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Analysis of Variability of Surface Heat and Impulse Fluxes and Water Vapor Content of the Atmosphere Over the North Atlantic Based on Satellite Microwave Data

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Abstract. The estimates of spatial and temporal variations of monthly mean values of the near-surface vertical turbulent fluxes of sensible, latent heat and impulse, and the atmospheric total water vapor content in the North Atlantic were obtained based on the data from satellite microwave measurements. The Gulf Stream, Newfoundland, and Norwegian areas, which are characterized by the highest intensity of ocean-atmosphere heat exchanges, are the focus of this study. The long-term trends in water vapor changes over these areas were estimated. Some peculiarities of water vapor dynamics were observed in 2010, which manifested as intensive oil spills in the Gulf of Mexico in the spring of that year, as well as strong summer dryness over the European part of Russia.

Keywords: microwave radiation, brightness temperature, ocean–atmosphere system, energy active zones, sensible, latent heat and impulse, near-surface fluxes, water vapor of the atmosphere, radiometers SSM/I and AMSR-E

Introduction

Even 25-30 years ago when shipboard surveys were regularly conducted in the ocean, their frequency and scope were insufficient to solve an array of scientific and application-specific problems. A recent rapid decrease of the aforementioned measurements has increased the role of satellite-referenced surveying of the World Ocean. Satellite performance capabilities (measurement accuracy, spatial resolution and, most importantly, on-orbit life) have been incessantly improving. Modern satellites perform continuous measurements of the Earth's own microwave (MW) radiation with a diurnal or semidiurnal temporal resolution, thus, providing specialists with global and continuous meteorological and oceanographic information. At the same time, the nature of the tasks has changed from determining separate parameters of the ocean surface and atmosphere (ocean surface temperature, near-water wind velocity, atmospheric water vapor content) based on fragmentary measurements (obtained by first satellites: Kosmos-243, Nimbus-5, Kosmos-1056, Kosmos-1151) to using satellite estimates to determine their long-term variability (months, years).

The paper focuses on analyzing the spatial and temporal variations of monthly mean values of vertical turbulent fluxes of sensible, latent heat and impulses on the ocean surface and atmospheric total water vapor content – all of which comprise climate-forming factors.

The geographical area of research is the North Atlantic with coordinates 67°N, 95°W – 0°N, 0°W with a focus on the areas with the most intensive ocean–atmosphere heat exchanges: the Gulf Stream, Newfoundland, and Norwegian energy-active zones.

The results of regular measurements were obtained from the microwave radiometer (MR) SSM/I (Scanning Sensor Microwave/Imager) on the DMSP meteorological satellites and the AMSR-E (Advanced Microwave Scanning Radiometer) on the oceanographic satellite EOS Aqua. The technical characteristics of these satellites and their capabilities are presented in [1-3]; primary and thematic (secondary) processing of satellite measurement data is described in [4].

Separate findings on the possible usage of data gathered from satellite MR measurements for analyzing water vapor fields in the North Atlantic are set forth in works [5, 6].

Spatial and seasonal variability of monthly mean fluxes and water vapor in the North Atlantic

After processing the AMSR-E radiometer measurements (ascending and descending orbits of the EOS Aqua satellite) for November 2009 through December 2010 in the fragment of the North Atlantic with coordinates 67°N, 95°W – 0°N mean daily values of the sensible, latent heat and impulse fluxes were obtained. Subsequently, basing on them flux monthly mean values with a resolution of 0.25 degrees latitude and longitude (Figure 1 gives examples of processed data for February and August 2010) were calculated.

High temporal and spatial variability of all flux types can be noted in the North Atlantic. The highest flux intensity is exhibited during summer season, reaching peak values in July. The tropical zone east of Cuba in spring–summer seasons, as well as in October-September is characterized by increased values of this parameter. This zone belongs to the regions of tropical cyclone genesis, formation and passage. The seasonal peculiarity of impulse flux behavior lies in the minimal contrasts during summer season, whereas during fall–winter seasons contrasts essentially increase. The sensible heat fluxes are latitude-dependent: the most intensive fluxes are in the north of the Atlantic. Their value lowers on nearing equatorial latitudes.

Figure 1 illustrates a very important result — the possibility of monitoring the Gulf Stream in the sensible heat flux field from space with the spatial resolution of 0.25 x 0.25° provided by modern satellite microwave radiometric instruments.

Satellite estimates of the monthly mean values of total (sensible and latent) heat flux were compared with those of the famous OAFlux (oaflux.whoi.edu) archive in the location areas of ocean weather ship stations (weather ships) M (MIKE – 66° N, 0.5° W), D (DELTA – 44° N, 41° W) and H (HOTEL – 38° N, 71°W). These locations correspond to the Norwegian, Newfoundland and Gulf Stream energy-active zones. Comparison results demonstrate agreement between satellite and archive data.

Figure 2 shows estimates of the monthly mean values of total atmospheric water vapor content obtained by processing measurement data from the EOS Aqua satellite AMSR-E radiometer in 2009 and 2010.

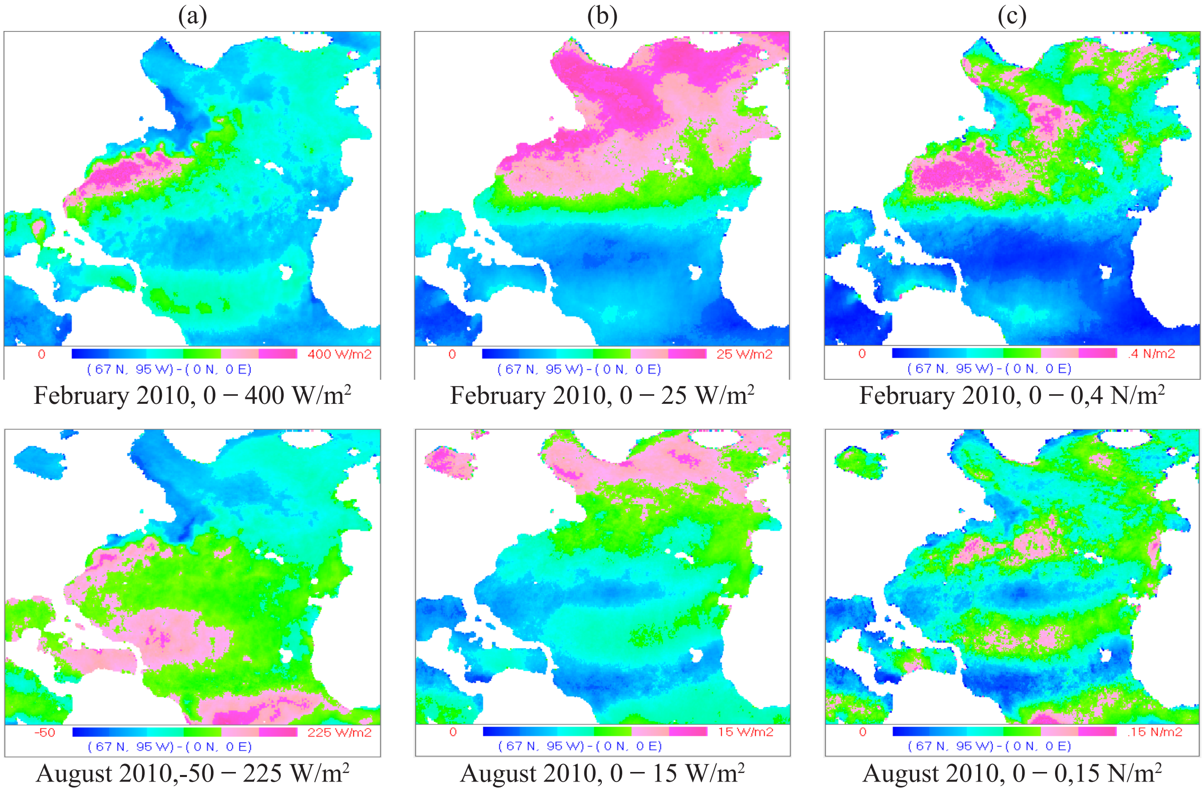

Fig.1. Spatial distribution of latent (a), sensible (b) heat fluxes and impulse (c) in the North Atlantic in 2010 according to AMSR-E radiometer data.

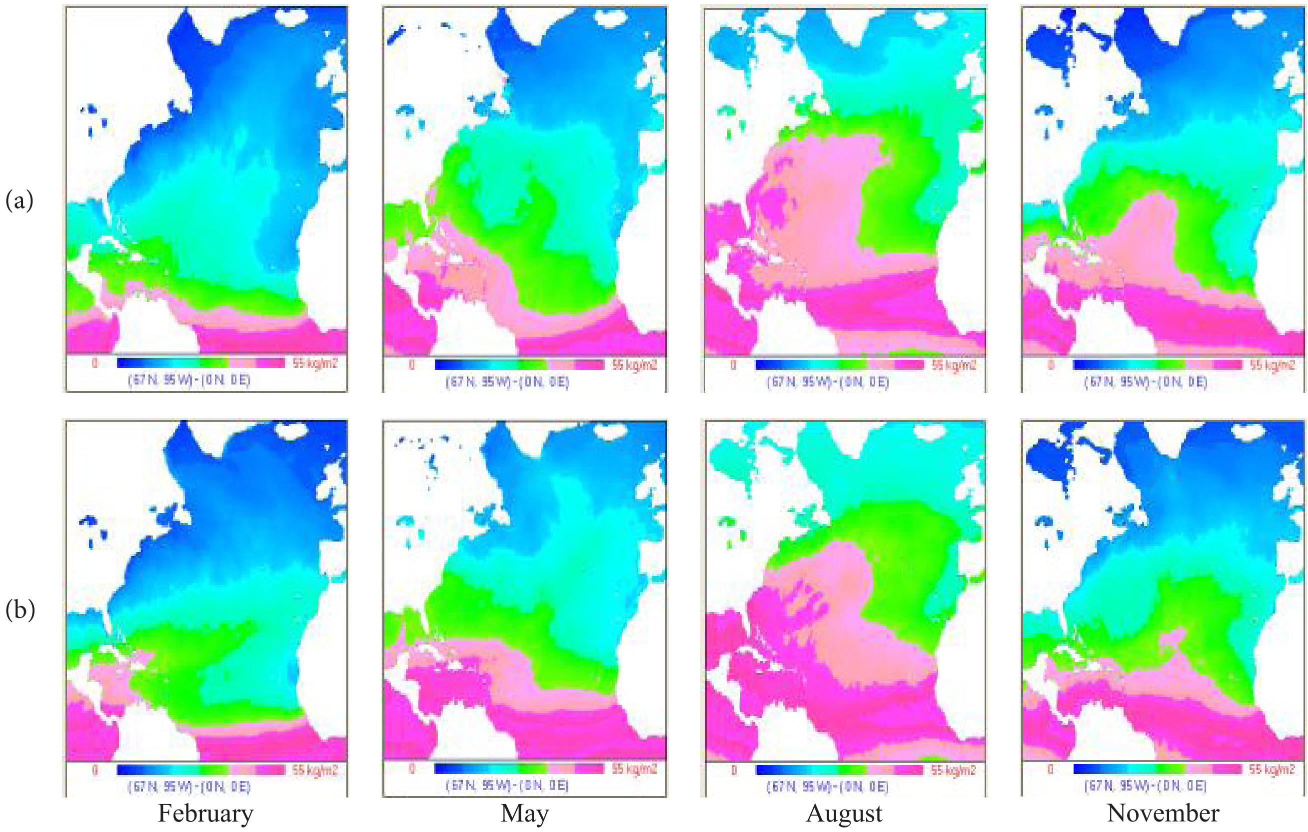

Fig.2 Spatial distribution of monthly mean values of total atmospheric water vapor content in the North Atlantic: (a) in 2009 (b) in 2010.

The picture of water vapor distribution in the North Atlantic is noticeably "striped" (delimited by latitudes). Figure 2. shows that the distribution has a well-defined latitudinal pattern (atmospheric humidity increases from lower latitudes to higher ones) and, yet, this parameter is highly contrasting as it varies from 15 to 55 kg/m^2 depending on the geographical latitude and season.

Interannual atmospheric water vapor variations in energy-active zones of the North Atlantic

The estimates of monthly mean atmospheric total water vapor content in the North Atlantic with a 0.25 latitude and longitude spatial resolution over the period 1988 – 2011 were obtained on the basis of the results of processing AMSR-E radiometer measurements over the period 2002–2011, supplemented by measurements of the radiometer SSM/I during the period 1988 – 2001. The temporal dynamics of water vapor in energy-effective zones M, D and H are given further in more detail.

Figure 3 gives monthly mean atmospheric total water vapor content values in North Atlantic zones M, D and H from 1988 to 2011 received in different years from SSM/I and AMSR-E radiometers

The illustration shows a noticeable effect of increasing water vapor quantity during these years that is clearly observed in zones D and H.

The increase of mean annual values of atmospheric water vapor content in the period 1996 – 2005, for example, in zones M, D, H amounted to 1, 1.1 and 1.5 kg/m^2 respectively. For the sake of comparison, we shall note that according to recent estimates received from GOME-SCIAMCHY (Global Ozone Monitoring Experiment-SCanning Imaging Absorption spectrometer for Atmospheric CHartographY) and HOAPS (Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data) global variations of atmospheric water vapor during this period [7] were equal to 0.3–0.5 kg/m^2.

When evaluating global water vapor variations, probably, smoothing out the influence of such dynamic and contrasting, yet local, zones of the World Ocean, such as the energy-effective zones of the North Atlantic, the El Niño zone in the Pacific Ocean and others, plays a certain role.

Figure 4 illustrates mean interannual water vapor value variability in the Gulf Stream and Newfoundland energy-active zones over the period 1992 – 2011

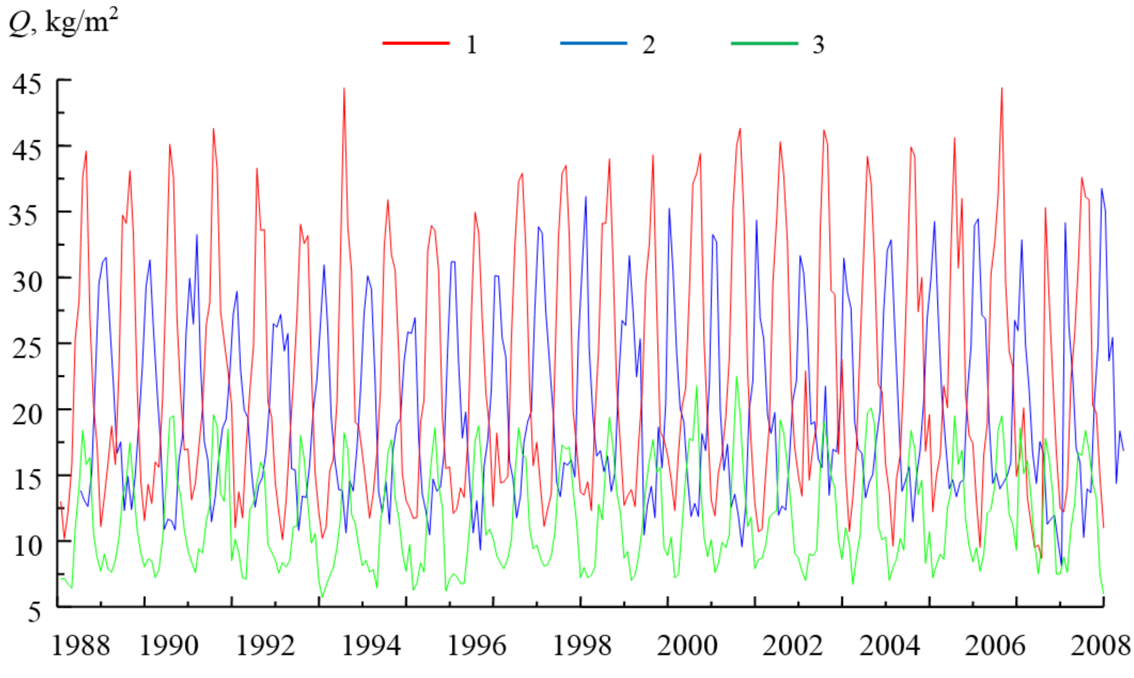

Fig.3 Long-term changes of monthly mean atmospheric total water vapor content values Q in North Atlantic zones H (1), D (2), M (3).

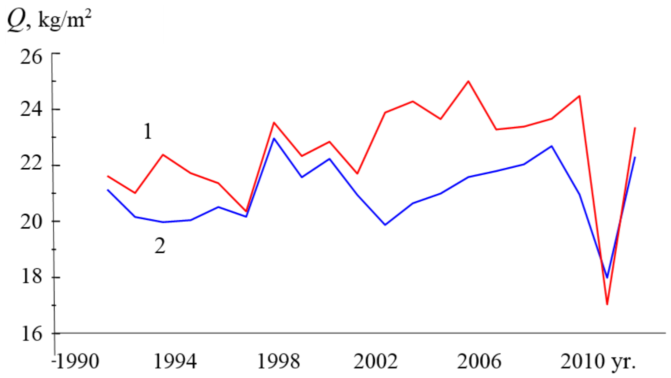

Fig.4. Variations of atmospheric total water vapor content in the Gulf Stream (1) and Newfoundland (2) energy-active zones of the North Atlantic during 1992–2011.

Zones H and D stand out in the illustration and are characterized by a sharp decrease of water vapor in 2010 (at the time of large oil spills in the Gulf of Mexico). The reduction of ocean surface evaporation in the Gulf Stream energy-active zone and the decrease in heat transfer to other zones in the Gulf Stream area explain this observation.

Conclusion

The main results obtained by analyzing AMSR-E and SSM/I radiometer measurement data:

1. The possibility of monitoring the Gulf Stream and its spatial/temporal variations in the sensible heat flux field from space with the spatial resolution of 0.25 x 0.25° was demonstrated.

2. An increase of monthly mean values of the atmospheric total water vapor content in the Gulf Stream, Newfoundland and Norwegian-Greenlandic energy-active zones of the North Atlantic from 1998 to 2011 was shown.

3. A sharp decrease of atmospheric total water vapor content in 2010 during intensive oil spills in the Gulf of Mexico in the spring, as well as strong summer dryness over the European part of Russia was discovered.

Therefore, radiometer scanners, such as the SSM/I and AMSR-E radiometers, are capable of serving as effective instruments for studying climate-forming factors: long-term spatial and seasonal variability of vertical turbulent heat, vapor and impulse fluxes on the ocean surface, atmospheric total water vapor content. This, in its turn, confirms the indispensability of space methods and Earth remote sensing systems in solving problems of hydrometeorology and climatology.

References

1. Hollinger P.H., Peirce J.L., Poe G.A. SSM/I instrument evaluation. *IEEE Trans. Geosci. Rem. Sensing*. 1990, Vol. 28, No. 5, pp. 781–790.
2. Kawanishi T., Sezai T., Ito et al. The advanced microwave scanning radiometer for the Earth Observing System (AMSR-E), NASDA's contribution to the EOS for global energy and water cycle studies. *IEEE Trans. Geosci. Remote Sens*. 2003, No. 48, pp. 173–183.
3. Grankov A.G., Mil'shin A.A. Sovremennoe sostoyanie sputnikovykh SVCh-radiometricheskikh sredstv dlya issledovaniya vzaimodeystviya okeana i atmosfery [The Modern Status of Satellite Microwave Radiometer Systems in the Studies of Ocean-Atmosphere Interaction]. *Problemy okruzhayushchey sredy i prirodnykh resursov* [Problems of Environment and Natural Resources]. 2016, No. 3, pp. 3–29. (in Russian)
4. Grankov A.G., Mil'shin A.A., Novichikhin E.P. *Radioizluchenie sistemy okean-atmosfera v ee energoaktivnykh zonakh* [Radio emission of the ocean-atmosphere system in its energy-active zones]. Saarbrucken, Lambert Academic Publishing, 2016, 314 p. (in Russian)
5. Grankov A.G., Mil'shin A.A., Shelobanova N.K., Chernyy I.V., Yazeryan G.G. Mnogoletnie variatsii vodyanogo para v Severnoy Atlantike po dannym sputnikovykh mikrovolnovykh izmereniy [Long-Term Variation of Total Vapor Over North Atlantic Using a Satellite Microwave Data]. *Raketno-kosmicheskoe priborostroenie i informatsionnye sistemy* [Rocket-Space Device Engineering and Information Systems]. 2015, Vol. 2, No. 2, pp. 47–52. (in Russian)
6. Mil'shin A.A., Shelobanova N.K., Grankov A.G. Mezhgodovye i vnutrigodovye variatsii vodyanogo para v Severnoy Atlantike po dannym sputnikovykh mikrovolnovykh izmereniy [Interannual and intraannual variations in total precipitable water over the North Atlantic from satellite microwave measurements]. *Meteorologiya i gidrologiya* [Russian Meteorology and Hydrology]. 2016, No. 8, pp. 18–25. (in Russian)
7. Mieruch S., Schroder M., Noltz S., Schulz J.S. Comparison of decadal global water vapor changes derived from independent satellite time series. *J. Geophys. Res*. 2014, No. 10, pp. 1–11.