A Site Atmospheric State Best Estimate of Temperature for Lauder, New Zealand

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Introduction

Site Atmospheric State Best Estimates (SASBEs, [1]) combine measurements from multiple instruments to create the best possible vertically resolved high temporal resolution time series of the parameter of interest above one 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 GCOS[a] Reference Upper-Air Network (GRUAN, [2]) 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.

[a]Global Climate Observing System

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 Invercargill (≈ 200km southwest of Lauder)

The temperature at one pressure level is calculated as:

$$T_{Lau}(t) = \alpha \cdot T_{RS}(t_{Lau}) + (1-\alpha)[T_{diur}(t) + \beta \cdot T'_{Lau}(t_{Inv})] \quad \text{Eq.(1)}$$

where α and β are weights accounting for the decaying influence of a measurement with time, i.e.

$$\alpha = exp\left(-\frac{(t_{Lau}-t)^2}{\tau_{Lau}^2}\right) \quad \text{Eq.(2)}$$

$$\beta = exp\left(-\frac{(t_{Inv}-t)^2}{\tau_{Inv}^2}\right) \quad \text{Eq.(3)}$$

The decay factors are chosen to be $\tau_{Lau} = 6h$ and $\tau_{Inv} = 4h$. t_{Lau}/t_{Inv} are the launch times of the radiosonde in Lauder/Invercargill and t is the given time at which the SASBE is calculated.

The following data are used:

- temperature/wind direction profiles from radiosondes launched at Lauder/Invercargill
- 2-meter temperature and pressure measured with an automatic weather station at Lauder/Invercargill
- NCEP-CFSR and MERRA reanalysis data sets to calculate the diurnal cycle at certain pressure levels above Lauder and Invercargill

The temperature anomaly above Lauder T'_{Lau} is calculated from the temperature anomaly above Invercargill T'_{Inv} using the following regression model:

$$T'_{Lau} = \alpha + \beta \cdot T'_{Inv} + \eta \cdot \Delta SP + \kappa \cdot \Delta ST' + \epsilon \quad \text{Eq.(4)}$$

where ΔSP is the surface pressure difference between Invercargill and Lauder and ΔST is the difference in surface temperature anomaly between Invercargill and Lauder. α, β, η, κ 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 k=1 uncertainty on the radiosonde is assumed as 0.25 K [5].

A general error propagation model for $x = f(u,v)$ is used:

$$\sigma_x = \sqrt{\sigma_u^2(\frac{\partial x}{\partial u})^2 + \sigma_v^2(\frac{\partial x}{\partial v})^2 + 2\sigma_{uv}^2(\frac{\partial x}{\partial u})(\frac{\partial x}{\partial v})} \quad \text{Eq.(5)}$$

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

$$\sigma_x = \sqrt{\sigma_u^2(\frac{\partial x}{\partial u})^2 + \sigma_v^2(\frac{\partial x}{\partial v})^2} \quad \text{Eq.(6)}$$

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

$$\sigma_{T_{Lau}} = \sqrt{\sigma_{T_{RS}}^2\left(\frac{\partial T_{Lau}}{\partial T_{RS}}\right)^2 + \sigma_{T_{diur}}^2\left(\frac{\partial T_{Lau}}{\partial T_{diur}}\right)^2 + \sigma_{T'_{Lau}}\left(\frac{\partial T_{Lau}}{\partial T'_{Lau}}\right)^2}$$
$$= \sqrt{\sigma_{T_{RS}}^2\alpha^2 + \sigma_{T_{diur}}^2(1-\alpha)^2 + \sigma_{T'_{Lau}}[(1-\alpha)\beta]^2} \quad \text{Eq.(7)}$$

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

Results

The SASBE has an hourly resolution and is available at the following pressure levels: ground, 925 hPa, 850 hPa, 700 hPa, 500 hPa, 400 hPa, 300 hPa, 200 hPa, 150 hPa, 100 hPa, 70 hPa, 50 hPa, 30 hPa, 20 hPa, 10 hPa. Currently the SASBE is calculated for the years 1996-2012. Figure 1 shows the different components of the SASBE for the 2nd Dec 2001. The uncertainty is given as a per datum value and is shown in the error bars around the black dashed line.

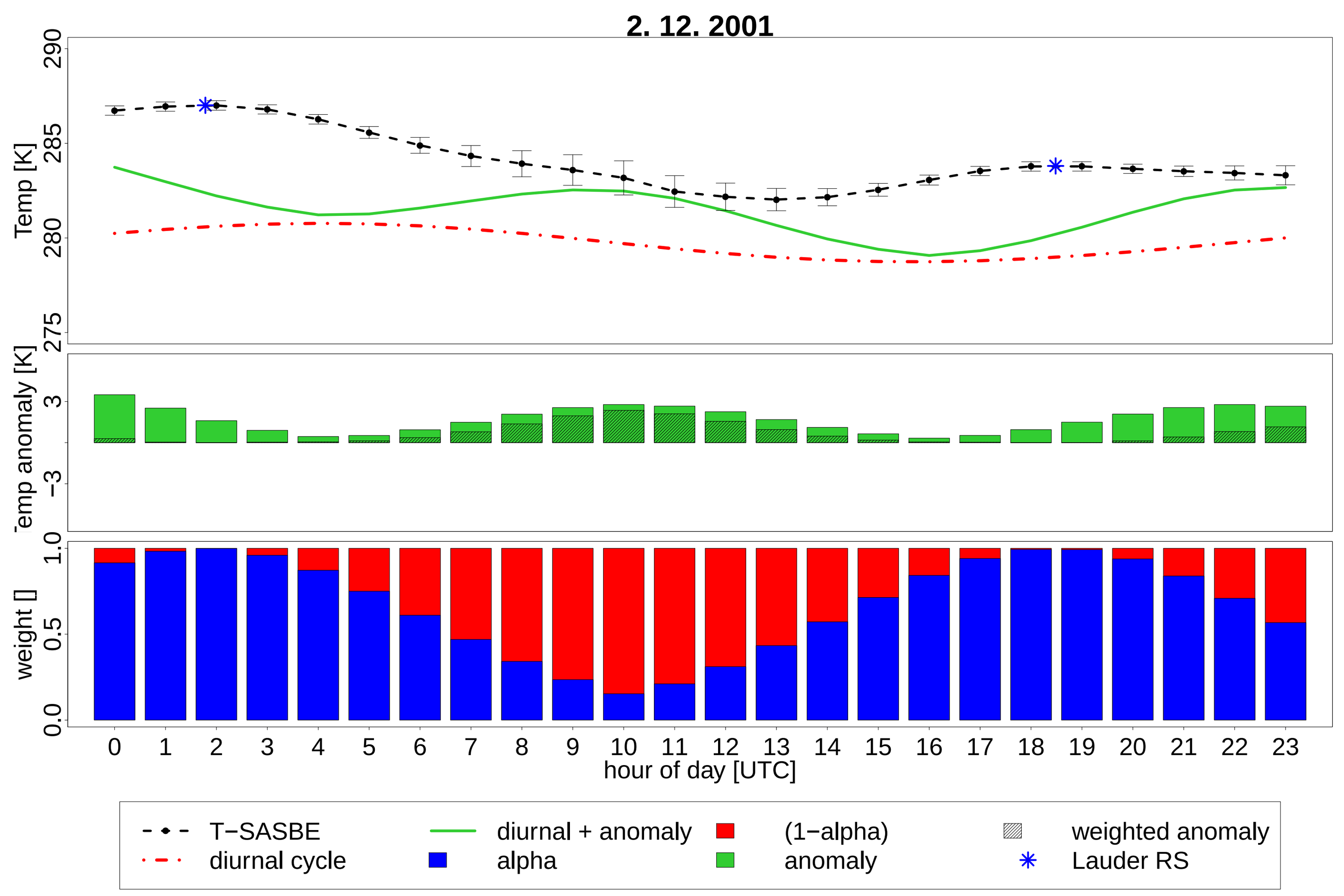

Figure 1: Components of the temperature SASBE at 850 hPa. Top panel: diurnal cycle (red dot-dashed), diurnal cycle plus temperature anomaly ($T_{diur}(t) + \beta \cdot T'_{Lau}(t_{Inv})$, green) and temperature SASBE ($T_{Lau}(t)$, black dashed) with associated error bars. The blue star gives the temperature measured with a RS launched from Lauder. Middle panel: Temperature anomaly ($\beta \cdot T'_{Lau}(t_{Inv})$ green bars) and weighted temperature anomaly ($(1-\alpha)\beta \cdot T'_{Lau}(t_{Inv})$,ruled). Bottom panel: Weights α (blue bars) and $(1-\alpha)$ (red bars).

Including the measurement made above Invercargill improves the SASBE in Fig.1 compared to using the diurnal cycle alone, as can be seen comparing the difference between the green/red line and the blue star (Lauder radiosonde measurement). This is analysed quantitatively in Fig.2 which shows the normalised squared residuals for each year. Including the Invercargill measurements decreases the residuals at all levels where measurements are available! Thus, it is valuable to integrate measurements made at the upper-air site in Invercargill into the temperature SASBE for Lauder.

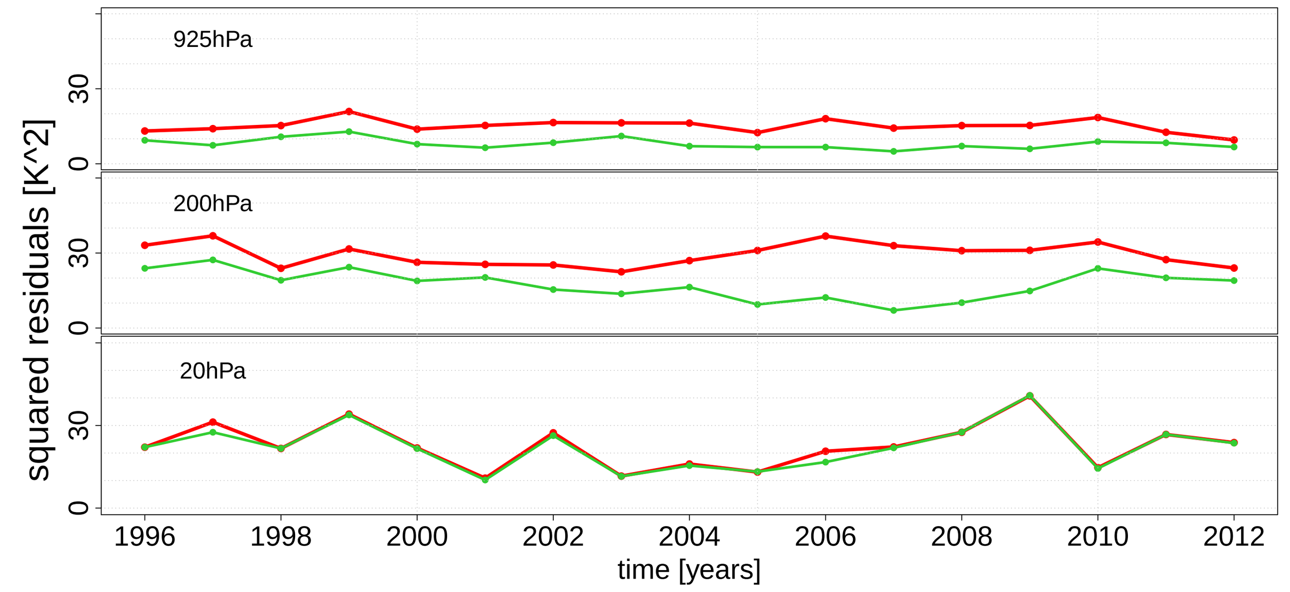

Figure 2: Normalized squared residuals between the Lauder RS measurements and (i) the diurnal cycle (red) and (ii) the diurnal cycle plus temperature anomalies retrieved from the regression model using the Invercargill RS (green).

Outlook

- Extend the time frame
- Use hourly ERA5 test dataset to test choices of variables, e.g. analyse autoregression to estimate decaying factor τ
- Publish the methodology in Earth System Science Data Journal
- Make the SASBE available to the scientific community
- Validate IASI and/or AIRS temperature retrievals above Lauder
- Funding dependend: Validation of top-of-the-atmosphere radiances with SASBEs for Lauder [6] envisioned as post-doc project

References

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