

# THERMODYNAMIC AEROLOGICAL CHARTS DIAGRAMS



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- Thermodynamic charts are used to represent the **vertical structure of the atmosphere**, as well as major **thermodynamic processes** to which moist air can be subjected.
- Thermodynamic charts can be used to obtain easily different **thermodynamic properties**, e.g.  $\theta$  (potential temperature) and moisture quantities (such as the specific humidity), from a given **radiosonde ascent**.
- Even though today it is possible to compute many quantities directly, thermodynamic diagrams are still **very useful** and remain **widely used**.

- Each diagram has lines of constant:
  - $p$ , pressure,
  - $T$ , temperature,
  - $\theta$ , potential temperature,
  - $q$ , saturation specific humidity.
  - saturated adiabats.
- One difficulty of all diagrams is that they are **two dimensional**, and the most compact description of the state of the atmosphere encompasses **three dimensions**, for instance,  $\{T,p,q\}$ .

- The simplest and most common form of the aerological diagram has **pressure** as the ordinate and **temperature** as the abscissa
  - the temperature scale is linear
  - it is usually desirable to have the ordinate approximately representative of height above the surface, thus the ordinate may be proportional to  $-\ln p$  (the **Emagram**) or to  $p^{R/c_p}$  (the **Stuve diagram**).

- The Emagram has the advantage over the Stuve diagram in that area on the diagram is proportional to energy:

$$dw = pdv = RdT - vdp$$

$$\oint dw = \oint RdT - \oint RT \frac{dp}{p} \quad RdT \text{ is an exact differential which integrates to zero}$$

$$\oint dw = -R \oint T d(\ln p)$$

- A chart with coordinates of  **$T$  versus  $\ln p$**  has the property of a **true thermodynamic diagram**, i.e. the area is proportional to energy.
- The logarithm of pressure is chosen for the vertical coordinate rather than the pressure itself because in an isothermal atmosphere height varies with  $\ln p$ , and hence for a realistic temperature profile the ordinate is roughly proportional to height.

# CONSTRUCTION OF THE STUVE DIAGRAM

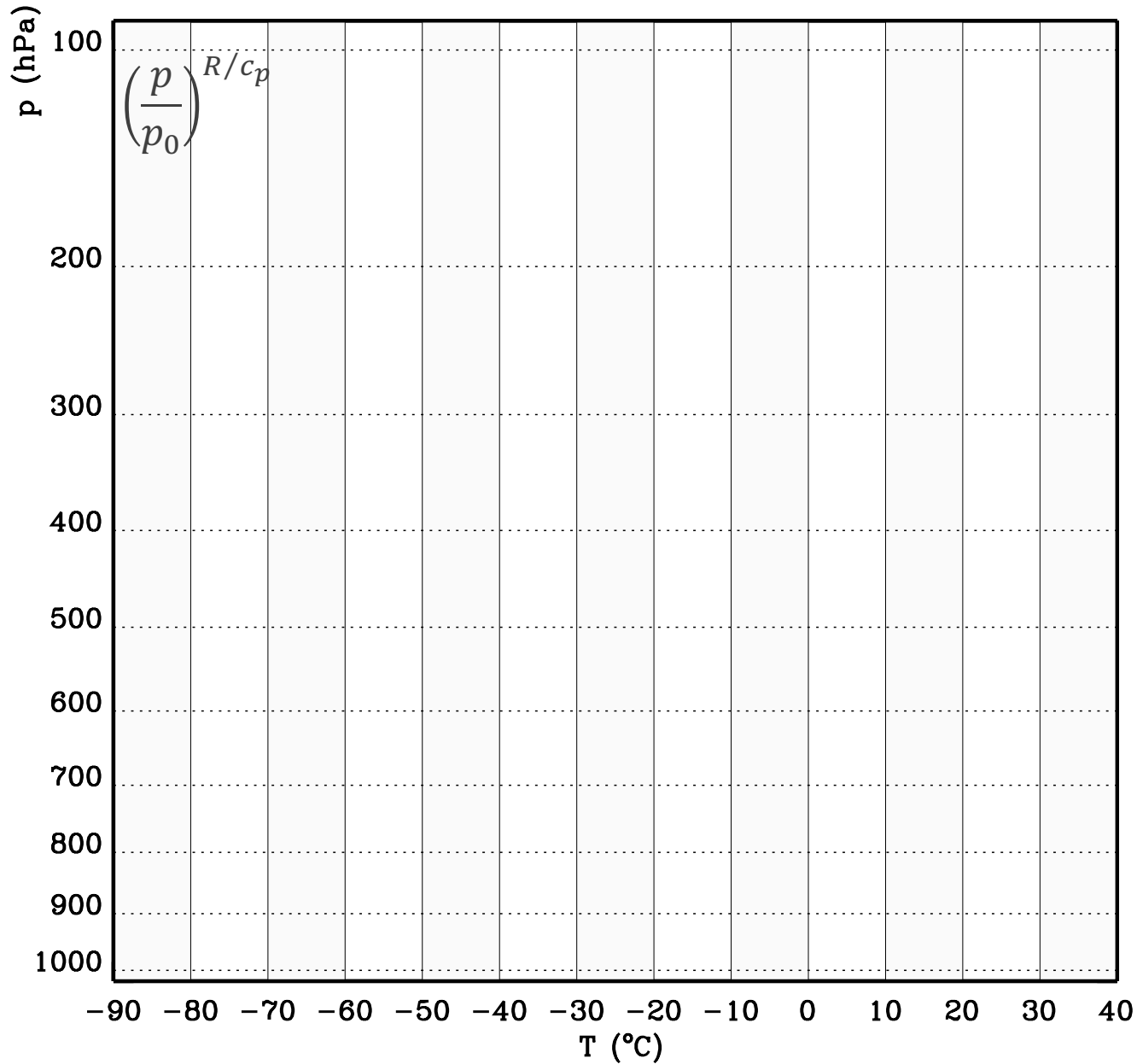
$$T, \left(\frac{p}{p_0}\right)^{R/c_p}$$

Simplicity of its construction

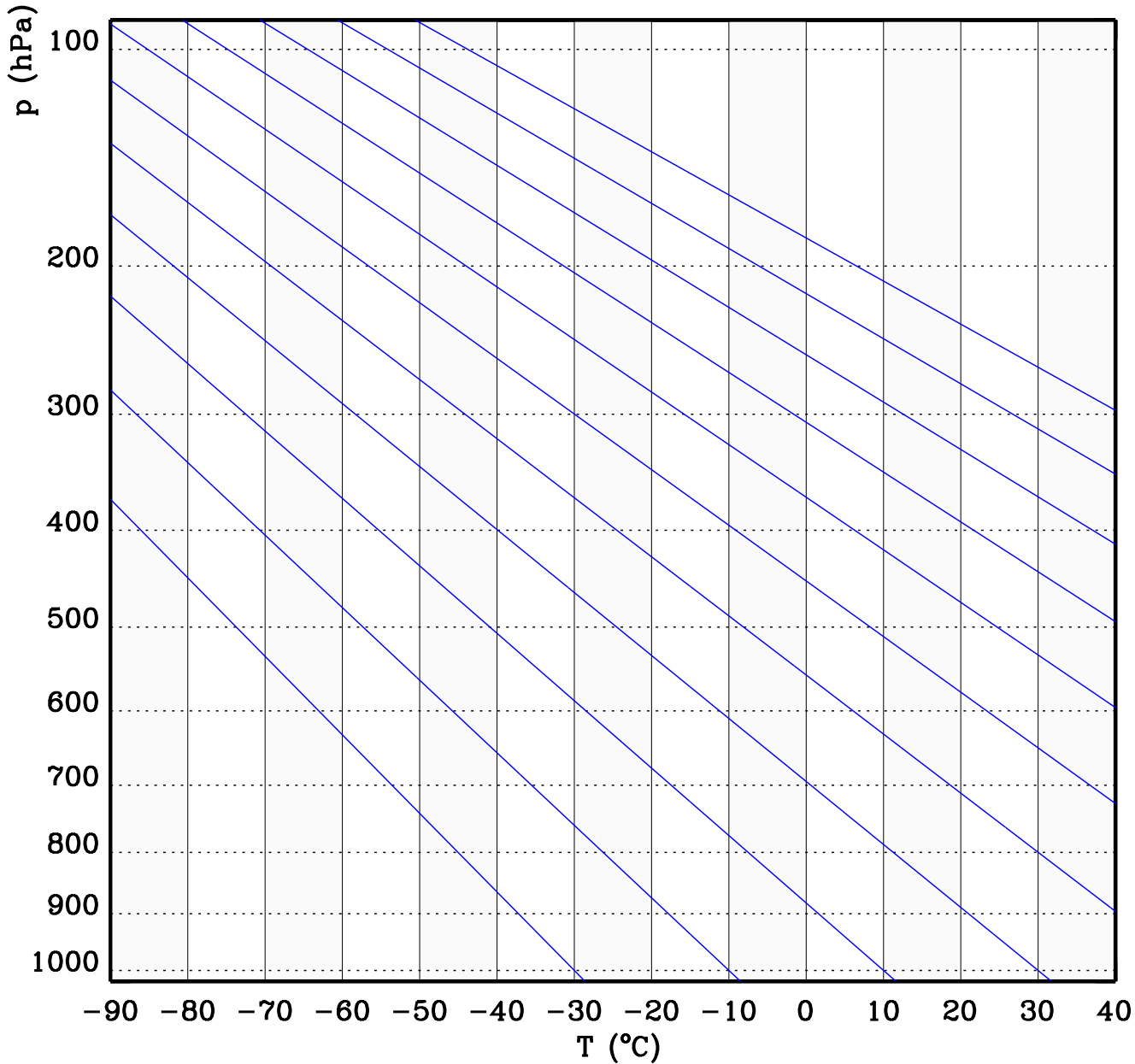


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# STUVE DIAGRAM

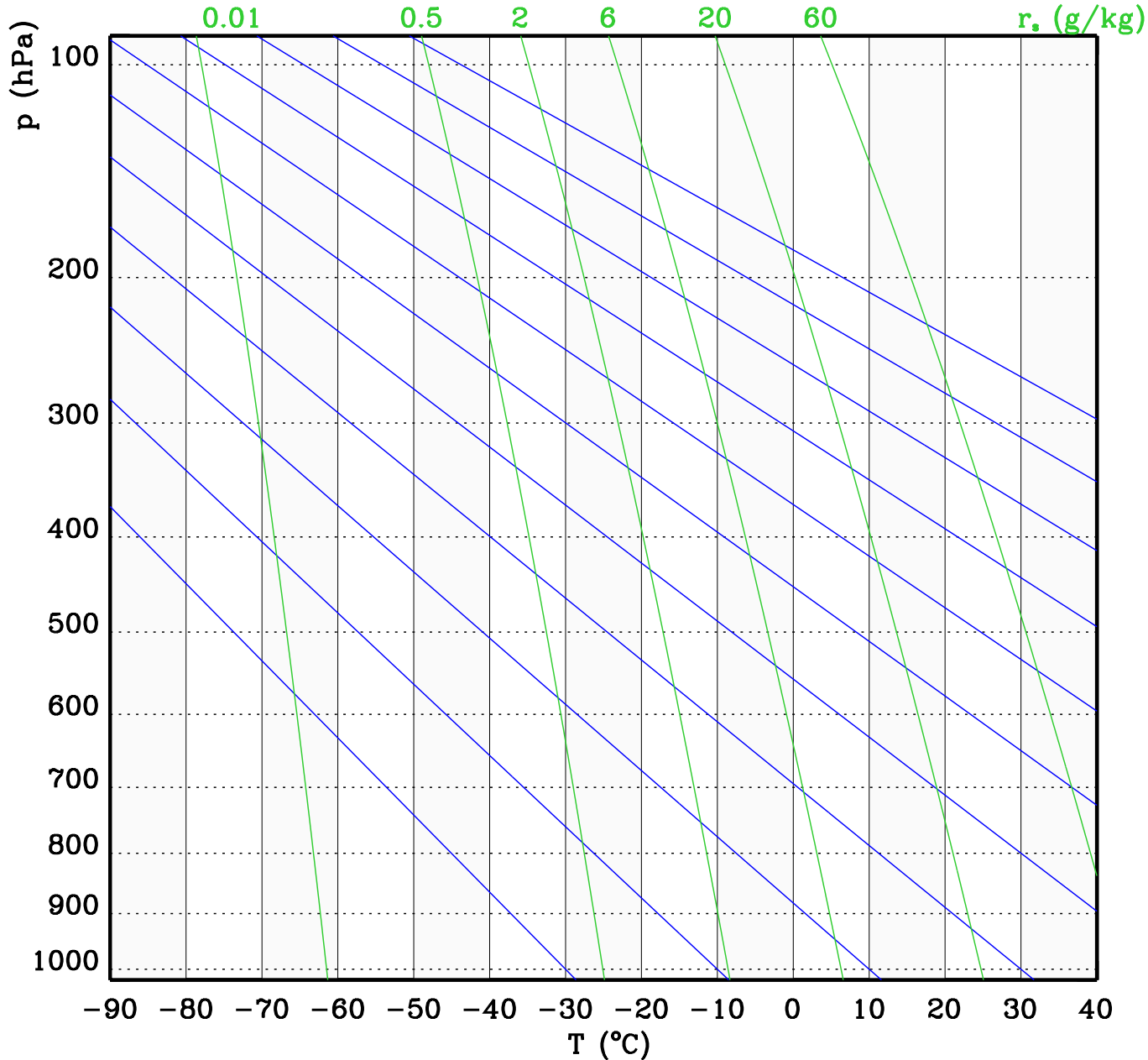


# STUVE DIAGRAM



$$\theta = T \left( \frac{p_0}{p} \right)^\kappa$$

# STUVE DIAGRAM

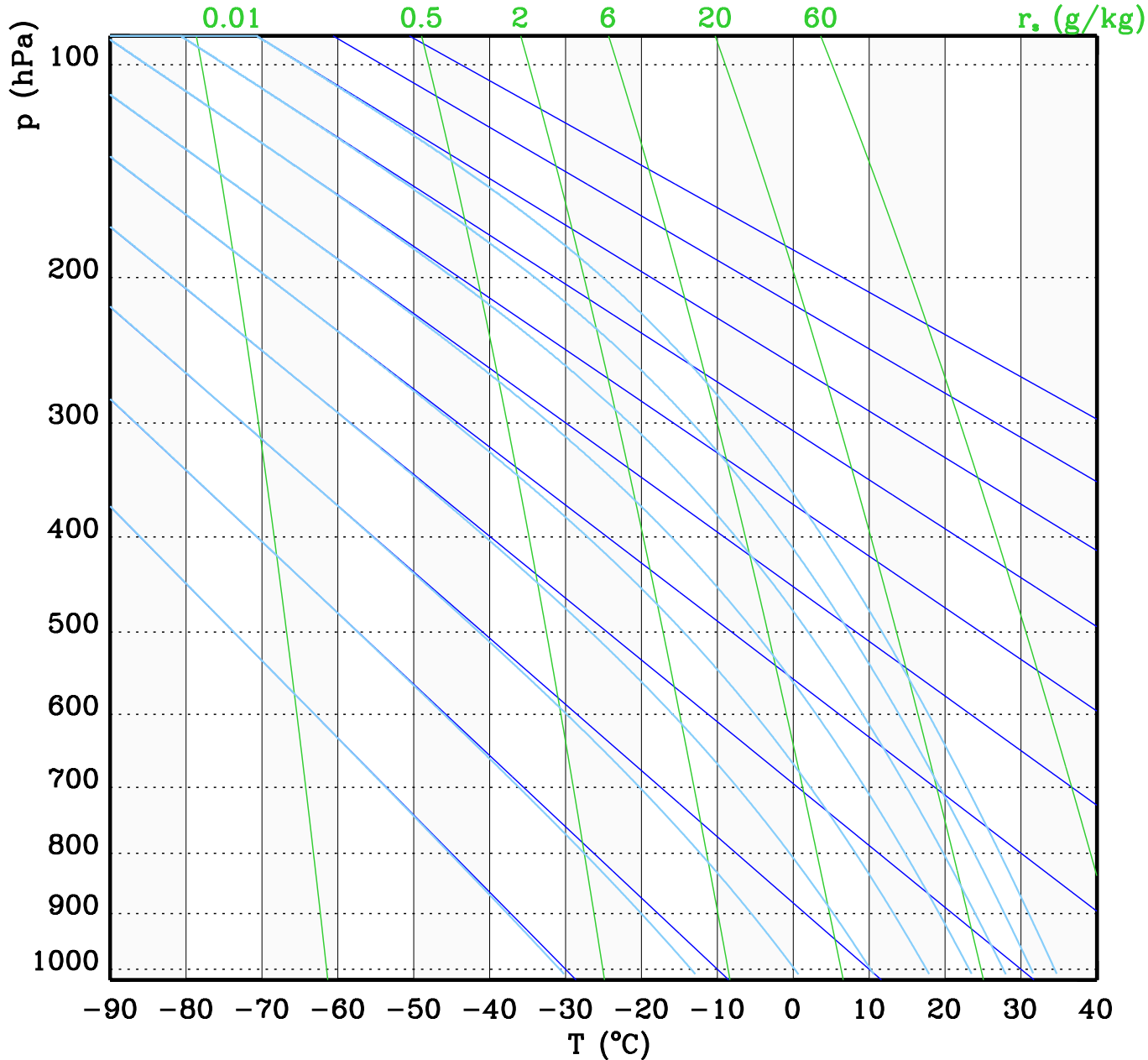


$$\theta = T \left( \frac{p_0}{p} \right)^{\kappa}$$

$$r_s = \varepsilon \frac{e_s(T)}{p - e_s(T)}$$



# STUVE DIAGRAM



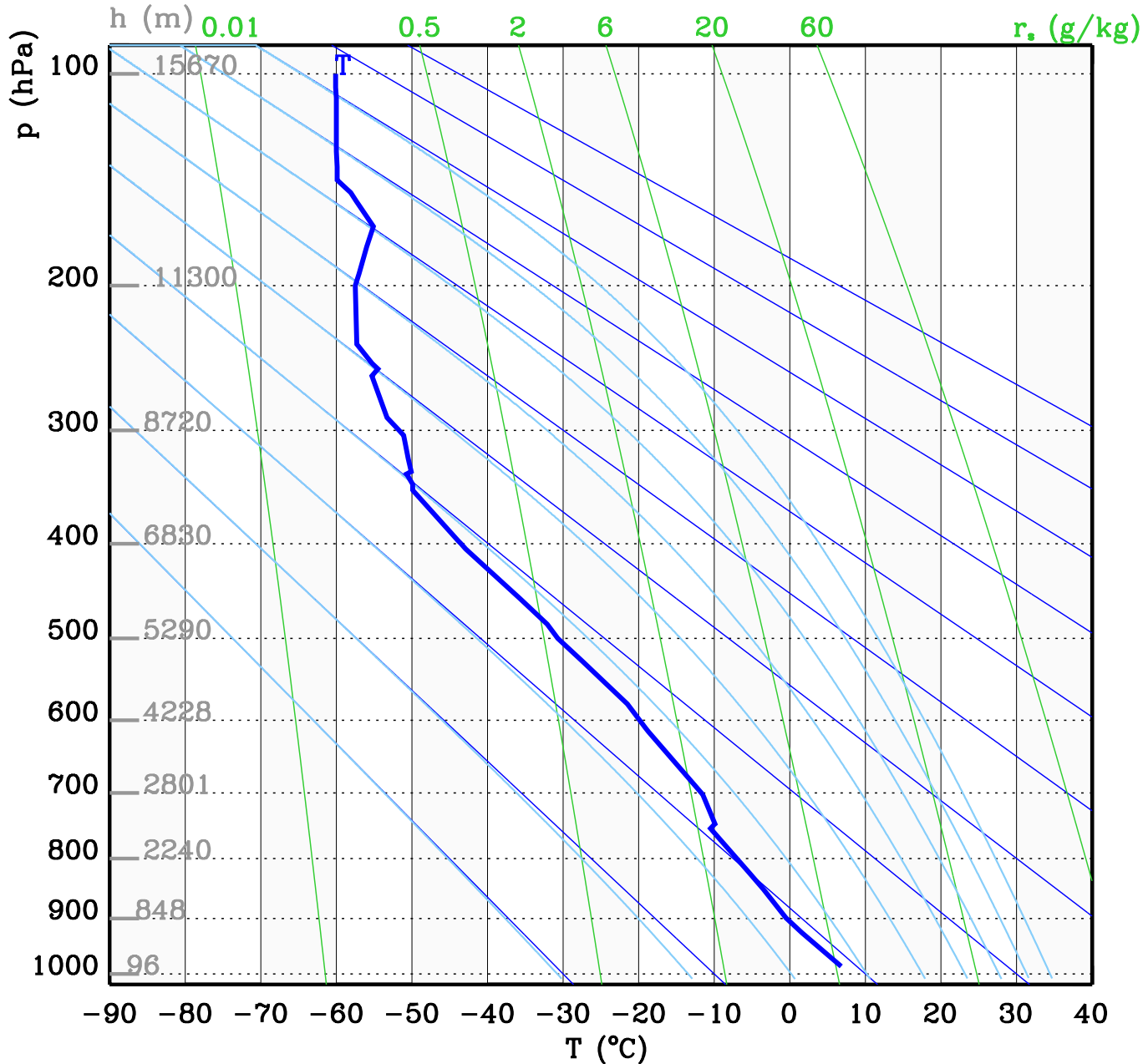
$$\theta = T \left( \frac{p_0}{p} \right)^{\kappa}$$

$$r_s = \varepsilon \frac{e_s(T)}{p - e_s(T)}$$

$$\theta_e = \theta \cdot \exp \left( \frac{L_{lv} r_s}{c_p T} \right)$$

# STUVE DIAGRAM

12374 Legionowo Observations at 12Z 11 Feb 2019



$$\theta = T \left( \frac{p_0}{p} \right)^\kappa$$

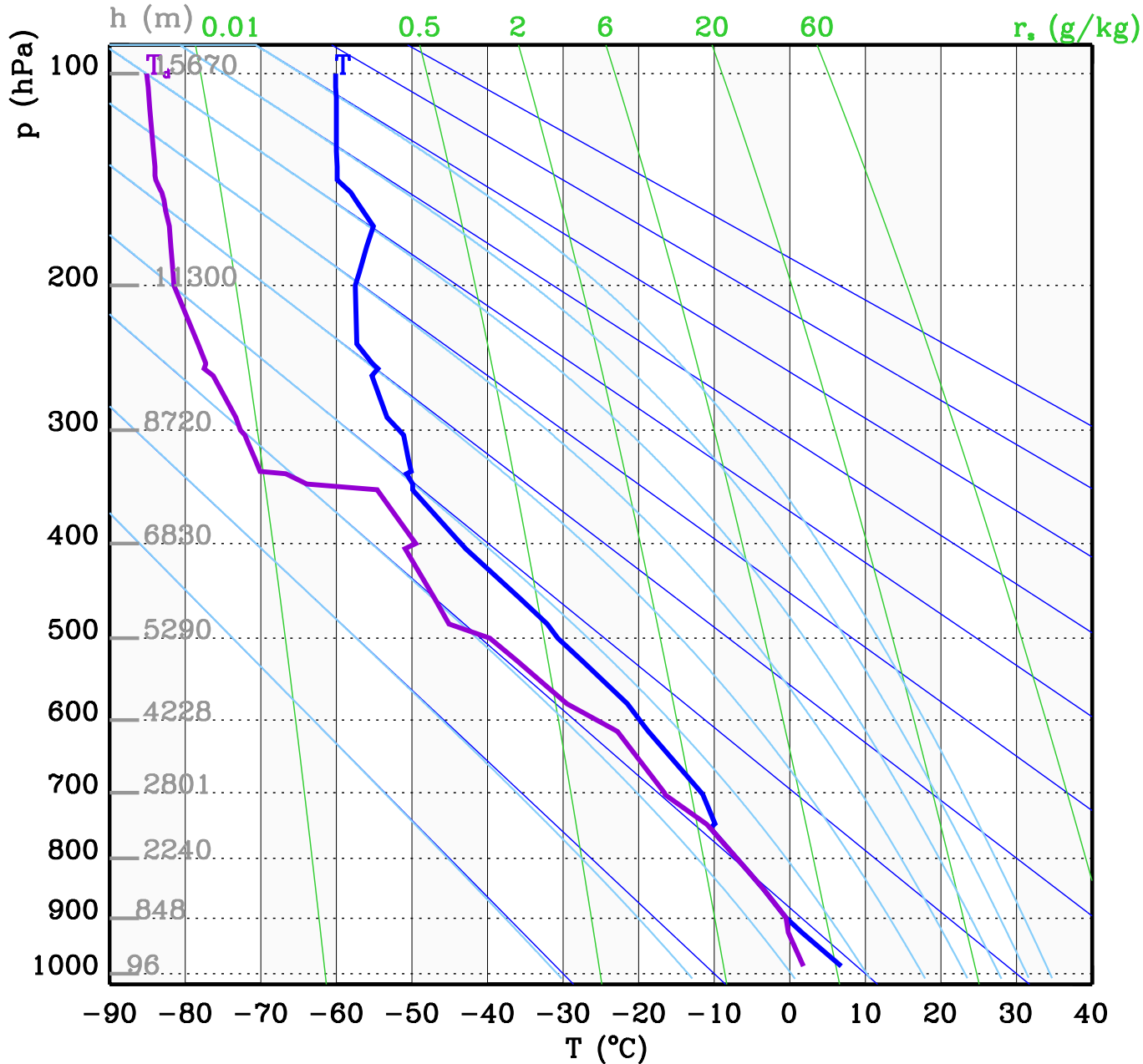
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T

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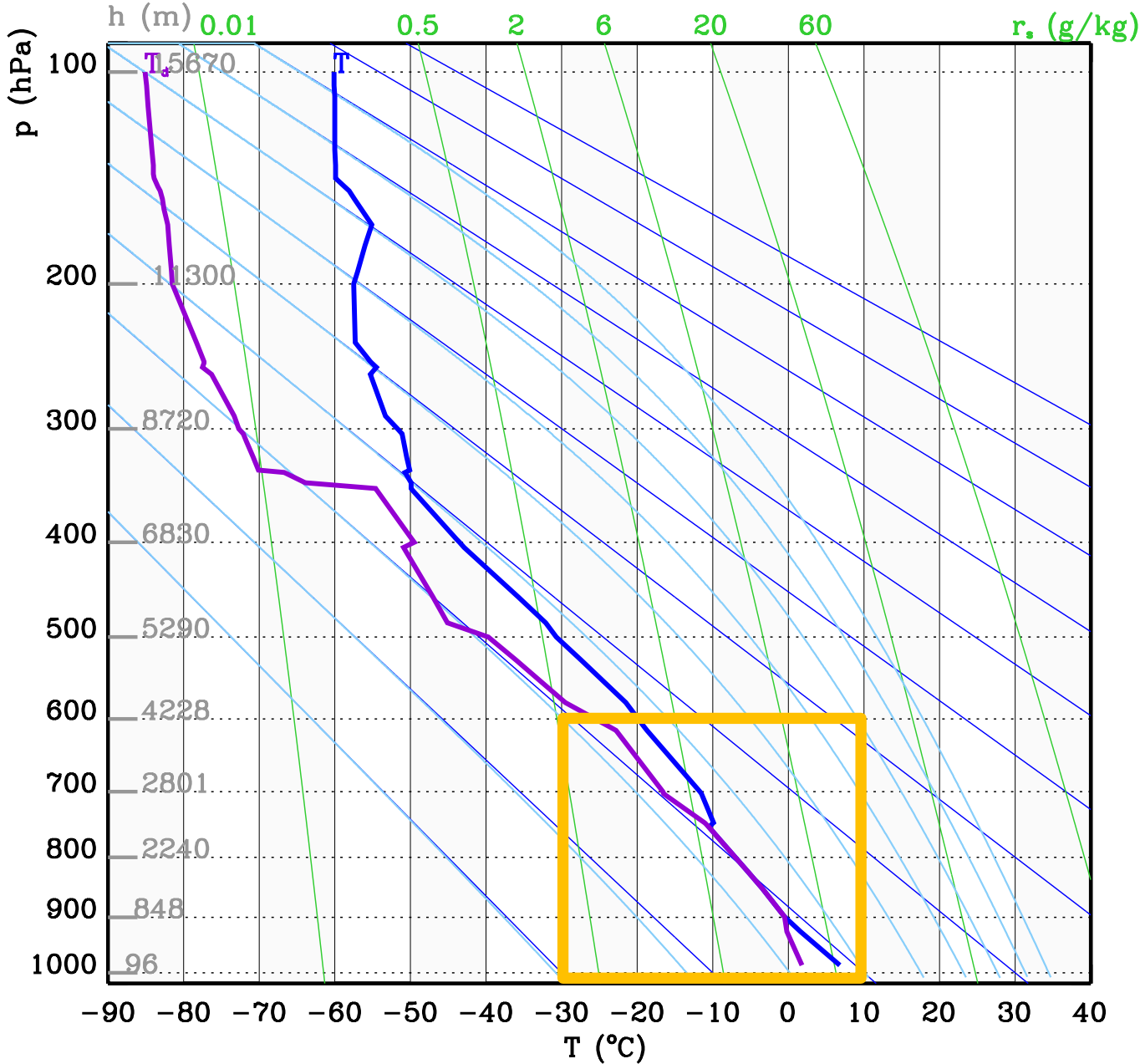
$$\theta_e = \theta \cdot \exp \left( \frac{L_{lv} r_s}{c_p T} \right)$$

$T$

$T_d$

# STUVE DIAGRAM

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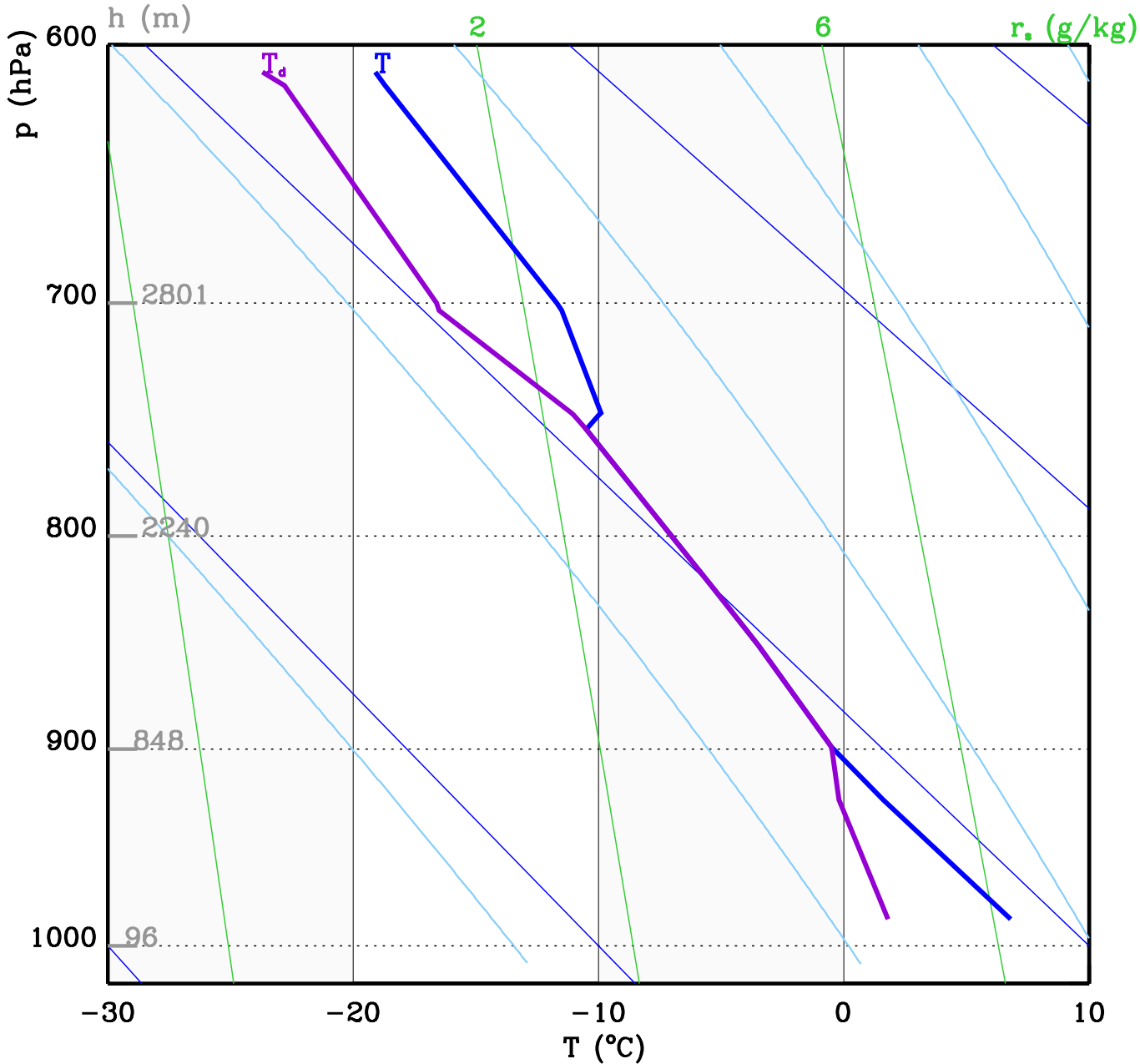
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$T$

$T_d$

# TEPHIGRAM

**Tephigram**, literally the  $T \varphi$  gram, where  $\varphi$  was originally used to denote potential temperature.

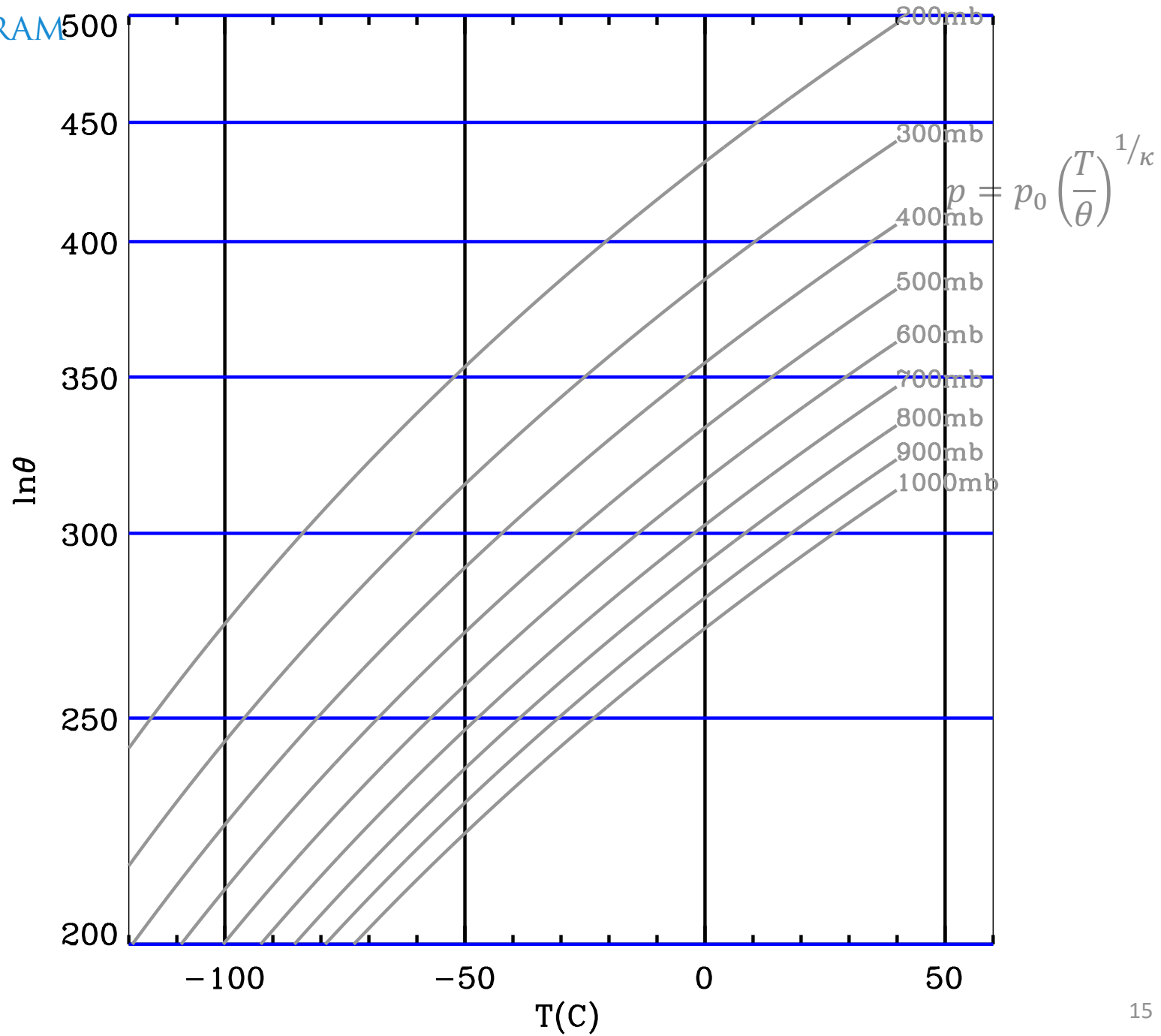
From the defining equation of entropy, it follows that the total heat added in a cyclic process is:

$$\oint dq = \oint TdS = c_p \oint Td(\ln \theta)$$

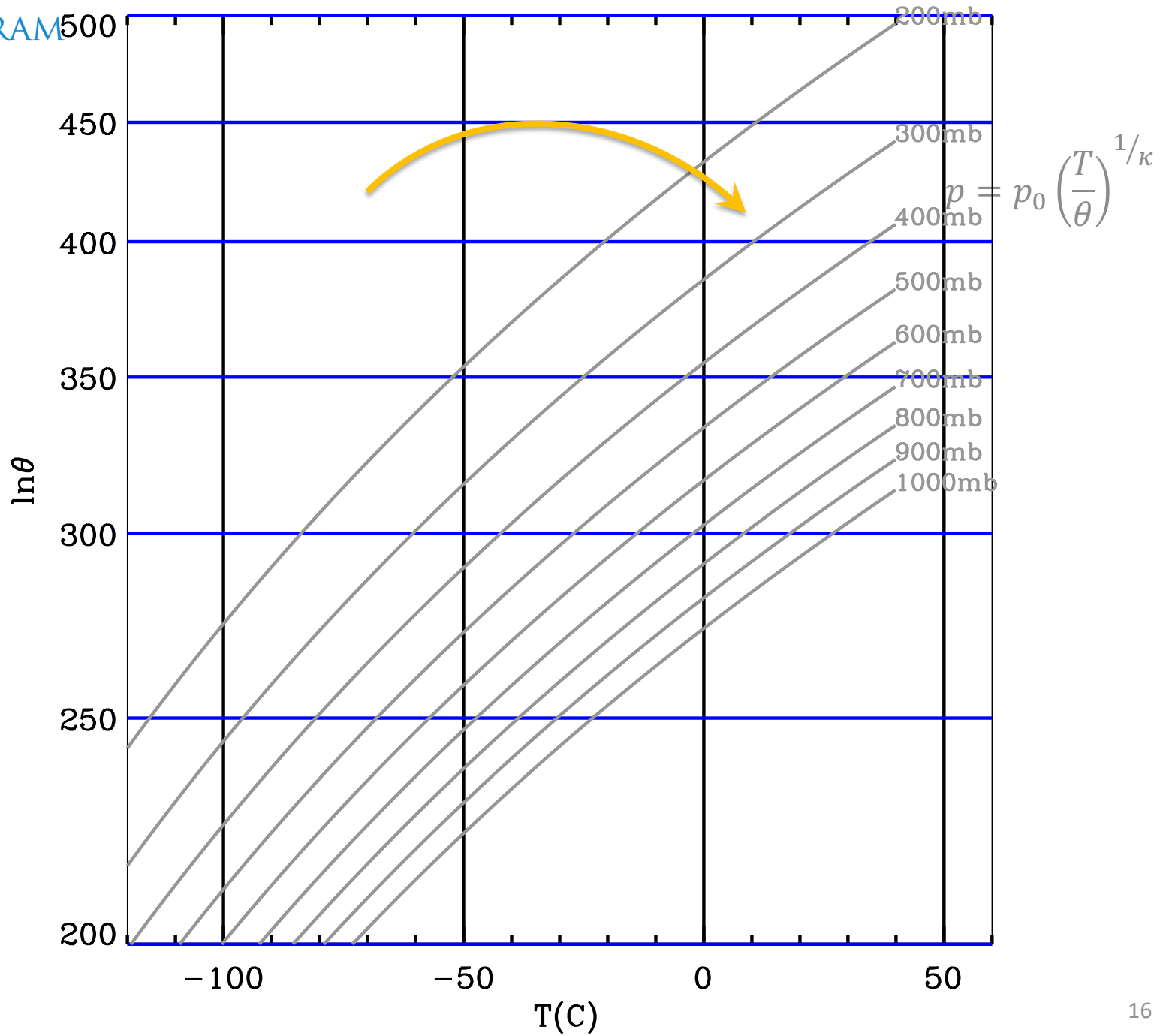
A chart with coordinates of  $T$  versus  $\ln \theta$  has the area-energy relation of a **true thermodynamic diagram**.

Usually **Tephigrams** are right-rotated so that the ordinate becomes roughly proportional to  $\ln p$  and hence height.



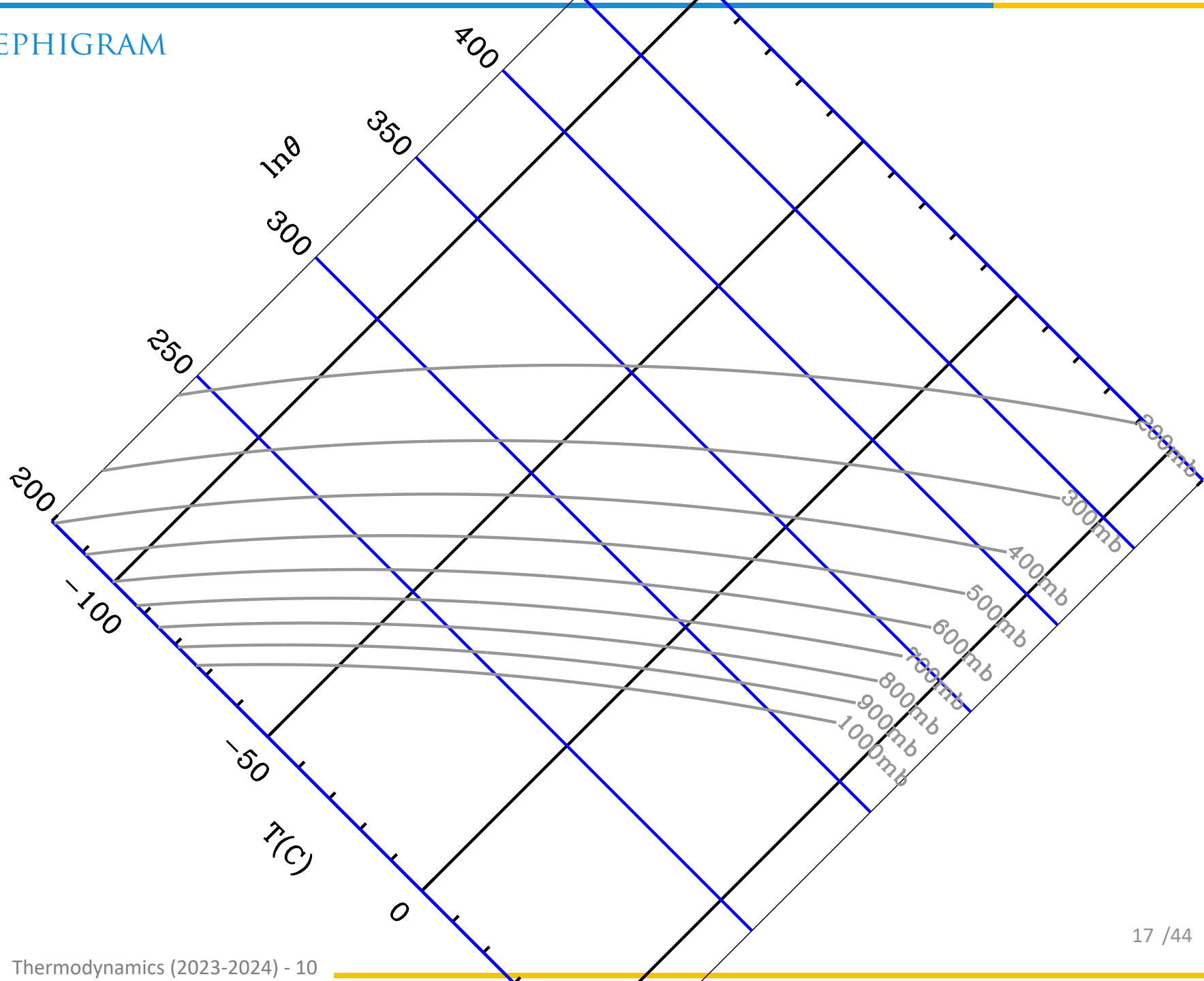


# TEPHIGRAM

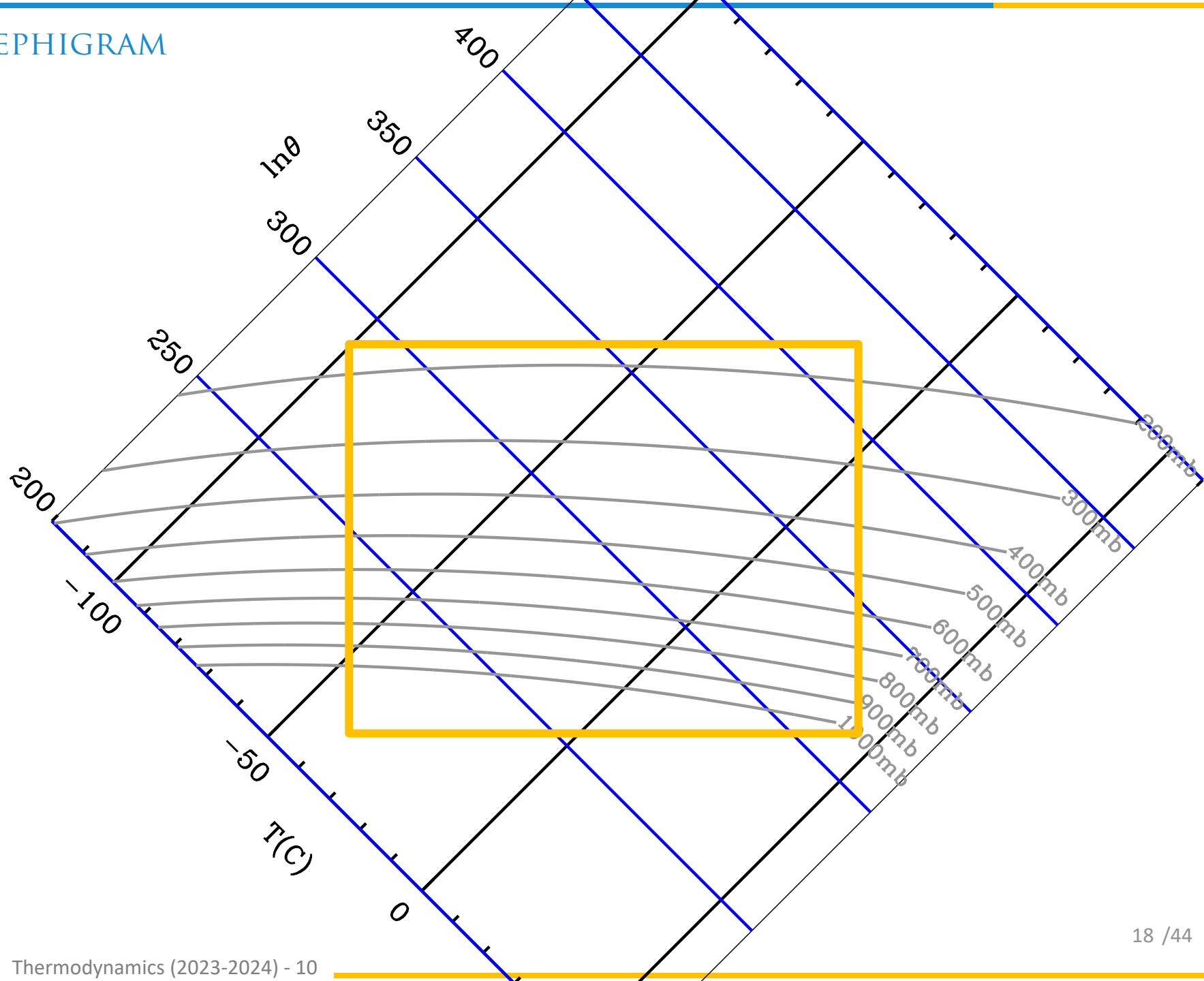




# TEPHIGRAM

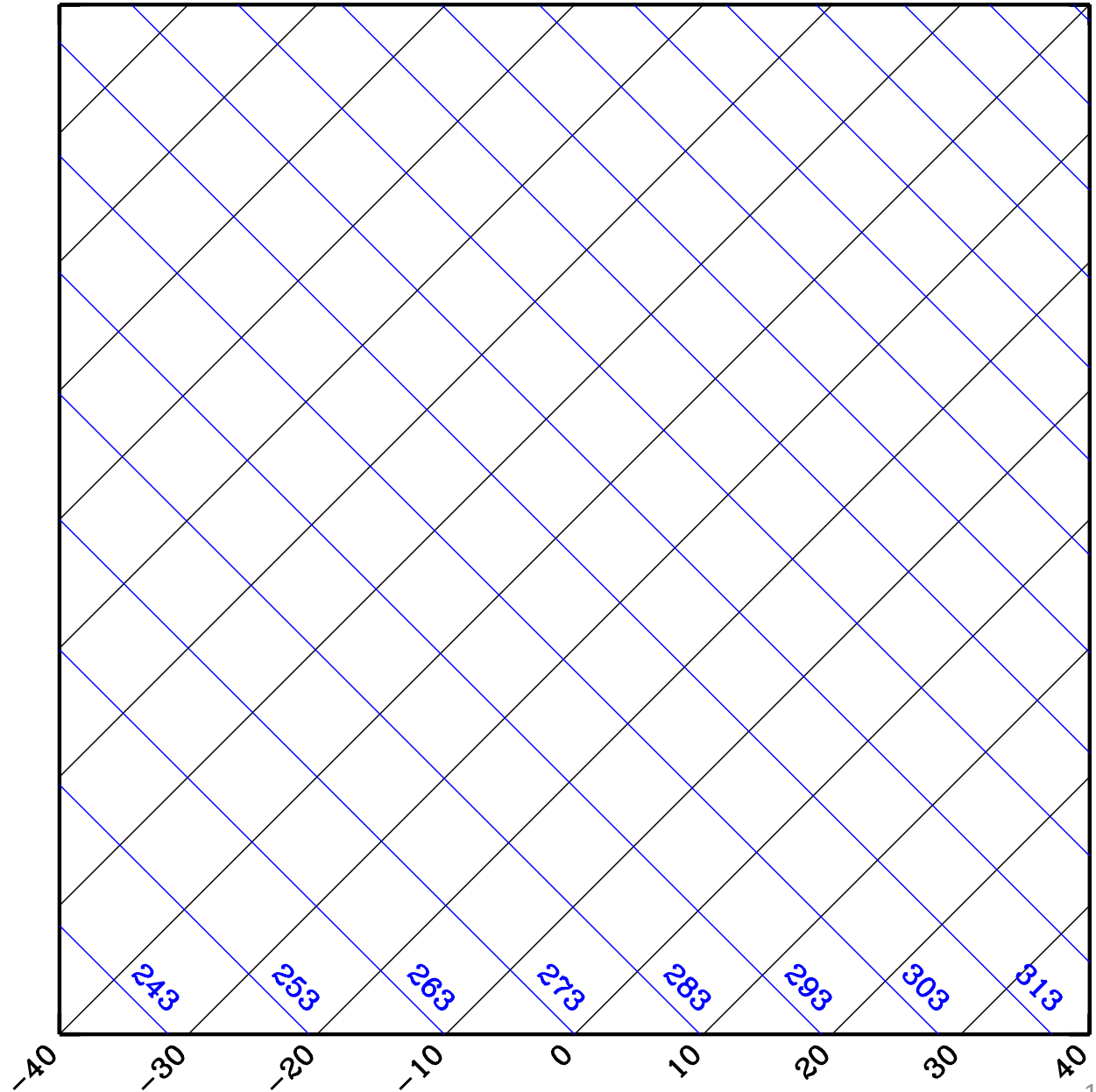


# TEPHIGRAM



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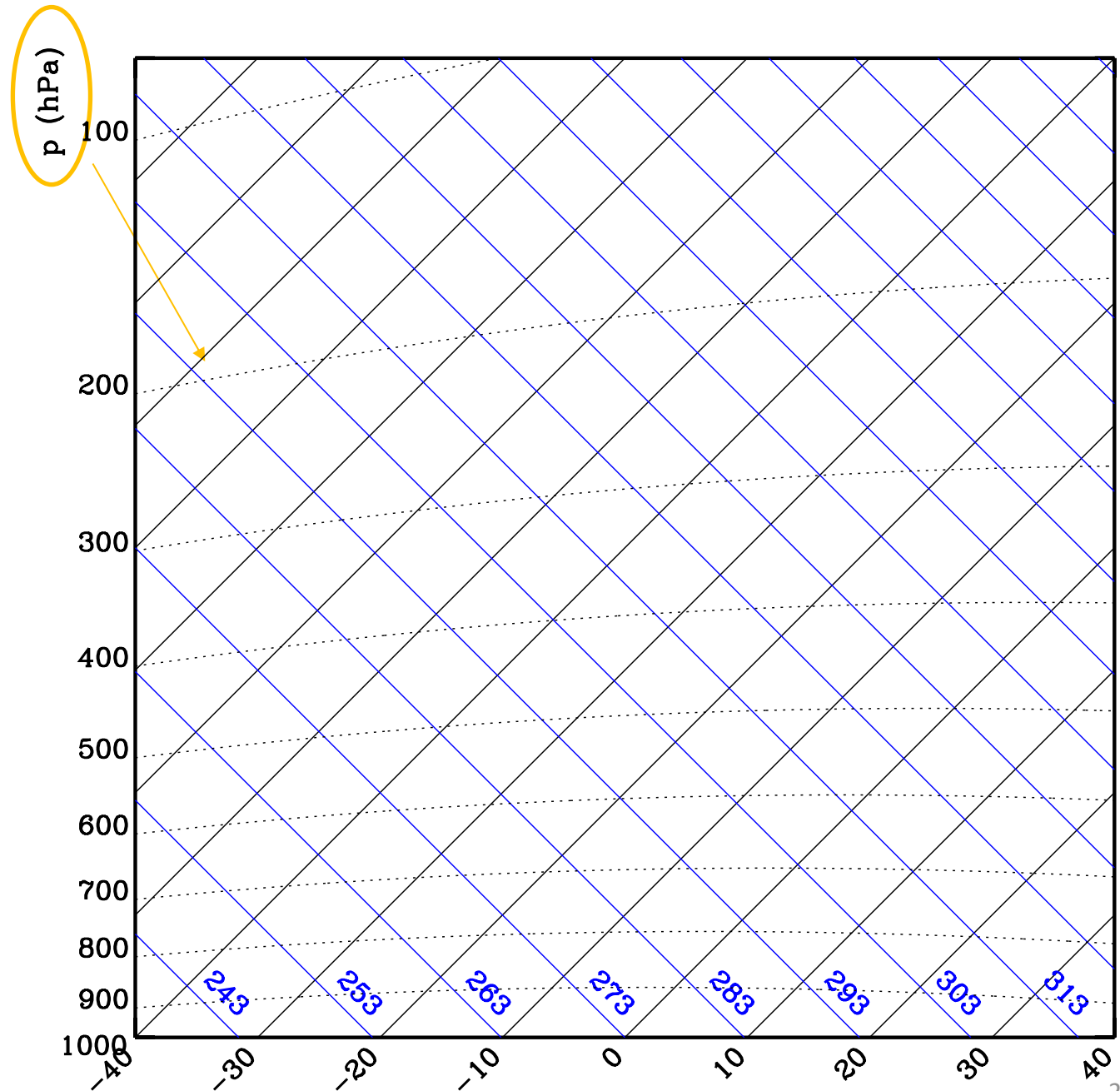
$$\theta = T \left( \frac{p_0}{p} \right)^\kappa$$



# TEPHIGRAM

$$p = p_0 \left( \frac{T}{\theta} \right)^{1/\kappa}$$

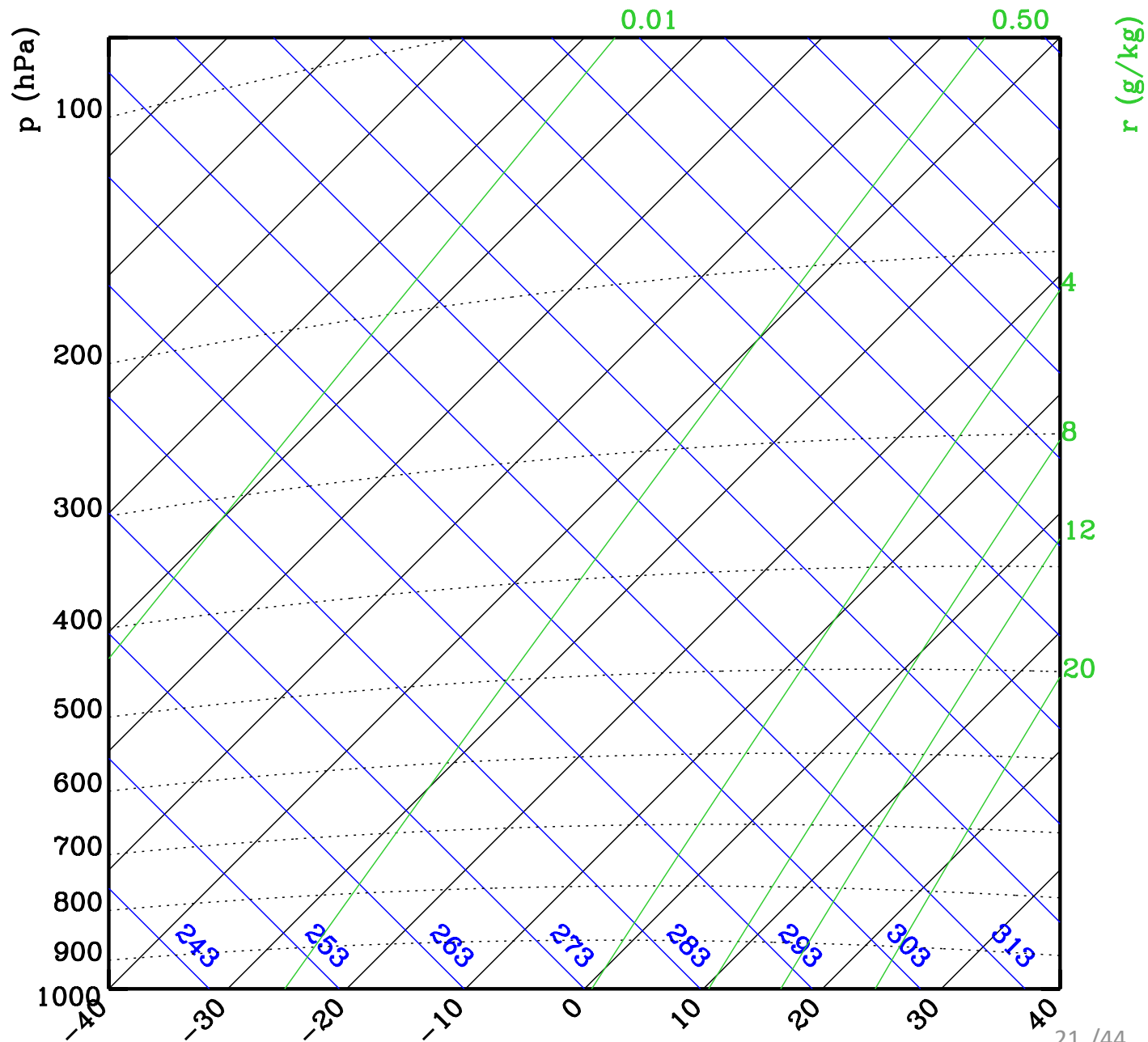
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# TEPHIGRAM

$$\theta = T \left( \frac{p_0}{p} \right)^\kappa$$

$$r_s = \varepsilon \frac{e_s(T)}{p - e_s(T)}$$

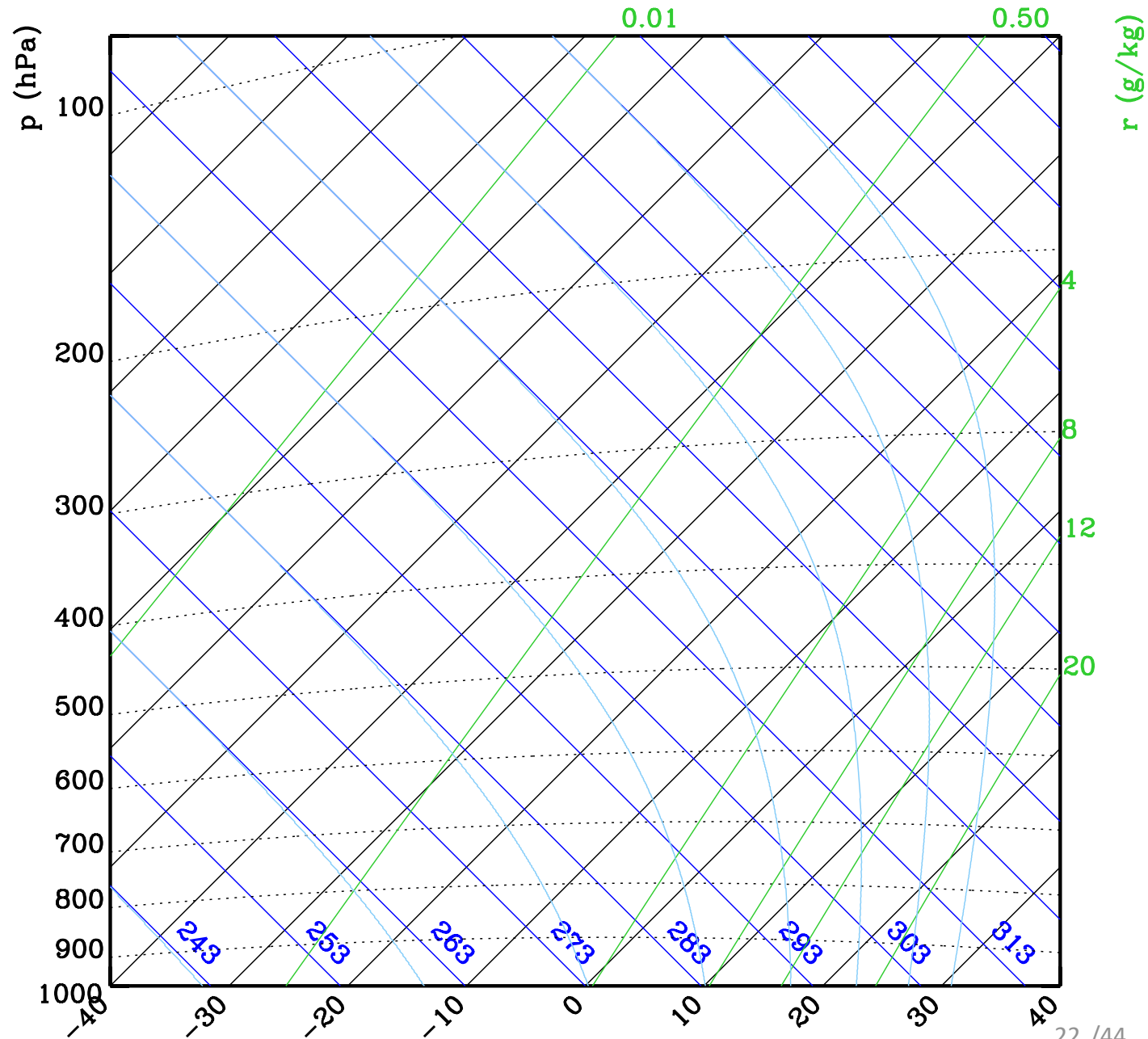


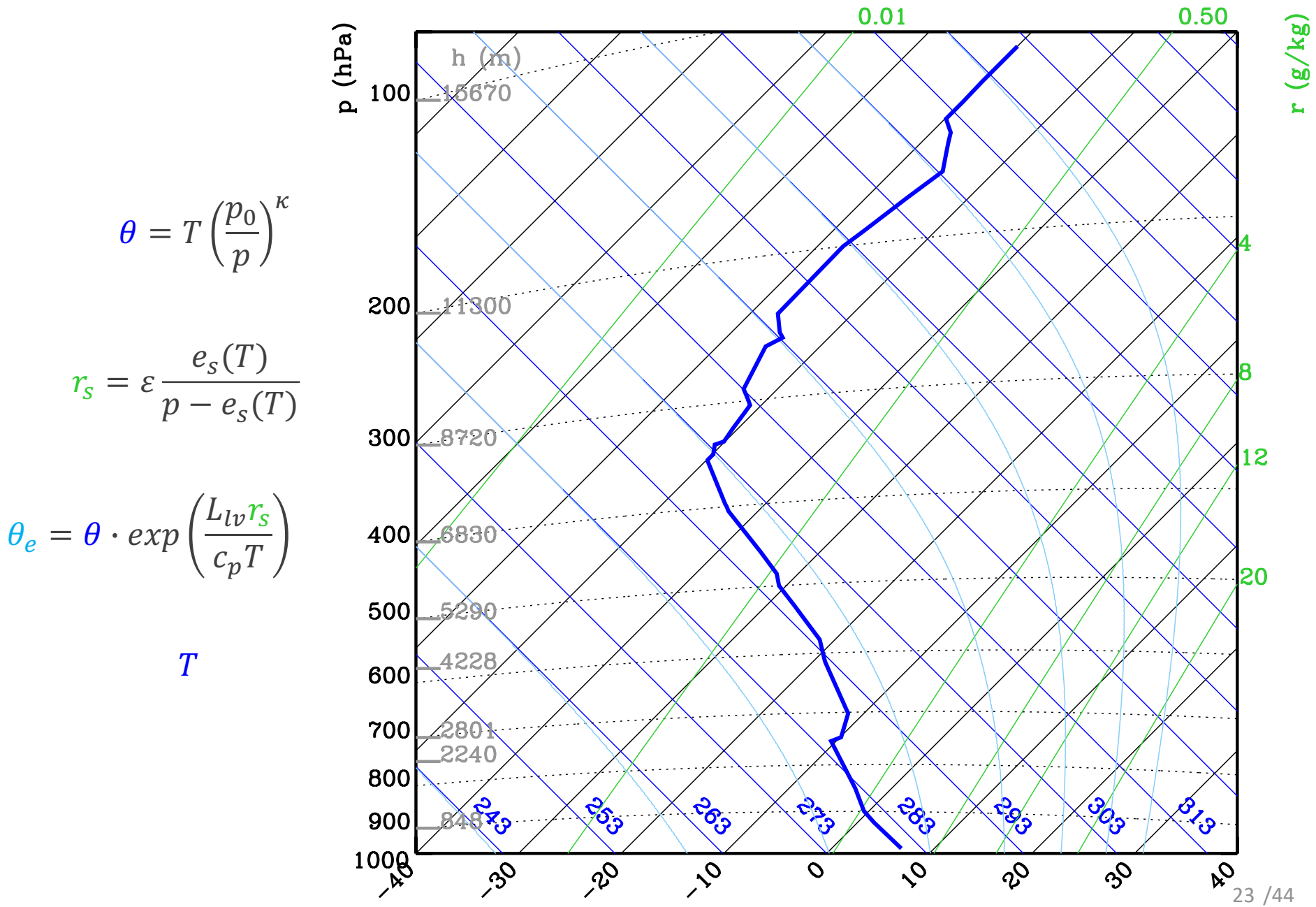
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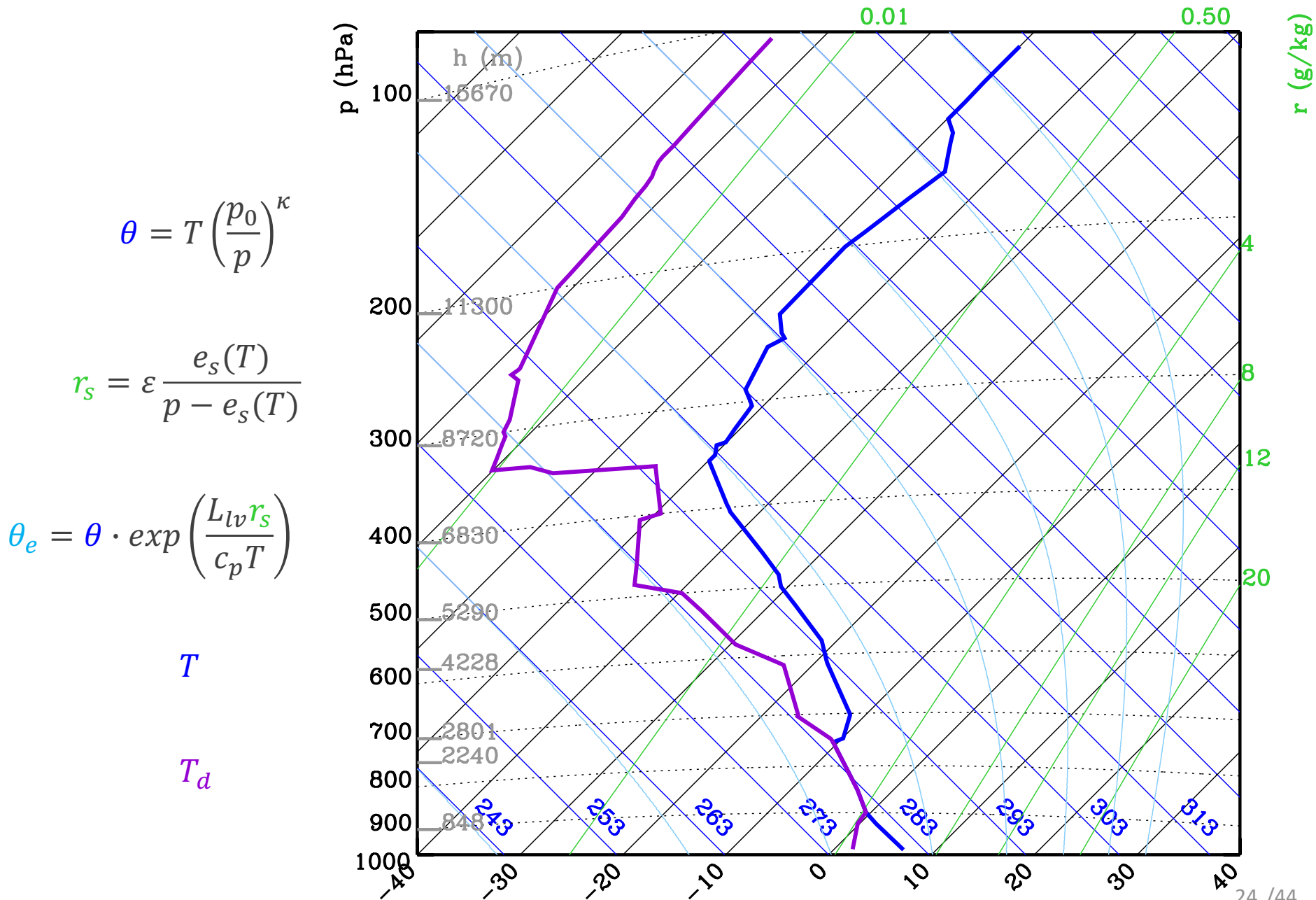
$$\theta = T \left( \frac{p_0}{p} \right)^\kappa$$

$$r_s = \varepsilon \frac{e_s(T)}{p - e_s(T)}$$

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# SKEW-T DIAGRAM

*Skew\_T* adopts temperature,  $T$  and  $\ln p$  as its thermodynamic coordinates.

The logarithm of pressure is chosen for the vertical coordinate rather than the pressure itself because in an isothermal atmosphere height varies with  $\ln p$ , and hence for a realistic temperature profile the ordinate is roughly proportional to height.

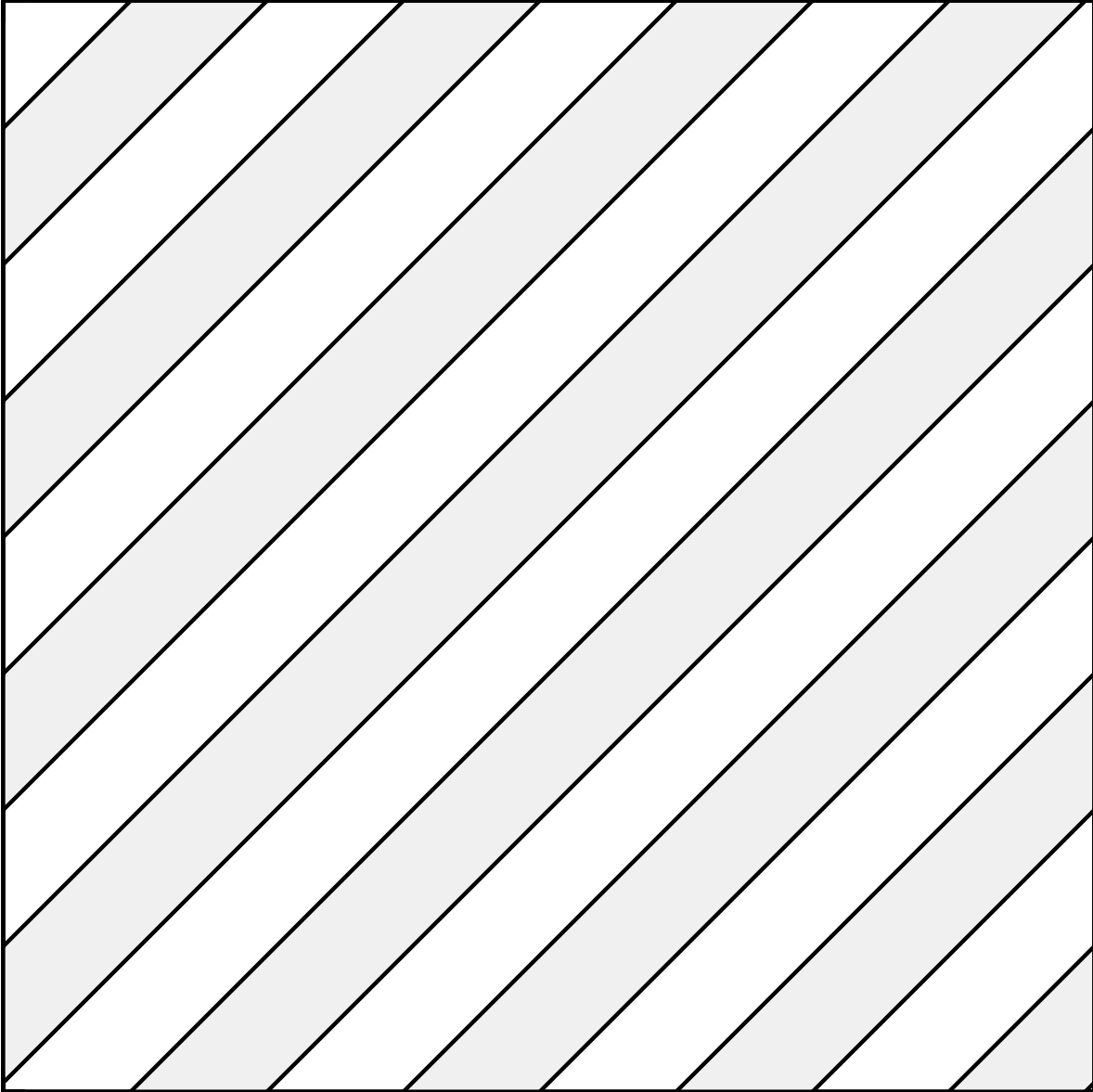
Isotherms are skewed at an angle of about  $45^\circ$  from the vertical. The exact angle of skewness is chosen so that adiabats and isotherms are orthogonal at 1000 hPa and  $0^\circ\text{C}$ .

A chart with coordinates of  $T$  versus  $\ln p$  has the property of a **true thermodynamic diagram**, i.e. the area is proportional to energy.

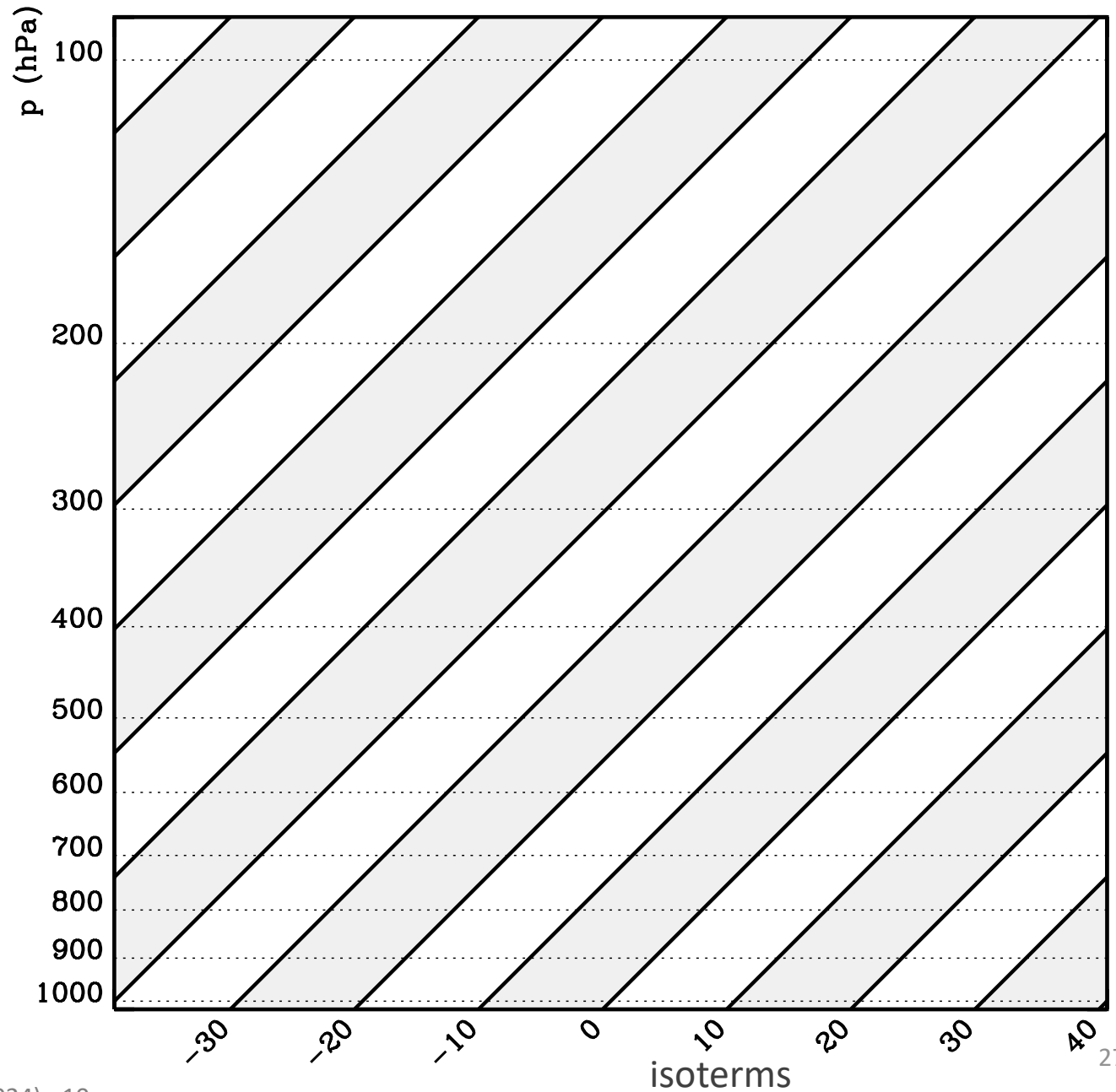


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# SKEW-T DIAGRAM

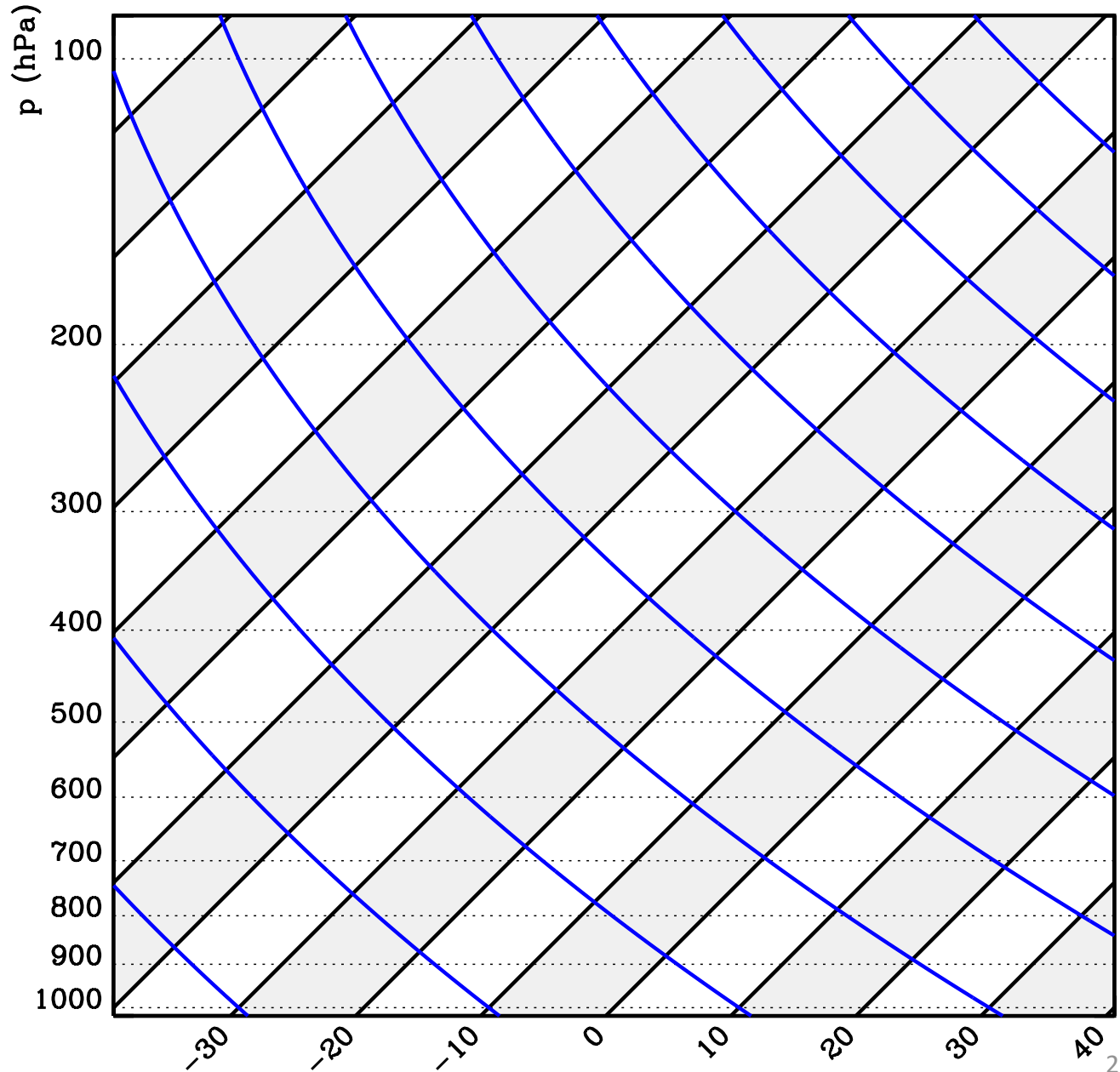


# SKREW-T DIAGRAM

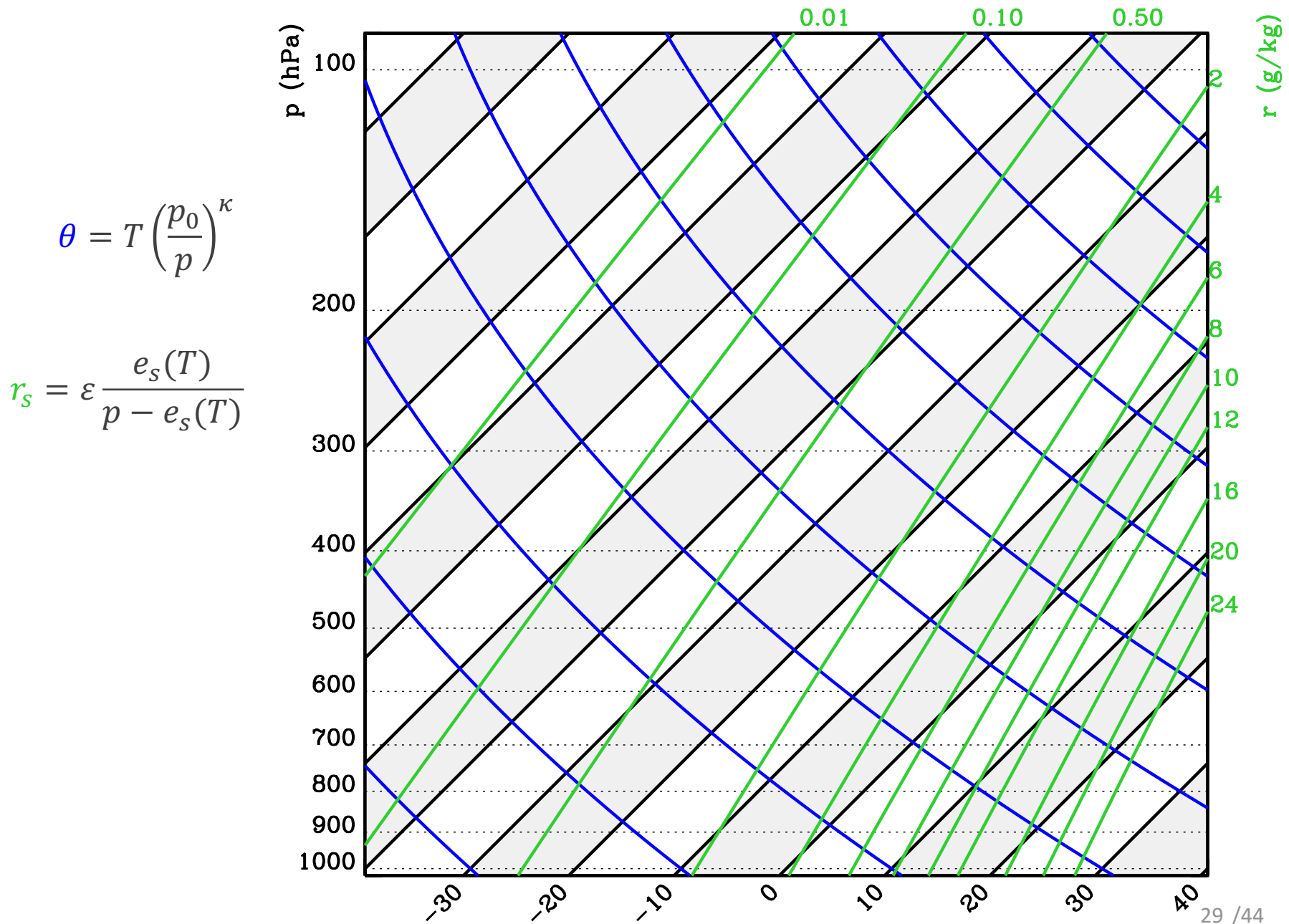


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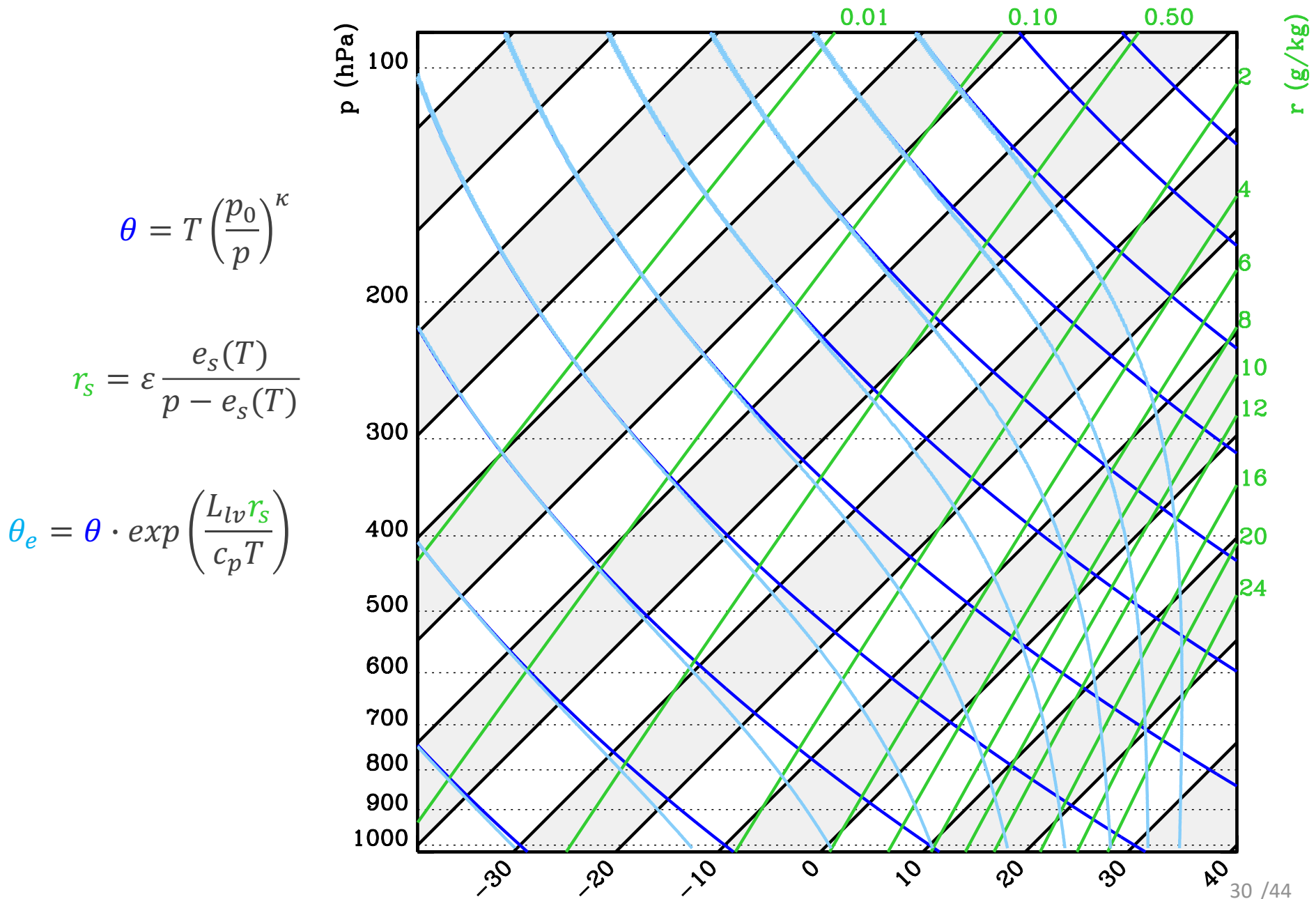
$$\theta = T \left( \frac{p_0}{p} \right)^\kappa$$



# SKREW-T DIAGRAM

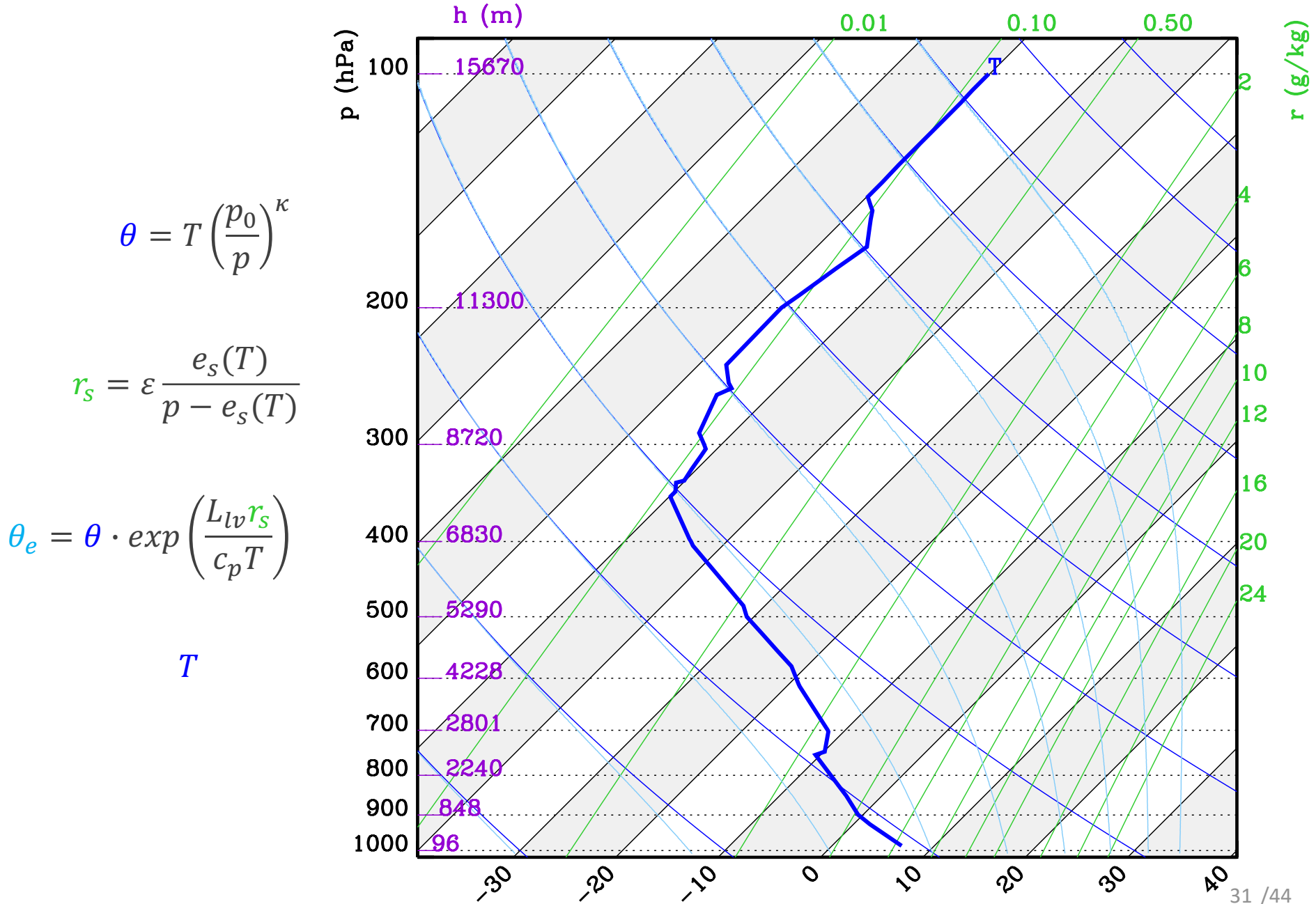


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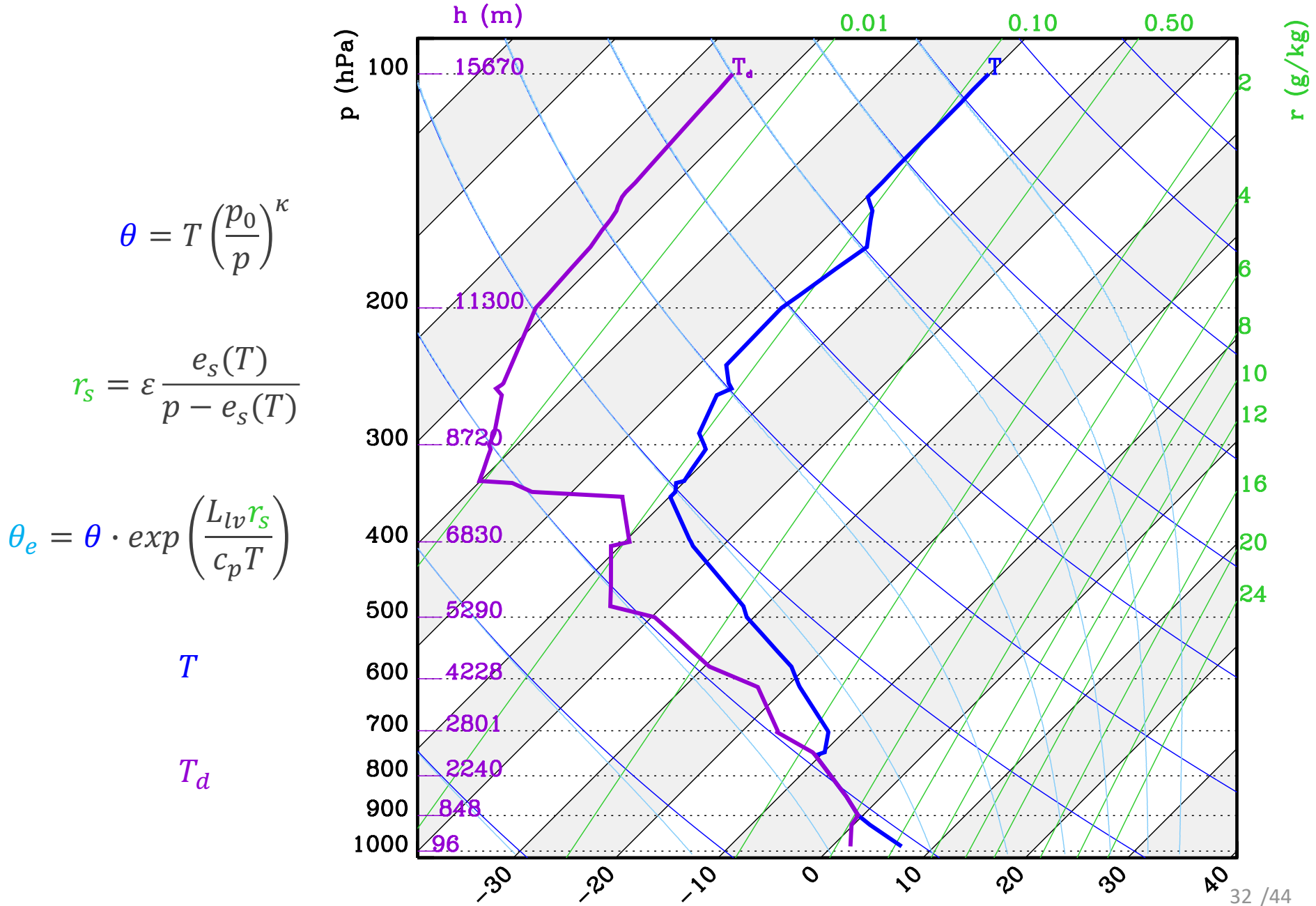
# SKREW-T DIAGRAM

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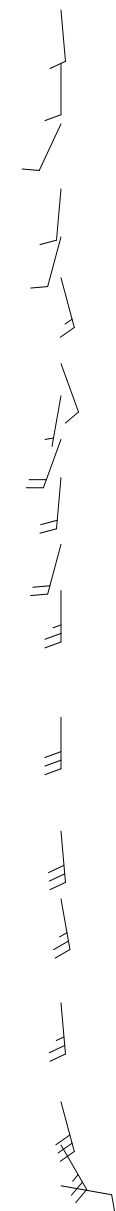
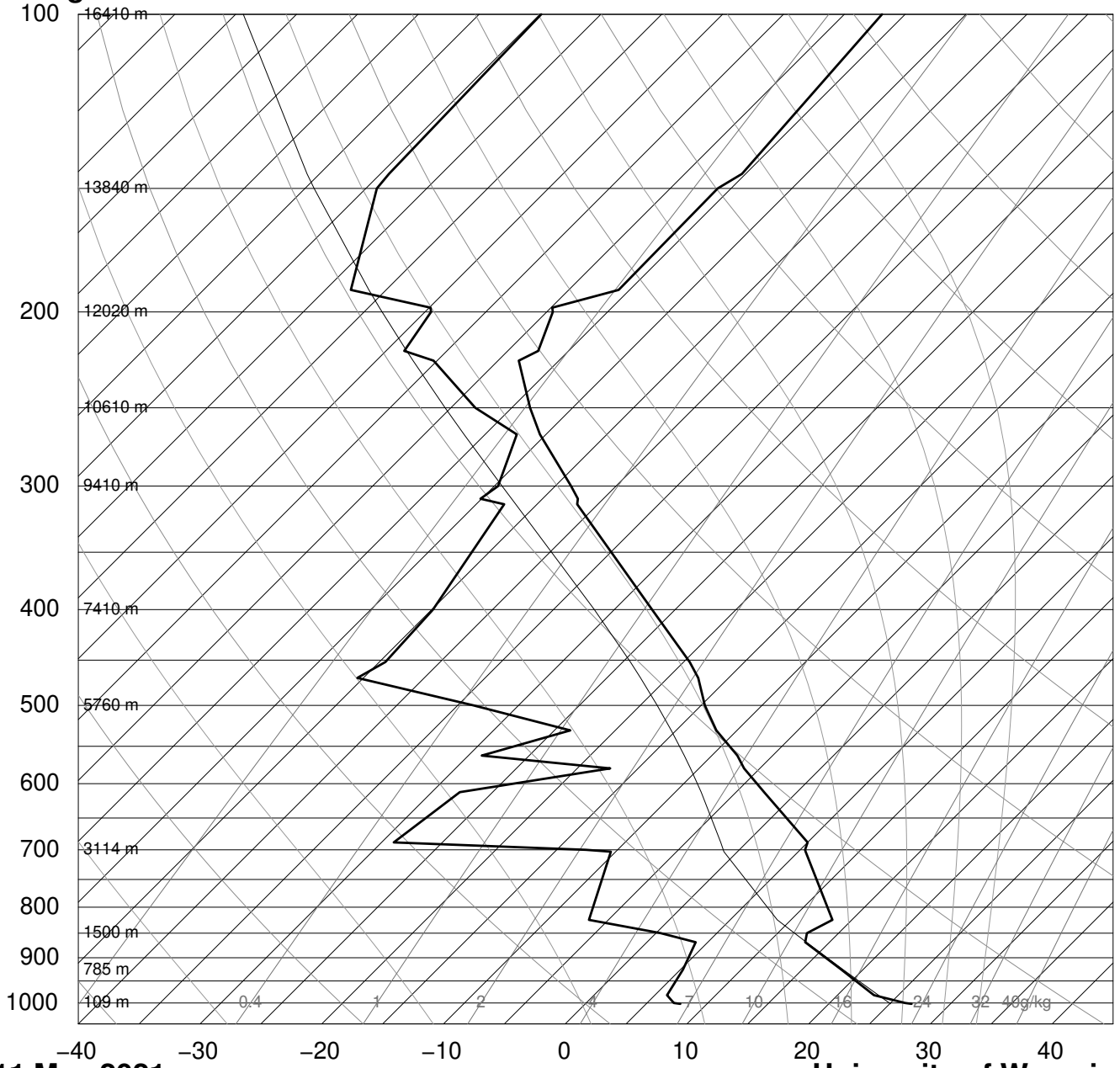
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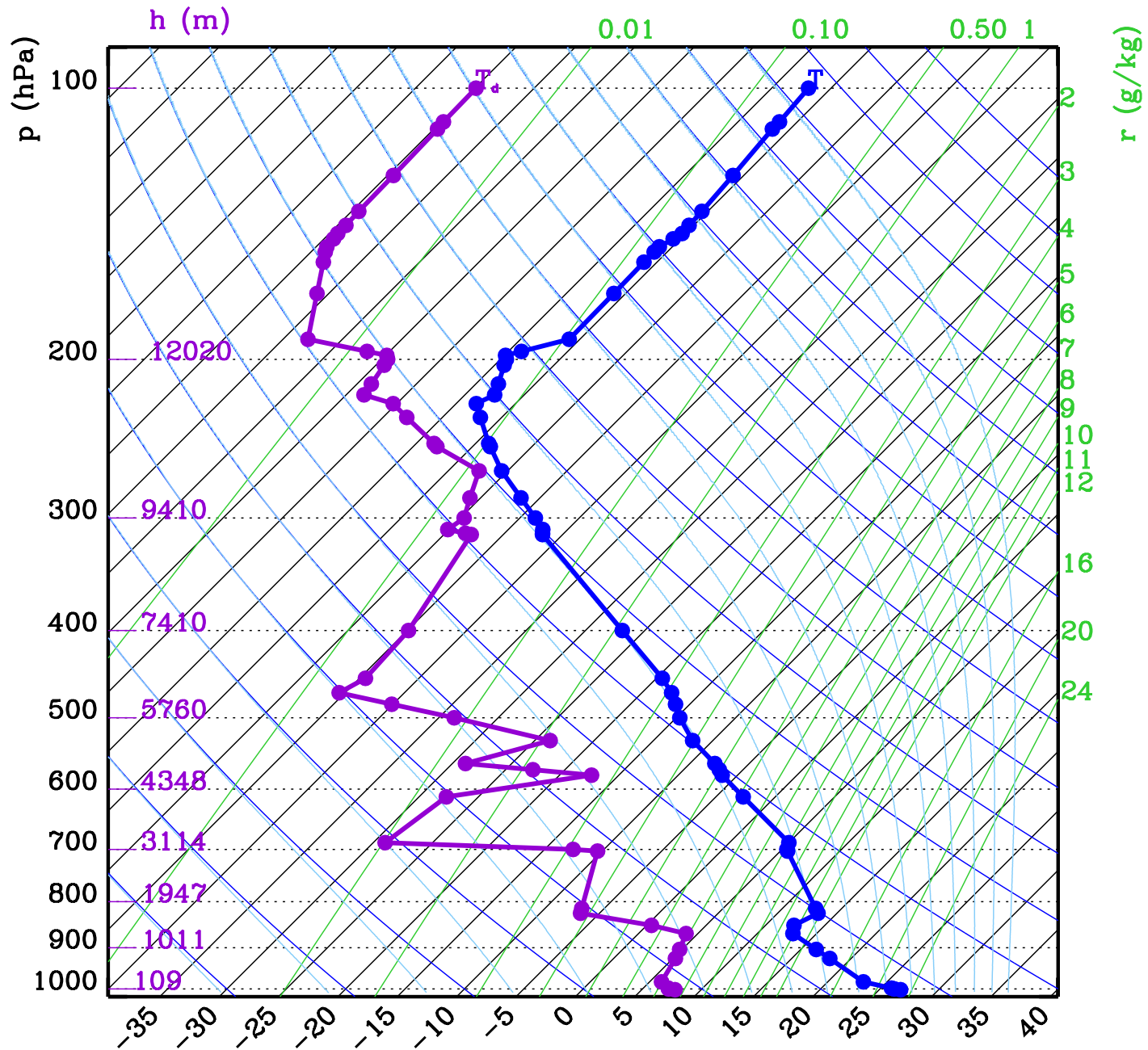


# 12374 Legionowo

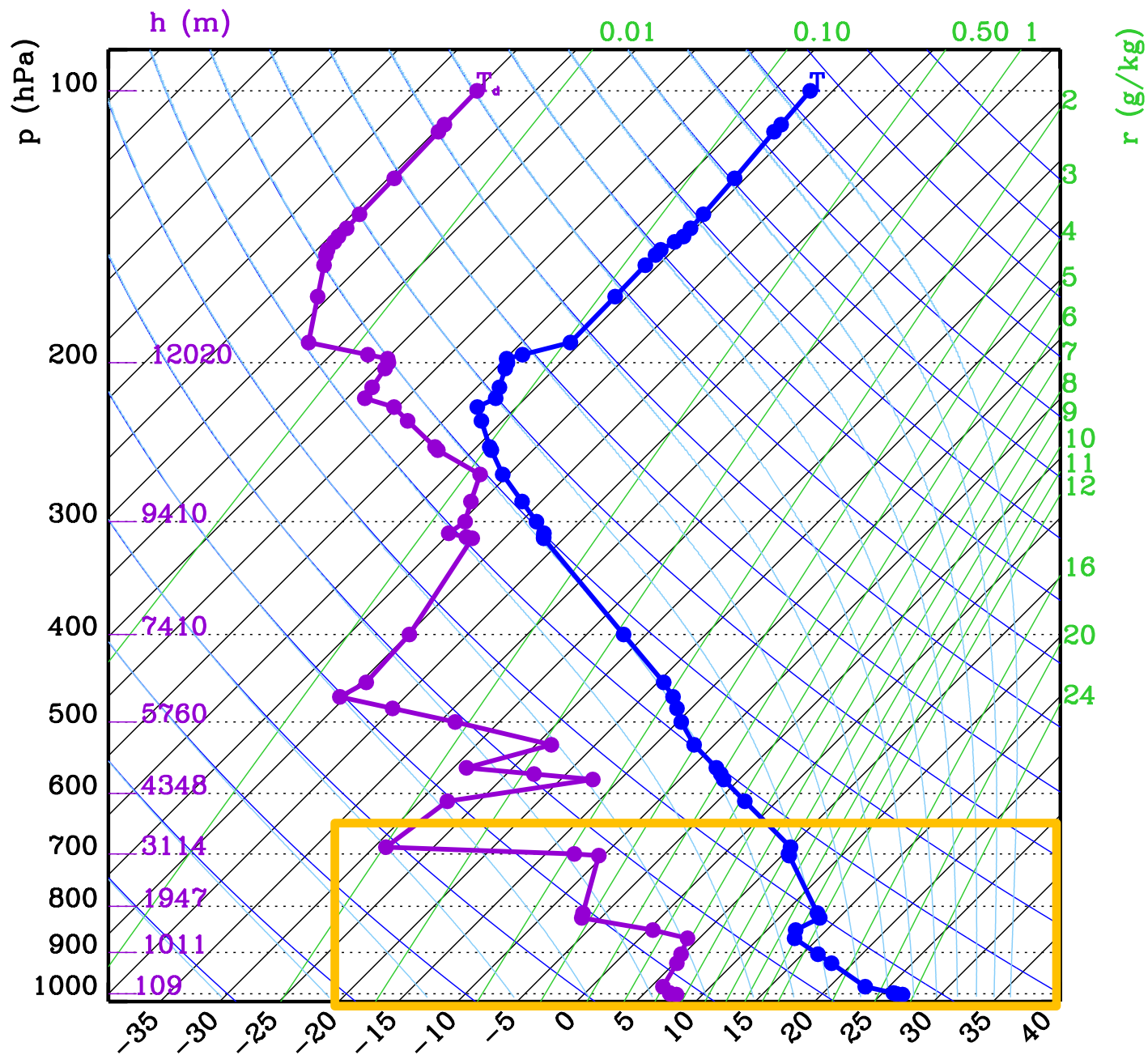


SLAT	52.40
SLON	20.96
SELV	96.00
SHOW	5.64
LIFT	3.87
LFTV	3.66
SWET	92.21
KINX	9.50
CTOT	15.10
VTOT	27.10
TOTL	42.20
CAPE	0.00
CAPV	0.00
CINS	0.00
CINV	0.00
EQLV	-9999
EQTV	-9999
LFCT	-9999
LCV	-9999
BRCH	0.00
BRCV	0.00
LCLT	275.7
LCLP	761.1
LCL	316.2
MLTH	298.0
MLMR	6.09
THCK	5651.
PWAT	15.71

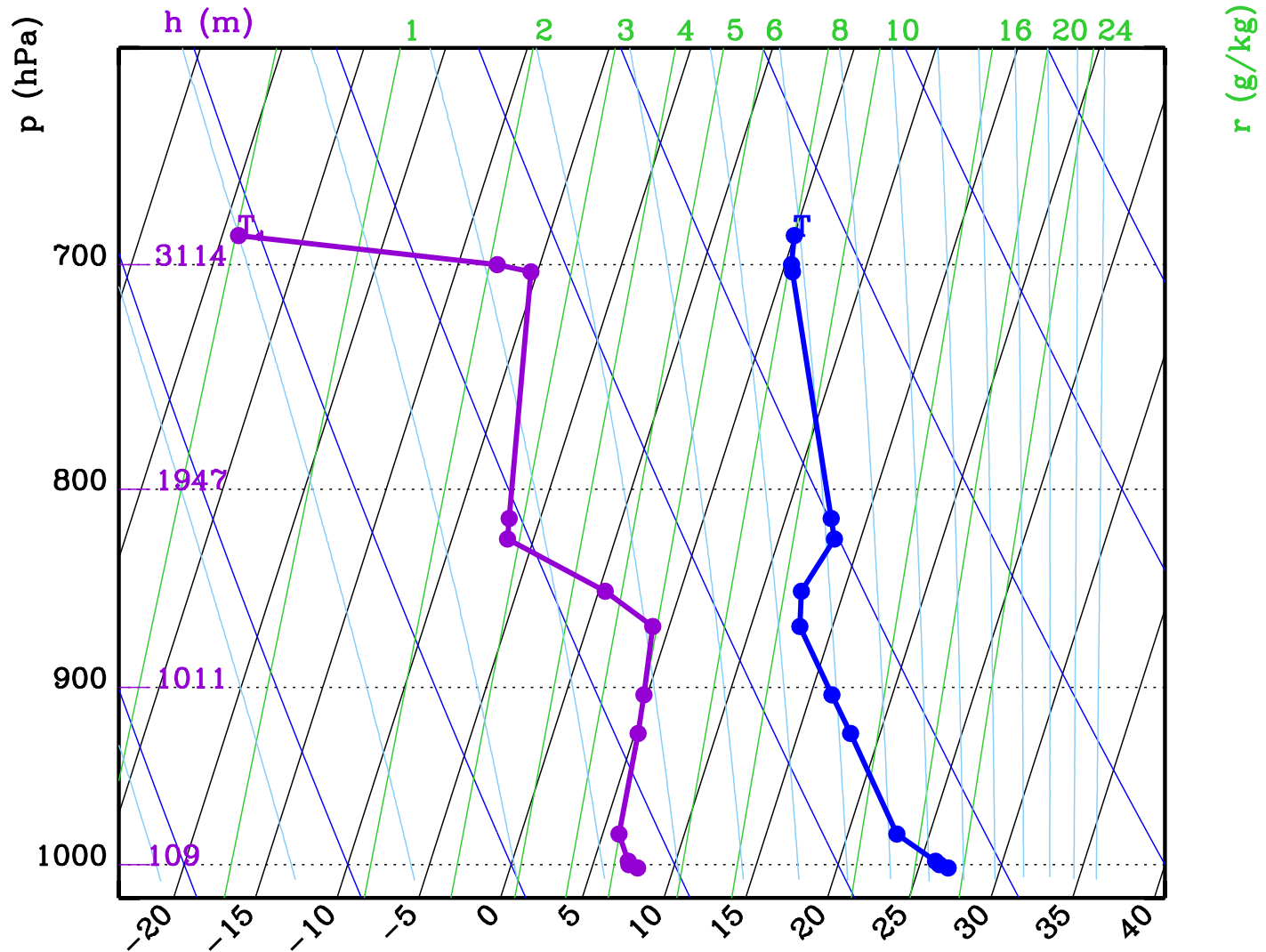
# 12374 Legionowo Observations at 12Z 11 May 2021



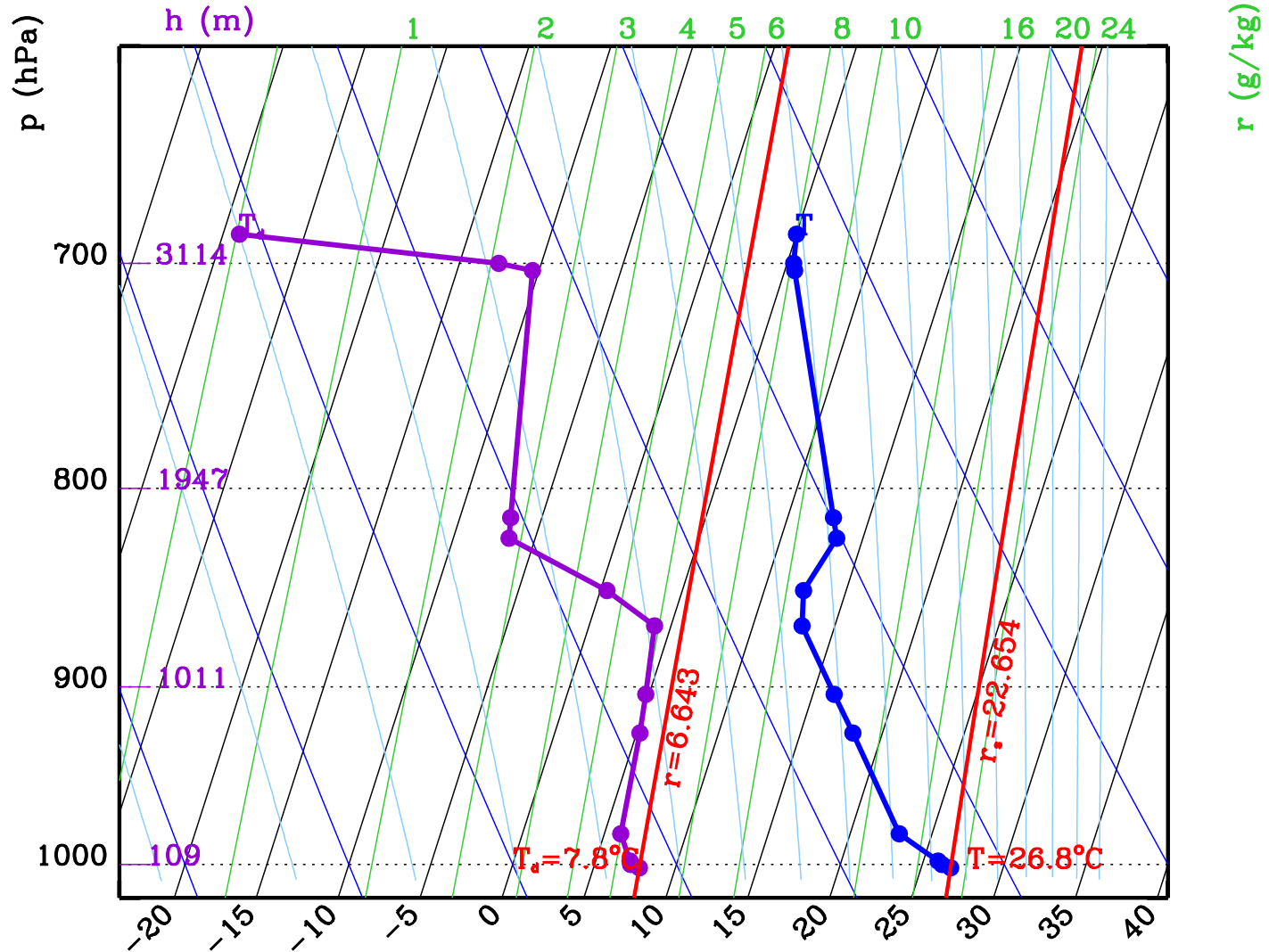
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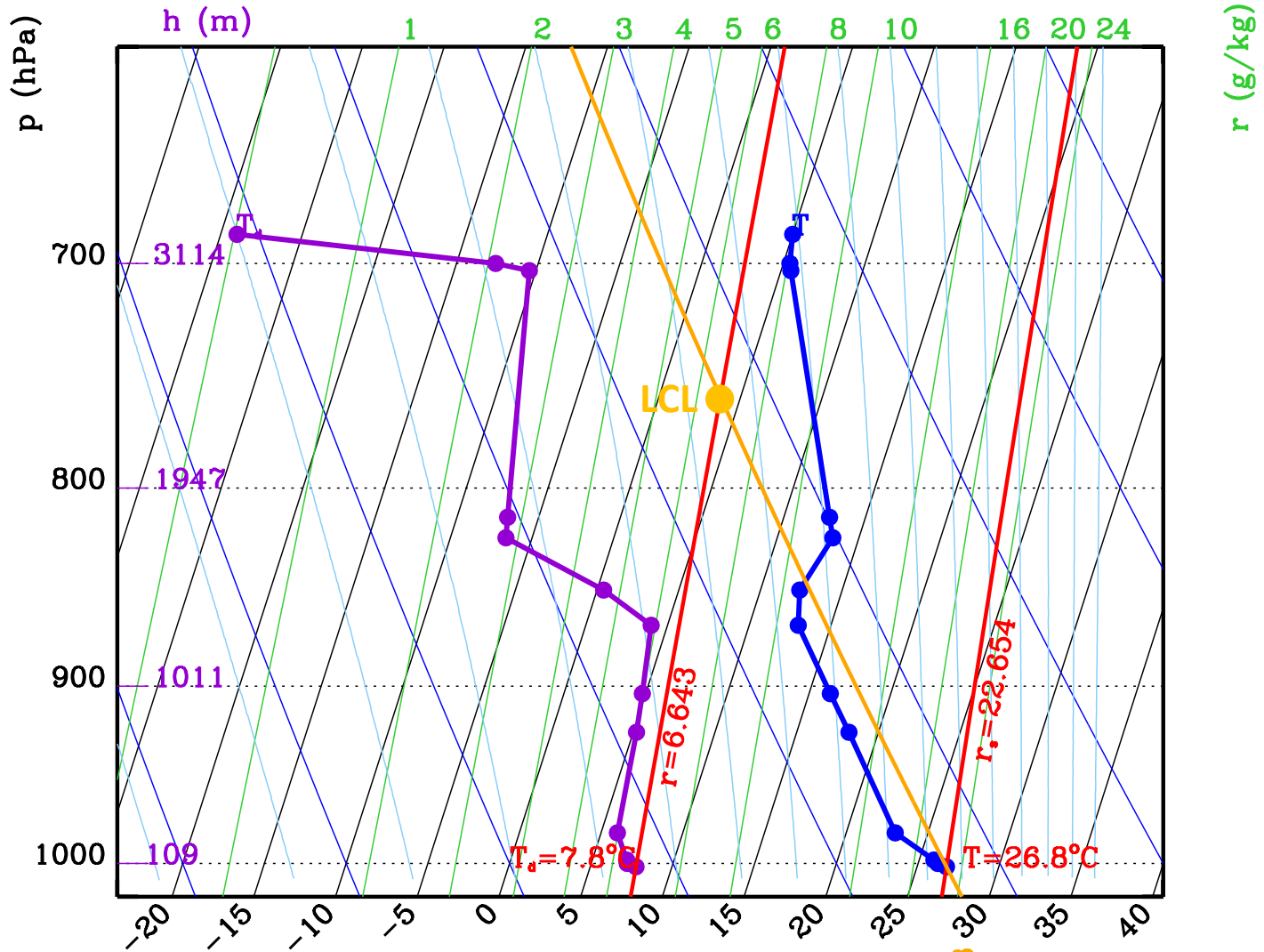


# 12374 Legionowo Observations at 12Z 11 May 2021



$RH = r/r_s = 29.3\%$   
 $RH = q/q_s = 29.8\%$   
 $RH = e/e_s = 30.1\%$

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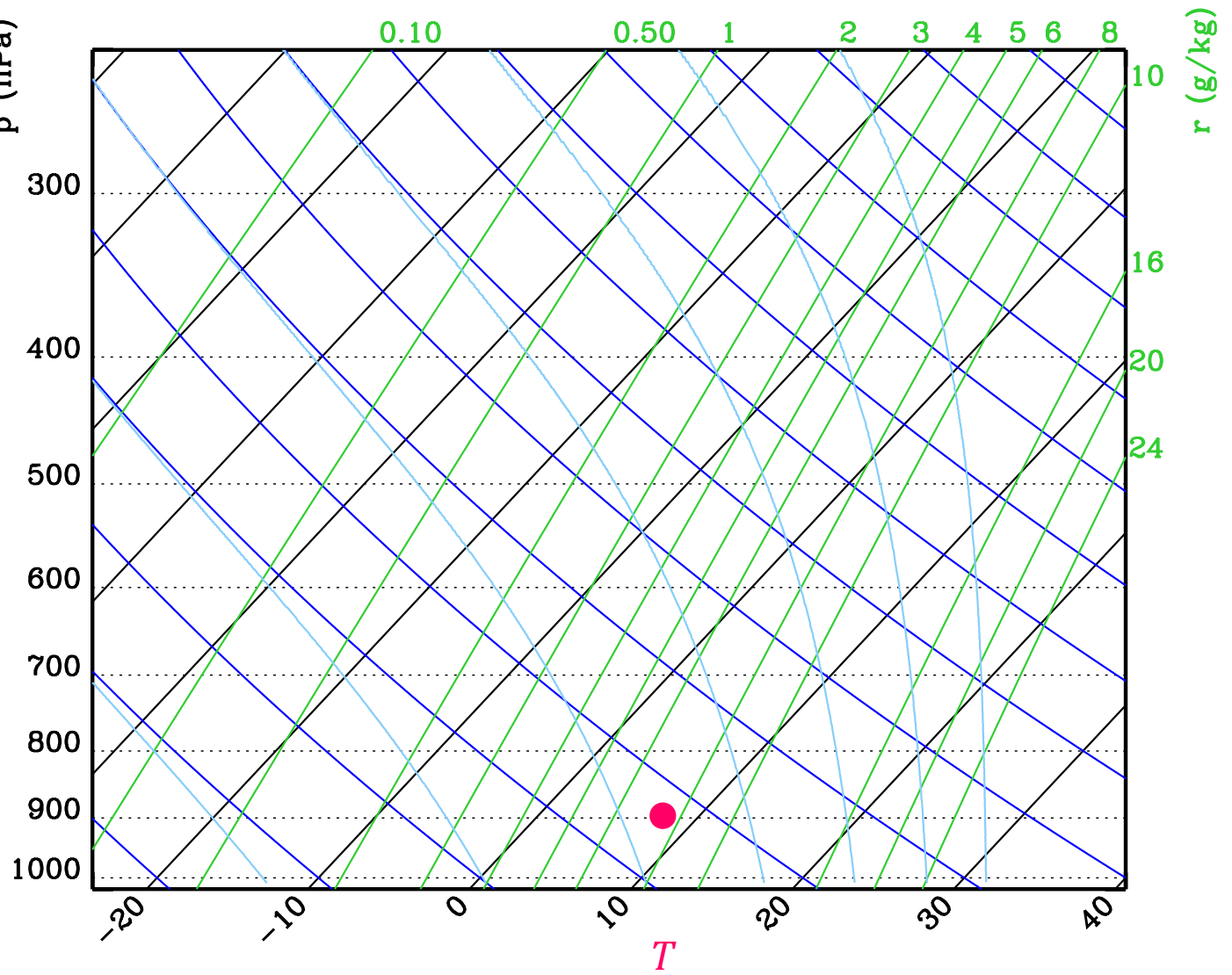
$RH = r/r_s = 29.3\%$   
 $RH = q/q_s = 29.8\%$   
 $RH = e/e_s = 30.1\%$

$T_{LCL} = 3.36^\circ\text{C}$   $p_{LCL} = 753\text{hPa}$   
 $T_{LCL} = 3.63^\circ\text{C}$   $p_{LCL} = 756\text{hPa}$   
 $T_{LCL} = 3.80^\circ\text{C}$   $p_{LCL} = 757\text{hPa}$

$\theta = 299.8$

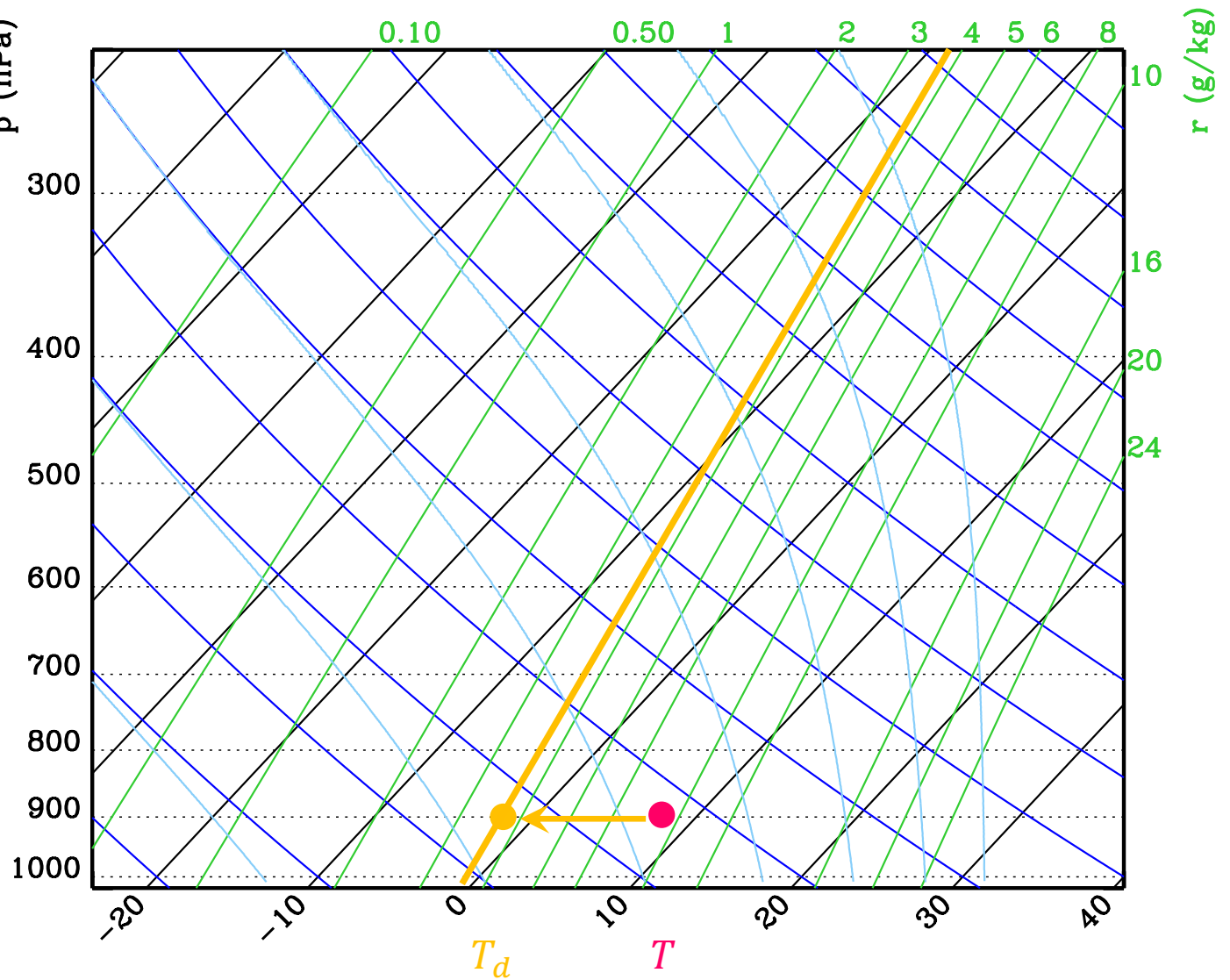


$T_o = 8^\circ\text{C}$   
 $p_o = 900 \text{ hPa}$   
 $r_o = 3.75 \text{ g/kg}$   
 $r_{s0} = 7.5 \text{ g/kg}$   
 $f_o = 50\%$



●  $T_o = 8^\circ\text{C}$   
 $p_o = 900 \text{ hPa}$   
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●  $T_d \approx -2^\circ\text{C}$



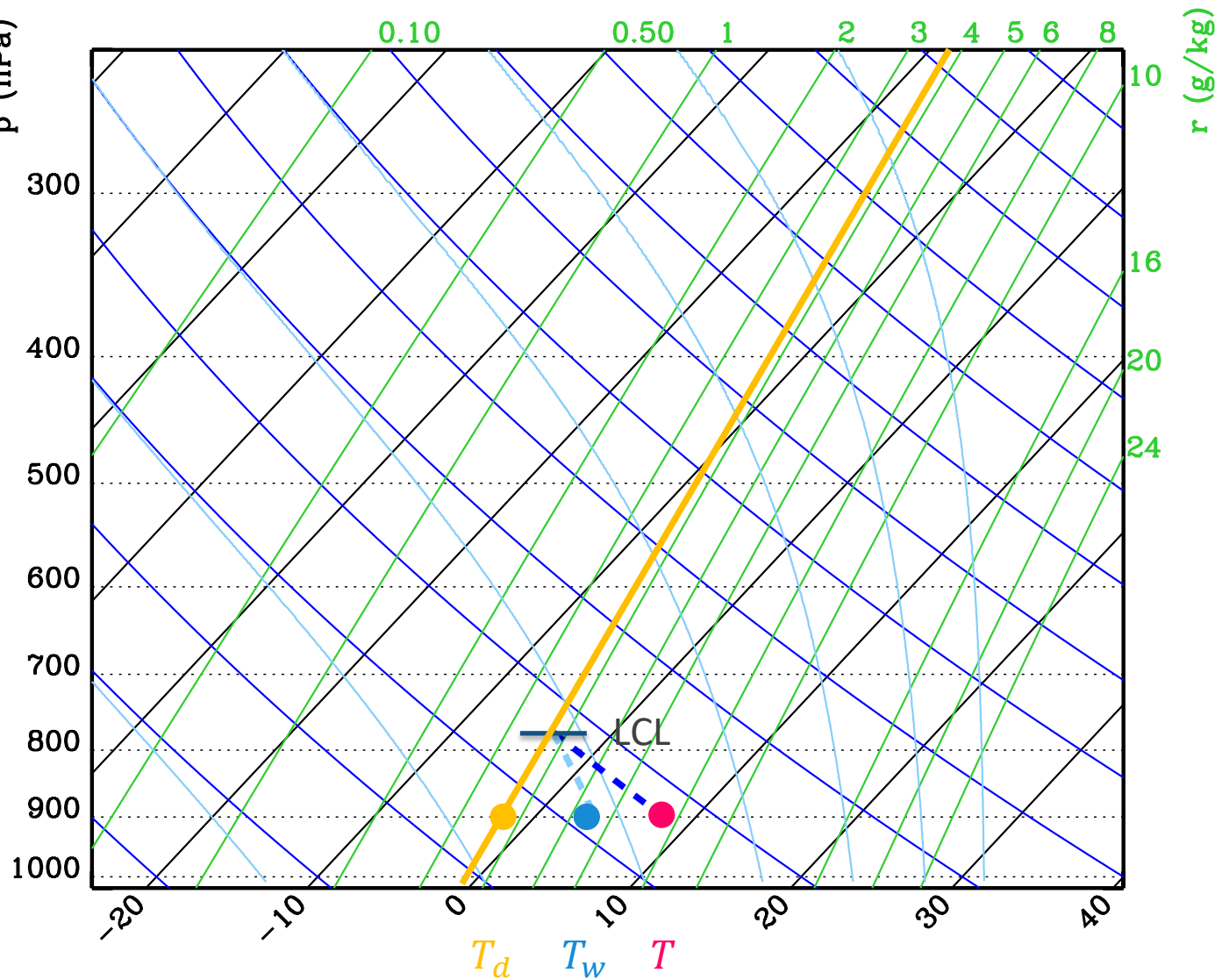


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●  $T_d \approx -2^\circ\text{C}$

●  $T_w \approx 3^\circ\text{C}$

$T_{LCL} \approx -3.8^\circ\text{C}$   
 $p_{LCL} \cong 774 \text{ hPa}$



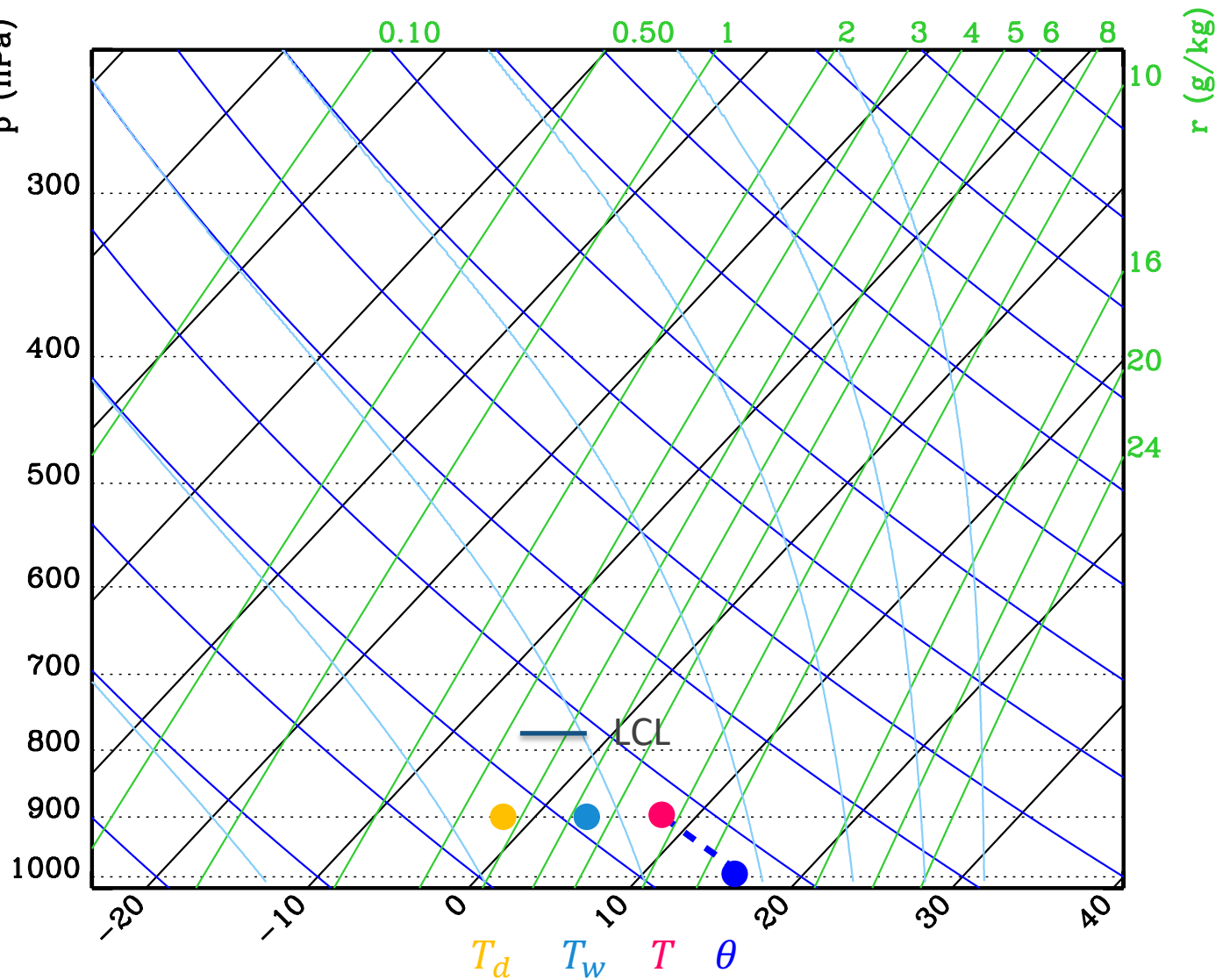
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●  $\theta \approx 16.6^\circ\text{C}$



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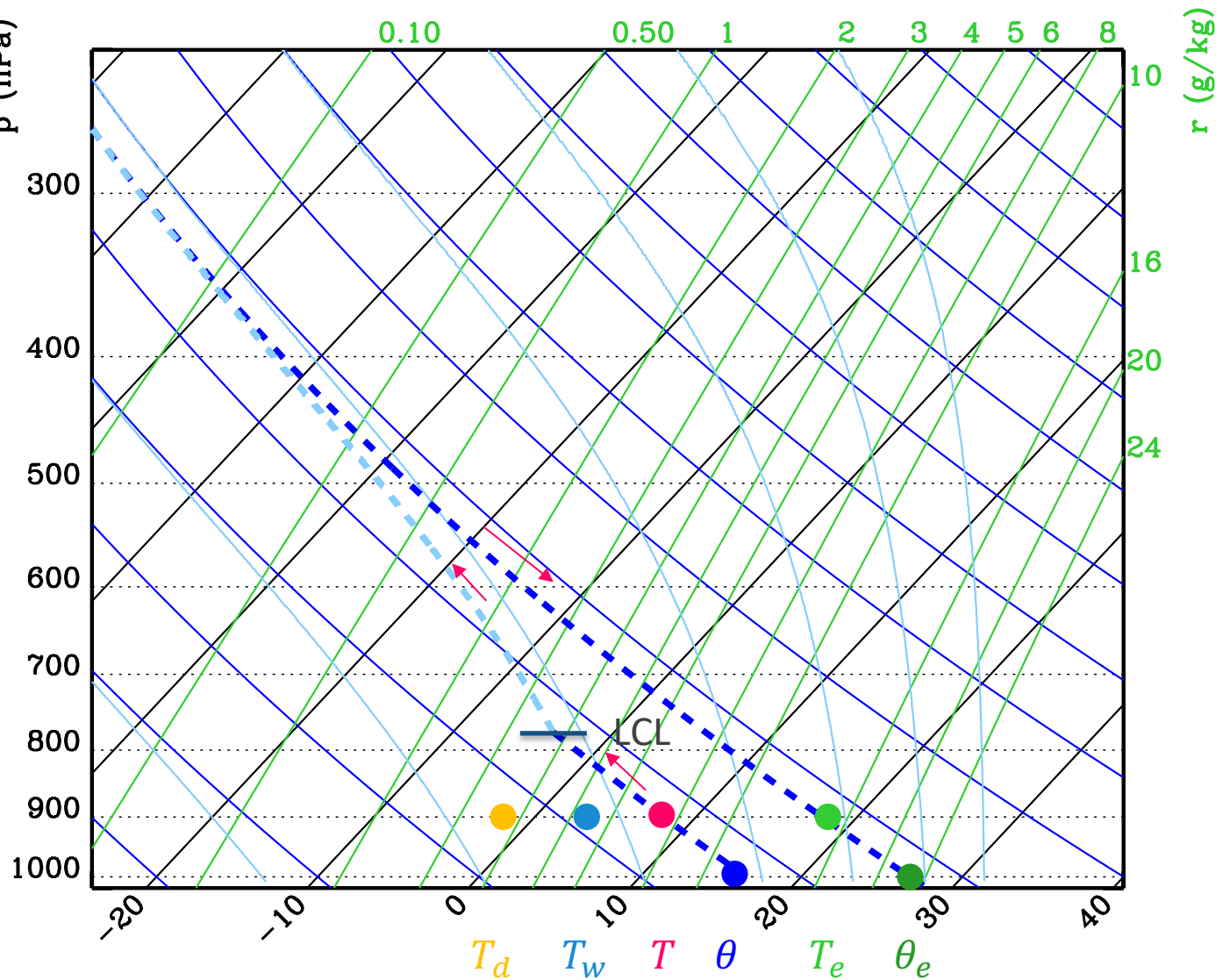
- $T_w \approx -3^\circ\text{C}$

- $T_{LCL} \approx -3.8^\circ\text{C}$   
 $p_{LCL} \cong 774 \text{ hPa}$

- $\theta \approx 16.6^\circ\text{C}$

- $T_e \approx 18^\circ\text{C}$

- $\theta_e \approx 28^\circ\text{C}$



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 $r_o = 3.75 \text{ g/kg}$   
 $r_{s0} = 7.5 \text{ g/kg}$   
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 $p_{LCL} \cong 774 \text{ hPa}$

●  $\theta \approx 16.6^\circ\text{C}$

●  $T_e \approx 18^\circ\text{C}$

●  $\theta_e \approx 28^\circ\text{C}$

●  $T_{se} \approx 26^\circ\text{C}$

●  $\theta_{se} \approx 36^\circ\text{C}$

