Goals for today:

21 Sept., 2011

Continue Ch 3 "Energy Balance & Temperature"

- Quiz on Friday – 25 min, 15 m.c. questions (Ch1 + Ch2 + map questions).
  Note: the way this course is graded implies that tests and assignments carry no "pass" or "fail" threshold

- Net radiation and the surface radiation budget

- Role of convective energy fluxes... the vertical component of the wind plays a crucial environmental role in the vertical transport of sensible and latent heat – as well as other entities such as carbon dioxide to or from the plant canopy, etc.

- The surface energy budget

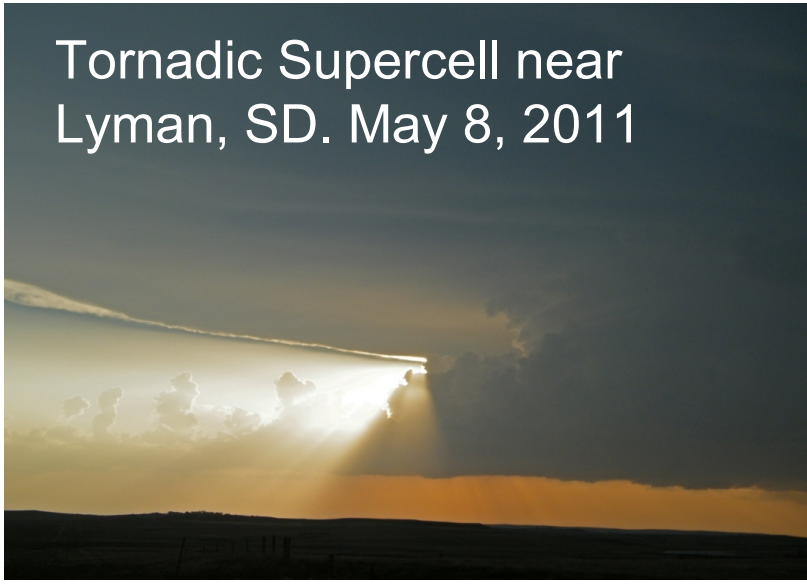
Atlas Talk – Tory 3-36 at 12 noon – 23 Sept.

Claire Martin – "How does a scientist end up with a full-time TV job?"

Claire Martin, '95 Bsc. "An award-winning weather forecaster and educator, Claire Martin has had a profound impact on weather reporting in Canada and around the world..."

Atmospheric Science Students' Group (ASSG)

Who we are: ASSG is a group dedicated to weather fanatics. Anyone can join, whether you just enjoy weather or are in the Atmo. Sci. Program. It basically comes down to a group of people who share an interest in weather/climate.



What we do:

- Laser tag/bowling/dinner nights
- Tour of Environment Canada
- Stony Plain Balloon Launch/Tour
- Planning our third annual storm chasing trip

NOAA and NCAR tours)

- More events to be planned
- **First meeting: next Wednesday, September 21st at 5pm in Tory 3-87**

Any questions/comments/concerns contact: Karmen Loyek (loyek@ualberta.ca) and Natasha Ridenour (ridenour@ualberta.ca)

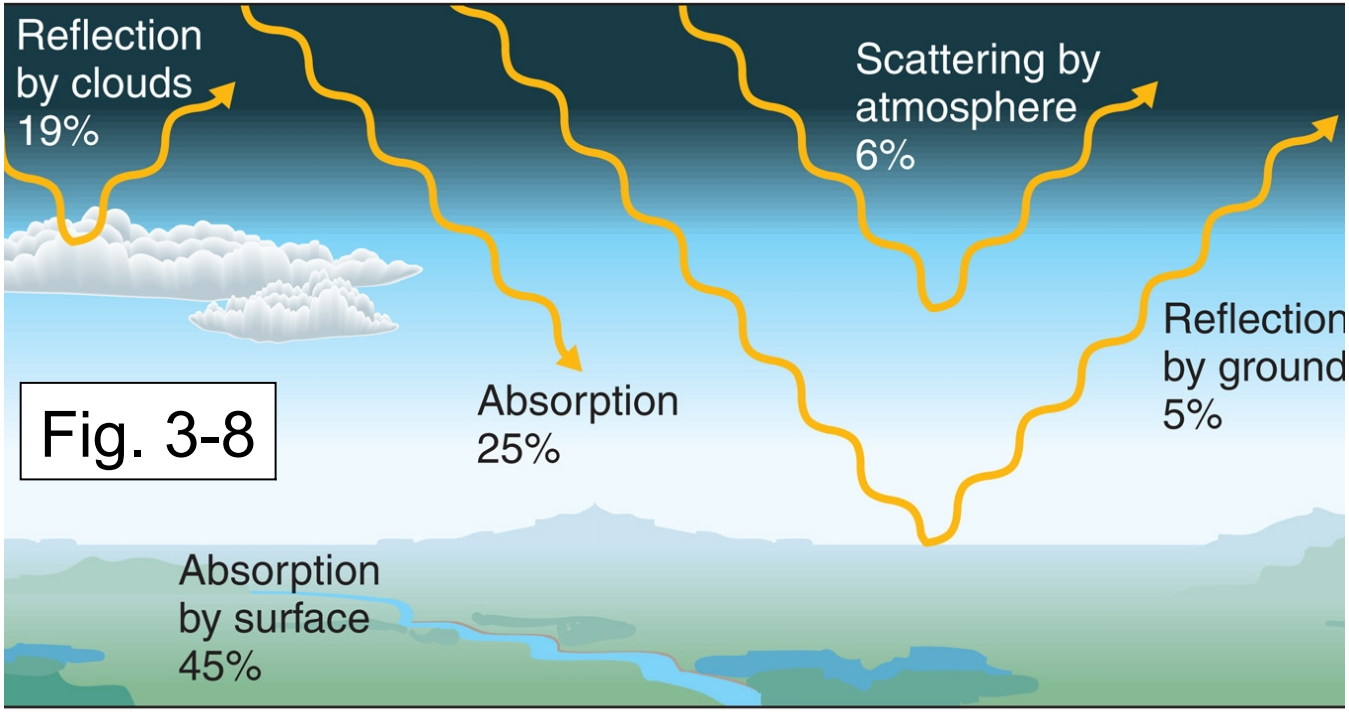


Fig. 3-8

clouds reflect 19%
atmos reflects 6%
gnd reflects 5%

30%

absorbed by earth-atmosphere: 70%

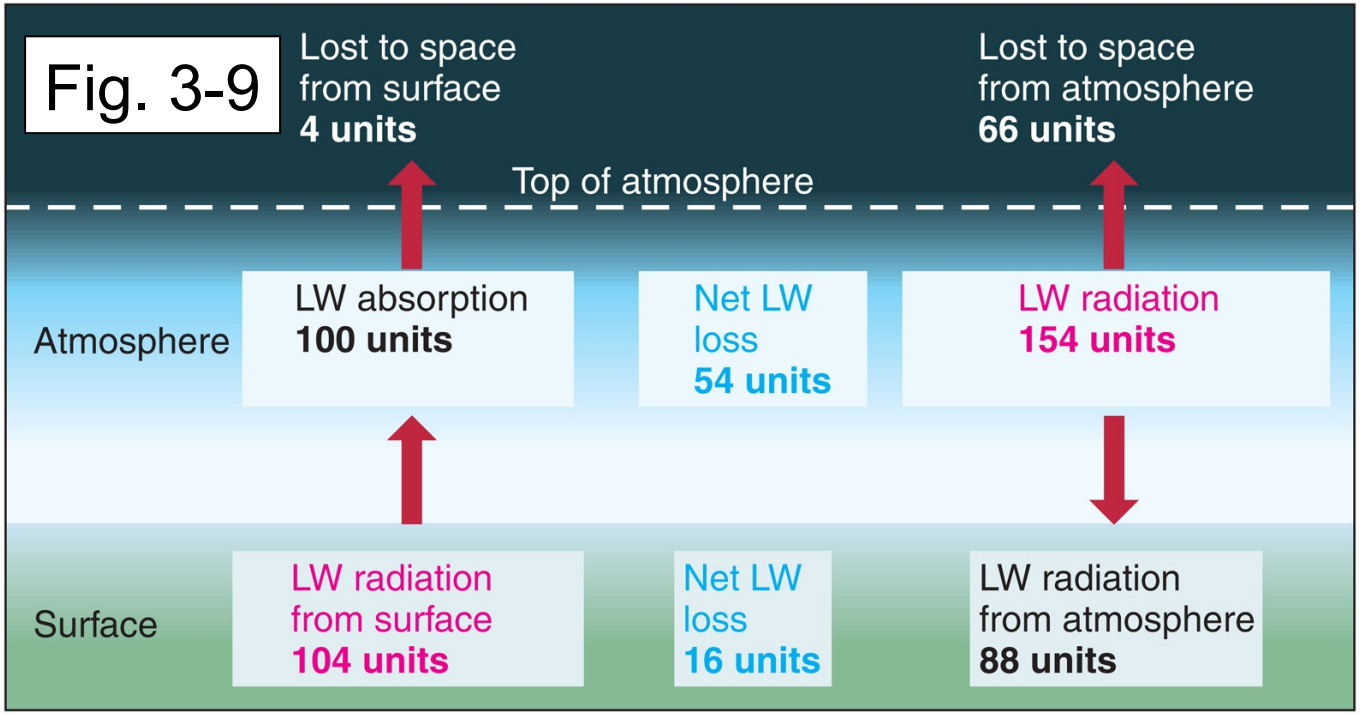
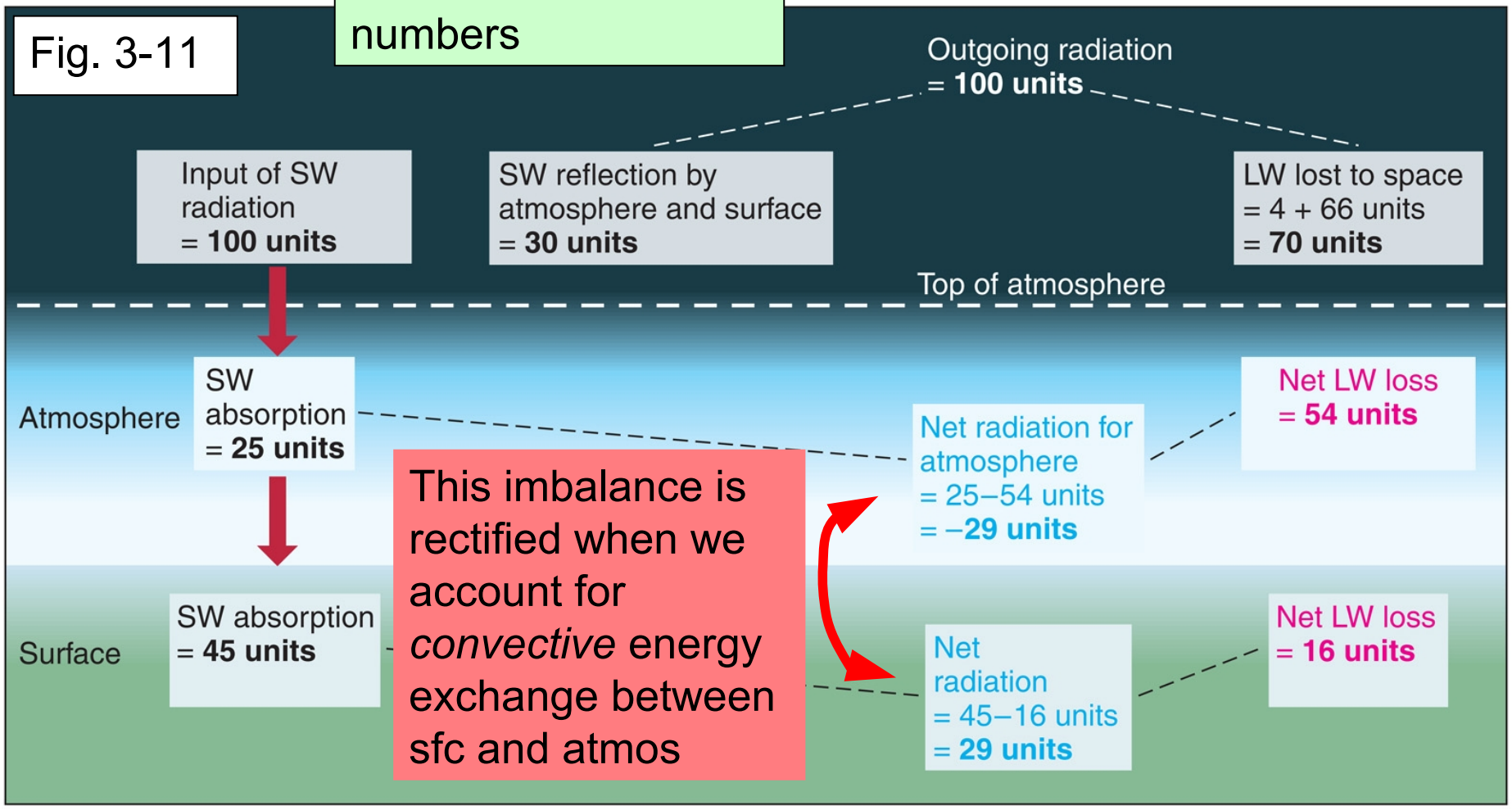


Fig. 3-9

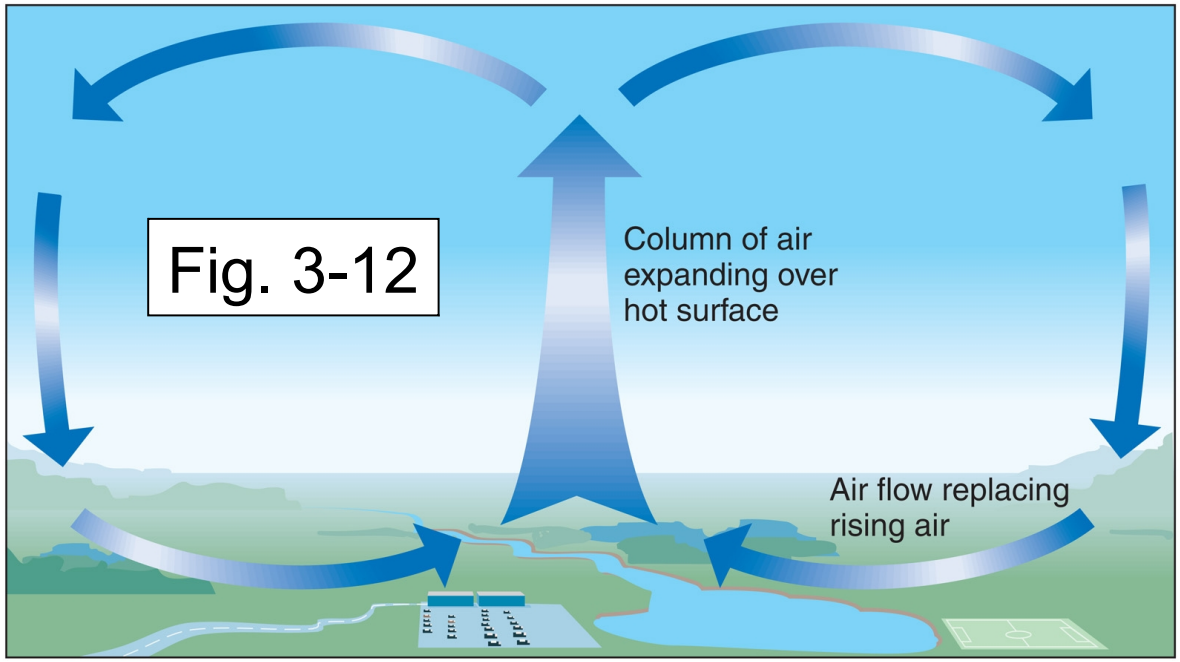
lost by earth-atmosphere: 70%

Global-annual (climatological) allwave (net) radiation balance

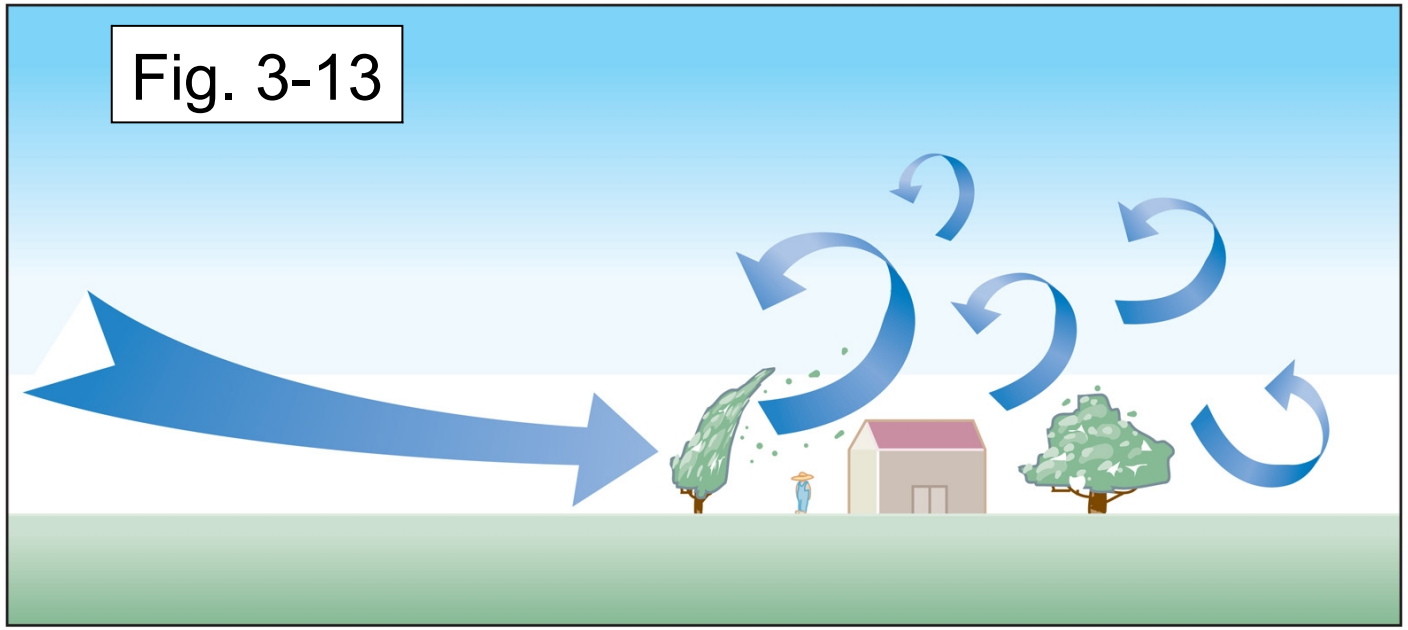
You don't have to *remember* all these numbers



Convective “mixing” may be spontaneous (buoyancy-driven, “free convection”)

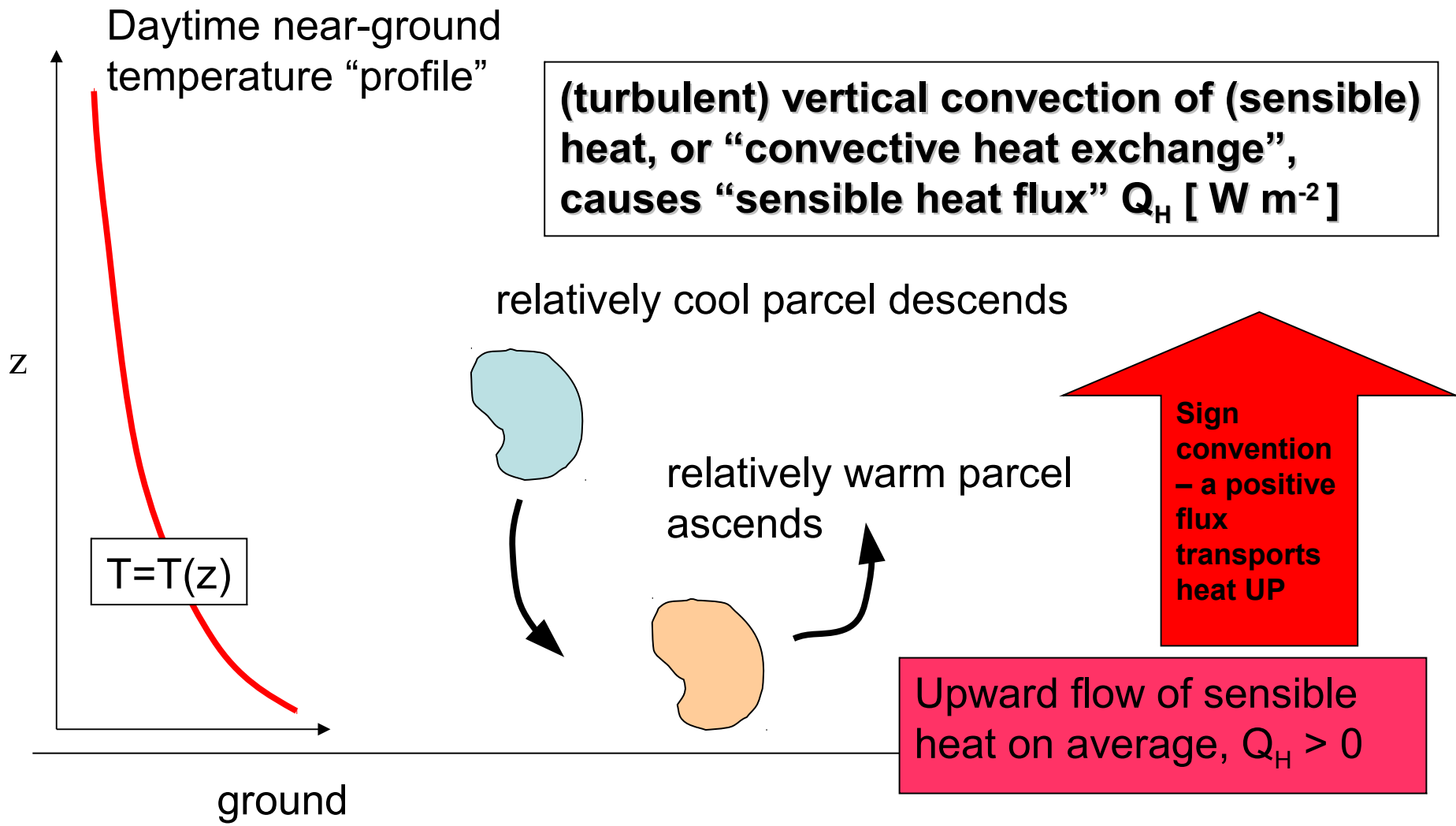


… or may be “forced”

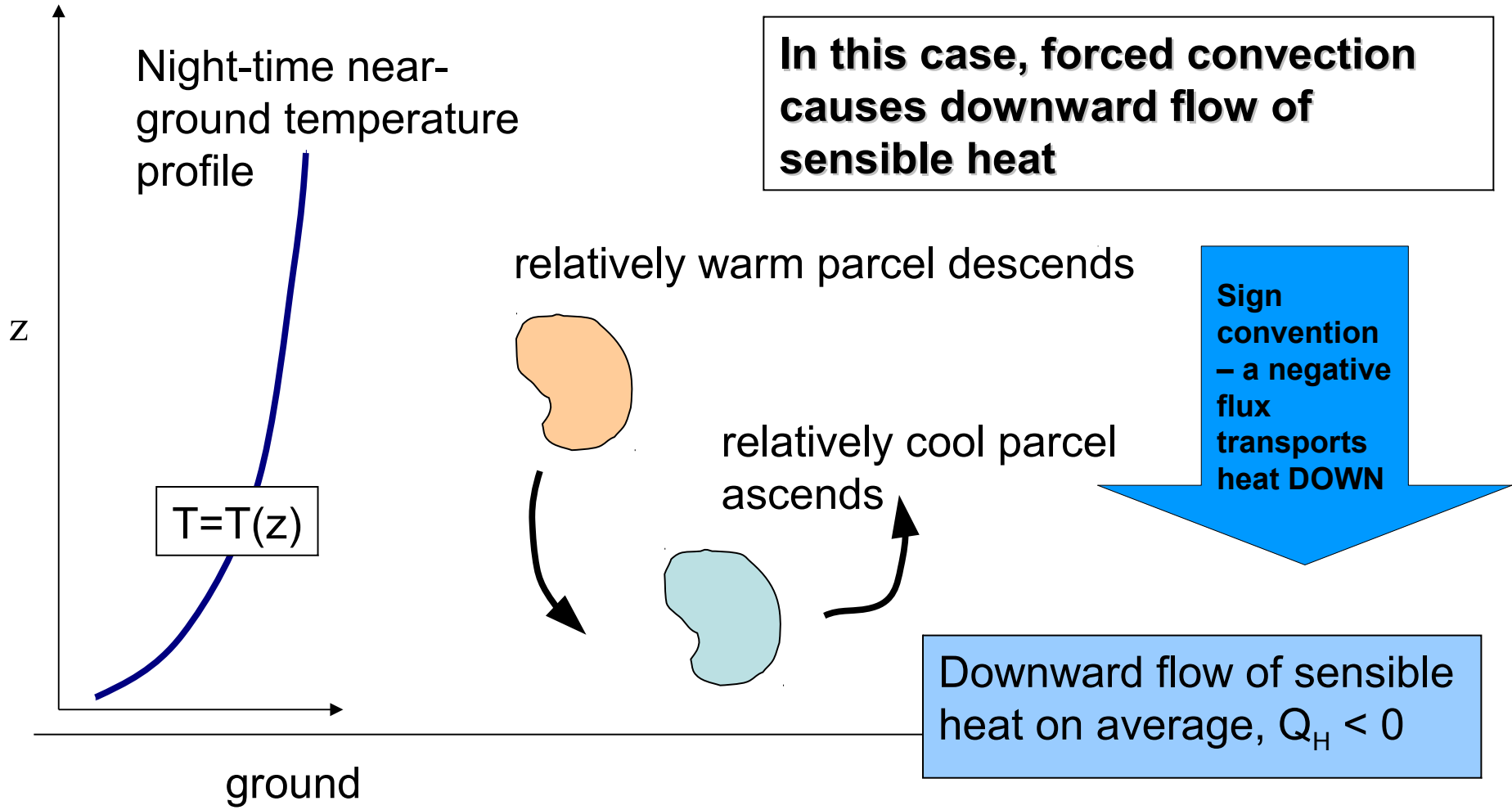


Role of (turbulent vertical) convection in local energy balance… day

- convection: transport by virtue of bulk motion of a fluid/gas
- turbulent vertical convection: vertical transport by eddies (fluctuating motion)
- sensible heat: thermal energy resident in kinetic energy of molecular motion



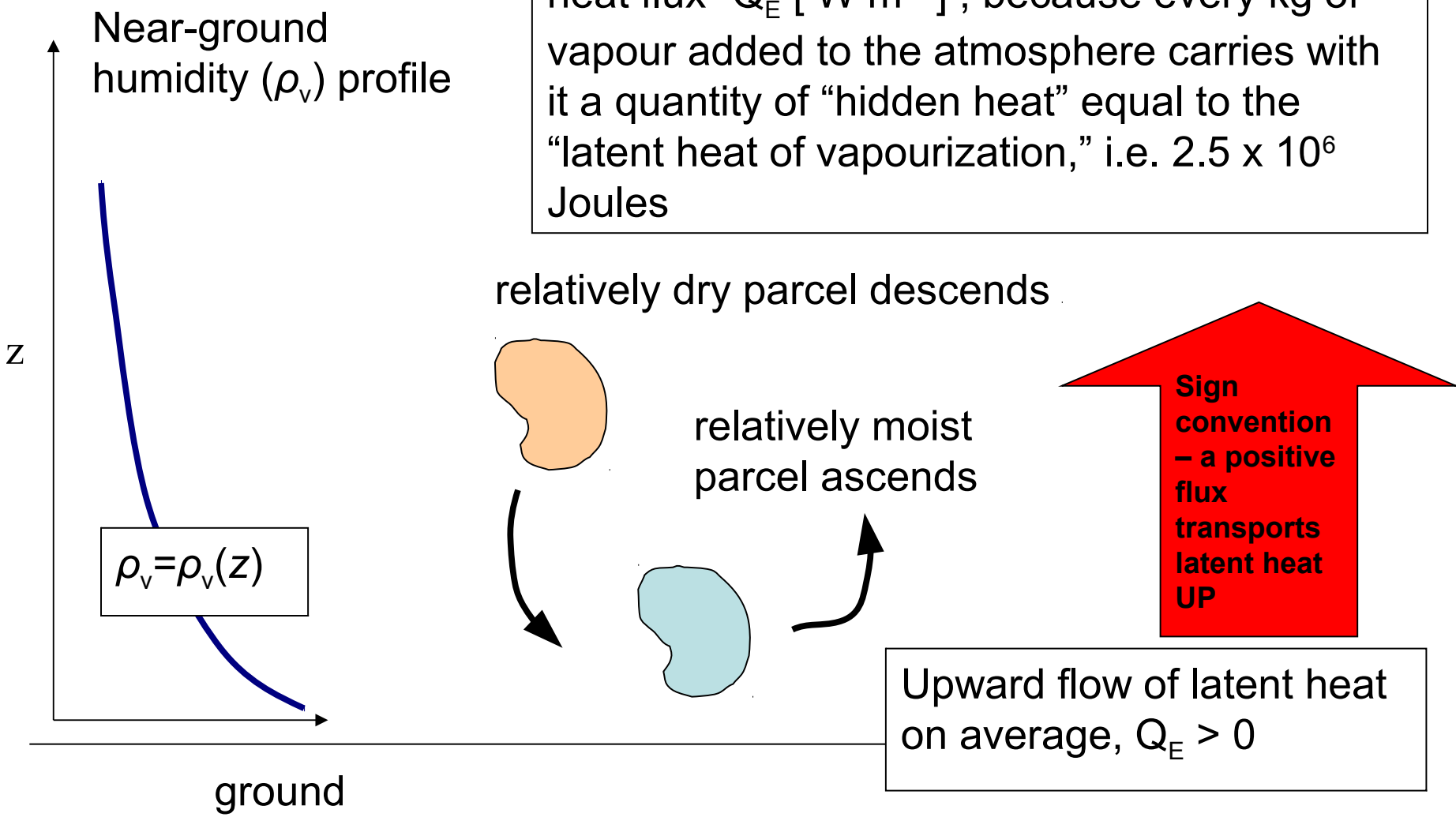
Role of (turbulent vertical) convection of sensible heat in local energy balance… night



Role of convection of latent heat in local energy balance…

- latent heat: energy that is recoverable upon phase change (condensation)

Vertical convection of vapour implies a "latent heat flux" Q_E [W m^{-2}] , because every kg of vapour added to the atmosphere carries with it a quantity of "hidden heat" equal to the "latent heat of vapourization," i.e. 2.5 x 10^6 Joules



Upward flow of latent heat on average, $Q_E > 0$

Global-annual (climatological) energy balance

You don't have to *remember* all these numbers

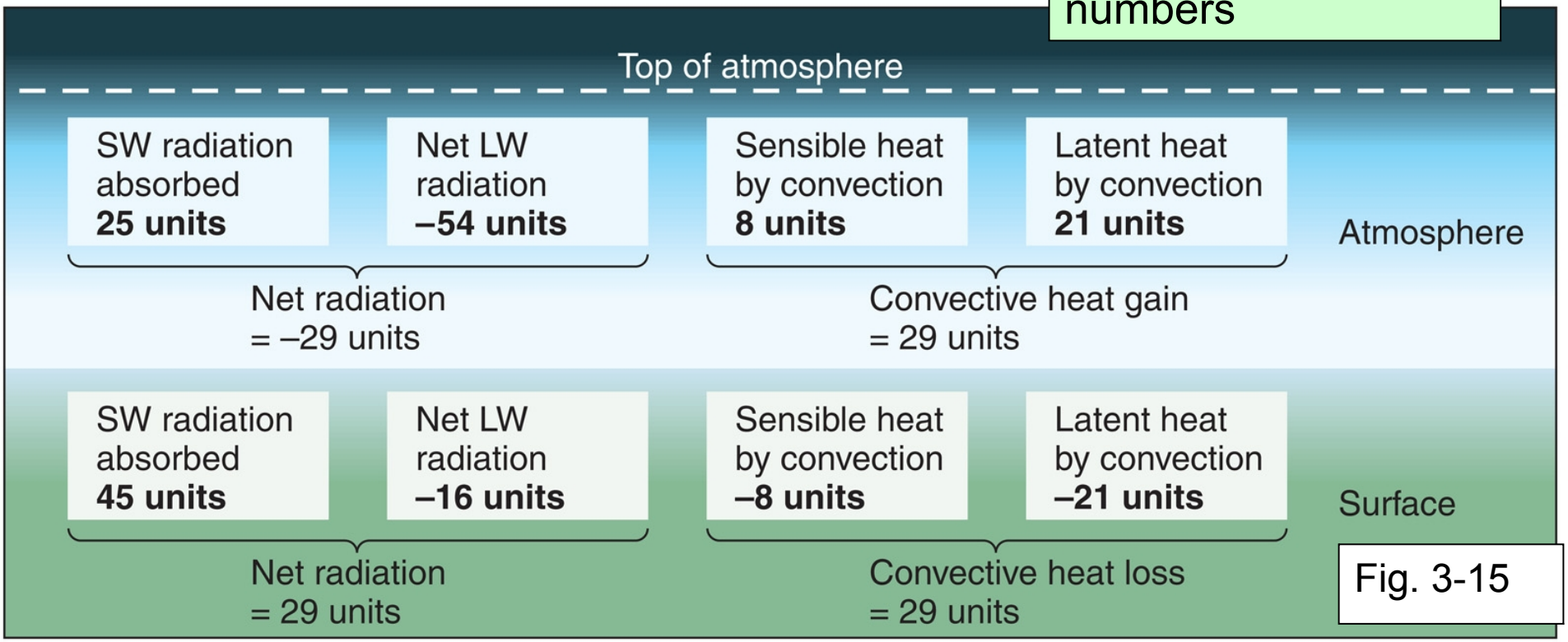
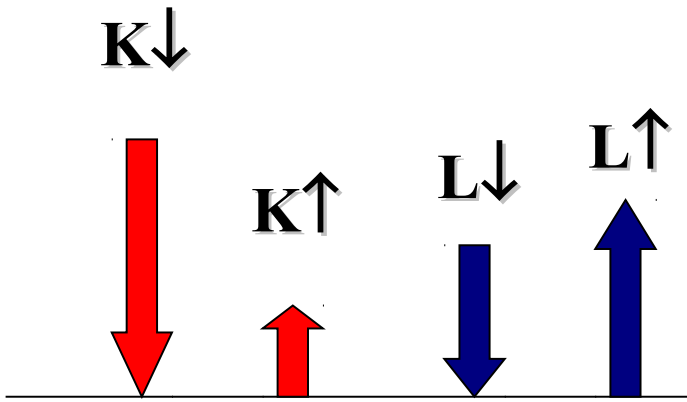


Fig. 3-15

Surface radiation budget



(not to scale. Each component is non-negative by definition)

surface albedo $\alpha = \frac{K\uparrow}{K\downarrow}$

$K^* = K\downarrow - K\uparrow$ **Net shortwave**

$L^* = L\downarrow - L\uparrow$ **Net longwave (can be negative)**

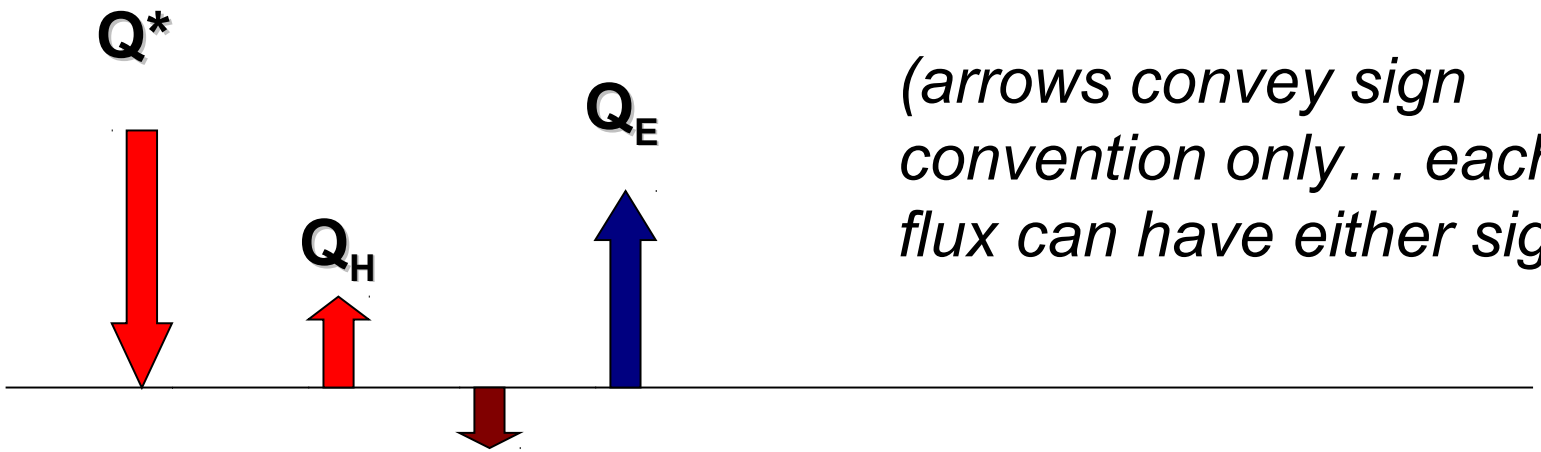
$Q^* = K^* + L^* = K\downarrow - K\uparrow + L\downarrow - L\uparrow$

Net allwave ("net radiation")

**during clear, dry skies $K\downarrow \sim 0.8\ S_0 \sin\theta$, i.e. about 80% of solar beam reaches ground (θ the solar elevation angle)

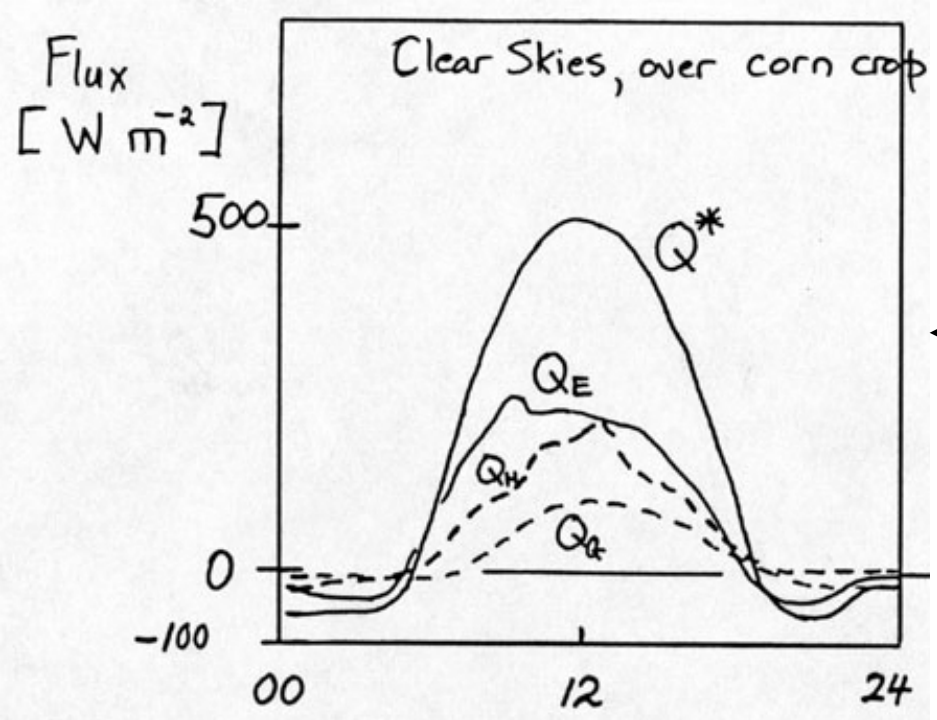
Surface energy budget

$$Q^* = Q_H + Q_E + Q_G$$



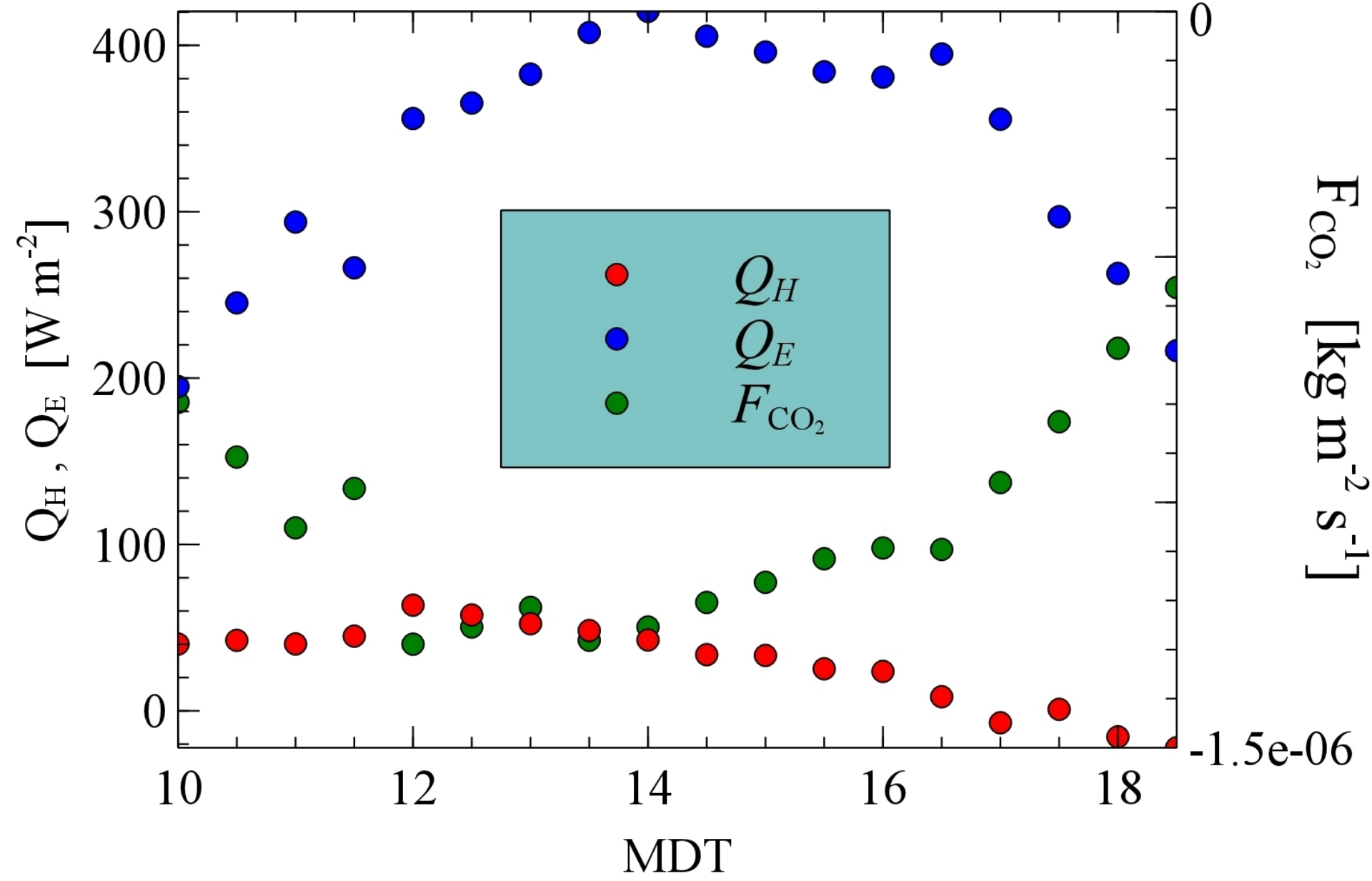
(arrows convey sign convention only… each flux can have either sign)

Q_G (= ground/lake/ocean heat flux)



example of the daily cycle; this case, surplus daytime radiant energy shared about equally by latent and sensible heat fluxes to the air

Fluxes of energy and carbon dioxide over wheat, , St. Albert, 1 Aug. 2011



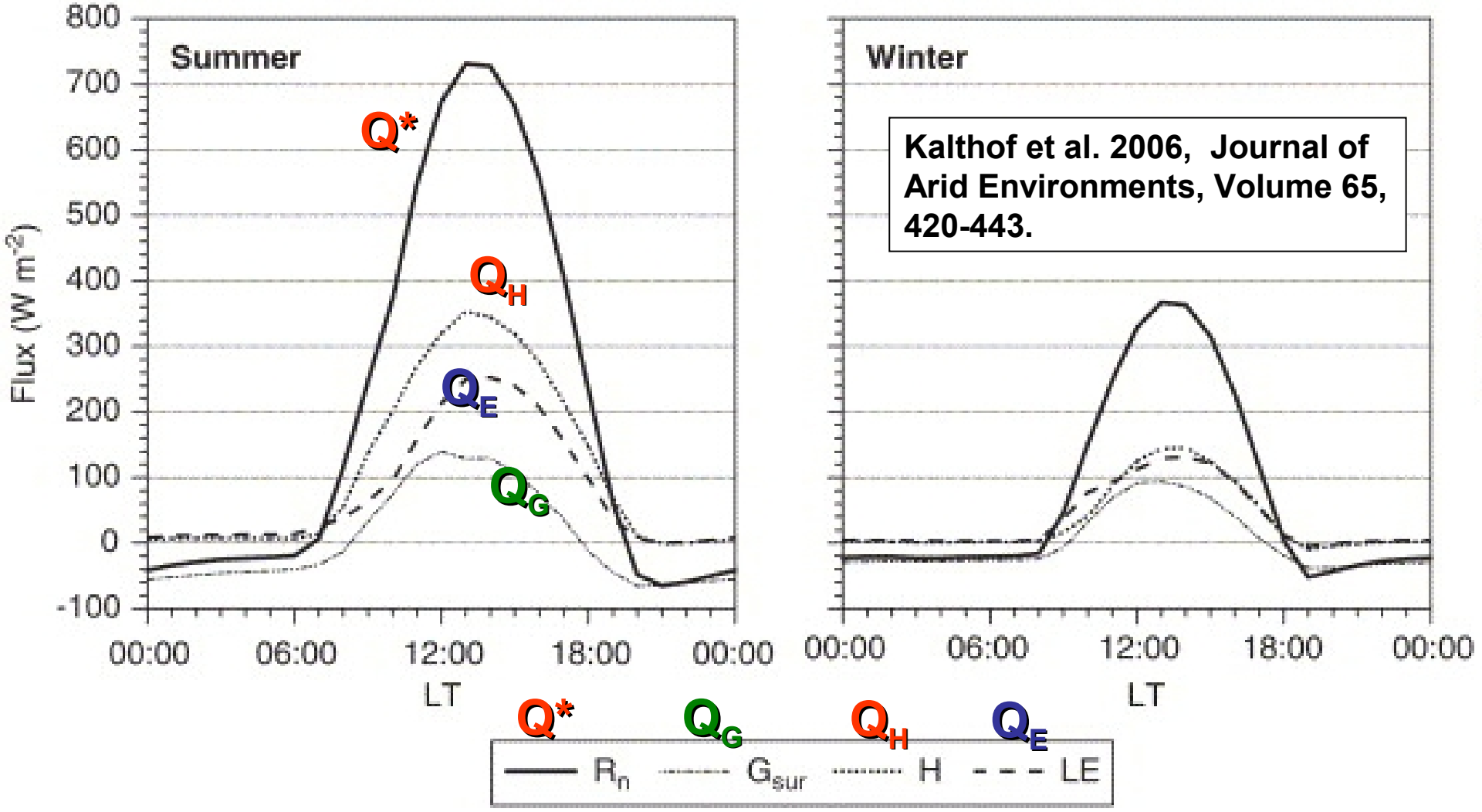
F_{CO2} < 0 (C_{O2} absorbed by crop). Rain in late July explains the dominance of Q_E over Q_H

- the local energy balance essentially defines local (“micro-”) climate

- the nature of the daily cycle in the energy balance is vastly different from place to place, day to day and season to season

- and must be captured (represented) by any weather or climate model

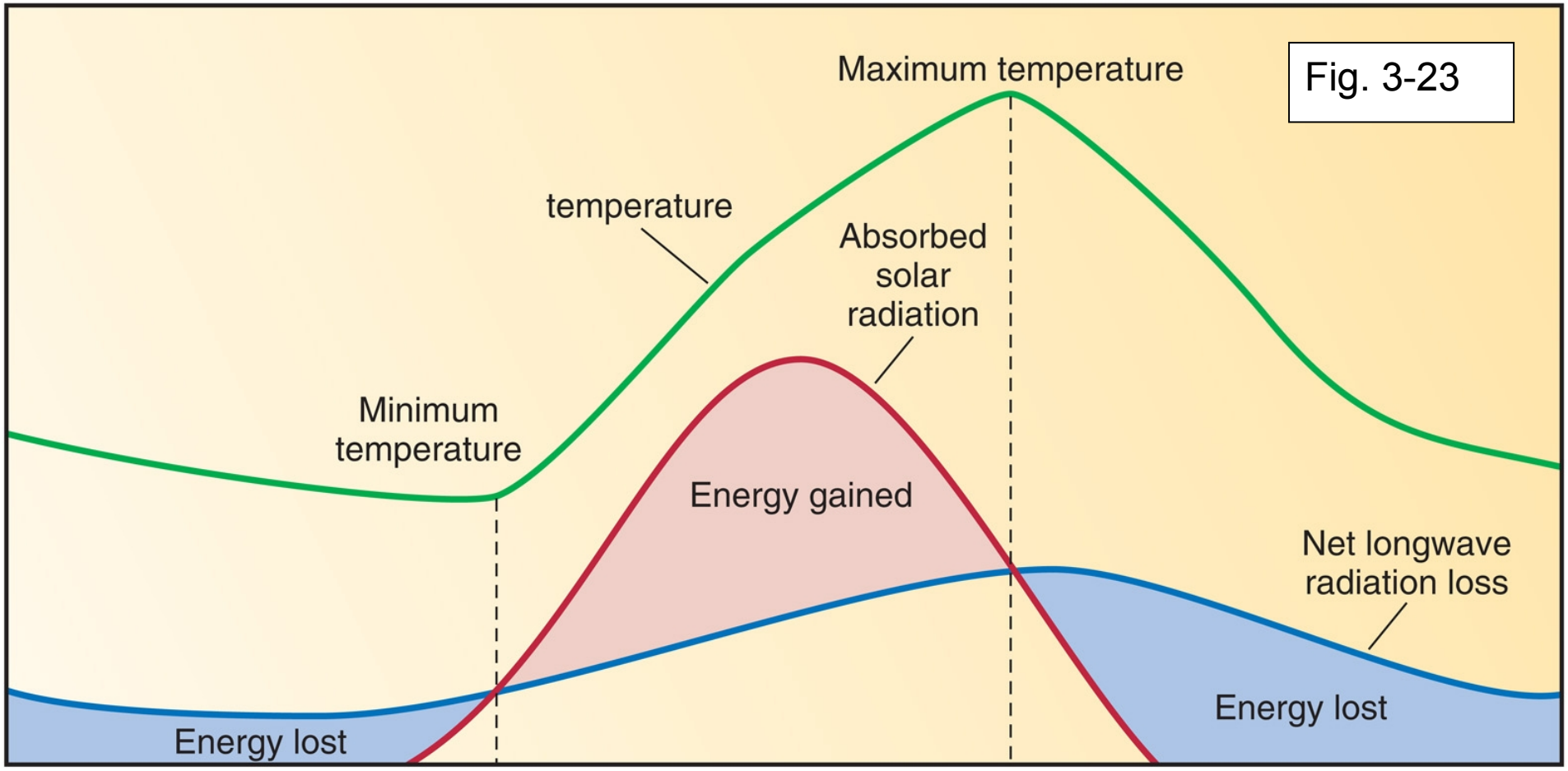
- radiation and energy budgets may be studied locally, or on a regional or global scale... previous slide gave the energy budget at a specific site on a specific day... next slide, a specific site but the fluxes for a given time of day are averaged over several years



Mean daily cycle of the energy balance components (net radiation, Rn; sensible heat flux H; latent heat flux LE; and soil heat flux, Gsur) for the summer and winter seasons, averaged over the years 2000–2002 for an arid valley in Chile. Latent heat flux less important than previous example.

Understanding the diurnal (daily) cycle in temperature

(similar principles apply for understanding the seasonal cycle)

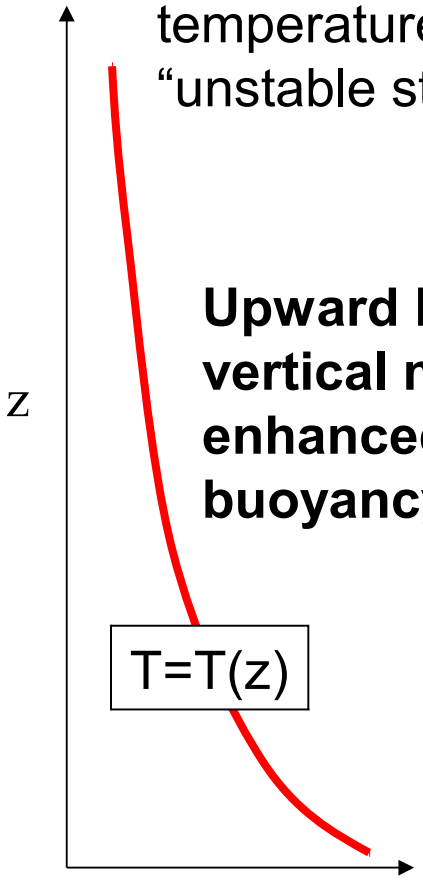


(a)

Coldest time of day is *after* sunrise; warmest is *before* sunset but long after solar noon

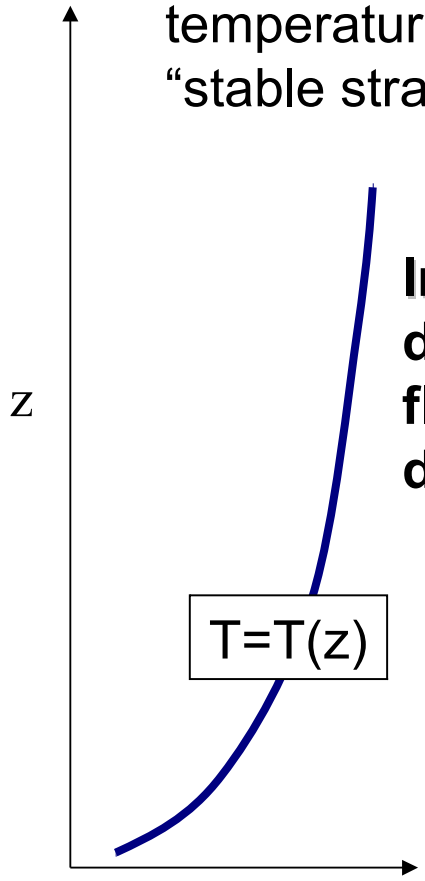
Diurnal cycle in near-ground stratification

Daytime near-ground temperature profile…
"unstable stratification"



Upward heat flow, vertical mixing enhanced by buoyancy

Night-time near-ground temperature profile…
"stable stratification"



Inversion … downward heat flow, mixing damped

Recall the notation T=T(z) means "T varies with z" or "T is a function of z"

Nocturnal Radiation Inversion

Cause …

- ground cooling: $Q^* < 0$, ie. outgoing longwave radiation exceeds incoming longwave
- then air above cools by convection (stirring), $Q_H < 0$

Conditions for severest inversion …

- clear sky, dry air
- long night with light wind

Result... radiation frost?

Photo :Keith Cooley