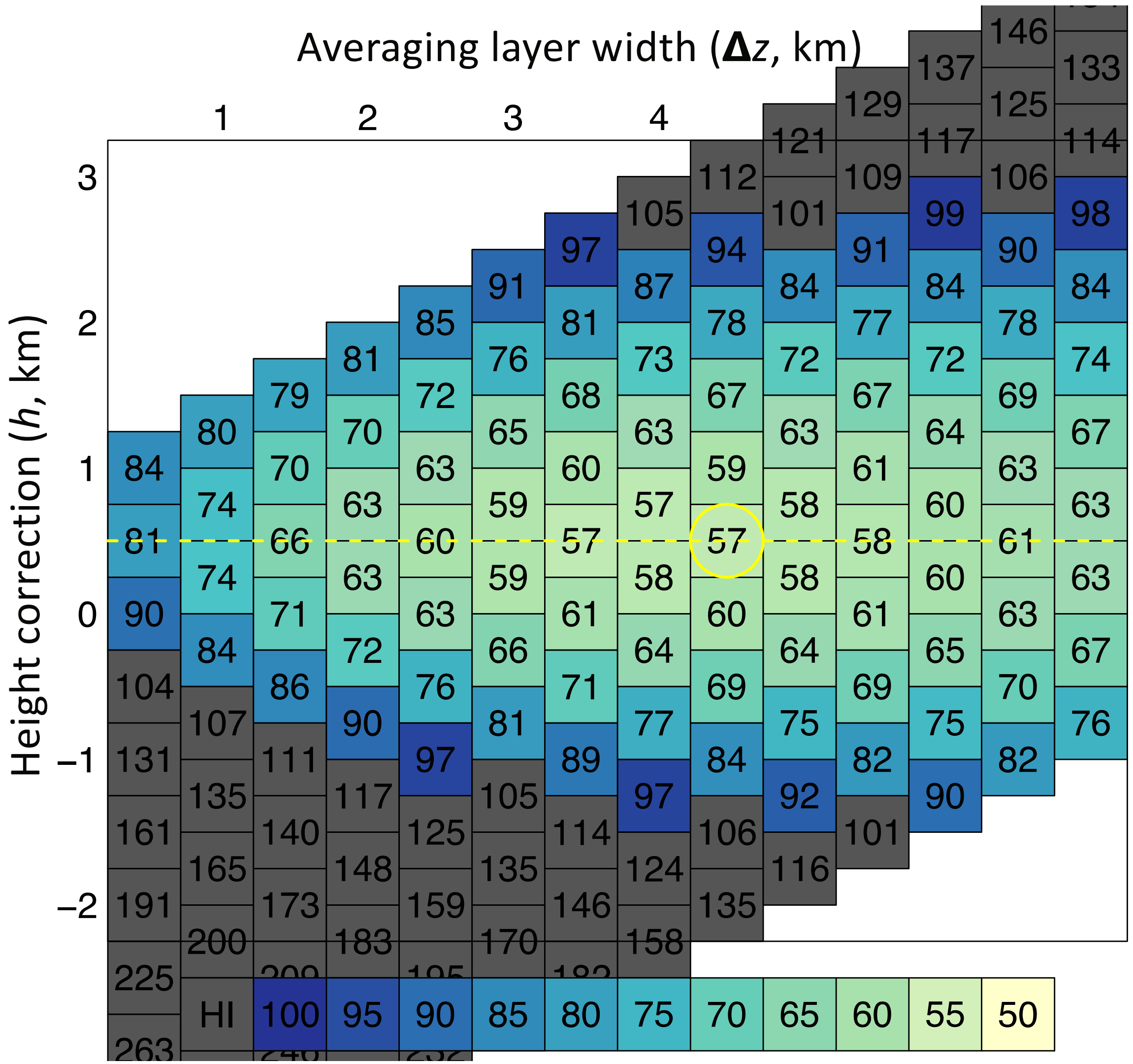
- Use 0.5 km vertical layers
- We solve the linear model for γ and δV to minimize the misfit.
- For each set of integration bounds, specified by *S* and *T* or equivalently height correction (*h*, km) and the averaging layer width (Δ*z*, km).
- Then we find the global optimum over *h* and Δ*z*.



AMVs and AEOLUS LOS winds

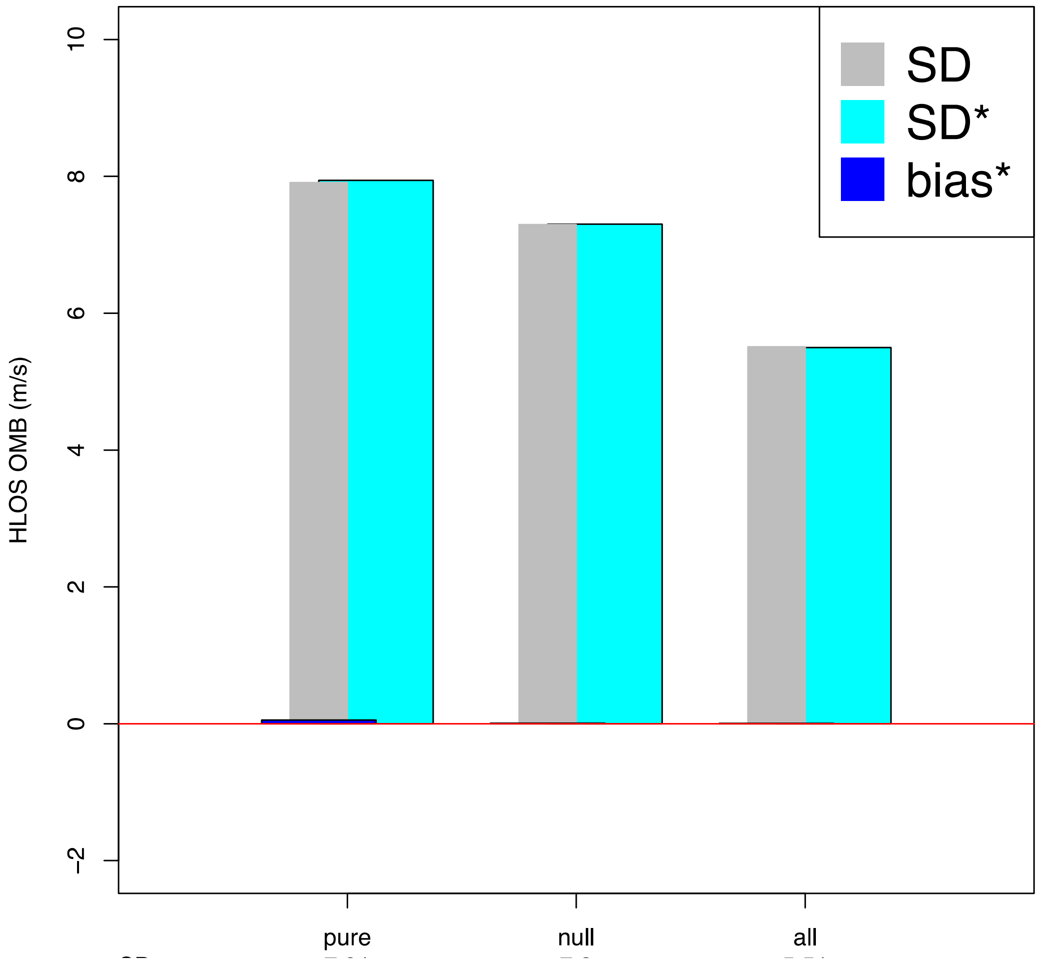
- We apply the FTC formulation to the HLOS Rayleigh winds from AEOLUS, treated as the background profile and the AMV winds projected onto the AEOLUS LOS as the observation
- Results are for 40 cycles (10 days), each cycle with about 3900 collocations: from 0000 UTC 21 April 2020 to 1800 UTC 30 April 2020
  - Sample size is 156294 collocations with $\Delta t<60$ min, $\Delta \log_{10}(p)<0.04$, and distance <100 km.
  - QC of both AMVs and Aeolus yields about 2/3 or 104109 collocations.
  - The Aeolus profile is interpolated to a grid of $\Delta z=0.5$ km centered on AMV height.
  - 1/3 of the collocations are reserved as a test sample, the rest are used for optimization (the tune sample).
  - Same method applies to any individual subset. Subsets are levels of factors.
    - Example, method factor has levels (**IR**, **Vis**, **WV**-cloud top, WV-**Clear**)

Minimizing J_o (global solution)



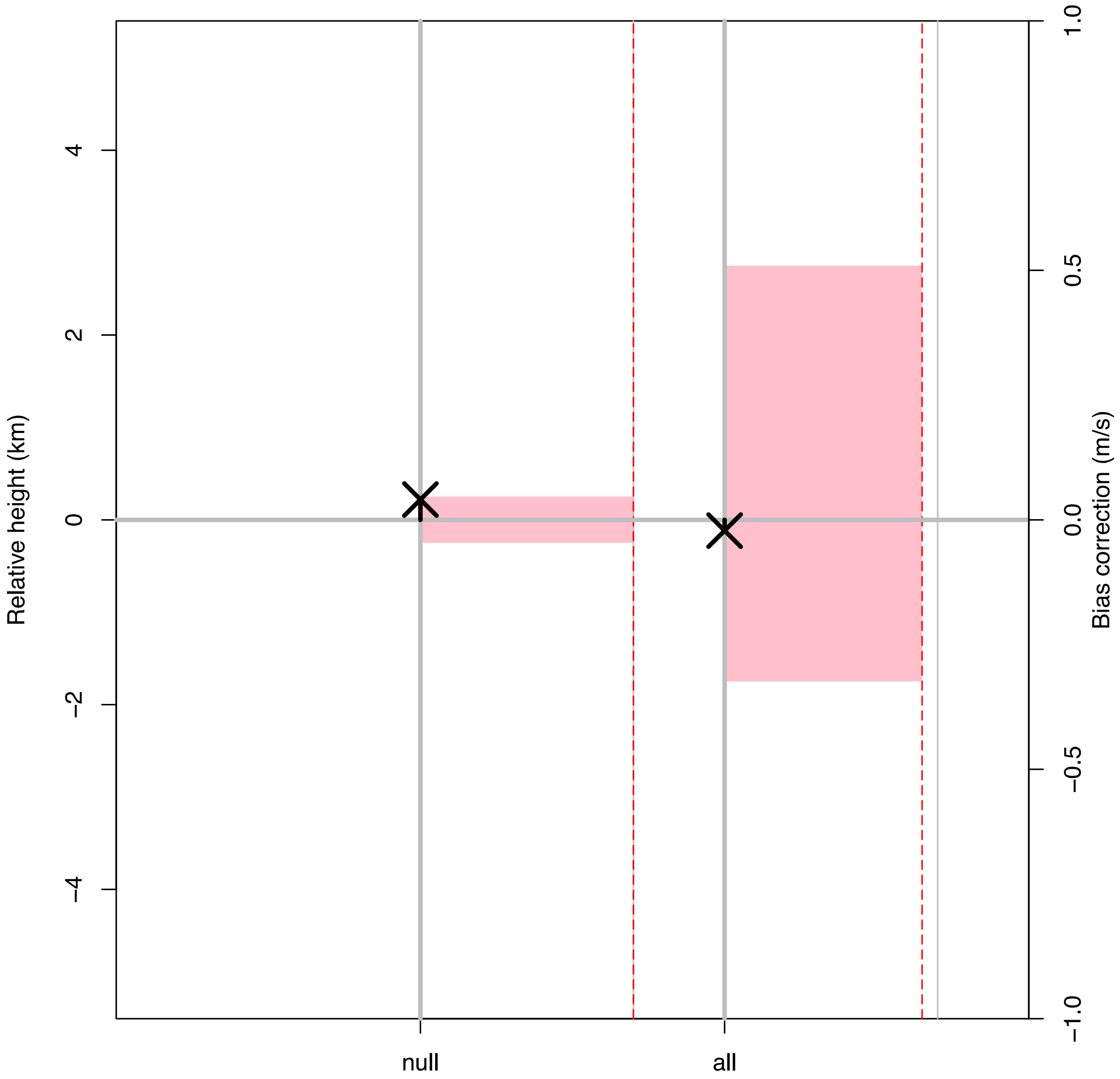
- Values plotted are J_o/J_n times 100
  - (i.e., percent of J_n)
  - $J_o = n\,\sigma_{OMB}^2$
  - Here σ_{OMB} is the standard deviation of O – H(B).
  - J_n is the null solution value of J_o (i.e., for h=0, Δz=1/2, γ=1 and δV=0). $J_n = n\,7.27^2$.
- Each value is the least squares solution for γ and δV for the given h and Δz
- Global minimum is 57 (or a 43% reduction in variance) at h=0.5 and Δz=4.5.

Global solution statistics



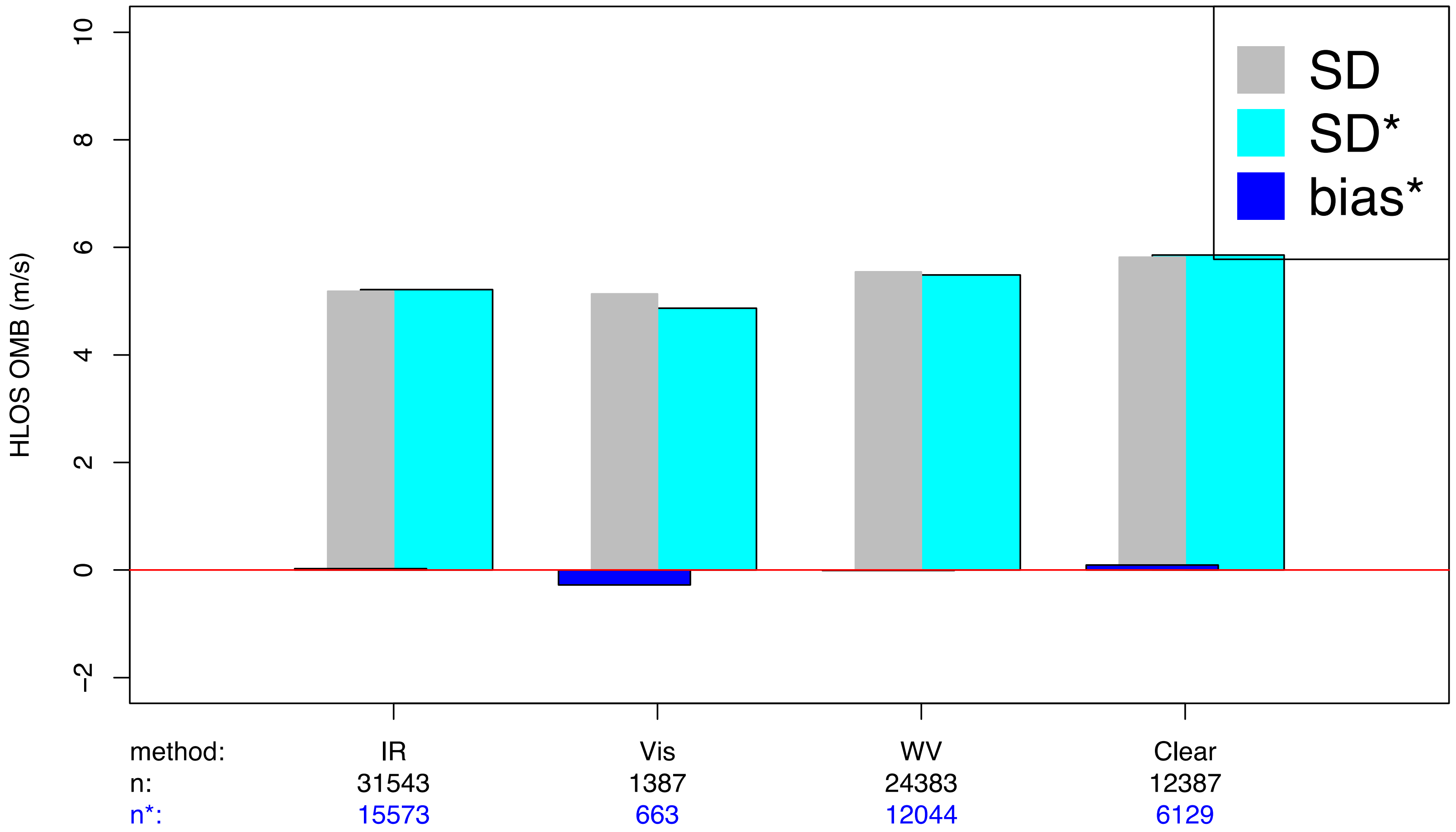
- Statistics barplot of OMB
  - * indicates independent test sample
- For pure collocation (no vertical interpolation), null (null hypothesis) and all (global optimization)
- N=(69700, 34409) (tune, test)
- sd (all)= (5.51, 5.5)
- sd (null)= (7.3, 7.3)
- reduction in variance = (43%, 43%)
- sd (pure)= (7.91, 7.95)

Global solution visualization



- Solution visualization for (null, all)
- Level 0 is the collocation level (thick grey horizontal line)
- Pink box shows levels averaged over (determined by h (0, 0.5) and Δz (0.5, 4.5) with width equal to γ (1.0, 0.93)
- X indicates δV (0.04, -0.02), right axis)
- For each solution, the thick grey, thin grey and dashed red vertical lines are at (0,1,γ)

Solution using method subsets



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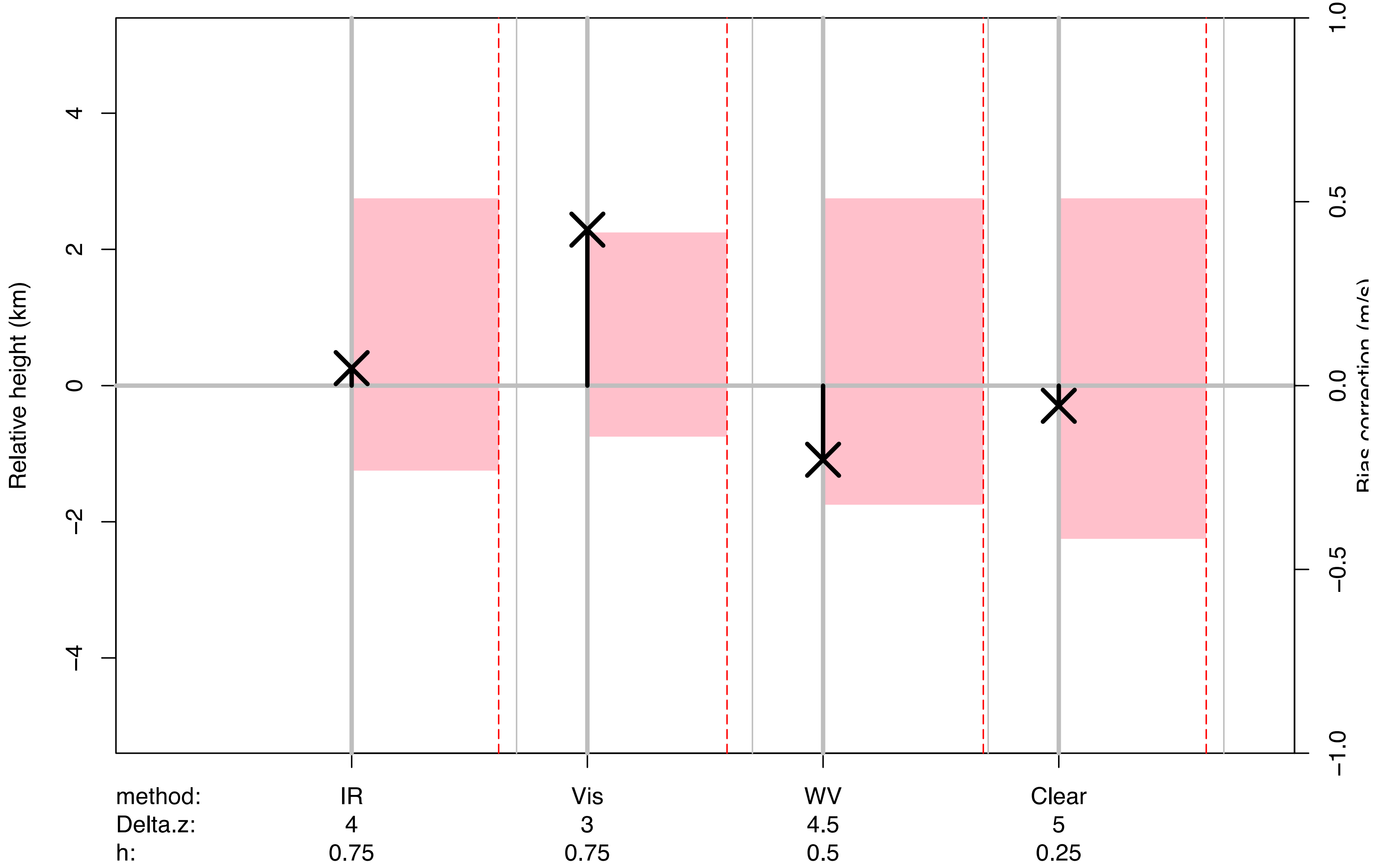
Solution using method subsets (tune)



Concluding remarks

- Error variance reduction of 40% on independent sample !!!
  - 50% using speed factor as additional predictor.
- One week yields only 100K collocations
  - Adequate for most of these results, but some factor levels do not have enough data
  - Not a problem for eventual GDAS VarFTC application which processes ~2M AMVs daily.
- These preliminary tests demonstrate the potential for the FTC observation operator for
  - Improving AMV collocations with profile wind data.
  - Characterizing AMVs. For example, summary results for the HLOS wind show that AMVs compare best with Aeolus wind profiles averaged over a 4.5 km layer centered 0.5 km above the reported AMV height.
  - Improving AMV observation usage within data assimilation (DA) systems. Lower estimated error and more realistic representation of AMVs with variational FTC (VarFTC) should result in greater information extracted.

Thank you

- Contact: ross.n.hoffman@noaa.gov
- A paper is under review at QJRMS
- Backup slides follow….

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Equivalently, the FTC observation operator may be rearranged in terms of linear function of a weighted average in the vertical

$$\widehat{\mathbf{V}} = \gamma\overline{\mathbf{V}} + \delta\mathbf{V} \tag{2}$$

$$\overline{\mathbf{V}} = \int w(z)\mathbf{V}(z)dz \Big/ \int w(z)dz \tag{3}$$

$$\gamma = \int w(z)dz \tag{4}$$

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Equivalently, but in discrete form, the FTC observation operator may be rearranged in terms of linear function of a weighted average of a small number of vertical layers

$$\widehat{\mathbf{V}} = \gamma\overline{\mathbf{V}} + \delta\mathbf{V} \quad (5)$$

$$\overline{\mathbf{V}} = \sum w_k \mathbf{V}_k / \sum w_k = \sum w'_k \mathbf{V}_k \quad (6)$$

$$w'_k = w_k/\gamma \text{ and } \gamma = \sum w_k \quad (7)$$

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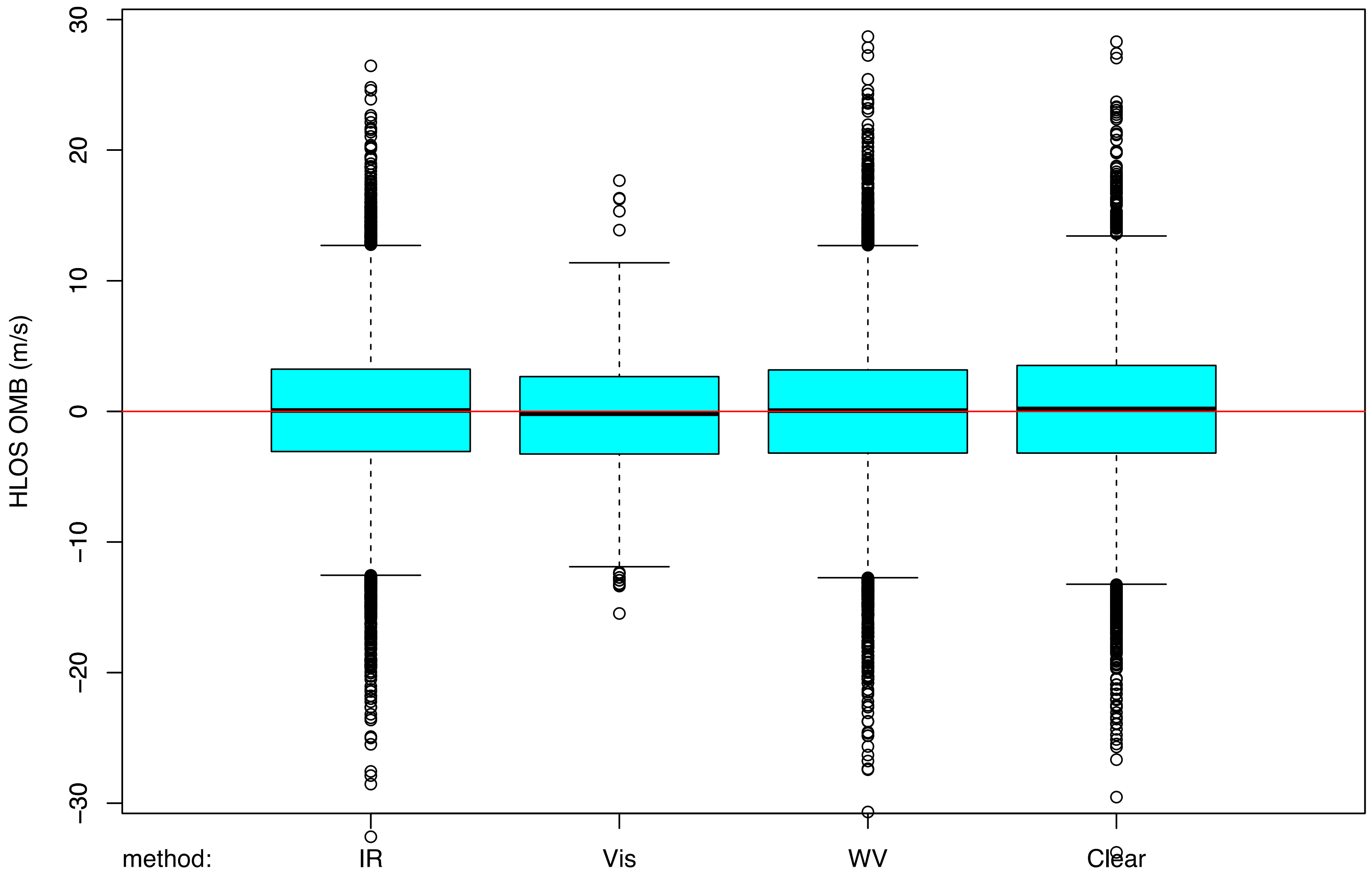
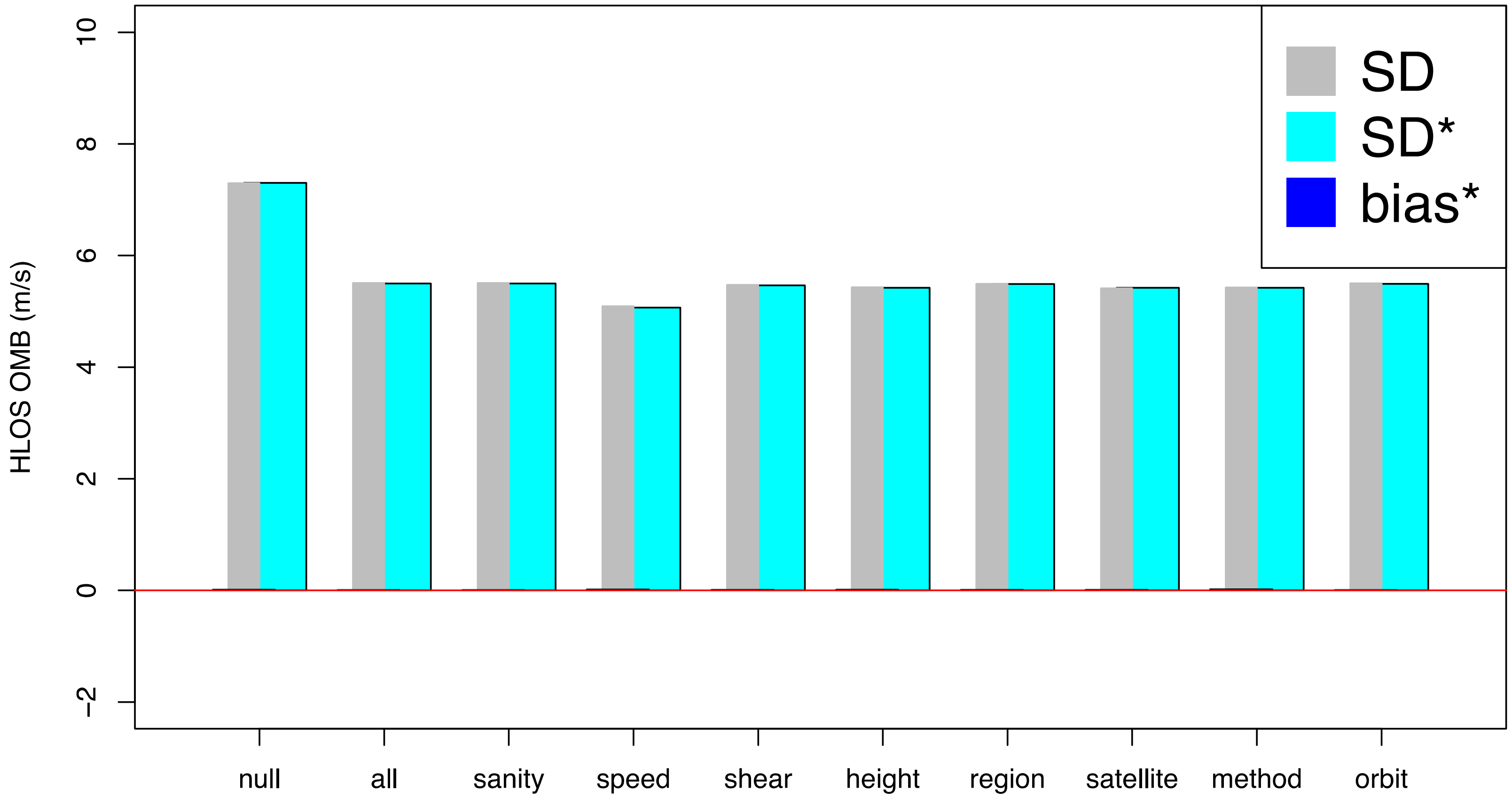
Solution using method subsets (test)



Solutions (test and tune samples)



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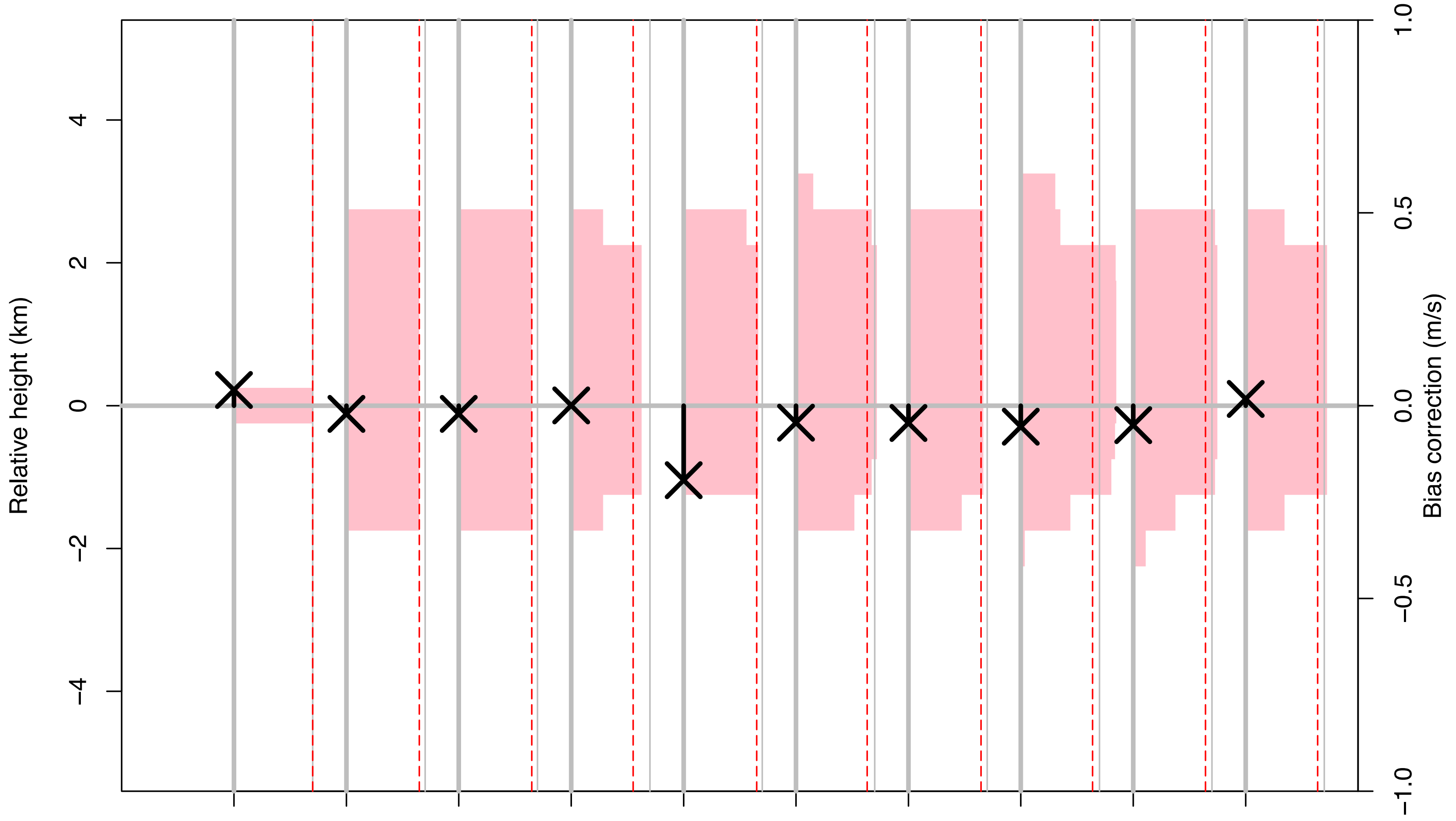

	null	all	sanity	speed	shear	height	region	satellite	method	orbit
Delta.z:	0.5	4.5	4.5	4.5	4	5	4.5	5.5	5	4.5
h:	0	0.5	0.5	0.5	0.75	0.75	0.5	0.5	0.25	0.5