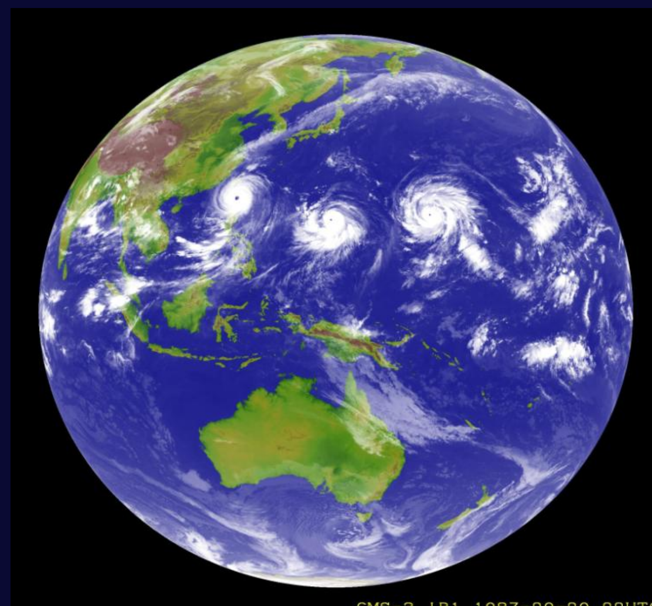
风云四号卫星资料用户培训班
2016年11月6-8日，北京

风云四号台风监测应用思路介绍



许映龙
国家气象中心
2016年11月7日

中国气象局
国家气象中心
NATIONAL METEOROLOGICAL CENTER OF CMA

主要内容

- 卫星监测台风的基本思路
- 卫星监测台风的重要性
- 国内外基于卫星的台风监测分析技术进展
- 风云四号卫星台风监测的应用思路
- 可能存在的主要困难

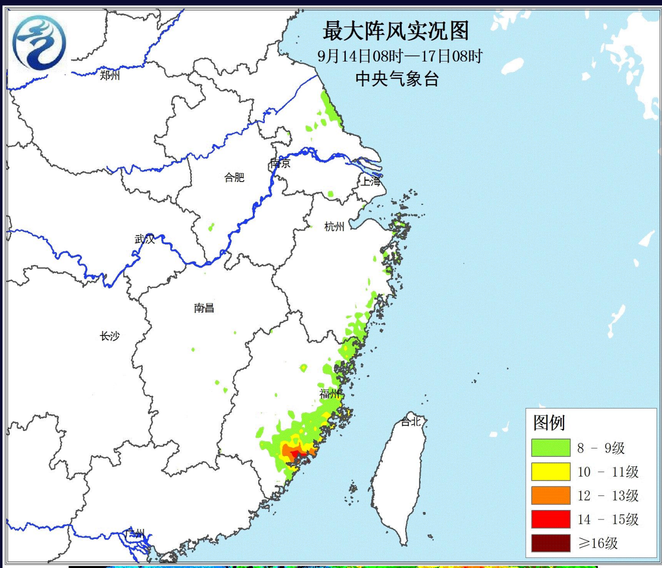
台风监测分析业务卫星应用的基本思路

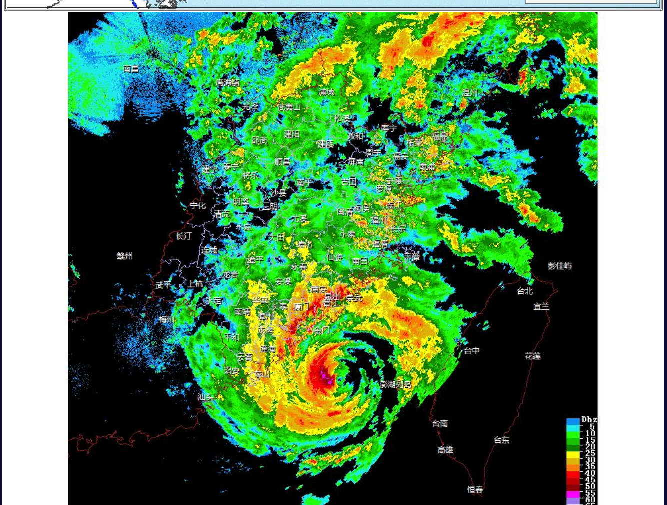
进一步强化台风监测分析业务的技术支撑，发展卫星监测客观定量分析方法

- ✓ 台风强度估计
- ✓ 台风中心位置确定
- ✓ 台风风雨精细信息的获取
- ✓ 台风环境诊断产品
- ✓ 多通道资料的融合应用
- ✓ 海上风场反演产品

卫星监测台风的重要性

- 1614号台风“莫兰蒂”登陆前强度确定





✓ 登陆时间：9月15日3时05分

✓ 登陆强度：48米/秒（15级）

✓ 观测最大风速：51.0米/秒（15级，2分钟平均）

15日2时55分，五缘大桥

49.8米/秒 （15级，10分钟平均）

15日3时01分，五缘大桥

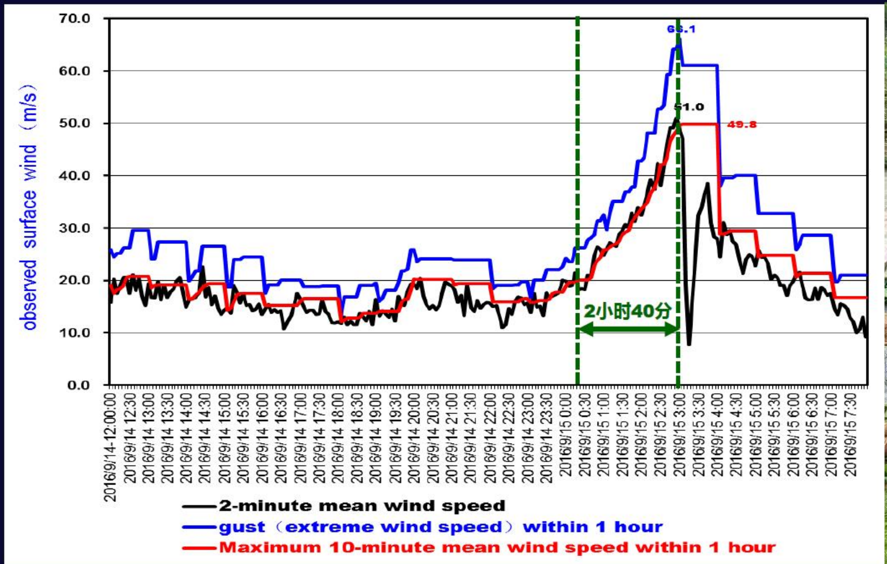
✓ 9月15日02时强度确定

- CMA：50米/秒（15级）
- JMA：42米/秒（14级）
- JTWC：45米/秒（14级）
- HKO：45米/秒（14级）
- CWB：40米/秒（13级）

台风强度确定

- **地面观测 --- 直接观测，最为精确的观测手段**
  - ✓ 海洋资料稀缺
  - ✓ 地面自动站、海岛站、浮标、石油平台、船舶等
  - ✓ 台风临近登陆（登陆前几小时或更短）

1614号台风“莫兰蒂”影响期间
厦门五缘大桥地面风速观测变化曲线
（2016年9月14日12时至15日07时55分）

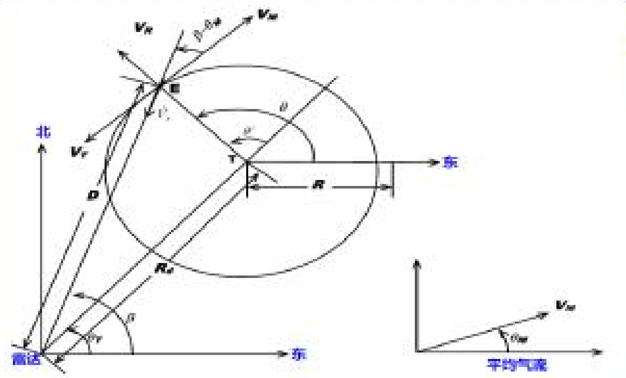


1614号台风“莫兰蒂”
影响期间厦门灾情

台风强度确定

● 雷达观测 --- 遥感观测

- ✓ 多普勒雷达径向速度
- ✓ 台风临近登陆（有效距离150公里以内）



台风环流的切向速度分量(V_T)和径向速度分量(V_R)、环境平均气流(V_M)与多普勒雷达径向速度分量(V_r)的几何关系

假设台风环流最大切向速度 $V_{T\max}$ 远大于其最大径向速度 $V_{R\max}$，可以用台风环流的最大切向速度 $V_{T\max}$ 来近似表示台风的强度。

由下式求出 $\hat{V}_r*D/R_d$ 的极小值和极大值(-A+B) 和(A+B)，计算得到A、B的值

$$\hat{V}_r*D(R,\theta')=R_d[-A\sin(\theta'-\theta_c)+B]$$

$$(\hat{V}_r*D/R_d)_{\min}=-A+B \qquad (\hat{V}_r*D/R_d)_{\max}=A+B$$

$$A=\frac{(\hat{V}_r*D/R_d)_{\max}-(\hat{V}_r*D/R_d)_{\min}}{2} \qquad B=\frac{(\hat{V}_r*D/R_d)_{\max}+(\hat{V}_r*D/R_d)_{\min}}{2}$$

若平均环境风速和风向为已知，可估计最大风速半径上的主环流速度 $V_{T\max}$

$$A=\sqrt{(V_T+\frac{R}{R_d}V_M\sin(\theta_T-\theta_M))^2+(V_R+\frac{R}{R_d}V_M\cos(\theta_T-\theta_M))^2} \qquad \text{(a)}$$

$$B=\frac{R}{R_d}V_R+V_M\cos(\theta_T-\theta_M) \qquad \text{(b)}$$

A、B代入(a)和(b)式，得到台风环流的最大切向速度 $V_{T\max}$ 和最大径向速度 $V_{R\max}$

$$V_{R\max}=\frac{R_d}{R_m}[B-V_M\cos(\theta_T-\theta_M)] \qquad V_{T\max}=-\frac{R_m}{R_d}V_M\sin(\theta_T-\theta_M)\pm\sqrt{A^2-\left[V_R+(\frac{R_m}{R_d}V_M\cos(\theta_T-\theta_M))\right]^2}$$

多普勒雷达径向速度与台风强度的关系

理想试验

表 1　模拟测试强度估计误差分析表（单位：米/秒）

项目	$V_{R\max}$ (m/s)	$V_{T\max}$ (m/s)	$\Delta V_T=V_{T\max}-V_{T_0\max}$ (m/s)
V_M=0m/s	0.000000E+00	39.596450	4.035454E-01
V_M=10m/s（西风）	-1.619711E-02	40.378020	-3.780212E-01
V_M=10m/s（东风）	5.508082E-02	39.537100	4.629021E-01
V_M=10m/s（东南风）	-2.272842E-06	39.594010	4.059868E-01
V_M=10m/s（西南风）	-1.801127	39.530980	4.690208E-01

0116号台风百合

表 2　实际测试的台风强度估计误差(m/s)

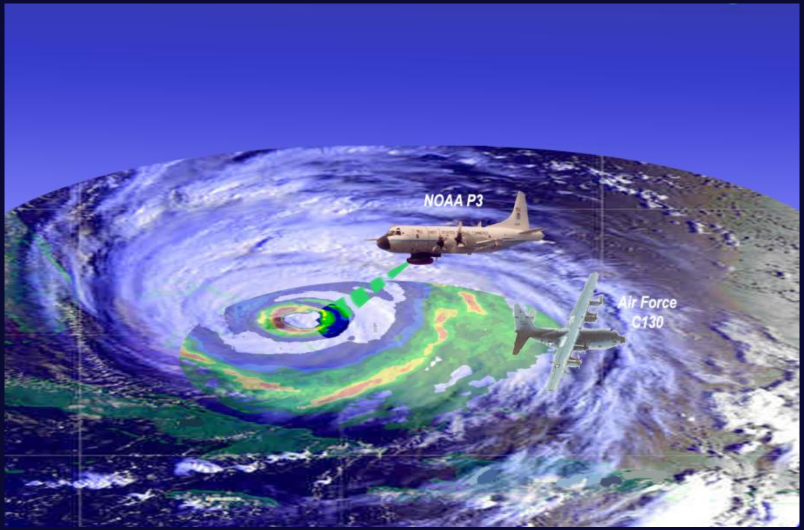
时间（北京时）	实际极端负径向速度	实际极端正径向速度	平均极端径向速度	估计强度	中央台定位	日本定位	美国定位	台湾定位
08 时	-47.41	39.93	43.67	42.76	40	39	46	33
09 时	-48.41	41.92	45.17	44.69				
10 时	-46.91	40.92	43.92	42.05				
11 时	-50.90	42.92	46.91	45.51	40	39		38
12 时	-47.91	41.92	44.92	41.64				
13 时	-44.92	46.92	45.92	46.22				
14 时	-47.91	42.92	45.42	43.49	40	39	46	40
15 时	-55.90	41.92	48.91	46.48				
16 时	-49.90	47.92	48.91	55.02				
17 时	-49.90	45.92	47.91	49.08	40	39		40
18 时	-55.90	44.92	50.41	47.41				
19 时	-59.90	47.92	53.91	48.12				
20 时	-58.90	55.92	57.41	53.57	40	33	44	40
21 时	-53.90	50.92	52.41	38.47				

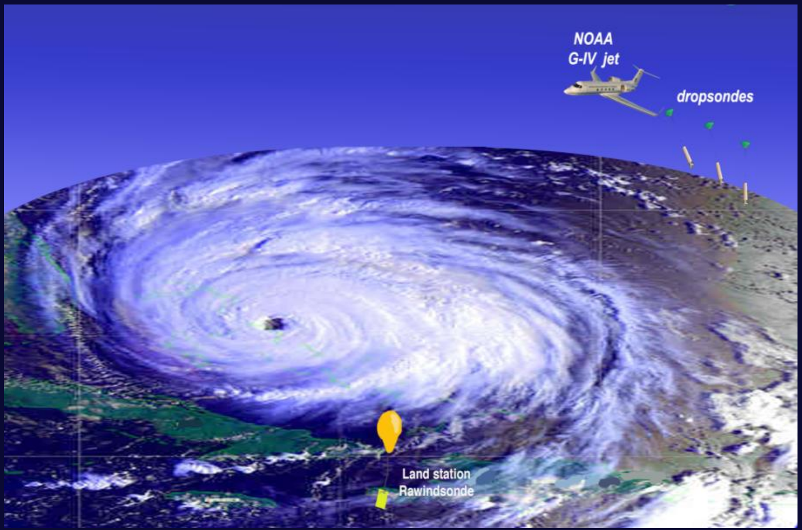
台风强度确定

- **飞机观测（Aerial reconnaissance）**

A typical reconnaissance mission

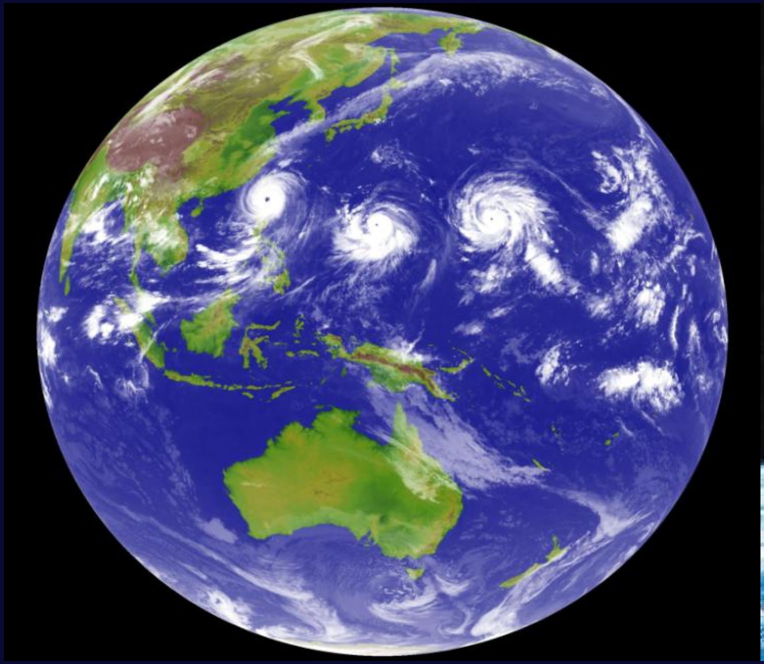
- ✓ 10,000 ft （700hPa） for hurricanes
- ✓ 5,000 ft （850hPa） for tropical storms
- ✓ 1,500 ft （457m） for pre-TC disturbances
- ✓ last from 10 to 12 hours
- ✓ a figure four or "alpha" pattern
- ✓ two to six center fixes possible.





台风强度确定

- **卫星观测 --- 遥感观测，最主要的观测手段**
  - ✓ 极轨气象卫星（探测时间有限、分辨率低）
  - ✓ 静止气象卫星（全天候）



地面观测系统的局限性 --- 及时预警的重要性（有效性）

东方之星沉船事件

World Meteorological Organization
Weather • Climate • Water

《Global Guide to Tropical Cyclone Forecasting》

- ✓ An observed coastal, island, buoy or ship wind is often interpreted as the **"'maximum' maximum"** wind at that distance from the center (e.g.,radius of maximum wind, or radius of 15 ms-1 wind). However, it should be interpreted as the **"minimum maximum" wind**. Why? Because there is very little chance that the sampled wind is located exactly at the point of the peak wind at that distance.
- ✓ Satellite techniques are now more accurate and render other techniques obsolete.
- ✓ Techniques for operationally combining and weighting various types of data are covered by Powell.

World Meteorological Organization
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- 第一届热带气旋卫星分析国际研讨会（IWSATC-1）

The first WMO International Workshop on Satellite Analysis of Tropical Cyclones（IWSATC-1）, Honolulu, Hawaii, USA, 13 to 16 April 2011

- 第八届国际热带气旋科学研讨会（IWTC-8）

The 8th WMO International Workshop on Tropical Cyclones （IWTC-8）, Jeju, Republic of Korea, 2-10 December 2014

- 第二届热带气旋卫星分析国际研讨会（IWSATC-2）

The Second WMO International Workshop on Satellite Analysis of Tropical Cyclones（IWSATC-2）, Honolulu, Hawaii, USA, 16-19 February 2016

IWSATC-1

IWTC-8

World Meteorological Organization
Weather • Climate • Water

Recommendations and Steps since the first WMO International Workshop on Satellite Analyses of Tropical Cyclones (IWSATC) in 2011 (Velden et. al 2012)

- Sharing of agency knowledge and techniques
- Highlighted similarities and differences in the methodologies especially in the application of the Dvorak technique
- CMA: Simplified Dvorak =>change to Dvorak（1984）in 2012
- JMA: 'Koba' Dvorak scale
- IMD: generally consider EIR Dvorak estimates too high for the North of Indian Ocean (NIO)
- Many agencies : adjustments to weakening rates
  allowed intensity rate rule
- A set of recommendations to start down a path towards a global congruence on intensity estimation procedures
- Dvorak (1984) should be the main technique in the global basins

国内外基于卫星的台风监测分析技术进展

● 台风业务定强的世界通用技术标准 --- Dvorak分析技术

✓ 一种利用卫星红外云图和可见光云图估计台风强度的统计方法

✓ 基于台风对流云型和一系列规则对强度估计（**measurement** ）

弯曲云带型

切变型

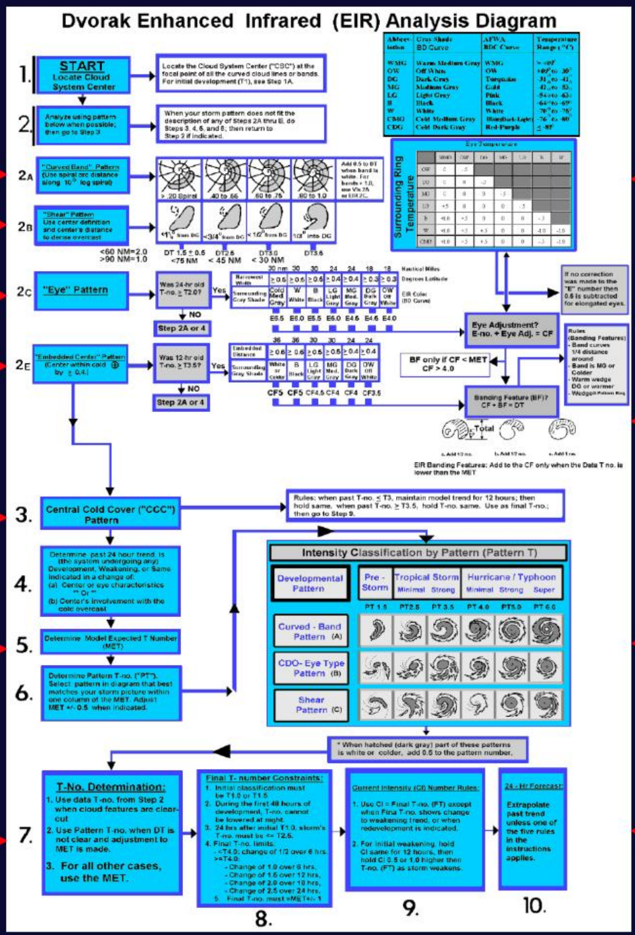
眼型

嵌入中心型

中心冷云盖型

过去24小时强度变化趋势

最终强度指数限定规则



Dvorak分析技术流程图

眼调整规则

带状特征调整规则

云型识别

现时强度指数限定规则

Dvorak分析技术的理论基础

Dvorak包含了台风强度发展的环境动力和热力因子

✓ **动力因子**

（1）云带弯曲程度反映了台风涡度的大小

（2）深对流偏离低层环流中心距离反映了高低空环境风切变的大小及其影响

✓ **热力因子**

（1）不同云型分类反映了对流发展的强度

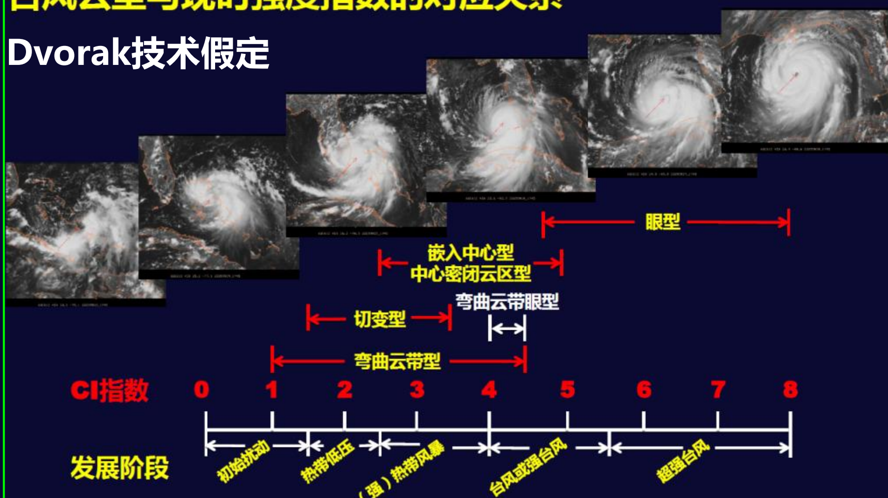
（2）台风眼区温度反映了台风内核的强度

● 什么是Dvorak技术

- ✓ **Dvorak技术假定（Premise）**
  - **台风强度发展的特定阶段与台风特定的云型特征存在对应关系**
- ✓ **利用卫星图像来估计台风强度的统计方法；**
- ✓ **使用资料：红外云图和可见光云图；**
- ✓ **基于云型和一系列规则估计台风强度；**
- ✓ **全球确定台风强度的通用方法；**
- ✓ **台风现场观测的一种替代手段；**
- ✓ **不是对风场、气压等气象要素的直接观测。**

台风云型与现时强度指数的对应关系

Dvorak技术假定



● Dvorak技术发展历程

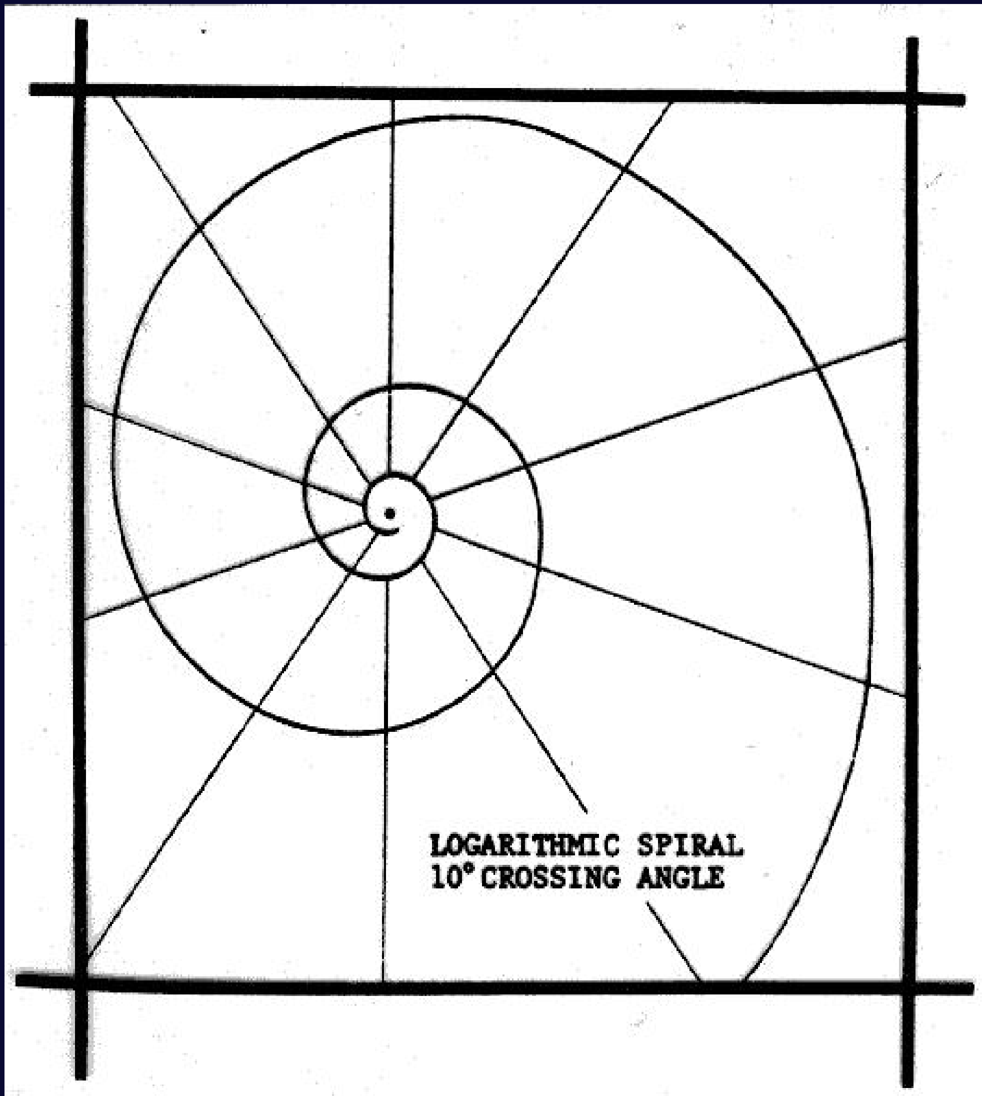
- ✓ **初始版本（1975年）**
- ✓ **中央气象台简化版本（1980年）**
- ✓ **最终版本（1984年）**
  - 从云型结构匹配和简单的发展和衰减模型转为注重分析台风云系统本身特征；
  - 台风的弯曲云带特征；
  - 低层环流中心偏离主体对流的距离；
  - 中心密闭云区的大小和云顶温度；
  - 眼区与其周围眼墙之间红外温差；
  - **全球台风强度估计标准（WMO,1987年）**
- ✓ **细化版本（1995年）**
  - 细化了台风发展和消亡阶段最终强度指数确定的约束规则
- ✓ **客观自动分析版本（1995年以后）**

台风业务定强的规范化培训

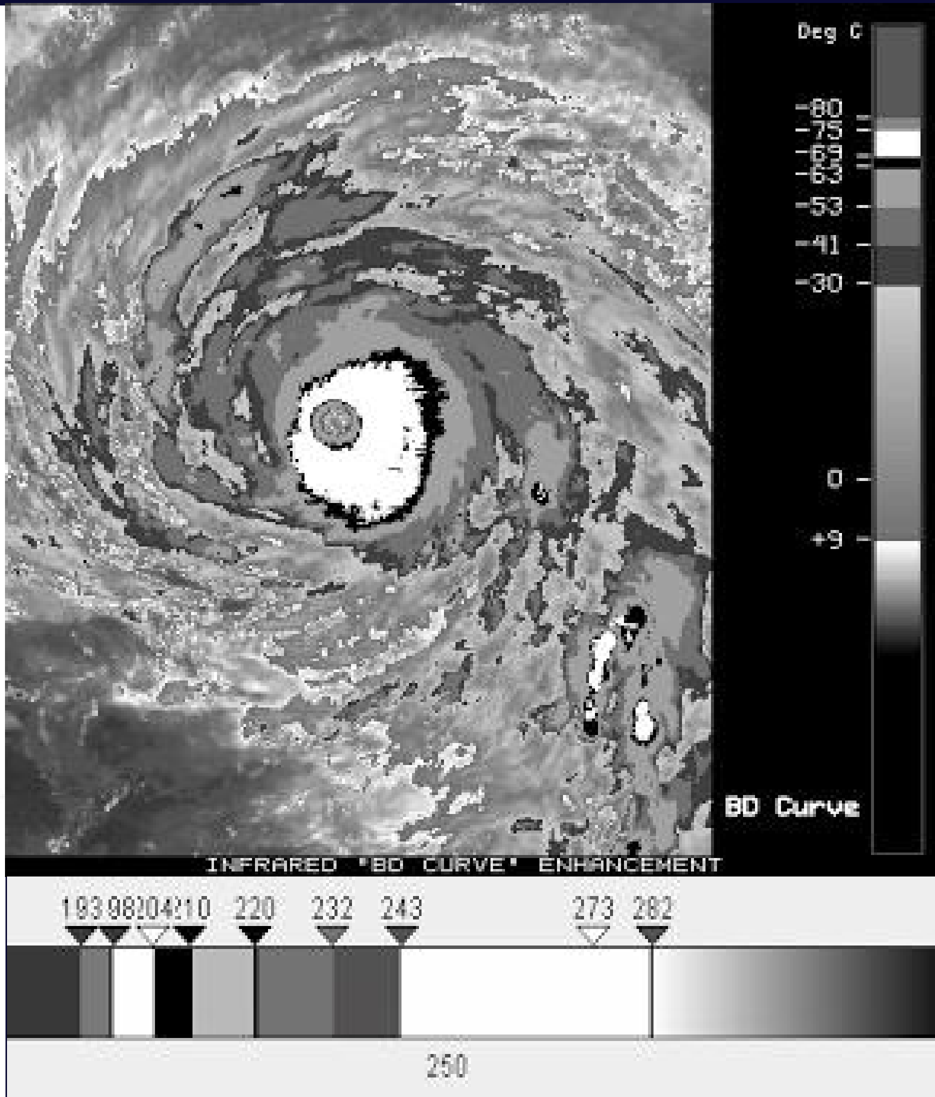
- **培训内容**
  - --- 台风定位流程及规范
  - --- 台风Dvorak定强技术流程
- **培训老师**
  - --- 香港天文台陈世倜
    (2012年2月22日至29日)
  - --- 美国关岛大学Mark Lander博士
    (2013年8月5日至16日)
- **参加人员**
  - --- 台风与海洋气象预报中心
  - --- 国家卫星气象中心
  - --- 上海台风研究所

Dvorak分析工具

10°的对数螺旋线板



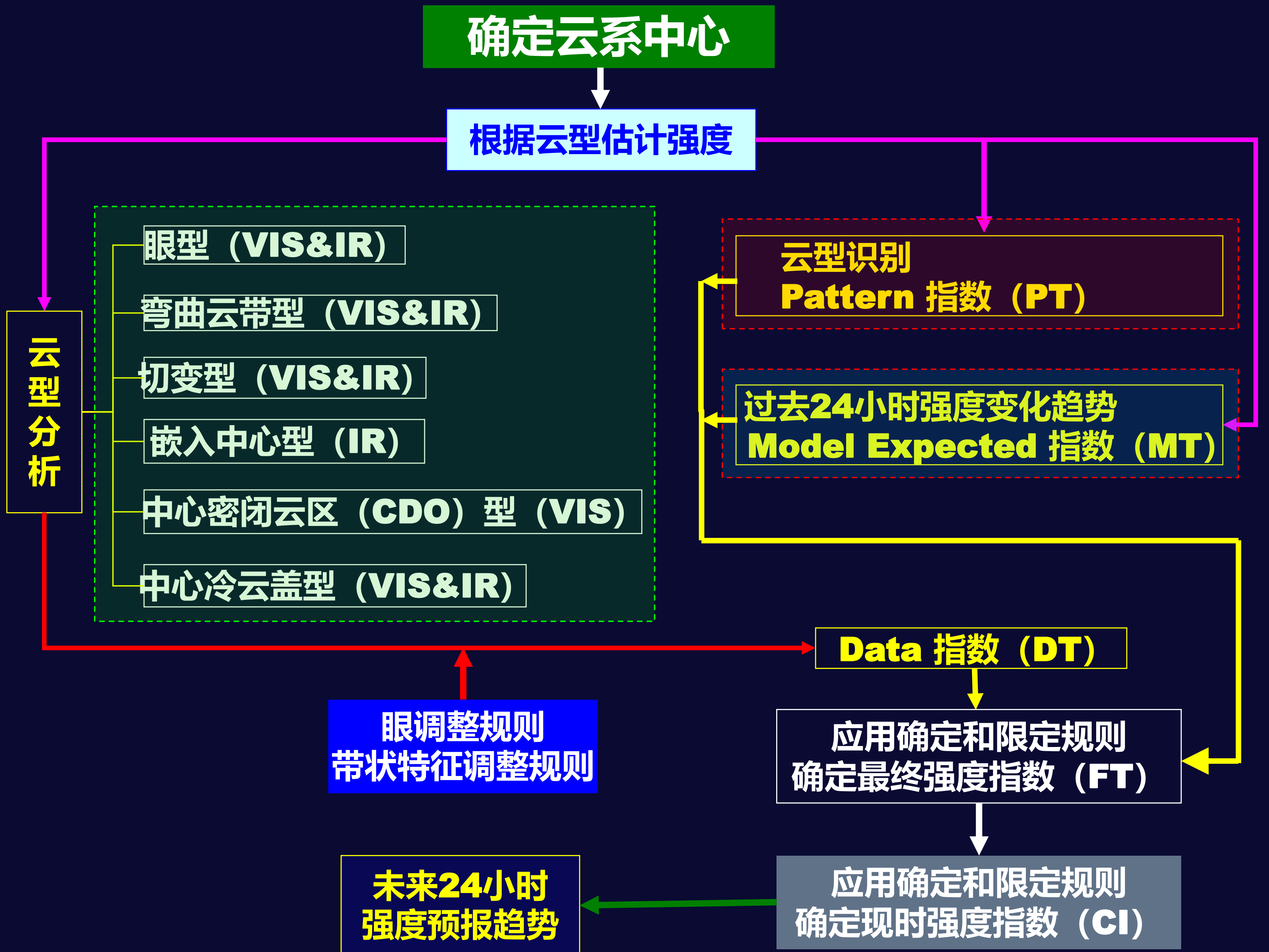
BD增强显示红外云图



Dvorak分析工具

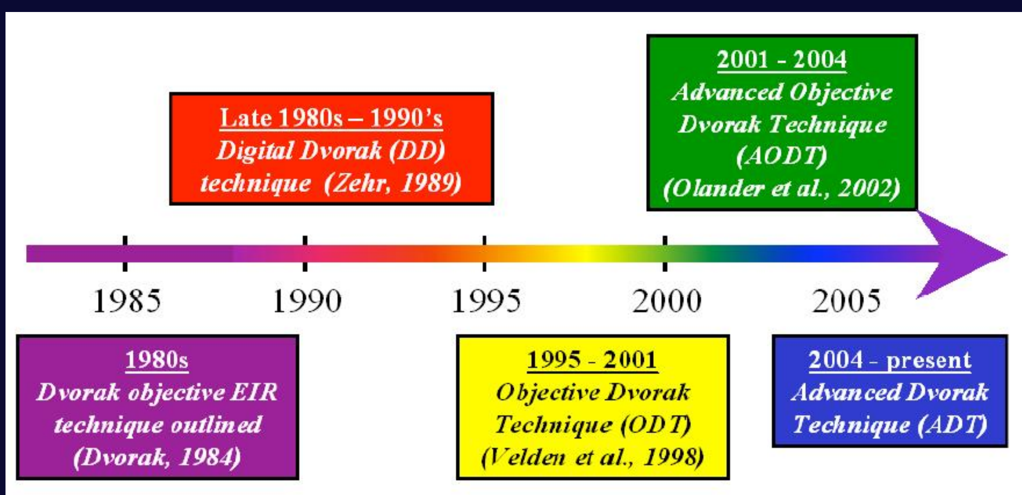
BD增强色彩显示范围及术语

Segment Number	Color Range	Cloud Top Temperature Range (°C)	Name/Abbreviation
2	0-255	>9.0	Warm Medium Gray (WMG)
3	109-202	9.0 to -30	Off White (OW)
4	60-60	-31 to -41	Dark Gray (DG)
5	110-110	-42 to -53	Medium Gray (MG)
6	160-160	-54 to -63	Light Gray (LG)
7	0-0	-64 to -69	Black (B)
8	255-255	-70 to -75	White (W)
9	135-135	-76 to -80	Cold Medium Gray (CMG)
10	85-85	<-80	Cold Dark Gray (CDG)

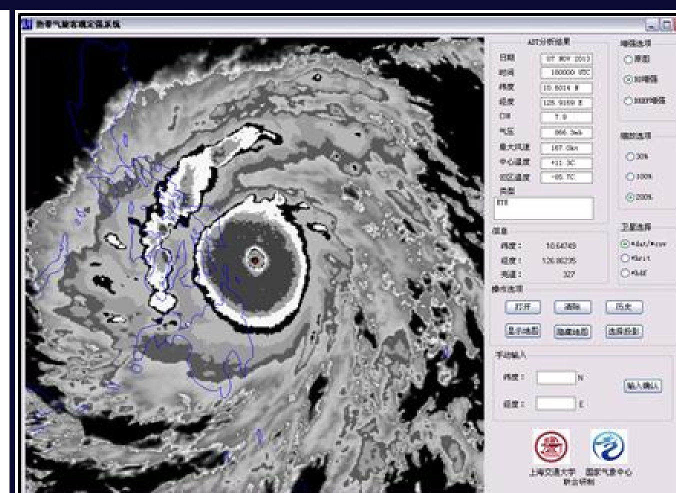

确定云系中心
根据云型估计强度
云型分析
眼型（VIS&IR）
弯曲云带型（VIS&IR）
切变型（VIS&IR）
嵌入中心型（IR）
中心密闭云区（CDO）型（VIS）
中心冷云盖型（VIS&IR）
云型识别
Pattern 指数（PT）
过去24小时强度变化趋势
Model Expected 指数（MT）
Data 指数（DT）
眼调整规则
带状特征调整规则
应用确定和限定规则
确定最终强度指数（FT）
应用确定和限定规则
确定现时强度指数（CI）
未来24小时
强度预报趋势

□ 基于静止气象卫星资料的台风强度客观估计系统

✓ 基于**Dvorak**技术、**FY2C/D/E/F**和**MTSAT-1/2**卫星和威斯康星大学开发的台风强度高级客观估计系统，**建立了台风强度客观估计系统**。鼠标点击或手工输入中心位置后，即可自动给出台风现时强度指数（**CI**）、中心最低气压和中心最大风速等强度信息。



台风业务定强Dvorak技术发展历程

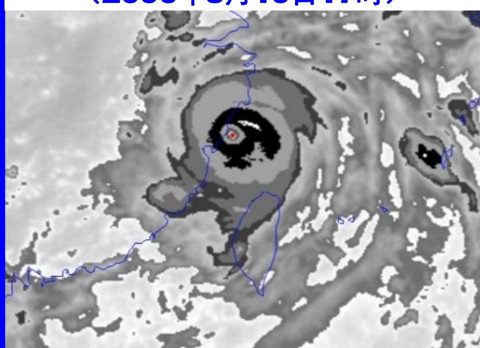


台风强度客观估计系统

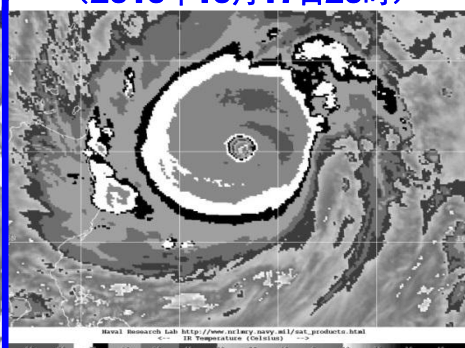
台风强度客观估计系统业务应用

- ✓ 业务试用结果表明，强度估计平均精度为**7.4-10.6hPa**，基本与美国技术水平相当。
- ✓ 针对极端台风，强度估计结果基本与飞机观测或地面观测一致。

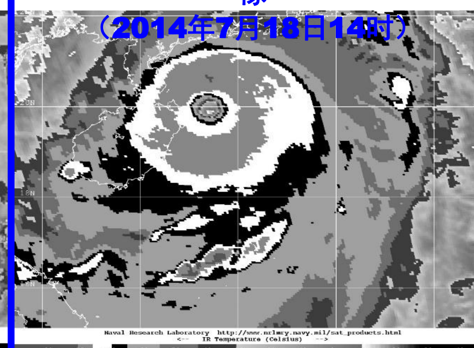
0608号台风“桑美”BD增强图像（2006年8月10日17时）



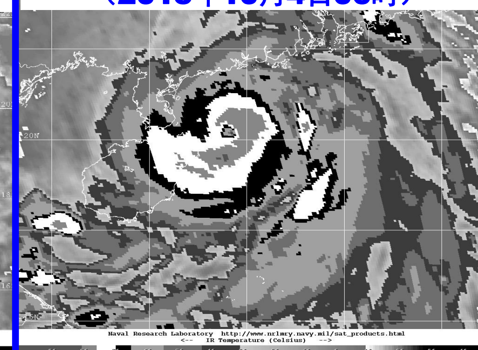
1013号台风“鲇鱼”BD增强图像（2010年10月17日20时）



1409号台风“威马逊”BD增强图像（2014年7月18日14时）



1522号台风“彩虹”BD增强图像（2015年10月4日06时）



“桑美” 客观估计结果 (2006年8月10日17时) 937.3hPa，54m/s 地面观测 (2006年8月10日17时) 936.4hPa，42.1m/s	**“鲇鱼” 客观估计结果 (2010年10月17日20时) 896hPa，74m/s 飞机观测 (2010年10月17日20时) 893hPa，78.2m/s**	**“威马逊” 客观估计结果 (2014年7月18日14时) 891.7hPa，75m/s 地面观测 (2014年7月18日13时50分) 899.2hPa，风速仪损毁**	**“彩虹” 客观估计结果 (2015年10月4日06时) 943.2hPa，51m/s 地面观测 (2015年10月4日12时40分) 943.8hPa，46.4m/s**

基于静止气象卫星资料的台风客观定位分析

基于数学形态学、图像处理及智能信息处理等理论技术，建立了基于**MTSAT**卫星云图资料的台风客观定位。

✓ 确定初始猜测位置（First-guess position）

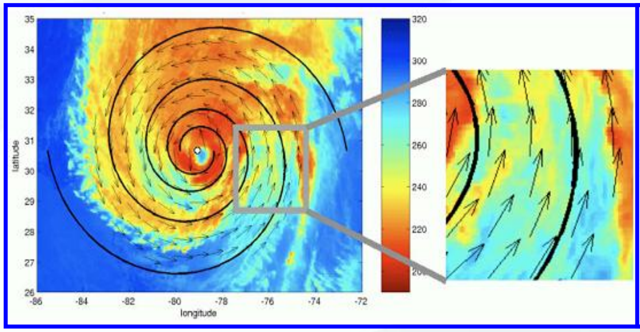
采用灰色系统预测方法，取前几帧图像中心点，预测当前帧中心点，作为初始点。

✓ 螺旋线中心定位：SC（Spiral Centering）

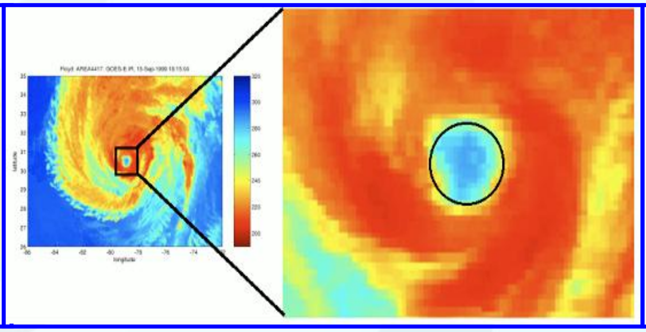
通过分析图像云顶温度梯度和不同分析区域内中心点的**5°log**螺旋线矢量的最大准线来得到台风中心点。

✓ 小尺度定位：RF（Ring Fitting ）

在增强的螺旋分析中心点（**SC**方法得到的中心点）周围搜索，在一个定义为眼墙的小环形区域内得到最强梯度。



螺旋线中心定位

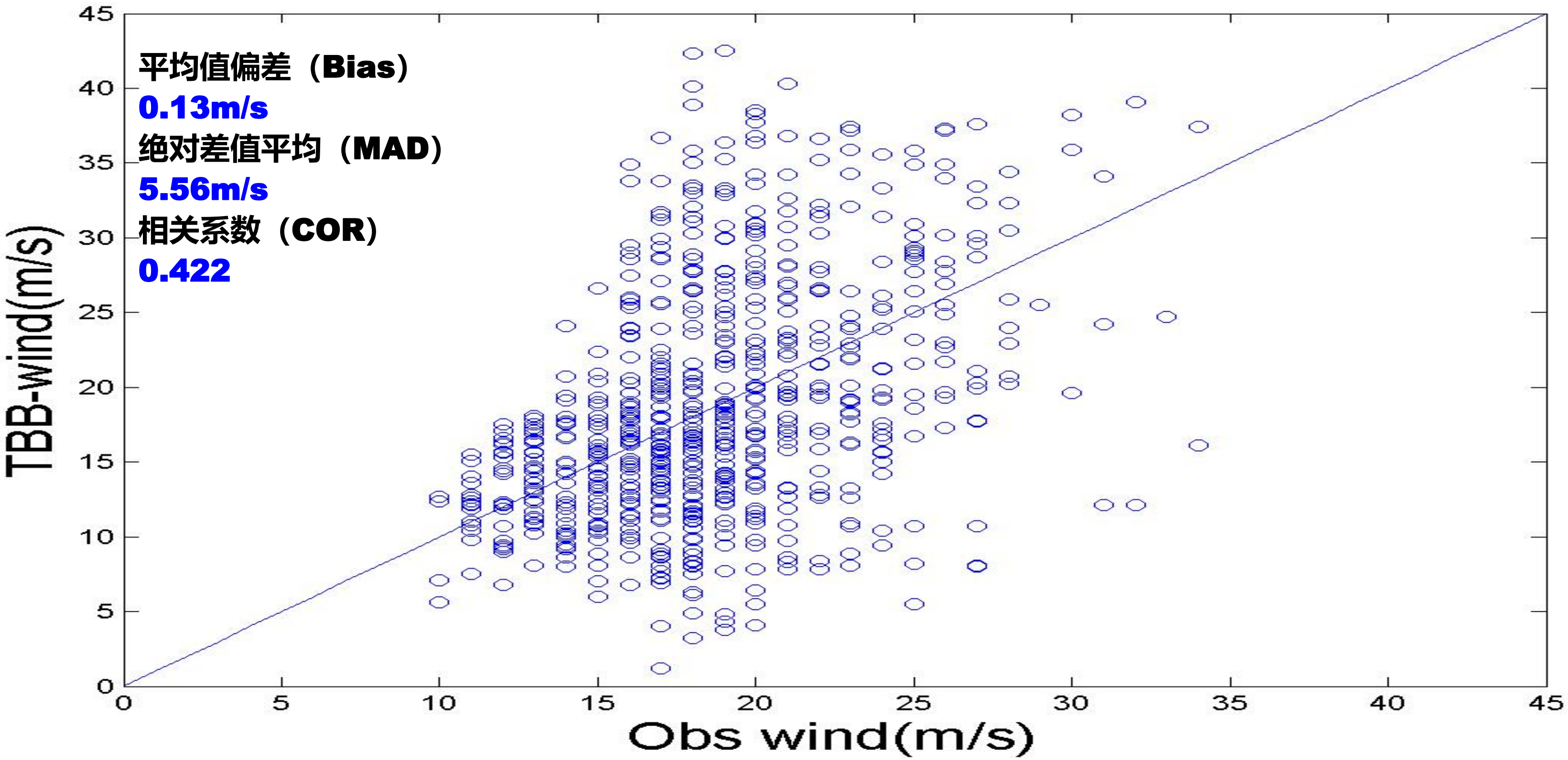


小尺度定位

基于 MTSAT 卫星红外云图的台风客观定位系统界面
（左：红外云图，右：可见光云图）

基于静止气象卫星的台风大风反演方法

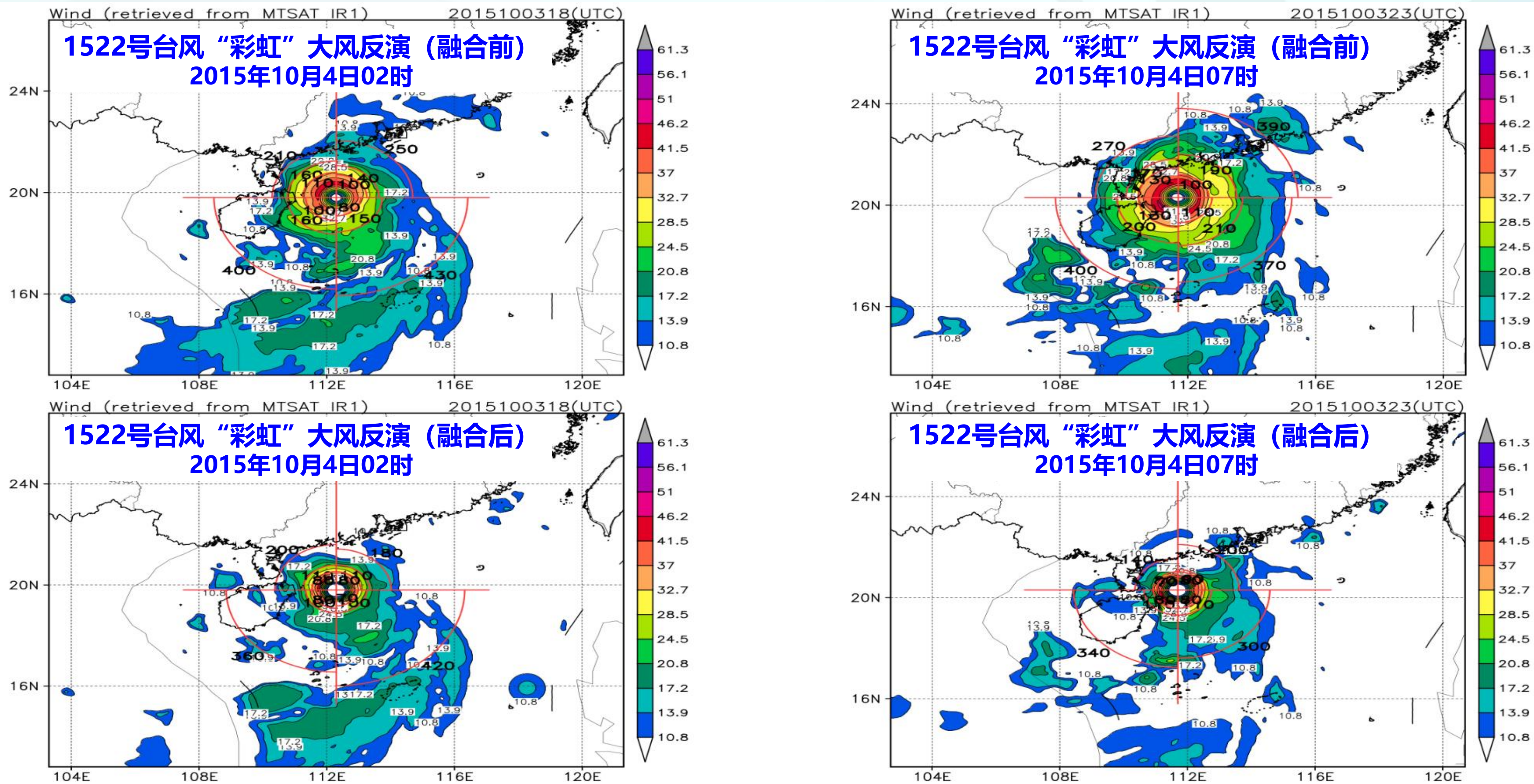
- ✓ 基于利用静止气象卫星**TBB**资料、**ECMWF**细网格资料**10**米风场、台风风速经验廓线和台风实时定位信息，建立了基于**TBB**资料的台风大风反演方法。
- ✓ 采用**Cressman**插值方法，将地面气象观测（含我国台湾及国外测站）、自动站加密观测、浮标、 船舶及**ASCAT**风场等多源资料与基于**TBB**资料的风场反演结果融合。



1211号台风“海葵”TBB反演大风与自动站观测大风对比

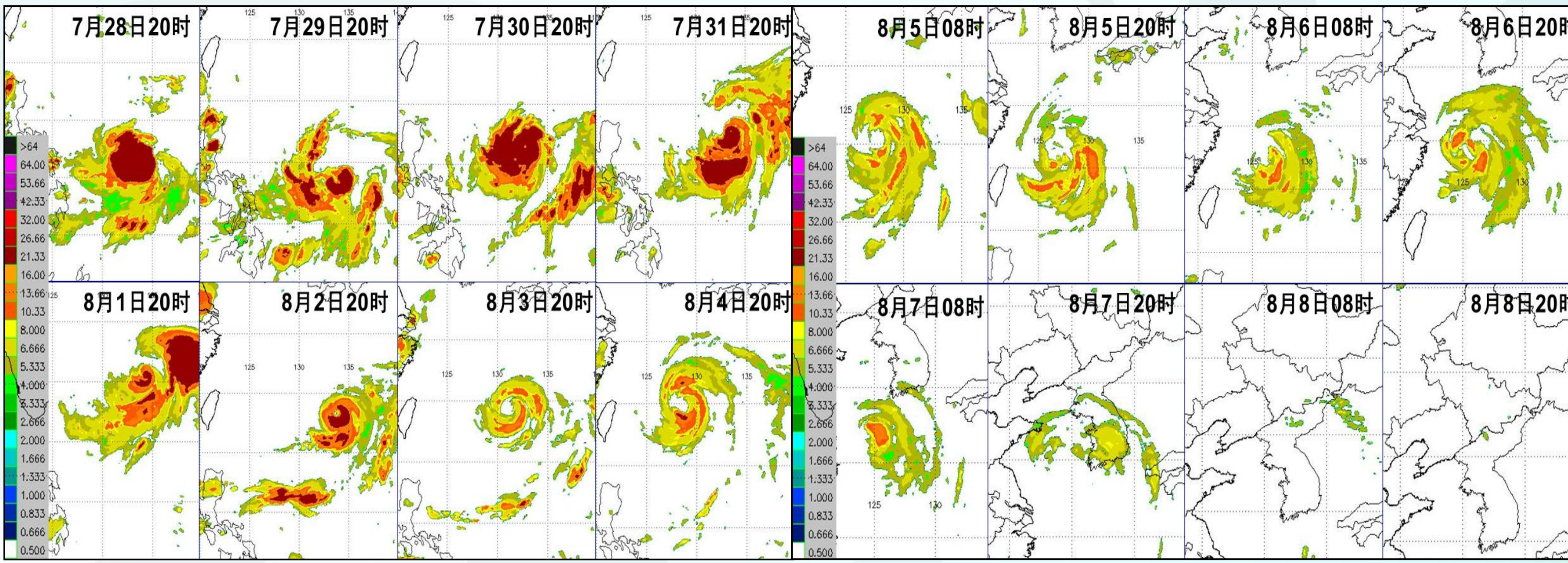
基于静止气象卫星的台风大风反演方法

- ✓ 基于利用静止气象卫星TBB资料、ECMWF细网格资料10米风场、台风风速经验廓线和台风实时定位信息，建立了基于TBB资料的台风大风反演方法。
- ✓ 采用Cressman插值方法，将地面气象观测（含我国台湾及国外测站）、自动站加密观测、浮标、 船舶及ASCAT风场等多源资料与基于TBB资料的风场反演结果融合。



台风降雨客观估计产品

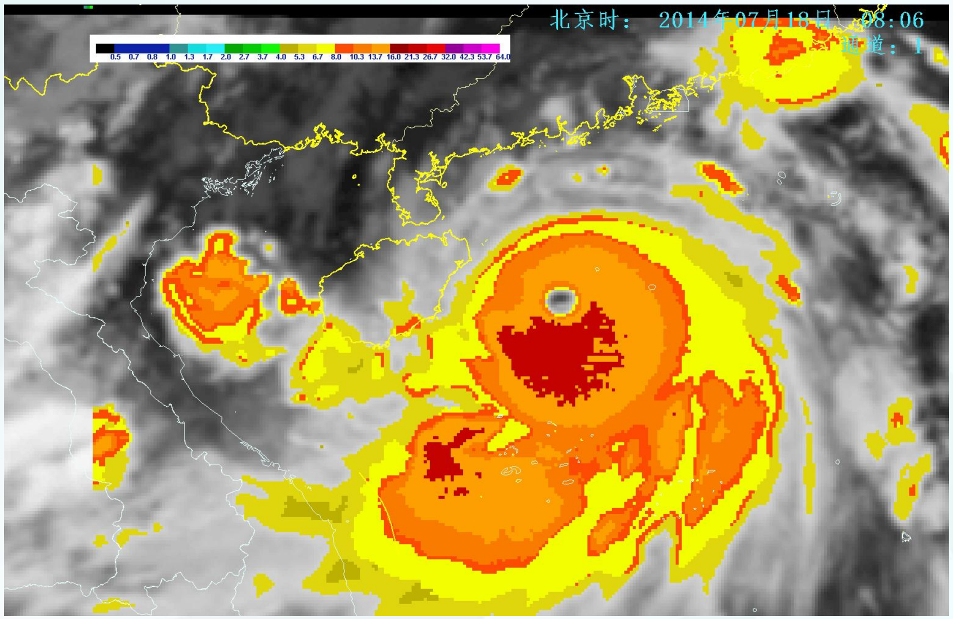
●预报员可以方便实时调阅FY2E卫星的1小时降雨估计产品，以了解台风降雨的分布和变化，为台风强降雨预报提供参考。

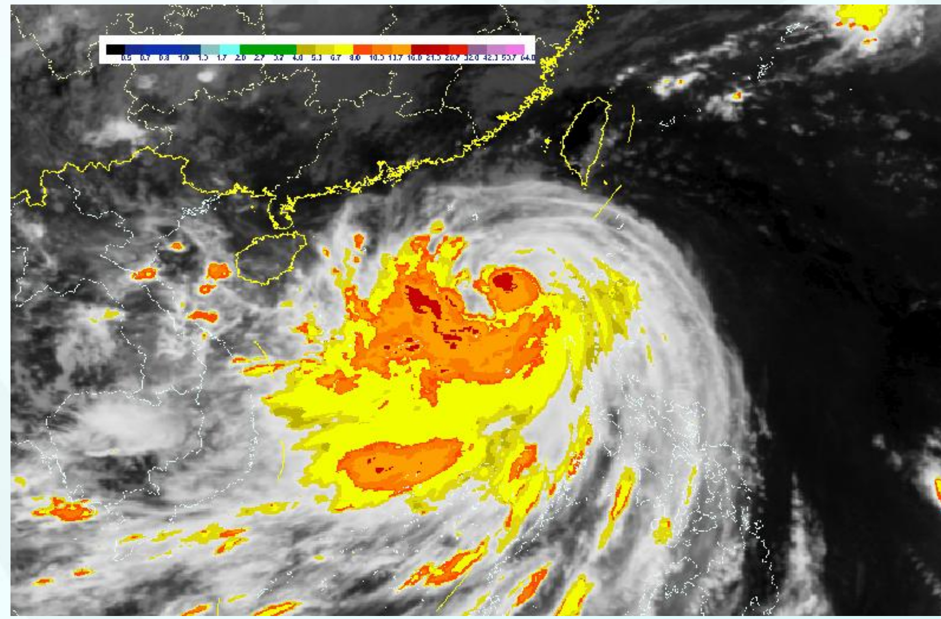


1109号超强台风“梅花”FY2E气象卫星1小时降雨估计演变
7月28日20时至8月4日20时

国家气象中心
NATIONAL METEOROLOGICAL CENTER

FY2F卫星加密降雨估计产品





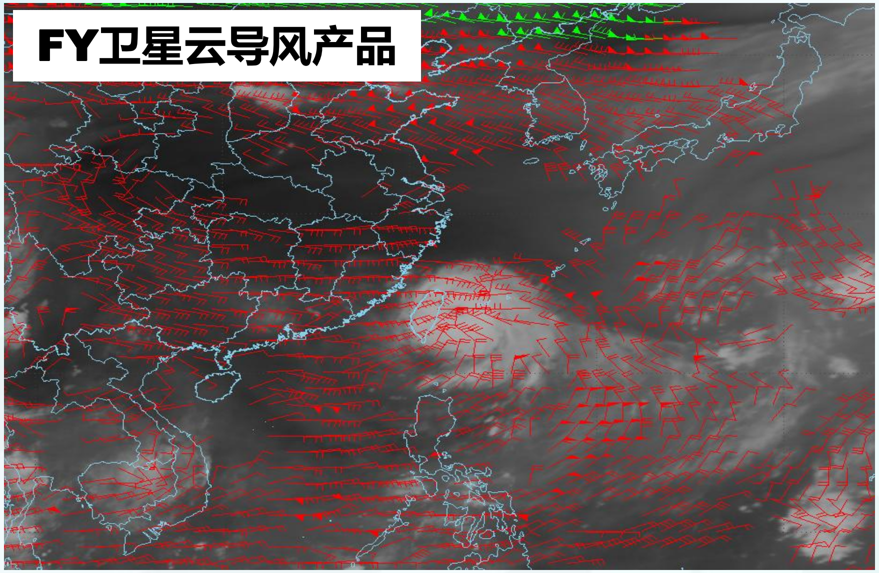
1409号超强台风“威马逊”
FY2F卫星降雨估计产品

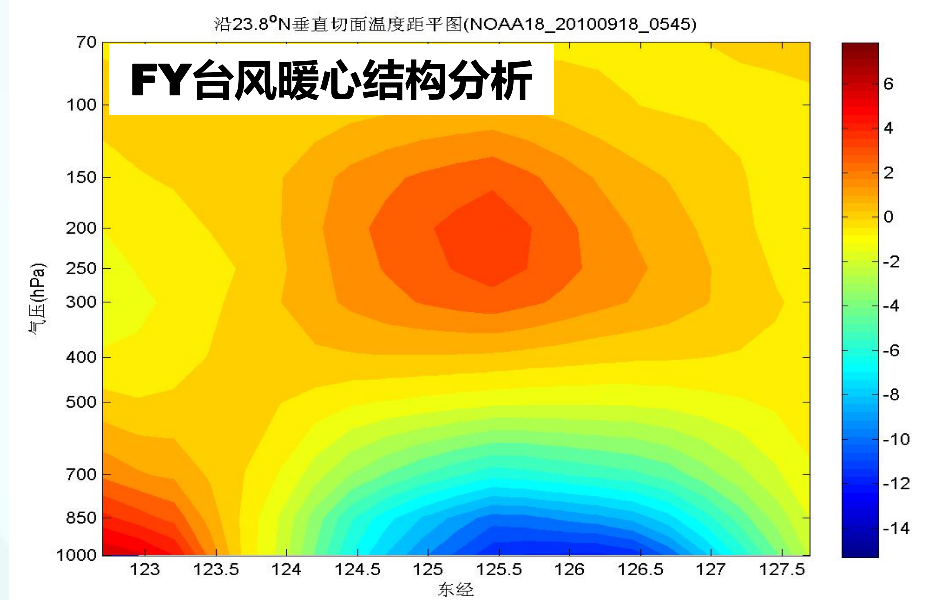
1415号强台风“海鸥”
FY2F卫星降雨估计产品

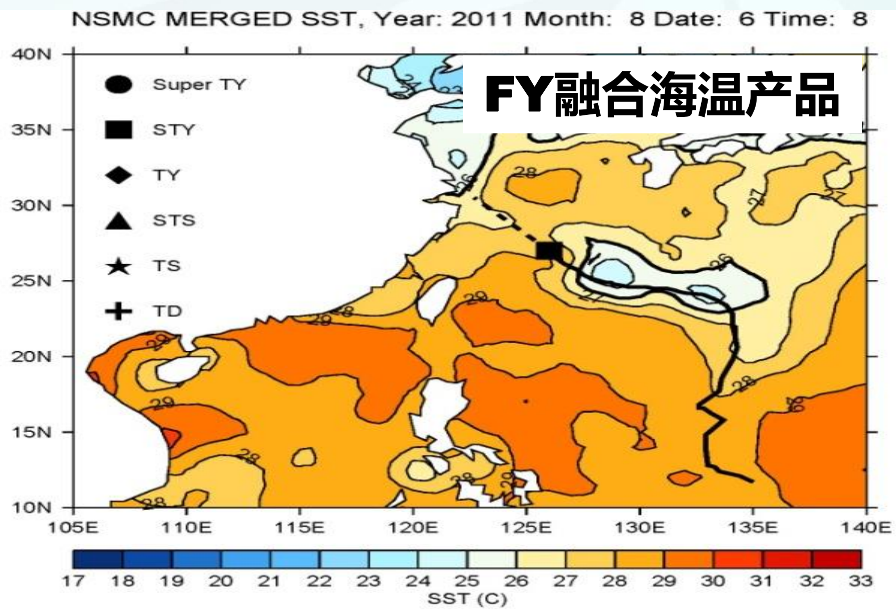
国家气象中心
NATIONAL METEOROLOGICAL CENTER

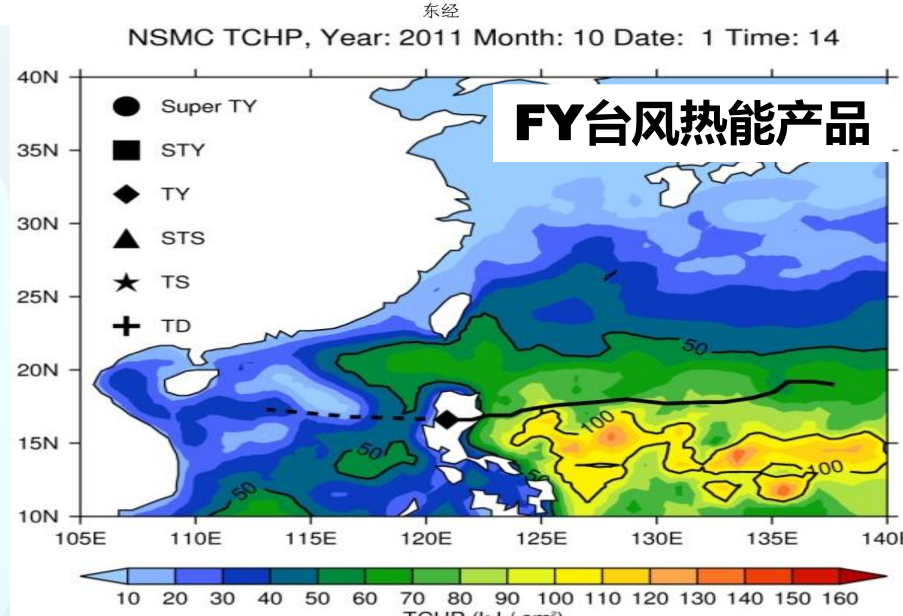
台风环境诊断分析产品

为台风强度变化预报提供支持

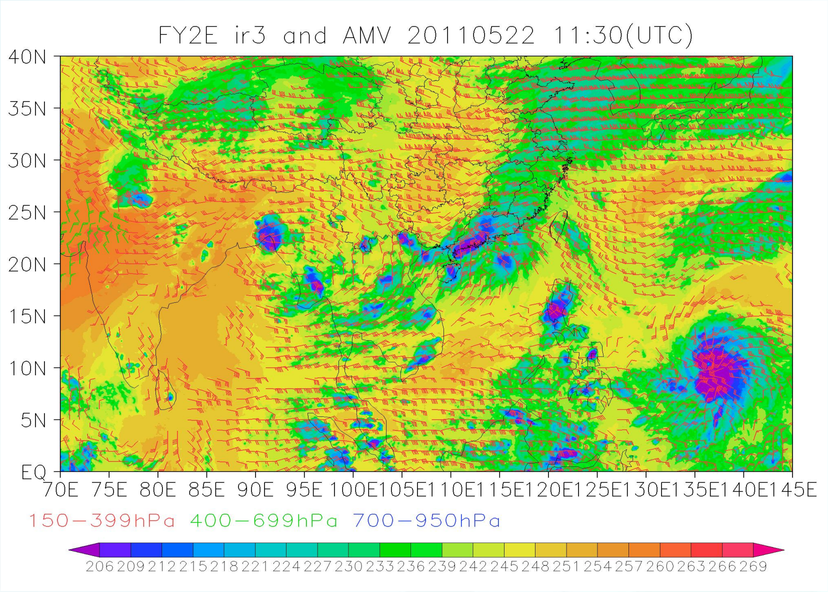




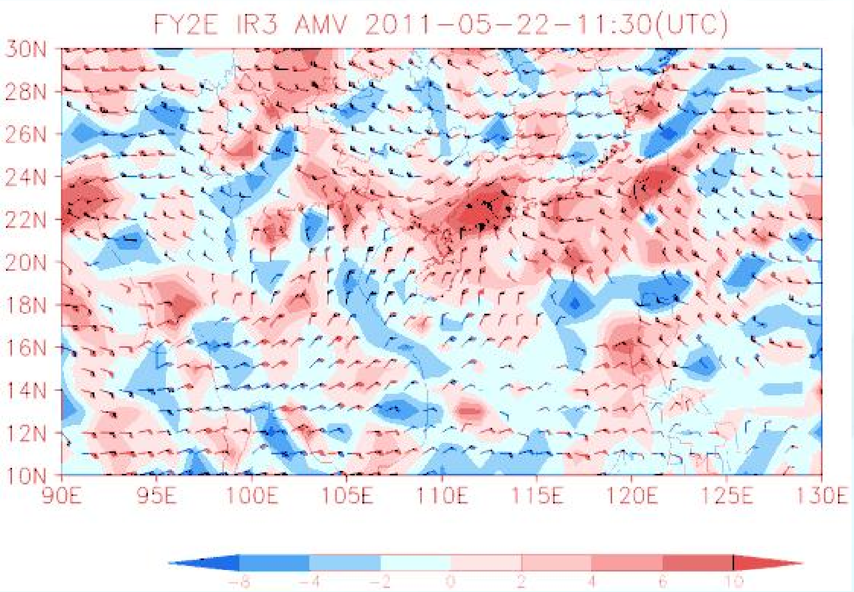




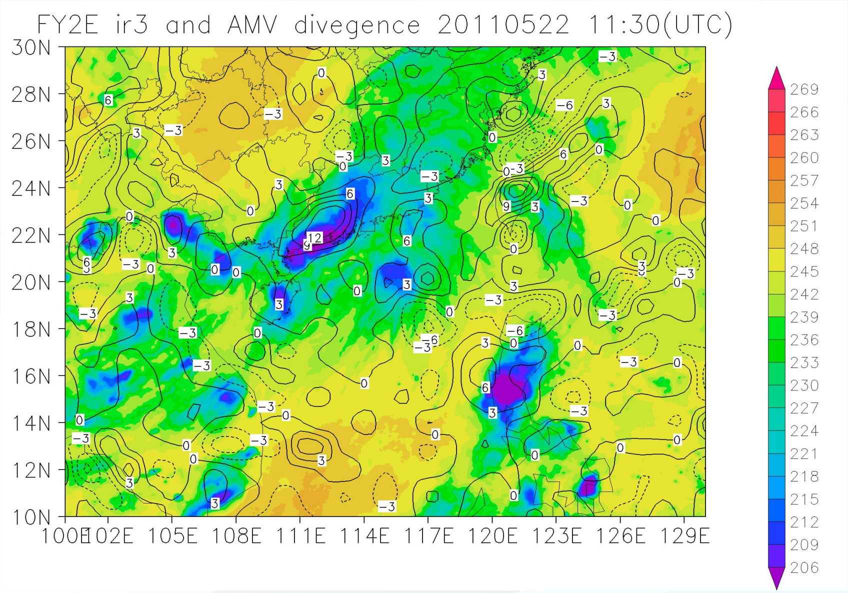
卫星云导风物理量诊断产品



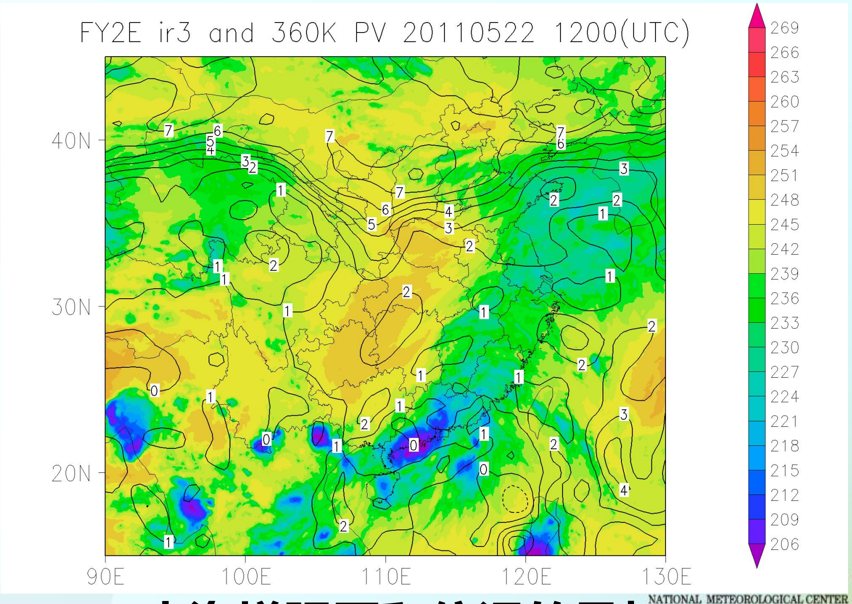
水汽增强图和云导风的叠加



云导风和导风散度场



水汽增强图和云导风散度



水汽增强图和位涡的叠加

ADT技术发展历程

ODT – Objective Dvorak Technique

（1995 – 2001，Velden et al., 1998）

- ✓ First attempt to automate EIR Dvorak Technique
- ✓ **Only for strong and greater intensities**
- ✓ **Manual storm center**

AODT – Advanced Objective Dvorak Technique

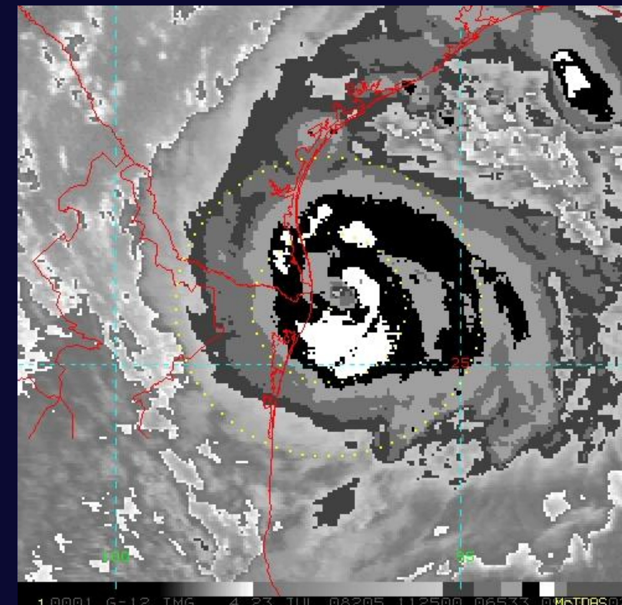
（2001 – 2004，Olander et al., 2002）

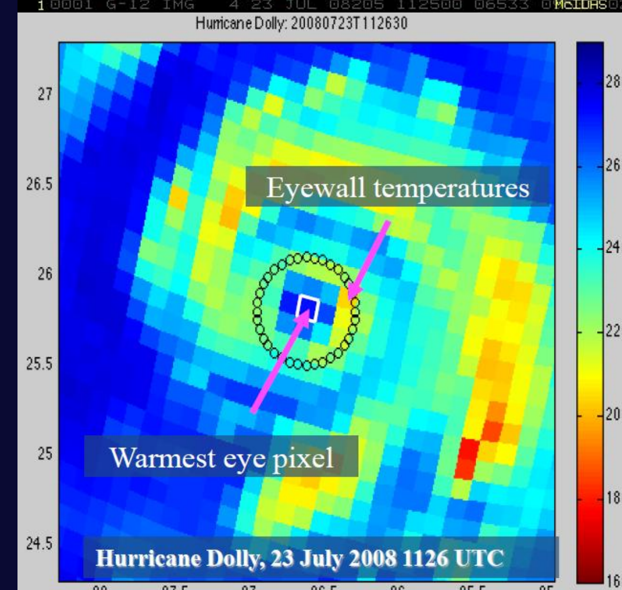
- ✓ **Expanded entire storm lifecycle**
- ✓ **Automated storm centering**

ADT – Advanced Dvorak Technique

（2004 - present，Olander and Velden, 2007）

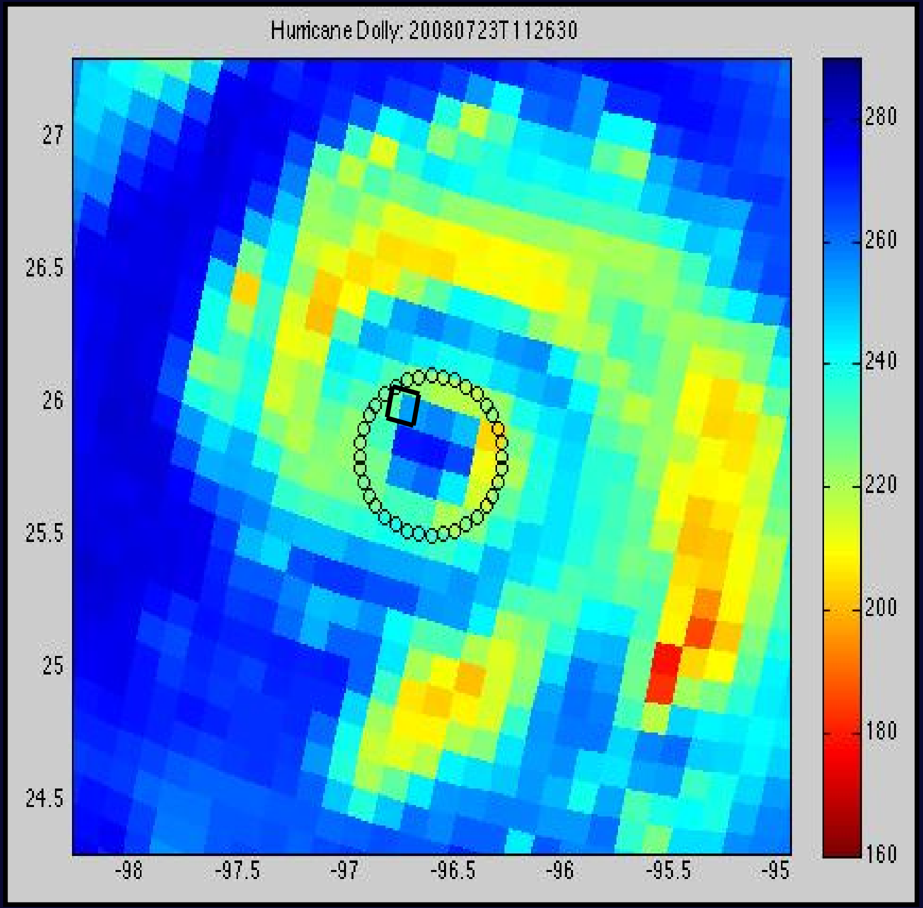
- ✓ New image objective analysis approaches
  Passive microwave imagers （85-92 GHz）





CIMSS ADT PMW（Passive Microwave) Analysis

Tim Olander & Chris Velden，2009， 2011

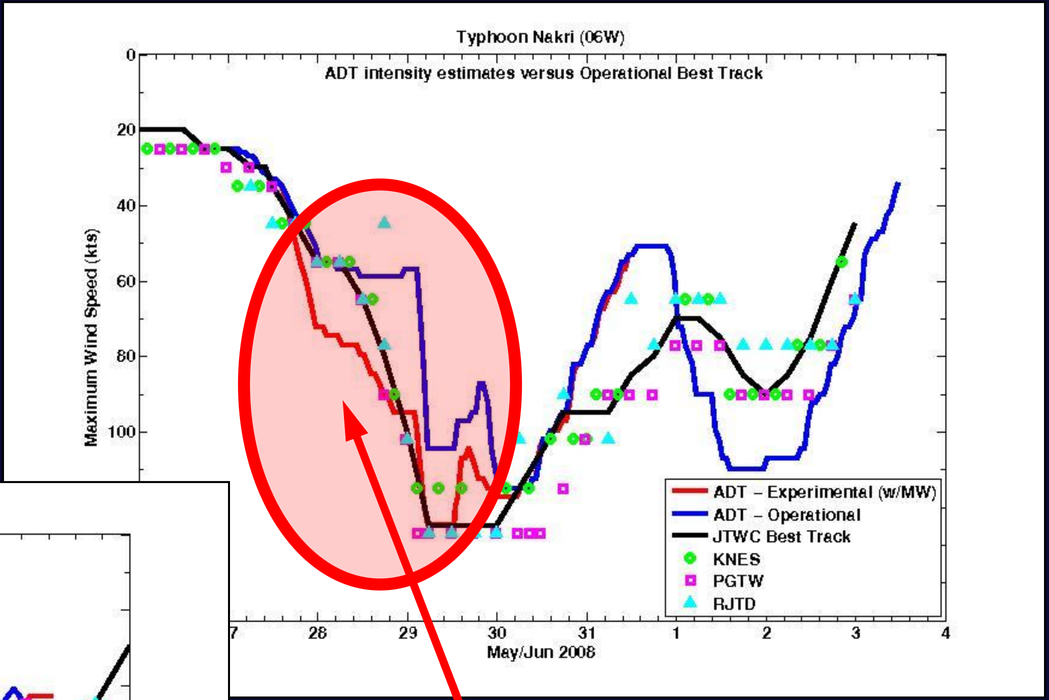


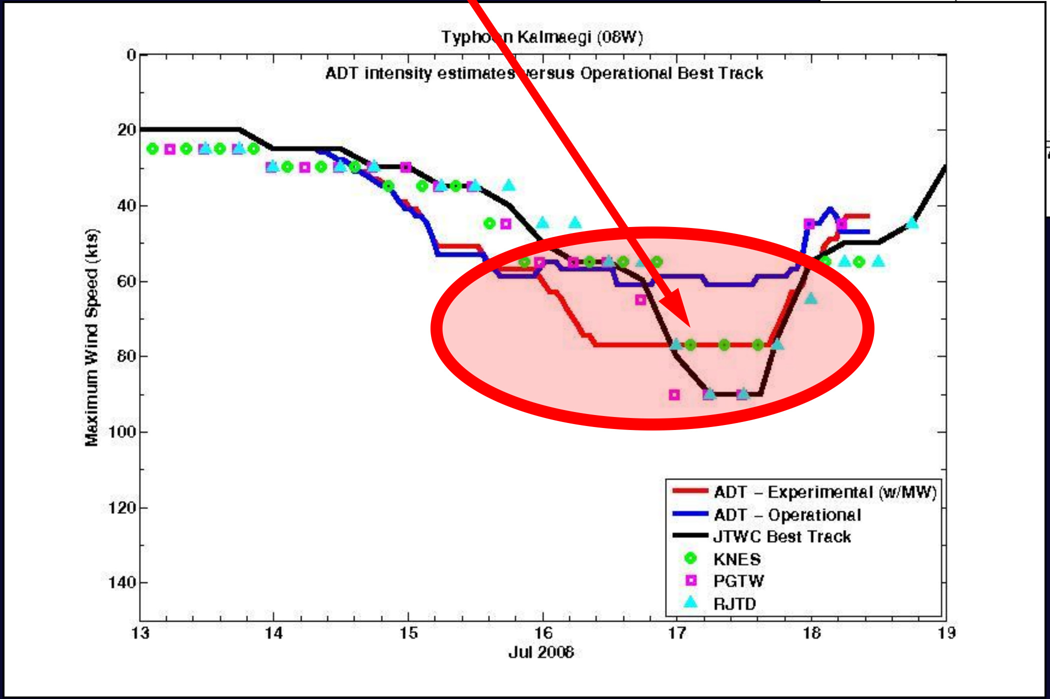
DMSP SSM/I 85GHz (H) brightness temperature

- Uses 85GHz brightness temperature signal to deduce organization of the developing eyewall/eye, and calculate an intensity score
- Successful in loosely differentiating between storms
  - Greater than ~72 knots
  - Greater than ~90 knots
- If thresholds are exceeded, PMW scores are converted to either T# of 4.3 or 5.0 in the ADT
- The scheme has been operating in ADT since 2008

Advanced Dvorak Technique PMW Intensity Estimate Score

Eliminated false intensity “plateau”; Closer to Best Track





More closely follows rapid intensification; More accurate maximum intensity resulted

Tim Olander & Chris Velden，2011

CIMSS Advanced Dvorak Technique
PMW Analysis : Textual/Graphical Products since 2013

Tropical Storm 22W

Passive Microwave (PMW) Intensity Information

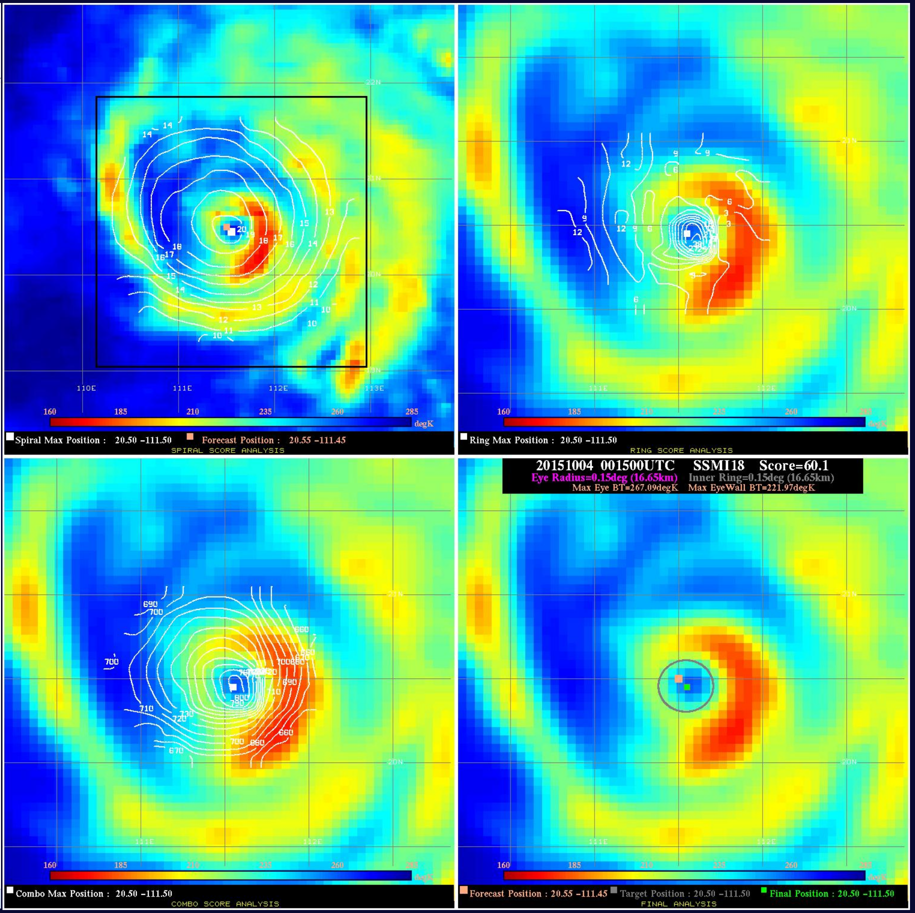
Advanced Dvorak Technique (ADT)

Version 8.2.1

Overpass Date	Overpass Time	Inten Score	Meaning	Ring Pct	Ring Diam	BTdiff	Wind Est	Sat	Forecast Lat	Forecast Lon	Final Lat	Final Lon	Target Lat	Target Lon	
20151001	043947	-11.5	N/A	72.6%	33.33	11.45	25.0	AMSR2	14.1	-124.8	14.1	-124.8	14.3	-124.0	Analysis Plot
20151001	094300	-2.0	N/A	49.3%	55.55	2.01	30.0	SSMI17	14.7	-123.5	14.7	-123.5	15.0	-123.0	Analysis Plot
20151001	094500	-3.0	N/A	63.0%	88.88	3.04	30.0	SSMI19	14.9	-123.2	14.9	-123.2	15.1	-122.9	Analysis Plot
20151001	185758	-42.5	N/A	100.0%	33.33	27.55	35.0	GMI	15.9	-121.5	15.9	-121.5	15.8	-121.2	Analysis Plot
20151001	190502	-32.1	N/A	100.0%	44.44	17.14	30.0	SSMI15	15.6	-121.2	15.6	-121.2	15.7	-121.2	Analysis Plot
20151001	222100	-32.1	N/A	N/A	N/A	0.00	30.0	SSMI19	15.9	-120.5	15.9	-120.5	16.4	-119.1	Analysis Plot
20151001	230100	-32.1	N/A	N/A	N/A	0.00	30.0	SSMI18	16.0	-120.3	16.0	-120.3	16.5	-119.5	Analysis Plot
20151002	173526	13.6	N/A	38.4%	99.99	13.62	55.0	AMSR2	17.8	-116.3	17.5	-116.6	17.5	-116.6	Analysis Plot
20151003	085144	16.9	N/A	23.3%	55.55	16.90	60.0	SSMI15	19.0	-114.1	19.0	-114.3	19.0	-114.3	Analysis Plot
20151003	110000	36.2	>65 kts	100.0%	55.55	21.23	60.0	SSMI19	19.3	-113.5	19.4	-113.5	19.4	-113.5	Analysis Plot
20151003	114100	44.8	>65 kts	100.0%	44.44	29.83	60.0	SSMI18	19.4	-113.4	19.4	-113.4	19.4	-113.4	Analysis Plot
20151003	181721	57.5	>65 kts	100.0%	44.44	42.55	80.0	AMSR2	19.9	-112.1	19.9	-112.2	19.9	-112.2	Analysis Plot
20151003	203557	45.3	>65 kts	100.0%	33.33	30.28	80.0	SSMI15	20.0	-111.9	20.0	-112.0	20.0	-112.0	Analysis Plot
20151004	001500	60.1	>85 kts	100.0%	33.33	45.12	95.0	SSMI18	20.5	-111.4	20.5	-111.5	20.5	-111.5	Analysis Plot
20151004	083702	65.1	>85 kts	100.0%	33.33	50.08	95.0	SSMI15	21.1	-110.6	21.3	-110.3	21.3	-110.3	Analysis Plot
20151004	104800	4.8	N/A	N/A	199.98	4.78	115.0	SSMI19	21.7	-109.9	21.9	-110.0	21.9	-110.0	Analysis Plot
20151004	113000	18.1	N/A	100.0%	33.33	3.13	115.0	SSMI18	21.8	-109.8	22.1	-110.0	22.1	-110.0	Analysis Plot
20151004	201836	18.1	N/A	N/A	N/A	0.00	80.0	SSMI15	22.5	-108.7	22.5	-108.7	22.5	-107.7	Analysis Plot
20151004	232000	0.8	N/A	N/A	155.54	.81	80.0	SSMI19	22.8	-108.3	22.8	-108.3	22.8	-107.6	Analysis Plot
20151005	000200	0.2	N/A	N/A	122.21	.17	80.0	SSMI18	22.8	-108.3	22.8	-108.3	23.1	-107.7	Analysis Plot
20151005	055531	0.2	N/A	N/A	N/A	0.00	80.0	AMSR2	23.3	-107.8	23.3	-107.8	23.5	-107.2	Analysis Plot
20151005	103700	0.2	N/A	N/A	N/A	0.00	80.0	SSMI19	23.8	-107.5	23.8	-107.5	23.7	-106.9	Analysis Plot

Legend:

- Date/Time are determined from PMW imagery at Forecast (initial guess) Lat/Lon position.
- Positive/Negative Latitude = North/South Hemisphere; Longitude = Western/Eastern Hemisphere.
- "Ring Diam" value indicates the estimated surface eyewall diameter in km (the MI eyewall edge diameter minus 10 km).
- "Ring Pct" is the percentage of the "ring" (eyewall inner boundary) that is 1) colder than the "hot spot" (warmest eye pixel) in the eye by 20K, or 2) the percentage that is a) colder than 232K and b) colder than the "hot spot" by 10K, whichever is greater.
- Values are red if Ring % <= 65, yellow/brown if Ring % <= 85 and green if Ring % > 85.

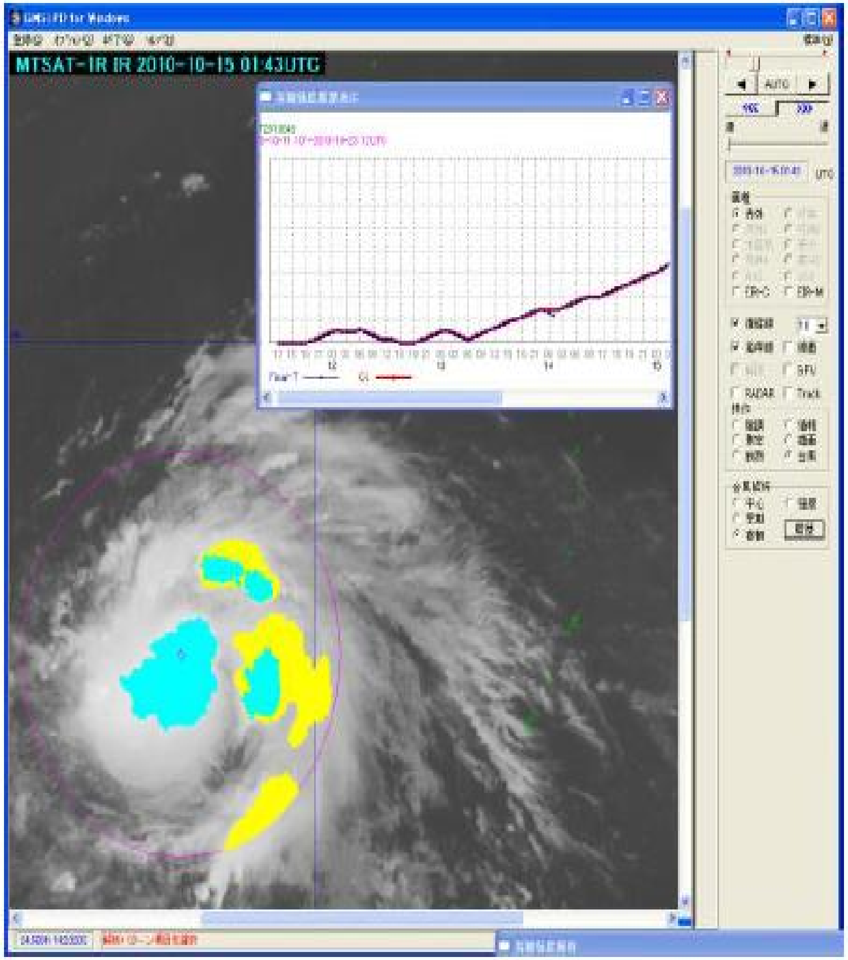


1522号台风“彩虹”PMW 强度分析结果

2015年10月4日08时15分

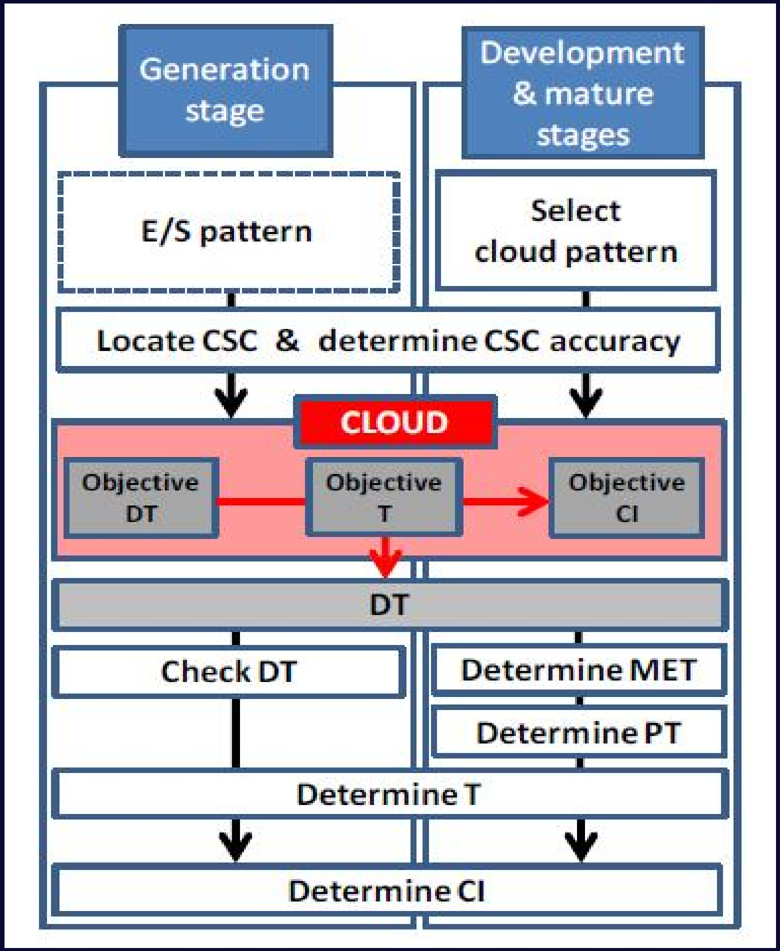
JMA Cloud Grid Information Objective Dvorak Analysis (CLOUD)

Kishimoto **etal,** 2013



JMA Cloud Grid Information Objective Dvorak Analysis (CLOUD)

Kishimoto **etal**, 2013



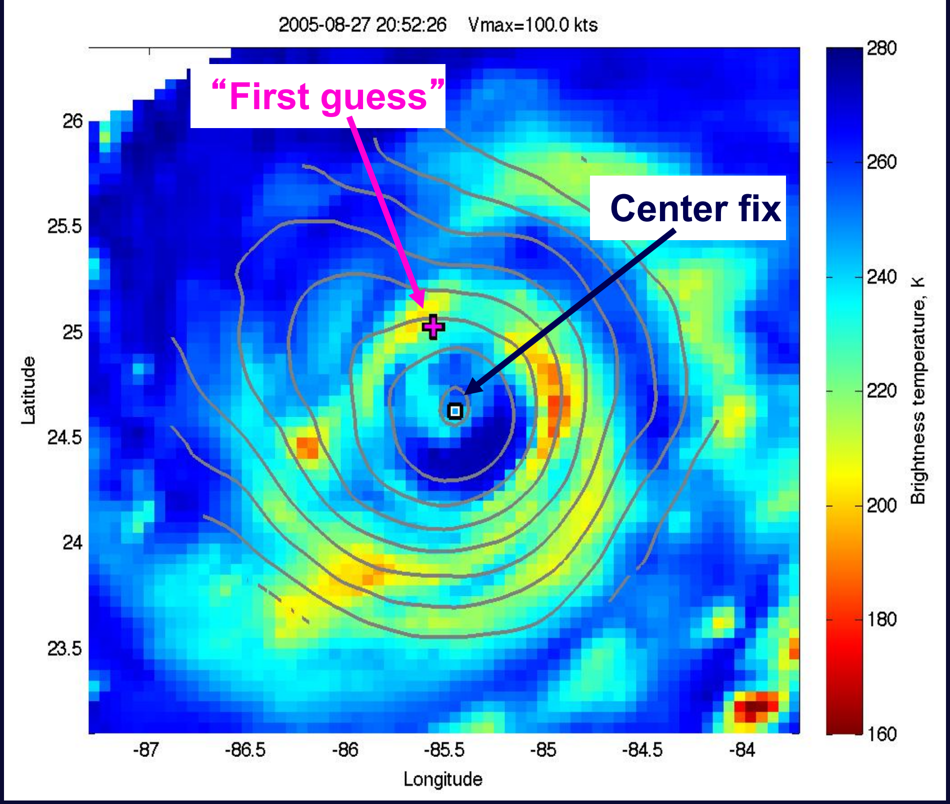
JMA CLOUD analysis procedure
Grey boxes: automatic processes
White boxes: manual processes

CIMSS Automated Rotational Center Hurricane Eye Retrieval (ARCHER) method

Wimmers & Velden, 2010
Olander & Velden，2009, 2011
Wimmers & Velden, 2016

Objective

- ✓ Automated, robust location of TC rotational centers in individual microwave or IR images
- ✓ Must be resilient to false eyes (moats), obstructions in the eye, partial eyes, partial scan coverage
- ✓ Must rely only loosely on a first-guess (forecast) position estimate
- ✓ Must apply to microwave and IR image

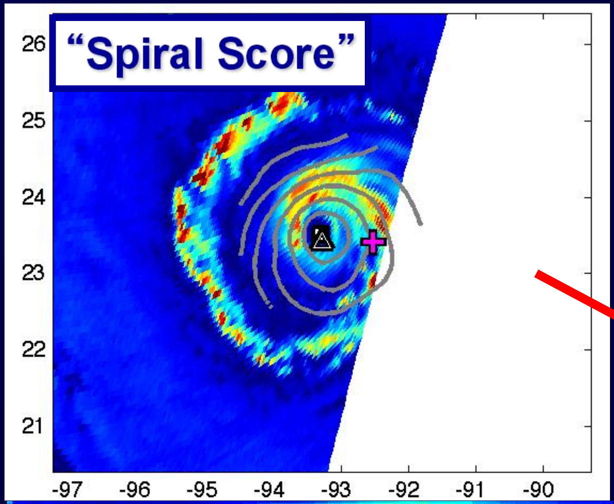


85 GHz (H) TMI retrieval

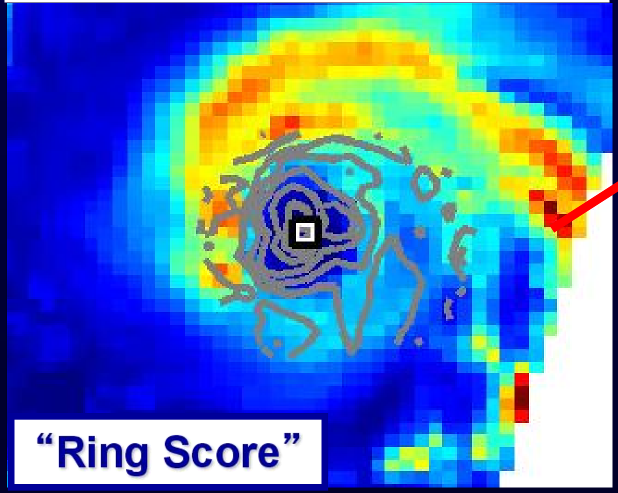
CIMSS Automated Rotational Center Hurricane Eye Retrieval **(ARCHER)** method

Wimmers & Velden, 2010
Olander & Velden, 2009, 2011
Wimmers & Velden, 2016

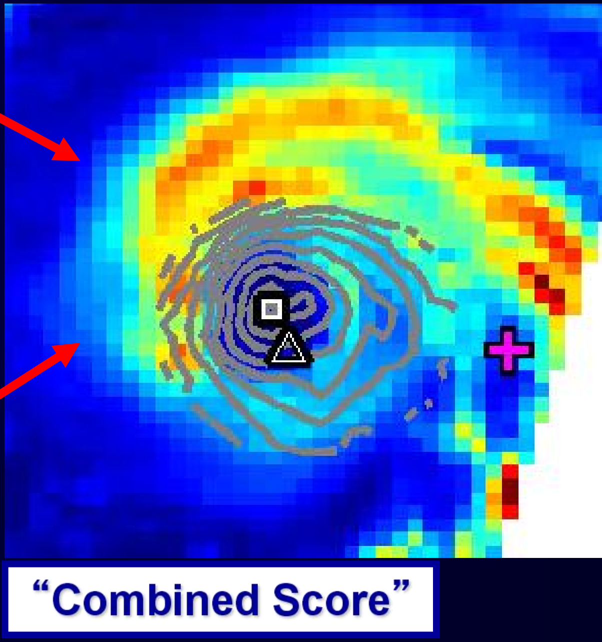
(1) Produce a 2D field (contoured) that expresses how well a location registers as the center of the **large-scale spiral** pattern



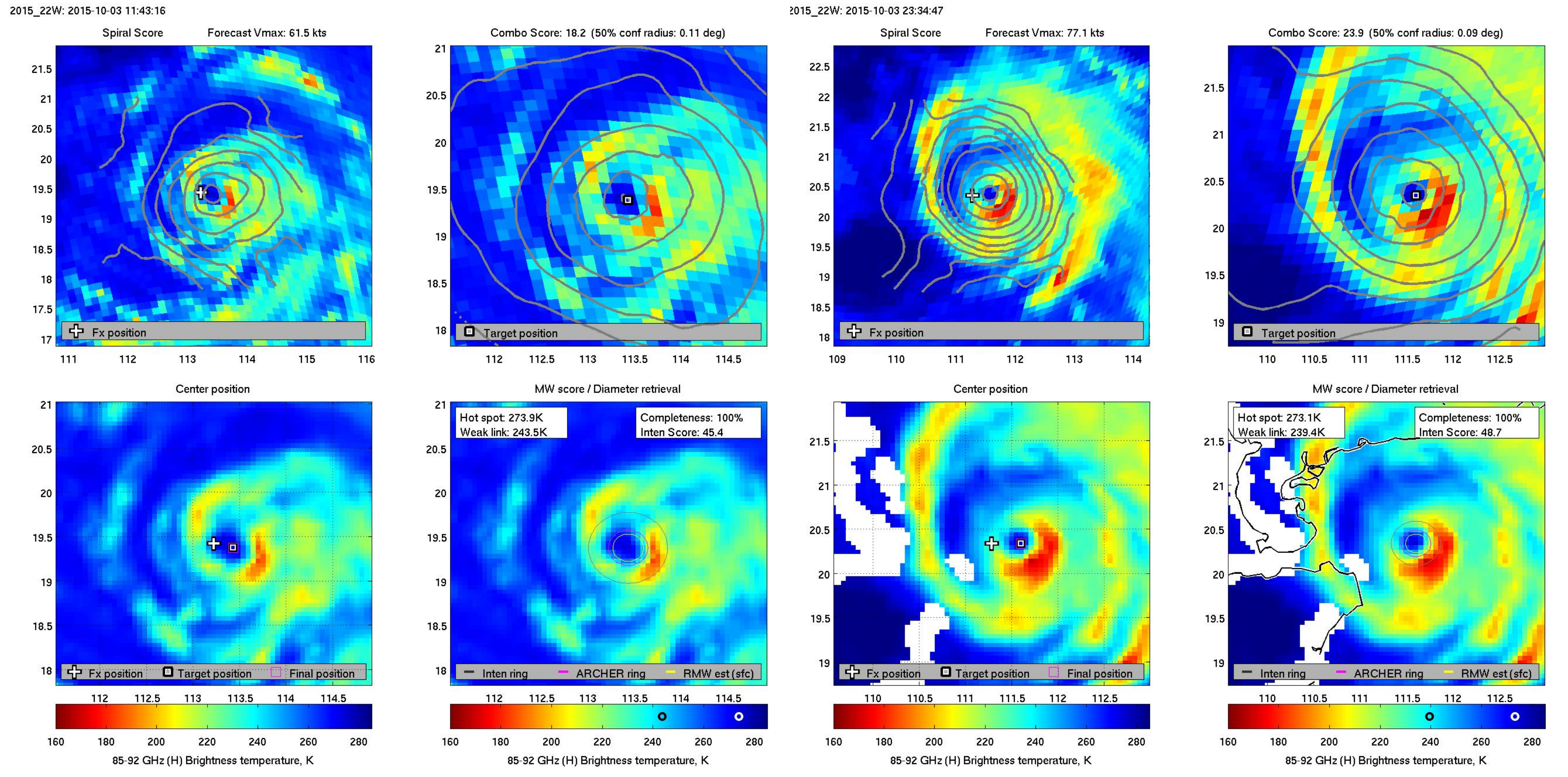
(2) Produce a separate 2D field that rates how well a location is centered inside **a circular ring** of convection



(3) Combine the two 2D fields as a weighted sum into a single score field



CIMSS ARCHER Analysis Web

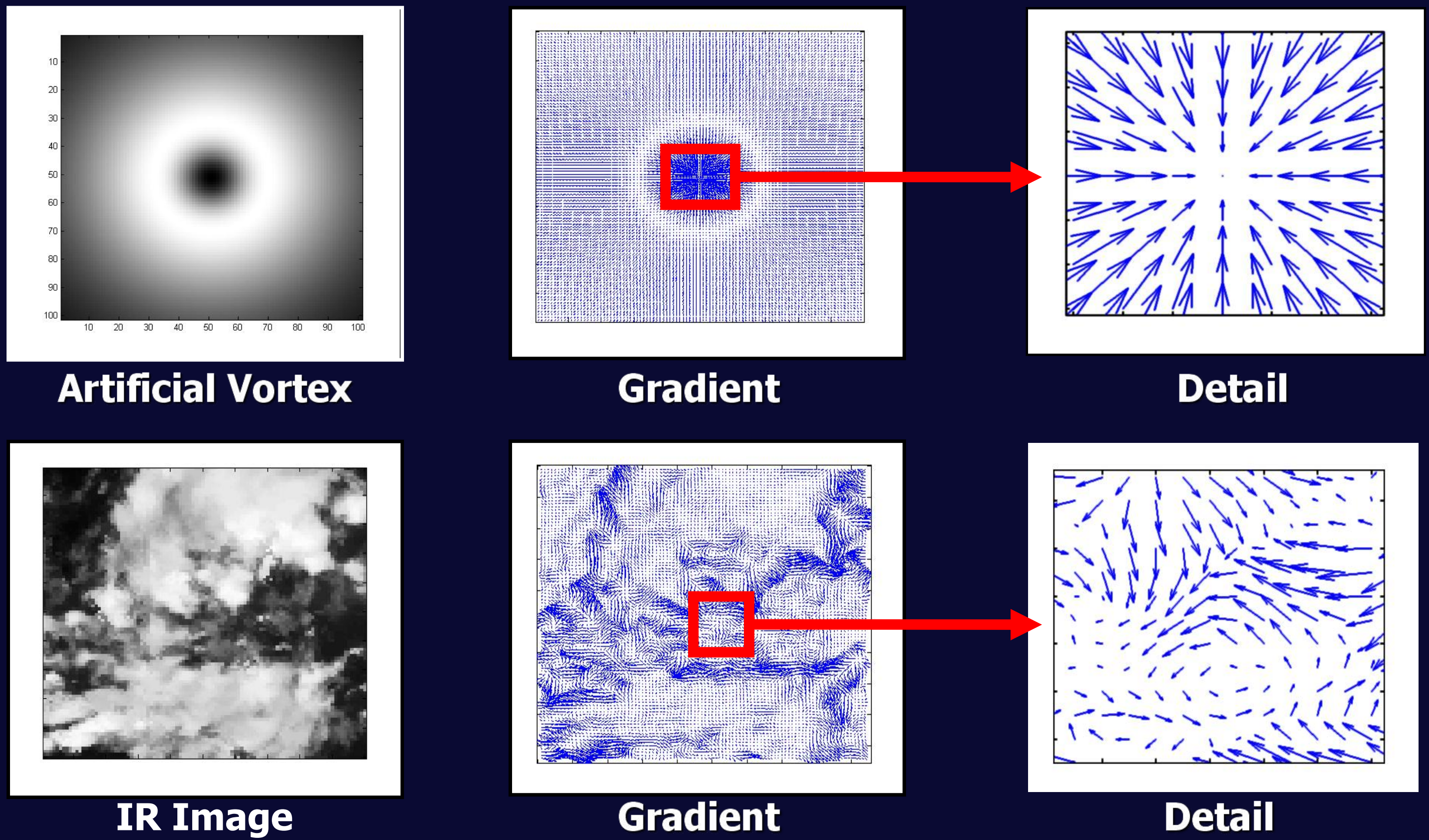


1522号台风“彩虹”ARCHER 强度和定位分析结果
2015年10月1日08时至5日20时

偏差角方差技术 (DAV-T)
Deviation Angle Variance – Technique

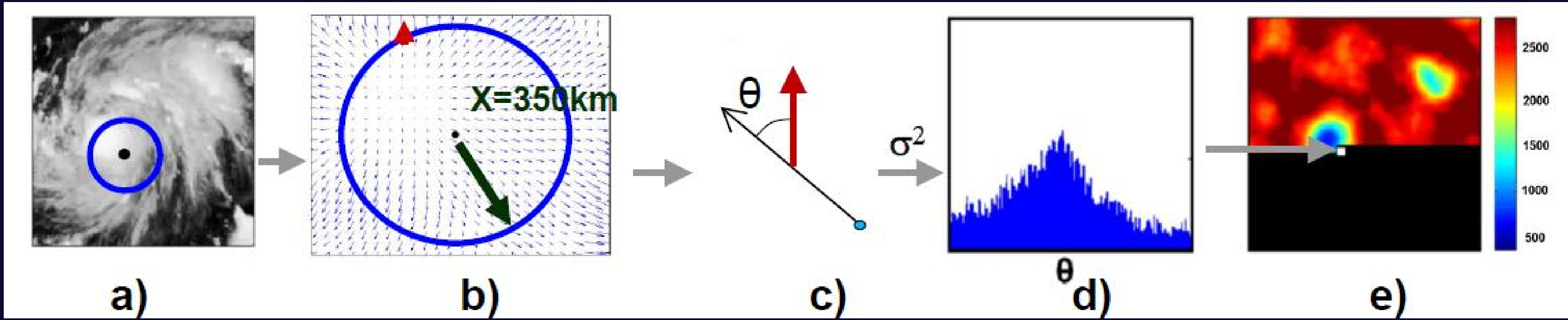
Ritchie etal, 2012

Objective IR-based method that measures level of axisymmetry



偏差角方差技术 (DAV-T)
Deviation Angle Variance – Technique

Source:
Pineros et al. , 2008, 2010, 2011
Kofron et al. , 2009
Ritchie etal, 2012, 2014
Wood et al., 2015



a) Calculate gradient of the brightness temperatures of IR image of interest
b) For a chosen center point draw radials to all pixels within a radius X.
c) Calculate the angle between the radial and the gradient at all pixels
d) Plot a frequency histogram of the angles and calculate the variance
e) Map the variance back to the center pixel location.

Note: higher variance → greater disorganization → lower intensity
lower variance → greater organization → higher intensity

Intensity: require 9 pixels around a specified center location (9-pixel average)

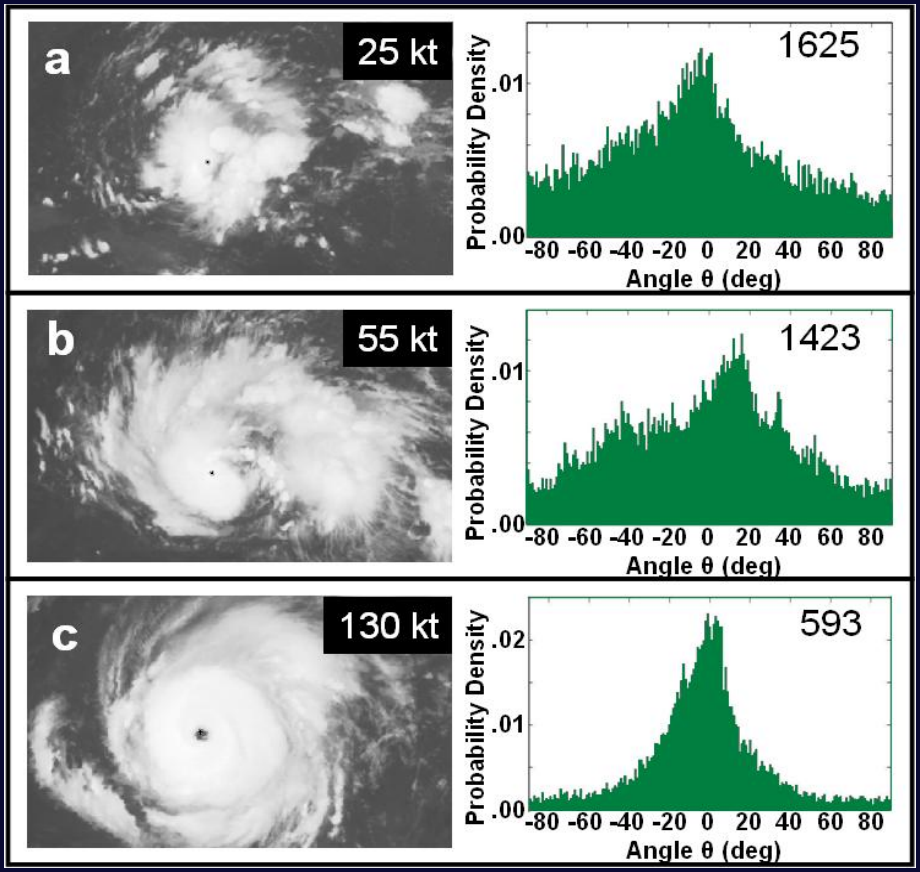
Genesis: require the full map of variances – locate regions where the variance falls below a statistically-determined threshold value for a detect.

ET (extratropical transition): case study

偏差角方差技术 (DAV-T)
Deviation Angle Variance – Technique

Ritchie etal, 2012

Hurricane Rita (2005)



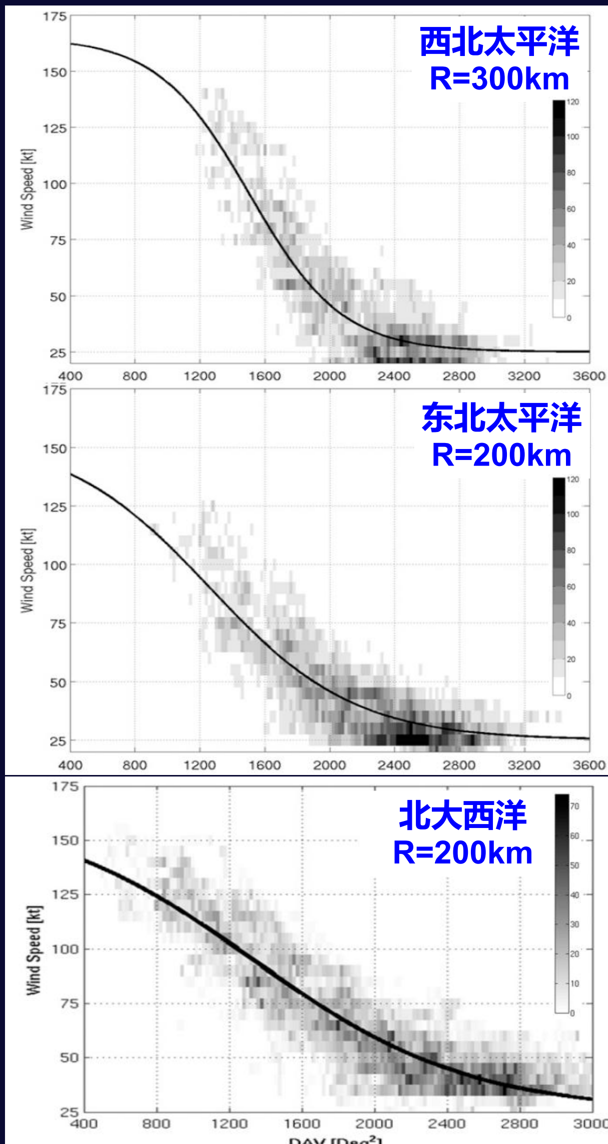
09/18/2005 08:15 UTC 25kt

09/19/2005 14:15 UTC 55kt

09/21/2005 14:15 UTC 130kt

偏差角方差（DAV）与台风强度的关系

Ritchie etal, 2012, 2014



西北太平洋

$$f(\sigma^2)=\frac{140}{1+\exp[\alpha(\sigma^2+\beta)]}+25$$

东北太平洋

$$f(\sigma^2)=\frac{130}{1+\exp[\alpha(\sigma^2+\beta)]}+25$$

北大西洋

$$f(\sigma^2)=\frac{140}{1+\exp[\alpha(\sigma^2-\beta)]}+25$$

σ^2 is the DAV value

α and β are two free parameters that describe the relation between the axisymmetry parameter and the best-track intensity estimates.

The number of DAV-T samples, RMSE(kt), and the number of samples either overestimated or underestimated for all **WNP/ENP/NA** samples categorized into bins based on JTWC/NHC's TC intensities

WNP （the western North Pacific）

Ritchie etal, 2012, 2014

Bin	No. of samples	RMSE (kt)	No. overestimated	No. underestimated
Tropical depression (<34 kt)	10 621	11.0	8693 (82%)	1928 (18%)
Tropical storm (34–63 kt)	6197	13.8	2065 (33%)	4132 (67%)
Typhoon (64–129 kt)	5324	19.5	1755 (33%)	3569 (67%)
Supertyphoons (>129 kt)	410	19.5	46 (11%)	364 (89%)

ENP （the eastern North Pacific）

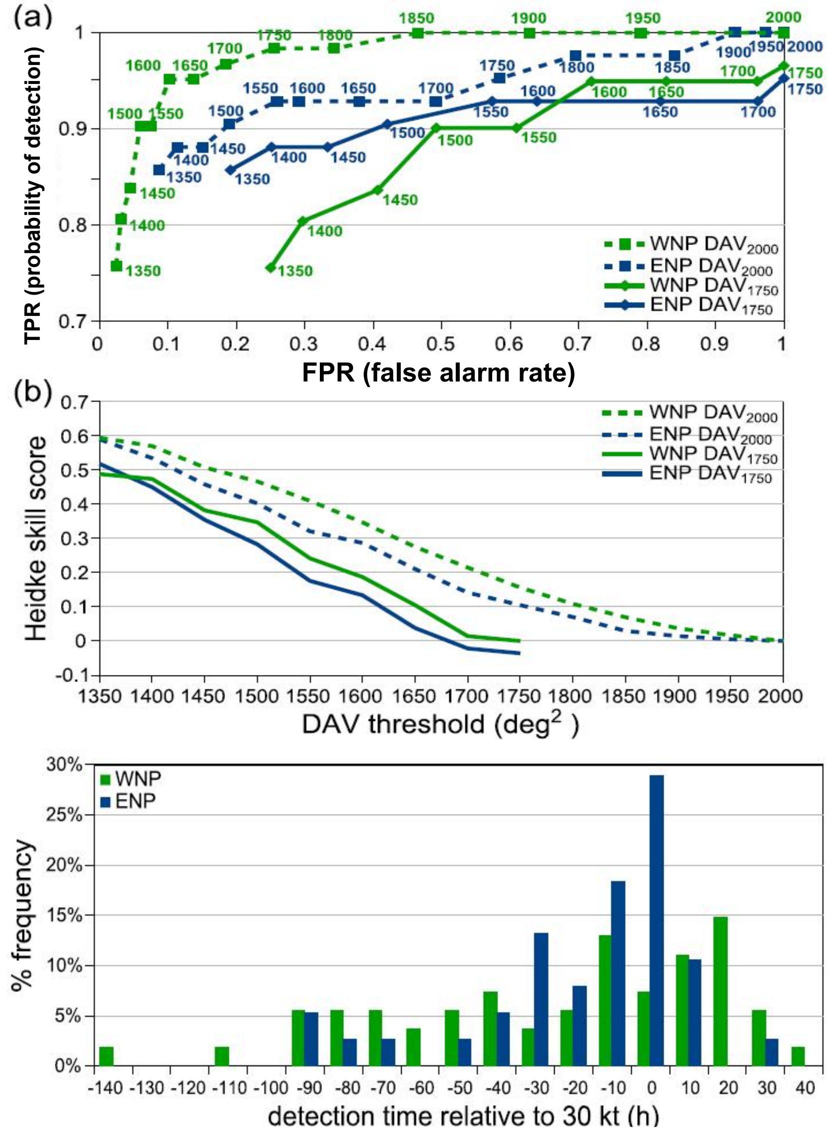
Bin	No. of samples	RMSE (kt)	No. overestimated	No. underestimated
Tropical depression (<34 kt)	10 254	10.0	8796 (86%)	1458 (14%)
Tropical storm (34–63 kt)	10 759	11.5	4198 (39%)	6561 (61%)
Categories 1 and 2 (64–95 kt)	4122	16.6	1405 (34%)	2717 (66%)
Categories 3–5 (>95 kt)	1912	26.1	213 (11%)	1699 (89%)

NA （the North Atlantic）

Bin	No. of samples	RMSE (kt)	No. overestimated (%)	No. underestimated (%)
Tropical storms	9896	11.0	5657 (57)	4239 (43)
Hurricane category 1	2892	12.5	1620 (56)	1272 (44)
Hurricane category 2	1522	12.5	676 (44)	845 (56)
Hurricane category 3	1453	12.6	532 (37)	920 (63)
Hurricane category 4	1513	17.7	309 (20)	1204 (80)
Hurricane category 5	347	32.4	0 (0)	347 (100)

基于DAV-T技术的台风生成监测

Wood et al., 2015



Detection time for DAV threshold of 1750°² in western (green) and eastern (blue) North Pacific.

- ✓ High threshold values of DAV-T (≥1850°²), all WNP TCs are correctly detected, but the false alarm rate(FPR) is also very high.
- ✓ Decreasing the threshold value to 1750°² removes one positive detection but also reduces the false alarm rate to 25.6%
- ✓ The best HSS at 1350°² (0.59) and decreases with increasing DAV thresholds.
- ✓ Lower DAV reflect more organized cloud
- ✓ A score of 0.156 for the 1750°² threshold, which detects all but one developing TC.
- ✓ Developing TCs are detected at a mean (median) time of 32.0h (18.5h) before the TC first intensifies to 30kt in the JTWC best track at 1750°².
- ✓ **Most developing cloud clusters are detected between 40h before and 20h after 30kt is reached, some extreme cases at the tail ends of the distribution.**

上海台风研究所基于MTSAT卫星的台风强度客观算法

Xiaoqin Lu & Hui Yu，2013

- Use MTSAT digital IR data to extract features within 135km related to TC intensity.
- Features computed are:
  - ✓ Number of convective cores
  - ✓ Distance of these cores to TC center
  - ✓ Core blackbody temperature
- Currently being used to aid in post-analysis

$$Vmax = 0.912V_{6h} + 0.009Num + 0.037Lon - 0.035Lat + 0.41DIS_{min} + 0.019TBB_{diff} + 5.467$$

- ✓ V_{6h}： the previous 6-hour old intensity estimate,
- ✓ Num： the number of convective cores
- ✓ Lon： the TC longitude
- ✓ Lat： the TC latitude
- ✓ DIS_{min}： the minimum distance between convective cores and the TC centre
- ✓ TBB_{diff}： the difference between maximum and minimum TBB values

Performance compared to CMA Best Track

TC group	MAE	RMSE	Sample size
Tropical depression	7.2	9.2	91
Tropical storm	5.7	7.3	118
Severe Tropical storm	5.3	6.4	76
Typhoon	5.7	7.0	72
Severe typhoon	15.0	16.0	29
Super typhoon	21.7	22.7	20

基于微波资料的台风强度客观估计算法

Ritchie etal, 2014

- Current satellite sensors and how they are used for TC intensity estimation

Name	Sensor type	Freq	Use
AMSU	Sounder	55 Ghz/ 89 Ghz	Intensity/Structure
SSMIS	Imager	91 Ghz	Eye Information
SSMIS	Sounder	55 Ghz	Intensity
ASMR2	Imager	89 Ghz	Eye Information
TRMM/TMI	Imager	85 Ghz	Intensity/Eye Info
SSMI	Imager	85 Ghz	Eye Information

- Four microwave based TC intensity methods in routine use developed by CIMSS, CIRA/NESDIS and JMA
  - ✓ AMSU --- CIMSS, CIRA/NESDIS, JMA and **CMA（业务试验）**
  - ✓ SSMIS --- CIMSS
  - ✓ ATMS/S-NPP --- CIMSS, CIRA

Sensor	Scanning Strategy	Resolution	Scan Swath
AMSU-A	Cross-Track	48/>80 km (nadir/limb)	2074 km
SSMIS	Conical	37.5 km	1707 km
ATMS	Cross-Track	31.6/>60 km (nadir/limb)	2503 km

Microwave temperature sounder scanning characteristics

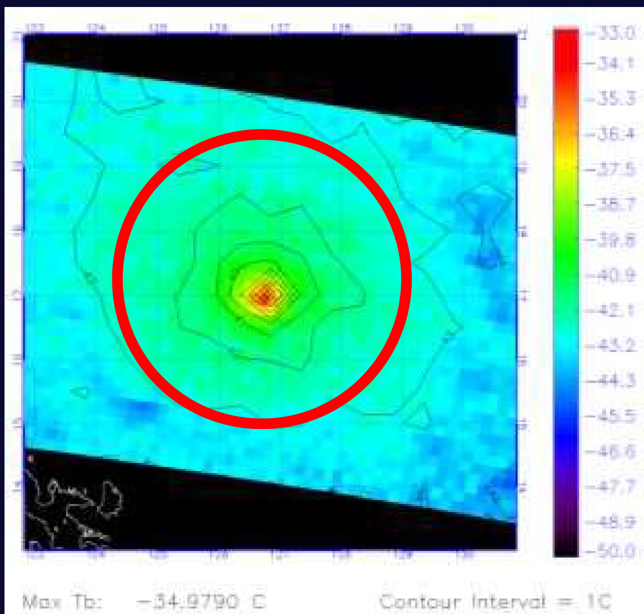
Sensor	Scanning Strategy	Resolution	Scan Swath
AMSU-B/MHS	Cross-Track	16/>30 km (nadir/limb)	2074 km
SSMIS	Conical	12.5 km	1707 km
ATMS	Cross-Track	16/>30 km (nadir/limb)	2503 km

Microwave moisture sounder/imager scanning characteristics

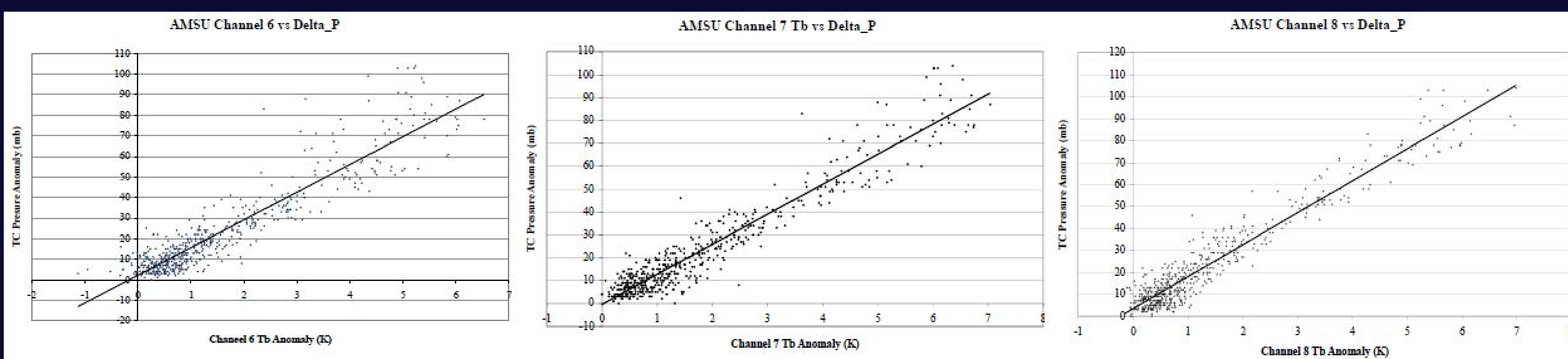
CIMSS AMSU Algorithm

Intensity Estimation: MSLP

Ritchie etal, 2014



- ✓ Compute environmental temperature
- ✓ Locate warmest pixel
- ✓ Calculate Tb anomaly
- ✓ Filter sample to remove all cases where TC eye is smaller than instrument resolution.
- ✓ Match anomalies to aircraft-measured MSLP anomaly
- ✓ Get relationship between Tb anomaly and MSLP anomaly



CIMSS AMSU Algorithm

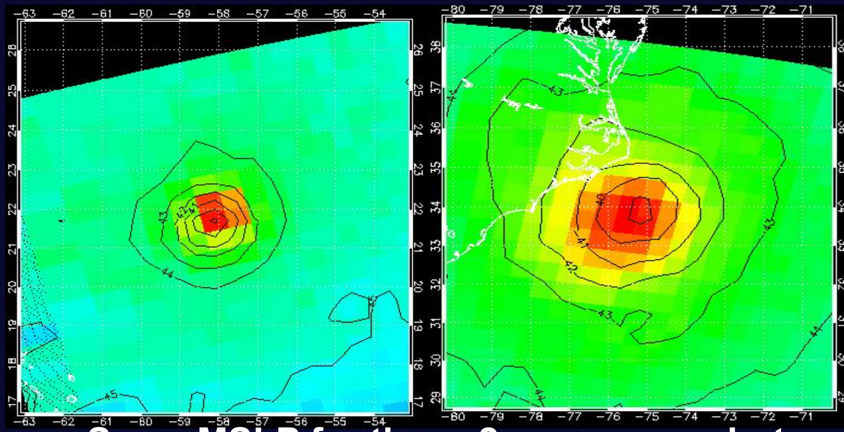
Ritchie etal, 2014

Intensity Estimation: Vmax

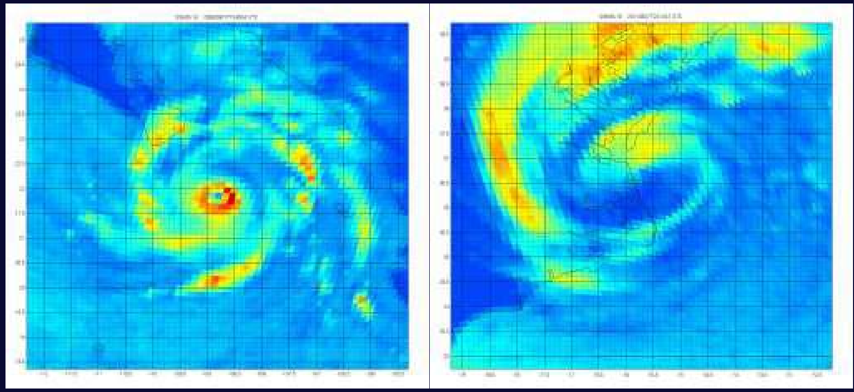
- Primary term = Instrument-measured MSLP anomaly from MSLP algorithm
- Secondary Term = Inner core Tb gradient
- Third term = Some measure of convective organization/magnitude
  - ✓ This relates to the efficiency of mixing momentum to the surface.
  - ✓ Derived from 89-91 GHz imagery

    For AMSU use AMSU-B.

    For SSMIS/ATMS use ARCHER



Same MSLP for these 2 warm cores but different Vmax



same MSLP for these 2 storms but different Vmax

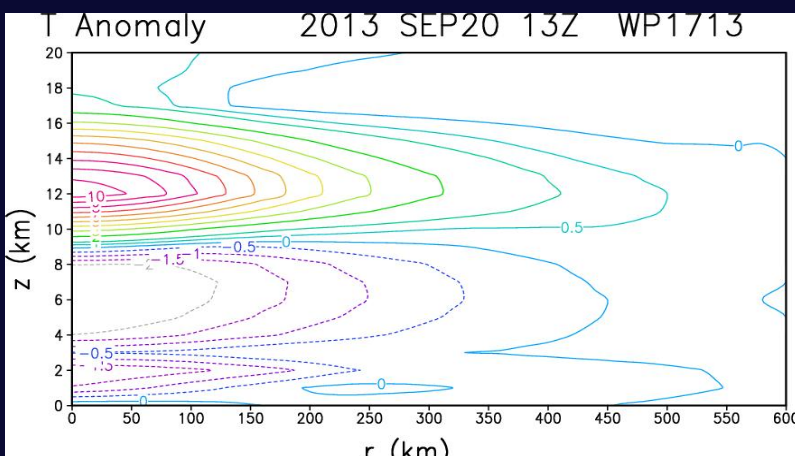
- Finally: Correct Vmax for storm motion

  latitude & TC size

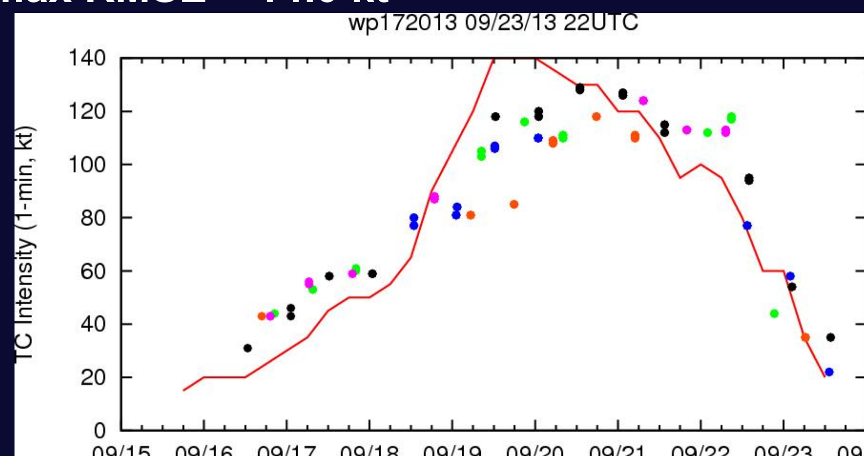
CIRA AMSU Algorithm

Ritchie etal, 2014

- Statistical-based temperature retrieval at 23 vertical level
- Tbs are corrected to account for AMSU-derived Cloud Liquid Water（CLW） and Ice Scattering Attenuation
- 6 Parameters Used in Multiple Regression to Estimate MSLP and Vmax
  - ✓ Maximum Tb anomaly
  - ✓ Scan resolution
  - ✓ Tangential wind at z = 5km
  - ✓ RMW at z = 3km
  - ✓ CLW
  - ✓ Derived pressure drop from 0-600 km
- Estimates of MSLP, Vmax and structure parameters（R34, R50 and R64）
- Performance
  - ✓ best for storms < 65 knots
  - ✓ Too weak bias when TC eye is small
  - ✓ Vmax MAE = 10.8 kt
  - ✓ Vmax RMSE = 14.0 kt



Temperature anomaly for Typhoon Usagi at 13UTC September 20 , 2013



CIRA AMSU Estimates for Typhoon Usagi at 13UTC September 20 , 2013

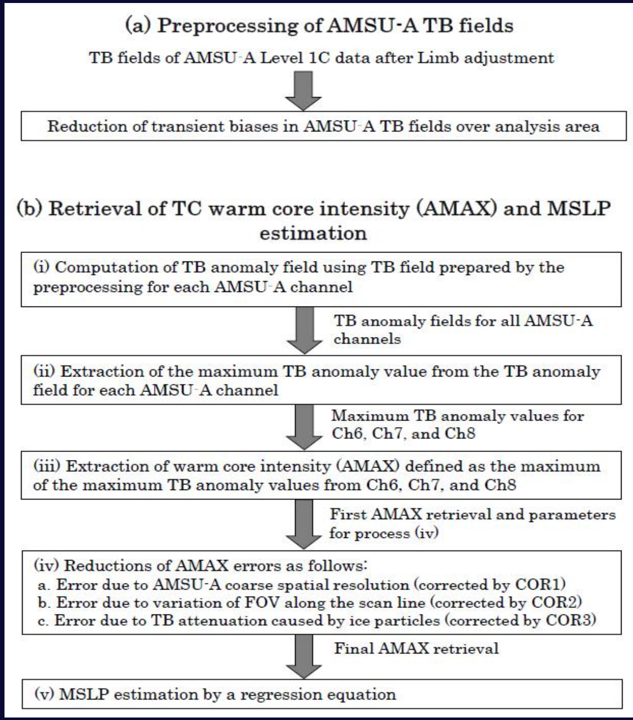
JMA AMSU Algorithm

Oyama, 2014

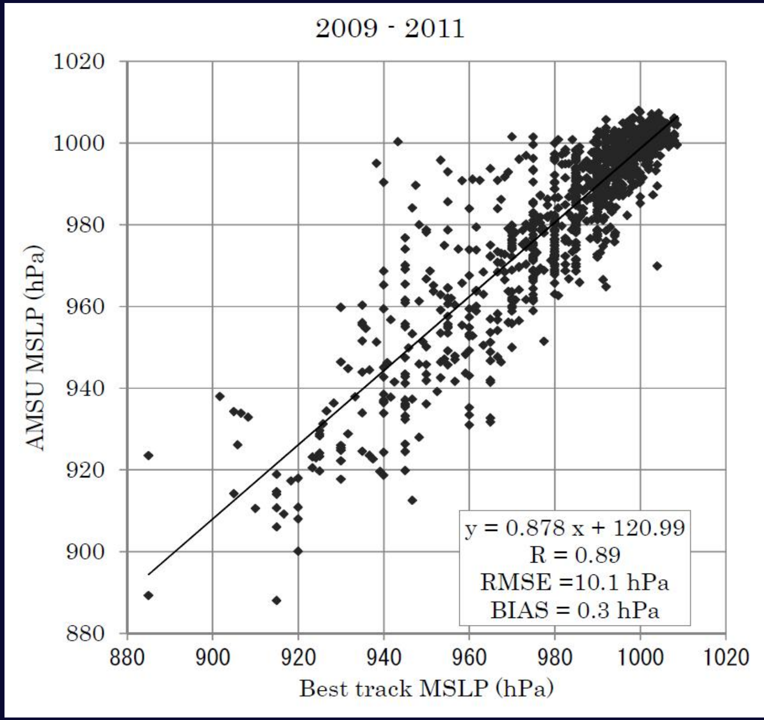
- Tb Anomalies derived from AMSU Channels 6-8
- Anomalies matched to 22 TCs in 2008 and tested against 57 TCs in 2009-2011
- Algorithm uses maximum anomaly from AMSU channels 6-8
- Bias correction is applied to estimates to account for position offset of AMSU Field of View（FOV）relative to true TC position based on JMA Best Track

$$P_o^{eye} \cong P_0^{env}[1 - Constant \times (<T^{eye}> - <T^{env}>)]$$

$<T^{eye}>$：台风中心的垂直平均温度； $<T^{env}>$：环境平均温度； P_0^{eye}：台风中心最低气压； P_0^{env}：环境气压



Flow charts showing modules for (a) the preprocessing of AMSU-A TB fields, and (b) the retrieval of TC warm core intensity (AMAX) and MSLP estimation



Scatter plots between AMSU MSLPs and BT MSLPs for 1,029 samples of TCs from 2009 to 2011. R is the correlation coefficient between AMSU MSLPs and BT MSLPs

国家气象中心基于AMSU的强度客观估计算法（2015）

- NCEP/AMSU资料和NCEP/FNL再分析资料
- 包括GFS资料转换、台风人工分析信息录入、AMSU资料提取、AMSU温度反演、台风流场反演和强度估计等5个模块
- 台风三维温度场反演产品、台风三维风场反演产品、台风中心位置、台风强度估计和台风不同方位的7/10/12级大风圈半径分析产品

主要技术路线

椭圆形平衡方程

$$f\nabla^2\psi + 2(\psi_{xx}\psi_{yy} - \psi_{xy}^2) + \psi_x f_x + \psi_y f_y = \nabla^2\phi$$

ω方程

$$\nabla^2(\sigma\omega) + f\zeta_a \frac{\partial^2\omega}{\partial p^2} = f\frac{\partial}{\partial p}(V_\varphi + V_\chi)\bullet\nabla\zeta + \frac{R}{p}(\nabla^2 V_\varphi + \nabla^2 V_\chi)\bullet\nabla T - f\frac{\partial}{\partial p}(\zeta\nabla^2\chi)$$

$$+ f\frac{\partial}{\partial p}(\omega\frac{\partial\zeta}{\partial p}) + f\frac{\partial}{\partial p}(\nabla\omega\bullet\nabla\frac{\partial\varphi}{\partial p}) - \frac{R}{C_P P}\nabla^2 Q$$

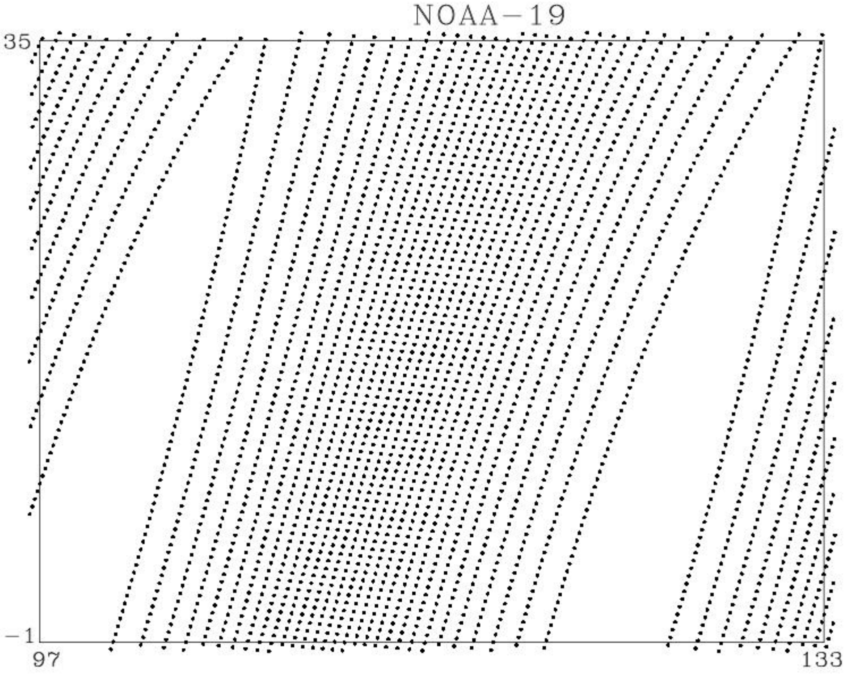
边界条件

$$\nabla^2\chi + \frac{\partial\omega}{\partial p} = 0$$

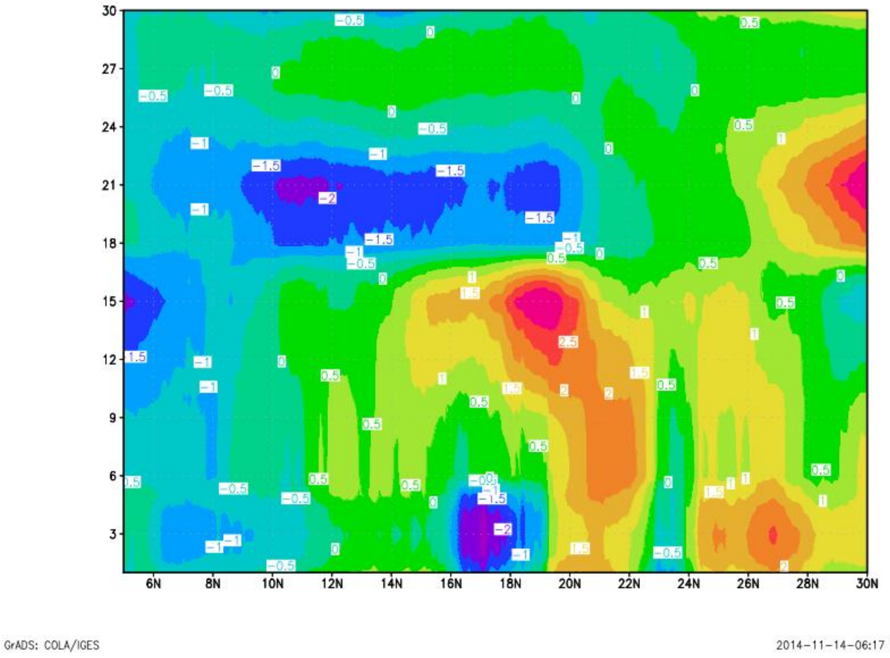
其中ϕ为位势高度，ψ为流函数，$\sigma = -(RT/p\theta)(\partial\theta/\partial p)$，$Q$为非绝热加热率。

1409号超强台风“威马逊”风场反演结果

资料：2014年7月17日18时AMSU-A资料和NCEP/FNL资料

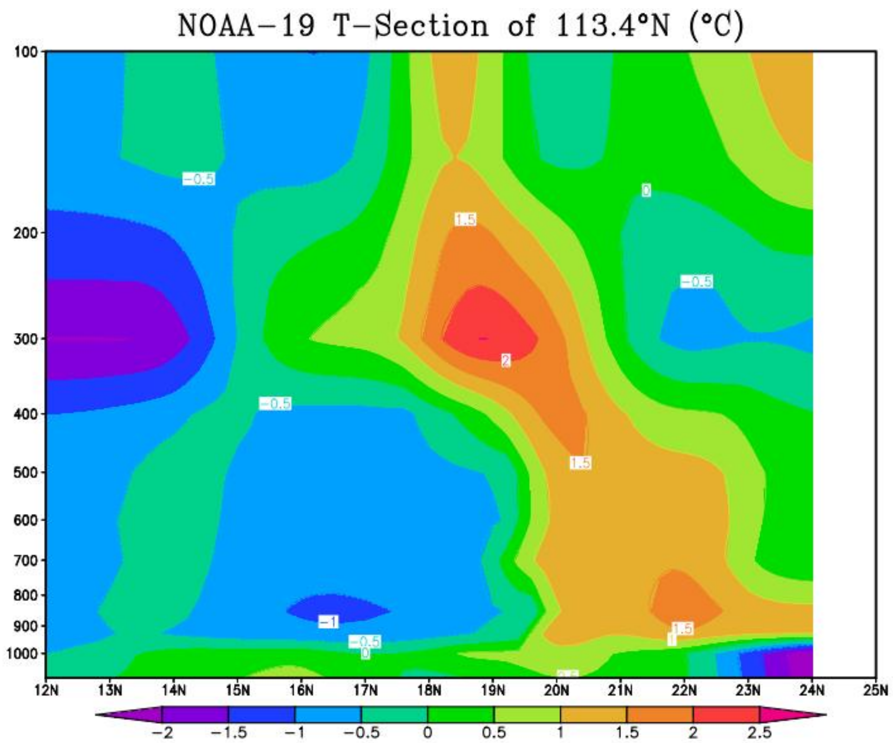


AMSU-A资料数据的覆盖范围

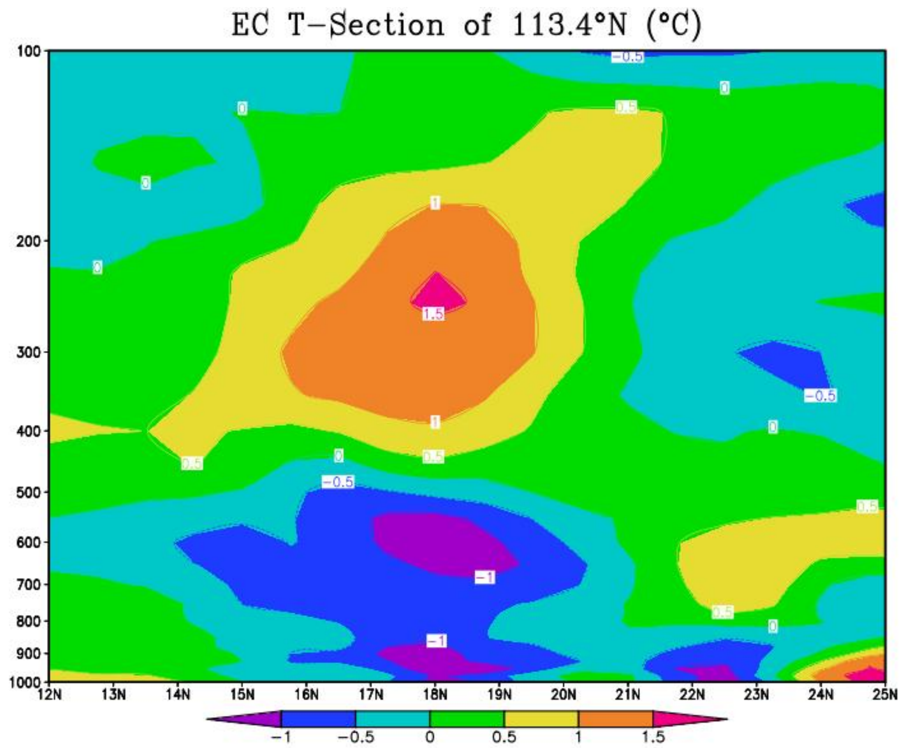


AMSU-A资料温度反演结果

台风三维温度场暖心距平反演结果分析

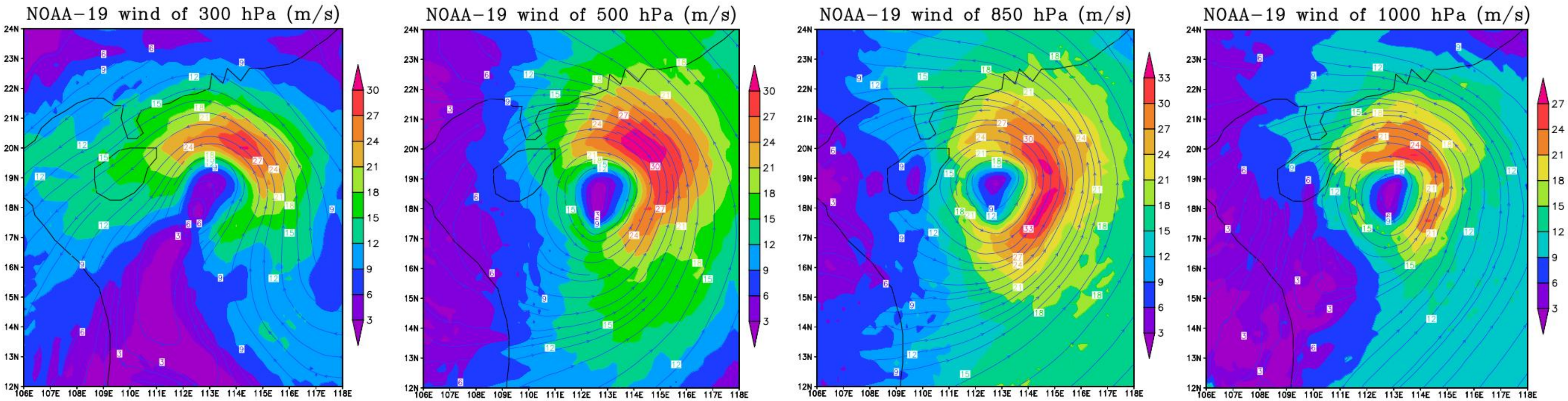


基于AMSU大气温度廓线资料反演的“威马逊”暖心距平

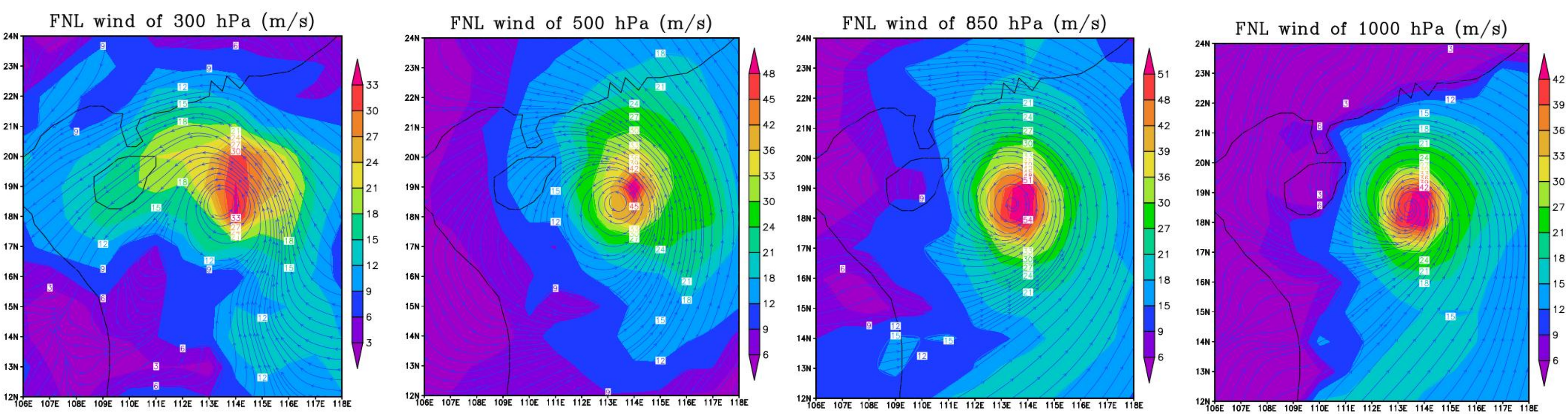


基于EC/ERA-Interim资料计算的“威马逊”暖心距平

台风三维风场反演结果分析

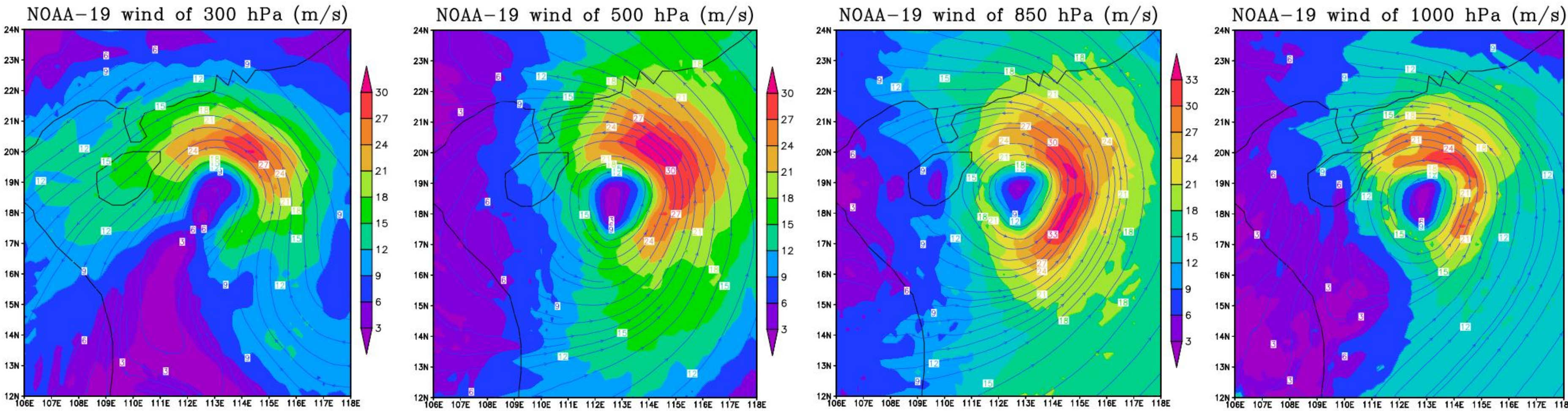


基于AMSU资料反演的“威马逊”风场分析

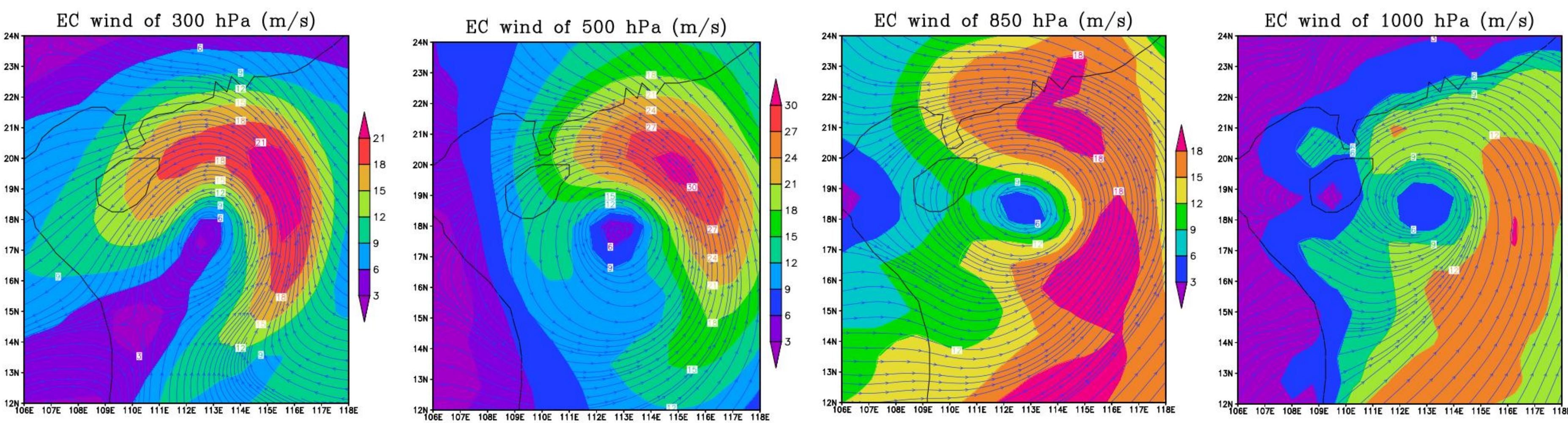


NCEP-FNL再分析场的“威马逊”风场分析

台风三维风场反演结果分析

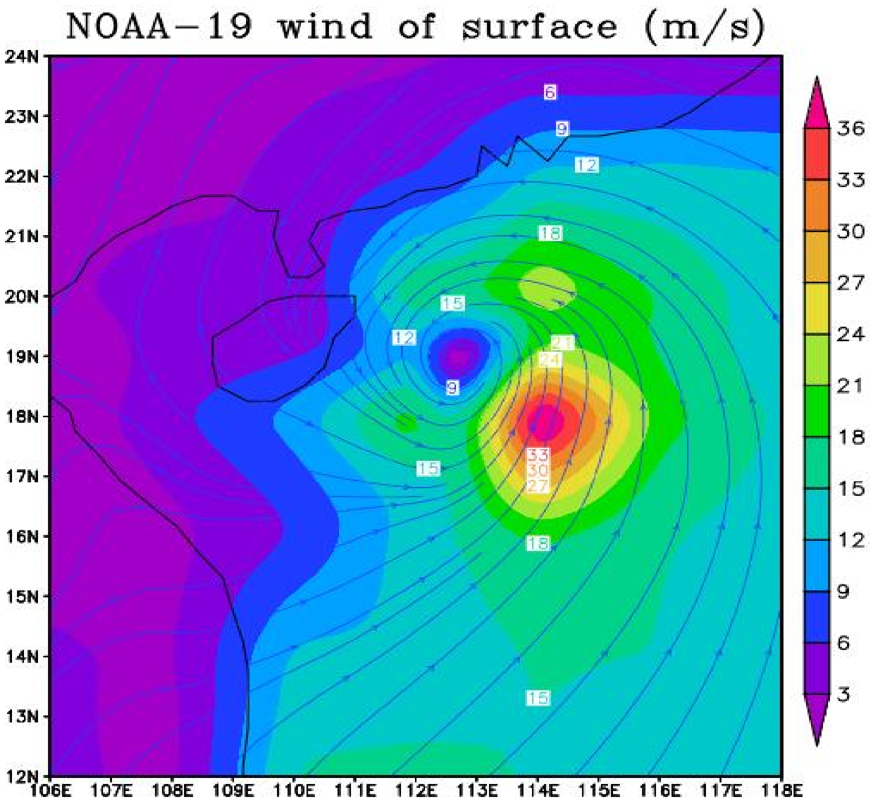


基于AMSU资料反演的“威马逊”风场分析

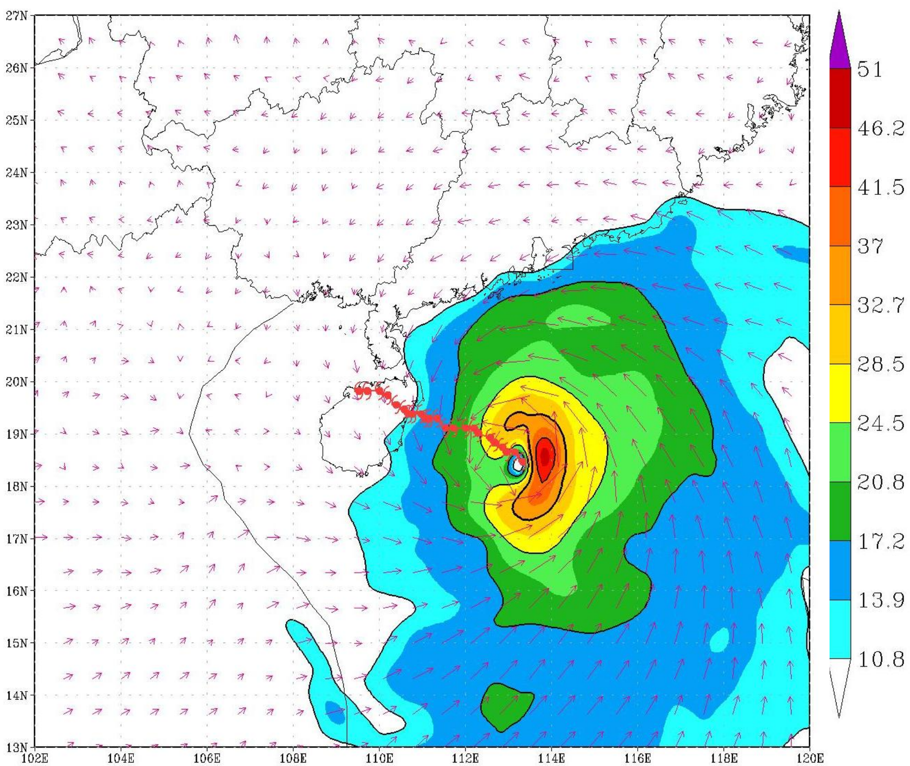


EC ERA-Interim再分析场的“威马逊”风场分析

台风海平面风场反演结果分析



基于AMSU大气温度廓线资料反演的
“威马逊”海平面10m风场



基于雷达资料快速同化的
“威马逊”海平面10m风场分析

台风强度和不同方位大风圈半径估计方法和结果分析

估计台风强度和大风圈半径分布涉及的计算因子（DEMUTH，2006）

强度估计因子	计算因子说明
MINP	Min surface pressure (hPa) at storm center
DP0	Pressure drop (hPa) at the surface from *r* 5 600 to 0 km
DP3	Pressure drop (hPa) at *z* 5 3 km from *r* 5 600 to 0 km
TMAX	Max temperature perturbation (8C), calculated as the temperature at *r* 5 600 km minus the temperature at each radius
ZMAX	Height (km) of max temperature perturbation (TMAX)
SS	Resolution (km) of AMSU footprint at storm center (swath spacing)
VMX0	Max wind speed (kt) at the surface
RMX0	Radius (km) of max winds at the surface
VMX3	Max wind speed (kt) at *z* 5 3 km
RMX3	Radius (km) of max winds at *z* 5 3 km
VBI0	Tangential winds at surface, averaged from *r* 5 0 to 250 km
VBI3	Tangential winds at *z* 5 3 km, averaged from *r* 5 0 to 250 km
VBI5	Tangential winds at *z* 5 5 km, averaged from *r* 5 0 to 250 km
VBO0	Tangential winds at surface, averaged from *r* 5 250 to 500 km
VBO3	Tangential winds at *z* 5 3 km, averaged from *r* 5 250 to 500 km
VBO5	Tangential winds at *z* 5 5 km, averaged from *r* 5 250 to 500 km
CLWAVE	CLW content (mm), averaged from *r* 5 0 to 100 km
CLWPER	Percentage of area with CLW values .0.5 mm from *r* 5 0 to 300 km
LAT*	Lat from NHC at storm center, interpolated to AMSU swath time

19个因子包括由AMSU-A大气温度廓线资料反演的气压场、风场、温度距平以及扫描范围和云水率等，其中，与气压场、风场、温度距平相关的因子是利用三维反演变量通过方位角平均计算得到。

台风强度和不同方位大风圈半径估计结果分析

台风“威马逊”中心位置、台风强度和不同方位大风圈半径反演估计结果与台风实时监测分析结果对比

		AMSU 风场反演系统计算结果	台风实时业务监测分析结果	误差
台风中心位置		18.46°N、113.34°E	18.4°N、113.4°E	9.33km
台风强度	中心风速（m/s）	45	50	5
	中心气压（hPa）	958	940	18
台风大风圈半径（单位：海里）	7 级风圈半径	105（NW） 119（NE） 78（SW） 86（SE）	115（NW） 115（NE） 110（SW） 110（SE）	10（NW） 4（NE） 32（SW） 24（SE）
	10 级风圈半径	53（NW） 58（NE） 43（SW） 46（SE）	70（NW） 70（NE） 70（SW） 70（SE）	17（NW） 12（NE） 27（SW） 24（SE）
	12 级风圈半径	34（NW） 37（NE） 29（SW） 31（SE）	30（NW） 30（NE） 30（SW） 30（SE）	4（NW） 7（NE） 1（SW） 1（SE）

反演估计得到的“威马逊”中心位置、中心风速、中心气压、7级风圈半径、10级风圈半径和10级风圈半径的误差分别为9.33公里、5米/秒、18百帕、4~24海里、12~27海里和1~7海里，其误差范围均在业务监测分析可接受的范围，基本与美国利用AMSU-A大气温度廓线资料反演精度相当。

台风强度和不同方位大风圈半径估计结果分析

(美国RAMMB)

台风“威马逊”中心位置、台风强度和不同方位大风圈半径反演估计结果与台风实时监测分析结果对比

		美国 RAMMB 风场反演系统计算结果	台风实时业务监测分析结果	误差
台风中心位置		—	18.4°N、113.4°E	—
台风强度	中心风速（m/s）	43	50	7
	中心气压（hPa）	973.4	940	33.4
台风大风圈半径（单位：海里）	7 级风圈半径	125（NW） 130（NE） 85（SW） 120（SE）	115（NW） 115（NE） 110（SW） 110（SE）	10（NW） 15（NE） 25（SW） 10（SE）
	10 级风圈半径	80（NW） 80（NE） 50（SW） 70（SE）	70（NW） 70（NE） 70（SW） 70（SE）	10（NW） 10（NE） 20（SW） 0（SE）
	12 级风圈半径	55（NW） 55（NE） 0（SW） 35（SE）	30（NW） 30（NE） 30（SW） 30（SE）	25（NW） 25（NE） 30（SW） 5（SE）

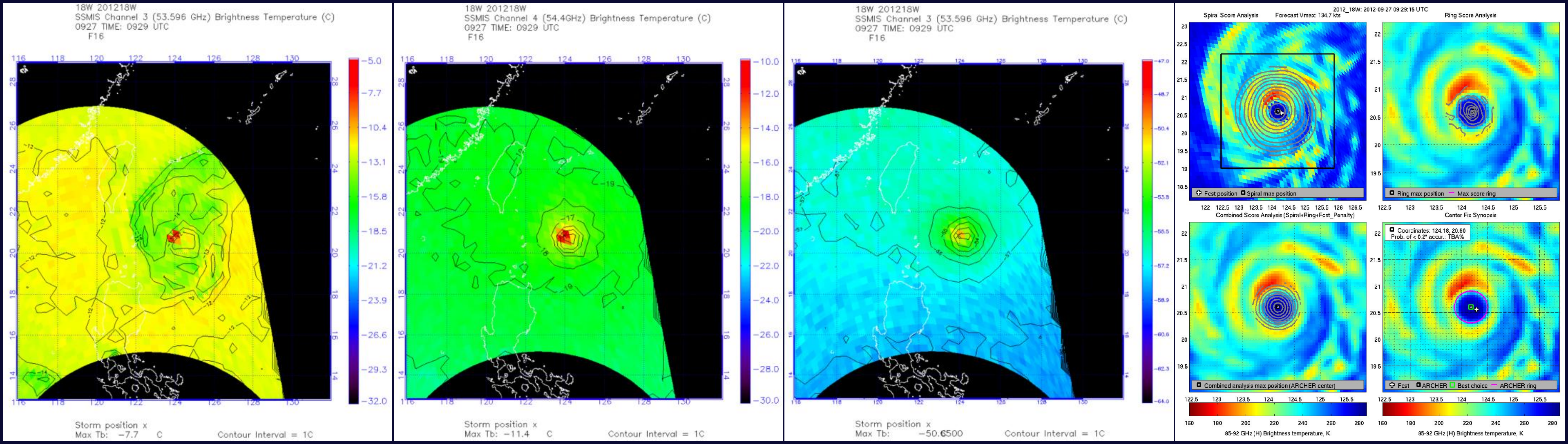
美国RAMMB反演估计得到的“威马逊”中心风速、中心气压、7级风圈半径、10级风圈半径和10级风圈半径的误差分别为7米/秒、33.4百帕、10~25海里、0~20海里和5~30海里。

CIMSS Objective Intensity Algorithm Based on Special Sensor Microwave Imager Sounder (SSMIS)

Ritchie etal, 2014

*SSMIS_Vmax = 0.7*p_anom + 2.0*max_grad + 0.4*archer_score + 37*

- ✓ p_anom： SSMIS derived MSLP anomaly,
- ✓ max_grad： the maximum Tb gradient determined within 120km of the TC centre
- ✓ archer_score： the intensity score determined by ARCHER



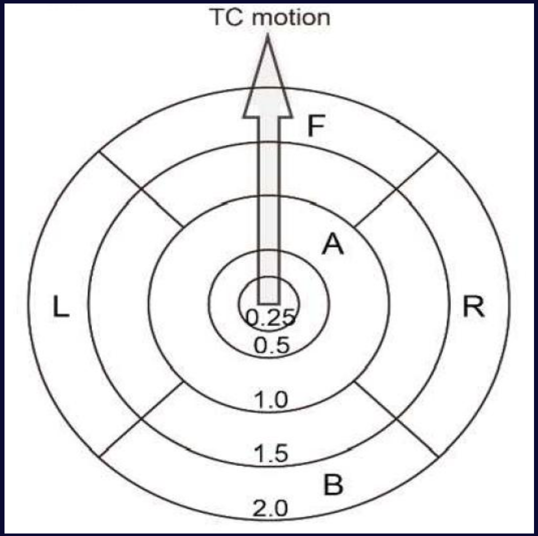
SSMIS channels 3, 4 and 5 show the TC warm core anomaly and ARCHER panel based on SSMIS 91GHz

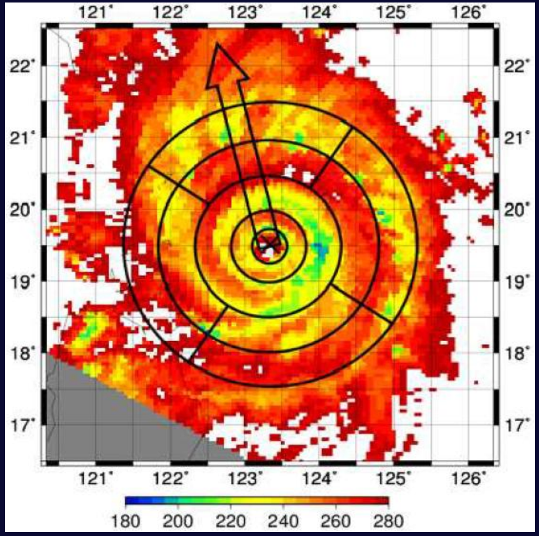
JMA Objective Intensity Algorithm based on TRMM/TMI Brightness Temperature Distribution

Sakuragi et al, v2014

- ✓ Cluster Analysis is performed for 19, 37 and 85 GHz Imagery
- ✓ Clusters are located either within a radial distance from the TC center or within quadrants aligned with the TC motion vector
- ✓ Regression analysis of the Tb associated with these clusters is then performed
- ✓ Some subjective re-classifying of the clusters is still

- ✓ **JMA introduced this method in 2014 and further refinements of the method are expected.**
- ✓ **In future, it may be expanded to AMSR2 or GPM data**





JMA TRMM/TMI cluster parameter regions along with an example TRMM PCT85 image for Typhoon Songda 0709 UTC May 27, 2011

CIMSS SATellite CONsensus Method （SATCON）

- 4 Members: CIMSS ADT, CIRA and CIMSS AMSU and CIMSS SSMIS algorithms
- Weighting each member according to the past statistical performance
- In future, S-NPP ATMS sounder

Ritchie etal, 2014
Velden & Herndon, 2014

$$\text{SATCON} = \frac{W_1W_2(W_1+W_2)E_3 + W_1W_3(W_1+W_3)E_2 + W_3W_2(W_3+W_2)E_1}{W_1W_2(W_1+W_2) + W_1W_3(W_1+W_3) + W_3W_2(W_3+W_2)}$$

W_n = weight of method n E_n = estimate of method n

Final SATCON = 0.25*P-W_MSW + 0.75*SATCON_MSW


Return to Homepage
Explanation Page

References
Search Schwerdtfeger Library by typing SATCON as search term

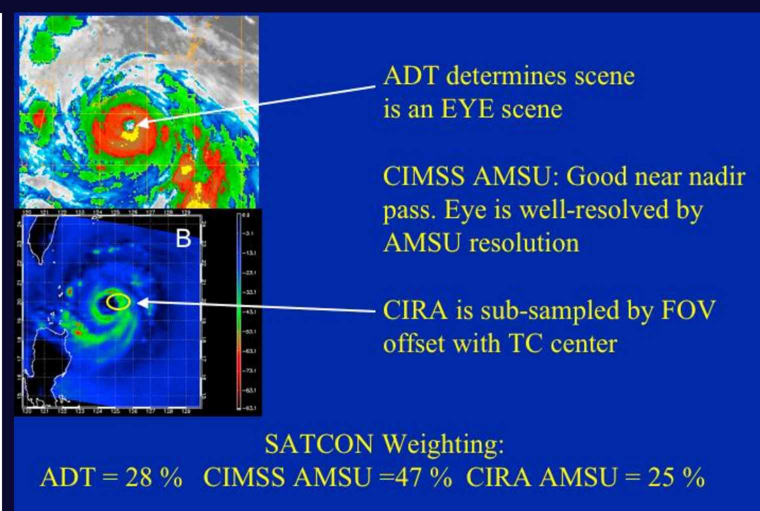
SATCON Change Log

UW-CIMSS
SATCON INTENSITY ESTIMATES

2016 Intensity Estimates

Atlantic: 01L ALEX
East Pacific
Central Pacific: 01C PALI
West Pacific
Indian Ocean
Southern Hemisphere (2016): 01P, 02P, 03S ANNABELLE, 04P, 05S BOHALE, 06P ULA, 07P VICTOR, 08S CORENTIN, 09S STAN, 10S DAYA, 11P WINSTON, 12P, 13S URIAH, 14P YALO, 15S EMERAUDE, 16P, 17S, 18P ZENA, 19S FANTALA, 20P AMOS

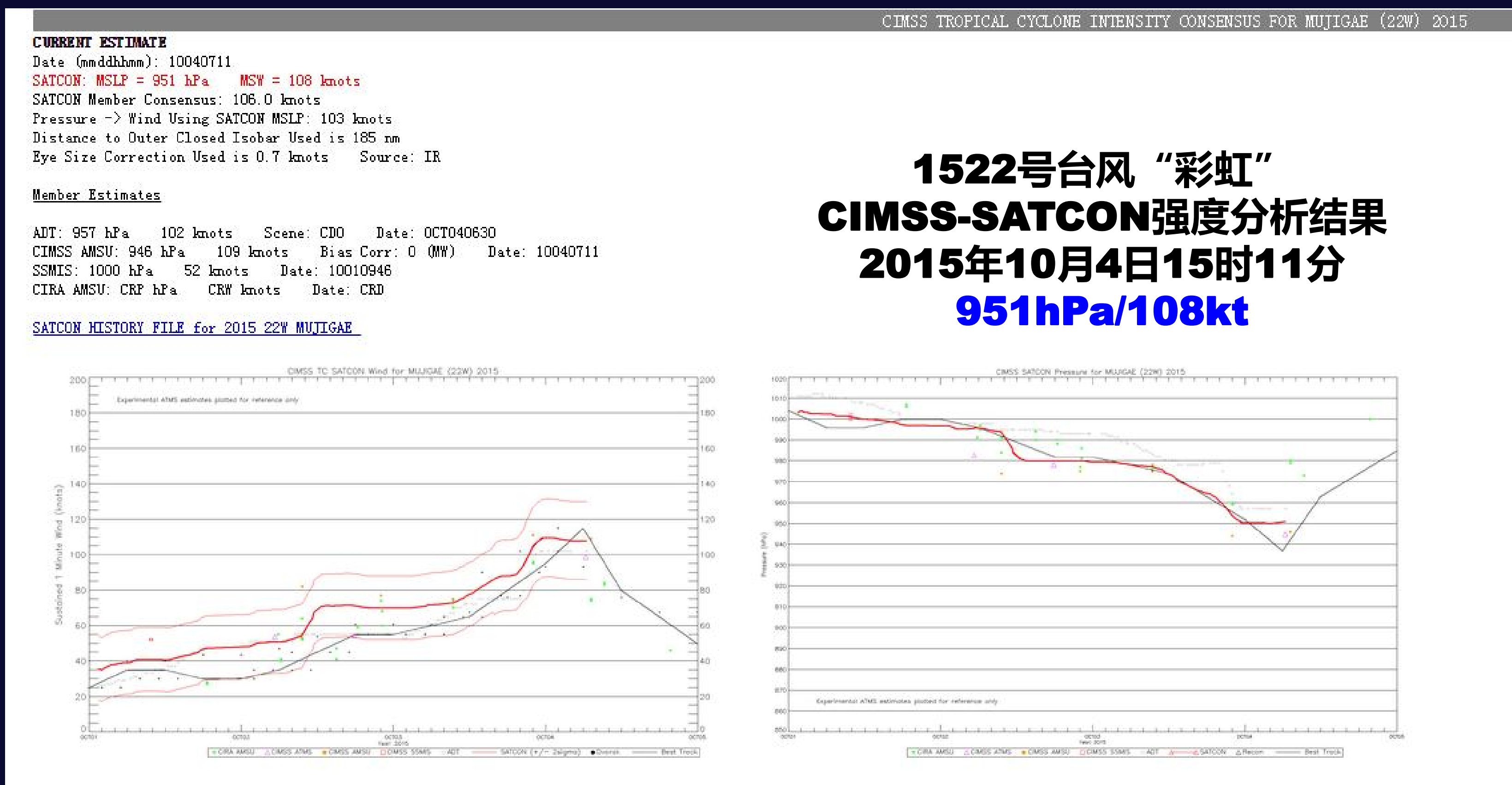
CIMSS SATCON Web



CIMSS SATellite CONsensus Method （SATCON）

- 4 Members: CIMSS ADT, CIRA and CIMSS AMSU and CIMSS SSMIS algorithms
- Weighting each member according to the past statistical performance
- In future, S-NPP ATMS sounder

Ritchie etal, 2014
Velden & Herndon, 2014



CIMSS SATCON Performance Results

Ritchie etal, 2014
Velden & Herndon, 2014

Homogenous N=275 compared to NHC recon-aided Best Track
Subj. Dvorak is the average subjective operational Dvorak

MSW (Kts)	CIMSS AMSU	CIMSS ADT	CIRA AMSU	CIMSS SSMIS	SATCON	Subj. Dvorak (Operational)
BIAS	-1.0	-0.6	-5.2	- 0.6	-0.9	0.2
AVG ERROR	10.0	9.0	12.1	8.3	6.7	7.0
RMSE	12.4	11.6	16.0	10.5	8.3	9.2

WPAC Performance
Aircraft verification during TPARC-08 and ITOP-2010

N = 18	SATCON Vmax	Dvorak Vmax
BIAS	- 1.5	- 4.9
AVG ERROR	8.4	10.8
RMSE	9.9	13.1

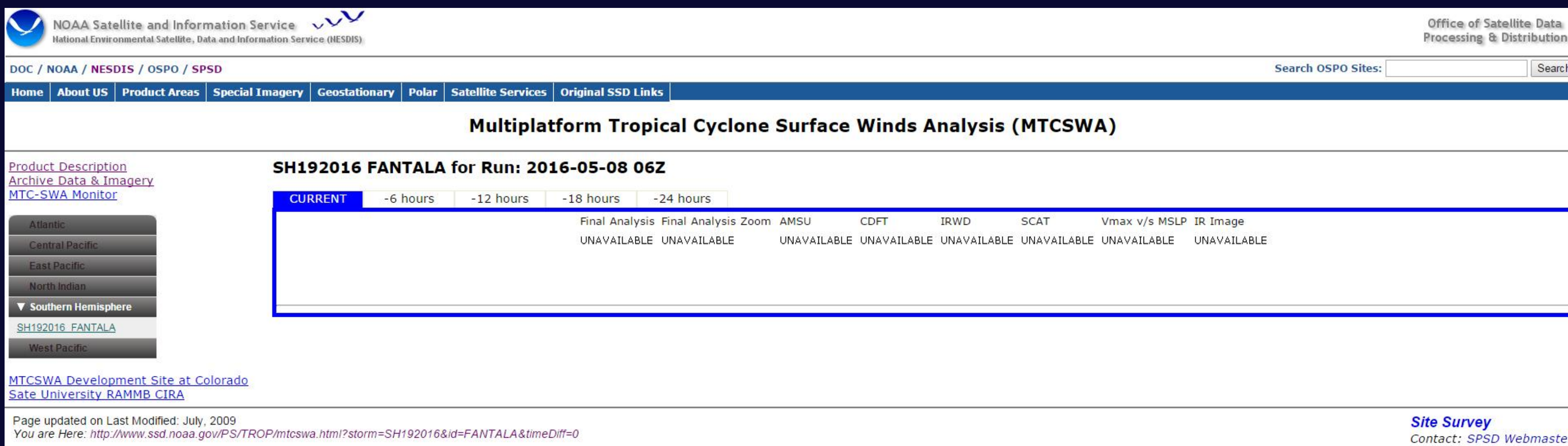
SATCON Vmax (上，knots) and MSLP (下，hPa) performances compared to individual members 2006-2012 with the NHC best track

N=1467	CIMSS AMSU	CMISS ADT	CIMSS SSMIS	**SATCON**
BIAS	-1.0	0.2	-1.0	**-0.9**
MAE	9.8	9.3	8.2	**6.9**
RMSE	12.1	12.0	10.4	**8.6**

N=1467	CIMSS AMSU	CMISS ADT	CIMSS SSMIS	**SATCON**
BIAS	0.7	3.4	1.4	**0.6**
MAE	4.6	9.0	5.9	**4.2**
RMSE	5.9	12.1	7.6	**5.4**

CIRA Multi-Platform Tropical Cyclone Surface Wind Analysis（MTCSWA）

- ✓ **NOAA/NESDIS**研发并实时发布的高分辨多平台台风海表风场资料
- ✓ 资料融合了多种卫星资料，包括**GOES**、**Meteosat**、**QuickScat**、**RapidSCAT**、**ASCAT**、**WindSat**、**SSM/I**以及**AMSU**反演风场和云导风资料。

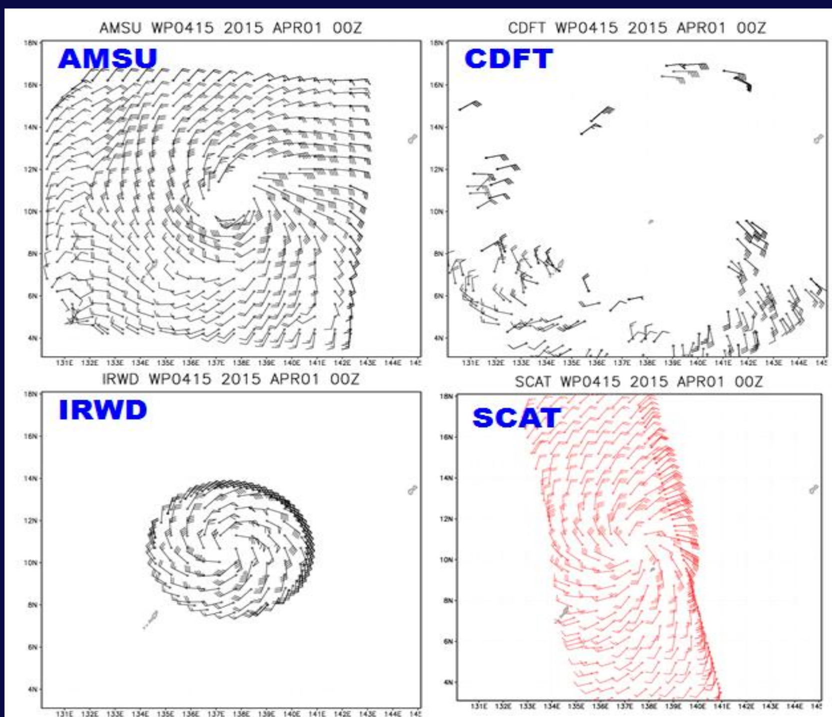


- ✓ **2015**年，利用**MTCSWA**资料，国家气象中心开展台风不同方位大风圈分析业务产品研发，研发台风不同方位**7/10/12**级风圈产品，为台风大风圈分析业务提供客观定量分析技术支持。

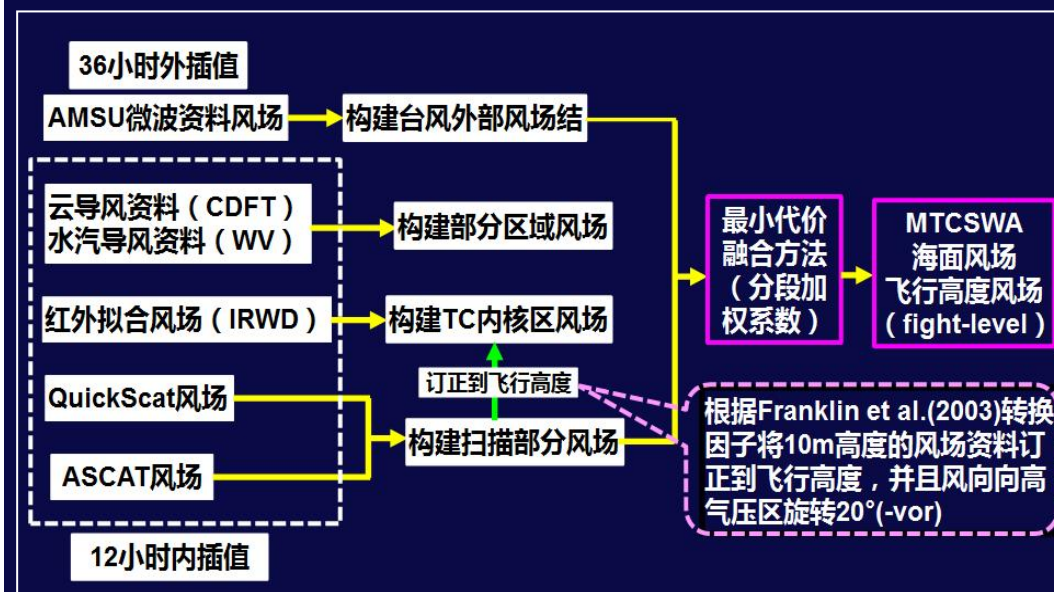
MTCSWA台风海表风场资料业务应用

融合多种卫星资料，通过融合技术构建台风10m风场

- ✓ 以台风中心为原点的7.5度为半径范围内
- ✓ 0.1×0.1度空间分辨率，约10km



主要技术流程



MTCSWA台风海表风场资料业务应用

提供逐6小时台风风圈特征分析参考产品

- ✓ 包括文本产品：各级风圈半径（km）、最大风速半径等
- ✓ 图片产品：不同颜色分别代表7、10、12级范围

WP09　2015071000

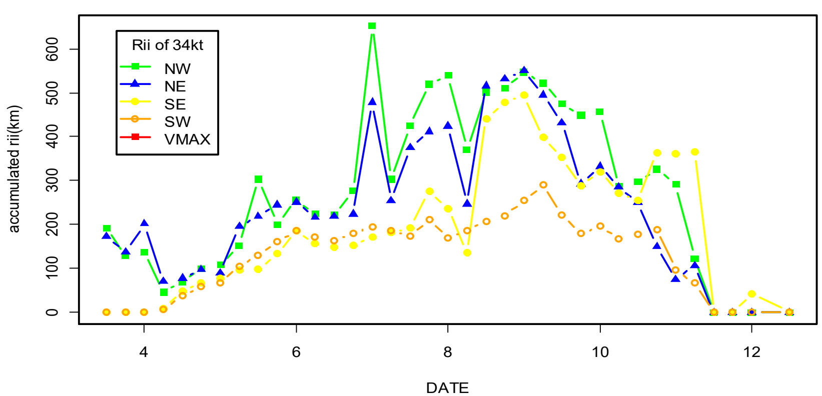
lat/lon of TC center:　25.5　125.6

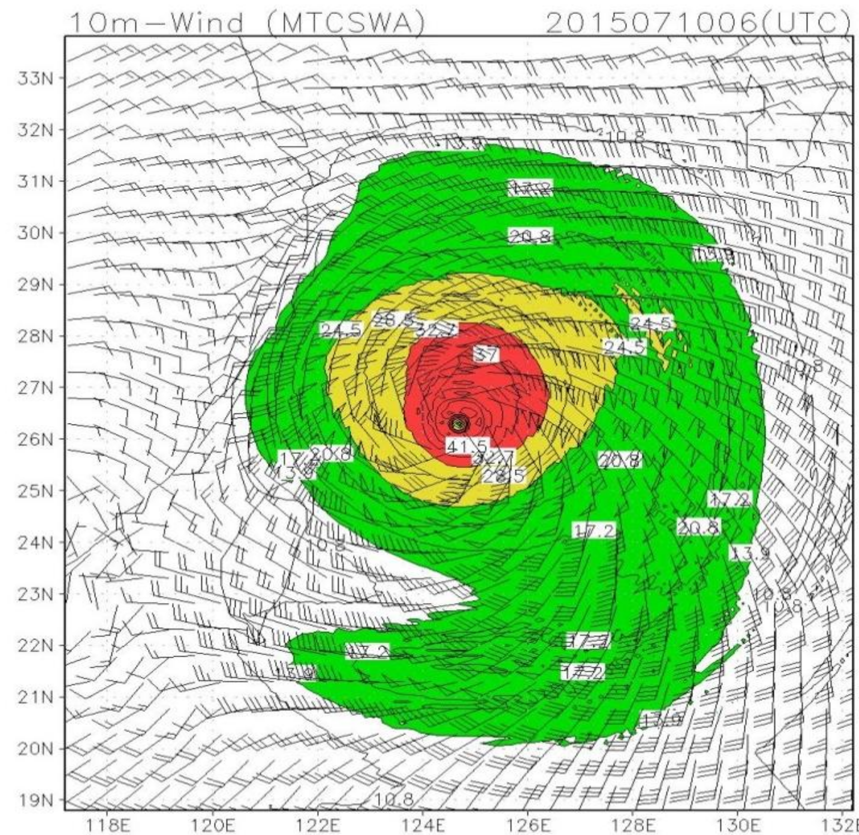
max value of wspd profile(m/s):　56.0

radii of max value in wspd profile(km):　30

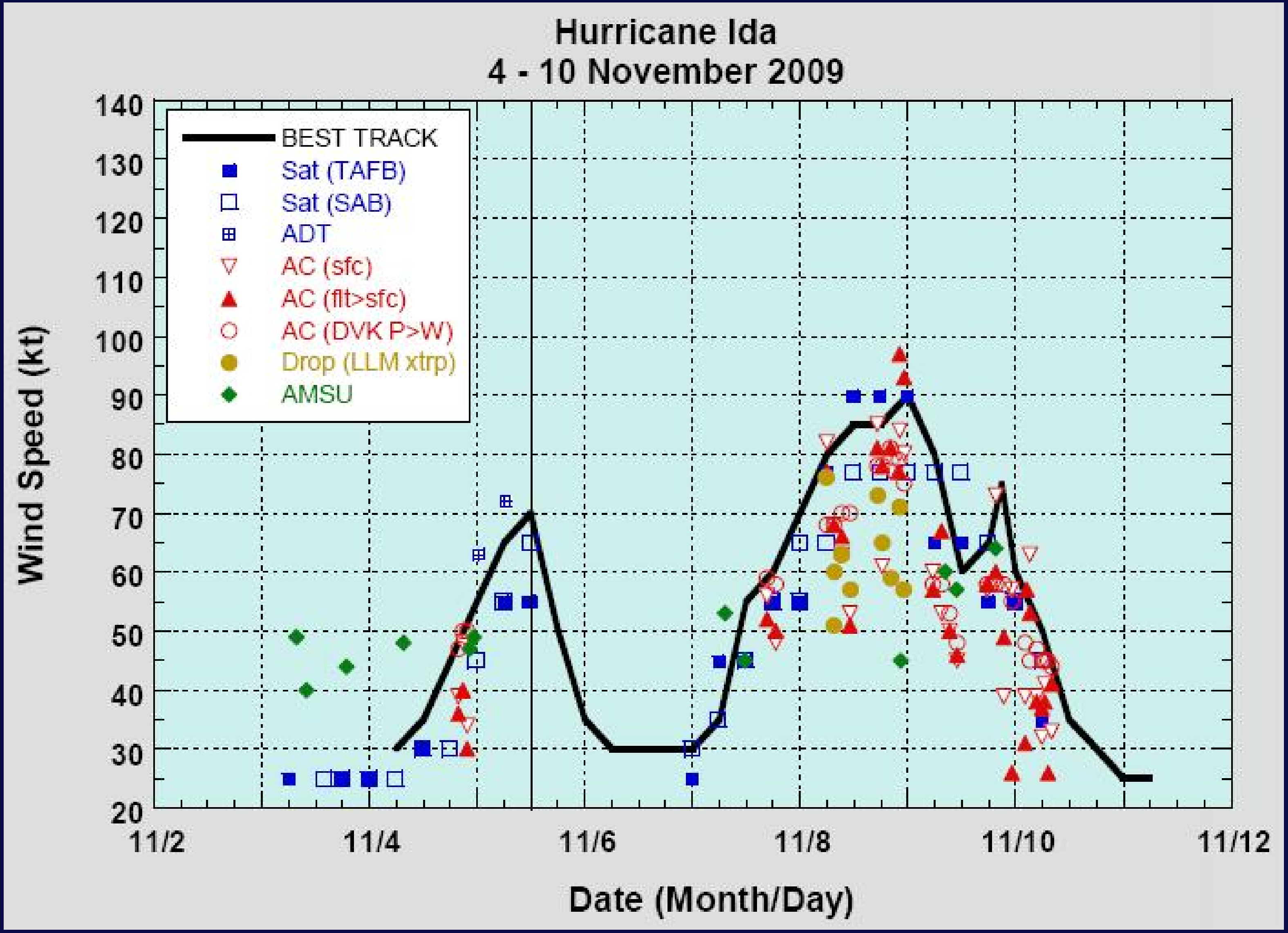
	NE	SE	SW	NW
radii of 28kts:	500	500	402	464
radii of 34kts:	500	500	352	439
radii of 50kts:	442	301	177	308
radii of 64kts:	320	114	74	158

R34 at four quadrants



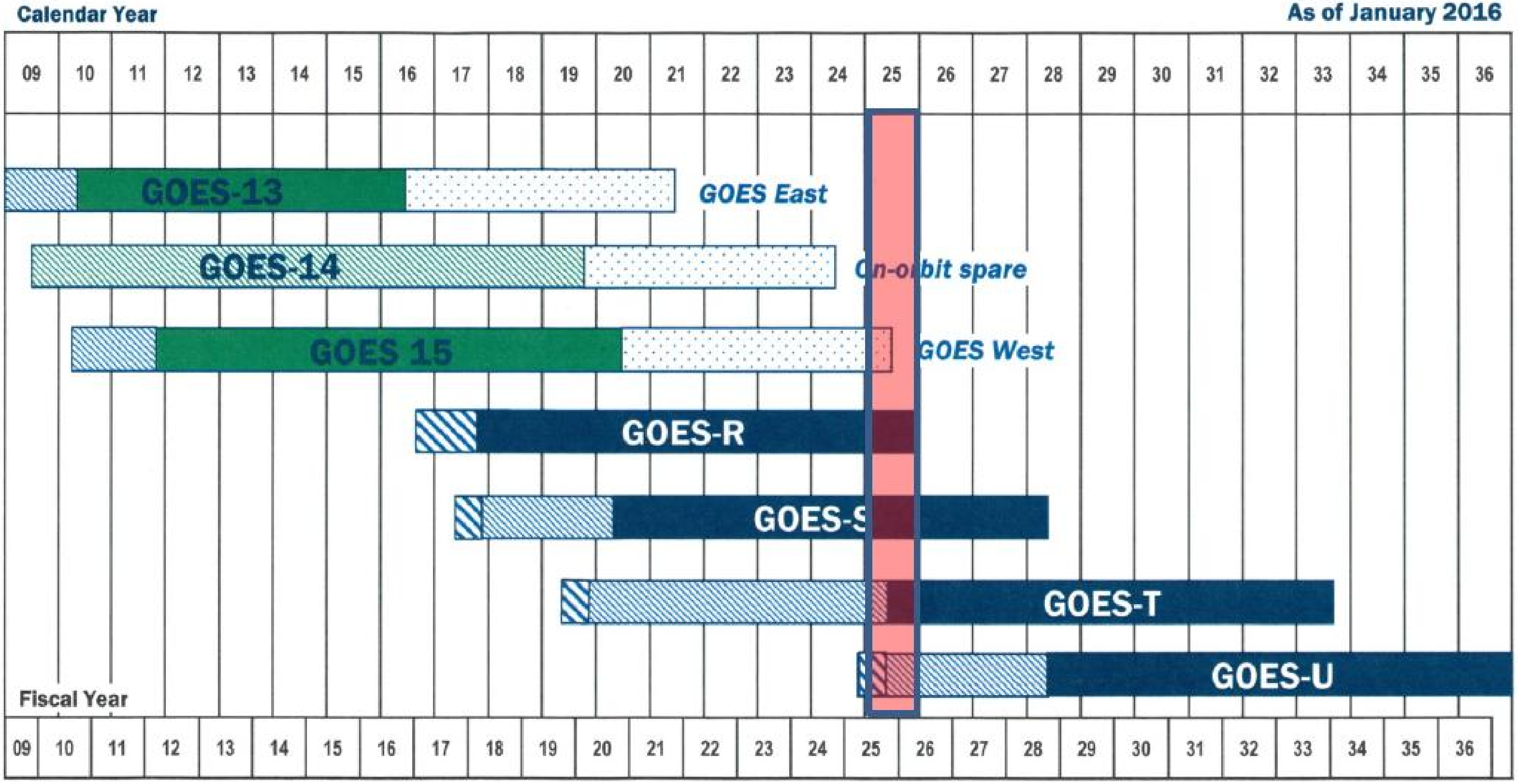


多通道资料的融合应用



Joe Courtney，2011

NOAA Geostationary Satellite Programs
Continuity of Weather Observations

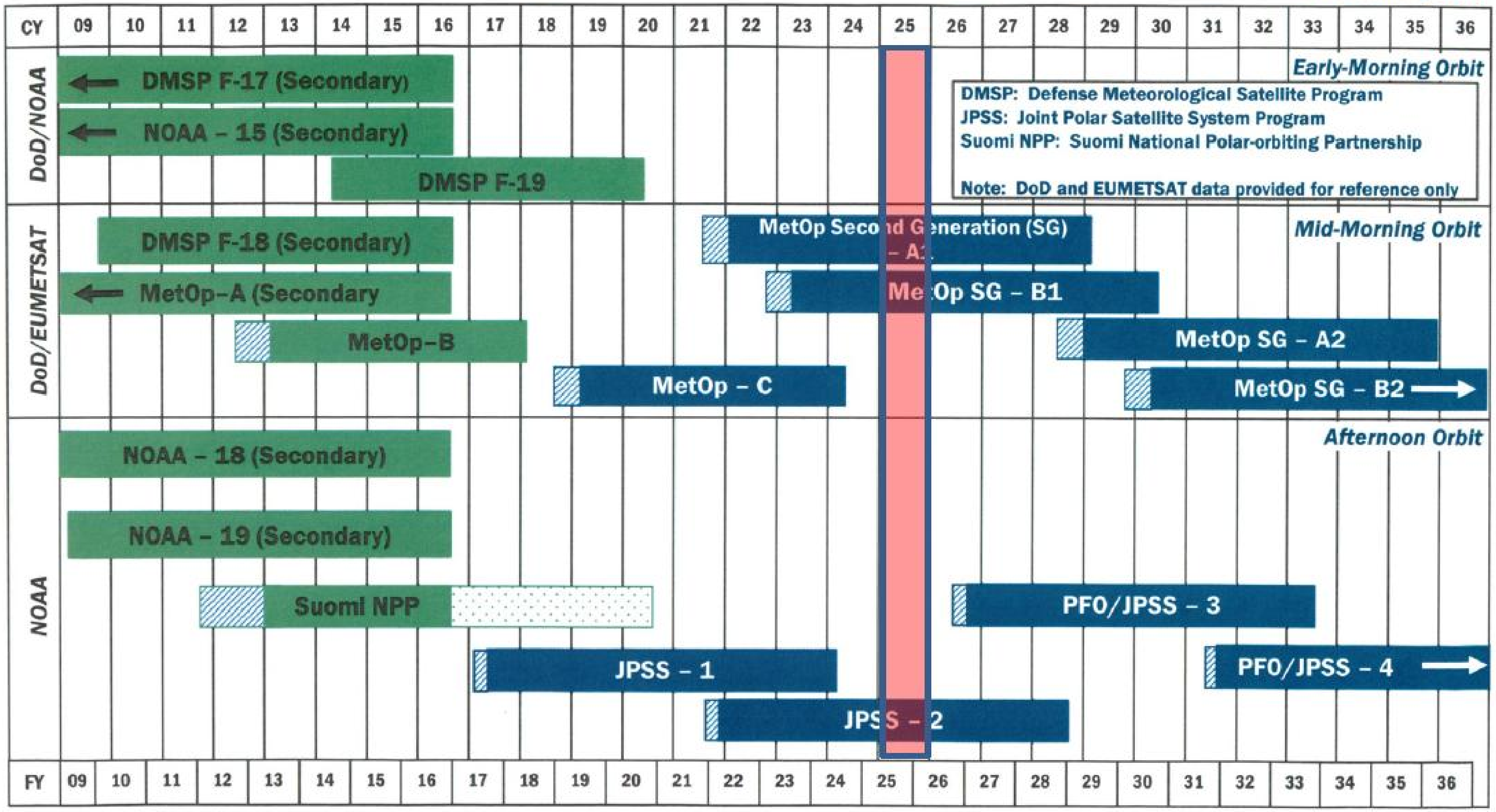


Approved: ______________________

Assistant Administrator for Satellite and Information Services

NOAA & Partner Polar Satellite Programs
Continuity of Weather Observations

As of January 2016



Approved: [signature]

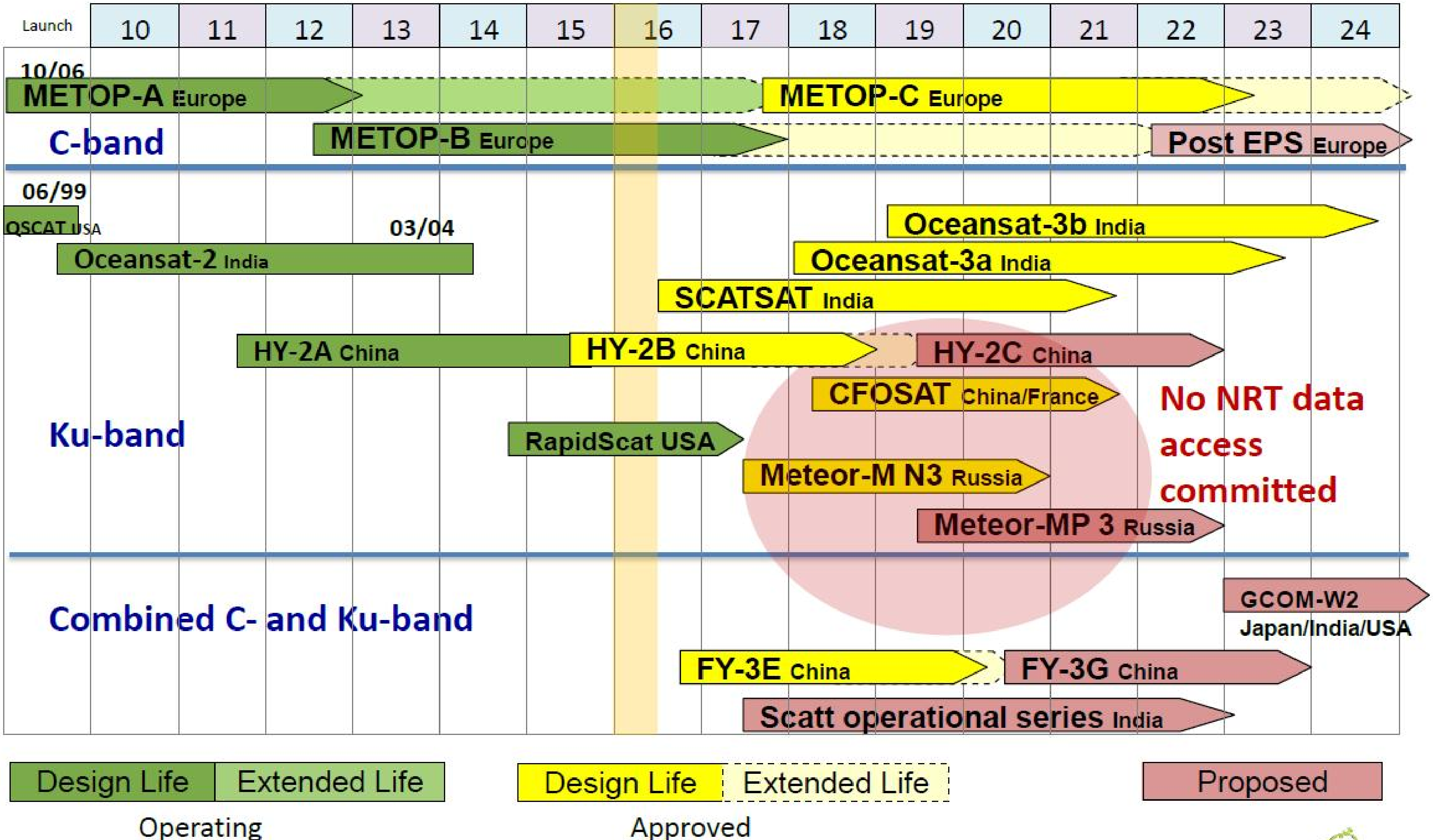
Assistant Administrator for Satellite and Information Services

- In orbit
- Post Launch Test
- Fuel-Limited Lifetime Estimate
- Planned Mission Life, from Launch Readiness Date
- Launched before Oct 2008
- Operational beyond Dec 2036

Note: Extended operations are reflected through the current FY, based on current operating health.

Ocean Vector Surface Vector Winds Constellation

Current status and Outlook – NRT data access



Courtesy: Dr. Mark Bourassa

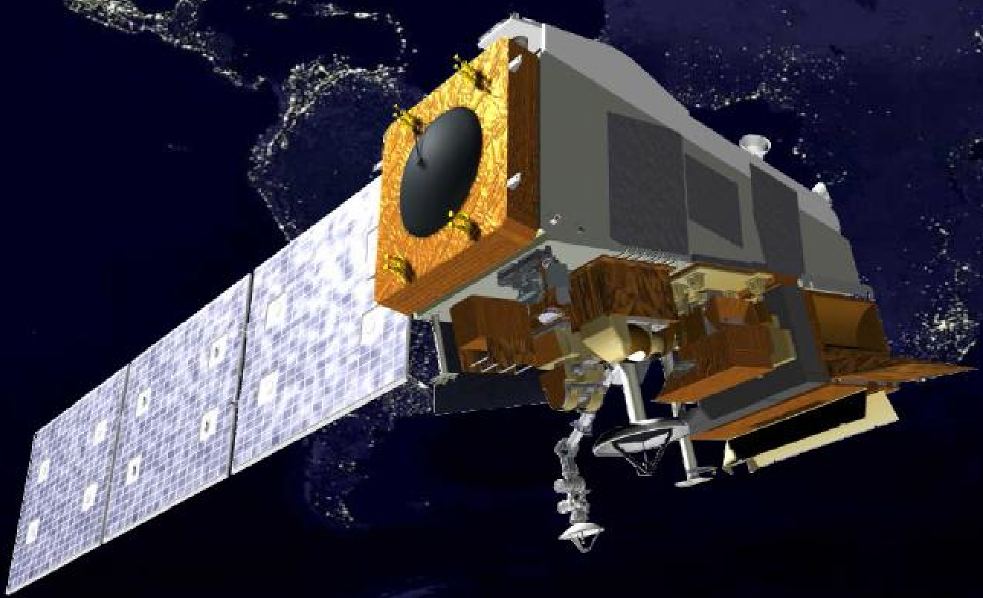
Source: WMO OSCAR database and direct interactions with agencies

Committee on Earth Observation Satellites

Joint Polar Satellite System (JPSS)

Polar Environment and Space Observations

NOAA Weather and Climate Observations



JPSS Instruments
ATMS - Advanced Technology Microwave Sounder
CrIS - Cross-track Infrared Sounder
VIIRS – Visible Infrared Imaging Radiometer Suite
OMPS - Ozone Mapping and Profiler Suite
CERES - Clouds and the Earth's Radiant Energy System

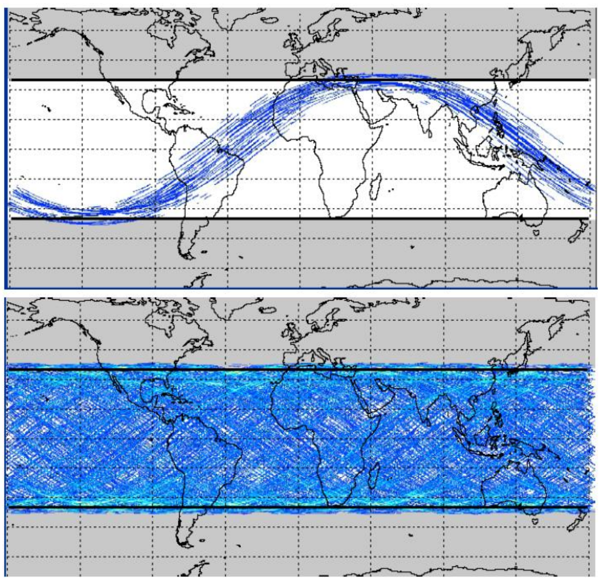
www.jpss.noaa.gov

Cyclone Global Navigation Satellite System (CYGNSS)

- ✓ A constellation of eight small satellites
- ✓ Deriving Surface Wind Speeds in Tropical Cyclones
- ✓ Launch Window Open at 08:00 EST on 12 Dec 2016

CYGNSS Earth Coverage

- 90 min (one orbit) coverage showing all specular reflection contacts by each of 8 s/c
- 24 hr coverage provides nearly gap free spatial sampling within +/- 35 deg orbit inclination



Courtesy Chris Ruf, University of Michigan, cruf@umich.edu

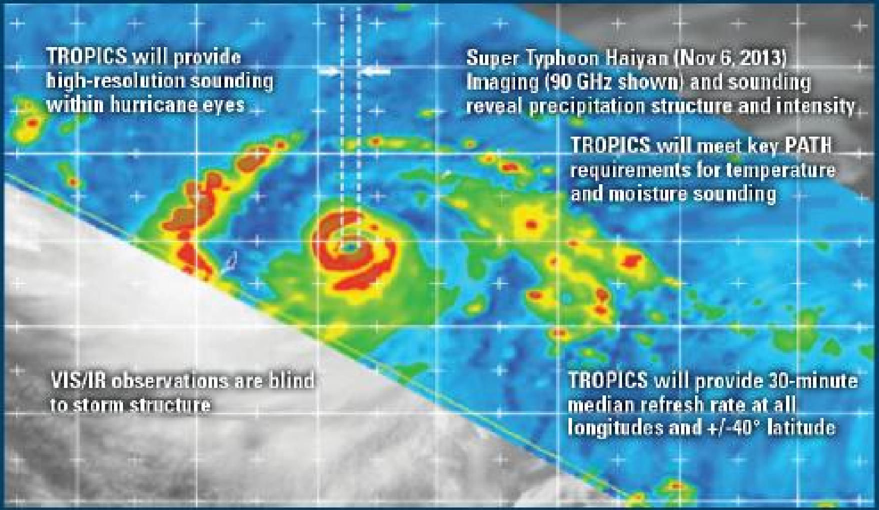
Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats

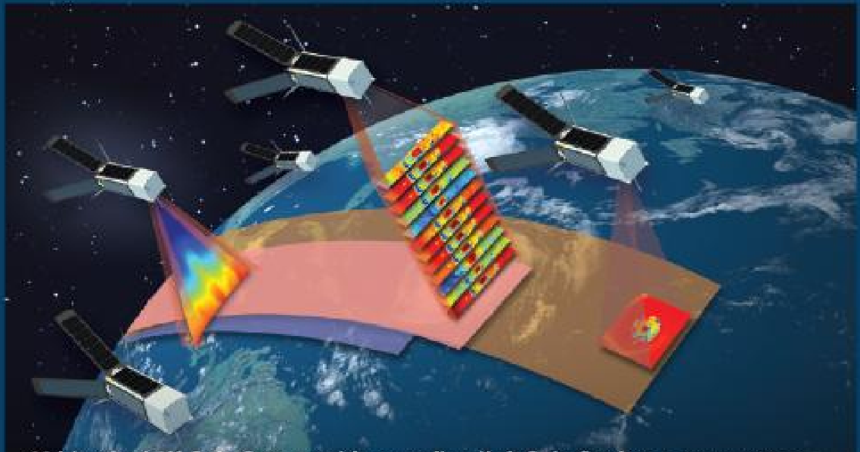
launch ~2019-ish

Bill Blackwell, MIT-LL
wjb@ll.mit.edu

Science Objectives

- Relate precipitation structure evolution, including diurnal cycle, to the evolution of the upper-level warm core and associated intensity changes
- Relate the occurrence of intense precipitation cores (convective bursts) to storm intensity evolution
- Relate retrieved environmental moisture measurements to coincident measures of storm structure (including size) and intensity
- Assimilate microwave radiances and/or retrievals in mesoscale and global numerical weather prediction models to assess impacts on storm track and intensity




12 identical 3U CubeSats provide sounding (left CubeSat has a temperature profile of a simulated Tropical Cyclone (TC) from a Numerical Weather Prediction (NWP) model) and 12-channel radiometric imagery (center CubeSat has simulated radiances from NWP model and radiative transfer model and the near right CubeSat has a single channel radiance image of a TC) with 30-minute median revisit rate to meet most PATH requirements.

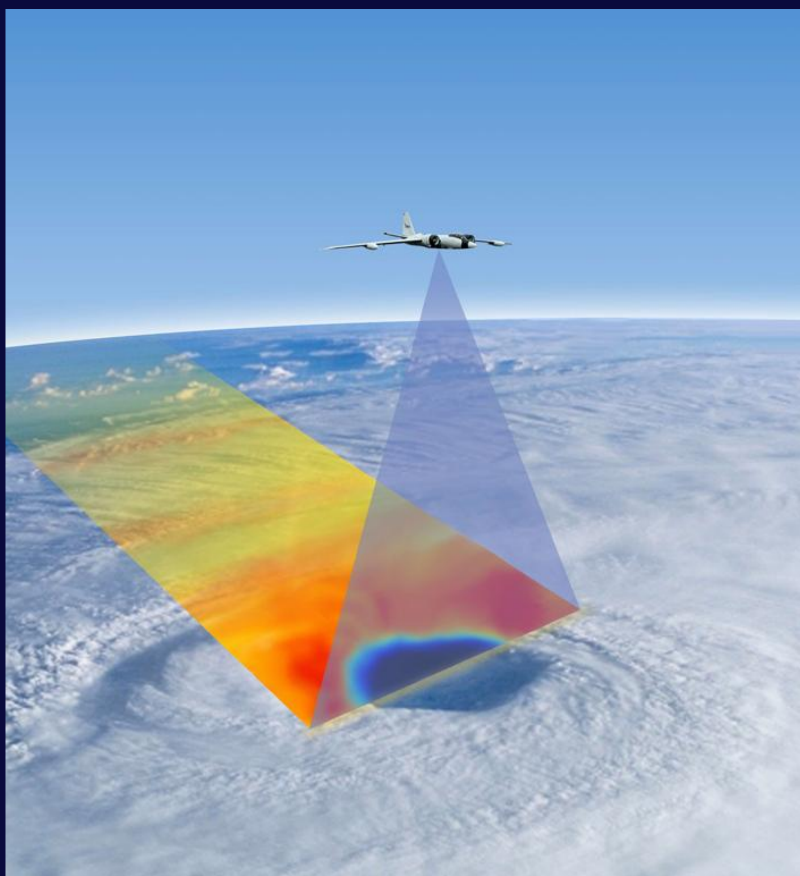
Significance to NASA

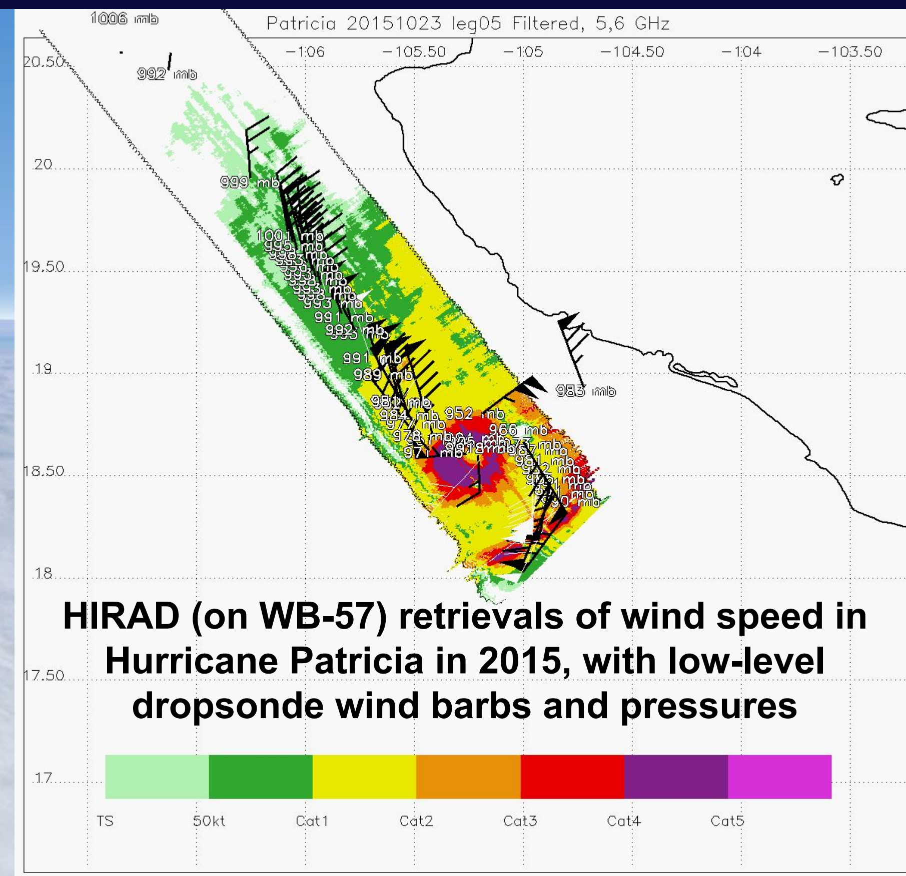
- First high-revisit microwave nearly global observations of precipitation, temperature, and humidity
- Fulfills most of PATH Decadal Survey mission objectives using a low-cost, easy-to-launch CubeSat constellation
- Complements GPM, CYGNSS, and GOES-R missions with high refresh, near-all-weather measurements of precipitation and thermodynamic structure
- Increases understanding of critical processes driving significant and rapid changes in storm structure/intensity

NASA Hurricane Imaging Radiometer (HIRAD)

- Dual-polarization version of HIRAD to measure wind speed and direction from Low Earth Orbit
- Want to develop airborne version of this capability first, then LEO

(Dan Cecil, NASA MSFC, 2016)





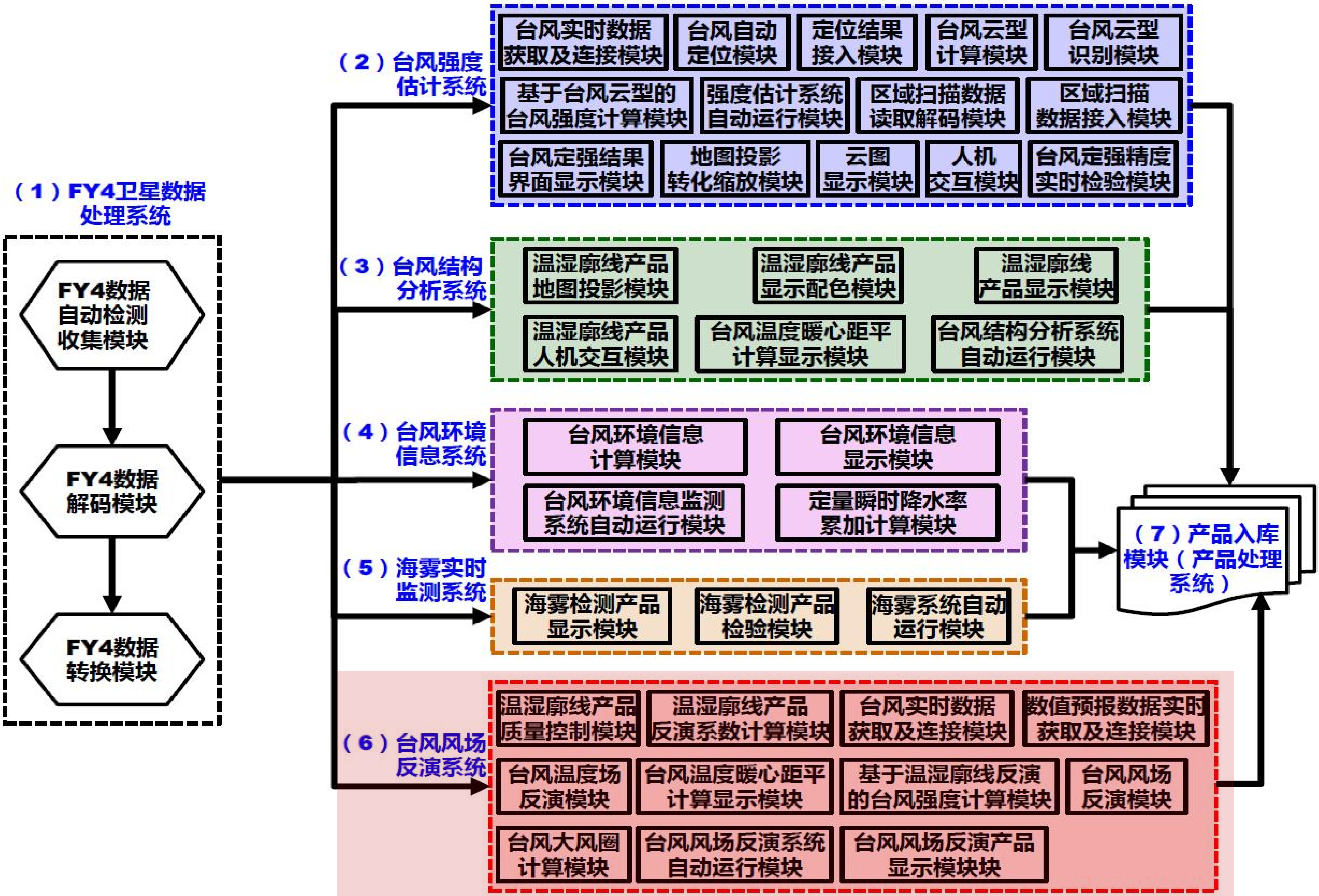
HIRAD (on WB-57) retrievals of wind speed in Hurricane Patricia in 2015, with low-level dropsonde wind barbs and pressures

风云四号卫星台风监测的应用思路

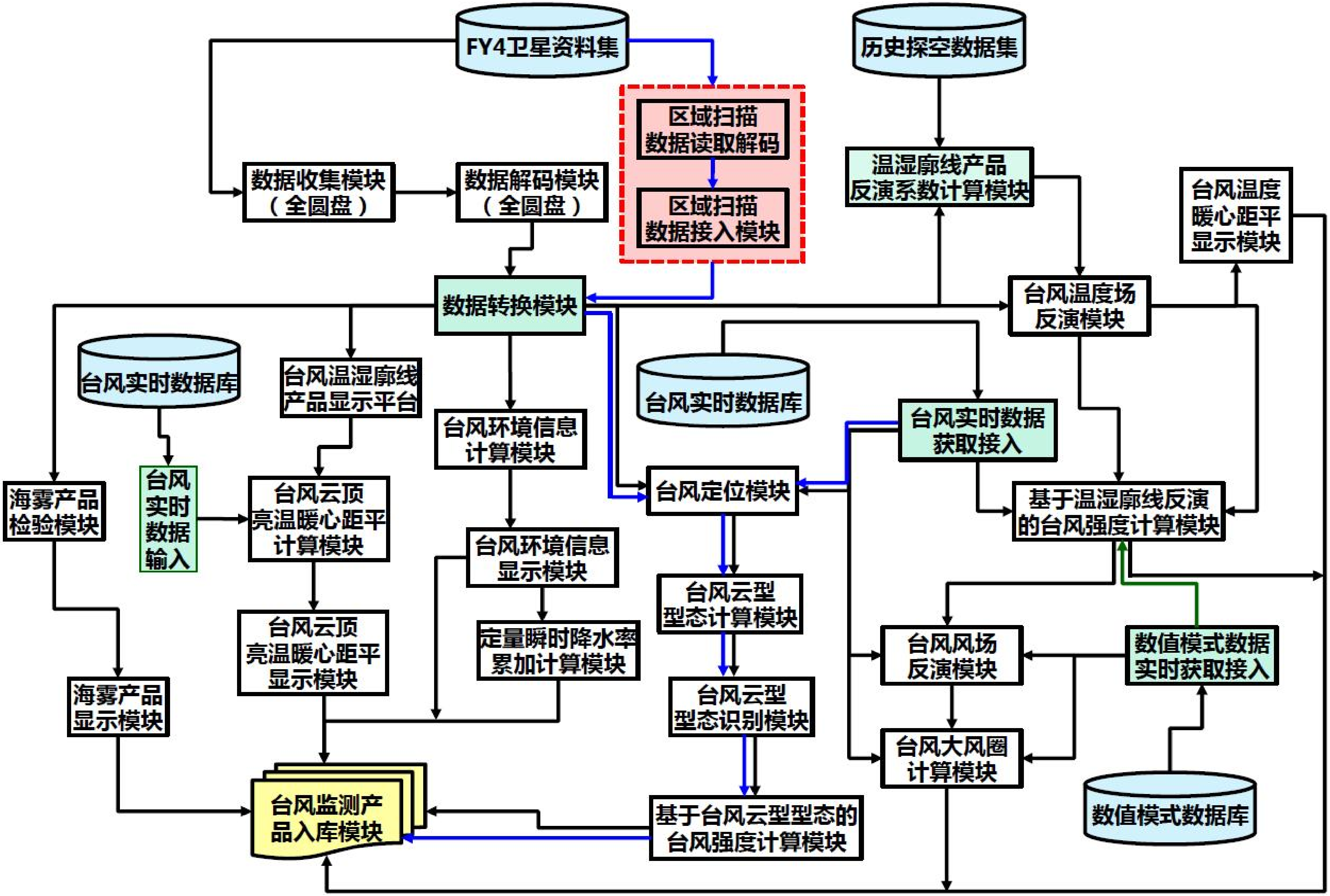
FY4 新一代气象卫星台风海洋气象监测分析产品一览表

序号	产品名称	时效	频次	空间分辨率	区域	数据格式	数据源	数据量	备注
1	全圆盘展宽数据	24	48	全圆盘	全圆盘	CSV	L1	4.8G	1天
2	全圆盘标称数据	24	48	全圆盘	全圆盘	HDF	L1	4.8G	1天
3	区域加密扫描数据	24	未定	未知	特定区域	CSV	L1	未知	1天
4	区域加密扫描数据	24	未定	未知	特定区域	HDF	L1	未知	1天
5	大气温度廓线	24	24	16KM	未知	HDF	L2	1.656G	1天
6	大气湿度廓线	24	24	16KM	未知	HDF	L2	1.656G	1天
7	红外云导风	24	8	64KM	未知	HDF	L2	0.16G	1天
8	水汽云导风	24	8	64KM	未知	HDF	L2	0.16G	1天
9	可见光云导风	24	8	64KM	未知	HDF	L2	0.16G	1天
10	1小时定量瞬时降水率	24	24	4KM	未知	HDF	L2	未知	1天
11	3小时定量瞬时降水率	24	8	4KM	未知	HDF	L2	未知	1天
12	6小时定量瞬时降水率	24	4	4KM	未知	HDF	L2	未知	1天
13	24小时定量瞬时降水率	24	1	4KM	未知	HDF	L2	未知	1天
14	海面温度	24	96	1KM	全圆盘	HDF	L2	7.68G	1天
15	雾检测产品	24	24	4KM	全圆盘	HDF	L2	2.88G	1天

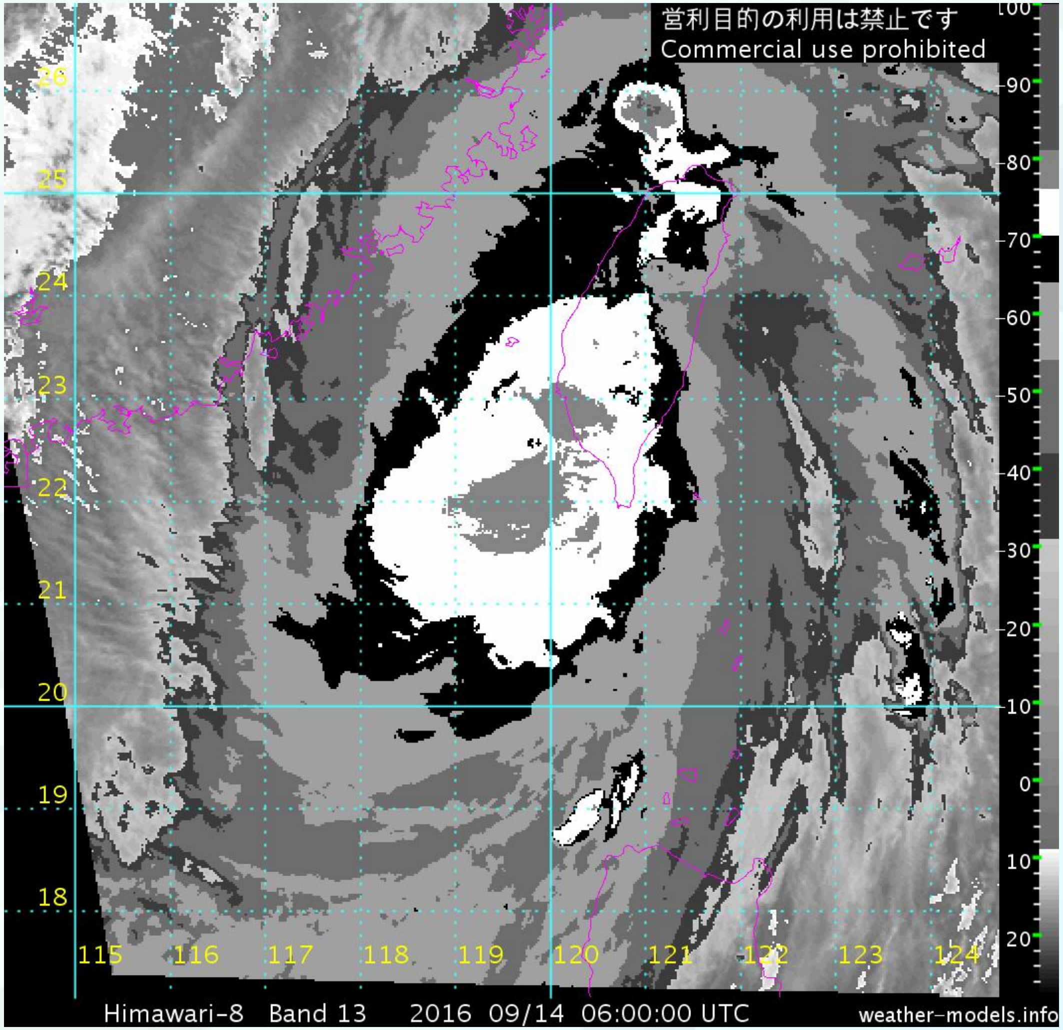
FY4新一代静止气象卫星台风监测分析业务框架



FY4新一代静止气象卫星台风监测分析业务流程



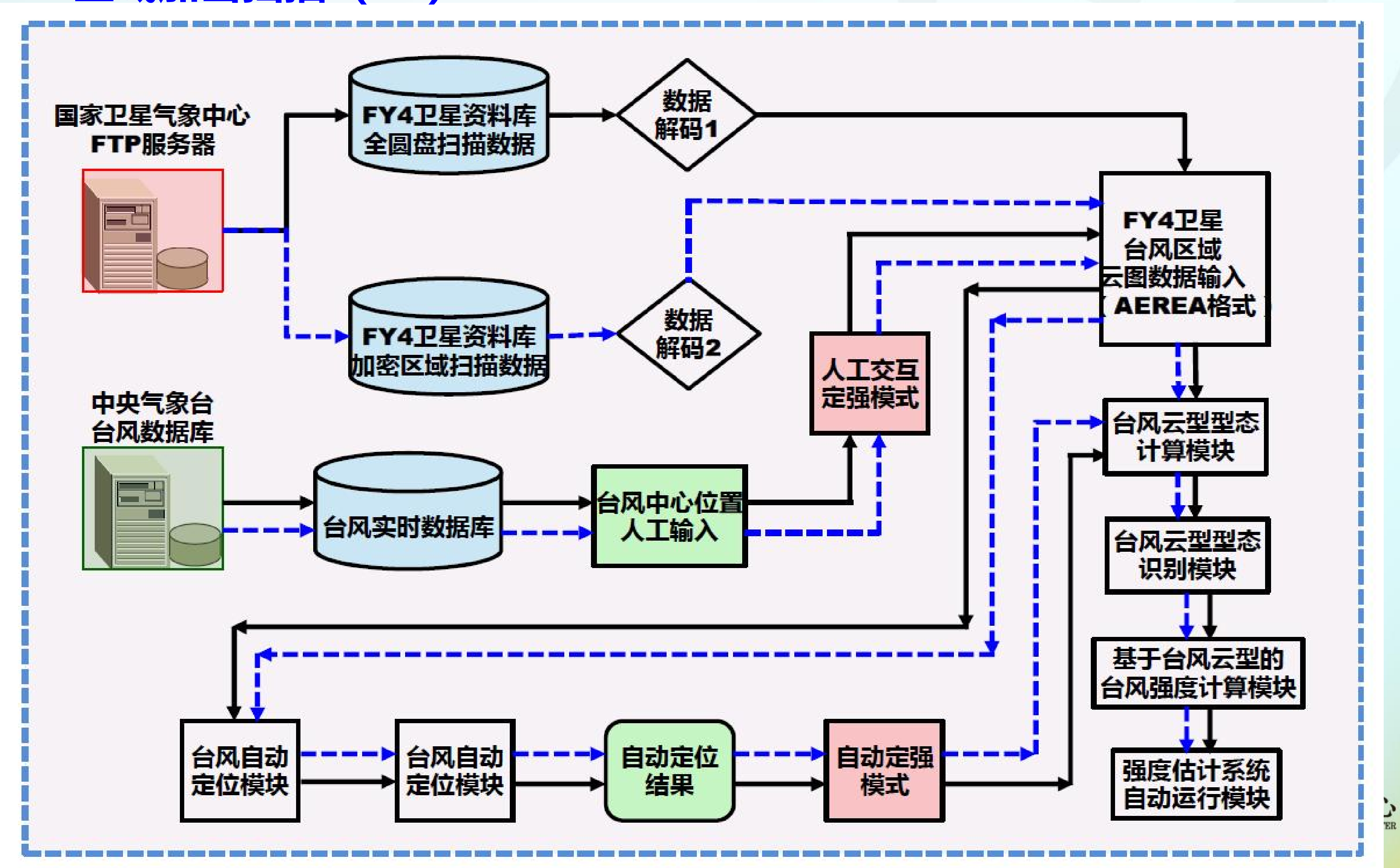
1614号台风“莫兰蒂”
Himawari-8卫星区域加密观测动画图像
（2016年9月14日14时至20时，2.5分钟间隔）



国家气象中心
NATIONAL METEOROLOGICAL CENTER

基于FY4新一代静止气象卫星的台风强度估计技术流程

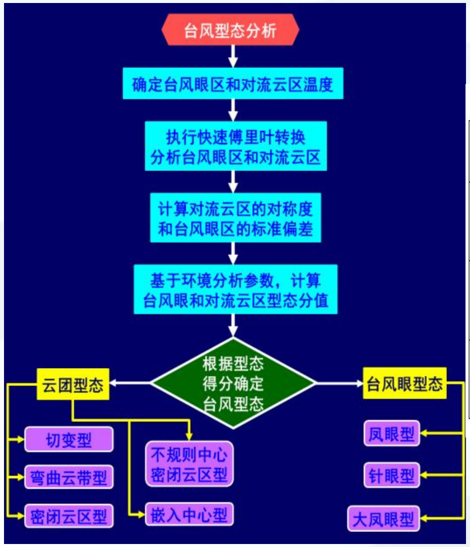
- ✓ 全圆盘扫描（L1）
- ✓ 区域加密扫描（L1）



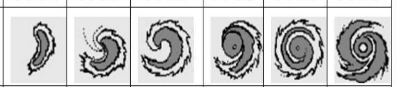
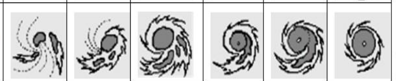
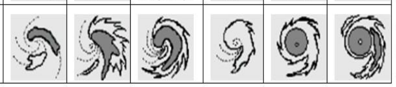
□ 基于FY4新一代气象卫星的台风客观定强系统

- ✓ 通过引进美国威斯康星大学研发的高级客观**Dvorak**技术，通过卫星数据解码、数学处理识别方法和计算机技术，实现台风云型特征（台风眼、螺旋云带等）、云顶温度、眼区温度、中心密闭云区等台风云系特征的自动识别，建立基于**FY4**新一代气象卫星的西北太平洋和南海台风强度客观估计系统。
- ✓ 采用**2012-2016**年中央气象台台风卫星现时强度分析指数结果、台风最佳路径数据，利用统计分析方法，建立台风中心风速、中心气压和现时强度分析指数的统计关系，并应用于台风强度客观估计系统。

台风型态分析 → 确定台风现时强度指数初估值 → 确定台风现时强度指数最终值 → 台风风压关系应用



台风云系型态的强度分类表

特征型态	热带低压	热带风暴	强热带风暴	台风	强台风	超强台风
	PT 1.5	PT 2.5	PT 3.5	PT 4.0	PT 5.0	PT 6.0
弯曲云带型						
密闭云区（CDO）和眼型						
切变型						

灰度代码（BD曲线）

环绕眼区的云系温度 \ 眼区温度	WMG	OW	DG	MG	LG	B	W
OW	0	–0.5					
DG	0	0	–0.5				
MG	0	0	0	–0.5			
LG	+0.5	0	0	0	–0.5		
B	+1.0	+0.5	0	0	0	–0.5	
W	+1.0	+0.5	+0.5	0	0	–1.0	–1.0
CMG	+1.0	+0.5	+0.5	0	0	–0.5	–1.0

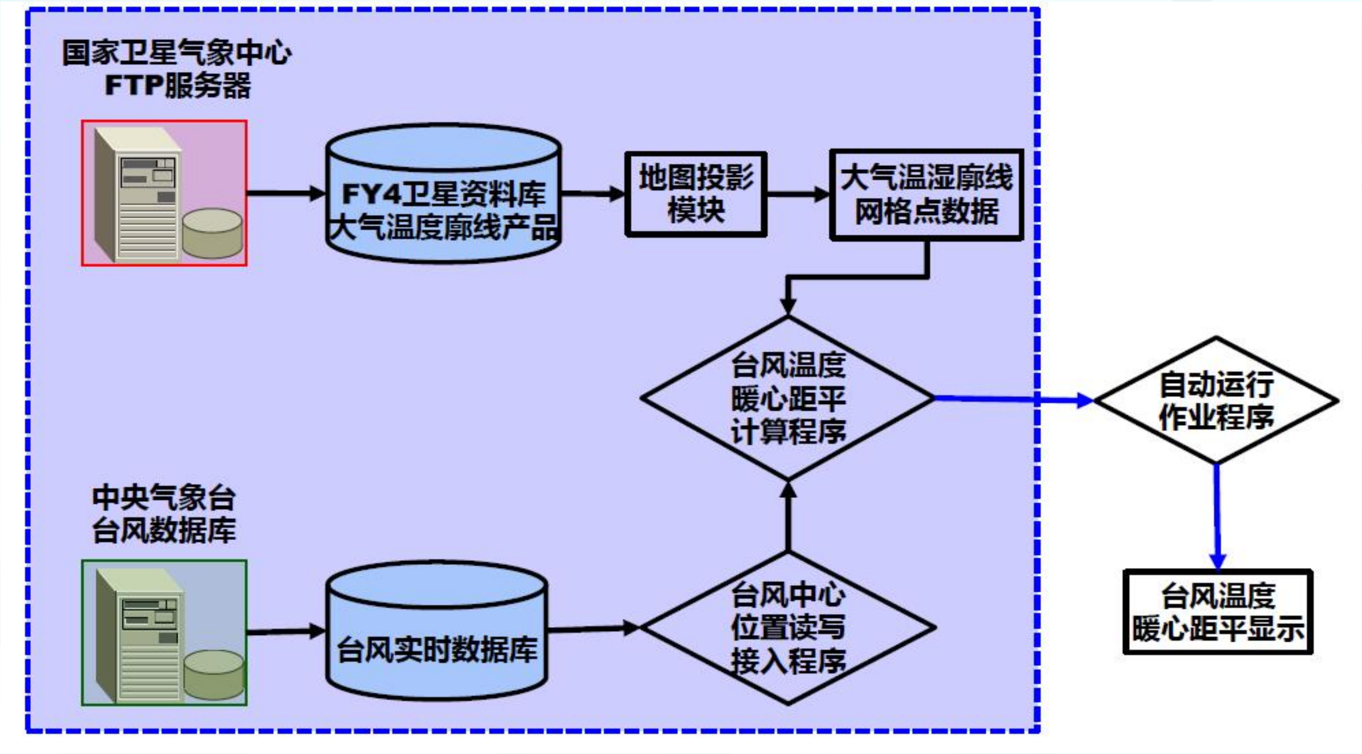
台风强度初估值修正表（眼型）

缩写	灰度		温度范围
WMG	Warm Medium Gray	暖中灰	>9°C
OW	Off White	灰白	+9 ~ –30°C
DG	Dark Gray	深灰	–31 ~ –41°C
MG	Medium Gray	中灰	–42 ~ –53°C
LG	Light Gray	浅灰	–54 ~ –63°C
B	Black	黑	–64 ~ –69°C
W	White	白	–70 ~ –75°C
CMG	Cold Medium Gray	冷中灰	–76 ~ –80°C
CDG	Cold Dark Gray	冷黑灰	≤ –81°C

CI 指数	中心风速	中心气压可取值范围（hPa）
2.5	18	995~998~1000
	20	990~995
3.0	23	982~990
	25	980~985
3.5	28	975~982
	30	975~980
4.0	33	970~975
	35	965~970
4.5	38	960~965
	40	955~960
5.0	42	950~955
	45	945~950
5.5	48	940~945
	50	935~940
6.0	52	930~935
	55	925~930
6.5	58	920~925
	60	915~920
7.0	62	910~915
	65	905~910
7.5	68	900~905
	70	895~900
	72	890~895
8.0	75	885~890
	78	880~885
	80	875~880

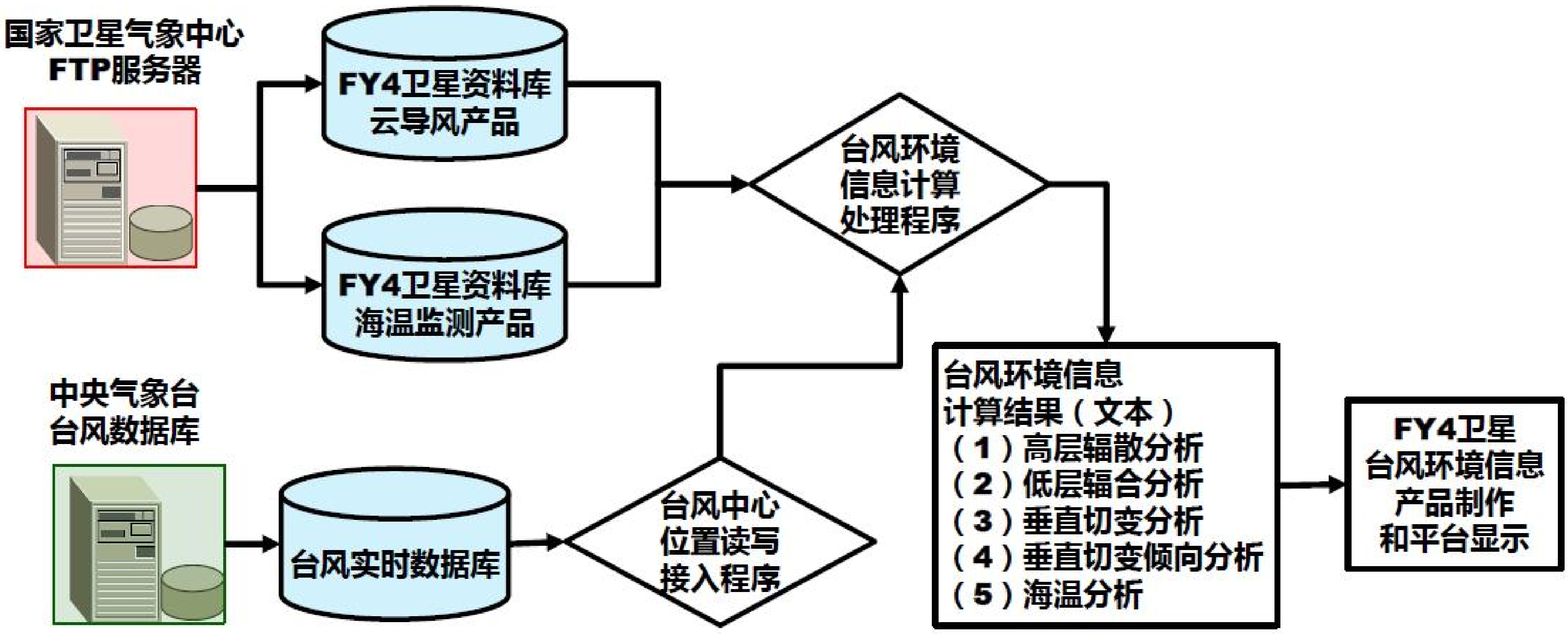
FY4新一代静止气象卫星大气温湿廓线产品业务应用

- ✓ 微波温度计（L2）
- ✓ 微波湿度计（L2）



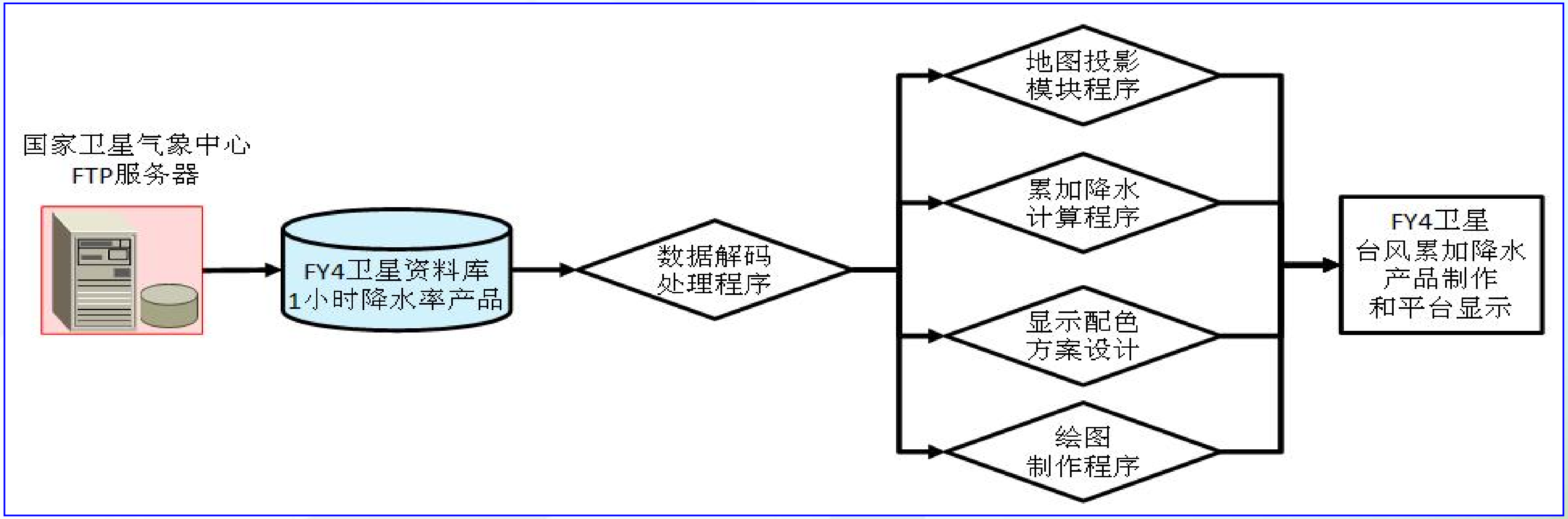
基于FY4新一代静止气象卫星的大气海洋环境监测分析业务

- ✓ 卫星云导风产品（L2）
- ✓ 海温产品（L2）
- ✓ 降水估计产品（L2）
- ✓ 海雾检测产品（L2）



基于FY4新一代静止气象卫星的大气海洋环境监测分析业务

- ✓ 卫星云导风产品（L2）
- ✓ 海温产品（L2）
- ✓ 降水估计产品（L2）
- ✓ 海雾检测产品（L2）



基于FY4新一代静止气象卫星的大气海洋环境监测分析业务

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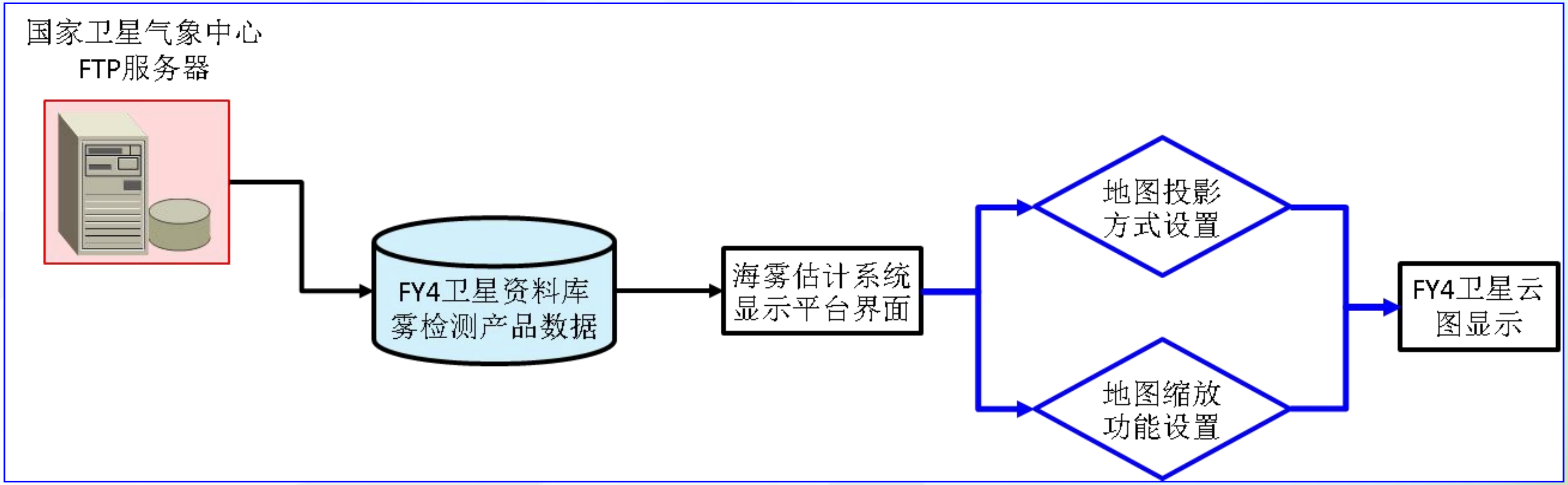


FY4新一代静止气象卫星业务应用可能存在的主要困难

✓ 数据格式

- **HDF**、**CSV**格式 **--- L1**、**L2**
- 难于解读（预报员）
- **台风卫星格点云图数据库（易解读）**

✓ 数据容量

- 每天至少**20G**
- 存储量大

✓ 数据质量

- 大气温度廓线产品
- 大气湿度廓线产品

✓ 数据空间分辨率

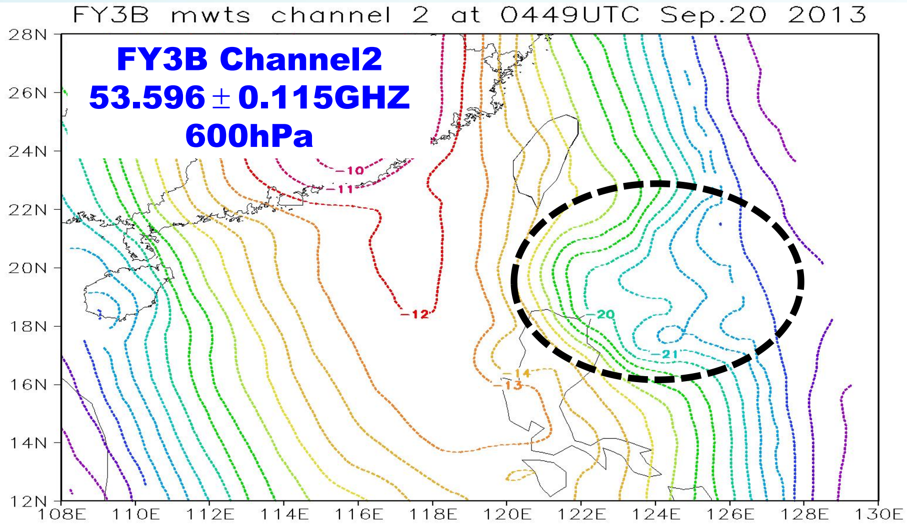
- 大气温度廓线产品（**L2**）
- 大气湿度廓线产品（**L2**）
- **L1**级产品

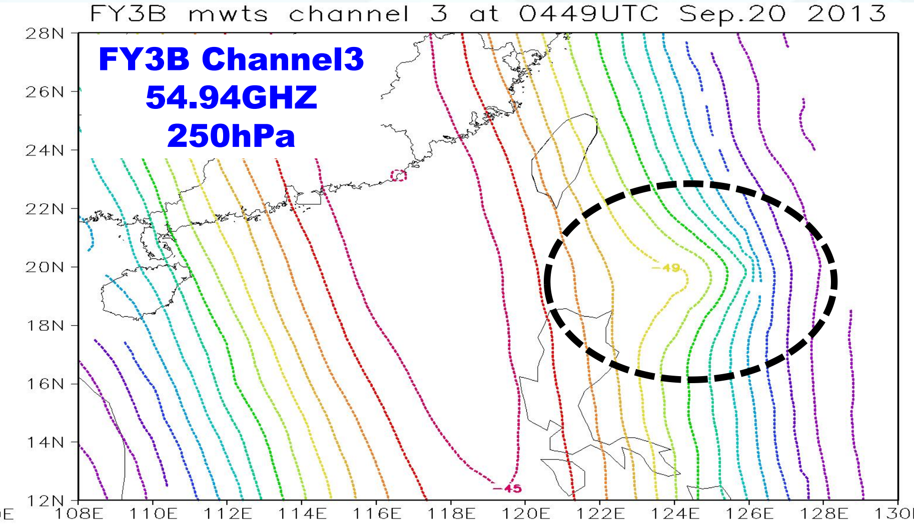
客观定量分析应用的精度

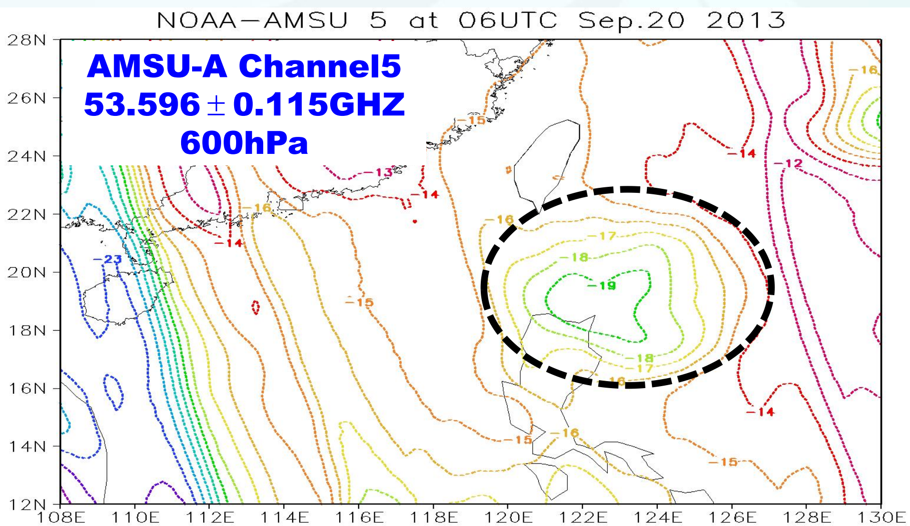
国家气象中心
NATIONAL METEOROLOGICAL CENTER

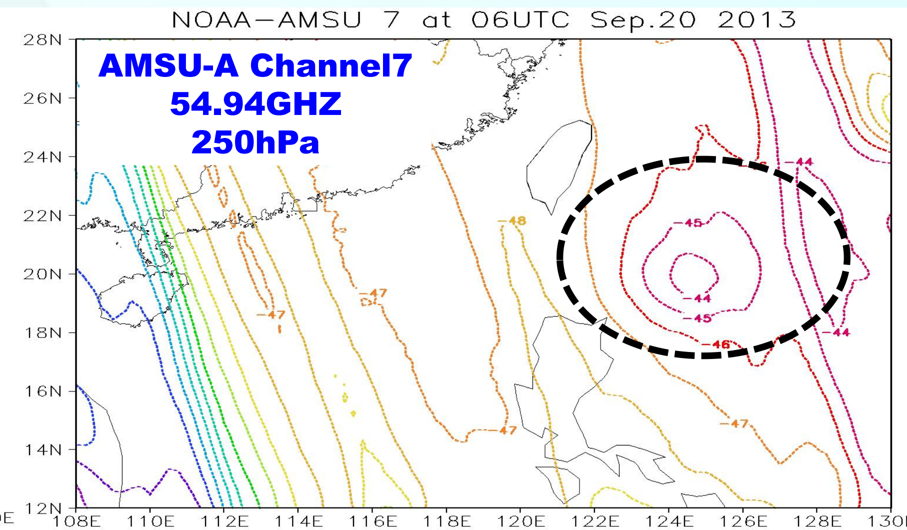
谢谢！

FY3B与AMSU-A微波温度计资料比较





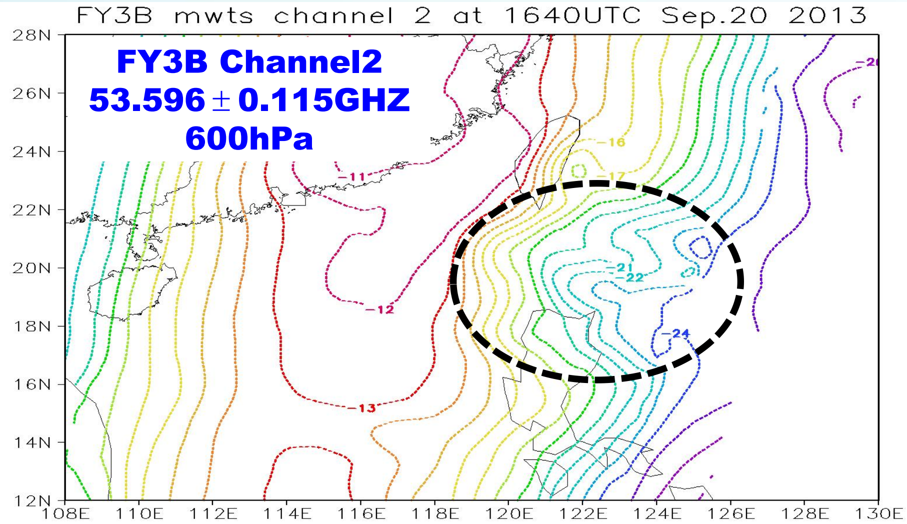


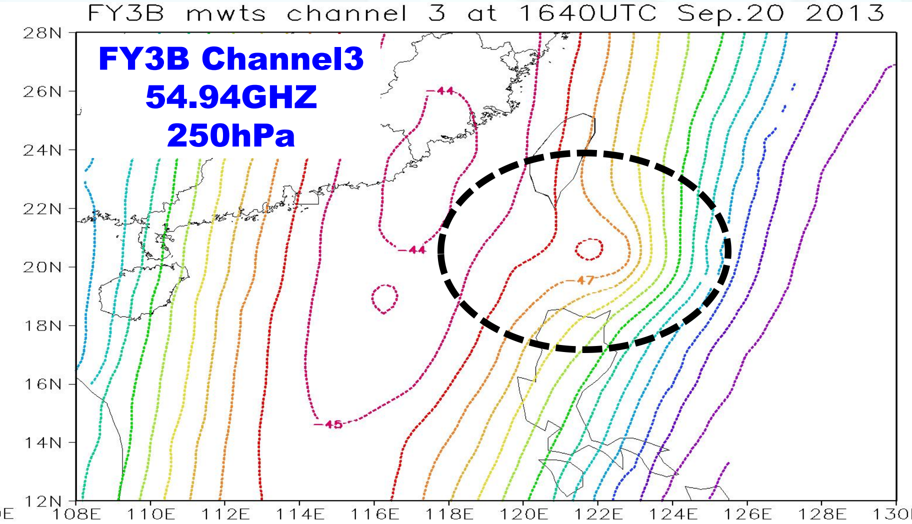


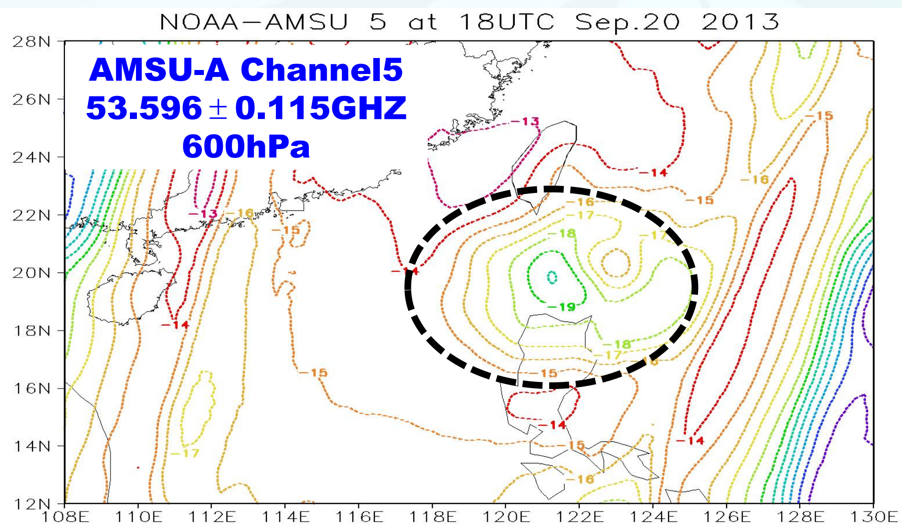
1319号超强台风“天兔”

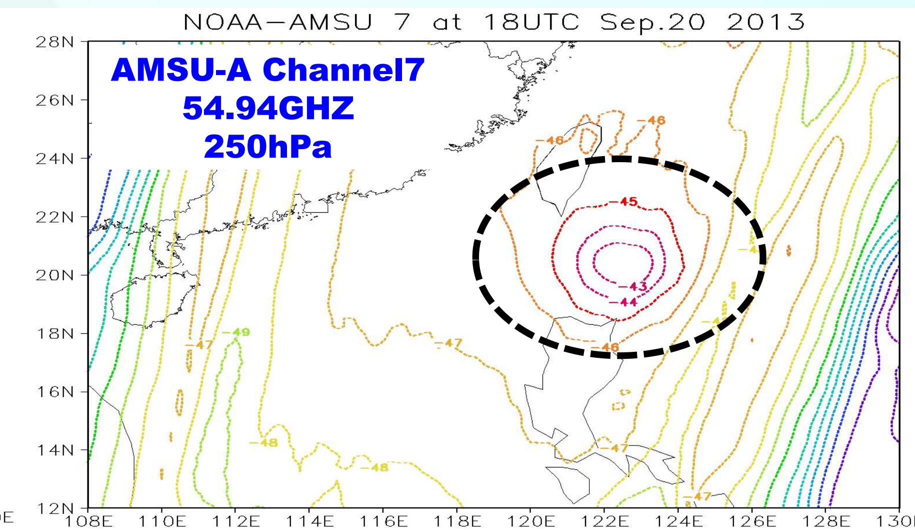
2013年9月20日04:49UTC FY3B
2013年9月20日06:00UTC AMSU-A

FY3B与AMSU-A微波温度计资料比较





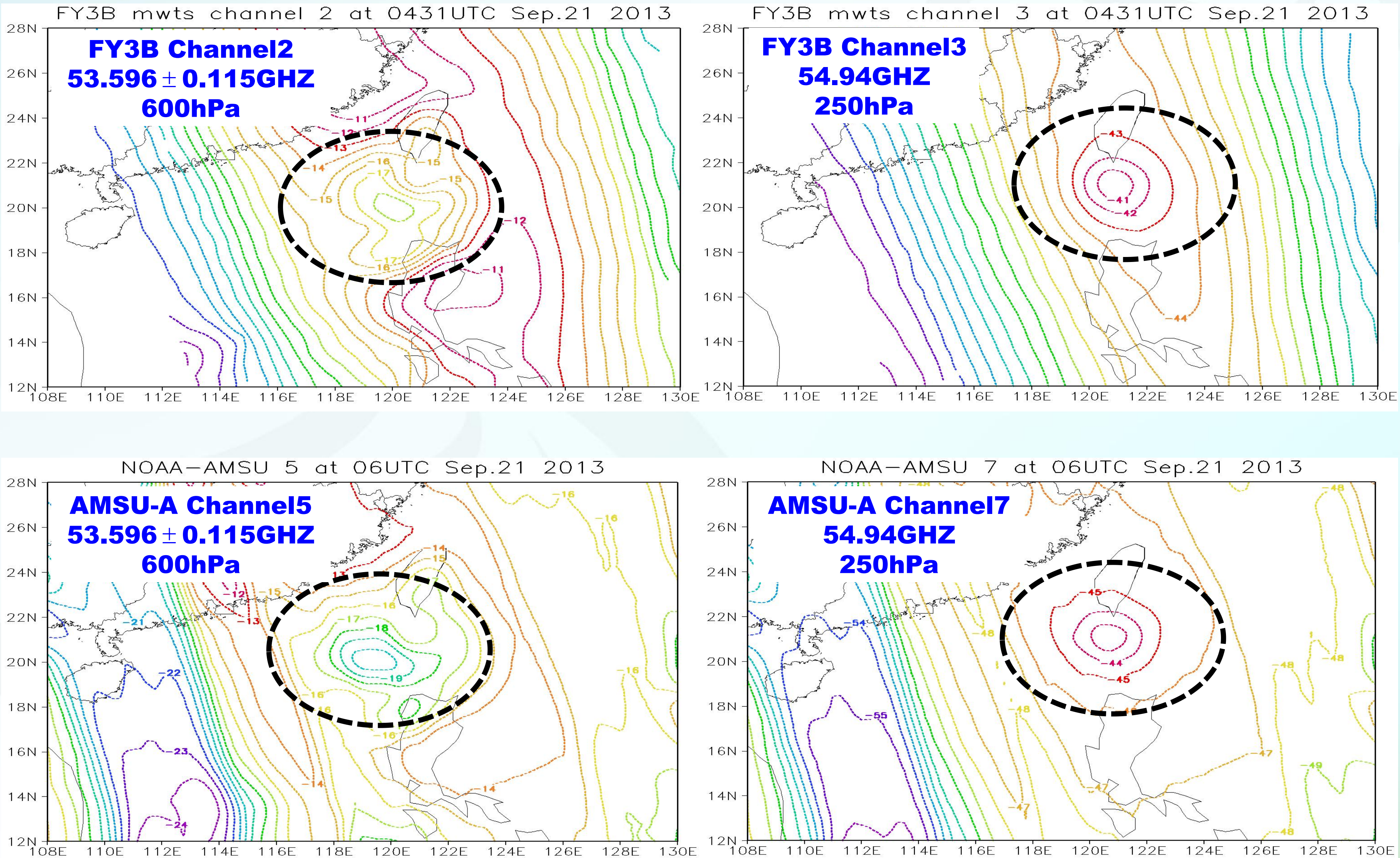




1319号超强台风“天兔”

2013年9月20日16:40UTC FY3B
2013年9月20日18:00UTC AMSU-A

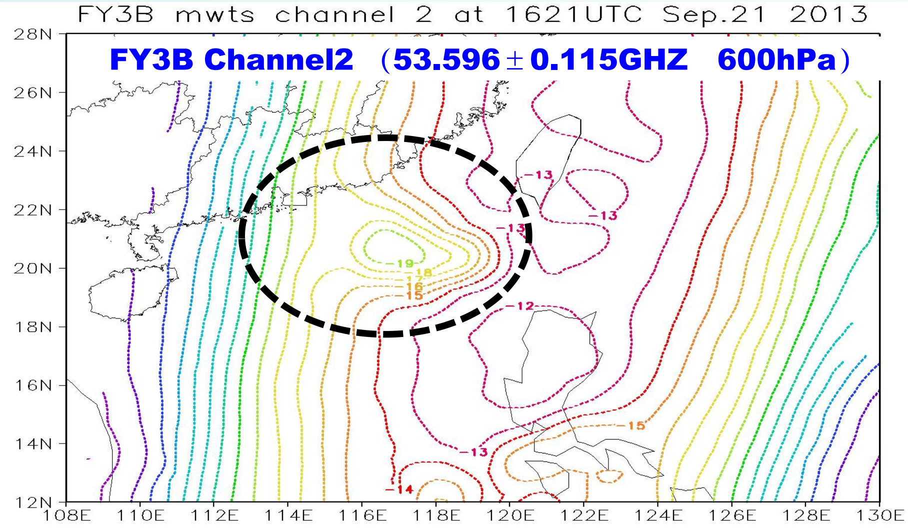
FY3B与AMSU-A微波温度计资料比较

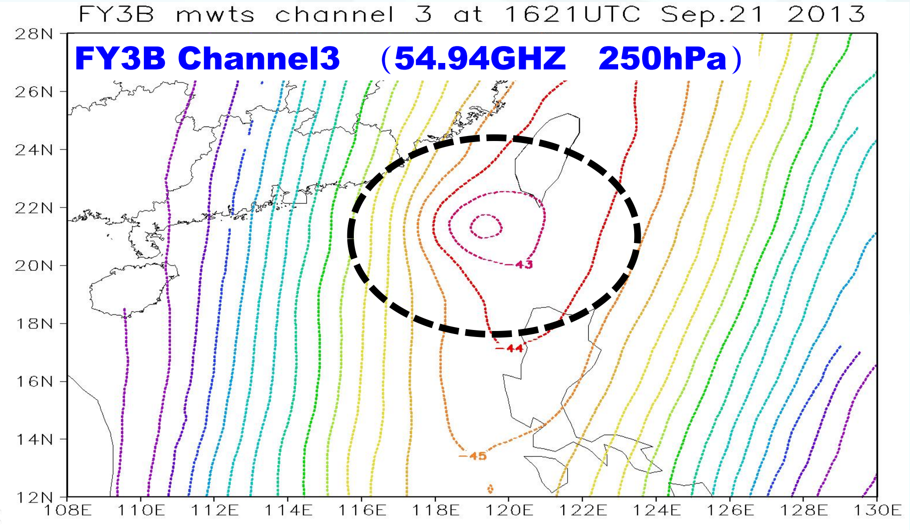


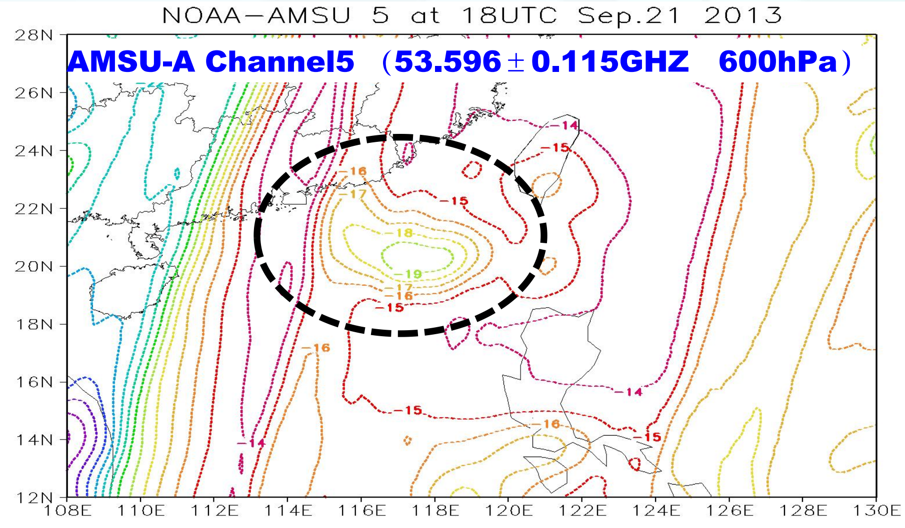
1319号超强台风"天兔"

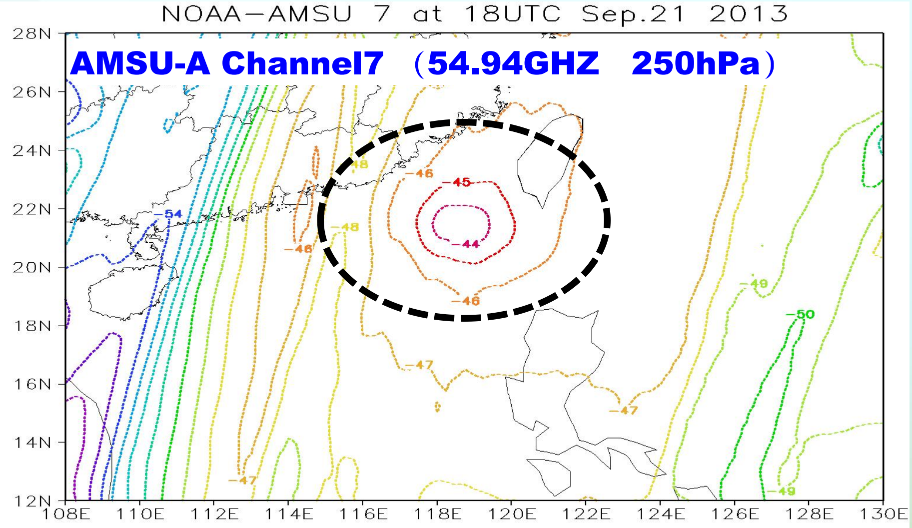
2013年9月21日04:31UTC FY3B
2013年9月21日06:00UTC AMSU-A

FY3B与AMSU-A微波温度计资料比较









1319号超强台风“天兔”

2013年9月21日16:21UTC FY3B
2013年9月21日18:00UTC AMSU-A