Estimating instability indices from MODIS infrared measurements over the Korean Peninsula

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Instability Indices (II)

II provides the air mass parameters that can be used for short term forecasting, in particular, severe storm warning.

- **Lifted Index:**
  \[ LI = T_{\text{obs}} - T_{\text{lifted from surface}} \text{ at 500 mb} \]

- **K-Index:**
  \[ KI = (T_{\text{obs}(850)} - T_{\text{obs}(500)}) + TD_{\text{obs}(850)} - (T_{\text{obs}(700)} - TD_{\text{obs}(700)}) \]

- **SK-Index:**
  \[ SKI = (T_{\text{obs(surface)}} - T_{\text{obs}(500)}) + TD_{\text{obs(surface)}} - (T_{\text{obs}(700)} - TD_{\text{obs}(700)}) \]

- **KO-Index:**
  \[ KO = 0.5 * ( \Theta_{e\text{obs}(500)} + \Theta_{e\text{obs}(700)} - \Theta_{e\text{obs}(850)} - \Theta_{e\text{obs}(1000)}) \]

- **Maximum Buoyancy Index:**
  \[ MB = \Theta_{e\text{obs(maximum bet surface and 850)}} - \Theta_{e\text{obs(minimum bet 700 and 300)}} \]
Interactive retrieval of the temperature and humidity profile (Ma et al., 1999)

\[ x_{n+1} = x_0 + (S_x^{-1} + K_n^T S_e^{-1} K_n)^{-1} \times K_n^T S_e^{-1} [(T_B - T_B^n) + K_n(x_n - x_0)] \]

Profile vector \( x \) at an iteration step \( n \) can be obtained from:

- \( x_0 \): first guess profile
- \( T_B \): observed EBBT
- \( T_B^n \): simulated TB for profile an an iteration step \( n \)
- \( S_x \): correlation matrix of first guess errors
- \( S_e \): error covariance matrix of observed TB and of radiation model
- \( K_n \): Jacobians, change of EBBT with a changed profile:
  \[ K_n(m,i) = \partial T_B^n(m)/\partial x_n(i) \], \( m \): channel numbers, \( i \): profile vector

EBBT = Equivalent Blackbody Brightness Temperature
<table>
<thead>
<tr>
<th>Primary application</th>
<th>channel #</th>
<th>Band width (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture profile</td>
<td>27</td>
<td>6.535-6.895</td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>7.175-7.475</td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>8.400-8.700</td>
</tr>
<tr>
<td>Surface temperature and TPW</td>
<td>31</td>
<td>10.780-11.280</td>
</tr>
<tr>
<td></td>
<td>32</td>
<td>11.770-12.270</td>
</tr>
<tr>
<td>Temperature</td>
<td>33</td>
<td>13.185-13.485</td>
</tr>
</tbody>
</table>
Retrieval procedures

- Forward model calculation to obtain EBBT
- Fast model calculation using RTTOV-7 (Jacobian calculation for the derivative)
- First guess field from the interpolation of KMA RDAPS forecast profiles (10 km resolution)

MODIS Observation Time

00 03 06 09

MODIS Observation Time
Flow chart

First guess profiles (RDAPS forecast data)

MODIS IR TBs
(TB_{obs, clear-sky})

TB_{cal}^{n}
(RTM: RTTOV)

TB_{cal}^{n} - TB_{obs} < \varepsilon?

Yes

T, q profiles

No

Updated T, q profiles

II calculation
MODIS channel TB simulation
(0300UTC 27 Oct. 2003)

Initial guess $x_0$

Retrieved profiles: $x_n$
Example of retrieved profiles
(July 31, 2004, at Osan Korea)

GOES 7 IR Images

Hourly rainfall (mm)
From the night of 27 Oct. 2003 to the morning of 28.

Fig. (c) and (d)

KI and LI from NASA GDAAC: They showed weak unstable conditions near the cloud edge but seemed to fail to predict thunderstorm shower associated with the frontal passage.
Case 1 (Cont.)

II from RDAPS profiles
(a) KI
(b) K0
(c) LI
(d) MB

II from retrieved profiles
(a) KI
(b) K0
(c) LI
(d) MB
Case 2 (31 July 2004)

- Convective storm in front of Typhoon Namtheun
- Scattered convective storm over the peninsula
- Forecasts on 31 July 2004 over the peninsula
  Central region – partly cloudy, Southern region – partly to mostly cloudy
Case 2 (Cont.)

KI from MODIS

GOES-9 VIS image

Rain gauge (mm/hr)

11:15 KST 31 Jul 2004
Summary and conclusions

- It was possible to derive air mass parameters with a satisfactory quality using a physical retrieval scheme.
- It seems to produce better air mass parameters than currently produced II by NASA GDACC.
- MODIS IR measurements may provide extra information to forecasters for the short-term forecasting.
- MW measurements over the H₂O and O₂ bands and window region may be used for obtaining II over the cloudy area.