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Indexes in the context of convective storms

Gunnar Noer

22.12.2015

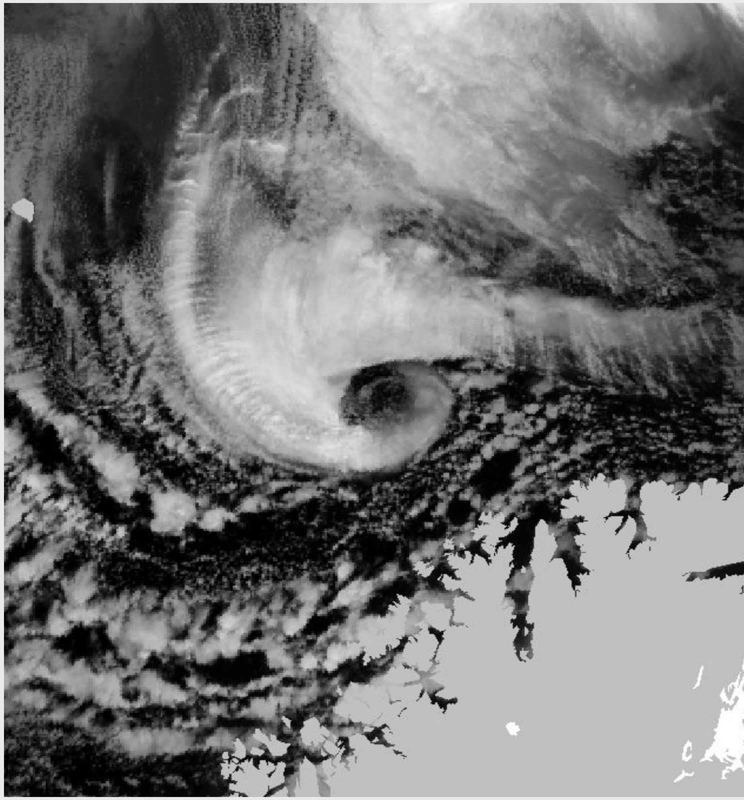
Arctic convection: Polar Lows:

Basic Methodology:

1. Cold air outbreak at the surface
   a. Supply of latent and felt heat from the Sea surface

2. Cold trough at 400 to 500 hPa
   a. moderate values of PVA, but lasting over time

3. The polar low index: $SST\text{-}T_{500} > 43^{\circ}C$
   a. Deep buoyant instability



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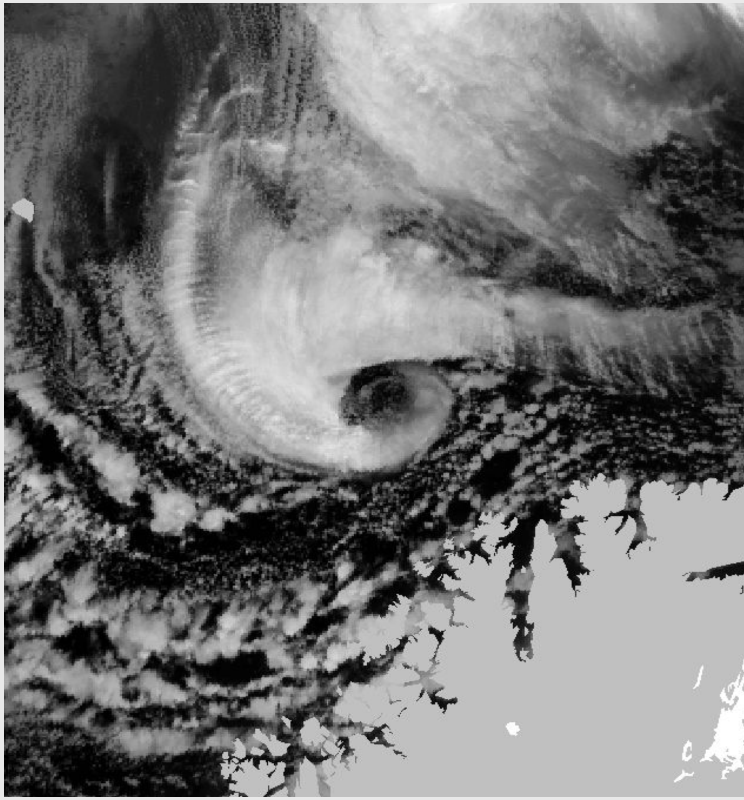

The Polar Low index

Polar Low Index = SST - T_{500}

Useful when convection is related to differences in the SST in the North Atlantic

Must be seen in context with

- advection of the airmass
- Longevity / the time aspect
- Baroclinic zones
- **Only attains values bove 42 - 44 ℃ when there is a risk of PL's**

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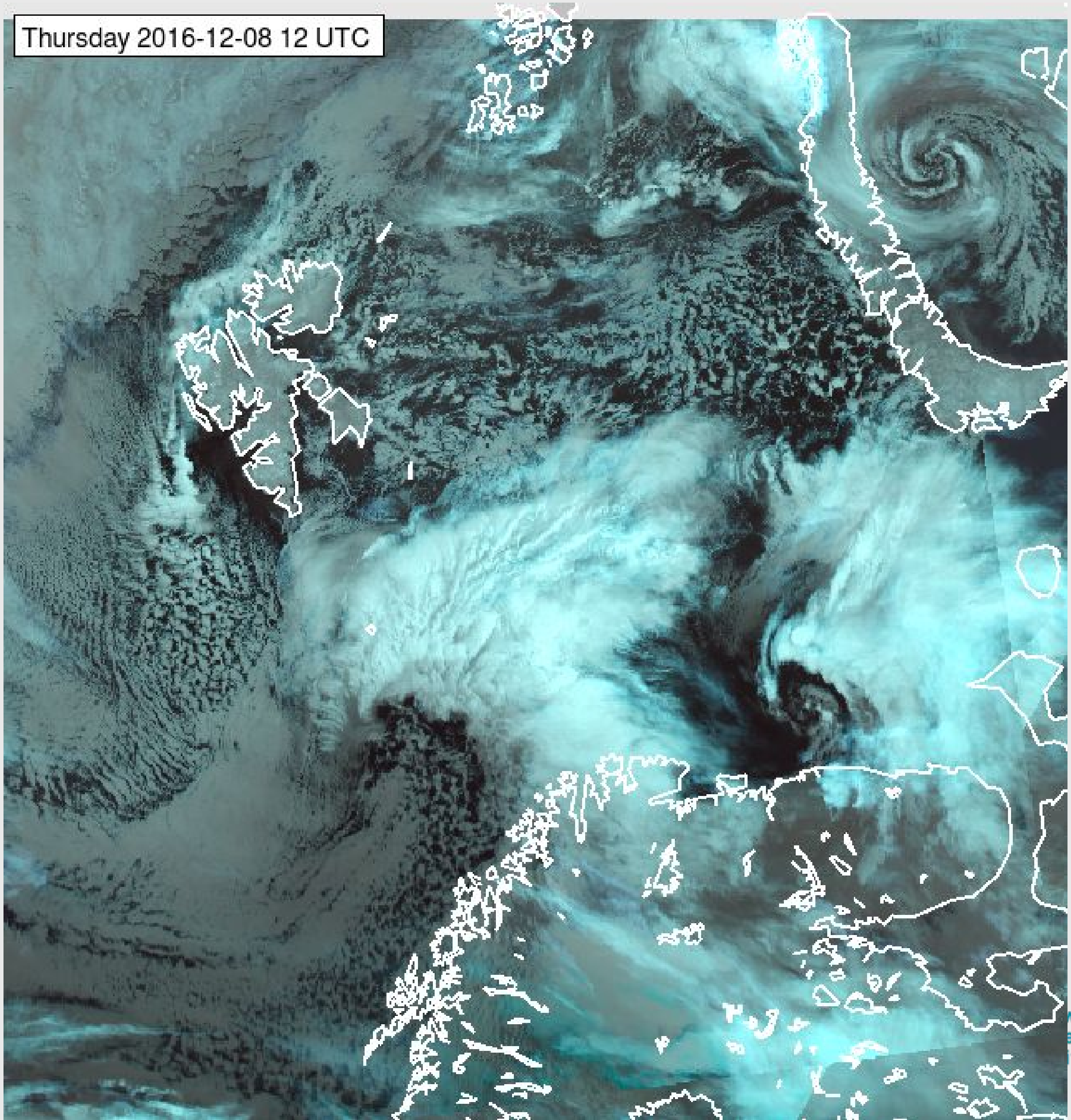
The polar low index:



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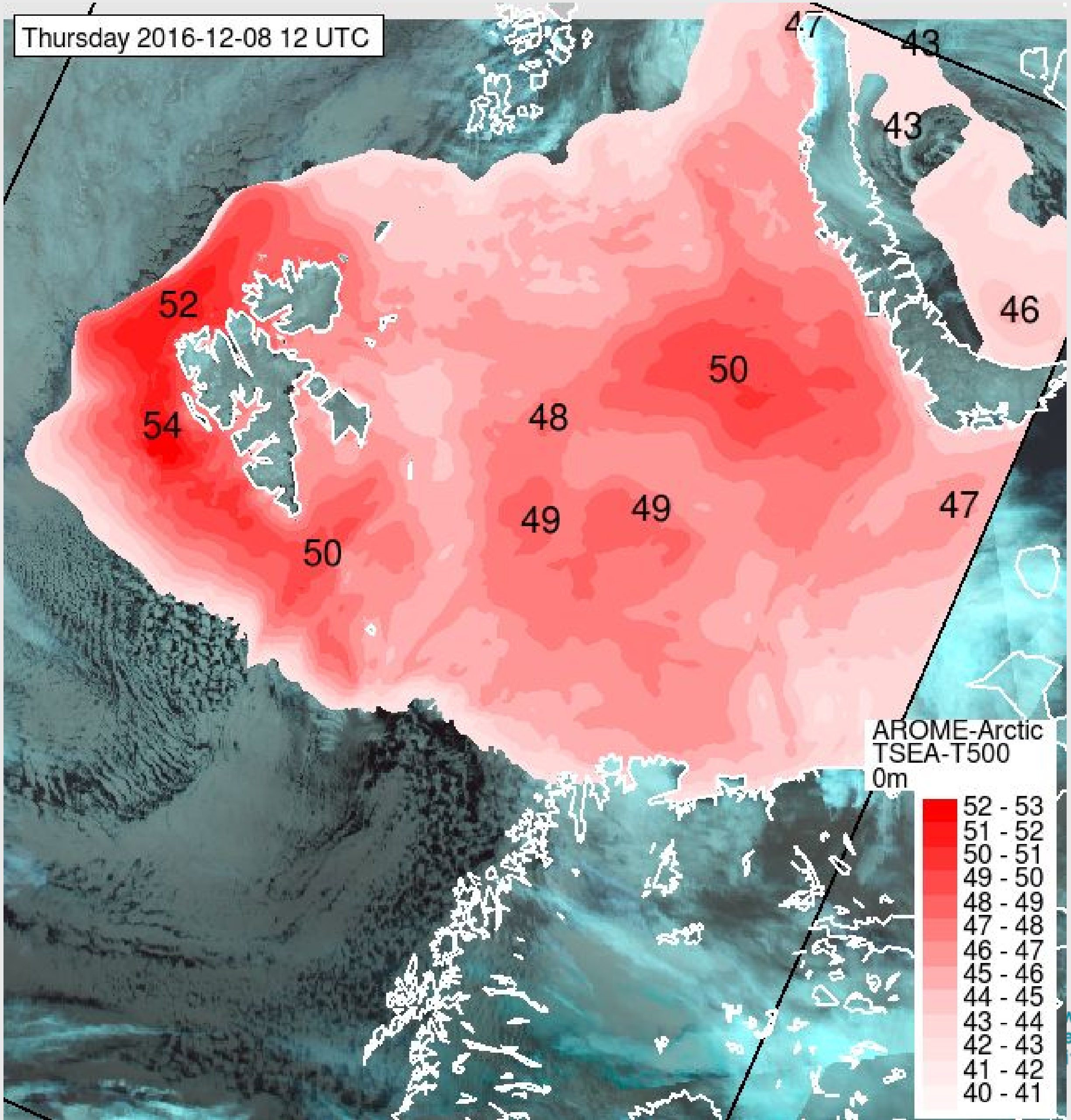
The polar low index:



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The convection indexes:

The SST-T_{500} has always been used to indicate the possibility of Polar Lows at MET-Norway. How about other indexes ?

- CAPE (Convective Available Potential Energy)
- K-index
- Total-Totals index
- Showalter / Lifted index

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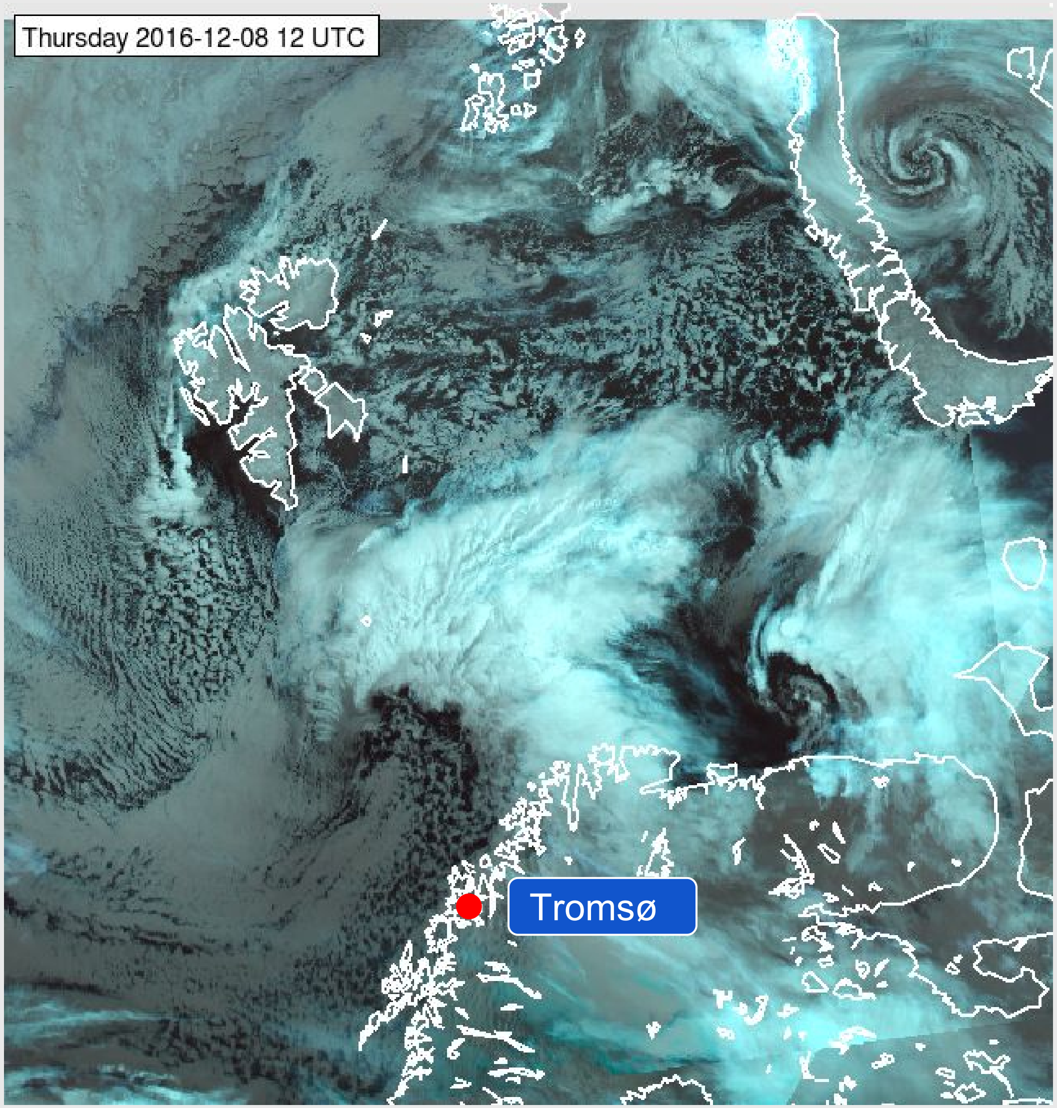
Three cases of convection:



Polar lows over the Barents sea 8. Dec. 2016

Model:

AROME-Arctic 00+12

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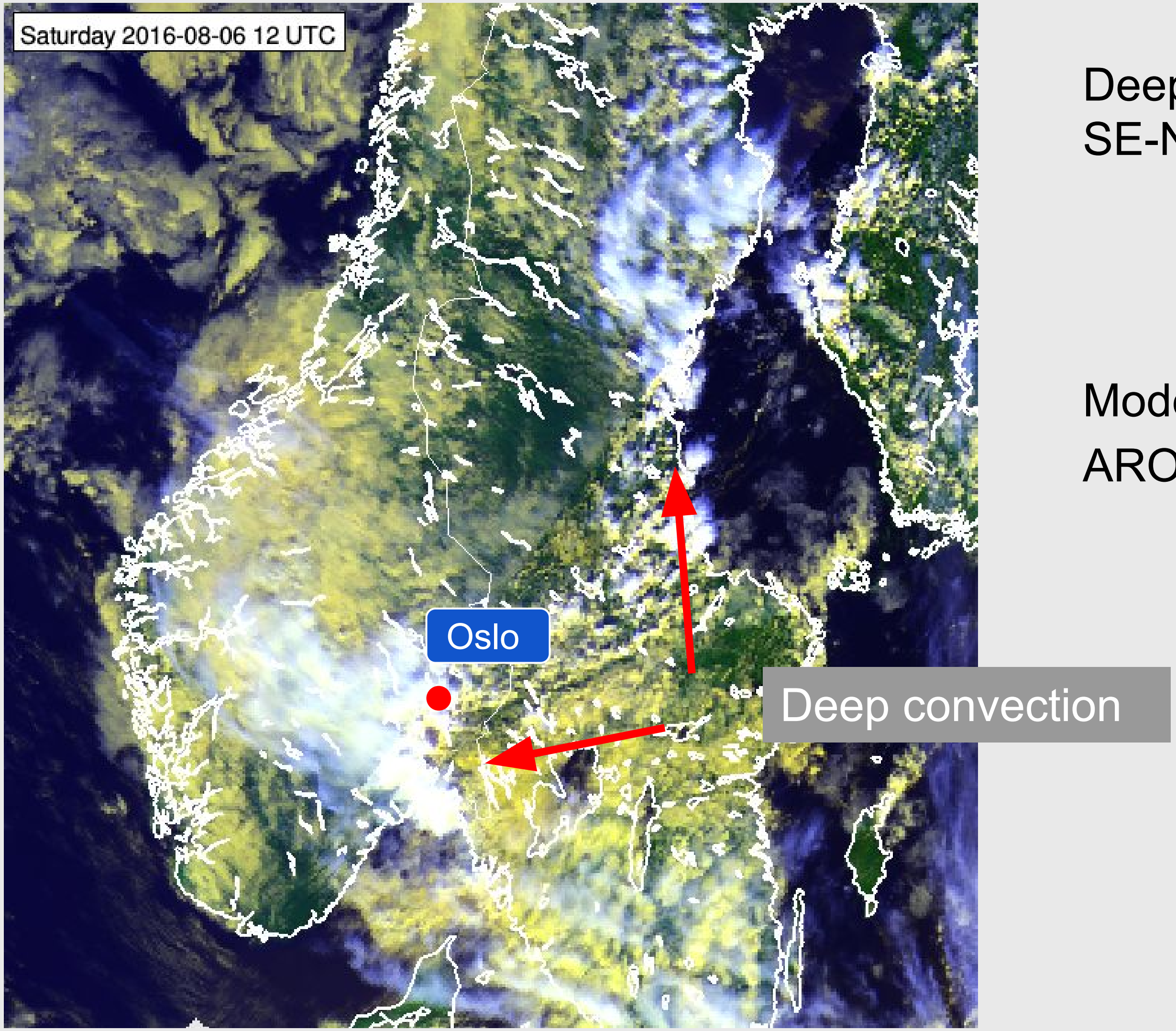
Three cases of convection:



Deep convection,
SE-Norway, August 2016

Model:

AROME-MetCoOp 00+12

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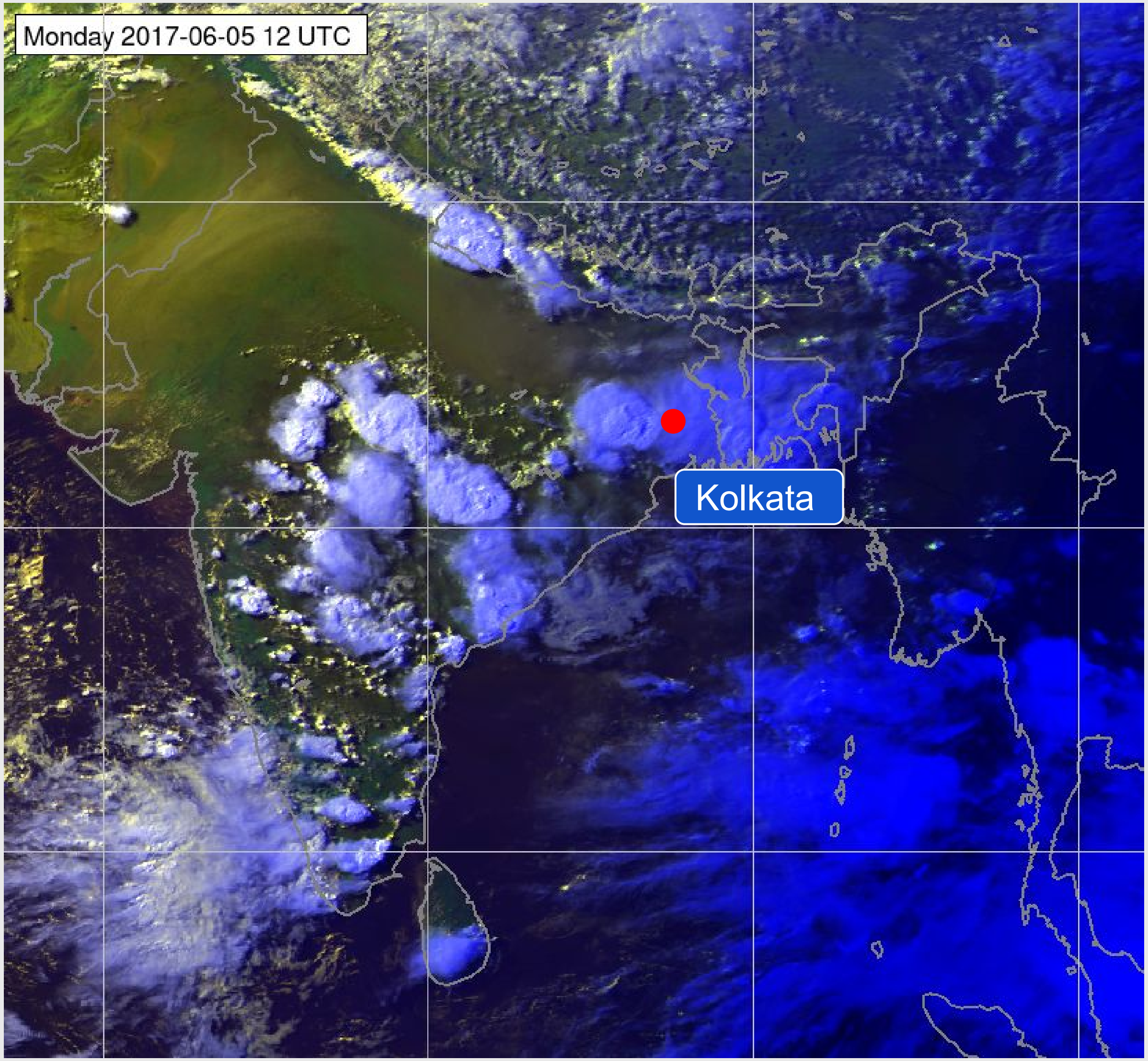
Three cases of convection:



Tropical pre-monsoon convection, May 2017

Model:

ECMWF_0.125 00+12

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The CAPE

Convective Available Potential Energy (CAPE)

CAPE is measure of the amount of energy available for convection

- the only index that takes in the actual conditions within the whole coloumn between LFC and EL

$$\mathrm{CAPE} = \int_{z_\mathrm{f}}^{z_\mathrm{n}} g \left(\frac{T_{\mathrm{v,parcel}} - T_{\mathrm{v,env}}}{T_{\mathrm{v,env}}} \right) dz$$

Presented from the ECMWF as a EFI parameter

BUT: Scores poorly both in tropical conditions (Tyagi et al. 2010) and in the context of PL's

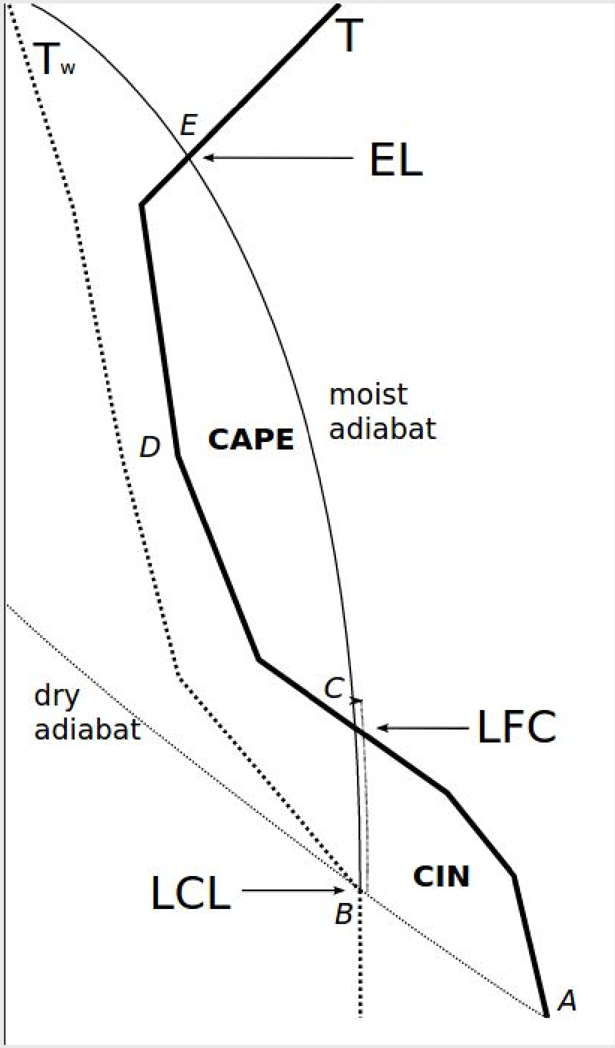
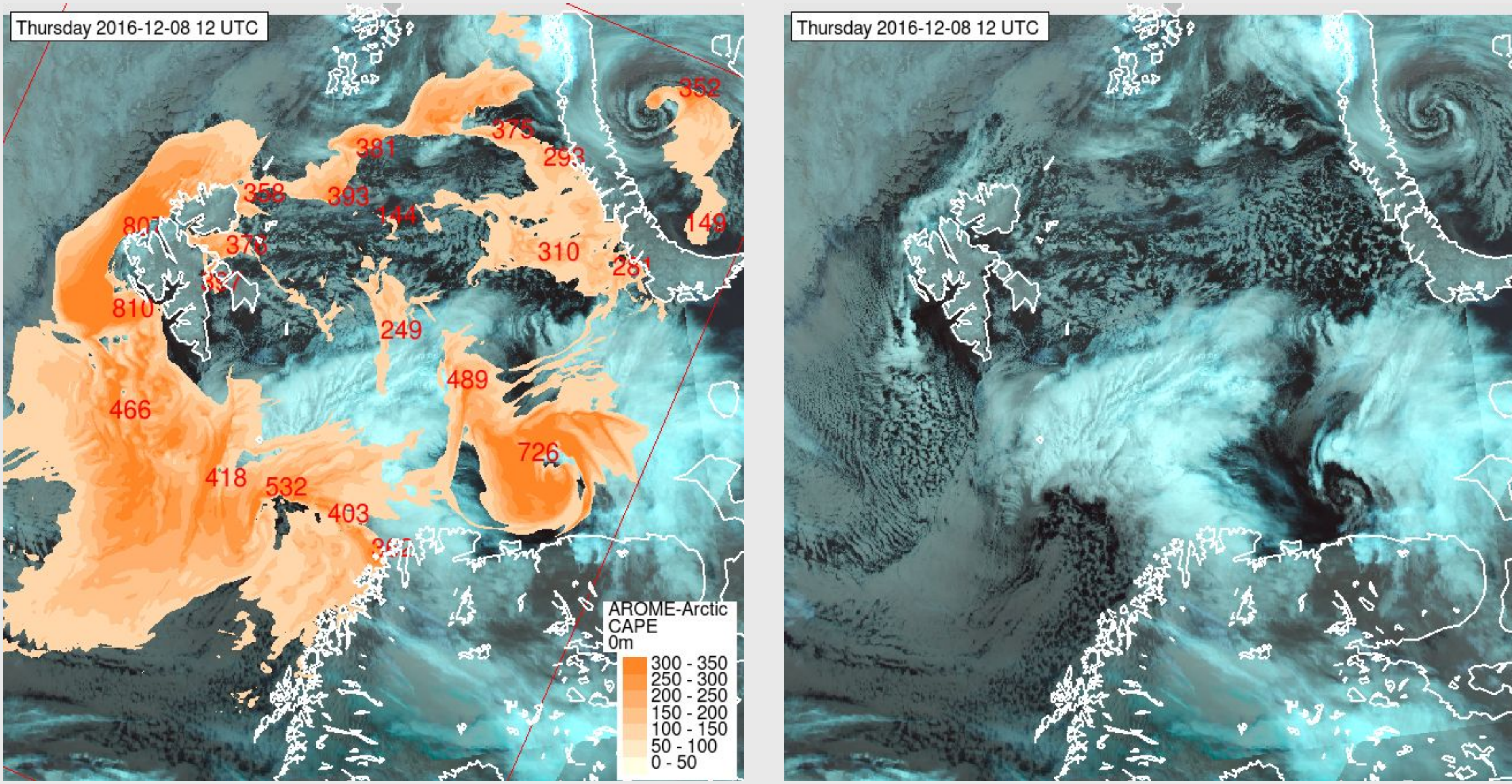


Illustration: Pierre_cb, Grische

The CAPE on the polar lows:



Winter Arctic Maritime: max values of 500 - 1000 J/kg

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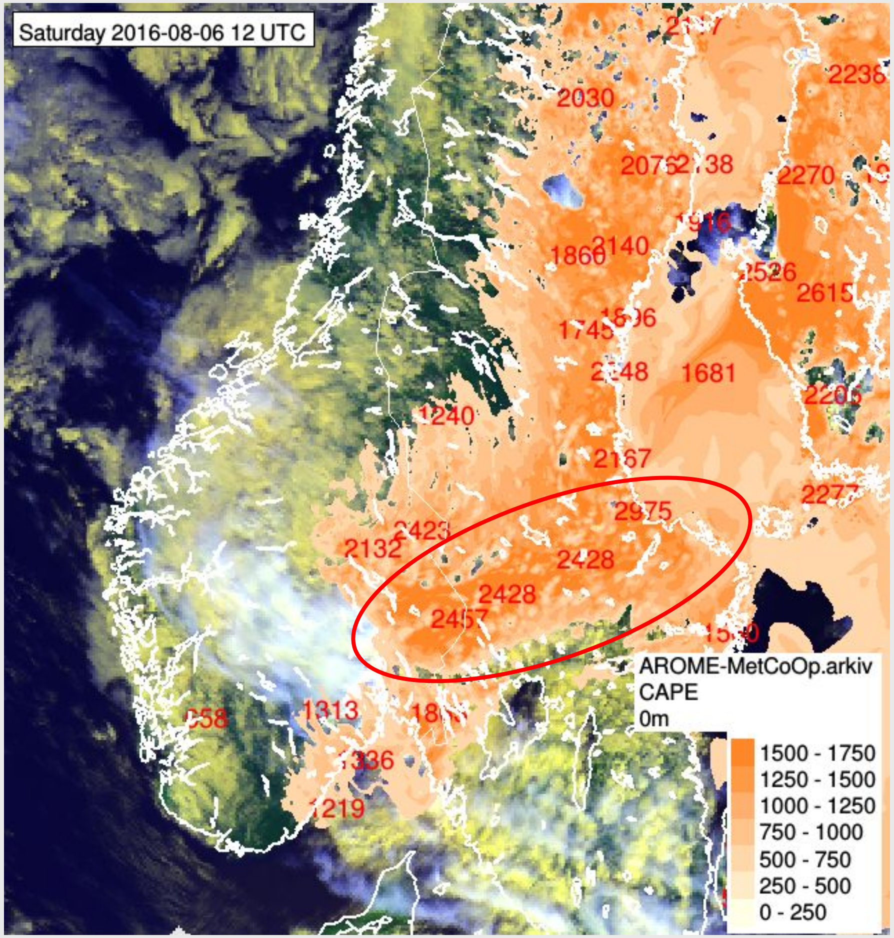
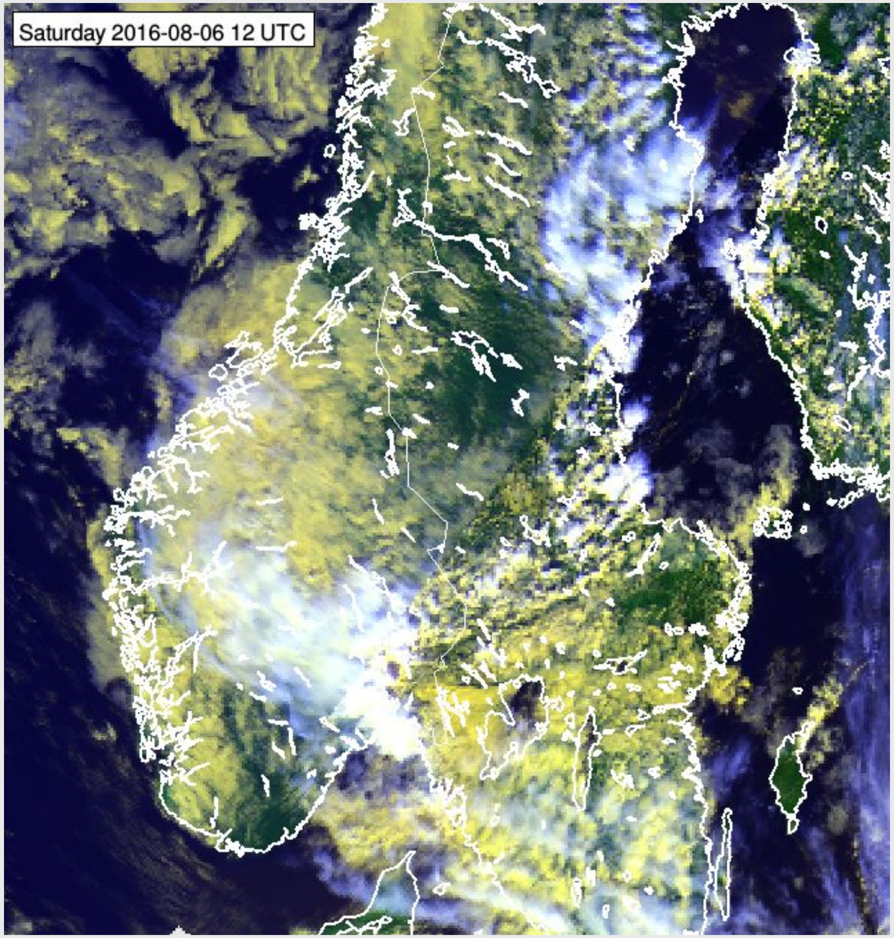
The Cape on Scandinavian summer convection:





Mid latitude continental summer: Max values of 2000 - 3000 J/kg

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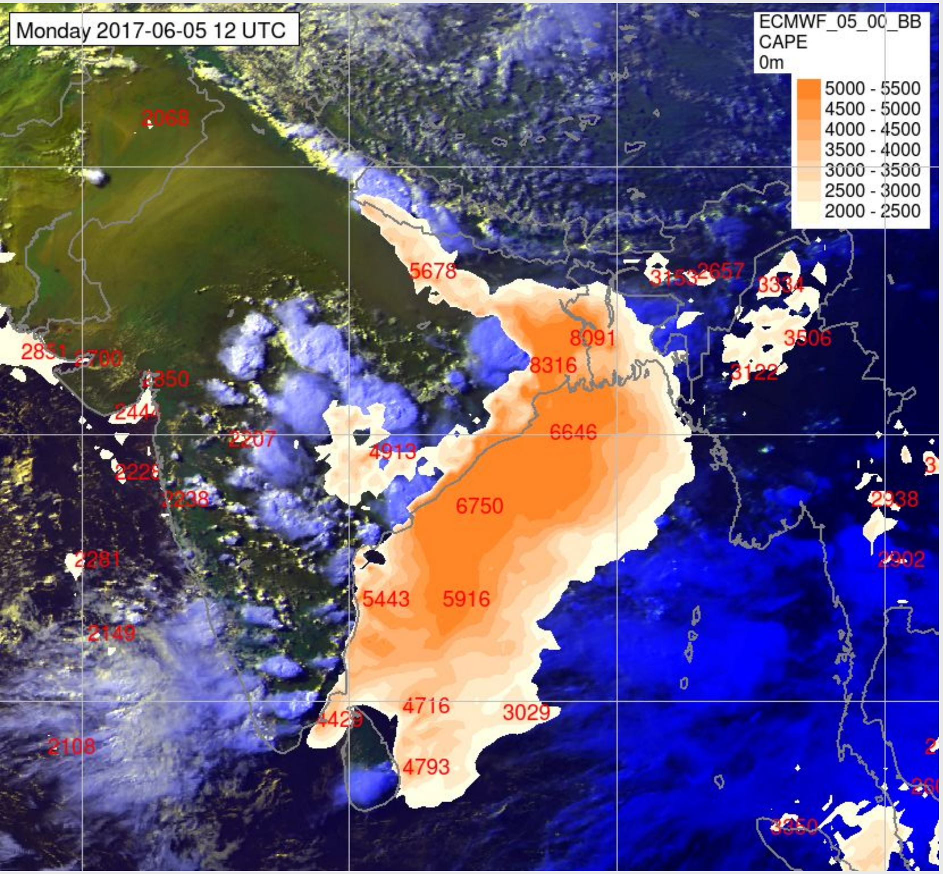
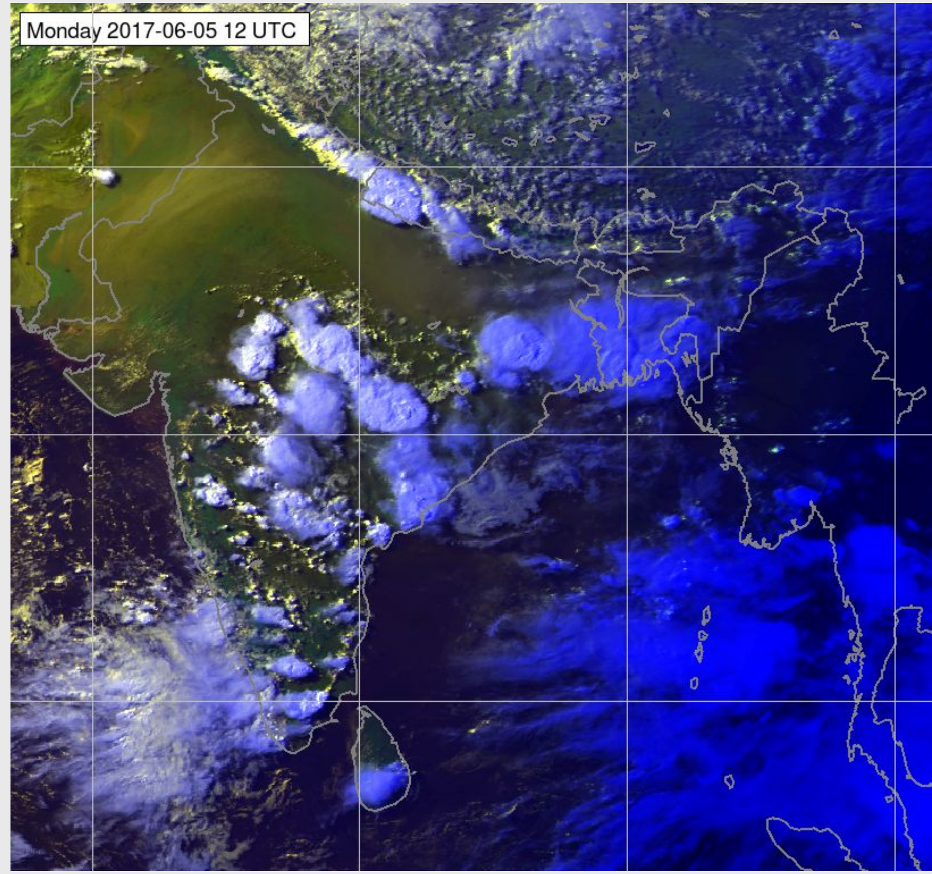
The CAPE for tropical pre-monsoon:





Tropical pre-monsoon: max values of 6000 - 8000 J/kg

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The K-index

The K-index (KI)

K-Index (K) = $(T_{850} - T_{500}) + T_{850} - (T_{700} - T_{d700})$

- Static instability from 850 hPa til 500 hPa
- Temperature at 850 hPa
- The moisture at 700 hPa

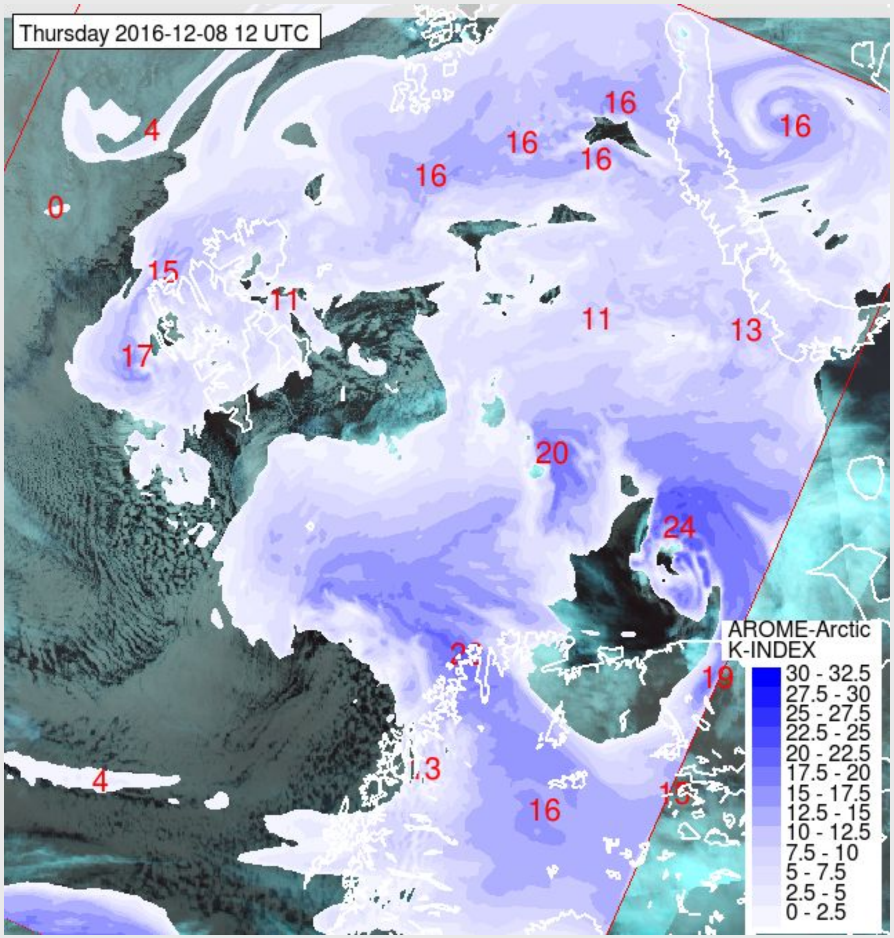
Location and season dependent e.g. tropics vs. mid-latitude.

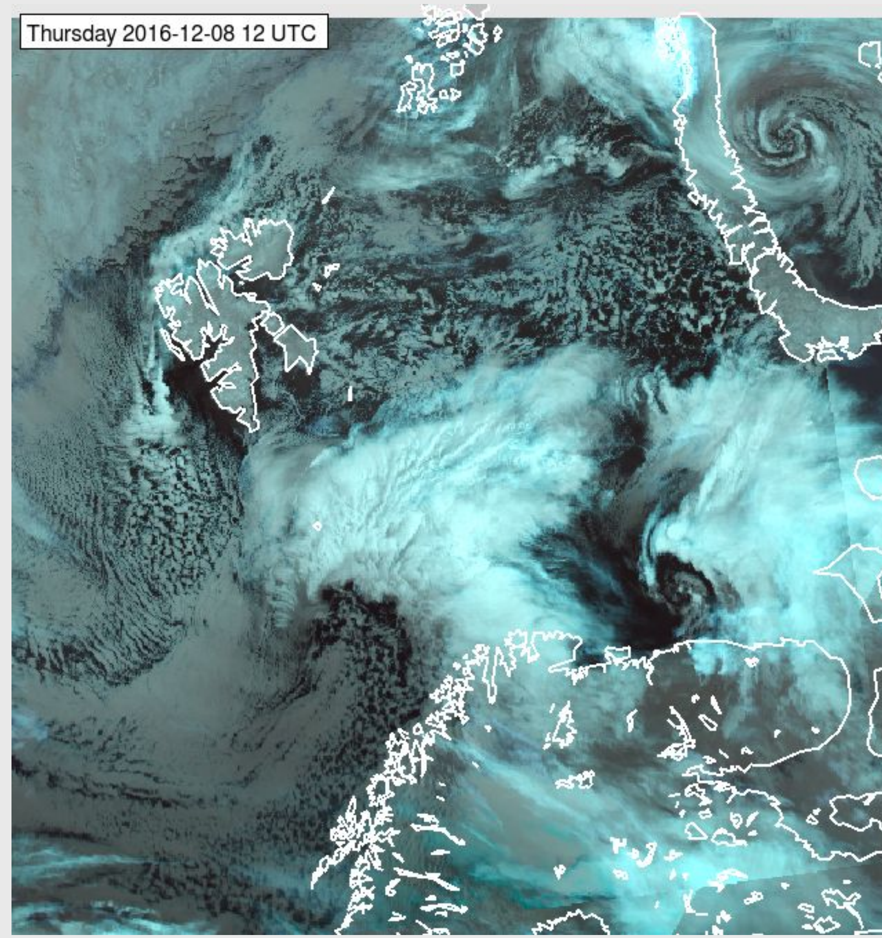
The role of the humidity at 700 hPa uncertain

No information on instability below 850 hPa

Commonly used and scores well in the Tropics (Tyagi et al. 2010), in mid-latitude and in the Arctic

The K-index for Polar lows





Winter Arctic Maritime: max values of 15 to 25K
Best fit in the Arctic for this case

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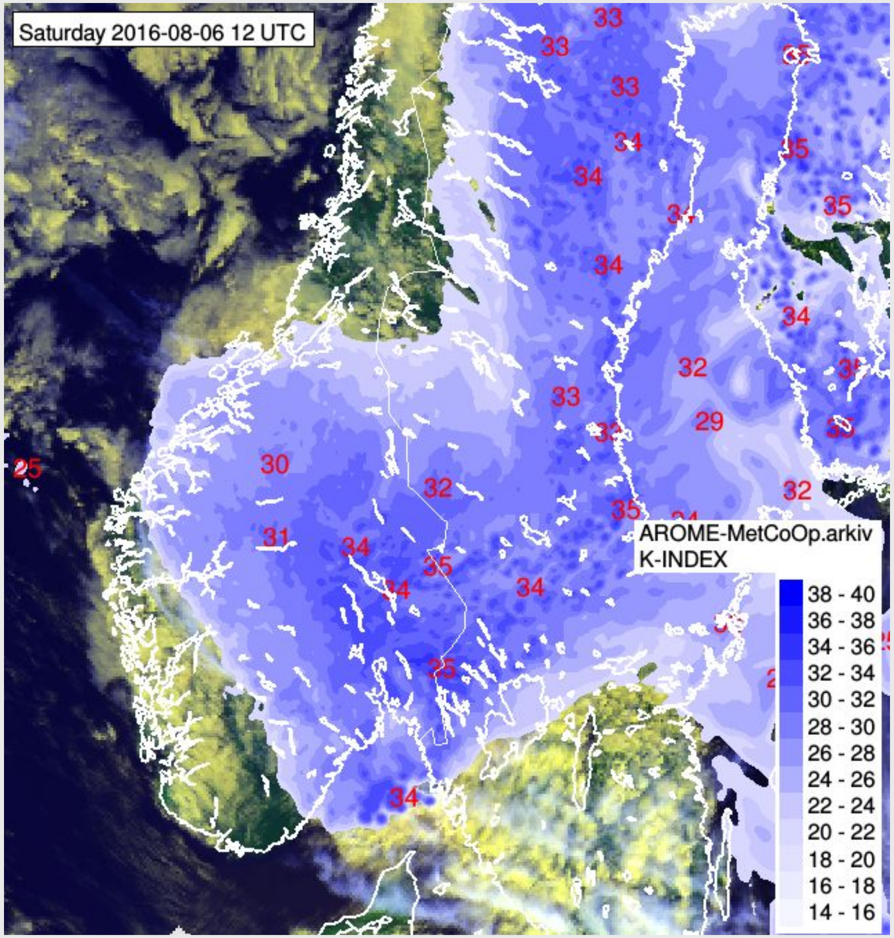
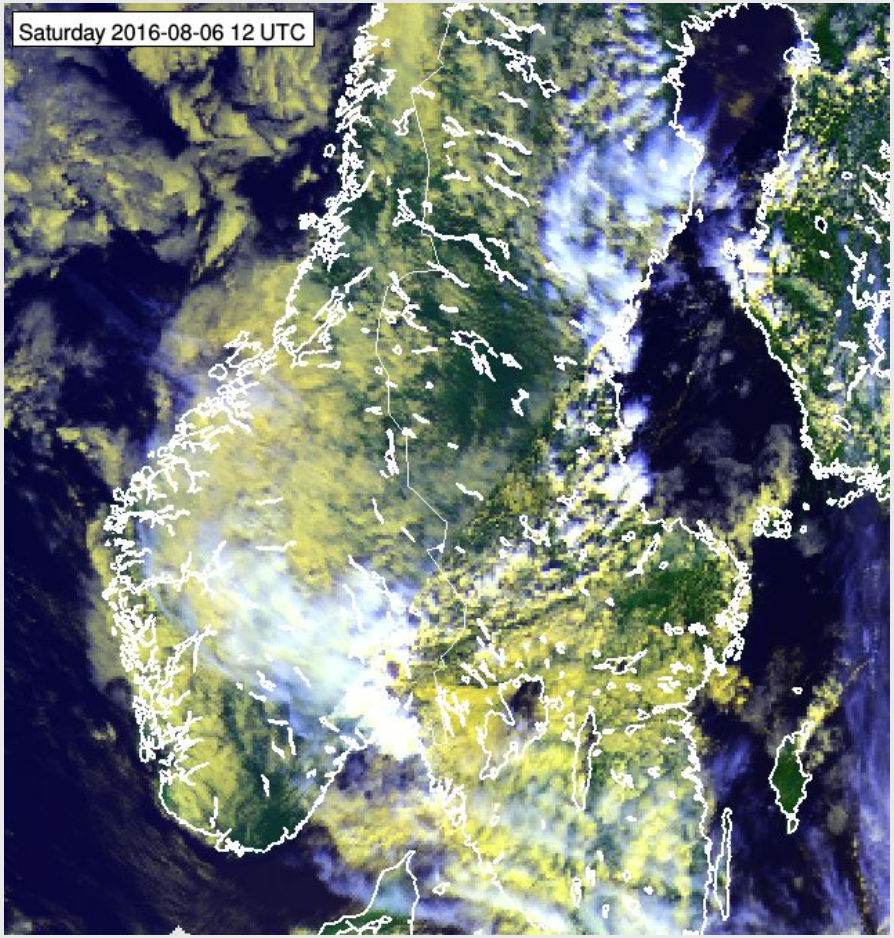
K-index for mid latitude continental summer convection





Mid latitude continental summer: max values of 25 to 35 K
Weak definition, Not unique to areas of deep convection

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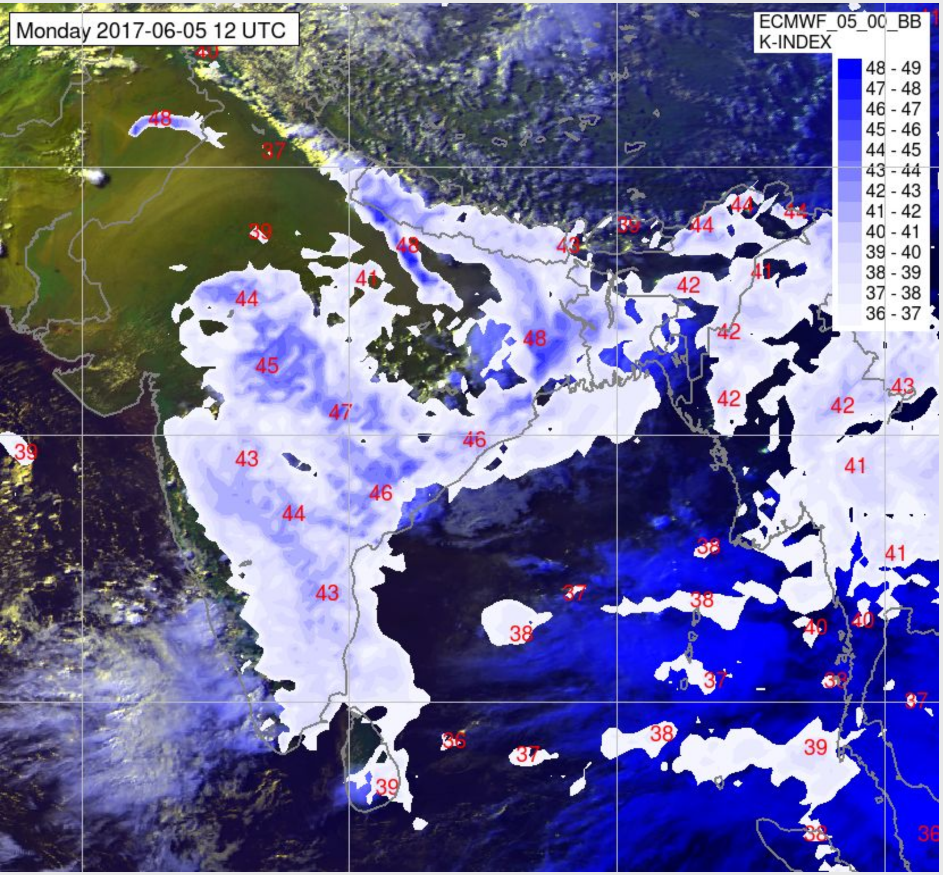
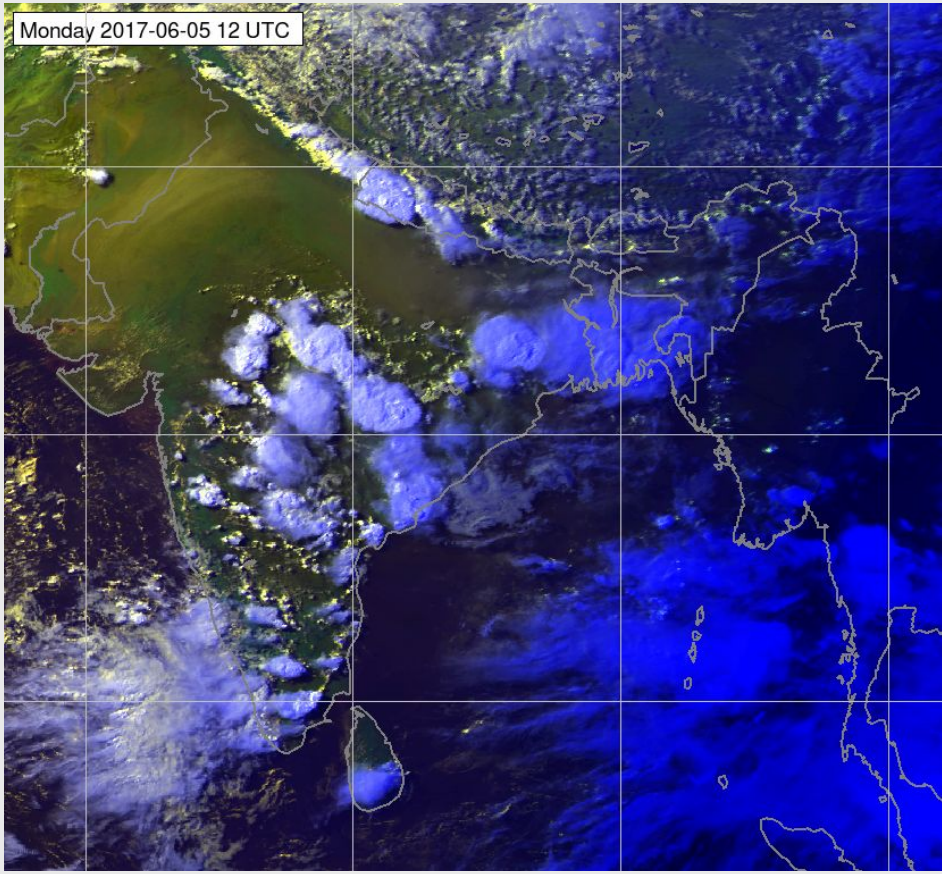
K-index for Tropical pre-monsoon





Tropical pre-monsoon: max values of 40 to 50K
Best fit in this case in the tropics.

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The Total-Totals index

The Total-totals index (TTI)

TTI = Vertical totals + cross totals = $(T_{850} - T_{500}) + (T_{d850} - T_{500})$

Addresses moisture at 850 hPa and static instability above 850

Season and location dependent

No info on conditions below 850 hPa, e.g. capping inversion below 850 hPa

Commonly used for assessment of convection

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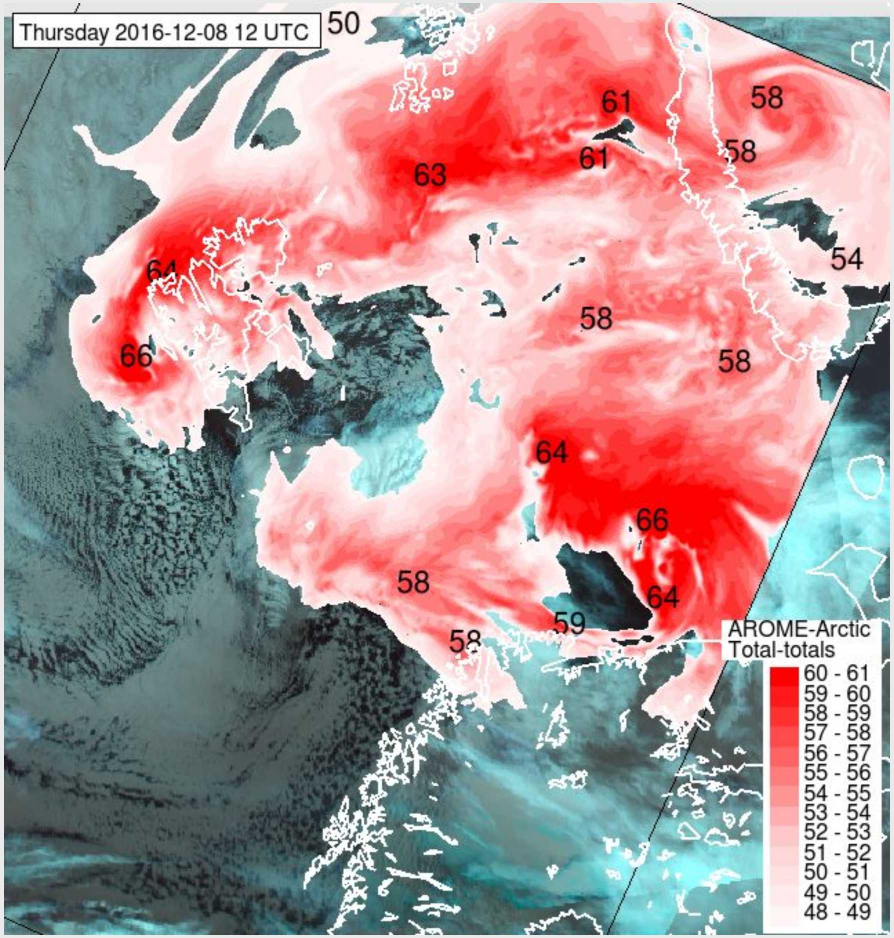
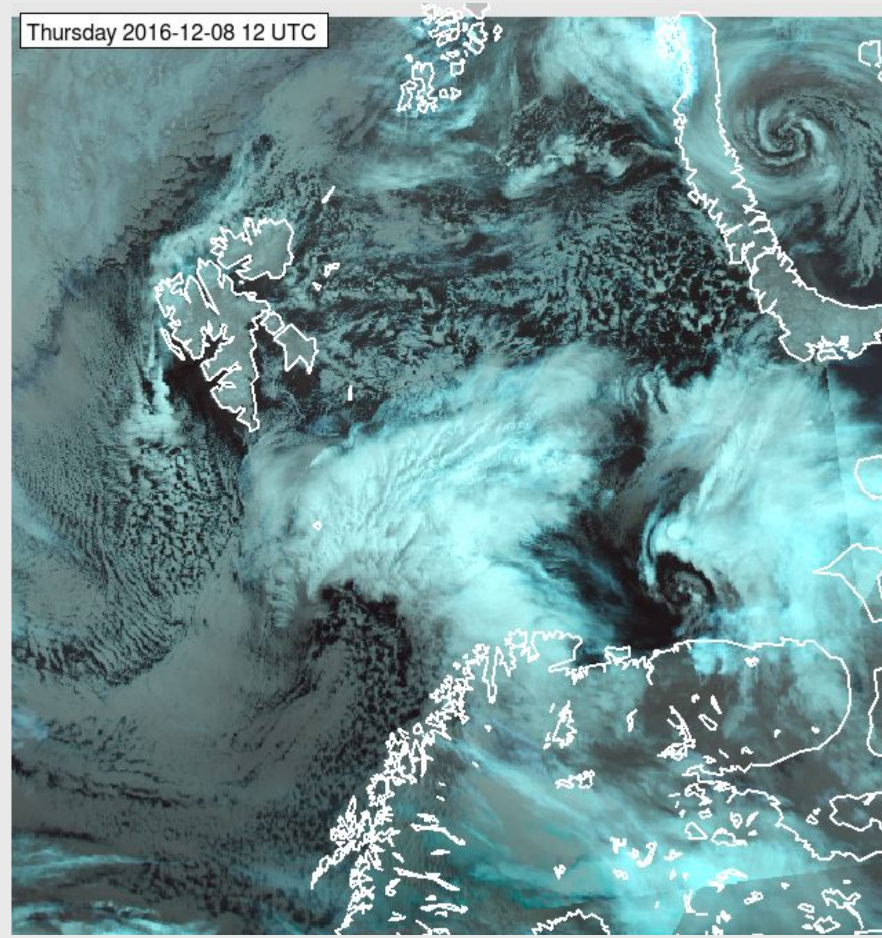
Total-Totals Index for Polar Lows





Winter Arctic Maritime: max values of 55 to 65 K
Definition: Not unique to PL's, but otherwise good
Highest values in the Arctic !

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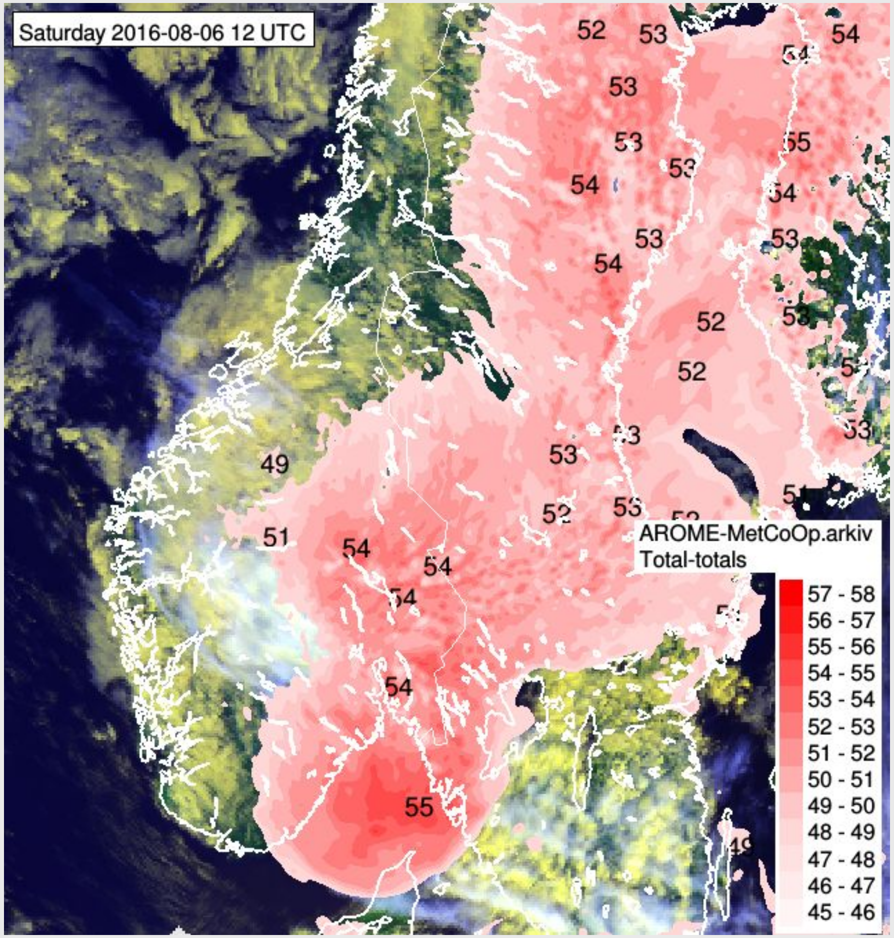
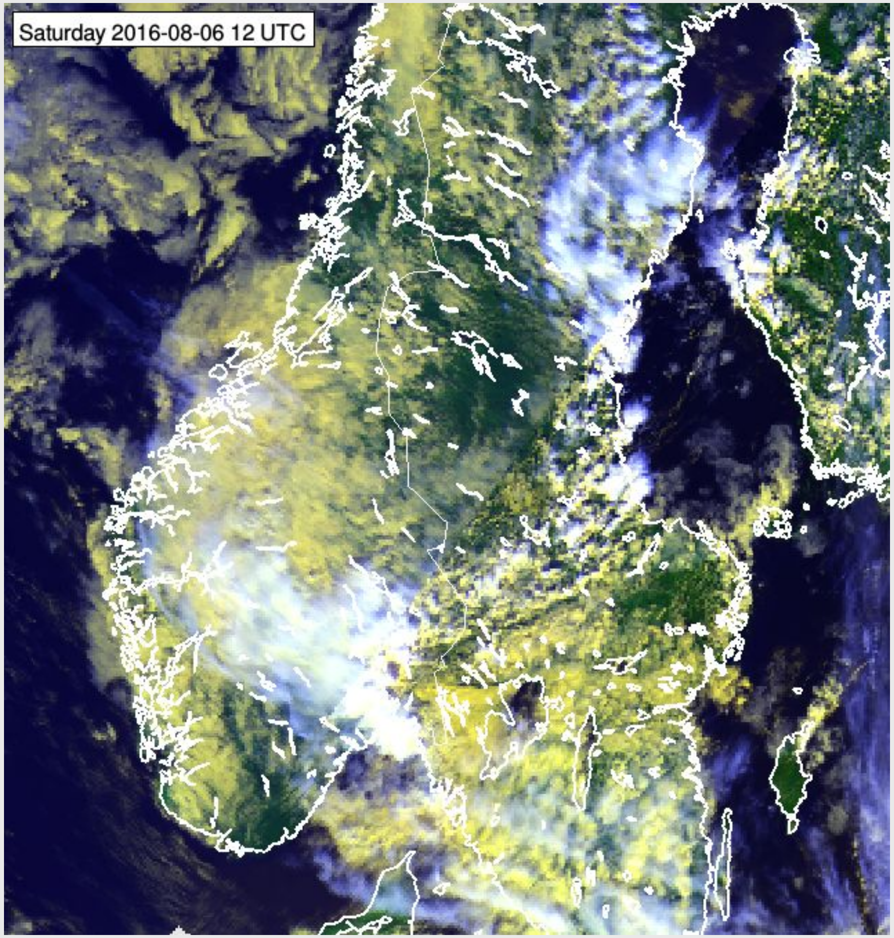
Total-Totals for mid-latitude continental summer convection





Mid latitude continental summer: max values of 55 to 60 K
Weak definition, not unique to areas of deep convection

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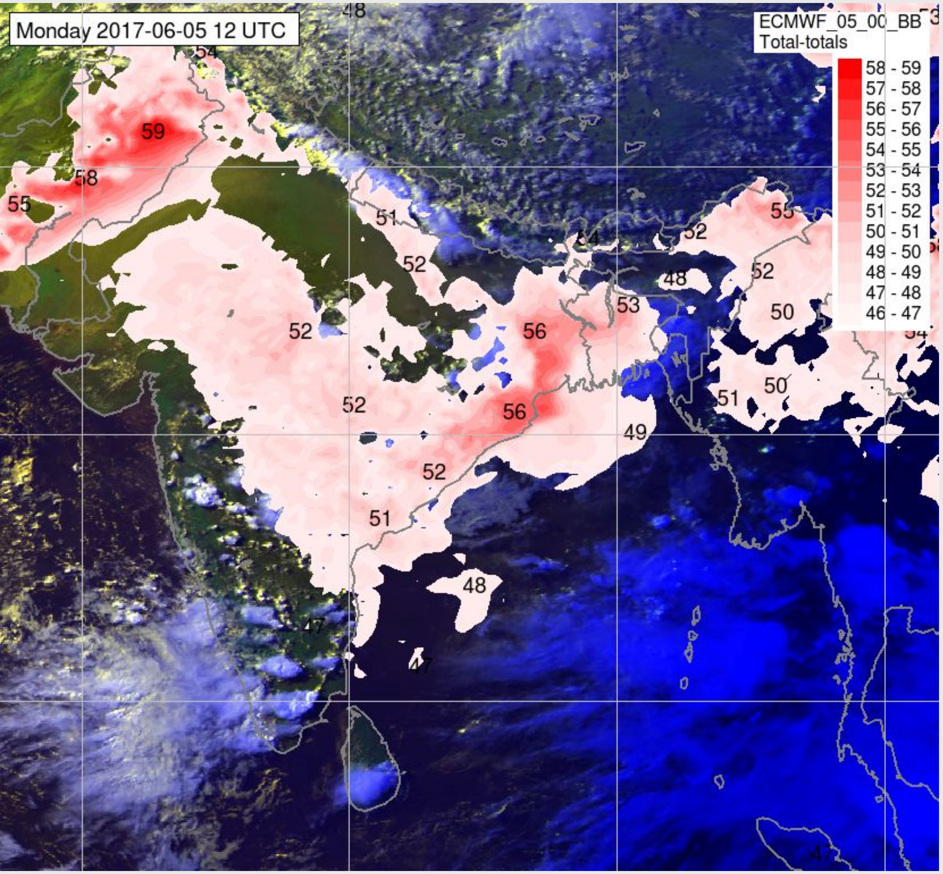
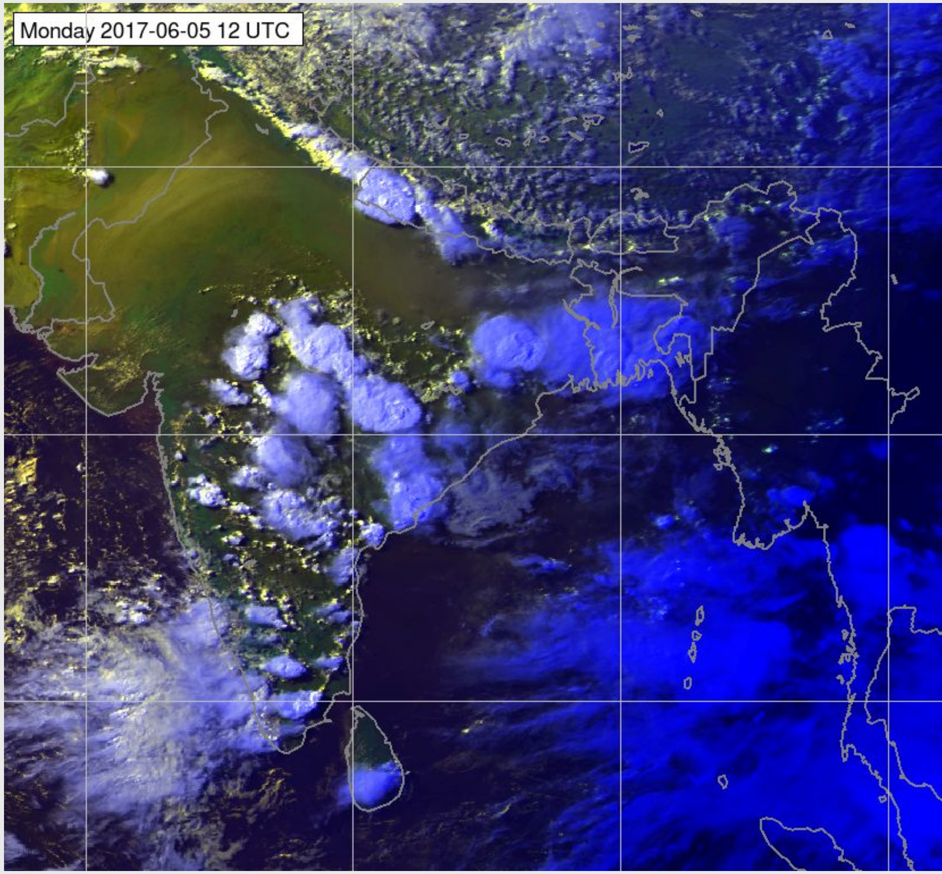
Total-Totals for Tropical pre-monsoon





Tropical pre-monsoon: values of 50 to 60 K

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The Showalter / Lifted index

Showalter / Lifted index

Showalter Index $= T_{p850} - T_{500}$ T_p = parcel temperature

Lifted Index $= T_{p950} - T_{500}$

- Basic tool for describing static instability up to 500 hPa.
- Showalter most common in mid latitudes, is unaffected by inversion in the PBL.
- Lifted index good in tropical regions with warm and humid conditions in the PBL (1000 to 850 hPa).
- In the arctic: Frequent surface inversions means that LI is usually less than SI, but otherwise similar.

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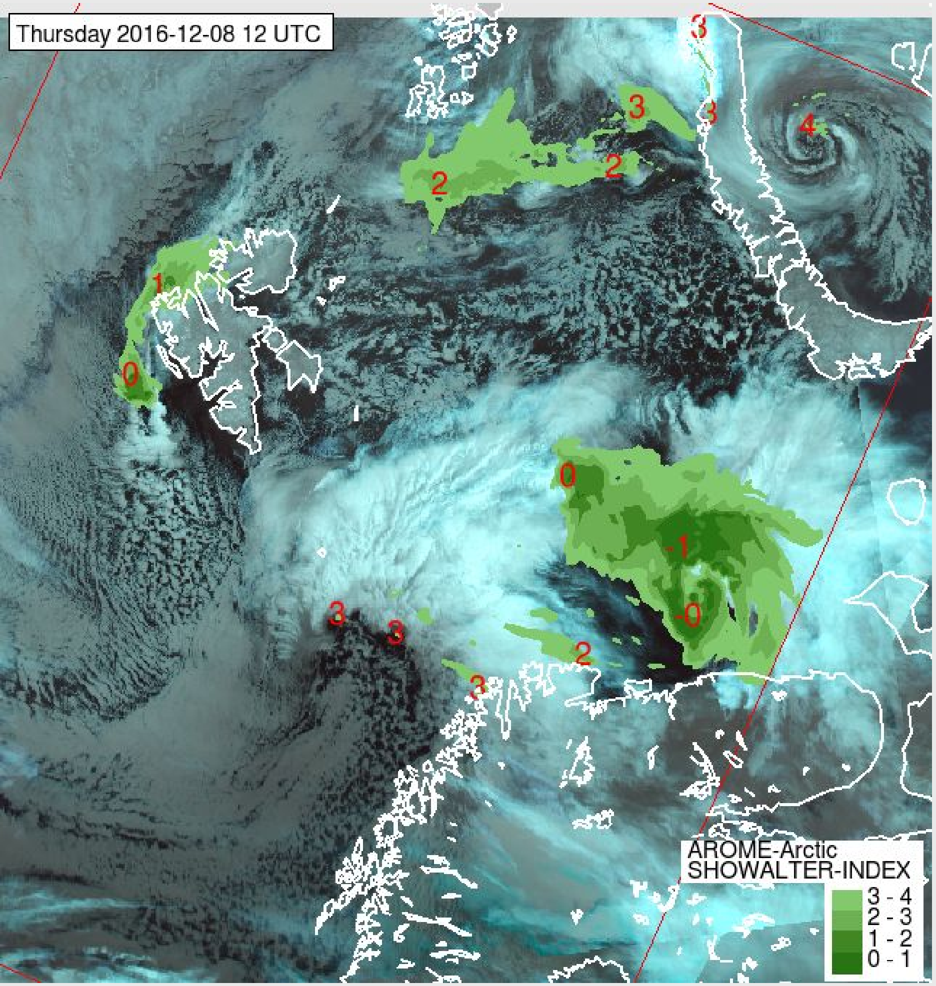
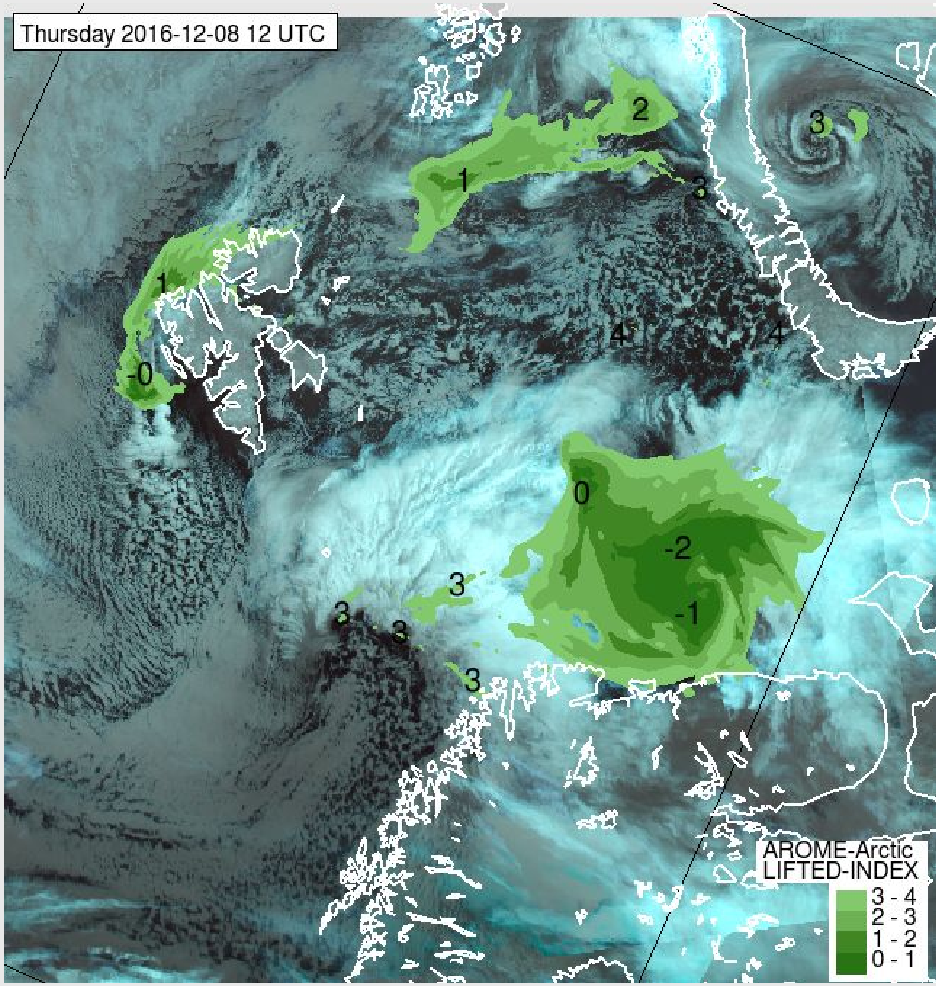
Showalter / Lifted index for polar lows:





Risk of convection if SI or LI < 0.

Marine Arctic: Minimum values of -2 to -3

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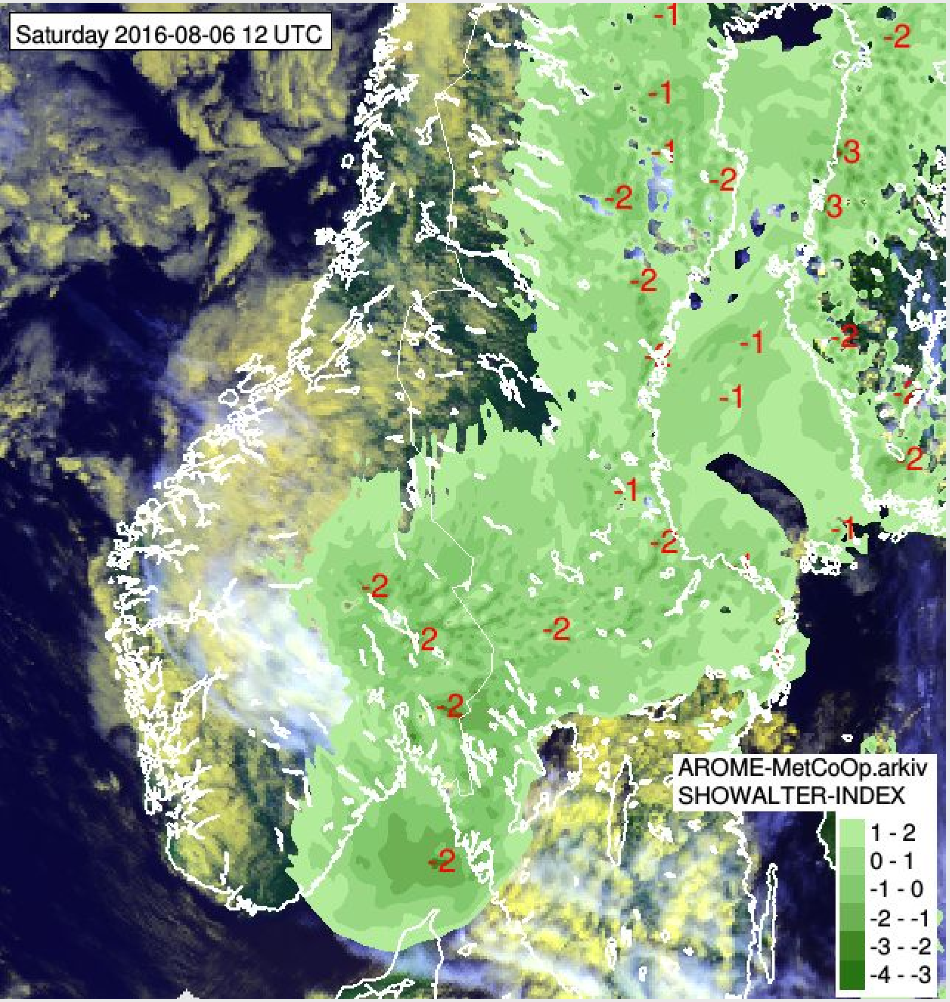
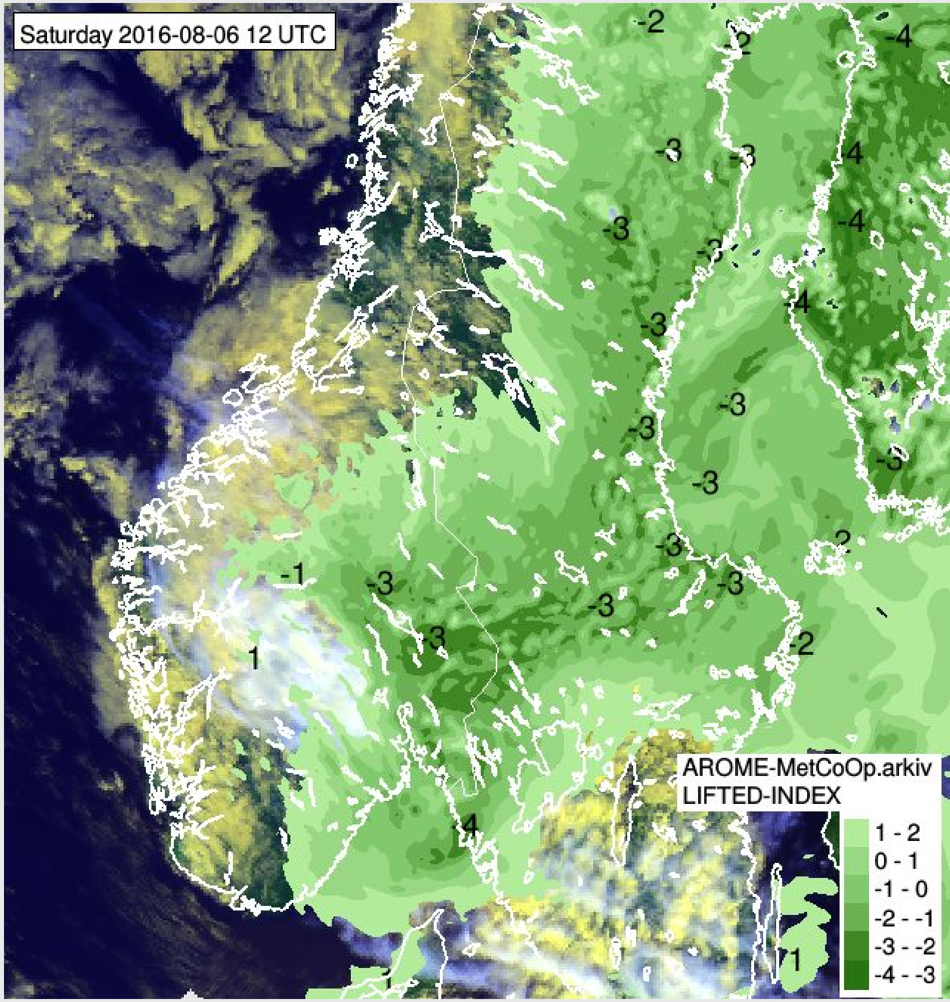
Showalter / Lifted index for mid. latitude summer continental convection:





Risk of convection if SI or LI < 0.

Mid latitude continental summer: Minimum values of -2 to -4

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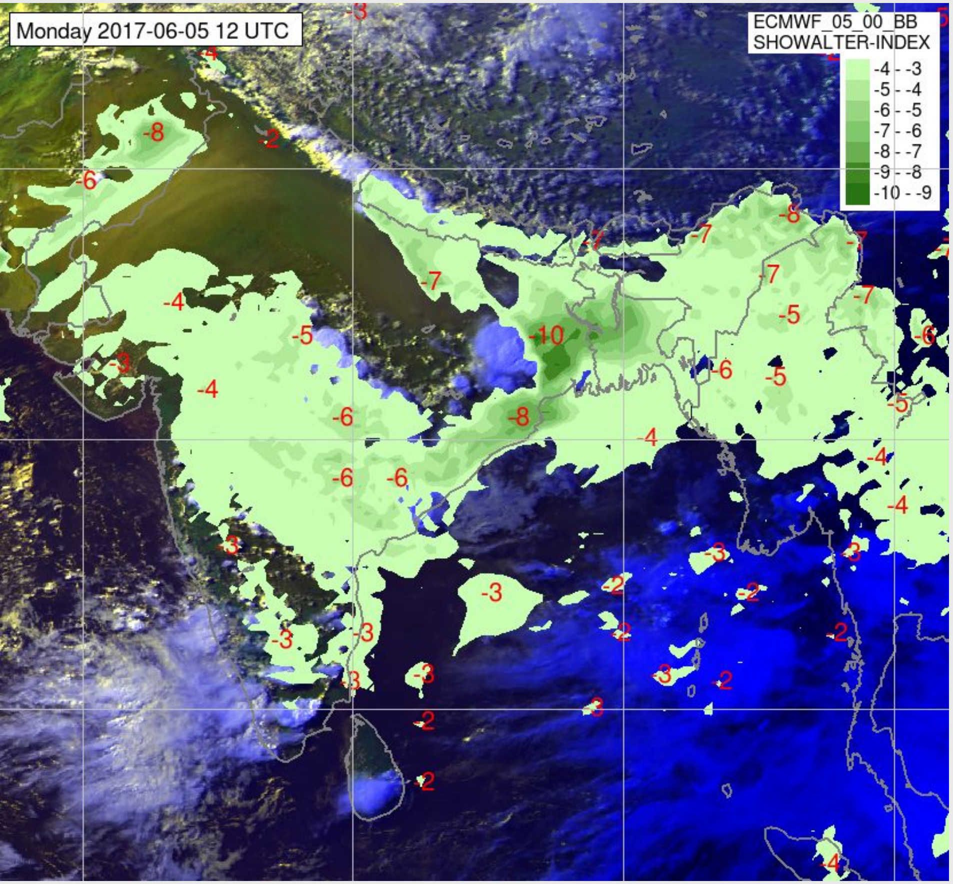
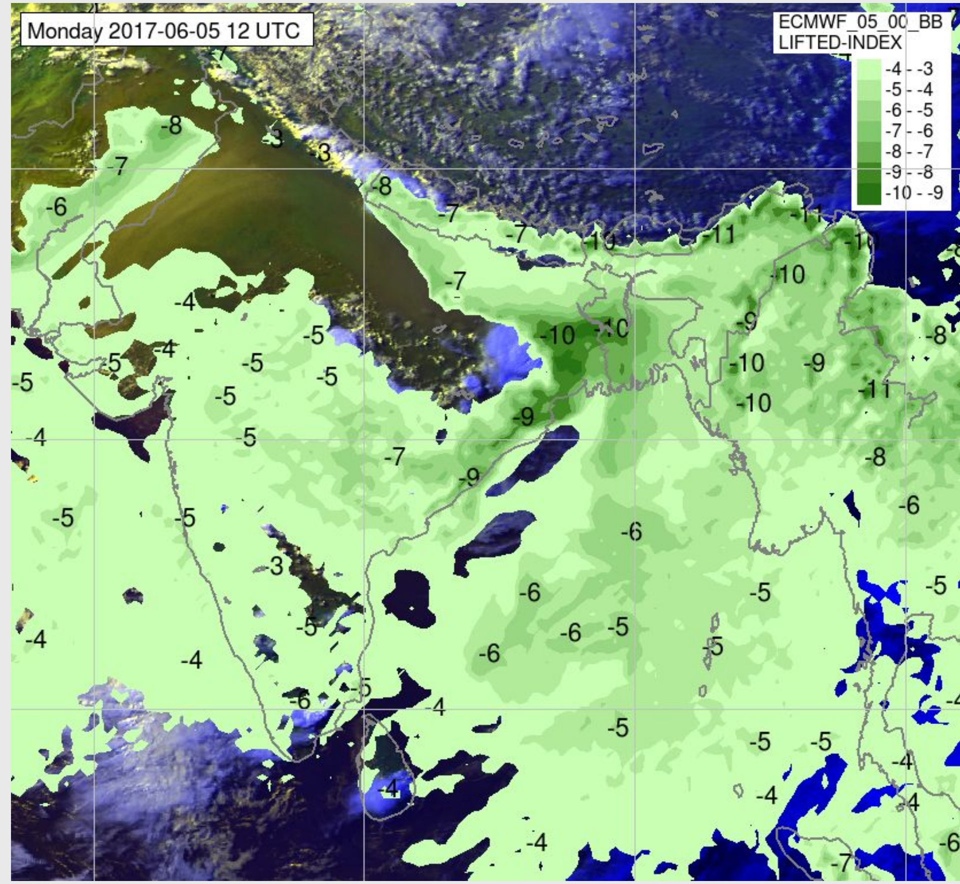
Showalter/Lifted index for tropical pre-monsoon





Risk of convection if SI or LI < 0.
Tropical pre-monoon: Min values -4 to -12
Showater better over sea.

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Summary:

- Several convection indexes exist and are widely used in the Tropics, at mid-latitudes and in the Arctic. Which one to use is often a matter of preference.
- Values differ according to location and season, and deterministic indexes are used locally with different thresholds. These can be normalized against model climate.
- Some indexes, like the Lifted Index and the Polar Low Index are effective, but with only local use and relevance.
- The CAPE and the Shear CAPE is currently the only convection index available with EFI on the ecCharts, but the CAPE is not always the best.

⇒ An EFI and SOT for the most common indexes; the K-index, Showalter and Total-Totals would be a welcome addition to the ecCharts.

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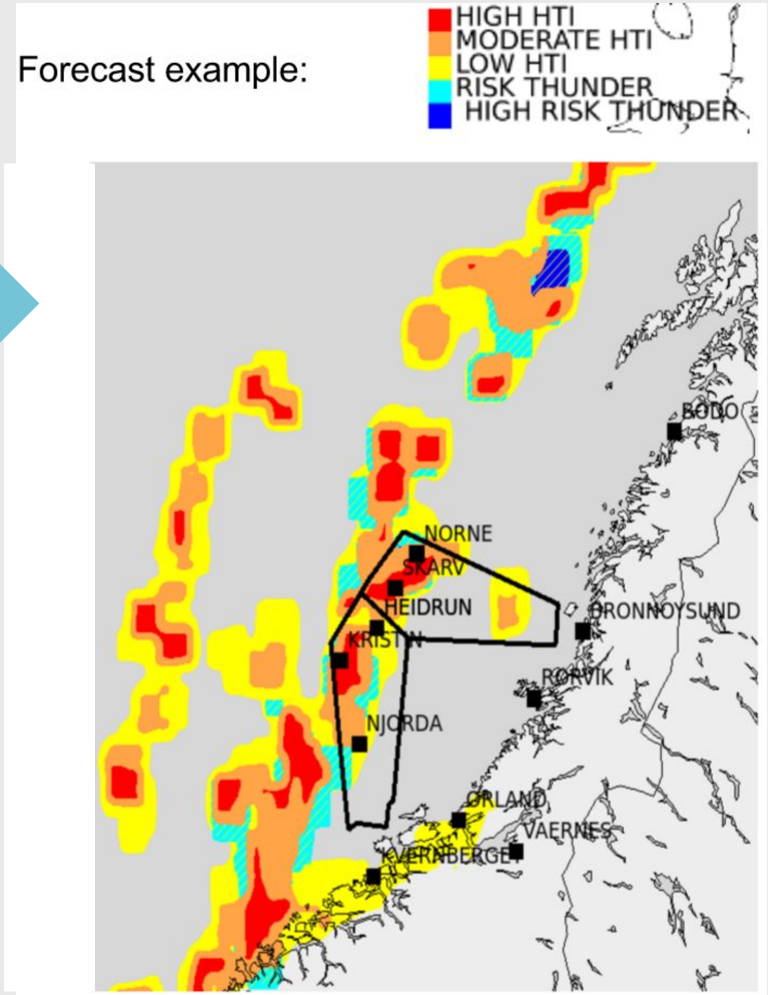
Other indexes should also be considered:

- The Norwegian thunder index:
  - Logistic regression on several indexes
  - Based on CAPE, Showalter and W_{700} with a statistical neighboring method
- Thunder index from the ECMWF
- The Severe WEAther Threat index (SWEAT)
  - Including vertical wind shear

Forecast example:



https://www.ippc.no/ippc/lightningmaps.jsp

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Questions ?

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Key consepts in convection:

Lifting Condensation Level (LCL):

From a given level (A), follow the dry adiabat

From the dew point at same level, follow the line of constant mixing ratio. The intersection of these two are the LCL (B).

The level where a lifted parcel reaches 100 % RH

Level of free convection (LFC):

From the LCL (B), follow the moist adiabat to the intersection with the environment temperature (C).

If the lapse rate of the environment air is greater than the moist adiabat, then this is the LFC

Convective available potential energy (CAPE):

The area above LFC between the moist adiabat and the moist adiabat from LCL

Convective Inhibition (CIN):

The energy that prevents a parcel to be lifted to LFC.

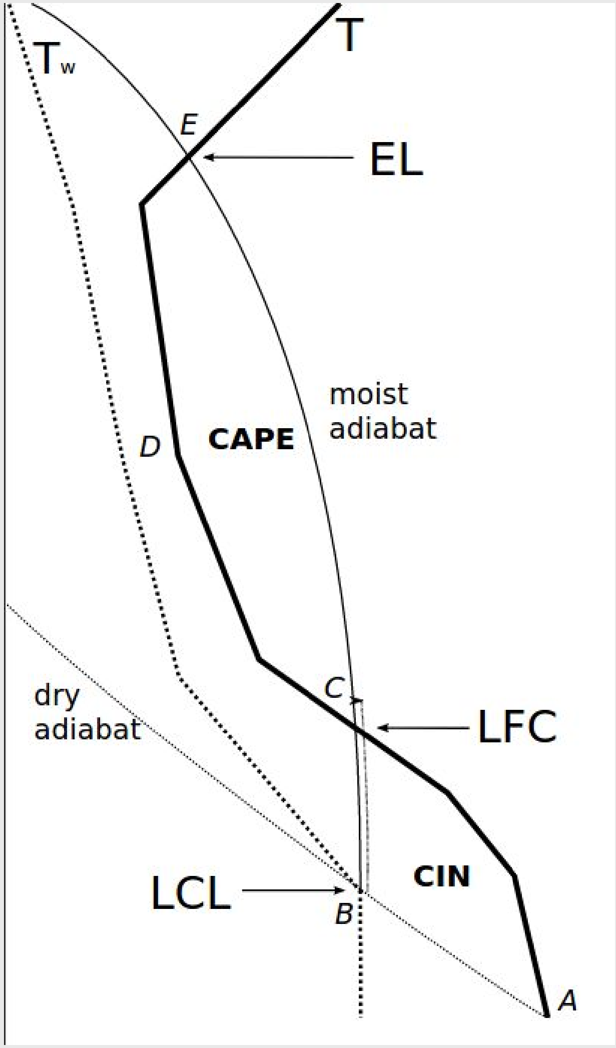

Illustration: Pierre_cb, Grische

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Threshold values for different indexes:

(Tyagi et al. 2010)

Table 4 Threshold values according to the maximum POD, minimum FAR, and best HSS, NSS, and μ for Kolkata

Index	Threshold	POD	FAR	CSI	TSS	HSS	MR	C-NON	BIAS	PC	NSS	μ	Hits	Misses	False	Non event hits
DEW	≥ 9	0.82	0.61	0.36	0.24	0.19	0.18	0.43	2.08	54.81	0.95	0.95	53	12	82	61
BI	≥ 98	0.26	0.64	0.18	0.05	0.06	0.74	0.79	0.73	63.05	0.44	0.62	16	46	29	112
HI	≤ 45	0.75	0.63	0.33	0.18	0.14	0.25	0.43	2.02	52.68	0.86	0.89	48	16	81	60
RH	≥ 45	0.72	0.64	0.32	0.14	0.11	0.28	0.42	2.00	51.44	0.75	0.76	47	18	83	60
LI	≤ -3	0.81	0.66	0.31	0.12	0.08	0.19	0.31	2.38	46.12	0.43	0.40	51	12	99	44
SWEAT	≥ 180	0.80	0.57	0.39	0.32	0.26	0.20	0.52	1.85	60.68	0.88	0.88	52	13	68	73
KI	≥ 24	0.85	0.60	0.37	0.27	0.21	0.15	0.43	2.11	55.77	0.98	0.98	55	10	82	61
TTI	≥ 46	0.68	0.60	0.33	0.21	0.17	0.32	0.53	1.71	57.69	0.67	0.64	44	21	67	76
CAPE	$\geq 1{,}000$	0.61	0.65	0.29	0.12	0.10	0.39	0.51	1.72	53.85	0.59	0.61	39	25	71	73
BRN	≥ 41	0.76	0.65	0.31	0.12	0.09	0.24	0.36	2.19	48.26	0.90	0.90	47	15	89	50
DCI	≥ 34	0.80	0.61	0.35	0.23	0.18	0.20	0.43	2.06	54.37	0.93	0.92	51	13	81	61

Threshold values (Tyagi et al. 2009)

Table 5 Threshold values of the thermodynamic indices reported in literature along with the suggested values emanating from the present study

Name of the index	Literature value	Present study
Dew point temperature at 850 hPa (°C)	>13 (Dhawan et al. 2008)	≥9
Boyden index	≥94 (Boyden 1963)	≥98
	>102.5 (Mukhopadhyay et al. 2003)	
	>94.6 (Haklander and Delden 2003)	
Humidity index	≤30 (Litynska et al. 1976)	≤45
	<19 (Mukhopadhyay et al. 2003)	
Relative humidity at 700 hPa (%)	>60 (Dhawan et al. 2008)	≥45
Lifted index (*K*)	≤−0.22 (Kunz 2007)	≤−3
	<−3 (Ackerman and Knox, online documentation)	
SWEAT	>300 (Schulz 1989)	≥180
	≥134 (Haklander and Delden 2003)	
K Index (°C)	≥20 (Peppler and Lamb 1989; Andersson et al. 1989)	≥24
	≥21 (Haklander and Delden 2003)	
	≥26.1 (Kunz 2007)	
	>30 (Ackerman and Knox, online documentation)	
Total totals index	≥46.7 (Haklander and Delden 2003)	≥46
	≥48.1 (Kunz 2007)	
	>48 (Ackerman and Knox, online documentation)	
Convective available potential energy (CAPE) ($J\ kg^{-1}$)	>896.8 (Mukhopadhyay et al. 2003)	≥1,000
Bulk Richardson number (BRN)	>40 (Revering, online documentation)	≥41
Deep convection index (*K*)	≥6.8 (Haklander and Delden 2003)	≥34

References:

Bhishma Tyagi, V. Naresh Krishna, A. N. V. Satyanarayana:

A study of thermodynamic indices in forecasting pre-monsoon thunderstorms over Kolkata during STORM pilot phase 2006 - 2008

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