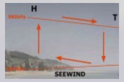
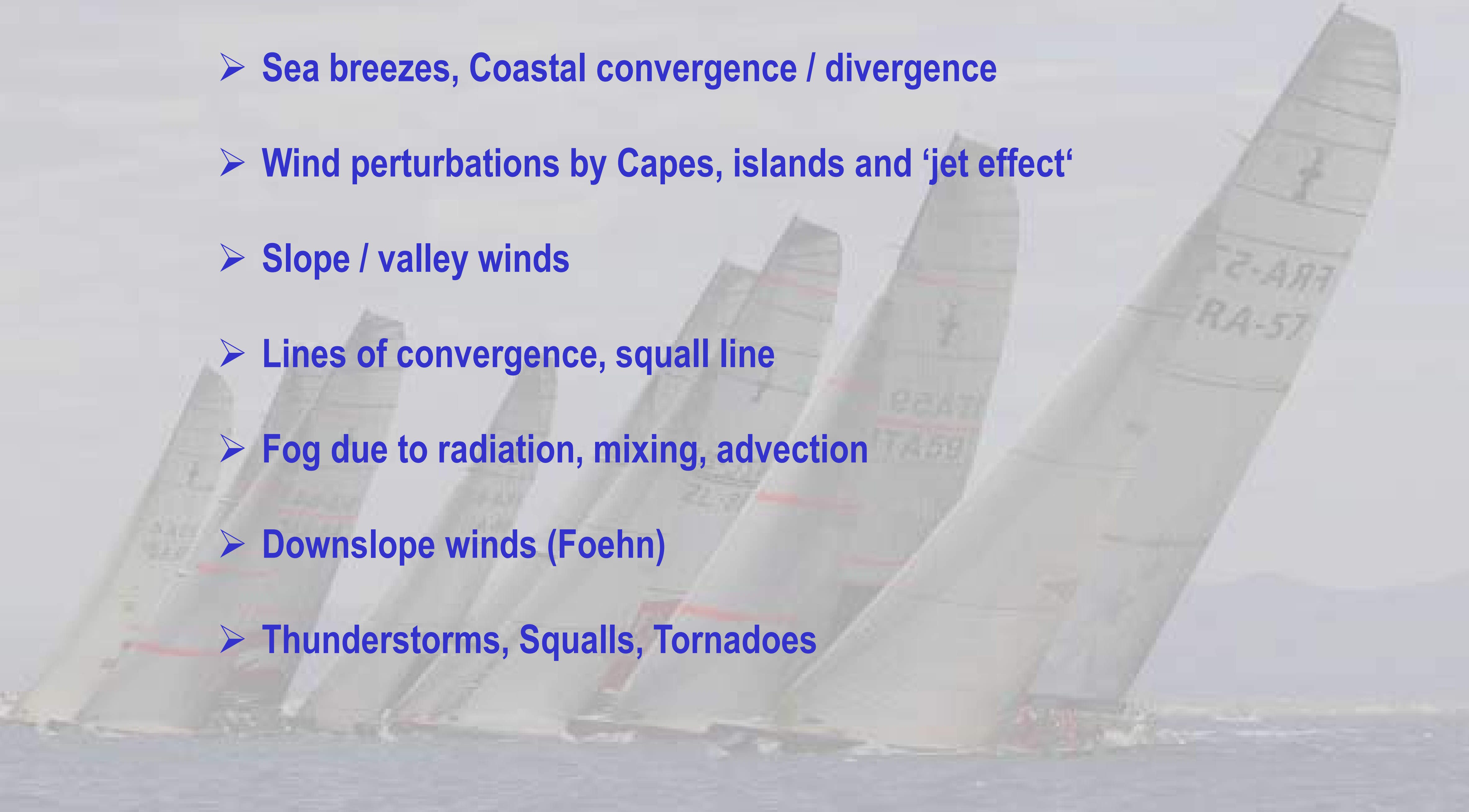
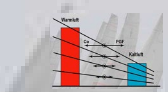


SMALL-SCALE PROCESSES

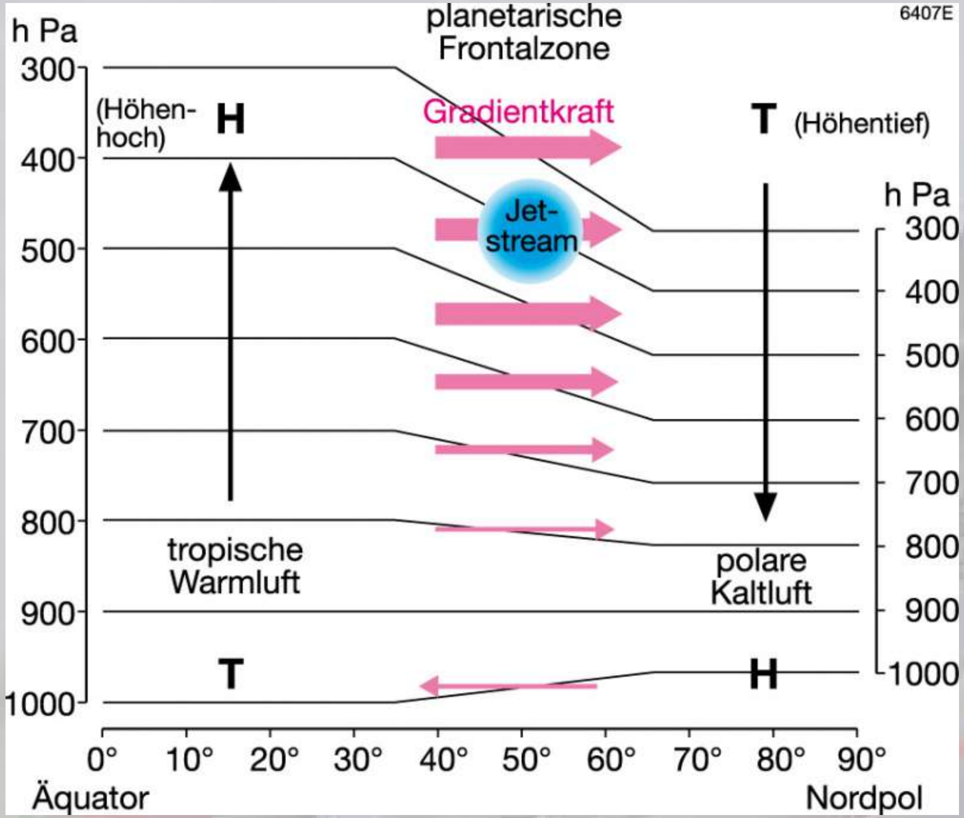


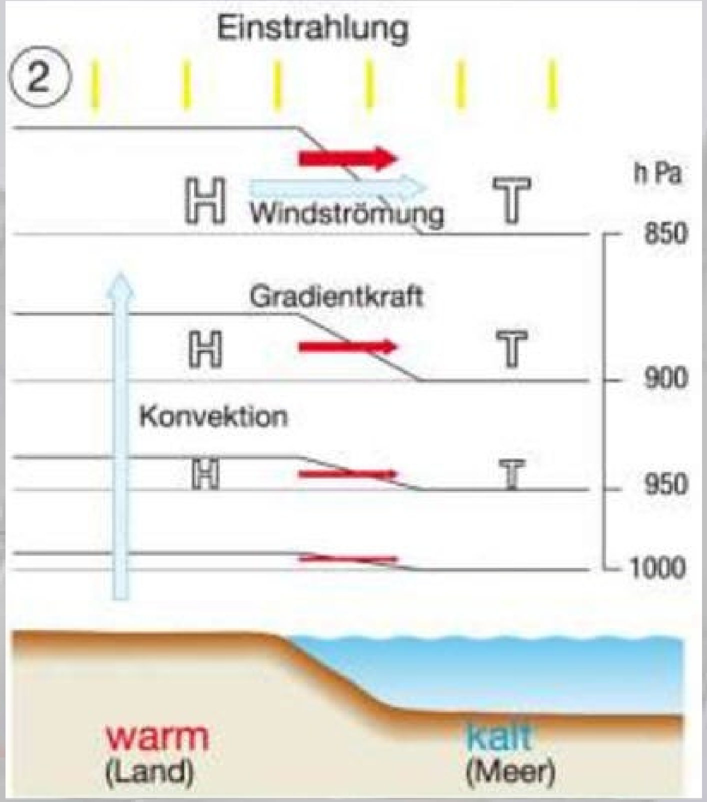
- Sea breezes, Coastal convergence / divergence
- Wind perturbations by Capes, islands and ‘jet effect‘
- Slope / valley winds
- Lines of convergence, squall line
- Fog due to radiation, mixing, advection
- Downslope winds (Foehn)
- Thunderstorms, Squalls, Tornadoes

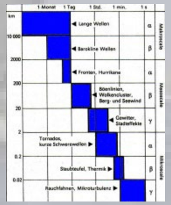
BASIC PARAMETERS – PRESSURE : VERTICAL STRUCTURE OF THE ATMOSPHERE



Consequences on different scales of the fact that the height of a surface of constant pressure (over 1000 hPa) is a function of and only of the mean temperature of the airmass between these layers

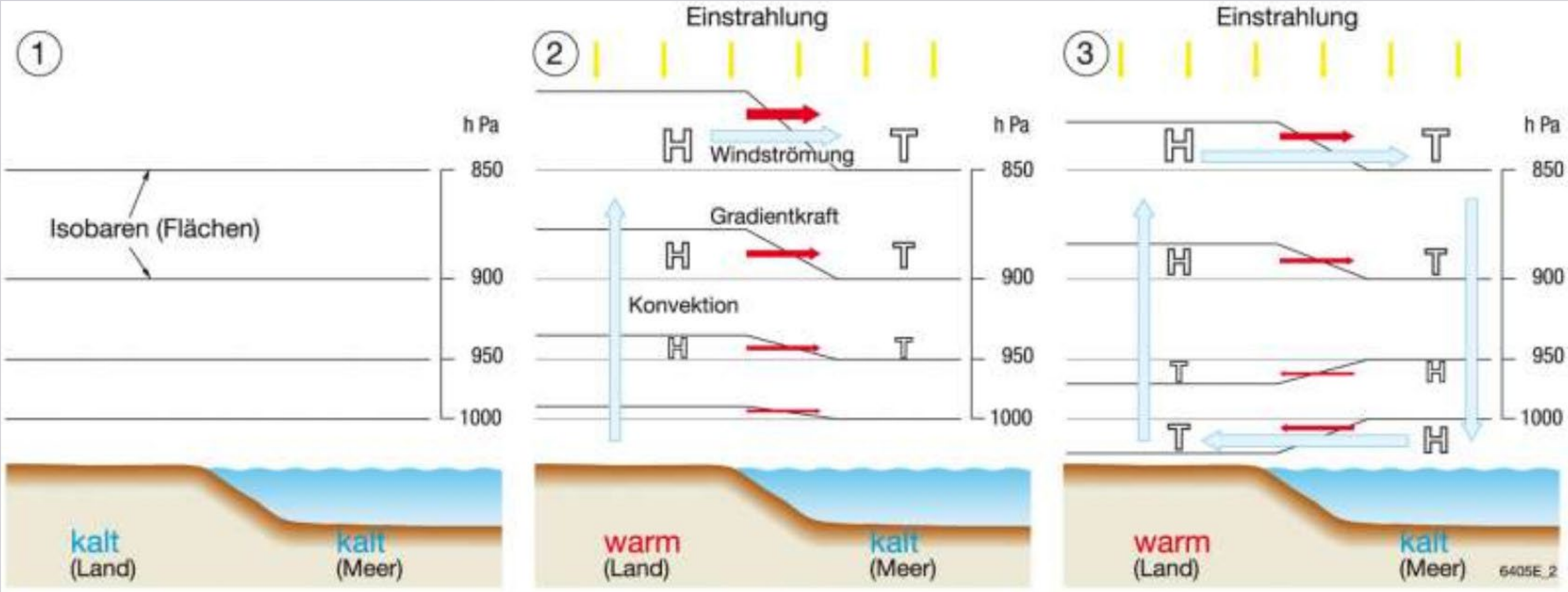






	Global circulation	Sea-breeze circulation
Horizontal scale	10000 km	10 km
Vertical scale	10 km	2 km
Time scale	months	one day

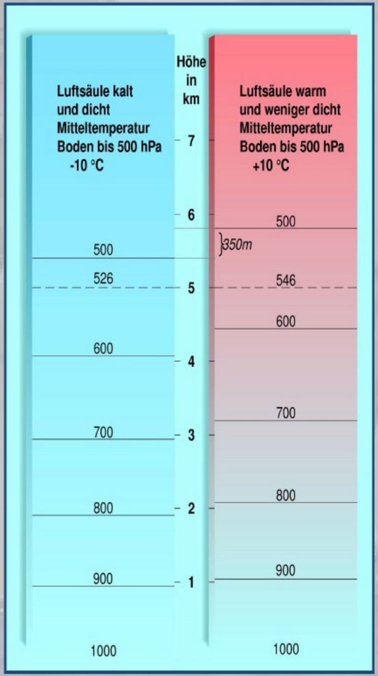
SEA-BREEZE CIRCULATION



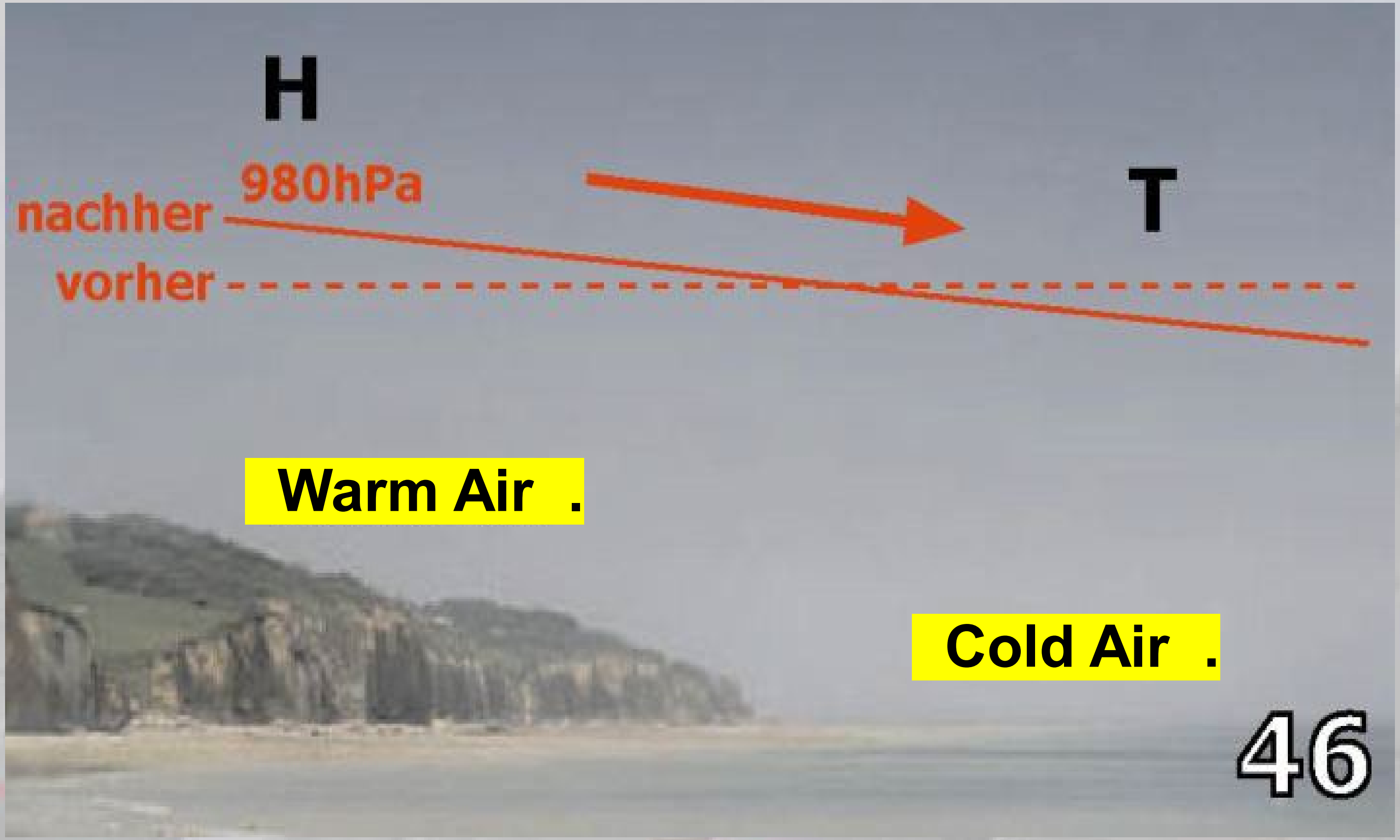
Cause of the sea-breeze

Lifting of surfaces of constant air pressure over land due to diurnal heating

Resulting horizontal pressure gradients from land to sea at height 1.5 km (850 hPa)

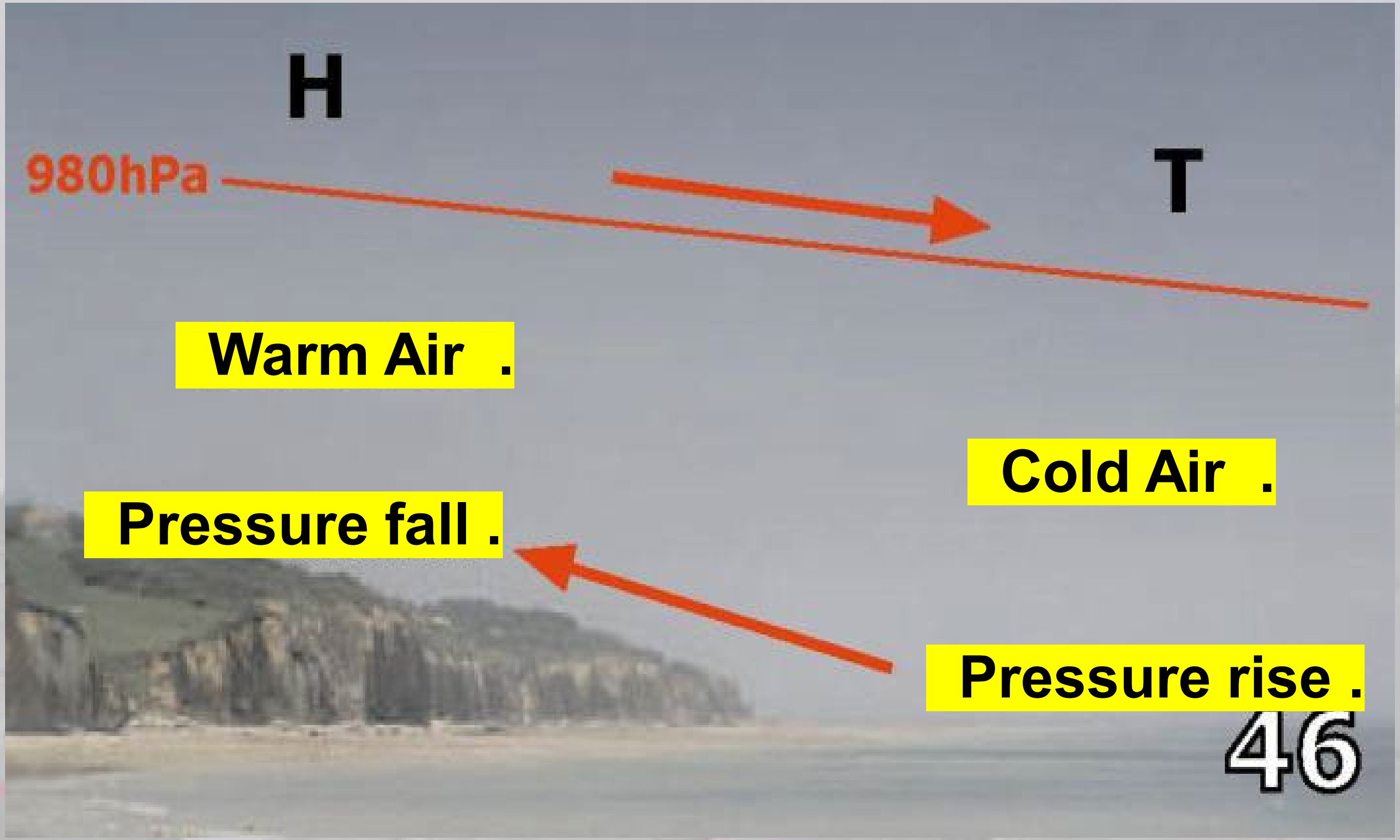


SEA BREEZE CIRCULATION



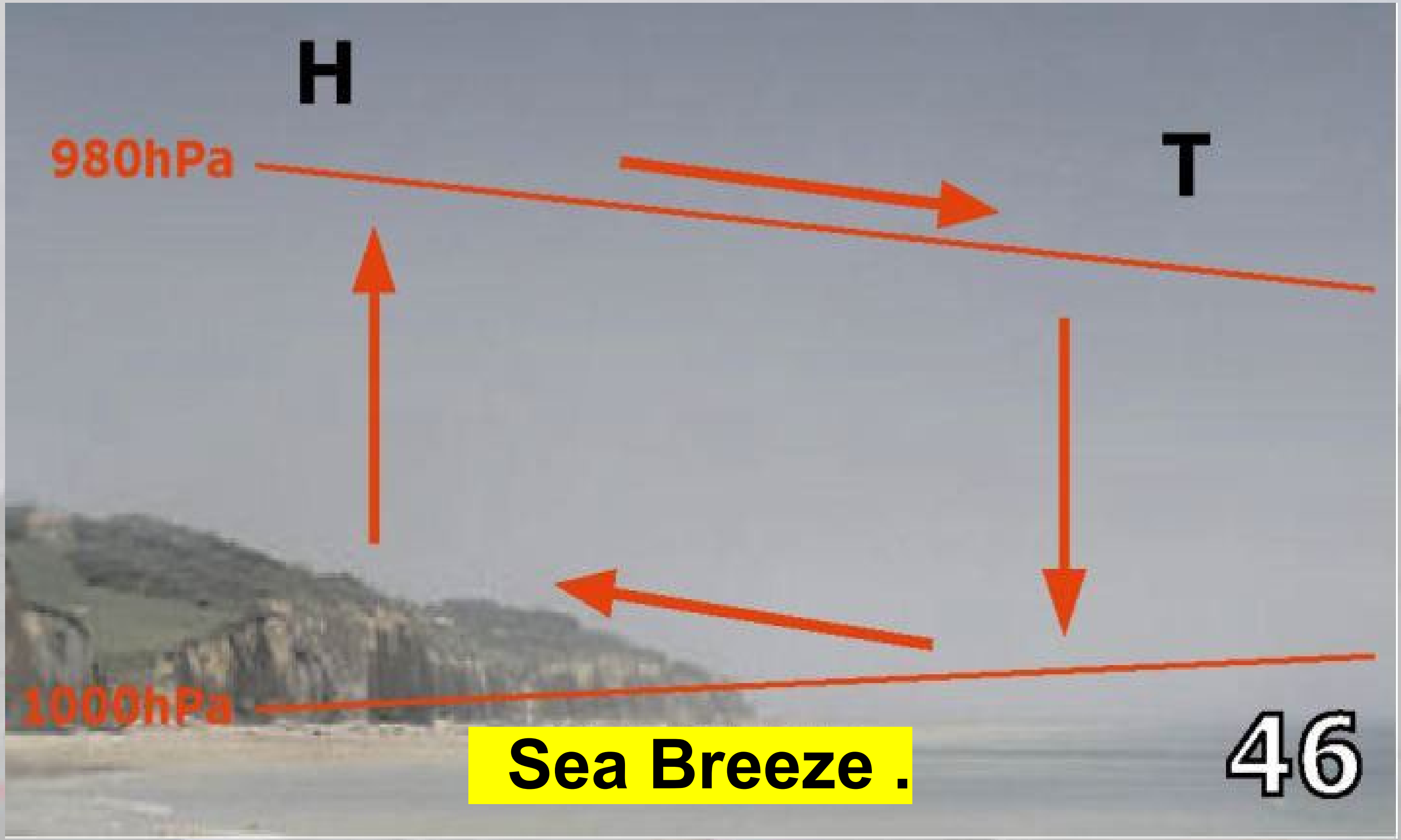
On-shore gradient wind strengthens the sea breeze,
Off-shore gradient wind reduces the sea breeze, even to lull

SEA BREEZE CIRCULATION



Forming of a sea breeze circulation requires a moderate gradient wind and a sufficient temperature difference between shore and sea

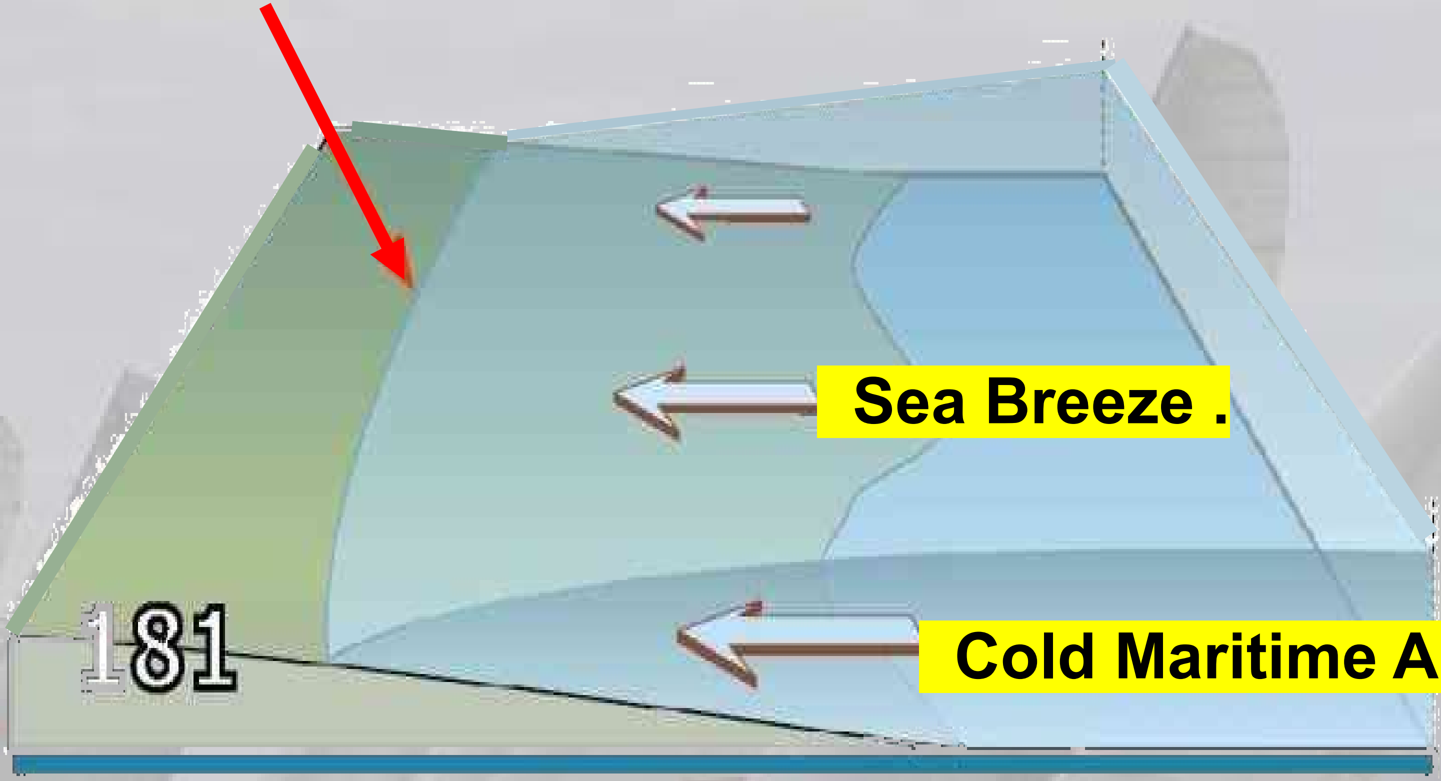
SEA BREEZE CIRCULATION



v^2 / dT v [mps]:   > 5 no sea breeze   < 1 likely   < 0.5 certain

e.g.: $v = 3$ mps, $T_{shore} = 30°$ $T_{sea} = 20°$ ergo 0.9: sea breeze possible

SEA BREEZE CIRCULATION



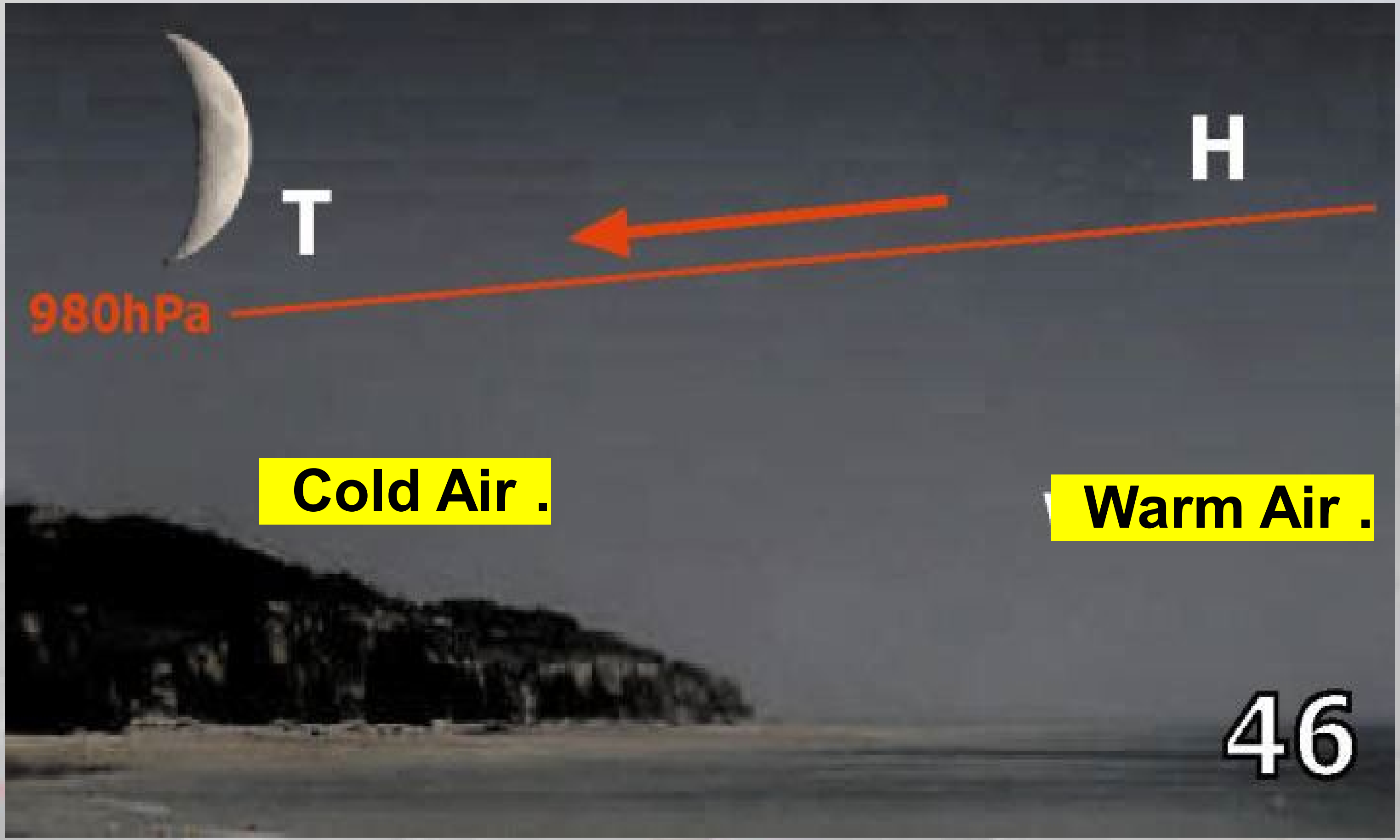
Sea Breeze Front .

Sea Breeze .

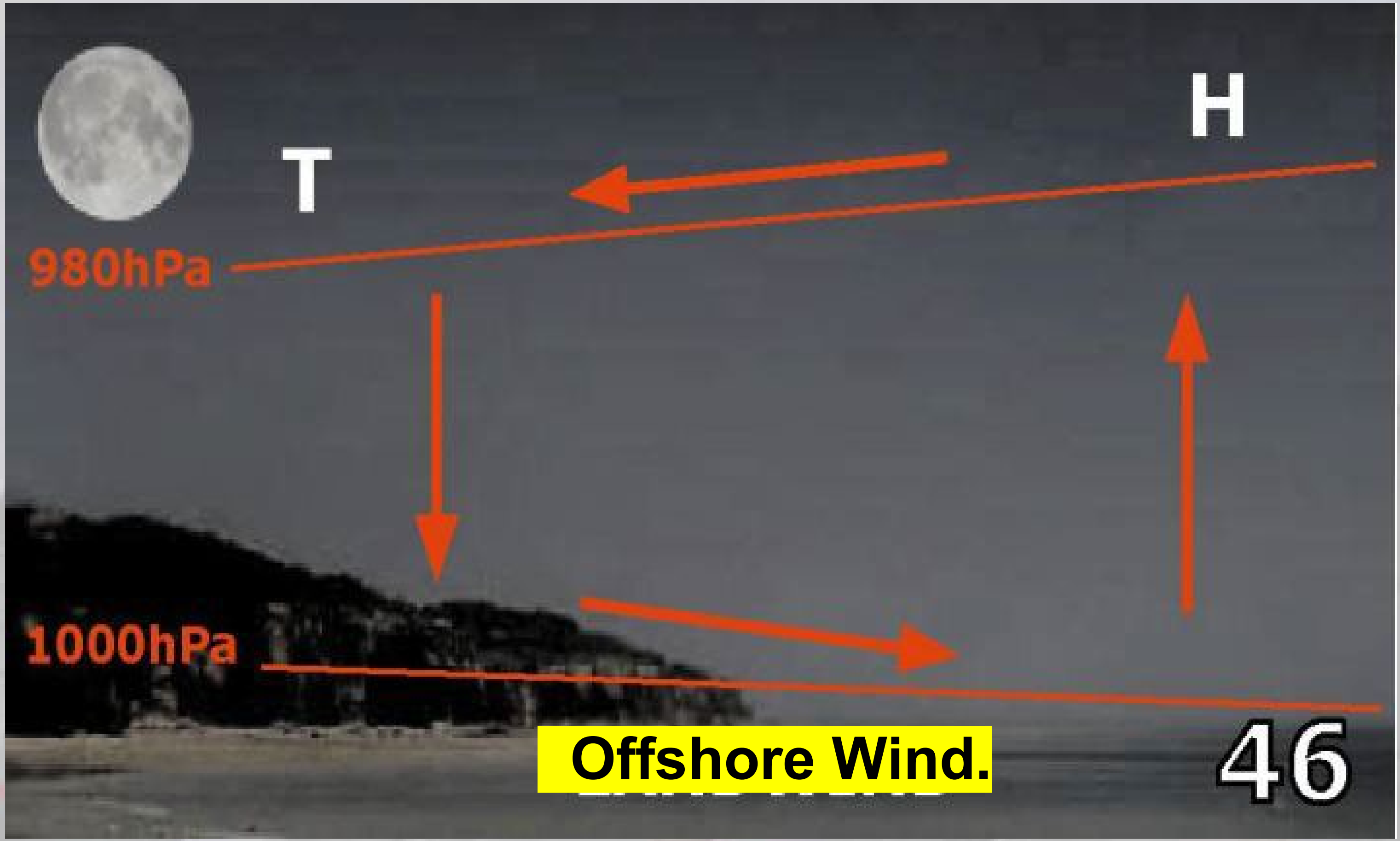
Cold Maritime Air .

Propagation of the sea-breeze front (up to 50 km inland)

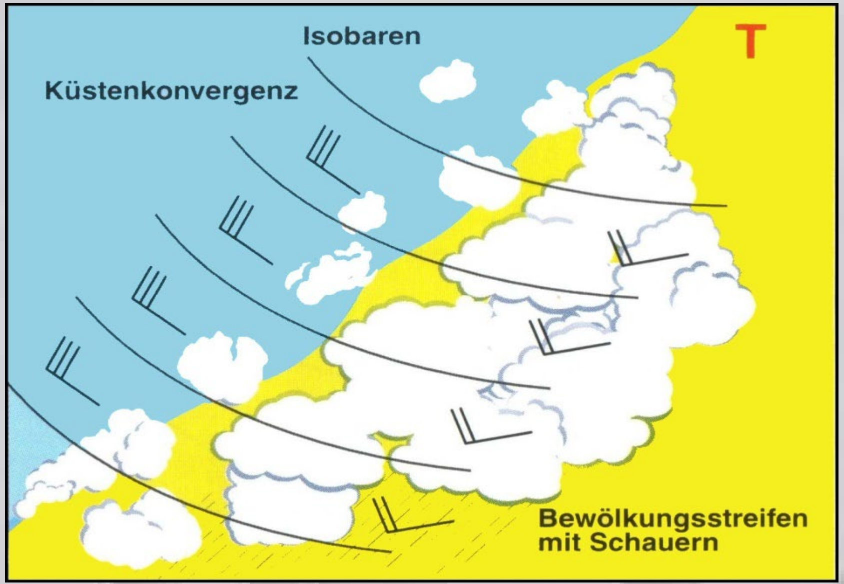
SEA BREEZE CIRCULATION



SEA BREEZE CIRCULATION

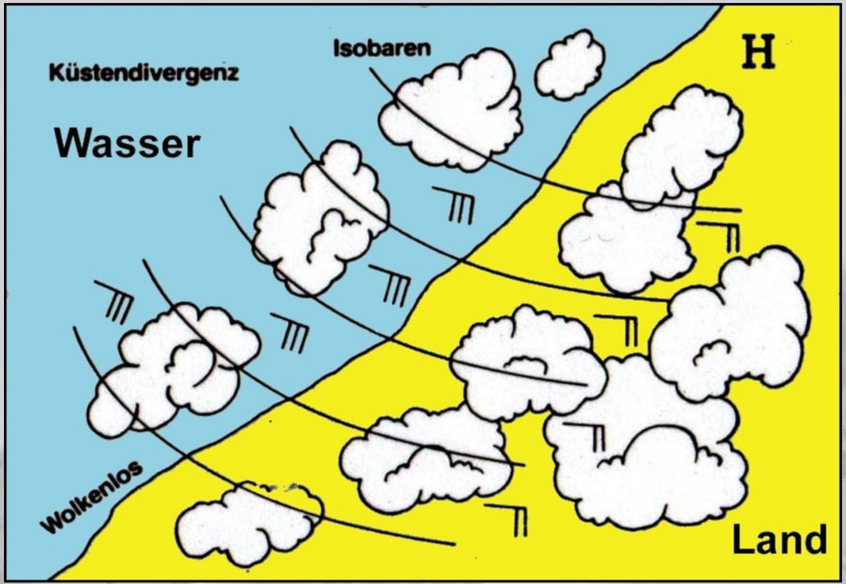


COASTAL CONVERGENCE / DIVERGENCE



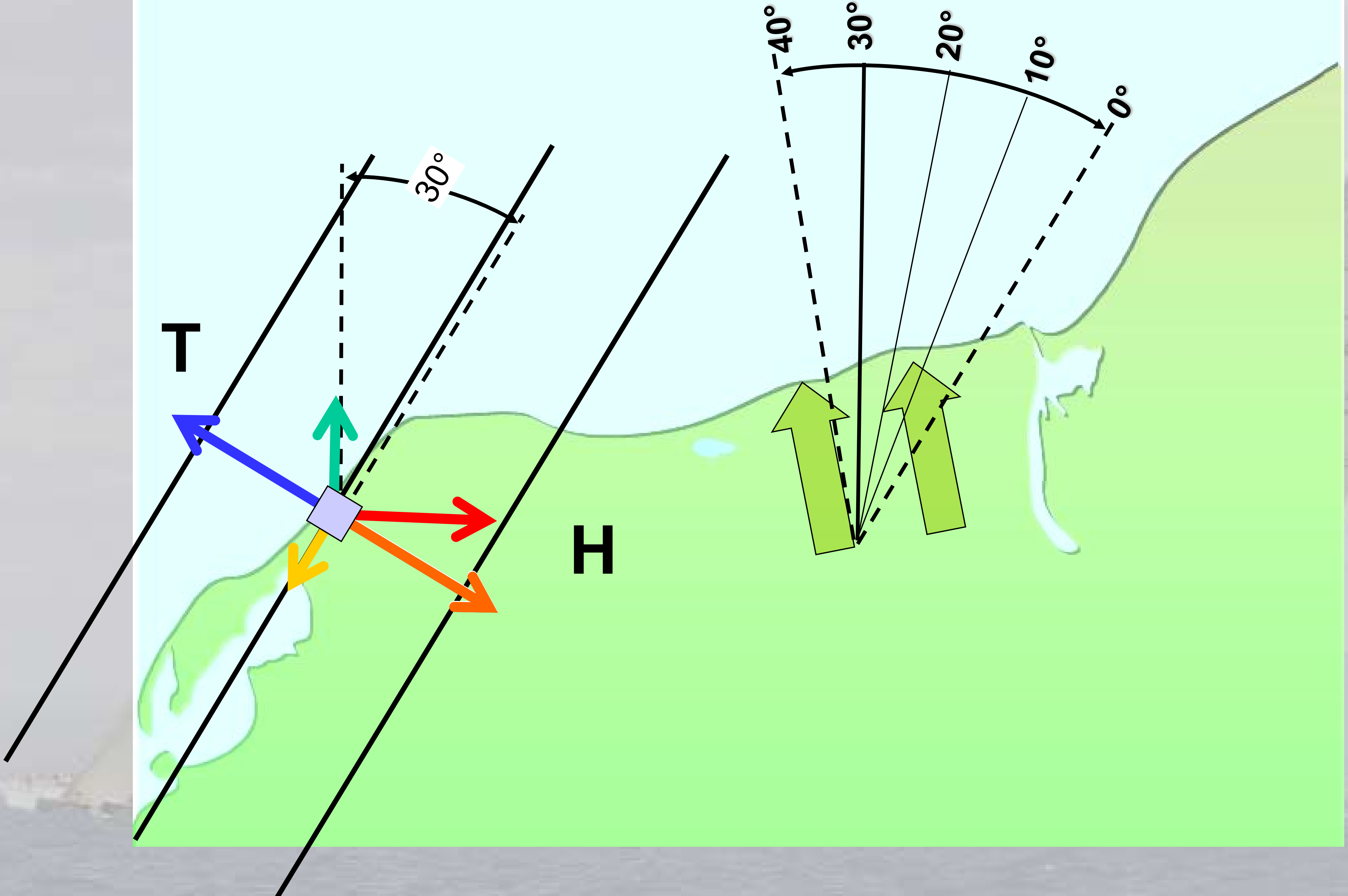
Coastal convergence

Increased friction over land, therefore reduced windspeed and Coriolis force results in lower deviation to the right, which means backening of the wind (to the left), associated with lifting of air parcel and forming of cumuliform clouds

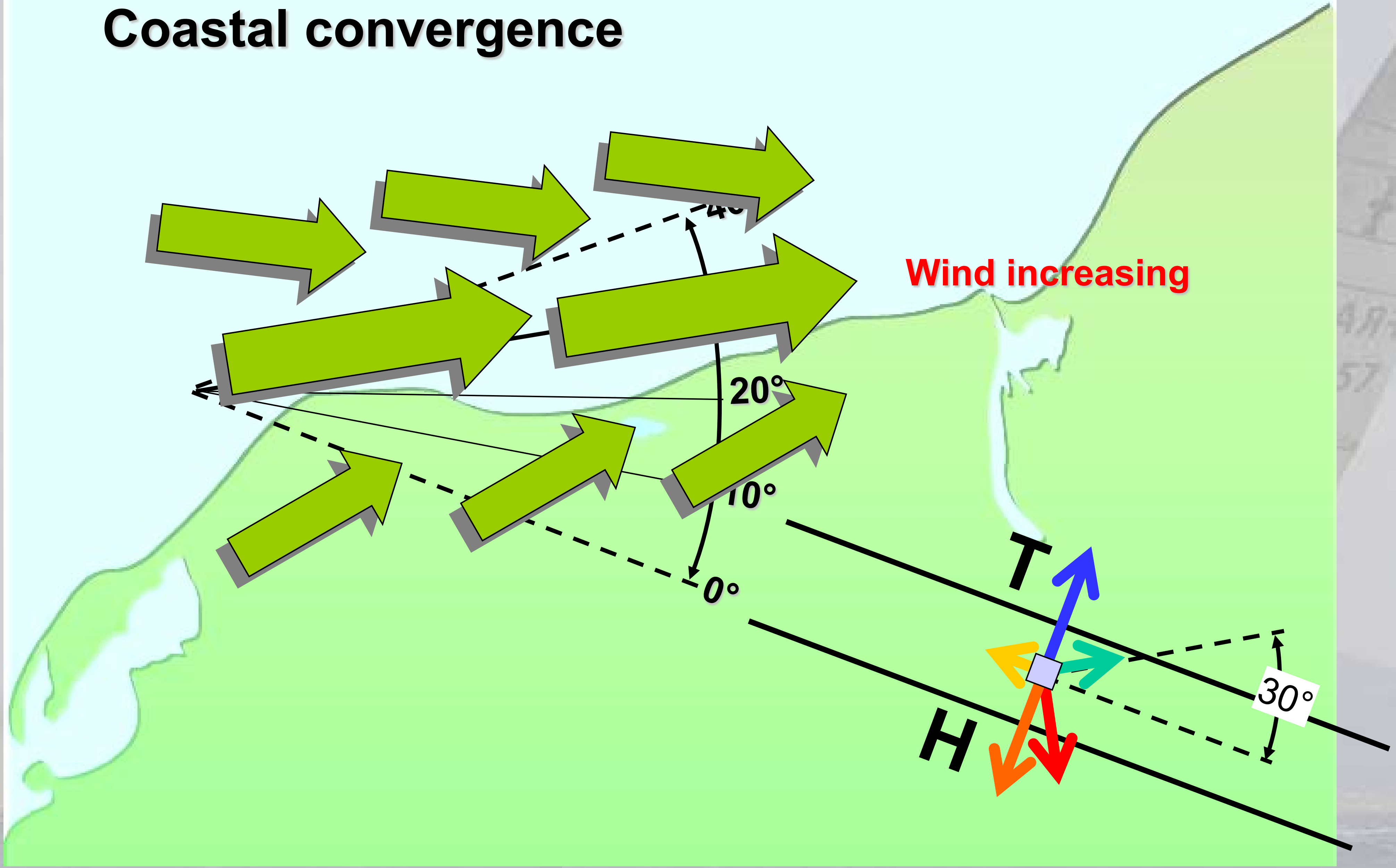


Coastal divergence

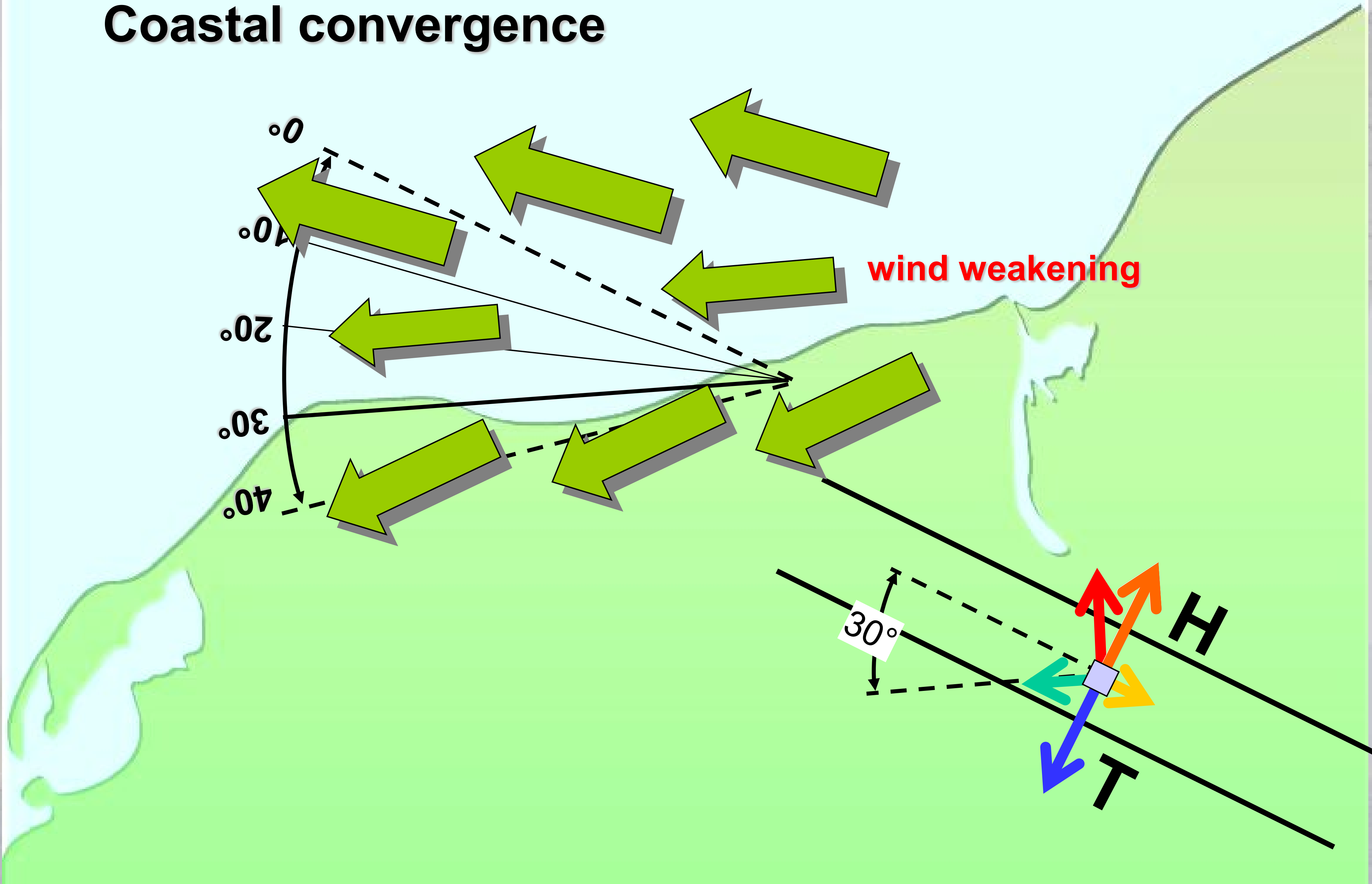
Reduced friction over sea, therefore increased windspeed and Coriolis force, results in higher deviation to the right, which means veering of the wind (to the right), associated with subsidence of air parcel and dissolution of clouds


40°
30°
20°
10°
0°
30°
T
H

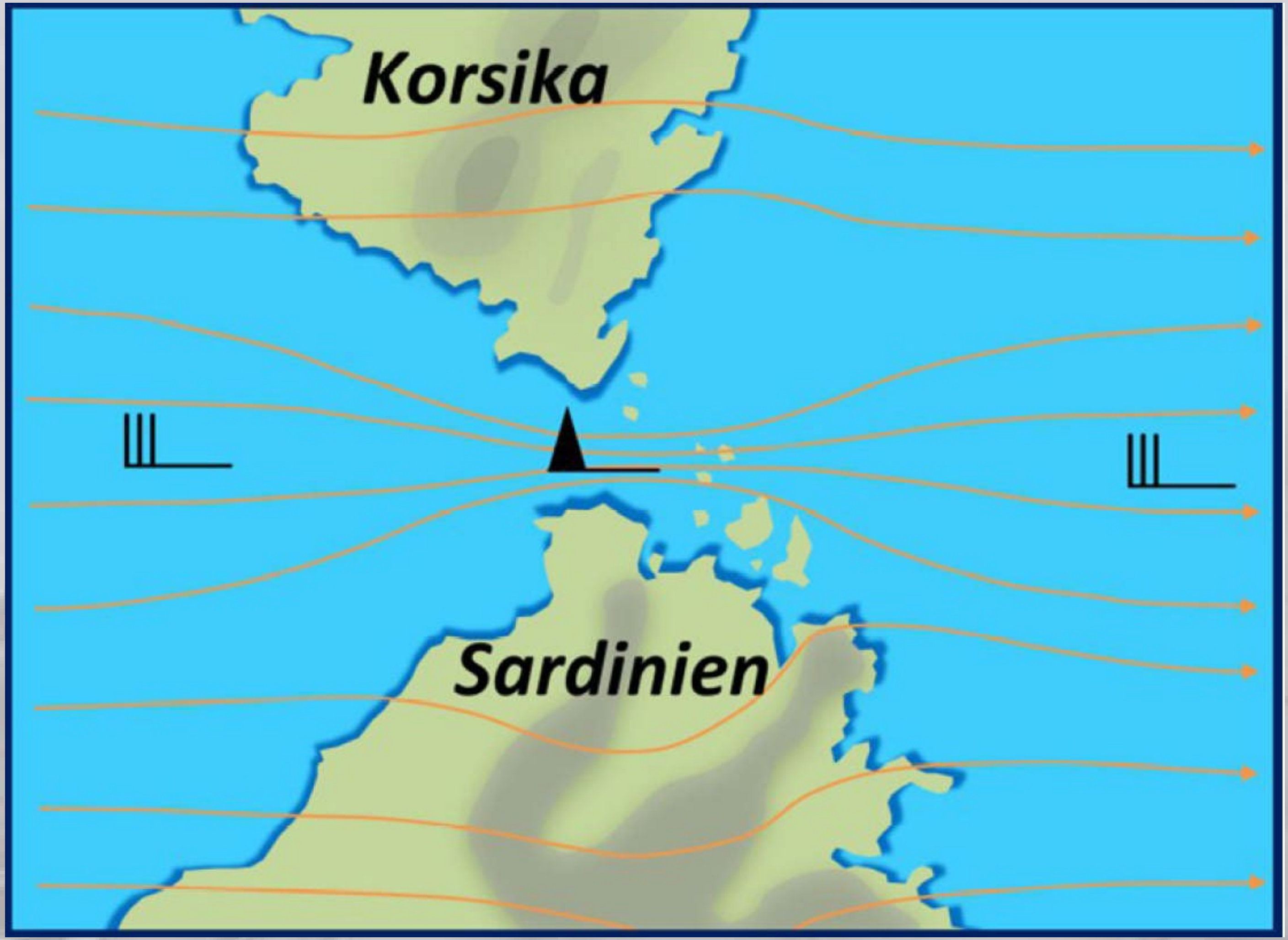
Coastal convergence



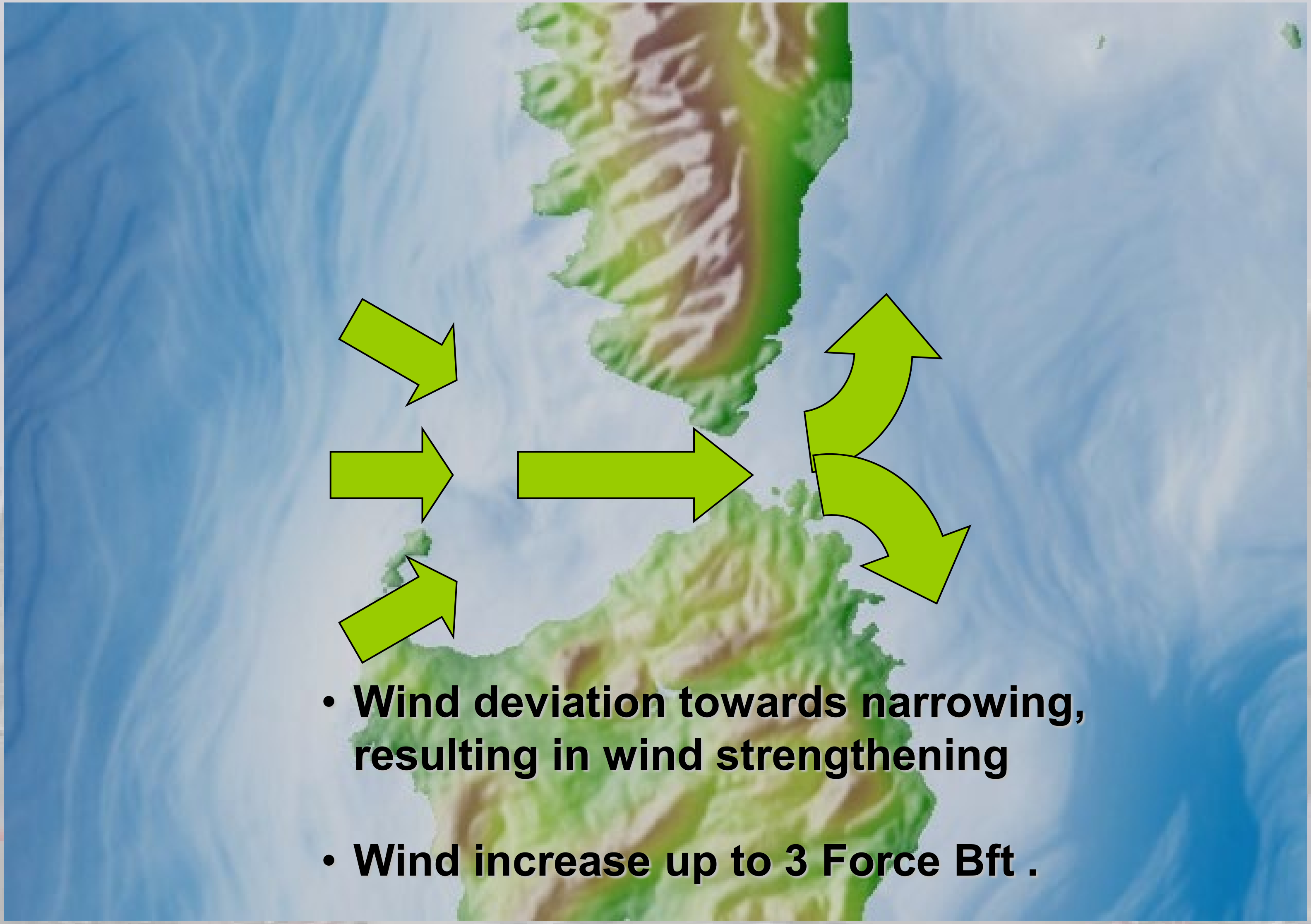
Coastal convergence



OROGRAPHIC EFFECTS: ‘JET EFFECT‘

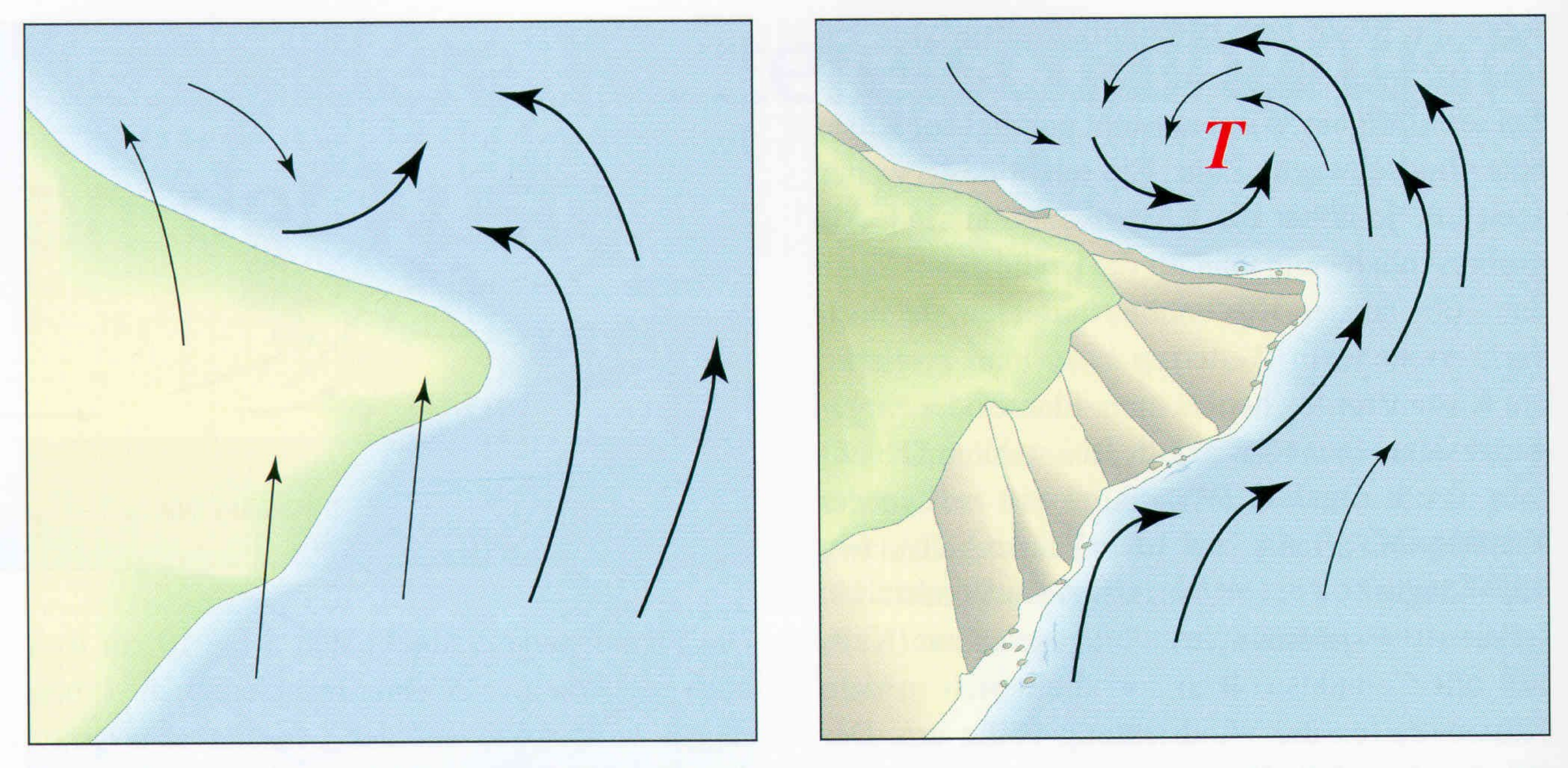


OROGRAPHIC EFFECTS: ‘JET EFFECT‘



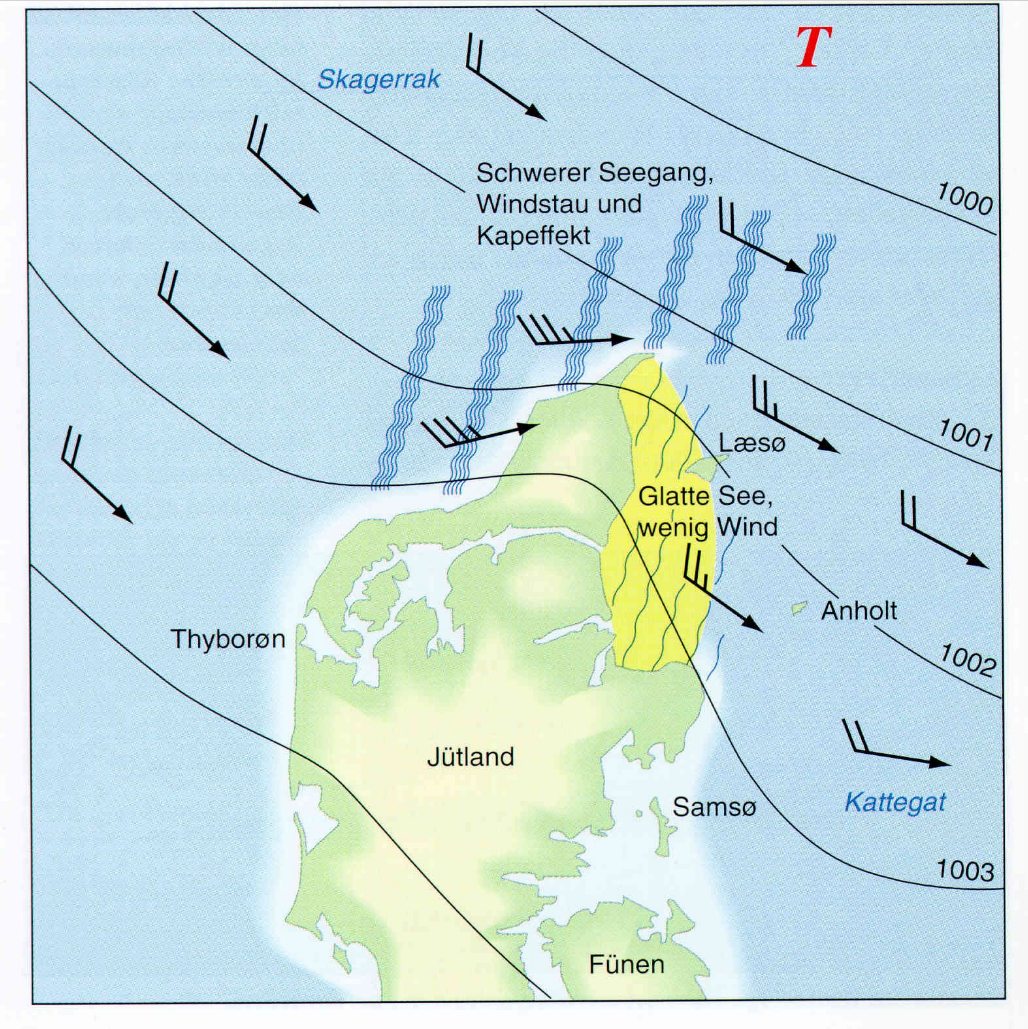
- **Wind deviation towards narrowing, resulting in wind strengthening**
- **Wind increase up to 3 Force Bft .**

COASTAL- / CAPE-EFFECTS



Flat land **Wind leeward of a ‘Huk‘** **steep coast**

COASTAL- / CAPE-EFFECTS



Effect of the northern tip of Jutland on wind and sea

OROGRAPHY: TURBULENT FLOW AROUND ISLANDS

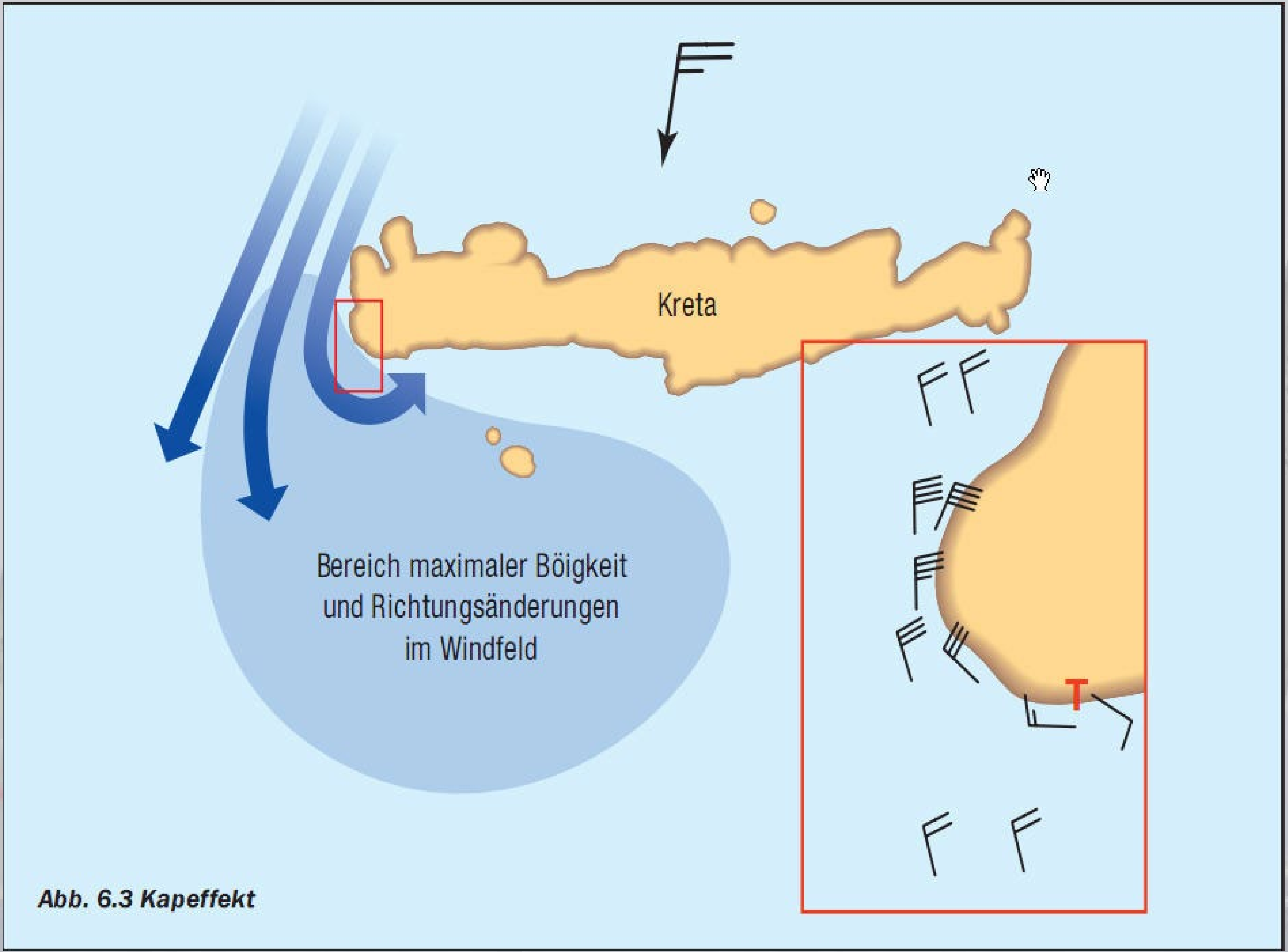
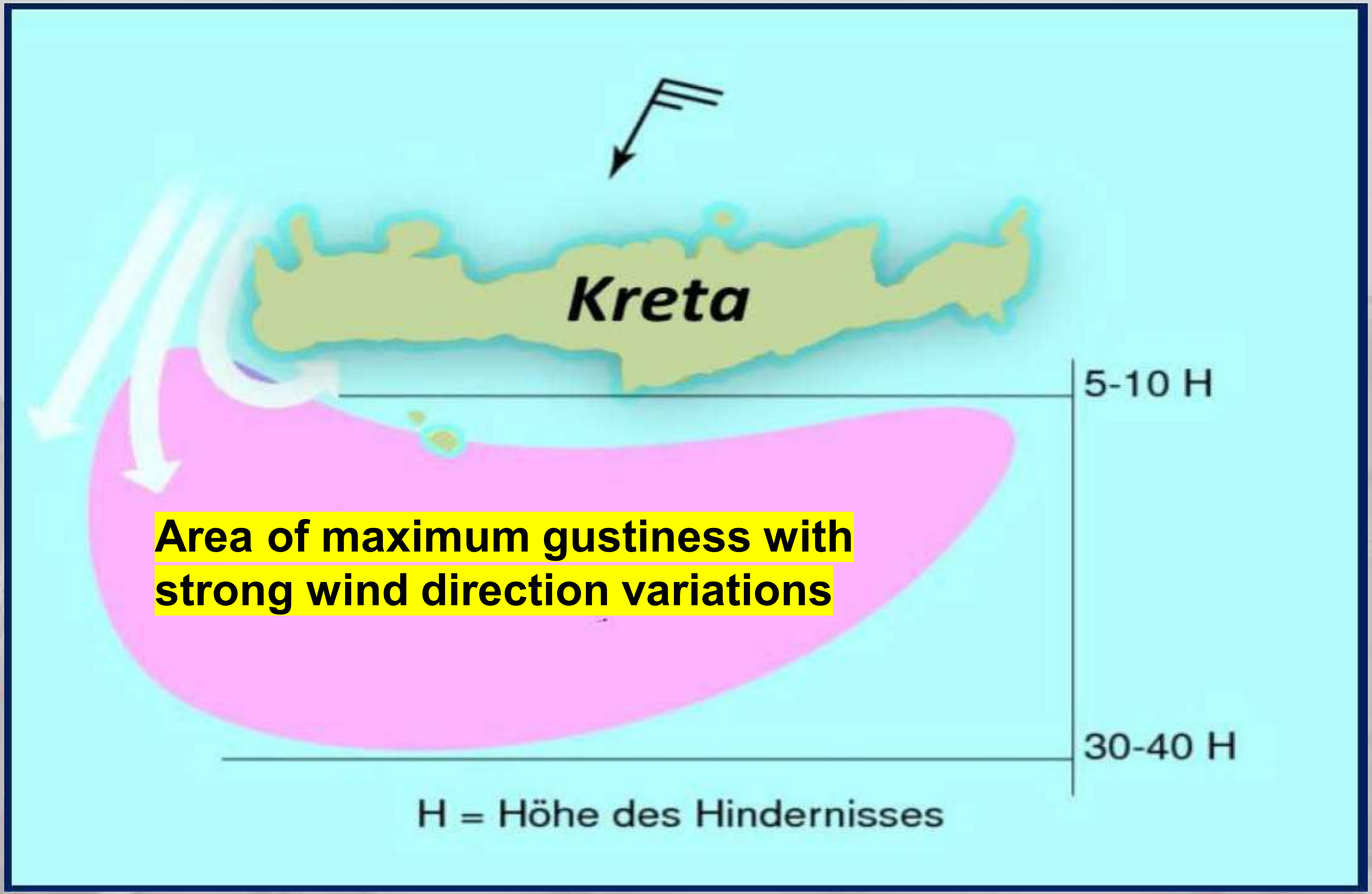


Abb. 6.3 Kapeffekt

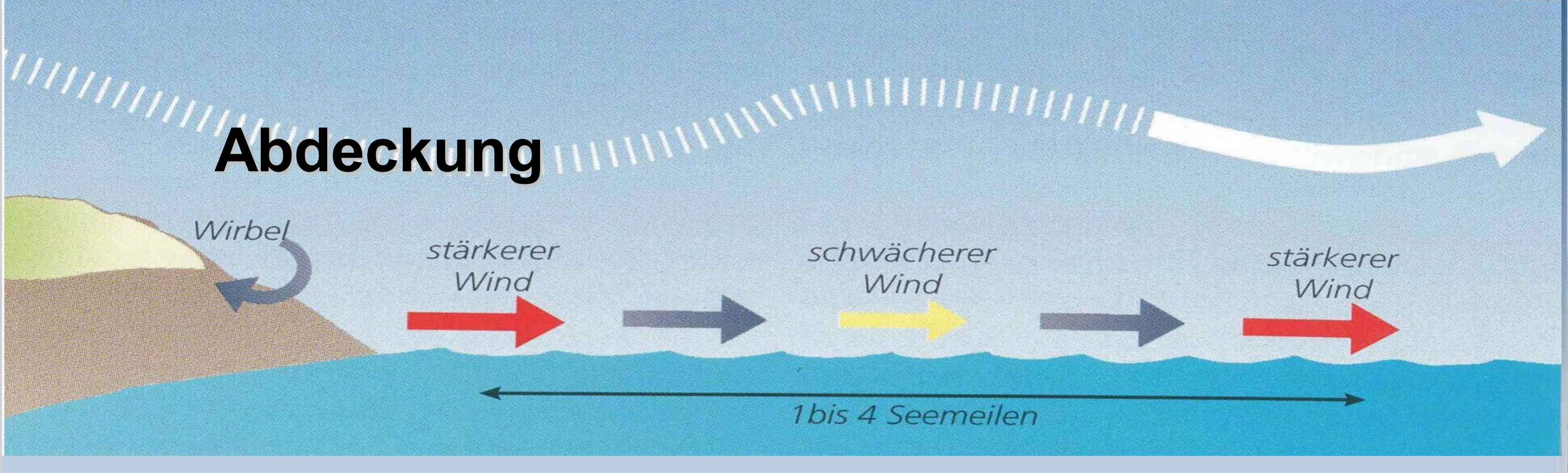
OROGRAPHY: TURBULENT FLOW AROUND ISLANDS

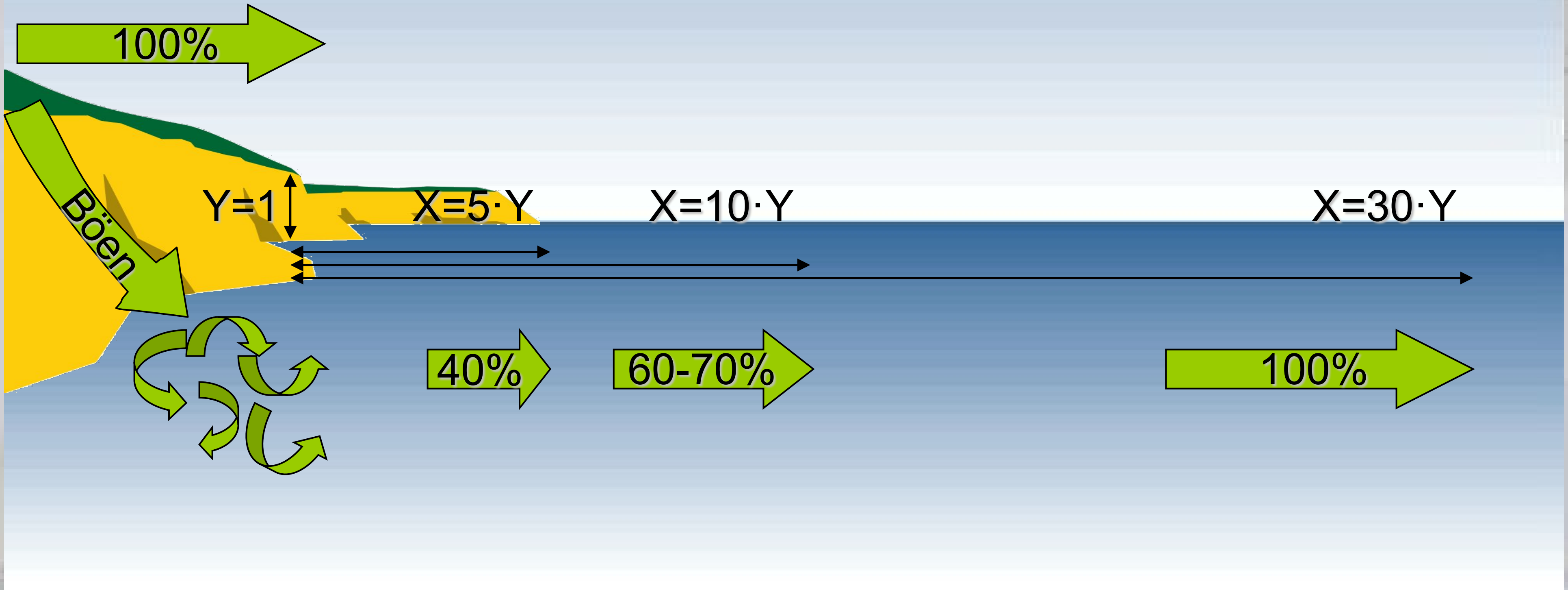


Area of maximum gustiness with strong wind direction variations

H = Höhe des Hindernisses

Abdeckung




100%

Böen

Y=1

X=5·Y

X=10·Y

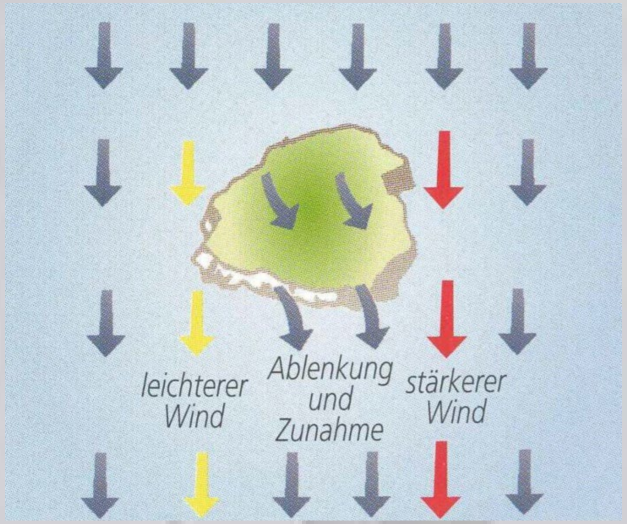
X=30·Y

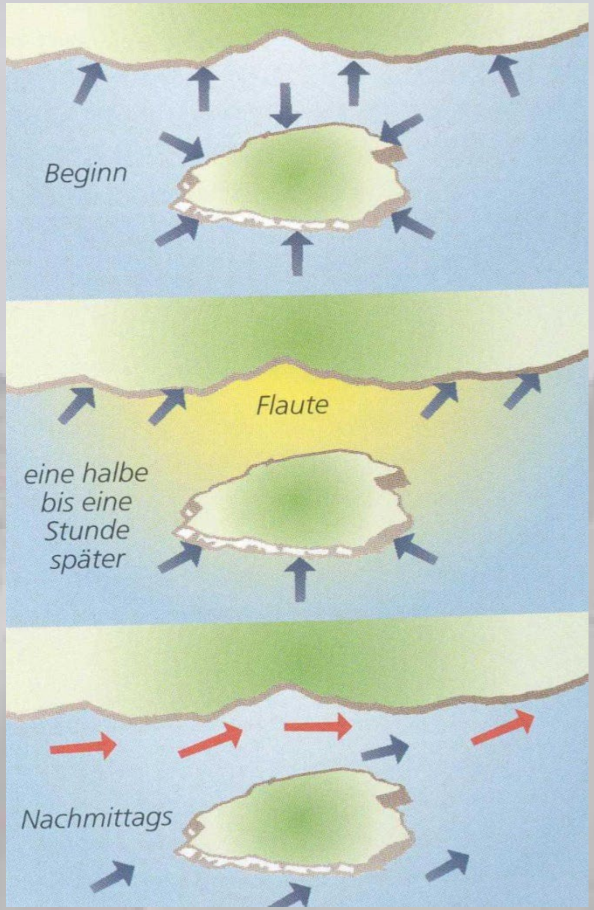
40%

60-70%

100%

WIND FLOW OVER SMALLER ISLANDS



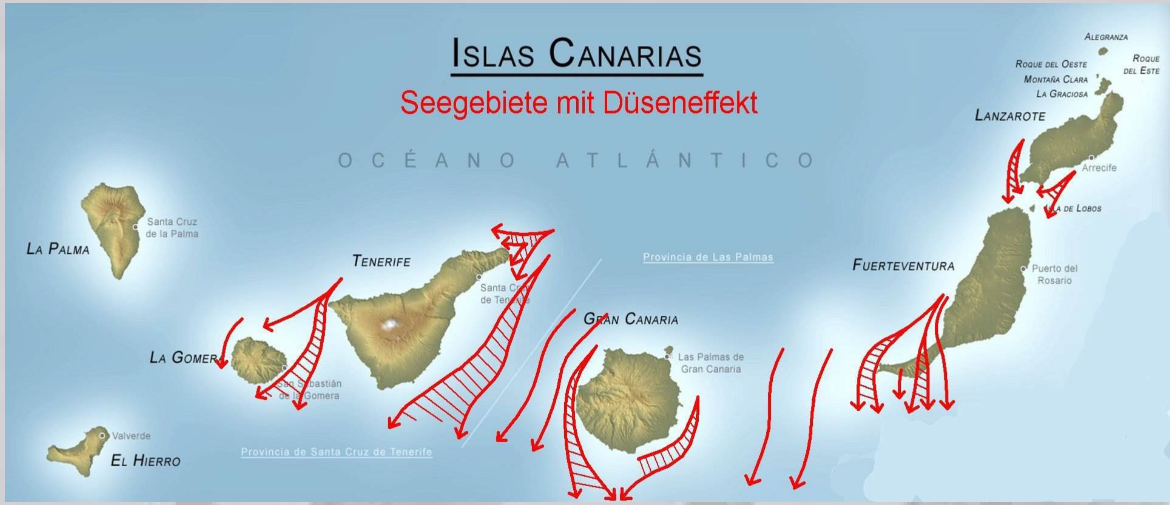


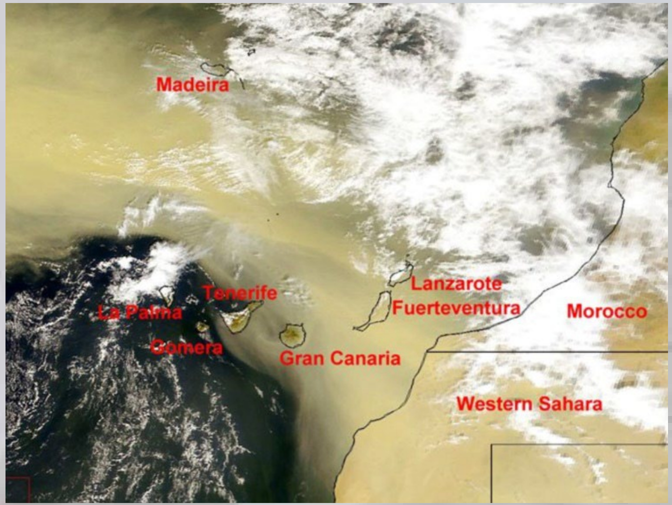
Due to increased friction of the island wind deviation over the island to the left

Example above:
Eastern shore: Convergence, wind increasing
Western shore: Divergence, wind weakening

Mainland and island are each forming individual sea breeze circulations resulting in lull in the sound. If the mainland sea breeze is strong enough, it can override the sea breeze of the island

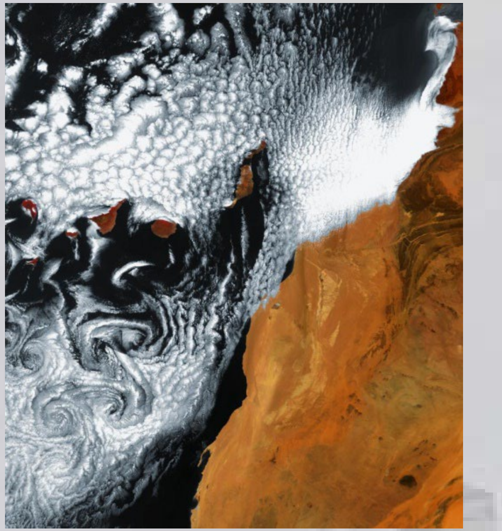
WIND FLOW OVER CANARY ISLANDS

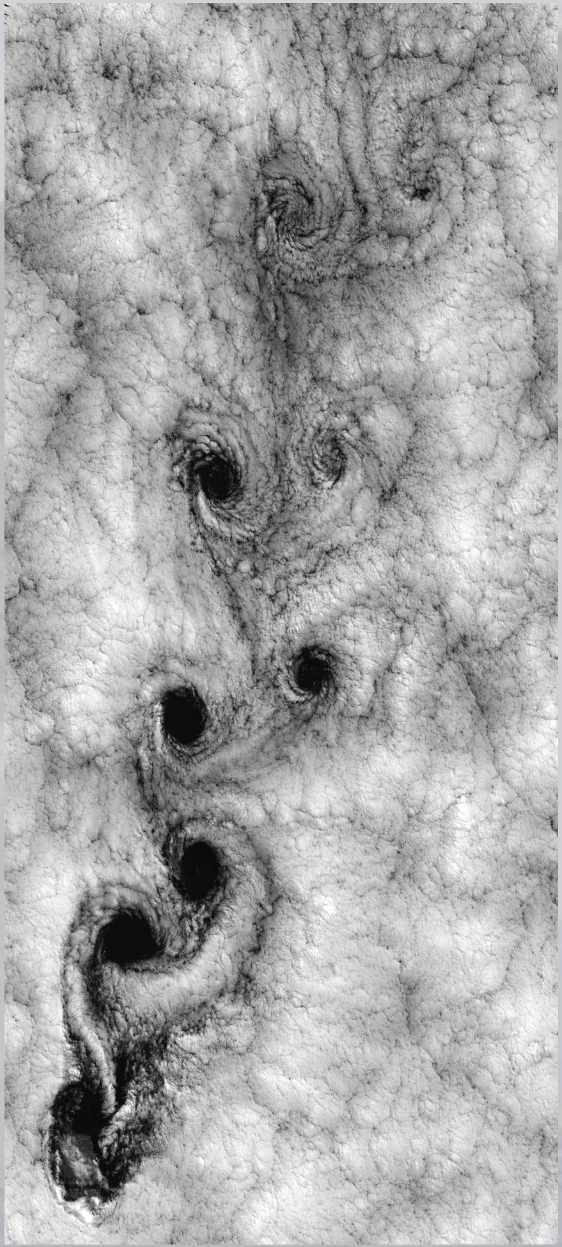




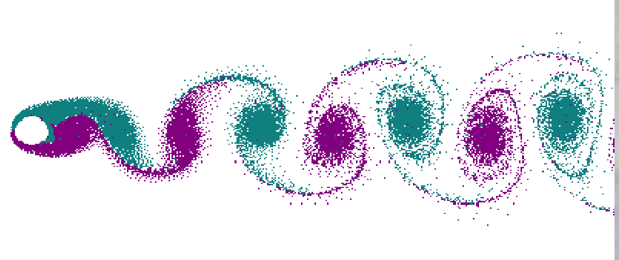
Trade wind	NE	All-seasons	moist, warm	Windward / leeward effects
Calima	E	Summer	dry, hot	Sahara dust
	S–W	Winter	Frontal systems, storm	
Cold air	N	Winter	almost rare	

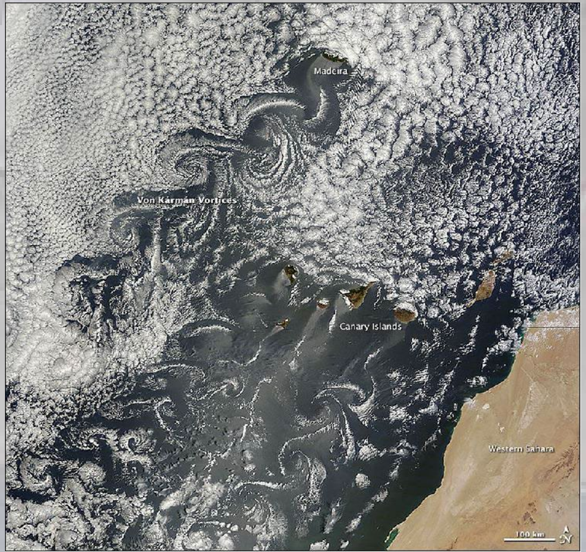
WIND FLOW OVER CANARY ISLANDS





Wind flow over the Canary Islands often induces Kármán vortices or even Kármán vortex streets





OROGRAPHIC WINDS : SLOPE / VALLEY WINDS

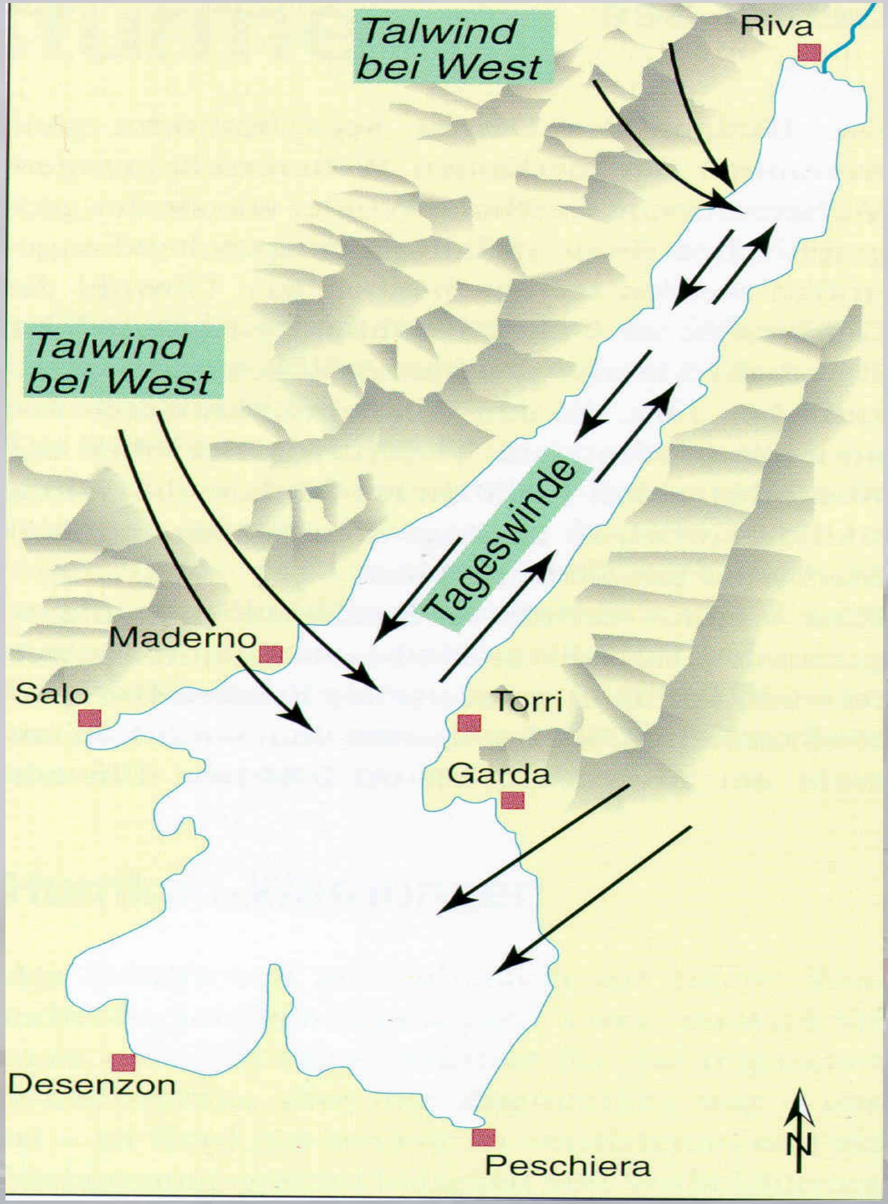
Processes during daytime

- Slope heating due to incoming solar radiation (Slope direction to the South is important)
- Forming of thermals
- Slope wind

Processes during nighttime

- Cooling due to outgoing IR-radiation
- Subsidence of cold / heavy air
- Valley wind

LOCAL WIND SYSTEMS LAKE GARDA



- Slope and valley winds Lake Garda
- Slope wind Ora from the South
  May-Sep 12:00-SS around Force 4
- Valley wind Pelér Vento from the North
  Jun-Sep 01:00-15:00 around Force 4-5

LINES OF CONVERGENCE

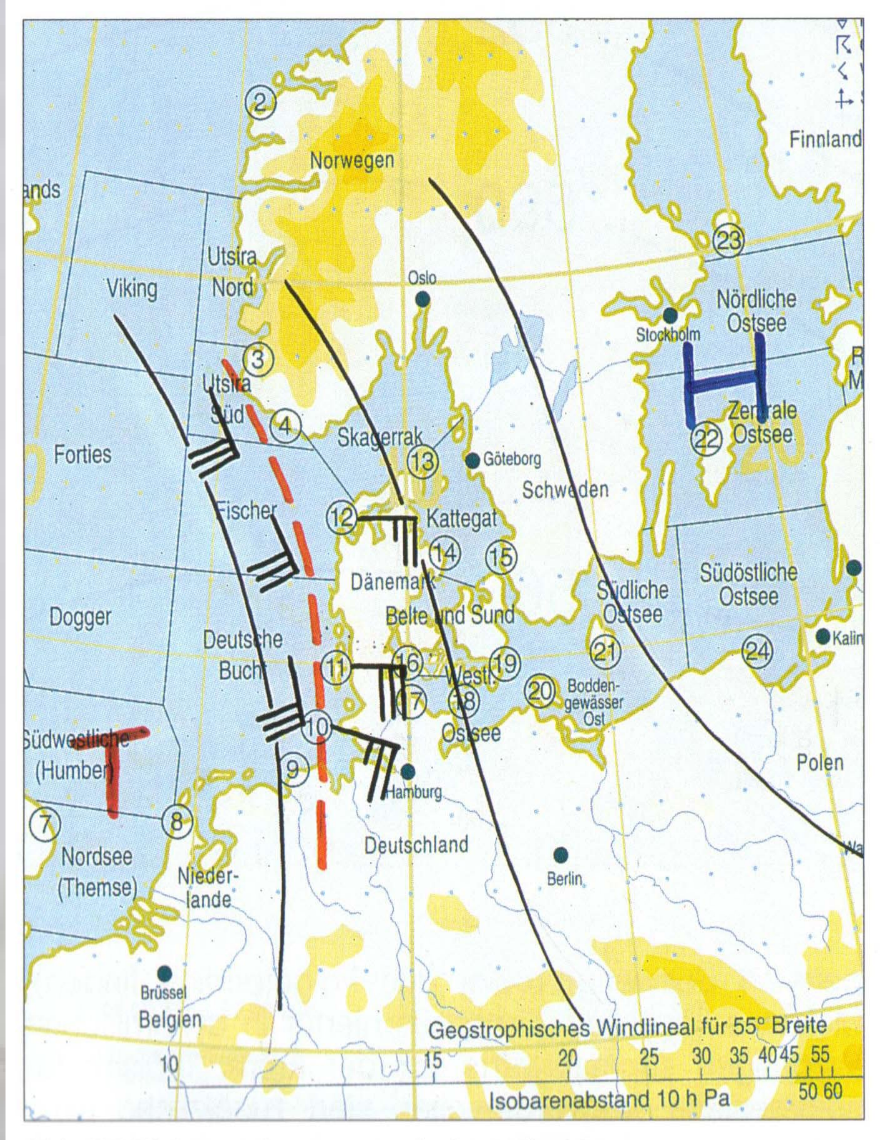
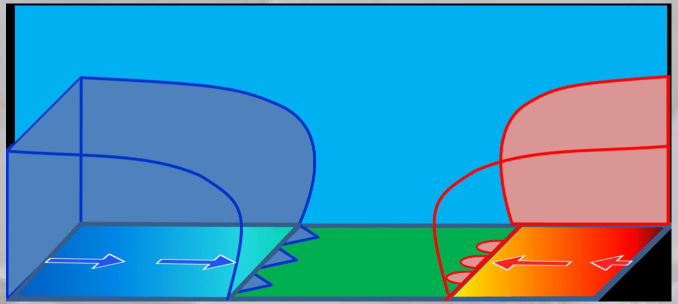
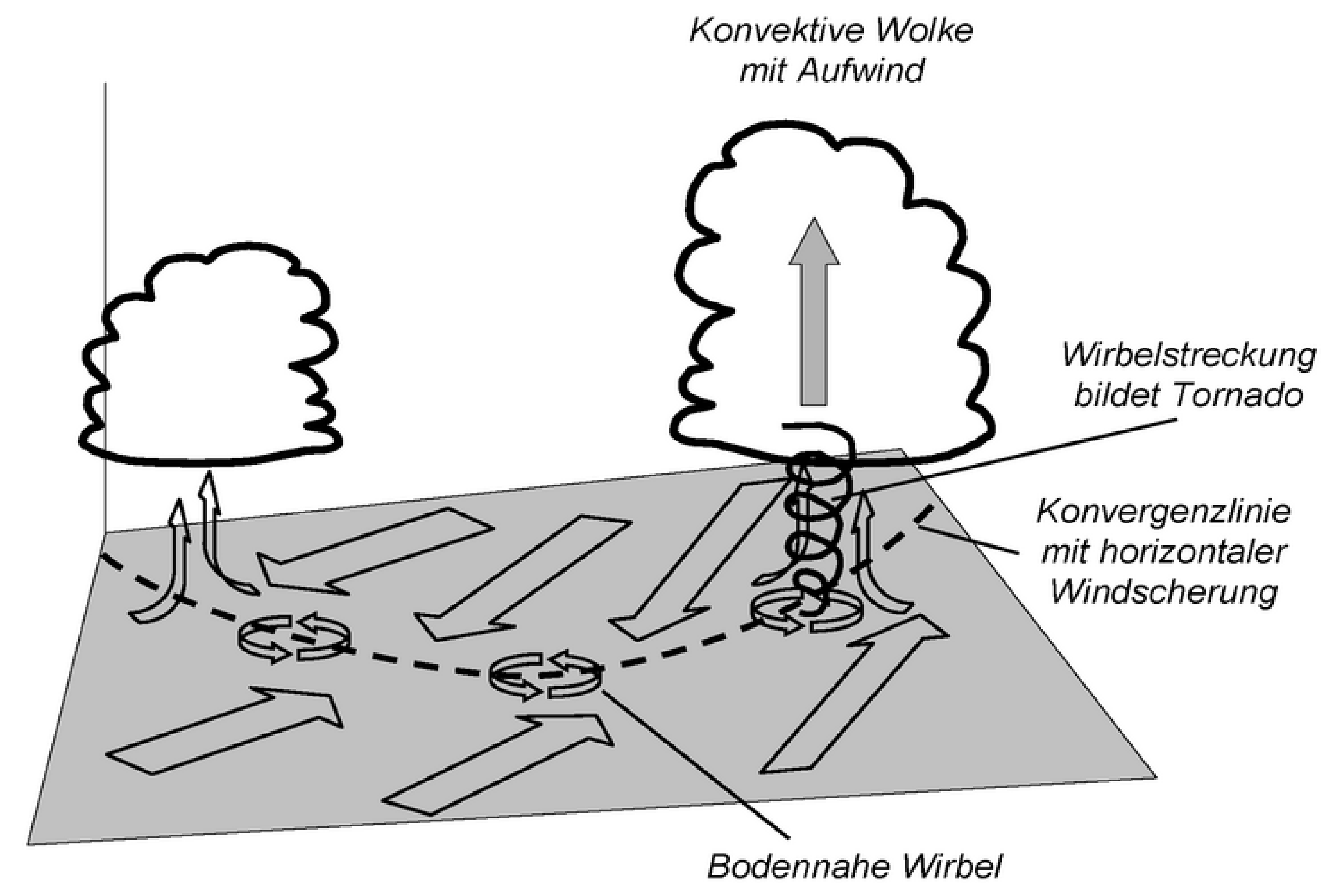


Abb. 5.7 Richtungskonvergenz (schematisch)

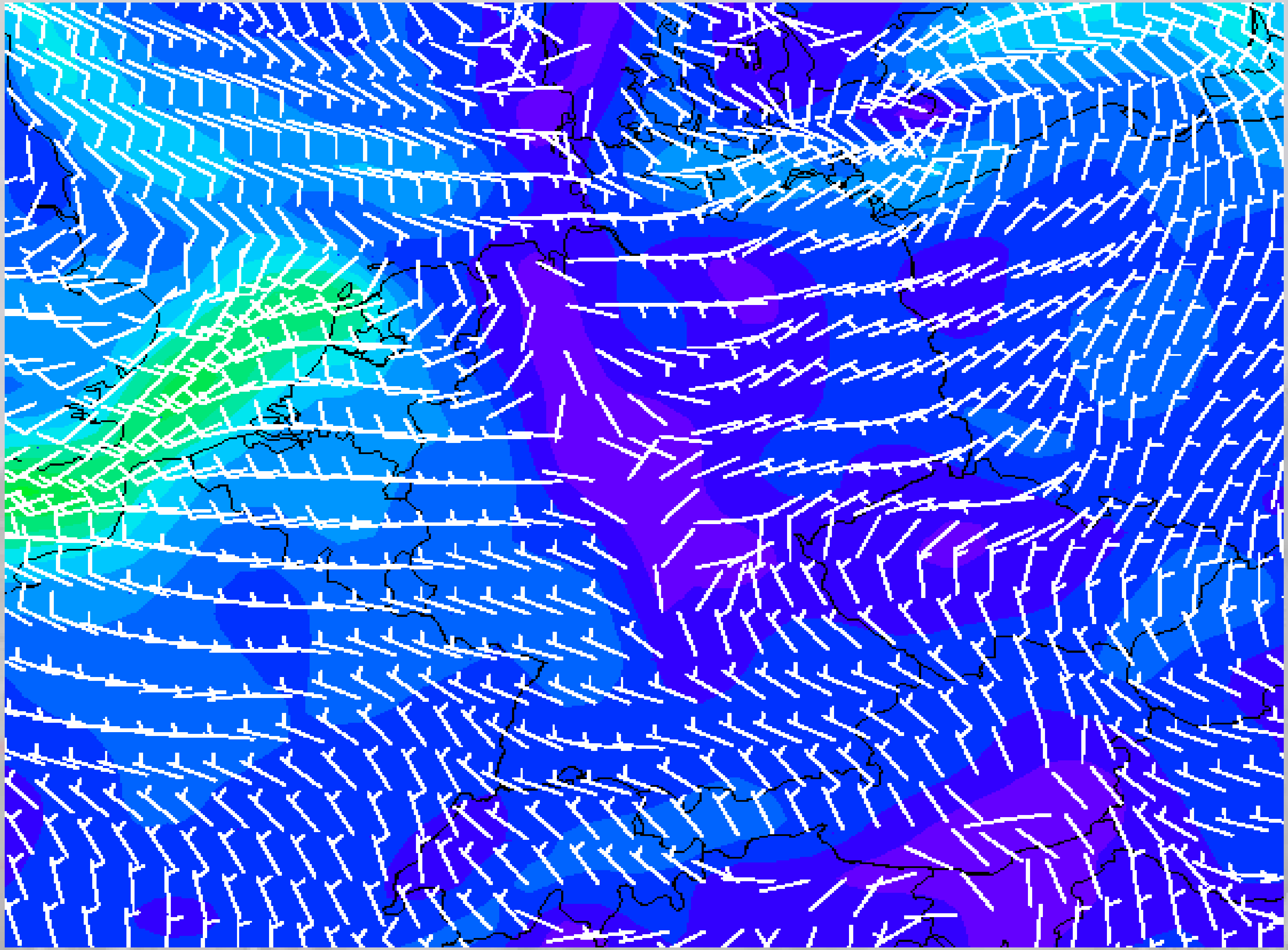
- Confluence of airmasses from different pressure systems
- Frequently ahead of coldfronts
- Intensification due to diurnal convection (Thunderstorm)
- Results in ascending of the air (Convergence)



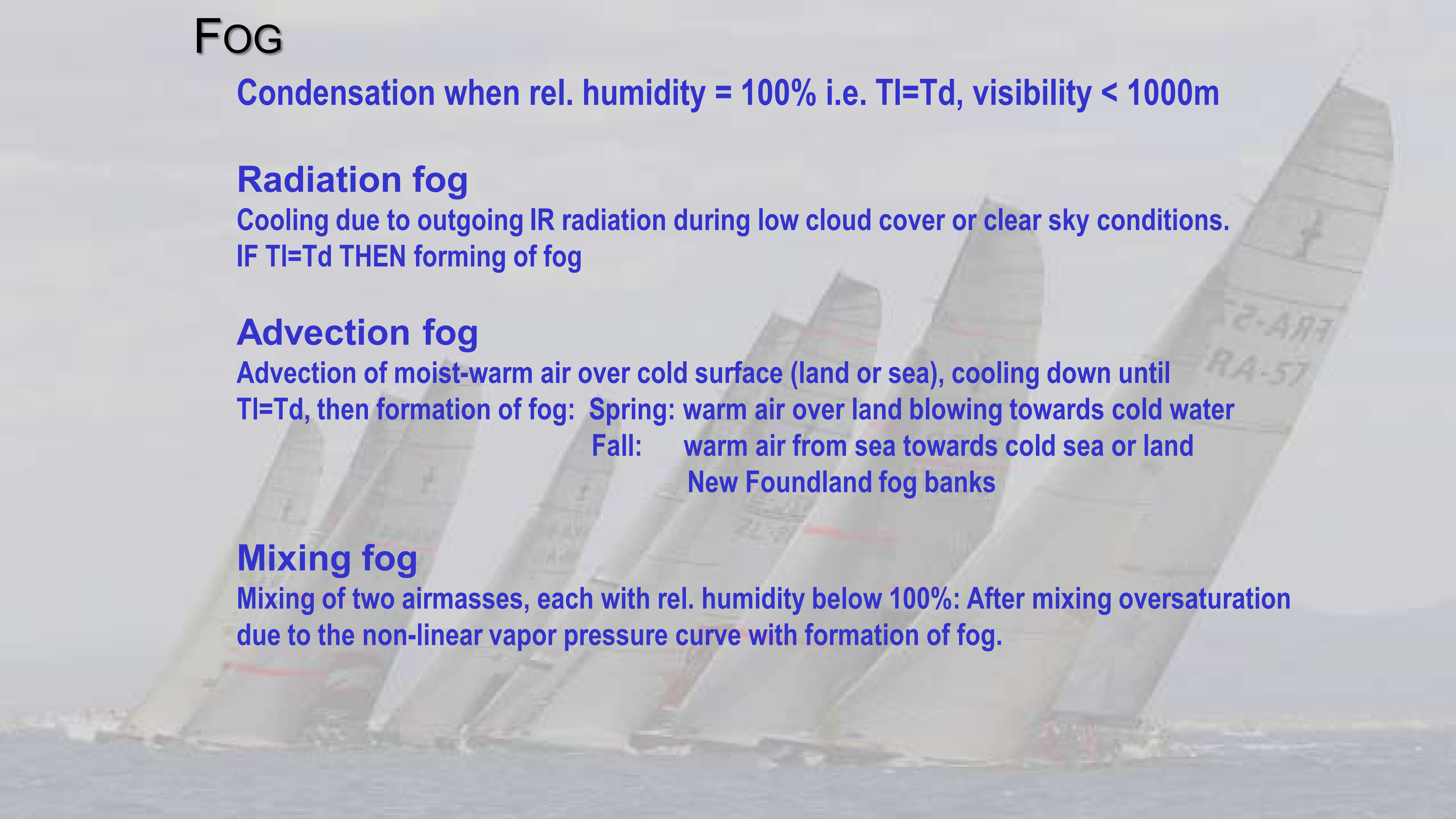
LINES OF CONVERGENCE



LINES OF CONVERGENCE



FOG



Condensation when rel. humidity = 100% i.e. Tl=Td, visibility < 1000m

Radiation fog

Cooling due to outgoing IR radiation during low cloud cover or clear sky conditions.
IF Tl=Td THEN forming of fog

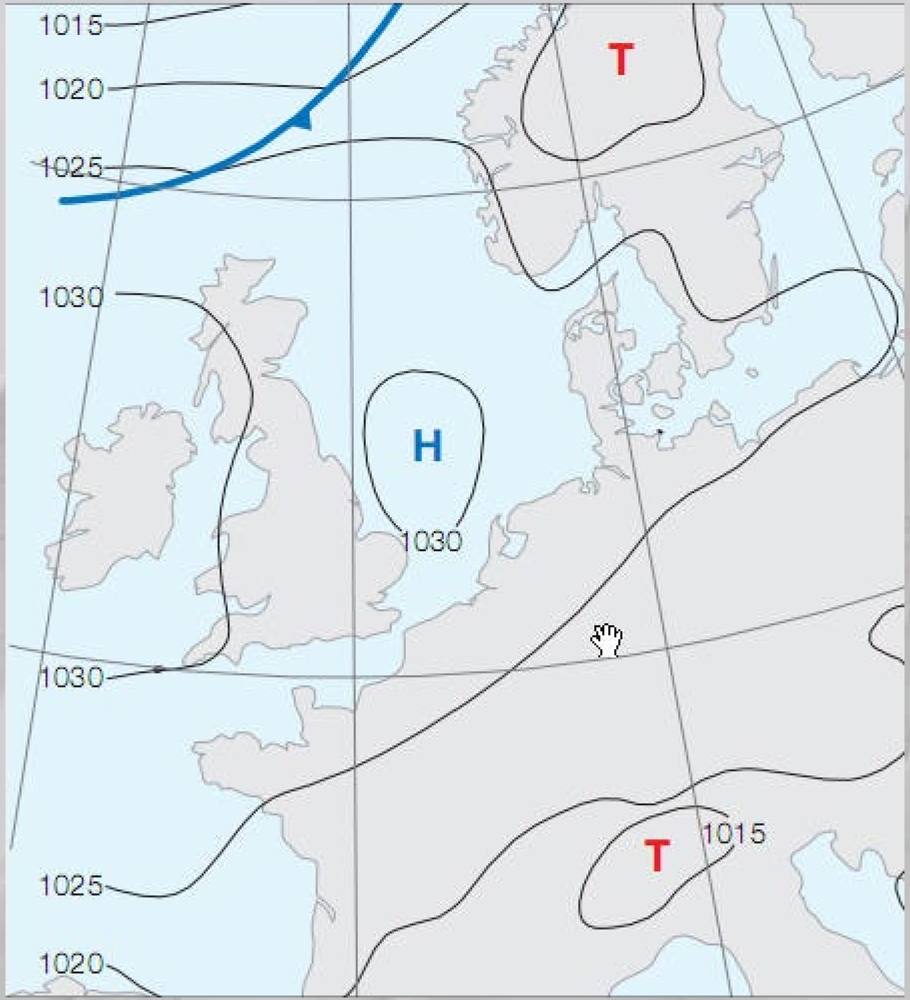
Advection fog

Advection of moist-warm air over cold surface (land or sea), cooling down until
Tl=Td, then formation of fog: Spring: warm air over land blowing towards cold water
Fall: warm air from sea towards cold sea or land
New Foundland fog banks

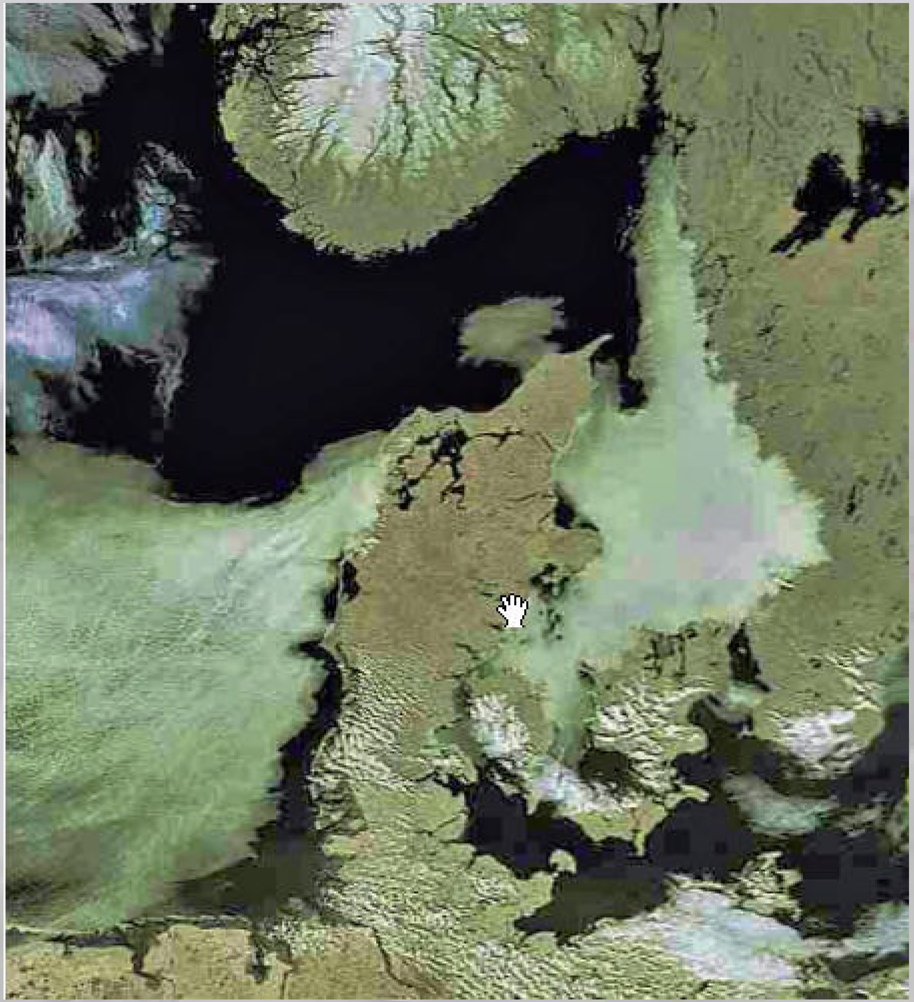
Mixing fog

Mixing of two airmasses, each with rel. humidity below 100%: After mixing oversaturation due to the non-linear vapor pressure curve with formation of fog.

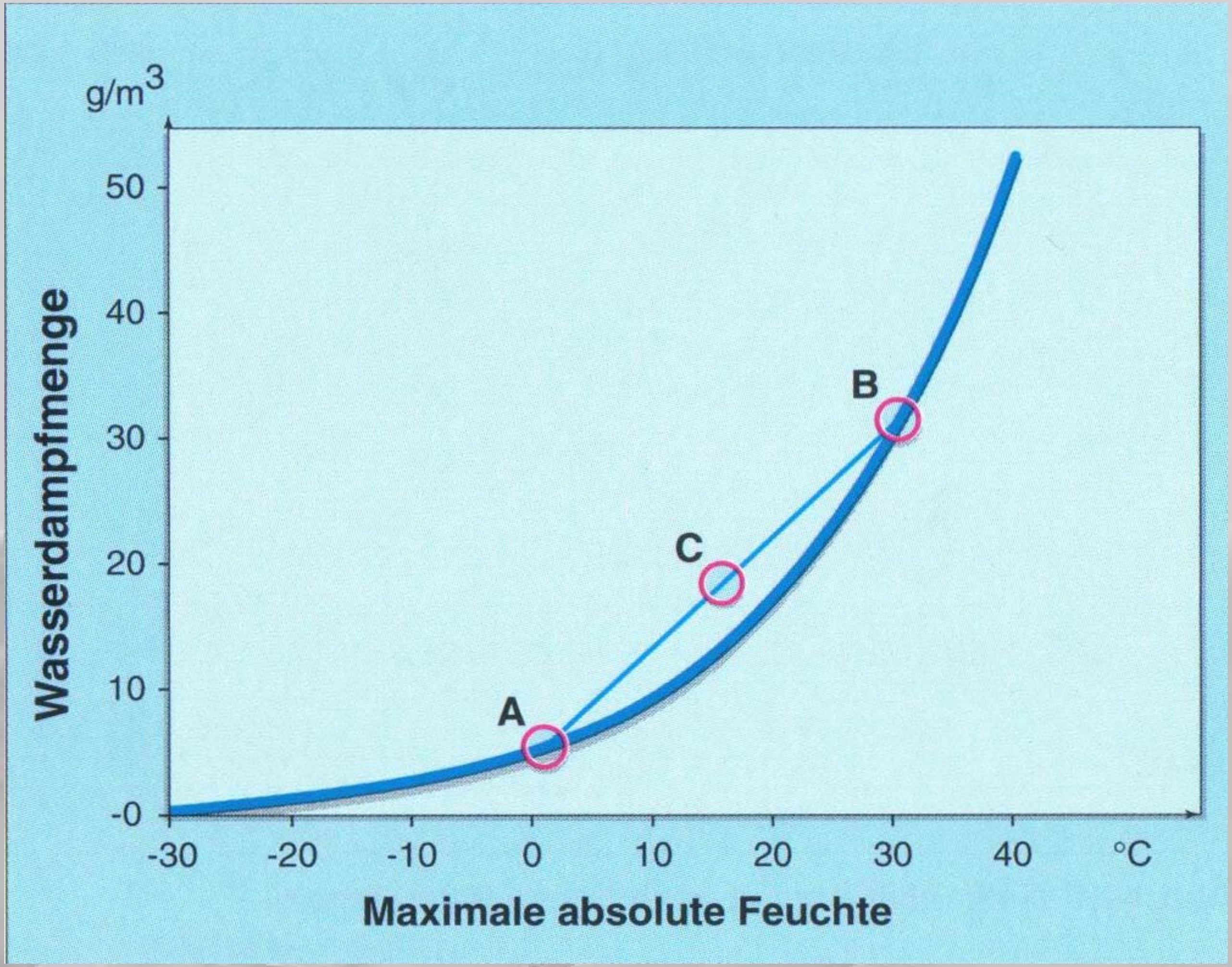
ADVECTION FOG OVER SEA



ADVECTION FOG OVER SEA

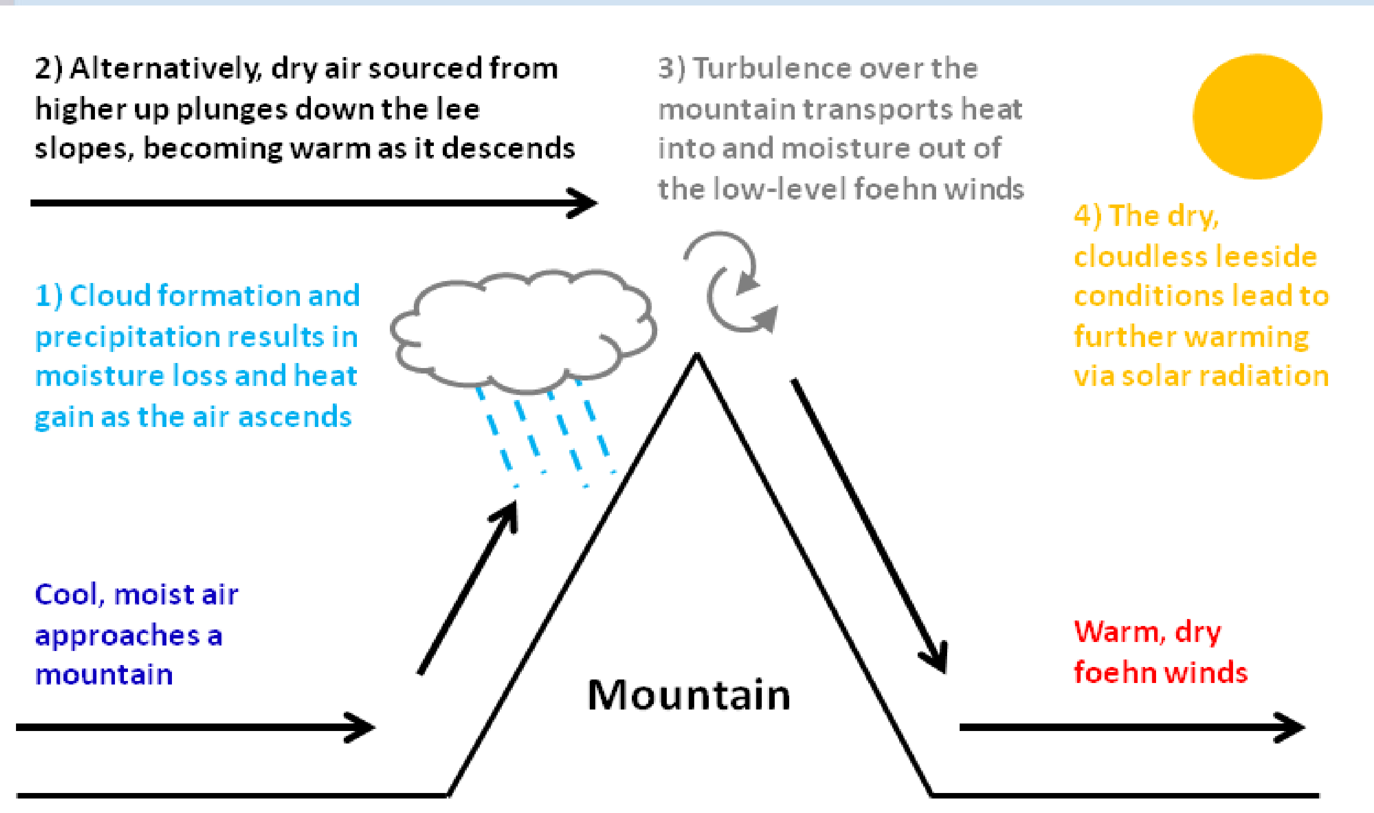


MIXING FOG



Airmass A and airmass B, each with rel.humidity just below 100%, not saturated : Mixing of both airmasses results in oversaturation (i.e. formation of fog) due to the non-linear water-vapor curve.

FOEHN: OVERFLOW OF MOUNTAINS



2) Alternatively, dry air sourced from higher up plunges down the lee slopes, becoming warm as it descends

3) Turbulence over the mountain transports heat into and moisture out of the low-level foehn winds

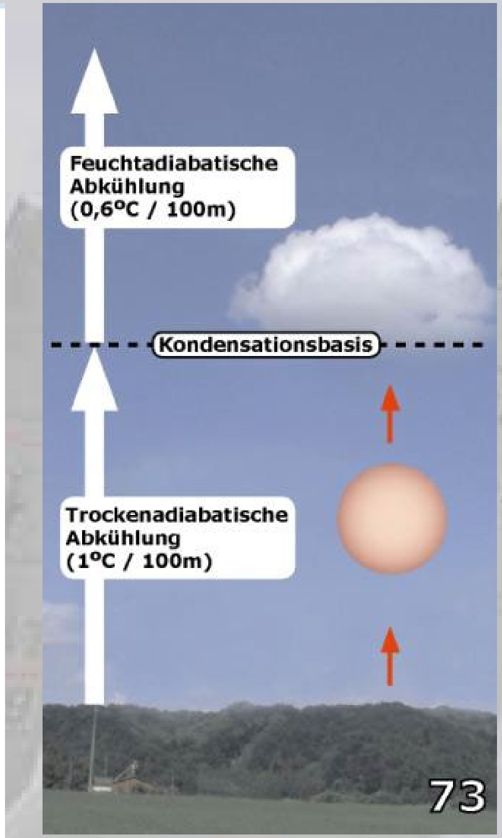
1) Cloud formation and precipitation results in moisture loss and heat gain as the air ascends

4) The dry, cloudless leeside conditions lead to further warming via solar radiation

Cool, moist air approaches a mountain

Mountain

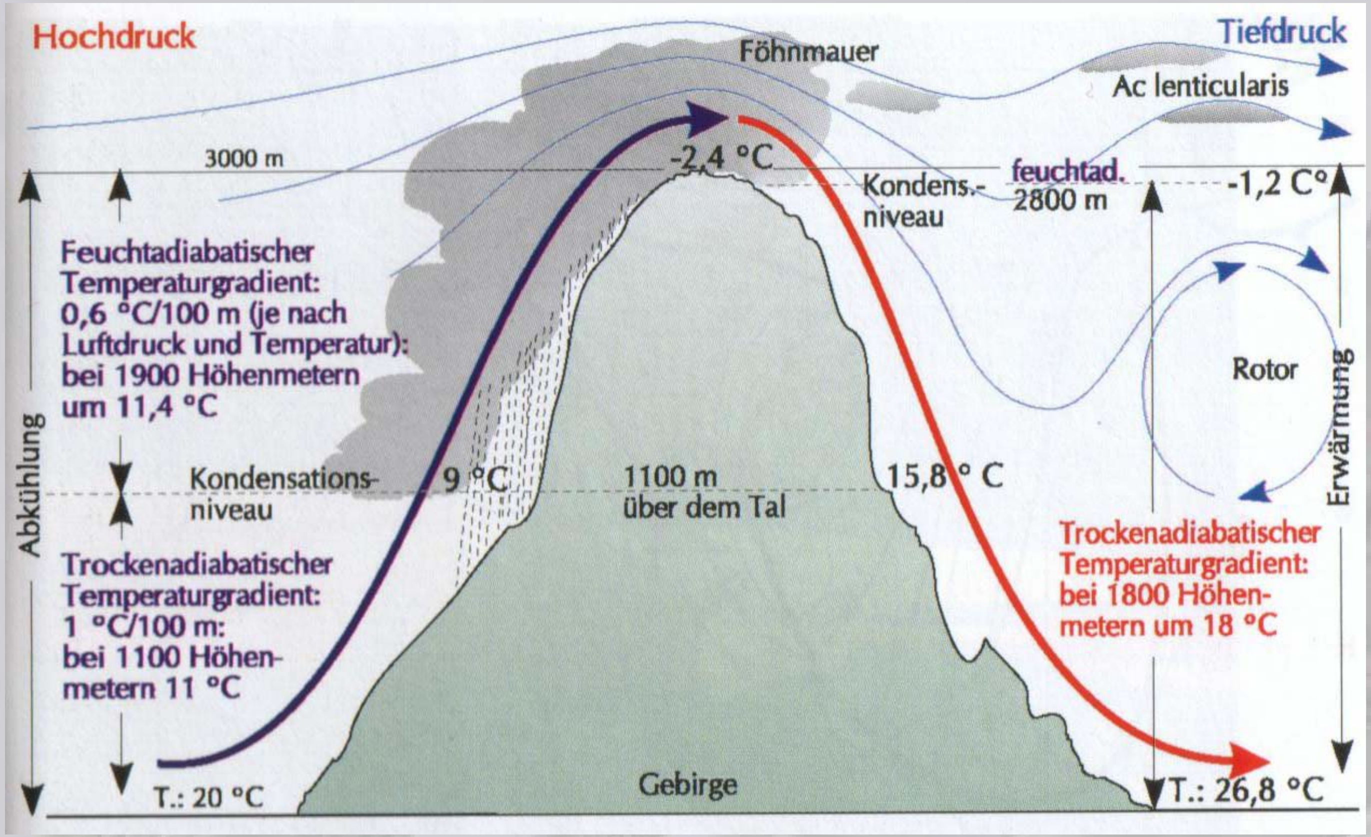
Warm, dry foehn winds

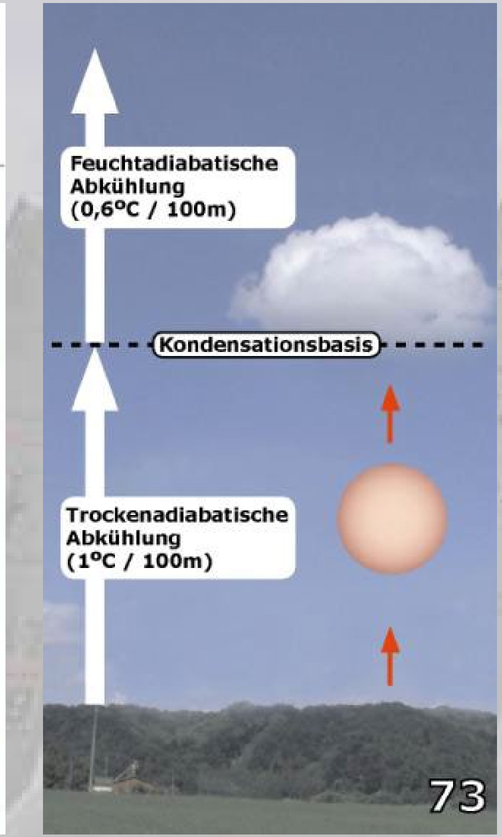


Conditions at surface (windward)	T(MSL) = 20 °C			
Dry-adiabatic cooling	T(1100m) = 9 °C	(1.0°C / 100m)	
Moist-adiabatic cooling	T(3000m) = -2.4 °C	(0.6°C / 100m)	rH=100%
Dry-adiabatic warming	T(MSL) = 26.8 °C	(1.0°C / 100m)	rH< 30%

Necessary Process: Water falling out, precipitation !

FOEHN: OVERFLOW OF MOUNTAINS





Conditions at surface (windward) T(MSL) = 20 °C

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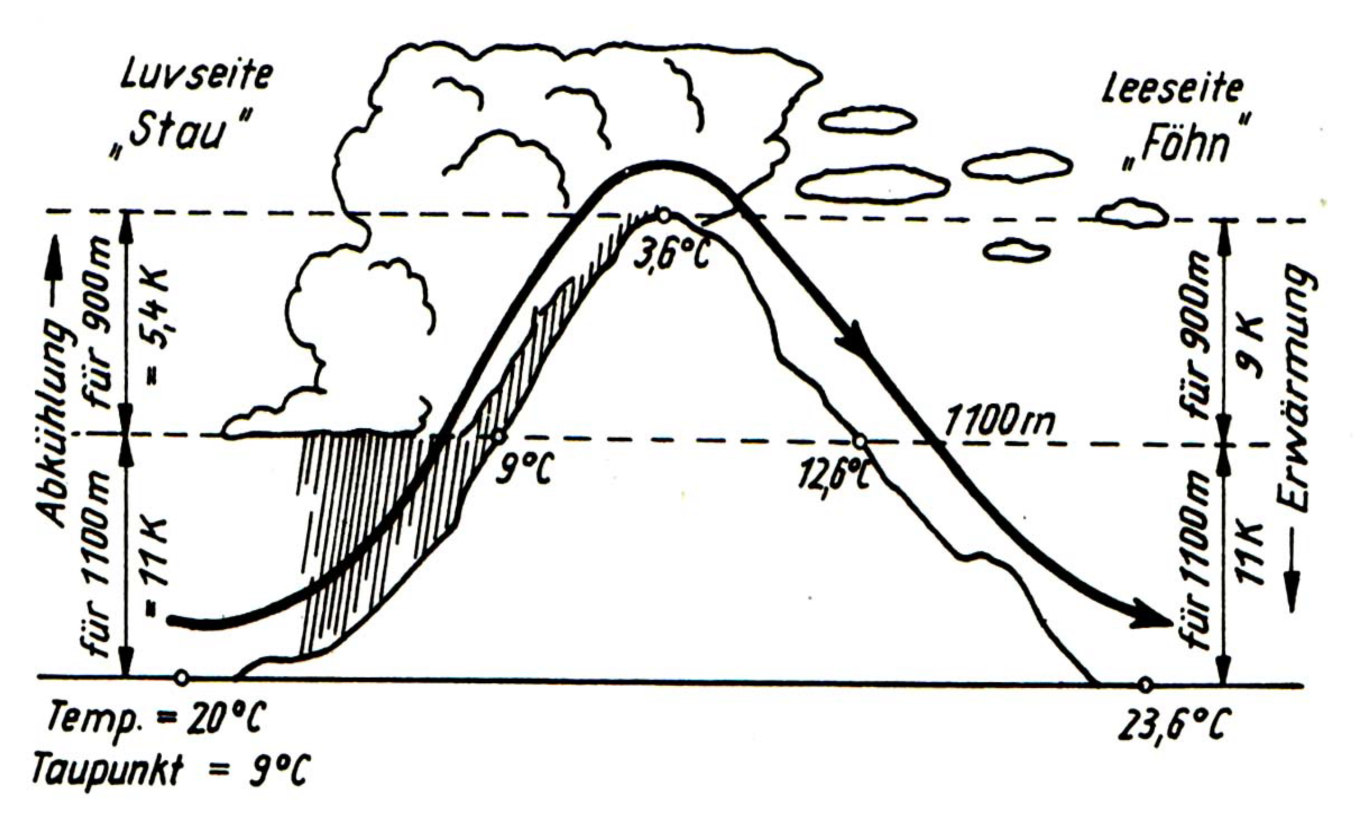
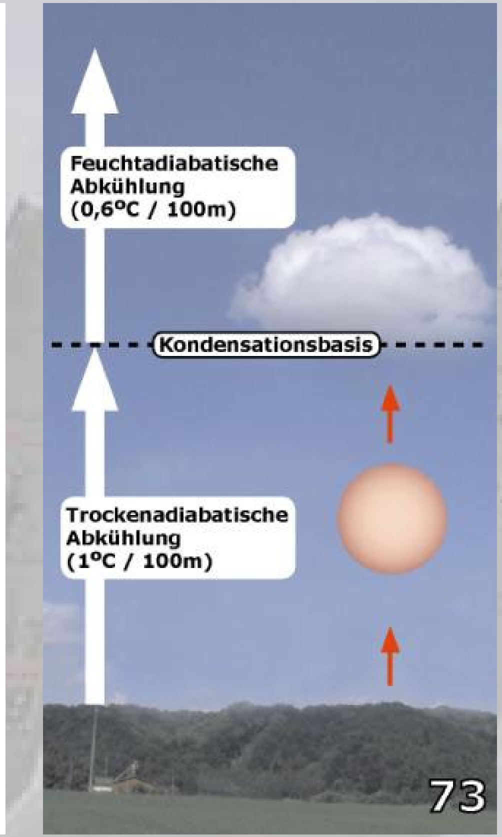
Dry-adiabatic warming T(MSL) = 26.8 °C (1.0°C / 100m) rH< 30%

Necessary Process: Water falling out, precipitation !

FOEHN: OVERFLOW OF MOUNTAINS, CHINOOK





Conditions at surface (windward)	T(MSL) = 20 °C		
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Dry-adiabatic warming	T(MSL) = 26.8 °C	(1.0°C / 100m)	rH< 30%

Necessary Process: Water falling out, precipitation !

FOEHN CLOUDS, FOEHN WALL, CHINOOK

FOEHN CLOUDS, BREAKING MOUNTAIN WAVES

BREAKING MOUNTAIN WAVES: SEVERE TURBULENCE !

BREAKING MOUNTAIN WAVES: SEVERE TURBULENCE !

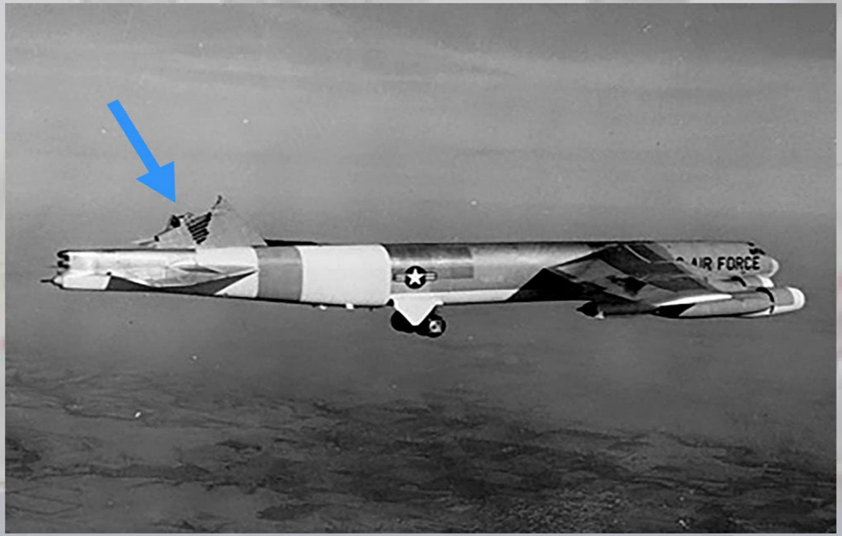
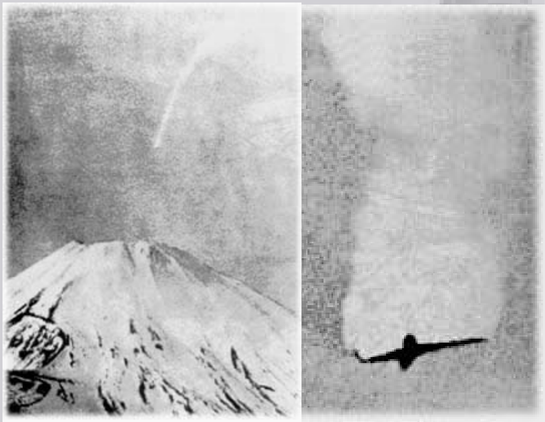



Photo by AirNikon http://www.Airliners.net


HOLIDAZE ©2008 Derek Freal

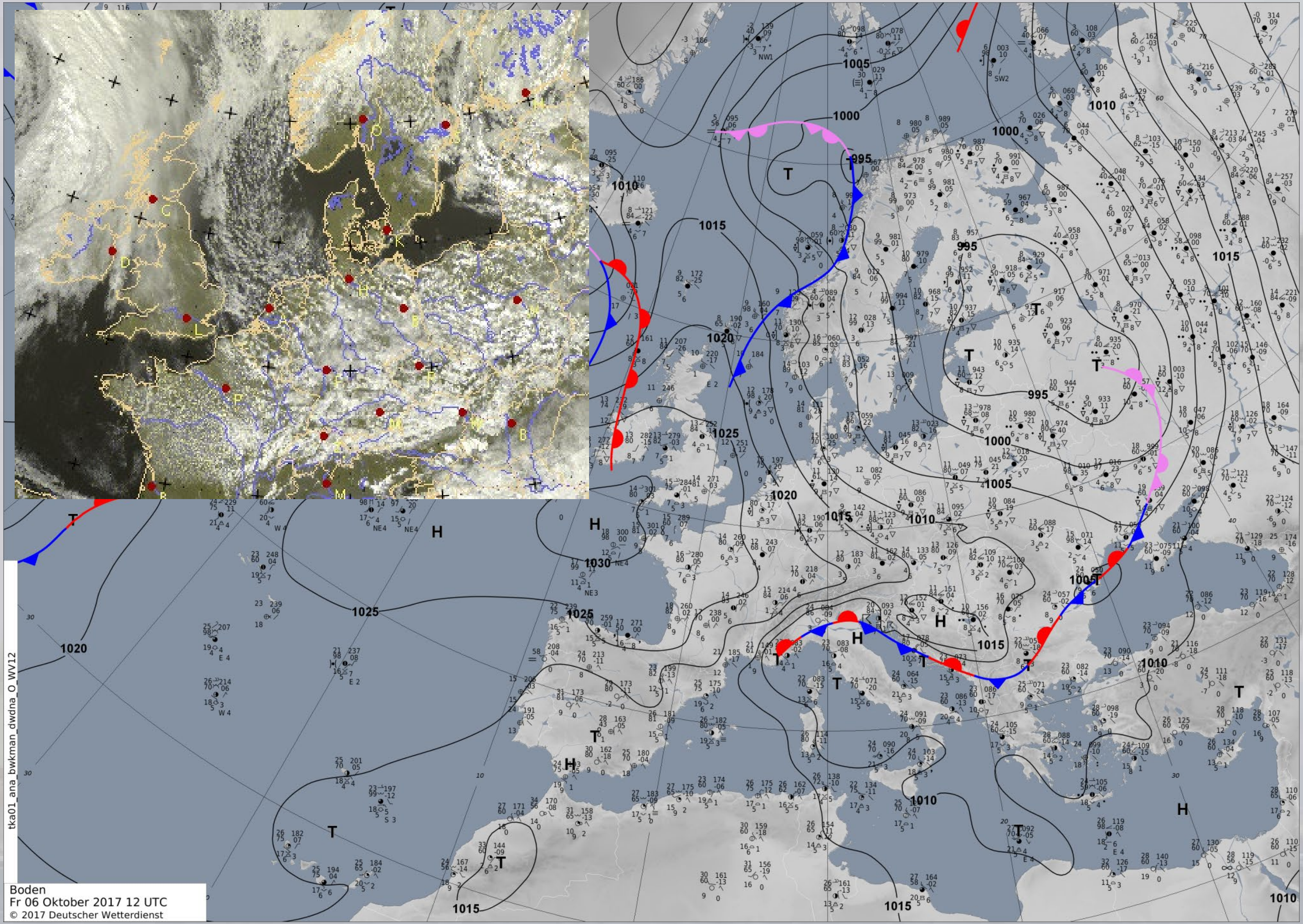

AirlineReporter.com

Mt.Fuji 5 Mar 1966
BOAC Boeing B707
SEV TURB 113 killed



Iridescent Foehn clouds

SCANDINAVIA FOEHN



Boden
Fr 06 Oktober 2017 12 UTC
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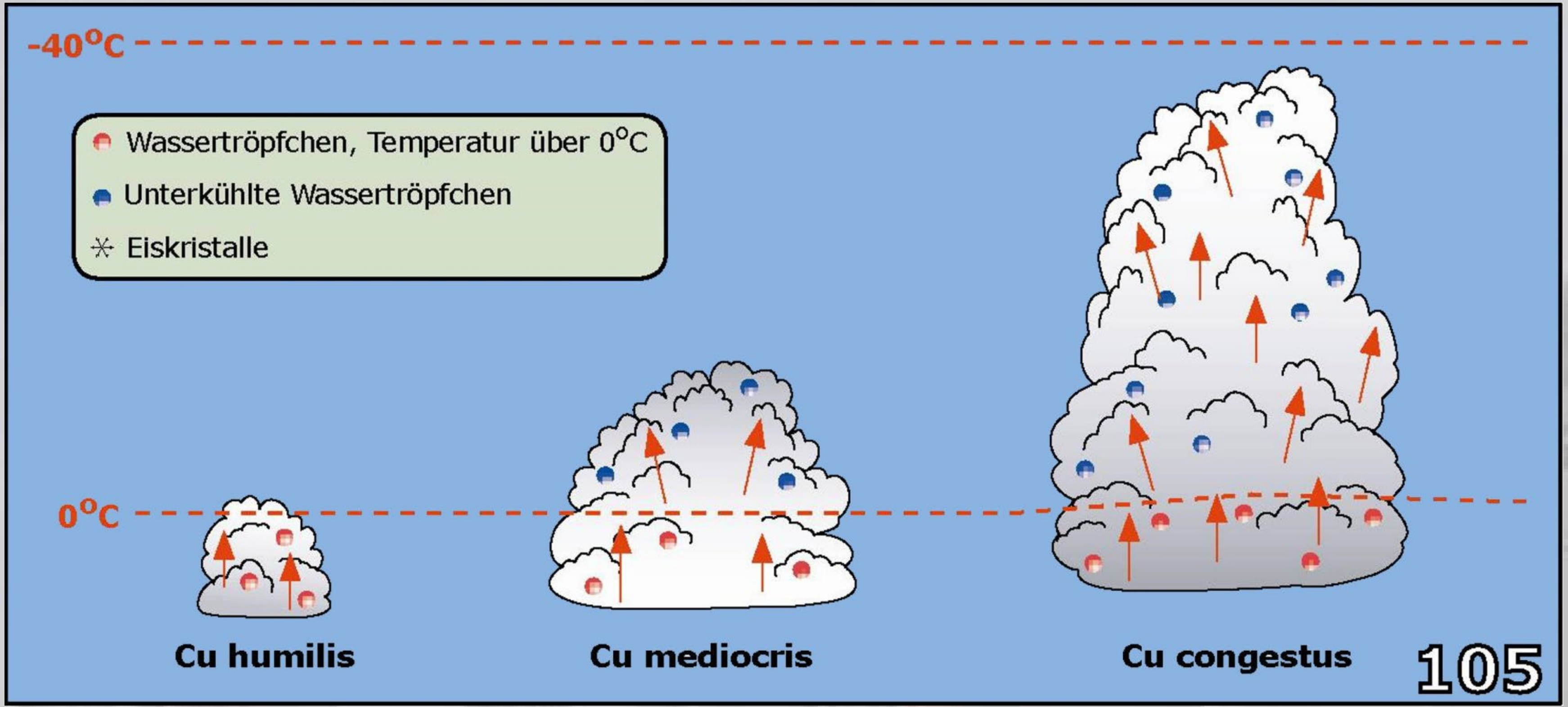
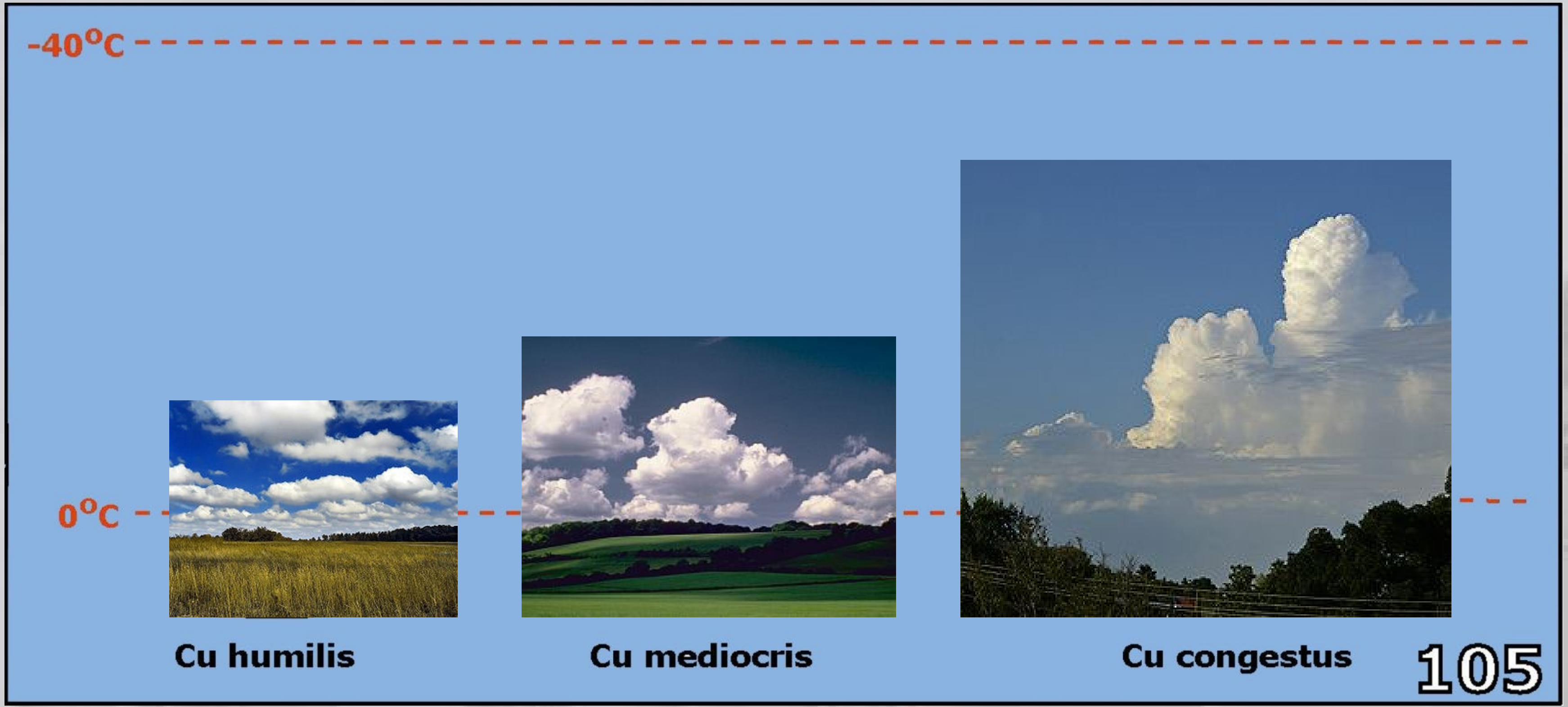
THUNDERSTORM



Required conditions

- Unstable stratification of the atmosphere
- Sufficient humidity
- Sufficient vertical temperature gradient due to
  - heating at the bottom: incoming solar radiation
  - cooling at the cloud top: outgoing IR-radiation

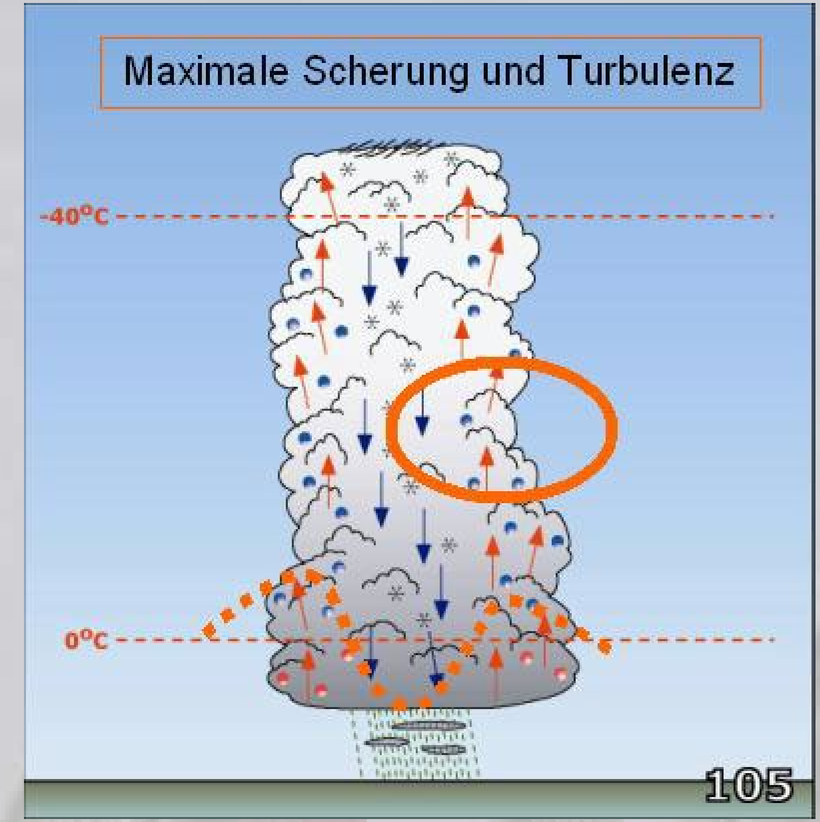
THUNDERSTORM

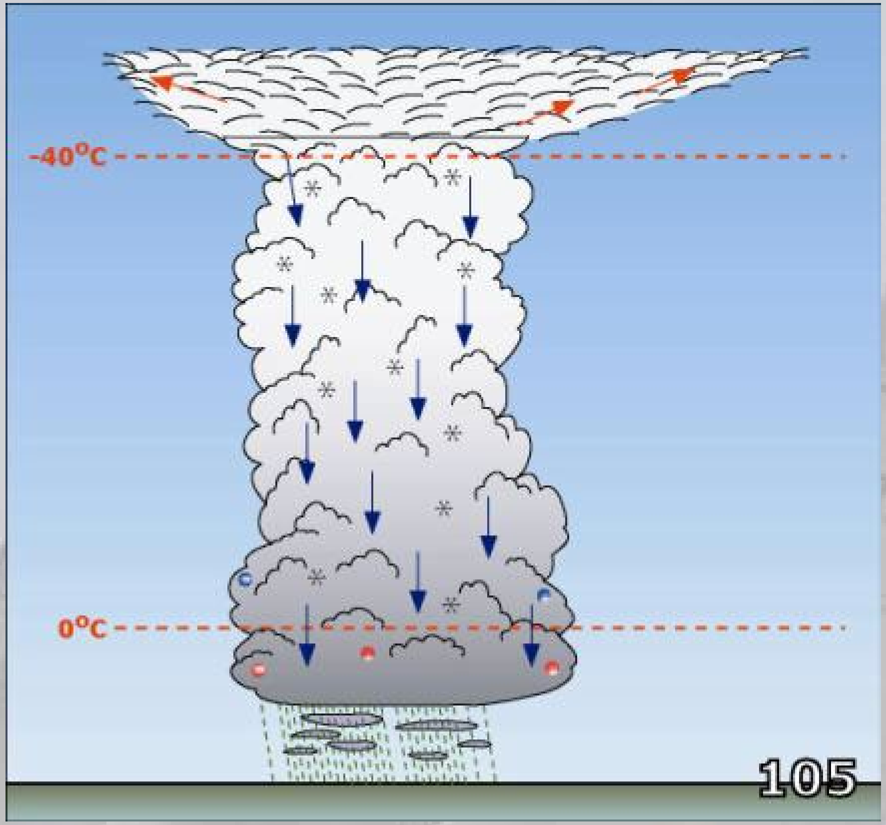


Required conditions

- Unstable stratification of the atmosphere
- Sufficient humidity
- Sufficient vertical temperature gradient due to
  - heating at the bottom: incoming solar radiation
  - cooling at the cloud top: outgoing IR-radiation

THUNDERSTORM





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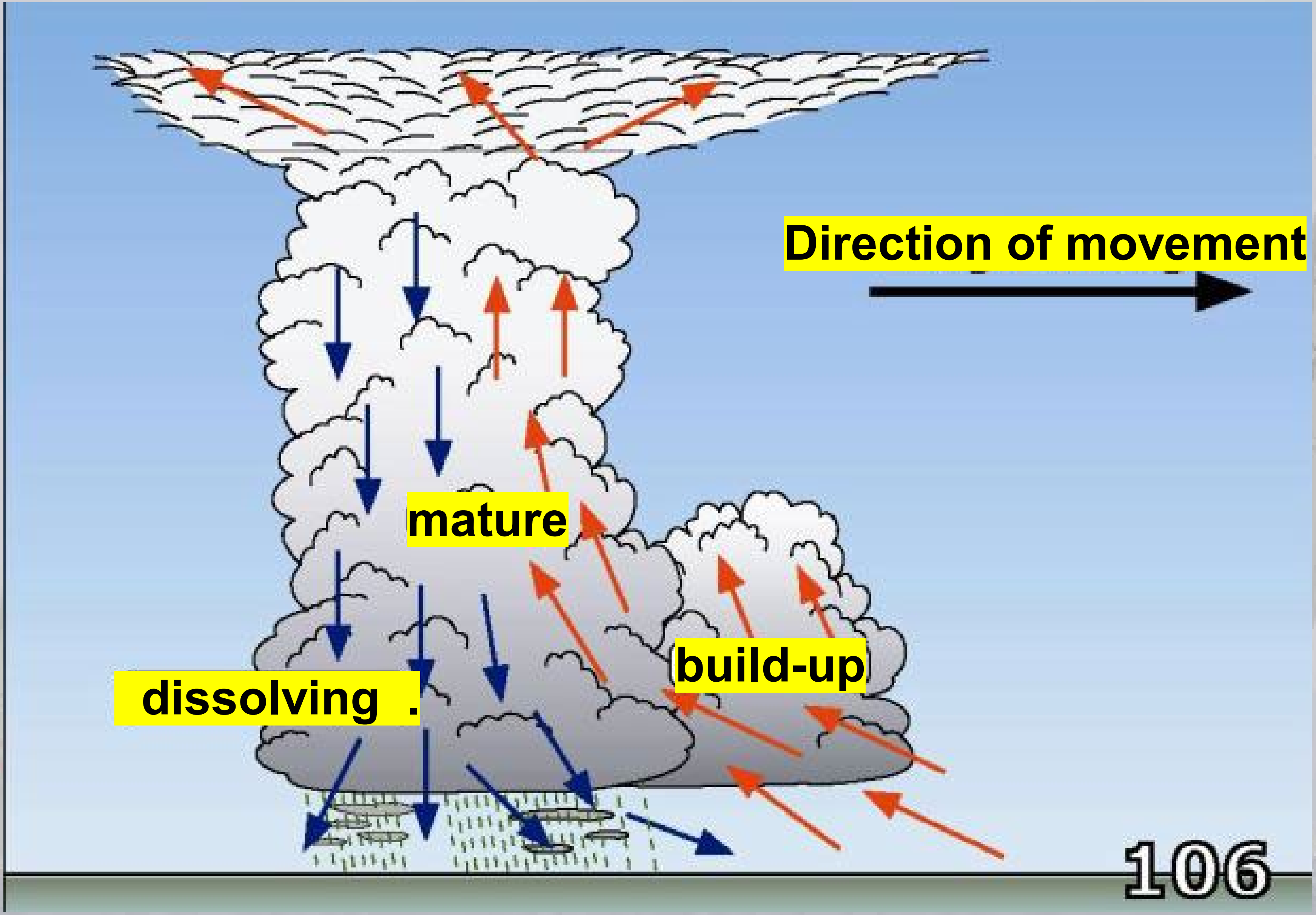
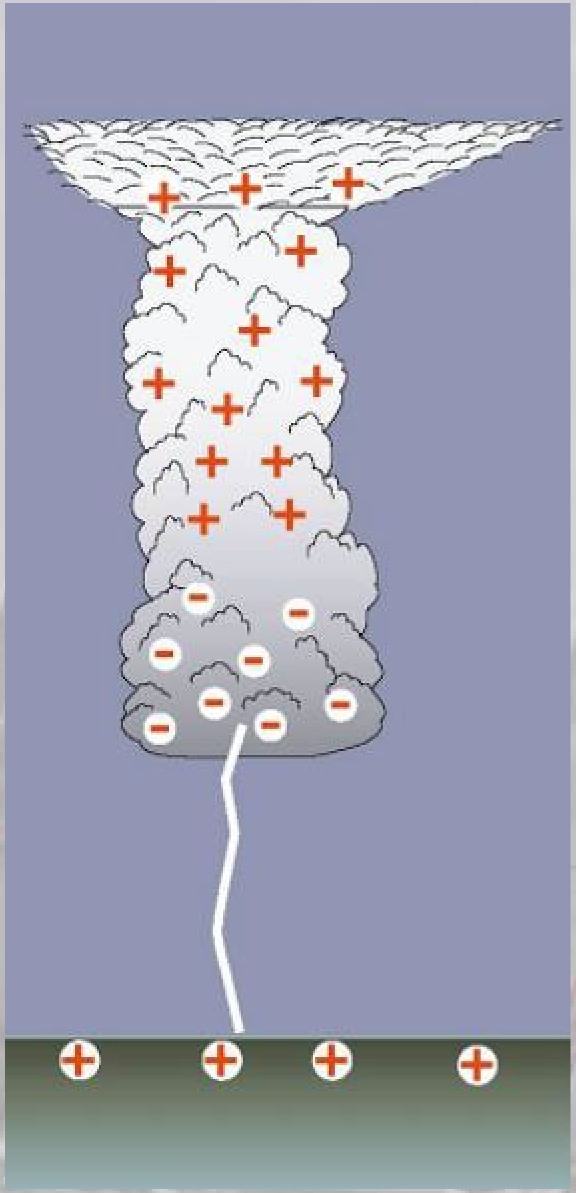


THUNDERSTORM

THUNDERSTORM



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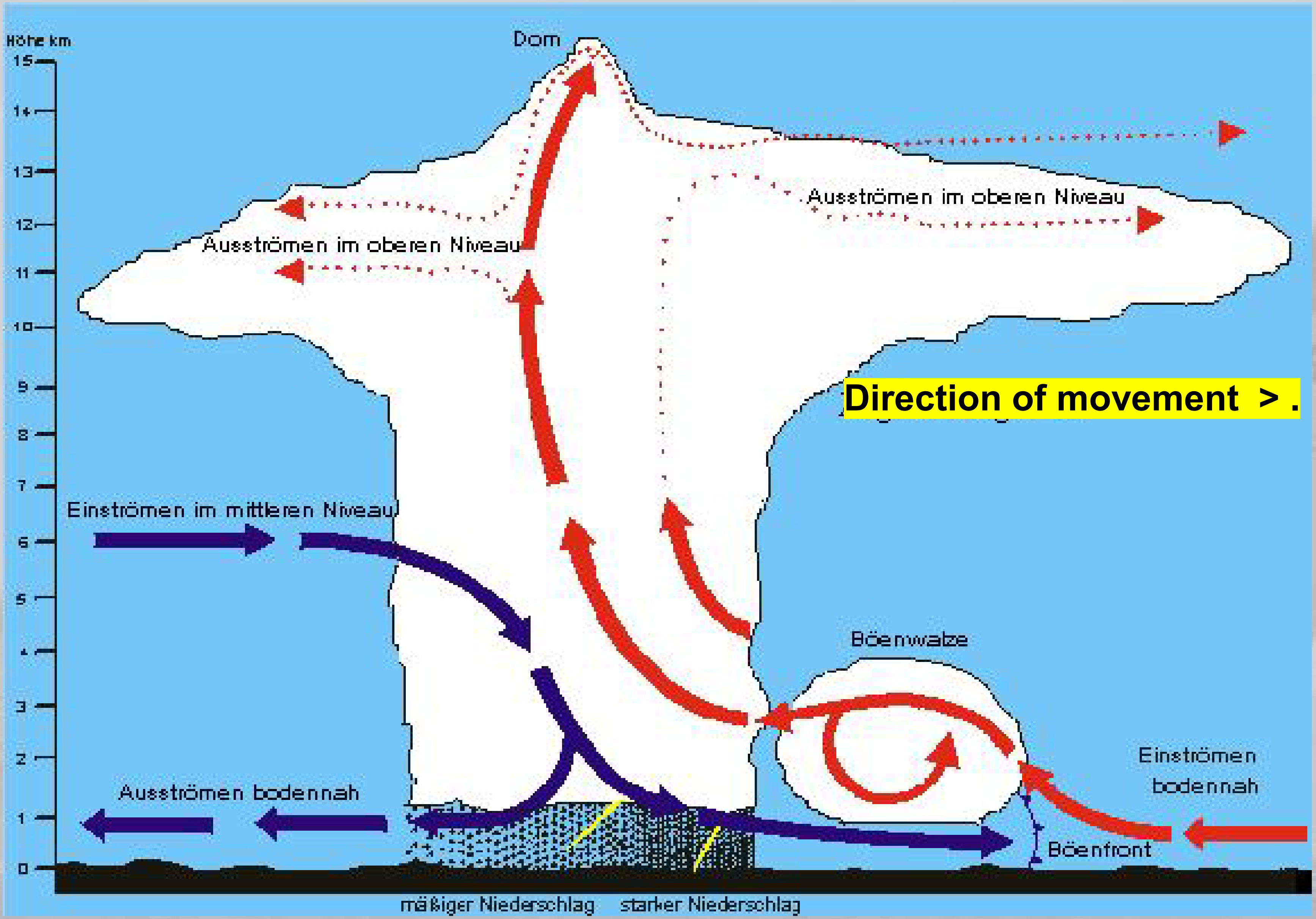
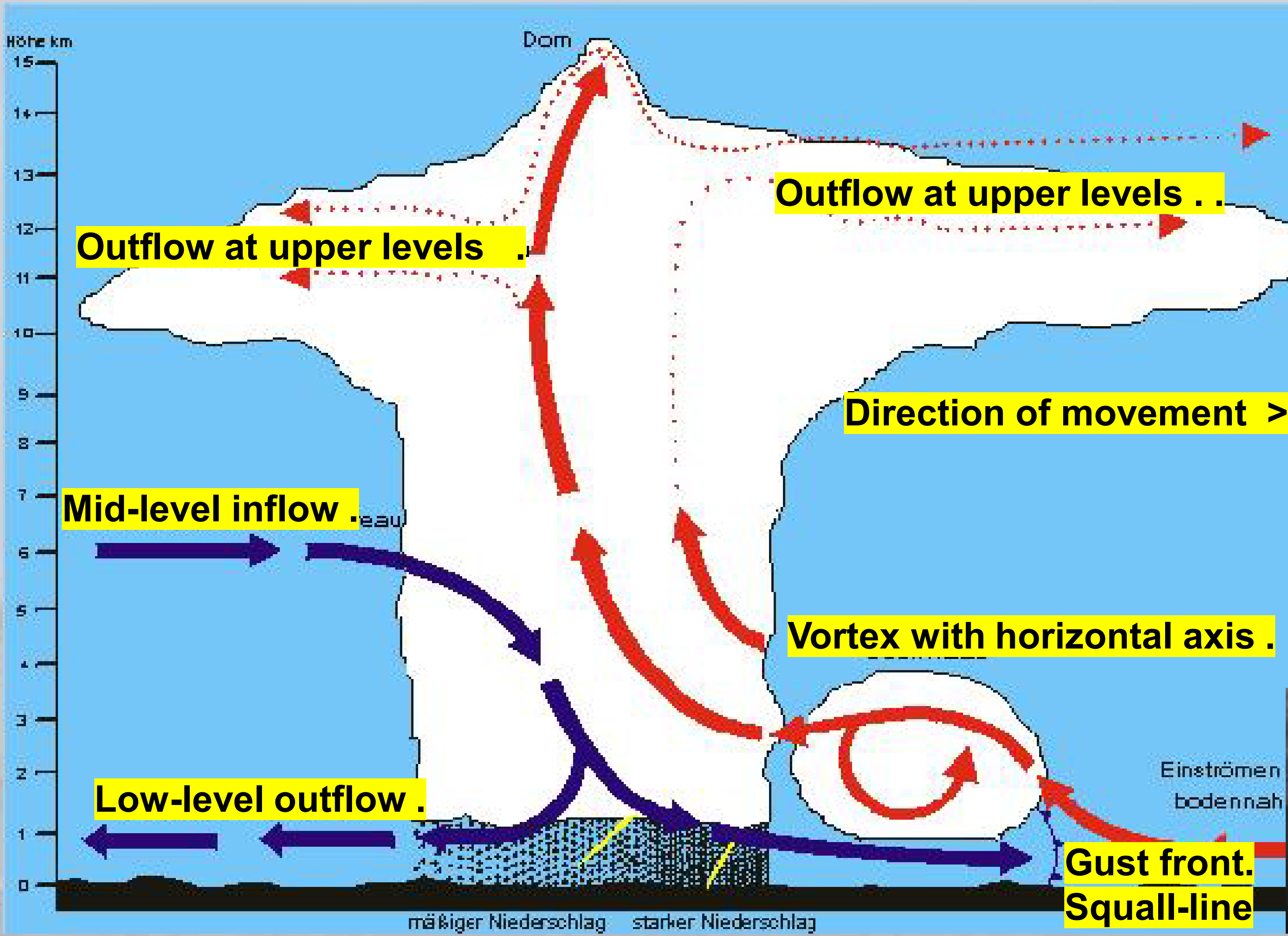


Direction of movement > .

THUNDERSTORM



Outflow at upper levels .

Outflow at upper levels . .

Direction of movement > .

Mid-level inflow .

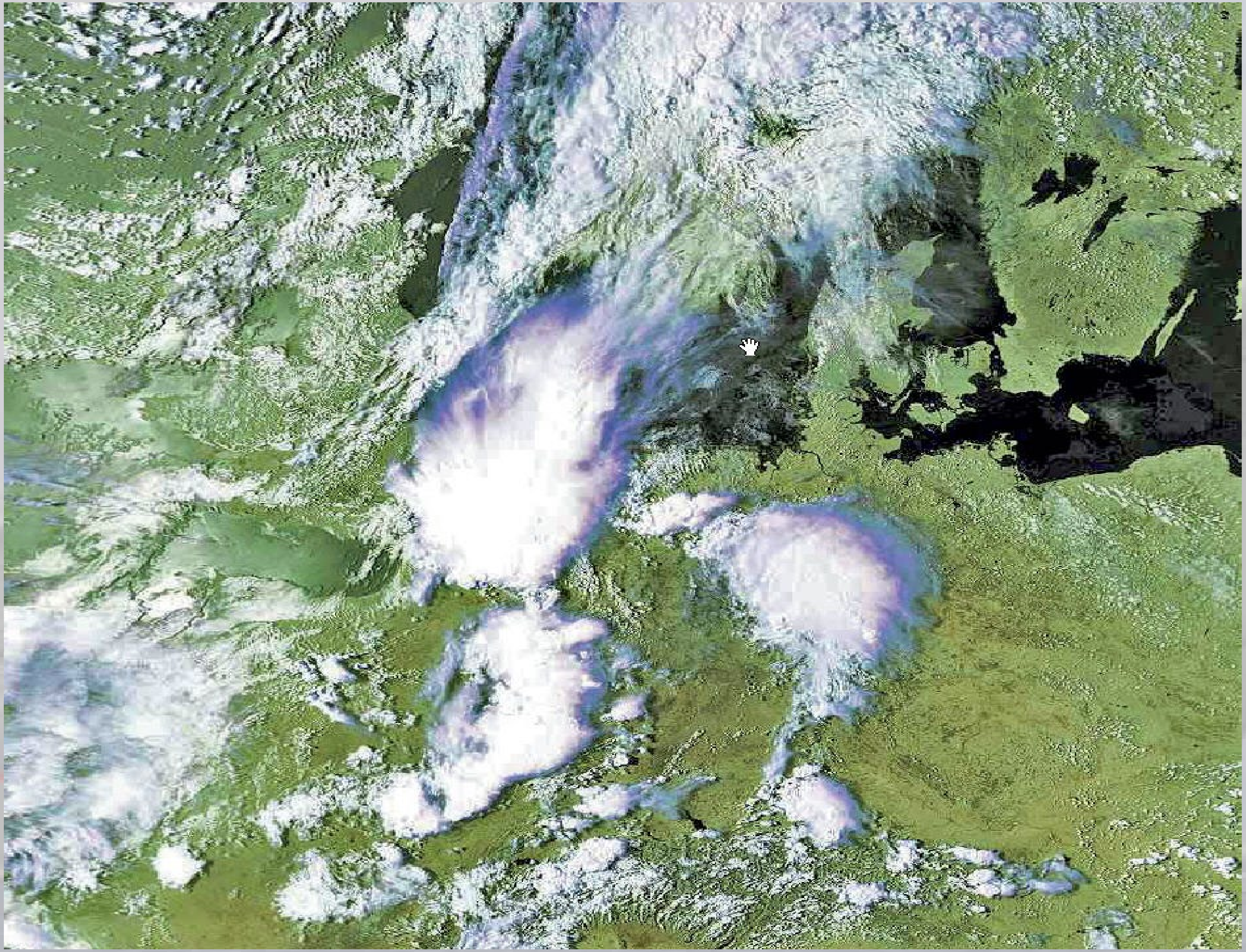
Vortex with horizontal axis .

Low-level outflow .

Gust front.

Squall-line

THUNDERSTORM: MCC MESOSCALE CONVECTIVE CLUSTER



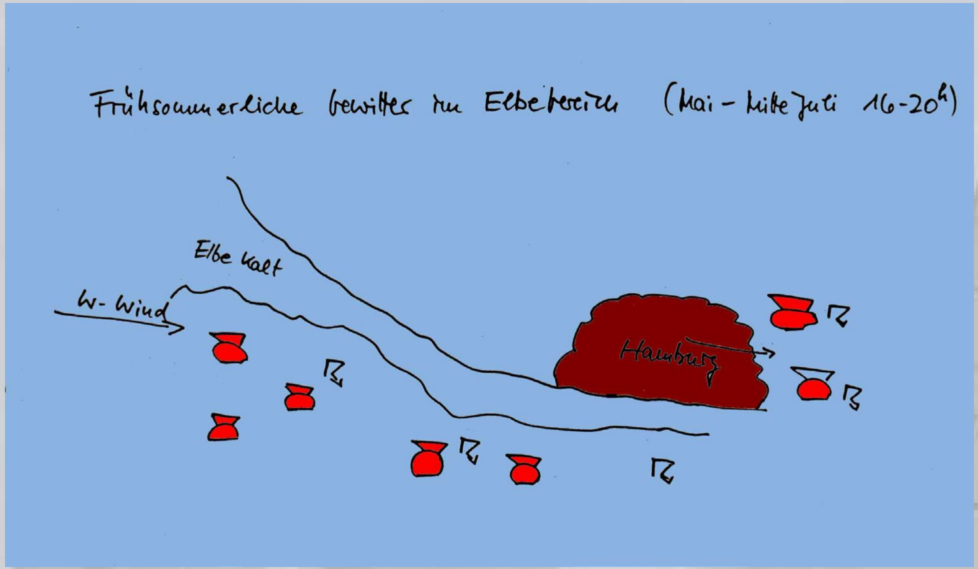
THUNDERSTORM: MCC MESOSCALE CONVECTIVE CLUSTER

THUNDERSTORM : ANNUAL VARIATION (RIVER ELBE)

Spring May 16-20 local time

T-Storm approaching from SW

Cold water of river Elbe forms a barrier the T-Storms cannot cross unless East of Hamburg (where river Elbe is much narrower)

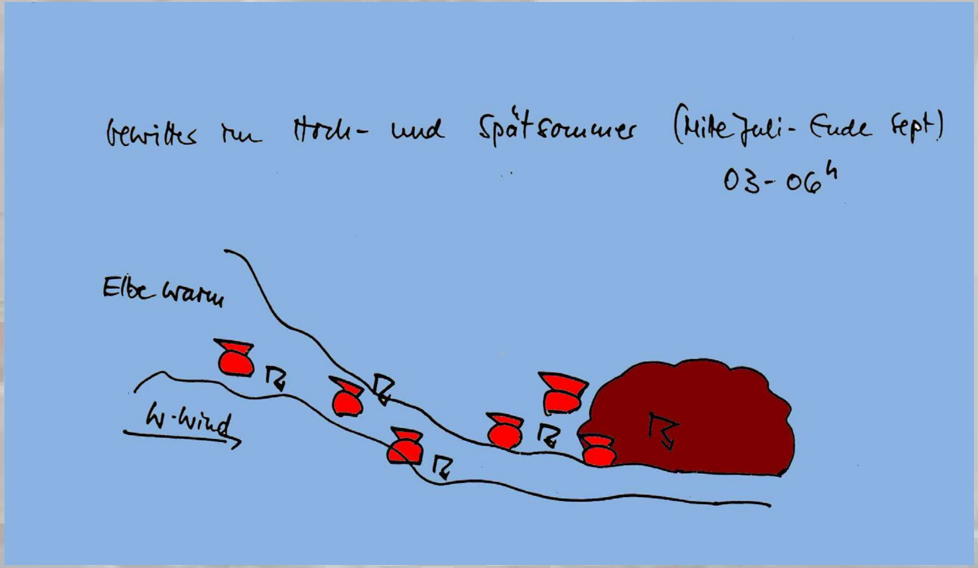


Autumn September 03-06 LT

Formation of T-Storms over river Elbe

- Warm water and cloud-top cooling due to outgoing IR-radiation

T-Storms follow the river Elbe, Even into tributaries (Stör) far into Schleswig-Holstein



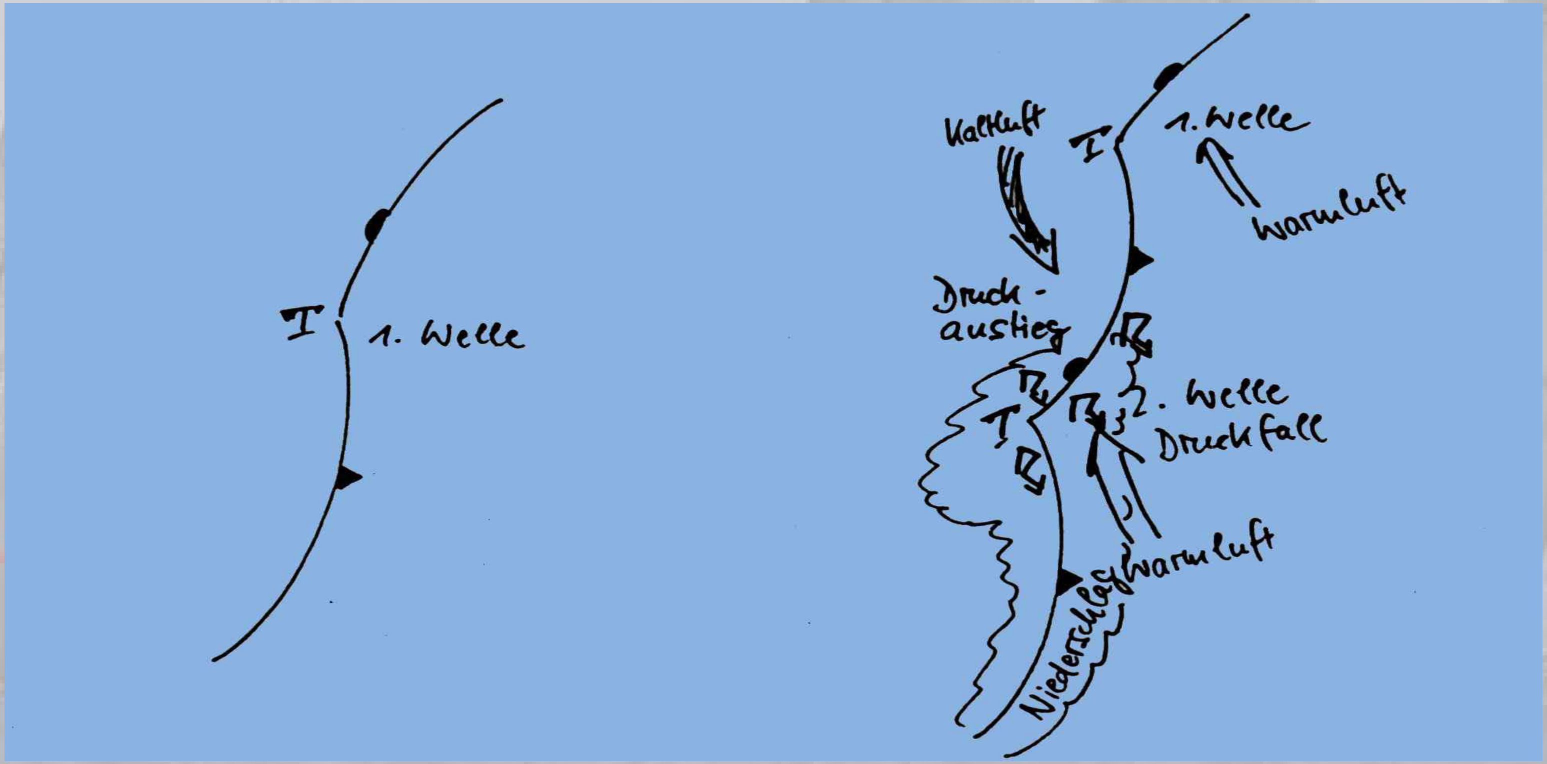
GEWITTER: LOW-LEVEL WARM AIR THUNDERSTORM

Synoptical condition for forming

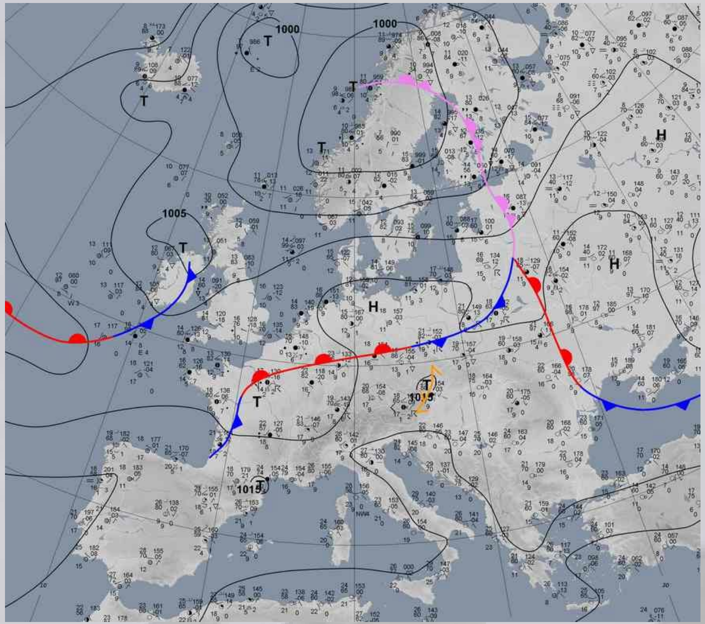
Low-level dynamic lifting of moist-warm air (low-level convergence, upper-level divergence, wave dirsturbance)

Moist-adiabatic stratification of the atmosphere

Release during second half of the night due to radiative cooling at the cloud-top



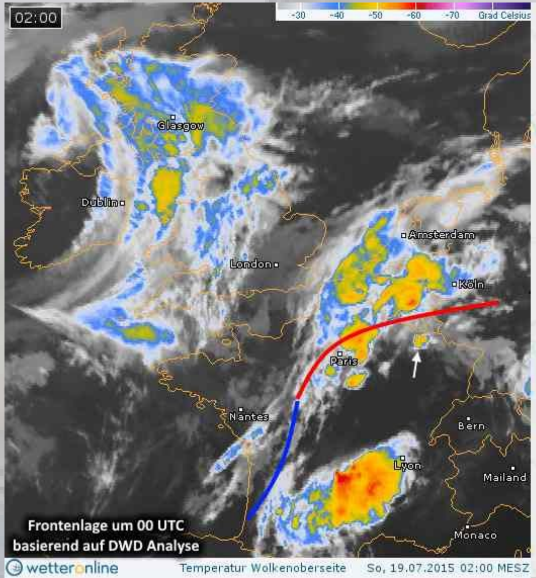
GEWITTER: LOW-LEVEL WARM AIR THUNDERSTORM

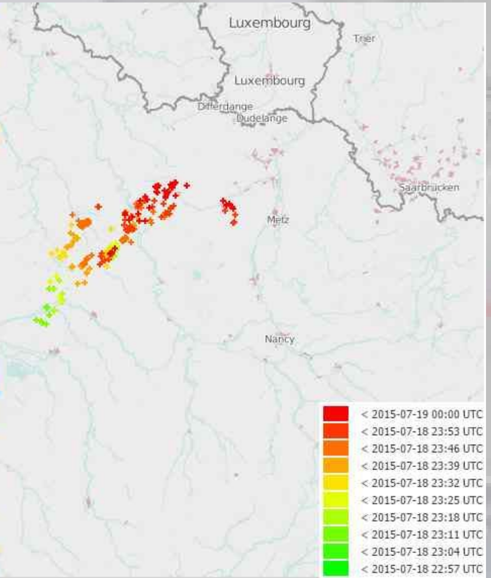


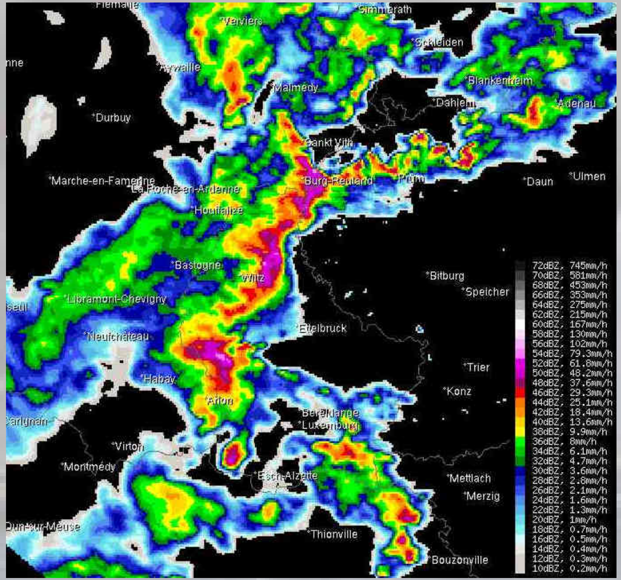
Synoptic situation on 19 July 2015

- Low-gradient southwesterly flow
- Upper air divergence downstream of a trough, resulted in dynamic lifting
- Sufficient unstable stratification (WLA)

Formation of Thunderstorms







TORNADOES

TORNADOES

TORNADO

When T-Storm only ?

When Tornado ?

TORNADO

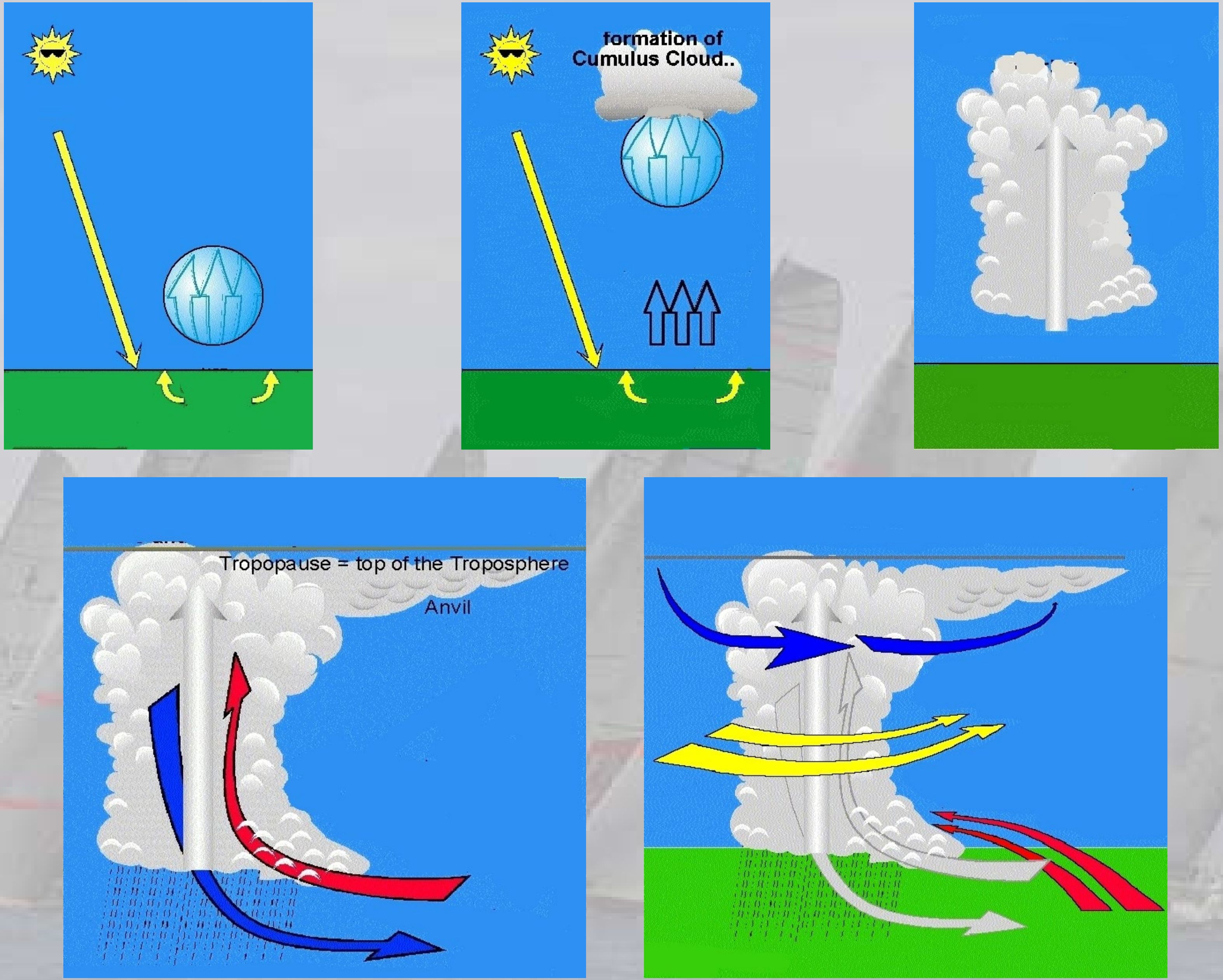
When T-Storm only ?

When Tornado ?

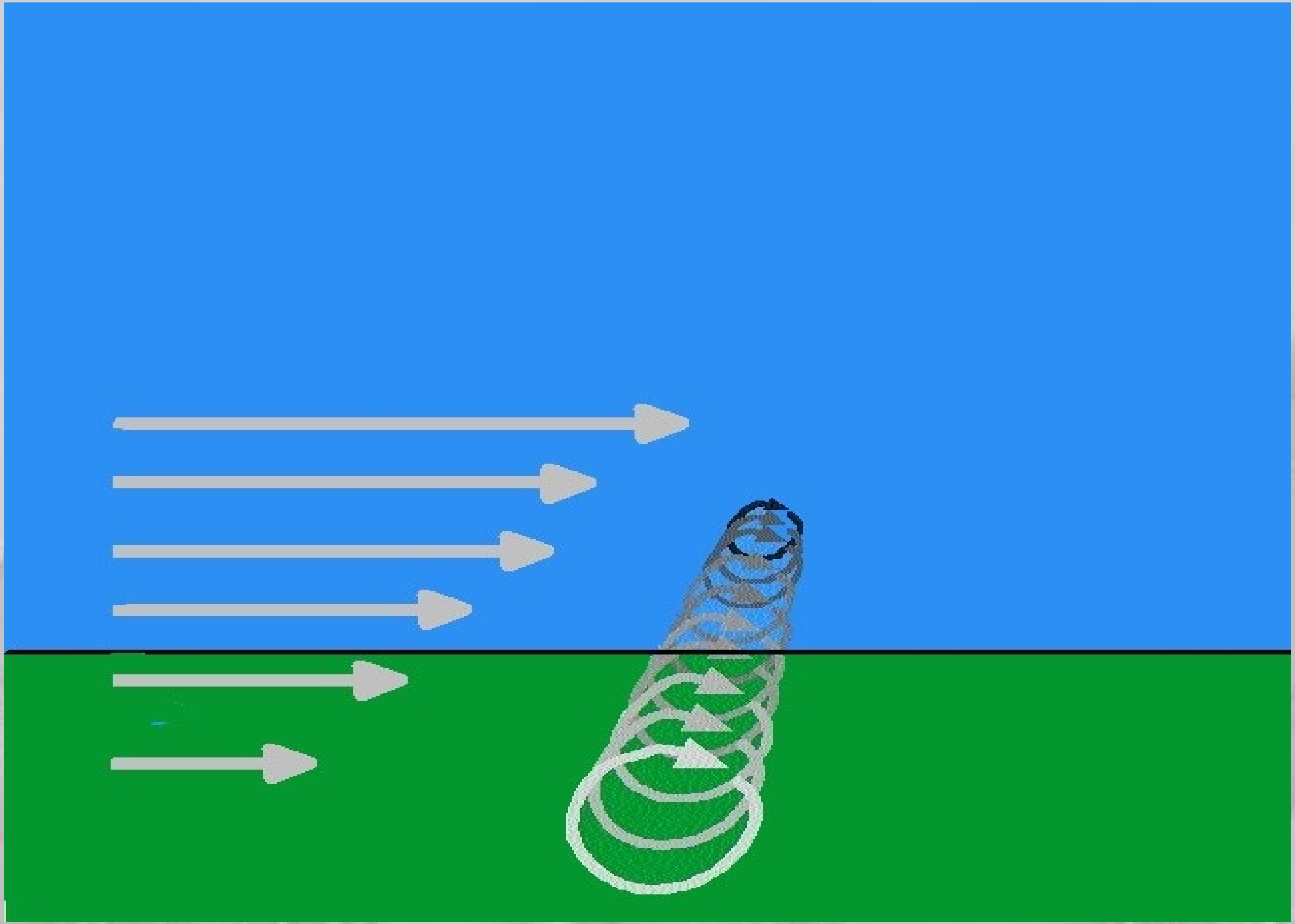
TORNADO

Or both ?

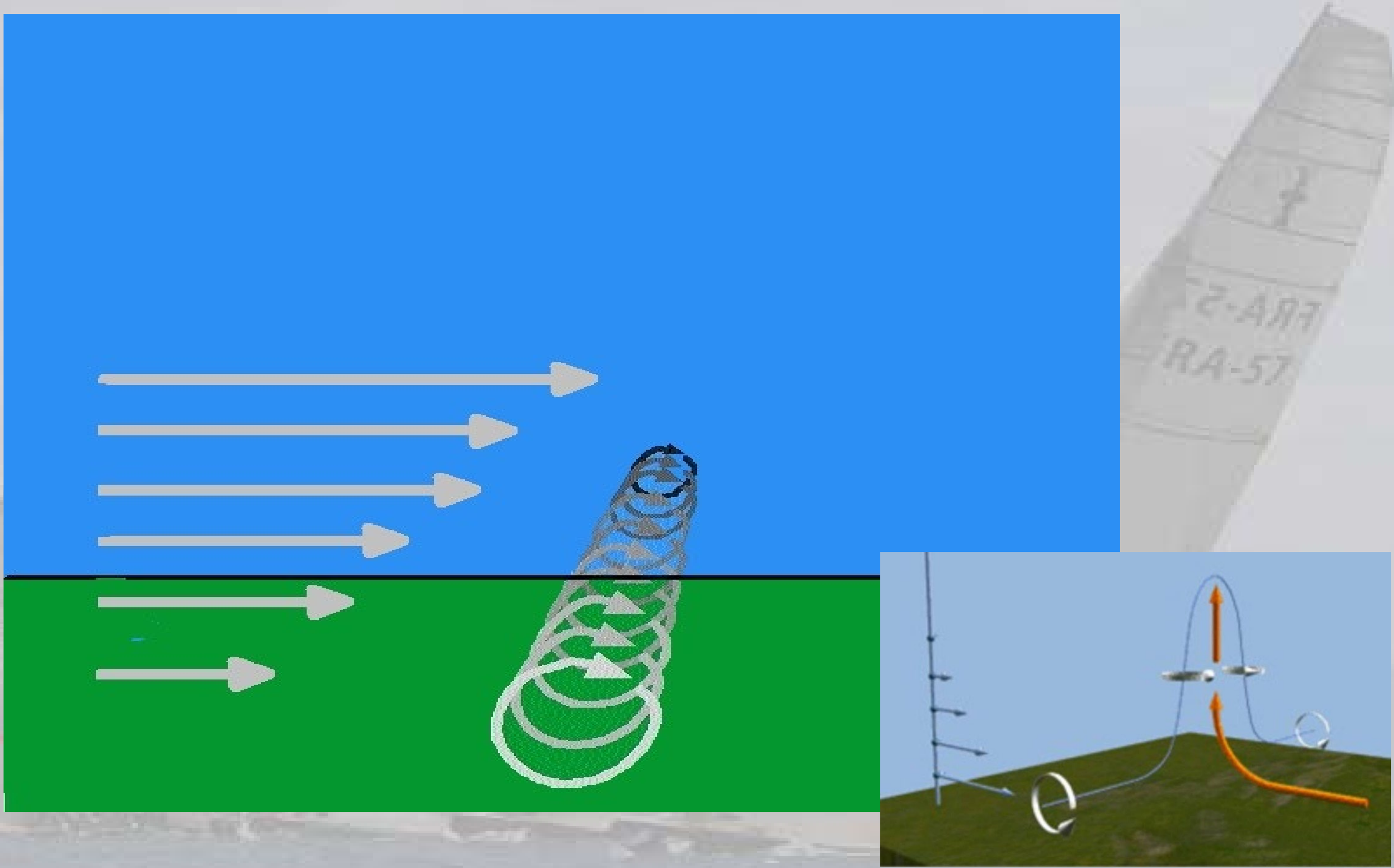
TORNADO


formation of
Cumulus Cloud..
Tropopause = top of the Troposphere
Anvil

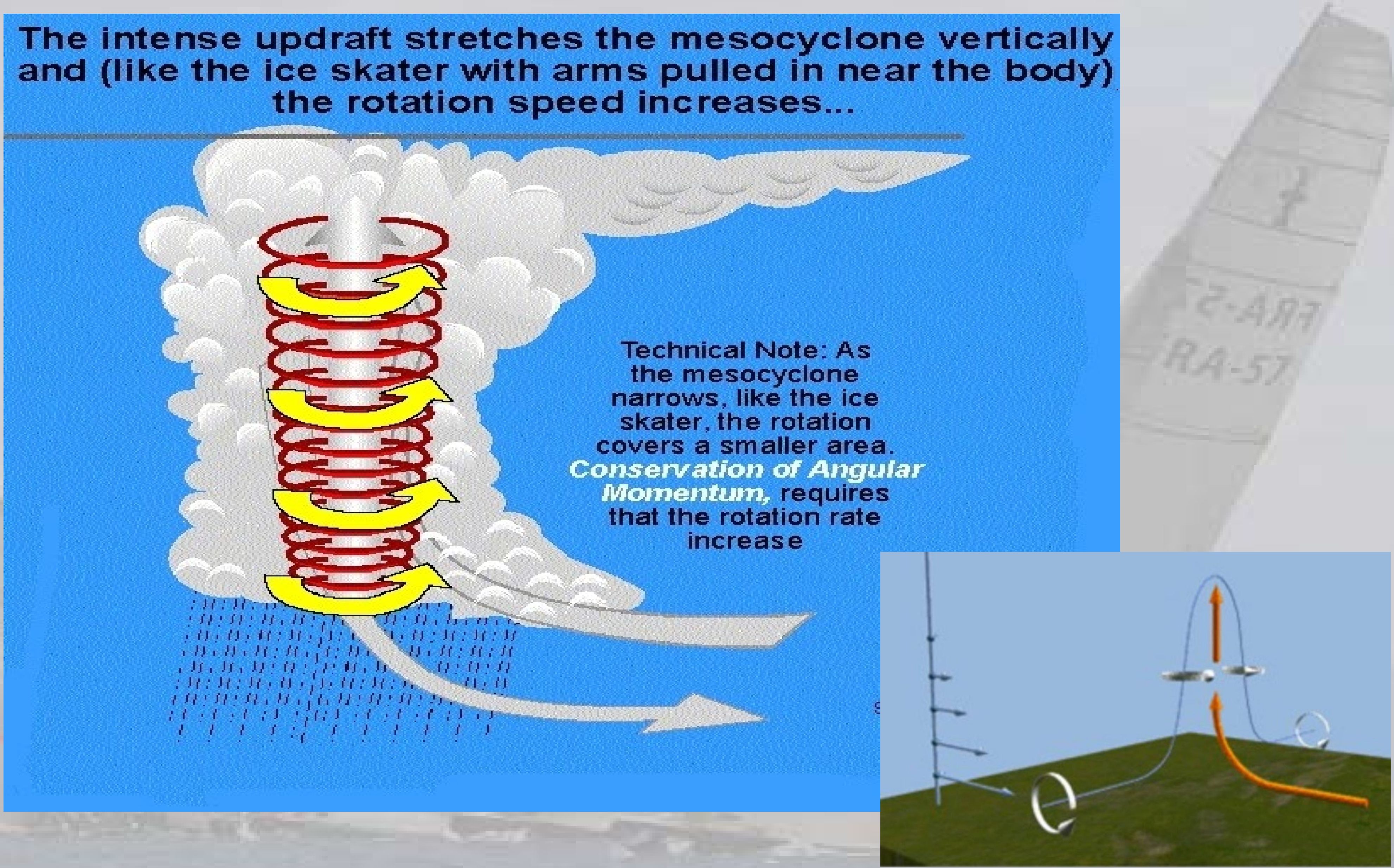
TORNADO



TORNADO



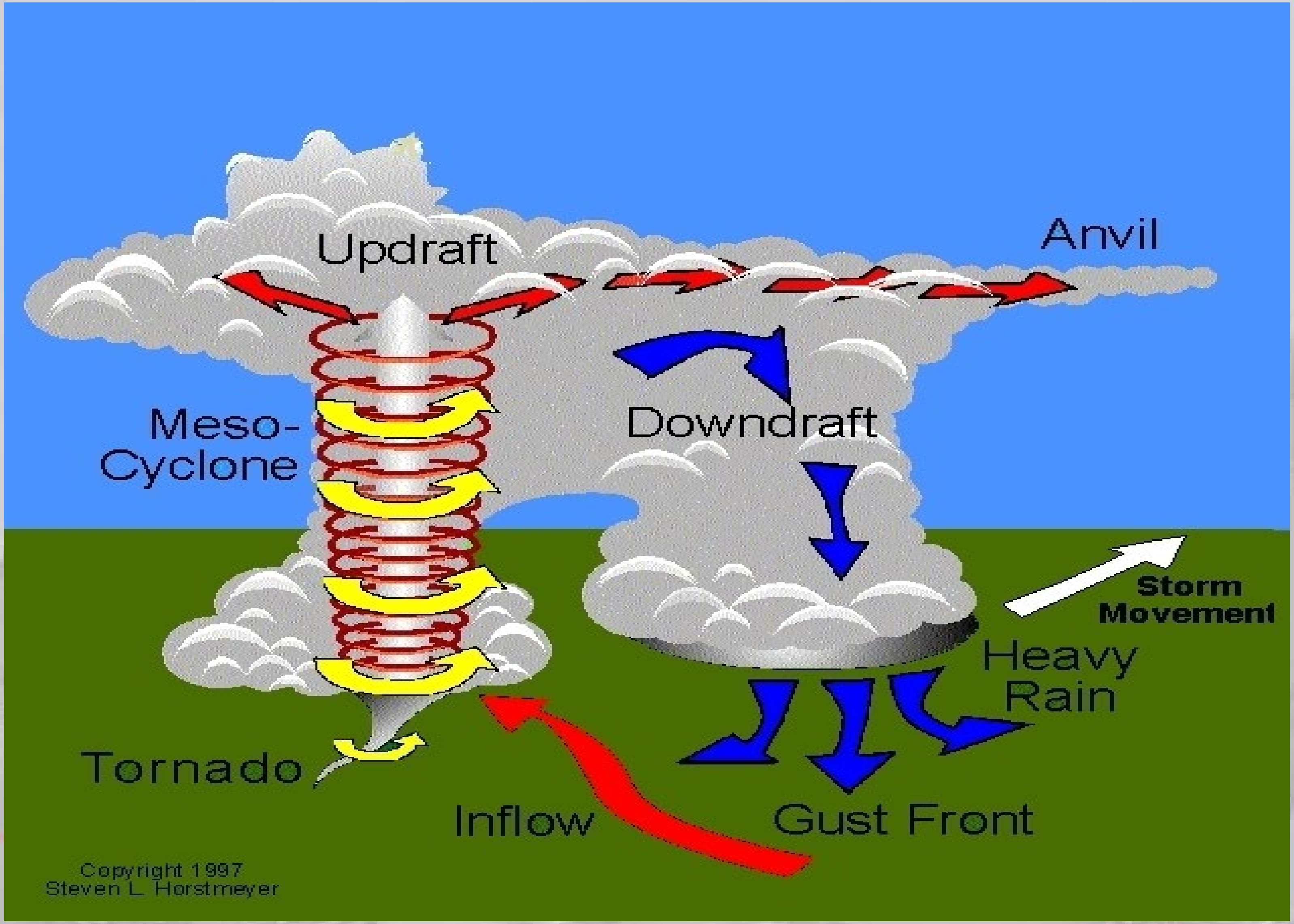
TORNADO



The intense updraft stretches the mesocyclone vertically and (like the ice skater with arms pulled in near the body) the rotation speed increases...

Technical Note: As the mesocyclone narrows, like the ice skater, the rotation covers a smaller area. ***Conservation of Angular Momentum,*** requires that the rotation rate increase

TORNADO



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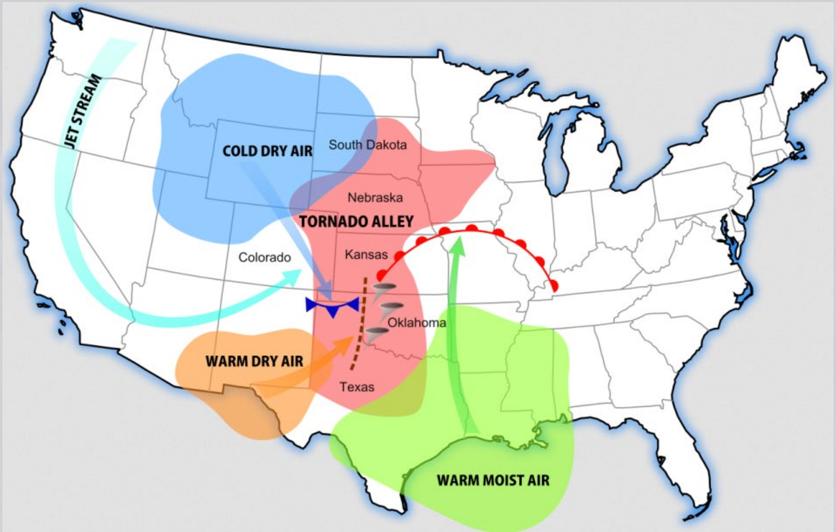
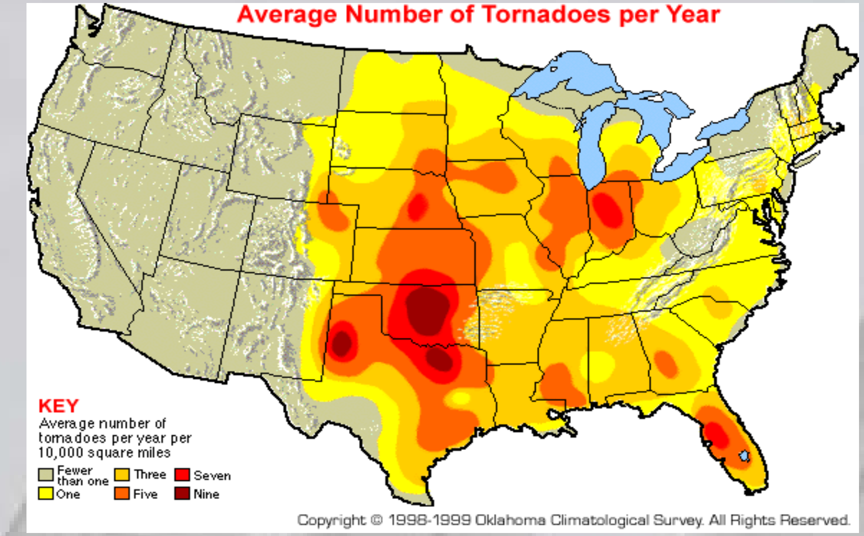
Steven L. Horstmeyer

TORNADOES: DISTRIBUTION OVER THE USA AND EUROPE





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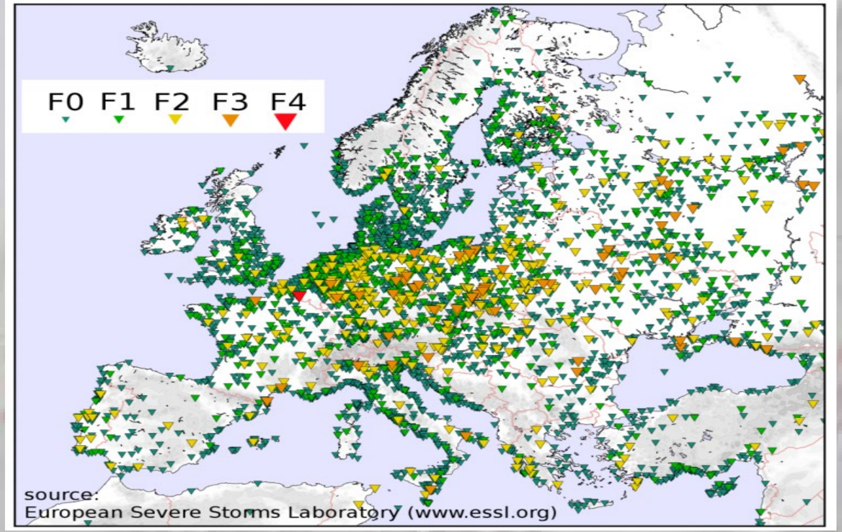
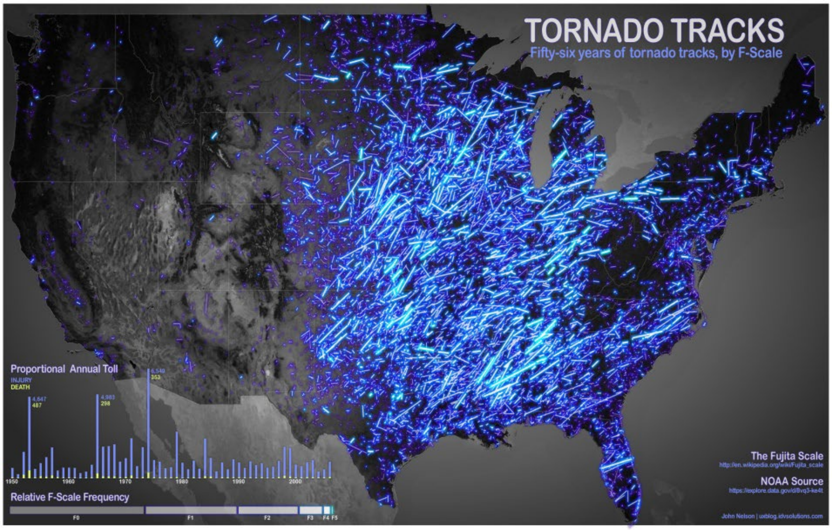
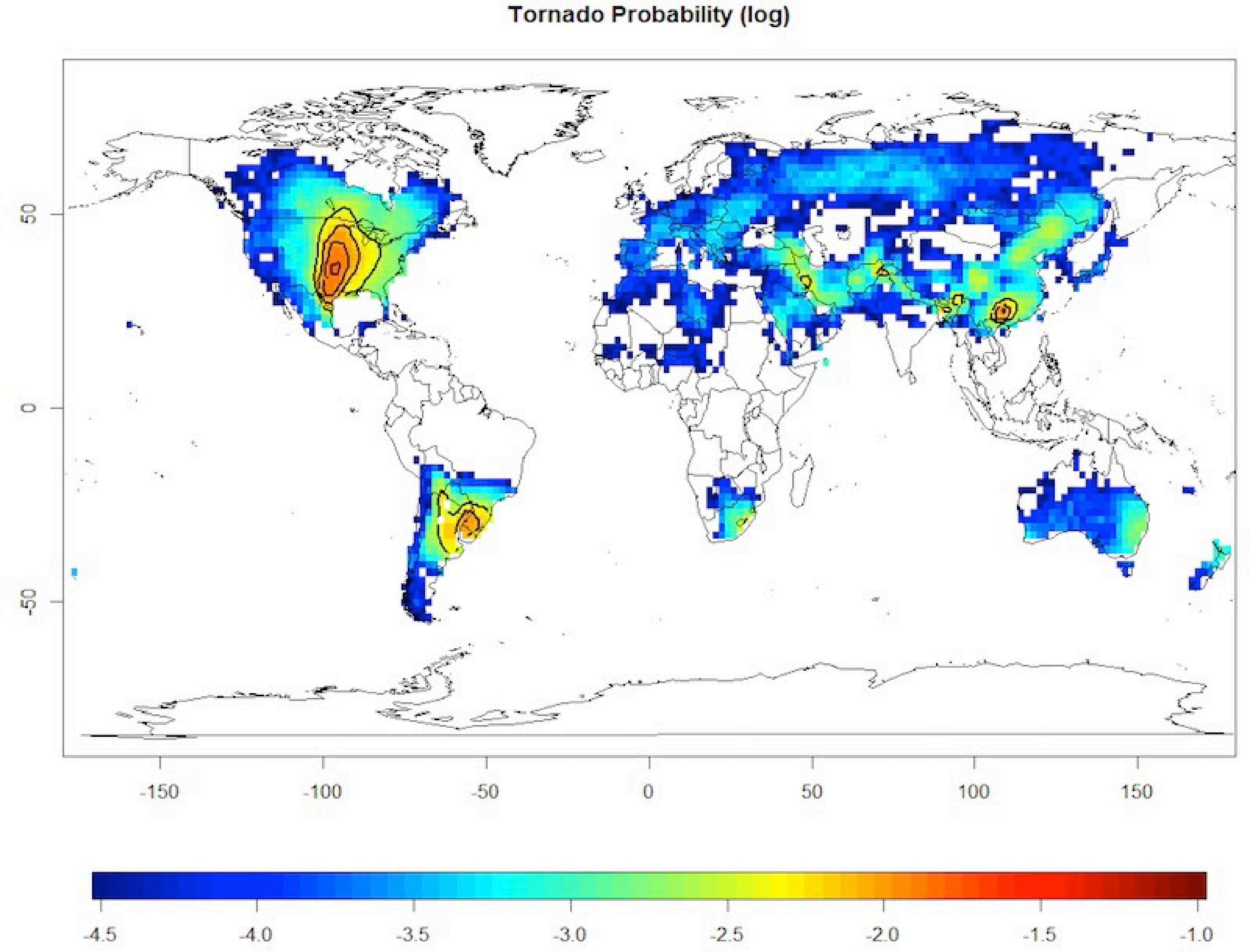


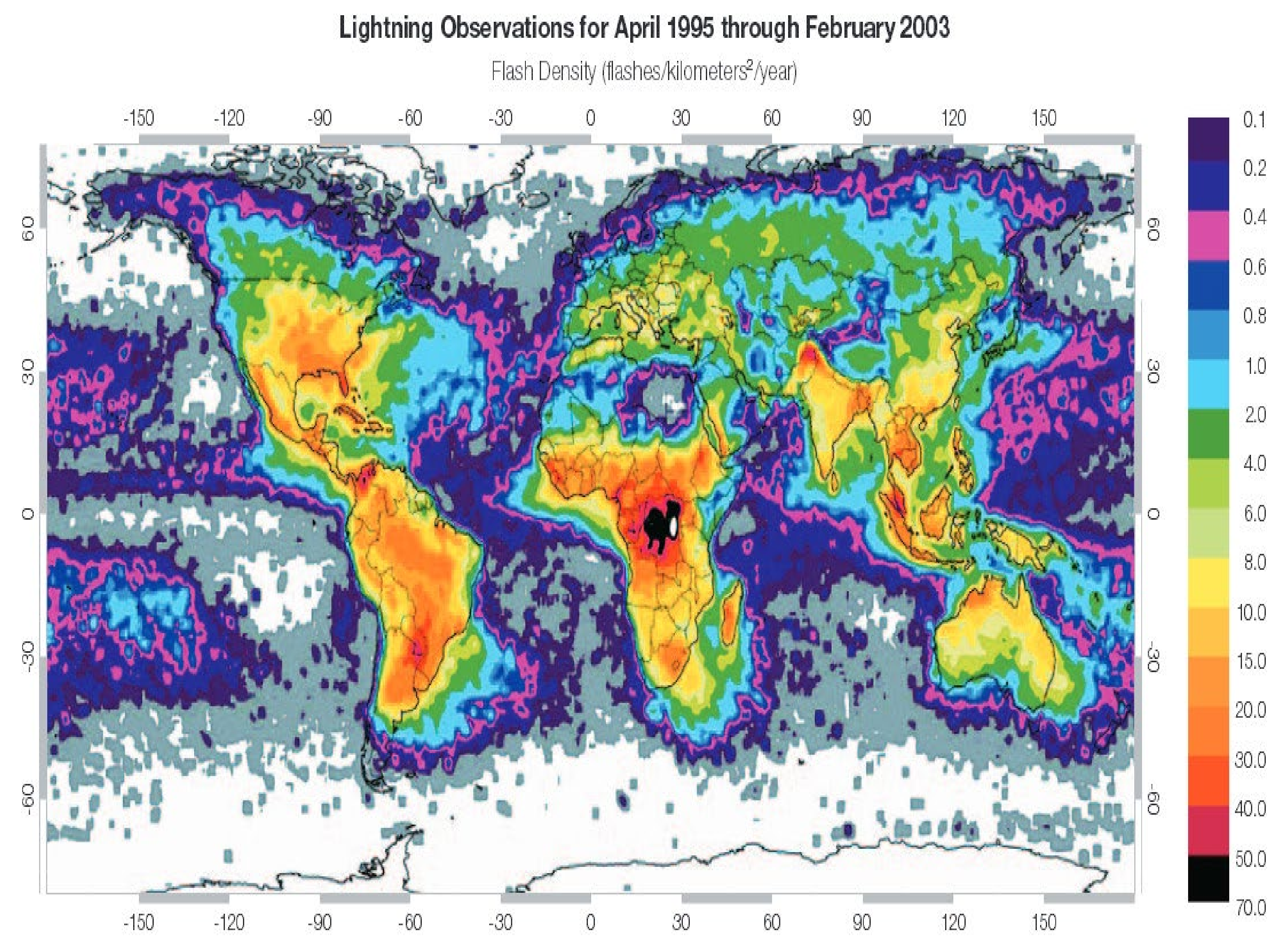
source:
European Severe Storms Laboratory (www.essl.org)



GLOBAL DISTRIBUTION OF TORNADOES



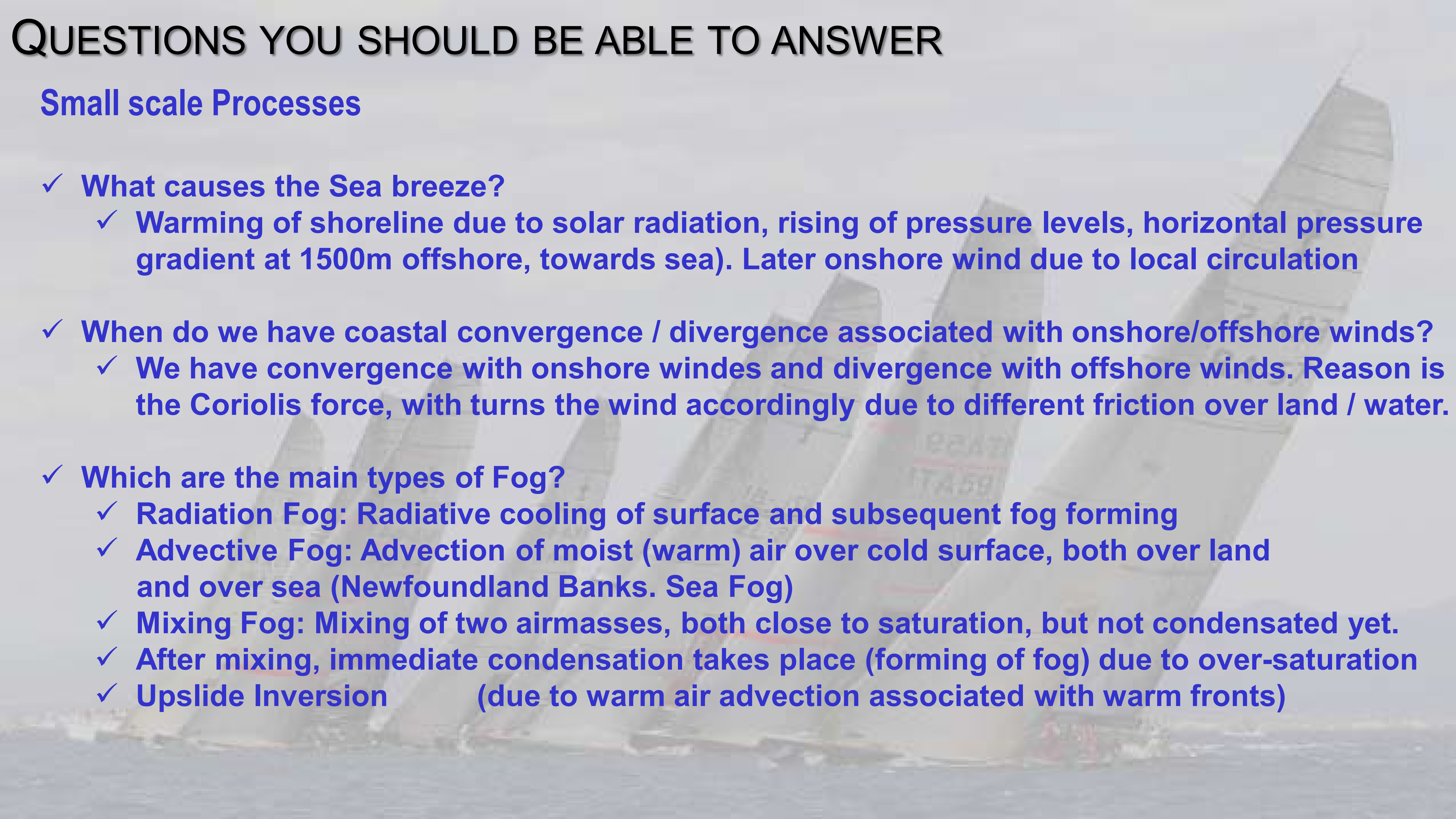
GLOBAL DISTRIBUTION OF LIGHTNINGS



Lightning Observations for April 1995 through February 2003

Flash Density (flashes/kilometers^2/year)

QUESTIONS YOU SHOULD BE ABLE TO ANSWER



Small scale Processes

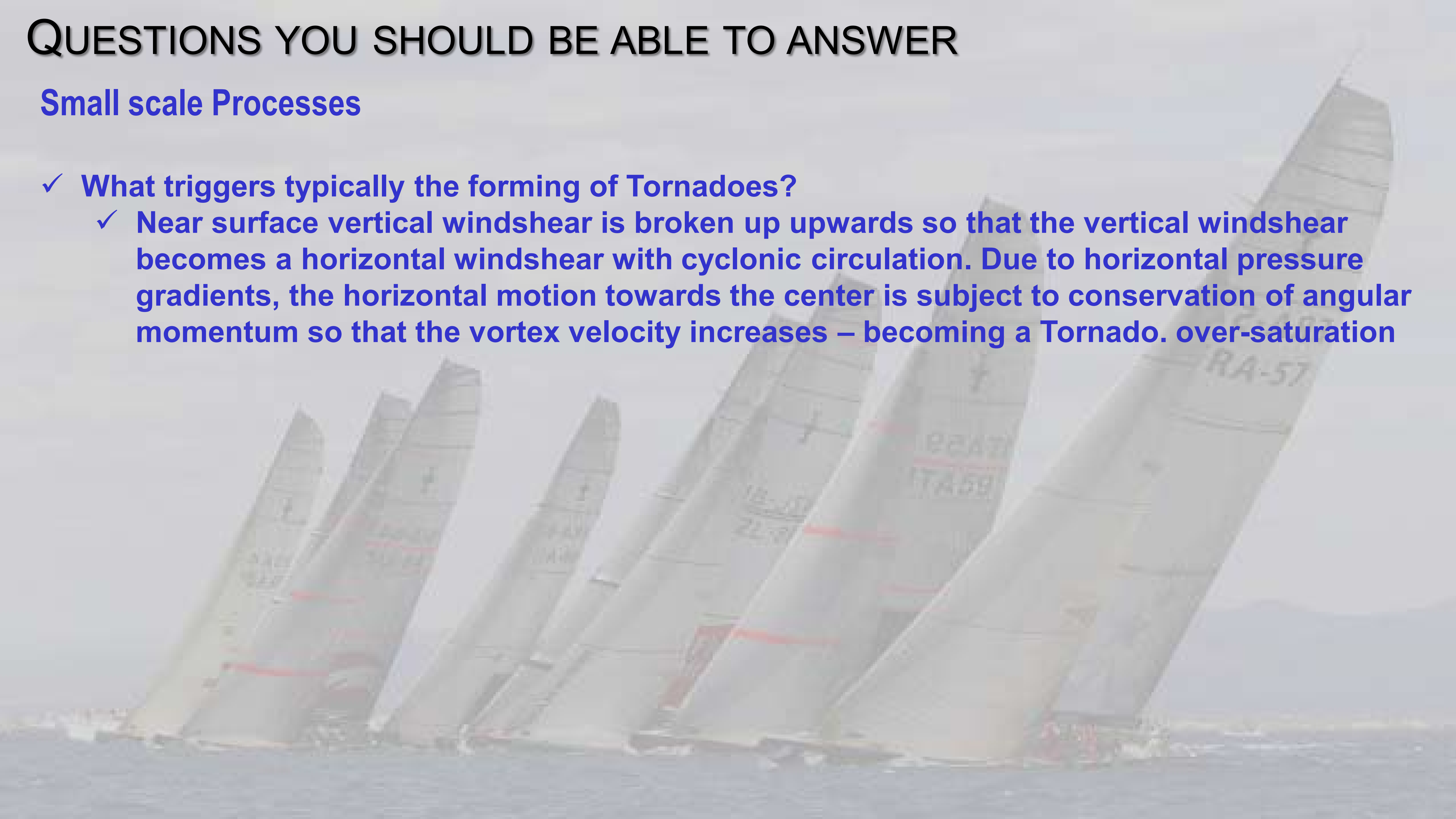
- ✓ What causes the Sea breeze?
  - ✓ Warming of shoreline due to solar radiation, rising of pressure levels, horizontal pressure gradient at 1500m offshore, towards sea). Later onshore wind due to local circulation

- ✓ When do we have coastal convergence / divergence associated with onshore/offshore winds?
  - ✓ We have convergence with onshore windes and divergence with offshore winds. Reason is the Coriolis force, with turns the wind accordingly due to different friction over land / water.

- ✓ Which are the main types of Fog?
  - ✓ Radiation Fog: Radiative cooling of surface and subsequent fog forming
  - ✓ Advective Fog: Advection of moist (warm) air over cold surface, both over land and over sea (Newfoundland Banks. Sea Fog)
  - ✓ Mixing Fog: Mixing of two airmasses, both close to saturation, but not condensated yet.
  - ✓ After mixing, immediate condensation takes place (forming of fog) due to over-saturation
  - ✓ Upslide Inversion (due to warm air advection associated with warm fronts)

QUESTIONS YOU SHOULD BE ABLE TO ANSWER

Small scale Processes



- ✓ **What triggers typically the forming of Tornadoes?**
  - ✓ **Near surface vertical windshear is broken up upwards so that the vertical windshear becomes a horizontal windshear with cyclonic circulation. Due to horizontal pressure gradients, the horizontal motion towards the center is subject to conservation of angular momentum so that the vortex velocity increases – becoming a Tornado. over-saturation**

FRA-5
FRA-57
ITA59
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