WEATHER WEB REMOTE OBSERVATION SYSTEM MODEL WEB-8700

PRELIMINARY BULLETIN WEB-8700

Model TDL-6200 Doppler Wind LIDAR

Radio-MET Weather Post RF linked met set

General Description

The Weather Web™ Remote Observation System (WxWEB) provides emergency response teams with real time meteorological parameters from multiple, spatially-separated locations. It can be rapidly deployed in a few minutes and provides a robust and fully automated system for continuous unattended observations.

Data from the Weather Web can feed numerical weather prediction models to provide decision-makers with life-saving information about the direction of chem-bio plumes. The Weather Web is based on TCP/IP networking and is compatible with common industry interface standards such as Java and ODBC.

Real time data supplants the range of traditional human observations by automating manually intensive tasks. Data are presented via a web browser in real time. The Weather Web system personnel to perform more important value-added tasks, and helps to eliminates subjectivity of human observers. In perilous situations, such as NBC attacks, it permits human personnel to leave affected areas for safer ground.

The Weather Web acquires data from remote RF-linked surface wind sets and Total Sky Imagers to obtain cloud data, and an eye-safe Total Doppler LIDAR for real time wind profiles. Each minute, the system automatically:

1. Acquires and databases all instrument data for later playback and study
2. Checks the TCP/IP network links
3. Processed cloud imager results
4. Runs a prediction model of anticipated cloud motion in the next ten minutes
5. Presents the most recent model run

Features

- Fully automated real time wind monitoring
- Solid state sensors provide reliability
- Standards based networking leverages your existing IT investment
- Requires minimal user training and no special client software at user workstations
- Database supports post-event audits

Applications

- Temporary or semi-permanent observing system for military/commercial applications
- Numerical Weather Prediction: Input for weather forecast models
- Ground truth validation of remote sensing platforms
- Spaceflight operations where the view to locations beyond the lower troposphere is critical to mission success
- Scientific research on global warming and climate change
- Labor reduction of human observers at cost-limited or remote/hostile locations

Keeping People Out of Harm's Way

When a nuclear, chemical or biological attack occurs, there are both short and long term impacts and casualties. Knowledge of current and future winds is critical to optimally moving people out of the death zone. The YES Weather Web is a rapid response deployable wind measurement system that can be used drive numerical weather prediction forecasts such as DTRA's plume dispersion models. Output from these operational models can then be used to direct tactical and emergency response teams.

In a nuclear attack, the obvious blast damage occurs instantly is followed by a radioactive cloud of debris that can reach to the lower stratosphere. For nuclear attacks upper air radiosonde soundings are necessary to provide vertical wind profiles to altitudes on the several dozens of km range. Pressure, temperature Humidity and wind data conventionally provided via Skew-T charts gives meteorologists key knowledge of the sate of the atmosphere and can be used to predict where fallout will occur. An automated upper air radiosonde system such as the YES Mobile ARL-9000 can provide this high altitude wind data, and it can be used to set initial conditions for operational mesoscale numerical weather prediction models such as COAMPS or MM5.

In contrast to nuclear events, chemical and biological attacks take place much closer to the ground, in the lower troposphere. Winds near the surface transport chemical or biological agents, and actually predicting what will happen to a plume in the boundary layer under stable conditions with a high degree of confidence remains an active research area by DTRA and others. The more stable the atmosphere is, the more difficult it becomes. The challenge here is to make accurate wind predictions with scarcity of data, and that is where the Weather Web enters the picture.

The Weather Web concept involves both a physical web of sensors geographically distributed about the combat/conflict area. It also provides relies on a virtual communications web of TCP/IP connections to both acquire sensor data and distribute it to decision makers in real time.

The Weather Web relies on software technologies such as SQL and Java to transparently provide data access to those who need it without requiring specialized software to reside on their local weather workstation. In times of disaster, there is simply no time to install or configure software. With the weather web, if a user is connected to the Internet backbone, they simply point a web browser at a URL. While the surface wind sensors are generally limited to a range of less than ten and require line of sight for their UHF 403 MHz links, access to it is limited only by the extent of the installed TCP/IP infrastructure.

At the core of the software is the Yankee Environmental Systems Data Acquisition system (YESDAQ), a powerful software system that automatically collects, archives and manages environmental sensor data from one or more surface observation sites. YESDAQ data can feed real time initial conditions for on line meteorological forecasting ingest systems such as LAPS. Once data are ingested and analysis fields are created, numerical weather prediction models can be run (such as MM5, ETA, RAMS, COAMPS, ARPS or WRF).

YESDAQ provides complete, unified remote instrumentation data management with support for Total Sky Imagers, Rotating Shadowband Spectroradiometers, LIDARs, Ceilometers, Surface Meteorological Sensors and Upper Air Automated Radiosonde Launchers. Using TCP/IP networking, YESDAQ collects instrument data in real time from anywhere on the network, while simultaneously displaying real time data via web browser clients.

As the following illustrates, YESDAQ supports automatic remote data collection from multiple instrument sources, relational database archiving of collected data, full data replication across multiple servers, remote visualization of archived data via web browsers and the capability to link to third-party forecast and analysis tools via ODBC.

Once remote sensor data is collected into YESDAQ, users can access it in real time via:

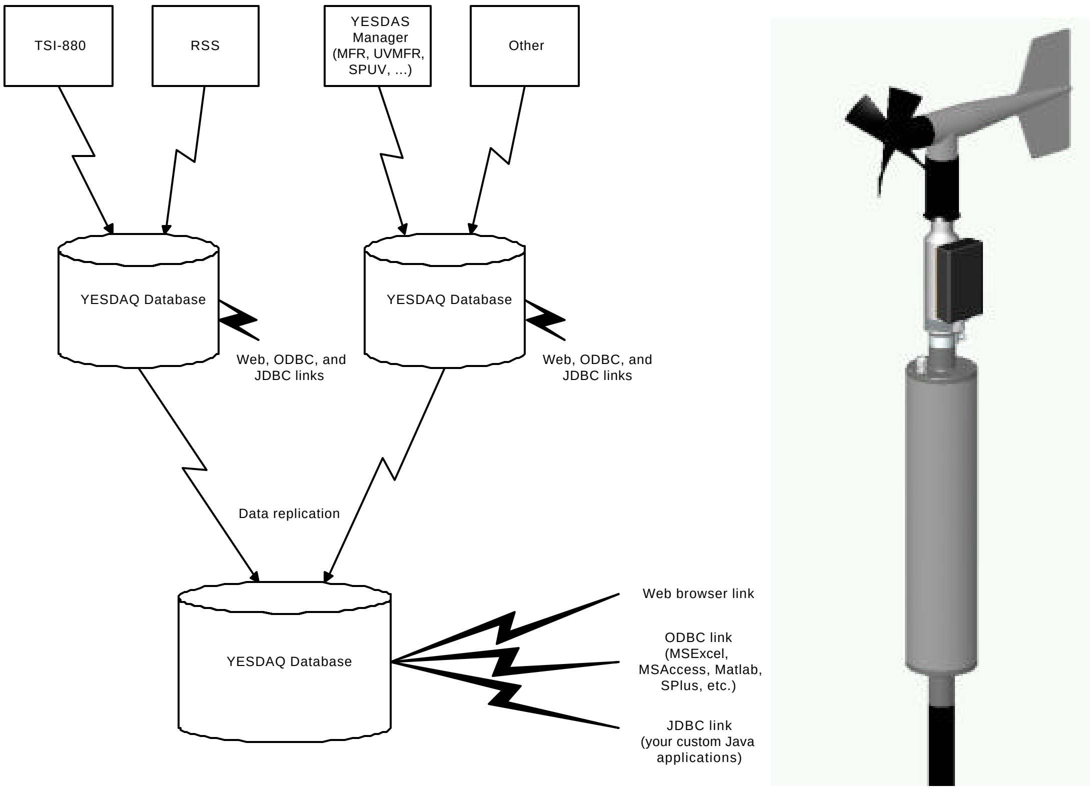


Figure 1. YESDAQ supports remote sensor data collection and display.

- A built-in Web server that provides access through any Java-enabled Internet Web browser both as raw text and graphically via the DVE for each instrument type.
- ODBC and JDBC drivers, which let you connect to the YESDAQ database and use third-party tools such as *Matlab*, *Splus, IDL*, or *Crystal Reports* to perform sophisticated analysis tasks (for example, cross-instrument data fusion, statistics, or linking to your own custom Java or MFC applications.)

YESDAQ is based upon MySQL, a licensed open-source technology that is highly reliable and well tested. Your data are not locked up in a proprietary system. When you direct your Web browser to data collected by a particular instrument, you are actually making live SQL requests into the database. Queries are then plotted via the instrument's DVE component to let you wade through data in a variety of ways.
Industry-standard ODBC and JDBC links let you use any number of third-party tools to perform specialized down stream data analysis, forecasting or sensor data fusion tasks. This flexible architecture lets you expand your data processing capabilities by adopting newer and better tools as software and networking technology improves. Other native programming interfaces are supported, including Perl.

A Look at Various Deployment Architectures

Because it is based on TCP/IP protocols, the system leverages the power of the Internet to both collect and distribute real time data from remote sites to users. Three basic topologies are supported: a single data type/instrument type with a single central server, mixed data types/instrument types with a central server, or multiple data types and several replicated servers. Managing any geographically distributed network requires careful planning and execution, as well as user training.
The following image shows a centrally managed wide area network of several surface sensor types.

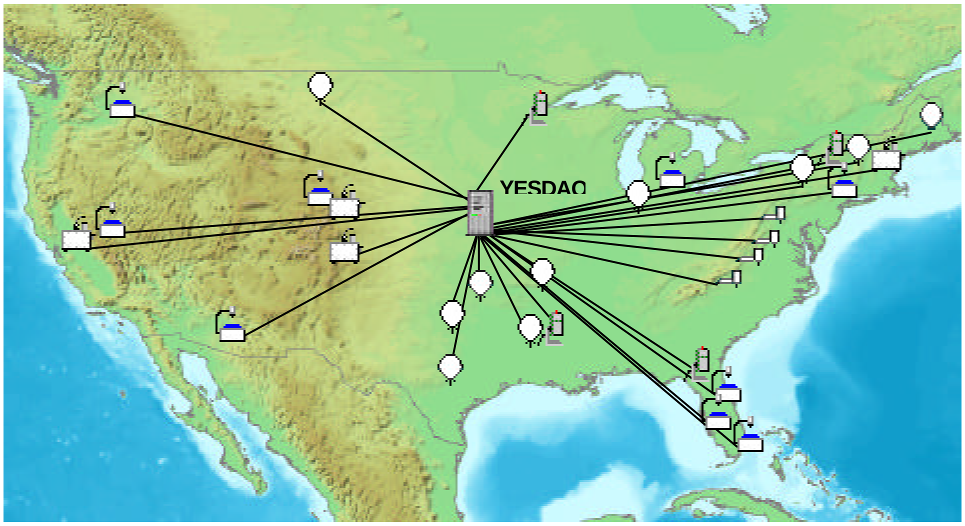


Figure 2. Heterogeneous (multiple data types/instruments), single server.

The next figure shows a distributed but homogenous network of sensors of the same type, centrally managed.

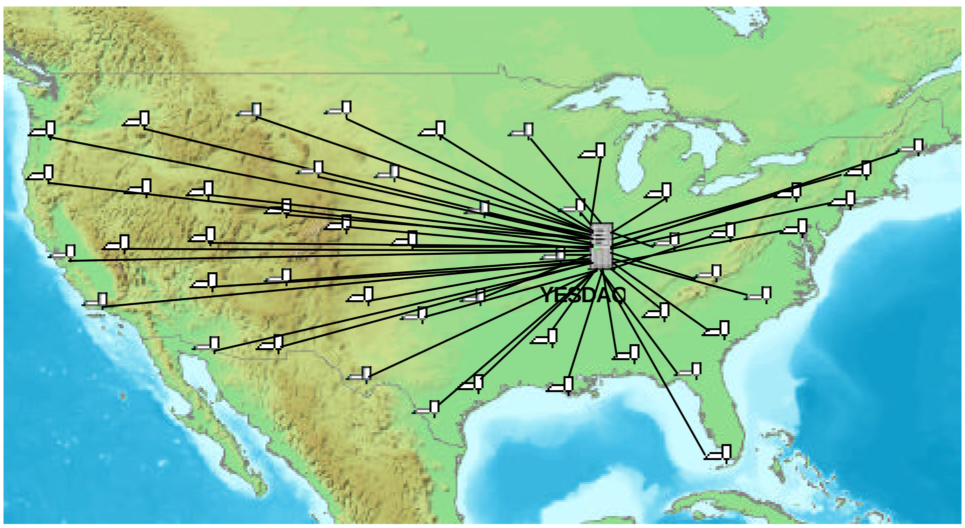


Figure 3. Homogenous (single data/instrument type) network, single server.

The next figure shows a distributed military weather network collecting data from multiple instrument types and replicating data across multiple YESDAQ servers that are located close to the end user downstream applications.

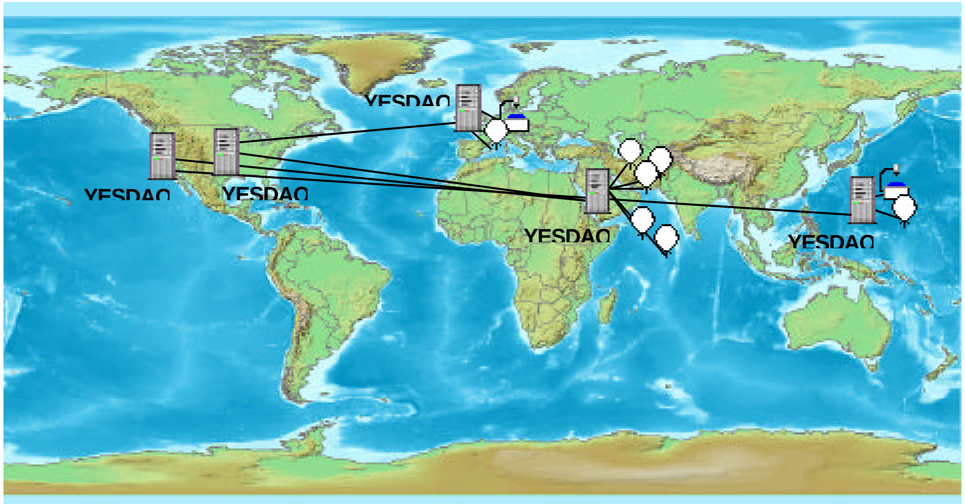


Figure 4. Multiple YESDAQ servers serving a geographically disperse suite of instruments. In this case data are replicated and users see a single, unified net view.

In this worldwide example, both Monterey CA, and Omaha NB forecast centers have YESDAQ hosts, with remote hosts at RAF Croughton in the UK managing a local Total Sky Imager and launcher, a host in Saudi Arabia managing a fleet of ARL launchers throughout the Middle East, and aboard a Navy aircraft carrier in the Pacific. Such a network can feed surface data in real time to existing weather prediction models and other no-casting forecast tools. Data fusion ranging from simple calculation of wind chill all the way to Total

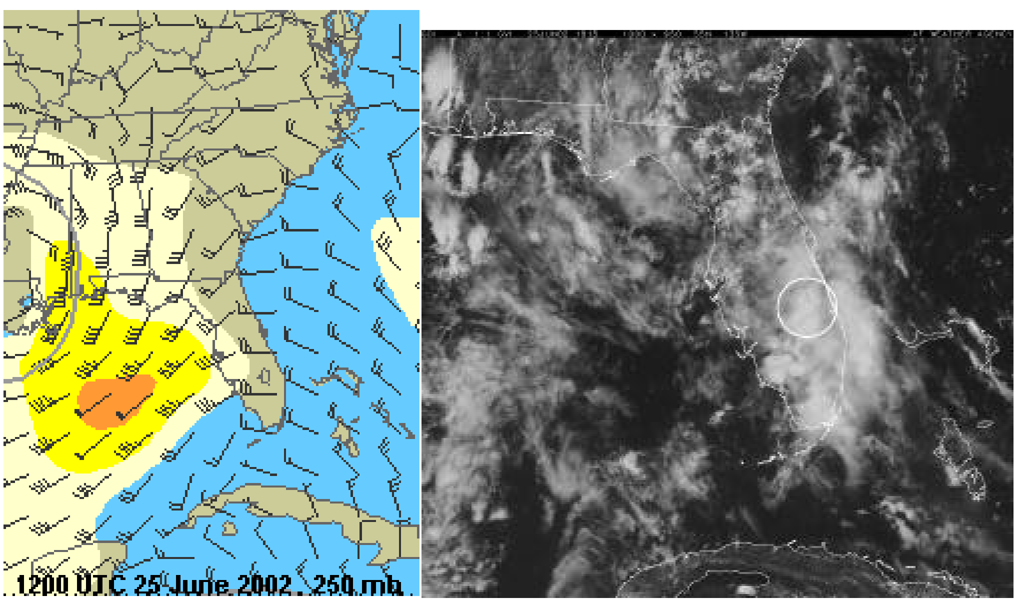


Figure 5. Numerical weather prediction model output, with satellite image. YESDAQ can feed initial conditions to models to improve forecast accuracy.

Sky Imager-based determination of winds at the cloud base are now possible. The Weather Web's underlying YESDAQ software has three primary software components: a Service Manager, the Windows NT database service, and an Application/Web service. Once instrument data is in the Weather Web's YESDAQ repository, you use the Date Visualization Engine to browse it graphically. DVE components such as the Skew T chart viewer provide visual data browsing for each type of sensor/instrument, allowing for specialized data displays across multiple sensor and data types.

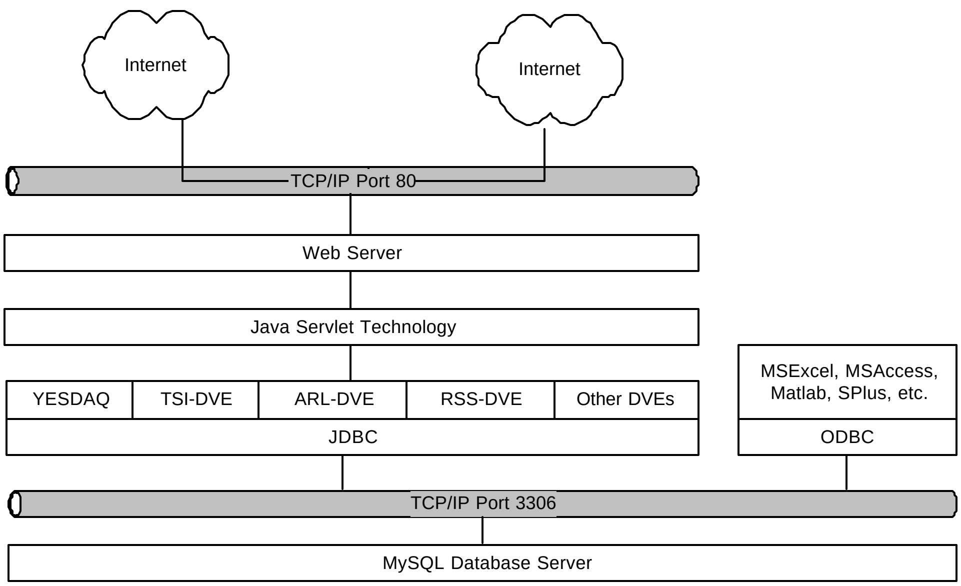


Figure 6. Component Architecture

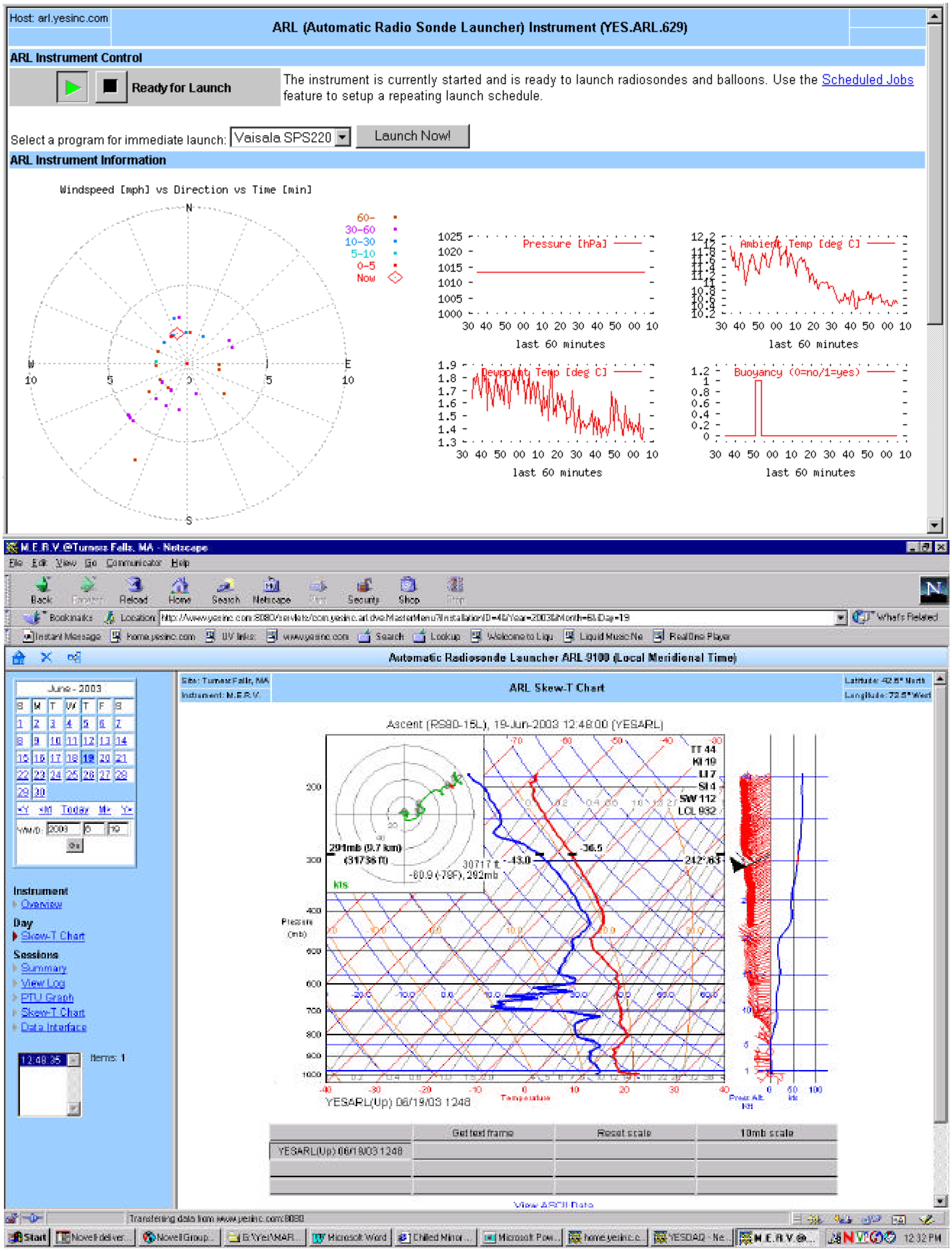


Figure 7. Weather web upper air radiosonde data presented via the web using Java Servlet technology.

Core Sensor Technologies

The weather web consists of multiple core wind sensor technologies: a network of battery powered, radio linked conventional surface anemometers, sky cameras (TSI-880) and a tracking, eye-safe Doppler wind lidar (TDL-6200) used to make cone volume scans of wind up to the boundary layer. Additional upper air wind data can be provided via the YES Automated Radiosonde Launcher (ARL-9000). The Weather Web can be rapidly deployed by minimally trained personnel and can feed data via TCP/IP into established back end models operating either in the field or at established weather prediction centers. Sky Imagers are optional.

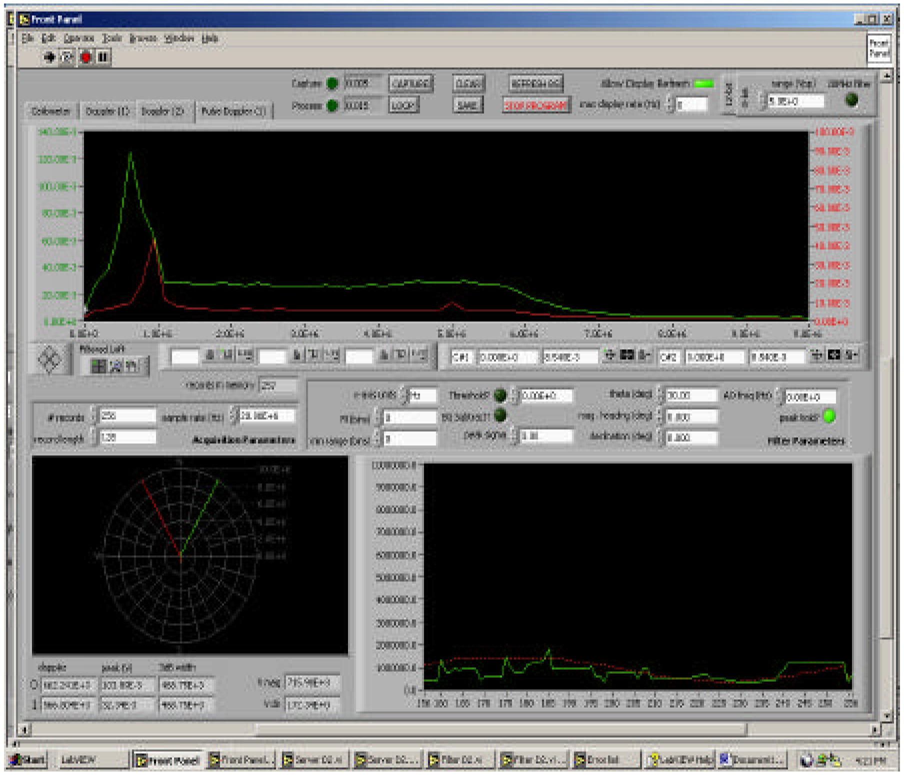
RF linked met set

Tracker-mounted wind lidar

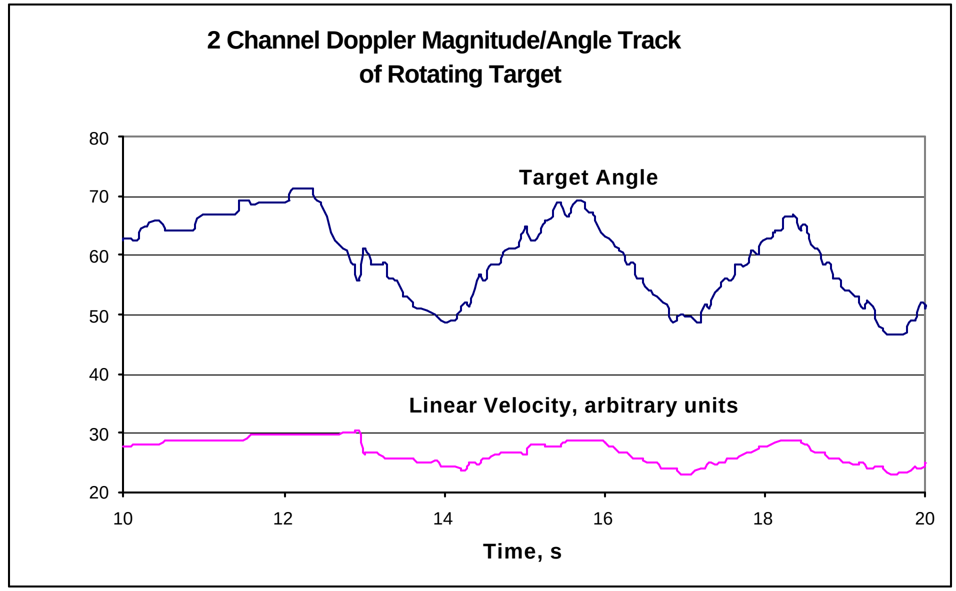
Total sky imager

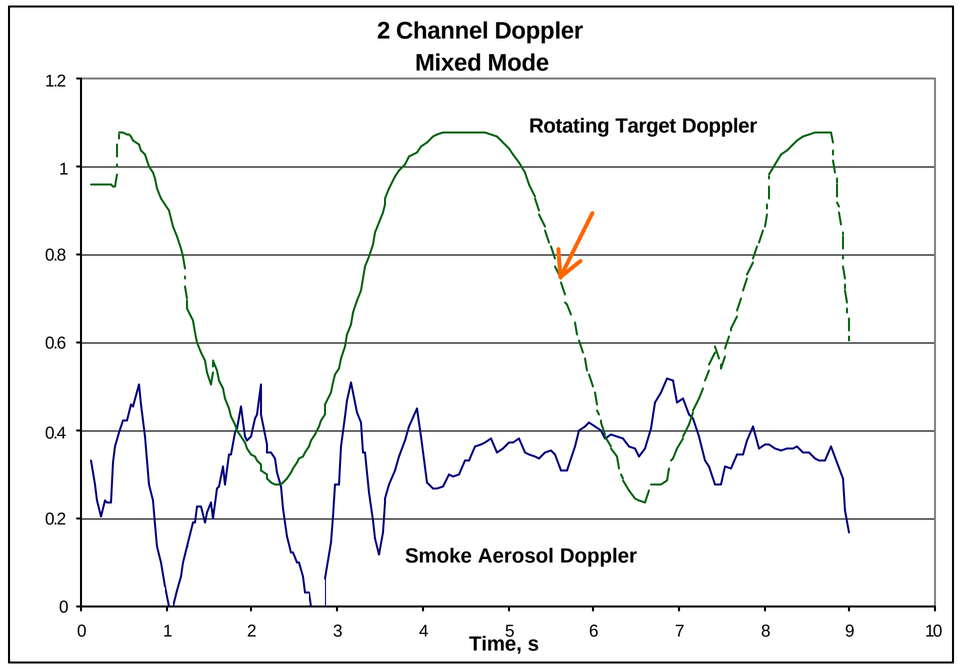
Examples of System Data

An example of lidar output during field testing appears below.

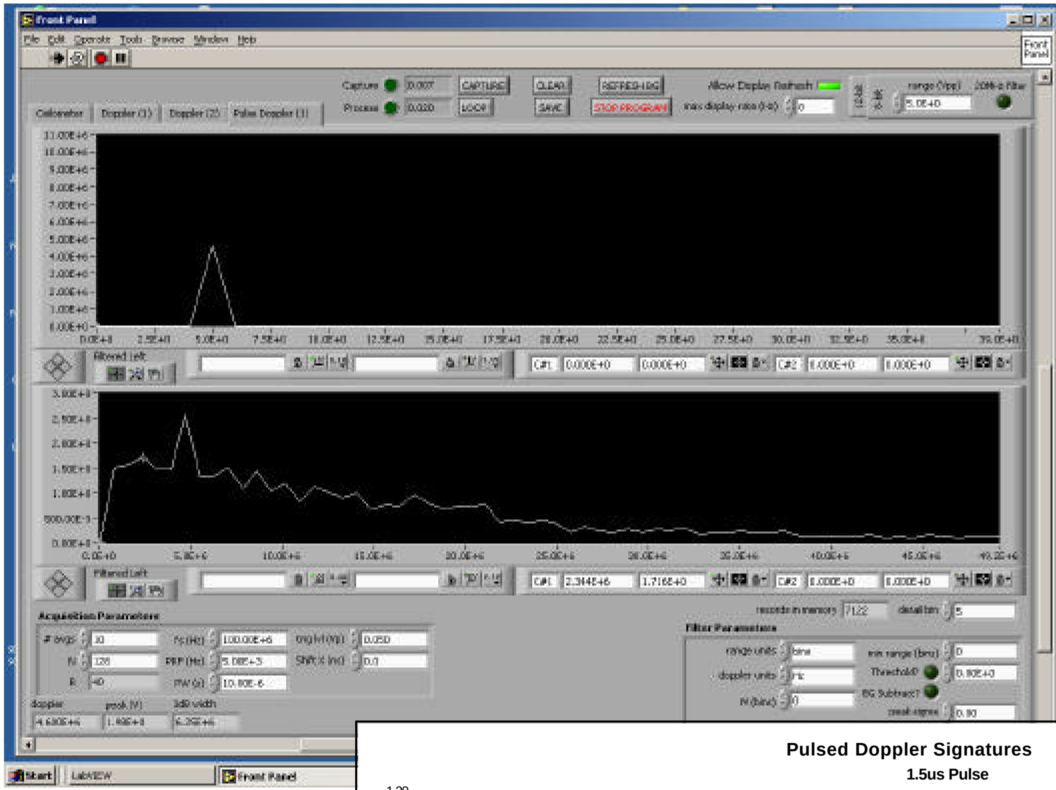


- **2 Channel CW Doppler Lidar Real Time Wind Display**

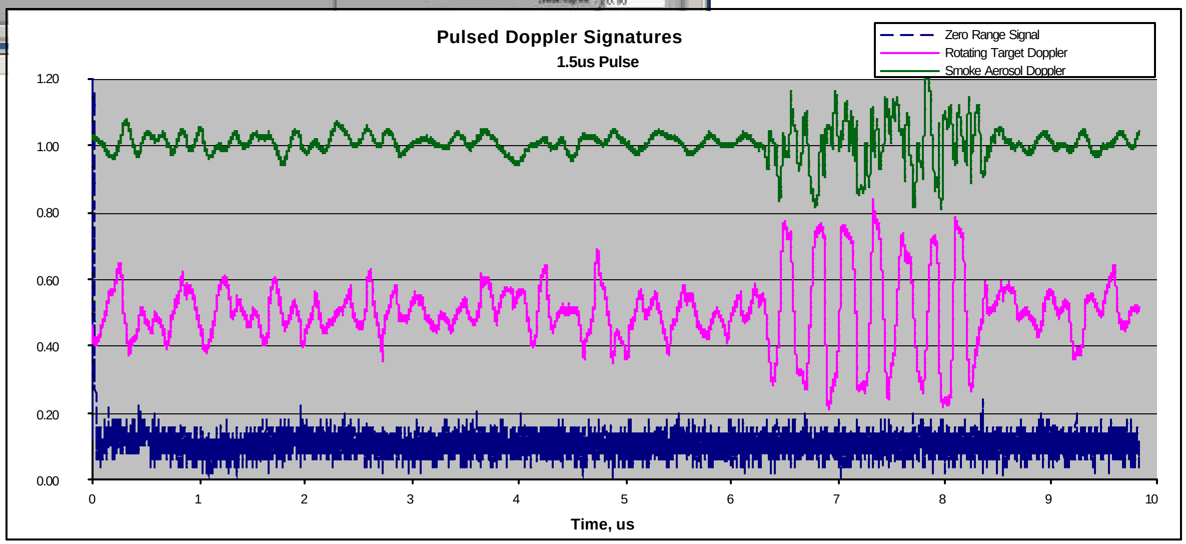




Magnitude/Angle Plot from Rotating Target

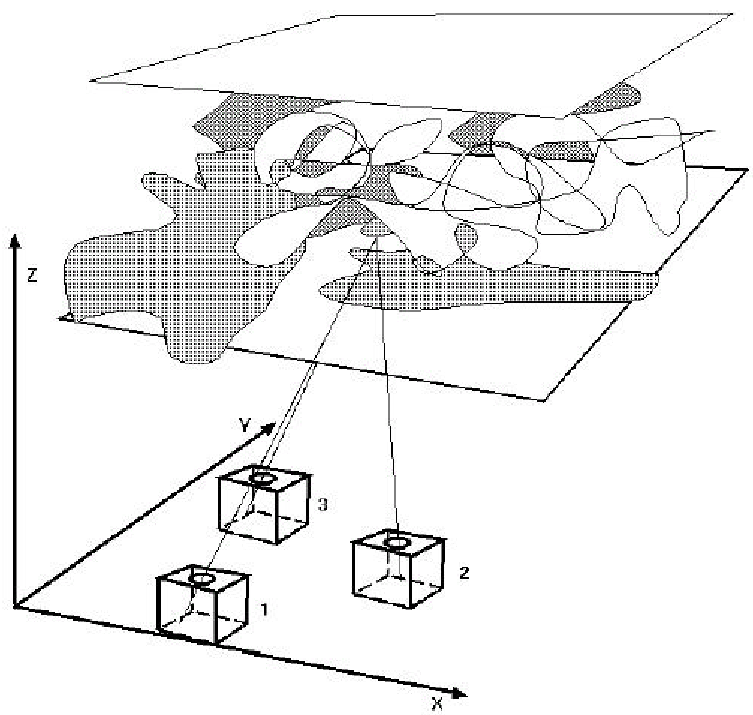


Single Channel Pulse Doppler Signal

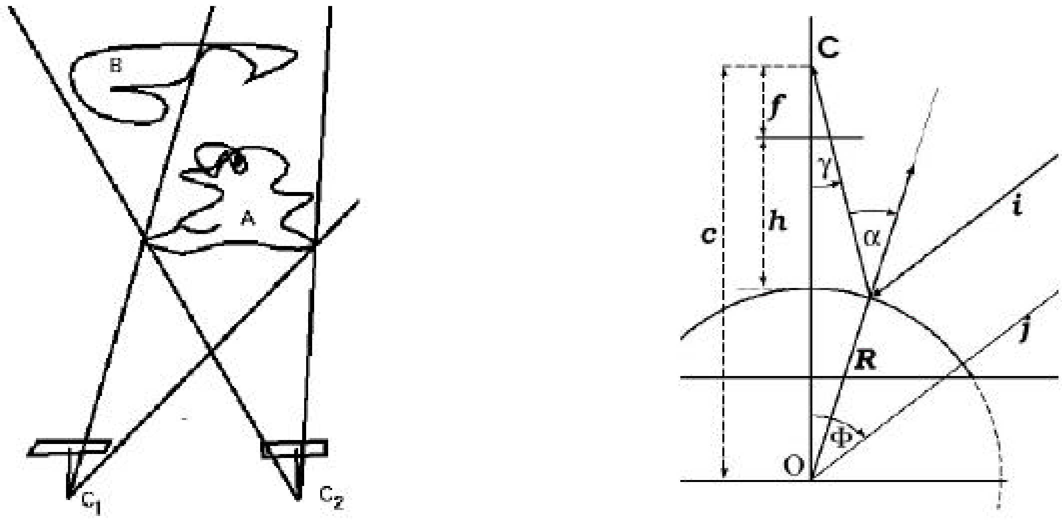


Cloud Motion Model Background

Cloud cover processing is described in the TSI data sheet - COPS uses TSI processed data to model future cloud motion based on a proprietary motion algorithm. Data from each of at least four spatially separated sky imagers is first concatenated into a single plane and corrected for spherical aberrations. RSS optical depth data provides backup for transparency and scattering calculations.

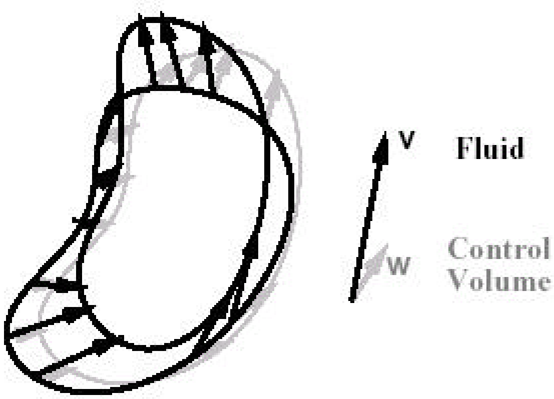


Multiple track cameras attempting to image a launch mission



The basic problem of cloud cover determination (left) and imager optical geometry details (right)

Consider the observation of a control volume which is moving according to a velocity field ω Just like the actual fluid velocity field (particle velocity field) this field can be thought of being inscribed on the fluid domain under observation. The velocity w of the field is assumed to be independent of the spatial velocity field of the fluid's velocity field v. A control volume (shown in light gray in the figure below) is moving with the grid, that is, its boundaries are moving at the velocity w at the spatial locations of the boundary. Transport equations can be stated for any field that is associated with the air flow,



General case of Reynold's transport theorem, describing fluid flow in a moving coordinate system.

Both the velocity υ of the fluid and the velocity ω of the grid are relative to a fixed Euclidean space. The control volume moves with the velocity field of the grid - its position a short time later is shown in light gray. The fluid that initially covered the control volume is soon in the region shown with black lines. Arrows show the displacements of individual particles on the surface of the control volume. Let ϕ be a smooth spatial field that is either scalar or vector valued. For any control volume that moves with the field w the rate of change is described as:

$$\frac{d}{dt}\int_{C_t} \psi dV = \int_{C_t} \psi' dV + \int_{\partial C_t} \psi \left((\boldsymbol{v} - \boldsymbol{w}) \cdot \boldsymbol{n} \right) dA$$

We imply here that the field ψ is actually "attached" to the particles, which are moving according to a spatial velocity field υ. It makes more sense to think of something that is transported by the velocity field. The symbol ψ' represents the change of the field, keeping the spatial location fixed, whereas ÿ would be the material change of the quantity while moving along with a particle.

The cloud field changes both due to transport and to local thermodynamic processes. There are two limiting cases: In the Eulerian description, the field ω is zero and in the Lagrangian description it is equal to the velocity of the movement, so that the second part disappears. As long as we are dealing with a stationary observer, we are dealing with the Eulerian description, so we set ω to zero, as we are stationary observers. Assume also that ψ represents some quantity that represents the visibility of water vapor in clouds. We arbitrarily assign a value of zero to represent no observable vapor.

Typical sequence of sky pictures, taken over a 5-minute period.

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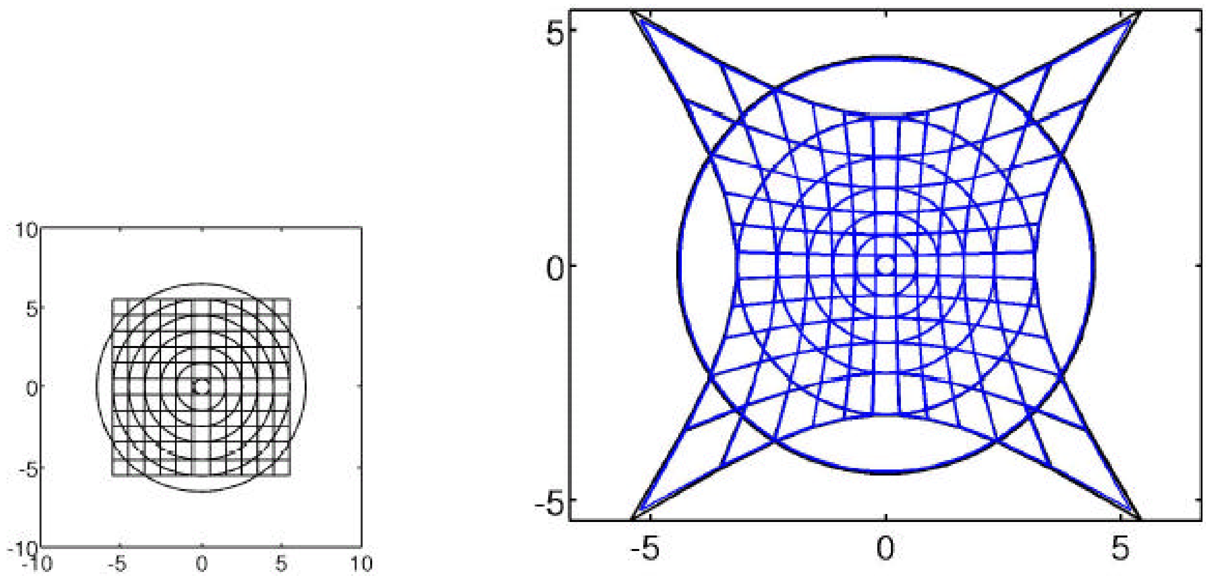
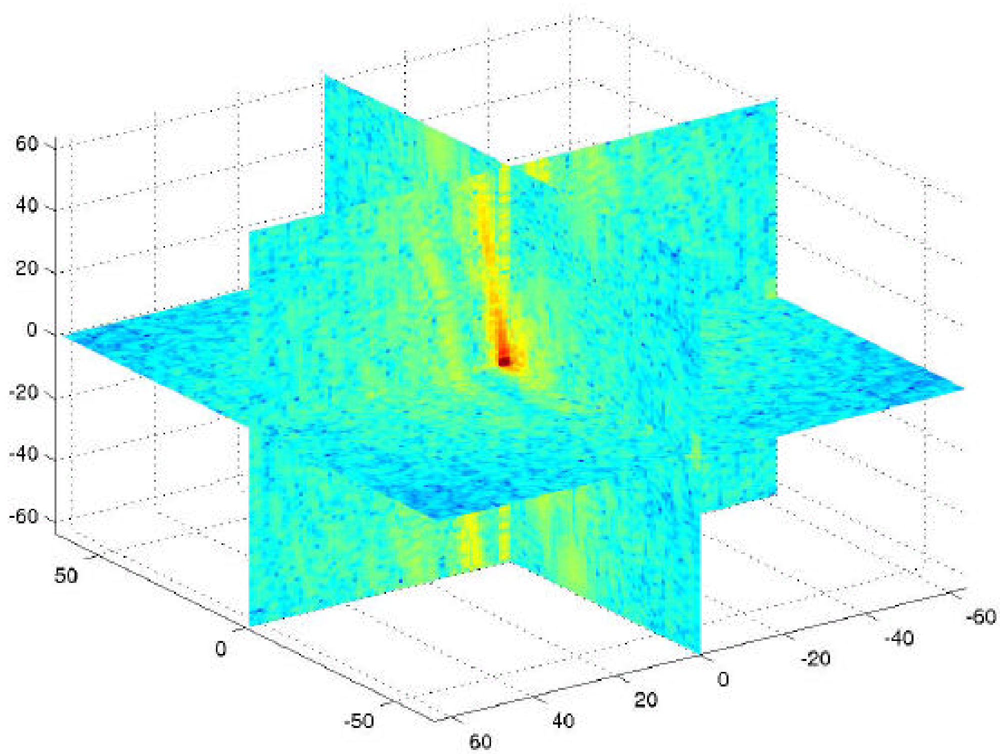
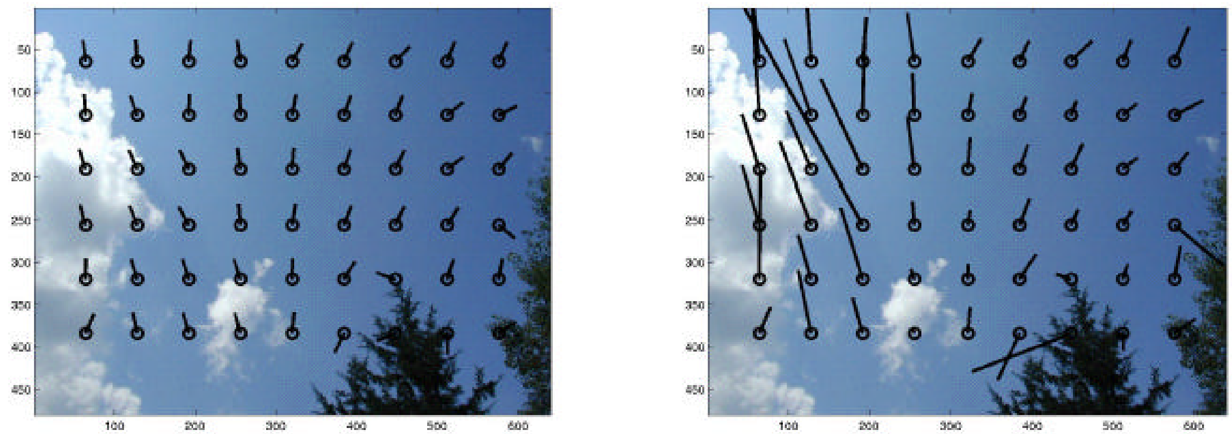


Mapping TSI's spherical imager data into plane geometry space

A 3D FFT is then used on a data set of 128x128x128 pixel values. Using a Hamming window in the frequency domain, a tensor, T, is calculated. In the spectral domain, data averaging is only done over the middle range of spatial frequencies, using a three-dimensional, rotationally symmetric weighting function.



Example of a 3D-spectral density in the k_x-k_y-ν space. This spectral density will be approximately a flat ellipsoid if there are some clouds moving in the same direction.



Estimated direction (left) and direction and magnitude (right) of the cloud field for a number of regions of interest in the image domain. The fat cloud to the left is the main reason for the high values of the speed: When studying the sequence as a movie one can see that this cloud is "boiling off." It begins suddenly to show the sky through which would appear to be a very fast upwards movement of the sky. The magnitude measurements on the right side are more reliable since they are mostly based on little clouds moving through.

Data Merge Facility

Managing a site for an extended period produces a sizable data repository. Data are collected and stored for later display or further analysis in YESDAQ, a mySQL-based open source relational database with ODBC/JDBC connectivity to other downstream applications.