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Visualization of Data Availability on Meteorological and Climatological Observation

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Abstract

Data visualization plays a crucial role in supporting the growth and development of a company because it enables organizations to transform raw data into meaningful information for decision-making. Through effective visualization, companies can gain deeper insights into their operational performance and become more proactive in managing the data resources they possess. This study focuses on the development of a dashboard to visualize observational data owned by the Technical Implementation Unit. The main objective of this research is to facilitate users in reading and understanding the catalog of data availability through an interactive visualization system. By utilizing Ben Fry's data visualization technique, which emphasizes the stages of acquiring, parsing, filtering, mining, representing, refining, and interacting with data, the dashboard is designed to present information in a structured and user-friendly format. The resulting dashboard provides users with a comprehensive overview of observational data availability, including data completeness, update status, and category distribution. Interactive features such as filtering, drill-down analysis, and real-time exploration allow users to quickly identify missing, incomplete, or outdated data records. This significantly improves the efficiency of data monitoring processes compared to conventional tabular reports. Furthermore, the dashboard supports better decision-making by enabling managers and staff to prioritize maintenance activities and ensure data quality standards are achieved. In conclusion, the implementation of an interactive data availability dashboard contributes positively to organizational efficiency by simplifying the processes of identifying, evaluating, and maintaining data completeness. The study demonstrates that combining Business Intelligence concepts, Ben Fry's visualization methodology, and Tableau software can produce an effective solution for modern data management needs.

Keywords: Business Intelligence, Dashboard, Data Catalog, Data Visualization, Tableau Softaware

I. Introduction

The development of information and communication technology makes searching for information and data through the internet easier to obtain and greatly helps the community in various life activities, be it in the

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fields of education, offices, commercial, industrial, and activities in other fields. One form of advances in information technology is the development of databases. Database is one of the most important components in information system, since it is the basis in providing information for the users and for the enterprise or the organization itself. Databases help companies to store, analyze, and present structured data for large amounts. In addition, we need a technique to communicate information clearly and efficiently to system users, which is called data visualization. Data visualization plays an important role in helping companies analyze and reason data so that it can be understood and processed easily.

Meteorology, Climatology and Geophysics Agency (BMKG) is an Indonesian Non-Departmental Government Institution responsible for carrying out government duties in the fields of meteorology, climatology, and geophysics. BMKG has many UPTs spread throughout Indonesia, which are divided into Meteorology Stations, Climatology Stations, and Geophysics Stations. BMKG provides a lot of important information related to weather forecasts, climate, earthquakes, magnetism, and so on. The information is disseminated periodically through television, print media, and electronic media [1]. To provide information services to the public, BMKG uses a special database system to store data on observation parameters and their availability. BMKG Database Center known as Pusat Database BMKG is a department of BMKG focused on maintaining and managing data which is divided into data management, data maintenance, and development divisions. BMKG Database Center has data catalogs containing observational data obtained from decades ago which is stored in BMKGSoft system. BMKGSoft is an internal system of Pusat Database BMKG which accommodates files in the form of Microsoft Excel files related to meteorological and climatological observation data received from all BMKG UPTs in Indonesia.

Based on previous research found there were difficulties in identifying earthquake-prone areas. All ofthe data collected must be organized systematically so that it can facilitate decision making. This research uses a business intelligent tool, Tableau, which can manage and visualize data quickly and easily and is able to analyze millions of data from various type of data sources. Data visualization using Tableau produces a dashboard that is very helpful for obtaining information on areas that are prone to landslides and areas that are safe. The existence of this dashboard helps the community to be more aware with information regarding the disaster and the countermeasures [2].

This study aims to visualize BMKG observation data catalog by creating a dashboard that presents a map of BMKG UPT's location points with graphs of the percentage of available meteorological and climatological observation data at each UPT so that it meets the needs of BMKG Database Center in reading the availability of data for each observation and simplify the process of maintaining data availability.

II. Related Works

A. Information System

An information system can be defined as a set of interrelated components that combine, process, and distribute information to support decision making and control in an organization. To support decision making, coordination, and control, information systems can also assist managers and organizations in analyzing problems, visualizing complex subjects, and creating new products or services. Three activities in the information system include input, process, and output. Input captures or collects raw data from within the organization or from its external environment. Then processes are carried out to convert the raw input into a meaningful form. The resulting output conveys the processed information to the people who will use it or to the activities where the information will be used. Information systems also require feedback, which is results that are returned to appropriate people or activities within the organization to assist in evaluating or improving the input stage. Actors such as customers, suppliers, stakeholders, and regulatory institutions relate to the organization as well as its information system [3].

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B. Business Intelligence

Business Intelligence (BI) is an emerging trend in improving decision support for business success. BI has a fast acceleration in analyzing often uncertain changes in the business environment and in making these changes. According to BI provides decision-making tools that guide businesses to achieve competitive advantage arising from these changes [4]. BI is an information system (IS) application used by businesses to collect, assimilate, and exploit information into the decision-making process [5]. BI is defined as the process of integrating data from different internal and external data sources that apply analytical tools and techniques to understand the information in the data, make decisions, and take action based on the understanding obtained [4].

C. Data Visualization

Data visualization is a field of study deals with the transformation of data into visual representations, where the target itself is an effective and efficient cognitive processing of data. The use of visualization techniques has the potential to improve data display and cognitive processing of data as well as reducing cognitive excessive workload for users. Information visualization involves the transformation of data. Extraction can be done through a computational process or a human transcription process, which aims to explore the data and create new insights. Some guidelines for the development of information visualization solutions include [6]:

1. To apply realistic techniques to improve the mapping of data elementsinto visual objects.
2. To minimize the actions the user has to perform.
3. To provide flexibility in achieving the same goal.
4. To provide functionality to represent additional information.
5. To arrange the visual layout spatially.
6. To apply design choices consistently.
7. To minimize cognitive load for users.
8. To provide users with information regarding alternatives if some action available.
9. To remove irrelevant or distracting information.
10. To consider reducing the data set.

As web-based visualization grew in popularity, various web-based development tools were introduced and widely used. Some studies rely on software such as Java Script, Google Earth, Tableau, and Many Eyes. Tableau has become one of the popular tools mainly used in the private sector and is gradually expanding its use to academia and public sector. Examples of institutions using Tableau are the Ohio State University Library for data visualization experiments and rapid analytics and United Nations (UN) who use Tableau as the standard for visual analytics throughout the United Nations system [7].

D. Observational Data

According to Indonesian legislation, UU No. 31 Tahun 2009, the definition of Data is the result of meteorological, climatological, and geophysical observations obtained at the observation station (UPT) [8]. This BMKG observation data contains the location of UPT owned by BMKG and what observations are made by UPTs spread throughout Indonesia.

1. Meteorology Observational Data

   Meteorological observations are carried out to obtain data of natural phenomena related to weather and are observations for long-term predictions, for example, for a year ahead. Meteorological observations include observations of surface air, rainfall intensity, agro-climate, pibal/radiosonde, satellite, and weather radar [9].

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2. Climatology Observational Data

   Climatological observations are carried out to obtain data or values of natural phenomena related to climate and air quality and are observations for short-term predictions, for example, predictions for the next two to seven days. Climatological observations include observations of post rain, evaporation, daily climate, air quality, phenology, and solar radiation [9].

E. Dashboard

Dashboard is a visual display of the most important information needed to achieve one or more goals; consolidated and organized in one screen so all the information needed can be monitored at a time. Then the definition of dashboard was developed into visual and interactive performance management tools that are displayed on a single information screen to achieve one or more individual and/or organizational goals, enabling users to identify, explore, and communicate where the problem requires action or change. This definition emphasizes interactivity and refines its purpose. In terms of visualization, dashboards can be either static or dynamic. Static dashboards that are often encountered are mostly in the form of printed reports and only provide information for a certain period of time. Dynamic dashboards, mostly web-dashboards, visualize data directly from the data warehouse, making them interactive and user-friendly [10].

F. Tableau

Tableau is software that can help users explore and understand their data by creating interactive visualizations. This software has the advantages to connects users with various data sources and helps users to create data visualizations with presentations in the form of charts, maps, dashboards, and stories through an interface that can be designed only in a simple way such as drag-and-drop [11]. The analysis process in Tableau requires little effort to learn the basic functionality [12]. Tableau has an interface in the form of a shelf-based visualization design display that allows users to put data dimensions, metadata, and measures into a specific shelf, each of which represents a various visual form such as a certain shape, a certain scale, and/or a certain color [13].

1. Calculated Field and Query on Tableau

   Calculated Field is used to create new data or columns from existing data in the data source. The values or members are determined by calculations using a query language known as Structured Query Language (SQL). This calculated field helps in grouping data, converting data field types (such as from string to date), collecting data, filtering results, and calculating ratios [14].

2. Filter on Tableau

   In Tableau, we can present interactive filters on the interface we design and customize them according to our point of view. To filter data, we need to extract the filters and filter the data sources, contexts, dimensions, and measures (by calculation). On the Tableau Desktop, a filter dialog box will appear to specify the type of filter when we add a field to the filter shelf [14].

III. Research Methods

This research was conducted by the author referring to the general data visualization technique presented by Ben Fry, and by using Tableau ver. 10.3. The data visualization processes to achieve good visualization presented by Ben Fry are as follows [15].

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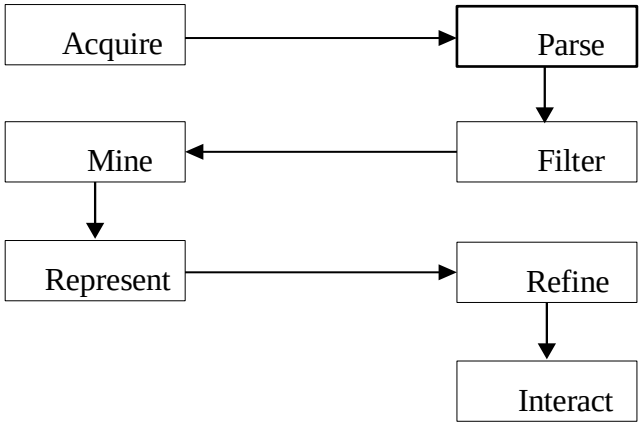

Figure 1. The Seven Stages of Visualizing Data by Ben Fry

A. Acquire

Observational data from all BMKG UPTs spread across Indonesia were converted into .xlsx data catalog files. In this study, the availability of data to be visualized is related to the meteorological and climatological observation data presented in Table 1.

Table 1. Observational Data Catalog List

Observation	Data Catalog File Name
Agm1a	katalog-data-agm1a.xlsx
Agm1b	katalog-data-agm1b.xlsx
Fklim	katalog-data-fklim.xlsx
Intensitas Hujan	katalog-data-intensitas hujan.xlsx
Me48	katalog-data-me48.xlsx
Penguapan	katalog-data-penguapan.xlsx
Pilot	katalog-data-pilot.xlsx
Pos Hujan	katalog-data-pos hujan.xlsx
Radiasi Matahari	katalog-data-radiasi.xlsx
Radiosonde	katalog-data-rason.xlsx

The entire catalog of meteorological and climatological observation data is then connected to the Tableau.

B. Parse

The data catalogs in Table 1 have the same fields (attributes) in them, which are as follows.

Table. 2 Data Comprehension

Field	Information
WMO ID	Identification number of UPTS

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Nama Stasiun	Name of Observation Station or UPT
Balai	The area where the station is located is based on are division
Longitude	Longitude coordinates of the observation station
Latitude	Latitude coordinates of the observation station
Data Awal	The first (initial) date of receipt of data
Data Akhir	Last date of receipt of data
Total Data	The amount of observational data stored at each station

Next, the data type of each field is determined by adjusting the data type format in Tableau.

Table 3. Data Type Mapping

Field	**Data Type**
WMO ID	String
Nama Stasiun	String
Balai	String
Longitude	Float
Latitude	Float
Data Awal	Date
Data Akhir	Date
Total Data	Number (whole)

C. Filter

At this stage, the first thing to do is to determine what information will be displayed on "Ketersediaan Data Pengamatan (Observational Data Availability)" dashboard. Then, it is necessary to select what variables or data will be used in the calculation process at a later stage to display information needed as follows.

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Table 4. Mapping Methods for Data Processing

Information Needs	Data	Visualization Methods
To search and to view a list of station names	Nama Stasiun	Multiple values dropdown filter on Tableau
To display station points based on the color of region area	Balai	Color mark card on Tableau
To calculate data percentage	a) Total Data b) Data Awal c) Data Akhir	Calculated field entitled "Presentase Data" with query: [TOTAL DATA] / (DATEDIFF ('day', [Data Awal], [Data Akhir]))
To display the percentage of observational data available in the database	Presentase Data	Calculated field named "Data yang Tersedia (%)" with query: [PRESENTASE DATA]*100
To display the percentage of observational data that is not available in the database	Data yang Tersedia (%)	Calculated field named "Data Tidak Tersedia (%)" withquery: 100 -[Data yang Tersedia (%)]

Table 5. Visualization Mapping

Information Needs	Diagram
Pemetaan stasiun dan UPT BMKG di Indonesia	Maps
Presentase Ketersediaan Data	Pie Chart
Persebaran stasiun dan UPT BMKG	Symbol

There are 11 (eleven) worksheets that will be created using Tableau to visualize the availability of BMKG observation data. These worksheets will later be inserted on "Ketersediaan Data Pengamatan" dashboard, including 1 worksheet displays the UPT Map and 10 worksheets that display the percentage of data availability for each observation along with metadata related to observational data, such as the initial date the data was obtained, the last date the data was obtained, and total data for each stored observation.

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D. Mine

After the raw worksheets are created, the calculated fields can be directly worked on each worksheet of the observation data catalog. As explained by the data processing method mapping table in Table 4, there are 3 (three) calculated fields that must be created, namely the calculated field "Presentase Data", calculated field "Data yang Tersedia (%)", and the calculated field "Data Tidak Tersedia (%)".

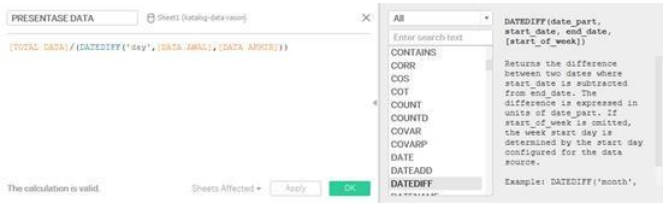

Fig. 2. Calculated Field "Presentase Data" on Worksheet "Rason"

E. Represent

Based on the visualization mapping table in Table 5 at the Filter stage, fields that are information needs are put into each worksheet. The initial step from the represent stage is to display the UPT map belonging to BMKG on the "UPT Map" worksheet by adjusting the location of the Longitude and Latitude of the UPT location on the symbol maps so that the distribution points of BMKG UPT will appear as shown in Figure 3. Next, the Station Name field is dragged into the filter shelf with multiple values dropdown option so that the filter card appears on the edge of the worksheet. This filter card is to view a list of station names, search for station names, also select one, several, or all UPT points user wants to display.

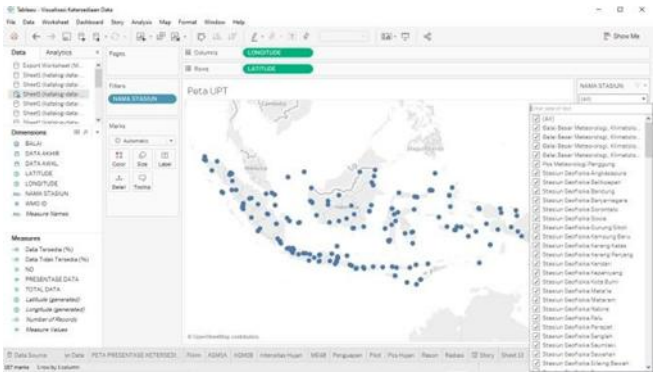

Fig. 3. UPT Distribution Point and Station Name Filter Card

Field Balai is put into the marks card with color option to distinguish the color of UPT points based on the region area. Then the Station Name and WMO ID fields are also dragged onto the marks card, but with detailed options, so that if the cursor is directed to one of the UPT points, the Station Name, WMO ID, Longitude, Latitude, and Balai infosrmation will be shown according to the UPT point directed by cursor (Fig. 4)

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Fig. 4. Regions and Detail Information of UPT

The next step is working on the observation data catalog worksheet. The observation data that will be visualized first is "Rason". After the Station Name field is put into column, Measure Names field is dragged on the filter shelf by selecting only calculated field “Data Tersedia (%)” and “Data Tidak Tersedia (%)” to be displayed as shown in Figure 5. Then the Measure Names field is put into the marks card with color option and Measure Values with the pie angle option to distinguish the color percentage of available data and data that is not available in the piechart. To display information related to the availability of observational data, we need to put the fields Balai, WMO ID, Data Awal, Data Akhir, and Total Data on the marks card with detail options (Figure 6).

Worksheet execution of observation data (agm1a, agm1b, climate, rain intensity, me48, evaporation, pilot, rain post, and radiation) uses the same steps and methods as the work on rason worksheet before.

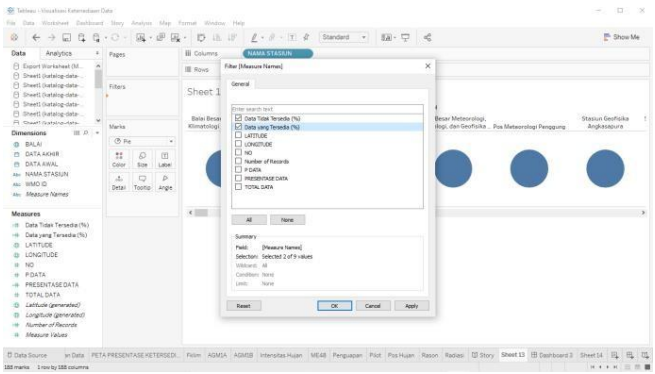

Fig. 5. Filter Measure Names

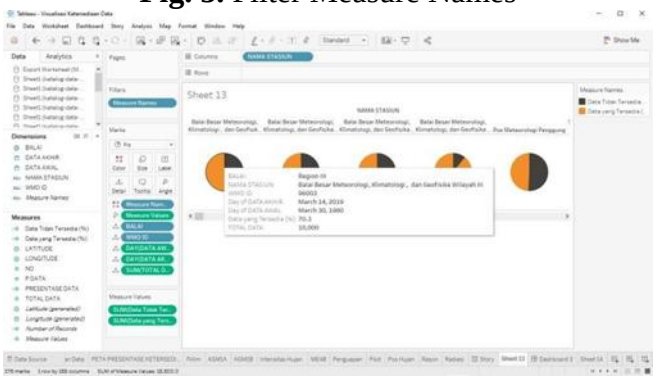

Fig. 6. Percentage of Data Available with Details

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F. Refine

The first step of the Refine process is to design the worksheets that have been created to further clarify the representation by calling for more attention to certain data (establishing a hierarchy) and modifying the shading format, field labels, and title captions on each worksheet. After refining each worksheet that has been created, the next step is to build the dashboard. All worksheets are entered on the "Availability of Observation Data" dashboard with the arrangement of the layout along with the addition of the BMKG logo and dashboard title. Then the size of the dashboard and the attributes used in the visualization that contribute to readability are modified and adjusted.

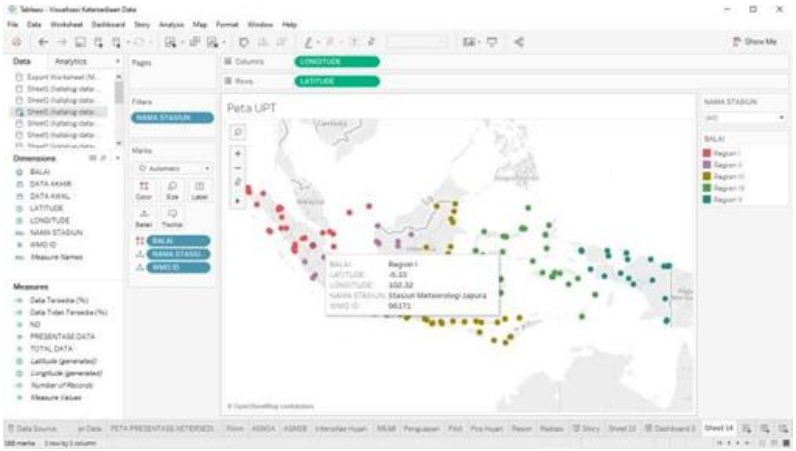

Fig. 7. Temporary Dashboard View

G. Interact

The main interaction used on the dashboard "Ketersediaan Data Pengamatan" is the action feature in the form of a filter. With the action, the worksheet "Peta UPT" is set as the source sheet and the worksheets "AGM1A", "AGM1B", "Fklim", "Intensity Hujan", "Me48", "Penguapan", "Pilot", "Pos Hujan", "Radiasi", and "Rason" are set as target sheets (Figure 10). The goal is that if one of the UPT points on the map is selected/clicked, the entire pie chart of available observation data percentage from the UPT will appear.

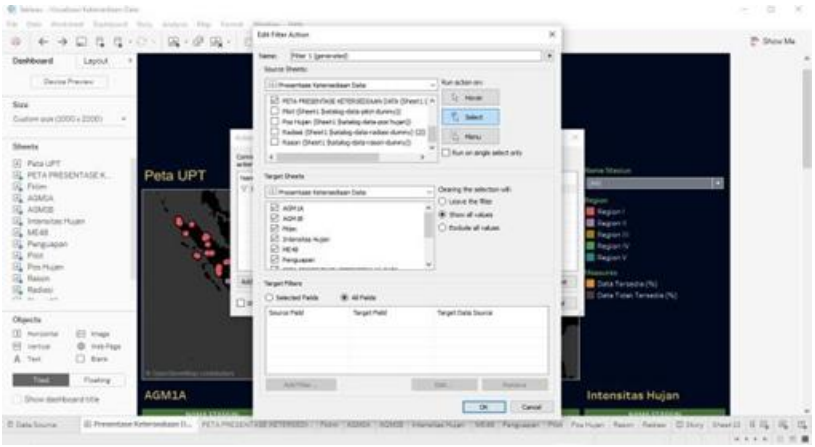

Fig. 8. Activiting Action

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Fig. 9. Stastion Name Search Box

Users are allowed to search for station/UPT names on the dashboard and select the UPT points they want to display. As in Figure 9, after one of the UPT points is clicked, the percentage of data availability for each observation at the UPT will appear along with detailed information related to the availability of the data, such as the initial date the data was received, the last date the data was received, and the total data stored.

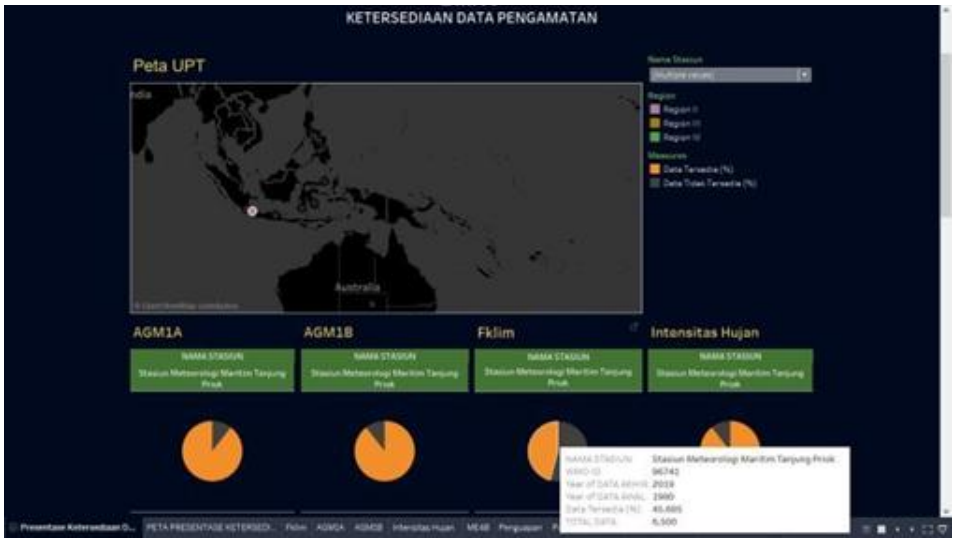

Fig. 10. Action on Dashboard

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Fig. 11. Dashboar of Observation Data Availability

IV. RESULTS

Based on interviews conducted with BMKG Database Center staff [19], the data maintenance workflow begins when Observer Staff at each UPT BMKG perform field observations and produce paper records. These records are subsequently digitized by UPT Data Staff into .xlsx files and transmitted to the BMKG Head Office. The Database Center then processes and stores these files in BMKGSoft, where a Python script converts them into standardized data catalog format. Database Management Staff previously checked data completeness manually by opening each .xlsx catalog file one by one, a process that was time-consuming and prone to human error given the large number of stations and observation types across Indonesia.

The acquire and parse stages successfully collected and structured ten .xlsx data catalog files representing ten types of meteorological and climatological observations, namely Agm1a, Agm1b, Fklim, Intensitas Hujan, Me48, Penguapan, Pilot, Pos Hujan, Radiasi Matahari, and Radiosonde. All ten files were found to share a uniform schema of eight fields: WMO ID, Nama Stasiun, Balai, Longitude, Latitude, Data Awal, Data Akhir, and Total Data. Each field was mapped to the appropriate data type in Tableau, with coordinate fields set as Float, date fields as Date, and Total Data as a whole number, ensuring accurate computation throughout the visualization process.

The filter and mine stages defined the key information requirements and produced three SQL-based calculated fields in Tableau. The field “Presentase Data” computes the ratio of total stored data to the expected total using DATEDIFF to calculate the number of days between Data Awal and Data Akhir. From this, “Data yang Tersedia (%)” converts the ratio into a percentage, and “Data Tidak Tersedia (%)” derives the complement (100 minus the available percentage). These three calculated fields serve as the analytical core of the dashboard, enabling dynamic and accurate representation of data completeness for each station and each observation type without requiring external computation.

The represent and refine stages produced eleven Tableau worksheets: one UPT Map worksheet displaying the geographic distribution of all BMKG stations across Indonesia with color-coded regional groupings (Balai), and ten observation worksheets each showing pie charts of available versus unavailable data percentages per station. Each worksheet embeds detailed metadata including WMO ID, Data Awal, Data

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Akhir, and Total Data. All worksheets were refined with custom formatting and subsequently assembled into the "Ketersediaan Data Pengamatan" dashboard, complete with the BMKG institutional logo and an optimized layout for both desktop and mobile web access.

The interact stage finalized the dashboard by implementing Tableau's action-based filter, configuring the UPT Map as the source sheet and all ten observation worksheets as target sheets. When a user clicks any station point on the map, the dashboard instantly displays all ten pie charts for that station alongside its complete metadata. Additional interactivity includes a multiple values dropdown search box for station name filtering and a tooltip hover feature that shows station identity and geographic details on cursor hover. The resulting dashboard significantly reduces the time required for data completeness monitoring, replacing the previous manual file-by-file checking process with a single-click interactive overview of all observational data availability across every BMKG UPT in Indonesia [2].

V. Conclusion

Observation Data Availability Dashboard is designed to visualize meteorological and climatological observations using data visualization techniques by Ben Fry and the business intelligent tools Tableau so that they can be accessed via desktop web and mobile. Data analysis and calculations were carried out using the Structured Query Language (SQL) presented by Tableau. This interactive visualization displays a map of the location of the BMKG observation station along with a graph of the availability of data per observation.

This easy-to-read interactive dashboard helps database management division of BMKG to find out the availability of observational data so that the process of completing data that is not yet available on the system becomes easier and faster. Some of the features presented in the dashboard are a station name search box with multiple values dropdown to allow users to search for several station points at once, an action feature that will display a graph of the percentage of data availability per observation when one station point is clicked, as well as detailed information features related to stations and metadata of data availability that will appear when the cursor is hovered over the station point

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