http://www.essl.org/

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High Impact Weather Event Week

A recipe for Thunderstorms

For EUMETRAIN

Speaker: Helge Tuschy

http://www.estofex.org/

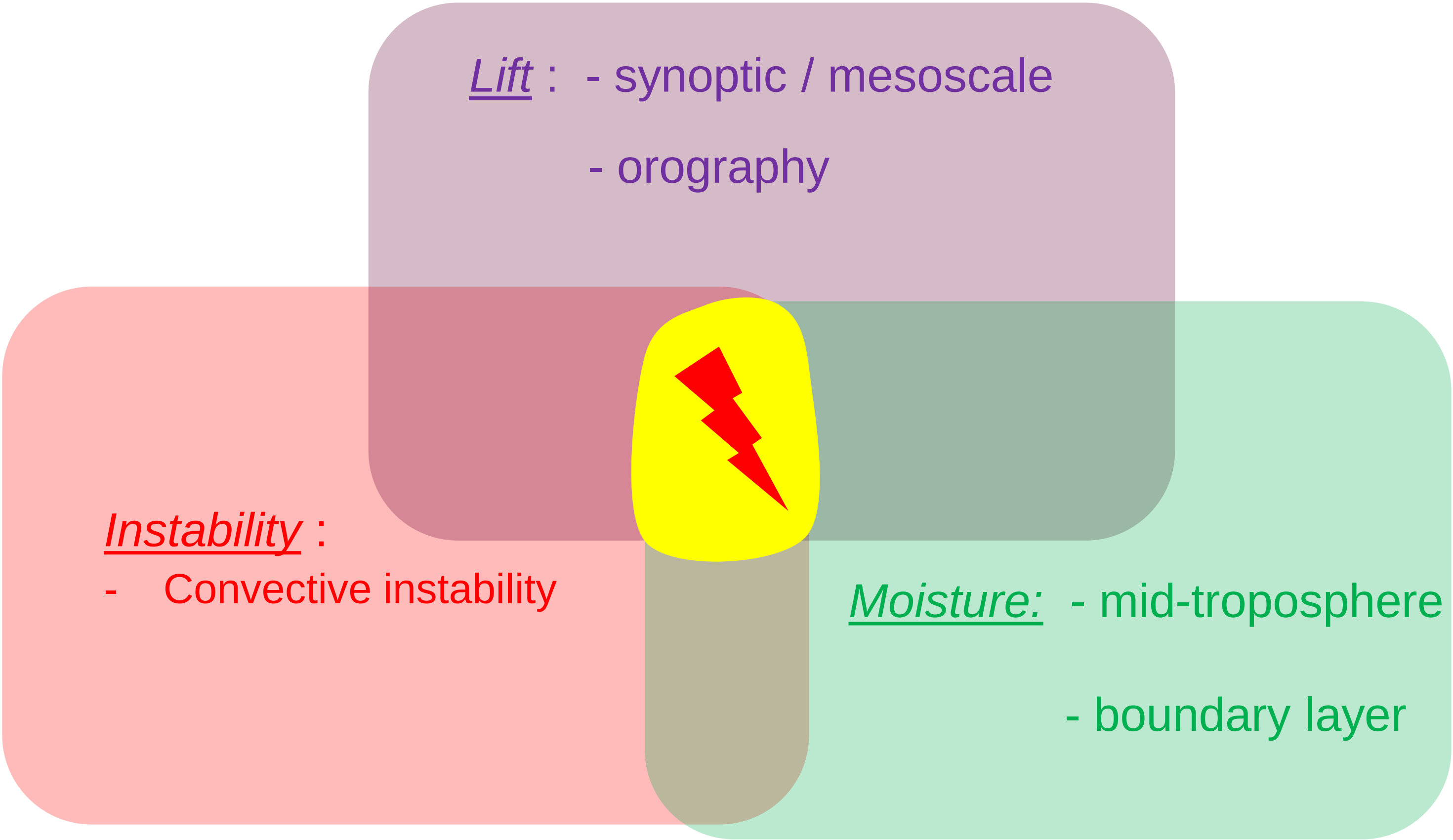
Short vita

- studied Meteorology / Geophysics at the Leopold-Franzens University of Innsbruck, Austria
- 2002, 2007 internships National Weather Service Amarillo, Texas
- 2004 and 2011 internships Storm Prediction Center (SPC)
- joined Hazardous Weather Testbeds in 2012 and 2013
- talks: ECSS, ICAM, media …
- forecaster at ESTOFEX / member of ESSL
- Since 2010 forecaster at DWD

The outline

- Ingredients-based forecasting method
- Hodograph
- Excessive rainfall with deep moist convection
- ESTOFEX – a very short overview

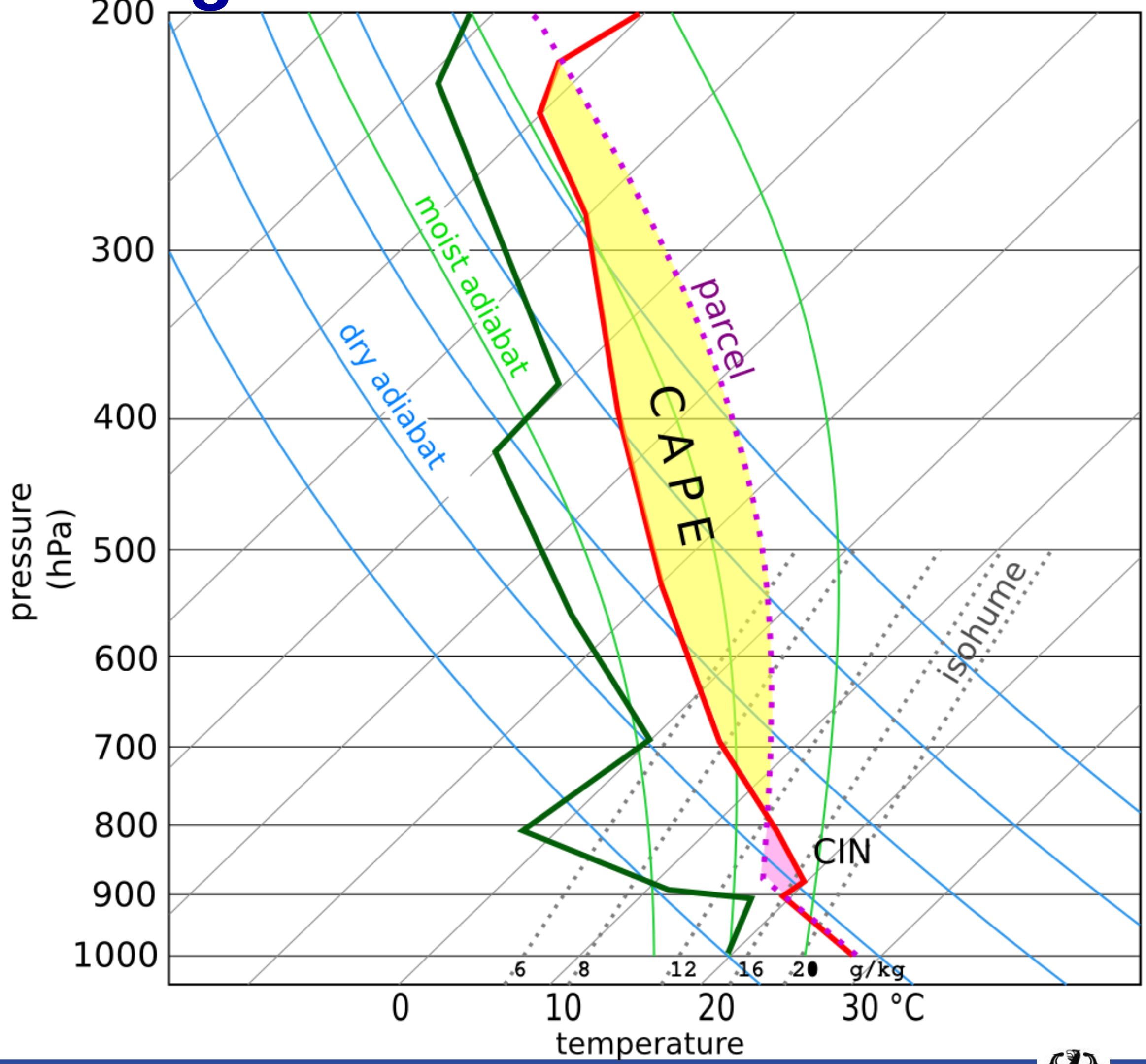
Basic ingredients for thunderstorms



Scientific forecasting of convection

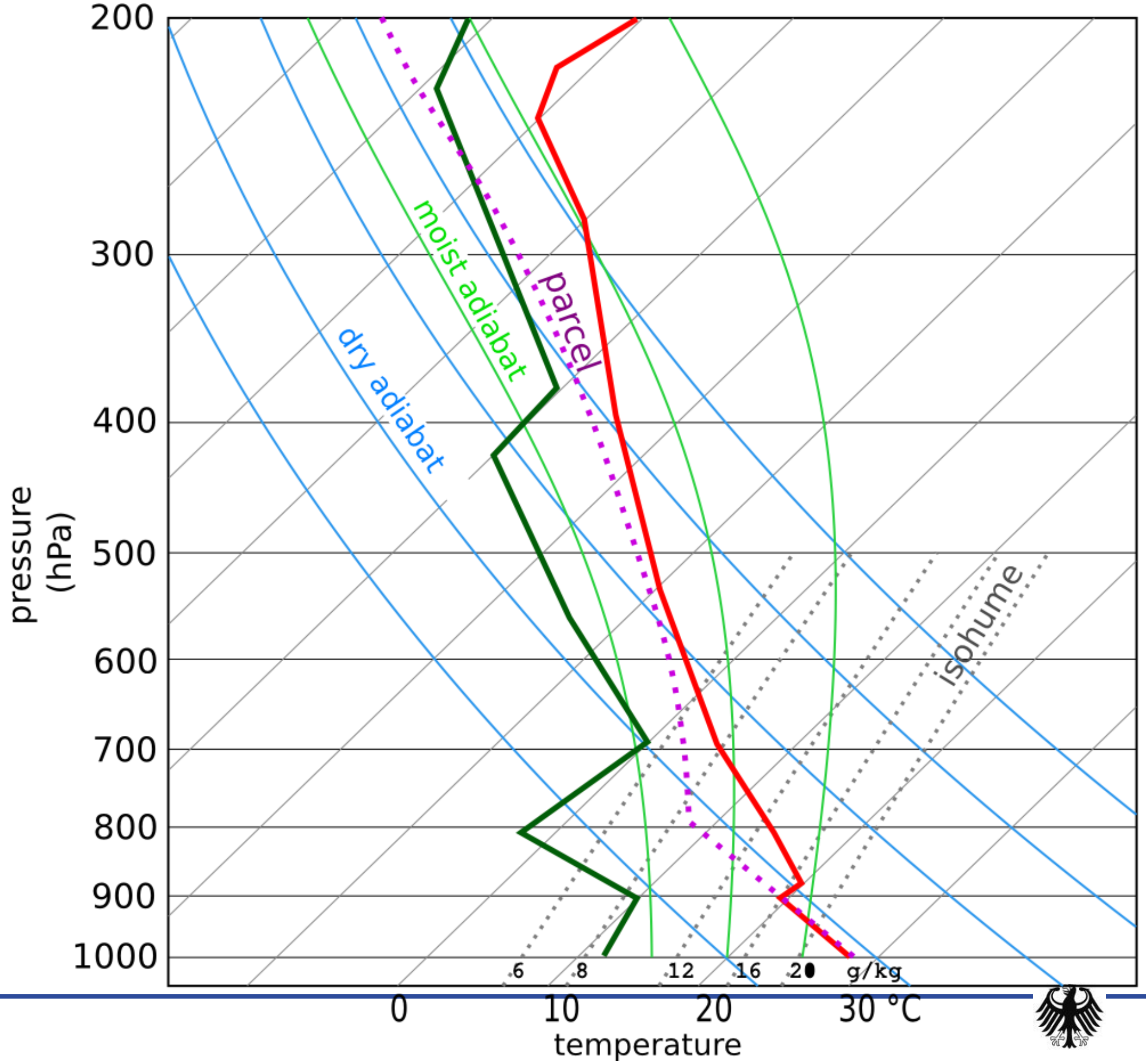
- A buoyant parcel means that the parcel has CAPE
- CAPE requires:

1. steep lapse rates
2. low-level moisture



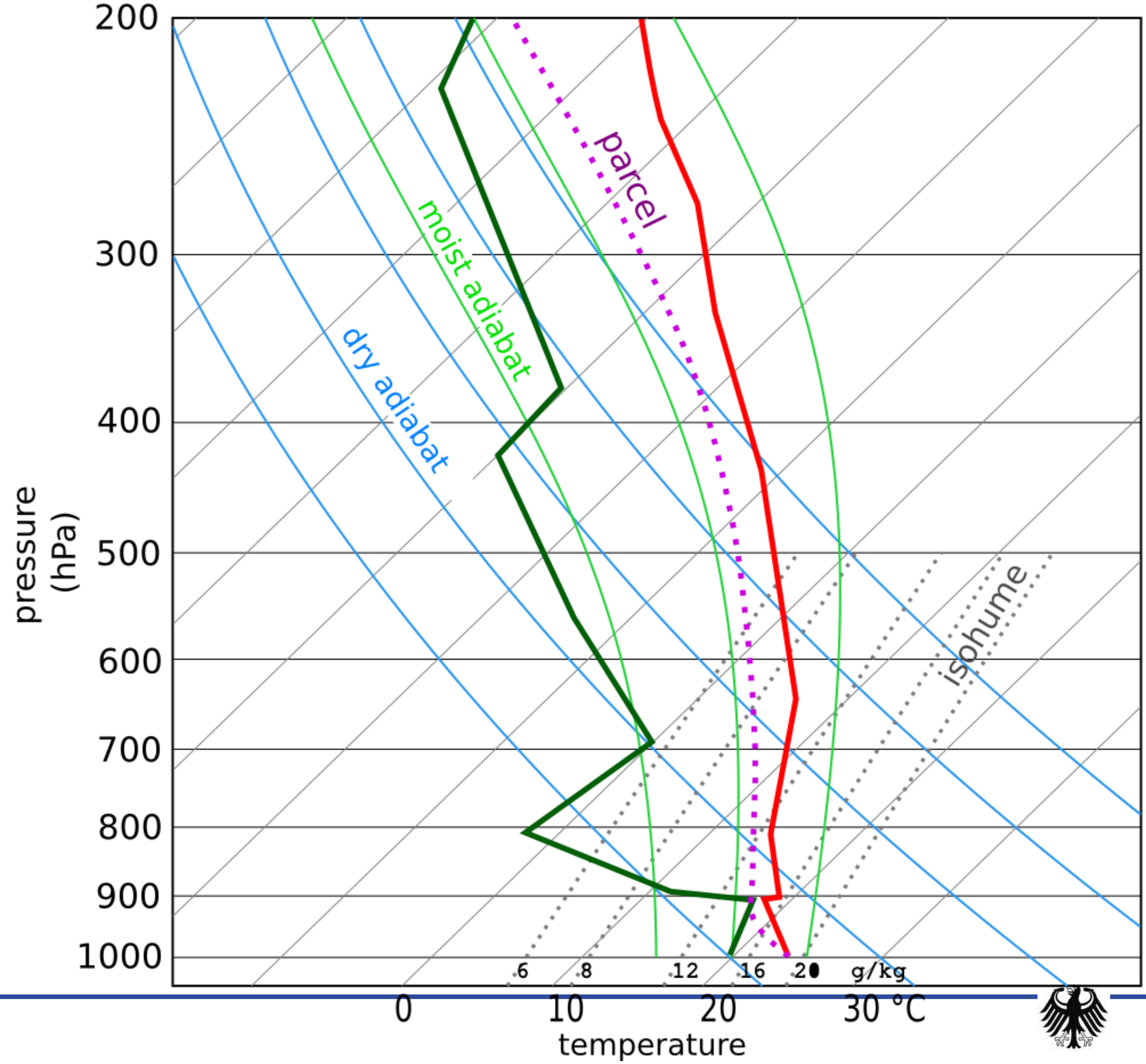
Scientific forecasting of convection

No moisture:
no CAPE



Scientific forecasting of convection

No lapse rates:
no CAPE either



Scientific forecasting of convection

In the atmosphere, low-level moisture and lapse rates evolve relatively independently:

One can track **low-level moisture**
- travels with *low-level winds*
- increases through evaporation
- decreases by condensation or mixing with drier air.

One can track **lapse rates**:
- conserved in geostrophic flow, travelling with *low to mid-level winds*
- modified slowly(!) by large-scale ascent and subsidence
- and rapidly by diabatic processes (heating, radiational cooling)

In contrast: **CAPE**, in model output just suddenly pop up.

@ EUMETSAT

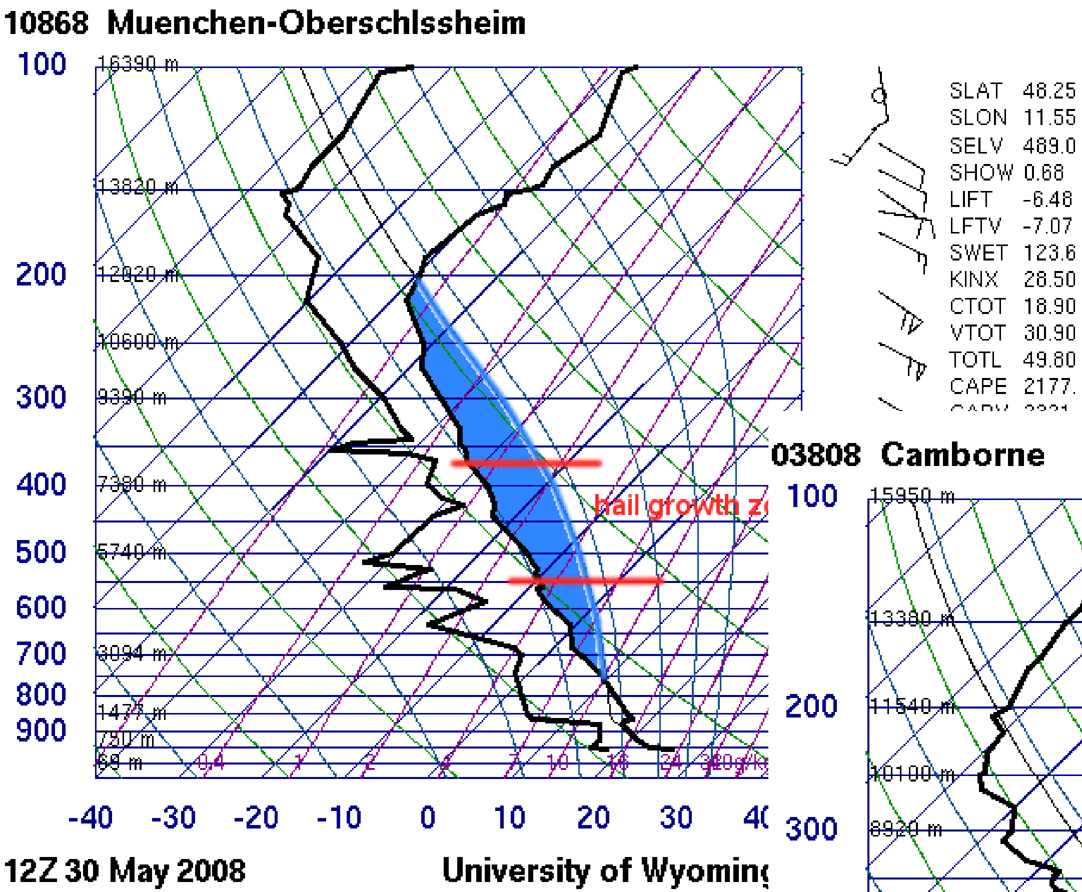
Convective forecast parameters

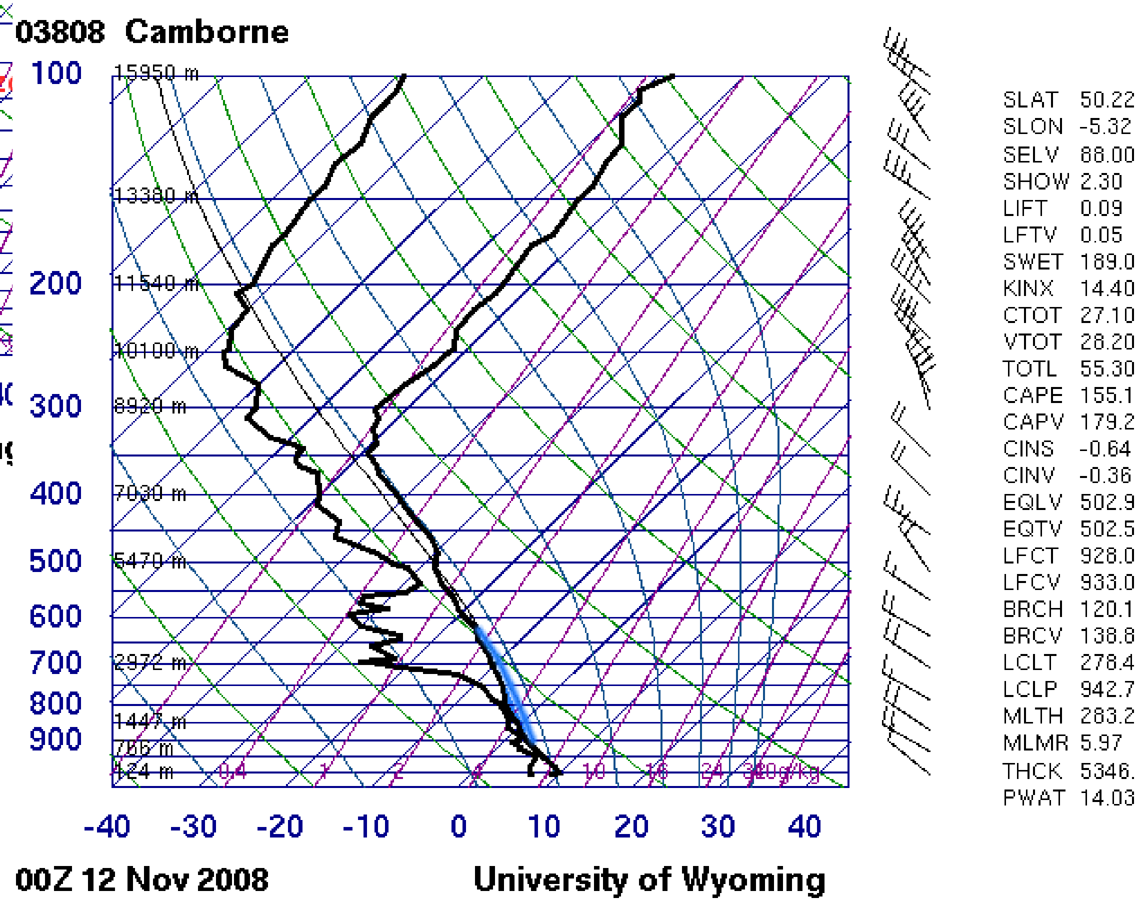
CAPE

MUCAPE:
Total amount of potential energy available to the most unstable parcel of air found within the lowest 300-mb of the atmosphere.

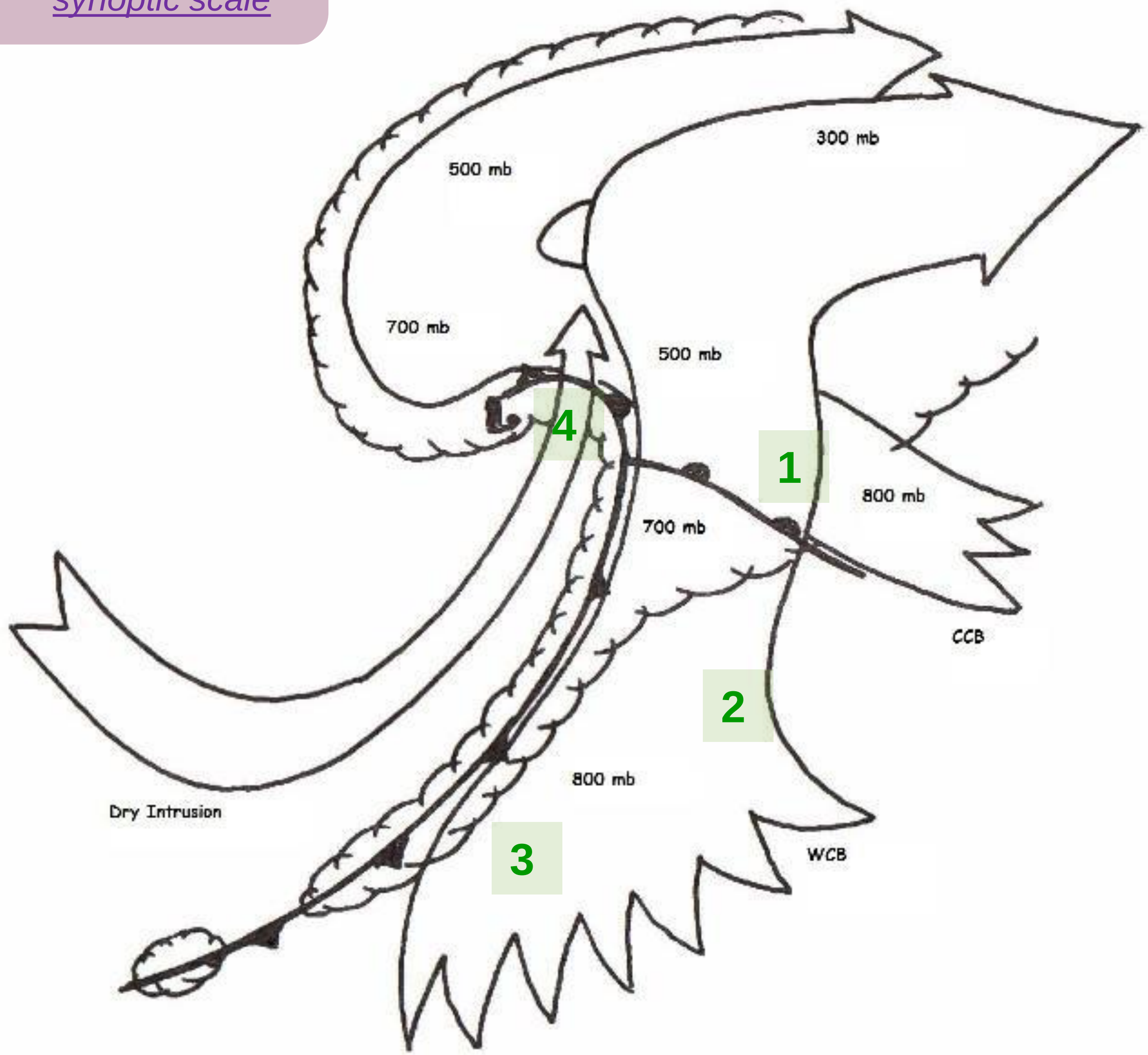
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

LLCAPE vs. mid-level CAPE





Lift
synoptic scale



Carlson (1980)

1 Elevated thunderstorms

2 Warm sector convection

3 Cold front

4 Potential instability build-up along cloud head

Lift

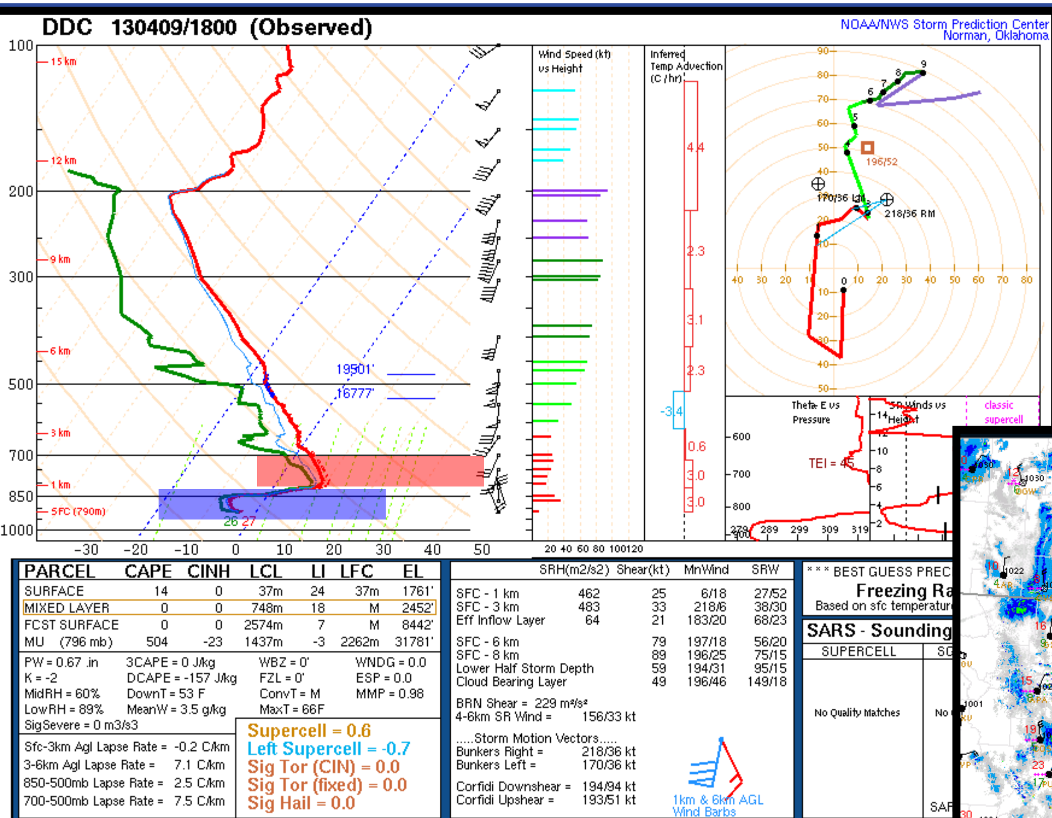
synoptic scale

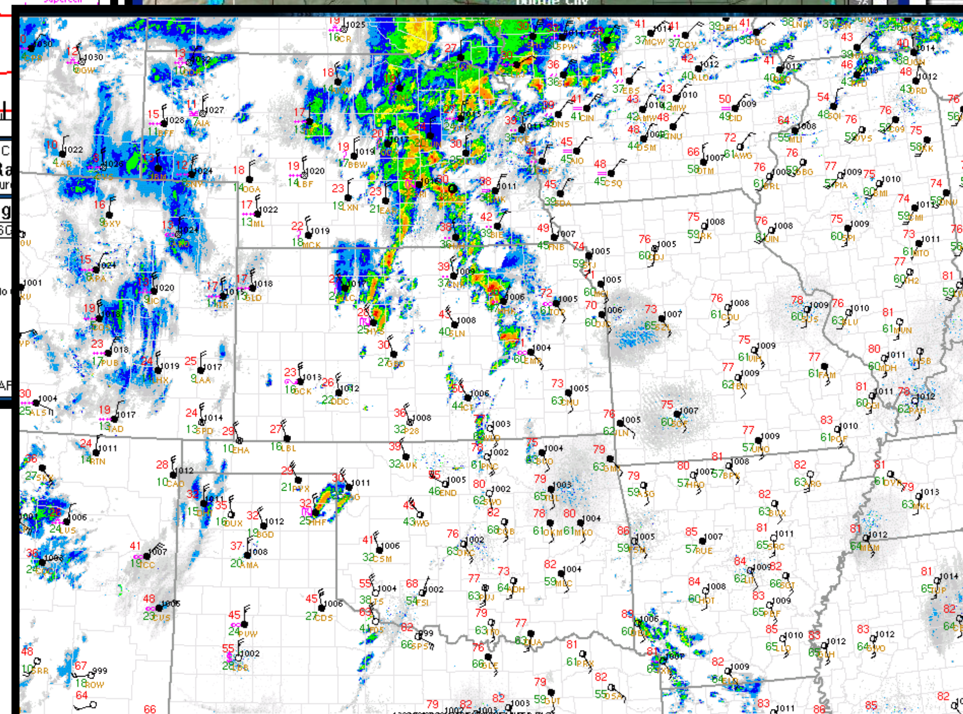
Deutscher Wetterdienst

Wetter und Klima aus einer Hand

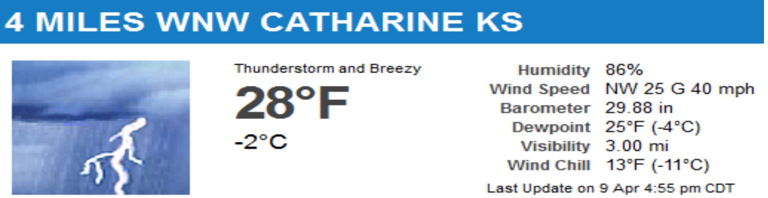
DWD

Elevated instability (e.g. north of warm front)





Quelle:
http://www.spc.noaa.gov/



Lift

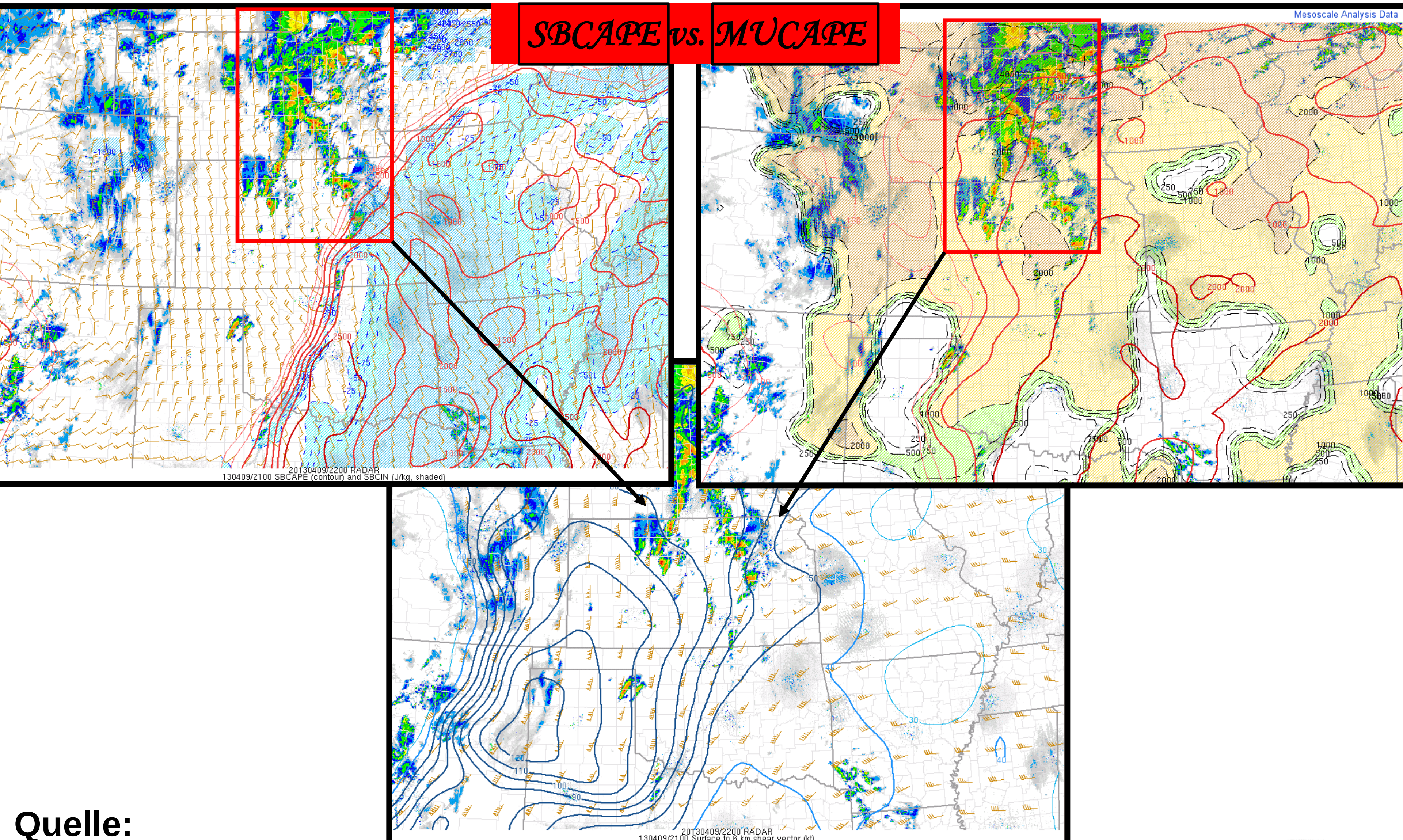
synoptic scale

Deutscher Wetterdienst

Wetter und Klima aus einer Hand

1

SBCAPE vs. MUCAPE

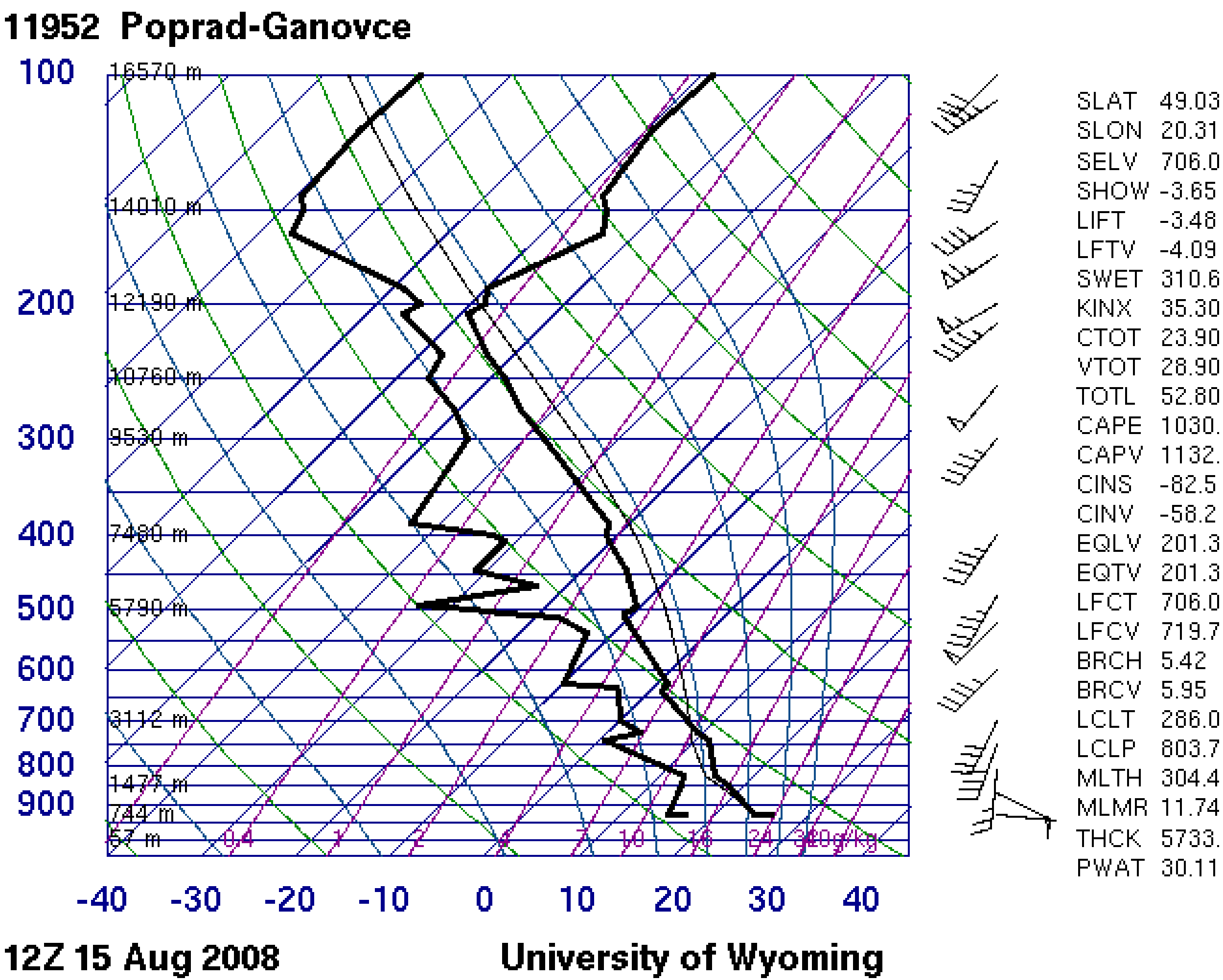


Quelle:

http://www.spc.noaa.gov/

Convection in warm sector

Tornado outbreak in Poland, 15th August 2008



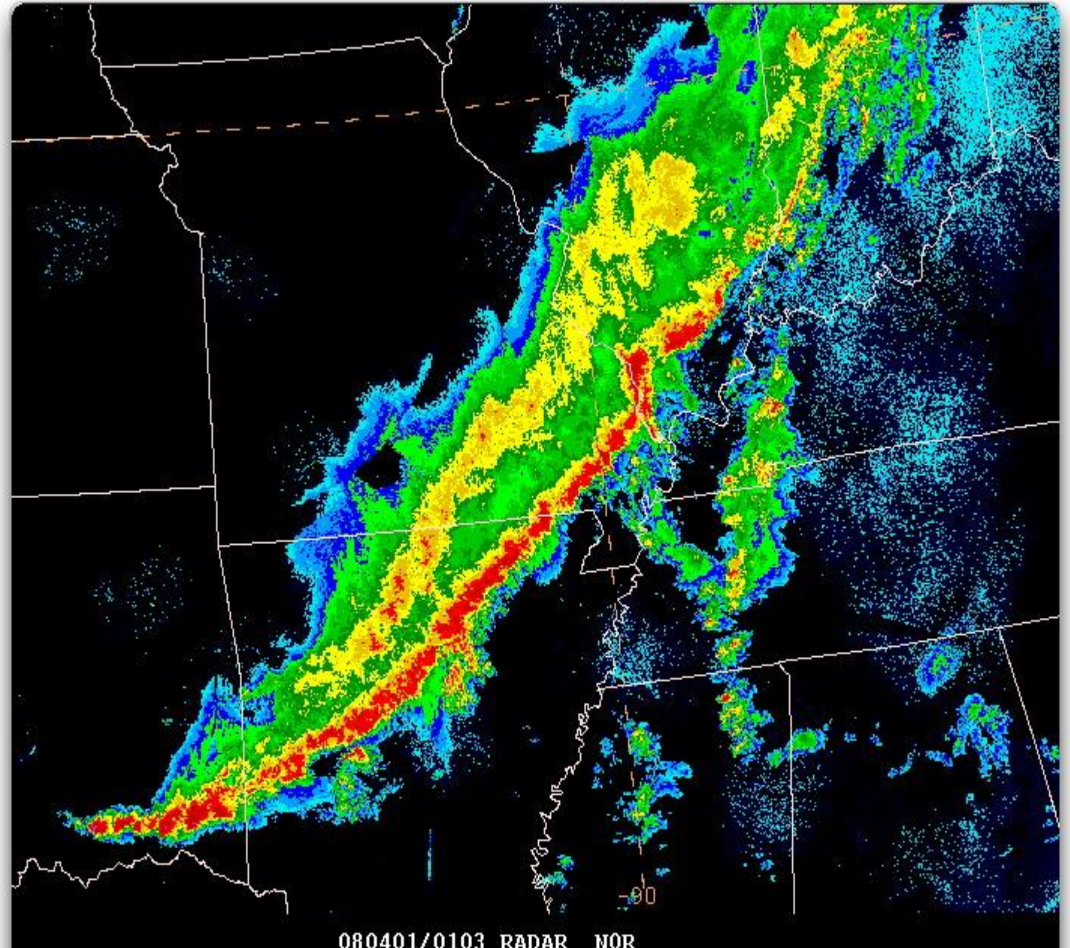
Break the cap:

-**Mesoscale forcing** (e.g. convergent boundary layer flow)

-Increase of **low-level moisture** (advection, evapotranspiration)

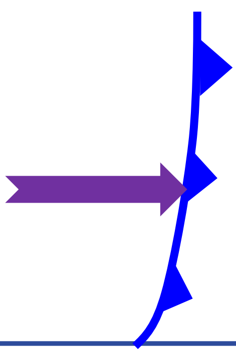
-**Diabatic heating** (cloud cover in warm sector)

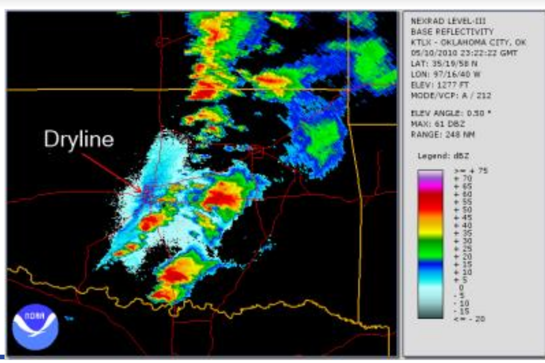
-**Synoptic lift** (short wave?)



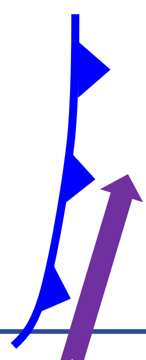
@ NWS Source: @ http://wattsupwiththat.com

- Strong cross-frontal circulation often results in widespread initiation
- Closer to best forcing of mid/upper-level trough
- Orientation of the shear vector is important for degree of line-up of thunderstorms:

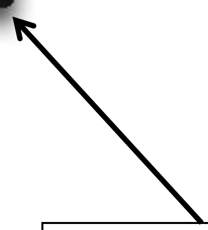




@ www.wunderground.com



e.g. 0-6 km shear vector



60-70 kt SW-erly 0-6 km shear vector

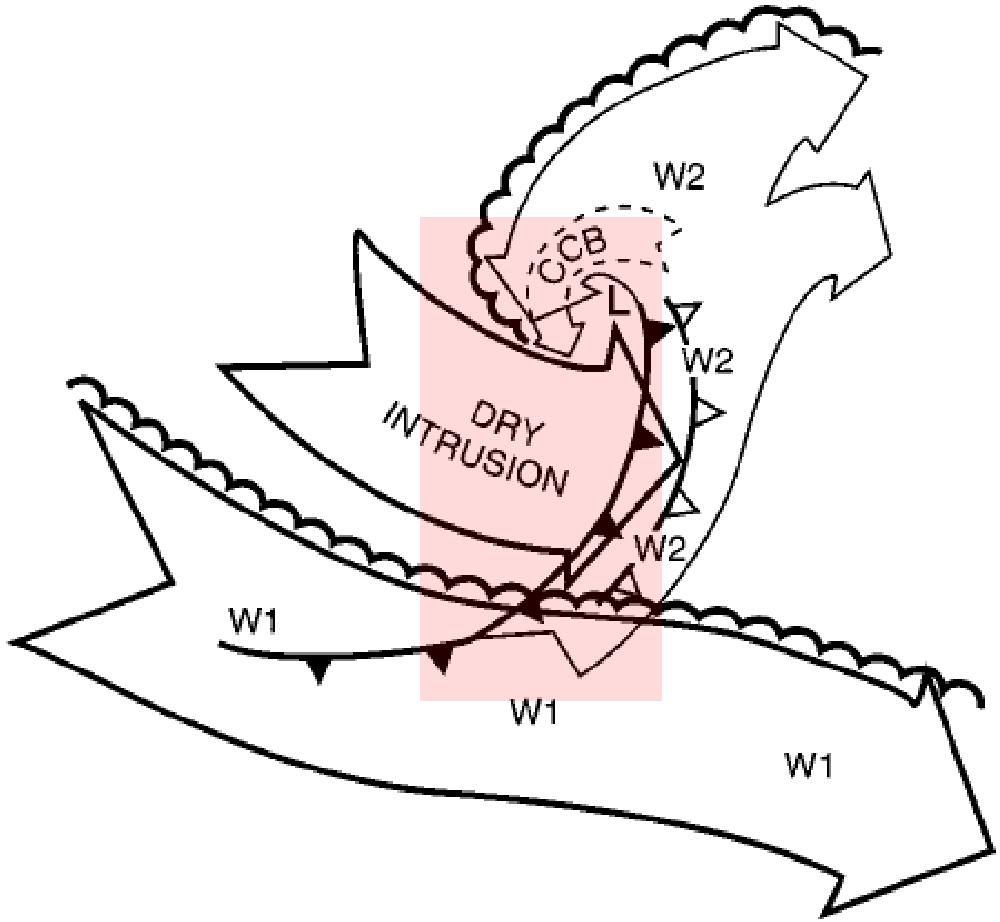
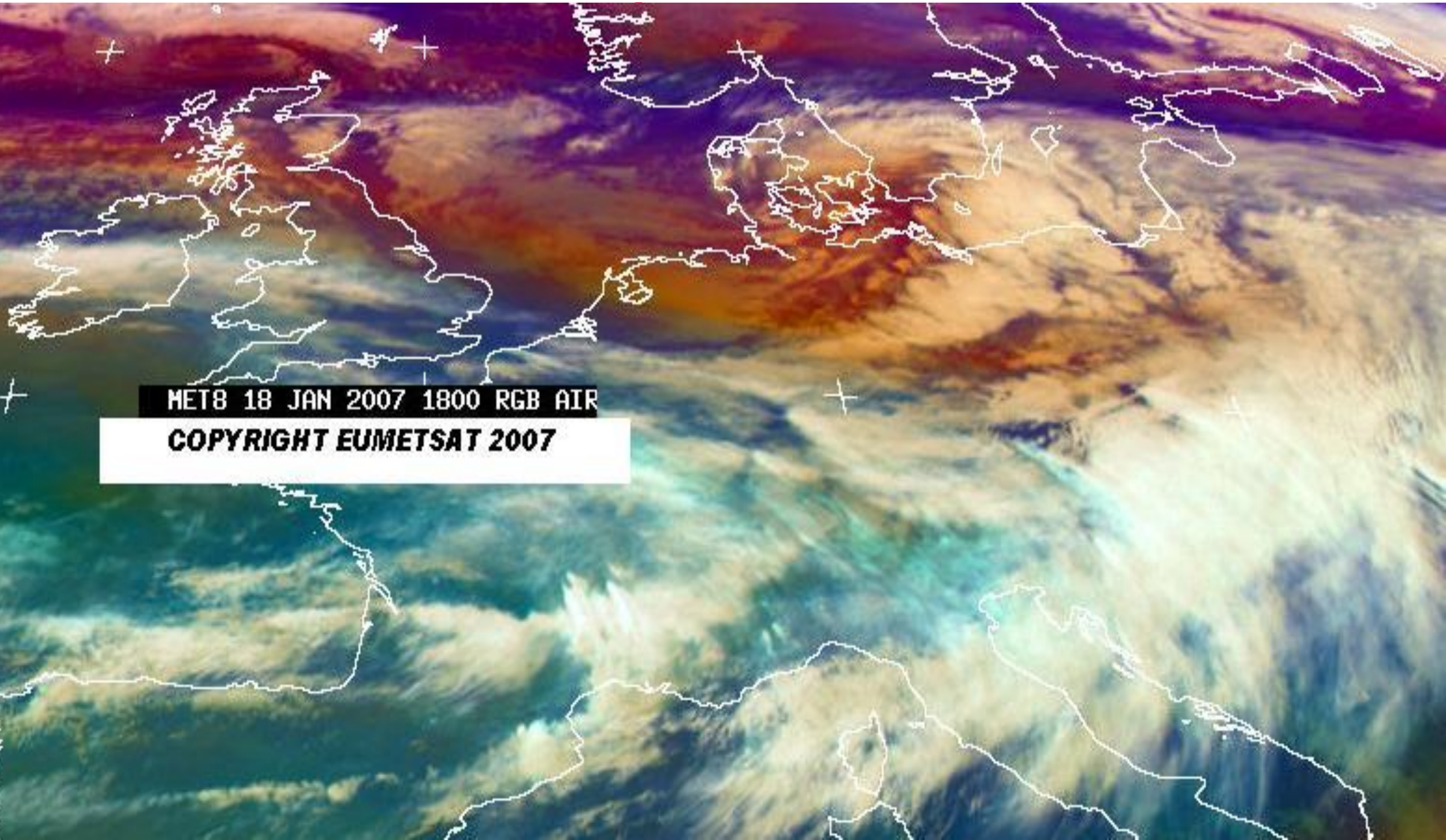


Figure 5. *Conceptual model showing system-relative airflow associated with the diffluent-flow type of cyclogenesis. The arrows labelled W1 and W2 are the primary and secondary warm conveyor belts. The dashed arrow labelled CCB is a cold conveyor belt. The dry intrusion is seen to overrun W2 over a broad region to produce an upper cold front at its leading edge. (After Young, 1994.)*

Kyrill 18/19.01.2007

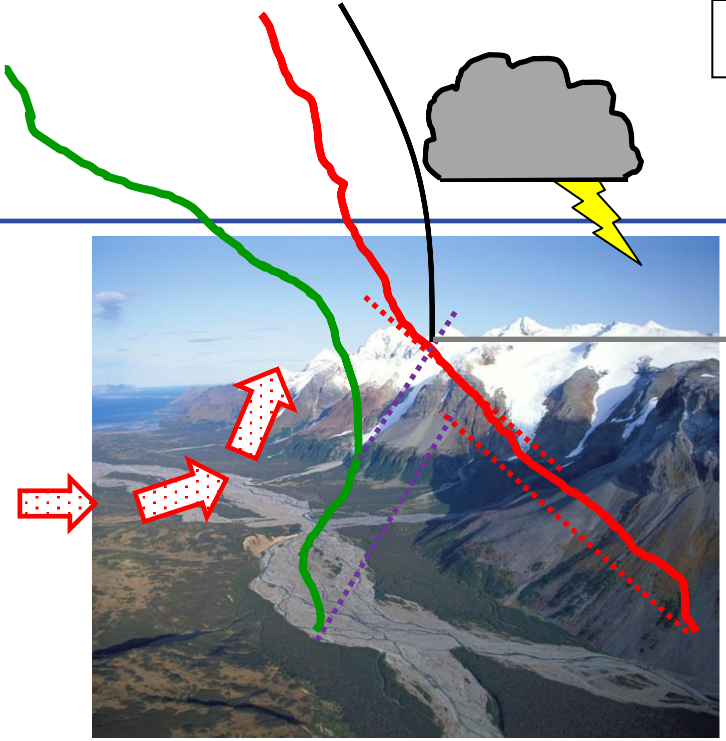


Lift

mesoscale

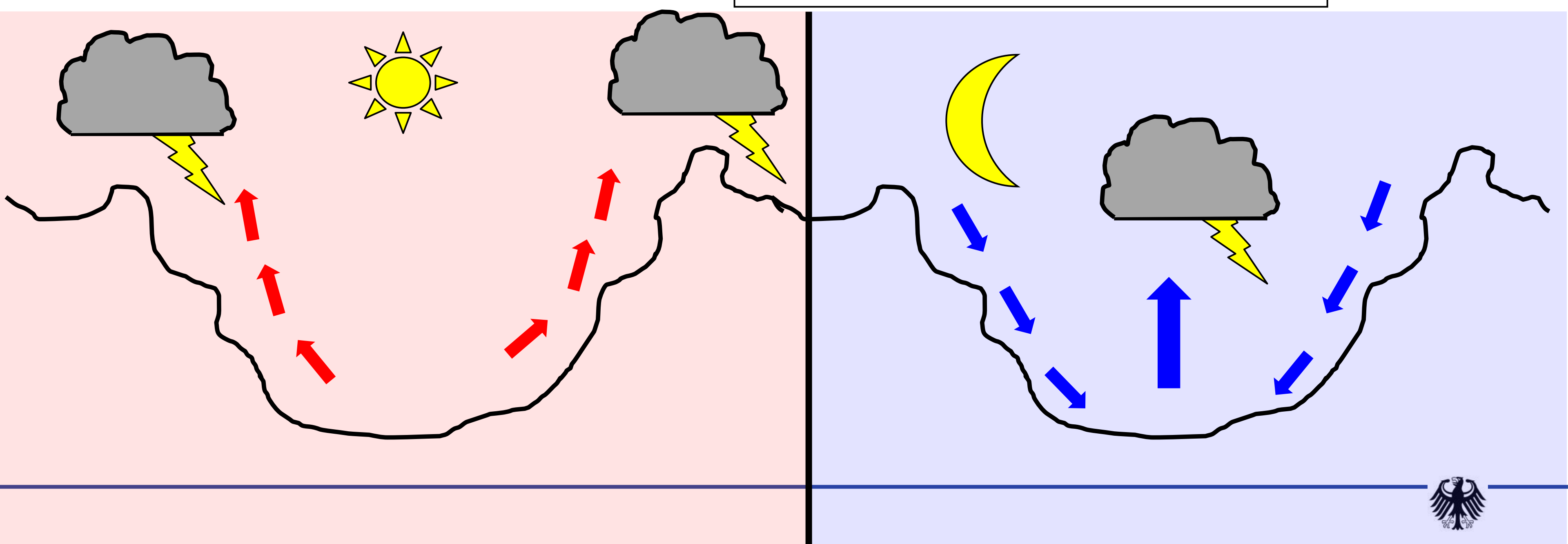
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Orographic lift

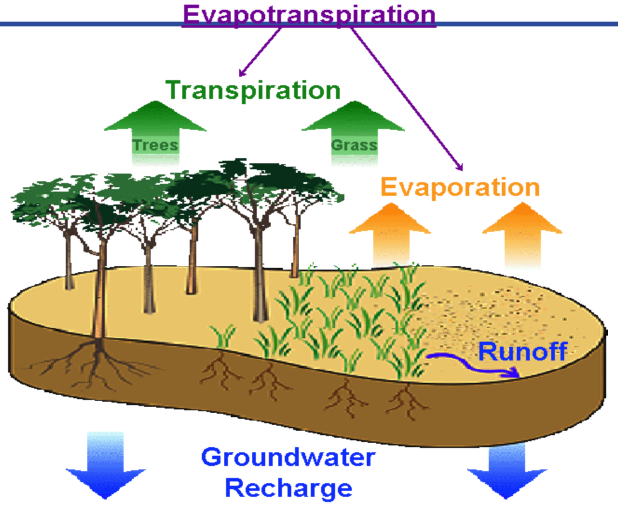


Lifted Condensation Level (LCL)

Mountain – Valley circulation

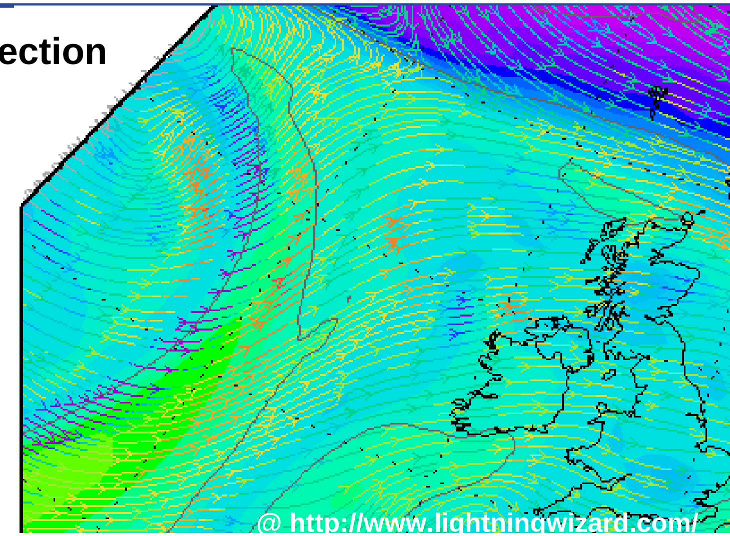


Moisture for thunderstorm development



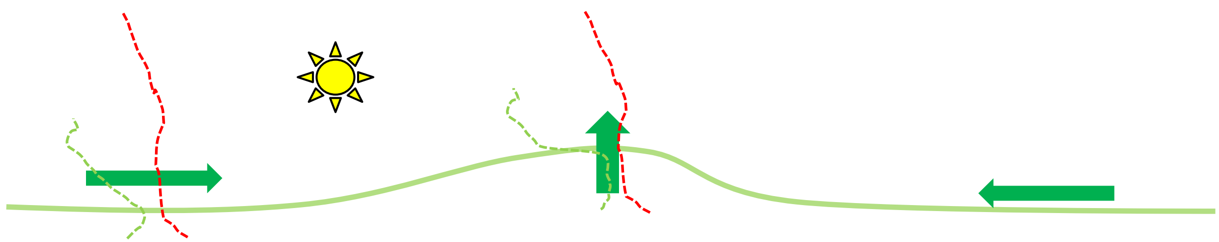
@ http://weather.vouhead.gr/vouhead-images/evapotranspiration002-en.gif

Advection

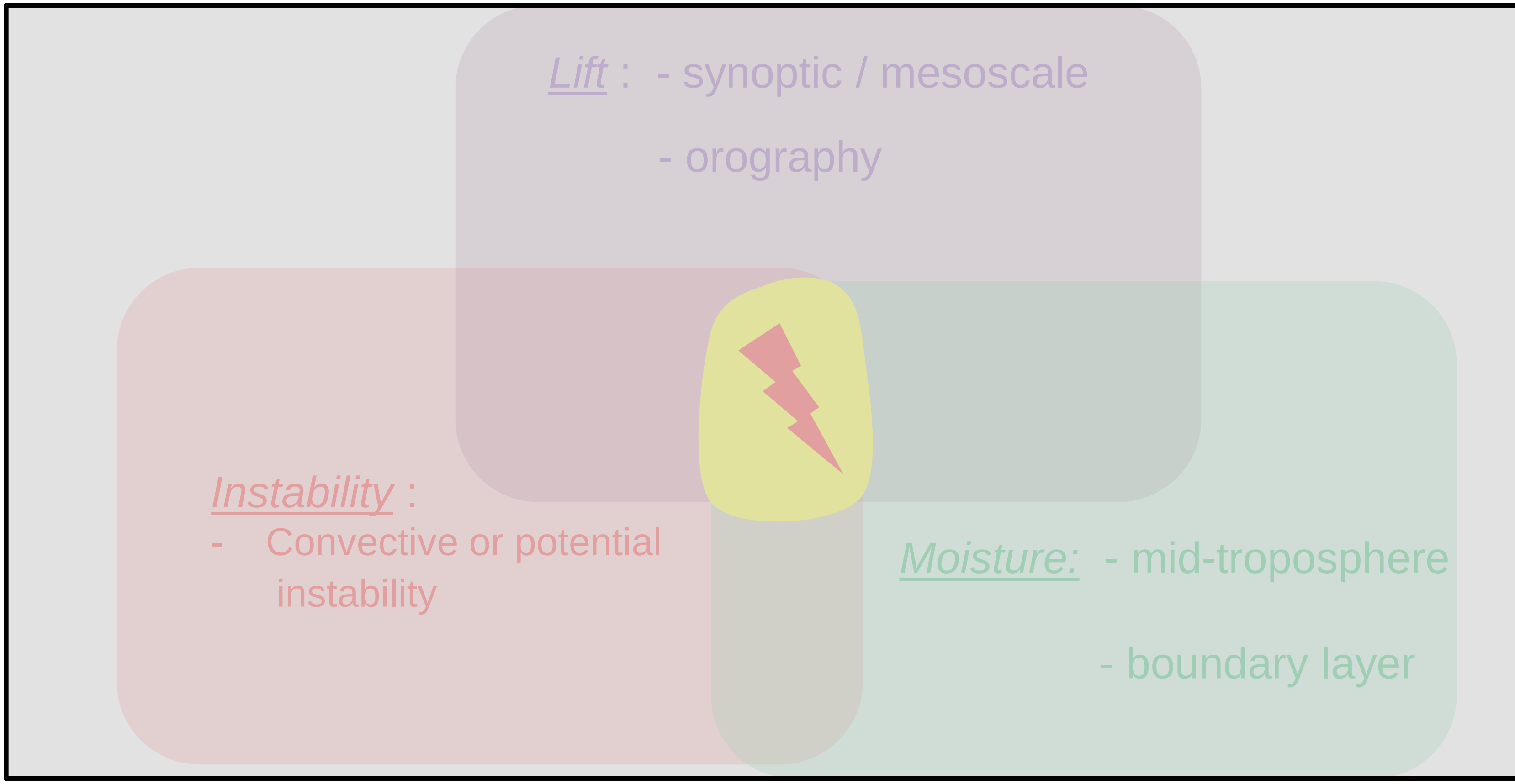


Moisture pooling along convergent „thermal“ boundary

-Moisture advection cannot create maxima, only translation of a maximum is possible
-Moisture convergence ~ velocity convergence ~ upward motion
➡ deepening of the boundary layer moisture ➡ less diurnal mixing



Basic ingredients for ***organized*** thunderstorms

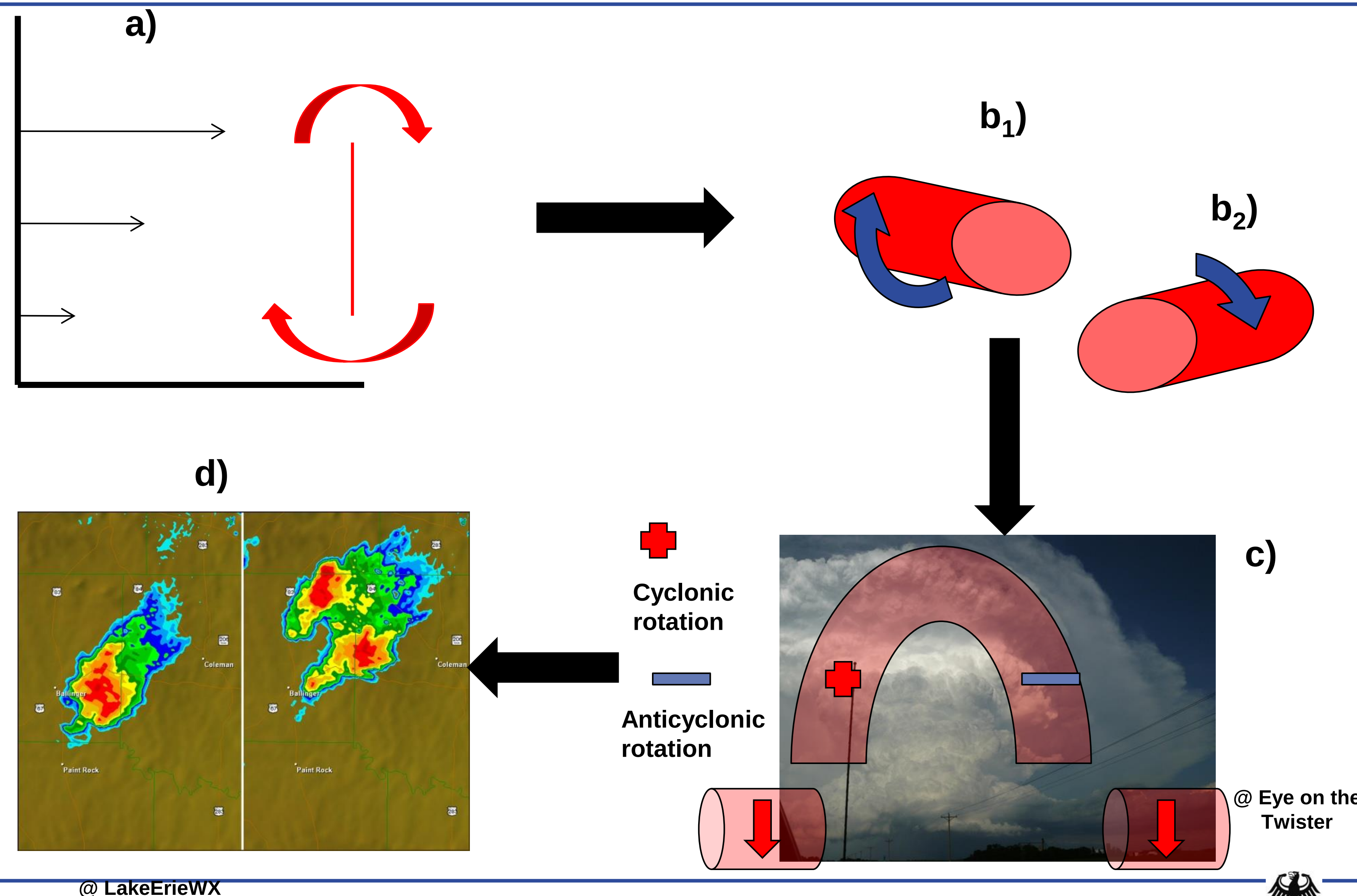


\+

wind shear
(speed and/or directional)

Convective forecast parameters: speed shear

Speed shear

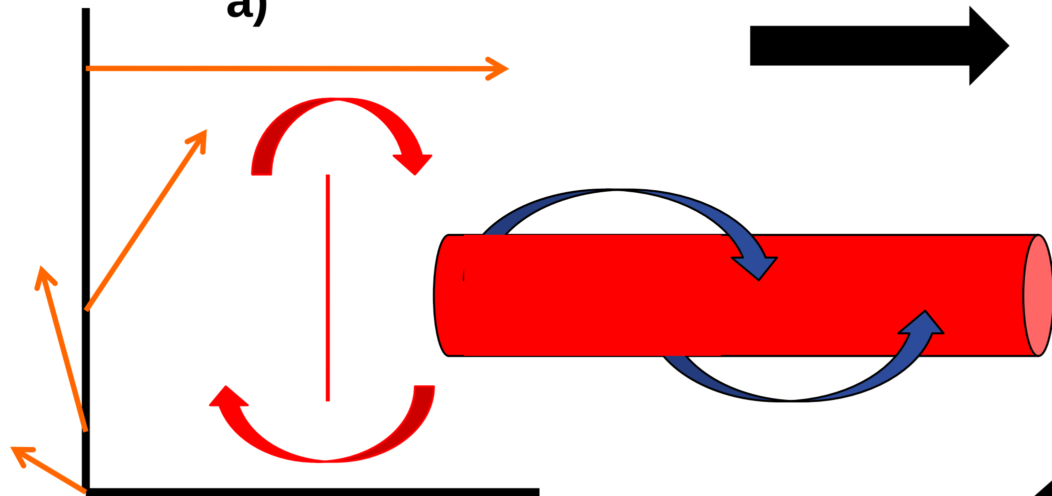

a)
b1)
b2)
c)
d)
Cyclonic rotation
Anticyclonic rotation
@ Eye on the Twister
Coleman
Ballinger
Paint Rock
Coleman
Ballinger
Paint Rock
@ LakeErieWX

Convective forecast parameters: directional shear

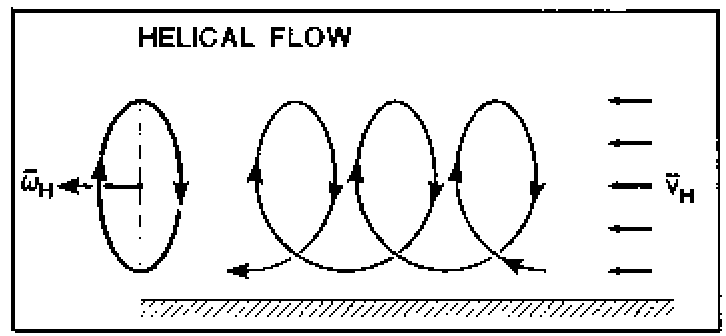
Speed and directional shear (helicity)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

a)

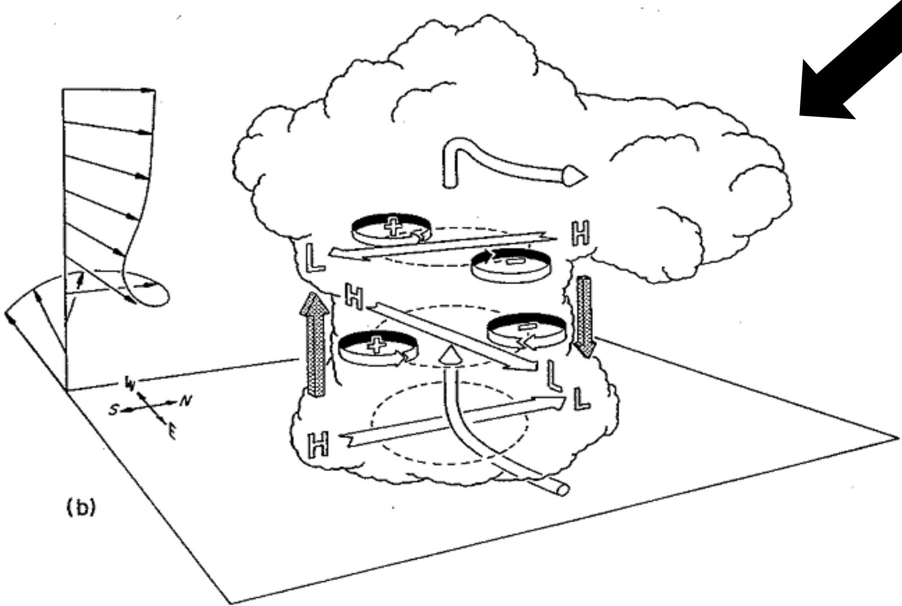


b)



@ A REVIEW FOR FORECASTERS ON THE APPLICATION OF HODOGRAPHS TO FORECASTING SEVERE THUNDERSTORMS
by *Charles A. Doswell III*

c)



@ Dynamics of tornadic thunderstorms
by *Joseph B. Klemp*

What is an hodograph ?

180 °

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

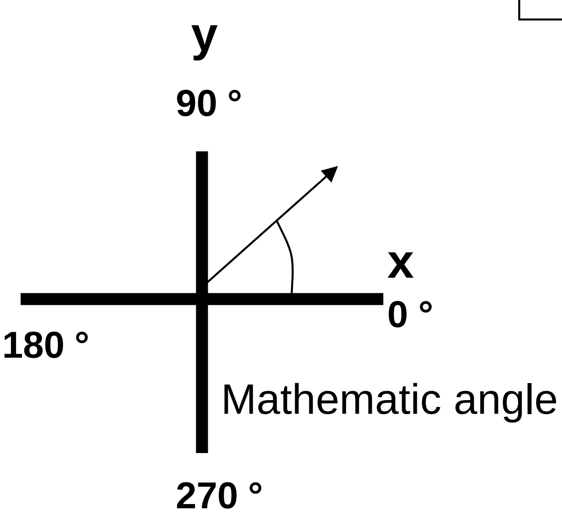
90 °

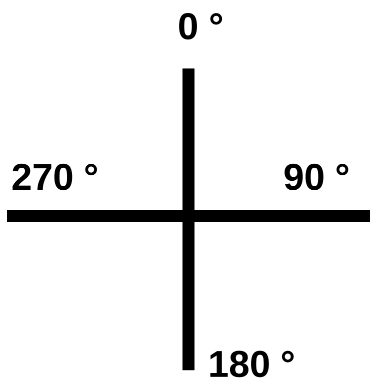
270 °

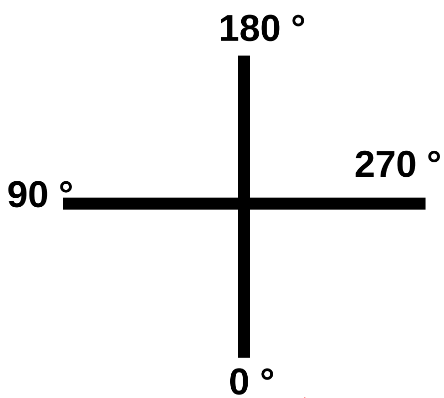
0 °

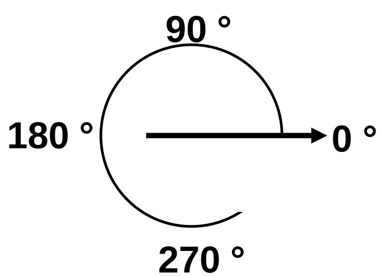
wind direction is defined to the y-axis

- 180°: in meteorology, we look, where the wind comes from

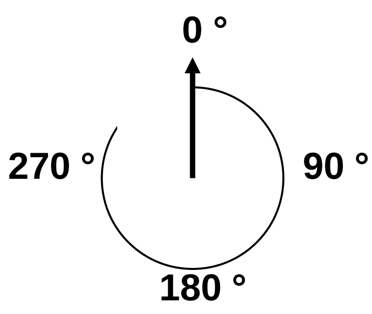








Mathematical



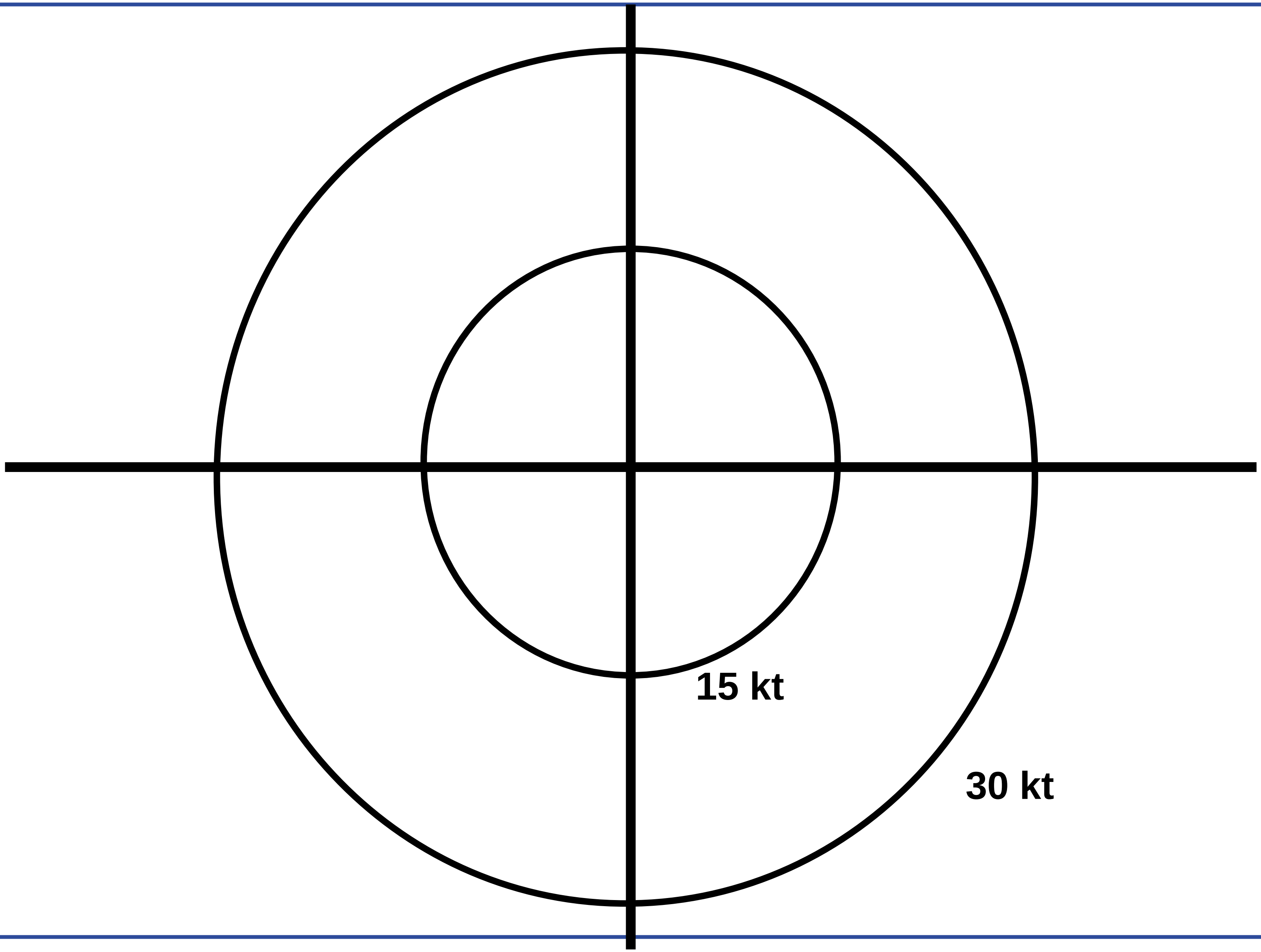
Meteorological

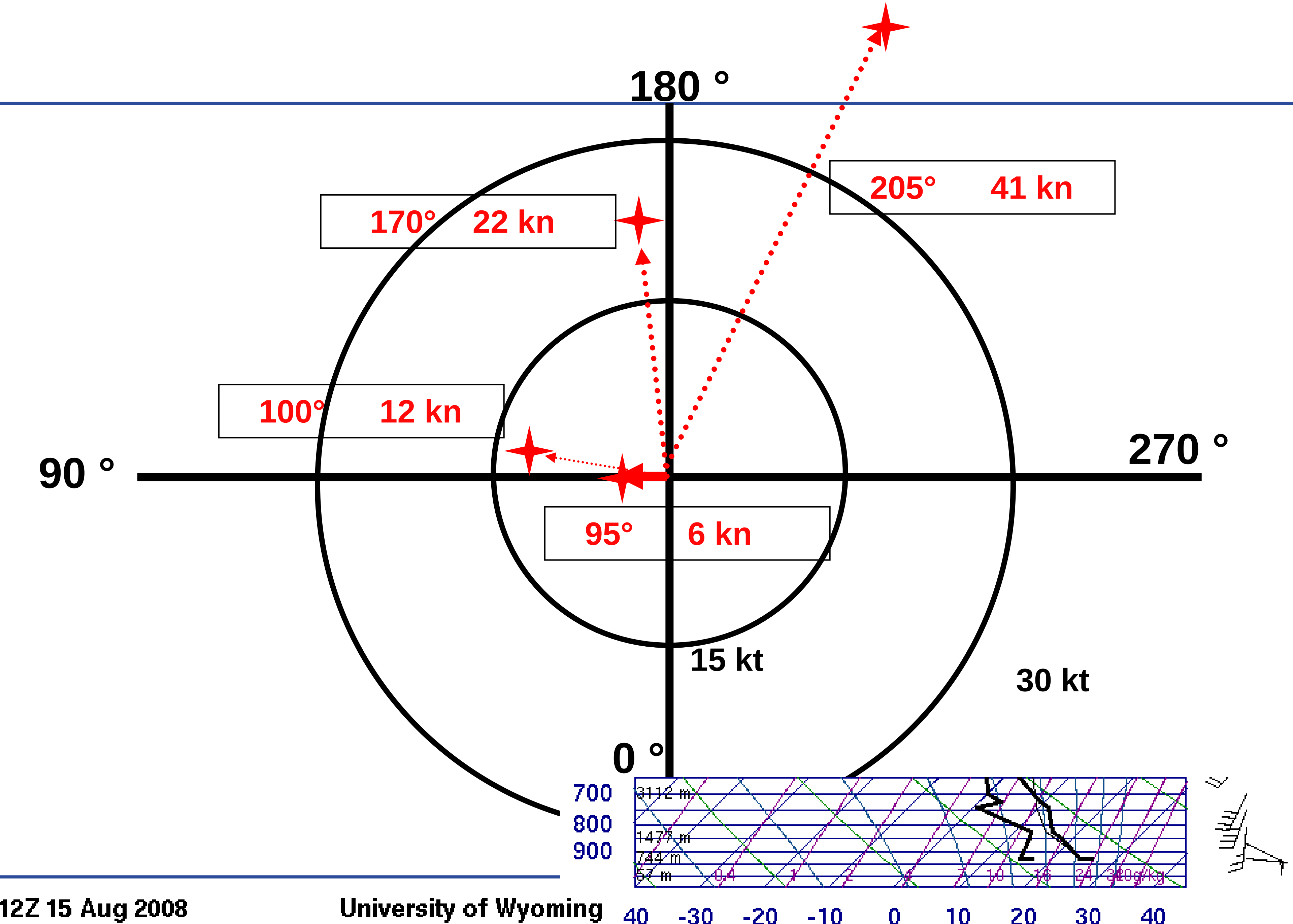
Hodograph

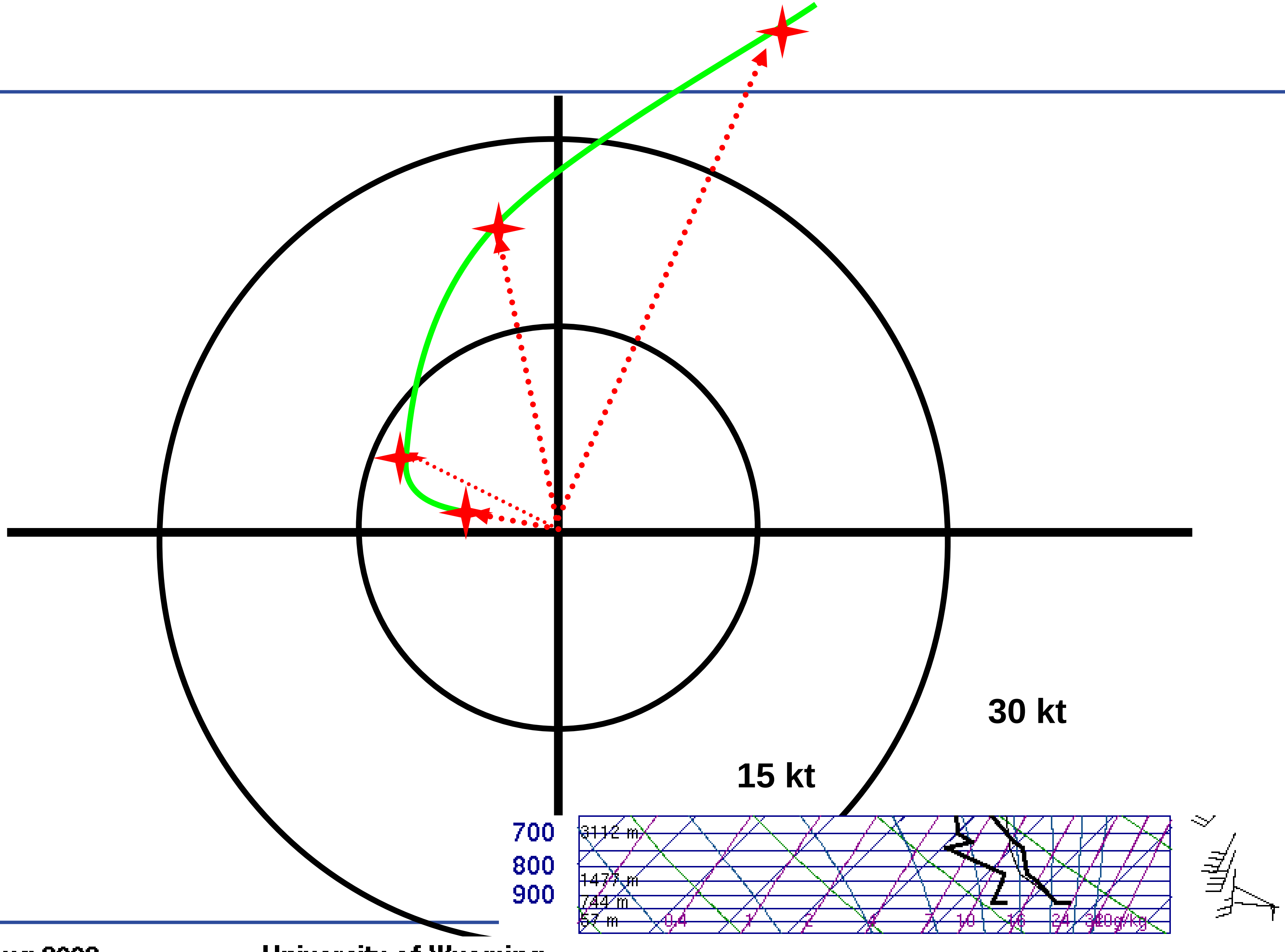
- ✓ north wind = from 0° or 360°
- ✓ east wind = from 90°
- ✓ south wind = from 180 °
- ✓ west wind = from 270°

→

- ✓ north wind = pointing to the N
- ✓ east wind = pointing to the E
- ✓ south wind = pointing to the S
- ✓ west wind = pointing to the W

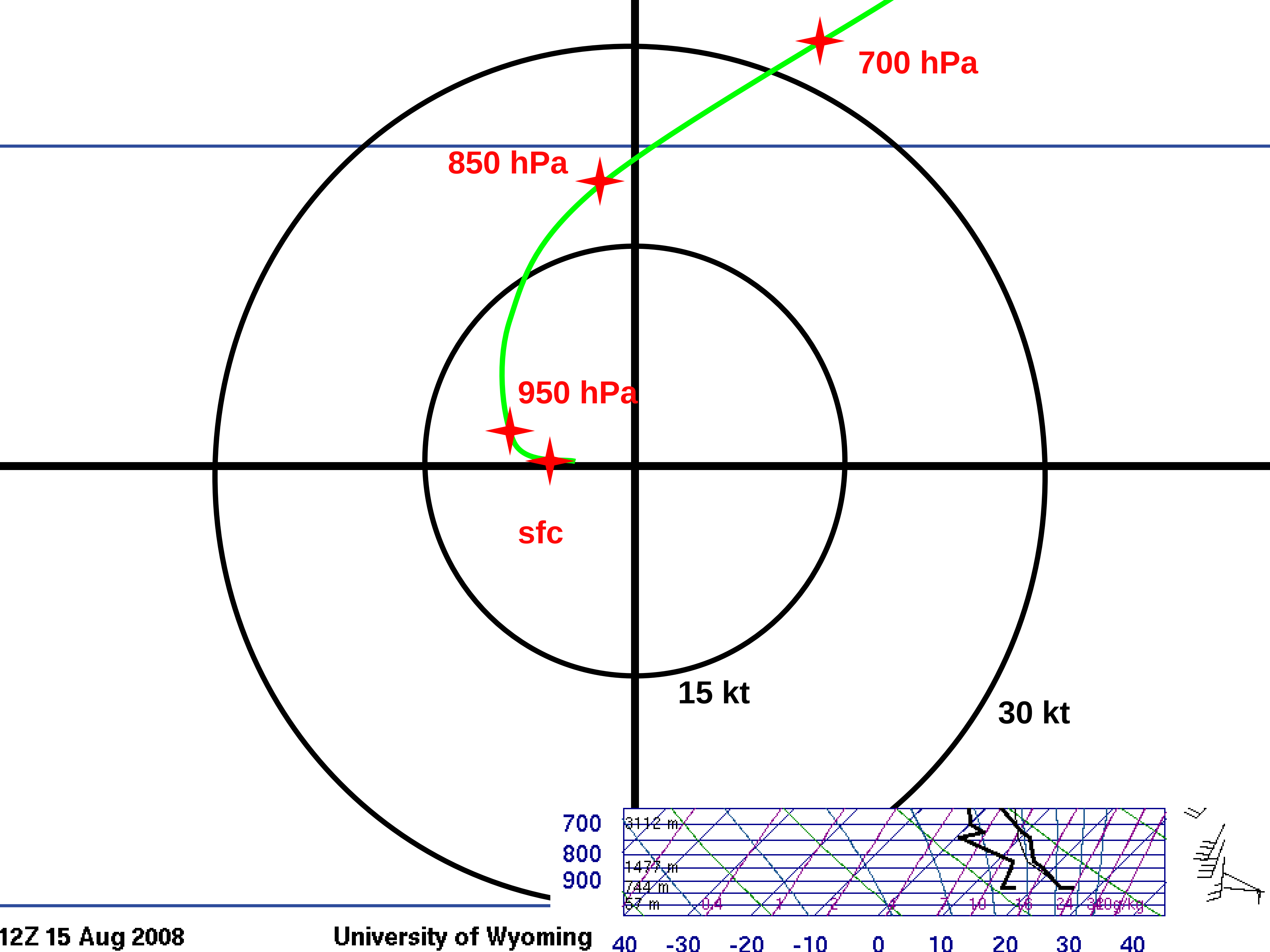

15 kt
30 kt


180 °
205° 41 kn
170° 22 kn
100° 12 kn
90 °
270 °
95° 6 kn
15 kt
30 kt
0 °
700
800
900
3112 m
1477 m
744 m
57 m
12Z 15 Aug 2008
University of Wyoming
40 -30 -20 -10 0 10 20 30 40



12Z 15 Aug 2008

University of Wyoming


700 hPa
850 hPa
950 hPa
sfc
15 kt
30 kt
700
800
900
3112 m
1477 m
744 m
57 m
12Z 15 Aug 2008
University of Wyoming
40
-30
-20
-10
0
10
20
30
40

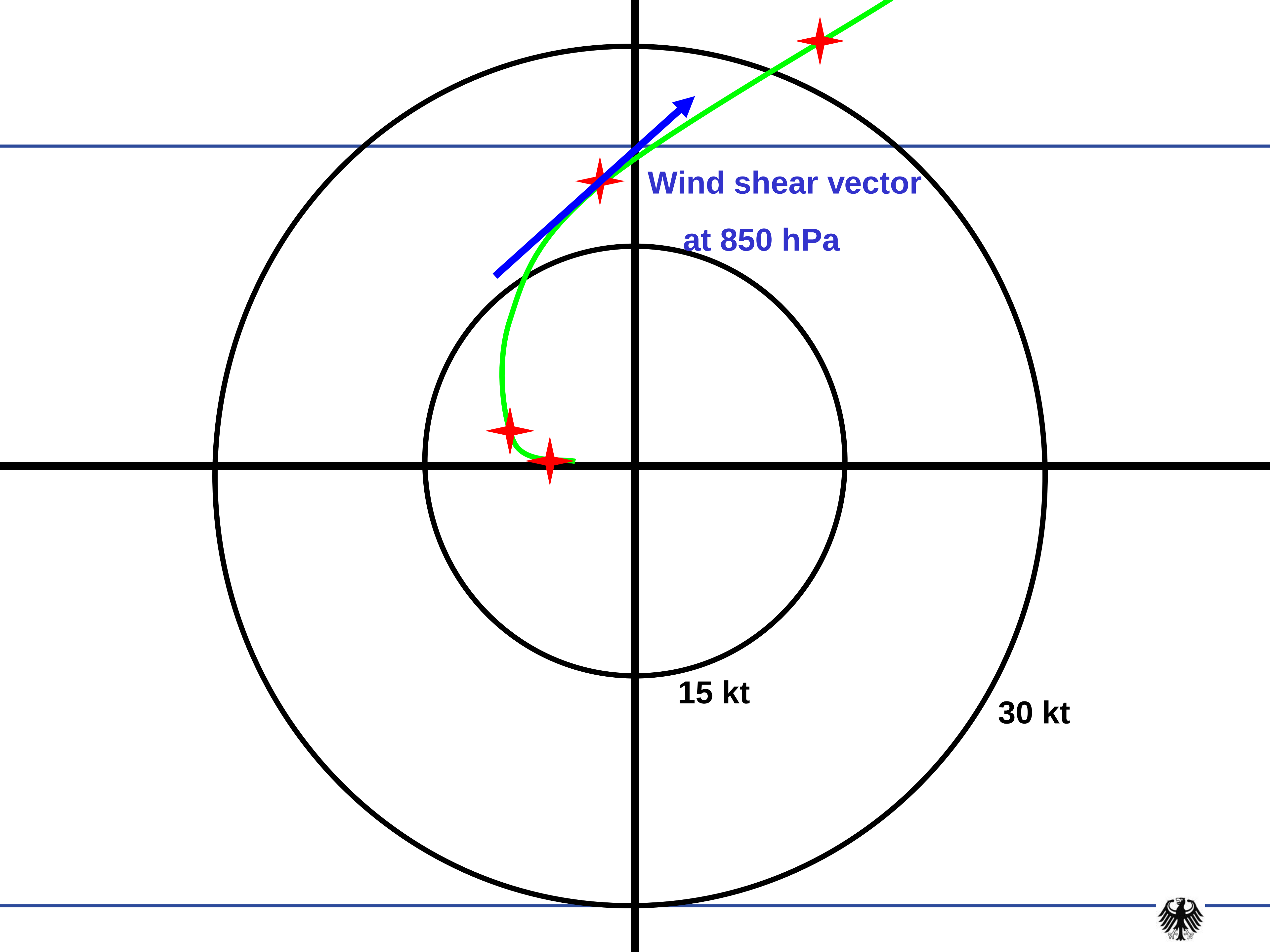
What do we see ?

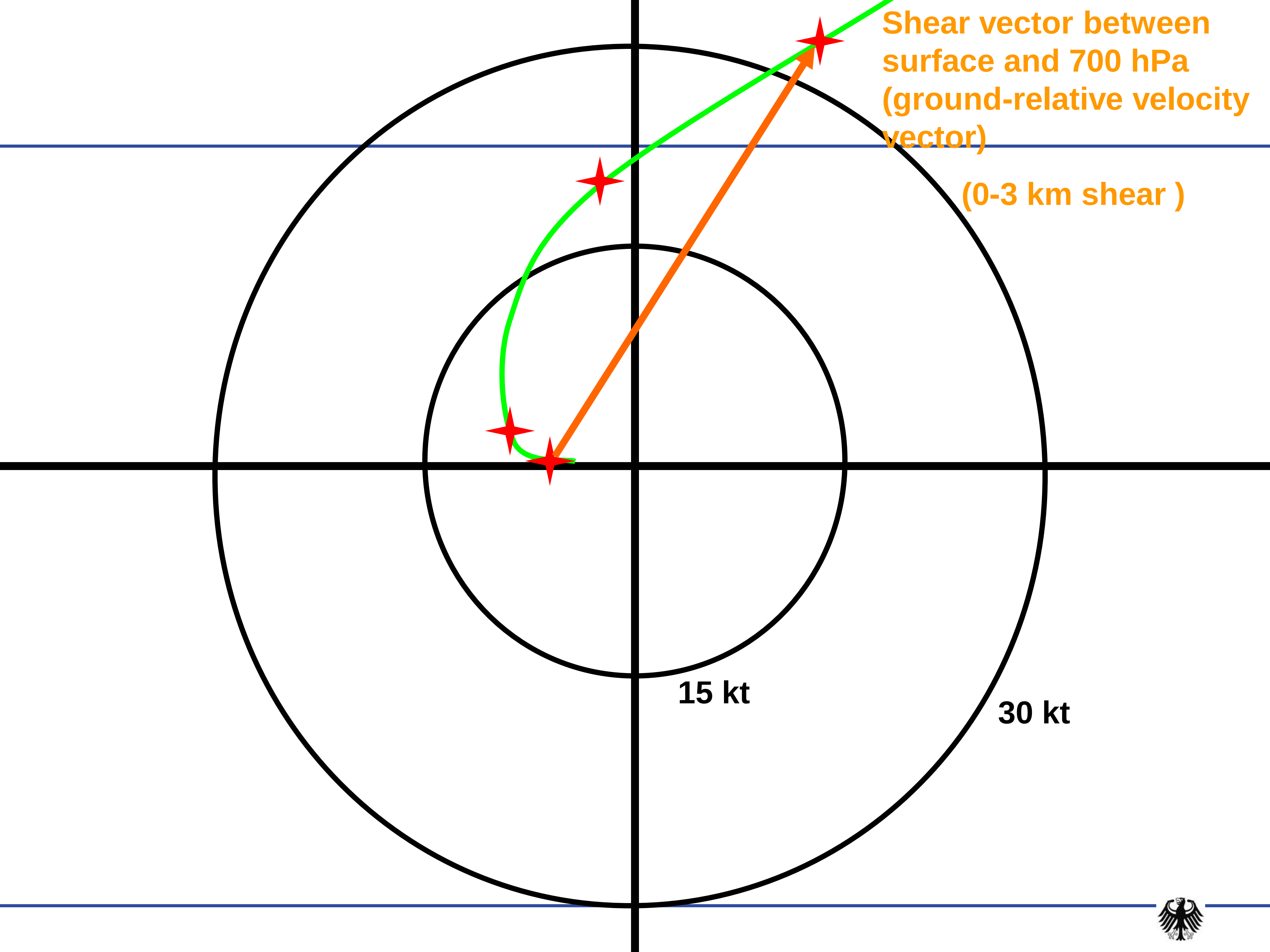
➔Wind speed increases (significantly) with height

➔Wind changes direction with height

Wind shear vector

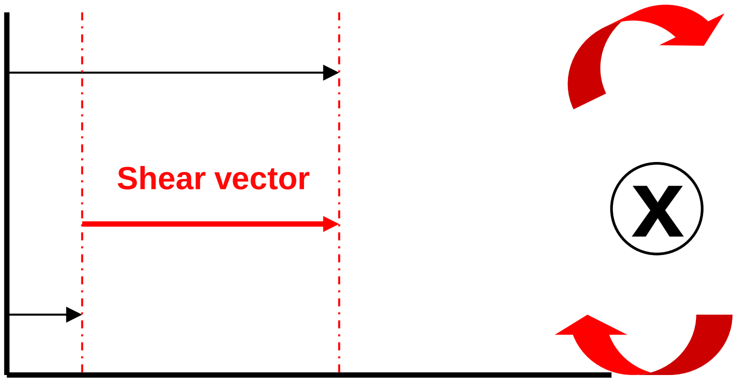
- tangent to the hodograph, pointing towards increasing altitudes
- Shear between 2 levels is vector between both levels (thermal wind vector)


Wind shear vector
at 850 hPa
15 kt
30 kt

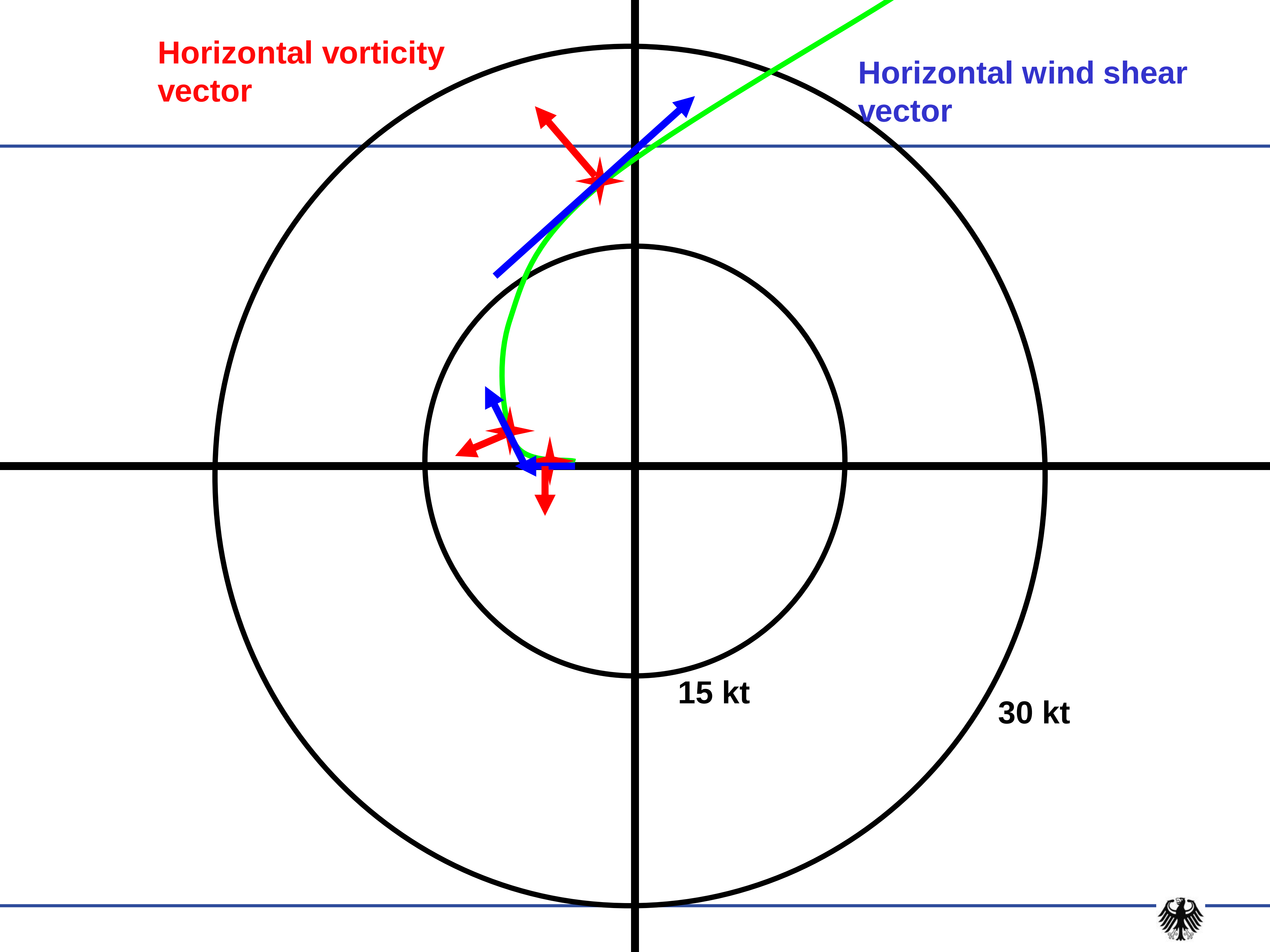

Shear vector between surface and 700 hPa (ground-relative velocity vector)
(0-3 km shear)
15 kt
30 kt

Horizontal vorticity vector

- Achieved either by buoyancy gradient or shear



Horziontal vorticity vector normal to the shear vector

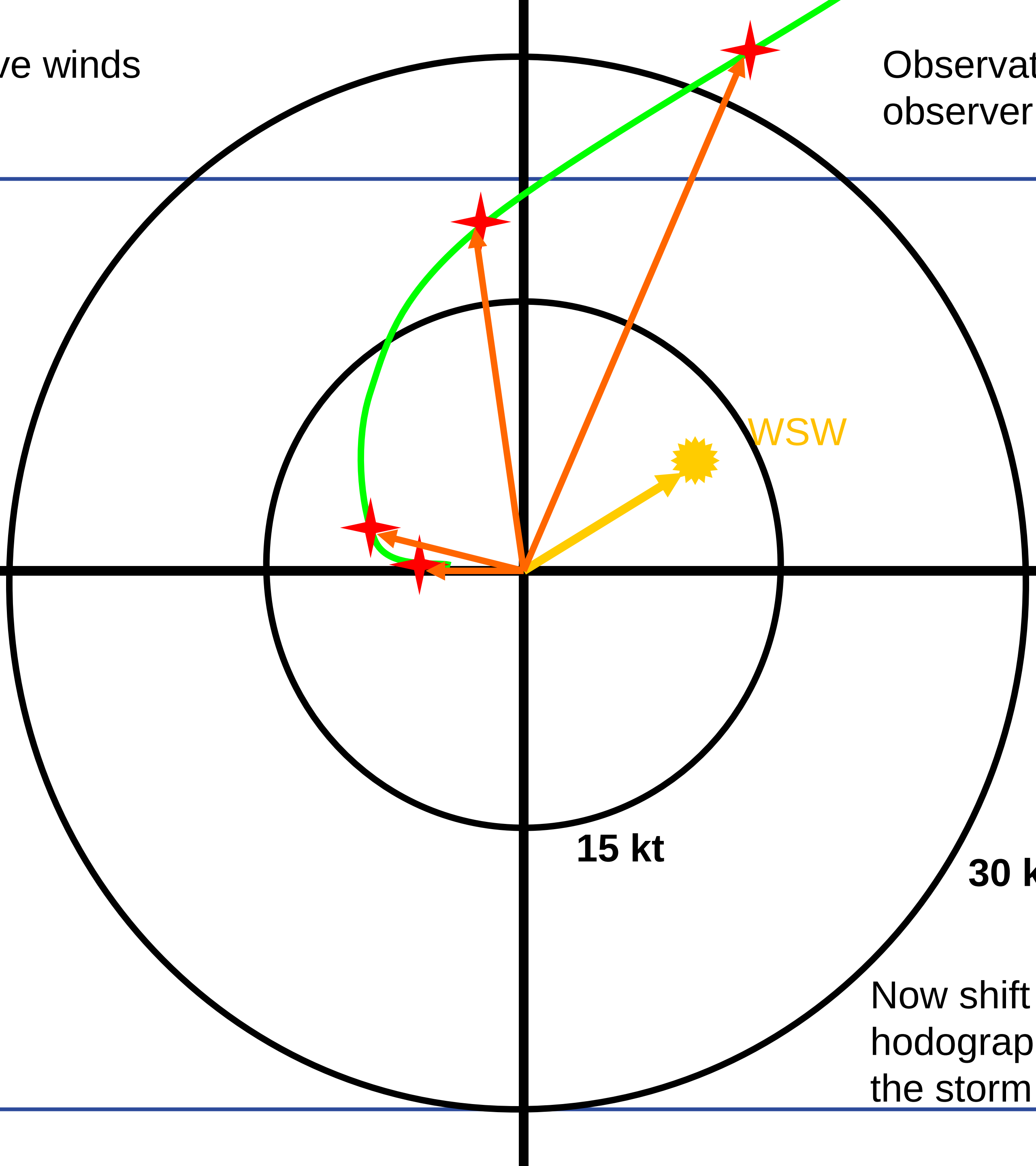

Horizontal vorticity vector
Horizontal wind shear vector
15 kt
30 kt

Storm relative wind

- ➔ Storm motion needed (e.g. Bunkers 30R75)
- ➔ Important wind to determine expected storm dynamics
- ➔ To see rotating updrafts, the storm-relative winds have to be aligned to the horizontal vorticity vector (streamwise helicity)

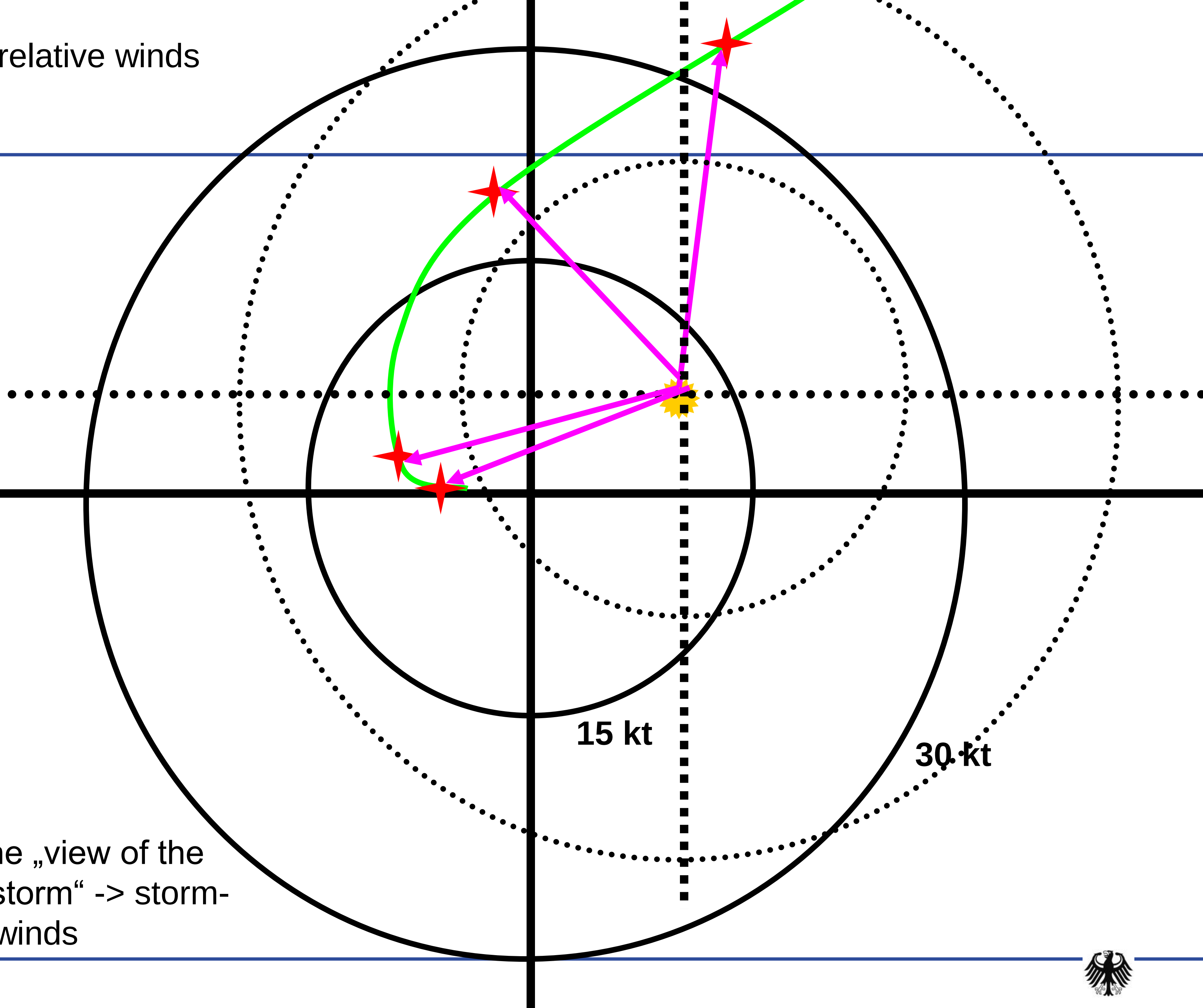
Storm relative winds

Observation for an observer



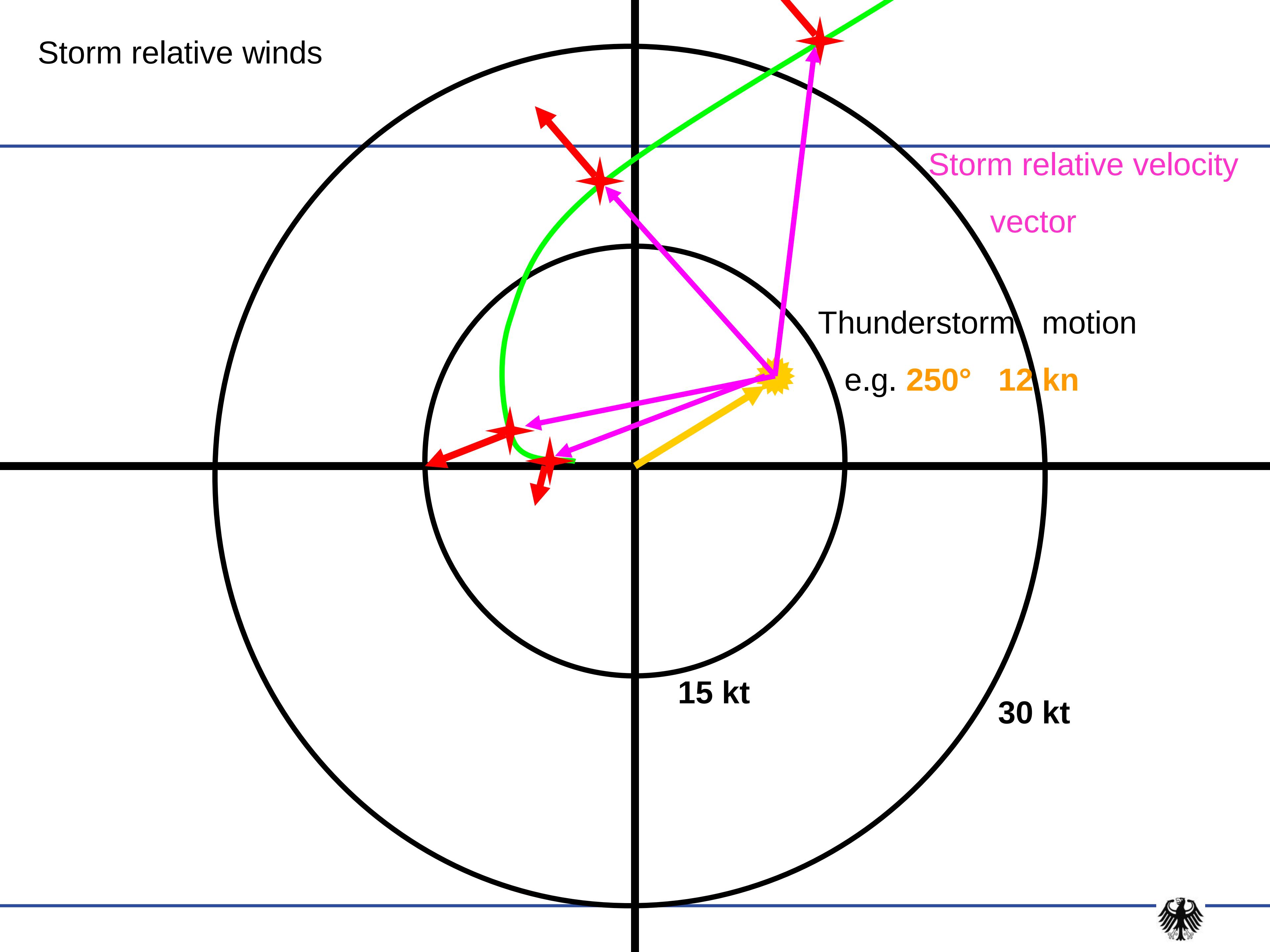
Now shift the hodograph towards the storm motion

Storm relative winds



That‘s the „view of the thunderstorm“ -> storm-relative winds

Storm relative winds

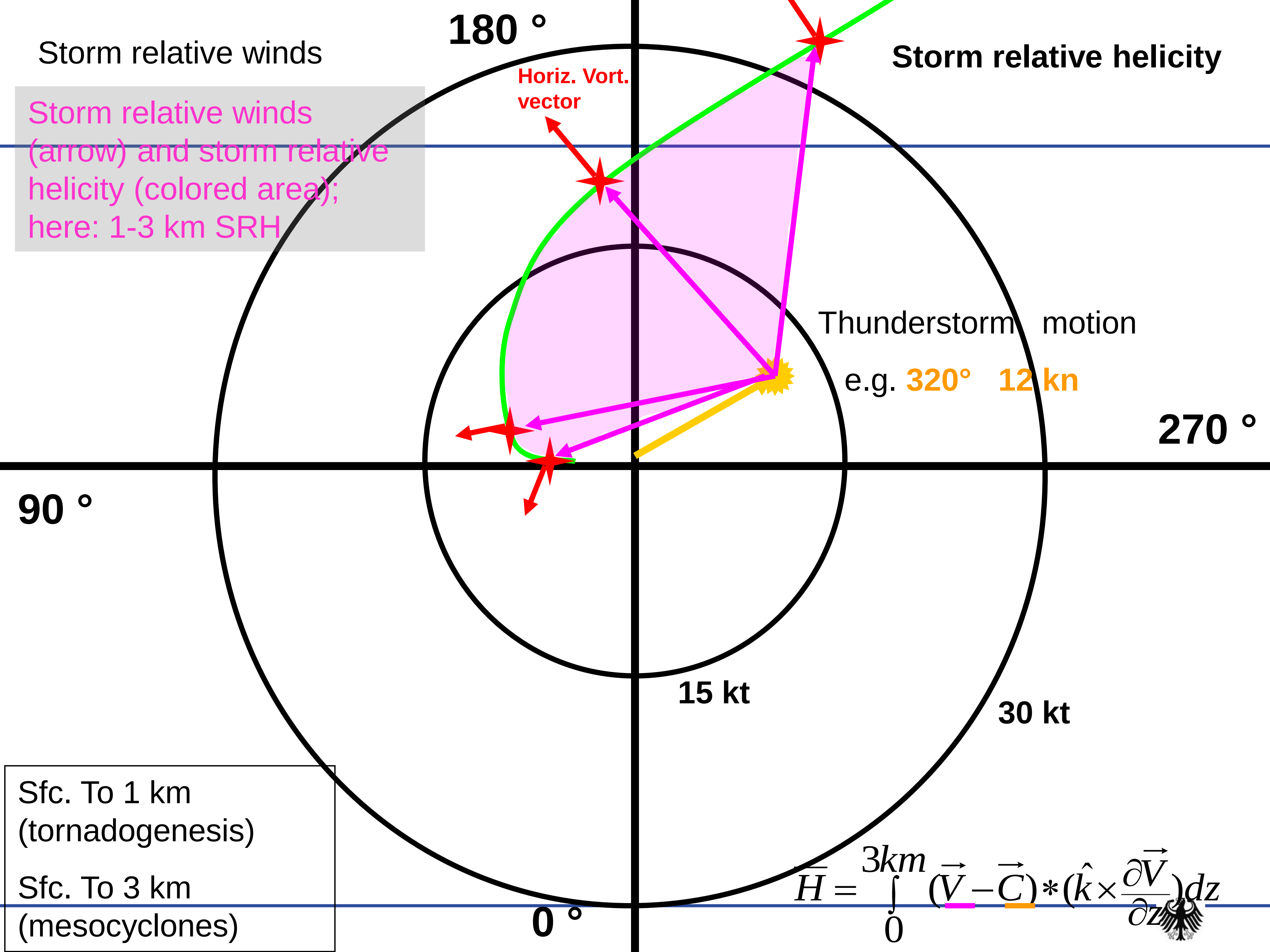


Favorable environment for organized updrafts

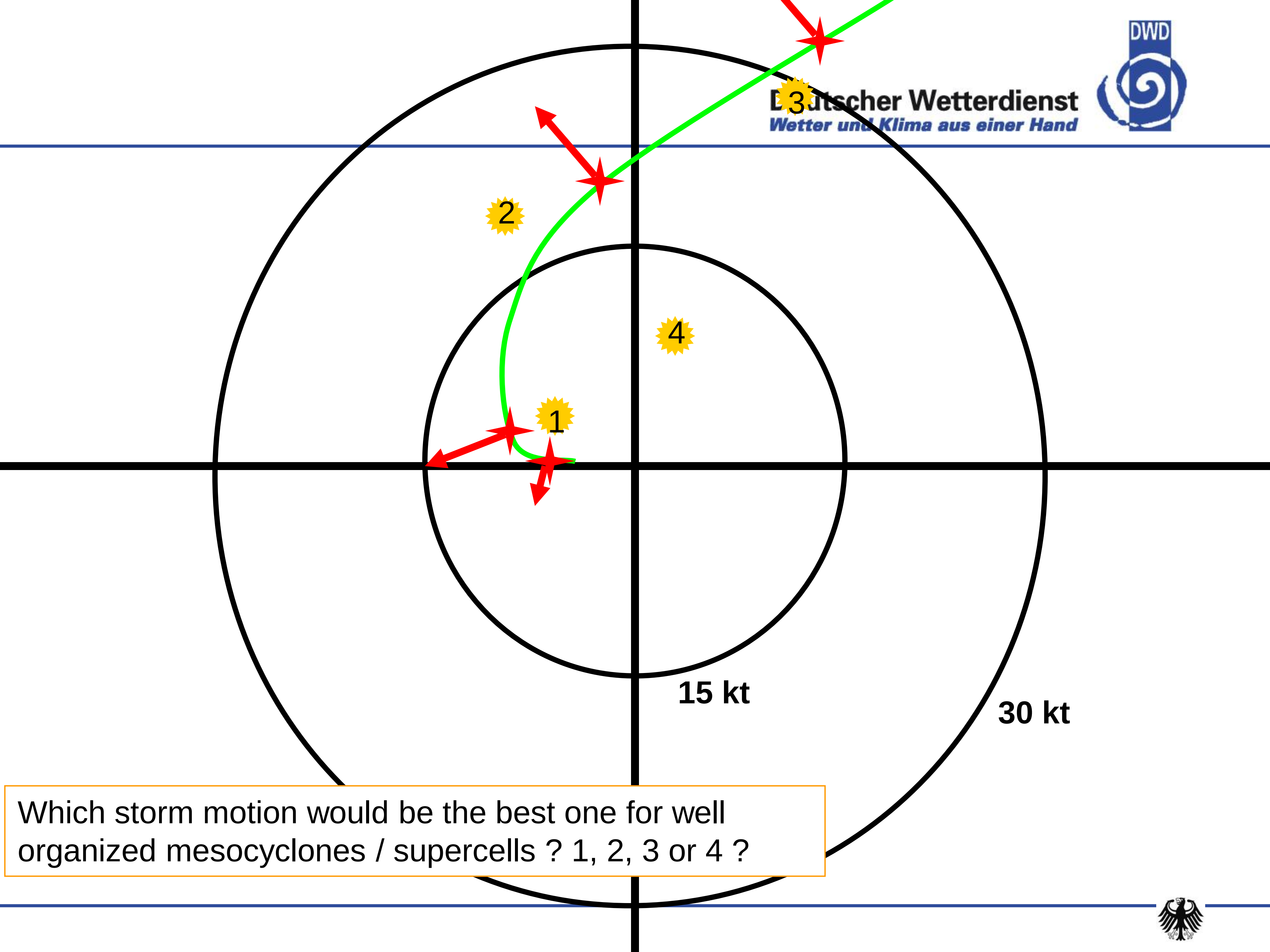
- Strong storm-relative winds within the low-levels (at least 10 m/s)
- Storm-relative vectors and horizontal vorticity vectors have to align nicely
- The wind shear vector has to reveal strong turning (veering or backing) with height

↓

Storm relative helicity (SRH or SREH for „environmental“)

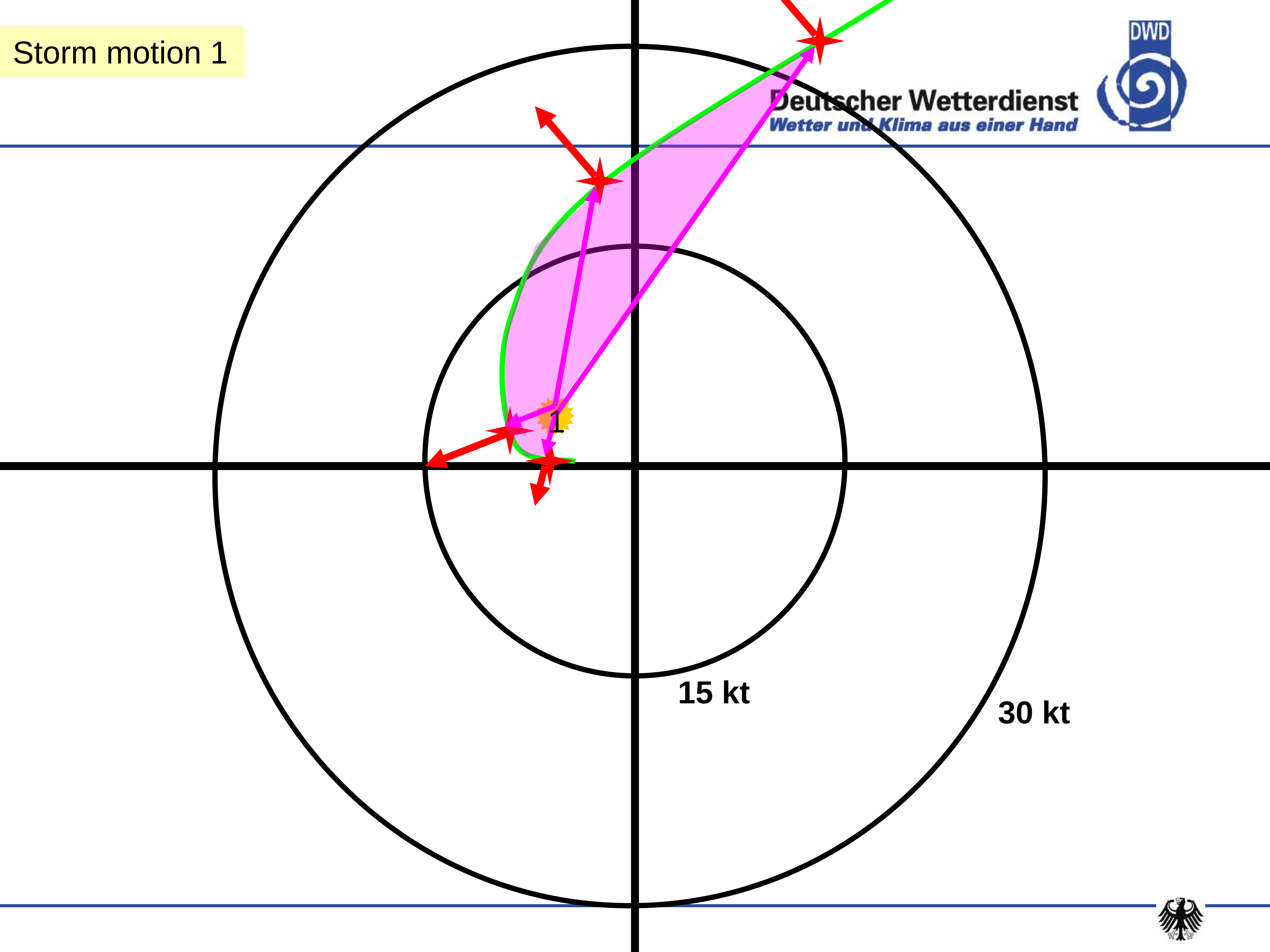


$$\overline{H} = \int_{0}^{3km} (\vec{V} - \vec{C}) * (\hat{k} \times \frac{\partial \vec{V}}{\partial z}) dz$$

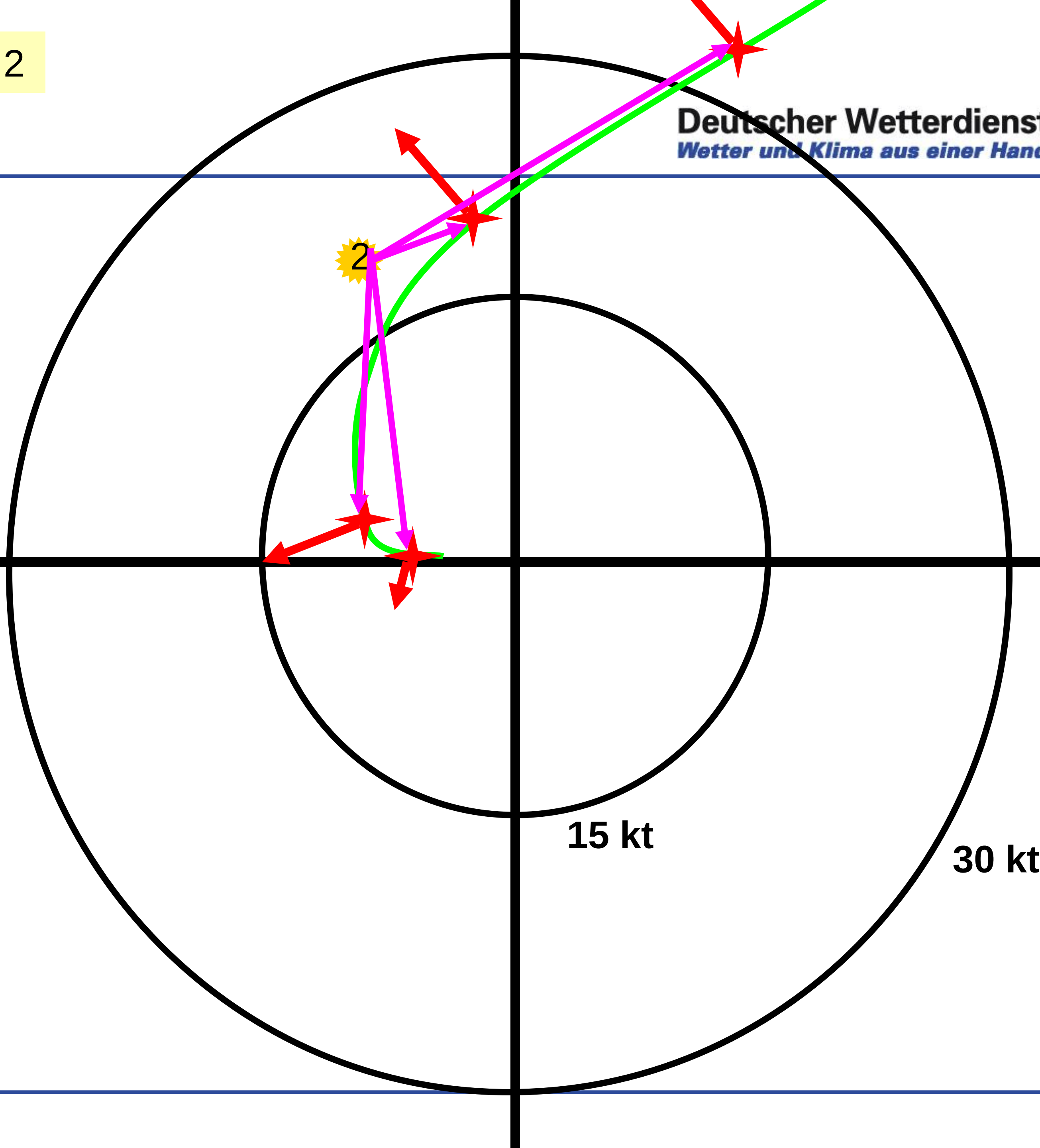


Which storm motion would be the best one for well organized mesocyclones / supercells ? 1, 2, 3 or 4 ?

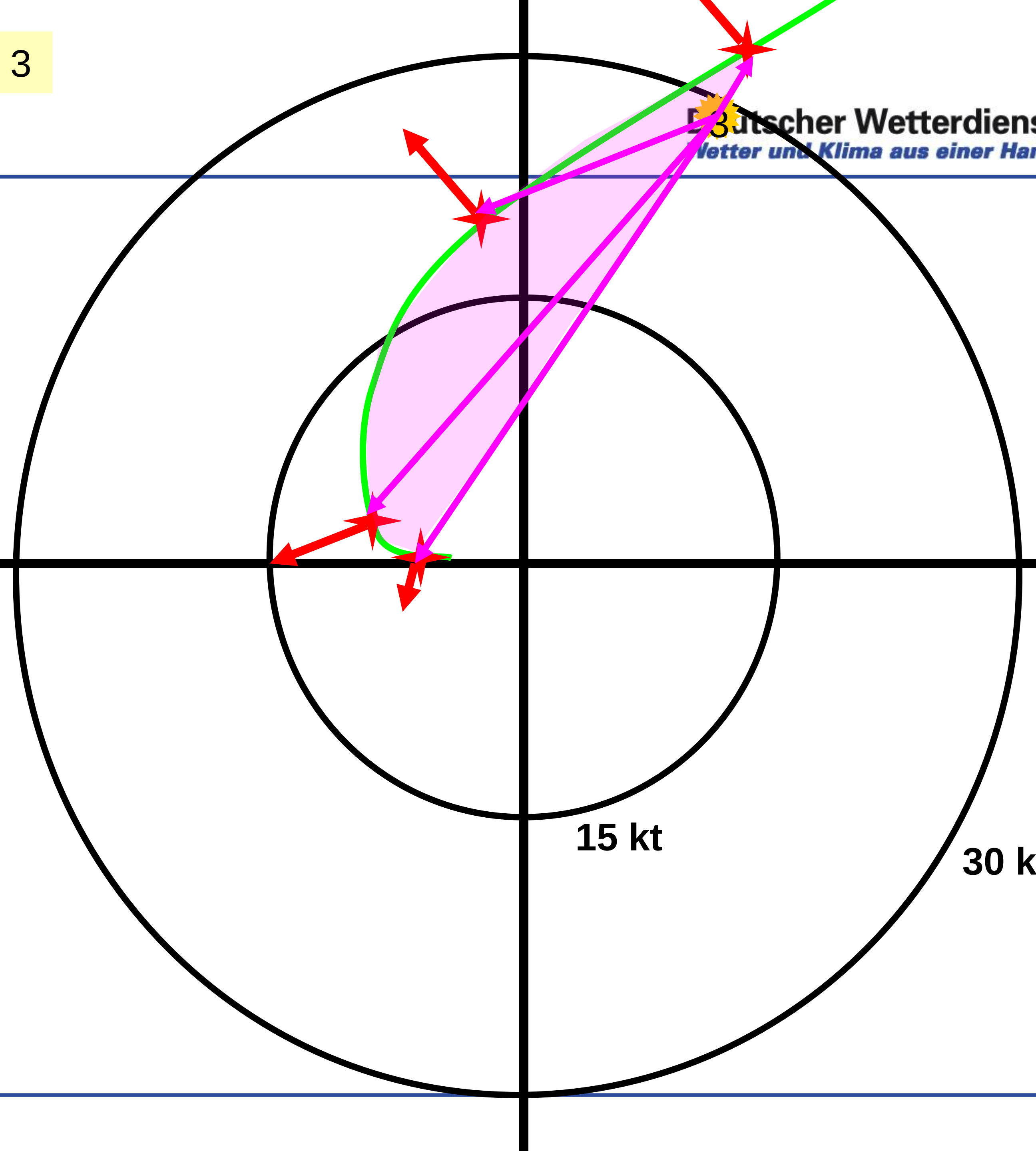
Storm motion 1



Storm motion 2



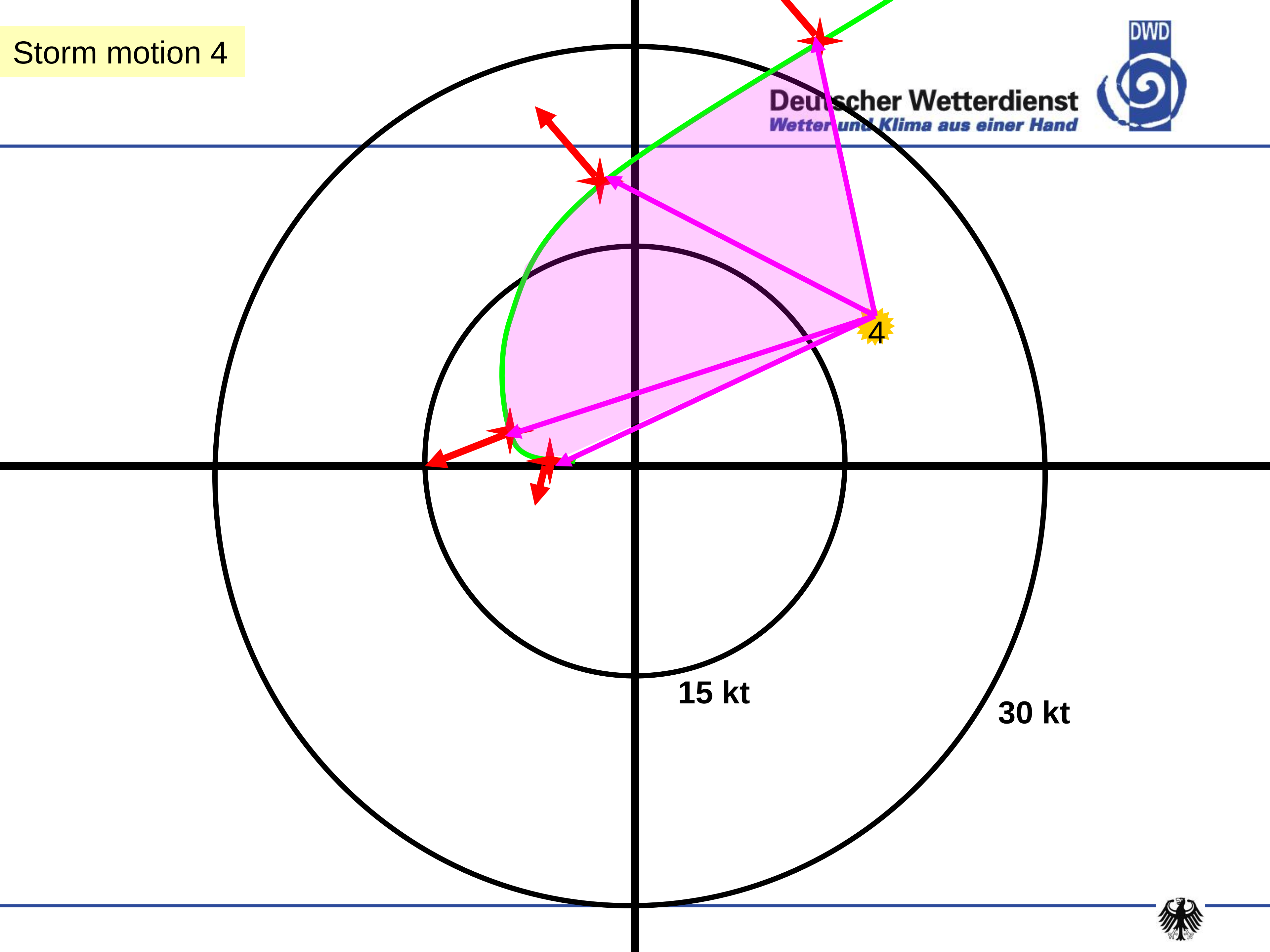
Storm motion 3

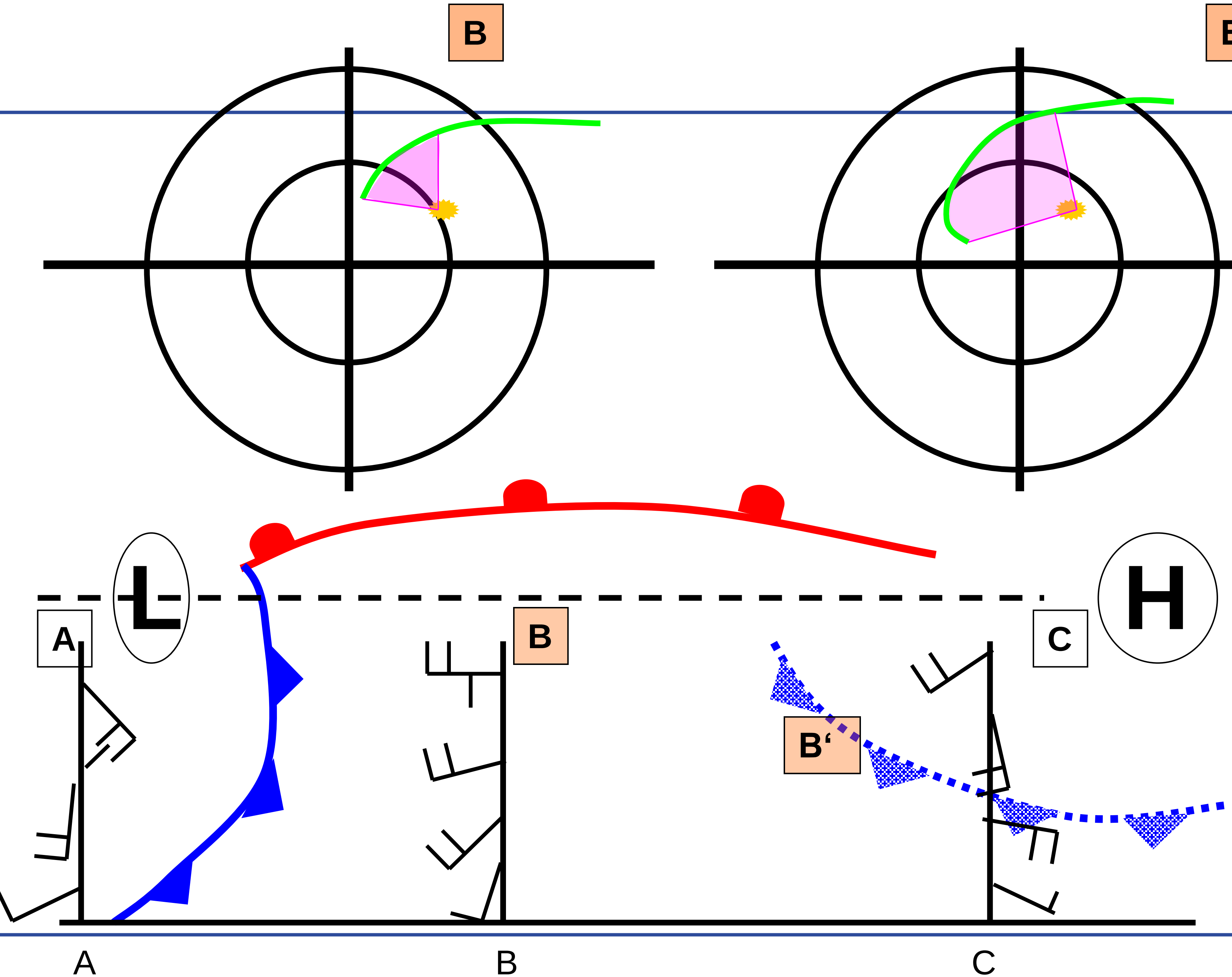


Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Storm motion 4

Deutscher Wetterdienst
Wetter und Klima aus einer Hand




B
B‘
L
A
B
H
C
B‘
A
B
C

Flash flood producing storms

The heaviest convective rainfall usually occurs in regions of high moisture, maximum ambient or elevated instability, best mesoscale lift and slow system movement. ***@ Ted Funk, WFO Louisville, KY***

The heaviest precipitation occurs where the rainfall rate is highest for the longest time ***@ Charles Chappell***

Hydrology

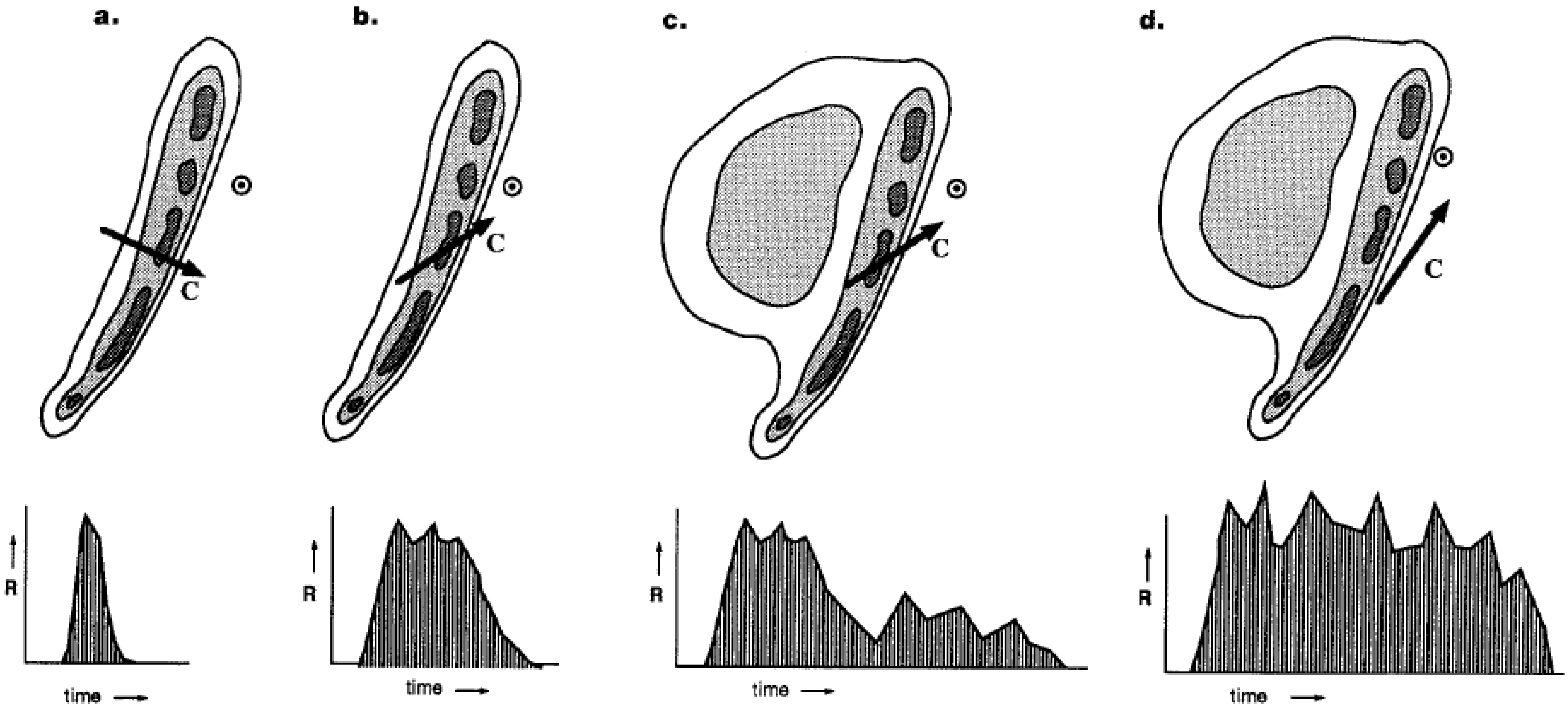
Orography

Long-time moisture

Land use

What causes storms to become flash flood producers?

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



Extreme rainfall with supercells

Source: www. whybecausescience.com

Most supercells **don't** offer **long-duration** excessive rain. Instead they can produce extreme rainfall amounts on a shorter time-frame. An example of the Dallas-Fort-Worth supercell in 1995*:

5 – **15** – **60** min time-frame

231 – *210* – 115 mm/h respectively // 120 mm

and Orlando, Florida supercell in 1996* :

1 – **5** min time frame

330 – *222* mm/h (mesonet measurements) //50 mm

- Final rainfall amount not exceptional for Texas, but rainfall rates were (**urban regions!**)

- Heaviest rain was observed during the weakning phase (collapsing) of supercell thunderstorms.

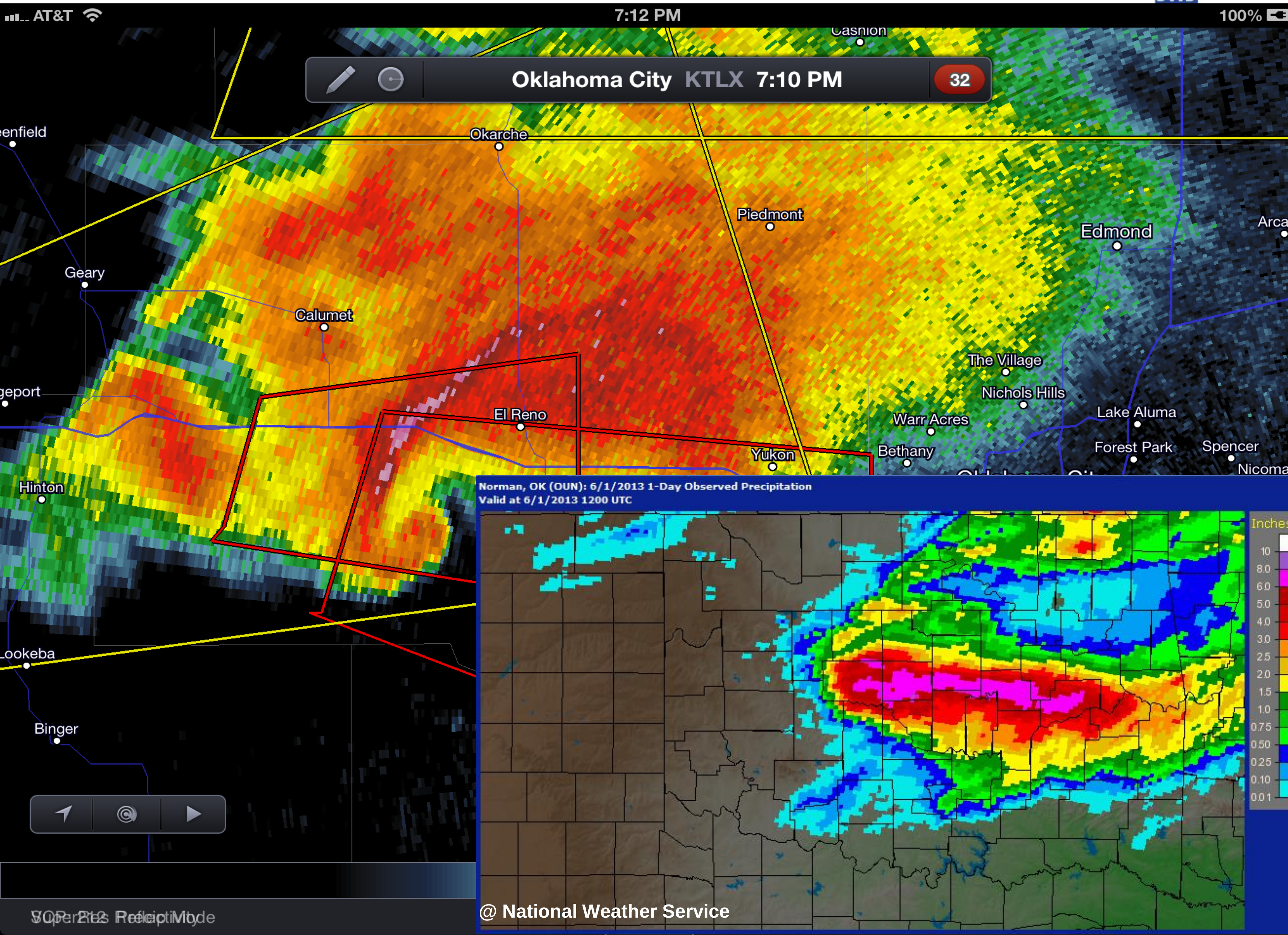
*__Extreme rainfall and flooding from supercell thunderstorms__
James A. Smith, Mary Lynn Baeck, Yu Zhang and Charles A. Doswell III

- ☺ Supercells have strong updrafts which ingest lots of moisture
- ☺ Supercell interaction with squall line (5th May 1995 Fort-Worth Dallas / 120 mm) , mesoscale boundaries (outflow) or orography -> influencing heavily storm motion
- ☺ Numerous supercells crossing a certain region with each preceeding storm worsening the flash flood problem

Radar mearuements like rain sum not always helpful in such events due to the varible Z (radar reflectivity)-R(rainfall rate) relationship (also: **hail contamination**)

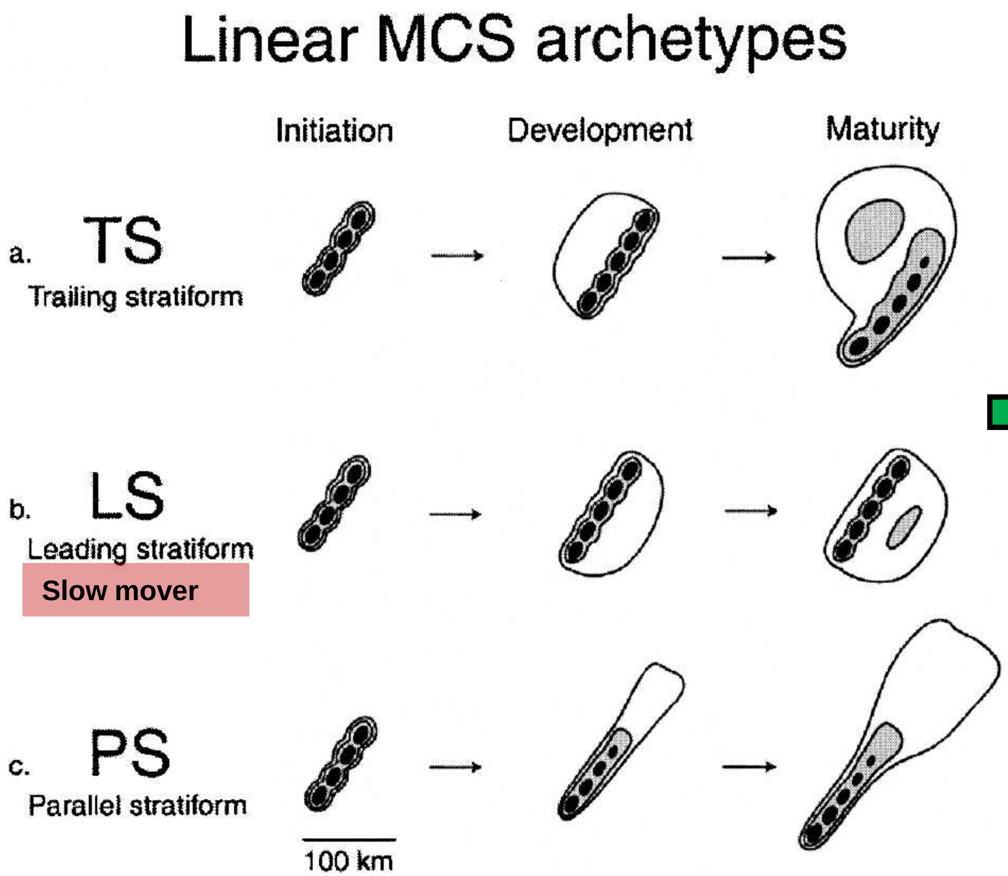
Hence rainfall maximum in radar representing hail with real rainfall maximum displaced!

Polarimetric radar data could/should lower that problem

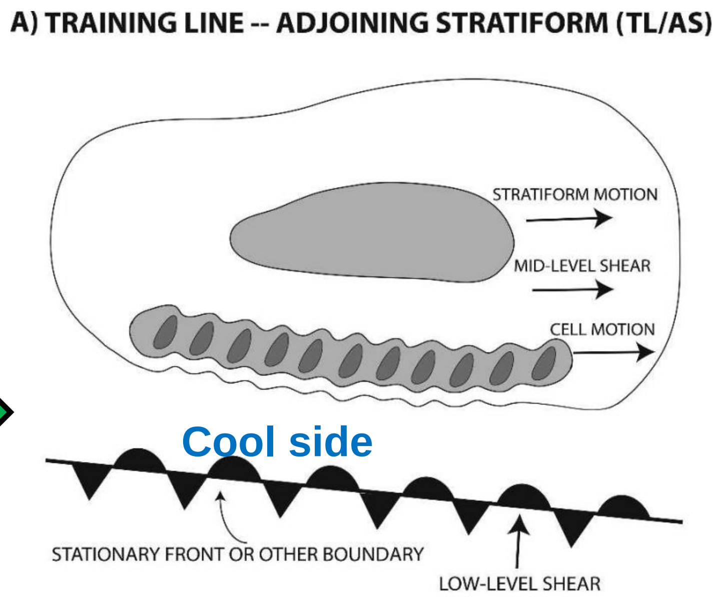


AT&T
7:12 PM
100%
Oklahoma City KTLX 7:10 PM
32
Okarche
Piedmont
Edmond
Geary
Calumet
El Reno
Yukon
Hinton
Binger
The Village
Nichols Hills
Warr Acres
Bethany
Lake Aluma
Forest Park
Spencer
Norman, OK (OUN): 6/1/2013 1-Day Observed Precipitation
Valid at 6/1/2013 1200 UTC
Inches
10
8.0
6.0
5.0
4.0
3.0
2.5
2.0
1.5
1.0
0.75
0.50
0.25
0.10
0.01
@ National Weather Service

Extreme rainfall event with mesoscale convective systems



Slow mover



- Large angle of low/mid-level shear vectors

- line-parallel mid-level shear **vs.** line-perpendicular shear of TS/LS

Frontal type heavy rainfall event Maddox et al. 79

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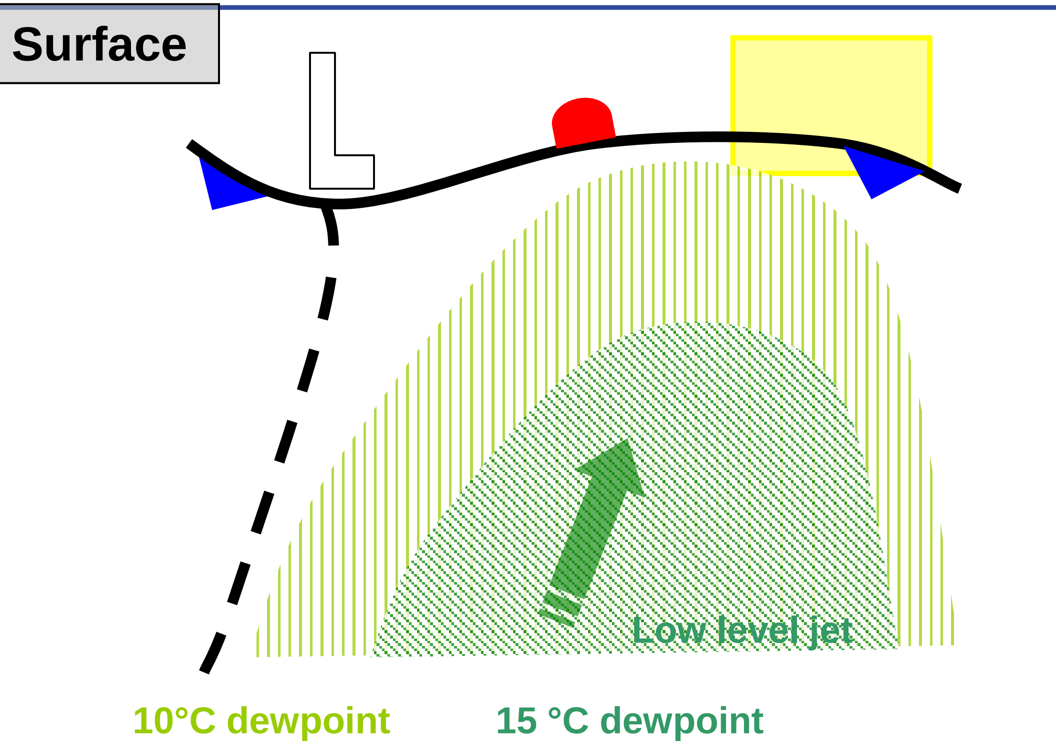

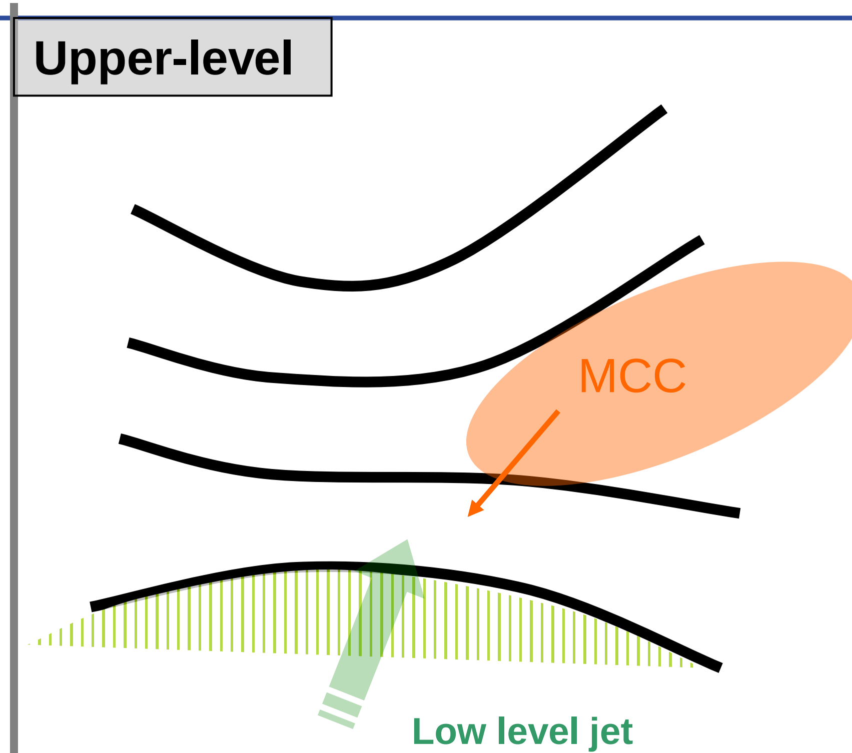

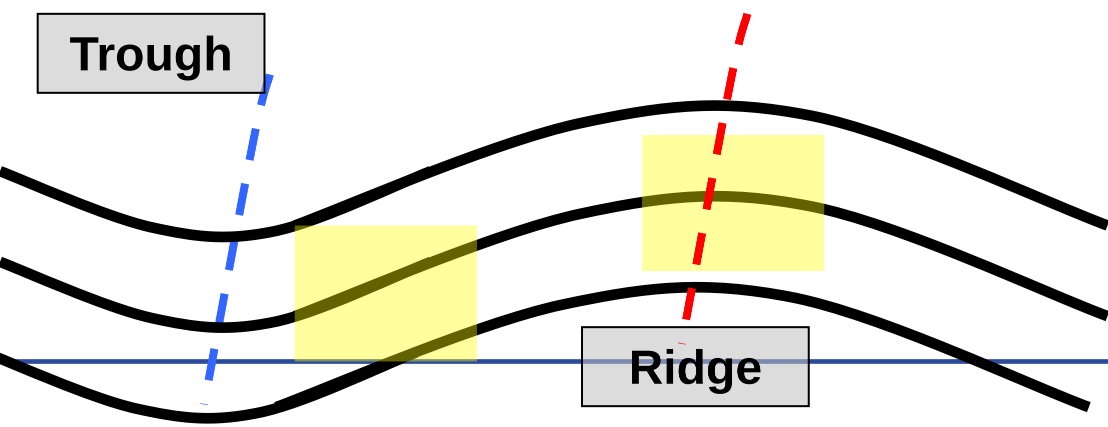

- weak flow at mid-levels
- Propagation offset by cell motion ⇨ training

Extreme rainfall event with mesoscale convective systems

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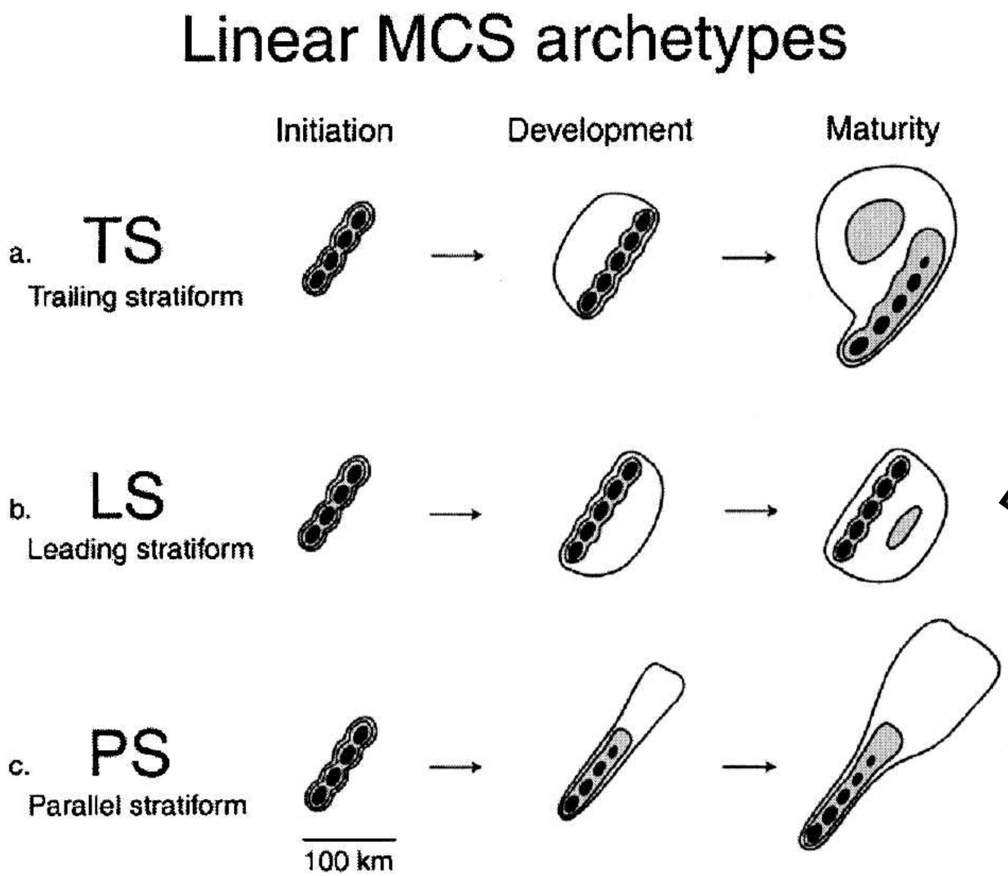
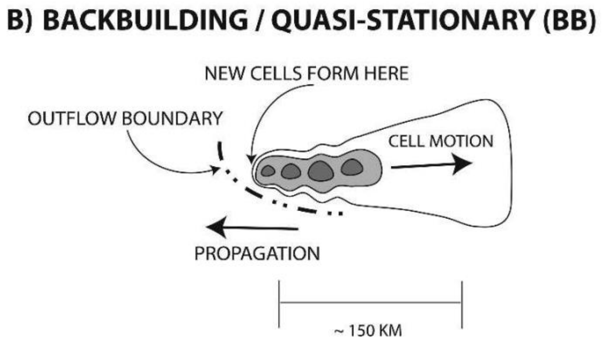


- Covering a smaller area but exceptionally high point rainfall totals e.g.
  309 mm/24h 6-7th May 2000 St. Louis, Missouri

- Occur in a variety of surface wx. patterns (**mesoscale/storm-scale!**)



Excessive rain can also be produced by convection with warm cloud tops (shallow convection), therefore not offering signatures which indicate intense convection (with potential significant rain) like:

Cold-U ring
Jumping anvil cirrus

E.g. storms in the Mediterranean sometimes show warm cloud tops but are prolific lightning producers with heavy rainfall amounts.

Look for ingredients!


Thank you very much for your attention !

Overview about the European Storm Forecast Experiemnt, ESTOFEX

European Storm Forecast Experiment (ESTOFEX) www.estofex.org

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estofex
since 2002

European Storm Forecast Experiment

- forecasts
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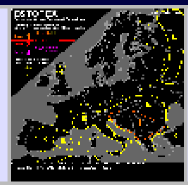
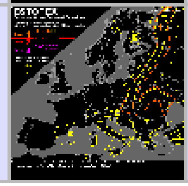
Forecasts

forecast	map	threat level	period	forecaster
Storm forecasts				
Storm Forecast issued: Thu 02 Jun 2011 12:49		1	Fri 03 Jun 2011 06:00 - Sat 04 Jun 2011 06:00 UTC	TUSCHY
Storm Forecast issued: Wed 01 Jun 2011 13:33		1	Thu 02 Jun 2011 06:00 - Fri 03 Jun 2011 06:00 UTC	GATZEN

The forecast archive can be found here.

Please note that forecasts produced by ESTOFEX are not warnings of imminent severe weather. Your national meteorological service carries the responsibility to warn you for severe weather. These warnings can be found on meteoalarm.eu.

Forecasters of ESTOFEX

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European Storm Forecast Experiment (ESTOFEX)

What is ESTOFEX?

An initiative of a team of European **meteorologists** and **students in meteorology** and serves as a platform for exchange of knowledge about severe convective storms in Europe and elsewhere.

! **ESTOFEX offers a GUIDANCE where organized convection is forecast. This guidance can be used by local forecast offices for daily warning preparation.** !

Which risk of (extremely) severe convective weather phenomena does ESTOFEX forecast ?

Severe convective weather phenomena:

- **tornado** (waterspouts)
- **hail** with a diameter of at least 2.0 cm
- **wind gusts** with a speed of at least 25 m/s (92 km/h or about 49 knots)
- **excessive rainfall** of at least 60 mm

Extremely severe convective weather phenomena:

- tornado; (E)F 2 or stronger
- hail with a diameter of at least 5.0 cm
- wind gusts with a speed of at least 33 m/s (119 km/h or about 65 knots)

The meaning of the level areas

1) E.g. probability of 15 % means a 15 % chance for that event to happen within a radius of 41 km around each point. May seem low, but compared to climatology, it is significant

2) **Level 0** expected probability of severe convection appears insignificant

3) **Level 1** most common threat level; low threat of severe weather

4) **Level 2** large confidence of severe storm occurrence and slight risk for extreme severe

5) **Level 3** major severe thunderstorm outbreak (e.g. 15th August 2008)

Issued: Wed 13 Aug 2008 21:18 Z

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