

# Спутниковое радиотепловидение системы океан-атмосфера Земли: задачи, подходы, технологии

Д.М. Ермаков (ФИРЭ РАН, ИКИ РАН)

# Атмосферные процессы

## мезомасштабные

Горизонтальный размер 10 – 1000 км

## синоптические

Горизонтальный размер > 1000 км

**Задача: описать эволюцию системы океан-атмосфера в терминах динамических и энергетических характеристик наблюдаемых в системе многомасштабных процессов**



Циклоны и антициклоны, фронты, воздушные массы

Тропические циклоны

Бризы, фены, бора, мезоциклоны, мезомасштабные комплексы (системы), конвекция

- Климатические исследования, в т.ч., полярный перенос, парниковый эффект;
- Прогноз погоды;
- Предсказание и мониторинг природных катастроф и их последствий

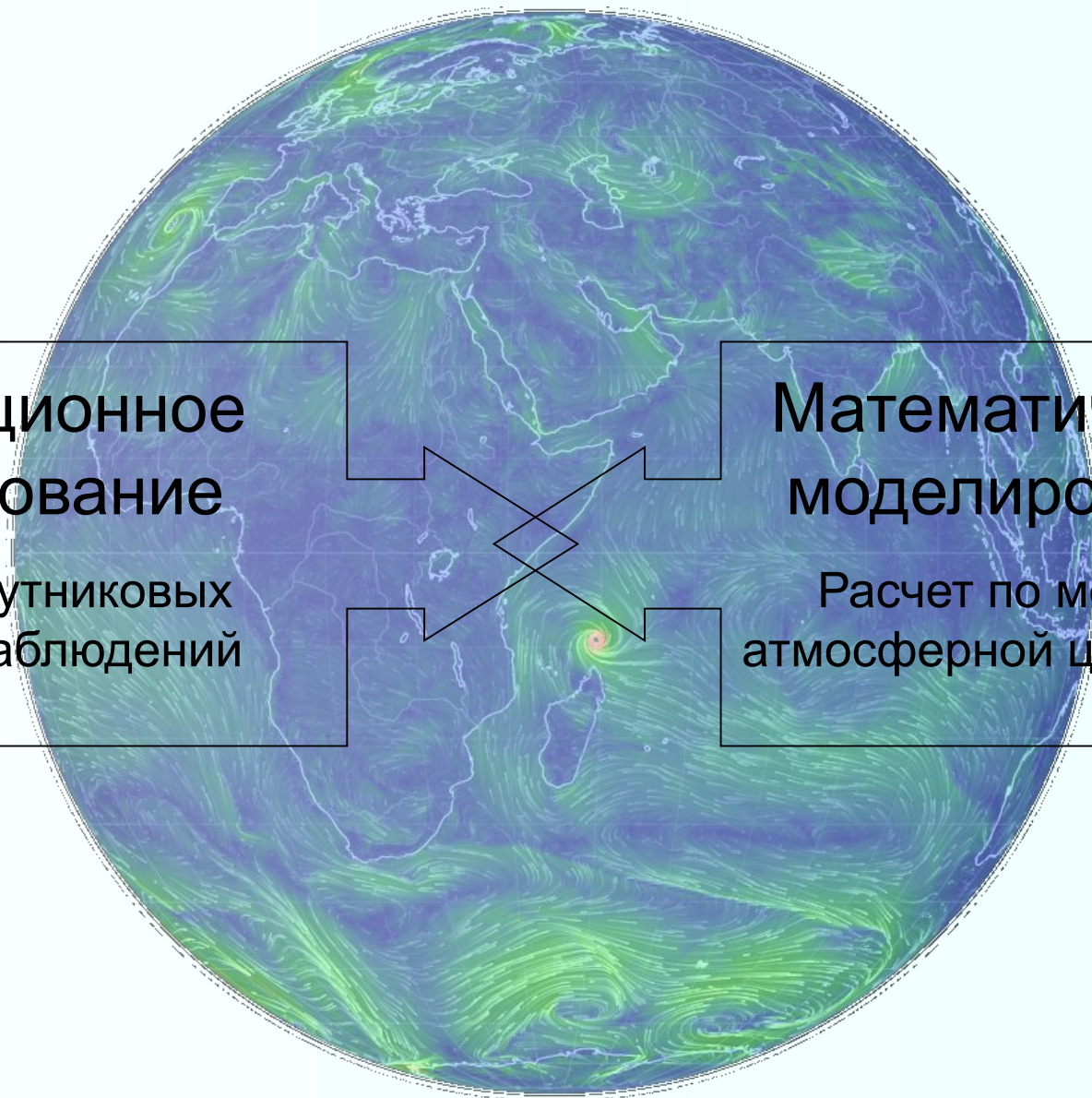
# Расчет атмосферной динамики

## Дистанционное зондирование

Анализ спутниковых и других наблюдений

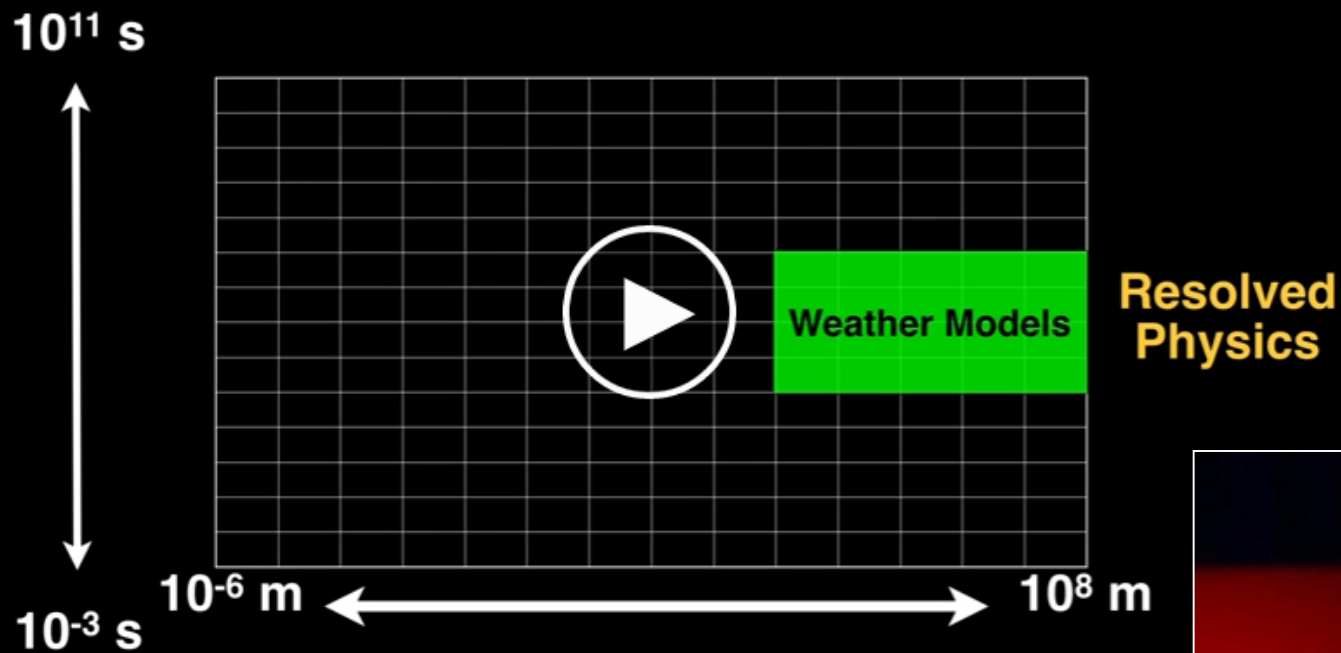
## Математическое моделирование

Расчет по моделям атмосферной циркуляции



# Иерархия масштабов: сложность и неустойчивость

## 14 Orders of Magnitude



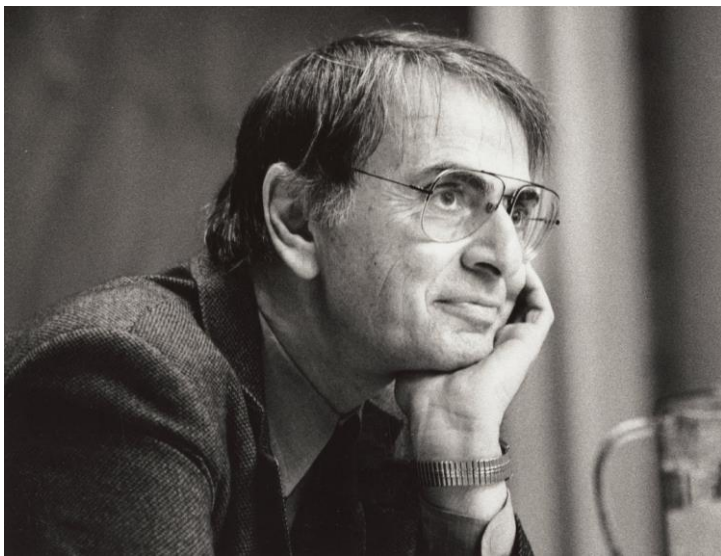
**Gavin Schmidt** (NASA)

The emergent patterns of climate change

TED



# Фундаментальная неустойчивость климата?



Карл Саган (1934 – 1996)

Следует обдумать климатическую историю нашей планеты-соседки [*Венеры*], во многом похожей на Землю, но раскалившейся настолько, что у нее на поверхности течет свинец.

Pale Blue Dot. A vision of the human future in space  
1994

# Моделирование и наблюдения



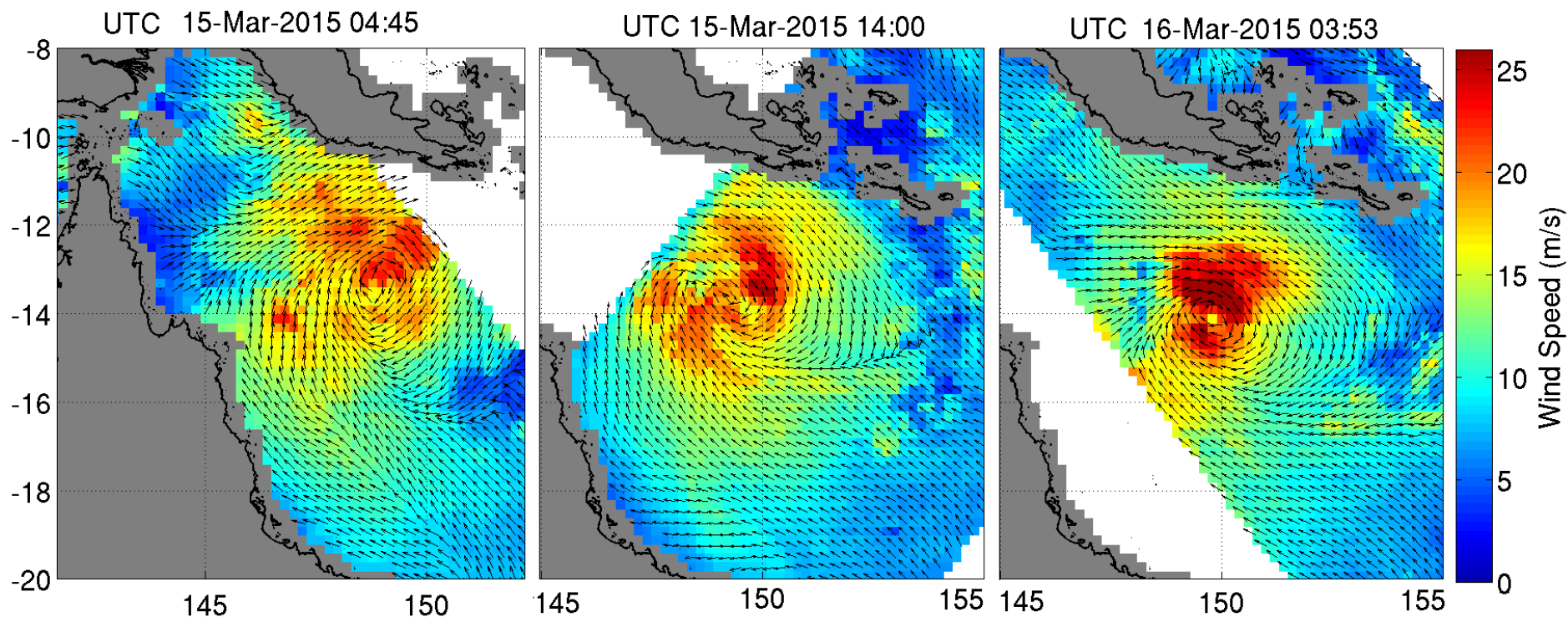
The screenshot shows a web browser displaying a TED talk. The URL in the address bar is [www.ted.com/talks/gavin\\_schmidt\\_the\\_emergent\\_patterns\\_of\\_climate\\_change](http://www.ted.com/talks/gavin_schmidt_the_emergent_patterns_of_climate_change). The TED logo is visible in the top left, and navigation links for Watch, Discover, Attend, Participate, and About are in the top center. A search bar and Log in/Sign up links are in the top right. The main content area shows a video player with a large play button in the center. The video frame shows a man (Gavin Schmidt) on a stage in front of a large screen displaying a map of the world with the text "Atmospheric column water vapour" and "High resolution Model". The TED logo is also visible on the stage. On the right side of the video player, there are icons for Watch later, Favorite, Download, and Rate. At the bottom of the video player, there are controls for Play, Volume, Subtitles, Transcript, and FullScreen. The video title is "Gavin Schmidt: The emergent patterns of climate change" and it was filmed in March 2014 at TED2014.

“If we had observations of the future we obviously would trust them more than models, but unfortunately observations of the future are not available at this time”

Tom Knutson and Robert Tuleya

# Возможности дистанционного зондирования

## 1. Поверхность: скорость приводного ветра

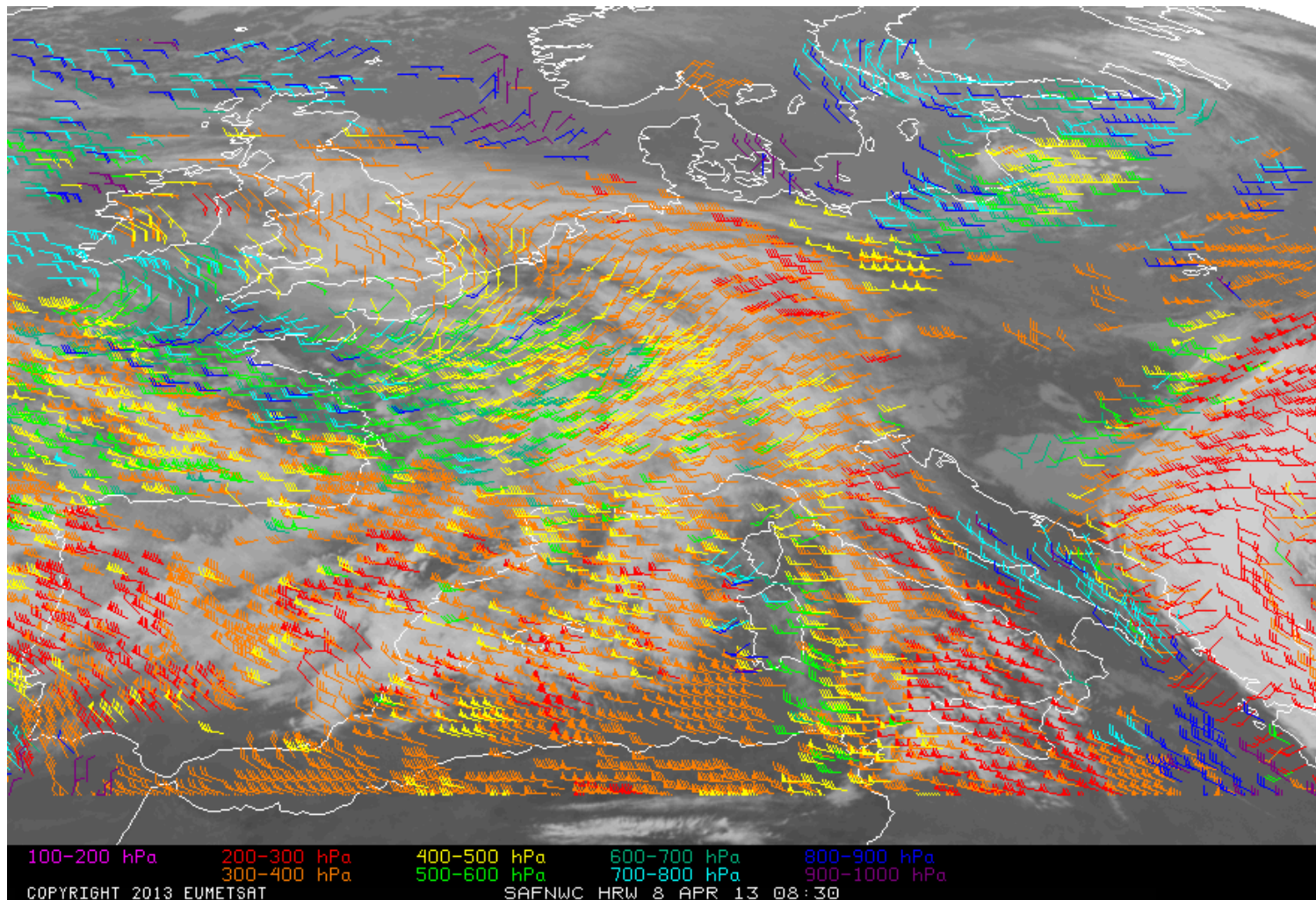


**Tropical Cyclone Nathan's Winds March 15-16, 2015 as seen by ISS-RapidScat**

<http://www.nasa.gov/jpl/rapidscat/nasas-new-wind-watcher-ready-for-weather-forecasters/>

# Возможности дистанционного зондирования

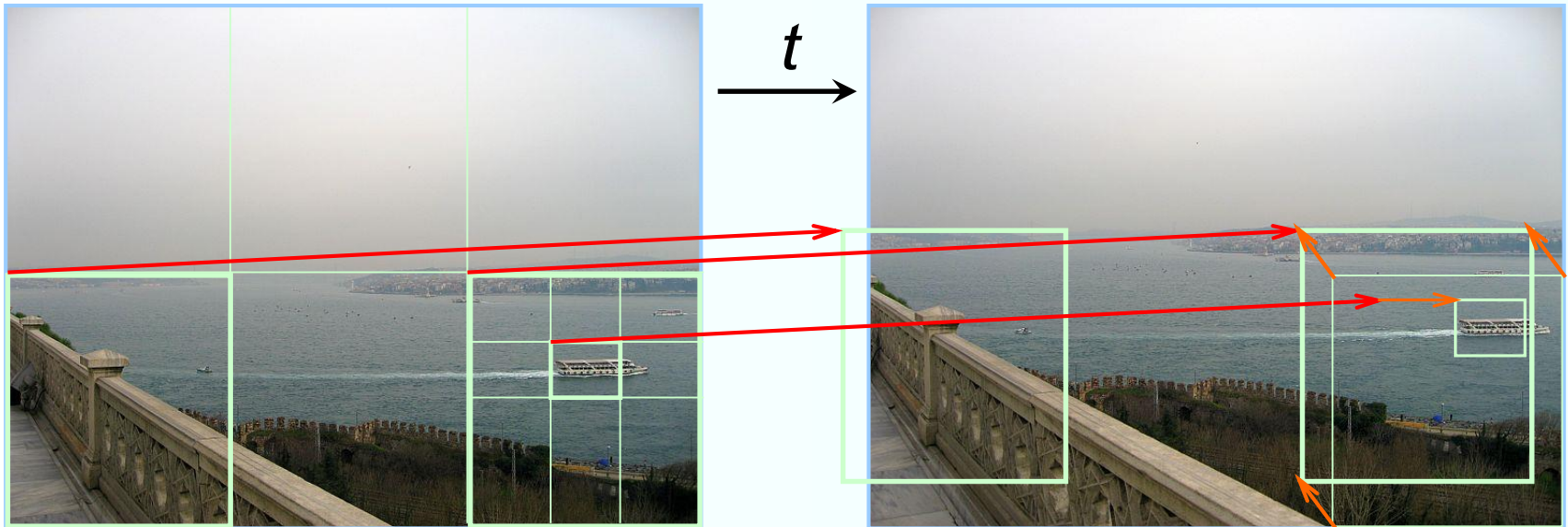
## 2. Высотные уровни: «векторы атмосферных движений»



<http://www.eumetrain.org/data/3/306/navmenu.php?tab=9&page=2.0.0>



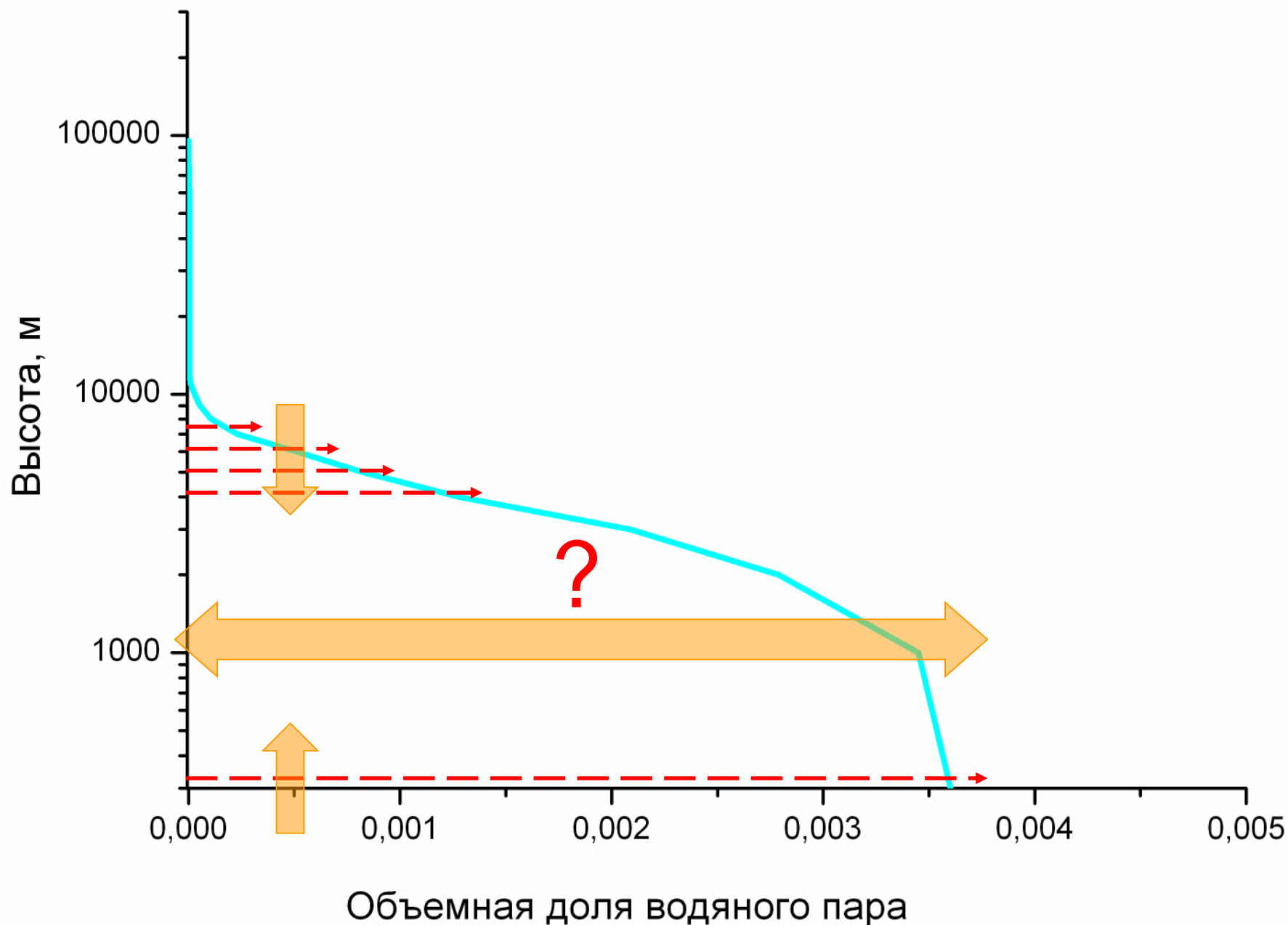
# Оценка и компенсация движения



$M(x,y)$  – векторное поле смещений

$V(x,y) = M(x,y) / t$  – поле скоростей

# Возможности дистанционного зондирования



# Wimmers, Velden: Seamless advective blending (2011)

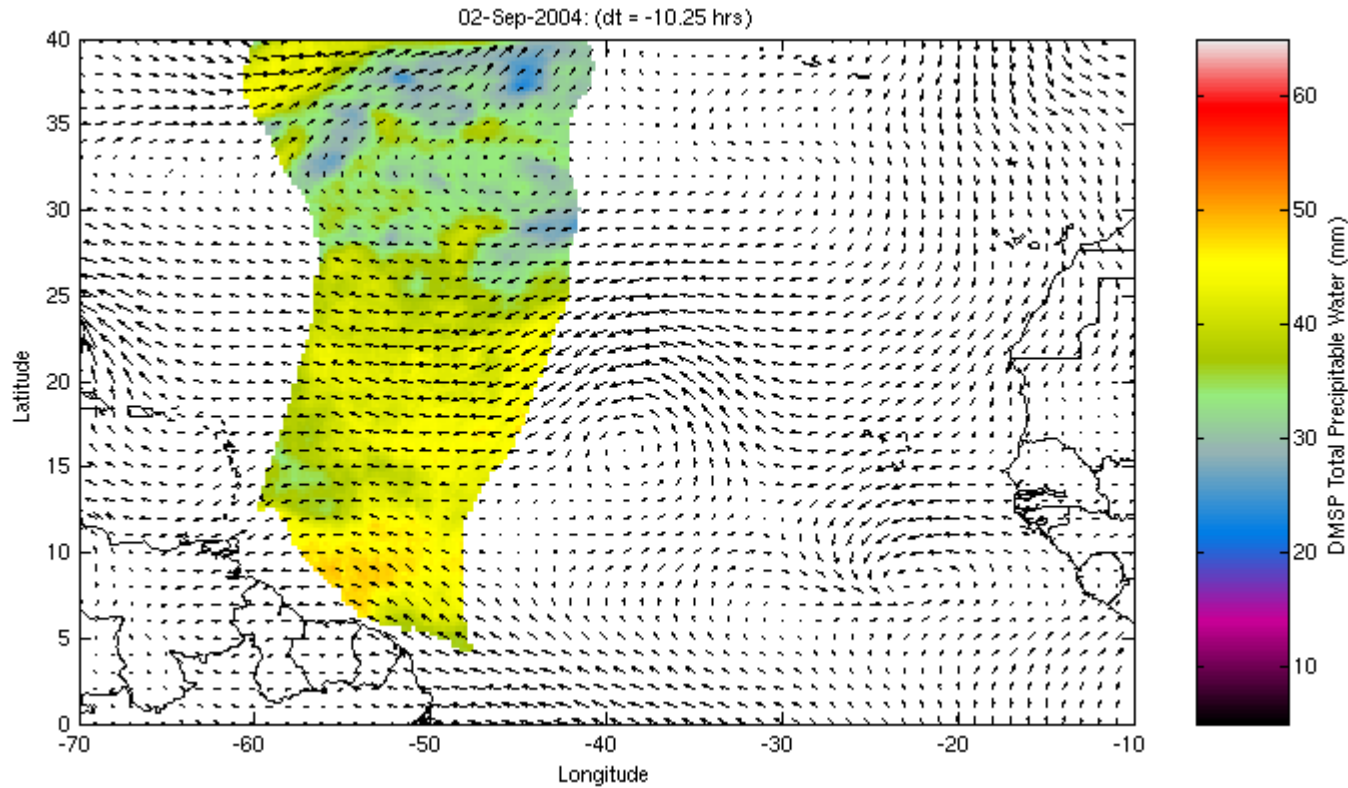
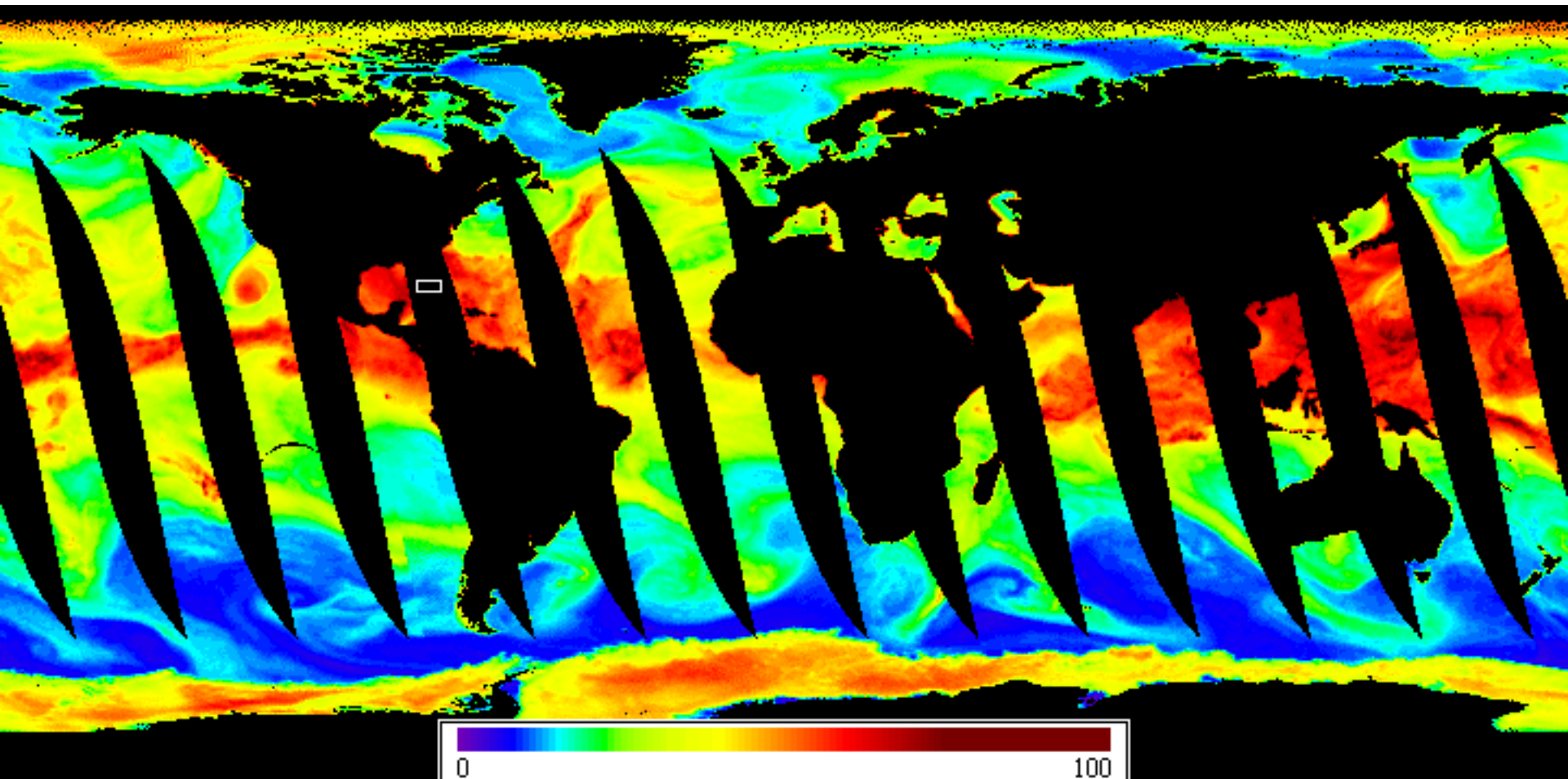


Table 2. Advecting wind profile weighting functions, by latitude.<sup>a</sup>

Height (hPa)	weight, $\leq 25^\circ$	weight, $\geq 50^\circ$
700	0.160	0.138
850	0.280	0.345
1000	0.560	0.517

<sup>a</sup> Valid for north and south latitude (always positive in this table). Weights between  $25^\circ$  and  $50^\circ$  latitude are calculated by linear interpolation.

# Пространственный охват и временное разрешение



SSM/I F13

26.08.2005

$$x^j = (x + L + j - 1) \% L + 1 \quad y^k = y + k \quad w_{x,y} = -1 \quad w_{x^{+1},y} \geq 0 \quad w_{x',y} = -1, w_{x^j,y} \geq 0, j = 1..l-1$$

$$d = \lceil l/2 - 0,5 \rceil \cdot 2 + 5 \quad x_B = x^{-d} \quad y_B = y^{-\lceil d/2 - 0,5 \rceil}$$

$$S(B, N) = \sum_{j=0}^{d-1} \sum_{i=0}^{d-1} |s_{i,j}| \quad s_{i,j} = \begin{cases} W_{x_B^i, y_B^j} - W_{x_N^i, y_N^j}, & \text{при } w_{x_B^i, y_B^j} = -1, w_{x_N^i, y_N^j} = -1, \\ 0, & \text{при } w_{x_B^i, y_B^j} \geq 0 \text{ или } w_{x_N^i, y_N^j} \geq 0. \end{cases}$$

*Ермаков Д.М., Раев М.Д., Чернушич А.П., Шарков Е.А.* Алгоритм построения глобальных радиотепловых полей системы океан-атмосфера высокой пространственно-временной дискретизации по спутниковым микроволновым измерениям // Исследование Земли из космоса. 2013. № 4. С. 72-82.

$$W_{x^{i+m}, y^{j+n}} := \begin{cases} W_{x^{i+m}, y^{j+n}} + W_J \cdot \exp(-2 \cdot m/d), & \text{при } w_{x^{i+m}, y^{j+n}} \geq 0, \\ W_{x^{i+m}, y^{j+n}}, & \text{при } w_{x^{i+m}, y^{j+n}} = -1. \end{cases} \quad \vec{v} = (v_x; v_y) = (1; 2 \cdot (y_B - y_S)/d)$$

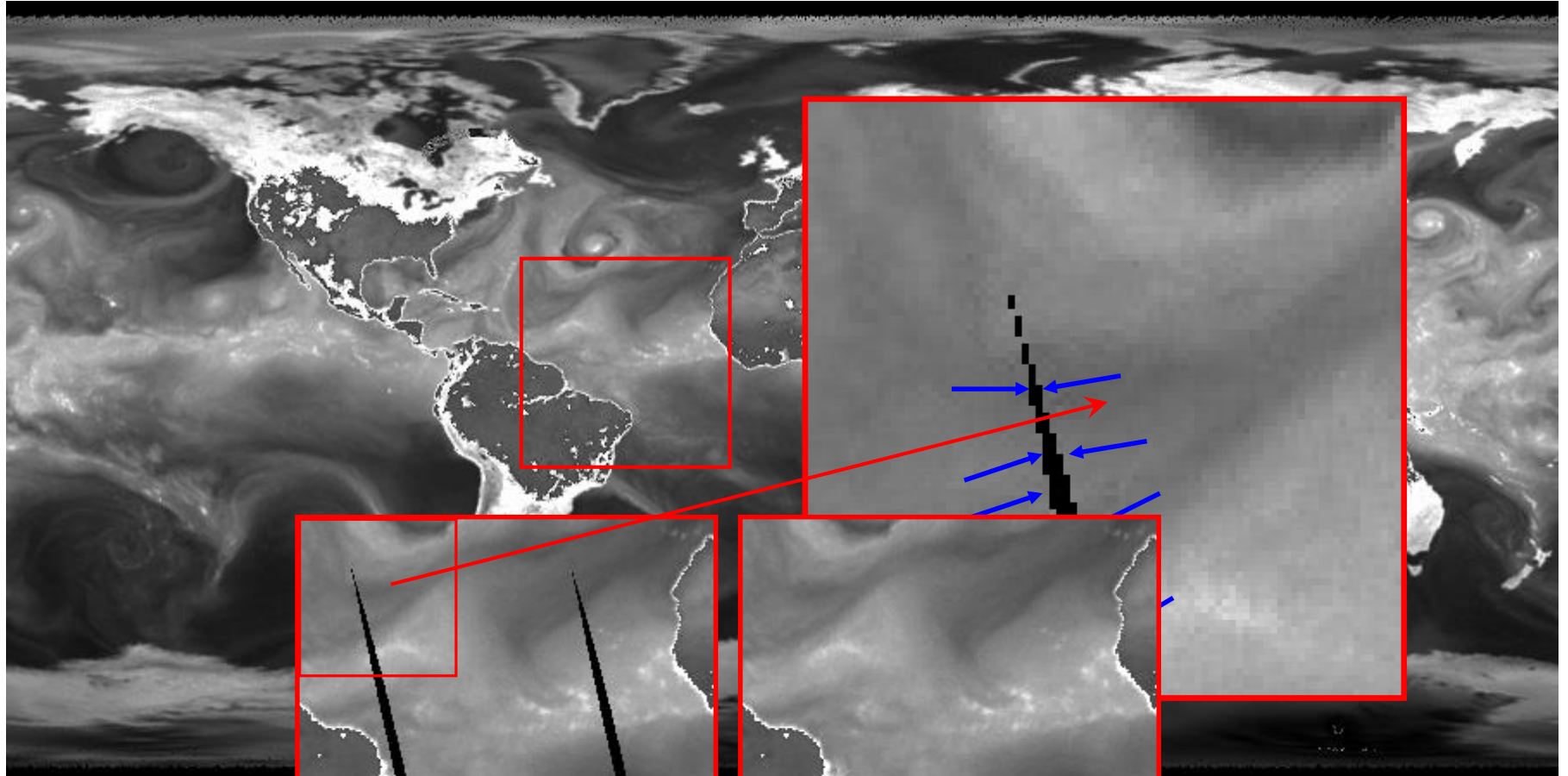
$$D = f \cdot d$$

$$w_{x^{i+m}, y^{j+n}} := \begin{cases} w_{x^{i+m}, y^{j+n}} + \exp(-2 \cdot m/d), & \text{при } w_{x^{i+m}, y^{j+n}} \geq 0, \\ -1, & \text{при } w_{x^{i+m}, y^{j+n}} = -1 \end{cases}$$

$$W_{x,y} := \begin{cases} W_{x,y} / w_{x,y}, & \text{при } w_{x,y} > 0, \\ W_{x,y}, & \text{при } w_{x,y} \leq 0. \end{cases}$$

$$n = \lceil m \cdot v_y \rceil, m = 1..D$$

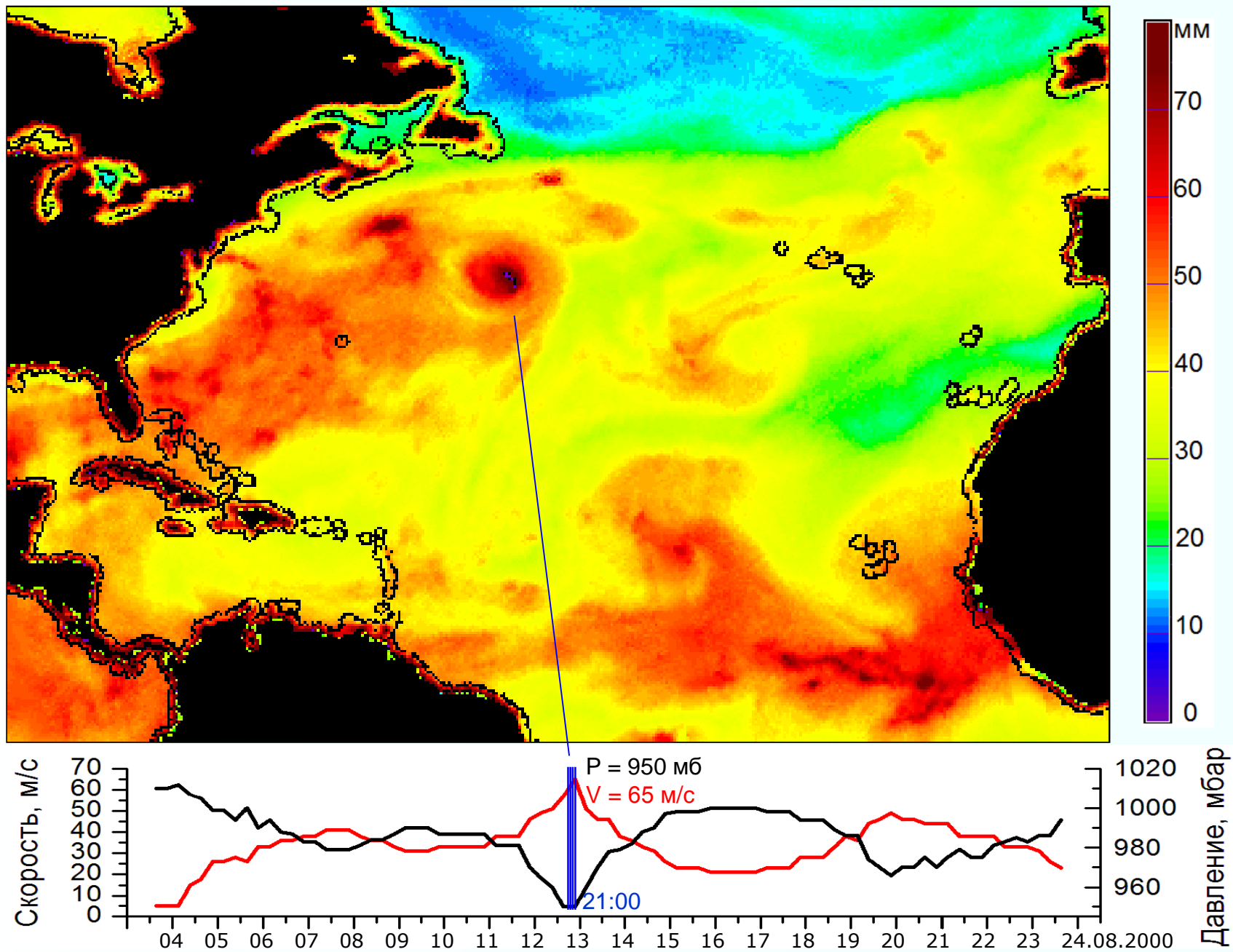
# Сшивка лакун: реализация



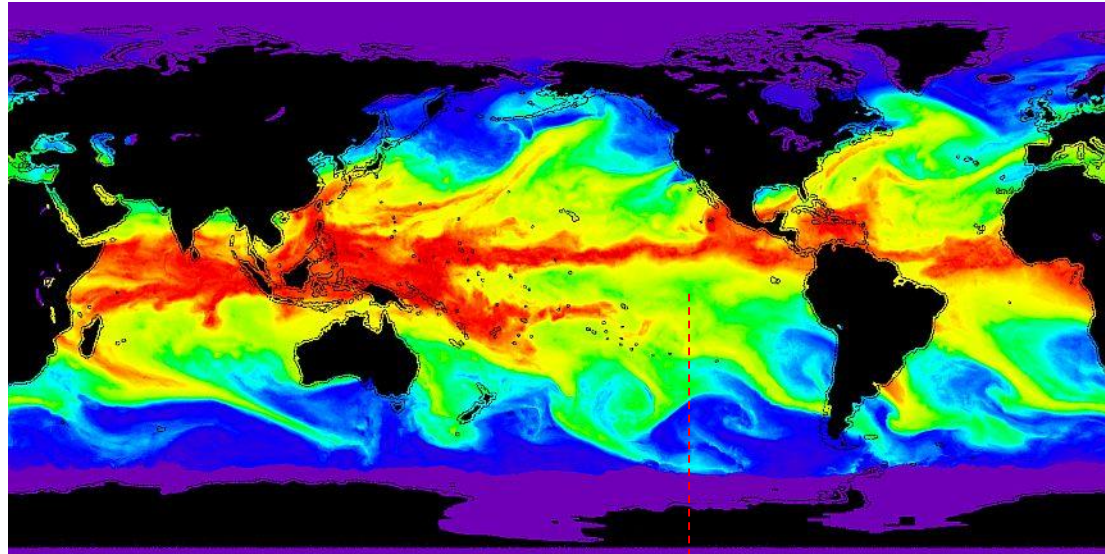
***F14A + F15A***

16/17 августа 2000 г.

# Пространственно-временная интерполяция

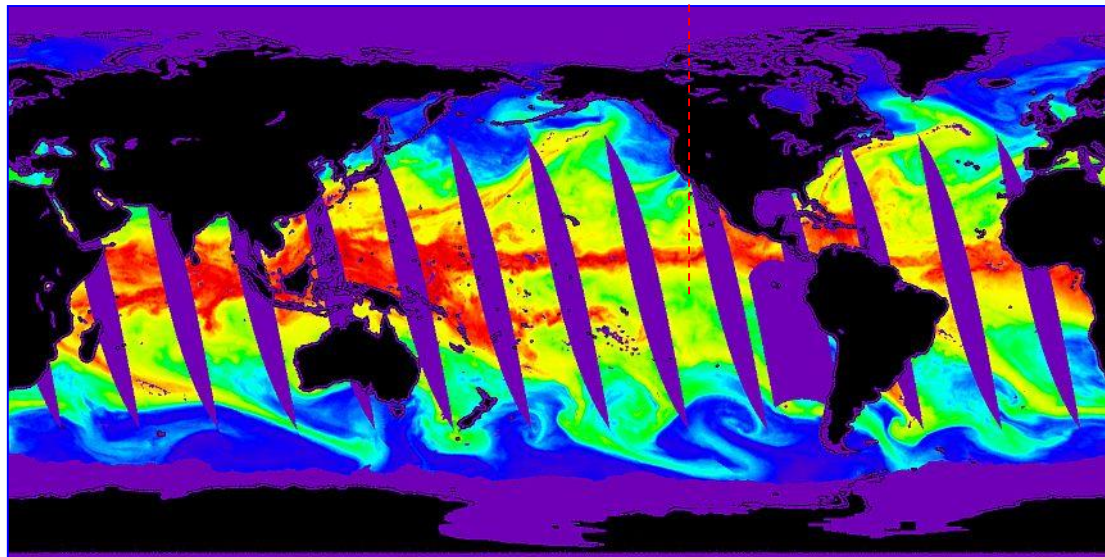


# Оценка точности интерполяции: методика

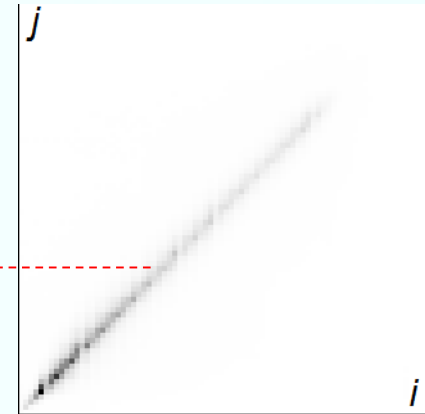


SSMIS F16 (*i*)

$\Delta t = -05:30$

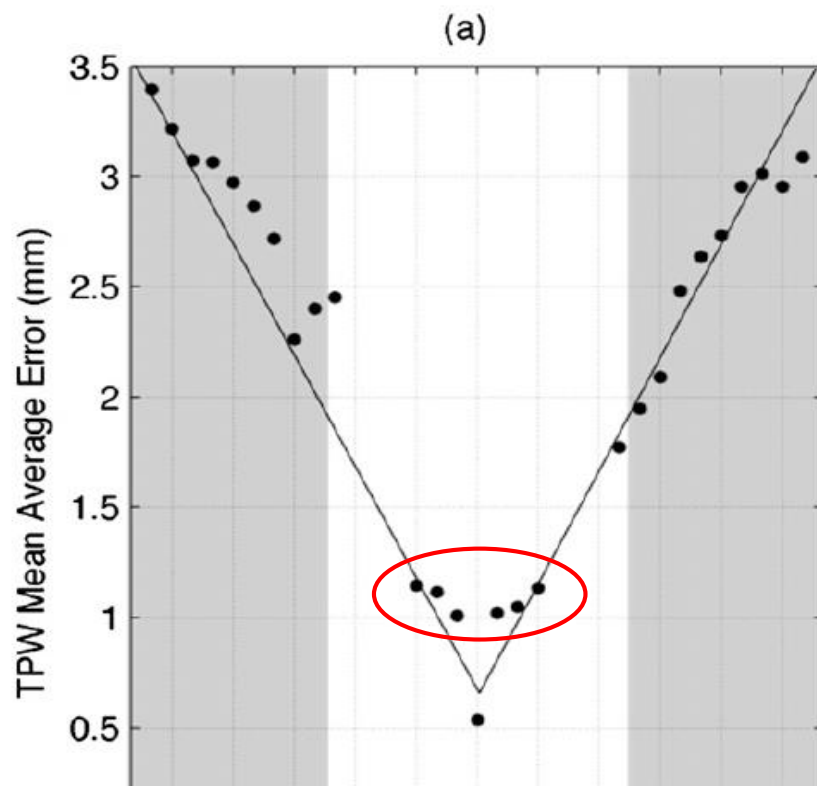
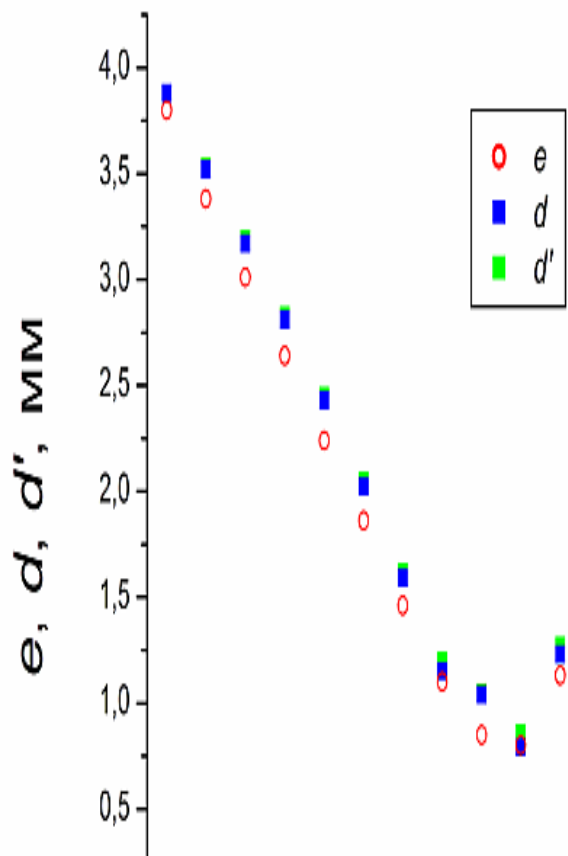


SSMIS F17 (*j*)





# Оценка точности интерполяции: результаты

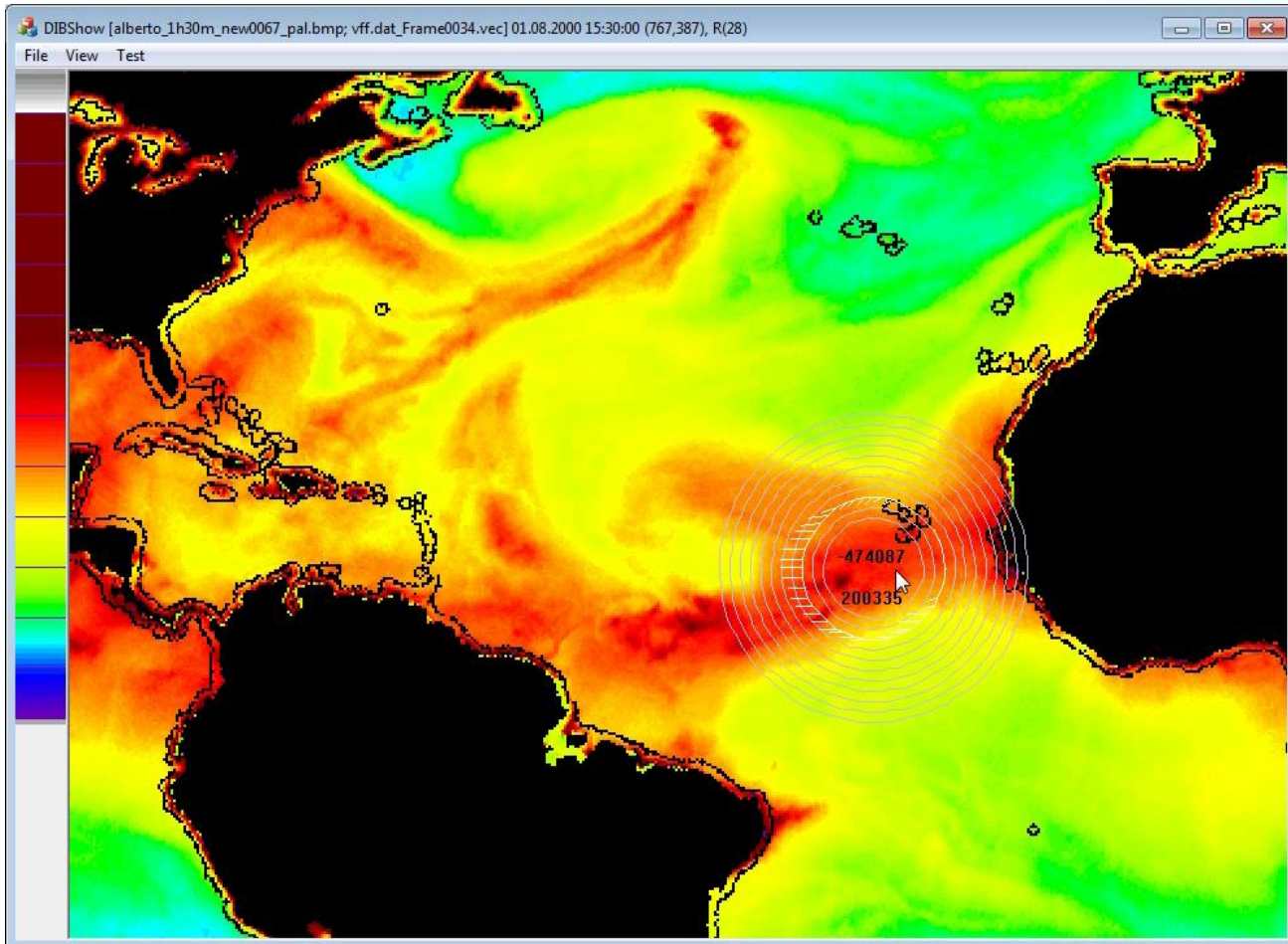


Ермаков Д.М., Шарков Е.А., Чернушич А.П. Оценка точности интерполяционной схемы спутникового радиотепловидения // Современные проблемы дистанционного зондирования Земли из космоса. 2015. Т. 12. №2. С. 77-88.

Погрешность 0,8 мм

Погрешность 0,5 (?) - 2,0 мм

# Оценки потоков. Адвекция скрытого тепла



V-поле

x

M-поле →

v

↓  
Потоки через  
произвольные  
контуры!

Ермаков Д.М., Шарков Е.А., Чернушич А.П. Оценка тропосферных адвективных потоков скрытого тепла над океаном при анимационном анализе радиотепловых данных спутникового мониторинга // Исследование Земли из космоса. 2014. № 4. С. 32-38.

H. Zhao, D. Tang, Y. Wang, 2008. Comparison of phytoplankton blooms triggered by two typhoons with different intensities and translation speeds in the South China Sea. *Mar. Ecol. Prog. Ser.*, 365, 57-65

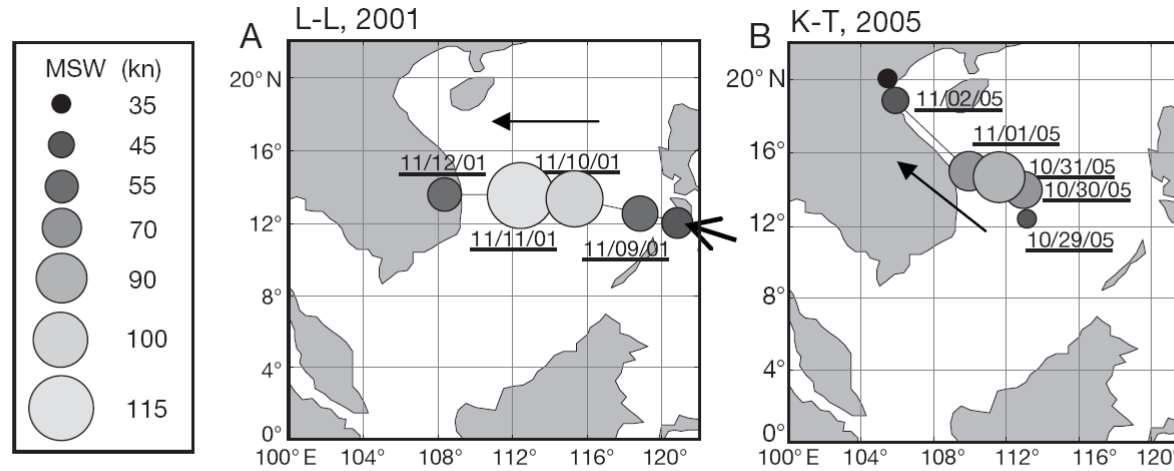
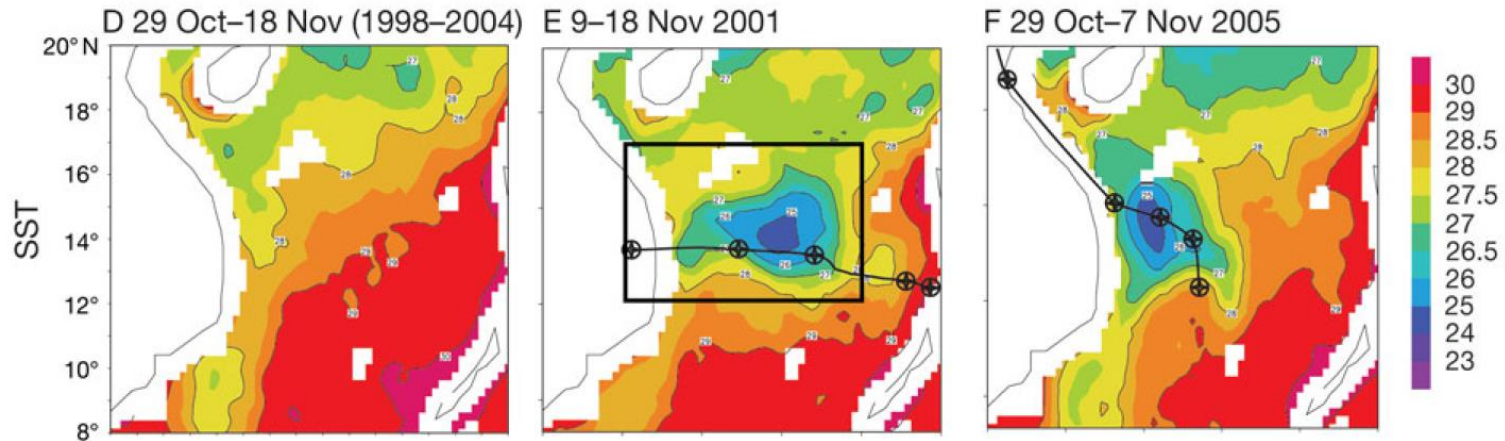


Fig. 2. (A) Track and intensity of typhoons Ling-Ling (L-L) (2001) and Kai-Tak (K-T) (2005) in the South China Sea (SCS). MSW: maximum sustained wind (in knots, 1 kn = 0.514 m s<sup>-1</sup>). Dates are given as mm/dd/yy



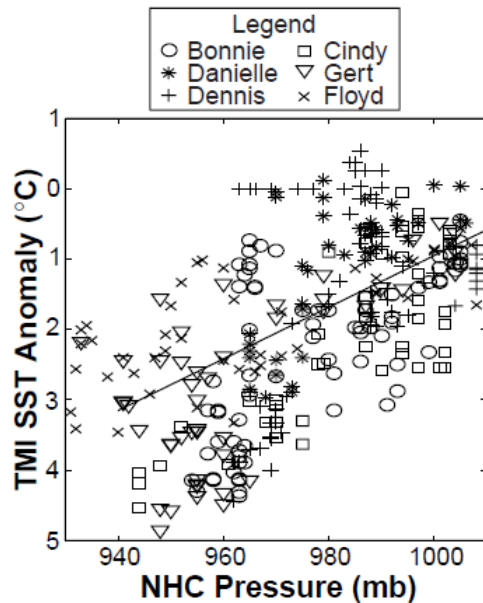


Figure 2. Relationship between hurricane storm induced SST anomalies and storm minimum pressure.

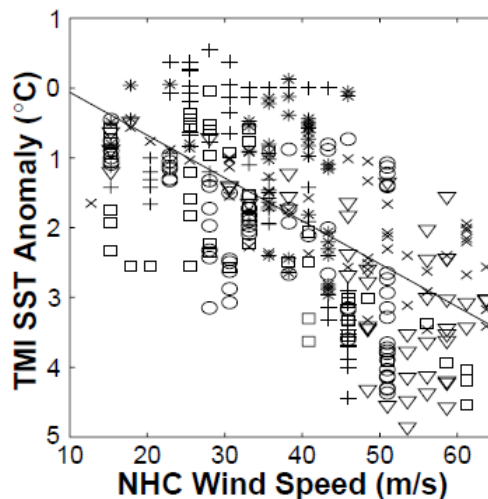


Figure 3. Relationship between hurricane storm induced SST anomalies and maximum sustained wind speed.

upwelling is generally to the right of the storm track, this 5 day time series of SST anomalies was calculated at several positions to the right of the track location. To find the location of the maximum upwelling at each position, the SST anomalies were temporally averaged. At the position with the largest temporally averaged anomaly, the maximum SST anomaly was identified. This value was then used to examine the relationship between maximum sustained wind speed and SST anomalies (Fig. 2) and minimum central pressure and SST anomalies (Fig. 3).

A weak linear relationship is seen in both Figure 2 and Figure 3. Stronger storms resulted in larger anomalies. The correlation is  $-0.62$  and  $0.57$ , respectively. Some of the scatter and the relatively weak correlation may be attributed to differences in the upper ocean thermodynamic structure between the Equatorial Atlantic and the North Atlantic and varying forward storm velocity, which effects development of vertical mixing. These results are obviously regionally dependent due to variations in the upper ocean structure.

#### 4. REFERENCES

- DeMaria, M. and J. Kaplan, 1994: Sea surface temperature and the maximum intensity of Atlantic tropical cyclones. *J. of Climate*, **7**, 1224-1334.
- Emanuel, K. A., 1999: Thermodynamic control of hurricane intensity. *Nature*, **401**, 665-669.
- Monaldo, F. M and T. D. Sikora, 1997: Satellite imagery of sea surface temperature cooling in the wake of hurricane Edouard (1996). *Mon. Wea. Rev.*, **125**, 2716-2721.
- Nelson, N. B., 1998: Spatial and temporal extent of sea surface temperature modifications by hurricanes in the Sargasso Sea during the 1995 season. *Mon. Wea. Rev.*, **126**, 1364-1368.
- Reynolds, R. W. and T. M. Smith, 1994: Improved global sea surface temperature analyses using optimum interpolation. *J. Climate*, **7**, 929-948.
- Wentz, F. J., C. L. Gentemann, D. K. Smith, and D. B. Chelton: Satellite measurements of sea-surface

М.С. Пермяков, 2007, автореферат дисс. д.ф.-  
М.Н.

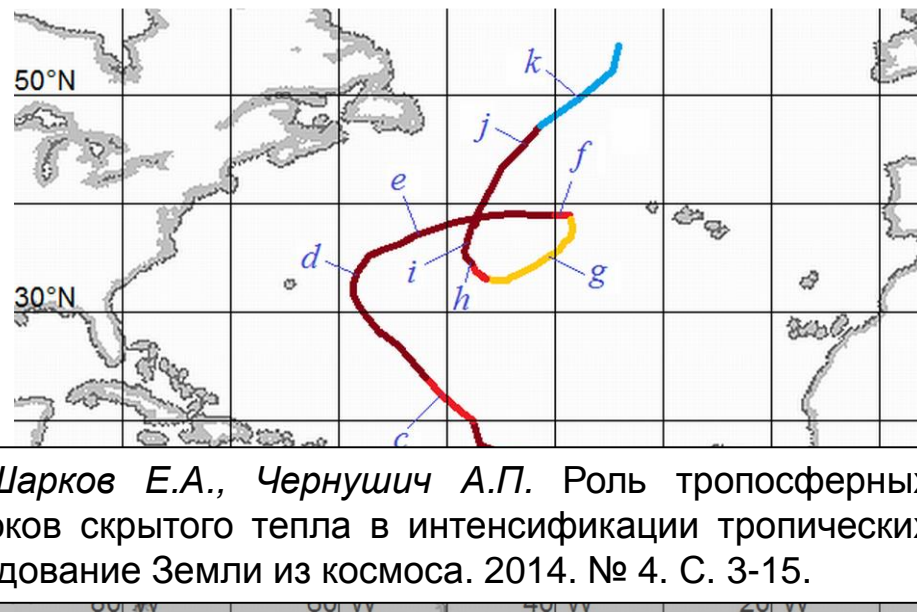
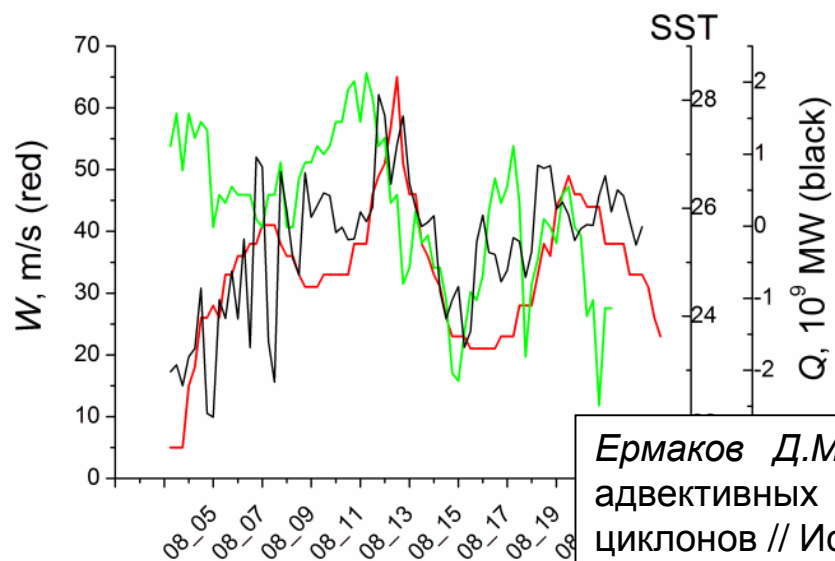
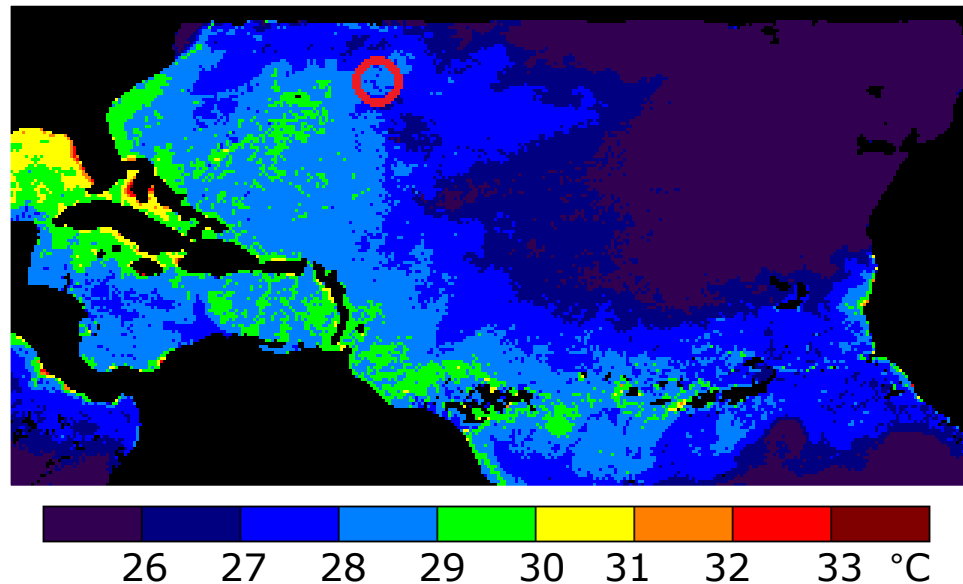
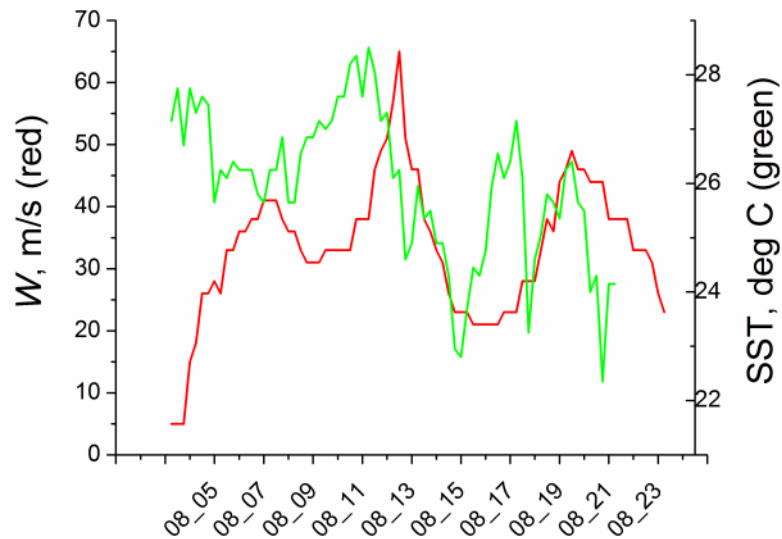
«По судовым гидрологическим данным показано, что «след» тайфуна в океане может быть теплым. На масштабах полигонов при прохождении тайфунов теплообмен возрастает не более чем в два раза, но потоки энергии ветра на поверхности могут превышать более чем на порядок их фоновые значения. Изменения теплосодержания и потенциальной энергии, соизмеримые с полной теплоотдачей и энергией ветра на поверхности за время воздействия тайфуна, прослеживаются только в верхнем перемешанном слое»

Э. Пальмен, Ч. Ньютон, 1973.

Циркуляционные системы атмосферы

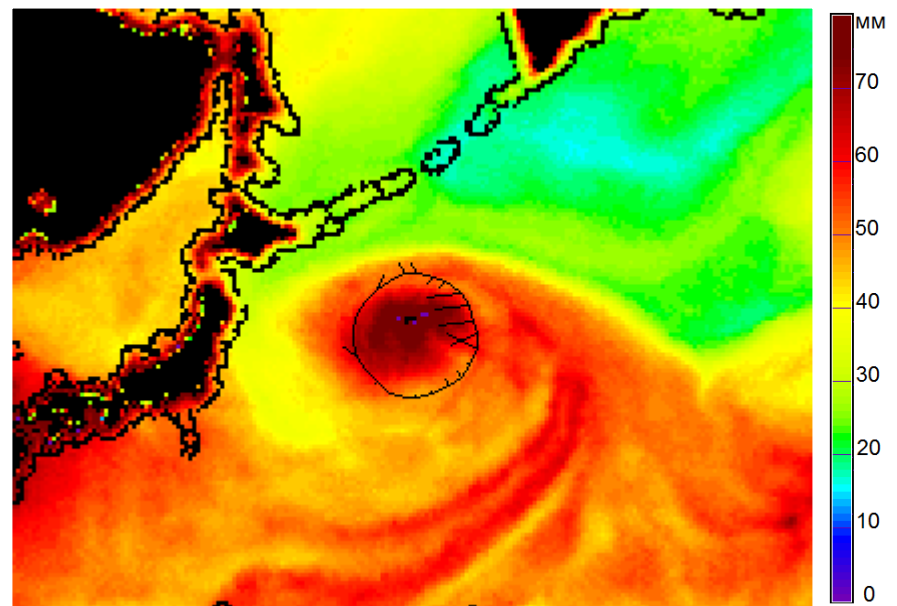
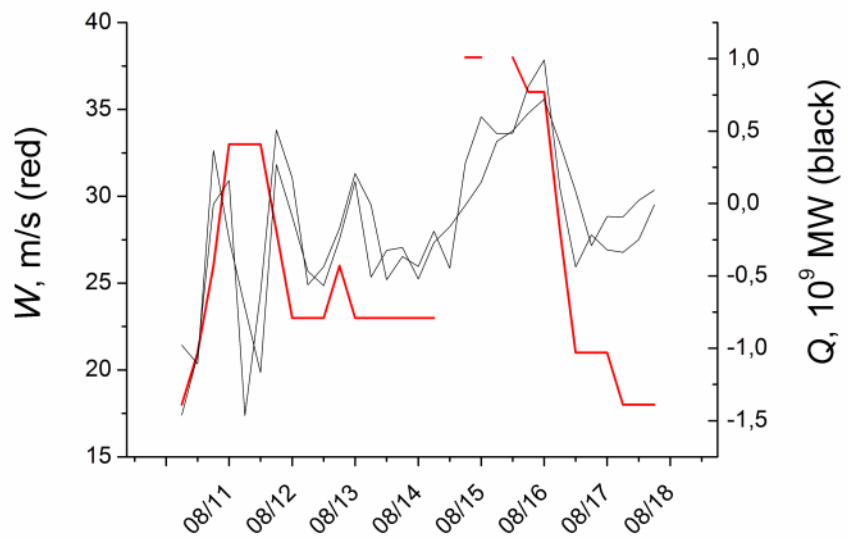
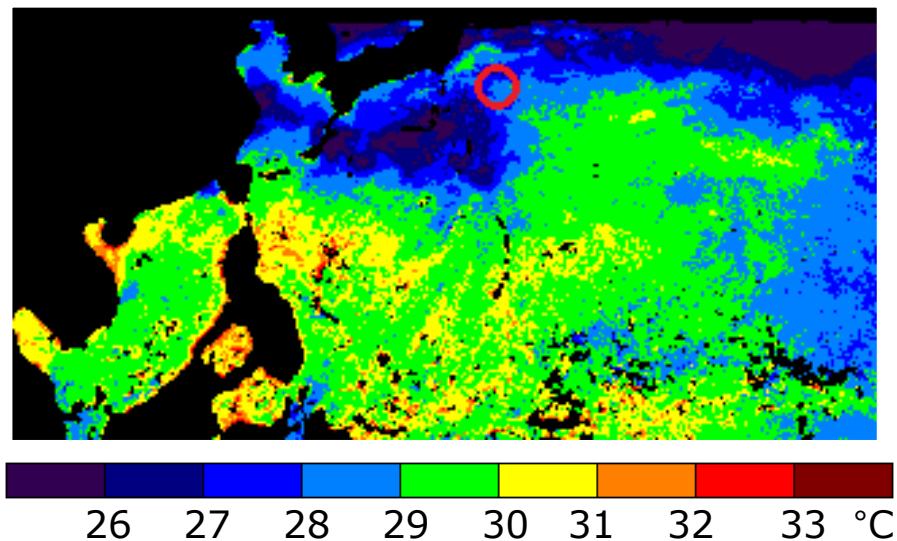
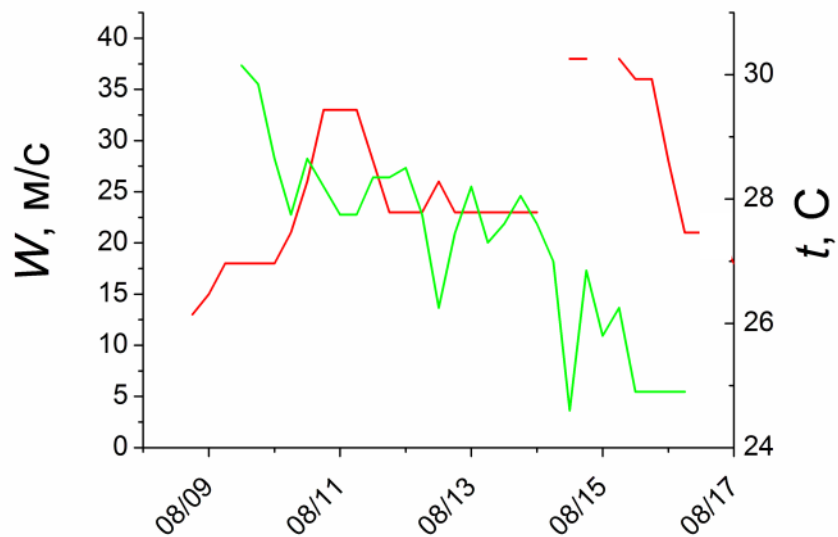
«...важнейшим источником полной энергии является боковой приток водяного пара во влажном приземном слое, но <...> дополнительный приток скрытого и ощутимого тепла от морской поверхности в области ядра также представляет источник тепла, которым пренебрегать нельзя»

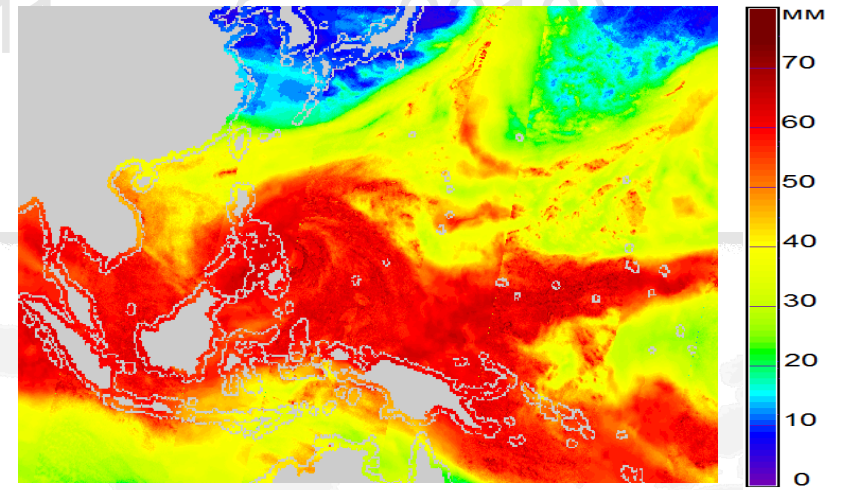
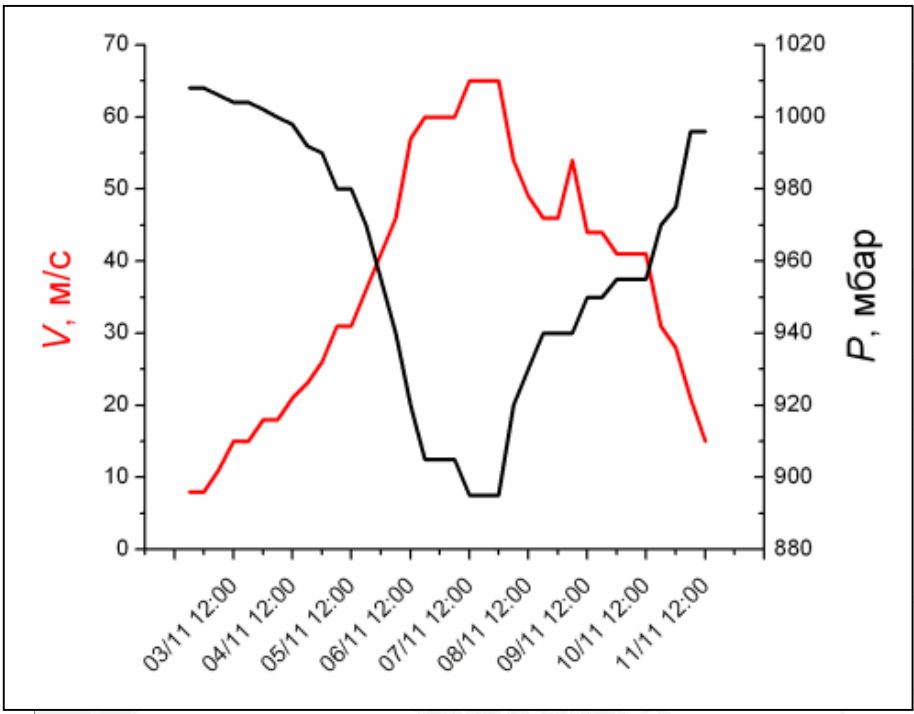
# Эволюция ТЦ Alberto: радиотепловидение



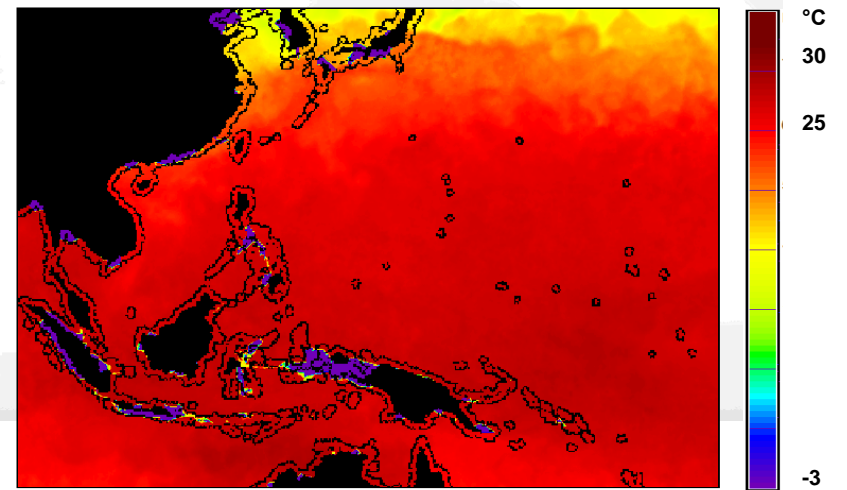
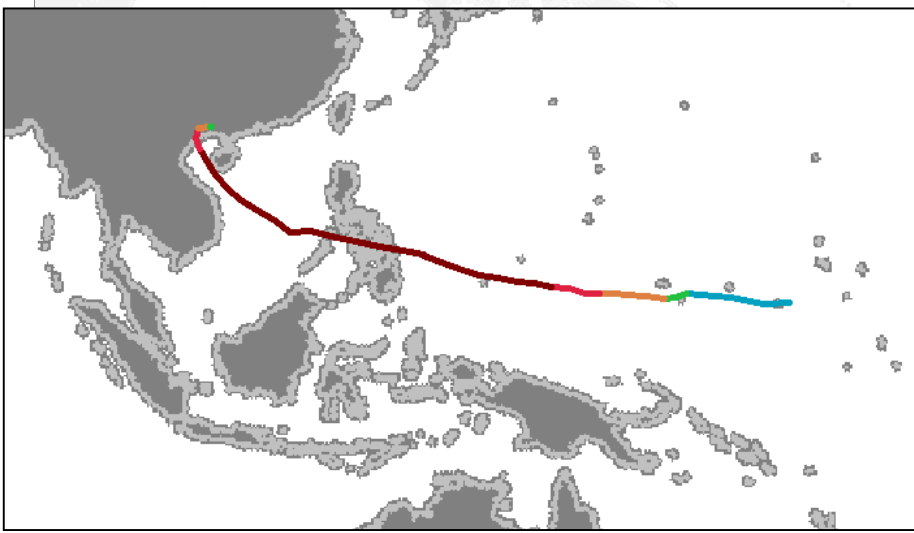
Ермаков Д.М., Шарков Е.А., Чернушич А.П. Роль тропосферных адвективных потоков скрытого тепла в интенсификации тропических циклонов // Исследование Земли из космоса. 2014. № 4. С. 3-15.

# Эволюция ТЦ Ewiniar: радиотепловидение





TPW: AMSR-2 (JAXA) + SSMIS (RSS)



SST: (по композитам RSS)



## 'Category-6' Supertyphoon Haiyan in

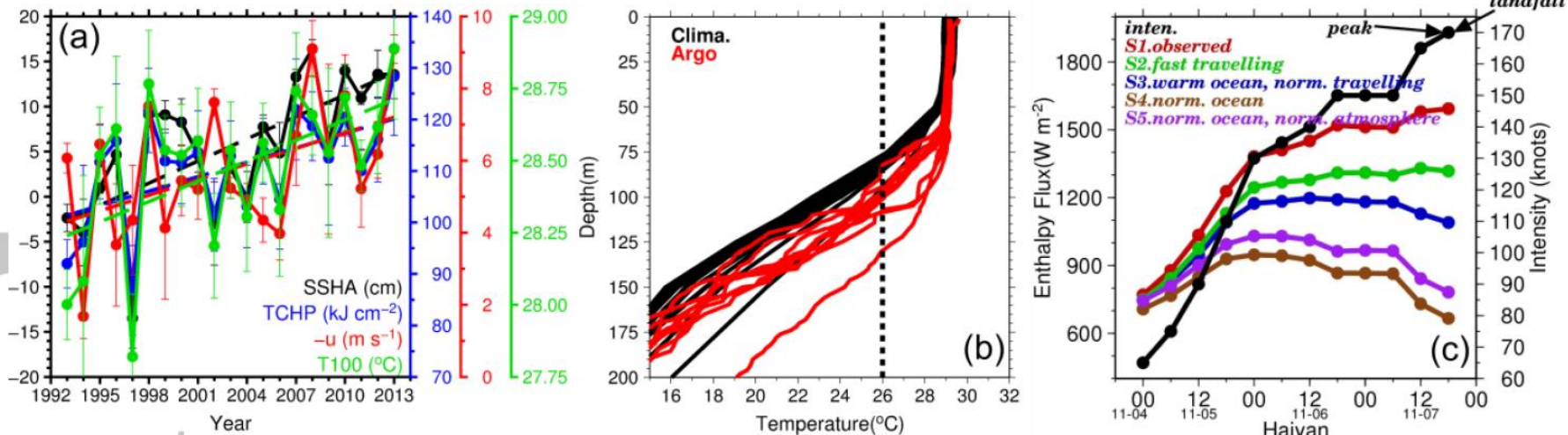
### Global Warming Hiatus: Contribution from Subsurface Ocean

#### Warming

I.-I. Lin\*, Iam-Fei Pun, and Chun-Chi Lien

*Department of Atmospheric Sciences, National Taiwan University, Taipei, Taiwan.*

With the extra-ordinary intensity of 170 kts, super-typhoon Haiyan devastated the Philippines in November 2013. This intensity is among the highest ever observed for tropical cyclones (TCs) globally, 35 kts well above the threshold of the existing highest category of 5. Though there is speculation to associate global warming with such intensity, existing research indicate that we have been in a warming *hiatus* period, with the *hiatus* attributed to the La Niña-like multi-decadal phenomenon. It is thus intriguing to understand why Haiyan can occur during *hiatus*. It is suggested that as the western Pacific manifestation of the La Niña-like phenomenon is to pile up warm subsurface water to the west, the western North Pacific experienced evident subsurface warming and created a very favorable ocean pre-condition for Haiyan. Together with its fast travelling speed, the air-sea flux supply was 158% as compared to normal for intensification.



<b>Genesis position</b>	177°E 7°N	178.6°E 3.8°N	145°E 12.7°N	164.2°E 5.6°N
<b>Distance from genesis to peak [km]</b>	5446	3452	2425	4202
<b>Avg. flux (genesis to Peak) [Wm<sup>-2</sup>]</b>	436	556	956	1025
<b>Distance-integrated Flux [Wm<sup>-2</sup> × km]</b>	2,373,964	1,918,134	2,318,047	4,307,407

1,6 KBT / M<sup>2</sup>



# Hurricane Research Division

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## Frequently Asked Questions

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### Subject: D7) How much energy does a hurricane release?

*Contributed by Chris Landsea (NHC)*

Hurricanes can be thought of, to a first approximation, as a heat engine; obtaining its heat input from the warm, humid air over the tropical ocean, and releasing this heat through the condensation of water vapor into water droplets in deep thunderstorms of the eyewall and rainbands, then giving off a cold exhaust in the upper levels of the troposphere (~12 km/8 mi up).

One can look at the energetics of a hurricane in two ways:

1. the total amount of energy released by the condensation of water droplets or ...
2. the amount of kinetic energy generated to maintain the strong swirling winds of the hurricane ([Emanuel 1999](#)).

It turns out that the vast majority of the heat released in the condensation process is used to cause rising motions in the thunderstorms and only a small portion drives the storm's horizontal winds.

#### • **Method 1) - Total energy released through cloud/rain formation:**

An average hurricane produces 1.5 cm/day (0.6 inches/day) of rain inside a circle of radius 665 km (360 n.mi) (Gray 1981). (More rain falls in the inner portion of hurricane around the eyewall, less in the outer rainbands.) Converting this to a volume of rain gives  $2.1 \times 10^{16}$  cm<sup>3</sup>/day. A cubic cm of rain weighs 1 gm. Using the latent heat of condensation, this amount of rain produced gives

$$5.2 \times 10^{19} \text{ Joules/day or}$$

$$6.0 \times 10^{14} \text{ Watts.}$$

This is equivalent to 200 times the world-wide electrical generating capacity - an incredible amount of energy produced!

#### TC FAQ

- [Basic Definitions](#)
- [Cyclone Names](#)
- [Cyclone Myths](#)
- [Cyclone Winds](#)
- [Cyclone Records](#)
- [Cyclone Forecasting](#)
- [Cyclone Climatology](#)
- [Cyclone Observation](#)
- [Real Time Info](#)
- [Historical Info](#)
- [Cyclone Prep](#)
- [Hurr. vs Tornado](#)

#### Links of Interest

- [Hurricane Field Program](#)
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## The power of a hurricane: An example of reckless driving on the information superhighway

Kerry A. Emanuel

Massachusetts Institute of Technology

One of the more problematic tasks of the research scientist is to convey to the public in an accurate but stimulating way the power and beauty of natural phenomena. The World Wide Web provides a new means to do this, and increasingly is used as a resource for scientific information by everyone from school children to professional scientists. How accurate is the information that is available on the Web? Is most of the information traceable to its source? As a very small experiment designed to address these issues, the author asked students in his tropical meteorology class to investigate how the power of a hurricane is being conveyed to the public via the Web. This article describes the surprising result.

### Of bombs and storms

A quick search turned up nine sites that refer to the power or energy of a hurricane. Of these, five state that a single hurricane over the course of one day releases an amount of energy equivalent to 400 20-megaton bombs. (A sixth states that this amount of energy is released in one *minute*. Presumably, this is a misquotation of another source.) As one megaton is equivalent to  $4.2 \times 10^{15}$  joules, the quoted power amounts to about  $4 \times 10^{14}$  watts. Only one of these five sites quotes a source – a popular book on hurricanes (Lee 1993). The sites range from the Web page of a high-school science teacher to the home page of a former director of the US National Hurricane Center. Two further sites, one from a small college and the other from an advanced placement high-school physics course, quote a power output of  $2 \times 10^{13}$  watts, but do not give sources. A final site states that the energy content of a hurricane is about  $10^{15}$  joules, but does not define what that pertains to.

### A simple estimate

In a popular textbook, Anthes *et al.* (1978) estimate that the latent-heat release in an average hurricane amounts to  $10^{14}$  watts. This is not perhaps a meaningful quantity, however, since most of the latent heat is used to raise the potential energy of air. (For example, the flow of moist, stable air over a mountain actually requires work to be done on the air, but large quantities of latent heat are released.) A more meaningful quantity is the rate of generation of kinetic energy, which in a steady hurricane also equals the rate of dissipation of kinetic energy. Bister and Emanuel (1998) showed that in a hurricane dissipation occurs mostly in the atmospheric surface layer, and that the corresponding dissipation rate per unit area,  $D$ , is given by:

$$D = \rho C_D V^3,$$

where  $\rho$  is the air density,  $V$  is a characteristic wind speed at low levels and  $C_D$  is the surface drag coefficient. Thus, integrated over the surface area covered by a circularly symmetric hurricane, the total power dissipated by the storm,  $P$ , is:

$$P = 2\pi \int_0^{r_0} \rho C_D V^3 r dr, \quad (1)$$

where  $r$  is the radius and  $r_0$  is some characteristic outer radius encompassing the storm. To evaluate Eq. (1) I shall assume that the velocity varies linearly with radius inside the radius of maximum winds,  $r_m$ , and that it has a profile outside of  $r_m$  similar to those used by Holland (1980) and Emanuel (1986). I also take the average sea-level air density to be  $1 \text{ kg m}^{-3}$  and use a drag coefficient of  $2 \times 10^{-3}$ . With these values, an average Atlantic hurricane with maximum winds of  $50 \text{ m s}^{-1}$  and a radius of maximum winds of  $30 \text{ km}$  dissipates  $3 \times 10^{12}$  watts. At the extreme end, a Pacific super-typhoon with a maximum wind speed of  $80 \text{ m s}^{-1}$  and a radius of maximum winds of  $50 \text{ km}$  dissipates  $3 \times 10^{13}$  watts. Thus the values quoted by most of the World Wide Web sites are too high by one to two orders of magnitude. Values quoted by two educational institutions

were consistent with power dissipated in large Pacific supertyphoons.

### Summary

While the World Wide Web can serve as a valuable source of information, it is clearly susceptible to the rapid propagation of misinformation, as demonstrated by this very small example. Problems of the kind illustrated here would be mitigated by careful referencing to source material, as is standard practice in printed publications. While a realistic estimate of power dissipation in an average hurricane is two orders of magnitude less than most values found on the Web, it is still an impressive quantity, equivalent to the world-wide electrical generation capacity as of 1 January 1996, as reported by the US Department of Energy.

### References

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- Bister, M. and Emanuel, K. A. (1998) Dissipative heating and hurricane intensity. *Meteorol. Atmos. Phys.*, **65**, pp. 233–240.
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- Lee, S. (1993) *Hurricanes*. Franklin Watts, New York, 63 pp.

Correspondence to: Prof. Kerry A. Emanuel, Program in Atmospheres, Oceans and Climate, Massachusetts Institute of Technology, Cambridge, MA 02139 USA.

# Пальмен, Ньютон. Циркуляционные системы атмосферы

## 15. Тропические циклоны, тайфуны, ураганы

### 15.6. Приходо-расход энергии

«Внутри круга радиусом  $1^\circ$  широты суммарная генерация энергии составляла до  $0,52 \cdot 10^{10}$  кДж/с. <...> Источник тепла для этой части равен  $36,5 \cdot 10^{10}$  кДж/с; следовательно, <...> лишь около 1,4% указанного количества преобразовывалась в механическую энергию»

«...для «среднего урагана» <...> генерация кинетической энергии в области радиусом  $6^\circ$  широты составляет  $1,5 \cdot 10^{10}$  кДж/с. <...> Приведение данных ... к соответствующим единицам дает величину источника тепла для всего циклона около  $63 \cdot 10^{10}$  кДж/с»

	УУ, $2^\circ$	Дези, $1^\circ$	Элен, $1^\circ$
Приток скрытого тепла (адвекция)	0,55 ПВт	0,37 ПВт	0,37 ПВт
Дополнительный источник тепла (от моря)	0,01 ПВт	0,03 ПВт	0,06 ПВт

# Kerry Emanuel, 1998, Weather

Power of a hurricane: an example of reckless driving on the information superhighway

Диссипация кинетической энергии:

$$R = 30 \text{ км}, V = 50 \text{ м/с} \rightarrow 0,003 \text{ ПВт}$$

$$R = 50 \text{ км}, V = 80 \text{ м/с} \rightarrow 0,030 \text{ ПВт}$$

Вертикальный поток полного тепла:

$$R = 100 \text{ км}, V = 85 \text{ м/с} \rightarrow 0,050 \text{ ПВт}$$

$$R = 50 \text{ км}, V = 85 \text{ м/с} \rightarrow 0,013 \text{ ПВт}$$

RESEARCH LETTER

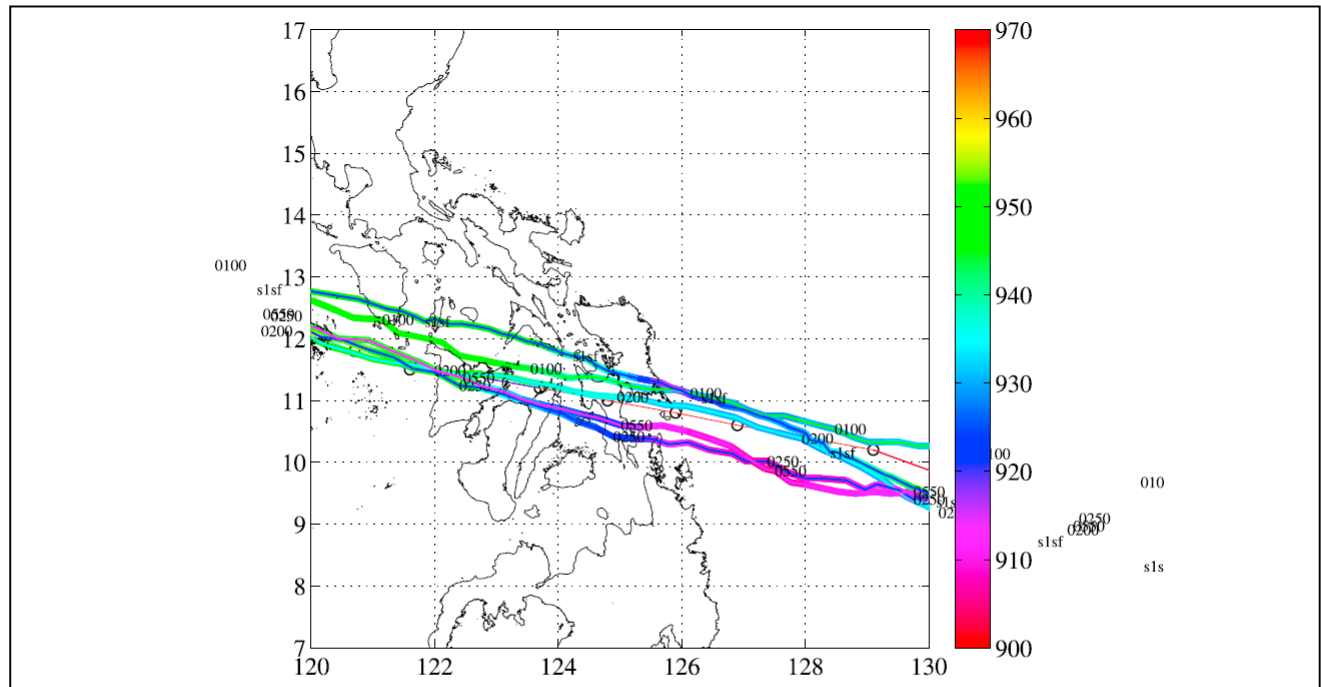
10.1002/2014GL060689

Key Points:

- Hindcast of typhoon Haiyan
- Local amplification of storm surge in the Leyte bay
- Seiche oscillation due to steep bathymetry by Philippines trench

Local amplification of storm surge by Super Typhoon Haiyan in Leyte Gulf

Nobuhito Mori<sup>1</sup>, Masaya Kato<sup>2</sup>, Sooyoul Kim<sup>3</sup>, Hajime Mase<sup>1</sup>, Yoko Shibutani<sup>1</sup>, Tetsuya Takemi<sup>1</sup>, Kazuhisa Tsuboki<sup>2</sup>, and Tomohiro Yasuda<sup>1</sup>

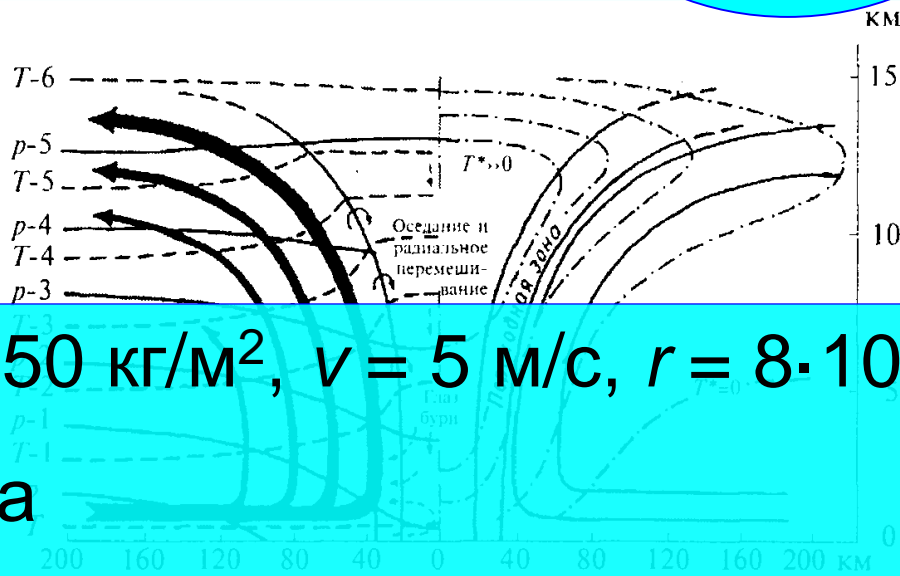


**Figure 1.** Track and minimum central pressure of Typhoon Haiyan (o: satellite data, numbers correspond to Weather Research and Forecasting/Cloud Resolving Storm Simulator (WRF/CReSS) simulations as abbreviated in Table A1). (a) East Visayas and (b) Tacloban and surrounding area with survey data (circles: measured inundation height).

(Figure A4). However, the initial growth of  $U_{10}$ ,  $P_{min}$ , and water surface elevation were qualitatively well simulated by the numerical models. The typhoon radius  $R_{max}$  was 50–100 km, equivalent in size to San Pedro

# Энергетический бюджет ТЦ

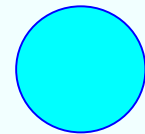
1 ПВт =  
 $10^9$  МВт



$W = 50 \text{ кг/м}^2$ ,  $v = 5 \text{ м/с}$ ,  $r = 8 \cdot 10^5 \text{ м}$ .

Тогда

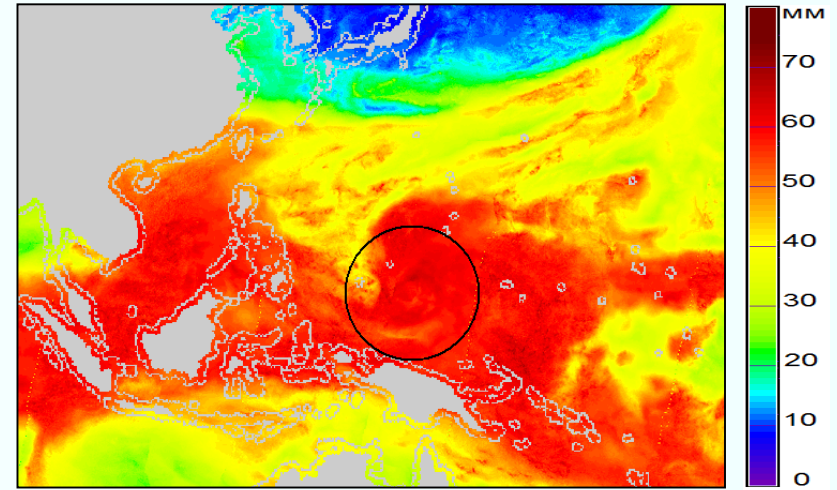
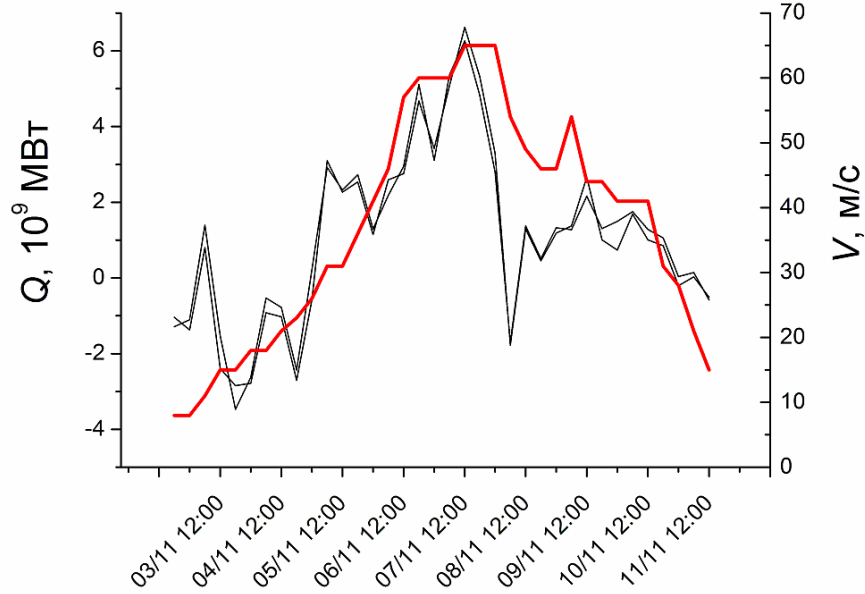
$$Q = q \cdot W \cdot 2\pi \cdot r \cdot v = 2.9 \text{ ПВт}$$



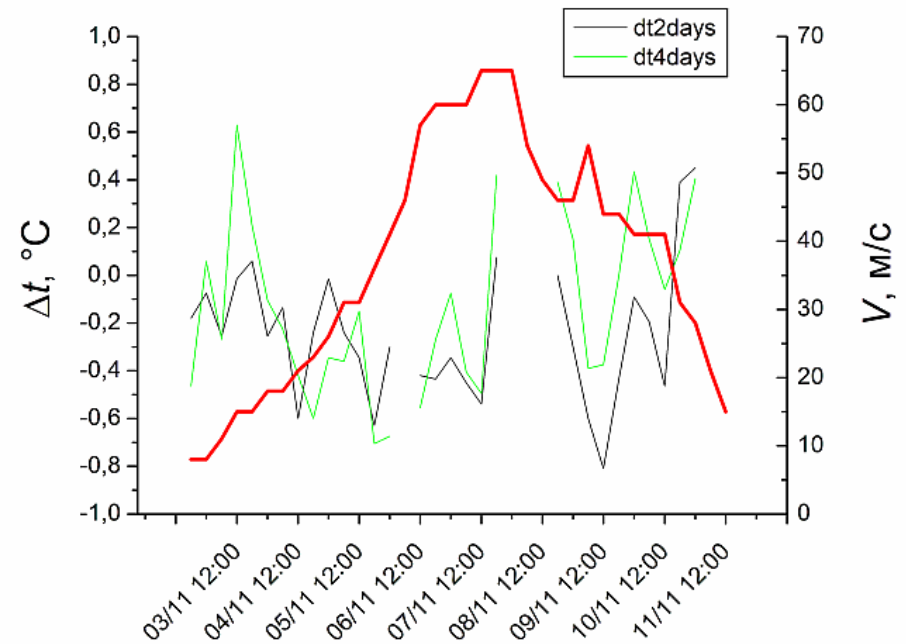
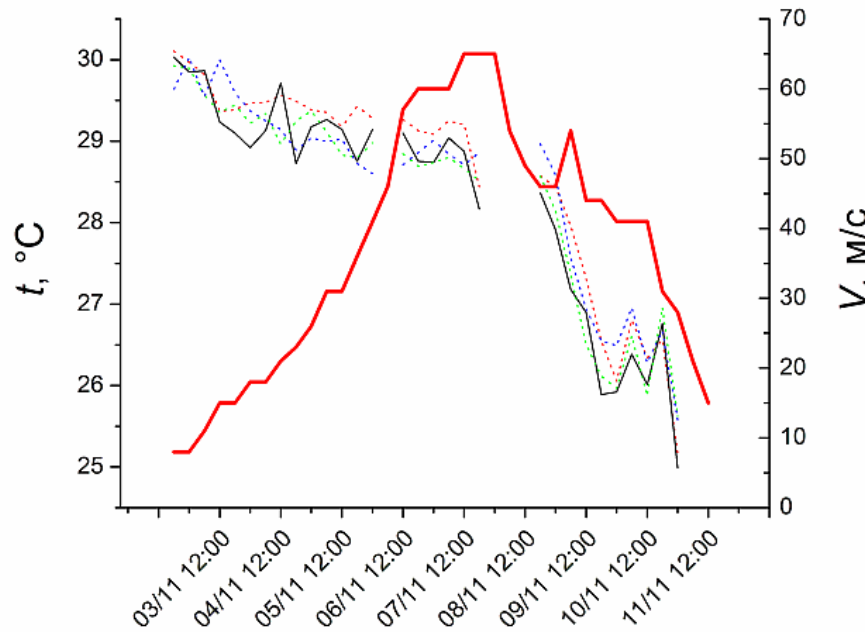
0,05 ПВт



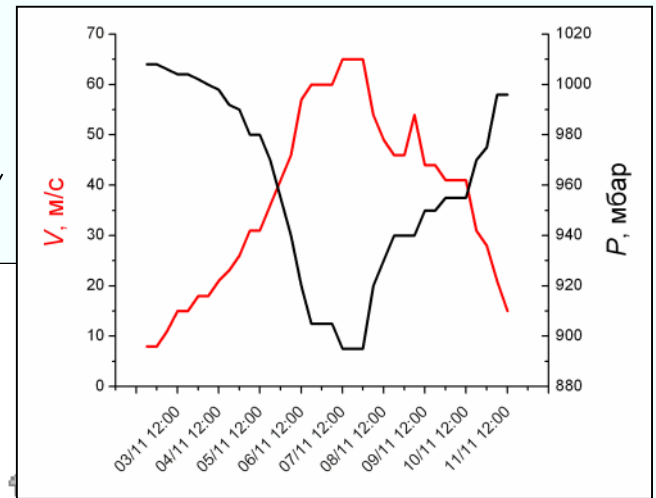
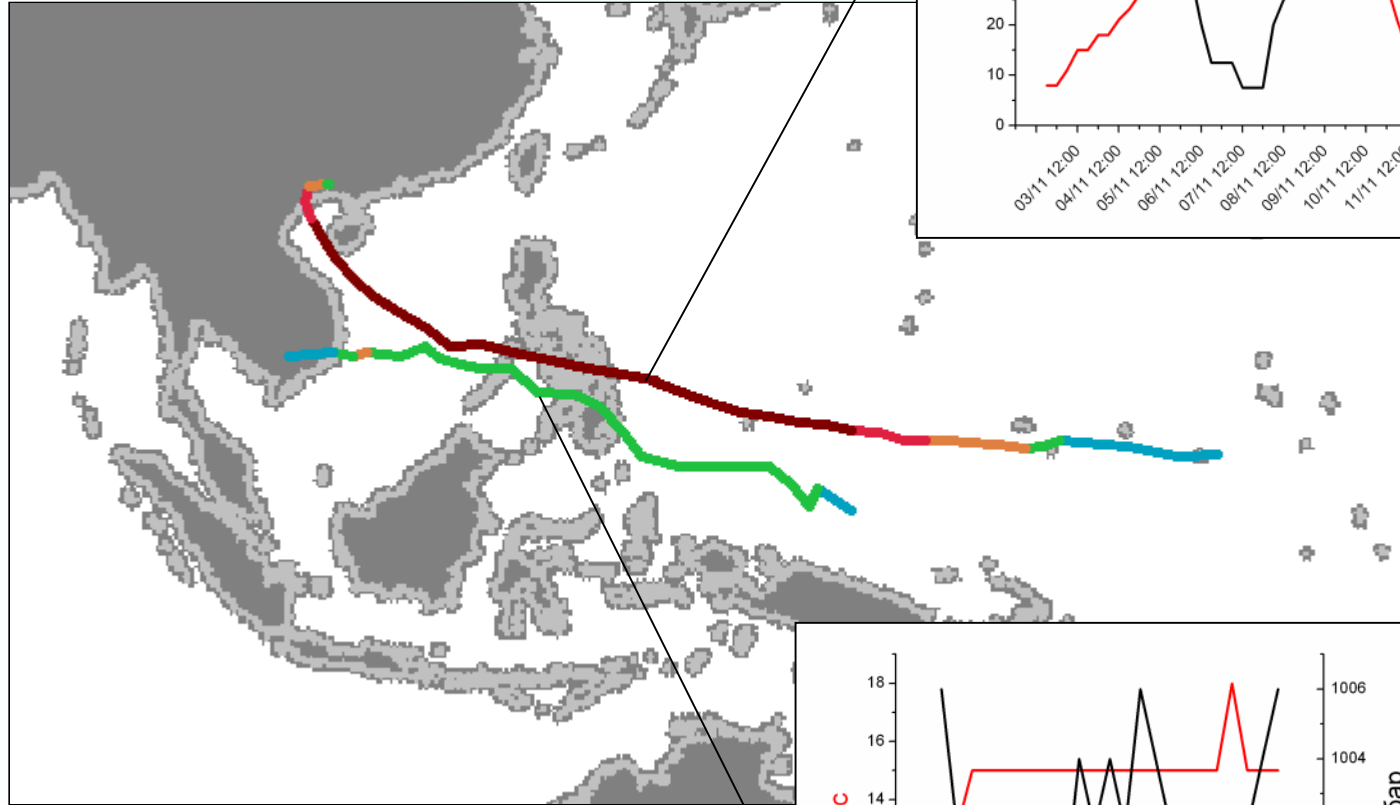
# Найян (NWP) 03 – 11 ноября 2013



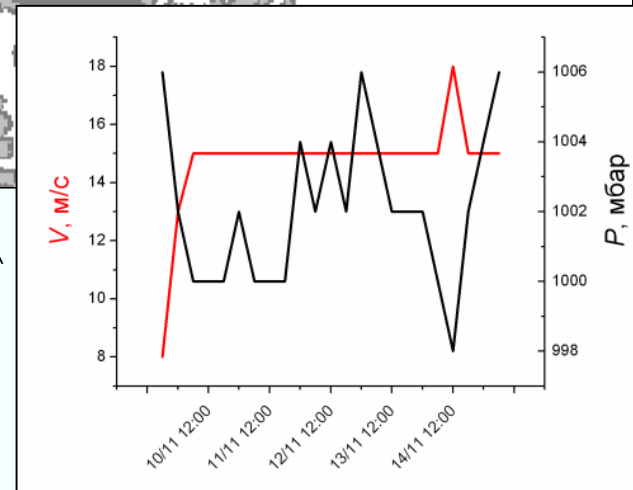
TPW, 05.11.2013



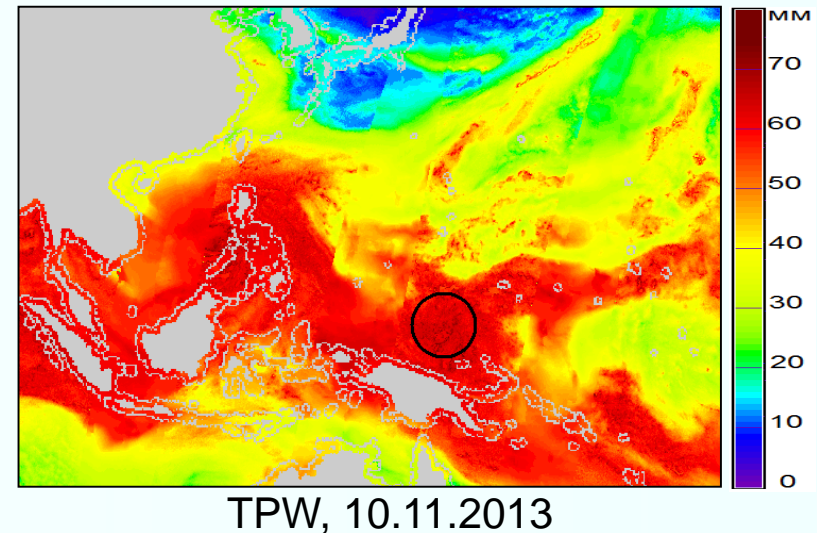
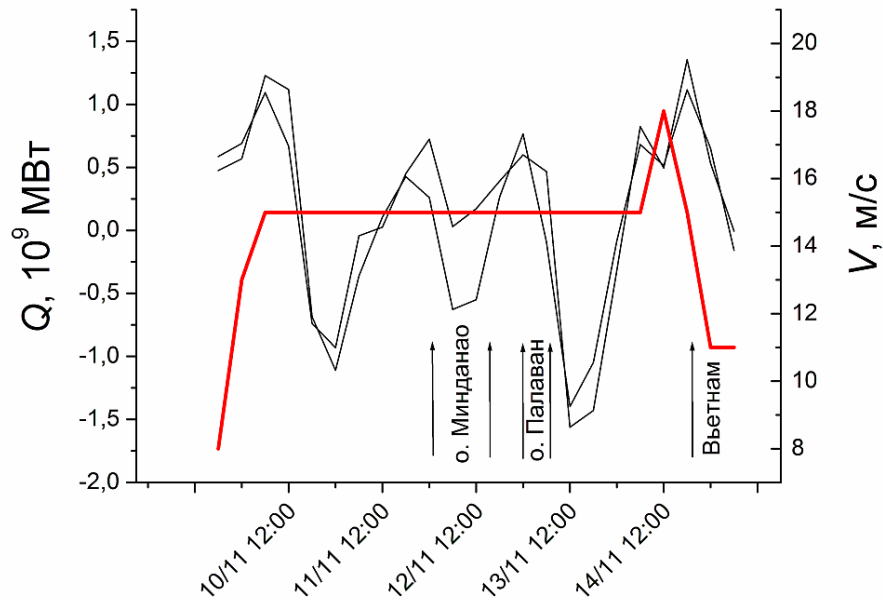
# Haiyan



# Podul

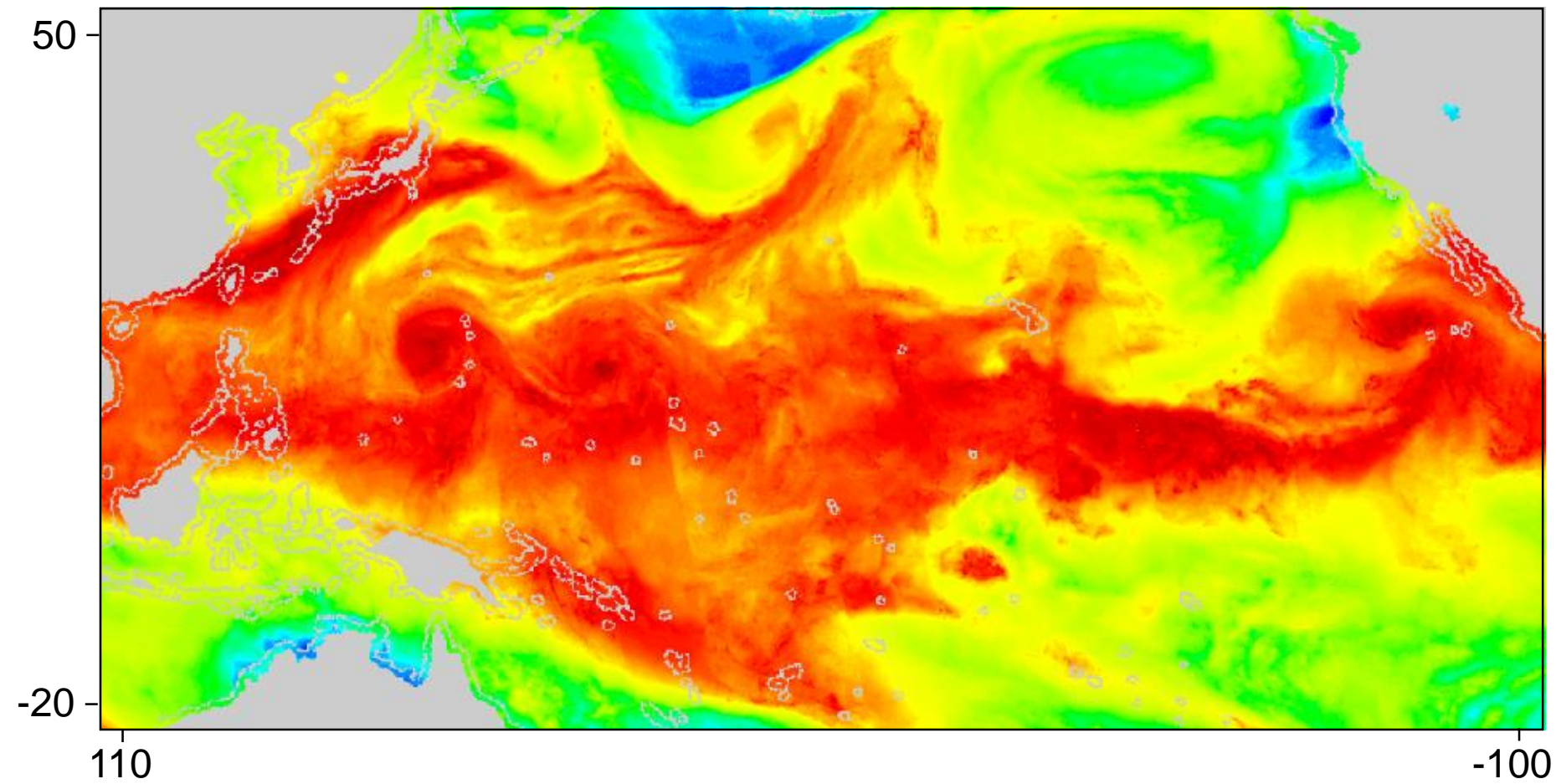


# Podul (NWP) 10 – 15 ноября 2013

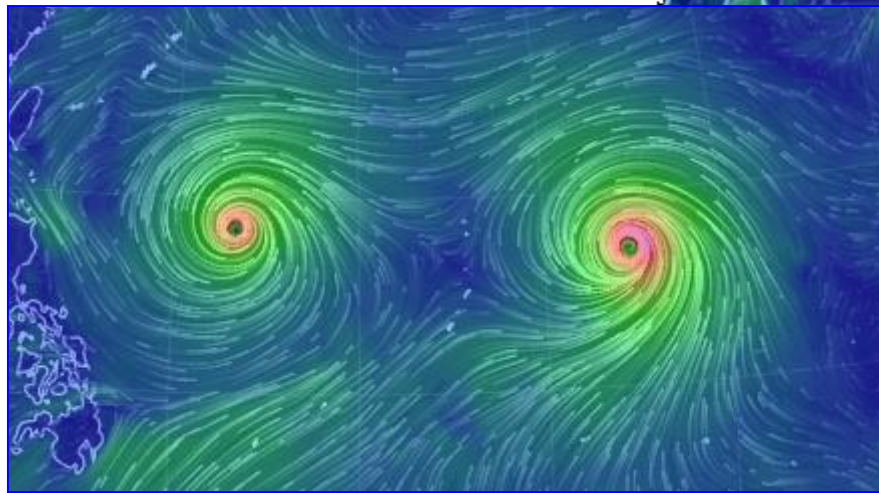
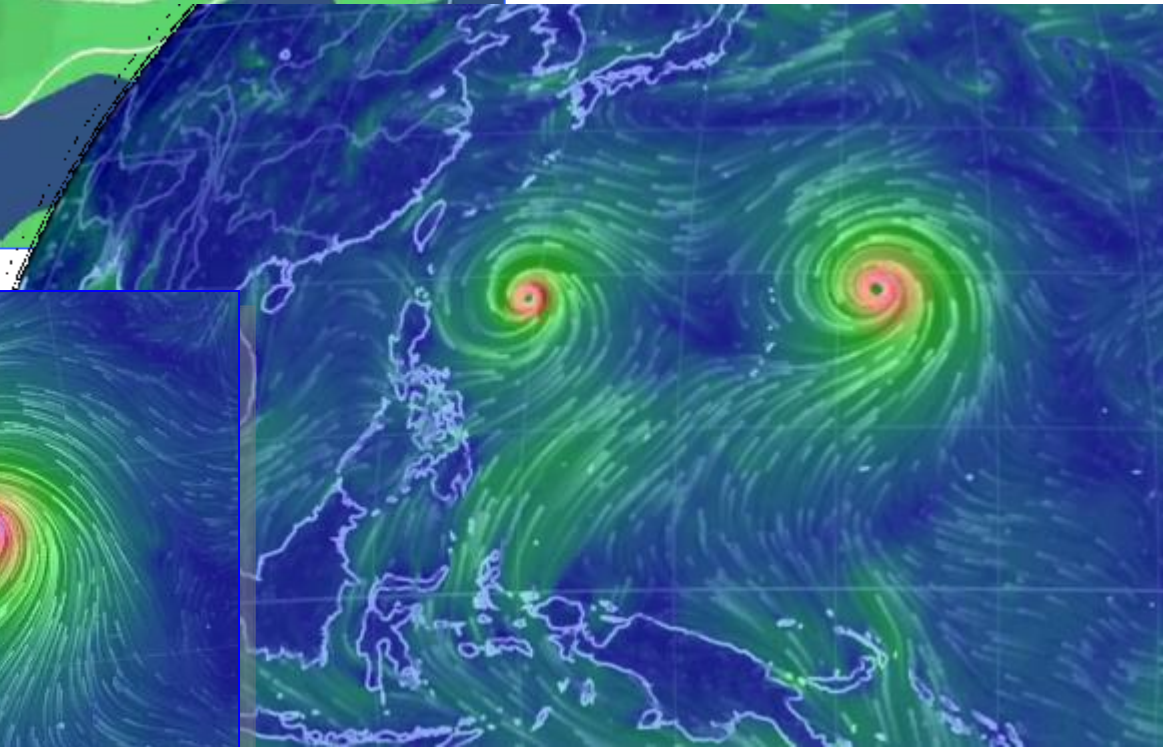
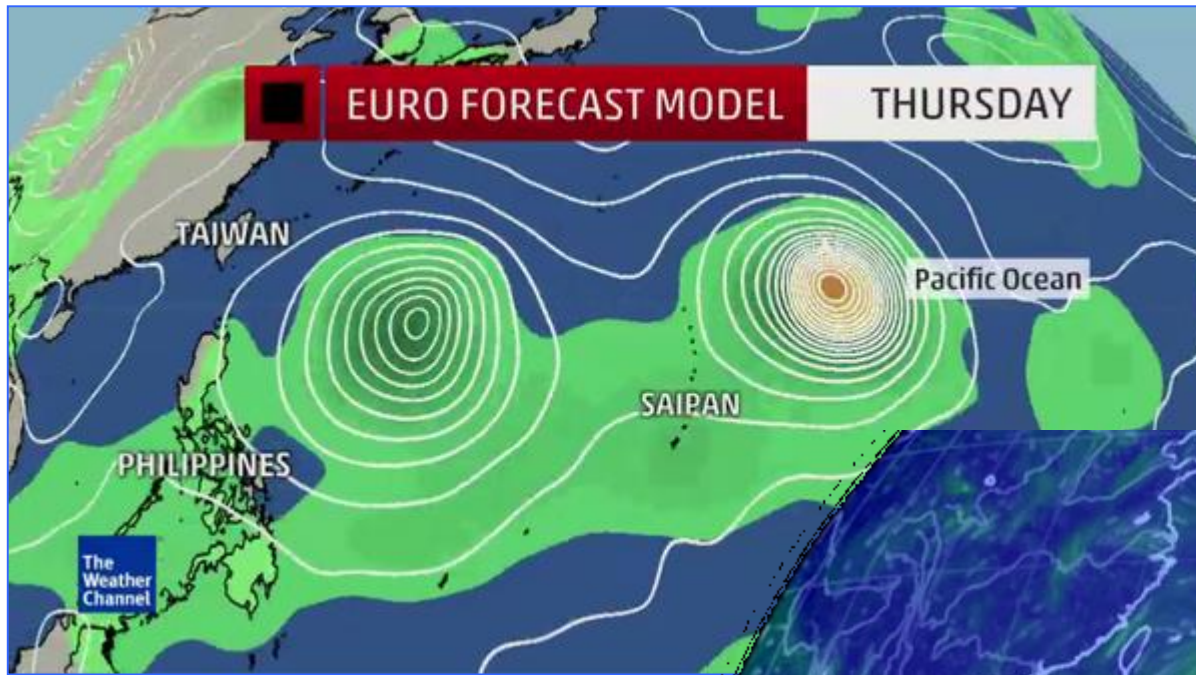


*Ermakov D.M., Sharkov E.A., Chernushich A.P.* Satellite radiothermovision of atmospheric mesoscale processes: case study of tropical cyclones // The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XL-7/W3, 2015 36th International Symposium on Remote Sensing of Environment, 11–15 May 2015, Berlin, Germany, pp. 179 – 186, doi:10.5194/isprsarchives-XL-7-W3-179-2015.

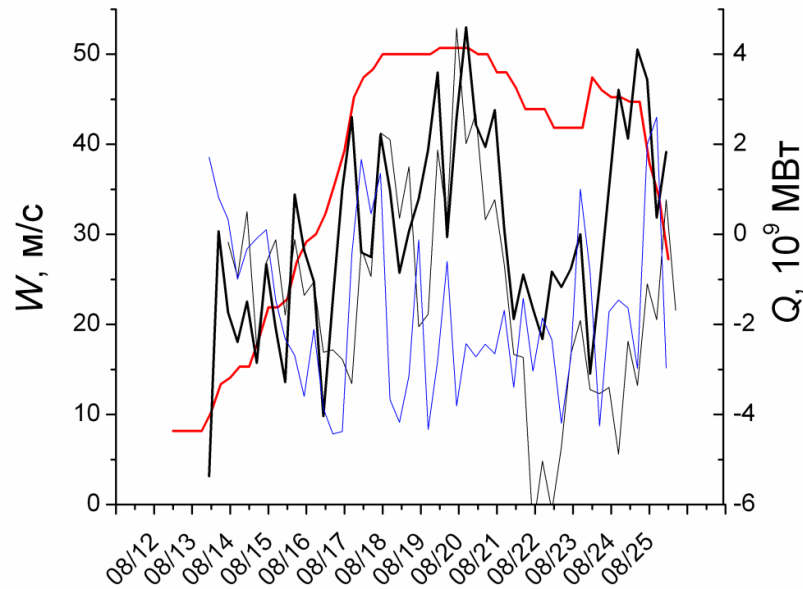
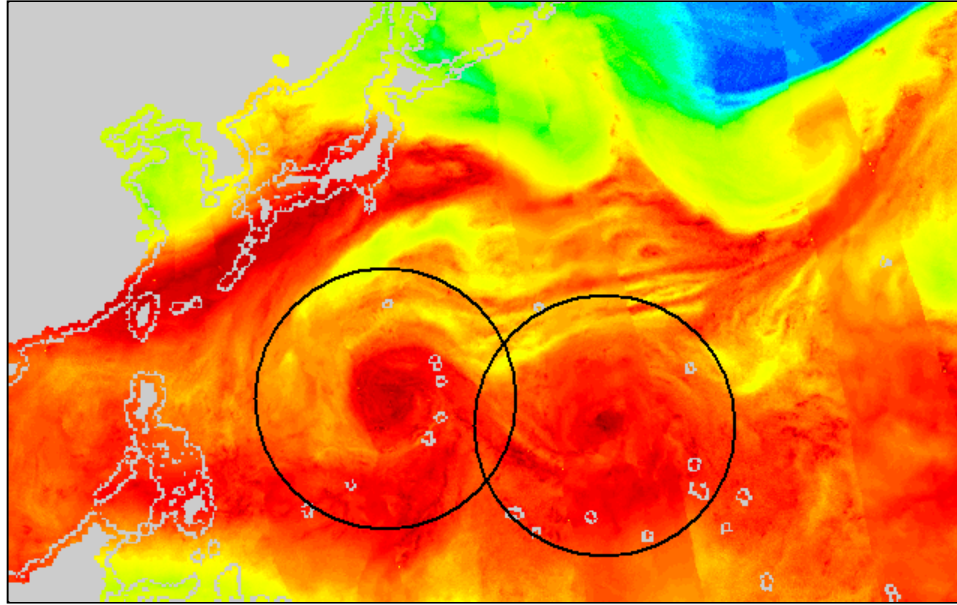
# Совмещение SSMIS и AMSR-2



# Goni + Atsani: система взаимодействующих ТЦ



# Goni + Atsani, потоки, общая граница



# От мезомасштабных к синоптическим процессам

SSMIS F16	01	02	03	04	05	06	07	08	09	10	11	12
2003										v7	v7	v7
2004	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7
2005	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7
2006	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7
2007	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7
2008	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7
2009	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7
2010	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7
2011	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7
2012	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7
2013	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7
2014	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7
2015	v7	v7	v7	v7	v7	v7	v7					

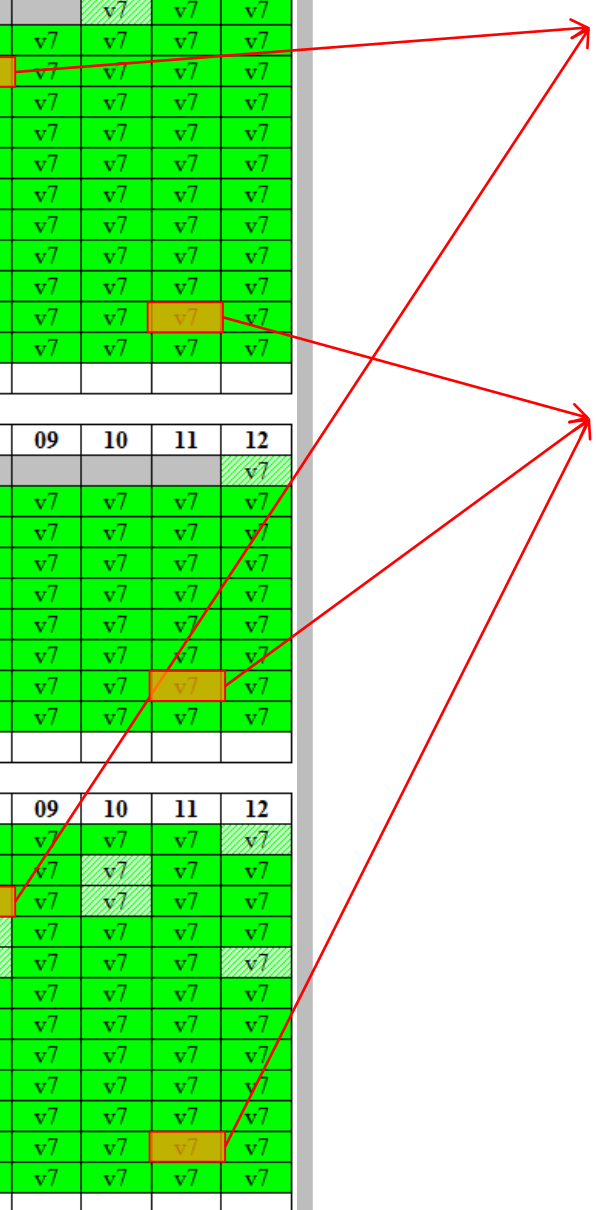
SSMIS F17	01	02	03	04	05	06	07	08	09	10	11	12
2006												v7
2007	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7
2008	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7
2009	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7
2010	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7
2011	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7
2012	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7
2013	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7
2014	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7
2015	v7	v7	v7	v7	v7	v7	v7					

WindSat	01	02	03	04	05	06	07	08	09	10	11	12
2003		v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7
2004	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7
2005	v7	v7				v7	v7	v7	v7	v7	v7	v7
2006	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7
2007	v7	v7	v7	v7	v7	v7		v7	v7	v7	v7	v7
2008	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7
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2010	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7
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2013	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7	v7
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2015	v7	v7	v7	v7	v7	v7						

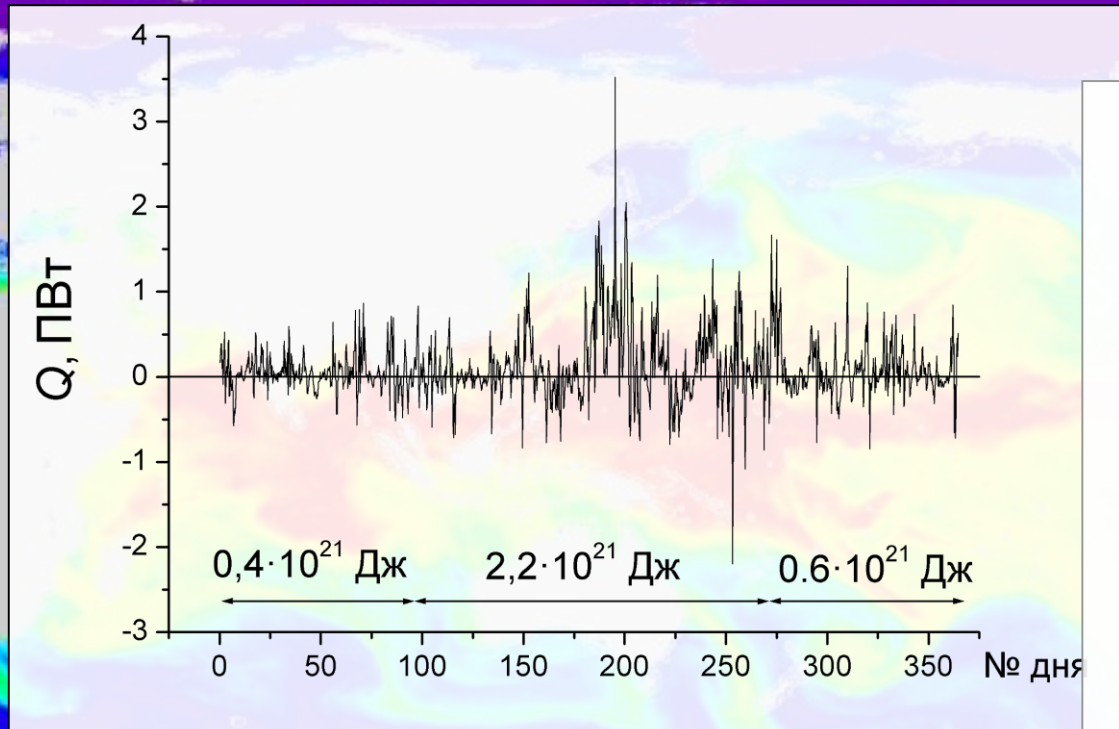
ТЦ Katrina

ТЦ Haiyan

ТЦ Podul



# Меридиональный поток скрытого тепла



12

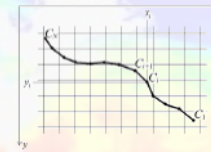


Рис. 1. Аппроксимация контура ломаной в системе координат изображения (расчетной сетки)

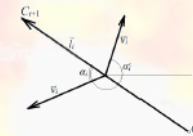


Рис. 2. Схема определения знака потока через элемент контура  $\vec{l}_i$  на широте  $\theta_i$ : «+» для  $\vec{V}_i$ ; «-» для  $\vec{V}_i'$

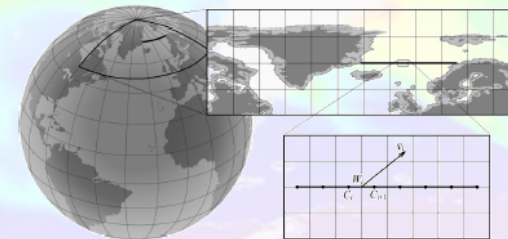
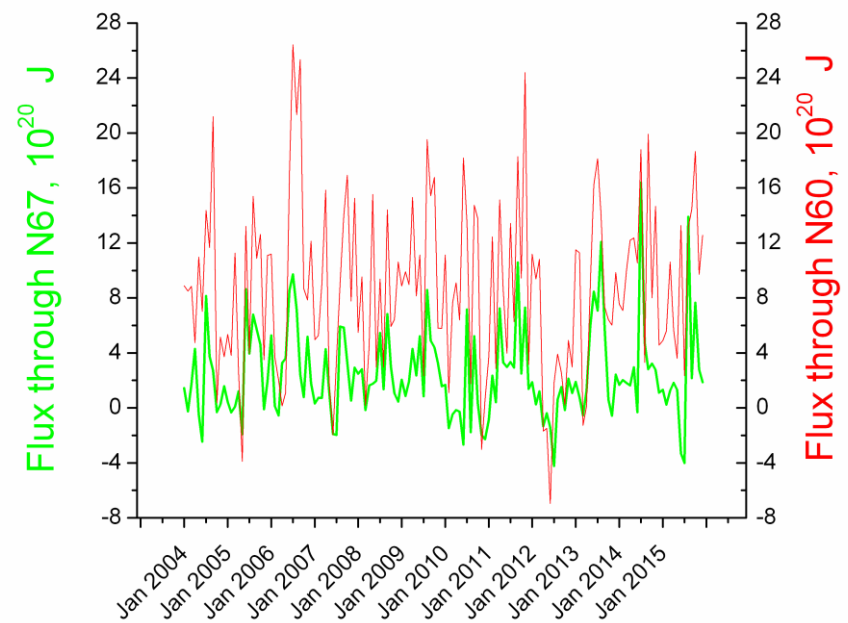
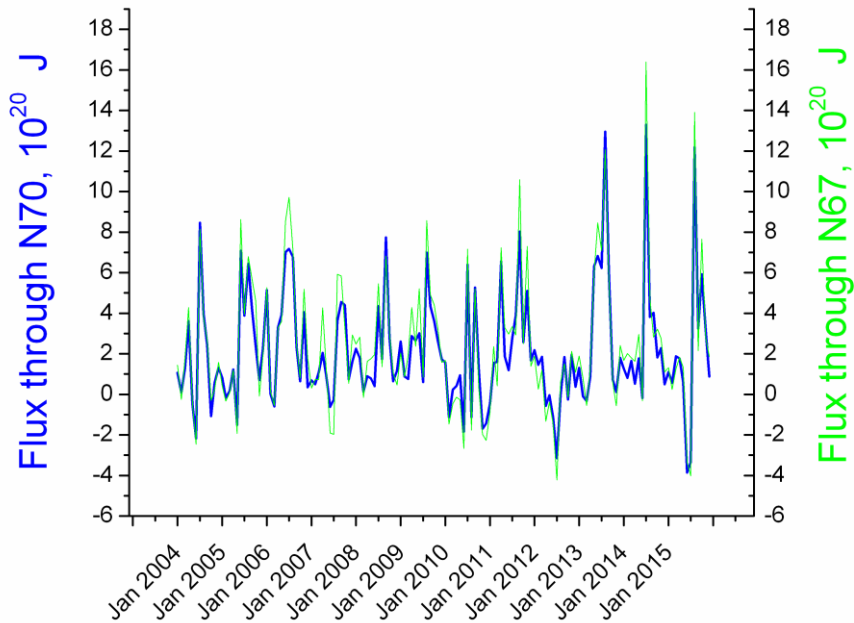
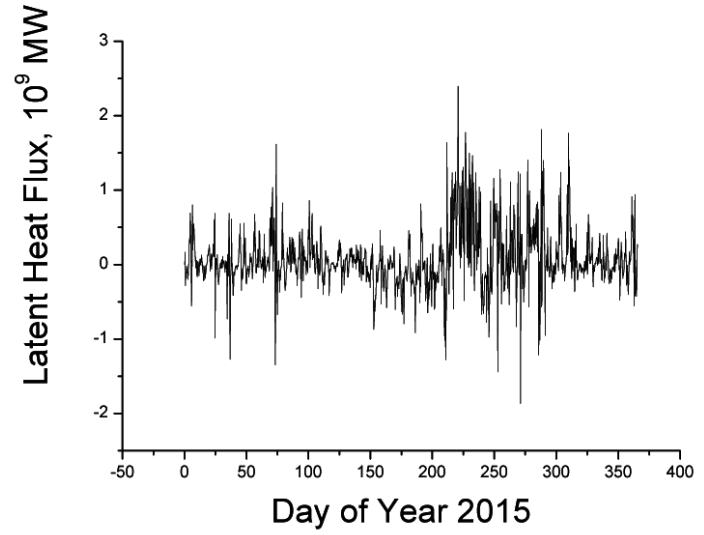


Рис. 3. Выбор контура для расчета меридионального переноса скрытого тепла (см. пояснения в тексте)

Ермаков Д.М., Шарков Е.А., Чернушич А.П. Спутниковое радиотепловидение на синоптических и климатически значимых масштабах // Исслед. Земли из космоса, 2016, №5, С. 3 – 9.



# Погода и климат Арктики



# Геопортал спутникового радиотепловидения

← → ↻ fire.fryazino.net/tpw/Default.aspx

**СПУТНИКОВОЕ РАДИОТЕПЛОВИДЕНИЕ:**  
**ДИНАМИКА ГЕОФИЗИЧЕСКИХ ПОЛЕЙ**

Анимация Поля Методика Публикации Новости Контакты

2015 ▼ Параметер: TPW ▼

**АНИМИРОВАННЫЕ ГЕОФИЗИЧЕСКИЕ ПОЛЯ**  
Динамика поля геофизического параметра атмосферы над акваториями Мирового океана: интегральное влагосодержание атмосферы (TPW) и водозапас облаков (CLW). Шаг по времени – 3 часа. Шаг сетки – 0,25°. Цветовая шкала значений в мм приведена справа.

Качество отображения анимированных полей зависит от пропускной способности сетевого соединения.  
Для получения полей в исходном виде откройте вкладку "Поля"

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# Интерактивный Калькулятор для Атмосферных Расчетов



СПУТНИКОВОЕ РАДИОТЕПЛОВИДЕНИЕ:

ДИНАМИКА ГЕОФИЗИЧЕСКИХ ПОЛЕЙ

ИРИ



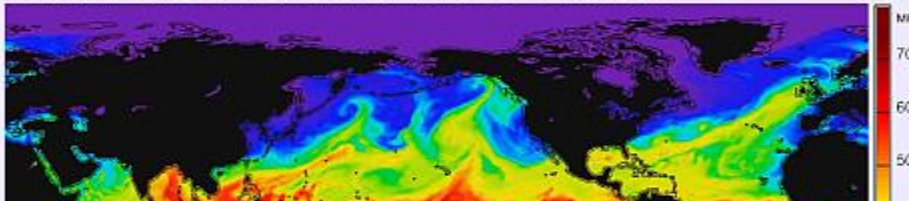
Анимация Поля Методика Публикации Новости Контакты

2015 Параметр: TPW

АНИМИРОВАННЫЕ ГЕОФИЗИЧЕСКИЕ ПОЛЯ

Динамика поля геофизического параметра атмосферы над акваториями Мирового океана: интегральное влагосодержание атмосферы (TPW) и водозапас облаков (CLW).

Шаг по времени – 3 часа. Шаг сетки – 0,25°. Цветовая шкала значений в мм приведена справа.



$$R[x,y=240..480,t]=100*\text{del}(tpw[x,y,t], sst[x,y,t])*sin(\text{latr}(y))$$

$$\text{del}(A,B)=(A-5,07)/0,38 - (B-27)/4$$

$$\text{latr}(y)=(90-0,25*y)*3,14159/180$$

Разработка принципов и программных средств экспресс-анализа быстроразвивающихся процессов в системе атмосфера - подстилающая поверхность Земли на основе виртуальной интеграции распределённых источников данных спутникового мониторинга

Грант РФФИ № 15-07-04422 (2015 – 2017 гг.)

- Простой синтаксис
- Расширяемость
- Виртуальная интеграция
- Распределенные вычисления

# Обновления геопортала

Satellite Radio thermal in X

fire.fryazino.net/tpw/News.aspx

**СПУТНИКОВОЕ РАДИОТЕПЛОВИДЕНИЕ:**  
**ДИНАМИКА ГЕОФИЗИЧЕСКИХ ПОЛЕЙ**

ИРИ

Анимация Поля Икар Методика Публикации Программы **Новости** Контакты

- 19.09.2016 Запущен сервис ИКАР.
- 15.09.2016 Добавлен раздел ИКАР.
- 23.06.2016 Запущен сервис заказа полей скорости приповерхностного ветра.
- 23.06.2016 Добавлены анимированные данные по скорости приповерхностного ветра.
- 07.06.2016 Запущен сервис виртуальной интеграции данных геопортала.
- 13.03.2016 Запущен сервис заказа полей водозапаса облаков.
- 20.02.2016 Добавлены анимированные данные водозапаса облаков.
- 26.01.2016 Исправлена ошибка в описании географической привязки данных.
- 24.01.2016 Добавлены анимированные данные интегрального влагосодержания за 2015 г.
- 23.12.2015 Добавлен раздел «Публикации».
- 30.11.2015 Запущена англоязычная версия портала.
- 25.11.2015 Добавлен раздел «Методика».
- 20.11.2015 Запущен сервис заказа данных.
- 17.11.2015 Запущен портал с анимированными данными интегрального влагосодержания за 2004 – 2014 гг.

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