Introduction

Site Atmospheric State Best Estimates (SASBEs) combine measurements from multiple instruments to create the best possible vertically resolved high temporal resolution time series of the parameter of interest at a single site. The SASBE contains all available knowledge of the state of the target variable at that site and includes an estimate of the uncertainty on each datum. Here, a temperature SASBE for the Global Reference Upper-Air Network (GRUAN) site at Lauder, New Zealand is presented. As upper-air measurements are sparse in the southern hemisphere, SASBEs for Lauder will be particularly valuable for satellite and model validation.

Methodology for the second version of the temperature SASBE

The temperature SASBE for Lauder is calculated from:

1. The temperature measured above Lauder.
2. The diurnal cycle of the temperature above Lauder.
3. The temperature anomaly above Lauder, calculated with a regression model from the temperature anomaly above Linemangill (≈ 200 km southwest of Lauder).

The temperature at one pressure level is calculated as:

\[ T_{LS}(t) = \alpha T_{RS}(t) + (1 - \alpha) T_{Inv}(t) + \beta T_{Lin}(t) \]

where \( \alpha \) and \( \beta \) are weights accounting for the decaying influence of a measurement with time, i.e.,

\[ \alpha = \exp \left( \frac{(t - t_0)^2}{\tau^2} \right) \]
\[ \beta = \exp \left( \frac{(t - t_0)^2}{\tau^2} \right) \]

The decay factors are chosen to be \( \tau_{Lauder} = 6h \) and \( \tau_{Linemangill} = 4h \).

\( T_{LS}(t) \) are the launch times of the radiosonde at Linemangill and \( t \) is the given time at which the SASBE is calculated.

The following data are used:

- Temperature/vertical wind/speed profiles from radiosondes launched at Linemangill/Lauder.
- 2-meter temperature and pressure measured with an automatic weather station at Lauder/Linemangill.
- NCEP/FSR and MERRA reanalysis data sets to calculate the diurnal cycle at certain pressure levels above Linemangill and Lauder.

The temperature anomaly above Linemangill \( T_{Inv}' \), is calculated from the temperature anomaly above Linemangill \( T_{Lin}' \), using the following regression model:

\[ T_{Inv}' = \alpha T_{Lauder} + \beta T_{Lin} + \Delta SP + \Delta ST + \epsilon \]

where \( \Delta SP \) is the surface pressure difference between Linemangill and Lauder and \( \Delta ST \) is the difference in surface temperature anomaly between Linemangill and Lauder, and \( \alpha, \beta, \epsilon \) are regression coefficients.

Uncertainty Propagation

The uncertainty is propagated through all calculations. The following uncertainty components are taken into account:

- Uncertainty on the regression coefficients are calculated following [3].
- The uncertainty on the diurnal cycle is estimated based on [4].
- The \( \kappa = 1.0 \) uncertainty on the radiosonde is assumed as 0.25 K [5].

A general error propagation model \( y = f(x) \) is used:

\[ \sigma_y = \sqrt{\left( \frac{\partial y}{\partial x_1} \sigma_{x_1} \right)^2 + \left( \frac{\partial y}{\partial x_2} \sigma_{x_2} \right)^2 + \ldots + \left( \frac{\partial y}{\partial x_n} \sigma_{x_n} \right)^2} \]

In the case of uncorrelated uncertainties, the last term is zero and the error propagation equation reduces to:

\[ \sigma_y = \sqrt{\left( \frac{\partial y}{\partial x_1} \right)^2 \sigma_{x_1}^2 + \left( \frac{\partial y}{\partial x_2} \right)^2 \sigma_{x_2}^2 + \ldots + \left( \frac{\partial y}{\partial x_n} \right)^2 \sigma_{x_n}^2} \]

This reduced error propagation law, ignoring the cross-correlation term is used here. Thus, the uncertainty on Eq.(1) is calculated as:

\[ \sigma_{T_{LS}} = \sqrt{\left( \frac{\partial T_{LS}}{\partial T_{RS}} \right)^2 \sigma_{T_{RS}}^2 + \left( \frac{\partial T_{LS}}{\partial T_{Inv}} \right)^2 \sigma_{T_{Inv}}^2 + \left( \frac{\partial T_{LS}}{\partial T_{Lin}} \right)^2 \sigma_{T_{Lin}}^2} \]

\[ = \sqrt{\sigma_{T_{RS}}^2 \alpha^2 + \sigma_{T_{Inv}}^2 \beta^2 + \left( 1 - \alpha - \beta \right)^2} \]

\[ \sigma_{T_{LS}} = \sigma_{T_{RS}} \alpha + \sigma_{T_{Inv}} \beta + \sigma_{T_{Lin}} \left( 1 - \alpha - \beta \right) \]

The errors are also propagated through the regression model including the uncertainties on the regression coefficients and on the measurements (≈ 12 uncertainty terms).

Outlook

- Extend the time frame
- Use the ERA5 (next dataset to test choices of variables, e.g., analysing a regression to estimate decaying factor \( \kappa \))
- Publish the methodology in Earth System Science Data Journal

References