Tropospheric circulation during the early 20th century Arctic warming

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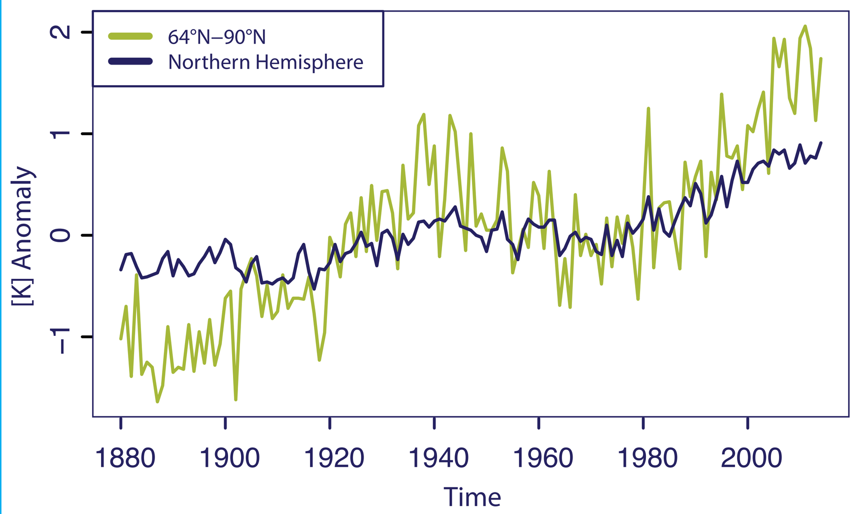
Background

- **The early twentieth century Arctic warming (ETCAW)** between 1920-1940 is an exceptional feature of climate dynamics in the last century and its warming rate was only recently matched by anthropogenic global warming amplification in the Arctic region.

- However, atmospheric warming during the ETCAW was strongest in the **winter mid-troposphere of the European sector** and is believed to be triggered by an exceptional **case of natural climate variability.**



Northern Hemisphere and Polar Temperature Anomalies
Yearly GHCN v3 + SST ERSST v4
1880-2014 with respect to 1951-1980

- **Beitsch et al. 2014** analysed the climatic conditions of 26 Arctic warming events within an Earth System model. They found a strong **increase of stationary atmospheric energy transport** into the Arctic during the warming event, whereas **transient and mean meridional energy transports decrease.**

- The case of the ETCAW underlines the importance of **yearly and decadal internal variability** in Arctic climate evolution.

? *How important is internal variability for the formation of this warming event?*

? *What are the atmospheric conditions and dynamics to sustain this warming?*

? *How well do recent centennial reanalysis datasets capture the event compared to general circulation models?*

? *Is it possible to quantify mid-tropospheric heat transport into the Arctic?*

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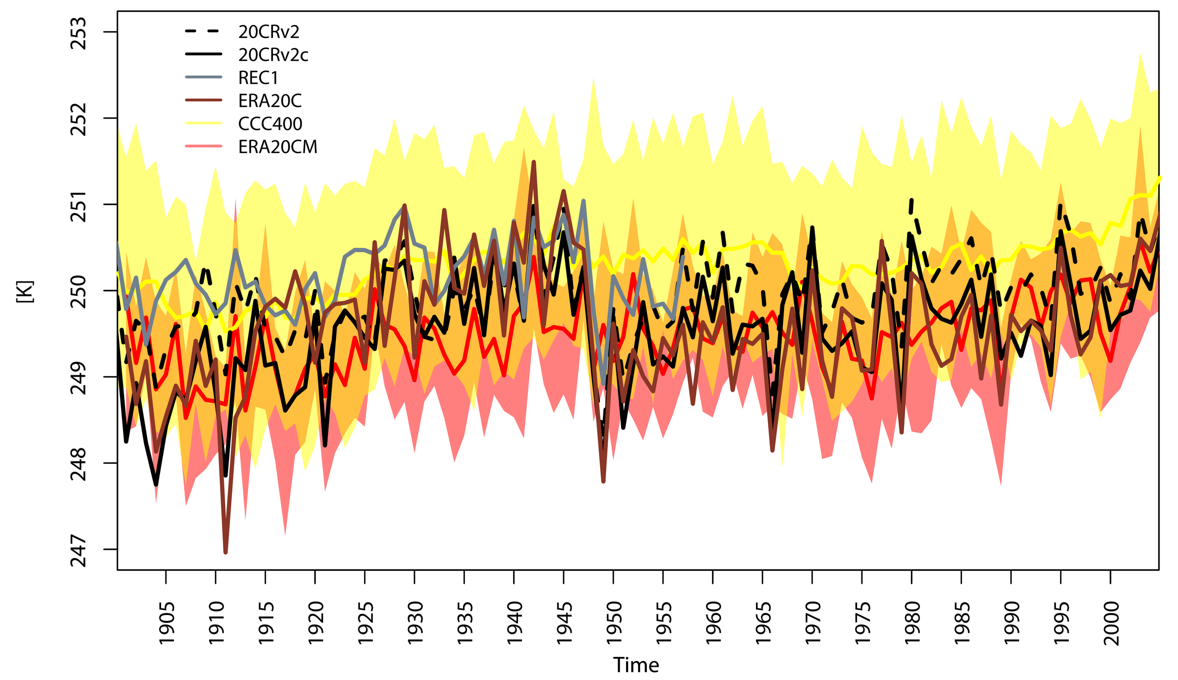
Results for Arctic winter at 700 hPa

Arctic temperature evolution



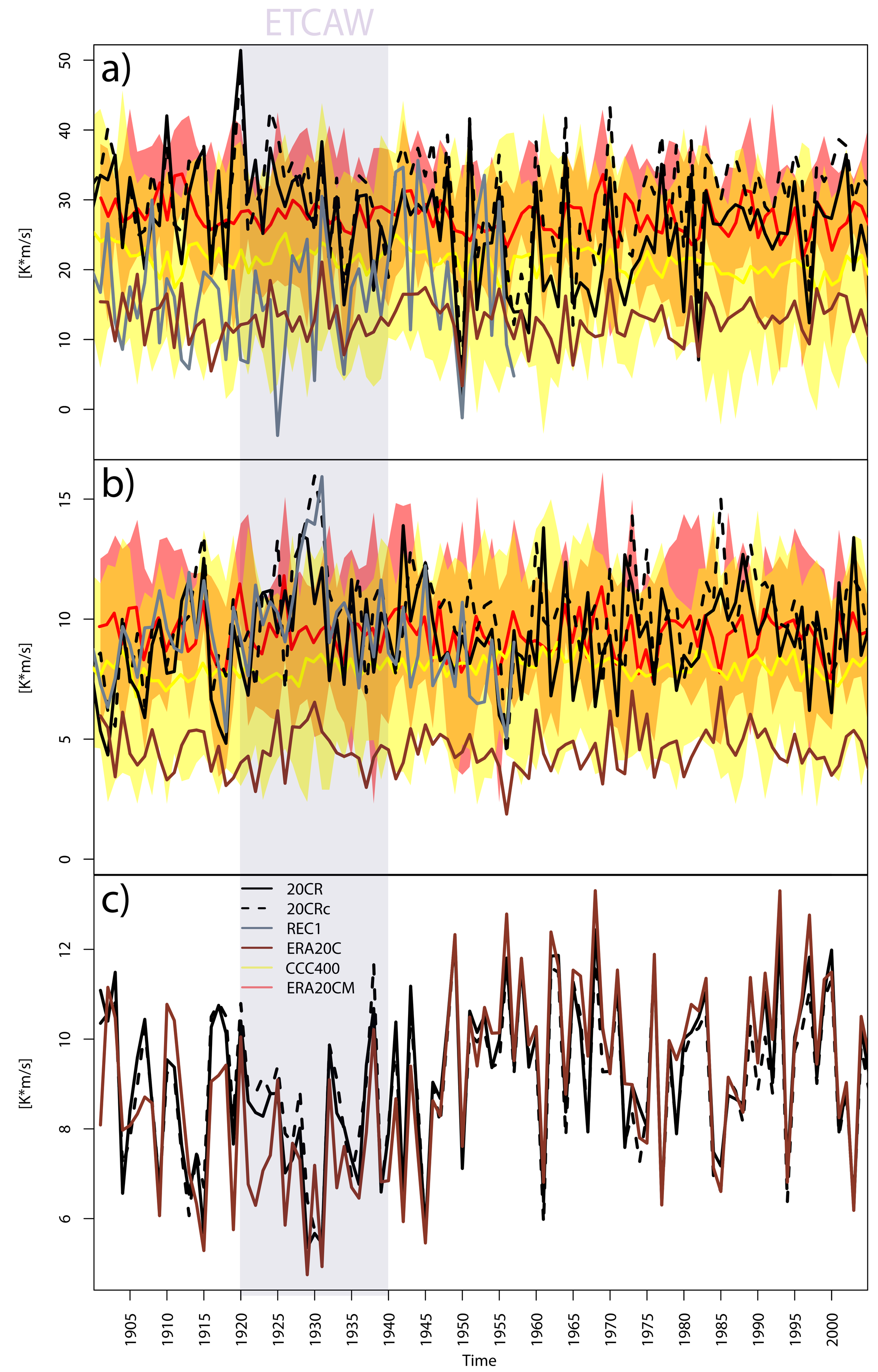
DJF 700 hPa field average temperature 1900 - 2005 for the Arctic (60°-90° N) in for the models CCC400 and ERA20CM, as well as the reanalyses 20CRv2, 20CRv2C, ERA20C and the reconstruction REC1.

- All four observation-based datasets **agree very well in temperature magnitude and correlation**, staying within the variability of the models. All datasets show a **mid-tropospheric temperature signal during the ETCAW**, which is unique in magnitude until the 21st century. In general, GCMs, reanalyses, and reconstructions values match well.

- We find an increase of **stationary edddy heat transport** at the timing of the warming in the REC1 and 20CRv2 datasets. This peak also fits the increased index values in the 1920s decade over the Atlantic and Pacific domain.
- Moreover, we find a decrease of **mean meridional heat flux** right before the warming in the independent upper-air reconstruction.
- The 1920s and 1930s show combined the lowest decadal values of **transient eddy heat flux** during the whole 20th century.

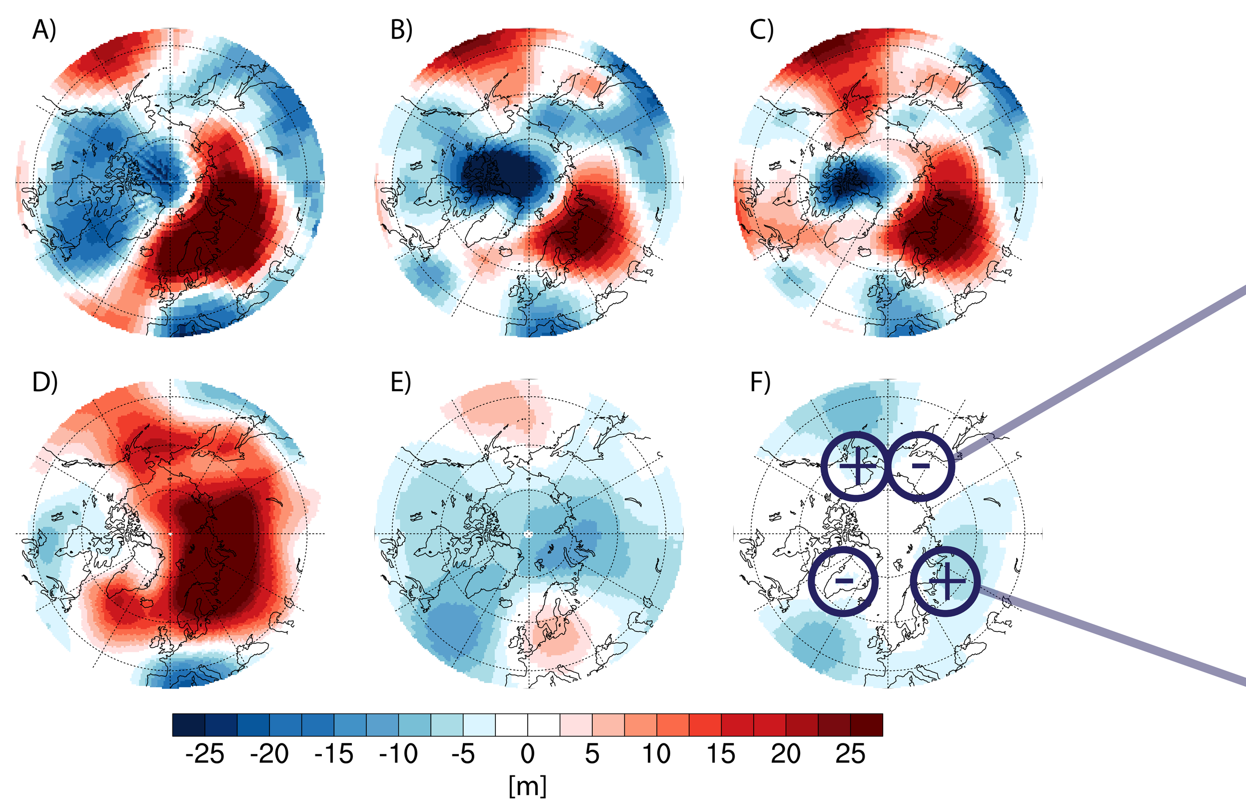
- Reanalyses and reconstruction depict a **strong positive geopotential height anomaly** over the Eurasian part of the Arctic with negative/weaker anomalies over Greenland. This pressure setup **enhances meridional winds** over the North Atlantic and **transports southern airmasses** into the Arctic domain.

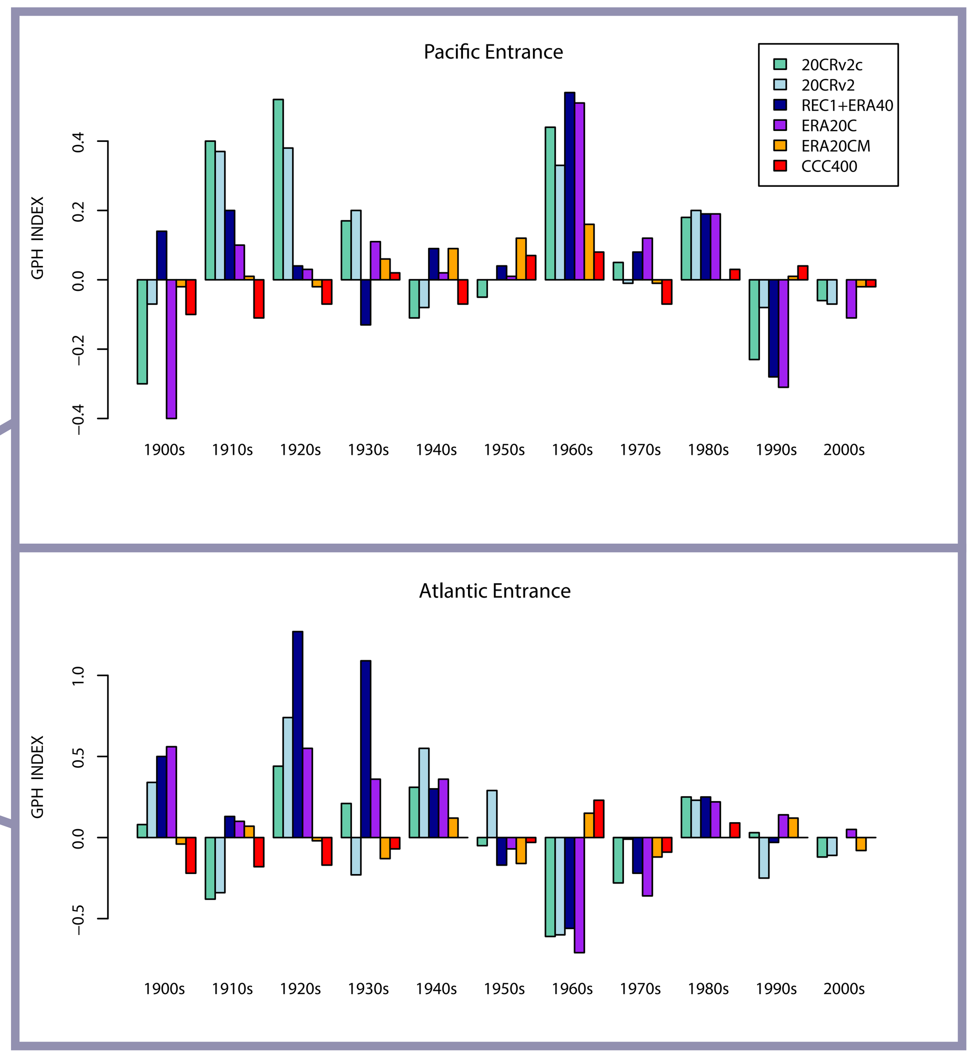
Heat fluxes



a) Mean meridional DJF heat flux at 60° N between 1900 - 2005 at 700 hPa for all gridded datasets, b) the same for stationary heat flux and c) the same for transient eddy heat flux, but only for reanalysis datasets .
Mean meridional flux in reanalyses metric might be unreliable due to surface wind errors in all three reanalysis datasets.

Atmospheric circulation setting





left: 700 hPa geopotential height anomalies for 1920-1939 with reference to 1971-2000 for early winter (DJF) in a) REC1+ERA40, b)20CRv2, c) 20CRv2c, d) ERA20C, e) ERA20CM ensemble mean, f) CCC400 ensemble mean. right) 700 hPa Geopotential height circulation index values for top) Atlantic sector, bottom) Pacific sector

Conclusions

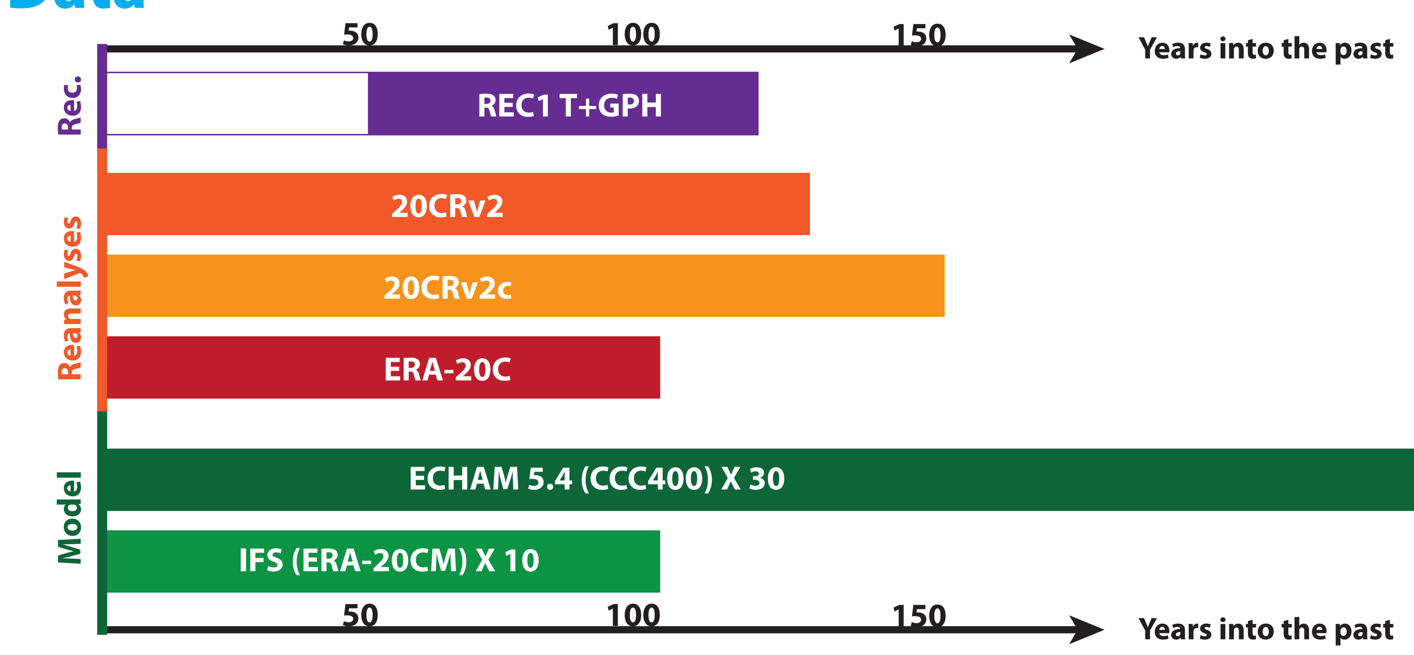
- Our results support a **meridionalisation of circulation** during the ETCAW. Surface and 700 hPa temperatures in **reanalyses agrees very well with reconstructed temperatures**.

- **SST and sea ice forcings are not sufficient to trigger the spatial pattern of the ETCAW.** Instead observational input is needed to compute the realistic circulation and heat flux response. Thus it can be concluded that the intrinsic atmospheric variability played a major part in the formation of the ETCAW signal.

- Utilizing the 700 hPa heat transport as surrogate for tropospheric processes, it could be shown that reanalysis and reconstruction datasets show **peak values of stationary heat flux for the ETCAW**. The independent reconstruction shows a decrease of mean meridional heat flux with a negative lag of about 5 years and the analysis of reanalyses exhibits a decrease of transient eddy heat flux into the Arctic domain (agreement with Beitsch et al 2014).

Setup

Data



- **REC1** upper air reconstructions (Griesser et al. 2010)

- **20CRv2** (Compo et al. 2011) **and 20CRv2c** (Cram et al. 2015) reanalysis

- **ERA-20C** reanalysis (Poli et al. 2015) **and ERA-20CM** (Hersbach et al. 2005) GCM ensemble

- **ECHAM5.4** ensemble GCM run (CCC400) (Bhend et al. 2012)

Methods

- We investigate the **cold season (DJF)** with a focus on the **700 hPa level** as a surrogate for mid-tropospheric processes. During boreal winter, temperature differences between polar and subpolar airmasses are strongest and Bekryaev et al. 2010 found that boreal **winter together with autumn showed the strongest warming signal**. Moreover, Overland and Turet 1994 stated that the poleward **energy transport is maximized between 800 and 600 hPa.**

- We compute **different components of northward heat transport at 700 hPa and 60° N** in the GCM, reanalysis and reconstruction datasets. The zonal mean northward heat flux at a certain level can be written as

Deviation from zonal average

Time mean

Mean meridional circulation flux

Stationary Eddy flux

Transient Eddy flux

Deviation from time average

Zonan mean

$$[\overline{vT}] = [\overline{v}][\overline{T}]+[\overline{v}^*\overline{T}^*]+[\overline{v'T'}]$$