**Chapter 1: Introduction**

Importance of data assimilation in numerical weather prediction using the WRF model. WRF is highly customizable, allowing researchers to configure the model to suit their specific study objectives and domains. WRF is an open-source model, fostering collaboration within the atmospheric science community. Researchers worldwide contribute to its development and improvement. WRF has a diverse range of applications, including:

*Operational Forecasting:* Providing short-term weather forecasts for operational meteorological agencies.

*Research Studies:* Conducting atmospheric research, climate studies, and regional weather simulations.

*Emergency Response:* Assisting in disaster preparedness and response by predicting severe weather events.

**Chapter 2: WRF Numerical Weather Prediction Model**

**2.1. Purpose and Overview:**

**2.1.1. Numerical Weather Prediction (NWP):**

Objective: The primary goal of the WRF model is to simulate and predict atmospheric processes to provide accurate short to medium-range weather forecasts.

Numerical Approach: WRF uses numerical methods to solve the fundamental equations governing atmospheric motion, thermodynamics, and other relevant processes.

**2.2. Model Components:**

**2.2.1. Dynamics Core:**

WRF supports multiple dynamical cores, including:

Advanced Research WRF (ARW): Developed by the National Center for Atmospheric Research (NCAR), ARW is a non-hydrostatic core suitable for a wide range of applications.

WRF Non-hydrostatic Mesoscale Model (NMM): Developed by the National Centers for Environmental Prediction (NCEP), it is another dynamical core option.

**2.2.2. Physics Parameterizations:**

WRF incorporates parameterization schemes for various physical processes, such as:

Radiation: Models the transfer of solar and terrestrial radiation.

Microphysics: Describes cloud and precipitation processes.

Land Surface: Represents interactions between the atmosphere and land.

**2.2.3. Grid Nesting:**

WRF supports nested domains, allowing users to simulate at different resolutions within a larger domain. This feature is crucial for capturing fine-scale atmospheric features in specific regions of interest.

**Chapter 3: Data Assimilation**

Similarly, this section should provide an explanation of data assimilation, its significance, and how it is applied in the context of WRF numerical weather prediction. Data assimilation is a process of combining observations with model simulations to improve the accuracy of the model's predictions. In the context of WRF (Weather Research and Forecasting) model data assimilation, the WRFDA (WRF Data Assimilation) system is commonly used. WRFDA includes several data assimilation methods, such as three-dimensional variational (3DVAR) and ensemble Kalman filter (EnKF), among others.

**Chapter 4: Implementation in R**

**4.1** Uploading Necessary Packages

In this part, the necessary R packages are loaded. These packages are essential for various tasks, such as handling netcdf files, data manipulation, visualization, etc.

**4.2** Assimilated WRF Data

Here, the code opens a netcdf file containing assimilated WRF output for domain 1. The file path and name are specified.

**4.3** Precipitation Prediction (Domain 1)

This part focuses on extracting precipitation data (RAINC and RAINNC) from the assimilated WRF output for domain 1. The code explains that to obtain total precipitation, the sum of convective and non-convective precipitation is calculated.

**4.4** Spatial Resolution (Domain 1)

The spatial resolution of domain 1 is extracted from the netcdf file and displayed.

**4.5** Forecast Period & Time Interval (Domain 1)

The code retrieves the forecast horizon and time interval for the assimilated WRF output for domain 1.

**4.6** Study Area (Domain 1)

This part visualizes the coverage of domain 1 on a map, including Turkey and its surrounding regions.

**4.7** Precipitation Prediction (Domain 2)

Similar to section 4.3, this part focuses on extracting precipitation data, but for domain 2.

**4.8** Spatial Resolution (Domain 2)

Extracts and displays the spatial resolution of domain 2.

**4.9** Forecast Period & Time Interval (Domain 2)

Retrieves the forecast period and time interval for domain 2.

**4.10** Study Area (Domain 2)

Visualizes the coverage of domain 2 on a map, including a comparison with domain 1.

**4.11** Additional Study Area Visualization

Another visualization focusing on the coverage of domain 2 within Turkey.

**4.12** Stations Across Domain 2

Displays information about gauge stations across domain 2.

**Chapter 5**

**Filtering and Data Cleaning**

**5.1 Gauges Data Loading**

*df\_gauges <- read.delim("path/to/gauges.txt", sep="|")*

*df\_gauges <- df\_gauges[, -c(3, 4)]*

*colnames(df\_gauges) <- c("Station", "Province", "Latitude", "Longitude", "Altitude")*

Explanation:

* The code reads a file named "gauges.txt" using read.delim, assuming it is a delimited text file (in this case, using the "|" separator).
* Columns 3 and 4 are dropped from the data frame (df\_gauges) using df\_gauges[, -c(3, 4)].
* Column names are assigned to the data frame.

**5.2 Data Cleaning and Formatting**

*df\_gauges$Province <- tolower(df\_gauges$Province) |> str\_to\_title()*

Explanation:

* The tolower function is used to convert the province names to lowercase.
* The str\_to\_title() function from the stringr package is applied to convert the province names to title case.

**5.3 Visualization**

**5.3.1 Gauge Stations Visualization:**

*df\_gauges |> gt()*

Explanation:

* The gt() function from the gt package is used for creating tables.
* The pipe (|>) operator is employed to pass the data frame (df\_gauges) into the gt() function.
* This code generates a table to visualize the gauge station information.

**Conclusion**

In summary, the integration of the WRF model with data assimilation techniques has proven to be a valuable tool for advancing our understanding of regional weather patterns. The outcomes of this study have practical applications in operational forecasting, research endeavors, and emergency response, contributing to the broader field of atmospheric science.

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