Development of OGC WPS-based Climate Data Visualization Service Using PyWPS and Matplotlib

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INTRODUCTION

Background

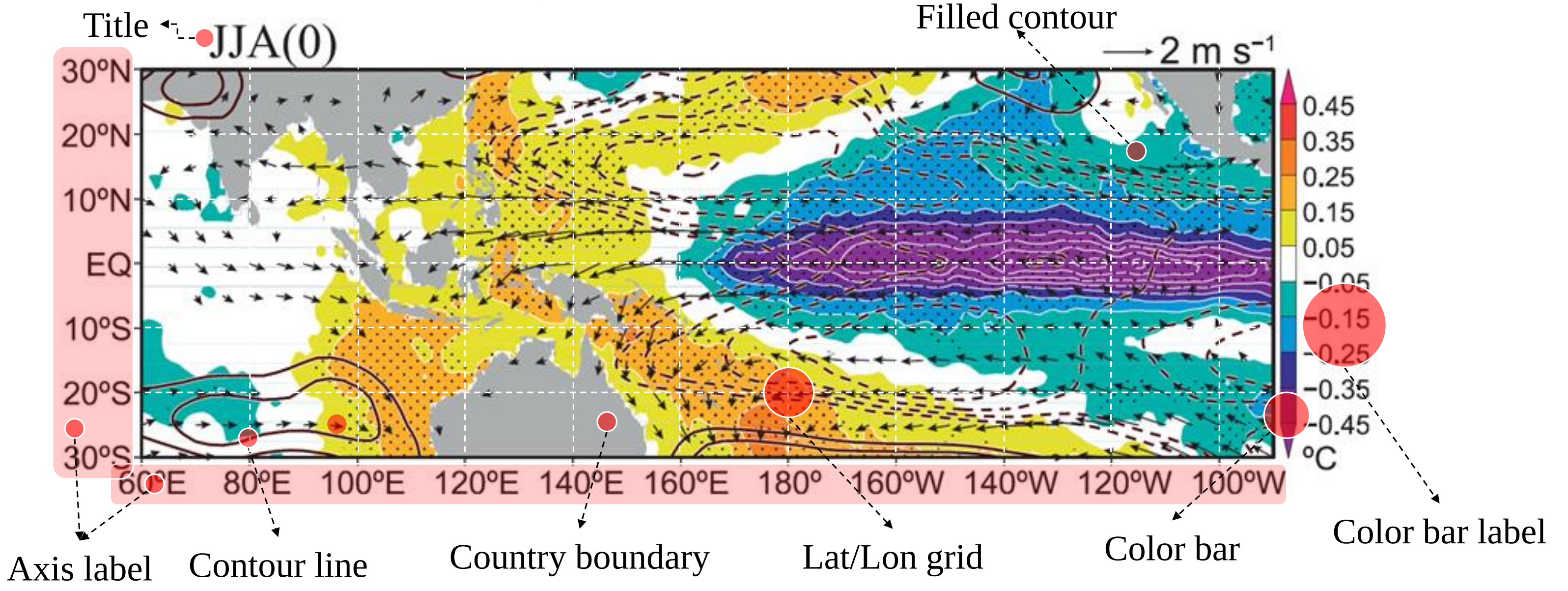
- Scientific climate data plays an increasingly important role in the research on unusual climate events caused by global warming and climate change
- Accordingly, increasing number of studies on climate data visualization
- However, unlike general data without location information, the data should plot with map elements such as projection, contour line, color bar, spatial data (i.e. land, coastline)
- Also, there are not the appropriate libraries that can be used in any environments (e.g. GUI program, web service, server system) and any program languages (e.g., C#, JAVA) to plot the scientific climate data on the map
- In general, script-based open source software (i.e. NCL, GrADS) has been used in the field of climate science
- Therefore, it is necessary to develop the climate data visualization service that can be used in any environments considering a low-bandwidth network environment

Objectives

- To develop OGC WPS-based climate data visualization service that can be used in any environments and any program languages
- To design a lighter climate data exchange format in order to provide to the countries that have a low-bandwidth network environment and a plot option format

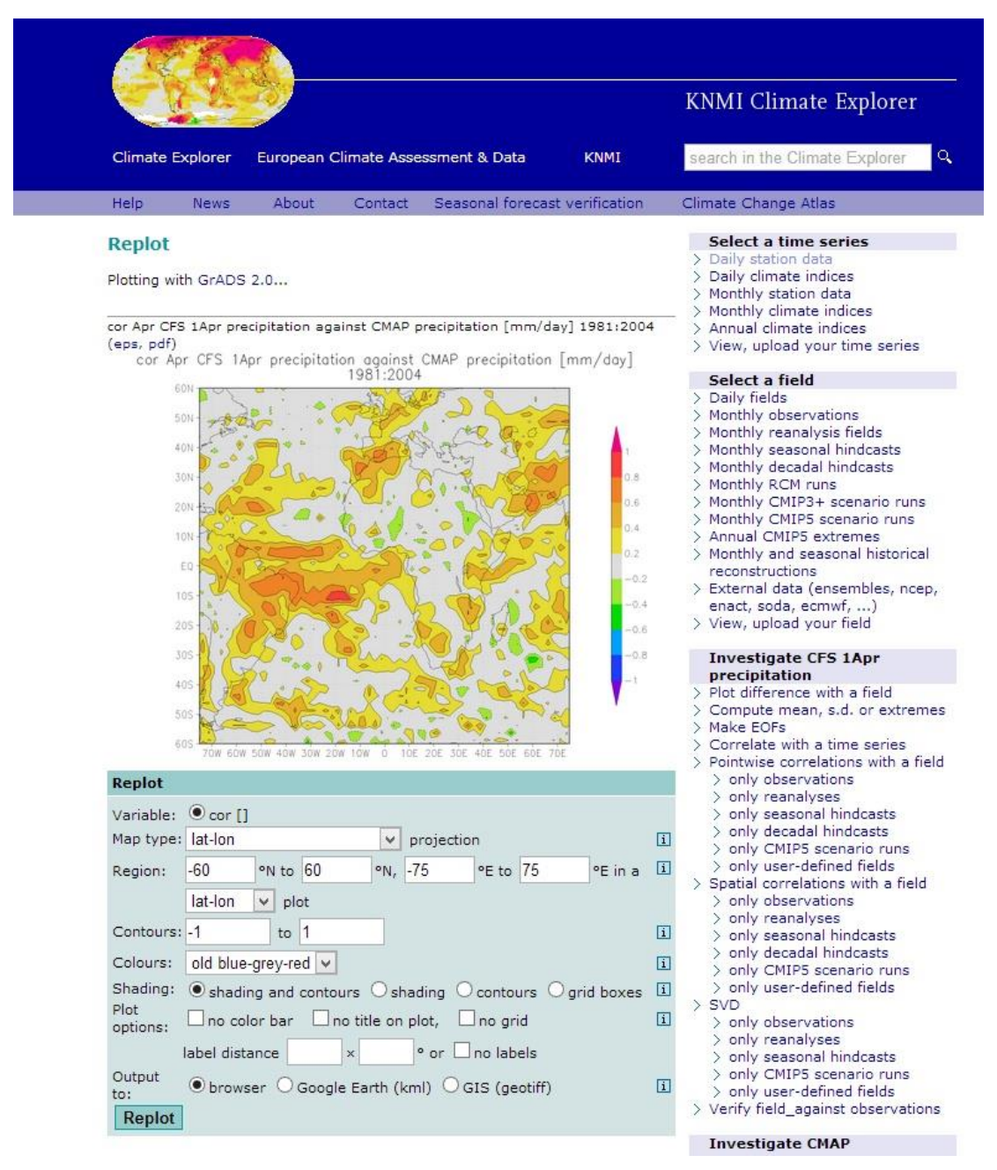
RELATED WORK

- **Map elements for visualizing climate data**



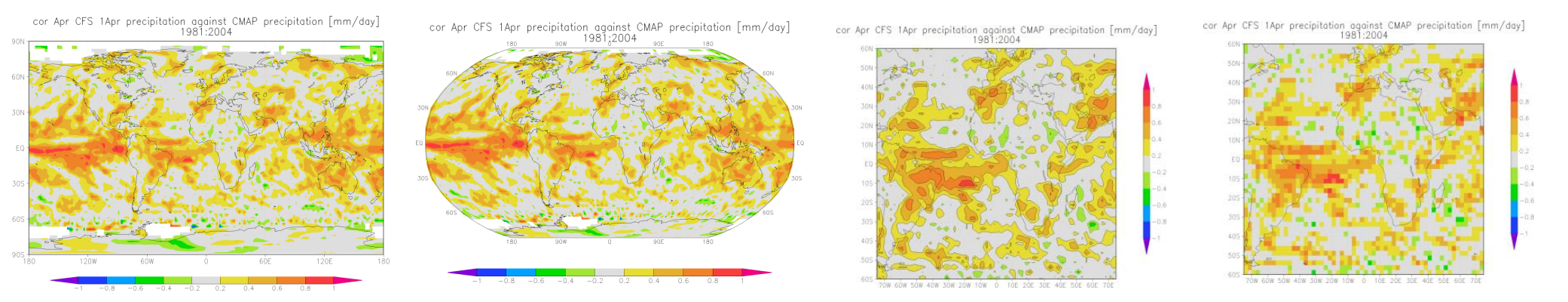
(Adapted from Yu Kosaka, J.S. Chowdary, ShangPing Xie, YoungMi Min, JuneYi Lee, 2012. Limitations of seasonal predictability for summer climate over East Asia and the Northwestern Pacific. Journal of Climate, 25(21), pp.7574-7589)

- **Case of Web-based Climate Information Service (KNMI – Climate Explorer)**


KNMI Climate Explorer
Climate Explorer · European Climate Assessment & Data · KNMI · search in the Climate Explorer
Help · News · About · Contact · Seasonal forecast verification · Climate Change Atlas
Replot
Plotting with GrADS 2.0...
cor Apr CFS 1Apr precipitation against CMAP precipitation [mm/day] 1981:2004 (eps, pdf)
Select a time series
Daily station data
Daily climate indices
Monthly station data
Monthly climate indices
Annual climate indices
View, upload your time series
Select a field
Daily fields
Monthly observations
Monthly reanalysis fields
Monthly seasonal hindcasts
Monthly decadal hindcasts
Monthly RCM runs
Monthly CMIP3+ scenario runs

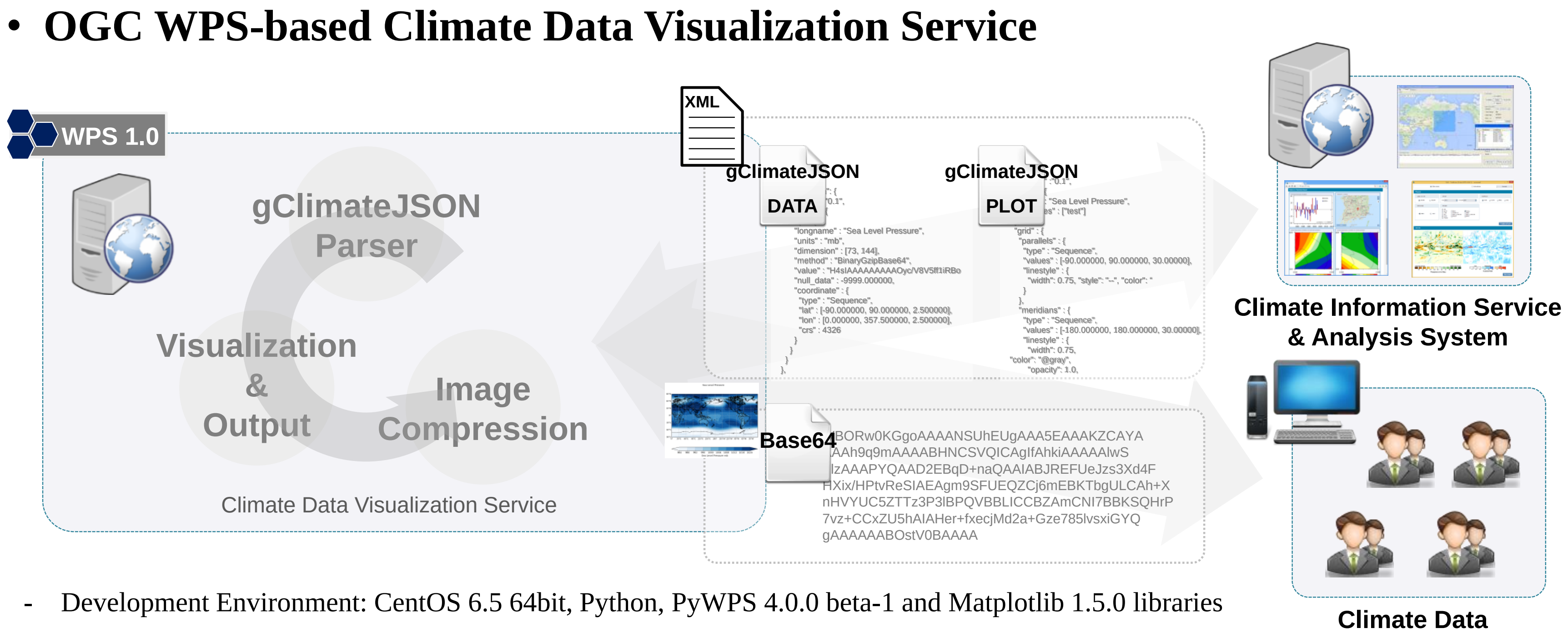
< KNMI – Climate Explorer (http://climexp.knmi.nl) >

- **Supports various map-based visualization options**
  - Various map projections
    lat-lon, North polar stereographic, South polar stereographic, Robinson
  - Shading
    shading and contours, shading, contours, grid boxes
  - Contour color
    blue-grey-red, red-grey-blue, grey-red, grey-blue, red-grey, etc.
  - No color bar, no title on plot, no grid, and no labels options


lat-lon projection · Robinson · Shading and contours · Grid boxes

SERVICE DESIGN

- **OGC WPS-based Climate Data Visualization Service**



"longname" : "Sea Level Pressure",
"units" : "mb",
"dimension" : [73, 144],
"method" : "BinaryGzipBase64",
"value" : "H4sIAAAAAAAAAOyc/V8V5ff1iRBo
"null_data" : -9999.000000,
"coordinate" : {
"type" : "Sequence",
"lat" : [-90.000000, 90.000000, 2.500000],
"lon" : [0.000000, 357.500000, 2.500000],
"crs" : 4326

"grid" : {
"parallels" : {
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"values" : [-90.000000, 90.000000, 30.000000],
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"opacity": 1.0,

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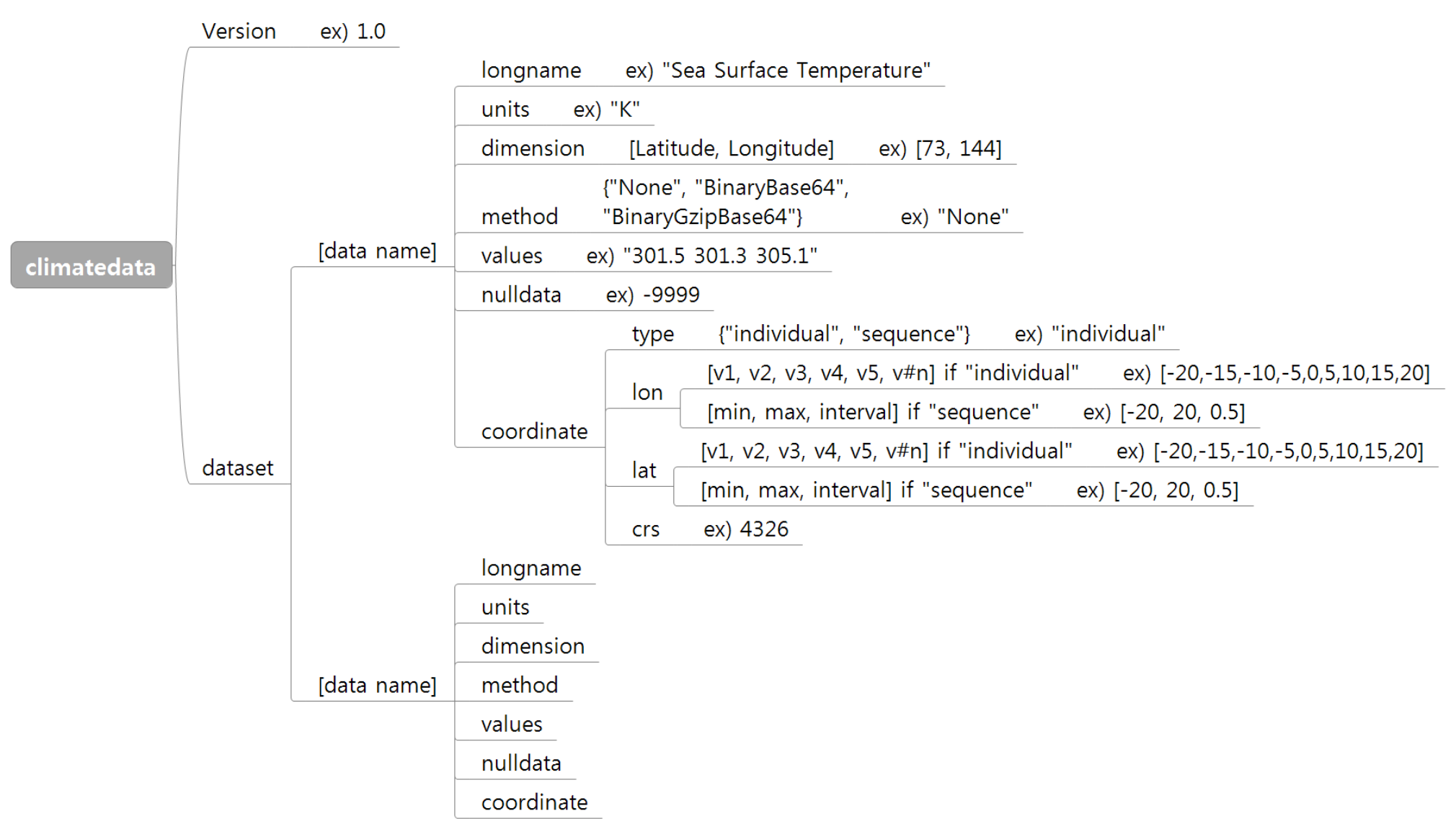
gAAAAAABOstV0BAAAA

- Development Environment: CentOS 6.5 64bit, Python, PyWPS 4.0.0 beta-1 and Matplotlib 1.5.0 libraries
- OGC WPS operation name: OpenWPS:CV_VisualizeNonSeries

- **gClimateJSON**


climatedata
Version ex) 1.0
dataset
[data name]
longname ex) "Sea Surface Temperature"
units ex) "K"
dimension [Latitude, Longitude] ex) [73, 144]
method {"None", "BinaryBase64", "BinaryGzipBase64"} ex) "None"
values ex) "301.5 301.3 305.1"
nulldata ex) -9999
coordinate
type {"individual", "sequence"} ex) "individual"
lon [v1, v2, v3, v4, v5, v#n] if "individual" ex) [-20,-15,-10,-5,0,5,10,15,20]
[min, max, interval] if "sequence" ex) [-20, 20, 0.5]
lat [v1, v2, v3, v4, v5, v#n] if "individual" ex) [-20,-15,-10,-5,0,5,10,15,20]
[min, max, interval] if "sequence" ex) [-20, 20, 0.5]
crs ex) 4326
[data name]
longname
units
dimension
method
values
nulldata
coordinate

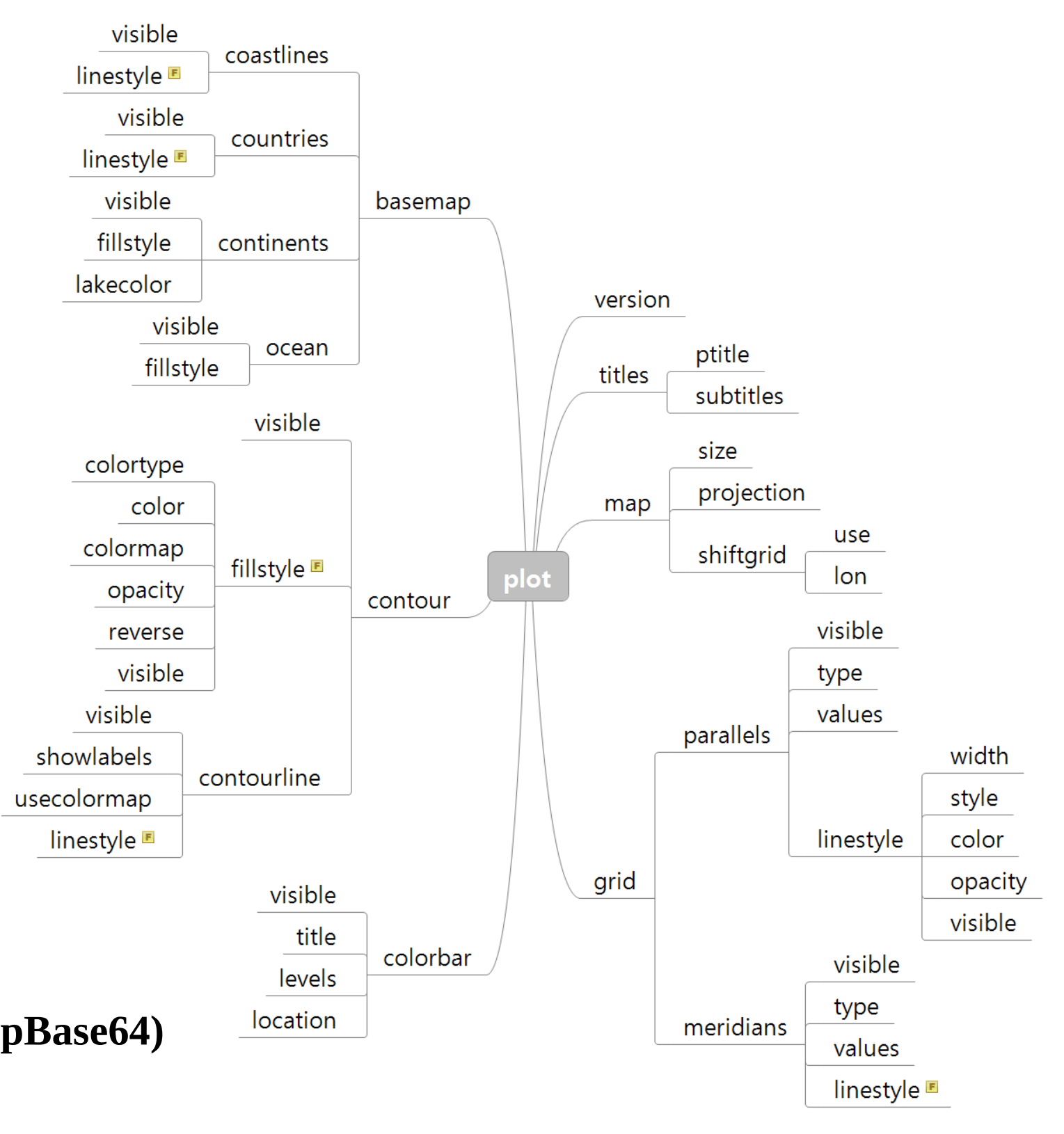
(1) JSON-based data structure

(2) Grid data notation by Base64 encoding algorithm (BinaryBae64, BinaryGzipBase64)

(3) Sequence data (e.g. latitude, longitude) notation (individual, sequence)

(4) CRS (Coordinate Reference System) attribute

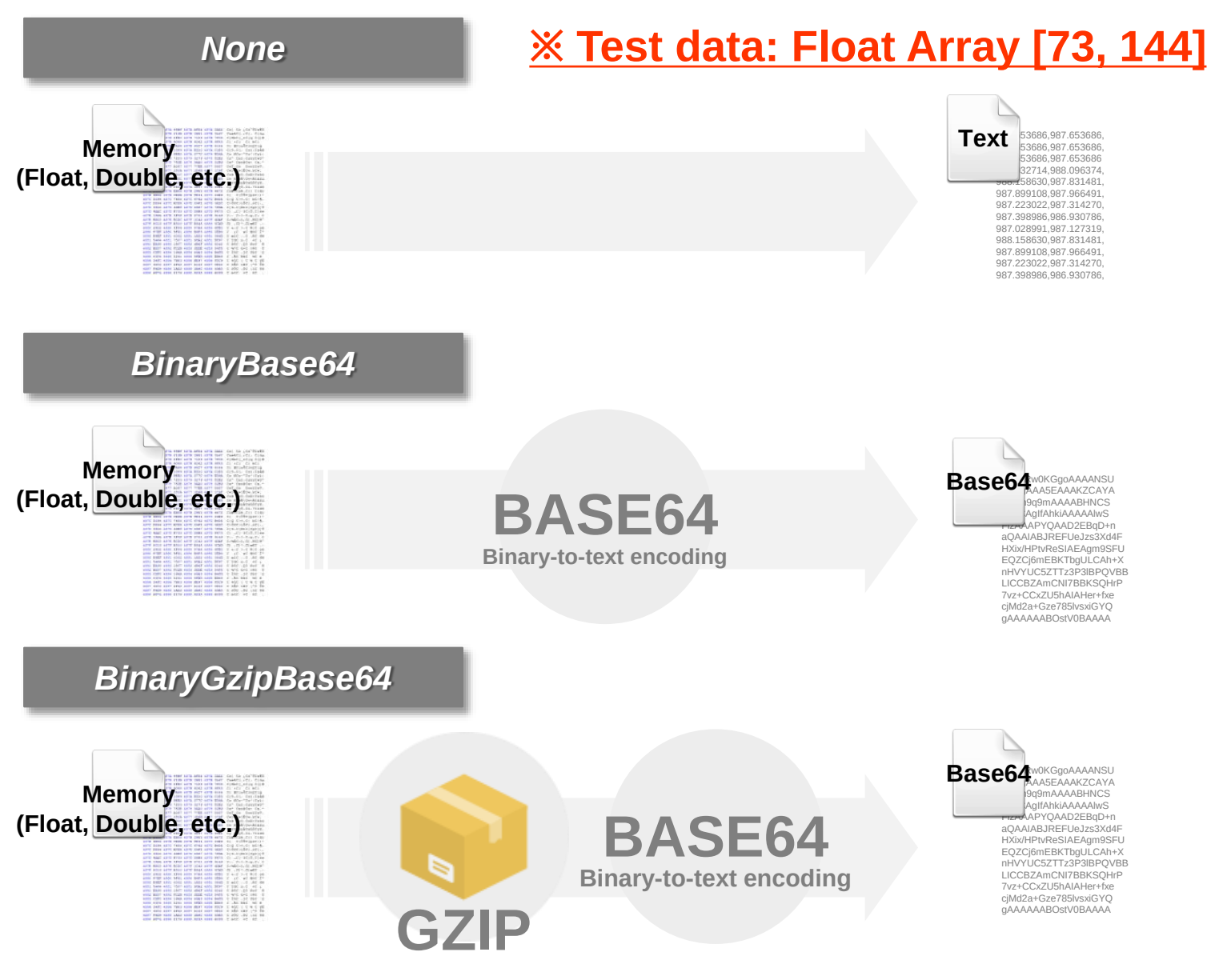
- **Plot option based on Matplotlib functions**



RESULTS

- **Comparison of data compression rates by grid data notation approaches**

※ Test data: Float Array [73, 144]



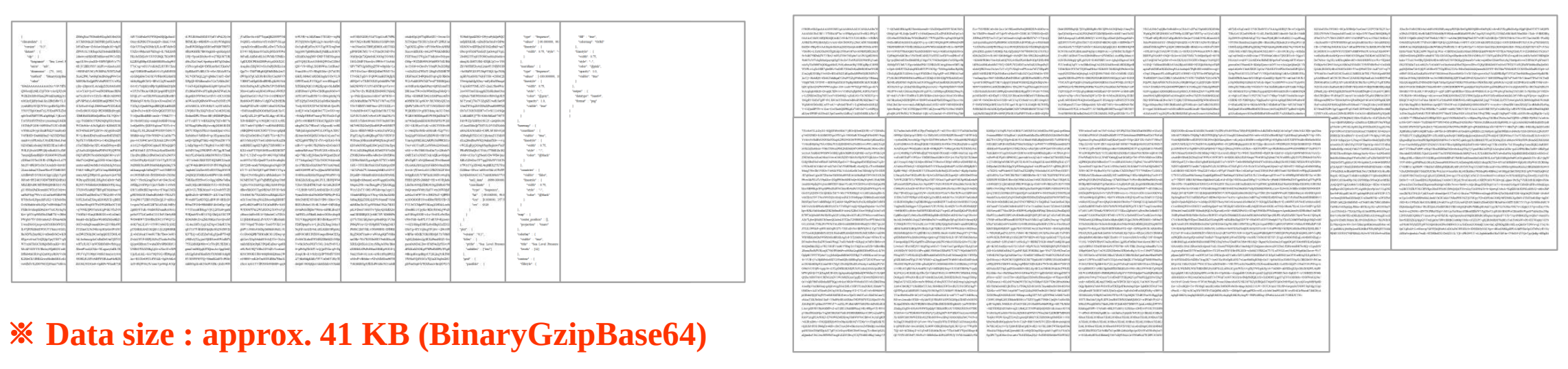
- Data size is decided by integer parts and decimal place value.
- Data Size: Approx. 95 KB (4th decimal place)

- Regardless of integer parts and decimal place value, data size is only decided by data type (float, double, etc.)
- Data Size: Approx. 56 KB

- Data size is smallest than above approaches because of data compressed by GZIP algorithm using binary data of data type (float, double, etc.)
- Data Size: Approx. 39 KB

- **Result of OGC WPS-based visualization service**

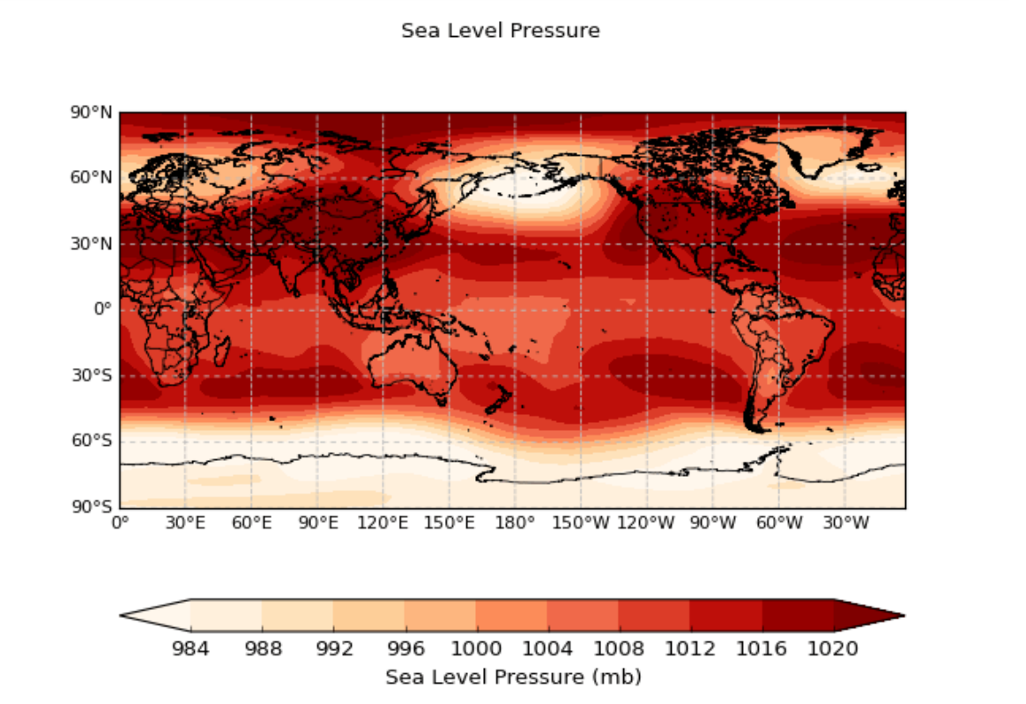
Request (gClimateJSON and plot option data)



※ Data size : approx. 41 KB (BinaryGzipBase64)

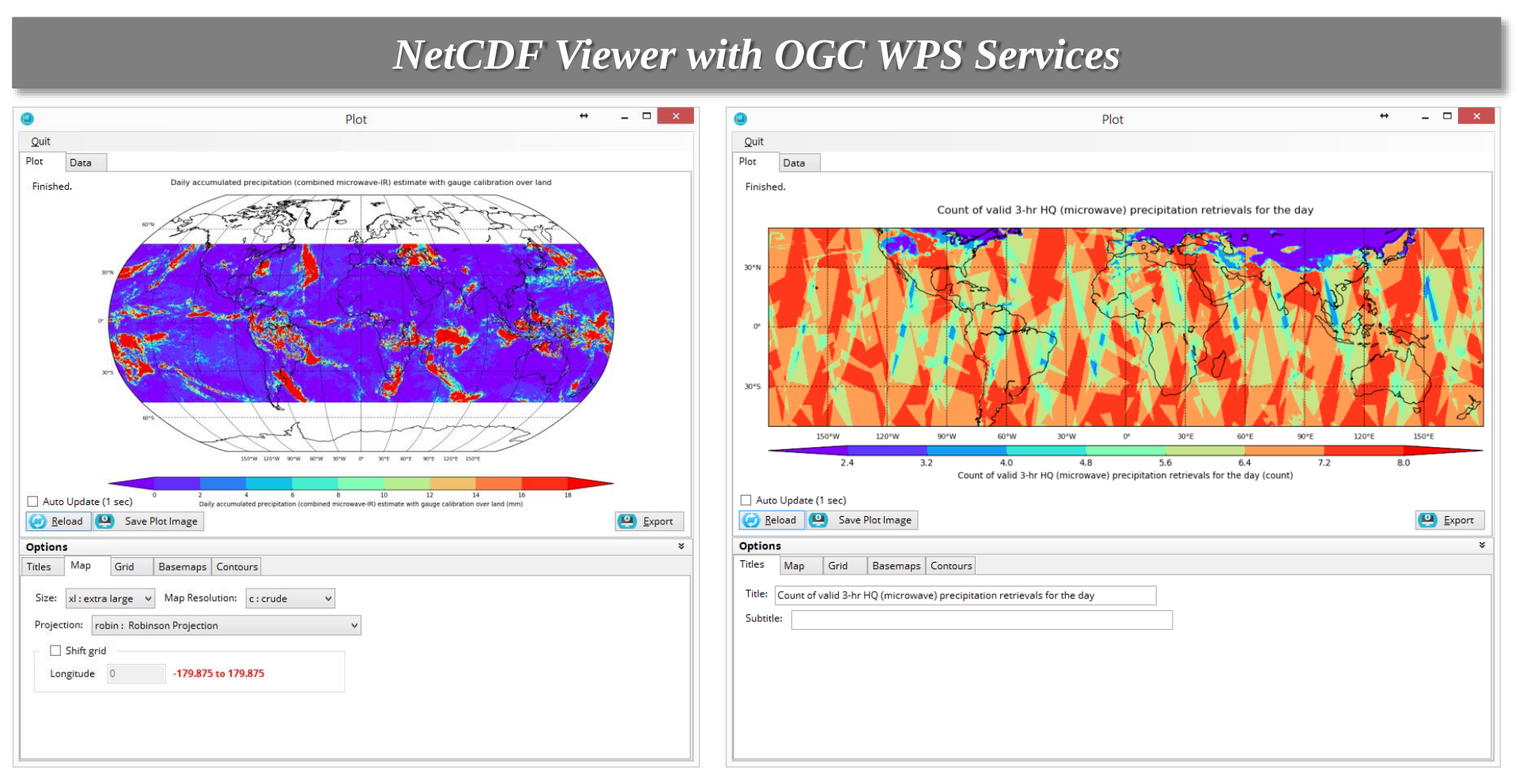
※ Data size : approx. 43 KB
(PNG image, 543 x 437, PNG Optimized-compression)
- Original data size: 107 KB (non-compression)

Result (png image)



- **Example of Windows Application using OGC WPS-based visualization service**

NetCDF Viewer with OGC WPS Services


Plot
Quit
Plot | Data
Finished.
Daily accumulated precipitation (combined microwave-IR) estimate with gauge calibration over land
☐ Auto Update (1 sec)
Reload | Save Plot Image | Export
Options
Titles | Map | Grid | Basemaps | Contours
Size: xl : extra large | Map Resolution: c : crude
Projection: robin : Robinson Projection
☐ Shift grid
Longitude 0 -179.875 to 179.875

Plot
Quit
Plot | Data
Finished.
Count of valid 3-hr HQ (microwave) precipitation retrievals for the day
☐ Auto Update (1 sec)
Reload | Save Plot Image | Export
Options
Titles | Map | Grid | Basemaps | Contours
Title: Count of valid 3-hr HQ (microwave) precipitation retrievals for the day
Subtitle:

- **Windows Application**
  - Programming Language: C#
  - Libraries: Scientific DataSet 1.3, APCC OGC.NET 0.1.0, APCC QFSciNetCDF.Net 0.1.0, SourceGrid 4.40, Fast Lightweight Expression Evaluator (flee) 0.9.26.0, ColorPicker Control, Json.NET 7.0.1
- **WPS Server**
  - OS: CentOS 6.5 x86_64
  - Web Server: Apache HTTP Server 2.4.12
  - Programming Language: Python 2.7.10
  - Libraries: PyWPS 4.0.0 beta-1, Matplotlib 1.5.0
  - * OGC WPS Operation Name: OpenWPS:CV_VisualizeNonSeries

CONCLUSION & REMARKS

- ❖ OGC WPS-based climate data visualization service was implemented using PyWPS and Maplotlib libraries for users (e.g. program developers) who are unfamiliar with climate data visualization
- ❖ The gClimateJSON exchange format with three grid data notation approaches (None, BinaryBase64, BinaryGzipBase64) was designed and suggested using BASE64 encoding and GZIP compression algorithm
- ❖ The suggested BinaryGzipBase64 notation approach was reduced by about 40 percent than None (written in pure text) approach
- ❖ The service can be provided on a low-bandwidth environment faster
- ❖ Also, users are able to take advantage of the data visualization, using scientific climate data, via the internet more easily and conveniently, making the service accessible to a larger range of users

FOSS4G BONN 2016

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