How well can we detect tropical cyclone tracks in the Reanalyses data

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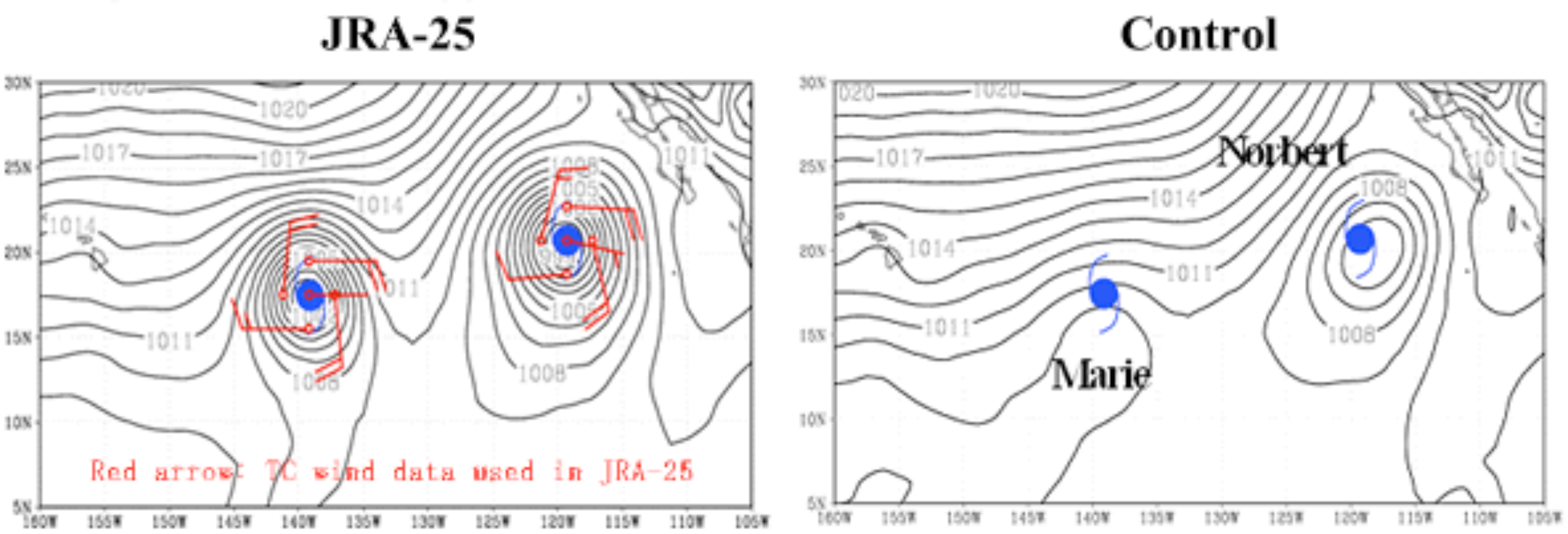
Impact of Fiorino TCR wind

1200 UTC 15 September 1990 in the eastern North Pacific



Questions

- How reliable are tropical cyclone detection and tracking codes we used?
- There are tropical cyclone best tracks archives for verification. But do we have a reliable high resolution meteorological analysis to test the code?
- Is there a way to decide the optimal criteria and thresholds use in the code? How the variation in these criteria and thresholds affect reliability?
- Can the same scheme (criteria and thresholds) applied to different model simulations?
- How the criteria and thresholds depend on data resolution? Is there a spatial scaling factor?

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Intercomparison of Mid Latitude Storm Diagnostics

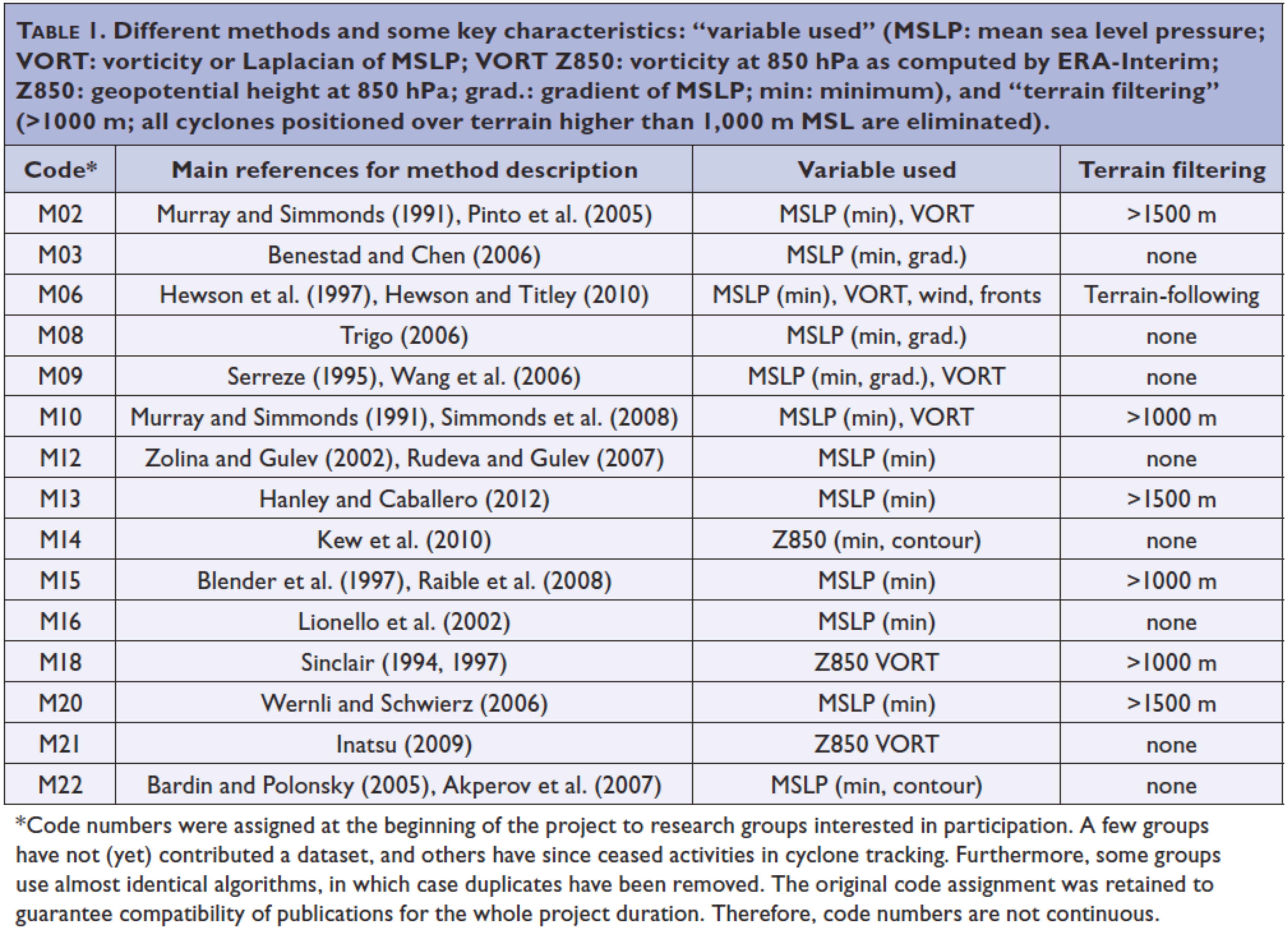

TABLE 1. Different methods and some key characteristics: "variable used" (MSLP: mean sea level pressure; VORT: vorticity or Laplacian of MSLP; VORT Z850: vorticity at 850 hPa as computed by ERA-Interim; Z850: geopotential height at 850 hPa; grad.: gradient of MSLP; min: minimum), and "terrain filtering" (>1000 m; all cyclones positioned over terrain higher than 1,000 m MSL are eliminated).

Code*	Main references for method description	Variable used	Terrain filtering
M02	Murray and Simmonds (1991), Pinto et al. (2005)	MSLP (min), VORT	>1500 m
M03	Benestad and Chen (2006)	MSLP (min, grad.)	none
M06	Hewson et al. (1997), Hewson and Titley (2010)	MSLP (min), VORT, wind, fronts	Terrain-following
M08	Trigo (2006)	MSLP (min, grad.)	none
M09	Serreze (1995), Wang et al. (2006)	MSLP (min, grad.), VORT	none
M10	Murray and Simmonds (1991), Simmonds et al. (2008)	MSLP (min), VORT	>1000 m
M12	Zolina and Gulev (2002), Rudeva and Gulev (2007)	MSLP (min)	none
M13	Hanley and Caballero (2012)	MSLP (min)	>1500 m
M14	Kew et al. (2010)	Z850 (min, contour)	none
M15	Blender et al. (1997), Raible et al. (2008)	MSLP (min)	>1000 m
M16	Lionello et al. (2002)	MSLP (min)	none
M18	Sinclair (1994, 1997)	Z850 VORT	>1000 m
M20	Wernli and Schwierz (2006)	MSLP (min)	>1500 m
M21	Inatsu (2009)	Z850 VORT	none
M22	Bardin and Polonsky (2005), Akperov et al. (2007)	MSLP (min, contour)	none

*Code numbers were assigned at the beginning of the project to research groups interested in participation. A few groups have not (yet) contributed a dataset, and others have since ceased activities in cyclone tracking. Furthermore, some groups use almost identical algorithms, in which case duplicates have been removed. The original code assignment was retained to guarantee compatibility of publications for the whole project duration. Therefore, code numbers are not continuous.

Neu et al., 2013, BAMS

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Intercomparison of Mid Latitude Storm Diagnostics

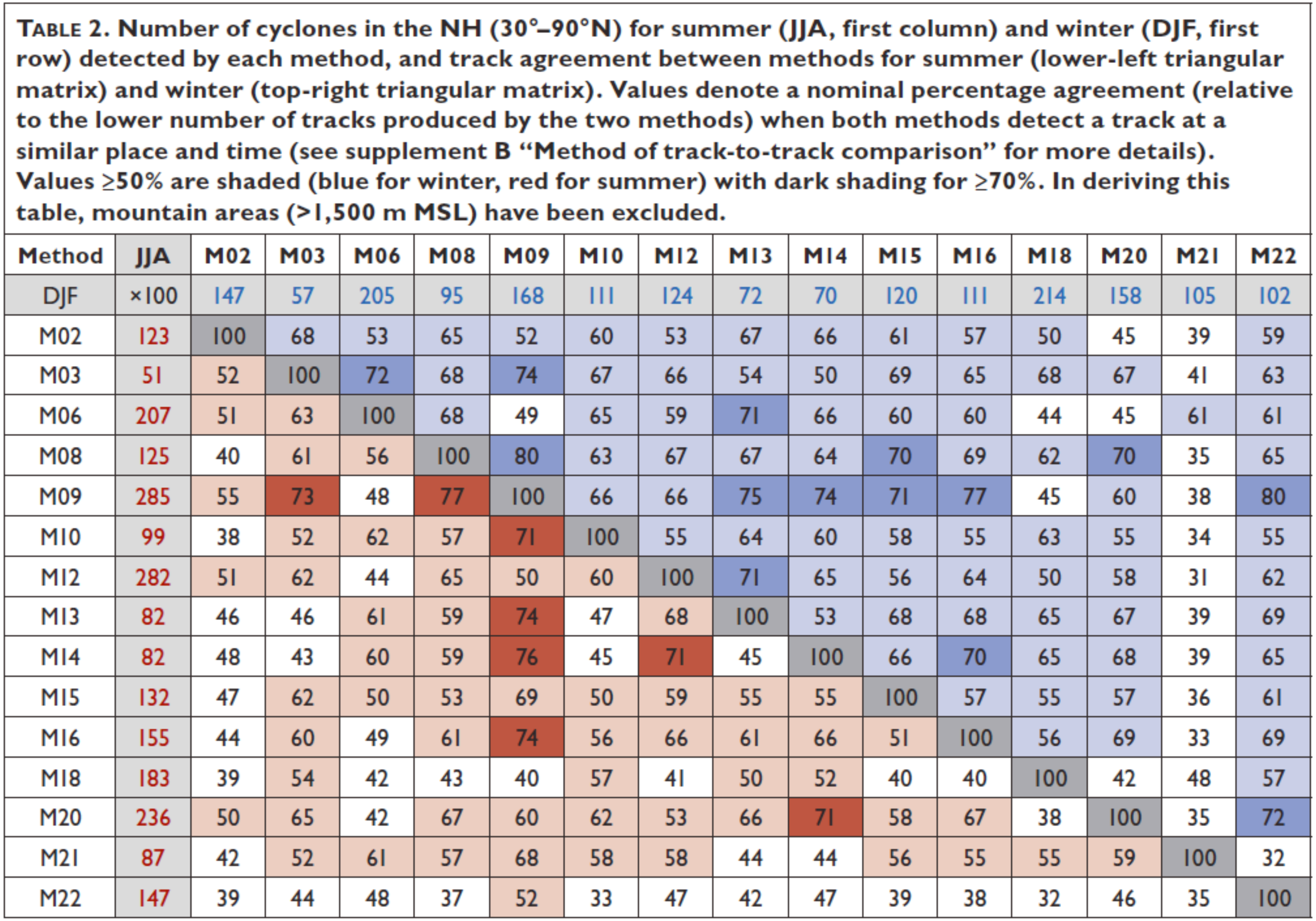

TABLE 2. Number of cyclones in the NH (30°–90°N) for summer (JJA, first column) and winter (DJF, first row) detected by each method, and track agreement between methods for summer (lower-left triangular matrix) and winter (top-right triangular matrix). Values denote a nominal percentage agreement (relative to the lower number of tracks produced by the two methods) when both methods detect a track at a similar place and time (see supplement B "Method of track-to-track comparison" for more details). Values ≥50% are shaded (blue for winter, red for summer) with dark shading for ≥70%. In deriving this table, mountain areas (>1,500 m MSL) have been excluded.

Method	JJA	M02	M03	M06	M08	M09	M10	M12	M13	M14	M15	M16	M18	M20	M21	M22
DJF	×100	147	57	205	95	168	111	124	72	70	120	111	214	158	105	102
M02	123	100	68	53	65	52	60	53	67	66	61	57	50	45	39	59
M03	51	52	100	72	68	74	67	66	54	50	69	65	68	67	41	63
M06	207	51	63	100	68	49	65	59	71	66	60	60	44	45	61	61
M08	125	40	61	56	100	80	63	67	67	64	70	69	62	70	35	65
M09	285	55	73	48	77	100	66	66	75	74	71	77	45	60	38	80
M10	99	38	52	62	57	71	100	55	64	60	58	55	63	55	34	55
M12	282	51	62	44	65	50	60	100	71	65	56	64	50	58	31	62
M13	82	46	46	61	59	74	47	68	100	53	68	68	65	67	39	69
M14	82	48	43	60	59	76	45	71	45	100	66	70	65	68	39	65
M15	132	47	62	50	53	69	50	59	55	55	100	57	55	57	36	61
M16	155	44	60	49	61	74	56	66	61	66	51	100	56	69	33	69
M18	183	39	54	42	43	40	57	41	50	52	40	40	100	42	48	57
M20	236	50	65	42	67	60	62	53	66	71	58	67	38	100	35	72
M21	87	42	52	61	57	68	58	58	44	44	56	55	55	59	100	32
M22	147	39	44	48	37	52	33	47	42	47	39	38	32	46	35	100

Neu et al., 2013, BAMS

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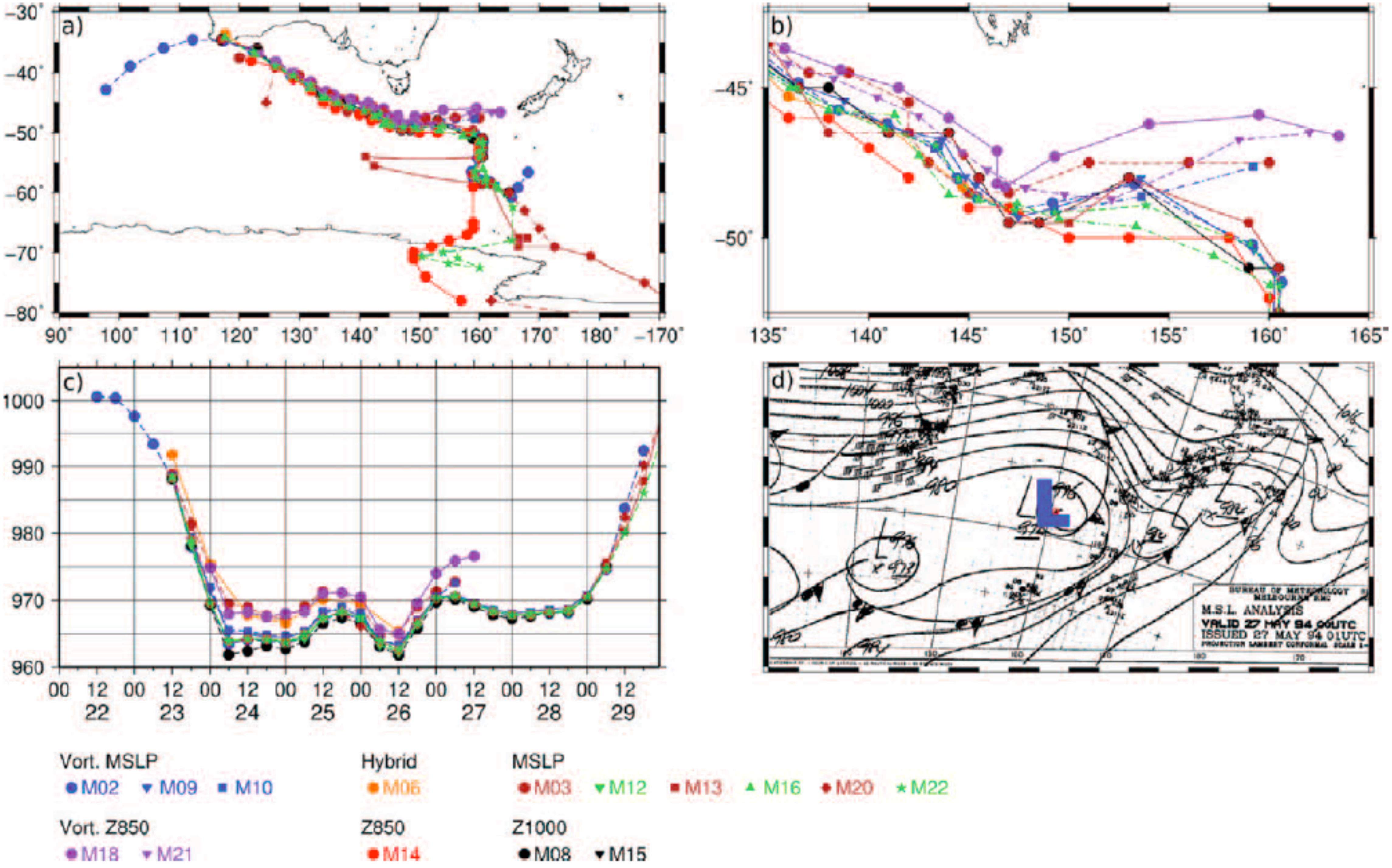
Intercomparison of Mid Latitude Storm Diagnostics



Neu et al., 2013, BAMS

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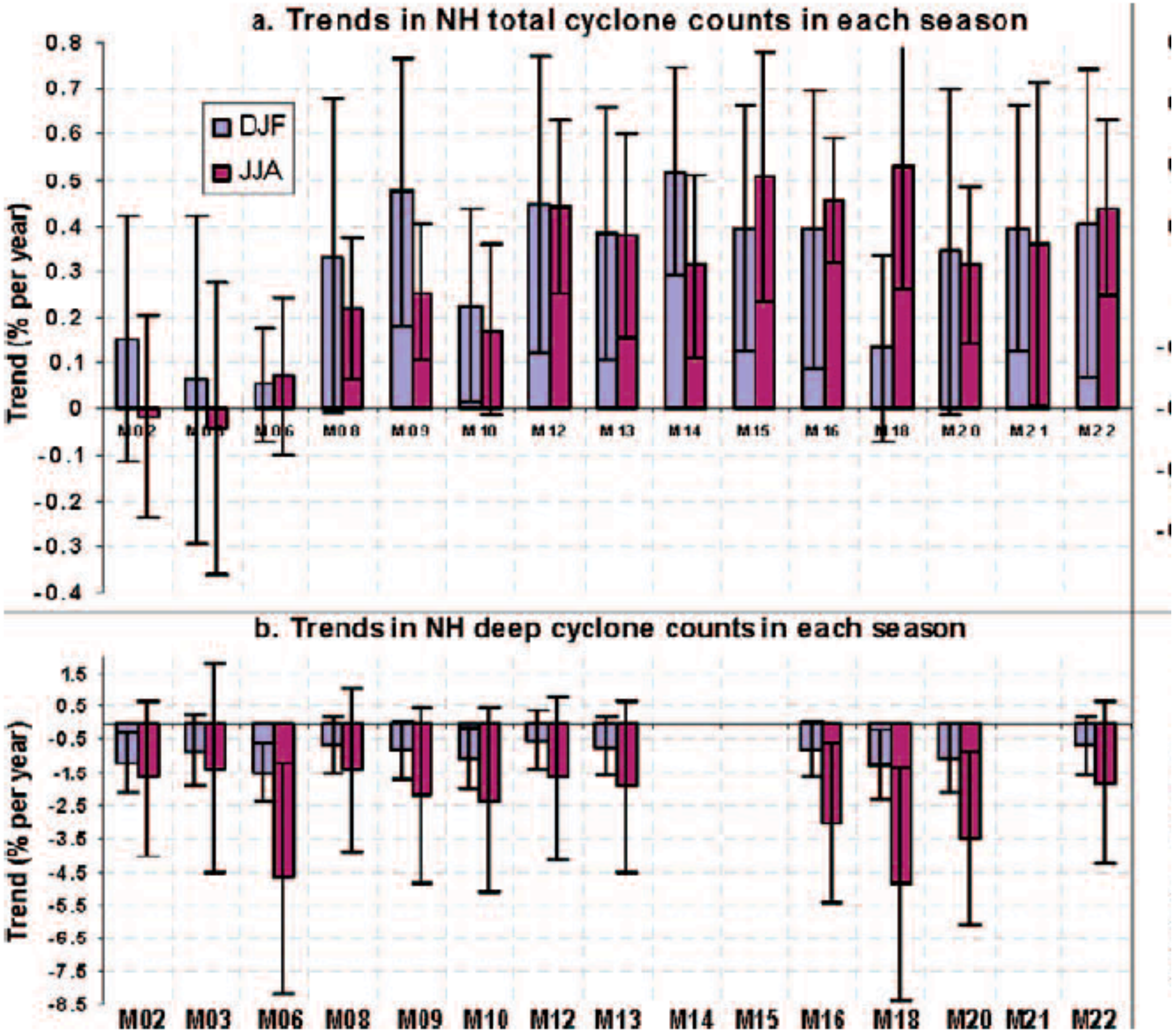

Neu et al., 2013, BAMS

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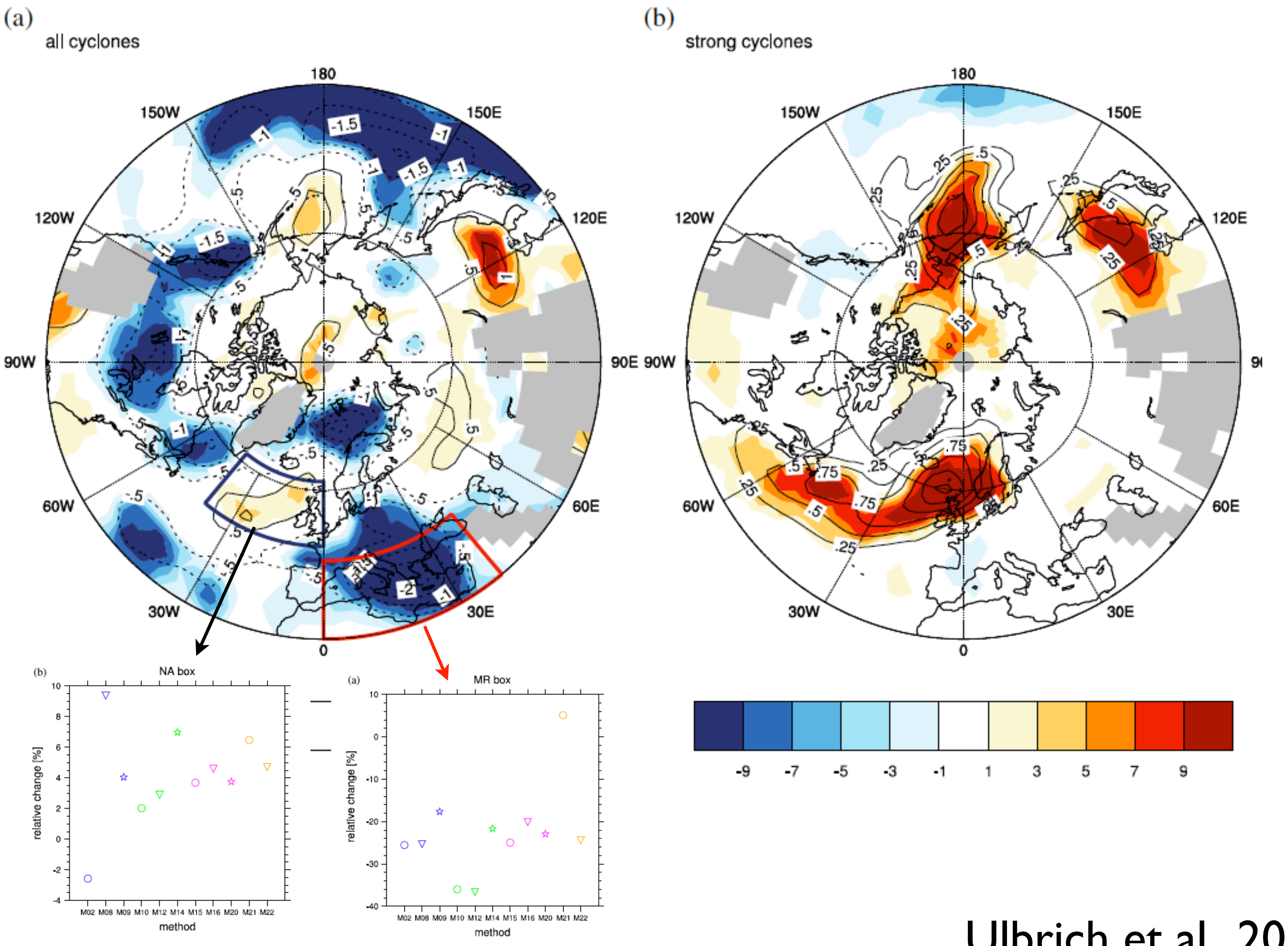


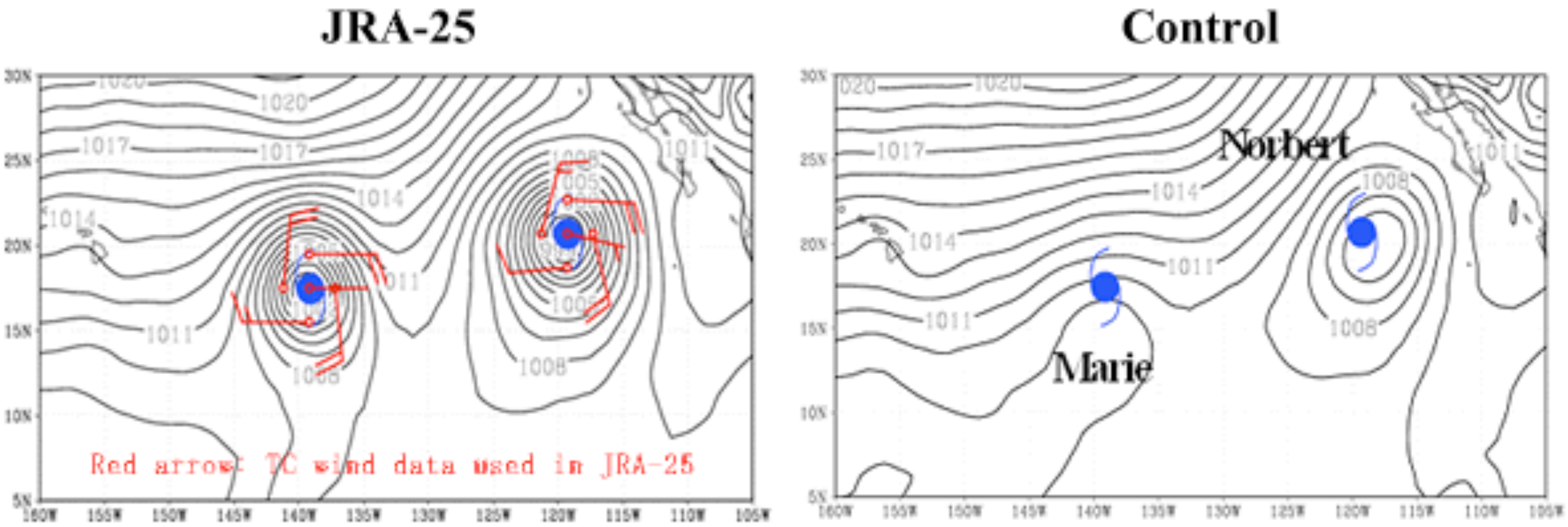
Ulbrich et al., 2013

Tropical cyclone in JRA25

Using the wind profile retrievals surrounding tropical cyclones (TCR) data results in a more realistic representation of the tropical cyclones compared to other reanalyses

Impact of Fiorino TCR wind

1200 UTC 15 September 1990 in the eastern North Pacific



Hatsushika et al. 2006

JRA-25 Overview

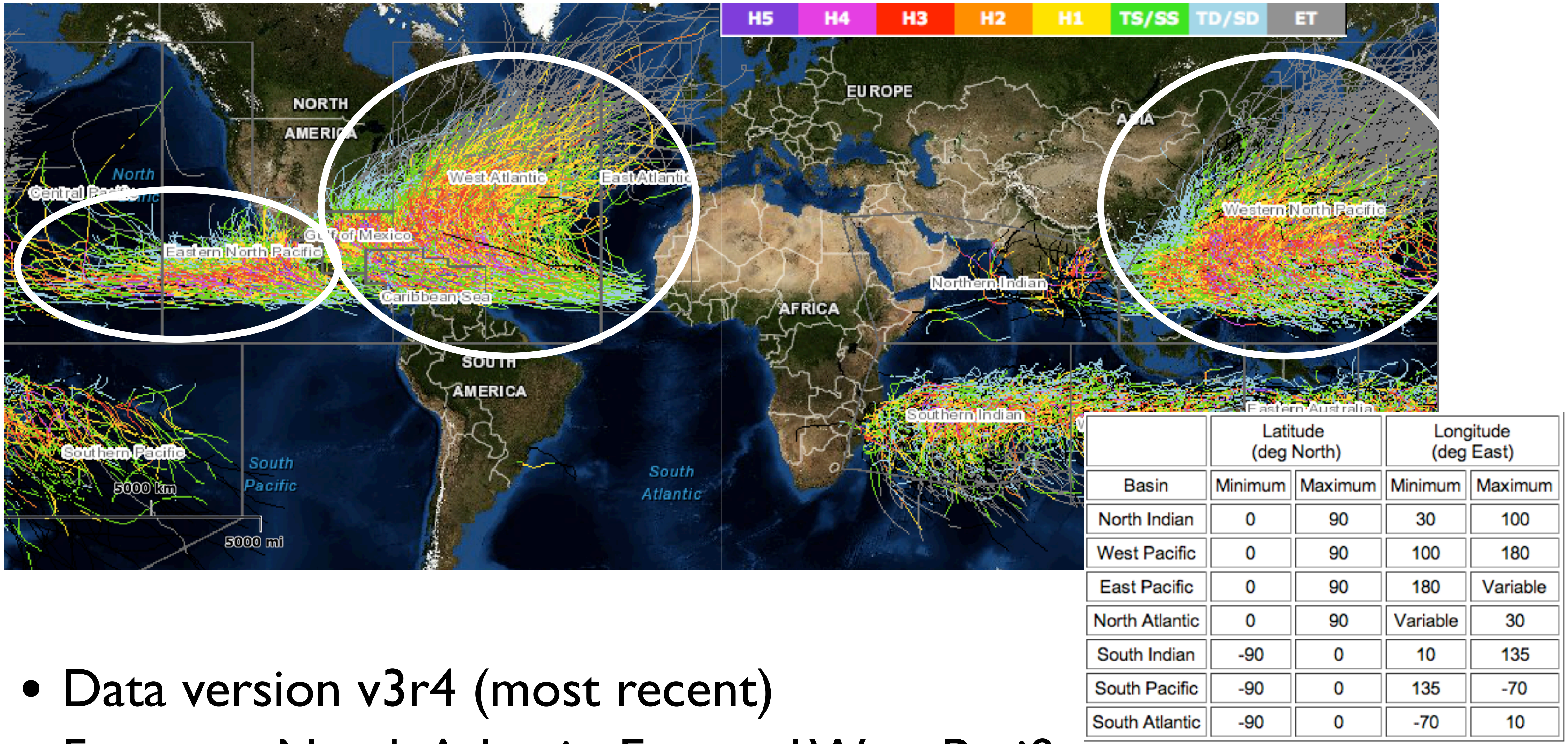
- Joint research project between JMA and CRIEPI
- Period: from Jan. 1979 to Dec. 2010 (use 1994 data)
- Global model resolution : T106L40 (data at 1.25° grid)
- Data assimilation : 3D-Var
- Assimilation system : JMA's operational system of April 2004.

  In addition, SSM/I PW, and TOVS radiance level 1c (SSU) and 1d (HIRS, MSU) were assimilated.
- JRA-25 was the first reanalysis to use the observational data outlined below

  Wind profile retrievals surrounding tropical cyclones (TCR), SSM/I snow coverage, digitized Chinese snow depth data, reprocessed GMS-AMV
- JRA-25 original boundary/forcing data

  Daily COBE SST and sea ice (Ishii 2005, IJC), daily 3D-ozone profile

IBTrACS



	Latitude (deg North)		Longitude (deg East)	
Basin	Minimum	Maximum	Minimum	Maximum
North Indian	0	90	30	100
West Pacific	0	90	100	180
East Pacific	0	90	180	Variable
North Atlantic	0	90	Variable	30
South Indian	-90	0	10	135
South Pacific	-90	0	135	-70
South Atlantic	-90	0	-70	10

- Data version v3r4 (most recent)
- Focus on North Atlantic, East and West Pacific
- Genesis of tracks start from the location when max wind larger than 35 knots (Tropical Storm and Cat 1-5 Hurricane)
- Use 1994 data for initial test
- Conversion of 10 min average wind to 1min (/0.88) over W Pacific

IBTrACS still have problems

```
start    20  1994     9    21    18    0.99    0.99
 164.80   14.80   20.47  998.00  1994    9    21    18
 164.20   15.70   20.47  998.00  1994    9    22     0
 164.10   16.70   20.47  998.00  1994    9    22     6
 164.00   17.80   23.40  996.00  1994    9    22    12
 163.70   19.00   23.40  994.00  1994    9    22    18
 163.10   20.70   29.25  985.00  1994    9    23     0
 162.70   22.20   38.02  970.00  1994    9    23     6
 162.30   23.30   40.95  965.00  1994    9    23    12
 161.80   24.30   40.95  965.00  1994    9    23    18
 161.10   25.10   40.95  965.00  1994    9    24     0
 160.40   25.70   40.95  965.00  1994    9    24     6
 159.50   26.40   40.95  965.00  1994    9    24    12
 158.00   27.30   40.95  965.00  1994    9    24    18
 155.40   28.20   35.10  975.00  1994    9    25     0
 153.00   28.20   32.17  980.00  1994    9    25     6
 151.50   28.00   29.25  985.00  1994    9    25    12
 150.60   27.50   26.32  990.00  1994    9    25    18
 150.70   27.80   23.40  992.00  1994    9    26     0
 151.20   29.20   20.47  994.00  1994    9    26     6
 150.60   31.30   20.47  994.00  1994    9    26    12
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 164.10   16.70   20.47  998.00  1994    9    22     6
 164.00   17.80   23.40  996.00  1994    9    22    12
 163.70   19.00   23.40  994.00  1994    9    22    18
 163.10   20.70   29.25  985.00  1994    9    23     0
 162.70   22.20   38.02  970.00  1994    9    23     6
 162.30   23.30   40.95  965.00  1994    9    23    12
 161.80   24.30   40.95  965.00  1994    9    23    18
 161.10   25.10   40.95  965.00  1994    9    24     0
 160.40   25.70   40.95  965.00  1994    9    24     6
 159.50   26.40   40.95  965.00  1994    9    24    12
 158.00   27.30   40.95  965.00  1994    9    24    18
 155.40   28.20   35.10  975.00  1994    9    25     0
 153.00   28.20   32.17  980.00  1994    9    25     6
 151.50   28.00   29.25  985.00  1994    9    25    12
 150.60   27.50   26.32  990.00  1994    9    25    18
 150.70   27.80   23.40  992.00  1994    9    26     0
 151.20   29.20   20.47  994.00  1994    9    26     6
 150.60   31.30   20.47  994.00  1994    9    26    12
 149.70   32.60   20.47  996.00  1994    9    26    18
 149.20   33.60   20.47  996.00  1994    9    27     0
 149.50   34.30   23.40  996.00  1994    9    27     6
 150.70   35.60   23.40  996.00  1994    9    27    12
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 153.10   37.60   20.47  996.00  1994    9    28     0
 155.00   38.30   20.47  998.00  1994    9    28     6
 157.10   39.00   20.47  998.00  1994    9    28    12
 158.00   39.00    0.00 1000.00  1994    9    28    18
 158.50   39.50    0.00 1004.00  1994    9    29     0
 162.00   40.00    0.00 1004.00  1994    9    29     6
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 178.50   41.00    0.00  992.00  1994    9    30     6
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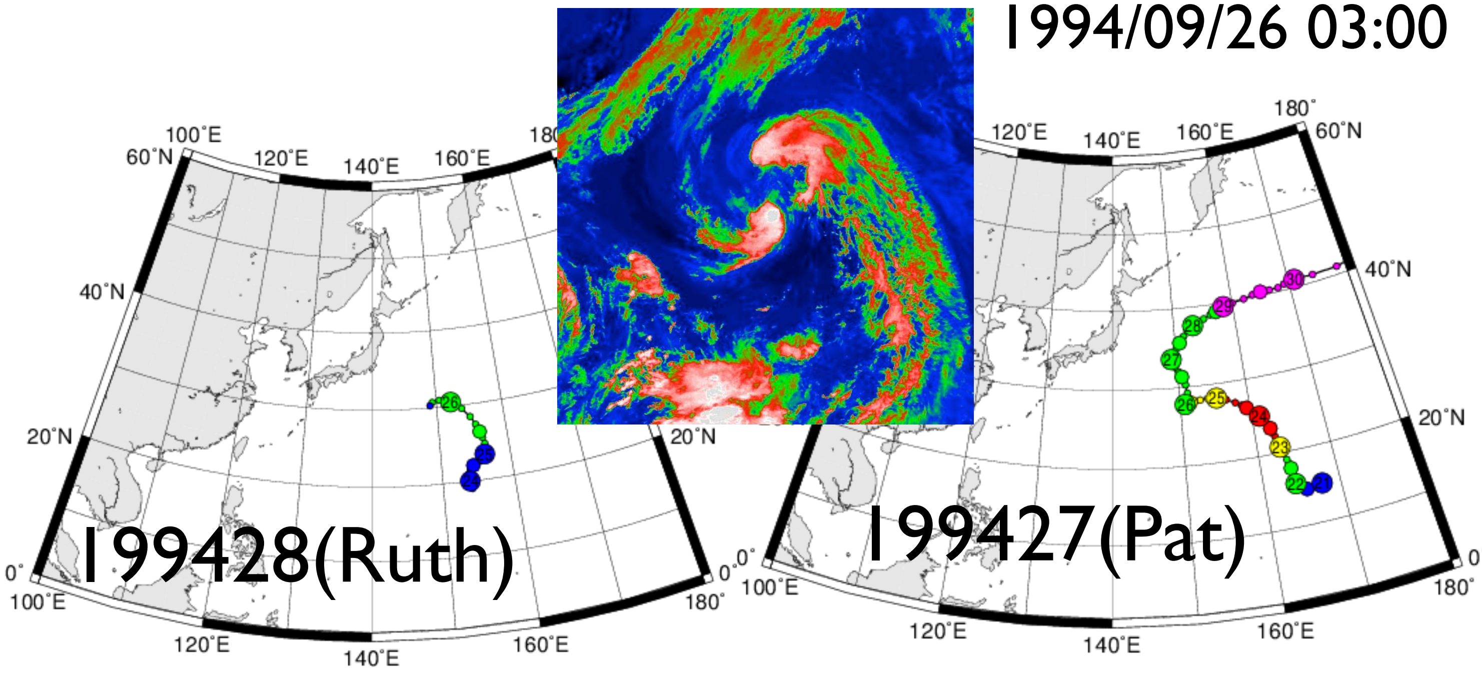


1994/09/26 03:00

199428(Ruth)

199427(Pat)

Tropical Storm Detection Scheme (Vitart et al., 1997, 2003)

- Local relative vorticity maximum at 850hPa > 6.0×10^{-5} s^{-1}.

  crit_vort = 6.0E−5
- The closet local minimum sea level pressure is detected and defines the center of the storm.

  Must exist within a ~1.4° radius of the vorticity maximum.

  It’s also for warm core 1st and 2nd center.

  crit_dist = 2.0 = ~1.4x1.4 （avoid minus distance for center to center）
- The minimum sea level pressure must increase by 4hPa in all directions from storm center within 4° radius.

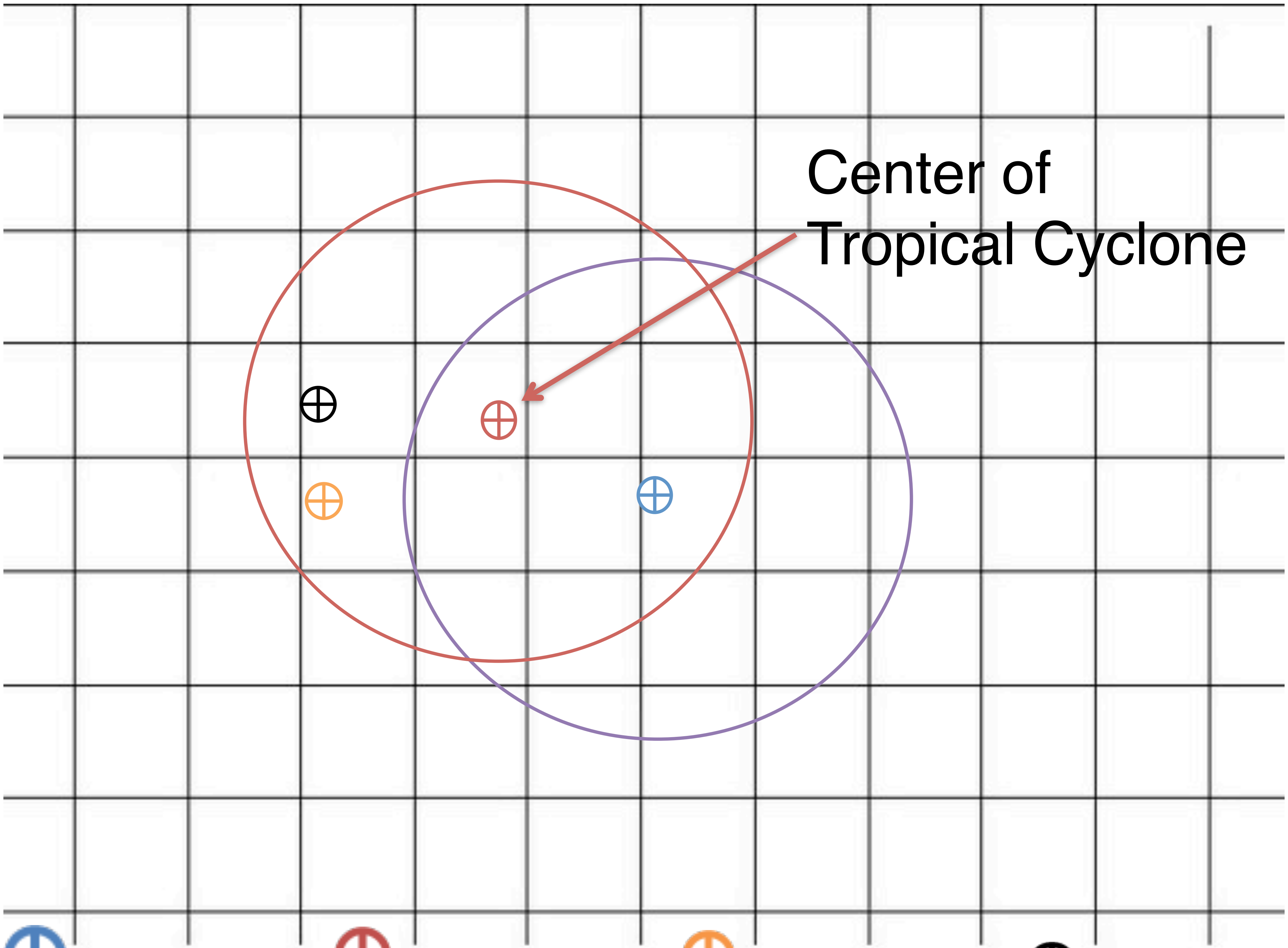
  crit_psl = 200.0 dist_psl = 3.0
- The closest local maximum in temperature averaged between 200hPa and 500hPa is defined as the 1st center of the warm core.

  The temperature must decrease by at least 0.2 K in all directions from the warm core 1st center within 3°radius.

  crit_twc = 0.2 dist_twc = 3.0
- The closest local maximum in thickness averaged between 200hPa and 1000hPa is defined as the 2nd center of the warm core.

  The thickness must decrease by at least 500 m in all directions from the warm core 2nd center within 3°radius.

  crit_thick = 100.0 dist_twc = 3.0



Center of Tropical Cyclone

⊕ vorticity center

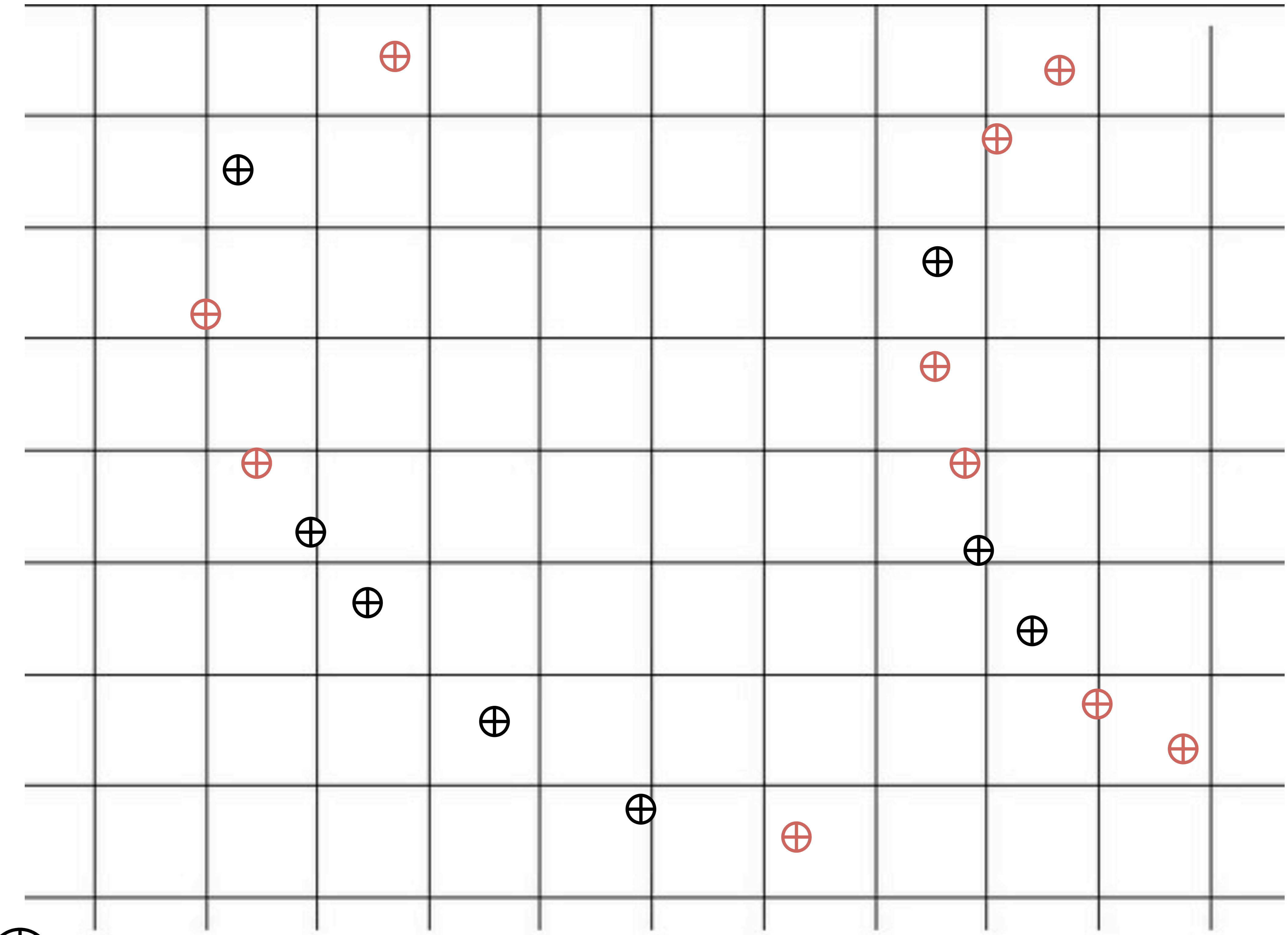
⊕ pressure center

⊕ warm core center

⊕ thickness center

Tropical Storm **Tracking** Scheme (Vitart et al., 1997, 2003)

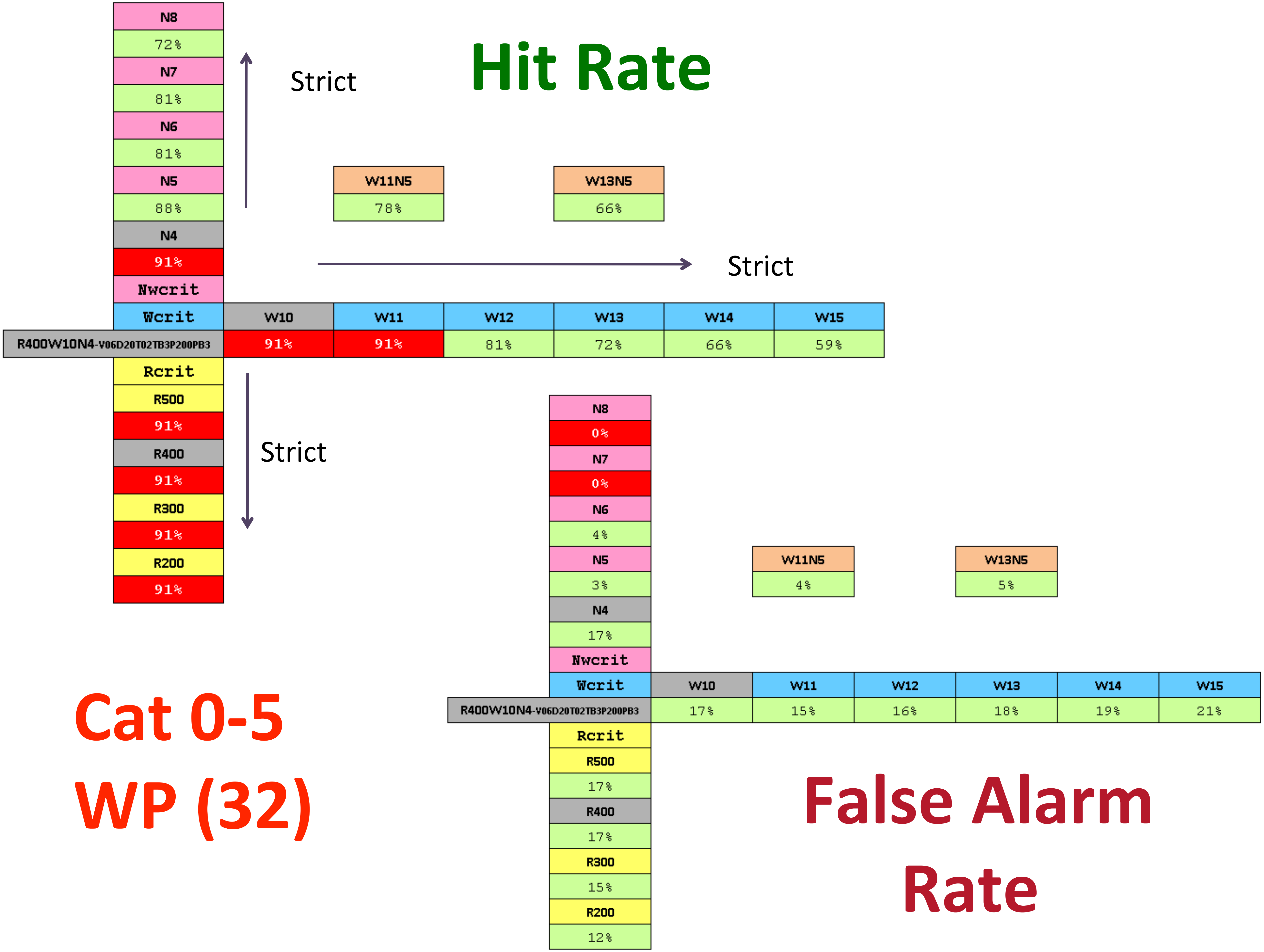
- For a given storm, we examine whether there are storms that appear on the following time step (6hr) at a distance of less than 400 km.
  If there is no such storm, then the trajectory is stopped.
  rcrit = 400.0
- It must satisfy a maximum 10m wind velocity > 10 m/s and **warm core** at the same time for 4 times during total life time.
  (not necessarily consecutive)
  wcrit = 10.0 nwcrit = 4.0
- The genesis point must satisfy maximum 10m wind velocity > 10 m/s



⊕ Satisfy warm core, thickness, and wind speed criteria

⊕ False in either one of the above criteria

Hit Rate



Strict

Strict

Strict

N8	72%
N7	81%
N6	81%
N5	88%
N4	91%
Nwcrit	

W11N5	78%
W13N5	66%

	Wcrit	W10	W11	W12	W13	W14	W15
R400W10N4-v06D20T02TB3P200PB3		91%	91%	81%	72%	66%	59%

Rcrit	
R500	91%
R400	91%
R300	91%
R200	91%

False Alarm Rate

N8	0%
N7	0%
N6	4%
N5	3%
N4	17%
Nwcrit	

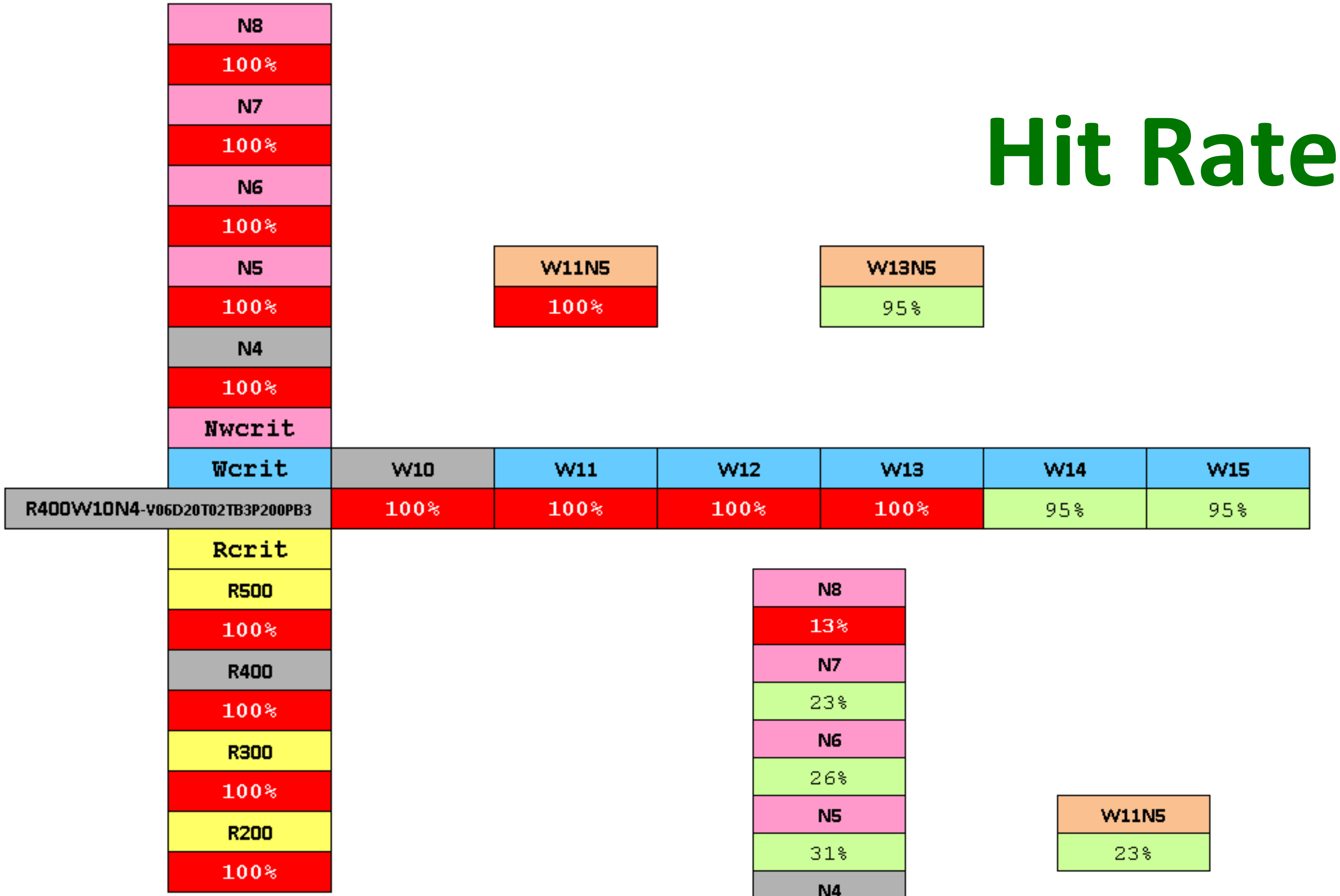
W11N5	4%
W13N5	5%

	Wcrit	W10	W11	W12	W13	W14	W15
R400W10N4-v06D20T02TB3P200PB3		17%	15%	16%	18%	19%	21%

Rcrit	
R500	17%
R400	17%
R300	15%
R200	12%

Cat 0-5
WP (32)

Hit Rate



N8	100%
N7	100%
N6	100%
N5	100%
N4	100%
Nwcrit	

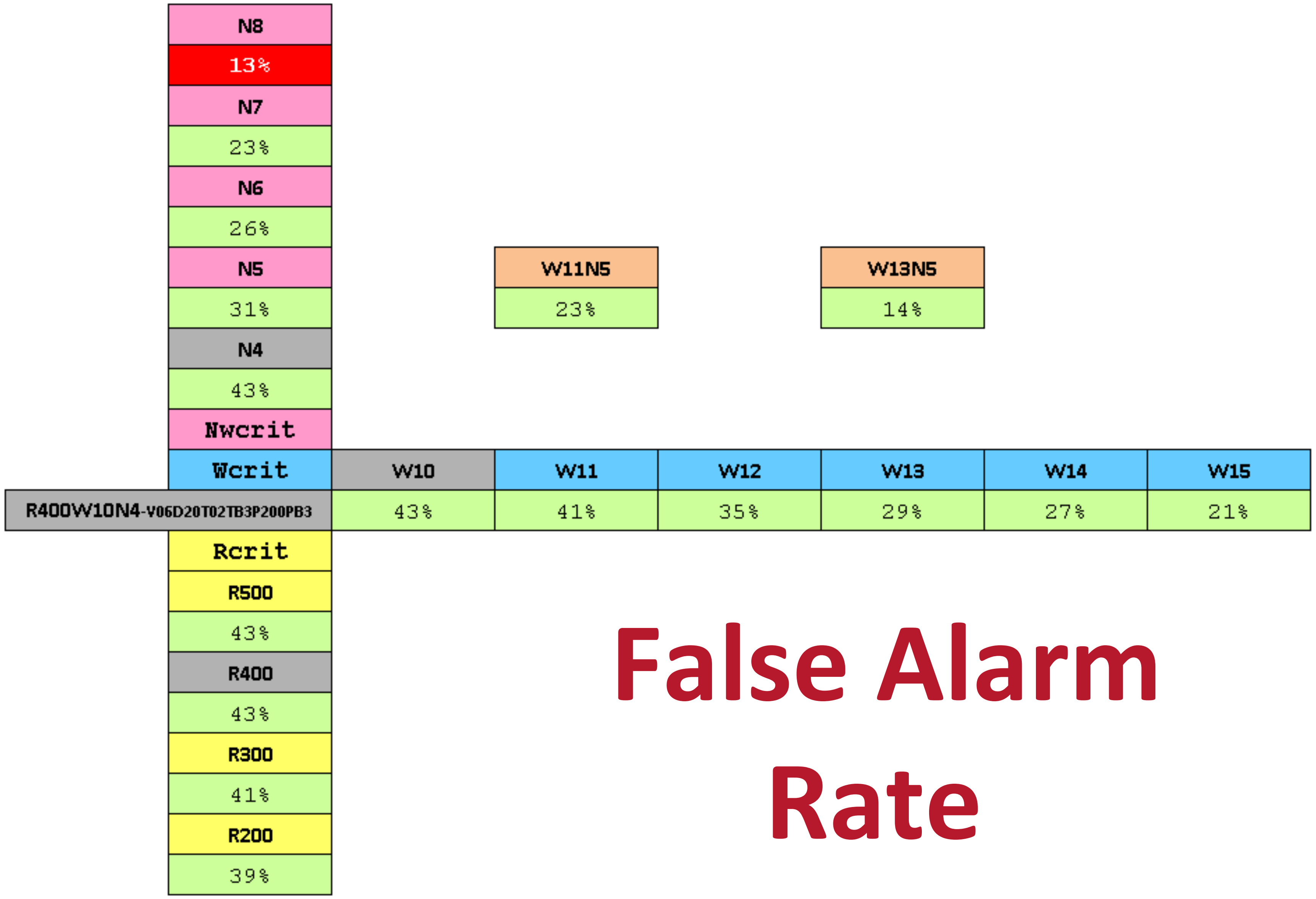
W11N5	100%
W13N5	95%

Wcrit	W10	W11	W12	W13	W14	W15
R400W10N4-V06D20T02TB3P200PB3	100%	100%	100%	100%	95%	95%

Rcrit	
R500	100%
R400	100%
R300	100%
R200	100%

Cat 1-5
WP (20)

False Alarm Rate



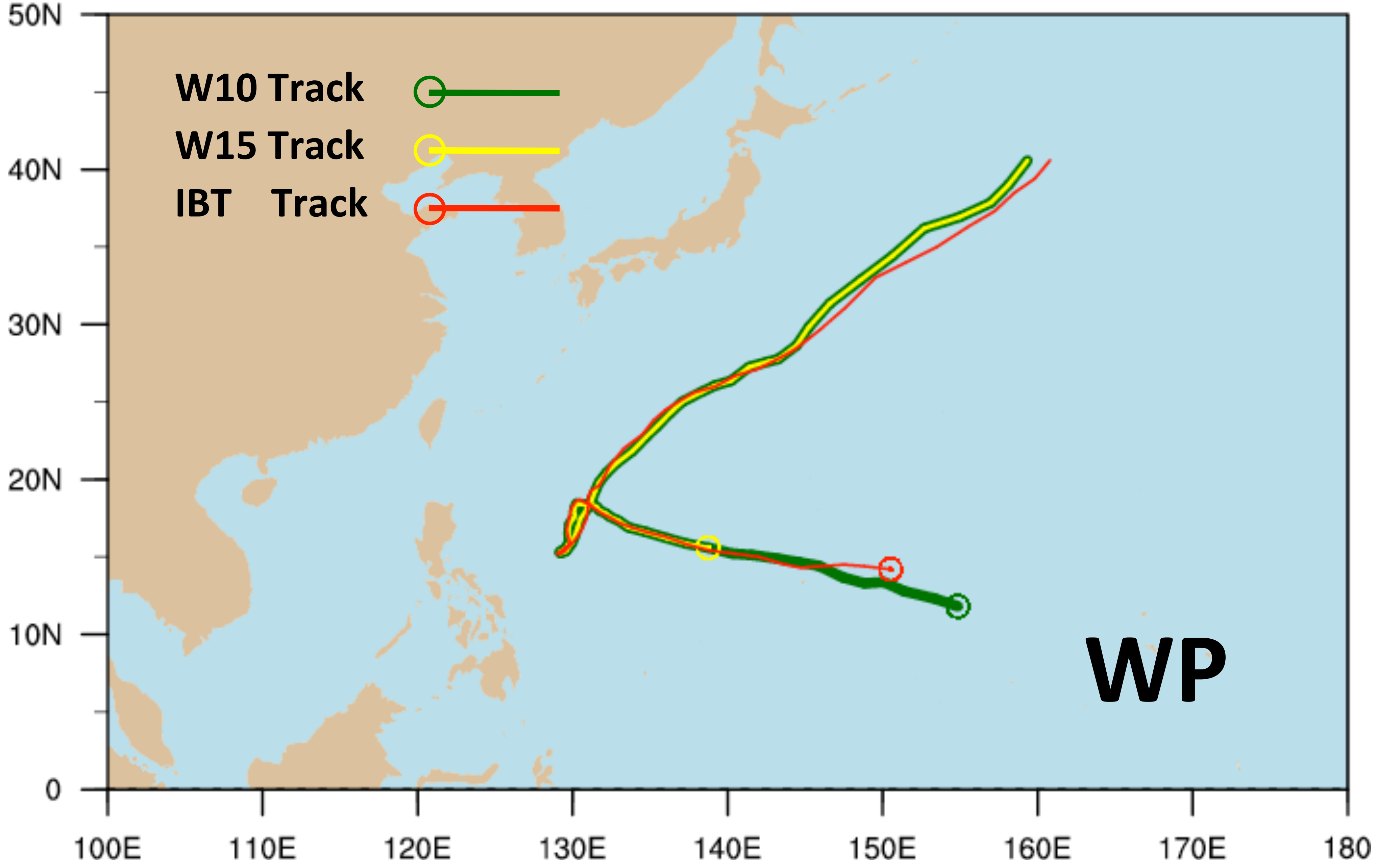
N8	13%
N7	23%
N6	26%
N5	31%
N4	43%
Nwcrit	

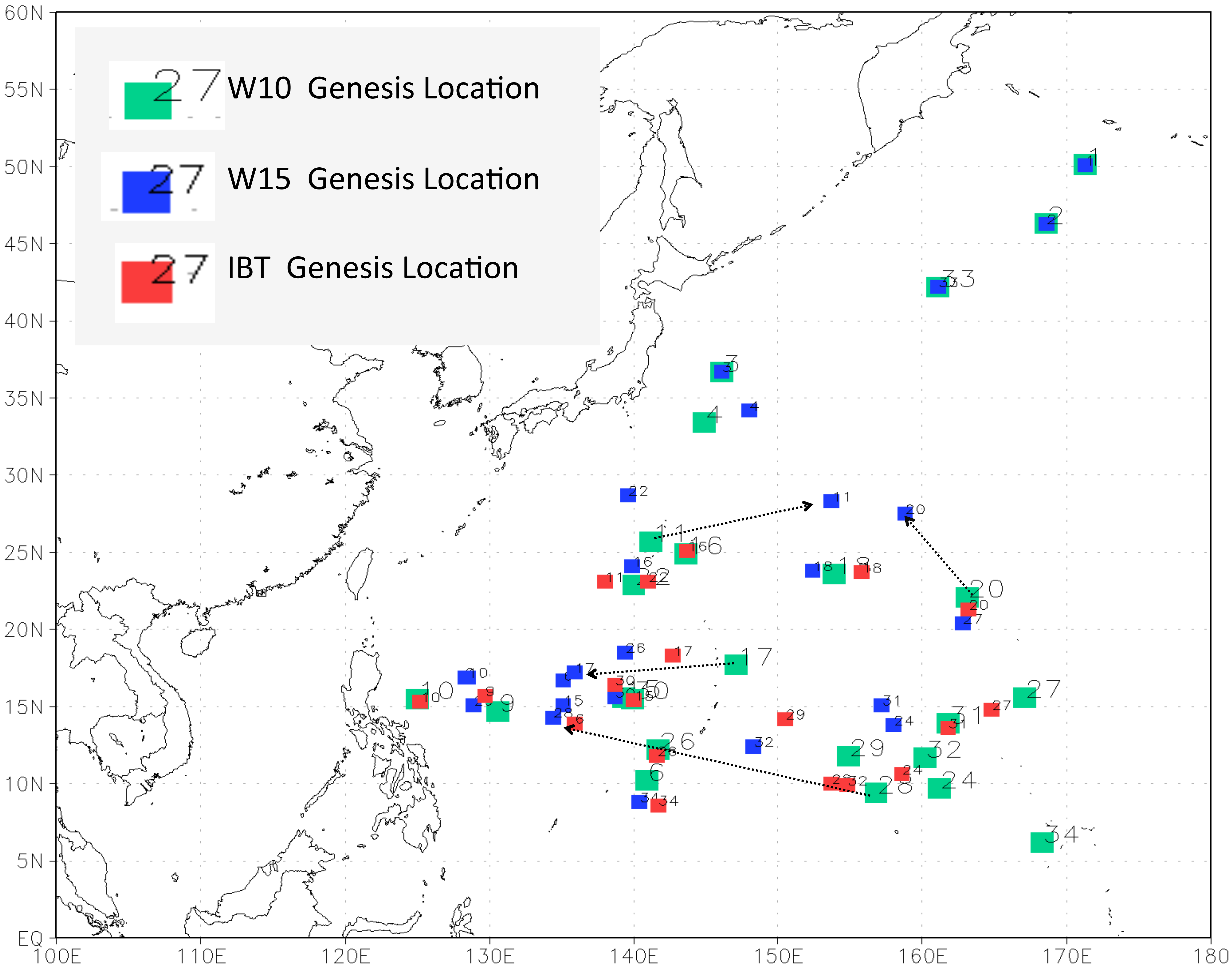
W11N5	23%
W13N5	14%

Wcrit	W10	W11	W12	W13	W14	W15
R400W10N4-V06D20T02TB3P200PB3	43%	41%	35%	29%	27%	21%

Rcrit	
R500	43%
R400	43%
R300	41%
R200	39%

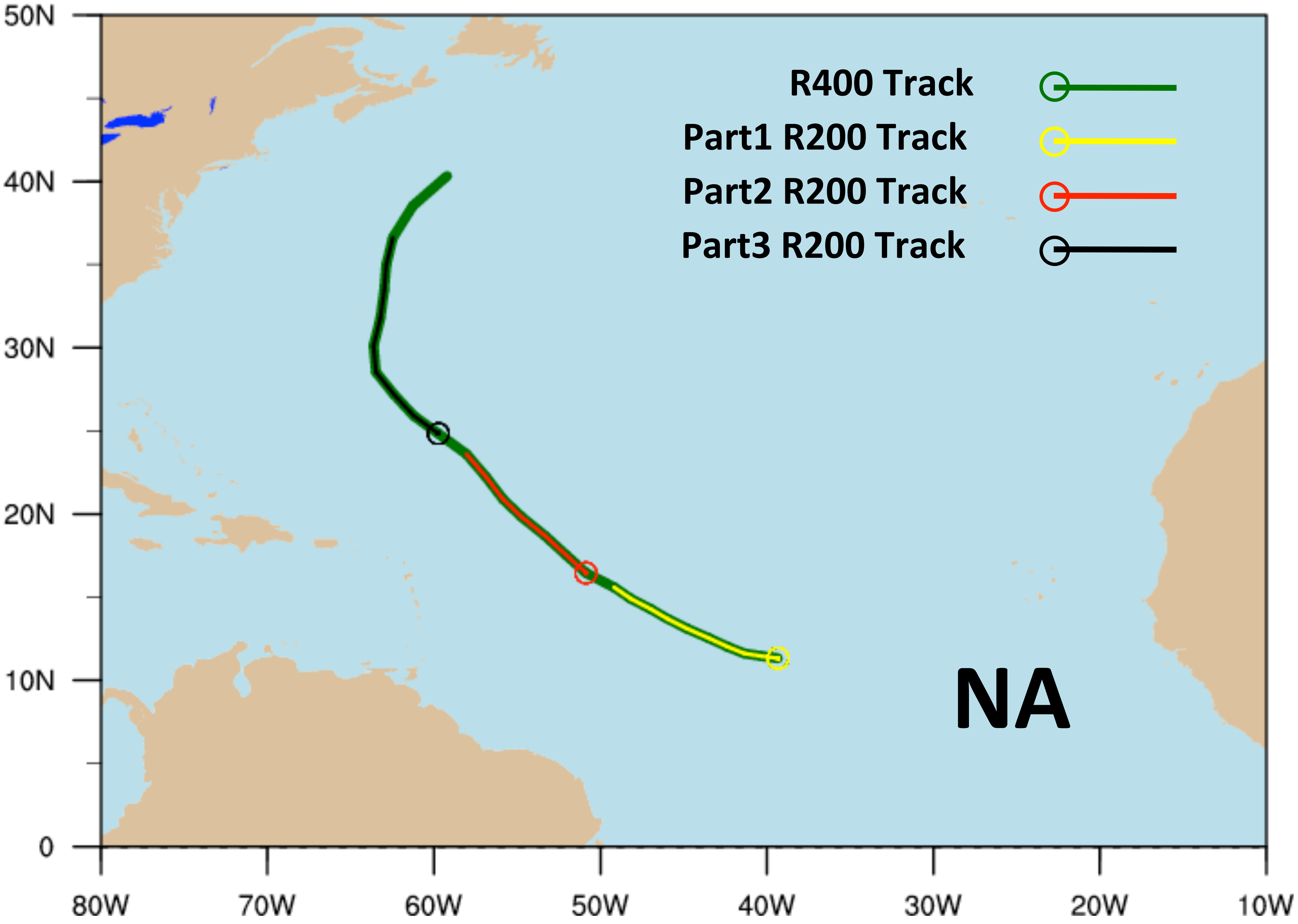
W10 W15 IBT longest Track





W10 Genesis Location
W15 Genesis Location
IBT Genesis Location
60N
55N
50N
45N
40N
35N
30N
25N
20N
15N
10N
5N
EQ
100E
110E
120E
130E
140E
150E
160E
170E
180

R400 vs R200 Track Impact



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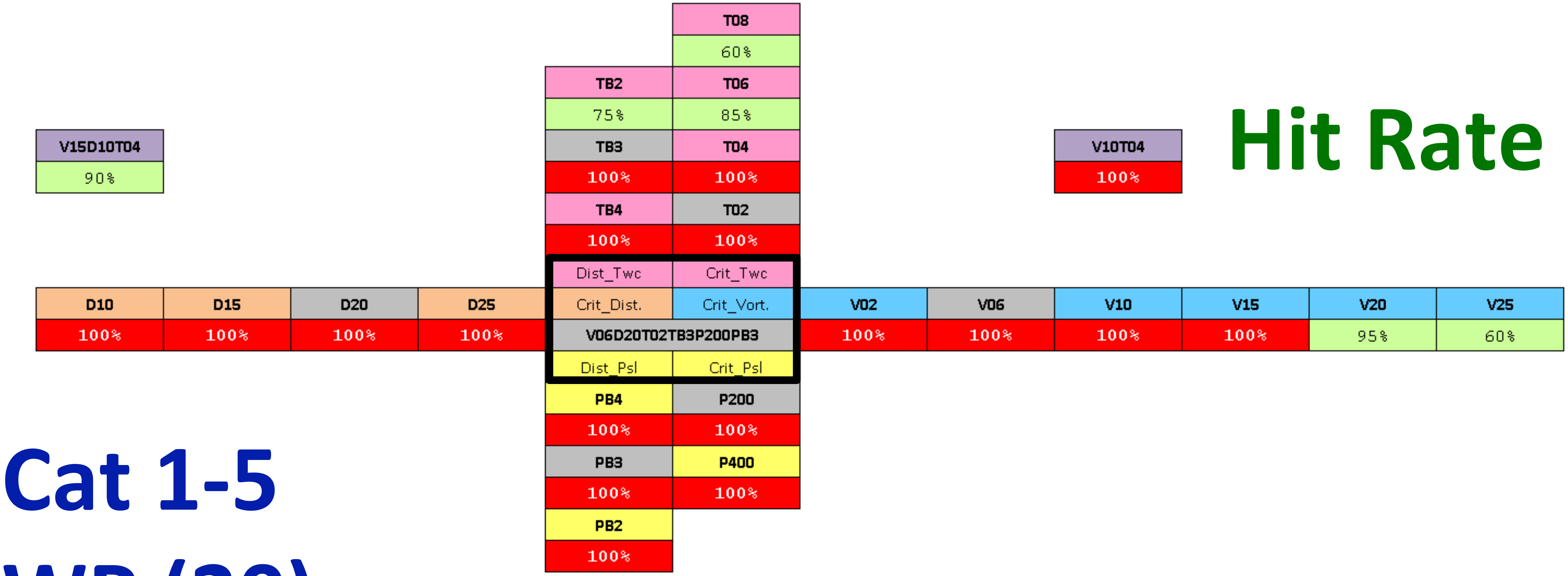
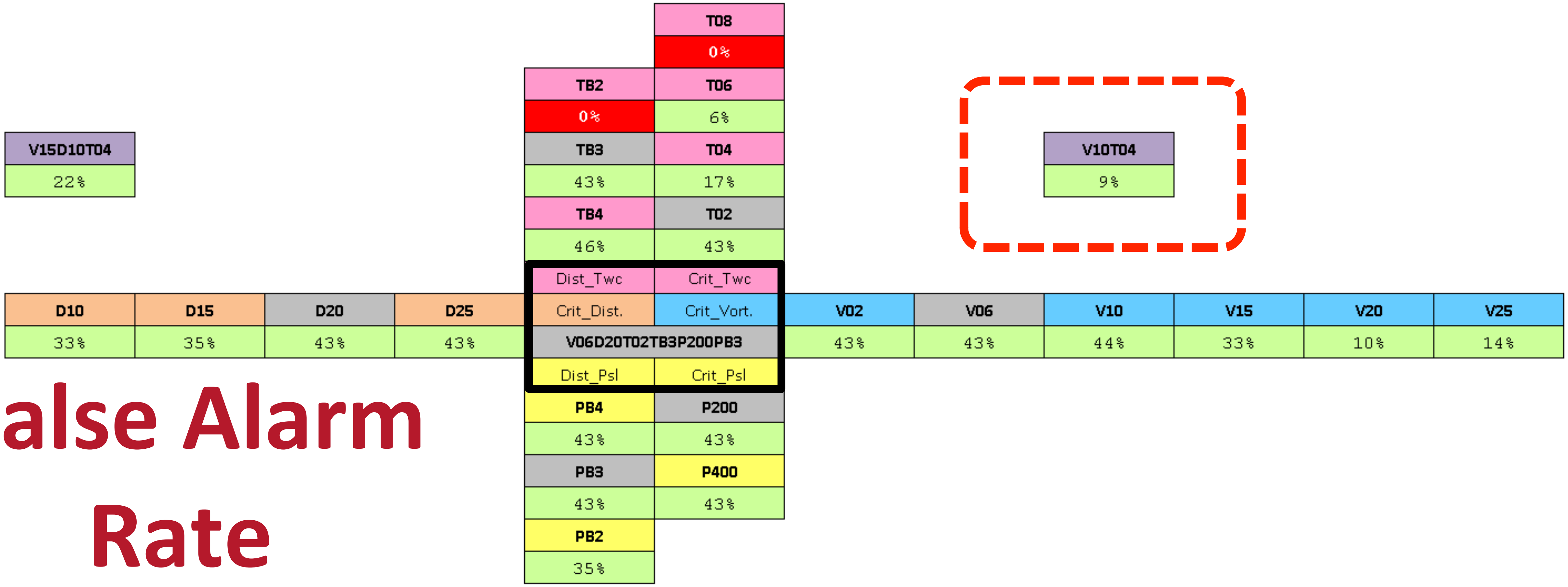


Dist_Twc
Crit_Twc
Crit_Dist.
Crit_Vort.
V06D20T02TB3P200PB3
Dist_Psl
Crit_Psl

V15D10T04	90%
T08	60%
TB2	75%
T06	85%
TB3	100%
T04	100%
TB4	100%
T02	100%
V10T04	100%
D10	100%
D15	100%
D20	100%
D25	100%
V02	100%
V06	100%
V10	100%
V15	100%
V20	95%
V25	60%
PB4	100%
P200	100%
PB3	100%
P400	100%
PB2	100%

Cat 1-5

WP (20)

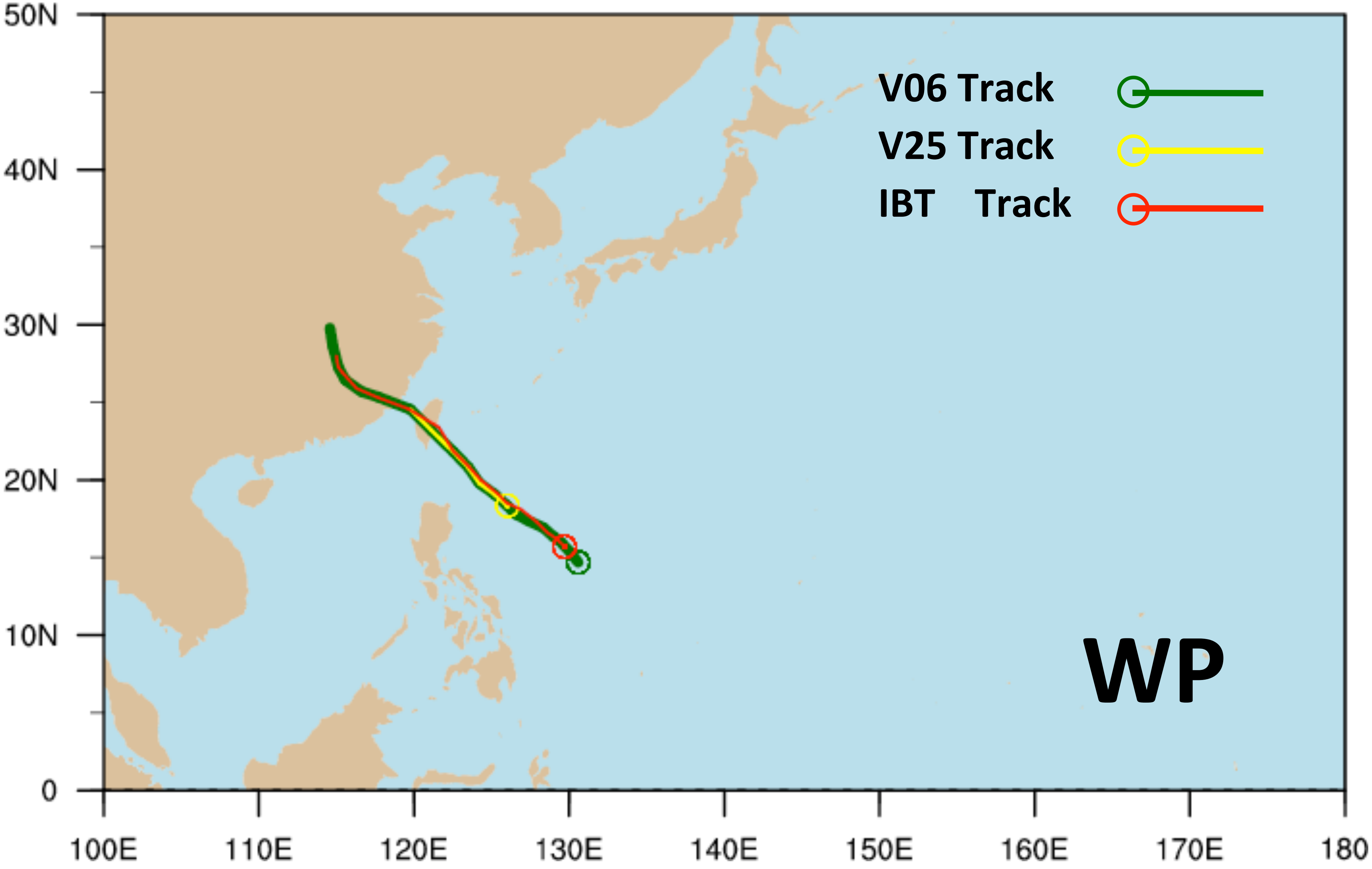


Dist_Twc
Crit_Twc
Crit_Dist.
Crit_Vort.
V06D20T02TB3P200PB3
Dist_Psl
Crit_Psl

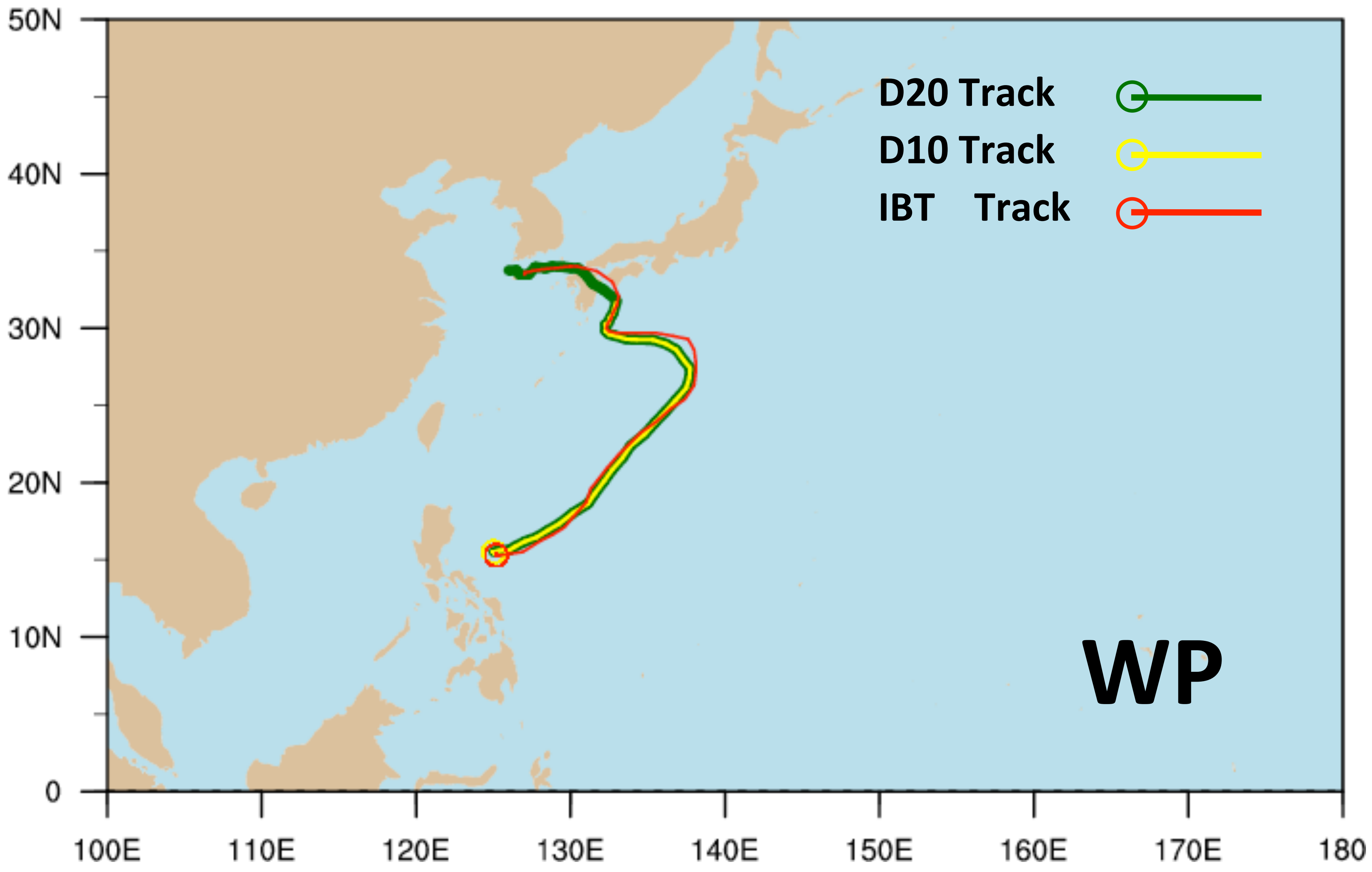
T08	0%
TB2	0%
T06	6%
V15D10T04	22%
TB3	43%
T04	17%
V10T04	9%
TB4	46%
T02	43%
D10	33%
D15	35%
D20	43%
D25	43%
V02	43%
V06	43%
V10	44%
V15	33%
V20	10%
V25	14%
PB4	43%
P200	43%
PB3	43%
P400	43%
PB2	35%

False Alarm Rate

V06 V25 IBT shortest Track



D20 D10 IBT Track Impact



Summary and Discussion

- We need very high resolution reanalysis data without false alarm to:
  - test the reliability of TC detection and tracking scheme
  - compare the different schemes
  - rescale the data and study the spatial scale dependence of criteria and thresholds used in the scheme
- Probably still need to tune the criteria and thresholds when the scheme is applied to different models (even at the same resolution). How to determine optimal criteria and thresholds?
- Not only TC number affected by the criteria and thresholds.
- Should we only target stronger TC (> Cat1) that has less ambiguity?
- ……...