Precipitation Characteristics of the Tropical Cyclone Life Cycle as Derived from a Satellite-borne Passive Microwave and Radar Dataset

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1. Introduction

This compilation of work contributes to tropical cyclone (TC) observational datasets by providing a comprehensive, global collection of space-borne passive microwave (PMW) and precipitation radar (PR) observations from developing and nondeveloping disturbances. Our goal is to further understand the role of precipitation towards the genesis and intensification of TCs, focusing not only on deep convection, but also shallow- to moderately-deep convection and stratiform rain.

The following questions are addressed:

(a) How are precipitation properties observed during the pregenesis stage of developing disturbances unique compared to those in nondeveloping?

(b) Are precipitation properties within a day of genesis unique compared to those earlier in the pregenesis stage?

(c) What precipitation properties differentiate storms that rapidly intensify (RI) v. those that do not?

2. Tropical Cyclone – Passive Microwave (TC-PMW) Dataset

DATA FROM A HISTORICAL RECORD OF PMW OVERPASSES OF TCs

Developing (DEV) - Combined "Invest" and TC best track data from the Automated Tropical Cyclone Forecasting System (ATCF)

Nondeveloping (NONDEV) – "Invest" tracks not associated with TCs in the ATCF

Genesis is defined by Tropical Depression (TD) classification by the NHC

NUMBER OF CASES

BASIN	DEVELOPING ('98-'15)	NONDEVELOPING ('03-'15)[1] ('09-'15)[2]
ATLANTIC (AL)	291	210 [1]
EAST PACIFIC (EP)	301	132 [1]
CENTRAL PACIFIC (CP)	33	51 [1]
WEST PACIFIC (WP)	508	359 [2]
NORTHERN INDIAN (IO)	96	81 [2]
SOUTHERN HEMISPHERE (SH)	463	284 [2]
Total	1692	1117

- **Passive Microwave (PMW) T_b from AMSR-E, TMI, SSM-I(S) 15-18**
- **Rainfall properties also from 0.25° TRMM 3B42 merged-IR product**
- **Large-scale properties from 1° NCEP FNL Analysis**

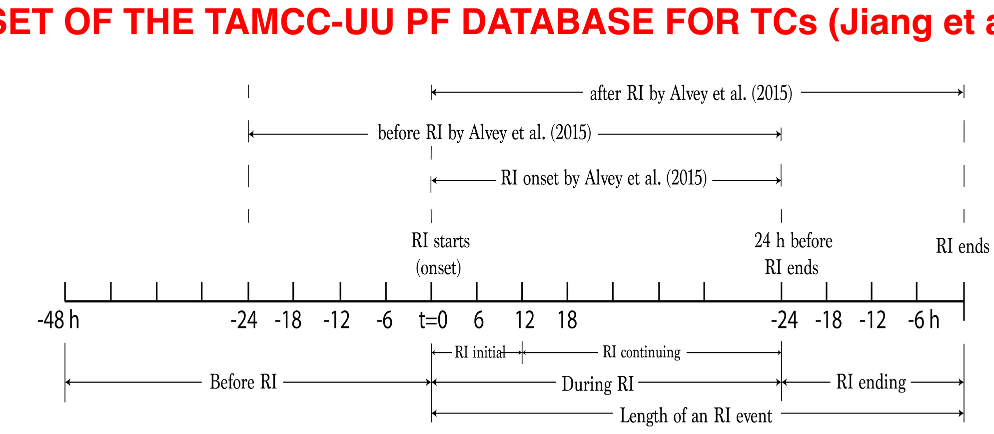
***** ALL ANALYSES ARE FOR WITHIN 3° OF THE CENTER *****
***** PMW DATA COVERAGE WITHIN MUST BE 100% *****

Satellite	Total Passes	% of Total	Passes with 100% Data Coverage in 3deg	% of Total Sat Passes	Passes with 100% Data Coverage in 1deg	% of Total Sat Passes	NONDEV Passes	% of Total Sat Passes	PRE Passes	% of Total Sat Passes	POST Passes	% of Total Sat Passes
TOTAL OVERPASSES FROM 1998-2013*												
AMSRE	10683	12.7	6063	56.8	8765	82.0	1916	17.9	1448	13.6	7319	68.5
TMI	20127	24.0	4090	20.3	13343	66.3	3052	15.2	2203	10.9	14872	73.9
SSMI(S)	53097	63.3	29213	55.0	43002	81.0	8291	15.6	6345	11.9	38461	72.4
	83907	100.0	**39366**	46.9	**65110**	77.6	**13259**	15.8	**9996**	11.9	**60652**	72.3

*** Data for 2014 and 2015 is currently being added to the TC-PMW and will not be shown ***
*** Data Additions in Progress ***
GMI AMSR2 IMERGE PF-based Classifications

3. Tropical Cyclone Precipitation Feature (TCPF) Dataset

SUBSET OF THE TAMCC-UU PF DATABASE FOR TCs (Jiang et al. 2011)

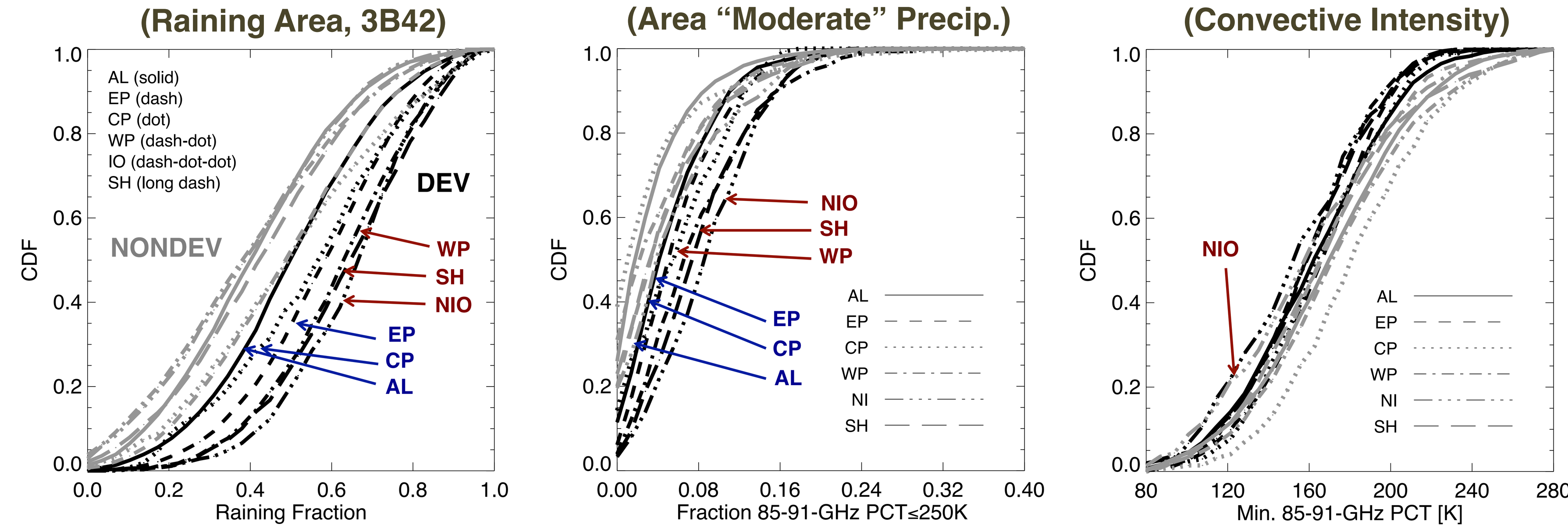


TAO ET AL. 2016, IN REVIEW

In the study shown here, pixel data from 16 yr of TRMM PR overpasses of TCs is composited for periods within a rapid intensification (RI) event (as shown above)

4. Tropical Cyclone Genesis

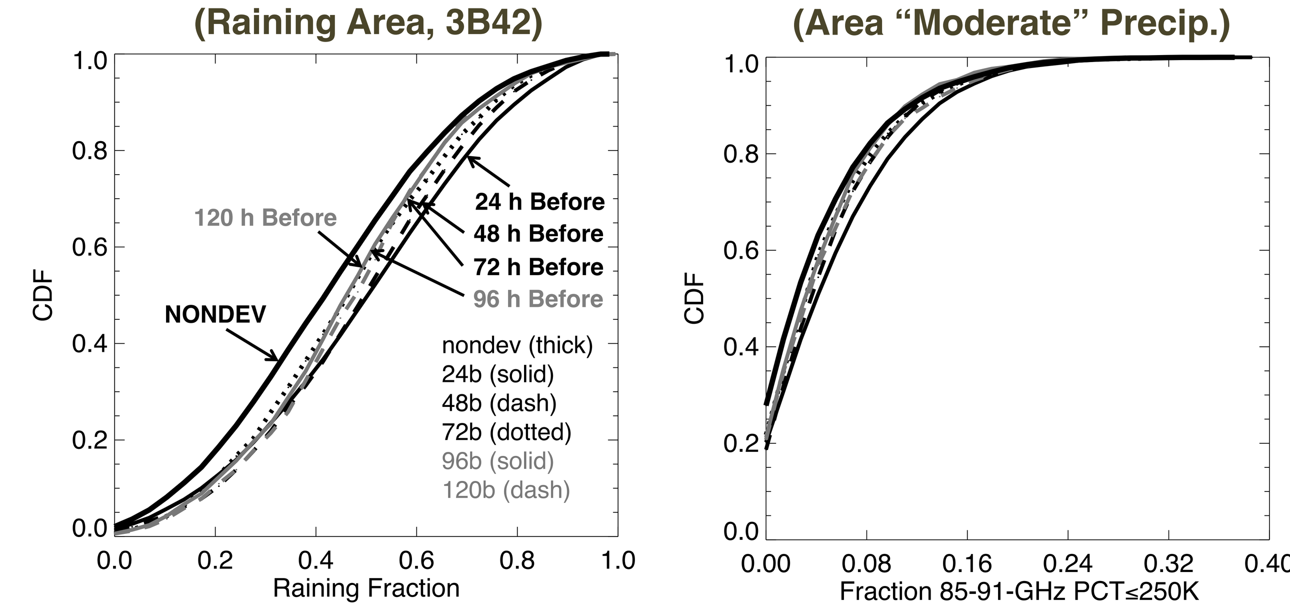
SEPARATED BY BASINS...



THE TC-PMW OFFERS UNIQUE SUBSETTING OPPORTUNITIES:

1. **Time before Genesis**
2. **By Ocean Basin**
3. **NHC Genesis Probability**

TIME BEFORE GENESIS FOR



The **areal coverage of rain** is largest in the *NIO, SH,* and *WP*; lowest in the *AL, EP,* and *CP*

The **difference in rainfall between DEV and NONDEV** is largest in the *NIO, SH,* and *WP*, and lowest in the *AL, EP,* and *CP*

The areal coverage of **"moderate" precipitation**, here defined as 85-9- GHz PCT ≤ 250 K is similar to the **rain coverage** from 3B42

Differences between **DEV** & NONDEV become less as the threshold PCT is lowered

SUGGESTS DIFFERENT GENESIS PATHWAYS AMONG BASINS

Convective intensity is generally greatest in *NIO* (both **DEV** and NONDEV), otherwise little difference among all other basins

CONVECTIVE INTENSITY SHOWS THE LEAST PREDICTABILITY FOR GENESIS; TOTAL RAINING AREA CONTRIBUTES MOST TO PREDICTABILITY

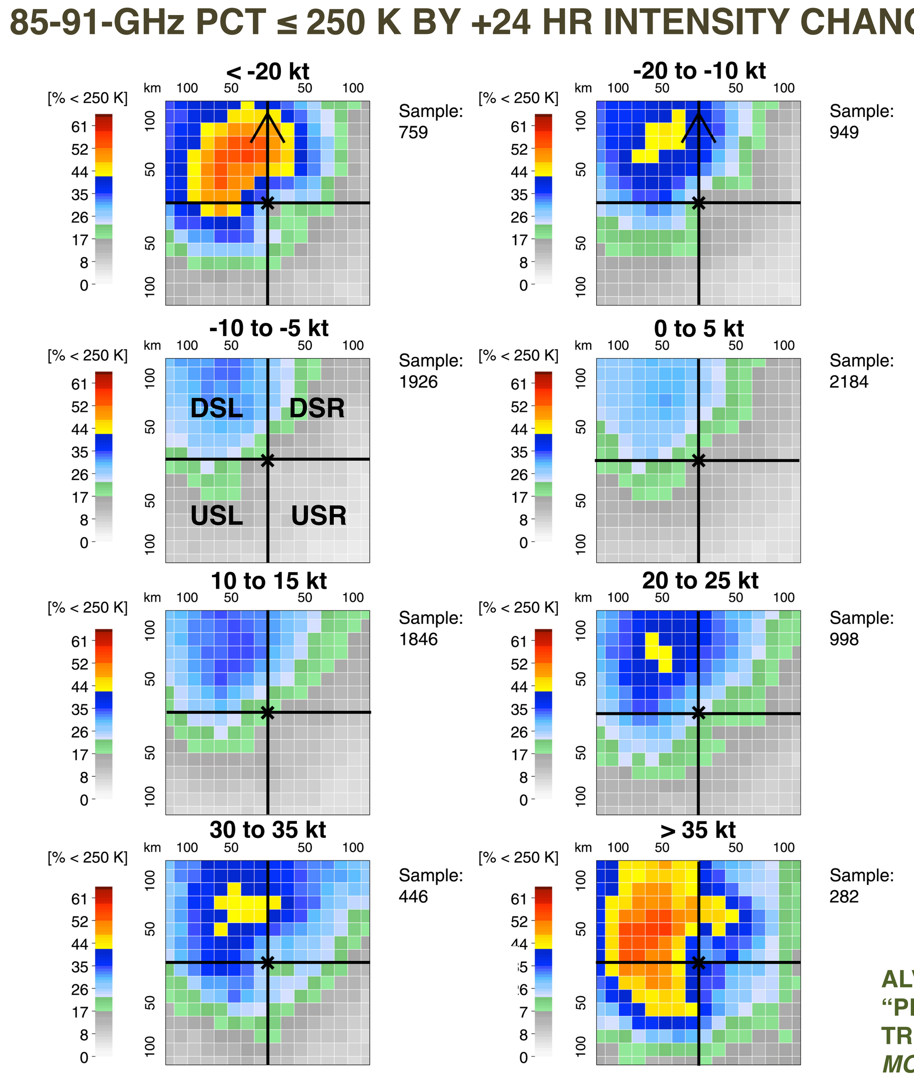
The **areal coverage of rainfall**, as quantified from 3B42, as well as **areal coverage of "moderate" precipitation** from PMW PCT, shows a small increase as genesis nears

Though INVEST tracks are generally only available within 72 hr in JTWC basins, all basins exhibit this tendency (not shown)

Convective intensity is similar throughout the genesis process

5. Tropical Cyclone Intensification

FREQUENCY DISTRIBUTION OF 85-91-GHz PCT ≤ 250 K BY +24 HR INTENSITY CHANGE



THE KEY TO INTENSIFICATION IS AN INCREASE IN THE AZIMUTHAL SYMMETRY OF PRECIPITATION

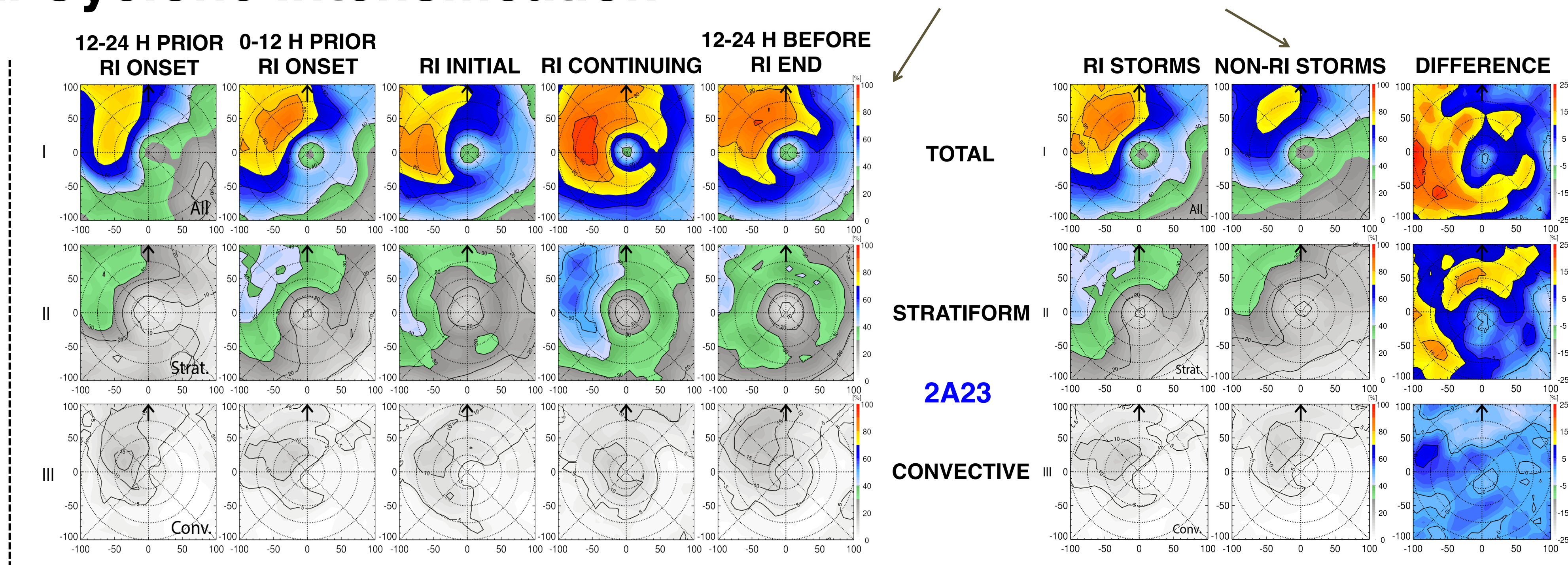
Rainfall coverage in the upshear quadrants **(USL/ USR)** increases with intensity change rate

Symmetry is already increasing **upshear** in the **6 h before the onset of RI** (not shown here)

Frequency of "intense" convection (PCT < 170 K) shows little difference between the **"pre-RI" stage** and the **"continuing RI" stage** (not shown here)

ALVEY III, G. R, J. ZAWISLAK, AND E. ZIPSER, 2015: "PRECIPITATION PROPERTIES OBSERVED DURING TROPICAL CYCLONE INTENSITY CHANGE. *MON. WEA. REV.*, 143, 4476-4492

RAINFALL OCCURENCE



Symmetry of total rain increases **prior to RI onset**; stratiform largely contributes to this increase

This is accompanied by a small decrease in **convective occurrence** just prior to RI onset (0-12 h)

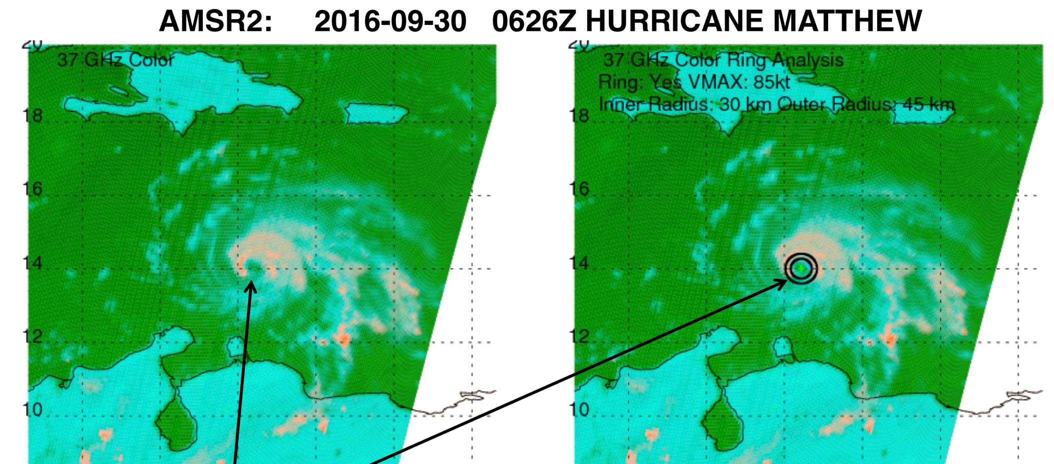
RI onset is characterized by an increase in **convection** in the **USL** quadrant, while **RI continuing** exhibits a symmetric distribution of both **stratiform and convection**

THE STRATIFORM CONTRIBUTION IS NOT ONLY GREATER THAN CONVECTION, BUT IT'S OCCURRENCE AND INCREASE IN AZIMUTHAL SYMMETRY DIFFERENTIATES STORMS THAT UNDERGO RI FROM THOSE THAT DO NOT

TAO, C., H. JIANG, AND J. ZAWISLAK, 2016: THE RELATIVE IMPORTANCE OF STRATIFORM AND CONVECTIVE RAINFALL IN RAPIDLY INTENSIFYING TROPICAL CYCLONES. *MON. WEA. REV.*, IN REVIEW.

6. Real-time Analysis and Forecasts

AMSR2: 2016-09-30 0626Z HURRICANE MATTHEW



The "cyan" ring likely indicates an increase in shallow to moderate convection, and is a very good predictor of RI (Kieper and Jiang 2012)

In the recent case of Matthew, this overpass occurred during the impressive RI period, and shows a "cyan" ring

Probability-based Microwave Ring RI Index (PMWRing-RII)

Quantifies probability of **RI** based on the **identification of a "cyan" ring** in the 37-GHz color product (left), as well as for **fractional coverage of 85-91-GHz PCT** < 225, 250 and 275 K

Probabilities are based on the historical record of TC-PMW overpasses

Must meet thresholds quantified for these PMW variables, as well as for environmental variables from the output of the Statistical Hurricane Intensity Prediction Scheme (SHIPS)

7. Conclusions

(a) How are precipitation properties observed during the pregenesis stage of developing disturbances unique compared to those in nondeveloping?

Greater coverage of rainfall, while convective intensity does not differentiate DEV and NONDEV storms

(b) Are precipitation properties within a day of genesis unique compared to those earlier in the pregenesis stage?

Appears to be an increase in rainfall coverage around the center within a day of genesis

(c) What precipitation properties differentiate storms that rapidly intensify v. those that do not?

Greater azimuthal precipitation symmetry, largely contributed by stratiform rain; although convective occurrence also needs to increase upshear

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