CERES CLOUDS STATUS

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CERES STM, Princeton, NJ, September 17, 2002
TOPICS

- Cloud mask changes

- Delivery of MODIS Edition 1a
  - Sensitivity to model errors
  - Calibration sensitivities
  - Validation from climatology
  - Validation from ARM data
  - Consistency with VIRS

- First Aqua MODIS data
  - Initial results
  - 1.6-µm channel (Yuck!)
CHANGES TO CLOUDS SINCE Beta2

1. Altered logic for phase discrimination to improve thin ice cloud selection.
   1.6-μm classifier not consistent for thin cloud class.
   If LBTM cloud class is high, the outcome is more likely ice than before

2. Clear-sky snow & ice models updated & refined (higher angle resolution),
   improved snow/ice maps, updating now occurs over snow/ice regions

3. Polar mask algorithm retuned, accounts for calibration differences

4. Welch MODIS classifier implemented (VIRS & MODIS algos separate), used in
   polar regions to aid phase discrimination

5. Monthly clear-sky startup maps generated for MODIS, daily updating now

6. NoVIS (1.6, 3.7, 11.0 μm) algorithm turned on over snow

7. Detection of clouds in glint regions refined => fewer false clouds
SENSITIVITY OF 3.7-µm TEMPERATURE TO FILTER

• MODIS analyses using VIRS cloud emittance models, but filter functions slightly different

  What is the impact on temperature?

• Compute TOA temperature for surfaces & clouds at various temperatures using cloud optical properties computed for VIRS & MODIS filter functions

• MODIS reflectance models have been computed and used
3.7-μm Brightness Temperature Difference

**NIGHT**

- $r_e = 8 \, \mu m$

Graphs showing $T_{MODIS} - T_{VIRS}$ (K) vs. viewing zenith angle for different values of $\tau_{cloud}$ (0.5, 2.0, 8.0, 32).

- Solid: $T_{cd} = 270K$
- Open: $T_{cd} = 285K$

Graphs for WCS showing different $T_{cd}$ values (200K and 250K) for solid and open conditions.
3.7-μm channel Brightness Temperature Differences
(MODIS - VIRS)

No Atmosphere

\[ \Delta T \text{ (K)} \]

- \[ T_{\text{clld}} = 200 \text{ K} \]

\[ \theta_o = 77.6^\circ \]

\[ \theta_o = 60.0^\circ \]

\[ \theta_o = 38.2^\circ \]

\[ \theta_o = 14.4^\circ \]

\[ \tau_{\text{cloud}} = 32, 8.0, 2.0, 0.5 \]

\[ 5^\circ, 90^\circ, \varphi \]

Viewing Zenith Angle
IMPACT OF VIRS EMITTANCE MODELS

• Daytime re differences should be variable between -0.5 and 0.5 µm
  - Sometimes warmer / colder than expected
• Daytime De differences should be variable, but potentially large
  - VIRS > MODIS for $\tau < 2$
  - MODIS > VIRS for $\tau = 2 - 10$

• Will impact nighttime thin cloud heights, more study needed

• Insert MODIS models later?
CALIBRATION EFFECTS

• VIRS & MODIS thermal calibrations differ by 0.1 to 0.5 K
  => 3.7-µm difference yields MODIS re is 0.5 µm < VIRS

• VIRS VIS reflectance greater at low values & smaller at high values
  => MODIS optical depths should be greater for thick clouds
  => MODIS optical depths should be slightly smaller for thin clouds
SURFACE COMPARISON VALIDATION

• ARM SGP
  - EVERYTHING APPEARS IN BOUNDS FOR PURE CLOUDS
  - LAND LOW-CLOUD HEIGHTS (use lapse rate approach)
    See Dong talk tomorrow

• ARM NSA FIRST TRIES
  - ON AVERAGE OK
    Instantaneous errors large for optically thin clouds
    Uttal talk?

SURFACE EMISSIVITIES COMPUTED BUT NOT USED AT NIGHT

- MAY AFFECT HEIGHTS & CLOUD DETECTION
- IMPACT UNDER STUDY
RESULTS
## CLOUD MASK CLEAR STATISTICS, DECEMBER 2000

### Day: csz > 0.1

<table>
<thead>
<tr>
<th>Category</th>
<th>Ocean</th>
<th>Land</th>
<th>Desert</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clr Good</td>
<td>0.920</td>
<td>0.759</td>
<td>0.971</td>
<td>0.853</td>
</tr>
<tr>
<td>Clr Weak</td>
<td>0.009</td>
<td>0.010</td>
<td>0.015</td>
<td>0.009</td>
</tr>
<tr>
<td>Clr Smoke</td>
<td>0.001</td>
<td>0.000</td>
<td>0.000</td>
<td>0.001</td>
</tr>
<tr>
<td>Clr Fire</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Clr Snow</td>
<td>0.017</td>
<td>0.228</td>
<td>0.009</td>
<td>0.108</td>
</tr>
<tr>
<td>Clr Glint</td>
<td>0.052</td>
<td>0.001</td>
<td>0.000</td>
<td>0.028</td>
</tr>
<tr>
<td>Clr Shadow</td>
<td>0.000</td>
<td>0.001</td>
<td>0.005</td>
<td>0.001</td>
</tr>
<tr>
<td>Clr Aerosol</td>
<td>0.002</td>
<td>0.000</td>
<td>0.000</td>
<td>0.001</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1.000</strong></td>
<td><strong>1.000</strong></td>
<td><strong>1.000</strong></td>
<td><strong>1.000</strong></td>
</tr>
</tbody>
</table>

7% increase!

### Night: csz < 0.1

<table>
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<th>Desert</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clr Good</td>
<td>0.704</td>
<td>0.661</td>
<td>0.717</td>
<td>0.687</td>
</tr>
<tr>
<td>Clr Weak</td>
<td>0.076</td>
<td>0.032</td>
<td>0.211</td>
<td>0.062</td>
</tr>
<tr>
<td>Clr Snow</td>
<td>0.220</td>
<td>0.307</td>
<td>0.072</td>
<td>0.251</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1.000</strong></td>
<td><strong>1.000</strong></td>
<td><strong>1.000</strong></td>
<td><strong>1.000</strong></td>
</tr>
</tbody>
</table>
**CLOUD MASK CLOUD STATISTICS, DECEMBER 2000**

**Day: csz > 0.1**

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<th>Desert</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cld Good</td>
<td>0.940</td>
<td>0.855</td>
<td>0.662</td>
<td>0.912</td>
</tr>
<tr>
<td>Cld Weak</td>
<td>0.038</td>
<td>0.042</td>
<td>0.088</td>
<td>0.047</td>
</tr>
<tr>
<td>Cld Glint</td>
<td>0.009</td>
<td>0.001</td>
<td>0.000</td>
<td>0.007</td>
</tr>
<tr>
<td>Cld N/R</td>
<td>0.030</td>
<td>0.068</td>
<td>0.250</td>
<td>0.042</td>
</tr>
<tr>
<td>Total</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
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**Night: csz < 0.1**

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<tr>
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<td>0.909</td>
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<td>0.908</td>
</tr>
<tr>
<td>Cld Weak</td>
<td>0.084</td>
<td>0.084</td>
<td>0.038</td>
<td>0.084</td>
</tr>
<tr>
<td>Cld N/R</td>
<td>0.007</td>
<td>0.009</td>
<td>0.053</td>
<td>0.014</td>
</tr>
<tr>
<td>Total</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
</tr>
</tbody>
</table>
MEAN CLOUD COVER, MODIS, DEC 2000

DAYTIME
MEAN CLOUD COVER, MODIS, DEC 2000

NIGHT
MEAN CLOUD COVER, MODIS, June 2001

Day
MEAN CLOUD COVER, MODIS, June 2001

night
EFFECTIVE CLOUD TEMPERATURE, MODIS, DEC 2000
MEAN EFFECTIVE CLOUD HEIGHT, MODIS, DEC 2000
NIGHT
MEAN EFFECTIVE ICE CRYSTAL DIAMETER, MODIS, DEC 2000

DAYTIME

De, μm
MEAN CLOUD LIQUID WATER PATH, MODIS DEC 2000

Daytime

g/m^2
MEAN WATER PATH, MODIS, DEC 2000, DAY

200012 Terra-MODIS_ValR1_024023 Mean Zonal Cloud Water Path (g/m²)
Ocean (Water Phase)  Land (Water Phase)

Ocean (Ice Phase)  Land (Ice Phase)

Latitude

Latitude

Latitude

Latitude
SOME REFERENCES


APPARENT PROBLEMS

- NIGHTTIME POLAR CLOUD MASK
  - too few clouds, need additional study
  - impact minimal on CERES because night in relatively dry atmosphere?

- POLAR DROPLET SIZES SEEM SMALL
  - Using SINT producing apparent discontinuity over snow/ice
  - additional study could help resolve the problem
  - current result better than alternative

- NIGHTTIME SHIFT IN CLOUD HEIGHT
  - Possibly due to lack of sfc emissivity at all wavelengths
  - Low cloud effect not apparent in overlap conditions
COMPARISONS WITH CLIMATOLOGY
Mean Cloud Fraction, June

MODIS (2001, 1-16)
Surface obs (1971-1996)
ISCCP (1984 - 1994)
MEAN CLOUD FRACTION, DEC

LATITUDE (°)

CLOUD FRACTION

SURFACE CERES ISCCP

ALL 0.632 0.563 0.669
60N - 60S 0.606 0.625 0.696
71-96 0.00 84-94
CONSISTENCY WITH VIRS
Scatter Plots for MODIS and VIRS Matchup

MODIS (200012021725) and VIRS (200012021654)
(stats for VIRS - MODIS)

Water Radius (μm)

- MODIS
  - number of boxes = 3329
  - mean = 0.4953
  - std = 2.4398

- VIRS
  - number of boxes = 1739
  - mean = 1.4022
  - std = 13.4658

Ice Diameter (μm)

- MODIS
  - number of boxes = 3329
  - mean = -3.7366
  - std = 9.3921

- VIRS
  - number of boxes = 1739
  - mean = -3.7669
  - std = 10.4462

Optical Depth (Water Phase)

- MODIS
  - number of boxes = 3329
  - mean = -3.7366
  - std = 9.3921

- VIRS
  - number of boxes = 1739
  - mean = -3.7669
  - std = 10.4462

Optical Depth (Ice Phase)

- MODIS
  - number of boxes = 3329
  - mean = -3.7366
  - std = 9.3921

- VIRS
  - number of boxes = 1739
  - mean = -3.7669
  - std = 10.4462

Δt = 31 min

V= 8.5
M= 8.0

V=21.4
M=25.1

V= 50.8
M=49.4

V= 6.1
M=9.8
Scatter Plots for MODIS and VIRS Matchup
MODIS (200012031805) and VIRS (200012031718)
(stats for VIRS - MODIS)

Water Radius (μm)

- Number of boxes: 1519
- Mean: 0.3298
- Std: 4.0259

Ice Diameter (μm)

- Number of boxes: 1700
- Mean: -3.7367
- Std: 21.0517

Optical Depth (Water Phase)

- Number of boxes: 1519
- Mean: -5.5597
- Std: 17.4317

Optical Depth (Ice Phase)

- Number of boxes: 1700
- Mean: -1.5403
- Std: 11.7743

Δt = 47 min
Scatter Plots for MODIS and VIIRS Matchup

Cloud Height (km) (20001203)

mean(virs-modis) = -0.3629
std (virs-modis) = 1.5915
number of matching boxes = 2474
Cloud fraction, June 2001, MODIS (day 1 - 16) vs. VIRS (month)

V = VIRS  
M = MODIS  
O = Ocean  
L = Land  
T = total

Cloud fraction for MODIS (day 1 - 16) and VIRS (month):
- MT = 52.2%  
- VT = 54.0%  
- VO = 59.2%  
- MO = 52.2%  
- VL = 42.5%  
- ML = 42.0%
Cloud phase, June 2001, MODIS (day 1-16) vs. VIRS (month)

V = VIRS
M = MODIS
O = Ocean
L = Land
w = water
i = ice

Ocean
- Vw 0.370
- Mw 0.333
- Vi 0.203
- Mi 0.219

Land
- Vw 0.225
- Mw 0.212
- Vi 0.158
- Mi 0.188
Cloud heights, June 2001, MODIS (1 -16) vs. VIRS (month)

Ocean

- Vv, 2.2 km
- Mv, 2.2
- Vv, 8.7
- Mv, 9.1

Land

- Vv, 3.7 km
- Mv, 3.5
- Vv, 8.7
- Mv, 9.0

Legend:
- V = VIRS
- M = MODIS
- O = Ocean
- L = Land
- w = water
- i = ice
Cloud heights, June 2001, MODIS (1-16) vs. VIRS (month)

- **V** = VIRS
- **M** = MODIS
- **O** = Ocean
- **L** = Land
- **w** = water
- **i** = ice

Ocean

- Vw, 2.2 km
- Mw, 2.2
- Vi, 8.7
- Mi, 9.1

Land

- Vw, 3.7 km
- Mw, 3.5
- Vi, 8.7
- Mi, 9.0
Cloud optical depth, June 2001, MODIS (week 1) vs. VIRS (month)

- **Ocean**
  - V: VIRS
  - M: MODIS
  - B: 7.0
  - M: 7.1
  - V: 14.0
  - M: 14.4
  - M-V: 0.1 ± 1.5
  - M-V: 0.4 ± 2.2

- **Land**
  - V: VIRS
  - M: MODIS
  - B: 9.8
  - M: 11.6
  - V: 17.4
  - M: 15.4
  - M-V: 2.8 ± 2.8
  - M-V: -2.0 ± 5.5

Legend:
- V = VIRS
- M = MODIS
- O = Ocean
- L = Land
- w = water
- i = ice
Cloud particle sizes, June 2001, MODIS (week 1) vs. VIRS (month)

V = VIRS  
M = MODIS  
O = Ocean  
L = Land  
w = water  
i = ice

Liquid

EFFECTIVE DIAMETER (µm)

30 40 50 60 70

VOi, 53.5
MOi, 54.4
VLi, 49.7
MLi, 44.6

EFFECTIVE RADIUS (µm)

µm

VOw, 14.7
MOw, 14.0
VLw, 11.3
MLw, 10.8

MO-VO: -0.7 ± 0.9 µm
ML-VL: -0.5 ± 0.6 µm

Ice

EFFECTIVE DIAMETER (µm)

50 55 60 65 70

VOi, 53.5
MOi, 54.4
VLi, 49.7
MLi, 44.6

EFFECTIVE RADIUS (µm)

µm

MO-VO: 0.9 ± 2.2 µm
ML-VL: -5.1 ± 2.7 µm
Cloud water path, June 2001, MODIS (1 - 16) vs. VIRS (month)

**Liquid Water Path (g m\(^{-2}\))**

- VO 64.4
- MO 66.5
- VL 69.1
- ML 82.8

**Ice Water Path (g m\(^{-2}\))**

- VO 261
- MO 288
- VL 295
- ML 272

Key:
- V = VIRS
- M = MODIS
- O = Ocean
- L = Land
- w = water
- i = ice
SUMMARY

• Cloud amount: **VIRS detects more cloud cover**
  - orbit times (MODIS designed for clear sky)
  - resolution differences, slight mask differences

• Optical depth: **VIRS has variable agreement with MODIS**
  - MODIS slightly greater on average (calibration, resolution), < 10% mean diff

• Effective size: **VIRS generally larger than MODIS** (ice over land greatest)
  - 0.5K difference in 3.7-µm cal => 0.5 µm Δε (< 10% bias)
  - Need updated 3.7-µm emissivity maps for thin clouds

• Water path: **Mixed results, < 10% difference on average, sampling differences**

• Heights: **Small differences on average, -0.2 km to 0.4 km** (ice)

• Future: examine calibration differences more closely & impact of cloud emittance models & surface emissivity data
NOTES

• VARIETY OF PROBLEMS IDENTIFIED
  
  SOME SOLVED
  
  OTHERS AWAIT SOLUTION
  
  NIGHTTIME IS BIGGEST PROBLEM AREA
  
  ADMS & FLUXES PROBABLY NOT AFFECTED MUCH

=> GO AHEAD AND RELEASE VERSION 1A

• CONTINUE WORKING ON SOLUTIONS
  
  HOPE FOR OPPORTUNITY TO MAKE LATER CHANGES
SUMMARY OF PRELIMINARY AQUA MODIS ANALYSES

• MODIS CHANNELS LOOK CLEAN EXCEPT FOR 1.6 µm
  - SELECT OTHER CHANNEL (1.24 or 2.13 µm)
  - GATHER STATS & DEVELOP MODELS

• ALGORITHMS WORKED WITH NO PROBLEMS
  - NEED TO VERIFY CALIBRATIONS

• MORE TO COME