Fronts

- Synoptic scale fronts form as a result of large scale deformation**... enhancing initially broad gradients of temperature (Markowski & Richardson, p115)
- A front is more realistically regarded as a discontinuity in temperature gradient than as a discontinuity in temperature (M&R p122)
- Temperature gradient is usually largest on the cold side of a front (M&R p120)

**Stretching deformation

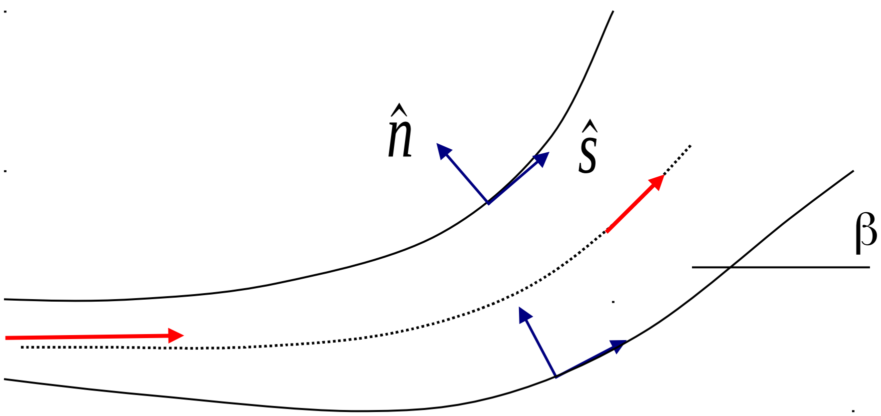
$$\gamma_{st} = \frac{\partial u}{\partial x} - \frac{\partial v}{\partial y} = \frac{\partial v}{\partial s} - v\frac{\partial \beta}{\partial n}$$

**Shearing deformation

$$\gamma_{sh} = \frac{\partial v}{\partial x} + \frac{\partial u}{\partial y} = \frac{\partial v}{\partial n} + v\frac{\partial \beta}{\partial s}$$

**Horiz. divergence

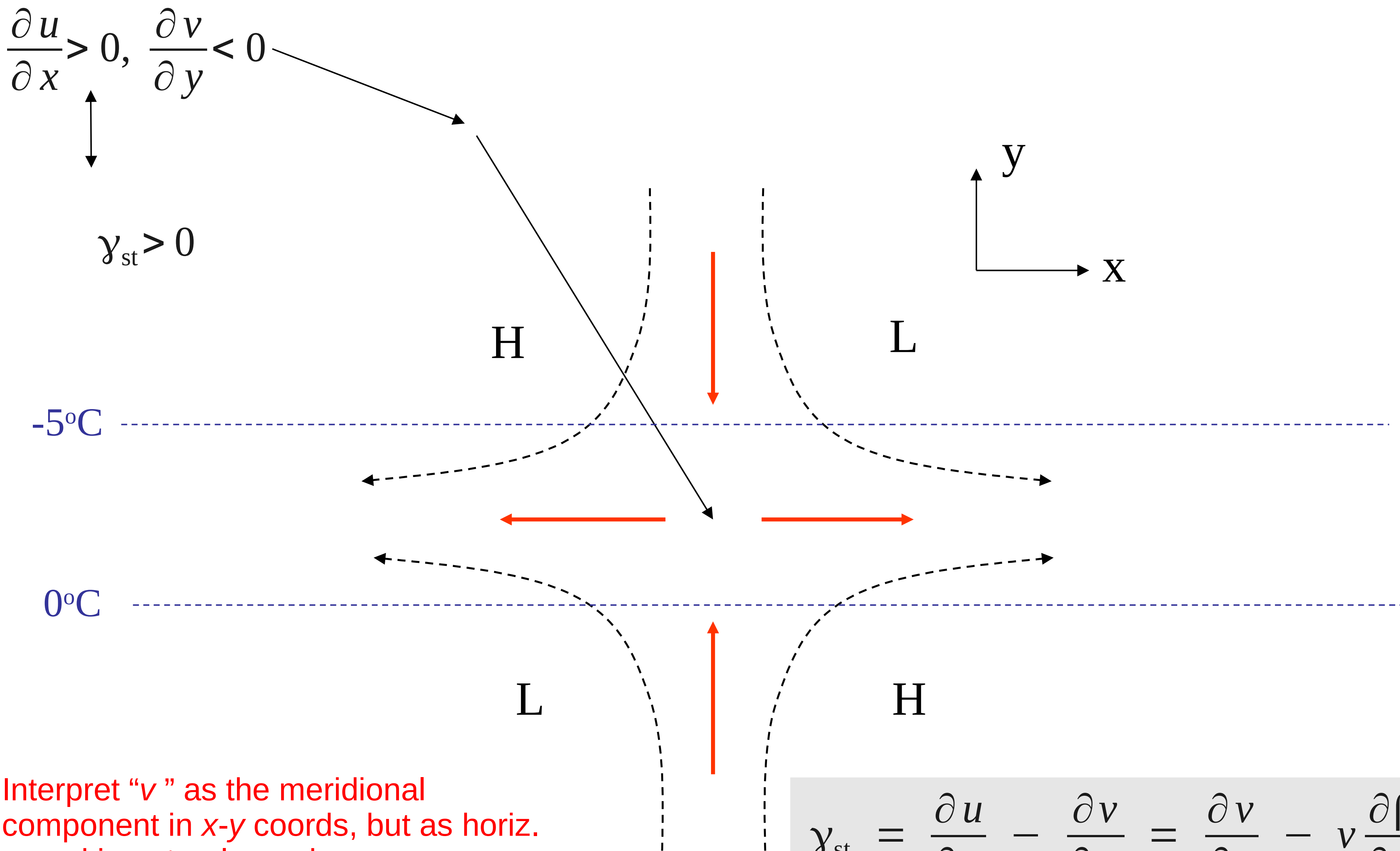
$$\delta = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}$$



$$\frac{\partial v}{\partial s} < 0 \qquad v\frac{\partial \beta}{\partial n} > 0$$

Interpret "*v* " as the meridional component in *x*-*y* coords, but as horiz. speed in natural coords

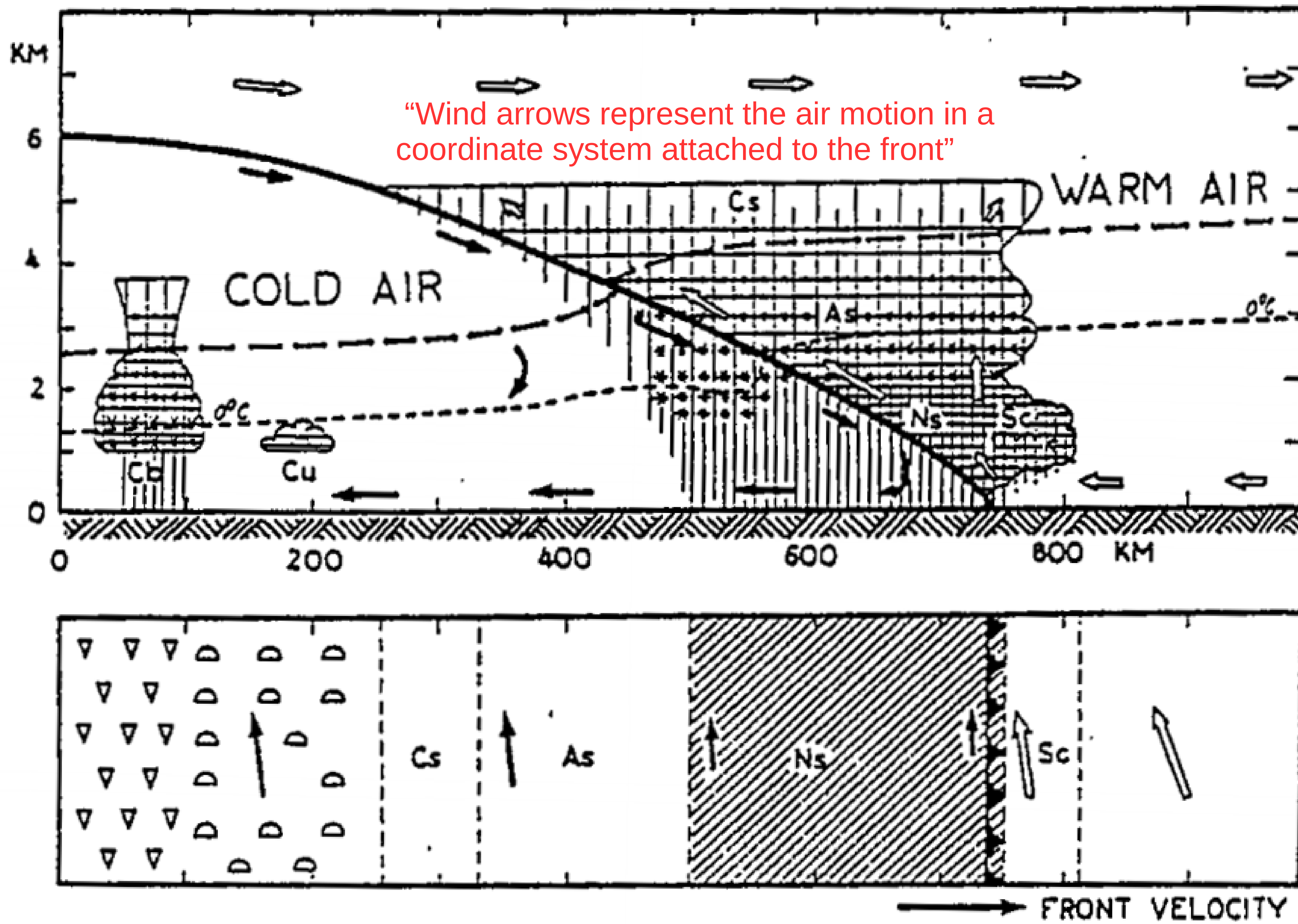
eas372_fronts.odp
JDW, EAS U. Alberta
See also
eas372_deformation_frontogenesis.odp
Last modified: 16 Mar. 2017



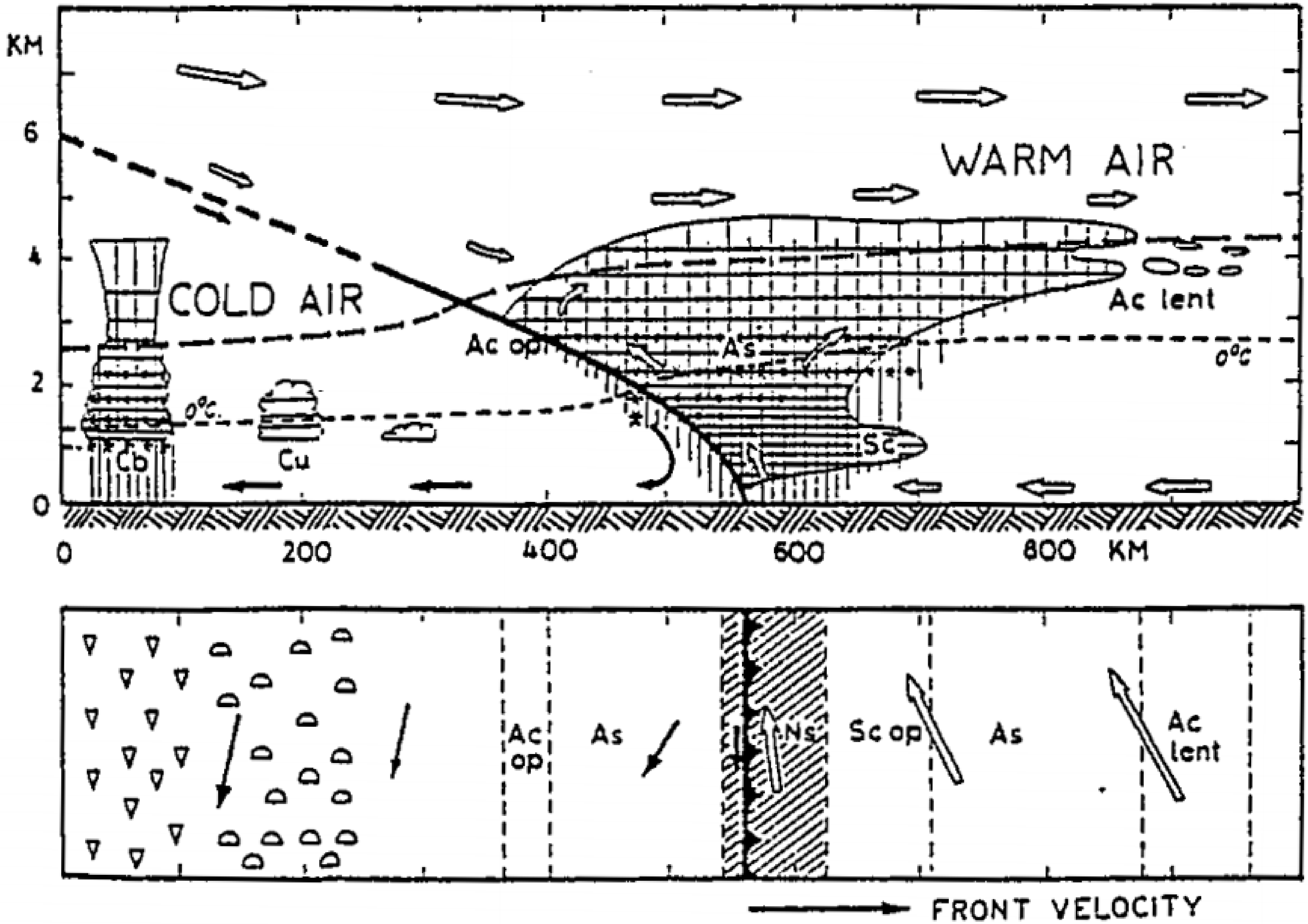
Interpret "*v* " as the meridional component in *x*-*y* coords, but as horiz. speed in natural coords

$$\gamma_{st} = \frac{\partial u}{\partial x} - \frac{\partial v}{\partial y} = \frac{\partial v}{\partial s} - v\frac{\partial \beta}{\partial n}$$

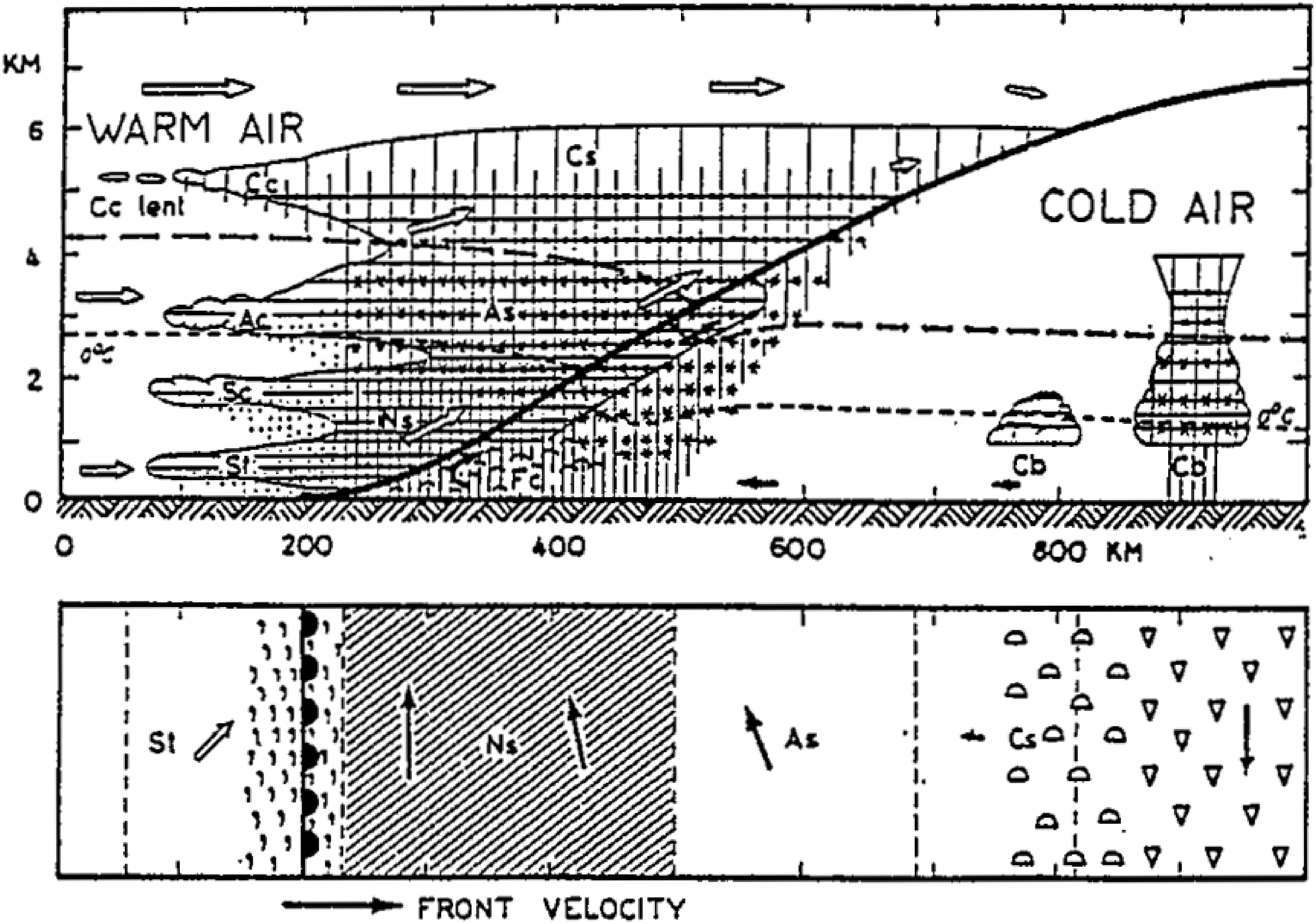
To evaluate which deformation component this exemplifies, focus on the centre-point. Streamline is undefined there, so we need to use the Cartesian axes. The stretching deformation is positive; however (assuming the contour pattern is symmetric) the shearing deformation is zero



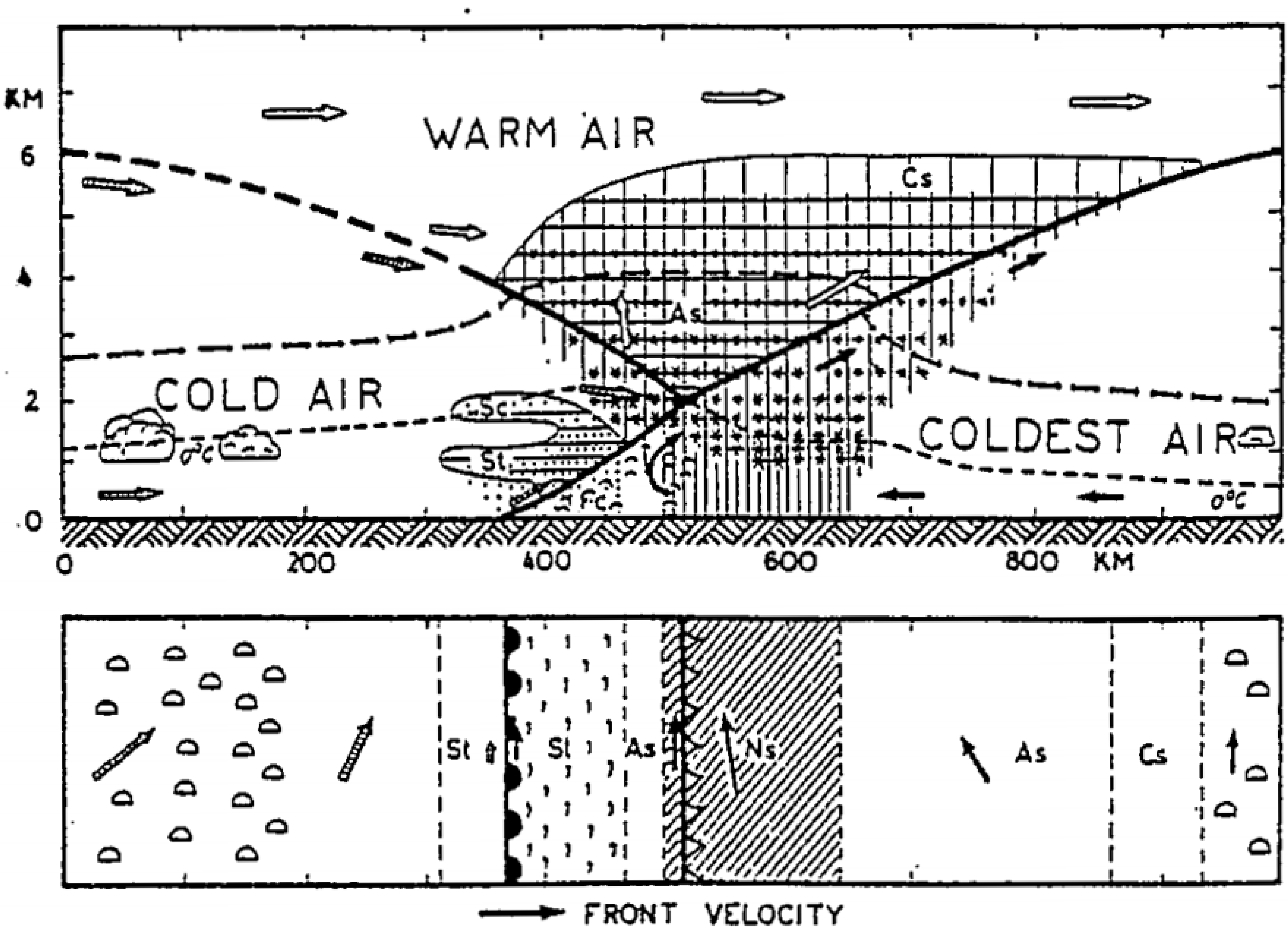
Fast moving cold front (Godske et al., 1957) “Fronts are called “active” when warm air ascends along the front surface and “inactive” when it descends



Slow moving cold front (Godske et al., 1957) . “Wind arrows represent the air motion in a coordinate system attached to the front”

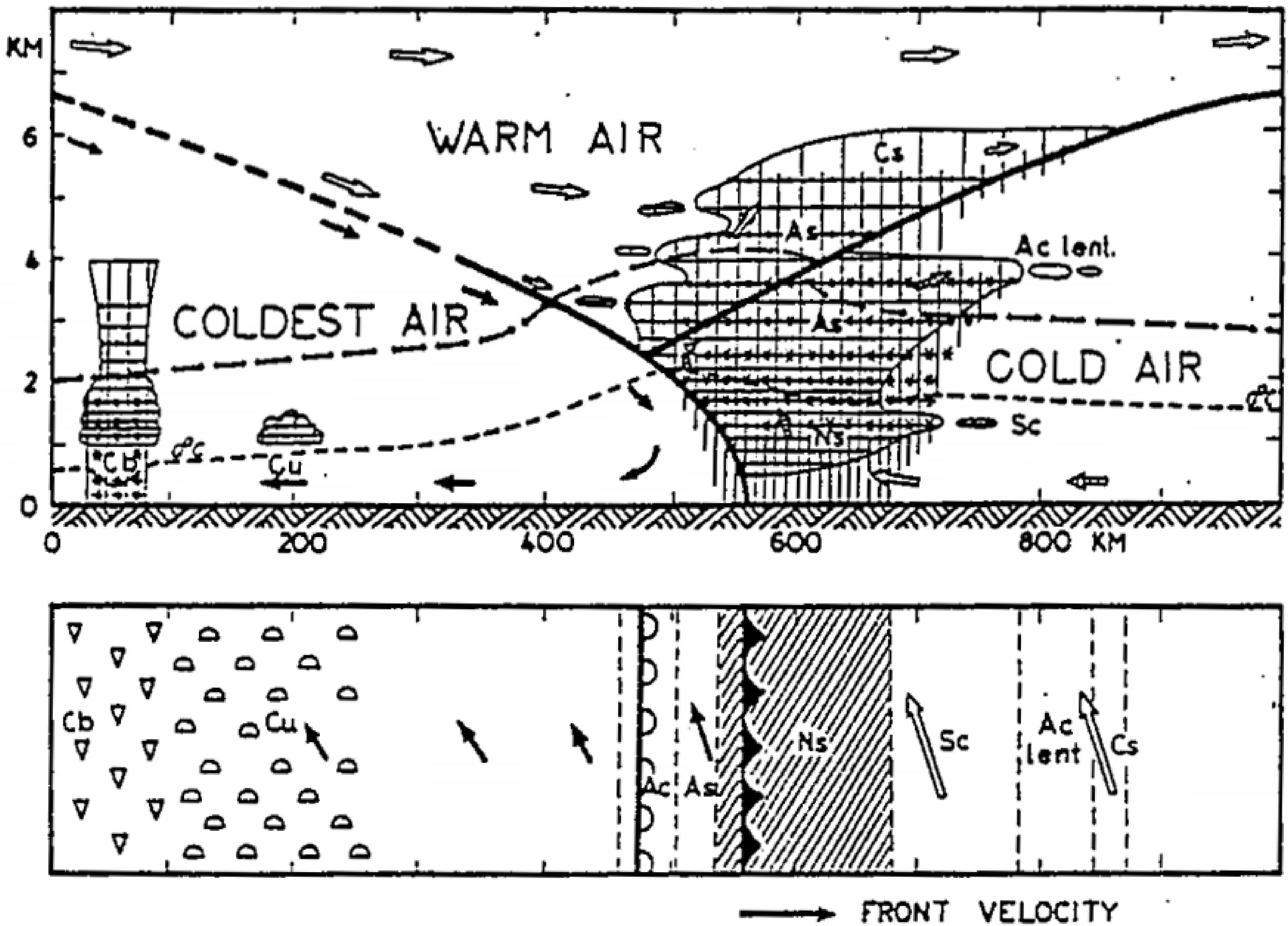


Warm front (Godske et al., 1957) “Wind arrows represent the air motion in a coordinate system attached to the front”



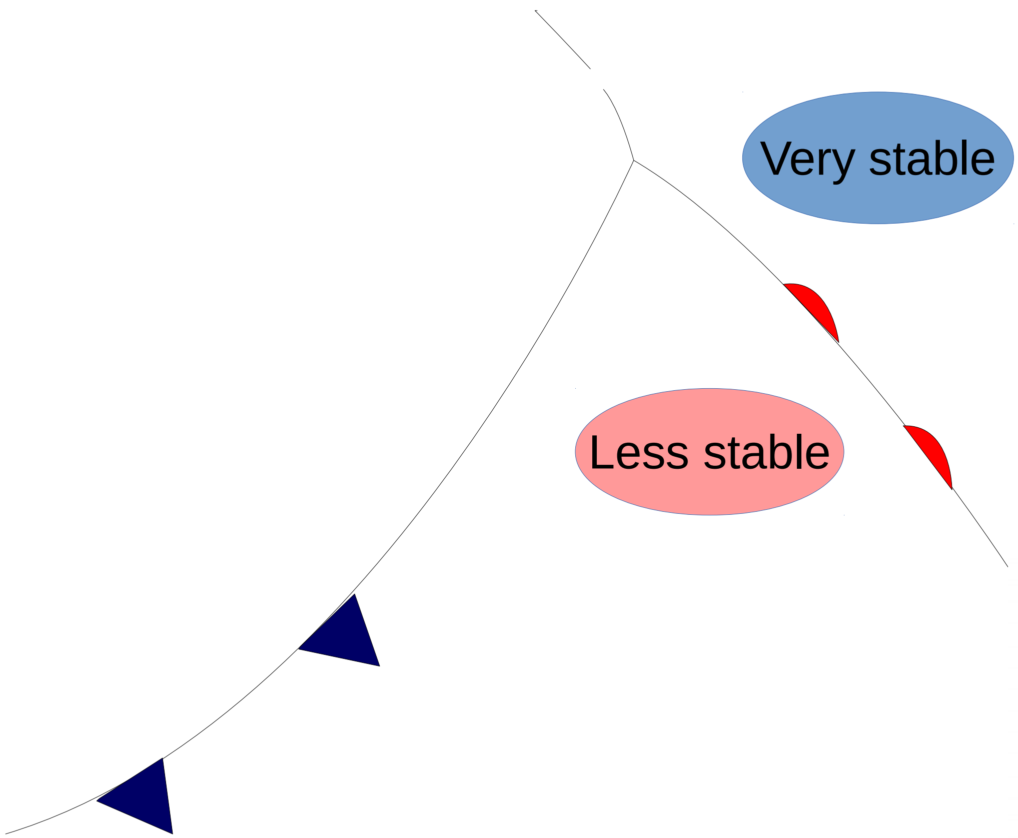
Occluded front – warm occlusion type (Godske et al., 1957)

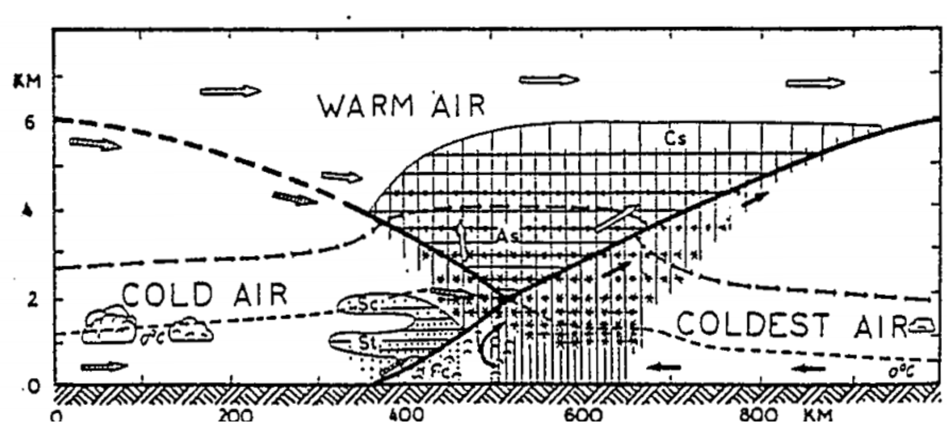
This is the more common type of occlusion – see over



Occluded front – cold occlusion type (Godske et al., 1957)

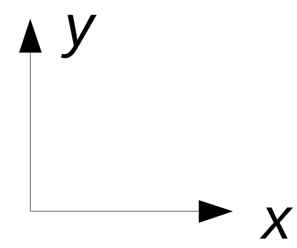
- It is now believed that the type of occlusion that forms depends on the difference in static stability of the two cold air masses enclosing the warm sector – the warm occlusion is almost always observed, and results when static stability of the column in the warm sector is less stable than that of the column In the cold air (Markowski & Richardson, p119)

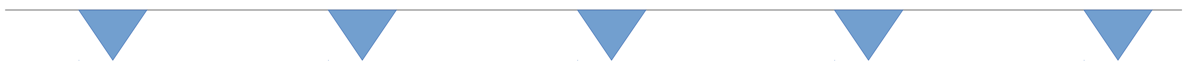




Frontogenesis

$$\frac{\partial \theta}{\partial y} < 0$$





Define $F = -\frac{D}{Dt} \frac{\partial \theta}{\partial y} < 0$ (rate of intensification of θ gradient following the front)

Neglecting any contribution due to surface heat input/loss or any internal heat source/sink (evaporation/condensation), Dθ/Dt =0. Manipulation gives an approximate expression

$$\frac{D}{Dt} |\nabla_h \theta| \approx \frac{|\nabla_h \theta|}{2} \left(\sqrt{\gamma_{st}^2 + \gamma_{sh}^2} \cos 2\beta - \delta \right)$$

In this formula (M&R 5.10) β is the angle between isentropes (lines of constant potential temperature) and the axis along which fluid elements are stretched

for the rate of advectively-caused frontogenesis, involving the divergence and deformation of the velocity field. Frontogenesis occurs whenever (paraphrasing M&R, p124):

- horizontal gradient in θ coincides with velocity *convergence*

  or

- *deformation* coincides with isentropes whose orientation relative to the flow is suitable

Markowski & Richardson Fig 5.4 (frontogenesis in unidirectional winds)

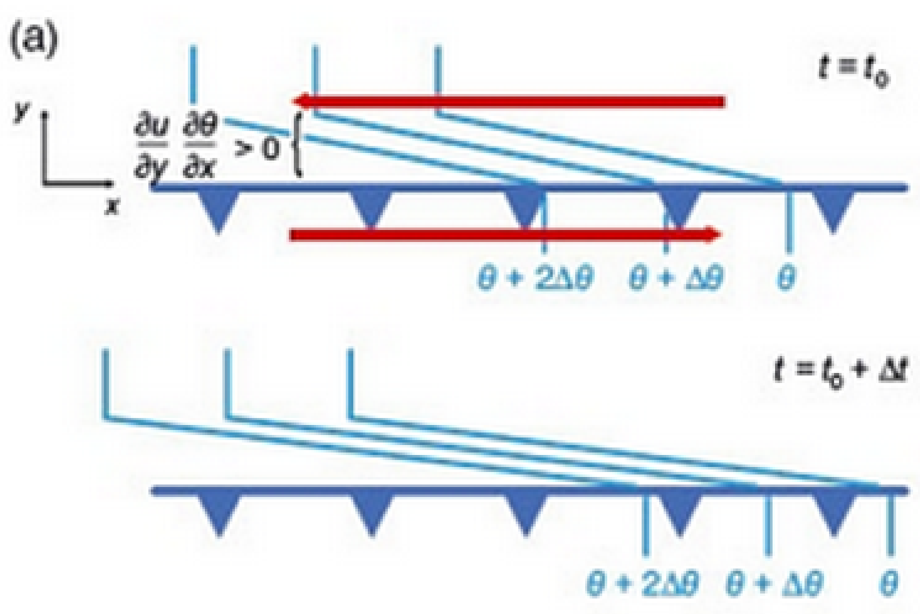
Frontogenesis due to shearing deformation

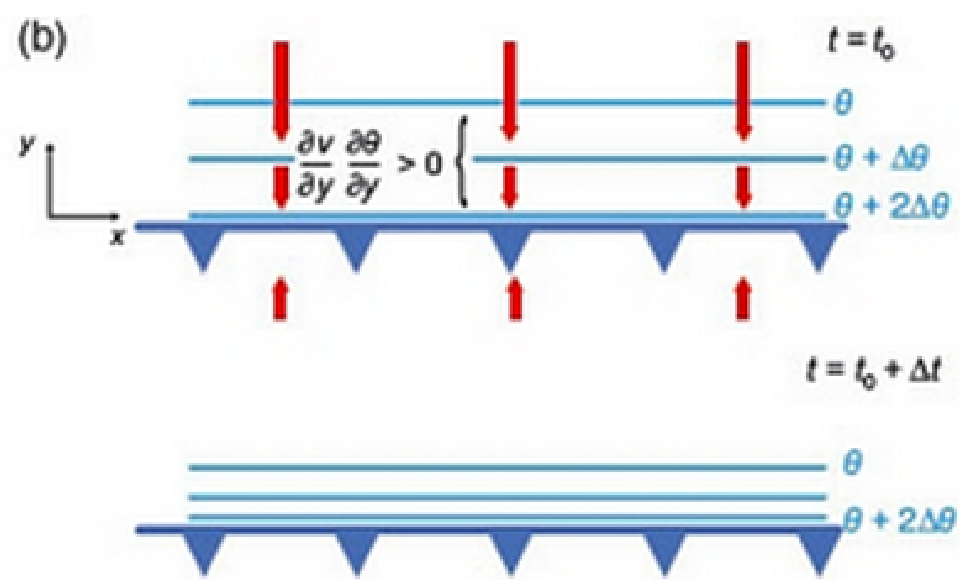
… due to convergence (and stretching deformation)

isentropes are locked in the flow

$$\gamma_{sh} = \frac{\partial v}{\partial x} + \frac{\partial u}{\partial y}$$

$$\gamma_{st} = \frac{\partial u}{\partial x} - \frac{\partial v}{\partial y}$$





Markowski & Richardson Fig 5.5, frontogenesis from stretching deformation

$\frac{\partial v}{\partial y} < 0 \quad \partial u/\partial x > 0 \quad \therefore \gamma_{st} > 0$