Available online at www.sciencedirect.com
ScienceDirect
Computers & Graphics 31 (2007) 370–379
COMPUTERS & GRAPHICS
www.elsevier.com/locate/cag

Visual Analytics

Designing a visual environment for exploration of time series of remote sensing data: In search for convective clouds

Ulanbek D. Turdukulov*, Menno-Jan Kraak, Connie A. Blok

ITC—International Institute of Geo-Information Science and Earth Observation, P.O. Box 6, 7500 AA Enschede, The Netherlands

Abstract

Interactive animated images are often the only means to explore large time series of meteorological data sets. However, despite being interactive, animations still lead to information overload. We firstly look at the factors limiting the exploratory use of animations for studies of precipitating cloud and argue that two main factors are responsible for that: data complexity and animation design based on images that mimic reality. Then we present an example of how the current approach to visualize time series of meteorological images can be improved by computational methods, particularly by feature tracking. Next, we describe the visualization environment and discuss the representational, data mining and interactive functionality resulting from such a combination in an environment that is specifically dedicated to visual exploration and analysis of precipitating clouds.

Keywords: Time series; Satellite images; Convective clouds; Data exploration; Feature tracking; Visualization; Animation; Visual image mining; Interaction

1. Introduction

Earth system science is a multidisciplinary science strongly linked to remote sensing data. Satellite sensors are often the only way to obtain the required information of large spatial coverage and of high temporal frequency. As a result, satellite image repositories are becoming the fastest growing archives of spatio-temporal information and the users are frequently confronted with this continuous flow of data that need to be explored. For example, METEOSAT second generation is continuously observing the earth's full disk and monitoring the earth–atmosphere system. On a regular day, it collects 96 images with the frequency of one image in 15 min (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.

The purpose of exploration is to find patterns, trends and relationships in these data sets in order to detect and predict the behavior of the precipitating cloud. One way of supporting the exploratory process is by developing visualization methods. The satellite images are presently explored mainly by animating 2D or 3D image sequences with user controlled video-type interactions (play forward/backward, pause/stop, etc.) (see, for example, [1,2]) . However, evaluation studies show that despite having these interactions, animations still lead to information overload. In addition, the users are dissatisfied, because this kind of exploration remains a subjective and time-consuming process. One way of supporting the exploratory process is by developing alternative visualization methods and enabling more interaction than the usual video type of controls. In this paper, we look at the visualization aspects of precipitating cloud exploration and the way this process can be improved.

We firstly look at the factors limiting the exploratory use of animated image sequences for meteorological studies

*Corresponding author. Tel.: +31 53 4874477; fax: +31 53 4874335.
E-mail addresses: turdukulov@itc.nl (U.D. Turdukulov), kraak@itc.nl (M.-J. Kraak), blok@itc.nl (C.A. Blok).

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doi:10.1016/j.cag.2007.01.028

and argue that two main factors are responsible for that: data complexity and animation design, containing images that are mimicking reality. Then we present an example of how the current approach to visualize time series of satellite data can be improved by computational methods, particularly by feature tracking. Next, we describe the visualization environment.

2. Factors limiting visual search in animated image sequences

Why does an animated sequence of images overwhelm the users, and why is its exploration a subjective, tedious and time-consuming process? There are two main reasons linked to the characteristics of the data displayed and animation design.

If the images are played in an animated sequence, the complexity of the real world is mimicked. But users who are interested in evolution of precipitating systems have to identify that type of clouds and visually concentrate on these highly dynamic objects. These users are bombarded with rapid sequences of changes that need to be sieved and tracked in space and time [3]. But change can only be consciously seen if a viewer pays attention to it, and human attention is a very limited resource [4,5], it can just be directed to a few (about 3–4) changing items at a time. Other changes will go unnoticed: the concept *change blindness* refers to the failure to detect change in the visual field [6]. It may happen when the view is interrupted (e.g., during eye movements, because of missing data values or illumination change). It also occurs when change is too slow to be noticed and when attention is overwhelmed by too many signals or by distractors whose features are perceptually more salient (e.g., by objects that suddenly appear/disappear, have a unique motion pattern, etc.) [7–10].

Interruption, too many motion signals and distractors all influence the exploration of animated meteorological images. In addition to the precipitating type, the images contain several other types of clouds—low-, medium and high-altitude clouds (e.g. overview is given in Fig. 1). Precipitating clouds can span for all the three altitude layers and have frequent developments and dissipations in their history. That is why the user finds tracking precipitating clouds from the animated images in the current design a 'subjective and tedious' process. Animated sequences of images can only be successfully used in an exploratory context if we move beyond the video-player metaphor, and interactive controls are provided (see e.g., in [11,12]).

Being exploratory, visualization in the current context should facilitate users in sieving the amount of information in time-series images in search for patterns, in temporal and spatial subsets, for objects of interest and relationships between those objects. For instance, if the user needs to find clouds of particular temperature gradient (for example, a negative temperature gradient indicates a possible convective type of precipitating clouds), there should be an option to obtain a summary overview of all temperature trajectories. That would help the user to focus on those subsets of the data where the desired cloud type occur, and not require the 'time-consuming process' of playing the entire animation to search for such objects. Quantitative summary of object attributes helps to solve the data complexity issues if it can be used to generate abstract and selective representations. In addition, quantitative summary of attributes is necessary for postexploratory use of images in monitoring, modelling and decision making activities.

In brief, for exploratory use, the visualizations of precipitating clouds should be abstract, based on quantitative data, enable various attributes to be mapped and have dedicated interactivity. One way to include this functionality is by providing computational support to the visual exploration process. We present such an approach in this paper by coupling computational methods—here used to detect and track clouds—with abstract and selective visualizations of the tracked information in a single exploratory environment. Working in a single environment has many advantages. It enables progressive knowledge construction because users can easily switch between a visual, qualitative approach and a quantitative, computational approach to the data. A qualitative approach can—for example—be useful for hypothesis generation or finding answers to vague questions like: 'What is happening?', 'Are there interesting patterns?', while the quantitative, approach can be used for data preprocessing, hypothesis verification, modelling, etc. [13,14]. We will describe the representational and data

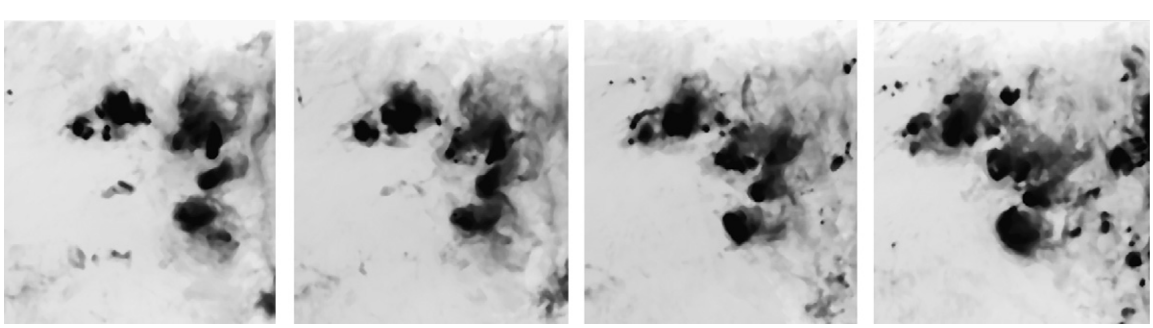

Fig. 1. Subset of the example data set: IR10.8 μm channel of METEOSAT showing cloud movement (darker objects due to lower temperature) at every hour starting at 10:00 h GMT on 25th April 2005.