Satellite investigations of polar lows over the Japan Sea

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Introduction

Winter mesoscale cyclones (MCs) are frequently observed over the Japan Sea where there are favorable conditions for their development when cold air mass moves across relatively warmer water. MCs are not often noted on the weather charts due to their small scales, short life time (typically between 12 and 72 hrs) and development in data sparse regions. They are difficult to forecast because of their rapid evolution and movement. The main sources of quantitative spatial data to examine these systems are satellite observations and fields of geophysical parameters retrieved from measurements conducted by various satellite sensors.

Polar lows (PLs), the most intensive MCs, are considered as a subtype. Up-to-date definition states: "*A polar low is a small, but fairly intense maritime cyclone that forms poleward of the main baroclinic zone (the polar front or other major baroclinic zone). The horizontal scale of the PL is approximately between 100 and 1000 km and surface winds near or above gale force”* (_Rasmussen and Turner, 2003_**).**

The purposes of this work:

- to get statistical estimates of mesoscale vortices;

- to apply passive and active microwave techniques for mesoscale vortices;

- to investigate structure and characteristics of mesoscale vortices by analysis of the Terra and Aqua MODIS visible and infrared images, QuikSCAT SeaWinds wind fields, the Aqua AMSR-E brightness temperatures *T*bs and fields of the total atmospheric water vapor content *V* and total cloud liquid water content *Q* retrieved from *T*bs.

Sensors, satellites and data

- **Promising sources of regularly available remotely sensed data to the MCs study are the Aqua Advanced Microwave Scanning Radiometer (AMSR-E), the QuikSCAT Seawinds scatterometer and Terra and Aqua MODIS spectroradiometer.** *All these sensors are characterized by a wide swath and possess improved spatial resolution and/or have additional spectral channels compare to such sensors as the SSM/I, AMSU, AVHRR, etc.*

The MCs were detected by screening Terra and Aqua MODIS images acquired in 2003-2008. Analysis of satellite images revealed two main cloud patterns accompanying the PLs: comma-shaped cloud patterns and spiral ones. Spiral PLs have considerable similarity to tropical cyclones including the presence of a clear eye at the centre of the cloud vortex and a warm core.

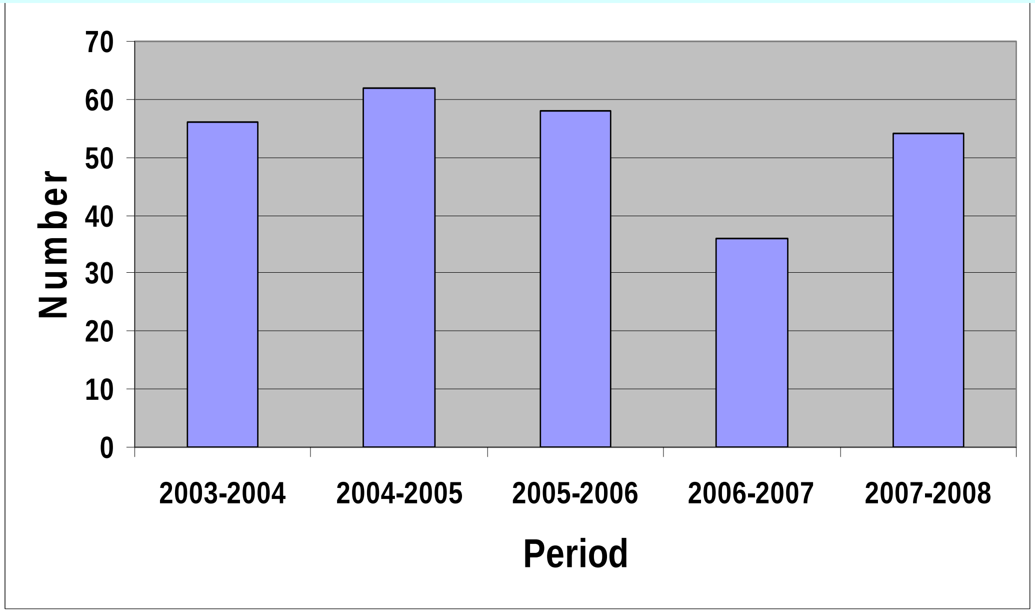
Statistics: limited data (1 year, *Kozo Ninomiya*)

Our preliminary statistics: 5 years 2003-2008, October – April

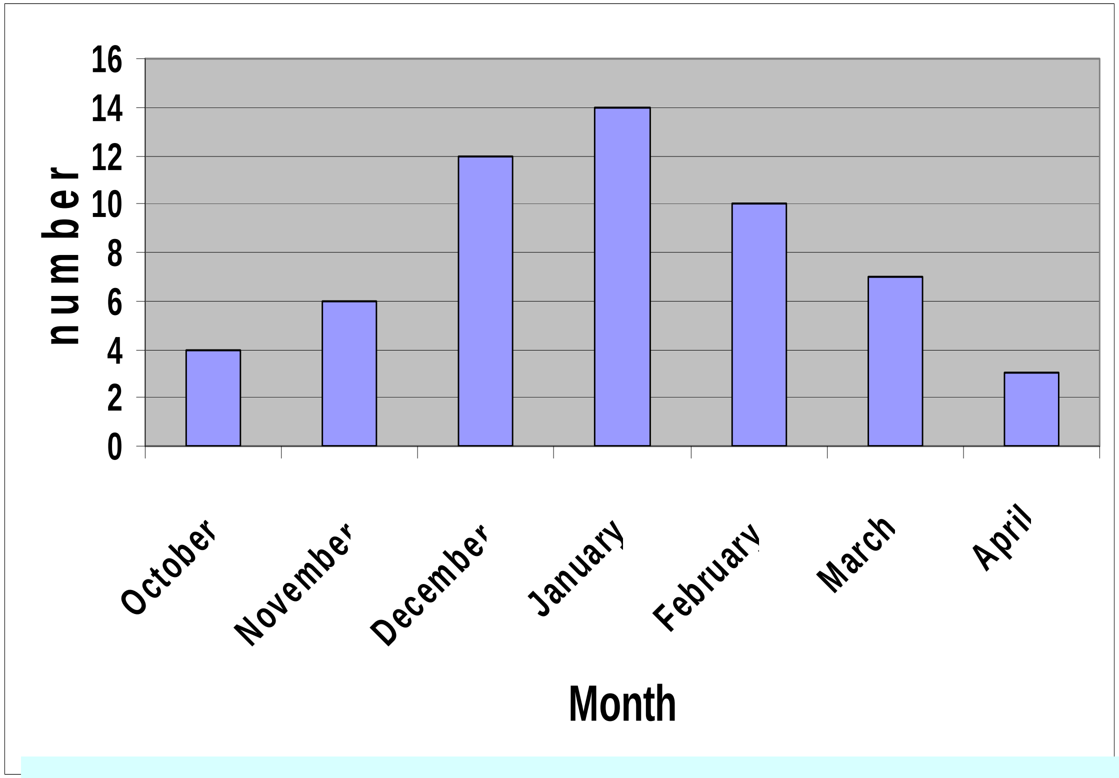
Yearly average number of MC: 53

Preliminary Statistics

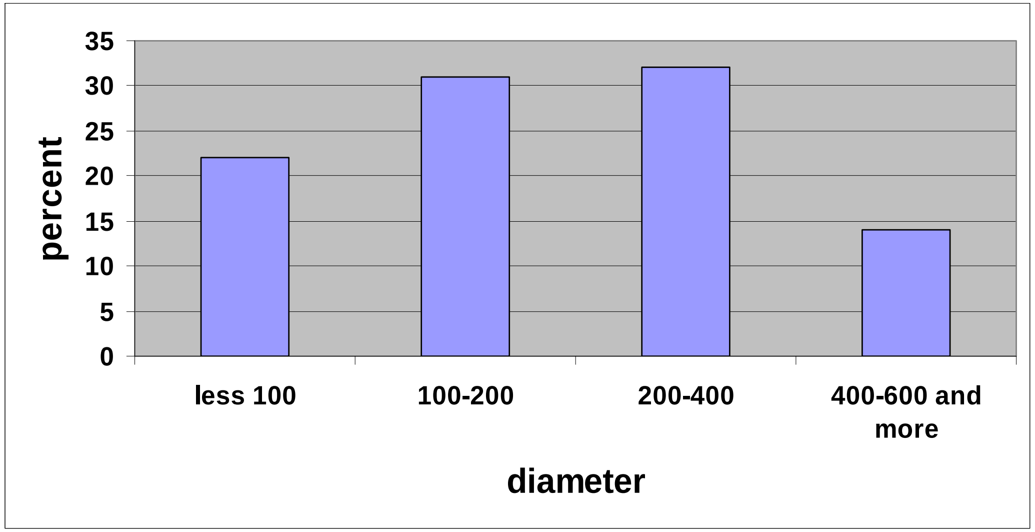
Yearly average number



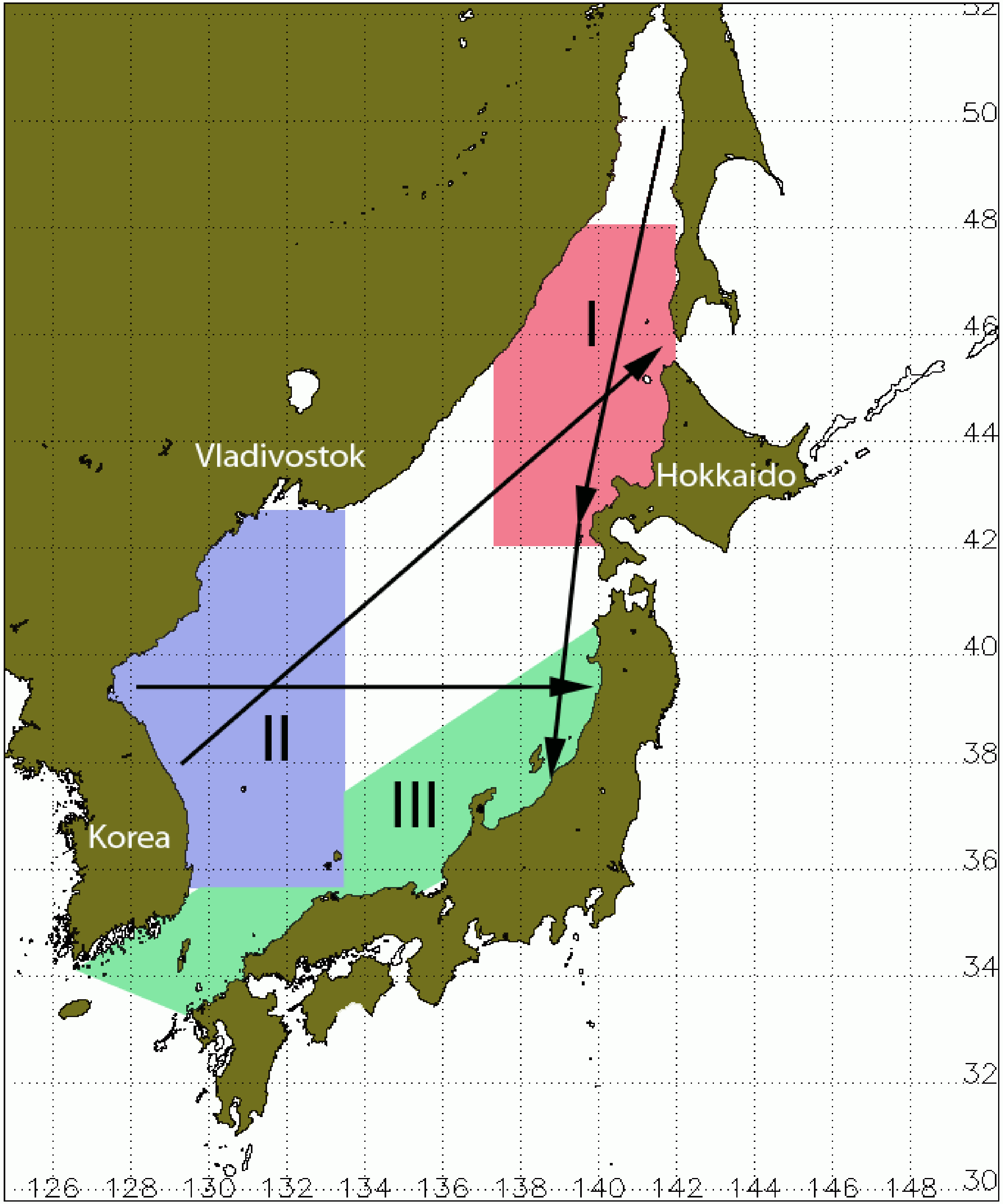
Monthly average number



The size of mesovortices, km



Life circle of the most MC is 0.5-1 days, some of them are observed 2 days and only a few till 3 days.



I, II and III are the main areas of mesoscale cyclogenesis.

Dark arrows show dominant tracks of the mesoscale vortices over the Japan Sea.

Approach

- **Probe MVs structure and evolution using:**
- **- Terra and Aqua MODIS visible/IR images (*cloudiness*)**
- **- Aqua AMSR-E brightness temperatures (*water vapor content* and *cloud liquid water*)**
- **- QuikSCAT SeaWinds and Envisat ASAR (*surface wind*)**
- **- Surface analysis, absolute topography and temperature field maps from JMA and KMA and SST reanalyses from NCEP-NCAR NOAA.**

- **Case studies:**
- **Japan Sea**

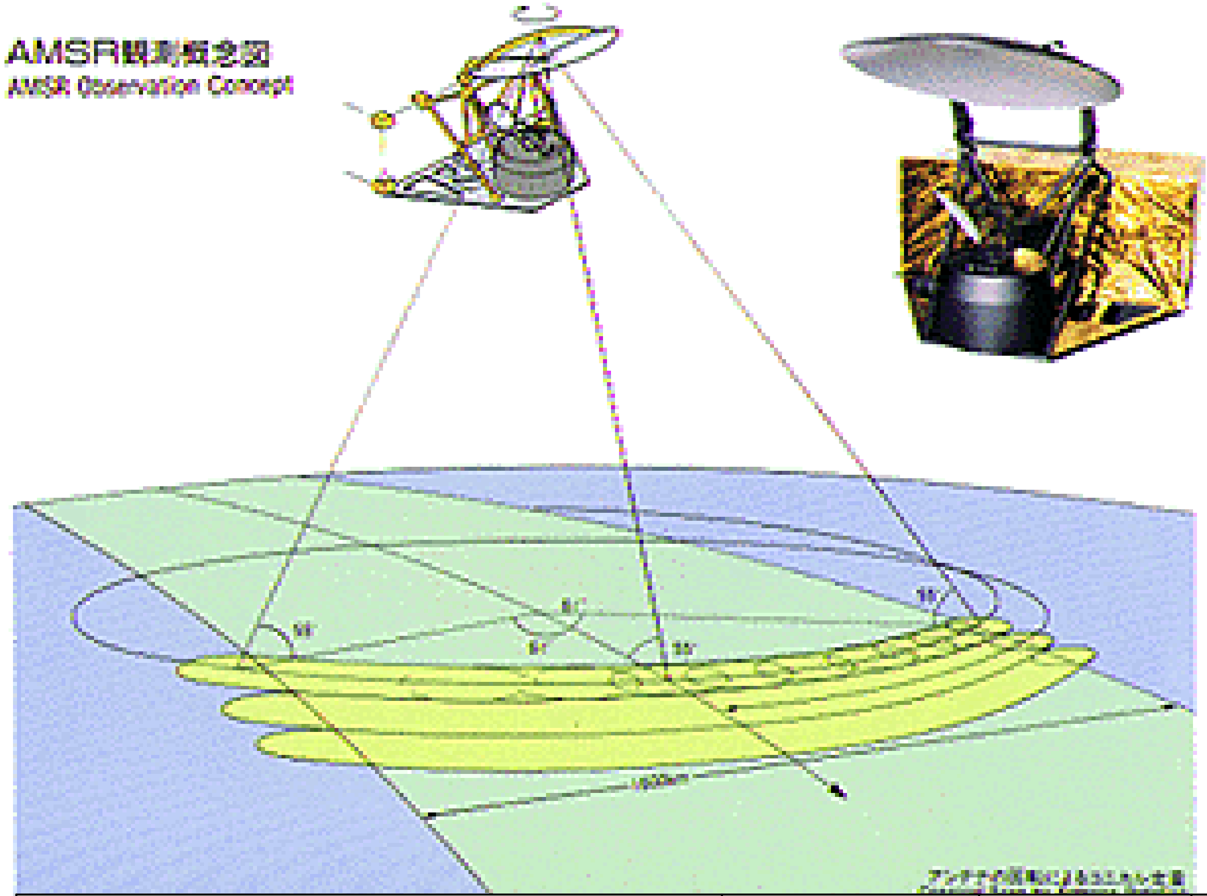
  Cold period 2003-2008

MODIS images of selected PLs were compared to

- **QuikSCAT-derived wind fields,**
- **Aqua AMSR-E-derived fields of total atmospheric water vapor content, total cloud liquid water content,**
- **surface analysis and upper-air analysis and**
- **radiosonde reports.**

Fields of atmospheric water vapor and cloud liquid water were derived by applying retrieval algorithms:

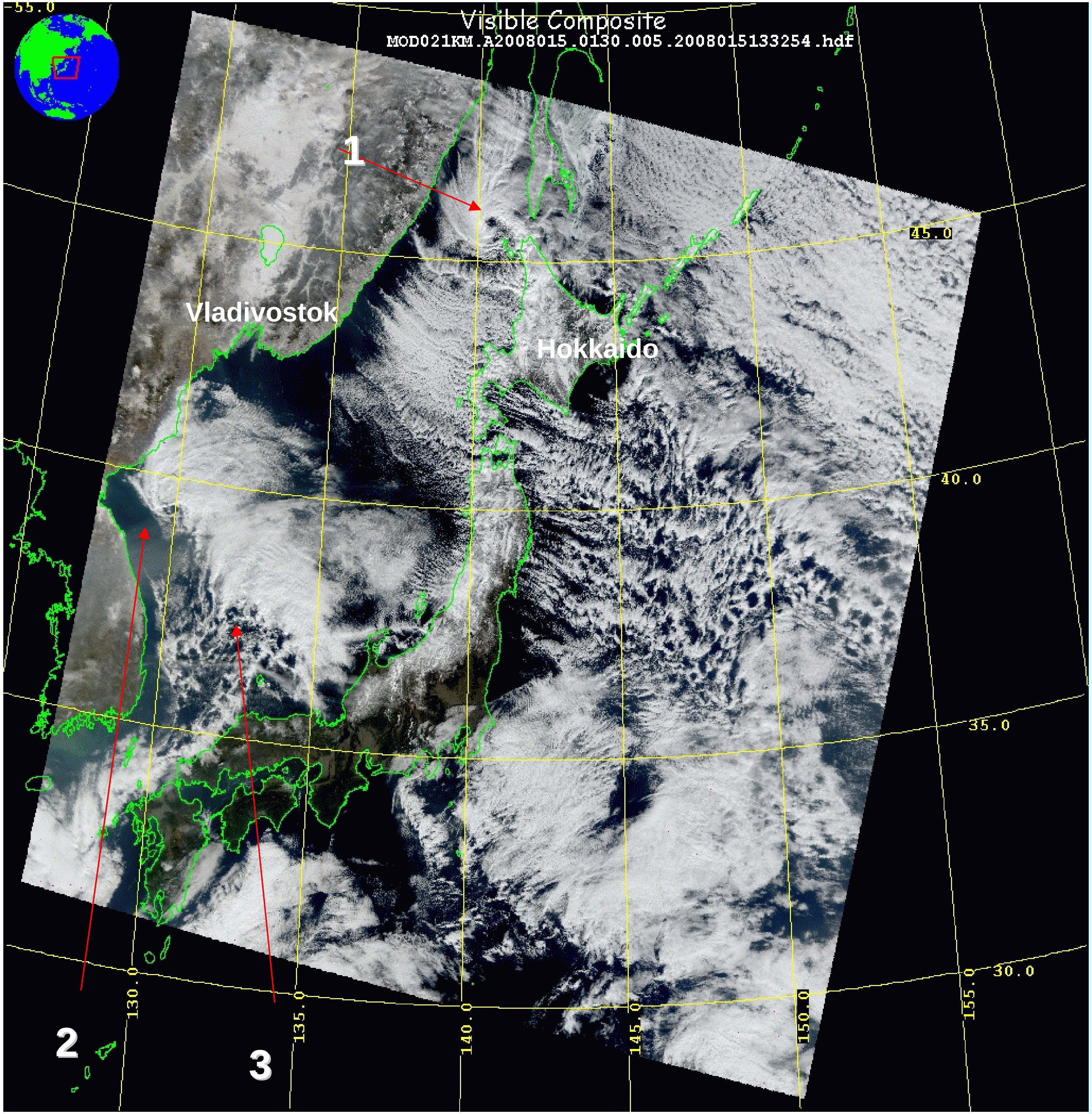
Mitnik L.M., and M.L. Mitnik (2003) Retrieval of atmospheric and ocean surface parameters from ADEOS-II AMSR data: comparison of errors of global and regional algorithms. *Radio Sciences.* V. 38, No. 4.



AMSR-E observation concept

Advanced Microwave Scanning Radiometer AMSR-E is an 6-frequency total-power microwave radiometer with dual polarization. AMSR has a conical scanning geometry.Incidence angle is 55 deg

Center frequency (GHz)	6.925	10.65	18.7	23.8	36.5	89.0 A	89.0 B
Band width (MHz)	350	100	200	400	1000	300	
Polarization	Vertical (V) and Horizontal (H)					V, H	
IFOV (km x km)	40 x 70	27x46	14x25	17x29	8 x14	3 x 6	
Sampling interval (km x km)	10 x 10					5 x 5	
Swath width (km)	Approximately 1450						



Terra MODIS

15 Jan 2008

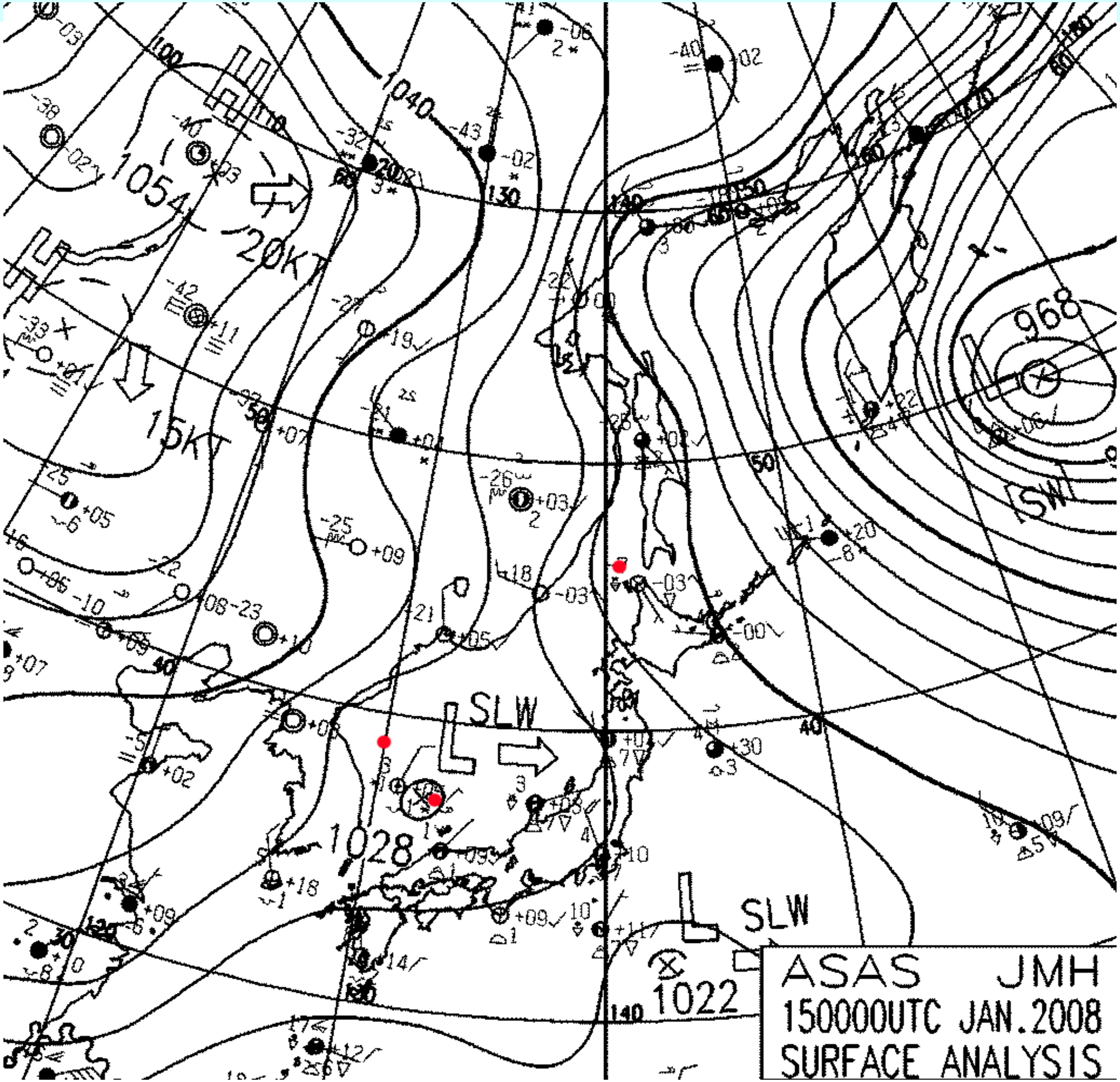
01:30 UTC

1 - developed mesoscale cyclone;

2 and 3 -forming mesocyclones over the Japan Sea.

Atmospheric and surface conditions for mesoscale cyclogenesis:

Favorable conditions for mesoscale cyclogenesis



Surface analysis map of the Japan Meteorological Agency

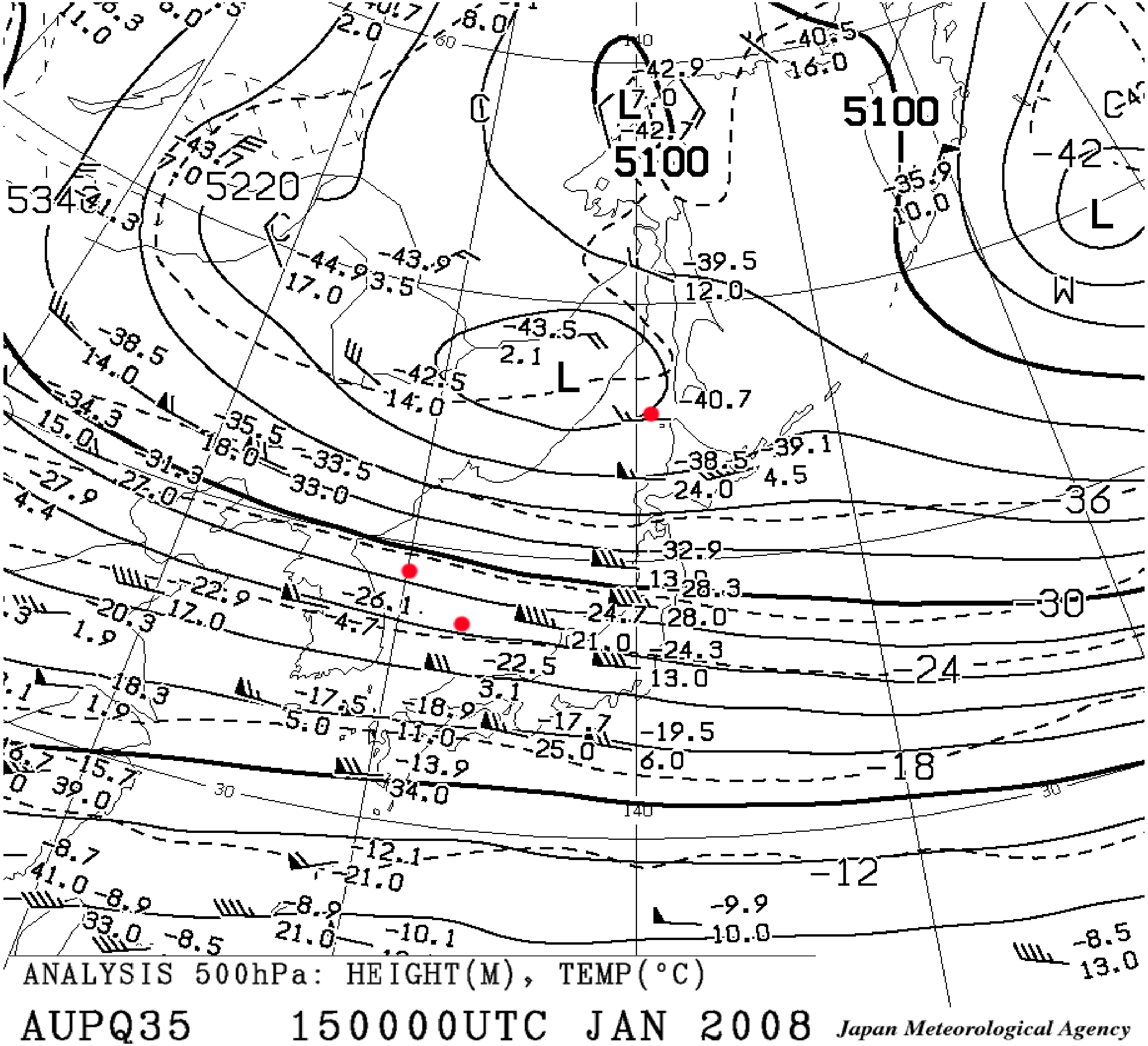
00:00 UTC

15 January 2008

Polar lows form at the rear of the deep synoptic-scale cyclones

Red dots show the centers of PLs

Favorable conditions for mesoscale cyclogenesis

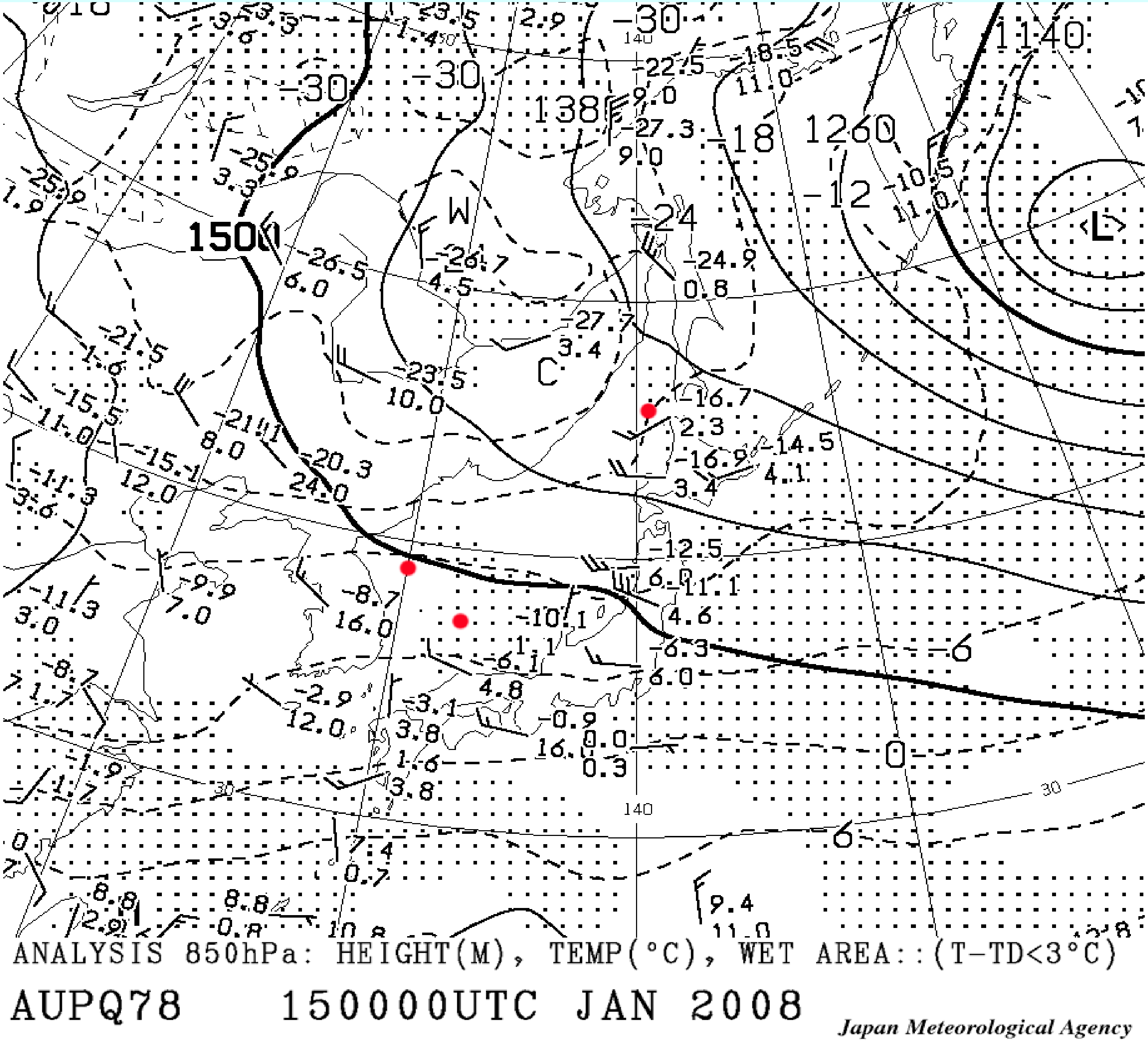


AT500
00:00 UTC
15 January 2008

Polar lows form under the upper-air depression and thermal trough at 500-hPa height to the north of the main frontal zone.

Red dots show the centers of PLs

Favorable conditions for mesoscale cyclogenesis



AT850

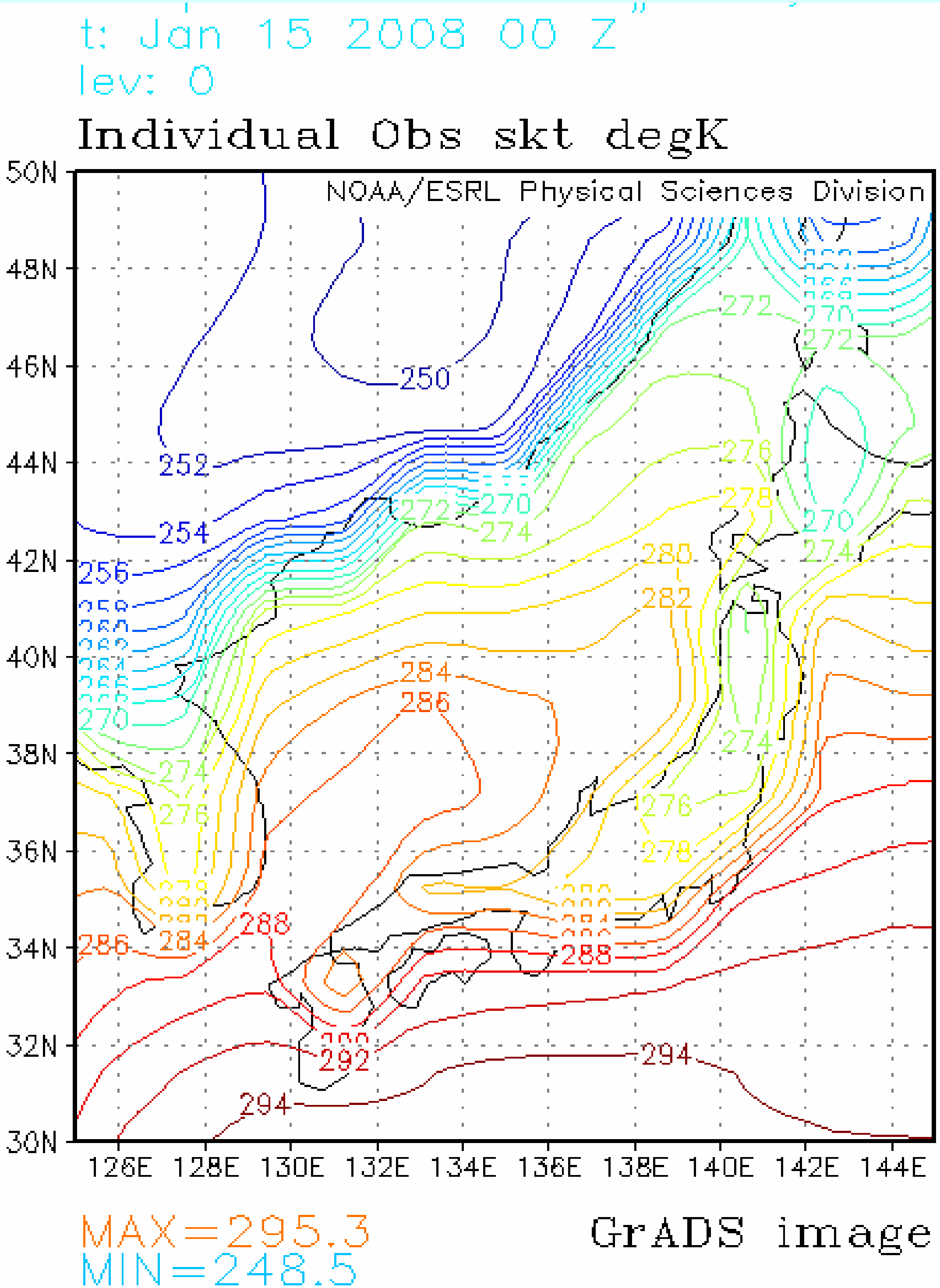
00:00 UTC

15 Jan 2008

Low-level baroclinicity

Red dots show the centers of PLs

Favorable conditions for mesoscale cyclogenesis



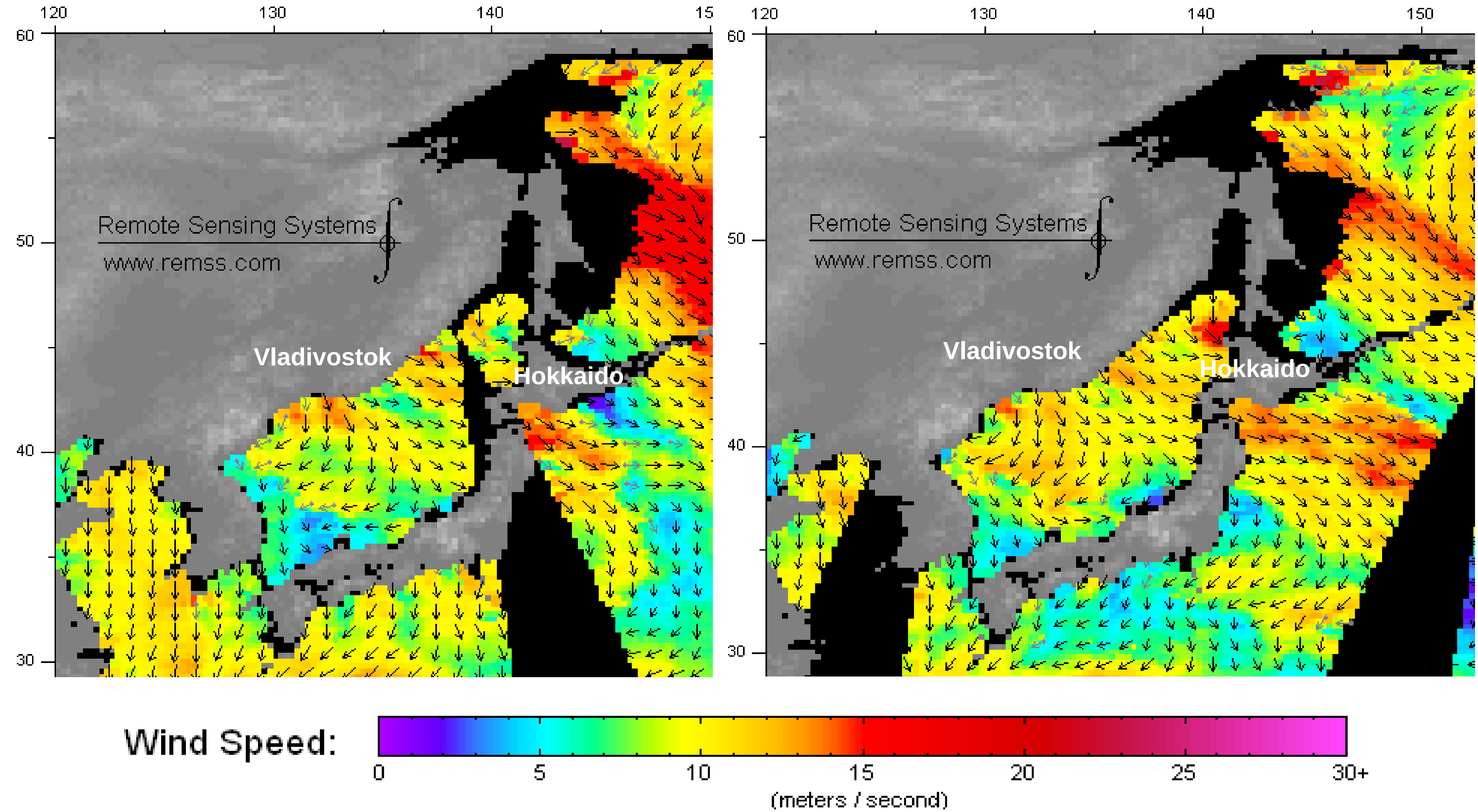
Large SST gradients along the ice edge or cold land.

Reanalysis

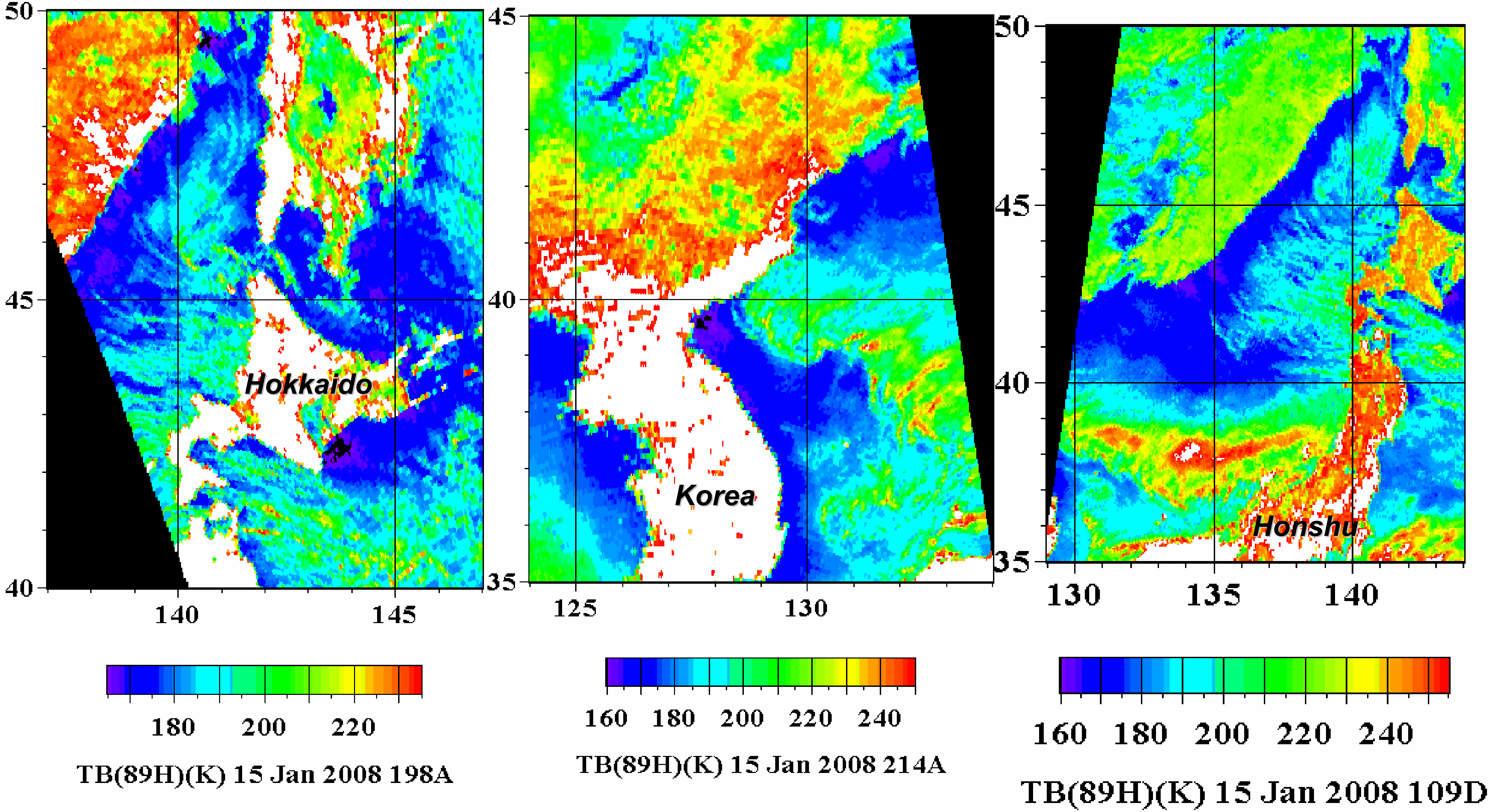
Land surface temperature and sea surface temperature

00:00 UTC

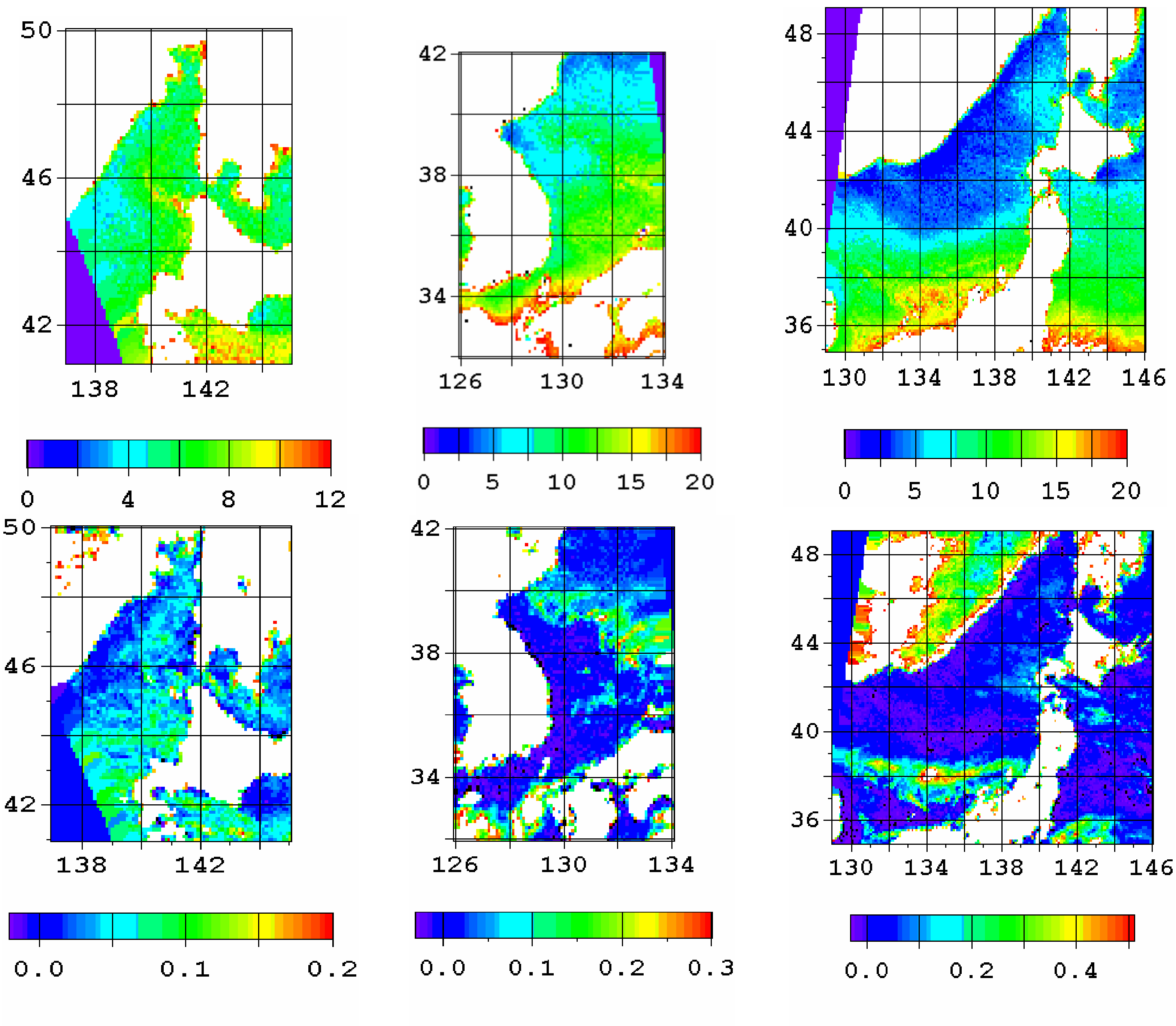
15 January 2008



QuikSCAT-derived wind fields showing formation of mesoscale vortices: 14 January at 20:54 UTC (*left*) and 15 January at 09:24 UTC (*right*)



Aqua AMSR-E brightness temperature fields at 89 GHz with horizontal polarization at 03:10 UTC (left), 04:45 (middle) and 16:45 UTC (right) on 15 January 2008



Total atmospheric water vapor content (kg/m2)

Total cloud liquid water content (kg/m2)

Aqua AMSR-E

03:10 UTC 15 Jan 2008

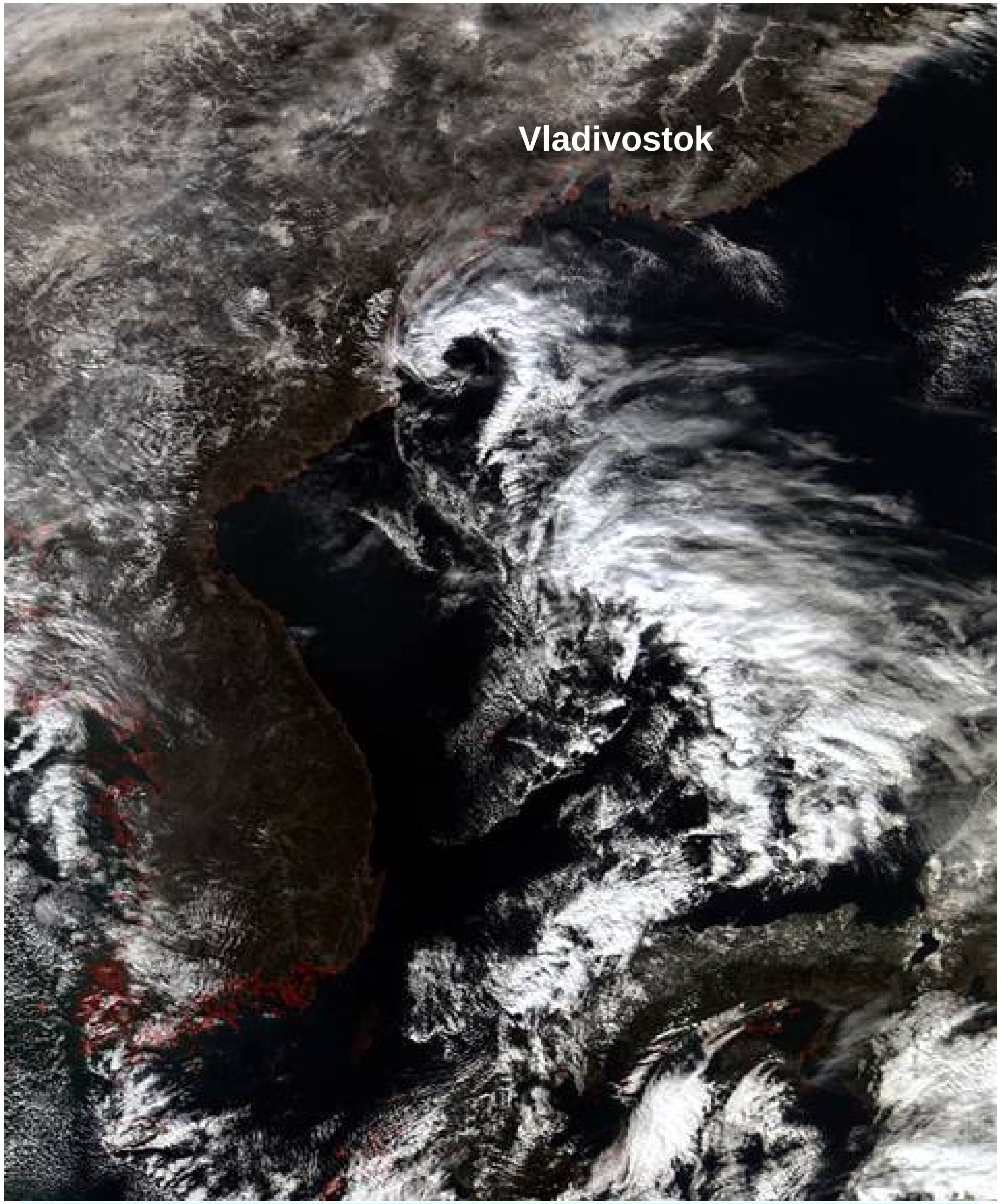
Aqua AMSR-E

04:45 UTC 15 Jan 2008

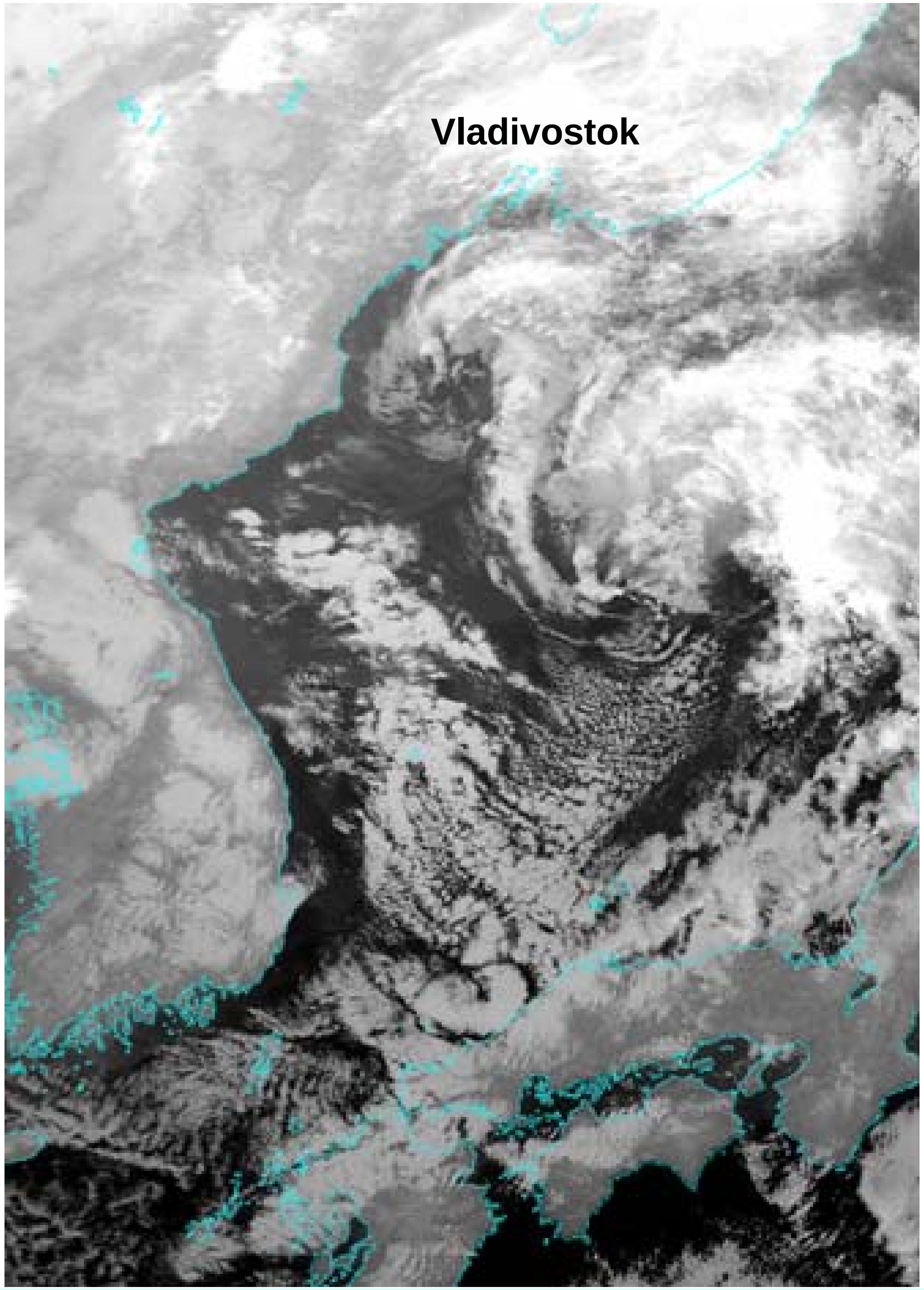
Aqua AMSR-E

16:45 UTC 15 Jan 2008

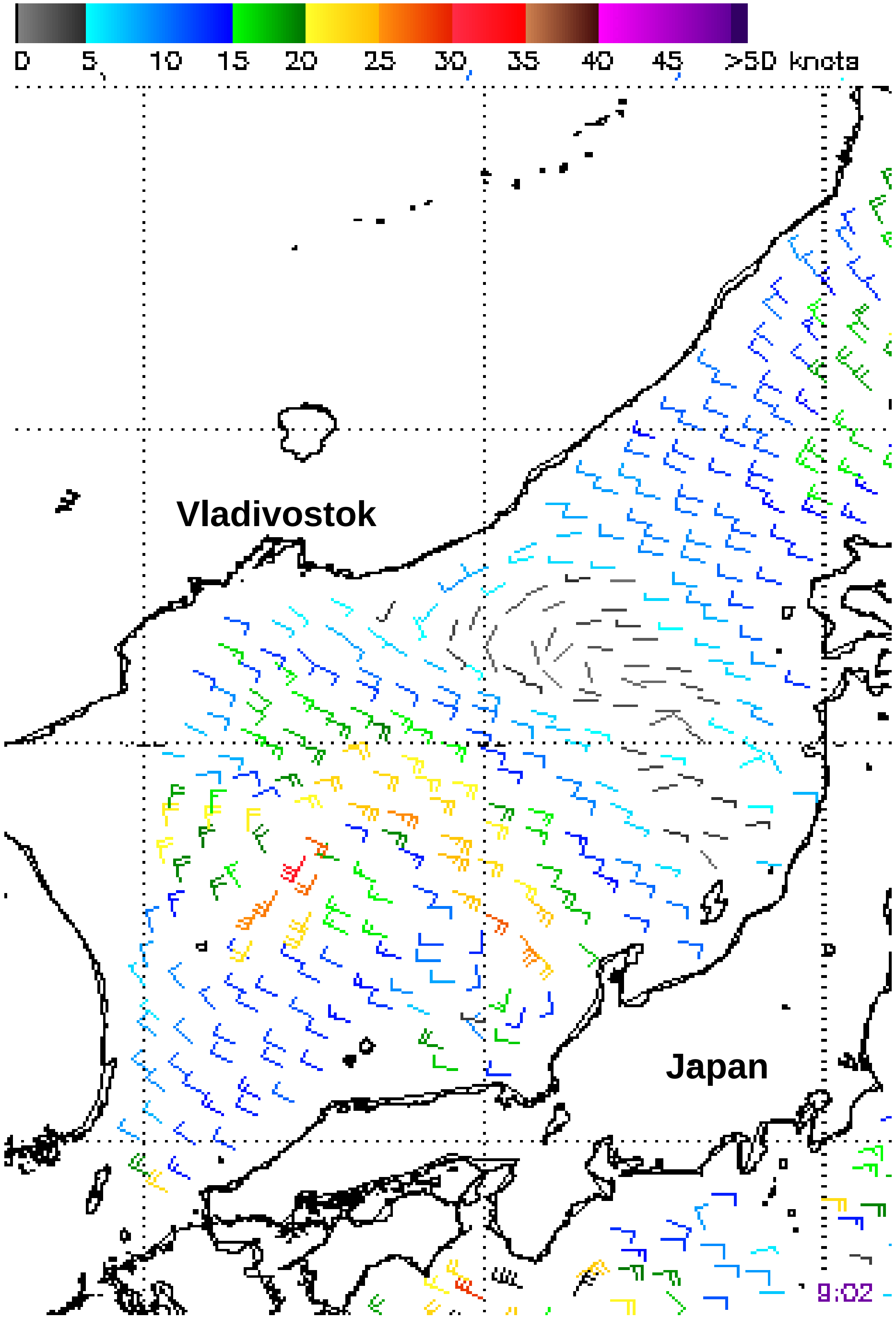
9 January 2006. Japan Sea



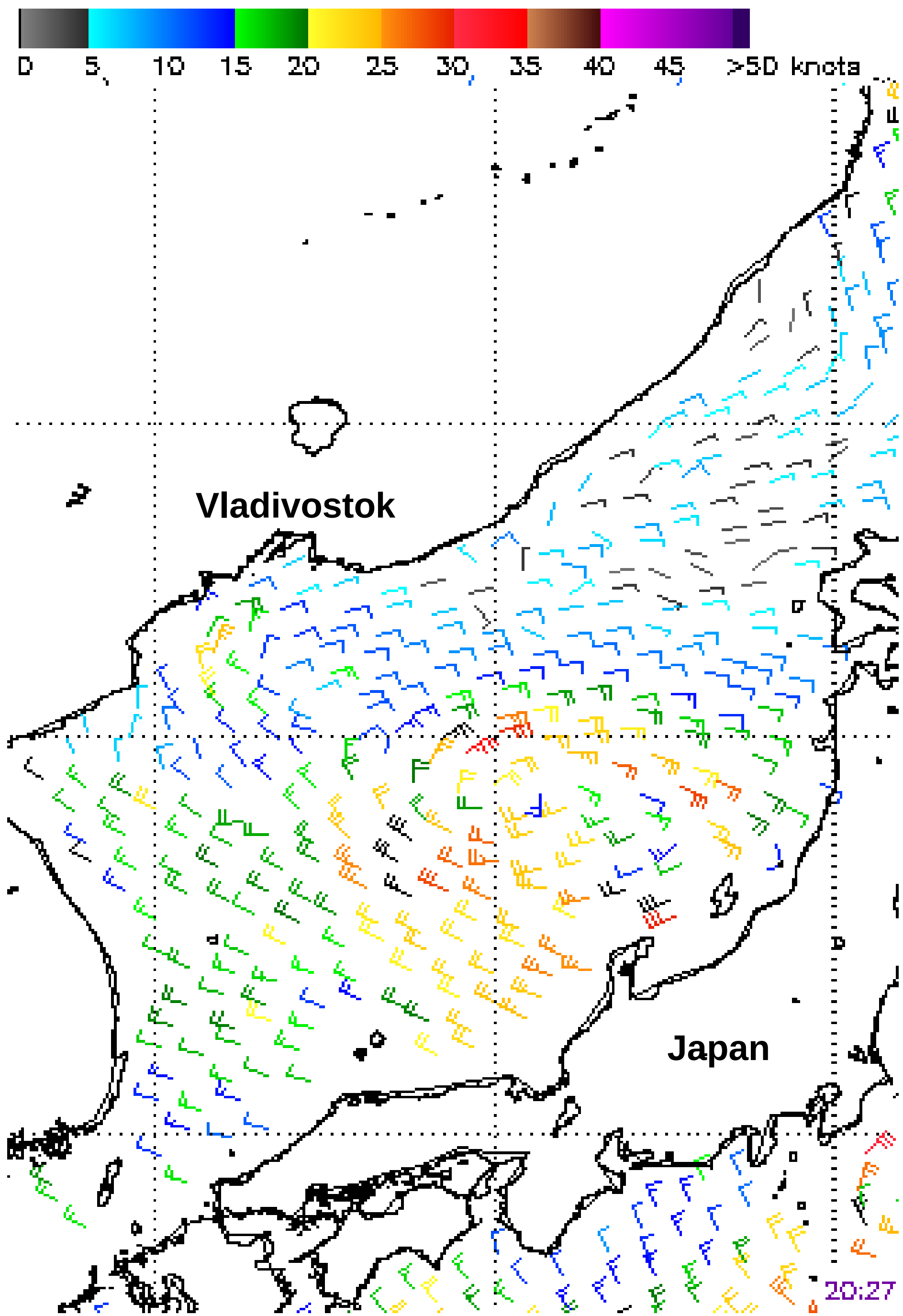
Aqua MODIS. 04:45 UTC 9 Jan 2006. Visible image.



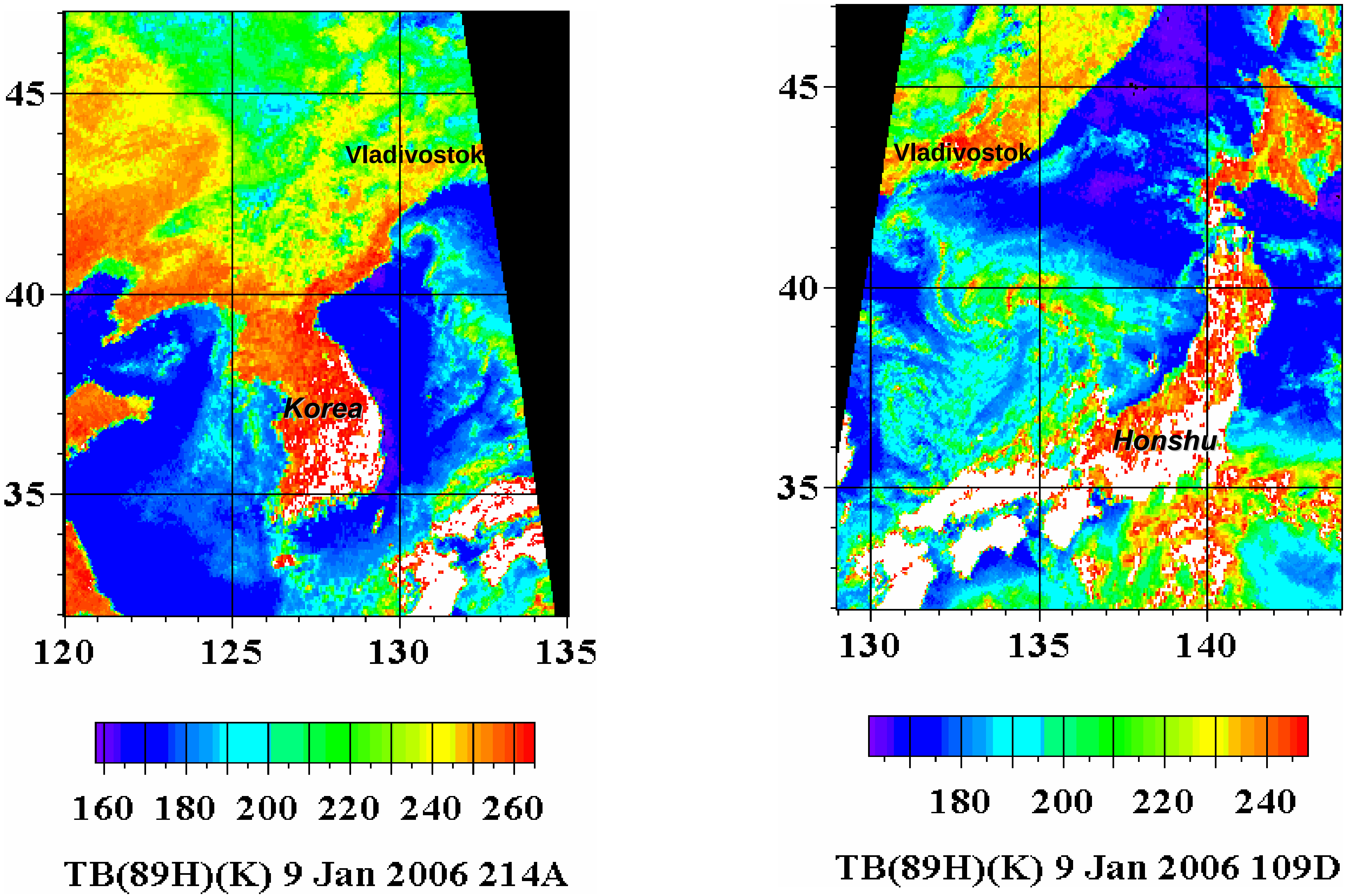
Aqua MODIS. 16:45 UTC 9 Jan 2006. Infrared image.



QuikSCAT for 09:02 UTC
9 January 2006

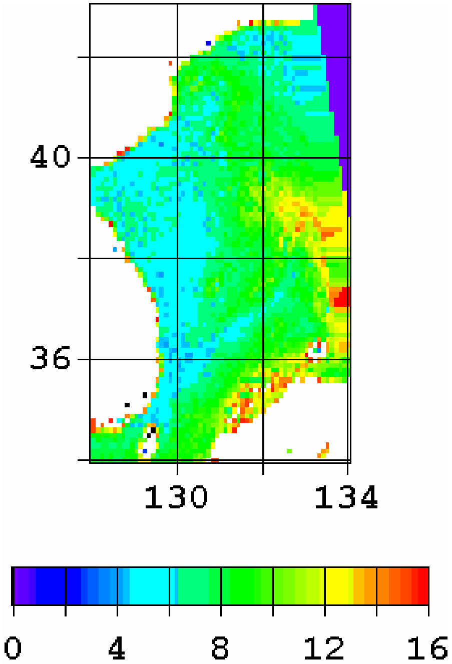


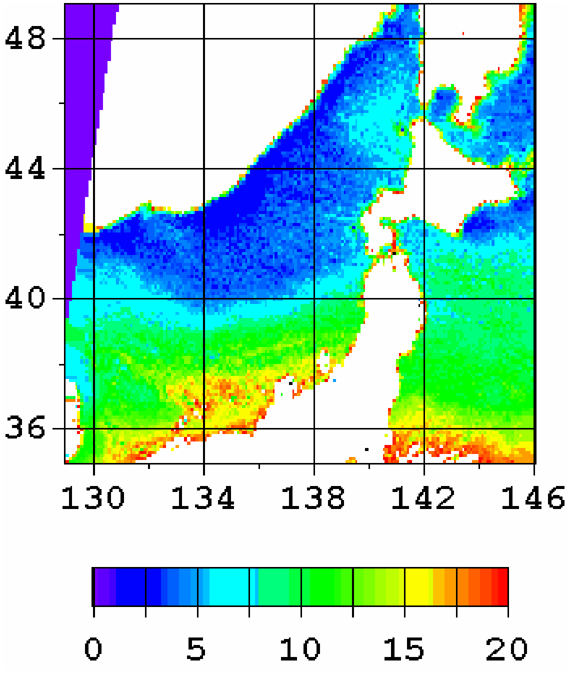
QuikSCAT for 20:27 UTC
9 January 2006



Aqua AMSR-E brightness temperature fields at 89 GHz with horizontal polarization at 04:45 UTC (left) and at 16:45 UTC (right) on 9 January 2006

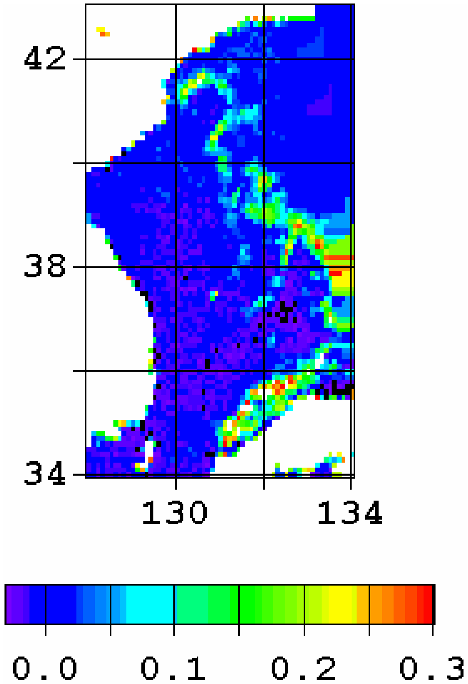
Total atmospheric water vapor content (kg/m2)





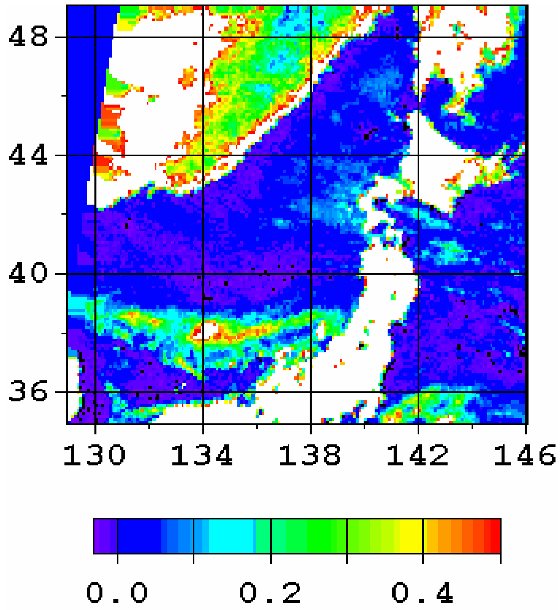
Total cloud liquid water content

(kg/m2)



Aqua AMSR-E

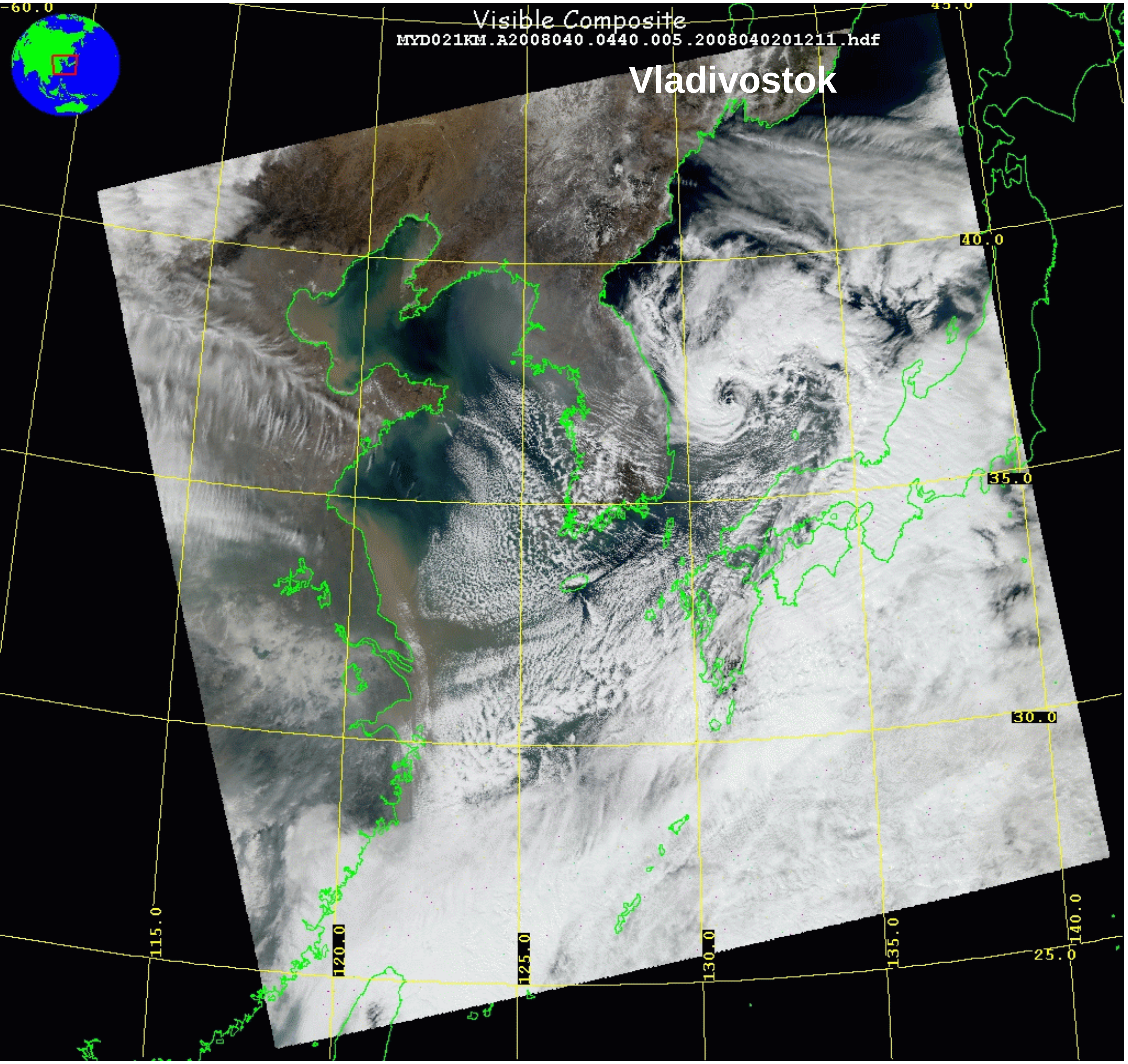
04:45 UTC 9 Jan 2006

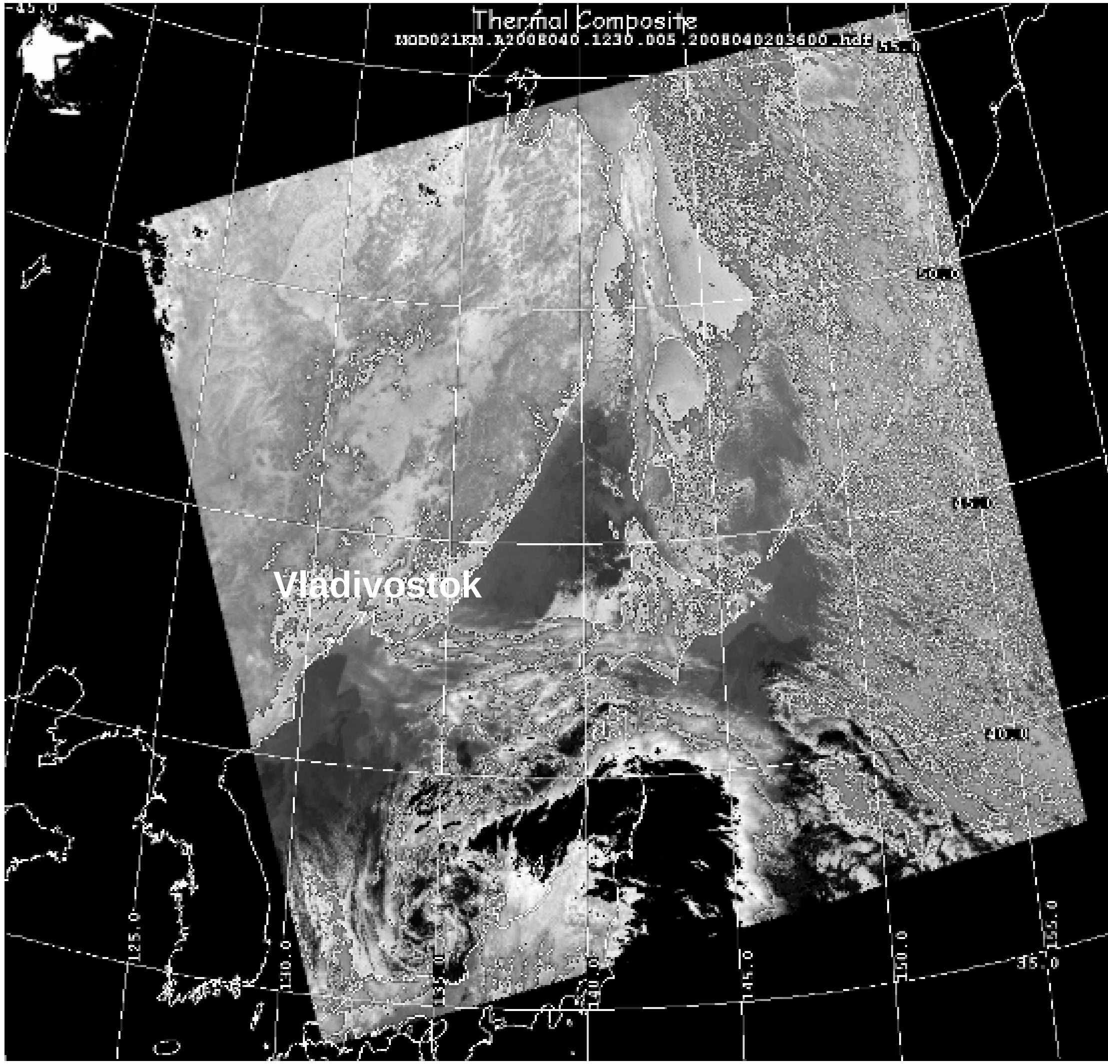


Aqua AMSR-E

16:45 UTC 9 Jan 2006

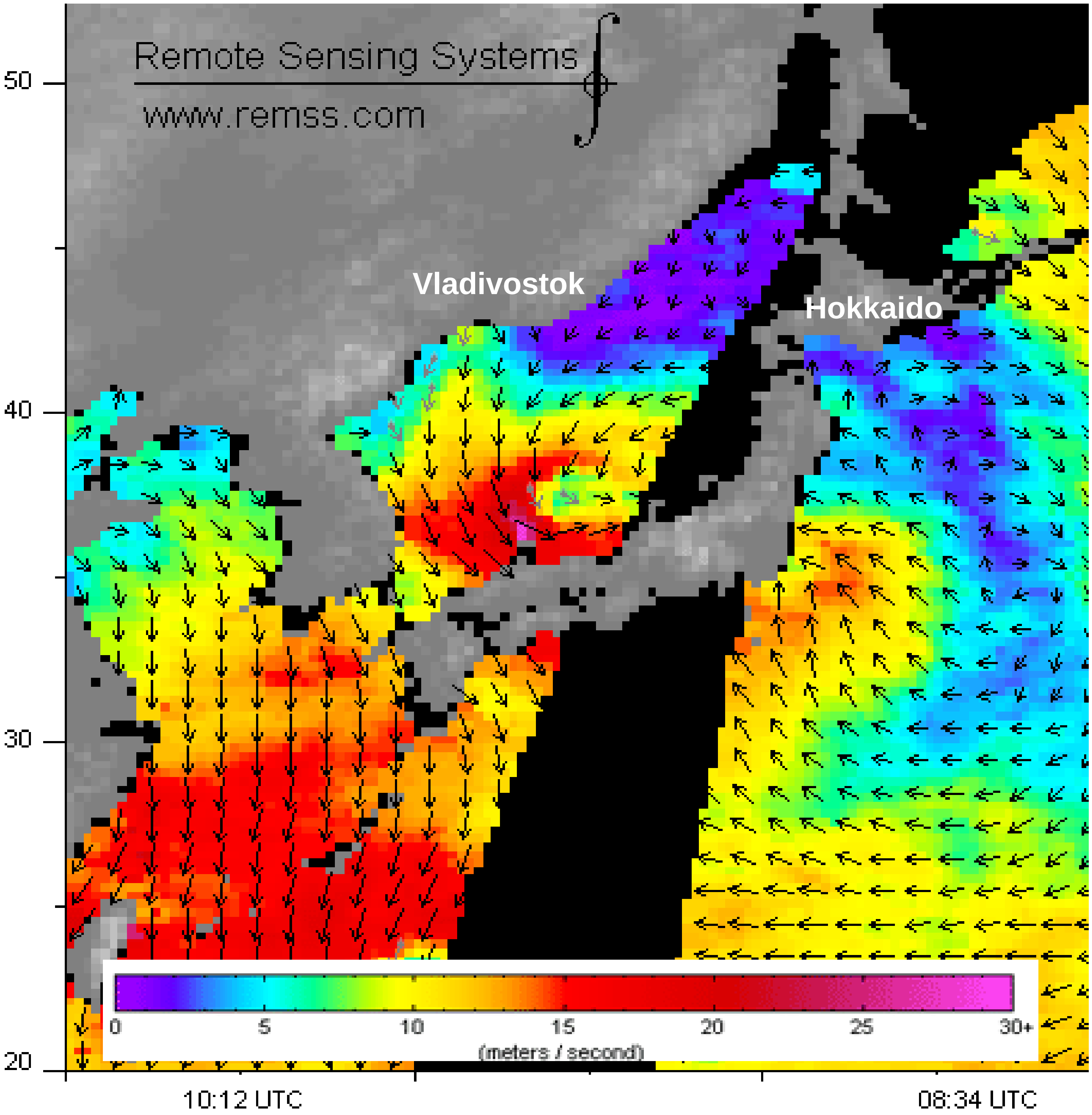
Polar low over the Japan Sea on 9 Feb 2008



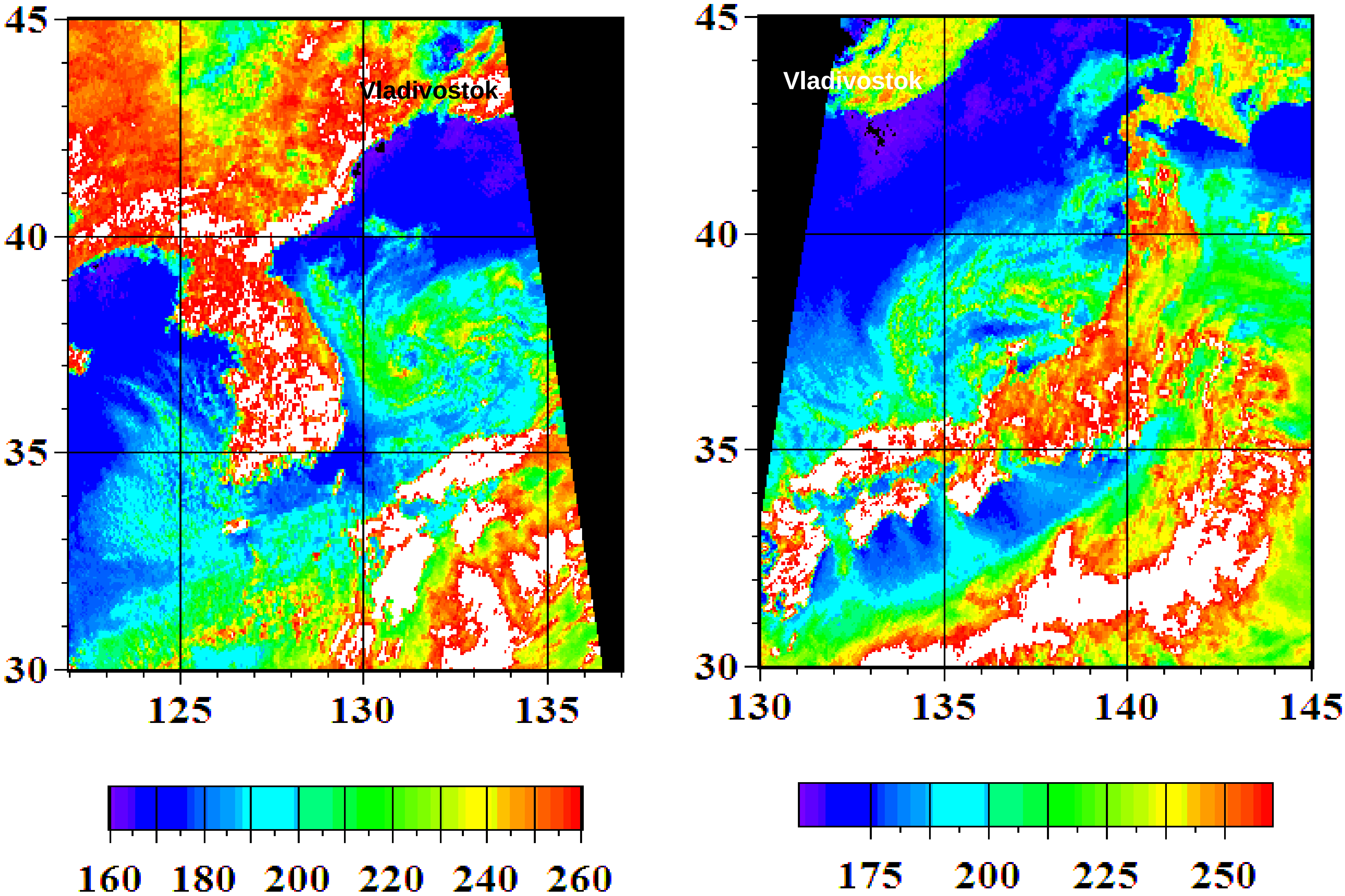


Aqua MODIS visible image
04:40 UTC

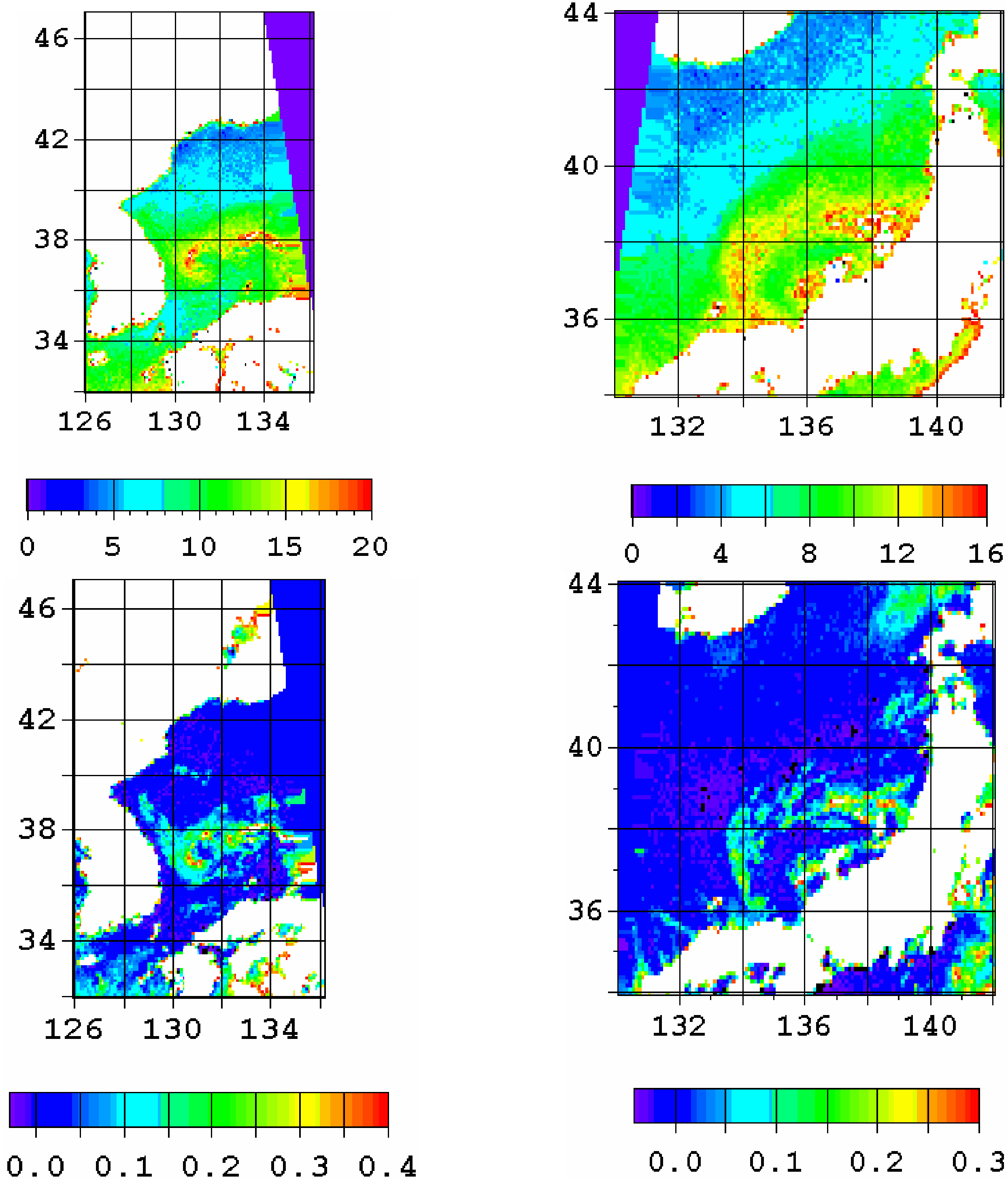
Terra MODIS Infrared image
12:30 UTC



QuikSCAT-derived wind field at 10:12 UTC on 9 Feb 2008



Aqua AMSR-E brightness temperature fields. 89 GHz, H-pol at 04:40 UTC (left) and 16:40 UTC (right) on 9 Feb 2008

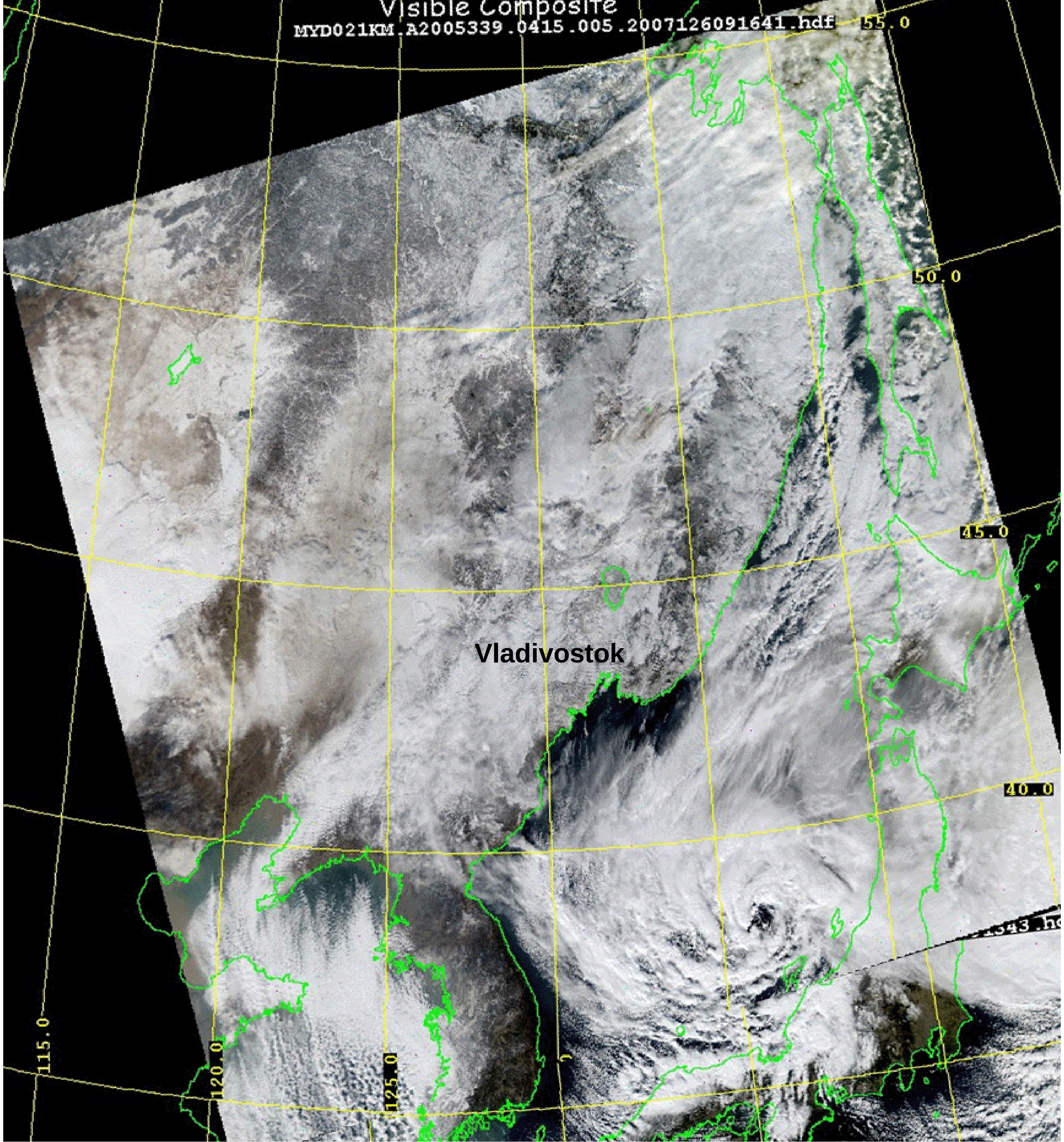


Total atmospheric water vapor content (kg/m2)

Total cloud liquid water content

(kg/m2)

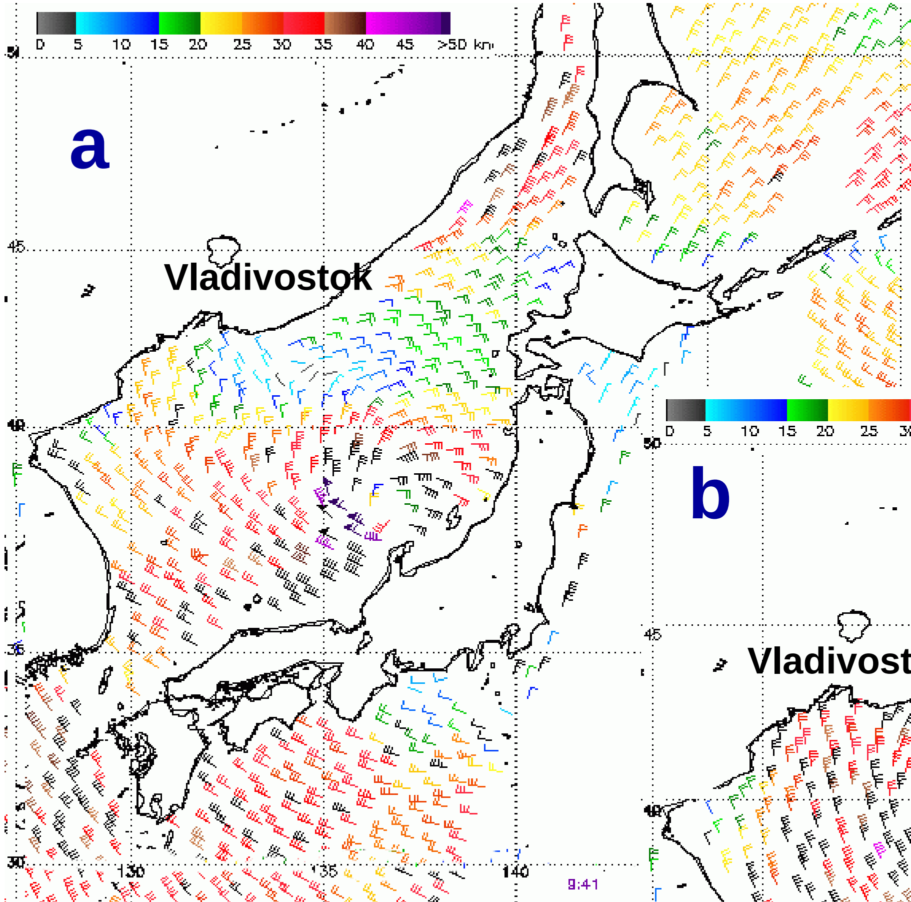
Aqua AMSR-E 04:40 UTC (left) and 9 16:40 UTC (right) 9 Feb 2008



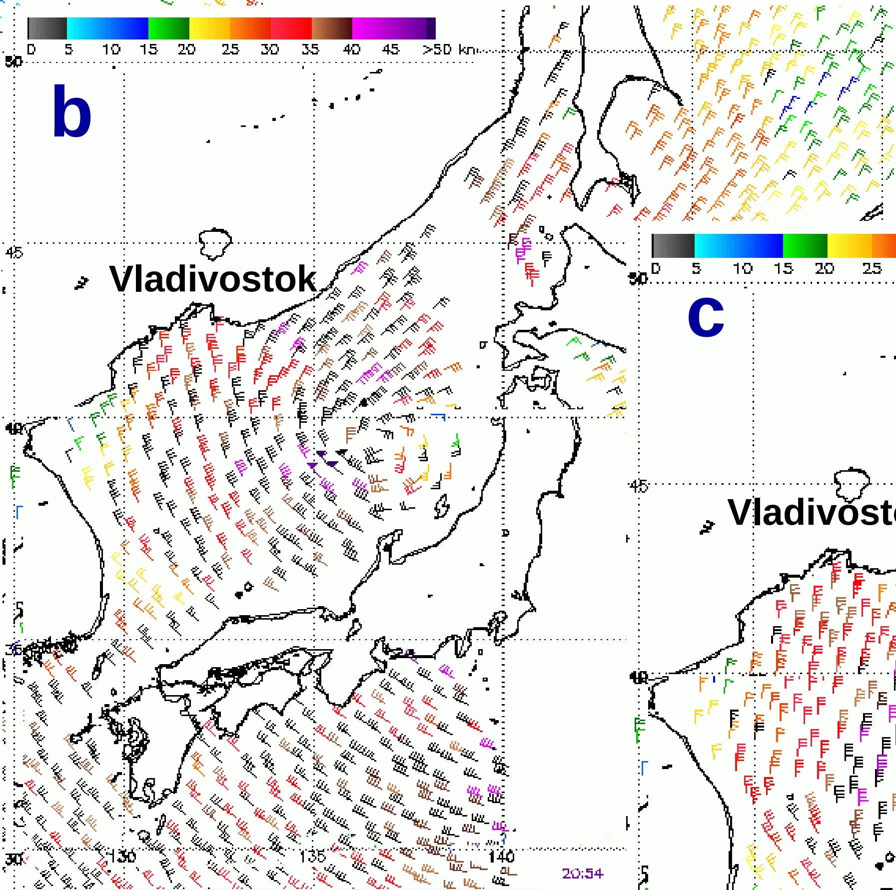
5 December 2005

Developed polar low over the Japan Sea on Aqua MODIS visible image at 04:15 UTC

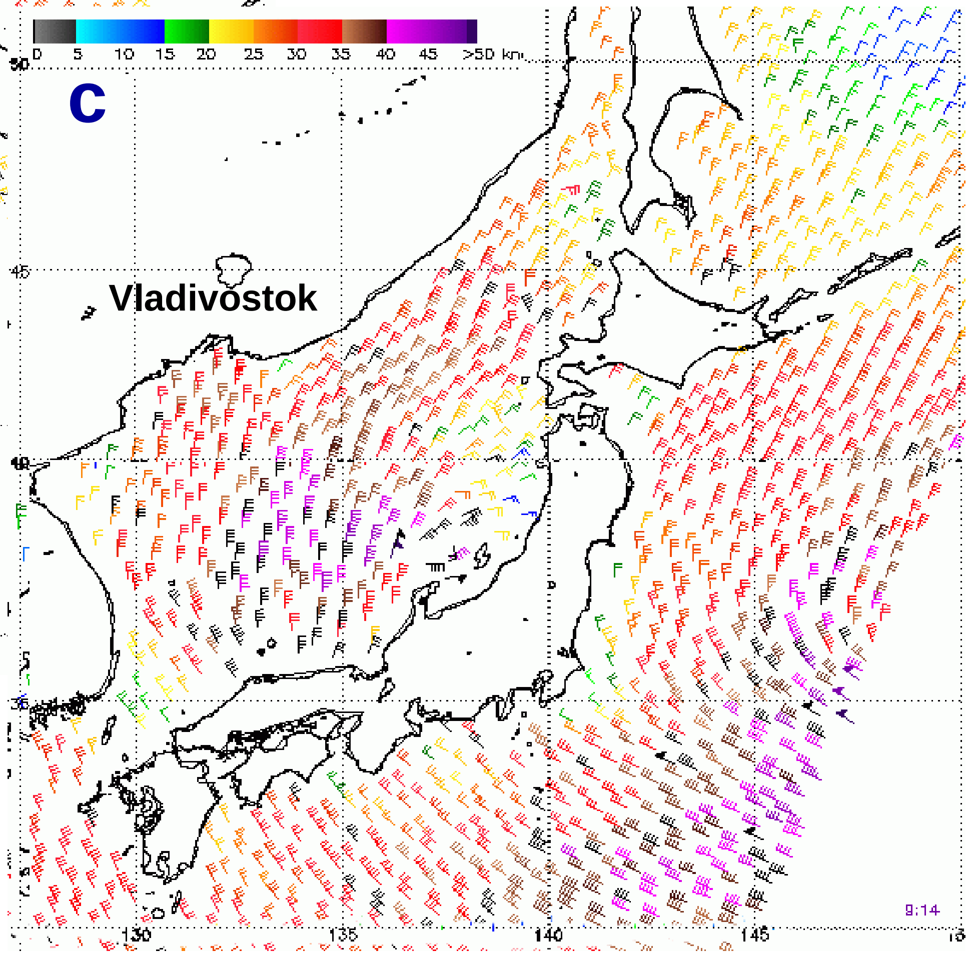
QuikSCAT-derived wind fields



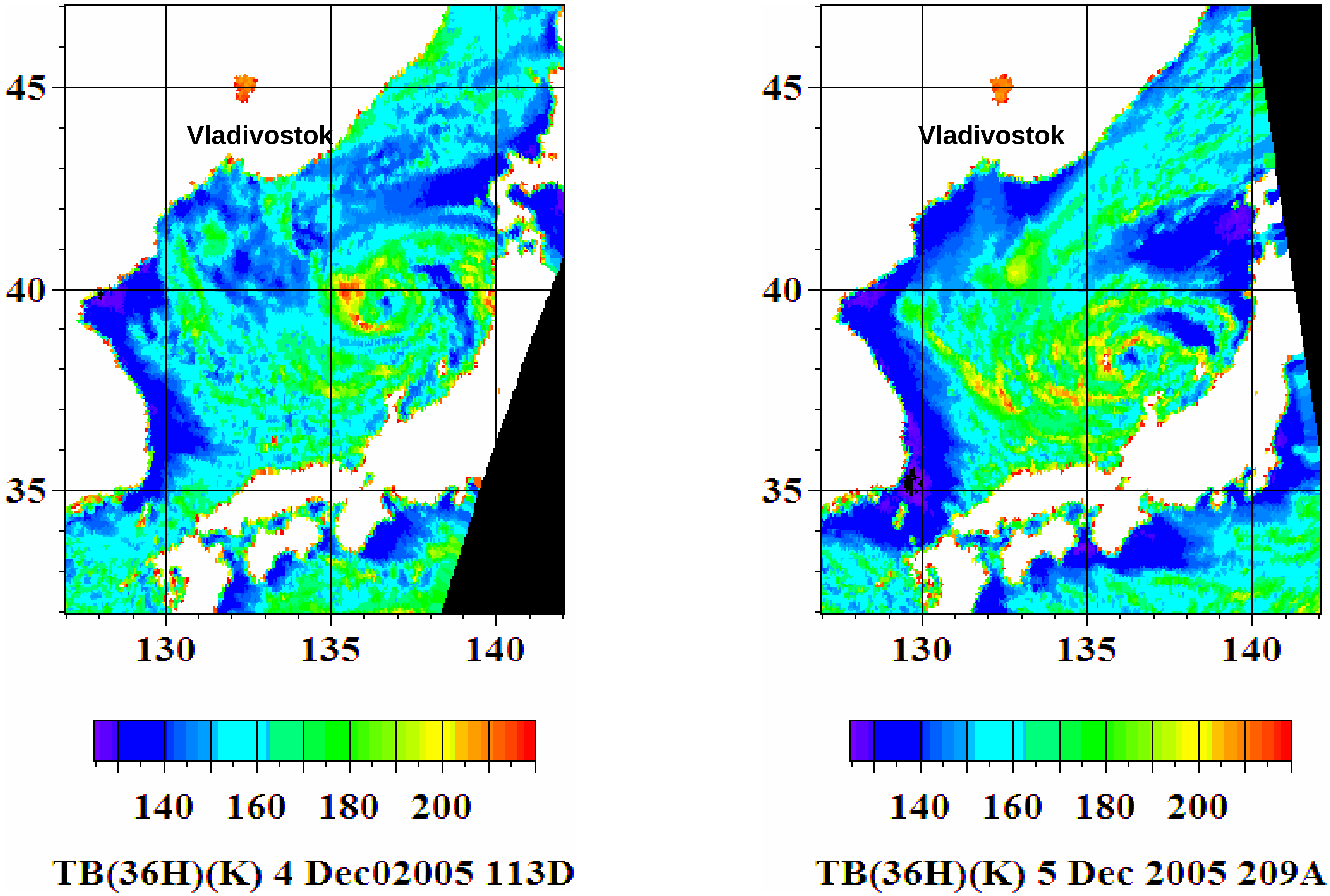
4 Dec 2005
09:41 UTC



4 Dec 2005
20:54 UTC



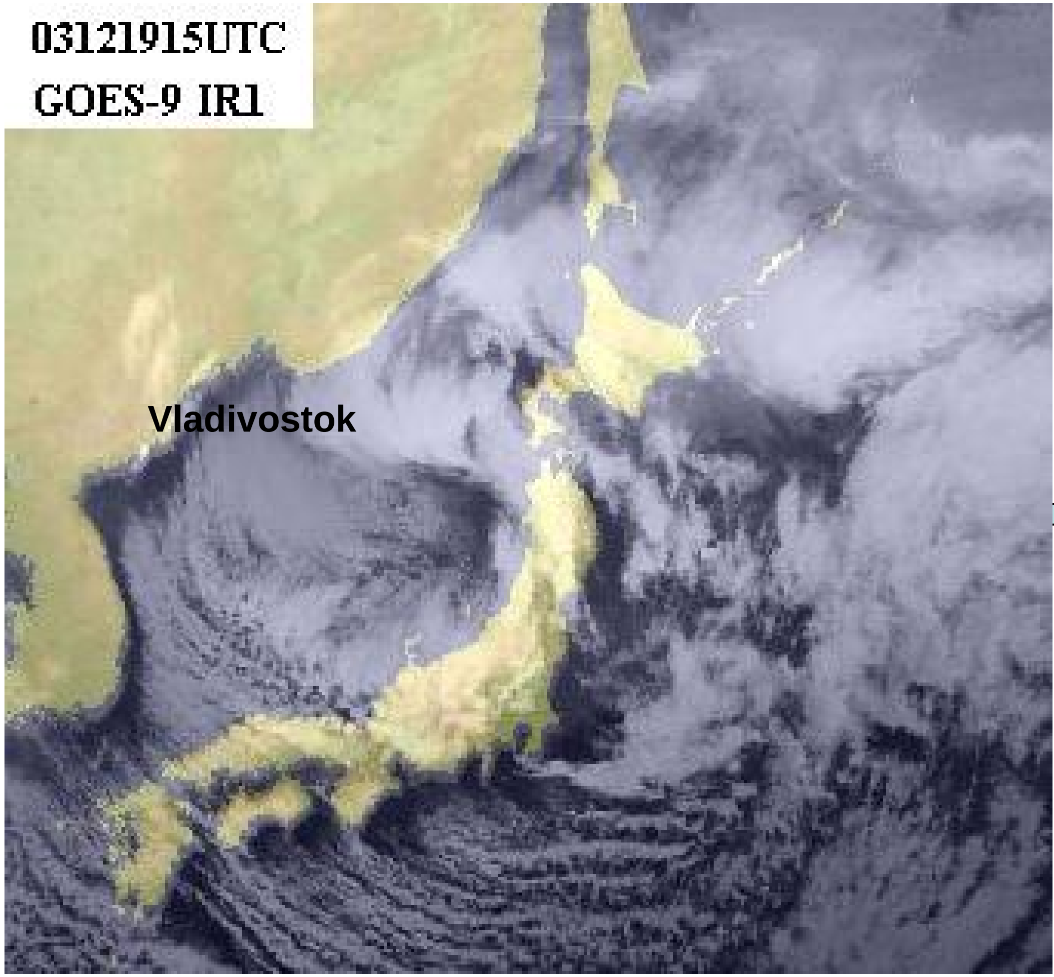
5 Dec 2005
09:14 UTC



Brightness temperature fields. Aqua AMSR-E 36 GHz H-pol at 17:10 UTC on 4 December (*left)* and at 04:15 UTC on 5 December (*right)*

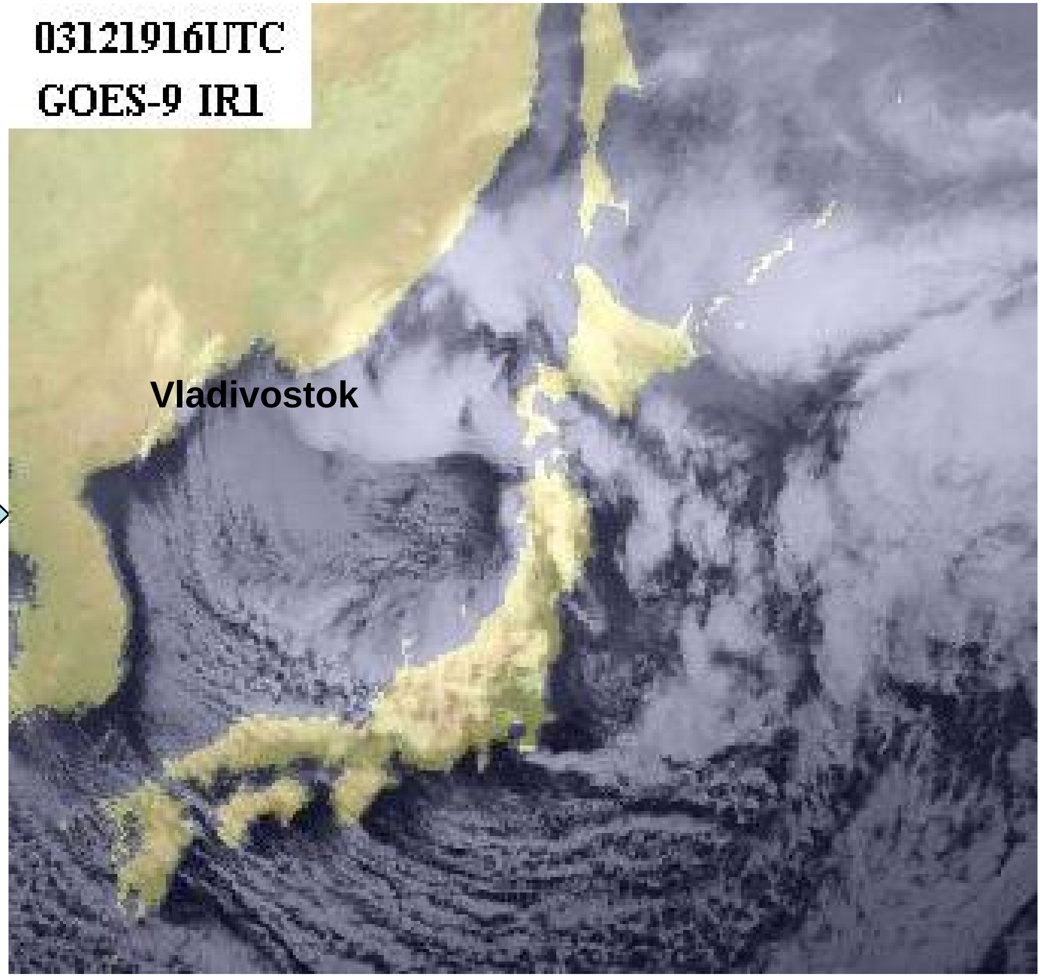
Polar low 19-20 December 2003

Initial stage



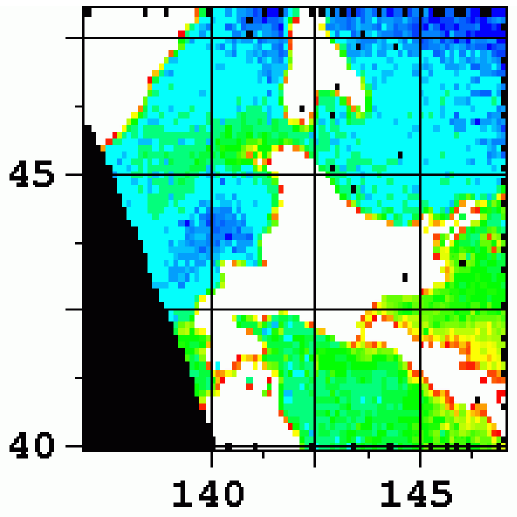
11-15 UTC 19 December

Developing stage

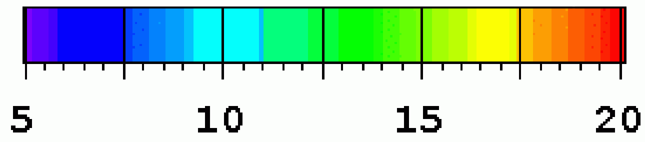


16 -21 UTC 19 December

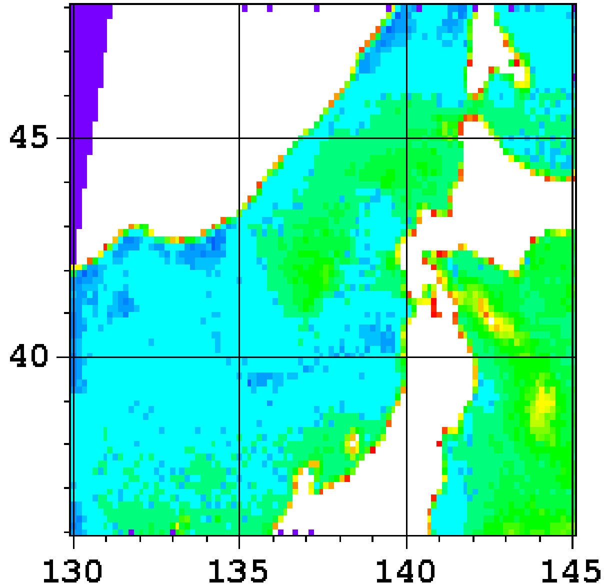
Jingtian Guo, Gang Fu. An Observational and Modeling Study of a Polar Low over the Japan Sea on 19 December 2003. *Ocean University of China, Qingdao*



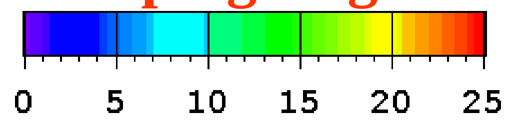
Initial stage 03 UTC

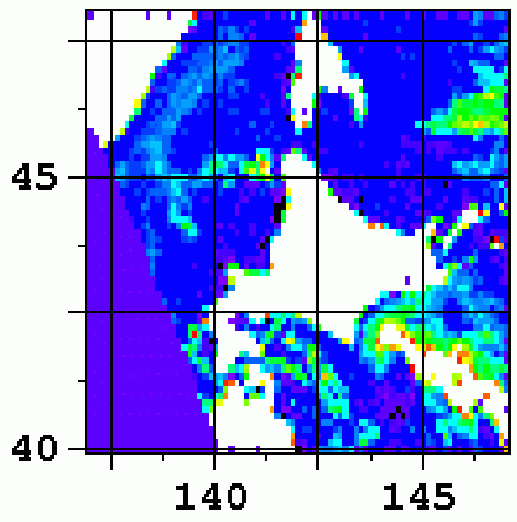


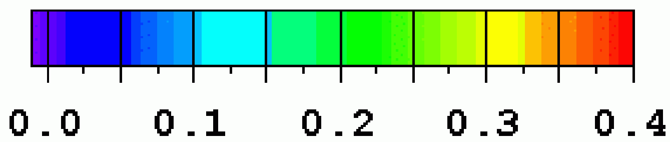
Total atmospheric water vapor content (kg/m2)



Developing stage 17 UTC

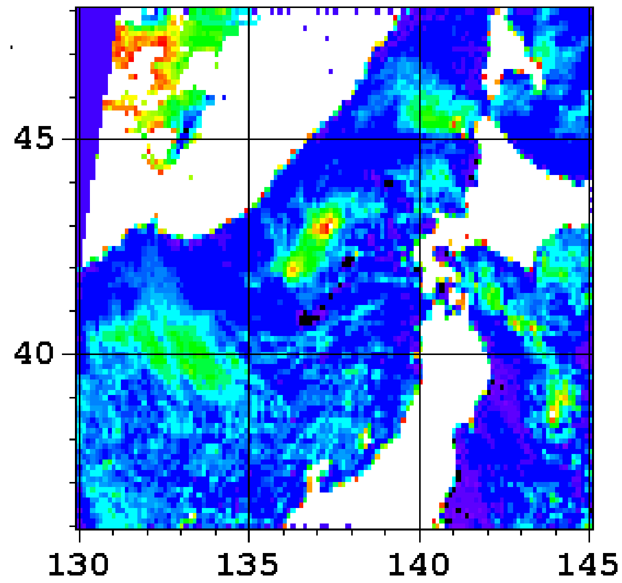


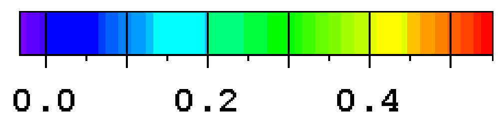




Cloud(kg/m2)19 Dec 2003 198A

Total cloud liquid water content (kg/m2)

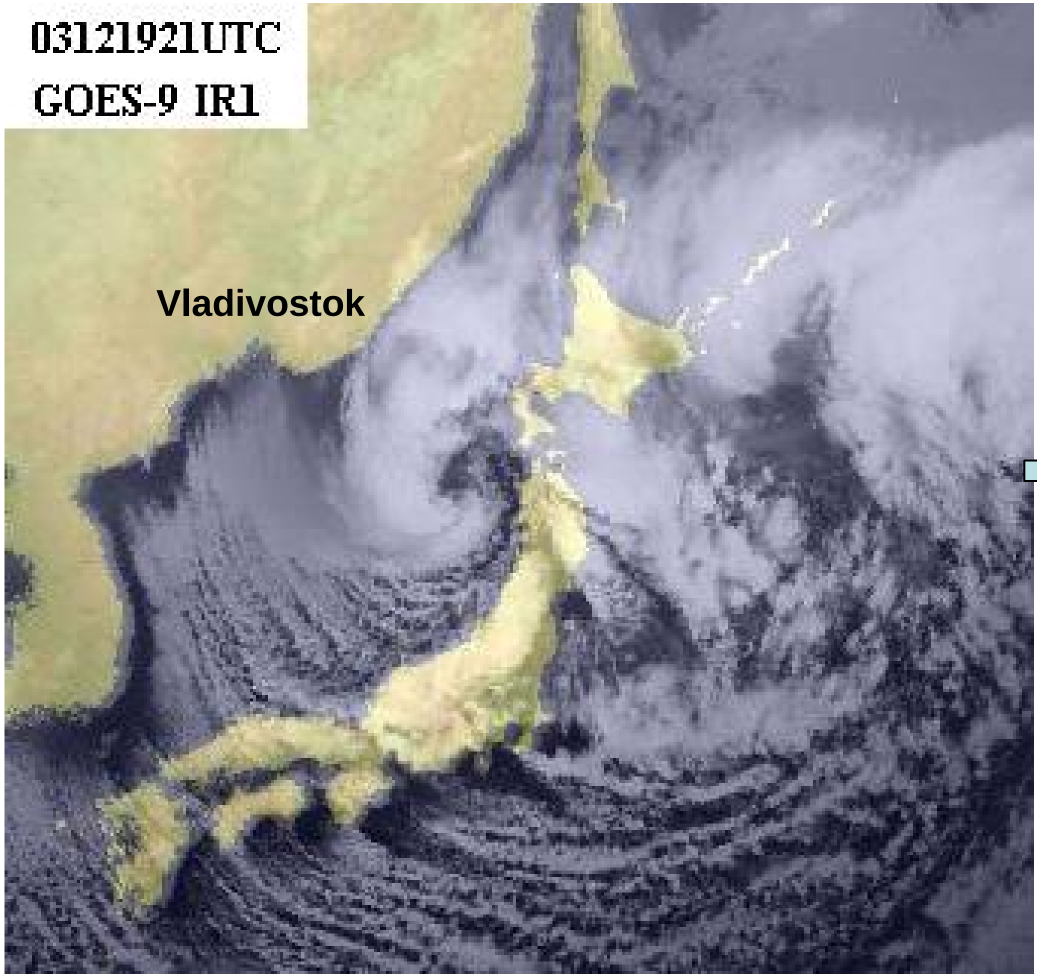




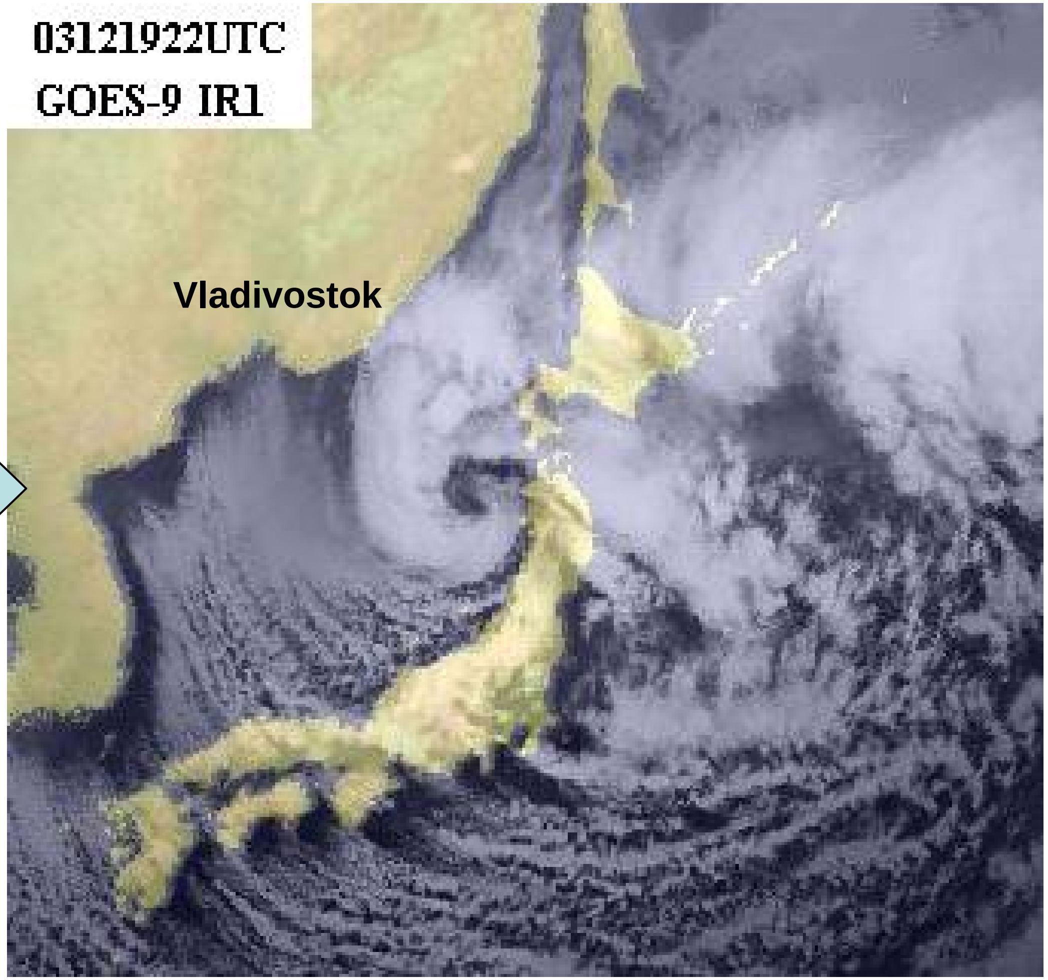
Cloud(kg/m2)19 Dec 2003 109D

Developing stage

Mature stage



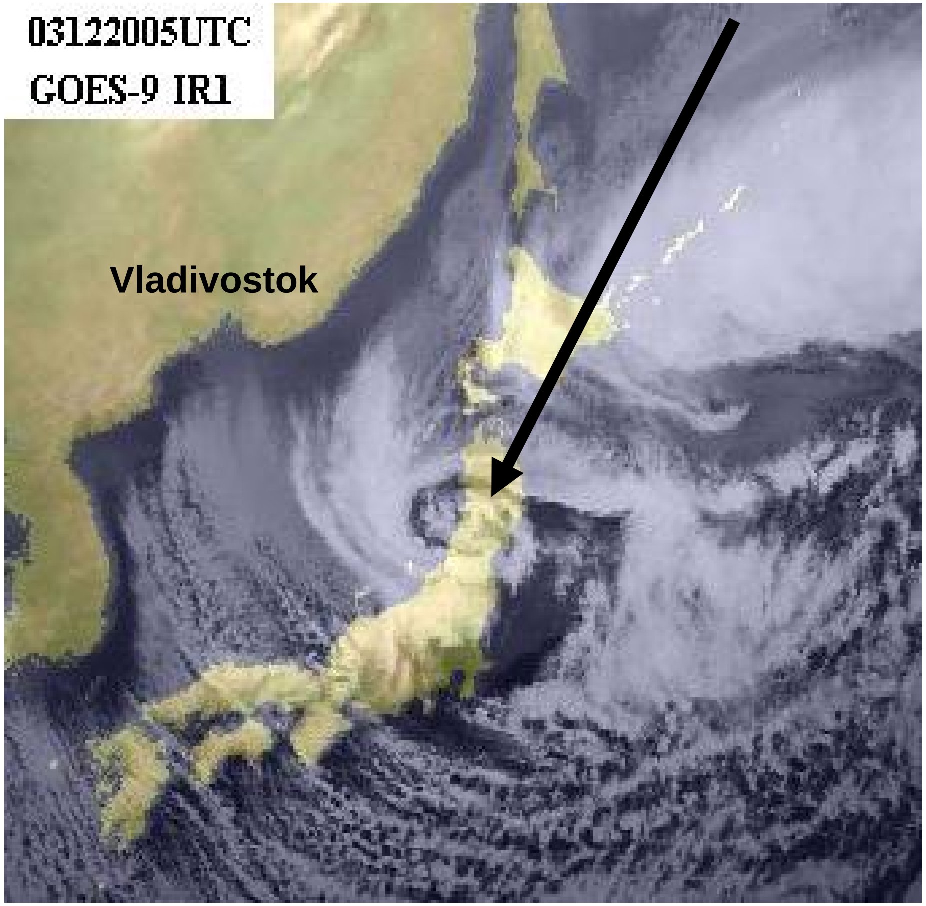
16 -21 UTC 19 December



22 UTC 19 – 05 UTC 20 December

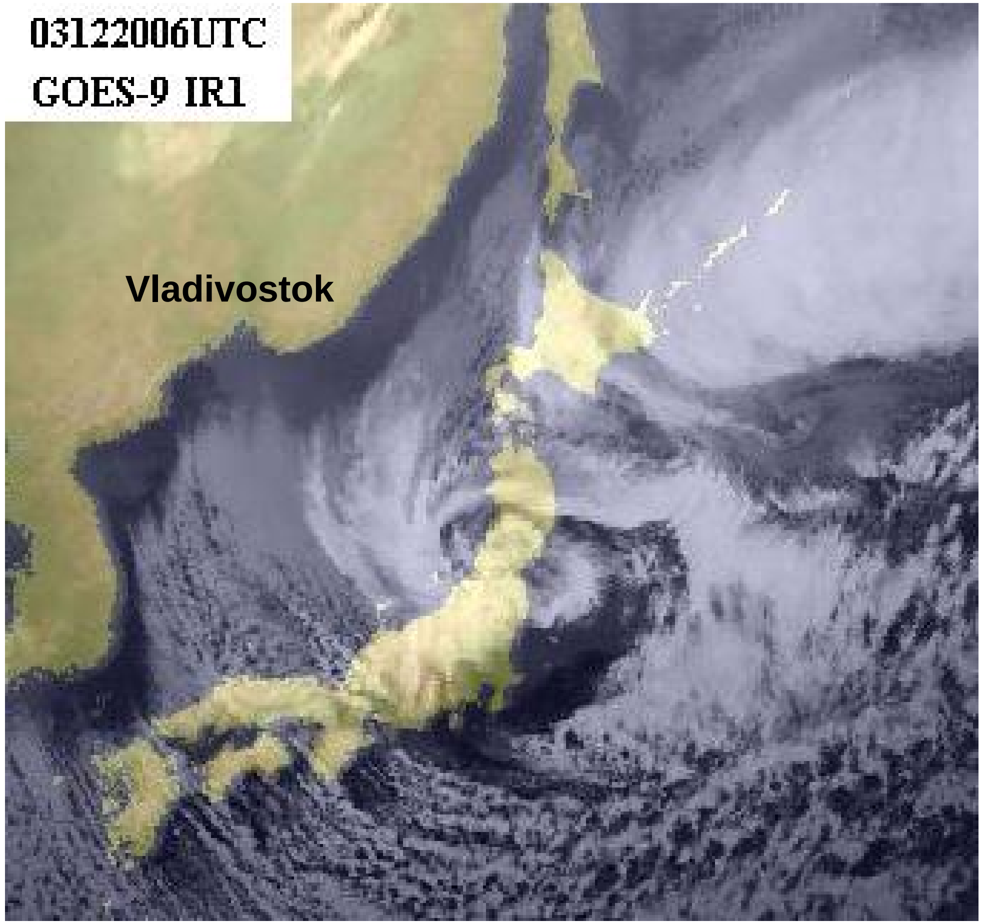
Mature stage

Two “wall eye”

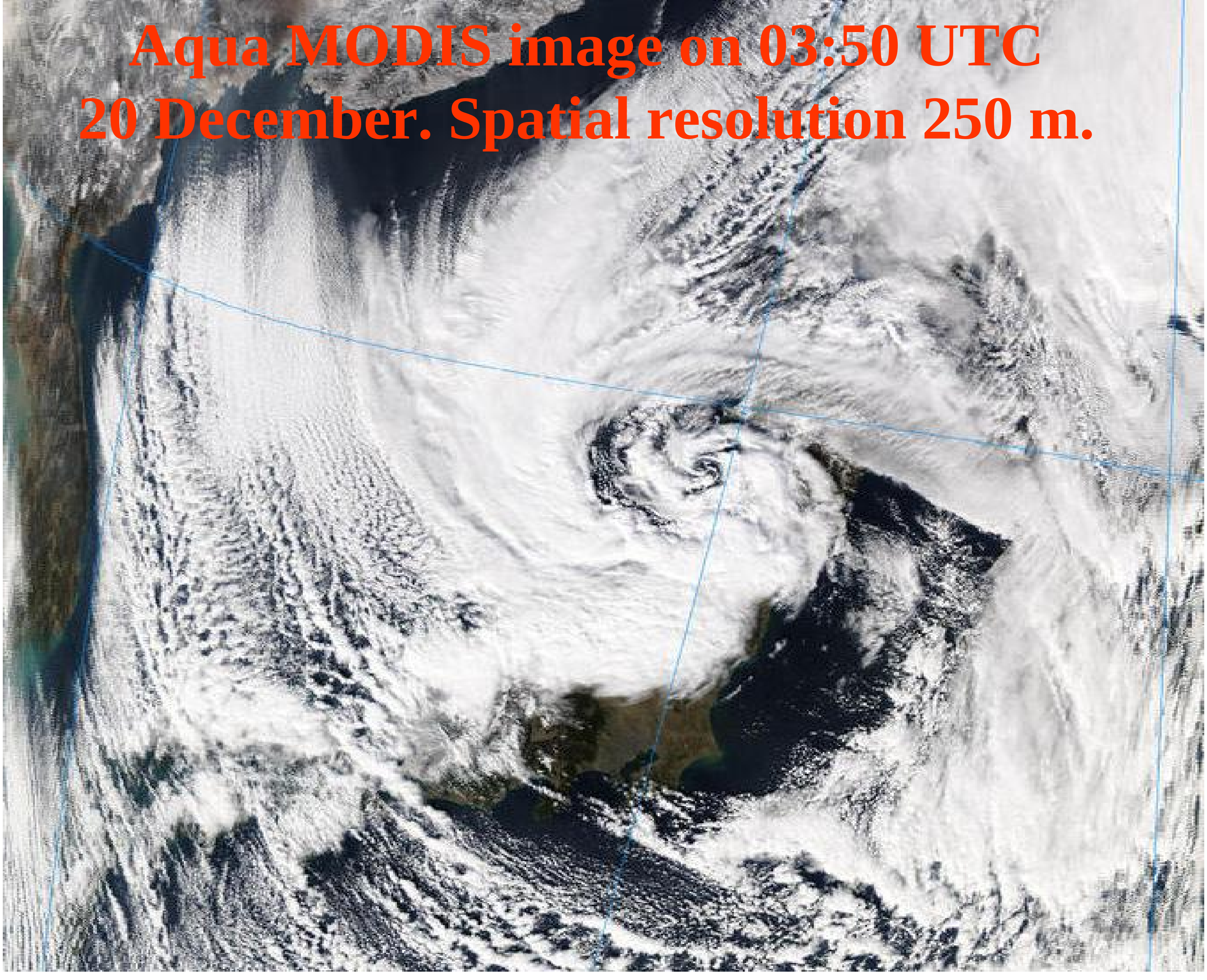


22 UTC 19 - 05 UTC 20 December

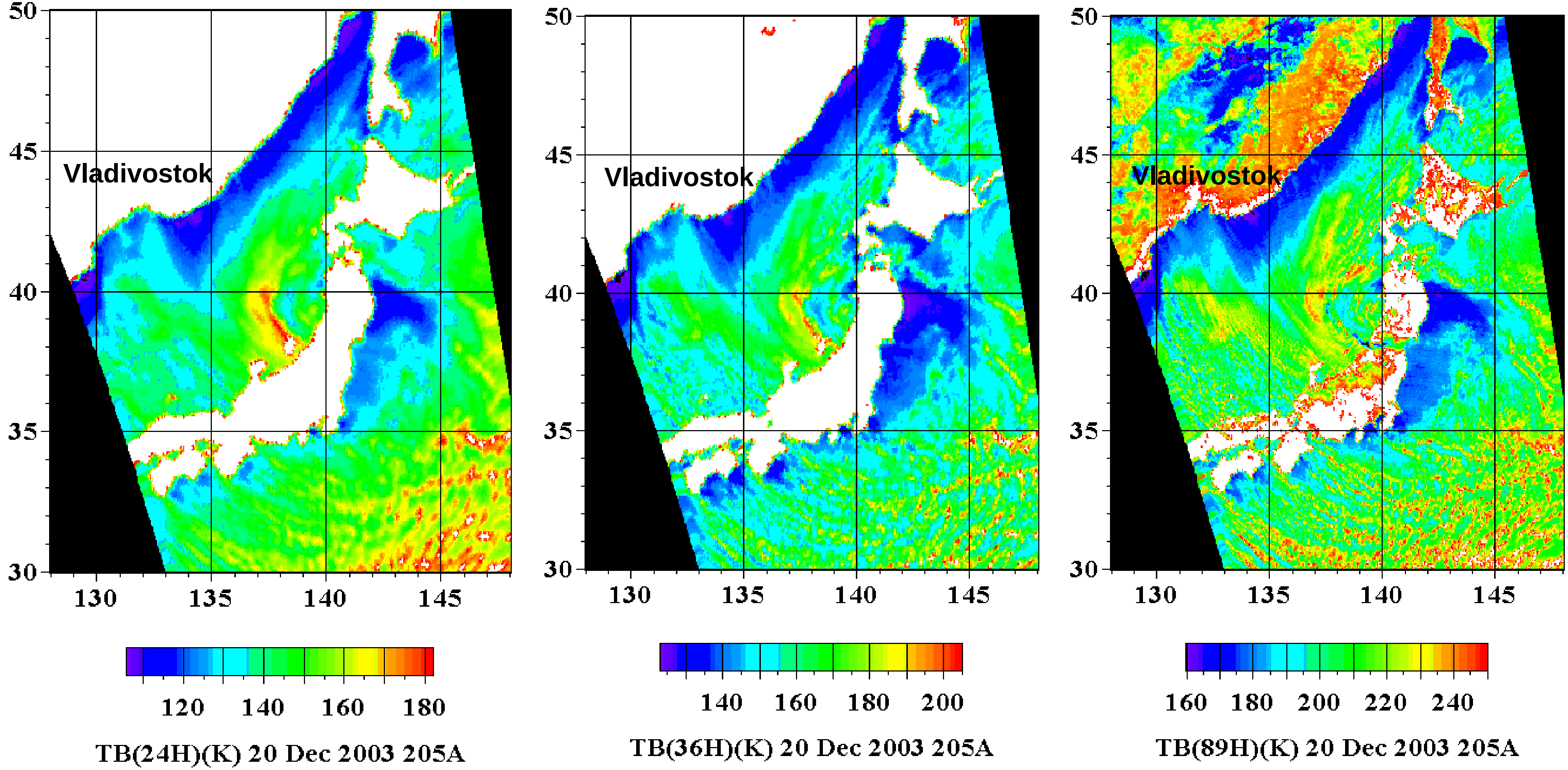
Dissipation stage



06-08 UTC 20 December

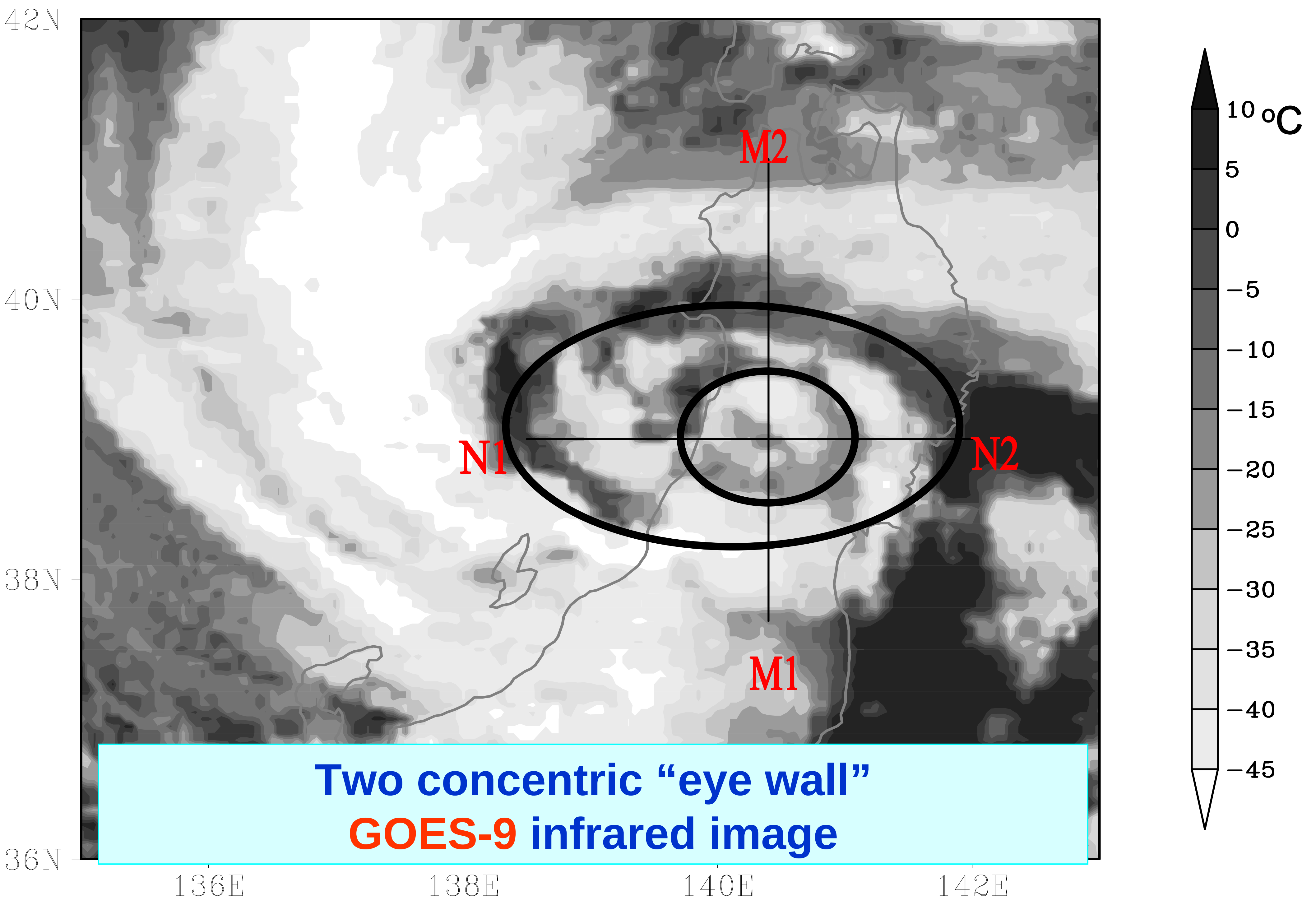

Aqua MODIS image on 03:50 UTC
20 December. Spatial resolution 250 m.

Aqua AMSR-E brightness temperature fields on 03:50 UTC 20 December 2003



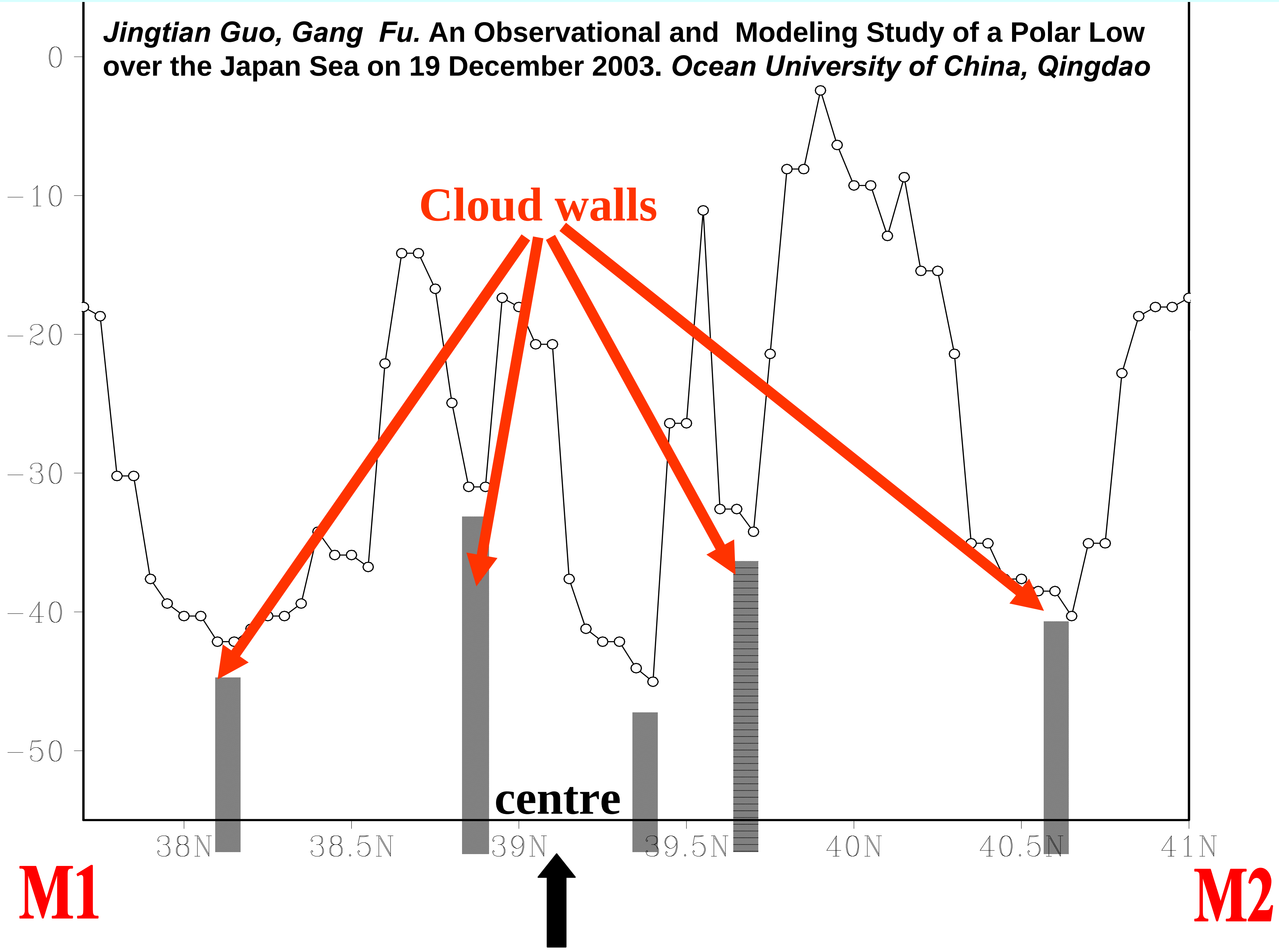
23.8 GHz | 36.5 GHz | 89.0 GHz

Brightness temperature at 04 UTC on 20 December 2003 (ºC)

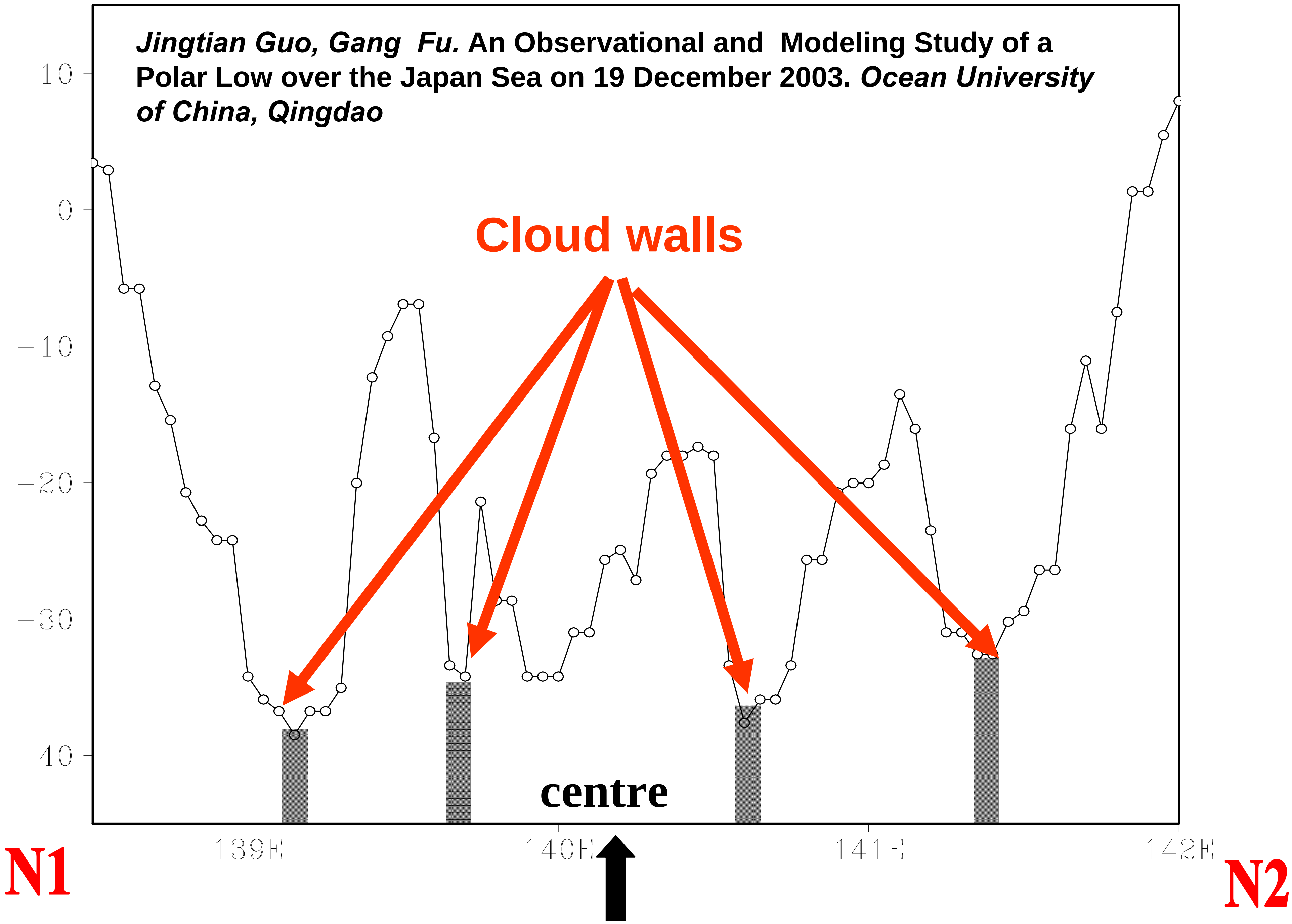


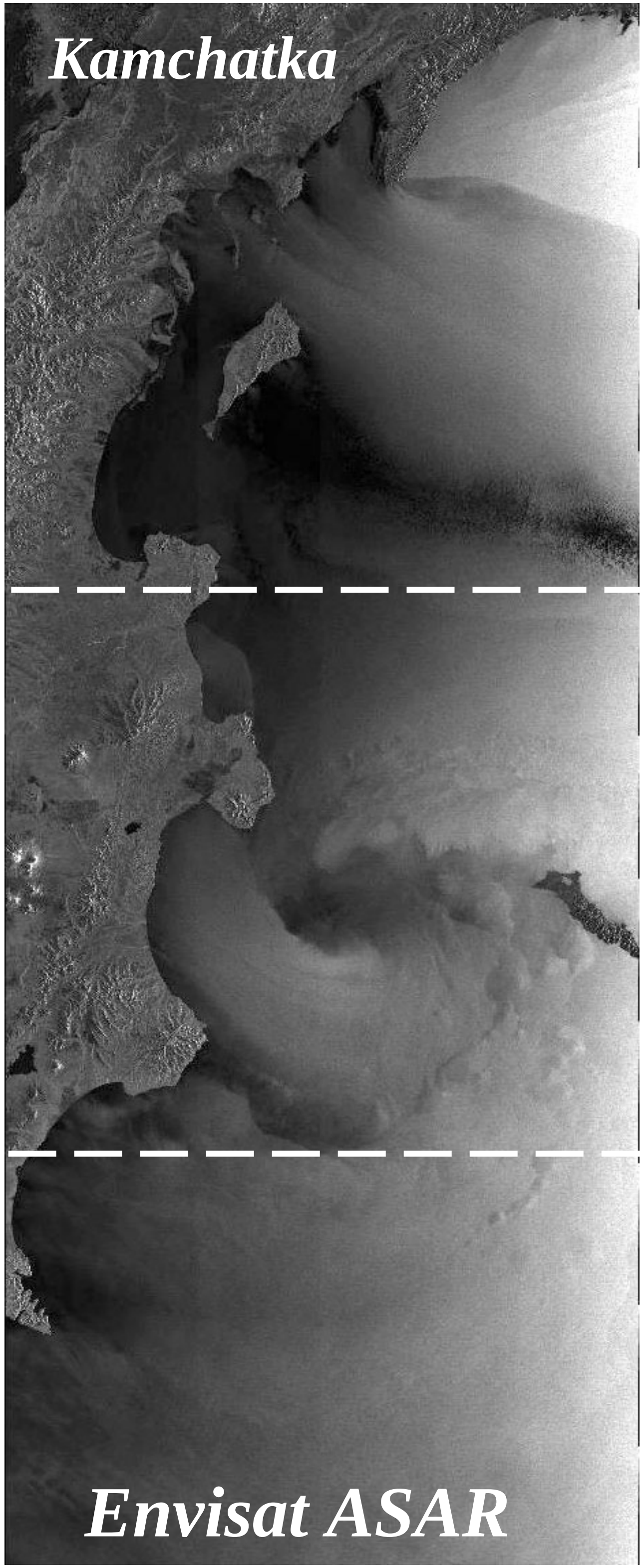
Two concentric "eye wall"
GOES-9 infrared image

Cross-section brightness temperature along M1- M2 (ºC)

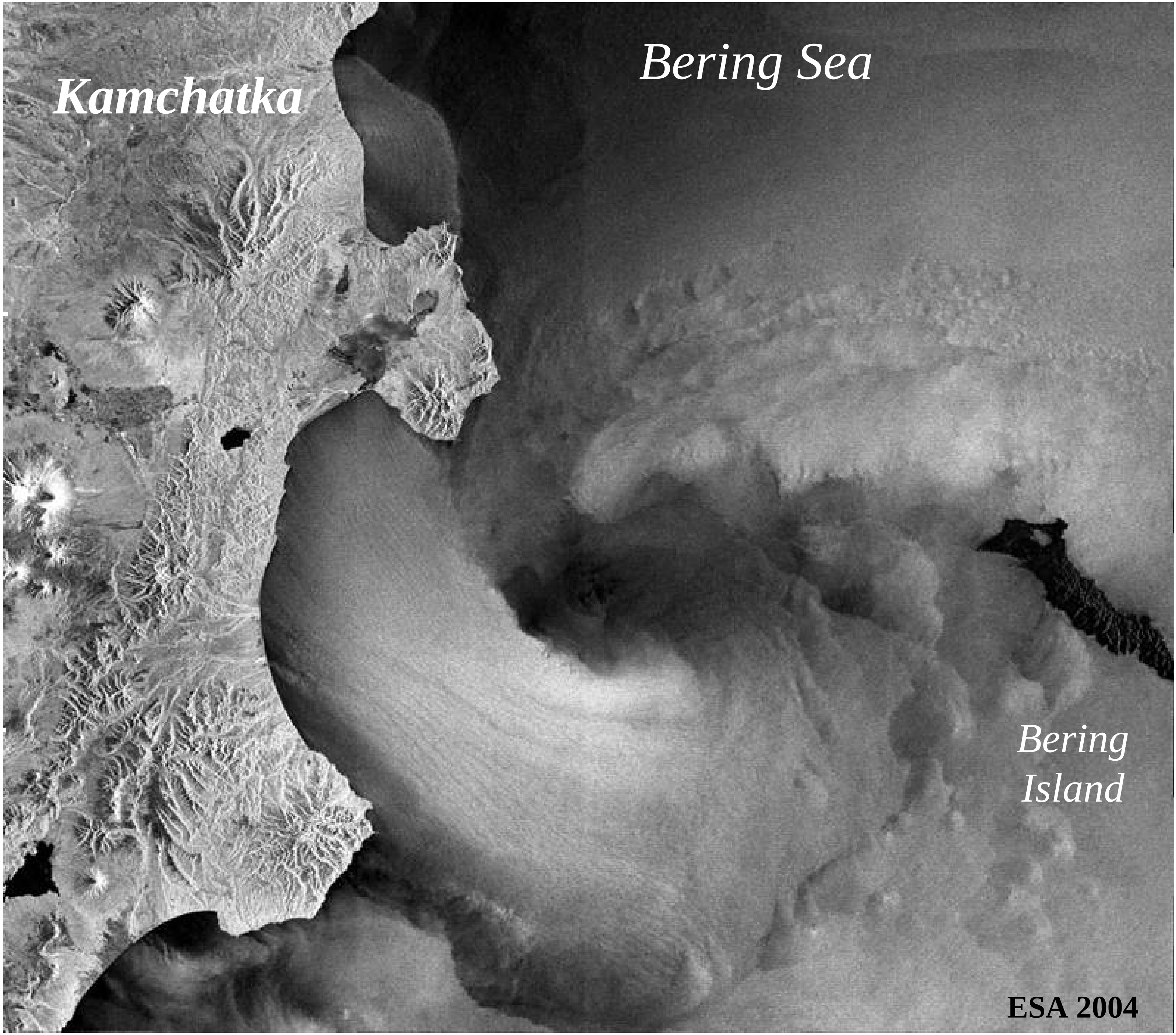


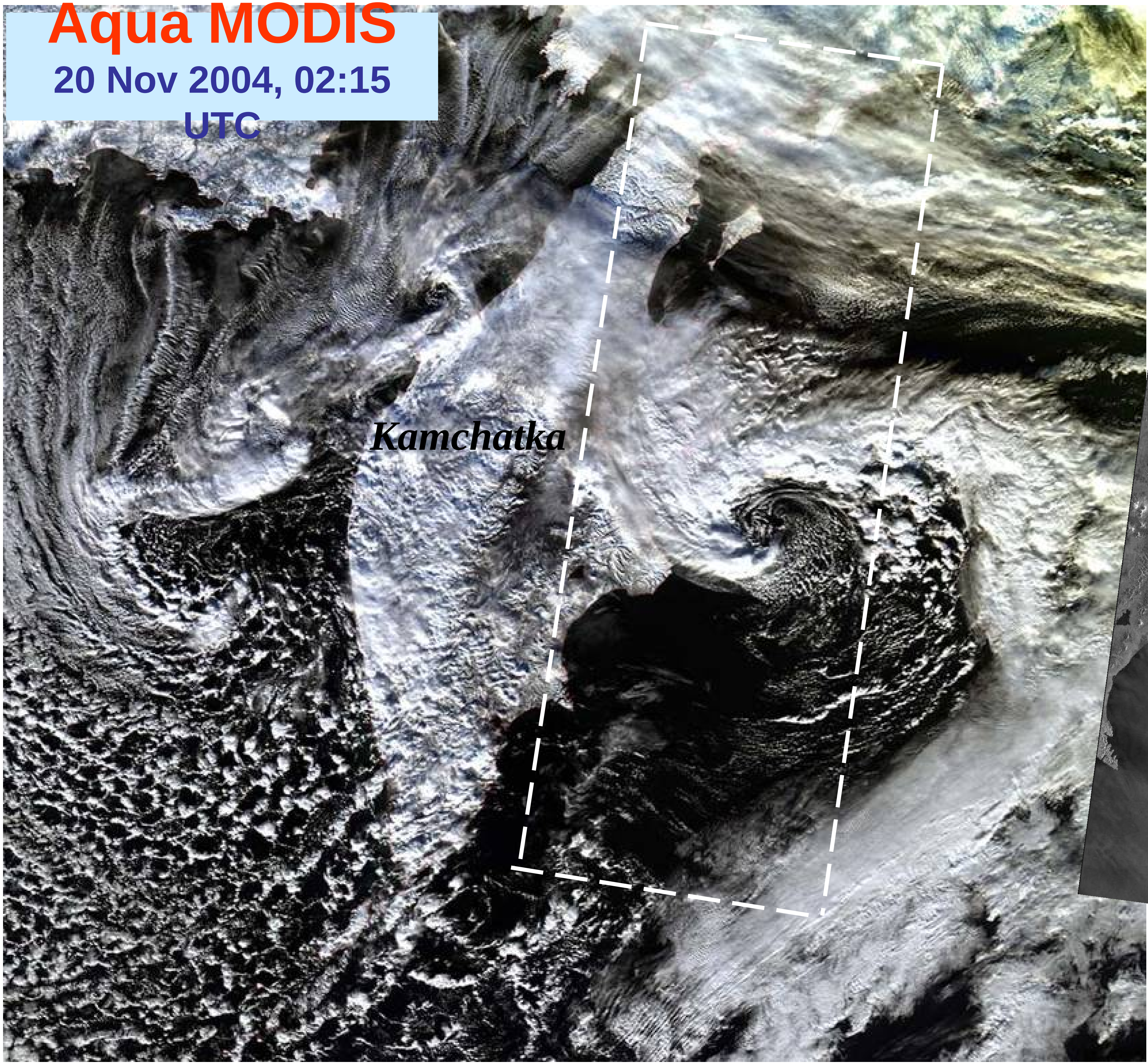
Cross-section brightness temperature along N1- N2 (ºC)

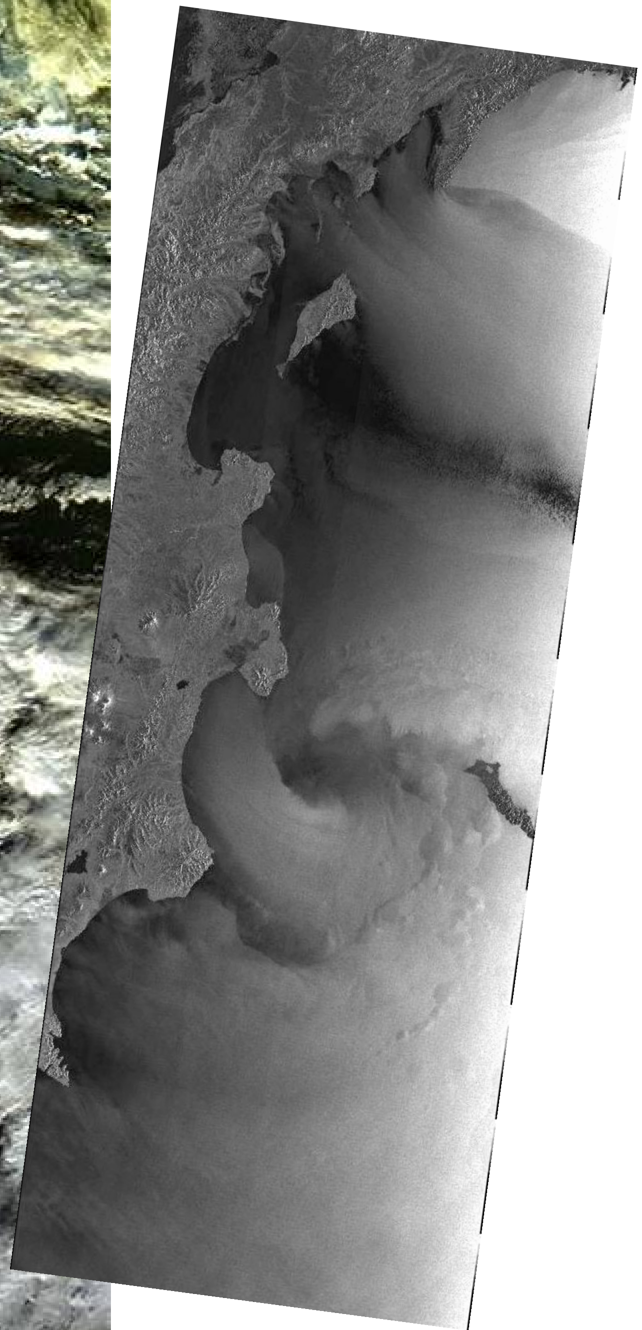




19 November 2004, 2328 UTC

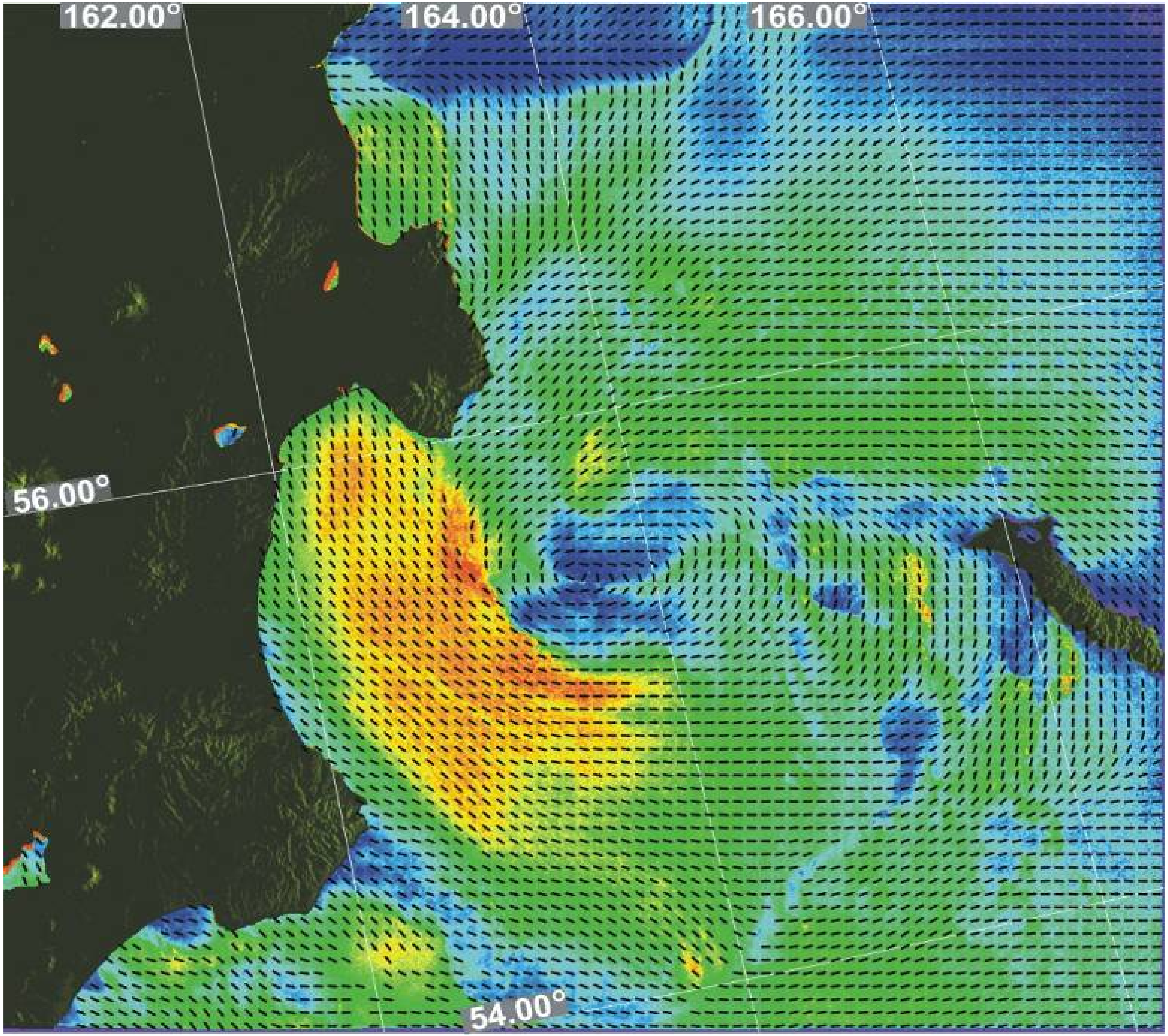



Aqua MODIS
20 Nov 2004, 02:15 UTC
Kamchatka



Wind field retrieved from ASAR image

http://w3g.gkss.de/staff/horstm/index.html



WiSAR wind speed retrieval

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Conclusions

Statistics of mesocyclones over the Japan/East Sea was obtained by analysis of visible and infrared MODIS images taken in 2003-2008. (yearly and monthly average numbers, size, areas of formations).

Efficiency of multisensor approach was demonstrated for several case studies.

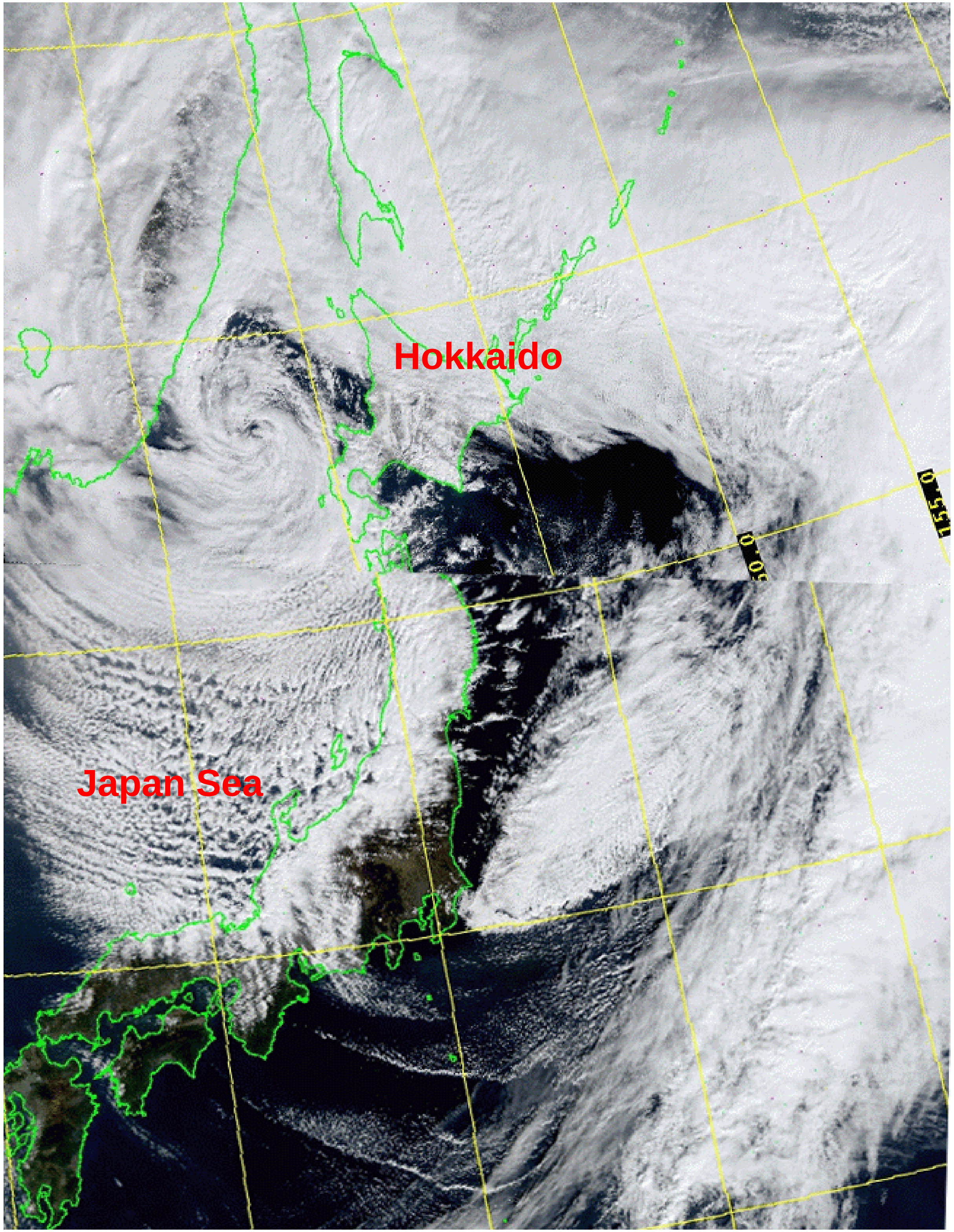
Application of passive and active microwave techniques allowed to get the quantitative spatial data on the total atmospheric water vapor content *V* and total cloud liquid water content *Q* for the mesoscale cyclones and surrounding areas in connection with their evolution, synoptic weather maps, etc.

Typical values of *V* = 3-6 kg/m2 for the northern MC and 5-10 kg/m2 for the southern MC. Typical *Q* values were equal to 0.1-0.2 kg/m2.

Fine and mesoscale structure of sea surface wind can be retrieved from satellite SAR images.

Statistics

- Period 2003-2008, October - April
- Preliminary statistic processing of MODIS images has shown that yearly average number of MC: 53
- Maximum yearly average number 62 in winter 2004-2005
- Minimum yearly average number 36 in winter 2006-2007
- Monthly average number 3-4 (October), 6 (November), 12 (December), 13-14 (January), 9-10 (February), 6-7 (March) and 3 (April).
- Life circle of the most MC is 0.5-1 days, some of them are observed 2 days and only several till 3 days.



Developed polar low over the Japan Sea on 15 February 2007

Intensification of air-sea interaction and formation of meso-scale rolls and cells.

Terra MODIS

15 February 2007

01:15 UTC