RAMS v6.0:

New Features, Future Plans, Current Apps

Craig J. Tremback
ATMET
ATmospheric, Meteorological and Environmental Technologies

Timeline

- Summer 2000 – v4.3 released
- July 2003 – v4.4 released (GPL Dec 2003, over 1700 registered for downloads since then)

Concurrently:

- 1998 - V5.0 started from a Brazilian project
- Jul 2002 – v5.02
- Jan 2003 – v5.03
- Apr 2003 – v5.04
- Sep 2003 – v5.05

v6.0 – First Alpha – Sep 2004 – Release Jan 2006

V6.1 – beta release "soon"

Developments for v5.xx

- New vertical coordinate (ADAP)
- Land surface scheme (LEAF) improvements
- Data assimilation schemes
- FDDA schemes
- History initialization option
- 1-way nest
- E-eps, E-l schemes from Silvia @ CNR, Torino
- Kain-Fritsch cumulus parameterization
- Simple urban canopy scheme
- Continued transition to Fortran 90

RAMS Data Assimilation Schemes

Recycle

*scheme which **recycles** prior forecast's fields of unobserved variables to initialize the current run*

- Numerous variables required on initialization are not observed
- Ability to specify soil and vegetation properties from previous forecast fields
- Can be extended to any field (clouds, etc.)
- Has been used successfully for soil moisture by several users over the years, but now is a standard option

RAMS Data Assimilation Schemes

Antecedent Precipitation Index

scheme which uses past (observed) precipitation to assist in defining the initial soil conditions for the start of a model run

- "Stripped-down" RAMS with only soil/vegetation schemes executed
- All atmospheric parameters specified from previous forecast
- Precipitation data specified from observations/radar/satellite
- Example:
  - 0000 UTC forecast time on the 30th
  - Back up to 0000 UTC on the 29th
  - Run RAMS in API mode for 24 hours
  - Initial soil moisture field available for 0000 UTC on 30th
- Provides initial soil moisture and all other soil/vegetation properties

RAMS Data Assimilation Schemes

Cumulus Inversion

scheme which uses past (observed) precipitation rates to compute convective heating and moistening rates

- All atmospheric parameters specified from previous forecast
- Precipitation data specified from observations/radar/satellite
- Convective parameterization is *"inverted"*
- Usually inputs atmospheric properties and outputs precipitation rate, heating and moistening profiles
- Inverted to input precipitation rate, still outputs heating and moistening profiles
- Intended for coarser grid spacings where convective parameterizations would be used
- Heating/moistening profiles are used in assimilation run (3-6 hours) prior to actual forecast start

RAMS Data Assimilation Schemes

Condensate Nudging

scheme which uses prior forecast's condensate to nudge fields during assimilation run

- Prior forecast results of condensate are used in assimilation run (3-6 hours) prior to actual forecast start
- Done in conjunction with other assimilation techniques
- Nudging done similarly to FDDA nudging
- Primarily intended for fog, low/mid-level stratus
- Of course, if forecast is very bad…

RAMS Data Assimilation Schemes

History Initialization

ability to start run by defining ALL fields from a previous run

- Designed to allow complete change of grid structure
- If grids match, direct copy of information; otherwise interpolation
- ALL fields from history file interpolated to new grid structure
- Primarily intended for use where a large difference exists between grids in original run and new run
- Example:
  - Emergency response system for Japanese nuclear plants (Mitsubishi Heavy Industries, Nagasaki)
  - Mesoscale forecast run down to 2 km grid
  - High-resolution dispersion run at scale of plant
  - Coarse grid – 50m spacing

RAMS Data Assimilation Schemes

One-way nest

ability to define fine grid boundaries from a previous run of a coarse grid

- Not intended as replacement where two-way nest can be used
- Nested grid has no affect on coarse grid
- More boundary reflection, requires more smoothing in boundary region than two-way nest (standard boundary nudging used)
- Example:
  - Mitsubishi

RAMS FDDA Schemes

Enhanced Analysis Nudging

nudges prognosed model fields to a gridded data analysis

- Previous options only allowed specification of nudging strength for all variables and all grids
- Option added to vary nudging strength:
  - on different nested grids
  - for different variables (wind, temperature, moisture, pressure)

RAMS FDDA Schemes

Observational Nudging

nudges prognosed model fields "directly" to the observations

- Designed to accommodate range of observations from 12-hour rawinsondes in large-scale runs to sonic anemometers in small-scale runs
- User-specified "update time" when observations are "analyzed" (typically every 15-30 minutes for standard obs)
- Each observation location is queried at update time
- If observation times are "close enough" in time, values are interpolated
- Observations are "analyzed" with 3-D Kriging interpolation scheme which produces variable and covariance fields
- Nudging proceeds with user-specified timescales which can vary by grid and variable

Changes for v6.0

- HDF5 file formats (developed and maintained at NCSA)
- Advantages
  - Standard, well documented. Effort underway to merge with netCDF
  - More efficient compression (V-format: 75% vs. binary (32-bit), HDF5: 75% vs. V-format)
  - Unlike V-format, exact binary is recovered on read…
  - … allows the removal of separate history files
  - HDF5 handles all bookkeeping, no need to keep track of where fields start on file
  - Fields and attributes can create a self-describing file (*head.txt files will eventually disappear)
  - Numerous 3rd-party apps to perform various tasks (h5diff, hdfview, etc.), some without need of file conversion
  - Can extract data to ASCII format (h5dump) without need of REVU (DUMP option)

Planned developments

- Lambert-Conformal projection
- Double precision "*time*"
- Funded by US Air Force
  - RRTM/CARMA radiation schemes
  - TEB urban canopy
  - ISAN replacement
- Graphical user interfaces

Lambert-Conformal Projection

- Primarily for compatibility with other models and applications

Double precision time

- To allow longer climate runs
  - Current single precision variable can run into problems after ~ 120 days on 32-bit machines
  - Double precision will allow ~ 3,000,000 years (if timestep is > 1sec)
  - Minor changes to RAMS and post-processing apps

RRTM Radiation schemes

- US-government funded software from AER, Inc.
- Validated by using line-by-line models
- Shortwave scheme uses up to 35 species (usually 7, O2, CO, CO2, etc.), 16 bands, clouds, aerosols
- BIG problem: original code takes 6 seconds per column on Athlon! Will investigate speed-ups
- Longwave scheme implemented in MM5 and WRF and is reasonable speed.

CARMA Radiation schemes

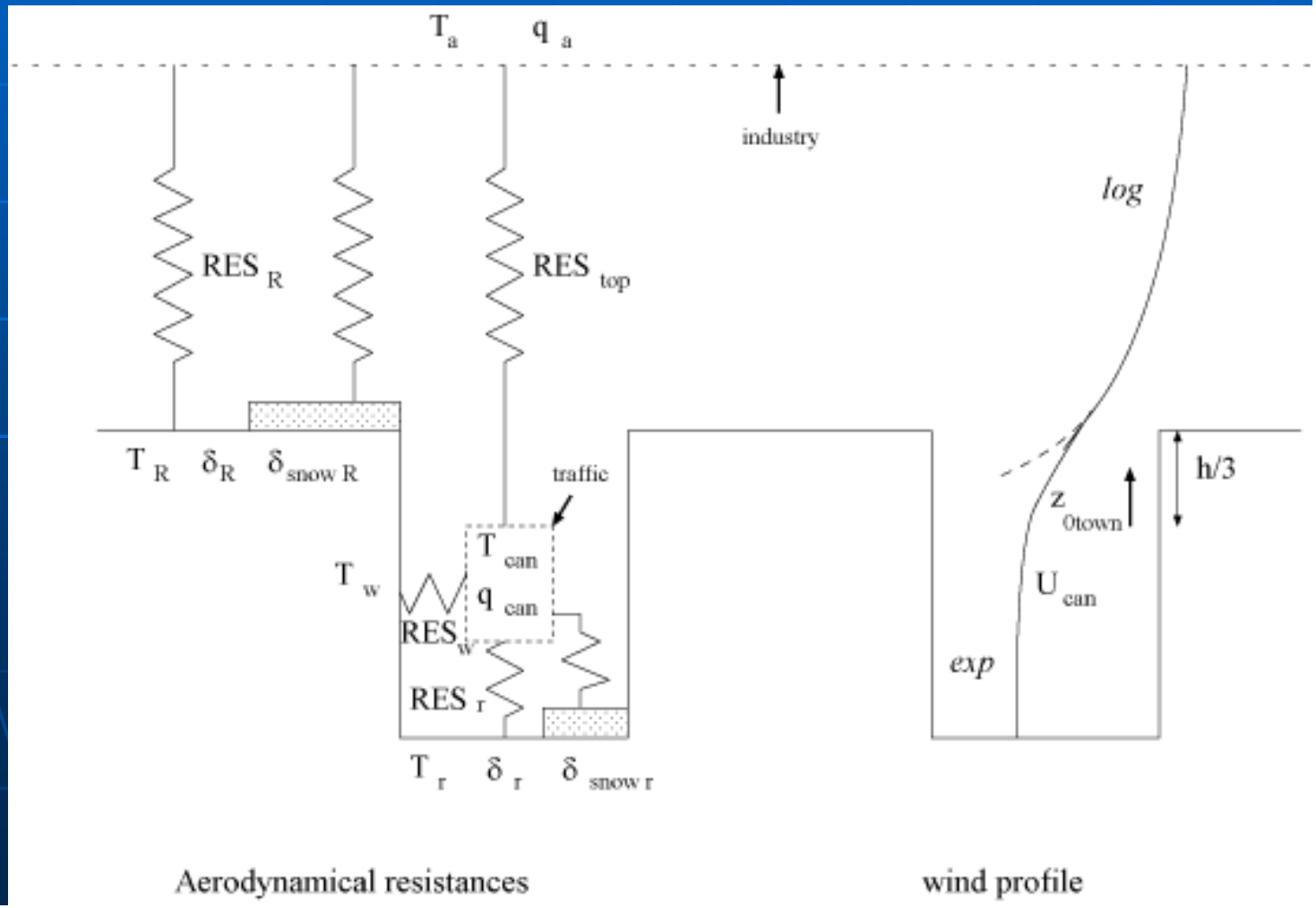
- From NASA
- Implemented by CPTEC in Brazil
- More sophisticated schemes which handle aerosols, etc.
- Reasonable execution speeds

TEB Urban Canopy

- Developed by Valery Masson from Meteo-France, we have received permission to distribute as part of RAMS
- Treats urban area as subgrid-scale entity
- Three surfaces: roofs, roads, walls
- Following figures from Meteo-France web site…

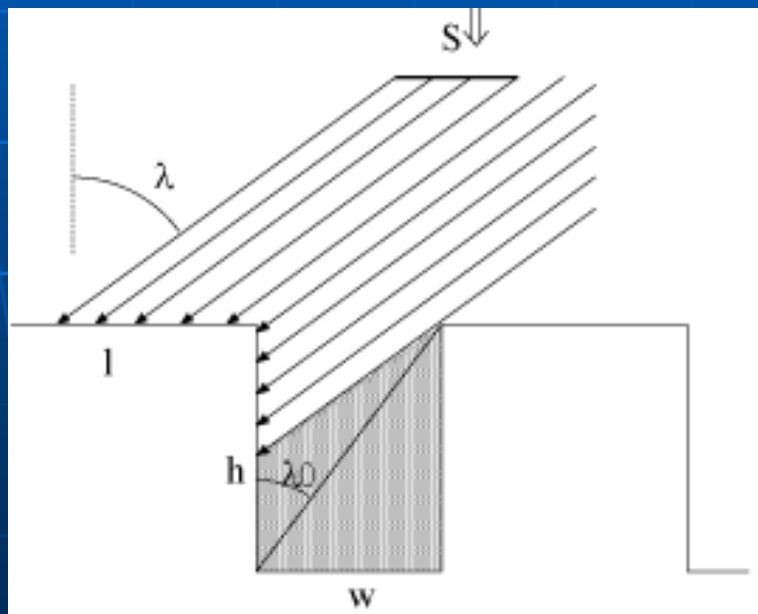
TEB Urban Canopy Features

Processes:



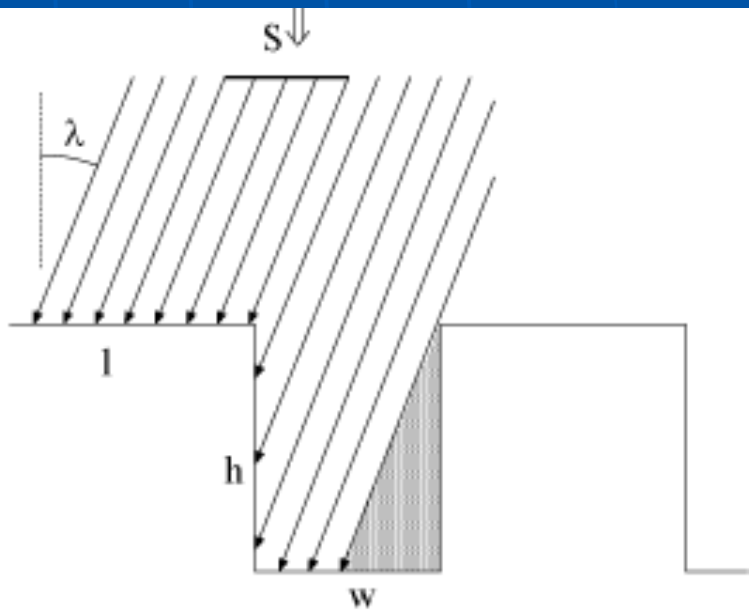
TEB Urban Canopy Features

Radiation:



road perpendicular to sun direction

Sun low over the horizon $\lambda > \lambda_0$



road perpendicular to sun direction

Sun high over the horizon $\lambda < \lambda_0$

TEB Urban Canopy Features

Inputs:

symbol	designation of symbol	unit
geometric parameters		
a_{town}	fractional area occupied by artificial material	-
a_{bld}	fractional artificial area occupied by buildings	-
$1 - a_{bld}$	fractional artificial area occupied by roads	-
h	building height	m
h/l	building height/width ratio	-
h/w	canyon height/width ratio[1]	-
Ψ_r	sky-view factors for road: $\Psi_r = [(h/w)^2 + 1]^{1/2} - h/w$	-
Ψ_w	sky-view factors for one wall: $\Psi_w = \frac{1}{2}\{h/w + 1 - [(h/w)^2 + 1]^{1/2}\}/(h/w)$	-
$z_{0_{town}}$	dynamical roughness length for the buildings/canyons system	m
radiative parameters		
$\alpha_R, \alpha_r, \alpha_w$	roof, road and wall albedos	-
$\epsilon_R, \epsilon_r, \epsilon_w$	roof, road and wall emissivities	-
thermal parameters		
$d_{R_k}, d_{r_k}, d_{w_k}$	thickness of the kth roof, road or wall layer	m
$\lambda_{R_k}, \lambda_{r_k}, \lambda_{w_k}$	thermal conductivity of the kth roof, road or wall layer	$Wm^{-1}K^{-1}$
$C_{R_k}, C_{r_k}, C_{w_k}$	heat capacity of the kth roof, road or wall layer	$Jm^{-1}K^{-1}$

TEB Urban Canopy Features

Computed:

symbol	designation of symbol	unit
prognostic variables		
$T_{R_k}, T_{r_k}, T_{w_k}$	temperature of the kth roof, road or wall layer	K
W_R, W_r	roof and road water interception reservoir	kgm^{-2}
W_{snowR}, W_{snowr}	roof and road snow interception reservoir	kgm^{-2}
T_{snowR}, T_{snowr}	roof and road snow temperature	K
$\rho_{snowR}, \rho_{snowr}$	roof and road snow density	kgm^{-3}
$\alpha_{snowR}, \alpha_{snowr}$	roof and road snow albedo	-
diagnostic variables		
T_{can}	canyon air temperature	K
q_{can}	canyon air specific humidity	kg/kg
U_{can}	along canyon horizontal wind	ms^{-1}
α_{town}	town effective albedo	-
$T_{s_{town}}$	town area averaged radiative surface temperature	K
input energy fluxes		
$L^{\downarrow}$	downwards infra-red radiation on an horizontal surface	Wm^{-2}
$S^{\downarrow}$	downwards **scattered** solar radiation on an horizontal surface	Wm^{-2}
$S^{\Downarrow}$	downwards **direct** solar radiation on an horizontal surface	Wm^{-2}
$H_{traffic}$	anthropogenic sensible heat flux released by in the canyon	Wm^{-2}
$LE_{traffic}$	anthropogenic latent heat flux released by the canyon	Wm^{-2}
$H_{industry}$	anthropogenic sensible heat flux released by industries	Wm^{-2}
$LE_{industry}$	anthropogenic latent heat flux released by industries	Wm^{-2}
other energy input		
T_{bld}	building interior temperature	K
output energy fluxes		
S^*_R, S^*_r, S^*_w	net solar radiation budget for roofs, roads and walls	Wm^{-2}
L^*_R, L^*_r, L^*_w	net infra-red radiation budget for roofs, roads and walls	Wm^{-2}
H_R, H_r, H_w	turbulent sensible heat flux for roofs, roads and walls	Wm^{-2}
LE_R, LE_r, LE_w	turbulent latent heat flux for roofs, roads and walls	Wm^{-2}
$G_{R_{k,k+1}}, G_{r_{k,k+1}}, G_{w_{k,k+1}}$	conduction heat flux between k^{th} and $k+1^{th}$ roof, road or wall layers	Wm^{-2}
H_{town}	town averaged turbulent sensible heat flux	Wm^{-2}
LE_{town}	town averaged turbulent latent heat flux	Wm^{-2}

ISAN Replacement

- Project in 2005 to perform review of current state of 3DVAR, 4DVAR, and Ensemble Kalman Filter and tested WRF 3DVAR scheme
- Expected to recommend general usage of WRF 3DVAR (it has been advertised so much!)
- But… group funding the study (AFTAC) needs data analyses for past events
- 3DVAR relies on error matrices, statistical relationship between grid point values and observations. Can be thought of as smoothing weights.
- Best if error matrices computed from a historical set of runs (like in operational settings).
- Not available for past runs. Ensembles can be generated, but if we need an ensemble, easier to use EKF scheme.

ISAN Replacement

- So…we decided to pursue an existing data analysis package that ingests a wide range of current observations…
- LAPS – Limited-area Analysis and Prediction System
- Developed at NOAA/FSL (Now NOAA/ESRL/GSD (Earth System Research Laboratory/Global Systems Division)

LAPS slides from:

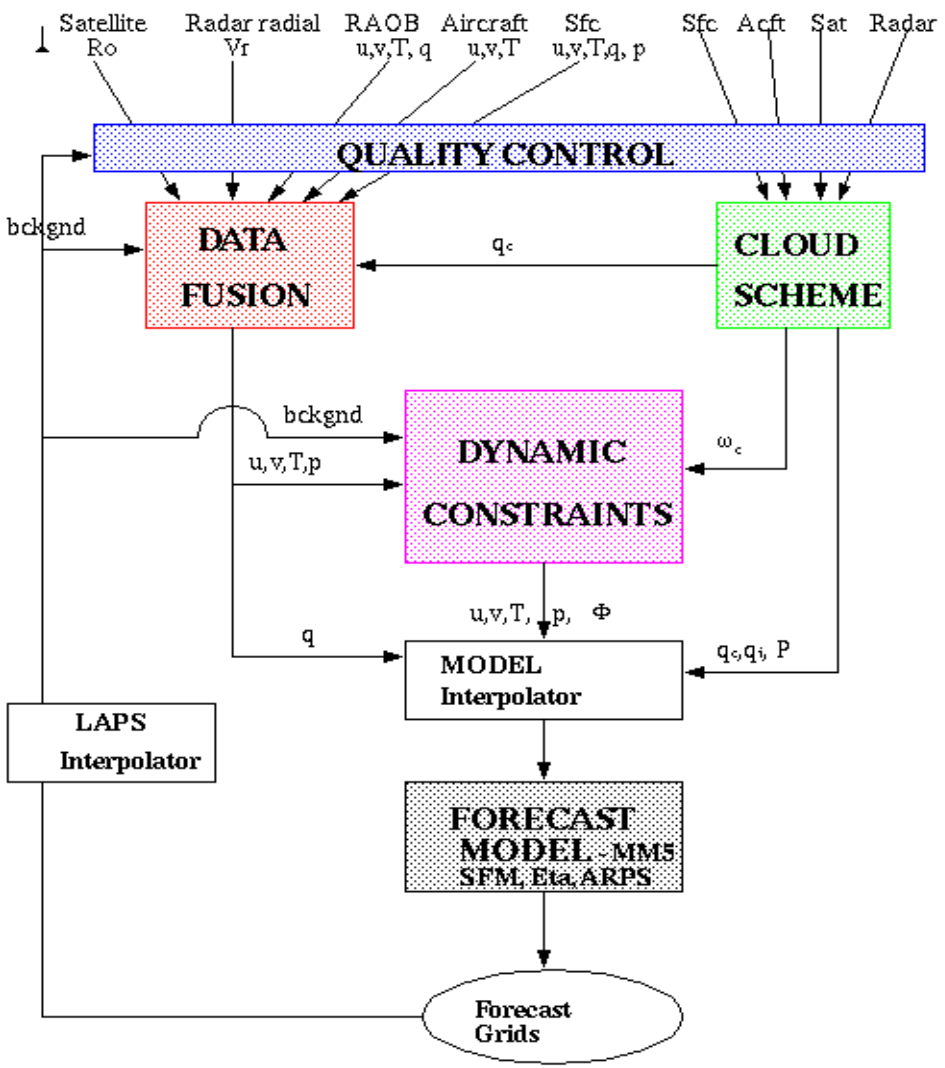
Local Data Assimilation and Modeling Applicable to NWS WFO Operations

Brent L. Shaw *
Local Analysis and Prediction Branch
Forecast Research Division
NOAA Forecast Systems Laboratory

LAPS Analysis Components

- Raw data ingest and quality control
- Analysis of state variables
  - Temperature
  - Winds
  - Moisture
- Cloud analysis
- Diagnostic variables
- Dynamic balance

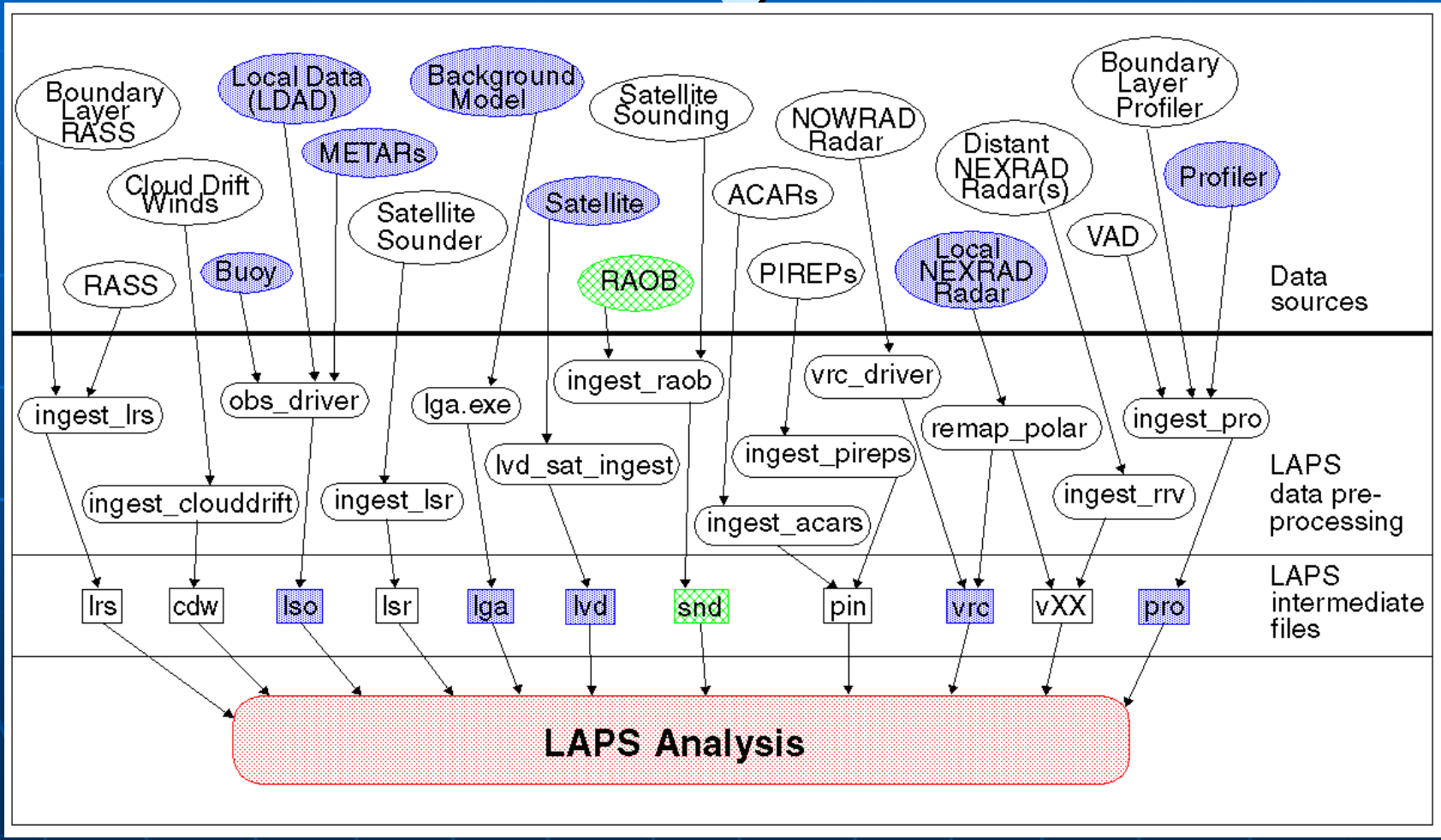
LAPS II Flow Diagram



Data Ingest

- Use all available sources
  - National data
    - Model grids from RUC or Eta for first-guess fields
    - METARs, satellite, wind profilers, ACARS, RAOBs, etc.
  - ***Local data*** - Often not available to national data assimilation systems!
    - Highway departments
    - Agricultural networks
    - Amateur radio (APRS) network
    - Universities

Data Ingest

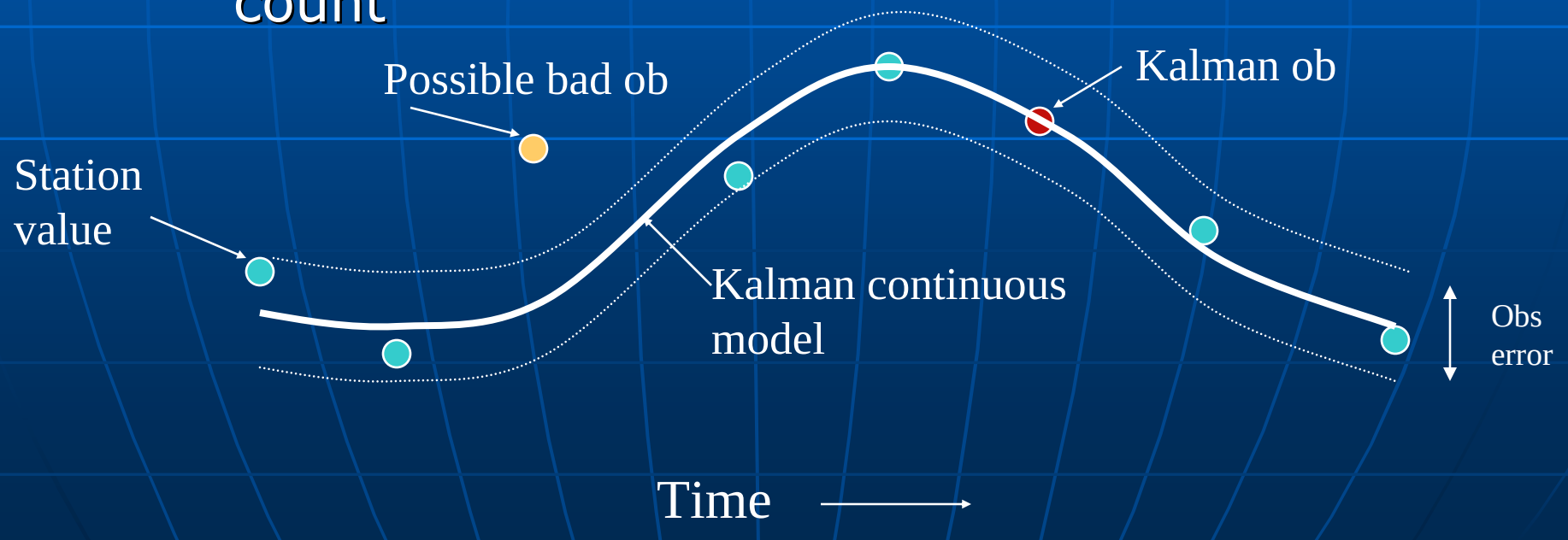

Boundary Layer RASS
Local Data (LDAD)
Background Model
Satellite Sounding
NOWRAD Radar
Boundary Layer Profiler
METARs
Distant NEXRAD Radar(s)
Profiler
Cloud Drift Winds
Satellite Sounder
Satellite
ACARs
VAD
RASS
Buoy
RAOB
PIREPs
Local NEXRAD Radar
Data sources
ingest_lrs
obs_driver
lga.exe
ingest_raob
vrc_driver
remap_polar
ingest_pro
lvd_sat_ingest
ingest_pireps
ingest_clouddrift
ingest_lsr
ingest_acars
ingest_rrv
LAPS data pre-processing
lrs
cdw
lso
lsr
lga
lvd
snd
pin
vrc
vXX
pro
LAPS intermediate files
LAPS Analysis

Quality Control

- Local data sets present QC challenges:
  - Poor siting
  - Poor maintenance
  - Poor communications
- Result: Inaccurate, irregular observations, leading to inconsistent analysis products and poor forecast initialization

Solution: Kalman Filter

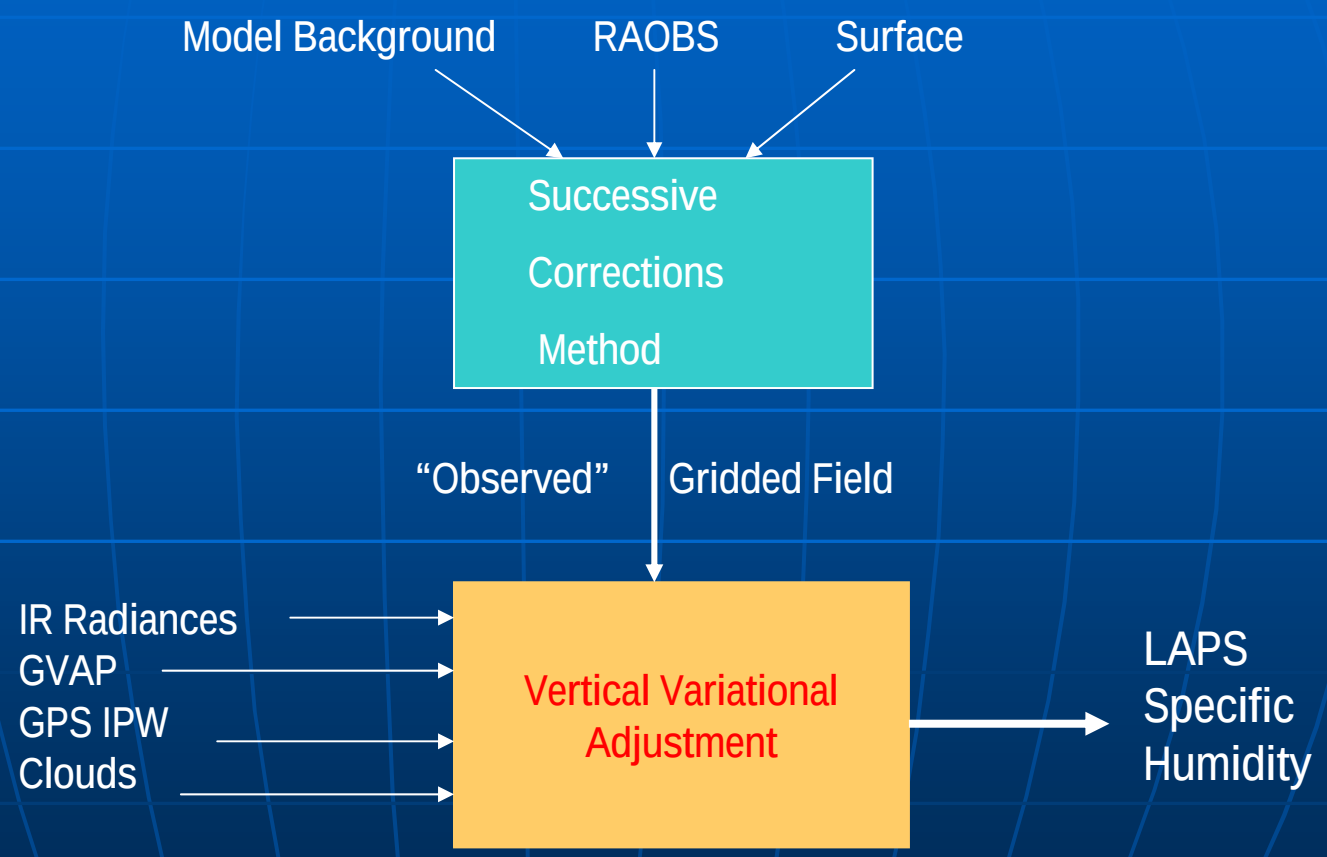
- Provides a continuous station estimate of observation based on self trend, buddy trends, and NWP – use for quality checking
- With missing obs – maintain constant station count



Kalman QC Advantages

- Adaptable to small workstations – works in observation space
- Accommodates models of varying complexity- Model error is a dynamic quantity within the filter, thus the scheme adjusts as model skill varies
- The Kalman Filter creates a data continuum not dependent on data density or observational regularity – products can be generated at any desired time.

Moisture Analysis



Moisture Analysis

Variational Adjustment

Minimize

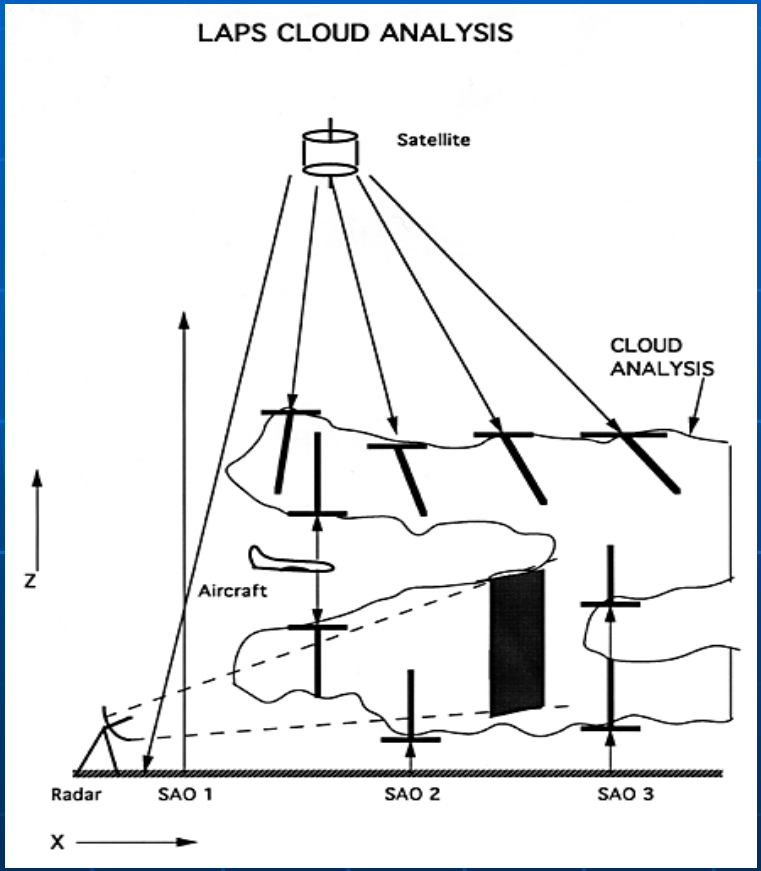
$$J = \sum_{i=1}^{n_{chan}} (R_i(T, O_3, cq) - R_i^o)^2 / E_{i,rad}^2 + (\sum_{k=1}^{n_{lvl}} c_k q_k - Q_{gps}^o)^2 / E_{gps}^2$$

$$+ \sum_{j=1}^{n_{gvap}} (\sum_{k=1}^{n_{lvl}} P_{jk} c_k q_k - Q_j^o)^2 / E_{j,gvap}^2 + \sum_{k=1}^{n_{lvl}} C_k (c_k q_k - q_s(T))^2 / E_{k,cld}^2$$

$$+ \sum_{k=1}^{n_{lvl}} (1 - c_k)^2 * E_{k,adj}^2 / E_{k,obs}^2$$

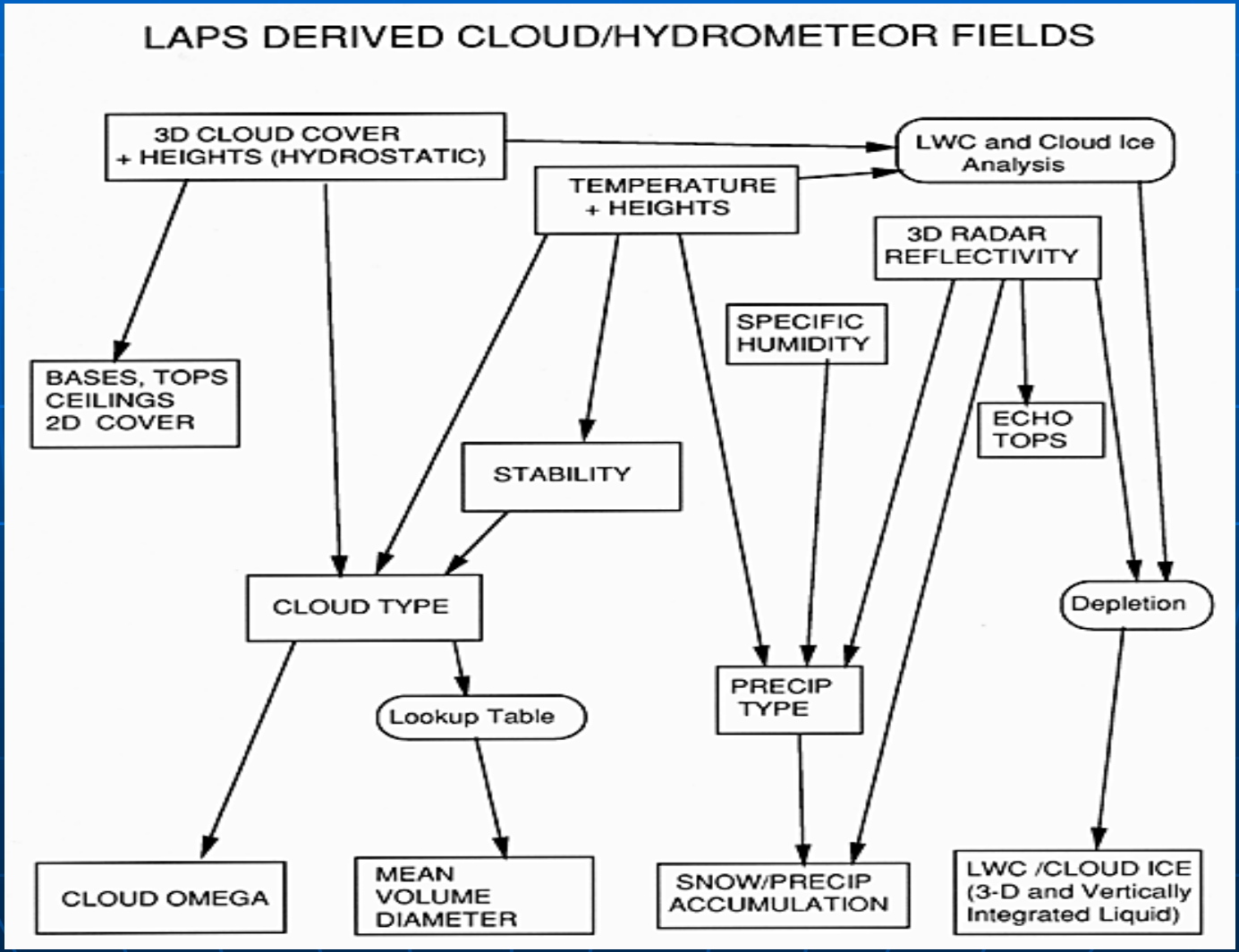
Solve for c_k

Cloud Analysis Scheme



- Uses satellite (Vis and IR)
- Aircraft observations
- Surface observations
- Radar
- Interpolates cloud obs to grid
- Cloud feeds back into water vapor analysis

Cloud Model


LAPS DERIVED CLOUD/HYDROMETEOR FIELDS
3D CLOUD COVER + HEIGHTS (HYDROSTATIC)
LWC and Cloud Ice Analysis
TEMPERATURE + HEIGHTS
3D RADAR REFLECTIVITY
SPECIFIC HUMIDITY
BASES, TOPS CEILINGS 2D COVER
ECHO TOPS
STABILITY
CLOUD TYPE
Depletion
PRECIP TYPE
Lookup Table
CLOUD OMEGA
MEAN VOLUME DIAMETER
SNOW/PRECIP ACCUMULATION
LWC /CLOUD ICE (3-D and Vertically Integrated Liquid)

Dynamic Adjustment

- Final step required for consistency between cloud and moisture analysis and the mass and momentum fields
- Retrieval of "observed" cloud vertical motion from LAPS cloud analysis and a simple 1-D cloud model
- Integral variational analysis constrained by full equations of motion and continuity, allowing clouds to impact mass and motion fields
- Explicit representation of model background error over entire grid

Dynamic Adjustment

- Adjustments are applied on <u>increment</u> from background field
- Minimization of time tendencies ensure smooth model start

Dynamic Balance Equations

Dynamic Balancing and Continuity Formalism

$$J = \sum_k \sum_j \sum_i O_V(\hat{u} - u')^2 + O_V(\hat{v} - v')^2 + O_\omega(\hat{\omega} - \omega_c^{'})^2 + O_\Phi(\hat{\Phi} - \Phi')^2$$

$$+ \mu(\hat{u}_t)^2 + \mu\ (\hat{v}_t)^2 + \lambda\ (\hat{u}_x + \hat{v}_y + \hat{\omega}_p)$$

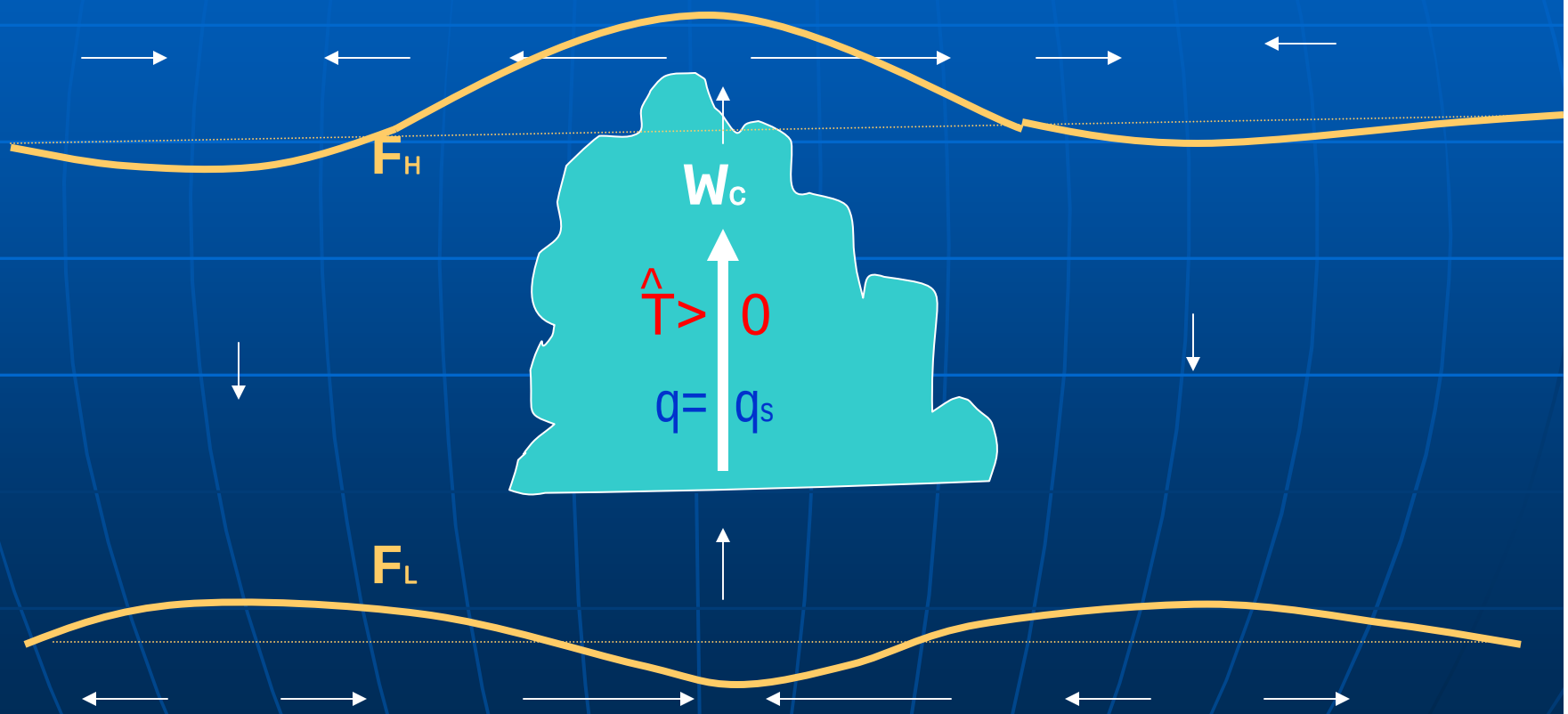
$$+ B_V \hat{u}^2 + B_V \hat{v}^2 + B_\Phi \hat{\Phi}^2 + B_\omega \hat{\omega}^2$$

$$\hat{u}_t = -(u_b \hat{u}_x + \hat{u} u_{bx} + v_b \hat{u}_y + \hat{v} u_{by} + \omega_b \hat{u}_p + \hat{\omega}\, u_{bp}) - \hat{\Phi}_x + f\,\hat{v} - D(\hat{u})$$

$$\hat{v}_t = -(u_b \hat{v}_x + \hat{u} v_{bx} + v_b \hat{v}_y + \hat{v} v_{by} + \omega_b \hat{v}_p + \hat{\omega}\, v_{bp}) - \hat{\Phi}_y - f\,\hat{u} - D(\hat{v})$$

( ) b are background quantities; (^) are solution increments from background;
( )' are observation differences from background

Cloud, Wind and Mass Dynamic Adjustment



Results of Analysis

- 3D Grids suitable for nowcasting
  - T, p, u, v, w
  - q_{vapor}, q_{cloud}, q_{rain}, q_{snow}, q_{ice}, $q_{graupel}$
  - Derived parameters
- Balance ensures suitability for *diabatic* model initialization
  - Hydrometeors initialized at t=0
  - Elimination of model spin-up problem!

LAPS Deficiencies (Features)

- Pressure vertical coordinate
- Uses a modified Barnes scheme for the majority of the variables
- LAPS can take significant time to execute.
- It can only handle one data time and one grid per execution.
- The code itself is broken into 38 executables, each performing its own distinct task, with its own memory structure, etc. PERL scripts control processing.

LAPS Development Tasks

1) Separate ISAN completely from RAMS
   - Use ISAN as a top-level driver for the LAPS code
   - Set up a common memory structure
   - Handle the calling of the various LAPS components, which will be converted from separate executables to subroutines.
   - This structure will also handle executing multiple data times and grids.
   - MPI calls (mostly) at this level

LAPS Development Tasks

2) Implement distributed memory parallelism (MPI) on the slowest LAPS components.
   - With a common memory structure, this task will be easier to implement and maintain.
   - MPI calls (mostly) at the driver lever.

LAPS Development Tasks

3) Implementation of a generalized height coordinate.
   - An "arbitrary" 3d array of heights defines the levels on which the processing is done. These heights can be defined in numerous ways: geopotential (to emulate pressure coordinates), terrain-following (as in RAMS), Cartesian, or any mixture that makes sense. WRF sigma-p coordinates should be able to be input easily.
   - Each LAPS component will need to be converted from the pressure coordinate to a height coordinate.
   - This cannot emulate isentropic coordinates, so we will explore the possibility of a hybrid coordinate.

LAPS Development Tasks

4) Explore Barnes alternatives.
   - Numerous possibilities
   - We will perform preliminary testing of various schemes, comparing with the current scheme, see how they perform, then implement the most reasonable.

LAPS Development Tasks

5) Observation file formats

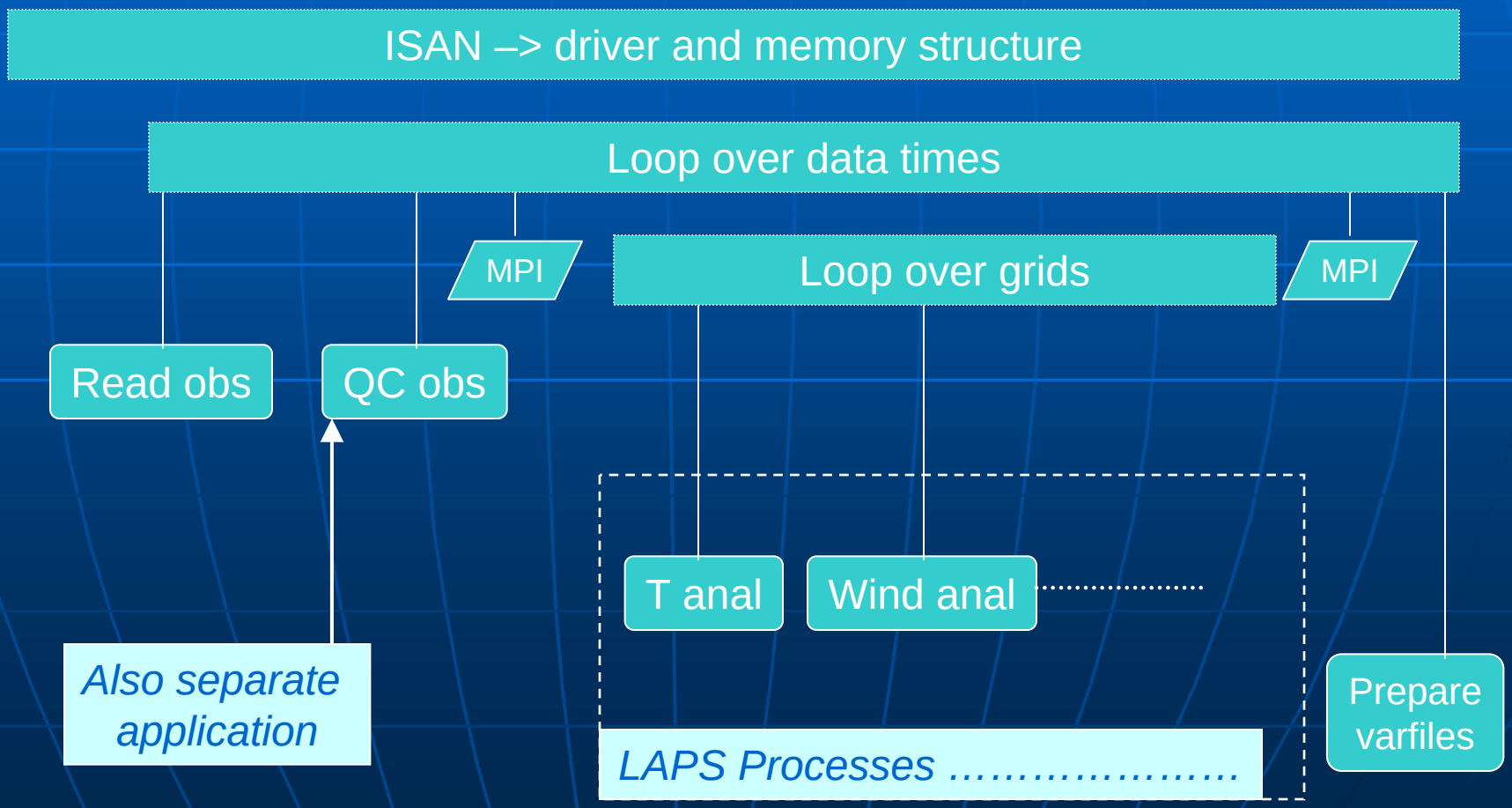
- LAPS uses specific ASCII formats, different than the RAMS GDF (Ralph) formats.
- Numerous other RAMS-related applications (ODA, revu_st, ODV, etc.) that uses the observational data
- Either a set of converters will be necessary, or if possible, come into agreement with FSL on a common data format.

LAPS Development Tasks

6) Observation quality control

- Several types of quality control are done as part of the current LAPS processing.
- However, the QC is done as part of the LAPS processing stream, meaning that LAPS has to be run with the observational components activated.
- Configure the general QC components into a separate application.
- Can include the things in our standalone package along with the various LAPS techniques. The new (hopefully standardized) file formats would have QC flags, like the current Ralph format, which the individual applications can use.

LAPS New Structure Schematic



Graphical User Interfaces

- RAMS
- CAMx
- iVAN
- New LAPS
- Observational Data Viewer (ODV)
- Emergency response system

Current Applications

Wind forecasting for renewable energy

- Parques eólicos (wind farms)

Wind forecasting for renewable energy

- Spain has second most number of wind turbines in the world (US is first, but Spain has most per capita)
- Iberdrola has about 100 different sites where wind turbines are installed, covering much of Spain
- Sites provide a challenge; in usual forecasting case, we verify for stations located in valleys (where people live)
- Wind farms are located on small-scale topography, usually on tops of ridge lines
- Further, turbines are located higher above ground than most observations

Wind forecasting for renewable energy

- The challenge: produce hourly wind forecasts for small-scale (~ 1 km), complex topography, over a large area (1000 x 1000 km) with reasonable computer resources

Wind forecasting for renewable energy

- Configure RAMS to cover the entire Iberian Peninsula at a reasonable resolution (4km)
- Forecasts are run 3 times per day (0000, 1200, 1800 UTC)
- Complete automation of operational system from data collection to model execution to web site updating (real-time graphics and verifications).
- Wind forecasts are given to another algorithm to compute energy production
- But 4 km resolution will not adequately resolve the topography….

Wind forecasting for renewable energy

- Perform adjustments on the 4km model output:
  - Use a diagnostic wind model (CALMET) using RAMS fields and higher resolution topography
  - Configure RAMS in a "diagnostic" mode:
    - Each hour, run RAMS for 10 minutes at 100m grid spacing
    - High-resolution topography
    - Allow wind field to come into adjust with topography
  - Statistical adjustment of raw model output
  - So far, "diagnostic" RAMS is producing best wind forecast results

Operational forecast systems

- Computer hardware:
  - Linux "Beowulf" cluster
  - Dual Xeon nodes
  - RAMS – 24 nodes
  - Gigabit interconnect
  - 1.2 TByte disk storage
  - Second cluster runs diagnostic RAMS

Operational AQ forecast systems in Spain

Operational AQ forecast systems

- New regulations by some of the Spanish autonomous governments require air quality forecasting systems be implemented if new power plants are built
- If forecast pollution will exceed a certain level, decisions may be made to reduce output of power plants or industries in the region
- Two air quality forecasting systems are under development using RAMS and CAMx

Operational AQ forecast systems

- Somewhat similar configuration to wind farm system
- Automated system:
  - Data collection and processing
  - Model execution (RAMS and CAMx)
  - Results and verifications posted on web site

Operational AQ forecast systems

- Forecasts 4 times per day (00, 06, 12, 1800 UTC), 36 hour forecasts
- Meteorological input data from NCEP in US
- RAMS grid configuration (40km, 10km, 2km, 500m)
- CAMx grid configuration (10km, 2km, 500m)
- Will be configured in assimilation mode, where current forecast will start from results of previous forecast

Operational AQ forecast systems

- Emissions most difficult part of accurate air quality forecasting. Using emissions from Corine-Aire dataset for Europe (50 km grid)
- Very little "observed" emission data to use; some point source information available from power plants
- Need to make assumptions to develop higher resolution gridded fields for CAMx
- Use of "surrogate" information (such as population) to redistribute emissions to higher spatial resolution

Episodic AQ simulations in Spain

- Episodic simulations are required by some autonomous governments when new power plants are built
- Equivalent of environmental impact statements required by some US states and EPA
- Over past four years, we have been involved in simulations for 8 locations

Episodic AQ simulations

- Each location defines 3 episodes: low, medium, and high pollution levels
- Seven day runs are made of RAMS and CAMx, first 2 days are "spin-up" days
- Control run is defined as gridded emissions with all existing point sources active, as occurred at the time
- Numerous sensitivity runs of each episode look at impact of varying the number of plants active

Episodic AQ simulations

- RAMS and CAMx resolutions down to 1 km in some cases
- Focus on NO_x, O_3, PM10
- Emissions continue to be difficult
- Both Corine-Aire and EDGAR global emission dataset were used

Episodic AQ simulations

- General results show:
  - Ozone verification were good for summer, less accurate in winter (more transport from regions outside of CAMx domain)
  - PM values were lacking emissions from natural sources. Dust from Sahara can be significant.
  - NOx showed a general low bias. Currently investigating the reasons.

USFS Fire-weather operational system

USFS - United States Forest Service

USFS Rocky Mountain Center (RMC)

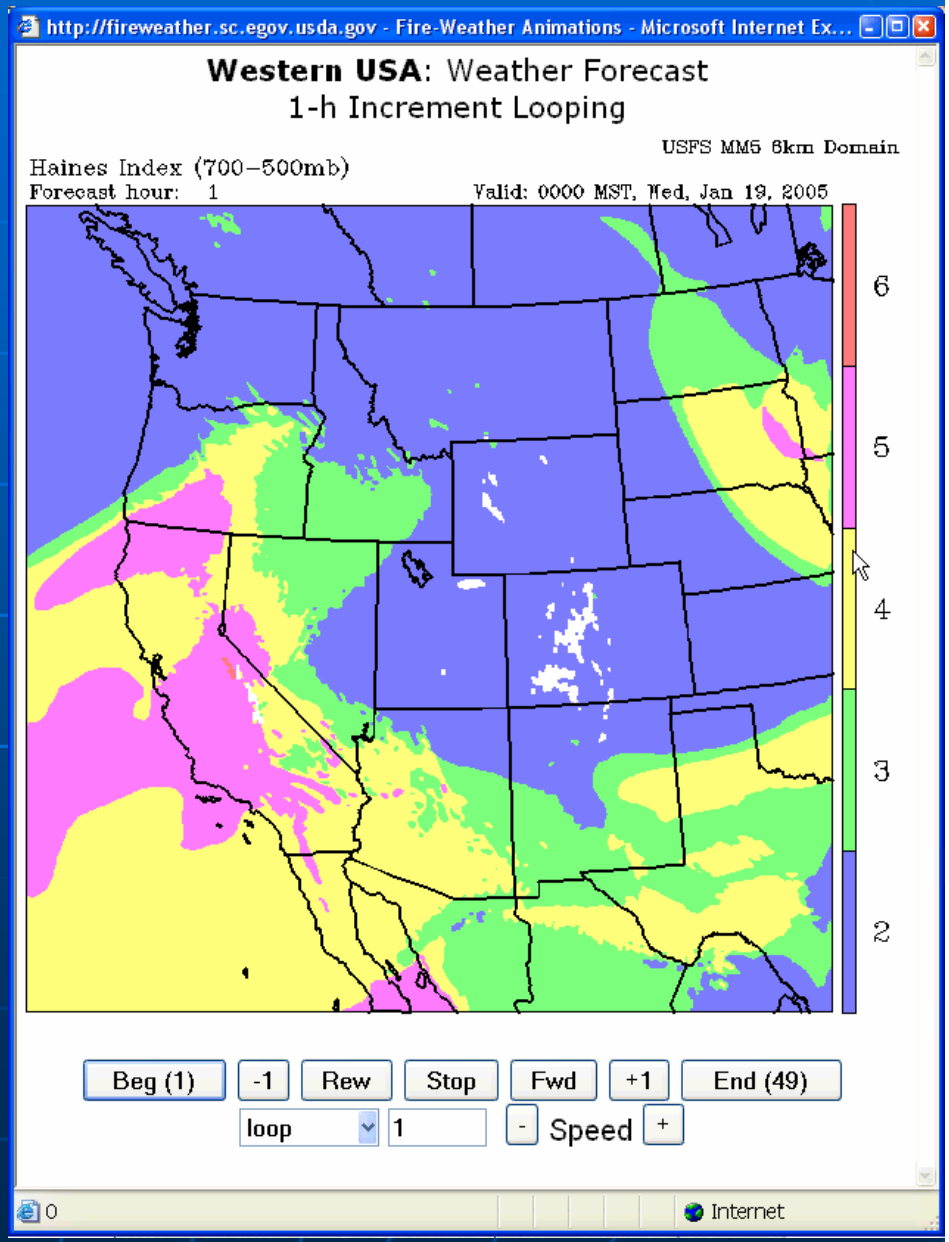
- **What information does RMC deliver ?**

- ***Observed* weather**, e.g. temperature, winds, relative humidity, precipitation amount, precipitation type, etc. and weather-based fire indices such as Fosberg, Haines, Ventilation etc.;
- ***Predicted* weather** up to 72 hours into the future;
- ***Point Forecasts***: predictions of weather parameters and fire danger indices at user-specified locations;
- ***Smoke Forecasts***: predictions of dispersion of surface 2.5 PM concentration from wildfires and prescribed burns;

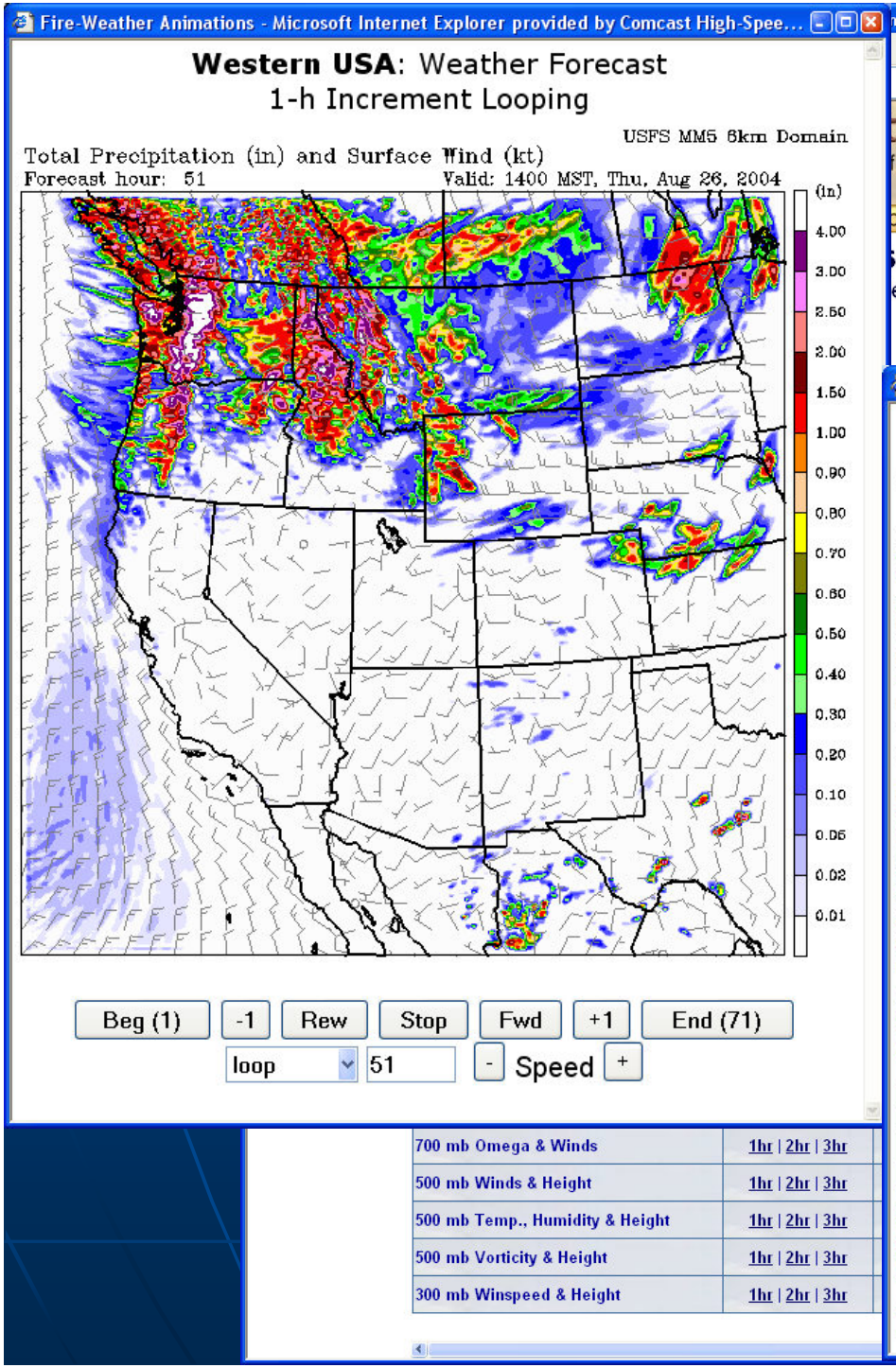
- **What geographic areas does the RMC Product cover ?**

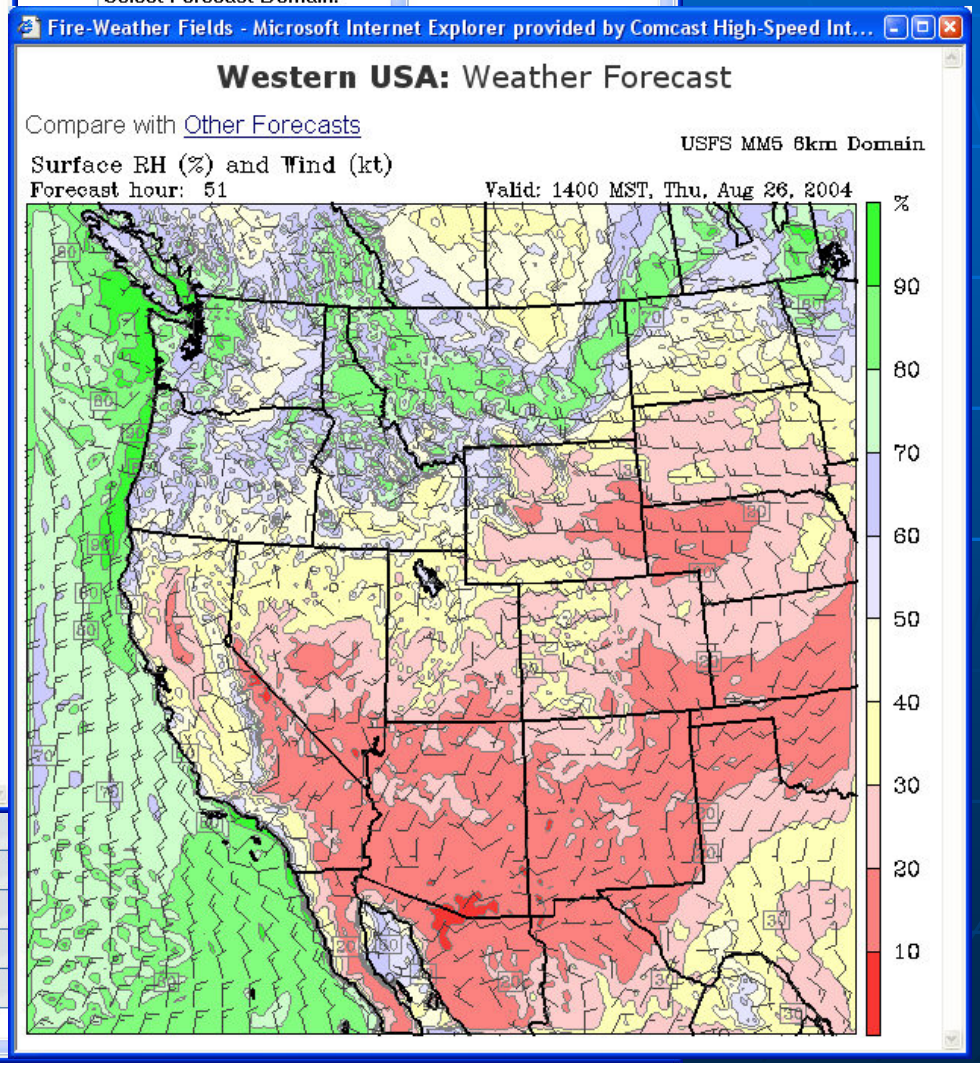
- ***Main Domain*** (6-km grid spacing) covers the entire Western USA;
- ***10 Subdomains*** (6-km resolution) covers Rocky Mountain Region, Southwest, Eastern Great Basin, and several individual states;

RMC Main Domain

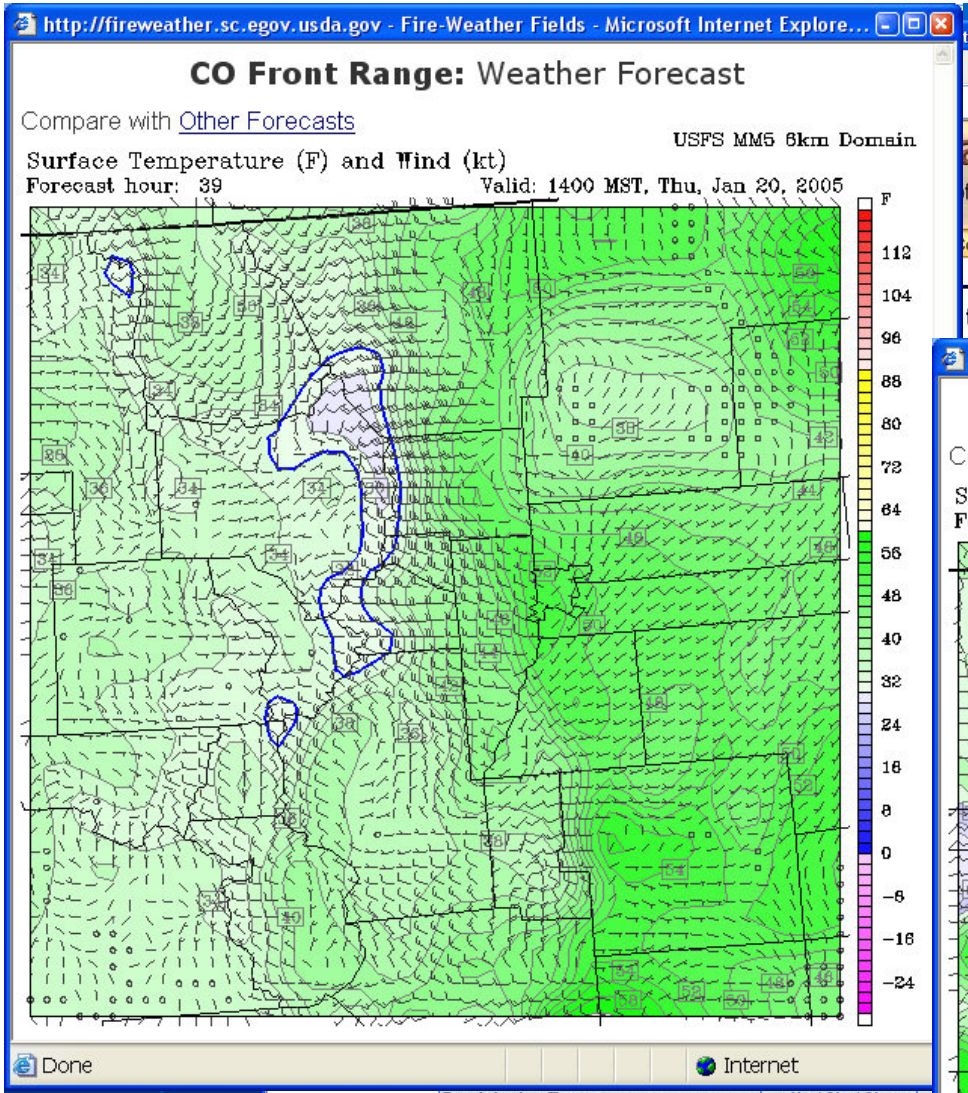


Regional Weather Forecast



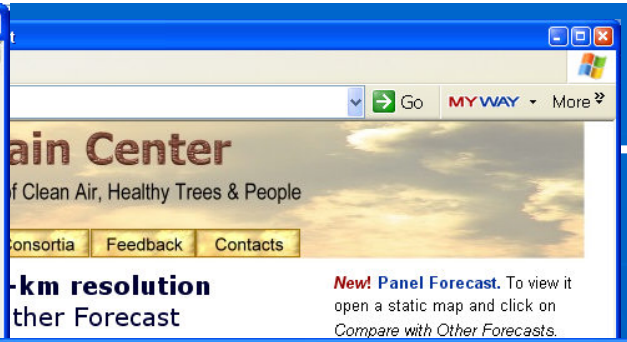


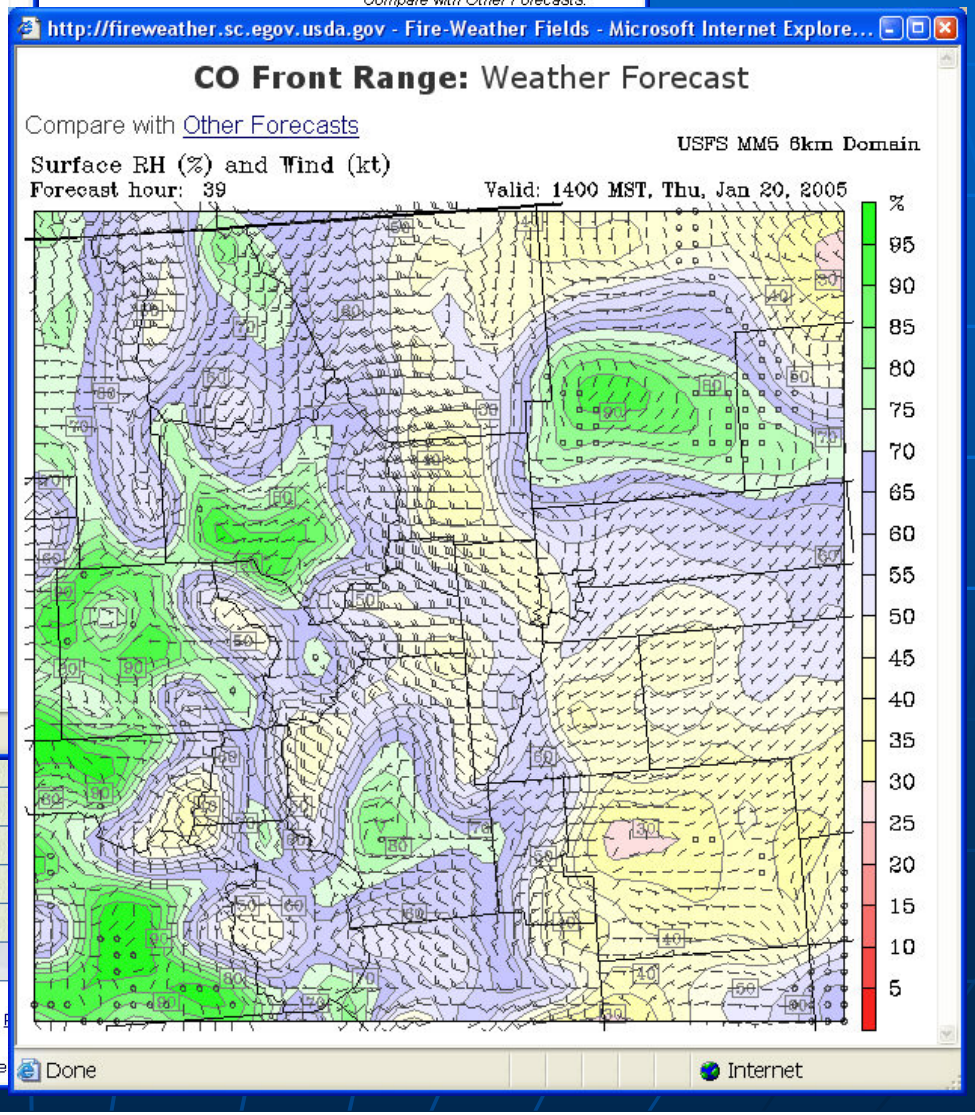
Regional Weather Forecast



Precipitation Type	1hr | 2hr | 3hr
Total Precipitable Water	1hr | 2hr | 3hr
Radar Reflectivity	1hr | 2hr | 3hr
Surface Latent Heat Flux	1hr | 2hr | 3hr
Surface Sensible Heat Flux	1hr | 2hr | 3hr
Cloud Cover	1hr | 2hr | 3hr

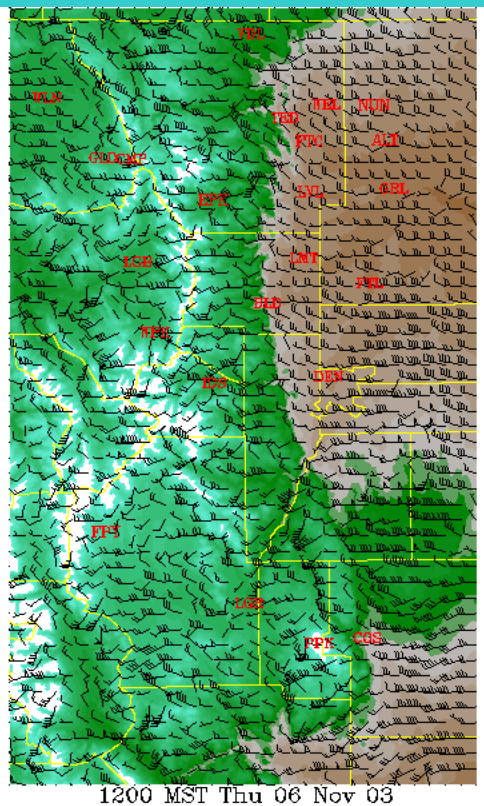
Webmaster: Ne





Very High Resolution Winds

Front Range

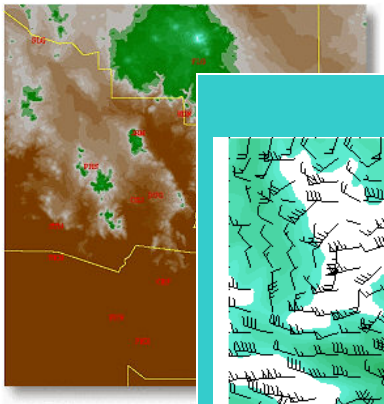


esolution Meteorological Fields

face Winds

Northern Arizona (700-m)

Forecast Initialization Time:



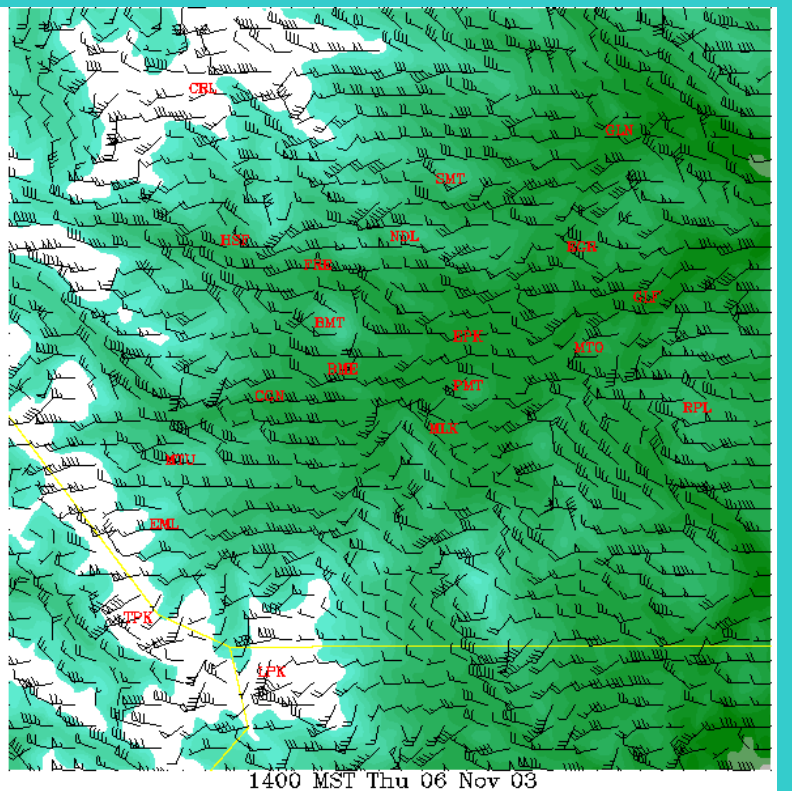
RMC has the capability to produce *mass-balanced forecast* hourly wind o
resolution (i.e. down to 90 meters) using MM5 output fields of coarser reso
downscaling is performed by LAPS special routines utilizing fine-scale top
provided by USGS (see **Disclaimer**).

The above domains illustrate the wind downscaling capability for two sampl
Colorado Front Range (180 x 300 km) and **Northern Arizona** (253 x 267
predicted (forecasted) for these domains at 600-m and 700-m resolution, r
into the future. To view a time animation of forecast winds for either domai
Initialization Time from the corresponding drop-down menu above.

High-resolution wind data are required to reliably predict fire behavior and
models such as FARSITE, and to produce detailed smoke forecasts. Such
the performance of models simulating the propagation and dispersion of pl
diseases.

Webmaster: Ned Nikolov (nnikolov@fs.fed.us)

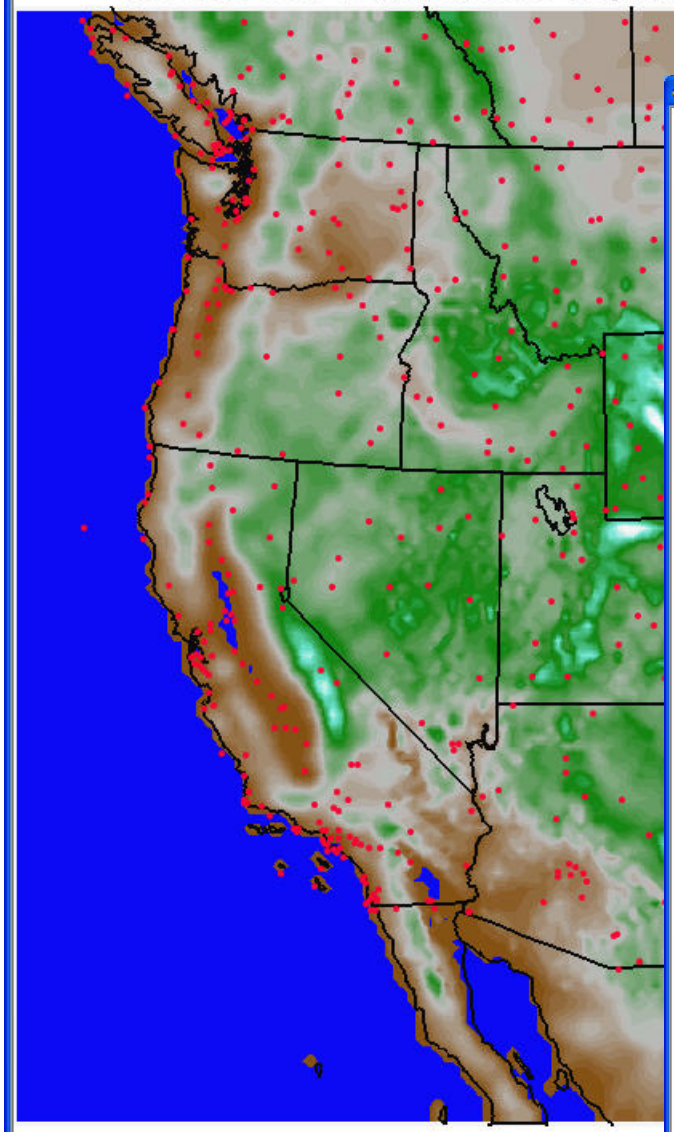
Estes Park



Point Forecast

RMC Point Forecast Map - Microsoft Internet Explorer provided by Comcast High-Speed Internet

***Western USA* Point Forecast Map:** METAR Sites (676 points).



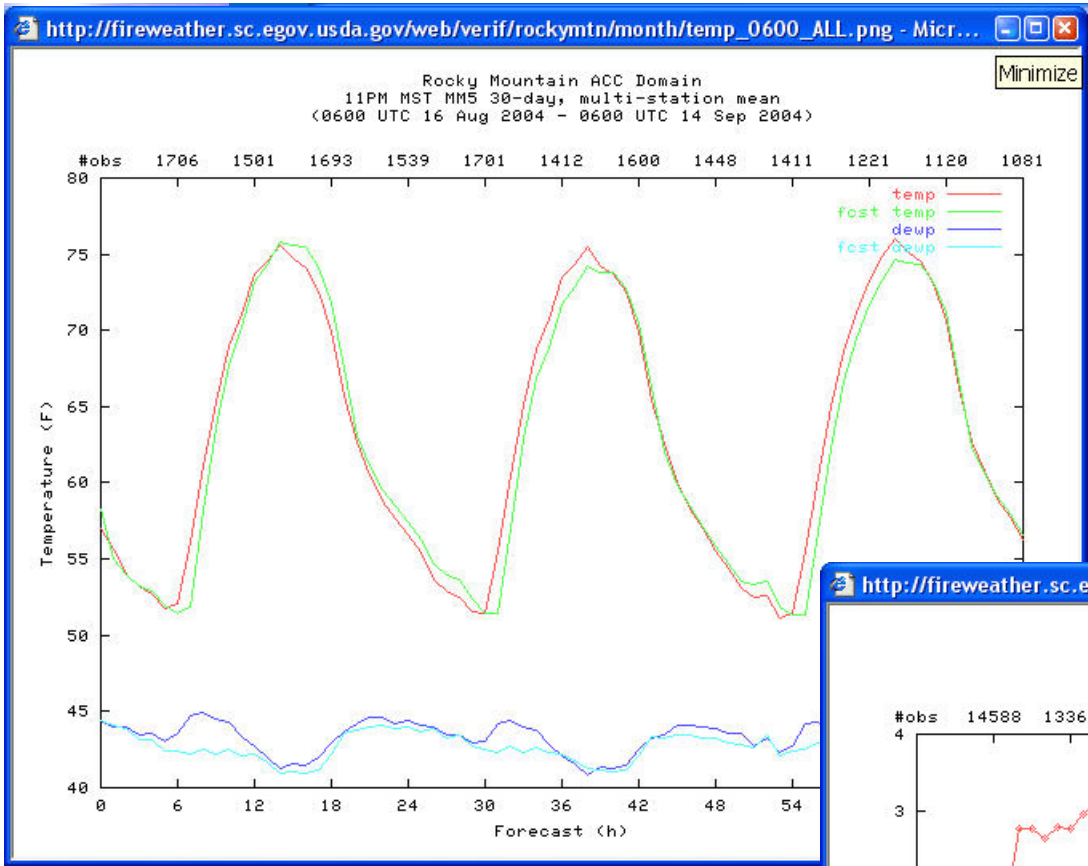
Forecast Format:
Tabular

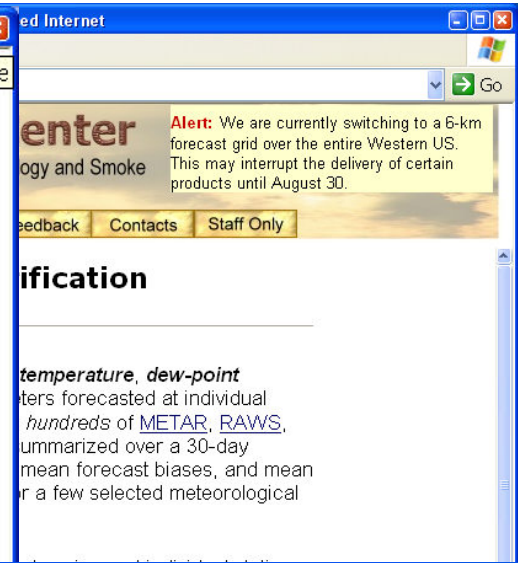
US Forest Service | Rocky Mount Research Stat

http://fireweather.sc.egov.usda.gov/web/forecasts/points/GROSSRESCO.txt - Microsoft Internet Explorer provided by Comcast High-

```
*****************************************************************************************
LOCATION: GROSSRESCO  LAT:  39.9576  LON: -105.3674  I:  317.78  J:  226.71
MM5  6.0 km  FORECAST CYCLE: 050190600  DOM:  1  MODEL ELEVATION:  7506 ft
*****************************************************************************************
DATE        TIME  TMP DPT RH  WIND    CEI VIS  WEATHER  PRECP SNOW VENT   MIXHT PBLWND HM HH Fbg
MST         MST   F   F   %   Dg@MPH  hft mile           in    in   KT-FT  FtAGL Dg@MPH
---------- ----- --- --- --- ------ --- ---- -------- ----- ---- ------ ----- ------ -- -- ---
01/18/2005 23:00  35  23  61 270/12 999 19.3 CLEAR     0.00  0.0   8064   659 280/14 **  2  18
01/19/2005 00:00  37  24  59 270/27 999 19.6 CLEAR     0.00  0.0   8982   295 270/35 **  2  38
01/19/2005 01:00  38  24  57 270/31 999 23.4 CLEAR     0.00  0.0  13168   394 280/39 **  2  45
01/19/2005 02:00  39  25  55 270/31 999 24.4 CLEAR     0.00  0.0  12444   371 270/39 **  2  46
01/19/2005 03:00  39  25  56 270/31 999 24.2 CLEAR     0.00  0.0  11944   358 270/38 **  2  46
01/19/2005 04:00  39  24  55 270/30 999 25.7 ISOCLOUD  0.00  0.0   9846   312 270/37 **  2  44
01/19/2005 05:00  40  24  52 270/29 314 31.3 MSLYCLDY  0.00  0.0   8639   279 280/36 **  2  44
01/19/2005 06:00  40  24  52 270/28 333 30.9 CLOUDY    0.00  0.0   9073   299 270/35 **  2  44
01/19/2005 07:00  40  24  52 270/27 314 30.5 CLOUDY    0.00  0.0   8507   292 270/34 **  2  41
01/19/2005 08:00  42  24  48 270/24 332 40.3 CLOUDY    0.00  0.0   6032   233 270/30 **  2  40
01/19/2005 09:00  44  24  45 270/18 314 45.6 MSLYCLDY  0.00  0.0   4078   207 270/22 **  2  31
01/19/2005 10:00  44  26  49 260/17 314 35.8 PTLYCLDY  0.00  0.0   4408   220 270/22 **  2  27
01/19/2005 11:00  44  28  52 260/19 314 30.3 PTLYCLDY  0.00  0.0   5177   236 260/24 **  3  29
01/19/2005 12:00  44  28  51 260/21 999 30.6 CLEAR     0.00  0.0   5458   226 270/26 **  3  32
01/19/2005 13:00  44  28  52 270/20 999 30.1 CLEAR     0.00  0.0   5033   207 270/26 **  4  31
01/19/2005 14:00  44  28  53 270/17 999 27.5 CLEAR     0.00  0.0   5168   220 270/23 **  3  26
01/19/2005 15:00  44  29  54 260/12 999 23.9 CLEAR     0.00  0.0   4043   203 270/17 **  3  18
01/19/2005 16:00  42  27  54 270/12 999 23.9 CLEAR     0.00  0.0   3176   164 280/16 **  2  17
01/19/2005 17:00  41  25  52 270/19 999 28.0 CLEAR     0.00  0.0   3138   138 270/23 **  2  28
01/19/2005 18:00  41  24  50 270/22 999 33.2 CLEAR     0.00  0.0   4004   171 270/26 **  2  34
01/19/2005 19:00  41  25  52 270/25 999 31.2 CLEAR     0.00  0.0   5348   200 270/30 **  2  38
01/19/2005 20:00  42  26  52 270/29 999 29.9 CLEAR     0.00  0.0   7605   240 280/37 **  3  45
01/19/2005 21:00  42  25  51 270/34 999 32.9 PTLYCLDY  0.00  0.0   8603   243 280/41 **  4  53
01/19/2005 22:00  43  25  48 270/34 352 39.0 CLOUDY    0.00  0.0   7696   220 280/40 **  4  55
01/19/2005 23:00  44  24  45 270/32 333 47.4 CLOUDY    0.00  0.0   6685   200 280/38 **  4  54
01/20/2005 00:00  43  24  46 270/34 352 43.6 PTLYCLDY  0.00  0.0   8283   236 270/41 **  4  57
01/20/2005 01:00  43  24  46 270/30 352 45.8 CLOUDY    0.00  0.0   7064   223 270/37 **  4  51
01/20/2005 02:00  43  23  43 270/26 372 52.4 CLOUDY    0.00  0.0   5370   194 270/32 **  3  46
01/20/2005 03:00  44  22  42 270/24 352 57.7 CLOUDY    0.00  0.0   4485   177 270/29 **  3  42
01/20/2005 04:00  44  22  40 270/21 352 63.3 CLOUDY    0.00  0.0   3492   154 270/26 **  4  39
01/20/2005 05:00  44  22  39 270/21 352 67.1 CLOUDY    0.00  0.0   3278   151 270/25 **  4  38
01/20/2005 06:00  44  21  40 260/19 352 60.7 CLOUDY    0.00  0.0   2553   131 260/22 **  3  34
01/20/2005 07:00  44  21  40 260/21 352 65.8 CLOUDY    0.00  0.0   3124   148 260/24 **  3  37
01/20/2005 08:00  43  21  40 270/24 372 65.9 CLOUDY    0.00  0.0   4183   174 270/28 **  3  43
01/20/2005 09:00  44  22  41 270/27 372 60.4 CLOUDY    0.00  0.0   6413   226 270/32 **  4  49
01/20/2005 10:00  45  23  42 270/27 372 56.7 CLOUDY    0.00  0.0   6493   223 270/33 **  4  48
01/20/2005 11:00  45  24  43 270/26 372 54.2 CLOUDY    0.00  0.0   5408   197 270/30 **  4  45
01/20/2005 12:00  46  24  42 270/25 372 54.4 CLOUDY    0.00  0.0   4888   180 270/30 **  4  44
01/20/2005 13:00  46  24  41 270/25 372 61.0 CLOUDY    0.00  0.0   4185   161 270/29 **  4  44
01/20/2005 14:00  46  23  39 270/25 372 66.5 CLOUDY    0.00  0.0   4521   171 270/29 **  4  45
01/20/2005 15:00  46  22  38 270/24 352 75.4 CLOUDY    0.00  0.0   4286   167 270/28 **  4  44
01/20/2005 16:00  46  19  34 270/23 352 97.1 CLOUDY    0.00  0.0   3343   141 280/27 **  4  45
01/20/2005 17:00  44  18  33 270/24 352 99.0 MSLYCLDY  0.00  0.0   3462   141 270/28 **  4  48
```

Forecast Verification



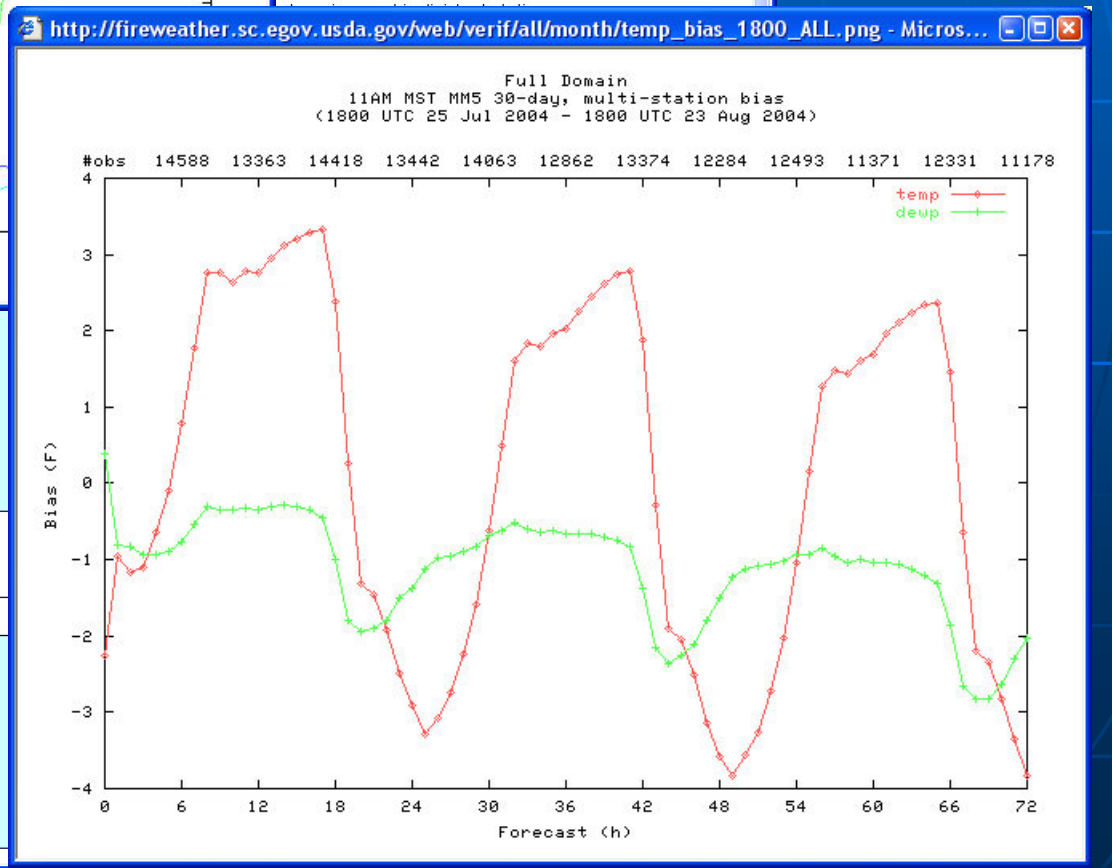


Time Series of Forecasted vs. Observed Data

Mean Forecast Bias

Mean Forecast Absolute Error

Verification Parameter
Time Series of Forecasted vs. Observed Data
Mean Forecast Bias
Mean Forecast Absolute Error



Smoke Dispersion Forecasts

fireweather.info - Microsoft Internet Explorer provided by Comcast High-Speed Internet

File Edit View Favorites Tools Help

Address http://FireWeather.info/

Staff Only

USDA FS
Fort Collins, CO

Rocky Mountain Center

Providing Weather Awareness in Support of Clean Air, Healthy Trees & People

About Us | Research | Tech. Trans. | Consortia | Feedback | Contacts

HOME

Observed Weather:
- Regional Maps
- Point Obs.
- High-Res. Data

Forecast Weather:
- Regional Maps
- Point Forecast
- High-Res. Data
- Verification *New*

SMOKE

Good Morning! The forecast for Fort Collins is here. Wed, Jan 19, 2005

United States Department of Agriculture – Forest Service
Rocky Mountain Research Station

Fire Maps | Fire Links | Fire News | *NEW!* RAWS Review

Real Time Fire-Weather Intelligence & Smoke Forecast for the Western USA.

We now provide **6-km Resolution** forecasts for

Mount Liebig (MT) Sep. 19-21, 2004
- Observed Weather
- Point Forecast (09/20)

Experimental Products

Observed Weather

Regional Maps:
- Western USA
- Rocky Mountain Area
- Eastern Great Basin
- Southwest Area
- Arizona
- California
- Colorado
- CO Front Range
- Idaho
- New Mexico
- Wyoming

Point Observations

High Resolution Winds

Weather Forecast

Regional Maps:
- North America
- Western USA
- Rocky Mountain Area
- Eastern Great Basin
- Southwest Area
- Arizona
- California
- Colorado
- CO Front Range
- Idaho
- New Mexico
- Wyoming
- Mexico *Demo* (18-km) *N*

Point Forecast:
- Map of All Locations
- Add / Remove Points

High Resolution Winds *N*

Forecast Verification (Bet
New

US Forest Service | Rocky Mountain Research Station | FCAMMS | National Fire Plan | CO Smo Program | Program

Alert Posting

Webmaster: **Ned Nikolov** (nnikolov@fs.fed.us)

http://fireweather.sc.egov.usda.gov - Prescribed Burn Editor - Microsoft Internet ...

Add Prescribed Burn

Enter **Name** (*up to 10 characters long*), **Latitude**, and **Longitude** (positive *degrees*) of the burn you want to add. To find the *exact* coordinates of a location, go to **TopoZone**. Smoke forecasts for new prescribed burns become available at the *next* model run.

Name:

Latitude:

Longitude:

State: Select:

Area (acres):

Date: 2004 Month Day

Time: Hour Minute

Ignition Duration (minutes):

Vegitation: Select:

Submit Reset

Done | Internet

Smoke Dispersion Forecasts

fireweather.info - Microsoft Internet Explorer provided by Comcast High-Speed Internet

File Edit View Favorites Tools Help

Address http://FireWeather.info/

Staff Only

USDA FS
Fort Collins, CO

Rocky Mountain Center

Providing Weather Awareness in Support of Clean Air, Healthy Trees & People

About Us | Research | Tech. Trans. | Consortia | Feedback | Contacts

HOME

Observed Weather:
- Regional Maps
- Point Obs.
- High-Res. Data

Forecast Weather:
- Regional Maps
- Point Forecast
- High-Res. Data
- Verification *New*

SMOKE

Western USA: 6-km resolution
36 to 48 hour Smoke Dispersion Forecast

Forecast Initialization Time:

RMC provides *real-time* prediction of smoke dispersion from ac
USA using the *BlueSky* Modeling System. *BlueSky* is developed
Pacific Northwest Research Station (PNWS) and the Northwest
(NWRMC) in Seattle WA. RMC runs *BlueSky* at 6-km resolution
forecast fields as environmental drivers. Smoke impact is displa
of **2-D *surface* concentration** of 2.5 micron-size particulate ma
fires, the smoke forecast is updated twice per day. ***To obtain s***
prescribed burns, please submit information through this Fo
prescribed burns become available at the next model run.

Click on the drop-down menu above to select a model initializati
dispersion forecast for ***up to 36 hours into the future*** .

For information about currently active wildfires, consult GeoMA
Southwest Morning Intelligence Report.

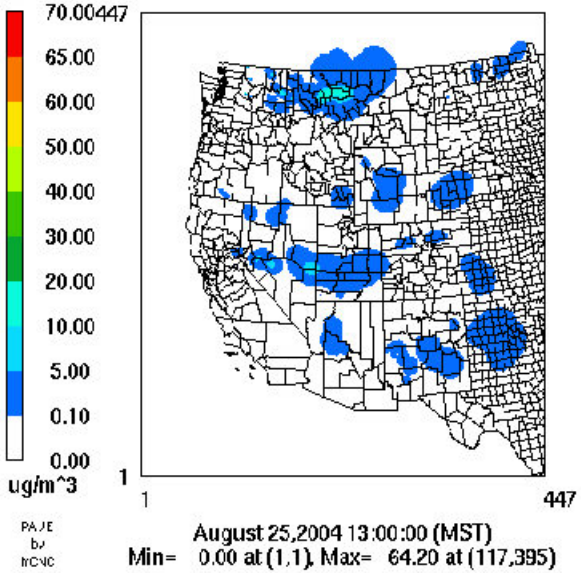
Webmaster: Ned Nikolov (nnikolov@fs.fe

Smoke Forecast - Microsoft Internet Explorer provided by Comcast High-Speed ...

Interior West: Smoke Dispersion Forecast
1-h Increment Loop

Wildfire Simulation

MM5 Forecast: 2004082418 (GMT)
Surface PM2.5 (NAAQS = 65 ug/m^3, 24hr avg)

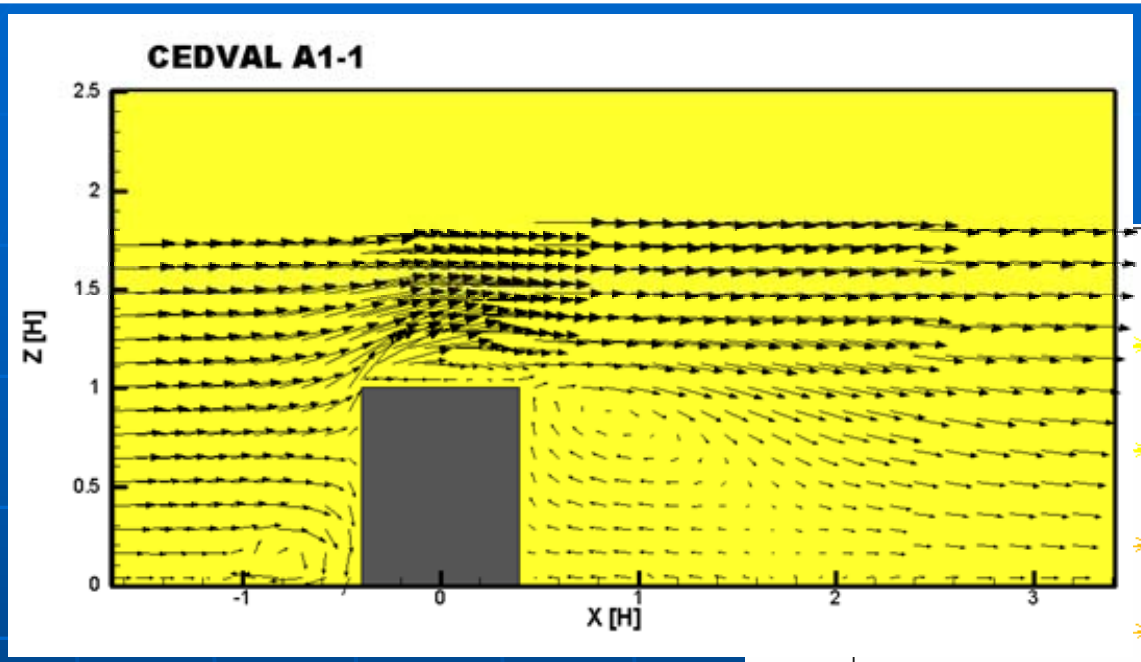


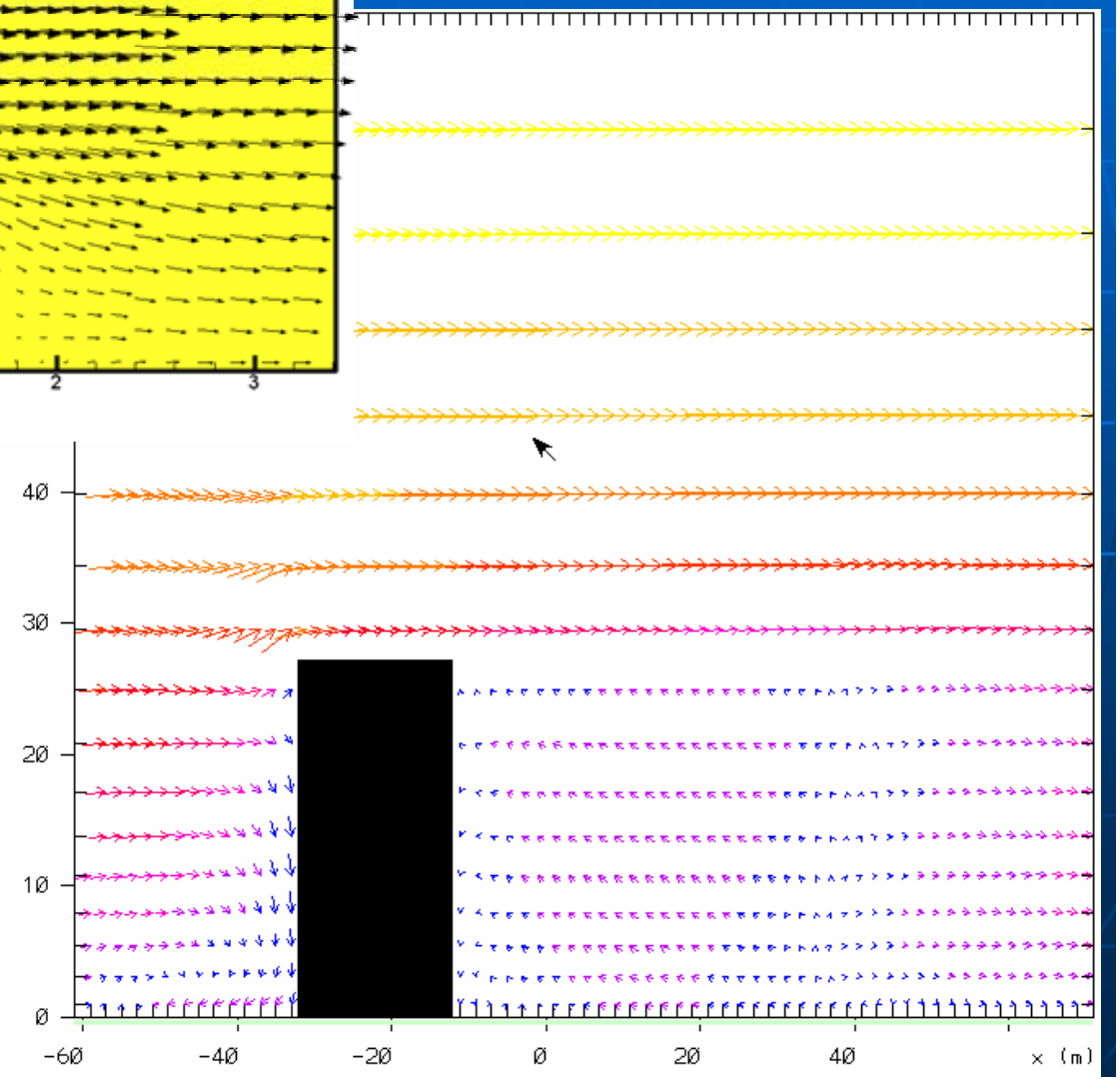
Beg (0) | -1 | Rew | Stop | Fwd | +1 | End (35)

loop | 26 | - Speed +

RAMS Very High-Resolution Simulations

Flow around a single building





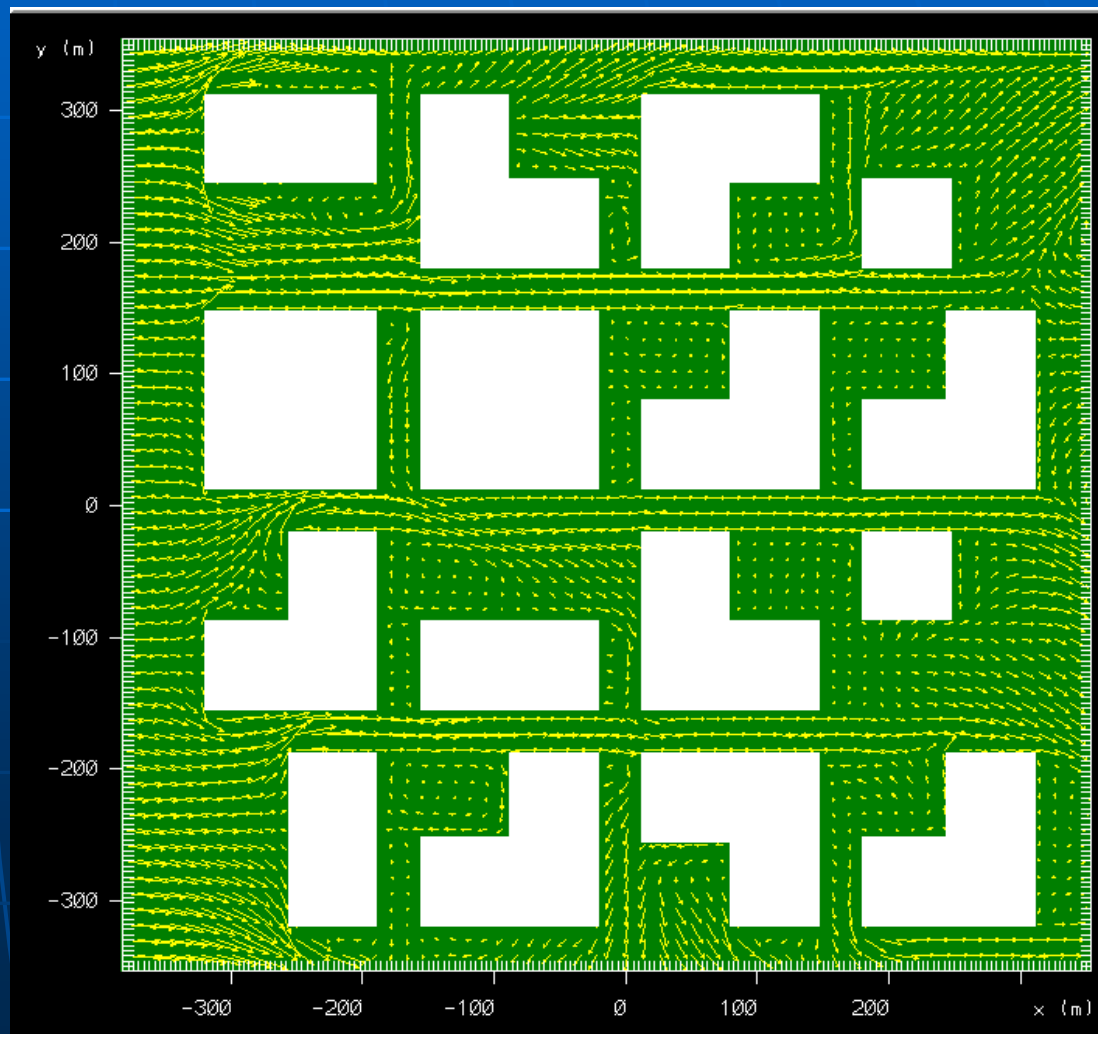
Building size:

Δx=20m Δy=30m Δz=25m

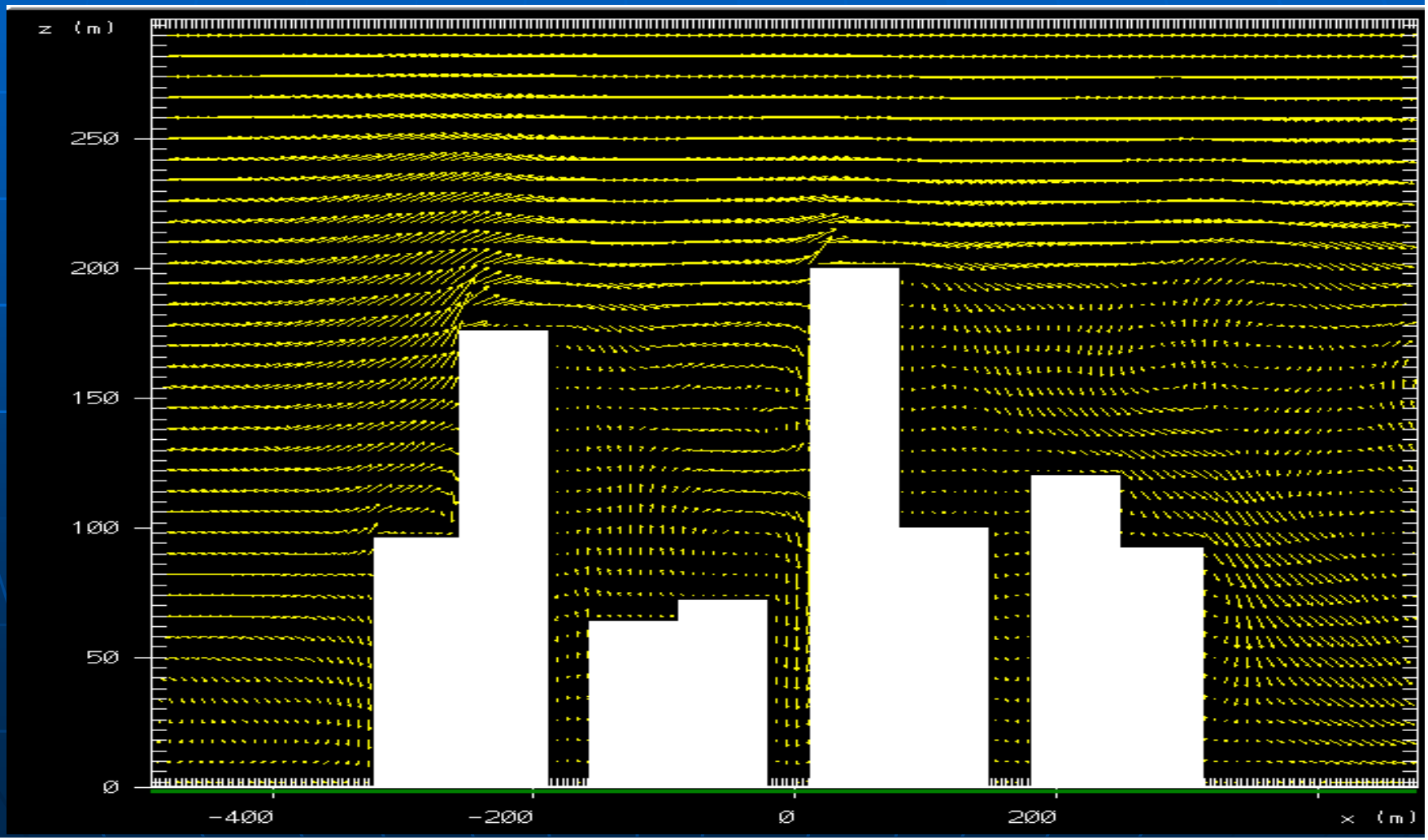
Cedval: 1:200

Flow through downtown region

- After 30 minutes of simulation
- 100m AGL



Flow through downtown region



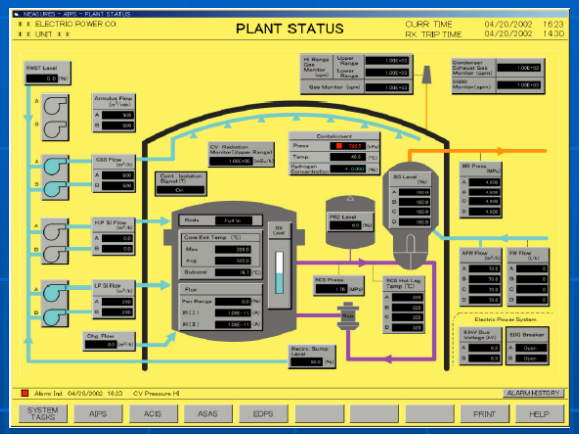
Emergency Response for Nuclear Power Plants

Mitsubishi Heavy Industries, Nagasaki, Japan

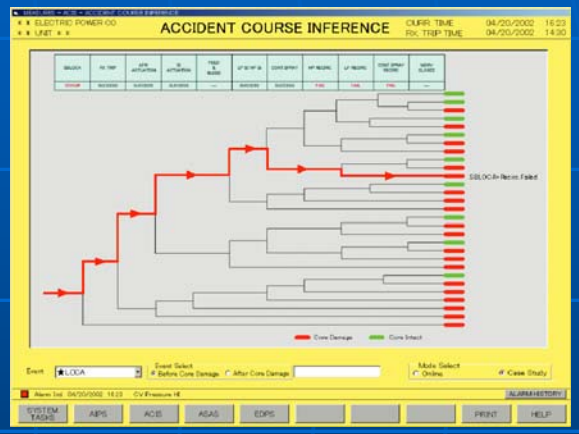
MHI MEASURES

(Multiple Radiological Emergency Assistance System for Urgent Response)

Accident Identification and Processing System (AIPS)

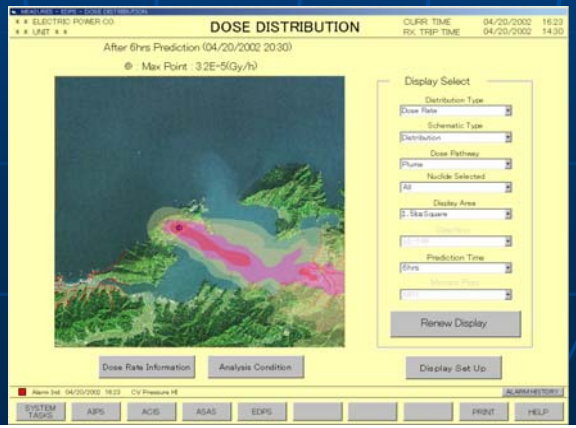


Accident Course Inference System (ACIS)



Accident Simulation Analysis System (ASAS)

Environmental Dose Projection System (EDPS)



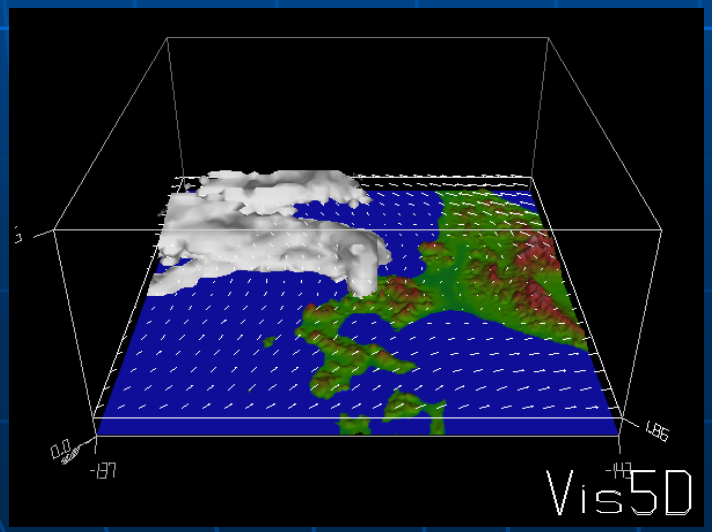
RAMS/HYPACT

MEASURES

Environmental Dose Projection System (EDPS)

Flow simulation

Radiation simulation



3-D radioactive cloud

animation