

# WEATHER MONITORING MODEL BASED ON SATELLITE DATA

(*Model Pemantauan Cuaca Berdasar pada Data Satelit*)

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*Weather monitoring model is closely related to the problem of objective analysis of the field of meteorology. The amount of meteorological data is quite substantial and hence the processing of these data is one of primary problems is dynamic meteorology. Therefore, a weather system model must consider atmospheric process, which can be built by mechanistic model rather than statistical approach. Integration of numerical model and spatial model will produce spatial weather information. It should be managed in one computerized system called as an information system for weather monitoring. The approach of the research was divided into five tasks. First task was satellite data capturing and extracting, second was development of numerical modeling based on dynamic and thermodynamic of atmospheric process, third was integration of numerical modeling and geographic information system in the spatial model, fourth was to develop graphical user interface and the fifth task was application of system in the real-world. Temporal resolution of this model is one day, however, in reality weather is temporal state of atmosphere condition that change any time. Moreover, this model only describes weather condition when data satellite on the day could be captured. Therefore, to increase the temporal resolution of this model, the input data could be added or integrated with other satellite data such as GMS satellite that has one-hour temporal resolution. Spatial resolution in this model is 50x50 kilometers square for global and 8x8 kilometers for regional area. Actually, for the spatial resolution, this model has been prepared as NOAA's spatial resolution. This model cannot simulate vertical distribution of atmosphere, so, it does not give information about relative humidity and precipitation. If air movement in vertical area could be simulated, the dew point temperature and lighting condensation level would be known therefore the relative humidity and precipitation could be predicted.*

**Keywords :** *atmosphere , information system, resolution, satellite data, spatial model,*

## INTRODUCTION

Weather is a temporal state of surface atmosphere and is one of natural phenomena that influences human activity and environmental conditions. Therefore, we could consider weather as a natural system with elements or factors that represent weather condition. If we called weather as a system, we could build a model as simplification of the weather system. A model of weather system may be used for understanding weather phenomena, monitoring and predicting the weather condition.

The progress of computer and geographical information technologies has supported the development weather prediction model. Weather system considers temporal and spatial dimension. There is which lead to representation of four dimensions. They comprise three spatial dimensions and one temporal dimension. Weather system model can be developed by integrating numerical model and geographic information system that can be used for weather monitoring or prediction.

Weather monitoring model is closely related to the problem of objective analysis of the field of meteorology. The amount of meteorological data is quite substantial and hence the processing of these data is one of primary problems is dynamic meteorology. Therefore, a weather system model must consider atmospheric process, which can be built by mechanistic model rather than statistical approach. This model will be an integration of spatial model to find information based on location and time of weather condition. In this research, model of weather system will be constructed to monitor a daily weather conditions. Integration of numerical model (as mechanistic model) and spatial model will produce spatial weather information. It should be managed in one computerized system called as an information system for weather monitoring.

## **OBJECTIVES**

The main objective of the study was to develop an information system for weather monitoring based on numerical model and geography information system. In addition, this objective could be described as specific objectives as follows:

- To develop model design for simulating weather condition based on surface temperature data that was extracted from NOAA AVHRR Local Area Coverage satellite and digital elevation data (DEM)
- To create algorithm and script of program for extracting NOAA AVHRR Local Area Coverage satellite data.
- To translate model design of weather monitoring system into computer algorithm
- To build a package of application software for implementing model design for monitoring daily weather variables.

## MATERIAL AND METHODS

### Location and Duration

The research was conducted at Laboratory of Master of Science in Information Technology for Natural Resources Management (MIT) and Agrisoft Laboratory at SEAMEO-BIOTROP Bogor. The study area is 60°N-60°S latitude / 0°E-270°E longitude and 23.5°N-23.5°S latitude / 82°E-164°E longitude.

### Research Area

The research area cover the development of weather monitoring model using integration of three different approach, namely numerical modeling of weather variables, spatial modeling for weather mapping and the development of graphical user interface that integrates numerical and spatial models.

### Required Tools

In this research, we use some supporting tools of software and hardware.

Software	Utilities
MS Visual Basic 6.0	Developed numerical and spatial modeling, spatial database
ESRI MapObjects LT	Developed spatial modeling
MS C++	Develop numerical and spatial modeling and satellite data processing
MS Acces 2000	Database building
PC Arc/Info 3.51	Spatial data collecting, capturing and processing
ArcView 3.1	Spatial data collecting, capturing and processing
ER Mapper 5.5	Image data collecting, capturing and processing
MovingMap ActiveX	Displayed result of model
Hardware	
PC Pentium III 730 (over clock) MHz 128 MB RAM	
Computer Server Pentium III 450 MHz 64 MB RAM	
Printer Color	

### Data Sources

The research employed three main source of data, namely :

- NOAA satellite raw data ( Local Area Coverage -LAC)
- Digital elevation model (DEM) data (scale: 1:1000000)
- Vector map of global and regional area.

## **Methodology**

The approach of the research was divided into five tasks. First task was satellite data capturing and extracting, second task was development of numerical modeling based on dynamic and thermodynamic of atmospheric process, third task was integration of numerical modeling and geographic information system in the spatial model, fourth task was to develop graphical user interface and the fifth task was application of system in the real-world. The method is presented in Figure 1. This research did not conduct model validation, due to limitation of measured data such as those were by radio-sonde and time constraint.

### ***Satellite data capturing and extracting***

Satellite data in this research were derived from NOAA-14 satellite. Those data were obtained from Internet in the form raw data which specific format data. Specific format data refers to satellite data that were derived by different machine language in one metadata. NOAA satellite data has three main formats; signed integer, unsigned integer and ASCII format. To extract information from satellite, we build a model for direct accessing using computer program. The program will translate information of raw data to numerical information in text format by which the data can be read by the numerical model.

### ***Numerical model for atmospheric process***

The numerical model for atmospheric process consider thermodynamic and dynamic of atmospheric processes. The basic task of this modeling is to formulate theoretical model of the dynamic and thermodynamic of atmospheric process for the purpose of creating justifiable weather system. This research attempts to formulate a theoretical model of weather system on the basis of hydrodynamic equation in a way, which leads to the simultaneous fulfillment of the conservation laws of the total momentum, the mass, and the total energy of a system.

### ***Integration numerical modeling and geographic information system***

Integration of numerical model and geographic information system is to produce spatial information. Spatial information describe data of the local climate conditions of averages of temperature based on altitude, normal conditions for energy balance based on latitude and longitude of locations. These data will be integrated with the data that provide by the numerical model. The integration of both data was handled by using MS Visual Basic computer program. The result of the integration is weather monitoring consisting attribute of weather element which has a certain spatial and temporal resolution decided.

### Graphical user interface

In this research, the user interfaces was build with emphasis on the graphical user interfaces and standard windowing environment to enable the users and operators access or use the system easier. In this case, the user interface customizing by MS Visual Basic Program.

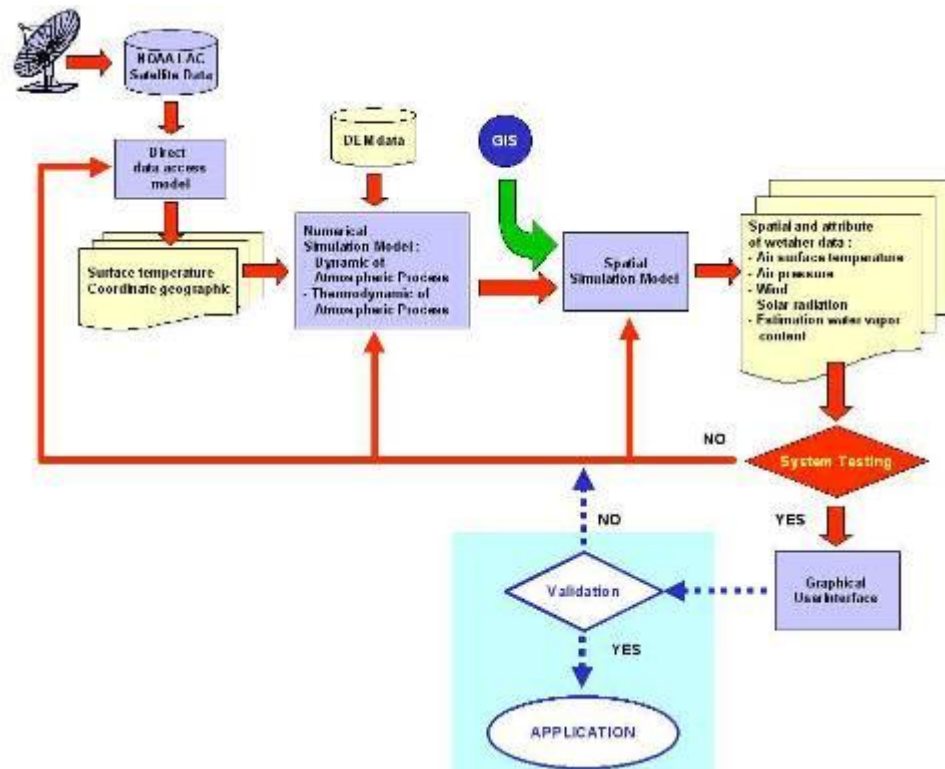


Figure 1. Block diagram of research methodology

## RESULT AND DISCUSSION

This model was designed to simulate five weather elements. There are air surface temperature, air pressure, wind, solar radiations and estimation of water vapor content. Each weather element is simulated in separate module of the entire computer program.

### Air Surface Temperature

The weather numerical model in this research used temperature data as the main input for simulating other weather element data. Source of temperature data provide two types of raw data. Those are NOAA satellite data and digital elevation model (DEM) data. NOAA satellite data provide surface temperature by converting raw NOAA data into ASCII data with XYZ

format. The surface temperature from NOAA data and DEM data was interpolated. The interpolation method is a kriging to estimation the temperature data for each parcel. The interpolation method is a kriging, a geostatistical gridding method that has been proven useful and popular in many fields.

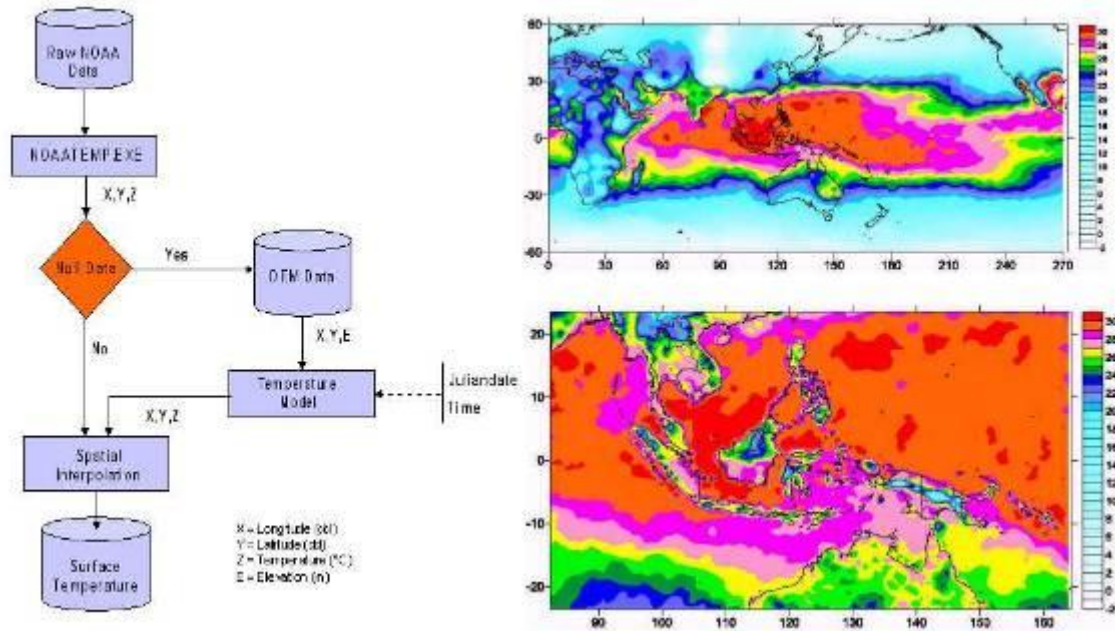


Figure 2. Logical flow to produce surface temperature data and Map of global surface temperature 02 June 2001 at global and regional area

This module produces two surface temperature data for each day. They are global and regional air surface temperature. The global surface temperature data has 50 x 50 kilometers square resolution while regional surface temperature has 8 x 8 kilometers square resolutions. Global surface temperature provides distribution of surface temperature value in tropical area.

### Atmospheric Pressure

The input data of the air pressure module are geographical coordinate and surface temperature of air parcel. The assumptions in this model are :

- acceleration of gravity ( $g_0$ ) :  $9.80665 \text{ ms}^{-2}$
- air parcel condition is hydrostatic equilibrium
- Initialization of air pressure ( $P_0$ ) : 1013.25 mbar
- Atmosphere height is less than 11 km which has the certain lapse rate and the value of  $\gamma = 6.5 \text{ K.km}^{-1}$

## Vertical distribution of atmosphere pressure

Vertical distributions of atmosphere module predict the distance of a certain pressure height from sea surface. Based on the above assumptions, module output is a geopotential height that could be achieved by each a pressure layers in the atmosphere. In this module the atmosphere divided into 9 layers of pressure. There are 900 mb, 850 mb, 800 mb, 750 mb, 700 mb, 650 mb, 600 mb, 550 mb and 500 mb. The module to calculate geopotential height is derived from Poisson's equation shown in Eq. 1.

The map of geopotential height with vector that represents direction of air movement is shown in Figure 3. Air moves from cold region into warm region. Cold air region is shown by less geopotential height while warm air region is represented by higher geopotential height. As a result, air mass from North and South sub tropical will move into tropical region (Figure 3). The velocity of air movement depends on distance between isolines of geopotential height called as horizontal gradient of geopotential height. The air movement velocity will increases with less distance between of the isolines. The velocity and direction of air movement is explained in different section 4.3.

$$\begin{aligned}
 p &= p_0 \left( 1 - \frac{\gamma z}{T_0} \right)^{\frac{g}{\gamma R}} \\
 \frac{T}{T_0} &= \left( \frac{p}{p_0} \right)^{\gamma R/g} \\
 \ln \frac{T}{T_0} &= \frac{\gamma R}{g} \ln \left( \frac{p}{p_0} \right) \\
 \ln(T_0 - \gamma z) - \ln T_0 &= \frac{\gamma R}{g} (\ln p - \ln p_0) \\
 (T_0 - \gamma z) &= \text{Exp} \left( \frac{\gamma R}{g} (\ln p - \ln p_0) + \ln T_0 \right) \\
 z &= \left( \frac{T_0 - \text{Exp} \left( \frac{\gamma R}{g} (\ln p - \ln p_0) + \ln T_0 \right)}{\gamma} \right) \text{meter}
 \end{aligned} \tag{1}$$

$p$  : certain atmosphere height (mbar)  
 $T_0$  : surface temperature  
 $g$  : gravity ( $\text{ms}^{-2}$ )  
 $\gamma$  : lapse rate ( $\text{Km}^{-1}$ )

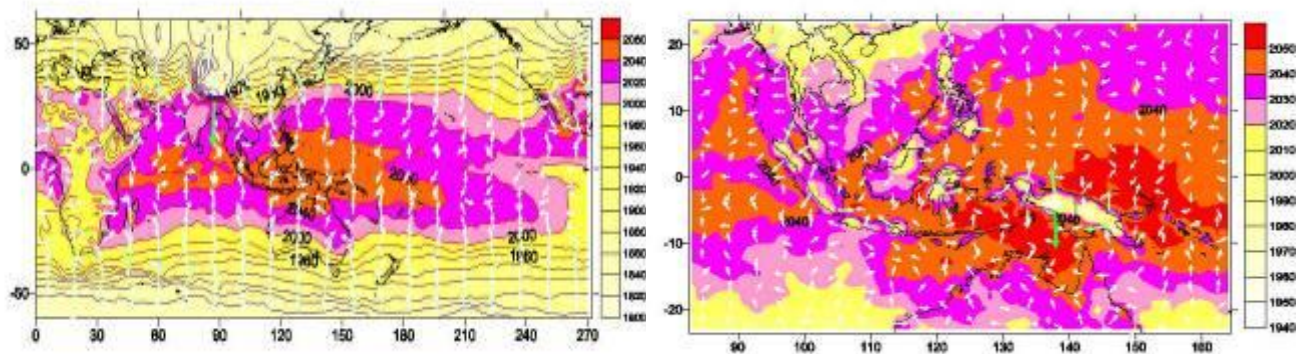


Figure 3. Variations of geopotential height (m) and estimation air movement

### Horizontal distribution of atmosphere pressure

In this model, horizontal distribution or variations of atmosphere pressure are defined as differences pressure value between air parcels on the constant height from sea surface level. The warm air has higher elevation than cold air. The high air column presents convergent area with upward air movement, whereas low air column presents divergent area with downward air movement. This model describes the direction of pressure gradient force at the horizontal plate. The pressure value is calculated using an equation that is derived from Poisson's equation then simulated using array of pressure until constant height to be achieved. The result of this module is pressure value at constant height ( $z$ ) for each air parcel. Commonly, the discussion of meteorology infrequently uses this method to presents distribution of pressure. However, this model is not supported by observation data on the surface. Therefore in this research we used it.

The output of model (isobar chart) is the air pressure pattern on a constant height chart (for example if height = 3 km). Whether this type of chart is not common in meteorology, but it is frequently used when we have to measure the actual air pressure value at many station by using radio sonde. Figure 4a presents an isobar chart on a constant height level (3000 meter) of Indonesia's Islands and it's surrounding on December 02, 2000. The graph of the output model presents that not all region which near  $0^\circ$  latitude has lower pressure then higher latitude (see Figure 4b). It is a selected data from  $105^\circ\text{E}$  to  $120^\circ\text{E}$  longitude. If we compare with the map data (Figure 4a) we will see that the land surface near  $0^\circ$  latitude is higher probability than sea surface to have a high pressure.



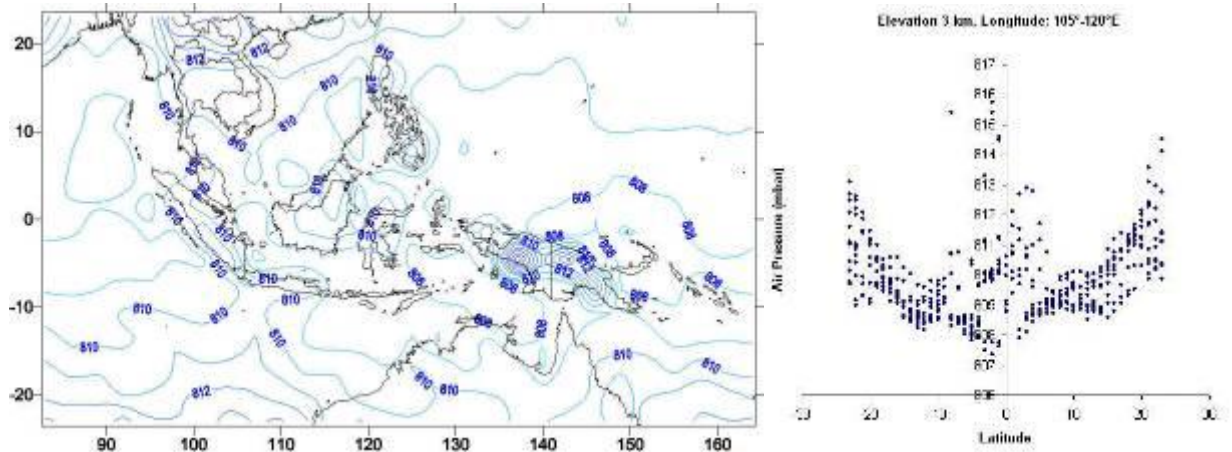


Figure 4. (a) Isobar (mb) chart ( $Z = 3000$  m) on 2 December 2000 and (b) Variation of air pressure value at  $Z = 3000$  m

### Wind

In the module of wind, direction and magnitude of wind are important variables. Both variables are generated from source data such as surface temperature, isobar chart (in XYZ and grid data format) and isoline of geopotential chart (in XYZ and grid data format). The module simulated three types of wind; geostrophic wind, gradient flow and thermal wind, where for each type of wind has the relation with the other types such as given by Figure 5.

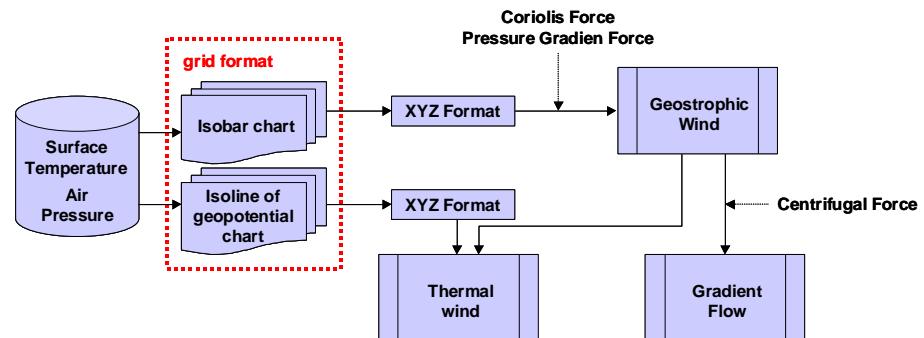


Figure 5. Logical flow of wind module

All input data of wind model is independent data. It means, each of data depend on the air parcel and does not has relation with other parcels, except, if those was interpolated. Therefore, before calculated the direction and magnitude of wind, the model need a grid relations to explain spatial and numerical derivative. When a numerical derivative is required, a central difference formula is used in the grid computations process and uses "compass-based" grid notation to indicate the neighboring grid nodes as presented in Figure 6. Using this grid notation, we can derive the difference equation approximations for the necessary derivatives at location  $Z$  as follows:

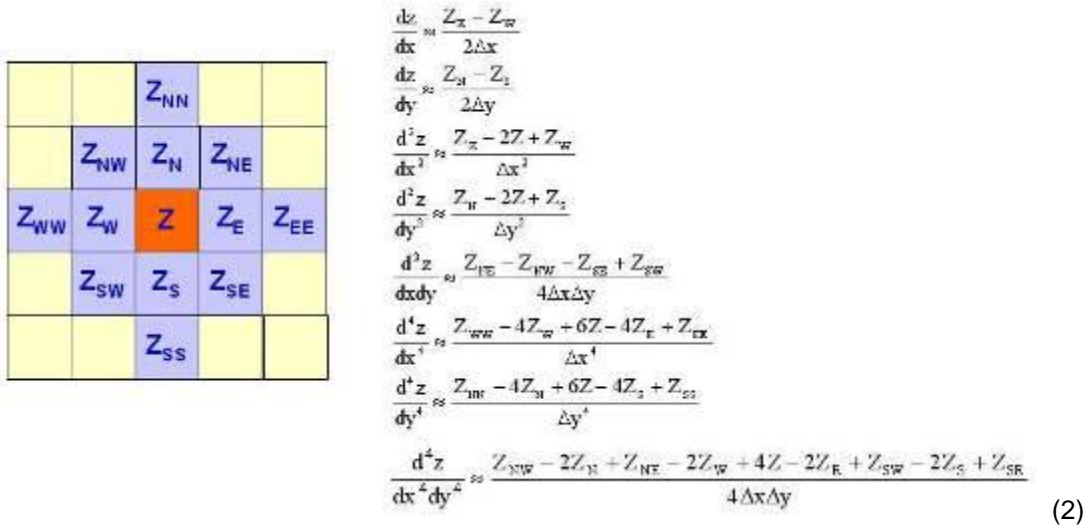


Figure 6. Illustration of grid compass-base

### Geostrophic Wind

Based on balancing of pressure gradient force and Coriolis force, the magnitude of geostrophic wind could be simulated with isobar chart as data input (in XYZ format data).

Magnitude of geostrophic wind is simulated using follows equations (derived from Eq. 2):

$$V_g = \frac{1}{2\rho\Omega \sin \phi} \left( \frac{p_{NW} - 2p_N + p_{NE} - 2p_W + 4p - 2p_E + p_{SW} - 2p_S + p_{SE}}{4\Delta x \Delta y} \right) \tag{3}$$

- $V_g$  : Magnitude of geostrophic wind ( $\text{ms}^{-1}$ )
- $\rho$  : Air mass specific was calculated using the empirics equation as a function that provide by temperature and pressure at certain level ( $\text{kg m}^{-3}$ )
- $\Omega$  : Rotation rate of the earth ( $7.29 \times 10^{-5} \text{ s}^{-1}$ )
- $\phi$  : Latitude position of the grid

Simulation of geostrophic wind is applied in global study area only. As we known that geostrophic wind has value more than zero if the latitude more than zero, otherwise it has significant value in middle and high latitude area and its value limit to zero in low latitude area. Figure 7 in below give an example of result simulation of geostrophic wind velocity on June 02, 2001.

From Figure 8, almost area has velocity are less than  $50 \text{ ms}^{-1}$ , especially in low latitudes. Otherwise, in middle and high latitude, the geostrophic wind velocity increase more than  $500 \text{ ms}^{-1}$  and it's developed a form such as curve. This curve is a flow around high pressure or low-pressure center. In this research could not identification that geostrophic flow around high or low pressure, so that, could not determine cyclone or anticyclone area and direction of geostrophic wind. But, based on theory can known that geostrophic wind direction is parallel isobar line.

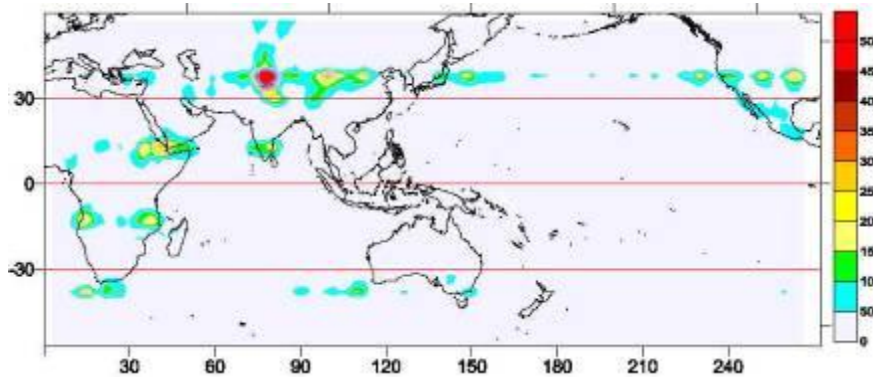


Figure 7. Velocity ( $\text{ms}^{-1}$ ) distribution of geostrophic wind on June 02, 2001

### Gradient Flow

The gradient flow is due to a combination of the pressure gradient force ( $\Delta p/\rho d$ ), Coriolis force ( $2\Omega V_g \sin \phi$ ) and centrifugal force ( $V^2/r$ ). Similar with the geostrophic wind simulation, it also uses central difference of grid notation using the first derivative of isobar. This derivation refers to the basic equation as follows.

$$v = \sqrt{\left| -2r \left( \frac{1}{\rho} \frac{p_{NW} - 2p_N + p_{NE} - 2p_W + 4p - 2p_E + p_{SW} - 2p_S + p_{SE}}{4\Delta x \Delta y} \right) \right|} \quad (4)$$

The wind gradient is a simulation process of the function that is generated from the three-way balances of forces in cyclonic flow, *i.e.* centrifugal force, coriolis force, and pressure gradient force. Therefore this simulation gives more detail in expressing an air movement (see Figure 8).

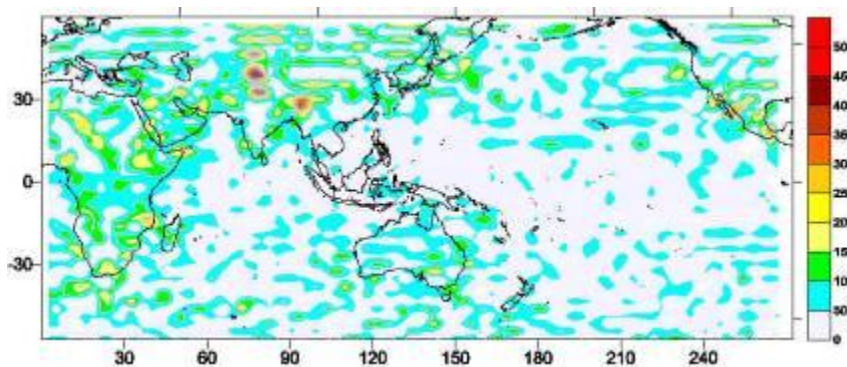


Figure 8. Velocity ( $\text{ms}^{-1}$ ) distribution of gradient wind on June 02, 2001

In Figure 8, the wind gradient presents the distribution of wind velocity in low latitudes. The highest velocity occurs mostly on land surface because the distance of isobar line is shorter than on sea surface or variations of pressure on land surface is higher than sea surface. This

state presents the difference heat capacity that influences the surface temperature where finally shows the different of air pressure on both surfaces.

### Thermal Wind

The combination of hypsometric and geostrophic equations gives a thermal wind equation which relates vertical shear of the geostrophic wind to horizontal temperature gradient. This model uses central difference of grid notation from the first derivative of temperature height. Therefore, the equation of thermal wind is given as follows.

$$v = \frac{g_0}{2\Omega \sin \phi} \frac{z_{NW} - 2z_N + z_{NE} - 2z_W + 4z - 2z_E + z_{SW} - 2z_S + z_{SE}}{4\Delta x \Delta y} \quad (5)$$

The Wind Direction module considers about the differences between cold and warm air or high and low pressure. Therefore, the input data for generating wind direction is geopotential height (presents the differences of warm and cold air) and the isobar chart (presents the differences of high and low pressure). Similar with the velocity of wind generation, wind direction also uses “compass base” as a basic to derive a direction. The differences of pressure for each parcel at certain elevation level from surface could be assumed as a terrain. Therefore, the wind direction refers to the aspect of terrain.

The terrain aspect operation is calculated from the downhill direction of the steepest slope at each grid node. This direction is perpendicular to the isobar lines at certain elevation on the surface, and exactly opposite from the gradient direction. Terrain aspect values are reported in azimuth, where 0 degrees points due North, and 90 degrees points due to East. The operation is given by:

$$A_T \approx 270 - \frac{360}{2\pi} \arctan 2 \left( \frac{p_N - p_S}{2\Delta y}, \frac{p_E - p_W}{2\Delta x} \right) \quad (6)$$

The velocity of thermal wind is given by Equation 5 while the direction is given by vector calculation of differences geopotential height which is derived from hypsometric equation (equation 6). In this research, the value of velocity was presented by color scale while arrow for the direction of wind.

The simulations of thermal wind in regional area give more detail in result than simulations in global area. In Figure 9a we see that the velocity of thermal wind is less than 20  $\text{ms}^{-1}$  for almost all areas. There are few areas have the velocity more than 280  $\text{ms}^{-1}$  which express low pressure or high geopotential height. High velocity can occurs in the area which

has high geopotential height and high thermal gradient. Figure 9b presents the relation between geopotential height and thermal wind velocity.

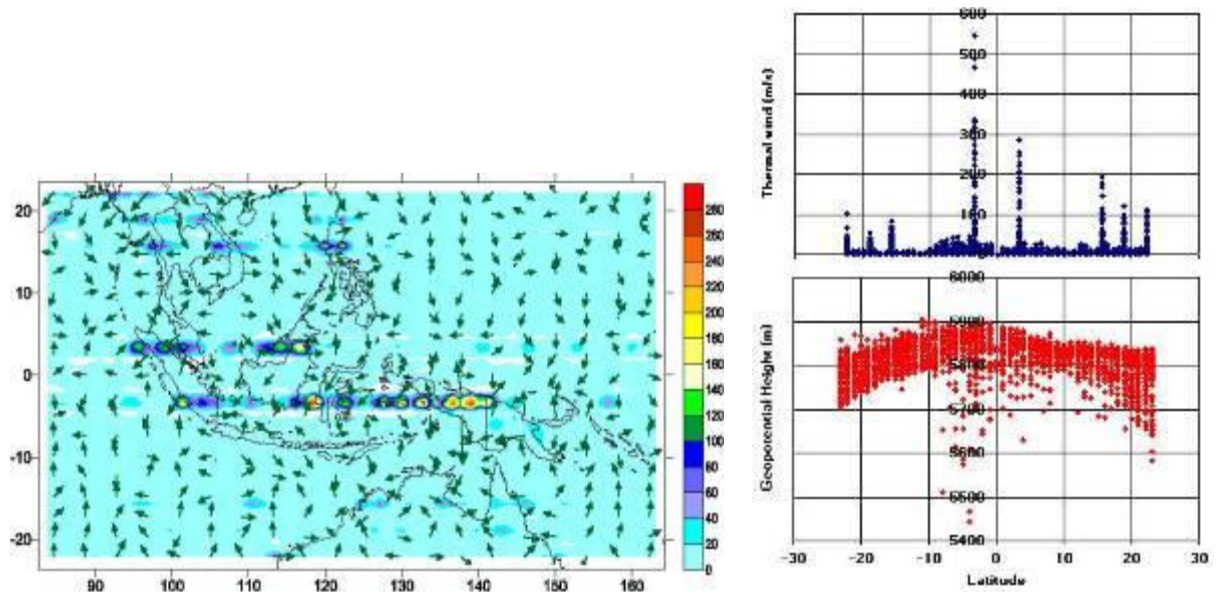


Figure 9. (a) The velocity and direction of thermal wind for South East Asia on June 02, 2001, (b) Relational geopotential height and thermal wind velocity

### Solar Radiation

Solar radiations module was built as a function of coordinate geography, time and surface temperature. Coordinate geography and time determines the potential value of solar radiation which is receive by earth surface. Temperature of surface data is used to generate the actual value when the satellite data was captured. Those all data will be combined with certain physical equation of electromagnetic wave.

In this research, Plank's equation is the first theory that is used to simulate the solar radiance value. This equation describes the quantum theory about energy that is transmitted by electromagnetic radiation in discrete unit (called photons). The second theory is blackbody radiation. It is a hypothetical body comprising a sufficient number of molecules absorbing and emitting electromagnetic radiation in all parts of the electromagnetic spectrum. In this model, the known data is surface temperature data for each coordinate. By those two equations, we can calculate the value of solar radiation on the earth surface. The surface temperature data, which was produced from extracting satellite data, is a result of the infrared spectrum on certain electromagnetic wavelength into radiance value conversion using the Plank's law. Therefore,



the equation to generate the solar energy value on the earth's surface could be expressed as follows.

$$Q = hc \frac{T}{2897} \quad (7)$$

The simulations of solar energy on the earth surface is a calculation of surface irradiance, therefore the result expresses an energy from reflectance of solar radiance and long wave radiance of surface that is received by satellite sensor. It gives irradiance value and maximum wavelength as an output of model.

Regional study area gives more detail information. In this research, the solar energy simulation is conducted on December 02, 2000 and June 02, 2001 where the results are presented in Figure 10. From Figure 10, on December 02, 2000, the area South of equator receives solar radiance more than the North area. In contrast, on June 02, 2001, the solar radiance in North area is more than the South area. In addition, the area that has a high value of solar irradiance on June is larger than on December.

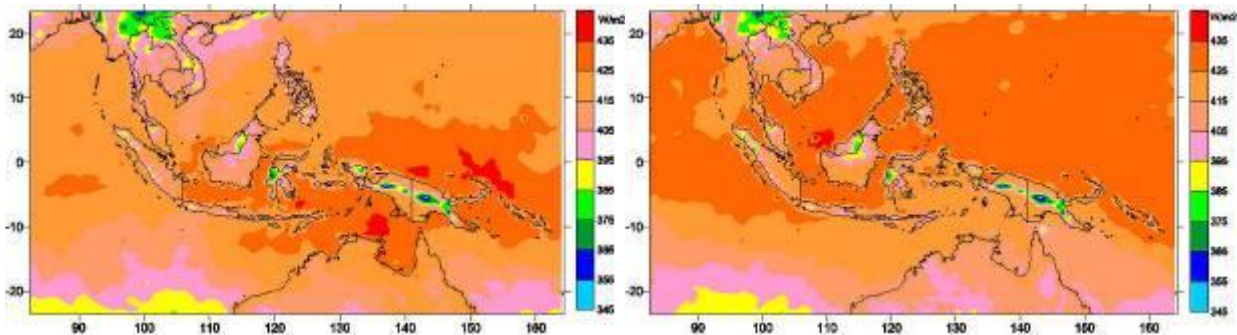


Figure 10. Distribution of average solar energy ( $Wm^{-2}$ ) which has been receives by earth surface in regional area on (left) December 02, 2000 and (right) June 02, 2001.

### Estimation of Water Vapor Content

Module of estimation of water vapor content consider about water vapor mass and cloud distribution. Those variables can be predicted from vertical distribution of solar energy. Cloud, water vapor and aerosol that are exist in the atmosphere influence the radiation transfer process, because they absorb and reflect some part of solar radiation.

The model of water vapor content estimation was build based on the mechanism of energy transfer as the basis to estimate the water vapor content. The assumption was used in this model is scale analysis for atmosphere content. Therefore, it is water vapor only as a

component that has to be taken into account as atmosphere content. Another assumption is constant in volume, therefore, the specific heat of water vapor used the value is  $1463 \text{ J kg}^{-1} \text{ K}^{-1}$ . The solar energy was absorbing by atmosphere could be calculated such as below:

$$Q_{\text{atm}} = Q_a - Q_s \quad (8)$$

The solar energy, which receives by earth surface, was substituted by using equation 7.

$$Q_{\text{atm}} = Q_a - hc \frac{T_s}{2897} \quad (9)$$

$Q_a$  is potential energy that receives on top atmosphere and as a function of latitude, solar declination angle and day. The equation is given by:

$$Q_a = 0.6258(H \sin \phi \sin \delta + \cos \phi \cos \delta \sin H) \quad (10)$$

Based on equation 4.17 can be seen that if absorption solar energy by atmosphere is high, it is presenting the high water vapor mass. The value of water vapor mass on certain area can be used as indicator to predict precipitations, because the high value will be increasing growing cloud. So, to get estimation of water vapor content in the atmosphere can used ratio between energy that absorb by atmosphere and energy that receive on top atmosphere is given by:

$$WV_p = \frac{Q_{\text{atm}}}{Q_a} \times 100\% \quad (11)$$

The result of water vapor content estimation can be seen in Figure 11. Its express two map, first map is condition on December 02, 2000 and second map is condition on June 02, 2001. Although just express solar radiance that absorb by the atmosphere, it could be used as assumption water vapor content in the atmosphere. Figure 12 is shown the solar radiance that absorbing by atmosphere.  $Q_a$  is solar radiance before it was absorb by atmosphere and  $Q_{\text{atm}}$  is solar radiance that was absorbing by atmosphere.

Actually, in this research was not done simulations to get water vapor mass. If it wants to calculate water content mass, so, it should consider about vertical distribution of air density and composition of atmosphere.

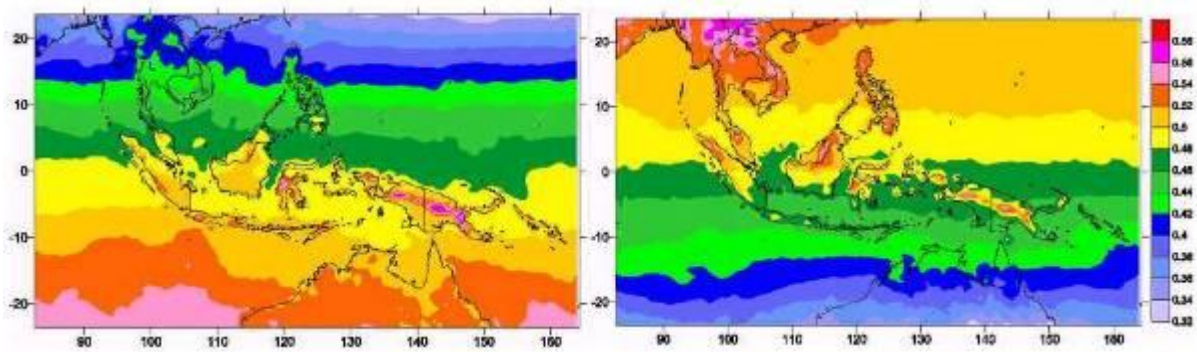


Figure 11. Estimation of relative water vapor content in the atmosphere (left December 02, 2000, right – 02 June 2001)

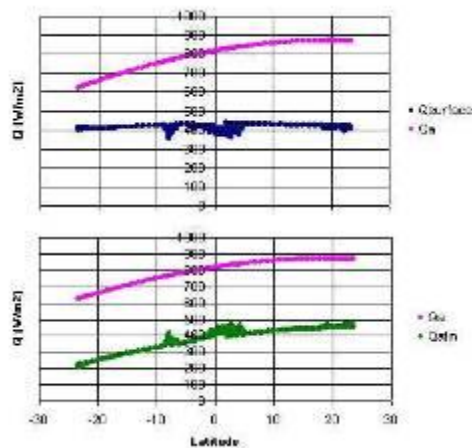


Figure 12. Sample of solar radiance on surface, atmosphere and on top atmosphere ( $Wm^{-2}$ )

### Graphical User Interface

In this research, a mode of user interface for weather prediction model is a graphical user interface (GUI) and it was build as a packet software application. It was written in Visual Basic 6.0 and was supporting some library file and activeX from other software. In this GUI, there are four major tasks that have to be handled. The first task is file management, second task is global data presenting, third task is Indonesia data presenting and the last one is description about this software and model. Each of tasks was presenting as menu of the application software and has the some sub-menu (Figure 13).



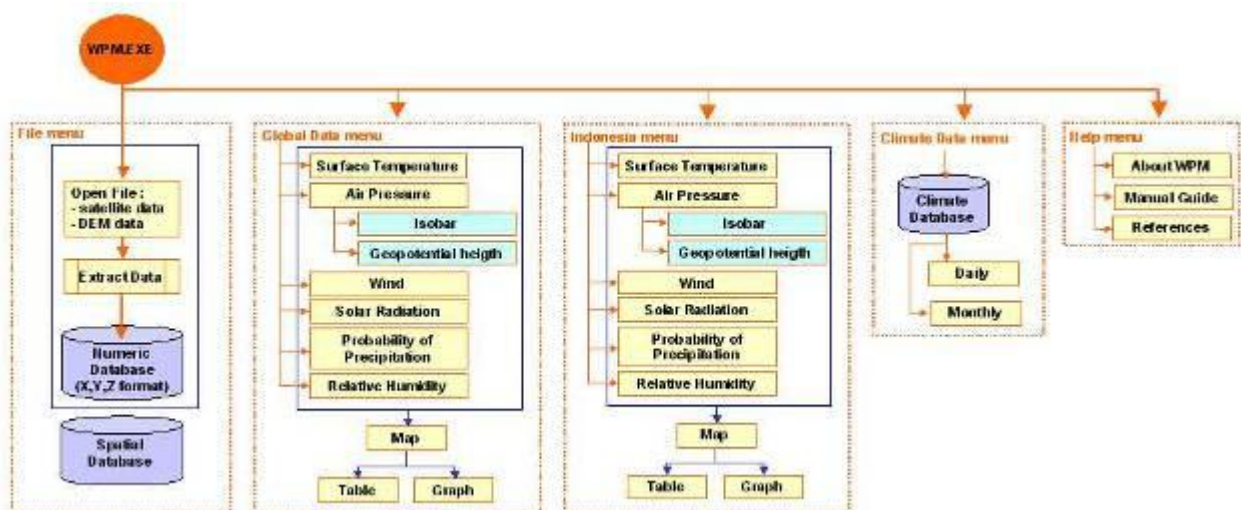


Figure 13. Graphical user interface menu

To present the result of model, GUI was build with three displaying as layout; there are map, table and graph or chart. The map was build with add the Surfer Library into project reference data and Moving Map activeX into project component of Visual Basic. Surfer library was used for create griding file and produce map of weather element which was overlaying with base map. Moving map activeX was used to displaying the map which was created by surfer library and has the property such as zooming out, zooming in and showing coordinate value of the map. Table and chart of weather element was building by using available activeX in Visual Basic, their area MS Flexgrid and MS Chart.

## CONCLUSIONS AND RECOMMENDATIONS

This research uses three techniques (modeling, geographic information system and remote sensing) to develop weather monitoring application software as implementation of information technology. Modeling that was used in this research is mechanistic model which describe atmospheric process and give weather element value as an output. Geographic information system was used to create spatial model to give geo-reference for the result of mechanistic model, therefore it is enable to be plotted on the map. Remote sensing technology was used to capture NOAA satellite data and extract it to produce a radians value as an input of mechanistic model.

The weather monitoring application software consists of three sub-model. The first sub-model is direct data access model which is used to capture and extract NOAA satellite data

automatically. The second model is numerical weather system model which is used to simulated weather element data. The last model is spatial model which is used to build relationship of weather element data between pixel or area of air column. By this software, users could get the information of weather elements data such as air surface temperature, air pressure, wind, solar radiation and water vapor content estimation.

As a model, it has some weakness such as temporal resolution, spatial resolution and vertical distribution process of atmosphere. Temporal resolution of this model is one day, however, in reality, weather is temporal state of atmosphere condition that change any time. Moreover, this model only describes weather condition when data satellite on the day could be captured. Therefore, to increase the temporal resolution of this model, the input data could be added or integrated with other satellite data such as GMS satellite that has one-hour temporal resolution.

Spatial resolution that was used in this model is 50x50 kilometers square for global area and 8x8 kilometers for regional area. Actually, for the spatial resolution, this model has been prepared as NOAA's spatial resolution. However, in this research, the computer processor and memory is not adequate to run the software in NOAA's spatial resolution. Therefore, it is highly recommended to use more powerful computer system.

This model cannot simulate vertical distribution of atmosphere, so, it does not give information about relative humidity and precipitation. If air movement in vertical area could be simulated, the dew point temperature and lighting condensation level would be known therefore the relative humidity and precipitation could be predicted.

Considering with weather prediction, this model could be used as initialization to predict the next weather condition (12 hour, 24 hour or 48 hour). However, this model must be validated using radio-sonde and surface data (weather station data). Therefore, this research should be continued with add new method to simulate vertical distribution of atmosphere and consider with surface morphology.

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