RS RAS Internship Report

Moritz M. Konarski

Applied Mathematics Department American University of Central Asia

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ntroduction

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Conclusion

Outline

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Introduction

Place of internship

- ► Federal State Budgetary Institution of Science Research Station of the Russian Academy of Sciences in Bishkek (RS RAS)
- ▶ employs 137 people
- ▶ founded in 1978
- researches seismic processes and develops geodynamic models [19]

Building an Application

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Educational internship tasks

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1. familiarize yourself with web resources providing access to NASA Earth Remote Sensing data

- 2. familiarize yourself with the scientific data format netCDF (Network Common Data Form)
- 3. study libraries used to work with the netCDF format in various computing environments

Industrial internship tasks

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1. register on the NASA Earthdata platform to access satellite data

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- 2. develop a library for working with netCDF files in the Python programming language (using satellite data as an example)
- 3. develop a computer application for data visualization and reanalysis of NASA MERRA-2 satellite data.

The end product

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▶ a Python application with a graphical user interface that:

- extracts variables from netCDF files and saves them to NPZ files
- ▶ takes those NPZ files and selects subsets of their data
- either exports that data or plots that data
- data can be heat map or time series

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What data are we using?

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► NASA Modern-Era Retrospective analysis for Research and Applications version 2 (MERRA-2)

specifically M2I3NPASM; Jan. 1, 1980 to Oct. 1, 2020

- ▶ covers whole globe, measurements every 3 hours [5]
- ▶ 14 variables with latitude, longitude, time, pressure level [26]:
 - surface pressure
 - specific humidity
 - temperature

Where do we get the data?

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► MERRA-2 data (M2I3NPASM) available at NASA Goddard Earth Sciences (GES) Data and Information Services Center (DISC) here

- ▶ requires account [22] but is free [21]
- ➤ a subset of the data can be downloaded, see Figure 2.1
- download is convenient using the command-line application wget

Data subset



Figure 2.1: OpenStreetMap, 34°N to 48°N and 65°E to 83°E

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What is the data format?

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► files are in NetCDF format (Network Common Data Form), stores multi-dimensional arrays

- ▶ is a data format and set of libraries [8]
- ▶ libraries exists for C, Java, Fortran, Python, ... [20]
- ▶ full M2I3NPASM file (1 day) is 1.1 GB in size [26], our selection (Figure 2.1) is about 6 MB
- ▶ has 4 dimensions and 14 variables
- ▶ also includes metadata

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Libraries I

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► I am working with Python, thus I need a Python library

- ► NetCDF library for netCDF4 available [7]
- ▶ maintained by the NetCDF developers
- very popular library
- ▶ table below lists all required libraries

Libraries II

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Name	Reference	Purpose
PyQt5	[11]	GUI, threading
os	[9]	working with directories
numpy	[27]	saving data and
		manipulating arrays
pandas	[25]	exporting data,
		creating date series
json	[4]	JSON files
datetime	[3]	working with dates
textwrap	[14]	wrapping text
math	[6]	testing for NaN

Libraries III

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Name	Reference	Purpose
cartopy	[2]	maps, borders
matplotlib	[23]	plots, saving plots
netCDF4	[7]	netCDF files
pathlib	[10]	file paths
re	[12]	regular expressions
webbrowser	[18]	open a web page in browser
sys	[13]	pass arguments
warnings	[17]	ignoring warnings

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Program requirements

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- ▶ netCDF data files (preferably M2I3NPASM)
- ▶ properly set up environment (see section 4.1 of my report)
- ▶ code for my program here or upon request

Demonstration

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▶ if the demonstration succeeded, go to Plot Results

▶ if it failed, continue here

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Data processor I

Satellite Data Modification and Plotting Program				×	
<u>H</u> elp					
Data Processor	Data Manager	Export Data	Plot Data		
Source Director	y Path				
No Source Direc	ctory Selected				
Select Sou	rce Directory				
Variables Availa	able for Extraction				
	•	Full Variable	Name		
Ex					
Accurate Progre	ess: 0%				
D					
Ready					

Figure 5.1: The Data Processor Tab

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Internship

	Select Source Directory	×
Look in: Comput	/home/moritz/Documents/internship.git/programs /	
Directory: Files of type:	year Directories	<u>C</u> hoose

Figure 5.2: The Source Directory Selection Popup

Data processor III

Satellite Data Modification and Plotting Program	×
<u>H</u> elp	
Data Processor Data Manager Export Data Plot Data	
Source Directory Path	
/home/moritz/Documents/internship.git/programs/.year	
Select Source Directory	
Variables Available for Extraction	
EPV Ertels Potential Vorticity	
Extract Cancel Extraction	
Accurate Progress: 0%	
Source Directory Selected	

Figure 5.3: Data Processor with loaded source Directory

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Data processor IV

	Sate	ellite Data Mod	dification and Plotting Program	×
<u>H</u> elp				
Data Processor	Data Manager	Export Data	Plot Data	
Source Director	ry Path			
/home/moritz/D	ocuments/internsh	ip.git/programs	:/.year	
Select Sou	rce Directory			
Variables Availa	able for Extraction			
EPV	•	Ertels Potenti	ial Vorticity	
Ex	tract	Canc	el Extraction	
Accurate Progre	ess: 38.071			
			38%	
Extracting Data				ail

Figure 5.4: Extraction in Progress

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Data manager I

ata Processor Data Manager Export Data Plot Data Source Directory Path No Source Directory Selected Select Source Directory Variable: Name Name: Long Name Units: Units Time Series Data Heat Map Data Select data parameters here: Parameter Unit Minimum Value Maximum Value Selected Min Value Selected Max Value Time Range Date Hours Latitude Range Longitude Range Level Range Plot Data		S	atellite Data M	odification and	Plotting Program	
Source Directory Path No Source Directory Selected Select Source Directory Variable: Name Name: Long Name Units: Units Time Series Data Heat Map Data Select data parameters here: Parameter Unit Minimum Value Maximum Value Selected Min Value Selected Max Value Time Range Date Hours Latitude Range Level Range Level Range Level Range Level Range	elp					
No Source Directory Selected Select Source Directory Variable: Name Name: Long Name Units: Units Time Series Data Heat Map Data Select data parameters here: Parameter Unit Minimum Value Maximum Value Selected Min Value Selected Max Value Time Range Date Hours Latitude Range Level Range Level Range Level Range Range Level Range Level Range Level Range Level Range Ra	ata Processor	Data Manage	er Export Data	Plot Data		
Select Source Directory Variable: Name Name: Long Name Units: Units Time Series Data Heat Map Data Select data parameters here: Parameter Unit Minimum Value Maximum Value Selected Min Value Selected Max Value Time Range Date Hours Latitude Range Longitude Range Level Range Level Range	Source Directory	Path				
Variable: Name Name: Long Name Units: Units Image: Time Series Data	No Source Directo	ory Selected				
Name: Long Name Units: Units Time Series Data	Select Source	e Directory				
Units: Units Time Series Data Heat Map Data Select data parameters here: Parameter Unit Minimum Value Maximum Value Selected Min Value Selected Max Value Time Range Date Hours Latitude Range Level Range Level Range	Variable: Name					
Time Series Data	Name: Long Nam	e				
Parameter Unit Minimum Value Maximum Value Selected Min Value Selected Max Value Time Range Date Hours Selected Min Value Selected Min Value Selected Max Value Latitude Range Selected Min Value Selected	Units: Units					
Time Range Date Hours Latitude Range Longitude Range Level Range	O		Heat Map Dat	a		
Latitude Range Longitude Range Level Range	Parameter	Unit	Minimum Value	Maximum Value	Colosted Min Value	
Longitude Range Level Range					Selected Mili Value	Selected Max Value
Level Range	Time Range	Date Hours			Selected MIII Value	Selected Max Value
		Date Hours			Selected MIII Value	Selected Max Value
Export Data Plot Data	Latitude Range				Selected Mill Value	
Export Data Plot Data	Latitude Range Longitude Range				Selected Mill Value	
	Latitude Range Longitude Range Level Range				Selected MIII Value	

Figure 5.5: The Data Manager Tab

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Data manager II

		ellite Data Modifi	cation and Plottir	ng Program	
elp					
ata Processor	Data Manager	Export Data P	lot Data		
Source Directory F	Path				
,		nip.git/programs/EP	v		
Select Source	Directory				
Variable: EPV					
Name: Ertels Pote	ntial Vorticity				
Units: K m+2 kg-1	s-1				
Time Series Da					
		Heat Map Data			
Select data param		Heat Map Data			
_		Minimum Value	Maximum Value	Selected Min Value	Selected Max Value
Select data param	eters here:	Minimum Value	Maximum Value 2020-08-31 21:00	Selected Min Value	Selected Max Value
Select data param	Unit	Minimum Value 2019-09-01 00:00		Selected Min Value	Selected Max Value
Select data param Parameter Time Range	Unit Date Hours Degrees North	Minimum Value 2019-09-01 00:00	2020-08-31 21:00	Selected Min Value	Selected Max Value
Select data param Parameter Time Range Latitude Range	Unit Date Hours Degrees North	Minimum Value 2019-09-01 00:00 34.0	2020-08-31 21:00 48.0	Selected Min Value	
Select data param Parameter Time Range Latitude Range Longitude Range Level Range	Unit Date Hours Degrees North Degrees East	Minimum Value 2019-09-01 00:00 34.0 65.0	2020-08-31 21:00 48.0 83.125 1000.0	Selected Min Value	
Select data param Parameter Time Range Latitude Range Longitude Range	Unit Date Hours Degrees North Degrees East	Minimum Value 2019-09-01 00:00 34.0 65.0	2020-08-31 21:00 48.0 83.125	Selected Min Value	

Figure 5.6: Data Manager with loaded Directory

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Data manager III

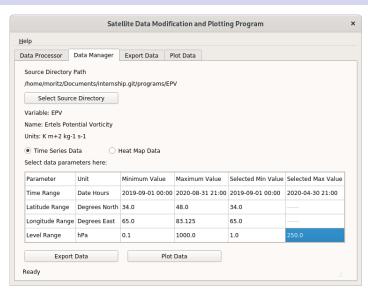


Figure 5.7: Data Manager in Time Series Mode

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Data manager IV

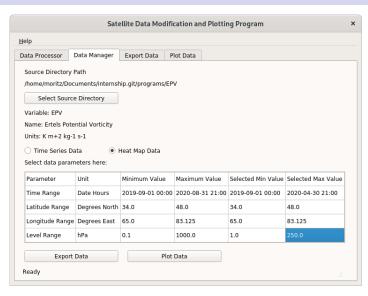


Figure 5.8: Data Manager in Heat Map Mode

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Data manager V

	Sate	ellite Data Modifi	ication and Plottir	ng Program	
elp					
ata Processor	Data Manager	Export Data F	Plot Data		
Source Directory F					
		nip.git/programs/PS	•		
Select Source	Directory				
Variable: PS					
Name: Surface Pre	essure				
Units: Pa					
Time Series Da Select data param	eters here:	Heat Map Data			
Parameter	Unit	Minimum Value	Maximum Value	Selected Min Value	Selected Max Value
Time Range	Date Hours	2019-09-01 00:00	2020-08-31 21:00		
Latitude Range	Degrees North	34.0	48.0		
Longitude Range	Degrees East	65.0	83.125		
Level Range					
Export	Data	Plot	Data		
Ready					

Figure 5.9: Data Manager with data without level

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Data exporter I

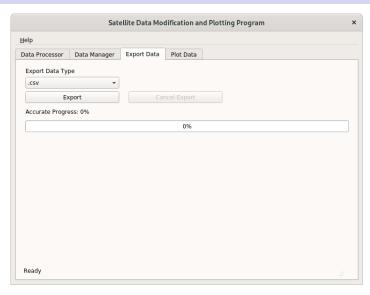


Figure 5.10: The Data Export Tab

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Figure 5.11: The File Number Warning Message

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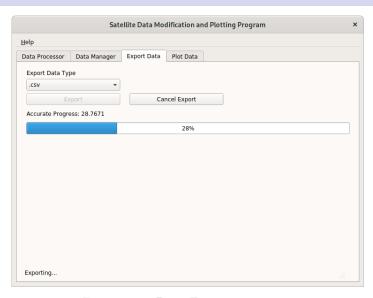


Figure 5.12: Data Export in progress

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Example of exported temperature data (in Kelvin)
$250 \text{ hPa}, (34^{\circ}\text{N}, 65^{\circ}\text{E})$

237.30182
236.86859
236.79724
236.82132
237.73062
238.40472
238.4401
238.20715
237.49396

Data plotter I

	Sat	ellite Data Mo	lification and Plotting Program	
<u>H</u> elp				
Data Processor	Data Manager	Export Data	Plot Data	
Plot File Type				
pdf	•			
Use Global Min Max		O Use Local	Min Max	
Plot Cities				
Plot		Can	cel Plotting	
Accurate Progre	ess: 0%			
			0%	
Ready				

Figure 5.13: The Data Plotter Tab for Heat Map Data

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Data plotter II

	Sate	llite Data Mod	lification and	Plottin	g Program			×
<u>H</u> elp								
Data Processor Dat	a Manager	Export Data	Plot Data					
Plot File Type								
pdf	•							
Use Global Min Ma	 Use Global Min Max 		○ Use Local Min Max					
Plot Cities								
Plot		Can	cel Plotting					
Accurate Progress: 0	%							
			0%					
Ready								

Figure 5.14: The Data Plotter Tab for Time Series Data

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Data plotter III

Satellite Data Modification and Plotting Program							
<u>H</u> elp							
Data Processor	Data Manager	Export Data	Plot Data				
Plot File Type							
pdf	•						
Use Global Min Max		O Use Local	ıl Min Max				
Plot Cities							
Plot		Can	ncel Plotting				
Accurate Progre	ess: 50.0						
	50%						
Plotting			all.				

Figure 5.15: Data Plotter in Progress

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Help website

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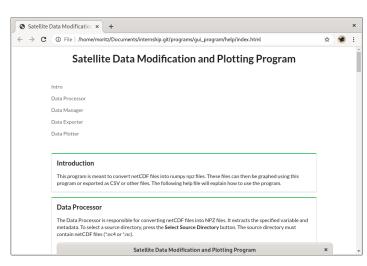


Figure 5.16: Screen Shot the Help section

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Temperature time series

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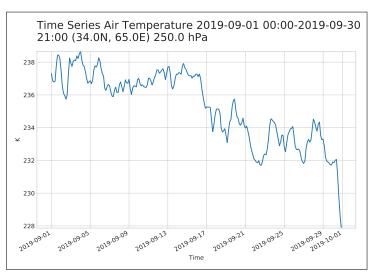


Figure 6.1: Time Series Plot for Air Temperature in Kelvin (K)

Temperature heat map I

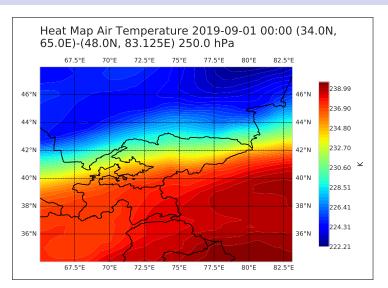


Figure 6.2: Heat Map Plot for Air Temperature in Kelvin (K)

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Temperature heat map II

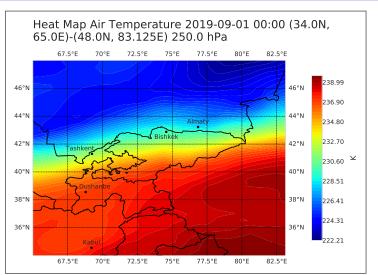


Figure 6.3: Heat Map Plot for Air Temperature in Kelvin (K) with Cities

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Purpose

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▶ use my program and gained skills

▶ investigate temperature structure of the troposphere, temperature inversion around the tropopause

Troposphere

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► lowest layer of atmosphere

▶ up to about 12km above surface

▶ temperature at top about -63°C or 210K [15]

 \blacktriangleright pressure is 1000 hPa to 200 hPa [16]

Tropopause

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boundary between troposphere and stratosphere

▶ demarcated by:

1. inversion of the temperature gradient [15]

2. increase in potential vorticity (rotation of air masses) [15]

3. increase of ozone mixing ratio (how much ozone in the air by mass or volume) [1]

▶ to investigate: make plots of variable vs. pressure

▶ plot specifics: M2I3NPASM, 01.09.2019 at 12:00, (40°N, 70°E)

Temperature

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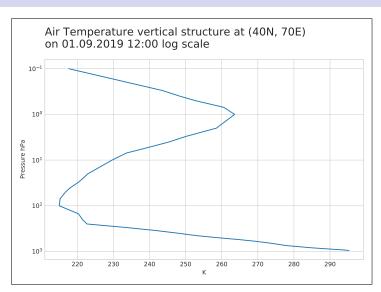


Figure 7.1: Air Temperature by Air Pressure

Potential Vorticity

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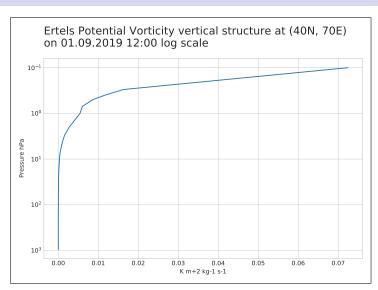


Figure 7.2: Ertel's Potential Vorticity by Air Pressure

Ozone Mixing

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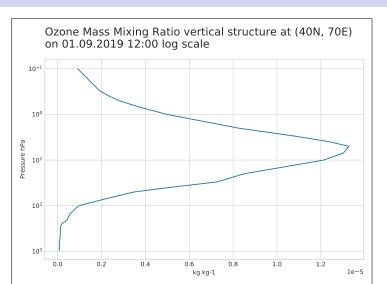


Figure 7.3: Ozone Mass Mixing Ratio by Air Pressure

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▶ tropopause temperature inversion in Figure 7.1 (caused by aerosols and molecules) [24] was in the right spot

- ▶ the ozone layer can be seen in Figure 7.3
- ▶ the potential vorticity in Figure 7.2 increased as expected
- ▶ the results obtained from the data analysis line up with the expected results

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Q and A

▶ working with satellite data, GUI/Python development is valuable

▶ all skills I learned will be useful for my future, for jobs, further studies, or even research

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References I

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	page	12.					

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Version 0.18.0. Accessed 17.11.2020. URL:

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Version 3.9.0. Accessed 17.11.2020. URL: https:

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 $[5] \quad {\rm M2I3NPASM~data}.$

Accessed 17.11.2020. URL:

 $\verb|https://disc.gsfc.nasa.gov/datasets/M2I3NPASM_5.12.4/summary.|$

 $[6] \quad {\rm math-mathematical\ functions}.$

Version 3.9.0. Accessed 17.11.2020. URL:

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 $\verb|https://unidata.github.io/netcdf4-python/netCDF4/index.html|.$

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 Version 3.9.0. Accessed 17.11.2020. URL: https://docs.python.org/3/library/os.html.
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