Methodology for the creation of meteorological datasets for Local Air Quality modelling at airports

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About ENVISA

Noise Studies
- ENHANCE
- Environmental Impact Assessment of CDA

Global Emissions & Local Air Quality
- AEM, ALAQS
- CAEP Goals Assessment
- Environmental Impact of Delays

Economics & Sustainability
- Cost Benefit Analyses
- Environmental Tradeoffs

6-9 October 2008
HARMO12 conference, Cavtat, Croatia
Overview of the presentation

1. Data requirements for Local Air Quality studies at airports
2. Three sources of meteorological data
   - Monitored data (METAR)
   - Numerical weather prediction models (WRF)
   - Archived data (Re-Analysis)
3. Methodology to create datasets for Local Air Quality studies
4. Case study: two airports in south-east England
Basic data for dispersion model

- Emission inventory results (time + space)
- Topography
- Chemistry
- Key meteorological data
  - Wind speed and direction (straightforward)
  - Temperature, pressure, humidity (depending on the dispersion model)
  - **Stability** (not directly measured !)
Three ways to obtain meteo data

1. METAR data - from monitoring stations located at airports (generated for aviation purposes, but very suitable for air quality studies)
2. WRF - from numerical weather models (high expertise of meteorology required)
3. Re-Analysis - from long term / large scale archived data
1. METAR Aviation Weather Reports

- from the French "METéorologique Aviation Régulière".
- Routine weather report from airports

<table>
<thead>
<tr>
<th>PROS</th>
<th>CONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very detailed monitoring - most METAR reports in the EU are half-hourly</td>
<td>Available only for airport opening hours (i.e. no data overnight)</td>
</tr>
<tr>
<td>Generated by automated sites</td>
<td>Stability must be calculated using other parameters</td>
</tr>
<tr>
<td>Usually reviewed by certified weather forecasters prior to being transmitted</td>
<td>Local scale only</td>
</tr>
</tbody>
</table>
1. METAR Weather Components

- Wind speed and direction
- Visibility
- RVR (Runway Visual Range)
- Cloud cover
- Temperature / Dew Point
- QNH (barometric pressure extrapolated to sea level)
- Recent weather
- Wind shear
- Trend
1. METAR Example: CROATIA

- METAR LDDU 171230Z 25008KT 210V310 9999 BKN043 20/04 Q1013 NOSIG
- METAR LDOS 171230Z 29006KT 9999 BKN030 11/05 Q1018 NOSIG
- METAR LDPL 171230Z 13005KT 000V360 9999 FEW055 19/03 Q1018 NOSIG
- METAR LDRI 171230Z VRB02KT 9999 FEW047 19/02 Q1018 NOSIG
- METAR LDSP 171230Z 07006KT 020V130 CAVOK 20/02 Q1015 NOSIG
- METAR LDZD 171230Z VRB06KT 9999 FEW050 20/03 Q1017 NOSIG
- METAR LDZA 171230Z VRB03KT CAVOK 16/02 Q1019 NOSIG

Extracted from NOAA METAR Data Access Web Site:
http://weather.noaa.gov/weather/metar.shtml
## 1. METAR Example Decoded Part A

- More comprehensively…

<table>
<thead>
<tr>
<th>ICAO</th>
<th>Station Name</th>
<th>Country</th>
<th>Location</th>
<th>Elevation</th>
<th>Time</th>
<th>Temperature</th>
<th>Dew Point</th>
<th>RH</th>
<th>Wind</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDDU</td>
<td>Dubrovnik-Cilipi</td>
<td>Croatia</td>
<td>42-34N 018-16E</td>
<td>170m</td>
<td>17 / 12:30Z</td>
<td>20.0°C</td>
<td>4.0°C</td>
<td>35%</td>
<td>WSW (250 degrees) at 4 m/s</td>
</tr>
<tr>
<td>LDOS</td>
<td>Osijek</td>
<td>Croatia</td>
<td>45-28N 018-49E</td>
<td>89m</td>
<td>17 / 12:30Z</td>
<td>11.0°C</td>
<td>5.0°C</td>
<td>66%</td>
<td>WNW (290 degrees) at 3 m/s</td>
</tr>
<tr>
<td>LDPL</td>
<td>Pula</td>
<td>Croatia</td>
<td>44-53N 013-55E</td>
<td>63m</td>
<td>17 / 12:30Z</td>
<td>19.0°C</td>
<td>3.0°C</td>
<td>35%</td>
<td>SE (130 degrees) at 3 m/s</td>
</tr>
<tr>
<td>LDRI</td>
<td>Rijeka/Omisalj</td>
<td>Croatia</td>
<td>45-13N 014-34E</td>
<td>85m</td>
<td>17 / 12:30Z</td>
<td>19.0°C</td>
<td>2.0°C</td>
<td>32%</td>
<td>Variable at 1 m/s</td>
</tr>
<tr>
<td>LDSP</td>
<td>Split/Kastel Sta</td>
<td>Croatia</td>
<td>43-31N 016-18E</td>
<td>21m</td>
<td>17 / 12:30Z</td>
<td>20.0°C</td>
<td>2.0°C</td>
<td>30%</td>
<td>ENE (70 degrees) at 3 m/s</td>
</tr>
<tr>
<td>LDZD</td>
<td>Zadar/Zemunik</td>
<td>Croatia</td>
<td>44-06N 015-22E</td>
<td>84m</td>
<td>17 / 12:30Z</td>
<td>20.0°C</td>
<td>3.0°C</td>
<td>32%</td>
<td>Variable at 3 m/s</td>
</tr>
<tr>
<td>LDZA</td>
<td>Zagreb/Pleso</td>
<td>Croatia</td>
<td>45-43N 016-04E</td>
<td>110m</td>
<td>17 / 12:30Z</td>
<td>16.0°C</td>
<td>2.0°C</td>
<td>39%</td>
<td>Variable at 2 m/s</td>
</tr>
</tbody>
</table>
### 1. METAR Example Decoded Part B

<table>
<thead>
<tr>
<th>ICAO</th>
<th>Station Name</th>
<th>Country</th>
<th>Visibility</th>
<th>Pressure</th>
<th>Sky Condition</th>
<th>Weather</th>
<th>Remarks</th>
<th>Heat Index</th>
<th>Wind Chill</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDDU</td>
<td>Dubrovnik-Cilipi</td>
<td>Croatia</td>
<td>&gt; 10000m</td>
<td>1012.9 mb</td>
<td>Broken clouds at 1300m</td>
<td></td>
<td></td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>LDOS</td>
<td>Osijek</td>
<td>Croatia</td>
<td>&gt; 10000m</td>
<td>1017.9 mb</td>
<td>Broken clouds at 910m</td>
<td></td>
<td></td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>LDPL</td>
<td>Pula</td>
<td>Croatia</td>
<td>&gt; 10000m</td>
<td>1017.9 mb</td>
<td>Few clouds at 1700m</td>
<td></td>
<td></td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>LDRI</td>
<td>Rijeka/Omisalj</td>
<td>Croatia</td>
<td>&gt; 10000m</td>
<td>1017.9 mb</td>
<td>Few clouds at 1400m</td>
<td></td>
<td></td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>LDSP</td>
<td>Split/Kastel Sta</td>
<td>Croatia</td>
<td>&gt; 10000m</td>
<td>1014.9 mb</td>
<td></td>
<td></td>
<td></td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>LDZD</td>
<td>Zadar/Zemunik</td>
<td>Croatia</td>
<td>&gt; 10000m</td>
<td>1016.9 mb</td>
<td>Few clouds at 1500m</td>
<td></td>
<td></td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>LDZA</td>
<td>Zagreb/Pleso</td>
<td>Croatia</td>
<td>&gt; 10000m</td>
<td>1019.0 mb</td>
<td></td>
<td></td>
<td></td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Deriving stability from observed data

- Stability is generally not monitored, so it must be derived from other observed parameters.
- Stability is based on the "Turner method" which is recommended by the US Environmental Protection Agency.
- The Pasquill-Gifford stability classes (A 'very unstable' to G 'very stable') are calculated based on the following variables:
  - wind speed
  - cloud cover (sky condition)
  - sun angle (time of day, latitude of airport)
2. MM5 Weather Model

- Meso-scale numerical weather prediction model
- From the US National Center for Atmospheric Research
- Free community model used by over 400 institutions in 30 countries

<table>
<thead>
<tr>
<th>PROS</th>
<th>CONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Used for weather prediction and weather data collection</td>
<td>Needs a high level of expertise in meteorology</td>
</tr>
<tr>
<td>Very accurate data on a very fine spatial and temporal grid</td>
<td>High computing time</td>
</tr>
<tr>
<td>Data available in 3D gridded format for sophisticated models</td>
<td>Complex input data (terrain, meteo) + format</td>
</tr>
<tr>
<td>Stability explicitly available</td>
<td></td>
</tr>
</tbody>
</table>
2. Mandatory MM5 Input Requirements

- **Gridded** 2D fields (surface data): sea-level pressure, sea-surface temperature, snow cover, sea ice cover, soil temperature, soil moisture

- **Gridded** 3D fields (upper air data): temperature, wind speed and direction, pressure, relative humidity, etc.

Note: Can Use NCEP/NCAR REANALYSIS 2 DATA SET
2. Observational Data for MM5

- **Optional** data
- Upper air observations: pressure, height, temperature, humidity, wind speed and direction (e.g. balloons and aircraft)
- Surface observations: winds, cloud cover, precipitation, maximum and minimum temperature (e.g. airports, weather stations, ships, buoys)

Note: can use METAR for surface data
2. MM5 Model Output: 2D Fields

- Cloud ceiling
- Accumulated precipitation
- Planetary boundary layer height
- Surface evaporation
- Soil moisture/temperature
- Surface/underground runoff
- Snow depth
- Surface roughness/friction
- Flight regulation (VFR, MVFR, IFR, LIFR) via post-processor
- Etc.

There are hundreds of fields available!
2. MM5 Model Output: 3D Fields

- Wind speed and direction
- Vertical wind shear
- Temperature
- Relative humidity
- Pressure
- Cloud/rain/snow/ice water content
- Radiation fluxes
- Clear air turbulence via post-processor
- Etc.

There are hundreds of fields available!
2. WRF Weather Model (New MM5)

- “Weather Research and Forecasting”
- Co-developed by research and operational communities
  - ARW core “Advanced Research WRF”
  - NMM core “Nonhydrostatic Mesoscale Model”
- Supersedes MM5
- Freely available
3. Re-Analysis data

- From two US National Centers:
  - for Environmental Prediction NCEP
  - for Atmospheric Research NCAR
- Analysis / forecast system prepares re-analysis data
- Over 80 different variables (temperature, relative humidity, U and V wind components, etc.)
- 17 pressure levels (heights)
- 2.5 x 2.5 degree grids, 4 times daily
- Diagnostic terms (radiative heating, convective heating, etc.) and accumulative variables (precipitation rate, etc.)
3. Re-Analysis data

<table>
<thead>
<tr>
<th>PROS</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Data available since 1948</td>
<td>Fixed spatial and temporal resolution. Data must be interpolated to be used in dispersion models.</td>
</tr>
<tr>
<td>Great set of information available (80 different variables)</td>
<td>Very coarse resolution (2.5 x 2.5 degree grid, 4 times a day)</td>
</tr>
<tr>
<td>Large datasets can be extracted quickly</td>
<td>Stability must be calculated based on other parameters</td>
</tr>
<tr>
<td>&quot;Good guess&quot; meteo data</td>
<td></td>
</tr>
</tbody>
</table>
Method to choose meteo data source

Is gridded met data required by LAQ model?

Yes

Choose MM5/WRF

No

Is METAR data available for the airport(s) and time frame of study?

Yes

No

Can the stability parameter(s) required by the LAQ model be estimated using REANALYSIS?

Yes

Is this a long-term study and/or multiple airport study?

No

Choose REANALYSIS

No

Can the stability parameter(s) required by the LAQ model be estimated using METAR?

Yes

Choose METAR

No
Case study at two airports

- Two airports in the same region: south-east England
- Distance between airports ~20 km
- For both airports, METAR data was available from the airport weather station
  - At airport A, reports were issued every 30 minutes
  - At airport B, reports were issued every hour but only for day-time
Approach followed (1)

Comparison of meteo data at airport A and airport B for common open hours for wind speed, direction and calculated stability.
Approach followed (2)

- Since differences in wind speed, in direction frequencies and in stability classes were small, it was decided to use the METAR data from airport A to estimate the meteo at airport B during the missing hours.

- This was also valid because the two airports were fairly close to each other.
Re-analysis data for S-E England
Re-analysis data

- Was also used to validate the results of the local air quality studies for policy usage
- Trends of the period 1979-2007 were compared with the year 2006 only
- The results showed that 2006 could be considered as a "standard year" because no particular extreme weather event suggest it was abnormal
- Therefore, the dispersion results (i.e. concentrations) were considered to be "standard" (from the met. point of view)
Conclusion

1. Detailed monitored data (METAR) should be preferred for airport air quality studies.
2. If no METAR reports exist at one airport, then airports in the surrounding area should be investigated.
3. Otherwise, use data from Numerical Weather Prediction models (or in the worst case, Re-analysis data).
4. Re-analysis data is best used to validate that the meteorological conditions of the dispersion period are not exceptional.
Web references

METAR Data Access Web Site:
http://weather.noaa.gov/weather/metar.shtml

Turner Method:
http://www.webmet.com/met_monitoring/641.html

MM5 model:
http://www.mmm.ucar.edu/mm5/

WRF model:
http://www.wrf-model.org/index.php

NCEP/NCAR Re-Analysis:
http://www.cdc.noaa.gov/cdc/data.ncep.reanalysis2.html
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Thank you for your attention!

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