Synergistic Cloud Clearing Using Aqua Sounding and Imaging Infrared Measurements

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- Cloud Clearing/Cloud Detection
- MODIS/AIRS Variable FOV Rtv.
- AIRS Cloud Clearing Assessment
- IMAPP (see Presentation/Poster for details)
- Co-location/Comparison
- Synergistic C.C. Approach
- Summary, Future Work & Goal

Sainte Adele, Canada
29 October 2003 - 4 November 2003
MODIS True Color Image – 24 August, 2002

Clouds are almost everywhere
Aqua Color Composite
Red: B1 (.645)
Green: B6 (1.64)
Blue: B31 (11.)

Cloud Phase
(Day time Alog.)

- Ice
- Water
- Mixed
- Uncertain
- Clear
- No Retrieval
See IMAPP Poster for Details
Global Aqua AIRS
6 September, 2002
High-spectral Resolution
Brightness temperature
Images and Spectra
AIRS Clear FOV Determination Using MODIS 1 km Cloud Mask

- Cloudy Scenes identified by MODIS cloudmask (adapted for AIRS FOVs)
- Clear if \( n_{99} + n_{95}/n_{Total} > 0.95 \)

**Clear Percentage: 13.5%**
Clear&Land: 6.1 %, Clear&Ocean: 7.4%
AIRS/MODIS Co-location Example

Scan Angle = 49

Scan Angle = 23.7

Nadir
Convoluting AIRS with MODIS SRFs

conv1 = *continuous* kcarta monochromatic calculation based on ECMWF profile coincident w/ 20 July granule 224 convolved w/ GOES10 SRFs

conv2 = *continuous* kcarta monochromatic calculation based on ECMWF profile coincident w/ 20 July granule 224 convolved w/ AIRS SRFs and then with GOES10 SRFs

* using channels w/ Bad_Flag == 0

<table>
<thead>
<tr>
<th>Band</th>
<th>1/cm</th>
<th>microns</th>
<th>“convError” = conv1-conv2 (K)</th>
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<tbody>
<tr>
<td>32</td>
<td>830.8</td>
<td>12.03</td>
<td>-0.00</td>
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<tr>
<td>33</td>
<td>748.3</td>
<td>13.36</td>
<td>0.20</td>
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<tr>
<td>34</td>
<td>730.8</td>
<td>13.68</td>
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<td>35</td>
<td>718.2</td>
<td>13.92</td>
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<tr>
<td>36</td>
<td>703.5</td>
<td>14.21</td>
<td>0.16</td>
</tr>
</tbody>
</table>

After
Dave Tobin
CIMSS
UW-Madison
MODIS Vs. AIRS
Good Co-located/Spectral agreement – can be used Synergistically

After
Dave Tobin
CIMSS
UW-Madison
AIRS Measurement Noise Filtering

- Calculate eigenvectors of observation covariance matrix
- Reconstruct observations using first eigenvectors
- Filter out random component of noise

Radiance [mW/m²/(cm⁻¹/sr)] at 654.7 cm⁻¹

Raw data

Filtered data (npc=10)

Filtered data (npc=30)

Filtered data (npc=50)

Filtered data (npc=100)
Cloud Clearing Noise Amplification Factor

\[
R_{\text{clear}} = R' + \eta_1 (R' - R_1) + \eta_2 (R' - R_2) + \ldots + \eta_K (R' - R_K)
\]

Need guess of clear radiances to solve the \( \eta \)s iteratively.

(K+1) FOVs are required to solve for \( R_{\text{clear}} \) with K cloud formations.
Reconstructed radiance \( R_{\text{clear}} \) contains an amplified random (measurement) noise \( \sigma' \):

\[
\sigma'^2 = \left[ (1 + \eta_1 + \eta_2 + \ldots + \eta_K)^2 + \eta_1^2 + \eta_2^2 + \ldots + \eta_K^2 \right] \sigma^2
\]

\( \sigma \): random (measurement) noise of radiances \( R_1, R_2, \ldots, R_{K+1} \)
Operational AIRS/AMSU Cloud Clearing Error Estimates
Good Performance Over Ocean Most of Time

Tropic

Mid-Latitude

Sub-Polar

Night

Day
Operational AIRS/AMSU Cloud Clearing Error Estimates

Good Performance Over Ocean Most of Time

Tropic  Mid-Latitude  Sub-Polar

Night

Day

Yellow – Max. C.C. Err.; Green – Min. C.C. Err.
Red – C.C. RMS Err.; Blue – AIRS FOV Noise
Operational AIRS/AMSU Cloud Clearing Error Estimates
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Operational AIRS/AMSU Cloud Clearing Error Estimates
Problematic Over Some Land Cases

Tropic  Mid-Latitude  Sub-Polar

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MODIS and AIRS Color Composite Images

MODIS True Color Composite Image, 1725 to 2050 UTC, September 2, 2003

MODIS (~1 km*)

AIRS (~14 km*)

*Resolution is specified as nadir view only
MODIS (1 km*) and AIRS (~14 km*) Cloud Phase Images

More mixed phase clouds occur in AIRS FOV/FOR

*Resolution is specified as nadir view only
MODIS 1 km Cloud Mask & Phase Images

Aqua MODIS, 1-kilometer Cloud Mask, 2003-08-02, 1725 to 2050 UTC

Aqua MODIS 1-kilometer Cloud Phase, September 2, 2003, 1725 to 2050 UTC

Mask

Phase

@ 1 km Nadir Resolution
AIRS Color Composite and Cloud Cleared Window Channel Images

Operational AIRS Cloud Cleared Tb Image

AIRS Level 2 Cloud-Cleared Radiance Product at 1000 cm⁻¹, September 2, 2003
MODIS/AIRS Synergistic Cloud Clearing Examples

Aqua MODIS 1-kilometer Cloud Phase, September 2, 2003, 1725 to 2050 UTC

[Map showing cloud phase coverage with color legend indicating unknown, mixed, ice, water, and clear conditions.]

Location of Land Case

Location of Ocean Case

CIMSS
Space Science and Engineering Center
MODIS/AIRS Co-located Cloud Phase Image

MODIS Cloud Phase Collocated with AIRS Granule 192, Land Case, Sept 2, 2003

AIRS FOV (17,11)
Lat 37.15, Lon -97.56

AIRS FOV (15,13)
Lat 36.98, Lon -96.55

Over Land

AIRS: 2003.09.02.192.L2.CC.v3.0.0.0.G03247002552.hdf
Cloud Clear BT Error [K] at center (4,5)
MODIS/AIRS Co-located TWP & Skin Temperature

Mean Values of TPW and Skin Temperature for clear MODIS pixels within AIRS FOVs, Land Case

δTPW = 0.5 cm
δTskin = 0.68 K
AIRS Single FOV Window Channel
Brightness Temperature Variations

Cloud Phase

8 degree Gradient

Window BT 1000 cm⁻¹ & 2616 cm⁻¹

Cloud Spectra

2 degree Gradient
AIRS FOR (3 by 3) Cloud Clearing Error Examples

AIRS.2003.09.02.192.L2.CC.v3.0.8.0.G03247002552.hdf
Cloud Clear BT Error [K] at center (4,5)

Max. C.C. Error

Min. C.C. Error
MODIS/AIRS Co-located Cloud Phase Image

MODIS Cloud Phase Collocated with AIRS Granule 174 FOVs, Ocean Case, Sept 2, 2003

Over Ocean

AIRS FOV (75,01)
Lat 15.45, Lon -55.65

AIRS FOV (73,83)
Lat 15.18, Lon -54.77

Cloud Clear BT Error [K] at center (27,25)

Space Science and Engineering Center
MODIS/AIRS Co-located TWP & Skin Temperature

Mean Values of TPW and Skin Temperature for clear MODIS pixels within AIRS FOVs, Ocean Case

Cloud Phase

TPW

Skin Tem.

δTPW = 0.45 cm
δTskin = 3.12K

Mean TPW = 2.70 cm
Mean Skin Temp = 293.39 K

Mean TPW = 2.75 cm
Mean Skin Temp = 294.61 K

Mean TPW = 2.79 cm
Mean Skin Temp = 295.21 K

Mean TPW = 2.86 cm
Mean Skin Temp = 296.34 K

Mean TPW = 2.92 cm
Mean Skin Temp = 295.34 K

Mean TPW = 2.89 cm
Mean Skin Temp = 295.44 K

Mean TPW = 3.02 cm
Mean Skin Temp = 296.01 K

Mean TPW = 3.01 cm
Mean Skin Temp = 295.32 K
AIRS FOR (3 by 3) Single FOV Window Channel Brightness Temperature Variations

Cloud Phase

9 degree Gradient

Window BT 1000 cm\(^{-1}\) & 2616 cm\(^{-1}\)

Cloud Spectra

3 degree Gradient
AIRS FOR (3 by 3) Cloud Clearing Error Examples

AIRS FOR (3 by 3) Cloud Clearing Error Examples

Max. C.C. Error

Min. C.C. Error
AIRS FOR (3 by 3) Cloud Clearing
Error Examples

Minimum C.C. Error Case

Cloud Clear Error Estimate

Difference between Averaged Clear and Cloud Cleared
Alternative Stand-Along IMAPP AIRS Cloud Clearing Approaches - Without Performing Profile Retrieval

• Noise filtering AIRS cloudy radiances prior to C.C. to minimize noise amplification
  • Use of minimum resources and ancillary data (besides available Direct Broadcast measurements)

• Synergistic AIRS/MODIS C.C.:
  • Use of MODIS clear radiance estimates
  • Use of MODIS for surface type/emissivity estimates
  • Use of MODIS level 2 (single pixel) TPW, Sfc-Tskin ..for Q.C.

• Variable C.C. Area (1 by 3; 2 by 2 FOVs; superobs or customized ..….)

• Evaluation of AIRS/AMSU Cloud Clearing Performance

• Optimal use of Cloud Cleared Radiances

**Goal**

Demonstrate Imaging/Sounding Synergy to improve yields of IR Data utilization