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Land surface state anomalies and related severe meteorological phenomena

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A conceptual approach (developed at NIMH-BAS) for quantitative description of land-atmosphere interactions and some regional applications at climate-weather extremes related with "dry"-"wet" anomalies in land surface state for territory of Bulgaria is presented. Based on specially designed experimental numerical schemes, combined with information from meteorological models, geostationary satellites Meteosat Second Generation and ground observations, knowledge about the environmental conditions for development of meteorological phenomena related to natural hazards (agrometeorological drought and yield reduction, forest fires and regions with increase risk, convective storms and soil overmoistening effects, climate forcing due to biomass burning) are extracted. The obtained results might serve as a methodological basis for further studies, operational applications, climatic assessments and forecasts as related to multifunctional risk from severe meteorological phenomena.

Key words: Land/atmosphere interactions, natural hazards, fire-carbon emissions, climate-wheather

INTRODUCTION

The importance of land-atmosphere interactions and all processes they involve for the climate system is increasingly being recognized. Similar to the oceans, land areas provide the lower boundary for the atmosphere, with which they exchange energy, water and chemical compounds such as CO2. While the role of land for climate variability has often been neglected in the past, recent studies have highlighted how land atmosphere interactions can be critical in modulating variations in climate on a range of temporal (seasonal to centennial) and spatial (local to global) scales. Land-atmosphere interactions tend to be particularly important in transitional zones between dry and wet climates. For present climate, this applies also to the Mediterranean region [1]. Moreover, these "hot spots" of land-atmosphere coupling are also inherently modified with shifts in climate regimes, for instance due to climate change. They can thus be displaced on longer time scales. One of the problems that are still underestimated is the assessment of the role of land-atmosphere interactions and Land Surface Processes /LSPs/ related to climate dynamics/extremes on a regional scale. The current study is focused on evaluation the land-atmosphere coupling for the region of eastern Mediterranean resulting in different levels in soil moisture and related evapotranspiration and the possible impacts of soil moisture on climate (weather) extremes on a local/regional scale.

Drought as a normal, recurrent feature of climate is one of the major environmental disasters in Mediterranean that has taken great influence to socio-economic development in the region. It does not belong to the group of climate extremes based on simple climate statistics, as anomalies in daily temperature or heavy rainfall amount that occur every year. Drought is a more complex event-driven extreme, which do not necessarily occur every year at a given location. In the current study drought on the vegetated land surface is referred as a "dry" biogeophysical cycling anomaly with a complex nature. Its assessment calls for a comprehensive and integrated approach, accounting for specific regional and local reveals with possibilities for drought extent and impacts to be monitored routinely by numerous indicators. In contrast, "wet" land surface anomalies might be produced by synoptic or mesoscale weather systems that in some cases may lead to soil overmoistening and produce floods over the land ("meteorological floods") or in case of deep convection in comparatively "dry" preconvective environment are often related to showers with hail.

The primary purpose of the work is to highlight typical climate-weather extremes where the land surface state is of relevance to the occurrence of natural hazards like: drought, agricultural yield reduction, disturbed environmental sustainability (via forest fires); convective storms and related severe

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weather. Accordingly, the main specific research objectives are focused to: 1) Present a methodological approach to extract knowledge from the combined use of ground observations, modelling of soil-vegetation-atmosphere interface and satellite imageries for near real-time detection and monitoring of weather-climate induced terrestrial natural hazards; 2) To test this approach as a research tool and in some operational applications for the region of Bulgaria; 3) To illustrate the results and current available knowledge by specific constrained case studies.

The complex approach of land surface analyses and its application for severe meteorological phenomena is developed by the first author. The second author has contribution in synoptic analyses of convective processes and the interpretation of related satellite products of atmosphere convective environment.

METHODOLOGY

In our preceding work [2] the developed conceptual framework for Land Surface Analyses (LSA) at the National Institute of Meteorology and Hydrology (NIMH) during the last 10 years and more was introduced. The adopted LSA concept in research and operational work is based on quantification of local-regional scale biogeophysical cycling (for territory of Bulgaria) at two different land cover types. A lot of biogeophysical indexes have been developed on the bases of SVAT modelling outputs or are inferred from satellite information and they both are introduced in operational mode (or applied as research tools). In this study, the approach adopted includes the combined use of the already developed local scale biogeophysical indexes on the bases of "SVAT.bg", meteorological indexes bases of space-time resolution of meteorological Meteosat Second Generation (MSG) geostationary satellites, as well as the application of new blended parameters between satellite products and ground observations from meteorological network. In terms with this, climate-weather extremes in land surface state related to disturbances in energy and water cycles, as well as some disturbances in terrestrial carbon cycling are studied on the bases of the following operationally inferred and applied quantitative characteristics:

- Index of site-scale Soil Moisture Availability (SMA) to different root zone depths, scaled by a 6-level threshold scheme and visualised by colour coded maps (SMAI), developed on the basis of "SVAT.bg" model outputs [3];
- Specialized meteorological SMAI Index with indicated effective rainfall or flood producing rainfall quantities. This Index is visualised by colour-coded maps and updated daily for wheat field land cover (LC) and run each 12 hour per day at grass LC;
- Land surface state (and vegetation water stress) characteristics on the basis of MSG SEVIRI data: Radiative skin temperature according to the LSASAF Land Surface Temperature (LST) product (http://landsaf.meteo.pt) and the temperature difference between LSA SAF LST and air temperature at 2 m height measured at synoptic stations (Tair). The temperature difference is constructed between the 5x5 pixels mean MSG LST values for the pixels containing corresponding synoptic station and corresponding Tair measured at this site. The CLC200 vegetation types classification is used;
- MSG satellite products for assessing air humidity: RGB DUST product and MPEF Total Perceptible Water (TPW) product;
- Colour enhanced IR images of MSG are used to depict the convective cloud systems;
- Carbon-equivalent emissions from vegetation fires according to the LSA SAF SAF Fire Radiative Power (FRP) product (derived every 15 min at the native SEVIRI pixel resolution). Biomass burning effects related to forest fuel moistening (depending on climate, fuel type and availability) of 2011 are assessed applying the Plant Functional Types (PFTs) concept according to a regional bioclimatic classification scheme [4].

WEATHER-CLIMATE EXTREMES IN LAND SURFACE STATE. CASE STUDIES AS EXAMPLES

Soil moisture availability to vegetation land cover is an important variable for evaluating vegetation transpiration, a key factor in models of ecosystem and carbon cycle processes, energy and water budgets of crop canopies, as well as a basic parameter in mesoscale atmospheric circulation models and forecasting systems. SMA being the main determinant of plant systems development, at the same time might serve as information source for "warnings" for environmental constrains.

The main limitation of its use is the lack of ground observations of key variables such as soil moisture or evapotranspiration. Approaches that allow obtaining indirect estimates of relevant land surface parameters such as soil moisture or evapotranspiration are very promising and could significantly advanced research in this field. In our work, different types of numerical schemes for studying LSPs and their extremes are applied and discussed below towards: their physical meaning and applicapability in detection and monitoring of extreme meteorological phenomena on land as well as requirements and capabilities of improving satellite applications for eastern Mediterranean in parallel to regional modelling in the scope of the current LSA SAF data usages.

Land-atmosphere coupling

Soil moisture, terrestrial vegetation, and atmospheric flows are parts of a complex interacting system, characterized by the presence of many feedback mechanisms between the various components. For example, soil moisture anomalies, associated with the lack of precipitation, have been suggested to play a crucial role in the variability of the large-scale water balance [5] and in determining the strength of summer heat waves at continental midlatitudes [6]. Precipitation has a clear impact on soil moisture: large rain events tend to wet the soil. To what extent, though, do land surface moisture and temperature states affect, in turn, the evolution of weather and the generation of precipitation? Such questions lie at the heart of much recent climatological research that addresses questions of land-climate interaction [5]. One of hypotheses in climate models is that the atmosphere responds strongly to anomalies in surface fluxes, which in turn respond to anomalies in land surface state, where term “land surface” refers to the combination of the vegetation canopy, the soil-atmosphere interface, and the top meters of the soil.

Soil-vegetation-atmosphere feedbacks are particularly important in water-limited ecosystems, where water is the main factor controlling vegetation growth. Through evapotranspiration, vegetation determines the flux of moisture from the soil to the atmosphere, i.e. the surface moisture flux. This can have significant effect on the hydrologic cycle, especially in regions where local precipitation recycling plays a relevant role such as continental Europe during summer. Despite the apparent association between soil moisture feedbacks and precipitation variability [7,8] the mechanisms that maintain or amplify drought are still not well understood.

Drought on the land surface

Drought is a part of the natural climate variability and therefore can be observed in all climate regimes. It is one of the most important natural disasters in Mediterranean, considered by many to be the most complex but least understood of all natural hazards, making it difficult to predict and monitor. One of the major problems in a drought investigation is its definition, which often depends on the user and on the geographical region in question (e.g. between tropical and arid climates) and this variety makes a single global definition for drought nearly impossible [9]. There are three universally recognized physically based forms of drought: meteorological, hydrological and agricultural. Meteorological drought is measured by a shortage of precipitation, hydrological drought is measured through a deficiency in the water supply relating to reservoir storage and streamflow, and agricultural drought is measured by a shortage in water available for plant growth or sufficient soil moisture to replace evapotranspirative loss.

Agricultural drought as a result of biogeophysical cycling. Although all types of droughts originate from a precipitation deficiency, it is insufficient to monitor solely this parameter to assess severity and resultant impacts. Dryness or absence of rain is not enough to constitute a drought. Physiological and physical signals of terrestrial vegetation water stress are important to be considered and this calls for an interdisciplinary approach in studying drought in the context of geophysical processes. In the Climate Prediction Center’s (CPC) percentile scheme, drought is defined as the number of consecutive days where a measured quantity (soil moisture or precipitation) is below a threshold [10] and classified by severity.

In accordance with all these knowledge, in our work drought on the land (i.e. agricultural drought) is characterized by two types of indexes. First, an original physically based SMA threshold scheme (comprising “dry”-, “wet”-anomalies and “optimal” conditions) with capabilities to reflect specific climate-soil environment for Bulgaria has been developed [3]. It is scaling soil moisture available to specific vegetation type accounting for the soil water capacity defined by maximum moisture content of capillaries in equilibrium with the force of gravity that is the field moisture capacity and the minimal of soil moisture that plant requires not to wilt are distinguished. Defining “dry”-“wet” conditions on land surface in this manner

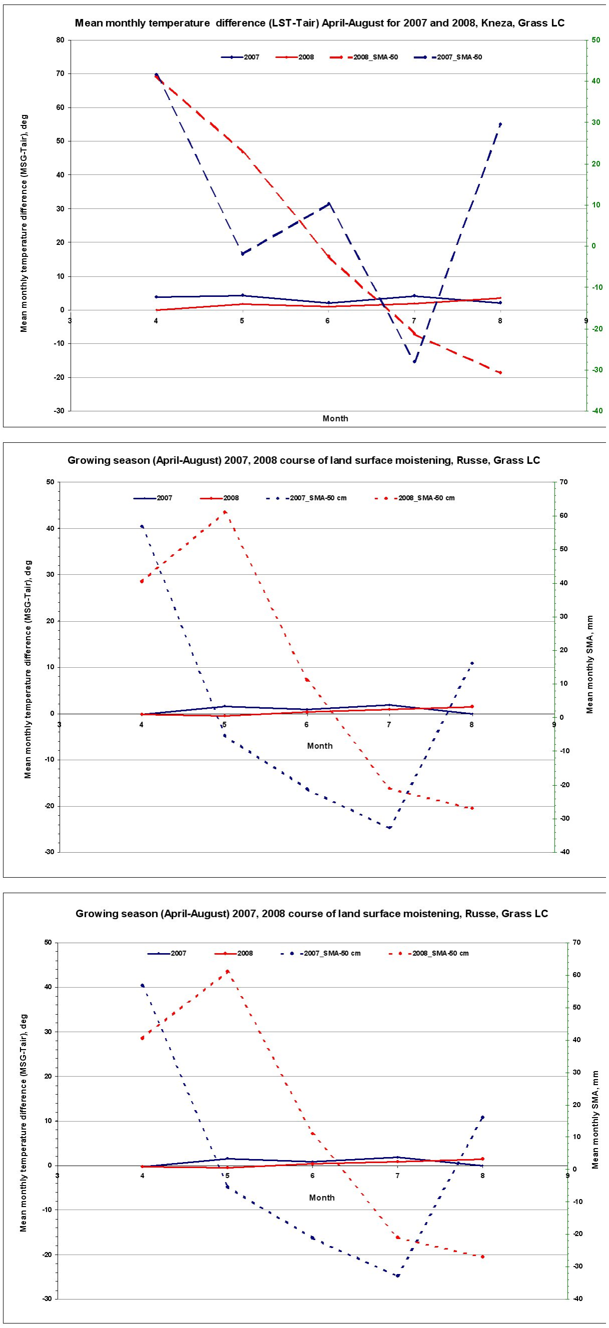


Fig. 1. Land surface moistening conditions (grass LC) derived by mean monthly values of: SMAI (dashed) and temperature difference between MSG LST and Tair (solid) for the (April-August) period of the 2007 (red) and 2008 (blue) for: (upper) central-north (Kneza), (middle) north-eastern (Russe), (lower) southern (Plovdiv) parts of Bulgaria.

eliminates biases between models, observations and climate, and provides a physical, consistent method of drought-overmoistening persistence and strength quantification at different climates and soils. It is also possible drought characteristic of interest: drought severity, magnitude, frequency, persistence or spatial extent to be derived. Second, the surface soil moisture dynamics is characterized in terms of the radiative skin temperature, as derived by the LSA SAF LST product on the basis of MSG information. LST is one of the key parameters in the physics of land surface processes on regional and global scales as it is involved in the processes of energy and water exchange with the atmosphere and its space variability is modulated by surface properties (like vegetation density and soil moisture).

As approximation of land surface moistening conditions, the temperature difference between LSA SAF LST (digital values at MSG pixel resolution) and Tair at synoptic stations measurements has been introduced. The reliability of this approach has been initially studied for selected periods of heat waves and “dry-optimal” land cover states for 2007 and 2012 [11]. 1200 UTC values of the temperature difference were used and compared with site-scale SMA assessment based on operational run of a 1D site-scale Soil-Vegetation-Atmosphere-Transfer “SVAT.bg” model to assess drought and pre-fire conditions. The mean monthly values of both indexes characterizing soil moistening for the (April-August) growing season periods of 2007 and 2008 (at grass LC) are depicted in Fig. 1. The trends in SMAI and the (LST-Tair) difference for three different climate-soil type environment are examined and compared for consistency. Although some specificity for each region, a similar trend of moistening conditions during the growing season for north-west (Kneza), north-eastern (Russe) and southern (Plovdiv) parts of Bulgaria are derived: more dry conditions for 2007, steadily depleted soil moisture according to SMAI in parallel to an increase of the temperature difference especially in cases of strong heat waves (like July of 2007). After precipitations (if any) this is reflected by a specific increase of SMAI as well as corresponding decrease in (LST-Tair) temperature difference.

Economic effects: agricultural drought and yield reduction. In general, drought in crop vegetation is defined as a stage when the soil moisture is not sufficient to meet the evapotranspiration demands of the plants. It is also well known that there will be drought for crops even though there is no meteorological drought by the definition. Thus, drought for crops is related not only with quantum of rainfall but also related to its distribution. The agricultural drought has several specificities like soil type, crop, crop variety, crop duration, time of occurrence (crop stage), quantity of deficiency, duration of deficiency, etc. Thus agricultural drought analyses often is restricted to a specific crop and specific location and also for a specific soil. For example, a given amount of rainfall may result in water stress conditions in light soils but not in heavy soils. Similarly, a given amount of rainfall may result in drought conditions in upland (wheat) but not in lowland (wheat).

Therefore, it is necessary to understand the concept of drought and assess the impact based on the specifities that exist in that area. For assessing drought it should be considered that growth, development and productivity of agroecosystems are strongly dependent on their functional coupling with the environment via biogeophysical and biogeochemical functional relations and feed back mechanisms. Knowledge about mass- and energy- exchange with the environment is possible after the energetic aspects of agroecosystem functioning are considered. Energetic modelling of exchange processes are here performed on the bases of thermodynamic description of agroecosystems functioning as open thermodynamic systems.

A conceptual thermodynamic approach for quantitative description of the energy flow conversions in living organisms, motivated and referred to as “surface-boundary approach” (SBA) in biothermodynamics [12] is here applied. From SBA viewpoint the analytical description of intensity-efficiency of energy conversions at a molecular level are quantified by applying linear irreversible thermodynamic of steady-state to the boundary surface between canopy leaves-environment. For quantification of specific ecosystem-site capacity to utilize the solar energy into biochemical energy and related growth response, the quantification of accompanying energetic looses (not involved in biochemical energy) is proposed. From a thermodynamic point of view these are characterized by the entropy production (or function of dissipation, Φ) in the main photosynthetic apparatus (i.e. function of dissipation, Φ) [12]. Φ quantified as a sum of the entropy produced during the heat- and the water- exchange between leaves and environment (the first and the second terms respectively of Eq. (1):

$$\Phi = T\frac{\triangle S}{\triangle t} = \Phi_H + \Phi_E = \frac{H \triangle T}{T \triangle t} + LE\frac{\triangle q}{\triangle t} \qquad (1)$$

where $\triangle S/\triangle t$ – the entropy production rate; E – evapotranspiration rate; H – leaf-air heat exchange rate; T – mean leaf-air absolute temperature; $\triangle T$– leaf-air temperature difference; $\triangle q = (q_s - q)$– the difference between specific air humidity at the transpiring leaf level and the surrounding air, respectively; q_s– specific humidity of saturated water vapour at the leaf surface at corresponding leaf temperature; L– latent heat of vaporization of water.

The entropy production in canopy leaves ($\Phi = T \triangle S/\triangle t$) is introduced as a complex biophysical state parameter and can reflect the environmental (climate-weather) resources and vegetation capacity to accumulate solar energy in biochemical energy (responsible for growth and yield production). This is a complex indicator of hydrothermal environmental conditions and the state of main photosynthetic apparatus (leaves) during the growing season. This biophysical state parameter is a function of meteorological parameters and soil hydro-physical properties, and thus can reflect the environmental (climate-weather) resources and vegetation capacity to accumulate solar energy in biochemical energy (responsible for growth and yield production).

Applying this approach, the relationship between winter wheat yield and climate-weather has been investigated for selected climate/soil conditions of north Bulgaria (referring the region of Russe from NIMH agrometeorological network) and of south Bulgaria (referring the region of Plovdiv). Drought occurrence during critical phenological phases affecting yield production is quantified by the entropy production for these periods. Φ is calculated for six growing seasons (2007-2012) according to Eq. (1) (using parameters derived from “SVAT.bg” model outputs) and compared with corresponding wheat yield production.

It is found a strong relation between accumulated energetic looses quantified by entropy production in canopy leaves and winter wheat yield, left plot of Fig. 2(left). for north-south- regions in Bulgaria. It is found that drought increases the entropy production after Eq. (1) and decreases the efficiency of metabolic processes and related yield production for both stations. For example, mean temperature difference in “dry May” of 2007 for region Russe is significantly higher than this in 2011 (6.93 vs. 3.45°C respectively) that corresponds to the lower yield observed (261/600 kg/dk correspondingly).

In addition, the temperature difference (LSA SAF LST-Tair) is applied as an approximation of the Φ values. In order to illustrate its applicability as a climatic

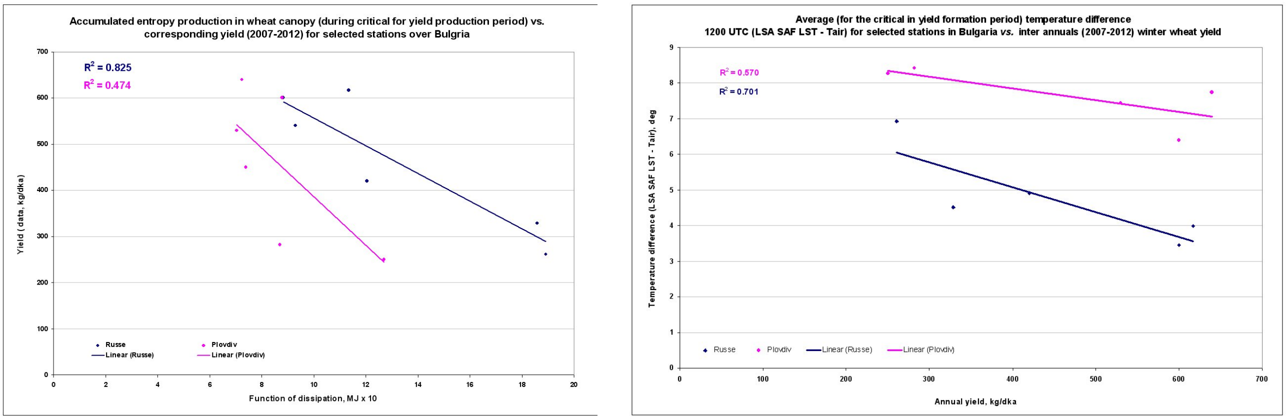


Fig. 2. Left: Comparison between dissipated energy and annual wheat yields (2007-2012) for Russe (blue) and Plovdiv (magenta). Right: Correspondence between mean inter-annual (MSG LST-Tair) difference and annual wheat (2007-2012) yields for Russe (blue) and Plovdiv (magenta).

index for characterizing bioenergetic resources, its relation to yield production is presented in right plot of Fig. 2(right).

These results show that drought effect might be assessed by a single complex index introduced by the entropy production, adequately reflecting the bioenergetic growth capacity of soil-agroecosystem system at specific climate-weather-soil-stage of crop development. Also (LST-Tair) might be a roughly approximation of climatic resources.

Environmental and security effects: Regional spatial distribution of vegetation fires as determined from geostationary satellite observations. Although humans are often the primary cause for fire occurrence, fuel types, moisture, and distribution vertically and horizontally, are very important for fire ignition and spread. Fuel moisture couples fire to climate as the fuel loads accumulate according to forest structure and composition at the specific climate conditions. Accounting this, the relation of climate, fire regimes and biomass burning effects across a range of environmental conditions and vegetation types on a regional scale is examined. To derive the forest fire regimes and link fire activity to specific fuel moistening/load (depending on climate, fuel type and availability), the Plant Functional Types (PFTs) concept is applied. Forest Functional Types FFTs definition according to a Bulgarian static equilibrium scheme for regional bioclimate classification [4] is explored in a comparative analyses with LSA SAF FRP product behaviour. The study is performed for 2011 having a "moderate" fire activity and referred to the region of SE-S Bulgaria. Three FFTs are distinguished and compared: FFT1 (Xeromesophytes, broadleaved in the Lower Forest Belt); FFT2 (Xerophytes, open deciduous, shrubs in Lower Forest Belt); FFT3 (Native coniferous, evergreen vegetation from Mid Forest Belt). The differences (and trends) in fuel moistening /and fire activity of each FFT during vegetation are evaluated on the basis of daily 0600 UTC LSA SAF LST digital values inferred at MSG pixel resolution for the growing season May-September of 2011 (left plot of Fig. 3), and by the total Carbon-equivalent emitted from biomass burning (right plot of Fig. 3). As can be seen, deciduous forests and shrubs FFT1 and FFT2 have higher skin temperature than these of coniferous from the Mid Forest Belt, FFT3. FFT2 composed predominantly by native dry oak stands and shrubs, are the most dry and fire prone areas confirmed also by the total number of MSG registered thermal anomalies (182 fire pixel detected) and highest Carbon-eq. released (right plot of Fig. 3). FFT3, composed predominantly by native coniferous stands at lower evaporative demands implying more wet environment are characterized by lower fire activity (30 fire pixel detected) that corresponds to lower climatic forcing (see right plot of Fig. 3). FFT1, composed predominantly by xero-mesophytes native deciduous oak stands, are the less fire prone area although the high evaporative demands (similar to FFT2) because of more precipitations, and thus providing the lowest climatic forcing (right plot of Fig. 3). The results indicate that the used LSA SAF parameters in the context of applied concept can be further exploited for characterizing climate-forest fire relations.

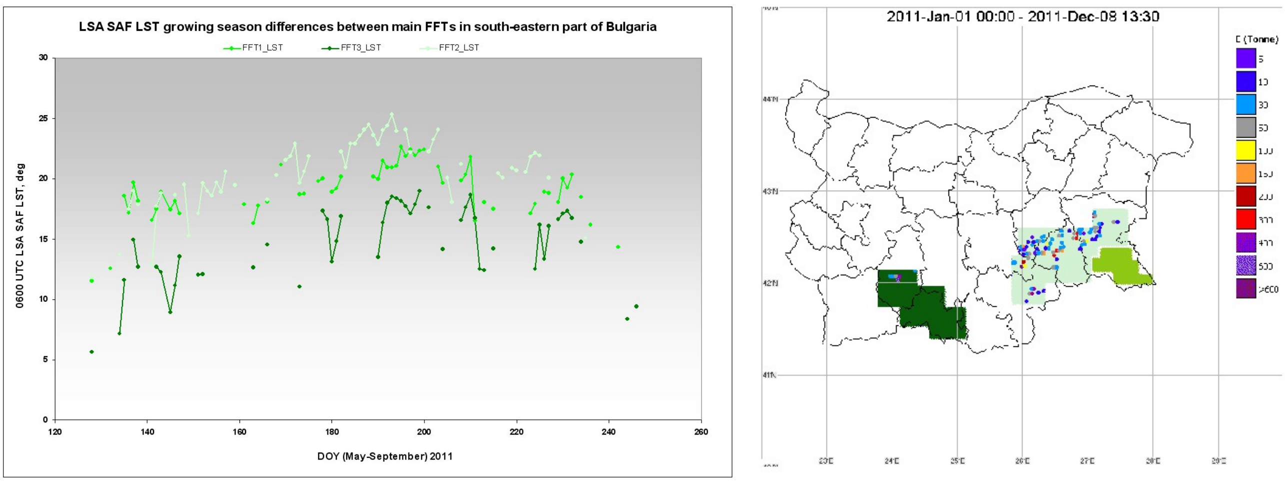


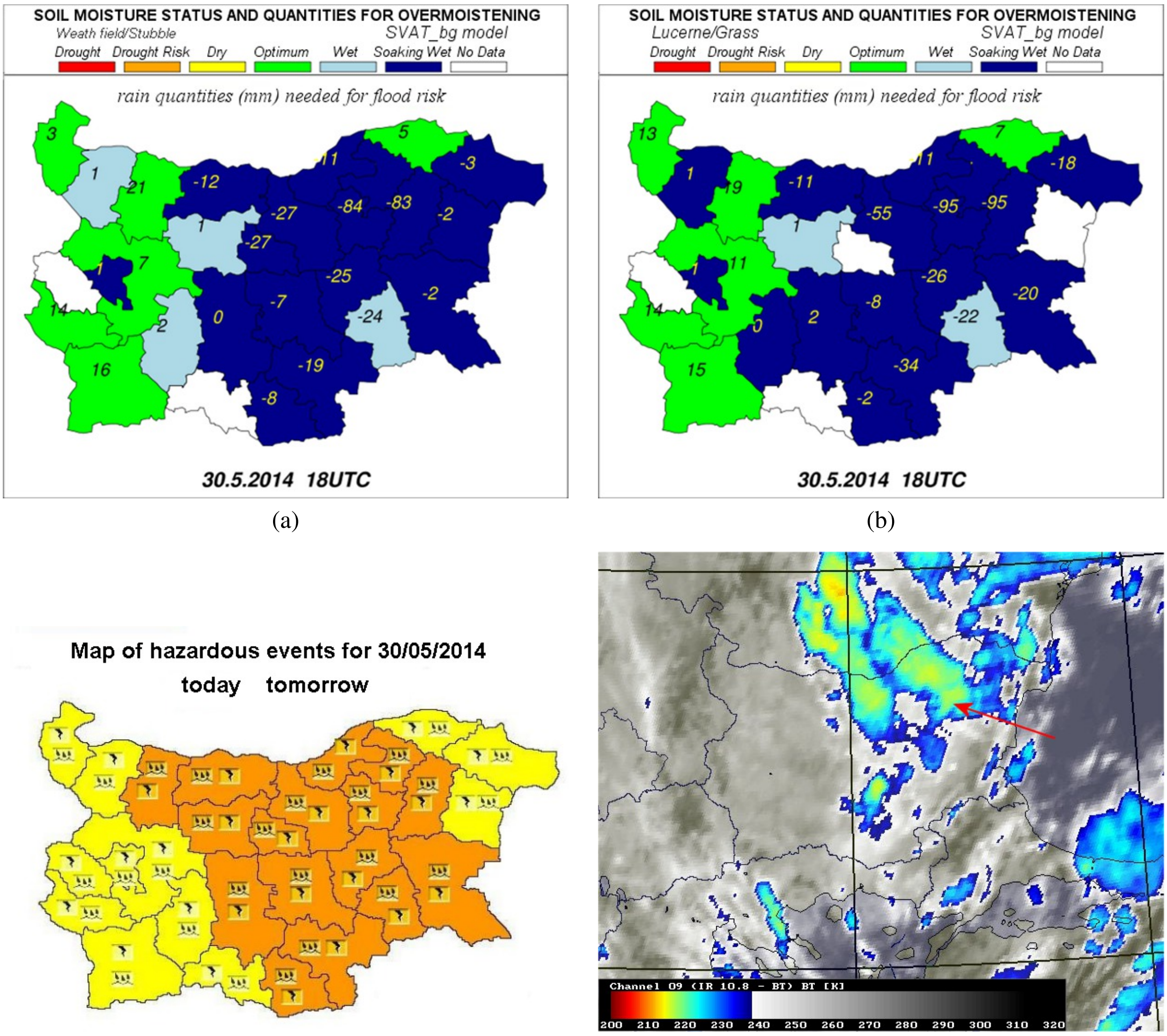
Fig. 3. Climate-fire relations at different native Forest Functional Types /FFTs/ in SE-S Bulgaria, May-September 2011. Left plot: The course of skin temperature 0600 UTC LSA SAF LST in stations representative for each FFT; Right plot: Carbon-eq. emitted by biomass burning MSG detections calculated on the bases of LSA SAF FRP product. FFT1 – bright green, FFT2 – light green, FFT3 – dark green.

Soil overmoistening and risk of flood

From operational perspective, besides the forecast of space-time structure of the rainfall, the initial soil water content is an important parameter within flash-flood predictions. Information about SM content from operational numerical weather prediction (NWP) models could be used for weather forecasting. However, in most operational atmospheric models the simulated prognostic variable "soil moisture" does not have an unambiguous meaning [13]. It is a strongly model-specific quantity with a dynamic range defined by the specific model formulation and the soil parameters such as porosity, hydraulic conductivity, wilting point, and layer depth, which are not known at the NWP model spatial and temporal scales.

Based on our knowledge about SMA after modelling of land-atmosphere interactions and accounting for local climate/soil for Bulgaria, a specialized index intended as a diagnostic tool for operational forecasting purposes of extreme weather events has been developed [3]. It is generated via visualized colour-coded maps indicating SMA in the region of each synoptic station (covering the main administrative regions of Bulgaria) in combination with a numerical part, which indicates the required flood-producing rainfall quantities (specific for each region and environmental conditions). In case of overmoistening conditions, the numerical part denotes the rainfall excess above the soil saturation moisture content. SMAI is generated for two land cover types: for wheatland cover it is updated daily and for grassland cover it is run twice per day. Actually the numerical part indicates the effective rainfall of any given region and time, which is considered as 100 per cent effective while computing the water balance at the specific water holding capacity of different soils. The utility of this approach in combination with NWP rainfall predictions was tested for diagnosis and prediction for two case studies of severe weather produced by deep convection and a rapid cyclogenesis developed at initial "dry"/"wet" soil moisture anomalies, respectively. In this study, this concept is further approved introducing an additional index for diagnosing pre-convective environment (paragraph 3.4.). Two other cases of flood-producing convective developments associated with different types of large-scale circulation patterns are considered below to illustrate the utility of the approach.

In the first case, deep convection developed over Bulgaria on 30 May 2014 in an environment of upper-level dynamic forcing through vorticity advection from north-east in strong blocking regime. The right plot of Fig. 4 (d) shows a satellite image in IR channel of MSG with cloud tops colder than -30°C colour enhanced. The process developed in the leading diffluent part of the upper level vorticity feature producing deep convective clouds with cloud top temperature less than -50°C (yellow). Thunderstorms with



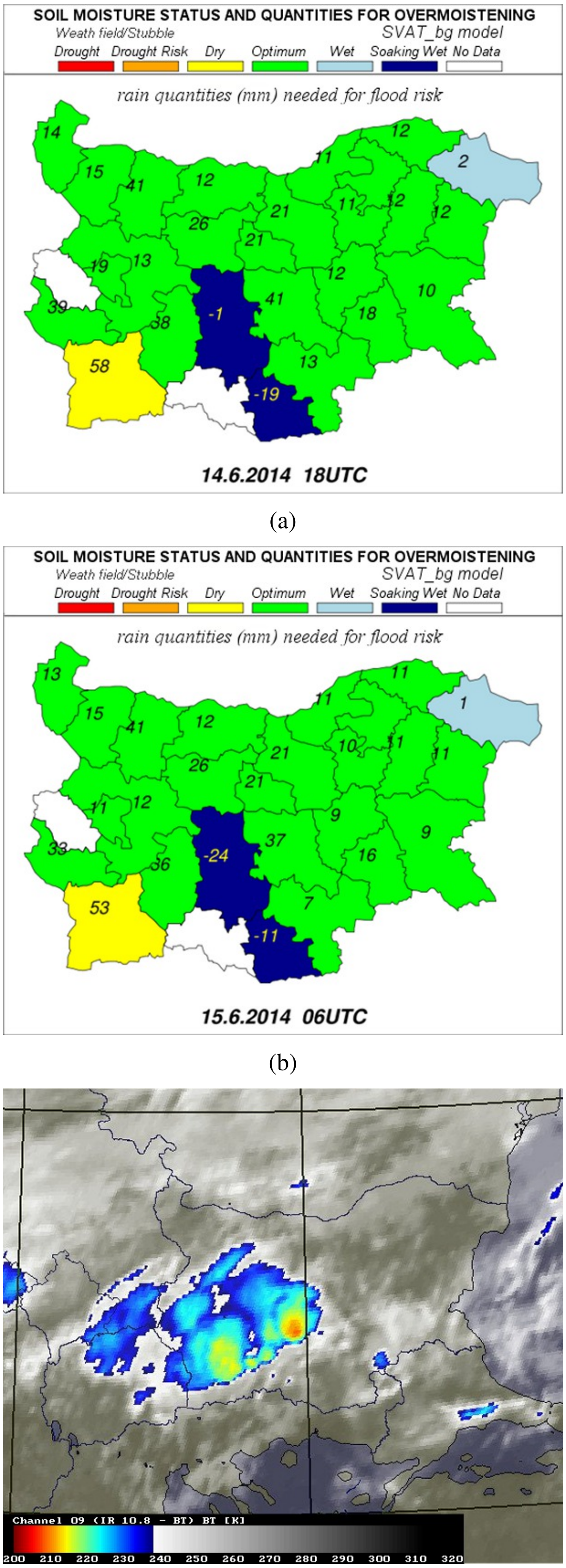
(a) (b)

(c) (d)

Fig. 4. Analyses of 30 May 2014 case: (a) Soil moistening at grass land cover according to SMAI, (b) Soil moistening at wheat field according to SMAI, (c) Weather severity warning according to Meteo Alarm forecast, (d) Colour enhanced IR image of MSG at 1330 UTC (cloud top temperature below -30°C coloured, ≤ -50°C yellow, ≤ -60°C red.

showers (40-60 l/m^2 precipitation) and hail were predicted for 11 administrative units of Bulgaria as well as for the other 17 regional units with expected rain up to 36 l/m^2). The corresponding operational Meteo Alarm product for Bulgaria with warnings for danger (orange) and potentially danger weather (yellow) is shown on Fig. 4(c).

The analyses of soil moistening reveals an "optimal" soil moistening (green colour) over the most part of the country. More precise analyses for the Shumen region (north-eastern part of Bulgaria) a green colour with 0 mm effective rainfall below overmoistening conditions is observed on 28 May 2014 (here not illustrated). After two consecutive days with precipitations (17.8 mm on 29 May and 96.0 mm on 30 May 2014) soil moisture capacity is full and large negative flood-producing quantities are indicated (for grass land in Fig. 4(a) and wheat field in Fig. 4(b). Based on the NWP guidance and the SVAT model analysis of SMAI, the operational forecast issued at NIMH of Bulgaria indicate probability for heavy rain and floods on 30 May 2014 `http://radar.bg/bg/2014-05-30/article`.



(a)

(b)

(c)

Fig. 5. Analyses of night tine 14-15 June 2014 case: (a) 14 June 2014, 1800 UTC soil moistening at grass land cover according to SMAI, (b) 15 June 2014, 0600 UTC soil moistening at grass land cover according to SMAI, (c) Colour enhanced IR image of MSG, 14 June 2014 2115 UTC (cloud top temperature below -30°C coloured, ≤ -50°C yellow, ≤ -60°C red.

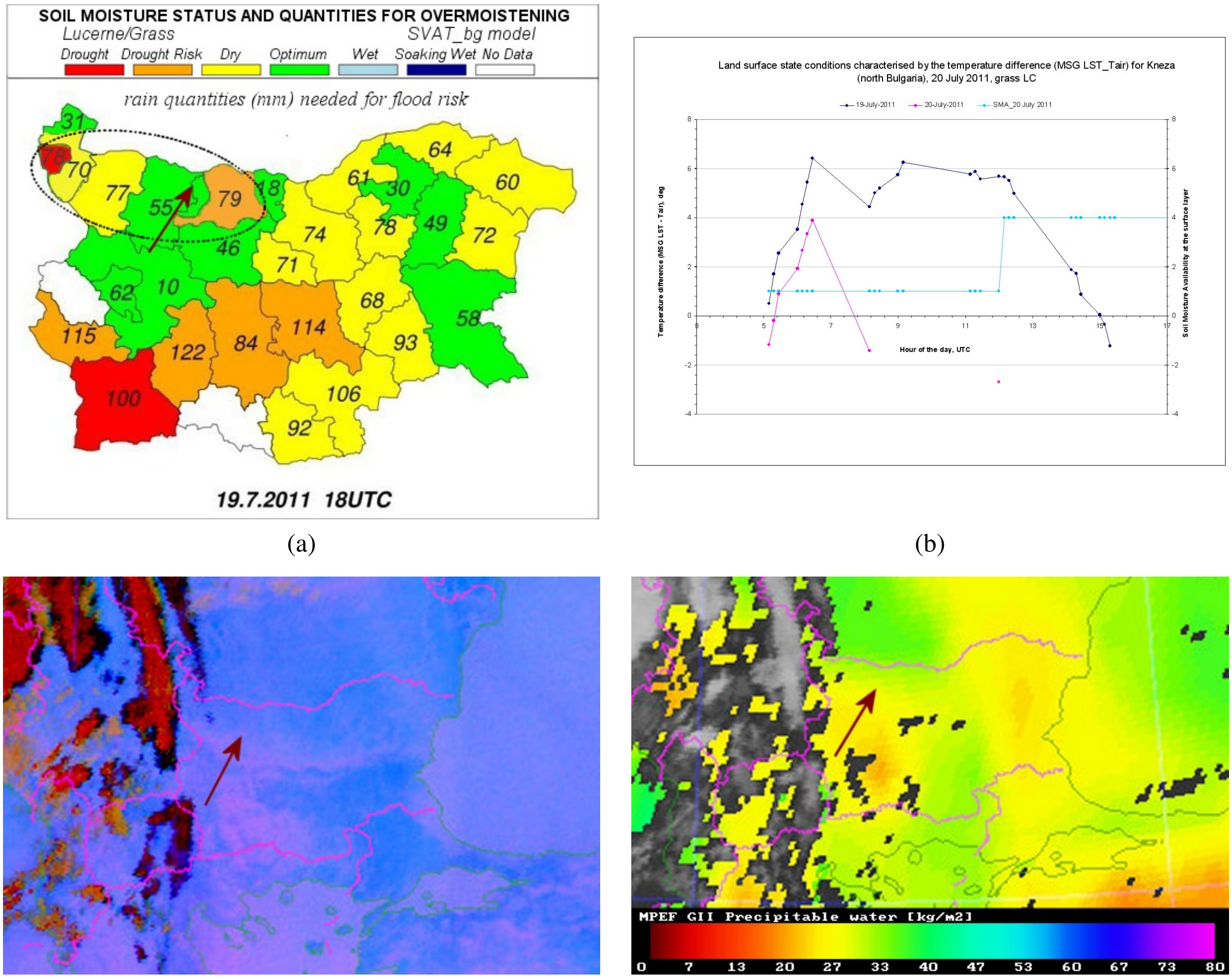
The second case-study is on a local convective development during the night time of 14-15 June 2014 that caused showers in town Plovdiv (south Bulgaria). This process is developed in a deformation zone of the upper-level flow. The colour enhanced IR image (Fig. 5 c) shows the existence of an overshooting top of the convective cloud system (red, less than – 60°C) that is indicative for severe weather.

Soil moistening analyses on 14 June 2014 at 0600 UTS shows “optimal” soil moistening (green colour with 4 mm effective rainfall below overmoistening conditions, here not illustrated). On 14 June at 18 UTC 6 mm precipitations are measured and this caused a slight overmoistening conditions according to SMAI map (Fig. 5(a), the left plot). After 24 mm additional rain quantities at 0600 UTC of 15 June are accounted, the midnight shower produced local overmoistening in Plovdiv and flooding (Fig. 5(b), the middle plot). However it was difficult to forecast such a local event `http://flip.bg/cluster/e7a4a0132ef30d318a64eea4d61c94dfskip=140`.

Convective storms: land surface effects

Soil moisture influences a number of processes in land-atmosphere interactions, some of which concern the initiation of convection, the influence on the surface temperature and the availability of moisture in the planetary boundary layer [14].

The convective storm on 20 July 2011, analysed in our preceding work [3] is here further studied using additional characteristics of land surface state and air moistening on the basis of MSG information. SMAI analysis shows that the pre-convection process developed at extremely dry low-level conditions. Soil moisture has been reduced to the wilting point (drought risk, orange/red colour) over the great part of northwestern Bulgaria (within the dashed ellipse zone) a day before the convection storm – the left plot of Fig. 6(a) also see [3] Fig. 4a. As an index of land surface pre-convective environment we introduce for application the radiative temperature on the land



(a) (b)

(c) (d)

Fig. 6. Surface moistening evolution in the area of convective storm development on 20 July 2011 derived by SVAT.bg output: (a) Colour-coded SMAI at grass land cover a day before, (b) daily course of temperature difference between MSG LST and air temperature during the storm (magenta) and a day before (dark blue) along with the SMA level (light blue). MSG satellite products showing air humidity: (c) RGB DUST at 0715 UTC (moist surface air in bluish, dry surface air in reddish) and (d) Total perceptible water at 0715 UTC. The area of convective storm development is indicated by arrows in (a), (c), (d).

surface (as an indicator of energy and water exchange on the land surface) derived through the LSA SAF LST product over Bulgaria. The difference between LST (digital values at MSG pixel resolution) and the air temperature measured at 2 m height from synoptic stations is applied as a diagnostic characterize of the near-surface state. Daily course of the temperature difference (LST-Tair) of cloud free pixels, approximating near-land surface moistening a day before the storm (Fig. 6(b), dark blue) is higher than this during the storm (magenta line). During the storm development (on the afternoon of 20 July 2011) the lowest cloud-free temperature difference of -2.68°C is detected at 1200 UTC, while for the same time slot a day before the temperature difference accounts to 5.69°C. During this "dry" case of convective storm showers (more than 40 mm for 30 min) were reported but in these dry soil conditions (seen in Fig. 6 (a)), floods were not able to occur. The severity of this case was due to damaging wind (maximum wind speed 24 m/s with gusts up to 42 m/s) and large hail (about 5 cm in diameter). 41 mm rain quantities measured at 1800 UTC on 20 July are reflected by the immediate increased SMA (Fig. 6(b), light blue).

As seen by the advanced satellite products the pre-storm environment are characterised by comparatively dry low-level air (more reddish in Dust RGB product on Fig. 6(c)) as well as comparatively lower values of TPW (yellow indication) on Fig. 6(d).

CONCLUSIONS

The investigation of land-atmosphere interactions is a growing interdisciplinary research field offering significant promises for climate research. This paper concentrates on some biophysical, hydrological and biogeochemical aspects of land surface processes on a regional/local scale for the environmental conditions of Bulgaria. Climate-weather extremes and severe meteorological phenomena are studied in relation to associated land surface state anomalies, their regional reveals and regimes. For that purpose, numerous numerical schemes integrating information from LS modelling, MSG observation, standard meteorological observations are introduced and applied.

— A SVAT model driven by standard meteorological observations was used to simulate the spatial variability and temporal evolution of soil moisture for the specific climate/soil environment over the country and used as a source for development meteorological products for assessing land surface states (including "dry", "wet" anomalies) in the operational environment of NIMH. Tuning these site-scale state variables with spatial-temporal MSG information for land and atmosphere moistening conditions, relation between soil moisture and features of deep convection development are analysed. The quality of these simulations are evaluated by real convective storms development;

— The proposed approach for quantification of biogeophysical cycling and its coupling with the biogeochemiocal cycle on a local and regional scale is of importance not only as a fundamental knowledge but has an operational and practical meaning for multifold biosphere and environmental applications: e.g. description and even prediction of economic looses due to agricultural drought effects on yield reduction; development of a regional bioclimatic classification for Bulgaria; assessing regimes of forest fires; defining the most fire-prone forest areas; quantification of possible climate change effects via biomass carbon-equivalent emissions. For each one of these climate-weather driven problems relevant research scheme has been developed and the results are illustrated by cases studies in the paper.

Results are encouraging as a basis for improving knowledge in further studies and operational applications on the bases of the proposed LSA concept in early detection, monitoring and climate services of the numerous climate-weather related meteorological processes and phenomena.

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АНОМАЛИИ В СЪСТОЯНИЕТО НА ЗЕМНАТА ПОВЪРХНОСТ И СВЪРЗАНИ С ТОВА ОПАСНИ МЕТЕОРОЛОГИЧНИ ЯВЛЕНИЯ

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(Резюме)

Докладът представя съвременния опит на Националния Институт по Метеорология и Хидрология (НИМХ-БАН) при анализ на физичното състояние на земната повърхност (като част от климатичната система) формирано на основата на функционалната връзка между енергетичния и водния цикъл. Разглеждат се локални оценки на достъпните за конкретен тип растителна повърхност количества енергия и вода за територията на България и техния принос за формиране на “сухи” и “влажни” аномалии свързани с възникване на опасни метеорологични явления.

Първостепенна задача на работа е разглеждането на типични режими на време-климат, при които състоянието на системата почва-растителност е от значение за формирането на опасни метеорологични явления като: преовлажнение и риск от порои; селскостопанска суша; дефицит в почвеното овлажнение и риск от растителни пожари. За диагноза на състоянието на земната повърхност и негови аномалии се прилага интегрален подход за количествено описание на биогеофизичния цикъл като се отчитат специфичните почвени и климатични условия за страната. Подходът включва съвместно използване на локални метеорологични оценки на оснавата на разработен метеорологичен числен SVAT модел (за описание на енерго- и водо-обмен в системата почва-растителност-атмосфера), информация от метеорологичните геостационарни спътници (MSG) и наземи наблюдения от националната метеорологична мрежа. На тази основа са разработени биогеофизични индекси (индекс за оценка достъпно количество почвена влага; количествена оценка на ефективни валежи; индекс за пожароопасен риск и др.) както и спътникови продукти (за детекция на термични аномалии; радиационна температура на земната повърхност и др.). Продуктите са въведени за оперативно използване в прогностичната среда на НИМХ с цел издаване на предупреждения.

Значението на методологията за регионални оценки на риска от опасни явления свързани с екстремуми на време и климат се илюстрира чрез изследване на примерни реални синоптични ситуации отнасящи се за: засушаването през зимния период на 2014 г. и свързаната с това повишена пожароопасност; дъждовния период през април-май 2014 г. и свързано с това почвено преовлажнение и порои; топлинни вълни и дефицит на почвено овлажнение определящи агрометеорологичната суша през 2007 г.