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Field of the atmospheric water vapor as a characteristic of heat and dynamic processes at the ocean surface observed by the microwave radiometric means from space

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An approach to indication and analysis of heat and dynamic processes at the ocean surface and in the atmosphere with the methods of satellite passive microwave radiometry is considered. It bases on a responsiveness of the oceanic and atmospheric up-going microwave radiation to these processes in the spectral band of its attenuation in the atmosphere water vapor, which seems to be as kind of window of the "radio visibility" from satellites. The effectiveness of that approach is caused by the fact that atmospheric water vapor is an active participant (agent) in its heat interaction with the ocean surface and, at the same time, serves as its reliable quantitative indicator. Measured from satellites natural microwave radiation of the atmospheric water vapor gives distinct signals of changes occurring in the frontal, storm and cyclonic zones in the ocean; they are manifested in the form of pics or jumps of the brightness temperature. The paper provides various examples of the study of such processes as the ocean-atmosphere heat interaction at the middle latitudes of the North Atlantic, origination and propagation of the tropical hurricanes in the Gulf of Mexico and Caribbean Sea, atmospheric water vapor transport in the tropical Atlantic and its influence on cyclogenesis in the Gulf of Mexico, etc. The data of satellite, ship and buoy measurements are widely used to attain and verify results of our study.

Keywords: Microwave radiometry, brightness temperature, satellite observations, heat processes, atmospheric water vapor, tropical hurricanes.

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Introduction

We can observe various processes in the World Ocean which exert influence on the weather conditions and people life activity: there are exist and modify constantly power currents transporting a heat to the continents, the strong hurricanes are originating and propagating, the temperature anomalies and heat fluxes at the water-air boundary are arising regularly.

These phenomena have mainly a heat nature and can be manifested themselves through the natural radiothermal (microwave) radiation observed by special means of remote sensing the Earth from space.

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The main problem of their studying from space is caused by the following reason: an intensity of natural microwave (MCW) radiation of the system ocean-atmosphere (SOA) brings an information not only on near-surface atmospheric layers (which are most active in forming the processes of energy exchanges with the oceanic surface), but also on the more high layers.

In this study, an approach to indication and estimation of intensity of heat processes at the ocean surface and in the atmosphere is describing. It based on a responsiveness of the ocean and atmosphere up-going MCW radiation to these processes in the spectral band of its attenuation in the atmosphere water vapor.

The paper considers several possibilities of using the data of passive MCW radiometric measurements from satellites in this band for localization and analysis of areas with high intensity of the ocean-atmosphere heat interaction (energy active zones), monitoring the areas of the tropical hurricanes origination and development.

Important applications in our research have been found in the data of long-term measurements from the SSM/I (Scanning Sensor Microwave Imager) and SSMIS (Special Sensor Microwave Imager Sounder) radiometers of the DMSP satellites, AMSR-E (Advanced Microwave Scanning Radiometer) radiometer of the EOS Aqua satellite, and AMSR 2 radiometer of the GCOM-W1 satellite, accumulated in the archives NSDIC (National Snow and Ice Data Center), RSS (Remote Sensing Systems company), Hurricane Satellite (HURSAT) microwave dataset, and JAXA (Japan Aerospace Exploration Agency) Data Providing Service.

Archives of global measurement from the Advanced Microwave Imager/Sounder MTVZA-GY of the Meteor-M satellite No. 2-2, which are accumulating recently, also have good potential [*Boldyrev et al.*, 2008; *Cherny et al.*, 2017; *Chernyavsky et al.*, 2018].

From the history of formation of satellite microwave radiometry

Only few people (mainly, radiophysicists) have notion that all natural objects around us are the sources of thermal radiation in the range of millimeter, centimeter and decimeter radiowaves.

At the first sight a possibility to measure this radiation might be appeared amazing. Really, its intensity in this spectral band (where the Rayleigh-Jeens approximation of the Plank function is valid), is decreased visibly with increasing the wavelength.

It is follows from this formula that we deal with a very weak emissivity. For example, when jumping from the wavelength $\lambda = 10$ µm in infrared part of electromagnetic spectrum to the wavelength $\lambda = 10$ cm at microwaves we get a fall of the natural radiation intensity in 1×10^8 times. This state can be improved by taking into account the fact that that the devices detecting and measuring the natural radiation in this range of wavelengths – microwave radiometers, – possess a much more sensitivity then receivers operating at infrareds (IR radiometers). Transparent estimates show that minimal sensed radiation intensity is in 1×10^9 less as compared to IR-radiometers. This advantage fully covers the reducing an emissivity of natural objects at microwaves in comparison with the infrareds.

The thermal radiation at microwaves (MCW radiation) of natural objects brings information about their heat and other properties; this is used for a long time in studying the celestial bodies with by means of radiotelescopes.

Later, the idea of using the highly sensitive receivers to measure the natural Earth microwave radiation from artificial satellites was realized in 1960th. Successful experiments curried out from the satellites Cosmos-243 (1968), Cosmos-384 (1970), Nimbus 5 (1972) became the foundation for developing a new direction in remote sensing of the Earth – the satellite microwave radiometry.

Results of the first experiment carried out from the satellite Cosmos-243 have demonstrated the possibility of using the MCW radiometric methods to retrieve a spatial and temporal variability of the water surface temperature in the World ocean, the water vapor content in the atmosphere from the space [*Armand et al.*, 1977; *Basharinov et al.*, 1971; *Wilheit*, 1978]. The meridional profiles of these parameters have been published by leading oceanographic and meteorological journals and became the visiting card of this satellite.

At present the MCW radiometric methods side by side with IR radiometric and radar methods are widely used in everyday studies of the Earth from space.

Operation of the satellite passive MCW radiometric systems, measuring a natural Earth radiation does not envisage an installation of artificial radiators (emitters) used in radiolocation systems. These means are absolutely harmless for the biological substances; such their property as the obscurity in the air is highly appreciated by military specialists.

The radiowaves are slightly absorbed and scattered by the clouds, and so the satellite MCW radiometric methods of the Earth remote sensing are practically all-weather as compared to the IR radiometric methods.

Diagnosis of heat processes at the ocean surface and in atmosphere

In the early 1980th a new approach to interpretation and processing the data of MCW radiometric measurements was pioneered at the Institute of Radioengineering and Electronics RAS. This approach corresponds to the idea of using the measurement data not only to convert them into accepted parameters in geophysics (temperature, moisture content of the objects, etc.) but also to characterize generalized indicators related, for example, with the heat and moisture transfer through the boundary of natural mediums.

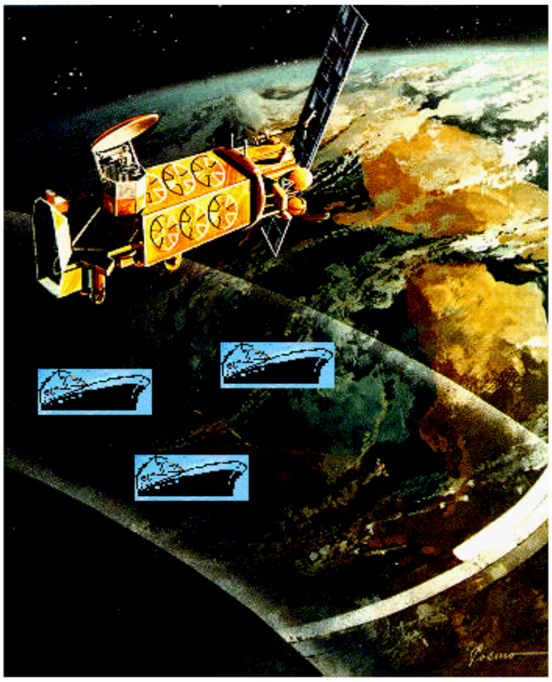
Some results of realization of these ideas were demonstrated in [*Reutov*, 1986; *Reutov and Shutko*, 1987; *Shutko and Reutov*, 1987], where was shown that the SOA brightness temperature at centimeters and decimeters is closely attached to the so called radiation index of dryness of the land, which characterizes the heat and moisture balance at the Earth.

Afterwards, these results were confirmed during numerous experimental studies of land covers carried out in 1980th in the USSR and abroad with use of the aircrafts, helicopters, and hang-gliders, equipped by MCW radiometers [*Shutko*, 1986].

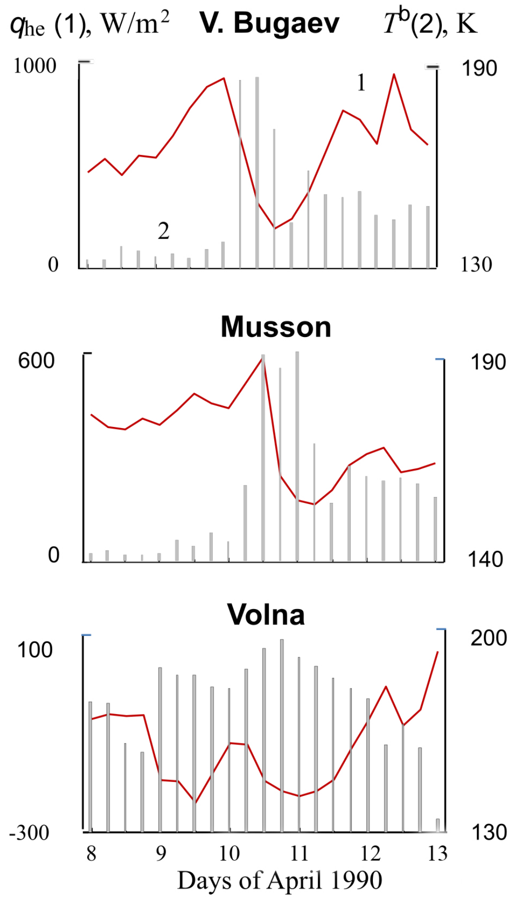
Later, such approach was applied to studying the heat processes at the ocean surface and in atmosphere with use of American and Russian meteorological satellites. An appreciable advantage was attained due to the idea of combining of meteorological and aerologic data obtained in the vessel experiments NEWFOUEX-88 and ATLANTIC-90 in the North Atlantic [*Gulev et al.*, 1992; *Lappo et al.*, 1989] and results of simultaneous MCW radiometric measurements from the DMSP satellite F08 (with radiometer SSM/I) launched in June 1987 [*Hollinger et al.*, 1990]**. The researches were planned and realized independently by different organizations in the USA and former USSR: in the frame of the program RAZREZY [*Dymnikov et al.*, 1984]. Influence of energy-active zones of the North Atlantic on the climate short period variations was studied, while the satellite measurements were performed in accordance with the program DMSP – Defense Meteorological Satellite Program [*Boucher and Stier*, 2010; *DMSP*, 1997] (Figure 1a).

**Data from the satellite F08 made available to us by the NASA Marshall Spaceflight Center.

The Norwegian, Newfoundland, and Gulf Stream zones of the North Atlantic situated in a course of the Gulf Stream and North Atlantic current and exerting appreciable influence on the weather conditions of Europe and European part of Russia were considered as the areas of our paramount interests. These areas referred to as energy active zones are remarkable for a strong energetics of the ocean-atmosphere heat and dynamic



(a)



(b)

Figure 1: MCW radiometric survey of the meteorological satellite F08 in areas of carrying out of experiments NEWFOUEX-88 and ATLANTEX-90 aboard the research vessels V. Bugaev, Musson and Volna in the Newfoundland energy active zone of the North Atlantic (a). Variations of the surface total heat fluxes q_{he} (1) (in Watts per square meter) according to ship measurements carried out on the vessels V. Bugaev (42.3°N, 46°W), Musson (41.3°N, 41°W) and Volna (48.2°N, 46°W) in the experiment ATLANTEX-90) and brightness temperature T^b at the wavelength 1.35 cm (2) from the F08 SSM/I radiometer (b). There are clear relations between brightness temperature and heat fluxes variations.

interaction as well as a considerable response of an intensity of MCW radiation (brightness temperature) on these effects. An intensity of the ocean near-surface heat fluxes can be attain to 2000 Watt per square meter here. At the same time, the brightness temperature contrasts (up to tens of Kelvins) exceed the range of changeability of MCW radiation intensity for many natural factors such as the spatial and temporal variability of the ocean surface temperature, the wind speed increase (decrease) in the storm areas, etc.

Already the first results [*Grankov and Milshin*, 2010] of combining the satellite and vessel measurements data pointed to a close relation between the SOA brightness temperature in the spectral band of the radiation attenuation in the atmospheric water vapor (at the vicinity of the wavelength 1.35 cm) and vertical turbulent fluxes of sensible and latent heat in the near-surface atmosphere layer (0–10 m) (Figure 1b). But at the same time it was established that the satellite-derived brightness temperature contrasts can amount to 30–40 K, which noticeably exceeds the value of their variations produced by the processes of vertical transfer of heat and moisture in the atmosphere boundary layer (0–1000 m), where the upgoing MCW radiation is forming mainly.

This phenomenon is caused by a presence of the mechanism of horizontal (advective) heat and moisture transfer in the atmosphere [*Grankov et al.*, 2014]. Horizontal movements in the near-surface and overlying atmosphere layers determine the change of their temperature and moisture characteristics, which produce the change of the vertical turbulent fluxes of a total (sensible and latent) heat at the ocean surface. Following the data obtained during the experiments NEWFOUEX-88 and ATLANTEX-90 such shifts in the atmosphere heat regime are accompanied by bursts of the total water vapor content of the atmosphere as well as the SOA brightness temperature at the wavelength 1.35 cm. Thus, this model of forming the processes heat exchange between the ocean and atmosphere is able to explain observed in situ direct relations between the near-surface heat fluxes and the SOA natural radiation in this band of microwaves.

Later, the studies of the relationships between characteristics of the SOA natural radiation at microwaves and heat processes at the ocean surface and in atmosphere were continued in the frame of the joint NASA-ROSCOSMOS project on research of the Earth from space (contract NAS15-10110). Also, these researches were supported by the Russian Foundation for Basic Research (grant No. 94-05-16234-a) and International Science and Technology Center (grant No 3827).

Because of the radio visibility of the heat processes at the ocean surface from space the spectral band of resonance attenuation of natural radiation in the atmosphere water vapor was the center of attention in these researches.

Below, several examples of using the satellite measurement data in this band of the MCW wavelength range will be considered. The examples given include the short-period (synoptic) phenomena with lifetime of 5–7 days (mainly in cyclonic and stormy areas of the ocean) and slow processes with the monthly and yearly periods of variability. Some of these results are covered in the monograph [*Grankov and Milshin*, 2016]; the rest ones have been obtained recently.

Approach of the hurricanes

Satellite MCW radiometric means let us to observe a close correlation between variability of the SOA brightness temperature and atmosphere meteorological characteristics during time periods preceding the approach of the hurricanes.

The response of these characteristics was studied during approach of the strong tropical hurricane Katrina in the Florida Straight in August 2005 [*Knabb et al.*, 2023] in the region of the buoy station SMKF1 (Sombrero Key) being a part of the NOAA National Data Buoy Center network. Synoptic variations in the following SOA characteristics were analyzed and compared for the period of 19–24 August, which preceded arrival of the hurricane: air humidity in a 10 m surface layer near SMKF1 and the SOA brightness temperature measured with the EOS Aqua AMSR-E radiometer at the wavelength 1.26 cm (Figure 2a,b,c).

In another case, in the coastal region of the Black Sea (Gelendzhik, Golubaya Bay, the territory of the Southern Branch of the Shirshov Institute of Oceanology RAS), the meteorological studies of atmospheric parameters were carried out simultaneously in a period that preceded a strong storm (Figure 3a,b,c). The measurements were carried out in September–October 2010 using meteorological sensors mounted at the pier's end, which were compared with the data of measurements over the water area adjacent to the Golubaya Bay from the EOS Aqua AMSR-E radiometer at the wavelength 1.26 cm. It is impossible to use the satellite data for the water area of this bay, since its size is several times smaller than the spatial resolution of this channel of the AMSR-E radiometer.

In both cases the effect of the atmosphere moisture "pumping" over ocean areas during hurricane (sea storm) approaching, which became apparent in the stable increase of the atmosphere humidity as well as the SOA brightness temperature in the vicinity of the line of MCW radiation absorption by the water vapor. This phenomenon can be useful for elaboration of the methods of fore-

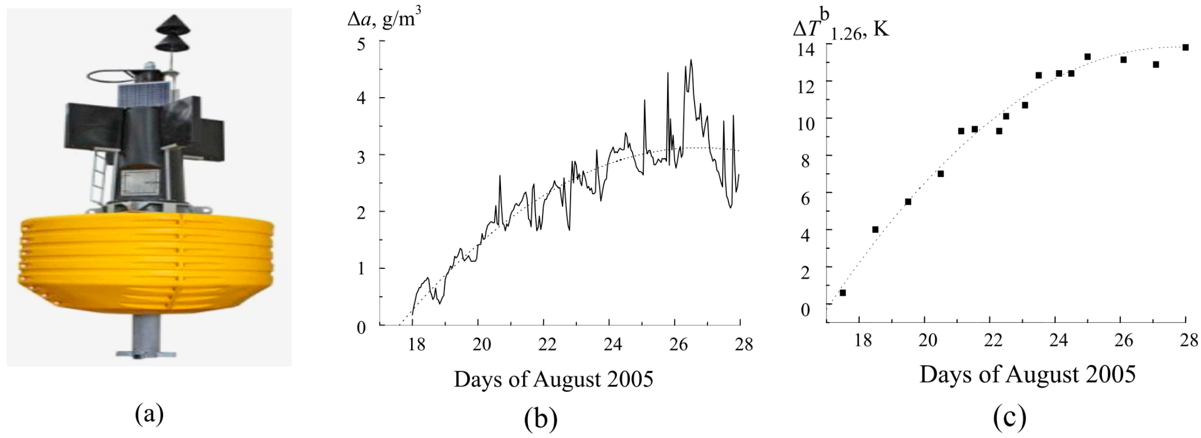


Figure 2: NOAA network buoy station SMKF1 (a). Variations of the near-surface air humidity Δa (in grams per cubic meter) according to the station SMKF1 measurements (24.38°N, 81.07°W) (b) and SOA brightness temperature ΔT^b at the wavelength of 1.26 cm (c) with the data from the EOS Aqua AMSR-E radiometer in August 2005.

casting the rate and terms of tropical hurricanes (storms) approaching to one or another ocean area or its coast where its appearance is regular and expectable.

Propagation of the tropical hurricanes in the ocean

The spatial and temporal dynamics of the propagation of tropical hurricanes and atmospheric fronts in the ocean can be studied using data from regular satellite measurements of the SOA brightness temperature in the band of the resonance absorption of MCW radiation by the atmosphere water vapor.

The results of the brightness temperature measurements from the EOS Aqua AMSR-E radiometer in this range illustrate the propagation of the tropical hurricane Katrina from its origin (Bahamas) to the southern coast of the United States (Louisiana) in the period from 24 to 30 August 2005 (Figure 4a). The appearance of hurricane Katrina in or at another area of the Gulf of Mexico is marked by a sharp burst of the brightness temperature caused by an increase of the atmosphere water vapor at the time of Katrina's coming (Figure 4b).

Figure 5 demonstrates the temporal and spatial variability of daily values of the total water vapor content in the atmosphere mapped to a 0.25° grid along the trace of propagation of hurricane Wilma. This hurricane was formed in October 2005 over

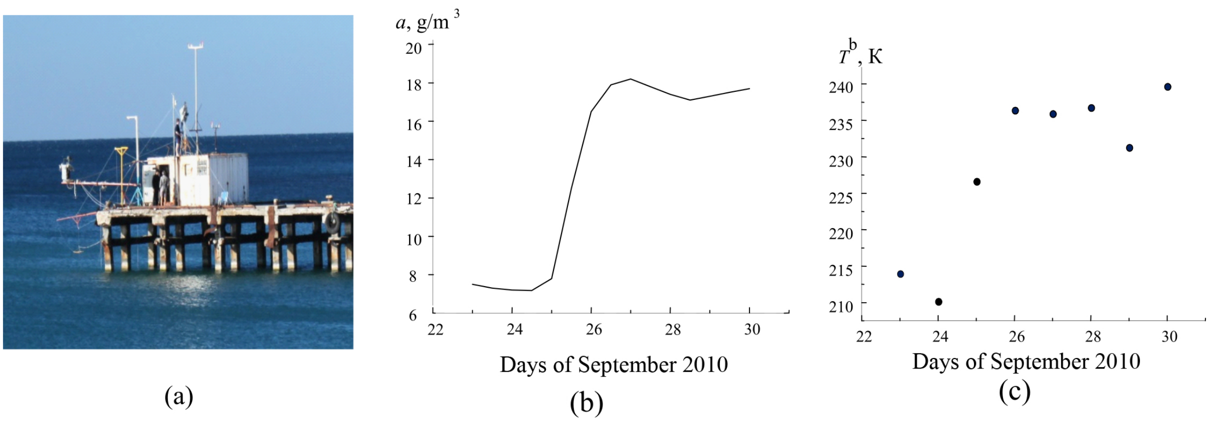


Figure 3: Pier with installed complex of meteorological sensors in the Blue Bay of the Black sea (Gelendzhik), September 2010. Increase in the near-surface air humidity a (according to meteorological measurements made in September 2010 from the pier in the Blue Bay of the Black sea) (a) and the SOA brightness temperature T^b at the wavelength 1.26 cm (data obtained by the EOS Aqua AMSR-E radiometer) (b).

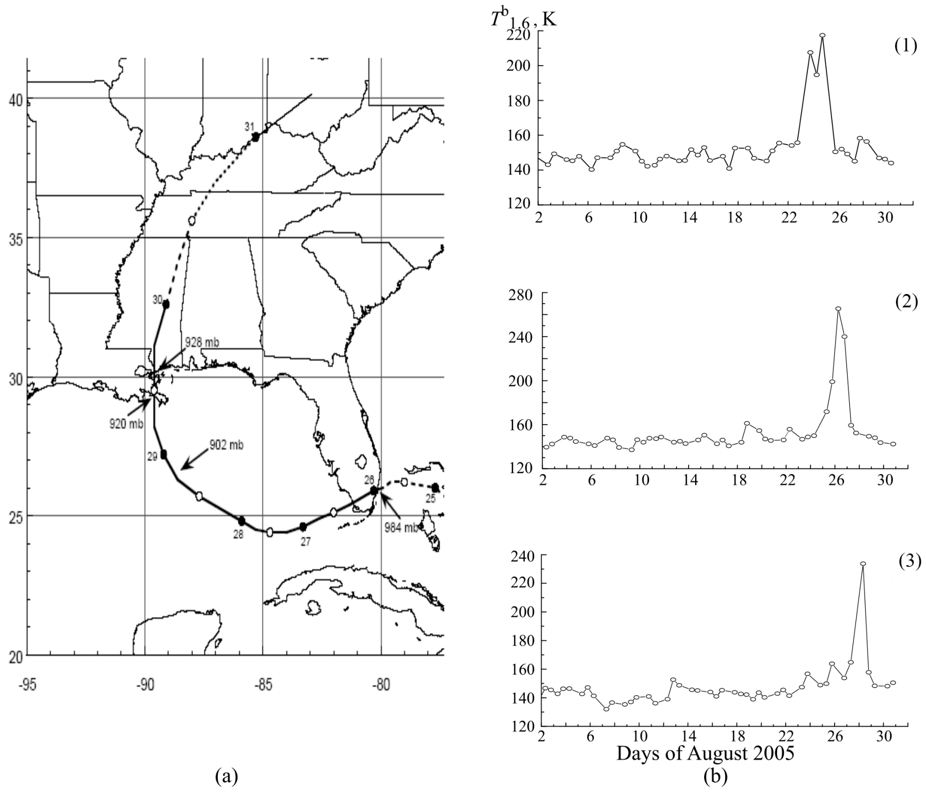


Figure 4: Trajectory of hurricane Katrina propagation from the area of its arising: figures are the days of August 2005 [*Knabb et al.*, 2023] (a). Variations of the brightness temperature T^b at the wavelength 1.6 cm on the horizontal polarisation measured by AMSR-E radiometer at several points of Katrina trajectory: 1) (26°N, 78°W); 2) (25°N, 83°W); 3) (27°N, 89°W) (b). The movement of the brightness temperature peaks in the Bermuda area and in the Gulf of Mexico coincides with the trajectory of the hurricane.

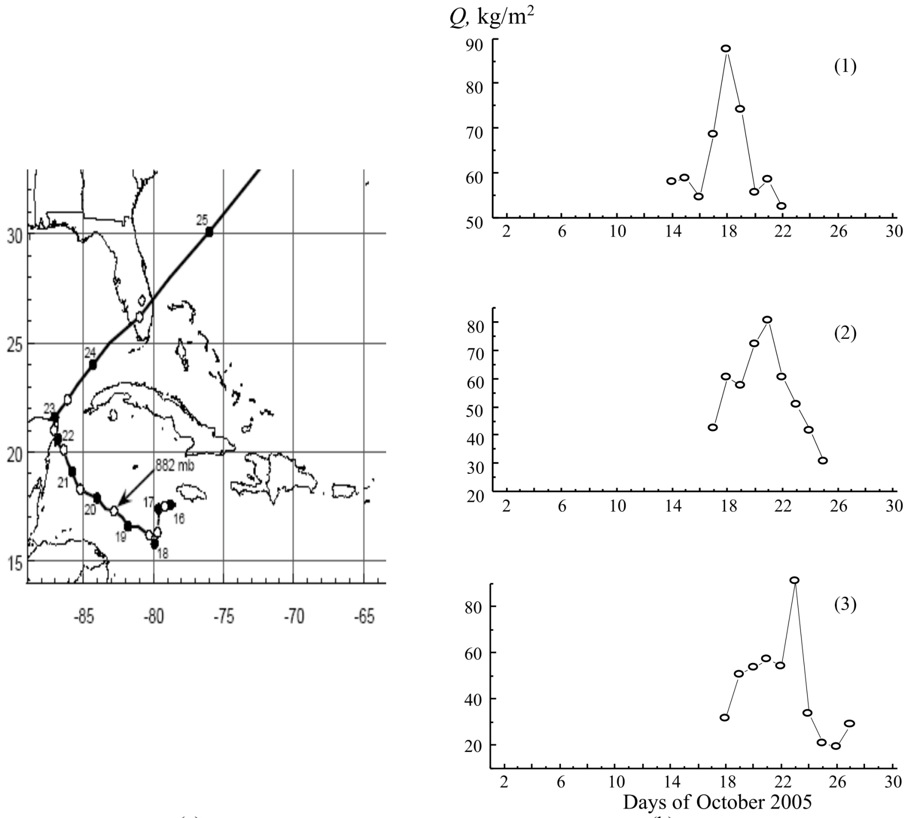
the Caribbean Sea, turned toward the Gulf of Mexico on 18 October and continued its route in the Atlantic basin along the east coast of the United States [*Pasch et al.*, 2006]. It follows from the illustrations that the atmosphere water vapor can be served as the marker of propagation of hurricane Wilma along its trace.

Because the peak values of the atmosphere moisture correspond to the moments of passing the hurricane through one or another ocean area, we can evaluate approximately the rate of transfer of the water vapor along the trajectory of its propagation. It follows from Figure 5 for example, that this value can be of 200–300 km/days for hurricane Wilma at the stage of its development (18–24 October). In addition, such estimates can be derived by using the data on the time localisations of peak values of the SOA brightness temperature in the band of attenuation of MCW radiation in the atmosphere water vapor. For example, it is followed from Figure 4 that the rate of the water vapor transfer along the trajectory of hurricane Katrina propagation can reach 300 km per days during 26–27 August and 450 km per days during 28–29 August.

Dynamics of atmospheric water vapor fields and origin of the hurricanes in the Gulf of Mexico

The results of satellite monitoring of atmospheric water vapor fields in the Gulf of Mexico indicate their close connection with the processes of the origin and development of hurricanes in the Gulf.

The analysis of statistical characteristics of spatial variability of the atmospheric total water vapor content in the area 21.75–28°N, 85.5–95.758°W of the Gulf of Mexico Figure 6 during the periods of origin and development of hurricanes Humberto (2007), Lorenzo (2007), Bret (1999), Katia (2017) was carried out (Figure 7). The data from the DMSP satellites (SSM/I and SSMIS radiometers), EOS Aqua (AMSR-E radiometer) and GCOM-W1 (AMSR 2 radiometer) were used at the same time. Histories of the hurricanes are given in the reports of USA National Hurricane Center [*Avila*, 2019; *Blake*, 2007; *Franklin*, 2007; *Lawrence and Kimberlain*, 2001].



(a) (b)

Figure 5: Trajectory of hurricane Wilma propagation from the area of its arising: figures are the days of October 2005 [*Pasch et al.*, 2006] (a). Variations of the atmosphere total water vapor content Q derived from AMSR-E radiometer at several points of Wilma trajectory: 1) (15.8°N, 79.9°W); 2) (19.1°N, 85.8°); 3) (24°N, 84.3°) (b). The movement of the atmospheric water vapor peaks in the in the Caribbean Sea and in the Gulf of Mexico coincides with the trajectory of the hurricane.

The effect of a strong decrease in the spatial dispersion (smoothing) of the atmospheric water vapor field in the Gulf of Mexico before the transition of these tropical formations from the stage of a tropical storm to the stage of a hurricane, regardless of their synoptic histories (Figure 7). This result may be useful for the development of technologies for early diagnosis of the origin of hurricanes in the Gulf of Mexico.

It should be noted, that the areas of origin of the hurricanes Bret, Lorenzo and Katia coincided with the intratropical convergence zone (equatorial depression), which is an area of intensive tropical cyclogenesis.

Water vapor transport in the tropical Atlantic and cyclogenesis in the intratropical convergence zone

Satellite means of passive MCW radiometric sensing let us to select areas in the tropical Atlantic with a high content of water vapor in the atmosphere and storm zones associated with tropical waves initiating the processes of cyclogenesis in the intratropical convergence zone.

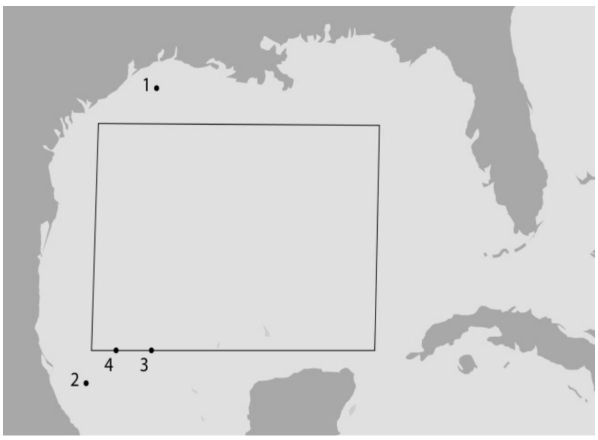


Figure 6: Position of the selected area in the Gulf of Mexico and the areas of origin of the tropical formations Humberto (1), Lorenzo (2), Bret (3), Katia (4) at the moments of their transition from the stage of a tropical storm to the stage of a hurricane.

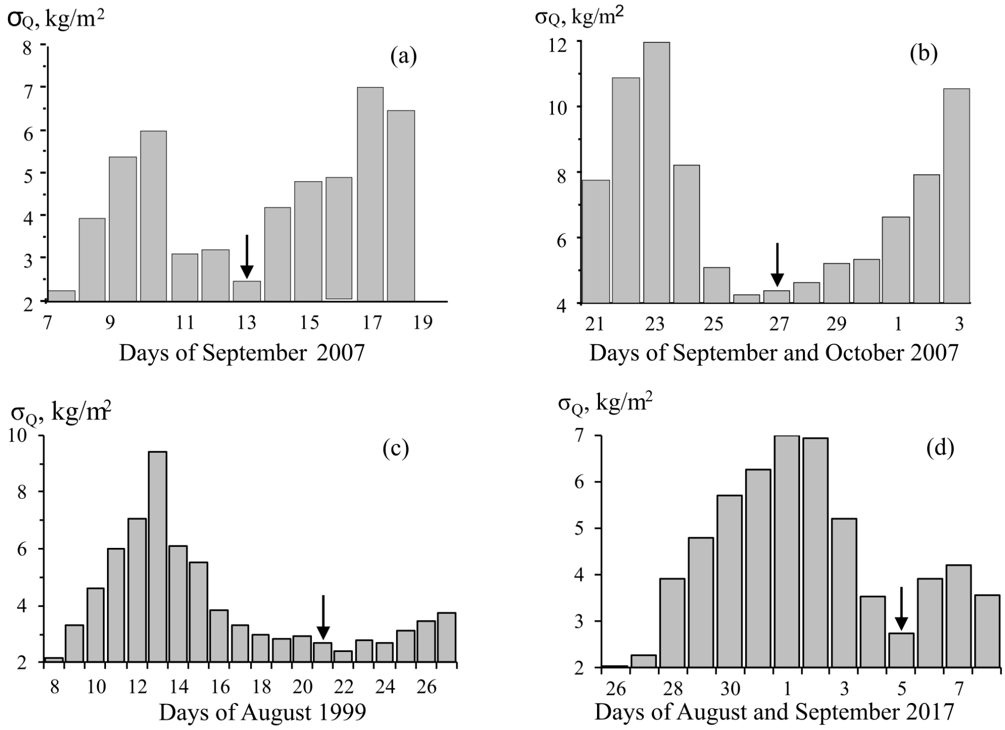


Figure 7: Standard deviations of the total atmospheric moisture content σ_Q from the daily average values in the Gulf of Mexico during the periods of origin and development of the Humberto (a), Lorenzo (b), Bret (c) and Katia (d) hurricanes. The arrow marks the moment of transition of the tropical formations to the hurricane stage. A smoothing of atmospheric water vapor fields in the Gulf before the hurricanes origin is observed.

As an example, Figure 8 shows the spatial and temporal variability of the total atmospheric water vapor Q content and near-surface wind speed V fields in the region of 0–35°N, 100–20°W of the tropical Atlantic in the period 22.08.2004–03.09.2004, proceeding the hurricane Frances origin (26.08.2004). We used the data of measurements from the EOS Aqua AMSR-E radiometer; these data are available from the NCIDC archive as well as the satellite radiothermovision geoportal [*Ermakov et al.*, 2013, 2016]. A history of the hurricane Frances is given in the report of USA National Hurricane Center [*Beven*, 2014].

Figure 8 indicates the area in the tropical Atlantic with a high content of water vapor in the atmosphere (up to 60 kg/m^2) and high intensity of wind speed (above 25 m/s) moving from the west coast of Africa to the Gulf of Mexico. Its trajectory, according to [*Beven*, 2014], corresponds to propagation of a tropical wave initiating TH Frances origin.

Variability of monthly mean heat fluxes in energy active zones of the North Atlantic

The previous examples illustrate the application of satellite MCW radiometric methods for localization of heat processes at the ocean surface and in the atmosphere, existing in the synoptic range of time scales (5–7 days).

The data of long-term satellite MCW radiometric measurements (over seasons, several years) in the band of the radiation resonance absorption by atmospheric water vapor allow us to estimate variability of climatically significant parameters of the ocean–atmosphere system. Control of the average monthly heat and moisture flows at the interface of the system during the year (from month to month) and several years (from year to year) are seems to be accessible for this instrumentation.

This is evidenced, for example, from results of comparison of mean monthly total (sensible and latent) heat fluxes from the archive of OAFlux (Objectively Analyzed Air-Sea Heat Fluxes) global dataset for the period of 2003–2011 with values of the monthly mean SOA brightness temperature derived from the EOS Aqua AMSR-E device measurements at the wavelength 1.6 cm (horizontal polarization). The comparison between average monthly AMSR-E and OAFlux data was carried out for the following regions in the North Atlantic: M (MIKE, 66°N, 0°W), D (DELTA, 44°N, 41°W), and H (HOTEL, 38°N, 71°W) located in the Norway, Newfoundland, and Gulf Stream energy active zones, respectively (Figure 9a).

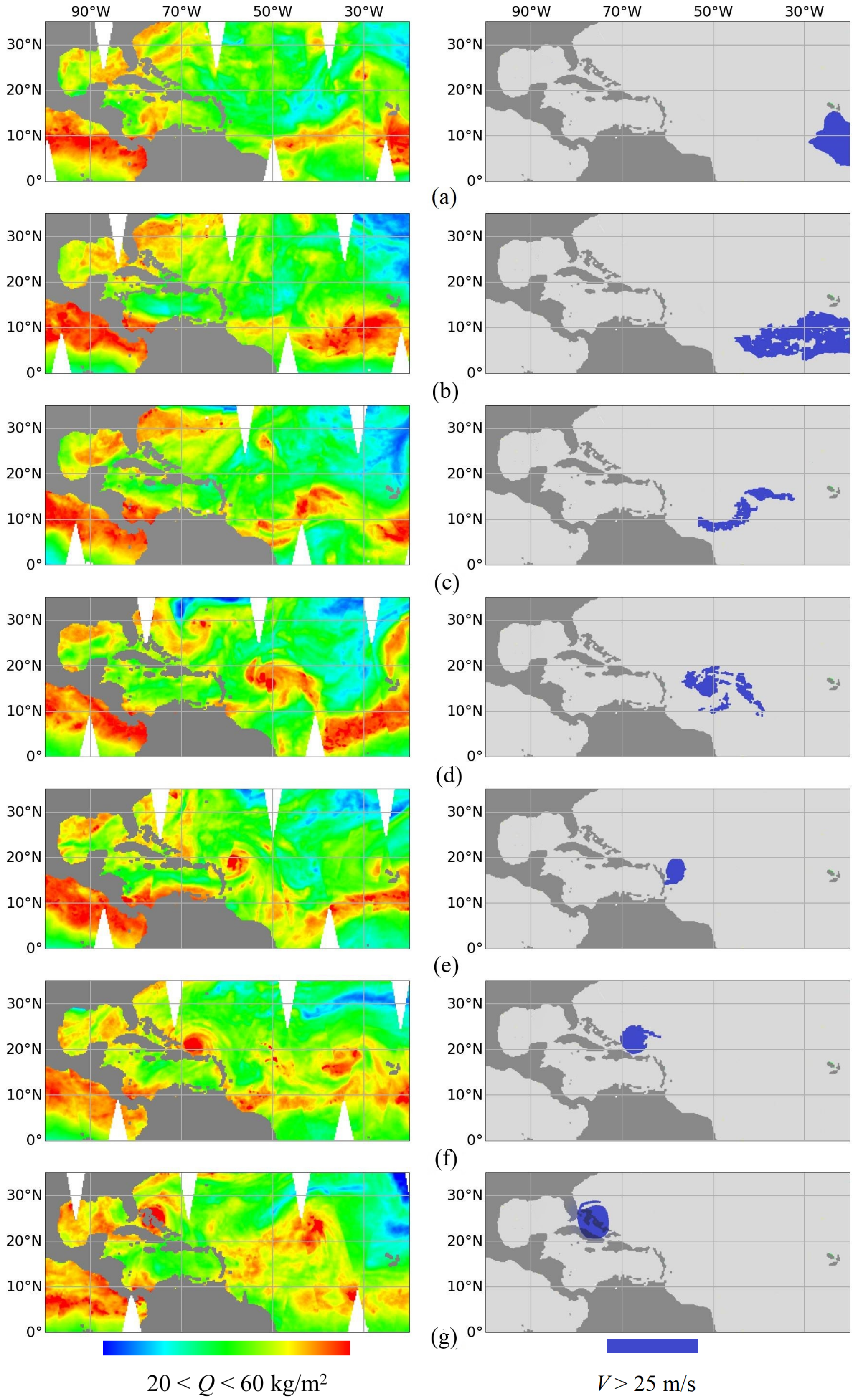
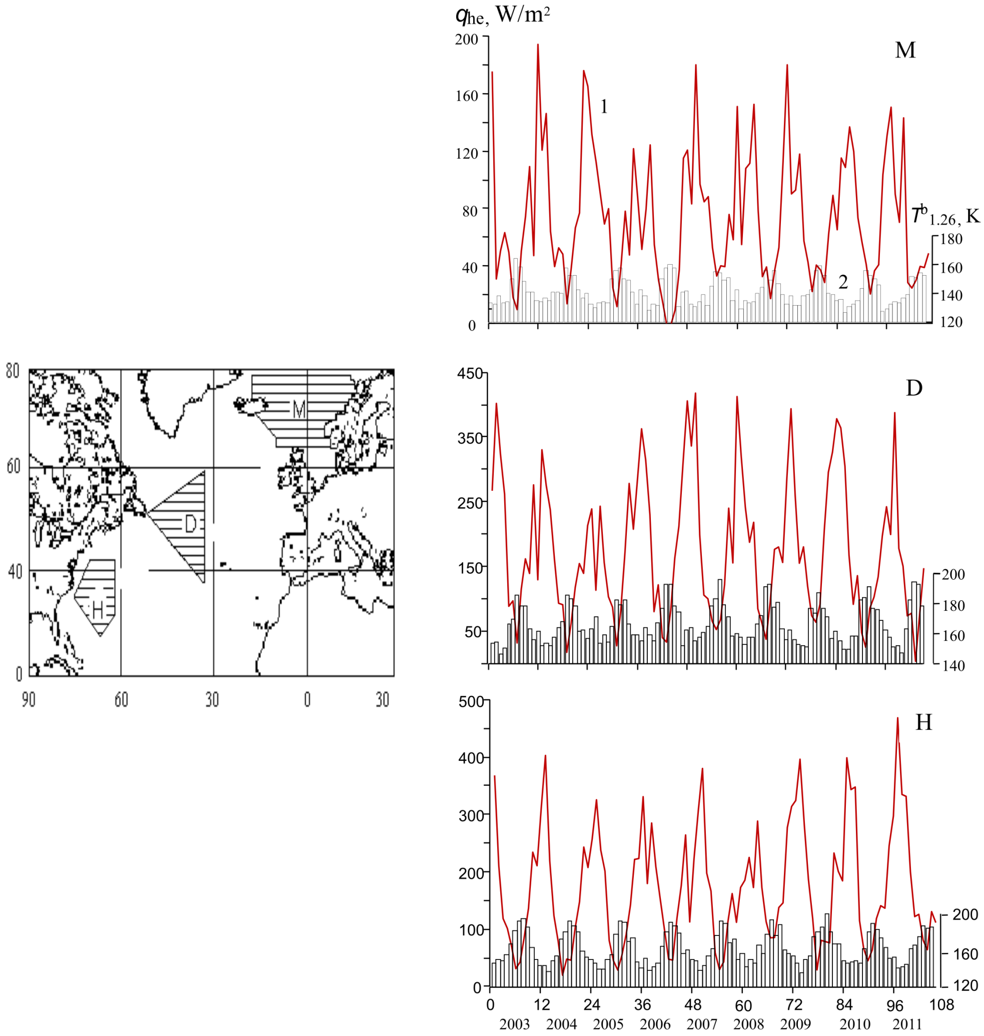


Figure 8: Evolutions of the total atmospheric water vapor content Q and near-surface wind speed V fields: (a) – 22.08; (b) – 24.08; (c) – 26.08; (d) – 28.08; (e) – 30.08; (f) – 01.09; (g) – 03.09. White wedge–shaped areas are the blind spots of the AMSR-E radiometer resulted from the divergence of its scanning bands. A tropical wave is detected by the AMSR-E radiometer 5 days before the hurricane Frances origin (26.08.2014).



(a) (b)

Figure 9: Location of Norwegian, Newfoundland, and Gulf Stream active zones and the ocean weather stations M, D, and H in the North Atlantic (a). Comparison of the OAFlux monthly mean fluxes of total heat q_{he} and AMSR-E brightness temperatures T^b at the wavelength 1.26 cm in the areas M, D, H during 2003–2011 (b). A high correlation between seasonal and interannual variations in average monthly heat fluxes on the sea surface and brightness temperatures are observed in the areas M, D, H of the North Atlantic.

These results indicate a close relationship between seasonal and interannual variations in monthly mean values of the surface heat fluxes and COA brightness temperature in the spectral band of MCW radiation absorption by the atmosphere water vapor resonance radiation (Figure 9b).

The data of long-term satellite MCW radiometric measurements can be used to assess the seasonal dynamics (observations during the year) of the heat regime of the system ocean–atmosphere to detect its changes caused not only by natural but also man-made causes, and their assessment. As a result of the April 2010 oil spill in the oil-producing areas of the Gulf of Mexico at the head of the Gulf Stream, a unique material for the study of emergency situations of this kind with the help of satellite MCW radiometric methods has appeared. According to the data on the SOA brightness temperature at the wavelength 1.26 cm measured from the EOS Aqua satellite, a significant decrease in the total water vapor content in the atmosphere in the Gulf Stream and Newfoundland energy active zones of the North Atlantic after the spread of oil spills into these zones was detected (Figure 10).

The occurrence of this phenomenon can be explained by a decrease in evaporation of moisture from the ocean surface due to surface oil films in the area of spills and a decrease in heat transfer to other areas in the course of the Gulf Stream. This

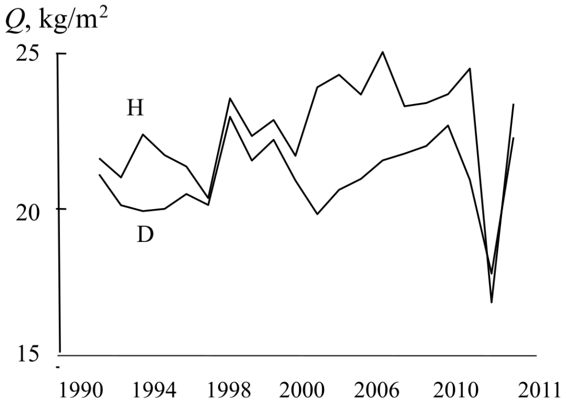


Figure 10: Dynamics of changes in the total water vapor content in the atmosphere Q and its peculiarity in 2010. There is a sharp decrease in the average annual values of the total water vapor content in the atmosphere in the D and H regions of the North Atlantic after the beginning of oil spills in May 2010.

assumption was made earlier by J. Zangari from the Frascati Institute based on satellite IR radiometric long-term measurements.

Conclusions

The examples presented show the appreciable possibilities the method of indication and analysis of heat processes at the ocean surface and in atmosphere based on the measurements of an intensity of natural MCW radiation of the system ocean-atmosphere in the spectral band of its resonance attenuation in the atmospheric water vapor. The effectiveness of that approach is caused by the fact that atmospheric water vapor is an active participant (agent) in its heat interaction with the ocean surface and, at the same time, serves as its reliable quantitative indicator.

The horizontal (advective) transfer of heat and moisture in the boundary layer of the atmosphere (turbulence layer) plays a decisive role in the formation of the relationship between the brightness temperature in the region of radiation (absorption) of atmospheric water vapor and thermal processes at the ocean surface. This result may be of considerable interest to specialists in the field of satellite microwave radiometry of the ocean and atmosphere.

Such areas of the World Ocean as the Gulf Stream, Newfoundland, Norwegian-Greenland energy active zones of the North Atlantic, as well as the Gulf of Mexico can serve as a kind of testing grounds for studying heat and dynamic processes at the interface of the ocean and atmosphere using means of satellite MCW radiometry. The significant contrasts of brightness temperature are regularly observing here in the spectral band of MCW radiation attenuation in the atmospheric water vapor.

This band can serve as a kind of "radio visibility window" at microwaves for observing and analyzing from space such changeable processes at the ocean surface and in atmosphere as thermal and dynamic interaction between the ocean and the atmosphere, the approach of atmospheric fronts and storm zones, the origin and propagation of tropical hurricanes. The examples given also show, that satellite measurements in this spectral band allow us to observe and study slower processes in the range of seasonal and interannual time scales. These data allow us to estimate seasonal and long-term variability of heat and moisture exchange between the ocean and atmosphere in energy-active zones of the North Atlantic, as well as long-term variability of the atmospheric vapor transfer in areas of the Gulf Stream and North-Atlantic currents. The results obtained can be widely used in oceanology, meteorology, and climatology.

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