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Radar Visualization in the NinJo Project

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Abstract. NinJo is a collaborative meteorological forecaster visualization workstation project led by the Deutscherwetterdienst (DWD) and includes MeteoSwiss (MCH), Danish Meteorological Institute (DMI), and the Meteorological Service of Canada (MSC). The MSC has the lead for the visualization of radar data for the consortium. A basic philosophy of NinJo is that it is a geo-referenced data viewer and not an image viewer. This implies that rendering of the screen image is always done directly from the data and interactive data probing using the mouse uses the original data and not the rendered visualization. The data is stored in its native format, rather than stored in a common internal format, in order not to degrade the it. Zooming in will result in a visualization that shows the full details and resolution of the original data.

The consortium members use radar in different ways – for weather surveillance, for severe weather and for hydrological applications – and have different radar products that reflect these applications. The project must resolve the diverse requirements and also combine the products and outputs from diverse legacy radar processing systems, scan strategies, products and data formats. In addition, processing of radar products from neighboring countries is also a requirement. The system uses composites (pre-generated or generated on the fly) in the main scene with "drill down" capability to either single radar products, to cell views, to vertical profiles, to cross-sections and to probe data. Using the geo-referencing data concept, the radar data can be visually (and can be mathematically) combined with other meteorological and non-meteorological data for efficient and effective decision-making and forecast production.

1 Introduction

Historically, radar processing and visualization systems were self-contained and stand-alone systems because of the nature, the processing and timely requirements of the radar products. With data increasing, information requirements increasing and as processing and visualization concepts and forecasting requirements mature and evolve, integrated displays are needed that are efficient and effective, that increase the accessibility to and improved the information from the meteorological data. Meteorological visualizations systems were also "stove piped" with considerable infrastructure duplication. They displayed degraded image products. While adequate for the time, the systems were difficult to evolve, extend or expand to meet the new demands.

NinJo (Koppert et al., 2004) is a new workstation for the integrated visualization of meteorological data. It is a software development project led by the Deutscherwetterdienst (DWD). The Danish Meteorological Institute (DMI), the Swiss Meteorological Service (MCH) and the Meteorological Service of Canada (MSC) are partners.

NinJo will allow the integrated visualization of radar data with all other meteorological data (Fig. 1). However, the data, the processing and the use of the data in the various meteorological services are quite diverse. In this paper, we briefly describe the various legacy systems, the NinJo framework, the integration of radar data into NinJo and how the various and diverse data and visualization requirements are met.

2 The Legacy Systems

The DWD operates a network of 16 Doppler radars. The radars operate with a complex scan strategy (Schreiber, 2001) where most products are generated on a 15 min cycle from a volume scan with a specialized horizon following low level precipitation product generated every 5 min. Products include low level PPI (PL), Echo top (PE), radial
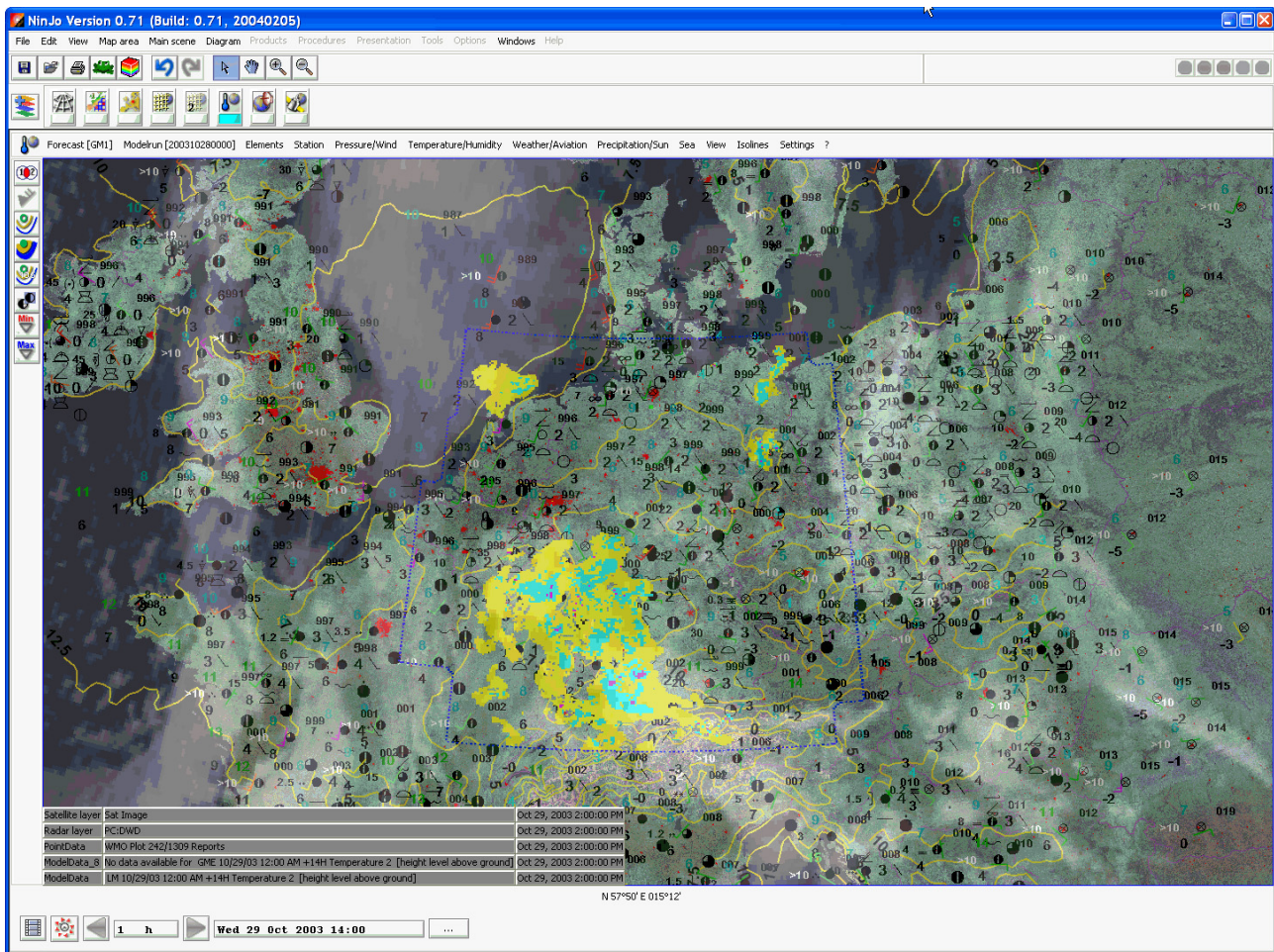
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Fig. 1. An example of a NinJo rendering of surface data (station plots, pressure contour), satellite IR data (with transparent rendering) and radar data showing a mesoscale convective system.

velocity (PR), horizontal shear (PW), VAD, data cube (PZ), composites (PC, PI, PZC) and accumulations (DX, DXC, DH, DHC). Initially, the radar products were quantized at three bits in a run length coding format and in a polar-stereographic projection. The DWD has now introduced the MURAN processing system that is capable of producing 8 bit data polar co-ordinate products in netCDF format for NinJo (Malkomes et al., 2002). In addition, CONRAD objects, a separate radar processing system for convective storm identification are also included (Lang, 2001).

The DMI produces a limited number of radar products every 10 min. These include a CAPPI (PL), a composite (PC) and a data cube product (PZ) in an 8 bit gnomonic projection.

The MCH (Joss et al., 1998) operate a network of three Doppler radars where a complete 5 min volume scan is generated by 2 interleaved twelve elevation 2.5 min volume scans. There are products generated from both the 2.5 minute half volume scan and from the 5 min complete volume scan. Products are generated at the radar site and also centrally in Zurich. The products include max R (RH, TG), precipitation (PH), reflectivity (ZY), accumulation (VY), data cube (OY), VAD (WD) and VPR (XD), radial velocity (UY) and com-

posites (OYC, RLC, PLC, TGC) in Swiss cylindrical and in radar polar coordinates. Initially, the products were in 4 bit color (GIF encoded) but will now be generated in BUFR 8 bit format for NinJo.

The MSC (Lapczak et al., 1999) operates a network of 31 radars with a ten minute scan cycle consisting of a 5 min conventional cycle and a 5 min Doppler cycle. A variety of products are produced by the CARDS system (CAPPI, MAXR, Echo Top, radial velocity, severe weather algorithms etc.) with "drill down" to "cell view" functionality (Joe et al., 2003; Joe et al., 2004). The user is able to view a variety of composite radar products and able to drill down, via pointing and clicking, to single radar products or to storm specific (cell) views containing a multi-product view of a specific storm (Fig. 2). These cell objects are similar to the CONRAD and WDSS objects (Johnson et al., 1998). An interactive functionality of the client is the ability to create and display arbitrary vertical cross-sections through the radar volume scans. The MSC system produces a variety of proprietary output formats including a "tag-data" format and a "numeric" user defined format.
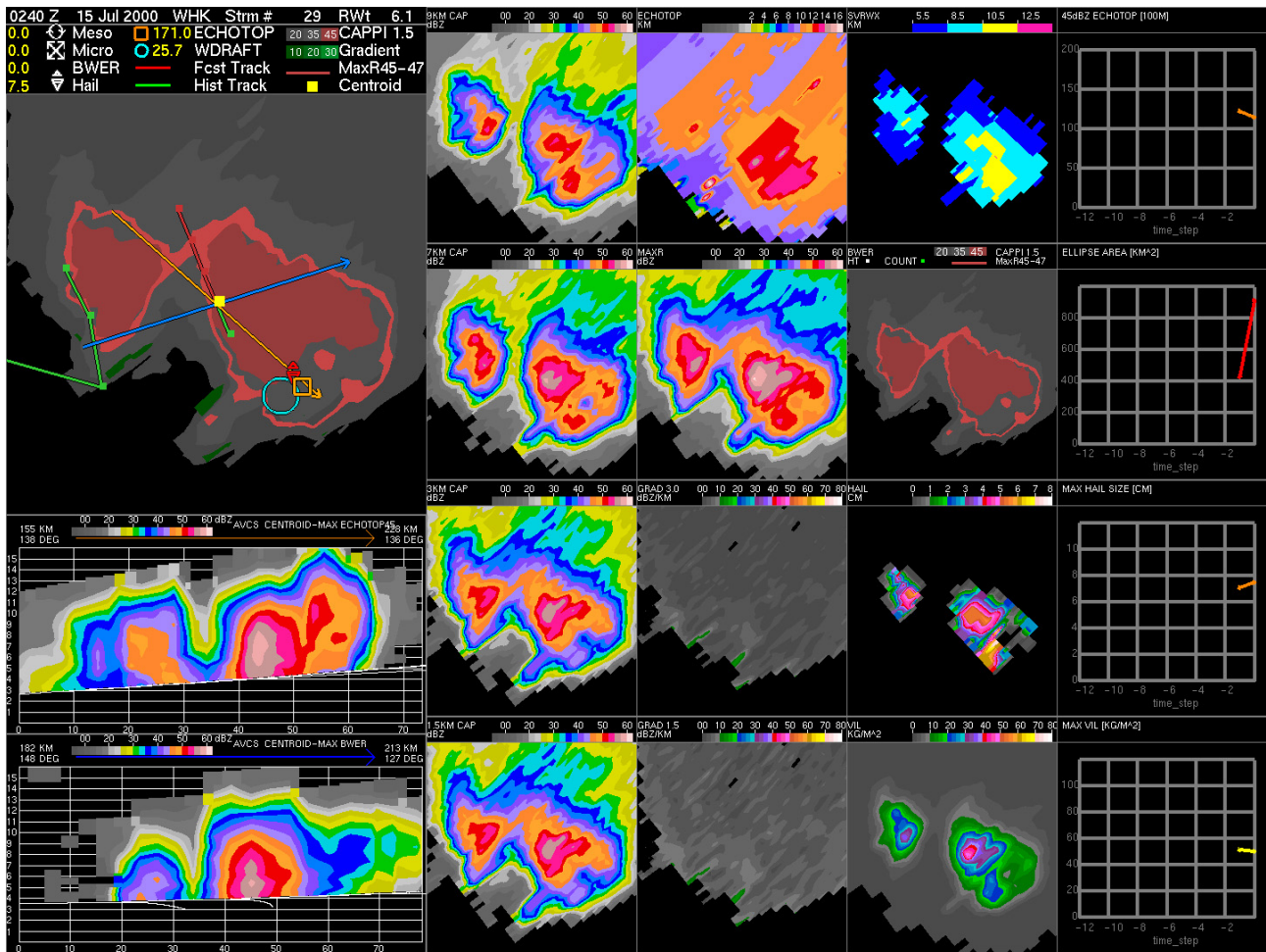
Fig. 2. An example of a "cell view" where the geographical domain of the product is dynamically determined by the location of the cell. The cell view consists a variety of products which succinctly aid in the analysis and diagnosis of the severity of a convective storm. The various sub-panels are configurable.

External radar products are also used. In Europe, radar products from neighboring countries are exchanged via the BUFR format. These may be single radar products or composites. In Canada, data from the US radars arrive in the proprietary NIDS or Level 3 format. In Europe, the external products are generally a single low level reflectivity product whereas the U.S. list of products is considerable (Crum and Alberty, 1993).

In the near future, it is anticipated that better precipitation estimation products and new products that express data quality and the uncertainty of the precipitation estimates will be available. MCH is also developing object processing for heavy rain events (Hering et al., 2004) as well as continental scale nowcasting products (German et al., 2002). It is expected that processing of the radar data will require other types of data and vice versa.

3 NinJo

In very broad terms, the NinJo workstation is a client-server design and the first version focuses on data visualization

(Koppert et al., 2004). Data is stored in its natural form in the NinJo server. It should be emphasize that NinJo is a data and not a product viewer. The data is rendered into an image and re-projected on the fly within the NinJo client.

Individual data is rendered on "layers" or image planes which are merged and visualized on the screen. The layers can be re-ordered by the user and each layer has its own specific menus and toolbars to select, visualize and process its associated data. The geographic view of the data is determined by the NinJo client.

4 The Radar Layer Design

The different radar products and data are used in different ways among the different partners. In order to resolve the differences and diversities, a configurable product/data ingest, a common internal data representation, a flexible data access mechanism and a comprehensive re-projection and rendering client are needed (see Fig. 3). Within the NinJo concept, the cross-section, the cell object display functionality are presented in other layers.
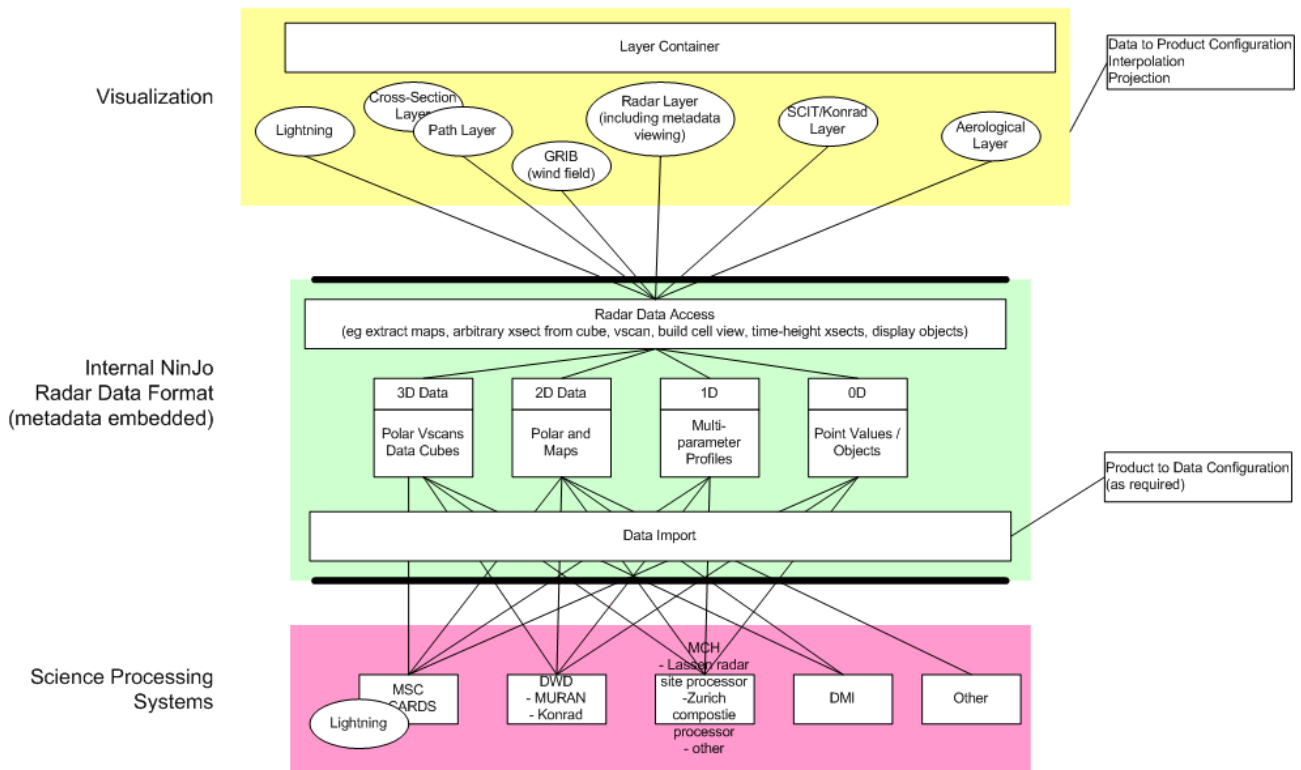
Fig. 3. The software design of the radar related NinJo components. Legacy systems are shown on the bottom, the internal radar data is shown in the middle and the visualization client layers are on top.

To resolve the diverse data and products, a common internal "data" representation is ereased. In order not to degrade the data (any further in some cases), the data is stored in the received co-ordinate system. Color values or indices in image products are transformed via configuration files to data values. In most cases, legacy systems were modified to produce data values as a result of the NinJo project.

The projection of the visualization is flexible and determined by the client through a menu selection of a projection type and an interactive graphical selection of the projection domain (which determine the projection parameters). Therefore the re-projection from the natural co-ordinates of the data to the visualization co-ordinates is done in the client. The client also performs the color rendering as well.

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 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 algorithms (maximum value, nearest radar or prioritized product) are coded to handle data/product overlap. Sophisticated compositing

algorithms are left to the legacy (and future) processing systems.

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 all can be overlaid. With the path being defined on an arbitrary map domain, multi-segment and multi-radar cross-sections are required (see Fig. 4).

The cell objects are handled by a SCIT (Storm Cell Identification and Tracking) Layer. The SCIT layer 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 a detailed cell view product.

In the server, data is stored in its "natural" form. In the case of volume scan radar data created by the radar acquisition computer, it is in polar coordinate form. For a data cube produced by a legacy processing system, it will be in a Cartesian form in some projection – e.g. gnomonic or polar-stereographic. The data ingest portion of the server does not degrade or re-project the data. Legacy products that
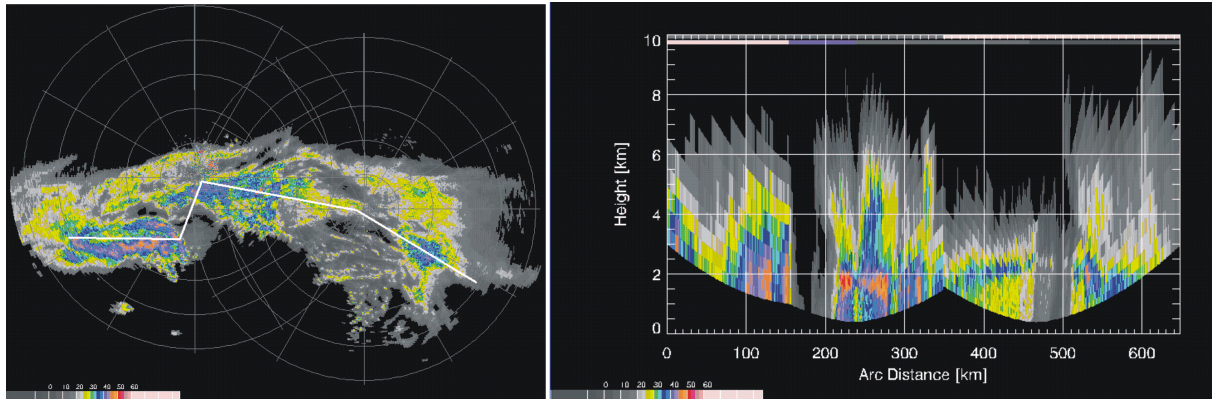
Fig. 4. A prototype example of a multi-radar, multi-segment cross-section. The color bars at the top of the cross-section indicate radar and segment transitions.

are composed of PPI's and max reflectivity-principle axes cross-sections will be dis-aggregated into separate data products and re-aggregated in the client. 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.

Animation of products with different time cycles is handled by displaying a product beginning at its valid time until its validity duration has expired. The validity duration of a product can exceed the time interval between cycles. This can result in "jerky" radar animations. It is envisioned that, in future, it is possible to interpolate the images to a common time cycle. Note that with many of the other data sets, the time interval of the information is generally much longer (e.g. 1–3 hour time steps between model output) than radar data. Within NinJo, the user will be able to set the cycle interval for the display.

There was no clear choice for an internal storage format for the radar data or products. BUFR is a WMO standard for radar products but is not complete (e.g. 16 bit data or floating point data such as for rainfall rates or rainfall accumulations or for weather objects). In the end, netCDF was selected mainly because of the existing experience with it within the NinJo project, it's ability represent 2D and 3D data in a consistent fashion, the available supporting API's. HDF5 used in the Baltex Radar Data Center is not sufficiently mature and is not yet accepted as a standard (Michelson, 2001). There is also an emerging effort to merge HDF5 and netCDF (Rew and Hartnett, 2004).

With the NinJo concept, various data products are served to a "cell view" component which extracts, re-projects and renders the visualization. The contents of the cell view are configurable and dependent on the available existing products. The geographical domain of the cell view is flexible and it could be as large as the domain of a single radar. So, this component will also be used to re-aggregate the single radar with principle axes cross-section products as well.

5   Conclusions

NinJo is a Java-based software workstation being developed by a consortium led by the DWD. The target date for version 1.0 is by the end of 2004. The first version focuses on the integrated visualization of meteorological data. It is designed to overcome the limitations of traditional "stove piped" workstations of the past to allow for future expandability and extensibility and for the future development of integrated forecasting and forecast production applications (e.g. automatic monitoring or warning production). Radar functionality is segregated into several NinJo layers or components - radar, cross-section, aerological and SCIT.

A key concept of NinJo is data and not image visualization. Data is retained in it natural form and re-projected and rendered on the fly. The client will determine the geographical domain of the visualization. So each piece of data must be geo-locatable and must be fully describable (e.g. units). Radar data comes in diverse forms and is used in many different ways. The radar layer is designed to overcome the diversity and deficiencies of legacy processing systems.

The integrated visualization of radar data is a major leap forward for forecasting and nowcasting. For example, the analyst will be able to visualize the location of radar, satellite, model and surface data all on a single screen which will enable effective and efficient analyses and diagnoses of the meteorological situation. With the participation and contribution of several consortium members, new capabilities and functionalities are and will be realized – e.g. on the fly composite, SCIT capability, cell views and in the future better quantitative precipitation estimation products using a variety of data and nowcasting products.

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