Goals for today:

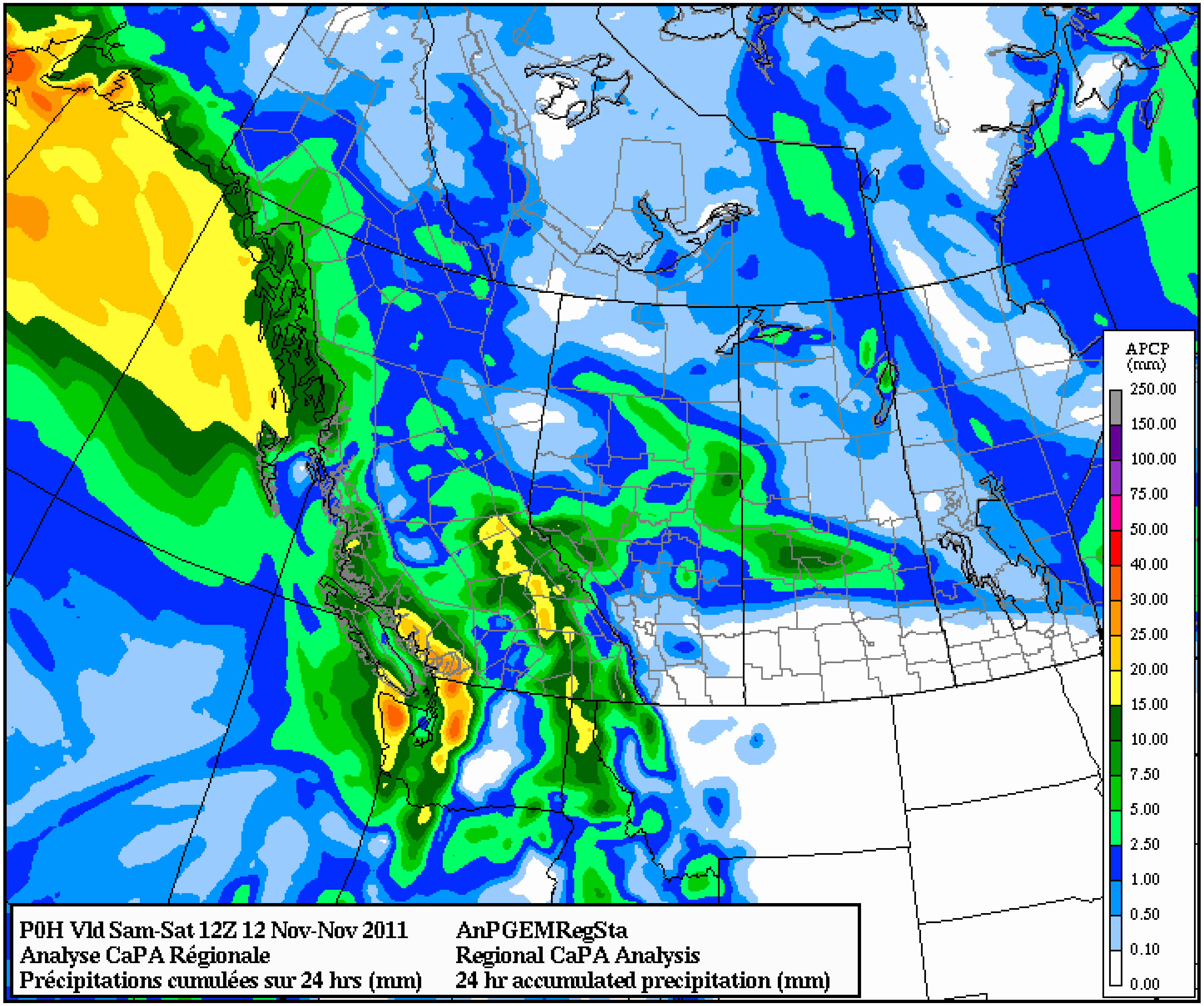
14 Nov., 2011

- ***Complete Ch. 10 "Midlatitude Cyclones" – conveyor belt model***
- ***Begin Ch. 11 "Lightning, Thunder & Tornadoes"***

Quiz 3 next Monday (22 Nov.) to cover from p236 in Chapter 8 of the textbook to the end of Chapter 10, i.e. material covered from Monday 24 Oct. through Monday 14 Nov. inclusive.

lec25.odp
JDWilson vers 13 Nov. 2011

Last Wednesday's class gave MSC's forecast for precip overnight Friday – here the analysis, giving 24-hr accumulation to 12Z Saturday morning



We did indeed wake to a thin cover of snow on Saturday

“Conveyor belt” conceptual model of midlatitude cyclone

- originates with Carlson 1980 (“Airflow through midlatitude cyclones and the comma cloud pattern,” *Monthly Weather Review*, Vol. 108) and earlier authors including Browing 1971 (*Weather*, Vol. 26)

- consistent with the earlier ideas of a frontal structure and waves aloft

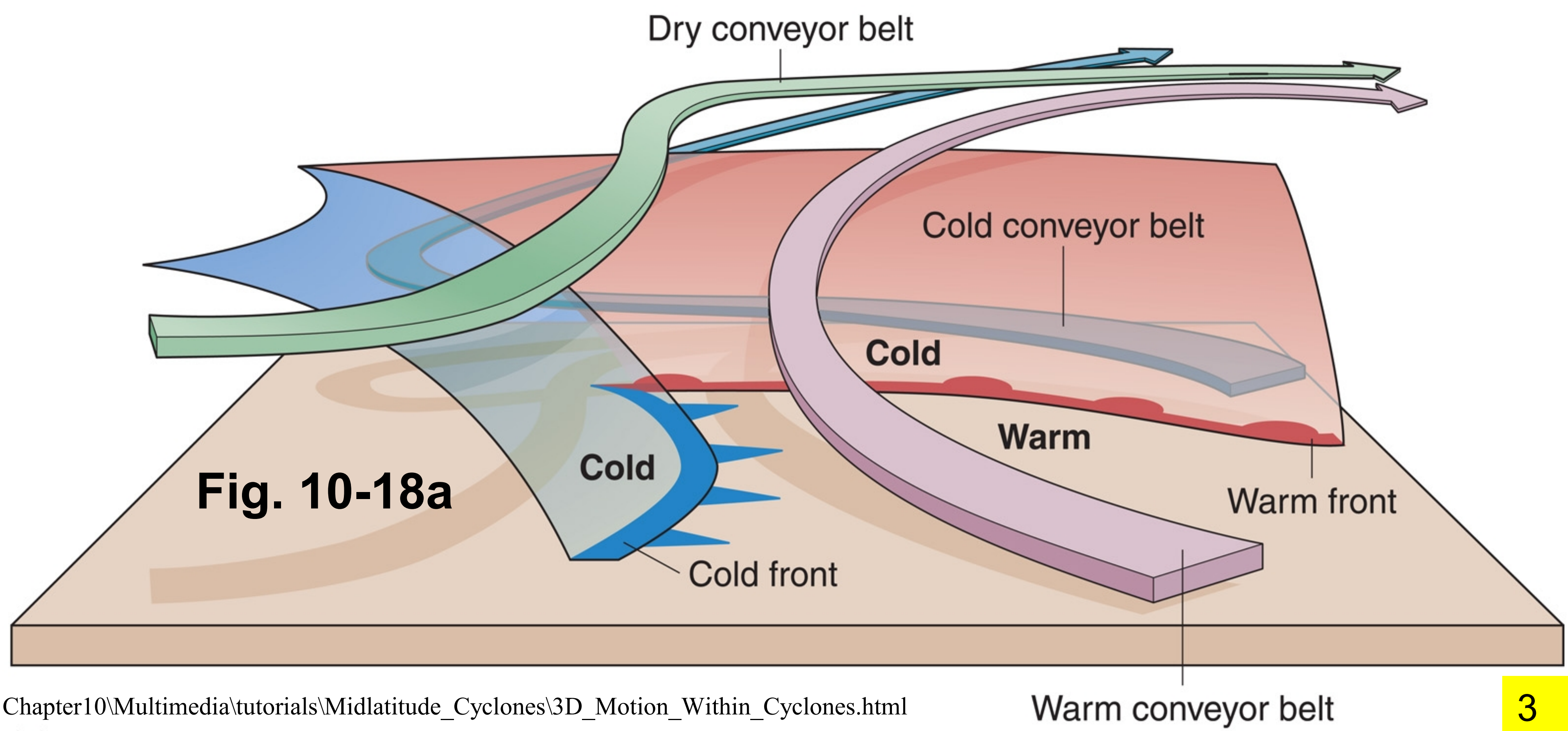
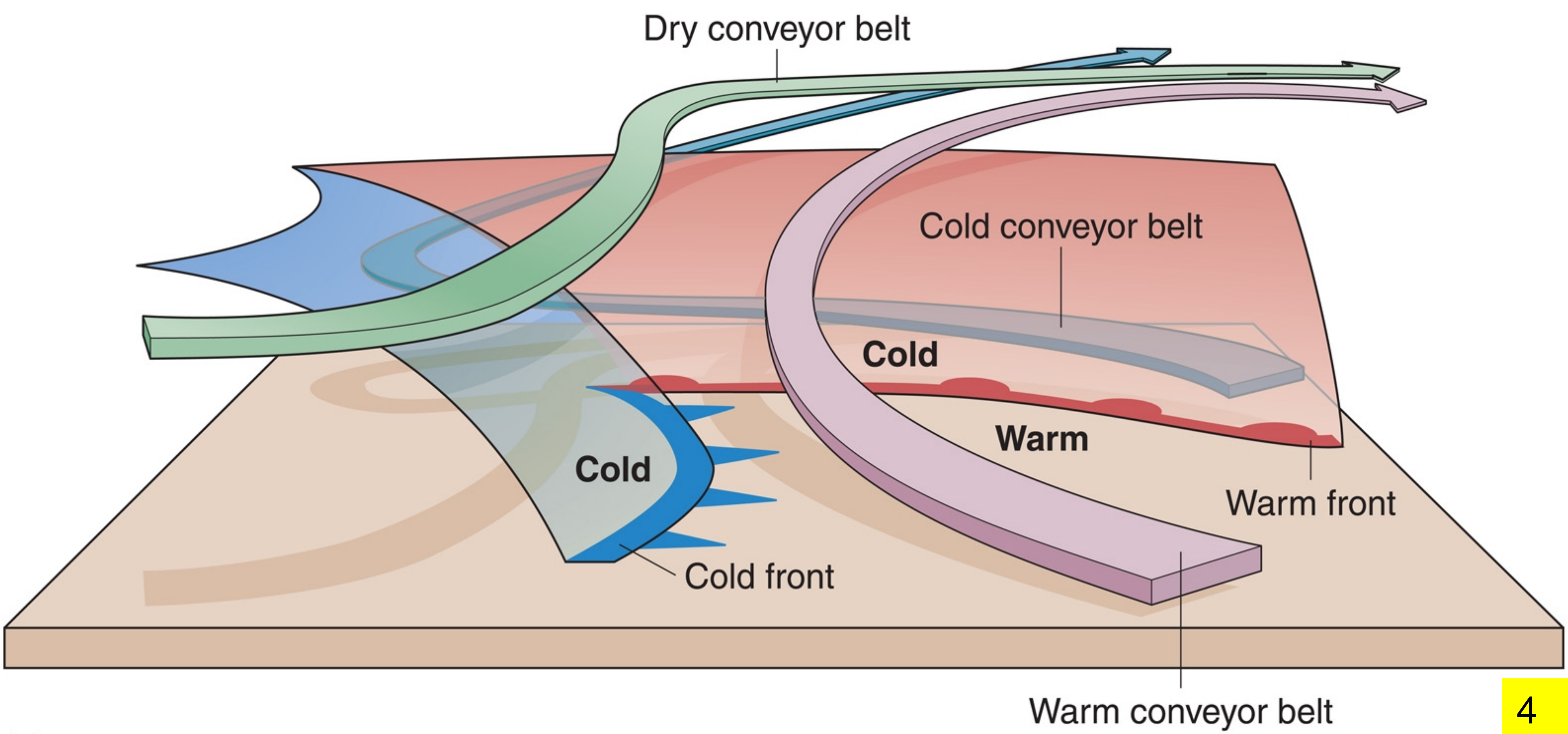


Fig. 10-18a

Chapter10\Multimedia\tutorials\Midlatitude_Cyclones\3D_Motion_Within_Cyclones.html

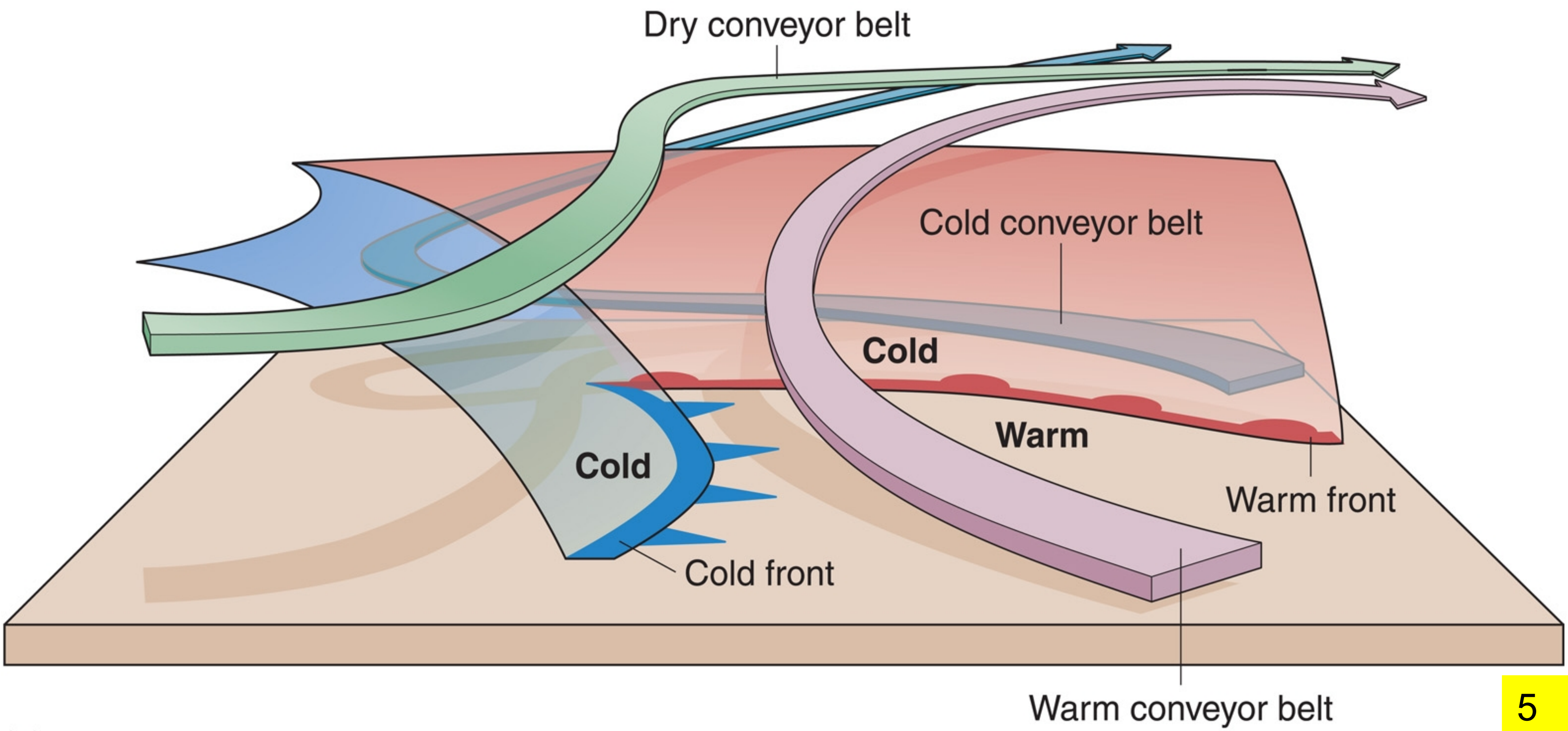
“Conveyor belt” model of midlatitude cyclone

- warm belt (high dewpoint) overruns warm frontal surface and its ascent results in cloud & precipitation – turns right and merges with W or SW upper winds of trough exit region



"Conveyor belt" model of midlatitude cyclone

- cold belt (drier) is a surface easterly on the cold side of the warm front, and it is moistened by precip falling from the warm belt. This belt also ascends, and turns anticyclonically to merge with W or SW upper winds of trough exit region



“Conveyor belt” model of midlatitude cyclone

• dry belt is a cold upper westerly – separates the cloud bands of the warm and cold belts. “Brings the coldest air** into the cyclone” (p321)

***of course it is normal for the upper troposphere to be cold. Here “coldest air” needs to be interpreted as air with the coldest “potential temperature.” Potential temperature of a parcel at level p is the temperature it would have if lowered adiabatically to the 1000 hPa level*

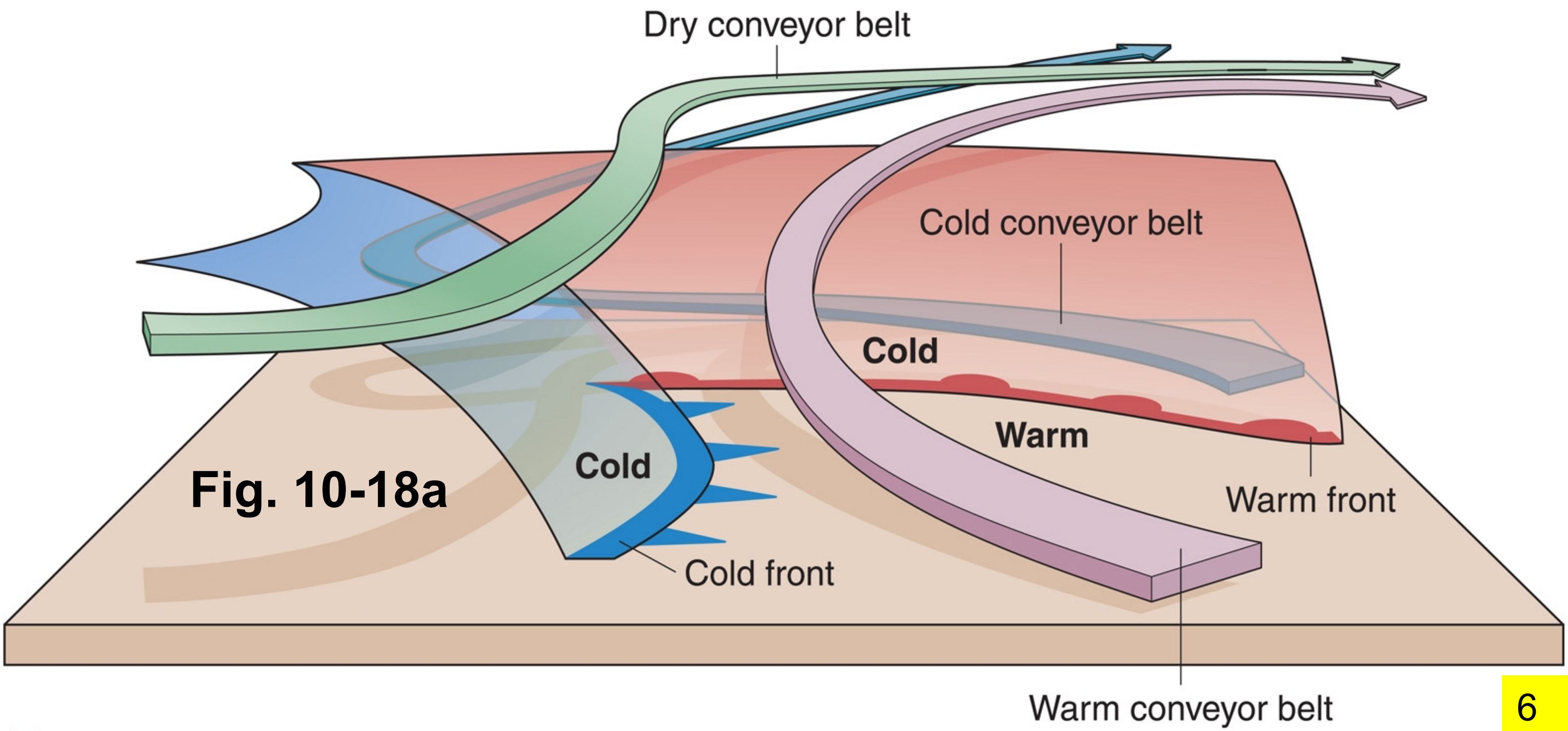
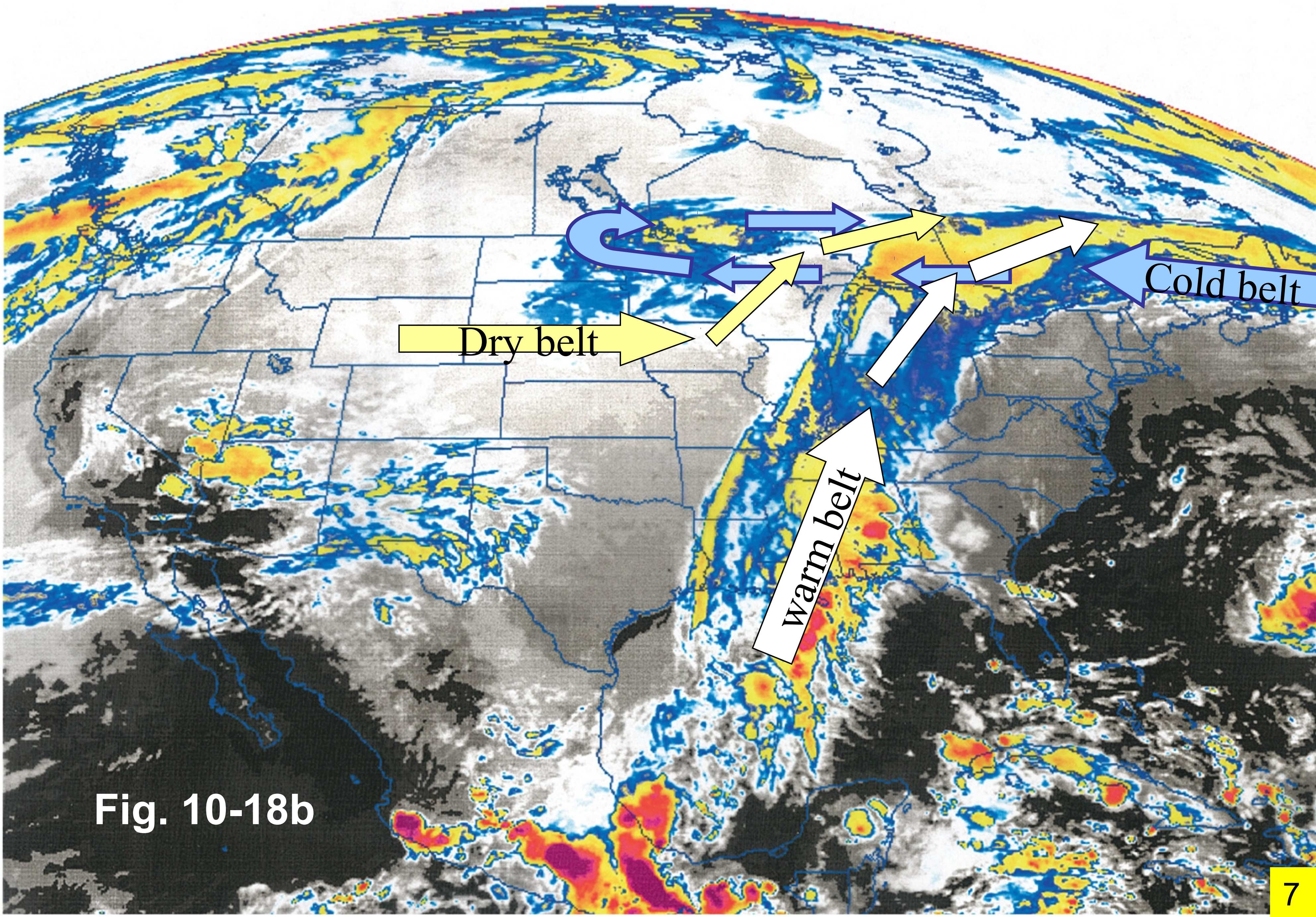
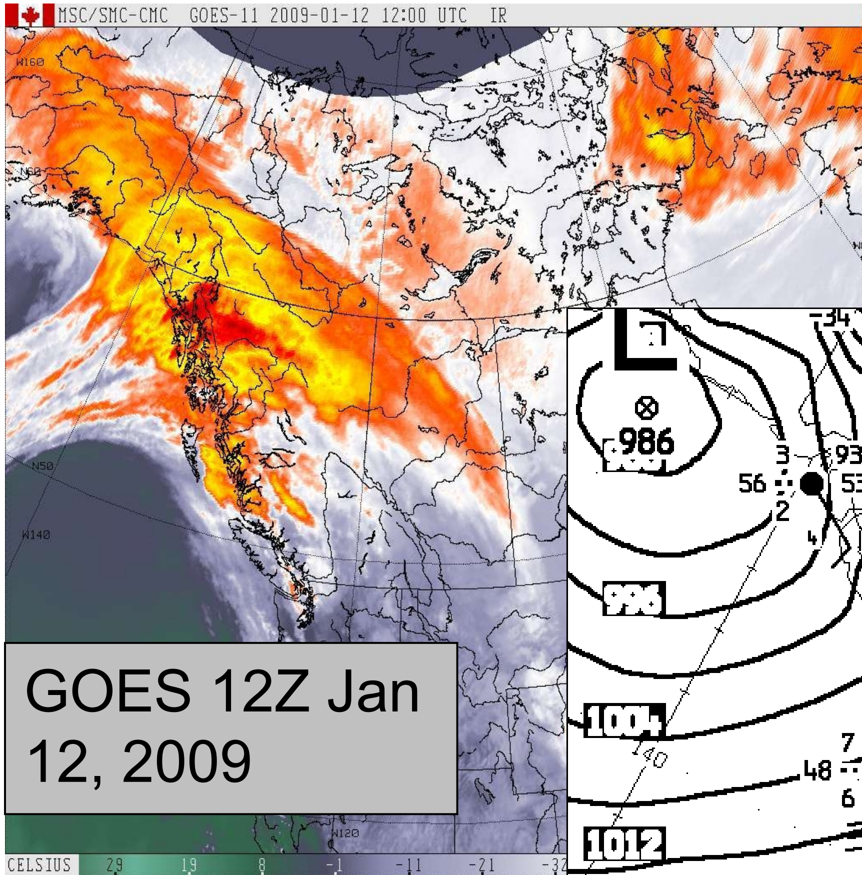


Fig. 10-18a

"Conveyor belt" model superposed on satellite cloud image

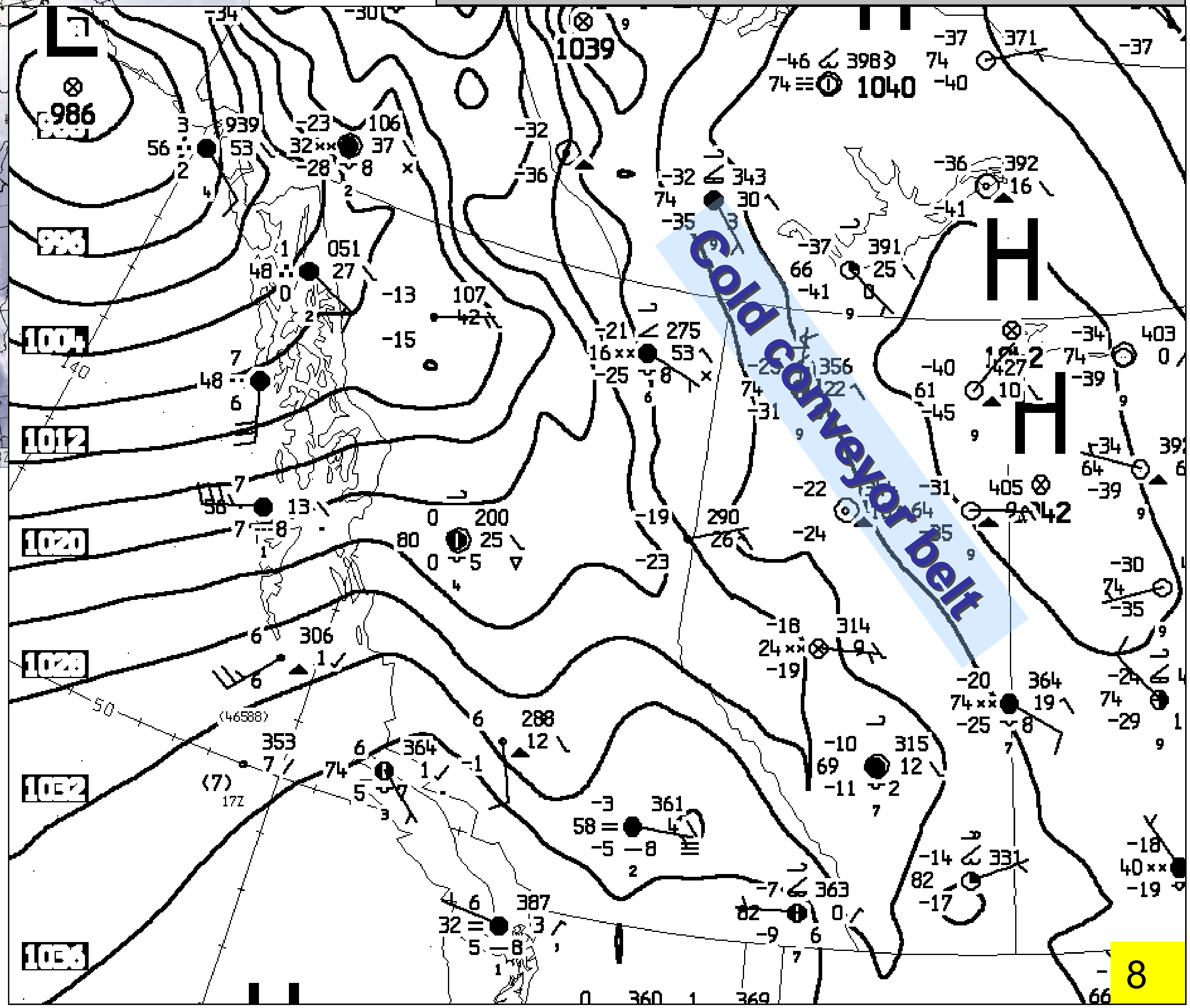


- Cold surface south-easterly north of warm front

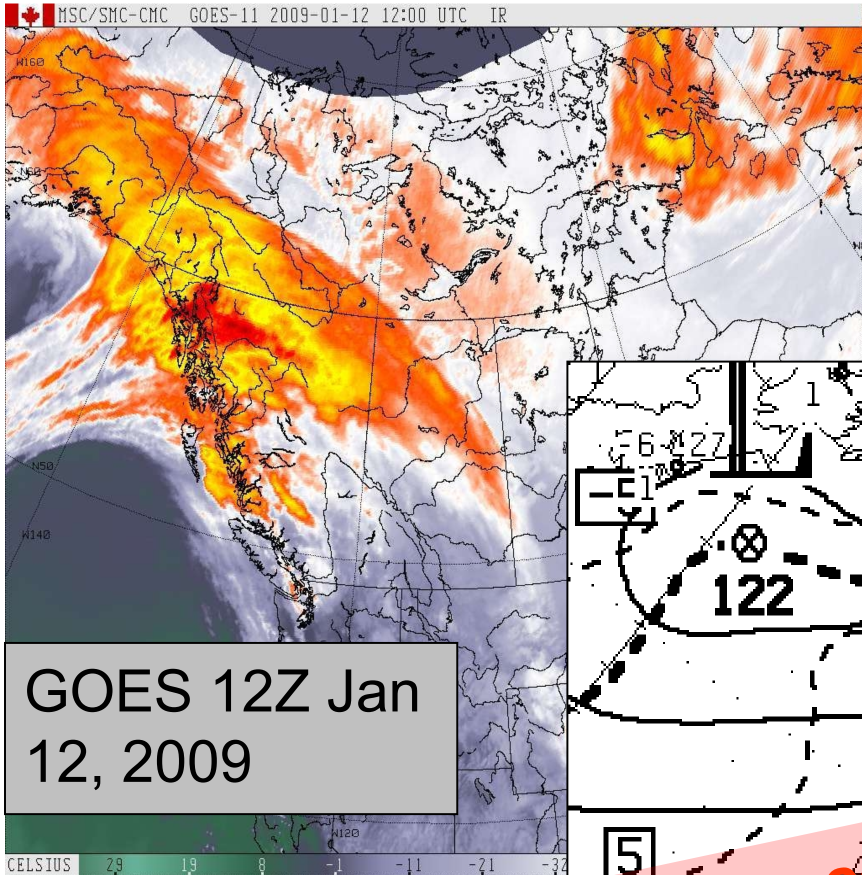


GOES 12Z Jan 12, 2009

CMC sfc analysis 18Z Jan 12, 2009



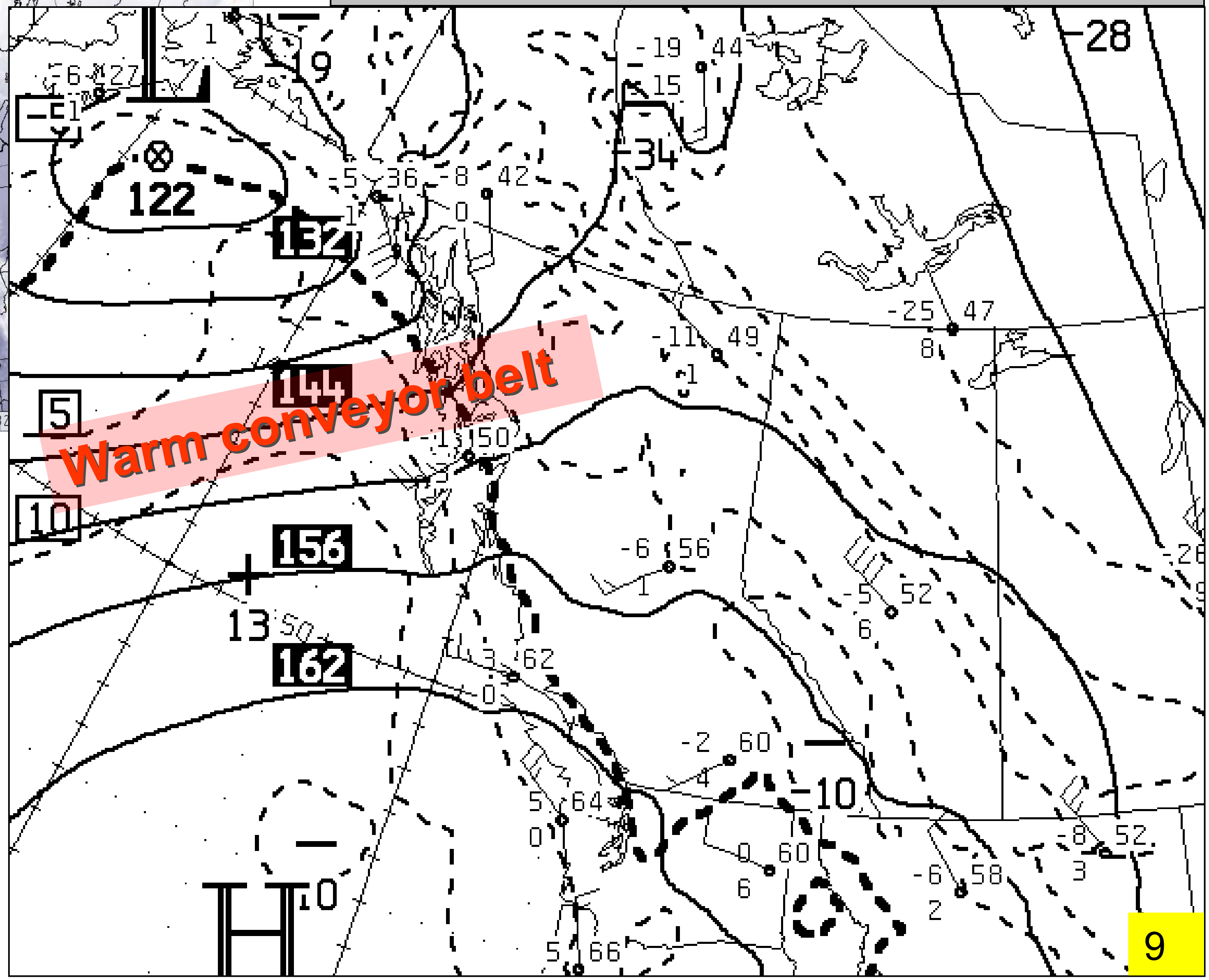
Interpretation of a case over W. Canada in terms of the conveyor belt model:



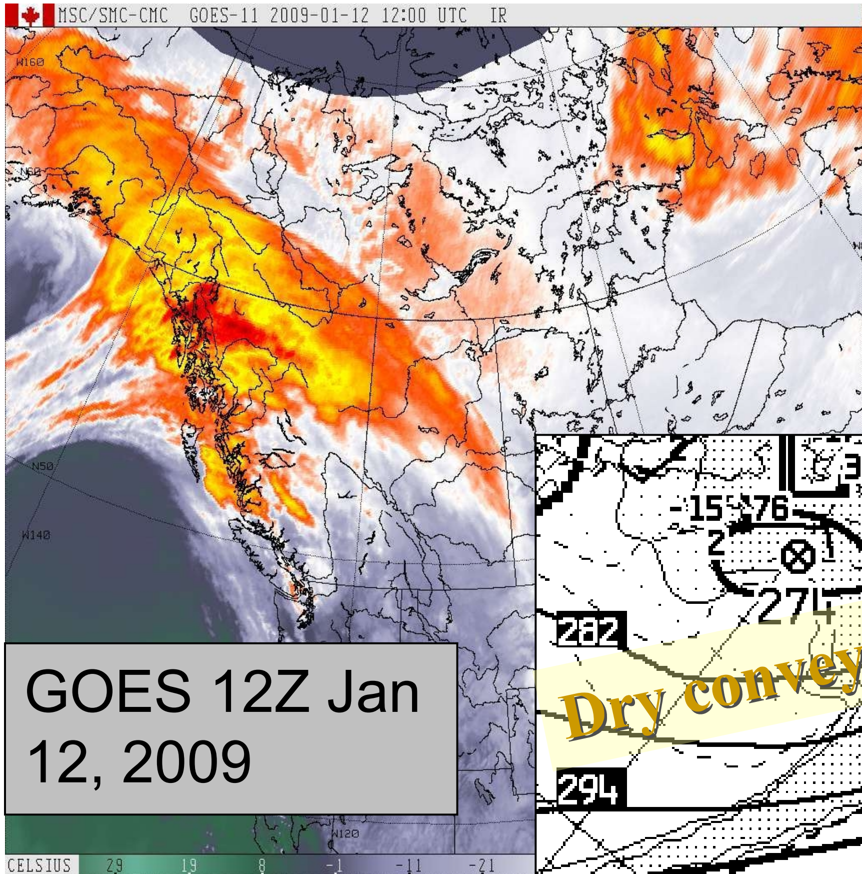
GOES 12Z Jan 12, 2009

- mild air advecting from warm sector, overruns cold surface south-easterly

CMC 850 hPa analysis 18Z Jan 12, 2009

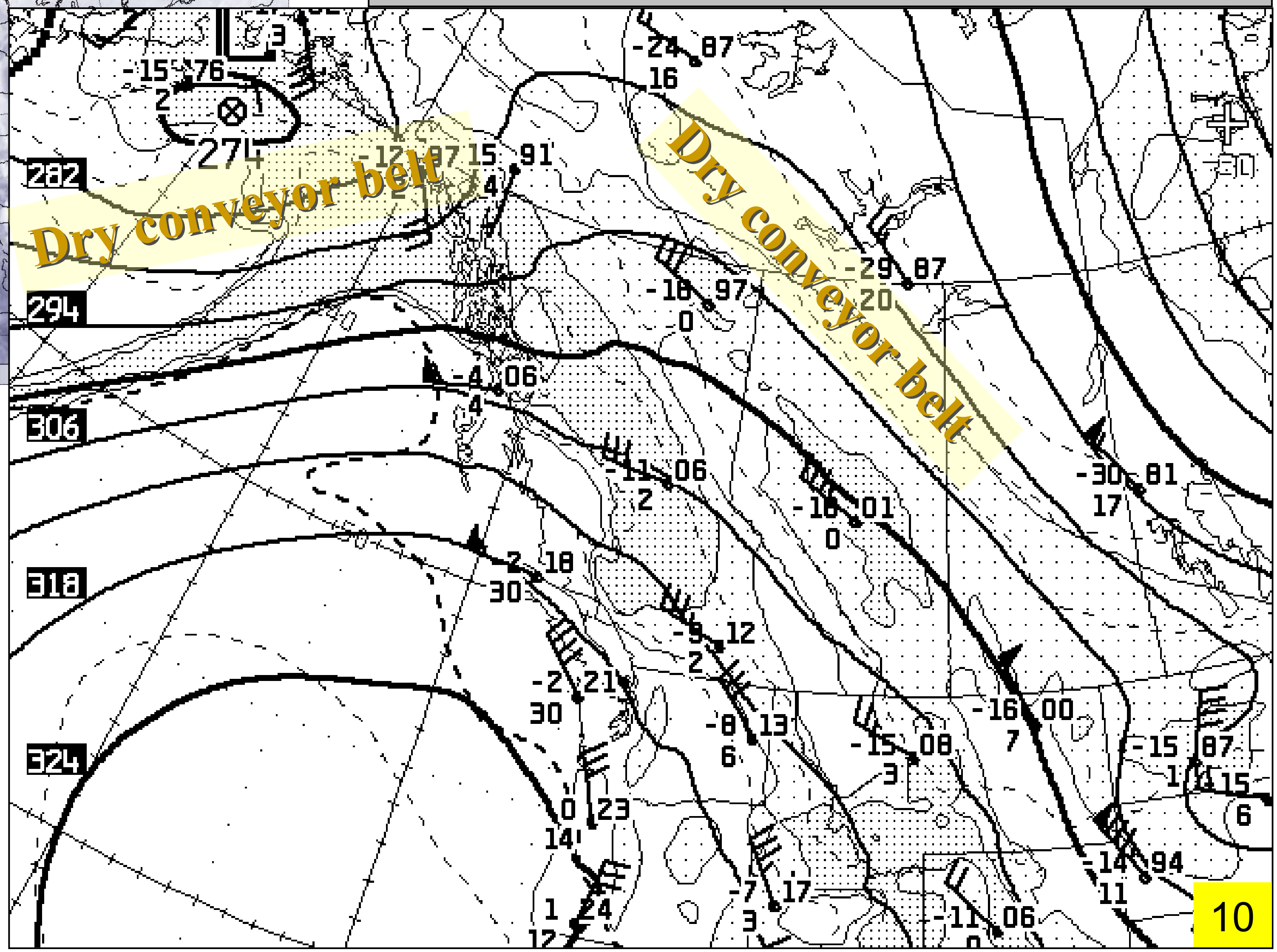


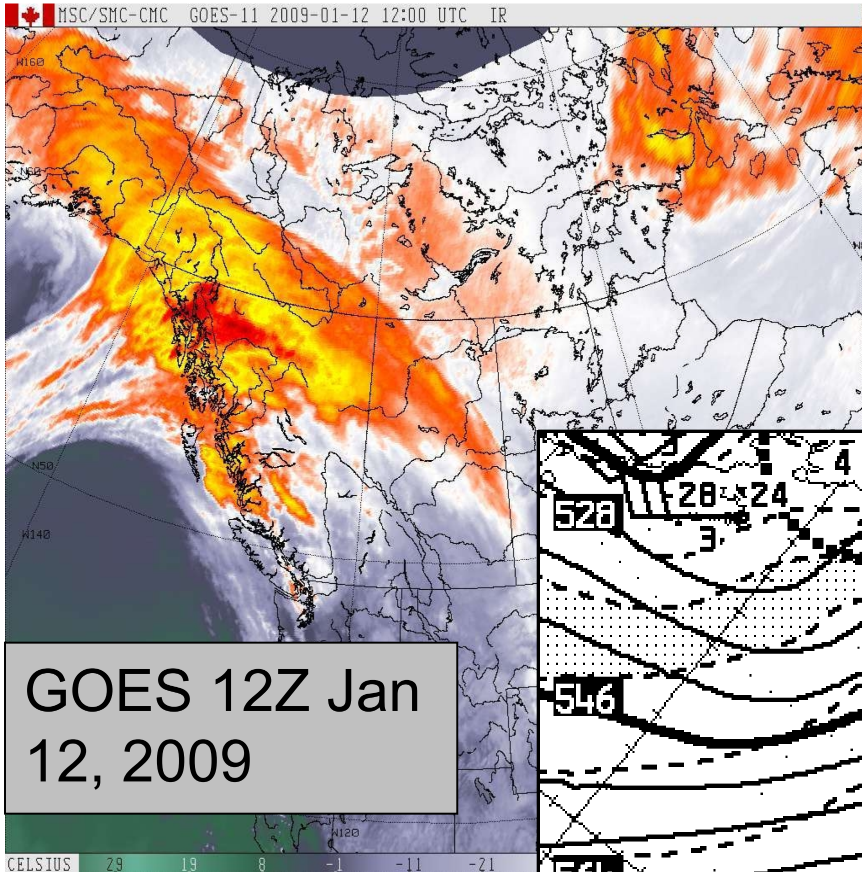
• dry air at 700 hPa corresponds to dry conveyor belt?



GOES 12Z Jan 12, 2009

CMC 700 hPa analysis 18Z Jan 12, 2009

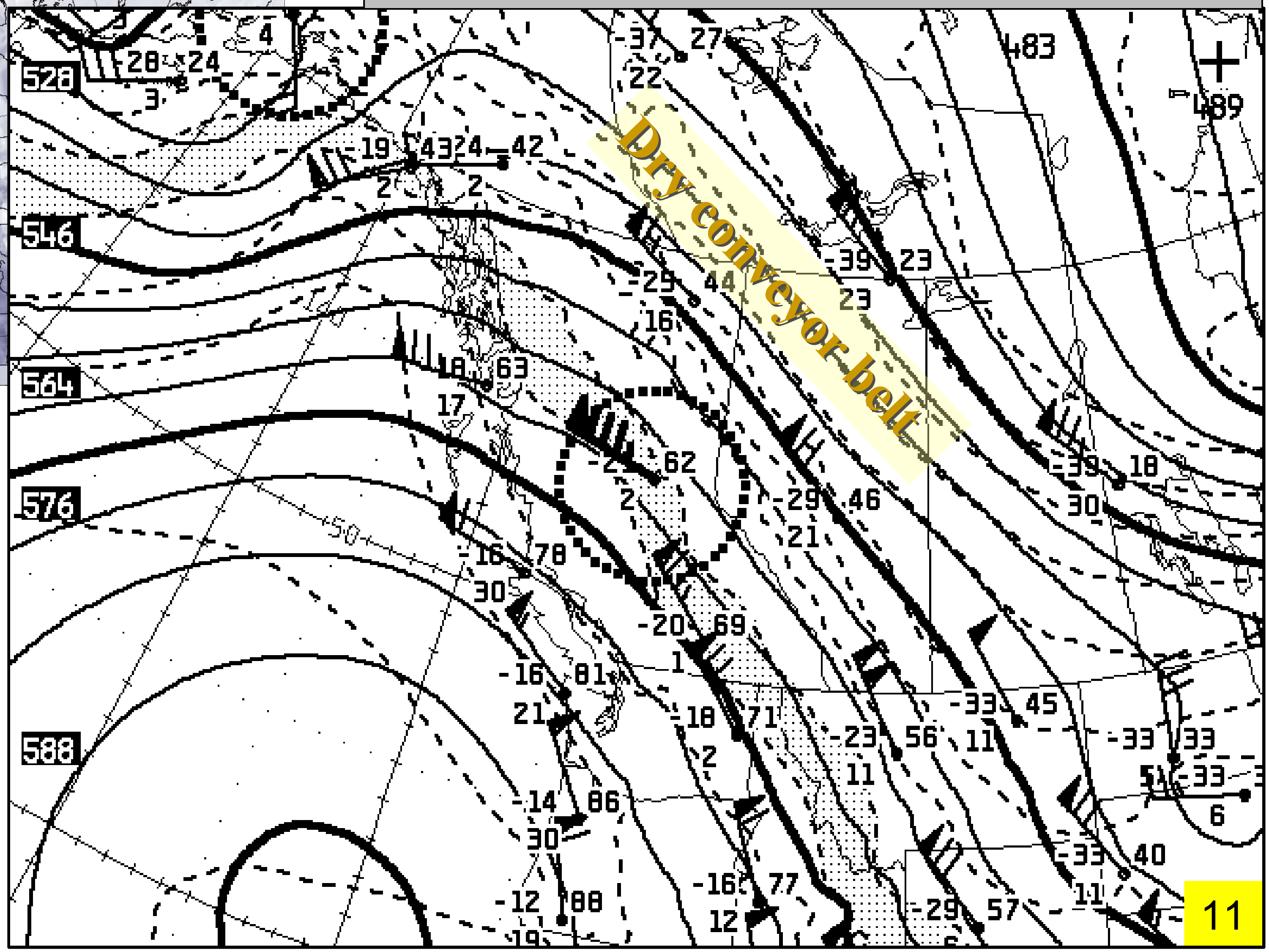




GOES 12Z Jan 12, 2009

- cold, dry air at 500 hPa corresponds to dry conveyor belt?

CMC 500 hPa analysis 12Z Jan 12, 2009



Conveyor belt model is *conceptual* – thus its fit to observed scenario(s) is imperfect, and entails subjectivity

Ch. 11 “Lightning, Thunder & Tornadoes”

How far away is the lightning? Velocity of sound is about 0.3 km s^{-1}. Time the delay from flash to thunder, and multiply by 0.3 – that's the range in km.

- id

Lightning

• 80% of lightning is within cloud (cloud-cloud lightning)

• lightning occurs only in precipitating clouds that extend above the freezing level

• thus the mechanism of charge separation within cloud is connected with ice crystal processes

• Upon collisions, “ice crystals surrender negative ions” to graupel or hail stones, which carry that charge toward cloudbase – result: negative charge at cloudbase

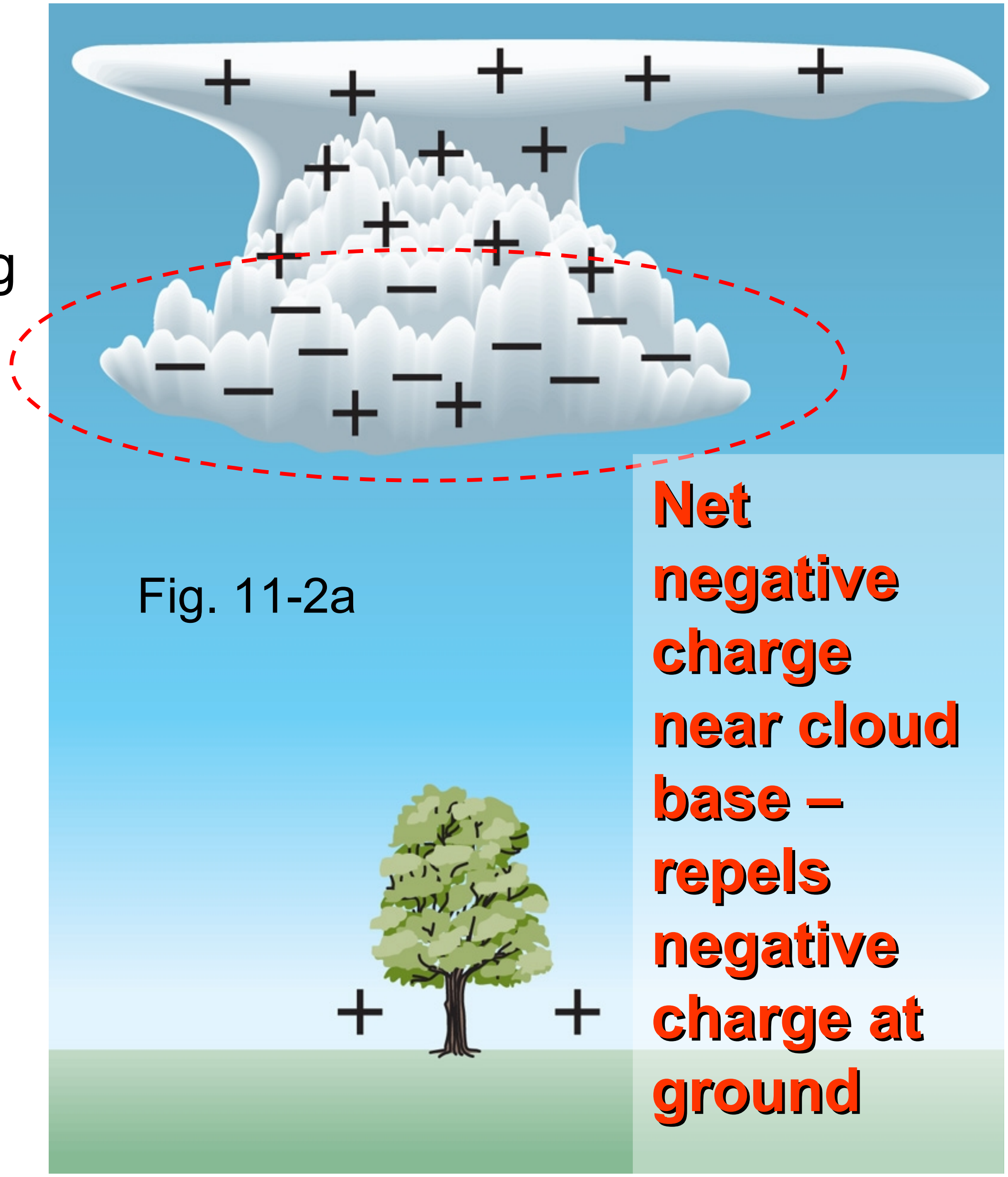


Fig. 11-2a

Lightning – establishing the conductive path

• lightning event preceded by staggered advance downward of a shaft of negatively charged air, the "stepped leader"

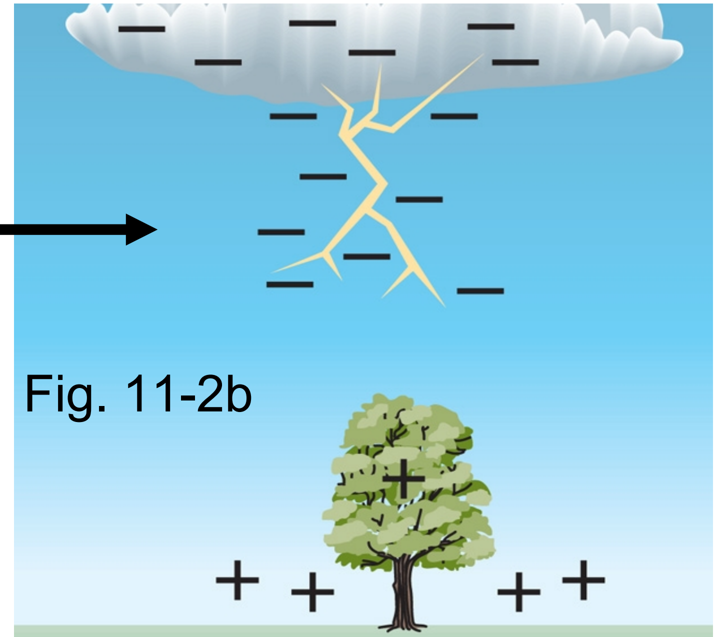


Fig. 11-2b

• channel only 10 cm diam, steps of ~ 50 m in ~1 *μ*sec followed by pauses of ~50 *μ*sec as electrons accumulate

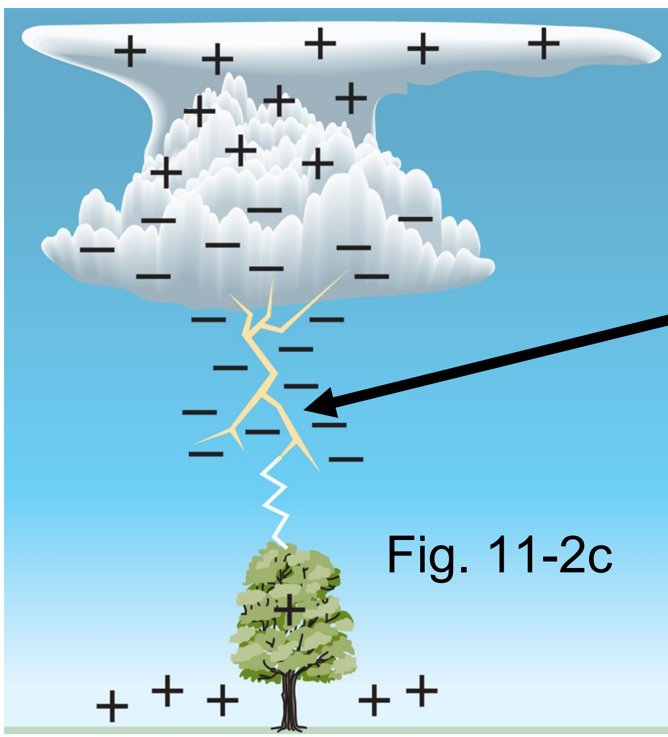


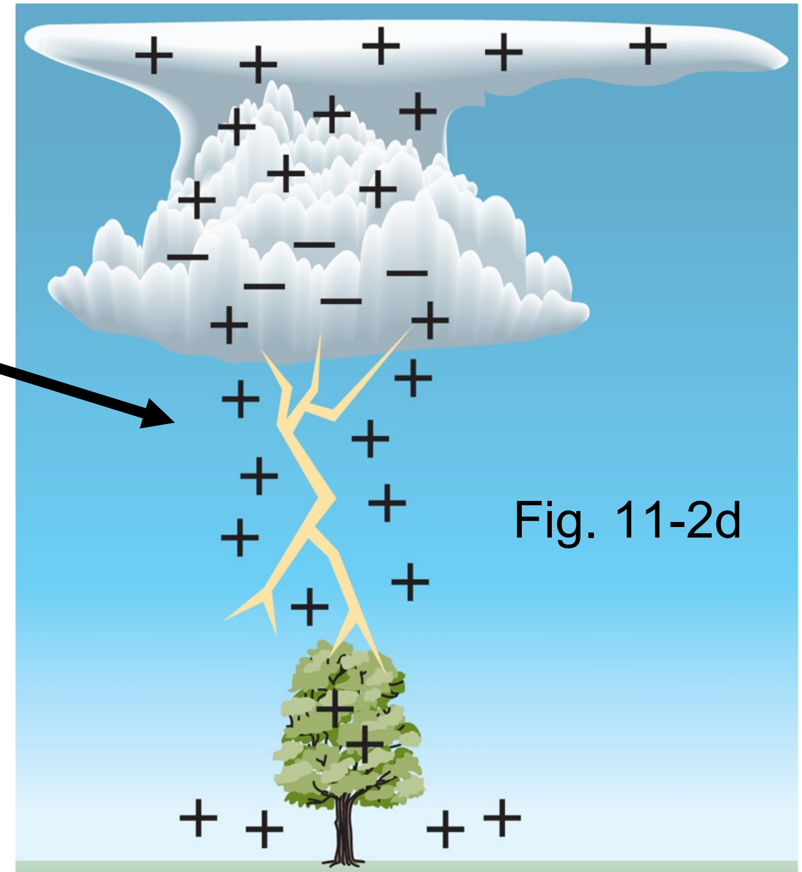
Fig. 11-2c

• when stepped leader approaches ground a spark surges up from ground to complete the charged (therefore conductive) channel

Lightning – the discharge

• the first of a number of "strokes" occurs, current ~ 10^4 amps, air heated to ~ 30,000K – rapid expansion producing thunder

• results in ***partial*** discharge of the cloud



• this transfer of negative charge to ground sustains earth's mean electric field

• another leader ("dart leader") works its way down and the process is repeated for the second flash… and so on

• result is flow of negative charge to ground

Buoyant acceleration of an air parcel

Let ***W*** be the vertical velocity of an air parcel, and let Δ***W*** be the change in ***W*** over time interval Δt. Then Δ***W*** **/**Δ***t*** is the parcel's acceleration.

Let $T_0(z)$ be the height-varying temperature of the environment, and let ***T'*** be the difference between the parcel's temperature and the environment at the same level (*z*).

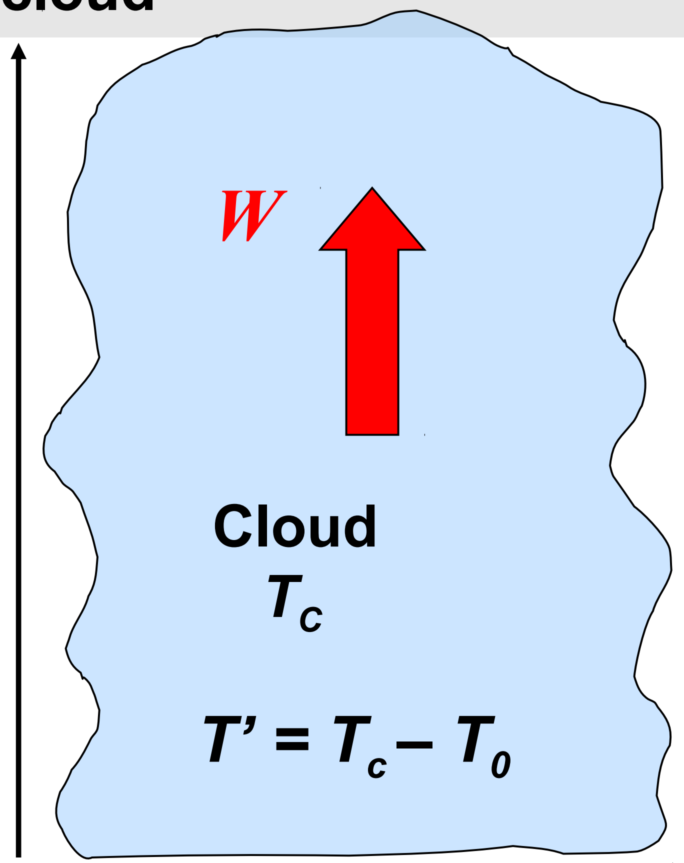
Newton's law can be written:
(this is an approximation)

$$A = \frac{\Delta W}{\Delta t} = g \frac{T'}{T_0}$$

The pressure gradient force and gravity almost balance each other (they do so exactly in an unstratified, hydrostatic atmosphere); but the parcel's temperature deviation ***T'*** gives rise to the "reduced gravity" force gT'/T_0 which may have either sign.

Vertical velocity in a deep convective cloud

- note: $T_C(z)$ follows moist adiabat



- accel'n: $$A = g\,\frac{T_C - T_0}{T_0}$$
- rise time: $$t = \frac{h}{W}$$
- accel'n x time: $$W = A\ t = g\,\frac{T_C - T_0}{T_0}\,\frac{h}{W}$$
- rearrange: $$W^2 = A\ t\ W = g\,\frac{T_C - T_0}{T_0}\,h \quad \sim \quad 10\ \frac{5}{300}\ 10000$$

What is a thunderstorm?

• organized (coherent) 3-dimensional mesoscale atmospheric circulation occupying almost entire depth of troposphere. Occurs in an atmosphere whose state is "conducive," and locally modifies that state

• co-ordinated, self-perpetuating pattern of winds (*U,V,W*), pressure (*P*), temperature (*T*) and humidity (*Q*) that can persist for at least several tens of minutes, and (in many cases) for hours

• energy derives from pre-existing store of gravitational potential energy & latent heat

• Airmass thunderstorm: short-lived, isolated, scattered occurrence within warm humid airmass, self-extinguishing

• Severe thunderstorm: winds exceed nearly 100 kph or hailstones exceed nearly 2 cm or storm spawns tornado. Updrafts and downdrafts remain separated; require very warm, humid surface air, conditional instability, wind shear + trigger

Thunderstorm - occurs in conditionally unstable atmosphere** - why?

• To get energetic cloud, must release stored potential energy (warm, moist near-ground air) over a small area – "concentration" or "focusing" of energy release

• In conditionally-unstable atmosphere unsaturated parcels rising will experience a restoring force… but those few that rise high enough to saturate, will result in deep, energetic clouds whose updraft causes surface convergence – sucking in the energy (warm, moist air) to this "focal point"

• "Trigger" selects the updrafts which "succeed" to produce deep convection – trigger points may relate to unequal pattern of surface heating, or to terrain slopes or irregularities, or (in case of "severe thunderstorm") frontal lifting

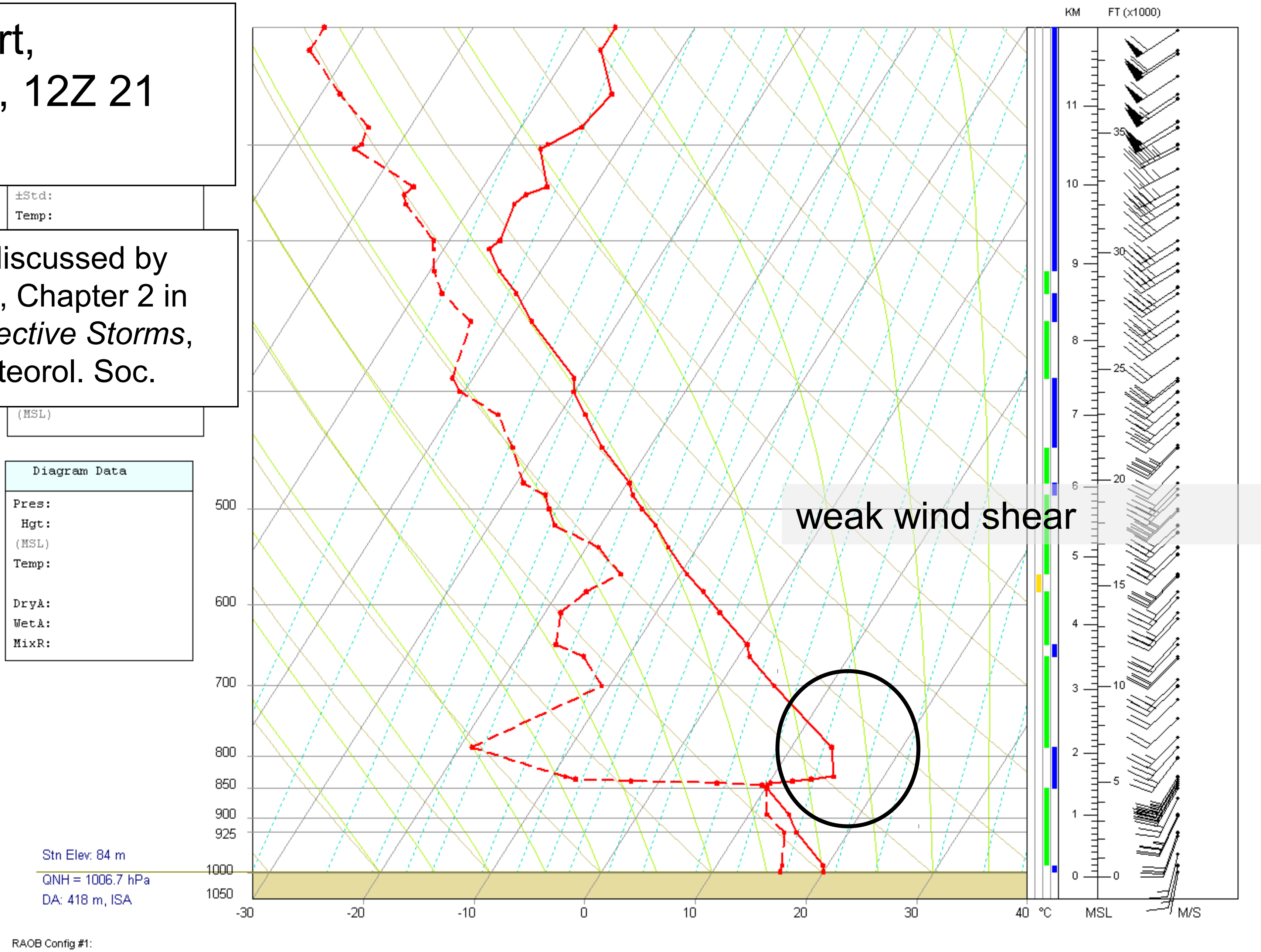
• An elevated temperature inversion may suppress deep convection for a time, but the "Potential Instability" (Sec. 6-2, not examinable) is such that an eventual storm that does develop is likely to be all the more explosive

** or in a "potentially unstable" atmosphere – where a warm moist layer lies beneath a warmer but drier layer; when both are lifted together the lower promptly saturates and thereafter cools more slowly than the upper, resulting in destabilization of the column

Thunderstorm – a "potentially unstable" column & capping inversion

Shreveport, Louisiana, 12Z 21 Jan 1999

Sounding is discussed by Doswell et al., Chapter 2 in *Severe Convective Storms*, American Meteorol. Soc.



Airmass thunderstorm – cumulus stage

• successive surges of warm moist air form light Cu whose evaporation humidifies the column; progressively deeper Cu

• cloud builds upward at up to about 5 to 20 m s^{-1}

• when cloud grows above freezing level Bergeron process initiates

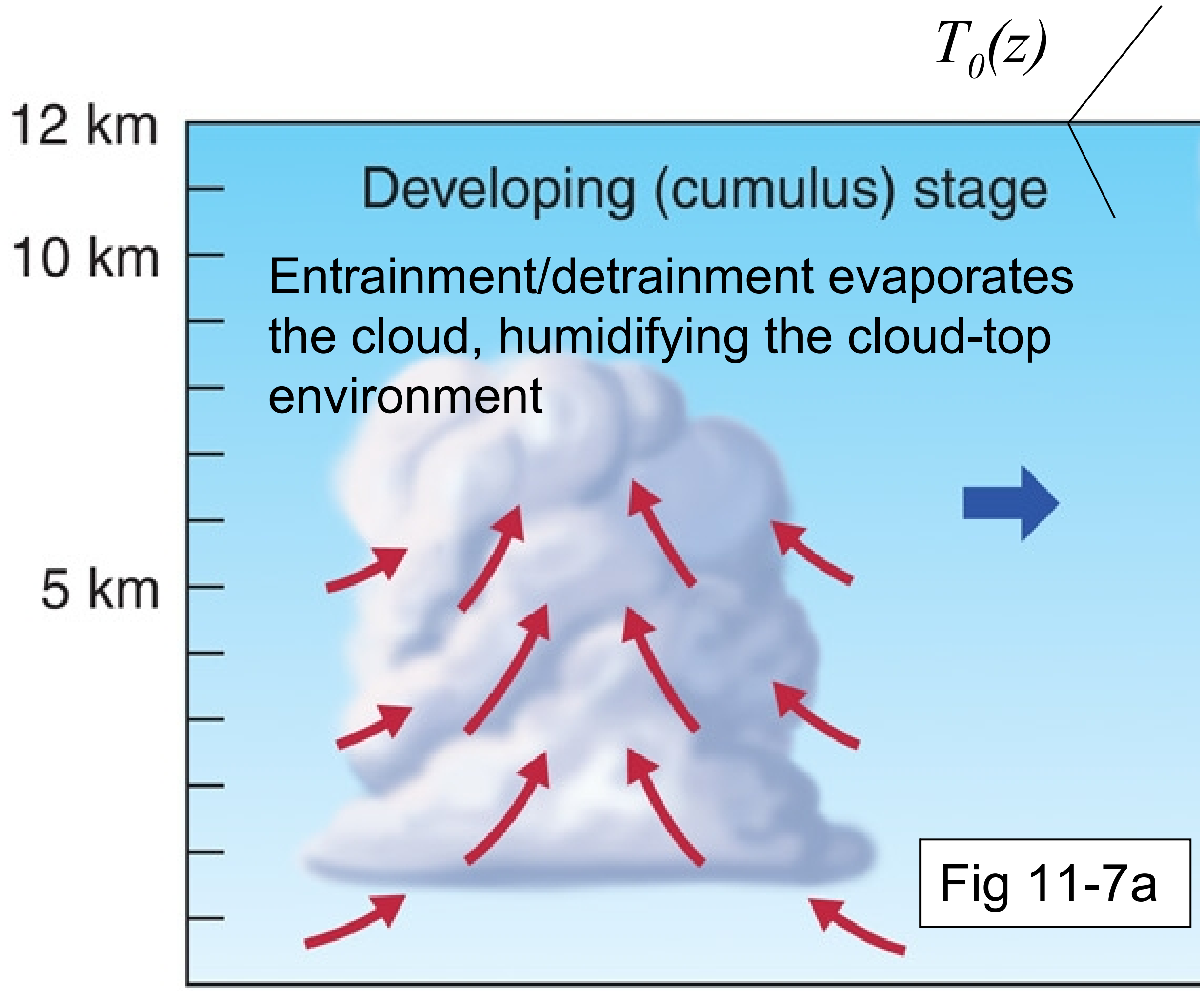


Fig 11-7a

Airmass thunderstorm – mature stage

• weight of rain and/or graupel initiates downdraft; if precip falls into unsaturated air (eg. mixed in by entrainment), its evaporation chills the downdraft

• storm consists of several such cells (updraft + downdraft) of differing ages

• there may or may not be an anvil (depending on whether there is wind shear near the inversion that limits cloud growth)

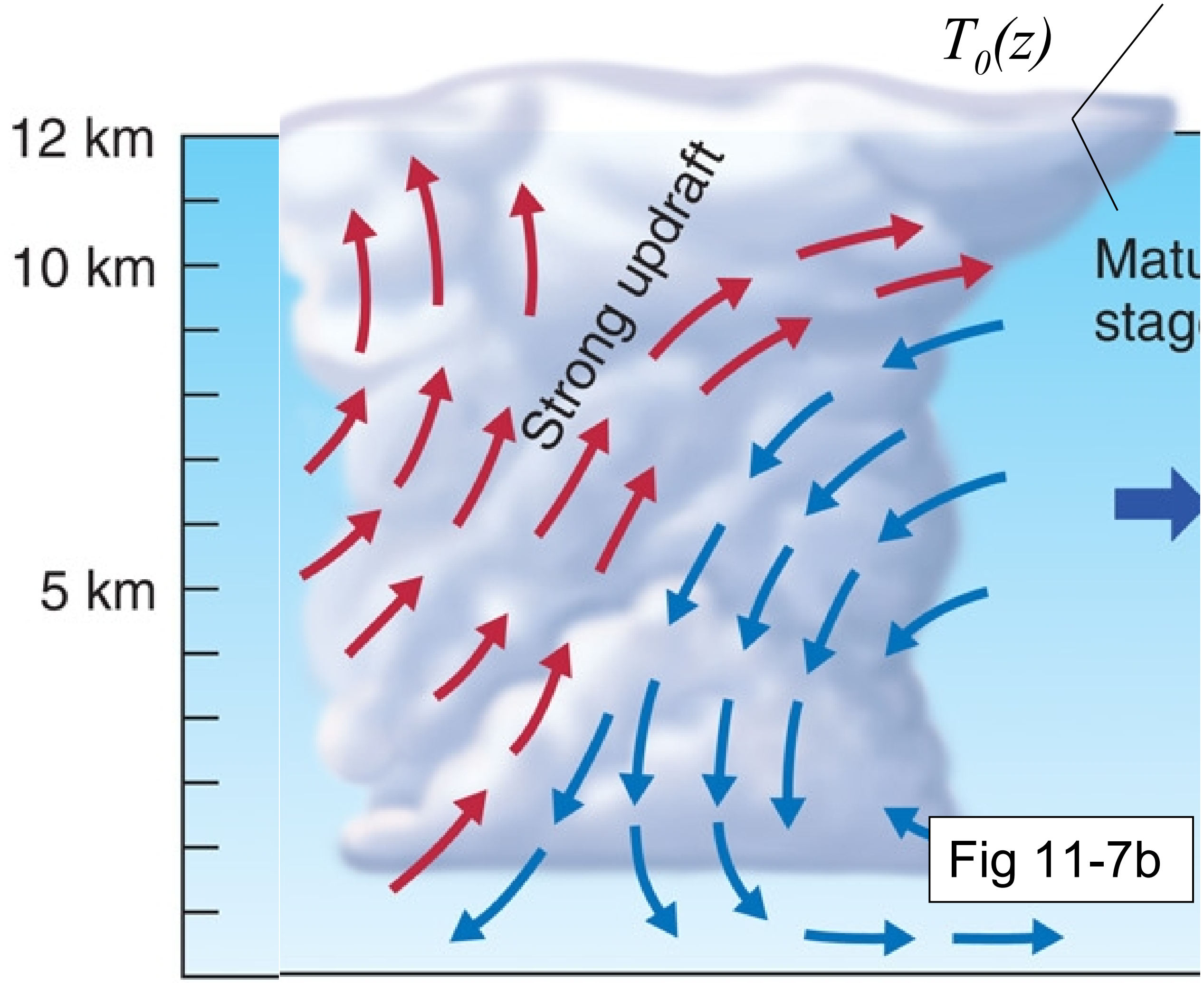


Fig 11-7b

Airmass thunderstorm – dissipating stage

- downdraft kills off the updraft

- most of the precip particles (water & ice) evaporate again

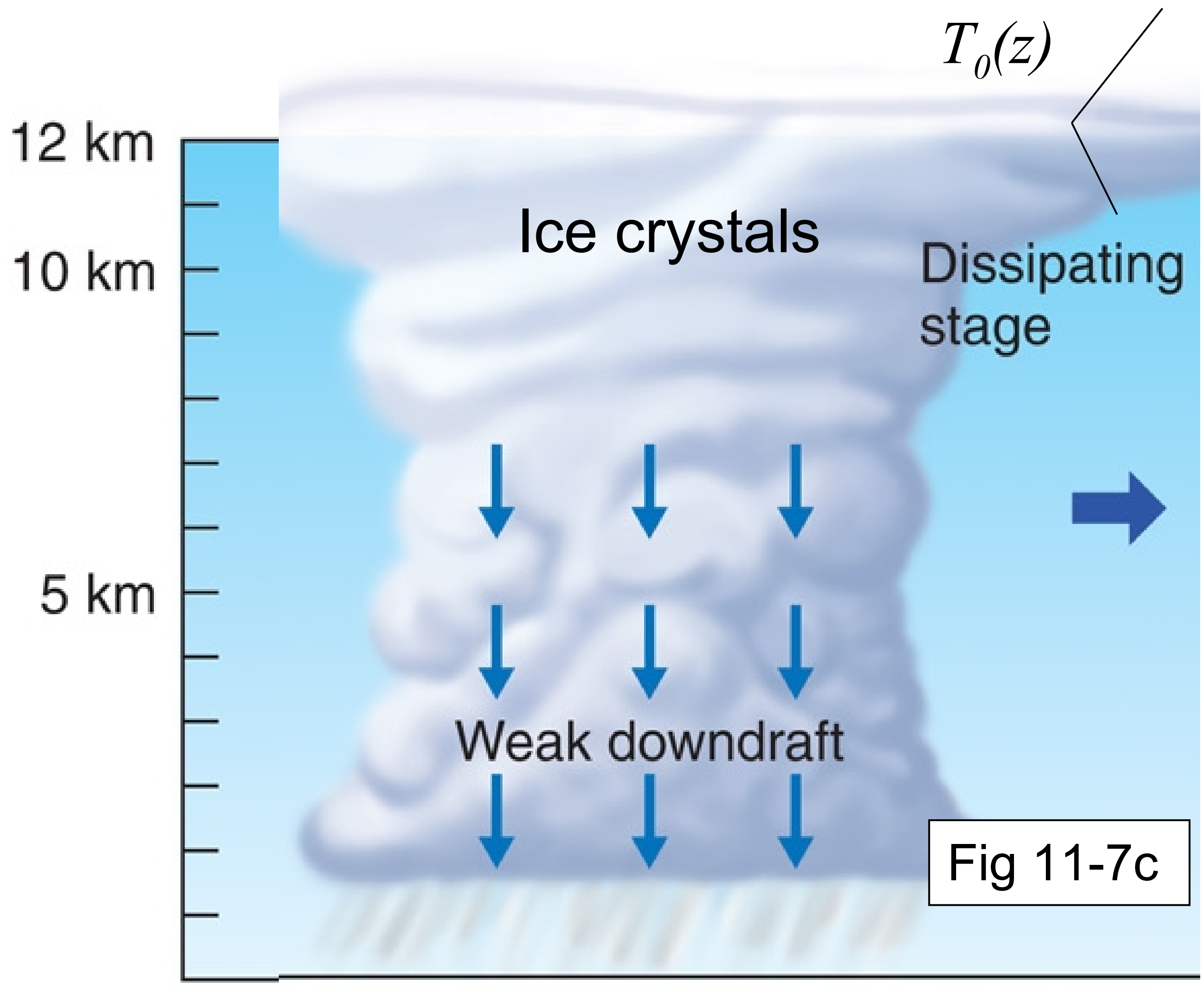


Fig 11-7c