The Transport of Air Pollutants in Asia: A Report on Thailand Air Quality Modelling Effort

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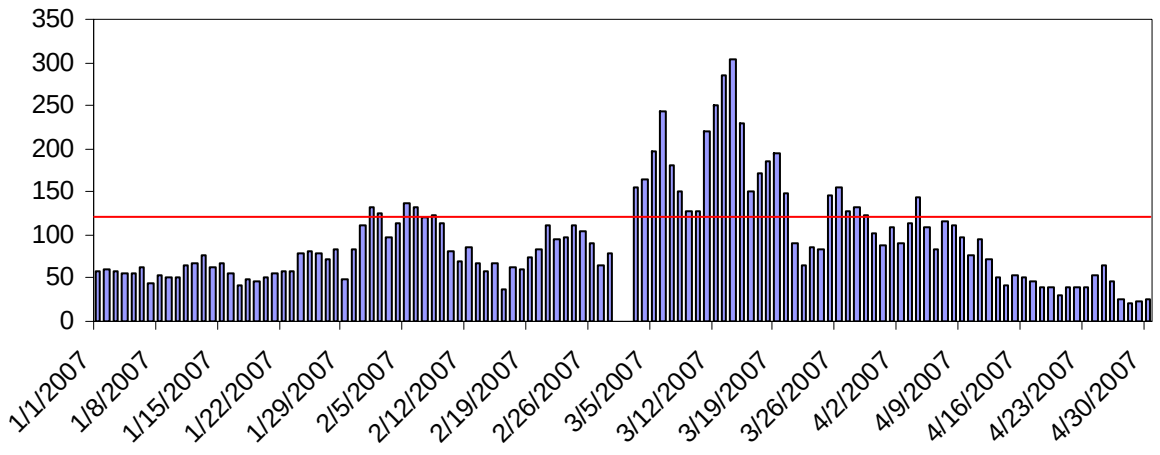
I.March-2007 Haze Problem in UNR

- Valleys: Chiang Mai (economic center), Lamphun, Lampang, etc.
- Haze started to pick up around late Feb. and peaked during Mar.
- Elevated PM10 exceeded national standard (120 ug/m3, 24-hr average)
- For example, at a monitoring station in Chiang Mai
  - 284 ug/m3 on Mar. 13
  - 304 ug/m3 on Mar. 14
- Greatly affect people in region (indoor stay, hospitalization, and commuting), transportation, and tourism

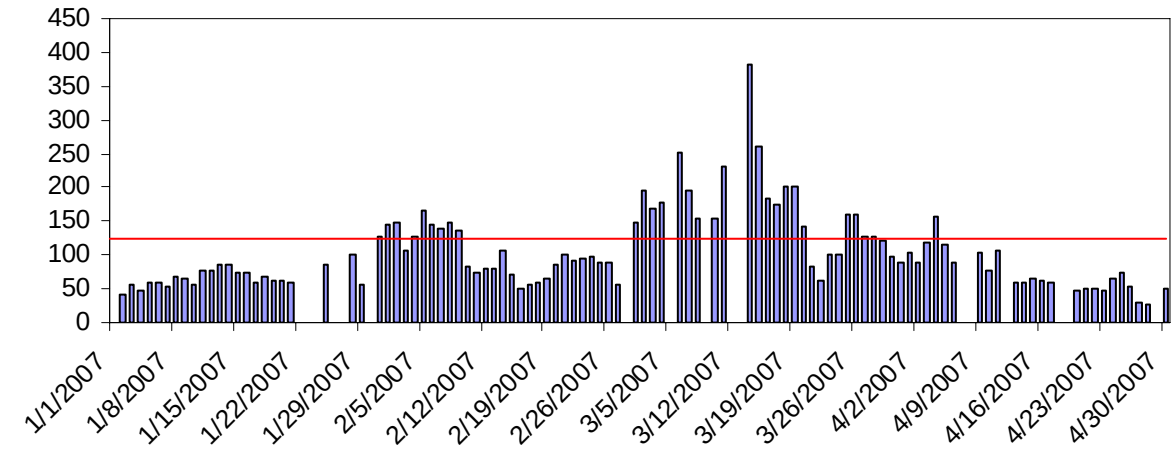
Daily PM10, Government Center, Chiang Mai



PM10 National Standard

120 ug/m3 (24-hr Average)

Daily PM10, Yuparaj Wittayalai, Chiang Mai



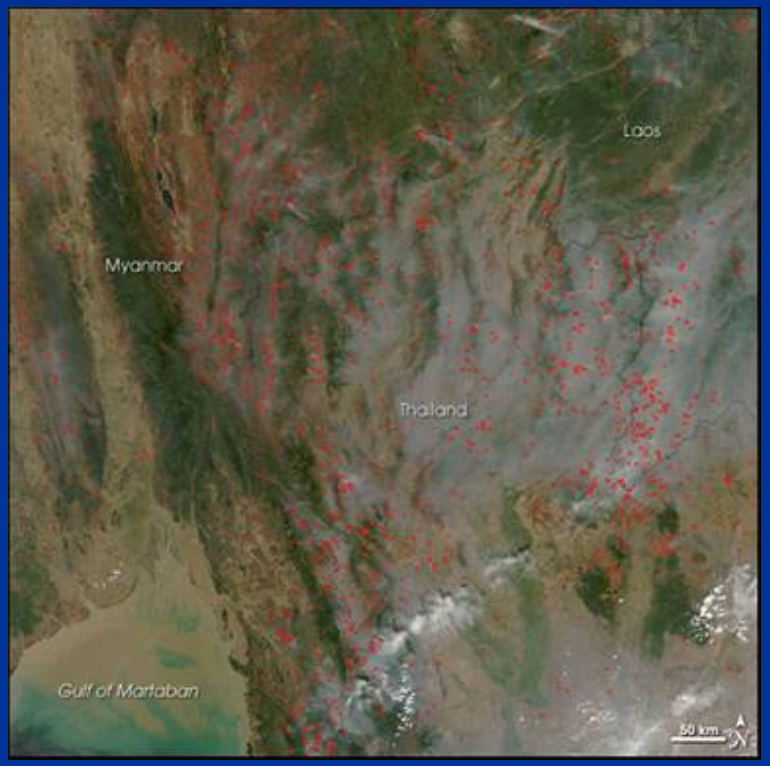
PM10 National Standard

120 ug/m3 (24-hr Average)

Source: www.pcd.go.th

Fire Detection by Satellites

- **Sensor: MODIS (MOderate Resolution Imaging Spectrometer)**
- **Hosting Satellites: Earth observation “TERRA” and “AQUA” of NASA**



MODIS-AQUA on Mar. 4, 07

MODIS-AQUA on Mar. 13, 07

earthobservatory.nasa.gov/NaturalHazards

Photos from News

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AP

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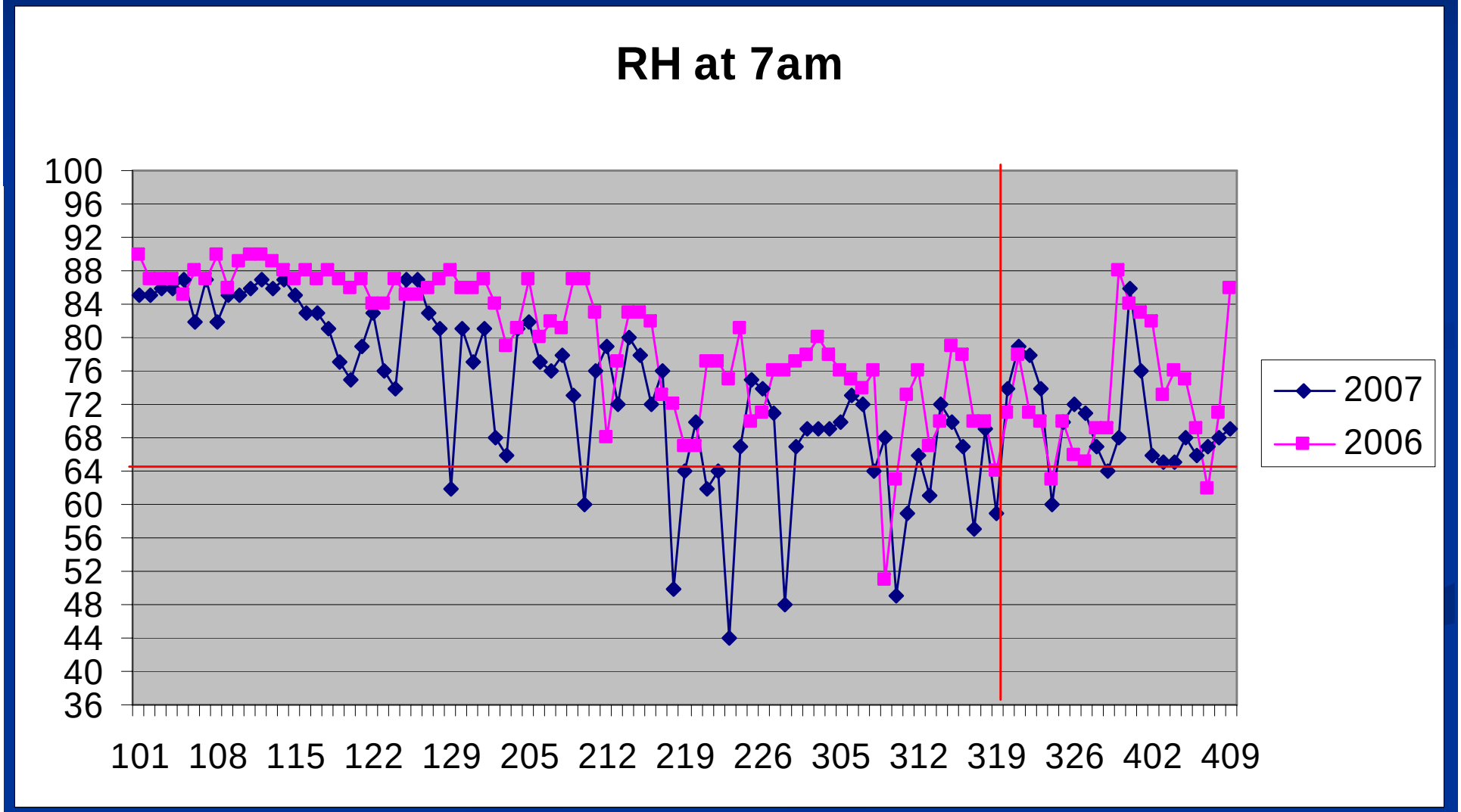
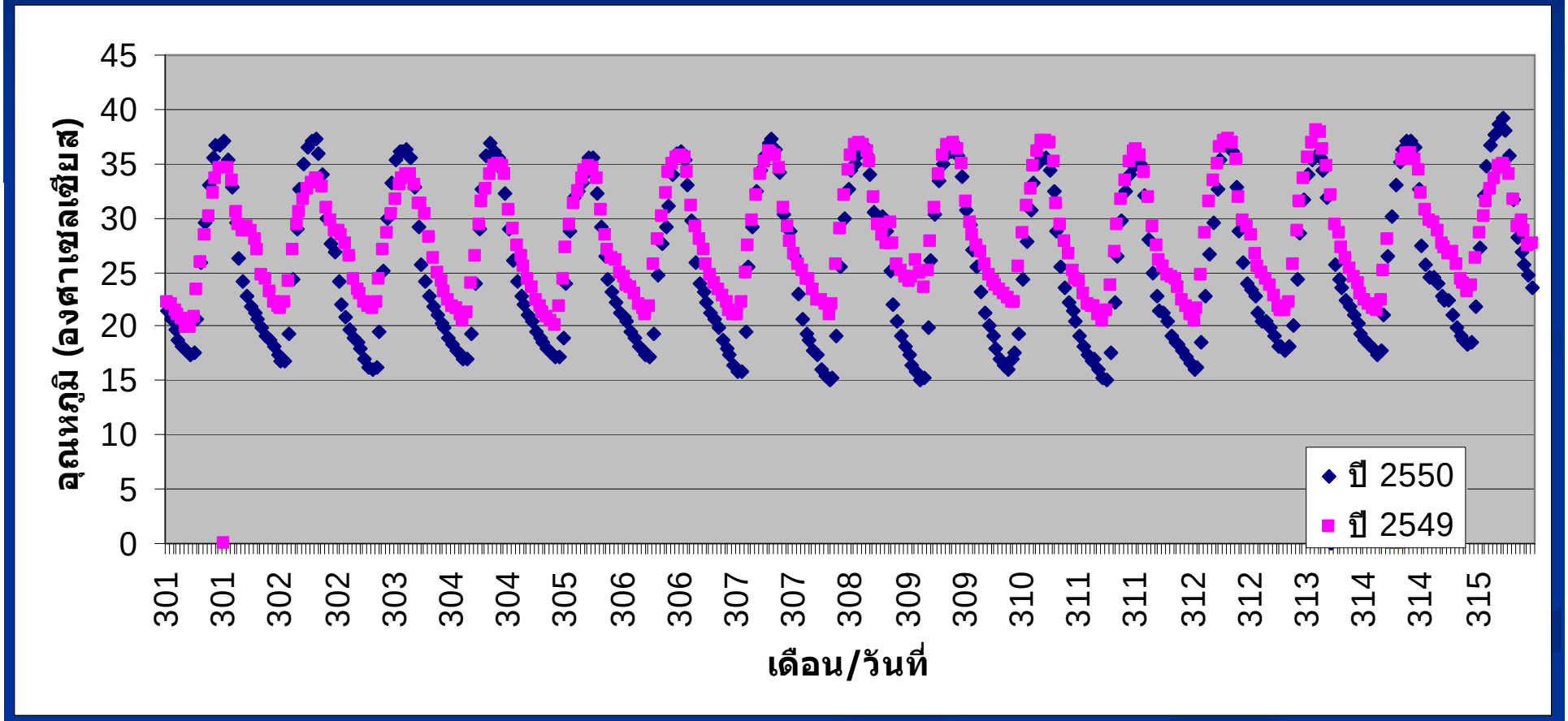
March-2007 Haze Problem in UNR

- **March: In annual drought + fire + harvest/post-harvest season**
- **Haze started to pick up around late Feb. and peaked during Mar.**
- **Elevated PM10 exceeded national standard (120 ug/m3, daily-average)**
- **Greatly affect people in region (outdoor limit, hospitalization, and commuting), transportation, and tourism**
- **Receive tremendous attention from general public and governmental and private sectors**

Meteorological factors during the Haze episode: Relative Humidity



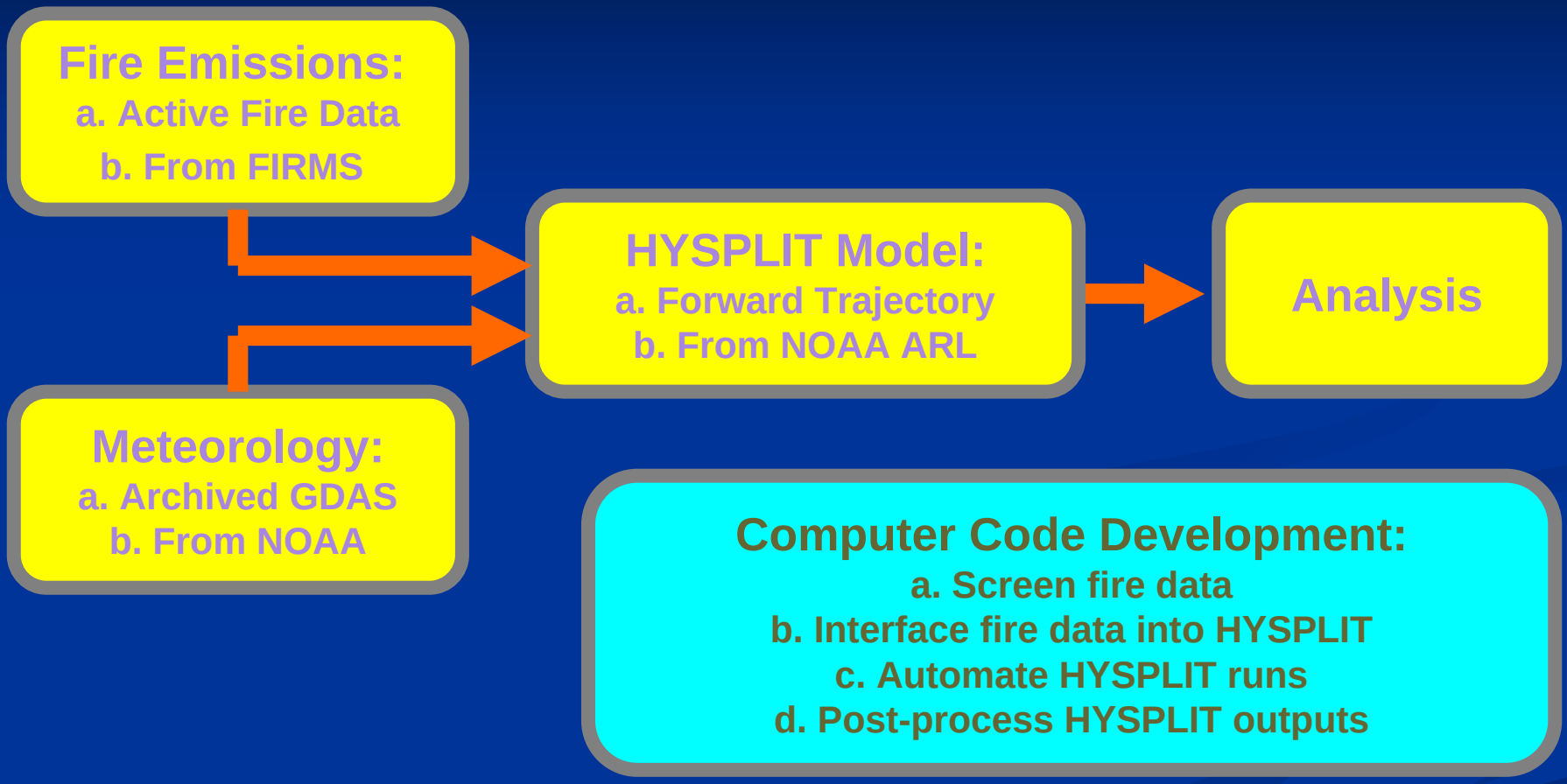
Meteorological factors during the Haze episode: Temperatures



How fire emissions in UNR and regions nearby contribute to UNR haze problem using a modelling technique

- March-2007 UNR haze pollution presents a very complex problem
- Many key factors involved:
  - Fire emissions and other emissions
  - UNR & regions nearby
  - Topography: Mountainous, valleys, and plains
  - Air quality information: Available but still limited
  - Meteorology
- So many questions to answers: Their roles to haze problem
- Goal: Attempt to examine

Tools and Components



FIRMS: Fire Information for Resource Management, University of Maryland and NASA, US

NOAA: National Oceanic and Atmospheric Administration, US

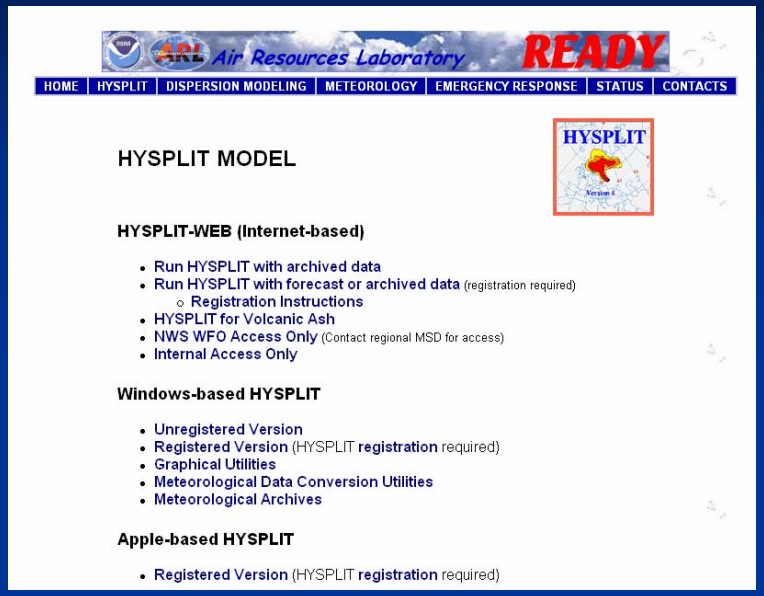
ARL: Air Resources Laboratory, NOAA, US

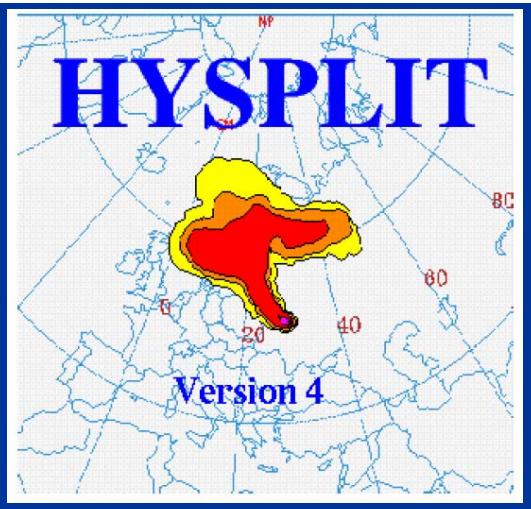
FIRMS

http:maps.geog.umd.edu/firms

- **Active fire data extracted: Time, Date, Lat, Lon, Detection Confidence**

HYSPLIT

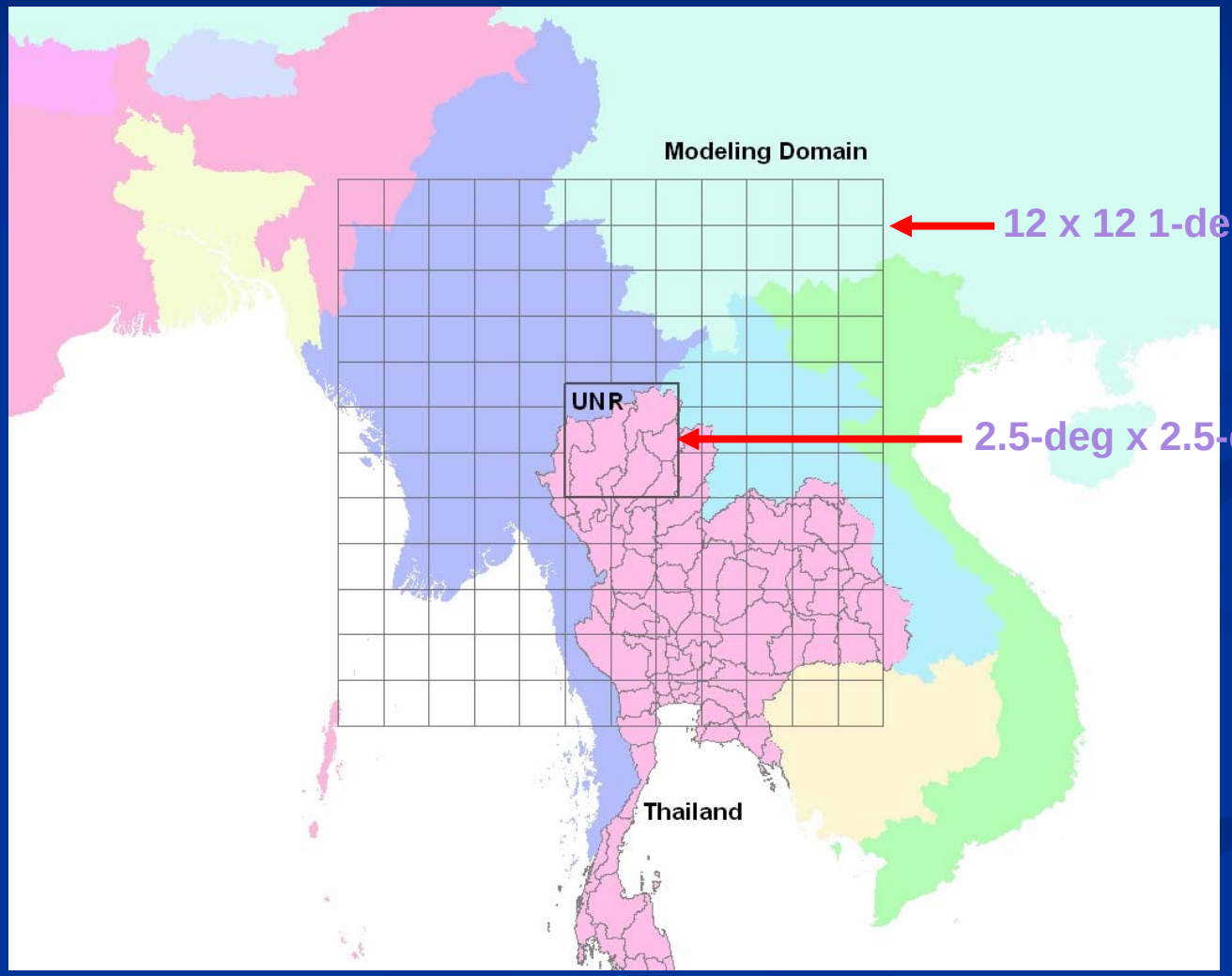




- Hybrid Single-Particle Lagrangian Integrated Trajectory
- Web-based and Workstation-based (WINDOWS or LINUX)
- Advanced, state-of-science, and non-commercial, suitable for research and operational use
- Simulation modes: Trajectory (forward and backward), dispersion, historical, and forecast
- GUI-driven or Command-driven

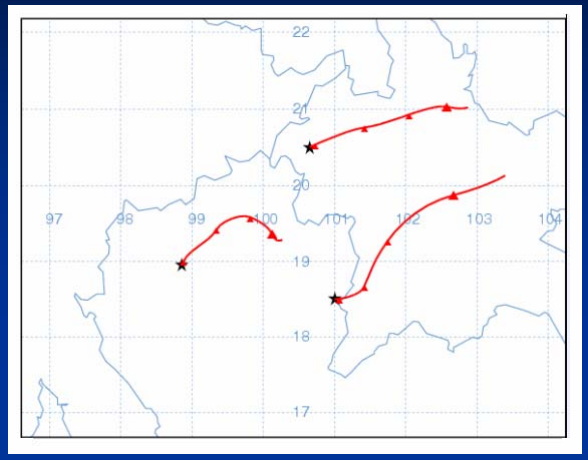
http://www.arl.noaa/gov/ready/hysplit4.html

Modelling and Receptor Domains

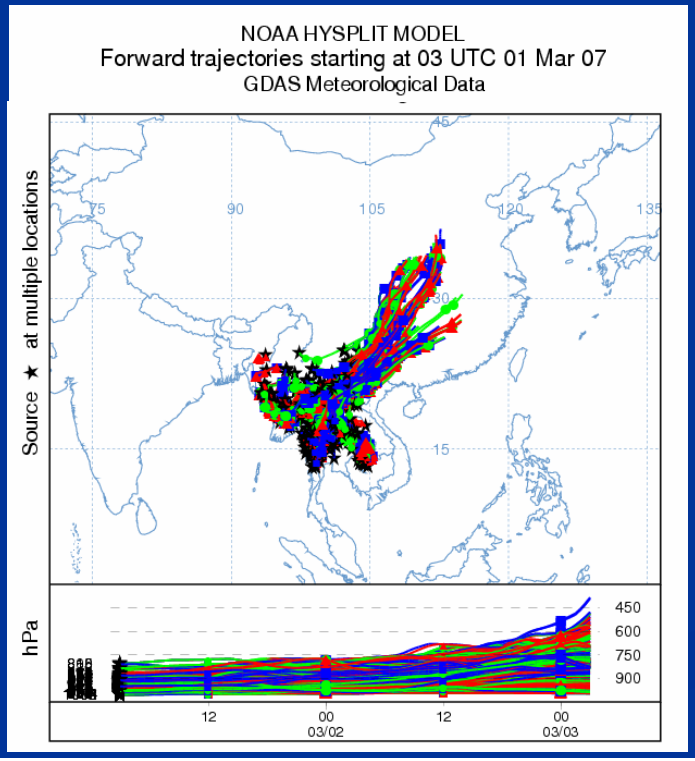


Simulation Setup

Hypothetical Case



Current Case



- Forward trajectory modeling
- Standard run with archived GDAS met
- Fire emission modeling:
  - Each fire burns 24 hr (uniformly)
  - To reduce computational resources, fire emissions are released in 6-hr interval
- Each trajectory tracked for 48 hr
- > 60,000 original hotspots processed
- Time resolution of tracking trajectory end points = 0.5 hr
- Degree of contribution of a fire: Linearly proportional to no. of times trajectory falls within UNR

Potential Fire Contributions

Mar. 2-8, 2007

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.3	0.9	0.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.1	0.3	3.7	4.8	5.3	0.8	0.0	0.0	0.0	0.0	0.0
0.0	0.1	0.2	0.5	7.1	13.5	8.8	1.4	0.0	0.0	0.0	0.0	0.0
0.0	0.1	0.4	0.6	9.2	7.9	5.5	3.0	0.0	0.0	0.0	0.0	0.0
0.0	0.1	0.4	1.0	1.4	11.2	3.9	0.9	0.1	0.0	0.0	0.0	0.0
0.0	0.0	0.2	0.0	0.5	3.2	0.7	0.2	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

- In percent (%) from grid cells in mother domain to haze pollution in UNR
- Dashed-Line Box = UNR

Source: Manomaiphiboon, Kasemsan (2007) Joint Graduate School for Energy and Environment (JGSEE), Bangkok

Mar. 9-15, 2007

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1	0.0	0.0	0.0	0.2	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.0
0.0	0.1	0.0	0.4	0.9	1.7	0.4	0.2	0.1	0.1	0.1	0.0	0.0
0.1	0.0	0.1	0.6	4.4	8.0	7.2	0.6	0.3	0.1	0.2	0.0	0.0
0.0	0.3	0.6	1.0	10.5	14.3	5.3	0.9	0.4	0.2	0.2	0.1	0.0
0.0	0.5	1.2	1.0	8.2	8.9	2.0	1.9	0.4	0.3	0.1	0.1	0.0
0.0	0.4	0.3	0.3	2.9	7.2	0.8	0.5	0.5	0.0	0.0	0.1	0.0
0.0	0.0	0.1	0.0	0.1	0.9	0.1	0.1	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.1	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0

- In percent (%) from grid cells in mother domain to haze pollution in UNR
- Dashed-Line Box = UNR

Source: Manomaiphiboon, Kasemsan (2007) Joint Graduate School for Energy and Environment (JGSEE), Bangkok

Mar. 16-22, 2007

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.6	1.3	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	1.0	1.7	3.6	0.5	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.3	1.0	3.4	8.4	5.3	0.4	0.0	0.0	0.0	0.0	0.0
0.0	0.5	1.6	2.9	8.9	6.4	1.9	1.1	0.0	0.0	0.0	0.0	0.0
0.0	0.4	1.6	1.4	8.6	8.3	1.4	1.8	0.4	0.0	0.0	0.0	0.0
0.0	0.2	0.3	0.5	4.6	7.0	0.7	0.7	0.5	0.0	0.0	0.1	0.0
0.0	0.0	0.1	0.0	0.3	3.4	0.9	0.4	0.3	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.1	1.9	0.2	0.1	0.1	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0

- In percent (%) from grid cells in mother domain to haze pollution in UNR
- Dashed-Line Box = UNR

Source: Manomaiphiboon, Kasemsan (2007) Joint Graduate School for Energy and Environment (JGSEE), Bangkok

Conclusions

- **Potential fire emissions and their contribution to UNR haze problem for a March-2007 episode using trajectory modeling**
- **Distinct variation in weekly contribution: Meteorology factor**
- **Contribution :**
  - **Always large from local fires in UNR (++++)**
  - **Trans-border transport from Myanmar (+++) and Laos (+)**
  - **Transport from regions lower than UNR (++ to +++)**
- **Considered preliminary and more work needed to be done:**
  - **Reliability and temporal/spatial coverage of active fire data**
  - **Fire emission modeling**
  - **Use dispersion modeling (not trajectory modeling)**
  - **Detailed meteorological analysis, possibly with meteorological modeling**
  - **Weekly investigation to daily (or hourly) investigation**

II. Regulatory Air Model for a Seaside Industrial Complex

- throughout 2007, PCD has taken a key role in improving and using a lagrangian puff dispersion model CALPUFF, approved by US EPA as a long-range transport regulatory model and a short-range model for complex terrain

- The application is to find the maximum ground level concentrations (a criterion used by the board of environmental policy for decisions on the approval of new industrial facilities) of the two gaseous pollutants; sulfur dioxide and nitrogen dioxide.

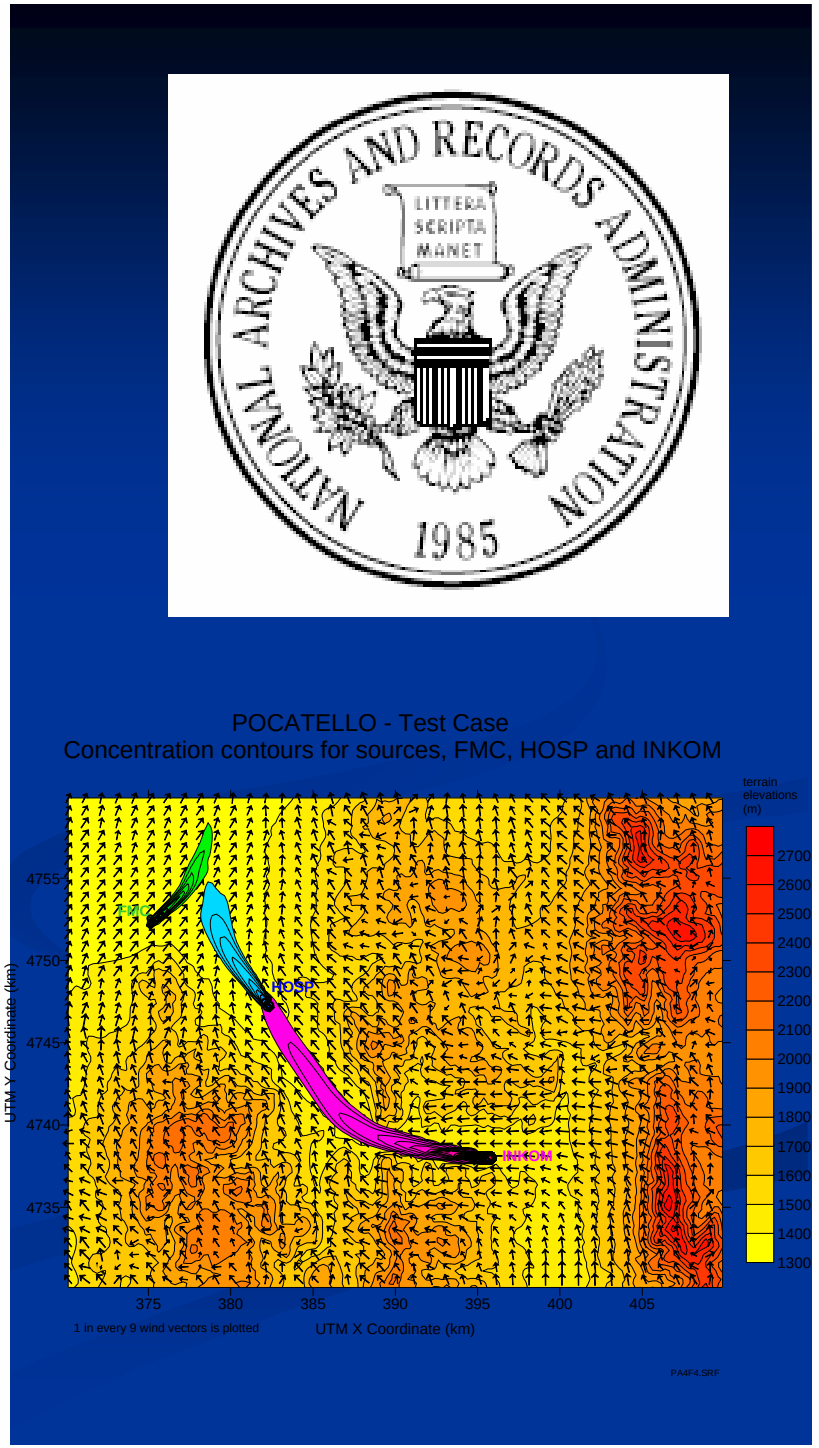
EPA completed limited evaluation of several long range transport (LRT) models against two sets of field data and evaluated results.[59] Based on the results, EPA concluded that long range and mesoscale transport models were limited for regulatory use to a case-by-case basis. However a more recent series of comparisons has been completed for a new model, CALPUFF (Section A.3). Several of these field studies involved three-to-four hour releases of tracer gas sampled along arcs of receptors at distances greater than 50km downwind. In some cases, short-term concentration sampling was available, such that the transport of the tracer puff as it passed the arc could be monitored.

On April 15, 2003 we published a Notice of Final Rulemaking (NFR; 68 FR 18440) that adopted CALPUFF in appendix A of the *Guideline*. We also made various editorial changes to update and reorganize information, and removed obsolete models. We

Differences on the order of 10 to 20 degrees were found between the location of the simulated and observed center of mass of the tracer puff. Most of the simulated centerline concentration maxima along each arc were within a factor of two of those observed. It was concluded from these case studies that the CALPUFF dispersion model had performed in a reasonable manner, and had no apparent bias toward over or under prediction, so long as the transport distance was limited to less than 300km.[60]

7.2.8 Complex Winds

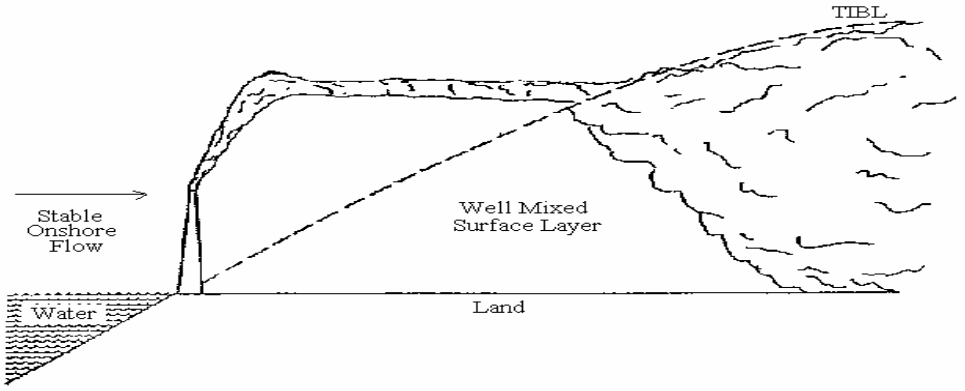
a. *Inhomogeneous Local Winds*. In many parts of the United States, the ground is neither flat nor is the ground cover (or land use) uniform. These geographical variations can generate local winds and circulations, and modify the prevailing ambient winds and circulations. Geographic effects are most apparent when the ambient winds are light or calm.[79] In general these geographically induced wind circulation effects are named after the source location of the winds, *e.g.*, lake and sea breezes, and mountain and valley winds. In very rugged hilly or mountainous terrain, along coastlines, or near large land use variations, the characterization of the winds is a balance of various forces, such that the assumptions of steady-state straight-line transport both in time and space are inappropriate. In the special cases described, the CALPUFF modeling system (described in Appendix A) may be applied on a case-by-case basis for air quality estimates in such complex non-



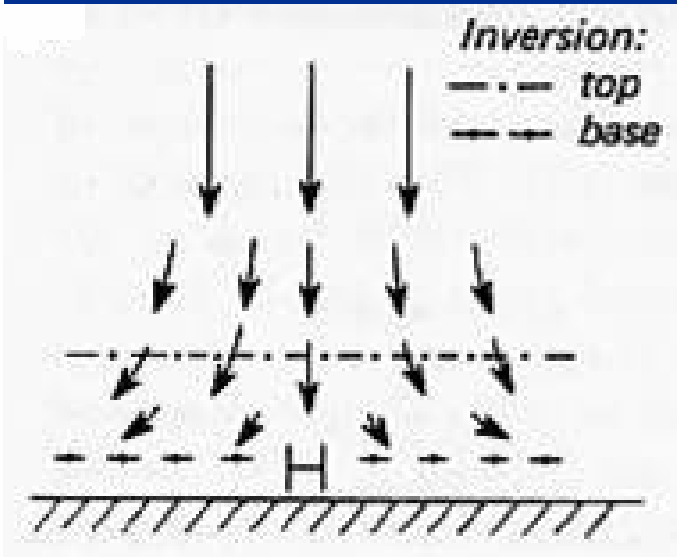
steady-state meteorological conditions. The purpose of choosing a modeling system like CALPUFF is to fully treat the time and space variations of meteorology effects on transport and dispersion. The setup and application of the model should be determined in consultation with the appropriate reviewing authority (paragraph 3.0(b)) consistent with limitations of paragraph 3.2.2(e). The meteorological input data requirements for developing the time and space varying three-dimensional winds and dispersion meteorology for these situations are discussed in paragraphs 8.3.1.2(d) and 8.3.1.2(f). Examples of inhomogeneous winds include, but aren't limited to, situations described in the following paragraphs (i)—(iii):

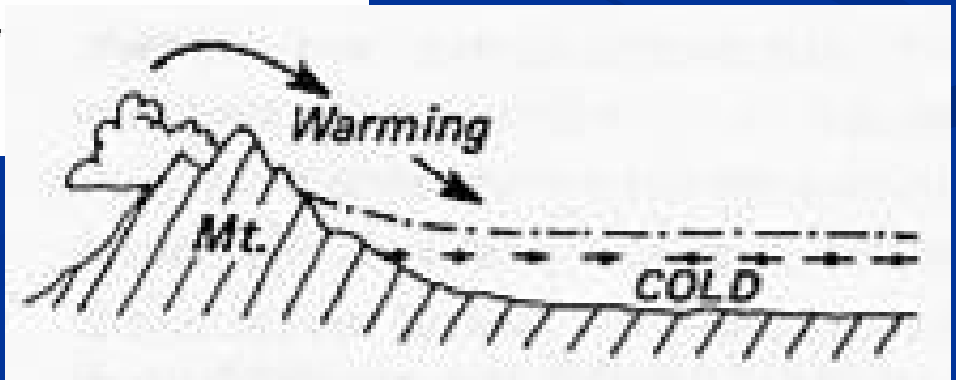
i. *Inversion Breakup Fumigation.* Inversion breakup fumigation occurs when a plume (or multiple plumes) is emitted into a stable layer of air and that layer is subsequently mixed to the ground through convective transfer of heat from the surface or because of advection to less stable surroundings.

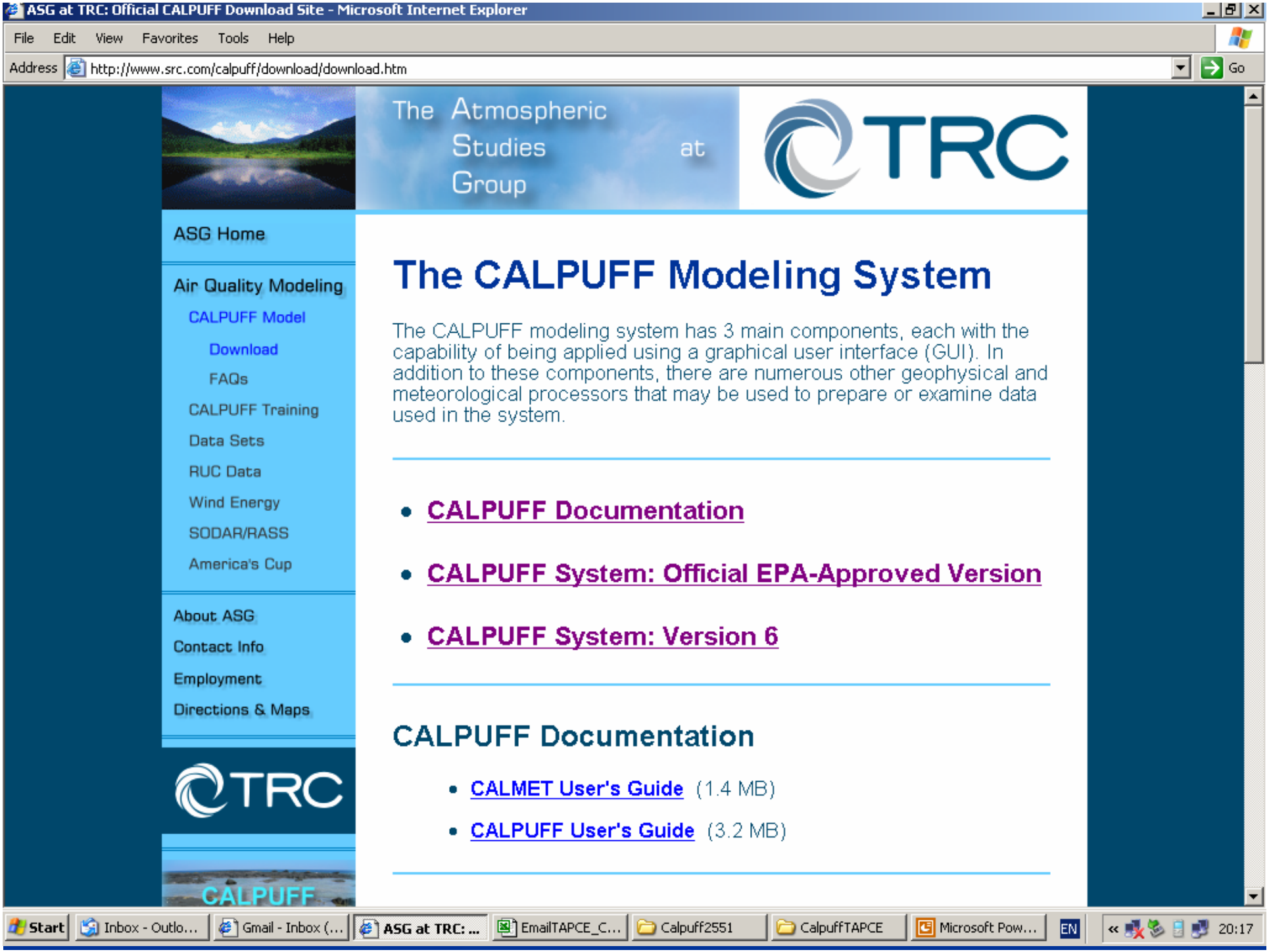
ii. *Shoreline Fumigation.* Fumigation can be an important phenomenon on and near the shoreline of bodies of water. This can affect both individual plumes and area-wide emissions. When fumigation conditions are expected to occur from a source or sources with tall stacks located on or just inland of a shoreline, this should be addressed in the air quality modeling analysis. The Shoreline



iii. *Stagnation*. Stagnation conditions are characterized by calm or very low wind speeds, and variable wind directions. These stagnant meteorological conditions may persist for several hours to several days. During stagnation conditions, the dispersion of air pollutants, especially those from low-level emissions sources, tends to be minimized, potentially leading to relatively high ground-level concentrations. If point sources are of interest, users should note the guidance provided for CALPUFF in paragraph (a) of this subsection. Selection of the appropriate model for applications where stagnation is of concern should be determined in consultation with the appropriate reviewing authority (see Section 3.0(b)).






ASG at TRC: Official CALPUFF Download Site - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Address http://www.src.com/calpuff/download/download.htm
Go
The Atmospheric Studies Group at
TRC
ASG Home
Air Quality Modeling
CALPUFF Model
Download
FAQs
CALPUFF Training
Data Sets
RUC Data
Wind Energy
SODAR/RASS
America's Cup
About ASG
Contact Info
Employment
Directions & Maps
TRC
CALPUFF
The CALPUFF Modeling System
The CALPUFF modeling system has 3 main components, each with the capability of being applied using a graphical user interface (GUI). In addition to these components, there are numerous other geophysical and meteorological processors that may be used to prepare or examine data used in the system.
CALPUFF Documentation
CALPUFF System: Official EPA-Approved Version
CALPUFF System: Version 6
CALPUFF Documentation
CALMET User's Guide (1.4 MB)
CALPUFF User's Guide (3.2 MB)
Start
Inbox - Outlo...
Gmail - Inbox (...
ASG at TRC: ...
EmailTAPCE_C...
Calpuff2551
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Microsoft Pow...
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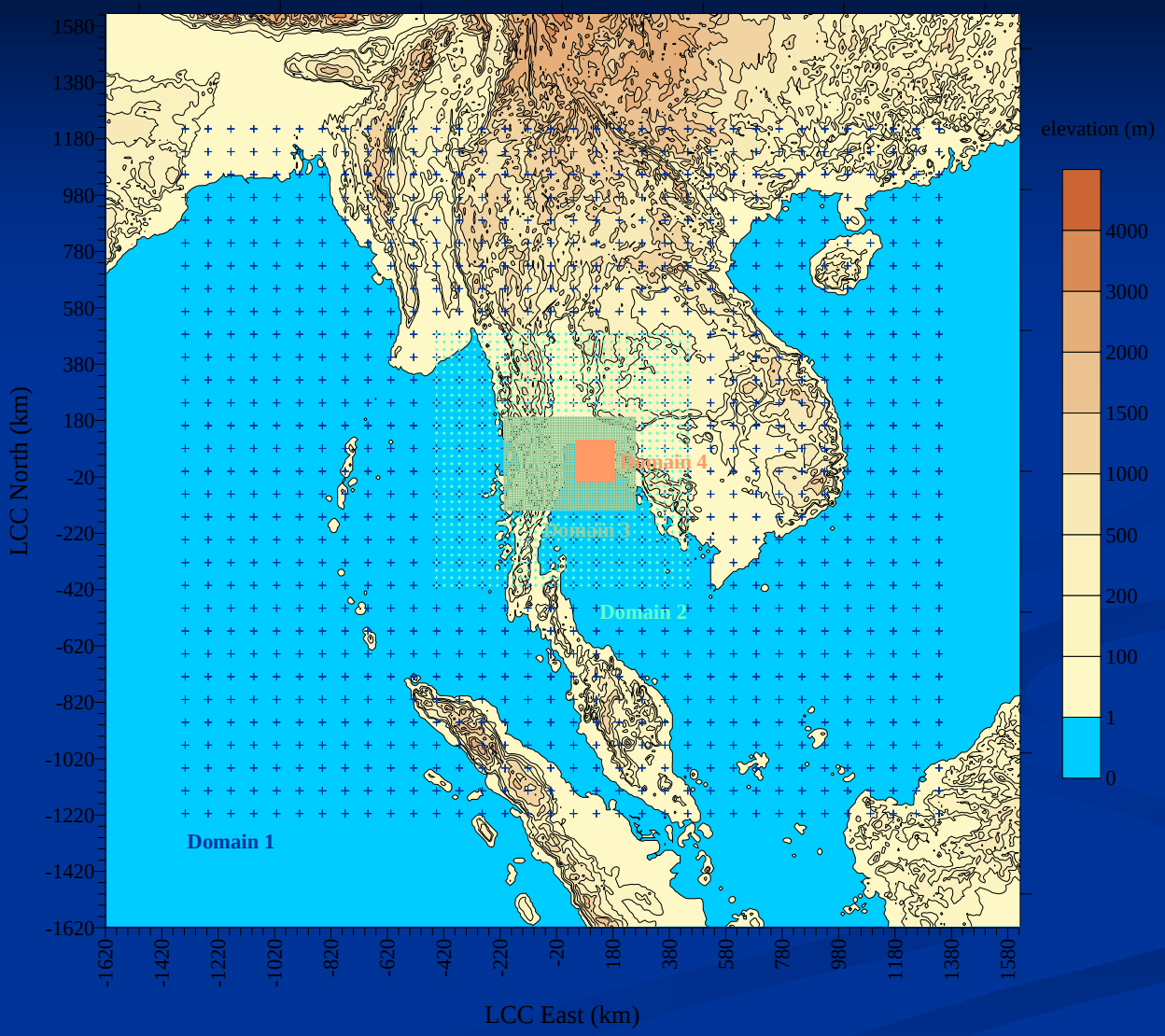
II. Regulatory Air Model for a Seaside Industrial Complex

- The study is crucial to the development of the Maptaphut industrial complex on the Eastern Seaboard of Thailand, where the 291 point emissions sources were considered their impacts to an array of community receptors set within a geographic domain characterized by gently rolling hills and 25 km of coastline.
- CALPUFF uses meteorological input data from its meteorological preprocessor, CALMET, which incorporates data from surface stations in additions to output from a prognostic meteorological model, MM5.

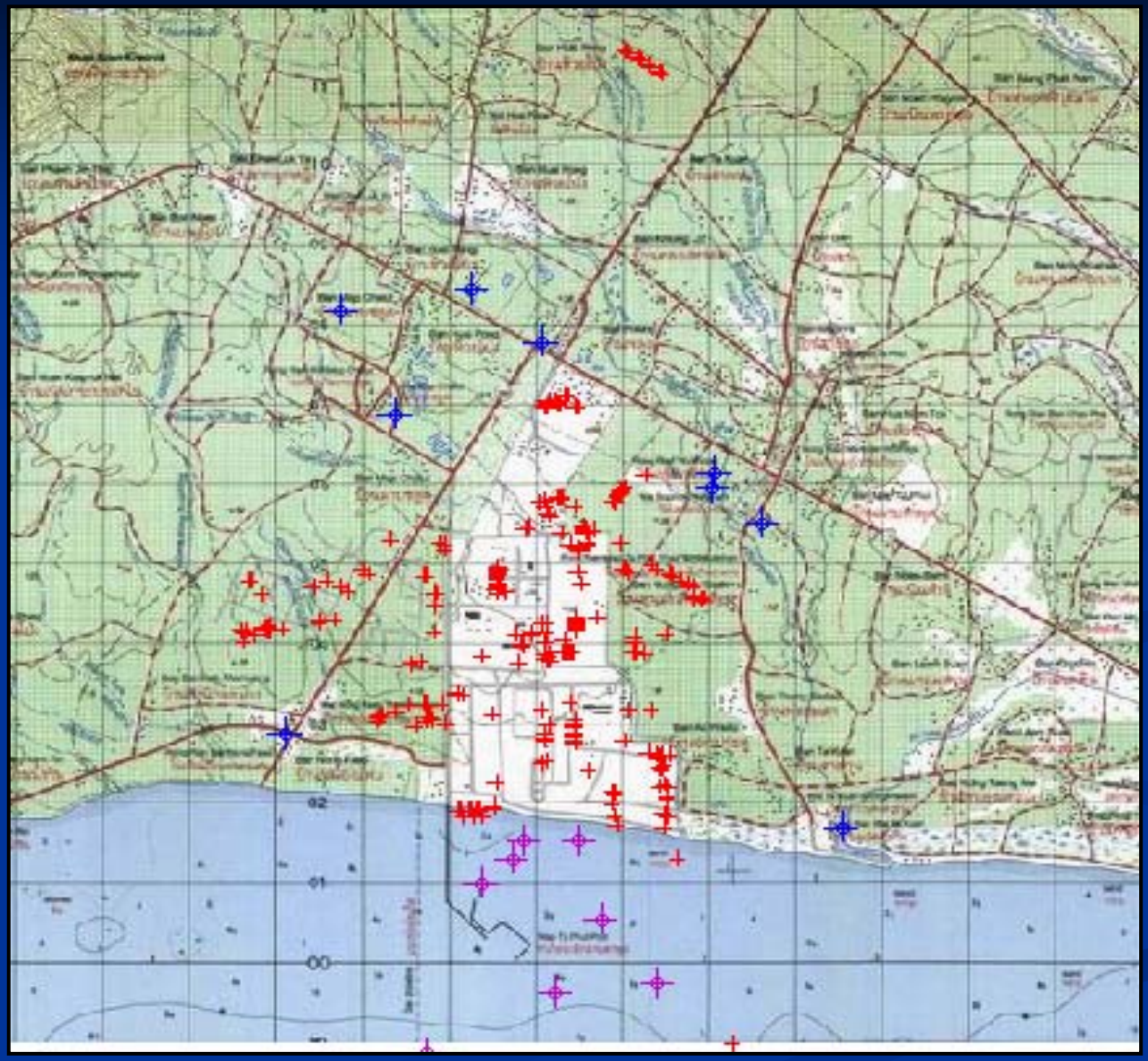
MM5 Domains for Thailand (MTP Project)



D1: 2673 km x 2430 km (34 x 31 - DX = 81 km)
D2: 891 km x 891 km (34 x 34 - DX = 27 km)
D3: 459 km x 324 km (52 x 37 - DX = 9 km)
D4: 135 km x 144 km (46 x 49 - DX = 3 km)

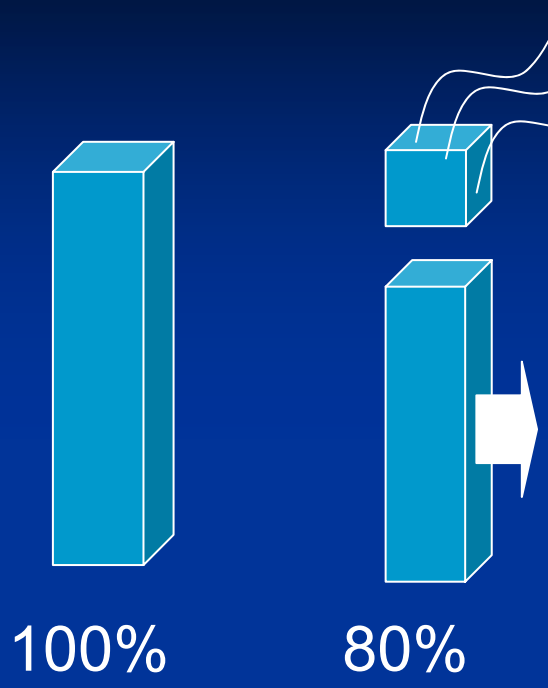
Source: J. Scire, Atmospheric Studies Group, TRC. Reproduced with permission of TRC.

Emission sources and air quality/meteorological stations in MTP Area

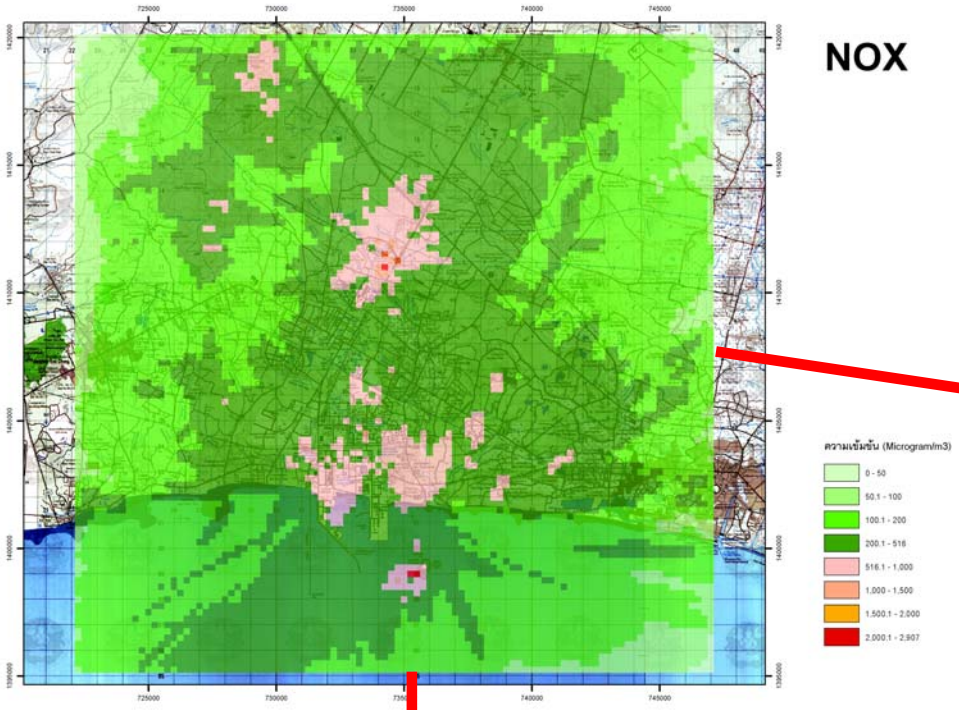


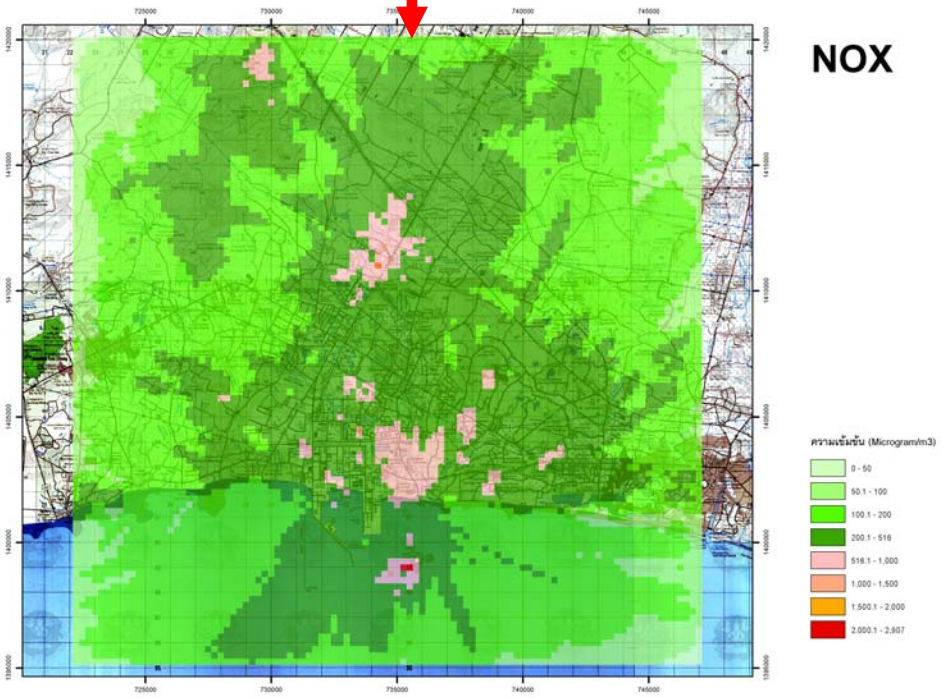
+ Industrial point source + Marine point sources + Air Quality and Meteorological Stations

Policy measures for New Projects in the MTP area



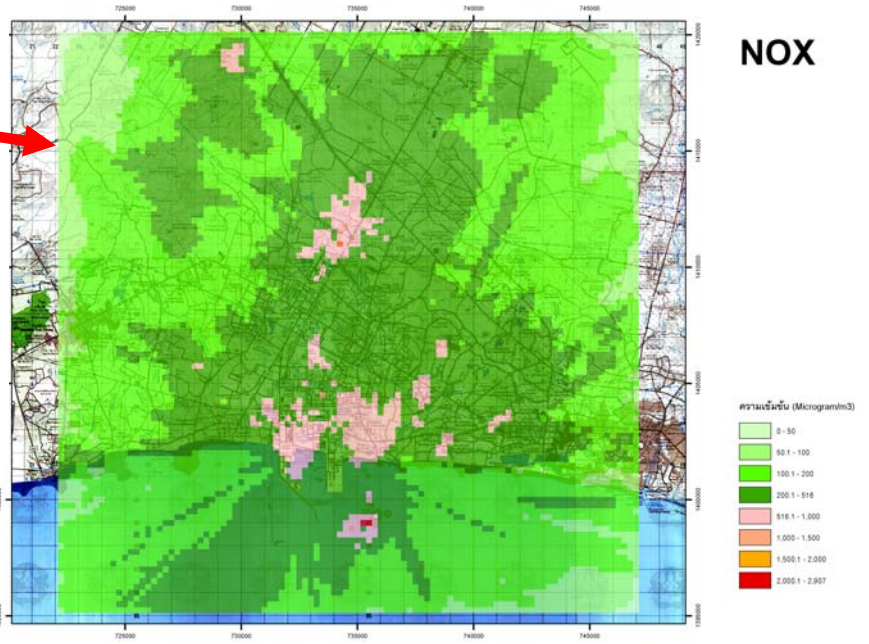
The work raises public interest on how to specify a cap on total emission and a fair goal for emission trading and maintaining acceptable level of ambient air quality





ก่อน มีโครงการใหม่

มีจุดรับที่เกินค่ามาตรฐานอยู่ 184 จุด



หลัง มี 9 โครงการใหม่

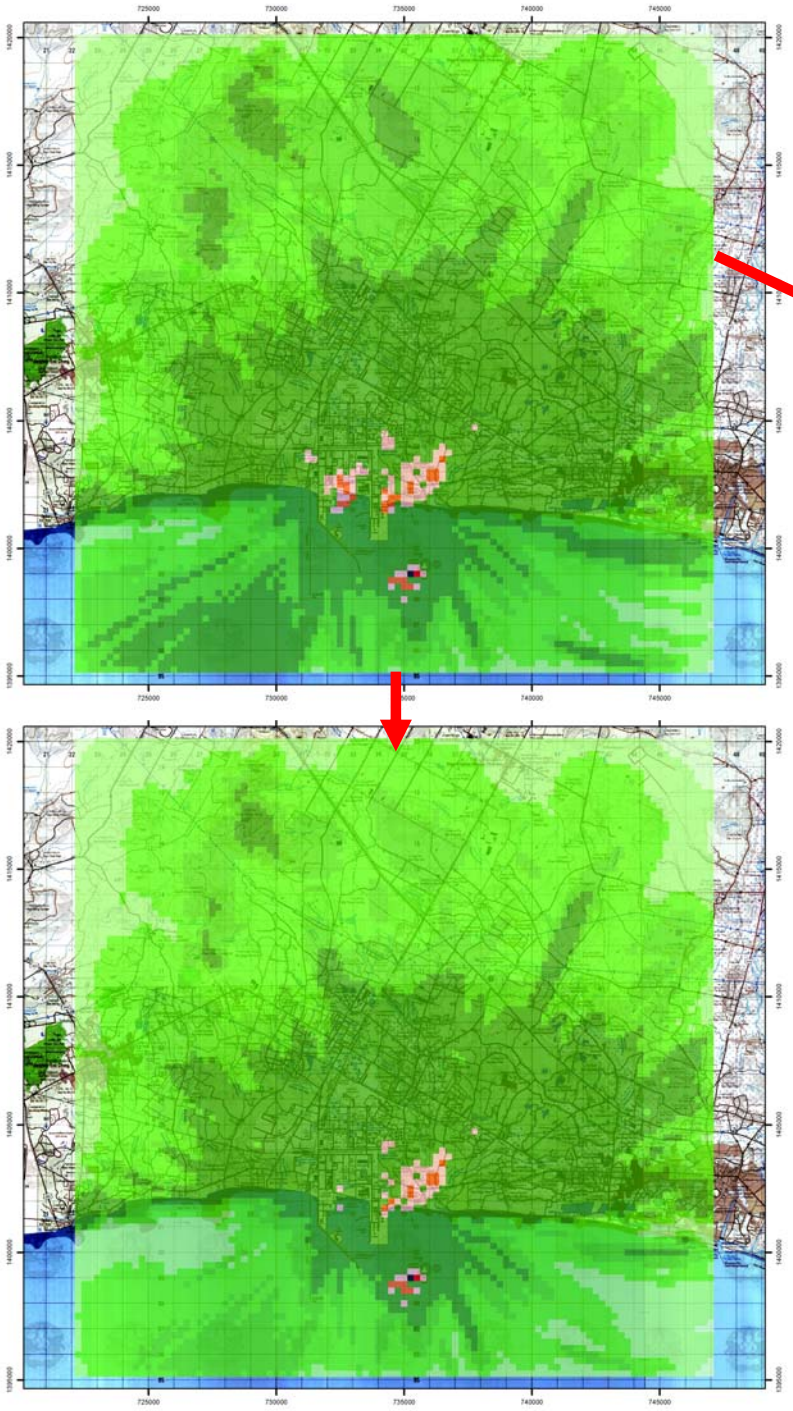
(ไม่รวมโกลว์ 700 MW)

จุดที่เกินค่ามาตรฐานเหลือเพียง 139 จุด

หลัง มี 10 โครงการใหม่

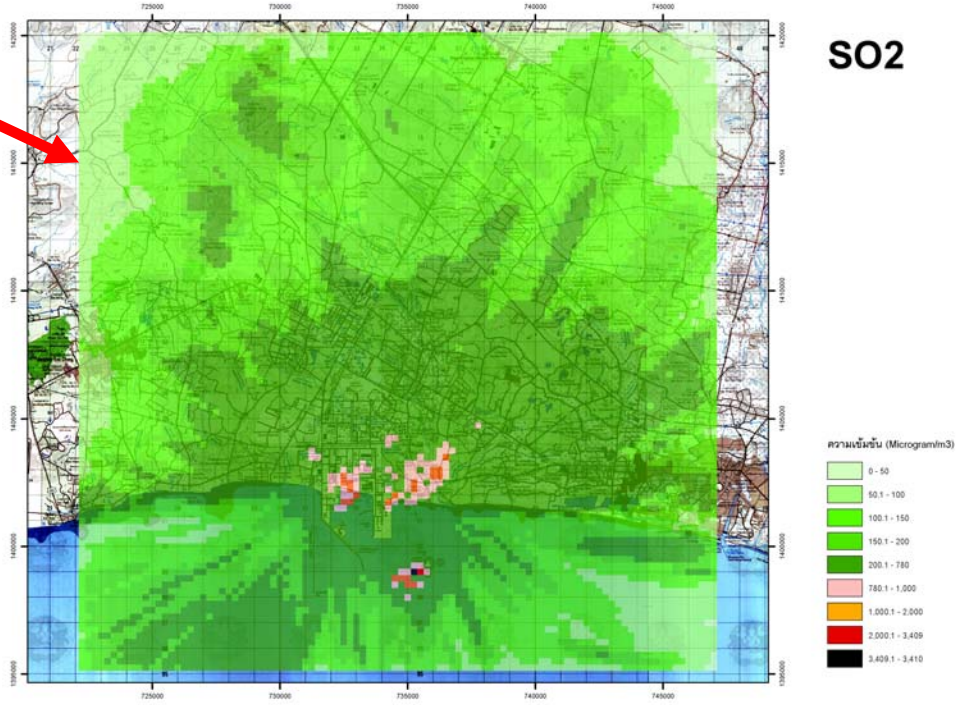
(รวมโกลว์ 700 MW)

จุดที่เกินค่ามาตรฐานเหลือเพียง 120 จุด



ก่อน มีโครงการใหม่

มีจุดรับที่เกินค่ามาตรฐานอยู่ 27 จุด



หลัง มี 9 โครงการใหม่

(ไม่รวมโกลว์ 700 MW)

จุดที่เกินค่ามาตรฐานเหลือเพียง **21** จุด

หลัง มี 10 โครงการใหม่

(รวมโกลว์ 700 MW)

จุดที่เกินค่ามาตรฐานเหลือเพียง 24 จุด

ASG at TRC: SODAR/RASS System Available for Lease - Microsoft Internet Explorer

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SODAR/RASS System: Available for Lease

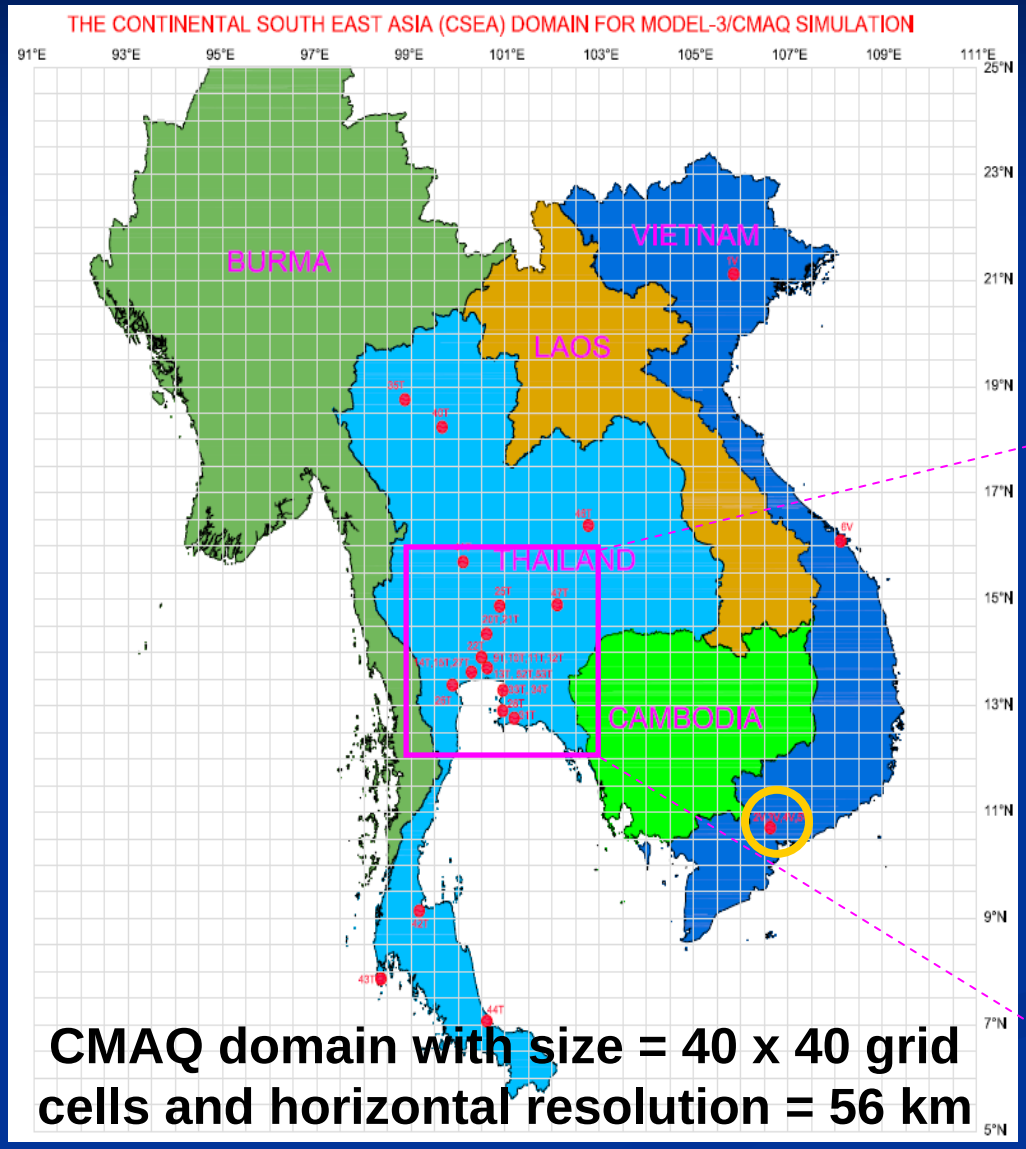
This SODAR/RASS System (shown in the picture below) is virtually new having spent only four months in the field during the 2002-2003 America's Cup season.

The particular system setup being leased here is unique in its ability to operate off of either AC power or solar supply, in addition to having its own backup generator. This means that it can be used virtually anywhere in the world.

Internet

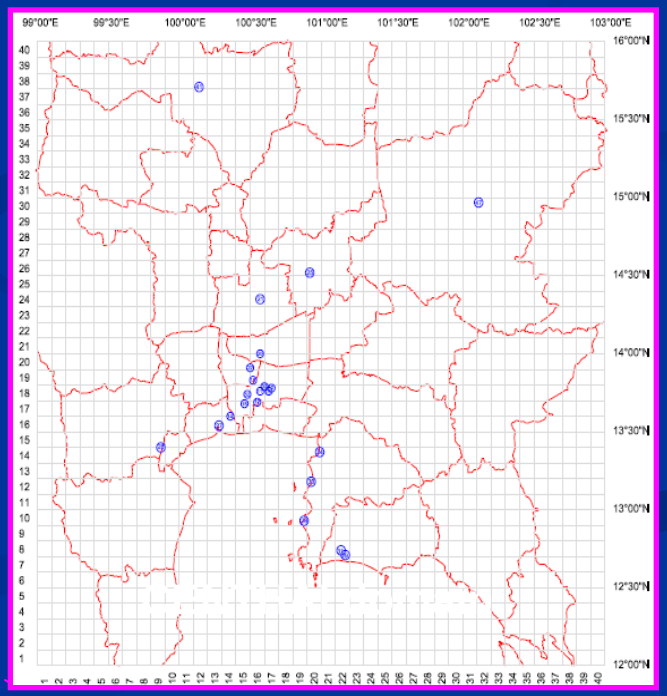
Start | Inbox - Outlook Express | Gmail - Meeting Idea Req... | ASG at TRC: SODAR/R... | Microsoft PowerPoint - [... | EN | 21:57

CMAQ Modeling Domain



CMAQ domain with size = 40 x 40 grid cells and horizontal resolution = 56 km

- **HCM city (4 stations) and Central Thailand Region, CENTHAI, (16 stations), are used for model evaluation**
- **Real time ozone forecasting made for CENTHAI domain**



Source: Nghiem, L. and Nguyen Thi, K. O.; AIT

II. PCD's Progress on Air Modelling

- In the year 2006, PCD has purchased a Linux Cluster with 16 PCs running on dual CPUs and setting up of the cluster through effort of the team is going on till now.
- Four PCD staff keep learning how to administrate the system with modelling tools like MM5 and Models-3/CMAQ.

Conclusion (I)

- The air quality modelling work at PCD, Thailand, is going on various scales.
- Fire emission datasets for HYSPLIT forecasting has become the first priority in dealing with haze early warning.
- The capacity to run CALPUFF has been implemented and public understanding on the issue is thought to be important to the progress in enforcing policy on air quality control.

Conclusion (II)

- Long-range transboundary air pollution could be the next component that requires careful model study.
- It is hoped that once the Linux Cluster set up at PCD is installed with chemical transport models like:

  - Models-3/CMAQ (near future collaboration with Asian Institute of Technology and JGSEE) and/or

  - STEM (potential future collaboration with Dr. Narisara Thongboonchu of King Mongkut Institute of Technology at Ladkrabang),

  full chemistry should be used for assessing local episodes like ozone and fine particulates problems.