Polar low dynamics: conducive environments & the role of moisture

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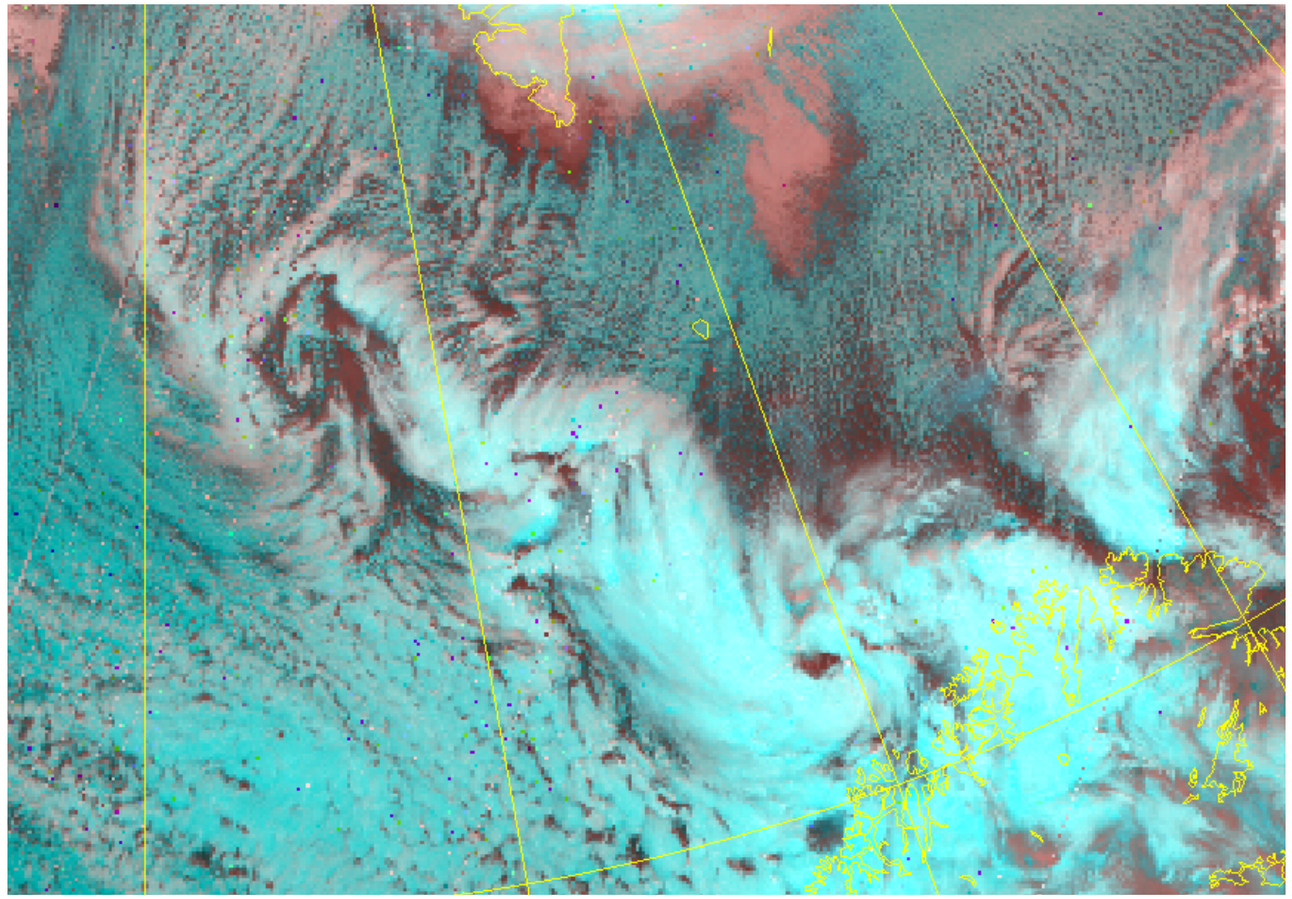
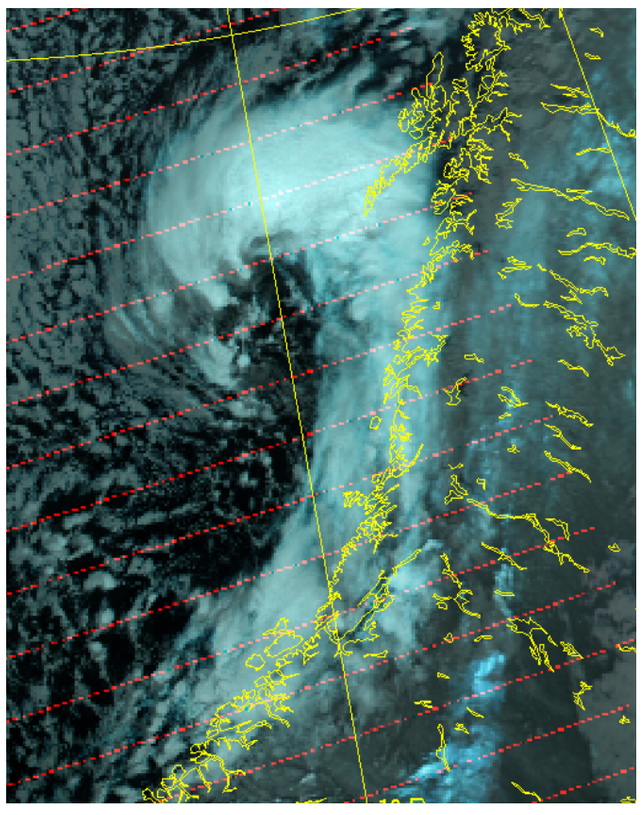
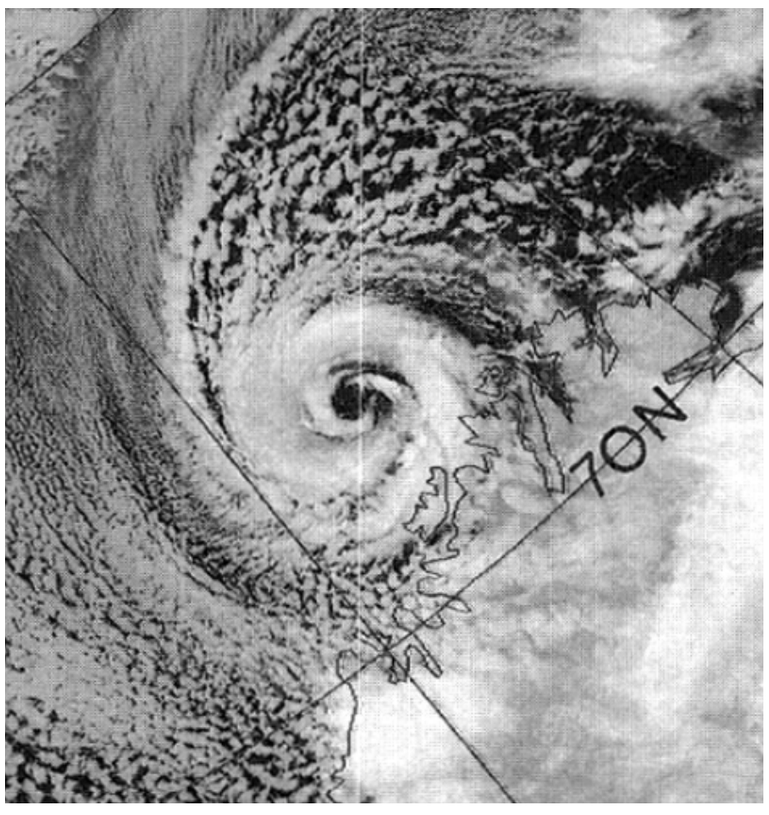
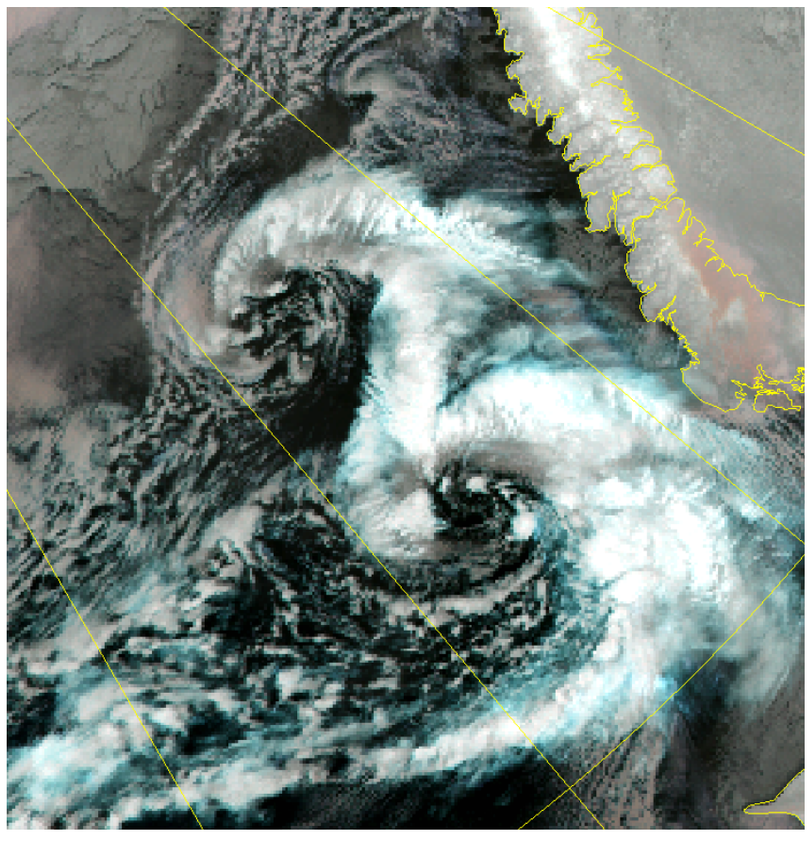


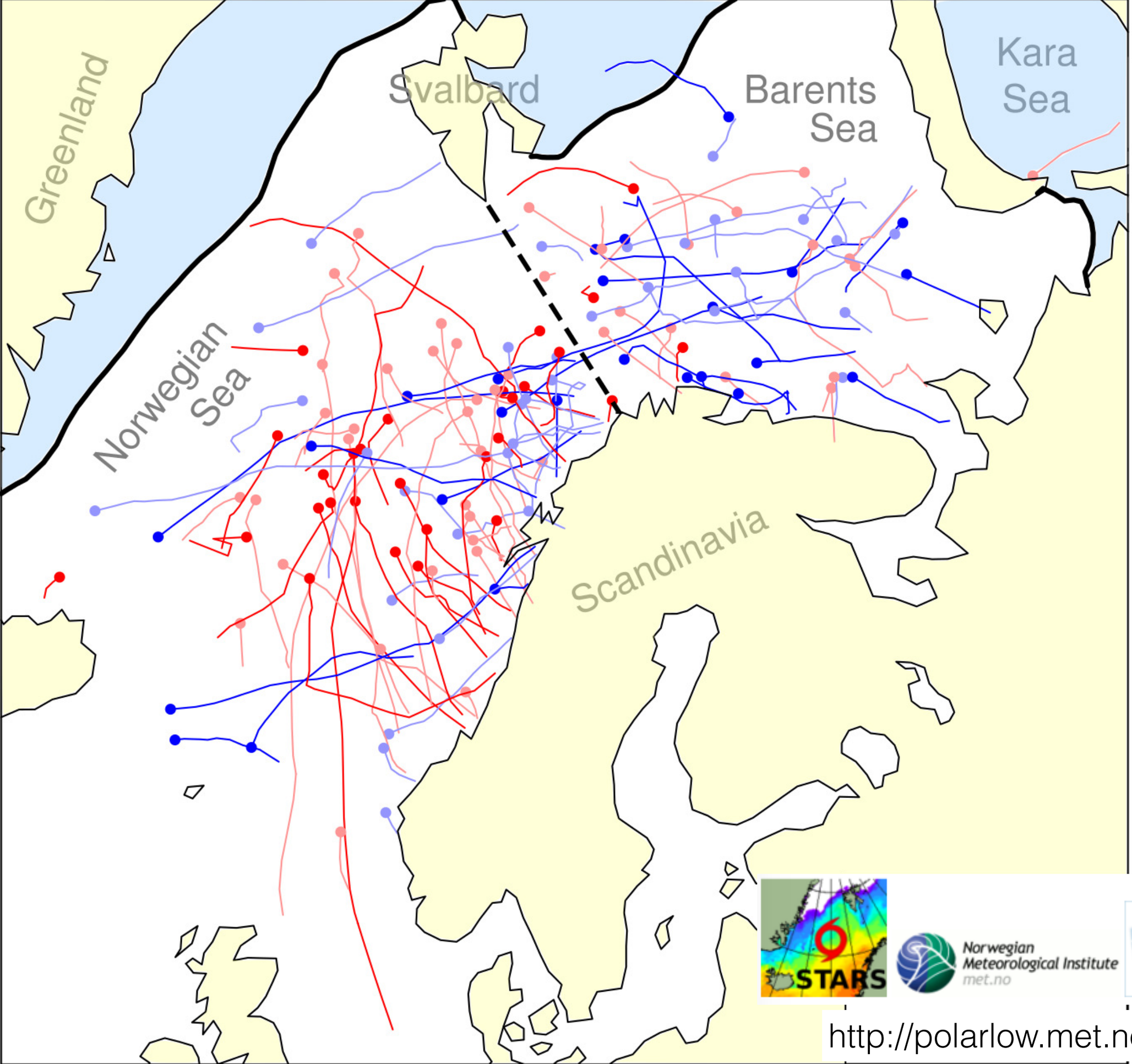
Polar lows:

- maritime, high latitudes
- short lived (~ 1 day)
- intense (wind > 15 m s^{-1})
- small (D~300 km)









2002-2011

131 cases

based on:
satellite products &
NWP forecasts

http://polarlow.met.no/

Vertical shear

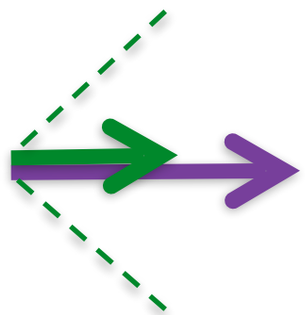
thermal wind

$$U_t = \left(-\frac{1}{f}\frac{\partial \phi(925-700)}{\partial y}, \frac{1}{f}\frac{\partial \phi(925-700)}{\partial x} \right)$$

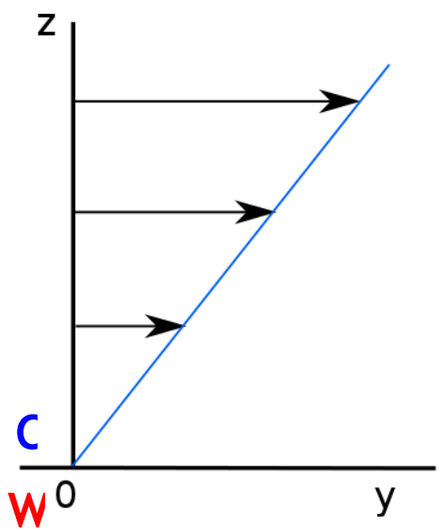
mean wind

$$U_s = (\overline{u}(925-700), \overline{v}(925-700))$$

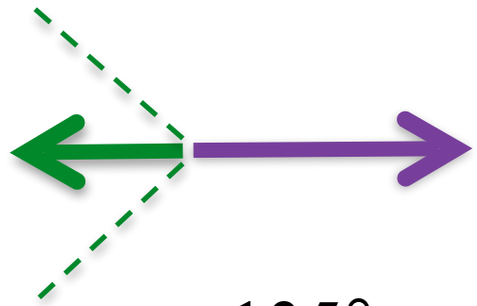
$$cos\alpha = \frac{U_t \cdot U_s}{\|U_t\| \|U_s\|}$$



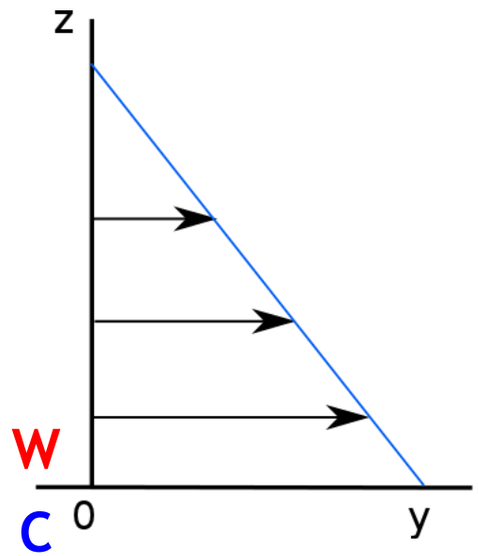
$\alpha < 45°$



FORWARD SHEAR



$\alpha > 135°$

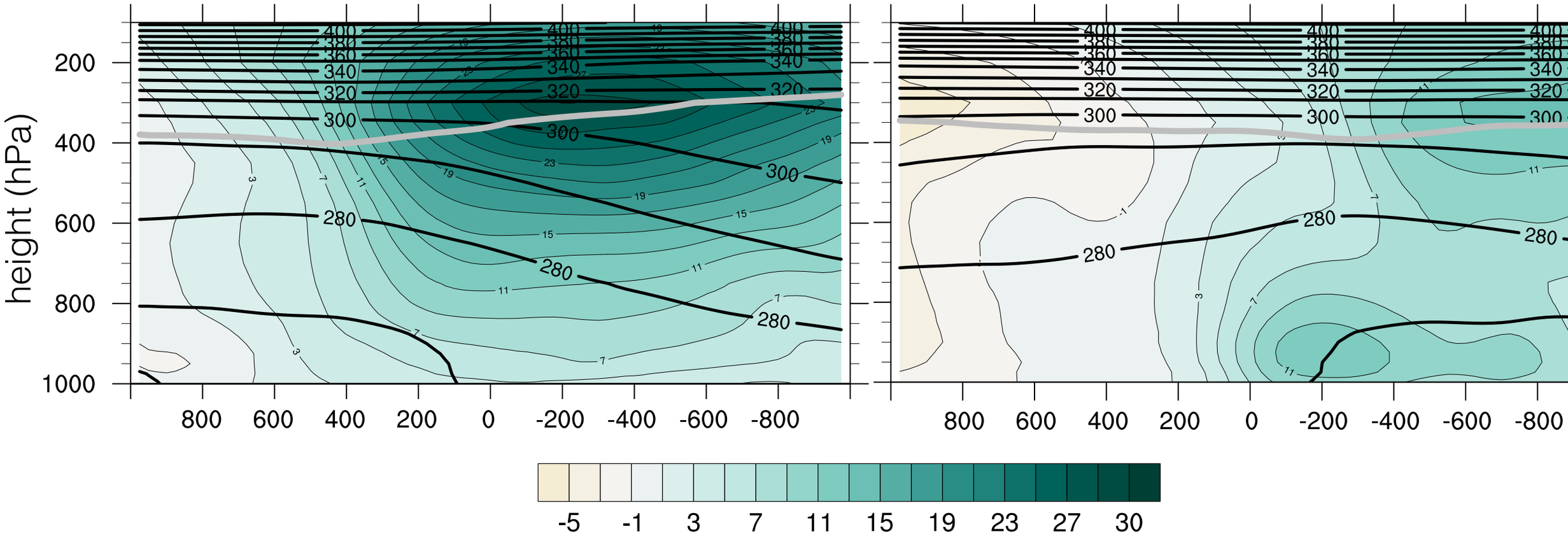


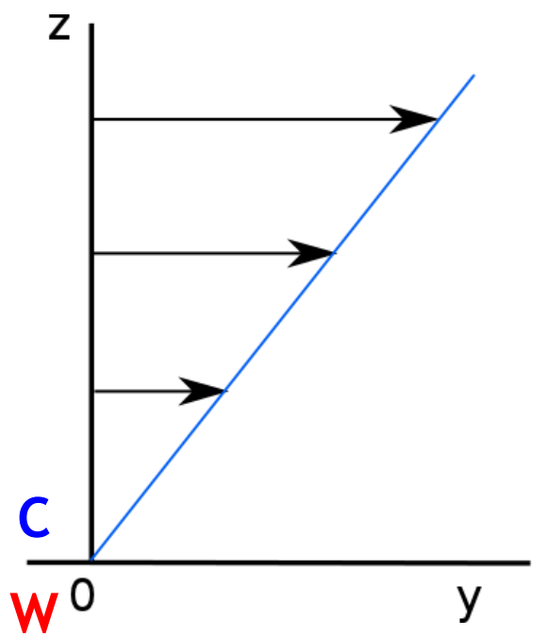
REVERSE SHEAR

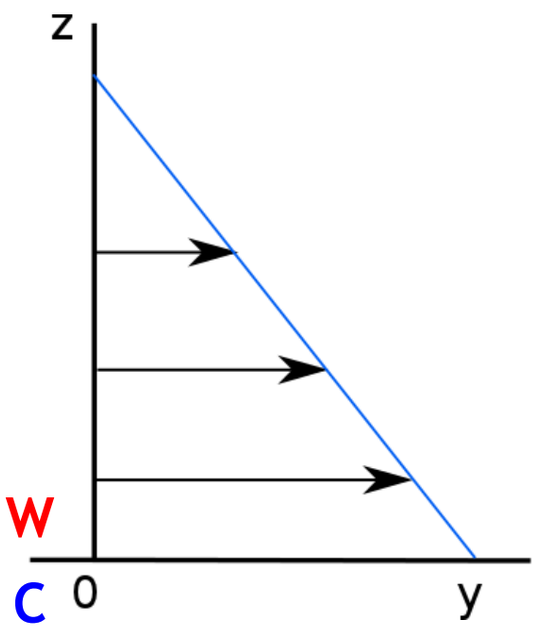
Vertical cross-section: perpendicular to propagation direction

FORWARD SHEAR

REVERSE SHEAR

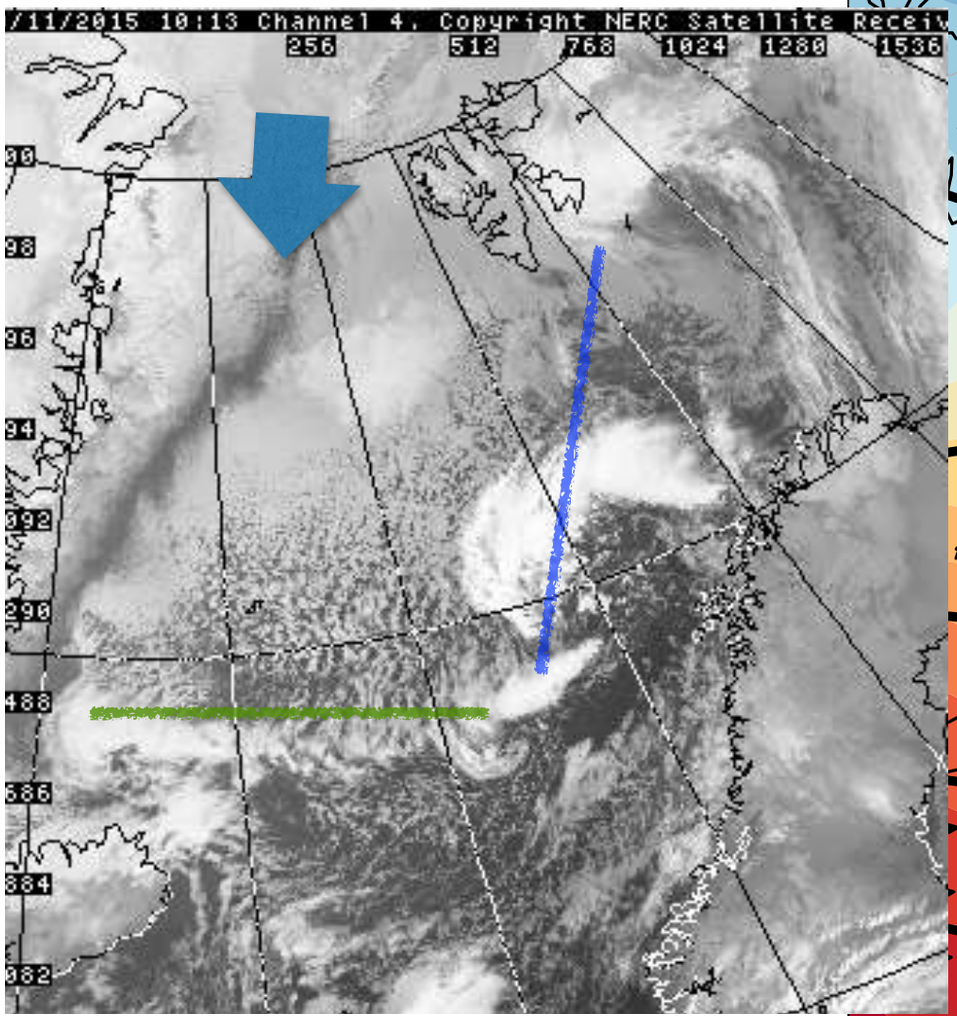




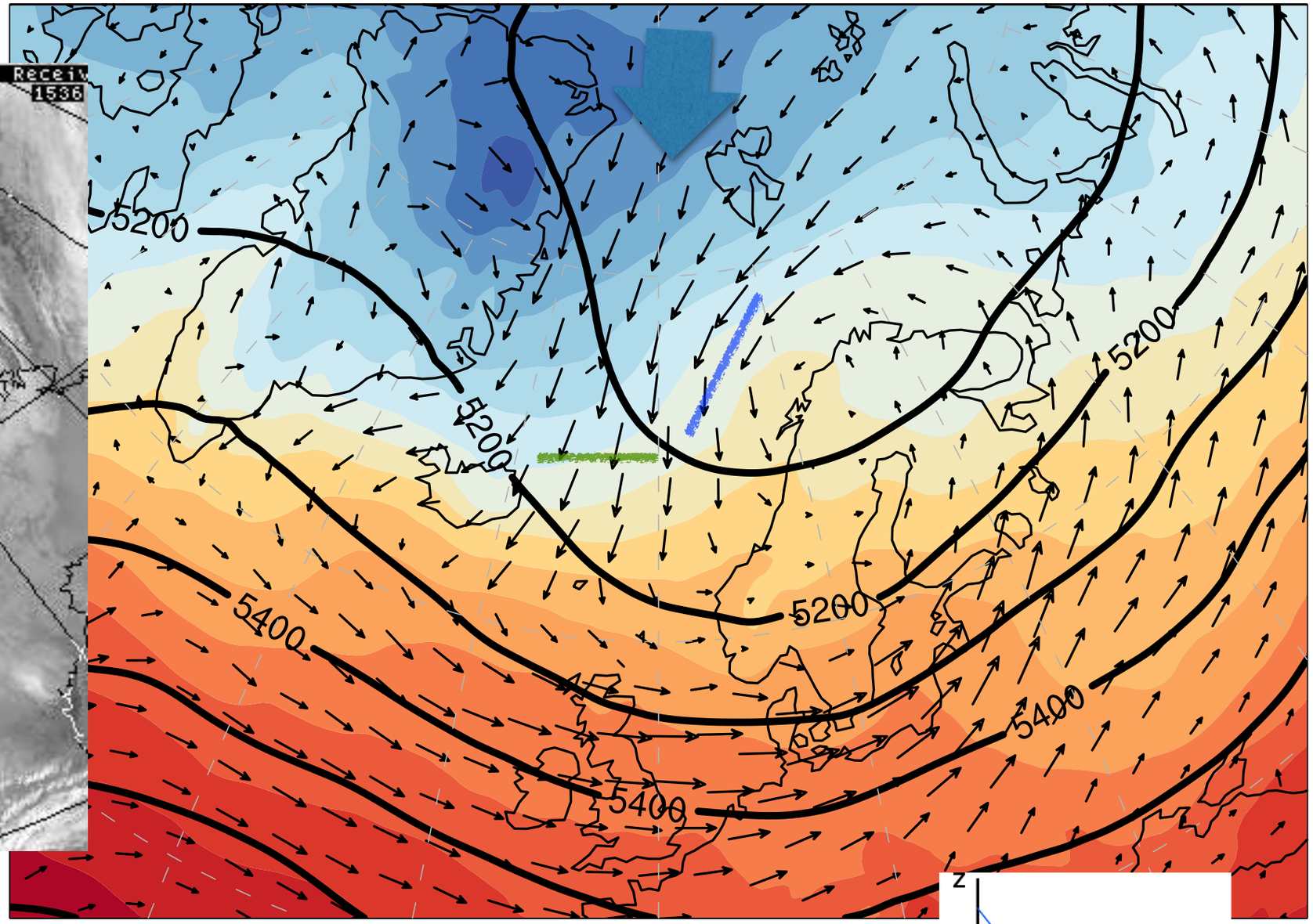


REVERSE SHEAR

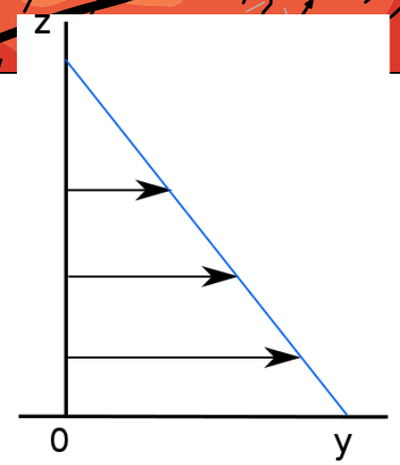
case



composite



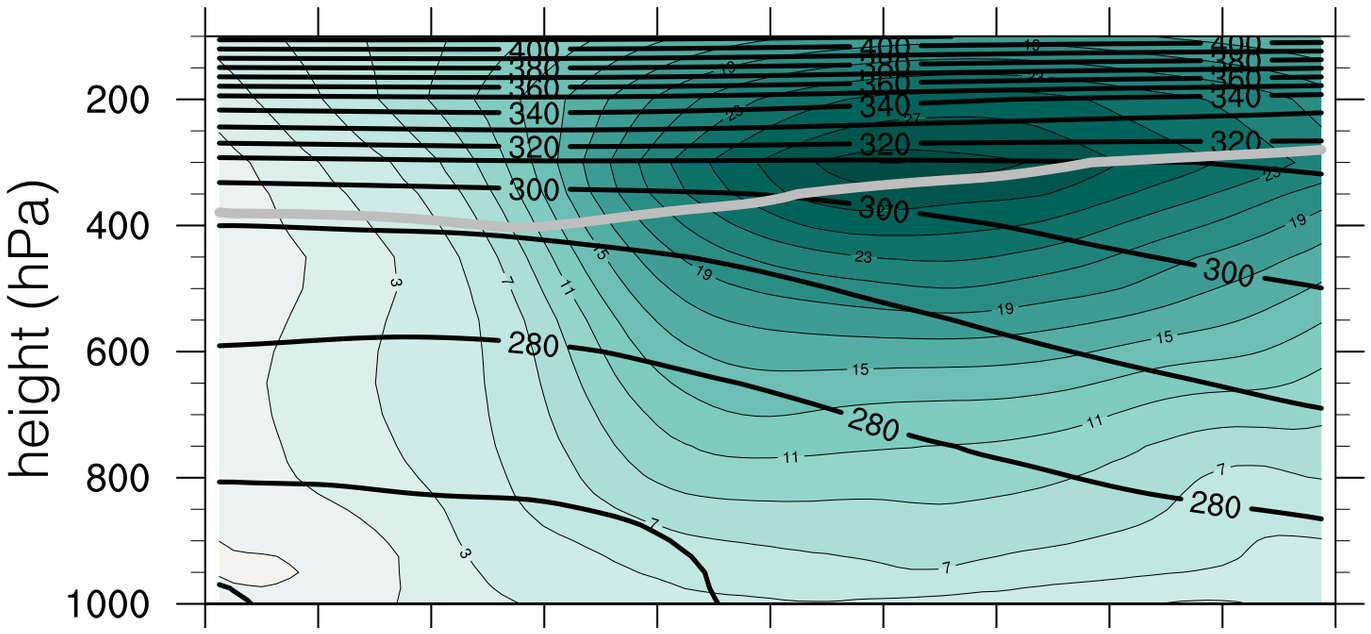
wind @ 950hPa (arrows)
pot.temp.@ 950 hPa (shading)
ght @ 500 hPa(lines)

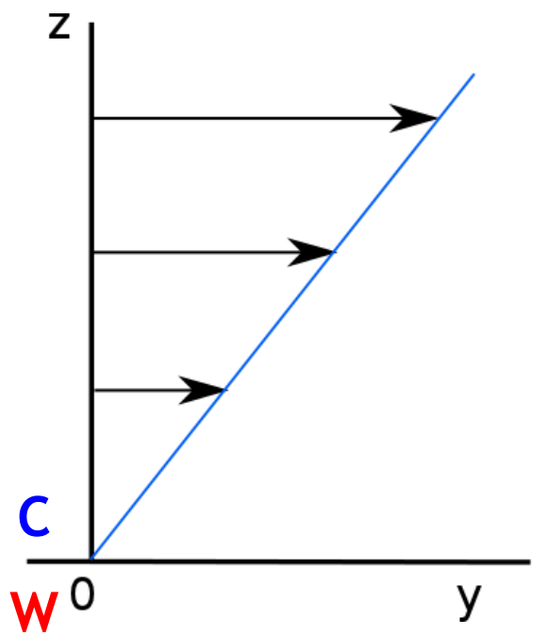


Terpstra et.al. (2016) MWR.

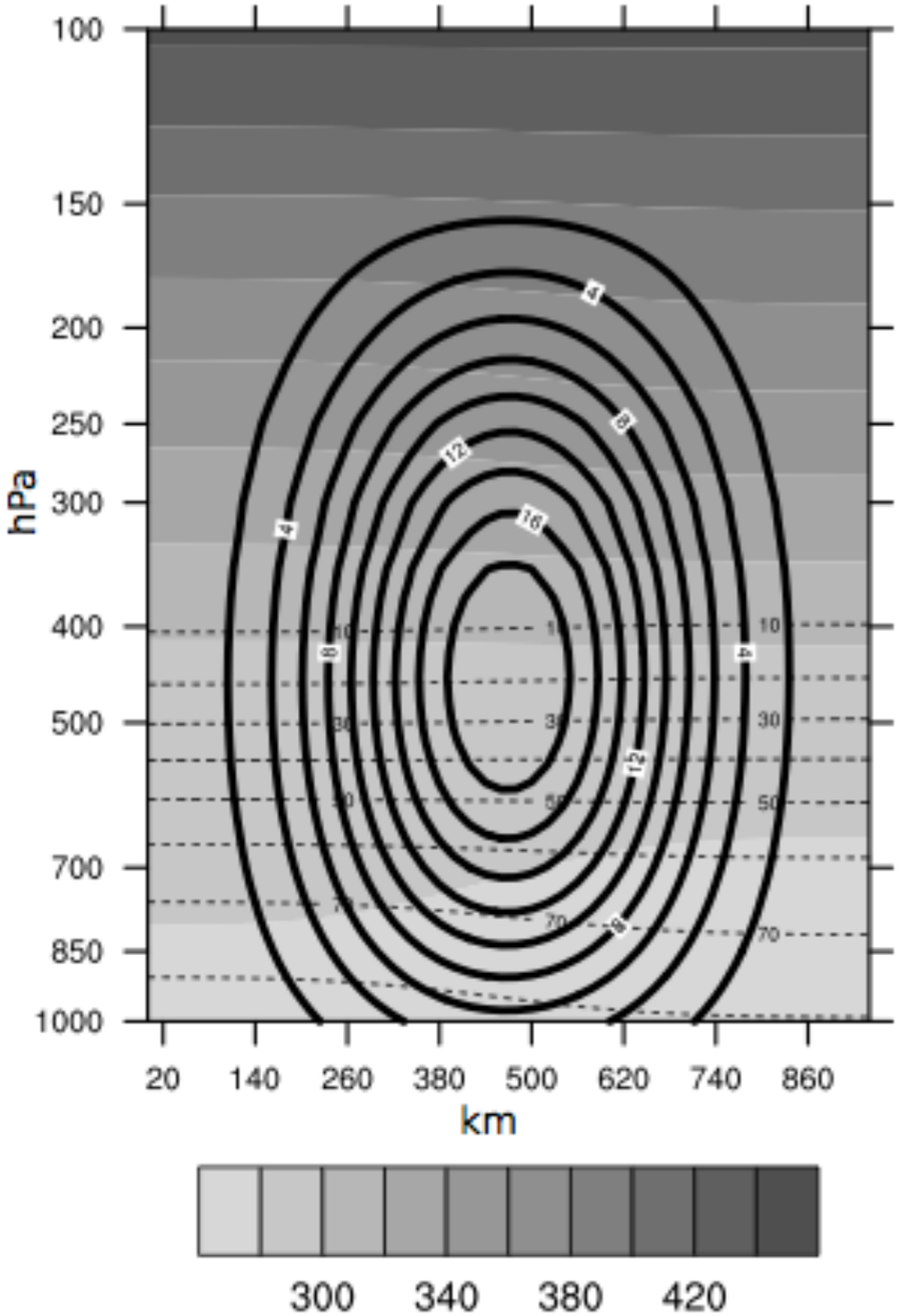
FORWARD SHEAR

Composite





Simplified



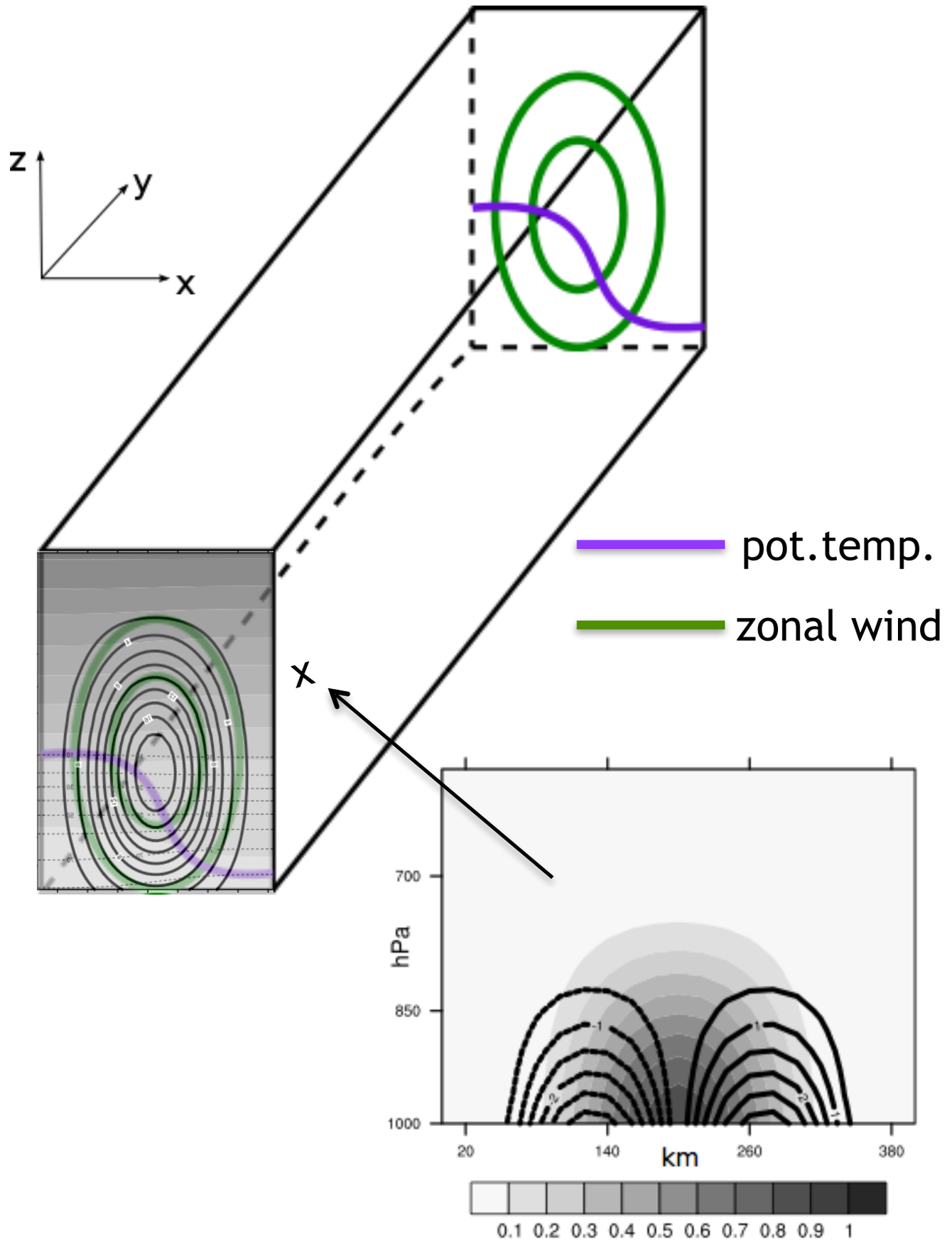
WRF

idealized baroclinic channel

- domain: 7500x2000x25 km
- hor. resolution: 20x20 km
- vert. levels: 61
- periodic zonal BC
- parameterization:
  - microphysics [Lin]
  - cumulus [Grell]
  - no surface fluxes/PBL/radiation

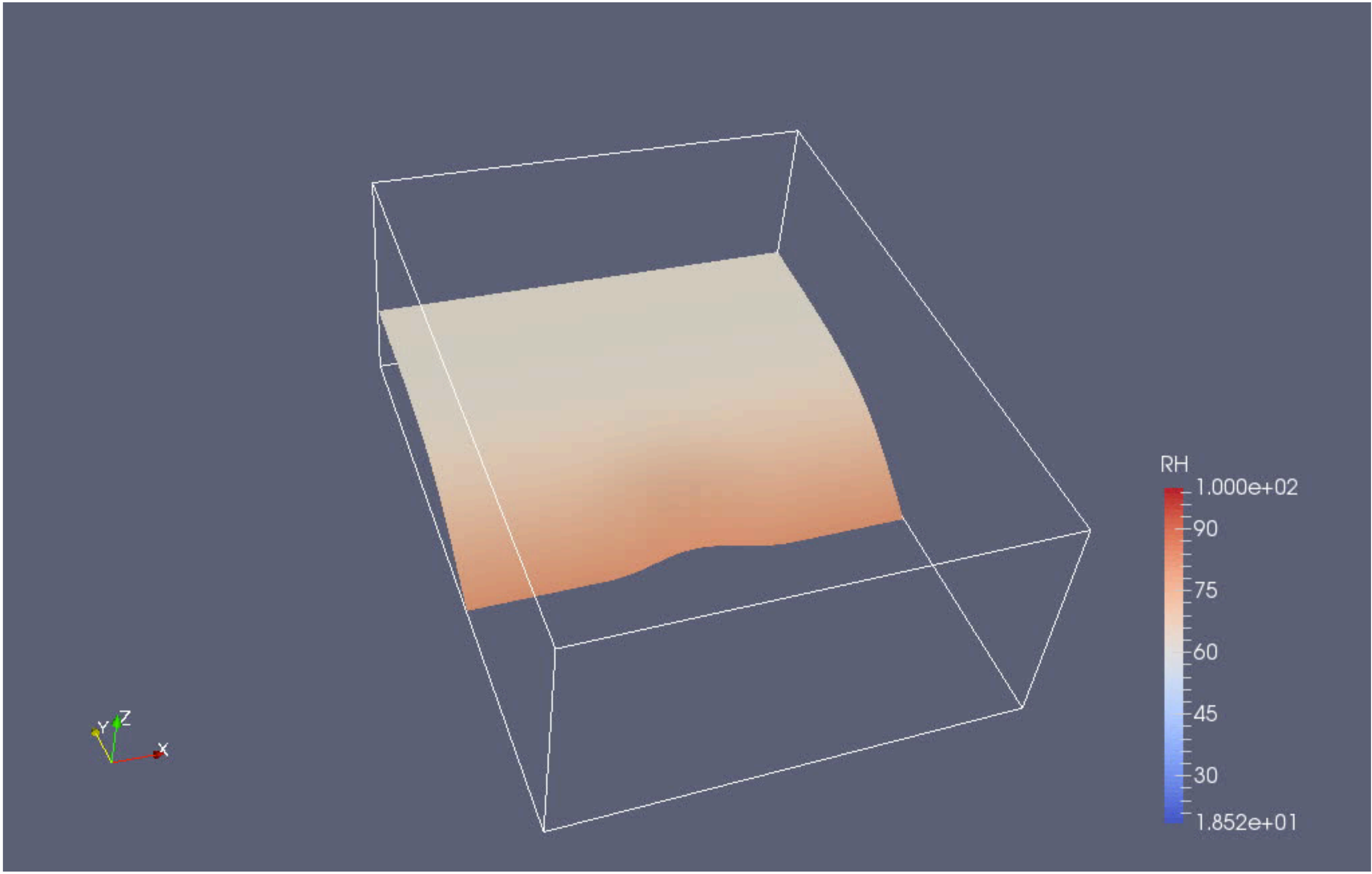
Experimental setup:

- symmetric zonal uniform jet
- surface temp. ~273 K
- tropopause: ~6.0 km
- f-plane: f=1.36e-4 s^{-1} ~70N
- surface rel. hum.: 80 %
- perturbation: surface based, cyclonic, warm perturbation



Terpstra, A. and Spengler, T. (2015) MWR

Idealised moist-baroclinic cyclone-development

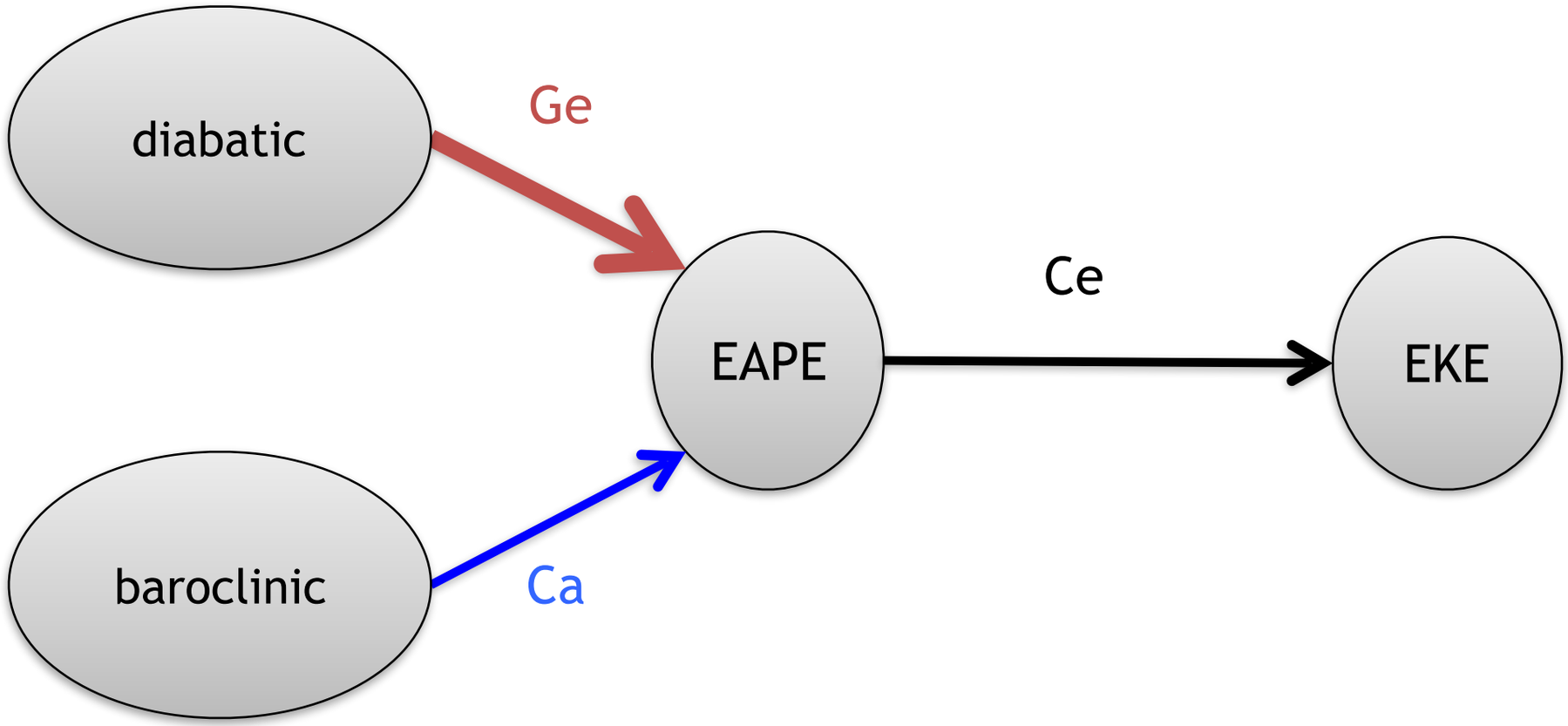


Energetics

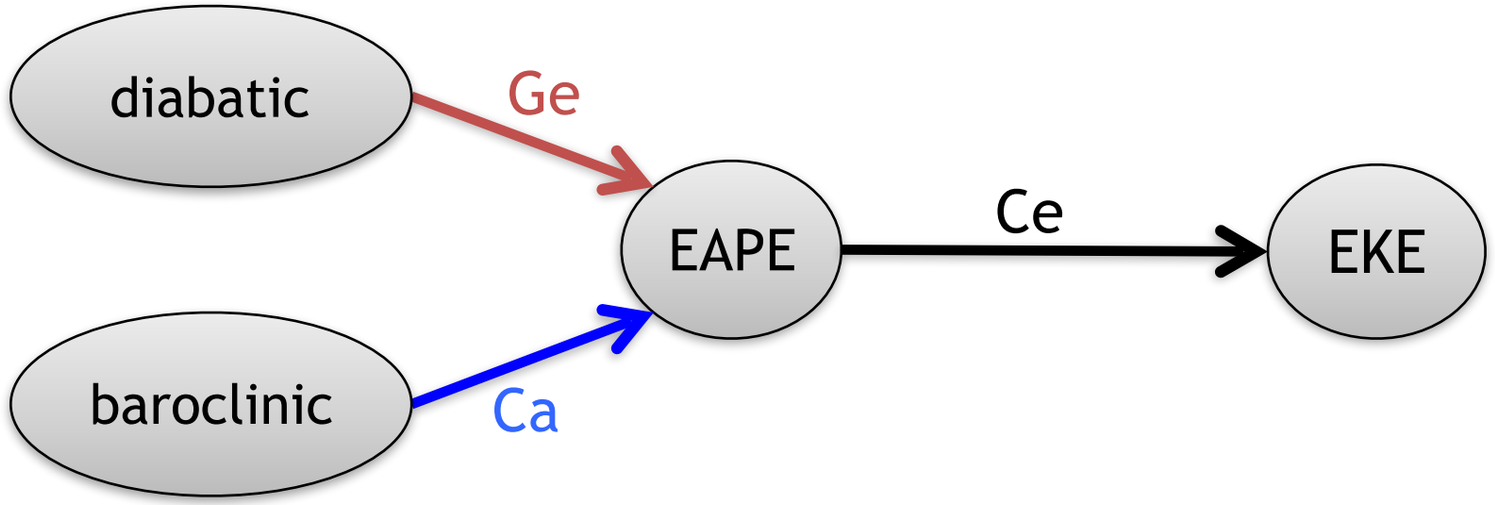
$$Ce = \frac{-1}{g} \int \frac{R_d}{p} \overline{[w'T']} dp$$

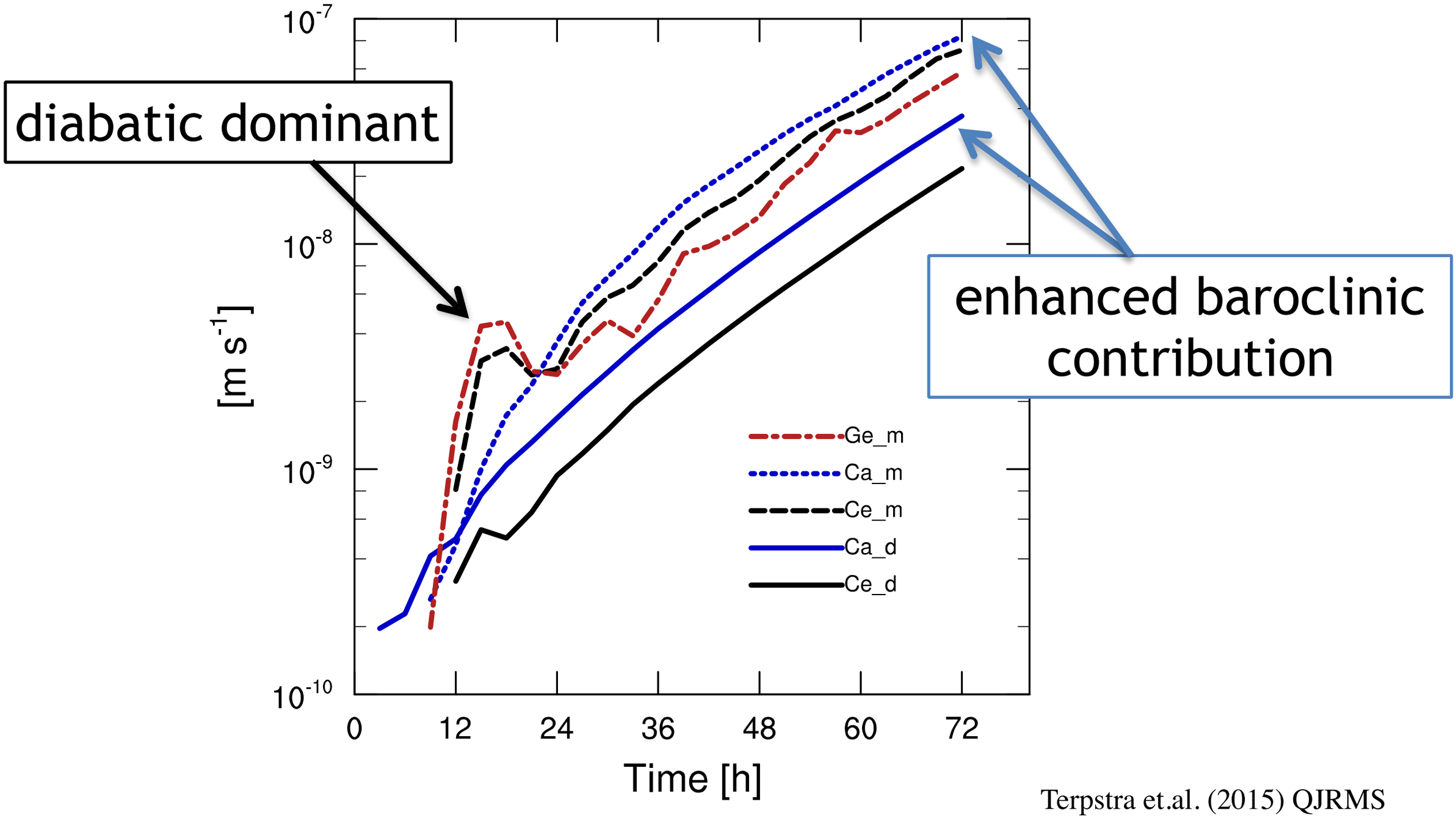
$$Ca = - \int \frac{\overline{[v'T']}}{\overline{\sigma}} \frac{\partial [T]}{\partial y} dp - \int \frac{\overline{[w'T']}}{\overline{\sigma}} \overline{\frac{\partial [T]^*}{\partial p}} dp$$

$$Ge = \int \frac{\overline{[Q'T']}}{c_p \overline{\sigma}} dp$$



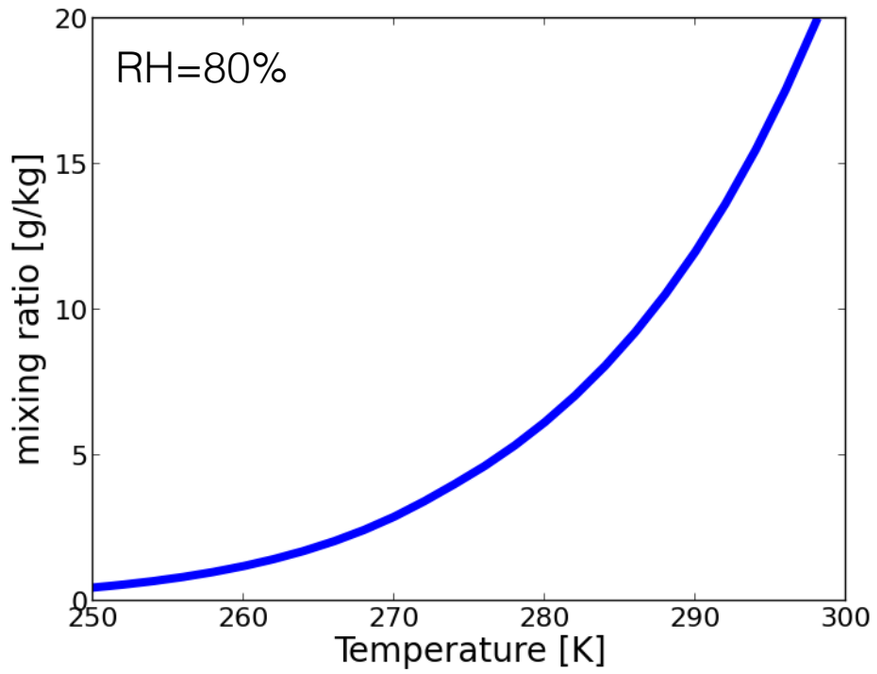
Energetics



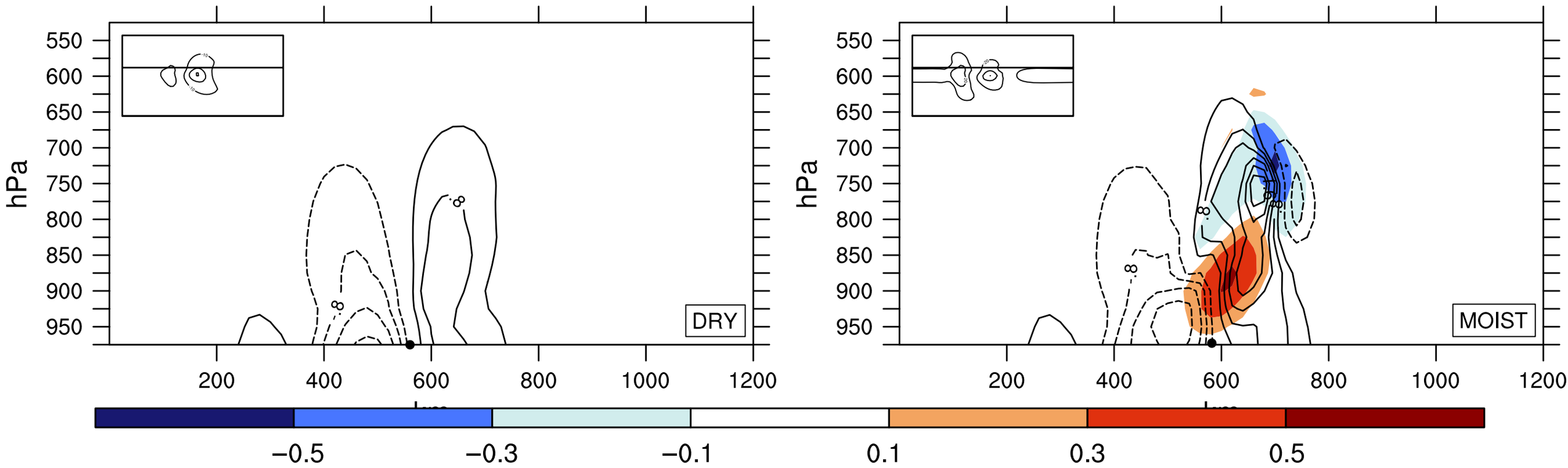


Terpstra et.al. (2015) QJRMS

DRY vs MOIST



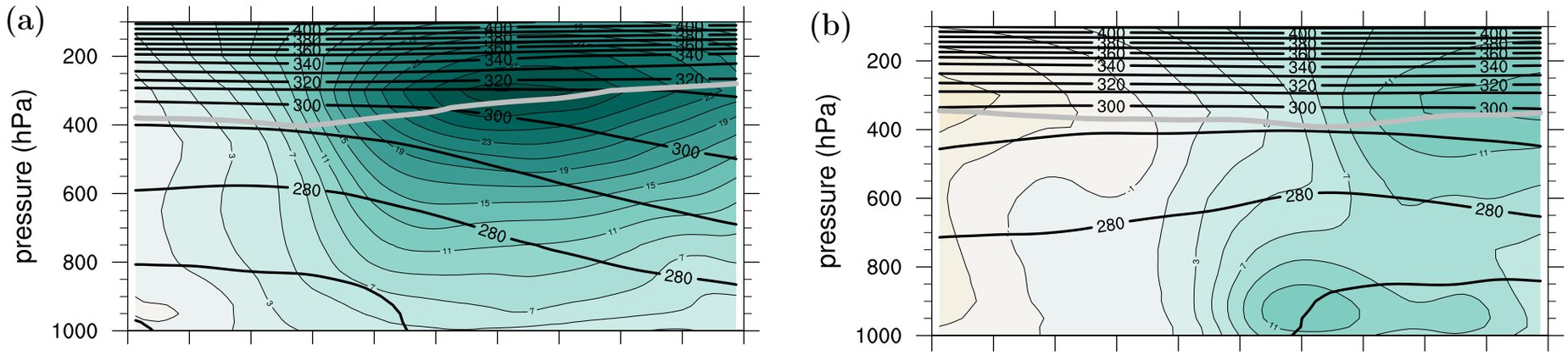
$$\frac{D}{Dt}PV = \boldsymbol{\omega} \cdot \boldsymbol{\nabla}\dot{\theta}$$



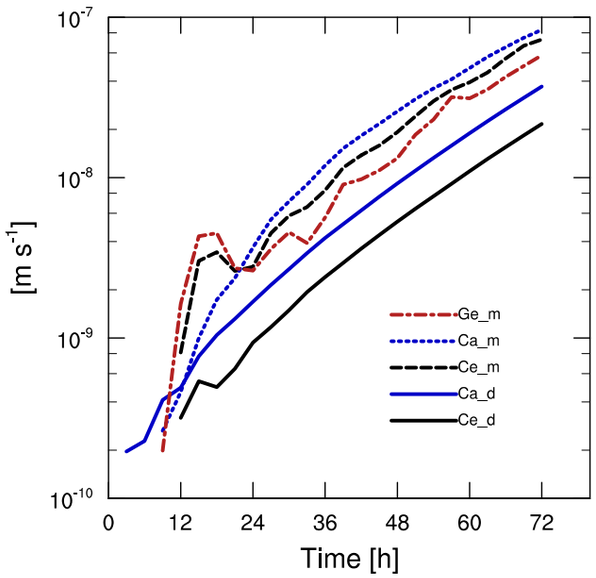
Terpstra et.al. (2015) QJRMS

Conclusions

- forward & reverse shear environments —> both baroclinic
- polar low genesis at flanks of cold-air outbreaks
- reverse shear polar lows: probably frontal instabilities



- diabatic processes important for cyclone intensification, despite low absolute values of moisture



References

- Terpstra, A., T. Spengler, and R. Moore. 2015. Idealised simulations of polar low development in an Arctic moist-baroclinic environment. *Quart. J. Roy. Meteorol. Soc.* **141**: 1987-1996
- Terpstra, A., T. Spengler. 2015. An initialization method for idealized channel simulations. *Mon. Weather Rev.* **143**: 2043-2051
- Terpstra, A., C. Michel, and T. Spengler. 2016. Forward and reverse shear environments during polar low genesis over the North East Atlantic. *Mon. Weather Rev.* **144**, 1341-1354