Eddy kinetic-energy redistribution in quasi-geostrophic flows: implication for midlatitude winter storms.

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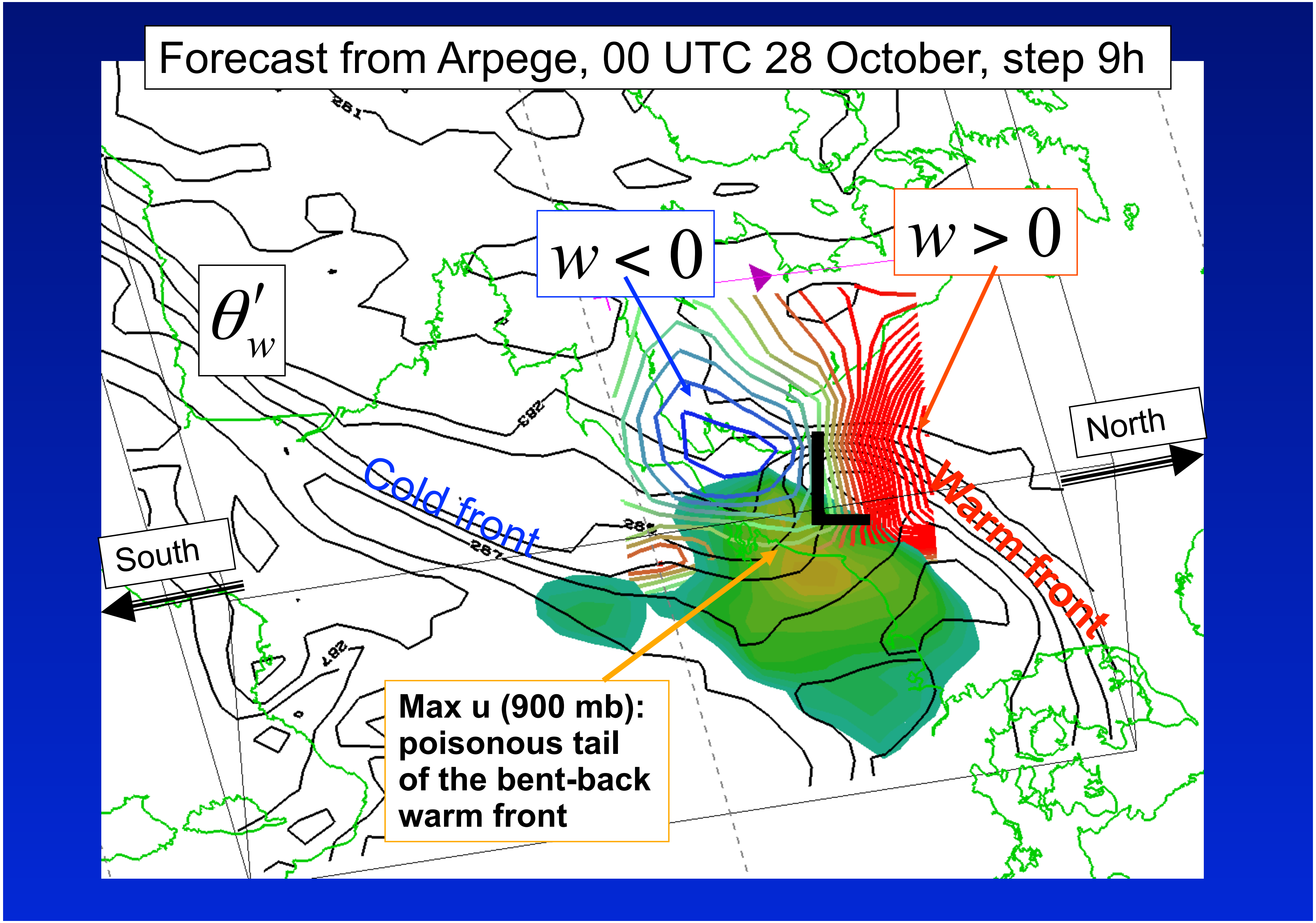
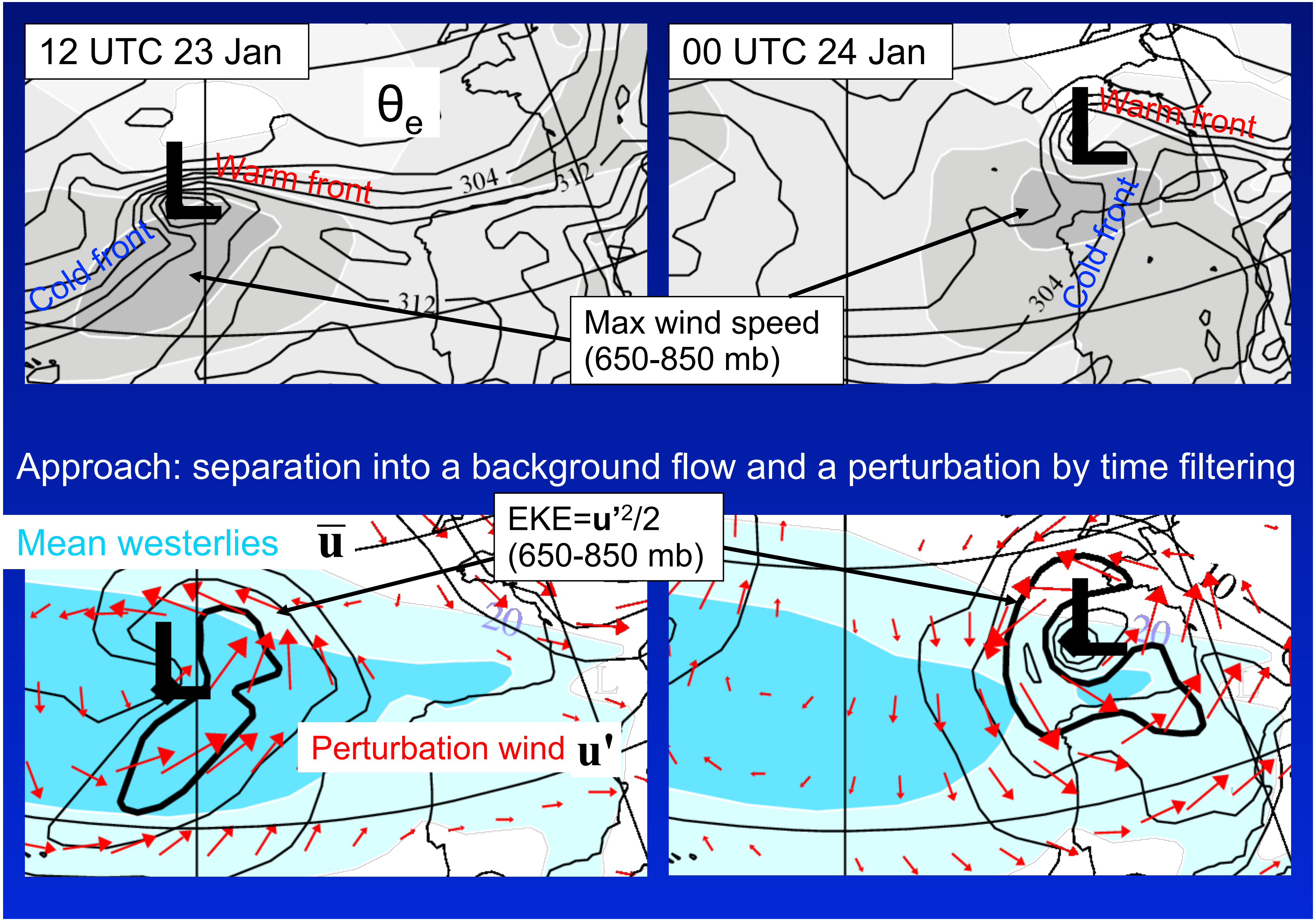
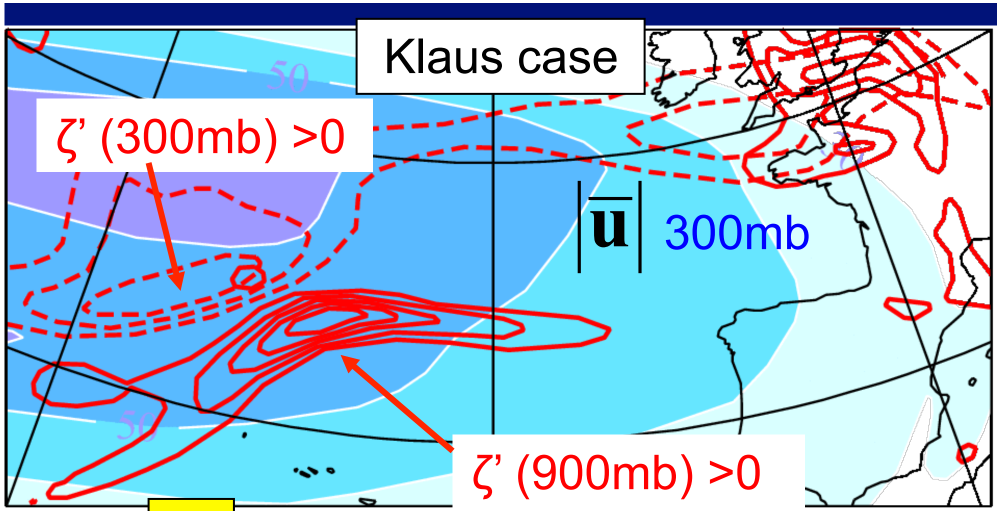
A 3D easterly view of the storm Christian (Oct 2013)



Example of the storm Klaus (24/01/09)



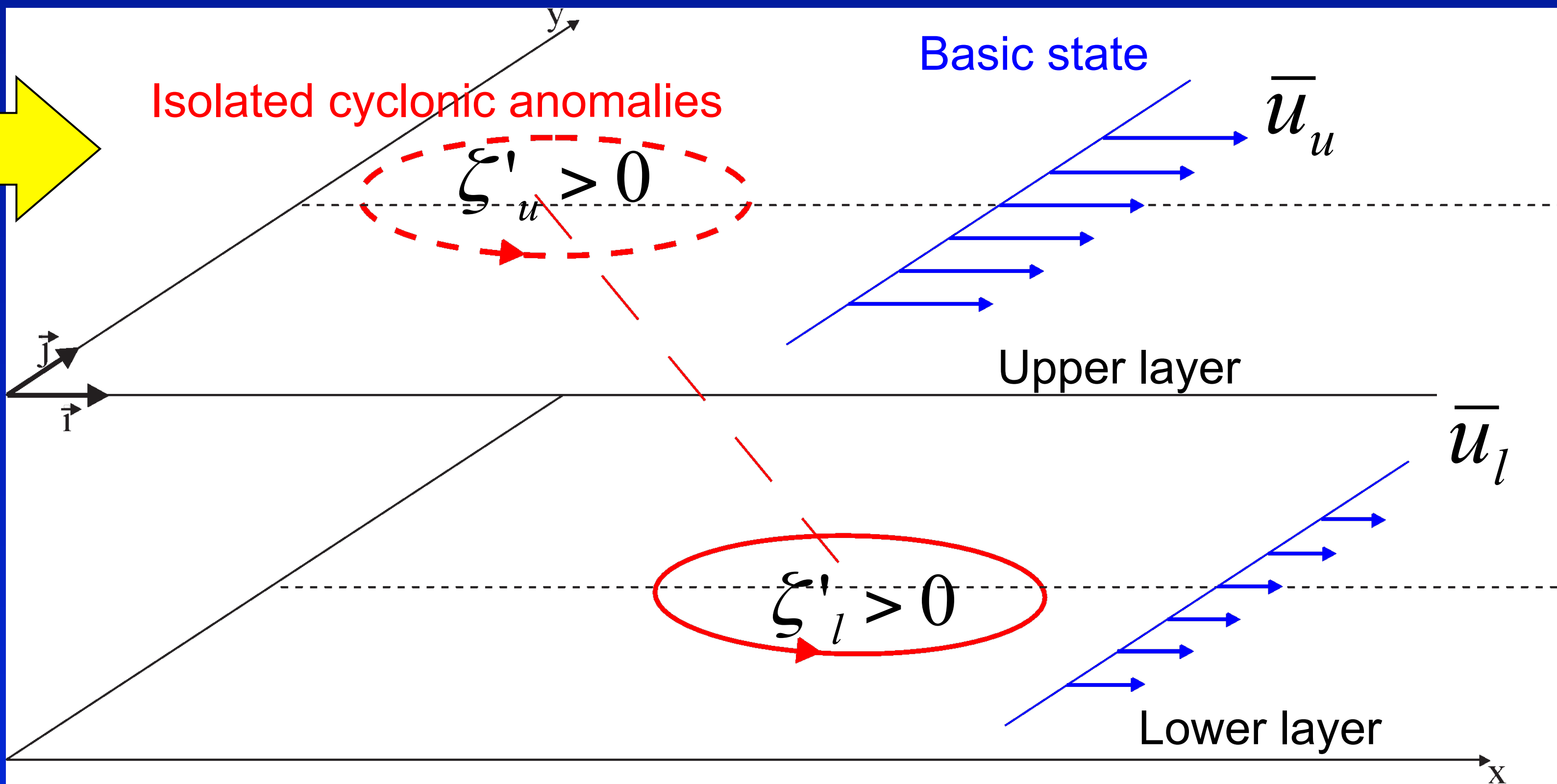
Idealized study: use of the two-layer quasi-geostrophic model



$$q_u = \Delta\psi_u + f - \lambda^{-2}(\psi_u - \psi_l)$$
$$q_l = \Delta\psi_l + f + \lambda^{-2}(\psi_u - \psi_l)$$

$$\partial_t q_k + \mathbf{u_k}.\nabla q_k = 0$$

λ **Rossby radius of deformation**



The eddy kinetic energy (EKE) equation

$$\frac{\partial}{\partial t}\frac{\mathbf{u'}^2}{2} = -\mathbf{u'}\cdot(\mathbf{u}\cdot\nabla\mathbf{u})' - \mathbf{u'_a}\cdot\nabla\Phi'$$

Φ geopotential

$\mathbf{u}$ geostrophic wind

$\mathbf{u_a}$ ageostrophic wind

Pressure work

$$-\mathbf{u'_a}\cdot\nabla\Phi' = \omega'\frac{\partial\Phi'}{\partial p} - \nabla\cdot(\mathbf{u'_a}\,\Phi') - \frac{\partial}{\partial p}\left(\omega'\Phi'\right)$$

Baroclinic conversion | Horizontal ageostrophic geopotential fluxes | Vertical ageostrophic geopotential fluxes

$$\mathbf{u_a} = \nabla\chi - \frac{1}{f_0}\mathbf{k}\times\nabla\phi_a$$

$$\nabla^2\phi_a = 2J(u,v) + \nabla\left(\frac{\beta y}{f_0}\nabla\Phi\right)$$

Diagnostic equation for ageostrophic scalar ϕ_a

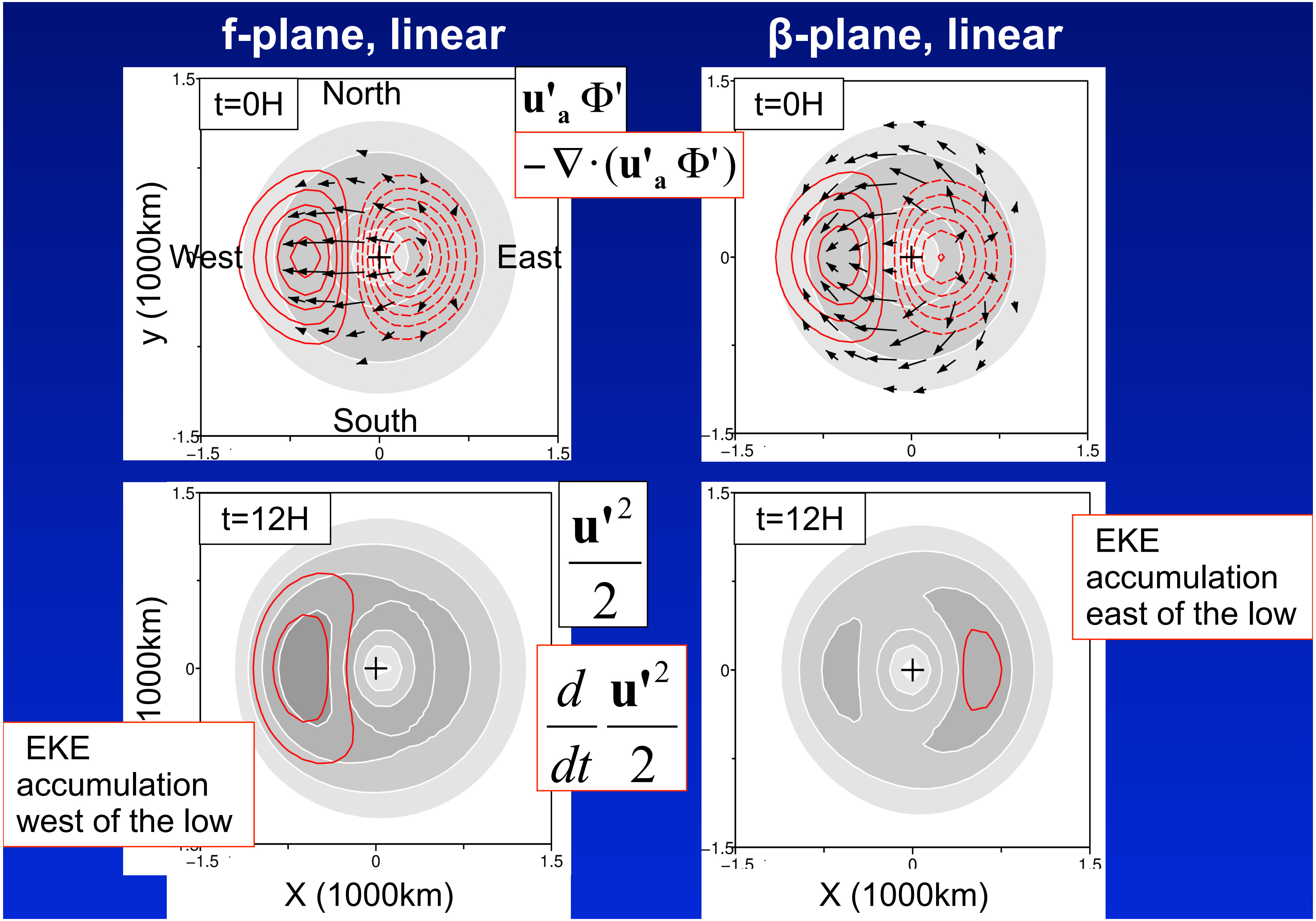
$$s^2\nabla^2\omega + f_0^2\frac{\partial^2\omega}{\partial p^2} = -2\nabla\cdot\mathbf{Q} + f_0\beta\frac{\partial v}{\partial p}$$

Omega equation

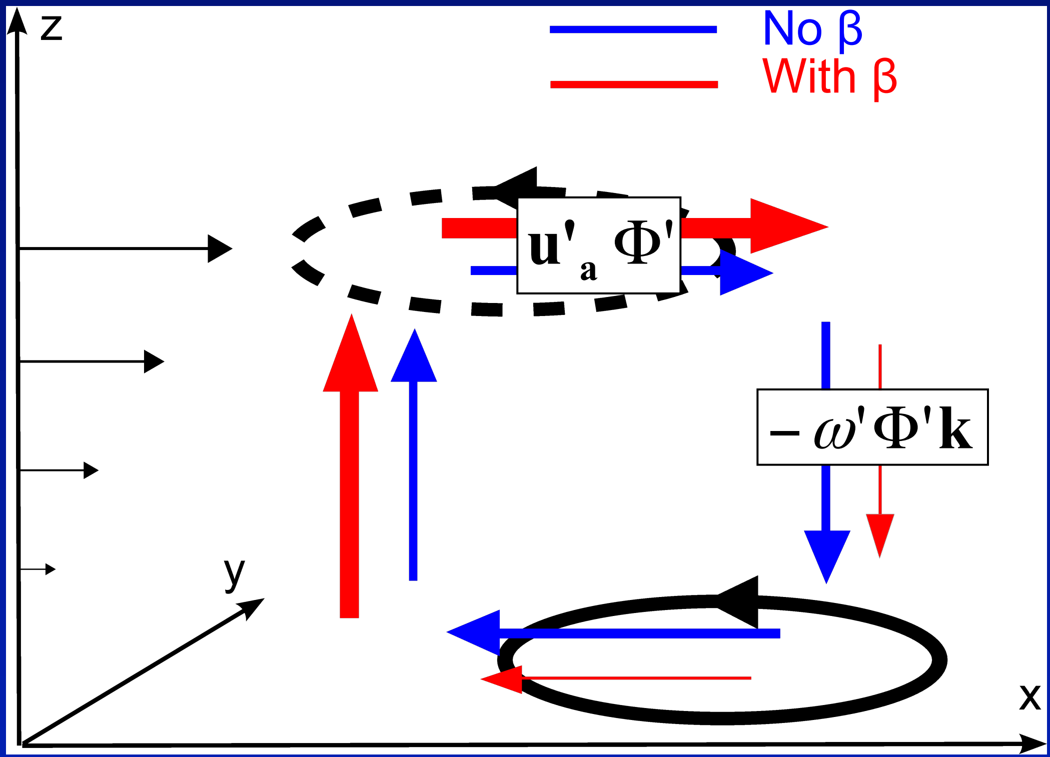
Q-vector

$$\nabla^2\chi = \frac{\partial\omega}{\partial p}$$

EKE redistribution at the lower layer in presence of the vertical shear



Role of β and the vertical shear in EKE redistribution



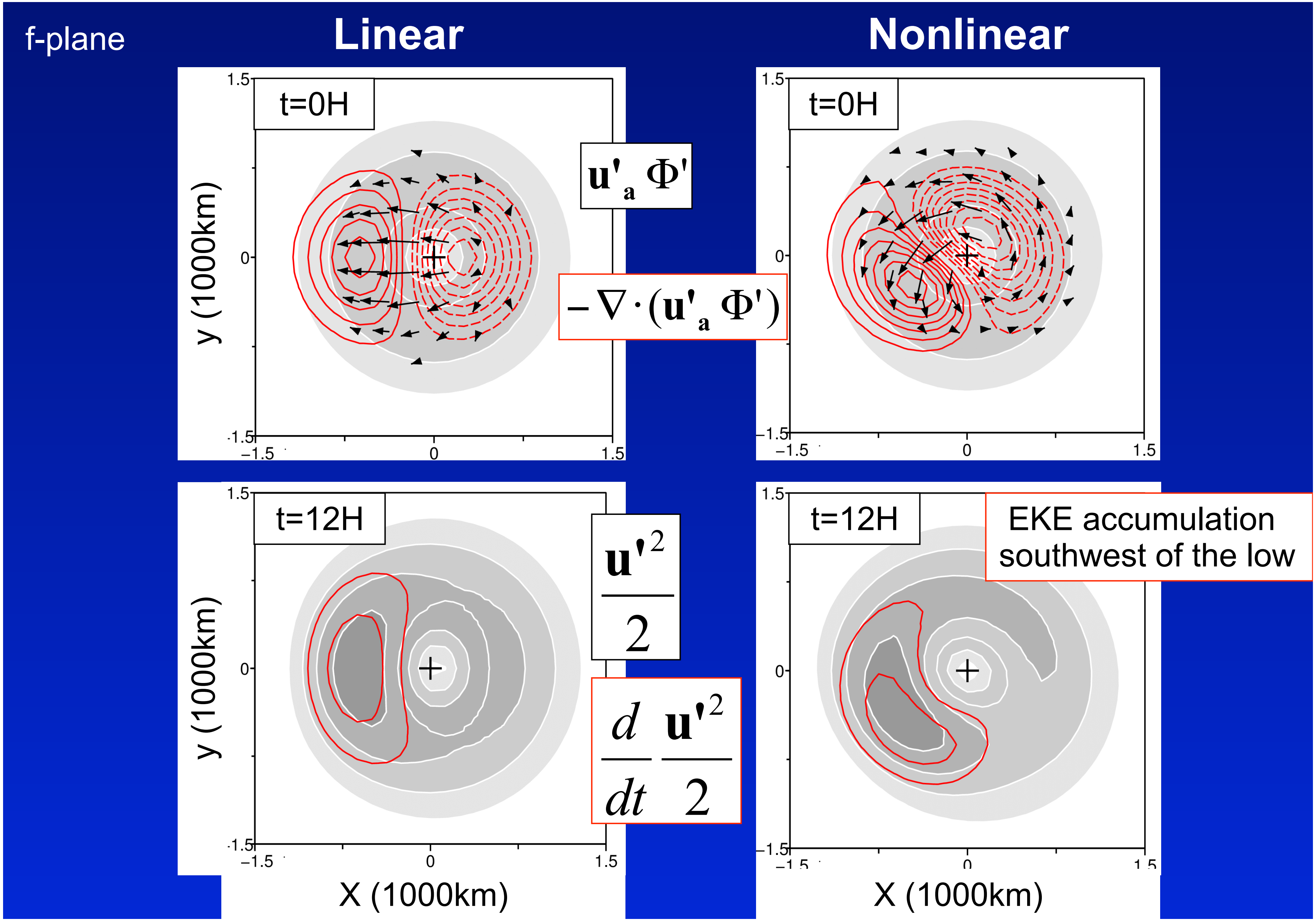
β increases the upward transfer and decreases the downward transfer, so a sink of energy for the lower layer !!!

Wavelike disturbance assumption (wavenumbers m, K)

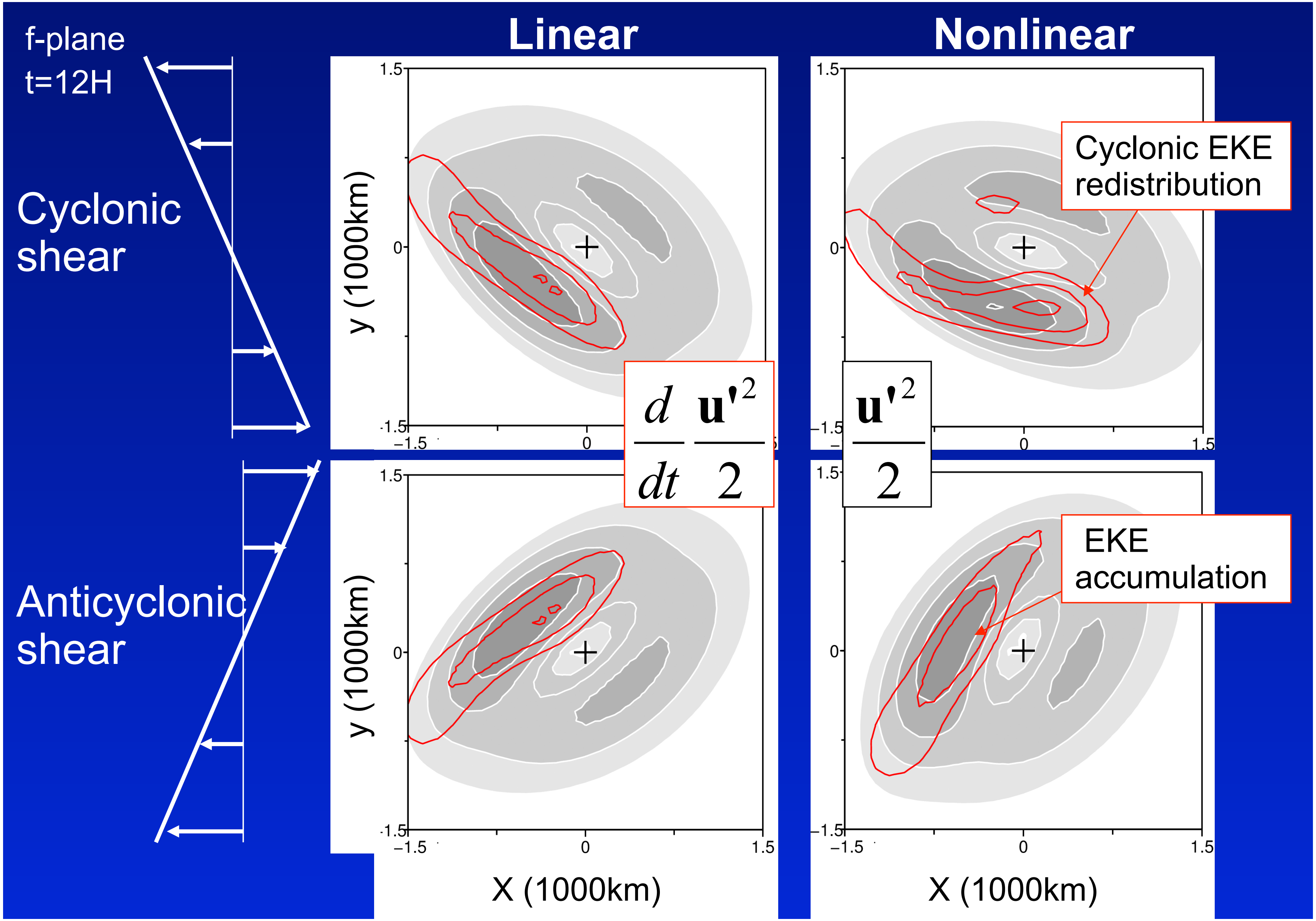
$$u'_{al} \approx \frac{m^2}{f_0(K^2+2\lambda^{-2})}\left\{-(\bar{u}_{u0}-\bar{u}_{l0})\lambda^{-2}(\psi'_u+\psi'_l)+\frac{\beta}{K^2}\left((K^2+\lambda^{-2})\psi'_l+\lambda^{-2}\psi'_u\right)\right\}$$

$$\omega' \approx \frac{K^2\lambda^{-2}}{s\lambda^{-1}(K^2+2\lambda^{-2})}\left\{-(\bar{u}_{u0}-\bar{u}_{l0})(v'_u+v'_l)+\frac{\beta}{K^2}(v'_u-v'_l)\right\}$$

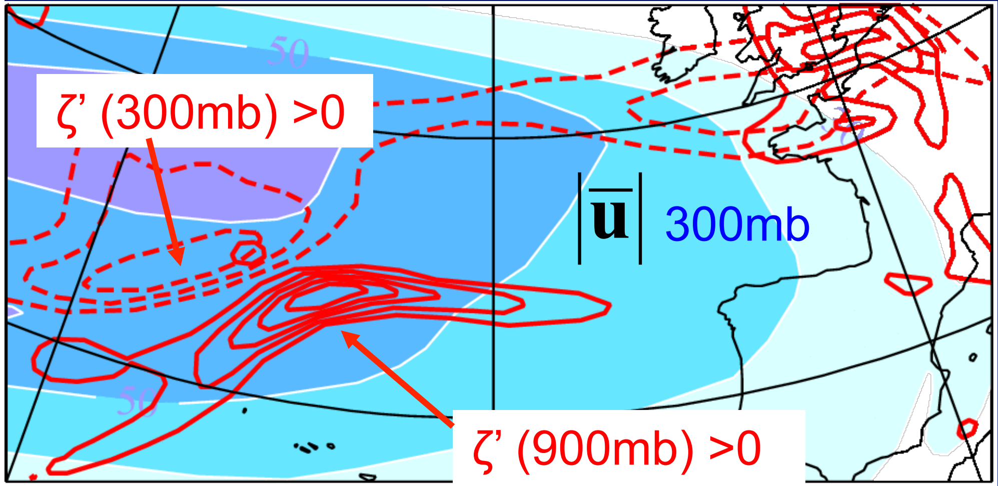
Role of nonlinearities in EKE redistribution



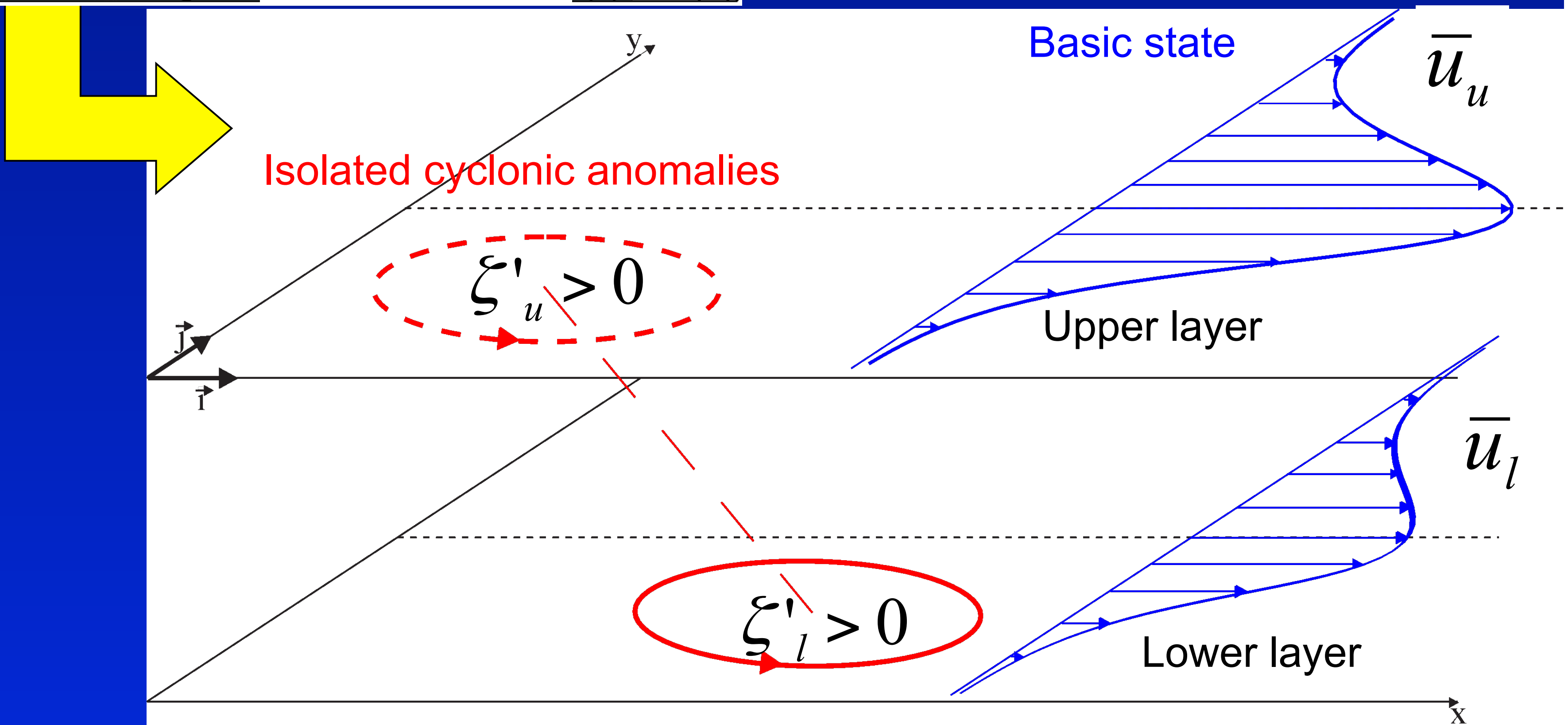
Role of background lateral shear in EKE redistribution



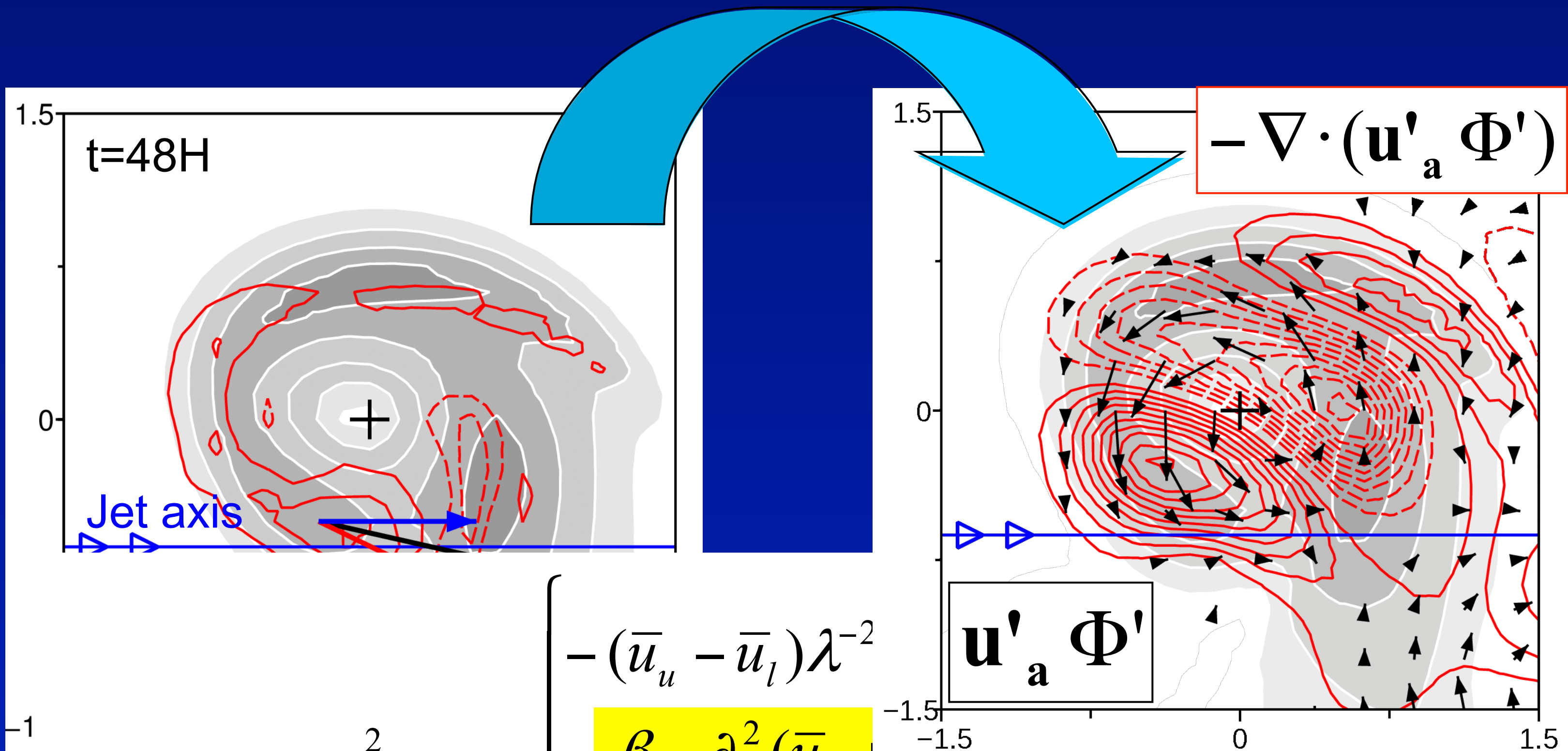
Isolated cyclonic anomalies initiated south of a westerly jet



Isolated cyclonic anomalies initialized south of a meridionally confined zonal jet



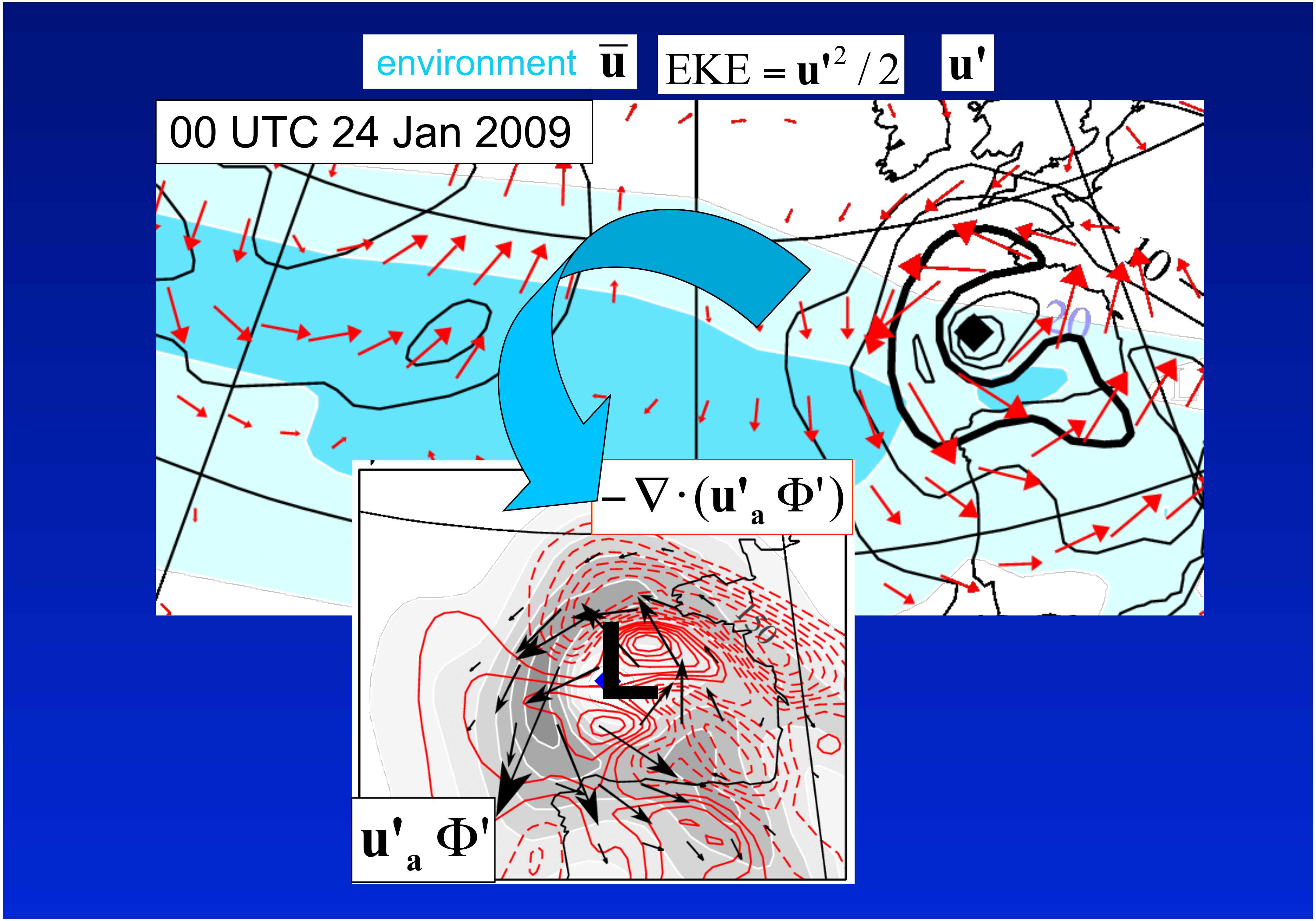
Evolution of the idealized jet-crossing cyclone



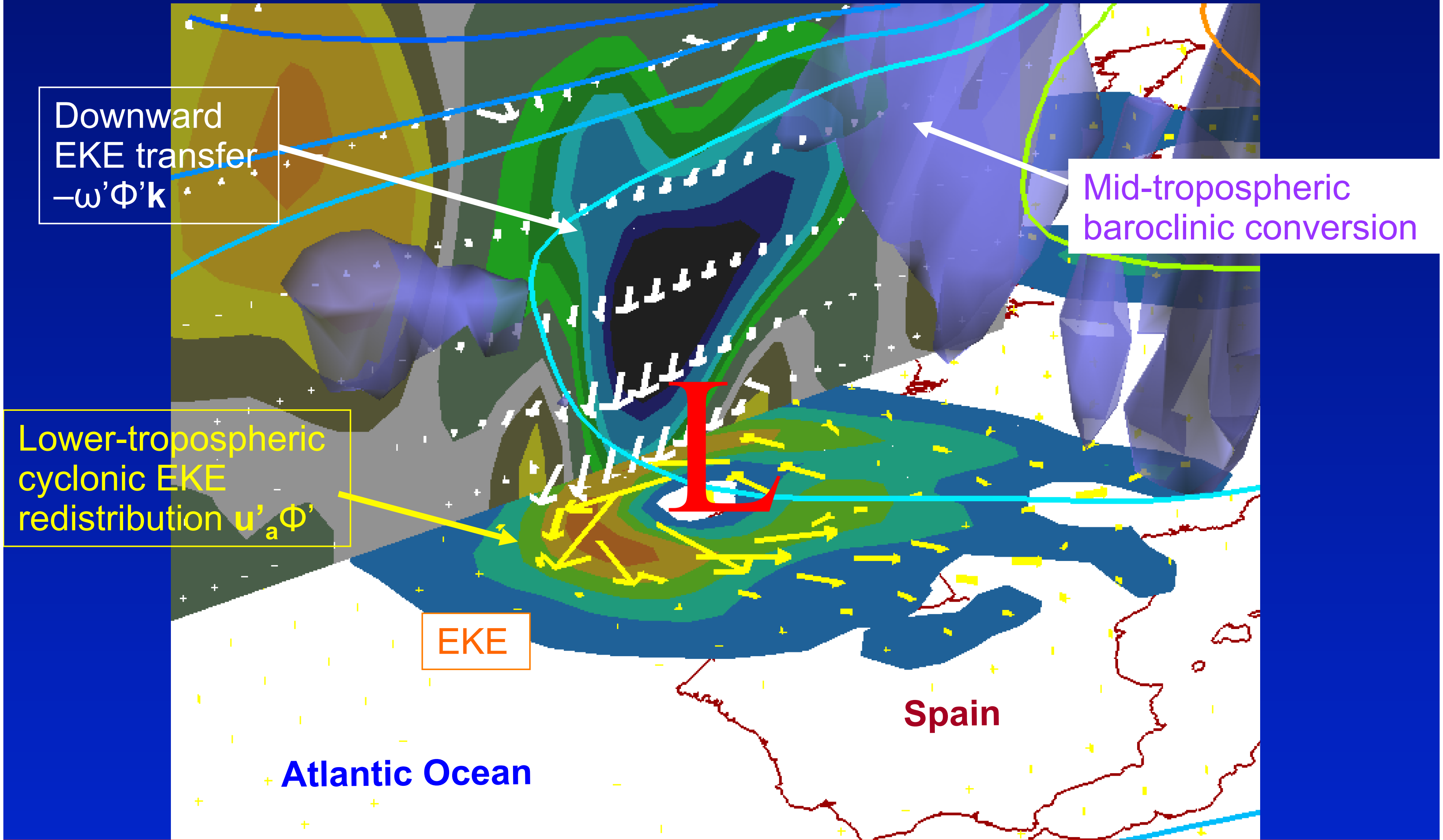
$$u'_{al} \approx \frac{m^2}{f_0(K^2+2\lambda^{-2})}\left\{ -(\bar{u}_u-\bar{u}_l)\lambda^{-2} + \frac{\beta-\partial_y^2(\bar{u}_u+\bar{u}_l)}{K^2}\left((K^2+\lambda^{-2})\psi'_l+\lambda^{-2}\psi'_u\right) + \frac{K^2+2\lambda^{-2}}{K^2}\left(\partial_y^2\bar{u}_u-\partial_y^2\bar{u}_l\right)\psi'_l \right\}$$

$$\omega' \approx \frac{K^2\lambda^{-2}}{s\lambda^{-1}(K^2+2\lambda^{-2})}\left\{-(\bar{u}_u-\bar{u}_l)(v'_u+v'_l)+\frac{\beta-\partial_y^2(\bar{u}_u+\bar{u}_l)}{K^2}(v'_u-v'_l)\right\}$$

Interpreting EKE distribution during for the storm Klaus



A 3D view as a summary



<u>Conclusion</u>: the background flow controls EKE redistribution processes !
<u>Outlook:</u> how is it related to the formation of mesoscale jets (sting jets, Browning, 2004; Gray et al. 2011) ?