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Spatial Analysis of Near-Surface Air Humidity: Which Variable?

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Problem

- Grid data of daily surface air humidity is usually produced for one variable (mostly relative humidity).
- Some applications require another variable (e.g. calculating evapotranspiration requires vapor pressure). Users then convert variables with a temperature grid.
- But conversions are valid for instantaneous values only, not for daily means, because of non-linearity.
- How large are the related errors? Is there a preferred choice of variable to minimize conversion errors?

Experiment

- Use data at Swiss stations (daily and 10-minute) to infer daily mean of variable Y from X via conversion (X → Y). Compare inferred to true values.

Results

- Inferring e, Δe, T_d or ΔT_d from u, introduces an error. It is mainly systematic (a bias). e and T_d are overestimated, Δe and ΔT_d underestimated. (Fig. 1)
- The bias is larger in summer than in winter. It is small on mountains (~4%), moderate in flatland (SMA, Fig. 1) and large in valleys (SIO, Fig. 2).
- The bias can exceed 10% in terms of the difference to saturation (Fig. 1 & 2, red stars).
- Conversions starting from ΔT_d are much less biased than those from other variables (Fig. 2).
- The bias is a consequence of the diurnal covariation of rel. humidity and temperature (see box below).

Conclusions

- Converting between moisture variables in grid datasets is unavoidable, but introduces a bias.
- Inferring vapor pressure deficit from relative humidity can lead to a bias of >10% (too moist). This is likely relevant in applications.
- It is more suitable to provide dew-point temperature difference in grid datasets, rather than relative humidity, because conversions produce less bias so.

Conversion bias explained for u → e :

$$\bar{e} = \overline{u(h) \cdot e_s(t(h))}$$

$$= \overline{u(h)} \cdot \overline{e_s(t(h))} + \overline{(u(h) - \bar{u})(e_s(t(h)) - \bar{e_s})}$$

$$\approx \overline{u(h)} \cdot e_s(\overline{t(h)}) + \overline{(u(h) - \bar{u})(e_s(t(h)) - \bar{e_s})}$$

$$= \hat{\bar{e}} + cov(u, e_s)$$

Inferred $\hat{e}$ and true e daily mean vapor pressure differ by a covariance term. The term is negative. In the daily course, u is small when $e_s(t)$ is high. As a result, e is overestimated and Δe underestimated when inferred from u.

Humidity Variables:

Relative Humidity u

Vapor pressure e

Vapor pressure deficit Δe

Dew point temperature T_d

Dew point temp difference ΔT_d

Specific humidity s

Conversion $u \rightarrow e$:

true: $\bar{e} = \overline{u(h) \cdot e_s(t(h))}$

inferred: $\hat{\bar{e}} = \overline{u(h)} \cdot e_s(\overline{t(h)})$

$\hat{\bar{e}} \neq \bar{e}$

e_s : saturation pressure
t : air temperature
h : times of the day
overbar : daily mean

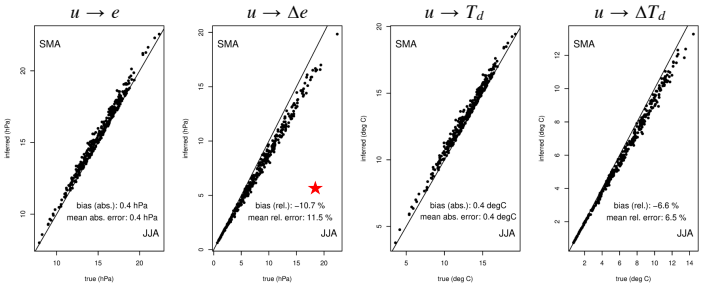


Figure 1: Scatterplot of inferred (y-axis) vs. true (x-axis) daily mean moisture variables. Inferred values are derived from daily mean relative humidity and temperature by conversion. Panels are for variables e, Δe, T_d and ΔT_d (from left to right). Results for station SMA (Zürich, flatland). Each point is for a summer day (4 years, 2018-2021).

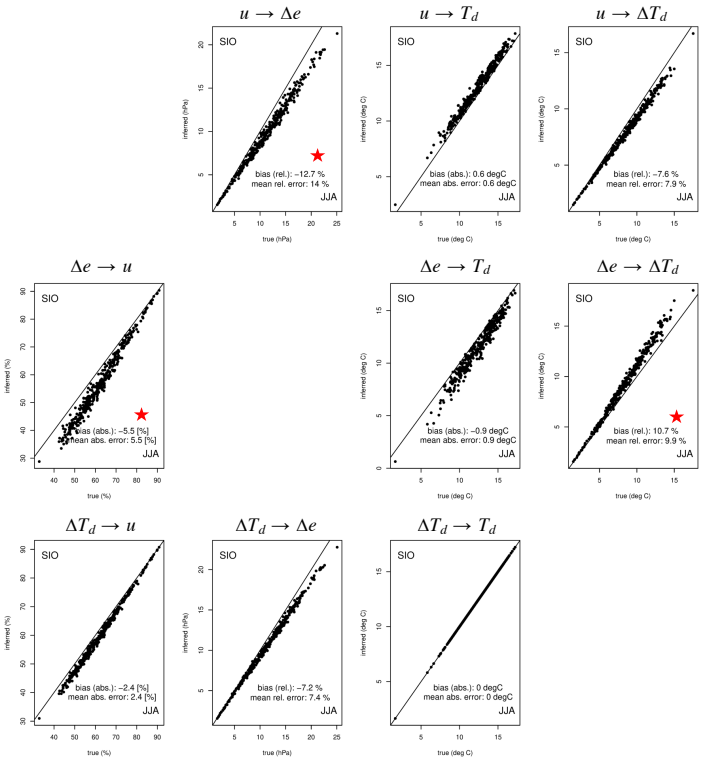


Figure 2: Scatterplot of inferred (y-axis) vs. true (x-axis) daily mean moisture variables. Target variables run over columns (u, Δe, T_d, ΔT_d), source variables over rows (u, Δe, ΔT_d). Results are for station SIO (in Alpine valley) and summer, but differences in errors/biases between source variables is similar for other stations and seasons.

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