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SimVis: An Interactive Visual Field Exploration Tool Applied to Climate Research

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A R S C l i S y s

Abstract

Climate research often deals with large multi-dimensional fields describing the state of the atmosphere. A novel approach to gain information about these large data-sets has become feasible only recently using 4D visualization techniques. The *SimVis* (Simulation Visualization) software tool, developed by the VRVis Research Center (Vienna, Austria), uses such techniques to provide access to the data interactively, and to explore and analyze large three-dimensional time-dependent fields. Non-trivial visualization approaches are applied to provide a responsive and useful interactive experience for the user.

In this study we use *SimVis* for the investigation of climate research data sets. Several climate models and reanalysis data sets are explored, with the final goal to find the most sensitive and robust climate change indicator amongst pre-defined potentially useful parameters. The focus lies on the UTLS (Upper Troposphere-Lower Stratosphere) region, in view of future applications of our findings to RO (Radio Occultation) climatologies.

First results showing the capability of *SimVis* to deal with climate data, including trend time series and spatial distributions of selected parameters are presented.

Data

The data sets explored are the ECHAM5 A2 scenario simulations for the IPCC 4th Assessment Report (MPI-M Hamburg) for the time period 1966 to 2059 and the ERA-40 (ECMWF) reanalysis data set for the time period 1966 to 1997. Seasonal means of the model and reanalysis data are used at a resolution of 2.5° x 2.5° in latitude and longitude and at 18 pressure levels ranging from 1000 hPa to 10 hPa. The investigated parameters are temperature, refractivity, and geopotential height shown for the summer season (JJA).

Method-*SimVis*

To apply the *feature-based* visualization technique (where *feature* refers to interesting subsets of the data) of *SimVis* to climate data, we investigate additional derived parameters, namely the linear trend calculated as a 10-years moving difference over a smoothed field and the signal-to-noise-ratio (SNR), defined as the ratio of the decadal trend to the detrended standard deviation. In the following we present exemplary results showing the potentials of *SimVis* to load and analyze the whole field at once, to interactively select features of the data set, showing its characteristics, and to search for robust indicators.

Results

Figure 1: ECHAM5 A2,Temperature (K); JJA seasonal means

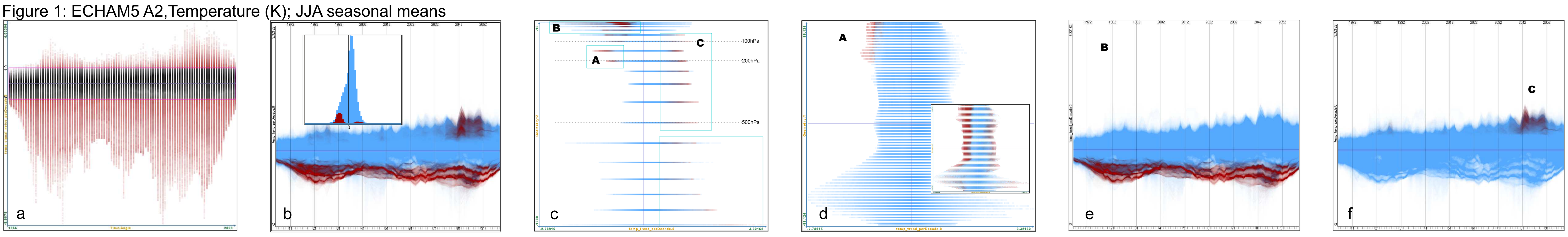
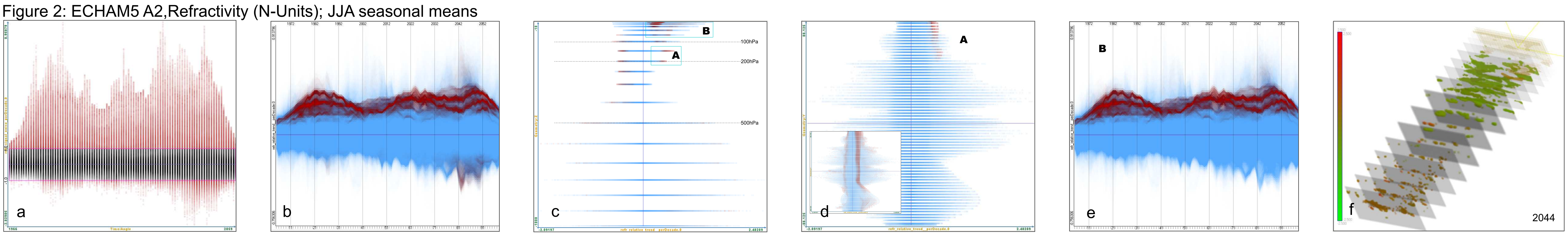


Figure 2: ECHAM5 A2,Refractivity (N-Units); JJA seasonal means



a: The *SimVis* scatterplot shows all SNR values occuring in the dataset for each timestep. Values of the |SNR| greater than 1 are selected here (red), for temperature T (Fig. 1a) and refractivity N (Fig. 2a).

b: Trend variation in time shown as trend per decade for T (Fig. 1b) and as relative trend for N (Fig. 2b). Note the inverse behaviour of T and N trends. Data fulfilling |SNR|>1 in red.

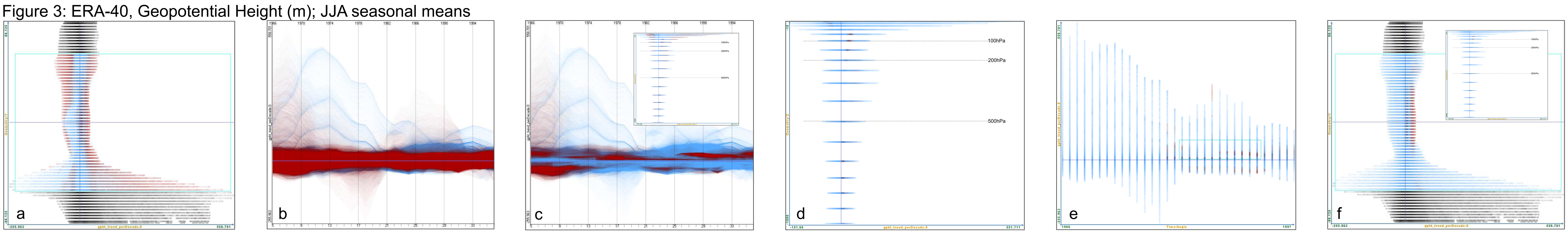
c: The scatterplot shows the trend per decade (x-axis) versus pressure (y-axis) with 18 levels ranging from 1000-10hPa. |SNR|>1 in red. **A**, **B**, **C** indicate further selections.

d: Scatterplots showing trend distribution (x-axis) versus latitude. Data points for which the combination of |SNR|>1.0 and selection **A** holds are marked red. Insets: SNR selection only.

e: Trend variation in time with the combined selection **B** and |SNR|>1. Selection **B** uncovers that the negative T (positive N) trend as pronounced feature in Fig. 1b (2b) stems from the lower stratosphere.

f: The combined selection **C** and high SNR uncover significant positive T trends in the upper troposphere (cf. Fig. 1b). Fig. 2f shows an example of the *SimVis* 3D-view. Only areas with |SNR|>1 are colored.

Figure 3: ERA-40, Geopotential Height (m); JJA seasonal means



a: Distribution of the trend per decade versus latitude (y-axis). |SNR|>1 in red. Selection of the latitude region 60°N to 60°S since ERA-40 shows deficiencies in southern high latitudes.

b: Trend variation in time ranging from 1966 to 1997. Selection of the latitude region 60°N to 60°S only. Most of the outlier values (blue) disappear with this selection.

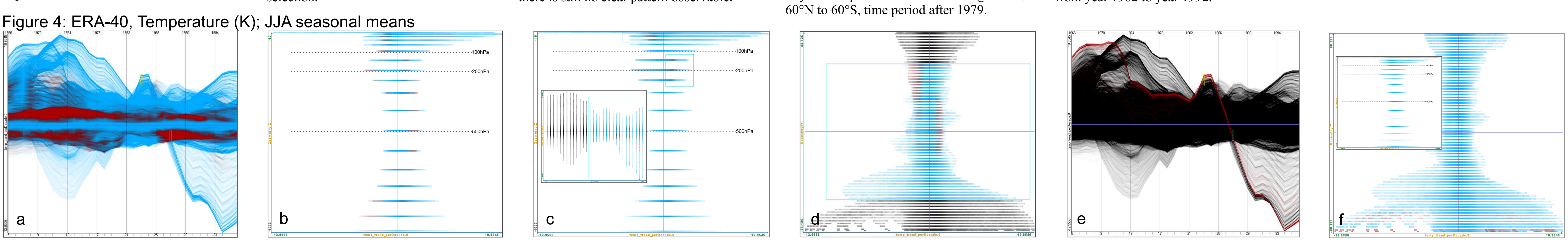
c: Trend variation in time ranging from 1966 to 1997. Selection of the latitude region 60°N to 60°S and high SNR (red). Inset: In the height distribution for the same selections there is still no clear pattern observable.

d: This improves a lot when only the time period after 1979 is selected where ERA-40 includes satellite data. The resulting height distribution is shown with three selections to yield the pattern shown in red: high SNR, 60°N to 60°S, time period after 1979.

e: As a further example for the examination of certain features of the dataset, a discontinuity in the time variation of the geopotential height trend (compare Fig. 3c) is selected from year 1982 to year 1992.

f: The latitude and height (inset) distribution reveals that the higher trend values starting around 1987 stem from the tropical lower stratosphere.

Figure 4: ERA-40, Temperature (K); JJA seasonal means



a: Trend variation in time. Selected are high SNR and latitudes of 60°N to 60°S (red). Most outliers vanish with this selections.

b: Height distribution of temperature trends with same selections as in Fig. 4a applied.

c: Same as Fig. 4b but limitating the time range to the post-1979 era yields a clean pattern structure with best results in the UTLS region.

d: The latitude distribution of the temperature trend in ERA-40 for all previous selections: high SNR and post-1979 era (red).

e: Selections can also be made in the *SimVis* time variation view. As an example one distinct curve is selected showing a high variation of the T trend over time.

f: The corresponding pattern in space occurs only at high southern latitudes and at the topmost pressure level indicating that this is just a spurious feature.

Conclusions and Outlook

We demonstrated the investigation of large climate data fields with *SimVis* on basis of the localization of trends with high SNR in space and in time. Temperature and refractivity show robust and sensitive trends in the LS region in the ECHAM5 model run. Deficiencies in the ERA-40 reanalyses could be detected. Ongoing work focuses on the application of the findings to RO observations and on the intercomparison of different climate fields.

Acknowledgments: This work was supported by the Austrian Science Fund (FWF; Project INDICATE P18733-N10).