Satellite Derived Instability Indices – some further insights (part II) Sensitivity Analysis

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What is the sensitivity analysis?

Sensitivity analysis is the study of how the uncertainty in the output of a mathematical model or system (numerical or otherwise) can be apportioned to different sources of uncertainty in its inputs.

Question: If we change the input temperature or humidity a little how much does the output CAPE change?

Why we do this?

- The sensitivity analyses show us what CAPE is mainly sensitive to.
- Which parts (which levels) of the temperature and humidity profiles are the most important, most dominant in the CAPE calculation?

- The main question is:
- Can SEVIRI (MTG FCI, IRS) data improve considerably the first guess (background) NWP profiles in these levels?

- If the satellite retrieving algorithm can improve considerably the temperature and/or humidity information on the levels the CAPE is mainly sensitive to – then it make sense to retrieve it from SEVIRI data, (MTG FCI or IRS sounder data).

Several different methods are existing – local method using the partial derivative of the output (CAPE) with respect to the input factors (T,q).

CAPE is the function of the temperature (T) and humidity (q):

$$CAPE(T_1, T_2, \ldots, T_n, q_1, q_2, \ldots, q_n), \text{ where } n \text{ is the number of the vertical levels}$$

The partial derivative are:

$$\frac{\partial CAPE(T_1, T_2, \ldots, T_n, q_1, q_2, \ldots, q_n)}{\partial T_i}, \text{ where } i = 1, \ldots, n$$

$$\frac{\partial CAPE(T_1, T_2, \ldots, T_n, q_1, q_2, \ldots, q_n)}{\partial q_i}, \text{ where } i = 1, \ldots, n$$

How to calculate the derivates of the CAPE?

The derivative is the limit of the difference quotient as the difference approaches zero, if this limit exists.

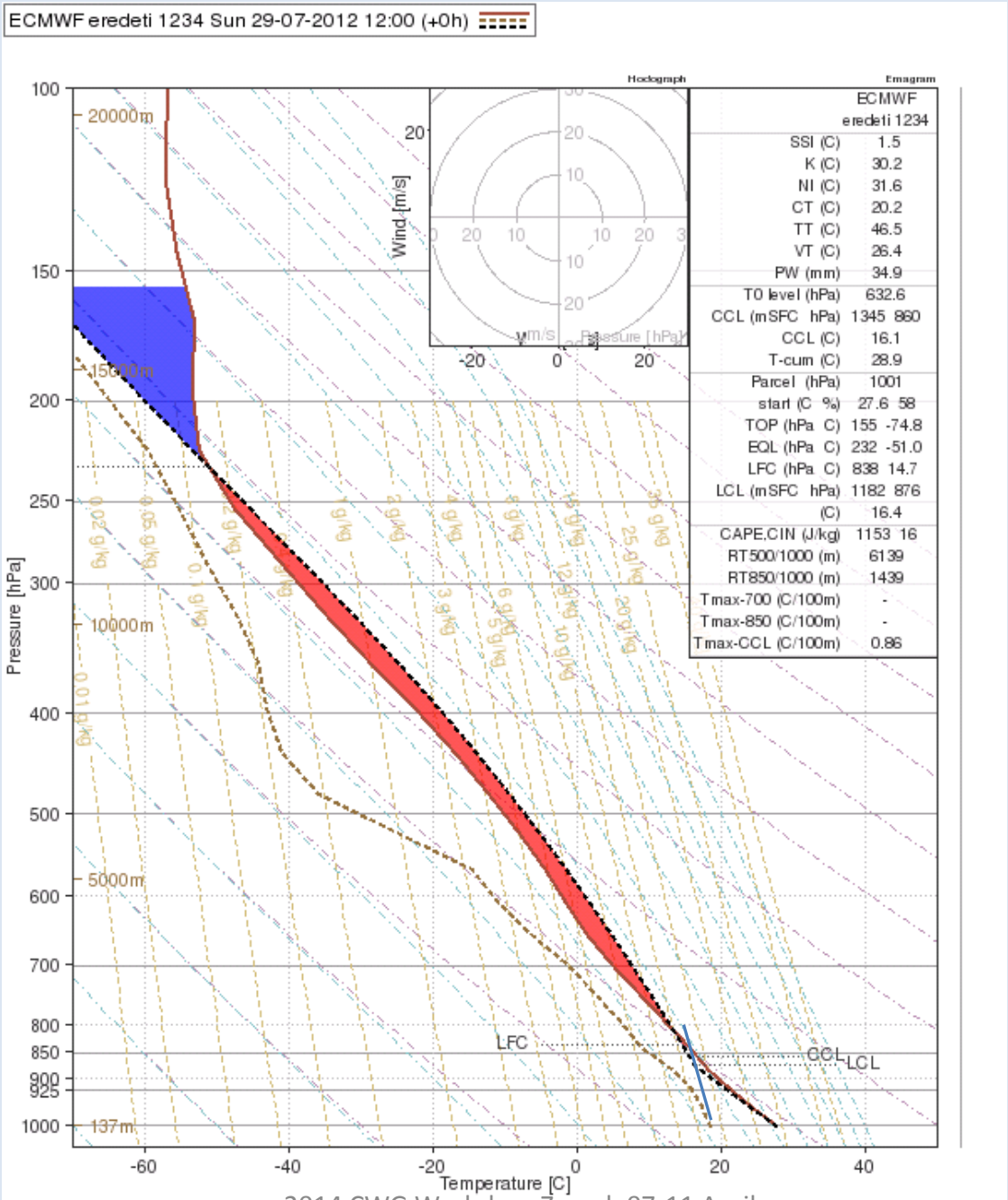
$$\frac{dCAPE}{dT} = \lim_{\Delta T \to 0} \frac{\Delta CAPE}{\Delta T}$$

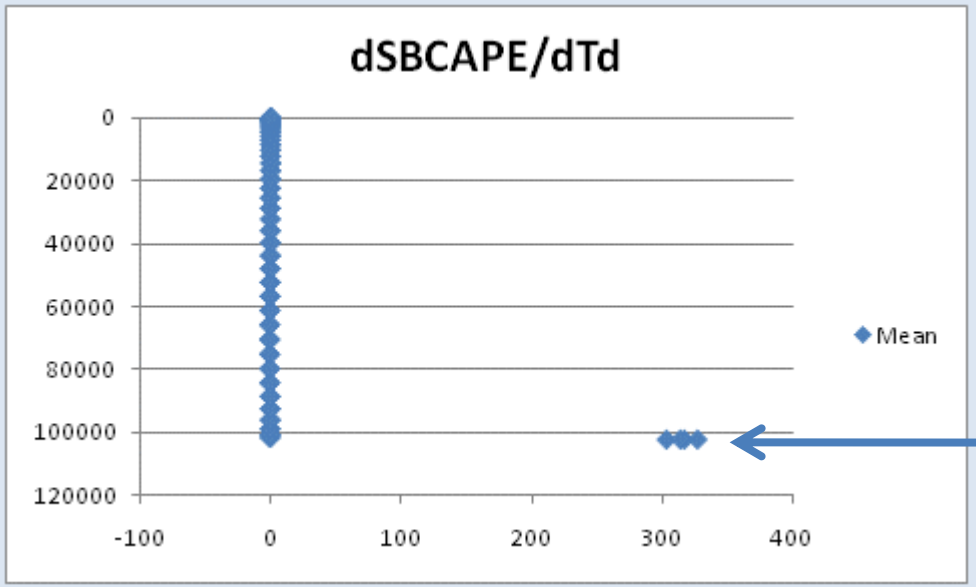
In practice we need to find a „small enough ΔT and ΔTd" to calculate the derivatives.

We decided to determine the partial derivates for a couple of profiles using different T and Td differences.
Namely: 1.5, 0.75, 0.5, 0.25, 0.1, -1.5, -0.75, -0.5, -0.25, -0.1

We found that the derivates behave differently for some of the vertical levels and for the various CAPEs.

We calculated the partial derivatives for individual pixels to understand the changes better.


ECMWF eredeti 1234 Sun 29-07-2012 12:00 (+0h)
Hodograph
Emagram
Wind [m/s]
ECMWF
eredeti 1234
SSI (C) 1.5
K (C) 30.2
NI (C) 31.6
CT (C) 20.2
TT (C) 46.5
VT (C) 26.4
PW (mm) 34.9
T0 level (hPa) 632.6
CCL (mSFC hPa) 1345 860
CCL (C) 16.1
T-cum (C) 28.9
Parcel (hPa) 1001
start (C %) 27.6 58
TOP (hPa C) 155 -74.8
EQL (hPa C) 232 -51.0
LFC (hPa C) 838 14.7
LCL (mSFC hPa) 1182 876
(C) 16.4
CAPE,CIN (J/kg) 1153 16
RT500/1000 (m) 6139
RT850/1000 (m) 1439
Tmax-700 (C/100m) -
Tmax-850 (C/100m) -
Tmax-CCL (C/100m) 0.86
20000m
15000m
10000m
5000m
137m
LFC
CCL
LCL
Pressure [hPa]
Temperature [C]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80000
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120000
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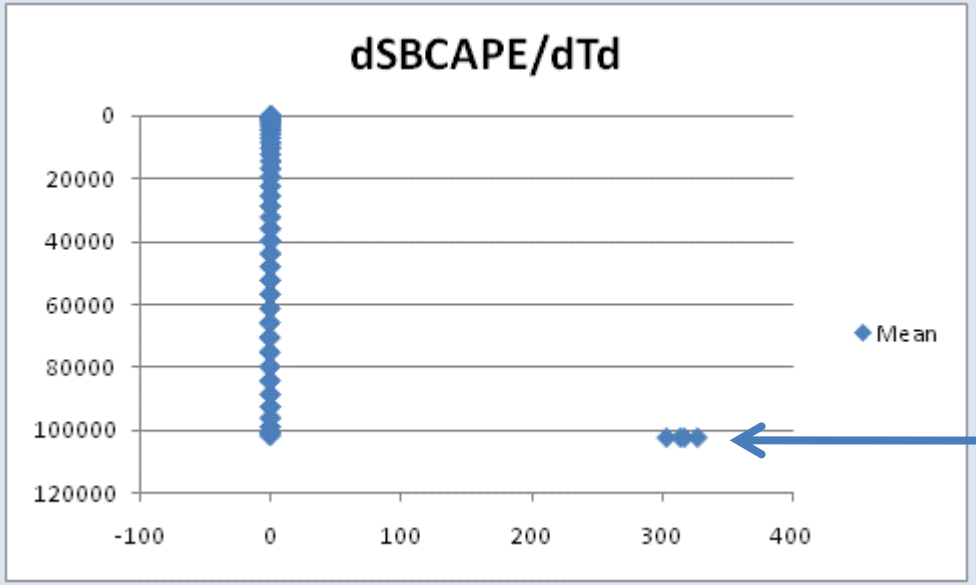
100
200
300
400
Mean

surface



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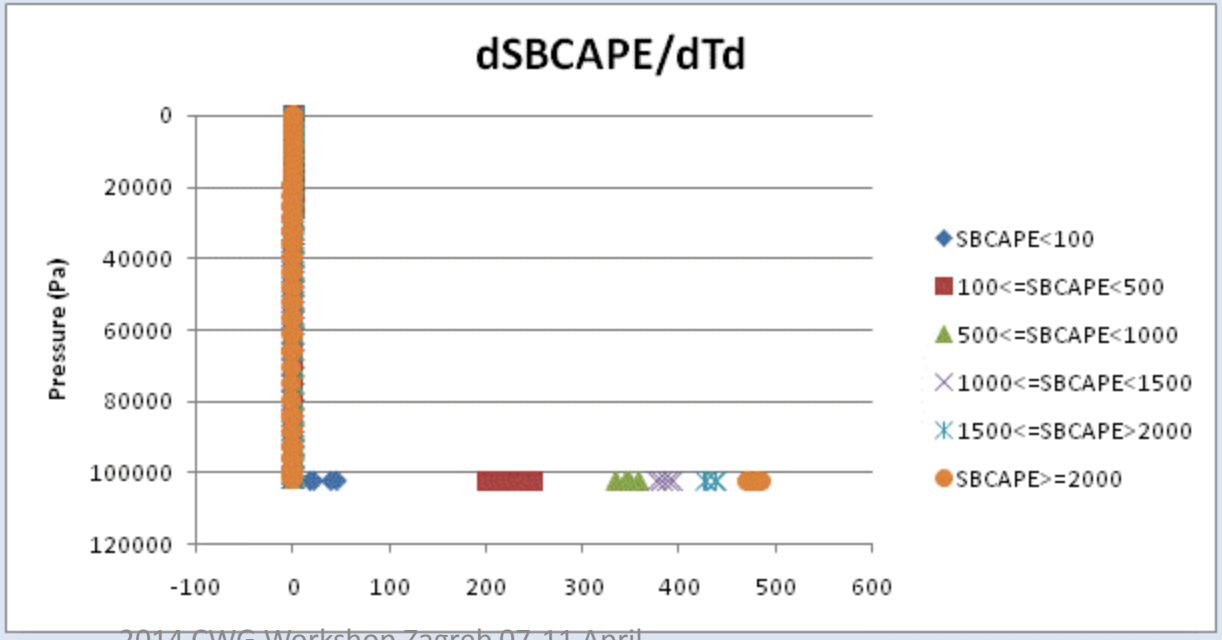
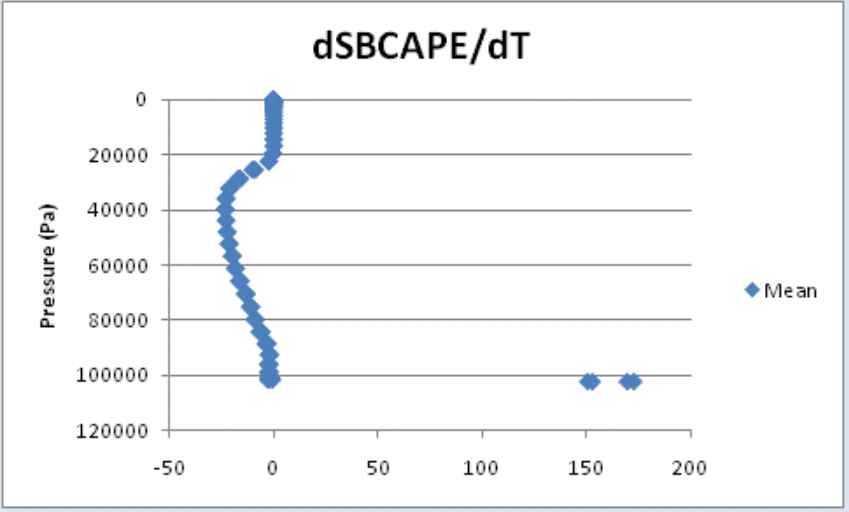
Numbers of pixels	22306	10504	8149	4194	1652	665

surface

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40000
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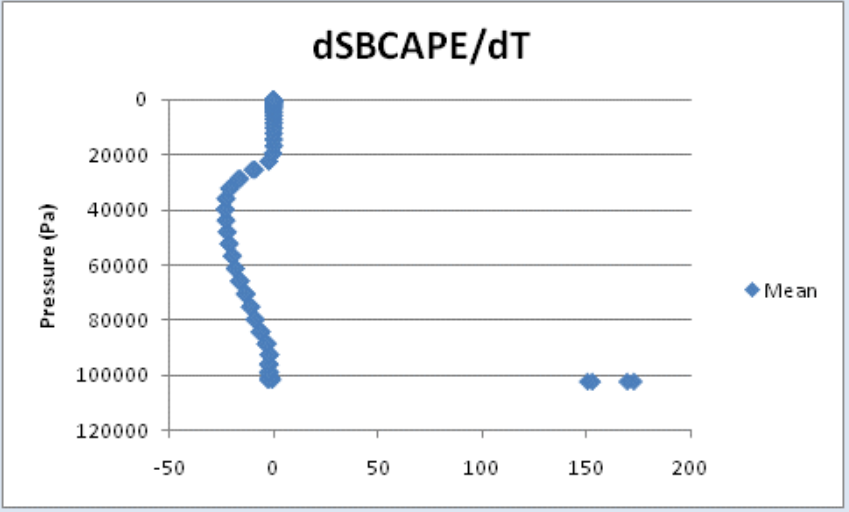
80000
100000
120000
-50
0
50
100
150
200
Mean


dSBCAPE/dT
Pressure (Pa)
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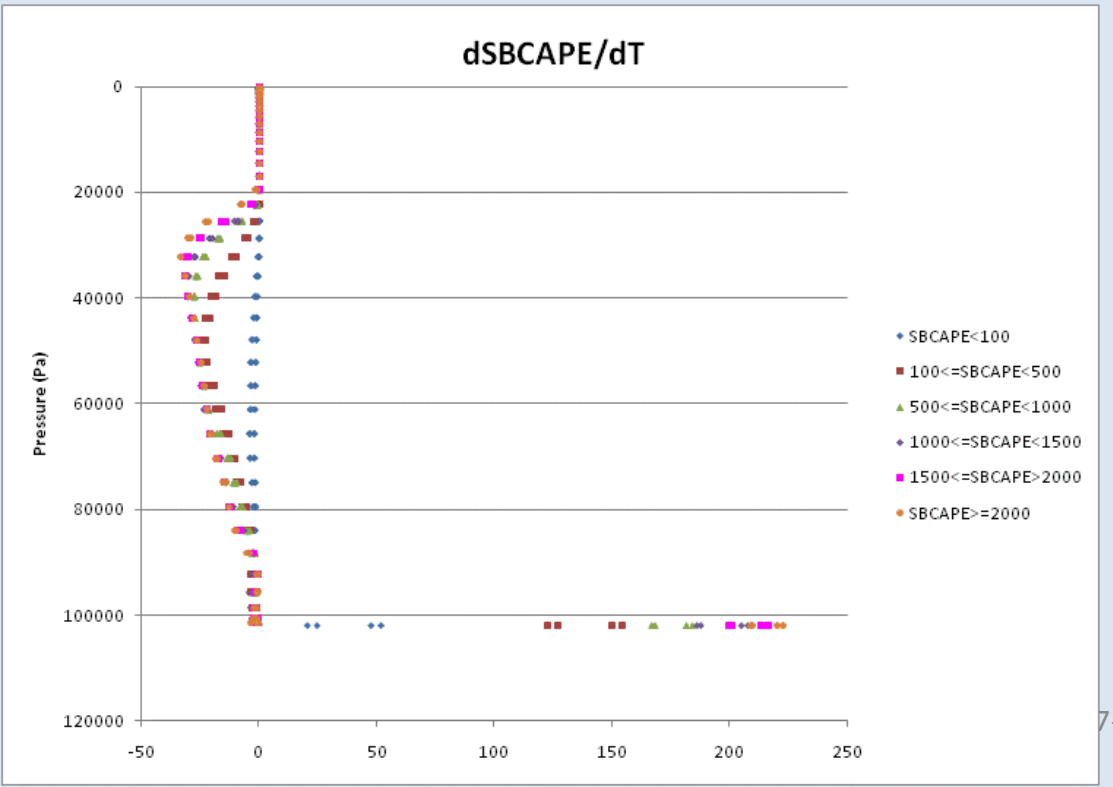
40000
60000
80000
100000
120000
-50
0
50
100
150
200
Mean


dSBCAPE/dT
Pressure (Pa)
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40000
60000
80000
100000
120000
-50
0
50
100
150
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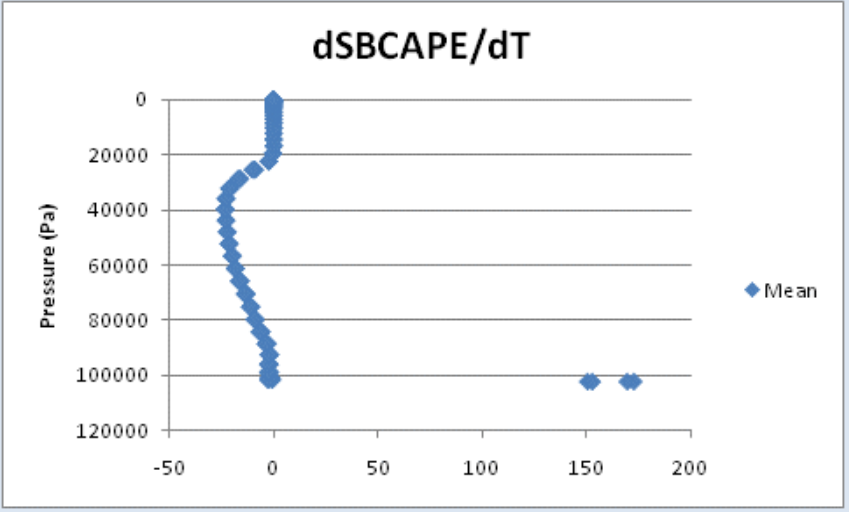
1000<=SBCAPE<1500
1500<=SBCAPE>2000
SBCAPE>=2000


dSBCAPE/dT
Pressure (Pa)
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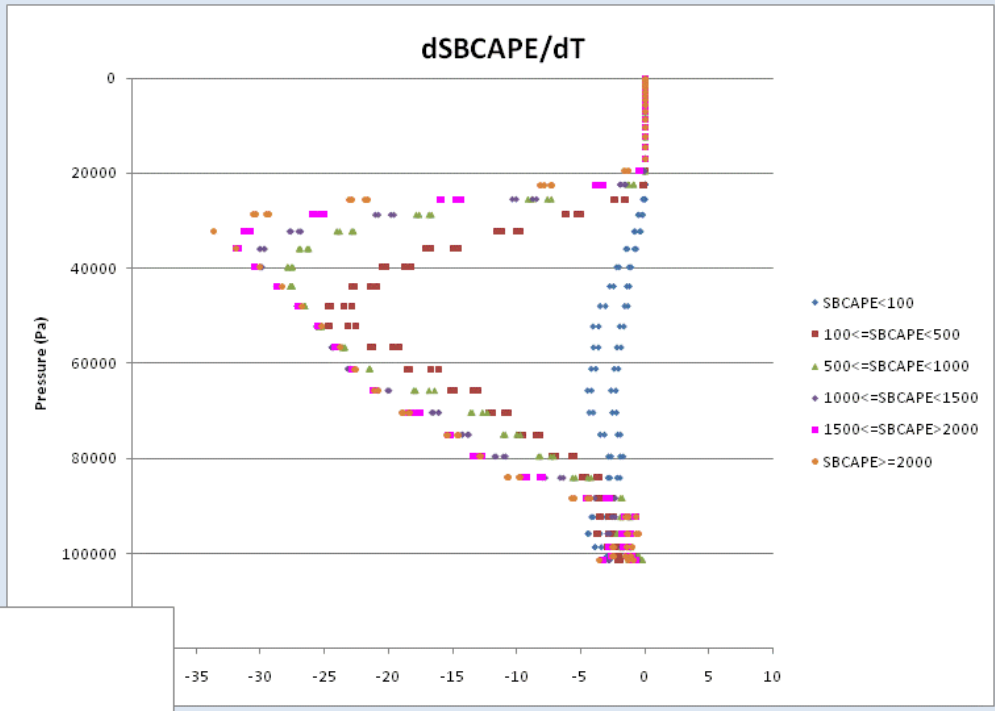
40000
60000
80000
100000
120000
-50
0
50
100
150
200
Mean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Pressure (Pa)
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40000
60000
80000
100000
-35
-30
-25
-20
-15
-10
-5
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5
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SBCAPE<100
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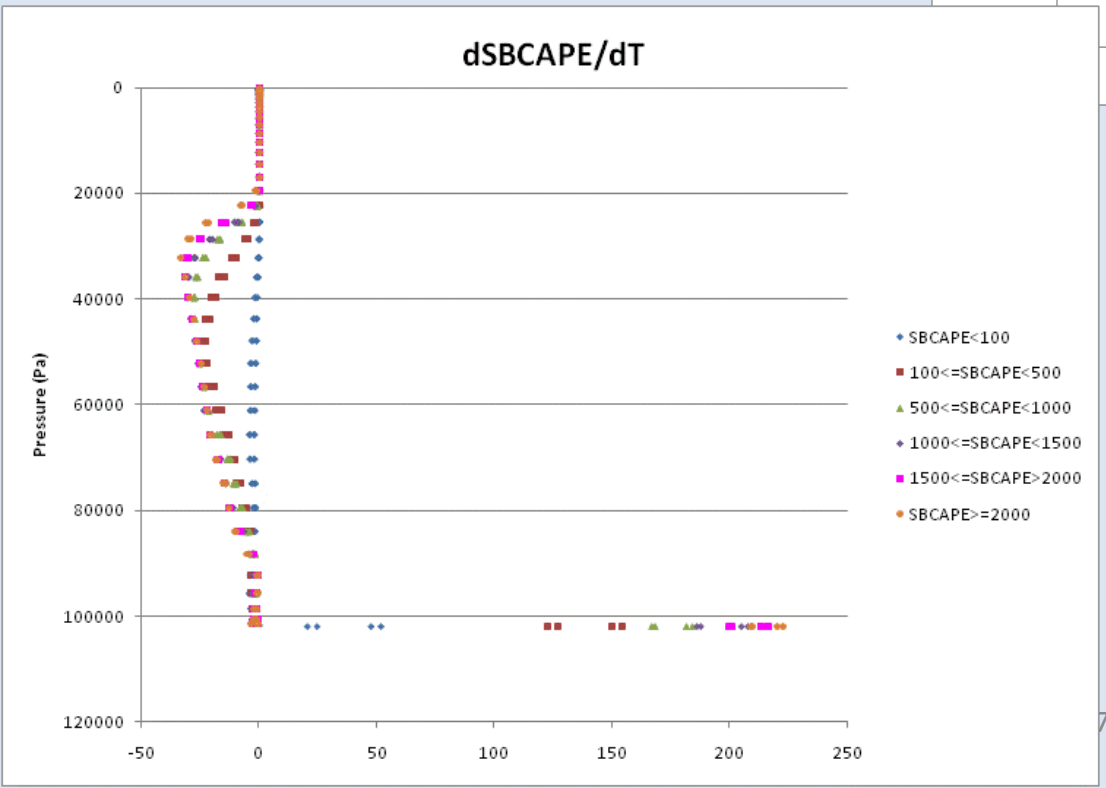
500<=SBCAPE<1000
1000<=SBCAPE<1500
1500<=SBCAPE>2000
SBCAPE>=2000


dSBCAPE/dT
Pressure (Pa)
0
20000
40000
60000
80000
100000
120000
-50
0
50
100
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200
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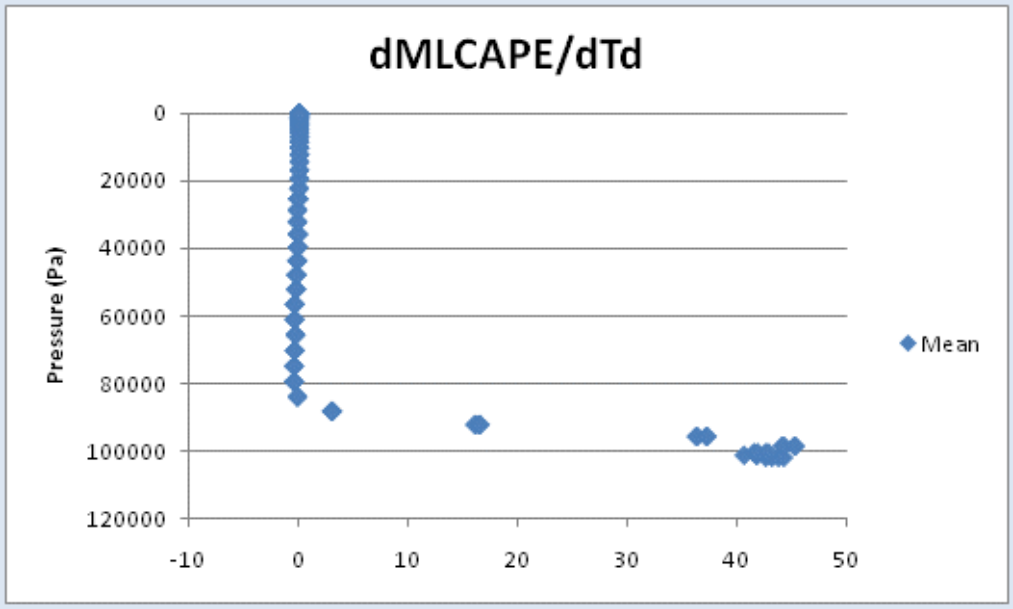
SBCAPE<100
100<=SBCAPE<500
500<=SBCAPE<1000
1000<=SBCAPE<1500
1500<=SBCAPE>2000
SBCAPE>=2000


dMLCAPE/dTd
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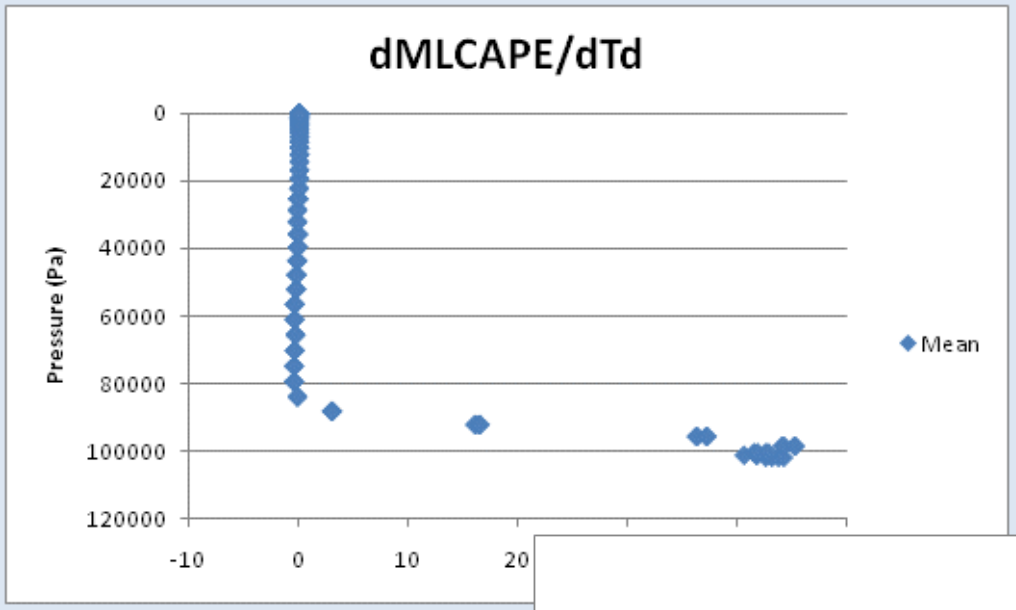
40000
60000
80000
100000
120000
-10
0
10
20
30
40
50
Mean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Pressure (Pa)
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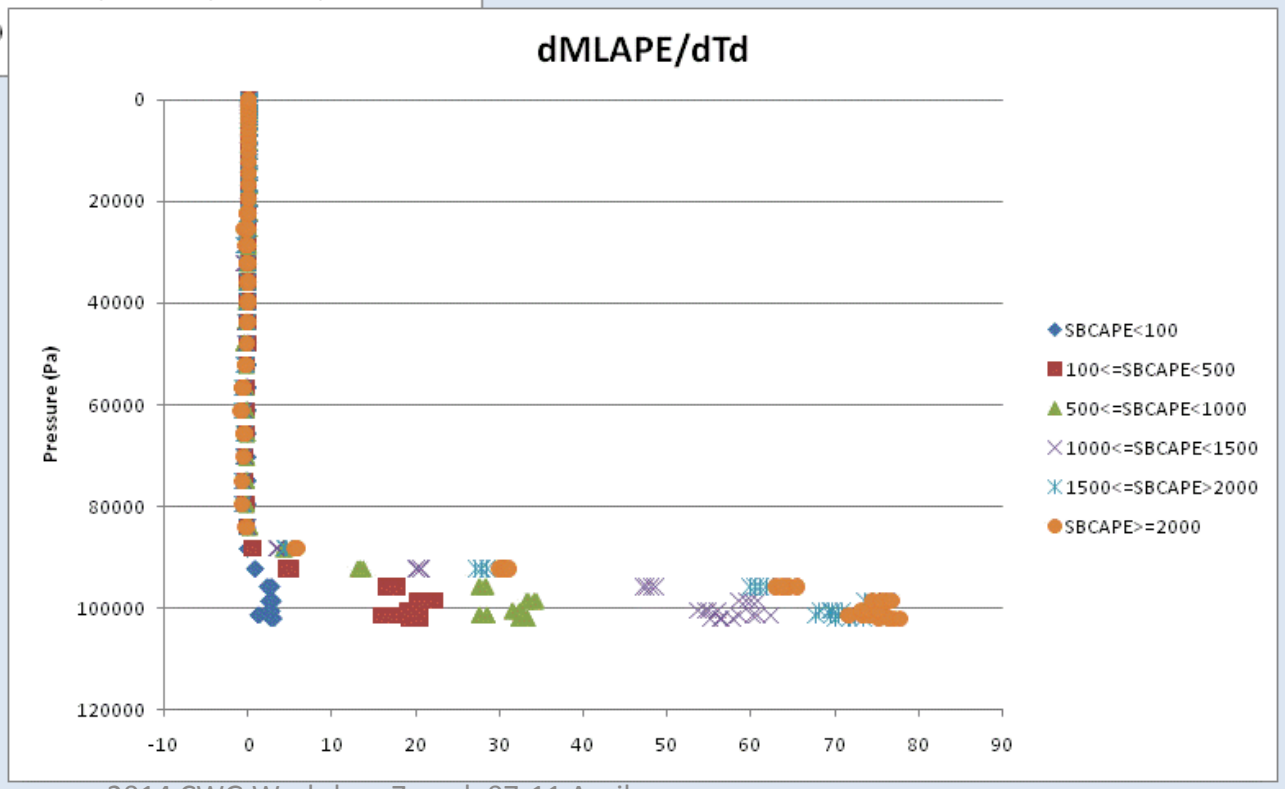
40000
60000
80000
100000
120000
-10
0
10
20
Mean


dMLAPE/dTd
Pressure (Pa)
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40000
60000
80000
100000
120000
-10
0
10
20
30
40
50
60
70
80
90
SBCAPE<100
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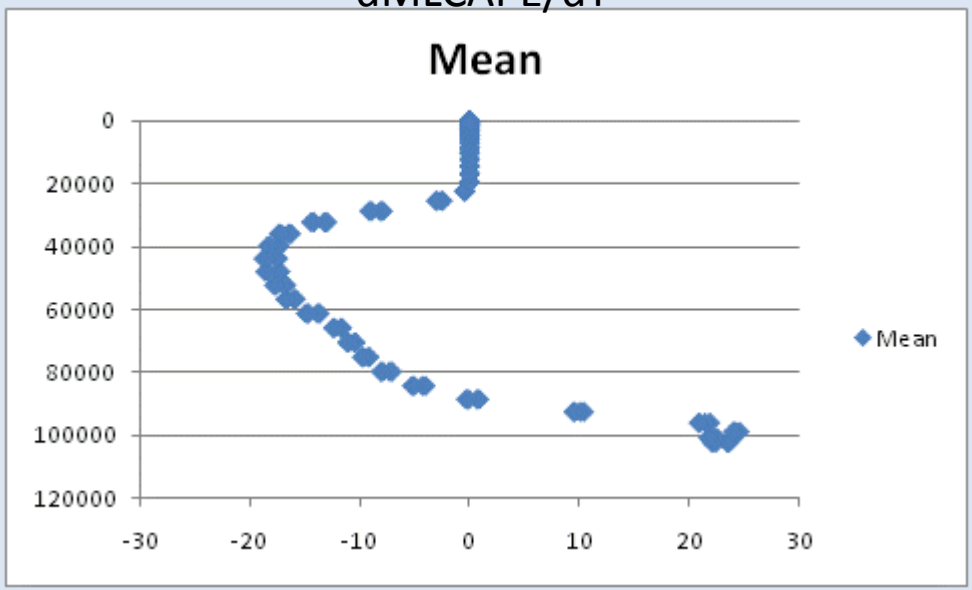
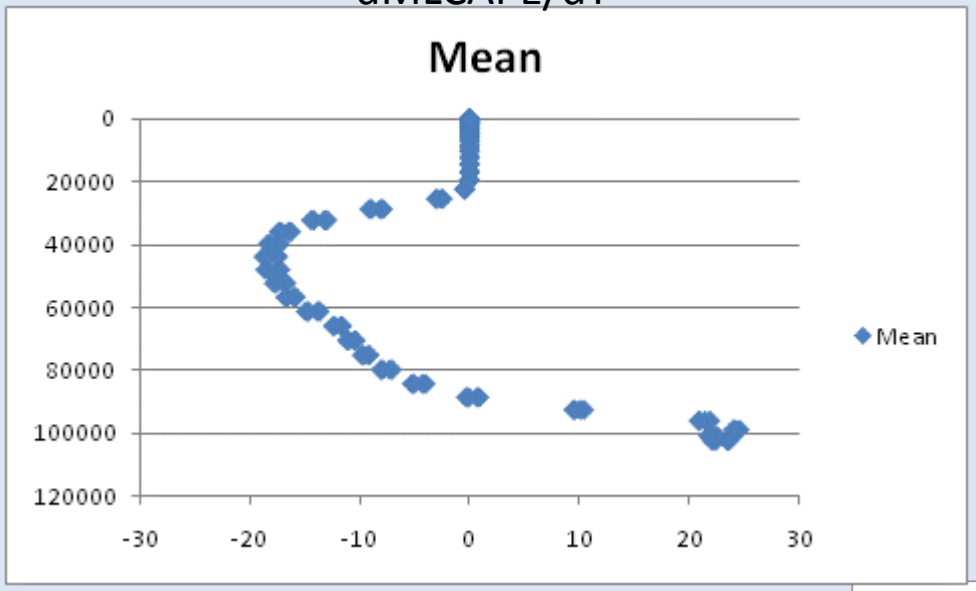
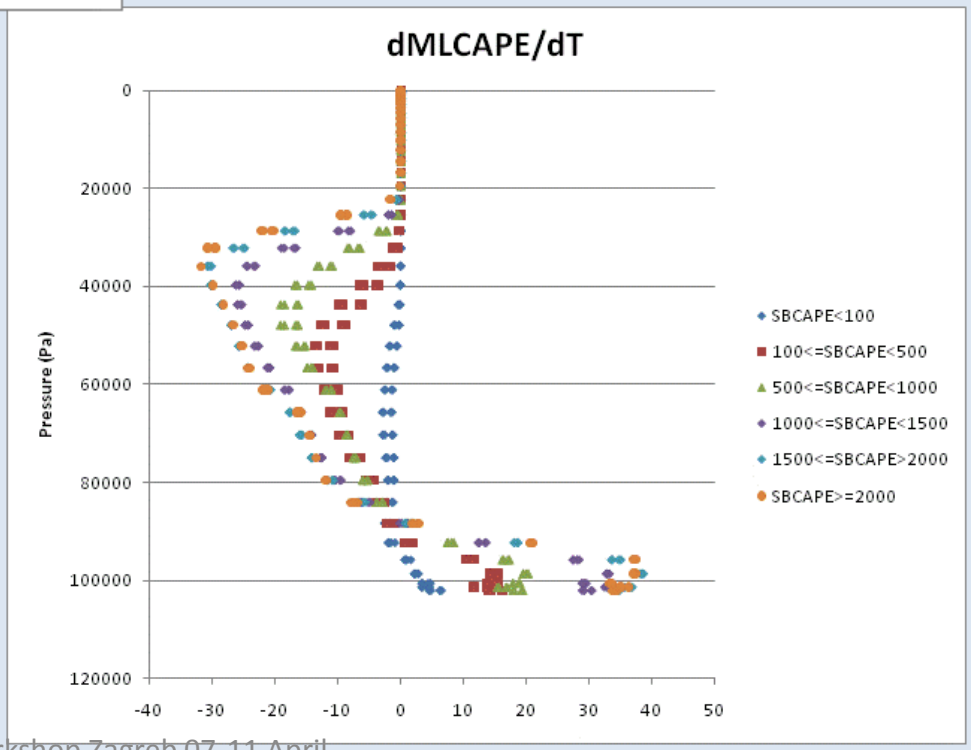
500<=SBCAPE<1000
1000<=SBCAPE<1500
1500<=SBCAPE>2000
SBCAPE>=2000

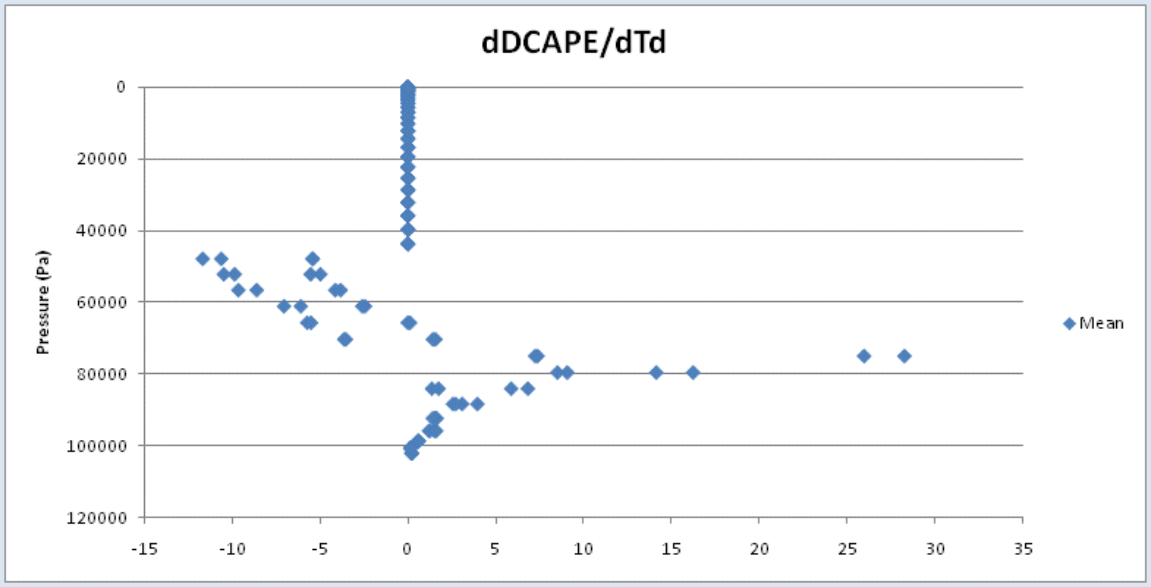
dMLCAPE/dT


Mean
0
20000
40000
60000
80000
100000
120000
-30
-20
-10
0
10
20
30
Mean

dMLCAPE/dT

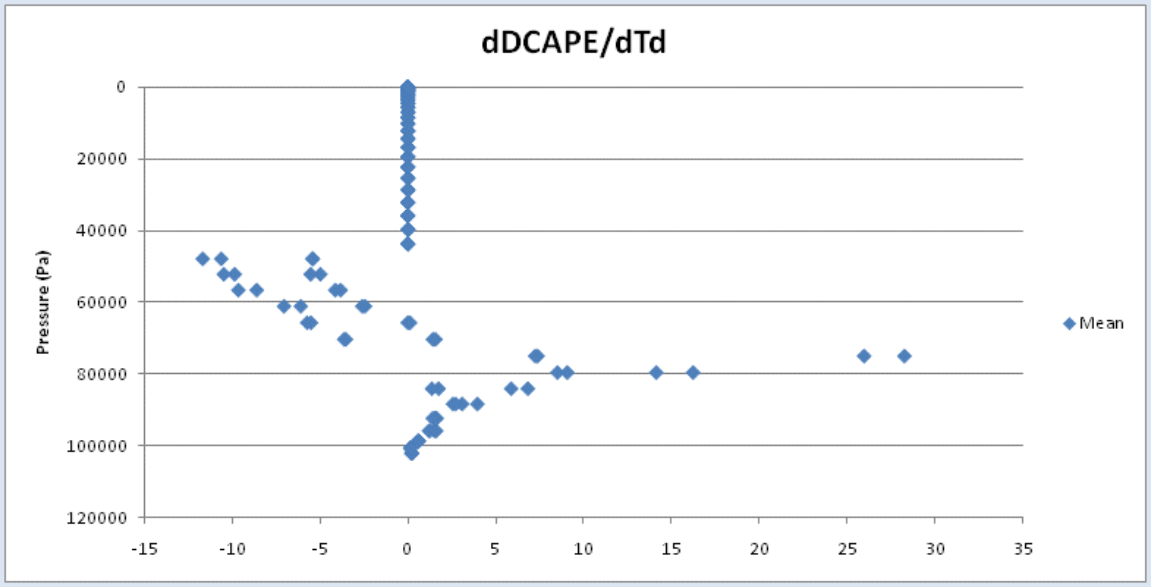

Mean
0
20000
40000
60000
80000
100000
120000
-30
-20
-10
0
10
20
30
Mean


dMLCAPE/dT
Pressure (Pa)
0
20000
40000
60000
80000
100000
120000
-40
-30
-20
-10
0
10
20
30
40
50
SBCAPE<100
100<=SBCAPE<500
500<=SBCAPE<1000
1000<=SBCAPE<1500
1500<=SBCAPE>2000
SBCAPE>=2000



SBCAPE>100

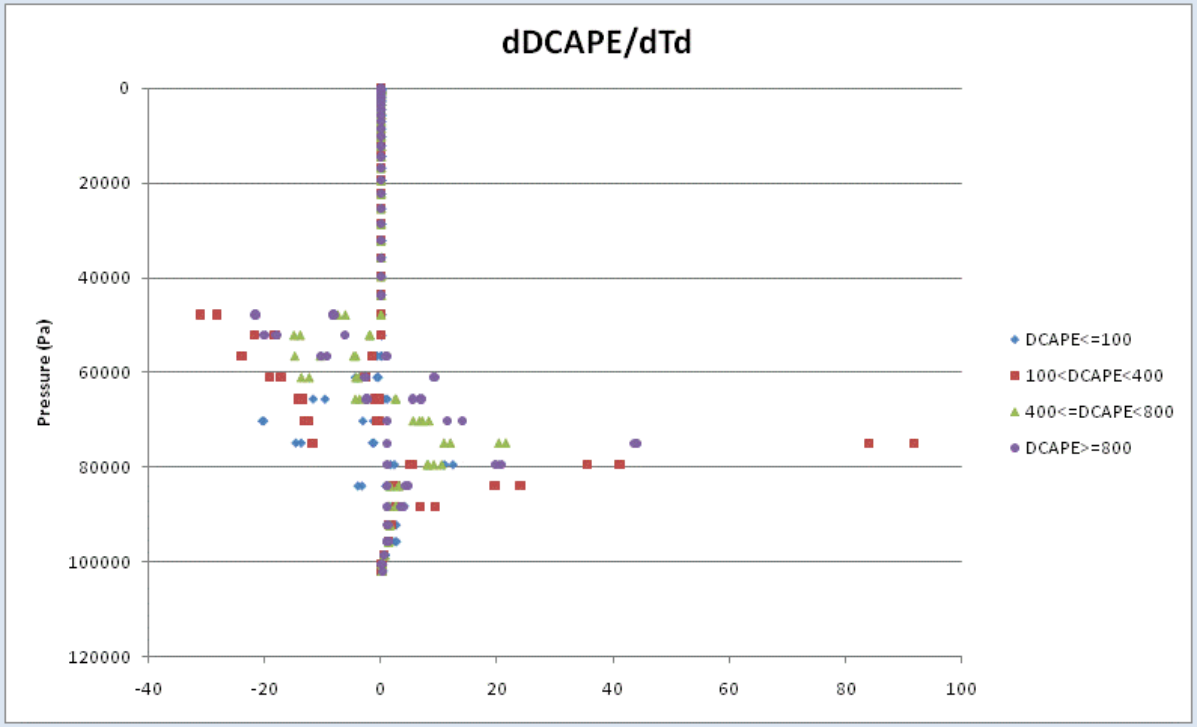
Only sensitive to the level where we start to sink the parcel. (The level where the equivalent potential temperature is the smallest between 500 and 850 hPa layer.)

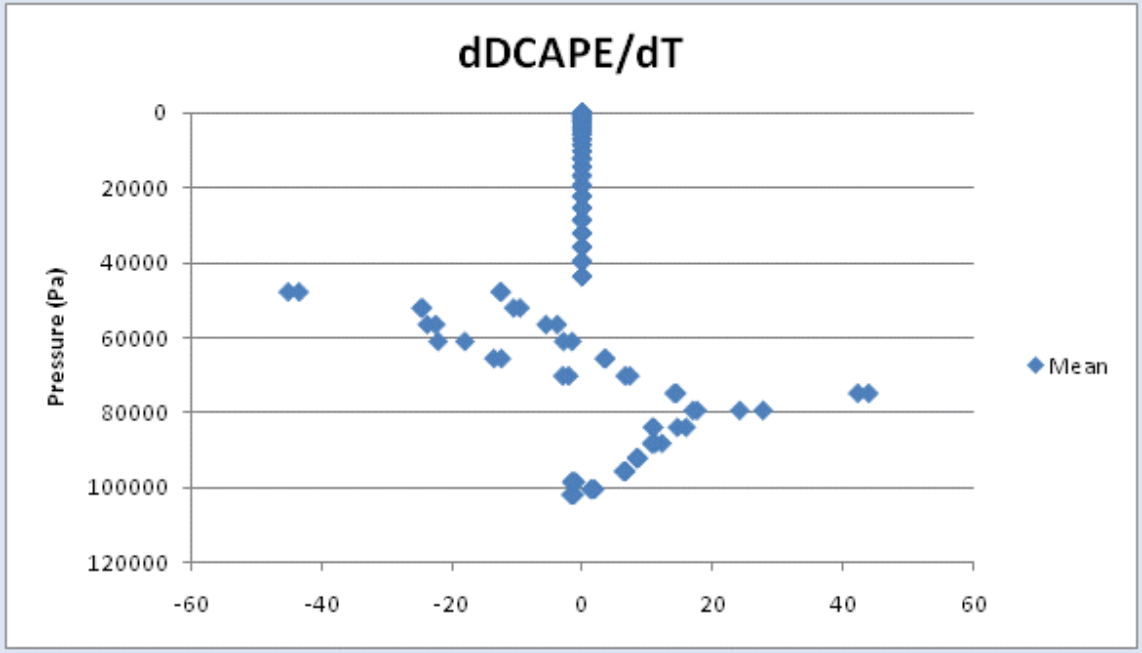


	DCAPE<=100	100<DCAPE<400	400<=DCAPE<800	DCAPE>=800
Number of pixels	218	678	7556	5826

SBCAPE>100

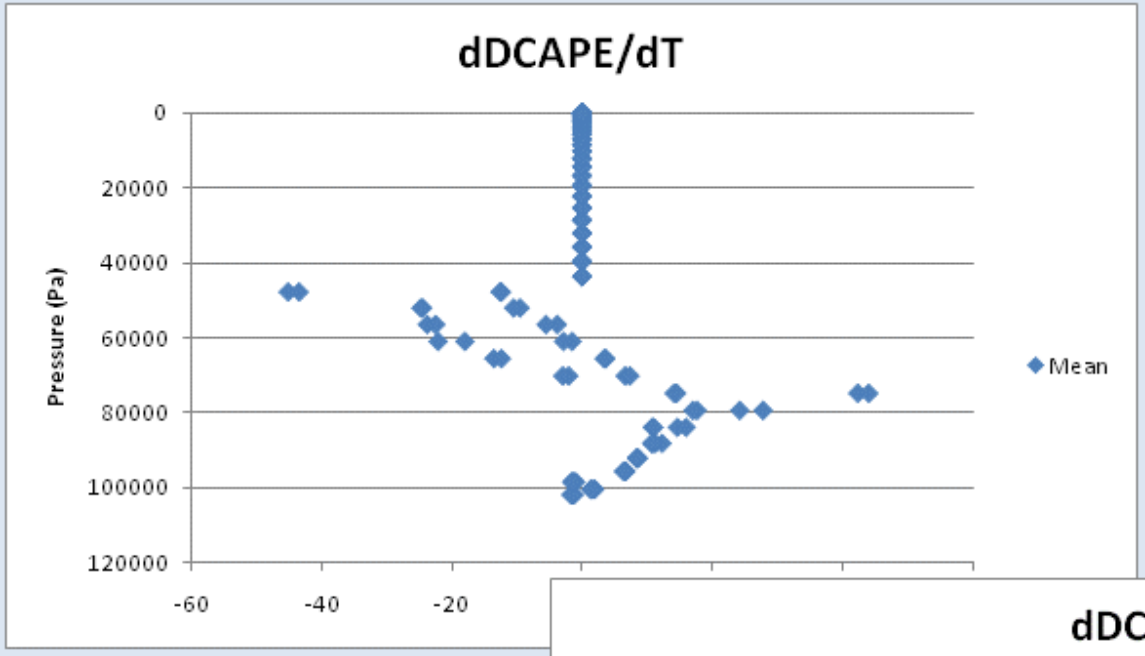
Only sensitive to the level where we start to sink the parcel. (The level where the equivalent potential temperature is the smallest between 500 and 850 hPa layer.)





It is most sensitive to the level and its neighborhood where we start to sink the parcel.

When we change the temperature near the starting level the equivalent potential temperature is also changing thus the starting level can change.



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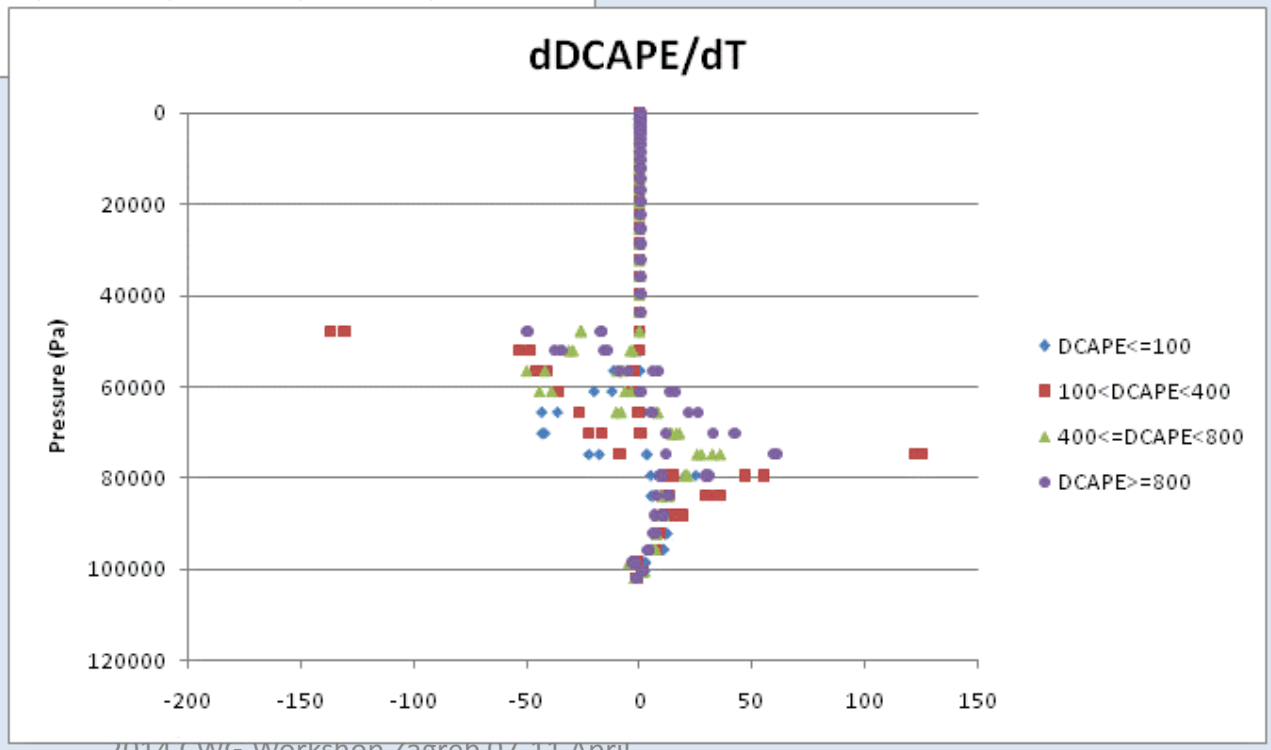

	SBCAPE	MLCAPE	DCAPE
Temperature	- Mainly surface -levels between 800 and 200 hPa (increasing with height) - one order of magnitude less then the surface derivatives - for larger CAPE values the derivatives are larger – more sensitive	- most sensitive for the lowest 100 hPa layer (~under 900 hPa) - second maximum where the positive area ends – higher for larger CAPE values (~ between 500 and 300 hPa) - two maximums are comparable	-where we start to sink the parcel - the levels below it, the sensitivity deceases to the surface
Humidity	- Surface	- Where is start to lift the parcel from. (lowest 100 hPa)	- Where we start to sink the parcel from (between 500 850 hPa)

Conclusions

To calculate SBCAPE from satellite retrievals might not be the best idea – it is very sensitive to the surface humidity and temperature. It might be useful to combine the satellite retrieved profiles with surface measurements.

We found the MLCAPE more promising. It is less sensitive to the initial values. The satellite retrieval gives us a smooth profile – we have the humidity more for a layer then for a level. When we mix the lowest 100 hPa layer we get a mean value which is more often closer to the reality.

The DCAPE is mostly sensitive to the middle layer of the atmosphere where the satellite gives the most information on the humidity thus it might be a better candidate to be calculated from satellite retrieved profiles.

The MUCAPE is mostly useful to estimate the probability of elevated convection. MUCAPE is very different from SBCAPE for example in case of some kind of blocking, i.e. thermal inversion. Unfortunately, thermal inversions are often missed in the NWP profiles, neither the satellite algorithm will not retrieve an inversion if it is not forecasted by NWP data.

More information on the lower levels of the atmosphere for example new channels on MTG FCI, VIS0.9 – humidity of the layer near to the surface, or to detect better the thin Ci clouds could also help.

The MTG IRS might also have possibilities to improve the humidity and maybe also the temperature profiles.

Thank you for the attention!