25 Years of Paramaribo sonde observations: Evidence of climate change in the Tropics

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Paramaribo station is located on the north coast of South America, where the ITCZ passes twice a year (southward and northward). Ozonesondes are released weekly since 1999 and form the base of a multiple linear regression (MLR) trend analysis that provides evidence of climate change in the Tropics. Key findings include (i) the upper troposphere is warming at a larger rate than the surface warming of around 0.5 K, stabilizing the troposphere, and (ii) a thickening of the troposphere resulting in an increase in the tropical tropopause height by up to 300 m is measured, - at least partially - explaining the trend profile shapes in temperature, ozone and zonal winds around the tropopause.

Paramaribo station, Suriname (5.8°N, 55.2°W)

Figure 1 shows Paramaribo station, operational for 25 years, located on the north coast of South America. This allows air from both hemispheres to be recorded and studied, as well as the ITCZ itself, as it migrates in two different states of development and direction (northward vs. southward) over Paramaribo.

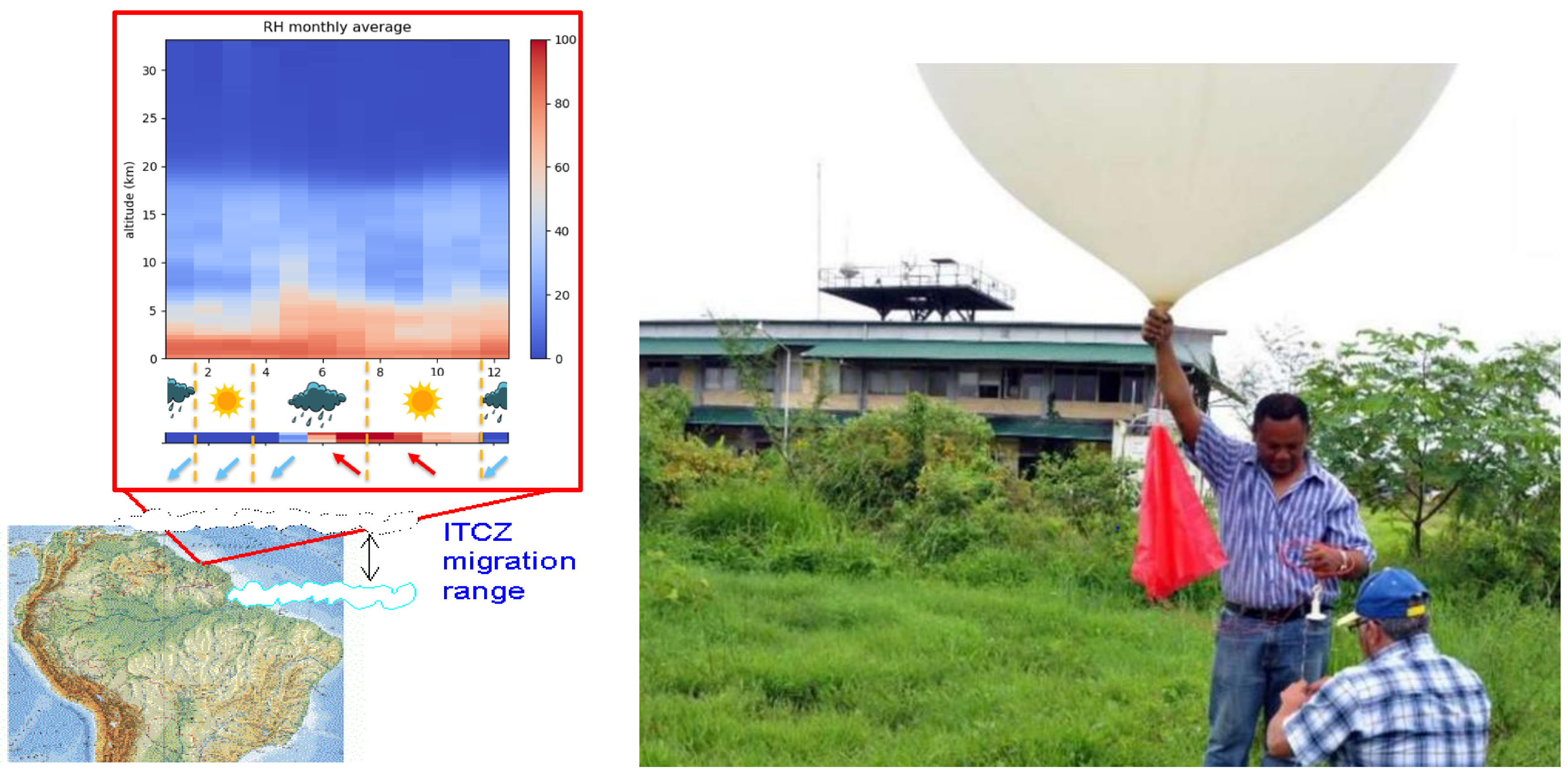

Fig. 1 Paramaribo station in relation to the ITCZ migration range (left), including long-term annual cycle of relative humidity over Paramaribo, indicated rainy (cloud) and dry (sun) seasons in relation to the northeast (blue arrow) and southeast trade winds (red arrow).

Results

The profile trends shown in Figures 2 and 3 are based on a MLR analysis on the homogenised time series of 25 years of radiosonde observations at Paramaribo. Our findings are largely in line with scientific literature:

- A climate warming by about +0.5 °C at the surface (cf. IPCC AR6).
- An amplified warming in the upper tropical troposphere by more than a factor 2-3. According to Vergados et al (2020) and Keil et al. (2023) this is caused by latent heat release.
- An increase in the zonal-mean wind in the lower stratosphere (Kang et al., 2022).
- From the tropopause upwards a stratospheric cooling.
- A slightly negative trend in lower stratospheric ozone, largely to be attributed to the observed upward trend in tropopause height (see discussion).

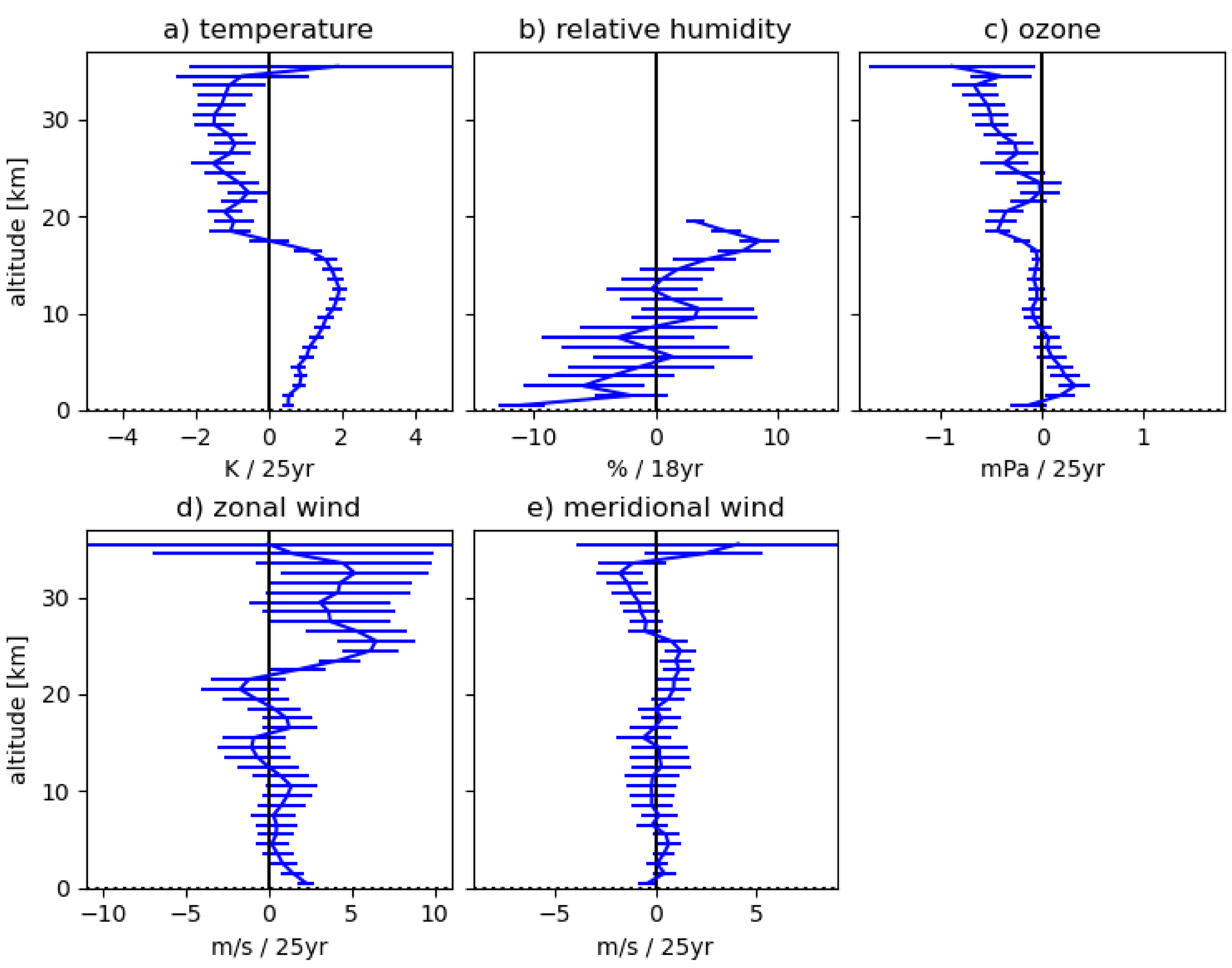

Fig. 2 Trend-height profiles from MLR analysis, performed on homogenised and de-seasoned parameters depicted (with 2 sigma error bars). QBO and ENSO are included in the MLR. Corrections for launch time are made using corresponding daily cycles from ERA5 reanalysis. Corrections for radiosonde changes (RS80 → RS92 → RS41) are based on Steinbrecht et al. 2008 and Jing et al. 2021 for temperature and on ongoing dual launches (⍰RS92 → RS41) in De Bilt for humidity.

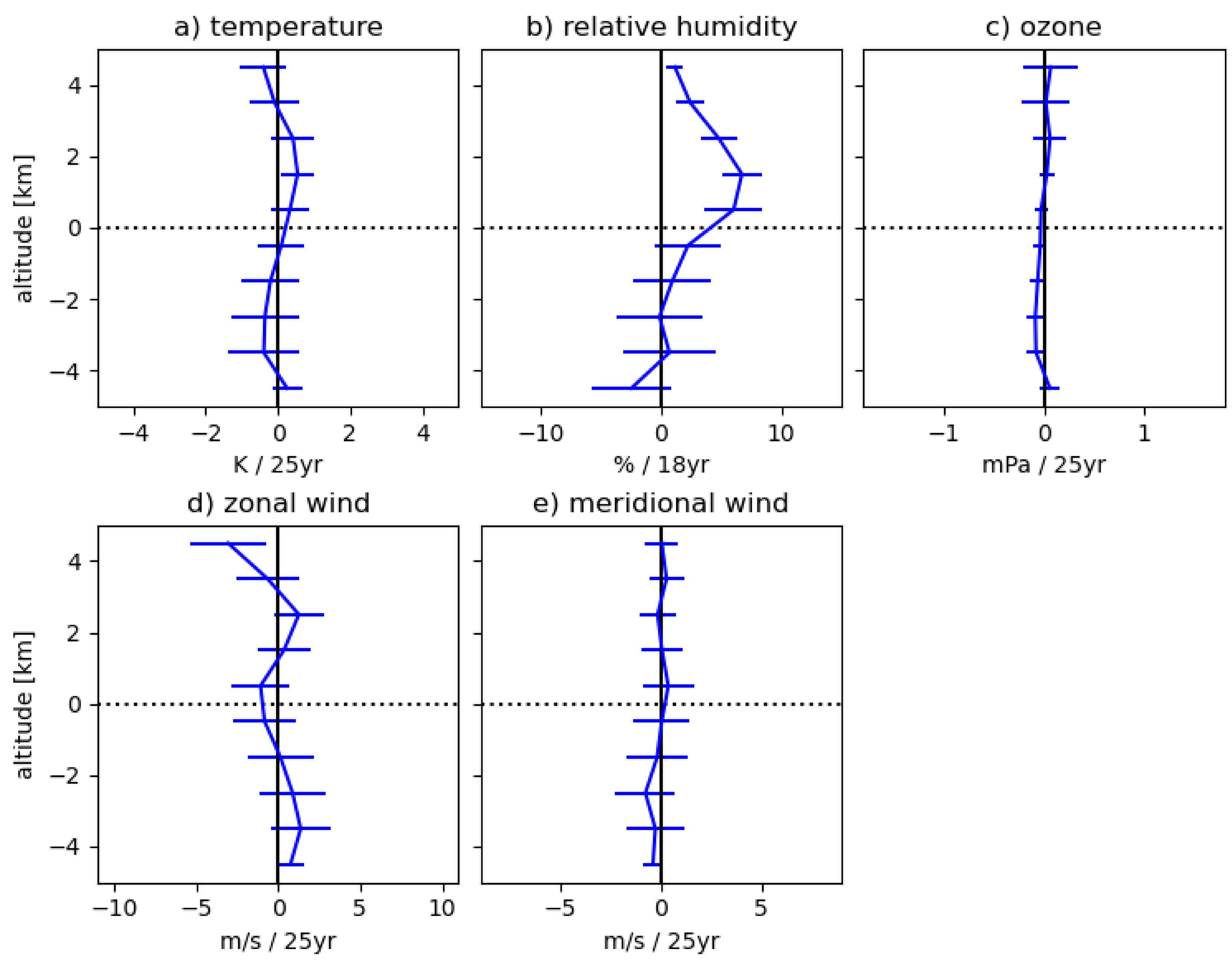

Fig. 3 MLR trend profiles with respect to tropopause height (km), performed on the same homogenized dataset as in Figure 2.

- An increase in lower stratospheric water vapour. Although there is no change in tropopause temperature measured at Paramaribo station, the upward transport of water vapour could still increase in (sub-)tropical areas with increasing tropopause temperatures (Ueyama et al., 2023).
- Relative to tropopause height, temperature and ozone profile trends around the tropopause become insignificant, showing that the profile trends in this region are predominantly caused by a thickening of the tropical troposphere caused by global warming (see discussion).

Discussion

The difference in the trend profile shapes in Figures 2 and 3 can be explained by an observed increase in the registered tropopause height by about 300 ± 130 m over the 25-year time period. To some extent this might be explained by pressure bias of RS80 with respect to RS92 of about +0.2 hPa (Steinbrecht et al, 2008), and a subsequent pressure bias of RS92 with respect to RS41 of about +0.5 hPa (Kawai et al., 2017). However, this combination of pressure biases can only partly (max ~50%) explain the observed increase in tropopause height.

To illustrate the importance of a change in tropopause height on the temperature trend profile shape, Figure 4 shows the difference between two temperature profiles with the orange profile being 0.5 K warmer at the surface than the blue profile and uplifting the tropopause by 300m for identical tropopause temperature. Consequently, the resulting lapse rate of the orange profile is more stable than the blue profile. The difference plot in the middle resembles the temperature trend profile shape in Figure 2. The similarity suggests a contribution of the observed tropopause height increase on the amplified warming in the upper tropical troposphere, potentially reducing the relative contribution of latent heat release.

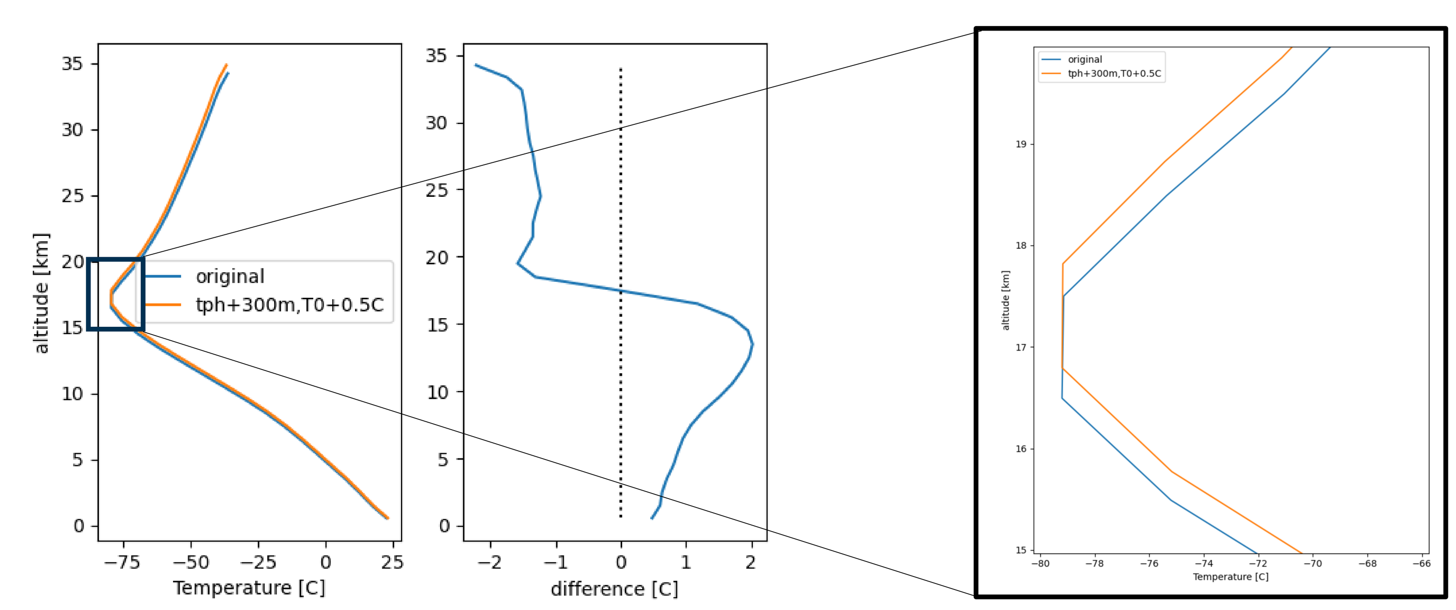

Fig. 4: Sensitivity of the average temperature profile (blue) to a 0.5 K surface warming and 300m uplifted tropopause height for identical tropopause temperature (orange) on the left, with an inset on the right, and the temperature difference profile in the middle.

Jing et al., 2021, DOI: 10.3390/atmos12070857
Kang et al., 2022, DOI: 10.1126/sciadv.abm7229
Kawai et al., DOI: 10.5194/amt-10-2485-2017
Keil et al., 2023, DOI: 10.1002/qj.4526
Steinbrecht et al 2008, DOI: 10.1175/2007JTECHA999.1
Ueyama et al, 2023 DOI:10.1029/2022JD037135
Vergados et al., 2020, DOI: 10.1029/2020EA001597

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