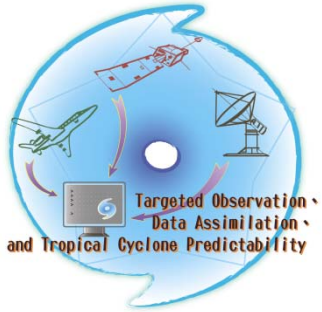
Targeted Observations for Improving Tropical Cyclone Predictability – DOTSTAR, TH08, TCS-08, and T-PARC

Chun-Chieh Wu

Acknowledging collaborators in DOTSTAR and T-PARC:

Po-Hsiung Lin, Jan-Huey Chen, Shin-Guan Chen, TDRC, COOK (NTU), Chi, Yeh, Wu, Cheng, Chen (CWB), PL Lin (NCU), CH Liu, K.-H. Chou (CCU), Chia Chou (RCEC), AIDC, Sim Aberson (HRD), T. Nakazawa, M. Yamaguchi (JMA/MRI), Sharan Majumdar (U. of Miami), Melinda Peng, Simon Chang, C. Reynolds (NRL), Martin Weissmann (DLR), R. Buizza (ECMWF), Tim Li (IPRC), Mu Mu (LASG, CAS), S. Park (Ewha Univ.), H. M. Kim (Yonsei Univ.), D. Parsons, C. Davis, W.C. Lee (NCAR), Q. Zhang (PSU)

Grants: NSC, CWB, RCEC/Academia Sinica, ONR



Outline:

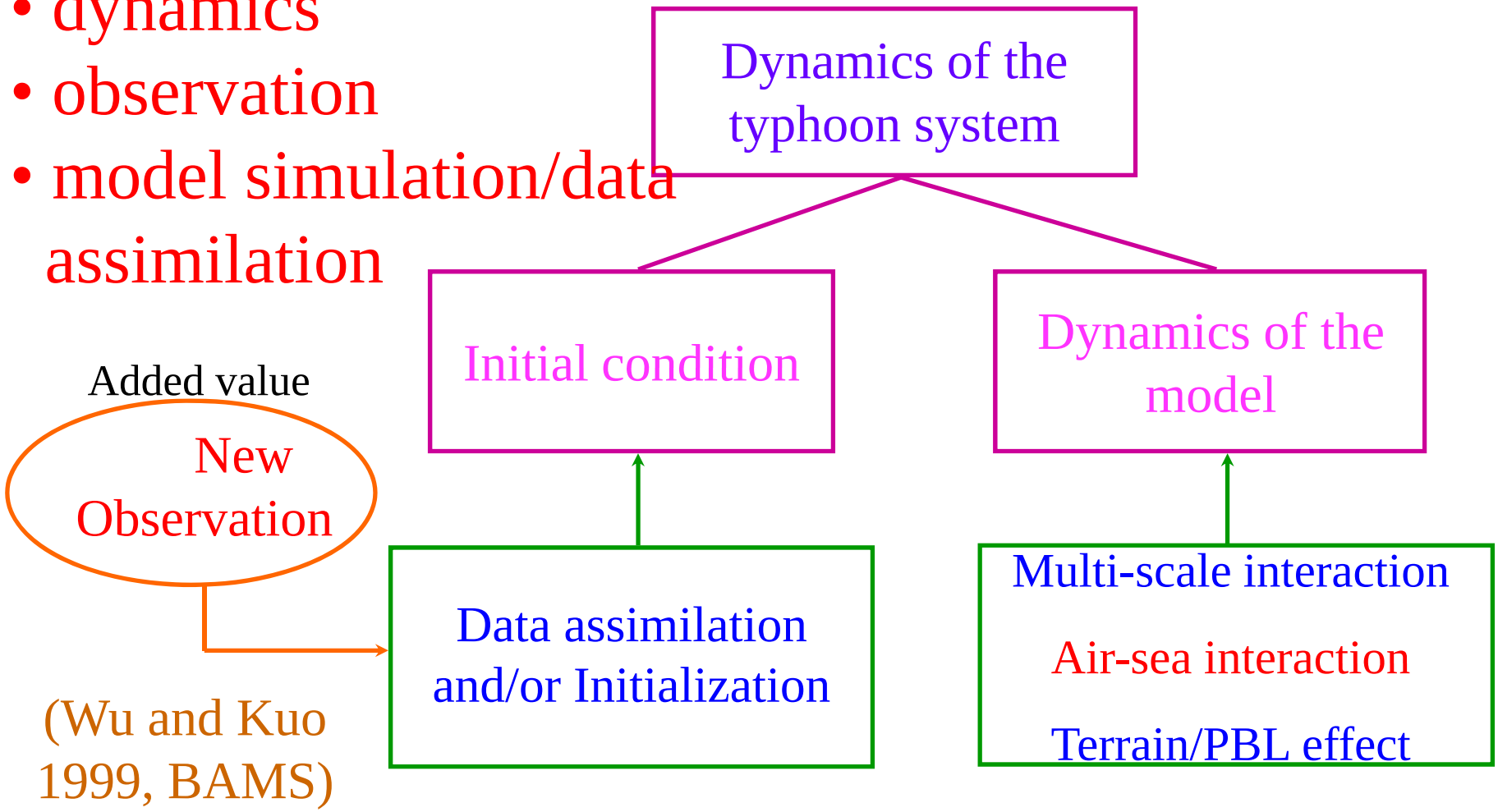
- Overview of DOTSTAR and T-PARC
- Typhoon Sinlaku (2008)
    - Impact of targeted observation
    - EnKF data assimilation in TC
    - Eyewall evolution
    - Typhoon-ocean interaction
- DOTSTAR, TCS-10 and ITOP
- Future work

Improving the understanding and prediction of the TC systems

(in memory of Dr. Yoshio Kurihara)

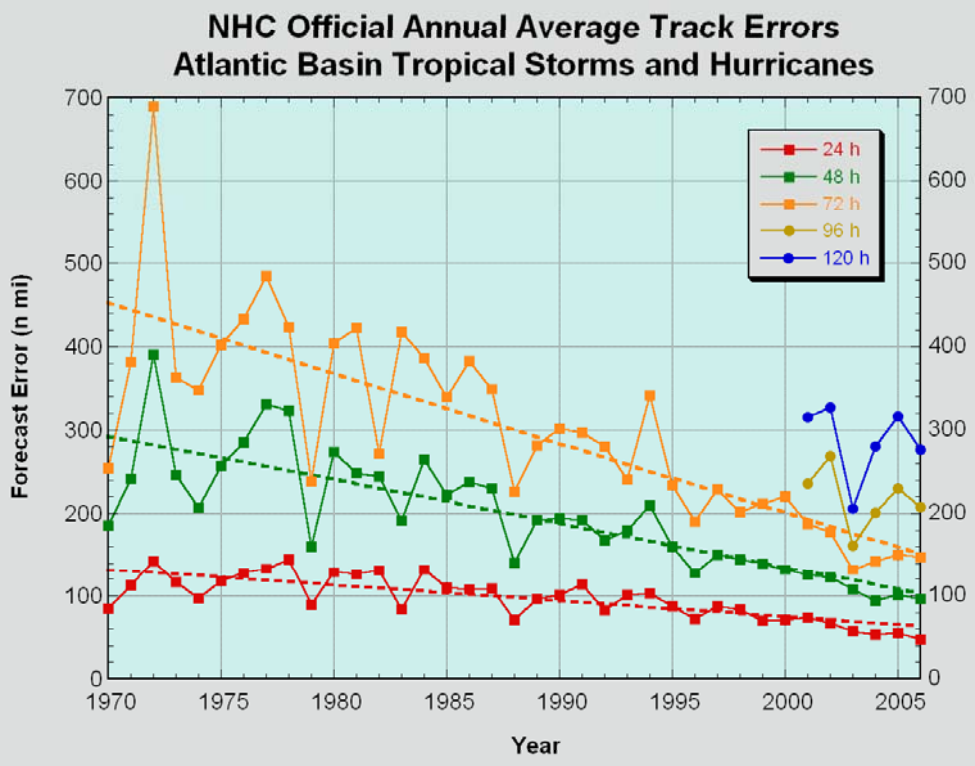
Key issues:

- dynamics
- observation
- model simulation/data assimilation

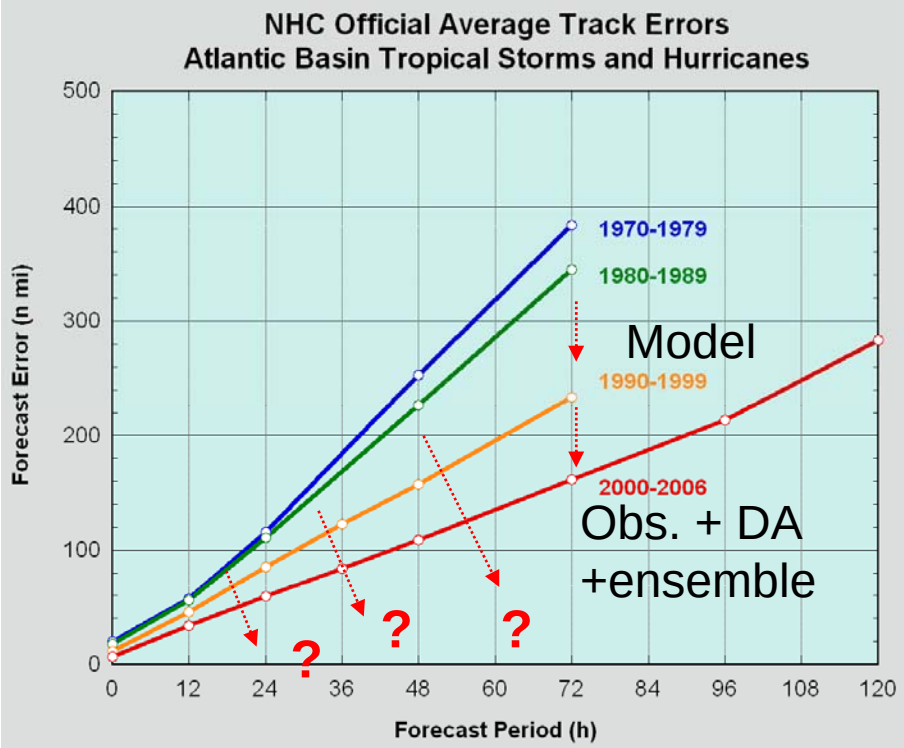


(Wu and Kuo 1999, BAMS)

Long-term decreasing trend in TC track prediction errors



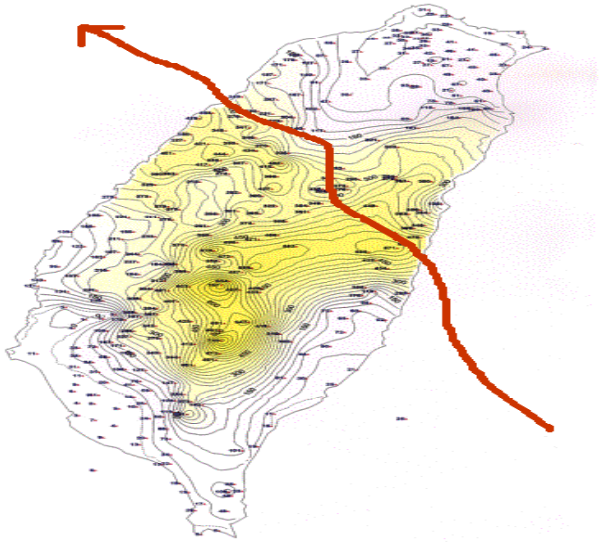
From NHC

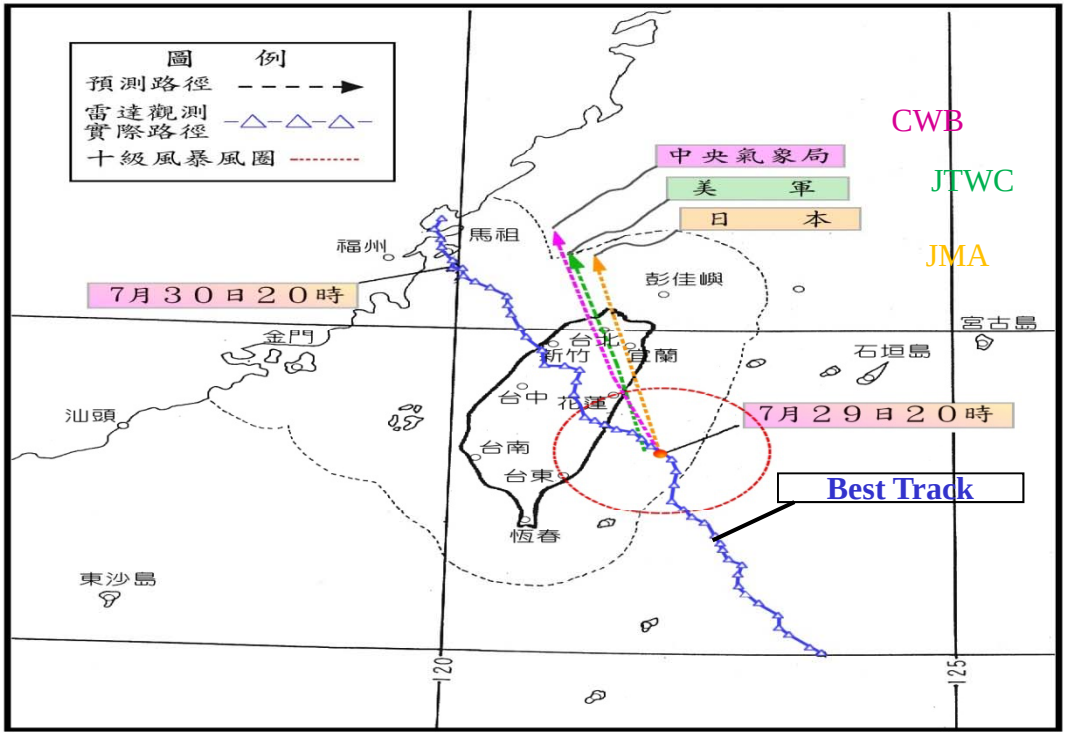


Why?

Push the limit of predictability?

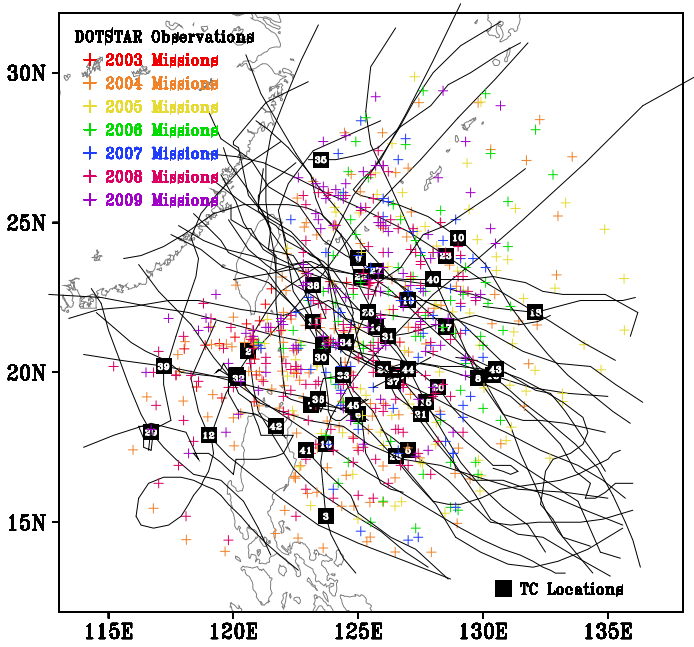
Sensitivity and vulnerability to track forecast error





Track and total rainfall of Typhoon Torajie on July 29-July 31, 2001.

Dropwindsonde Observations for Typhoon Surveillance near the Taiwan Region (DOTSTAR, 2003 – 2009)



Up to present, 45 missions have been conducted in DOTSTAR for 35 typhoons, with 751 dropwindsondes deployed during the 239 flight hours.

30 **typhoons affecting Taiwan**

23 typhoons affecting (mainland) China

7 typhoons affecting Japan

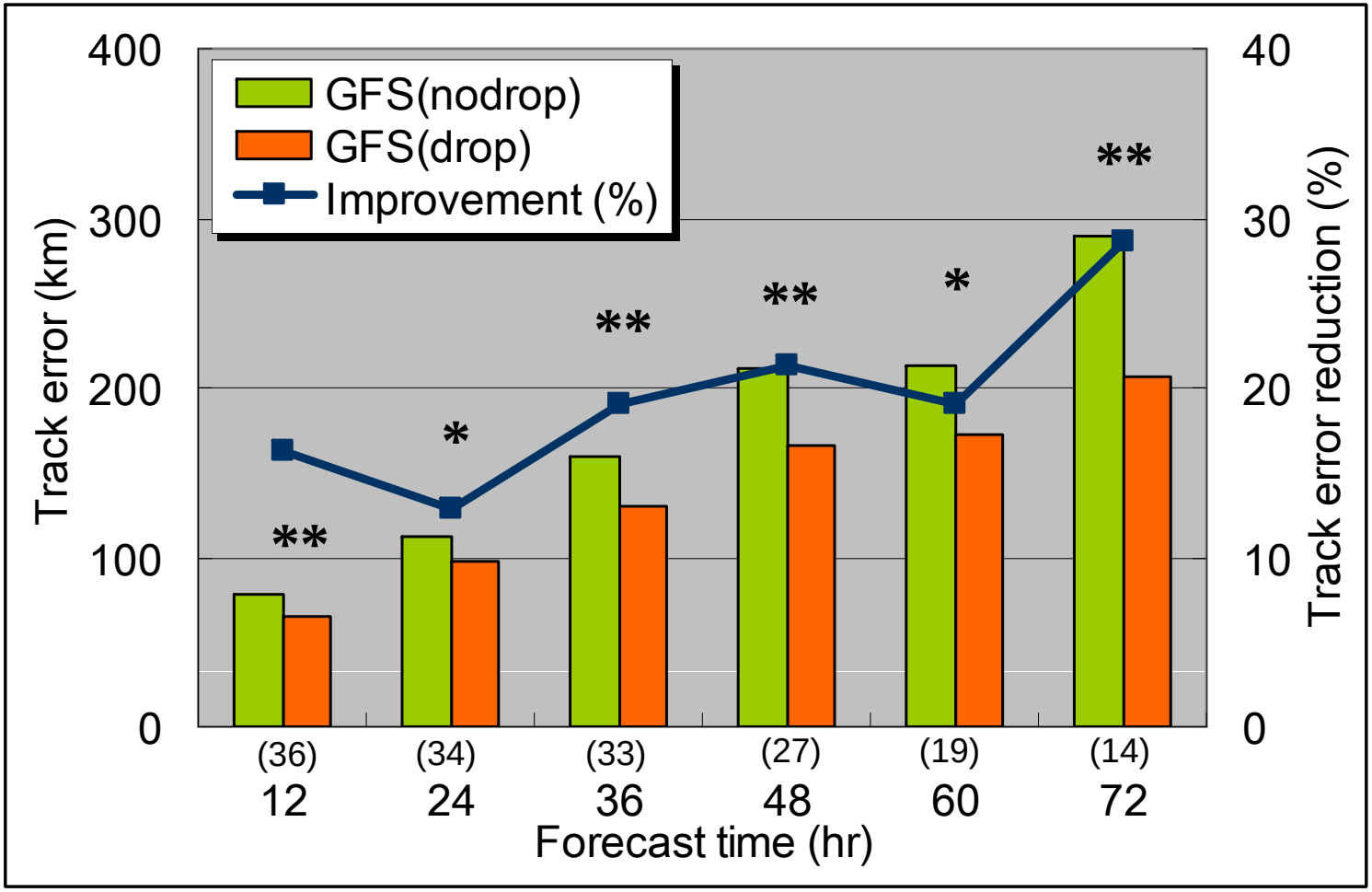
3 typhoons affecting Korea

10 typhoons affecting Philippines

- Useful real-time data available to major operational forecast centers
- Impact to the track forecasts to models in major operation centers (NCEP/GFS, FNMOC/NOGAPS, JMA/GSM)
- Targeted observation

Wu et al. (2005 BAMS, 2007a JAS, 2007b WF, 2009a,b,c MWR), Chou and Wu (2008 MWR), Chen et al. (2009 MWR), Yamaguchi et al. (2009 MWR), Chou et al. (2009 JGR)

NCEP GFS Impact from 2003 to 2008 (All 36 cases)



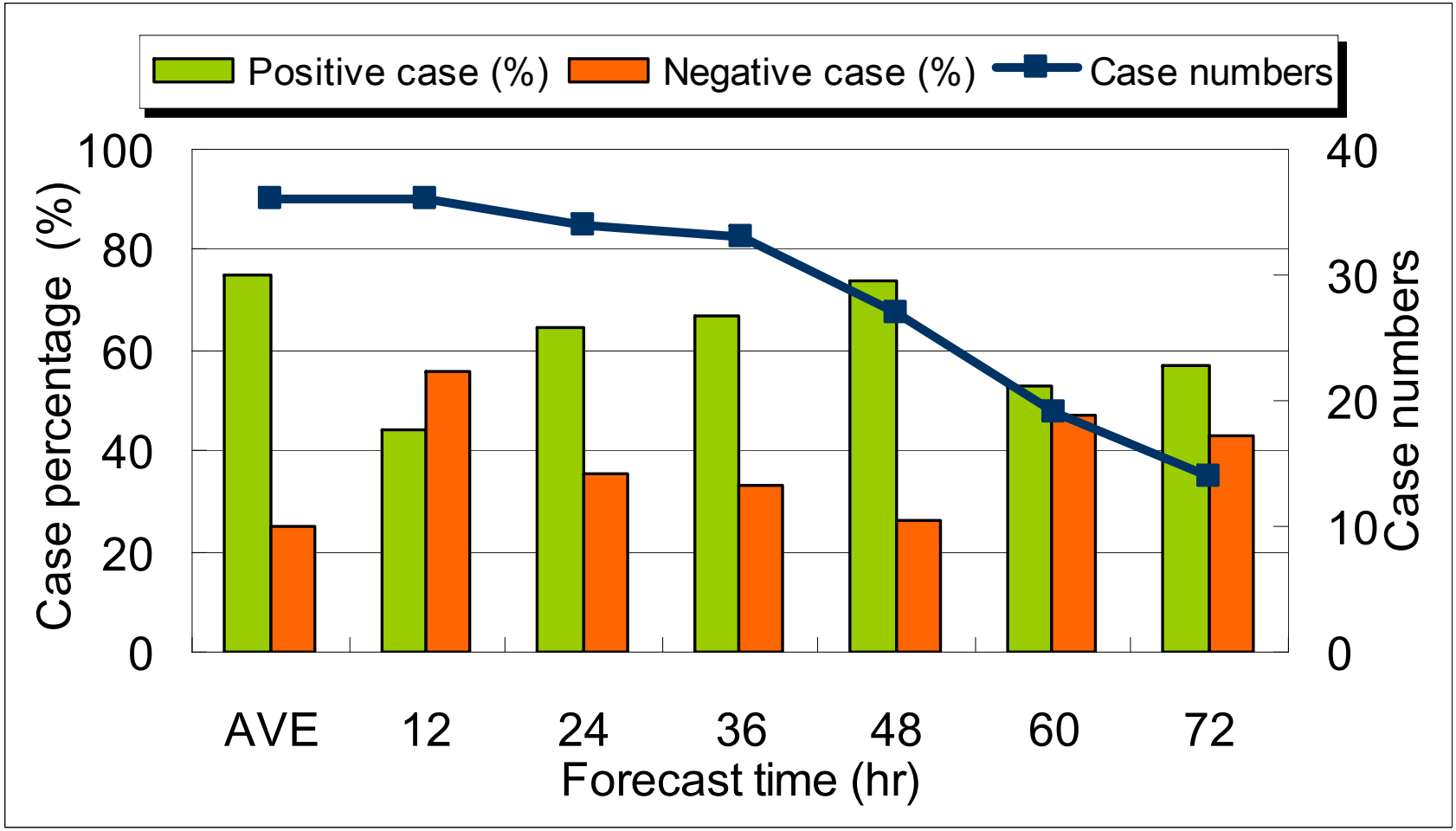
Paired t-test statistical examination

*** : statistically significant at the 90% confidence level**

**** : statistically significant at the 95% confidence level**

Wu et al. 2009d

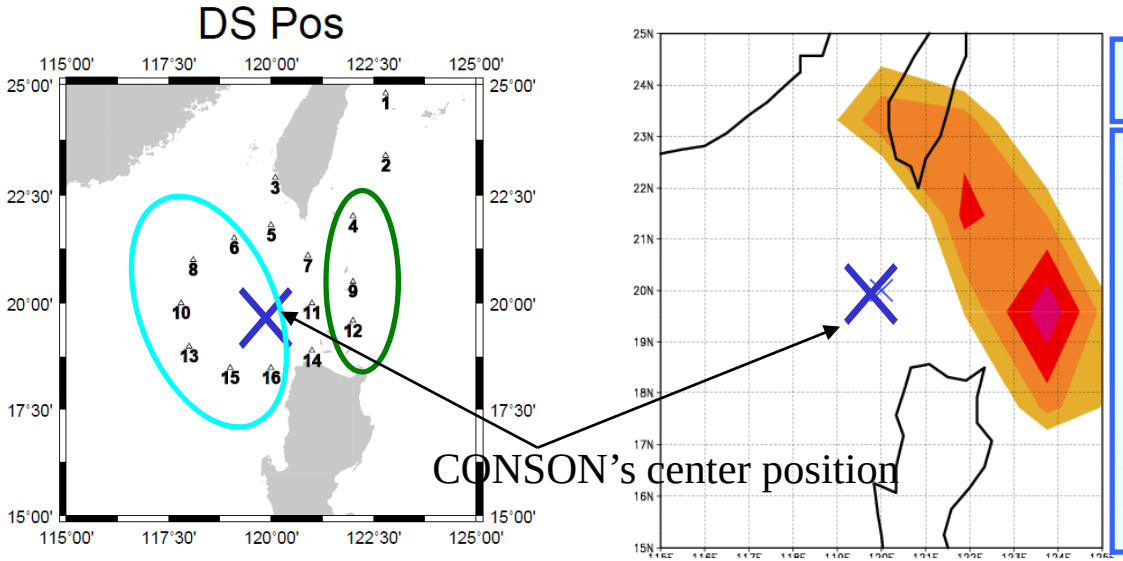
NCEP GFS Impact from 2003 to 2008



Targeted observations in DOTSTAR and T-PARC

- Since 2003, several objective methods, have been proposed and tested for operational/research surveillance missions in the environment of Atlantic hurricanes conducted by HRD/NOAA (Aberson 2003) and NW Pacific typhoons by DOTSTAR (Wu et al. 2005).
  - **NCEP/GFS ensemble variance**
    (collaborating with Aberson) **(Aberson 2003)**
  - **ETKF**
    (collaborating with Majumdar) **(Majumdar et al. 2006)**
  - **NOGAPS Singular Vector** **(Peng and Reynolds 2006)**
    (collaborating with Reynolds and Peng)
  - **Adjoint-Derived Sensitivity Steering Vector (ADSSV)**
  - **JMA moist Singular Vector** **(Wu et al. 2007b)**
    (collaborating with Yamaguchi) **(Yamaguchi et al. 2007)**
  - **ECMWF Singular Vector** **(Buizza et al. 2006)**

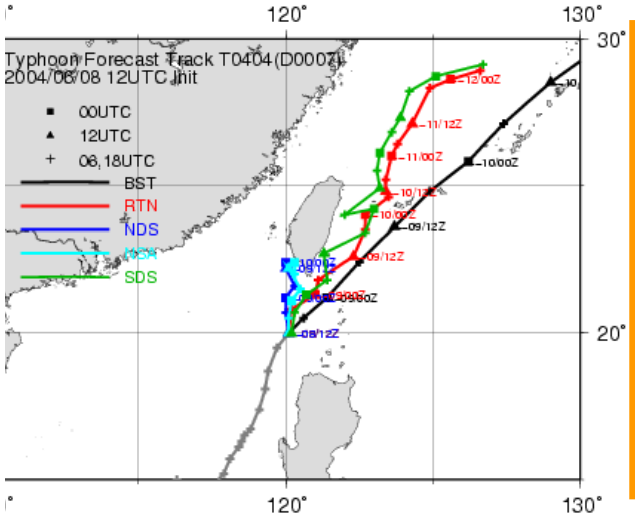
Impact of DOTSTAR data:



Sensitive analysis result

- Sensitive region shows vertically accumulated total energy by the 1st moist singular vector.
- Targeted area for the SV calculation is 25N-30N, 120E-130E.

OSE result on CONSON's (2004) track forecast



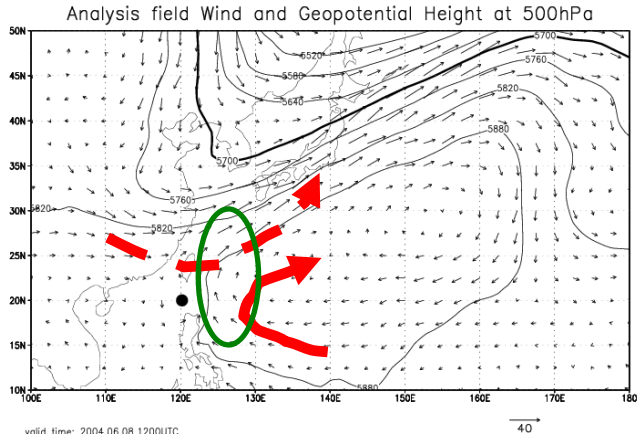
Red: (I) all dropsonde obs

Blue: (II) no dropsonde obs

Green: (III) Three dropsonde obs within the sensitive region

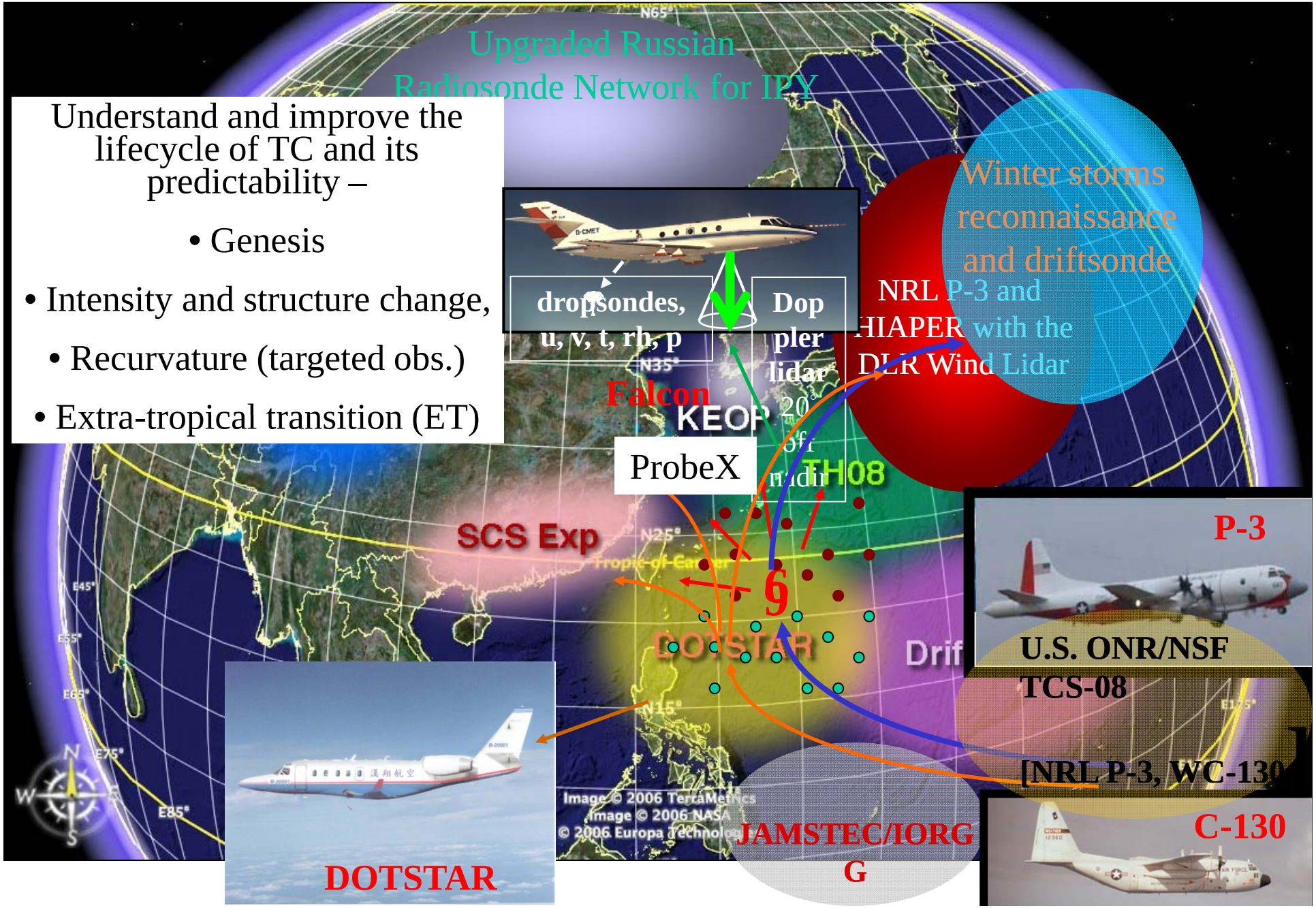
Light blue: (IV) Six dropsonde obs outside the sensitive region

Wind & Z at 500hPa



(Yamaguchi et al. 2009, MWR)

THORPEX-PARC Experiments (2008) and Collaborating Efforts



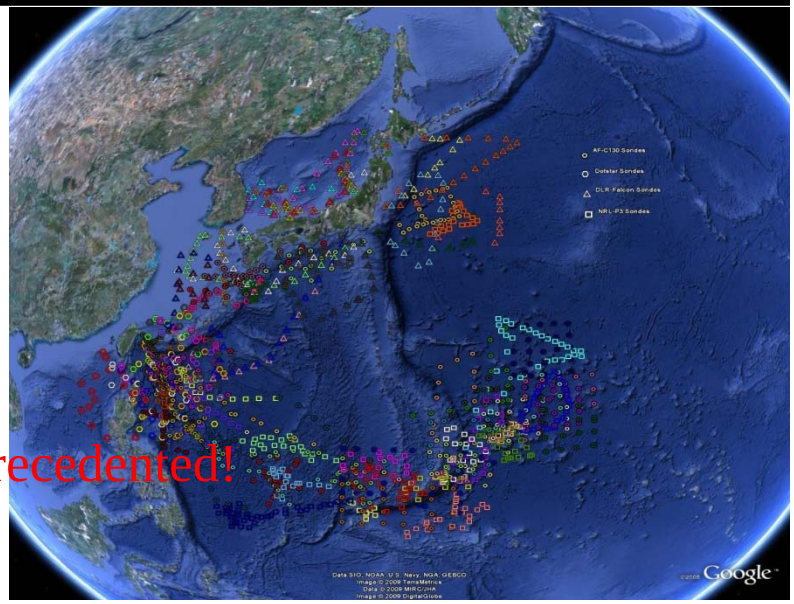
WMO THORPEX-PARC (2008)

T-PARC planning meeting, Japan, 2008

THORPEX
Pacific Asian Regional Campaign
ProbeX TCS-08 TH-08
DOTSTAR
T-PARC

Targeted Observations
Data Assimilation
and Tropical Cyclone Predictability

DOTSTAR

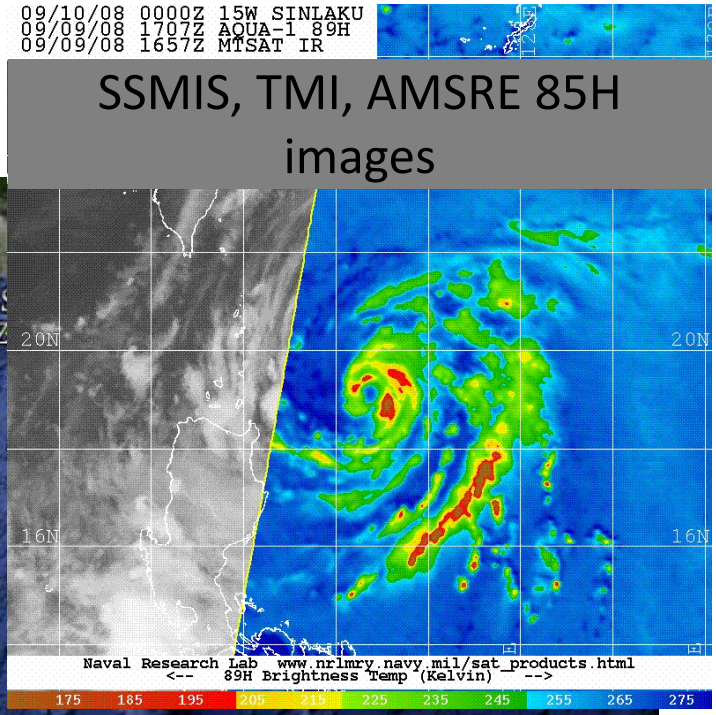


DOTSTAR + Falcon + P3 + C130,

52h + 85h + 165h + 215h = 507h flight hours, unprecedented!

173 + 328 + 604 + 343 = 1448 dropwindsondes

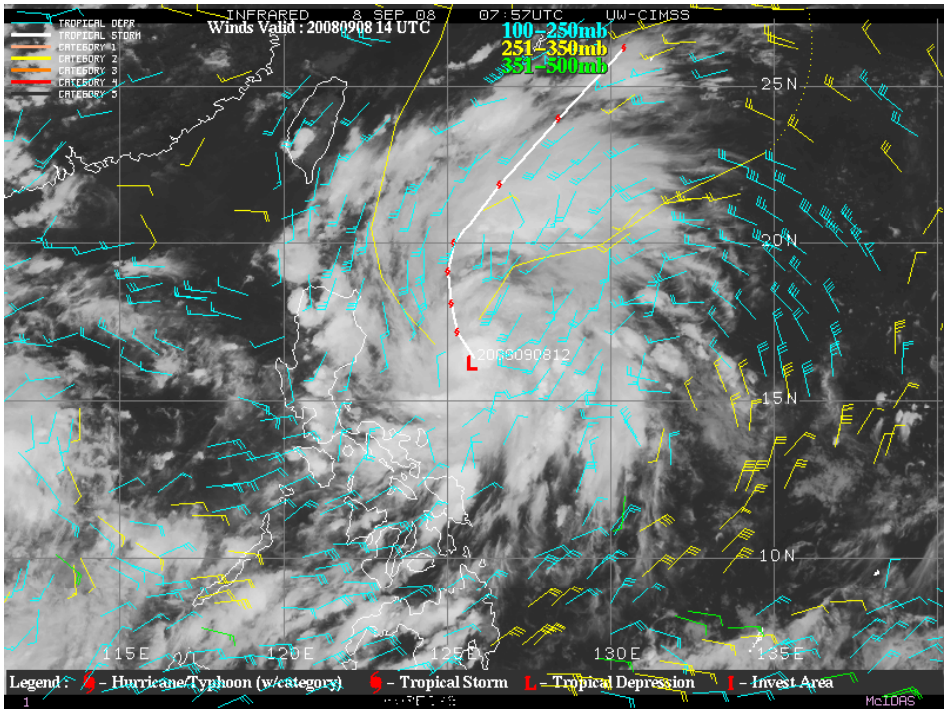
Typhoon Sinlaku (2008)



- The concentric eyewall structure can be clearly viewed from the satellite images at 0445Z , 0900Z, and 1134Z on September 11.
- When Sinlaku went through an eye wall replacement cycle on September 11, it started to weaken.
- The new primary eyewall formed at 2132Z 11 SEP.

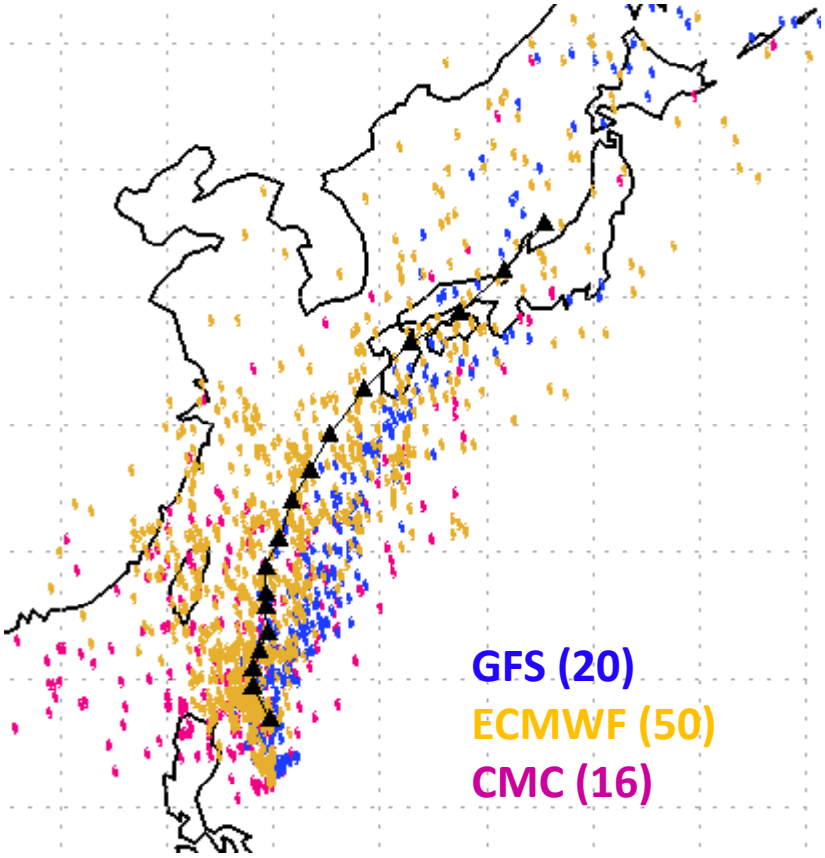
Sinlaku. Concept for Targeting Operations. 21 UTC, 20080908

Potential threat of TC to land

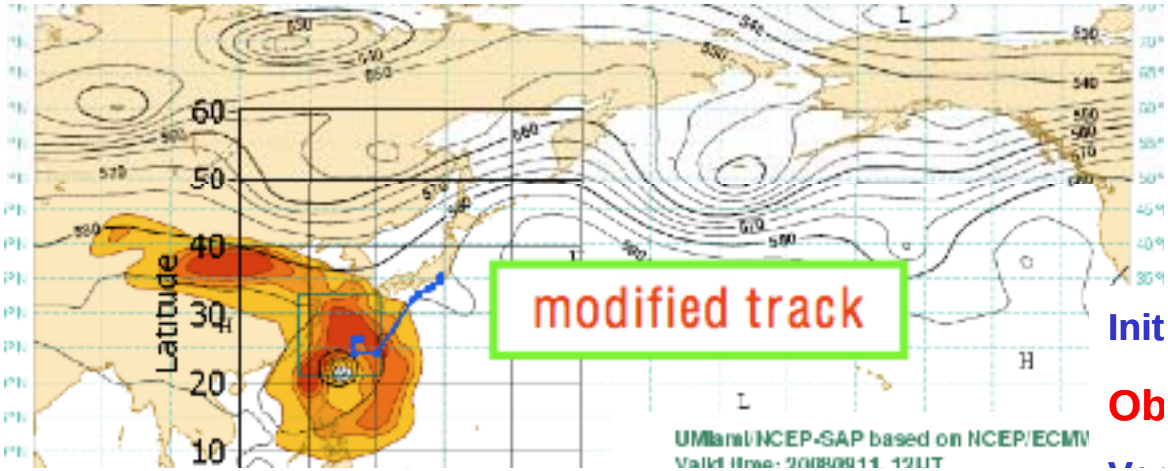


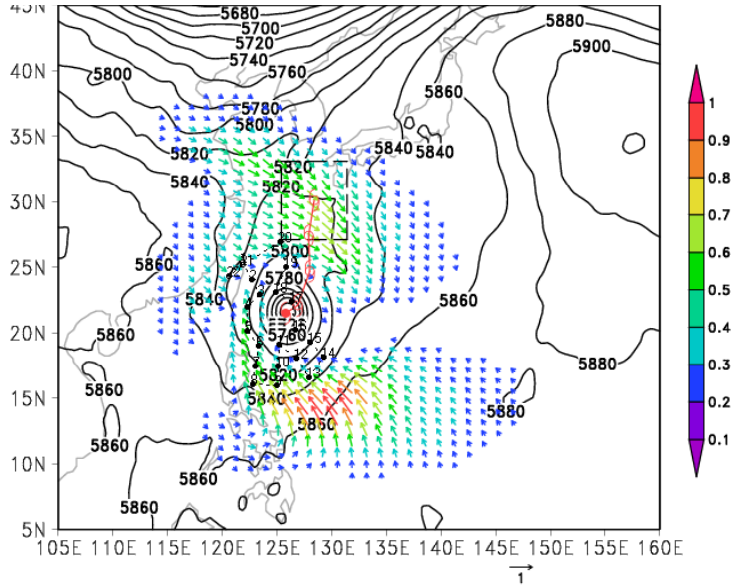
Courtesy CIMSS/U.Wisconsin

Uncertainty in ensemble track forecasts

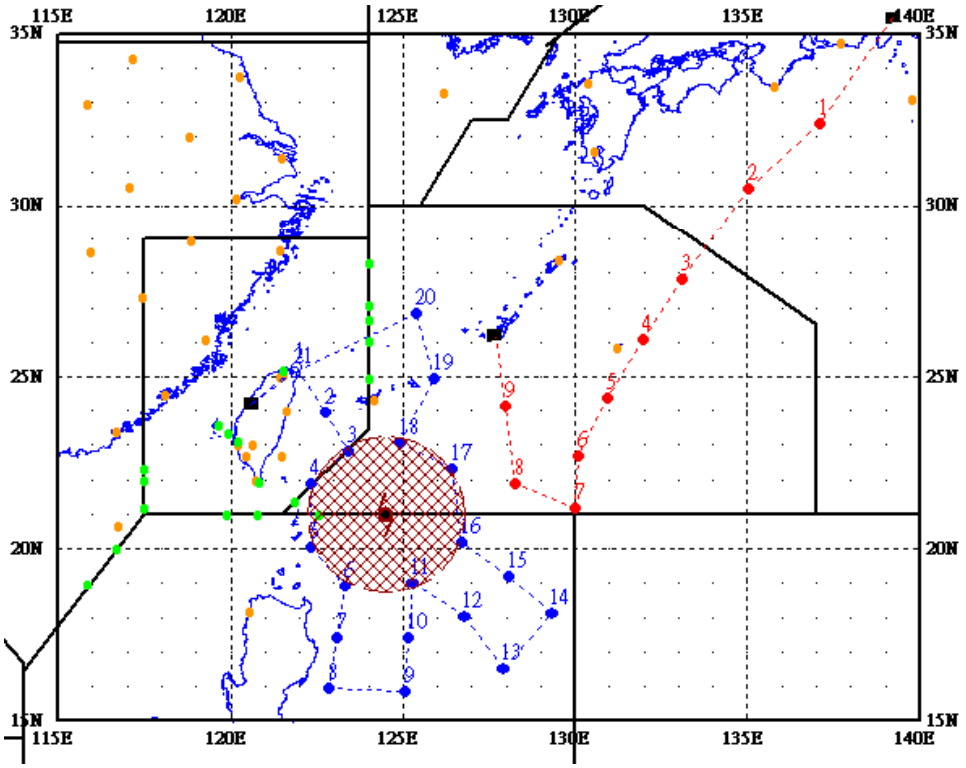


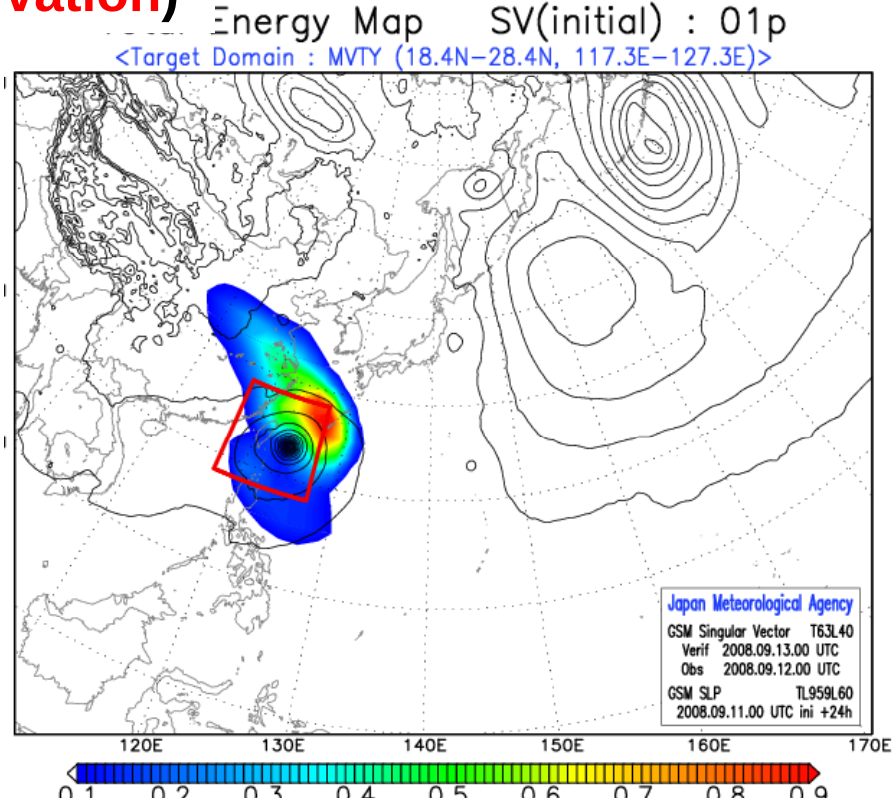
Uncertainty about strength of steering flow, and landfall location (if any)

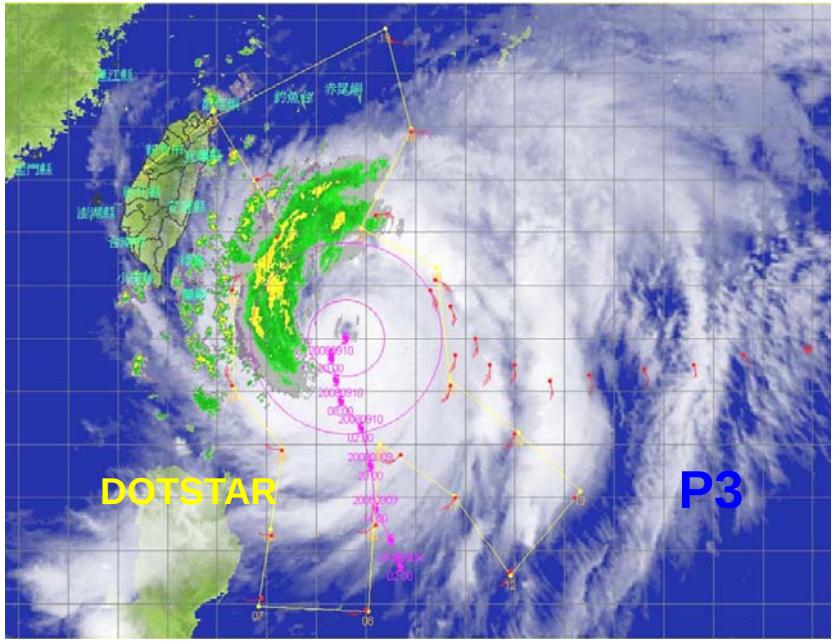




DOTSTAR Flight Plan (BLUE) and FALCON Flight Plan (1) (Red)
10-11 September 2008 (Targeted observation)



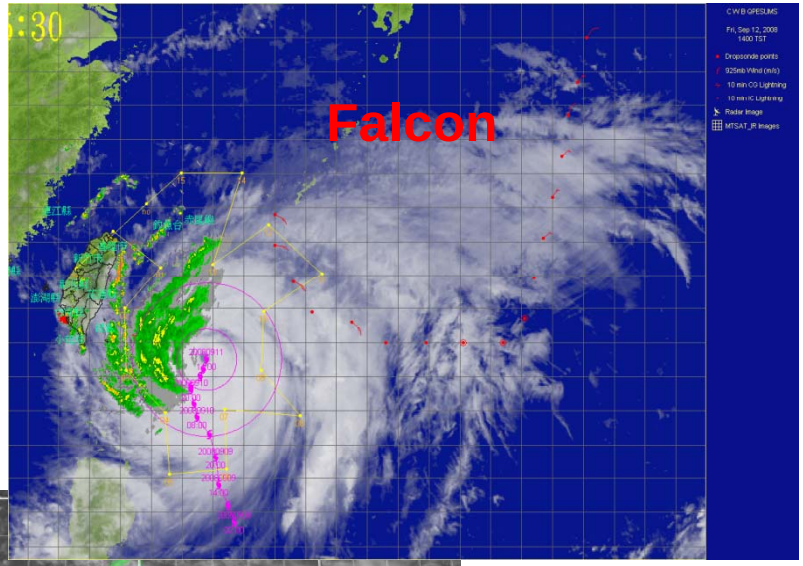




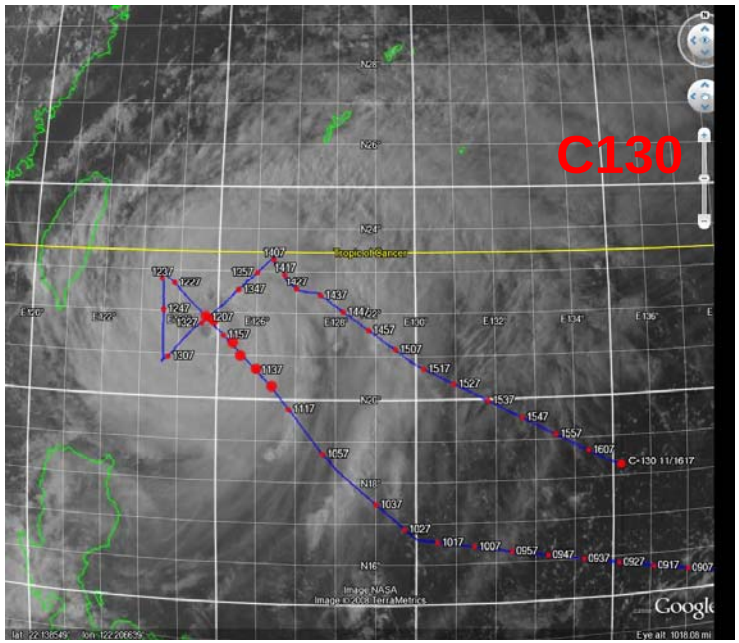
11 September, 2009, Typhoon Sinlaku

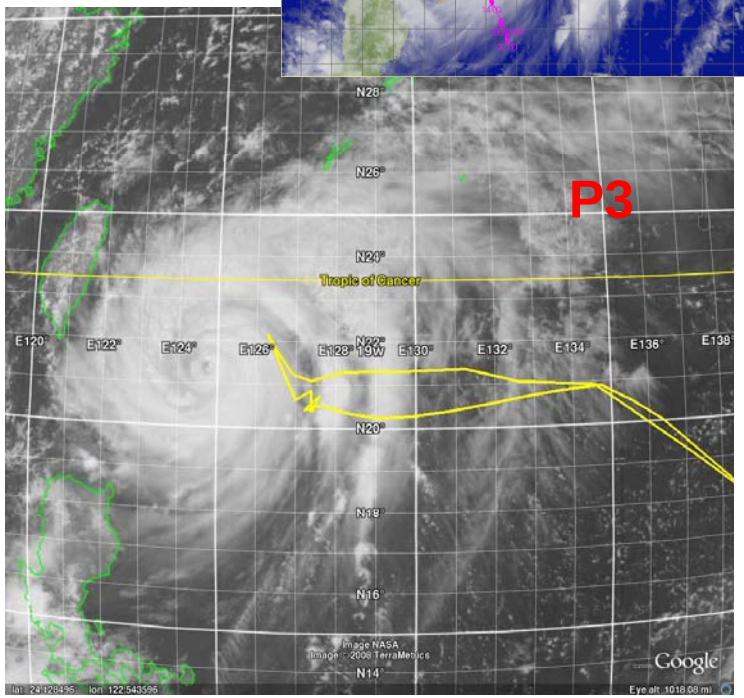
DOTSTAR + Falcon + P3 + C130 Flight tracks

T-PARC



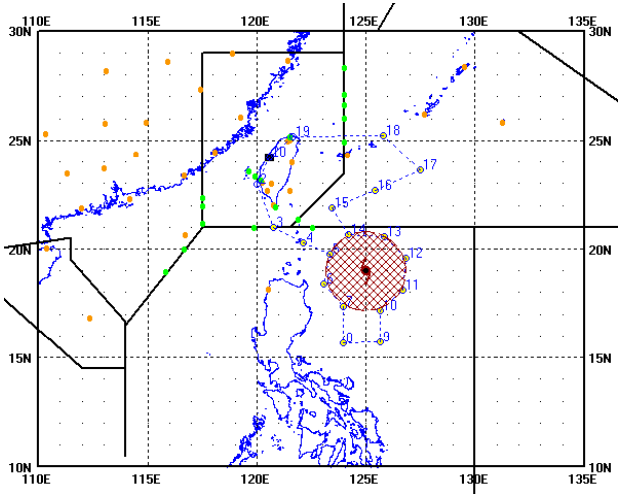
First time with four aircrafts observing typhoons over NW Pacific ocean

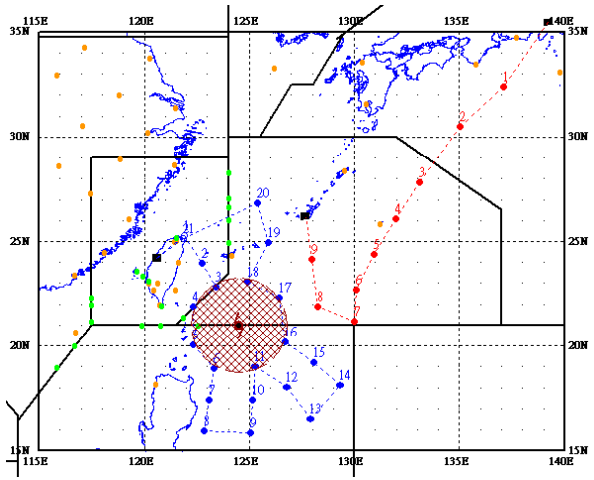




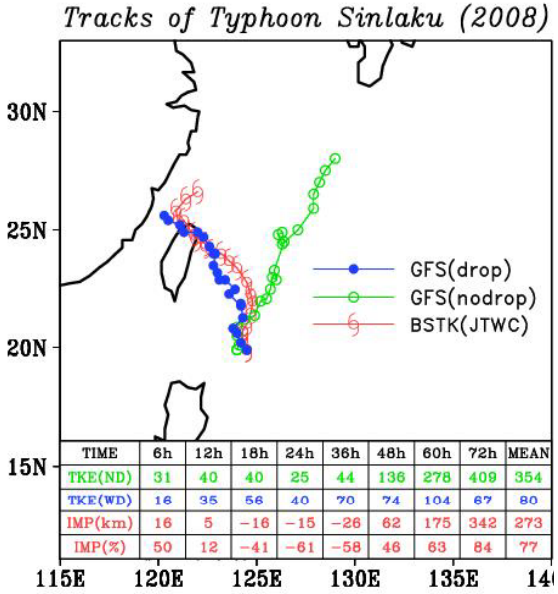
Impact of dropwindsondes to NCEP GFS forecasts of Sinlaku

00 UTC Sept. 10, 2008; 00 UTC Sept. 11, 2008

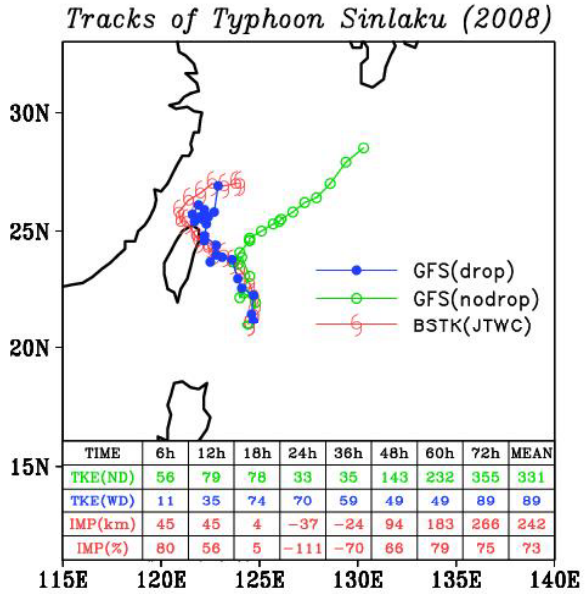




Degradation due to the inner-core dropsonde data (Aberson 2008)



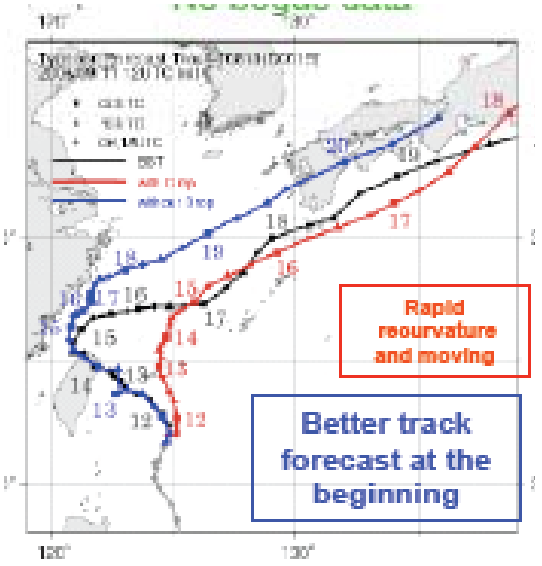
TIME	6h	12h	18h	24h	36h	48h	60h	72h	MEAN
TKE(ND)	31	40	40	25	44	136	278	409	354
TKE(WD)	16	35	56	40	70	74	104	67	80
IMP(km)	16	5	−16	−15	−26	62	175	342	273
IMP(%)	50	12	−41	−61	−58	46	63	84	77



TIME	6h	12h	18h	24h	36h	48h	60h	72h	MEAN
TKE(ND)	56	79	78	33	35	143	232	355	331
TKE(WD)	11	35	74	70	59	49	49	89	89
IMP(km)	45	45	4	−37	−24	94	183	266	242
IMP(%)	80	56	5	−111	−70	66	79	75	73

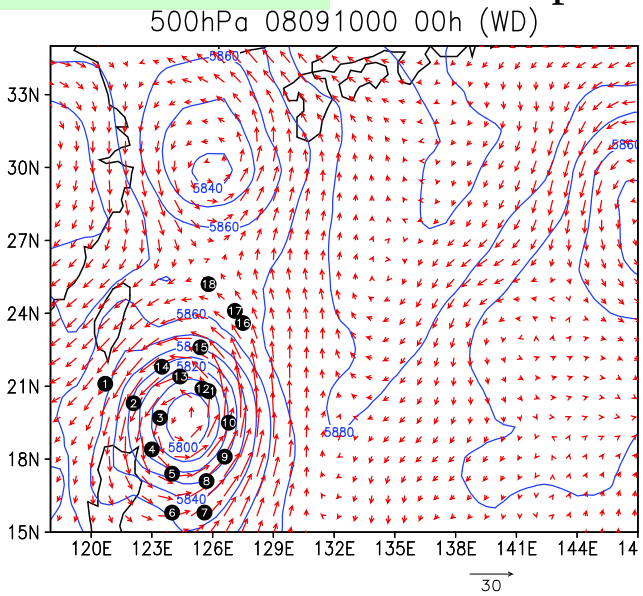
(Wu et al. 2009e)

12 UTC Sept. 11, 2008



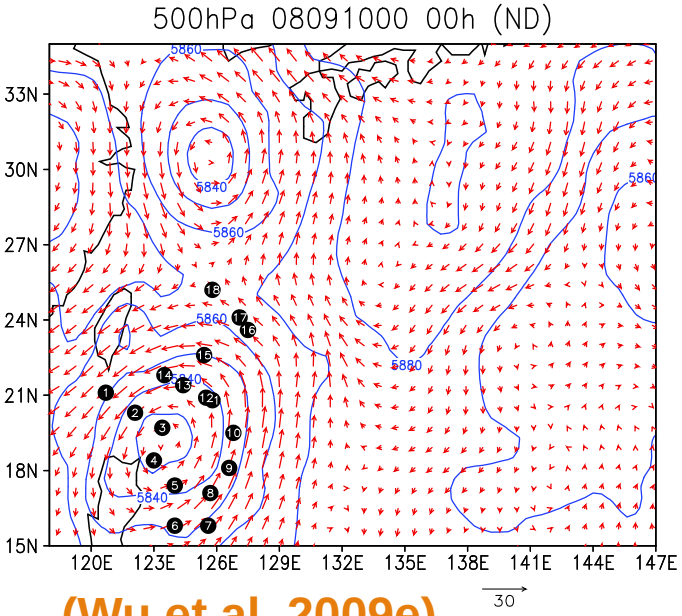
(JMA/GSM, from Nakazawa)

2008091000 with dropsondes

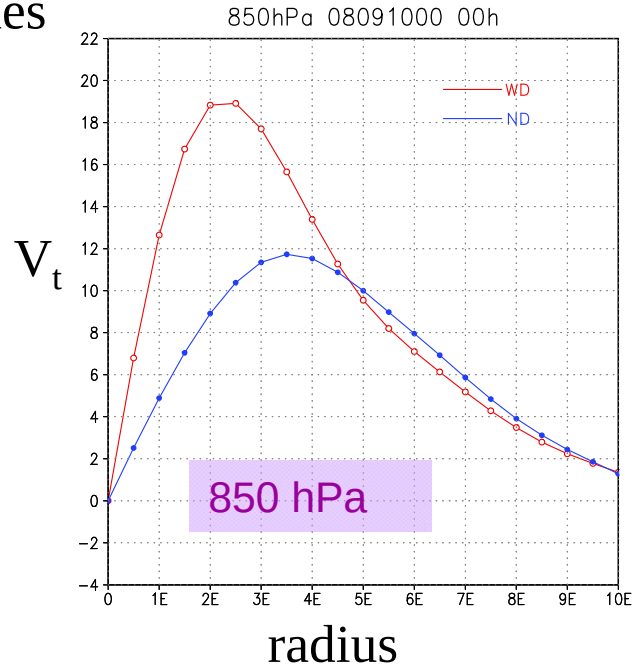


500 hPa

No-dropsondes



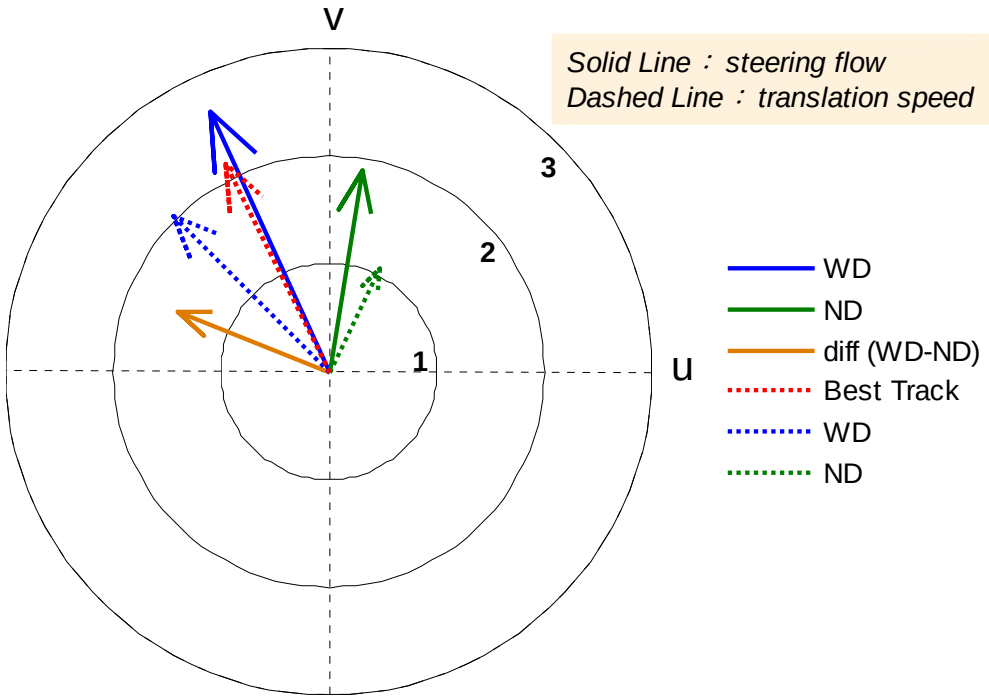
(Wu et al. 2009e)



V_t

Impact of dropwindsondes:

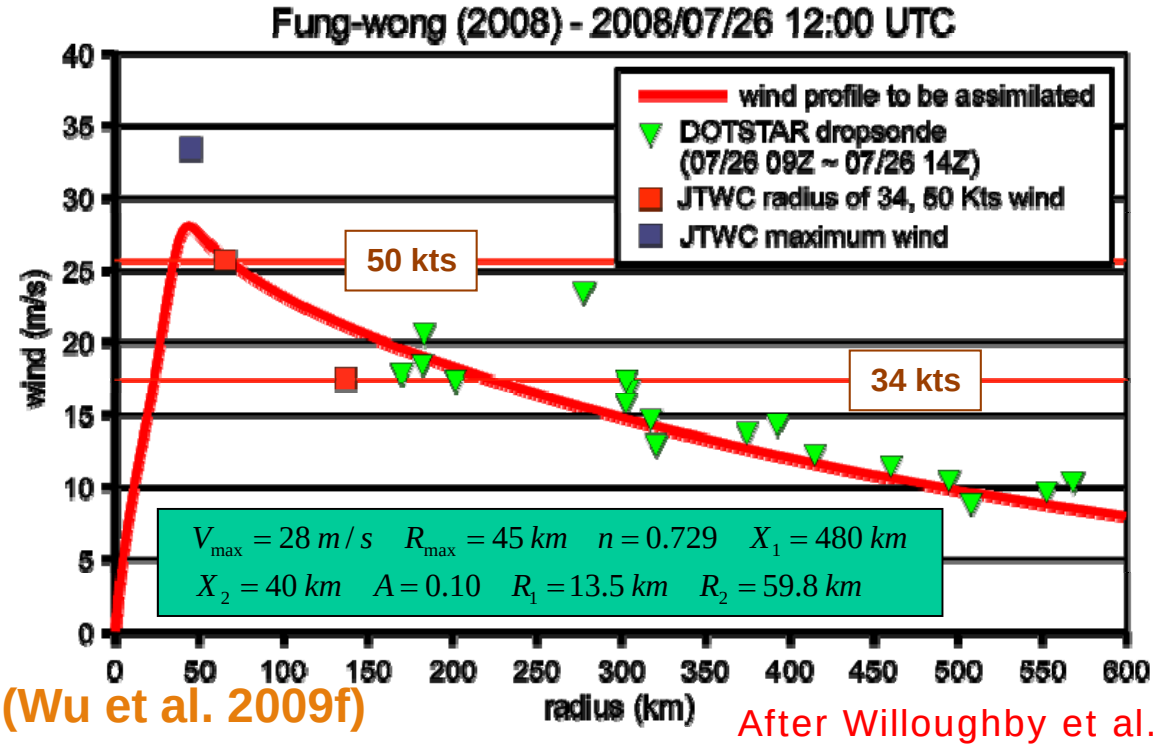
- Strengthened storm vortex
- Decreased RMW
- Strengthened subtropical ridge, enhancing northwestward steering flow



EnKF data assimilation

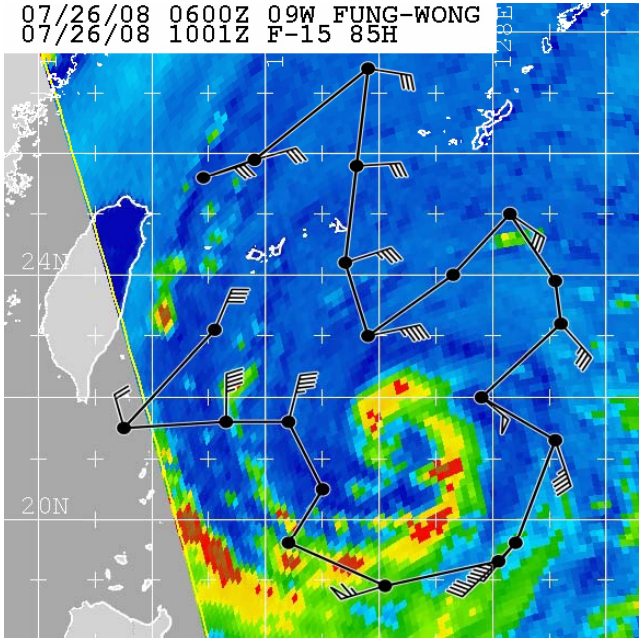
Observations: position, motion vector, axisymmetric structure

- 3 hour besttrack data, interpolated to 30 minutes interval by cubic-spline method.
- TC radius (34, 50 kts) data from JTWC.
- DOTSTAR (Wu et al. 2005, 2007) surface wind data (MBL150, Franklin 2003) on 26 July. 1200 UTC (final time of the initialization period).



(Wu et al. 2009f)

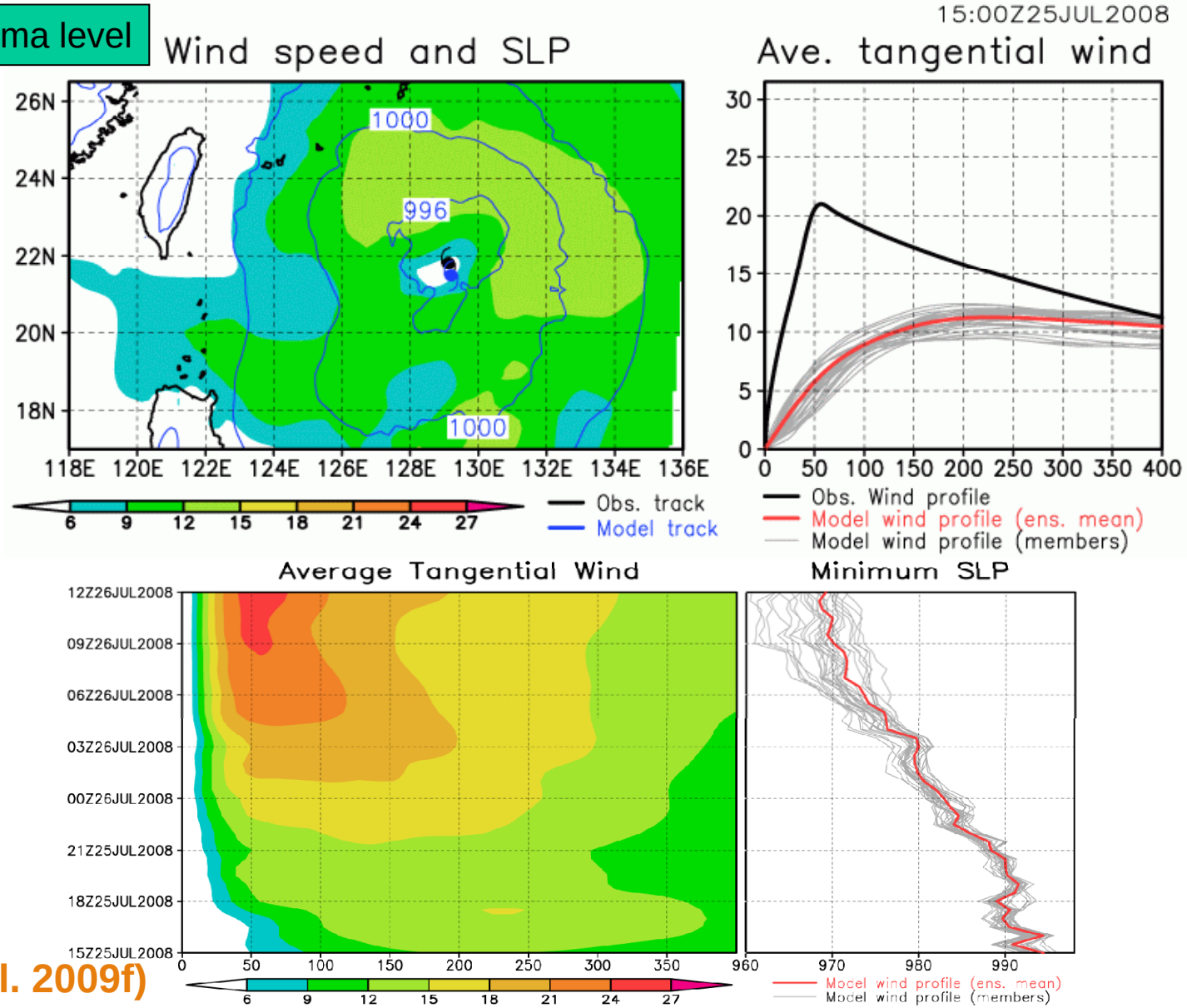
DOTSTAR flights



After Willoughby et al. (2006)

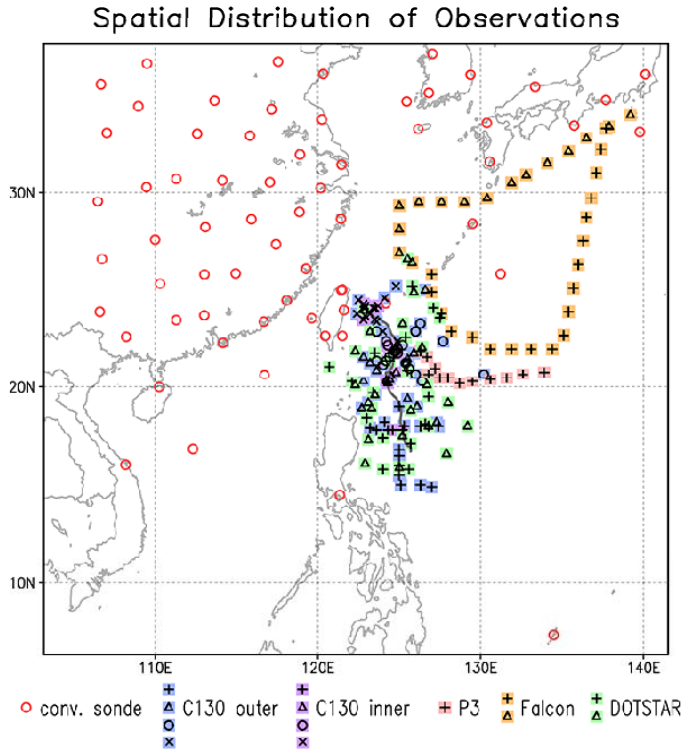
Experiment "TK-MS"

Lowest sigma level

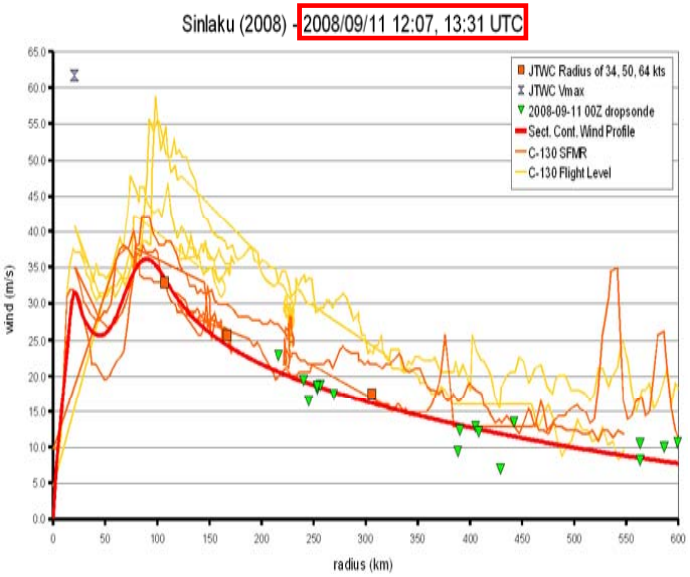


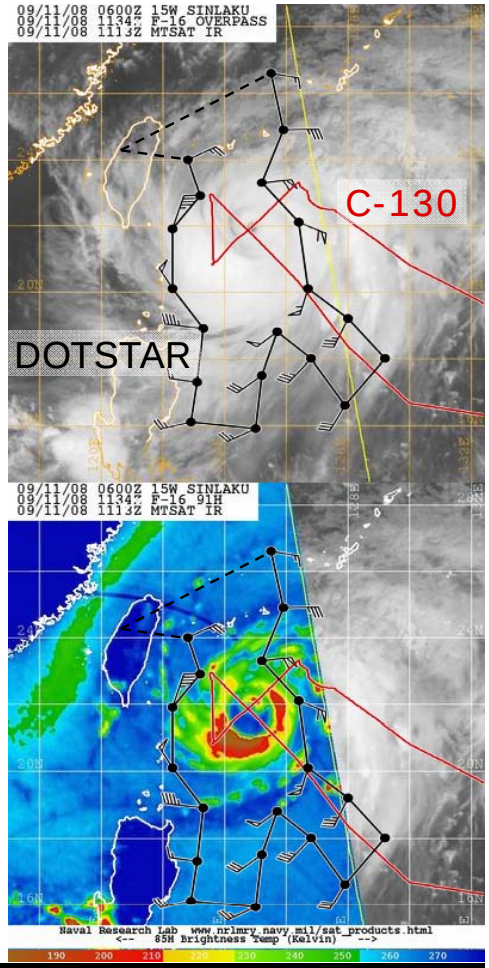
(Wu et al. 2009f)

Observations (2008/09/08 17:00 ~ 09/13 03:00 UTC)



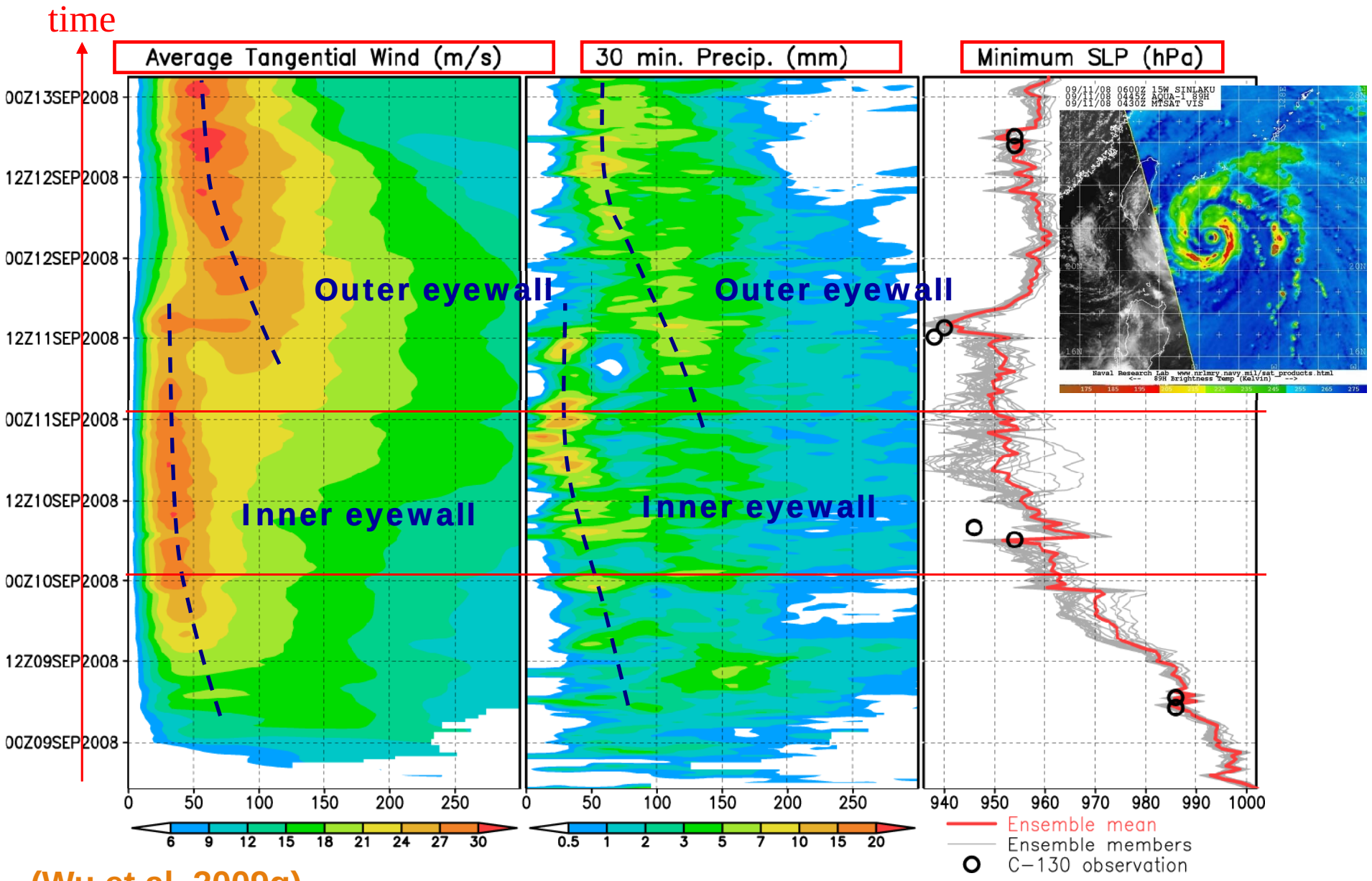
Axisymmetric tangential wind profile from 4 C-130 flights, DOTSTAR, and JTWC estimate.





	Conv. radiosonde	Dropwindsondes				
		DOTSTAR ASTRA	DLR Falcon	NRL P-3	USAF C-130	
					Inner core	Others
Total available (Wu et al. 2009g)	623	36 (2 flights)	34 (2 flight)	12 (1 flight)	20	57 (4 flights)

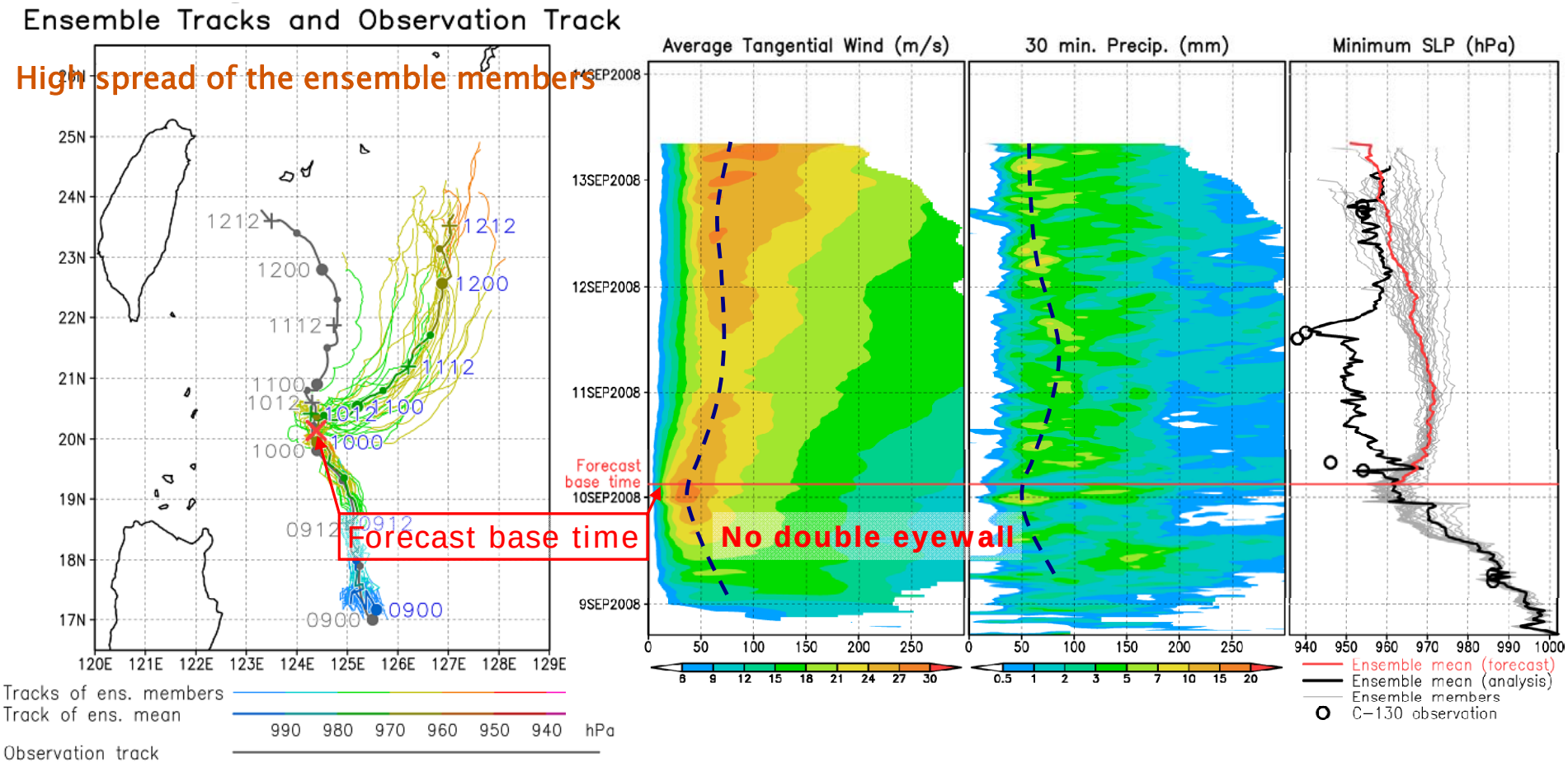
Experiment "TK-MS-TP-ALL"



(Wu et al. 2009g)

Forecast "TK-MS-TP-ALL" at 1003Z

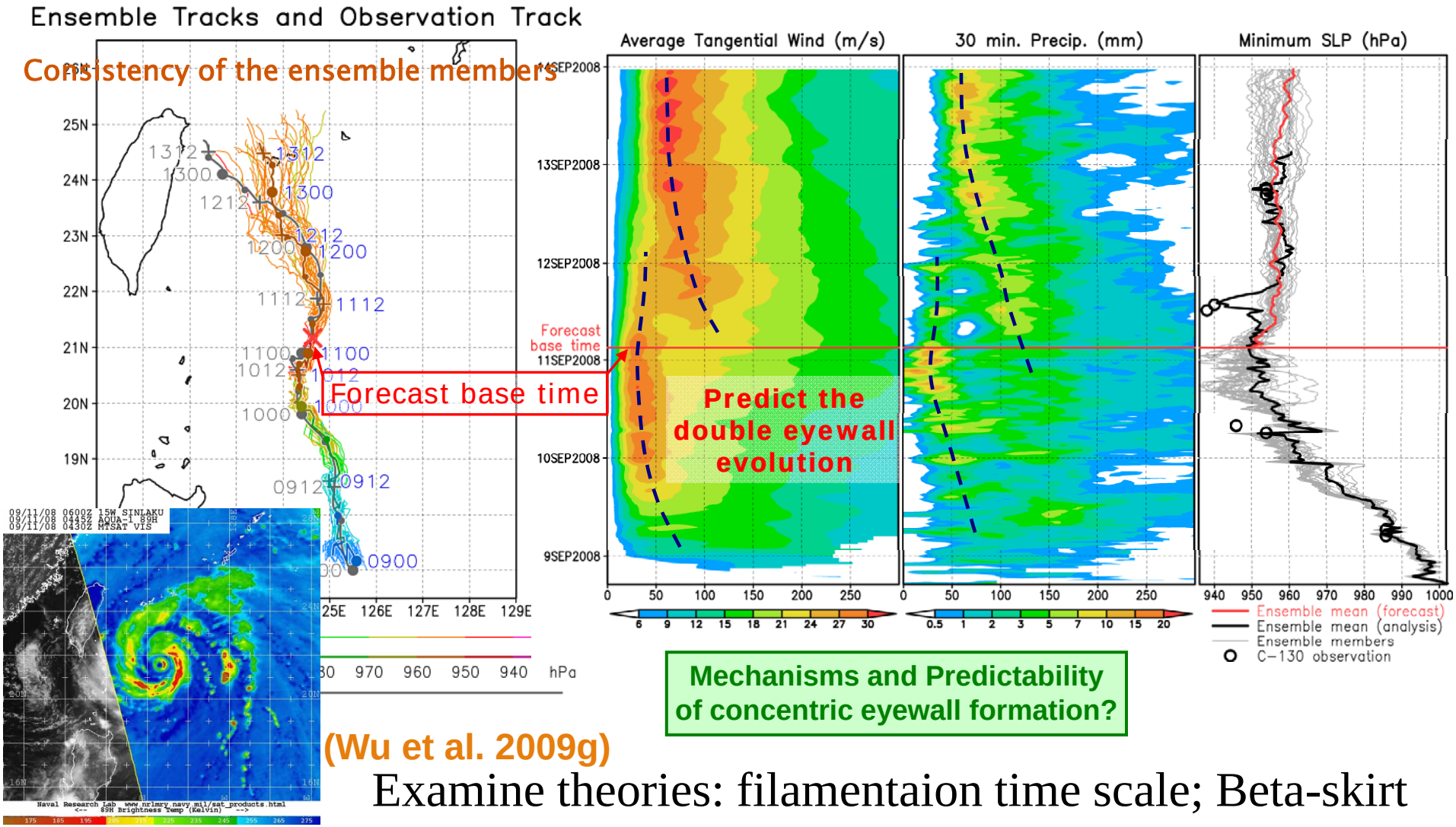
- Ensemble forecast started from 2008/09/10 03:00



(Wu et al. 2009g)

Forecast "TK-MS-TP-ALL" at 1103Z

- Ensemble forecast started from 2008/09/11 03:00 UTC.



Examine theories: filamentaion time scale; Beta-skirt

Future perspectives

- Validation and OSE studies: added value and data assimilation (cost-effective?)
- Understanding and physical interpretation of the structure of the targeted guidance products (ADSSV, SV, ETKF), along with the PV dynamics
- Targeted observations of other data (especially the satellite data: satellite thinning)
- EnKF data assimilation and dynamical analyses
- Intercomparison of targeted schemes - to gain more insights into the physics of targeted observations
- Intercomparison of the data impact to different model systems in T-PARC
- TCS-11 and ITOP

Internal wave and Typhoon-Ocean interaction Project in the Western North Pacific and Neighboring Seas (ITOP, 2010)

ITOP planning meeting, Taipei, 2008

- DOTSTAR, TCS-10, and ITOP coordination
- Investigation of the roles of upper ocean thermal structures (eddies and/or wakes) on typhoon-ocean interaction.
- Understanding the feedback of the typhoon-ocean interaction to typhoon intensity and structure evolution.
- Numerical simulation experiments (WRF-PWP coupled model) with the T-PARC (and TCS-10) and ITOP data.