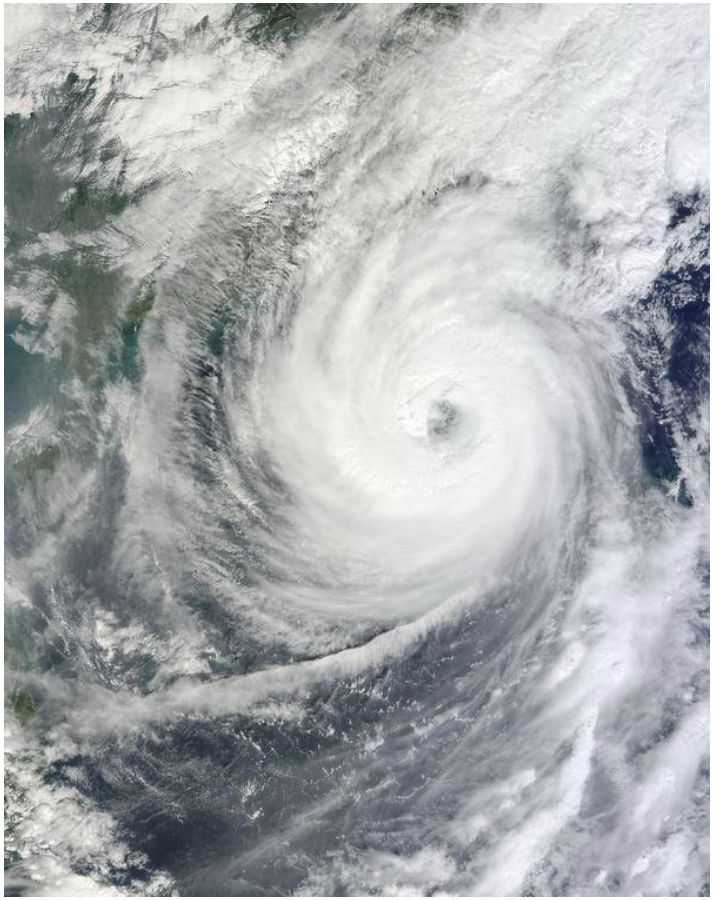


Yu. I. Troitskaya,
V.Kazakov,
N.Bogatov,
O.Ermakova,
M.Salin,
D.Sergeev
A. Kandaurov,
G.Baidakov
M.Vdovin

Institute of Applied Physics

Remote sensing of severe weather conditions over the sea. I.Methods (on example of TC Megi)

BEAUFORT SCALE

Force		Anemometer reading mph	kmh	m/s	knts	Description		Effect on kite
0		0-1	<1	<0.3	0-1	Calm; smoke rises vertically.	Calm	Launch frustration
1		1-3	1-5	0.3-1.5	1-3	**Direction of wind shown by smoke drift, but not by wind vane.**	**Light air**	Very large lightweight deltas, Rokkaku etc, may fly on a light line
2		**4-7**	**6-11**	**1.5-3.3**	**4-6**	**Wind felt on face; leaves rustle; ordinary vanes moved.**	**Light Breeze**	Sutton ff30 lofts 650g at 3.5mph
3		**8-12**	**12-19**	**3.3-5.5**	**7-10**	**Leaves and small twigs in constant motion; wind extends light flag.**	**Gentle Breeze**	
4		**13-18**	**20-28**	**5.5-8.0**	**11-16**	**Raises dust and loose paper; small branches are moved.**	**Moderate Breeze**	Drogue needed on Flowform kites
5		**19-24**	**29-38**	**8.0-10.8**	**17-21**	**Small trees in leaf begin to sway; crested wavelets form on inland waters.**	**Fresh Breeze**	
6		25-31	39-49	10.8-13.9	22-27	Large branches in motion; whistling heard in telegraph.	Strong Breeze	Reduce kite size increase line weight & drogue size
7		32-38	50-61	13.9-17.2	28-33	Whole trees in motion; inconvenience felt when walking.	Near Gale	
8		39-46	62-74	17.2-20.7	34-40	Breaks twigs off trees; generally impedes progress.	Gale	
9		47-54	75-88	20.7-24.5	41-47	Slight structural damage occurs (chimney-pots and slates removed).	Severe Gale	
10		55-63	89-102	24.5-28.4	48-55	Seldom experienced inland; trees uprooted; considerable structural damage occurs.	Storm	
11		64-72	103-117	28.4-32.6	56-63	Very rarely experienced; accompanied by wide-spread damage.	Violent Storm	
12		73-83	≥118	≥32.6	64-71		Hurricane	

KAP not possible without severe risk of injury to operator and equipment.

Classification of Tropical Cyclone Intensity around the World

North Atlantic and Eastern North Pacific: Saffir-Simpson Scale

Saffir-Simpson Cathegory	Maximum Sustained 10m-wind speed (1min average)
	m/s
1	33-42
2	43-49
3	50-58
4	59-69
5	70+

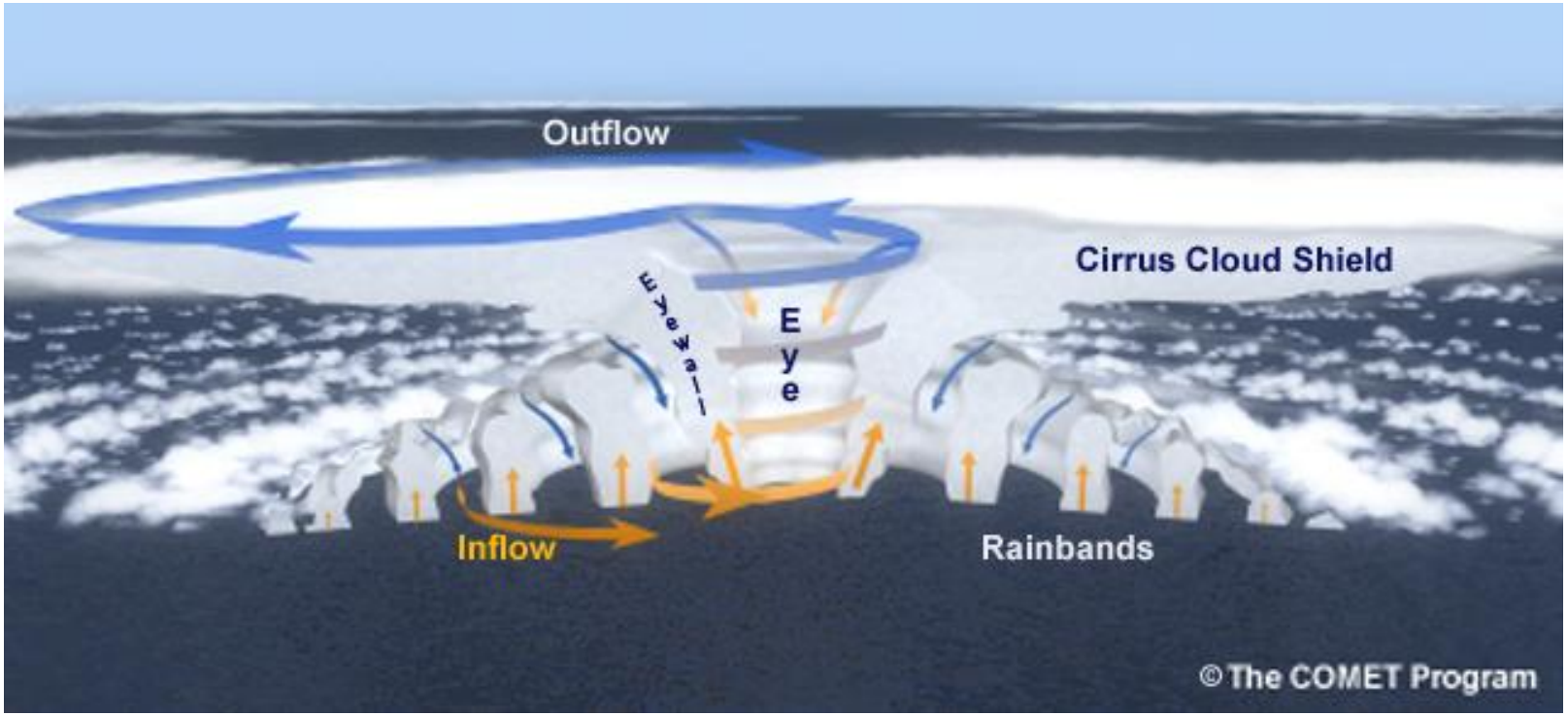
Australian Region: Gust Wind Speed Ranges for Tropical Cyclones

Cathegory	Range of strongest gust
	m/s
1	<34
2	34-47
3	47-63
4	63-78
5	>78

Western North Pacific categories

Cathegory	Maximum Sustained 10m-wind speed (10 min average)
	m/s
Tropical Storm	17 - 33
Typhoon	34 - 63
Super typhoon	>63

A Mature Tropical Cyclone is an intensive vortex in the atmosphere with the diameter about 500-600 km



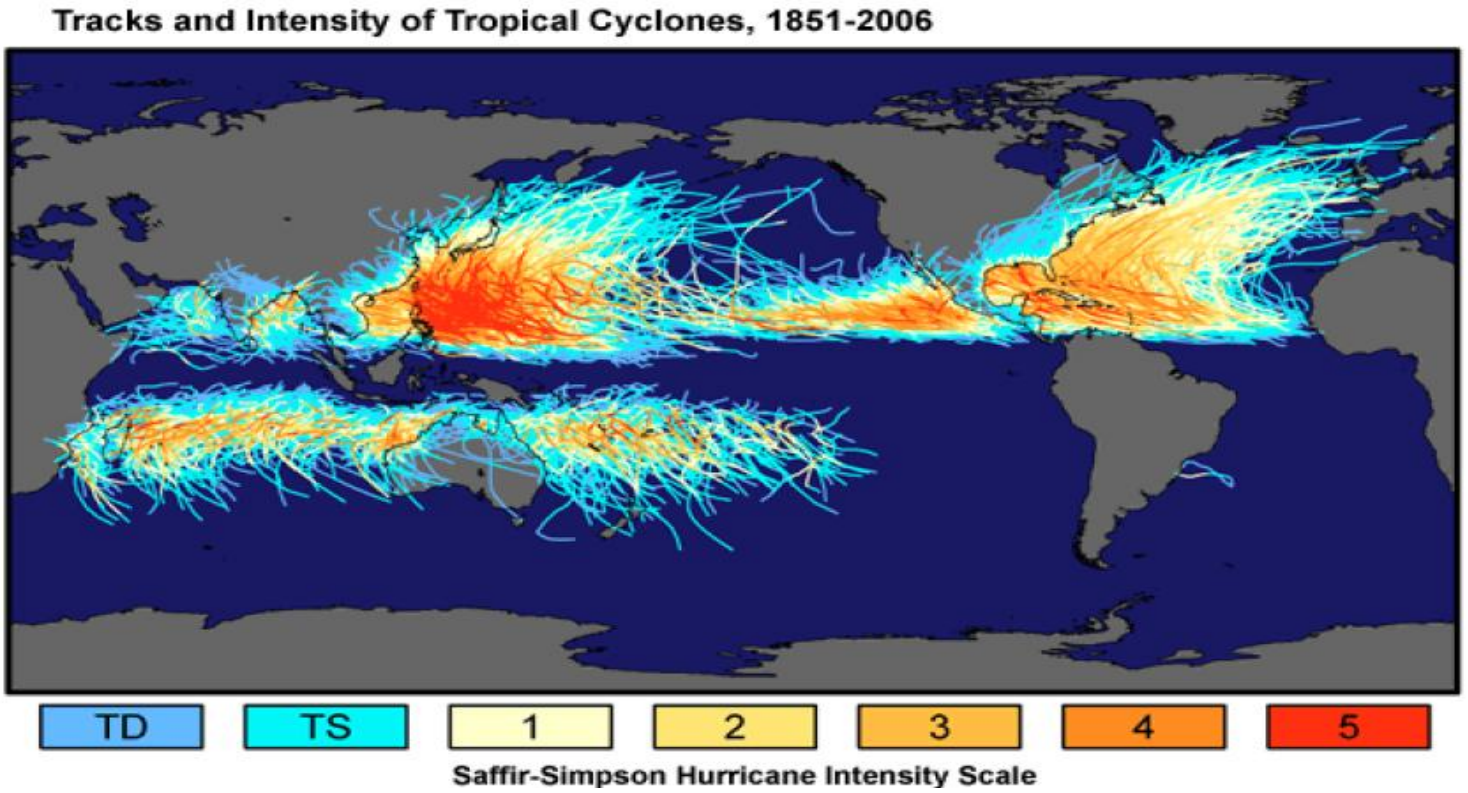
Main structural elements of tropical cyclones; (i) boundary layer inflow, (ii) clear central eye, (iii) eyewall, (iv) cirrus shield, (v) rainbands, and (vi) upper tropospheric outflow.

Webster, P. J., Holland, G. J., Curry, J. A. & Chang, H.-R. 2005 Changes in tropical cyclone number, duration, and intensity in a warming environment. Science 309, 1844–1846.

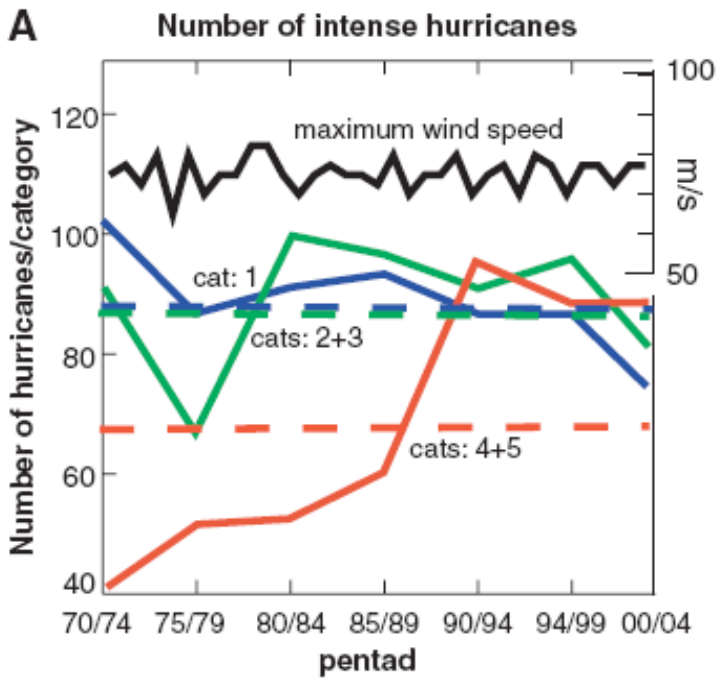
Annually about 50 tropical cyclones are observed

Total annual number of the sum of categories 4 and 5 (wind speed >60 m/s) is 18

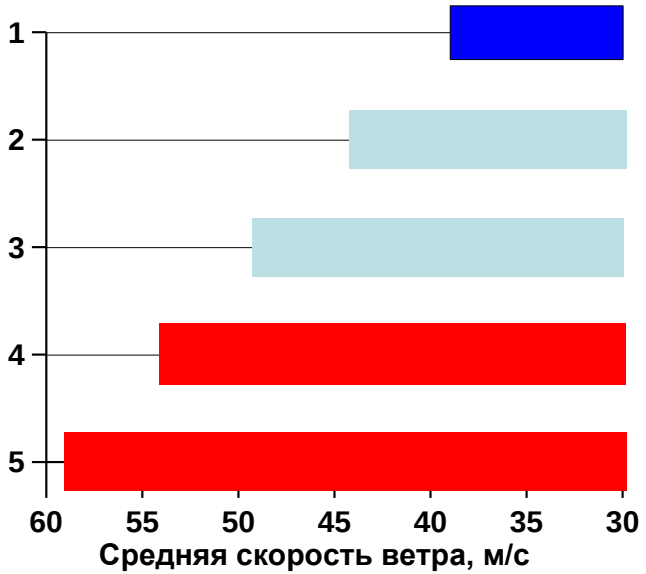
TC are observed in the tropical zone (usually 5-20 latitude) under conditions of wet hot atmosphere, where deep convection can develop.



Интенсивность ураганов по шкале Саффира-Симпсона (категории от 1 до 5).



Шкала ураганов Саффира-Симпсона



Общее число штормов категории 1 (синяя кривая), сумма категорий 2 и 3 (зеленая кривая) и сумма категорий 4 и 5 (красная кривая) за 5-летний период. Из **Webster, P.J., et al., 2005: Changes in tropical cyclone number, duration and intensity in a warming environment. Science, 309, 1844–1846.**

Tropical cyclones

Tropical cyclones are the most hazardous weather systems

- strong winds
- storm surge
- wind-driven waves
- heavy rainfall and flooding
- tornadoes
- lightning

Strong wind and wind stress, Philippines , typhoon Megi, 18 october 2010

Storm surge, wind waves. Philippines , typhoon Megi, 18 october 2010

Heavy rain and flooding, Philippines , Taivan, typhoon Megi, october 2010

Records

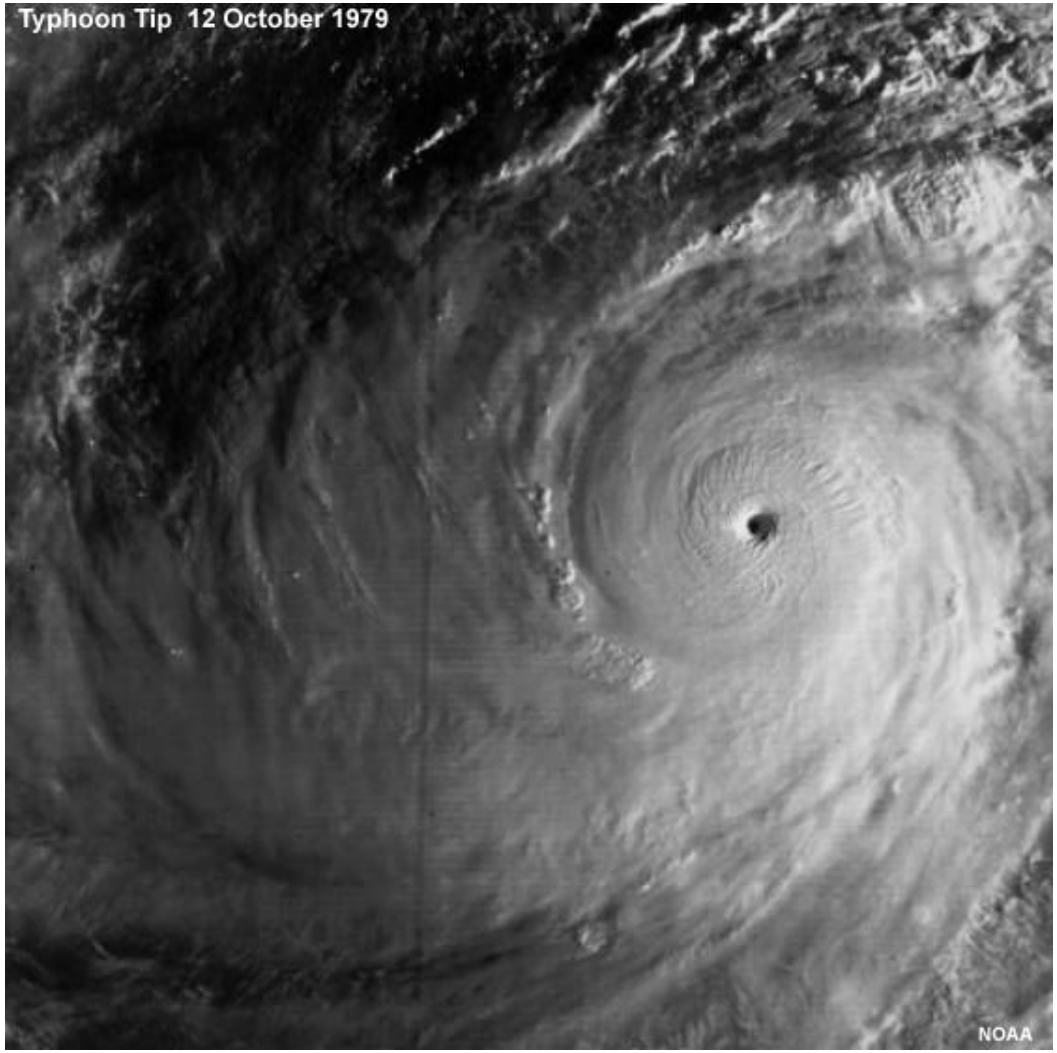
Minimum pressure

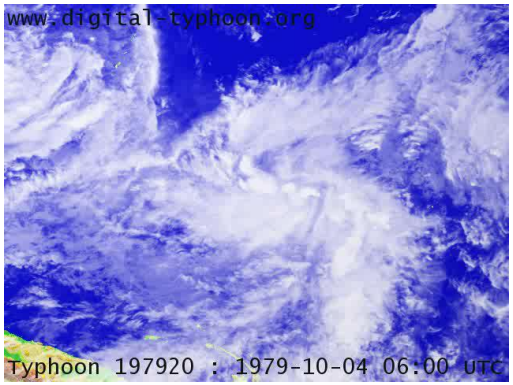
Cyclone	Season	Pressure hPa	inHg
Tip	1979	870	
Nora	1973	875	
June	1975	875	
Ida	1958	877	
Kit	1966	880	
Rita	1978	880	
Vanessa	1984	880	
Wilma	2005	882	
Nina	1953	885	
Joan	1959	885	
Irma	1971	885	
Forrest	1983	885	
Megi	2010	885	

Maximum wind speed

Name	1-min sustained wind	10-min sustained wind
Tip (1979)	305 km/h (190 mph)	260 km/h (160 mph)
Megi (2010)	305 km/h (190 mph)	230 km/h (145 mph)
Keith(1997)		205 km/h (125 km/h) (10-min),
Vera (1959)	315 km/h (195 mph)	
Sarah(1959)	305 km/h (190 km/h)	

Supertyphoon Tip (1979) – The Most Intense Tropical Cyclone on Record





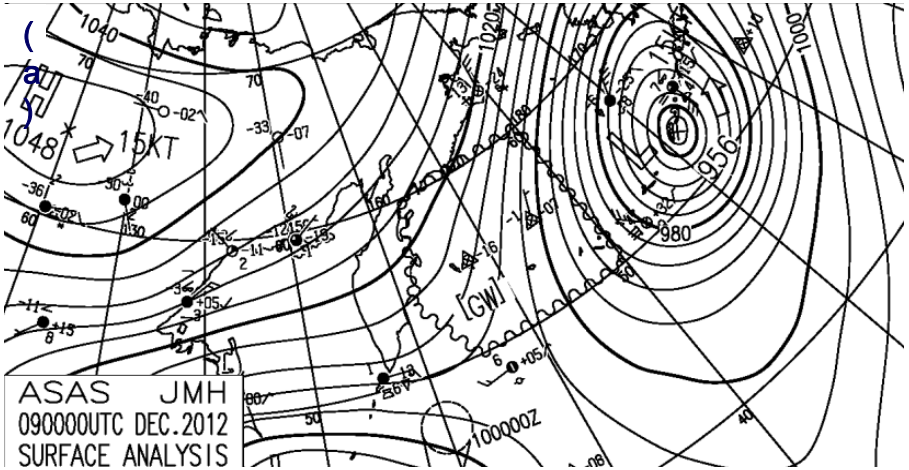
Supertyphoon Tip was legendary for its spatial extent as well as its intensity – most of the North Pacific basin appeared to be rotating! At its most intense, the minimum sea level pressure of Tip was measured at 870 hPa at 0353 UTC on 12 October 1979.100 The estimated maximum sustained (1-minute) surface wind was 85 m s-1 (305 km h-1).

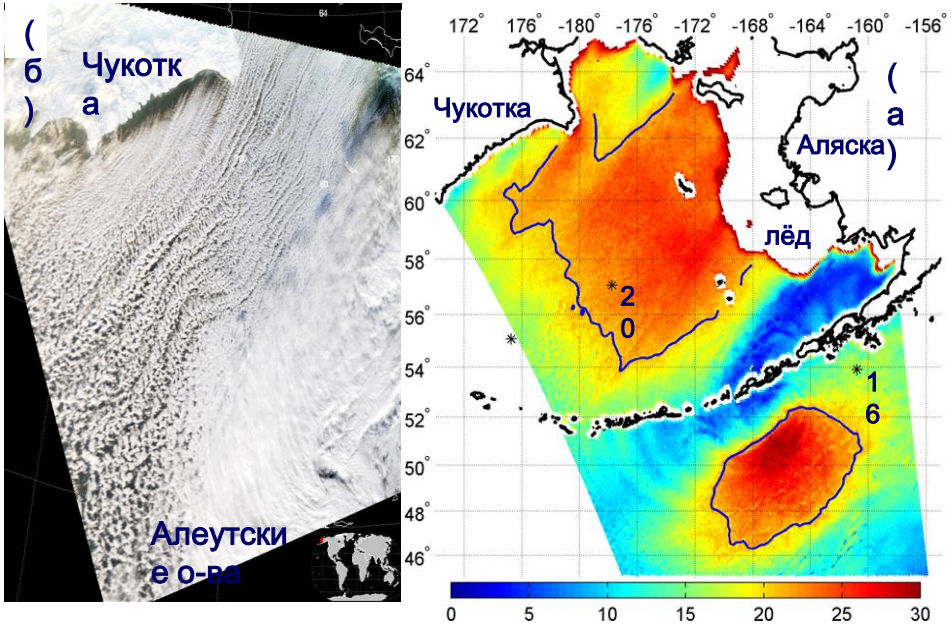
Importance of investigation tropical cyclones for high and midlatitudes

1. Polar lows and quasi-tropical cyclones of midlatitudes
2. Extratropical Transition, dangerous for Far East of RF

Examples of severe wind conditions over the sea

Cold air advection



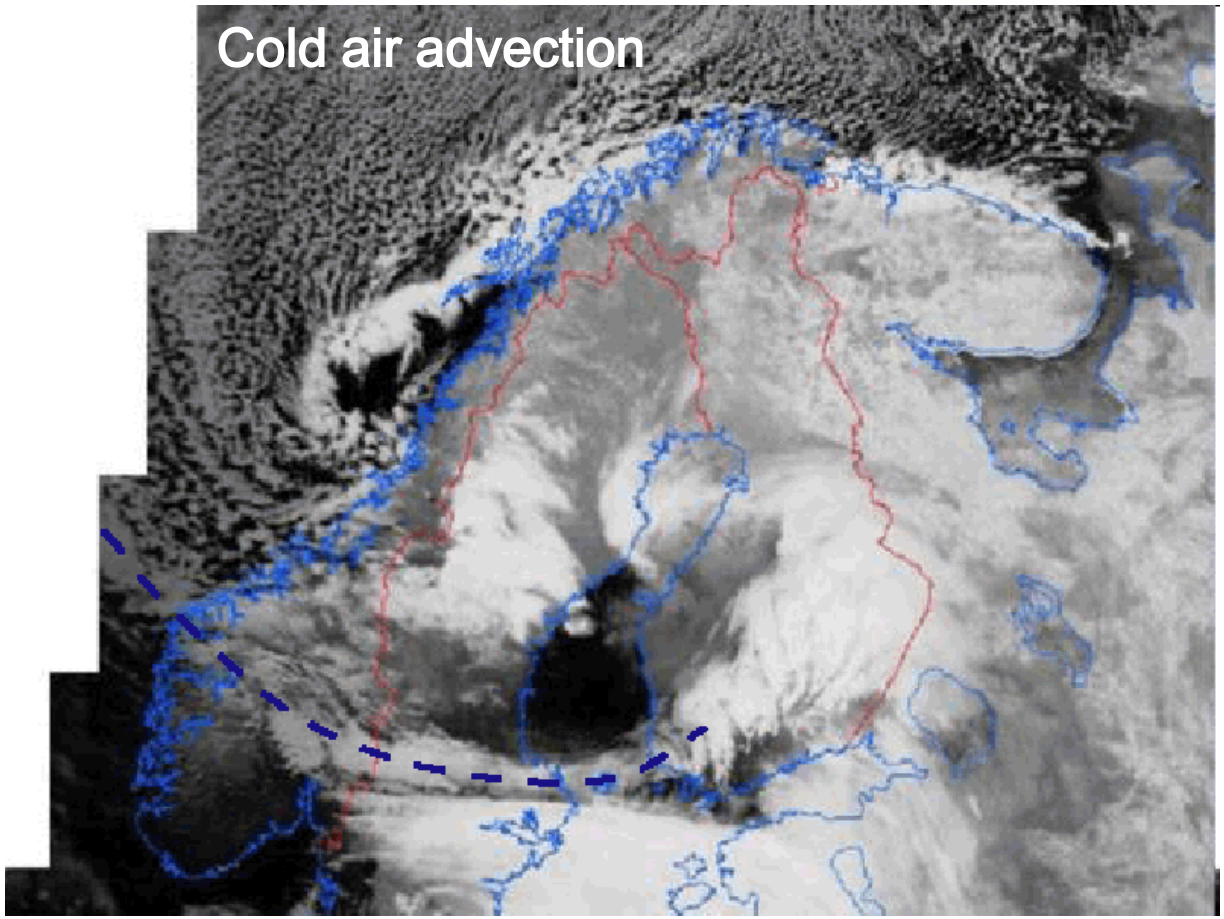


Cold air advection over Barents sea 9 December 2012.: surface analysis map by Japanese MetOffice, 00 GMT
(a), visible image obtained with a spectroradiometer MODIS Aqua satellite at 00:10 GMT.
(b) Wind speed according to the radiometer AMSR2 at 0:05 Gr. December 9.

Examples of severe wind conditions over the sea

Arctic front

30 January 1998/01.29 UTC NOAA IR image (channel 5)



Polar lows

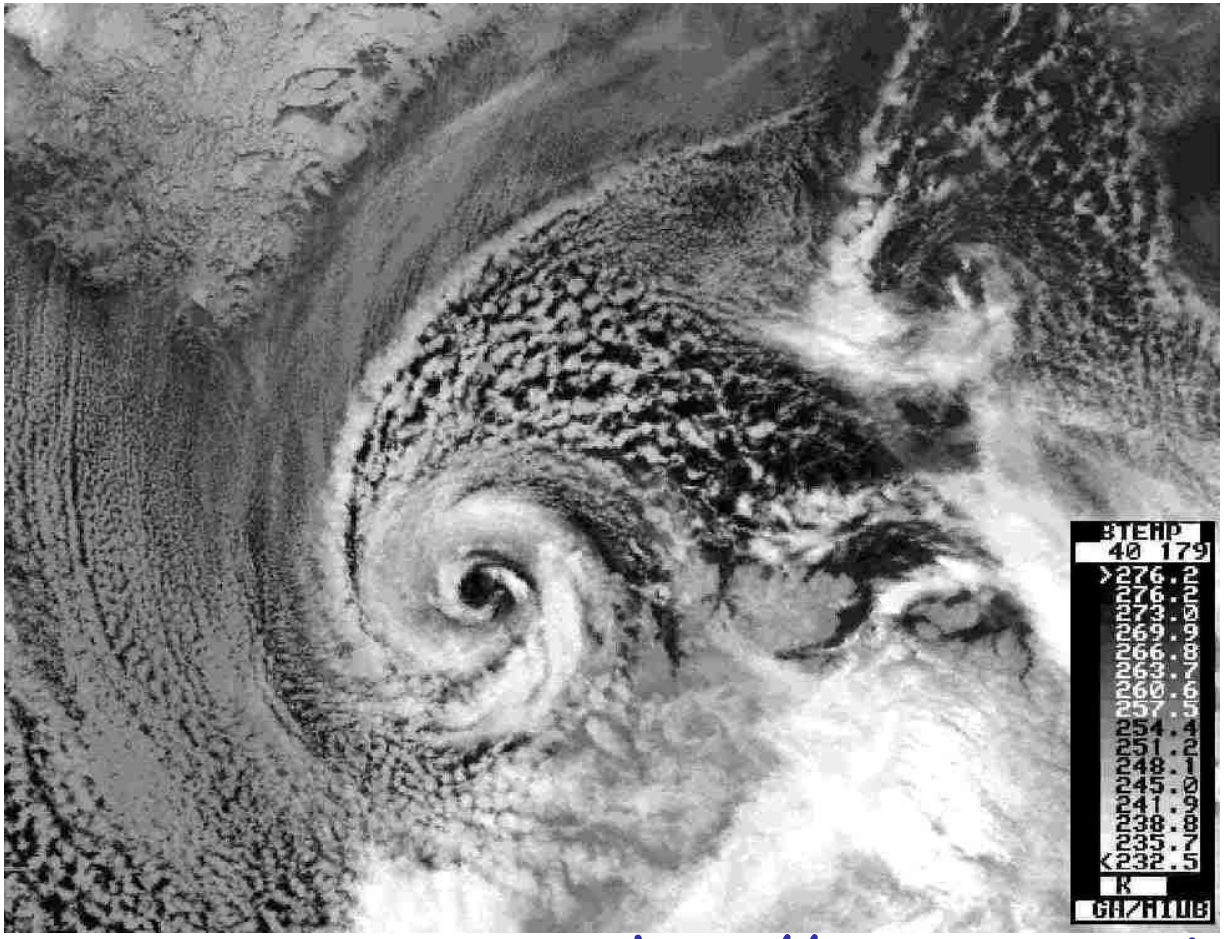
Animation 13-16 October 1993.

Infrared images 04+14 UTC 13th, 06+14 UTC 14th, 05+13 UTC 15th and 05+13 UTC 16th October.

http://www.meteo.uni-bonn.de

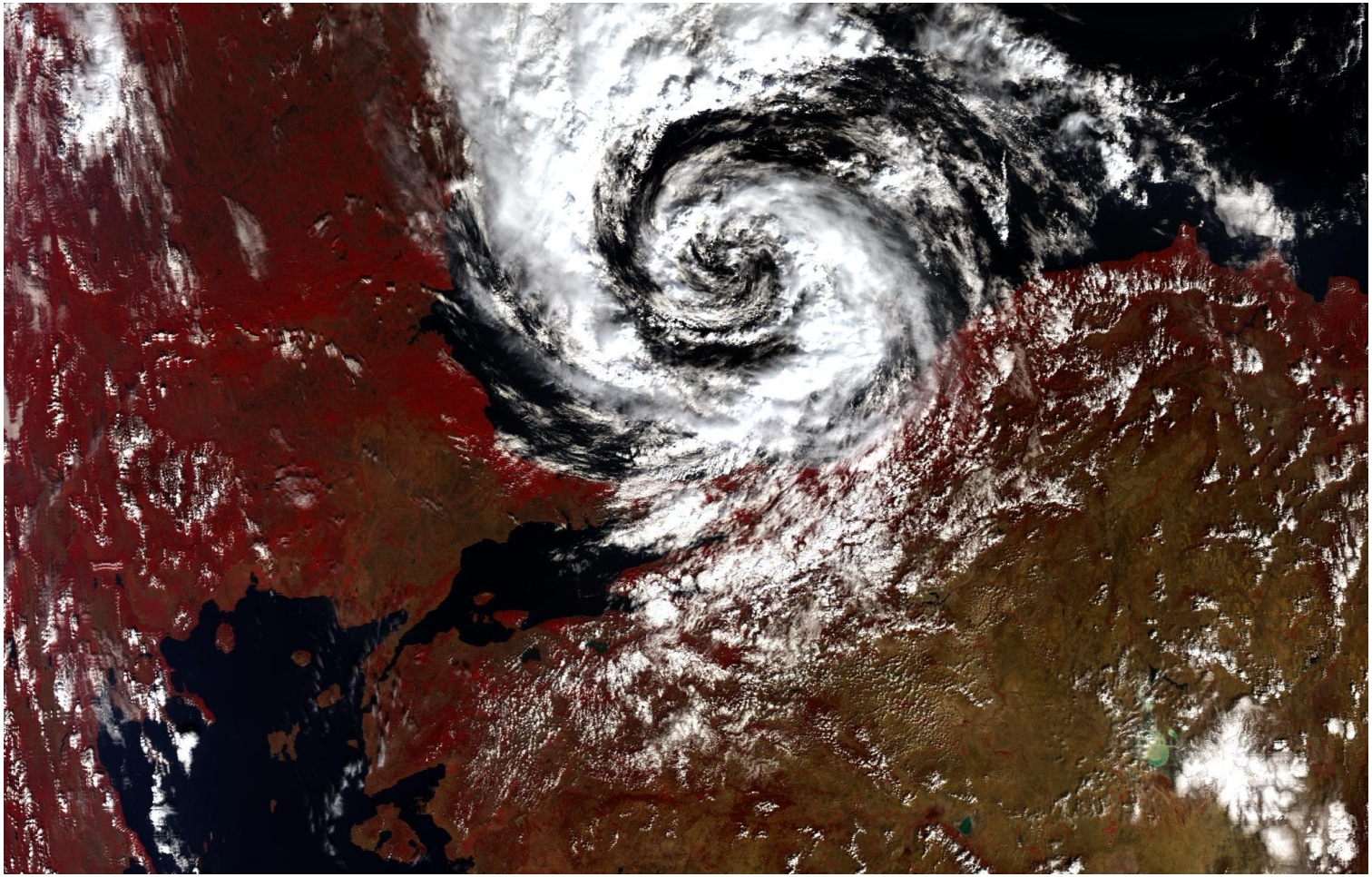
A "most beautiful" polar low over the Barents Sea 27

February 1987 (wind speeds up to 20 m/s)



http://www.meteo.uni-bonn.de

Black sea 27 September 2005



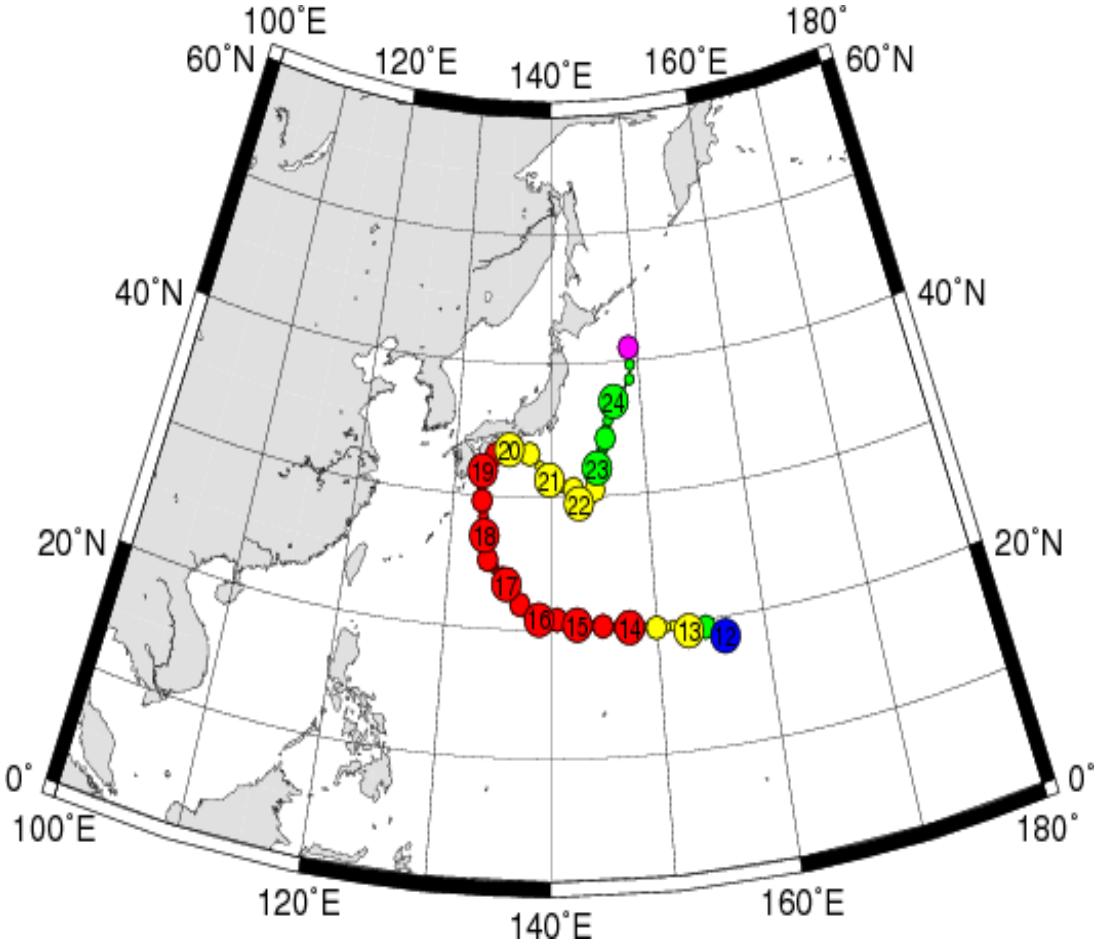
Importance of investigation tropical cyclones for high and midlatitudes

1. Polar lows and quasi-tropical cyclones of midlatitudes
2. Extratropical Transition, dangerous for Far East of RF

Extratropical Transition, dangerous for Far East of RF

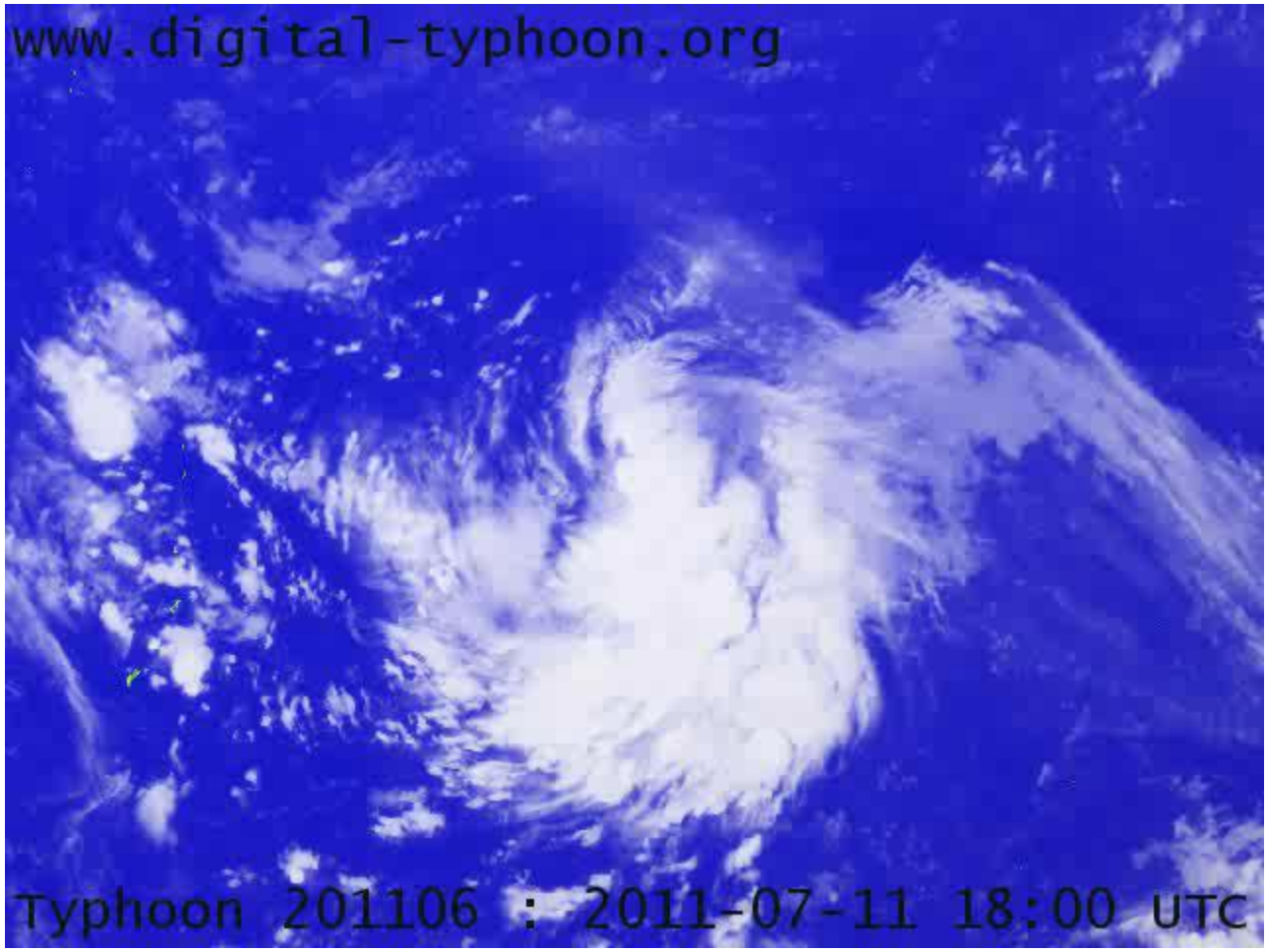
Typhoon 201106 (MA-ON)

Birth
2011-07-12 06:00:00 UTC
Death (Latest)
2011-07-24 12:00:00 UTC
Lifetime
294 (hours) / 12.250 (days)
Lifetime [JMA]
294 (hours) / 12.250 (days)
Minimum Pressure
935 (hPa)
Maximum Wind
95 (knots)
Largest Radius of Storm Wind
180 (nm) / 330 (km)
Largest Diameter of Storm Wind
280 (nm) / 520 (km)
Largest Radius of Gale Wind
550 (nm) / 1020 (km)
Largest Diameter of Gale Wind
900 (nm) / 1670 (km)



Extratropical Transition, dangerous for Far East of RF

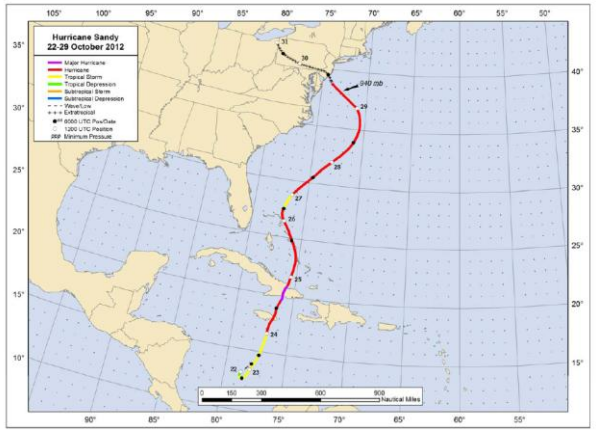
Typhoon 201106 (MA-ON)

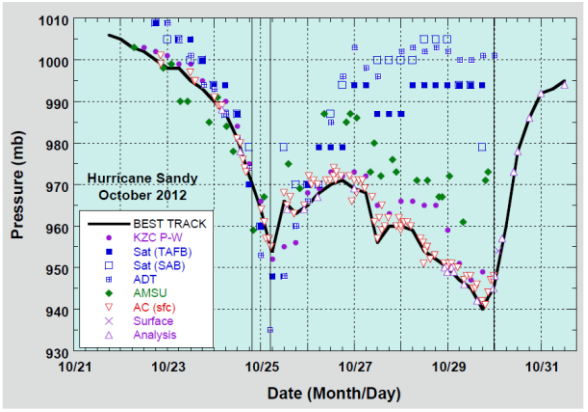


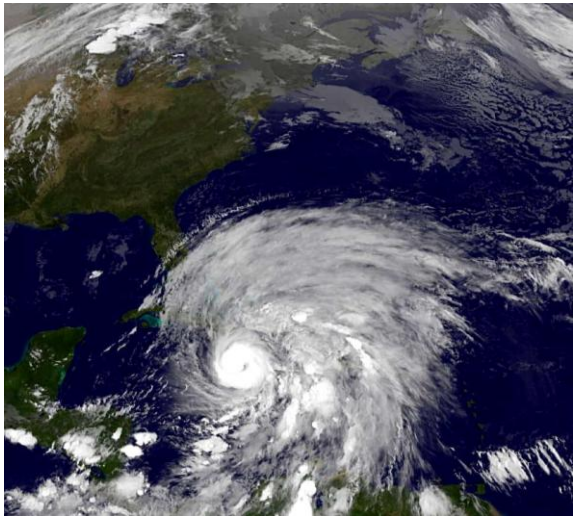
Examples of severe wind conditions over the sea

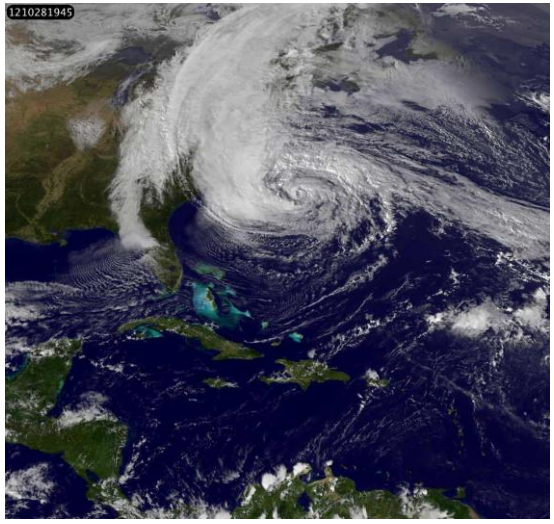
Extratropical Transition

Superstorm Sandy

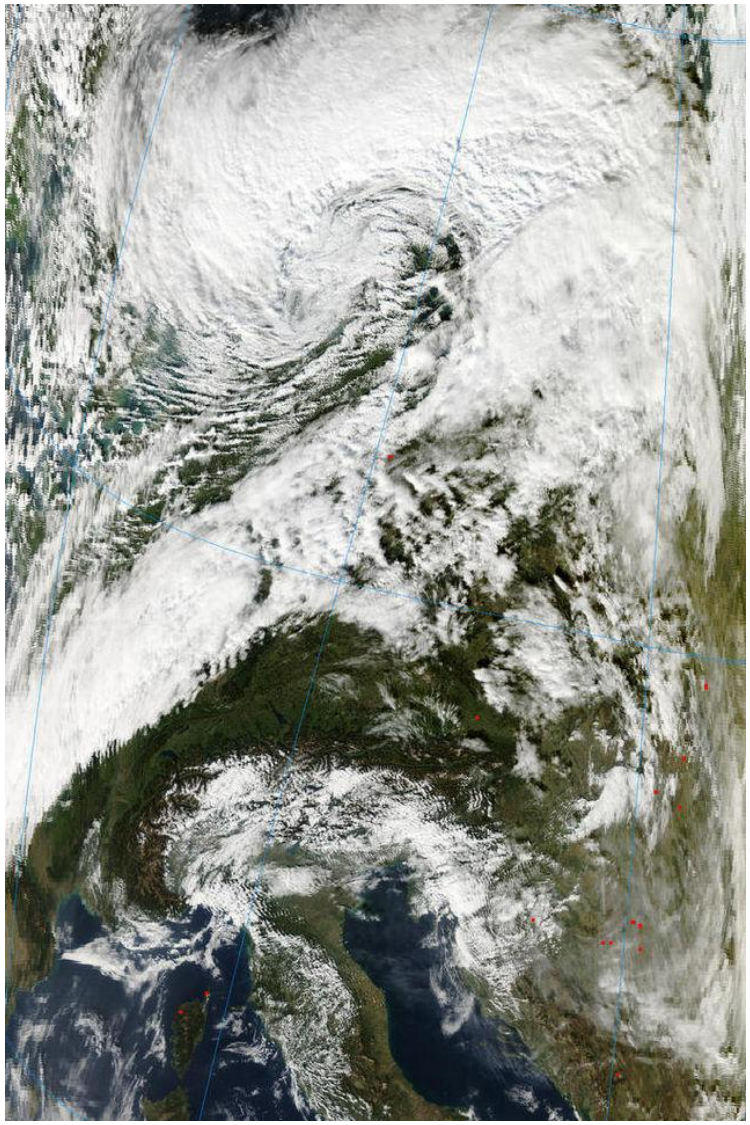








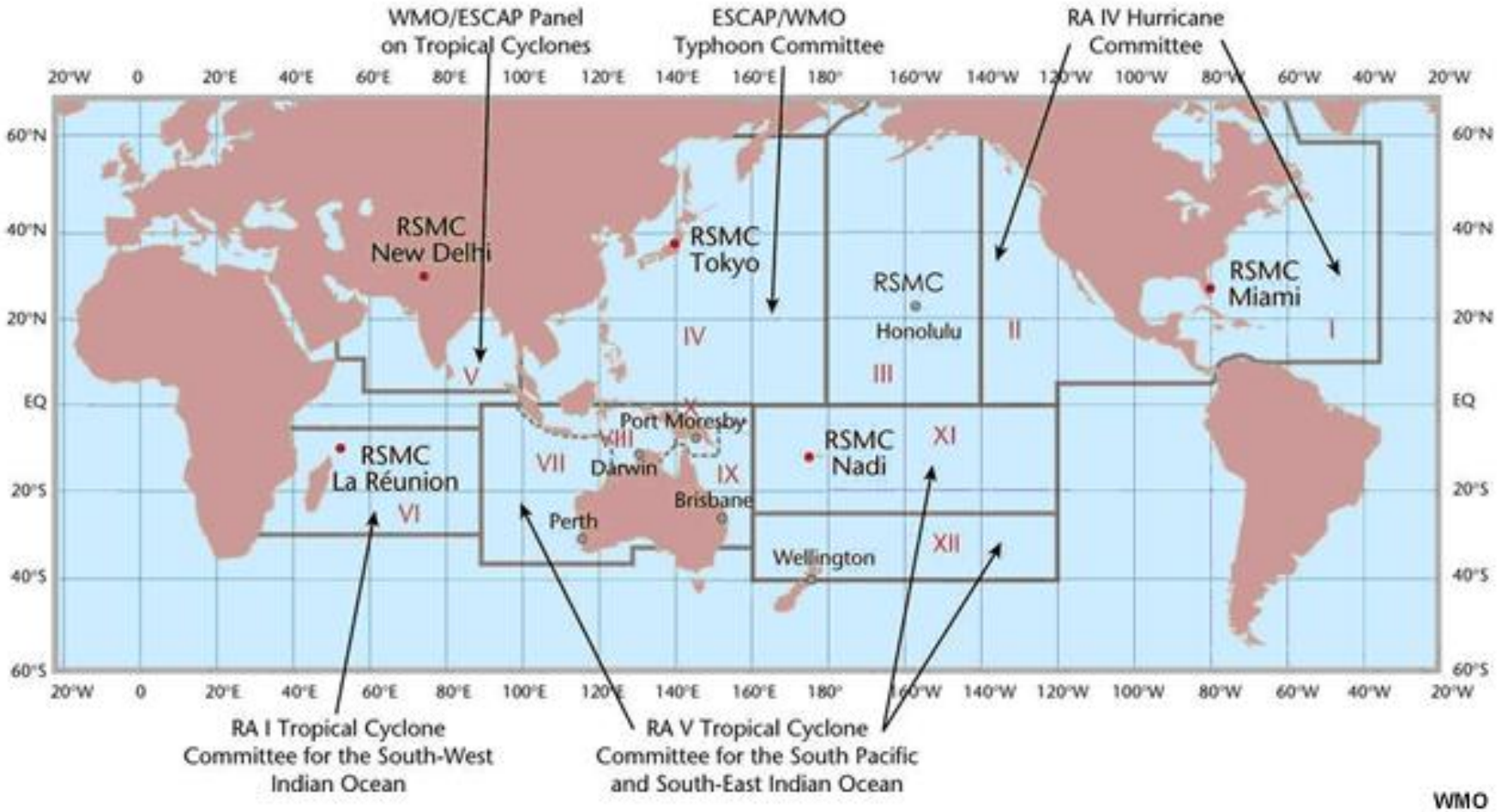
St. Jude storm



For the European continent, and including, for Russia represent a significant threat to the active deep cyclones, which are often formed especially in the north-east Atlantic in the positive phase of the North Atlantic Oscillation.
They are also characterized by conditions of storm and hurricane wind: for example, the wind speed in a hurricane St. Jude in October 2013 reached up to 53 m / s, which corresponds to a category 3 hurricane on the scale Saffir-Simpson hurricane.

Role of satellite remote sensing for monitoring and operational forecast of tropical cyclones

Regional Specialized Meteorological Centres (RSMCs) for monitoring and warning TC

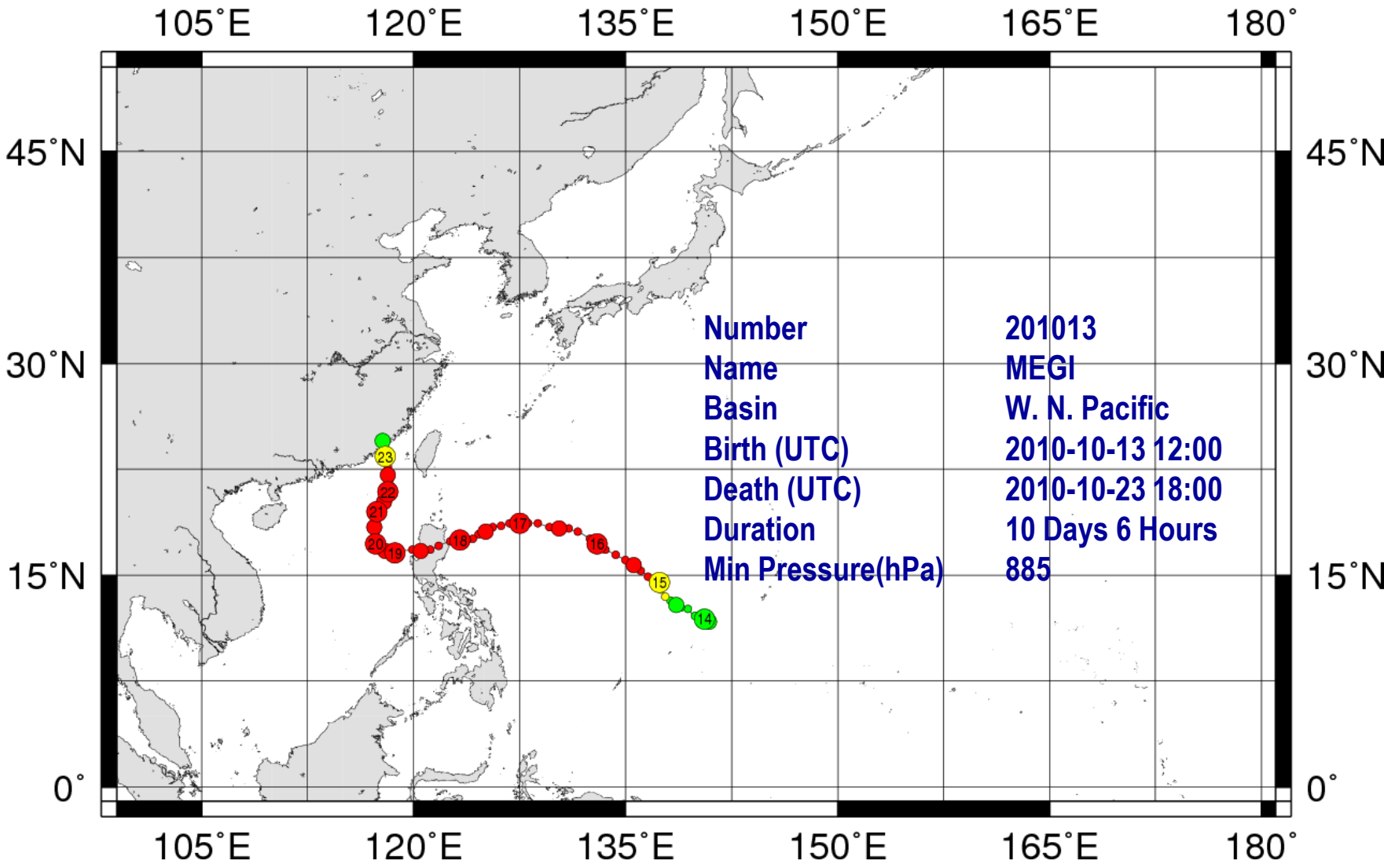


The global system of satellite monitoring in 2008

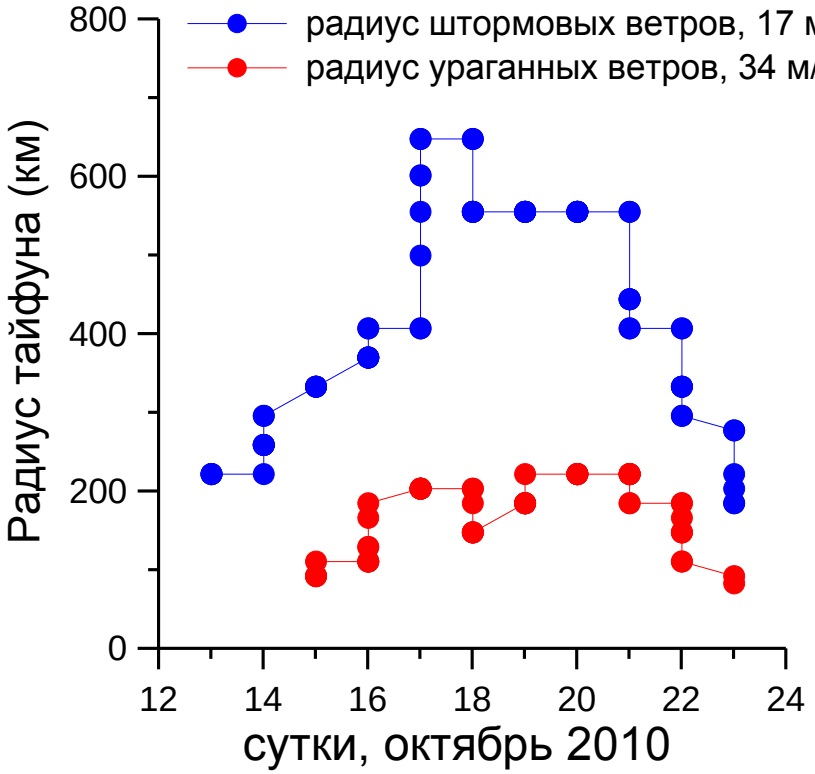
MTSAT 145.0E
6.5 - 7.0 μm
Mid-IR / Water Vapour

Typhoon MEGI

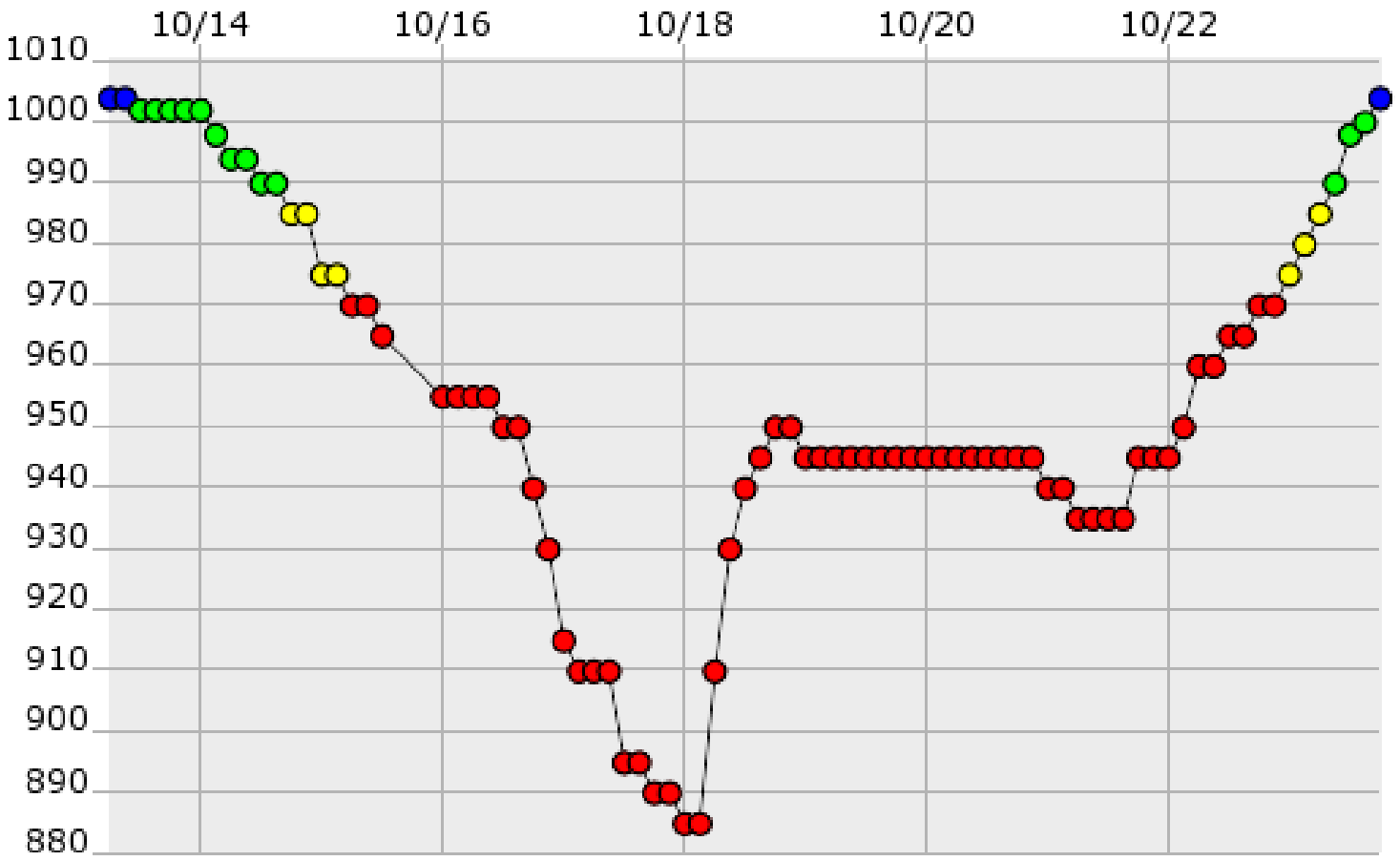
Trajectory (typhoon Megi).



Radii winds of 17 m / s and 34 m / s and the maximum wind speed (typhoon Megi).

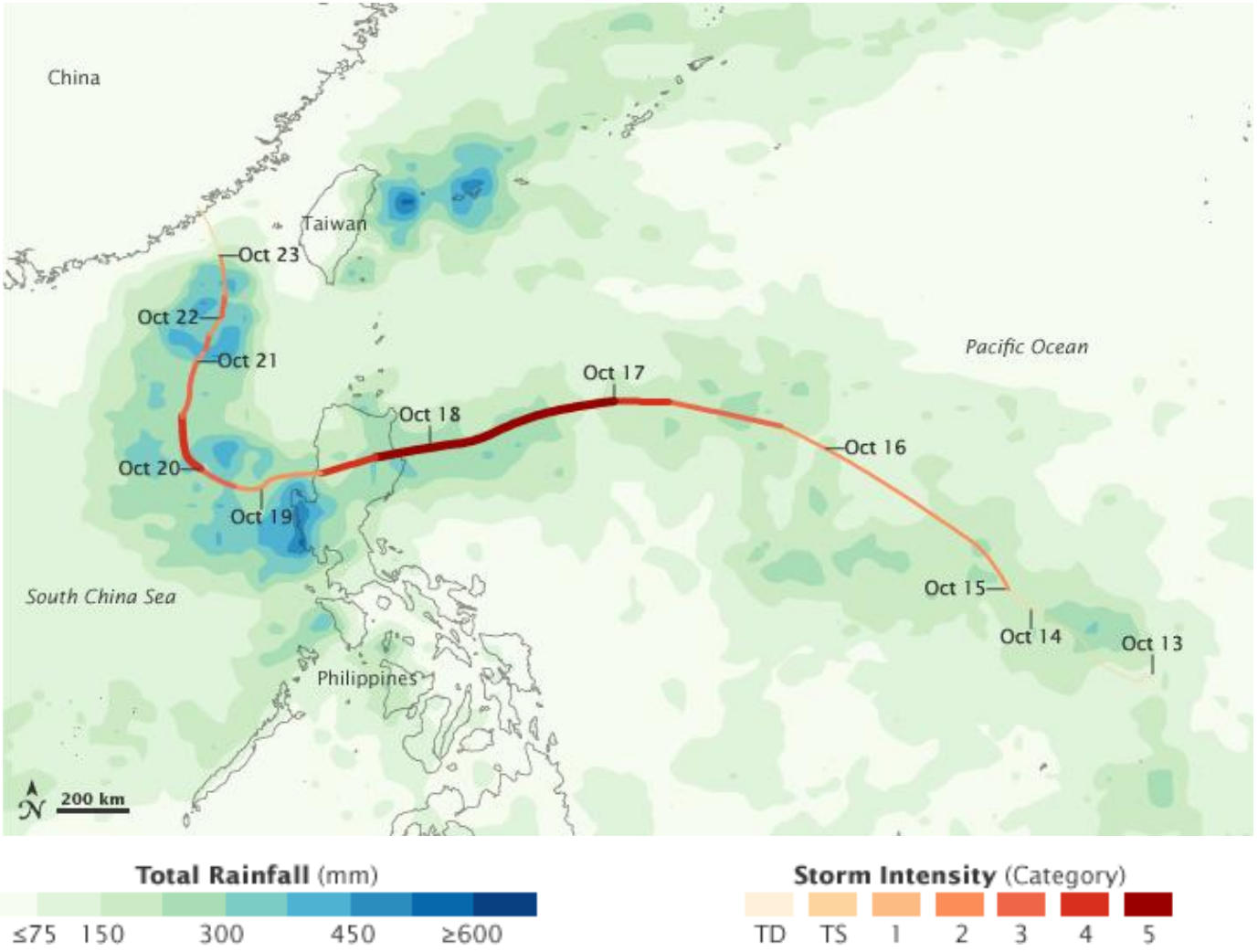


Pressure at the center (typhoon Megi).



Total rainfall

Multisatellite Precipitation Analysi, NASA's Goddard Space Flight Center

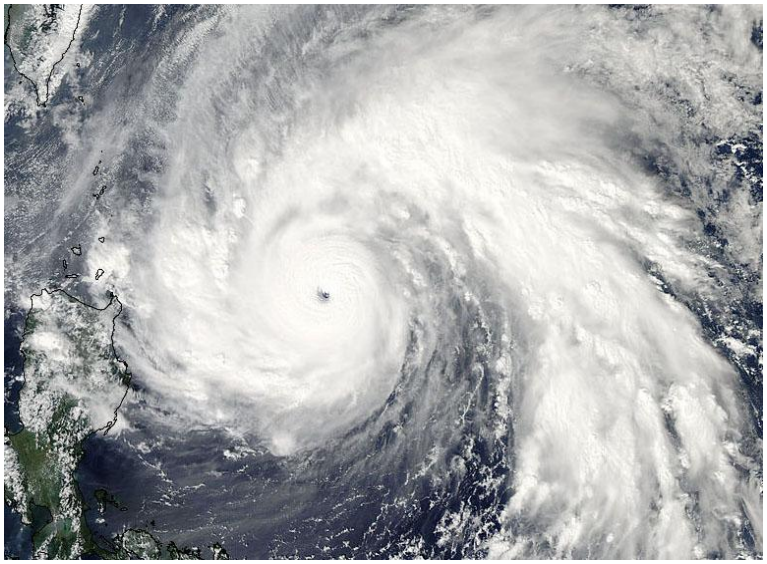


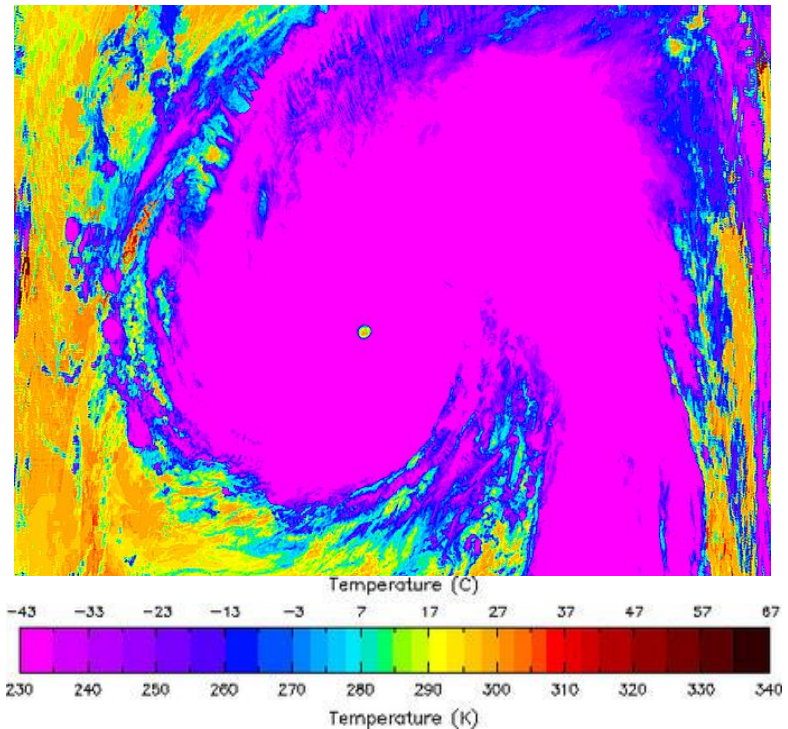
Quantitative information on the typhoon was obtained mainly from data

- microwave radiometer AMSR-E (satellite Aqua),
- scatterometer ASCAT (satellite MetOp),
- SAR ASAR (satellite Envisat),
- radiometer TMI (satellite TRMM)
- Cloud Profile Radar (satellite CloudSat).

Visible and IR images

- spectroradiometer MODIS (satellites Terra и Aqua).





Aqua MODIS

Видимый диапазон (а) и

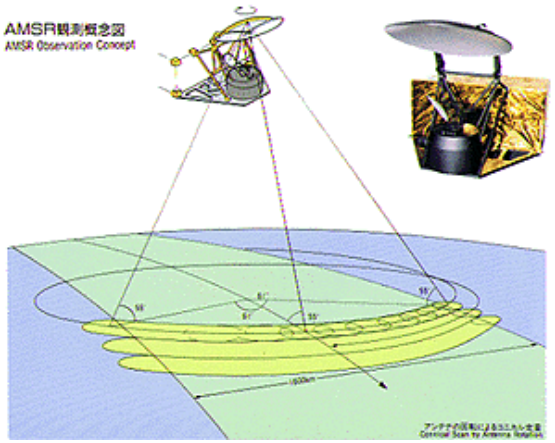
Температура поверхности океана (б)

17.10.2010

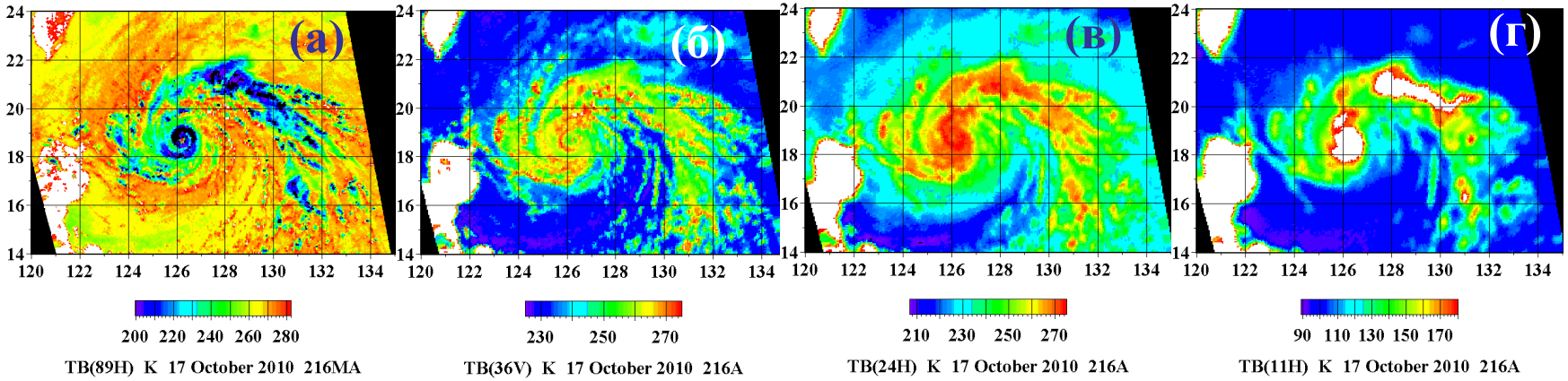
04:55 UTC

Aqua-MODIS

Aqua Advanced Microwave Scanning Radiometer AMSR-E



AMSR-E measures the brightness temperatures of the atmosphere-ocean system with the vertical (V) and horizontal (H) polarizations at frequencies of 6.9, 10.7, 18.7, 23.8, 36.5 and 89.0 GHz. *Instant field of view changes from 40 x 70 km to 3x 6 km. Incidence angle 55 deg, swath width is 1450 km.*

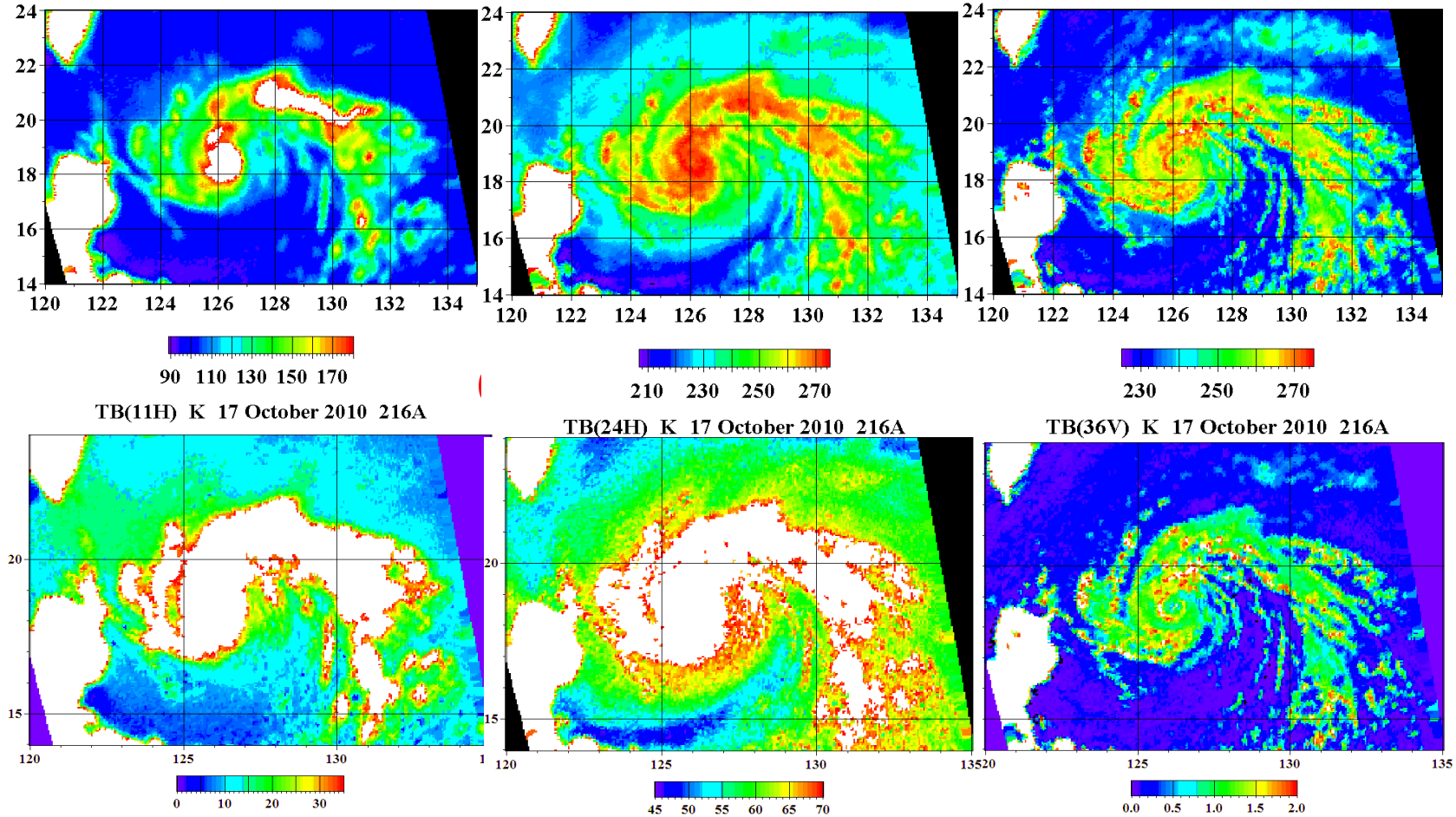


Тайфун Megi. Aqua. 17 октября, 04:55 Гр. P_{min} = 910 мб.
MODIS, AMSR-E:
(а) Тя(89Г), (б) Тя(10.7Г), (в) Тя(23.8В), (г) Тя(36.5В)

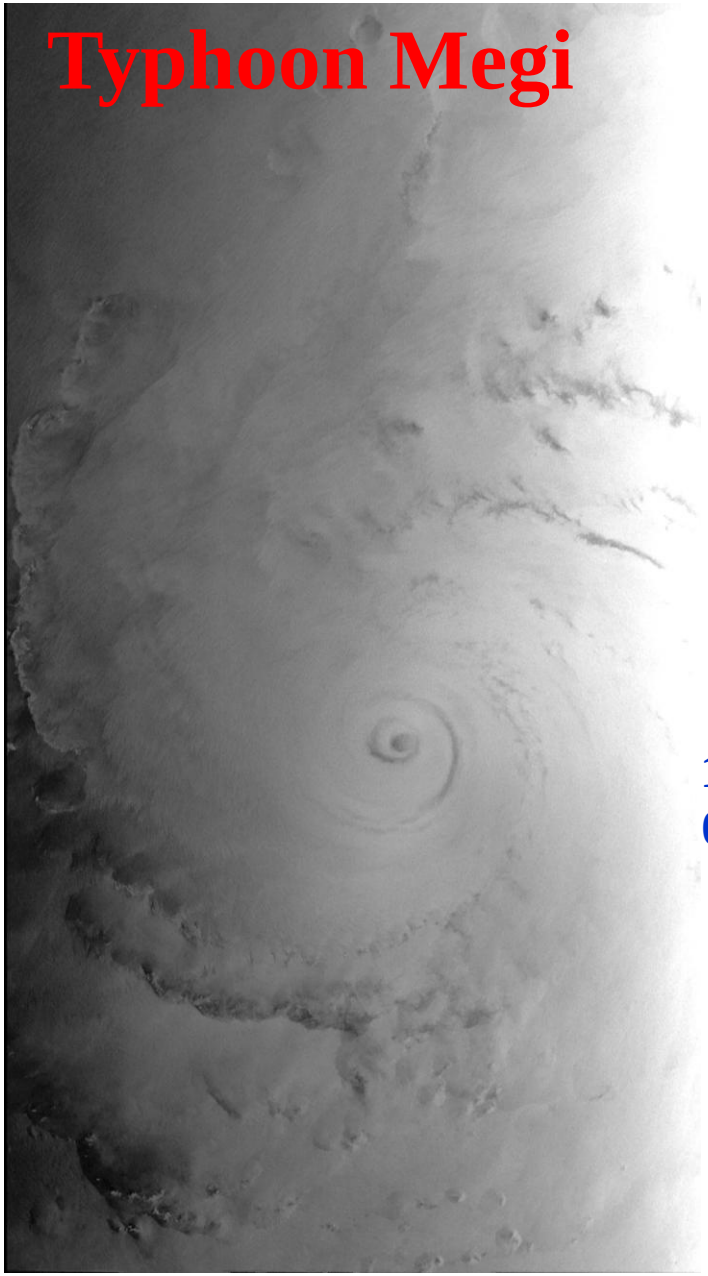
Brightness temperatures Тя(10.7Г), Тя(23.8В) and Тя(36.5В) and wind speed, water vapor content and liquid water clouds, 04:55 UTC 17 October 2010.

Алгоритмы: Mitnik L.M., Mitnik M.L. *Radio Science*. 2003. V. 38. no 4.

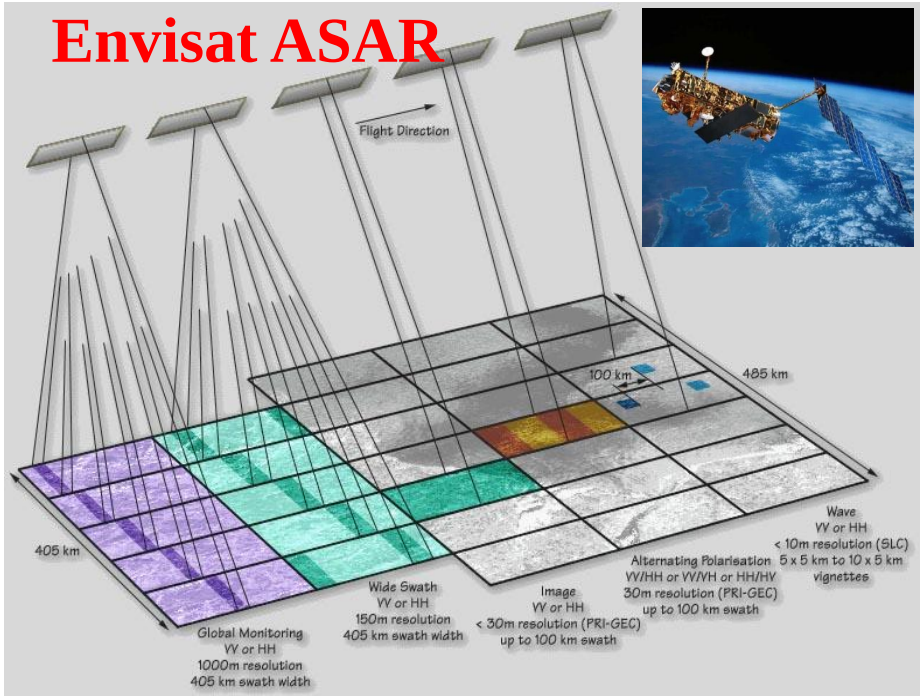
. Mitnik L.M., Mitnik M.L. *Proc. IGARSS 2010*, Honolulu, Hawaii, IISBN 978-1-4244-9566-5. P. 558-561.



Typhoon Megi



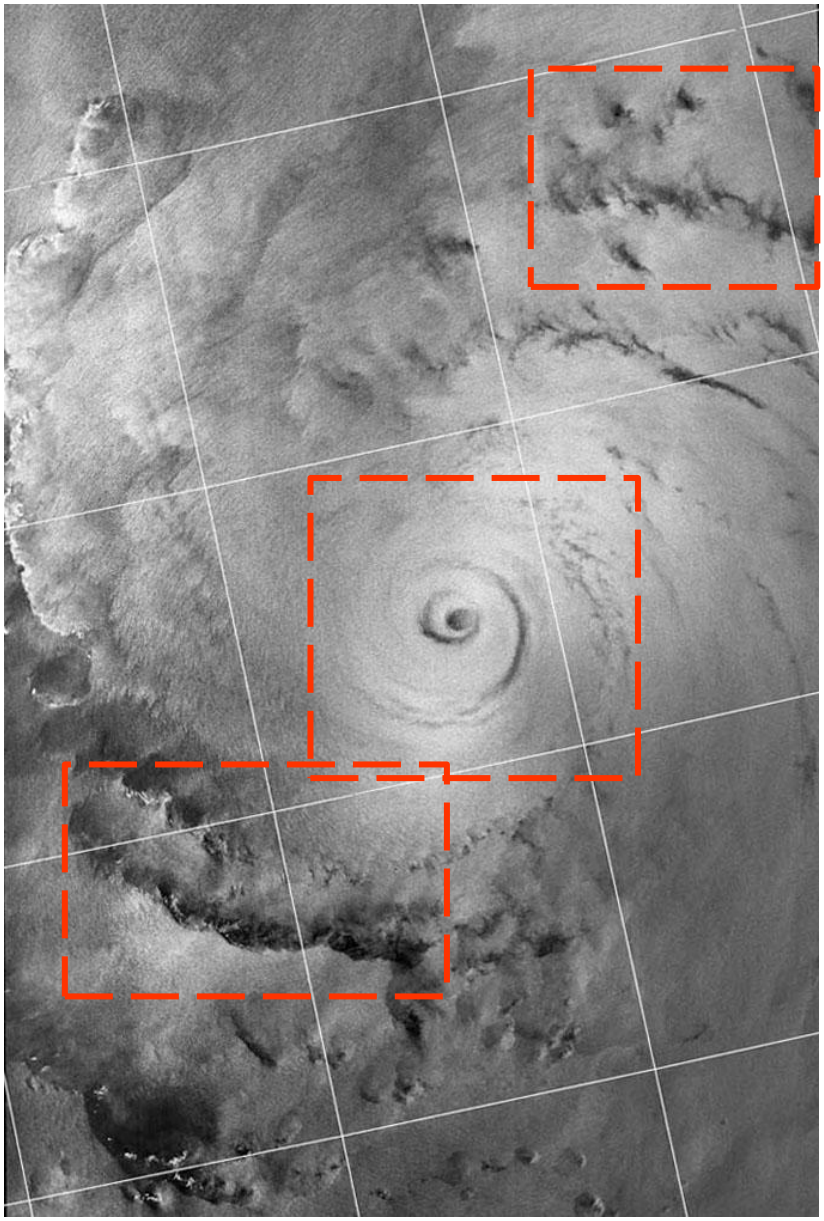
Envisat ASAR

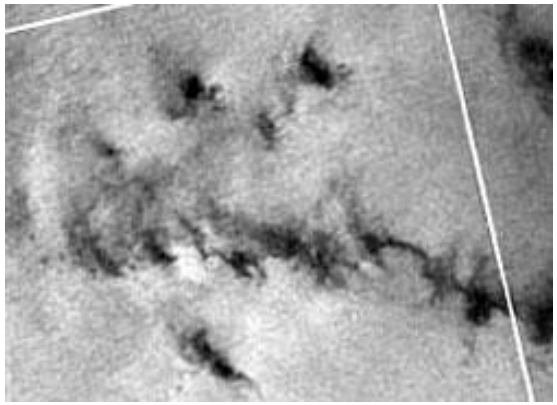


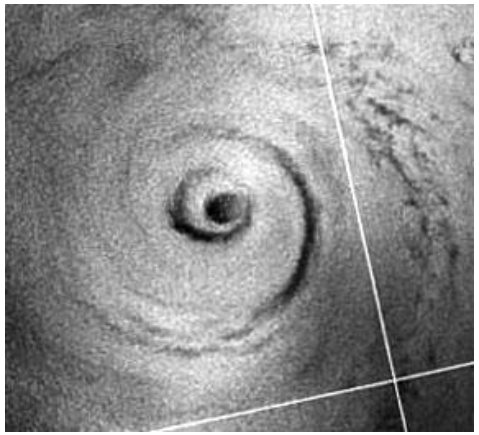
17 October
01:22 UTC

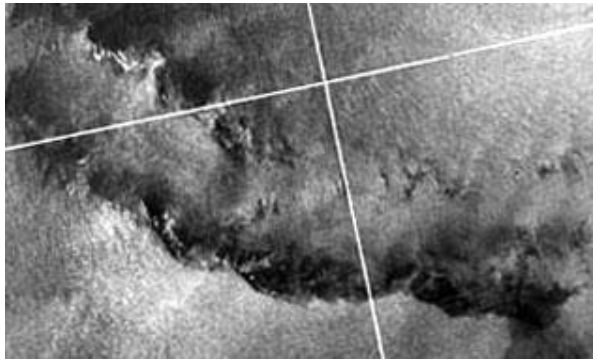
P_{min} = **910 mb**

SENSOR	ASAR
Frequency, GHz	5.3
Wavelength, cm	5.6
Polarization	VV, HH
Incidence angle, deg	15-45
Swath width, km	100-405
Ground resolution, m	25 x 25 150x150









Обработка В.А. Дубины (*ТОИ ДВО РАН*)

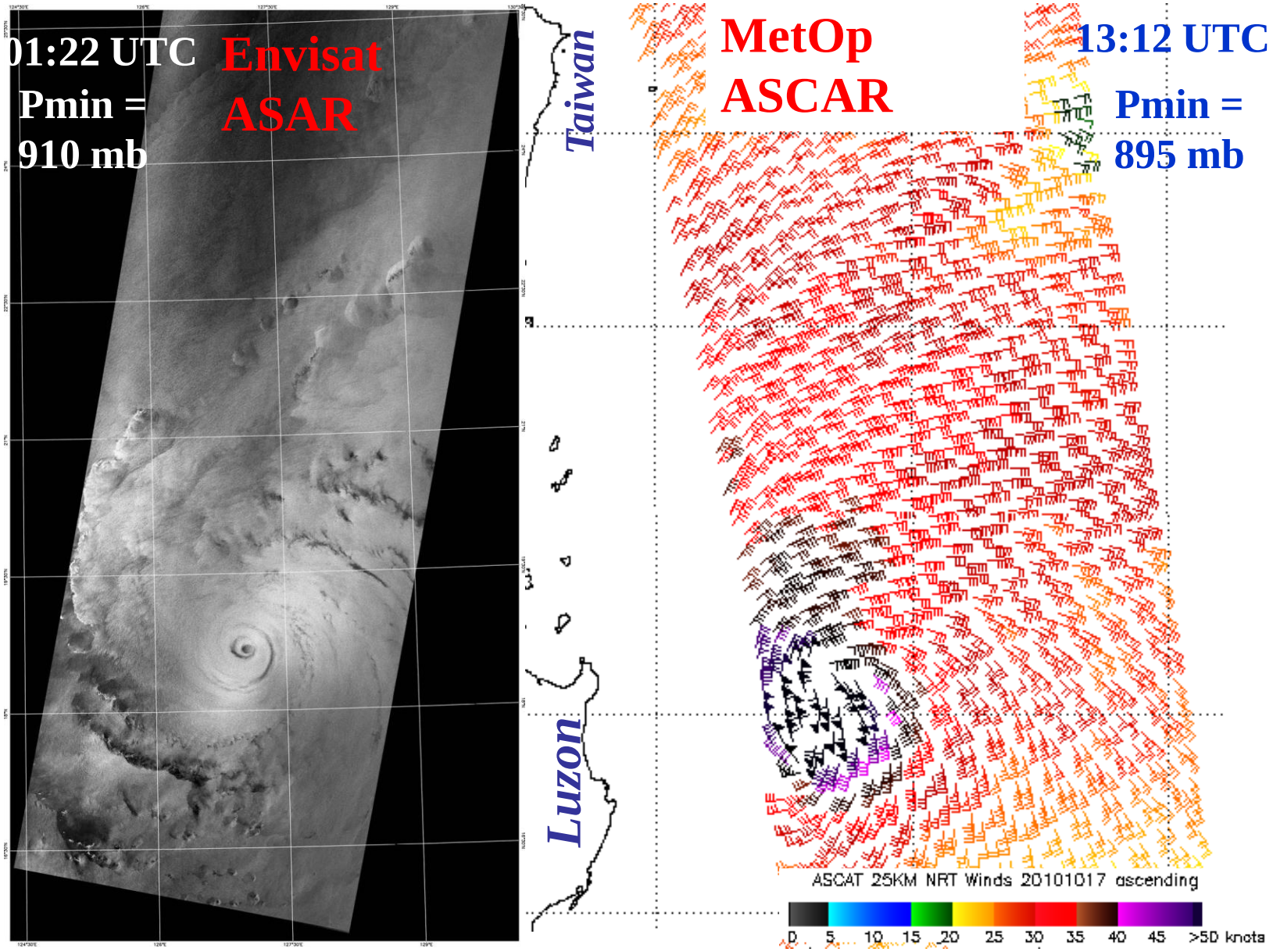
rain cells

Направление зондирования

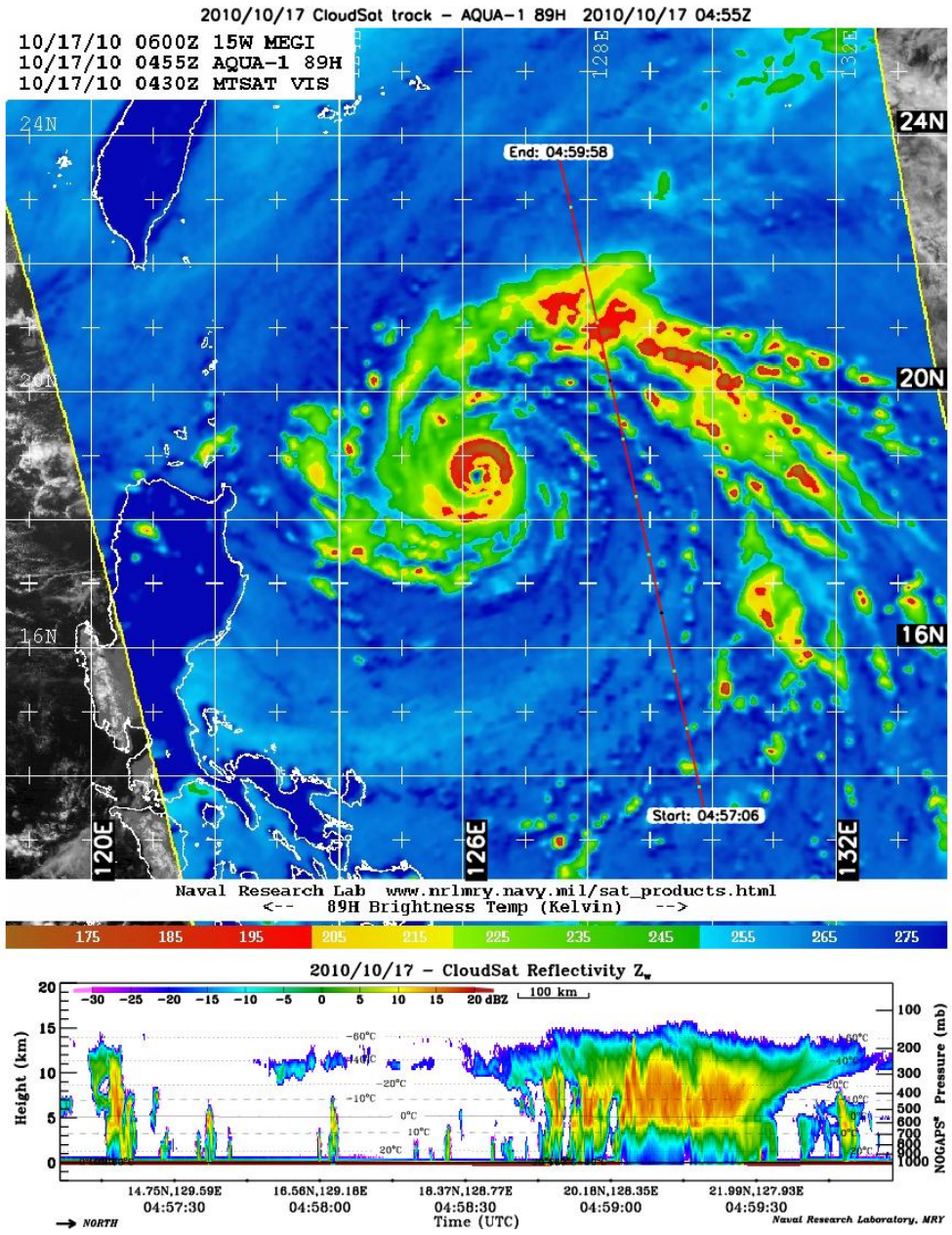
Eye and eye wall

P_{min} = 910 мб

Rain band, squalls


01:22 UTC
Pmin =
910 mb
Envisat
ASAR
Taiwan
Luzon
MetOp
ASCAR
13:12 UTC
Pmin =
895 mb
ASCAT 25KM NRT Winds 20101017 ascending
0 5 10 15 20 25 30 35 40 45 >50 knots

http://cloudsat.atmos.colostate.edu/



Typhoon Megi

17 October 04:55 UTC

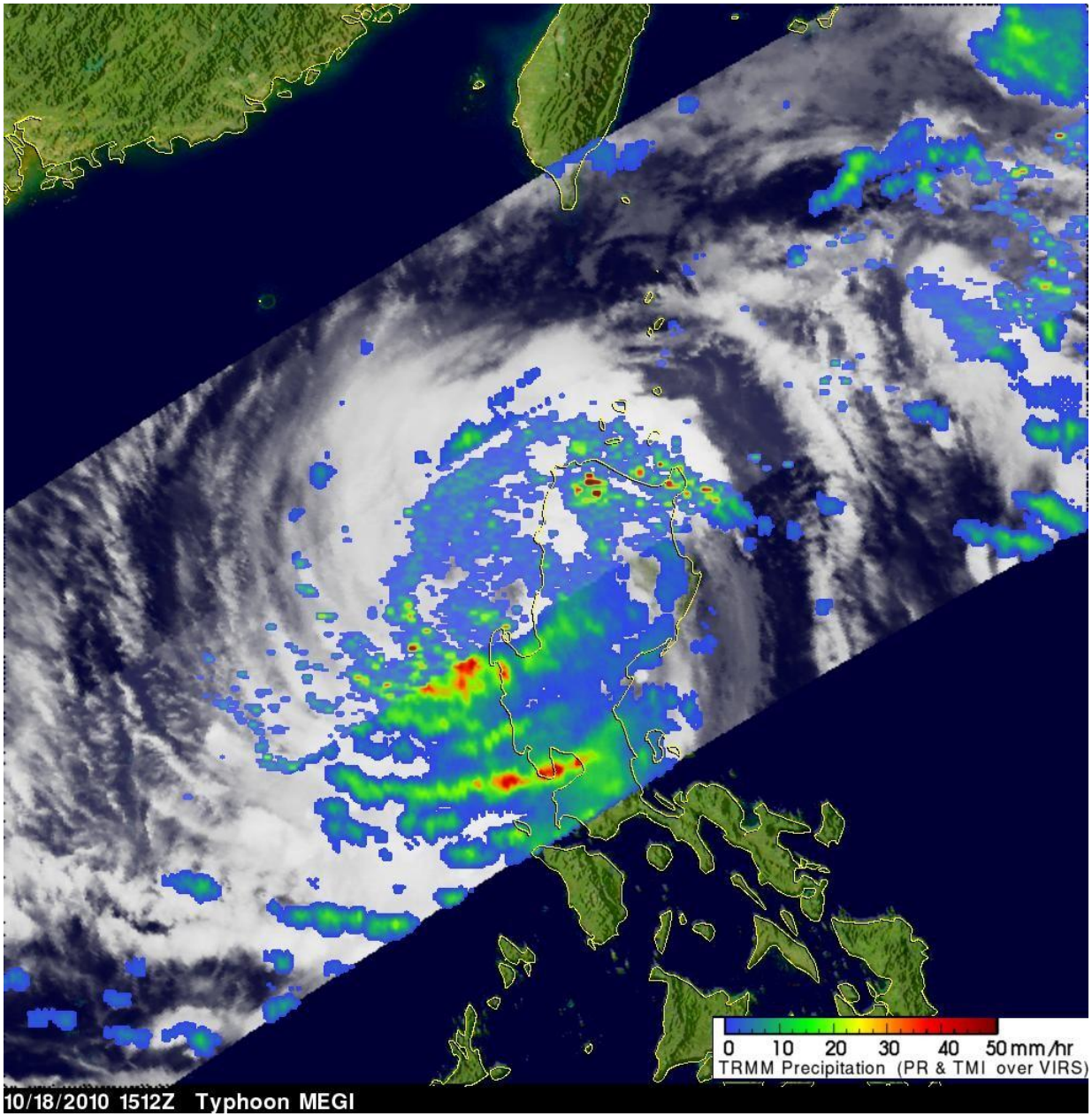
Aqua AMSR-E

Tb(89H) NRL Monterey Marine Meteorology Division

CloudSat

CloudSat uses 94-GHz nadir-looking radar to observe clouds and precipitation from space. The radar measures the power backscattered by clouds as a function of distance from the radar.

Pulse width	3.3 μsec
Data window	0-25 km
Antenna size	1.85 m
Vertical resolution	500 m
Cross-track resolution	1.4 km,
Along-track resolution	1.7 km



Typhoon Megi's rainfall was taken from the TRMM satellite on October 18 at 1512 UTC.
The rainfall over Luzon, and the northern Philippines was moderate to heavy.
Red areas represent rainfall at over 50 mm/hr.

Image Credit: NASA/SSAI, Hal Pierce

Conclusions

- Tropical cyclones are the most dangerous weather systems
- In mid and high latitudes tropical-like cyclones are observed under favorable conditions
- In mid latitudes there is a dangerous phenomena like extra-tropical transition (Sandy)
- Passive methods of Satellite remote sensing enables to measure wind speed, water vapor content and liquid water clouds
- Errors increase at strong winds due to
  - Saturation of the radar return at strong winds
  - Decrease of microwave radiation penetrating strong clouds

Novel methods are required

Thank you for your attentlon