Exploring the Differences in Deep Convective Transport Characteristics Between Quasi-Isolated Strong Convection and Mesoscale Convective Systems Using Seasonal WRF Simulations

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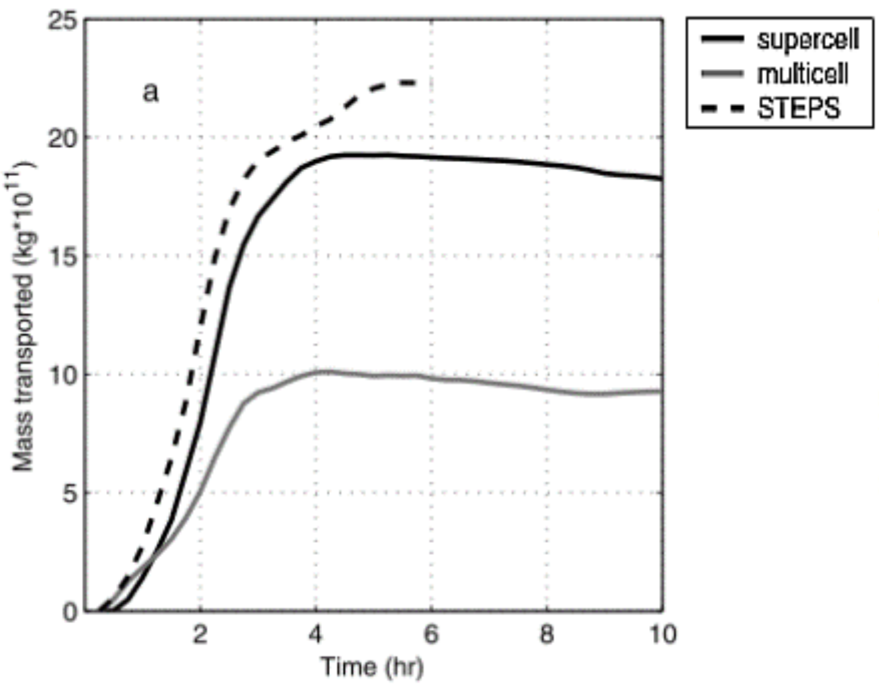
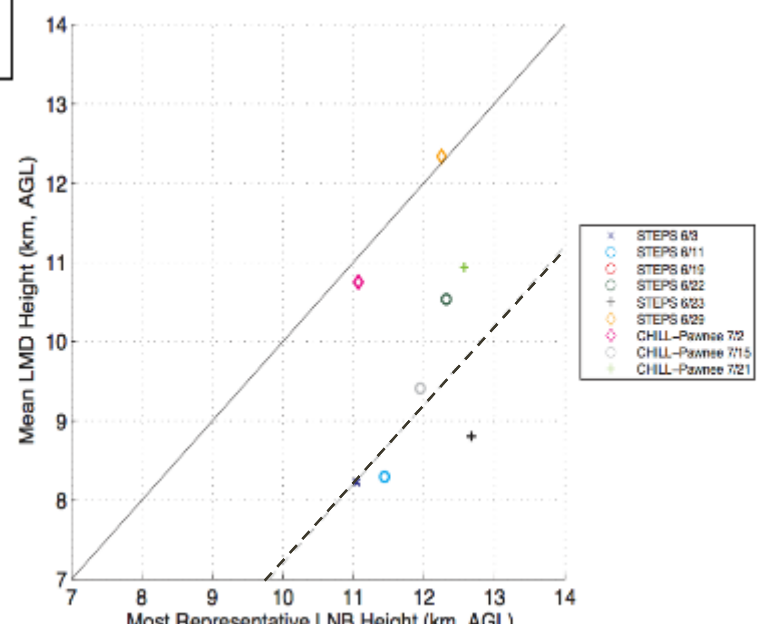
Motivations

- Mass Transport
  - Convection is an efficient and important mechanism by which the transport of chemical constituents from the planetary boundary layer (PBL) to the upper troposphere/lower stratosphere (UTLS) region occurs (e.g. Dickerson et al. 1987; Mullendore et al. 2005; Barth et al. 2007; Lawrence and Salzmann 2008)
- Previous Studies
  - Focus of study was on either a single type of convection, or general cumulus convection (e.g. Thompson et al. 1994; Stenchikov et al. 1996; Barth et al. 2007; Halland et al. 2009)

Basis and Purpose of Study

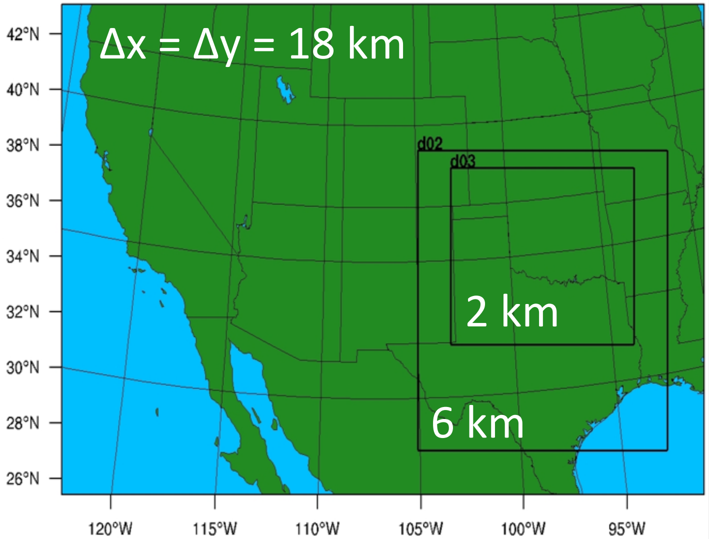
- Differences in transport characteristics between a supercell and a multicell have been recognized (Mullendore et al. 2005; Mullendore et al. 2013).
- In terms of Magnitude…
  - Mullendore et al. (2005)
- And altitude…
  - Mullendore et al. (2013)
    - Supercells = ◆





Model Setup

- Model
  - Weather Research and Forecasting model with chemistry (WRF-CHEM)
- Analysis Period
  - 15 – 31 May 2007 (17 days)
    - Shear zone convection
  - 01 – 13 July 2007 (13 days)
    - Sub-tropical warm sector convection
- Discretization
  - Vertical
    - Added resolution in UTLS
      - ~9-13 km
      - Equal 250 m spacing



Thunderstorm Classification

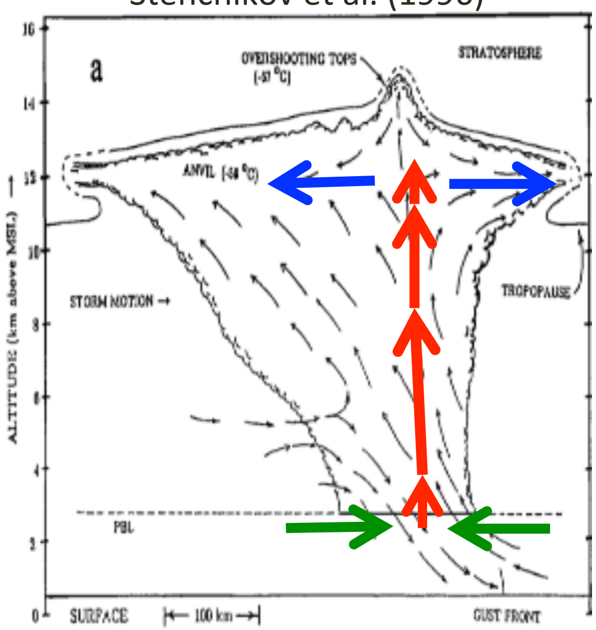
Green = Agrees with Schoen and Ashley (2011)
Red = Determined from Testing

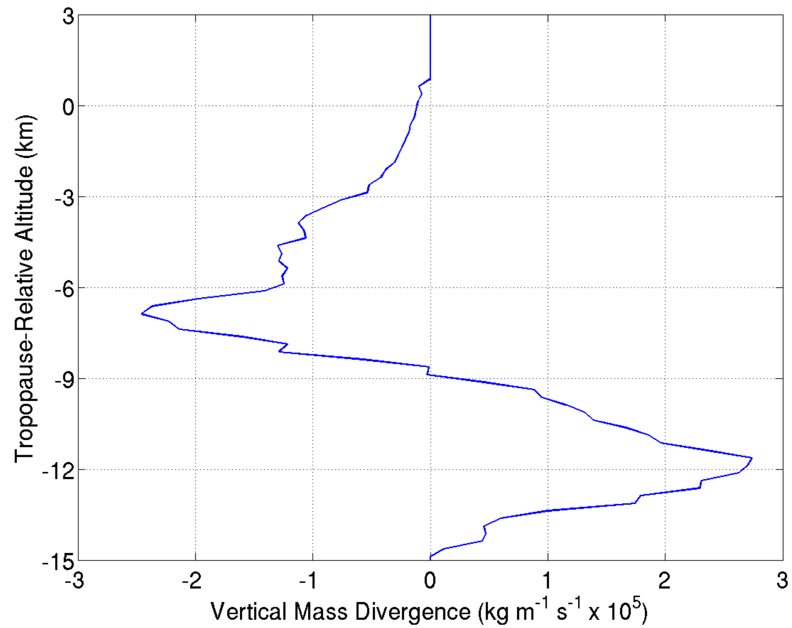
	Weak Convection (WC)	**Quasi-Isolated Strong Convection (QISC)**	**Mesoscale Convective System (MCS)**
Radar Reflectivity Characteristics	< 40 dBZ everywhere in object	**≥ 40 dBZ at least 1 point in object**	**≥ 40 dBZ at least 1 point in object**
Areal Characteristics (Reflect. > 0 dBZ)	**Can be any size**	**< 7000 km²**	**≥ 7000 km²**

Deep Convection and Analysis

- Deep convection defined as $w \geq 2$ m s^{-1} at $z = 4$ km AND $w \geq 5$ m s^{-1} at $z = 8$ km
- Vertical mass divergence [$\partial(\rho w)/\partial z$] was calculated for each column of deep convection and columns were summed together (Mullendore et al. 2009).
  - Only positive vertical velocities were used

Stenchikov et al. (1996)

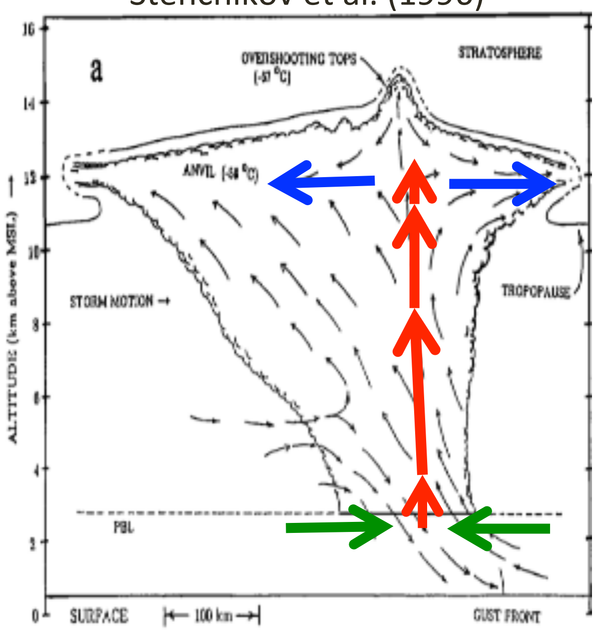


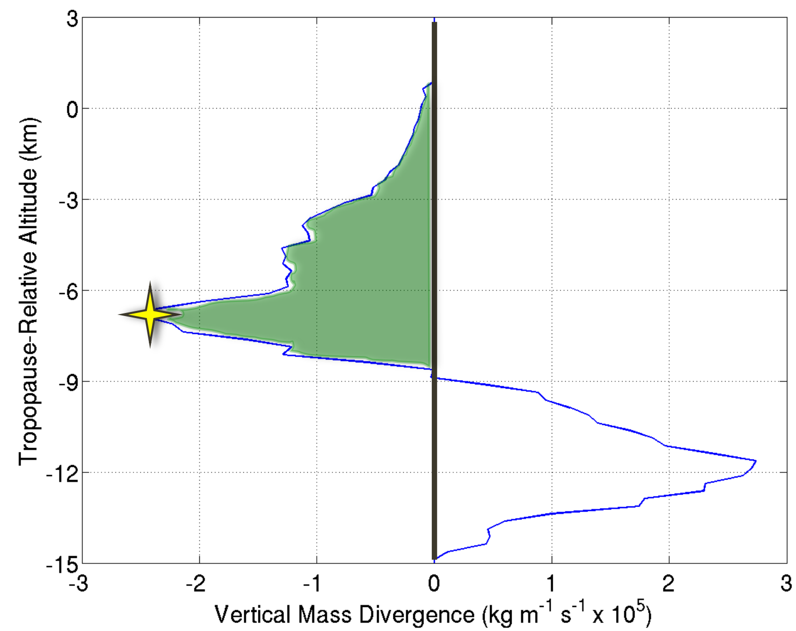


Deep Convection and Analysis

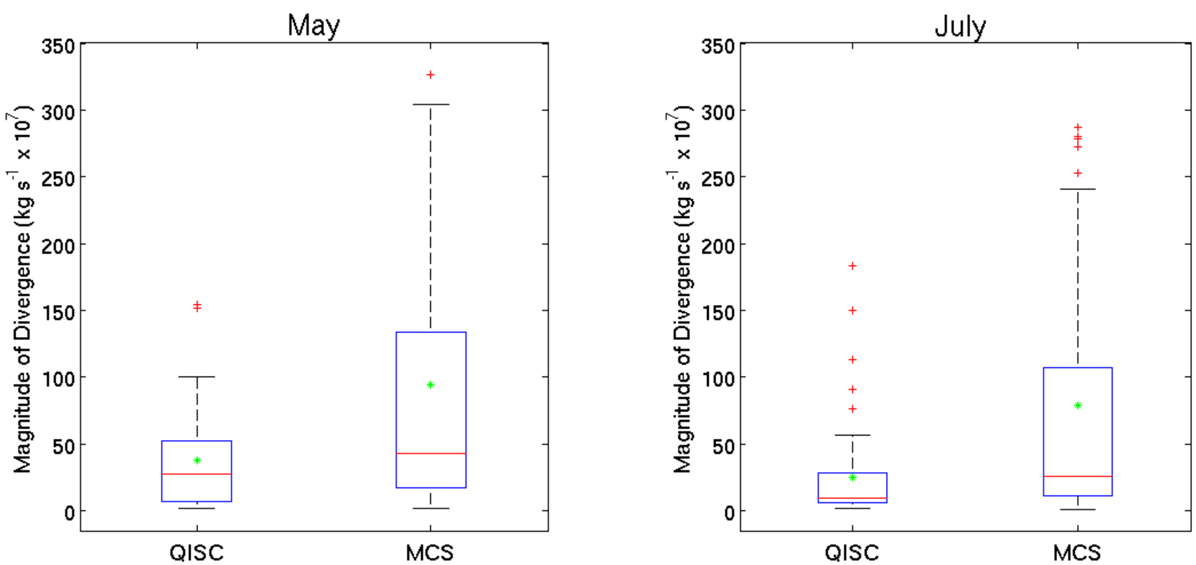
- Analyzed vertical convergence (horizontal divergence) for analysis
  - Level of Maximum Detrainment (LMD, Mullendore et al. 2009; 2013) determined from maximum vertical convergence
    - Calculated relative to NARR tropopause heights mapped onto analysis domain
  - Magnitude of the vertical convergence calculated as proxy for amount of detrainment

Stenchikov et al. (1996)





Transport Magnitude Per Object

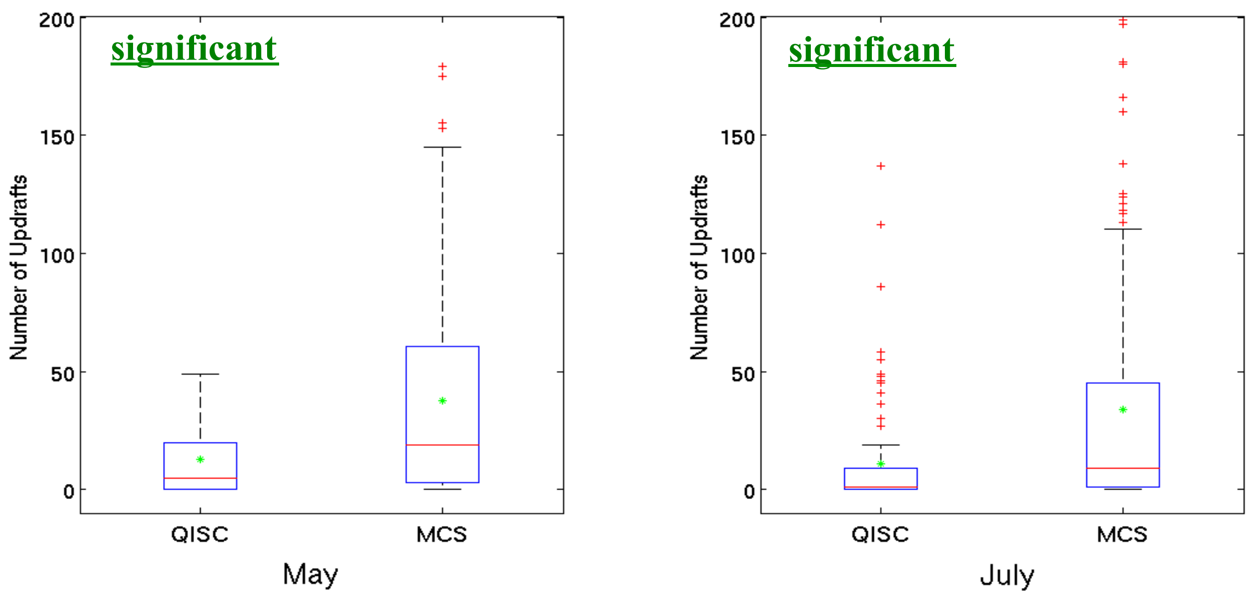


38 183 # Hours 92 138

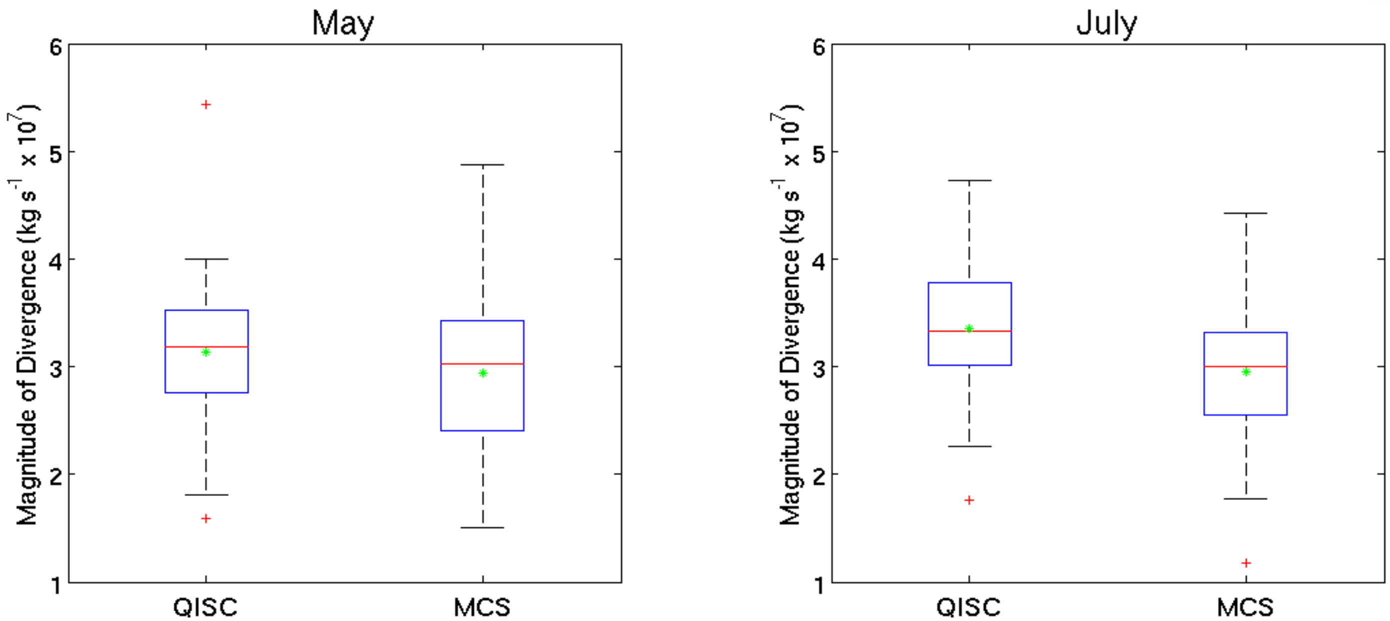
- Box and Whisker Distributions of magnitude
    - Each hour where QISC or MCS dominant represents 1 point in the plot
    - Green Asterisk – Mean value
- For Both May and July:
    - MCS detrains **statistically significantly** more mass out of the updrafts *per deeply convective complex* than QISC

Number of Deeply Convective Updrafts

- Deep Convection Defined as:
  - $w \geq 2$ m s^{-1} at $z = 4$ km AND $w \geq 5$ m s^{-1} at $z = 8$ km
- There is a relationship between the amount of deep convective updrafts and the detrainment out of the updrafts per deeply convective storm complex



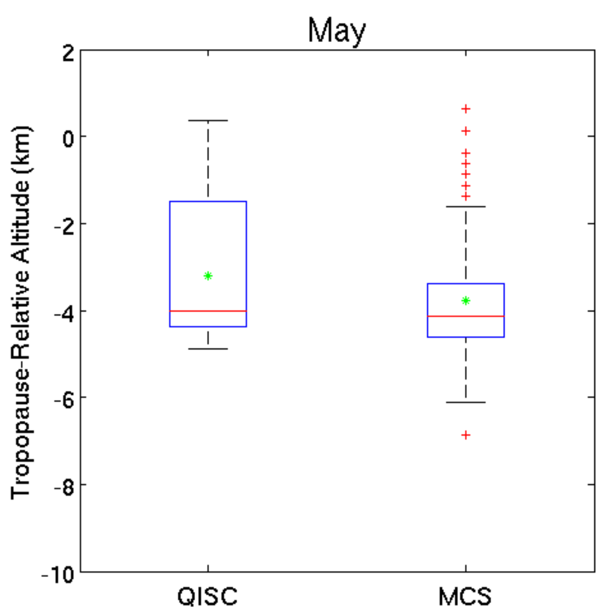
Transport Magnitude Per Updraft

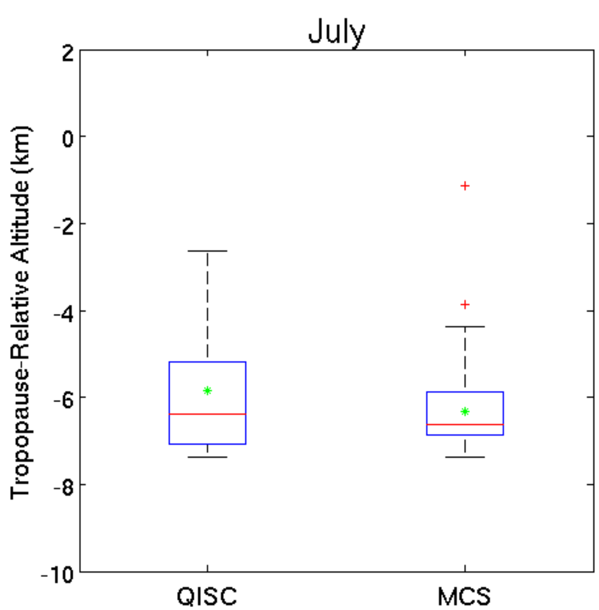


- Magnitude of Detrainment Per Updraft
- For May:
  - QISC does **not statistically significantly** detrain more mass out of the updrafts *per updraft* than MCS
- For July:
  - QISC detrains **statistically significantly** more mass out of the updrafts *per updraft* than MCS

Transport Altitude (Tropopause-Relative)

- Due to difference in environment, tropopause height at least 2 km higher in July than in May
  - Could Lead to reason why July maxes at ~-2.5 km and May > 0 km
- In both May and July, the QISC LMD, relative to the altitude of the tropopause, is **statistically significantly** higher than that of the MCS





Results

- Summary of Results:
  - Differences are MCS – QISC
  - Ratios are MCS / QISC

	Differences and ratios of mean values of transport characteristics between MCS and QISC regimes			
	Detrainment *Per Deeply Convective Storm Complex*	# of Deeply Convective Updrafts	Detrainment *Per Updraft*	Tropopause-Relative LMD Altitude
May	2.4:1	2.9:1	0.9:1	-583 m
July	3.1:1	3.1:1	0.8:1	-487 m

Conclusions

- The MCS regime capable of detraining > 2 times the amount of mass out of updrafts per storm complex than QISC.
  - Due in part to significantly more updrafts in MCS's
- QISC updrafts, individually, are much stronger and more efficient transporters than MCS updrafts
  - Able to detrain more mass at a higher altitude relative to the tropopause
    - Better chance for QISC to have irreversible transport to the stratosphere than an MCS

- Objective classification of storms for deep convective transport studies important
  - Accounts for variability in overall transport budget due to different storm types
    - Not realized at global transport model scales (where convection parameterized)