Eddy Length Scale Response to Static Stability Change Using Linear Response Function of an Idealized Dry Atmosphere

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Author will be present in the chat channel for discussion during 15:00-15:30 (UTC +2) on May 8 (Fri)

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Eddy length scale is important

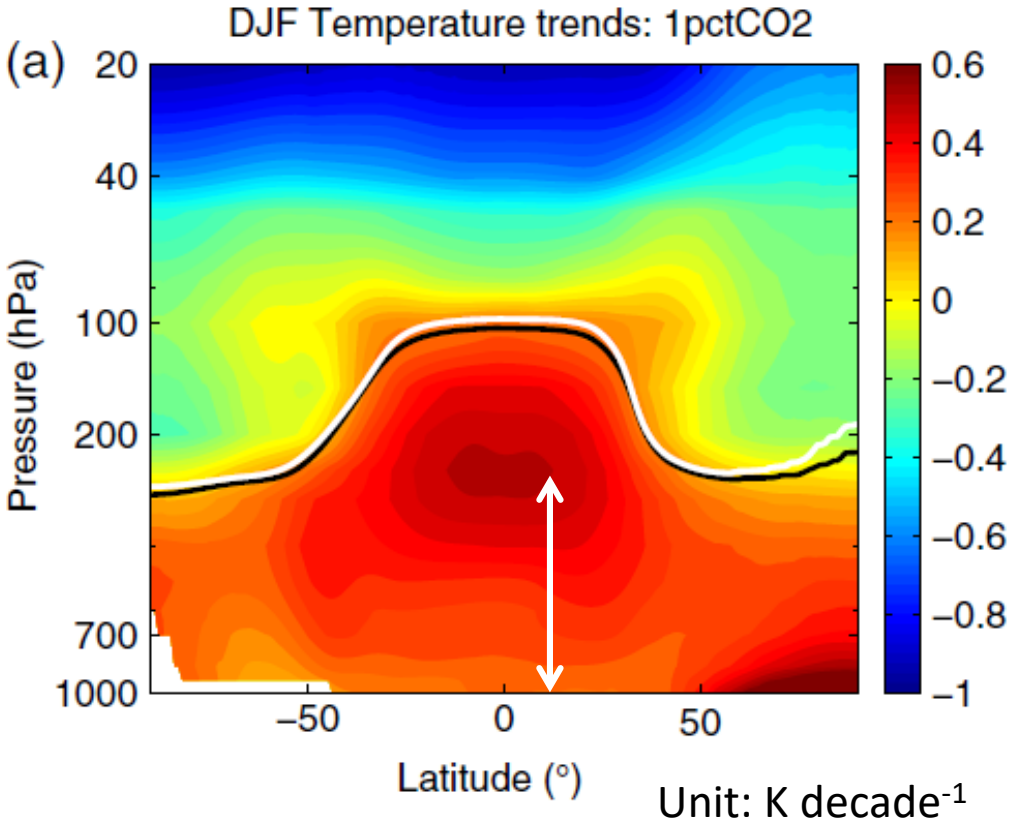
- Controls mid-latitude temperature variability (Schneider et al. 2015)

$$\overline{\theta'^2} \sim \left(\partial_y \bar{\theta}\right)^2 L'^2$$

- Sets latitudes where eddies dissipate/reflect (e.g., Kidston et al. 2011)

Eddies' response to static stability

- Under climate change, static stability (*N*) increases in mid-latitude
- Theoretical interest

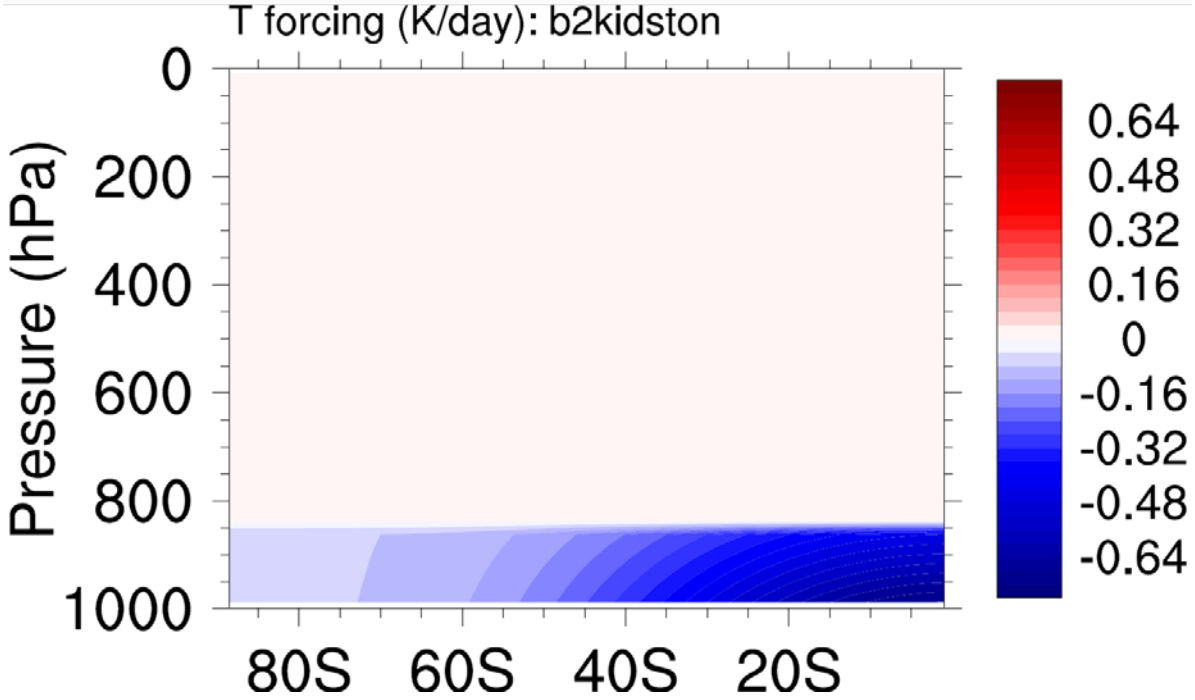


Unit: K decade^{-1}

Vallis et al. 2014

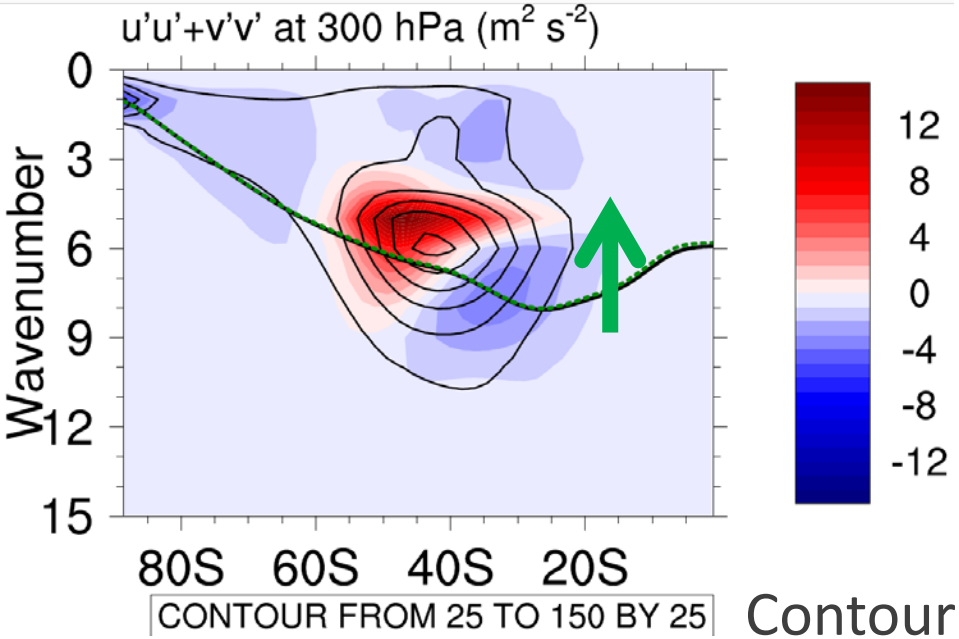
Past trial to increase static stability

- Kidston et al. 2011 tried to increase static stability by **cooling air near surface**



Past trial to increase static stability

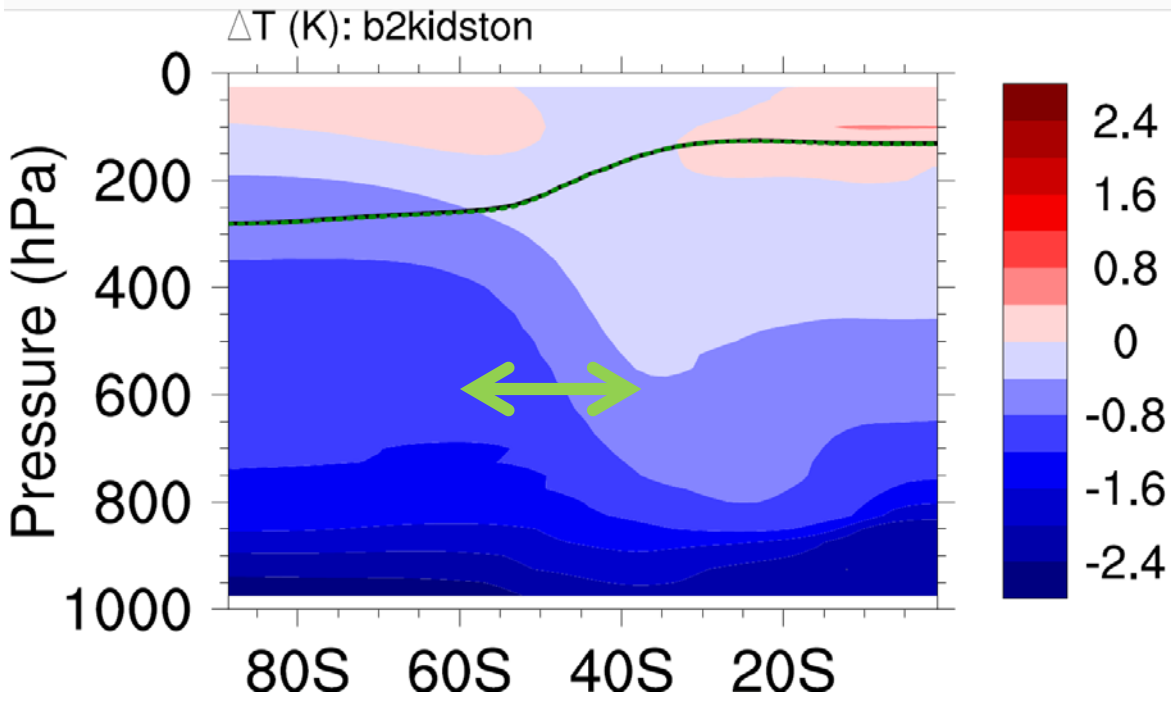
- Kidston et al. 2011 tried to increase static stability by **cooling air near surface**
- They found eddy length scale **increases**



Contour: control run
Shading: change in $N\uparrow$ run

Kidston made a great trial but…

- **Meridional temperature gradient ($|\partial T/\partial y|$) increased** unfortunately
- Hard to attribute to static stability



Using linear response function, …

Linear response function (matrix $\mathbf{L}$) **linearly relates** target mean state change (vector $\bar{\mathbf{x}}_{\mathbf{target}}$) and required forcing (vector $\bar{\mathbf{f}}_{\mathbf{1}}$) as:

$$\bar{\mathbf{f}}_{\mathbf{1}} = -\mathbf{L}\bar{\mathbf{x}}_{\mathbf{target}}$$

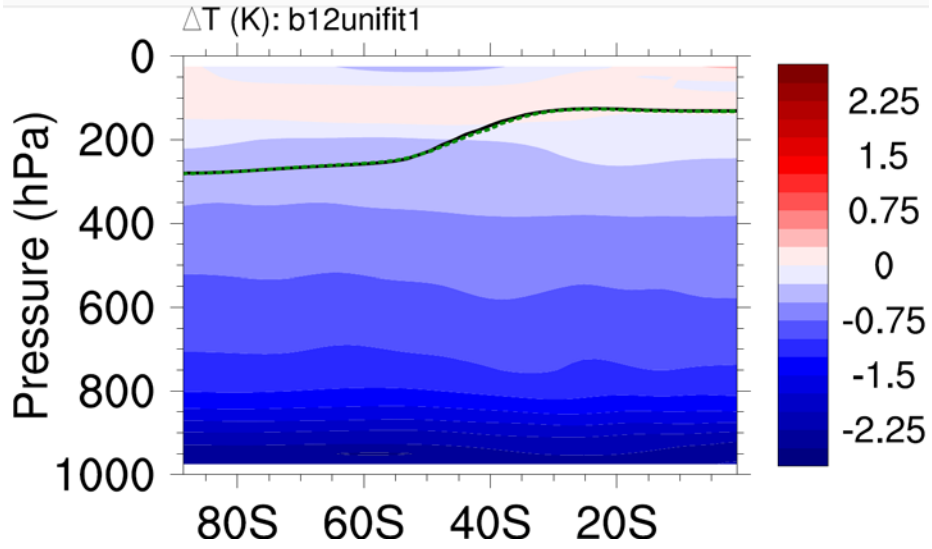
Without linear response function, one has to make a guess for forcing.

We conduct clean experiment

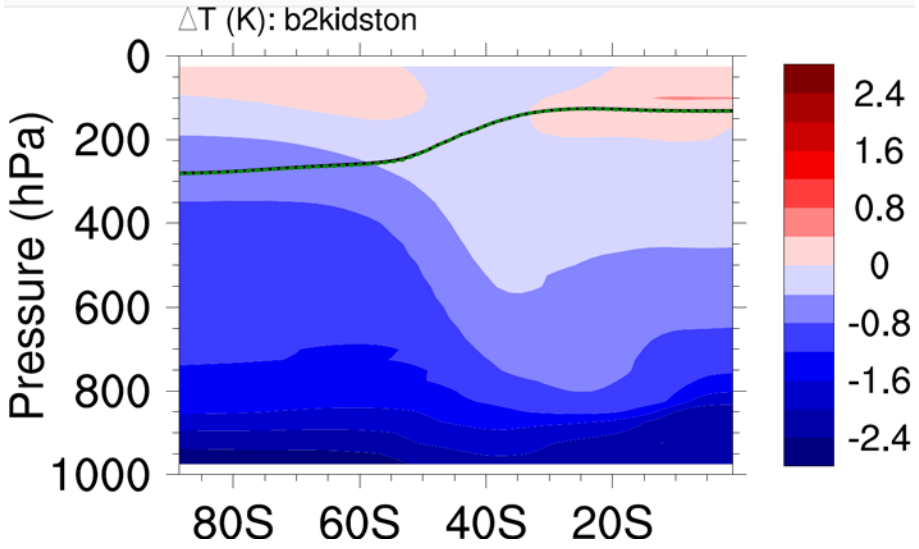
Our clean experiment:

- increases static stability
- w/o changing meridional temperature gradient

Ours

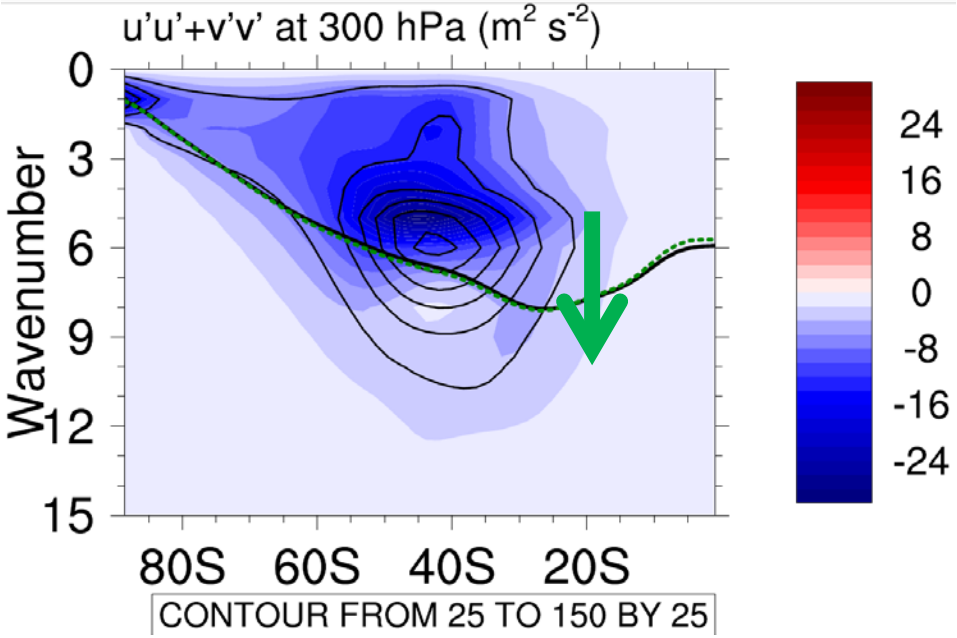


Kidston et al. 2011

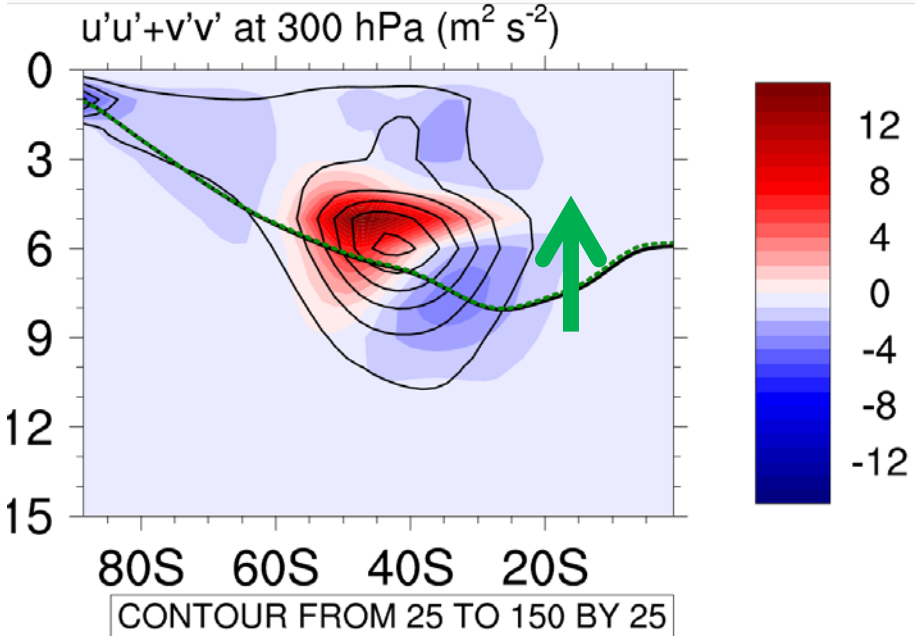


How eddy length scale responds?

Ours



Kidston et al. 2011



Contour: control run

Shading: change in $N\uparrow$ run

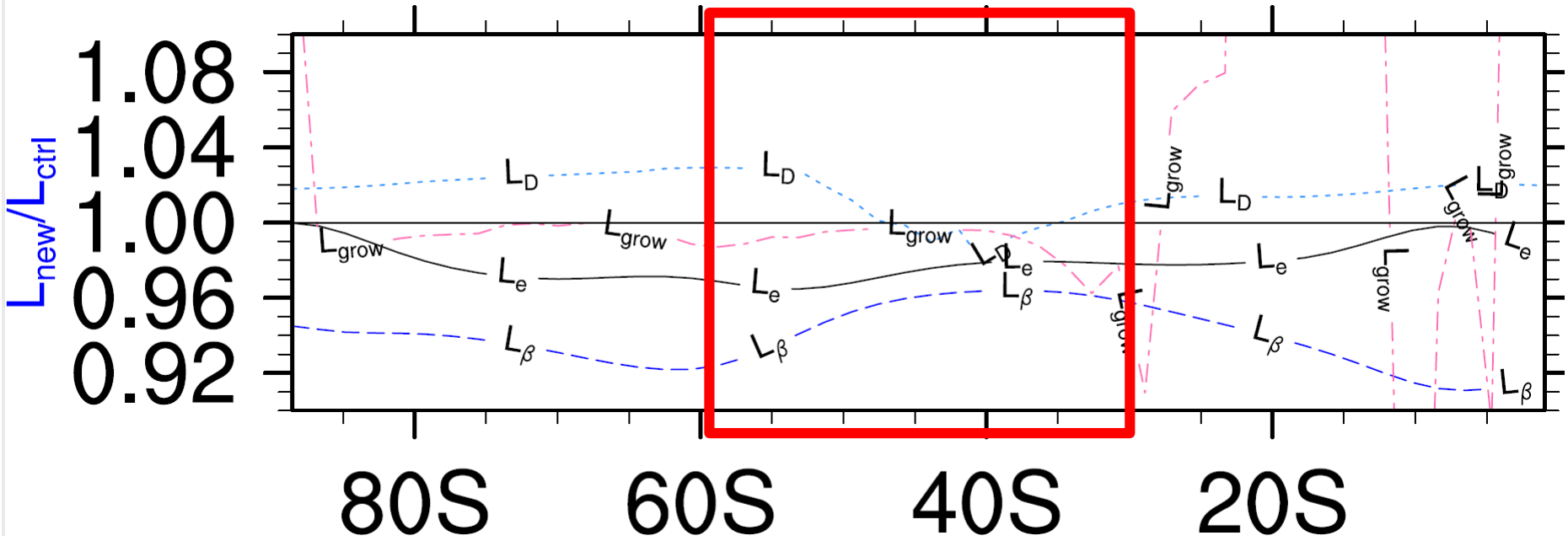
Eddy length scale **decreases** as static stability increases in our clean experiment

Opposite to Kidston et al.

Eddy length scale propositions

- Rossby radius, $L_D = NH/f$
- Maximum baroclinic growth scale, L_{grow}
- Rhines scale, $L_\beta = \left[\frac{\mathrm{EKE}^{1/2}}{\beta}\right]^{1/2}$
- Kuo scale, $L_K = \left[\frac{\bar{U}_{\mathrm{max}}}{\beta}\right]^{1/2}$

Length scale propositions evaluated



- Energy-containing zonal scale: **-2~-3%**
- Rossby radius: **+2%**
- Maximum baroclinic growth scale: **-1%**
- Rhines scale: **-4~-8%**
- Kuo scale (not shown): **0%**

No single length scale works well

Our clean experiment finds…

- Eddy length scale **decreases** as static stability↑
- **No single length scale matches well**

References

Kidston, J., Vallis, G. K., Dean, S. M., & Renwick, J. A. (2011). Can the increase in the eddy length scale under global warming cause the poleward shift of the jet streams? *Journal of Climate*, 24(14), 3764–3780. https://doi.org/10.1175/2010JCLI3738.1

Hassanzadeh, P. & Kuang, Z. (2016a). The linear response function of an idealized atmosphere. Part I: Construction using Green's functions and applications. *Journal of the Atmospheric Sciences*, 73(9), 3423–3439. https://doi.org/10.1175/JAS-D-15-0338.1

Vallis, G. K., Zurita-Gotor, P., Cairns, C., & Kidston, J. (2014). Response of the large-scale structure of the atmosphere to global warming. *Royal Meteorological Society*, 141, 1479-1501. https://doi.org/10.1002/qj.2456

Schneider, T., Bischoff, T., & Płotka, H. (2015). Physics of changes in synoptic midlatitude temperature variability. *Journal of Climate*, 28(6), 2312-2331. https://doi.org/10.1175/JCLI-D-14-00632.1