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:**

  $LI = T^{obs} - T^{lifted\ from\ surface}$ at 500 mb

- **K-Index:**

  $KI = (T^{obs(850)} - T^{obs(500)}) + TD^{obs(850)} - (T^{obs(700)} - TD^{obs(700)})$

- **SK-Index:**

  $SKI = (T^{obs(surface)} - T^{obs(500)}) + TD^{obs(surface)} - (T^{obs(700)} - TD^{obs(700)})$

- **KO-Index:**

  $KO = 0.5 * (\Theta_e^{obs(500)} + \Theta_e^{obs(700)} - \Theta_e^{obs(850)} - \Theta_e^{obs(1000)})$

- **Maximum Buoyancy Index:**

  $MB = \Theta_e^{obs(maximum\ bet\ surface\ and\ 850)} - \Theta_e^{obs(minimum\ bet\ 700\ and\ 300)}$

Physical retrieval

Interactive retrieval of the temperature and humidity profile (Ma et al., 1999)

$$\mathbf{x}_{n+1} = \mathbf{x}_0 + (\mathbf{S}_x^{-1} + \mathbf{K}_n^T \mathbf{S}_e^{-1} \mathbf{K}_n)^{-1} \times \mathbf{K}_n^T \mathbf{S}_e^{-1} [(T_B - T_B^n) + \mathbf{K}_n (\mathbf{x}_n - \mathbf{x}_0)]$$

Profile vector **x** at an iteration step n can be obtained from:

- $\mathbf{x}_0$: first guess profile
- T_B: observed EBBT
- T_B^n: simulated TB for profile an an iteration step n
- $\mathbf{S}_x$: correlation matrix of first guess errors
- $\mathbf{S}_e$: error covariance matrix of observed TB and of radiation model
- $\mathbf{K}_n$: Jacobians, change of EBBT with a changed profile:
  - $\mathbf{K}_n(m,i) = \partial \mathbf{TB}^n(m) / \partial \mathbf{x}_n(i)$, m: channel numbers, *i*: profile vector

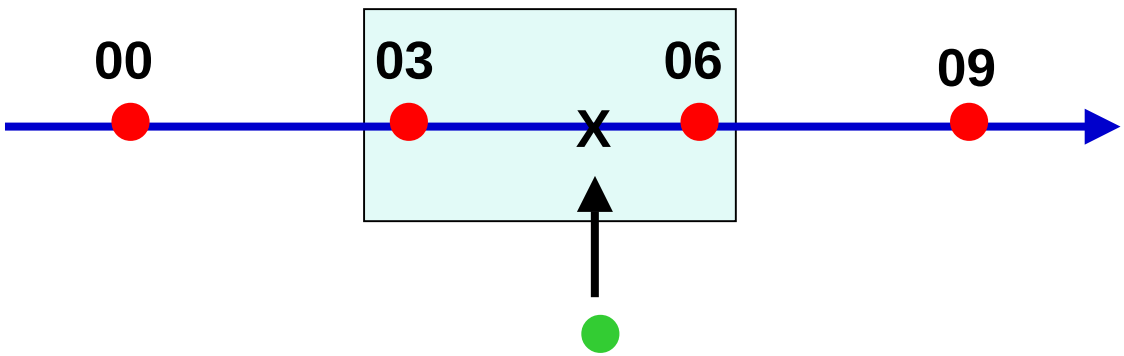
EBBT = Equivalent Blackbody Brightness Temperature

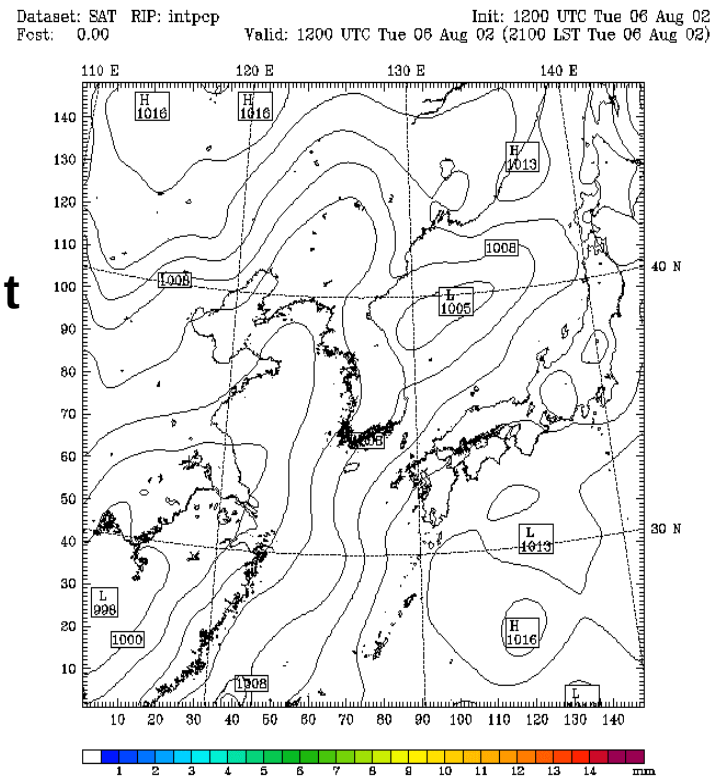
MODIS IR channels used in this study

Primary application	channel #	Band width (μm)
Moisture profile	27 28 29	6.535-6.895 7.175-7.475 8.400-8.700
Surface temperature and TPW	31 32	10.780-11.280 11.770-12.270
Temperature	33	13.185-13.485

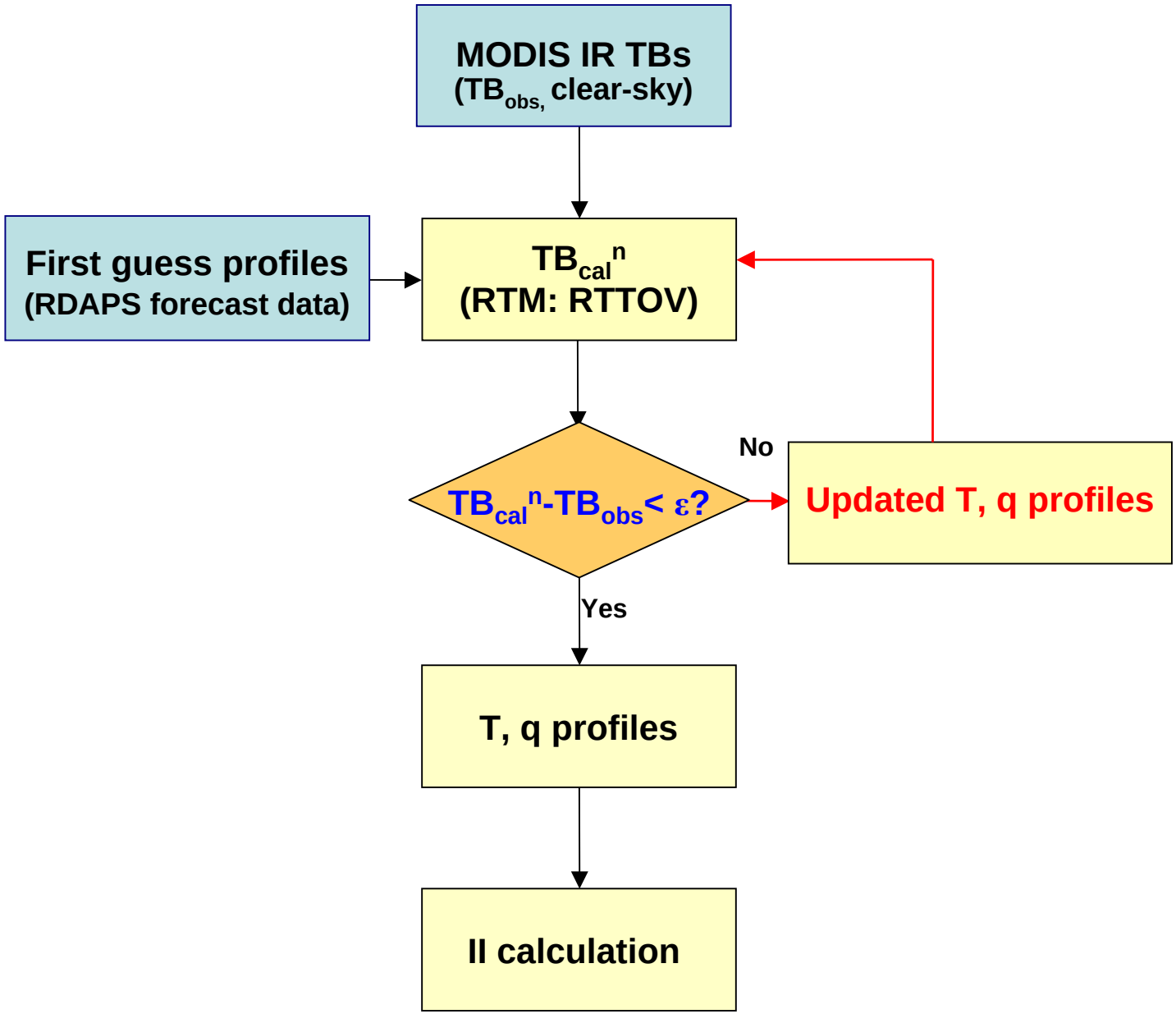
Retrieval procedures

- 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)

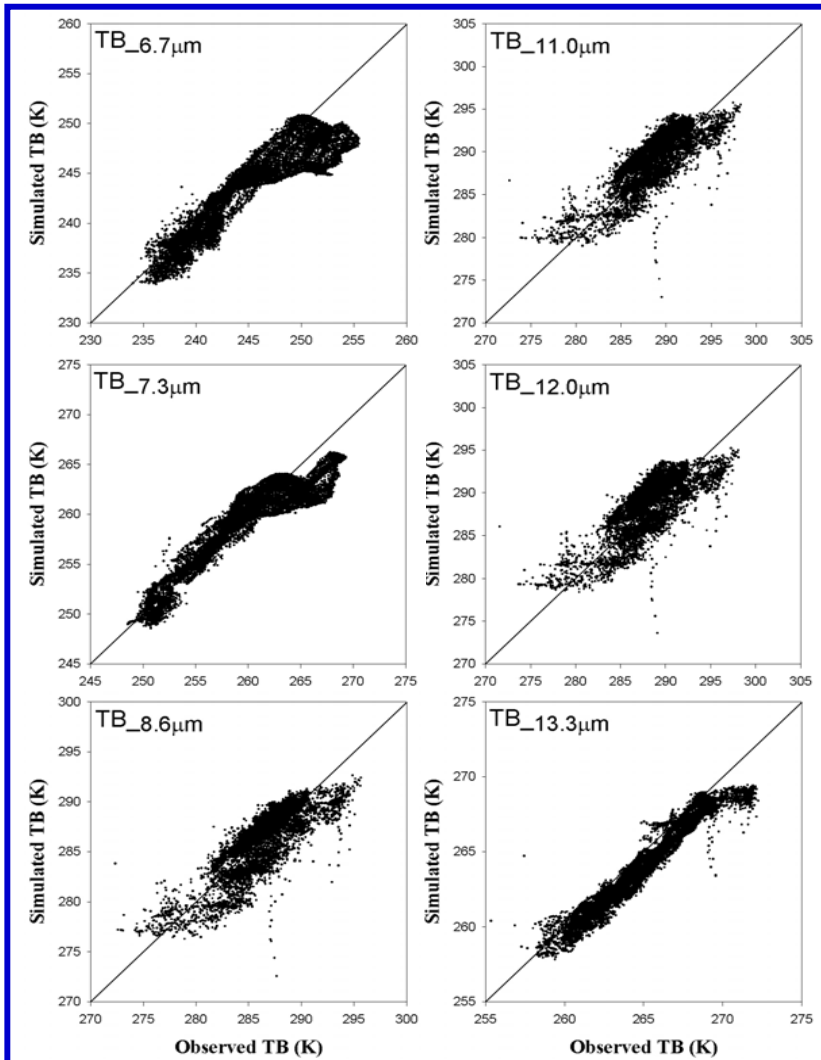


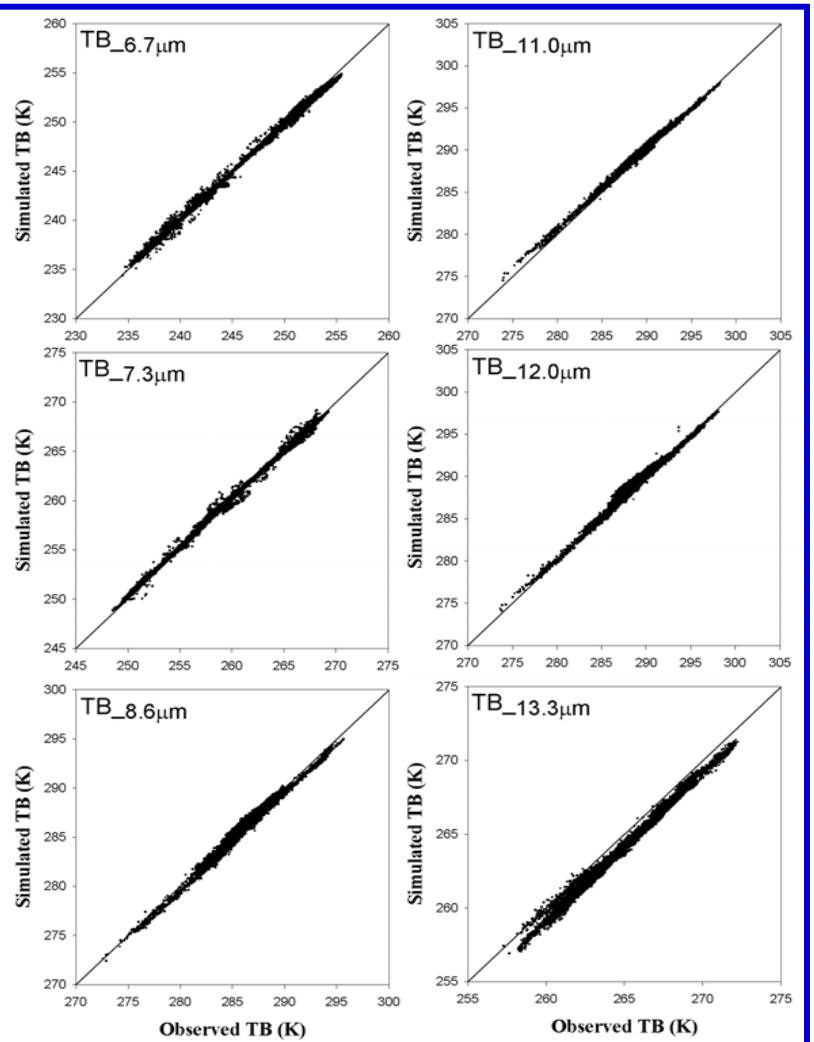


Flow chart


MODIS IR TBs
(TBobs, clear-sky)
First guess profiles
(RDAPS forecast data)
TBcal n
(RTM: RTTOV)
TBcal n-TBobs< ε?
No
Updated T, q profiles
Yes
T, q profiles
II calculation

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



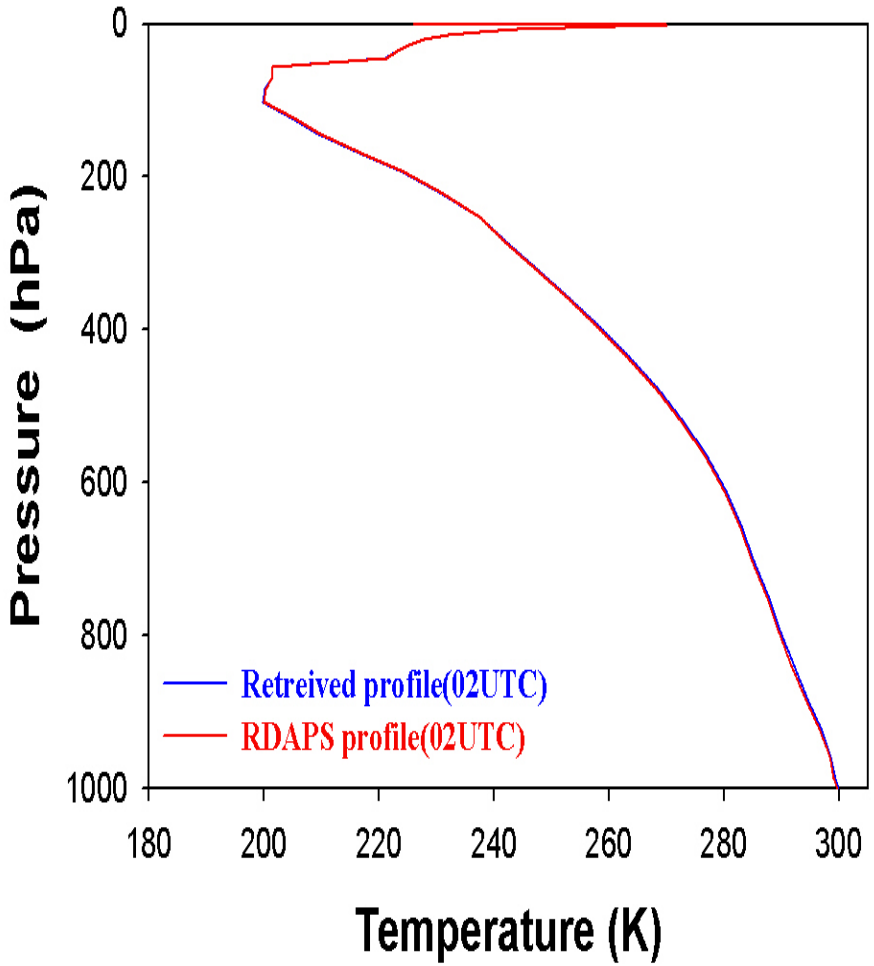


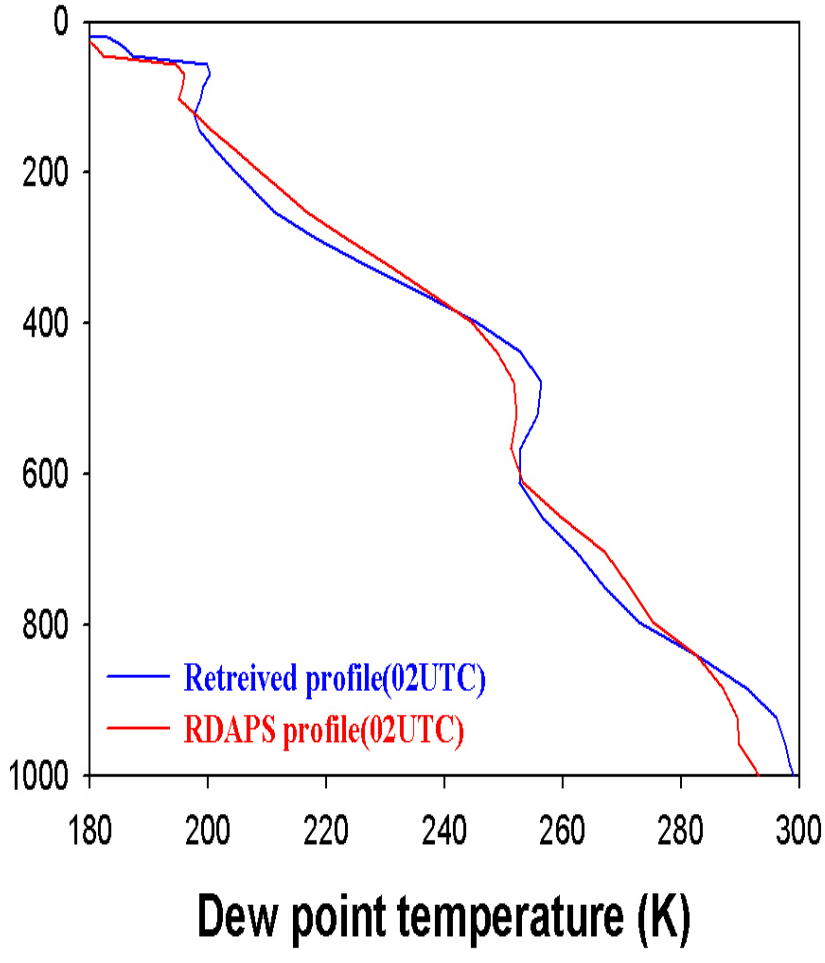
Initial guess x_0

Retrieved profiles : x_n

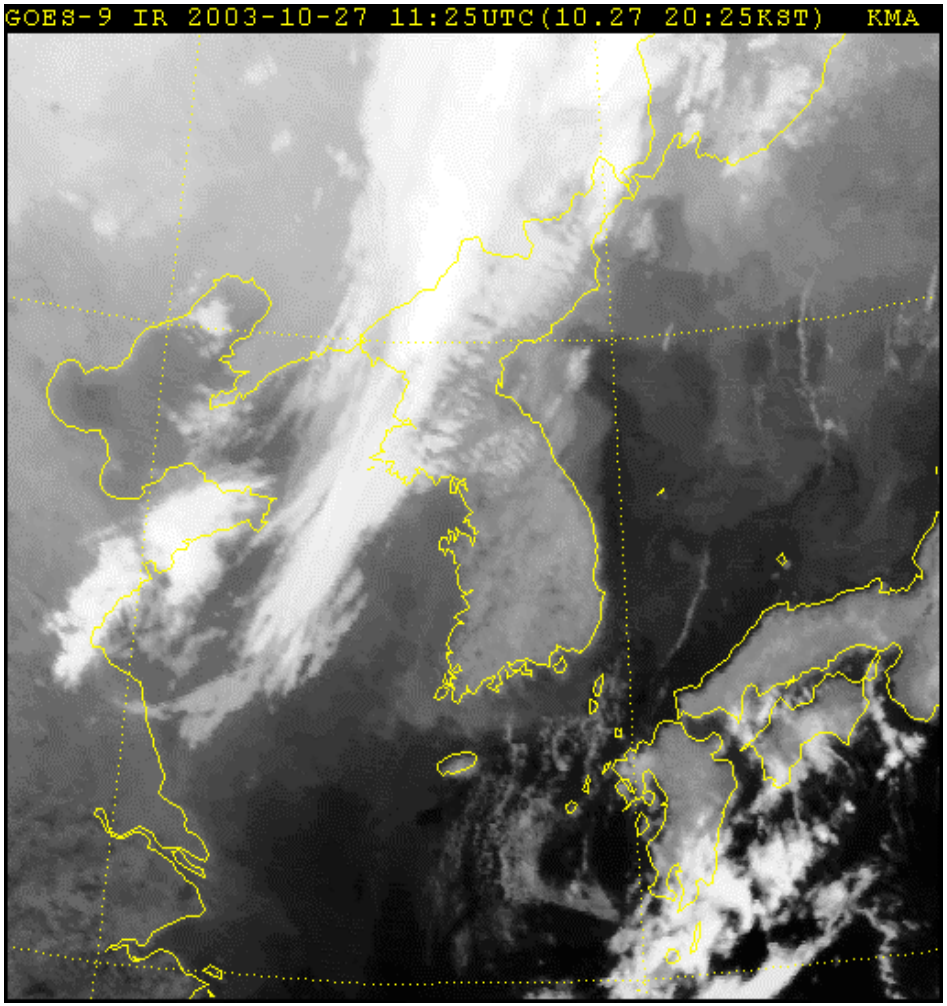
Example of retrieved profiles

(July 31, 2004, at Osan Korea)

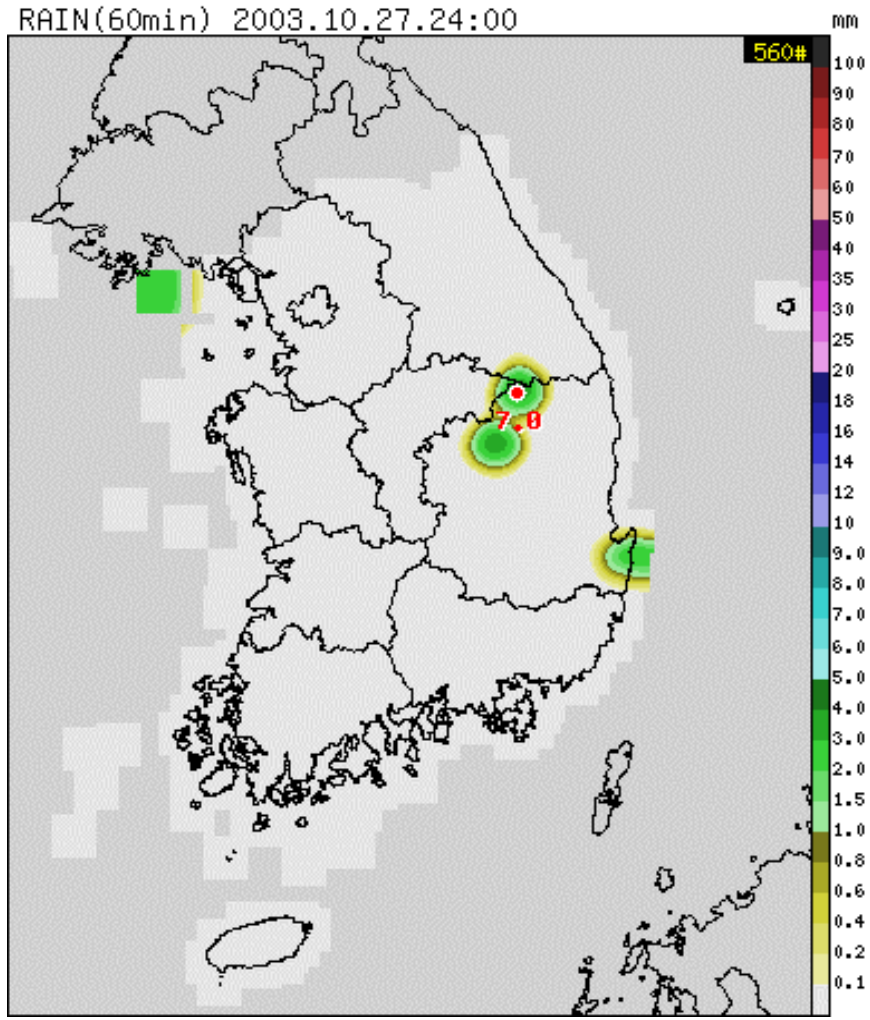




Case 1: Frontal passage (27-28 Oct. 2003)



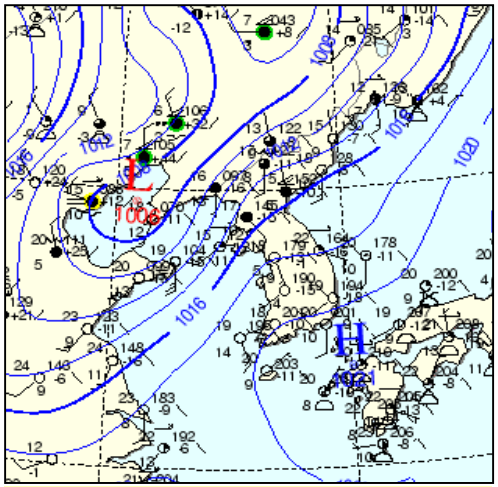
GOES 7 IR Images



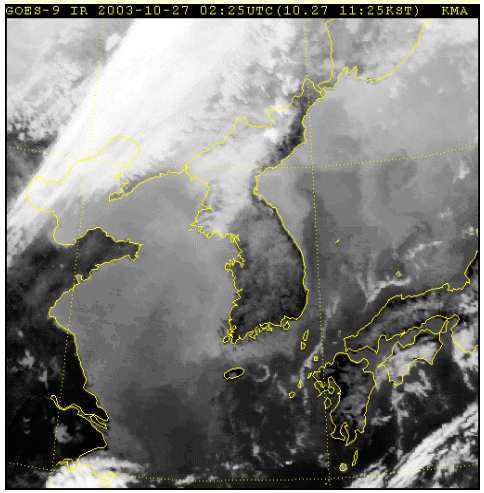
Hourly rainfall (mm)

Case 1 (Cont.)

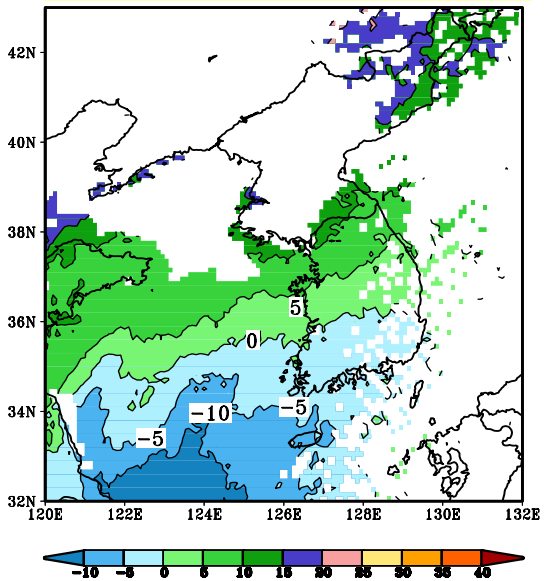
(a) Surface weather map



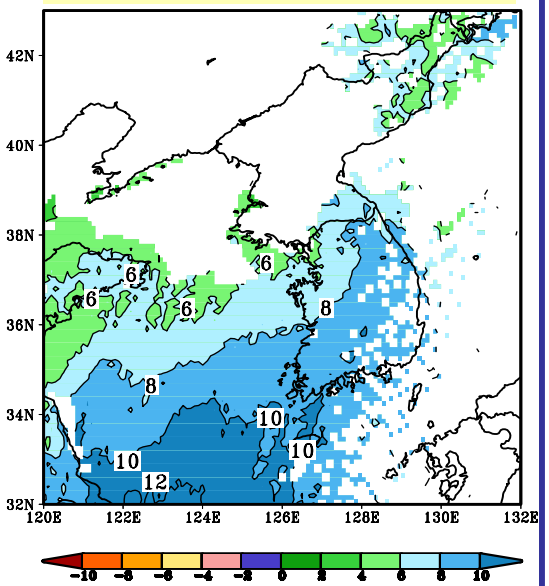
(b) GOES IR image



(c) KI from GDAAC



(d) LI from GDAAC



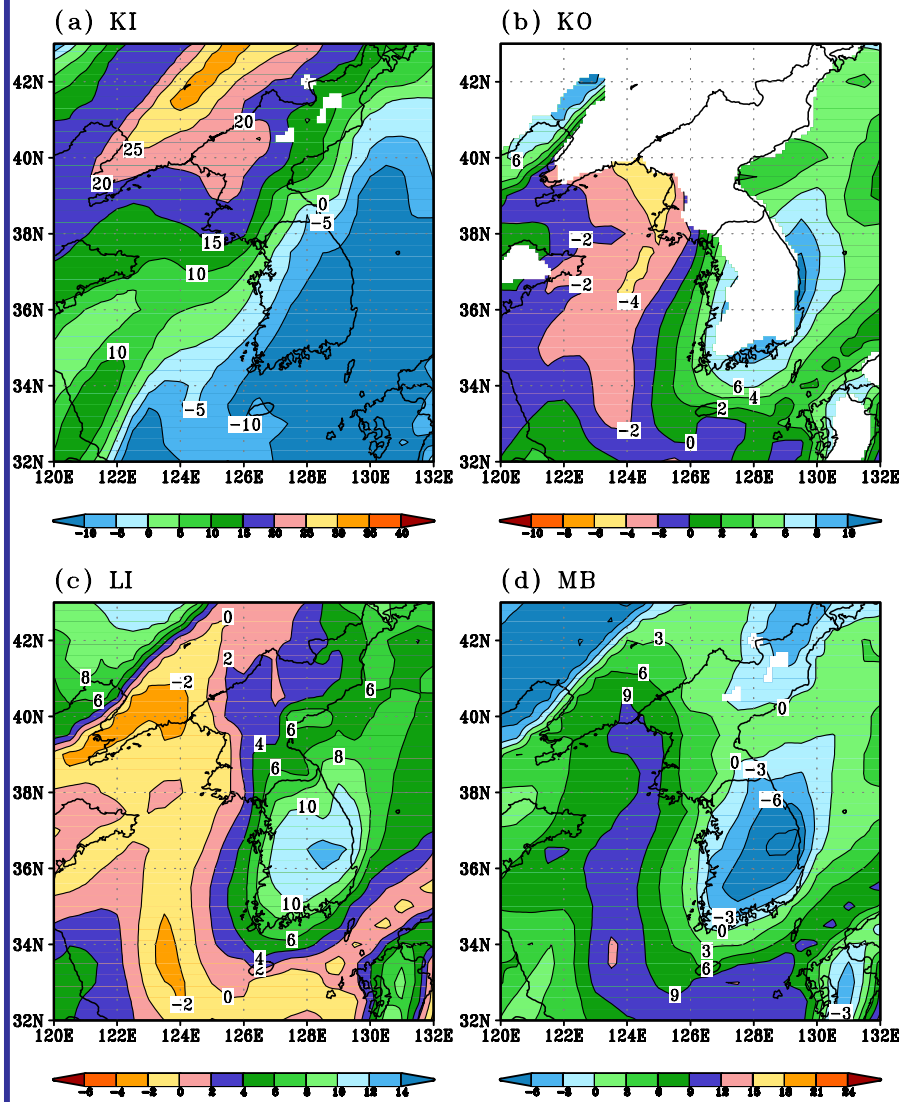
From the night of 27 Oct. 2003 to the morning of 28.

Fig. (c) and (d)

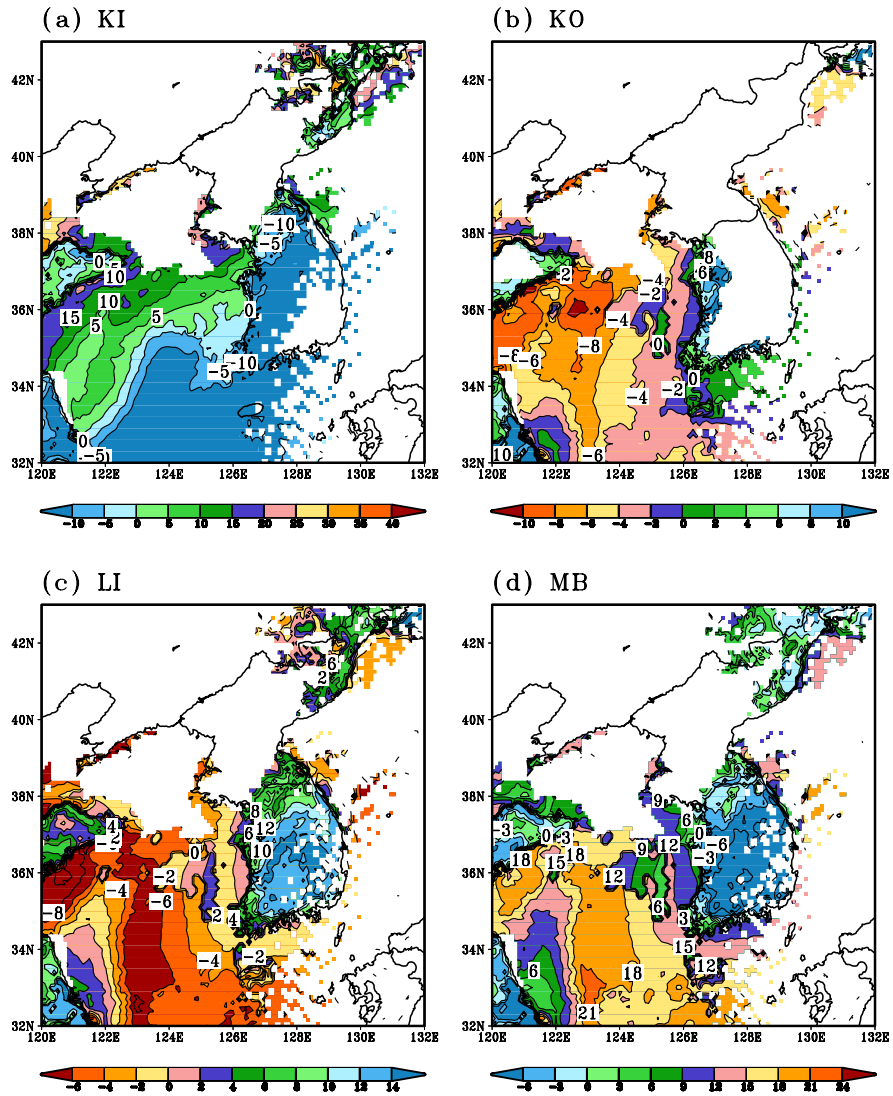
<u>KI and LI from NASA GDAAC</u>: They showed weak unstable conditions near the cloud edge but seemed to fail to predict thunderstorm shower associated with the frontal passage.

Case 1 (Cont.)

II from RDAPS profiles

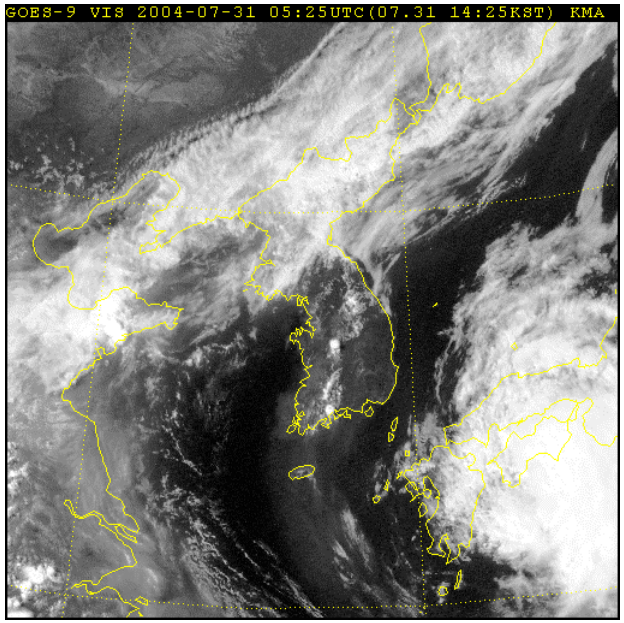


II from retrieved profiles

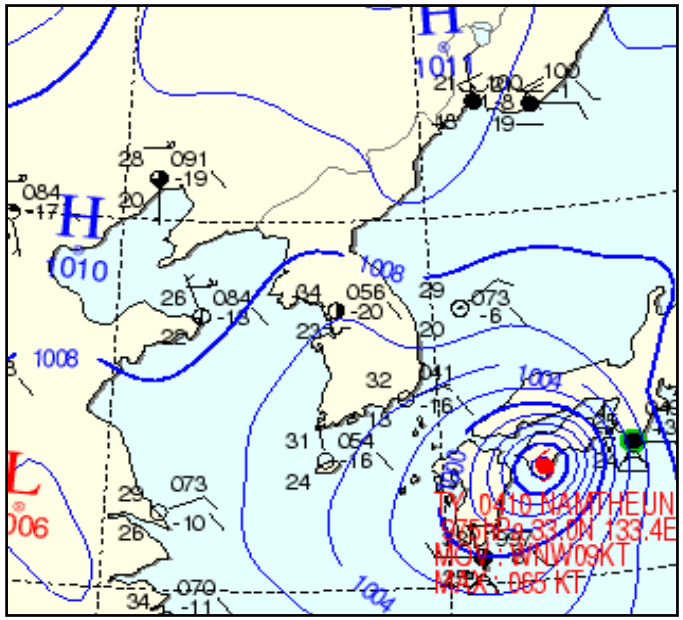


Case 2 (31 July 2004)

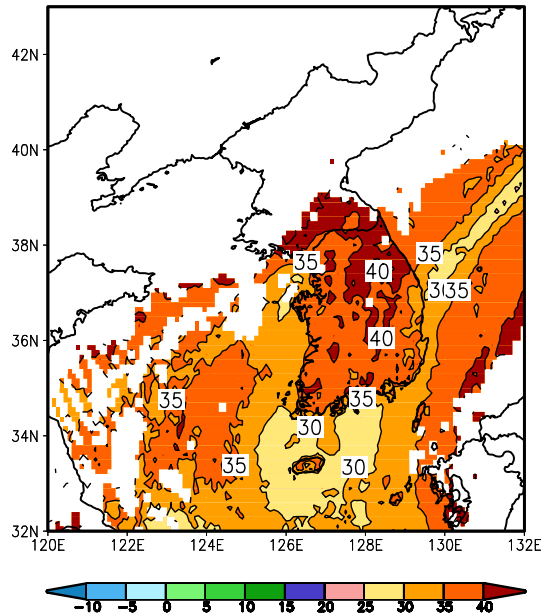
GOES VIS image



Surface weather map



KI from NASA GDAAC



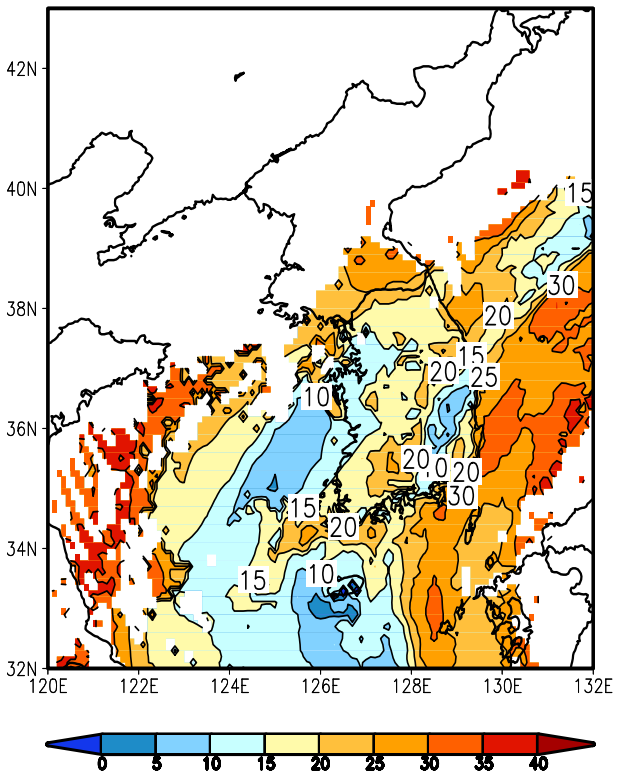
~1500 KST 31 July 2004

~1100 KST 31 Jul 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

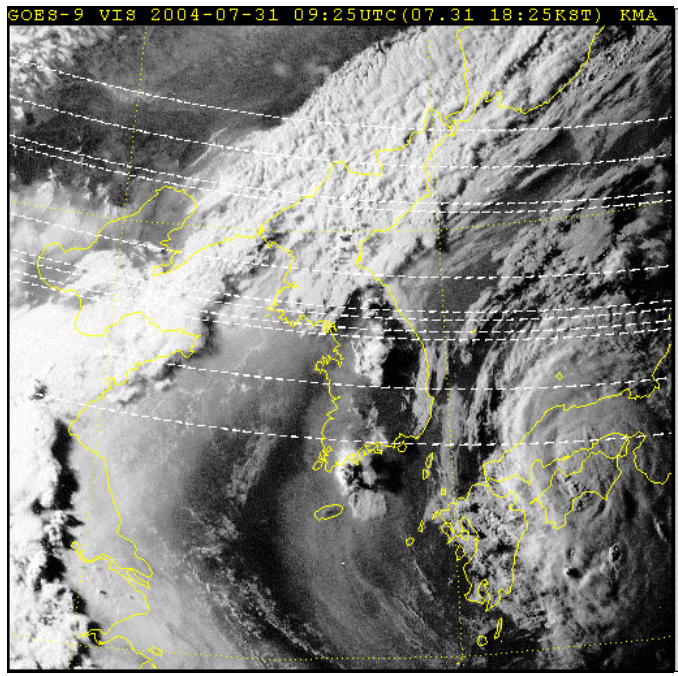
Case 2 (Cont.)

KI from MODIS

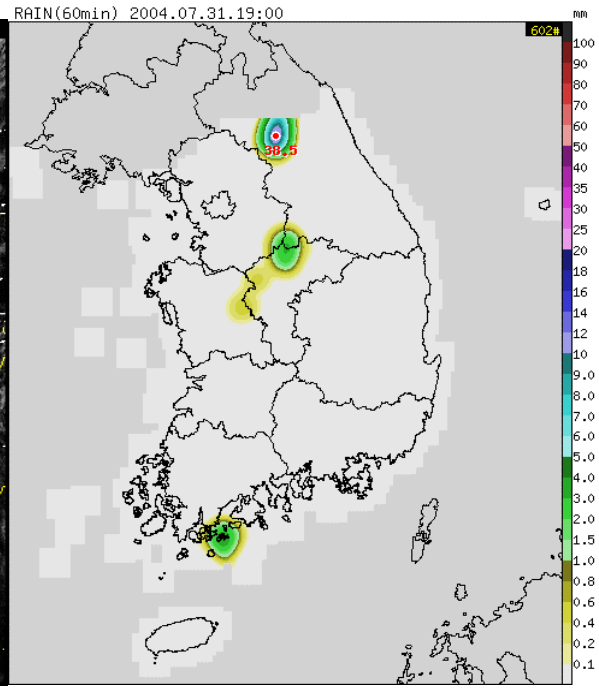


11:15 KST 31 Jul 2004

GOES-9 VIS image



Rain gauge (mm/hr)



19 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 H_2O and O_2 bands and window region may be used for obtaining II over the cloudy area.**