Penn State-DTRA High-Resolution Meteorological Modeling for the Torino Winter Olympics

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Torino 2006

WRF Users' Workshop

Boulder, CO

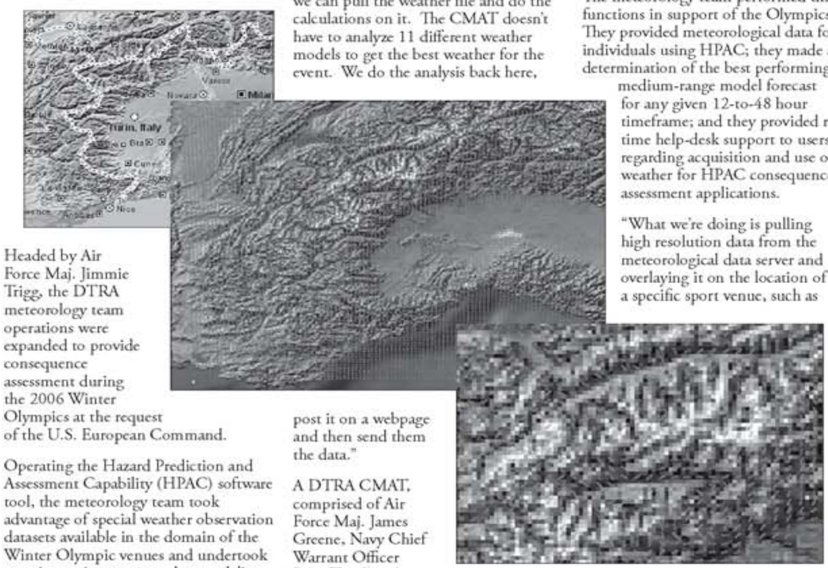
21 June 2006

DTRA Connection article…

DTRA team models wind, weather in support of Winter Olympics

by Irene Smith

Tracking snow and cold winds flowing from the Alps, the Defense Threat Reduction Agency's weather models and meteorology team supported the 2006 Winter Olympic Games in Turin, Italy.



Headed by Air Force Maj. Jimmie Trigg, the DTRA meteorology team operations were expanded to provide consequence assessment during the 2006 Winter Olympics at the request of the U.S. European Command.

Operating the Hazard Prediction and Assessment Capability (HPAC) software tool, the meteorology team took advantage of special weather observation datasets available in the domain of the Winter Olympic venues and undertook a project to improve weather modeling at high resolution.

The varied terrain provided a special challenge to the modelers on the meteorology team. Half of the Olympic venues were located in the mountains to the west of Torino, while the rest were located on the relatively flat plain in and around Pinerolo and the city of Torino to the east.

"Back at DTRA, we're making it easier for the Consequence Management Team (CMAT) to do their job," Trigg said. "If bad weather is predicted to happen during the curling competition, we can pull the weather file and do the calculations on it. The CMAT doesn't have to analyze 11 different weather models to get the best weather for the event. We do the analysis back here, post it on a webpage and then send them the data."

A DTRA CMAT, comprised of Air Force Maj. James Greene, Navy Chief Warrant Officer Peter Terrill and defense contractor Chris Schinnerer, was forward deployed to Stuttgart, Germany, to provide weather modeling to support hazard and consequence assessment operations

The HPAC and other tools use high-resolution weather data along with other environmental and source term information to produce estimates of the spread of accidentally or intentionally released hazardous material, such as chemical, biological, radiological, nuclear, and high explosive (CBRNE) agents.

The meteorology team performed three functions in support of the Olympics. They provided meteorological data for individuals using HPAC; they made a determination of the best performing medium-range model forecast for any given 12-to-48 hour timeframe; and they provided real-time help-desk support to users regarding acquisition and use of weather for HPAC consequence assessment applications.

"What we're doing is pulling high resolution data from the meteorological data server and overlaying it on the location of a specific sport venue, such as snowboarding," Trigg said. "Gathering 1.6 kilometer resolution data from the U.S. Air Force Weather Agency (AFWA), we then add high resolution weather data over the area and plot the flow and direction of the wind as it comes out of the mountains."

Prior to the Olympics, DTRA partners at Pennsylvania State University (PSU) and the U.S. National Center for Atmospheric Research (NCAR) established data collection and assimilation, and forecast modeling projects that used special weather station observations provided by Italy's ARPA Piemonte, the environmental agency for the region.

At Penn State, a version of the Mesoscale Model-5 (MM5) was prepared to use the special observation data to forecast weather in a four-nest configuration. At NCAR, versions of MM5 and the Weather Research and Forecast (WRF) models were integrated into a real-time four-dimensional data assimilation program which used the special Olympic weather data to initialize these models.

Navy Chief Warrant Officer Peter Terrill (right) and defense contractor Chris Schinnerer, members of a DTRA Consequence Management Assessment Team forward deployed to Stuttgart, Germany, provide weather modeling to support hazard and consequence assessment operations at the Winter Olympics.

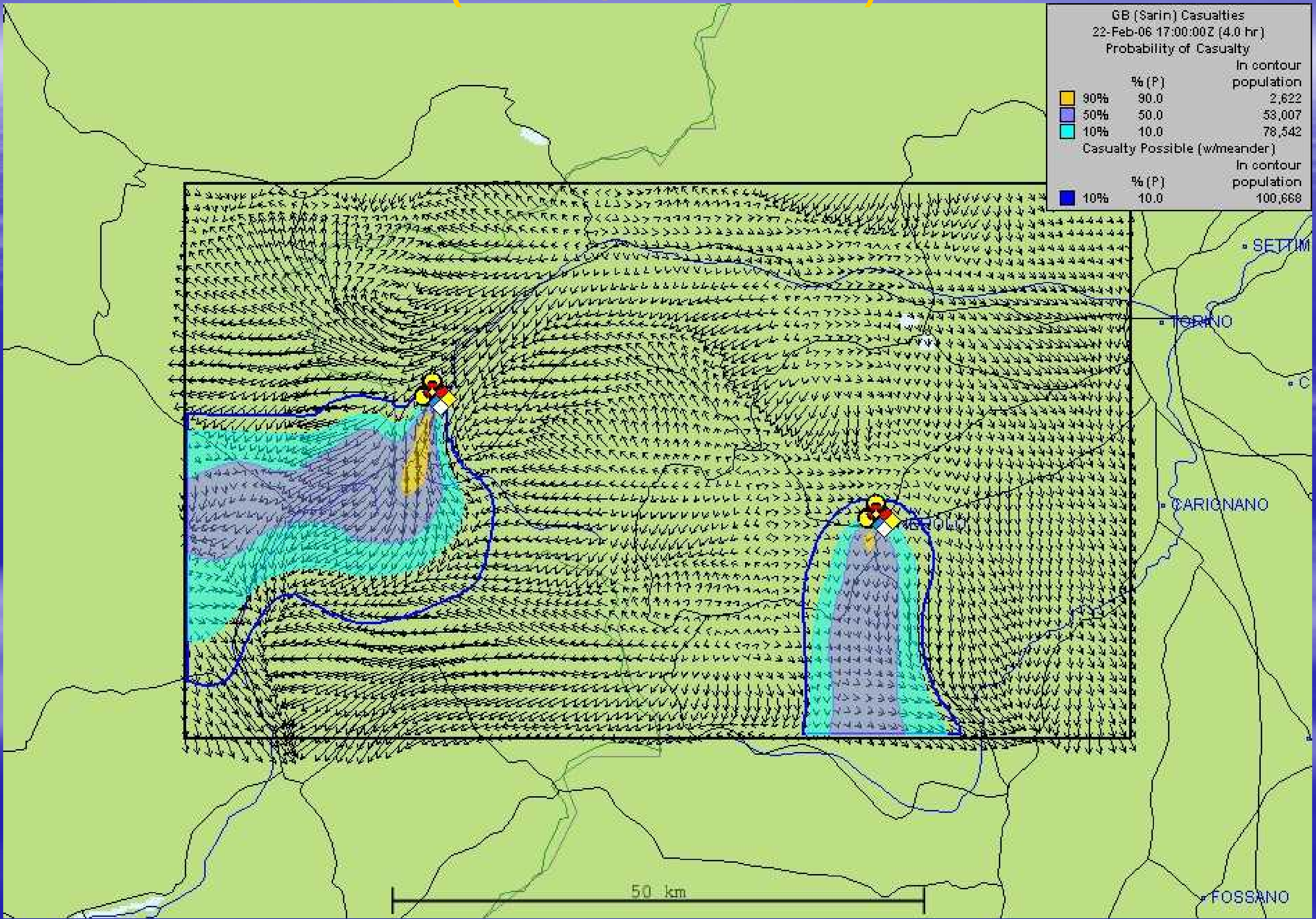
Dr. David Staufer, Penn State meteorology department, remarked, "It is very satisfying to apply our advanced technologies in numerical weather predication and data assimilation. So far our high-resolution meteorological modeling and data assimilation system has performed very well in capturing the localized mountain flows in and around the Olympic venues."

Two other DTRA partners provided independent weather forecast models against which the PSU and NCAR model data was compared against. The AFWA provided its MM5 forecast model data and the U.S. National Oceanic and Atmospheric Administration's National Centers for Environmental Prediction provided data from a special version of their WRF model.

"We learned several important lessons during this project," Trigg said. "More research is needed for quantifying model uncertainties in the inputs and outputs of transport and dispersion models. The meteorology team and its partners used this experience to improve several areas of its weather support operations. We plan to expand upon this experience during upcoming field tests, and to further improve and expand the capability to provide accurate high-resolution weather forecast information to hazard and consequence assessment operations." ■

Irene Smith is a DTRA public affairs specialist.

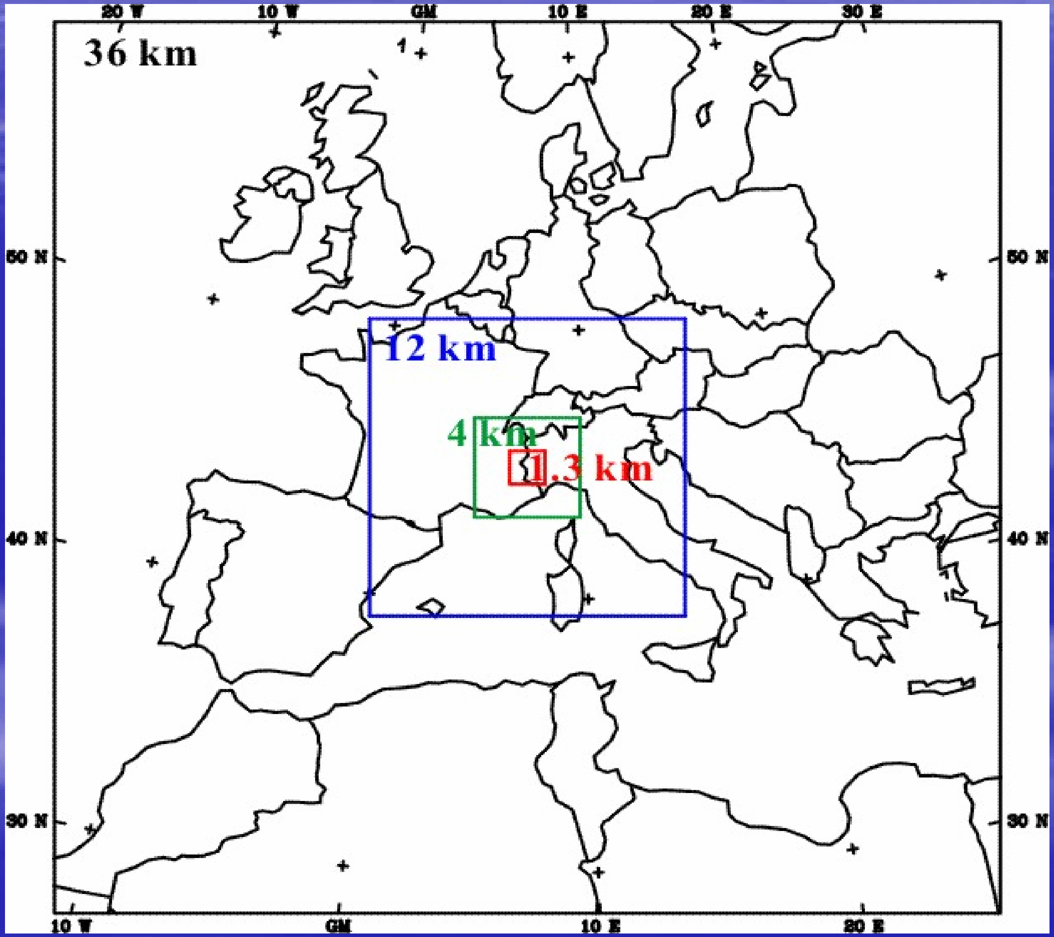
PSU 1.3km Feb. 22/13-17 UTC plumes, Feb. 22/14 UTC winds (Feb. 22/00 UTC model)



Objectives

- Overview MM5 realtime forecast results for entire Olympics period, and the added value of finer model grid resolutions.
- Investigate effects of model initialization (FDDA) in MM5, and the performance of MM5 vs. WRF baseline (no FDDA) experiments, using subset of six cases representing different weather conditions during Olympics period.

MM5/WRF 4-Domain Configuration for 2006 Winter Olympics

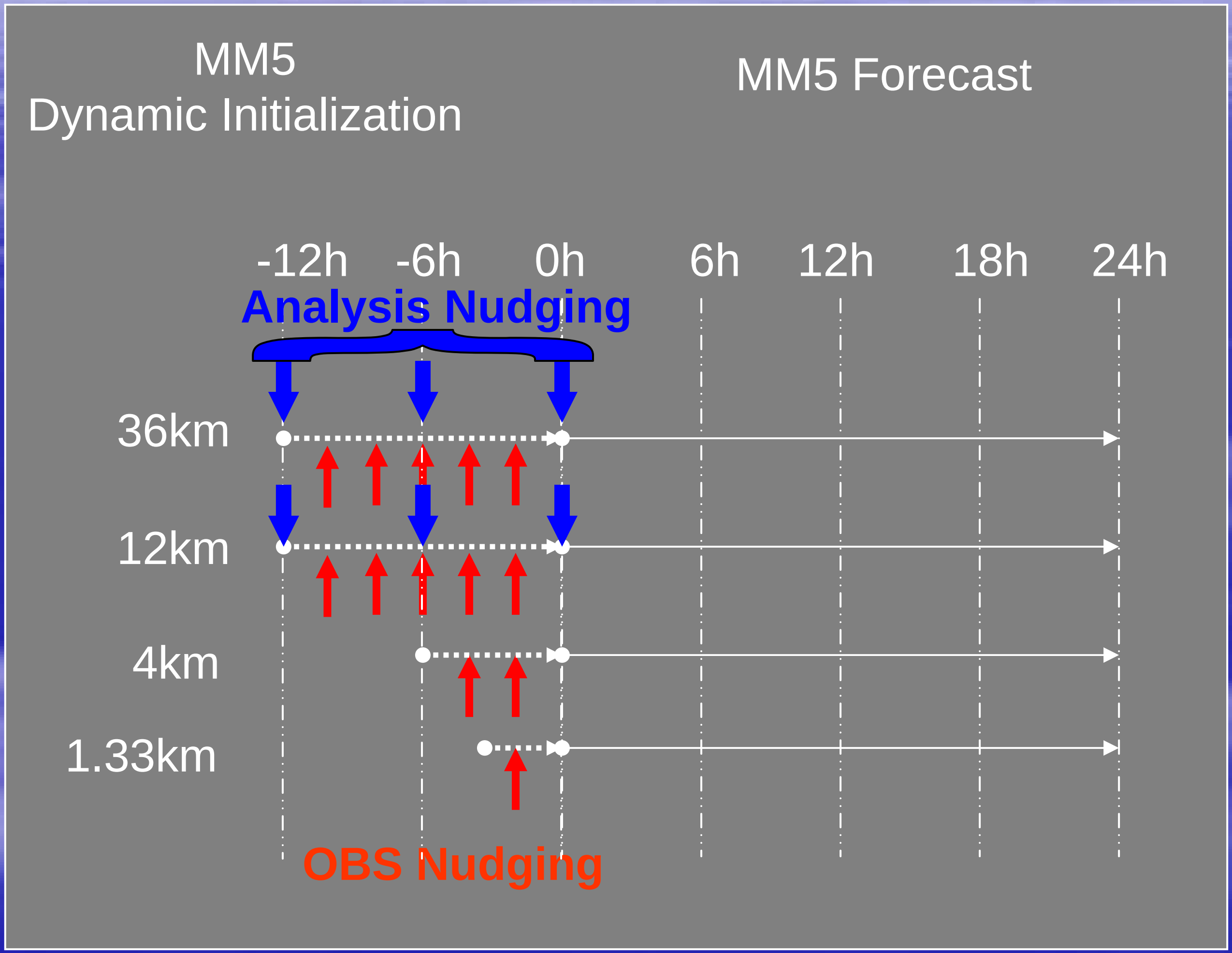


“Running Start” of NWP Model

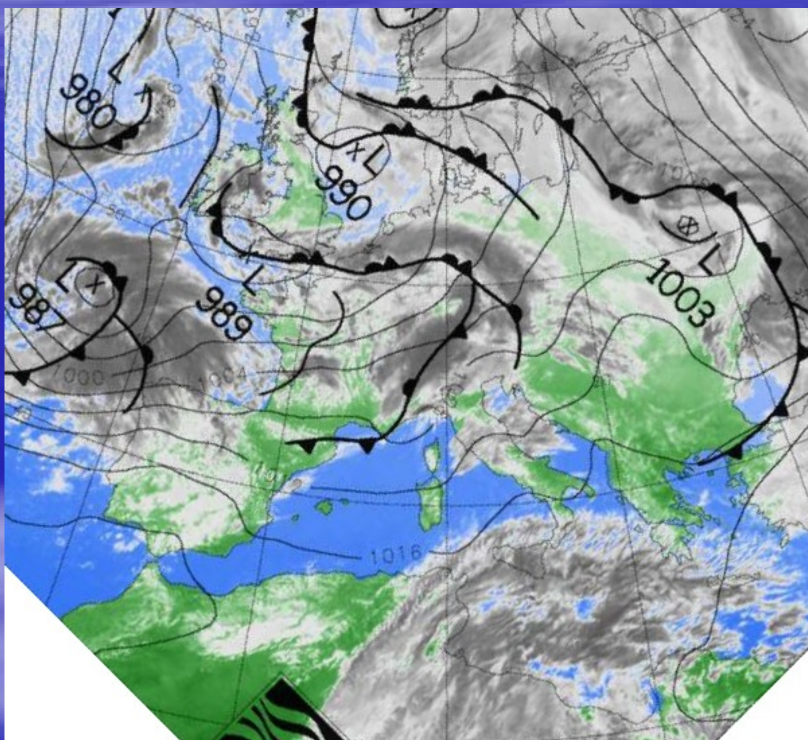
- Penn State computer forecasts for the Olympics were produced twice daily using a “running start” dynamic initialization method in which all standard surface and upper-air weather observations - and also special data in and around the Olympics venues – go into the model initial conditions… along with detailed snow cover information from satellite.

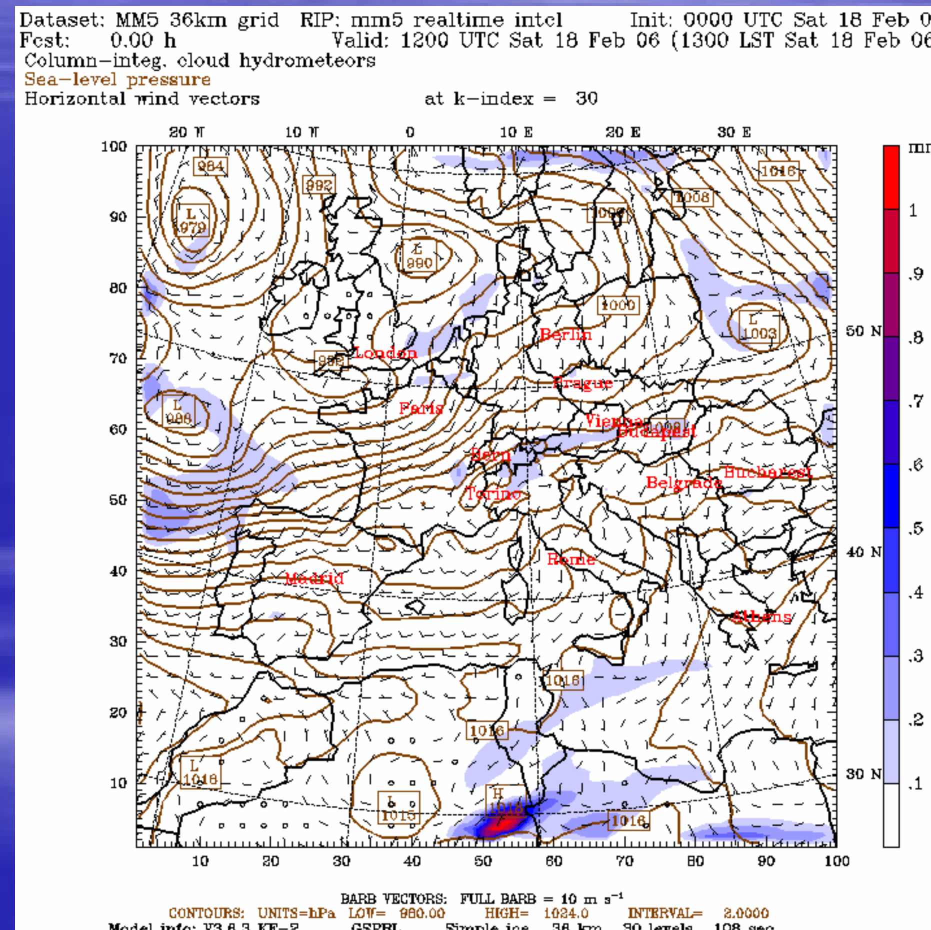
- The model solution has “spun-up” cloud and precipitation patterns even at the initial time (t = 0 h), and thus forecasts based on these initial conditions are also much improved …

MM5 Initialization Scheme used for 2006 Winter Olympics

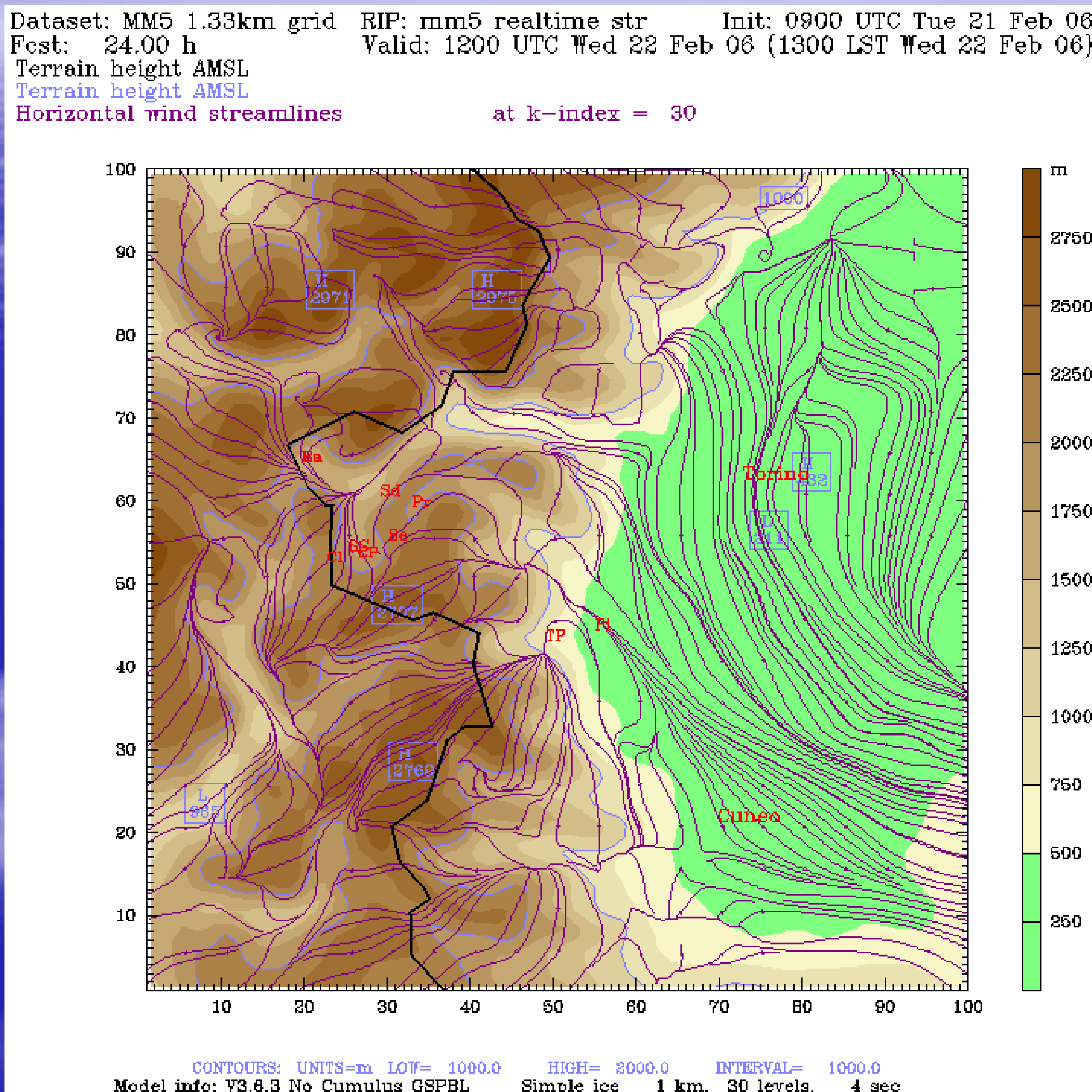


Observed and Model Cloud (t=0h) 1200UTC February 18, 2006

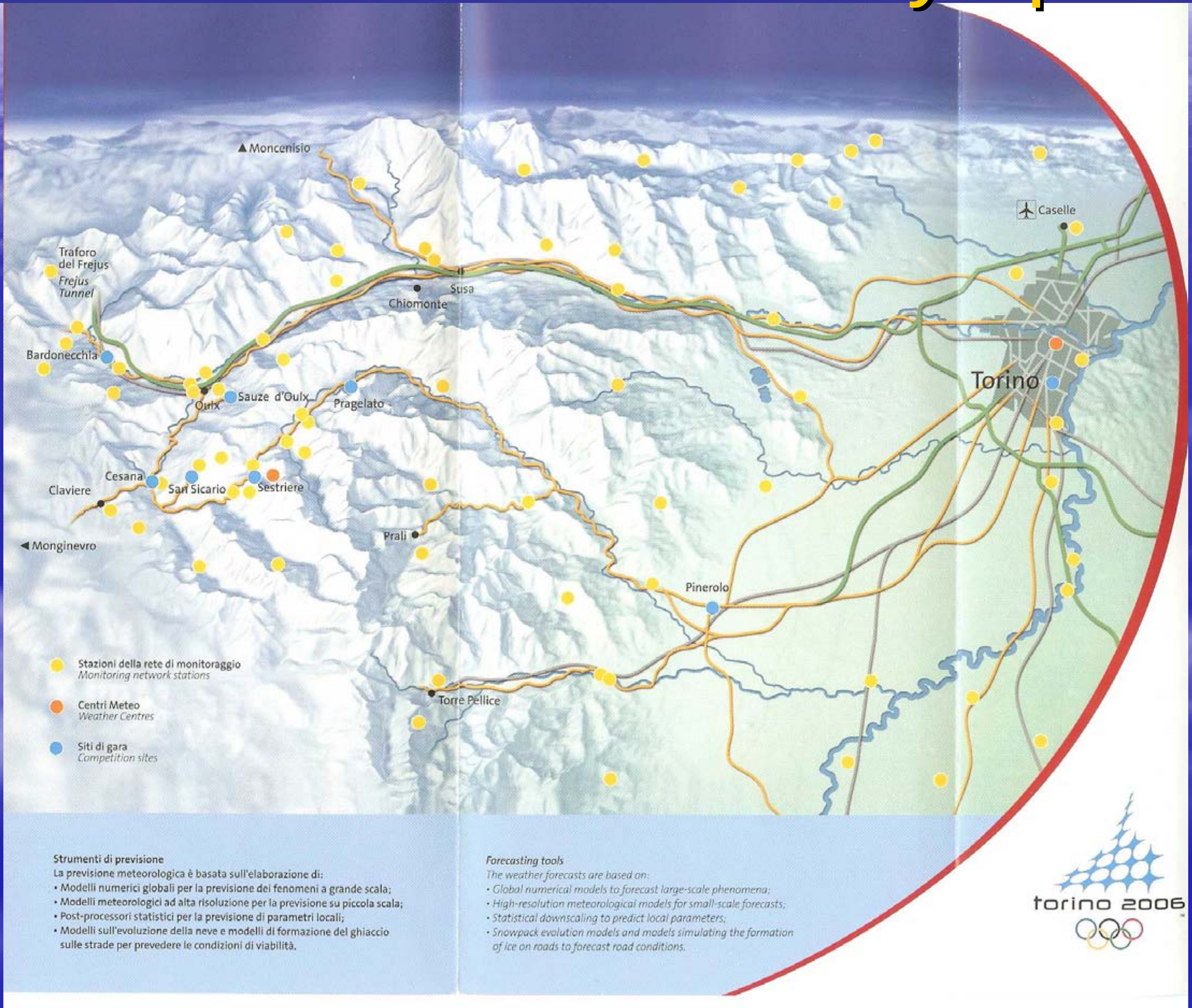




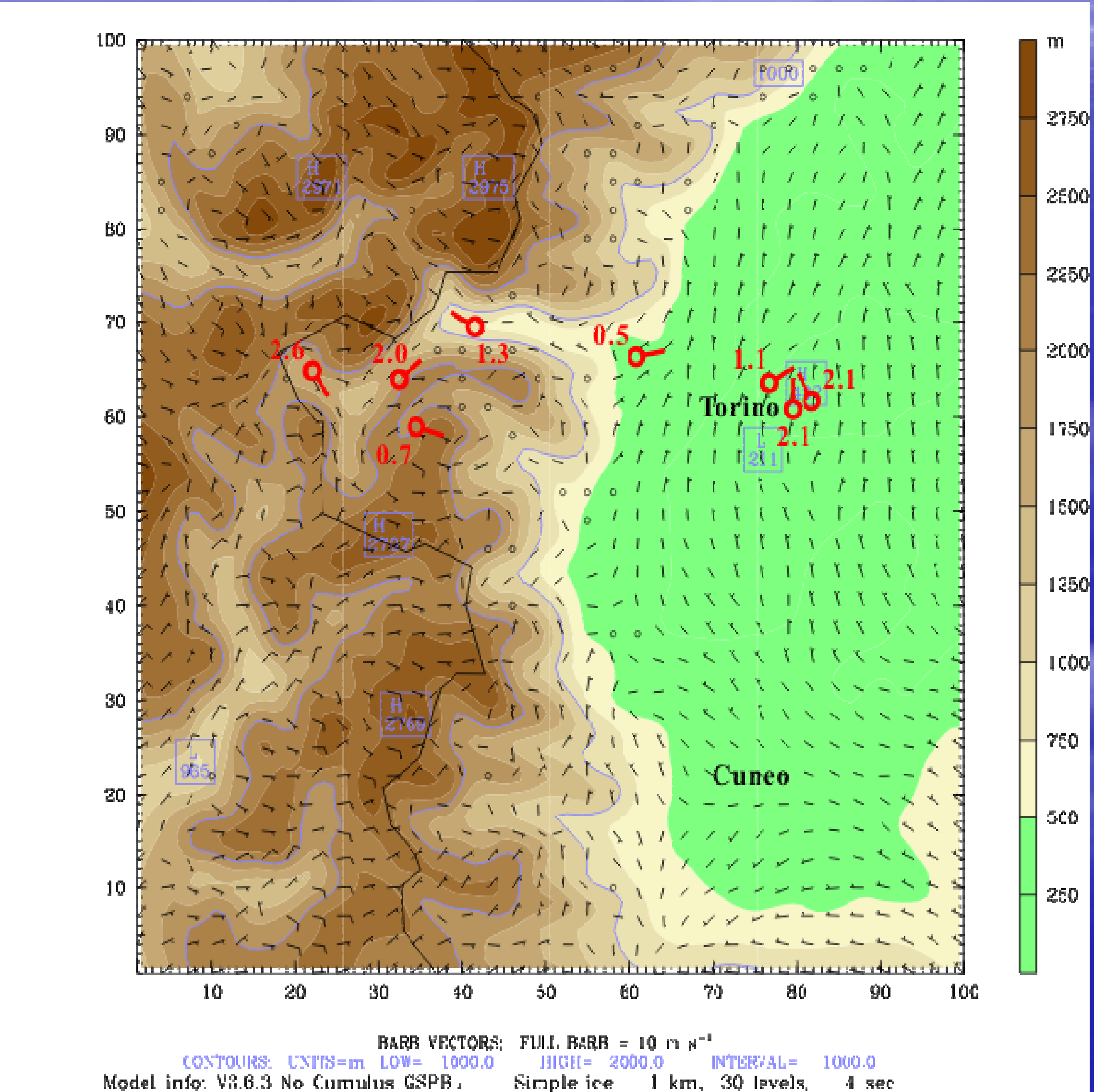
1.33 km Resolution



Venue Locations for the 2006 Winter Olympics

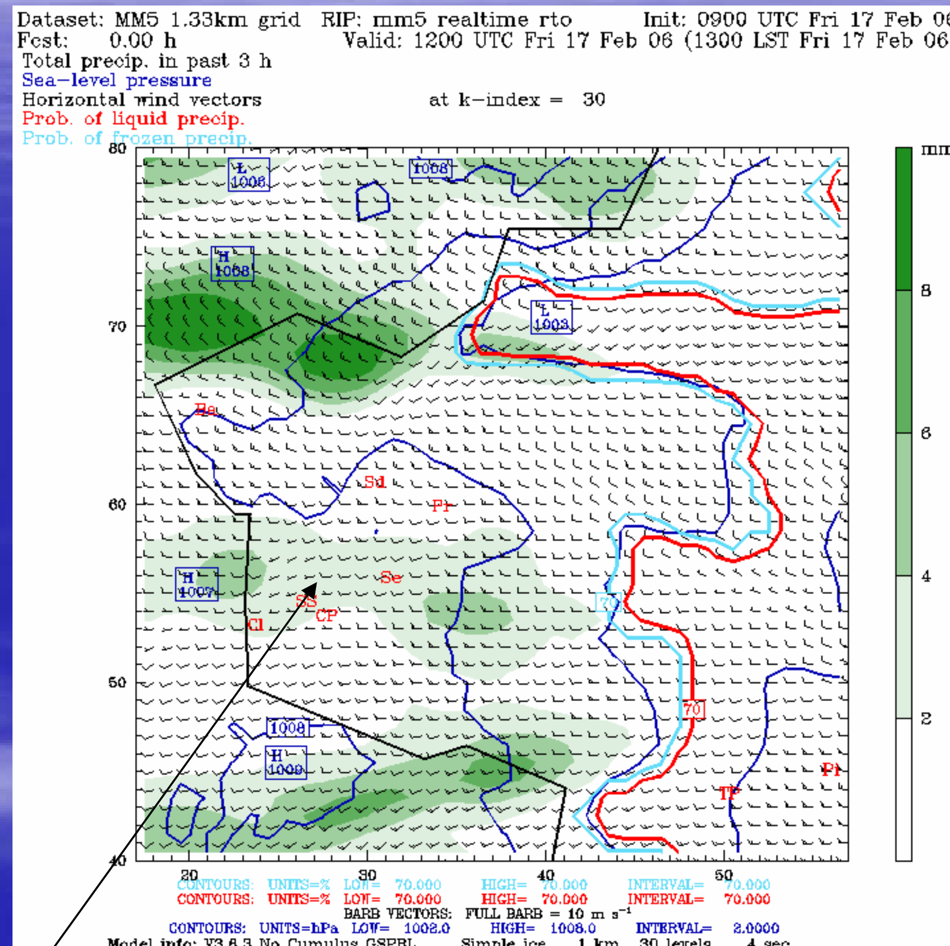


18-h Forecast of Surface Layer Winds with Mesonet Observations (red) on 1.3 km Domain Valid at 18 UTC, 21 February 2006



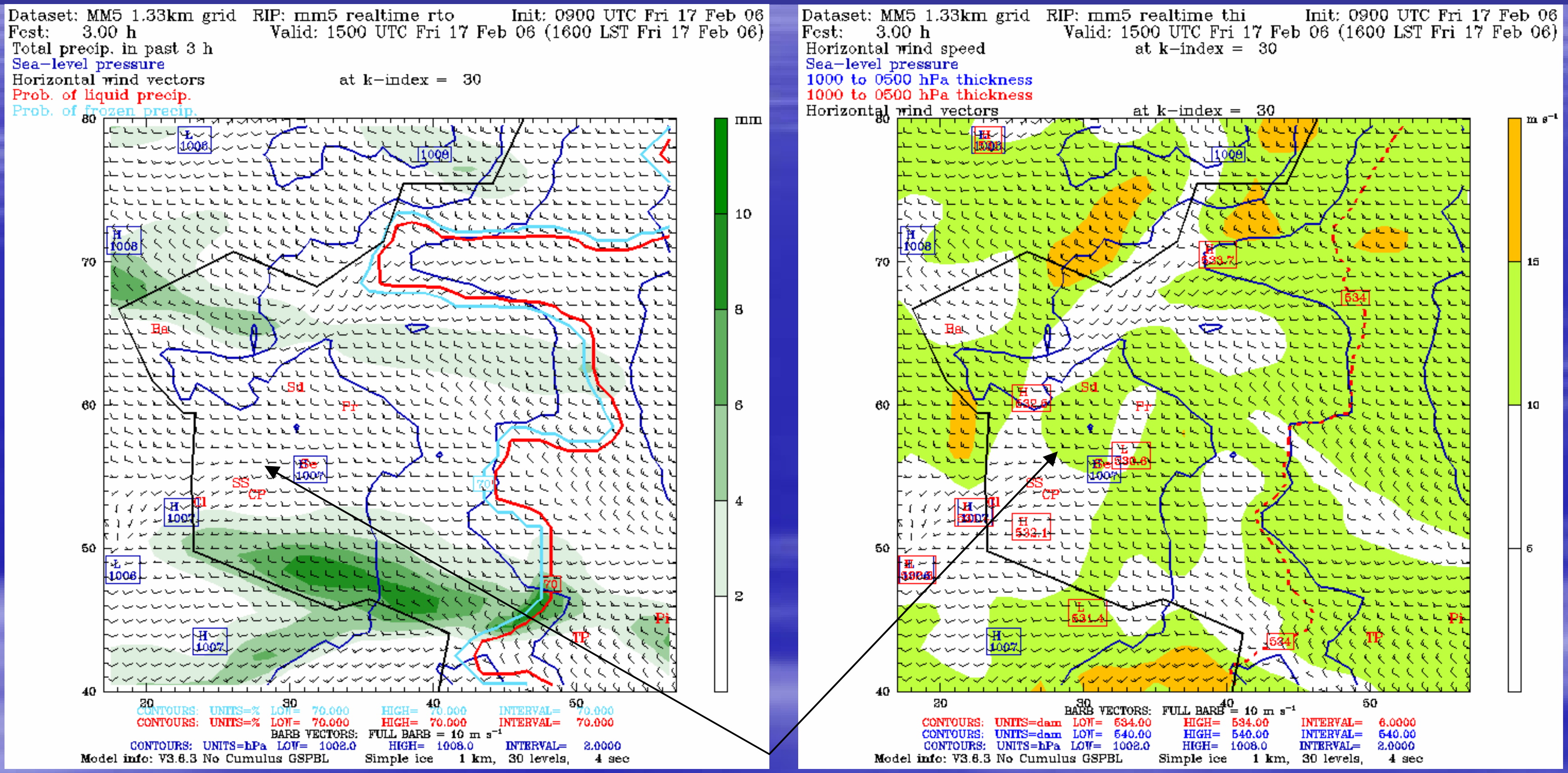
February 17, 2006
Initial Postponement Due to Snow

- Venues shown on the 1.33-km grid:
  Ba: Bardonecchia (snowboarding)
  Pi: Pinerolo (curling)
  Pr: Pragelato (ski jumping/x-country)
  CP: Cesana Pariol (luge/skeleton/bobsled)
  SS: Cesana-San Sicario (biathlon)
  Sd: Sauze d'Oulx (freestyle skiing)
  Se: Sestriere (alpine skiing)
  Cl: Claviere (training)
  TP: Torre Pellice (training)
  Torino (skating/hockey)



12:59 AS COURSE WORKERS CONTINUE AWAY: The race has already been delayed one hour, and now it's going to be delayed at least another 15 minutes, as the word from FIS is that the new start-time is 13:15 CET!
(Excerpt from http://www.eurosport.com/alpineskiing/torino/2005-2006/live_mtc111414.shtml)

February 17,2006
Although skies are clear…high winds result in cancellation

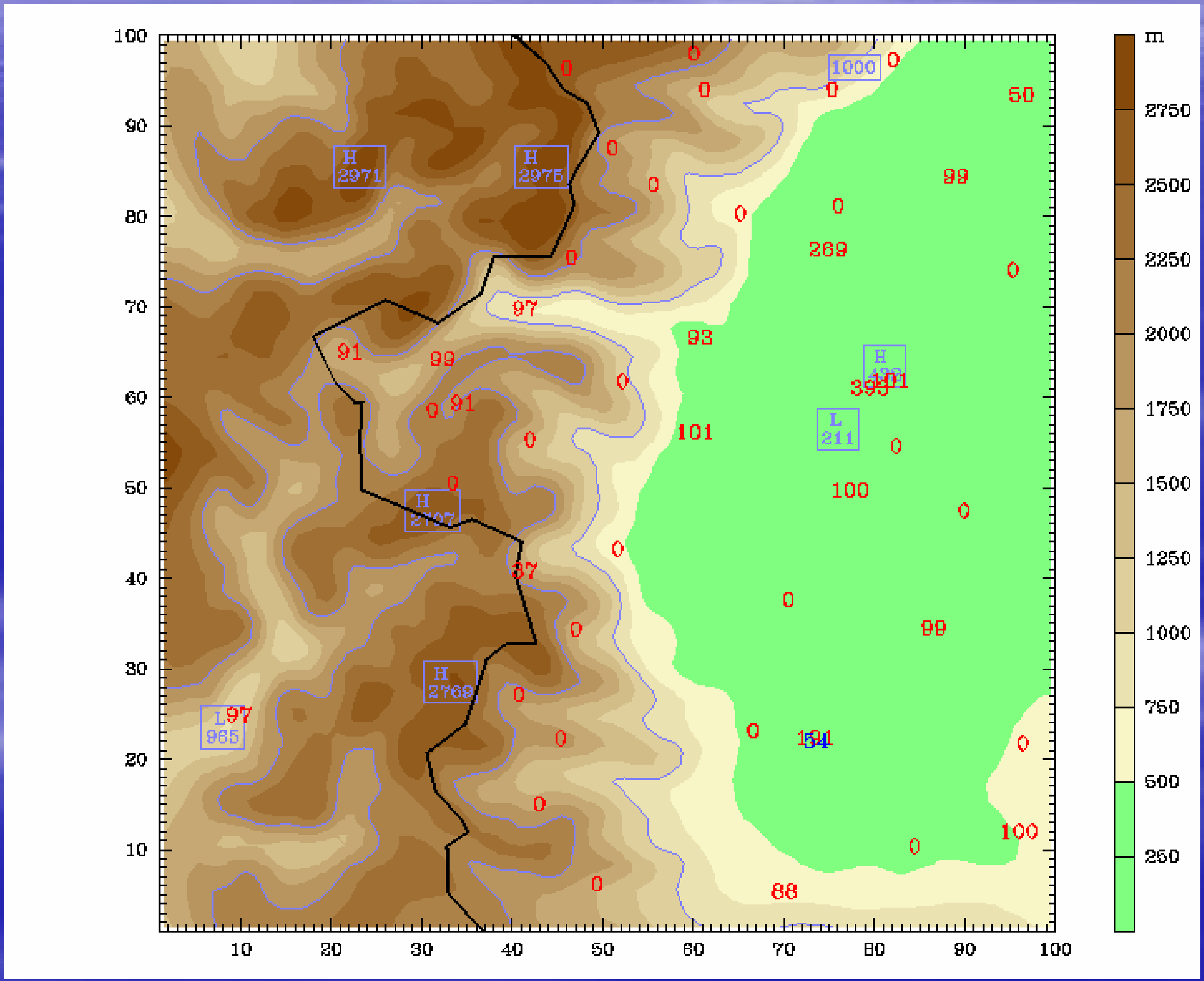


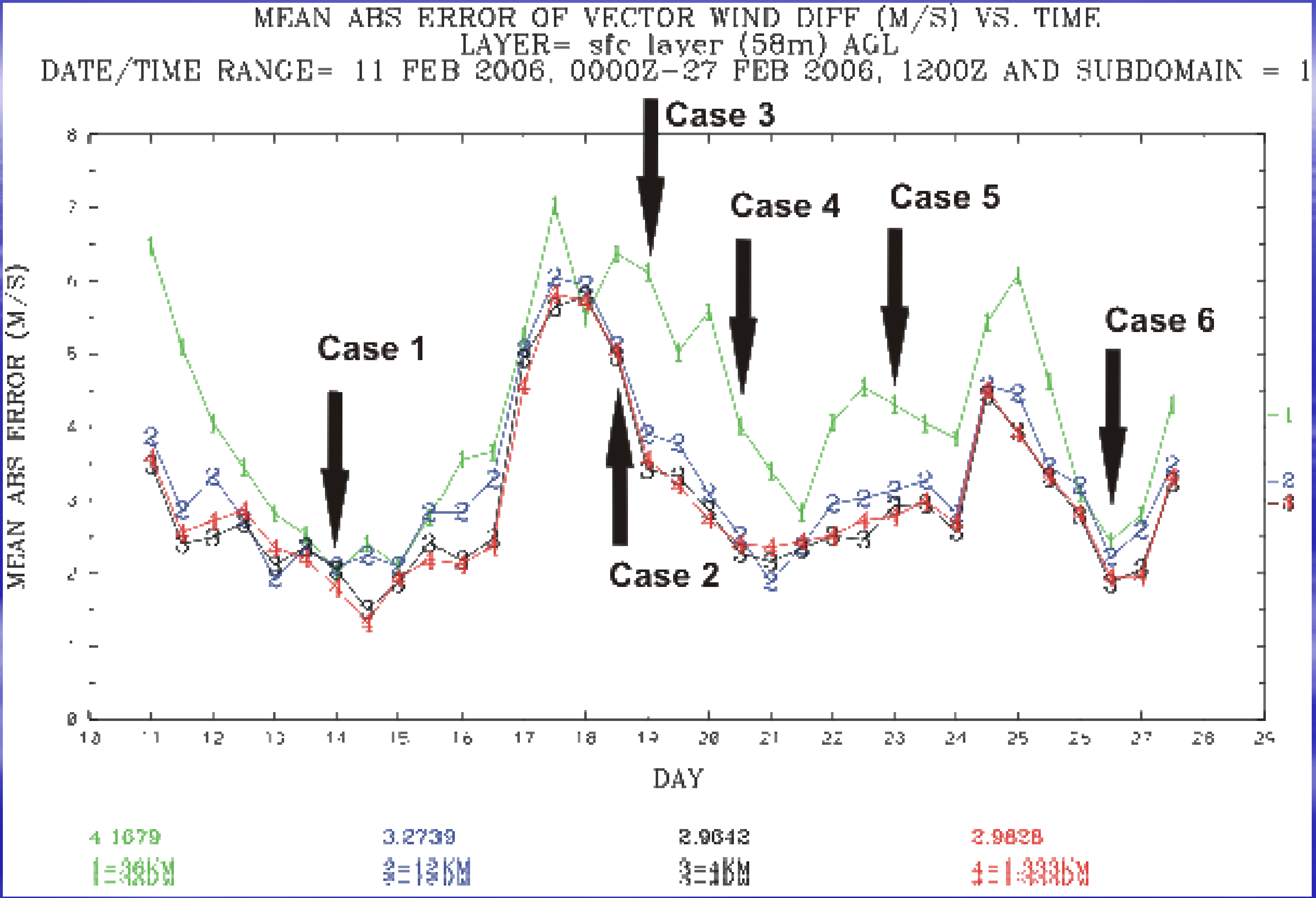
13:16 FLEISS IS ALREADY DOWN: The wind got under her skis, and almost blew her off the course on her first jump as she crashes into the snow!!!! BUT SHE'S DUSTED HERSELF OFF AND IS GOING TO FINISH

13:23 OFFICIAL ANNOUNCEMENT: Race cancelled due to poor weather conditions!!!! The ladies will now move to Sestriere for the slalom portion, as this could have a big impact on the final result.

(Excerpt from http://www.eurosport.com/alpineskiing/torino/2005-2006/live_mtc111414.shtml)

Number and Locations of Surface Mesonet Wind Observations

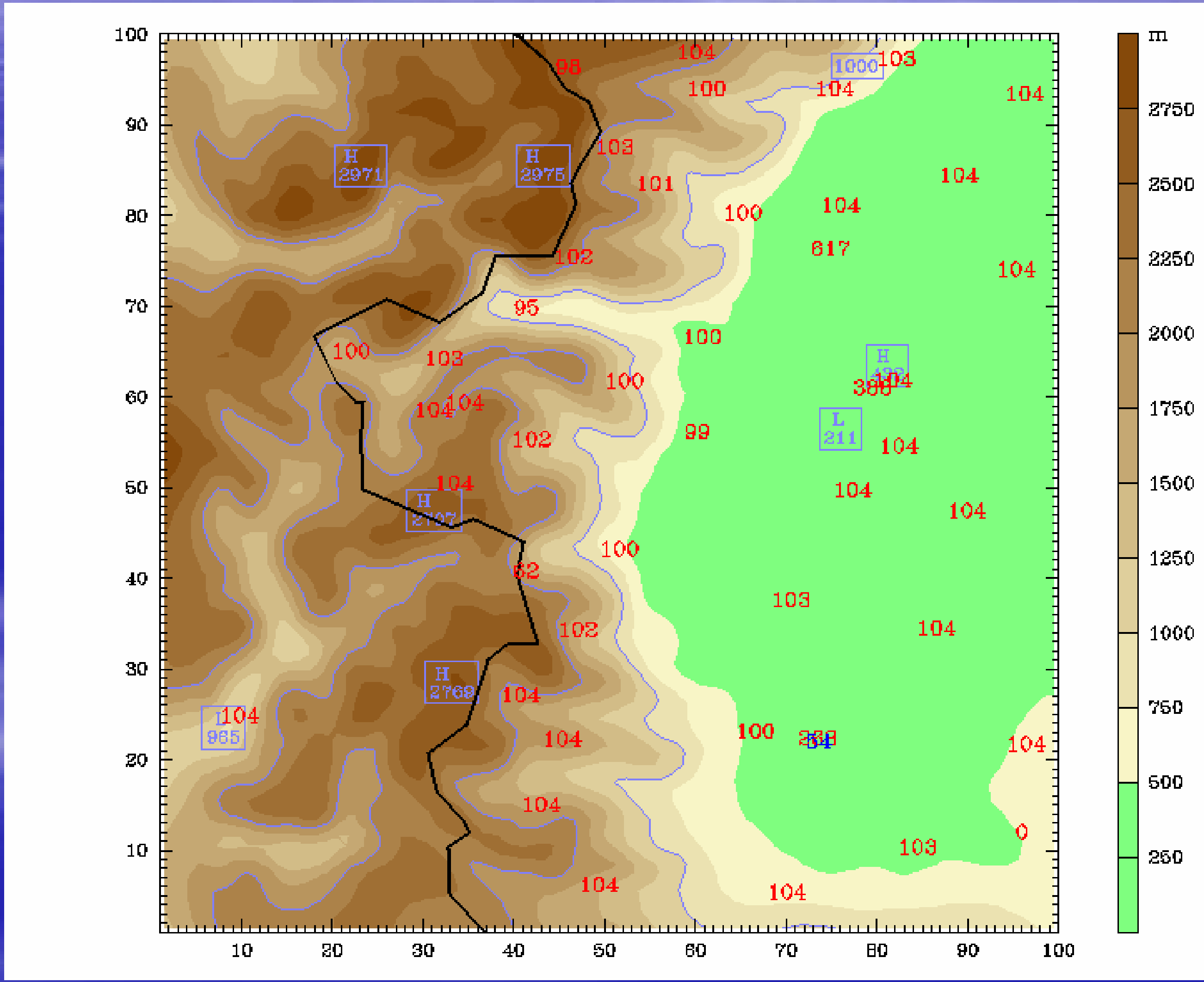


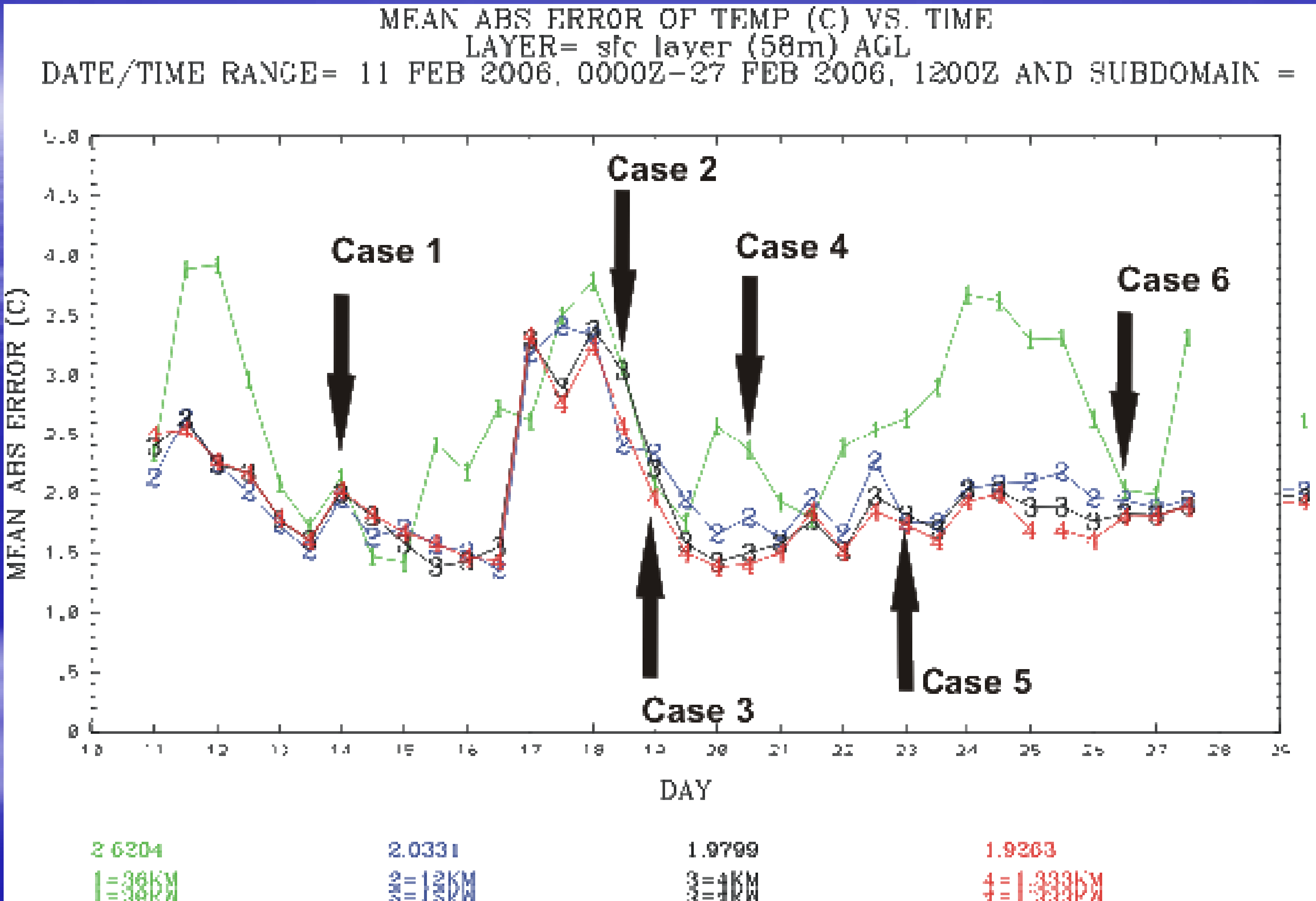

MEAN ABS ERROR OF VECTOR WIND DIFF (M/S) VS. TIME
LAYER= sfc layer (58m) AGL
DATE/TIME RANGE= 11 FEB 2006, 0000Z-27 FEB 2006, 1200Z AND SUBDOMAIN = 1
Case 1
Case 2
Case 3
Case 4
Case 5
Case 6
MEAN ABS ERROR (M/S)
DAY
3.2739
2.9642
2.9628

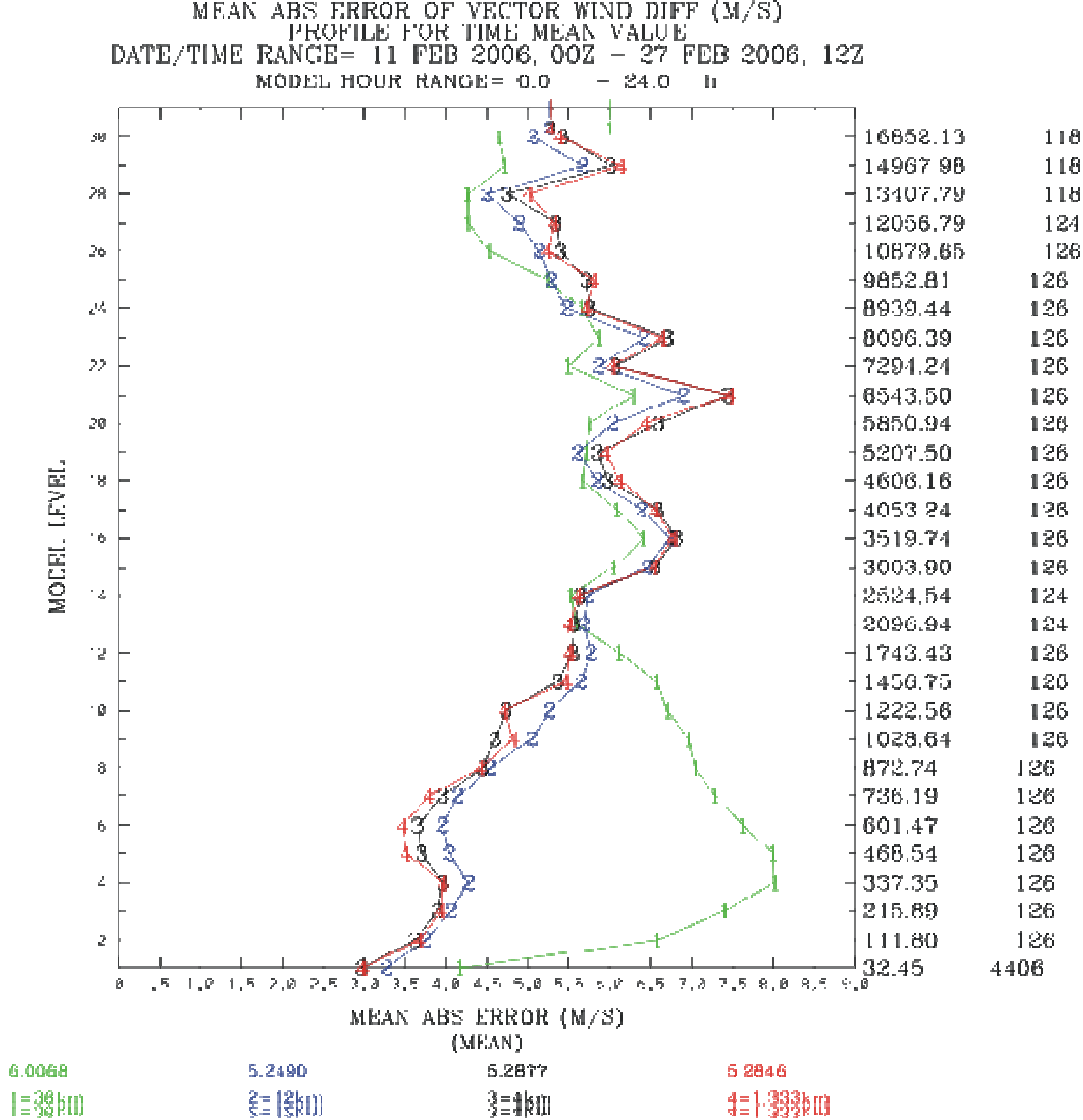
Case Descriptions

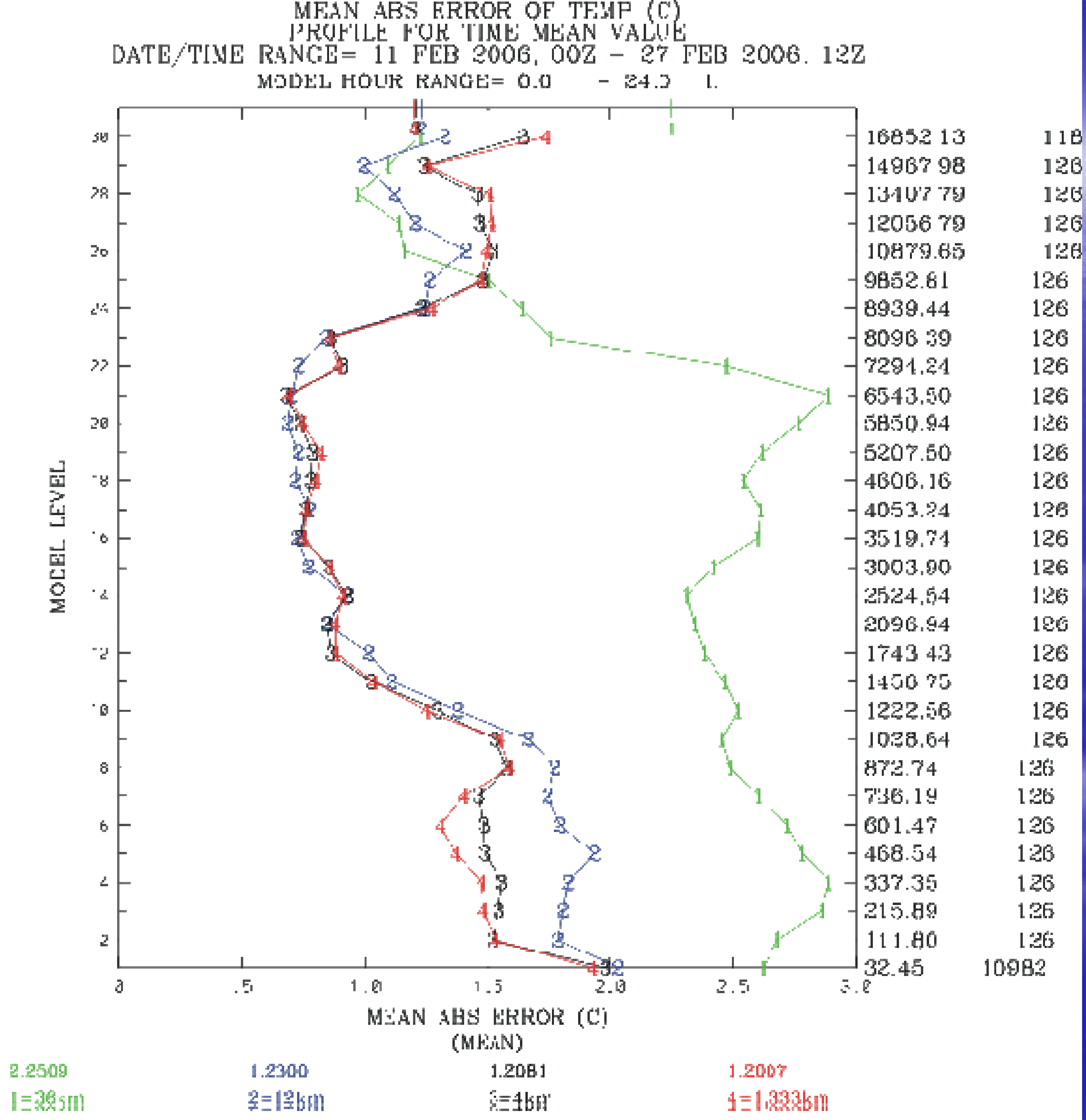
Case 1	00 UTC, 13 Feb 2006 - 00 UTC, 14 Feb 2006	Dry
Case 2	12 UTC, 17 Feb 2006 – 12 UTC, 18 Feb 2006	Precip/Wind in Mountains
Case 3	00 UTC, 18 Feb 2006 – 00 UTC, 19 Feb 2006	Precip in Mountains
Case 4	12 UTC, 19 Feb 2006 – 12 UTC, 20 Feb 2006	Precip in Mountains and on Plains
Case 5	00 UTC, 22 Feb 2006 – 00 UTC, 23 Feb 2006	Precip on Plains
Case 6	12 UTC, 25 Feb 2006 – 12 UTC, 26 Feb 2006	Light Precip in Mountains and on Plains

Number and Location of Surface Mesonet Temperature Observations




MEAN ABS ERROR OF TEMP (C) VS. TIME
LAYER= sfc layer (58m) AGL
DATE/TIME RANGE= 11 FEB 2006, 0000Z-27 FEB 2006, 1200Z AND SUBDOMAIN = 1
MEAN ABS ERROR (C)
DAY
Case 1
Case 2
Case 3
Case 4
Case 5
Case 6
2.6204
2.0331
1.9799
1.9263
1=36KM
2=12KM
3=4KM
4=1.333KM

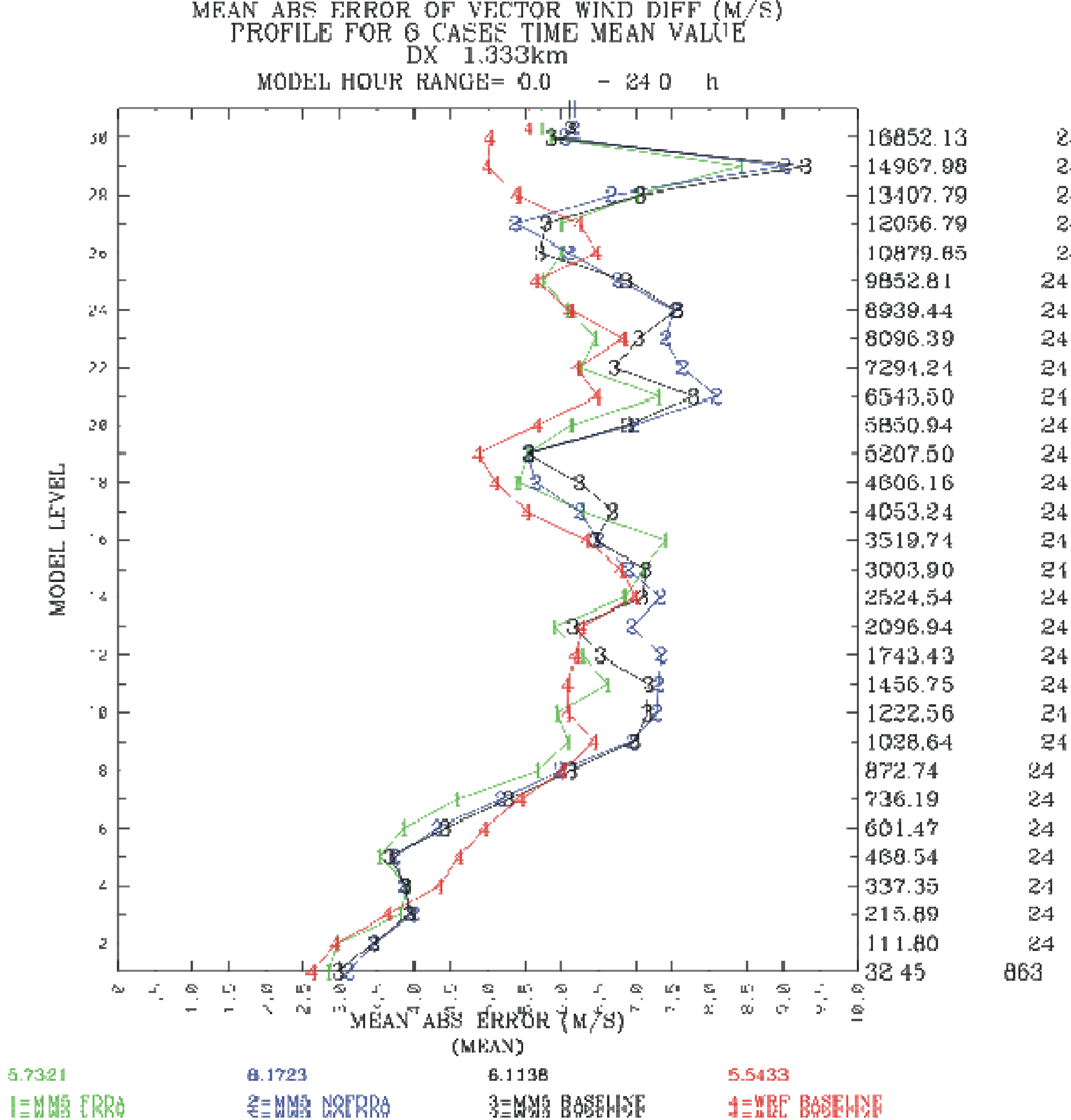

MEAN ABS ERROR OF VECTOR WIND DIFF (M/S)
PROFILE FOR TIME MEAN VALUE
DATE/TIME RANGE= 11 FEB 2006, 00Z - 27 FEB 2006, 12Z
MODEL HOUR RANGE= 0.0 - 24.0 h
MODEL LEVEL
MEAN ABS ERROR (M/S)
(MEAN)
16852.13 118
14967.98 118
13407.79 118
12056.79 124
10879.65 126
9852.81 126
8939.44 126
8096.39 126
7294.24 126
6543.50 126
5850.94 126
5207.50 126
4606.16 126
4053.24 126
3519.74 126
3003.90 126
2524.54 124
2096.94 124
1743.43 126
1456.75 120
1222.56 126
1028.64 126
872.74 126
736.19 126
601.47 126
468.54 126
337.35 126
215.89 126
111.80 126
32.45 4406
6.0068
5.2490
5.2877
5.2846

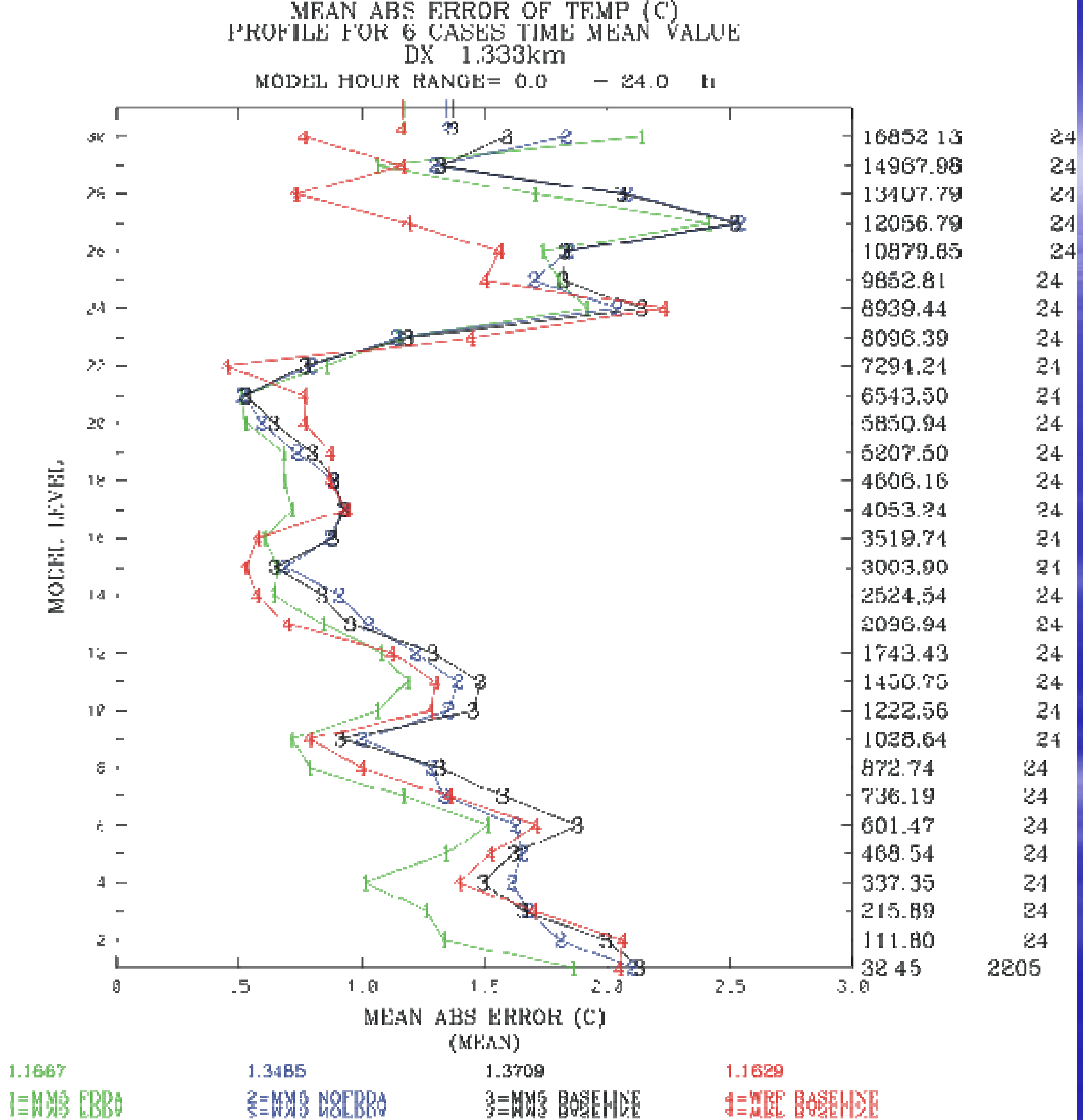


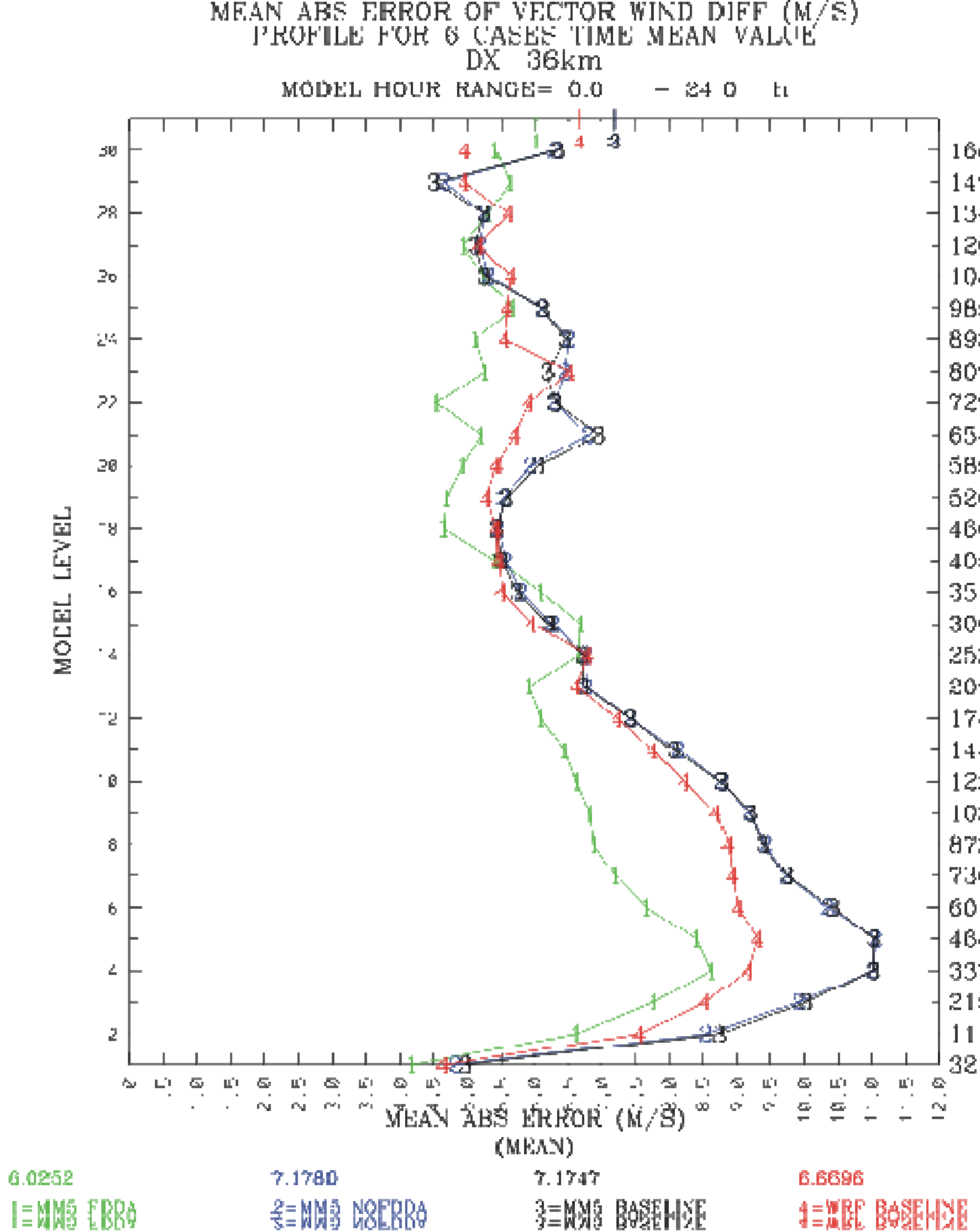
MEAN ABS ERROR OF TEMP (C)
PROFILE FOR TIME MEAN VALUE
DATE/TIME RANGE= 11 FEB 2006, 00Z - 27 FEB 2006, 12Z
MODEL HOUR RANGE= 0.0 - 24.0
MODEL LEVEL
MEAN ABS ERROR (C)
(MEAN)
2.2509
1.2300
1.2081
1.2007

MM5 and WRF Experimental Design

Exp. No.	Exp. Name	PBL Physics	Microphysics	CPS (36/12 km)	Radiation	Dynamic Initialization
1	MM5 FDDA	Penn State GSPBL	Simple Ice	KF2	LW: RRTM SW: Dudhia	36km: 12hr AFDDA&OFDDA 12km: 12hr AFDDA&OFDDA 4km: 6hr OFDDA 1.3km: 3hr OFDDA
2	MM5 NOFDDA	Penn State GSPBL	Simple Ice	KF2	LW: RRTM SW: Dudhia	None
3	MM5 BASELINE	M-Y Eta TKE PBL	Simple Ice	KF2	LW: RRTM SW: Dudhia	None
4	WRF BASELINE	M-Y-J Eta TKE PBL	WSM 3-class simple ice scheme	KF2	LW: RRTM SW: Dudhia	None

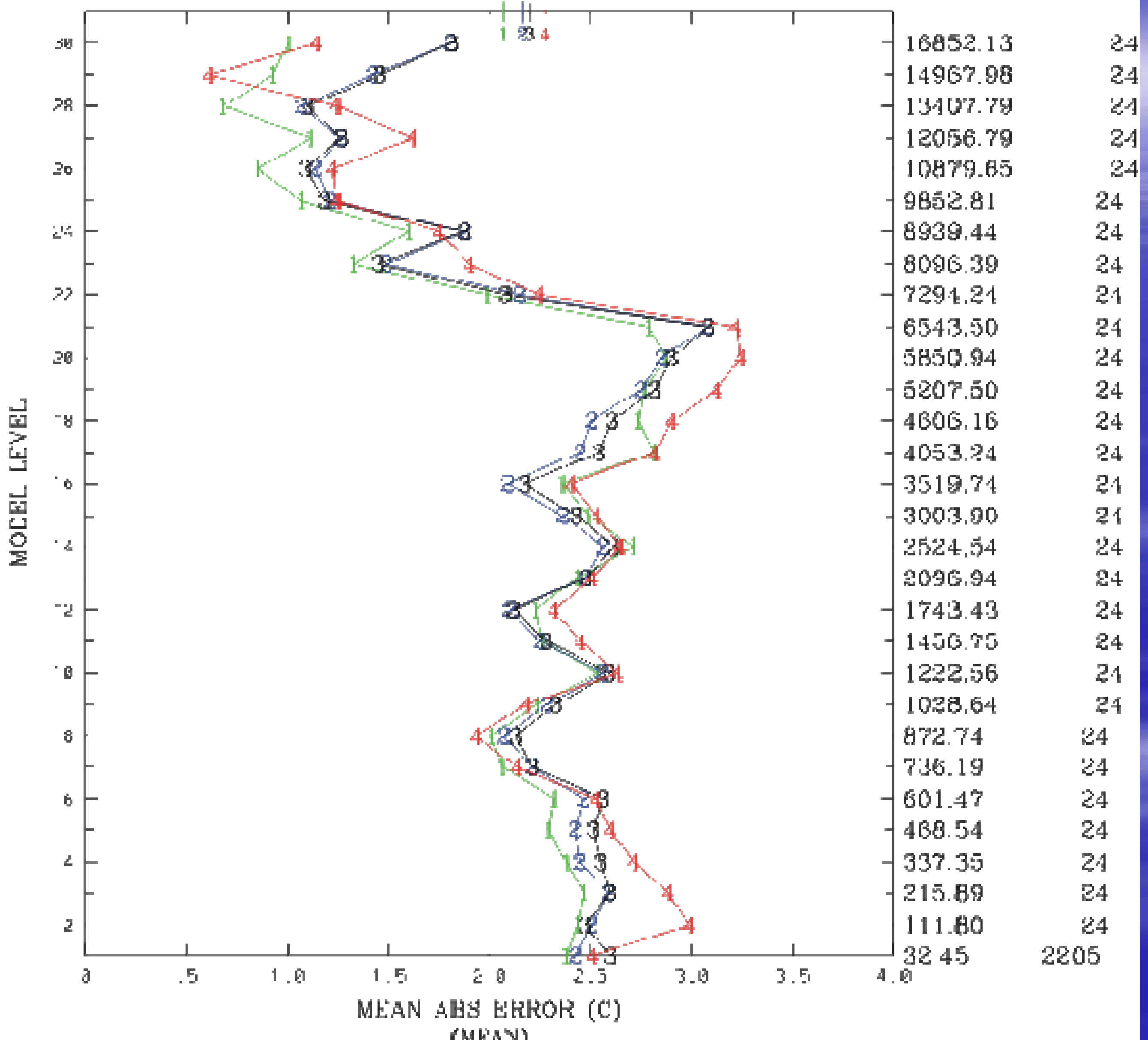

MEAN ABS ERROR OF VECTOR WIND DIFF (M/S)
PROFILE FOR 6 CASES TIME MEAN VALUE
DX 1.333km
MODEL HOUR RANGE= 0.0 - 24.0 h
MODEL LEVEL
MEAN ABS ERROR (M/S)
(MEAN)
5.7321
6.1723
6.1138
5.5433
1=MM5 ERRA
2=MM5 NOERRA
3=MM5 BASELINE
4=WRF BASELINE


MEAN ABS ERROR OF TEMP (C)
PROFILE FOR 6 CASES TIME MEAN VALUE
DX 1.333km
MODEL HOUR RANGE= 0.0 - 24.0 h
MODEL LEVEL
MEAN ABS ERROR (C)
(MEAN)
16852.13 24
14967.98 24
13407.79 24
12056.79 24
10879.65 24
9852.81 24
8939.44 24
8096.39 24
7294.24 24
6543.50 24
5850.94 24
5207.50 24
4606.16 24
4053.24 24
3519.74 24
3003.90 24
2524.54 24
2096.94 24
1743.43 24
1450.75 24
1222.56 24
1036.64 24
872.74 24
736.19 24
601.47 24
468.54 24
337.35 24
215.89 24
111.80 24
32.45 2205
1.1667
1.3485
1.3709
1.1629
1=MM5 EDDA
2=MM5 NOEDDA
3=MM5 BASELINE
4=WRF BASELINE



MEAN ABS ERROR OF VECTOR WIND DIFF (M/S)
PROFILE FOR 6 CASES TIME MEAN VALUE
DX 36km
MODEL HOUR RANGE= 0.0 - 24.0 h
MODEL LEVEL
MEAN ABS ERROR (M/S)
(MEAN)
6.0252
7.1780
7.1747
6.6696
1=MM5 FDDA
2=MM5 NOFDDA
3=MM5 BASELINE
4=WRF BASELINE

MEAN ABS ERROR OF TEMP (C)
PROFILE FOR 6 CASES TIME MEAN VALUE
DX 36km
MODEL HOUR RANGE= 0.0 – 24.0 h



Summary

- The 24-h forecasts at 36-km, 12-km, 4-km and 1.3-km resolutions - including the “running starts” necessary for accurate short-term forecasts - took less than 4 hours of wall clock time on our 42-CPU parallel computer…
- Our NWP system predicted the very localized mountain flows in and around the Olympics venues when large-scale weather conditions were weak, and also the complex interactions of the terrain with the larger scale weather-producing systems when stormy conditions prevailed…
- The NWP model was able to forecast many of the adverse weather conditions that postponed or cancelled some of the Olympics events

Summary (Cont.)

- Forecast results were generally improved using higher model grid resolutions. The statistical differences were relatively small between the 4-km and 1.3-km grids, although subjective analysis revealed greater mesoscale details using 1.3-km resolution.

- Results using 12-km model resolution were more similar to the finer grid results than the 36-km results.

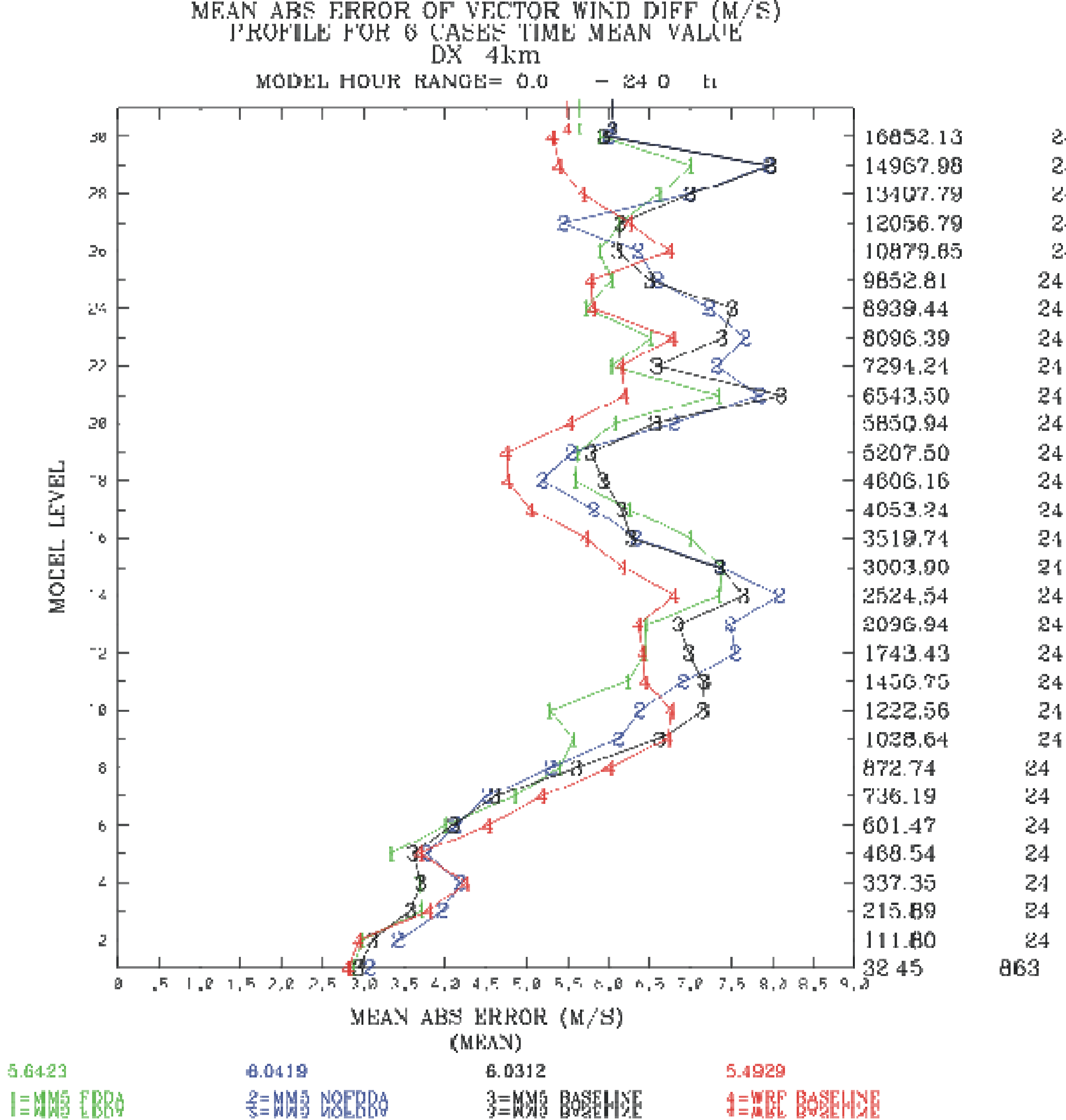
- Similar statistics between the finer resolution grids do not necessarily mean that the HPAC-predicted plumes would be similar. Higher resolution is needed to resolve complex terrain effects.

Summary (Cont.)

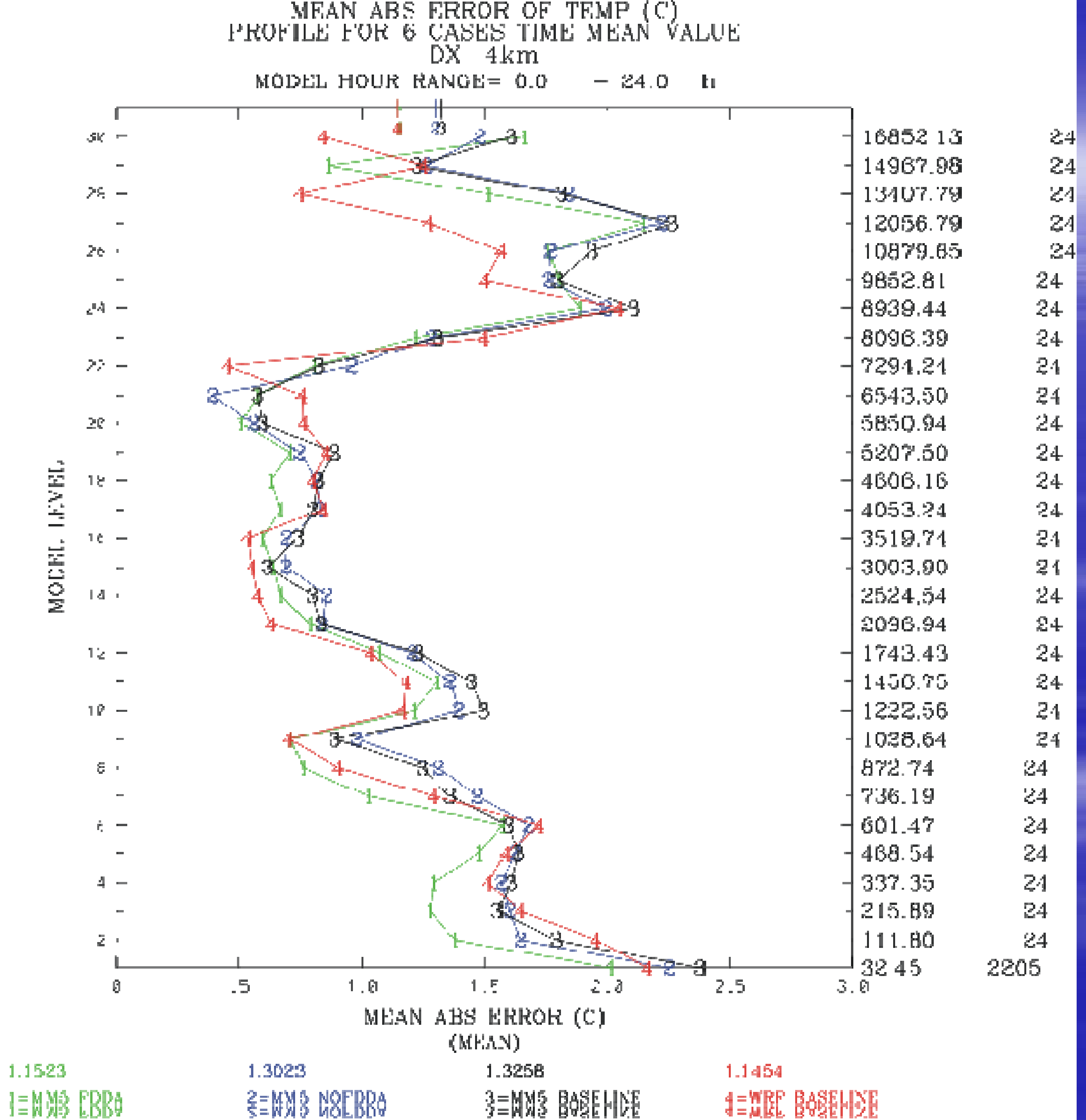
- Realtime model forecasts were produced every 12 hours throughout the Olympics period for DOD use (hazard prediction and consequence assessment), and also displayed interactively via the internet for general use.
- Running start FDDA (dynamic initialization) consistently produced lower statistical errors on average at all four grid resolutions, for the 24-h forecast period over the 1.3-km Olympics domain, for the six cases representing different weather conditions.
- FDDA created the largest improvements over all of the model experiments.
- MM5 and WRF baseline (no FDDA) results were generally very similar.

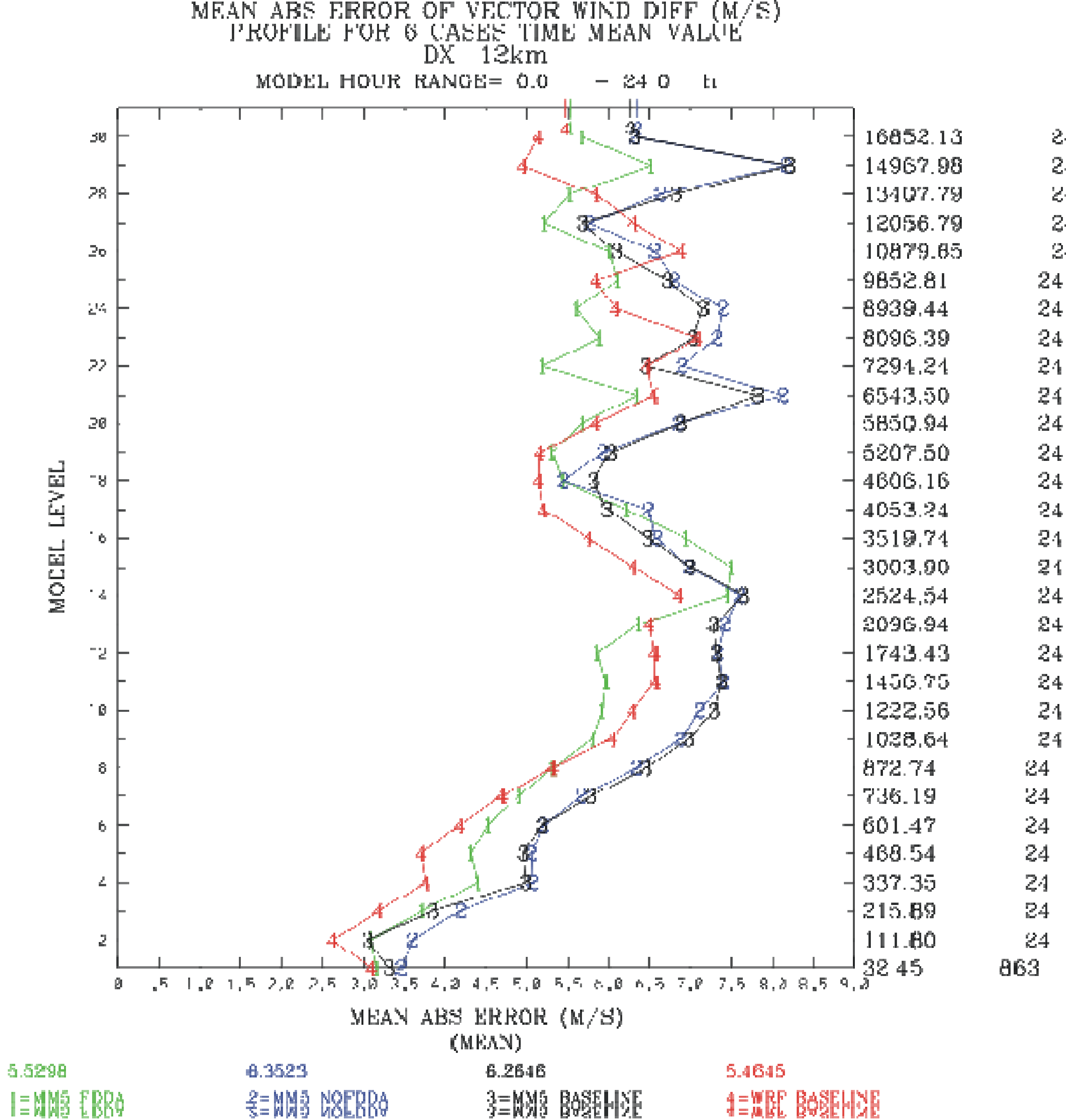
Questions

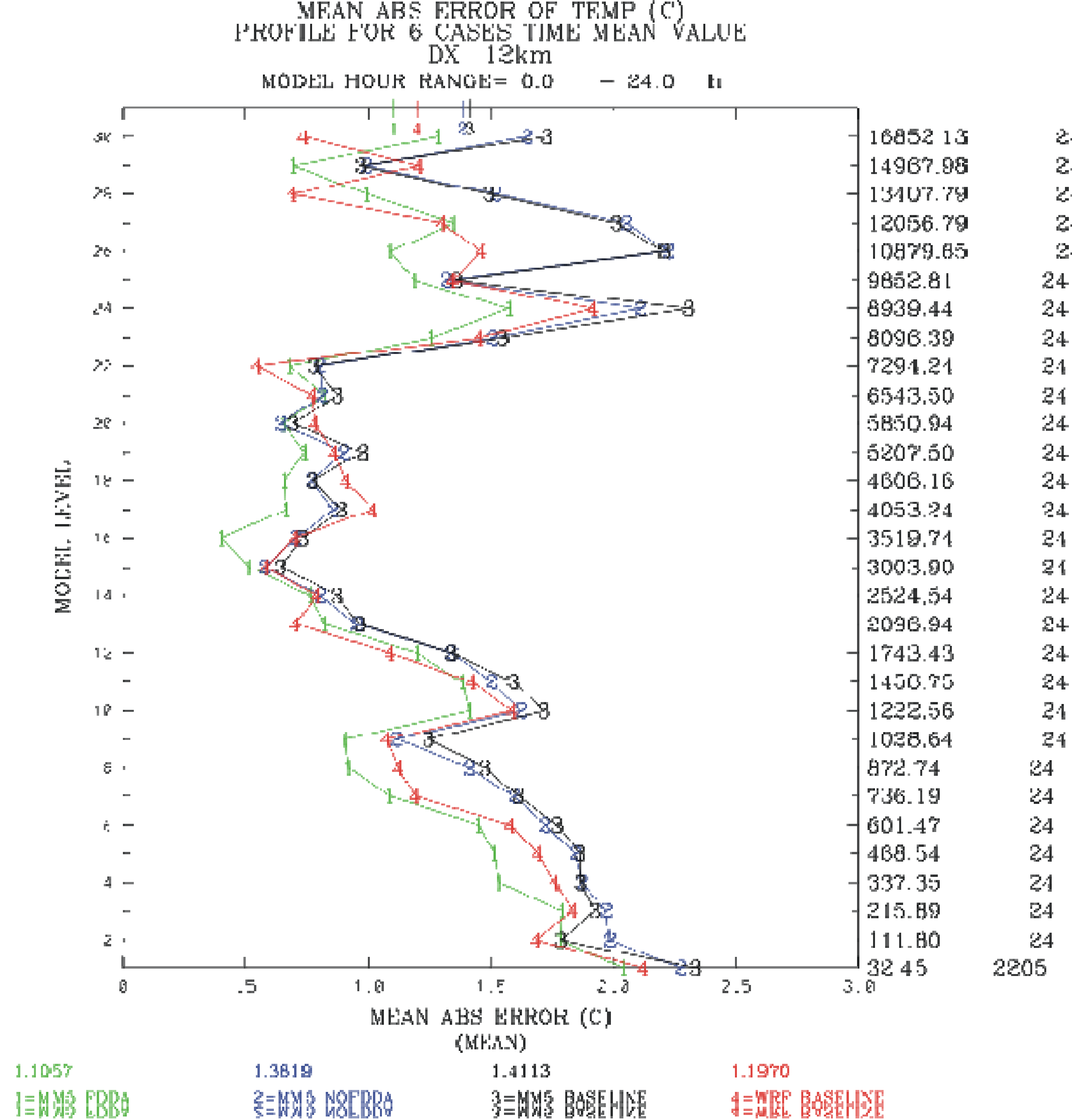
Supplementary Slides



MEAN ABS ERROR OF VECTOR WIND DIFF (M/S)
PROFILE FOR 6 CASES TIME MEAN VALUE
DX 4km
MODEL HOUR RANGE= 0.0 – 24.0 h
MODEL LEVEL
MEAN ABS ERROR (M/S)
(MEAN)
5.6423
6.0419
6.0312
5.4929
1=MM5 FDDA
2=MM5 NOFDDA
3=MM5 BASELINE
4=WRF BASELINE


MEAN ABS ERROR OF TEMP (C)
PROFILE FOR 6 CASES TIME MEAN VALUE
DX 4km
MODEL HOUR RANGE= 0.0 - 24.0 h
MODEL LEVEL
MEAN ABS ERROR (C)
(MEAN)
0 .5 1.0 1.5 2.0 2.5 3.0
16852.13 24
14967.96 24
13407.79 24
12056.79 24
10879.65 24
9852.81 24
8939.44 24
8096.39 24
7294.24 24
6543.50 24
5850.94 24
5207.50 24
4606.16 24
4053.24 24
3519.74 24
3003.90 24
2524.54 24
2096.94 24
1743.43 24
1450.75 24
1222.56 24
1036.64 24
872.74 24
736.19 24
601.47 24
468.54 24
337.35 24
215.89 24
111.80 24
32.45 2205
1.1523
1.3023
1.3258
1.1454
1=MM5 EDDA
2=MM5 NOEDDA
3=MM5 BASELINE
4=WRF BASELINE


MEAN ABS ERROR OF VECTOR WIND DIFF (M/S)
PROFILE FOR 6 CASES TIME MEAN VALUE
DX 12km
MODEL HOUR RANGE= 0.0 - 24.0 h
MODEL LEVEL
MEAN ABS ERROR (M/S)
(MEAN)
16852.13 24
14967.98 24
13407.79 24
12056.79 24
10879.65 24
9852.81 24
8939.44 24
8096.39 24
7294.24 24
6543.50 24
5850.94 24
5207.50 24
4606.16 24
4053.24 24
3519.74 24
3003.90 24
2524.54 24
2096.94 24
1743.43 24
1456.75 24
1222.56 24
1028.64 24
872.74 24
736.19 24
601.47 24
468.54 24
337.35 24
215.89 24
111.80 24
32.45 863
5.5298
6.3523
6.2646
5.4645
1=MM5 FDDA
2=MM5 NOFDDA
3=MM5 BASELINE
4=WRF BASELINE


MEAN ABS ERROR OF TEMP (C)
PROFILE FOR 6 CASES TIME MEAN VALUE
DX 12km
MODEL HOUR RANGE= 0.0 - 24.0 h
MODEL LEVEL
MEAN ABS ERROR (C)
(MEAN)
16852.13
14967.98
13407.79
12056.79
10879.65
9852.81
8939.44
8096.39
7294.21
6543.50
5850.94
5207.50
4606.16
4053.24
3519.71
3003.90
2524.54
2096.94
1743.43
1450.75
1222.56
1036.64
872.74
736.19
601.47
468.54
337.35
215.89
111.80
32.45
2205
1.1057
1.3819
1.4113
1.1970
1=MM5 FDDA
2=MM5 NOFDDA
3=MM5 BASELINE
4=WRF BASELINE