Using GIS in Preparing Combat Climatological Products and Services

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Paper Abstract

This presentation will highlight the GIS techniques utilized to provide combat climatological products and services to the DoD community by the Air Force Combat Climatology Center (AFCCC), Asheville, NC. These techniques will include the use of ArcInfo, Python geoprocessing scripts to automate raster generation, Spatial Analyst, and Tracking Analyst to build climatological products. Additionally, the presentation will address AFCCC use of the Australian National University's ANUSPLIN interpolation software to build rasters which consider multi-variate surfaces such as elevation combined with temperature, precipitation, slope, wind direction, etc., and then subsequently ingest them into ArcInfo to build the final climatological product. The discussion will include future AFCCC initiatives to extend Web-based, GIS-enabled customer support and deploy interactive web services on all enclaves. And finally, it will address efforts to move towards Machine-to-Machine (M2M) climatology support with C2 systems and focus on those challenges along the way ahead.

Introduction

The Air Force Combat Climatology Center (AFCCC) uses various GIS techniques to provide timely and tailored climatologic weather products for US Forces, DoD, and allied nations. The AFCCC organization is in the process of transitioning from a desktop GIS environment to an enterprise approach using its Oracle database with ArcGIS Server 9.2.

AFCCC maintains the DoD's most complete repository of worldwide weather data. On an average day, we ingest and store about 5 GB of data…

- 1,700 Upper Air Observations
- 240,000 Surface Observations
- 150,000 Aircraft Observations
- 45,000 Temperature Profiles
- 220,000 GOES Wind Profiles
- Limited Numerical Models

We have some categories of weather data in our archives dating back to January, 1901 and currently store about 10 TB of weather data for operational use.

Data Management

AFCCC receives weather data from over 10,000 weather stations around the world. Analysts often use GIS to search reporting stations and audit the data to generate statistical reports or export them to ArcView for further analysis.

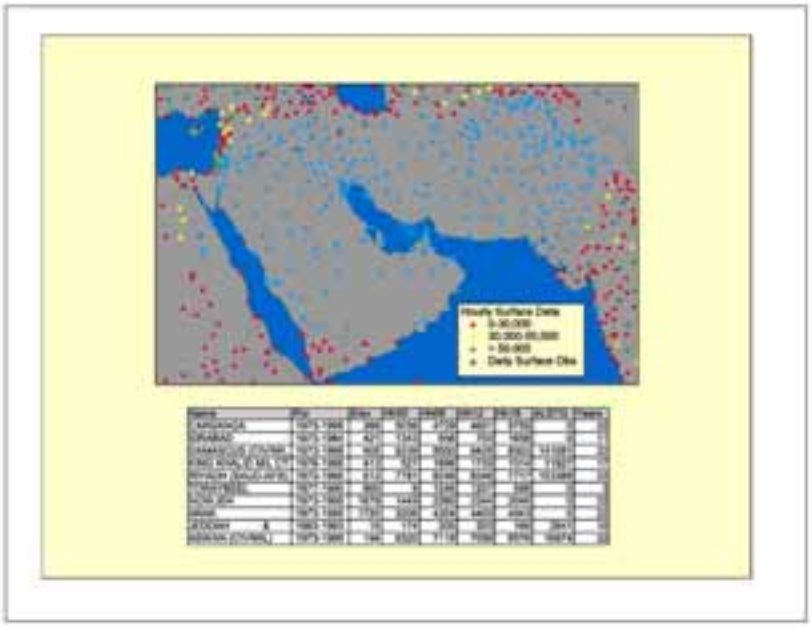

Figure 1. Illustration of managing hourly surface data observations.

Data Quality Control

Often, incoming climatologic data will have missing values or various types of errors which must be identified and corrected. Data queries can be used to identify missing values or highlight erroneous data records in an attribute table. Upon completion of data quality control procedures, the data can then be archived in the Oracle relational database or disseminated directly to customers.

Figure 2. Example of observation errors among adjacent stations in Mexico.

In Figure 2, some unusual values appeared in several weather observational reports coming from relatively nearby stations in Mexico. Upon further study of these three stations in addition to several others in the same vicinity, AFCCC made the determination that some input errors and computational errors had in fact taken place during the reporting. We used an inset of DTED to ensure that the primary stations of interest were situated on relatively the same terrain elevation.

Data Analysis

Data analysis, visualization and climatological product generation are the central applications of GIS at AFCCC. Many of the climatological products and services at AFCCC are using the Operational Climatic Data Summary (OCDS) as the foundation data for product generation.

Operational Climatic Data Summary

- OPERATIONAL CLIMATIC DATA SUMMARY

- STATION: TEHRAN (CIV/MIL) IRAN STATION #: 407540 ICAO: OIII
- LOCATION: 3541N 5121E ELEVATION (FEET): 3908 LST = GMT + 3
- PREPARED BY: AFCCC/DOO, DEC 1998 PERIOD: 7301-8112, 8902-9712

- NOTE: GAP IN POR IS DUE TO IRAN-IRAQ WAR

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SOURCE NO.		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
1. TEMPERATURE (F)														
EXTREME MAX	1	64	69	77	87	96	105	107	105	99	87	77	67	107
MEAN DAILY MAX	1	43	48	57	70	80	91	97	95	88	75	61	49	72
MEAN	1	36	41	50	63	72	83	89	87	79	66	52	42	65
MEAN DAILY MIN	1	31	35	42	54	62	71	78	77	69	58	46	37	55
EXTREME MIN	1	7	13	16	31	37	50	57	54	50	37	24	16	7
# DAYS GE 90	1	0	0	0	0	4	20	29	25	13	0	0	0	91
# DAYS LE 32	1	17	10	4	0	0	0	0	0	0	0	1	9	41
# DAYS LE 0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2. PRECIPITATION (INCHES)														
MAXIMUM	2	4.7	4.8	6.1	4.0	2.4	1.0	0.6	0.9	0.8	1.9	3.7	3.2	15.3
MEAN	2	1.5	1.5	1.6	1.3	0.6	0.1	0.1	0.1	0.1	0.4	0.9	1.2	9.4
MINIMUM	2	0	0	0.1	0	0	0	0	0	0	0	0	0.2	3.6
MAX 24 HR	3	1.6	1.6	0.9	1.5	0.5	0.5	0.4	0.9	0.5	0.6	1.4	1.5	1.6
# DAYS GE .004	4	11	8	10	7	7	3	2	1	1	4	4	9	67
# DAYS GE .5	1	1	1	1	1	1	0	0	0	0	0	1	1	7

Figure 3. Operational Climatic Data Summary (OCDS)

The example above in Figure 3 of an OCDS illustrates a couple of weather parameters provided in monthly summarizations as well as the corresponding annual value. In a complete OCDS, there are eight tables containing over 60 weather parameters which can be ingested into GIS for further processing in producing climatological maps.

In Figure 4, you can see the widespread dispersion of world reporting stations which share their weather data in a digital format. AFCCC takes this raw data and prepares monthly summarization for use is creating standard and tailored GIS climatological products and services.

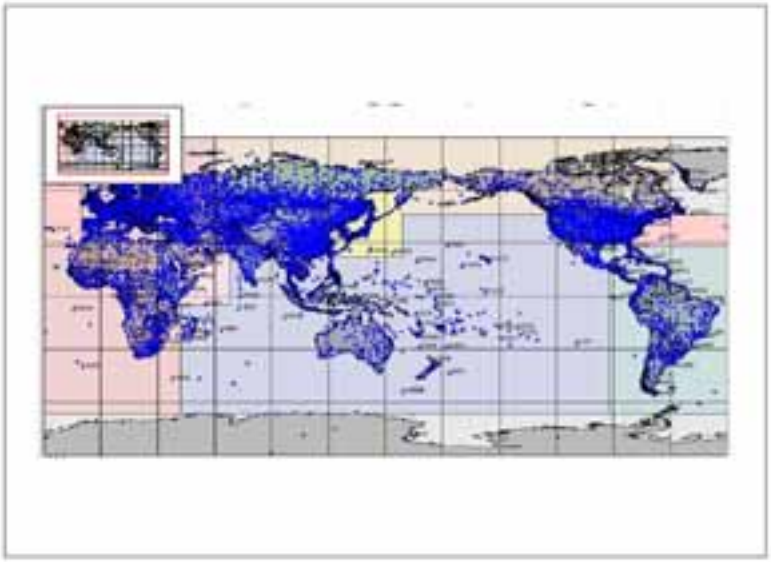

Figure 4. OCDS station locations – 10,001 stations and increasing

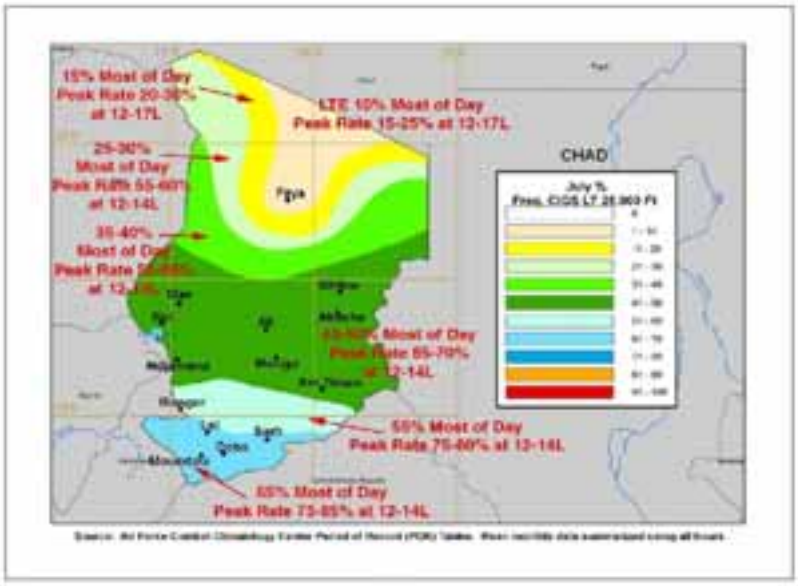

Figure 5. Detailed climatologic analysis and narrative generation for Chad

This product was generated with ArcInfo and a Python geoprocessing script. The climate analyst has added some tailored weather criteria to meet the customer requirement in this particular region.

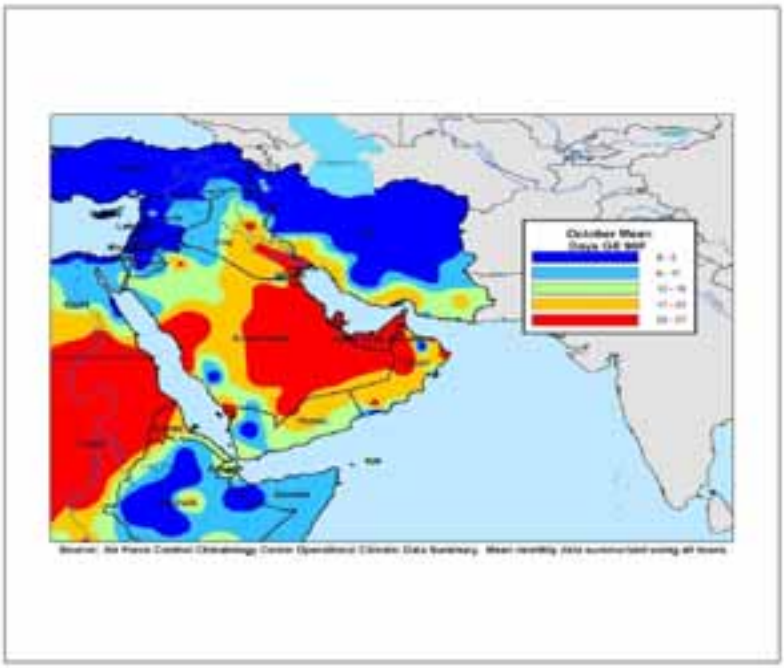

Figure 6. Analyze OCDS data for October mean days ≥ 90ºF

The above product is generated is the same method as that for Figure 7 and illustrates number of days in October where the mean temperatures are greater than or equal to 90ºF.

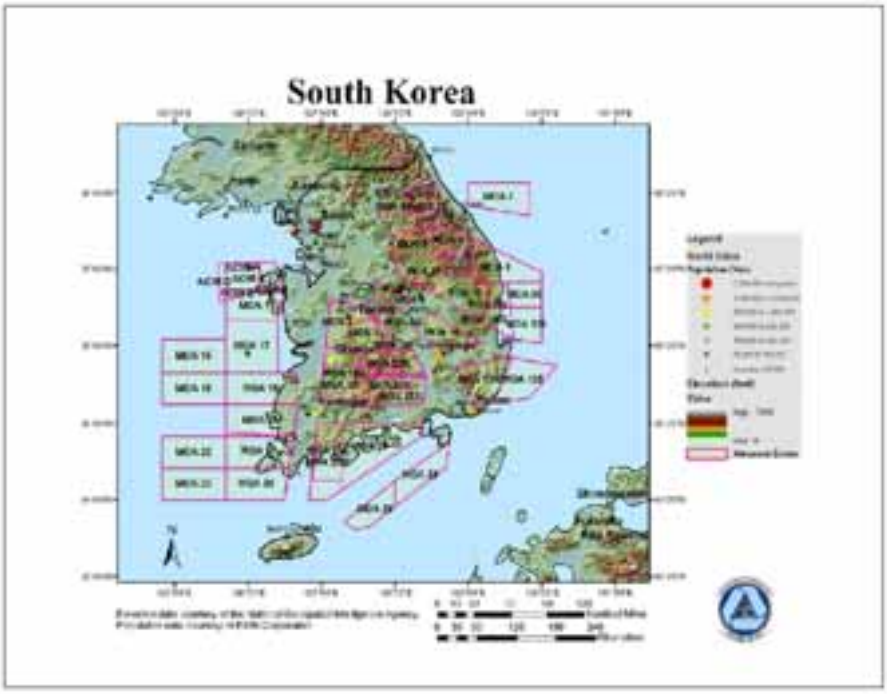

Figure 7. Elevation map with airspace overlays to develop weather prediction rules of thumb.

The above product used DTED level 1 data to enhance the topographic surface of the map. In addition to the designated flight zone overlays, the product also

included airport locations or ICAOs (International Civil Aviation Organizations) where there are weather stations. The Air Force weather forecasters utilize this type of product to predict the effects of mountainous or raised relief on approaching storm formations.

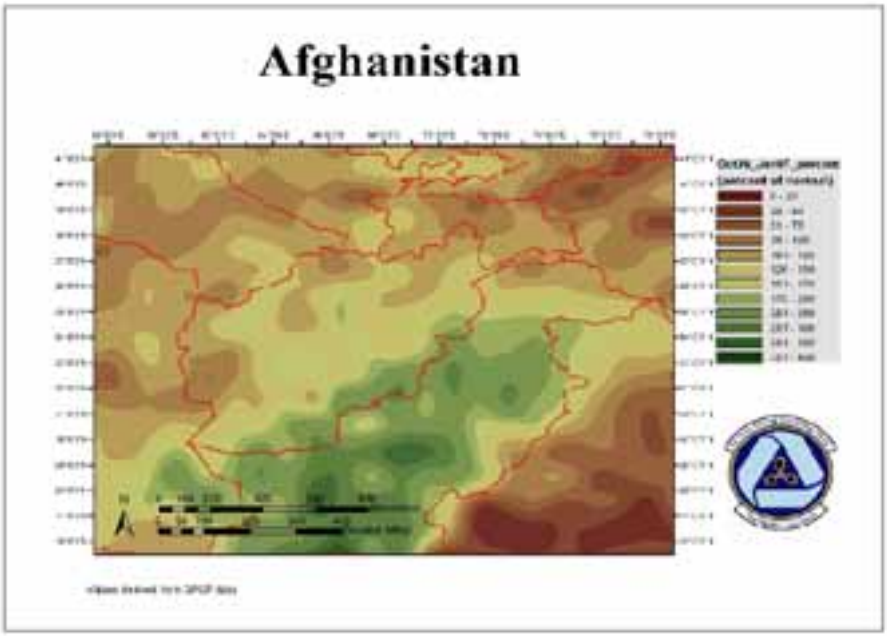

Figure 8. Spatial Analyst interpolation with Tensioned Spline

In Figure 8 above, the Spatial Analyst tool was used to interpolate between the gridded data points of the Global Precipitation Climatology Project (GPCP) data. GPCP is a global precipitation data set on a 1x1 degree grid. The percent of normal precipitation for each grid point was first calculated and then the Tensioned Spline interpolation scheme was used to generate the shapefile. The resulting data was overlayed to help determine water runoff and locate areas with flooding potential. The resultant bolstered troop safety in Afghanistan.

Land/Water Masking

Lat	Lon	Count_
-90	-180	1
-89.67	-180	1
-89.67	-128.57	1
-89.67	-77.14	1
-89.67	-25.71	1
-89.67	25.71	1
-89.67	77.14	0
-89.67	128.57	0
-89.33	-180	0
-89.33	-152.31	1
-89.33	-124.62	1
-89.33	-96.92	0
-89.33	-69.23	0
-89.33	-41.54	1
-89.33	-13.85	1

Figure 9. Masking coordinates over water within a 10km buffer around land

The project in Figure 9 was a feasibility/proof of concept for the purpose of modeling some nuclear, biological, and chemical dispersion. The goal was to create a relatively small, transportable dataset for use on a laptop computer. We used ArcInfo and Spatial Analyst to determine which of approximately 500,000 data points were over water and within a 10km buffer of land. The ultimate goal was to create a high resolution dataset and attempt to scale back the points over water where lower resolution data was adequate. In Figure 9 below, the output from ArcInfo was plotted into IDL (Interactive Data Language) for final display of the resulting points.

Figure 10. Resulting buffer file imported into IDL

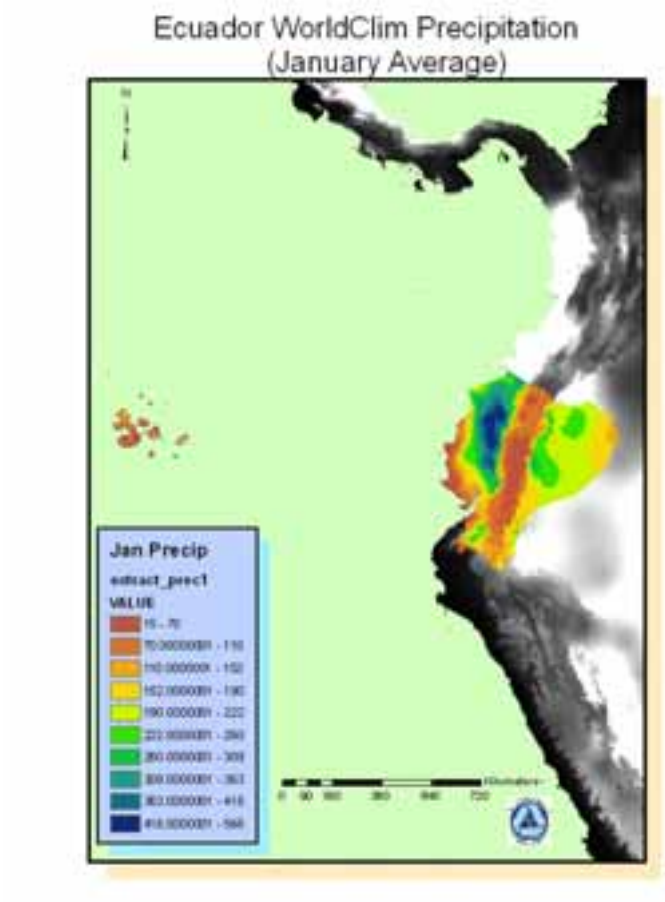

Figure 11. WorldClim precipitation data set masked for Ecuador

Station Data With ANUSPLIN Variables

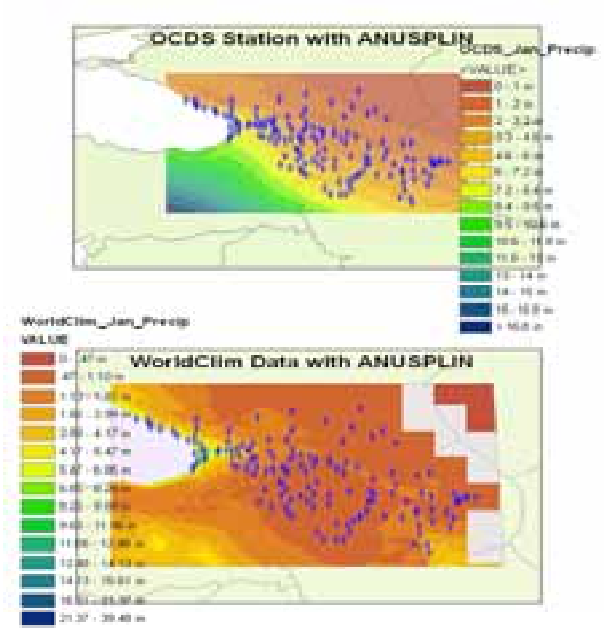

Figure 12. Comparison between OCDS data and WorldClim data over the Caucasus region using NGA and SRTM Digital Terrain Elevation Data (DTED)

According to Mike Hutchinson, the creator of the ANUSPLIN program, the aim of the ANUSPLIN package is to provide a facility for transparent analysis and interpolation of noisy multi-variate data using thin plate smoothing splines. ANUSPLIN also permits transformation of both independent and dependent variables and permits processing of data sets with missing data values. When a transformation is applied to the dependent variable, ANUSPLIN permits back-transformation of the fitted surfaces, calculates the corresponding standard errors, and corrects for the small bias that these transformations induce. This has been found to be particularly convenient when fitting surfaces to precipitation data and other data that are naturally positive or non-negative.

Regarding the WorldClim dataset, the research meteorologists Robert J. Hijmans, Susan E. Cameron, Juan L. Parra, Peter G. Jones, and Andy Jarvis in their paper entitled, "Very High Resolution Interpolated Climate surfaces for Global Land Areas," state that compared to previous global climatologies, WorldClim has the following advantages: the data are at a higher spatial resolution (400 times greater or more); more weather station records were used; improved elevation data were used; and more information about spatial patterns of uncertainty in the data is available. The complete WorldClim data is available for download at www.worldclim.org.

Tracking Analyst

AFCCC is currently experimenting with ESRI's Tracking Analyst extension to track lightning occurrences and display them in time-phased animations. Additionally, there are frequent customer requests for evidentiary climatologic data for use in forensic climatology applications. We believe that Tracking Analyst will facilitate enhanced visualization and monitoring of the historical weather events of particular interest to decision makers, Command investigations, and the military justice system.

Python Geoprocessing Scripts

- # Get cell size for raster grids if required
-
- # Get mask file for raster grids if required
-
-
- # Process csv file(s)
-
- # Read this in from the gisopts.txt file
-
-
- # Process: Make XY Event Layer
-
- # Process: Save To Layer File
-
- # Process: Set Mask if requested
-
- # Generate the IDW rasters

Figure 13. Python basic modules to automate creation of climatologic maps

AFCCC currently uses Python similar to the script modules in Figure 12 to automate map generation for climatological summary reports for various areas of customer interest. The OCDS database is used in a comma delimited format along with ArcView software to produce very high quality maps. The first part of the process is to convert the comma delimited data file into a gridded or raster dataset. This is the actual geoprocessing part of the whole process. Scripting with Python enables geoprocessing tasks to be executed outside on ArcGIS. The second and last step is to take this visualized dataset and export it to a

JPEG or TIFF. Python also enables the user to schedule the map production by executing the geoprocessing tasks at a predetermined time.

The Future

AFCCC is currently transitioning from a desktop GIS architecture to an enterprise GIS design integrated with our Oracle relational database across all three secure enclaves. We also plan to expand web services and web-based climatological data availability through upgrades in our current ArcIMS and ArcGIS Server 9.2. We are working closely with the National Climatic Data Center (NCDC) which is co-located in the same building with AFCCC and with our Headquarters, the Air Force Weather Agency at Offutt AFB, Nebraska.

The future for climatological weather data is moving towards machine-to-machine direct data access with C2 systems and greater net-centric applications. The technology and resources challenges include enormous data quality issues and maintaining consistent and reliable quality control procedures through maximum automation of these processes. Also the climatology data must be ingested in the new JMCLIM portion of the Joint METOC database. Additionally, there will be increased demand for online customer access for data sets and fewer requirements for finished products.

Acknowledgments

ESRI for various country data and supporting shapefiles
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WorldClim organization for worldwide datasets from www.worldclim.org

Appendices - None

End Notes - None

References

AFCCC 5-year GI&S Strategic Roadmap, April 2007.

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"Coelum Ad Proelium Elige"
Choose the Weather for Battle