Using Geospatial Databases and Graphical Information Systems in Operational Avalanche Forecasting

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Since 1950 avalanches have killed more people in the state of Colorado than any other natural hazard, and in the United States, Colorado accounts for one-third of all avalanche deaths. The Colorado Avalanche Information Center (CAIC) is a state government agency tasked with reducing the impact of avalanches on visitors, residents, and the economy of Colorado. The CAIC provides education and forecasting for winter recreation and maintenance operations along state and federal highways. The CAIC's forecast area includes over 15 mountain ranges, highways through 17 mountain passes, and a total area of nearly 120,000 km^2. This area includes a myriad of operations, installations, and topographic features that area affected by avalanches. In 2005 the CAIC teamed with Avalanche Mapping to create a geospatial database of these elements and information typically recorded for avalanche forecasting operations (Greene et al., 2009). Some of the elements that have been combined into this database include: the information contained in avalanche atlases for highway corridors; avalanche areas in mechanized winter recreation operations, backcountry huts and other facilities; metadata of automated weather stations operated by state, federal and private groups; groomed snowmobile tracks; historical avalanche accidents; avalanche paths surveyed for land-use and zoning applications. The database also included current and historical information on avalanche frequency and explosive. Although the digital-elevation model in the database is too course to conduct effective modeling of snow and avalanche processes, this database has proven to be an effective operational tool as a catalog of information that pertains to avalanche operations in a vast and complex mountain area.

Greene, E., D. Atkins, K. Birkeland, K. Elder, C. Landry, B. Lazar, I. McCammon, M. Moore, D. Sharaf, C. Sterbenz, B. Tremper, and K. Williams. 2009: *Snow, Weather, and Avalanches: Observation Guidelines for Avalanche Programs in the United States*, American Avalanche Association, Pagosa Springs, Colorado, USA, pp 150.

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A GIS Database for Avalanche Forecasting in Colorado, U.S.A.

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1 Introduction

Since 1950 avalanches have killed more people in the state of Colorado than any other natural hazard. Accidents in Colorado account for one-third of all avalanche deaths in the United States since 1950. The Colorado Avalanche Information Center (CAIC) is a state government agency tasked with reducing the impact of avalanches on visitors, residents, and the economy of Colorado. Forecasters use a variety of data with a geospatial component in daily operations. We built a single platform that includes as much of these data as possible. The system allows forecasters to access large amounts of data with a single query and without changing computers or software.

The CAIC provides education and forecasting for winter recreation and maintenance operations along state and federal highways. The CAIC's forecast area includes over 15 mountain ranges, 30 stretches of highway through 17 mountain passes, and a total area over 120,000 km^2 (Figure 1). This area includes a myriad of operations, installations, and topographic features that are affected by avalanches. In 2005 the CAIC teamed with Avalanche Mapping to create a geospatial database of these elements and information typically recorded for avalanche forecasting operations.

2 Methods

Our approach:

1) Collect all of the data we use on a daily basis or that we need during weather and avalanche cycles
2) Put it into a single platform allows multiple pathways to finding that information
3) For some parameters (e.g. avalanche paths) we have created application specific layers (Figure 2)

Data sources:

Geo-referenced data from existing sources (e.g. Department of Transportation, National Weather Service, Colorado Geological Survey, United States Geological Survey

Digitized old publications or maps provided by other groups (e.g. Avalanche surveys and atlases, trails, hut locations)

3 Summary

We have created a database using a geographic information system (GIS) that contains as much of the data we use for avalanche forecasting into one platform. The system is a catalog of information that we use during forecasting operations and is not used to estimate or derive additional parameters. It provides quick and easy access to information. It also allows us to create figures for different types of education programs using the same data we use for forecasting operations.

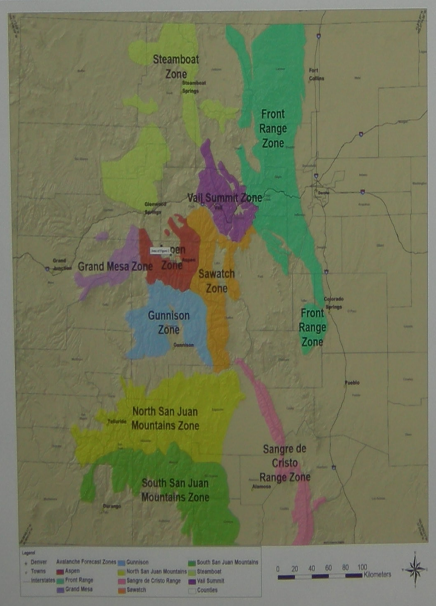

Figure 1: An overview of the area covered by the Colorado Avalanche Information Center including county boundaries, major highways, and the backcountry forecast zones. The red square is the location of Figure 2.

Figure 2: The area surrounding the town of Aspen, Colorado. This region includes many of the components included in the Colorado Avalanche Information Center's GIS database.

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The Colorado Statewide Snow Avalanche Path GIS Database and Project Data Sources and Usages:

The GIS data for the project is sourced from multiple places:

1. **CAIC:** historic avalanche information on occurrence, accidents, weather stations and forecast zones, and mountain ranges.
2. **CDOT:** roads, milepost, railroads, engineering regions.
3. **Avalanche Mapping:** avalanche paths, accidents, weather stations, snow machine and hut system trails and huts.
4. **USGS:** basemap data, hydrology, topographic maps.
5. **ESRI:** basemap demographic data, streams, National Geographic Topos and Icube aerial imagery streamed from the web.
6. **USFS:** ski area boundaries.

GIS Data List

Base Data Layer Name	Layer Description and Type
Above_7000ft	Area of Sq miles and kilometers over 7000 feet.
CDOT_Eng_Regions	CDOT regions of the state.
CO_Cities	Cities.
CO_Counties	Counties.
CO_Mtn_Ranges	Mountain Ranges.
CO_Mtn_Summits	Mountain Summits.
CO_Rds	State highways generalized for mapping purposes.
COBndry	State boundary.
COWXStations	Weather Stations.
ESRIStreams	State wide detailed streams USGS/NHD sourced.
ForecastOfficeZones	Forecast area extent of each CAIC office.
ForestService_Rds	Roads on USFS land.
Highways2010	Details State highways current year.
Interstates	Interstates.
Milepost	State highway milepost.
MjRivers	Major rivers.
NHDWaterBodies	Lakes.
Quad24K	24K Topographic map sheet grid.
Ski_Area_Bndry	Ski Area boundaries
SnowMachineTrails	Snow machine trails
TenAvZones	10 avalanche/mountain range area forecast zones.
TenthMtnHuts	Tenth Mountain Huts
TenthMtnTrails	Tenth Mountain Trails

Avalanche Data Layer Name	Layer Description and Type
AvpathAccidents	Point layer of avalanche accident locations.
BackCountryAvpaths	Avalanche paths observed in the backcountry.
CDOTRds	Avalanche paths that effect CDOT roads.
CntyRdAvpaths	Avalanche paths that effect County roads.
ExplosivesUse	Explosive mitigation points.
LandUseAvPaths	Avalanche paths that effect land use.
MapbookExtents	Map page extent for highway corridor map books.
Obs1	General weather observations based on SWAG.
Obs2	General avalanche observations based on SWAG.
SkiareaAvpaths	Avalanche paths within ski area boundaries.

GIS Software Applications Used in the Project

The GIS software used to build this project is ESRI ArcGIS package. ArcMap and Catalog are used for data development and management. ArcReader/Explorer is used for the delivery and dissemination of the project. ArcPad is used for field data collection with GPS.

Data Design and Usage

The data in this project is designed to collect and display information of historically occurring avalanches and accidents and for doing analysis along roads and on other human infrastructure. This is done by developing/using vector data at a 1:24K (USGS topo sheet) scale. We do not try to do avalanche forecast modeling on USGS DEM (Digital Elevation Model) data. The DEM data was originally developed at 30 meter resolution and the 10 meter data currently available is a resample version of that data. There have been papers[1] published on the inaccuracies of DEM data and that the potential margin of error can be 70-100 ft. There have been avalanche accident deaths in Colorado in small pockets that deposited in stream bed terrain trap and killed the victim. There is no way to model these types of occurrences at that scale. Modeling with DEMS can be useful to assess potential avalanche hazard and then decide if an area is in need of further field investigation but not in avalanche prediction. This can be useful in road and power transmission corridors and can be used as a step in deciding if an area needs to have a mitigation/management plan in place.

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September 2010
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[1]From Gene Dial, Geoeye, 1999 Digital Elevation Model Accuracy Tests.