Cloud retrievals for severe weather forecasts

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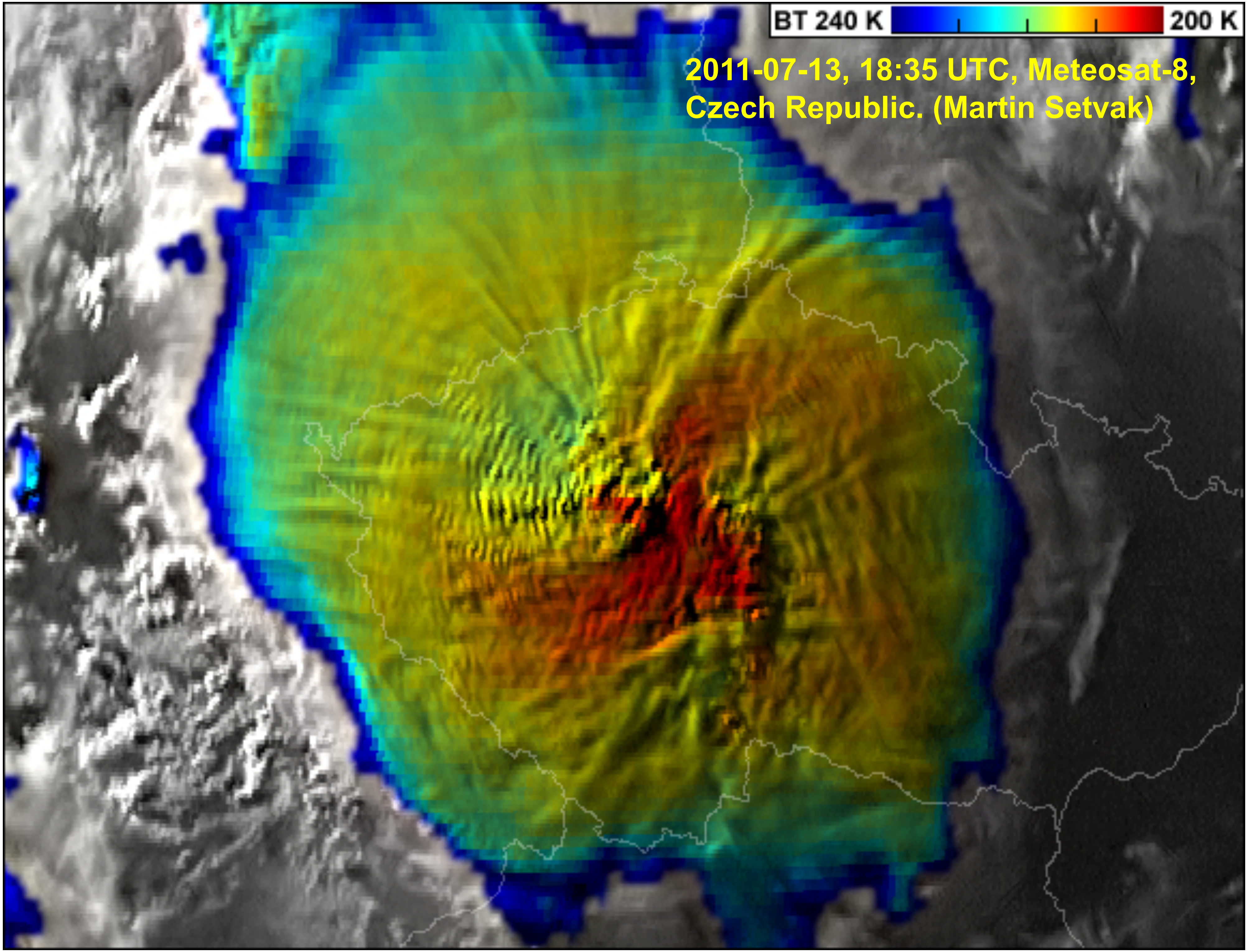


BT 240 K
200 K
2011-07-13, 18:35 UTC, Meteosat-8,
Czech Republic. (Martin Setvak)

These storms are already in progress and can be detected by radars.
How can we get advance warnings?

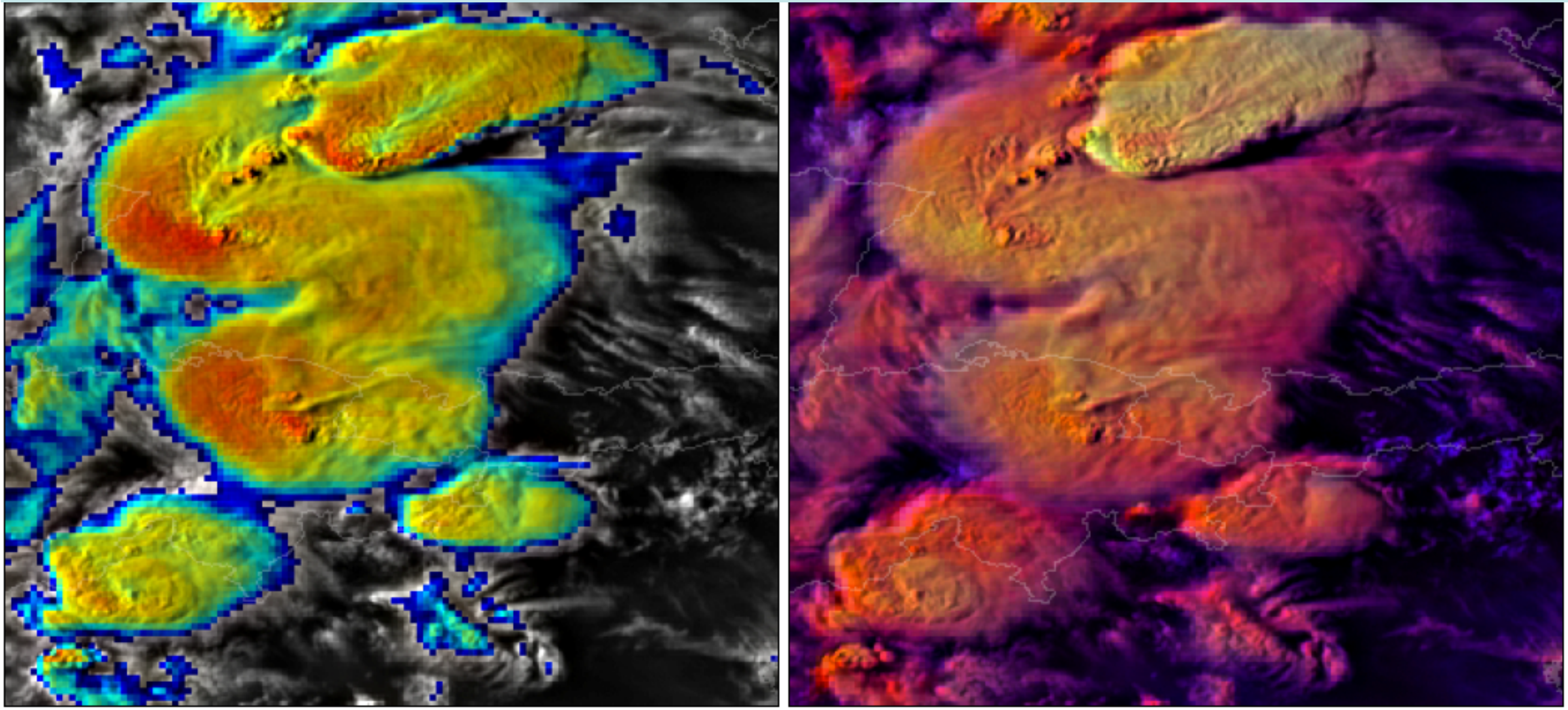


Figure 3: 2011-07-12, 17:40 UTC. Examples of the Meteosat-8 (MSG-1) HRV / IR10.8-BT (left) and HRV / Storm RGB (right) sandwich products – convective storms above central and south Germany.

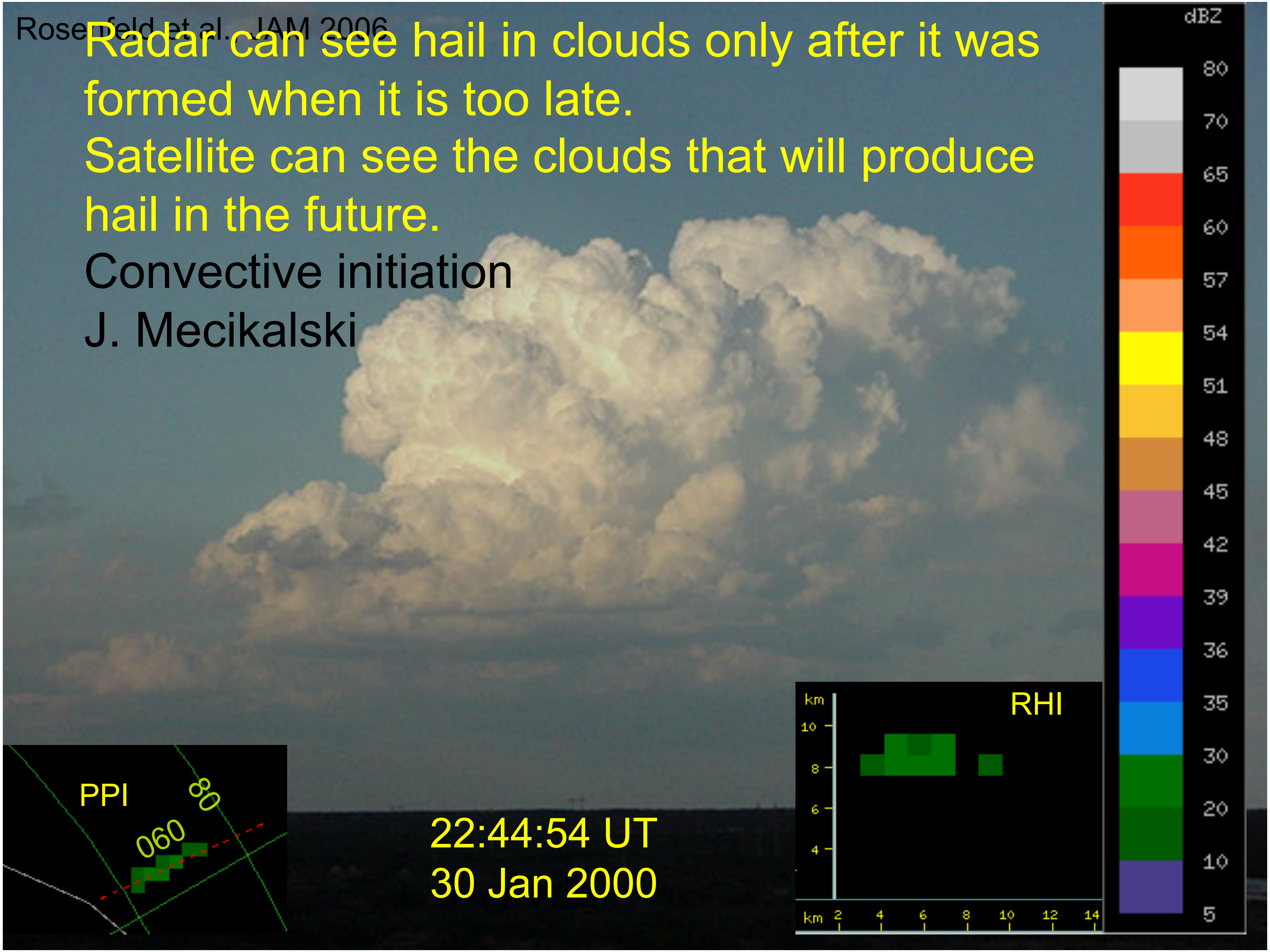
Rosenfeld et al., JAM 2006

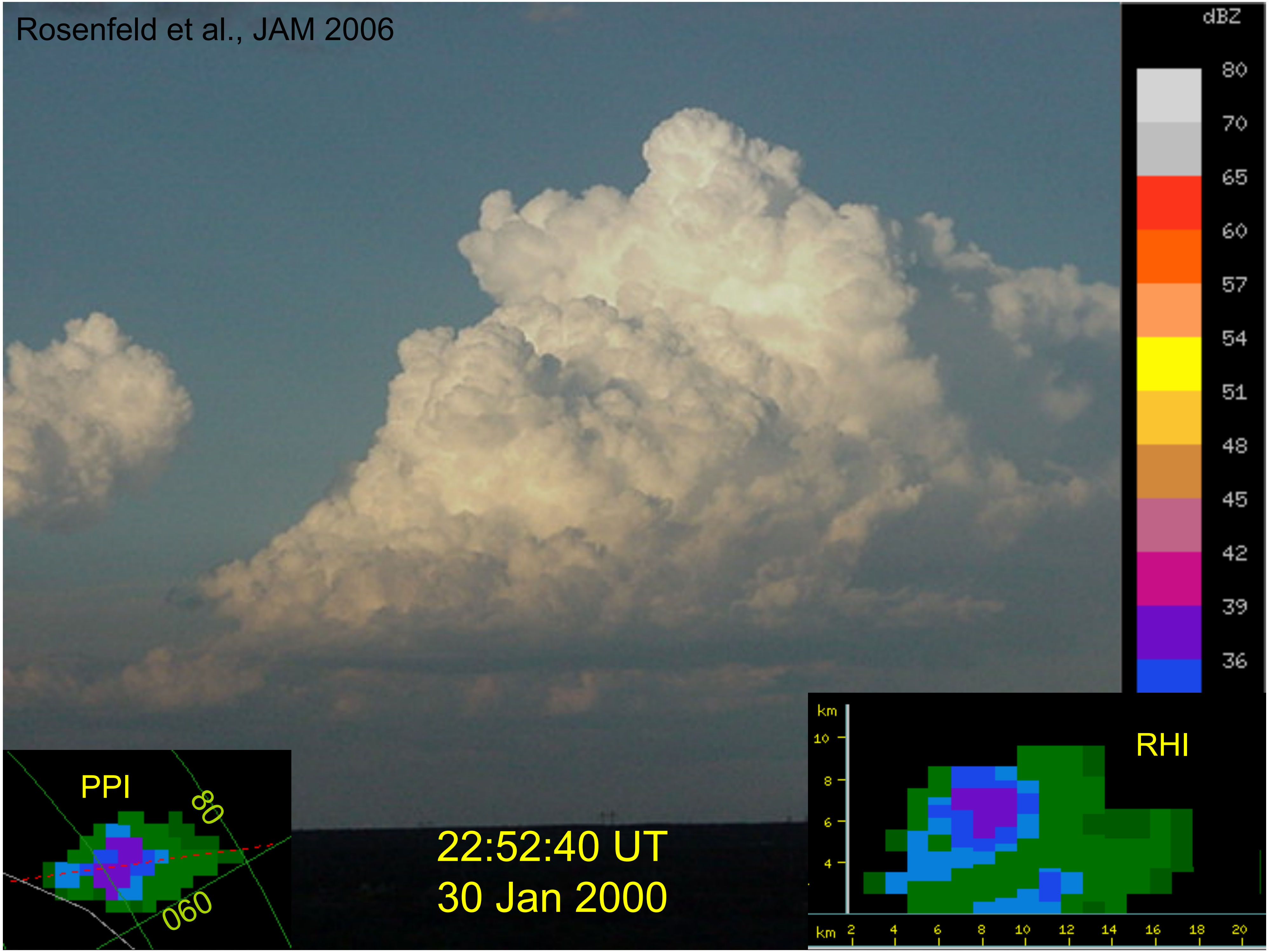
Radar can see hail in clouds only after it was formed when it is too late.

Satellite can see the clouds that will produce hail in the future.

Convective initiation

J. Mecikalski



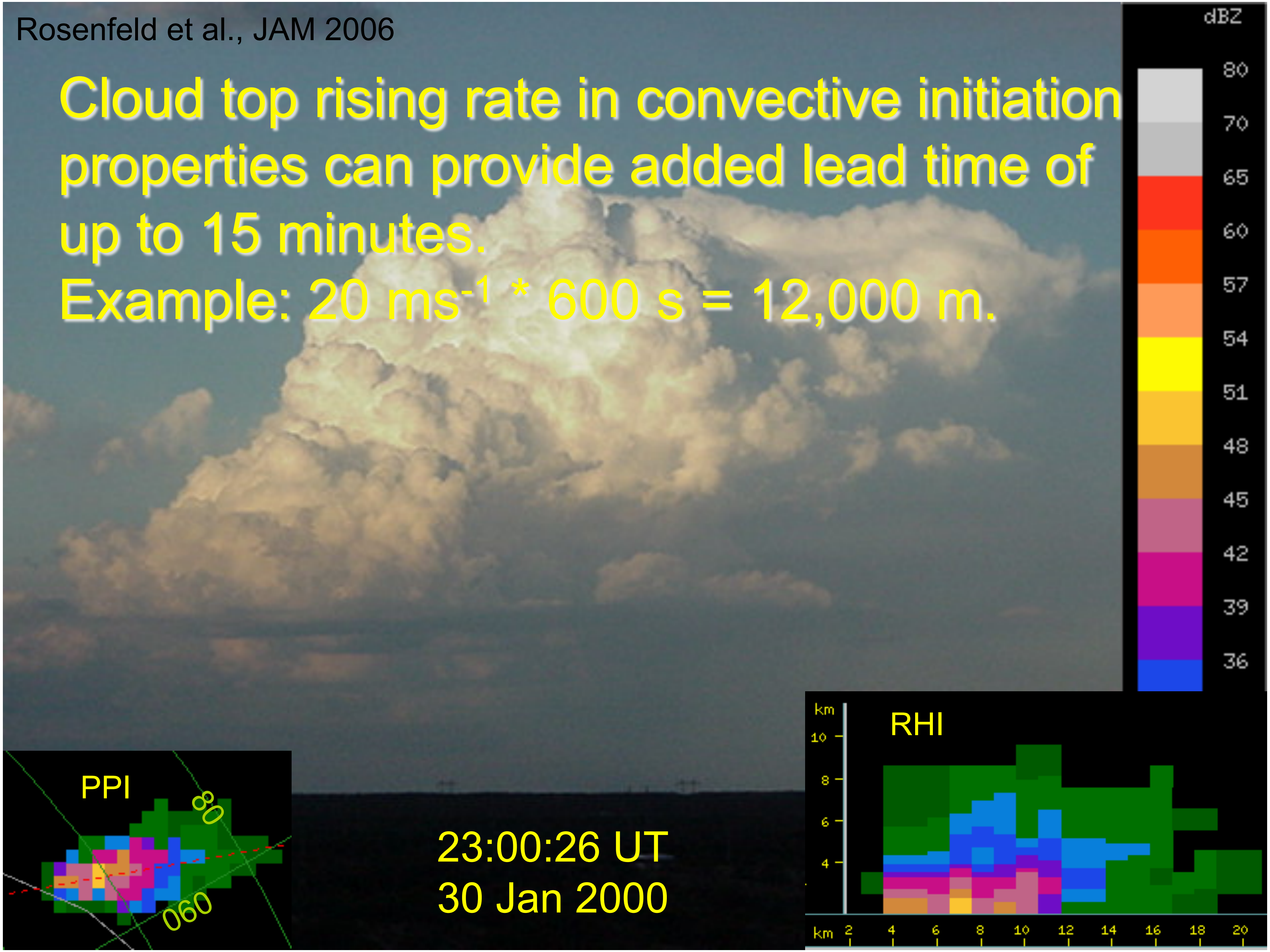


Rosenfeld et al., JAM 2006
dBZ
80
70
65
60
57
54
51
48
45
42
39
36
PPI
80
060
22:52:40 UT
30 Jan 2000
RHI
km
10
8
6
4
km 2 4 6 8 10 12 14 16 18 20

Rosenfeld et al., JAM 2006

Cloud top rising rate in convective initiation properties can provide added lead time of up to 15 minutes.

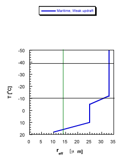
Example: $20\ ms^{-1} * 600\ s = 12,000\ m$.



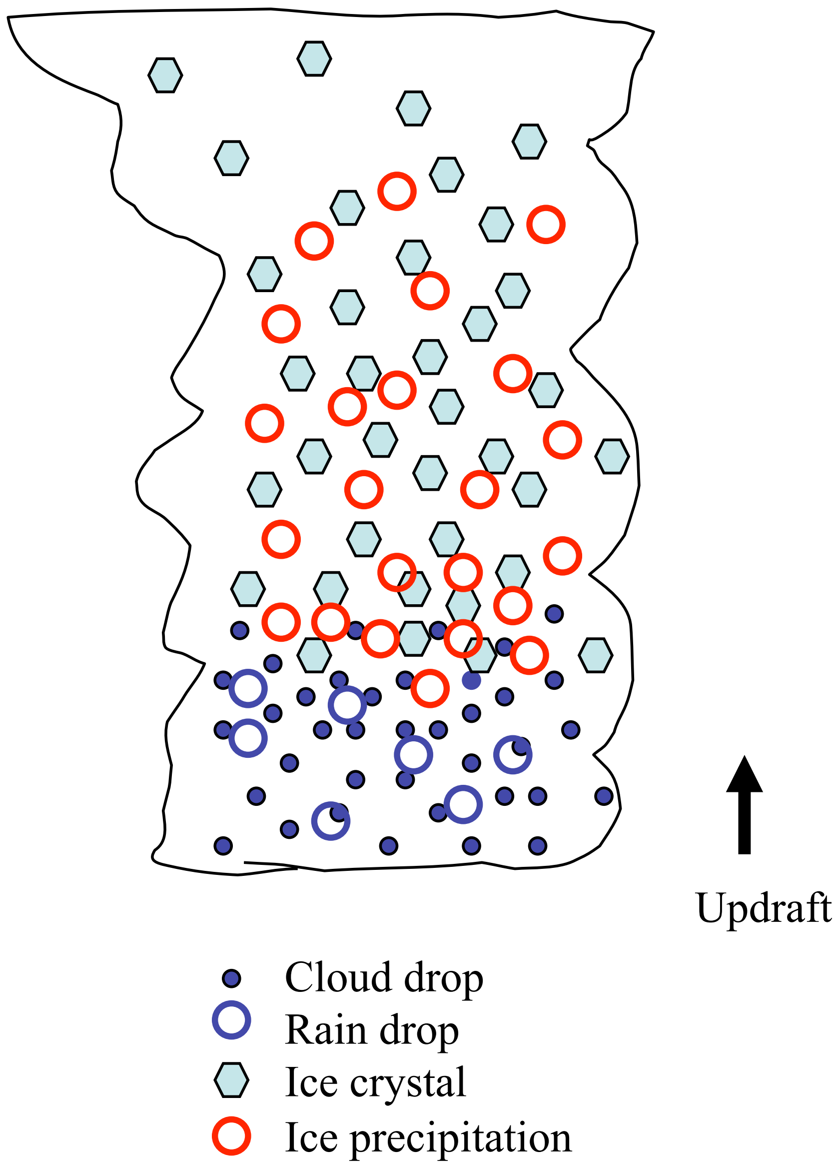
Q: How can we get longer lead times?

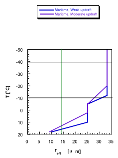
A: Developing clouds are organized by mergers of short lived bubbling convective towers. Their vigor is a predictor of the future storm.

This can be inferred by their height dependent microstructure.

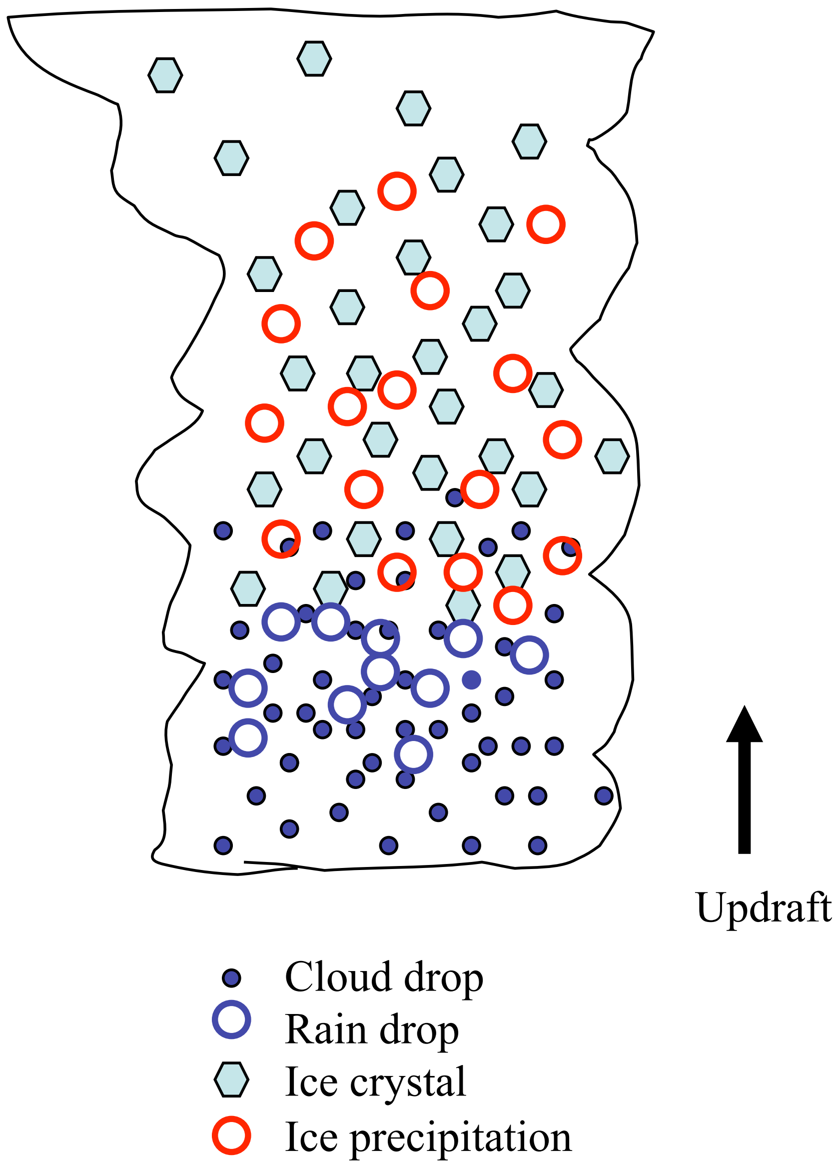


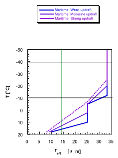
Maritime, Weak Updraft



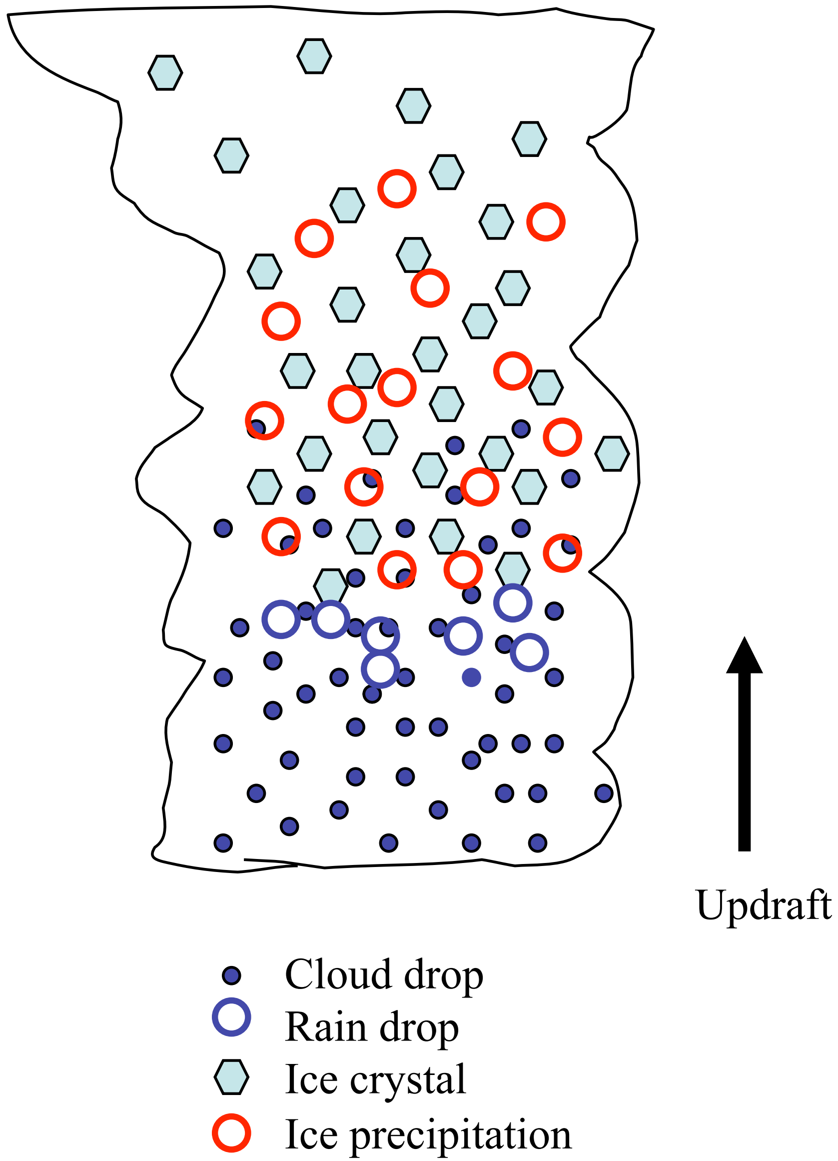


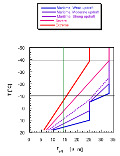
Maritime, Moderate Updraft



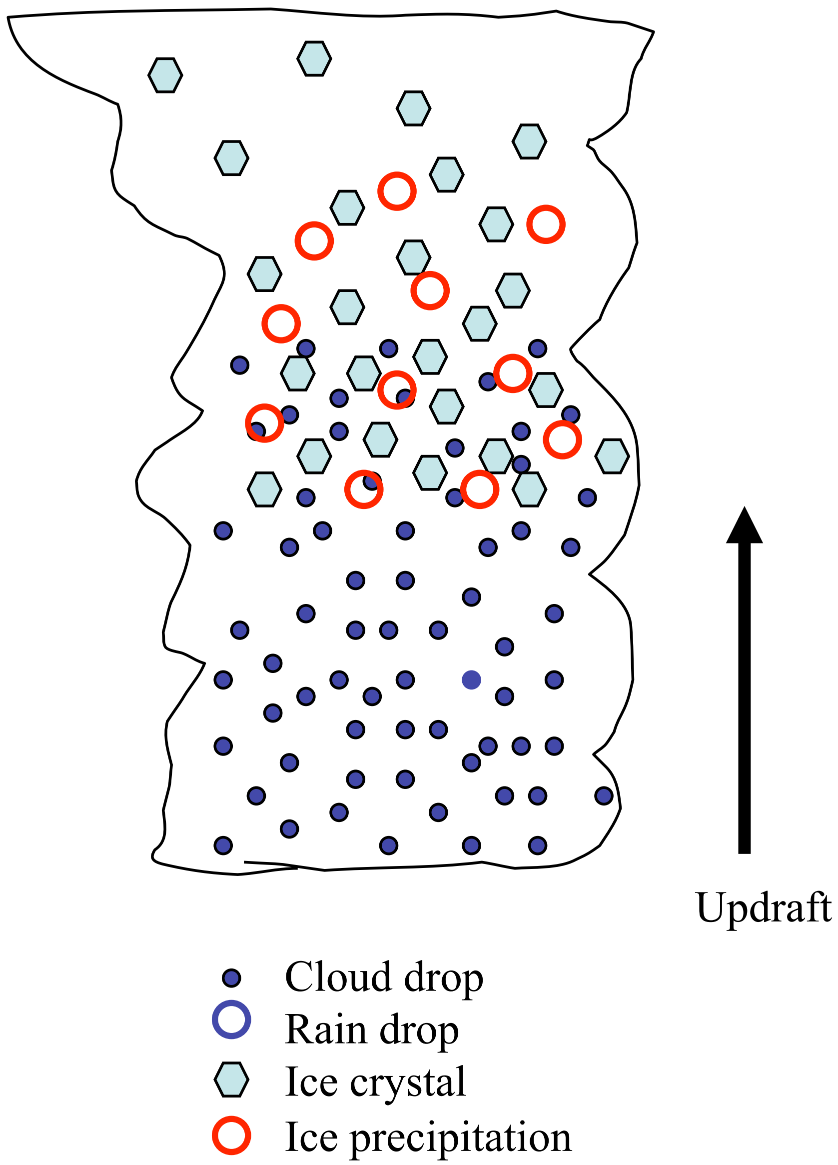


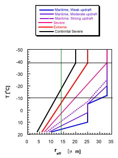
Maritime, Strong Updraft



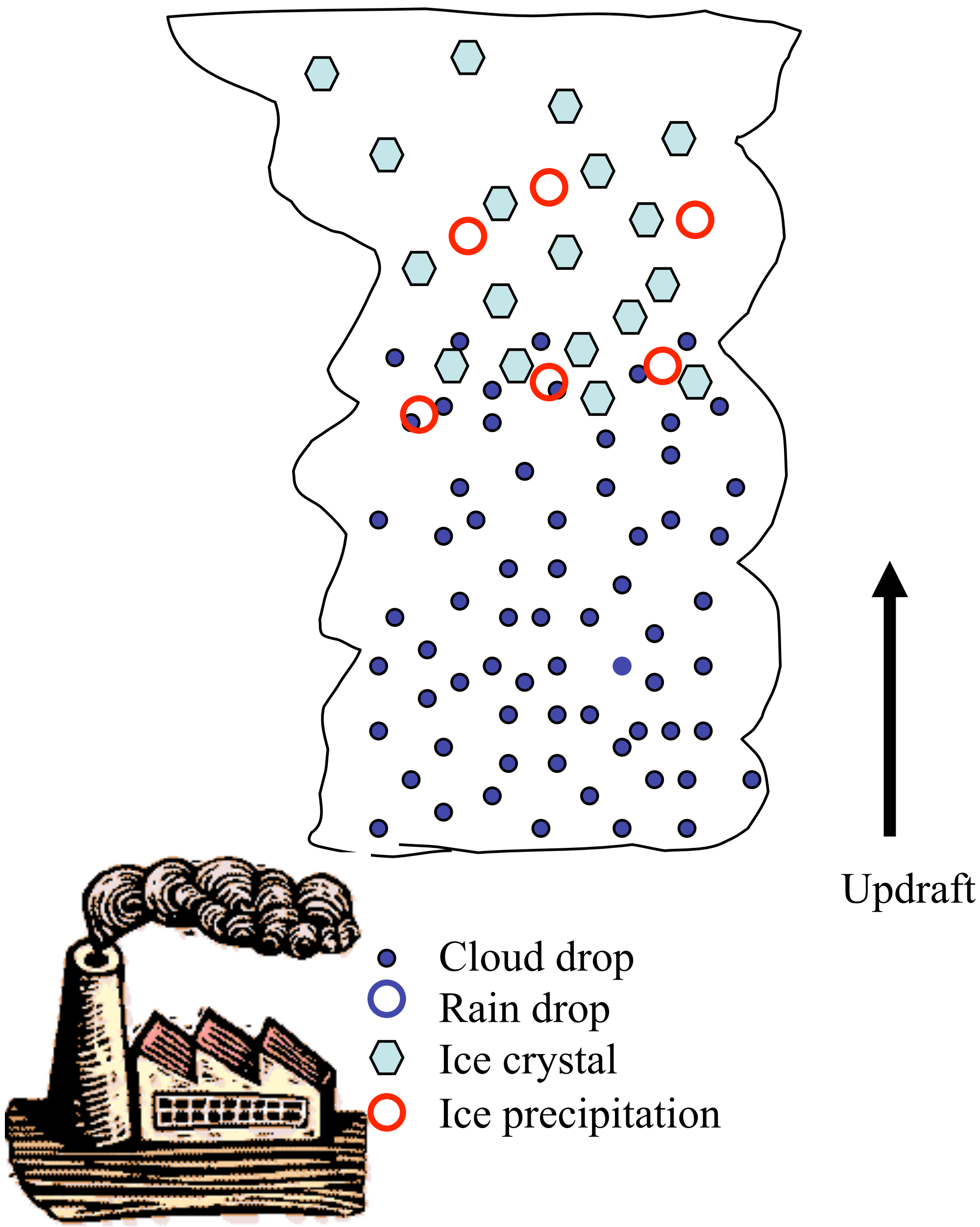


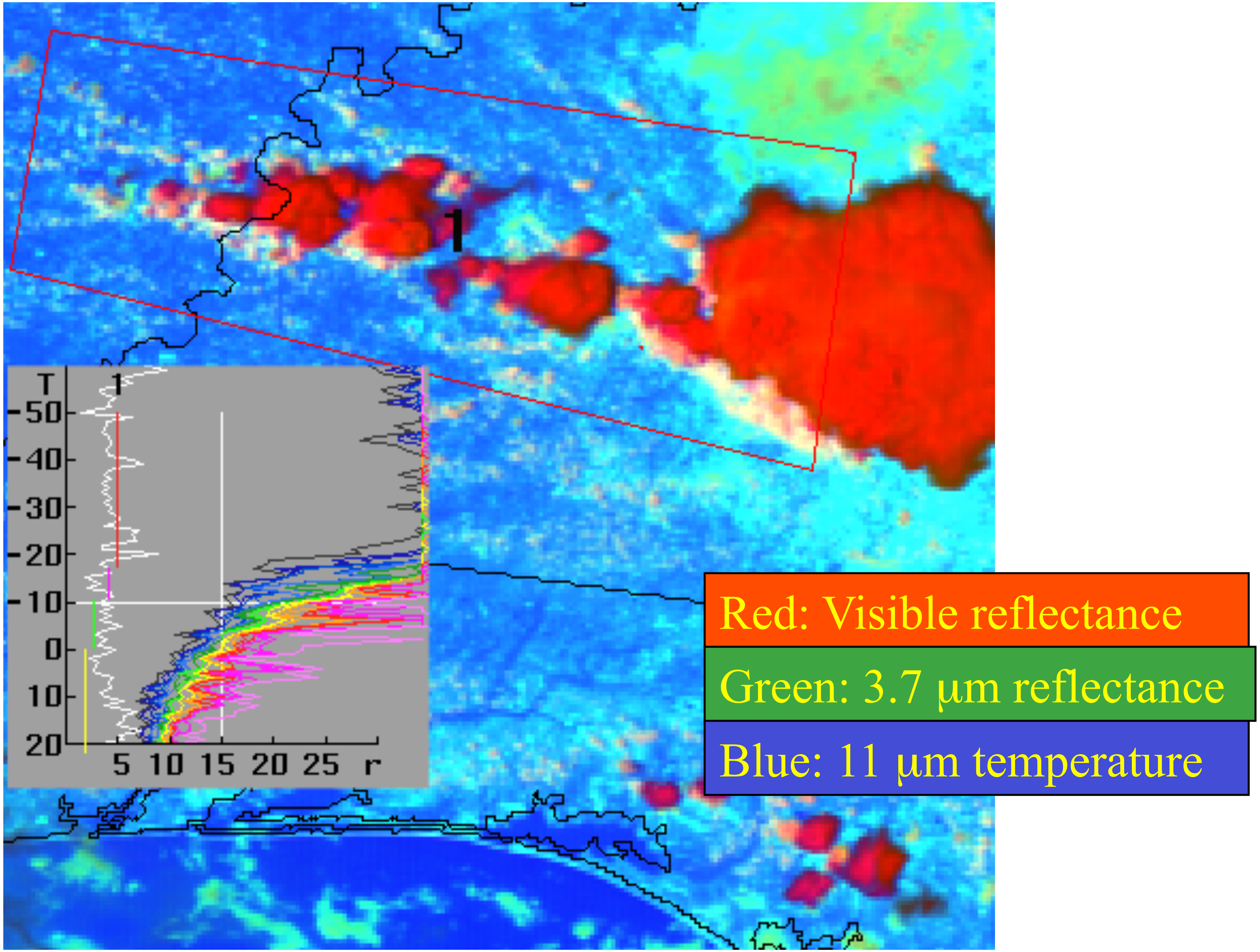
Extreme


Updraft
Cloud drop
Rain drop
Ice crystal
Ice precipitation



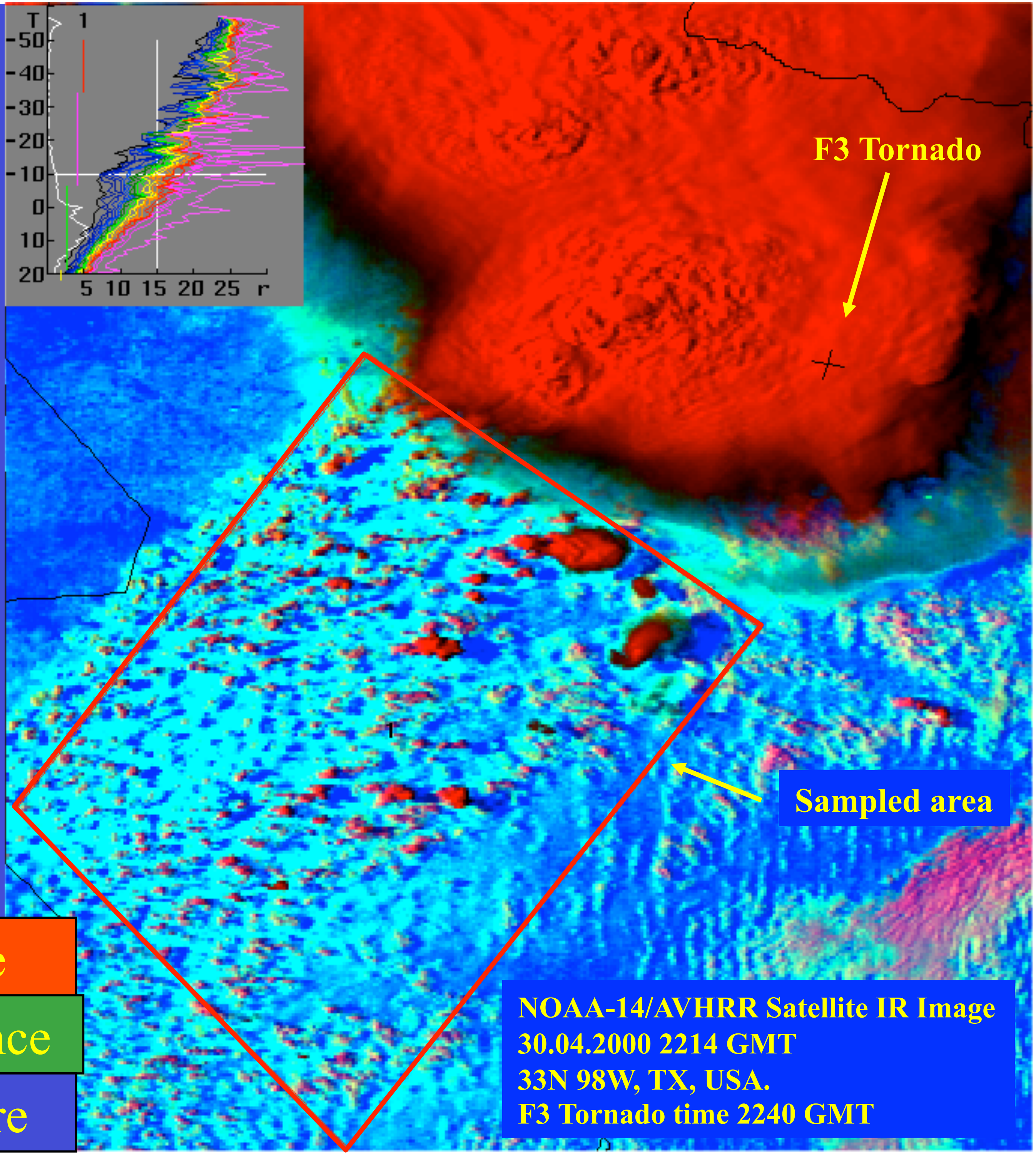
Continental Severe





Non-severe convective storm. The image is based on the NOAA-AVHRR overpass on 28 July 1998, 20:24 UTC, over a domain of 232x222 AVHRR 1-km pixels. The cloud system is just to the north of the Florida Panhandle.

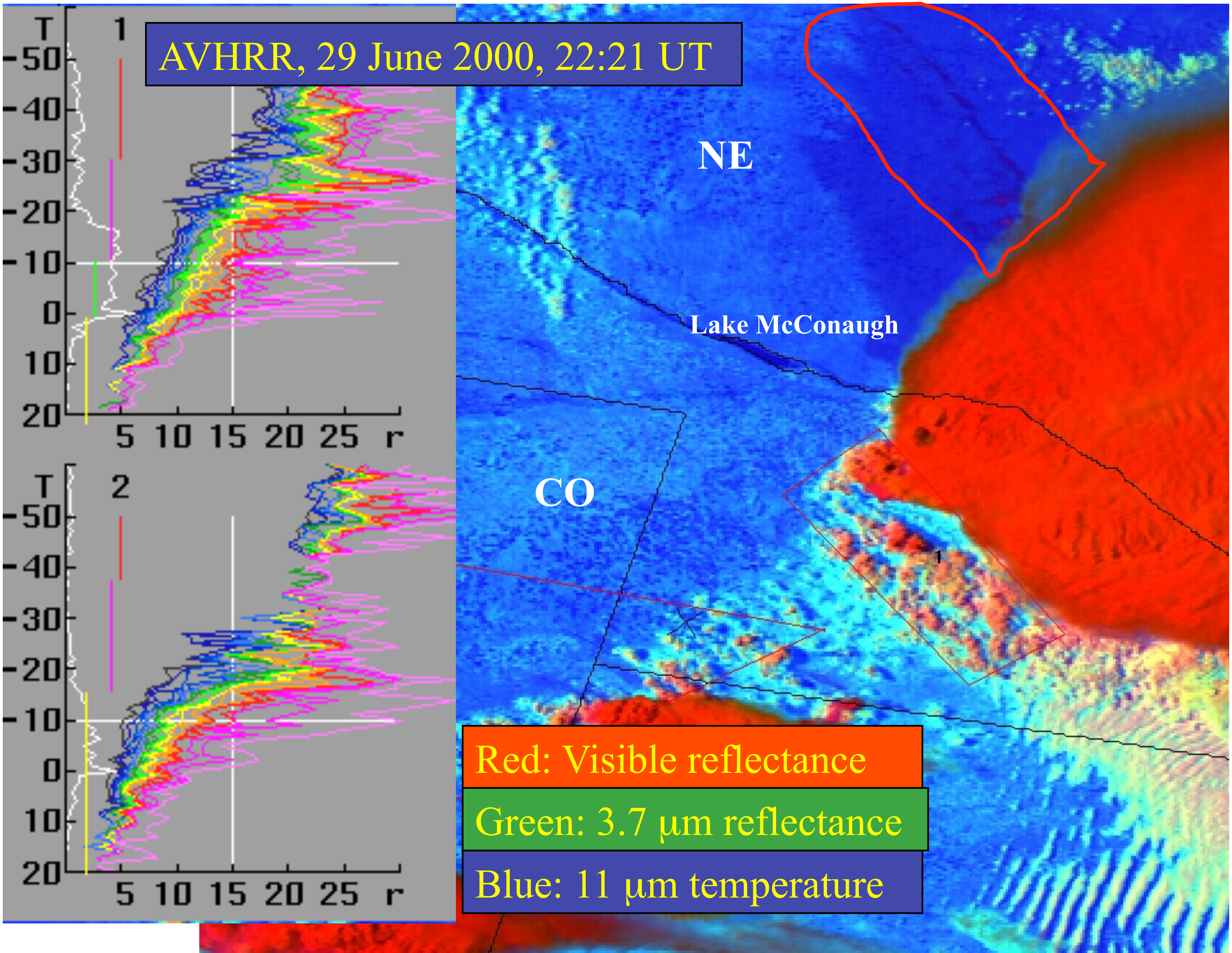
A tornadic storm with 2.5 inch hail. The image is based on the NOAA-AVHRR overpass on 30 April 2000, 22:14 UTC, over a domain of 333x377 AVHRR 1-km pixels. The cloud occurred just to the SE of the Texas panhandle. The location of a reported F3 tornado at 22:40 is marked by a rectangle.



Red: Visible reflectance

Green: 3.7 µm reflectance

Blue: 11 µm temperature



AVHRR, 29 June 2000, 22:21 UT
NE
Lake McConaugh
CO
Red: Visible reflectance
Green: 3.7 µm reflectance
Blue: 11 µm temperature
T
1
-50
-40
-30
-20
-10
0
10
20
5 10 15 20 25 r
2

Microphysical profiles of severe storm clouds that produce Tornado and large Hail

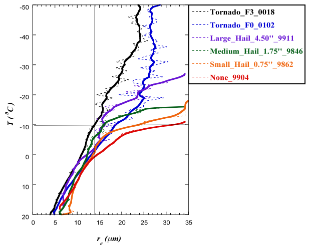
Discussions:

a. Tornado profile differs significantly from profiles of large Hail and "None" clouds.

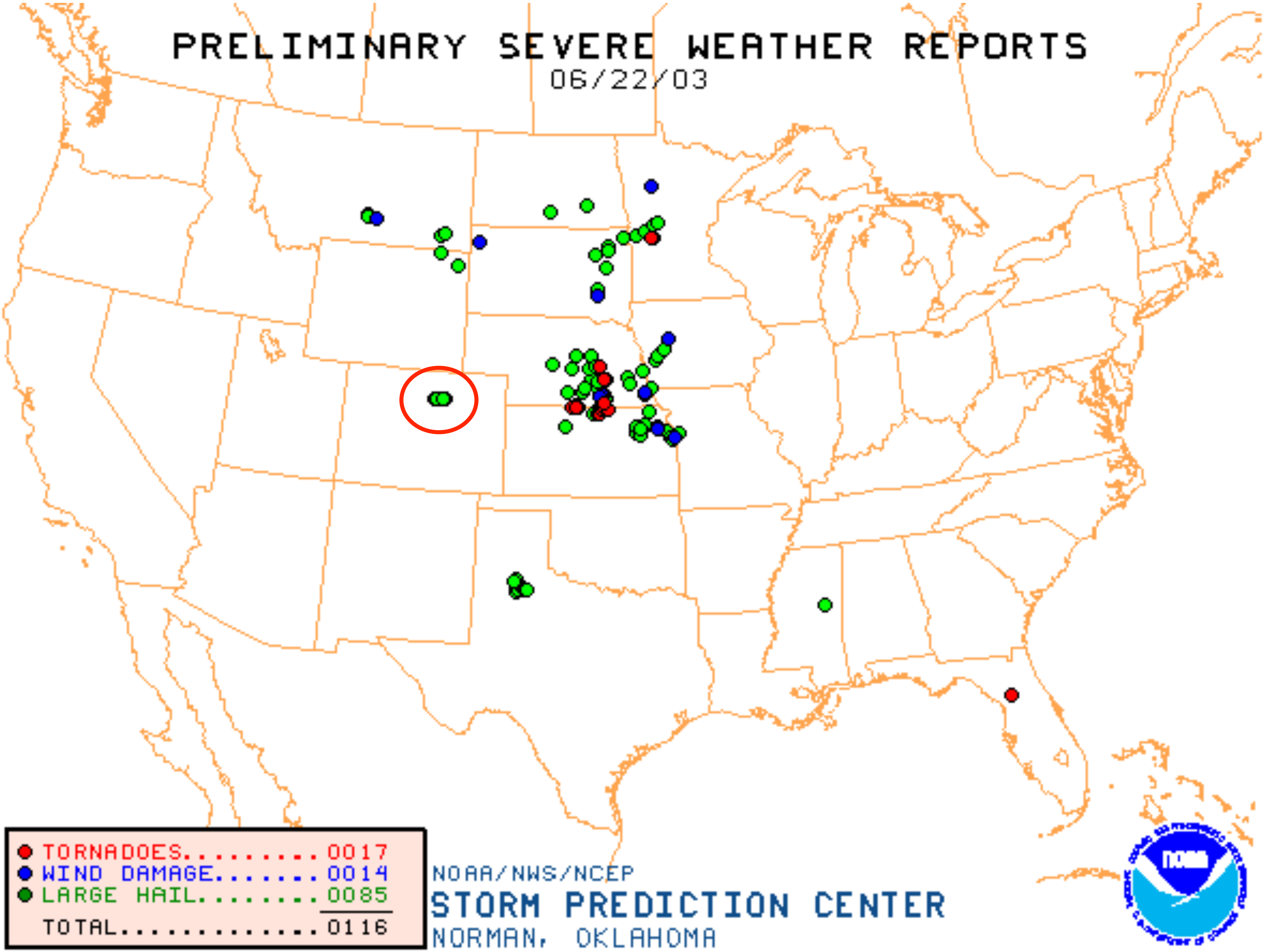
b. In Tornado clouds r_e increases linearly up to a very cold glaciation temperature, with lack of rapid growth of r_e in the mixed phase zone.

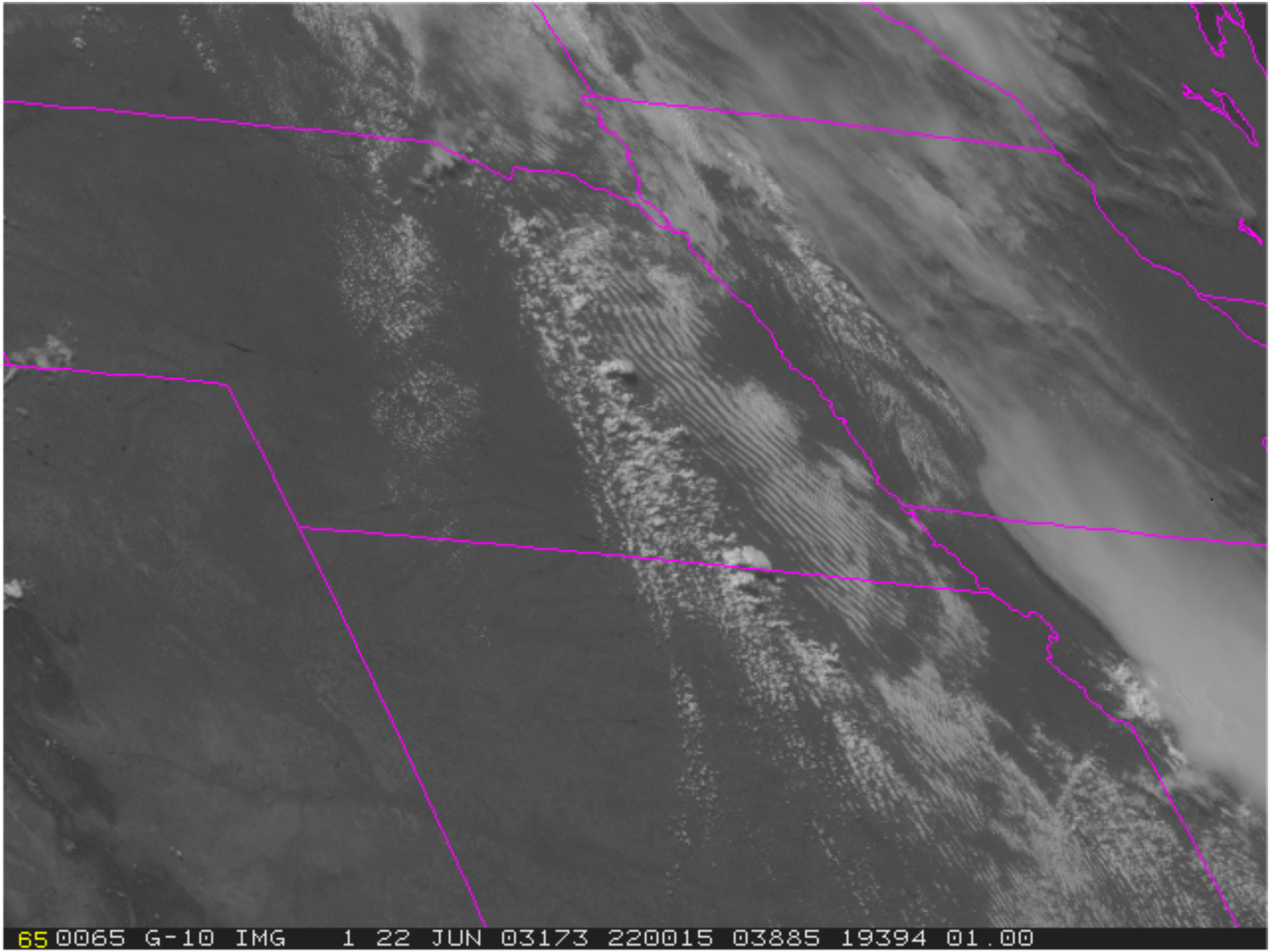
c. Both Hail and "None" profiles include rapid growth of cloud droplets with cloud height before glaciation temperature, breaking the Linear Zone.

d. More microphysically continental cloud bases lead to more severe dynamic effects visible at the higher elevations.

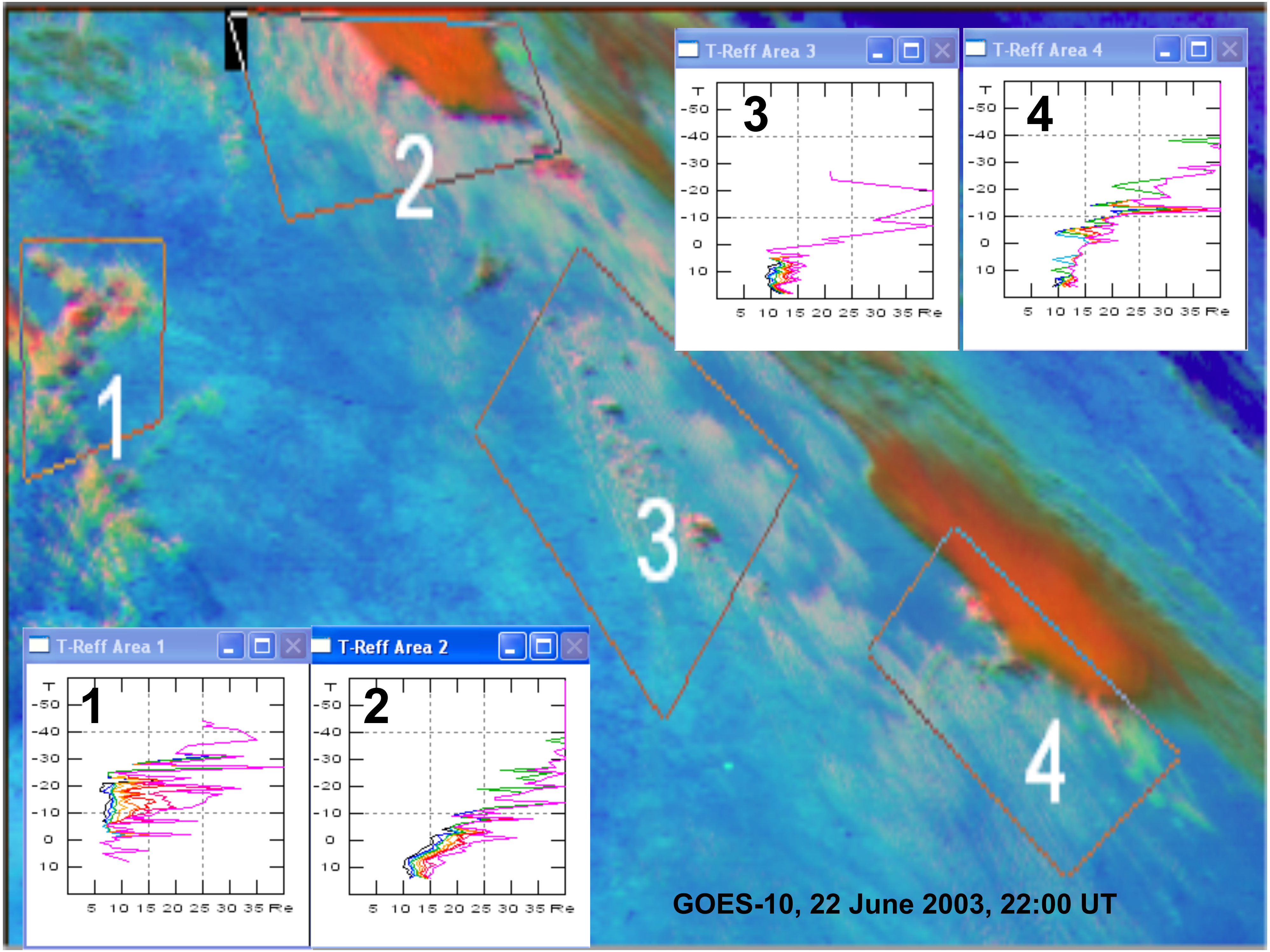


Schematic T-r_e profiles of Tornado (black, blue), only large Hail (purple, green and orange) and None (red) clouds according to the 50^{th} percentile.

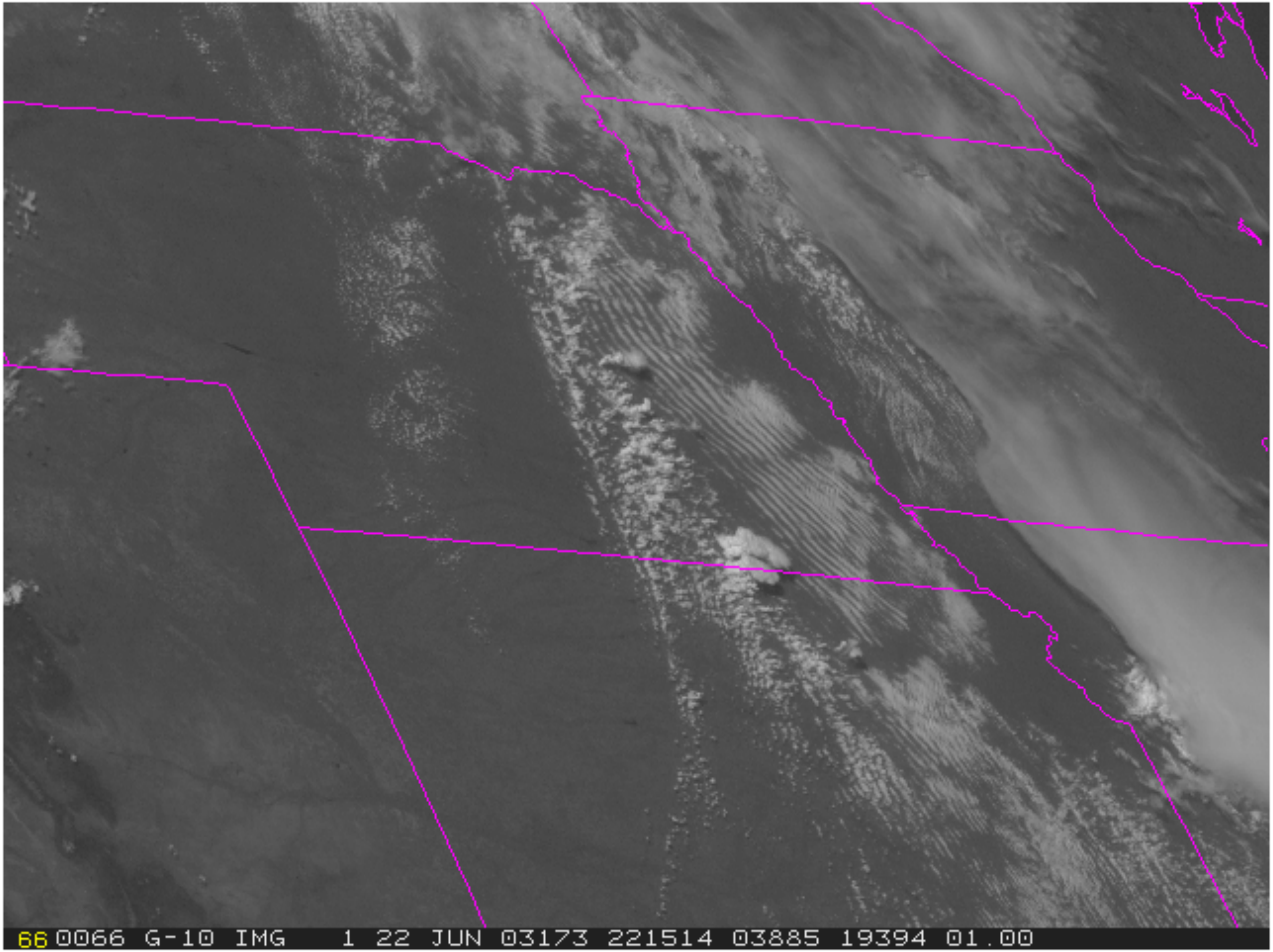

PRELIMINARY SEVERE WEATHER REPORTS
06/22/03
TORNADOES.........0017
WIND DAMAGE.......0014
LARGE HAIL........0085
TOTAL.............0116
NOAA/NWS/NCEP
STORM PREDICTION CENTER
NORMAN, OKLAHOMA

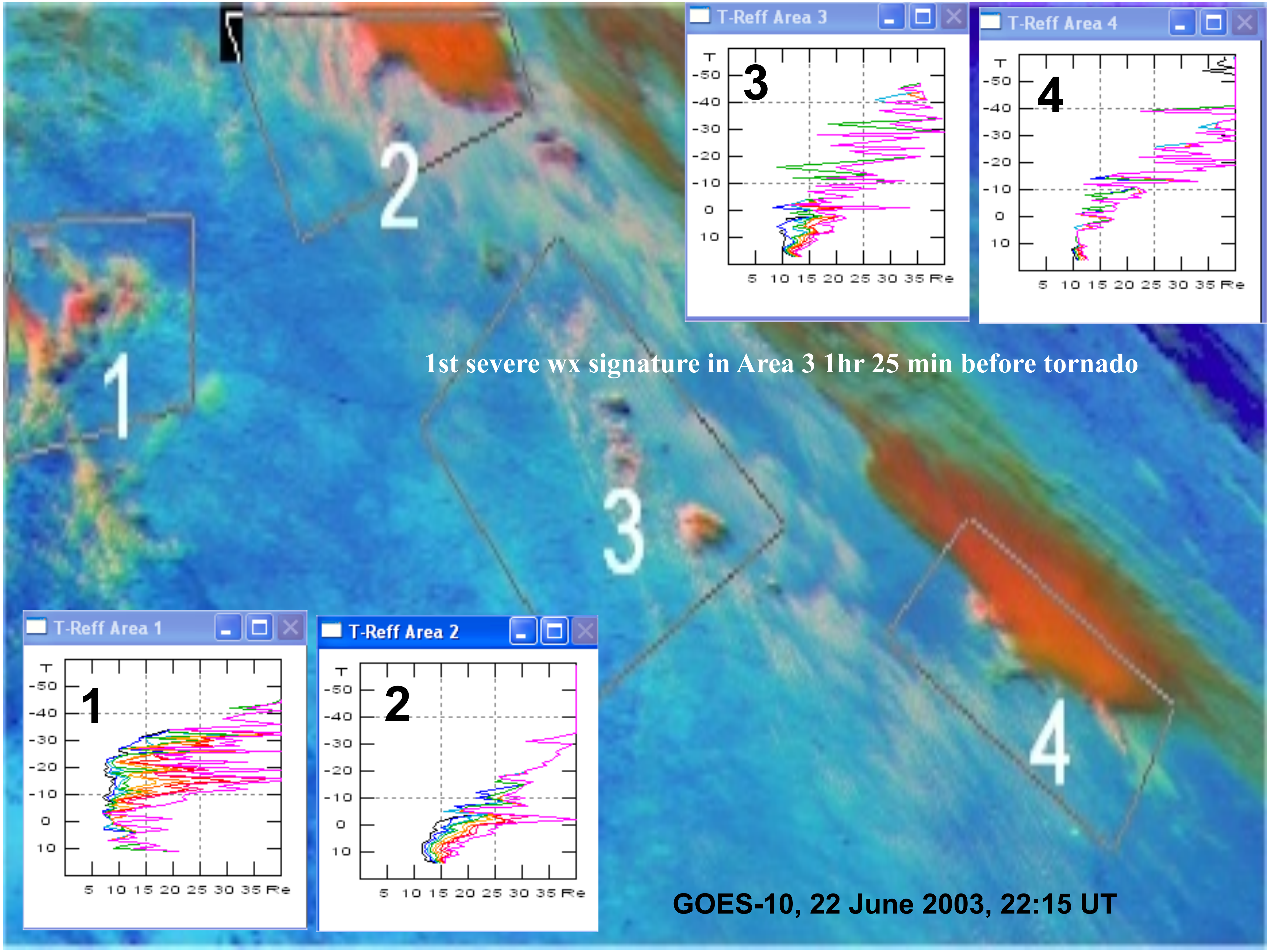


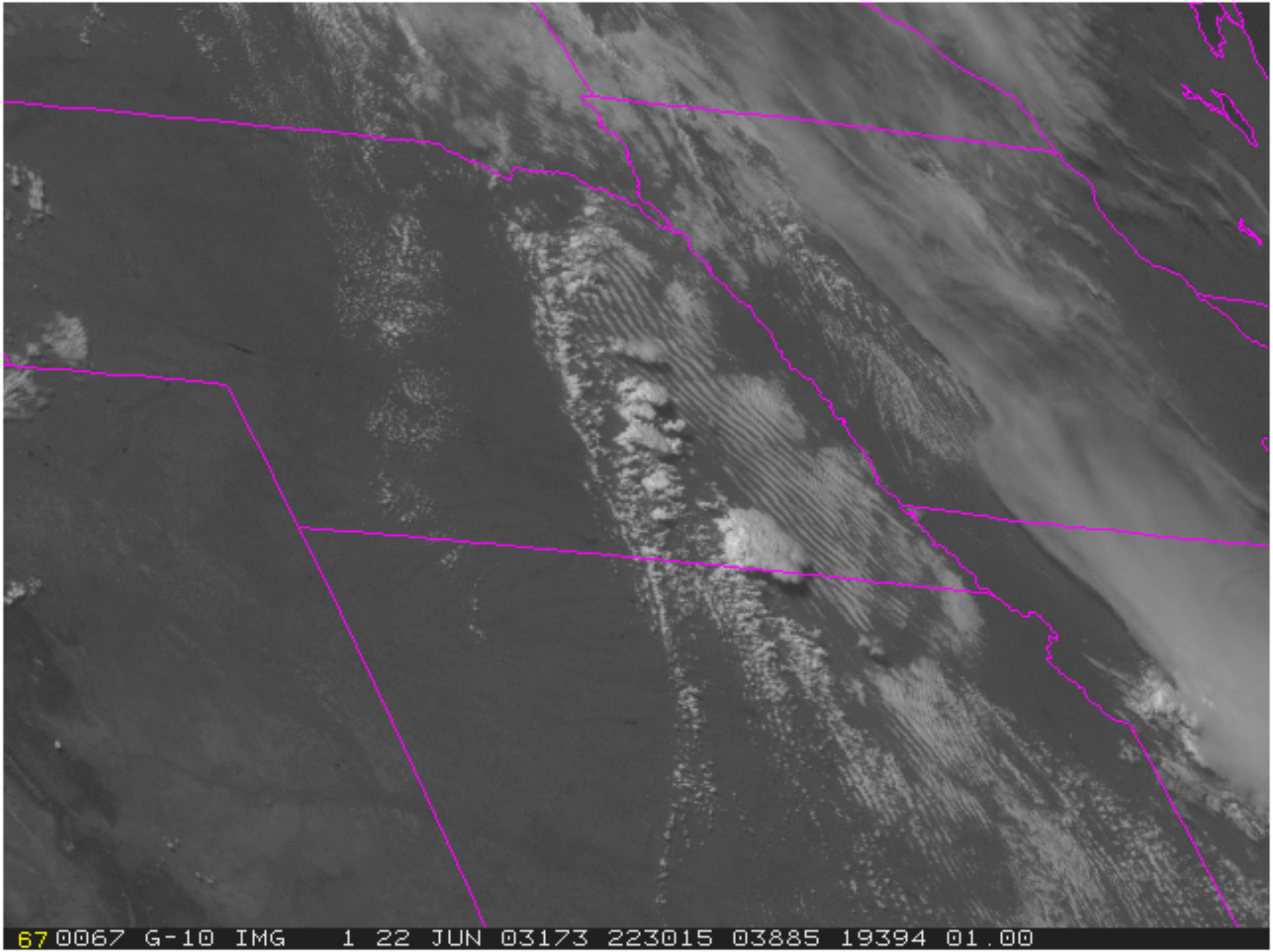
65 0065 G-10 IMG 1 22 JUN 03173 220015 03885 19394 01.00

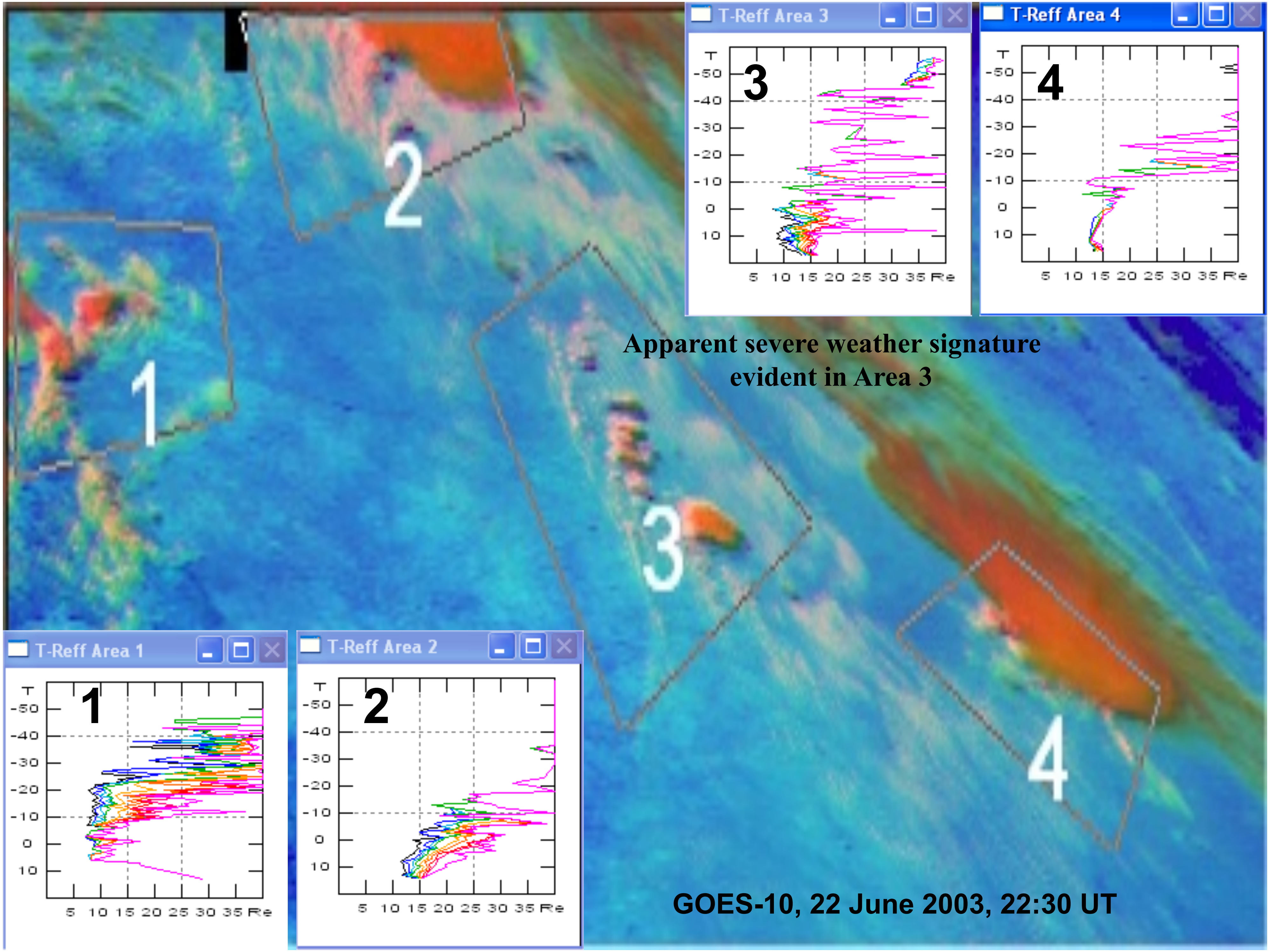


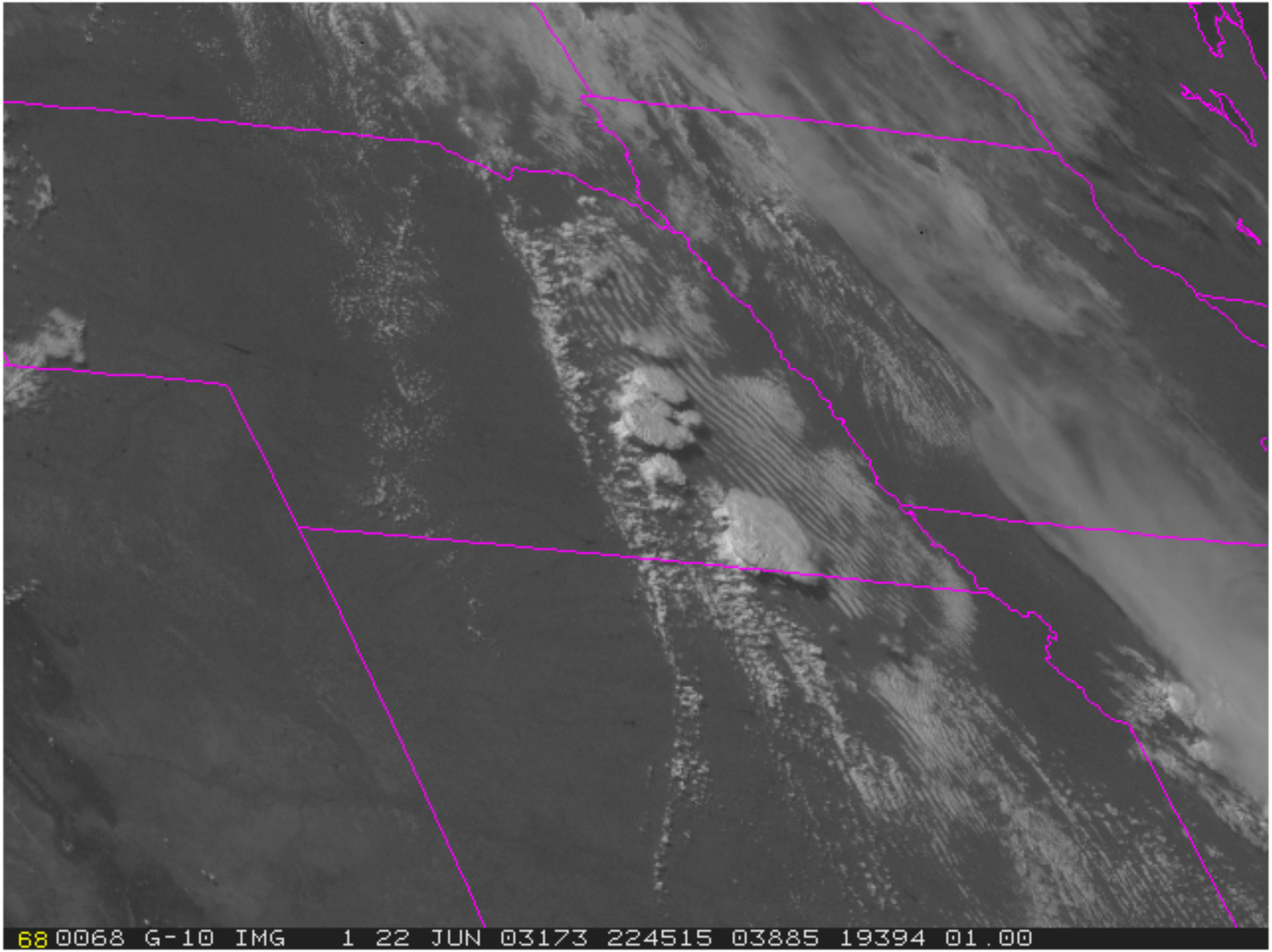
GOES-10, 22 June 2003, 22:00 UT


66 0066 G-10 IMG 1 22 JUN 03173 221514 03885 19394 01.00


T-Reff Area 1
T-Reff Area 2
T-Reff Area 3
T-Reff Area 4
1
2
3
4
T
-50
-40
-30
-20
-10
0
10
5 10 15 20 25 30 35 Re
1st severe wx signature in Area 3 1hr 25 min before tornado
GOES-10, 22 June 2003, 22:15 UT


67 0067 G-10 IMG 1 22 JUN 03173 223015 03885 19394 01.00


T-Reff Area 3
T-Reff Area 4
T-Reff Area 1
T-Reff Area 2
T
-50
-40
-30
-20
-10
0
10
5 10 15 20 25 30 35 Re
1
2
3
4
Apparent severe weather signature
evident in Area 3
GOES-10, 22 June 2003, 22:30 UT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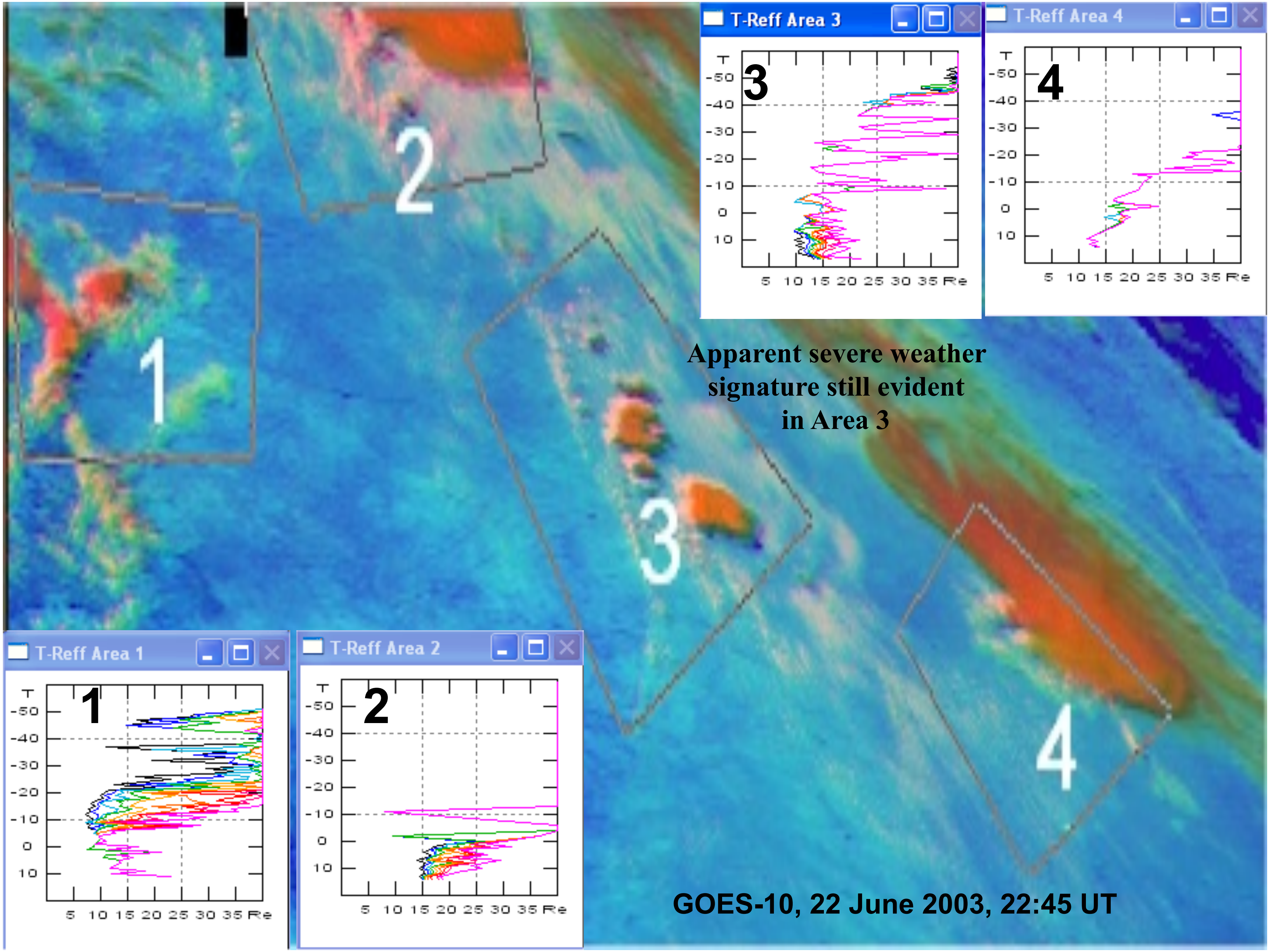
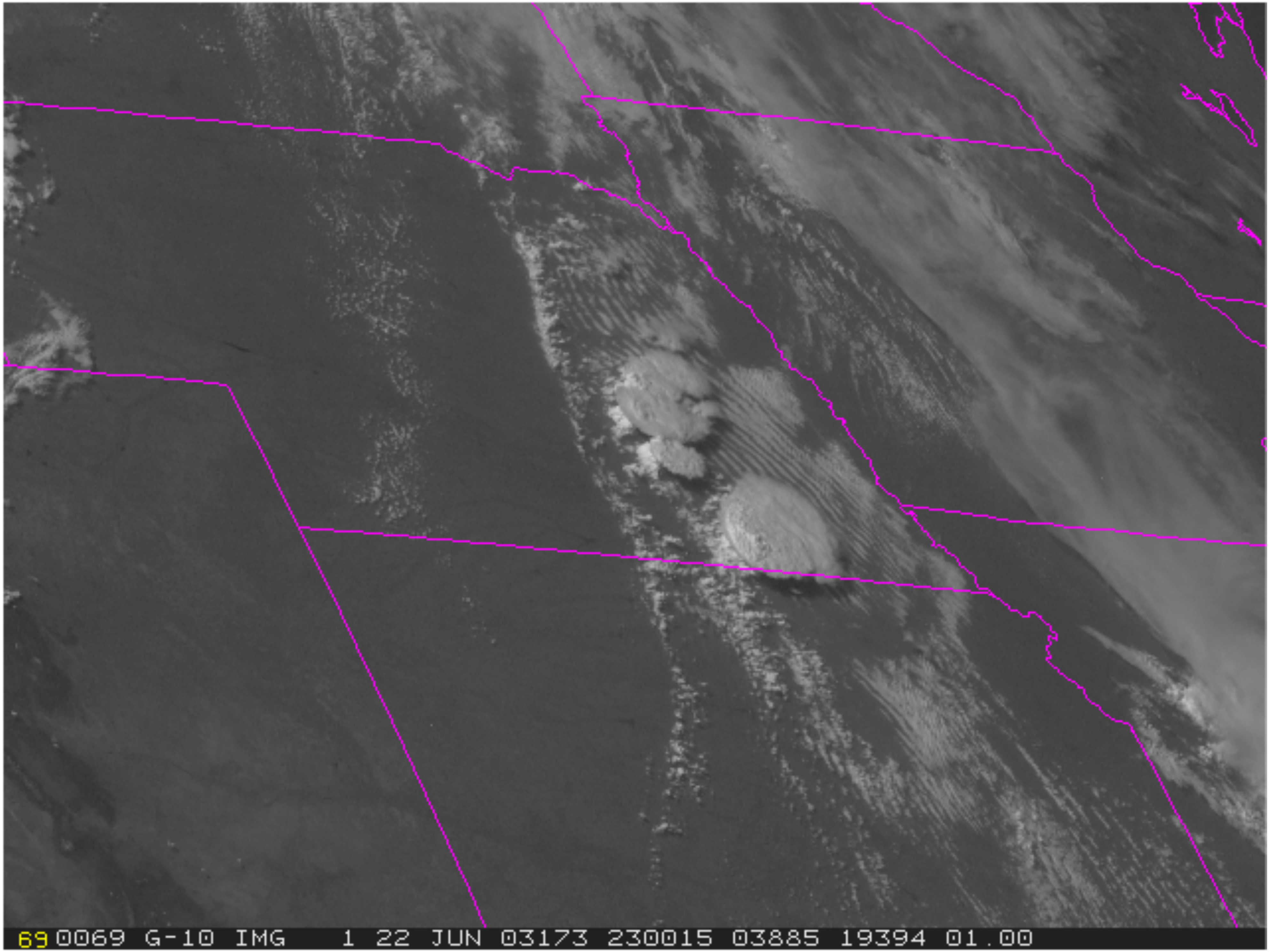
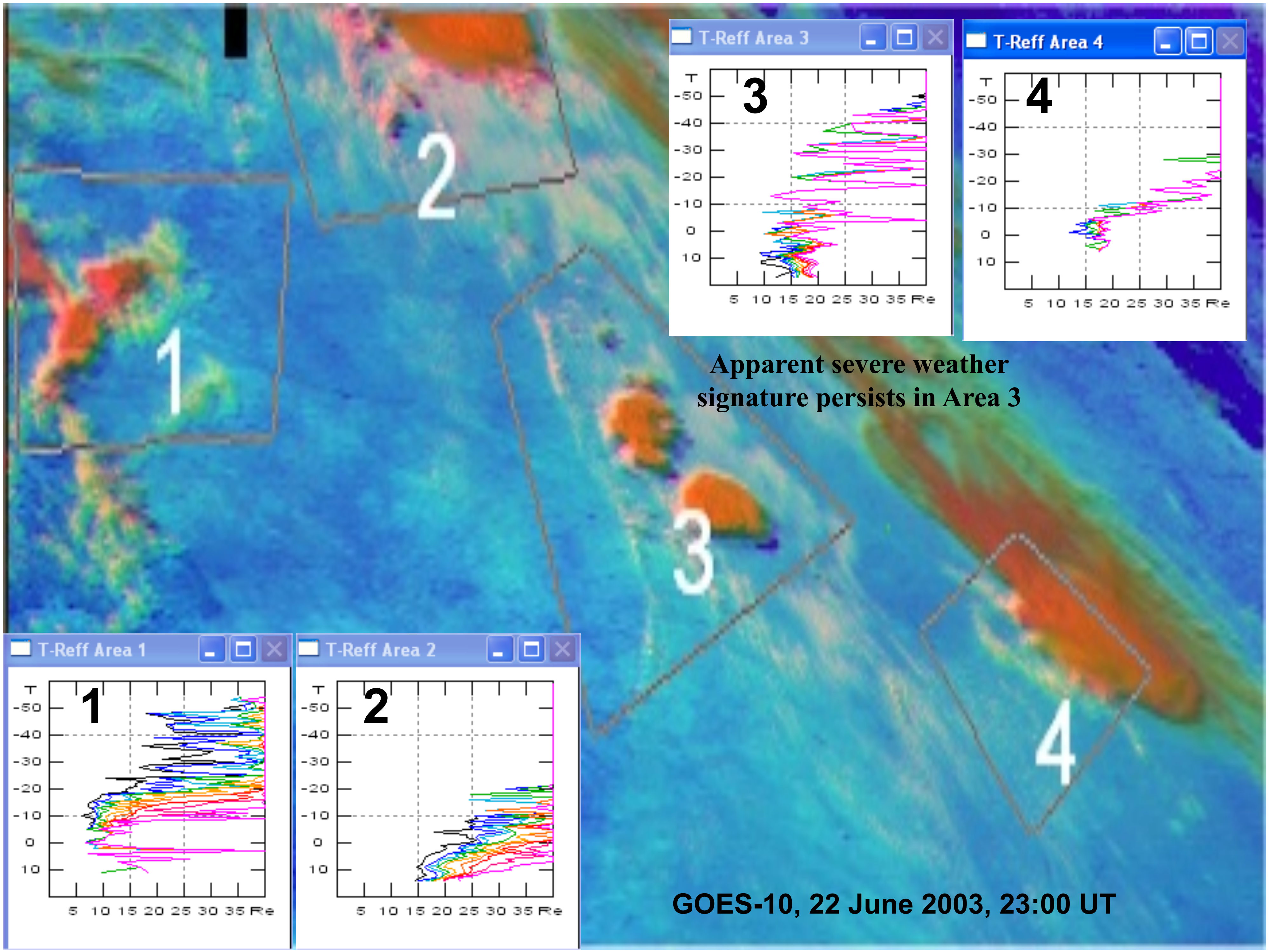
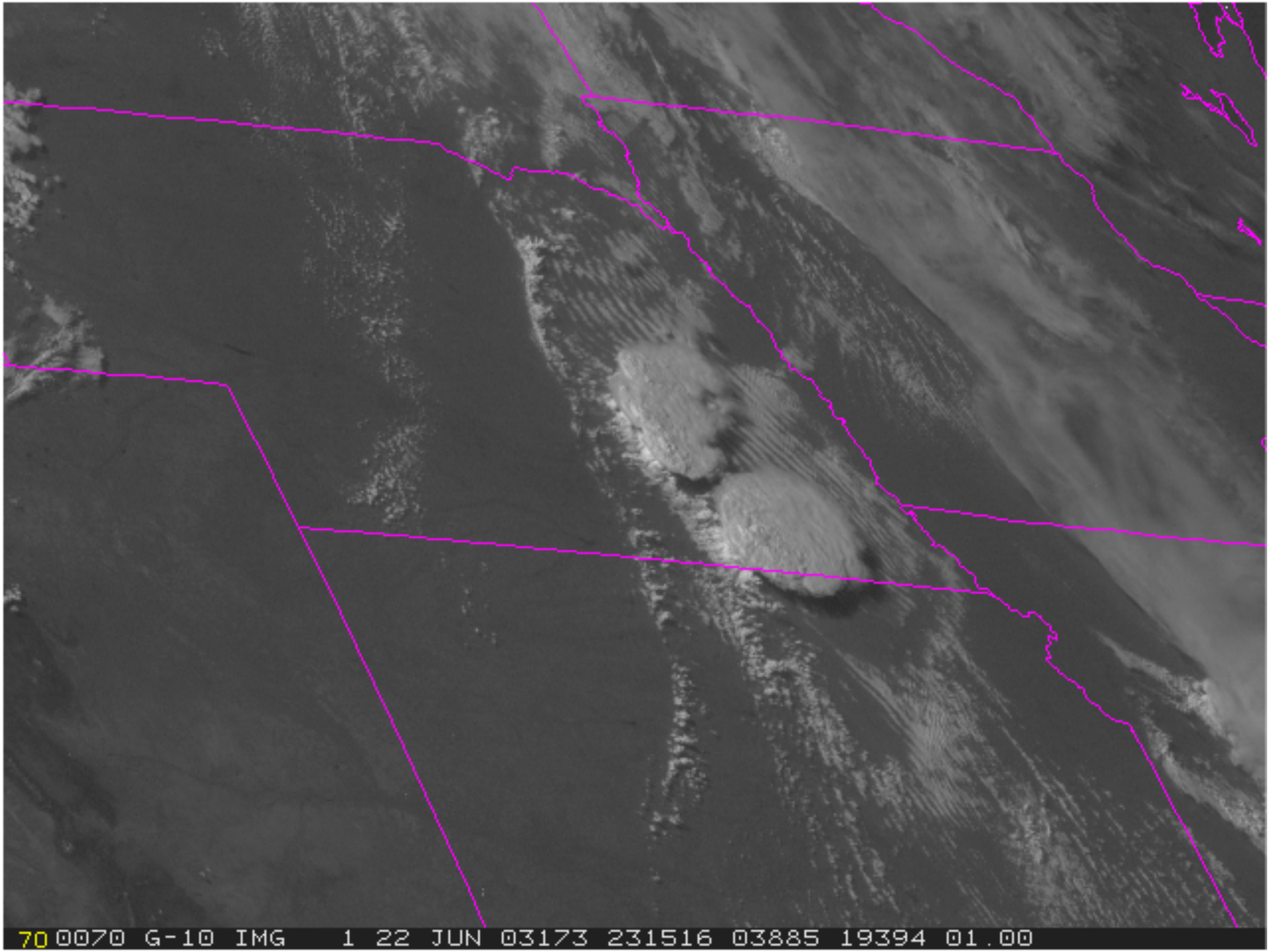
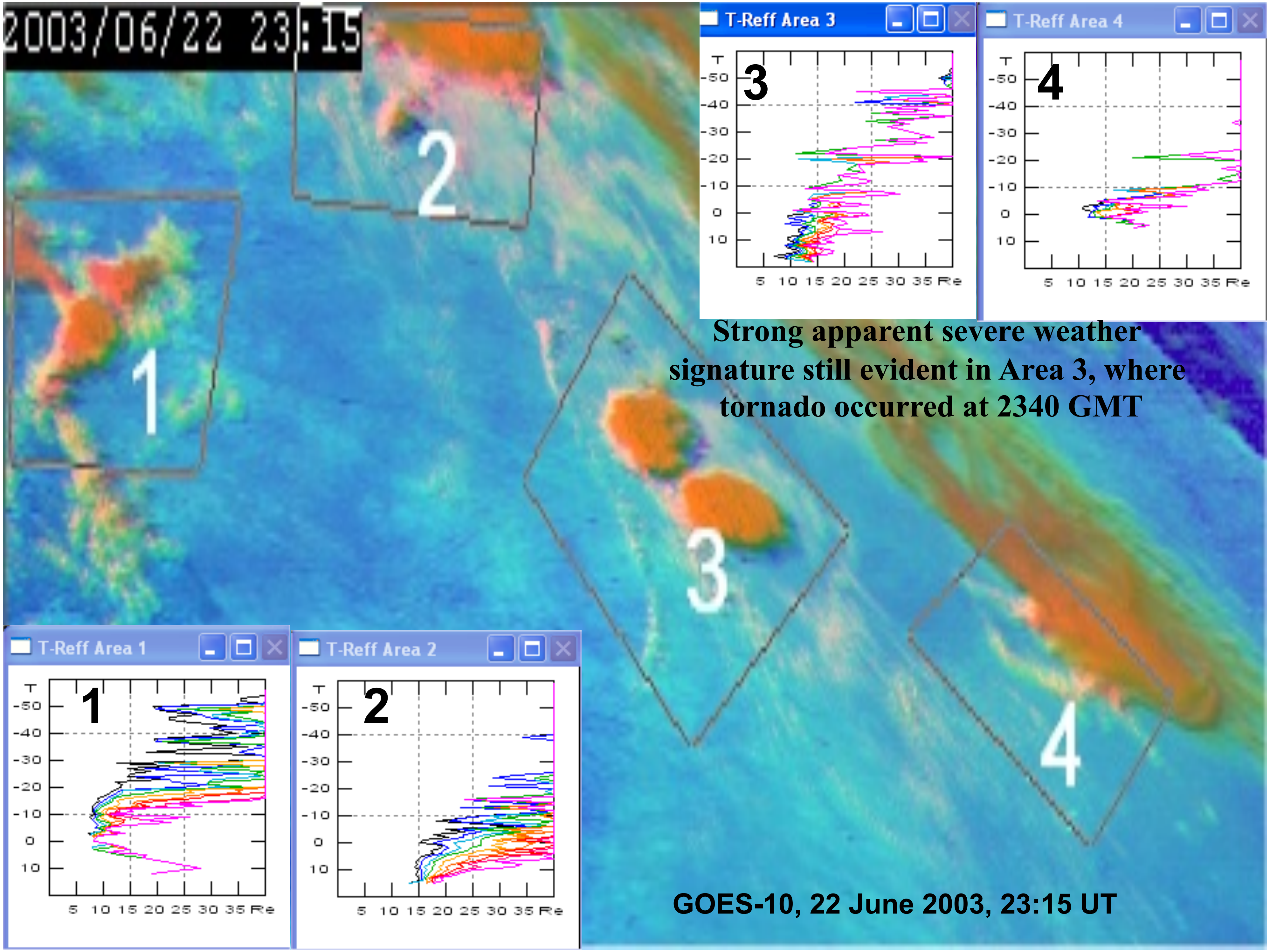
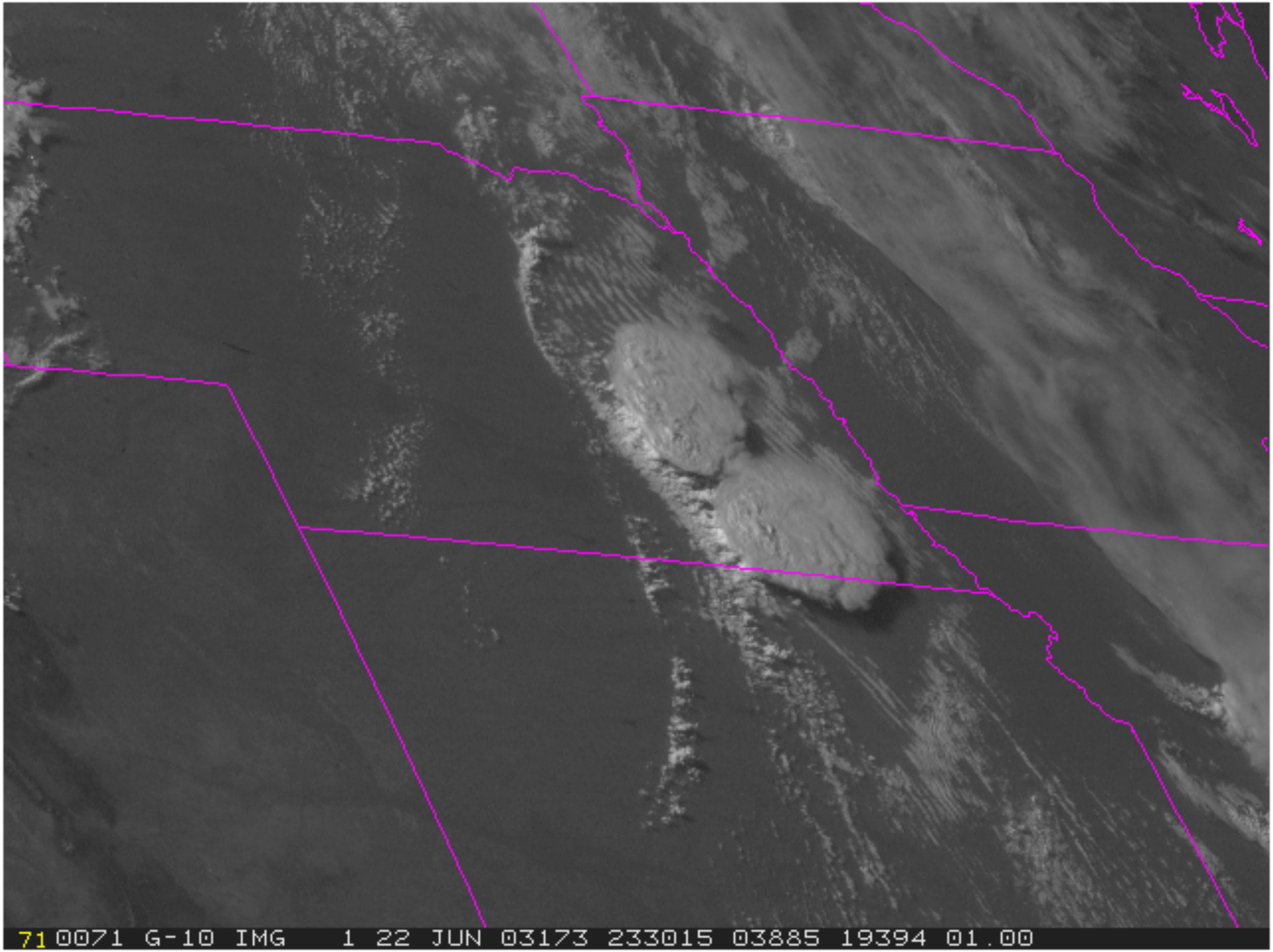

T-Reff Area 1
T-Reff Area 2
T-Reff Area 3
T-Reff Area 4
1
2
3
4
Apparent severe weather signature still evident in Area 3
GOES-10, 22 June 2003, 22:45 UT


69 0069 G-10 IMG 1 22 JUN 03173 230015 03885 19394 01.00


T-Reff Area 3
3
T
-50
-40
-30
-20
-10
0
10
5 10 15 20 25 30 35 Re
T-Reff Area 4
4
T
-50
-40
-30
-20
-10
0
10
5 10 15 20 25 30 35 Re
2
1
3
4
Apparent severe weather signature persists in Area 3
T-Reff Area 1
1
T
-50
-40
-30
-20
-10
0
10
5 10 15 20 25 30 35 Re
T-Reff Area 2
2
T
-50
-40
-30
-20
-10
0
10
5 10 15 20 25 30 35 Re
GOES-10, 22 June 2003, 23:00 UT


70 0070 G-10 IMG 1 22 JUN 03173 231516 03885 19394 01.00


2003/06/22 23:15
1
2
3
4
T-Reff Area 1
T-Reff Area 2
T-Reff Area 3
T-Reff Area 4
T
-50
-40
-30
-20
-10
0
10
5 10 15 20 25 30 35 Re
Strong apparent severe weather signature still evident in Area 3, where tornado occurred at 2340 GMT
GOES-10, 22 June 2003, 23:15 UT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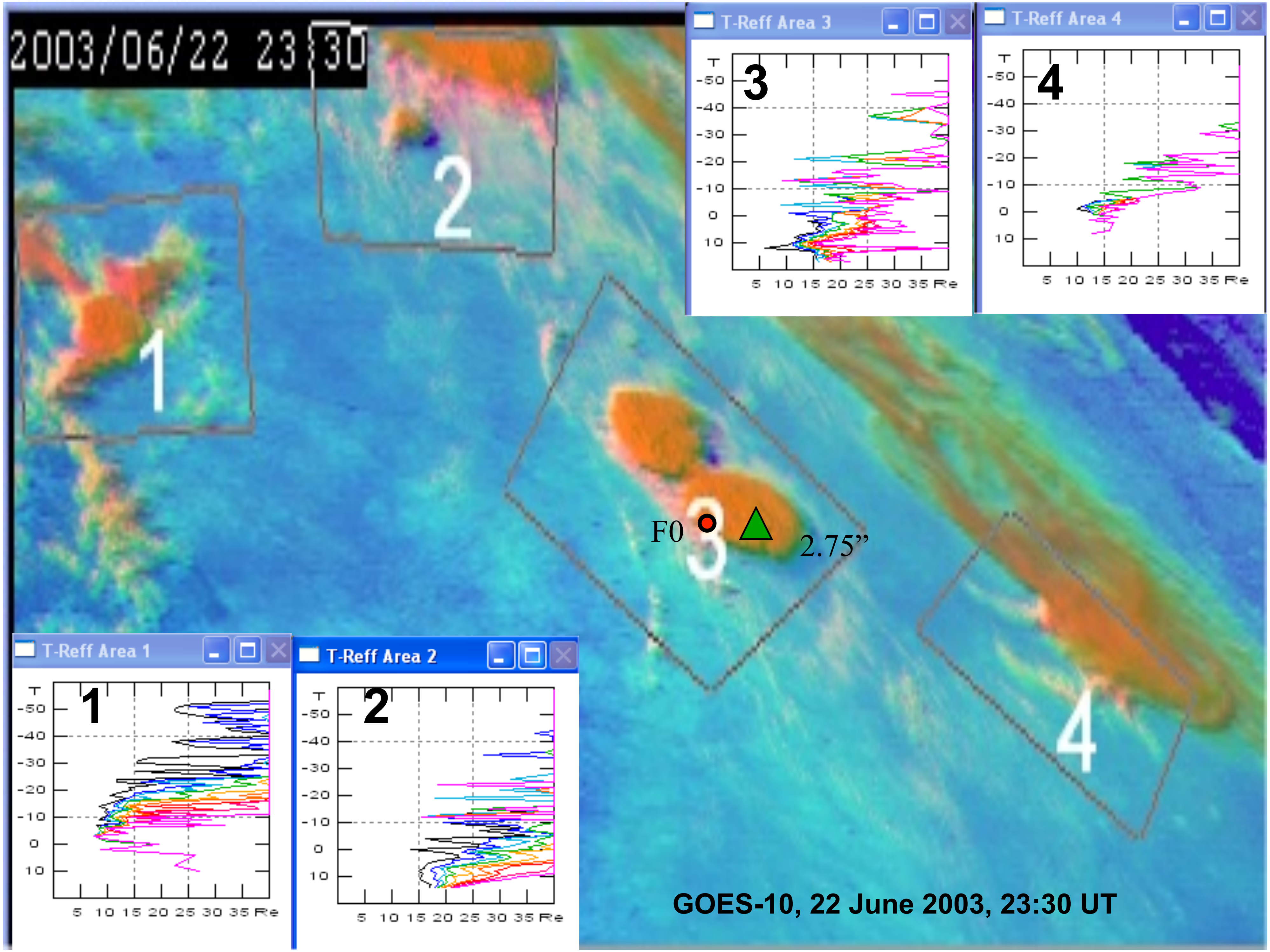
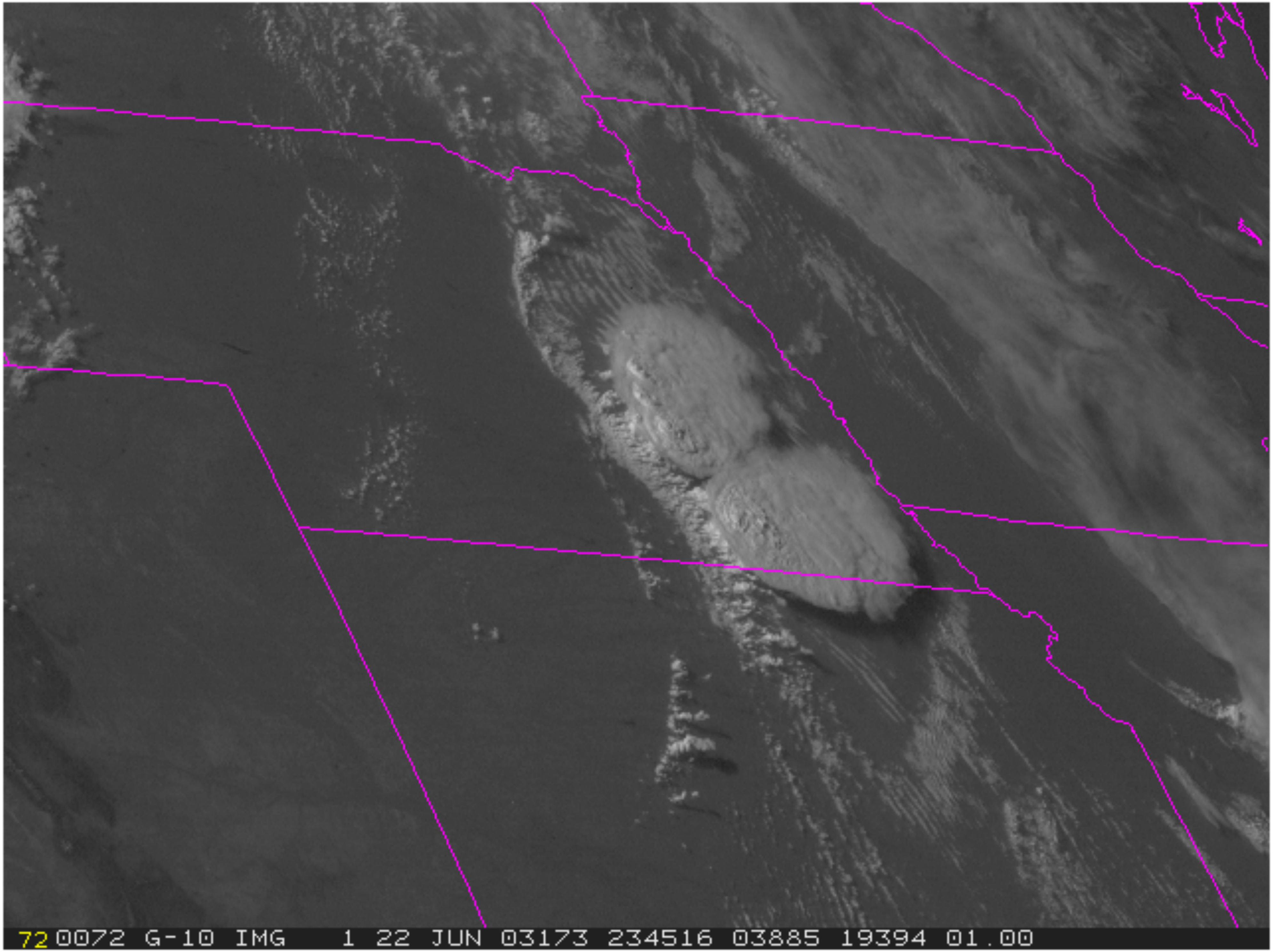
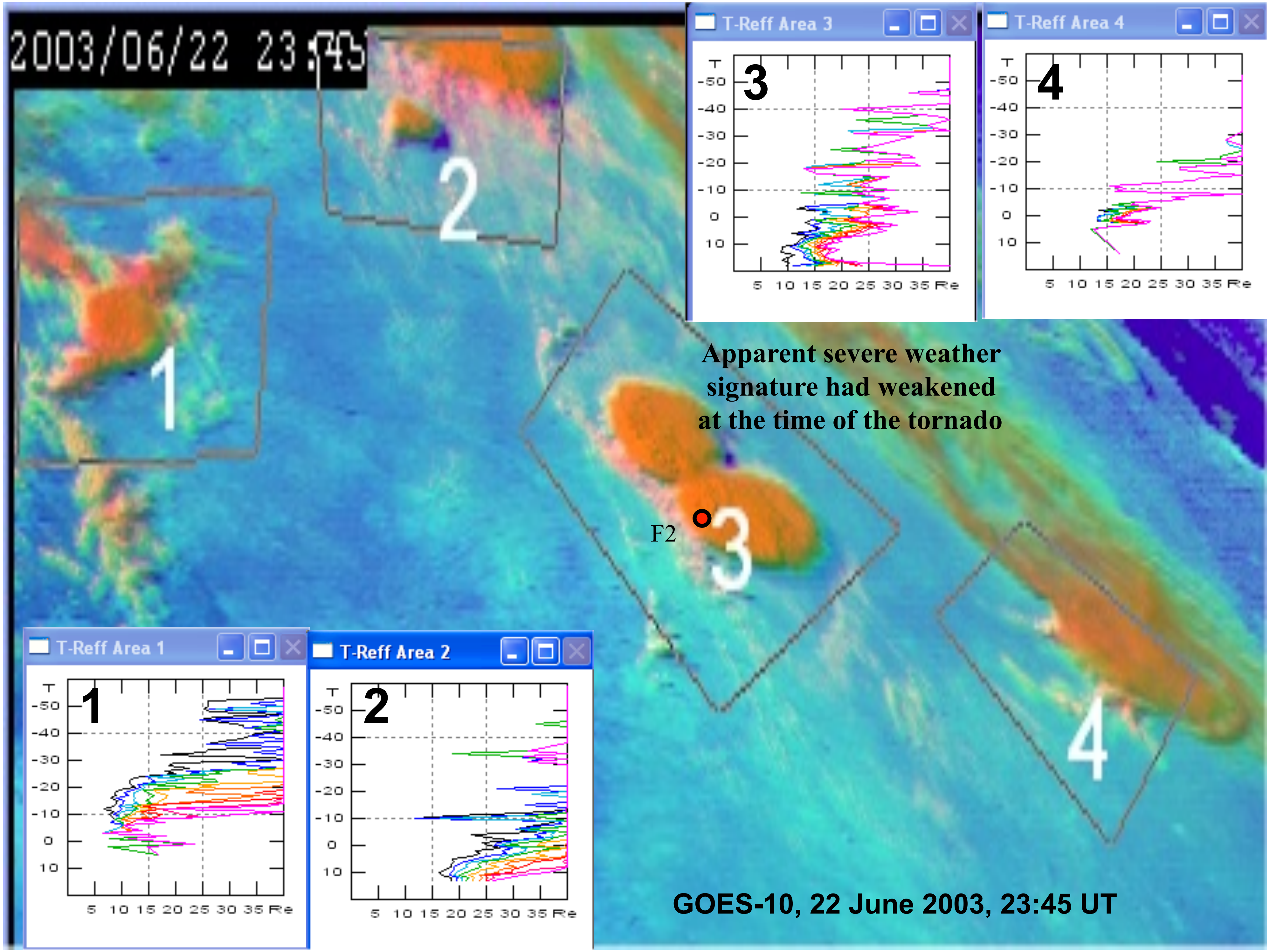
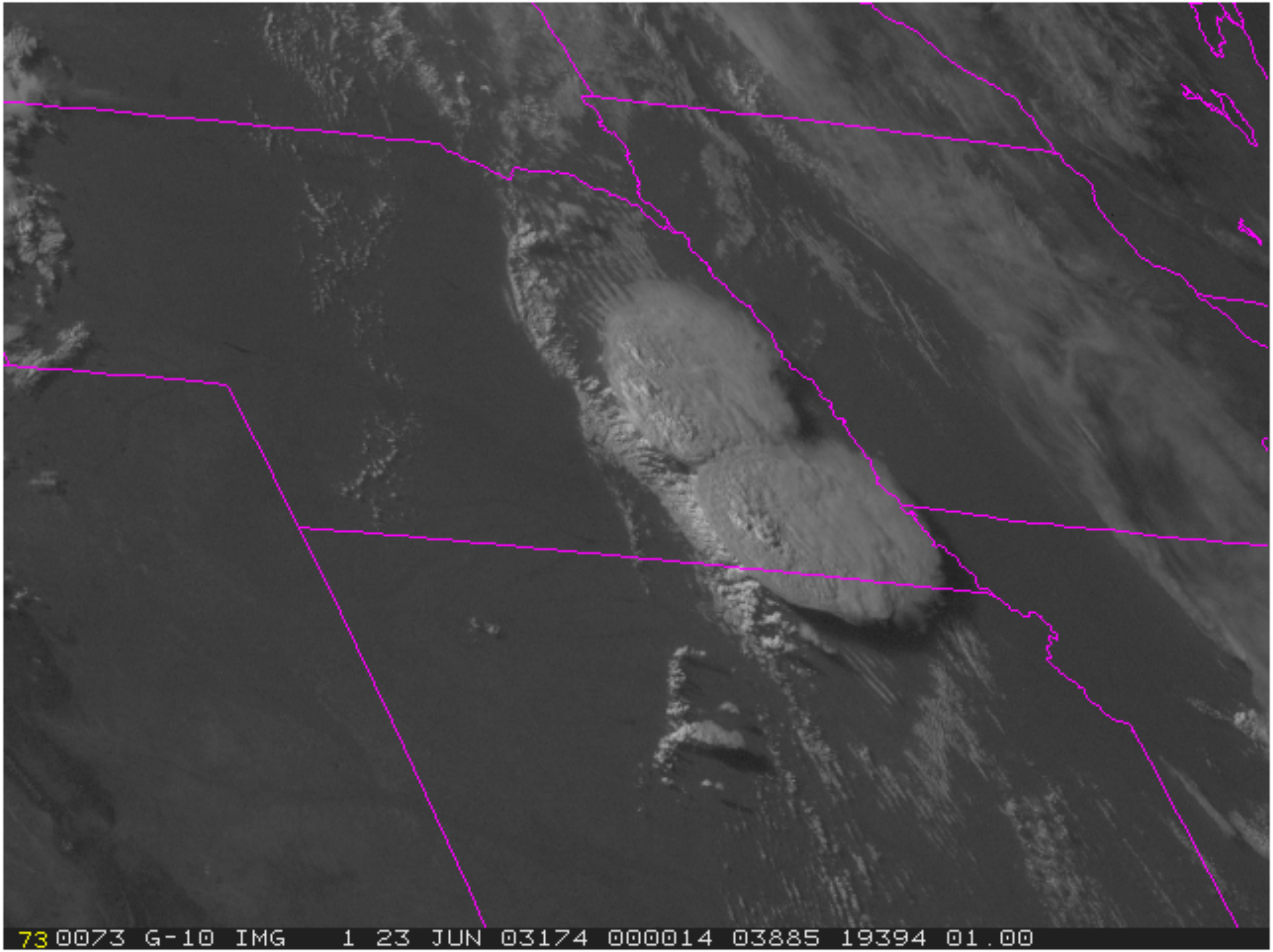


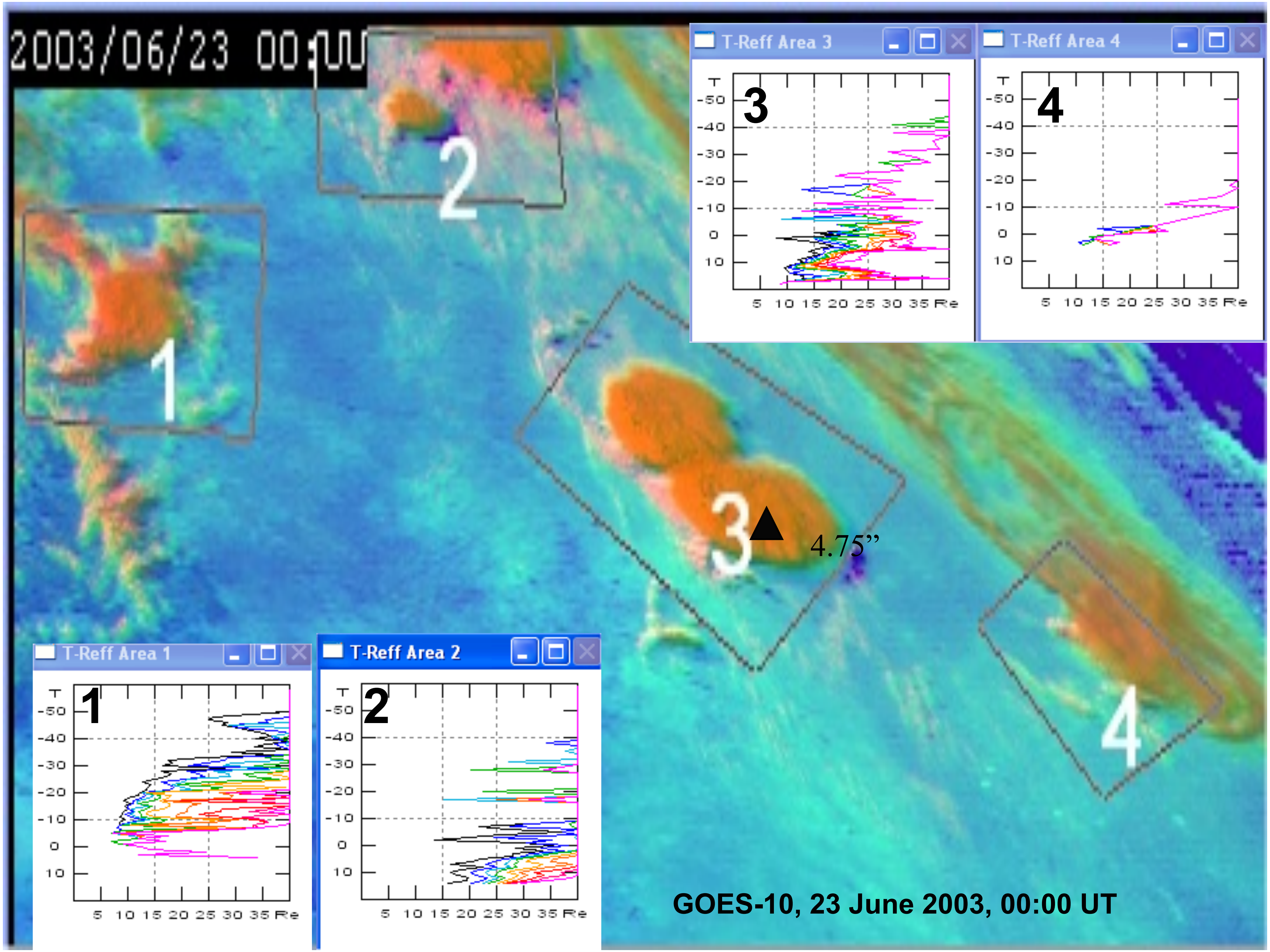
2003/06/22 23:30
T-Reff Area 1
T-Reff Area 2
T-Reff Area 3
T-Reff Area 4
T
5 10 15 20 25 30 35 Re
F0
2.75”
GOES-10, 22 June 2003, 23:30 UT


72 0072 G-10 IMG 1 22 JUN 03173 234516 03885 19394 01.00

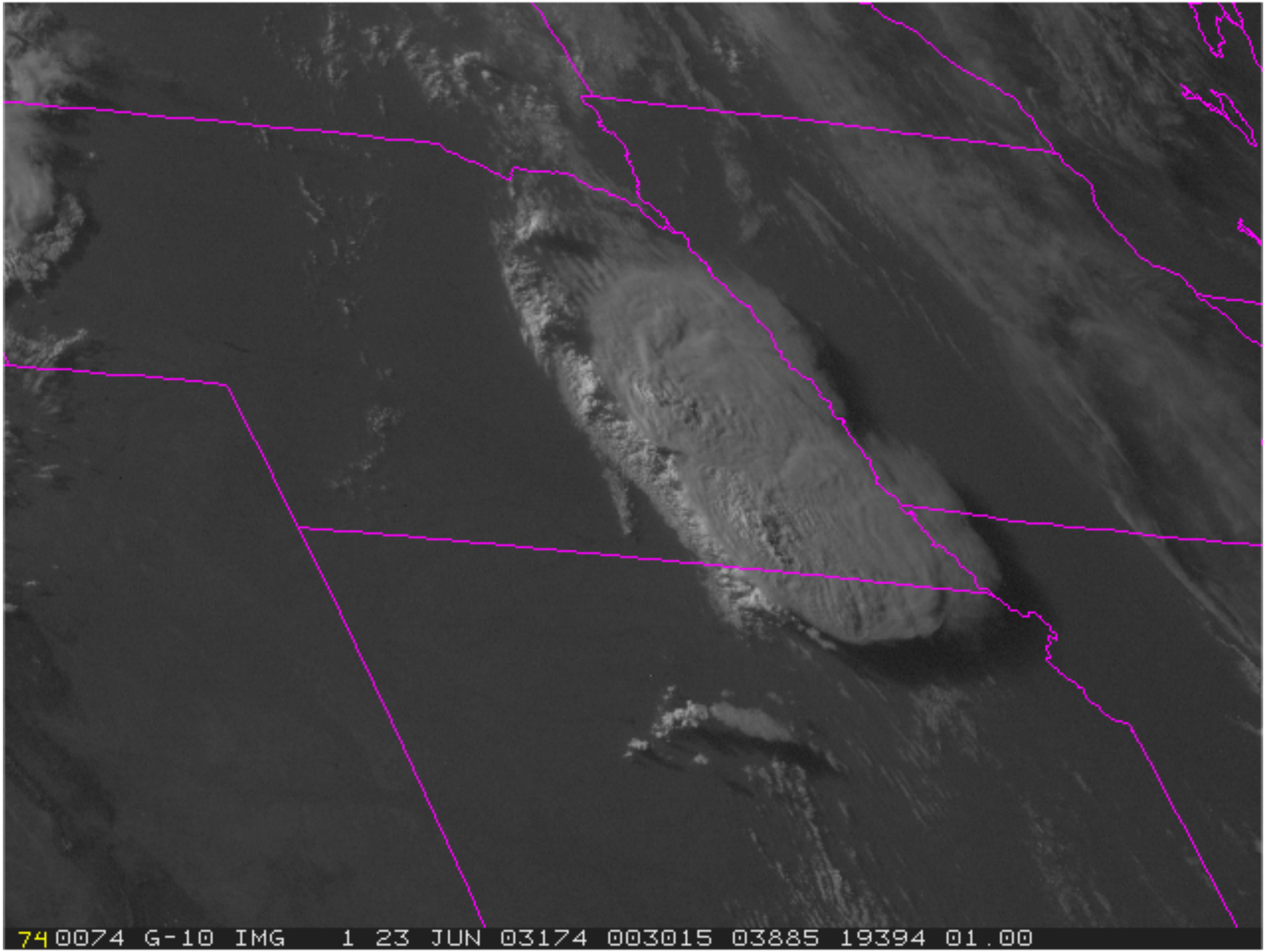


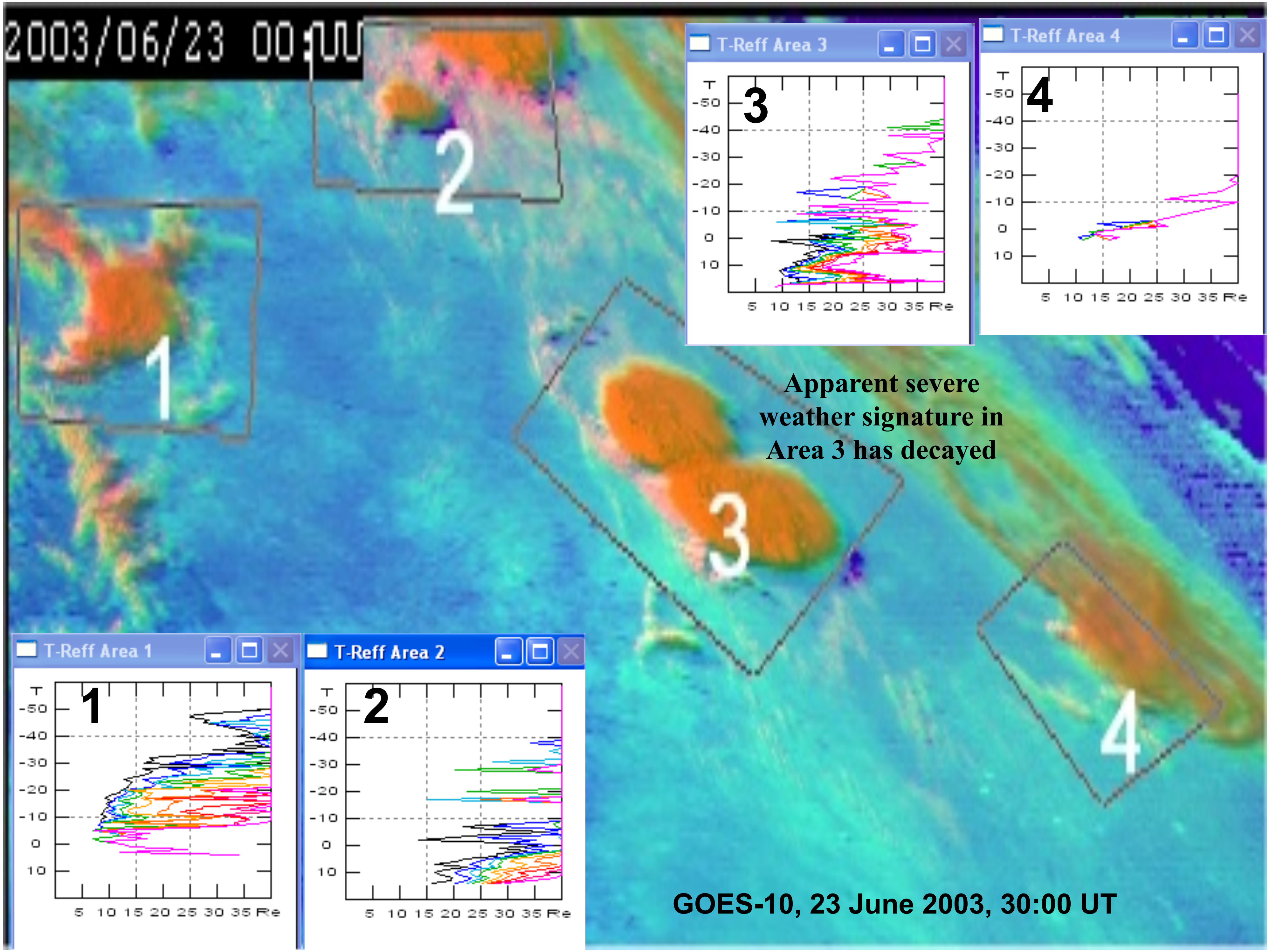
2003/06/22 23:45
T-Reff Area 3
T-Reff Area 4
T-Reff Area 1
T-Reff Area 2
T
-50
-40
-30
-20
-10
0
10
5 10 15 20 25 30 35 Re
1
2
3
4
F2
Apparent severe weather signature had weakened at the time of the tornado
GOES-10, 22 June 2003, 23:45 UT


73 0073 G-10 IMG 1 23 JUN 03174 000014 03885 19394 01.00



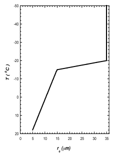
2003/06/23 00:00
T-Reff Area 1
T-Reff Area 2
T-Reff Area 3
T-Reff Area 4
1
2
3
4
T
-50
-40
-30
-20
-10
0
10
5 10 15 20 25 30 35 Re
4.75”
GOES-10, 23 June 2003, 00:00 UT


74 0074 G-10 IMG 1 23 JUN 03174 003015 03885 19394 01.00

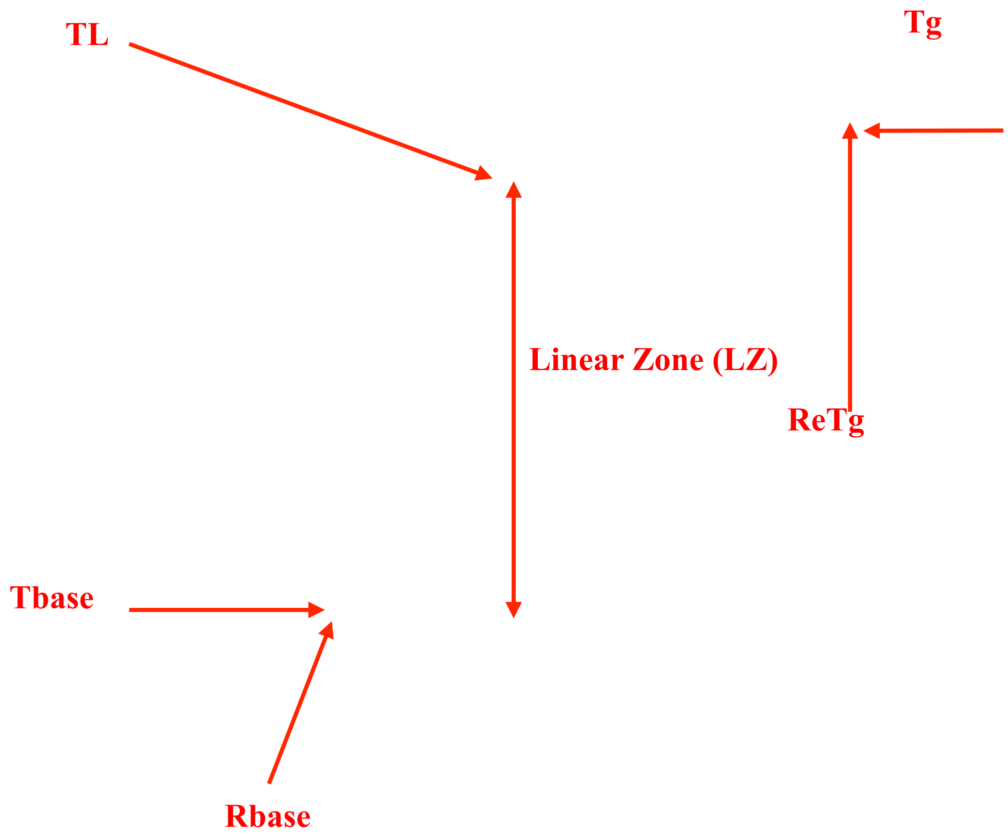


2003/06/23 00
1
2
3
4
T-Reff Area 1
T-Reff Area 2
T-Reff Area 3
T-Reff Area 4
T
-50
-40
-30
-20
-10
0
10
5 10 15 20 25 30 35 Re
Apparent severe weather signature in Area 3 has decayed
GOES-10, 23 June 2003, 30:00 UT

The microphysical parameters



1. Tbase – temperature at cloud base.
2. Rbase – effective radius at cloud base.
3. T14 – temperature where the effective radius exceeds the 14 micron precipitation threshold.
4. LZ – Linear Zone. Layer within the cloud where the effective radius increases with cloud height (measured by cloud top temperature).
5. TL – temperature where the LZ ends.



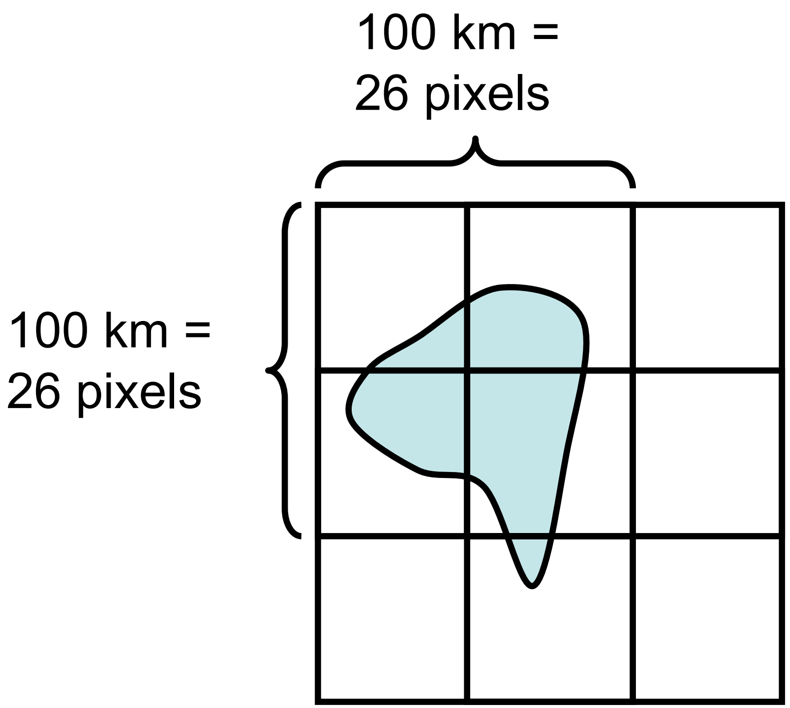
Scoring more points when:

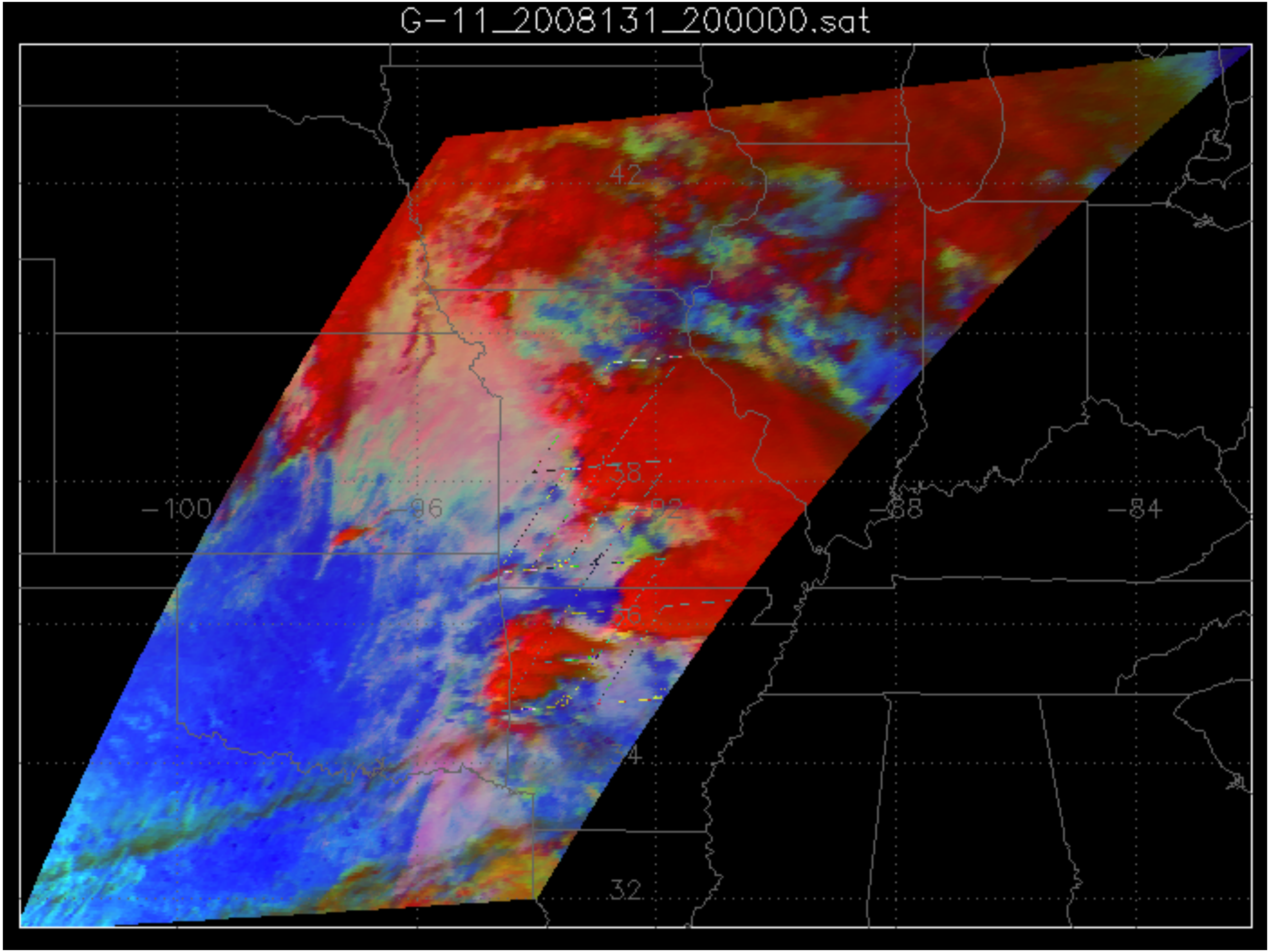
- Glaciation temperature (Tg) is colder
- Re at Tg is smaller
- T-Re profile is more linear and less noisy
- Cloud base temperature is warmer

Automatic detection system

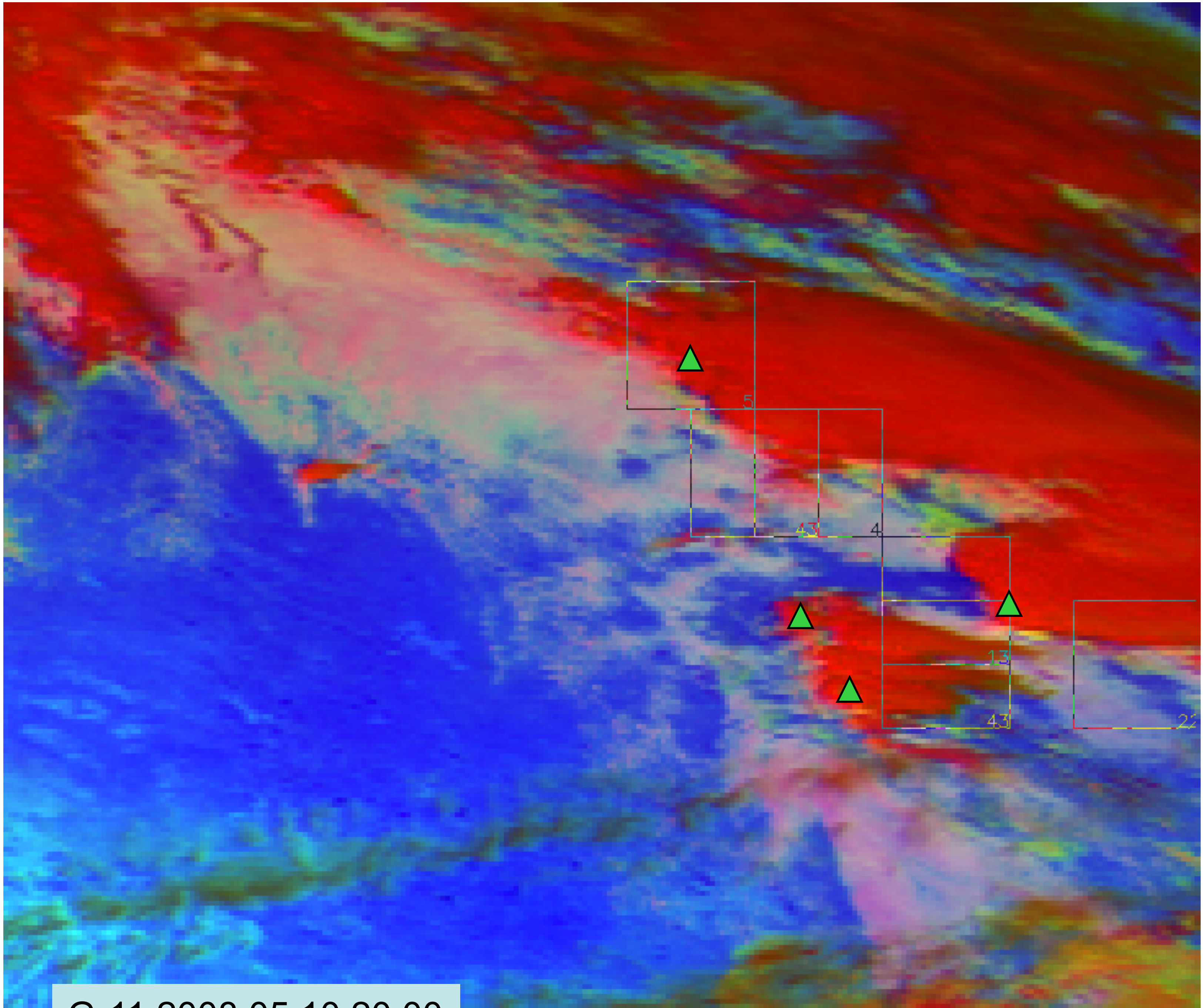
- Calculates cloud top T and Re in running windows of 26x26 pixels, ~ 100x100 km
- Screening out non-severe T-Re profiles
- Scoring and display of severe T-Re profiles and creating “Early Alerts” (EA).
- Posting the EA on the satellite image.
- Posting the images on a web site.

Early alerts area definition

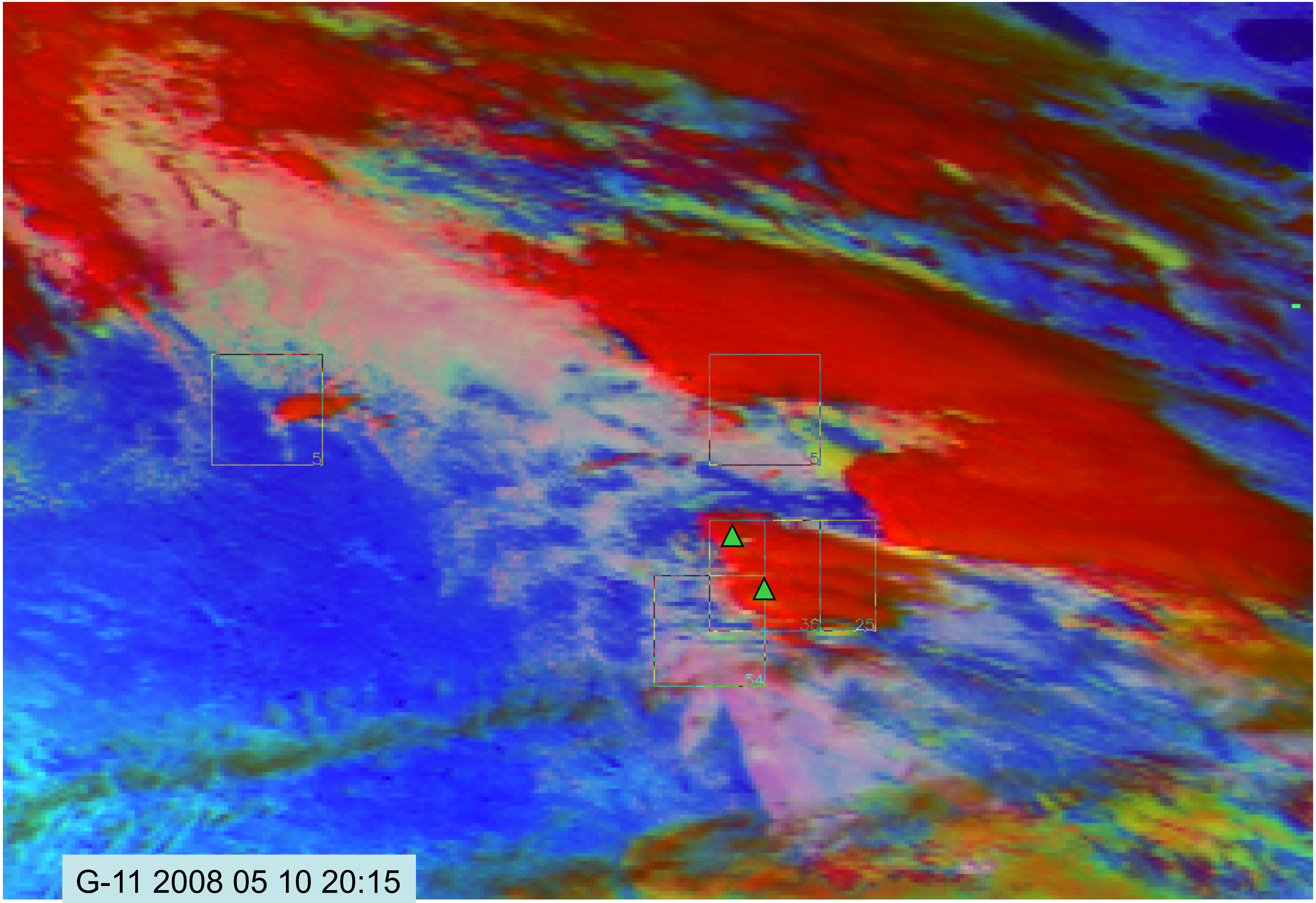


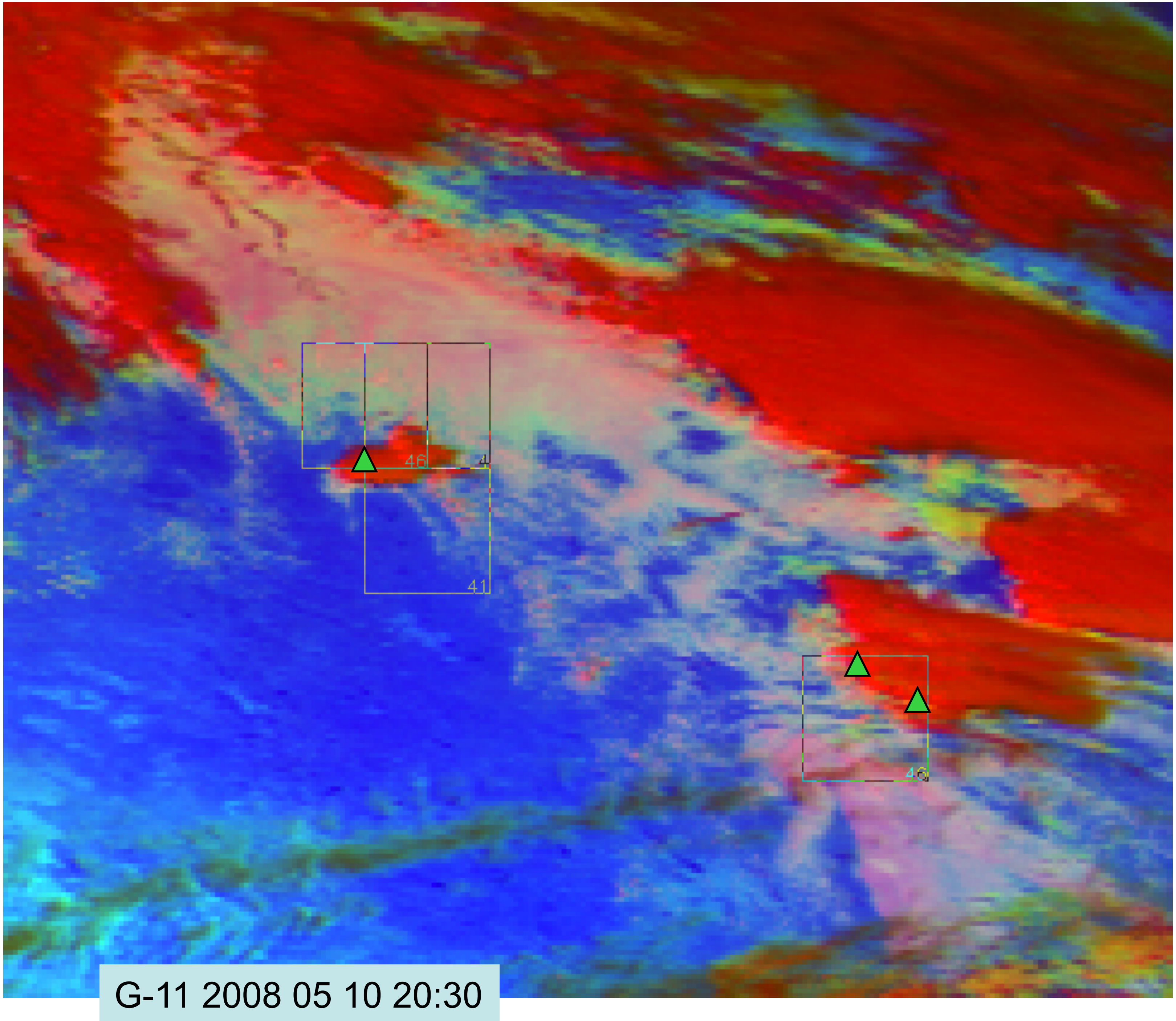


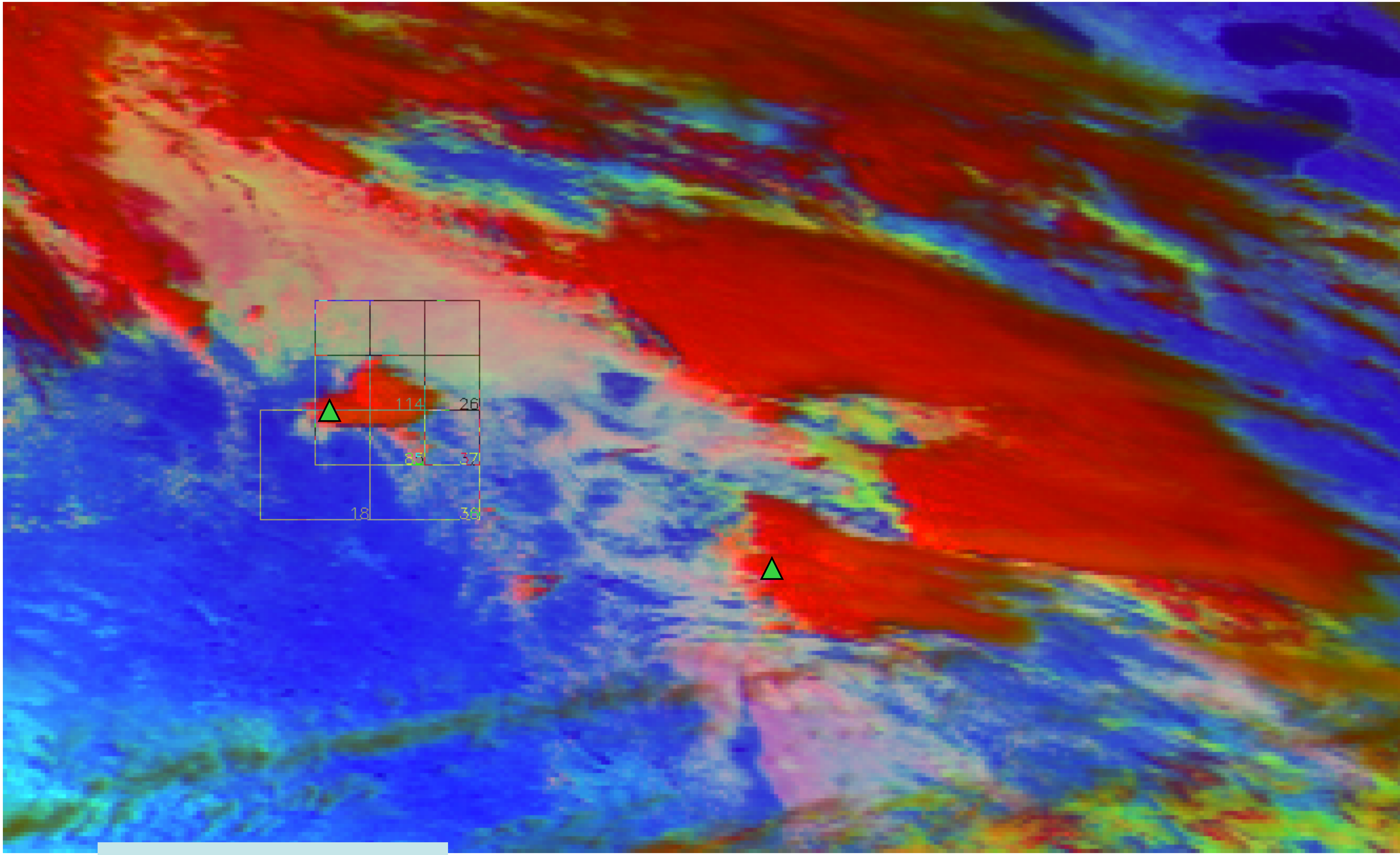
G-11_2008131_200000.sat
42
38
36
32
-100
-96
-92
-88
-84



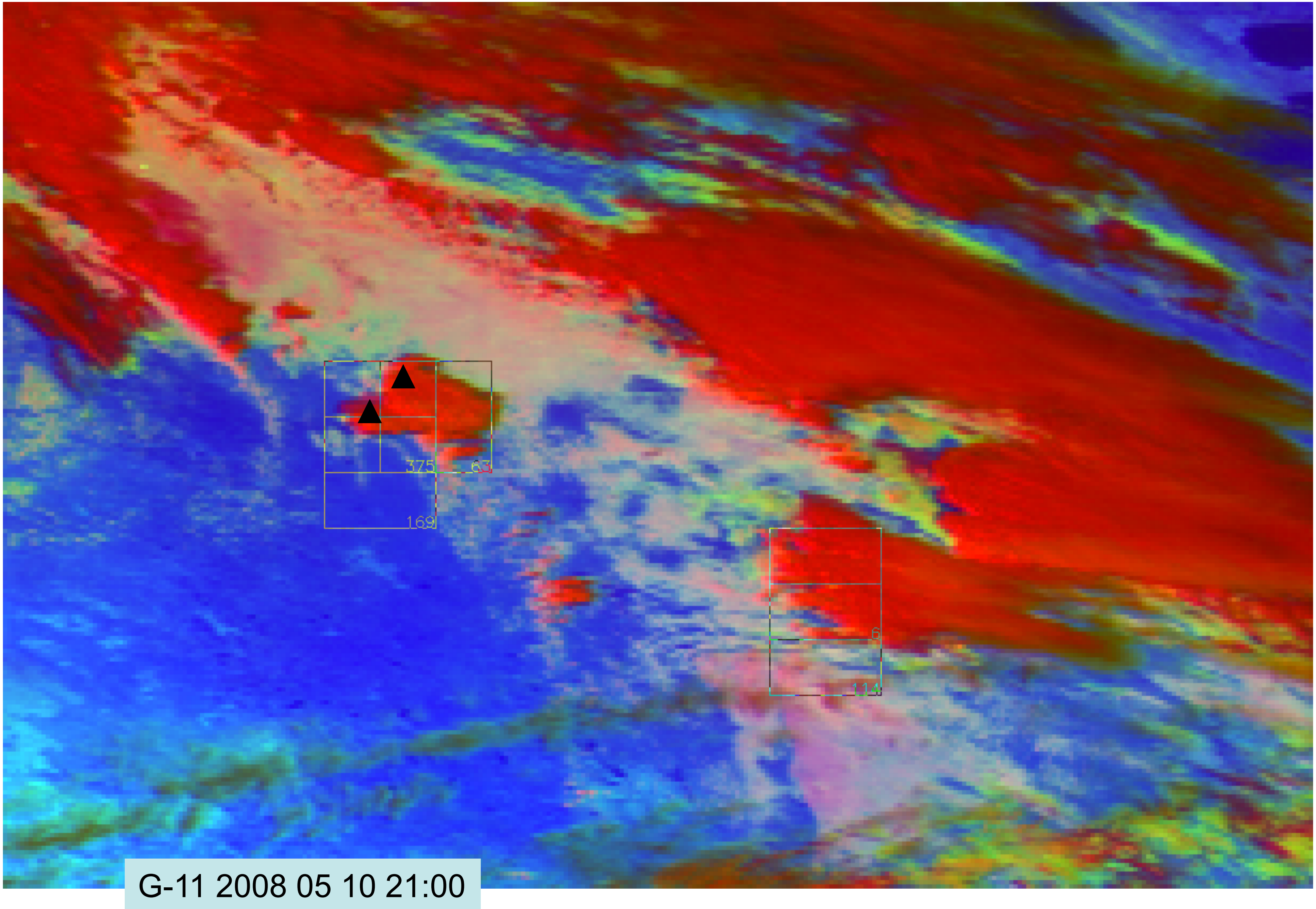
G-11 2008 05 10 20:00

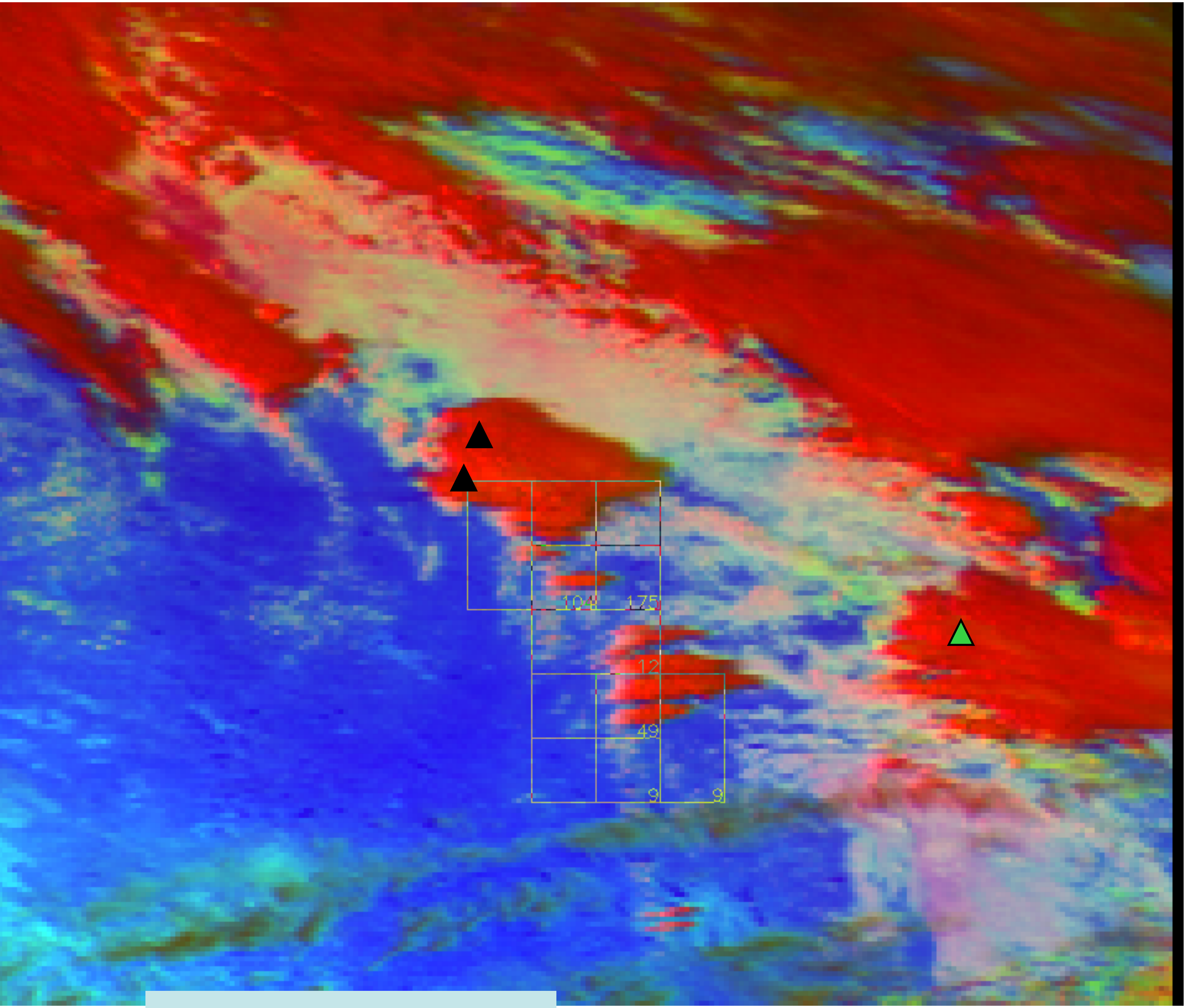

5
5
36
25
54
G-11 2008 05 10 20:15


46
4
41
46
G-11 2008 05 10 20:30

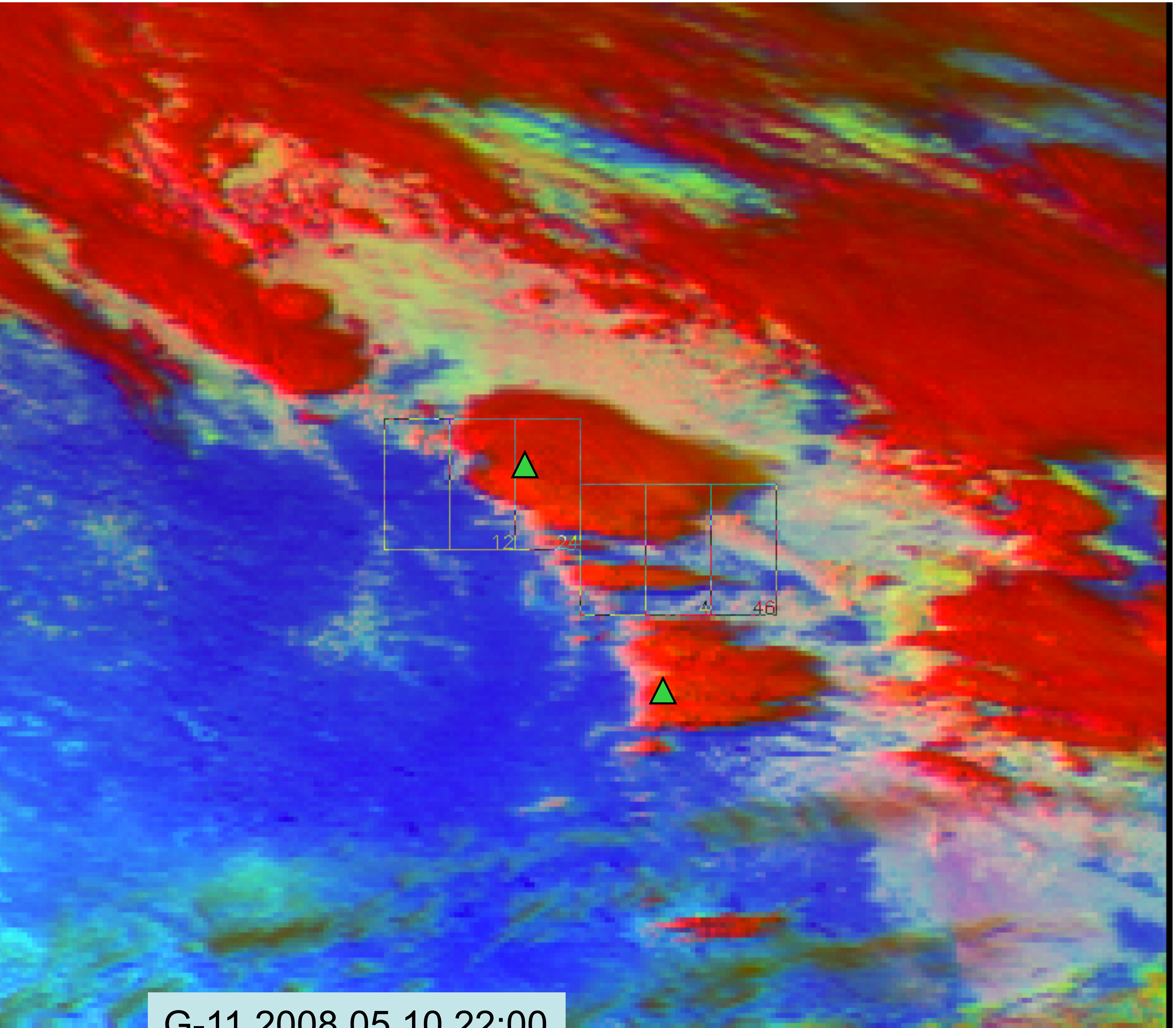


G-11 2008 05 10 20:45

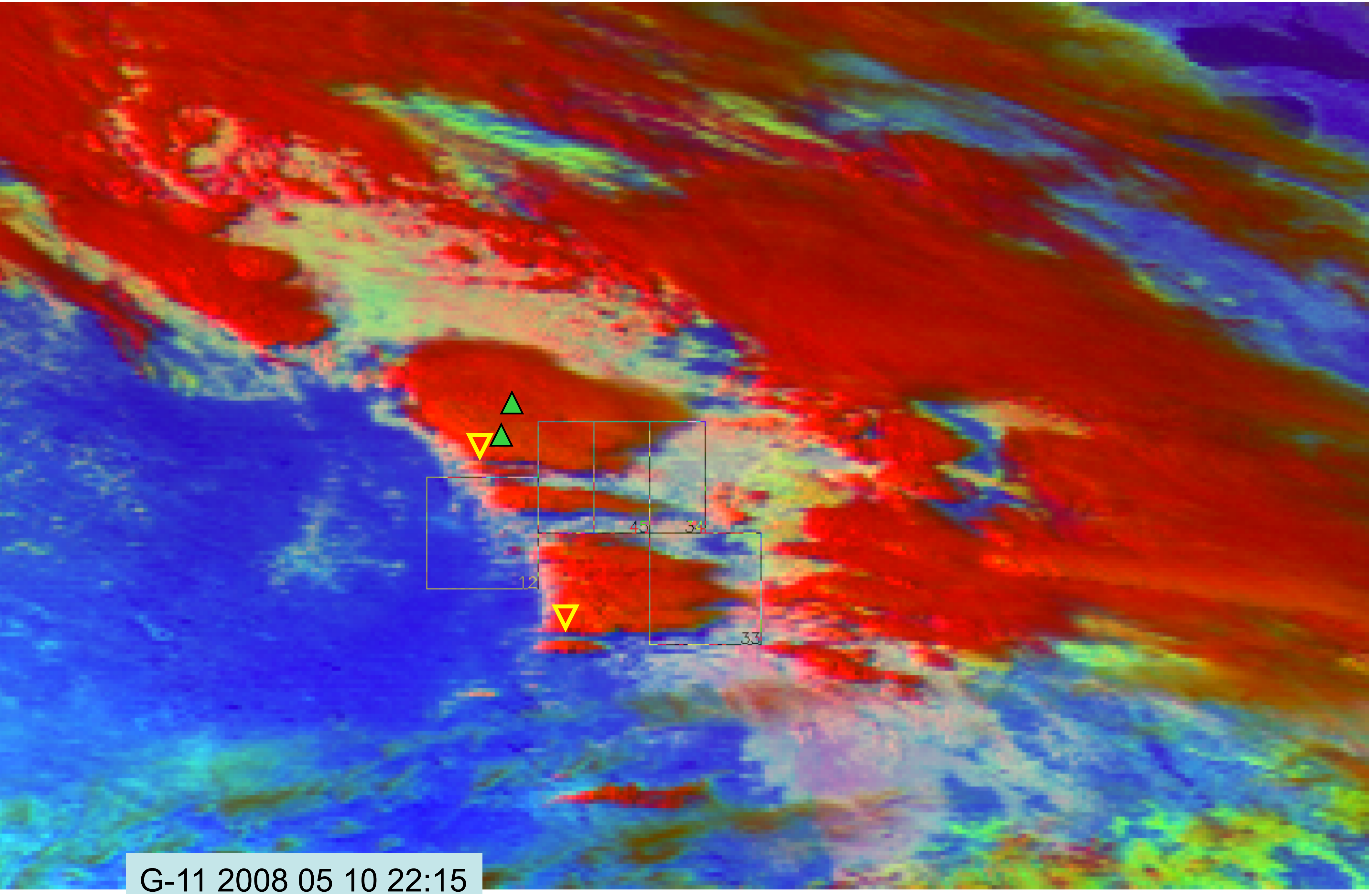

375
63
169
6
114
G-11 2008 05 10 21:00



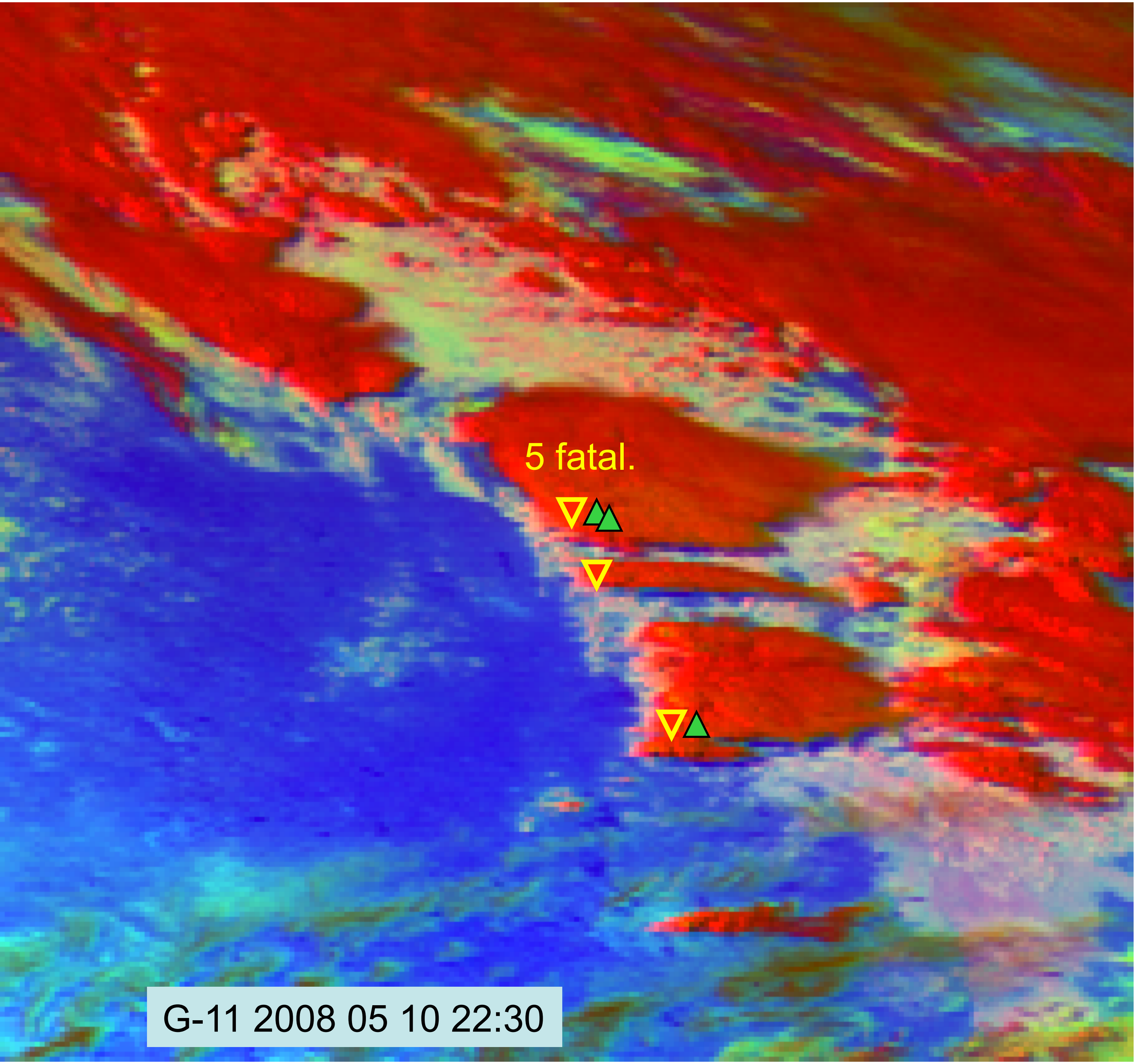
G-11 2008 05 10 21:30

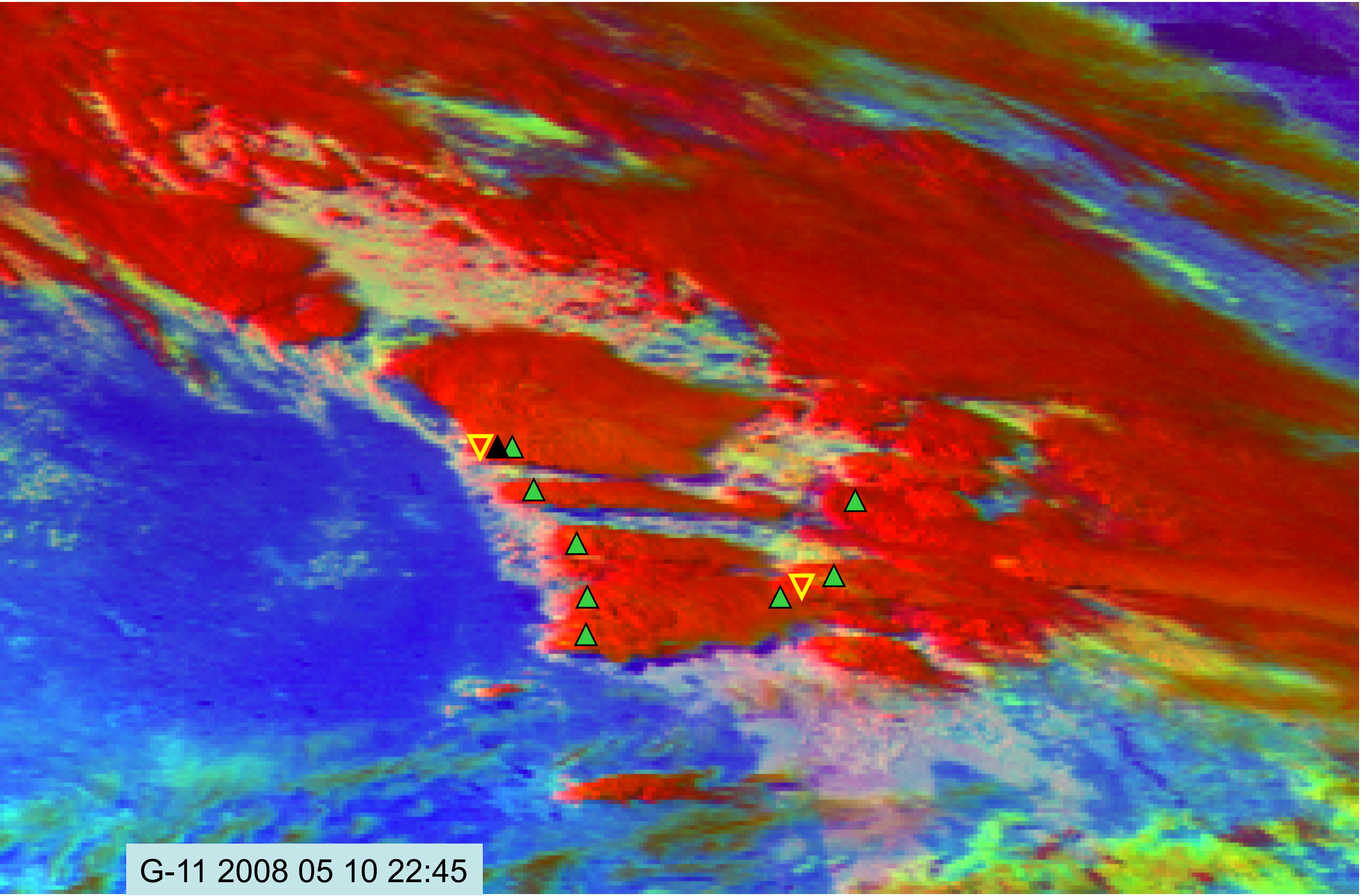


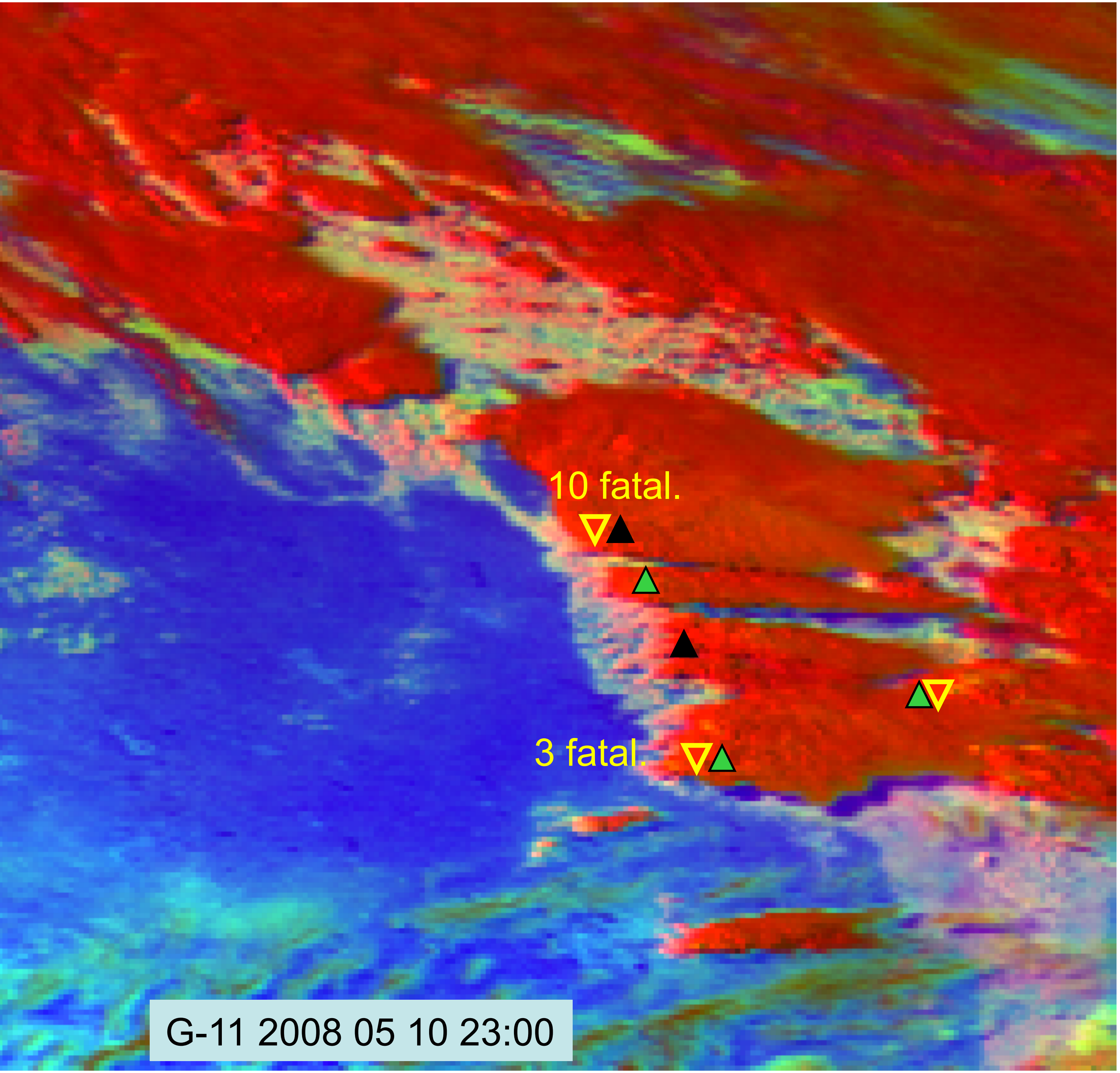
G-11 2008 05 10 22:00



45
34
12
33
G-11 2008 05 10 22:15


5 fatal.
G-11 2008 05 10 22:30


G-11 2008 05 10 22:45


10 fatal.
3 fatal.
G-11 2008 05 10 23:00

Evaluation of performance

Forward tracking of 663 Early Alerts, for finding if they were hits or false alarms.

Hits: 48.9%   Avg. lead time: 70 minutes

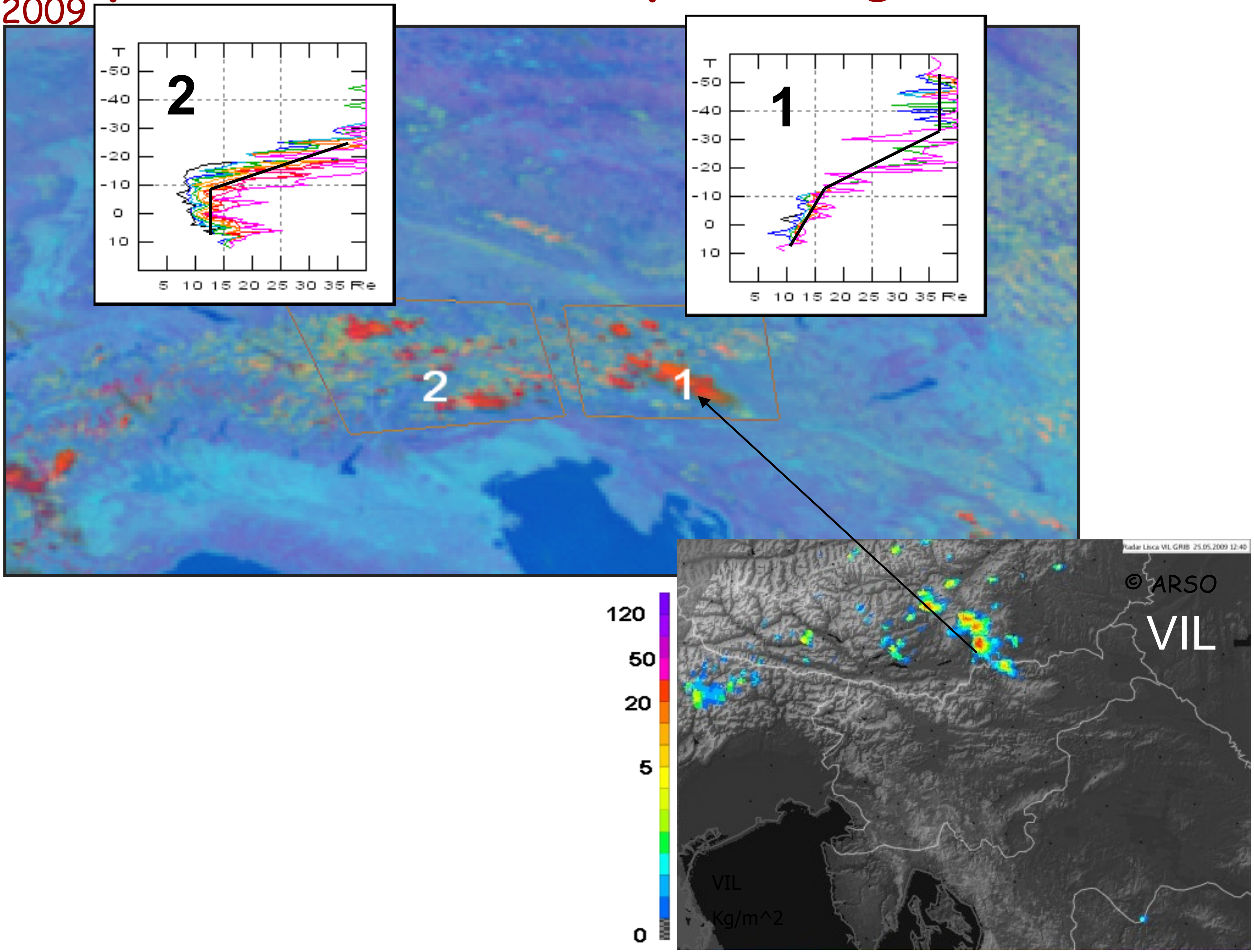
Backward tracking of 1603 reported severe storm events, for finding if they were predicted or missed:

Hits: 55.1%   Avg. lead time: 100 minutes

The lead time is much longer than any single cell lifecycle!

12:42 UTC
25 May 2009

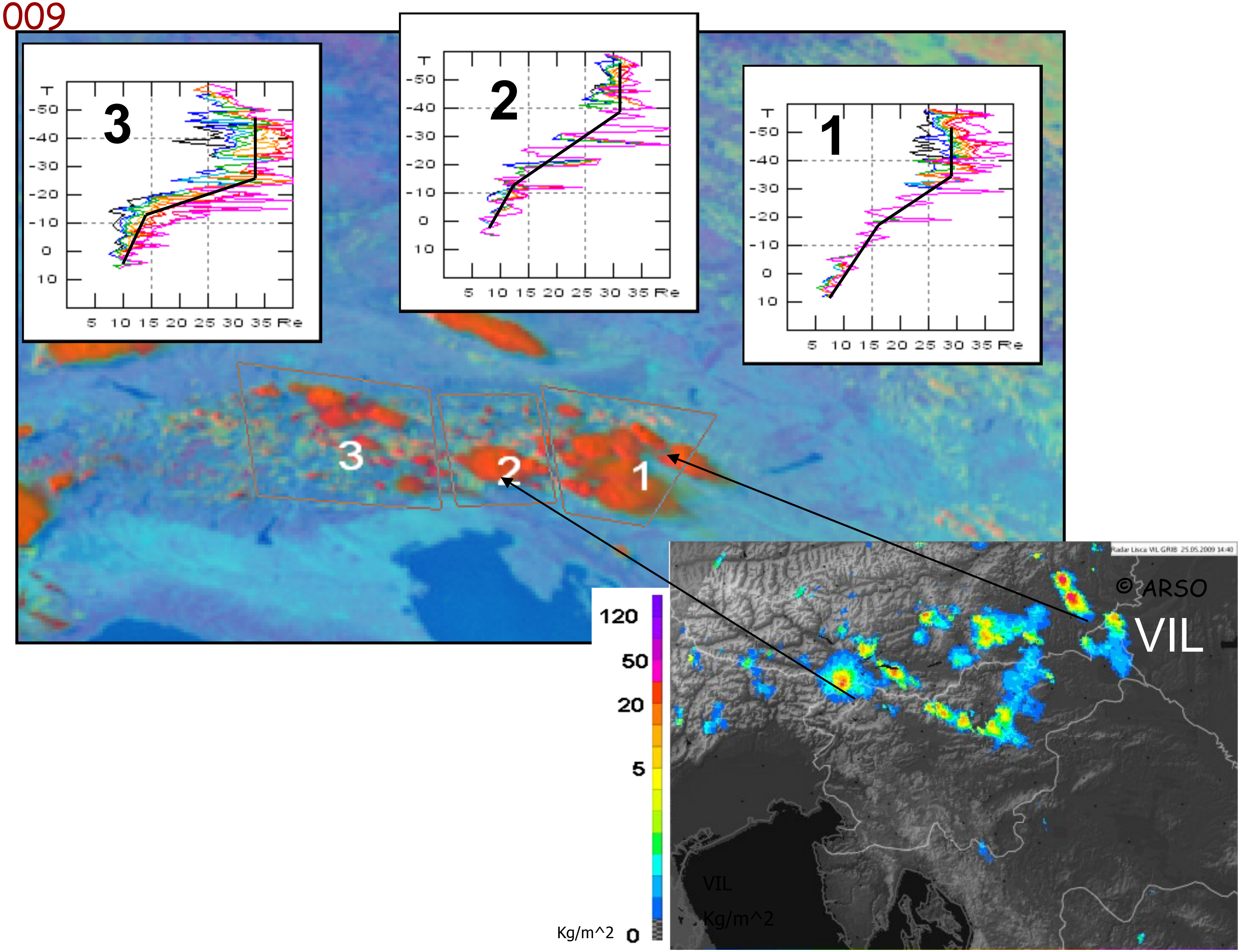
Early convection, already showing threat in 2



14:42 UTC

25 May 2009

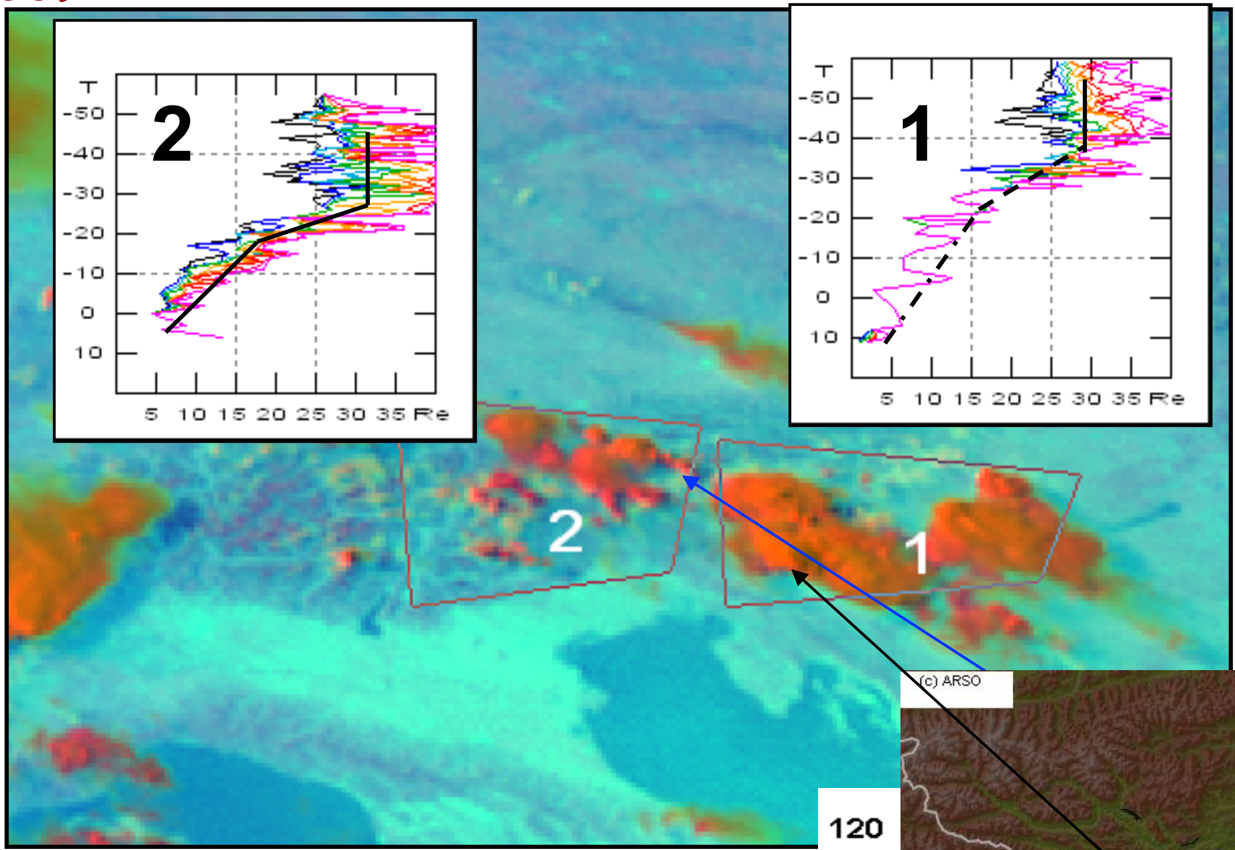
Severe profiles in 1 and 2



16:27 UTC

25 May 2009

Large hail occurs in 1

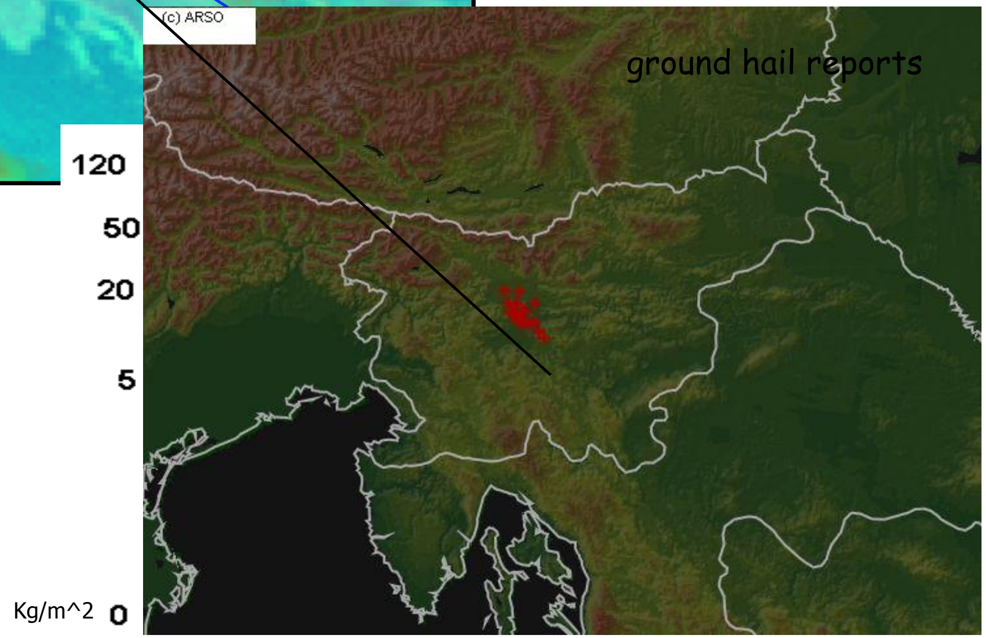


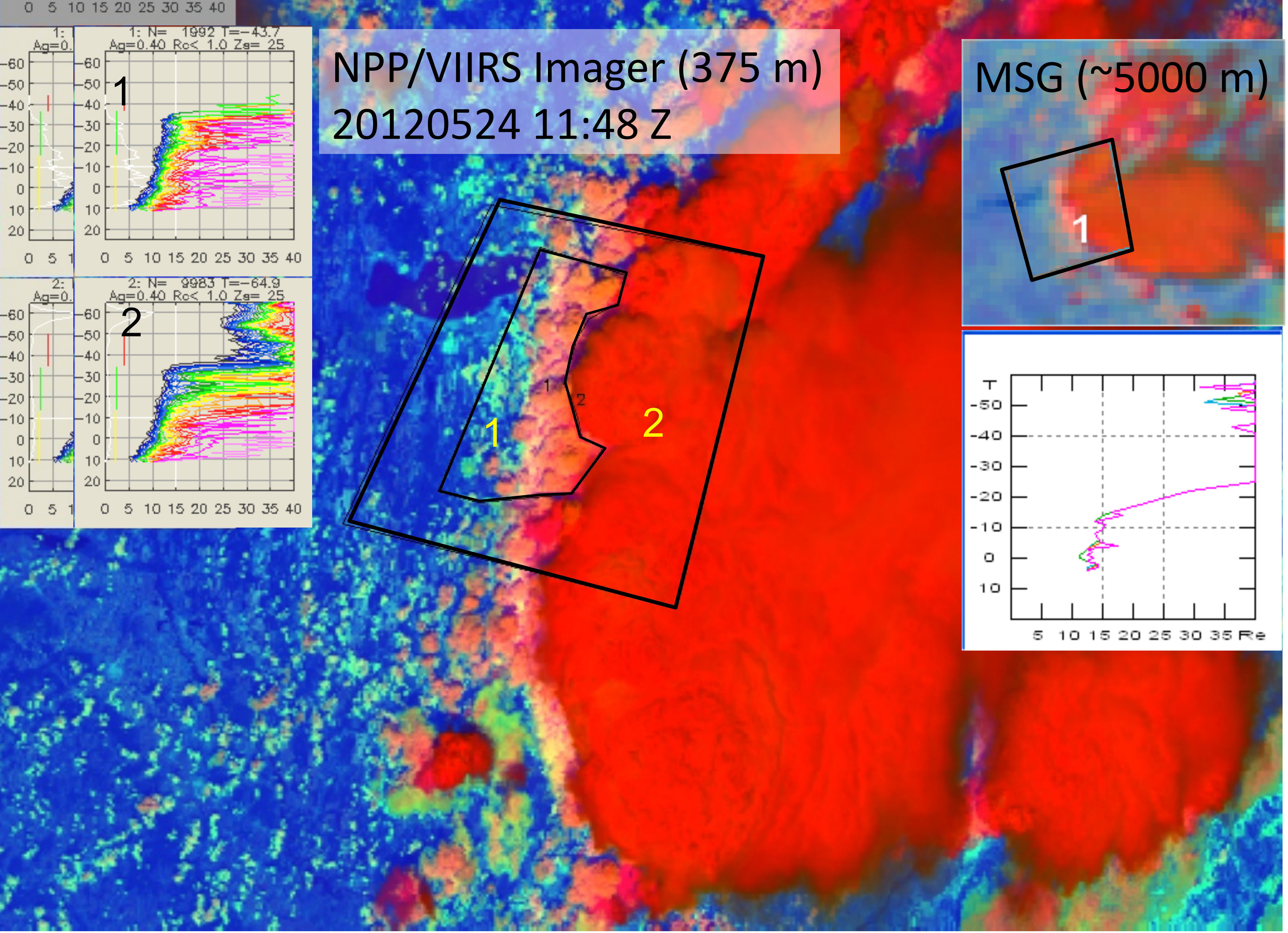
Large hail

(6-7 cm diameter)

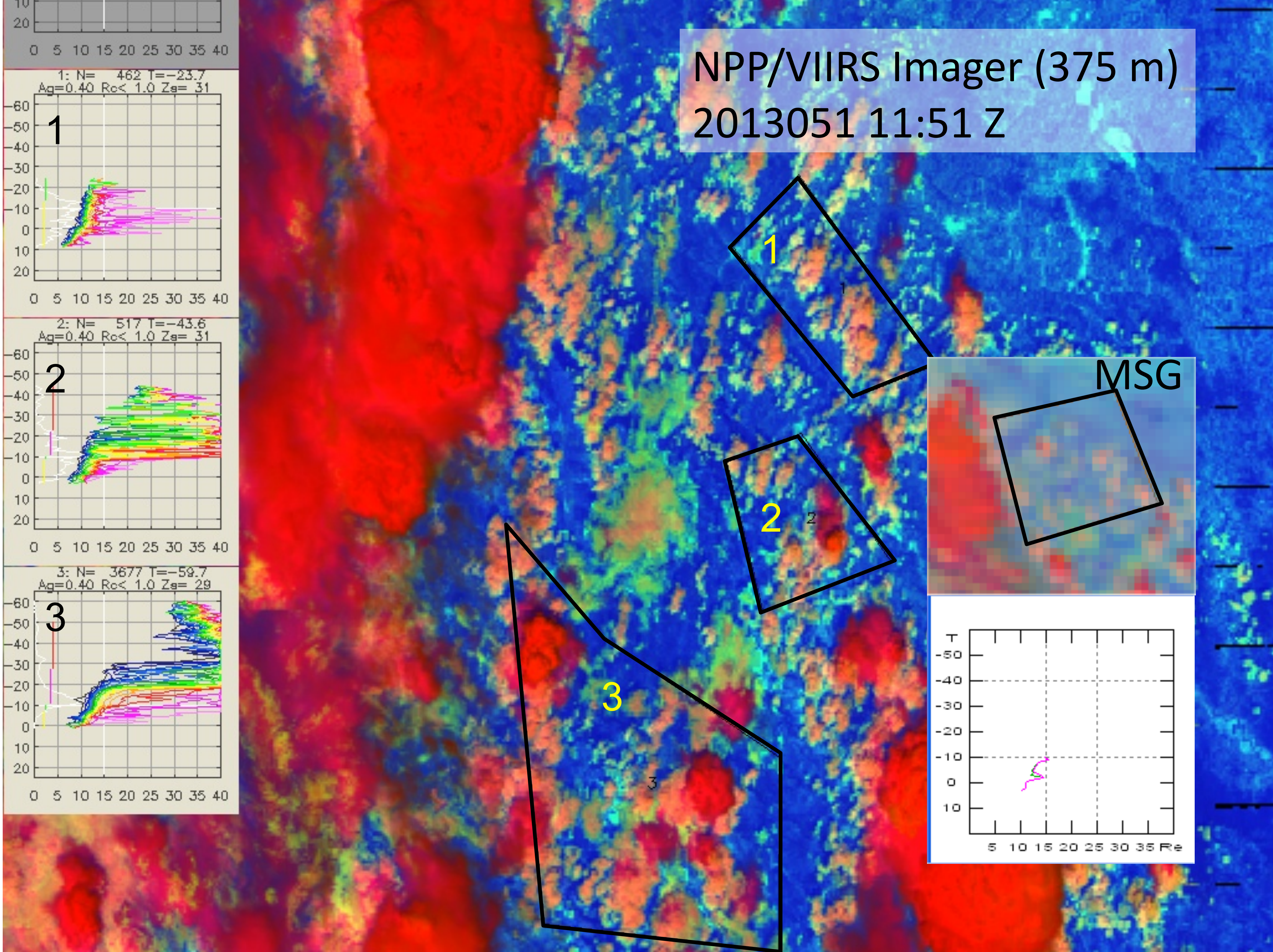
16:30-17:00 UTC

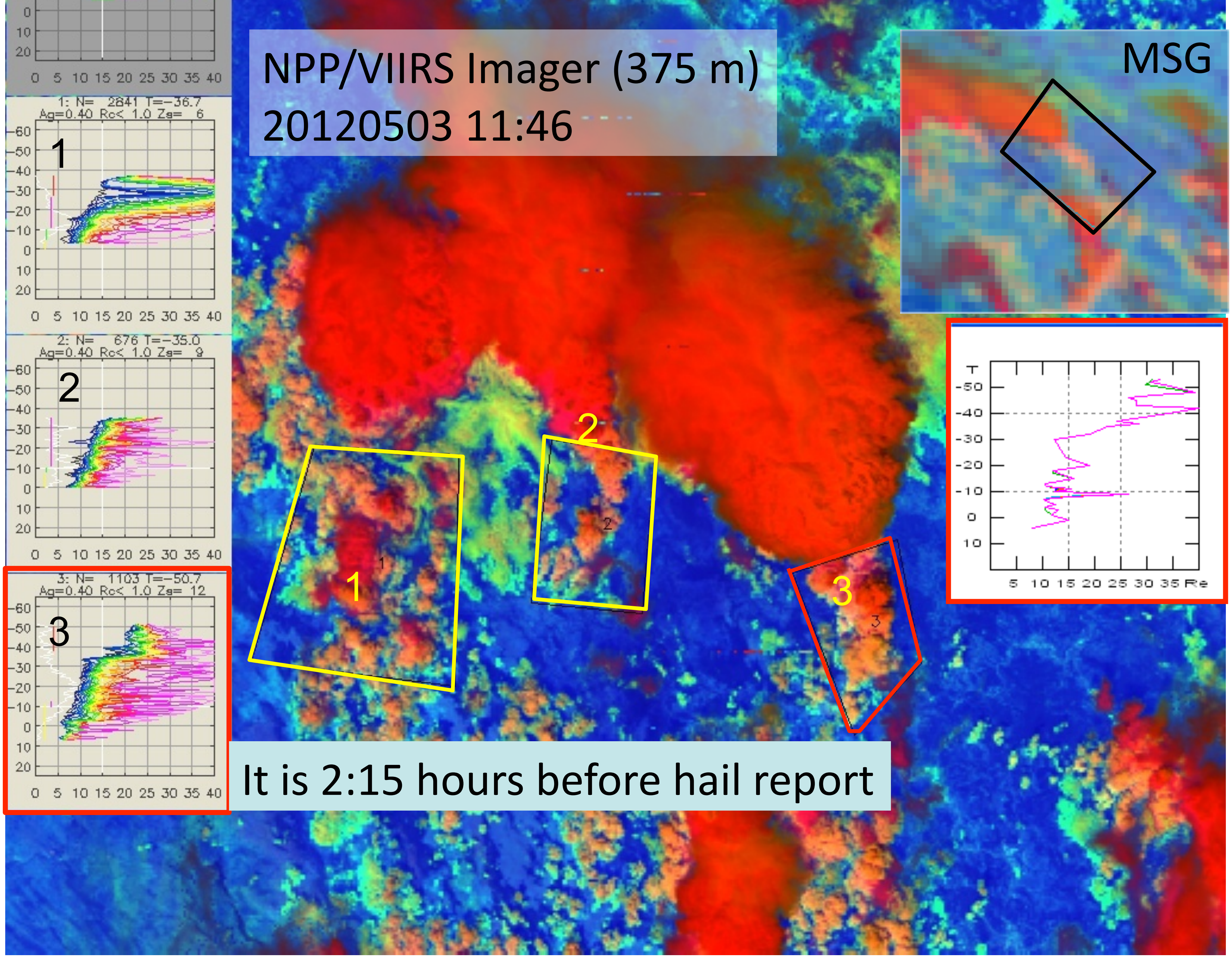
(Reports from ESSL)



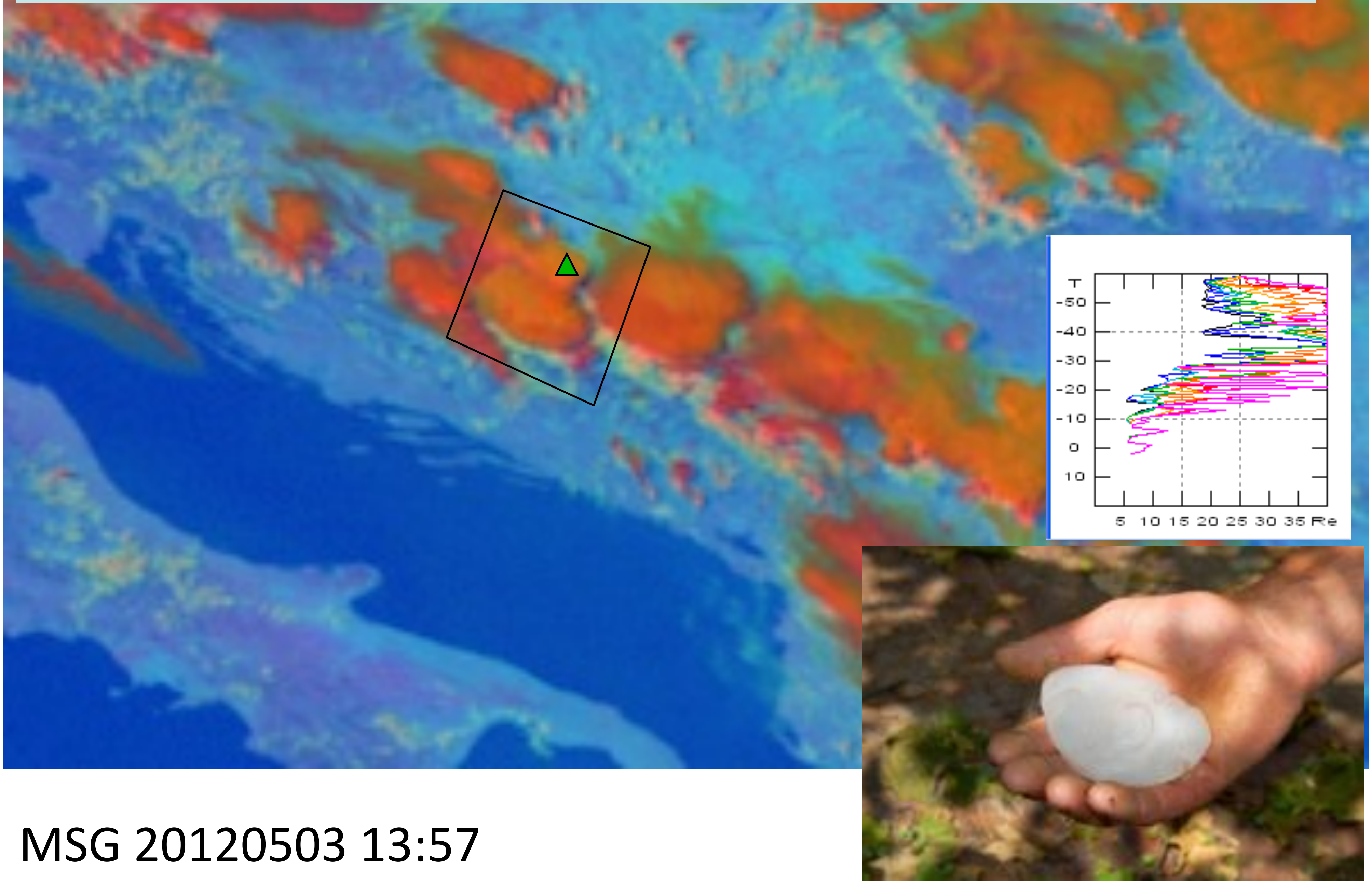


NPP/VIIRS Imager (375 m)
20120524 11:48 Z
MSG (~5000 m)
1: N= 1992 T=-43.7
Ag=0.40 Rc< 1.0 Ze= 25
2: N= 9983 T=-64.9
Ag=0.40 Rc< 1.0 Ze= 25
1
2
T
Re

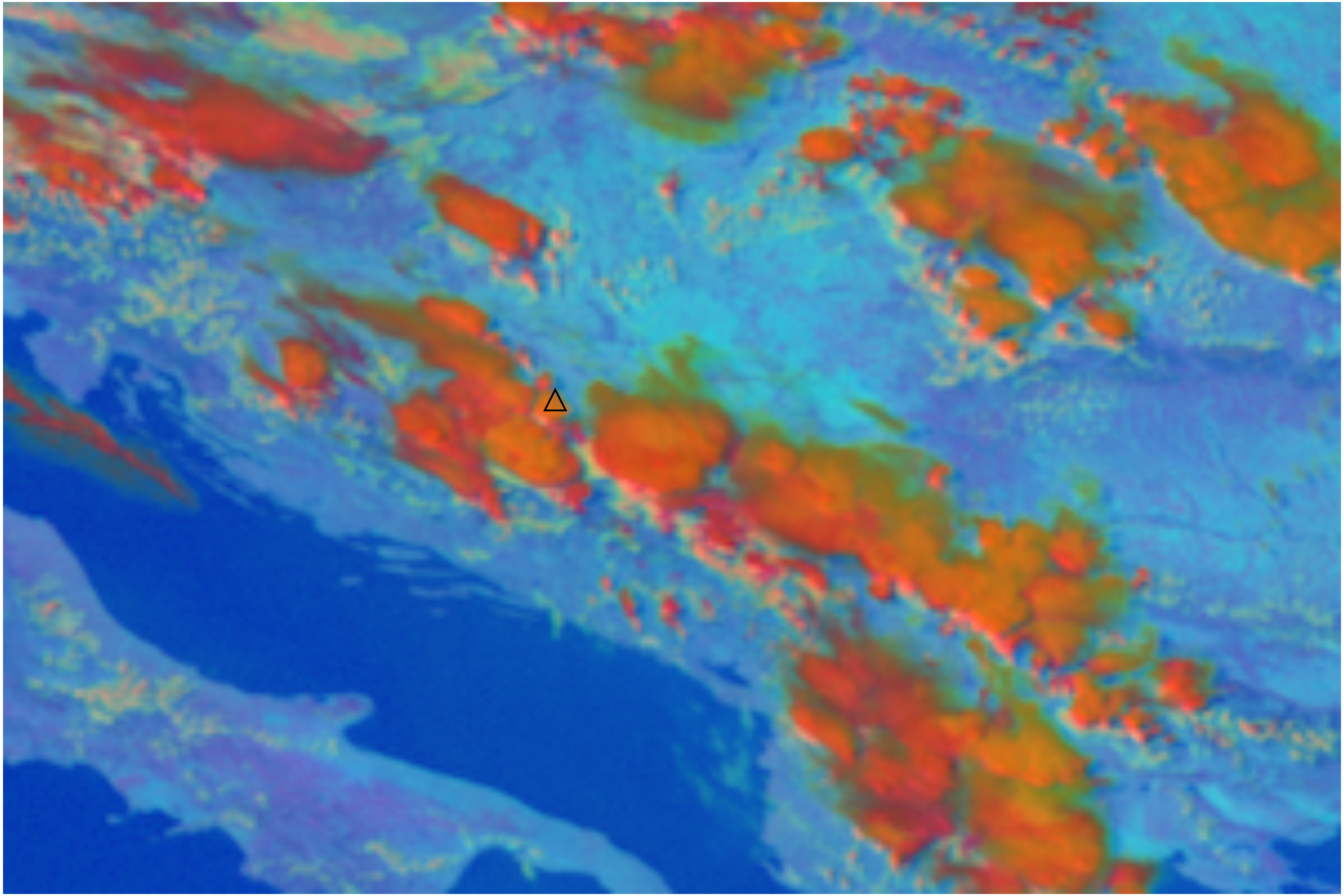

NPP/VIIRS Imager (375 m)
2013051 11:51 Z
1: N= 462 T=-23.7
Ag=0.40 Rc< 1.0 Zs= 31
2: N= 517 T=-43.6
Ag=0.40 Rc< 1.0 Zs= 31
3: N= 3677 T=-59.7
Ag=0.40 Rc< 1.0 Zs= 29
1
2
3
MSG
T
Re


NPP/VIIRS Imager (375 m)
20120503 11:46
MSG
1: N= 2841 T=-36.7
Ag=0.40 Rc< 1.0 Zs= 6
2: N= 676 T=-35.0
Ag=0.40 Rc< 1.0 Zs= 9
3: N= 1103 T=-50.7
Ag=0.40 Rc< 1.0 Zs= 12
It is 2:15 hours before hail report

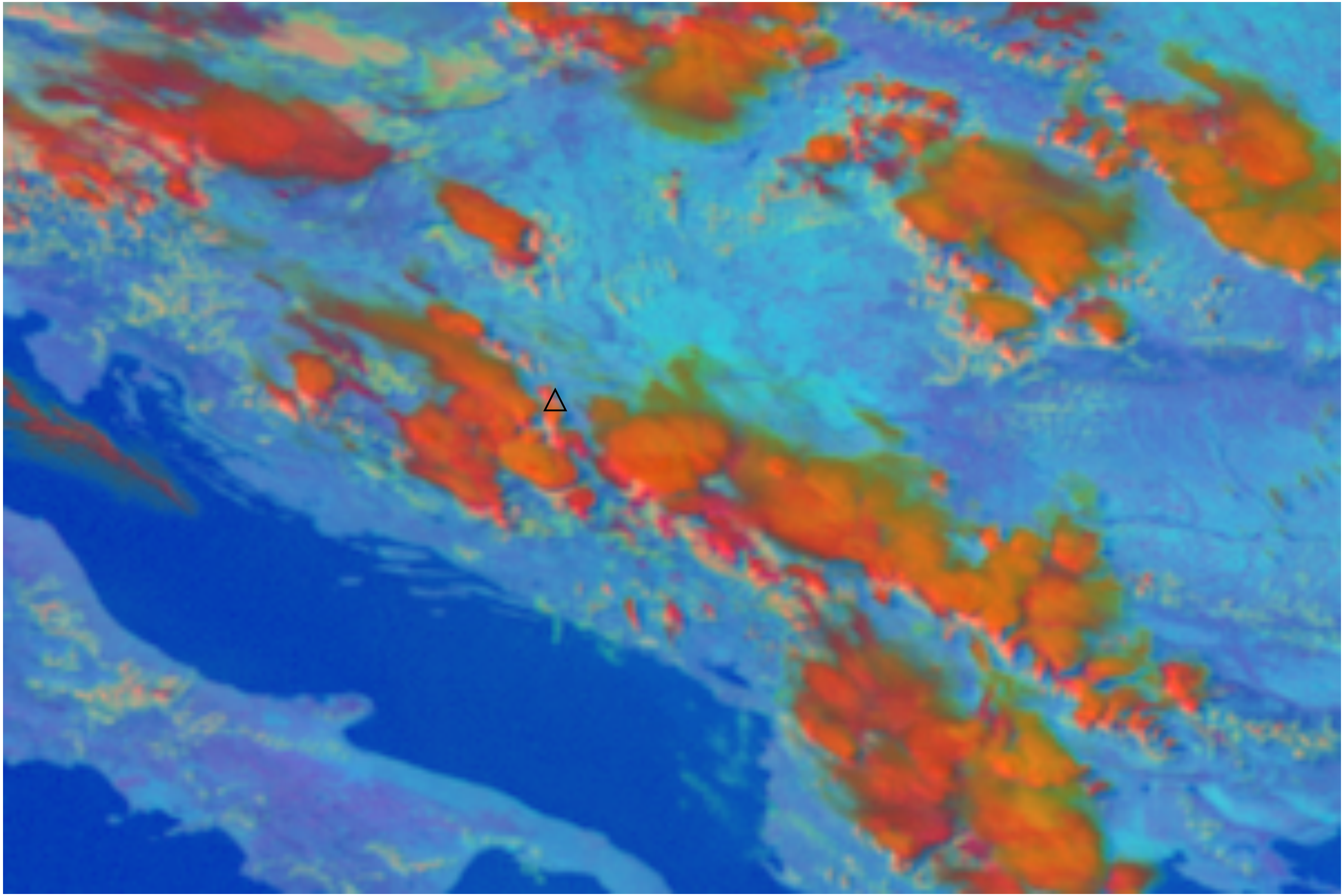
Can’t get good T-r_e because the anvils obscure the feeders: Weak wind shear; Shear towards the satellite (westward).



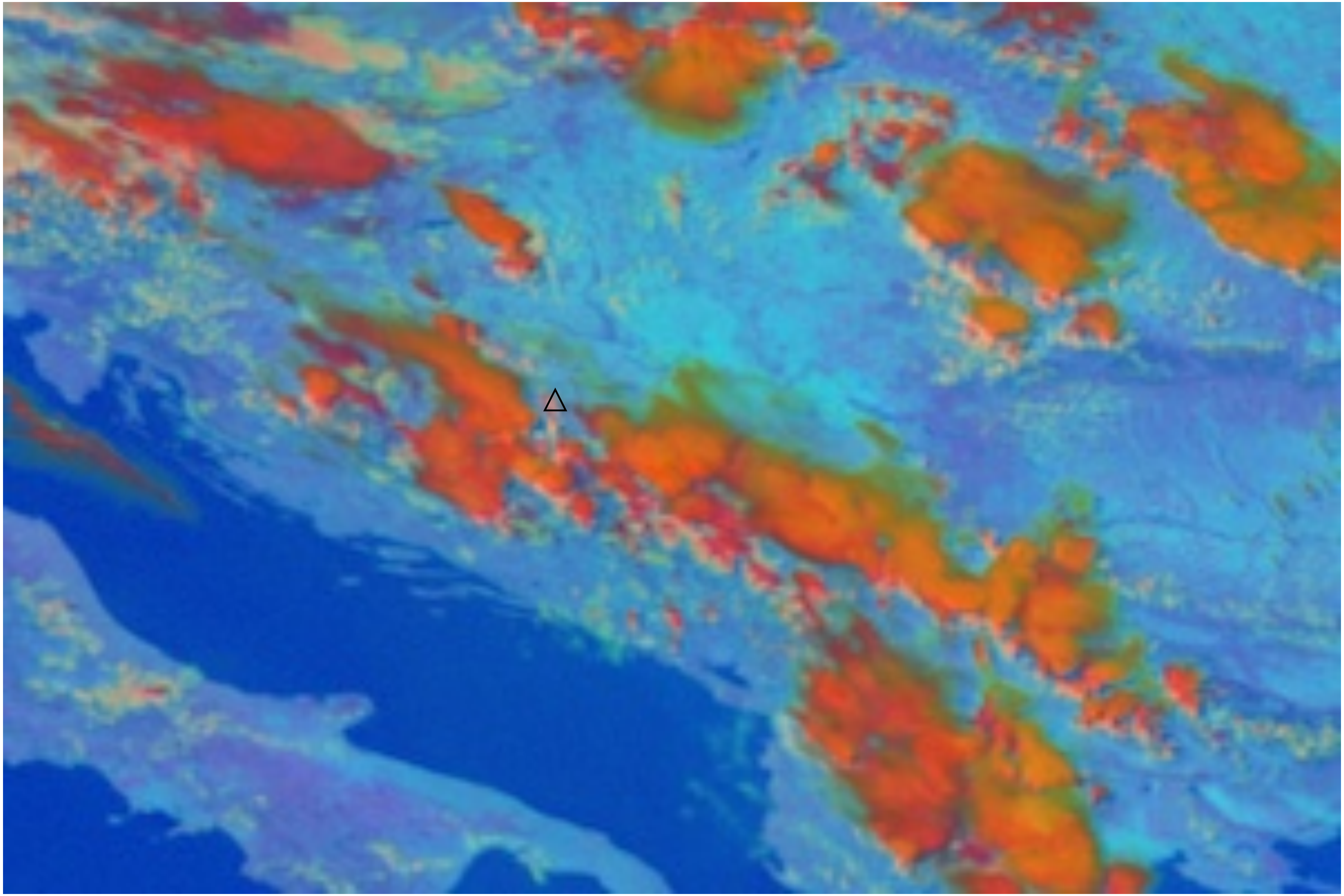
MSG 20120503 13:57



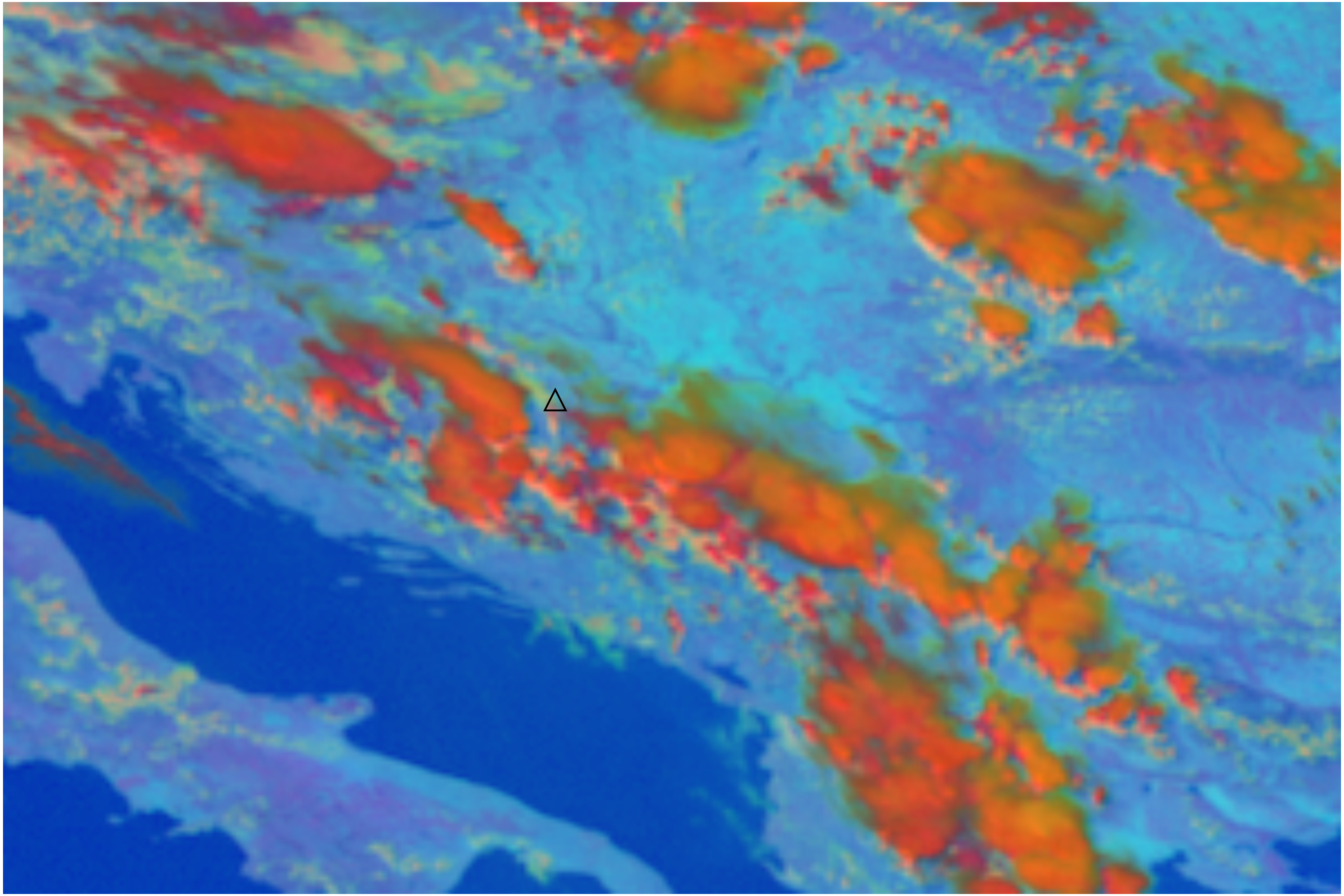
MSG 20120503 13:42



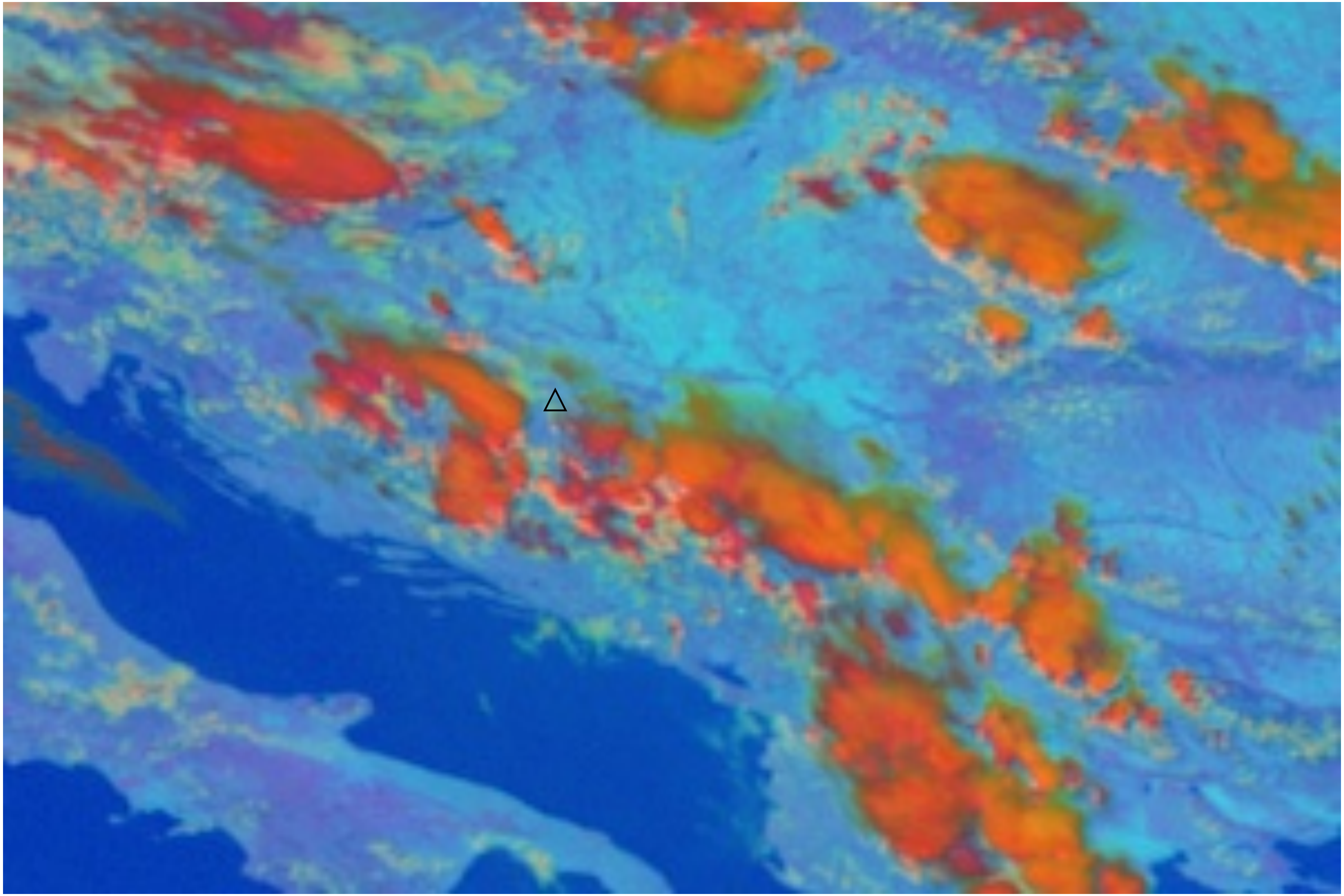
MSG 20120503 13:27



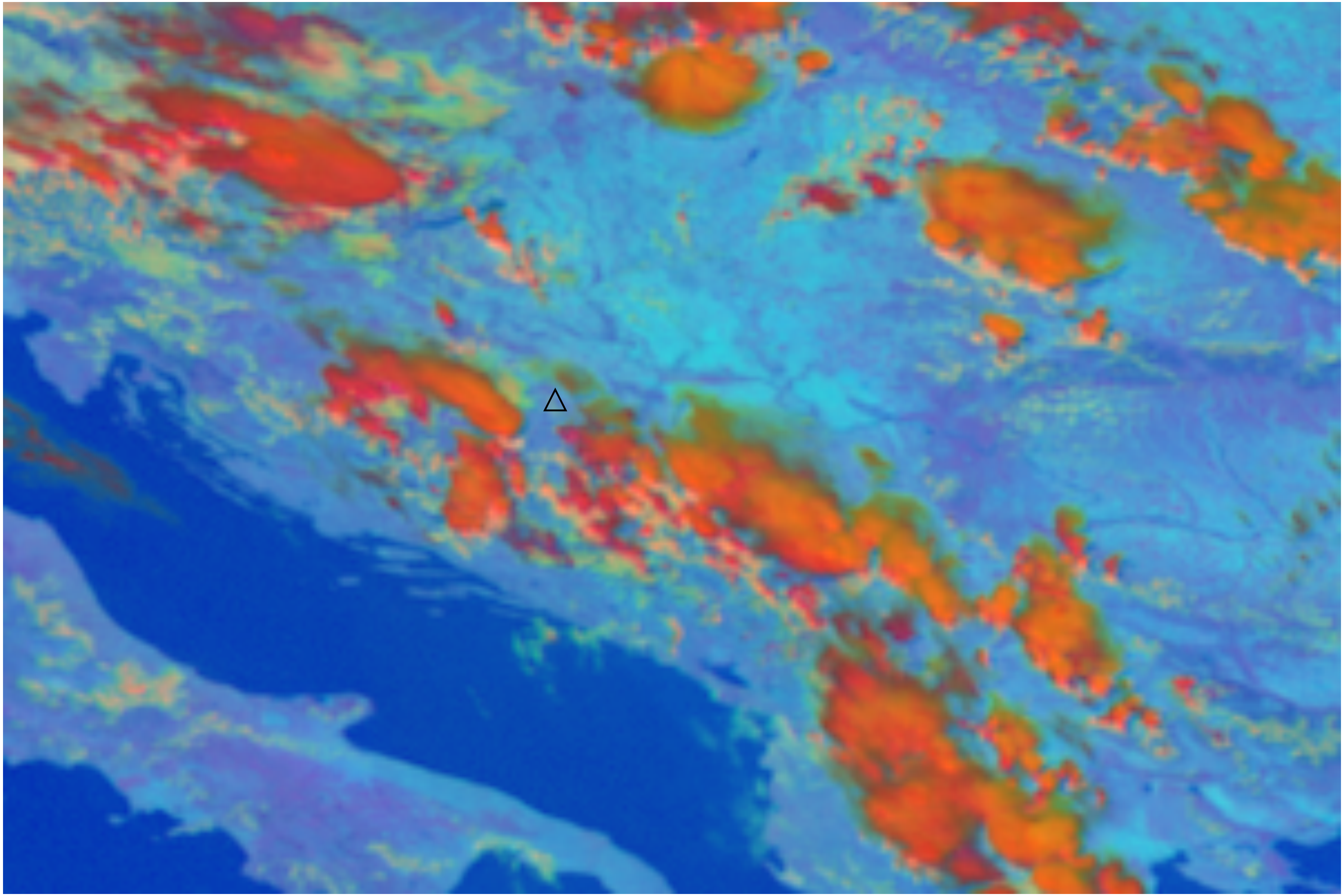
MSG 20120503 13:12



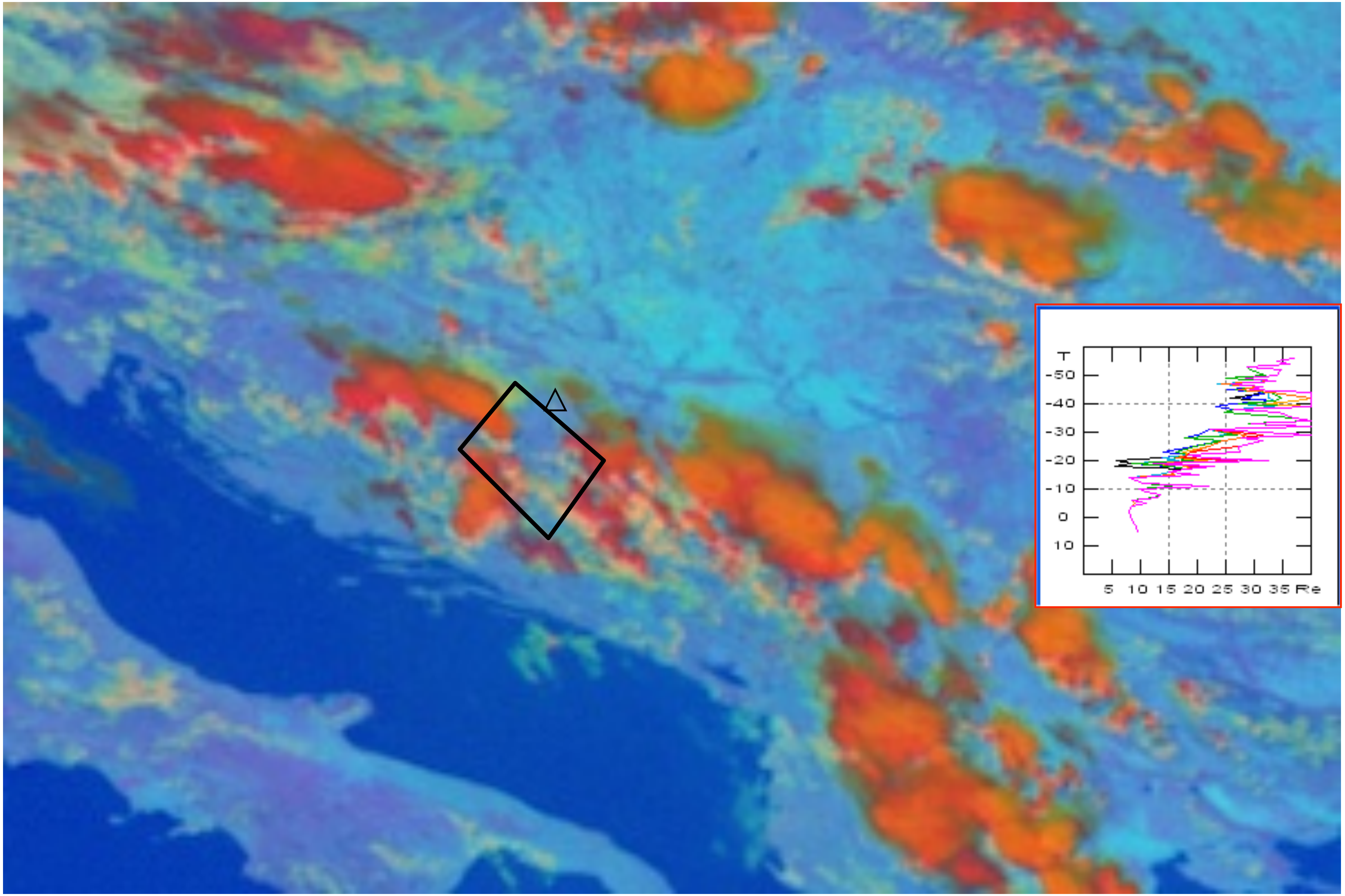
MSG 20120503 12:57



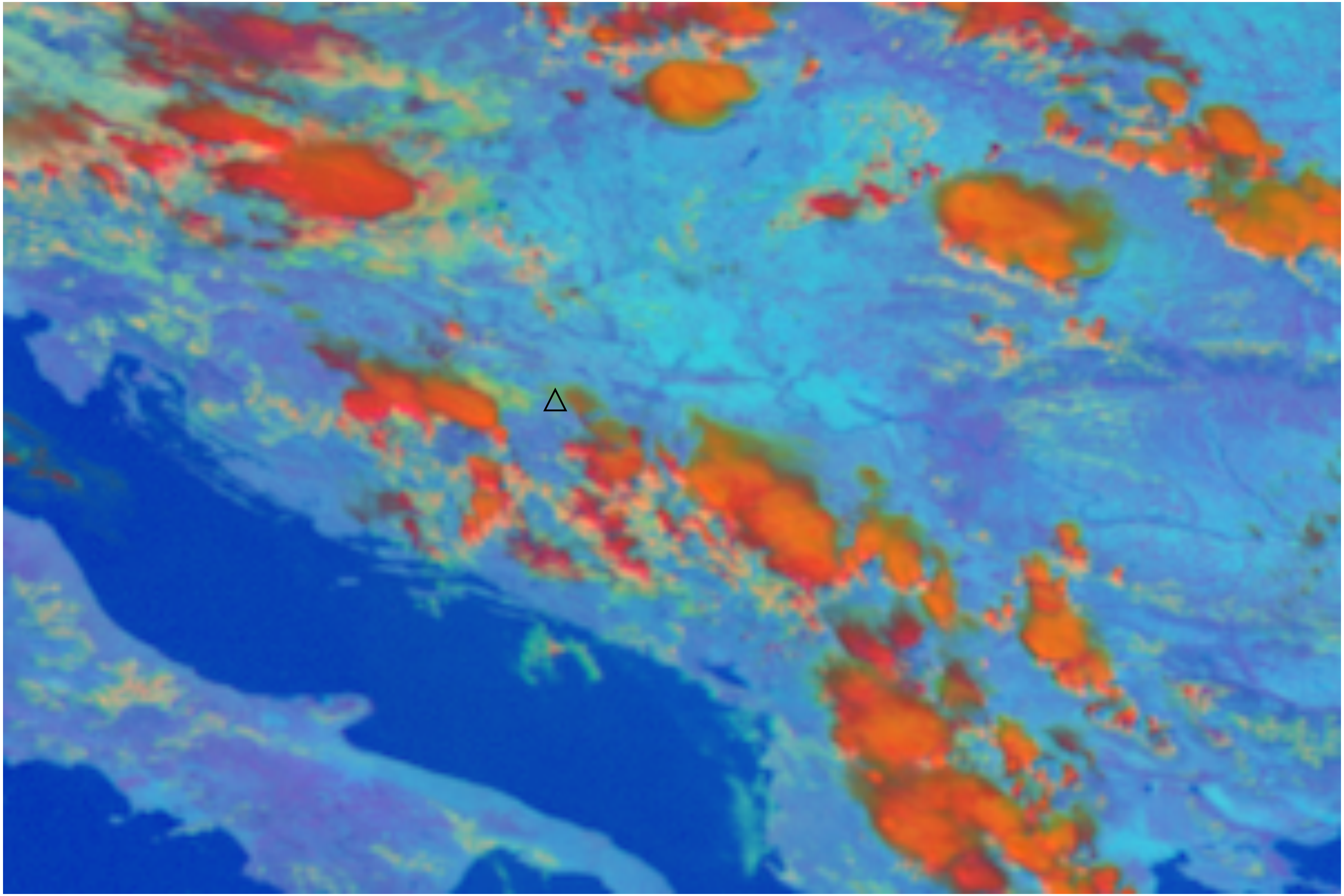
MSG 20120503 12:42



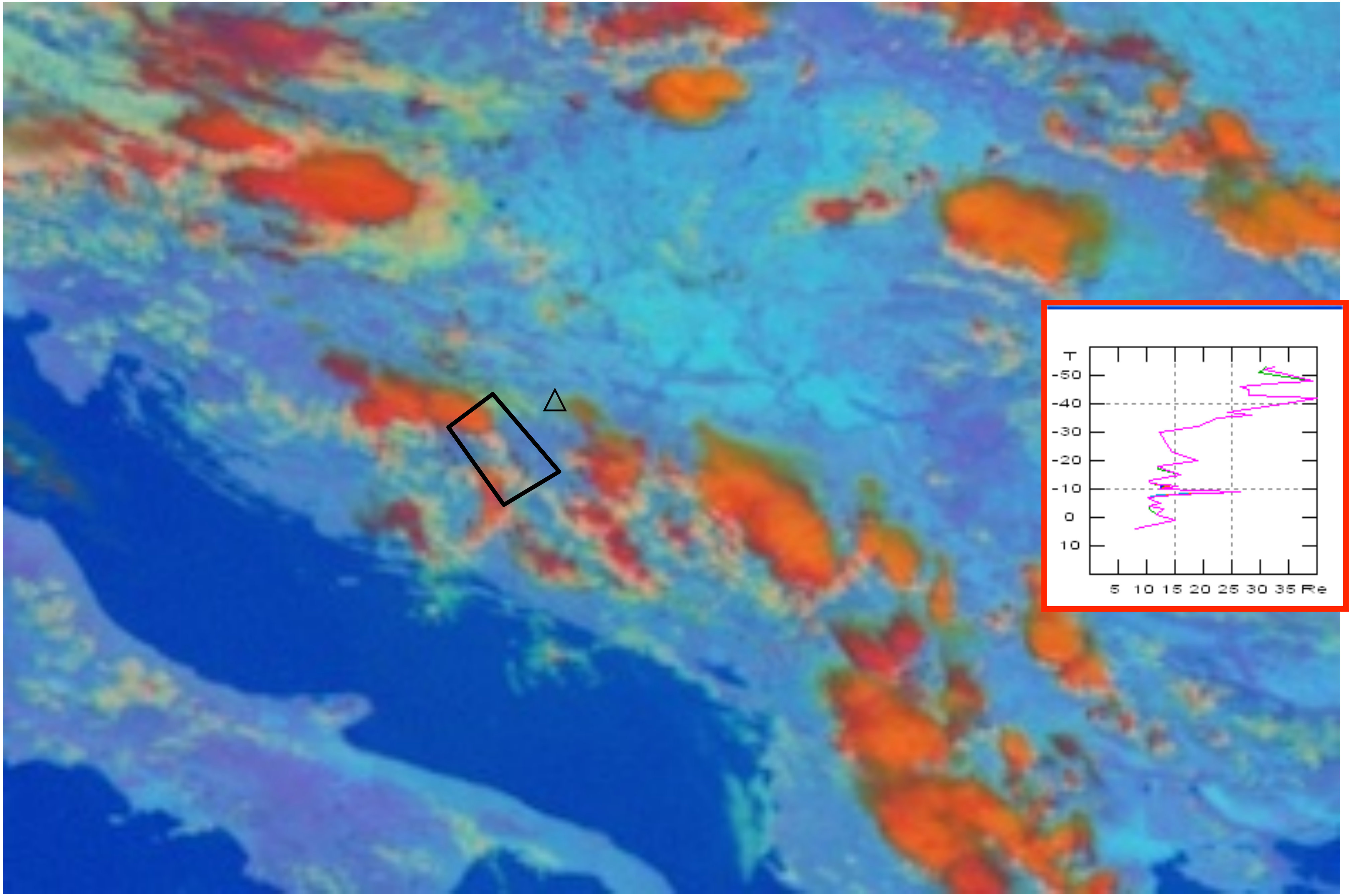
MSG 20120503 12:27



MSG 20120503 12:12



MSG 20120503 11:57



MSG 20120503 11:42

MSG automatization?

Attempt to predict severe storms based on MSG (done with John Mecikalski) as done for SPC did not show nearly as much skill. The causes are:

1. The areas of interest lie at much higher latitude (45-55N vs. 27-40N in the USA), thus with poorer satellite view.
2. The wind shear in these northerly latitudes in summer is weaker, leading to anvils expansion obscuring the feeder clouds.
3. The wind shear is often from east to west, with anvils further obscuring the feeders from satellite view.
4. Validation data set of ESWD is very partial, thus missing many severe storms, and cannot be used for validating that a given storm is not severe.

These shortcomings can be overcome with better satellite resolution. The 1-km microphyscal resolution of the MTG may be sufficient, but it remains to be seen.

Summary

- Cloud microstructure can provide the propensity of the cloud environment to develop severe storms for a lead time well beyond the lifecycle of individual storm cell.
- The satellite resolution is a major limitation, mainly over Europe, due to viewing geometry and meteorological reasons.
- NPP/VIIRS and MODIS can detect the severe storm signature also over Europe, thus giving hope that the MTG will be suitable for automatization of the methodology.
- Combination with radar and lightning detection is expected to be powerful.