Tropical Cyclone Interaction with an Upper Level Cold Core Low

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Preview

1) Increased geopotential height gradient enhances radial outflow

- Cold core low (CCL) decreases heights away from TC
- Results in faster storm intensification and broader TC structure

$$\frac{Du}{Dt} = -\frac{\partial \Phi}{\partial r} + \frac{v^2}{r} + f_0 v$$

2) CCL interaction has significant influence on TC movement

- Used potential vorticity (PV) tendency diagnostic approach
- Due to CCL influence on TC outflow and secondary circulation

3) CCL induces a deeper and more radially extensive outflow layer

- Negative height gradient favors radial outflow
- Influenced by decreased inertial stability

TC-CCL interaction has implications for both storm <u>intensity</u> and <u>track</u>!

Experiment Design

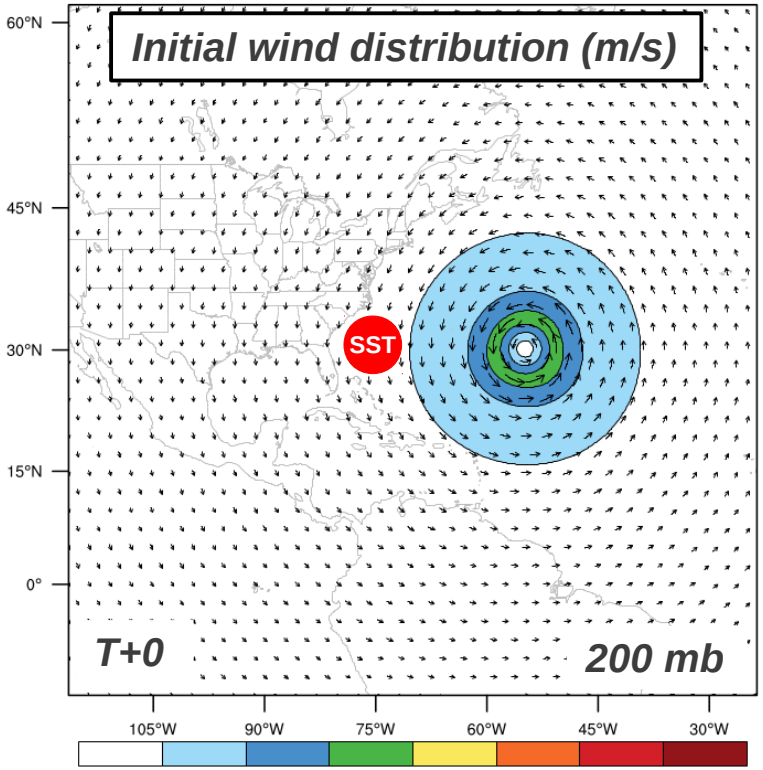
1) WRF-ARW v.3.6
- 72-hr integration
- 300 x 300 grid point single domain at 30 km resolution
- 31 vertical levels
- F-plane and full curvature
- Dunion (2011) moist tropical sounding
- Aquaplanet (no land)

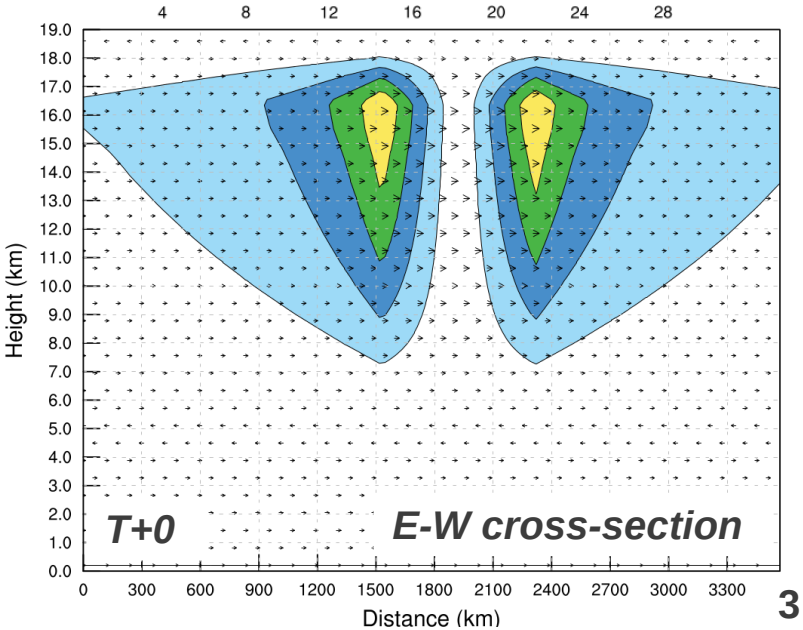
2) Physics parameterizations
- WSM6 microphysics
- RRTMG radiation
- Kain-Fritsch convection
- Noah LSM
- YSU PBL

3) TC generated using SST gradient (24 hrs)
- $SST(r) = 311 - 10*(r^2/Rmax^2)$ $\quad r \leq Rmax$
- $SST(r) = 301$ $\quad r > Rmax$
- Rmax = 360 km

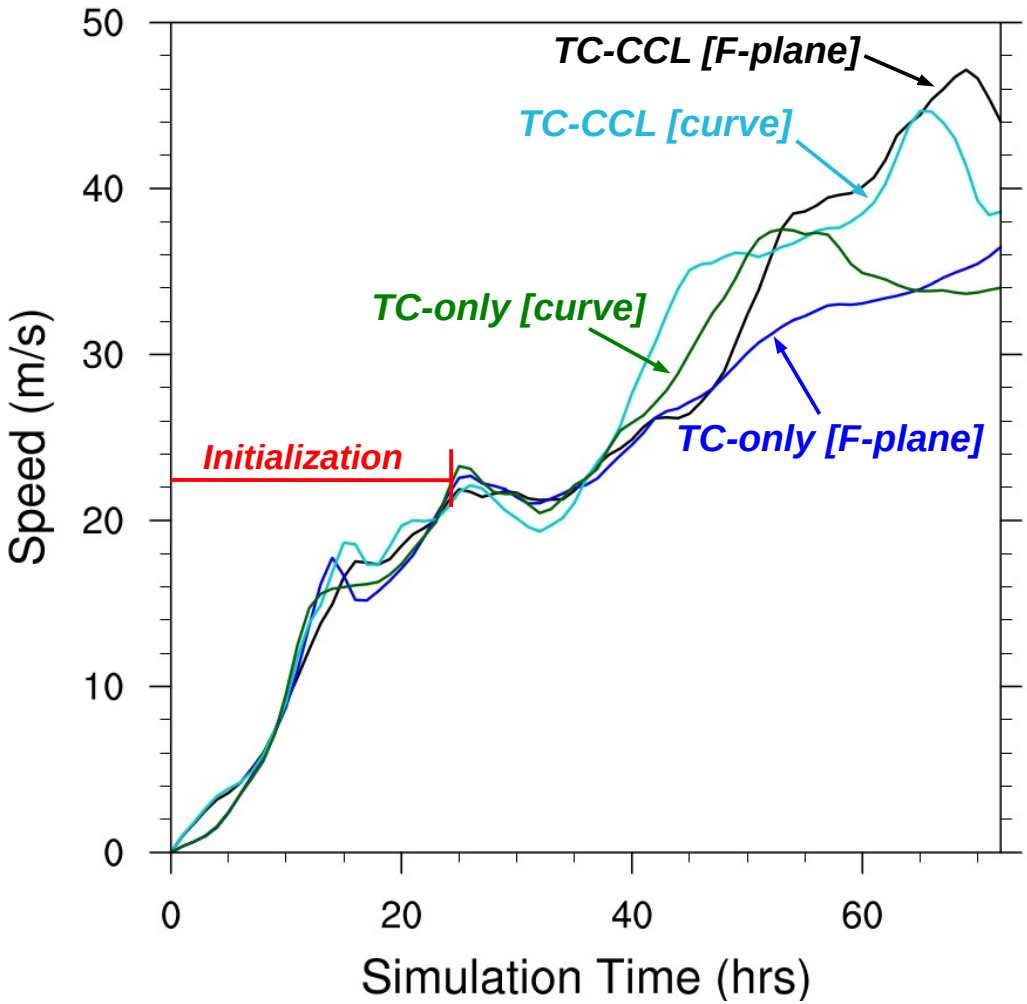
4) CCL placed using modified WRF TC bogus scheme
- Max wind: 20 m/s
- RMW: 400 km
- Depth: 100-500 mb

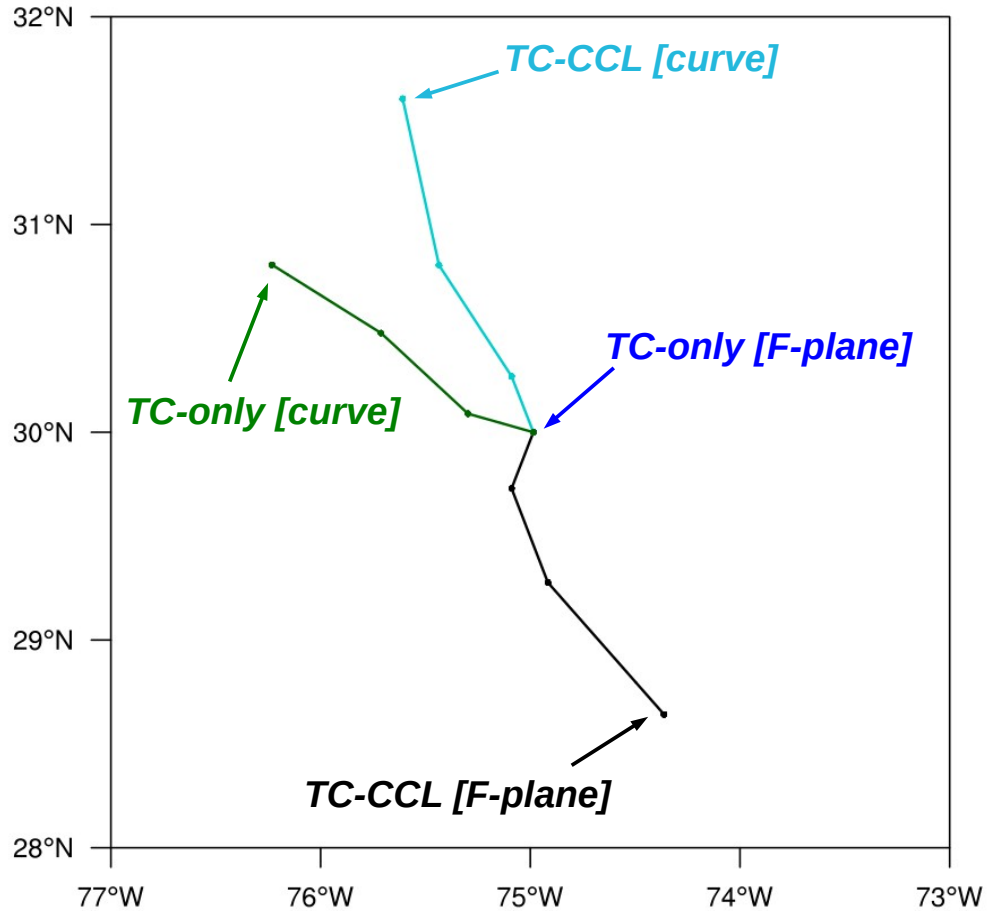
5) TC-CCL separation distance about 2000 km

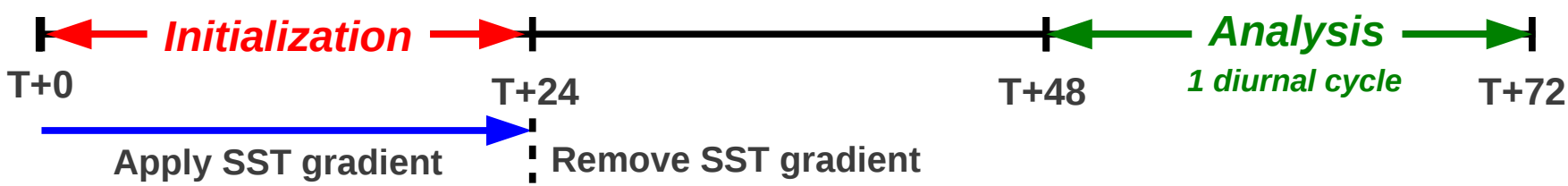




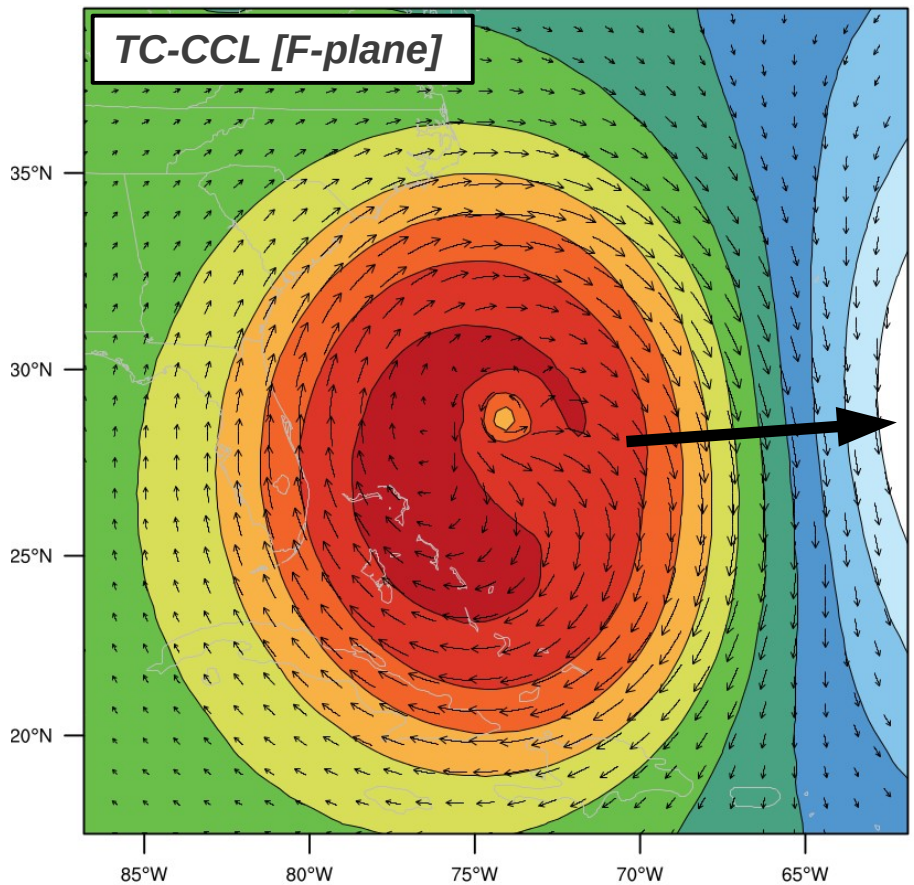
Maximum Wind Speed and TC Track

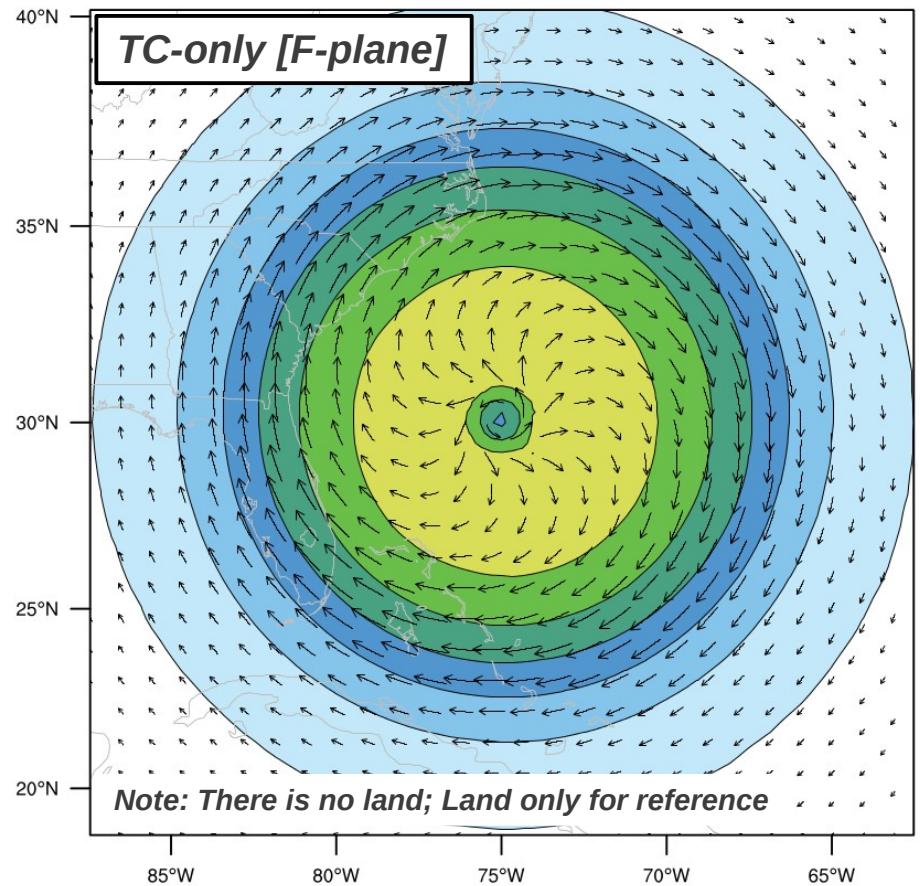


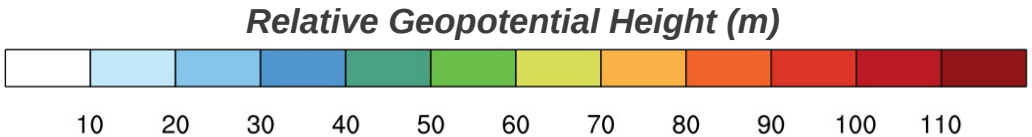




24-hr Avg 200 mb Geopotential Height



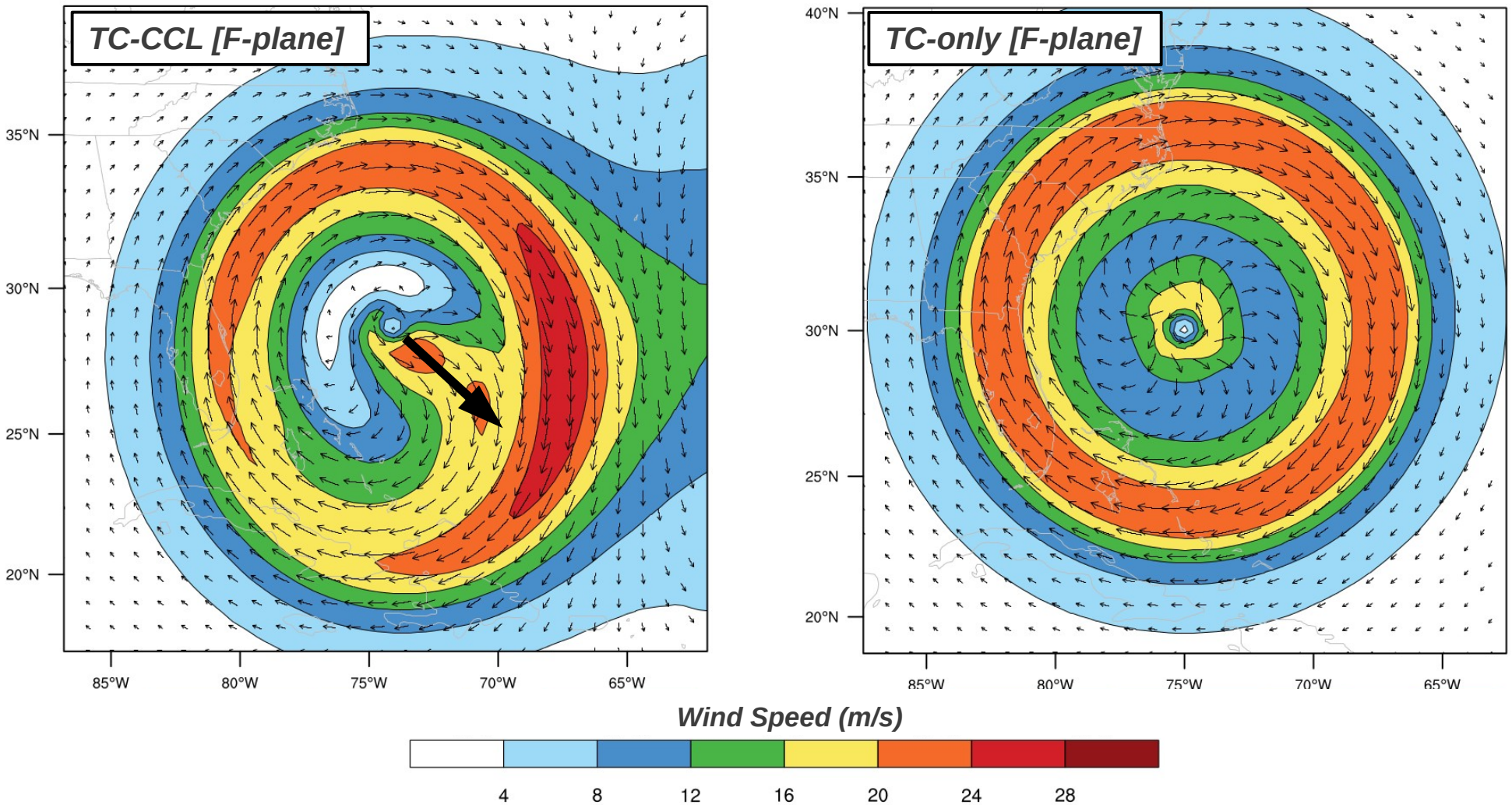




$$\frac{Du}{Dt} = -\frac{\partial \Phi}{\partial r} + \frac{v^2}{r} + f_0 v$$

- CCL enhances the radial geopotential height gradient
- Height gradient depends on horizontal and vertical temperature distribution (e.g. CRF)

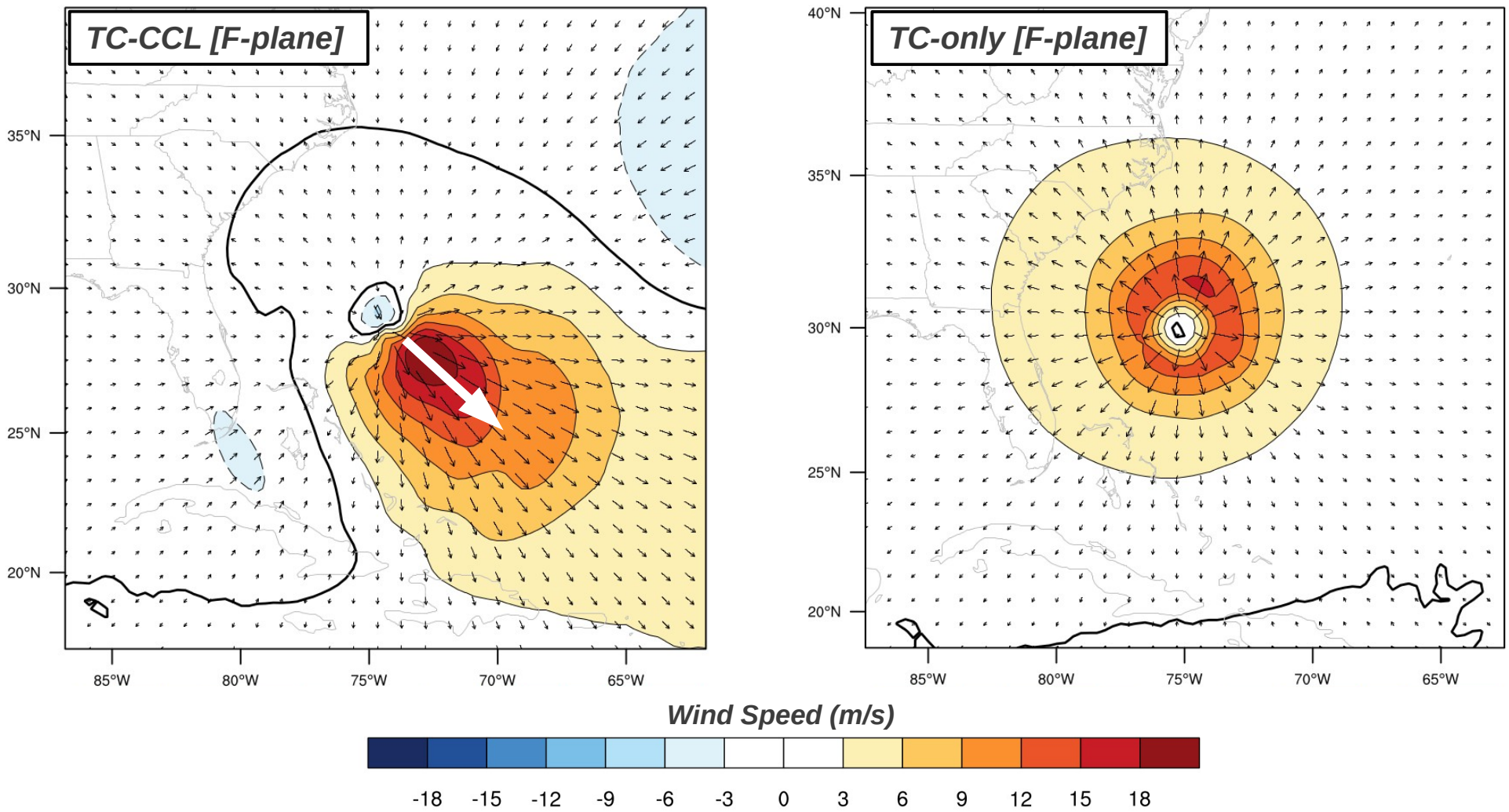
24-hr Avg 200 mb Wind Speed



$$\frac{Du}{Dt} = -\frac{\partial \Phi}{\partial r} + \frac{v^2}{r} + f_0 v$$

- Increased height gradient induces radial outflow to the east
- Anticyclonic tangential winds counter radial acceleration

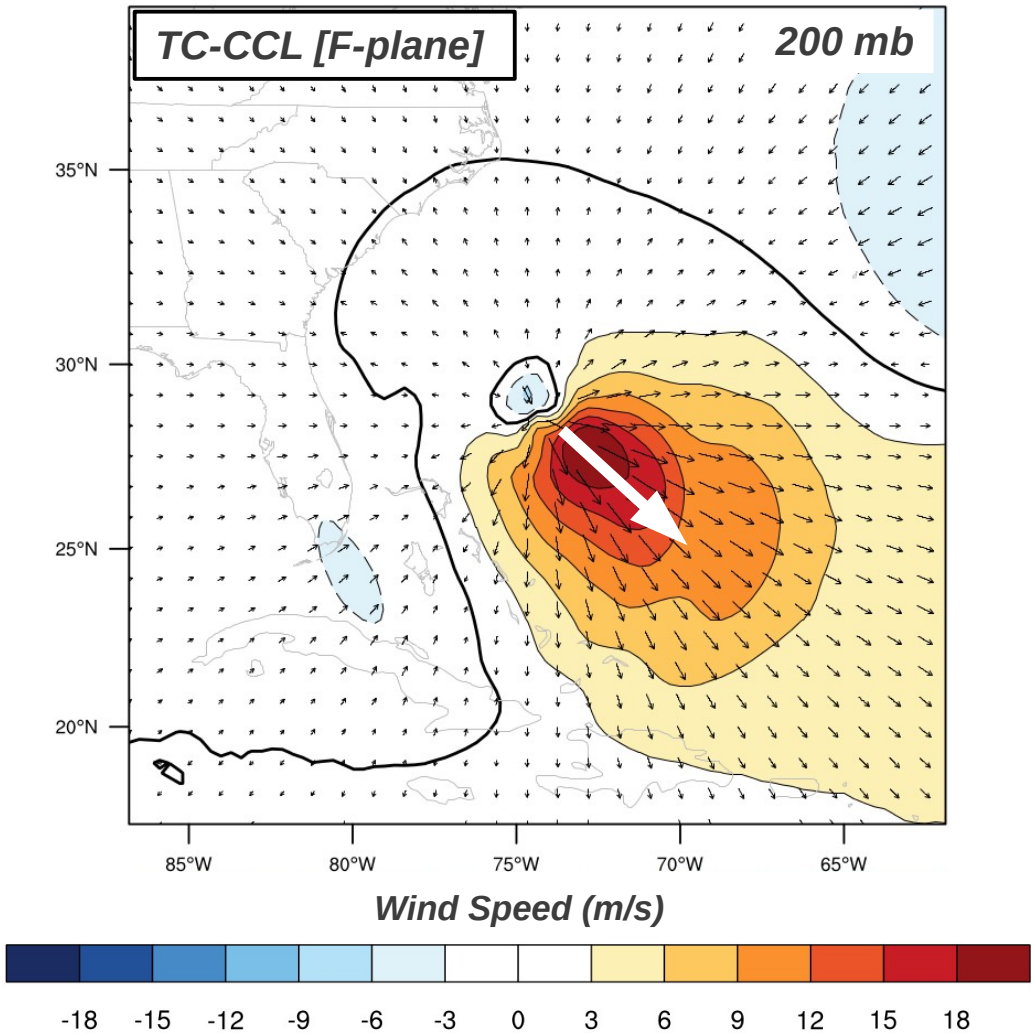
24-hr Avg 200 mb Radial Wind

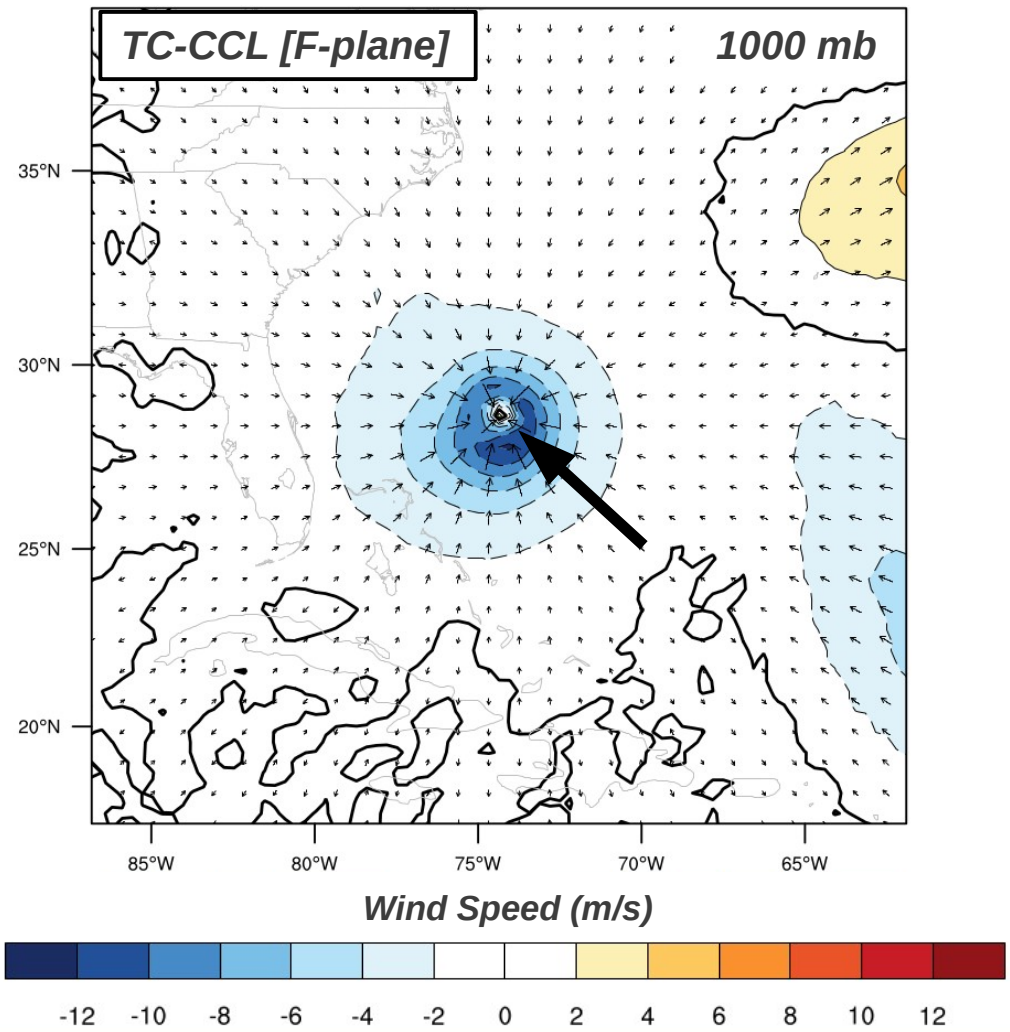


$$\frac{Du}{Dt} = -\frac{\partial \Phi}{\partial r} + \frac{v^2}{r} + f_0 v$$

- Stronger geopotential height gradient generates stronger radial outflow

24-hr Avg 200 mb Radial Wind

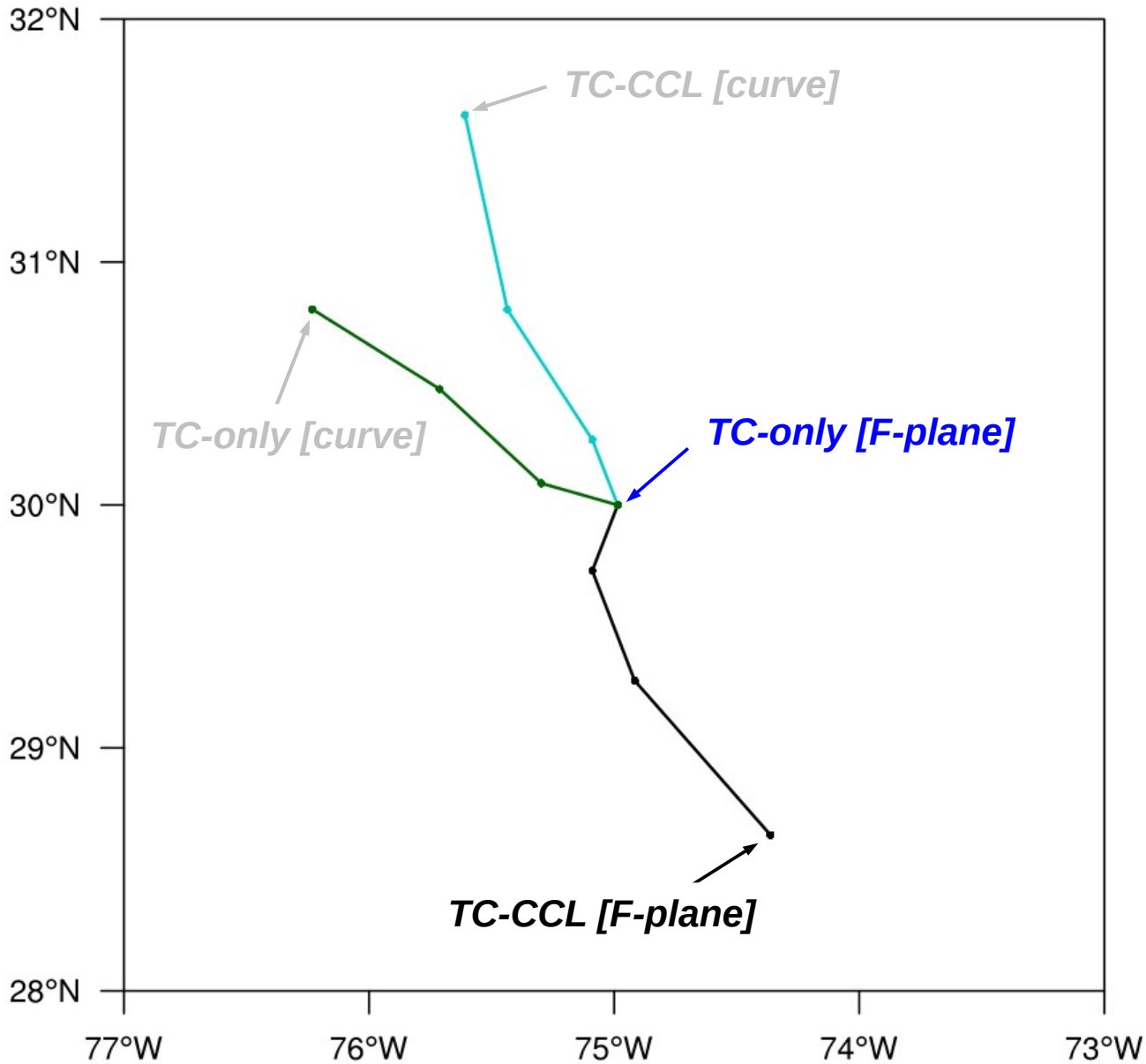




$$\frac{Du}{Dt} = -\frac{\partial \Phi}{\partial r} + \frac{v^2}{r} + f_0 v$$

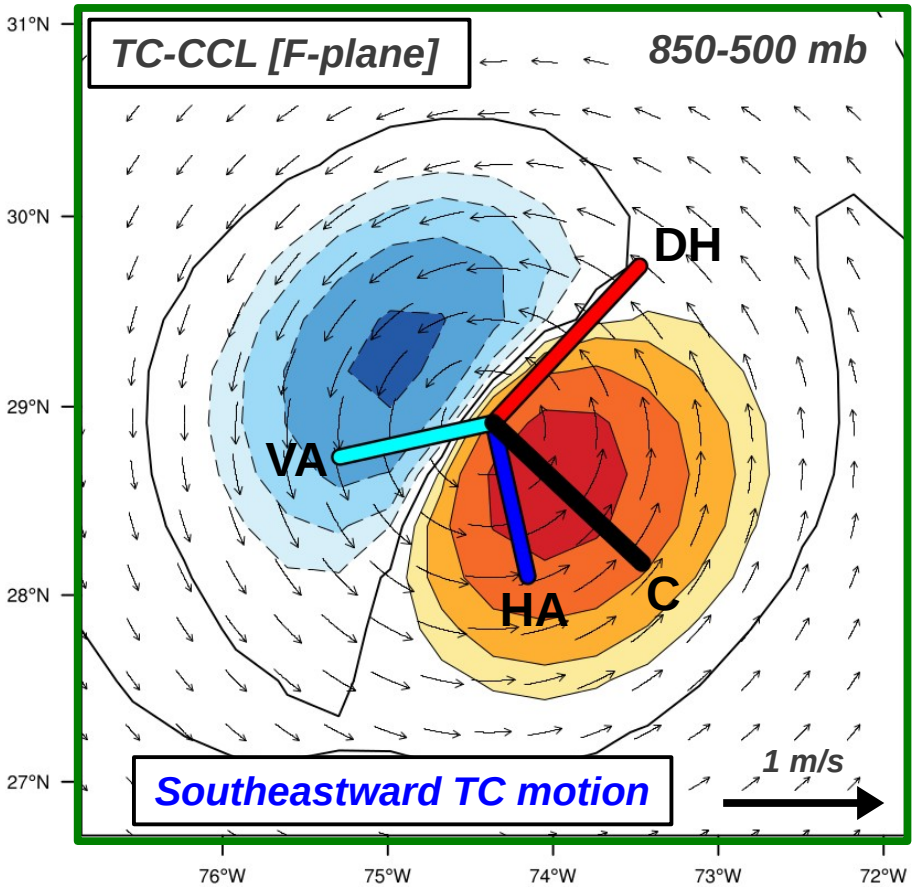
- CCL can be considered an extension of the TC secondary circulation

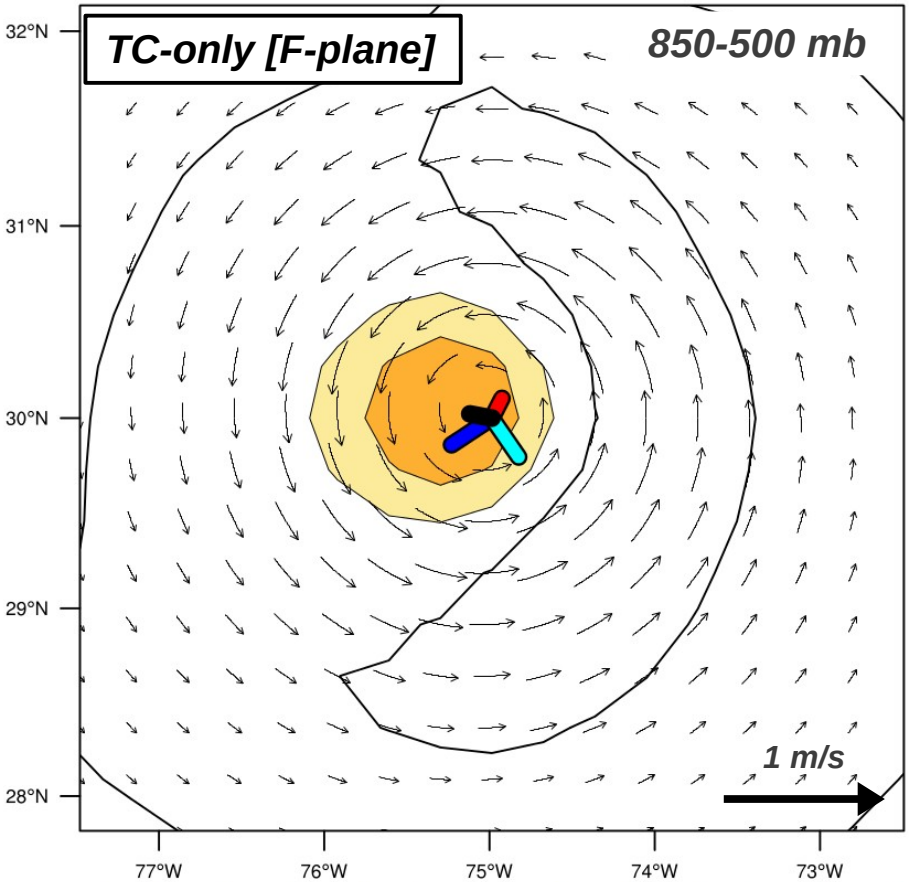
TC Track – 24 hr interval



- TC-only [F-plane] run is “stationary”

24 hr Avg PV Tendency





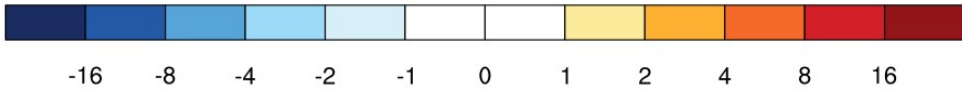
TC motion (C)

Horizontal PV Advection (HA)

Diabatic Heating (DH)

Vertical PV Advection (VA)

PV Tendency (10^{-11} K m^2 kg^{-1} s^{-1})

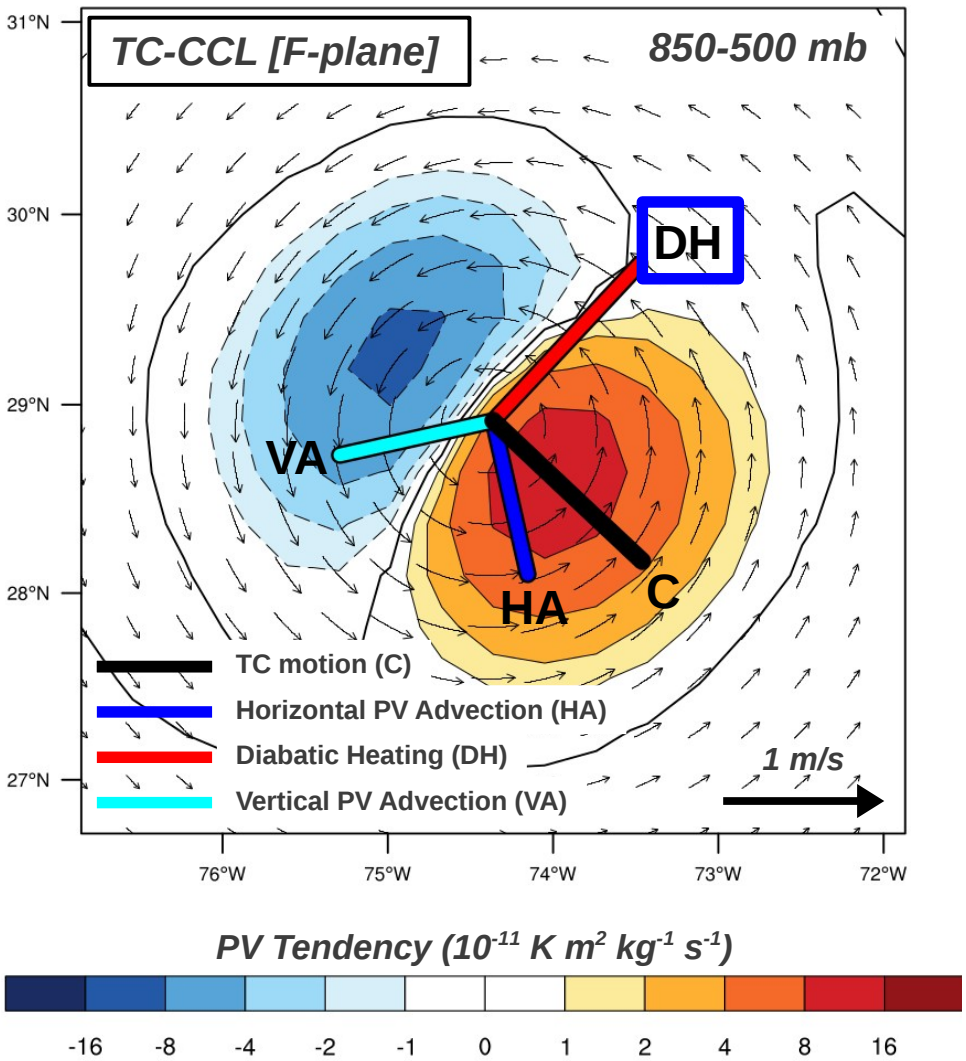


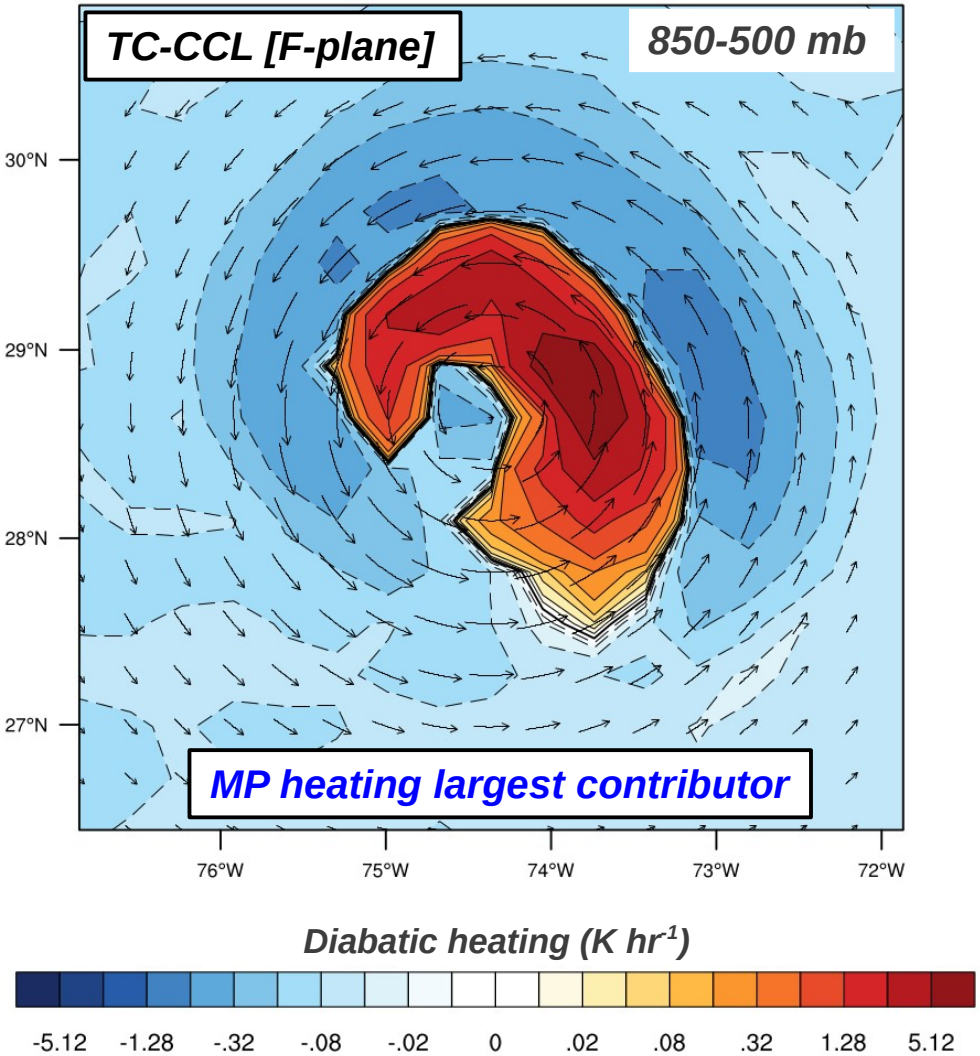
$$\underbrace{\left(\frac{\partial P}{\partial t}\right)_1}_{\mathbf{C}} = \Lambda_1 \left\{ \underbrace{-\mathbf{V}\cdot\nabla P}_{\mathbf{HA}} - \underbrace{\dot{\sigma}\frac{\partial P}{\partial \sigma}}_{\mathbf{VA}} - \underbrace{\frac{g}{p_s}\nabla_3 \cdot \left(-\frac{Q}{C_p \pi}\mathbf{q} + \nabla\theta \times \mathbf{F} \right)}_{\mathbf{DH}} \right\}$$

Wu and Wang (2000)

- Complicated interactions...terms not independent...

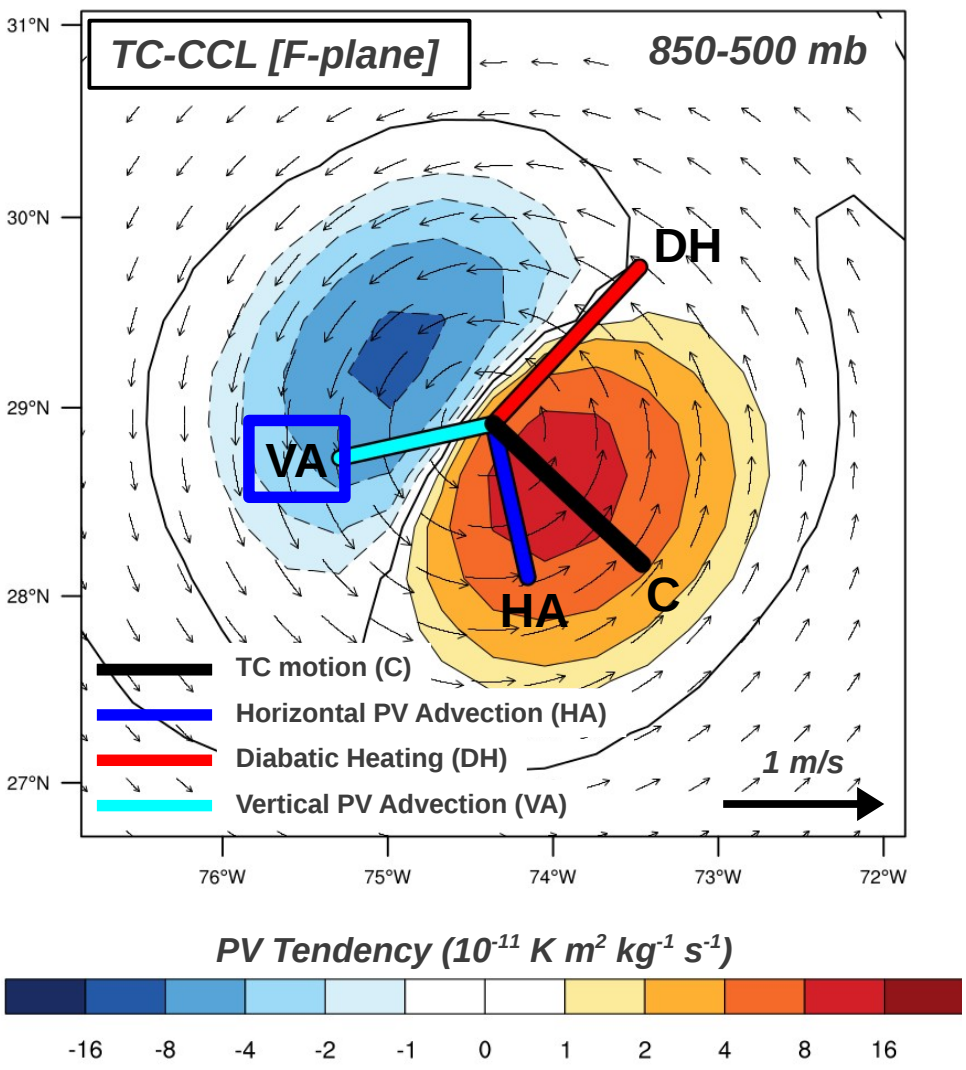
24 hr Avg PV Diabatic Heating

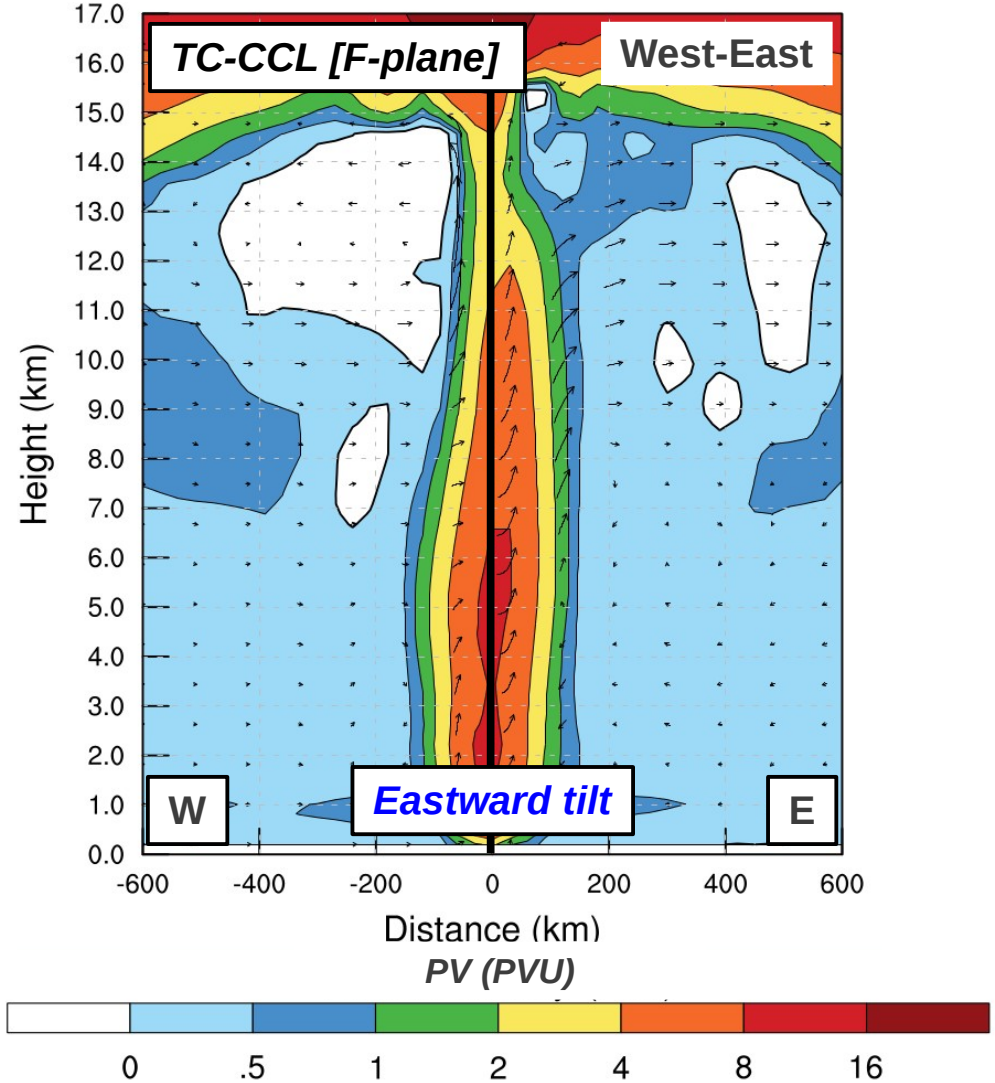




- Diabatic heating points toward max diabatic heating rate (i.e. latent heat release, CRF)

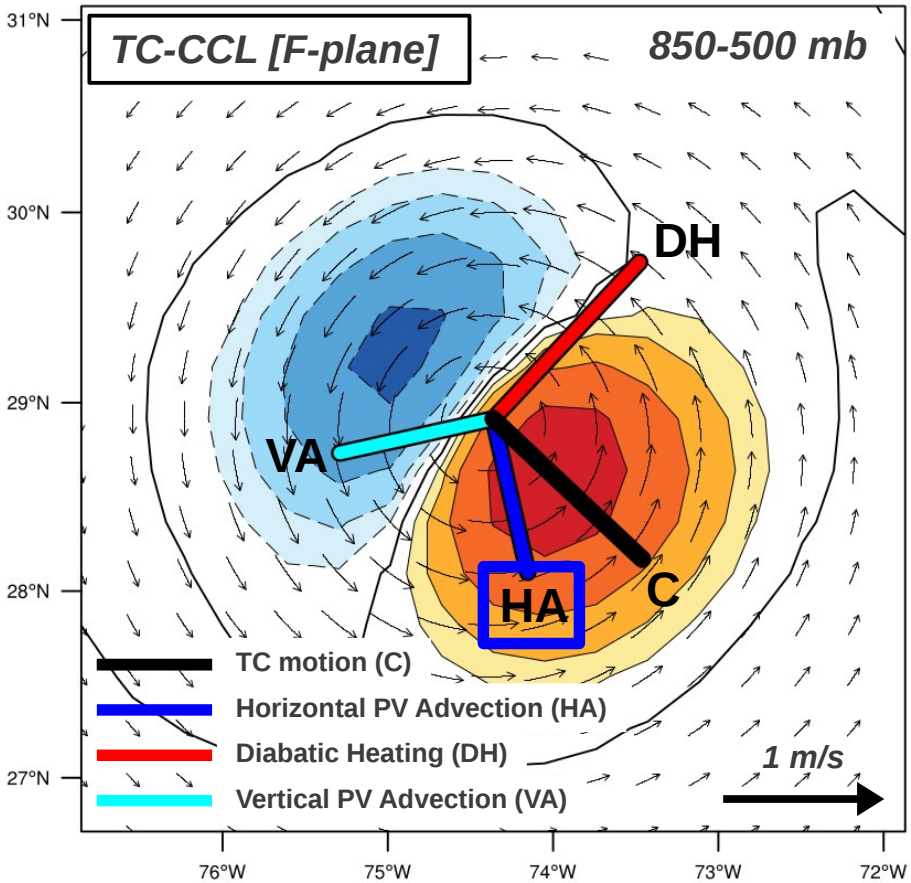
24 hr Avg Vertical PV Advection





- Eastward tilt associated with stronger secondary circulation due to CCL

24 hr Avg PV Tendency



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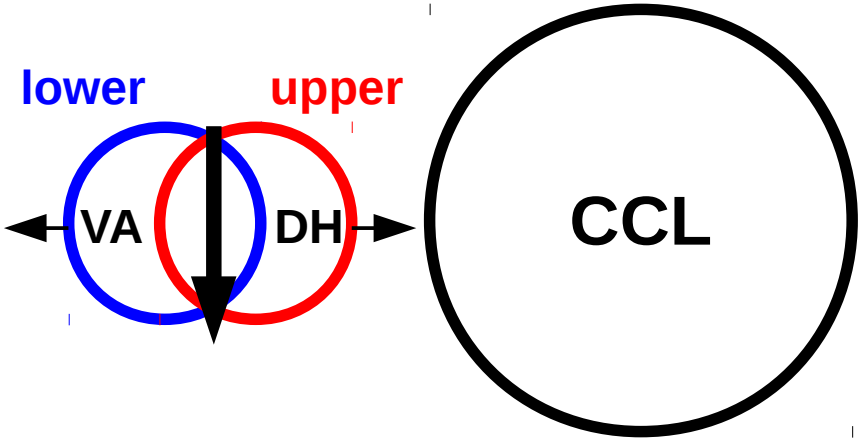
No Beta-effect

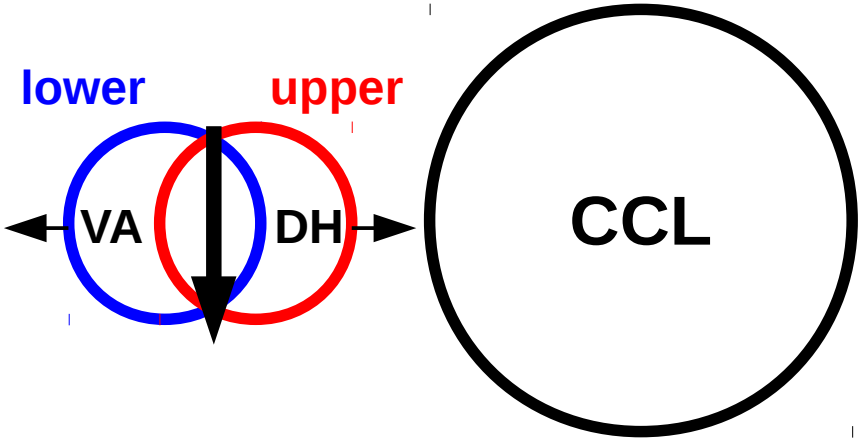
- Not intuitively clear...HA directed ***southward*** in lower-levels and ***northward*** in upper-levels

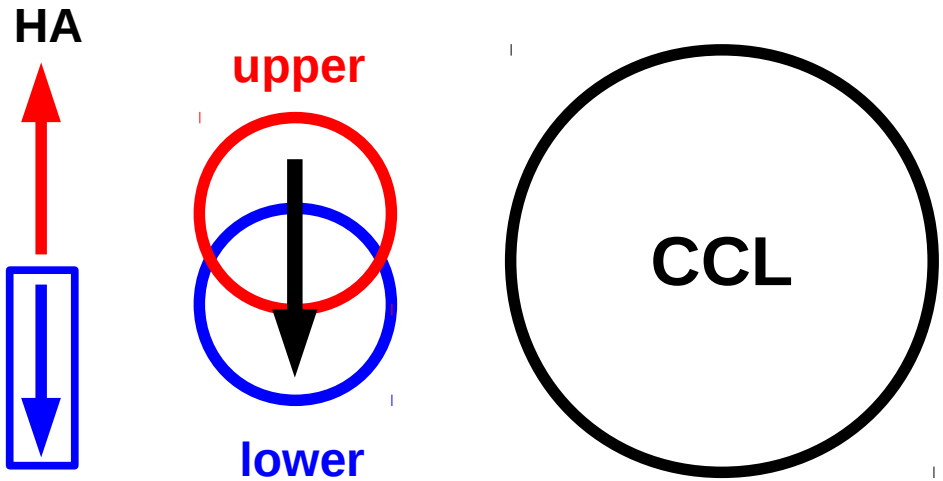
24 hr Avg PV Tendency



- Northerly shear from CCL unopposed

24 hr Avg PV Tendency

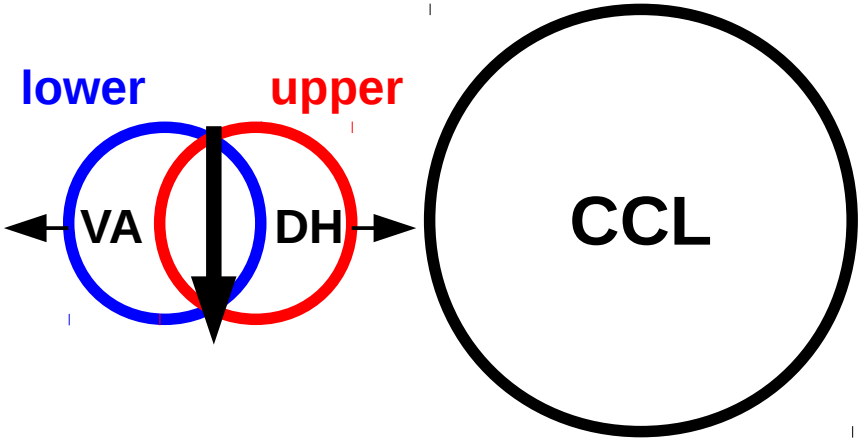


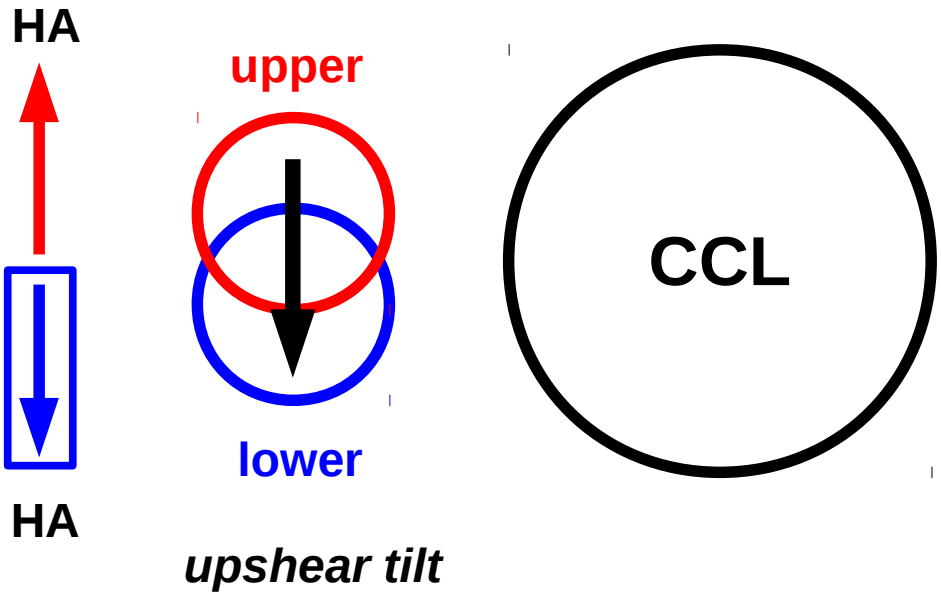


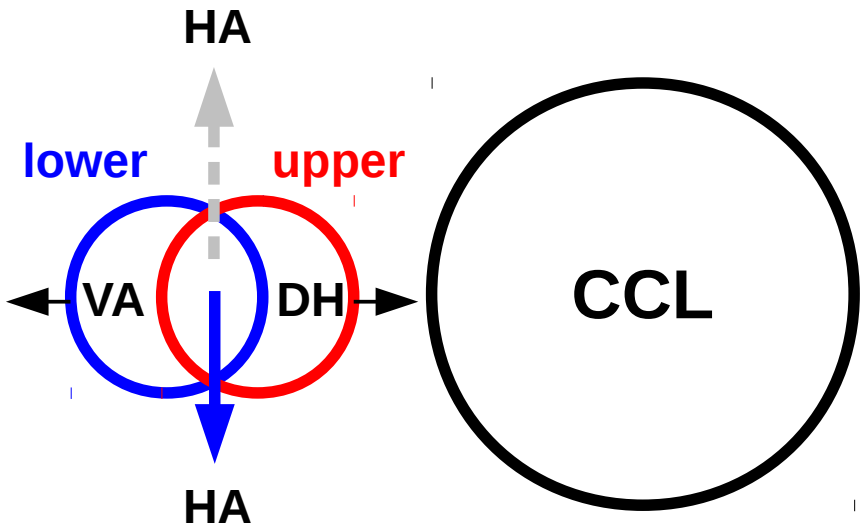
upshear tilt

- HA response serves to tilt TC northward to counter shear...similar to VA

24 hr Avg PV Tendency

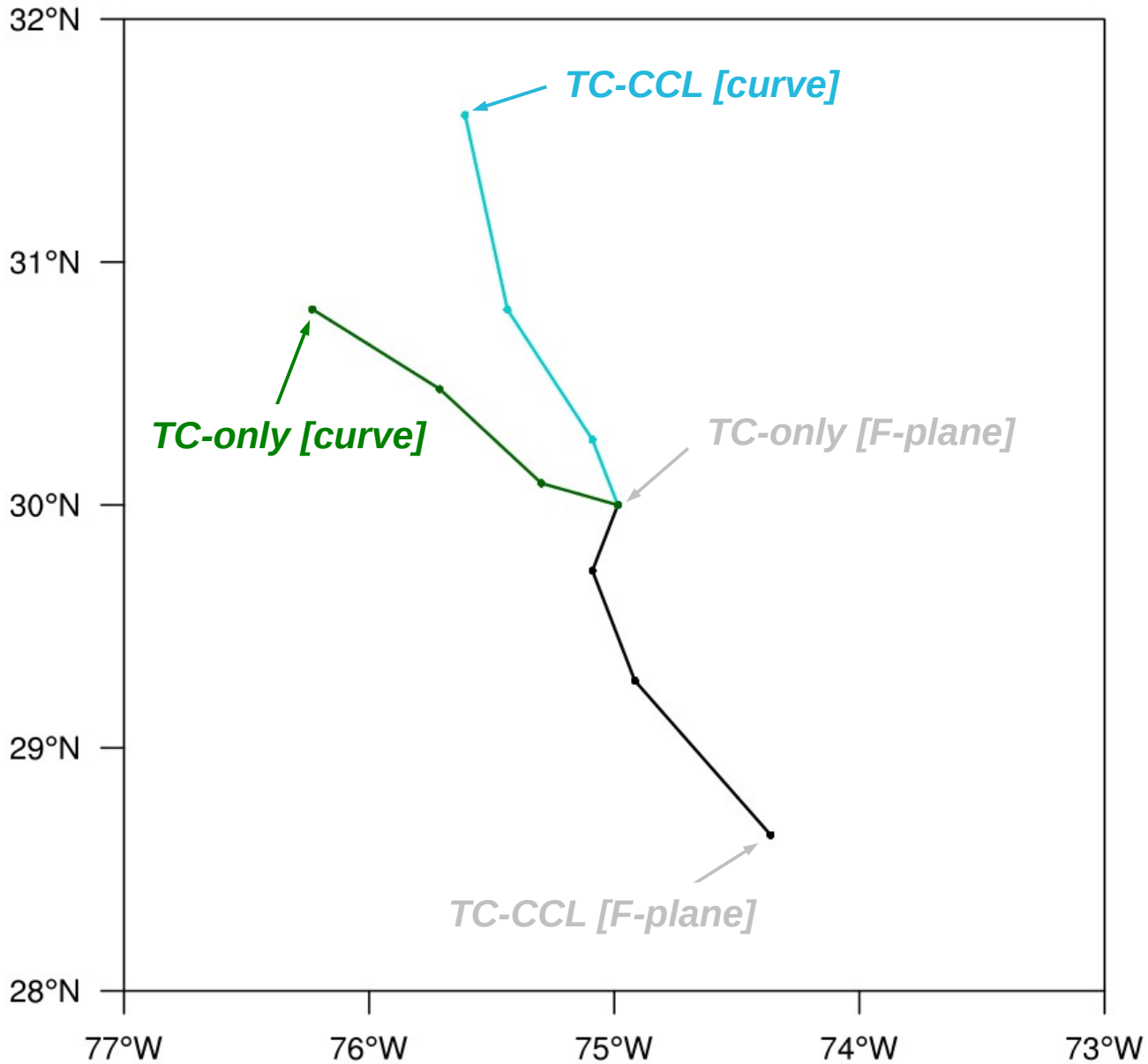






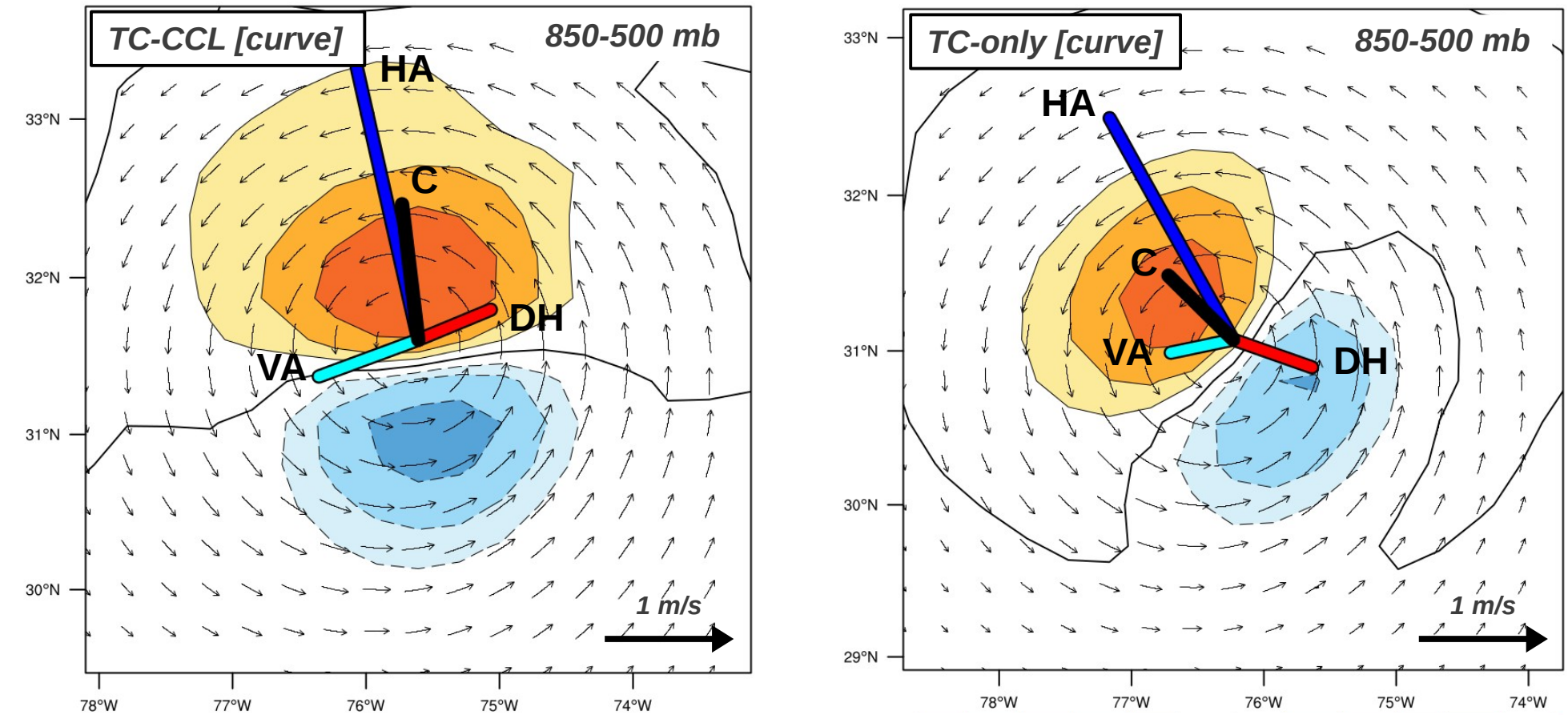
- Upper-level HA cancels shear, lower-level HA is unopposed and influences TC motion...

TC Track – 24 hr interval



- TC-CCL interaction has implications for forecasting TC landfall

24 hr Avg PV Tendency



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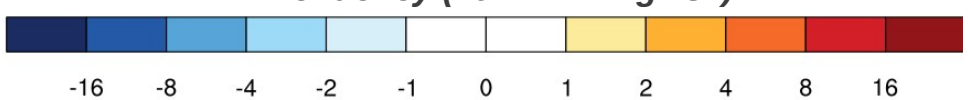

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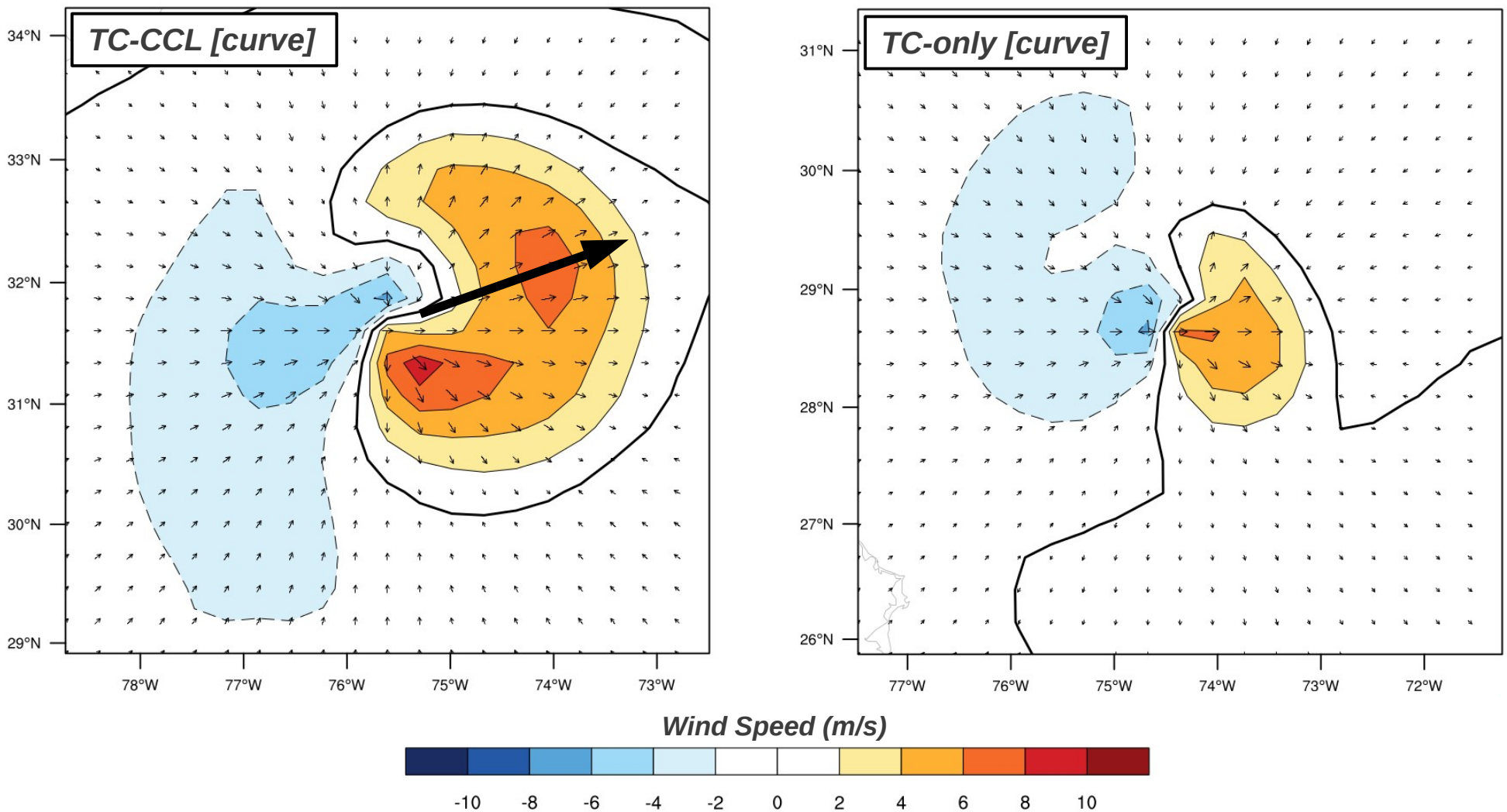
Wu and Wang (2000)

- CCL interaction results in more eastward HA component

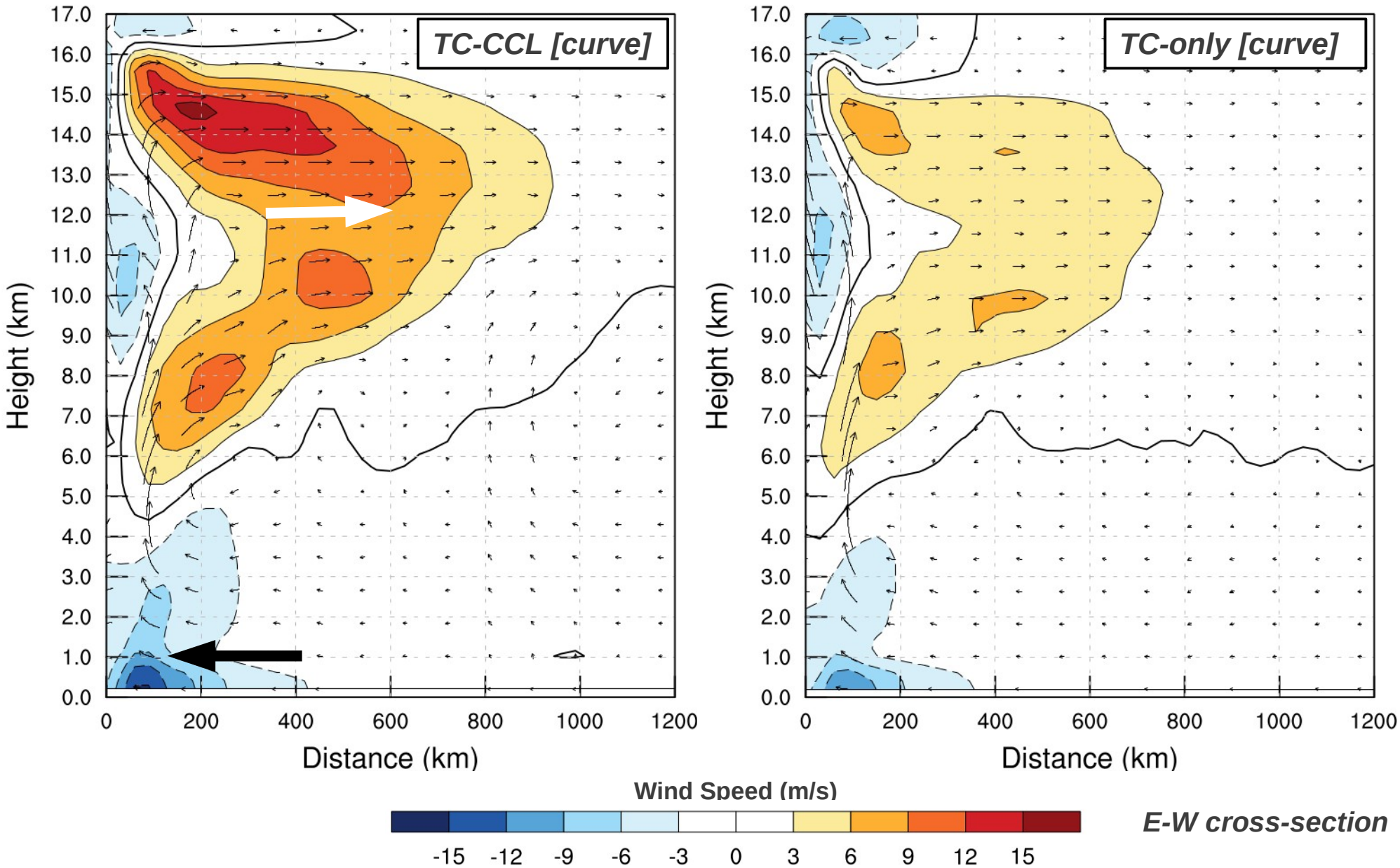
24 hr Avg 500 mb Radial Wind



$$\frac{Du}{Dt} = -\frac{\partial \Phi}{\partial r} + \frac{v^2}{r} + f_0 v$$

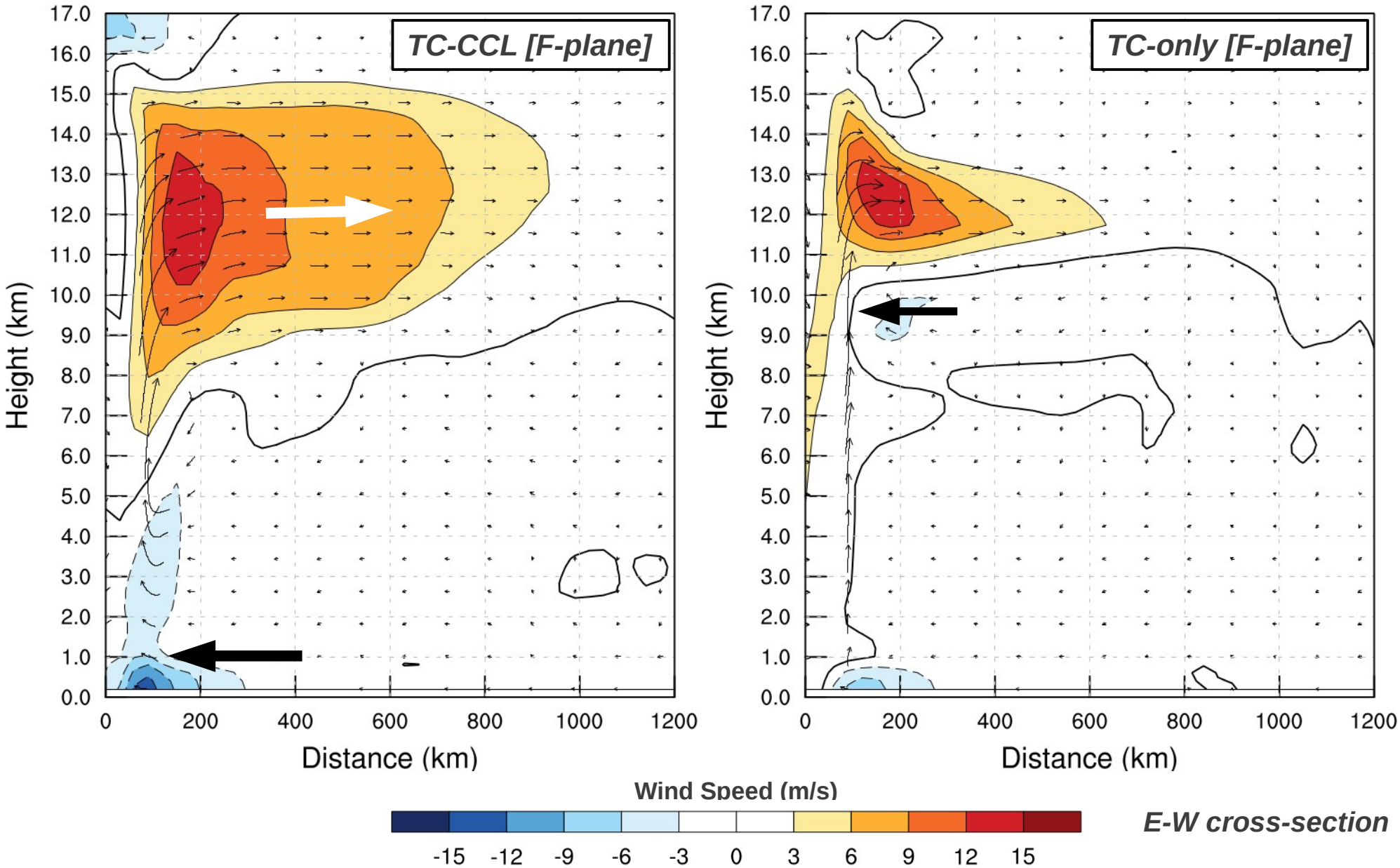
- CCL induces stronger and more asymmetric radial outflow

24-hr Avg Radial Wind



- CCL induces a deeper and more radially extensive outflow layer

24-hr Avg Radial Wind



- CCL induces a deeper and more radially extensive outflow layer

Summary

1) Increased geopotential height gradient enhances radial outflow
- Results in faster storm intensification and broader TC structure

2) CCL interaction has significant influence on TC movement
- Due to CCL influence on TC outflow and secondary circulation

3) CCL induces a deeper and more radially extensive outflow layer
- Influenced by height gradient and decreased inertial stability

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FUTURE WORK

1) Are results consistent with observations?
2) Examine temporal evolution of features
3) Investigate TC structural changes associated with CCL interaction
4) Apply results to TC-longwave trough interaction

Questions?