Air Quality Monitoring and Forecasting In China (AMFIC)


National Satellite Meteorological Center/CMA

R.J. van der A c, B. Mijling

Royal Netherlands Meteorological Institute
Outline

1. Scientific Background
2. What is AMFIC?
3. What we got from AMFIC?
4. Summary
1. Scientific Background

Composition - Climate

Ozone & Surface UV

Air Pollution

- Aerosol
- Radiatively Active Trace Gases
- Chemically Active Trace Gases
<table>
<thead>
<tr>
<th>Chemical species</th>
<th>Air Quality</th>
<th>Oxidation Capacity</th>
<th>Climate</th>
<th>Stratospheric Ozone Depletion</th>
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<td>CO</td>
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</table>
Policy In China

- Chinese Government sign the agreement on the Kyoto Protocol
- Beijing Olympics: an environment-friendly Olympics (Green Olympics)
- Shanghai Expo: Better City, Better Life

Space Research Information Day
## Satellite Chemistry/Atmosphere Missions

<table>
<thead>
<tr>
<th>SOUNDER</th>
<th>MISSION</th>
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<tbody>
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<td>TOMS</td>
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<td>MET 8005</td>
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<tr>
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<td>ADEOS</td>
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<tr>
<td></td>
<td>PROBA</td>
</tr>
<tr>
<td>FY-3A</td>
<td>Aura</td>
</tr>
<tr>
<td></td>
<td>Envisat</td>
</tr>
<tr>
<td></td>
<td>Metop</td>
</tr>
</tbody>
</table>

**Sounding strategy:**
- [ ] door
- [ ] Sun/noon correlator
- [ ] Inter-calibration
- [ ] multi-target
- [ ] Spectral range:
  - SWIR
  - LWIR
  - MW
  - multi-sensor

**Prepared by:** NACG
**Source:** http://www.esa.int/NDCS_EstMC/About.html

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**FY-3A**

**Aura**

**Envisat**

**Metop**
- Dragon I 2004 - 2008
- Dragon II 2008 - 2012
Atmospheric Composition monitoring by ENVISAT
Scientific Research Progress

- Symposium
- Joint proposal
- Joint Workshop
- Scientists Exchange
**FP6-2005-Space-1: 2007 – 2009**  
**PI: Ronald van der A**

### Contract Preparation Forms

**Specific Targeted Research or Innovation Project**

<table>
<thead>
<tr>
<th>Proposal Number</th>
<th>Proposal Acronym</th>
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**Proposal Title:** Air quality Monitoring and Forecasting In China

**Duration in months:** 24

**Call (part) identifier:** FP6-2005-Space-1

**Abstract (max. 2000 char.)**

AMFIC addresses atmospheric environmental monitoring over China. The aim is to develop an integrated information system for monitoring and forecasting tropospheric pollutants over China. The system uses satellite and in situ air quality measurements and modelling to generate consistent air quality information over China. The data will cover the recent years and the actual situation including an air quality forecast for several days ahead. Air pollutants covered are ozone, nitrogen dioxide, sulphur dioxide, formaldehyde, carbon monoxide, methane and aerosol/particulate matter.

The proposed system will supplement and broaden the existing ground-level monitoring and air quality assessment activities in China. Satellite data will cover regions where no ground-based stations are available, air quality models fill-in the sparse temporal and spatial sampling of the measurements and connect them in a physically consistent manner.

The system targets environmental agencies in China, some of whom are participating in AMFIC, and assist them in their reporting duties on air quality. A case study for the city of Shenyang will be demonstrated. The proposed project will also improve our understanding of the transport of air pollution within, from and to China. AMFIC builds on aspects of the ESA GMES Atmosphere Service Element PROMOTE which has a strong potential for providing the European atmospheric monitoring contribution to GEOSS.
2. What is AMFIC?

- KNMI Royal Netherlands Meteorological Institute, Netherlands (PI)
- BIRA-IASB Belgium Institute for Space Aeronomy, Belgium
- VITO Flemish institute for technological research, Belgium
- DUTH Democritus University of Thrace, Greece
- NOA National Observatory of Athens, Greece
- LAP-AUTH Lab. of Atmospheric Physics, Greece
- FMI Finnish Meteorological Institute, Finland
- IFE University of Bremen, Germany
- NSMC National Satellite Meteorological Center, China
- IAP-CAS Institute of Atmospheric Physics, China

AMFIC
Air quality Monitoring and Forecasting In China
AMFIC

- AMFIC addresses **atmospheric environmental** monitoring over China.
- The system uses **satellite** and **in situ** air quality measurements and **modelling** to generate consistent air quality information over China.
- The data will cover the recent years and the actual situation including an **air quality forecast** for several days ahead.
- The aim is to develop an **integrated information system** for monitoring and forecasting tropospheric pollutants over China.
- Air pollutants covered are **ozone**, **nitrogen dioxide**, **sulphur dioxide**, **formaldehyde**, **carbon monoxide**, **methane** and **aerosol/particular matter**.

2012/4/20

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Objectives

- Monitoring air pollutants over China
  - Focused on SO$_2$, O$_3$ (smog), NO$_2$, CO, CH$_4$, HCHO and aerosols

- Regional modeling of air quality
  - Nested model on city level (test case Shenyang)

- Validation of model and measurement results
  - Extensive number of ground observations available

- Forecasting of air quality China
  - 2 day forecast for air pollutants in the heavy populated east of China

- User service (in line with INSPIRE directives)
Advantage of AMFIC

The proposed system will supplement and broaden the existing ground-level monitoring and air quality assessment activities in China. Satellite data will cover regions where no ground-based stations are available; air quality models fill-in the sparse temporal and spatial sampling of the measurements and connect them in a physically consistent manner.

Practice of AMFIC

The system targets environmental agencies in China, some of whom are participating in AMFIC, and assists them in their reporting duties on air quality. A case study for the city of Shenyang will be demonstrated. The proposed project will also improve our understanding of the transport of air pollution within, from and to China. AMFIC builds on aspects of the ESA GMES Atmosphere Service Element PROMOTE which has a strong potential for providing the European atmospheric monitoring contribution to GEOSS.
AMFIC Infrastructure

Air Quality Monitoring and Forecasting in China

Air Quality Monitoring

- NO2, O3, SO2
- CO, CH4
- AEROSOL
- UV/VIS of GOME, SCIAMACHY
- IR spectrum of SCIAMACHY
- AATSR

Validation and analysis

- Ground-based measurement
- Chemical model results

Air quality forecasting

- Assimilation of retrieval result (TM)
- Forecasting the air pollution
Satellite products

- **GOME / SCIAMACHY / OMI**
  UV/VIS retrievals  (KNMI, BIRA-IASB)
  - Tropospheric O$_3$
  - Tropospheric NO$_2$
  - SO$_2$
  - Formaldehyde (CH$_2$O)

- **SCIAMACHY**
  IR retrievals  (IFE)
  - CH$_4$, CO and CO$_2$

- **ATSR**  (FMI, IAP-CAS, NSMC)
  - Aerosols
Global Numerical Weather Forecasting Model: ECMWF to provide the meteorological condition
Regional Air Quality Model: CHIMERE (0.25 × 0.25°)
Emission Database: INTEX-B 2006 (Zhang and Streets)
Chinese Partners In AMFIC

- National Satellite Meteorological Center  
  (NSMC/CMA: Dr./Prof. Zhang Peng)

- Chinese Academy of Meteorological Sciences  
  (CAMS/CMA: Dr./Prof. Zhang Xiaoye)

- Anhui Institute of Optical and Fine Machine  
  (AIOFM/CAS: Dr./Prof. Liu Wenqing/ Dr. Liu Jianguo)

- Environmental Science and Engineering Department, Fudan University  
  (Dr./Prof. Chen Jianmin, Dr. Cheng Tiantao)

- Institute of Atmospheric Physics, Chinese Academy of Sciences  
  (IAP/CAS: Dr./Prof. Liao Hong)
Involved Activities in China

1) In-situ measurement (SO$_2$, NO$_2$, O$_3$, CO)
2) Ground-based Remote Sensing (SO$_2$, NO$_2$, O$_3$, CO)
3) Chemical Transportation Model
4) Retrieval Algorithm (Aerosol, SO$_2$, NO$_2$, O$_3$)

Courtesy to Ronald van der A (KNMI)
3. What we got from AMFIC?

- Satellite Retrieval Algorithm Development
- Satellite Product Validation with in-situ Measurements
- Temporal and Spatial Trend of Atmospheric Composition over China from Satellite Products
- Satellite Data Assimilation into Regional Air Quality Model
- Air Quality Forecasting and Demonstration over China
Satellite Retrieval Algorithm Development

- Atmospheric Profile
- Total Ozone Amount
- Ozone Profile
- Aerosol
- Dust
- \( \text{NO}_2 \)
- \( \text{SO}_2 \)
- \( \text{CH}_4 \)
- \( \text{CO}_2 \)
- \( \text{CO} \)

11 instruments on board FY-3A/B, including:

- VIRR: Visible and Infra-Red Radiometer
- MERSI: Medium Resolution Spectral Imager
- IRAS: Infrared Atmospheric Sounder
- MWTS: MicroWave Temperature Sounder
- MWHS: MicroWave Humidity Sounder
- MWRI: MicroWave Radiation Imager
- SBUS: Solar Backscatter Ultraviolet Sounder
- TOU: Total Ozone mapping Unit
- SIM: Solar Irritation Monitor
- ERM: Earth Radiation Monitor
- SEM: Space Environment Monitor

developed

on going

2012/4/20
AOD Month Average Global from MERSI/FY-3A

MERSI AOT at 550nm in Mar
Greece Forest Fire

August 24, 2009
Ozone Product Comparison

GOME2 total O₃ in Dobson unit

FY3 total O₃ in Dobson unit

OMI total O₃ in Dobson unit

TOI与OMI臭氧总和结果相对偏差（%）
（根据2008年7月17日结果统计，横坐标代表样本编号）
Ozone hole Monitoring from TOU/FY-3A

From 300 DU decrease to lower than 100 DU

Year 2008

Year 2009
Ozone hole near the arctic area

Polar stratospheric clouds

Total ozone amount

polar stratospheric clouds generated by polar vortex release Halogen atoms
Ozone valley in Tibetan Plateau

Total Ozone of TOU/FY-3A  2009-09-22
Satellite Product Validation ------ blank area in China

More than 70 sites over the world
Ground-based remote sensing for air quality

AMFIC STATIONS:

- One **FTIR** station in NSMC/Beijing (long-term)
- Three **MaxDOAS** station (long-term)

**Beijing, Anhui, Shanghai**

- 10 stations in BEIJING for Olympic campaign- **MaxDOAS**
  (Short-term: July 2008-September 2008)
- Four GAW stations - **Thermo and Brewer spectrophotometers** (long-term)
  
  Waliguan, LinAn, ShangDianZi and LongFengShan
- 28 **CE-318** stations for AOD (long-term)

Products:

- Vertical Column amounts of O$_3$, NO$_2$, SO$_2$ etc
- AOD
- Vertical Column amounts and profile of CO, CH$_4$, N$_2$O etc

Operated by CAWAS
In-Situ Measurements from Ground Stations

Four GAW stations-Thermo

Space Research Information Day
FY-3A/TOU, OMI O₃ product validation
Ground Based Remote Sensing by hyperspectral Radiometer
Main parameters of MAX-DOAS and FTIR

<table>
<thead>
<tr>
<th>Instrument Type</th>
<th>MAX-DOAS</th>
<th>FTIR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacture</td>
<td>Germany BRUKER</td>
<td>China AIOFM/CAS</td>
</tr>
<tr>
<td>Measured Spectrum</td>
<td>700 - 5000 cm(^{-1}) (IR/NIR)</td>
<td>300 – 700 nm (UV/VIS)</td>
</tr>
<tr>
<td>Spectral Resolution</td>
<td>0.0035 cm(^{-1}) (Max)</td>
<td>0.4 – 1.5 nm</td>
</tr>
<tr>
<td>Detected Target</td>
<td>O(_3), NO(_2), SO(_2), OC(_1)O, BrO …</td>
<td>O(_3), H(_2)O, NO, N(_2)O, NO(_2), HNO(_3), CO, CH(_4), CO(_2), HF, HCl, ClONO(_2) ...</td>
</tr>
</tbody>
</table>
Ground-based remote sensing by MAX-DOAS
Young Visiting Scientist at IMK

Retrieval Algorithm: PROFFIT 9.5 (IMK, Frank.Hase)
OMI NO$_2$ validated with MAX-DOAS of NSMC
Result shows: the total column amount deviation for CH4 is less than 20%, IASI results higher than FTIR measurement; deviation for N$_2$O is less than 10%.

IASI CH$_4$, N$_2$O validated with ground-base FTIR measurement
CARSNT
China Aerosol Remote Sensing Network

![Map of China with monitoring stations](image1)

![Image of aerosol remote sensing equipment](image2)

![Graph showing AOD measurements](image3)
Aerosol Optical Depth Validation

The difference of AOT between NSMC and NASA

TERRA_2006_03_30

Xi ngLong(117.578° E, 40.396° N)

AOT (550nm)

AERONET观测
MODIS反演

DATE


2012/4/20 Space Research Information Day 41
Trend, seasonal cycle, and sources of atmospheric composition Over China

- Aerosol
- Ozone
- NO$_2$
- SO$_2$
- CH$_4$
- CO
- CO$_2$
Aerosol Pattern over China by MODIS AOD 2005-2008

Seasonal Averaged

North East Part of China
Year Averaged
Distribution of tropospheric ozone over TP and comparison with the nearby area in different seasons during 1979-1992

TOR (Tropospheric ozone residual) Data
The trend, seasonal cycle, and sources of tropospheric NO2 over China during 1997—2006

1996

10-Year’s tropospheric NO\textsubscript{2} column density concentration (1996—2006) (unit: $10^{15}$ molecules cm\textsuperscript{-2})

The paper has been published by *Sciences in China: D*
East area (110–1230E, 30–400N)

West area (80–1000E, 30–400N)

West (0.6 10E15 molec/cm²)

East (9.3 10E15 molec/cm²)
Ten years increment of troposphere NO$_2$ over the four typical regions

Jingjinji Region (111–1200E, 30–400N)
Yangtze delta region (116–1220E, 29–340N)
Sichuan Basin (104–1070E, 29–310N)
Pearl River Delta region (111–1160E, 21–240N)
Ten years increment of tropospheric NO\textsubscript{2} over megacities in China

Table 1 Tropospheric NO\textsubscript{2} vertical columns over megacities in China

<table>
<thead>
<tr>
<th>City</th>
<th>Mean Concentration NO\textsubscript{2} in 1997 (10^{15} molec/cm\textsuperscript{2})</th>
<th>Linear Trend in NO\textsubscript{2}, (10^{15} molec/cm\textsuperscript{2}/year)</th>
<th>Growth (Reference Year 1997) %</th>
<th>Regression coefficient</th>
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<tbody>
<tr>
<td>Beijing</td>
<td>12.7</td>
<td>2.3</td>
<td>18.0</td>
<td>0.82</td>
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<tr>
<td>Shanghai</td>
<td>13.0</td>
<td>2.0</td>
<td>20.0</td>
<td>0.77</td>
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<tr>
<td>Tianjin</td>
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<td>1.7</td>
<td>13.1</td>
<td>0.85</td>
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<tr>
<td>Guangzhou</td>
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<td>16.4</td>
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<tr>
<td>Chengdu</td>
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<td>0.7</td>
<td>19.1</td>
<td>0.85</td>
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<tr>
<td>Chongqing</td>
<td>3.7</td>
<td>0.7</td>
<td>19.0</td>
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<tr>
<td>Background (86\textdegree E \times 40\textdegree N)</td>
<td>0.6</td>
<td>-0.03</td>
<td>-5.2</td>
<td>0.56</td>
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</table>
Correlation between NO2 and vehicles population during 1996~2006
Effect assessment with satellite data during Temporary traffic control

Traffic control during forum on China-Africa cooperation in 2006

Traffic control during the "Lucky Beijing" series comprehensive test competition in 2007
Tropospheric SO$_2$ over China during 2005-2007

Tropospheric SO$_2$ vertical columns in DU averaged during 2005 - 2007 over China
CH4 Temporal and spatial distribution —— SCIMACHY

Spring

Summer

Autumn

Winter
CH4 Temporal and spatial distribution — AIRS (300 mba)

Spring

Summer

Autumn

Winter
The increasing trend for CO in the west region of China is at magnitude of a few thousandths, but in the east the increasing trend is at magnitude of few hundreds.
Seasonal variation of CO over China
CO2 Temporal and spatial distribution —— AIRS (500mba)
Papers published

30 Papers, 10 in SCI/EI within recent 5 years


Introduction

**AMFIC** addresses atmospheric environmental monitoring over China. The aim is to develop an integrated information system for monitoring and forecasting tropospheric pollutants over China. The system uses satellite and *in situ* air quality measurements and modelling to generate consistent air quality information over China. The data will cover the recent years and the actual situation including an air quality forecast for several days ahead. Air pollutants covered are ozone, nitrogen dioxide, sulphur dioxide, formaldehyde, carbon monoxide, methane and aerosol/particulate matter.

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A list of participants of AMFIC can be found [here](#).

Final meeting in Beijing

The [final meeting](#) of the AMFIC project will take place in Beijing at 23 October 2009, and is open to all interested users of the data products. Participants can take advantage of combining this meeting with the Regional Air Quality Management conference on control of NOx sources, held at 26-27 October, also in Beijing.

Calendar

Select a day

Year: 2009
Month: October
Day: 11

Submit

Images of 11 October 2009

NO₂
Cloud Fraction

SO₂
AER

previous day
previous month
next day
next month
# AMFIC validation data sets

<table>
<thead>
<tr>
<th>Name</th>
<th>Latitude</th>
<th>Longitude</th>
<th>NO2 OMI</th>
<th>SO2 SCIA</th>
<th>SO2 OMI(1)</th>
<th>CO SCIA(2)</th>
<th>Aerosol</th>
<th>Total 03 OMI</th>
<th>CH20 SCIA</th>
<th>CH20 GOME-2</th>
<th>Trop. 03 GOME-2</th>
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East China – Ozone peak value

CHIMERE surface $O_3$ peak value, F0, 12 Oct 2012

Ozone concentration [µg/m³]

0 50 100 150 200 250 300
中国空气质量监测与预报

选择区域 中国东部

CHIMERE surface $O_3$ peak value, F0, 12 Oct 2009

O$_3$ concentration [$\mu$g/m$^3$]

2012/4/20

Space Research Information Day
Aerosol optical depth on the first ten days of August, 2008 from MERSI/FY-3A

Histroy data from MODIS, and 2008 data from MERSI/FY-3A

AOD Monthly Average (2005〜2008) over Beijing Area

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<th>Month</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
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<td>July</td>
<td>0.5137</td>
<td>0.6850</td>
<td>0.6081</td>
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<td>Aug</td>
<td>0.6161</td>
<td>0.5408</td>
<td>0.5657</td>
<td>0.3722</td>
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<td>Sept</td>
<td>0.4005</td>
<td>0.4358</td>
<td>0.5179</td>
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30% AOD decrement means the traffic control policy cleans the atmosphere effectively.
NO$_2$ reductions detected during 2008 Olympic Games


GOME-2, 2007

GOME-2, 2008

NO$_2$ reductions
GOME-2 observations against CHIMERE simulations

Beijing

Shijiazhuang

Tianjin

NO$_2$ reductions
-65%

-75%

75%
- Dr. Peng Zhang, National Satellite Meteorological Center, China Meteorological Administration (AMFIC - Air Quality Monitoring and Forecasting in China – project partner)

On the AMFIC project, its results (air quality forecasts for cities such as Shanghai, Beijing and Shenyang), and the experience of China-EU space research cooperation

Powerpoint presentation [14 MB]
4. Summary

- Good platform for cooperation: MOST-ESA bilateral cooperation
- Common research interest: Air Quality, Earth Care
- Deep communication and discussion among the scientists
- Some knowledge about the European System: such as budget, audit
Thank you!