Data Analysis and Visualization using NCARG NCL

Gurbrinder Kaur

Abstract— The NCAR Command Language is a product of the Computational & Information Systems Laboratory at the National Center for Atmospheric Research (NCAR) and sponsored by the National Science Foundation. It is a free interpreted language designed specifically for scientific data processing and visualization. The NCAR Command Language (NCL) is a data analysis and visualization environment developed primarily at CISL in deep collaboration with a number of core scientific groups. NCL enables scientists to effectively read, analyze, and visualize their geoscientific data on platforms ranging from personal laptops to high performance computers.

Index Terms— NCAR Command Language(NCL) ,Geographic Information System (GIS),World Research and Forecasting System (WRF), Cluster Of Sys tems of Metadata for Official Statistics (COSMOS).Regional Climate Model (RCM).

1 INTRODUCTION

Meteorological and climatic data visualization and analysis are essential for researchers and forecasters to understand and apply these data. Such data are inherently spatially variable and hence the use of a Geographic Information System (GIS) represents a useful solution for the management of vast spatial meteorological and climatic datasets for a wide number of applications [1]. The powerful mapping capability of GIS is a primary factor that makes it attractive to the atmospheric community Layer-based visualization also supports the comparison of various aspects of a meteorological data set, and its spatial properties can be highlighted by incorporating geospatial information in GIS.[2] The abundant position-based information and analysis functions on land surfaces of GIS, e.g. topographic analysis, land-use changes, urban interface and water resources, make it useful for studying interactions between the land surface and the atmosphere. For example, topographic analysis based on GIS has significantly contributed to improvements in the precipitation estimates derived from Special Sensor Microwave/Imager data over the Tibetan Plateau[3]. Topographic analysis was also used to enable a spatial and temporal analysis of road surface temperatures across the West Midlands of England [4]. Spatial analysis capabilities are another factor which promote the use of GIS in the atmospheric community. For example, geostatistical analyses in GIS have been widely used in climate data interpolation Given these capabilities of GIS, it has been applied in many facets of the meteorological field such as forecast model verification[3] , air pollution prediction [4], agrometeorological zoning , hy drometeorological forecasting and as an education tool [5].

Although GIS strategies have become increasingly popular in meteorological applications [6] commercial GIS software packages are normally very expensive and complex in operation for most users in meteorological fields. Furthermore, they are not able to conveniently deal with some popular meteorological data formats such as GRIB and NetCDF. Consequently, the atmospheric science community has developed several customized data visualization and application tools such as Grid Analysis and Display System (GrADS), Ferret, and NCAR Command Language (NCL).

2 NCL DATA MODELS

2.1 WEATHER RESEARCH AND FORECASTING (WRF) MODEL:

Weather Research and Forecasting Model is Used for both research and operational forecasting. WRF has two dynamical cores: The Advanced Research WRF (ARW) and Nonhydrostatic Mesoscale Model (NMM). The Advanced Research WRF (ARW) and Nonhydrostatic Mesoscale Model (NMM) are dynamical cores.

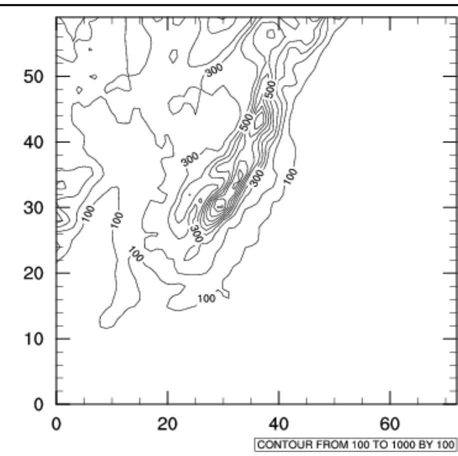

Fig. 1. Output of a single field plotted using WRF Model

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2.2 RCM MODEL:

Regional Climate Models (RCMs) work by increasing the resolution of the GCM in a small, limited area of interest. An RCM might cover an area the size of western Europe, or southern Africa – typically 5000km x 5000km. The full GCM determines the very large scale effects of changing greenhouse gas concentrations and volcanic eruptions on global climate. The climate calculated by the GCM is used as input at the edges of the RCM for factors such as temperature and wind. RCMs can then resolve the local impacts given small scale information about orography (land height) and land use, giving weather and climate information at resolutions as fine as 50 or 25km.

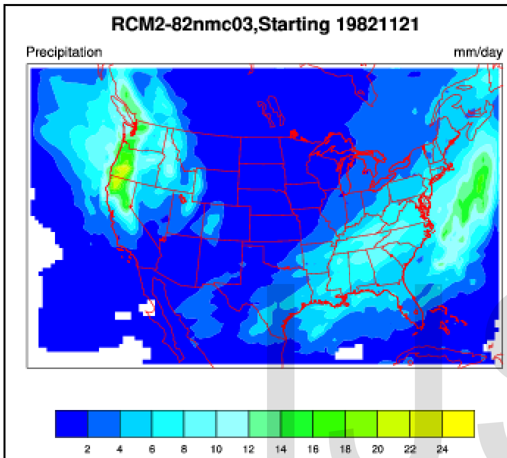

Fig. 2. A color precipitation plot using a netCDF version of the data

2.3 CONSORTIUM FOR SMALL-SCALE MODELING-COSMO MODEL:

The COSMO-Model is a nonhydrostatic limited-area atmospheric prediction model. It has been designed for both operational numerical weather prediction (NWP) and various scientific applications on the meso-β and meso-γ scale. The COSMO-Model is based on the primitive thermo-hydrodynamical equations describing compressible flow in a moist atmosphere. The model equations are formulated in rotated geographical coordinates and a generalized terrain following height coordinate. A variety of physical processes are taken into account by parameterization schemes.

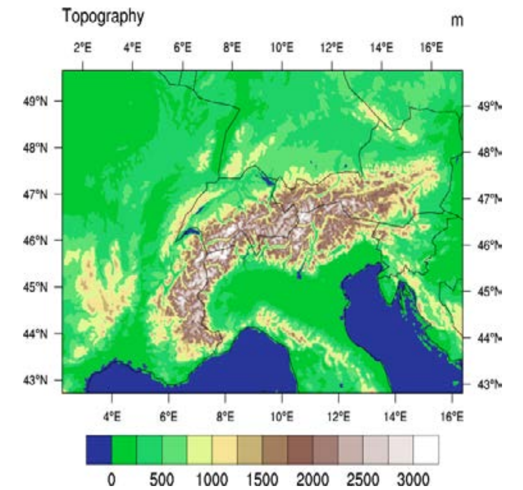

Fig.3 2D contour plot with the correct geo-referencing of the field in rotated-latlon-coordinates in Cosmo Model

2.4 EARTH SYSTEM MODELING

A coupled climate model is a computer code that estimates the solution to differential equations of fluid motion and thermodynamics to obtain time and space dependent values for temperature, winds and currents, moisture and/or salinity and pressure in the atmosphere and ocean. Components of a climate model simulate the atmosphere, the ocean, sea, ice, the land surface and the vegetation on land and the biogeochemistry of the ocean. The Earth System Modeling Framework (ESMF) is "software for building and coupling weather, climate, and related models". The ESMF "ESMF_RegridWeightGen" tool has been incorporated into NCL for generating weights for interpolating (regridding) data from a one grid to another.

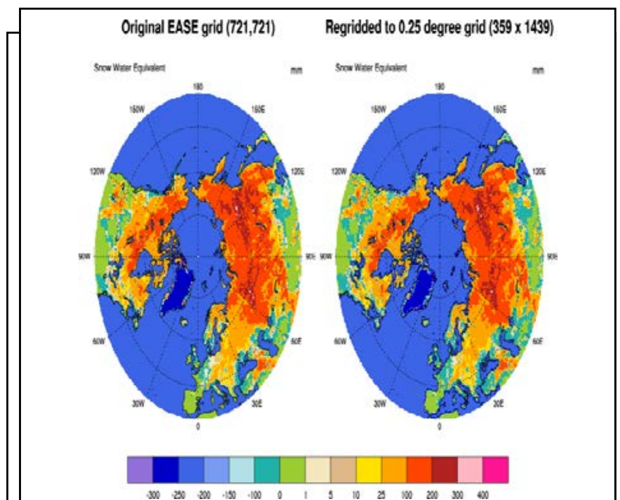

Fig.4 Regridding using Earth System Model in NCL

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3 Supported File Formats

NetCDF is a set of software libraries and self-describing, machine-independent data formats that support the creation, access, and sharing of array-oriented scientific data. It is commonly used in climatology, meteorology and oceanography applications, especially for four dimensional gridded data sets from model output. Several conventions, e.g. Climate and Forecast (CF) and Cooperative Ocean/Atmosphere Research Data Service (COARDS), were adopted to promote the interchange and sharing of files created with the NetCDF API. The format is supported by many software packages, e.g. NCL, GrADS, NCO [7] and ArcGIS. In MeteoInfo, NetCDF grid data with CF conventions can be opened. NetCDF data from WRF and CMAQ model output are also supported.

GRIB is a data format commonly used in meteorology to store and exchange historical and forecast weather grid data. It is standardized by the World Meteorological Organisation's (WMO) Commission for Basic Systems. Currently there are two versions of GRIB in operational use. Data formatted according to the first GRIB edition are slowly being converted over to the second GRIB edition. GRIB is a self-describing binary format and the data are packed to increase storage efficiency.

In the GrADS data format, raw binary data and metadata are stored in separate files. The metadata file is called the data descriptor file and contains a complete description of the binary data as well as instructions for decoding tools such as where to find the data and how to read it. The GrADS data format and the software were developed and maintained by the Institute of Global Environment and Society (IGES).

HDF-EOS (Hierarchical Data Format—Earth Observing Systems) is a self-describing file format based upon HDF for transfer of various types of data between different machines. It is a standard format to store data collected from EOS satellites. HDF-EOS5 is based on the HDF5 data model.

ARL packed data format is used by the NOAA Air Resource Laboratory. An ARL packed data file consists of a series of fixed length records, one for each meteorological variable.[8] The records are arranged in a time series with surface fields followed by upper air fields. Each record contains an ASCII header and is followed by the packed binary data, one byte per gird point. The HYSPLIT (Hybrid Single-Particle Lagrangian Integrated Trajectory) model is popular for computing air mass trajectories and complex dispersion simulations using input meteorological data in the ARL packed data format[9]. The output trajectory, concentration and particle data formats are also supported in MeteoInfo.

MICAPS (Meteorological Information Comprehensive Analysis and Process System) is an operational data visualization software tool for forecasters in the China Meteorological Bureau (CMA). It defines many kinds of meteorological data formats for surface or upper observations, model outputs, satellite observations and typhoon pathways.

Several ASCII station data and grid data formats are also supported by MeteoInfo to meet the demand of using simple and human readable data under some conditions. SYNOP is a numerical code, called FM-12 by WMO, used for reporting weather observations made by manned and automated weather stations. METAR is an aviation routine weather report with the description of the meteorological elements observed at an airport at a specific time. It is highly standardized through the International Civil Aviation Organization (ICAO). At present only the cycle METAR data of NOAA (http://weather.noaa.gov/weather/metar.shtml) is directly supported by MeteoInfo. NOAA ISH is a worldwide database of hourly and synoptic data. Longitude/latitude Station Data format is a custom station data format in MeteoInfo. Two ASCII grid data formats are supported: ESRI ASCII Grid Data; and Surfer ASCII Grid Data.

Data format	Data type	File type	Development by
NetCDF	Grid	Binary	Unidata
GRIB 1 and 2	Grid	Binary	WMO
GrADS binary	Grid and station	Binary	IGES
HDF EOS5	Grid and swath	Binary	HDF group and NASA
ARL packed	Grid	Binary	NOAA ARL
HYSPLIT output	Grid, station and trajectory	Binary	NOAA ARL
MICAPS	Grid, station and trajectory	Most are text	CMA
SYNOP	Station	Text	WMO
METAR	Station	Text	ICAO
NOAA ISH	Station	Text	NOAA
Longitude/latitude station	Station	Text	MeteoInfo
ESRI ASCII grid	Grid	Text	ESRI

Table. 1 Data types Supported in NCL

Conclusion:

MeteoInfo is a free and comprehensive software package which is used for meteorological data visualisation and analysis. It includes a .NET class library, a desktop application, and the capability for users to write scripting programs using the IronPython language for complex data analysis and automatic execution. The class library contains some basic components of a GIS system and can be used in software development as a simple GIS library. Many popular meteorological data formats are supported by the library and data models have been implemented to manage meteorological and GIS data sets. The meteorological data model also provides the ability for complex meteorological analysis using grid and station data. GIS layers can easily be created from the meteorological data set according the data properties and are supported by the wContour library. These attributes make MeteoInfo a step forward towards bringing GIS into meteorological fields. The MeteoInfo desktop application has been developed based on the MeteoInfo class library with a well arranged GUI which helps improve the efficiency of visualizing and understanding the properties of various meteorological data sets. The different aspects of the data set can be extensively viewed with the dimensional and drawing setting options. The layout interface provides the ability to generate high-quality and publication-ready plots. The scripting ability with IronPython language makes MeteoInfo a powerful tool for data analysis and automatic operation. MeteoInfo can be run on the Windows platform with. Netframework3.5 or on Linux-like systems with Mono. Looking forward, some meteorological data formats such as NetCDF, GRIB and HDF-EOS are very complicated and the library needs to be improved for better reading and writing of such data sets. At present MeteoInfo contains only a few traditional GIS spatial analysis functions, e.g. clipping andselecting by location. The analysis functions available for grid data in the meteorological data models, including interpolation and contouring, should also be implemented for the GIS raster layer to improve the spatial analysis ability of raster data. More spatial functions such as buffering and overlay are needed to enhance the ability to analyse vector data.

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