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SEVERE WEATHER FORECASTING TOOLS IN THE NINJO WORKSTATION

Paul Joe[1], Hans-Joachim Koppert[2], Dirk Heizenreder[2]
Bernd Erbshaeusser[2], Wolfgang. Raatz[2], Bernhard Reichert[2] and Michael Rohn[2]
[1]NinJo Project, Meteorological Service of Canada
4905 Dufferin St., Downsview, Ontario
M3H 5T4, CANADA

[2]Deutscher Wetterdienst, 44 Kaiserlei, Offenbach, Germany

1. INTRODUCTION

NinJo is a meteorological workstation, collaboratively developed by the Deutscher Wetterdienst (DWD), the Bundeswehr Geophysical Service (BGS), the Danish Meteorological Institute (DMI), MeteoSwiss (MCH) and the Meteorological Service of Canada (MSC) (Koppert et al 2004). A key feature of the workstation is that it is designed for a generic method of handling of data, of visualization and of forecast applications so that it can integrate a variety of data in an efficient and logical manner to enable the development of “user friendly” software (Koppert 2002). Once imported into NinJo, the various data can be used for visualization or integrated into various forecast applications.

One of the key features of the software is the software design which separates the various functions of data import, data base, data access, visualization, GUI and applications. In this sense, the system is generic and allows for software re-use and a reduction in code that results in efficient development, rapid prototyping and reduced maintenance requirements.

In the spring of 2005, DWD initiated a new program of providing severe weather warnings for the convective season. Germany gets about 23 tornadoes per year (Dotzek 2003). Previously, the research group in DWD developed a prototype severe weather thunderstorm identification application (KONRAD, Lang 2001) for specific end users (emergency and civil managers) or private weather providers provided severe weather watches via the internet. In the MSC, the severe weather warning program has been in effect since the late seventies or early eighties. In the MCH, the emphasis has been on precipitation events.

Corresponding Author: Paul Joe, Meteorological Service of Canada, 4905 Dufferin St., Downsview, Ontario, Canada, M3H 5T4 email: paul.joe@ec.gc.ca tel: 416 739 4884

A cornerstone of the severe weather program is tools to aid the forecaster in detecting thunderstorms, decision-making and the management of warnings. The timely development of NinJo workstation, the DWD “Action Program 2003”, and various radar and satellite thunderstorm processing allowed the initiation and development of this new severe weather warning program within the DWD and to enhance the programs at meteorological institutes of other consortium members or future licensees.

There are several tools already available or in development. In this paper, we will describe:

- Basic data visualization
- Radar processing
- Cell processing and display
- Lightning
- Automatic monitoring of data/cells
- Warning forecast area selection
- Automatic monitoring of warnings

These various components of Ninjo provide a comprehensive suite of applications to aid the forecaster in making timely and accurate decisions.

2. DATA VISUALIZATION

All two-dimensional data can be overlaid on the window and in the same projection – e.g., radar, satellite, model and point data (Fig. 1). A basic concept of NinJo is to separate the visualization and processing of different types of data into different layers or components. Each layer can be manipulated using various color rendering techniques independent of the other layers and/or with functionalities specific to the data type. Four of the most useful generic capabilities are: (i) the ability to visualize various data by the addition, subtraction or hiding of layers; (ii) the ability to change the order of the layers; (iii) transparency which allows data to be seen through other data and (iv) access to data. All the data is correctly georeferenced to a common projection. The NinJo client is a data and not an image viewer. In the past, data was represented as images and multiple images were used which resulted in a loss of data quality, resolution, situational awareness or geographical mis-registration. This is particularly useful when zooming in to see more detail. As the user zooms in, the integrity of the data is maintained.

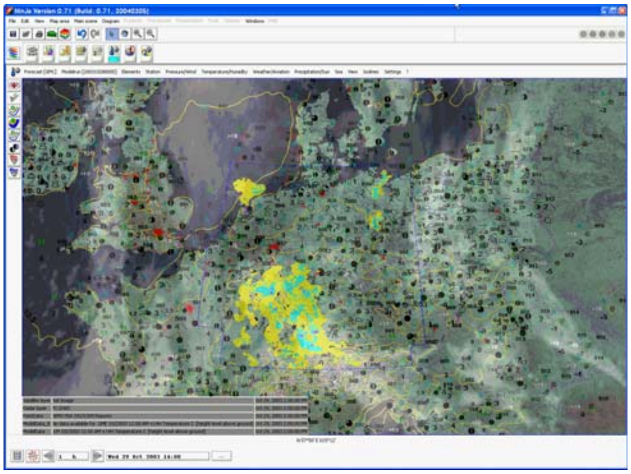


Figure 1: An example of a NinJo rendering of surface data (station plots, contouring), satellite IR data (transparent rendering) and radar data.

The ability to overlay and see through one data to another is a very powerful method of assessing the meteorology of the situation. For example, the relationship between the storm height revealed by satellite combined with the low level radar echo can be used to assess the storm morphology, overcoming the “cone of silence” and other radar echo top artifacts. The inclusion of surface data allows the analyst to assess the relationship of the storm with respect to low level moisture sources (and other factors) for the assessment of potential growth.

Piece-wise, multi-radar cross-sections are a new capability. Radar cross-sections are often used at the storm scale to look for thunderstorm features such as hook echoes or bounded weak echo regions. However, since the geographical domain of view is determined by the user and not by the data, a multi-radar cross-section capability is requirement of the software design and has great serendipitous benefit to the user for synoptic assessment in the vertical plane and thus allows a new way of looking at data and assessing the meteorological situation. For example, radar data can be overlaid with cross-sections from upper air observations or from model data for better synoptic to mesoscale analysis and diagnosis.

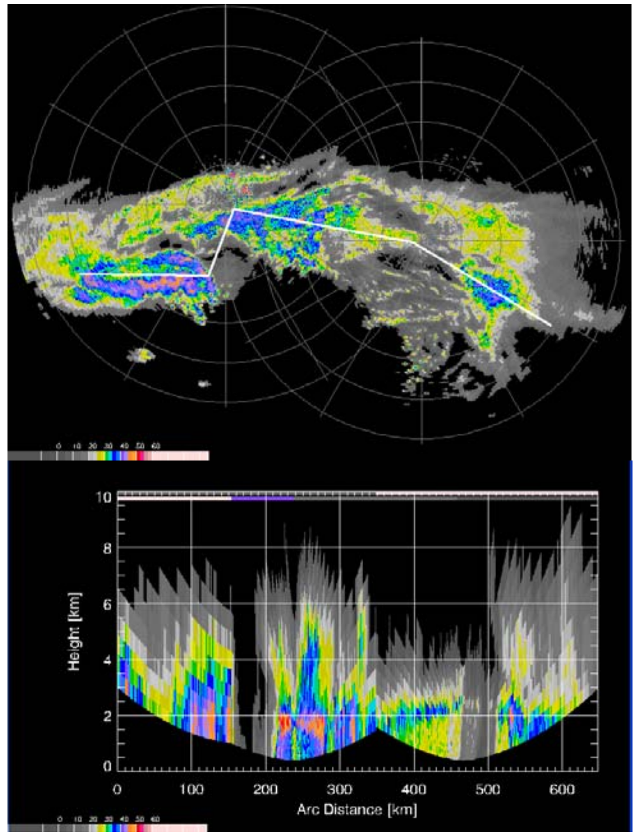


Figure 2: A prototype example of a multi-radar, multi-segment cross-section. The top figure shows the path on a horizontal plane of the vertical cross-section shown in the bottom from radar data. Note the color bars at the top indicate radar transitions and segment transitions.

3. RADAR PROCESSING/VISUALIZATION

One of the most complex data processing issues for NinJo was that of radar data. The consortium members use different radars, different processing hardware and software. They produced different end products, in different file formats and operate with different scan strategies (Joe et al, 2004). There were also requirements to ingest radar imagery or data from neighboring countries. From user perspective, the data is also used for different purposes, ranging from general weather surveillance, airport operations, severe weather and hydrology.

In order to resolve the differences and diversities, a configurable product/data import, a common internal data representation, a flexible data access mechanism and a comprehensive re-projection and rendering client was needed. In order not to degrade the data (any further in some cases), the data is stored in the co-ordinate system as they are received and re-projected on the fly in the client. Within the NinJo concept, two-dimensional data, the vertical cross-section data, the cell object displays and interactive functionalities are visualized in separate layers. VAD data will be handled by the aero logical layer.

Since the viewing geometry is determined by the NinJo client and not by the radar product, the normal way of viewing radar data will be in a "composite" mode. So the radar client must be able to render diverse single radar or composite data products with different time cycles into composites "on-the-fly". In order to resolve the possible diversity of products (e.g., PPI vs. CAPPI) and to handle the possibility of missing data, each ingested radar data/product is associated (through configuration) with a time stamp and a valid duration. The diverse products are grouped, via configuration, to resolve product differences (i.e., ppi vs. cappi, single radar vs. composite) to form a "combo" product. Simple composting algorithms (maximum value, nearest radar or prioritized product) are coded to handle data/product overlap (see Fig. 1). Sophisticated compositing algorithms are left to the legacy (and future) processing systems.

Legacy products that are composed of PPI's and max reflectivity-principle axes cross-sections are dis-aggregated into separate data products. The NinJo radar data model consists of 3D (e.g., volume scan, data cubes), 2D (e.g., CAPPI, PPI, MAXR, etc), 1D (e.g., VAD, VPR) and 0D (e.g., objects) types.

Not all legacy products explicitly contained the geographical information required to properly locate the data in a GIS sense. Image type products must be transformed from pixel values to data values to enable data probing functionality. All of these issues are handled via a radar data/product catalog (RDC) which explicitly contains the missing "meta data". The protocol is that the information contained within the legacy data/products takes precedence over the RDC.

There was no clear choice for an internal storage format for the radar data or products. In the end, the internal data format chosen was netCDF. BUFR is a WMO standard for radar products but is not complete for the variety of products produced by the various systems such as 16 bit data, floating point values (rainfall rates, accumulations) or objects. However, both DWD and MCH have chosen BUFR as their format for their radar data for import into NinJo for a variety of reasons. This results in a major effort to completely define BUFR templates for all of their products.

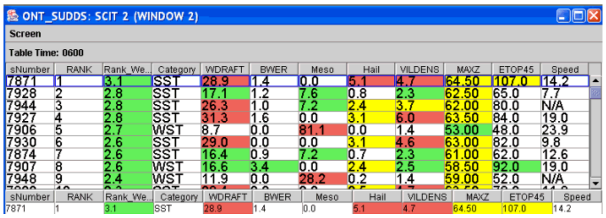
Interactive cross-section functionality is handled by the NinJo path layer and the cross-section component. The path layer is used to define control points along a path and the NinJo cross-section component extracts the vertical plane of data from the volume scans or data cubes and renders the image. The path/cross-section component works with multiple meteorological data sets (model output, radiosonde, radar) which can be overlaid. With the path being defined on an arbitrary map domain, multi-segment and multi-radar cross-sections are required (see Fig. 2).

4. CELL PROCESSING/VISUALIZATION

Three members of the consortium (DWD, MCH, MSC) have developed or initiated sophisticated processing for the algorithmic detection of thunderstorm cells from both radar and satellite data (CARDS Joe et al 2003, KONRAD Lang 2001, TRT Hering 2004, Joe et al 2004). The Rapidly Developing Thunderstorm (RDT) satellite nowcasting application of Eumetsat-SAF project was adopted by DWD as part of the Action Plan 2003 program to improve short term forecasting. An extrapolation nowcasting component will be added to the satellite cell detections.

The cell objects are visualized by the SCIT (Storm Classification Identification and Tracking) Layer (Johnson et al 1998). The functionality will consist of a table listing the cell objects, a capability of rendering a color coded indication of the cell locations/tracks on its own layer. The table and the cell locations can be referenced to each other and to a cell view product so that displaying an entry in the table, or on the SCIT layer will highlight the other with a capability of displaying (drilling down) a detailed cell view product.

With the NinJo concept, various data products can be aggregated to create "cell view" component. This is a multi-panel product that all have the same geographical domain but with different products (Fig. 4 and 5). These products are used to provide both a quick and detailed assessment capability for the analyst. In the CARDS system, these views are centered on the cell detections and are pre-generated for speed of access.


ONT_SUDDS: SCIT 2 (WINDOW 2)

Screen

Table Time: 0600

sNumber	RANK	Rank_We...	Category	WDRAFT	BWER	Meso	Hail	VILDENS	MAXZ	ETOP45	Speed
7871	1	3.1	SST	28.9	1.4	0.0	5.1	4.7	64.50	107.0	14.2
7928	2	2.8	SST	17.1	1.2	7.6	0.8	2.3	62.50	65.0	7.7
7944	3	2.8	SST	26.3	1.0	7.2	2.4	3.7	62.00	80.0	N/A
7927	4	2.8	SST	31.3	1.6	0.0	3.1	6.0	63.50	84.0	19.0
7906	5	2.7	WST	8.7	0.0	81.1	0.0	1.4	53.00	48.0	23.9
7930	6	2.6	SST	29.0	0.0	0.0	3.1	4.6	63.00	82.0	9.8
7874	7	2.6	SST	16.4	0.9	7.2	0.7	2.3	61.00	62.0	12.6
7907	8	2.6	WST	16.6	3.4	0.0	2.4	2.5	58.50	92.0	19.0
7948	9	2.4	WST	11.9	0.0	28.2	0.2	1.4	59.00	52.0	N/A

sNumber	RANK	Rank_We...	Category	WDRAFT	BWER	Meso	Hail	VILDENS	MAXZ	ETOP45	Speed
7871	1	3.1	SST	28.9	1.4	0.0	5.1	4.7	64.50	107.0	14.2

Fig. 3a: An example from the CARDS system where cell detections are presented in an interactive table format. Colors are used to indicate severity. The table is sorted by a severity index ('rank weight'). Selecting a cell via the table highlights the cell of the geographical display and vice versa so the user can quickly assess the veracity of the machine detections and for the human assessment of the storm severity and decision making. Drill down to a cell view is another interactive capability.

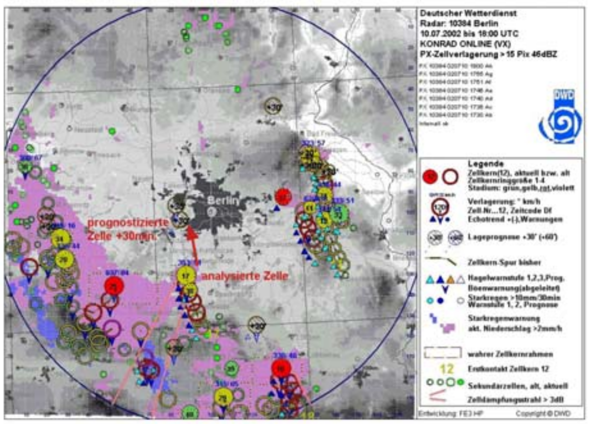


Fig. 3b: An example of KONRAD cells (from DWD's KONRAD system). Besides the capabilities described in the previous caption, in the NinJo system, the user will be able to select a cell and see a pop up window of the cell properties and open a new cell view window (next figure).

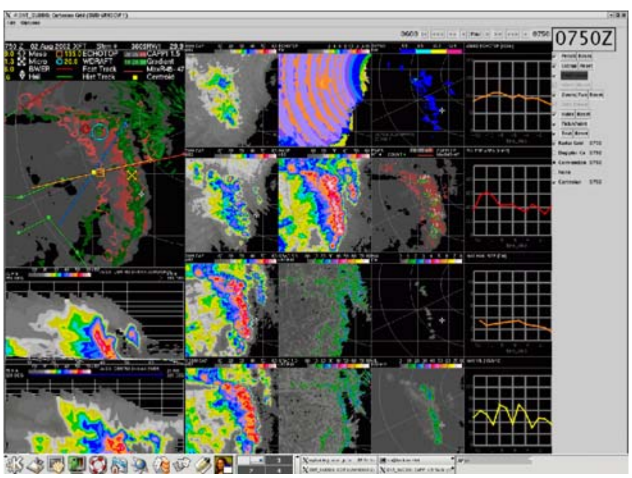


Fig. 4: An example of a CARDS "cell view" product. The user will be able to select a cell from the main window (geoDisplay or from the table) to show a detailed pre-calculated view of the storm. In this case, various CAPPI's at different heights are show (second column from left), automated cross-sections are drawn (bottom left), an ensemble view of the algorithm outputs (upper left) and time histories (right column) to name a few of the products.

A new functionality is the ability to interactively create cell views. Using the NinJo infrastructure, even non-radar data (satellite, model, etc) can be included in the visualization without re-coding. It is an example of excellent software design and re-use. The user will be also able to interactively re-configure the data that they want to see and save it for latter use.

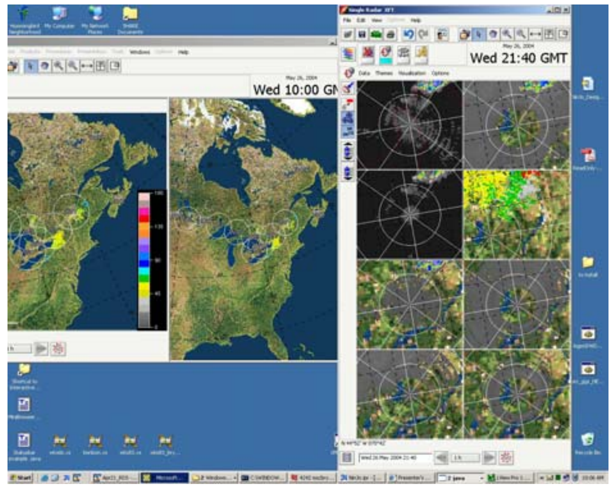


Fig. 5: A prototype interactive cell view drill down. This allows the user to specify any geographical area to invoke a cell view for that area. It enables the interactive and detailed monitoring of weak cells at their nascent stage or areas where convective growth is expected on low level boundaries for example.

5. LIGHTNING

Lightning systems and their data is also quite diverse. Some report flashes only and some report strokes and flashes. Data can be shown using a time series color rendering or a polarity based rendering or both (Fig. 6). A cluster analysis identifies cluster centroids. At this time, this cluster object is visual only and is not part of any database. In the future, lightning cluster objects will be incorporated into general properties of the severe thunderstorm cell.

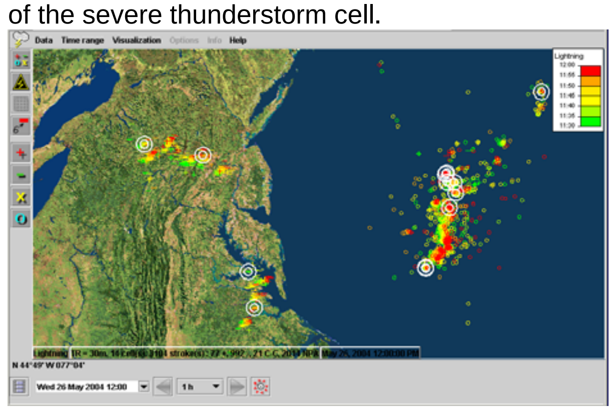


Fig. 6: A lightning example, show both time series (color) and polarity (symbol type).

6. AUTOMON DATA/FORECAST MONITORING

Automatic monitoring of point data or point data generated by application output, as in cell identification, can be configured for monitoring and alerting purposes. For example, surface temperatures or radar data can be compared to temperature thresholds or reflectivity thresholds to monitor air mass thunderstorm initiation or as simple severe storm development criteria.

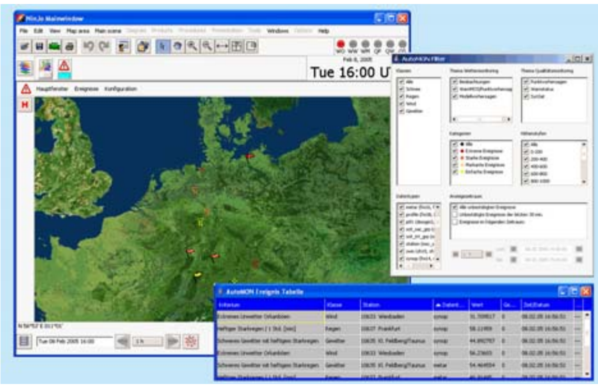


Fig. 7: AutoMON as a Layer in NinJo 1.0 (left window, warning indicators in the top right of the window) with Event Filter Window (top right window) and Event Table (bottom right window).

Satellite cloud top heights can be compared to tropopause heights to identify overshooting cloud tops or PIREPS turbulence reports can be monitored. The configurability of the system allows consistency of alerting and monitoring interfaces and for different forecasting philosophies and requirements to be implemented.

5. Warning – Editing, Production, Monitoring

The cell information can be used to identify warning regions. A tool called EPM (short for Editing, Production and Monitoring), allows the forecaster to select, edit or modify forecast warning regions provided the visual guidance provided by the cell identification systems. A variety of interactive techniques are used to select contiguous polygonal shapes. In the future, the storm tracks will be used to select the warning regions (Fig. 8).

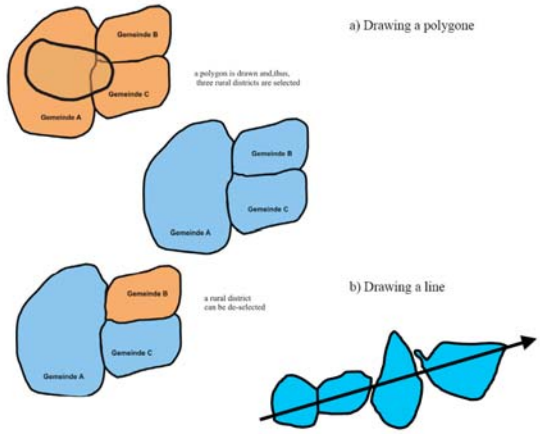


Fig. 8: Forecast area selection techniques include polygonal selection (upper left) or line selection (lower right) or area deselection (bottom left).

Warnings and their areas will be graphically monitored (Fig. 9a) with an associated table (Fig. 9b) that indicates the type of hazard type and duration. The EPM utilizes the AUTOMON component to monitor warnings against the observations and has a similar interface as shown in Fig. 7. This provides a very powerful real-time verification capability for the forecaster.

Fig. 9a: Graphical indication of the warned regions.

Versteckte Objekte

Bergstation A	Landkreis Calw	UW	Wind	12:00 - 18:00
Bergstation A	Landkreis Calw	WW	Schneefall	16:00 - 23:00
Talbrücke C	Landkreis Calw	WW	Wind	10:00 - 20:00
Bergstation A	Landkreis Freudenstadt	UW	Wind	12:00 - 18:00
Bergstation A	Landkreis Freudenstadt	WW	Schneefall	16:00 - 23:00
Gewerbegebiet B	Landkreis Freudenstadt	WW	Wind	10:00 - 20:00
Gewerbegebiet B	Landkreis Freudenstadt	WW	Schneefall	16:00 - 23:00
Höhenstraße C	Landkreis Rottweil	UW	Wind	12:00 - 18:00
Höhenstraße C	Landkreis Rottweil	WW	Schneefall	16:00 - 23:00

Fig. 9b: An example of the tabular representation of the warning regions and warnings.

Fig. 10 shows that by selecting a warning area, a time series representation of the warning and events within the warning area are displayed. The user will be able to call up the warnings to modify, cancel or extend warnings (not shown).

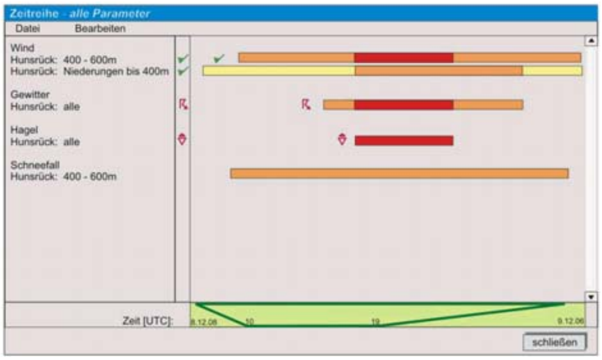


Fig.10: Selecting a warning region in Fig. 8a will produce a time series representation of the selected observations in the region (note the thunderstorm and hail icons).

6. OTHER RELEVANT NINJO CAPABILITIES

In this paper, we have concentrated on tools for severe weather. Other NinJo tools to aid nowcasting are also available. These include: (i) objectively optimized guidance, (ii) model modified output and (iii) formula editing. It is beyond the scope of this paper to describe these topics in detail (Reichert et al 2005).

The "OOG" project (Objectively Optimized Guidance) aims at evaluating the forecast data from different models and that produced from Nowcasting systems based on comparison with observation data and by means of objective procedures selecting an optimal forecast from which further production will be conducted. This utilizes the Adaptation component which extracts the observations from remote sensing data to contribute to the short term forecast portion of the OOG.

In the sub–project "MMO" (Modified Model Output) a tool is developed for manual editing of the OOG model data in a simple way. Also MMO provides a capability to "manually" select the optimal model in case that the objective procedures of the OOG do not provide a satisfying evaluation of the model data.

Other capabilities, beyond the scope of this paper, are the formula editing and weather object editing capabilities. In formula editing, the user will be able to create new parameters (e.g., storm relative helicity) to display and monitor by AUTOMON. In the specifications of SCIT, manual editing of thunderstorm weather objects and their tracks are required but await the relevant capabilities to be developed in the graphical editing package.

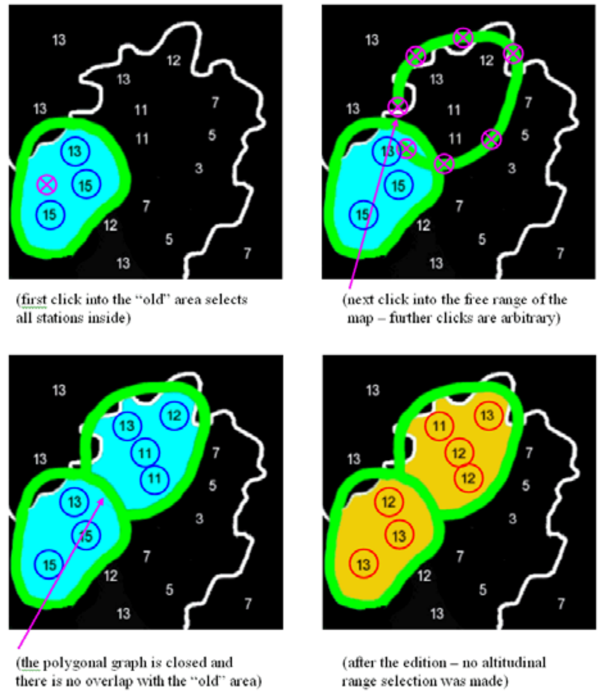


Fig. 11: A schematic showing area selection and subsequent editing of data using MMO.

7. SUMMARY

This paper briefly describes the capabilities of the NinJo workstation that support severe weather forecasting. Some of the requirements are driven by the overall concept of the software design and combines the requirements of the consortium members.

NinJo is a Java-based software workstation being developed by a consortium led by the DWD. The first version (released in March 2005) focused on the integrated visualization of meteorological data but version 1.1 and 1.2 will provide substantial number of tools for severe weather warnings and nowcasting. It is designed to overcome the limitations of traditional "stove piped" workstations of the past that focused on a particular type of data rather than a generic approach to the same functionality for all data. The design takes a user-centric viewpoint as the requirements driver rather than the traditional data-centric approach.

The design allows for future expandability and extensibility and for the development of integrated forecasting and forecast production applications. A significant aspect of the design is that data is being accessed by the client and rendered locally which preserves the integrity of the data. With a generic design approach, software development can proceed efficiently since software can be re-used.

The traditional radar functionalities are segregated into several NinJo layers or components – radar, cross-section, aerological, SCIT, AUTOMON, EPM and MMO/OOG. In the near future, formula editing and object editing are planned.

The initial version of NinJo was released in March 2005. The initial suite of severe weather capabilities, described in this paper, is expected in spring 2006 with the release of version 1.2. It is expected that the requirements will continue to evolve.

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9. REFERENCES

Dotzek, N., 2003: An updated estimate of tornado occurrence for Europe, Atmospheric Research, 67-68, 153-161.

Hering, A.M., C. Morel, G. Galli, S. Senesi, P. Ambrosetti and M. Boscacci, 2004: Nowcasting thunderstorms in the Alpine region using a radar based adaptive thresholding scheme, ERAD, Visby, 206-211.

Joe, P., Marie Falla, 2004: Radar Processing in NinJo, ERAD, Visby, xxx-xxx. http://www.copernicus.org/erad/2004/online/ERAD04_P_550.pdf

Joe, P., Marie Falla, Paul Van Rijn, Lambros Stamadianos, Trevor Falla, Dan Magosse, Lavinia Ing and James Dobson, 2003: Radar Data Processing for Severe Weather in the National Radar Project of Canada, 21st Conf. SELS, San Antonio, TX, AMS, 221-224.

Joe, Paul, Burgess, Don, Potts, Rod, Keenan, Tom, Stumpf, Greg, Treloar, Andrew. 2004: The S2K Severe Weather Detection Algorithms and Their Performance. *Weather and Forecasting*: Vol. 19, No. 1, pp. 43–63.

Johnson, JT., P. MacKeen, A. Witt, D. Mitchell, G. Stumpf, M. Eilts, and K. Thomas, 1998: The storm cell identification and tracking algorithm: An enhanced WSR-88D algorithm. *Wea. and For.*, 13, 263-276.

Koppert, H.K., A Java based meteorological workstation, IIPS, AMS, 2002, xxx-xxx. http://ams.confex.com/ams/annual2002/18IIPS/abstracts/29502.htm

Koppert, H.K., T.B.Pederson, B. Zuercher and P. Joe, 2004: How to Make an International Workstation Successful, AMS, IIPS, Seattle, xxx-xxx. http://ams.confex.com/ams/84Annual/20IIPS/abstracts/71789.htm

Lang, P., 2001: Cell Tracking and Warning Indicators Derived from Operational Radar Products, AMS, Munich, 30th radar conference, 207-211.

Reichert, B. K., Palmer, Z., Weiser, C., and C. Träger, 2005: AutoMON - The Automatic Monitoring and Alerting System for Significant Weather Events in the Meteorological Workstation NinJo, Proc. European Working Group on Operational Workstations (EGOWS) 21-24 June 2005, UK MetOffice, Exeter, Great Britain, 1-6.