CALIPSO Identification of Elevated Dust over Australia Compared with Air Quality Model Forecasts

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  - Feature Finder, Cloud-Aerosol Discrimination, Aerosol Sub-typing

- Method: – Australian Air Quality Forecast System Model

- Method: – Comparison of CALIOP VFM & AAQFS PM60 dust

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- Conclusions
**Aims of the AAQFS Validation Study**

**AIM:** To test, develop and validate the Australian Air Quality Forecast System Model by comparing forecast dust events with dust measured by CALIPSO. (Assumes CALIPSO represents “truth”)

**METHOD:** For a 2-month (dust season) period, save AAQFS model outputs along CALIPSO ground tracks for comparison with CALIPSO VFM. Conduct tests in five levels of increasing difficulty.

1. **Yes / No:** In any grid cell do AAQFS and CALIPSO agree on the existence or absence of a dust plume?
2. **Location:** How well do plume centroids agree?
3. **Dimensions:** How well do the vertical and horizontal extents agree?
4. **Type:** Do the aerosol types agree?
5. **Amount:** How well do the concentrations / AOT agree?
6. **Additional Test:** Height of mixed layer along path
Aim of This Current Analysis

Aim of this current analysis (an extension of the initial study) is to examine and report any information relevant to the CALIPSO analysis that can be deduced from comparison with the model forecasts. (N.B. not “validating” CALIPSO with a model!)

- Feature Finder performance in the relatively clean Australian skies
- Cloud – Aerosol Discrimination with (possibly) different aerosol types
- Aerosol Sub-typing under the above conditions

Reasons for manual rather than automated analysis:

1. Several difficulties exist in directly and automatically comparing the model forecasts with the data.
   - E.g. Dust events often obscured by overlying cloud bands.

2. CALIPSO does not always represent “truth”.
   - Algorithm performance depends on SNR
   - Algorithms not yet fully validated
In this study, Model dust forecasts are compared with CALIPSO Vertical Feature Mask.

CALIPSO Vertical Feature Mask is the result of analysing the calibrated, attenuated backscatter data using three sophisticated algorithms:

1. The Feature Finder (Selected Iterated Boundary Locator – SIBYL)

2. The Cloud-Aerosol Discrimination Algorithm

3. The Aerosol Sub-typing algorithm

Complete documentation on these algorithms is available from the CALIPSO website:

http://www-calipso.larc.nasa.gov/resources/project_documentation.php
Regional and urban grids

- meso_LAPS (0.05°) (Limited Area Prediction System)
- Chemical Transport Model (0.05 and 0.01°);
- gas-phase primary and photochemical smog species;
- aerosol species include dust, sea salt, primary aerosols (domestic wood combustion, motor vehicle) + secondary (simple) inorganic.
- 24-36 hour forecasts issued twice per day

Australian Air Quality Forecast System Model

- Emissions Processing System + Data
- Numerical Weather Prediction System
- Chemical/Transport Model
- 3-dimensional air pollution concentration forecasts
- Verification System + AQ data
- Web + Graphical Display Systems

Provided by the State Environment Agencies

Provided to the State Environment Agencies

Bureau of Meteorology

CSIRO
AUSTRALIAN AIR QUALITY FORECASTING SYSTEM

SOIL TYPE

LAI: June (Hua Lu 2003)

SOIL MOISTURE CONTENT (kg kg$^{-1}$)

PM$_{10}$ ($\mu$g/m$^3$)

Emissions (kg/s)

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CALIPSO Science Team Meeting
Paris, France, Mar 11-13, 2008
SAY: CALIPSO & AAQFS dust 7
Australian Air Quality Forecasting System

from Wain et al.
**Method – Comparison of Forecast & VFM**

- For the 2006 and 2007 Australian dust seasons (mid October – mid-December 2006 and November 2007 – early January 2008), save the AAQFS model forecasts of PM60 dust concentrations along the predicted CALIPSO orbit tracks, as indicated on the CALIPSO Validation Site for the AAQFS domain (10.5°S – 43°S, 110°E – 160.25°E) 
  - 2007 season only reported here
  - 190 available comparisons

- Download the corresponding CALIPSO Version 2.01 Vertical Feature Mask files

- Plot VFM Cloud-Aerosol Discrimination and VFM Aerosol Sub-typing Data and AAQFS PM60 dust forecasts on similar scales on the same page with CALIPSO Attenuated Backscatter Browse Image

- Inspect and compare plots visually and classify results.

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Classification of Results

Results have been assigned to the following (not mutually-exclusive) classes:

1. Model & VFM agree substantially
2. Model predicts dust where VFM obscured by cloud
3. Model predicted vertical dust extent (Zmax) < VFM
4. Model predicted dust location different from VFM
5. Model & VFM disagree – No feature seen in VFM or raw ABS* plot
6. Model & VFM disagree – VFM dust extent < than in raw ABS* plot
7. Model predicts dust where VFM not dust
8. VFM shows dust where model predicts clear conditions

* ABS = Attenuated Backscatter (Browse Image)
CALIOP VFM – AAQFS Comparison

CALIOP VFM Cloud- Aerosol Discrim.:  
1 = clear air, 2 = cloud, 3 = aerosol  
5 = surface, 6 = sub-surface  
7 = no signal - obscured

CALIOP VFM Aerosol sub-type:  
1 = Clean Marine, 2 = Dust  
3 = Polluted Continental, 4 = Clean Continental  
5 = Polluted Dust  
6 = Smoke, 7 = ?

AAQFS Predicted PM60 dust  
Smoke tracer overplotted in grey

Latitude (degrees South)
Forecast Dust Event Obscured by Cloud

CALIOP 532-nm attenuated backscatter: (CALIPSO Browse Image – NASA LaRC)

CALIOP VFM Cloud- Aerosol Discrim.:  
1 = clear air, 2 = cloud, 3 = aerosol  
5 = surface, 6 = sub-surface  
7 = no signal - obscured

AAQFS Predicted PM60 dust (µg/m³)
VFM shows incomplete extent of layer

CALIOP 532-nm attenuated perpendicular backscatter (/km/sr)

CALIOP VFM Cloud- Aerosol Discrim.:  
1 = clear air, 2 = cloud, 3 = aerosol  
5 = surface, 6 = sub-surface  
7 = no signal - obscured

AAQFS Predicted PM60 dust (\(\mu\)g/m\(^3\))
## Results Summary

<table>
<thead>
<tr>
<th>Category</th>
<th>Occurrences</th>
<th>% overpasses</th>
</tr>
</thead>
<tbody>
<tr>
<td>not mutually exclusive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Model &amp; VFM agree substantially</td>
<td>98</td>
<td>51.6</td>
</tr>
<tr>
<td>2. Model predicts dust where VFM obscured by cloud</td>
<td>98</td>
<td>51.6</td>
</tr>
<tr>
<td>3. Model dust vertical extent &lt; VFM</td>
<td>49</td>
<td>25.8</td>
</tr>
<tr>
<td>4. Model location different from VFM</td>
<td>8</td>
<td>4.2</td>
</tr>
<tr>
<td>5. Model &amp; VFM disagree –</td>
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<td>4.2</td>
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<tr>
<td>No feature seen in VFM or raw ABS plot</td>
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<tr>
<td>6. Model &amp; VFM disagree –</td>
<td>98</td>
<td>51.6</td>
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<tr>
<td>VFM dust extent &lt; than in raw ABS* plot</td>
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<tr>
<td>7. Model predicts dust where VFM not dust</td>
<td>14</td>
<td>7.4</td>
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<tr>
<td>8. VFM shows dust where model clear</td>
<td>41</td>
<td>21.6</td>
</tr>
</tbody>
</table>

* ABS = Attenuated Backscatter (Browse image)
Initial Conclusions

Model Performance:

- Model generally performs well with forecast locations in general agreement with data and horizontal extents generally comparable.
- Most common difference between model and data is that the predicted vertical extent of the dust event is smaller than detected by the lidar. (Model Limit)
- Further study needed on situations with low-cloud.

CALIPSO Algorithm Performance:

Good news (based on limited data used here):

- Feature finder finds most moderate to strong aerosol plumes.
- Cloud Aerosol Discrimination algorithm works well in most cases studied.
- Over continent, Aerosol sub-typing generally appears consistent with what would be expected from surface data, meteorology and model.

Further study?

- Detection of broad aerosol layers over the Australian continent where VFM often “patchy”
- Australian continent is relatively bright (sparsely vegetated over most of interior). So SNR is reduced by day.

- Aerosol loading, except in significant events like bushfires and dust storms, is relatively low. (So is there anything to worry about anyway?)

- Some studies (e.g. Ross Mitchell CSIRO) have reported that the dust in some areas is relatively highly absorbing because of the high iron content. (High absorption → Higher Sa → lower backscatter for a given AOT and therefore harder to detect?)

- Many passes over Australia show a decrease in backscatter over the continent relative to the surrounding oceans. (Drying out and shrinking of aerosols, dry deposition of the mainly salt aerosols?)