



wege entstehen, indem wir sie gehen  
*ways emerge in that we go them*

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Atmospheric Remote Sensing and Climate System Research Group

**ARSCISys**

# Trend Indicators of Atmospheric Climate Change based on GCM Scenarios and Reanalyses

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- 1 Background
- 2 Data
- 3 Method
- 4 Results
- 5 Conclusions

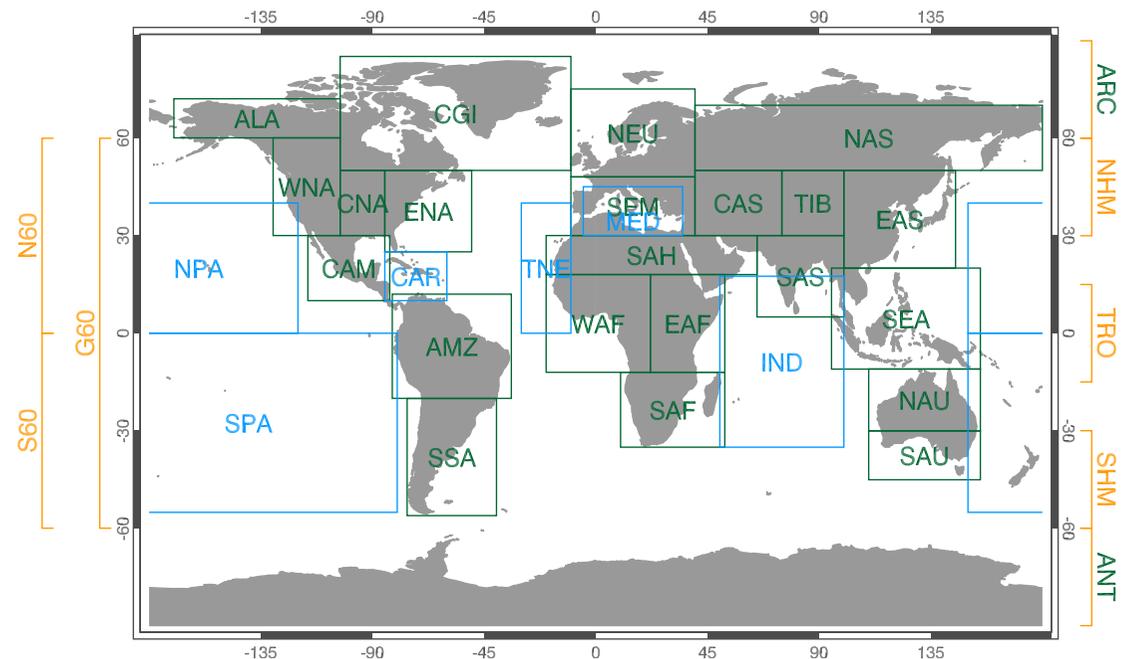
## Trend Indicators of Atmospheric Climate Change based on GCM Scenarios and Reanalyses. *And what about RO?*

- Upper troposphere-lower stratosphere (UTLS) parameters for climate change monitoring and diagnosis
- **Aim:** reveal optimal UTLS climate change indicators accessible by GPS-RO technique
- **Problem:** timeseries of RO climatologies are rather short (continuously since 2001)
- **Solution:** use in a first step GCM outputs and reanalyses to identify optimal indicators, then try to find these indicators in RO data

*RO timeseries not long enough, thus we use as proxy data...*

- 3 IPCC AR4 GCMs (1961–2060) of A2 and B1 scenario:
  - CCSM3/NCEP-NCAR (5/7 runs A2/B1)
  - ECHAMP5/MPI-Hamburg (3/3 runs A2/B1)
  - HadCM3/UK-MetOffice (1/1 run A2/B1)
- 2 Reanalyses (1961–2001):
  - ERA-40 (ERA-40)
  - NCEP/NCAR reanalysis (NCEP50)

- *Regions:*
  - 6 zonal mean regions
  - 30 regions according to IPCC AR4<sup>1</sup>
- *Seasonal and annual means*
- *RO accessible parameters investigated:*
  - 1 Air temperature ( $T$ )
  - 2 Geopotential height ( $Z$ )
  - 3 Refractivity ( $N$ )
  - 4 (Specific humidity ( $q$ ))



<sup>1</sup> J. H. Christensen et al. Regional Climate Projections. In: *Climate Change 2007: The Physical Science Basis*. [S. Solomon et al. (eds.)]. Cambridge University Press, UK, 2007.

- Methodology following Santer<sup>2</sup> and Wilks<sup>3</sup>
- Linear trends  $b$  for each pressure level, based on anomalies (with respect to the 1961–1990 climatological mean)
  - IPCC AR4 GCM: 50-year trends for the period 2001–2050
  - Reanalyses: 22-year trends for the period 1980–2001, excluding years with volcanic eruptions
- Strict criteria for significance testing
  - Students  $t$ -test considering lag-1 autocorrelation ( $AR(1)$ )
  - $AR(1)$  coefficient ( $r_1$ ) reduces effective sample size  $n_e = n \frac{1-r_1}{1+r_1}$  and thus standard error of trend ( $s_b$ )
  - $n_e$  also used to determine tabulated  $t$ -value
  - $t_{b,n_e} = \frac{b}{s_b}$

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<sup>2</sup>B. D. Santer et al. Stat. significance of trends and trend differences in layer-average atmospheric temperature time series. *J. Geophys. Res.*, 105(D6), 2000.

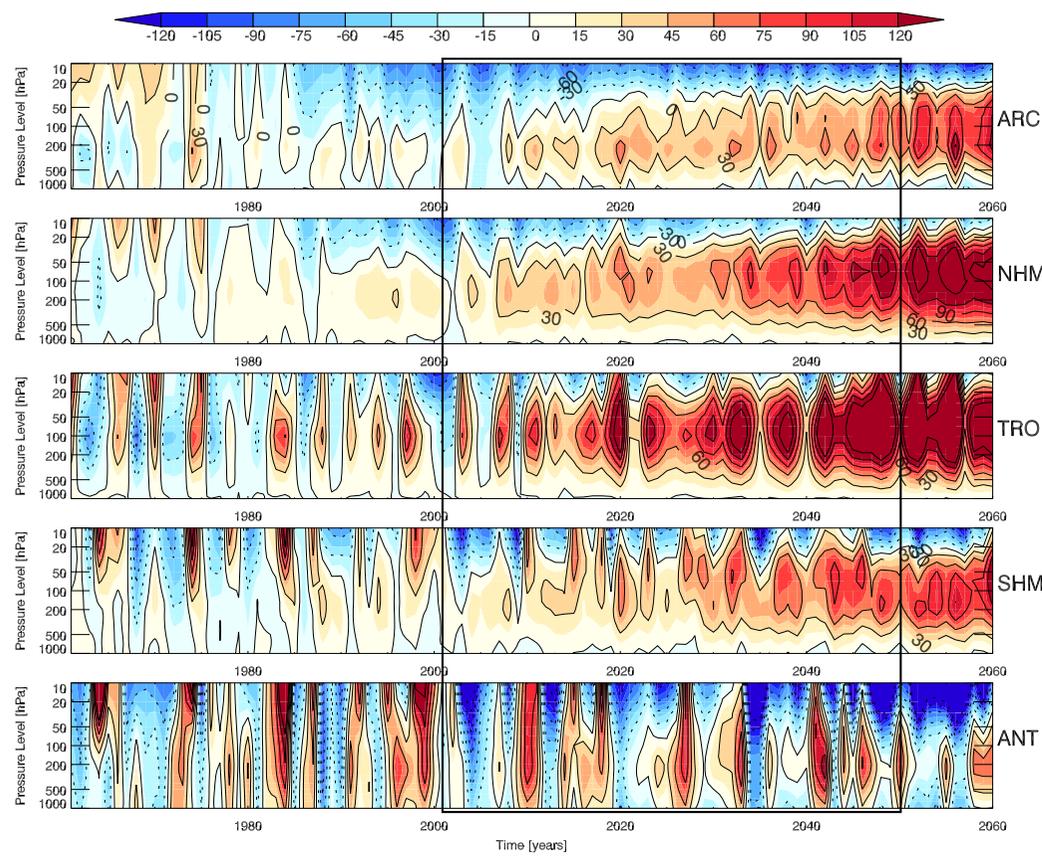
<sup>3</sup>D. S. Wilks. *Statistical methods in the atmospheric sciences*. Academic Press Inc., London, 2006.

# Timeseries of Anomalies

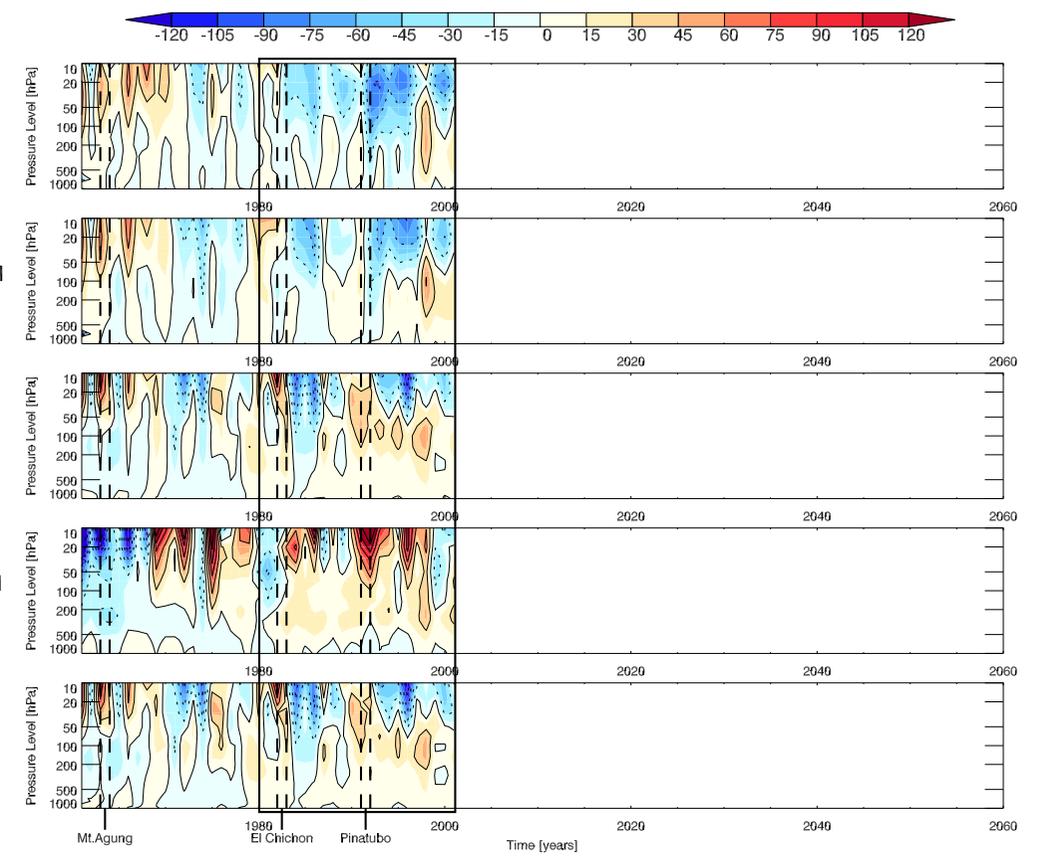
## GCM versus Reanalysis

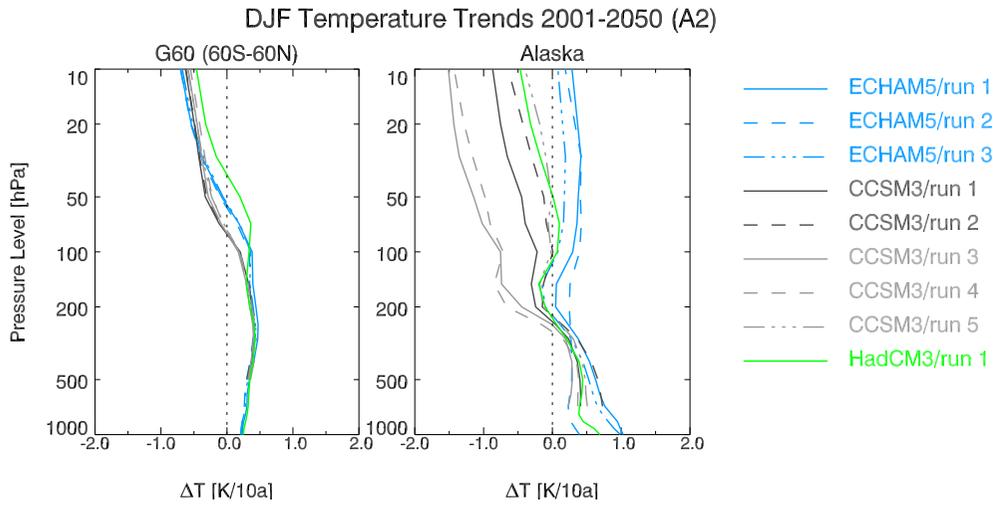


JJA Geopotential Height [m] Anomalies  
ECHAM5, 20c/A2, run 1, zonal means



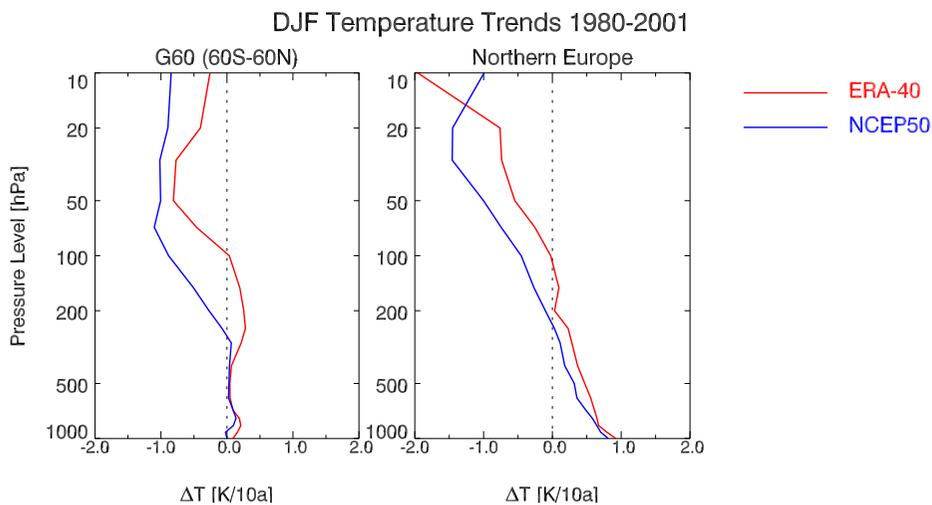
JJA Geopotential Height [m] Anomalies  
ERA-40, zonal means





### ● GCMs:

- trends agree quite well for most regions
- large discrepancies in high latitudes in winter hemisphere



### ● Reanalyses:

- good agreement on global scale and in 'populated' areas
- NCEP50 features generally stronger negative/less positive trends than ERA-40



Criteria for best trend indicators were formulated as follows:

### GCMs

- for each scenario all—or all but one—trends have the same algebraic sign,
- $R^2 \geq 0.50$  for at least 3/4 of all runs,
- at least 3/4 of all runs show a significance  $\geq 90\%$ .

### Reanalyses

- both trends have the same algebraic sign,
- $R^2 \geq 0.25$  for both reanalyses,
- both reanalyses show a significance  $\geq 90\%$ .

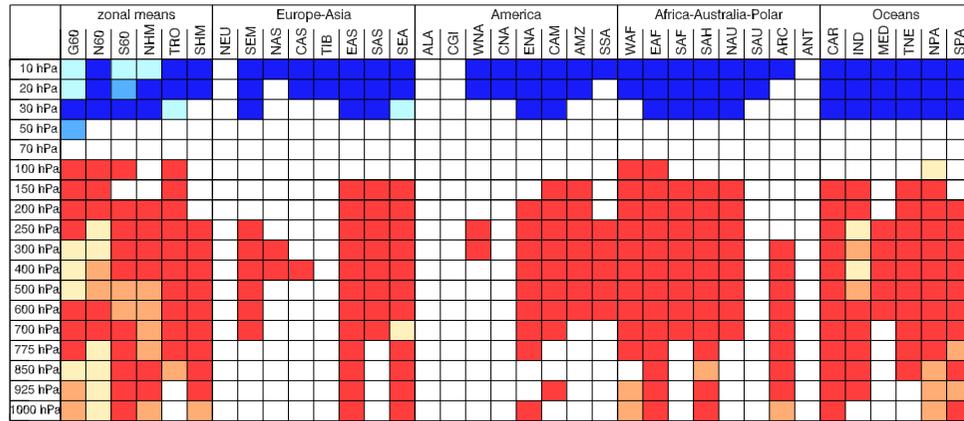
# Trend Indicators

## Temperature and Refractivity



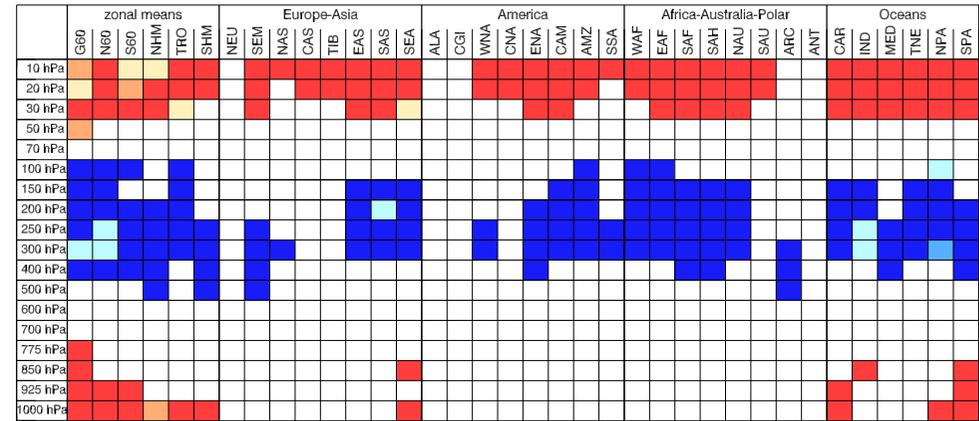
Temperature [K]: SON

IPCC4AR GCMs



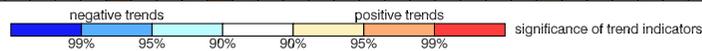
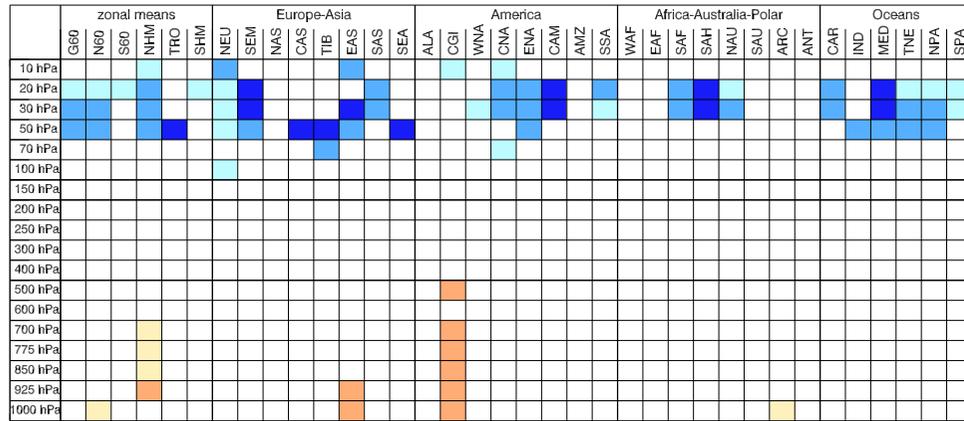
Refractivity [N units]: SON

IPCC4AR GCMs



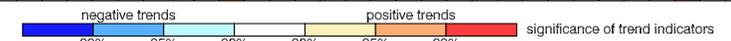
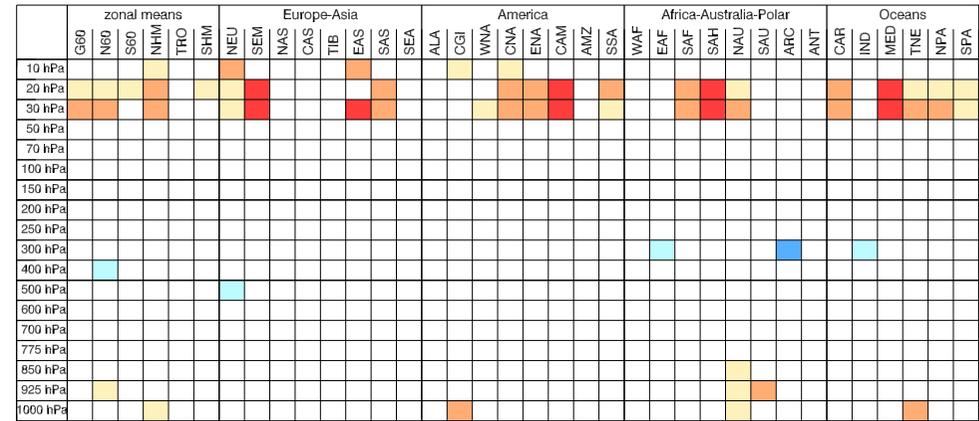
Temperature [K]: SON

Reanalyses



Refractivity [N units]: SON

Reanalyses



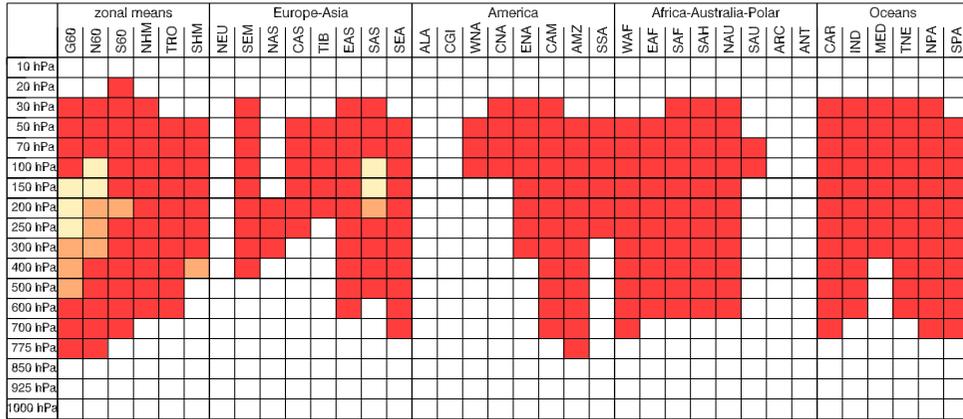
# Trend Indicators

# Geopotential Height



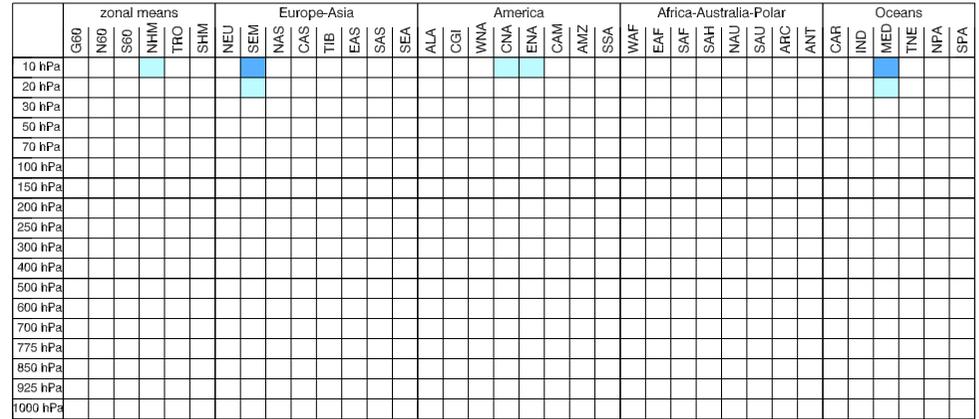
Geopotential Height [m]: SON

IPCC4AR GCMs

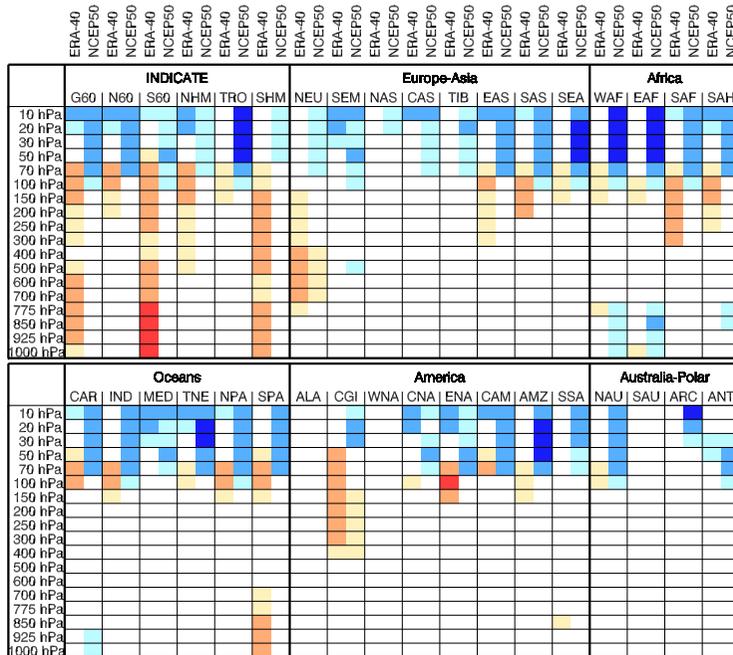


Geopotential Height [m]: SON

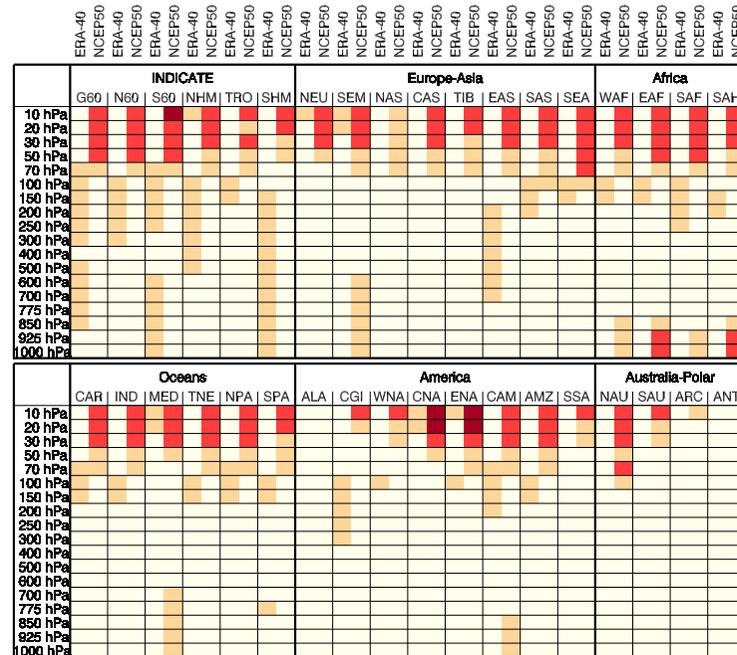
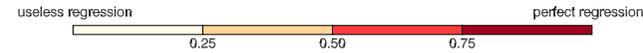
Reanalyses



significance of trends including lag-1 autocorrelation



goodness-of-fit measure (R<sup>2</sup>) for linear trend regression



RO accessible parameters allow the identification of geographical regions and height domains qualified for best trend indicators. Strongest signals are found in the summer (GCMs) and autumn (reanalyses) season.

- **Temperature** trends are best represented in the UT (400–100 hPa) and LS (30–10 hPa).
- **Refractivity**, is inverse proportional to temperature and a suitable trend indicator in 300–150 hPa and 30–10 hPa.
- **Geopotential height** is a suitable trend indicator in height regions (300–30 hPa), which are in parts not covered by the other parameters.
- **Specific humidity** was only investigated up to 100 hPa. Zonal means and the Arctic region are particularly good indicators in SON.