Web-based Mobile Client and Server Grid Data Service for Accessing High Resolution Weather Information

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Abstract—The new era of forecast decision model was led by the usage of numerical weather prediction to ensure forecast accuracy. Weather information providers give accuracy, speed and appropriate information to different basic needs of the users. Unfortunately, service providers that meet those three criteria are still rare (especially in developing countries). A combination of PC-Cluster, NWP (Numerical Weather Prediction) and GDS (Grid Data Service) can be used as a low-cost solution in providing weather information which meets those three criteria. This paper presents a proof-of-concept web-based application using GrADS (Grid Analysis and Display System), GrADS Data Server, and GrADS interface to PHP. This was designed to give access to the weather online database to the server-side, which can then assist users from the mobile client in representing the weather prediction. Although the features of the resulting information service (Web Service, GDS and User defined data access) can already assist users in accessing weather information, improvements are still needed especially for delivering of high resolution weather information.

Index Terms—Grids data server, weather information, NWP, high resolution weather.

I. INTRODUCTION

W ith the increasing in the incidence of disasters caused by weather factors, there is public awareness of the need for weather information which is delivered fast, precise and accurate as absolutely indispensable. Weather information, in general and specific terms, given to certain sectors – such as agriculture and transportation – are also needed. In addition, the information provided should be easily and quickly accessible (i.e. mobile).

The accuracy of weather forecasts is strongly influenced by the spatial resolution of the information provided. So as to obtain accurate results, the forecasts should have a resolution that can describe the dynamics of the atmosphere in the region. This typically requires higher resolutions.

Nowadays, there are numerous options to obtain the weather information while mobile, either through websites or mobile weather applications which can be accessed via computers or mobile devices such as smartphones.

Although the forecast information provided needs to have good accuracy and delivered fast, the National Weather Office (NWO) is also required to provide information that can be easily understood by the general public.

In relation to the weather information, business process models used to describe weather analysis and forecasting has been evolving due to the presence of numerical weather prediction (NWP) [1]. Traditionally, weather information was read from the subjectivity of the forecaster’s analysis. Thus the accuracy of the prediction was, more or less, dependent on the skill and knowledge of each forecaster. New business processes minimize the human factor by using NWP as a weather analyst and examined the dissemination of weather information. This business process still uses forecasters to verify the NWP output and calculate the forecast uncertainty for decision-making [2].

In addition to the benefits of NWP methods, there are some variables that need to be considered, ensuring the accuracy of the weather information provided. Other methods that are used for weather predictions often have results that are less than the NWP expectations. Therefore, we need more improvements to increase the accuracy of the NWP model. Furthermore, according to Hawick [3], spatial environment datasets (especially with high resolution information) still has many challenging problems with regards to storage, access and processing.

NWP is used to get high resolution weather forecast. NWP is described as a collection of computer programming languages which is a numerical representation of the physical
and dynamic equations that occur in the atmosphere (represented in the spatial grids). Therefore, the calculation of physical and dynamic equations is complex and the number of spatial grids is huge. It can only be done with High Performance Computing (HPC).

This paper studies the management of high-resolution weather data to improve the dissemination of information through the development of a NWP web-based data inquiry. It also looks at obtaining high-resolution weather predictions using the NWP model and the configuration of hardware and software (Open Source), including access to the NWP output data with features for users who have differing weather information needs.

The remainder of this paper is organized as follows: Section 2 discusses some related works on weather data service. Section 3 discusses an overview of grid computing for weather information. Section 4 briefly presents the server side of web-based grid data service and the mobile client is discussed in Section 5. Section 6 presents the result and discusses the weather information service. Section 7 concludes the paper and outlines areas for future work.

II. RELATED WORK

Management of huge distributed and shared data resources efficiently within wide area networks has been a topic for both scientific research and commercial application for some time now [4]. The National Weather Services (NWS) in developing countries – which usually has poor Internet bandwidth, limited infrastructure and lack of human resources – faces a more significant problem. Hence, any proposed solution to solve the problem of the dissemination of weather information in developing countries should be low cost, adaptable and applicable.

Over the years scientists have developed many proposals to eliminate the gap for distributing the weather information (please refer to Table 1). One of the most referenced systems is NOMADS (NOAA Operational Model Archive and Distribution System). It aims to build a public data center that can serve environmental datasets from NOAA and other organizations [5]. There are also plug-and-play applications such as DAPPER [6], THREDDS [7], and ERDDAP [8] that basically use OPeNDAP [9] as a protocol for delivering the huge amounts of data. For specific NWS purposes there are the KNMI (Koninklijk Nederlands Meteorologisch Instituut) Climate Explorer [10] and the ECMWF (European Centre for Medium-Range Weather Forecasts) MARS [11], while GrADS DODS [12] are the simplest applications that deliver GrADS readable format online access.

In general there are three types of data access services on NOMADS server:

- Direct Client Access
- Live Access Server
- Data Portals

Due to its convenience level, NOMADS has become one of the more frequently accessed servers. Nevertheless the application of that system for most countries (especially developing countries) is hard to implement. We believe the simplest way is to adopt some of these systems and apply them as needed to the specific situation.

![Fig. 1. The NOMADS Philosophy (redrawn and simplified from [13])](image)

Table 1: Research on Weather Information Systems Database

<table>
<thead>
<tr>
<th>Research Paper</th>
<th>Tools</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Real NOMADS Project: Access to Operational Model</td>
<td>OPeNDAP, CGI</td>
<td>GDS Server, pdisp and ftp2u application</td>
</tr>
<tr>
<td>Data and Value Added Products</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thematic Real-Time Environmental Distributed Data Services (THREDDS)</td>
<td>OPeNDAP, OGC Web Coverage Service, NetCDF subset, HTTP file transfer services and XML</td>
<td>Web based server, Live Access server, INGRID and GDS</td>
</tr>
<tr>
<td>DAPPER: An OpenDAP Server for In-Situ Data</td>
<td>OPeNDAP, NetCDF, Java NetCDF Library, WPS, SOS, OBIS</td>
<td>Web based application handling many output format</td>
</tr>
<tr>
<td>ERDDAP-The Environmental Research Division’s Data Access Program</td>
<td>OPeNDAP, WPS, SOS, OBIS</td>
<td>Web based server, Live Access server, INGRID and GDS</td>
</tr>
<tr>
<td>KNMI Climate Explorer: A Web-based Research Tool for High-Resolution Paleoclimatology</td>
<td>FORTRAN, CGI, GrADS, CDO, NCO, netCDF, Lapack dan Blas</td>
<td>Web based server including statistical analysis</td>
</tr>
<tr>
<td>MARS, ECMWF’s Meteorological Archive: Experience in Managing a Large Archive</td>
<td>FORTRAN dan C, Java</td>
<td>MARS language and web based application</td>
</tr>
<tr>
<td>The GrADS-DODS Server: An Open-Source Tool for Distributed Data Access and Analysis</td>
<td>OPeNDAP, XML, Java</td>
<td>Online database server</td>
</tr>
</tbody>
</table>

OPeNDAP provides the most flexibility for the user to access and compute grid data compared to other services. GDS provides sample access for clients to be able to analyze the use of the OPeNDAP protocol. GDS can serve a variety of data that is recognized by the GrADS, like the formats
netCDF, HDF, GRIB WMO and BUFR WMO. Analysis tools that have been able to use OPENDAP data are: GrADS, Ferret, Matlab, IDL [14].

III. SYSTEM OVERVIEW

In grid computation, which needs intensive computation power such as in NWP, the resource required is dependent on the amount of computation to be performed. Weather predictions on a large area such as Indonesia, obviously needs a heavy duty computing machinery to deliver daily weather predictions on time as a part of the system decision support. Several projects related to the usage of PC Clusters have been established in many disciplines [15]. To get excellent output, cluster computing is used especially in monitoring its operations, in debugging, in failure detection and for performance optimizations [16]. One example is the use of parallel computing technology embedded in a distributed system, providing an ideal and practical solution for multi-site organizations and especially for government agencies who need to extract the best value from bulk geographic data in GIS systems [3].

System requirements needed to run the NWP is dependent on the amount of computation to be performed. As the number of grid points that are calculated increases, the workload of the computers will also increase. According to [17], the minimum computer equipment needed to run one of the NWP models WRFEMS (Weather Research and Forecasting Environmental Modeling System) is a premium-class computer with at least 4GB of physical memory. However, in actuality this depends on the amount of computation to be performed.

A. NWP Computation Model

The main problem encountered in running the NWP is the needs of computing processing. The use of PC-Clustering (a collection of several PCs connected through a network [1]) is one solution to obtain large computational grid data at low cost [19-20].

HPC architectures (such as multi-core, multi-processor HPC platforms with access to fast networks) have an influence on the overall performance of an application [21].

A network consisting of one cluster master node and the 4 client nodes are used to perform computations. The server has an Intel specification (R) Xeon (R) E5640 2.66GHz 24 processor and 16GB of memory use for each server. The network is connected with Fast-Gigabit Ethernet switches for data traffic to cope with rapid and large data access.

To apply a cluster system to this problem area, we also require software that can integrate the entire computing systems in the cluster to serve a job. One such software is MPI (Message Passing Interface), which is a platform in a distributed-memory parallel super computer, where a process can be run separately in a communication node and use the High-Performance Switch [22].

This system uses MPICH (Message Passing Interface Chameleon) for the optimization of the cluster without disturbing any other processes running on the same system [22]. In other words, the process can be done multiple ways and aimed only at specific nodes. However, for reasons of computational requirements, all nodes (including the master node) are used to process data.

B. Weather Data Acquisition

The environmental data, such as atmospheric variable, is highly dynamic. As such the data input needed to predict the weather should be recent information in order to maintain the rapid changes in any parameter predicted [23]. Brusch [24] used the latest environmental information that uses radar and satellite data to provide storm prediction information. Kang also achieved this using AWS data to gain daily weather information to predict plant diseases [25]. Despite this, the basic understanding of the NWP and the weather is still required [26].

C. Grid Analysis and Display System (GrADS) Data Server

The main reason for using this application is that GrADS was commonly used by forecasters worldwide and is able to read 5 dimensions of data; 4 of which are commonly used in regular dimensional weather data (latitude, longitude, altitude and time level) and one other dimension that is used for the ensemble [27].

GDS allows users to access, to manipulate and to display data in a GrADS format via the GDS (online data server). GDS uses a combination of GDS and OPENDAP (the Open source Project for a Network Data Access Protocol) software, formerly known as DODS (Distributed Oceanographic Data System), to produce open-source solutions of weather information data services [28].

To serve the needs of GDS access, a server with the same
PC-Cluster specifications was set-up, with two 8 TB Network Attached Storage (NAS) for data storage.

Figure 3 shows a flow diagram of a GDS, which requires implementation of Java servlet on the server side. The Jakarta Project’s Tomcat package serves as a servlet execution environment so that the data is accessible via the internet.

![GDS Work Flow Diagram](image)

**Fig. 3. GDS work flow [12]**

All configurations are handled by a server configuration file in XML format which also defines the data that we want to display. The configuration file also gives control over resource usage of the GDS server. An administrator can restrict the use of CPU and memory to a request for access by restricting the number of users and the maximum size of a subset of the data cache [30].

GDS provides a server that can manage and serve the weather data. The server can easily be used to share data with others and can be used internally to reduce the load on the network access [30].

### IV. WEB-BASED SERVER

Although GDS has been able to deliver NWP data as an online-ready access product, typically not every user or forecaster has the ability to use it with certain applications, such as GrADS or MATLAB. It is also more time consuming to display any images or data extraction using that application with several codes needed, rather than accessing it under web-based service (user friendly application).

Improvements have been made to bypass the difficulties using GDS under a third party application, by using a PHP interface for GrADS. The PHP interface for GrADS is an alternative method of scripting GrADS that can take advantage of the unique capabilities of PHP [31].

#### A. Basic Features

This application simply delivers all of GrADS basic features into a web application. Users freely choose any settings to display value or images on certain locations or area by changing input values on the left side panel to display on the right side panel (saving images by using right click). Previously users needed to type a few lines of code to get the same output using a third party application. This application is also able to handle animated images by choosing a certain option provided. By choosing the latitude and longitude, users can easily pan their domain interest across Indonesia region.

![NWP Database Inquiry](image)

**Fig. 4. Web-based Database Service Layout**

The forecast information provided by the server is made available up to three days, within hourly time resolution with initial condition provided three days backwards. However, only basic weather parameters, such as precipitation, temperature and humidity at any certain pressure level are provided. To access more parameters, users can use the features of GDS.

Display features are divided into four groups based on how many varying dimensions are inserted. If there are no varying dimensions, the output panel will display the value of the parameter in a certain location, but if there is at least one varying dimension the output will be a graphic image (Figure 5). This web-based application is also capable of providing display output if there are four varying dimensions inserted that typical third applications, such as grads, are not capable of doing.

GDS link was provided to check the availability of the data. The full list of metadata should be checked using this link. It is very useful to browse the data, especially for new users. It also has direct access to data location that can be accessed using third party applications.

#### B. Raw NetCDF Data Access

Sometimes users need more than images to analyze the atmosphere condition, therefore they need the raw data to
identify atmosphere phenomena or verify the model output with some observation data. Hence, we provide an access button to download the data (in the NetCDF format) that is easily modified by users using the menu panel. The full feature of this application is provided in Figure 4.

To decrease the size of the downloaded file the NetCDF file is compressed into a zip file, reducing the time required for the download.

V. MOBILE GRID DATA

To obtain the data grid, we used the Weather Research and Forecasting Environmental Modeling System (WRF EMS) software, which is one of the NWP models. According to Rozumalski [4], the WRF EMS is a complete NWP model and is simple to use with a basic knowledge of NWP and the weather data. Compare with other NWP models the WRF EMS is more intended for operational use of weather forecasts than a model intended for research purposes.

There are several steps to obtain estimates of the output data grid in the WRF EMS model. The details are presented in Figure 5.

![WRF EMS flow diagram](image)

**Fig. 5.** WRF EMS flow diagram [4]

The first step is setting up a domain or local area that we want to predict. In this case, the predictions were made for a resolution of 27 km area in Indonesia with the following specifications:
- Latitude: 19.47° to 27.71°
- Longitude: 79.97° to 169.74°
- Altitude (pressure level): 1013mb to 10mb
- Time steps: 1 – 73 hours

These specifications are required by the NWP models to prepare the data information such as the study area, topographic data, the soil type and land use.

NWP Data input is obtained from GFS (Global Forecast System) NOAA which has a spatial resolution of 0.5 °. The data is downloaded each time a model needs to output a prediction. The results of processing these data will be data grid to be used as a source of weather information.

The total time needed from the HPC initial data preparation to obtain the output of the data grid is approximately 3 hours, using the HPC 5 nodes and a large output file about 2GB.

VI. RESULTS AND DISCUSSION

NWO, as a weather service provider, is usually thought to display information that is easily understood by users. Therefore, the information displayed is usually very diverse depending on the needs and knowledge of the users.

By using a combination of GDS, GrADS and GrADStoPHP software, we have built a web application that bridges the information needs of users with different requirements. The application of weather information is running in real-time online; as such it can be easily accessible. Moreover, simple computations of these data with the help of GDS can also be done.

To provide output data that is informative, we developed three (3) types of services that can provide information services to users who have different interests.

A. Web Service

This Web service is one of the most common types of service provided by any provider in the weather information. Data produced by NWP models will then be converted into the form of images/pictures and then uploaded into the website (Figure 6).

Predictions of some basic parameters such as rainfall,
temperature and humidity with different levels of user-accessible heights up to three days ahead with a range of hourly predictions.

A limitation of this type of service is that users can only view the parameters provided by the service providers, without the ability to modify the raw data.

B. GDS Access

To be able to modify the output data (e.g. display the parameters that are not displayed on the web service, perform data processing, displaying a particular domain, converting the data into another format, etc.) provided by a GDS, the information obtained is in a lot (62 parameters with different levels of altitude) because direct access to the raw data output of NWP models are possible.

Data access can be done using one of the data processing software using GrADS through port 8080. Therefore, users are required to use the data processing software, which can become obstacles for some users. Wide bandwidth is also required to access the large data.

GrADS Data Server - top level - wrf - 27km

GrADS Data Server - directory for /wrf/27km : 8 entries

1: 201205081200_inde: 201205081200_auw_wrfout_d01.grb info del das
2: 201205161200_inde: 201205161200_auw_wrfout_d01.grb info del das
3: 201205171200_inde: 201205171200_auw_wrfout_d01.grb info del das
4: 201205181200_inde: 201205181200_auw_wrfout_d01.grb info del das
5: 201205191200_inde: 201205191200_auw_wrfout_d01.grb info del das
6: 201205201200_inde: 201205201200_auw_wrfout_d01.grb info del das
7: 201205211200_inde: 201205211200_auw_wrfout_d01.grb info del das
8: 201205221200_inde: 201205221200_auw_wrfout_d01.grb info del das
back to parent directory

GrADS Data Server 2.6 (help using this server) - This page last updated 09/23 May 2012.

Fig. 7. GrADS data server screenshots

C. User Defined Data Access

User Defined Data Access is a web service that is used to overcome the obstacles encountered when accessing the web service and the GDS. In this feature, the user can freely choose the parameters they want to display without having to think about how to run weather data processing software.

An interactive web interface is used to allow users to select the desired parameters (example: Initial condition, latitude, longitude, time interval, the level of altitude and weather parameters). The resulting output can be either images or moving images such as those obtained at the web service access. All computation is done by the computer server so that the large bandwidth requirement to access the GDS can be overcome (e.g. when a lot of users are accessing simultaneously, and large transfer of data is required).

Accessing data using the User Defined Data Access is not as pleasant as using the GDS. But when compared with using a web service, data access using the User Defined Data Access is much better as the user does not have to think about how to deploy the weather data processing software (using the GDS). Therefore the User Defined Data Access can fill a needs-gap between a web service and the GDS.

Even with the advantages offered by each of these features, refinement and dissemination of the data is still required in order to provide appropriate information to the users.

D. GDS and User Defined Data Access Speed Comparison

WRF EMS data access speed in GDS server is analyzed by comparing data access using GDS (in this case client GrADS was used) and user defined data. The data access speed is calculated based on how fast data from GDS can be accessed using both techniques. Various air temperature data dimensions, i.e. time, latitude, longitude, and level, was used in analyzing the speed of these two techniques in accessing the data (see Table II).

Data access speed on user defined data is calculated based on the accumulation of the time required to process the data in the server and the time required by the client to download the data. Data access on GDS ignores the load burden caused by the high number of accesses by other users, and it was done not during the peak access time (done at night time).

Table 2: Air Temperature Data Dimensions

<table>
<thead>
<tr>
<th>Datasets</th>
<th>Time</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Height Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data 1</td>
<td>Vary (1-25 hours)</td>
<td>Fix</td>
<td>Fix</td>
<td>Fix</td>
</tr>
<tr>
<td>Data 2</td>
<td>Vary (1-25 hours)</td>
<td>Vary (9°S to 5°S)</td>
<td>Fix</td>
<td>Fix</td>
</tr>
<tr>
<td>Data 3</td>
<td>Vary (1-25 hours)</td>
<td>Vary (9°S to 5°S)</td>
<td>Vary (105°E to 115°E)</td>
<td>Fix</td>
</tr>
<tr>
<td>Data 4</td>
<td>Vary (1-25 hours)</td>
<td>Vary (9°S to 5°S)</td>
<td>Vary (105°E to 115°E)</td>
<td>Vary (1013 to 800 mb)</td>
</tr>
</tbody>
</table>

VII. CONCLUSION

This paper presents a weather information provider which provides accuracy, speed and appropriate information to different basic needs of the users. We propose the combination of PC-Clusters, NWP and GDS that can be used as a low-cost solution in providing weather information which meets those three criteria.

This paper also presents a solution for the server side to manage large weather information datasets using web-based application. By using GrADS, GDS, and GrADS interface to the PHP application, information was delivered for the users at a low-cost solution.

This approach was intended for internal users (forecasters) who know about the model output characteristic and
information. It also provides an improvement in the form of a statistics feature that can download raw data in text format, and compile some data input from other NWP models.

As a case study, the prediction of weather information for a resolution of 27 km area in Indonesia was discussed.

With the increasing number of smartphone users, an client-side application on smartphone devices (e.g. Android, iOS, Symbian, etc.) that can access the User Defined Data Access would be needed. This could be a promising direction for further development for mobile users who need to query specific weather information.

REFERENCES


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