WATERNET: THE NASA WATER CYCLE SOLUTIONS NETWORK - DANUBIAN REGIONAL APPLICATIONS

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Abstract

WaterNet is a new international network of researchers, stakeholders, and end-users of remote sensing tools that will benefit the water resources management community. This paper provides an overview and it discusses the concept of solutions networks focusing on the WaterNet. It invites Danubian research and applications teams to join our WaterNet network. The NASA Water cycle Solutions Network's goal is to improve and optimize the sustained ability of water cycle researchers, stakeholders, organizations and networks to interact, identify, harness, and extend NASA research results to augment decision support tools and meet national needs. Our team will develop WaterNet by engaging relevant NASA water cycle research resources and community-of-practice organizations, to develop what we term an "actionable database" that can be used to communicate and connect NASA Water cycle research Results (NWRs) towards the improvement of water-related Decision Support Tools (DSTs). Recognizing that the European Commission and European Space Agency have also developed many related Water Research products (EWRs), we seek to learn about these and network with the EU teams to include their information in the WaterNet actionable data base and Community of Practice. We will then develop strategies to connect researchers and decision-makers via innovative communication strategies, improved user access to NASA and EU - Danubian resources, improved water cycle research community appreciation for user requirements, improved policymaker, management and stakeholder knowledge of research and application products, and improved identification of pathways for progress. Finally, we will develop relevant benchmarking and metrics, to understand the network's characteristics, to optimize its performance, and to establish sustainability.

Keywords: *networking, land surface models, remote sensing, hydrologic modelling, mesoscale modeling.*

1 INTRODUCTION

WaterNet is a new international network of researchers, stakeholders, and end-users of remote sensing tools that will benefit the water resources management community. It was established in 2007 to bring together researchers and decision-makers involved in water cycle related work. This paper provides an overview and it discusses the concept of solutions networks focusing on the *WaterNet.* It invites Danubian research and applications teams to join our *WaterNet* network. The NASA Water cycle Solutions Network's goal is to "*improve and optimize the sustained ability of water cycle researchers, stakeholders, organizations and networks to interact, identify, harness, and* *extend NASA, ESA, and related research results to augment decision support tools and meet national and international needs".* Research results are the products of research that have been put in a form that end-users can readily apply in their decision-making processes, tools, models, etc. This paper also provides examples of research results that are readily available to users in the Danubian region with real-time web links to observations, analyses and forecasts of value to various decision-makers. It concludes with a request for Danubian researchers and decision-makers to join our WaterNet Community of Practice (CoP).

Key disciplines of interest

WaterNet addresses the full range of water cycle related disciplines and end-users from hydrology and meteorology to water resource, environmental systems and disaster managers. Figure 1 shows the conceptual flow of information across research disciplines to end-user decisions using the "Integrated System Solutions Approach". Note that this approach integrates new observations from remote sensing through water cycle models that produce water cycle predictions ranging from soil moisture to ocean currents (column 2). These water cycle research results are then input to water cycle decision support tools (DSTs) that use their information to produce decisions of value and benefit to the society and nation. DSTs range from models of agricultural efficiency to disaster management systems and river management daily and monthly time-step models.

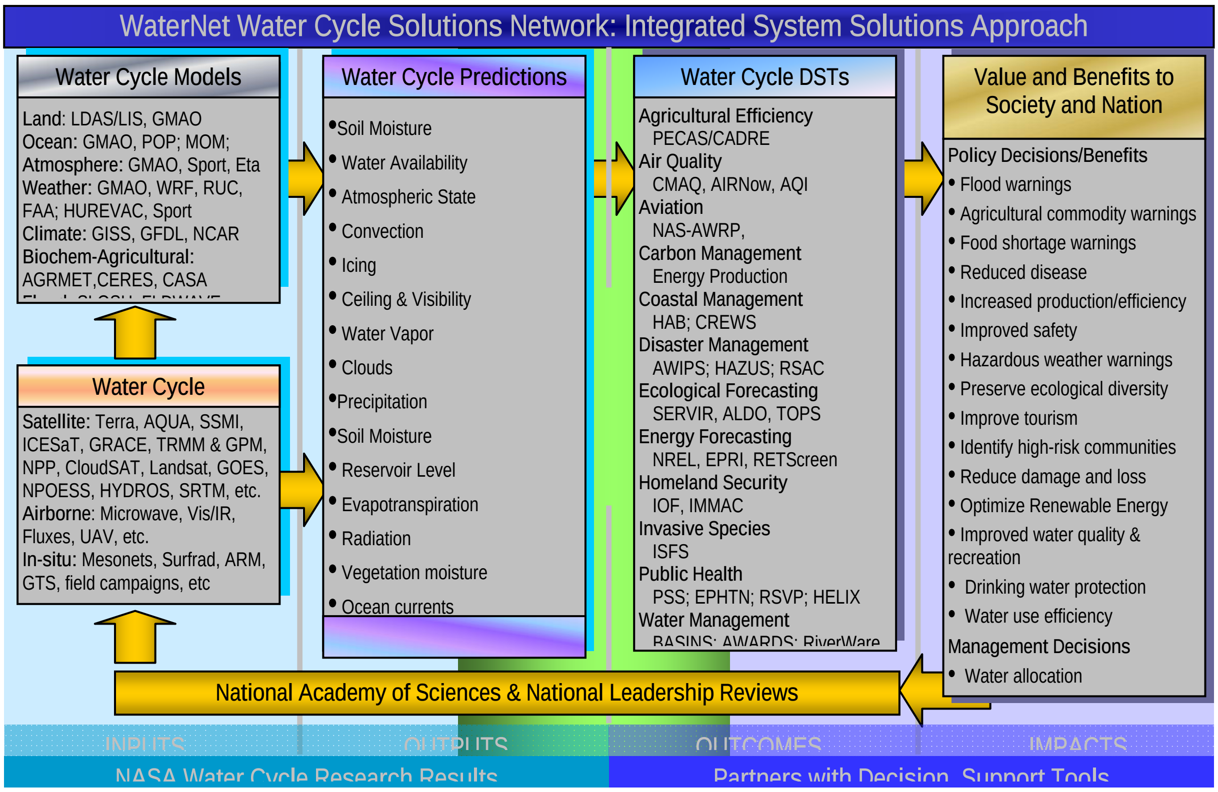

Figure 1. WaterNet Water Cycle Solutions Network: An Integrated System Solution Approach showing the multi-disciplinary nature of WaterNet and anticipated benefits to society.

1.2 Remote sensing observational and Land Surface Modelling capabilities

Remote sensing systems provide much information that may be used to initialize models with observations of precipitation, snow cover, soil moisture, ice shelf sizes, density, etc. Figure 2 shows the range of satellites available and planned from NASA and GEOSS related to the water and energy cycles..

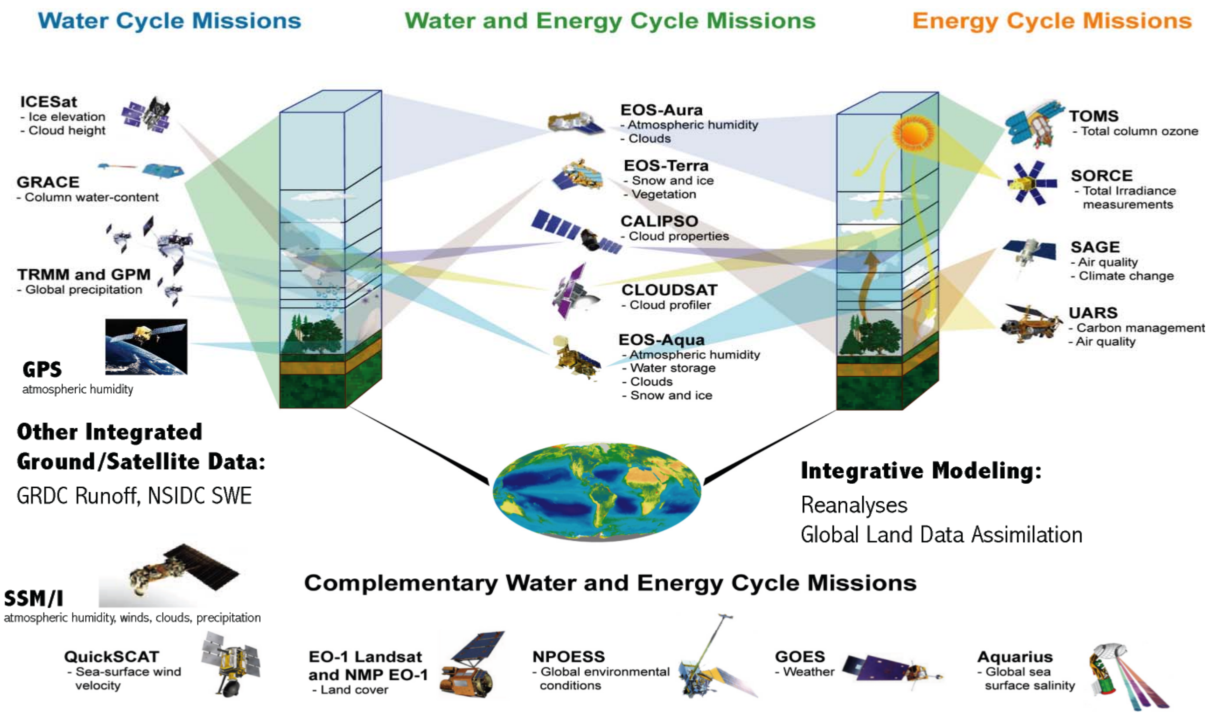

Figure 2. Water and Energy Cycle observation capabilities showing the satellites and the parameters observed and concept of integrative modelling to benefit society.

Data assimilation and modelling are the central focus of NASA's Land Information System which is designed to integrate remote sensing and in situ observations through advanced data assimilation techniques to drive land surface models (LSMs). These LSMs are able to use numerical physical and statistical models of surface hydrology to provide outputs of direct value to decision-makers from drought and water management teams to farmers and flood control emergency managers. Figure 3 shows the primary components of the Land Data Assimilation System (LDAS) and the outputs from Land Surface Models. The LDAS is operational over the United States and runs simulations at a spatial resolution of 1/8 degree (~12 km) to 1 km. It is run routinely to initialize the surface boundary conditions (energy and moisture fluxes) for the numerical weather forecast models of NOAA's National Centers for Environmental Prediction (NCEP). It is part of NASA's Land Information System (LIS) used for a variety of end-users and decision-makers. The Global Land Data Assimilation System (GLDAS) provides information over the Danubian region. Examples are provided in the next section.

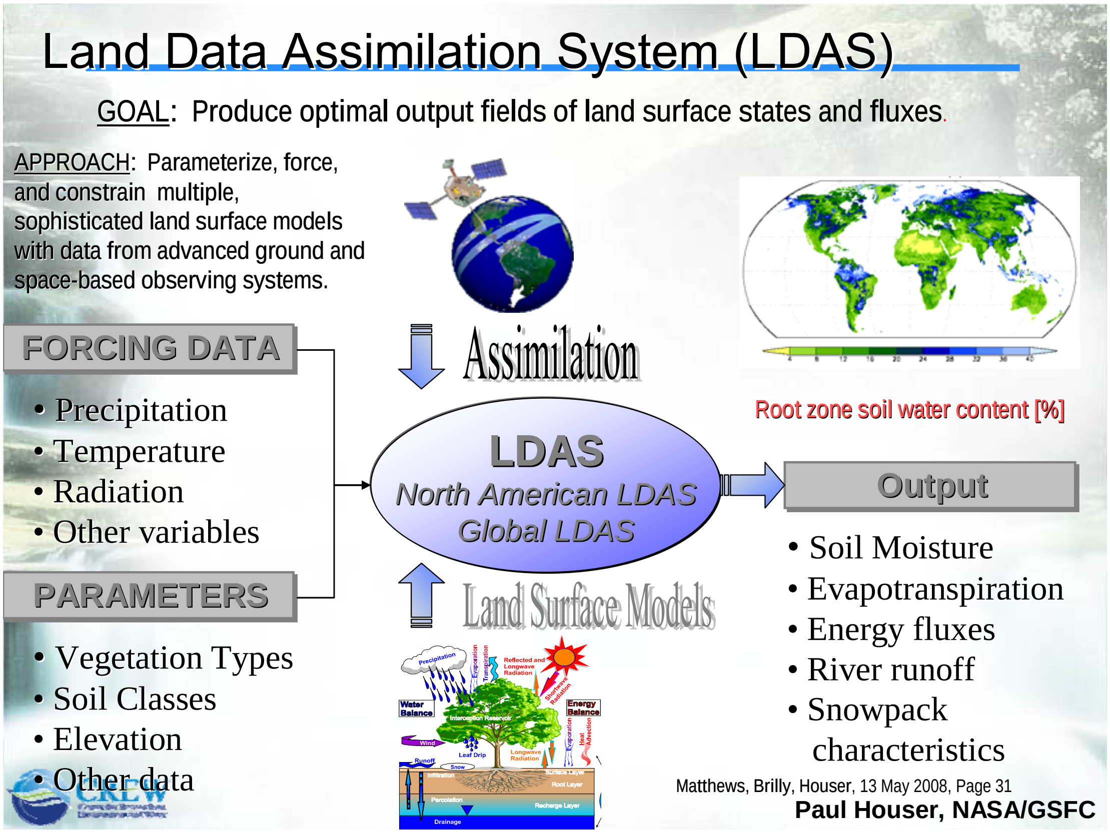

Figure 3. Land Data Assimilation System schematically showing the approach of integrating key forcing data, and parameters to drive land surface models that produce outputs of value to decision-makers.

2 DANUBIAN EXAMPLES OF RESEARCH RESULTS

The Global Land Data Assimilation System (GLDAS) integrates data much like LDAS but covers the globe. It's results are routinely available at 1 and 1/4 degree spacing. GLDAS results in March 2006 and June 2007 over the Danube provide an indication of the type of information available for decision-makers. These research results include Snow Water Equivalent (SWE), Quantitative Precipitation Estimates (QPE), surface soil moisture (Qs) and root zone soil moisture (0 to 10 cm depth average – Qsb). GLDAS analyses were performed using the GRaDS analysis tools.

The area examined by these analyses covers the headwaters to the mouth of the Danube. Figure 4 shows the region using Google Earth and locates points where time series were obtained.

Figure 4. Google Earth view of Danube analysis region used in GLDAS from the headwaters in Germany to the mouth in the Black Sea. Yellow Pins locate the time series inter-comparison points used to demonstrate the time and spatial sensitivity of the analysis.

2.1 Snow Water Equivalent

Snow water equivalent (SWE) analyses provide important information for water and emergency managers who are interested in the water supply and potential for floods in rivers fed by snow melt like the Danube. Figure 5.1 shows the GLDAS 0.25 degree grid spacing analysis on 15 March 2006. Note the maximum over the Alps (200-300 kg/m2) and in Montenegro (300-400 kg/m2). Figure 5.2 shows the melt of SWE by 31 March 2006 smaller areas and magnitude of 200 kg/m2 over Montenegro. Figure 6.1 Shows the time series of spatial sensitivity across the Alps at 46.9 N from Tyrol to South of Salzburg.

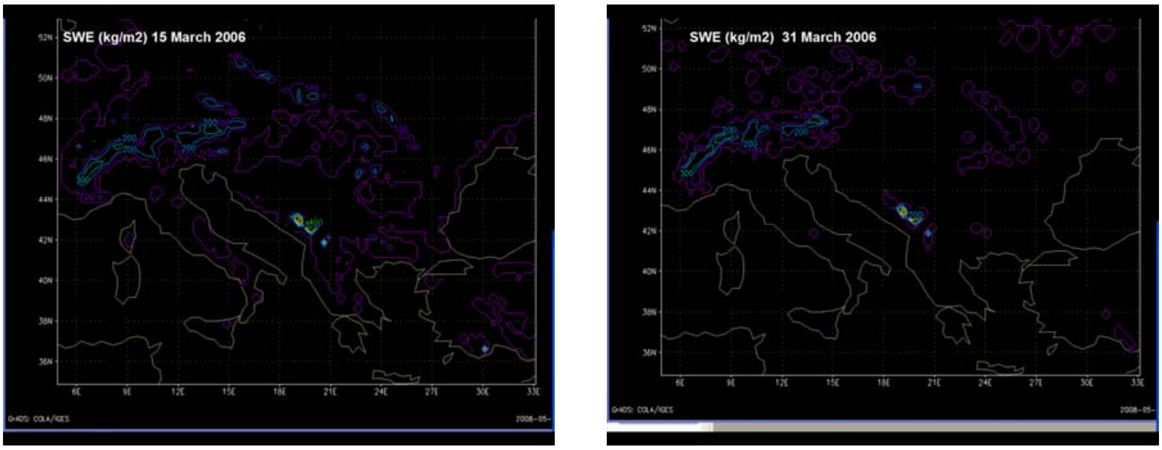

Figure 5.1 and 5.2 showing the area extent and magnitude of snow water equivalent over the Danube on 15 and 31 March 2006 respectively.

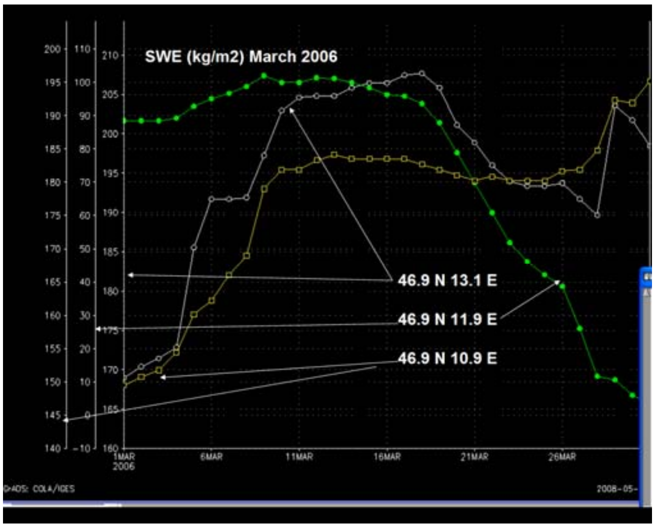

Figure 6. Time series of SWE at 46.9 N from 13.1 to 10.9 E showing the spatial and temporal sensitivity in GLDAS 0.25 degree analyses.

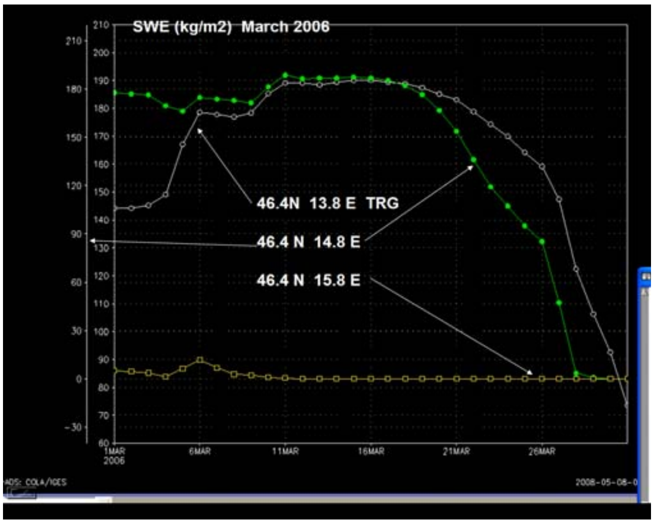

Figure 7. SWE time series at 46.4 N from Triglav in the Julian Alps to Ptuj on the Drava in the Panonian Plain dropping from 190 cm to 12 cm respectively, this is a plausible result.

Surface and subsurface runoff from GLDAS at Budapest show typical patterns of sensitivity in figure 8. The surface runoff is a direct response to precipitation and snow melt; however, the sub surface runoff appears as an aggregate effect of the surface and ground water flows.

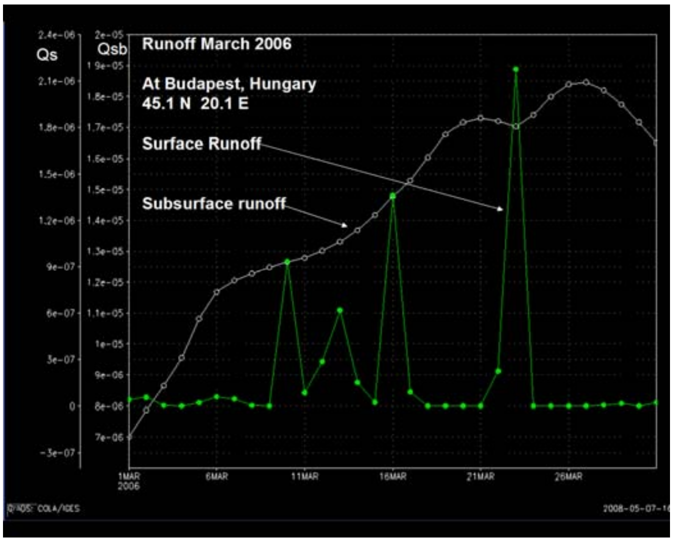

Figure 8. March 2008 time series of runoff at Budapest for surface and sub-surface runoff.

2.2 Precipitation analyses from remote sensing satellite data – TRMM-GPM

Analyses of the June 2007 drought conditions are shown for surface and 0-10 cm deep averaged soil moisture. These clearly show the convective spatial variability and areas of very dry conditions over the region.

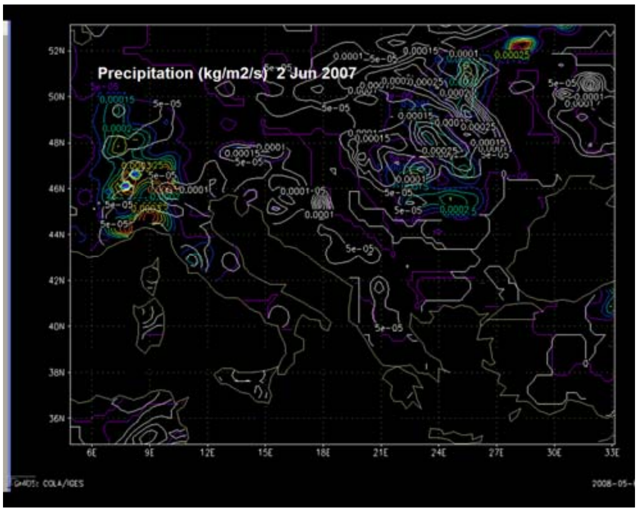

Figure 9. Precipitation pattern on 2 June 2007, showing a maximum over the Julian Alps and dry conditions in Greece where fires were a clear danger in 2007**.**

By 30 June the conditions through out the area had dried considerably as shown in the 30 June 2007 precipitation (fig. 10) and soil moisture (fig 11) analyses.

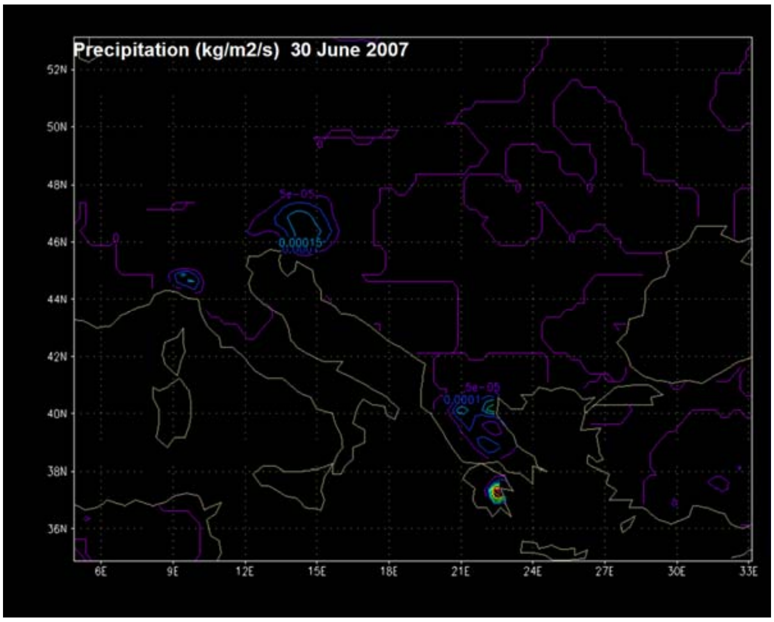

Figure 10. Precipitation from GLDAS on 30 June 2007 showing the very dry conditions in the Danube mouth region.

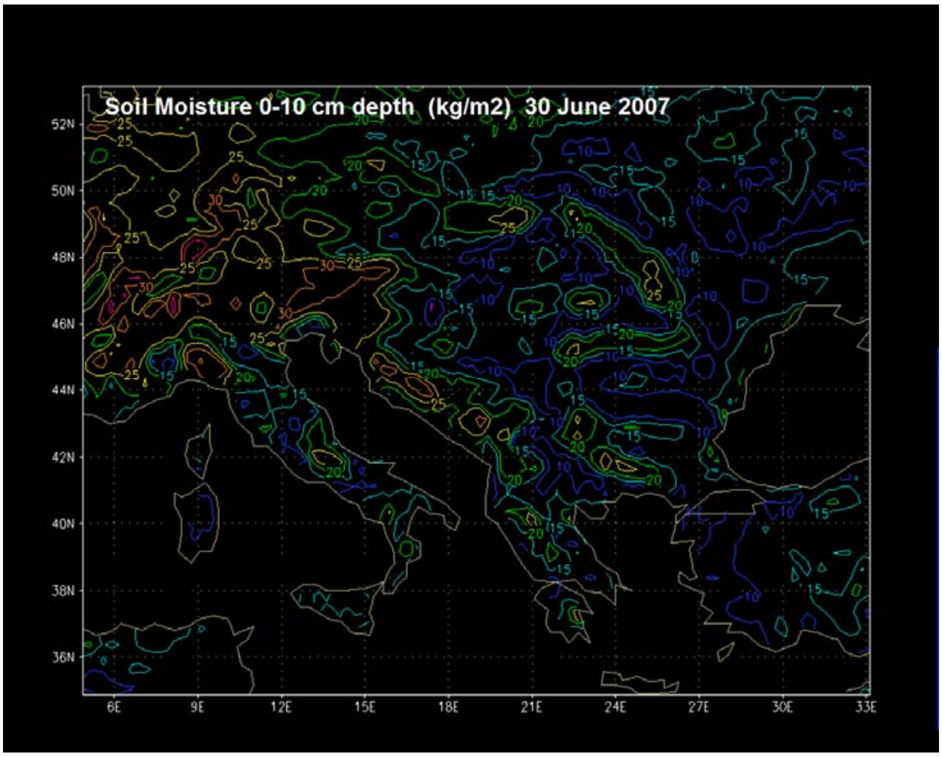

Figure 11. Soil moisture average from 0-10 cm depth on 30 June 2007 showing wet conditions in the Alps 25-30 kg/m2 vs dry 10-15 kg/m2 over Romania, Bulgaria and Greece.

Time series of precipitation and soil moisture clearly show the convective nature of precipitation and the integrating factors of soil moisture and the sensitivity of GLDAS to summer variations in soil moisture. Figure 12 shows the highest values over the Julian and Italian Alps with very dry conditions in Albania from 15-30 June. Differences between Budapest and Ljubljana also properly reflect the drier conditions in Budapest shown in figure 13.

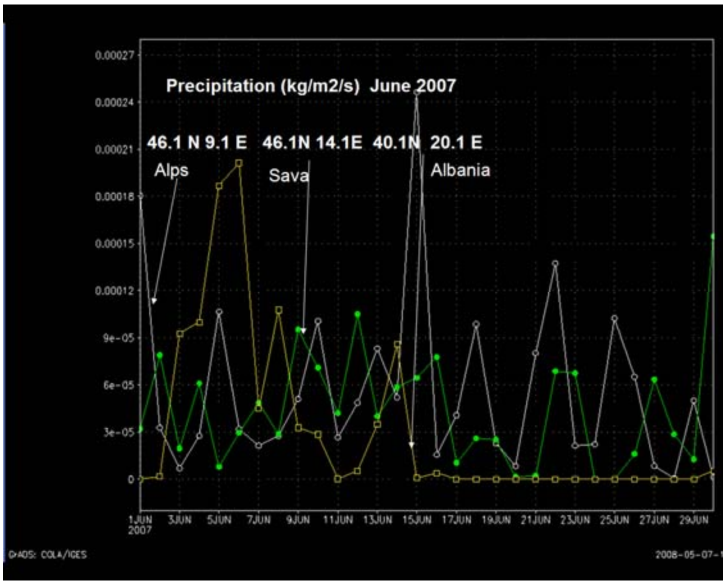

Figure 12. Time series of precipitation showing spatial and temporal variability from the Italian Alps to the Julian Alps and Albania from the GLDAS in June 2007 drought conditions.

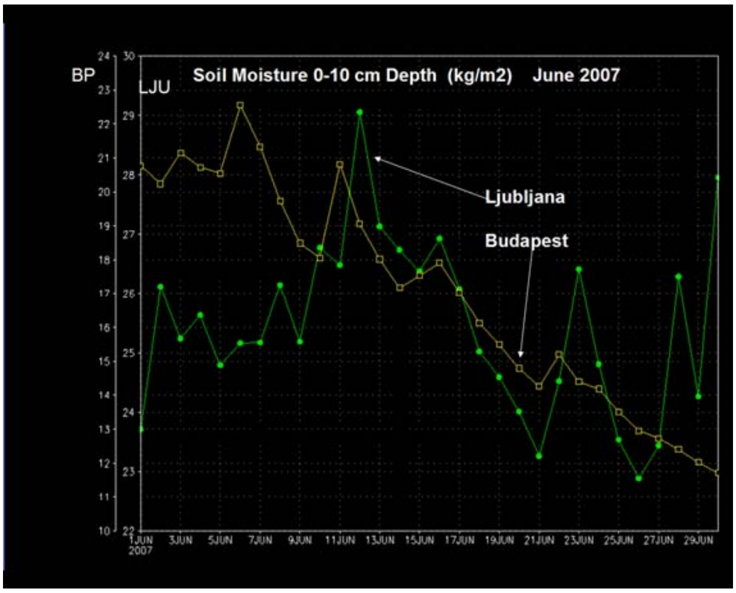

Figure 13. Time-series of root zone soil moisture (0-10 cm depth) showing differences predicted for Ljubljana and Budapest.

2.3 Extreme Flash Flood Event 18 September 2007

These examples from the extreme flash flood event of 18 September 2007 which caused over 250 M Euro in damages to roads, homes, and other infrastructure in the mountains west of Ljubljana indicate capabilities of mesoscale models and land surface models. Heavy and abundant precipitation which captured the western, north-western and northern parts of Slovenia on 18 September 2007, caused quick rise of river discharges especially in the region of Baška grapa, Davča, the Cerkljansko and Škofja Loka hills. In that area the streams Selška Sora, Davča and Kroparica caused real destruction. The Savinja was high in the middle and lower stream. The discharges of the tributaries Hudinja and Ložnica exceeded 100-year return period. The Dravinja flooded in the middle and lower stream. The return period of flood was between 50 and 100 years. On the most affected area the peak discharges exceeded the periodical maximum discharges measured at the water stations.

The operational Numerical Weather Prediction system at Environmental Agency of the Republic of Slovenia (EARS) consists of several potential configurations of the ALADIN limited area model. The configurations can be setup and run with optimal options regarding model physics and dynamics for a certain spatial resolution. At the present the spatial resolution is 9 km, which will be increased to 4 km in 2008. The initial and boundary conditions for the operational model come from either French Meteo, or the European Center for Medium Range Weather Forecasting (ECMWF). The 1-km Weather Research Forecasting (WRF) model Quantitative Precipitation Forecast (QPF) was reasonably good as shown in Figure 14.

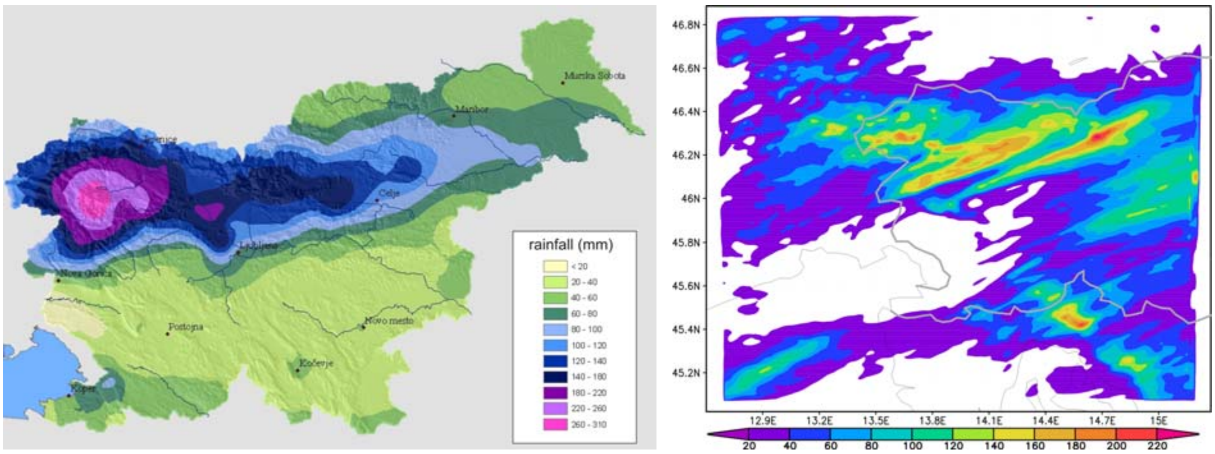

Figure 14. Observed precipitation on 18 September 2007 (left) and WRF model QPF for this event.

GLDAS results shown in figure 15 show the capability of the ¼ degree simulations for this extreme event. Clearly there is value in this simulation; however, a 1 km simulation would provide significant improvement, hence our recommendation to NASA to fund improvement of these model resolutions.

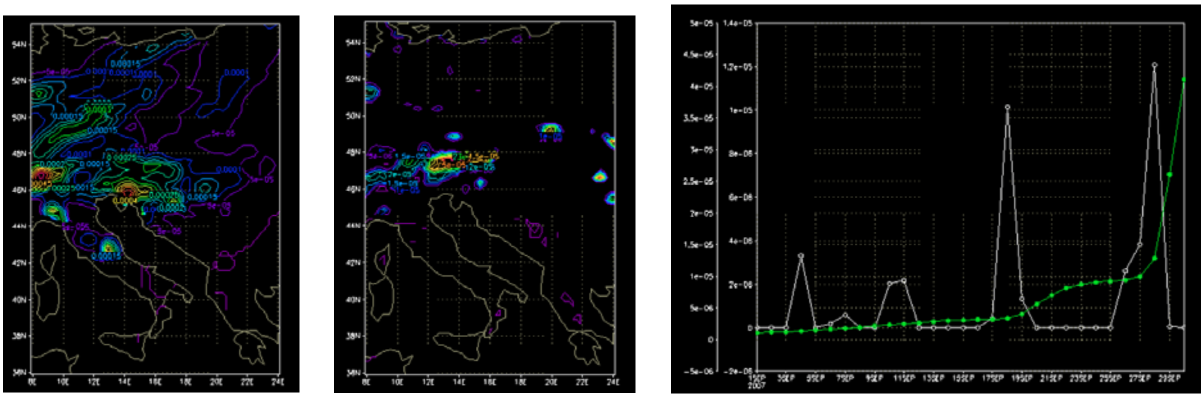

Figure 15. Examples from GLDAS on 18 September 2007 flood event-Rainfall rate (kg/m2/s), (runoff (kg/m2/s), and September time-series of precipitation (daily white, total surface and groundwater (green). Note the heavy precipitation maxima in the area of the flood, and time series maximum on that date.

3 REAL-TIME INFORMATION OVER THE DANUBIAN REGION

WaterNet seeks to facilitate the rapid access of information of immediate value to decision-makers by linking them to the research teams and their products. In this section we provide web links (highlighted) to products that are currently available on-line for direct access. These links are available at the hydrometdss.org web page under the top menu for WaterNet.

Forecasts of precipitation, soil moisture, temperature, and current analyses of weather for Europe from the GFS modelling system and GLDAS are updated each day. Model data is available for a suite of models using a variety of interactive tools at the CREW modelling web page. Satellite estimates of precipitation are available at the TRMM web site on a global basis. The European Commission's Joint Research Centre provides real-time analyses of soil moisture and drought conditions over Europe.

4 SUMMARY AND CONCLUSIONS

The WaterNet Water Cycle Solutions Network was described with examples of potential products. One key goal of WaterNet is to identify gaps in current technology and encourage NASA's and GEO funding to solve these problems to meet practical needs of decision-makers. WaterNet examples of various land surface model products over the Danubian Region were presented that show the type of information available for snow water equivalent, surface and sub-surface soil moisture, precipitation, and satellite estimates of precipitation from TRMM.

Established partnerships represent a cross-section of individual and networked NWRs and DSTs from government, private, and academic domains, that will enable us to quickly complete an operational solutions network, entrain more partner nodes and networks, and move *WaterNet* toward self-sustainability. EU projects like AWARE, and the flood and drought forecasting research efforts, and GMES projects are potential projects that may directly benefit from this *WaterNet* networking.

Specific goals and objectives, methods of communication, and invitation to join the *WaterNet* were discussed. Examples of NASA products from the MODIS, TERRA AQUA, and other satellites and Land Surface Model results over the Danubian countries show potential value added to water resource management in the region. Examples of snow water equivalent, soil moisture, surface temperature, runoff estimates showed how Global Land Data Assimilation System (GLDAS) and its Land Surface Models (LSM) are valuable for decision-makers.

Danube scientists, engineers, decision-makers and stakeholders are encouraged to join the WaterNet Community of Practice and express their interests and needs for research products that can meet their decision-making needs. Please contact us at **hydrometdss@comcast.net** or **phouser@gmu.edu**

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