Proceedings of 3rd Fire Behavior and Fuels Conference, October 25-29, 2010, Spokane, Washington, USA
Published by the International Association of Wildland Fire, Birmingham, Alabama, USA

Initialization of high resolution surface wind simulations using NWS gridded data

J. Forthofer[A], K. Shannon[A] and B. Butler[A B]

[A] US Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory, 5775 Hwy 10 W, Missoula, MT 59802
[B] Corresponding Author:email: bwbutler@fs.fed.us

Abstract
WindNinja is a standalone computer model designed to provide the user with simulations of surface wind flow. It is deterministic and steady state. It is currently being modified to allow the user to initialize the flow calculation using National Digital Forecast Database. It essentially allows the user to downscale the coarse scale simulations from meso-scale models to finer resolution.

Additional keywords: Wind modeling

Introduction
Wind can be the dominant environmental variable affecting wildland fire intensity and spread. When fire is burning in mountainous terrain winds can vary widely in speed and direction over scales of 3 to 200 ft. The result is rapid changes in fire intensity at small scales that can have significant influences on fire growth at larger scales. Fire analysts and managers have not had access to detailed wind speed and direction forecasts at the required level of detail. However, the advance of computer hardware capabilities, relative availability of GIS databases (elevation) and new advances in numerical solutions to the system of equations governing wind flow have led to the development of new tools capable of simulating surface wind flow.

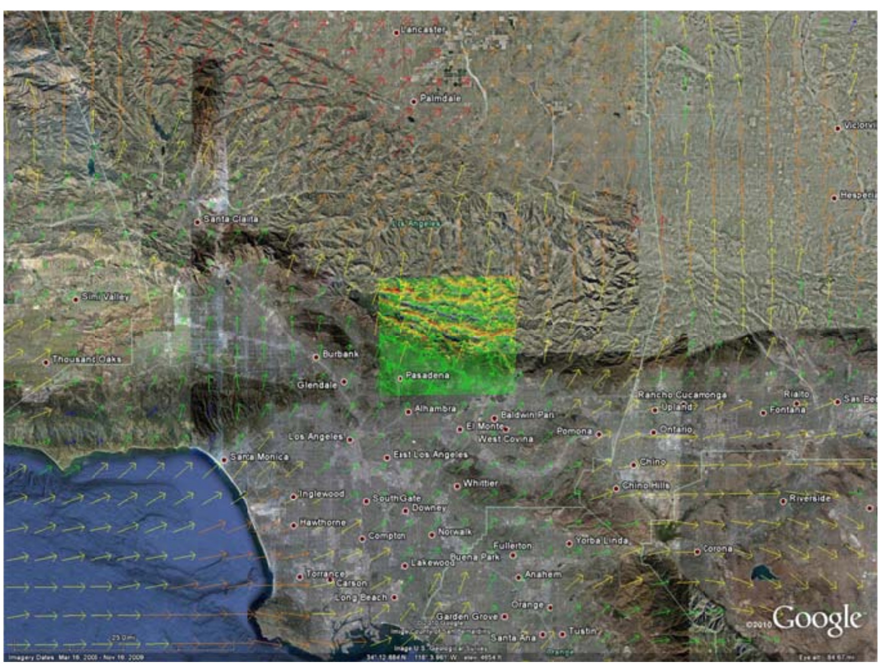
Discussion
Two general types of models exist: diagnostic and prognostic. Diagnostic models predict the wind field at one point in time, and are sometimes called steady-state models, they do not look forward in time. They are useful for situations requiring fast simulations, with limited computing resources and casual users such as disaster response applications. Prognostic models step forward in time. Most models used for weather forecasts are prognostic.

Diagnostic models fall into three categories according to the amount of physics incorporated. The simplest category models are based only on conservation of mass, termed here mass-consistent models (Geai 1987; Montero *et al.* 1998; Moussiopoulos and Flassak 1986; Ross 1990; Sherman 1978; Stone *et al.* 1984). The second diagnostic group solves a linearized momentum equation (Mason and King 1985; Mortensen *et al.* 1993; Oberheu and Mutch 1975; Walmsley *et al.* 1986). Computation times are similar to the mass-consistent models; but non-linear momentum effects occurring in steep terrain are not handled well (Lopes 2003). The third type of diagnostic model considers conservation of mass and momentum with some form of turbulence closure (Alm and Nygaard 1995; Apsley and Castro 1997; Castro *et al.* 2003; Kim *et al.* 2000; Lopes 2003; Maurizi *et al.* 1998; Raithby and Stubley 1987; Uchida and Ohya 1999; Undheim *et al.* 2006) and even conservation of energy (Montavon 1998). In many of these models a k-epsilon turbulence closure using the RNG variant (Yakhot and Orszag 1986) is used (Jones and Rosenfeld 1972). Simulations using the RNG k-epsilon turbulence model have been shown to handle non-linear flow effects such as recirculation better than mass-consistent models (Lopes 2003). Simulations take from a few minutes to a few hours on personal computers.

Transient, or prognostic models, include equations for the physics relevant to weather prediction such as conservation of mass, momentum, energy, moisture and radiant transfer. Because of the added physics, prognostic model forecasts require significant computing resources, have complex initial and boundary conditions, and require highly trained specialists to run them.

Some of the most widely used prognostic weather models in the United States are the Weather Research and Forecasting (WRF) model, the NCAR/Penn State Mesoscale Model 5 (MM5), and the Global Forecast System (GFS). The US National Centers for Environmental Prediction (NCEP) run operational forecasts down to 12 km resolution. Other non operational models are commonly run down to 4 km resolution. At these resolutions, many important local terrain influenced flow effects cannot be captured (Atkinson 1995; Kim *et al.* 2000).

In an effort to include the physics of prognostic models in the high resolution of simpler diagnostic models a recently developed wind model of type 1 was modified to incorporate output from prognostic models to initialize the flow field in the diagnostic calculation. This model is called WindNinja and is available from the US Forest Service Missoula Fire Science Laboratory.

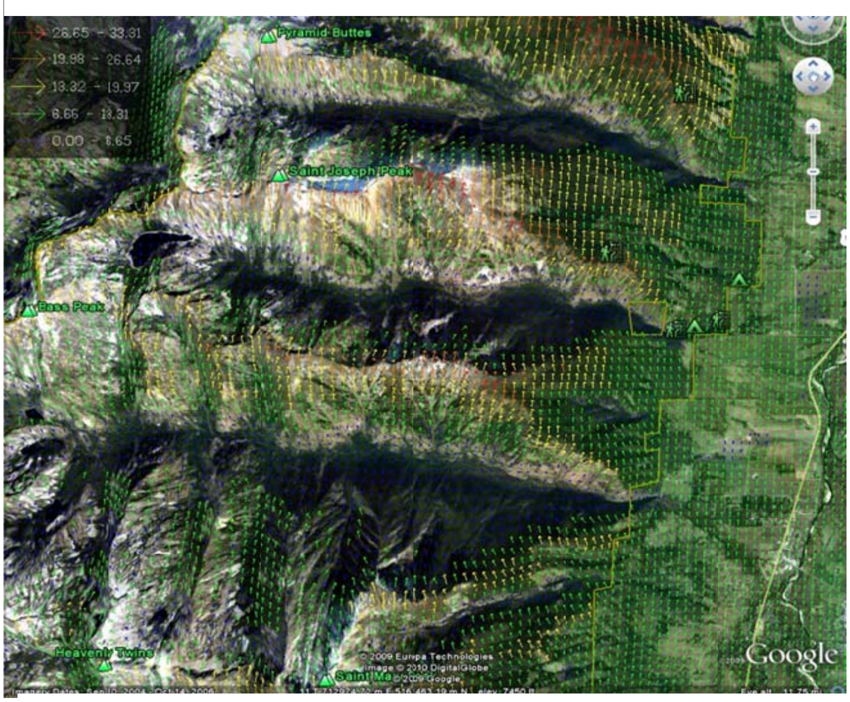


d

Fig. 1 presents a WindNinja grid on a broader simulation grid from a prognostic model. The horizontal resolution of the prognostic model is so large that local terrain scale features are not incorporated in the flow.

Fig. 2 presents a zoomed in image of the prognostic model output data grid. As shown, wind direction and speed are shown for relatively large terrain areas. Fig. 3 shows the same region but with the WindNinja output grid imposed. Local terrain features such as drainages, ridges and other terrain features seem to be more accurately presented.

small



1

The process is relatively straight forward. Several coarse scale weather models are run by NOAA National Centers for Environmental Prediction. These models range from 5km surface grids (NDFD) to 80km volume grids. These models can provide data from a point in time out to 3-7 days for a geospatial subset. WindNinja locates the data spatially and retrieves 3 days of data (this can change). WindNinja retrieves: Wind Speed and Direction, Temperature, Cloud Cover, and Geopotential Height if available.

If the coarse scale model is a surface model, such as NDFD, WindNinja initializes the surface with those data and initializes the rest of the volume as it would without coarse scale weather data, using a logarithmic profile. If the prognostic model output is volumetric, WindNinja interpolates those data to the internal volume mesh for the entire domain. Typically, the coarse scale weather model data is every 3-6 hours, 3 hours for the first 2-3 days, then every 6 hours after. WindNinja reads in the forecast, initializes the domain depending on the spatial dimensions, and does a run for each time step in the forecast.

Conclusions

A high resolution surface wind model has been modified to utilize data from a prognostic weather model at relatively coarse scale to initialize the calculation. A version of the model has been run using this option. Work continues on a GUI and final release version for distribution to wildland fire managers. This capability is unique in that it provides a physics based method for downscaling relatively coarse scale prognostic model data to 100-200m resolution. A release of this capability in the WindNinja software tool is expected in early 2011.

References

Alm LK, Nygaard TA (1995) Flow over complex terrain estimated by a general purpose Navier-Stokes solver. *Modelling, Identification and Control* **16**, 169-176.

Apsley DD, Castro IP (1997) Flow and dispersion over hills: Comparison between numerical predictions and experimental data. *Journal of Wind Engineering and Industrial Aerodynamics* **67-68**, 375-386.

Atkinson BW (1995) Introduction to the fluid mechanics of meso-scale flow fields. In 'Diffusion and transport of pollutants in atmospheric mesoscale flow fields'. (Ed. Dordrecht) pp. 1-20. (Kluwer Academic Publishers)

Castro FA, Palma JMLM, Silva Lopes A (2003) Simulation of the Askervein Flow. Part1: Reynolds averaged Navier-Stokes equations (k-epsilon turbulence model). *Boundary-Layer Meteorology* **107**, 501-530.

Geai P (1987) 'Methode d'interpolation et de reconstitution tridimensionelle d'un champ de vent: le code d'analyse objective MINERVE.' EDF/DER, HE/34-87.03.

Jones JM, Rosenfeld JLJ (1972) A model for sooting in diffusion flames. *Combustion and Flame* **19**, 427-434.

Kim HG, Patel VC, Lee CM (2000) Numerical simulation of wind flow over hilly terrain. *Journal of Wind Engineering and Industrial Aerodynamics* **87**, 45-60.

Lopes AMG (2003) WindStation - A software for the simulation of atmospheric flows over complex topography. *Environmental Modelling & Software* **18**, 81-96.

Mason PJ, King JC (1985) Measurements and predictions of flow and turbulence over an isolated hill of moderate slope. *Quarterly Journal of the Royal Meteorological Society* **111**, 617-640.

Maurizi A, Palma JMLM, Castro FA (1998) Numerical simulation of the atmospheric flow in a mountainous region of the North of Portugal. *Journal of Wind Engineering and Industrial Aerodynamics* **74-76**, 219-228.

Montavon C (1998) Validation of a non-hydrostatic numerical model to simulate stratified wind fields over complex topography. *Journal of Wind Engineering and Industrial Aerodynamics* **74-75**, 1762-1782.

Montero G, Montenegro R, Escobar JM (1998) A 3-D diagnostic model for wind field adjustment. *Journal of Wind Engineering and Industrial Aerodynamics* **74-76**, 249-261.

Mortensen NG, Landberg L, Troen I, Petersen EL (1993) 'Wind Atlas Analysis and Application Program (WAsP). Vol. 2: User's guide.' Riso National Laboratory, Roskilde, Denmark.

Moussiopoulos N, Flassak T (1986) Two vectorized algorithms for the effective calculations of mass-consistent flow fields. *Journal of Applied Meteorology* **25**, 847-857.

Oberheu RD, Mutch RW (1975) 'Summary of Tetan Wilderness by fuels, vegetation, topography, rate-of-spread, intensity and burnout potential.' Appendix D(42 PAGES), In: Teton Wilderness Fire Management Plan, USDA Forest Service, Bridger-Teton National Forest, Jackson, Wyoming.

Raithby GD, Stubley GD (1987) The Askervein Hill Project: A finite control volume prediction of three-dimensional flows over the hill. *Boundary-Layer Meteorology* **39**, 247-267.

Ross SD (1990) Effect of heat sums and of heat applied separately to shoots and roots on flowering in potted Picea glauca grafts. *Canadian Journal of Forest Research* **21**, 672-679.

Sherman CA (1978) A mass-consistent model for wind fields over complex terrain. *Journal of Applied Meteorology* **17**, 312-319.

Stone EC, Cavallaro J, Stromberg LP (1984) Spatial vegetation units used with a description method based on two levels of resolution to provide the requisite structural information. In 'California Reparian Systems: Ecology, Conservation, and Management'. Davis, California pp. 340-346. (University of California Press)

Uchida T, Ohya Y (1999) Numerical simulation of atmospheric flow over complex terrain. *Journal of Wind Engineering and Industrial Aerodynamics* **81**, 283-293.

Undheim O, Andersson HI, Berge E (2006) Non-linear, microscale modelling of th flow over Askervein Hill. *Boundary-Layer Meteorology*.

Walmsley JL, Taylor PA, Keith T (1986) A simple model of neutrally stratified boundary layer flow over complex terrain with surface roughness modulations (MS3DJH/3R). *Boundary-Layer Meteorology* **36**, 157-186.

Yakhot V, Orszag SA (1986) Renormalization group analysis of turbulence. I. Basic theory. *Journal of Scientific Computations* **1**, 3-51.