The effect of measured vs. estimated -40 cm subsurface temperatures on METRo forecasts

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BACKGROUND

Finland has an extensive road weather station network. The stations are equipped with an array of road surface and atmospheric sensors, but until recently there have been no subsurface sensors. During autumn 2012, the Finnish Centre for Economic Development, Transport and the Environment installed ten subsurface temperature (SST) sensors in selected locations. The motivation was to see if the additional information from below the road surface would improve the road forecasts.

Foreca has made road weather forecasts for the Finnish road weather stations for over a decade and in 2010 Foreca integrated the METRo road weather model into production. METRo was developed at Environment Canada. Since Canadian road weather stations had SST sensors, it is natural that METRo initialization relies on measured SSTs. To use METRo in production in Finland, it has been necessary to develop a separate module for estimating the SST based on the surface temperature history. In practice, this has been done by using METRo one-hour SST predictions as the measured value for the next hourly run, thus iteratively initializing the SST.

METHODS

To study the effect of measured vs. estimated SST on the forecasts, we ran one complete year of METRo forecasts from November 2012 to October 2013 first by using the SST estimation method currently in production and then by re-running the exact same routines, except substituting the real measured SST values in METRo input XML. We then compared the measured vs. estimated SST time series, and the road surface temperature (ST) forecast errors from these two runs.

RESULTS

The estimated and measured SST stay within a degree of each other if persistent bias is removed. The estimated SST diverges by a couple of degrees only in some situations of significant air cooling and warming. These include the first severe cooling events of the winter, and some warming events in late spring.

For most months of the winter, the METRo runs based on estimated SST produce better results on average. We assume this is due to many METRo configuration parameters having been optimized using several years of data from the Foreca production system. Some of these parameter optimizations affect the SST estimation and likely compensate biases in METRo forecasts, which now manifest themselves when uncompensated by the SST.

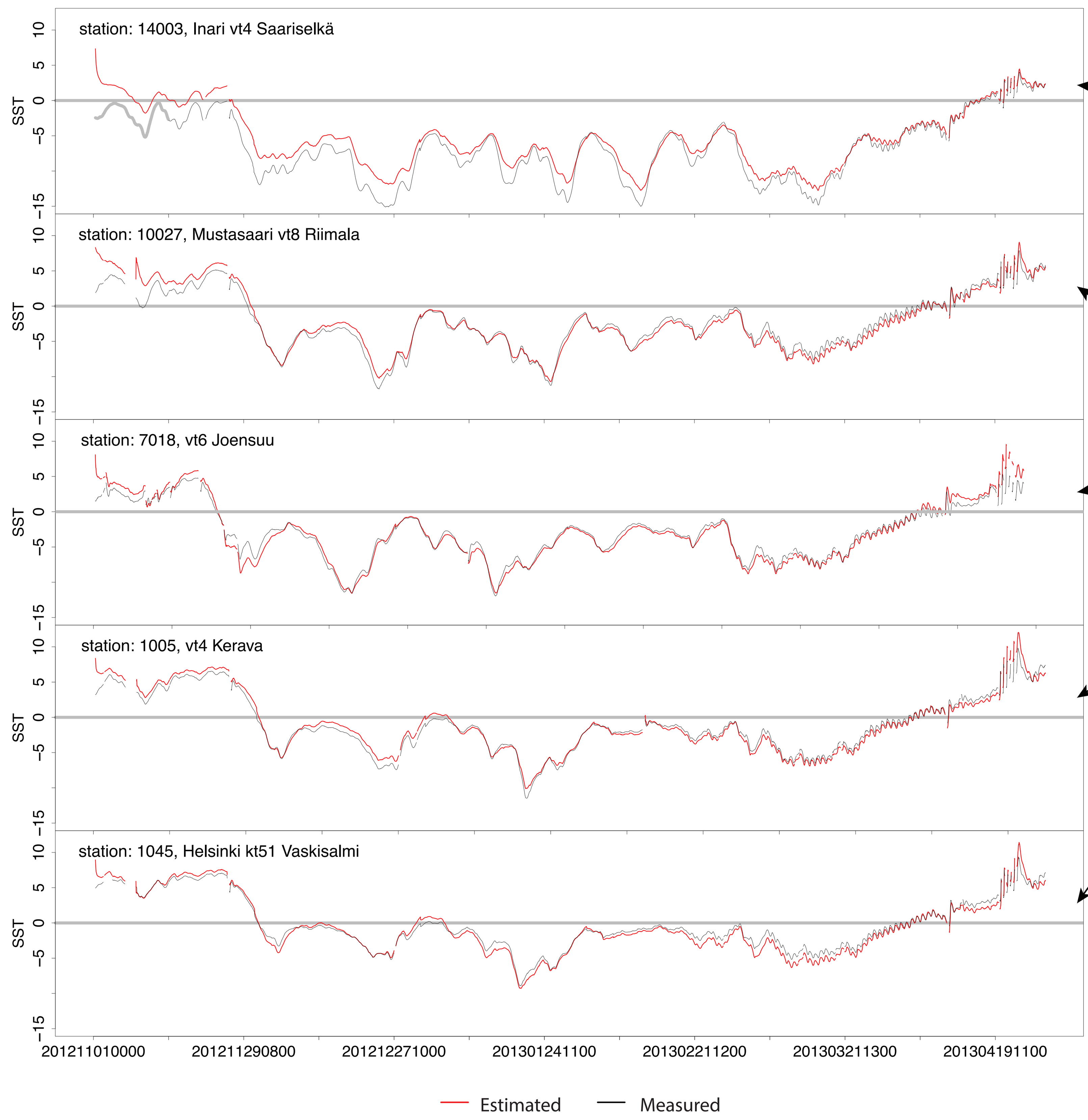
While SST estimation on average produces slightly smaller ST forecast errors, the difference is small and mostly random. Changes in the +9 h ST forecast due to estimated vs. measured SST are on average 0.11°C, see graph. Using measured SST improved the ST forecast in 43% of the forecasts and made it worse in 51% of the cases. In some cases the measured SST improved the ST forecasts consistently for a longer period, these cases are circled in the graphs on the right.

There is one special case where the SST sensors have a consistent positive effect. In case of a long break in the data series, it takes a day for the SST estimate to stabilize, while the measured SST is immediately correct. Examples of this can be seen in the data series.

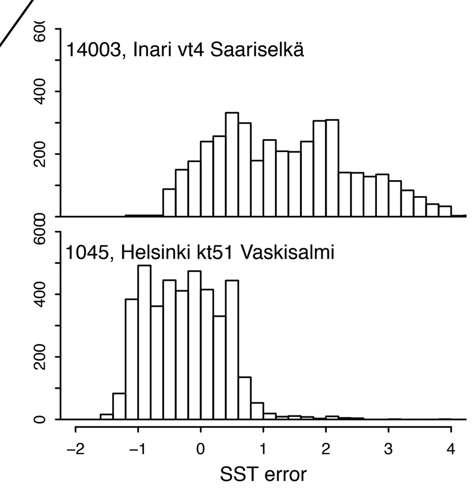
CONCLUSIONS

Subsurface temperature (SST) estimation works generally well. During winter period there seems to be on average one week per station where the SST measurement provides a clear advantage over the estimate. Such events can occur after rapid changes in air temperature, and after longer data breaks.

Subsurface temperature at -40cm

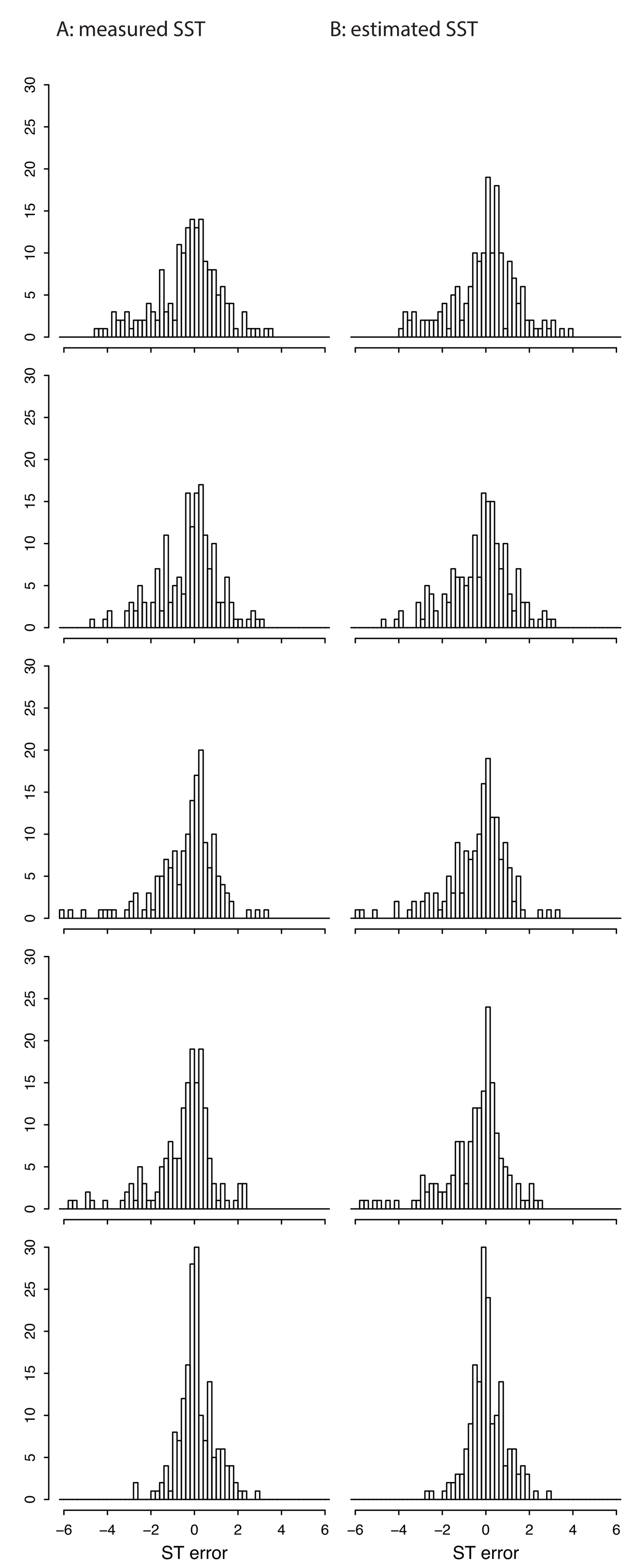


SST error



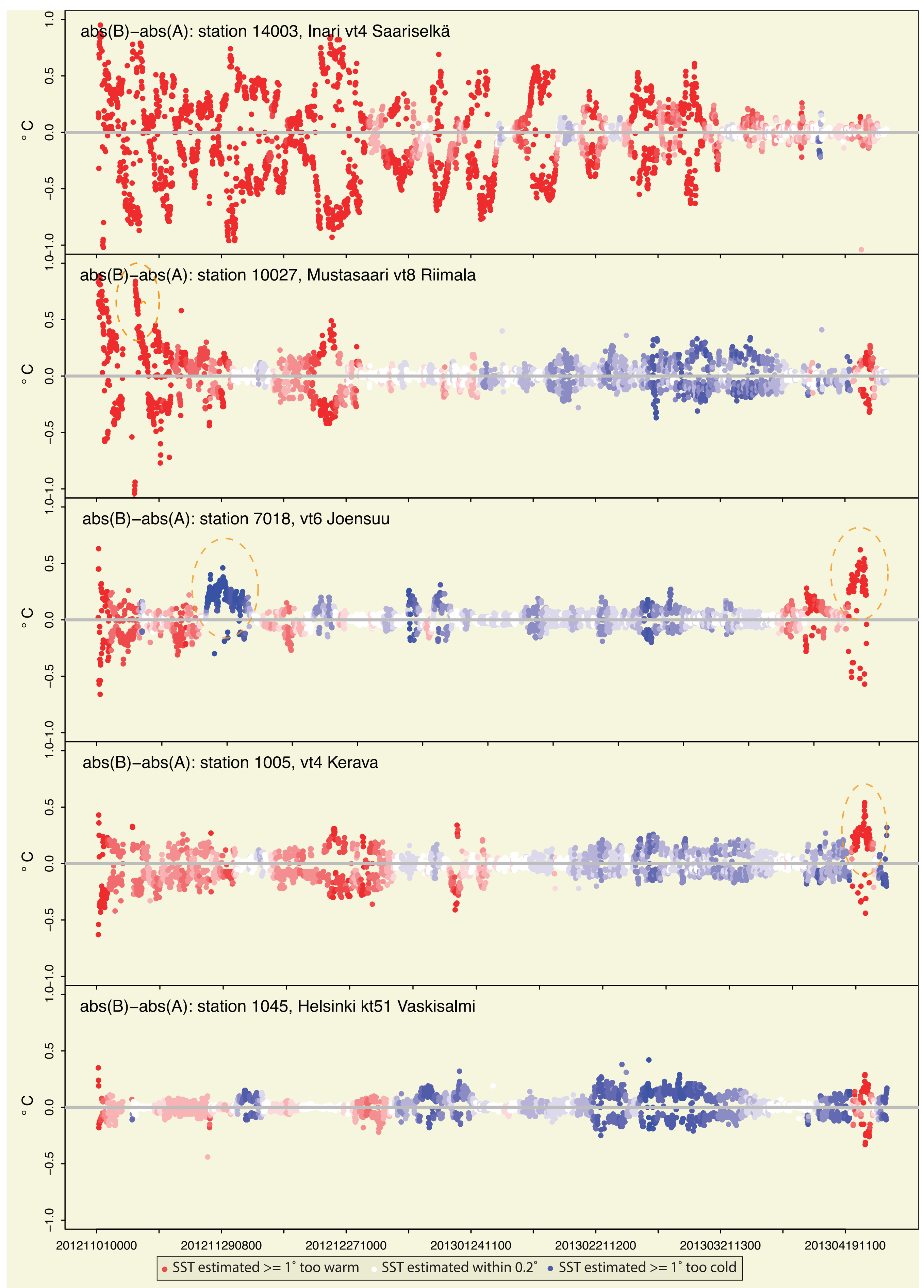
Station	MAE	SD
14003	1.45	1.09
1045	0.54	0.39

+9 h surface temperature forecast error



Station	ST MAE (measured)	ST SD (measured)	ST MAE (estimated)	ST SD (estimated)
all	1.35	1.61	1.33	1.60
14003	1.18	1.14	1.33	1.10
1045	1.03	1.17	1.04	1.17

Changes in the +9 h ST forecast error due to estimated vs. measured SST



Station	ST mean avg diff	ST mean diff SD
all	0.11	0.13
14003	0.22	0.20
1045	0.06	0.05

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