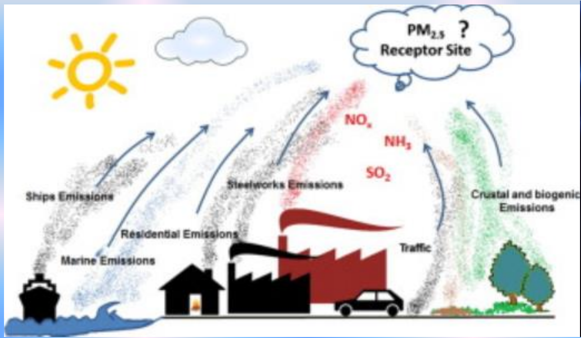
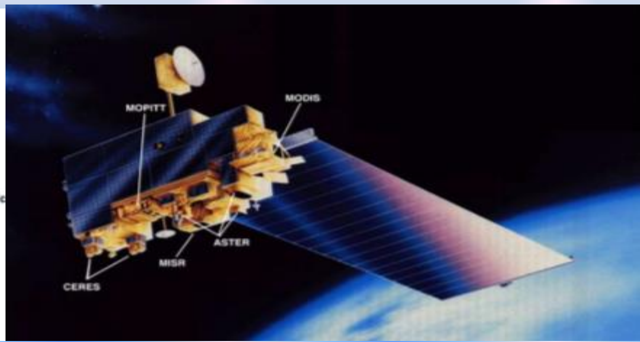
APN
ASIA-PACIFIC NETWORK FOR GLOBAL CHANGE RESEARCH

IESE

PROCEEDINGS

Training Workshops





“Applying PMF receptor model for $PM_{2.5}$ source appointment”

AND

“Processing MODIS AOD products for assessing biomass burning-related air pollution”

Hanoi, November 2021

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INTRODUCTION

These training workshops were parts of the activities under the research project "*Integrated Approach of In-situ Measurement, Modelling Techniques, and Advanced Satellite Remote Sensing for Mapping and Quantifying Contribution of Local and Regional Biomass Burning Sources to Air Pollution in Southeast Asian Countries*" (Project Reference Number: CRRP2019-11MY-Nguyen) which supported by the Asia Pacific Network for Global Change Research (APN). The training workshops were successfully organized with the mixed online and offline mode by the Institute of Environmental Science and Engineering (IESE), Vietnam in September and October, 2021.

The trainings aimed to provide the young and early-career scientists from the local agencies, academic and research institutions, professional associations, and private sector with the opportunities to develop their knowledge and skills with respect to applying the PMF receptor model for $PM_{2.5}$ source appointment and using MODIS AOD products for assessing biomass burning-related air pollution. The trainings not only enhanced the technical capacity and capability of the young and early-career scientists to apply the advanced technical tools in studying biomass burning and air pollution issues, but also provided the good opportunities for establishing the collaborative network among the participants for future researches, thus directly contributed to the APN Capacity Development Agenda.

BACKGROUND & RATIONALE

Southeast Asia (SEA) has been reported as one of the largest biomass burning source regions in the world. The regional haze known as "Asian Brown Cloud" resulting from biomass burning sources occurs almost every year in SEA, which has strong impacts on human health, environment, and global climate variations. In addition to biomass burning, the increased air pollution in the SEA countries has been also significantly influenced by a number of local emission sources such as transport, industry, construction, and long-range transported air pollutants from regional sources.

In order to provide strong evidences on the impacts of diverse sources (including biomass burning) to the local air quality for supporting policy- and decision-making activities in the SEA countries, there is a critical need to employ different technical tools for exploring and assessing the contribution of emission sources to the measured air quality. Among the useful tools commonly applied in air quality studies, the Positive Matrix Factorization (PMF) is a multivariate factor analysis technique used successfully among others at the US Environmental Protection Agency (US EPA) for the chemometric evaluation and modelling of air quality datasets. Meanwhile, the Moderate Resolution Imaging Spectroradiometers (MODIS) aboard U.S. National Aeronautics and Space Administration (NASA)'s Terra and Aqua satellites has been widely used as a cost-effective method to monitor the highly variable air pollution at both local and regional scales, which could complement the spatially limited coverage of traditional ground-based air quality monitoring stations and/or in-situ measurements. Despite of this, the application of these useful tools for air quality studies in the SEA countries has been limited due to the lack of technical capacity and capability. Therefore, it is necessary to develop and enhance the technical capacity and capability of scientists in the SEA countries, especially the young and early-career ones, for using those tools in air quality studies, towards providing the improved scientific evidences which needed for local and regional policy- and decision-making communities in developing effective policies and strategies for reducing air pollution in the region.

SUMMARY OF TRAINING WORKSHOPS

Training Workshop 1: "Applying PMF receptor model for $PM_{2.5}$ source appointment".

During the two-day training workshop (23-24 September 2021), the participants (mainly the young and early-career scientists from the local agencies, academic and research institutions, professional associations, and private sector) were provided with the knowledge and skills for applying PMF receptor model for $PM_{2.5}$ source appointment, including: preparing the input files required by PMF model and analysing the input data ($PM_{2.5}$ chemical data and uncertainty, plots); processing the model output files; handling the configuration file; initiating a base model run and analysing the base model results (residual analysis, observed/predicted scatter plot, observed/predicted time series, profiles/contributions, factor fingerprints, G-Space plot, factor contributions, base model displacement error, BS error, and BS-DISP error estimation, interpreting error estimate results); applying the rotational tools for advanced model run (Fpeak model run specification, constrained model operation); and model troubleshooting. The participants were trained on the job with "hands-on experience" using a real $PM_{2.5}$ datasets for the case of Hanoi City.

Training Workshop 2: "Processing MODIS AOD products for assessing biomass burning-related air pollution".

During the one-day training workshop (15 October 2021), the participants (mainly the young and early-career scientists from the local agencies, academic and research institutions, professional associations, and private sector) were provided with the basic knowledge and skills for processing MODIS AOD products for assessing biomass burning-related air pollution, including: how MODIS AOD (aerosol optical depth) products can be used for studying biomass burning-related air pollution; how to create a new user account, download, and process MODIS AOD products obtained from NASA website, and the software needed for processing the data; handling and processing the multi MODIS aerosol products with different resolutions using several algorithms (Dark Target, Deep Blue, and Dark Target Deep Blue Combined); using visualization tools (software and programming languages) to temporally and spatially interpret the MODIS AOD datasets. The participants were trained on the job with "hands-on experience" using a real MODIS AOD datasets for the case of Vietnam.

Key feedbacks from the participants through the two training workshops

- **Training Workshop 1:** the training materials were prepared with the understandable and detail information level for the trainee; the contents were well organised and focused on basic knowledge and practical skills for PMF base model run which appropriate to the capacity of the participants; the participants would need more real practices in order to master the rotational tools for advanced model run after the training.
- **Training Workshop 2:** the training materials were well prepared with the practical information which appropriate to the trainee for the step by step exercises in accessing, downloading, processing, and interpreting MODIS AOD datasets; there should be more similar trainings in the future on the topics of processing and using other parameters from MODIS satellite as well as datasets provided by the other satellites, that can be used in air quality studies.

ANNEXES

Annex 1: Workshop agenda

Annex 2: List of participants

Annex 3: Presentation of Training Workshop 1

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Annex 5: Training workshop photos

ANNEX 1: WORKSHOP AGENDA

Training Workshop 1: "Applying PMF receptor model for $PM_{2.5}$ source appointment" (23-24 September 2021)

Time	Contents
23 September 2021	
8h30 – 8h40	Opening & Welcome
8h40 – 9h00	Introduction of PMF model
9h00 – 10h15	Preparation of model input files and analysis of model input data
10h15 – 10h30	Break time
10h30 – 12h30	PMF base model run
12h30 – 13h30	Lunch break
13h30 – 14h30	Error estimation for PMF base model run
14h30 – 14h45	Break time
14h45 – 16h30	Exercises for PMF base model run
16h30 – 17h00	Q&A
24 September 2021	
8h30 – 10h15	Use of rotational tools for advanced model run
10h15 – 10h30	Break time
10h30 – 12h30	Troubleshooting; Q&A
12h30 – 13h30	Lunch break
13h30 – 15h30	Case study & Exercises for PMF model run
15h30 – 15h45	Break time
15h45 – 16h30	Discussions; feedbacks of the participants
16h30	Closing of the workshop

Training Workshop 2: "Processing MODIS AOD products for assessing biomass burning-related air pollution" (15 October 2021)

Time	Contents
8h30 – 8h40	Opening & Welcome
8h40 – 9h00	Introduction of MODIS AOD products used for air pollution studies
9h00 – 10h00	Creating user account & downloading MODIS AOD datasets
10h00 – 10h15	Break time
10h15 – 10h45	Resolution of MODIS AOD data & algorithms
10h45 – 12h30	MODIS AOD data processing
12h30 – 13h30	Lunch break
13h30 – 14h30	Data visualization tools
14h30 – 14h45	Break time
14h45 – 16h30	Assignment & exercises with a real MODIS AOD datasets
16h30 – 17h00	Discussions; feedbacks of the participants
17h00	Closing of the workshop

ANNEX 2: LIST OF PARTICIPANTS

No	Name of participant	Institution/Organization	Email
1	Phuc Nguyen Van	Vietnam Association of Civil Engineering Environment	phucnv088@gmail.com
2	Ha Le Thi Thanh	Faculty of Environmental Engineering, Hanoi University of Civil Engineering	haltt369@gmail.com
3	Thang Phan Viet	Vietnam Urban Environment and Industry Zone Association	pvthangmn@gmail.com
4	Hieu Pham Minh	Department of Remote Sensing	phamminhhieu0894@gmail.com
5	Hai Luong Ngoc	Faculty of Environmental Engineering, Hanoi University of Civil Engineering	hailuongngoc.386@gmail.com
6	Duc Pham Trung	Vietnam Urban Environment and Industry Zone Association	ptducbn83@gmail.com
7	Tu Tran Anh	Vietnam Association for Conservation of Nature and Environment	tuanhtran8289@gmail.com
8	Binh Hoang Van	Institute of Environmental Science and Engineering	binhhv278@gmail.com
9	Duong Nguyen Tien	Vietnam Association of Civil Engineering Environment	nguyenduong05.85@gmail.com
10	Hang Dang Thi	Vietnam Association for Conservation of Nature and Environment	danghang12391@gmail.com
11	Nuong Nguyen Thi	Institute of Environmental Science and Engineering	nuongnguyen1207@gmail.com
12	Anh Nguyen Tuan	Institute for Circular Economy and Urban Sustainability	anhtuannguyen2904@gmail.com
13	Thao Le Thu	Vietnam Association of Civil Engineering Environment	Le1thuthao@gmail.com
14	Thu Pham Minh	Research Group for Clean Air Solutions, Hanoi University of Civil Engineering	p.t.minh.thu03@gmail.com
15	Hung Tran Manh	Vietnam Environmental Agency	hung.tm.1387@gmail.com

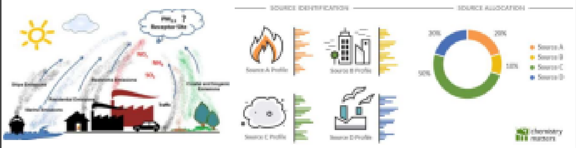
16	Duc Lai Hong	Institute of Environmental Science and Engineering	laihongduc33@gmail.com
17	Thao Do Thi	Institute of Environmental Science and Engineering	thao.thido1802@gmail.com
18	Khanh Nguyen Duy	Clean Air Technology Asia	khanhnd.0204@gmail.com
19	Dien Dang Dinh	Institute of Environmental Science and Engineering	dangdinhdien0283@gmail.com
20	Thanh Nguyen Sy	Faculty of Environmental Engineering, Hanoi University of Civil Engineering	thanhsynguyen3@gmail.com
21	Chinh Tran Van	Institute for Circular Economy and Urban Sustainability	chinhtv0709@gmail.com
22	Thai Pham Duy	Clean Air Technology Asia	pdthai2bn@gmail.com
23	Duc Luu Minh	Vietnam Urban Environment and Industry Zone Association	duclm02hn@gmail.com
24	Dat Nguyen Thanh	Institute of Environmental Science and Engineering	thanhdat.nguyen130491@gmail.com
25	Tu Dinh Quang	Research Group for Clean Air Solutions, Hanoi University of Civil Engineering	dinhqtu9207@gmail.com
26	Du Tran Huy	Clean Air Technology Asia	huydu.tran1812@gmail.com
27	Linh Nguyen Thi	Vietnam Association for Conservation of Nature and Environment	linhnt9707@gmail.com
28	Duy Tran Duc	Research Group for Clean Air Solutions, Hanoi University of Civil Engineering	duytranduc.1603@gmail.com
29	Vinh Ngo Ngoc	Institute for Circular Economy and Urban Sustainability	ngonv0794@gmail.com
30	Tuan Tran Anh	Vietnam Environmental Agency	tuantran03.83@gmail.com
31	Anh Nguyen Ngoc	Environmental Policy Institute	nguyenngocanhhn0995@gmail.com
32	Hien Lai The	Research Group for Clean Air Solutions, Hanoi University of Civil Engineering	hienlt.140597@gmail.com

ANNEX 3: PRESENTATION OF TRAINING WORKSHOP 1

Project "Integrated Approach of In-situ Measurement, Modeling Techniques, and Advanced Satellite Remote Sensing for Mapping and Quantifying Contribution of Local and Regional Biomass Burning Sources to Air Pollution in Southeast Asian Countries"

TRAINING WORKSHOP

Applying PMF receptor model for $PM_{2.5}$ source appointment



Hanoi, Sep 2021

Contents

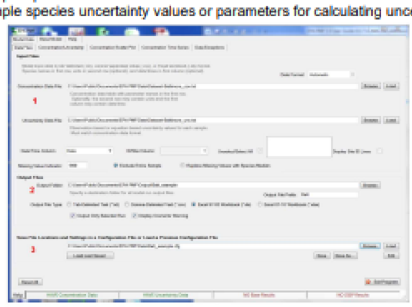
Positive Matrix Factorization (PMF)

- Multivariate (statistical) model
- Does not require comprehensive advance information on source compositions
- Incorporate time variation
- Non-negativity constraints (only non-negative factors)
- Rotation can be controlled by user
- Explicit least-squares approach to solving the factor analysis problem
- Individual data point weights
- Imposition of natural and other constraints, and
- Flexibility to build more complicated models
- On line information

I. GETTING STARTED

1. Input Files

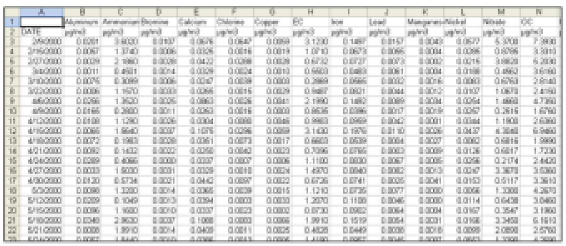
Two input files are required by PMF:
(1) sample species concentration values
(2) sample species uncertainty values or parameters for calculating uncertainty



Example of the Input Files screen.

Input Files (cont.)

Two input files are required by PMF:
(1) sample species concentration values
(2) sample species uncertainty values or parameters for calculating uncertainty



Example of formatting of the Input Concentration file.

Input Files (cont.)

Two input files are required by PMF:
(1) sample species concentration values
(2) sample species uncertainty values or parameters for calculating uncertainty

	A	B	C	D	E	F	G	H
1	unc	Aluminum	Ammoniu	Arsenic	Barium	Bromine	Calcium	Chlorine
2	2	0.00419	0.0525	0.00068	0.0068	0.0016	0.0038	0.002625
3	10	10	10	10	10	10	10	10
4								

Example of an equation-based uncertainty file.

$$Unc = \frac{5}{6} \times MDL$$

$$Unc = \sqrt{(Error\ Fraction \times concentration)^2 + (0.5 \times MDL)^2}$$

2. Output Files

The user can specify the output directory ("Output Folder"), choose the EPA PMF output file types ("Output File Type" radio buttons) and define a prefix for output files ("Output File Prefix").

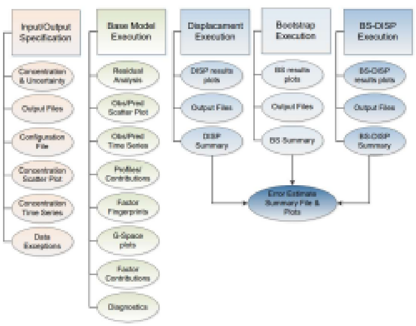
The "Output File Type" includes tab-delimited text (.txt), comma-separated variable (.csv), or Excel Workbook (.xls).

- ***_base.xls** – Profiles, Contributions, Residual, Run Comparison
- ***_diagnostics.xls** – Summary, Input, Base Runs

3. Configuration Files

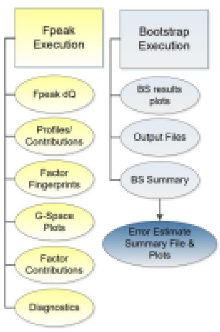
- The user must provide a name for a configuration file on the Input File Screen to create a configuration file.
- To choose a configuration file, the user can click on "Browse" to browse to the correct path or type in a path and name. The user can also press the "Load Last" button or simply press "Enter" on the keyboard to load the most recently used configuration file.
- The "Save" and "Save As" buttons can be used to save the current settings to an existing or new configuration file.

4. Suggested Order of Operations



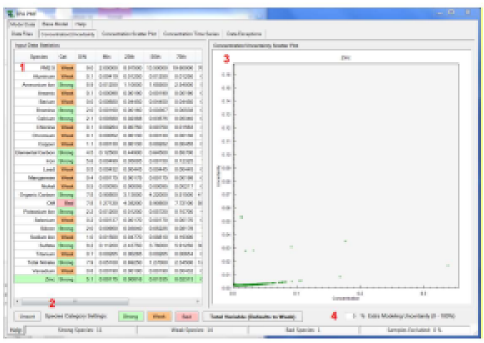
Flow chart of operations within EPA PMF – Base Model.

Suggested Order of Operations (cont.)



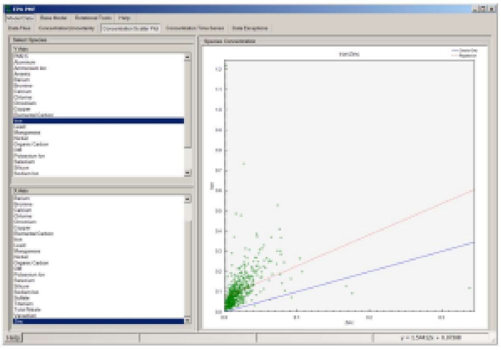
Flow chart of operations within EPA PMF – Fpeak.

5. Analyze Input Data: Concentration/Uncertainty



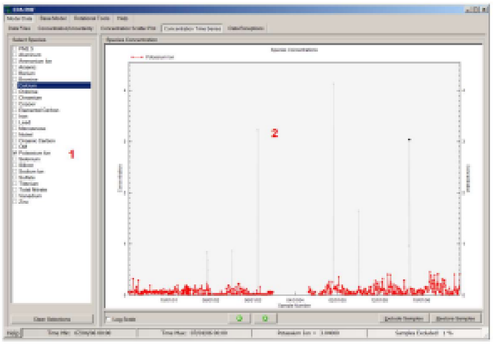
Example of the Concentration/Uncertainty screen.

5. Analyze Input Data: Concentration Scatter Plots



Example of a concentration scatter plot.

5. Analyze Input Data: Concentration Time Series

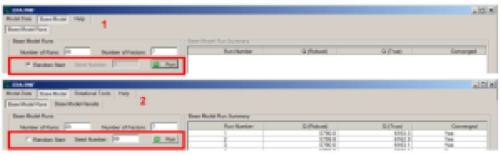


Example of the Concentration Time Series screen with excluded and selected samples.

6. Base Model Runs: Initiating a Base Run

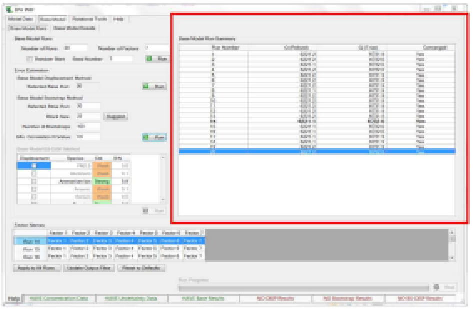
The following parameters need to be specified:

- "Number of Runs" – the number of base runs to be performed; this number must be an integer between 1 and 999. The recommended number of runs is 20, which will allow for an evaluation of the variation in Q.
- "Number of Factors" – the number of factors the model should fit; this number must be an integer between 1 and 999. The number of factors to be chosen will depend on the user's understanding of the sources impacting samples, number of samples, sampling time resolution, and species characteristics.
- "Seed" – the starting point for each iteration in ME-2; the default is Random Start, which tells the GUI to randomly choose a starting point for each run.



Example of the Base Model Runs screen showing Random Start (1) and Fixed Start (2).

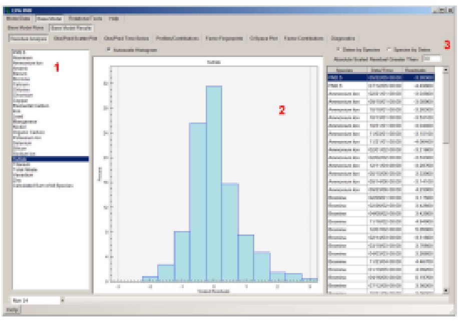
6. Base Model Runs: Base Model Run Summary



Example of the Base Model Runs screen after base runs have been completed.

6. Base Model Runs: Base Model Results

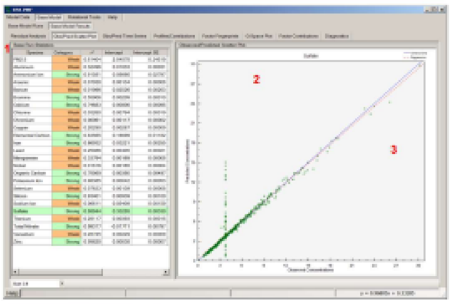
Residual Analysis



Example of the Residual Analysis screen.

Base Model Runs: Base Model Results

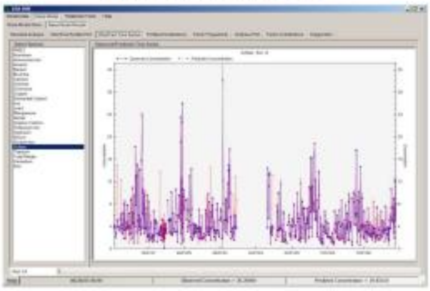
Observed/Predicted Scatter Plot



Example of the Obs/Pred Scatter Plot screen.

Base Model Runs: Base Model Results

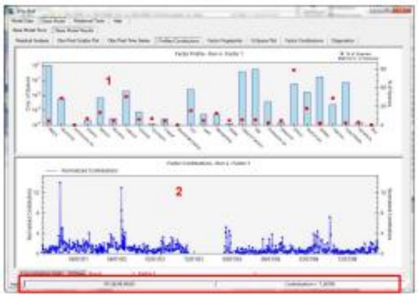
Observed/Predicted Time Series



Example of the Obs/Pred Time Series screen.

Base Model Runs: Base Model Results

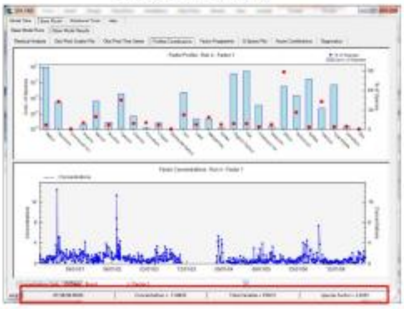
Profiles/Contributions



Example of the Profiles/Contributions screen.

Base Model Runs: Base Model Results

Profiles/Contributions



Example of the Profiles/Contributions screen with "Concentration Units" selected.

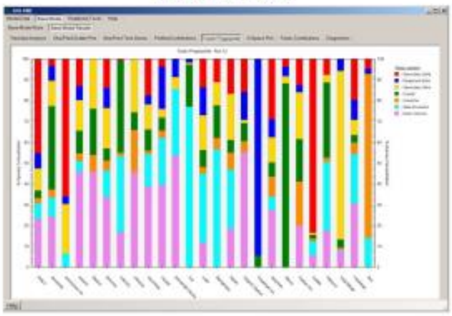
Base Model Runs: Base Model Results

Profiles/Contributions

Example of the Profiles/Contributions screen with "Q/Qexp" selected.

Base Model Runs: Base Model Results

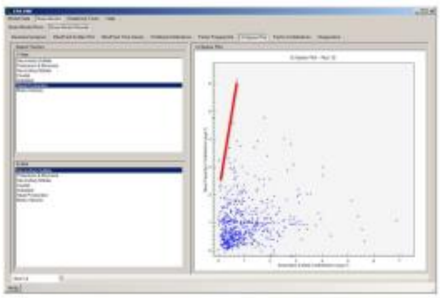
Factor Fingerprints



Example of the Factor Fingerprints screen.

Base Model Runs: Base Model Results

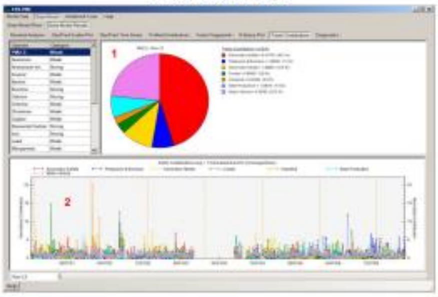
G-Space Plot



Example of the G-Space Plot screen with a red line indicating an edge.

Base Model Runs: Base Model Results

Factor Contributions



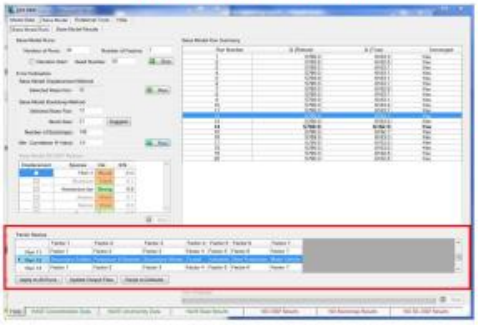
Example of the Factor Contributions screen.

Base Model Runs: Base Model Results

Output Files

- *_diag contains a record of the user inputs and model diagnostic information (identical to the Diagnostics screen).
- *_contrib contains the contributions for each base run used to generate the contribution graphs on the Profiles/Contributions tab. Contributions are sorted by run number. Normalized contributions are shown first, followed by contributions in mass units if a total variable is specified.
- *_profile contains the profiles for each base run used to generate the profile graphs on the Profiles/Contributions tab. Profiles are sorted by run number. Profiles in mass units are written first, followed by profiles in percent of species and concentration fraction of species total if a total mass variable is specified.
- *_resid contains the residuals (regular and scaled by the uncertainty) for each base run, used to generate the graphs and tables on the Residual Analysis screen.
- *_run_comparison contains a summary of the species distribution for each factor over all PMF runs and compared to the lowest Q(robust) run.
- *_base contains the *_contrib, *_profile, *_resid and *_run_comparison on separate worksheets in the same Excel Workbook. This output file only appears if the user selects "Excel Workbook" as the output file type.

6. Base Model Runs: Factor Names on Base Model Runs Screen

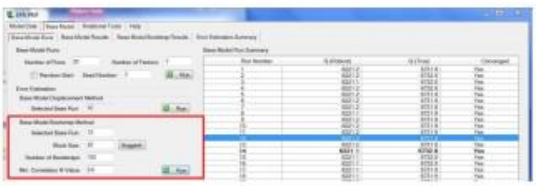


Example of the Base Model Runs screen with default base model run factor names.

7. Base Model Displacement Error Estimation

Example of the Base Model Displacement Summary screen.

8. Base Model BS Error Estimation



Example of the Base Model Runs screen highlighting the Base Model Bootstrap Method box

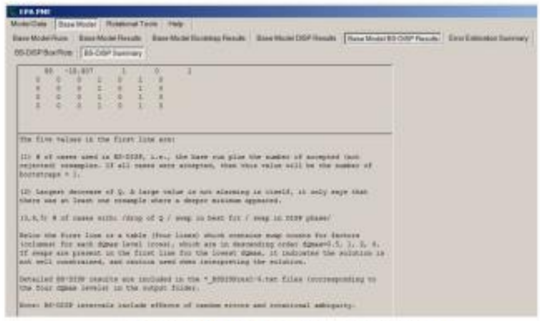
Base Model BS Error Estimation: Summary of BS Runs

Example of the Base Bootstrap Summary screen

Base Model BS Error Estimation: Base Bootstrap Box Plots

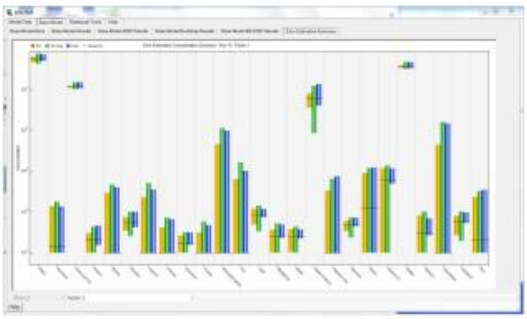
Example of the Base Bootstrap Box Plots screen

9. Base Model BS-DISP Error Estimation



Example of the Base Model BS-DISP Summary screen

10. Interpreting Error Estimate Results



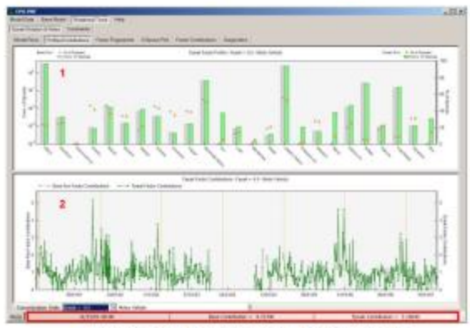
Error estimation summary plot

II. ROTATIONAL TOOLS

1. Fpeak Model Run Specification

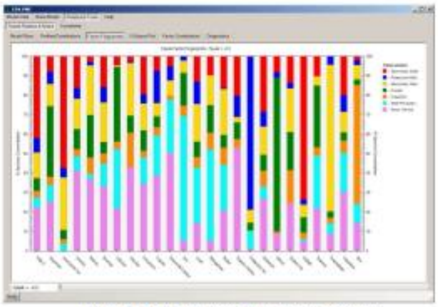
Example of the Fpeak Model Run Summary in the Fpeak Model Runs screen

1. Fpeak Model Run Specification: Fpeak Results



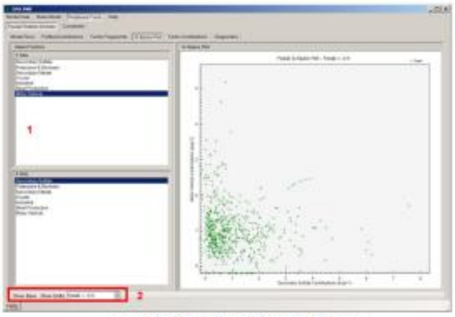
Example of the Fpeak Profiles/Contributions screen

1. Fpeak Model Run Specification: Fpeak Factor Fingerprints



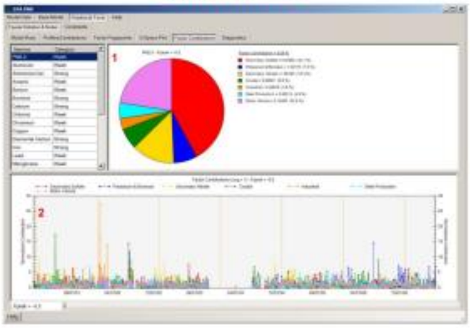
Example of the Fpeak Factor Fingerprints screen

1. Fpeak Model Run Specification: Fpeak G-Space Plot



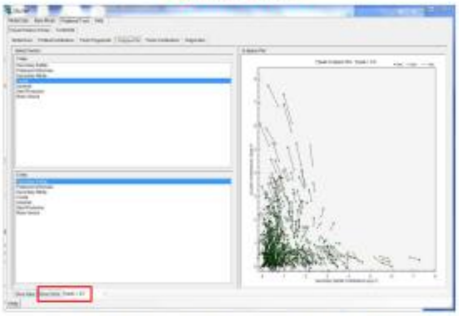
Example of the Fpeak G-Space Plot screen

1. Fpeak Model Run Specification: Fpeak Factor Contributions



Example of the Fpeak Factor Contributions screen

1. Fpeak Model Run Specification: Evaluating Fpeak Results



G-Space plot and delta between the base run contribution and Fpeak run contribution for each contribution point

2. Constrained Model Operation: Constrained Model Run Specification

Expression Builder – Ratio

2. Constrained Model Operation: Constrained Model Run Specification

Expression Builder – Mass Balance

2. Constrained Model Operation: Constrained Model Run Specification

Expression Builder – Custom

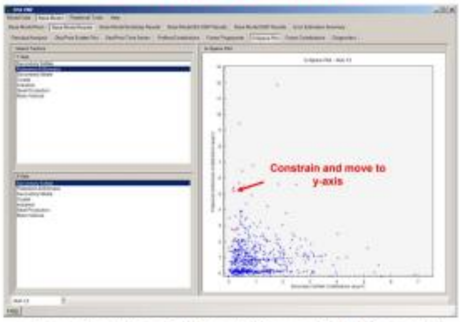
2. Constrained Model Operation: Constrained Model Run Specification

Example of expressions on the Constrained Model Runs screen

2. Constrained Model Operation: Constrained Model Run Specification

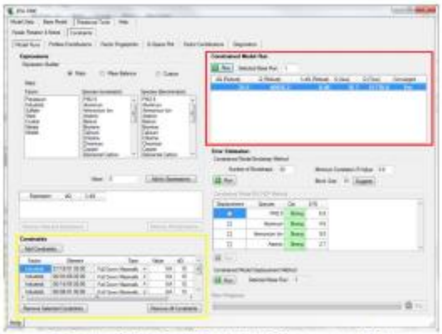
Selecting constrained species and observations

2. Constrained Model Operation: Constrained Model Run Specification



Example of selecting points to pull to the y-axis in the G-space plot

2. Constrained Model Operation: Constrained Model Run Specification

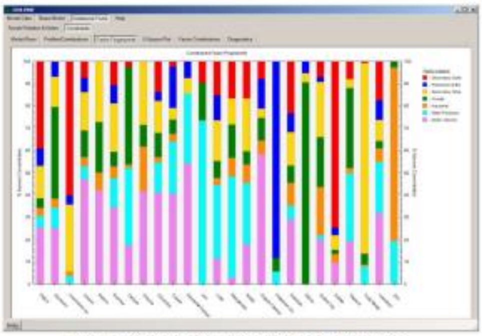


Example of the Constrained Model Run summary table

2. Constrained Model Operation: Constrained Profiles/Contribution Results

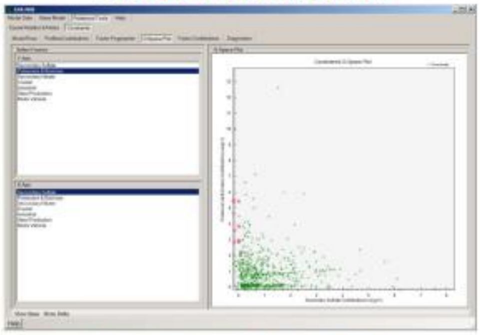
Example of the Constrained Profiles/Contributions screen

2. Constrained Model Operation: Constrained Profiles/Contribution Results



Example of the Constrained Factor Fingerprints screen

2. Constrained Model Operation: Constrained Profiles/Contribution Results

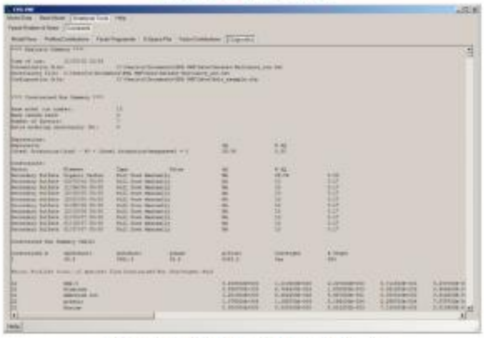


Example of the Constrained G-Space Plot screen

2. Constrained Model Operation: Constrained Profiles/Contribution Results

Example of the Constrained Factor Contributions screen

2. Constrained Model Operation: Evaluating Constraints Results



Example of the Constrained Diagnostics screen

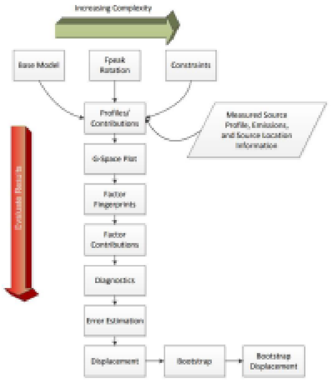
III. TROUBLESHOOTING

Common problems in EPA PMF 5.0

Problem	Error Message	Action
Cannot run base runs.	Access to the path 'C:\Program Files\EPA PMF 5.0\PMFData.txt' is denied. Please close all output files.	Turn off User Access Controls in Microsoft Vista
Column headers of concentration and uncertainty files do not match	Species names in uncertainty file do not match those in concentration file. Do you wish to continue?	If the names are correct, continue. If the columns are in a different order, correct and retry.
Number of columns in concentration file is not the same as in uncertainty file	Number of species in uncertainty file does not match the number of species in concentration file.	Select "OK" and examine input files. The same number of columns, in the same order, should be included in the concentration and uncertainty files. If named ranges are used, check that the ranges are defined correctly.
Number of rows in concentration file is not the same as in uncertainty file	Dates/times in uncertainty file do not match those in concentration file.	Select "OK" and examine input files. The same number of rows, sorted by the date/time, should be included in the concentration and uncertainty files. If named ranges are used, check that the ranges are defined correctly.
Blank cells are included in concentration file	Empty cells are not permitted in the concentration input file. Please check your data file.	Select "OK" and remove blank cells from input file before trying again.
Blank cells, zero values, or negative values are included in uncertainty file	Null, zero, and negative uncertainty values are not permitted. Please check your data file.	Select "OK" and remove inappropriate cells from input file before trying again.
Cannot save output files because one is open	The process cannot access the file 'file path and name' because it is being used by another process. Please close all output files.	Close file and select "Retry" or select "Cancel" to change the file path and name.

IV. TRAINING EXERCISES

PMF results evaluation process



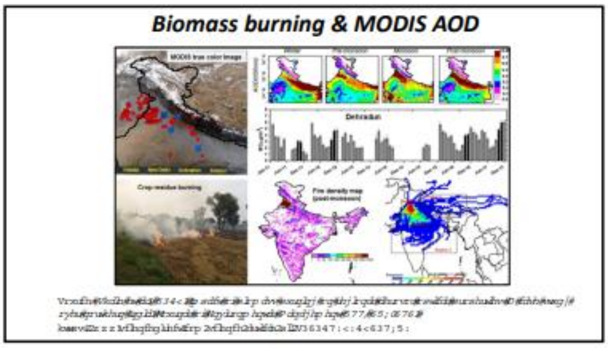
References

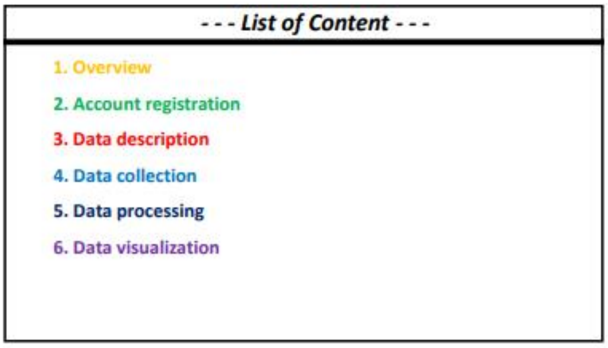
- **USEPA, 2014. EPA Positive Matrix Factorization (PMF) 5.0 Fundamentals and User Guide**

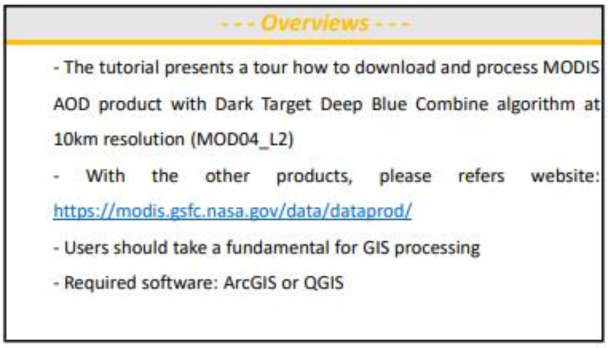
Q & A

Assignment & Practices

ANNEX 4: PRESENTATION OF TRAINING WORKSHOP 2

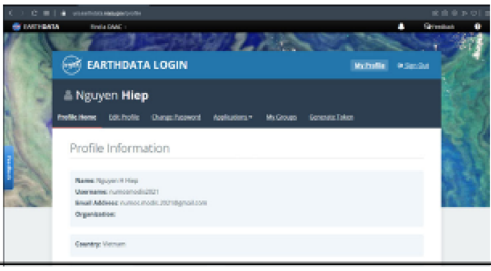






Account registration (cont.)

1. Check and modify the personal profile (optional)



- - - Data description - - -

MODIS Aerosol product is provided with three types of resolution including:

(1) Coarse-resolution : 10km (MOD04_L2 and MYD04_L2)

(2) Medium resolution : 3km (MOD04_3K and MYD04_3K)

(3) Fine resolution : 1km (MCD19A2)

Data description (cont.)

Several algorithms used to estimate the Aerosol Optical Depth (AODs) including:

(1) Dark Target

(2) Deep Blue

(3) Dark Target and Deep Blue Combined

Data description (cont.)

In addition, MODIS AOD products provides other parameters depending on each product. For instance:

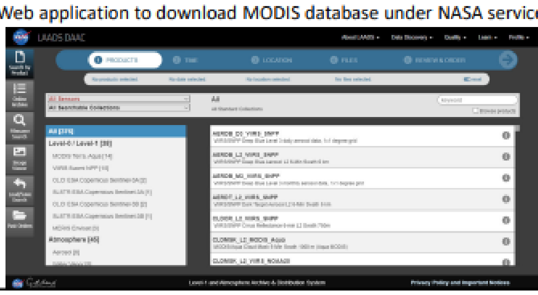
- MOD04_L2 and MYD04_L2 provide the AODs loading with three algorithm
- MOD04_3K and MYD04_3K provide the AODs loading with only Dark Target algorithm
- MCD19A2 provide AODs loading with two band (470nm and 550nm)

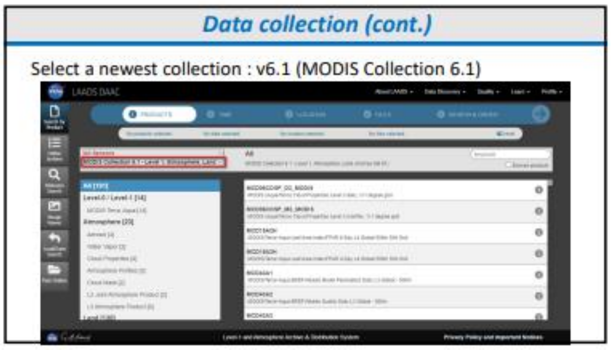
- - - Data collection - - -

1. Access a link : https://ladsweb.modaps.eosdis.nasa.gov/search/
2. Select the product collections with multi versions (v5, v6, v6.1)
3. Select the type of sensor (MOD/Terra or MYD/Aqua)
4. Select the MODIS AOD product
5. Select the time period
6. Select the area
7. Download the MODIS AOD product

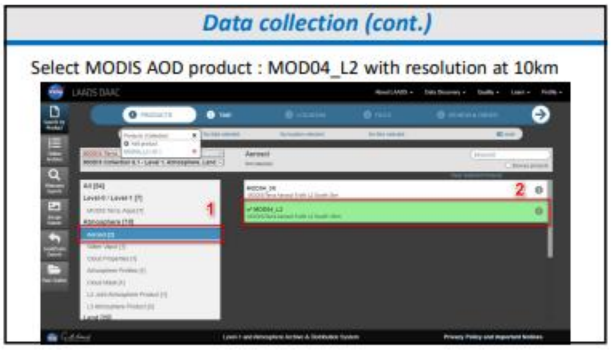
Data collection (cont.)

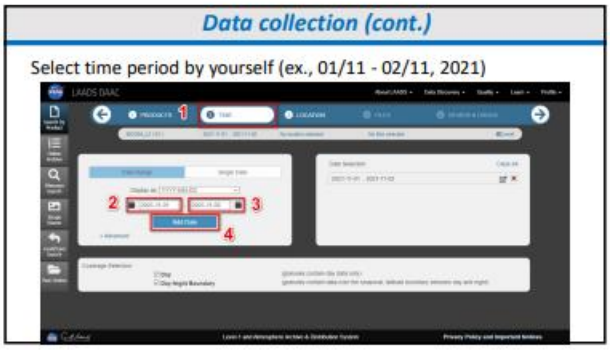
Web application to download MODIS database under NASA service

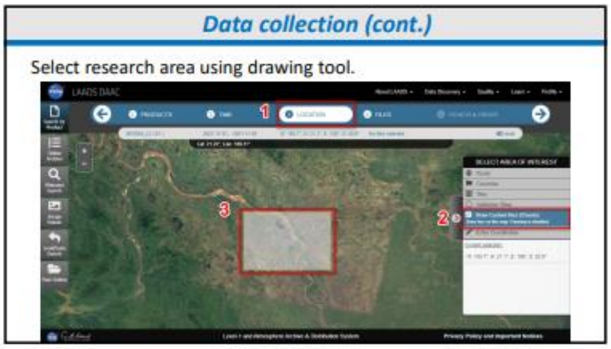


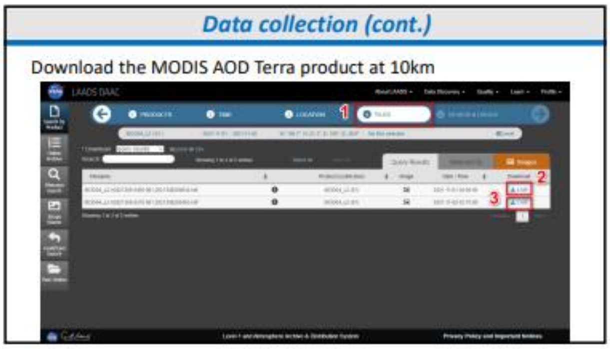

Data collection (cont.)
Select a newest collection : v6.1 (MODIS Collection 6.1)


Data collection (cont.)
Select the Terra sensor (MODIS: Terra)


Data collection (cont.)
Select MODIS AOD product : MOD04_L2 with resolution at 10km

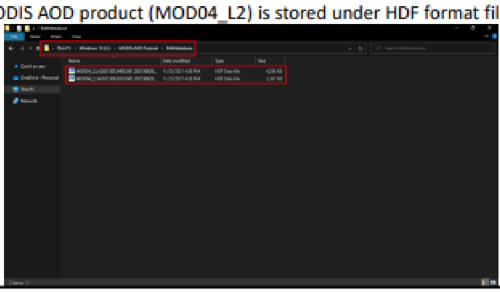

Data collection (cont.)
Select time period by yourself (ex., 01/11 - 02/11, 2021)


Data collection (cont.)
Select research area using drawing tool.


Data collection (cont.)
Download the MODIS AOD Terra product at 10km

Data collection (cont.)

MODIS AOD product (MOD04_L2) is stored under HDF format files

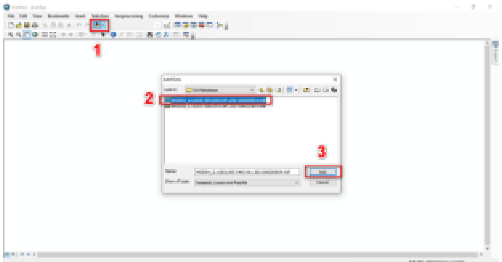


- - - Data processing - - -

1. Extract the Aerosol Optical Depth (AODs) value
2. Extract the Quality Flag for each pixel
3. Store the database under CSV format and RASTER format
4. Calculate the AODs value at a specific location (eg., Hanoi)

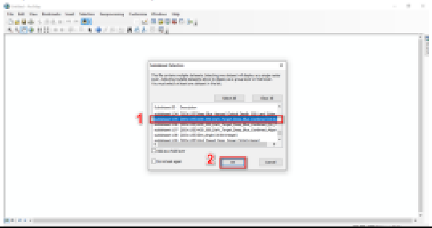
Data processing (cont.)

Import the HDF file into ArcGIS software with any version (9.x or 10.x)



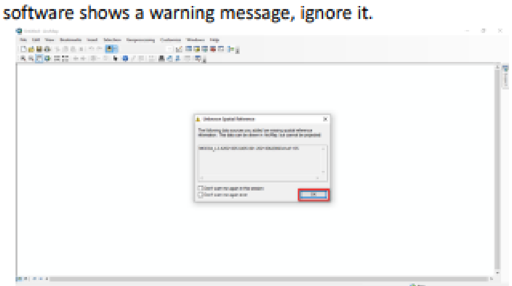
Data processing (cont.)

Select the type of dataset : AOD 550nm Dark Target Dark Blue Combine (subdataset 135)



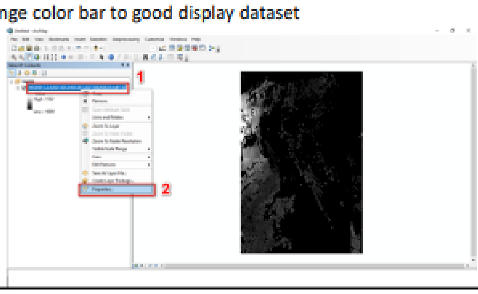
Data processing (cont.)

If software shows a warning message, ignore it.



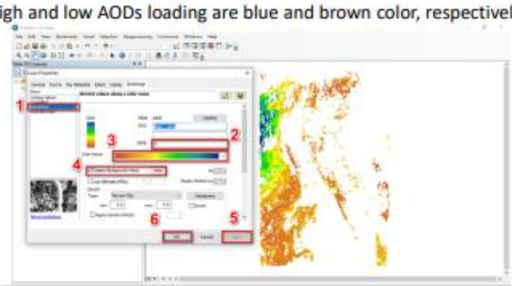
Data processing (cont.)

Change color bar to good display dataset



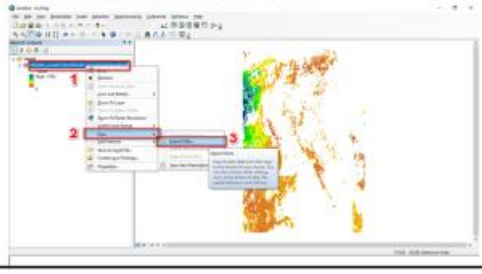
Data processing (cont.)

High and low AODs loading are blue and brown color, respectively



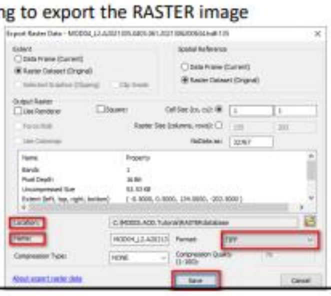
Data processing (cont.)

Extract the database under RASTER format



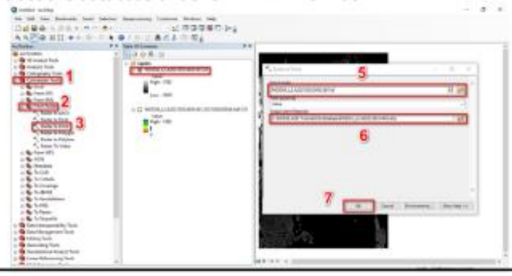
Data processing (cont.)

Add the setting to export the RASTER image



Data processing (cont.)

Extract the database under SHAPEFILE format



- - - Data visualization - - -

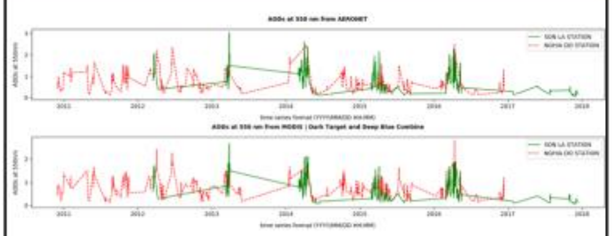
Several software and programming language can present the MODIS AODs product :

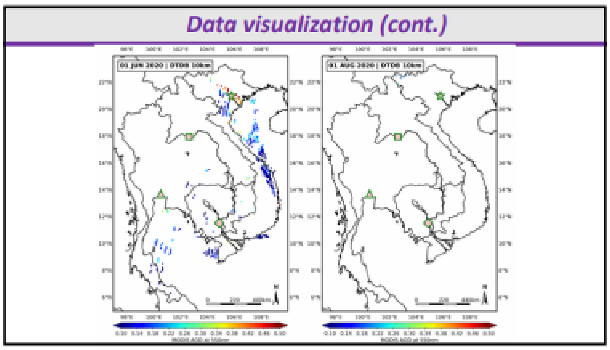
(1) Software : Techplot, Paraview, HDFview

(2) Programming language :

- Python using package seaborn, geopandas
- R using package ggplot2,
- MATLAB, Javascript, Julia

Data visualization (cont.)

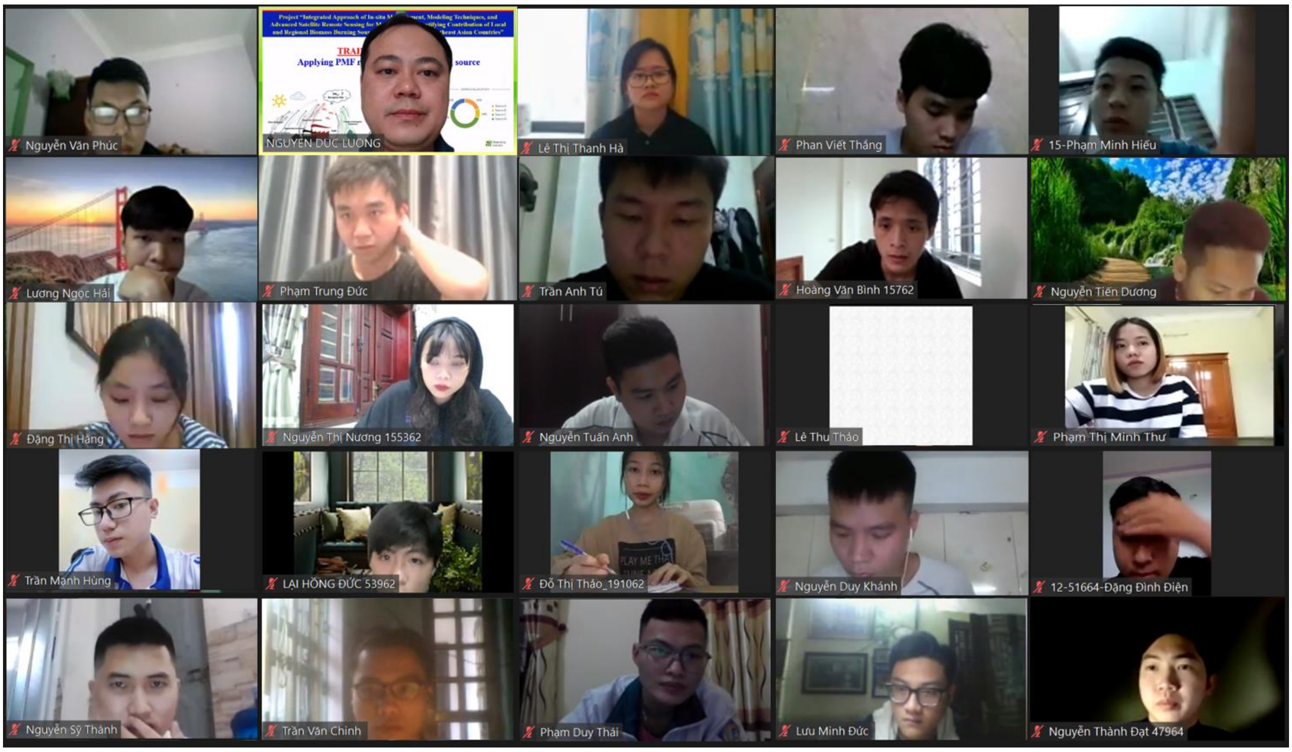




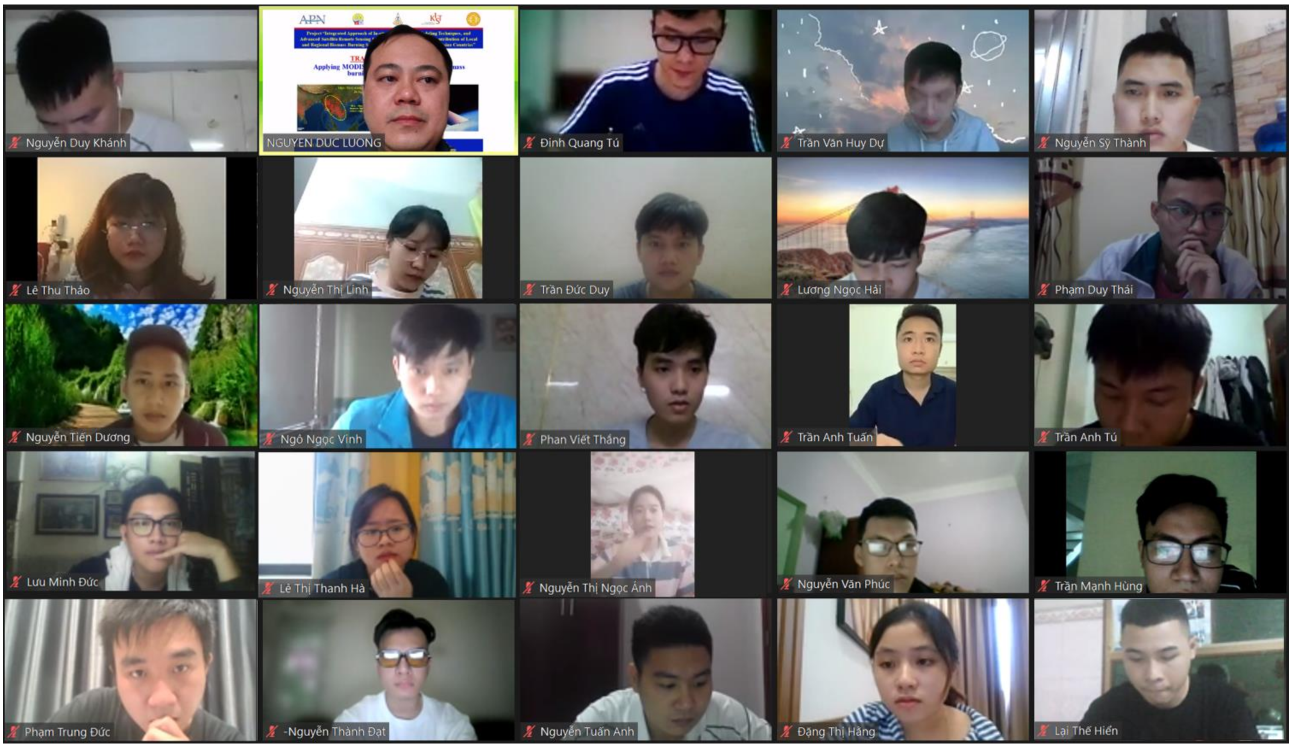
Q & A

Assignment & Practices

ANNEX 5:
TRAINING WORKSHOP PHOTOS



Training Workshop 1: Applying PMF receptor model for $PM_{2.5}$ source appointment



Training Workshop 2: Processing MODIS AOD products for assessing biomass burning-related air pollution