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SCHOOL OF ENERGY AND ENVIRONMENT

Angular momentum transport and tropical cyclone size changes

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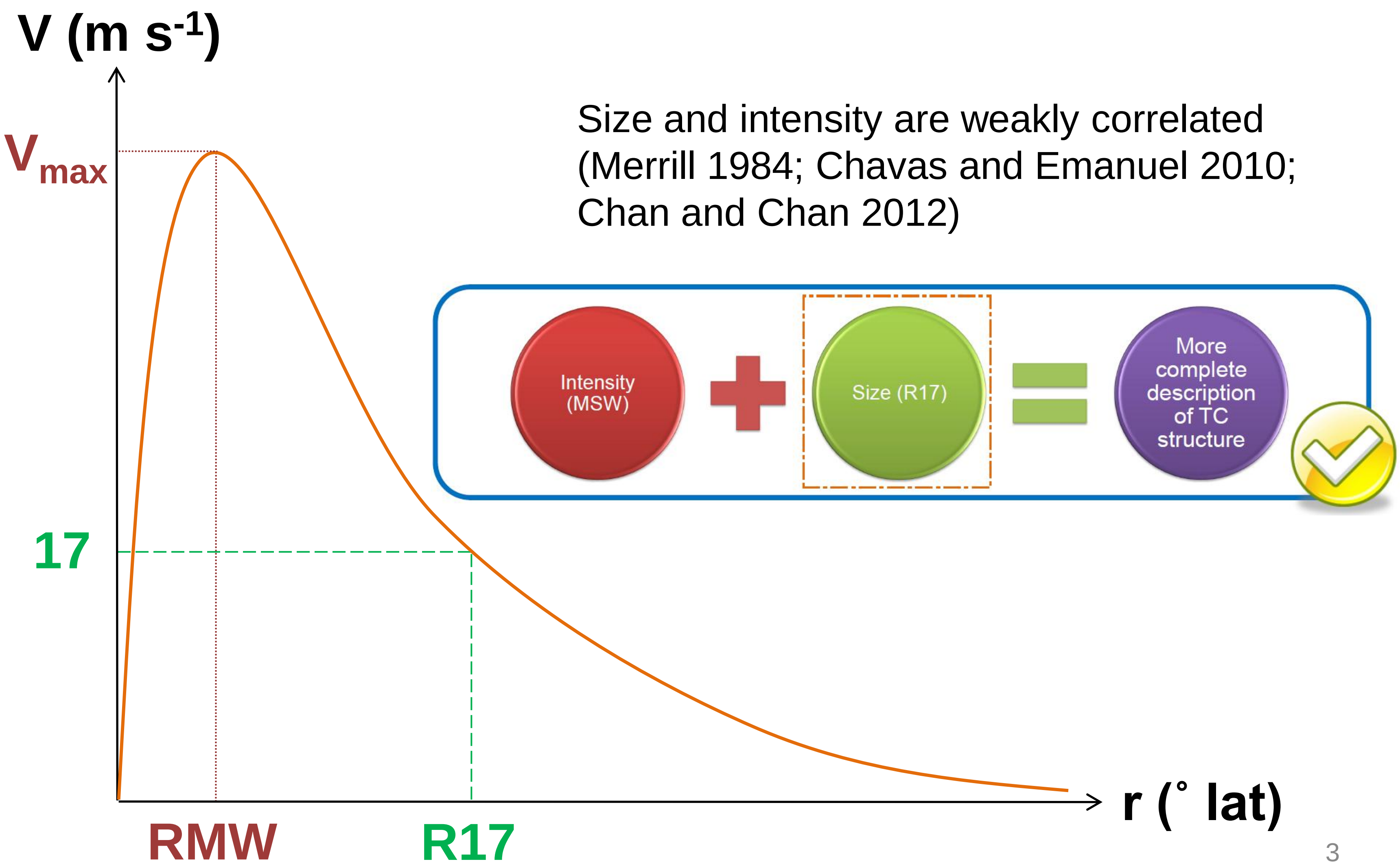
Chan, K. T. F., and J. C. L. Chan, 2012: Angular momentum transport and tropical cyclone size changes. *Mon. Wea. Rev.* (under review)

Outline

- Introduction and Objectives
- Data and Methodology
- Results
- Conclusions

TC Size and Intensity



Size and intensity are weakly correlated (Merrill 1984; Chavas and Emanuel 2010; Chan and Chan 2012)

Objectives

- To investigate the mechanism(s) on how the TC size changes using observational and reanalysis data
  - Dynamic factor: Change in Angular Momentum Transport
- To identify the synoptic flow difference between the size-increase (+ΔS) and size-decrease (–ΔS) TCs

Data

Data based on: Chan and Chan (2012)

- Observational data – TC size
  - REMSS QuikSCAT data
  - 0.25˚ lat x 0.25˚ lon
  - July 19, 1999 – Nov 19, 2009 **(Study period)**
- Reanalysis Data – TC AM
  - NCEP CFSR data
  - 0.5˚ lat x 0.5˚ lon

Categories

$\Delta S_{TCi} = S_{TCi}(t2) - S_{TCi}(t1)$
$\Delta I_{TCi} = I_{TCi}(t2) - I_{TCi}(t1)$
$t2 - t1 \leq 24$ h

WNP	I↑	I↓
S↑	191 (111) [I:+13.7, S:+0.42]	93 (51) [I:-12.4, S:+0.30]
S↓	68 (55) [I:+13.9, S:-0.22]	70 (42) [I:-11.6, S:-0.24]

NA	I↑	I↓
S↑	59 (31) [I:+12.3, S:+0.29]	57 (23) [I:-10.0, S:+0.26]
S↓	30 (22) [I:+11.2, S:-0.21]	38 (25) [I:-9.9, S:-0.27]

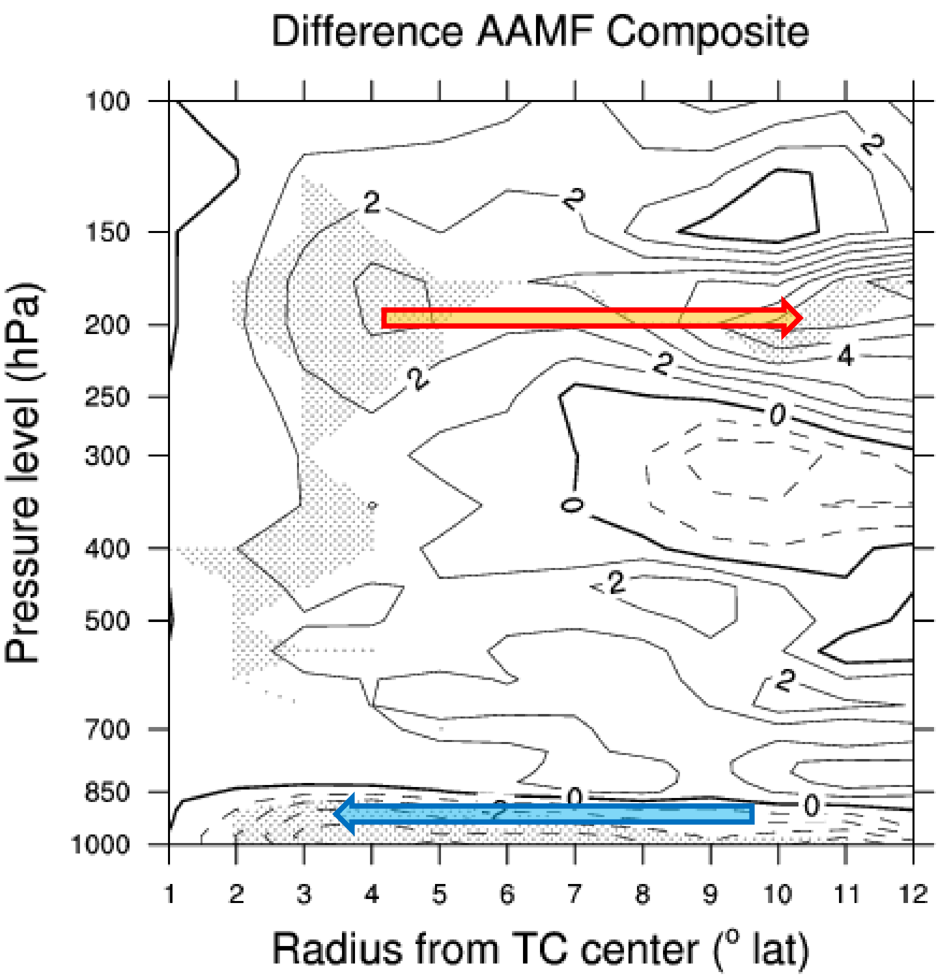
Angular momentum transports

$$M(r) = \underbrace{r\overline{v_\theta}\,\overline{v_r}}_{\text{Term A}} + \underbrace{r\overline{v_r'v_\theta'}}_{\text{Term B}} + \underbrace{\frac{f_0 r^2 \overline{v_r}}{2}}_{\text{Term C}} + \underbrace{\frac{r^2\,\overline{f v_r'}}{2}}_{\text{Term D}}$$

- Term A: Symmetric RAM (SRAM)
- Term B: Asymmetric or eddy RAM (ARAM)
- Term C: Symmetric Coriolis torque (SCT)
- Term D: Asymmetric or eddy Coriolis torque (ACT)

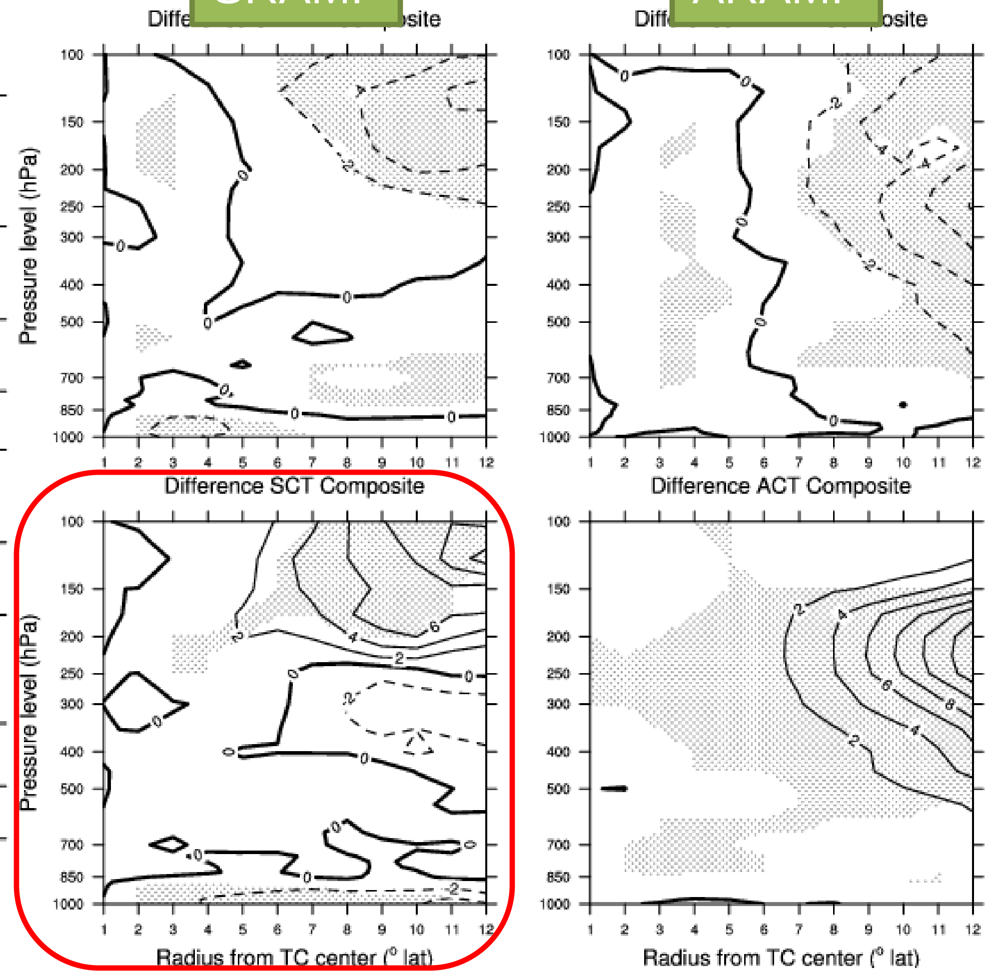
I↑S↑

WNP



SRAMF

ARAMF

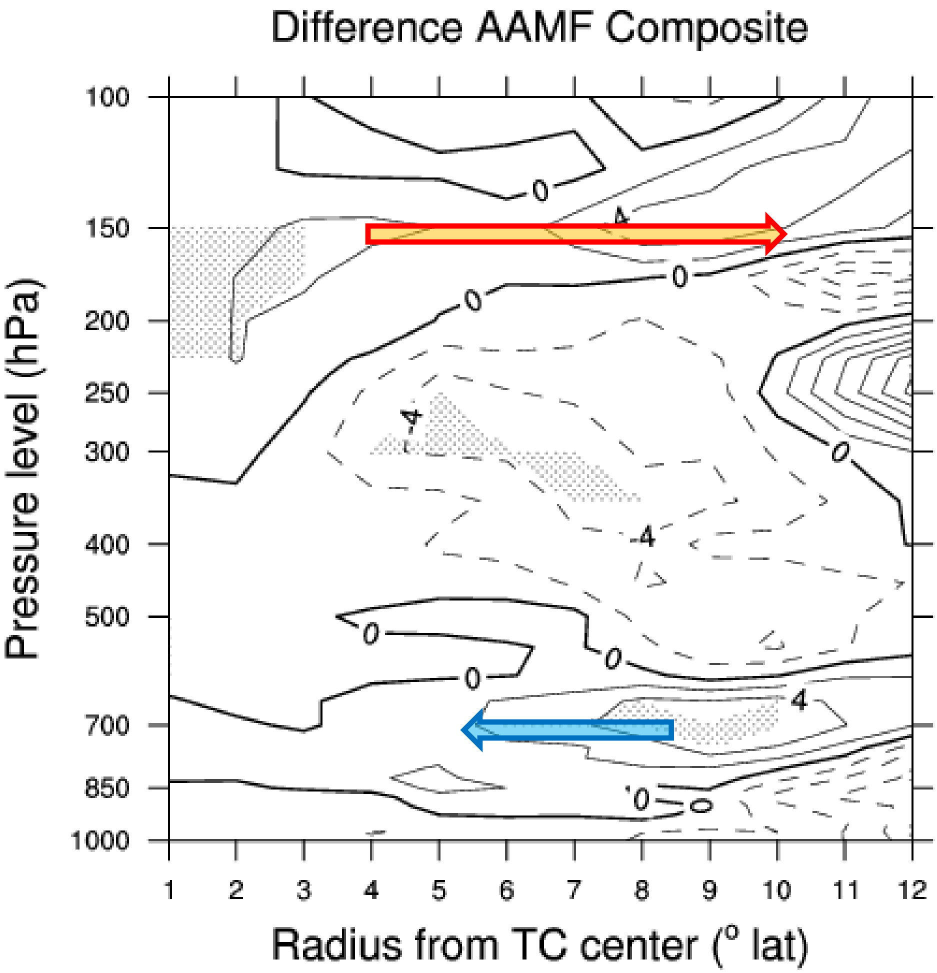


SCT

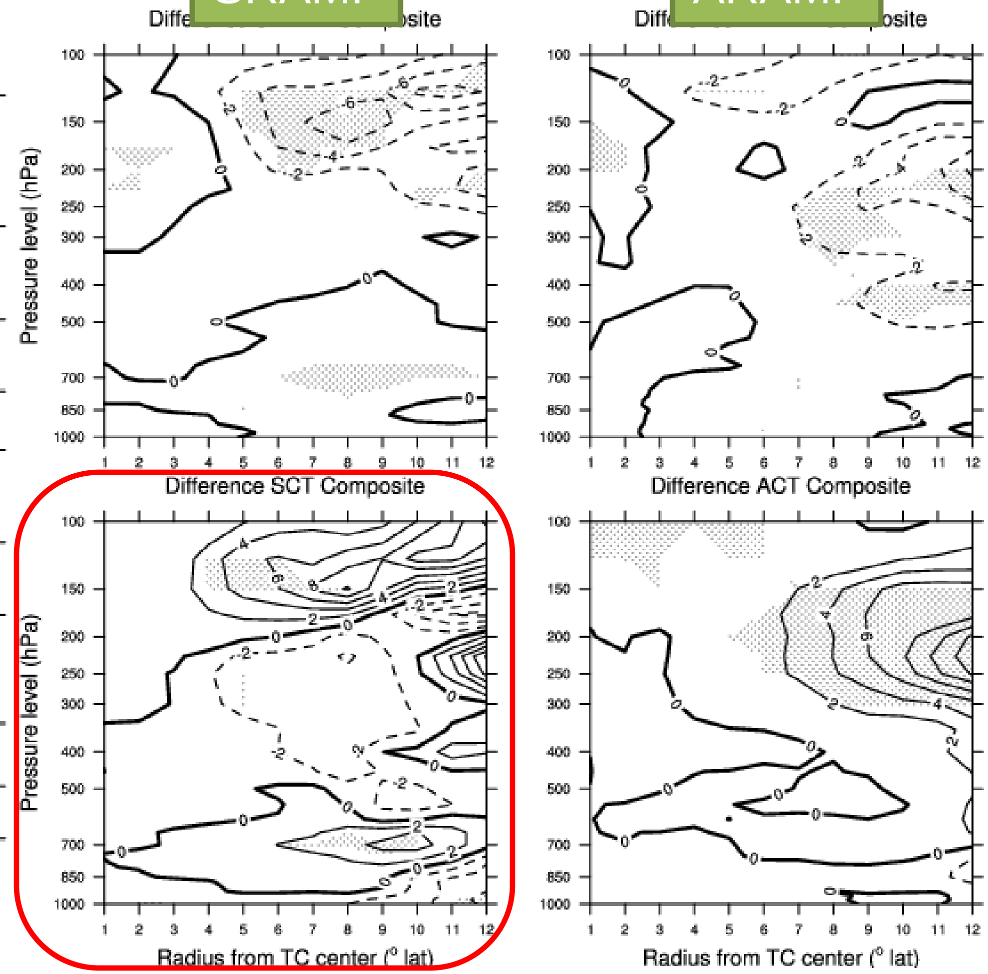
ACT

I↑S↓

WNP



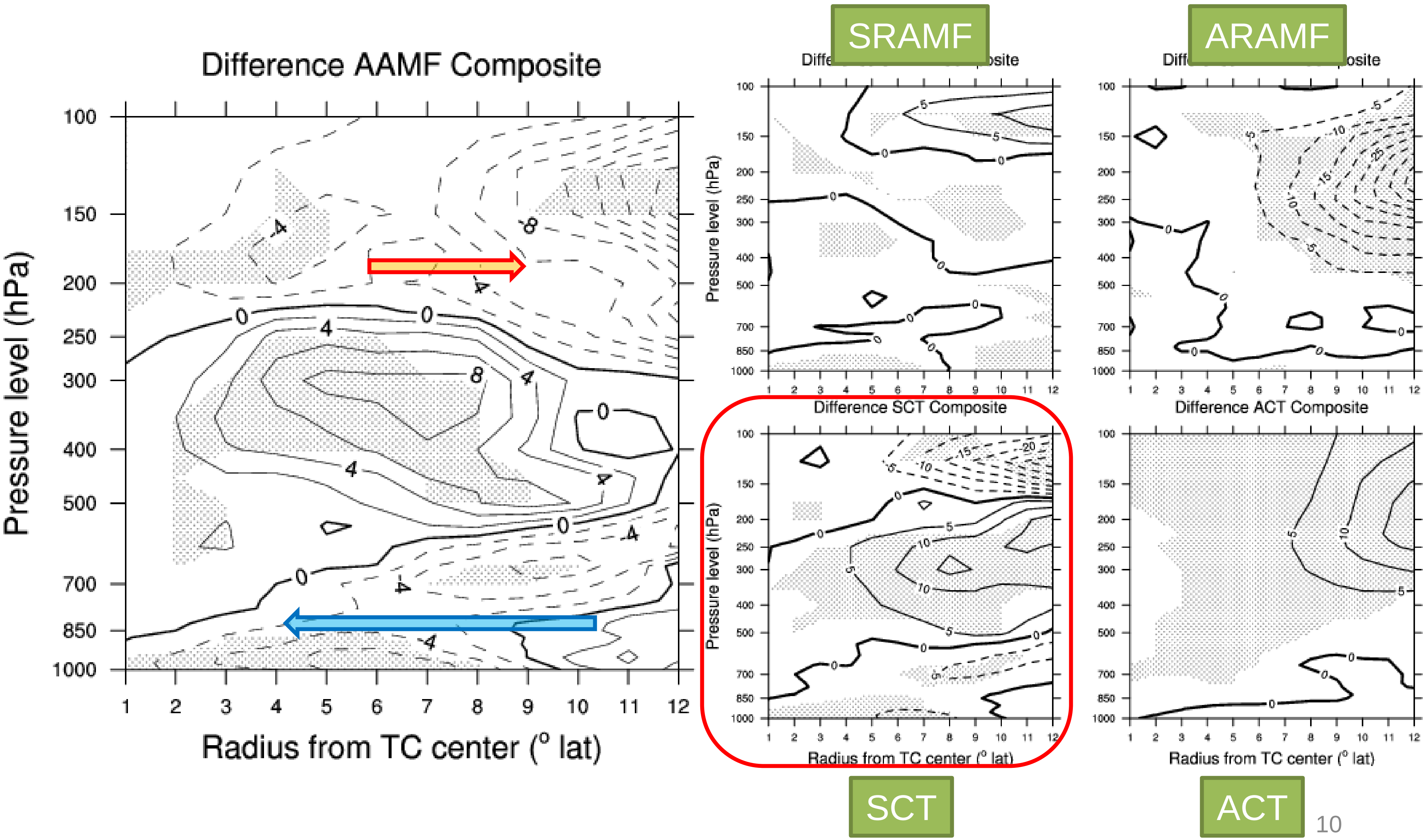
SRAMF   ARAMF



SCT   ACT

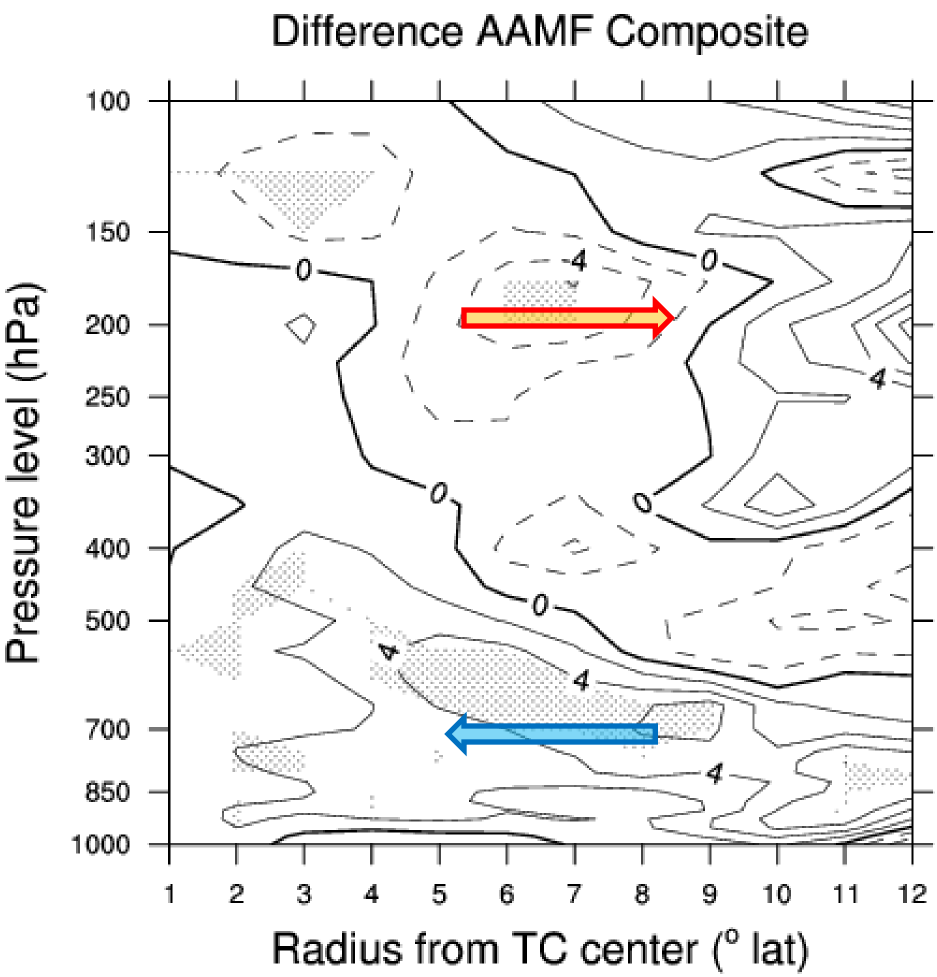
I↓S↑

WNP

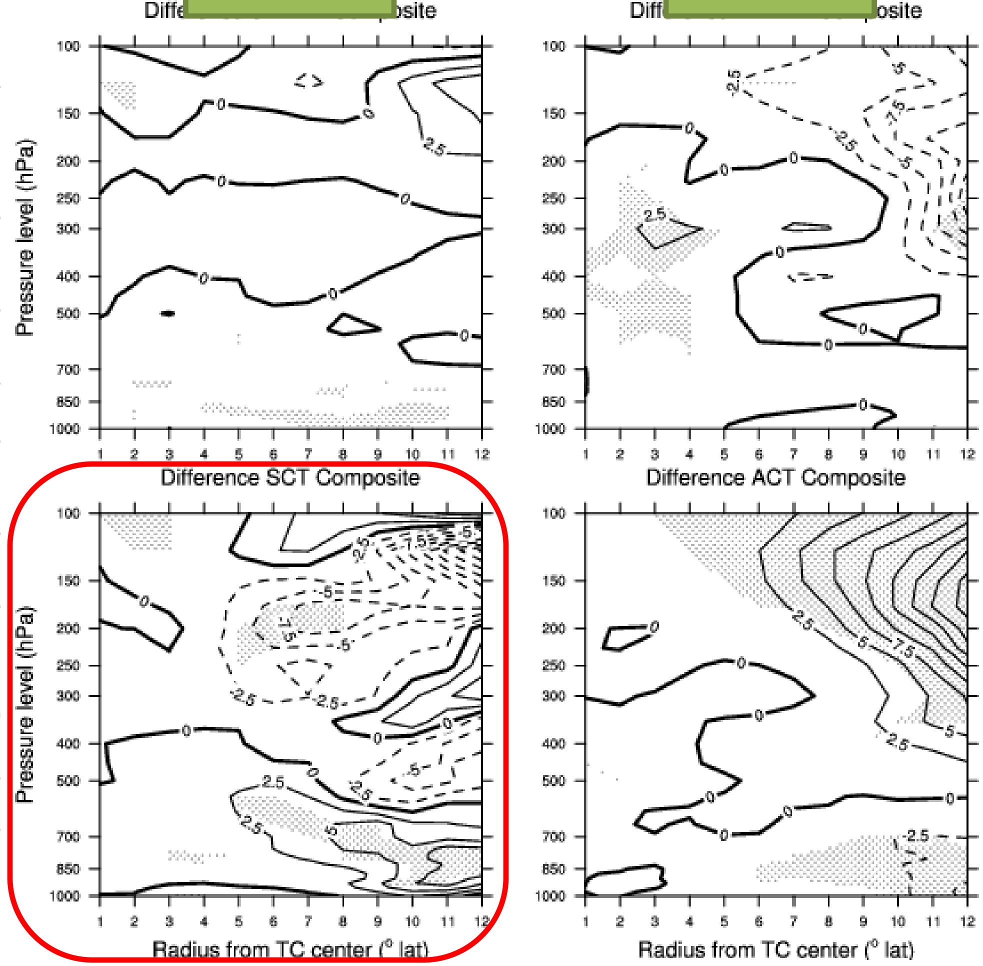

Difference AAMF Composite
Pressure level (hPa)
Radius from TC center (° lat)
SRAMF
ARAMF
Difference SCT Composite
Difference ACT Composite
SCT
ACT

I↓S↓

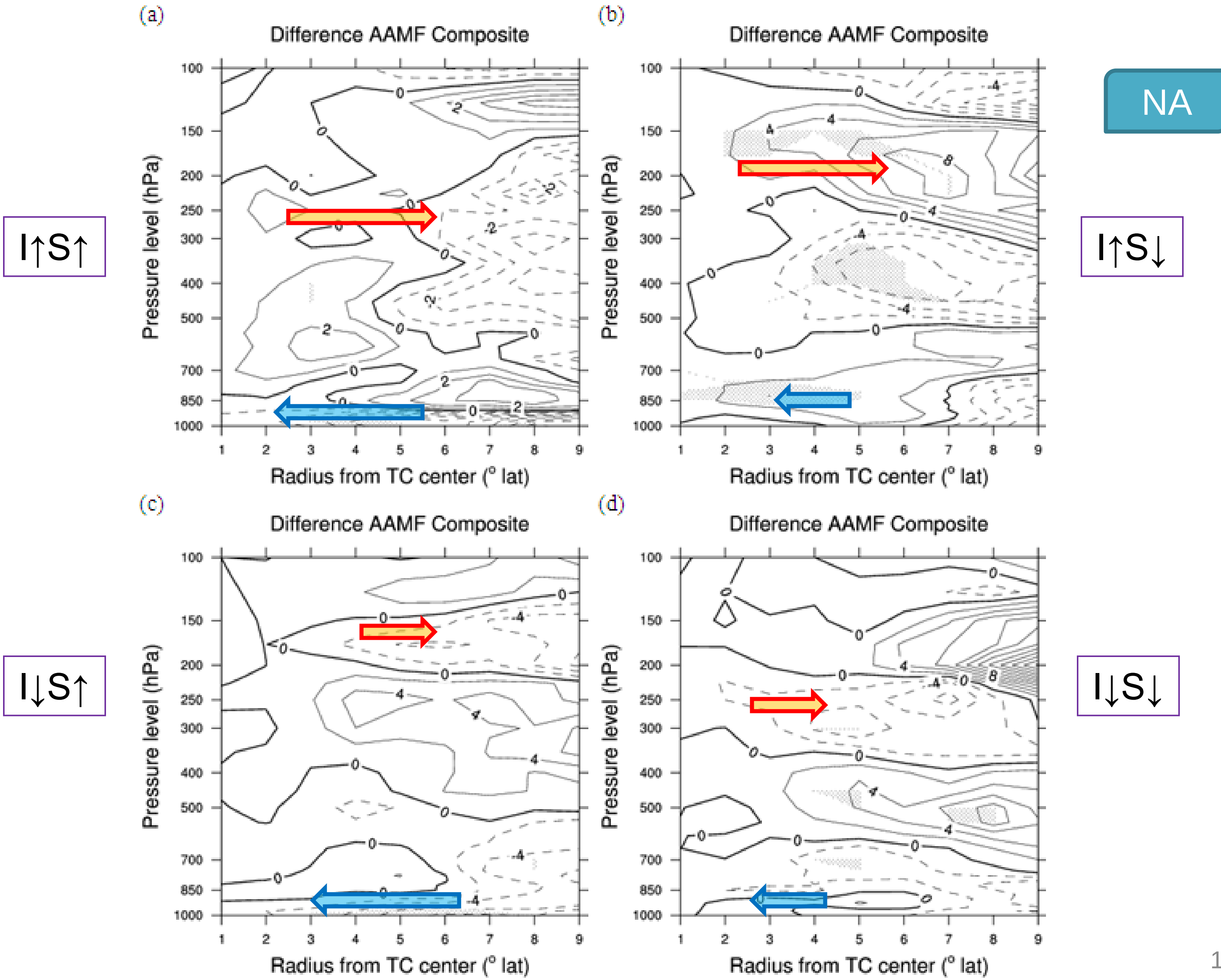
WNP



SRAMF ARAMF



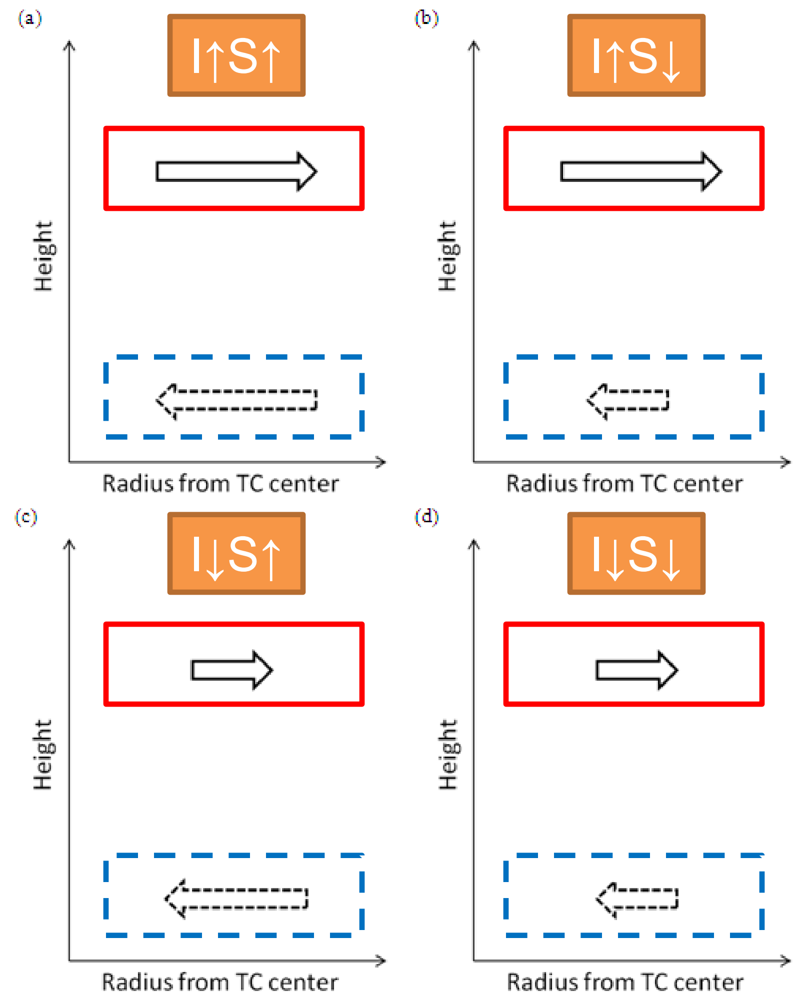
SCT ACT


I↑S↑
(a)
Difference AAMF Composite
(b)
Difference AAMF Composite
NA
I↑S↓
I↓S↑
(c)
Difference AAMF Composite
(d)
Difference AAMF Composite
I↓S↓
Pressure level (hPa)
Radius from TC center (° lat)

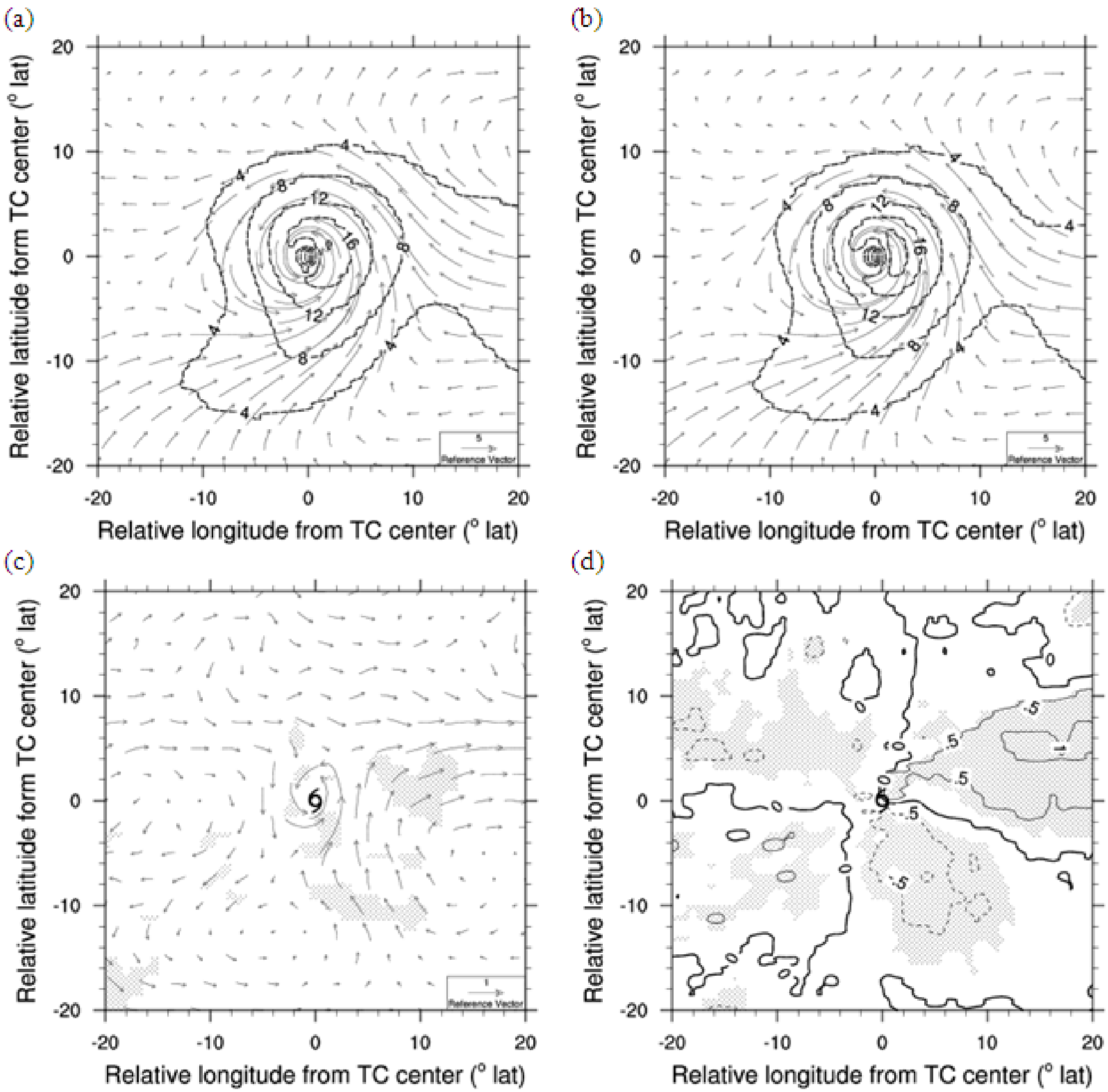
Possible mechanisms

- Change in size mainly depends on the change in the low level AM import
  (ΔS α Δlow.AM.im)

- Change in intensity mainly depends on the change in the upper level AM export
  (ΔI α Δupp.AM.ex)

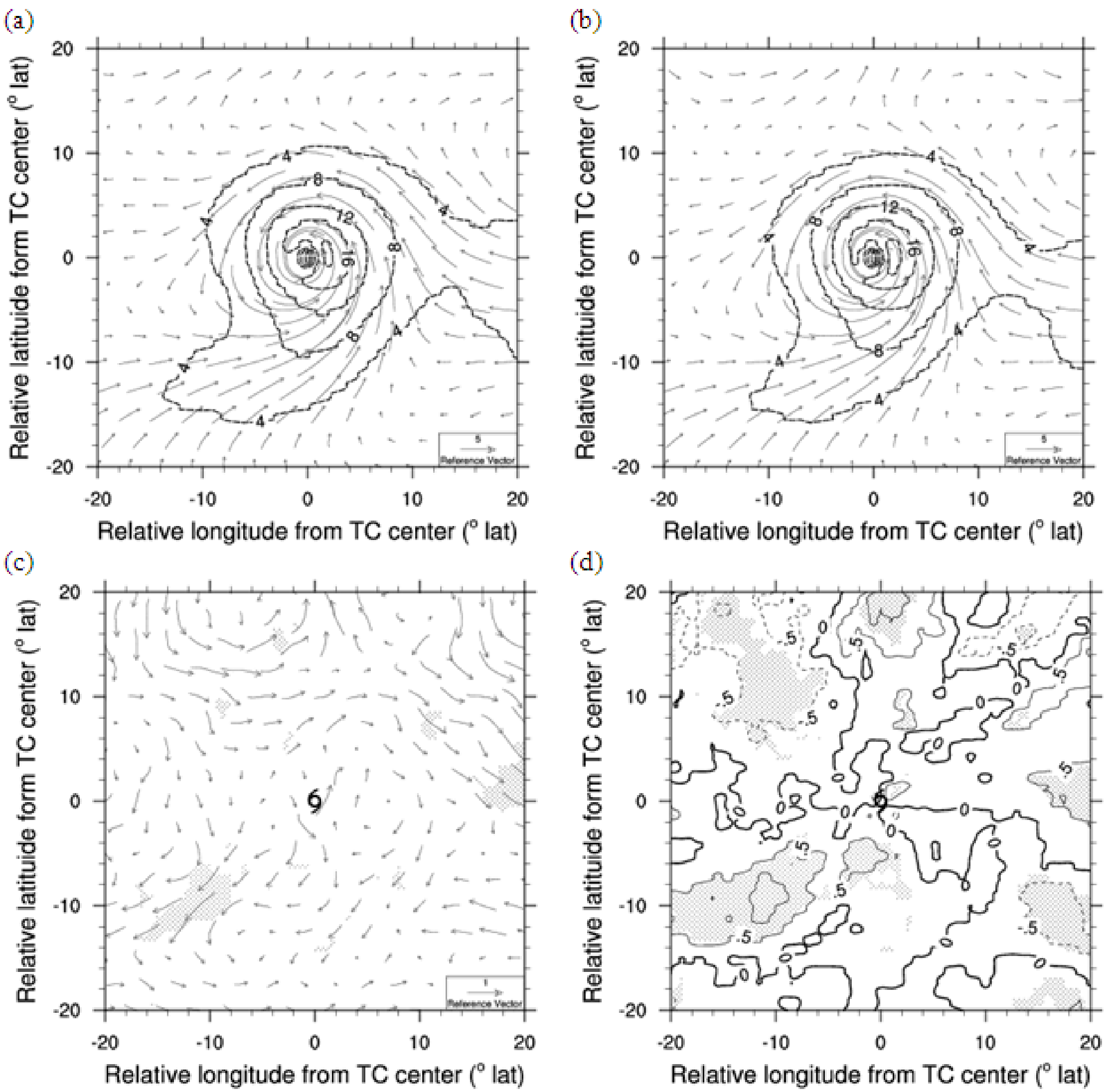


Size-increase (+ΔS) group WNP



- Significant strengthening of the anticyclone to the southeast of TC vortex
- Increase in inflow to the southeast
- Decrease in inflow to the east

Size-decrease (–ΔS) group WNP



- Decrease in inflow to the southwest of TC center
- No strengthening of anticyclone to the southeast

Conclusions

- In WNP and NA
  - $\Delta S \; \alpha \; \Delta low.AM.im$
  - $\Delta I \; \alpha \; \Delta upp.AM.ex$

Probably it is applicable to all ocean basins

- Size changes potentially due to the changes in
  - Low-level synoptic flow
  - TC movement

References

- Chan, K. T. F., and J. C. L. Chan, 2012: Size and Strength of Tropical Cyclones as Inferred from QuikSCAT Data. *Mon. Wea. Rev.*, **140**, 811–824
- Chavas, D. R., and K. A. Emanuel, 2010: A QuikSCAT climatology of tropical cyclone size. *Geophys. Res. Lett.*, **37,** L18816, doi:10.1029/2010GL044558.
- Merrill, R. T., 1984: A comparison of large and small tropical cyclones. *Mon. Wea. Rev.*, **112,** 1408-1418.

Thank you!

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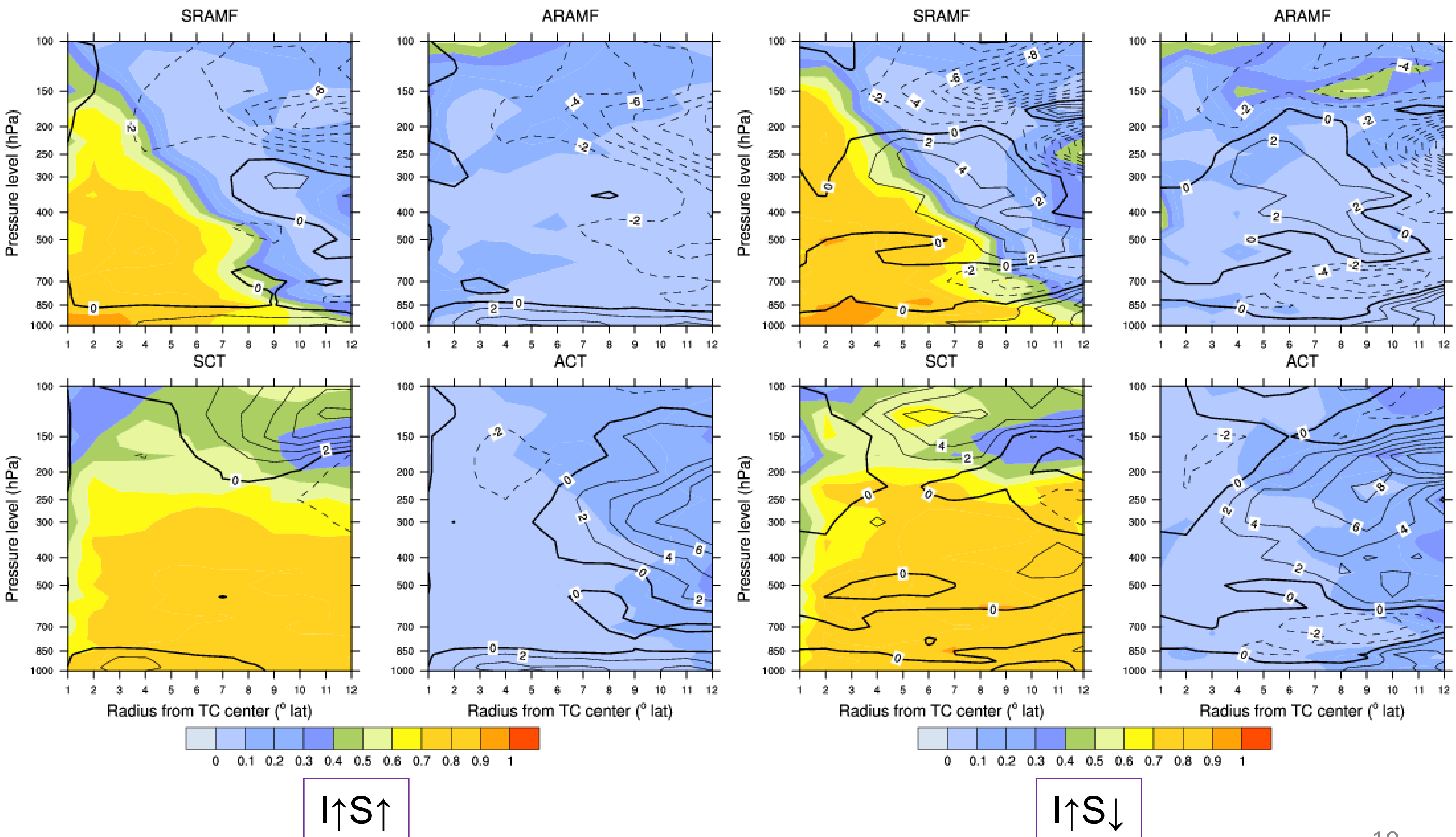
Why the change in SCT is the most relevant contributor to the change in AAMF?



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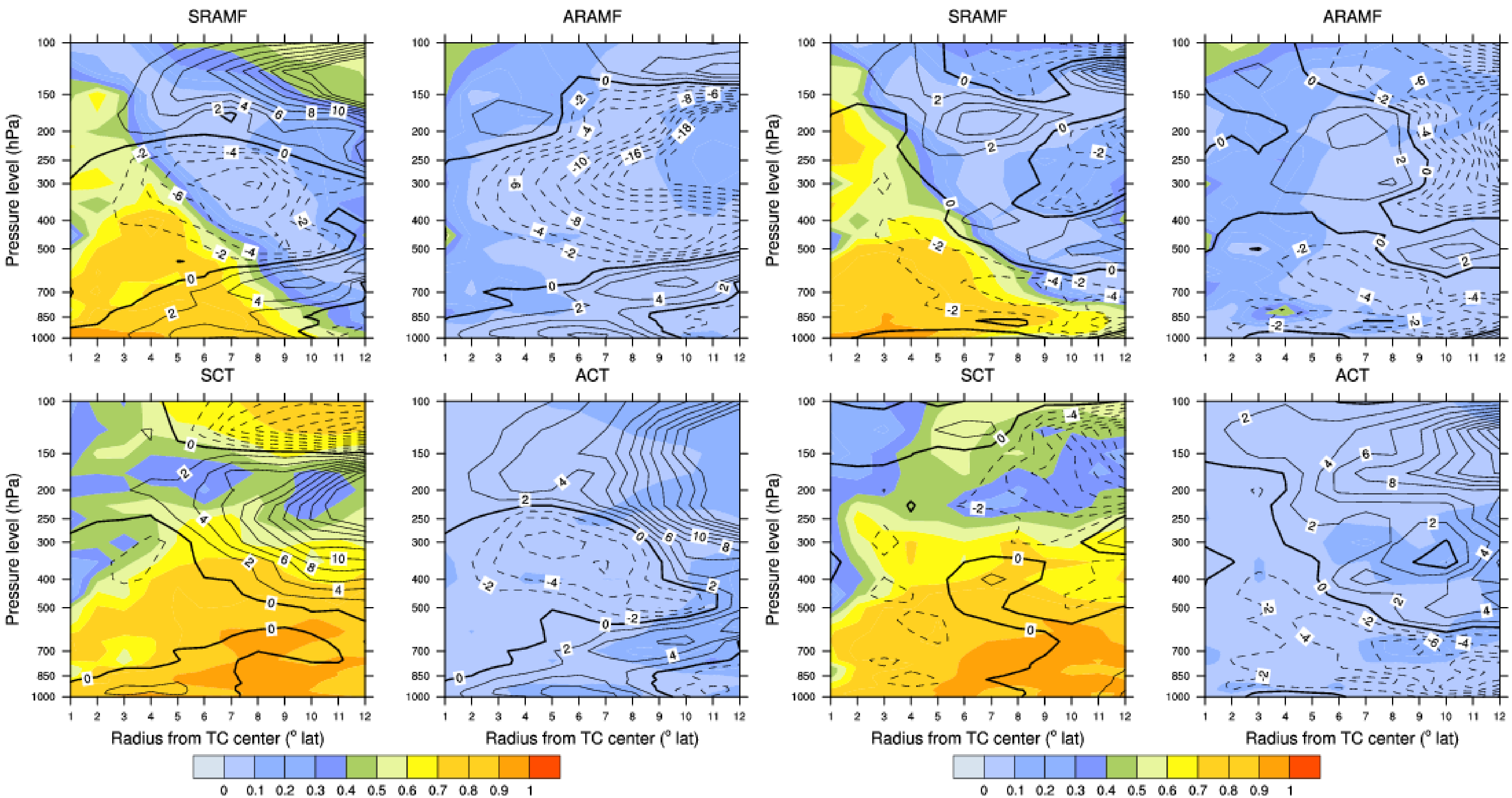

I↓S↑

I↓S↓

Observational Data – TC Size

Data based on: Chan and Chan (2012)

- REMSS QuikSCAT data
  - Satellite ocean-surface wind
  - 2-times daily (ascending and descending paths) at the same location
  - 0.25˚ lat x 0.25˚ lon
  - Time, Wind speed, Wind direction, Rain flag
- Data selection criteria
  - July 19, 1999 – Nov 19, 2009 **(Study period)**
  - TC must be at tropical storm (TS) intensity or above (MSW≥17 m s^{-1})
  - The TC center must be covered by the swath
  - The distance between the TC center and the edge of the swaths must be > 1˚ lat
  - More than 50% of the TC circulation is covered by the swath
  - The TC circulation should have no extensive wind-discontinuity problem
  - Azimuthally-averaged wind speed profile must reach 17 m s^{-1} or above after filtering all rain-flagged data
  - R17 is not close to any landmass
  - No rain-flagged data point is used

Angular momentum transports

$$\mathrm{AAM} = \mathrm{RAM} + \mathrm{EAM}$$
$$= v_\theta r + \frac{1}{2} f r^2$$

Absolute angular momentum (AAM)
Relative angular momentum (RAM)
Earth angular momentum (EAM)
Coriolis parameter (f)

$$v_r = \overline{v_r} + v_r'$$
$$v_\theta = \overline{v_\theta} + v_\theta'$$

Tangential wind (v_θ)
Radial wind (v_r)
Each wind can be separated into symmetric and asymmetric parts

$$M(r) = \frac{\int_0^{2\pi} \left(v_\theta r + \frac{f r^2}{2} \right) v_r r d\theta}{\int_0^{2\pi} r d\theta} \Rightarrow M(r) = r\overline{v_\theta}\,\overline{v_r} + r\overline{v_r' v_\theta'} + \frac{f_0 r^2 \overline{v_r}}{2} + \frac{r^2 \overline{f v_r'}}{2}$$

(f_0 is the Coriolis parameter at TC center)

Transitions of TC size

R17	WNP (˚lat)
Small (25th percentile)	1.41
Medium	1.41-2.61
Large (75th percentile)	2.61

Growing (+ΔS) TC

Transition name	Initial size	Final size	No. of cases (TCs)
sS	s	S	51 (38)
sM	s	M	48 (45)
sL	s	L	0 (0)
mM	m	M	131 (71)
mL	m	L	42 (39)
lL	l	L	79 (39)

Shrinking (–ΔS) TC

Transition name	Initial size	Final size	No. of cases (TCs)
Ss	S	s	25 (22)
Ms	M	s	12 (12)
Mm	M	m	84 (55)
Ls	L	s	0 (0)
Lm	L	m	14 (12)
Ll	L	l	32 (22)

Small, Medium and Large +ΔS and –ΔS TCs

- The extent, the intensity, and the dynamics (especially the radial winds) of the environmental lower tropospheric wind surges can affect the TC size
- Increase and decrease in low-level inflow are found in growing and shrinking TCs, respectively

Changes in TC movement WNP

	+ΔS group	–ΔS group
Sample size	351	167
No. of TCs	131	95
Mean direction (˚)	153.6	158.7
Mean direction change (˚)	3.5	1.8
ΔU (km/h)	2.48	2.27
ΔV (km/h)	**1.93**	**0.57**

TC movement preferences WNP

	Small	Medium	Large	All
Sample size	203	402	208	813
No. of TCs	108	126	69	176
Mean latitude (°)	19.5	21.6	21.9	21.2
Mean direction (°)	144.6	154.5	155.2	152.2
Mean U (km/h)	-7.05	-4.06	-4.38	-4.89
Mean V (km/h)	**7.64**	11.49	**14.29**	11.25

Angular momentum transports

Term A

Term C

Reminder

$$M(r) = r\overline{v_\theta}\,\overline{v_r} + r\overline{v_r' v_\theta'} + \frac{f_0 r^2 \overline{v_r}}{2} + \frac{r^2 \overline{f v_r'}}{2}$$

Term B

Term D

If $\Delta \overline{v_r} \cong 0$, then Δf_0 becomes important

- Term A: Symmetric RAM (SRAM)
- Term B: Asymmetric or eddy RAM (ARAM)
- Term C: Symmetric Coriolis torque (SCT)
- Term D: Asymmetric or eddy Coriolis torque (ACT)