Visual exploration for Nowcasting of precipitating convective clouds in time series of remote sensing data

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Nowcasting is the shortest type of forecasts ranging from 0-18 hours and operating on fine spatial scale, typically less than eleven kilometers (less than the scale of the numerical models). In nowcasting remotely sensed data are mainly used to verify the numerical model since some fine spatial scale structures are usually not 'caught' by the numerical model. METEOSAT Second Generation is typical meteorological satellite observing the earths full disk and monitoring the earth-atmosphere system. On a regular day, it collects 96 images with the frequency of one image in 15 minutes (where each image is a composite of 12 channels). These images are mainly used for meteorological applications. Exploring, analyzing and nowcasting precipitating clouds is one of such applications, since one type of precipitating clouds, namely convective clouds is often associated with storms and severe weather conditions.

Convective storms result from an updraft of warmer air. As the air rises it is cooled adiabatically so that eventually it will reach the same temperature as the surrounding air and come to rest. Before that happen, however, it may be cooled down below the dew point. Should this convection column continue to develop the cloud may grow into thunderstorm or *Cumulonimbus*(Cb) type of cloud, from which heavy rain or hail will issue [1] (Figure 1).

Cumulonimbus storm can effect agricultural production. Their storm cells can produce heavy rain particularly of a convective nature, hail and flash flooding, as well as straight-line winds. Cumulonimbus clouds also contain severe convection currents, with very high, unpredictable winds, particularly in the vertical plane and therefore can be dangerous to the aviation.

The purpose of search or exploration is to find patterns, trends and relationships in these images in order to detect and predict the behavior of the convective cloud. One way of supporting the exploratory process is by developing visualization methods. Images are presently explored by animating image sequences with user controlled interactions (play, stop, change rate of animation etc.). However, evidences from the evaluation studies show rather mix trend - despite being interactive, animations still lead to information overload, limiting their exploratory usage [2], [3], [4], [5], [6], [7], [8]. In addition, the

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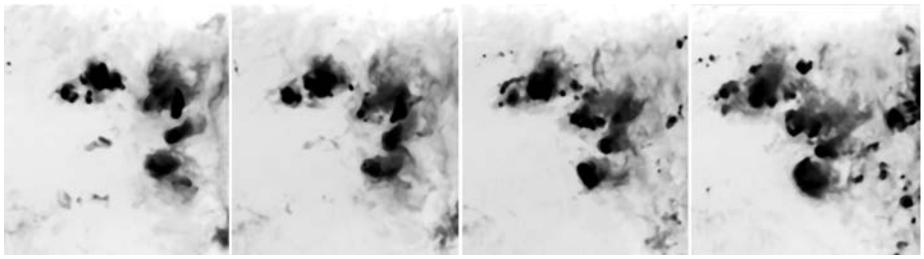

Figure 1: Convective clouds as seen on satellite images - IR*10.8* μm image of METEOSAT showing Cb cloud development of one hour over equatorial Africa on 28 July 2006 , 10-00 GMT. Convective clouds generally appear darker due to lower temperatures

users are dissatisfied, because this kind of exploration remains subjective and time-consuming process. This paper therefore concentrates on the designing a prototype integrating computational and a number of (linked) visualization methods for exploration of convective clouds from time-series of satellite images.

Firstly, two main factors are identified that limit the exploratory use of animations for the study of convective clouds: data complexity and animation design, containing images that are mimicking reality. Therefore, a cartographic approach is proposed with options to generate more abstract and selective representations.

Secondly, an example is presented of how the current approach to visualize time series of meteorological images can be improved by computational methods, particularly by feature tracking. We detect precipitating clouds using the method developed by Kidder [9] using METEOSAT images (Figure 2).

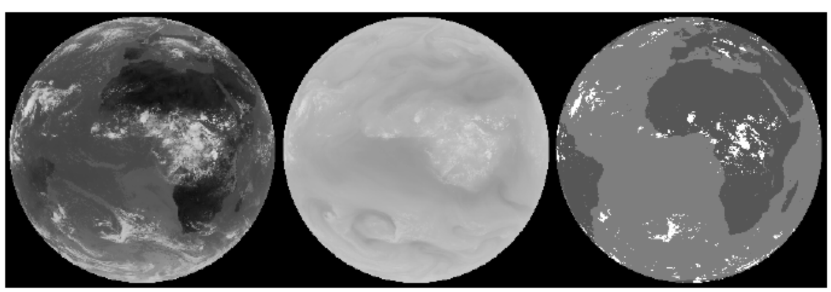

Figure 2: Band IR*10.8*μm (left); band WV*6.2* μm (center); Precipitating Clouds = IR*10.8* μm - WV*6.2*μm $< 11^{\circ}$ K (right). Source: [9]

Then we show how cloud extracting and tracking can reduce the initial complexity of time-series image data sets: each cloud feature can be described in terms of its attributes (position, size, image intensity, etc.) and its lifetime. This offers explicit quantitative, as well as abstract and richer graphical representations of each cloud's evolution. In particular, the proposed multiple views in combination with the traced cloud paths can show the essence of the objects evolution and history. Abstract representations help the user to search for objects of interest. For example, convective clouds are revealed by mapping the mean intensity attribute into radius and color of spheres in the Event Graph (Figure 3). Convective clouds are also found by the direct manipulation of intensity trajectories in the Attribute Graph (Figure 4). And selective interactivity assist the user in focusing the attention on the particular type of clouds (Figure 5).

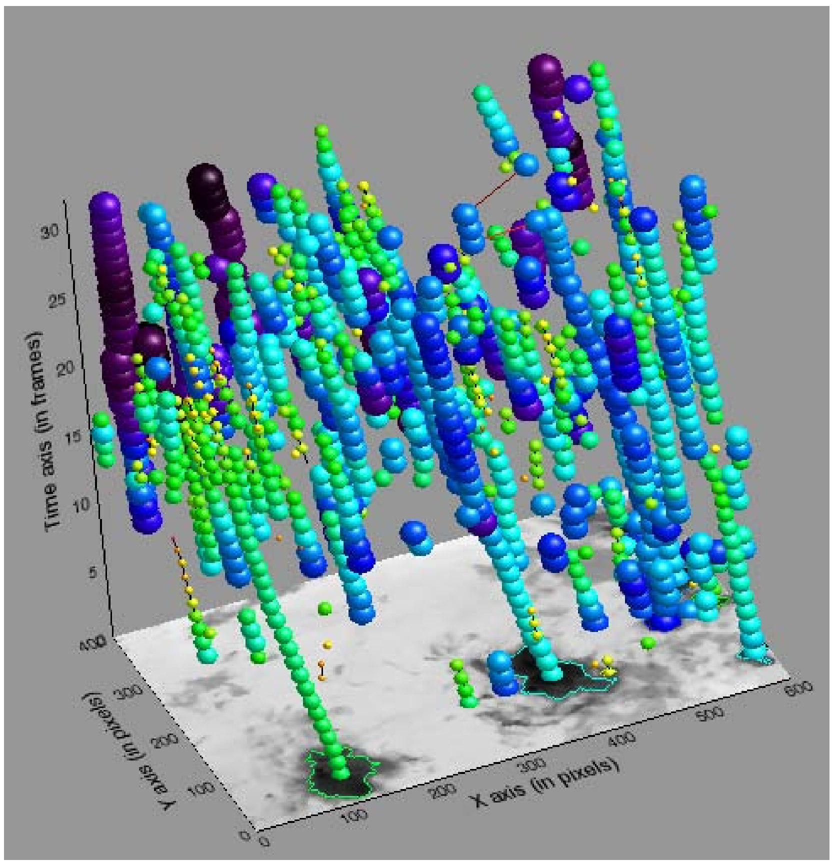

Figure 3: Visual search for convective type of precipitating clouds. Mean Intensity attribute is *inversely* mapped into radius and *proportionally* mapped into color of the sphere making convective clouds to 'stand out' of the image (darker and larger icons are most probably the convective clouds). 'Rainbow' color palette is used.

Feature tracking algorithm essentially simulates a human visual tracking process. However, contrary to the human visual tracking process, the proposed method detects changes in spatial objects regardless of the numbers of objects

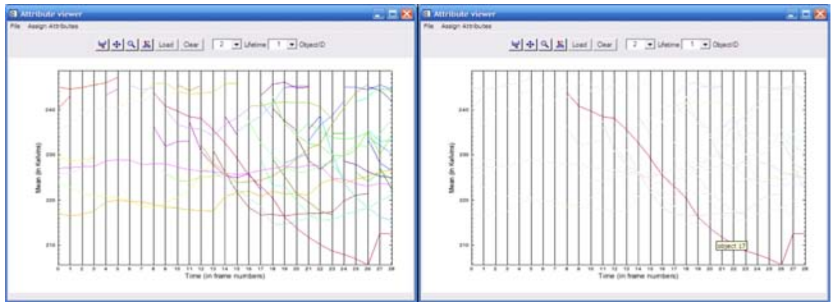

Figure 4: Convective clouds are found by the direct manipulation of intensity trajectories in the Attribute Graph - a negative temperature gradient indicates a possible convective type of precipitating clouds.

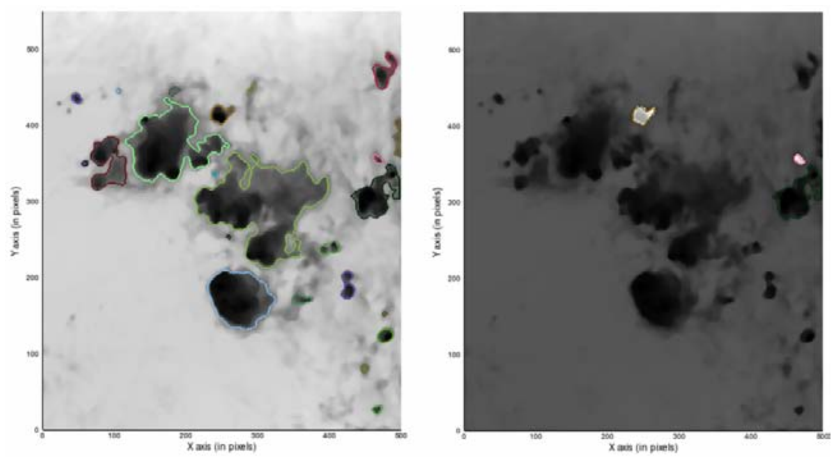

Figure 5: Animation overview indicating frame 20 (left) and the same frame of animation with superimposed graphics to indicate position and movement of the selected object in time (right). Note that contour of the brushed object were retained and that the transparency of the image was manipulated to highlight the brushed object in the right image

present in the scene and does not depend on perception and experience of the observer. Thus, with the presented functionality, the meteorological scientists can pay more attention to higher order visual tasks comparison and its related activities: exploration of convective clouds and generating hypothesis about their dynamics and evolution.

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