Free software in Meteorology

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The Faculty of Physics – Institute for Meteorology

- The Faculty of Physics - University of Belgrade is organizing four undergraduate and master groups of studying:

Group of studying	budget	self-financing
General Physics	25	0
Theoretical and experimental Physics	50	0
Computer and applied Physics	40	10
Meteorology	**25**	**5**

Meteorology

- Meteorology applies physical and mathematical methods to understand and forecast the processes in the atmosphere that determine a weather and climate.
- **Weather** – the state of the atmosphere. Weather consists of the short-term (minutes to days) variations in the atmosphere.
- **Climate** – the long-term average of weather, typically averaged over a period of 30 years.
  It is typically characterized in terms of suitable averages of the climate system, taking into consideration the variability in time, as well as extremes (minimum and maximum values).

Climate change

- **Climate variability** – The temporal variations around a mean state for timescales longer than those associated with synoptic weather events.
- **Climate change** – Any systematic change in the long-term statistics of climate elements (such as temperature, pressure, or winds) sustained over several decades or longer (AMS Glossary).

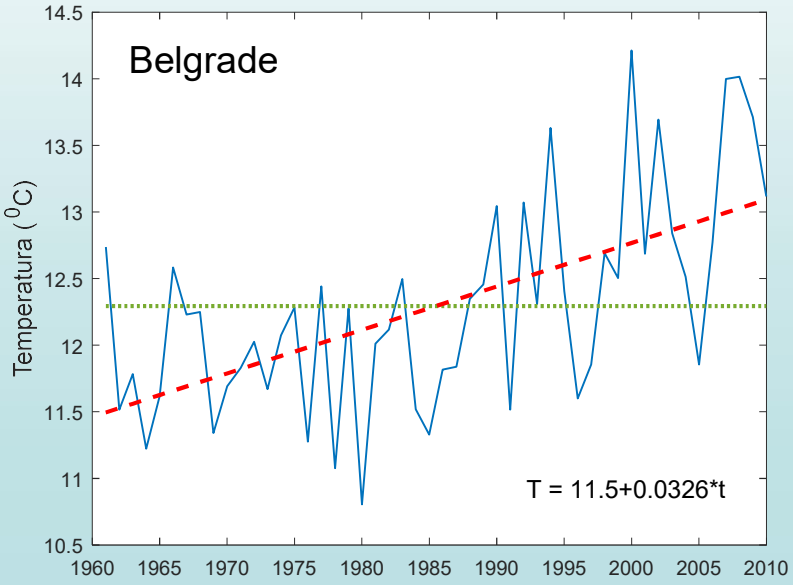


Figure: Annual mean temperature in Belgrade with linear trend during the period 1961-2010.

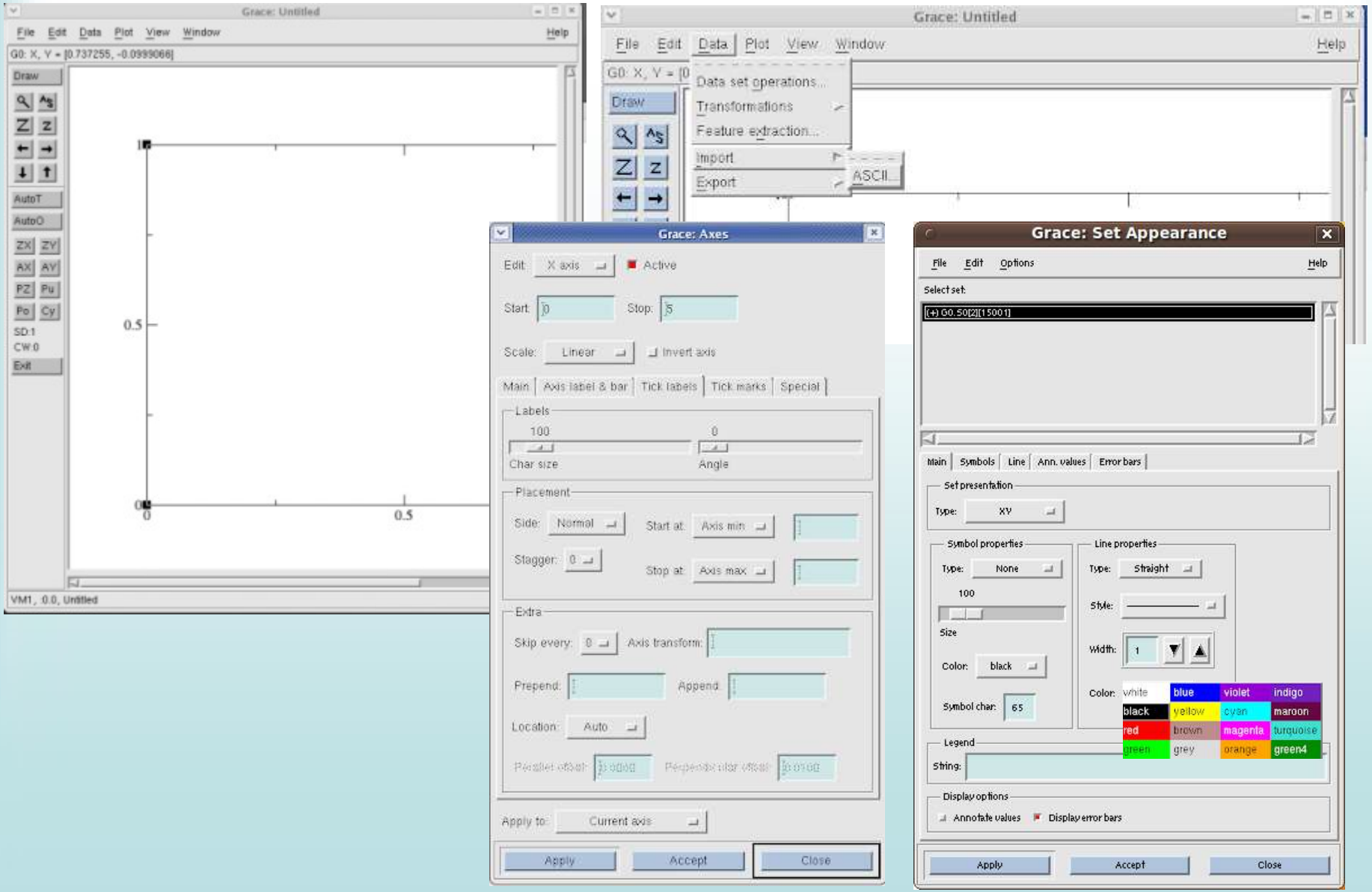
Studying Meteorology

- A computer laboratory is equipped with 16 personal computers with Linux 4.9 and LibreOffice 5.
- Free software is in use at the following courses:
  - Statistics in Meteorology,
  - Programming in Meteorology,
  - Micrometeorology,
  - Modelling of the Atmosphere I,
  - Modelling of the Atmosphere II,
  - Climatology,
  - Applied Meteorology and
  - Weather Forecast.

Free software

- GNU Fortran - GFortran (https://gcc.gnu.org/fortran/);
- Xmgrace (an early name for Grace) - GRaphing, Advanced Computation and Exploration of data;
- The Grid Analysis and Display System – GrADS;
- LibreOffice (https://www.libreoffice.org/)

Xmgrace, set


Grace: Untitled
File Edit Data Plot View Window Help
Draw
Data set operations...
Transformations
Feature extraction...
Import
Export
ASCII...
Grace: Axes
Edit: X axis
Active
Start: 0
Stop: 5
Scale: Linear
Invert axis
Main
Axis label & bar
Tick labels
Tick marks
Special
Labels
Char size
Angle
Placement
Side: Normal
Start at: Axis min
Stagger: 0
Stop at: Axis max
Extra
Skip every: 0
Axis transform:
Prepend:
Append:
Location: Auto
Apply to: Current axis
Apply
Accept
Close
Grace: Set Appearance
File Edit Options Help
Select set:
(+) G0.S0[2][15001]
Main
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Line
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Error bars
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Type: XY
Symbol properties
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Width: 1
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maroon
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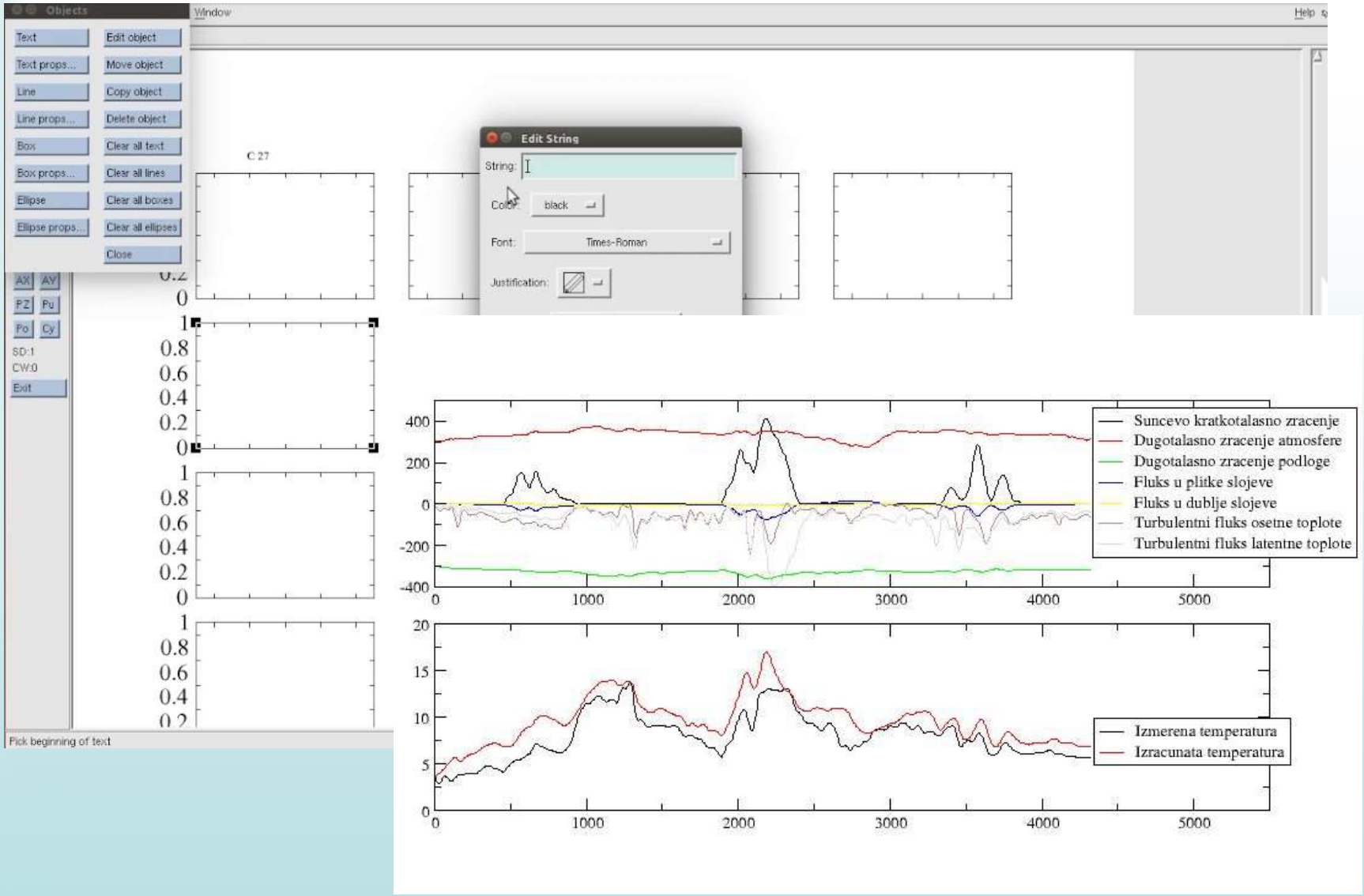
Legend
String:
Display options
Annotate values
Display error bars
Apply
Accept
Close

Xmgrace

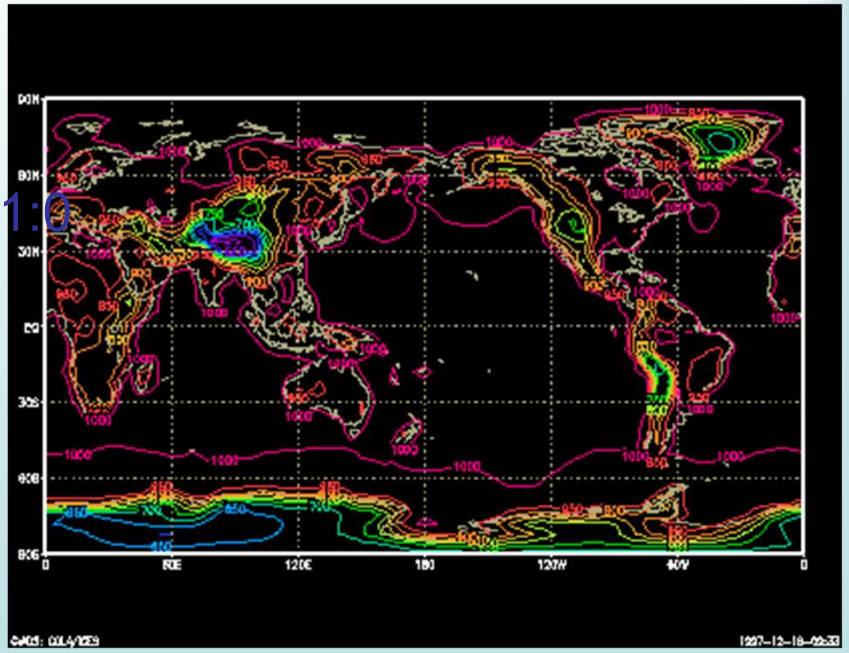

Objects
Text
Edit object
Text props...
Move object
Line
Copy object
Line props...
Delete object
Box
Clear all text
Box props...
Clear all lines
Ellipse
Clear all boxes
Ellipse props...
Clear all ellipses
Close
Window
Help
Edit String
String:
Color:
black
Font:
Times-Roman
Justification:
C 27
AX
AY
PZ
Pu
Po
Cy
SD:1
CW:0
Exit
Pick beginning of text
Suncevo kratkotalasno zracenje
Dugotalasno zracenje atmosfere
Dugotalasno zracenje podloge
Fluks u plitke slojeve
Fluks u dublje slojeve
Turbulentni fluks osetne toplote
Turbulentni fluks latentne toplote
Izmerena temperatura
Izracunata temperatura

GrADS
(Graphic Analysis and Display System)

- The Graphic Analysis and Display System (GrADS), developed/supported at COLA/George Mason University, is freely available.
- An interactive desktop tool that is used for easy access, manipulation, and visualization of earth science data.
- GrADS has a SDF (**S**elf **D**escribing **F**ile) interface that can read a netCDF or HDF (Scientific Data Sets) file.

Plotting in GrADS

- To create a plot in GrADS use commands similar to these:
  - ga-> sdfopen pressure.nc
    Found displayable variable ps with 0 levels in SDF file.
    Data file pressure.nc is open as file 1
    LON set to 0 360
    LAT set to -89 89
    LEV set to 0 0
    Time values set: 1980:1:1:0 1980:1:1:0
    ga-> d ps



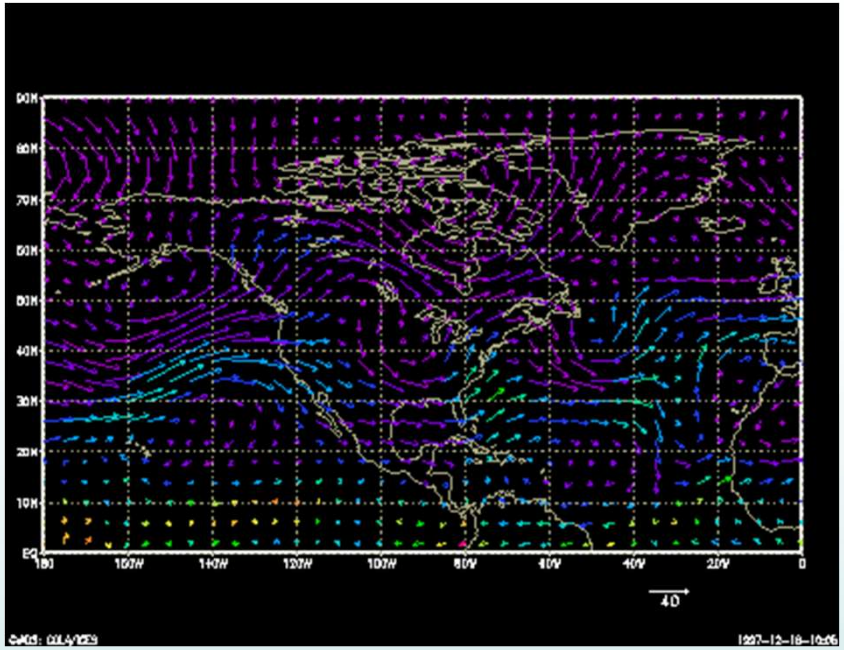
- ga-> q file
  - ga-> set lon -20 40
  - ga-> set lat 30 70
- ga-> d air.1 – air.2

query

display

Wind vector in GrADS

- ga-> clear
- ga-> set gxout vector
- ga-> d u;v



- ga-> clear
- ga-> d ave(hgt,t=1,t=5)

the 5 day mean

http://cola.gmu.edu/grads/gadoc/tutorial.html

Statistics in Meteorology

- Students use LibreOffice Calc and LibreOffice Writer.

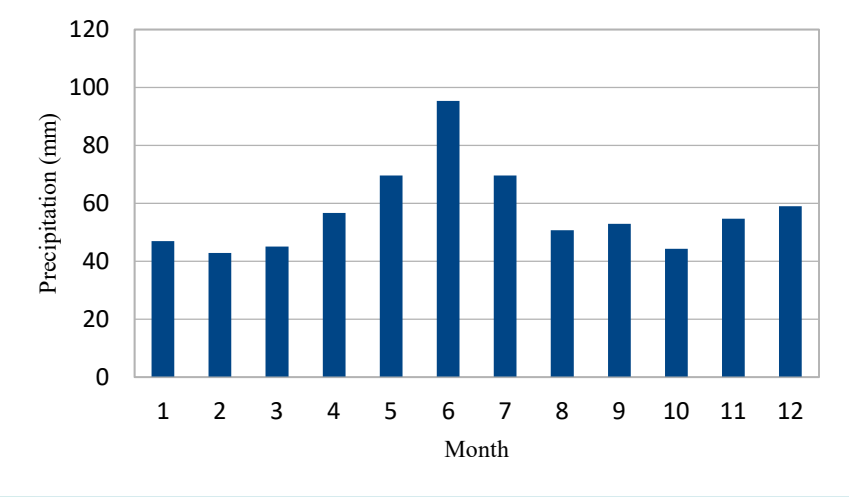


Figure: Precipitation regime in Belgrade during the period 1961-2018.

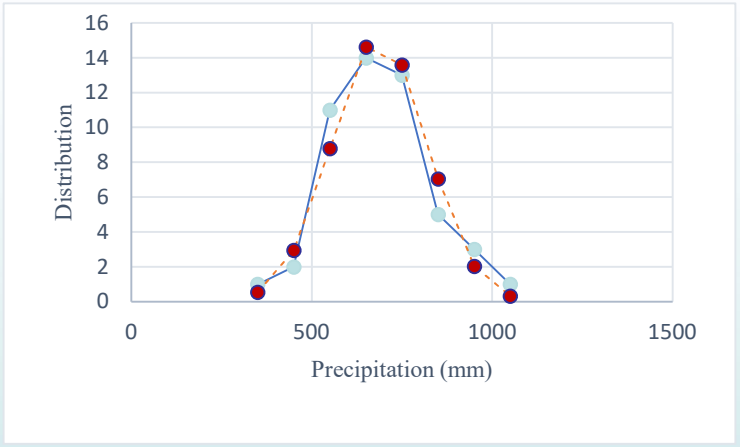


Figure: Frequency distribution (solid line) and Normal probability density function (dashed line) of annual precipitation sums in Belgrade.

M. Unkašević, D. Vujović, I. Tošić, *Zbirka rešenih zadataka u Klimatologiji i Primenjenoj meteorologiji*. Univerzitet u Beogradu-Fizički fakultet, Savezni hidrometeorološki zavod, 238 pp, 2002

Climatology

- Students run codes in GFortran, and use Xmgrace for visualization of obtained results.

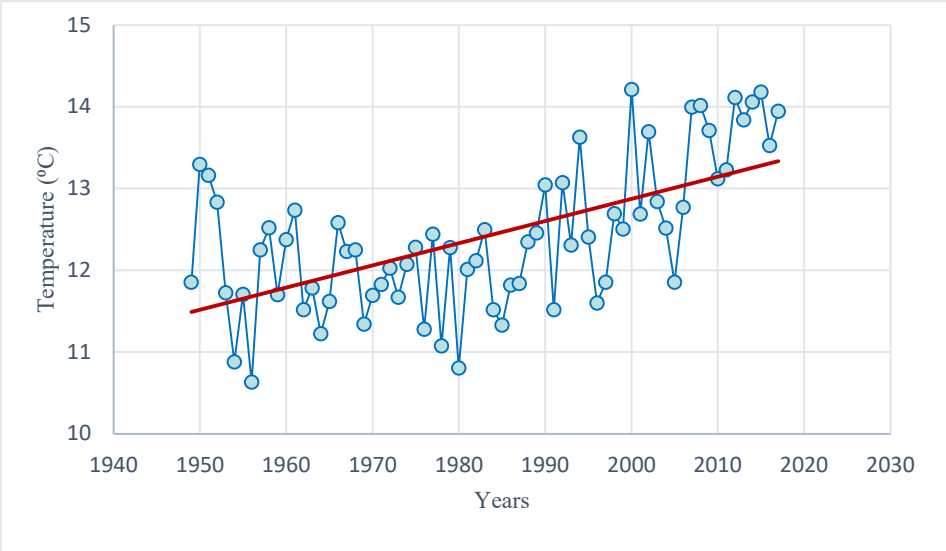


Figure: Annual mean temperature in Belgrade with linear trend during the period 1961-2018.

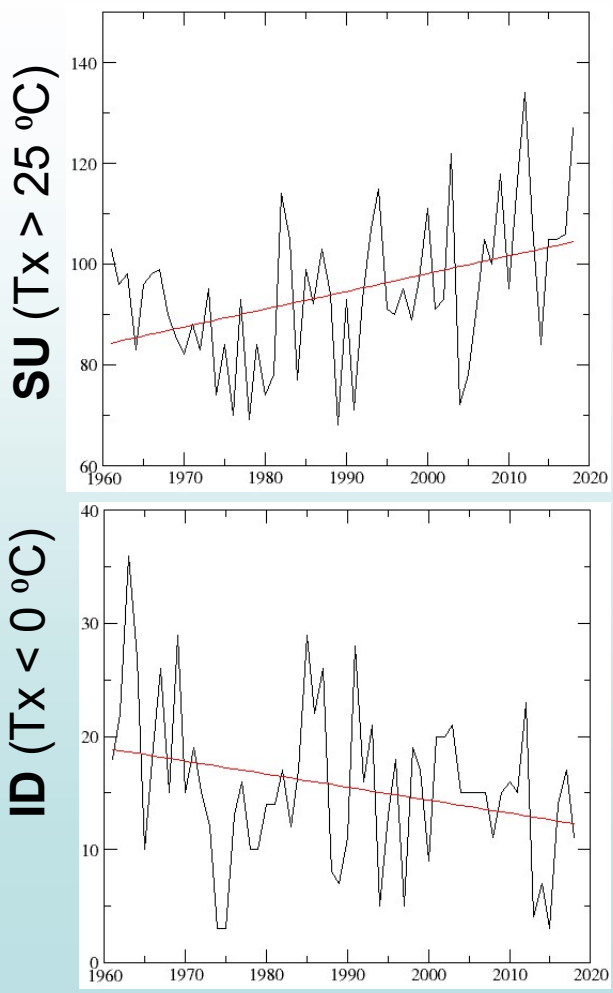


Figure (right): Annual number of summer days (SU) and ice days (ID) in Kraljevo with linear trend during the period 1961-2018.

Modelling of the Atmosphere I

- The one-dimensional linear advection equation

$$\frac{\partial u}{\partial t} + c\frac{\partial u}{\partial x} = 0 \qquad u = u(x, t)$$

$$\frac{\mathrm{d}U}{\mathrm{d}t} = f(U,t) \quad U = U(t)$$

- The Adams-Bashforth scheme

$$\frac{U^{n+1} - U^n}{\Delta t} = \frac{3}{2} f^n - \frac{1}{2} f^{n-1}$$

- Centered finite difference quotient **CKKR**

$$\left(\frac{\partial u}{\partial x}\right)_{j,t_0} \approx \frac{u(x_{j+1,}t_0) - u(x_{j-1,}t_0)}{2\Delta x}$$

- Backward finite difference quotient **UKKR**

$$\left(\frac{\partial u}{\partial x}\right)_{j,t_0} \approx \frac{u(x_{j,}t_0) - u(x_{j-1,}t_0)}{\Delta x}$$

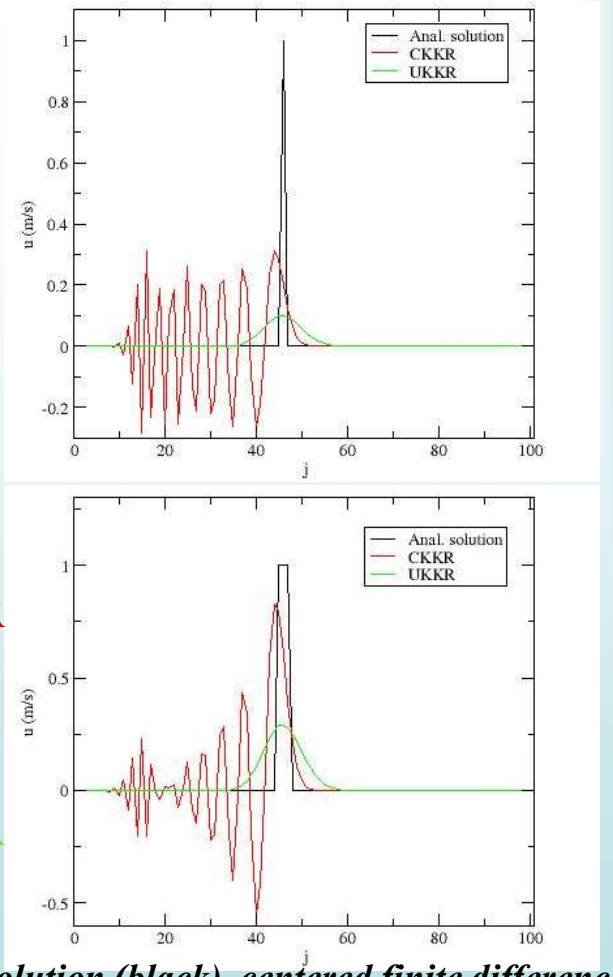


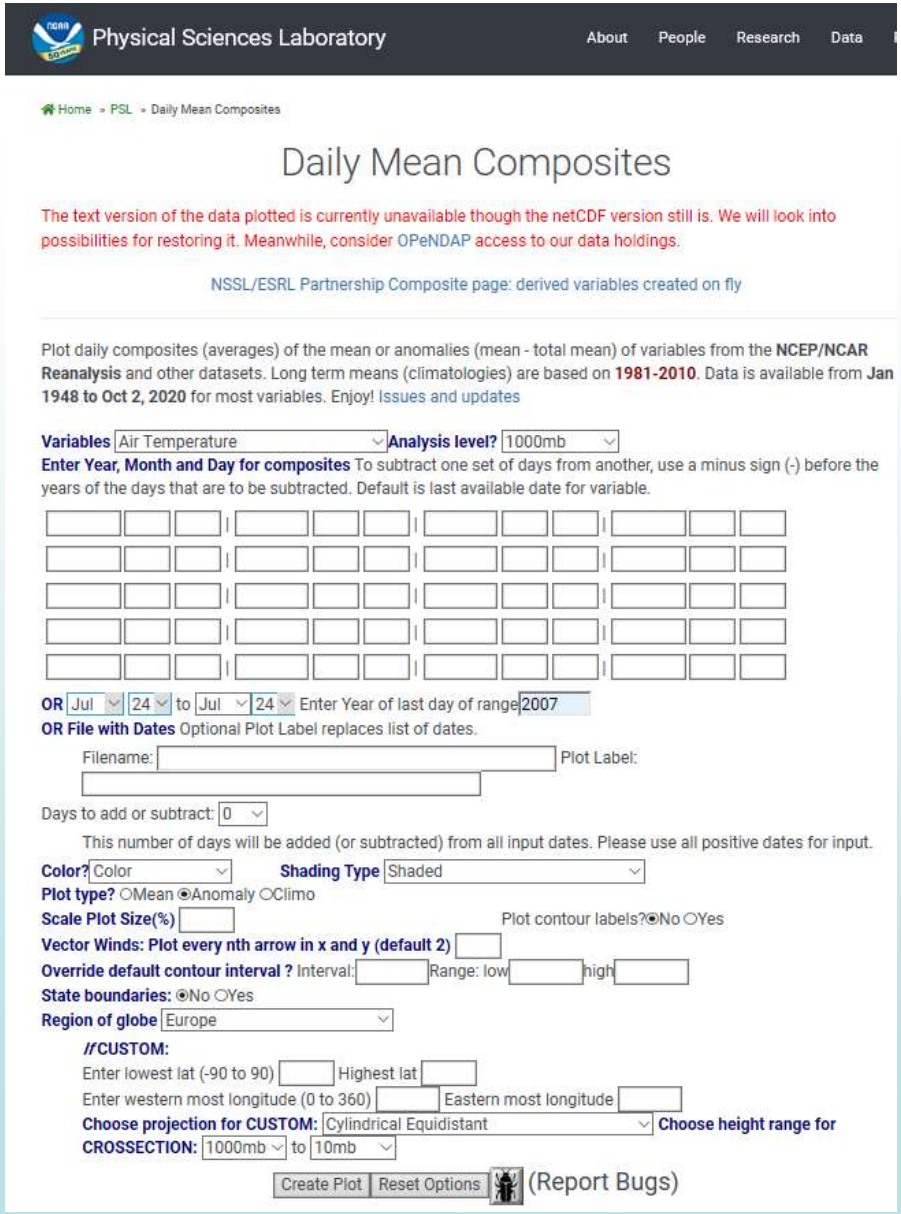
Figure: Analytical solution (black), centered finite difference quotient (CKKR, red) and backward quotient (UKKR, green) for initial perturbation in: one point (top) and three points (bottom).

B. M. Gavrilov, I. Tošić, M. Rančić, *Numerical Methods in Meteorology: Solved problems*. Lap Lambert, 172 pp, 2014

Free software in research

- GrADS is extensively used free software in meteorological research for displaying meteorological fields.
- Daily values of air temperature, geopotential height, and vector wind are obtained from the gridded dataset of the National Center for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) Reanalysis Project https://psl.noaa.gov/data/composites/day/
- All gridded values are saved as the Network Common Data Form (NetCDF) and imported in GrADS for a mapping.

https://www.psl.noaa.gov/data/composites/day/



The maximum temperature of 44.9 ºC

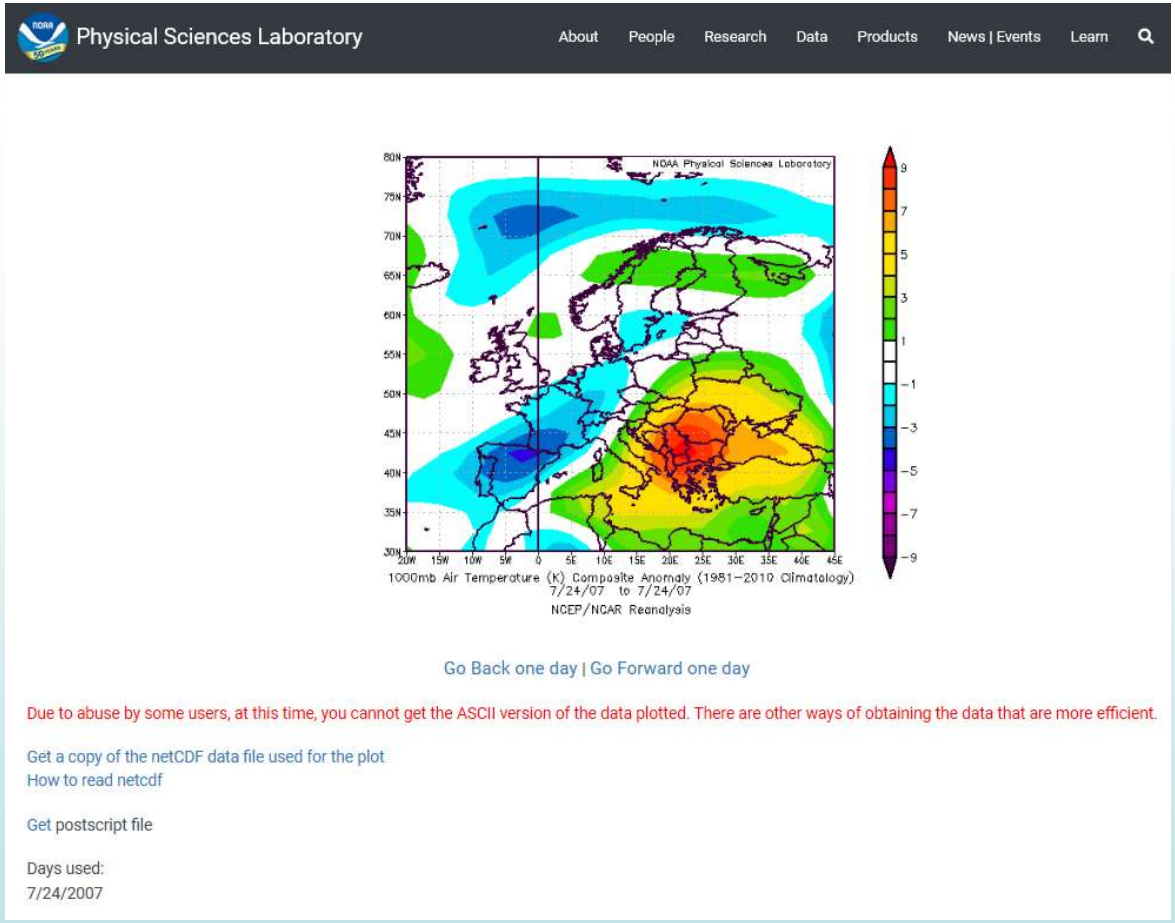


Figure: Temperature anomaly of 24 July 2007 at 1000 hPa over Europe, based on the 1981–2010 reference period.

Extreme precipitation in May 2014

- Belgrade (109.8 mm), Valjevo (108.2 mm) and Loznica (110 mm)

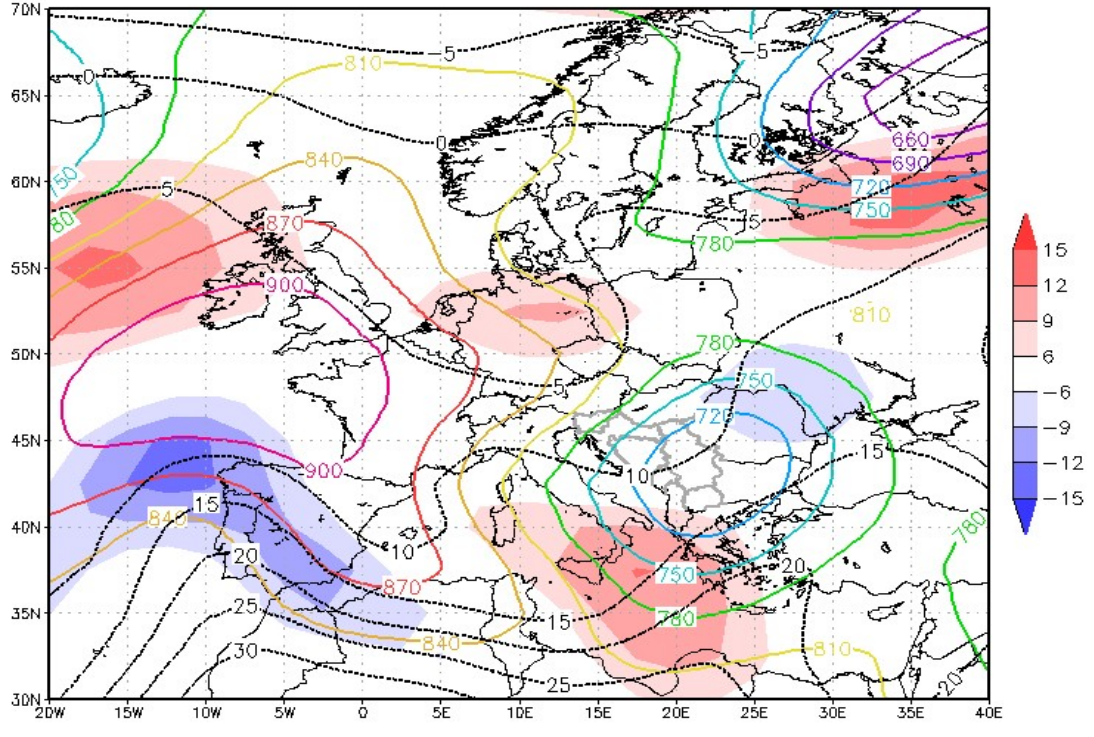


Figure: Synoptic situation on 14 May 2014:

a geopotential height (gpm, continuous line), temperature (°C, dashed line) and horizontal wind speed (shaded) at 925 hPa.

I. Tošić, M. Unkašević, S. Putniković, "Extreme daily precipitation: the case of Serbia in 2014," *Theoretical and Applied Climatology*, vol. 128, pp. 785–794, 2017

A long-range transport

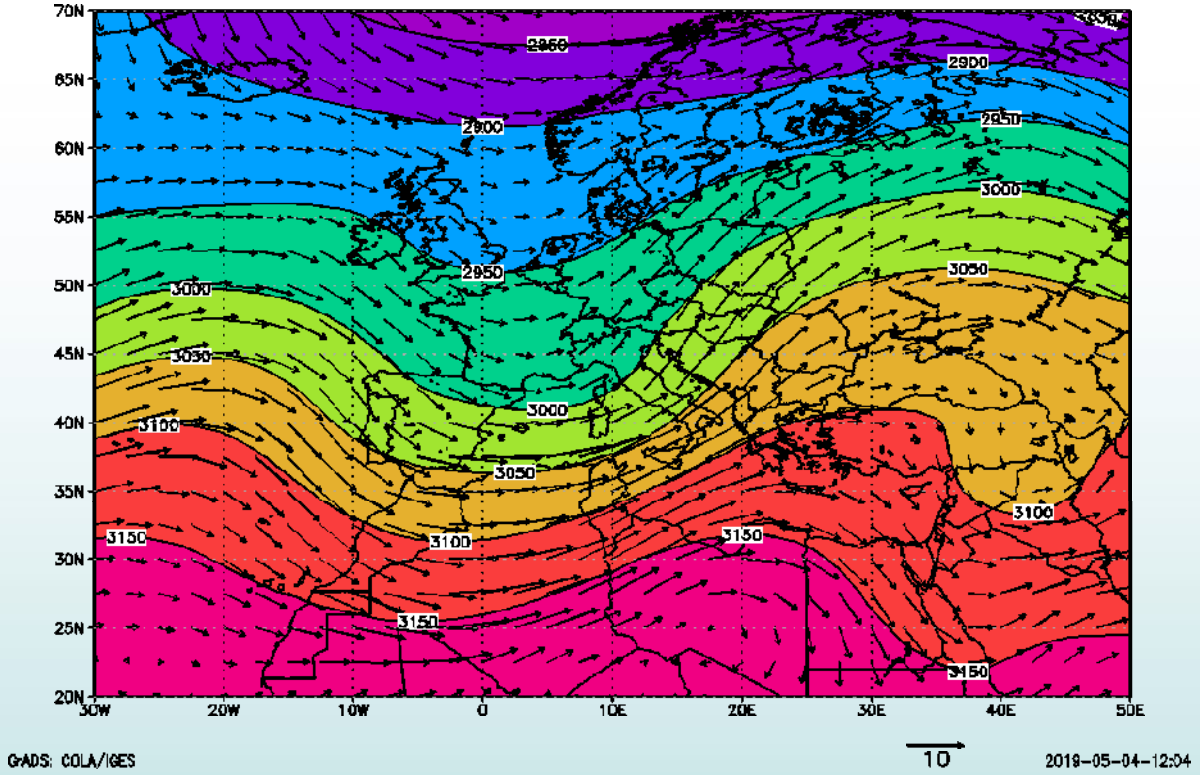


Figure: A composite geopotential height (m) and wind flow (m/s) map for days of 18 events analysed from March 2012 to December 2013

D. S. Đorđević, I. Tošić, S. Sakan, S. Petrović, J. Đuričić-Milanković, C. D. Finger, P. Dagsson-Waldhauserova, "Can volcanic dust suspended from surface soil and deserts of Iceland be transferred to Central Balkan similarly to African dust (Sahara)?" *Frontiers in Earth Sciences*, vol. 7:142, 2019

Conclusions

- Free open source software might be good candidate for both students and researchers in meteorology.
- Xmgr is a 2D plotting tool for X-terminals used in education for visualization of meteorological data.
- GrADS is extensively applying in visualization of meteorological fields in education and research.
- Incorporation of other free software, for example Python.