The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

1861-35

European Conference on Severe Storms (ECSS 2007)

10 - 14 September 2007

Development of an operational thunderstorm forecast system for air traffic

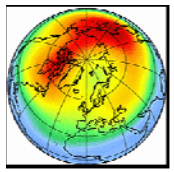
FORSTER Caroline
Institut fuer Physik der Atmosphere, DLR Oberpfaffenhofen
Muencher Str. 20
D 82234 Wessling
GERMANY

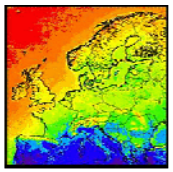
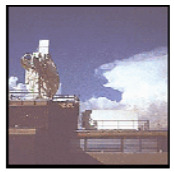
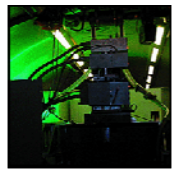
Development of an operational thunderstorm forecast system for air traffic

WxFUSION: Weather Forecast User-oriented System Including Object Nowcasting

Caroline Forster and Arnold Tafferner
DLR Oberpfaffenhofen
Institut für Physik der Atmosphäre

Photo: www.finnmoeller.dk



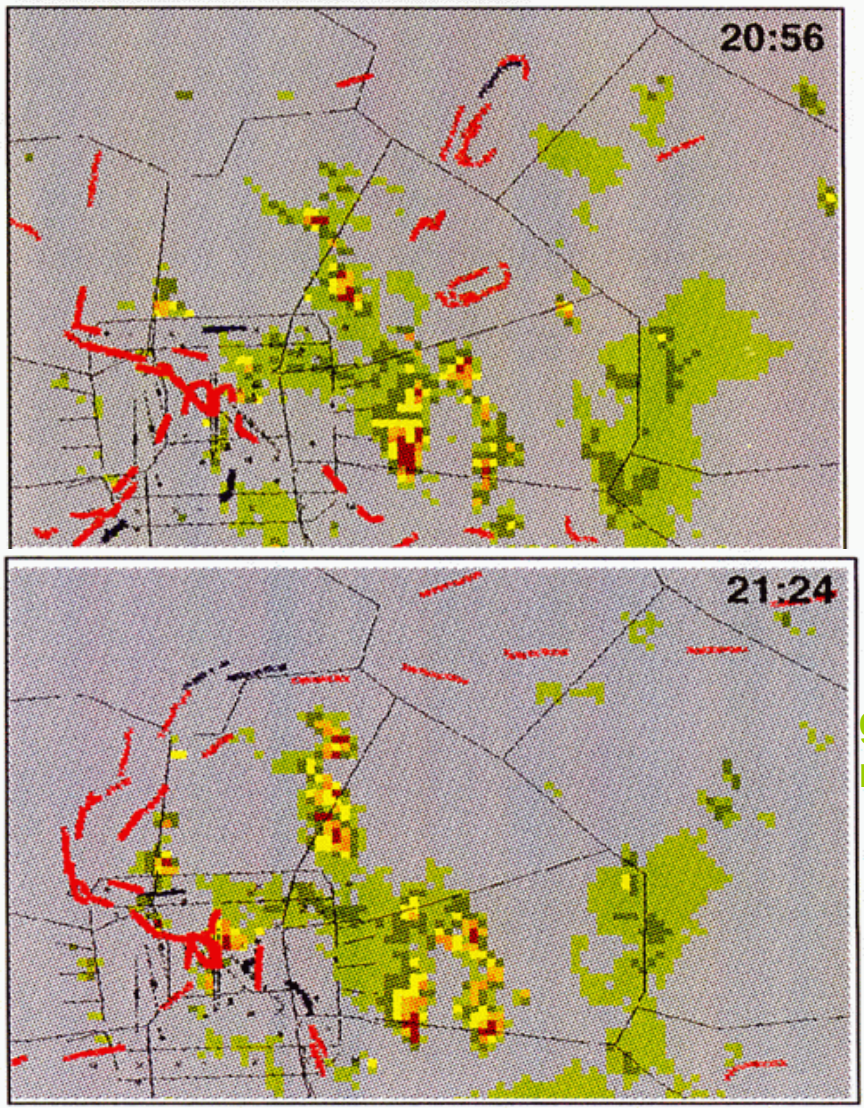
DLR Institut für Physik der Atmosphäre

Motivation

Capacity: up to 90% of all delays during the summer months are due to thunderstorms (Quon, 2006)

Flight safety: thunderstorms are the most important threads of all weather hazards (results of a survey with pilots within FLYSAFE)

There is a clear need for integrated systems that analyse and forecast weather hazards as precisely as possible in order to enable the mitigation of the weather hazard's effects



Airport Dallas terminal area

red: flight tracks

green to dark red: radar reflectivity

J. E. Evans, 1997

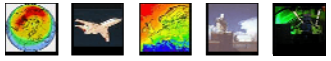
Motivation

Motivation

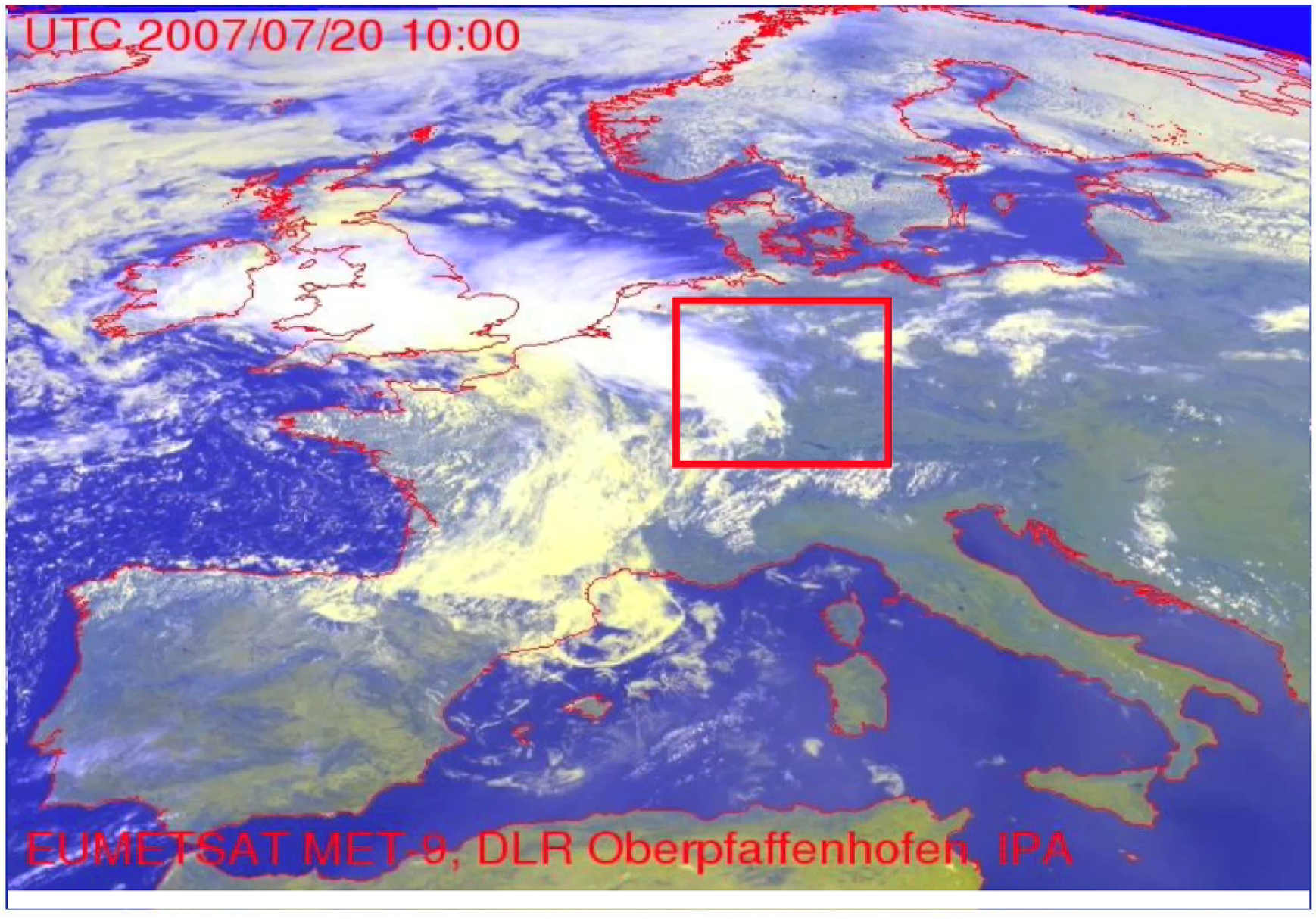
- several integrated weather forecast systems have been developed in the U.S., e.g.
  - Integrated Terminal Weather System (ITWS, Evans and Ducot, 1994)
  - NCAR Auto-Nowcast System (Mueller et al., 2003)

- in Europe such a system does not exist to date

- a number of nowcasting and forecasting tools are available: challenge of combining them



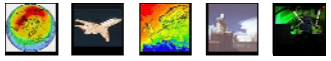
new high resolution remote sensing data:
MSG rapid scans (5 Min temporal resolution)



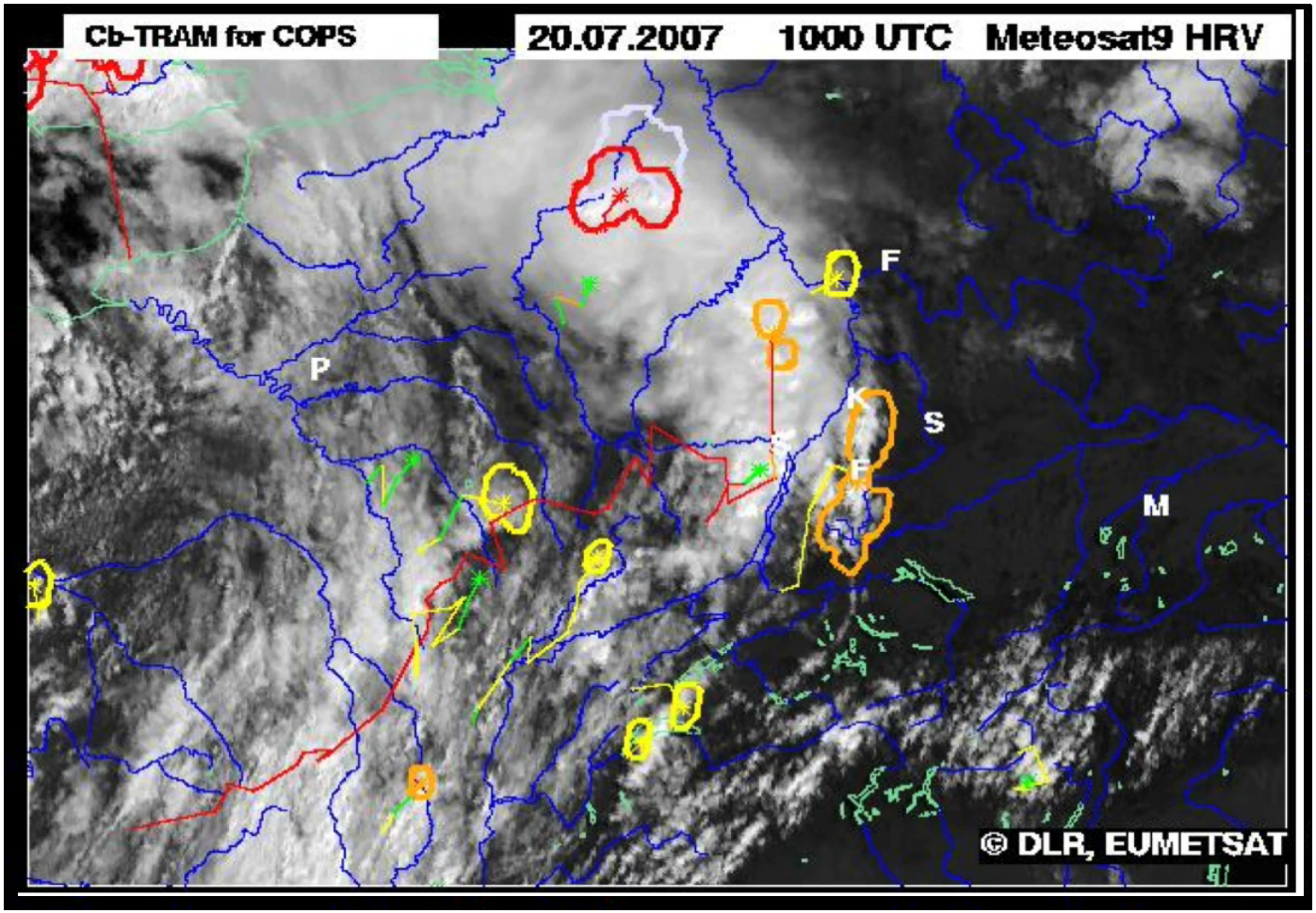
movie

CB-TRAM CumuloniBus TRacking And Monitoring (Zinner et al., 2007)

- **Use of Meteosat SEVIRI and ECMWF Data**
  - **pyramidal image matching algorithm (Mannstein et al., 2002)**
  - **combination of HRV, IR and WV data**
  - **HRV info to localize the most active convective cells (roughness)**
  - **Identification of severe thunderstorms with the aid of IR and ECMWF tropopause temperatures**
- **3 warning levels**
  - **onset of convection/development, first development of clouds**
  - **rapid development/strong cooling at cloud top**
  - **mature thunderstorm**
- **time resolution 15 Min. (5 Min. with METEOSAT third generation!)**
- **nowcasts (15, 30, 45, 60 Minuten) with extrapolation**



CB-TRAM: Cumuloni**B**us **TR**acking **A**nd **M**onitoring using MSG satellite data



yellow:
onset of convection

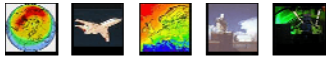
orange:
rapid development

red:
mature thunderstorm

grey:
30 Min. nowcast

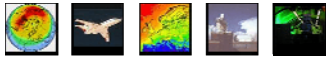
(Zinner et al., 2007)

movie

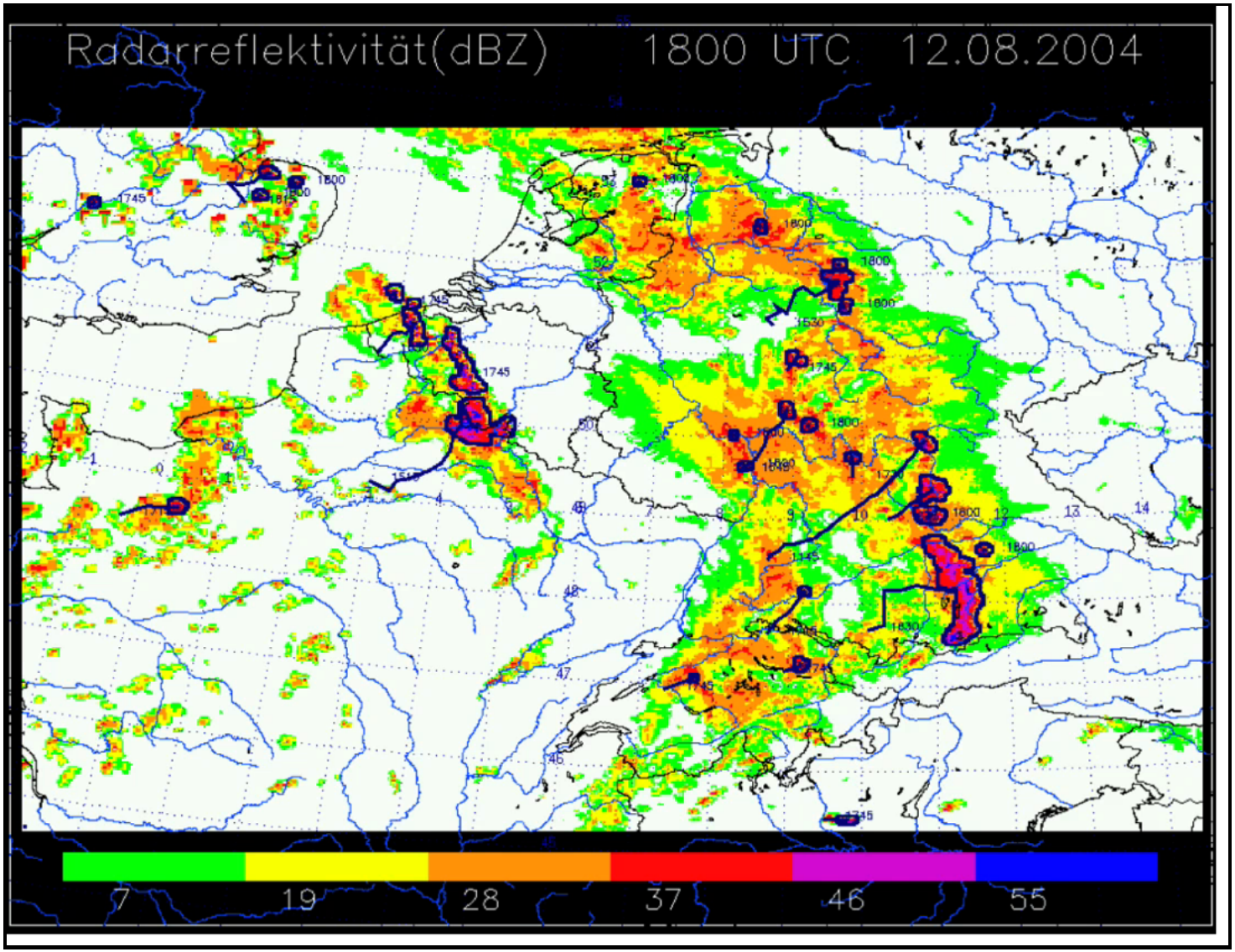


Pyramidal Matching Algorithm (Mannstein et al., 2002)

- Coarse-grain both images by averaging of 2^F pixels onto one pixel element
- Compute a displacement vector field that minimizes the squared difference within the range of +/- 2 pixel elements
- Repeat step 2 at successively finer scales
- Displacement vector for every pixel results from the sum over all scales



RAD-TRAM Radar TRacking And Monitoring using DWD radar composite (Kober et al., 2007)

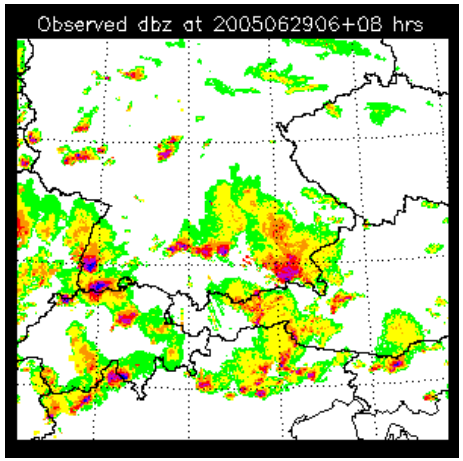


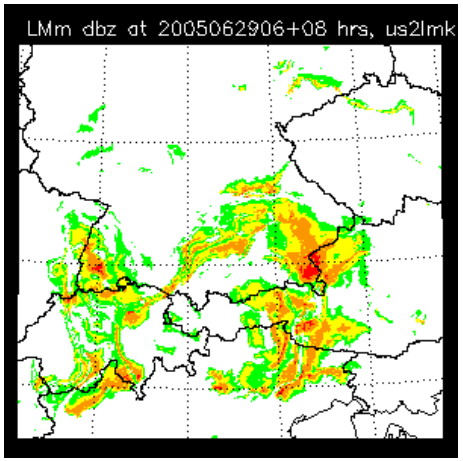
Radar reflectivity in dBZ

dark blue contours: precipitation cell >37dBZ

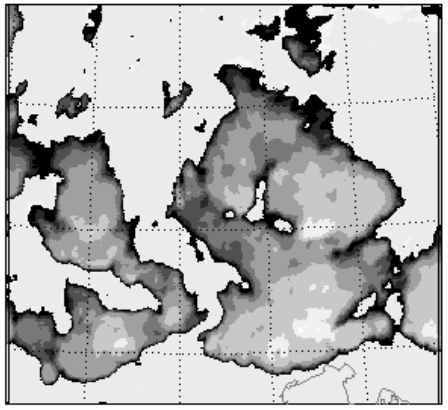
Pyramidal Matching Algorithm and a new displacement-based Forecast Quality Measure

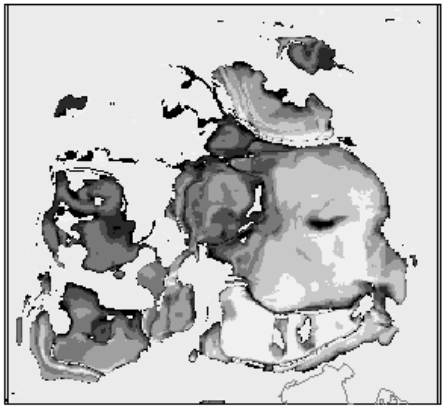
Radar





Meteosat 8





Observation

LMK Forecast

$$FQM = \frac{1}{A}\sum_{A}\max\left(c_1 \cdot DIS, c_2 \cdot LSE\right)$$

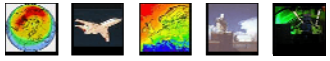
$$c_1 = DIS_{\max}^{-1}$$

$$c_2 = \left(BT_{\max} - BT_{\min}\right)^{-2}$$

DIS: displacement vector

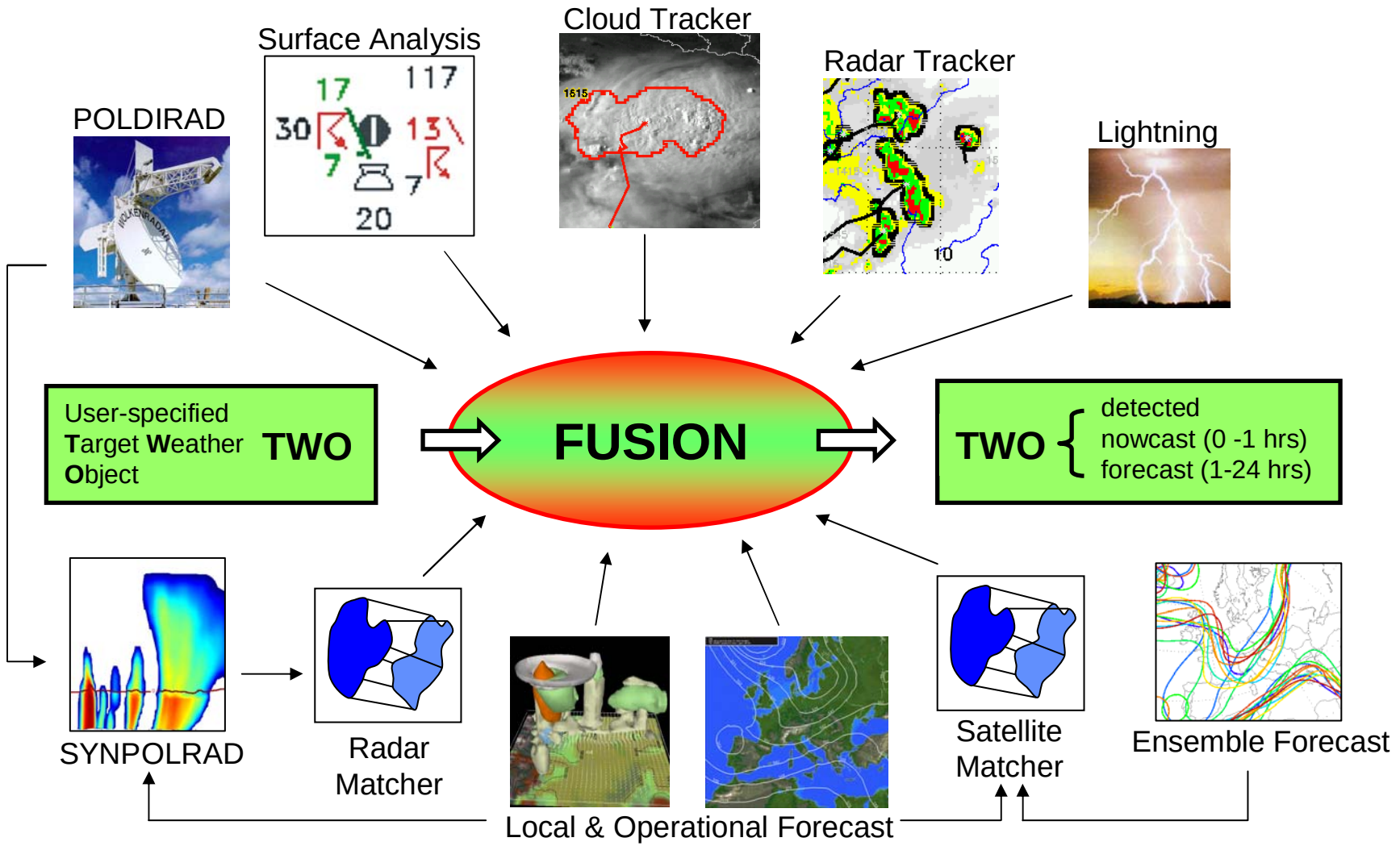
LSE: local squarred error

(Mannstein et al., 2002; Keil and Craig, 2007)

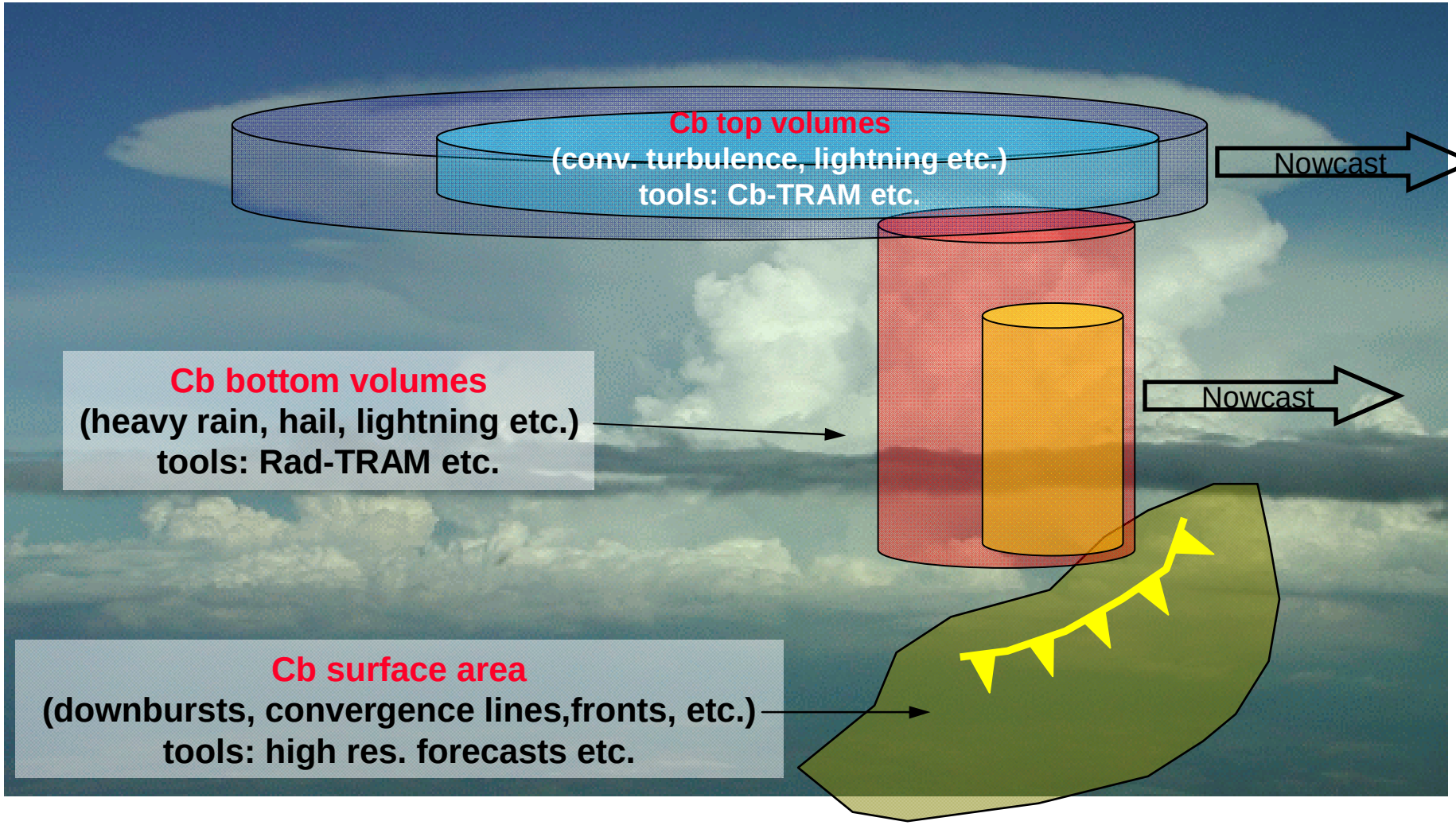


WxFUSION

Weather **F**orecast **U**ser-oriented **S**ystem **I**ncluding **O**bject **N**owcasting



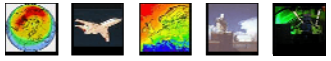
Thunderstorm as TWO



WxFUSION output parameters for TWO (included in XML file):

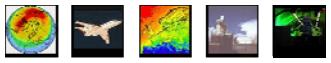
- geometrical: size, volume, track, trend
- weather attributes (hail, heavy rain, level of turbulence, …)
- hazard levels (moderate, severe)
- confidence level (based on data availability, coherency in time)

.....



Data fusion through:

- nowcast based on extrapolation methods (0-1 hour), e.g. Cb-TRAM and Rad-TRAM
- forecast based on numerical models, e.g. ensemble forecasts, high resolution forecasts
- combination of nowcast and forecast by selecting the forecast that agrees best with observation
- probabilistic methods
- fuzzy logic (allows to deal with imprecise observations, combination of membership functions of various data (fuzzy sets), incorporation of expert knowledge)



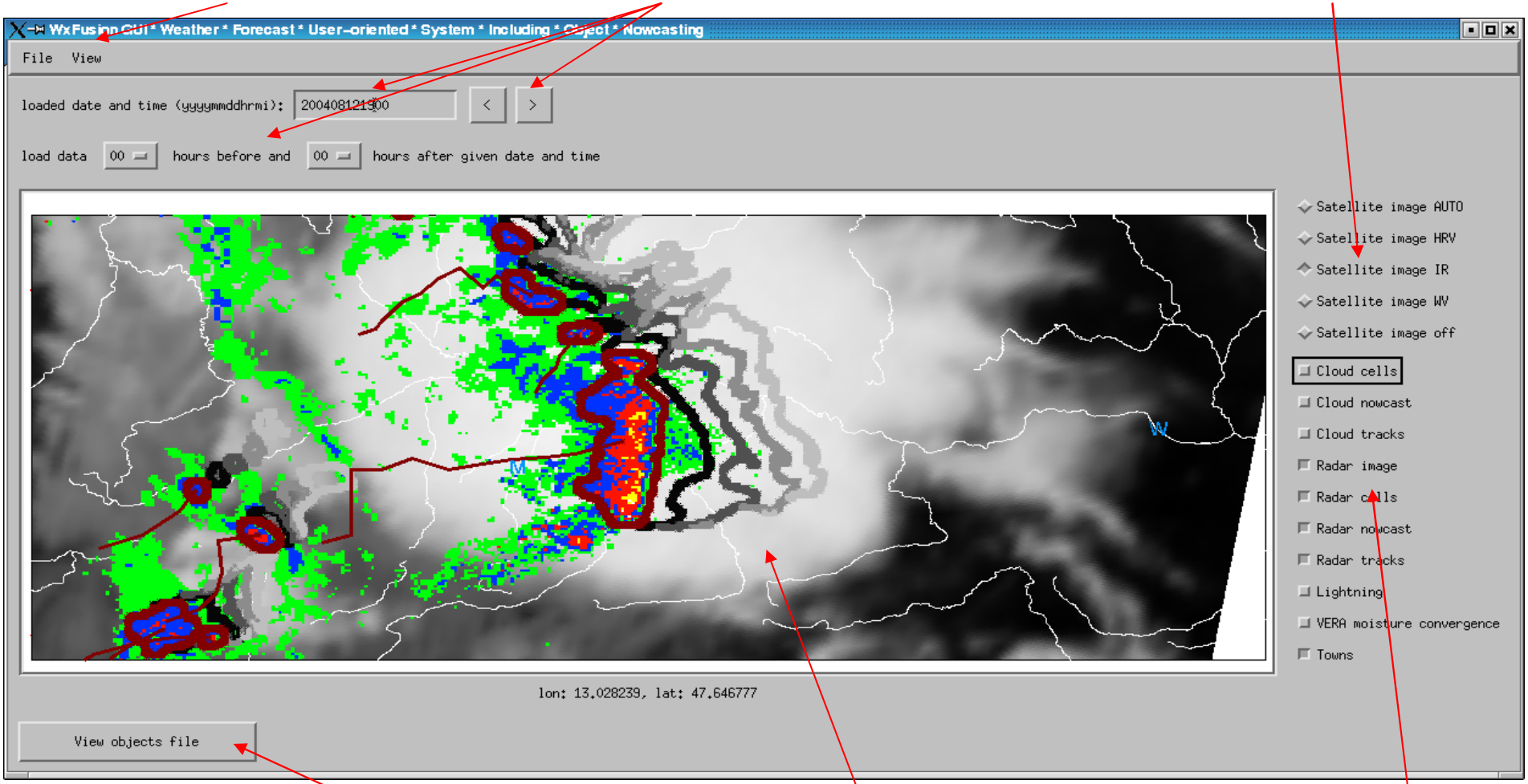
WxFUSION Graphical User Interface

Weather **F**orecast **U**ser-oriented **S**ystem **I**ncluding **O**bject **N**owcasting

Area and viewing mode selection

Date/Time selection & scroll

background switches



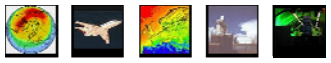
Textual output on weather object parameters like propagation speed, precipitation rate, hail occurrence

Display for overlay of data, here: Radar reflectivity, IR sat. image, radar cells, nowcast & tracks

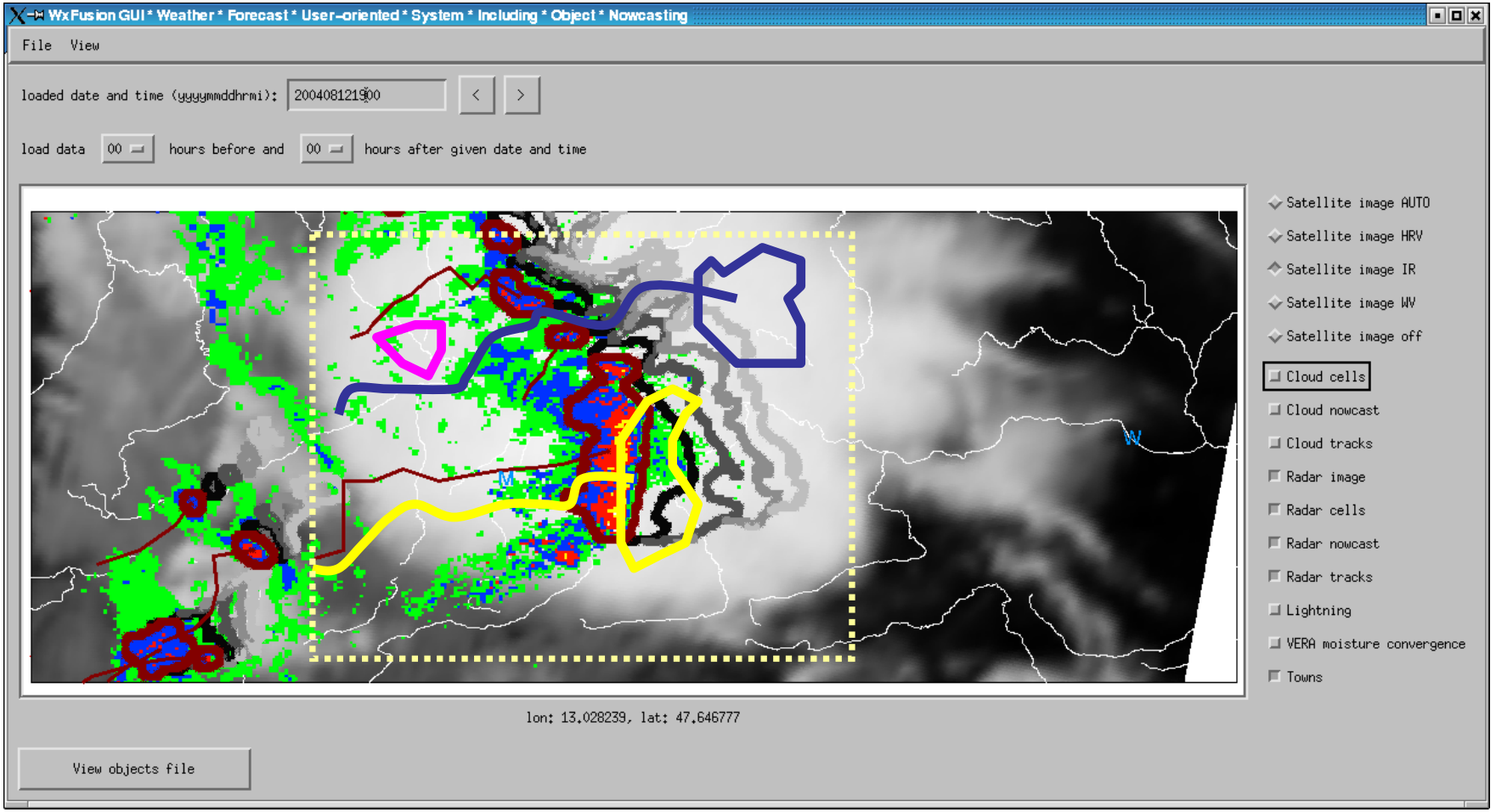
Data switches

DLR

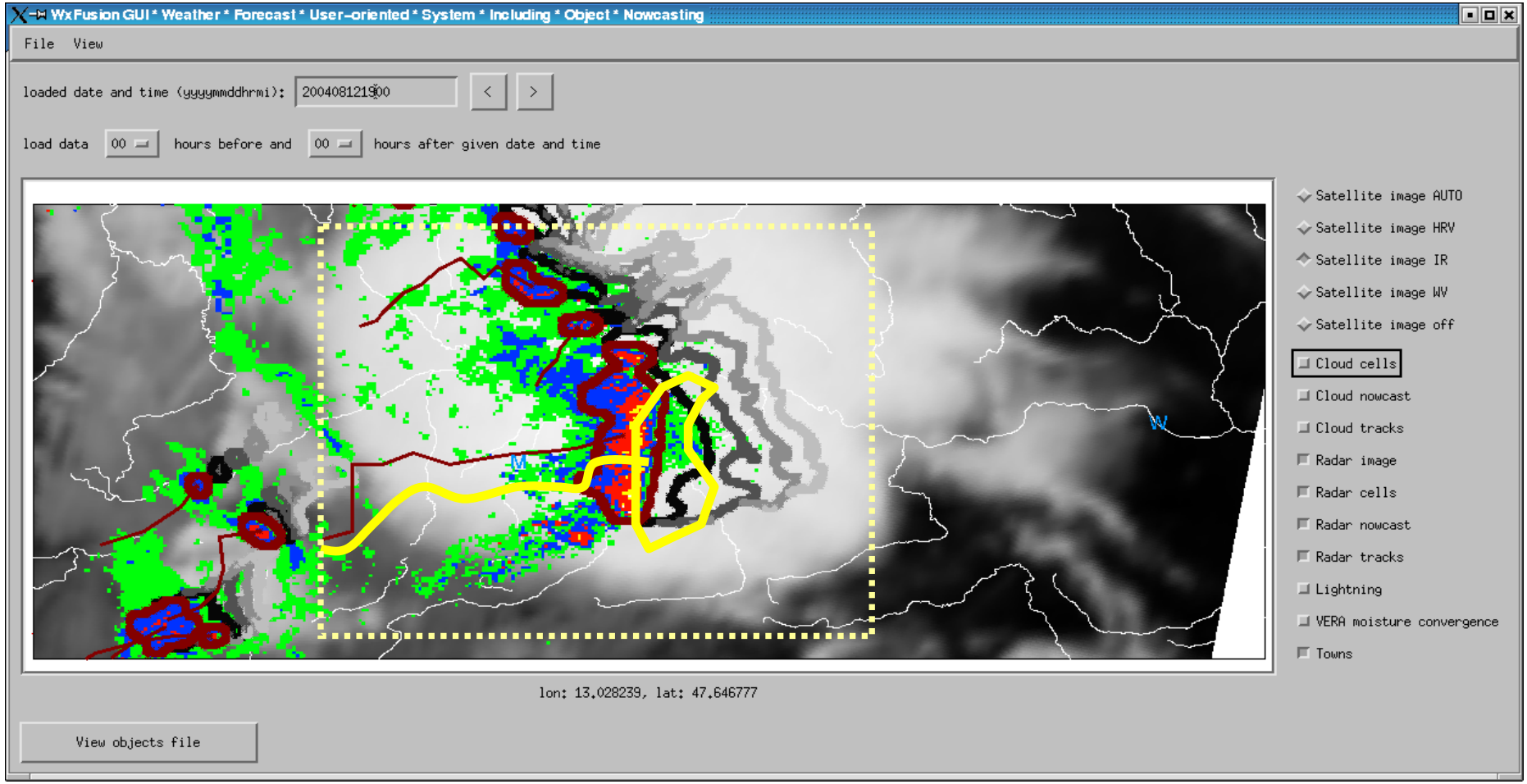
Institut für Physik der Atmosphäre



WxFUSION: Selection of best forecast

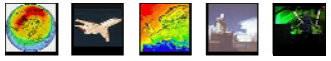


WxFUSION: Selection of best forecast



Selection based on tracking convective features in real and synthetic satellite and radar images:

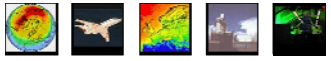
- Define search windows in space and time
- Look for existing features (ev. several thresholds) in available forecasts within these windows
- Determine quality based on size, displacement, overlap, intensity distribution, history



Special features of WxFUSION

Weather **F**orecast **U**ser-oriented **S**ystem **I**ncluding **O**bject **N**owcasting

- User specified output of objects and their parameters/attributes
  - adjustment to local and operational constraints (e.g. at airports)
  - user (Pilot/ATC/ATM) can choose objects he is interested in
  - objects can be chosen for specific weather situations (thunderstorms/winter conditions)
- combination of nowcasting and forecasting (selection of best forecast member) plus probabilistic methods
- combination of different data sources using fuzzy-logic
  - accounting for the uncertainties when describing weather phenomena (parameter ranges instead of fixed thresholds)
  - accounting for forecaster's experience
  - output of severity levels (user specified)



DLR Project "Wetter & Fliegen" ("Weather & Flying")

Goal: Improve security and efficiency of air traffic through

Weather information in the TMA and **optimising aircraft technology**

Structure: