A Comparison of High-Resolution Mesoscale Simulations using MM5 and WRF-ARW for the 2006 Winter Olympics

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Objectives

- Run MM5 and WRF-ARW for six case periods during the Winter Olympics using similar configurations
- Perform a statistical analysis on the finest domain (1.333-km resolution)
- Perform a subjective analysis of model results from both models

Case Descriptions

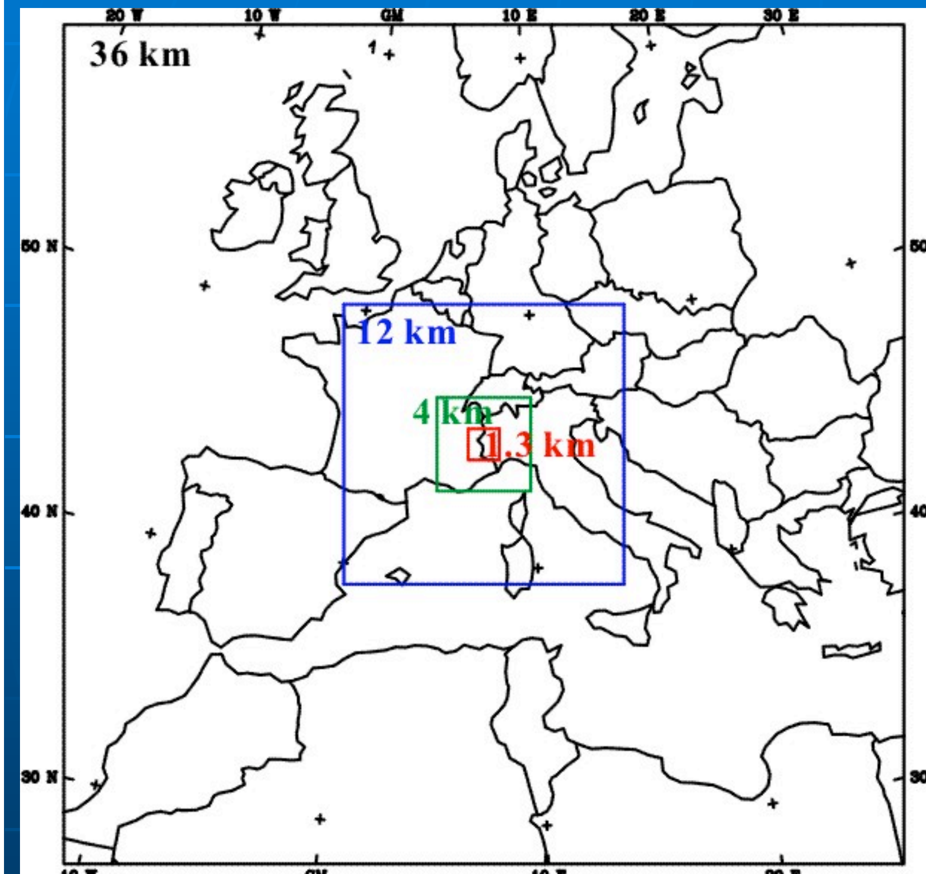
Case 1	00 UTC, 13 Feb 2006 - 00 UTC, 14 Feb 2006	Dry
Case 2	12 UTC, 17 Feb 2006 – 12 UTC, 18 Feb 2006	Precip/Wind in Mountains
Case 3	00 UTC, 18 Feb 2006 – 00 UTC, 19 Feb 2006	Precip in Mountains
Case 4	12 UTC, 19 Feb 2006 – 12 UTC, 20 Feb 2006	Precip in Mountains and on Plains
Case 5	00 UTC, 22 Feb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

MM5 and WRF Experimental Design

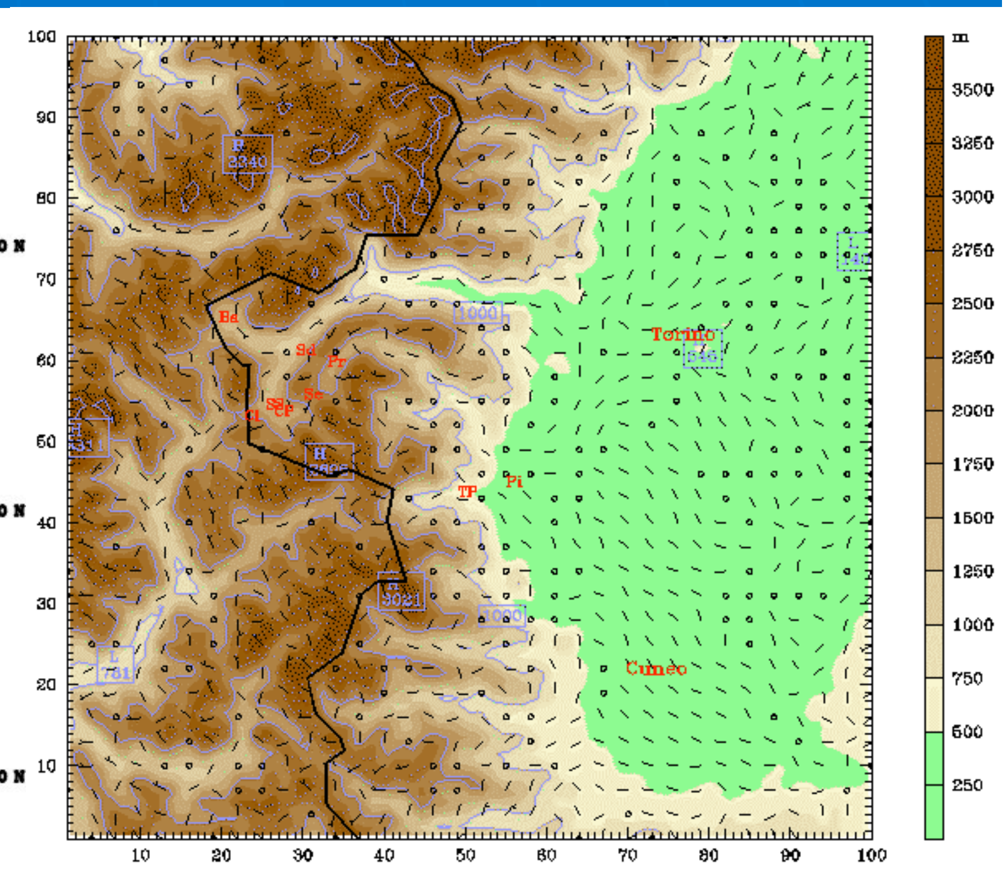
Exp. Name	PBL Physics	Microphysics	CPS (36/12 km)	Radiation	Dynamic Initialization
Realtime MM5	GS TKE	Simple Ice	KF2	LW: RRTM SW: Dudhia	DI
MM5 BASELINE	M-Y Eta TKE PBL	Simple Ice	KF2	LW: RRTM SW: Dudhia	None
WRF BASELINE	M-Y-J Eta TKE PBL	WSM 3-class simple ice scheme	KF2	LW: RRTM SW: Dudhia	None

Starting: -12h Ending: +24h

Domain Configuration & Terrain



Four one-way nested domains using ndown steps

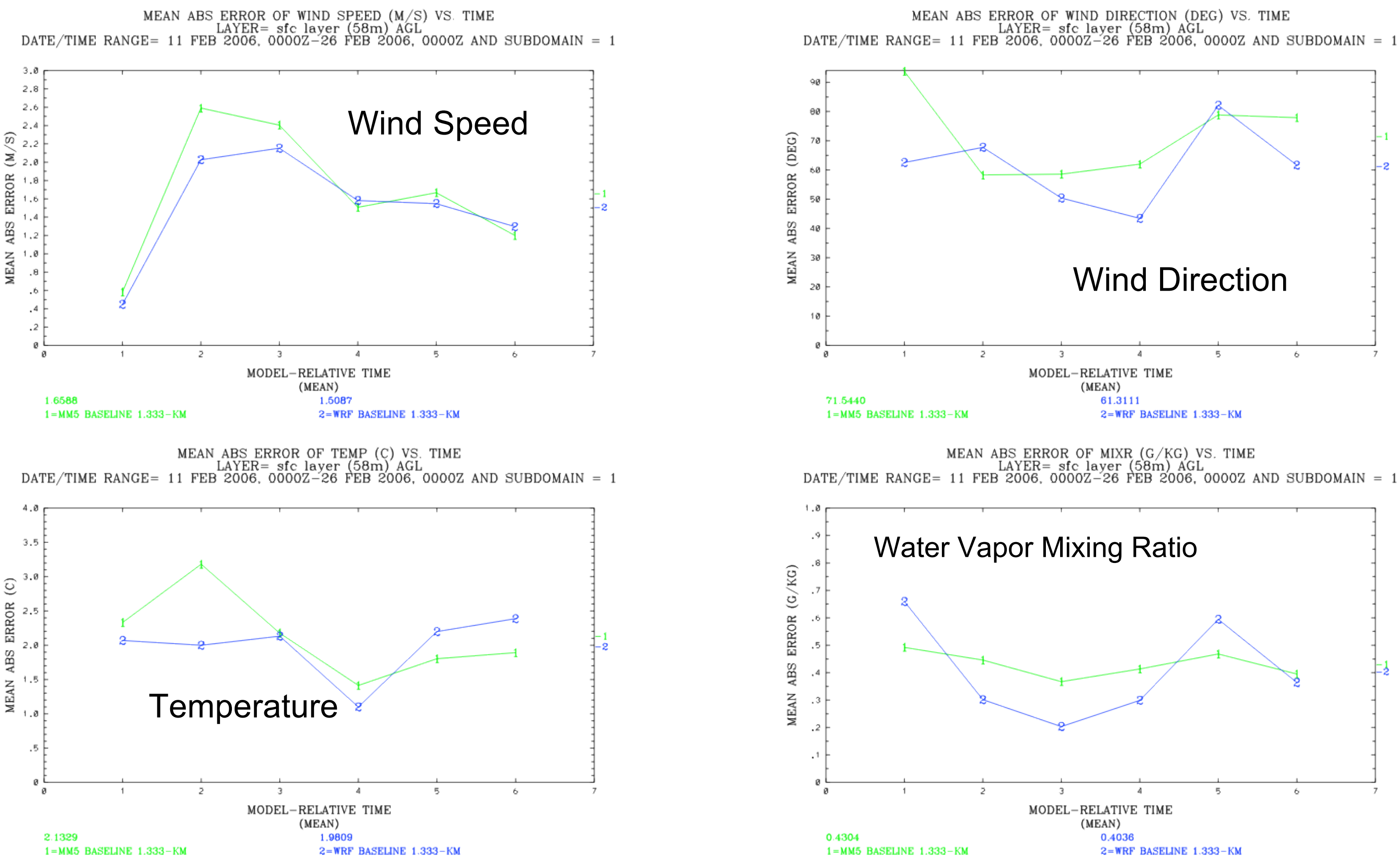


1.333-km domain terrain

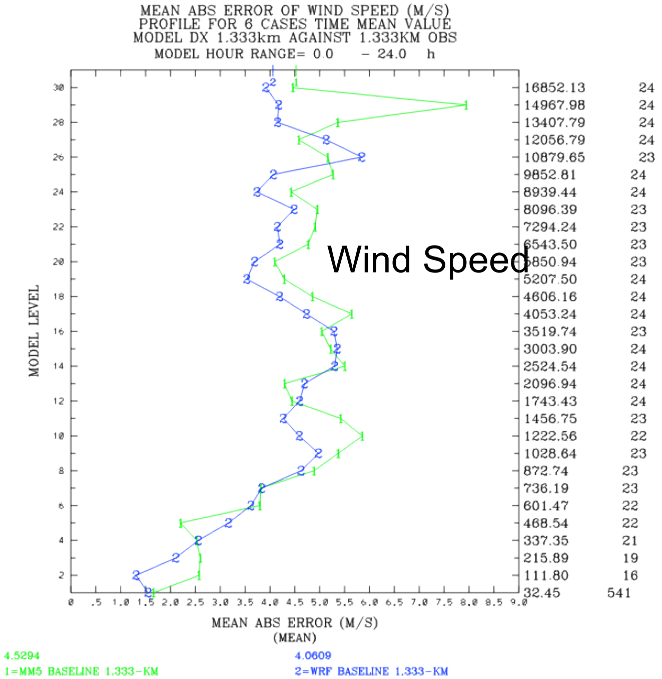
Statistical Evaluation

- Mean Absolute Error (MAE) calculated for wind speed, direction, temperature and mixing ratio on the 1.333-km domain
- Time series statistics
  - Individual case averages
  - Average of all six cases
- Vertical profile statistics
  - All vertical levels
  - Six-case average

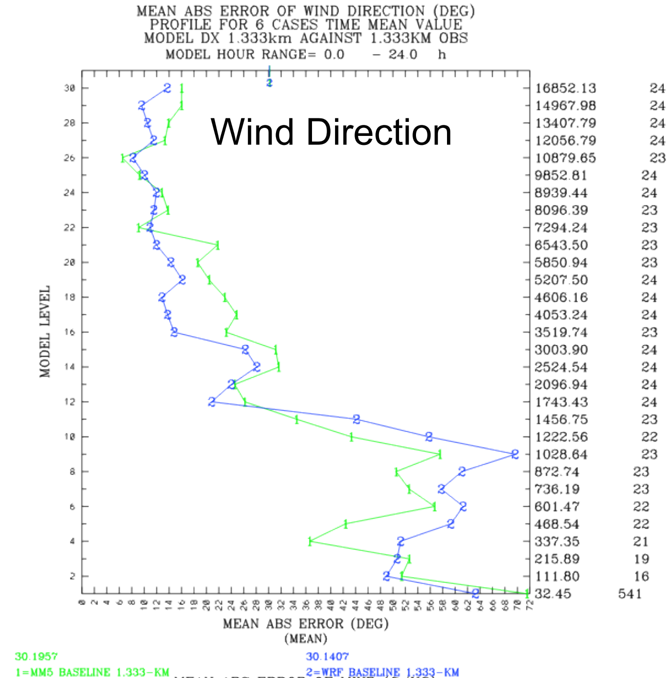
1.333-km Grid Surface-Layer MAE



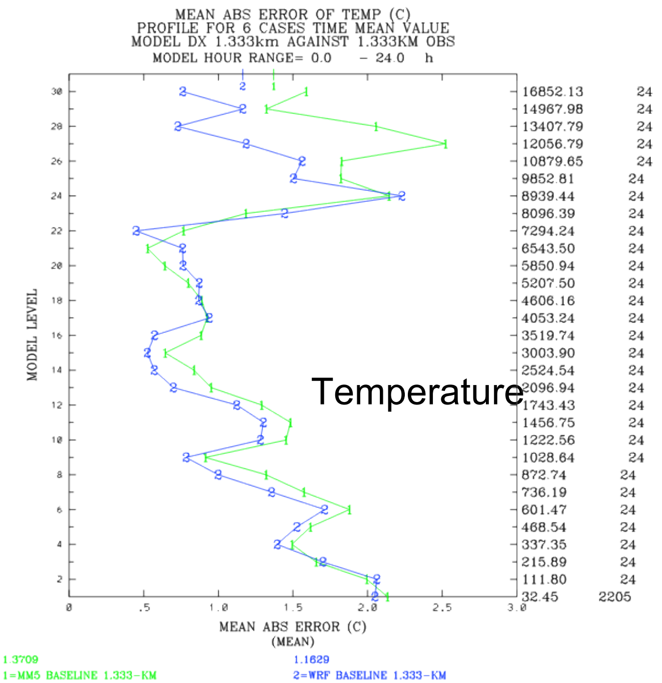
MAE
1.333-km



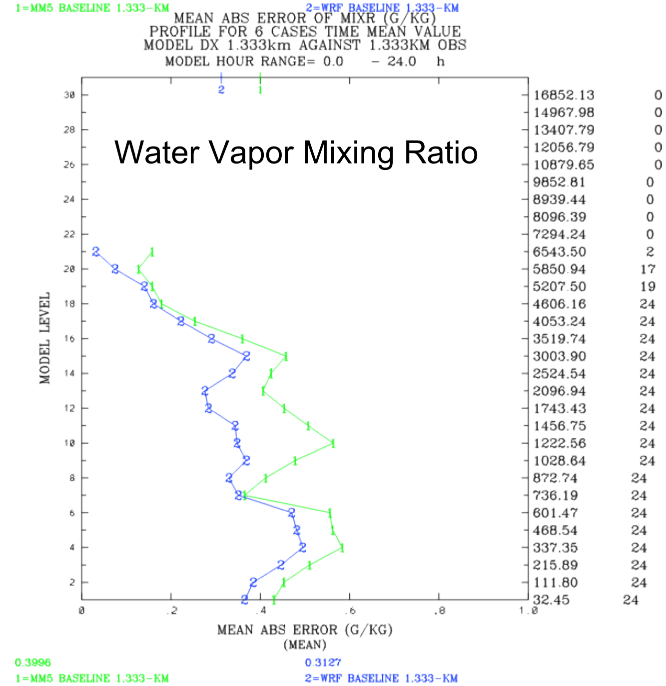
MEAN ABS ERROR OF WIND SPEED (M/S)
PROFILE FOR 6 CASES TIME MEAN VALUE
MODEL DX 1.333km AGAINST 1.333KM OBS
MODEL HOUR RANGE= 0.0 - 24.0 h
Wind Speed
MODEL LEVEL
MEAN ABS ERROR (M/S)
(MEAN)
4.5294
1=MM5 BASELINE 1.333-KM
4.0609
2=WRF BASELINE 1.333-KM



MEAN ABS ERROR OF WIND DIRECTION (DEG)
PROFILE FOR 6 CASES TIME MEAN VALUE
MODEL DX 1.333km AGAINST 1.333KM OBS
MODEL HOUR RANGE= 0.0 - 24.0 h
Wind Direction
MODEL LEVEL
MEAN ABS ERROR (DEG)
(MEAN)
30.1957
1=MM5 BASELINE 1.333-KM
30.1407
2=WRF BASELINE 1.333-KM



MEAN ABS ERROR OF TEMP (C)
PROFILE FOR 6 CASES TIME MEAN VALUE
MODEL DX 1.333km AGAINST 1.333KM OBS
MODEL HOUR RANGE= 0.0 - 24.0 h
Temperature
MODEL LEVEL
MEAN ABS ERROR (C)
(MEAN)
1.3709
1=MM5 BASELINE 1.333-KM
1.1629
2=WRF BASELINE 1.333-KM



MEAN ABS ERROR OF MIXR (G/KG)
PROFILE FOR 6 CASES TIME MEAN VALUE
MODEL DX 1.333km AGAINST 1.333KM OBS
MODEL HOUR RANGE= 0.0 - 24.0 h
Water Vapor Mixing Ratio
MODEL LEVEL
MEAN ABS ERROR (G/KG)
(MEAN)
0.3996
1=MM5 BASELINE 1.333-KM
0.3127
2=WRF BASELINE 1.333-KM

Statistical Results

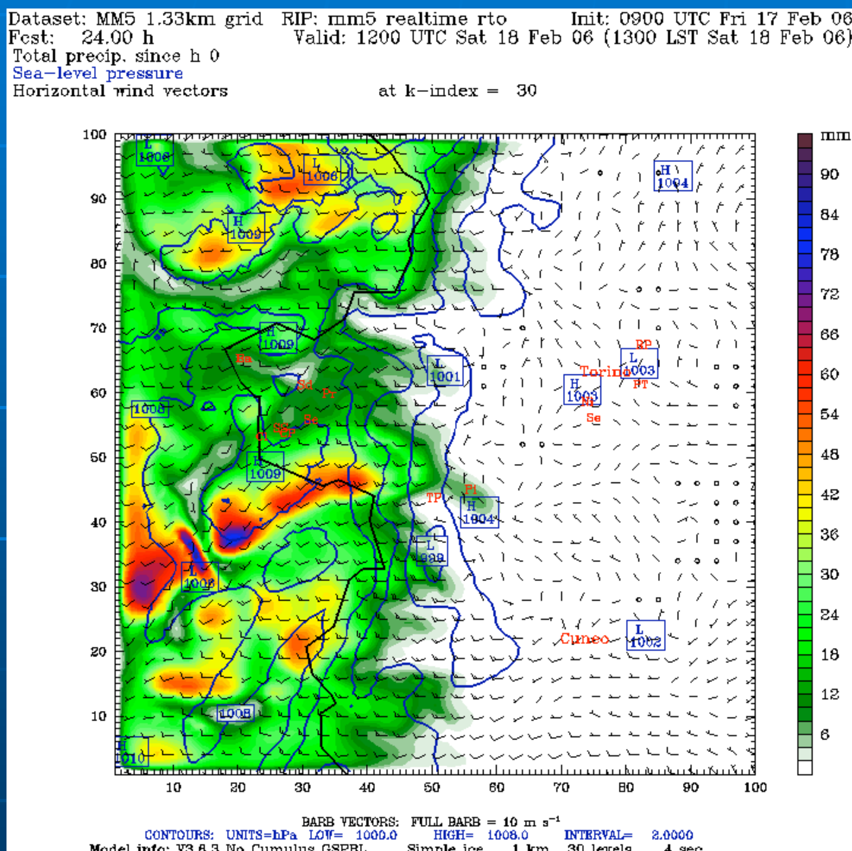
- Six-case average stats show:
  - WRF-ARW has a slight statistical advantage over MM5 at the surface on the 1.333-km domain (significance not tested)
  - WRF-ARW also has a slight statistical advantage in the vertical, especially for mixing ratio.
- Case by case, neither model has a distinct advantage for all variables

Subjective Comparisons

- MM5 vs WRF-ARW
  - WRF consistently has less spatial precipitation coverage
  - WRF has unrealistic spikes in precipitation amounts along the lateral boundaries that do not exist in MM5 (occurs when using one-way nests with ndown steps)
- WRF-ARW v2.1 vs. WRF-ARW v2.2
  - More pronounced boundary noise in v2.2

Case 2
12UTC 17 Feb - 12UTC 18 Feb
Precip/Wind in Mountains

Realtime MM5 OBS



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Data observed in the single venues: last update on 18/02/2006 at 15:00 local time

Venues	Sky	Temp.(°C)	Umidity (%)	Wind (m/s)	Total Precipitations (mm)	Last 24h new snow (cm)	Web Cam
Pinerolo palaghiaccio		8.4	70	NNE 1.80	-	-	
Cesana San Sicario		1.1	64	SSW 2.30	-	5	
Sauze d'Oulx-Jovenceaux		3.0	79	SSW 2.30	-	3	
Pragelato		2.6	60	WSW 1.70	-	1	
Sestriere Borgata		2.2	51	S 2.90	-	2	
Sestriere Colle		0.7	44	W 5.70	-	3	
Cesana Pariol		2.7	61	SSW 2.30	-	5	
Torino esposizioni		5.0	91	N 1.90	-	-	
Bardonecchia		4.4	41	WSW 2.90	-	9	
Pragelato Plan		2.0	62	NNW 1.20	-	1	
San Sicario Fraiteve		-0.8	68	W 5.10	-	6	
View of the Italian side from the French border							

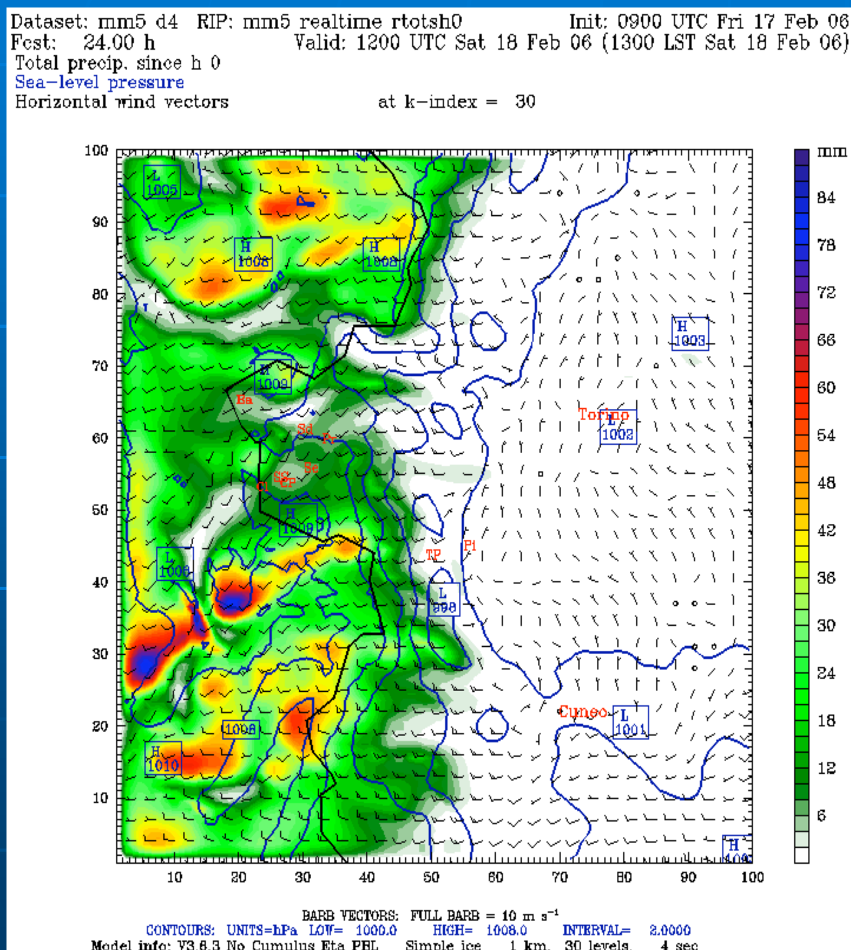
24-h Total Precip

Case 2

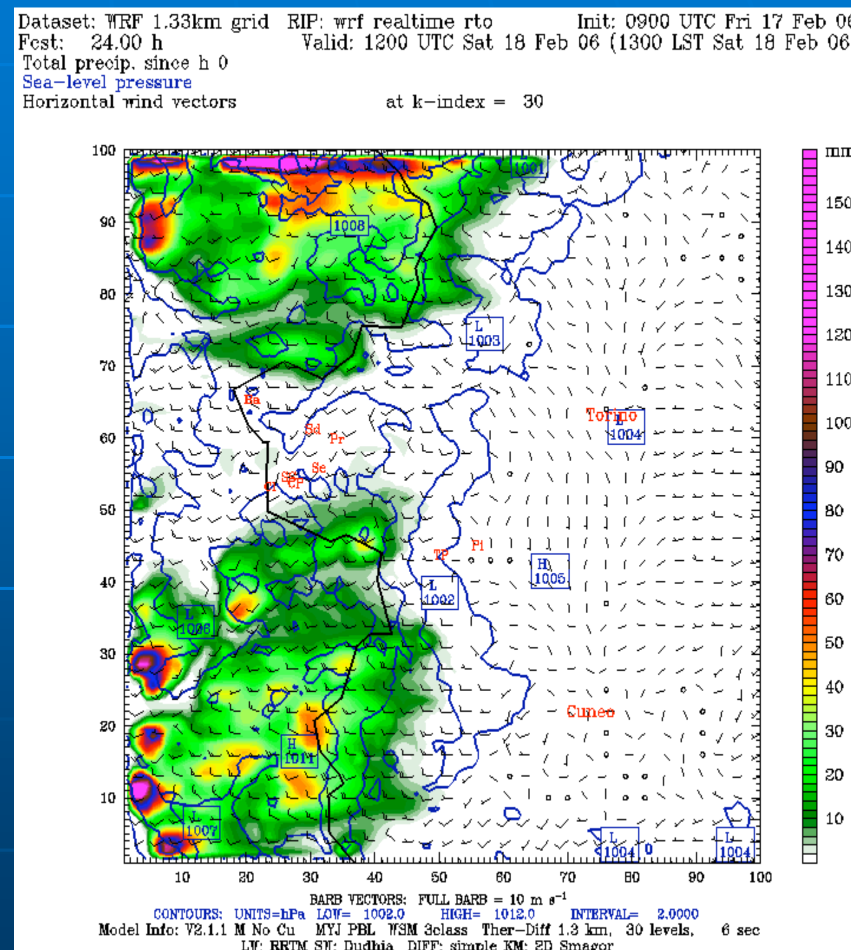
12UTC 17 Feb - 12UTC 18 Feb

Precip/Wind in Mountains

MM5



WRF2.1



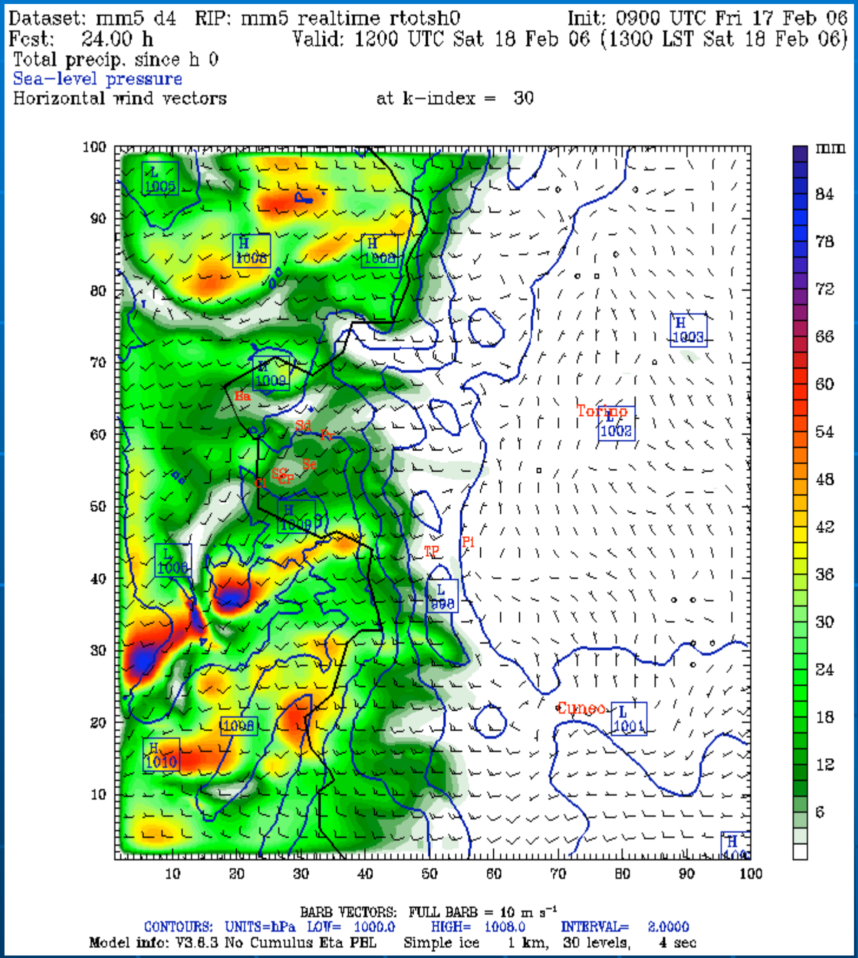
24-h Total Precip

Case 2

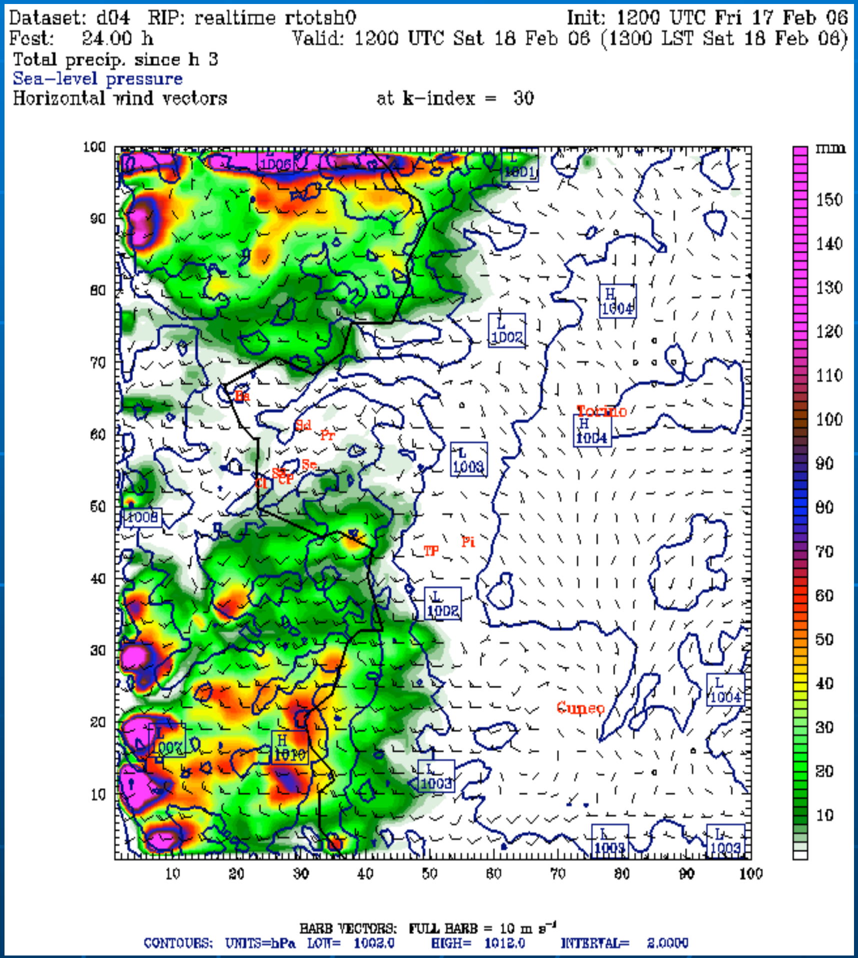
12UTC 17 Feb - 12UTC 18 Feb

Precip/Wind in Mountains

MM5



WRF2.2



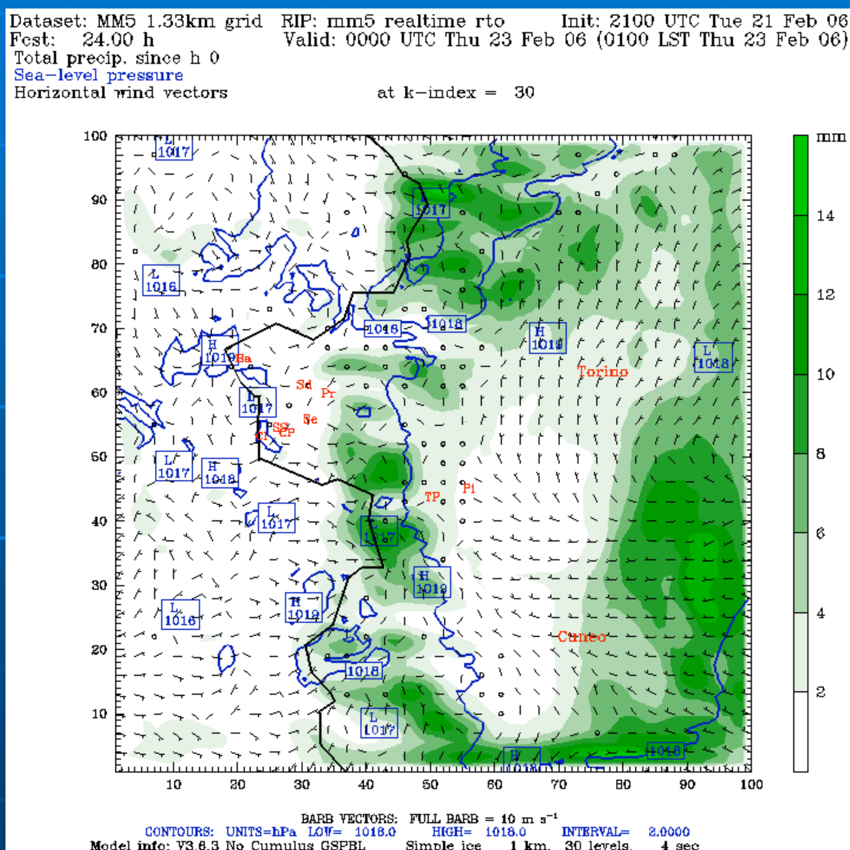
24-h Total Precip

Case 5

00UTC 22 Feb - 00UTC 23 Feb

Precip on Plains

Realtime MM5 | OBS



Weather data belong to Arpa Piemonte. Use allowed mentioning the source.

Data observed in the single venues: last update on 23/02/2006 at 02:00 local time

Venues	Sky	Temp.(°C)	Umidity (%)	Wind (m/s)	Total Precipitations (mm)	Last 24h new snow (cm)	Web Cam
Pinerolo palaghiaccio		3.7	92	N 1.00	-	-	
Cesana San Sicario		-5.0	85	SW 1.60	-	-	
Sauze d'Oulx-Jovenceaux		-1.9	100	SW 1.60	-	-	
Pragelato		-3.4	87	SE 0.40	-	-	
Sestriere Borgata		-5.5	79	SSE 0.70	-	-	
Sestriere Colle		-7.0	84	NE 1.40	-	1	
Cesana Pariol		-5.8	99	SW 1.60	-	-	
Torino esposizioni		5.1	84	S 0.30	-	-	
Bardonecchia		-4.2	79	SSW 0.70	-	-	
Pragelato Plan		-4.2	99	SE 0.70	-	-	
San Sicario Fraiteve		-6.7	85	ENE 2.90	-	1	

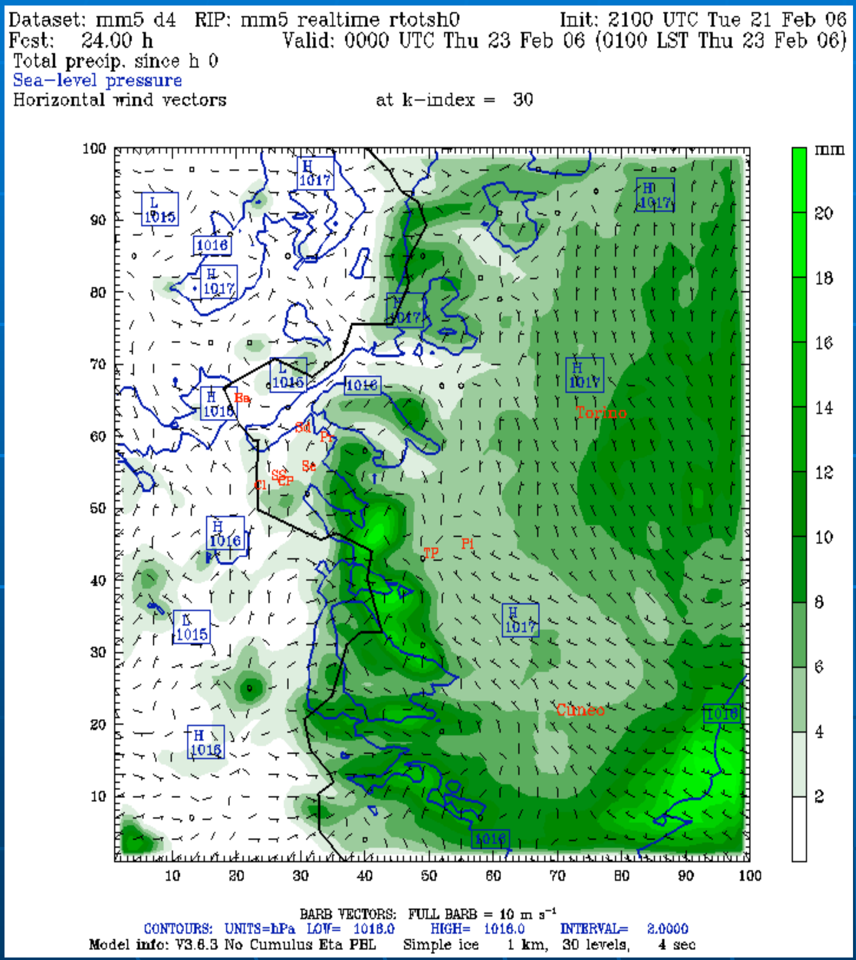
View of the Italian side from the French border

Pinerolo palaghiaccio

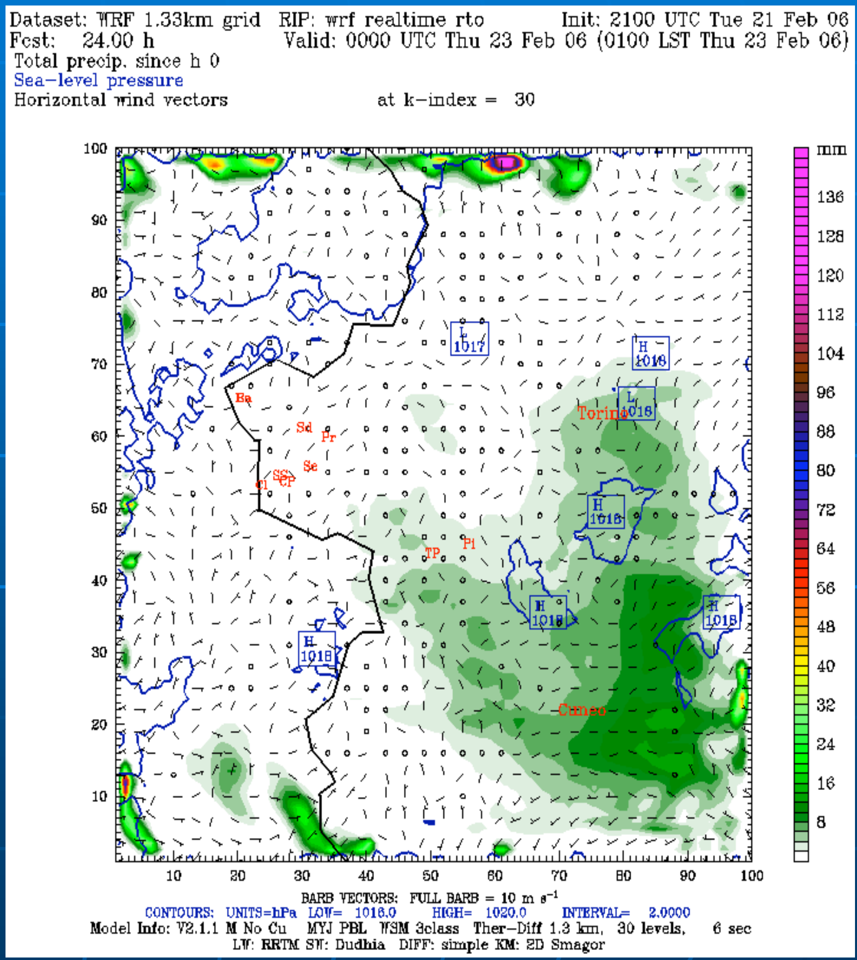
24-h Total Precip

Case 5
00UTC 22 Feb - 00UTC 23 Feb
Precip on Plains

MM5



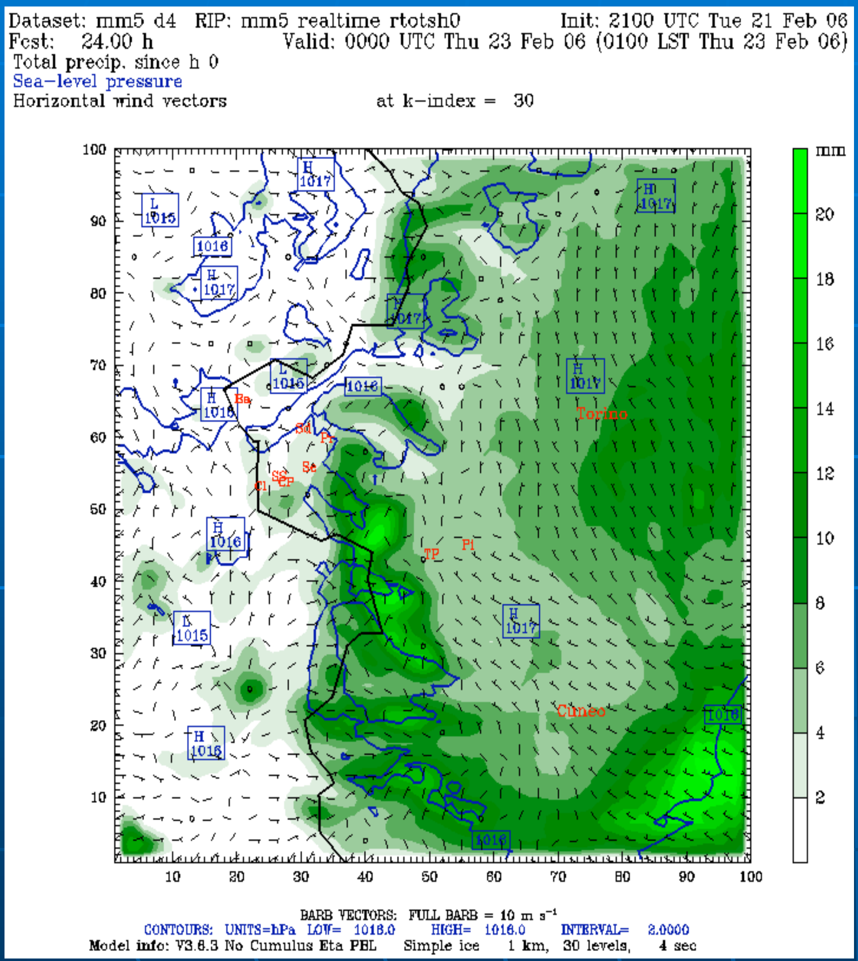
WRF2.1



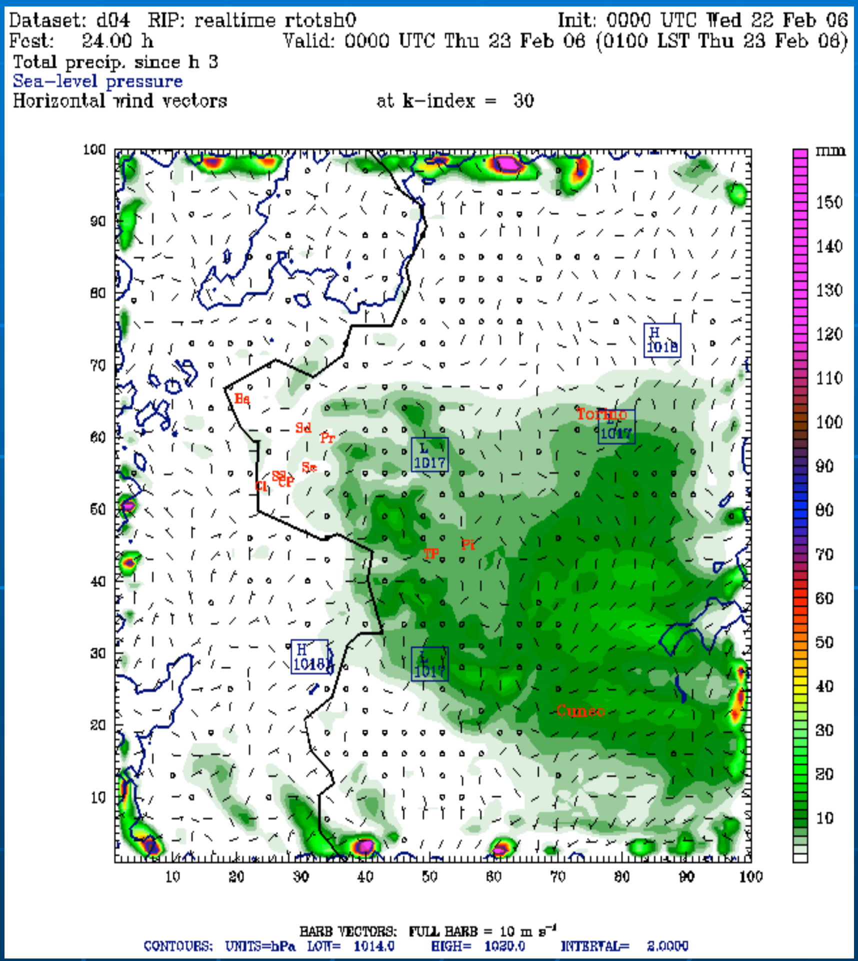
24-h Total Precip

Case 5
00UTC 22 Feb - 00UTC 23 Feb
Precip on Plains

MM5



WRF2.2



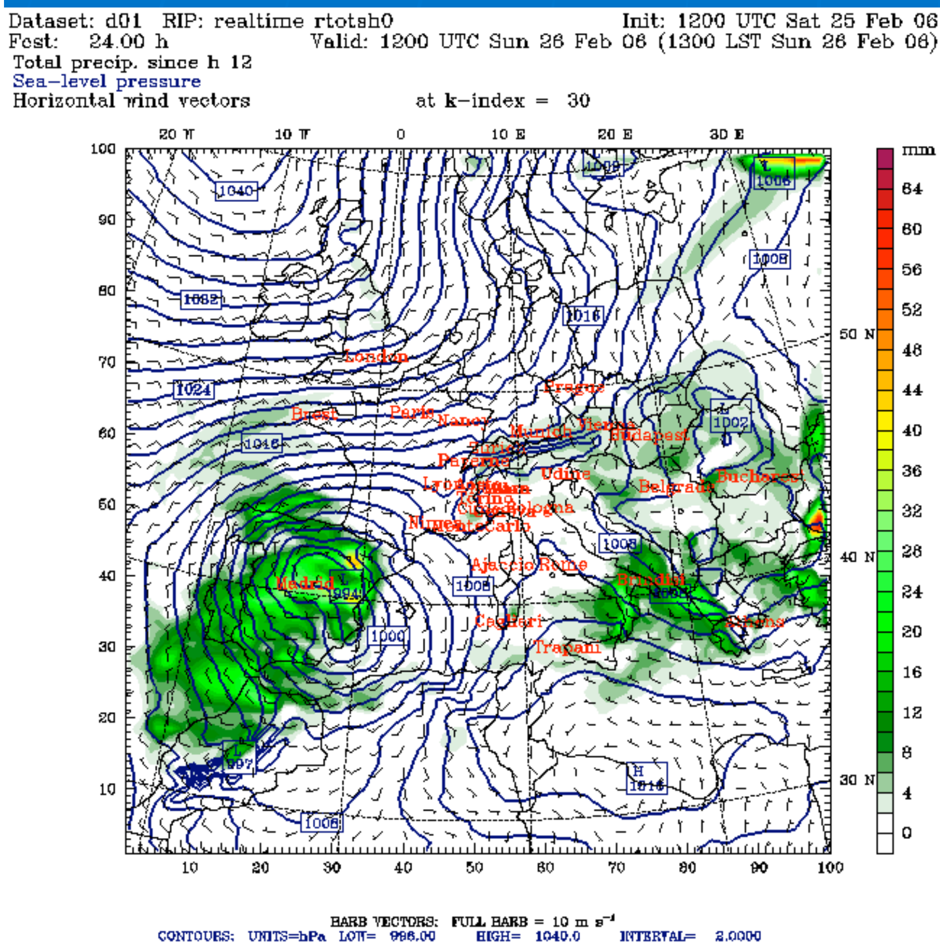
24-h Total Precip

Why does this noise exist?

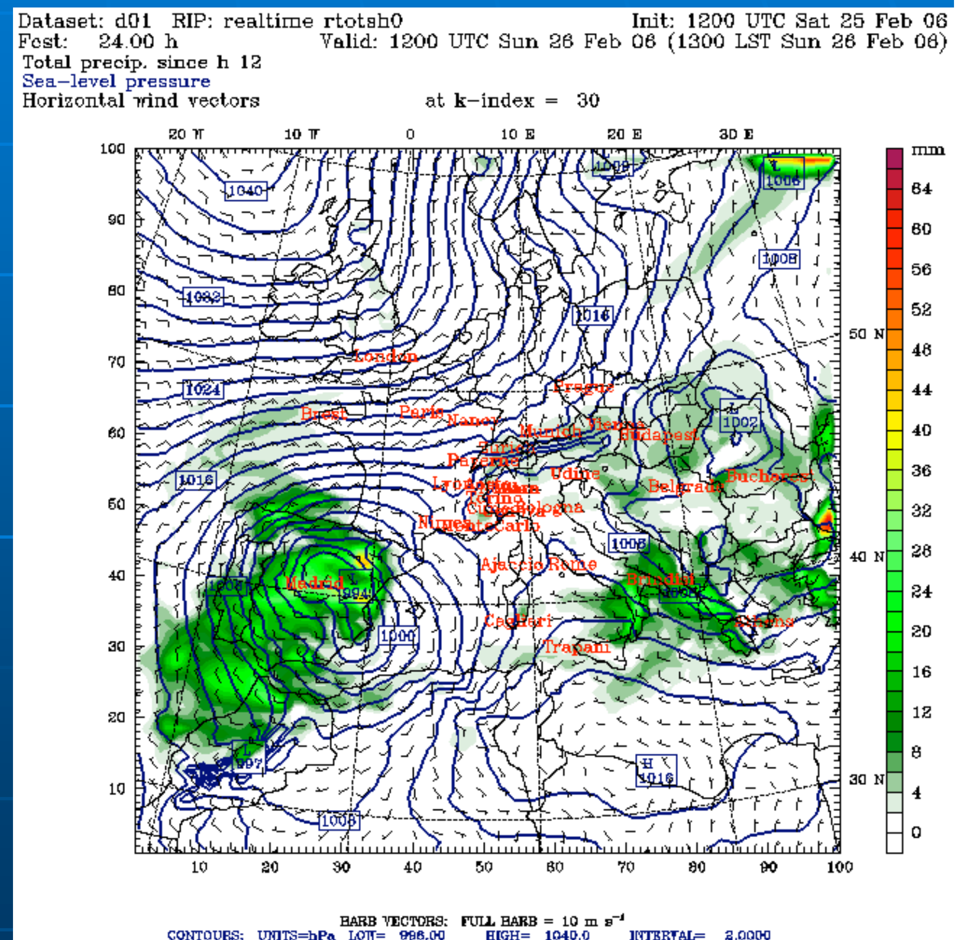
- Tests were performed with Case 6 to isolate the problem
  - Run all four domains with ndown
  - Run all four domains in the same job (with no feedback)

36-km Grid

without ndown

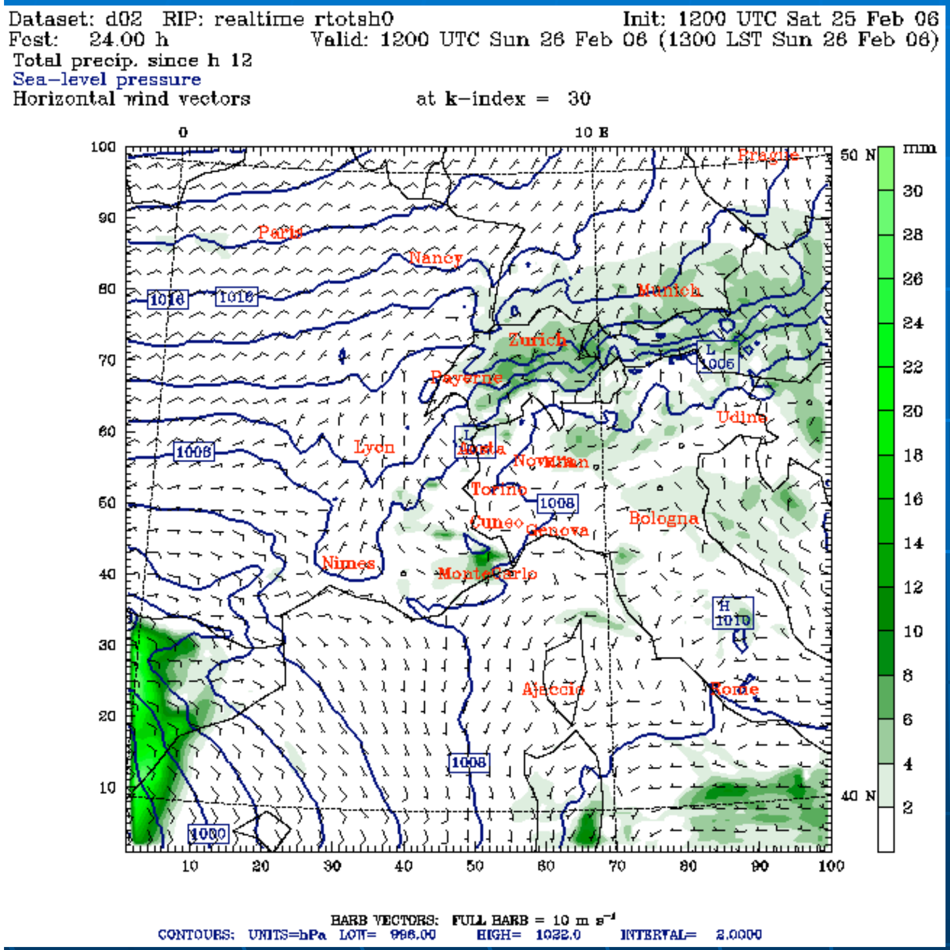


with ndown

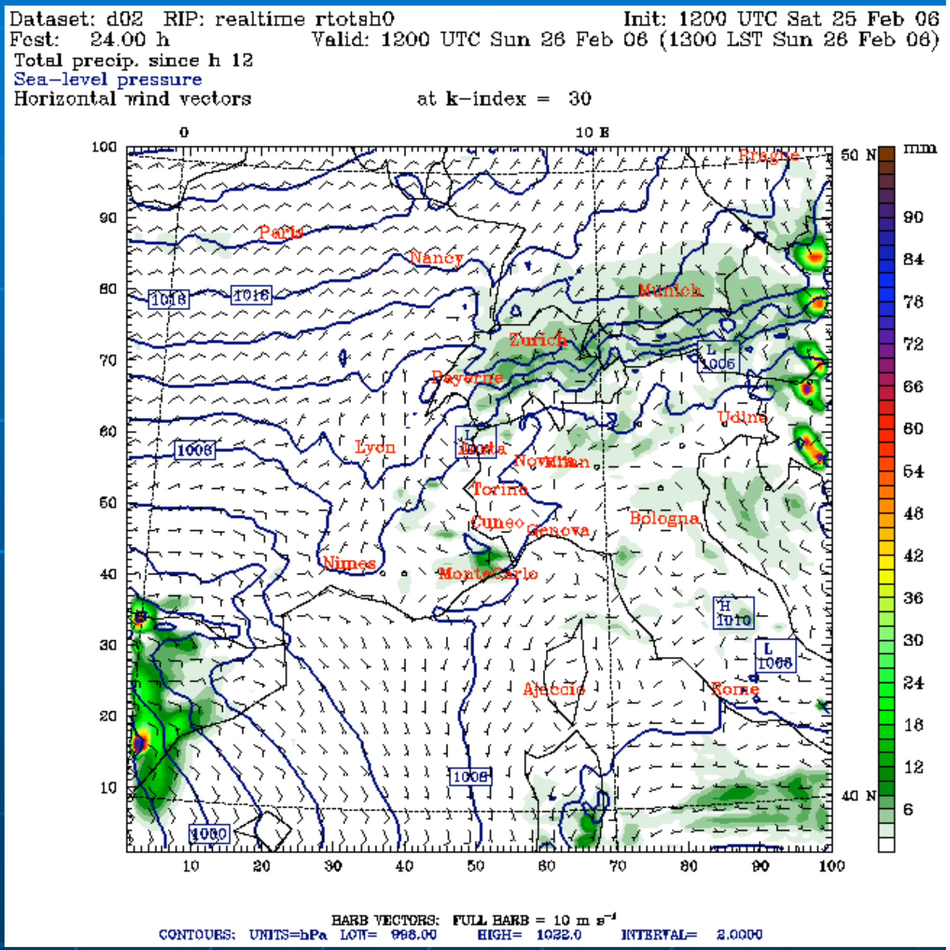


12-km Grid

without ndown

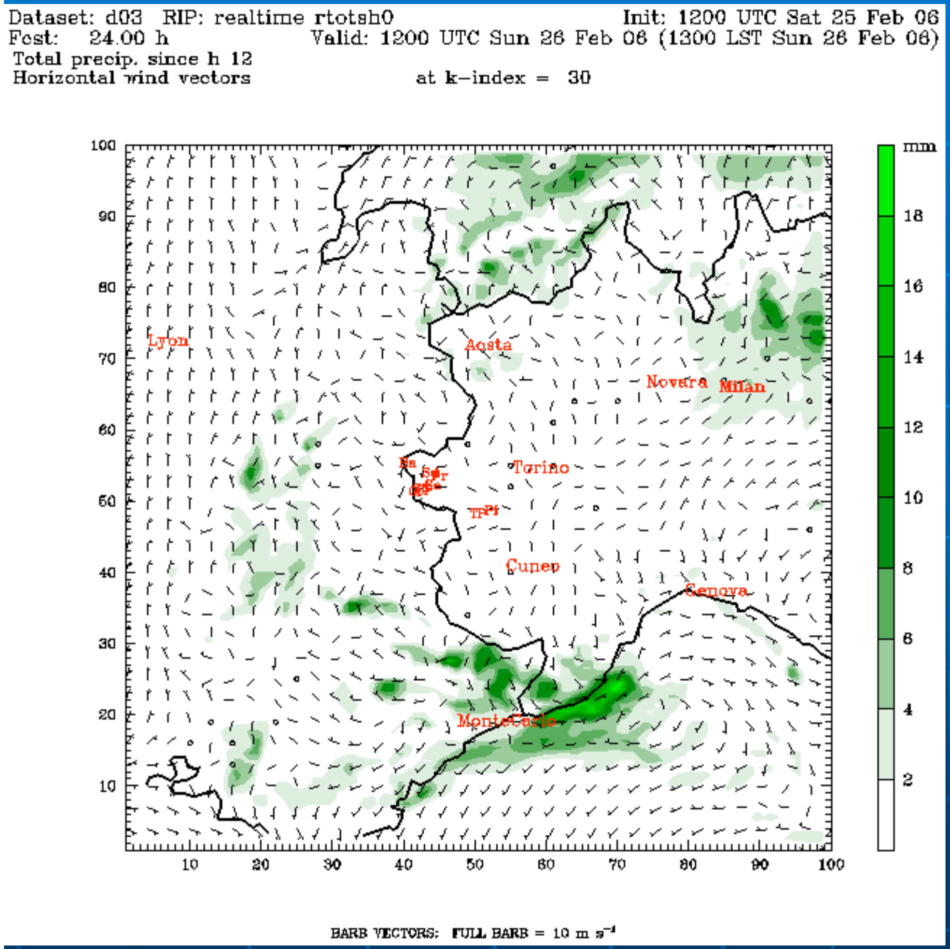


with ndown

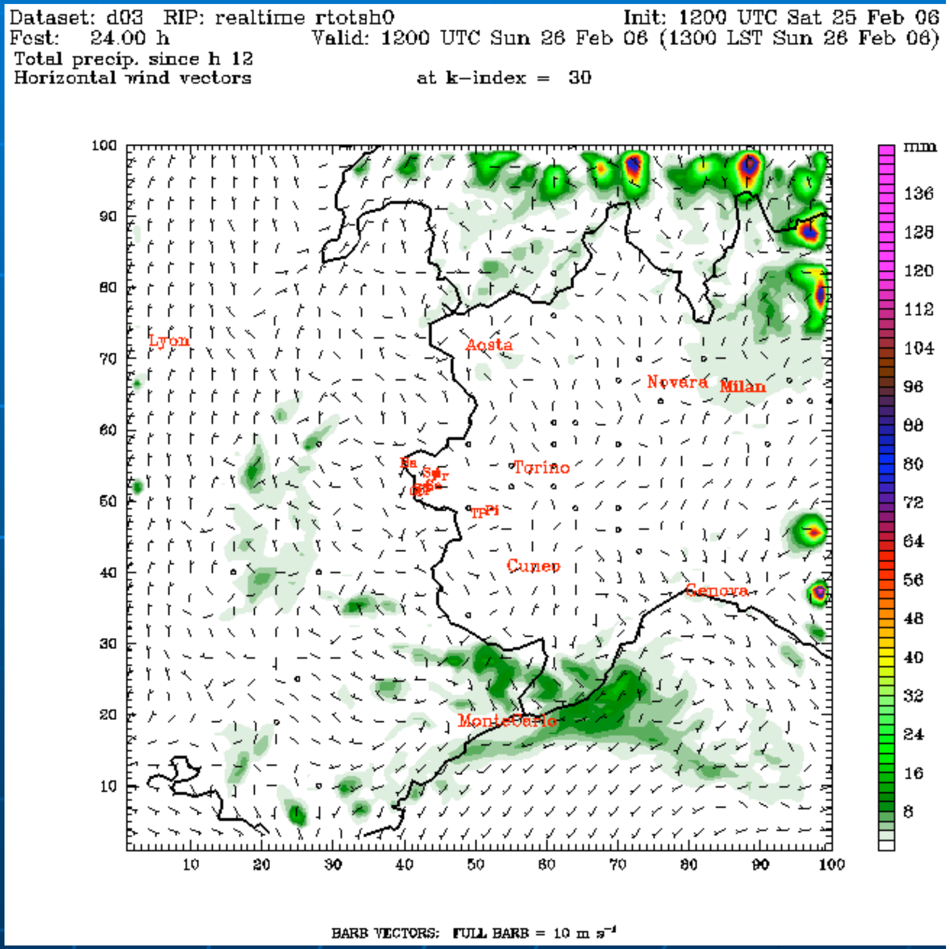


4-km Grid

without ndown

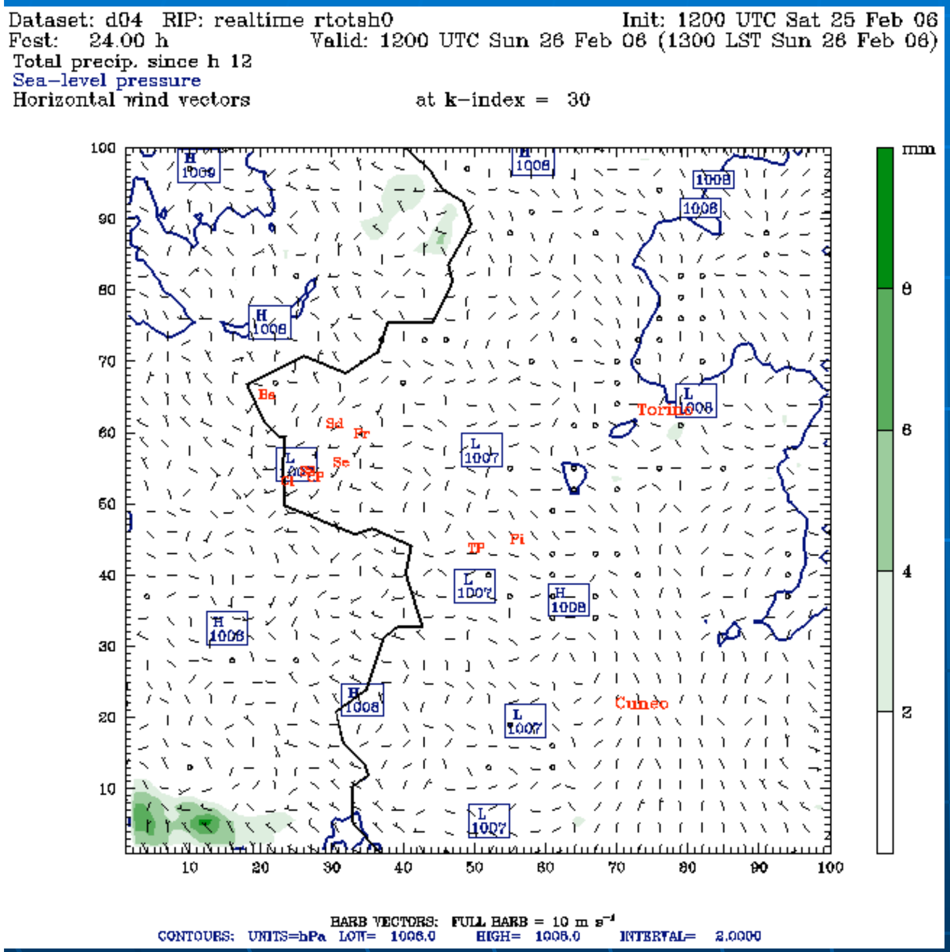


with ndown

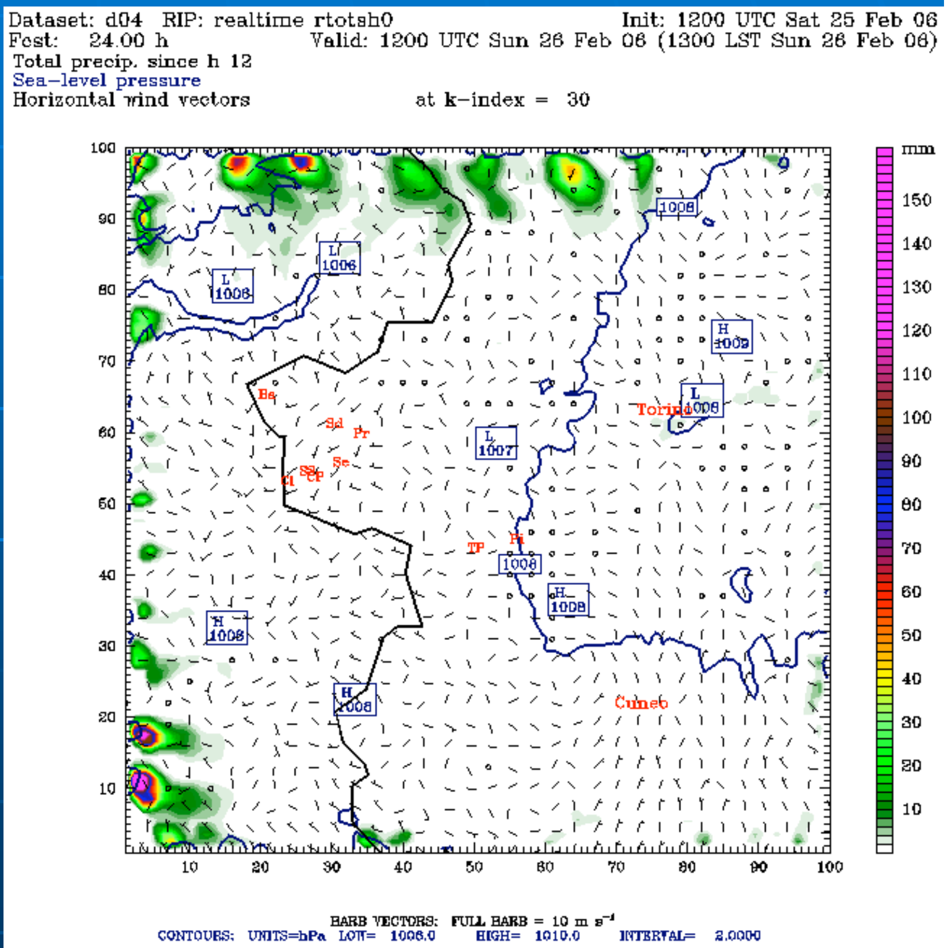


1.33-km Grid

without ndown



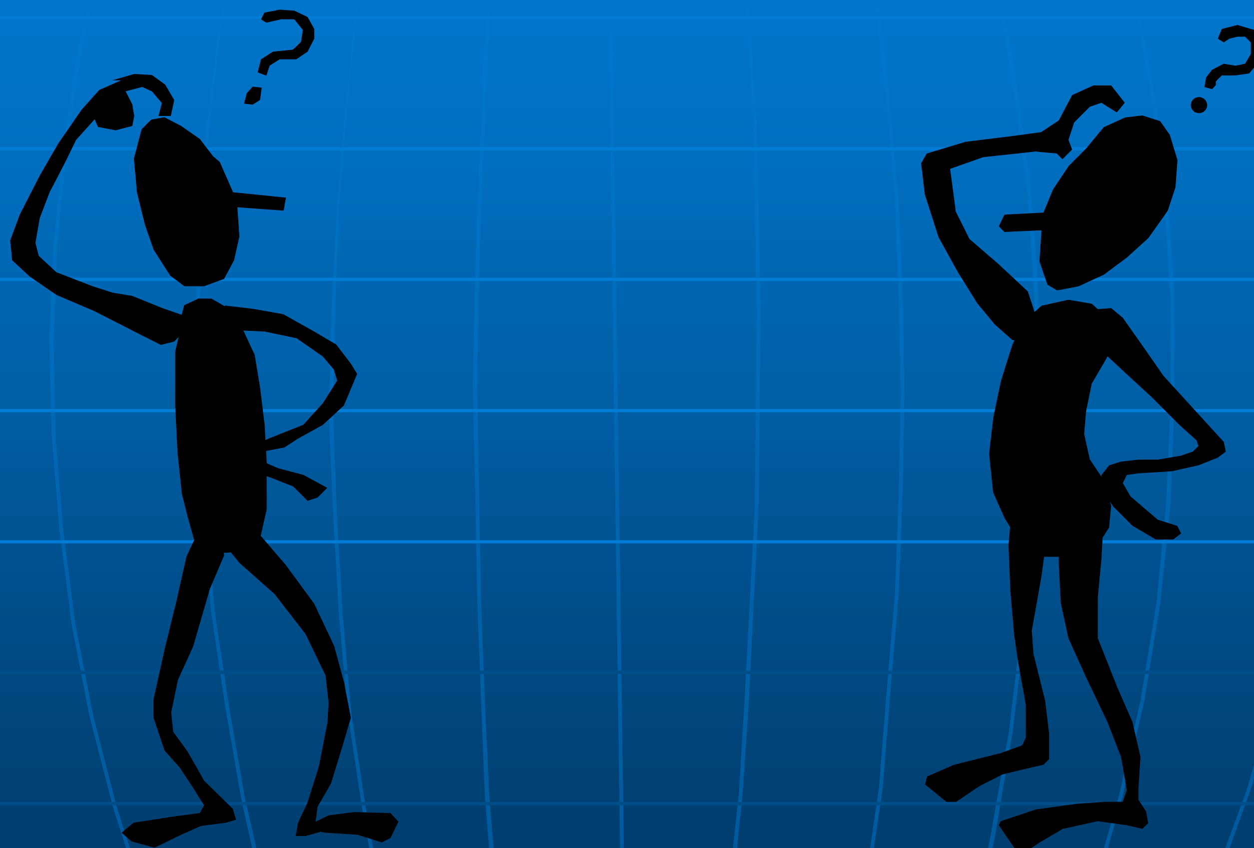
with ndown



Conclusions

- Statistics show that WRF-ARW has a slight advantage over MM5 averaged over all six cases
  - Note: Statistics are calculated well within the domain, away from the lateral boundary noise
- In general, WRF-ARW predicts less spatial coverage of precipitation than MM5
  - Is this due to mass conservation within the domain?
- Subjective analysis shows noise in the precipitation field around the lateral boundaries
  - This is only a problem with one-way nests using ndown steps
  - This problem is known, and is being investigated by NCAR

Questions



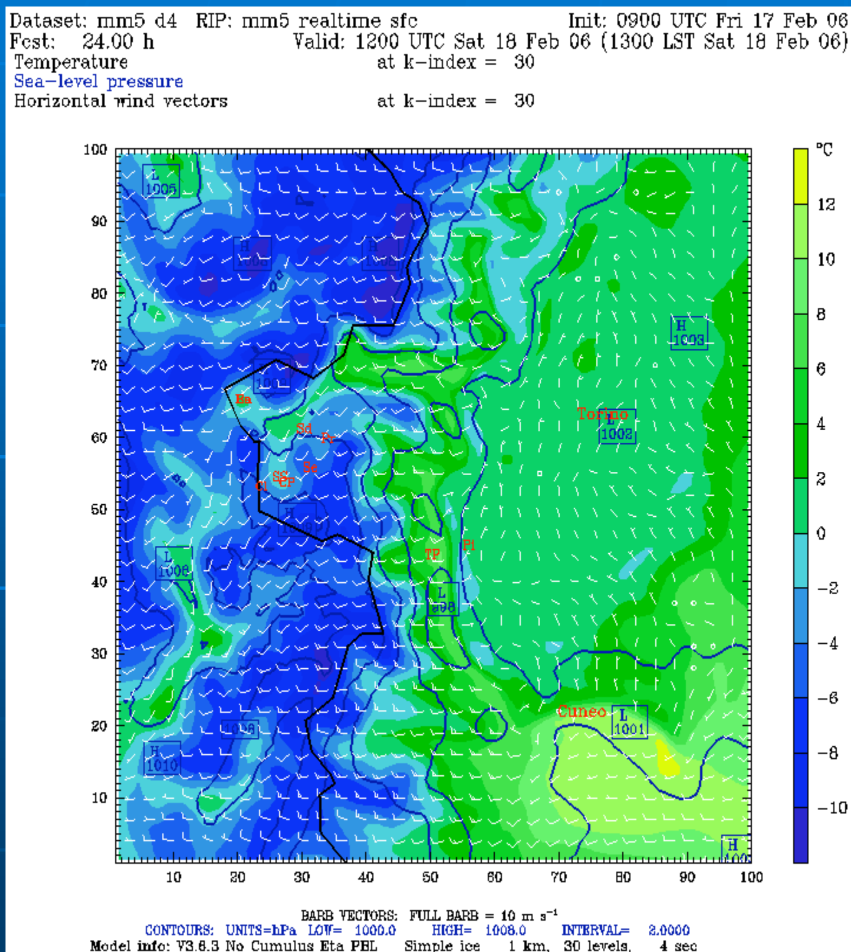
Supplemental Slides

Case 2

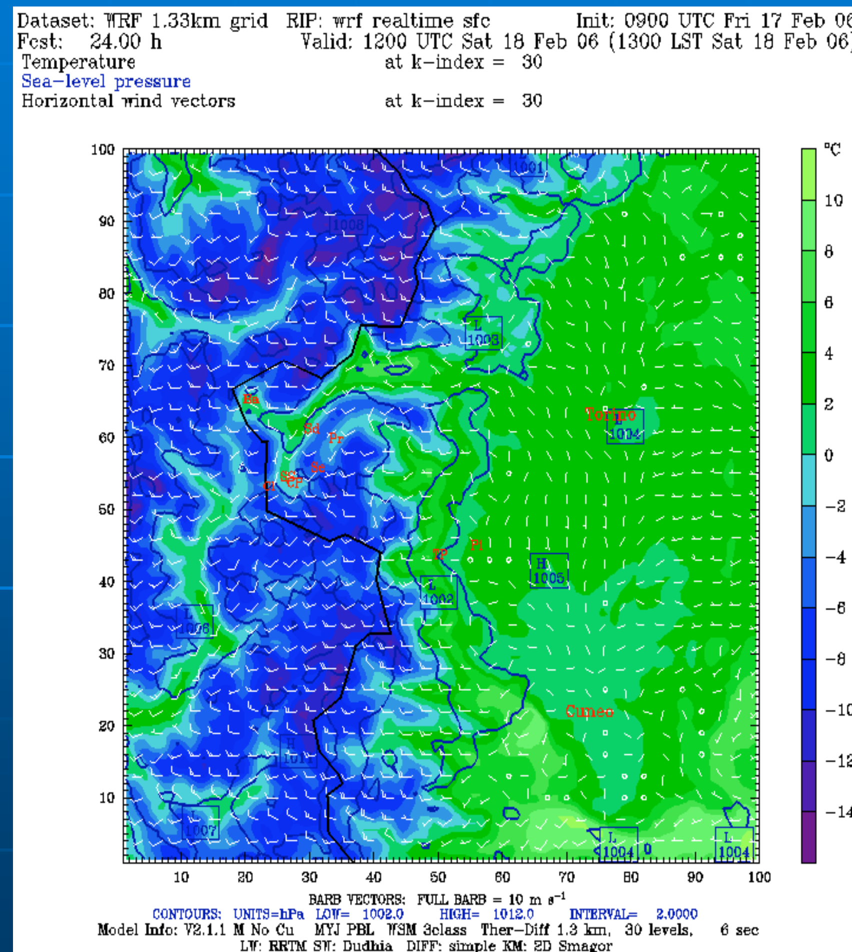
12UTC 17 Feb - 12UTC 18 Feb

Precip/Wind in Mountains

MM5



WRF2.1



Surface Layer Temperature

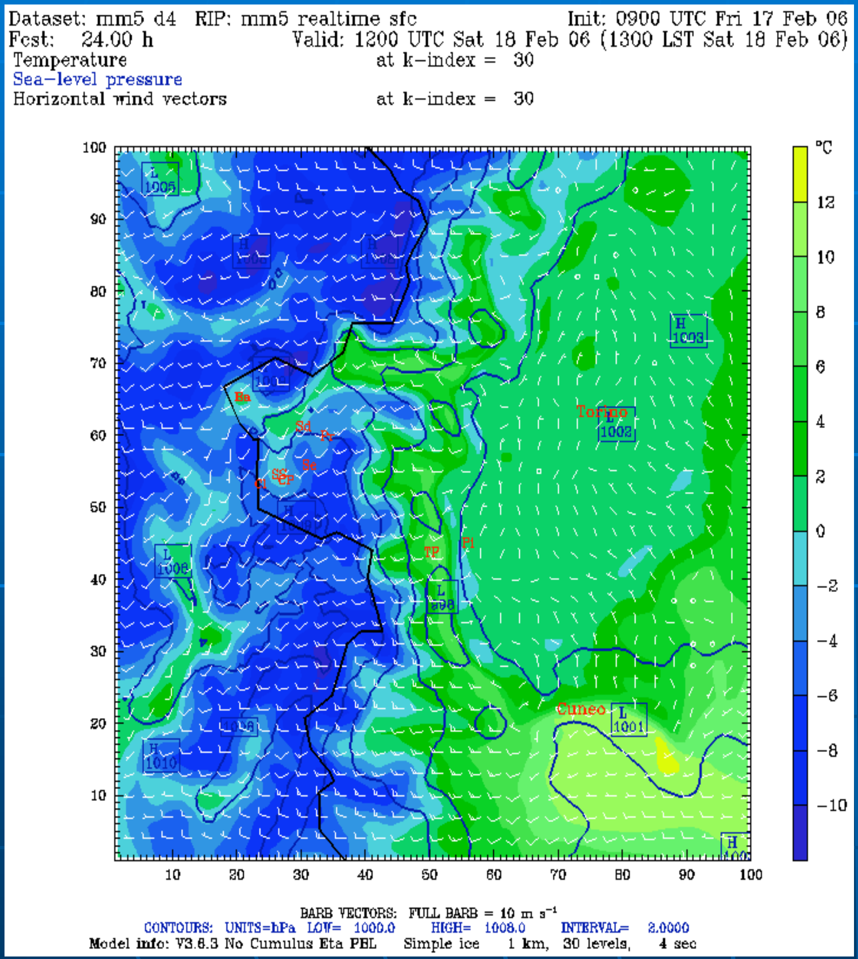
Case 2

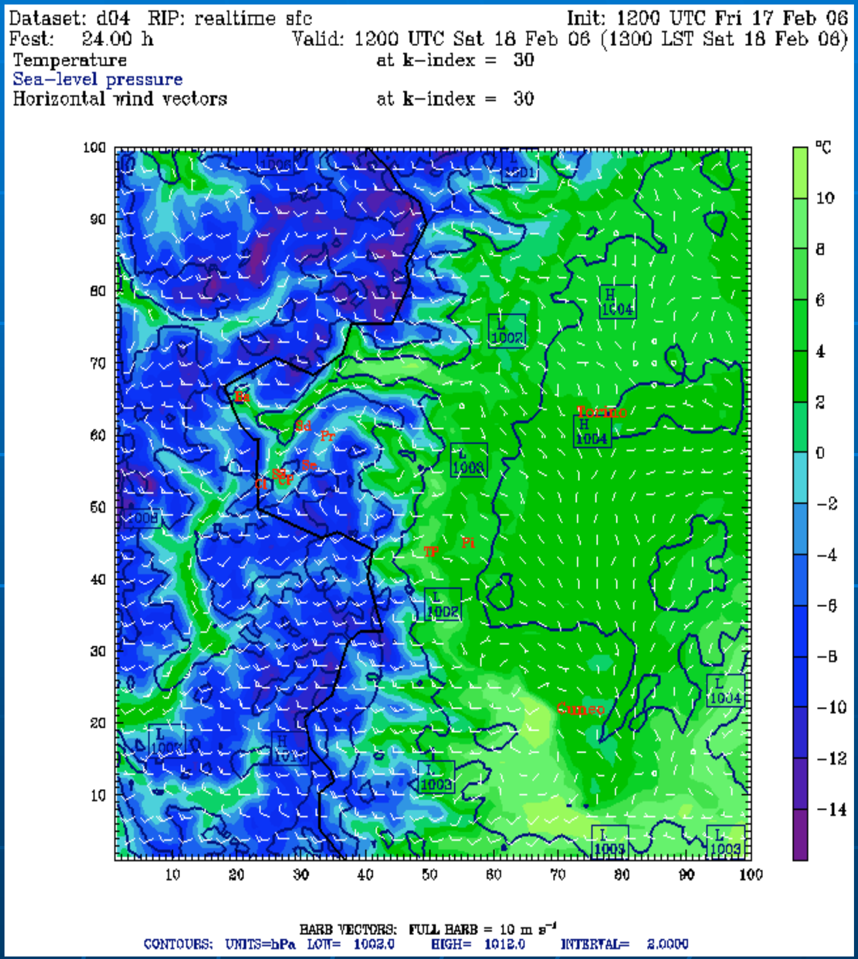
12UTC 17 Feb - 12UTC 18 Feb

Precip/Wind in Mountains

MM5

WRF2.2





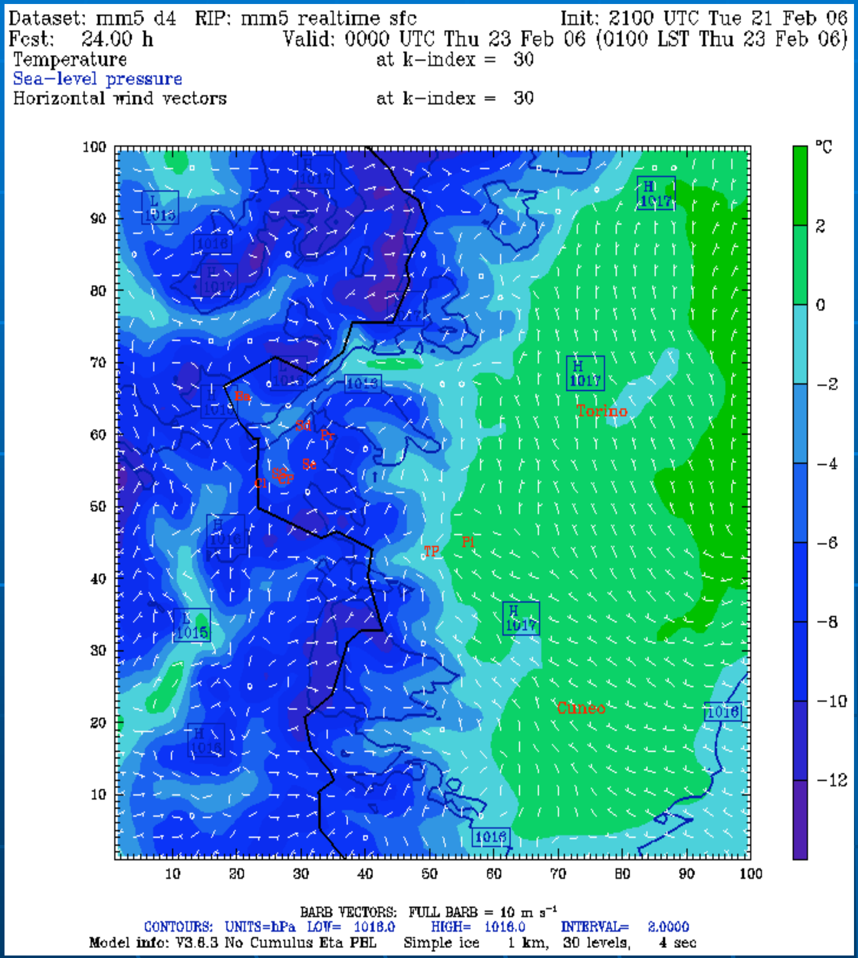
Surface Layer Temperature

Case 5

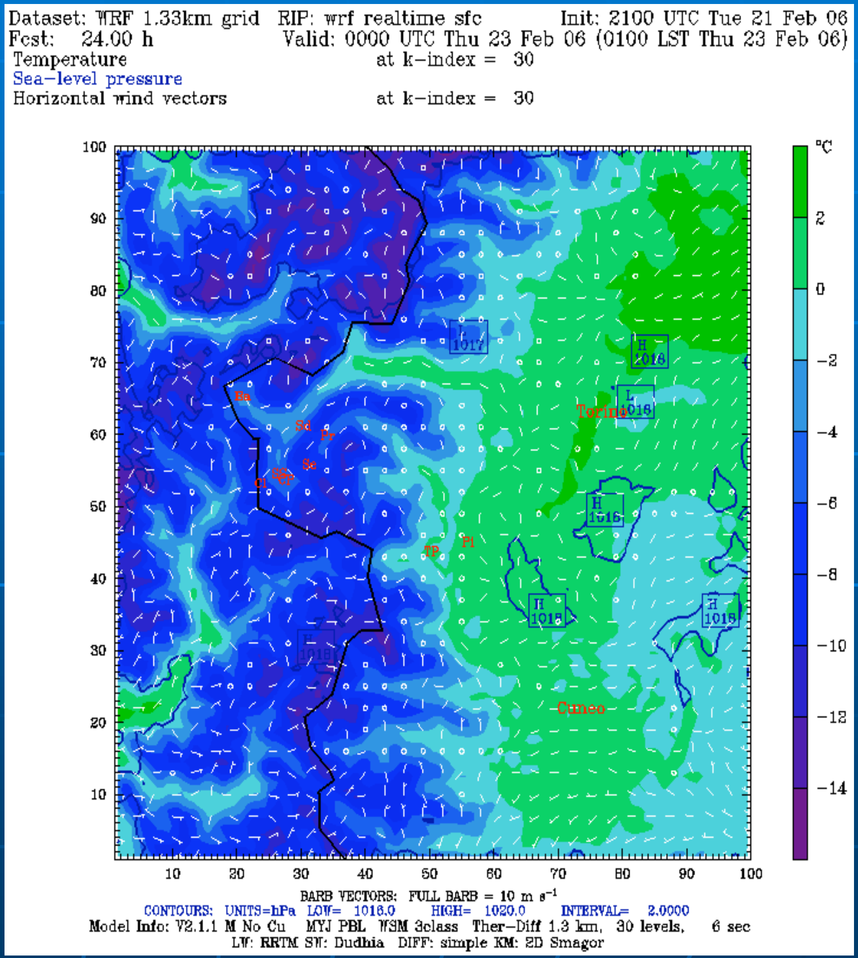
00UTC 22 Feb - 00UTC 23 Feb

Precip on Plains

MM5



WRF2.1



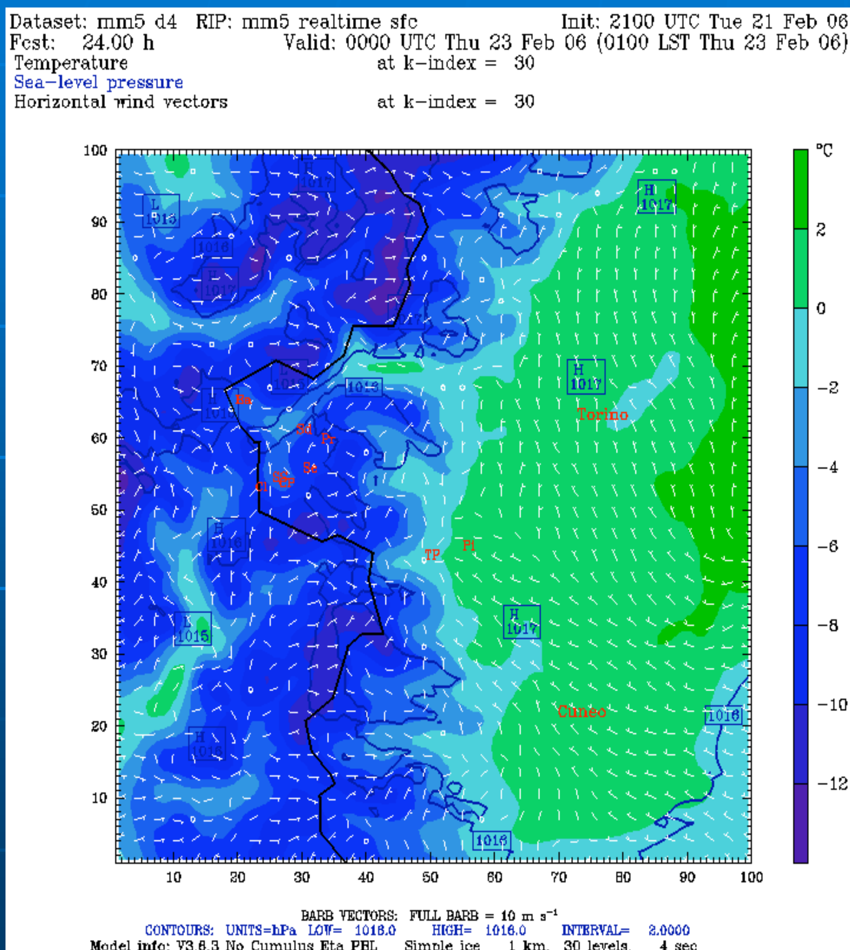
Surface Layer Temperature

Case 5

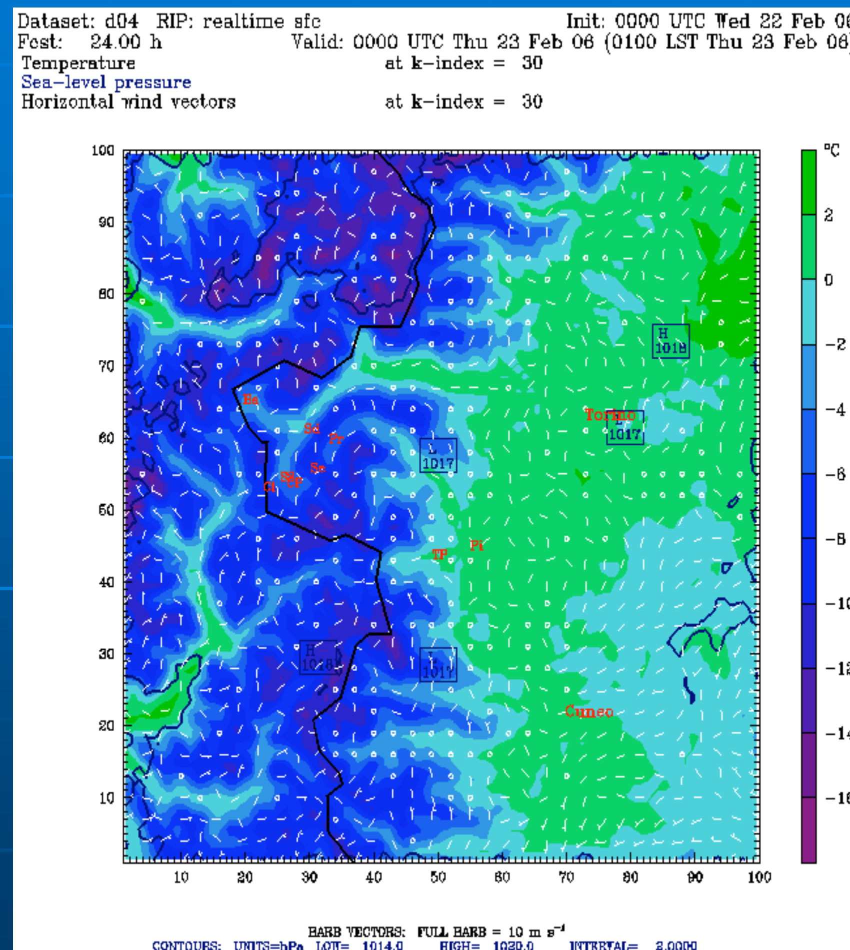
00UTC 22 Feb - 00UTC 23 Feb

Precip on Plains

MM5



WRF2.2



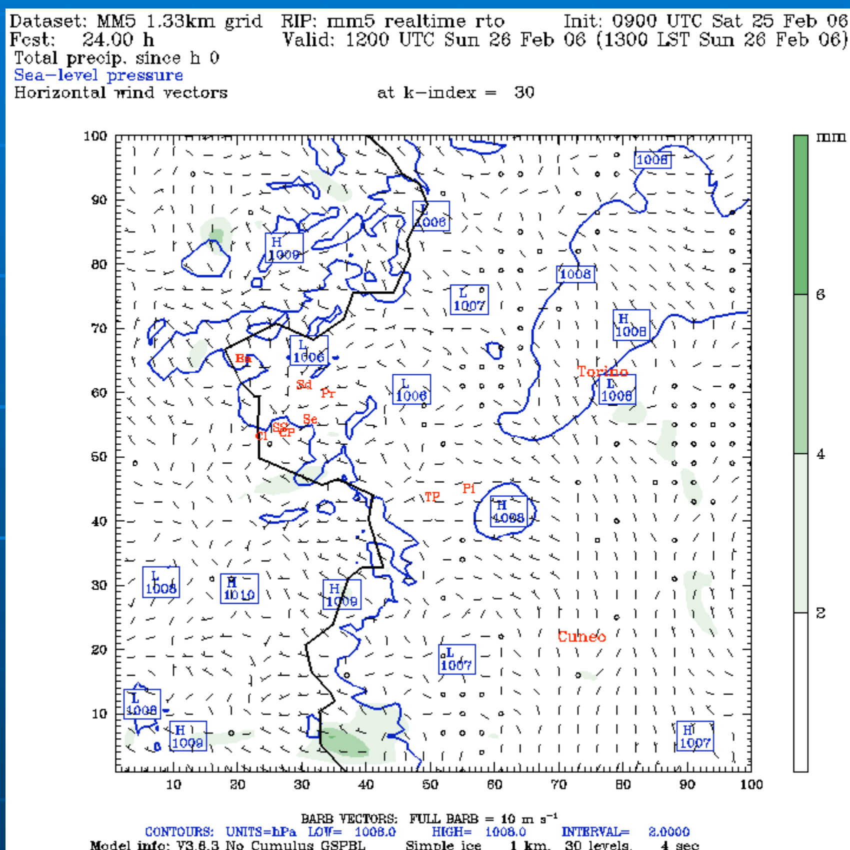
Surface Layer Temperature

Case 6

12UTC 25 Feb - 12UTC 26 Feb

Light Precip in Mountains and on Plains

Realtime MM5 OBS



ARPA Piemonte - The weather and snow service at the Games

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Data observed in the single venues: last update on 26/02/2006 at 13:00 local time

Venues	Sky	Temp.(°C)	Umidity (%)	Wind (m/s)	Total Precipitations (mm)	Last 24h new snow (cm)	Web Cam
Pinerolo palaghiaccio		6.8	67	S 2.00	-	-	
Cesana San Sicario		-	-	SW 2.40	-	2	
Sauze d'Oulx-Jovenceaux		5.3	27	SW 2.40	-	2	
Pragelato		3.1	26	SW 3.10	-	2	
Sestriere Borgata		1.1	26	SSW 3.10	24	2	
Sestriere Colle		-1.3	44	W 4.40	-	2	
Cesana Pariol		-	-	SW 2.40	-	2	
Torino esposizioni		7.4	63	S 1.70	-	-	
Bardonecchia		2.2	25	WSW 1.70	2	1	
Pragelato Plan		1.4	30	SSW 5.80	-	2	
San Sicario Fraiteve		-0.7	34	SW 5.30	-	2	

View of the Italian side from the French border

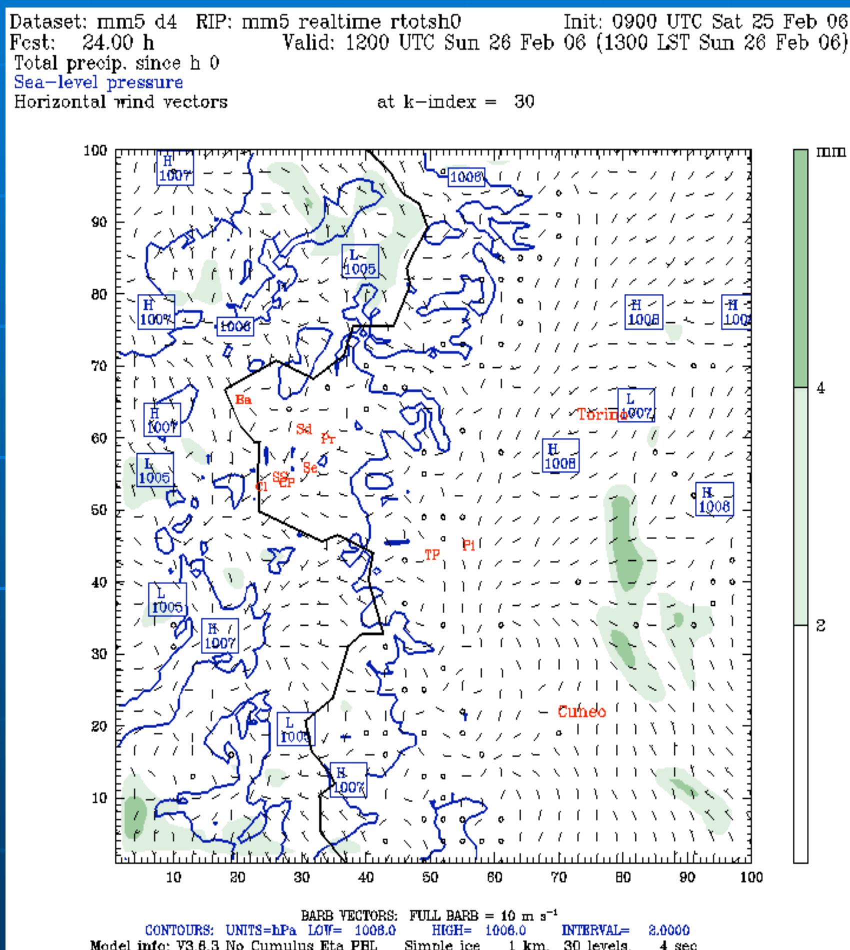
24-h Total Precip

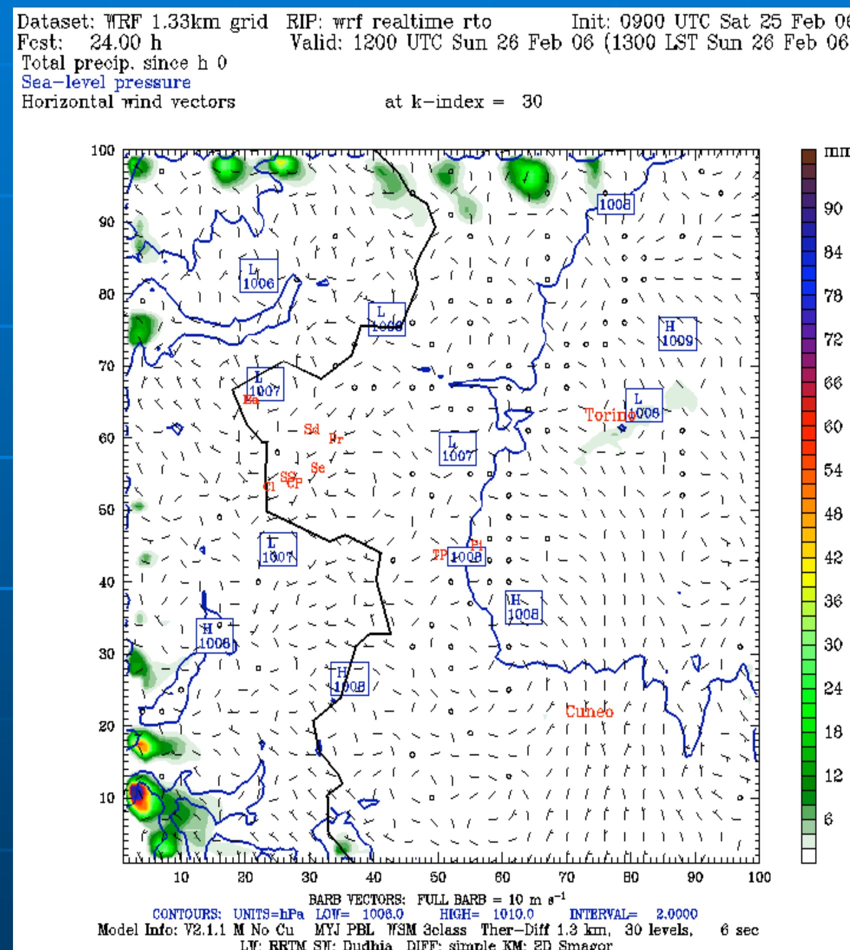
Case 6

12UTC 25 Feb - 12UTC 26 Feb

Light Precip in Mountains and on Plains

MM5 WRF2.1

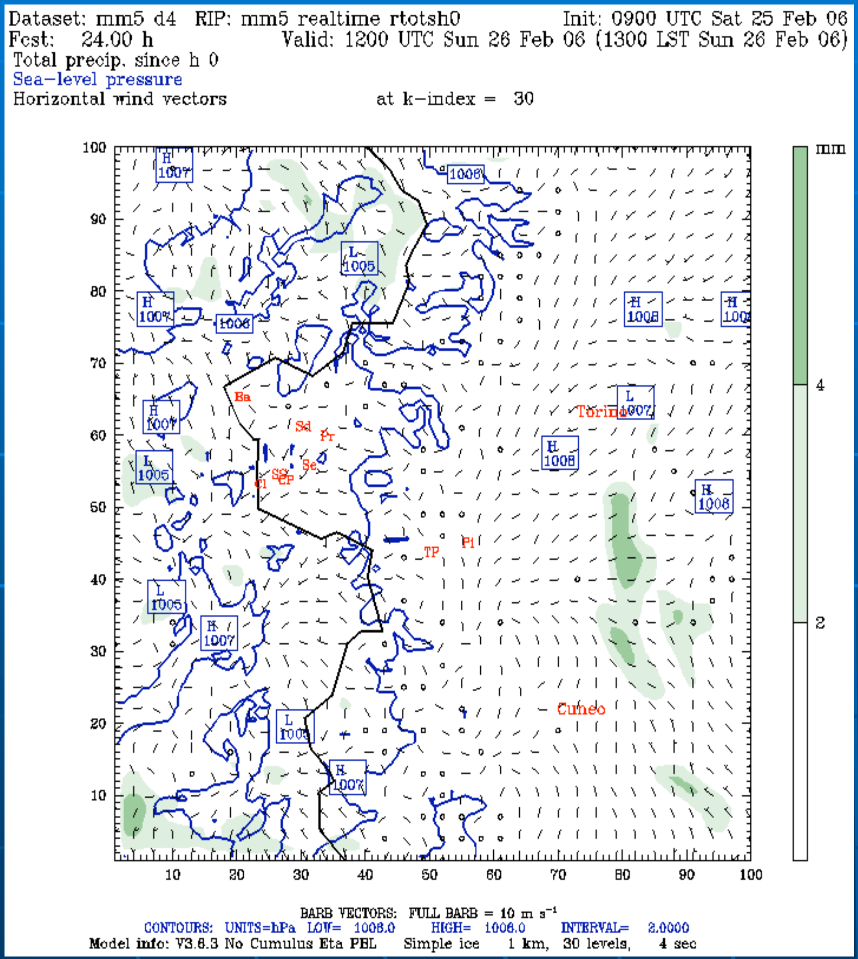


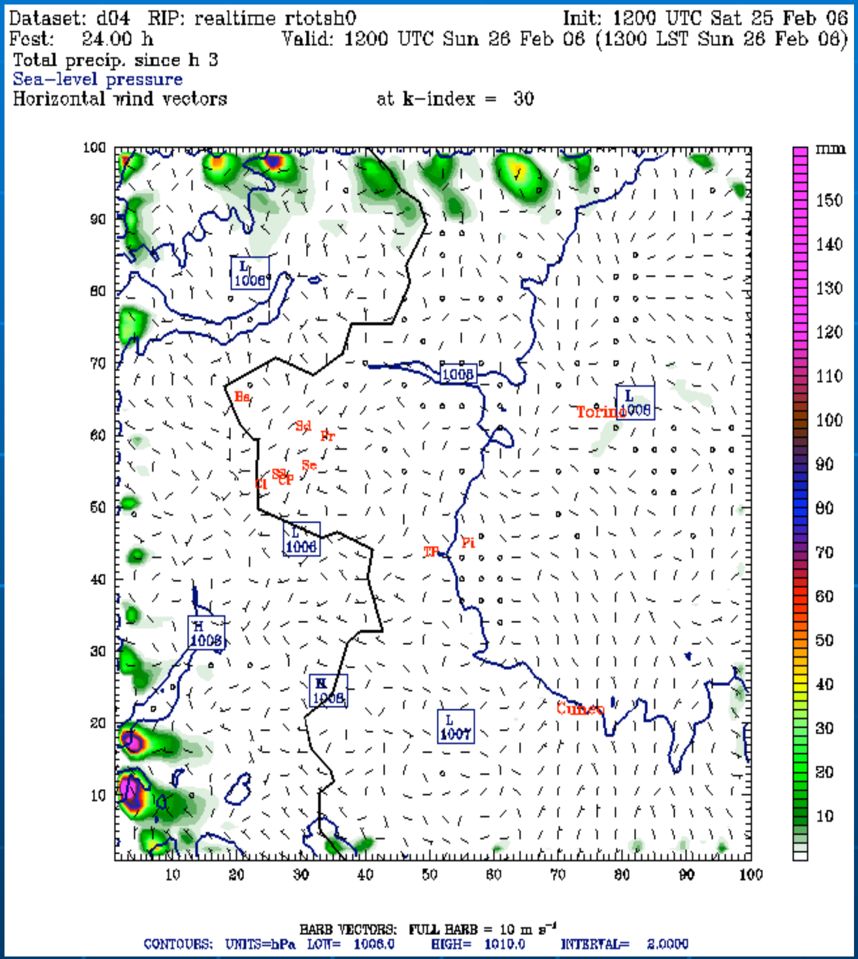


24-h Total Precip

Case 6
12UTC 25 Feb - 12UTC 26 Feb
Light Precip in Mountains and on Plains

MM5 WRF2.2





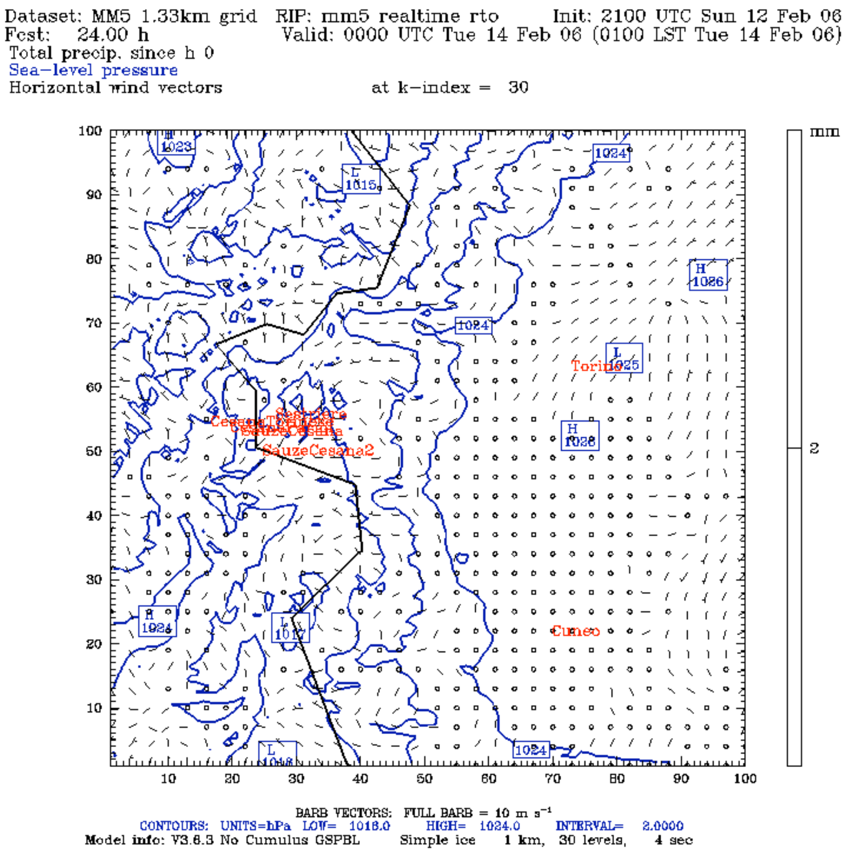
24-h Total Precip

Case 1

00UTC 13 Feb - 00UTC 14 Feb

Dry

Realtime MM5

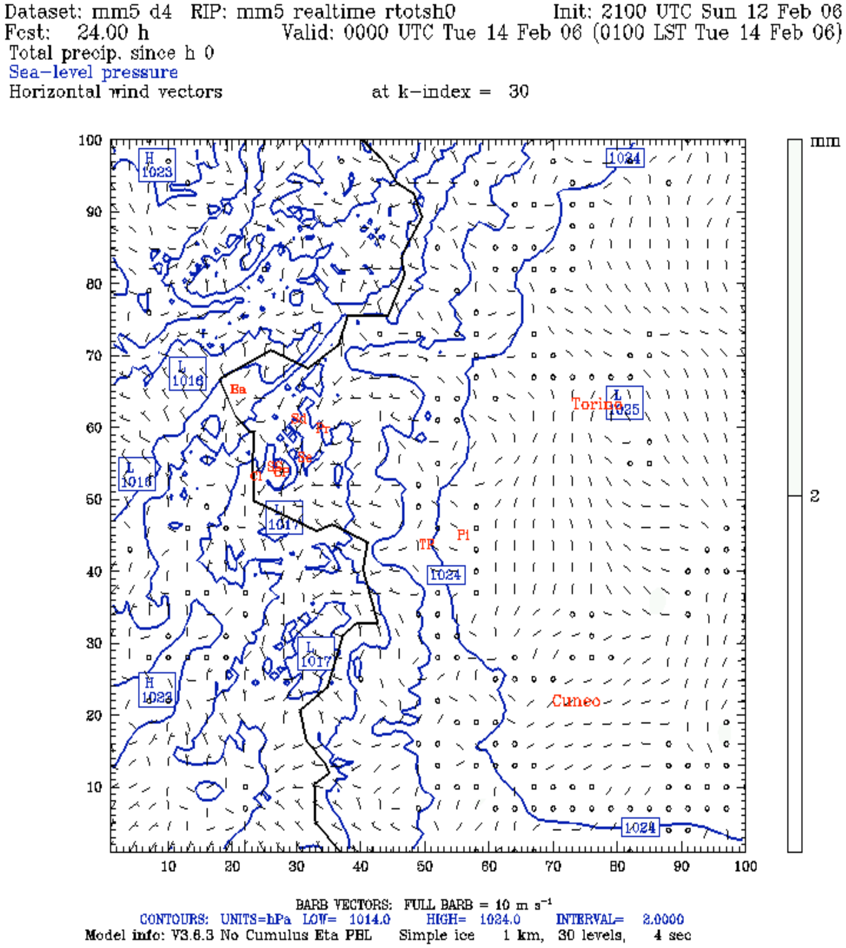


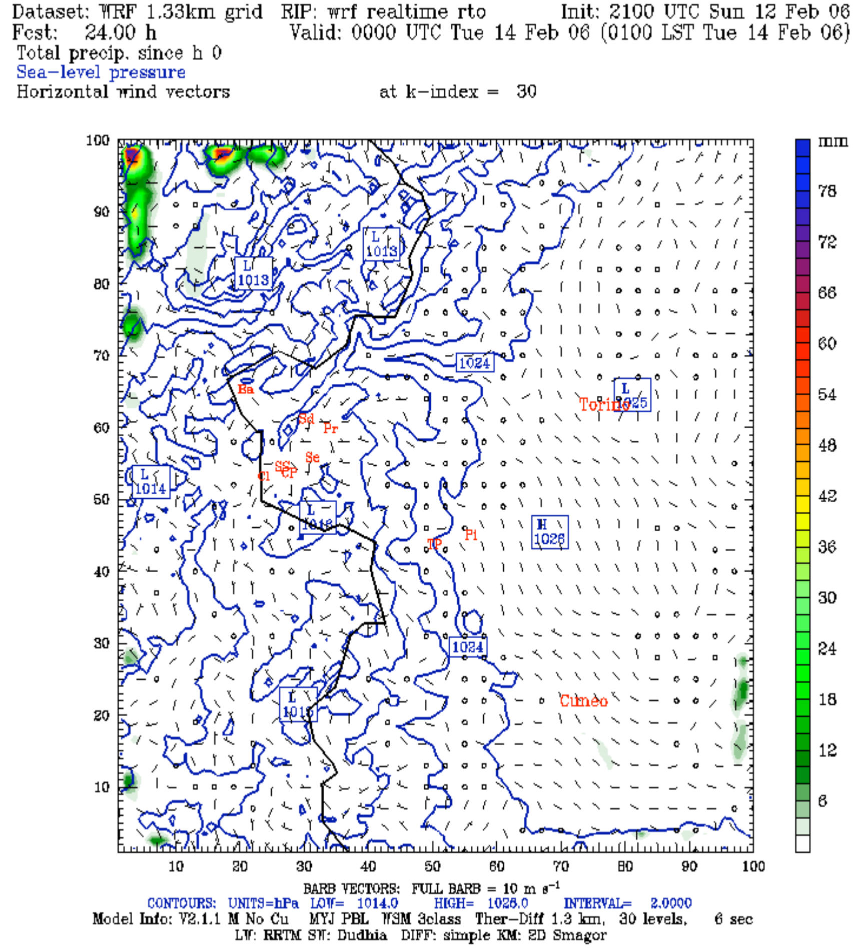
No Precipitation

24-h Total Precip

Case 1
00UTC 13 Feb - 00UTC 14 Feb
Dry

MM5 WRF2.1





24-h Total Precip

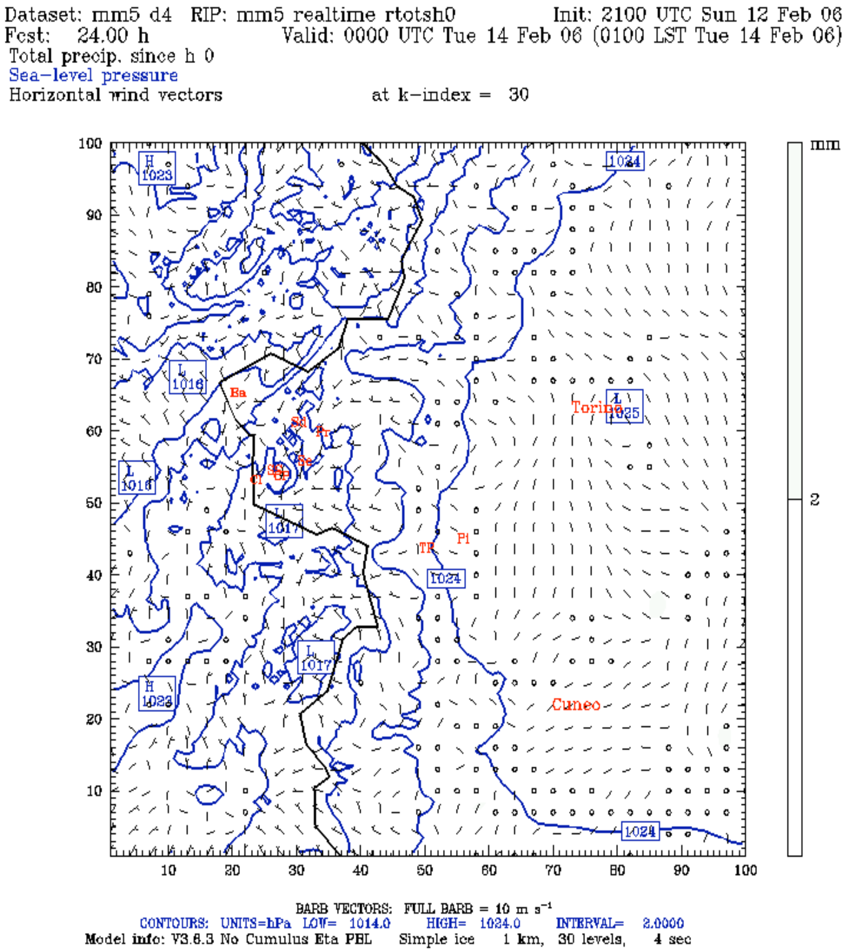
Case 1

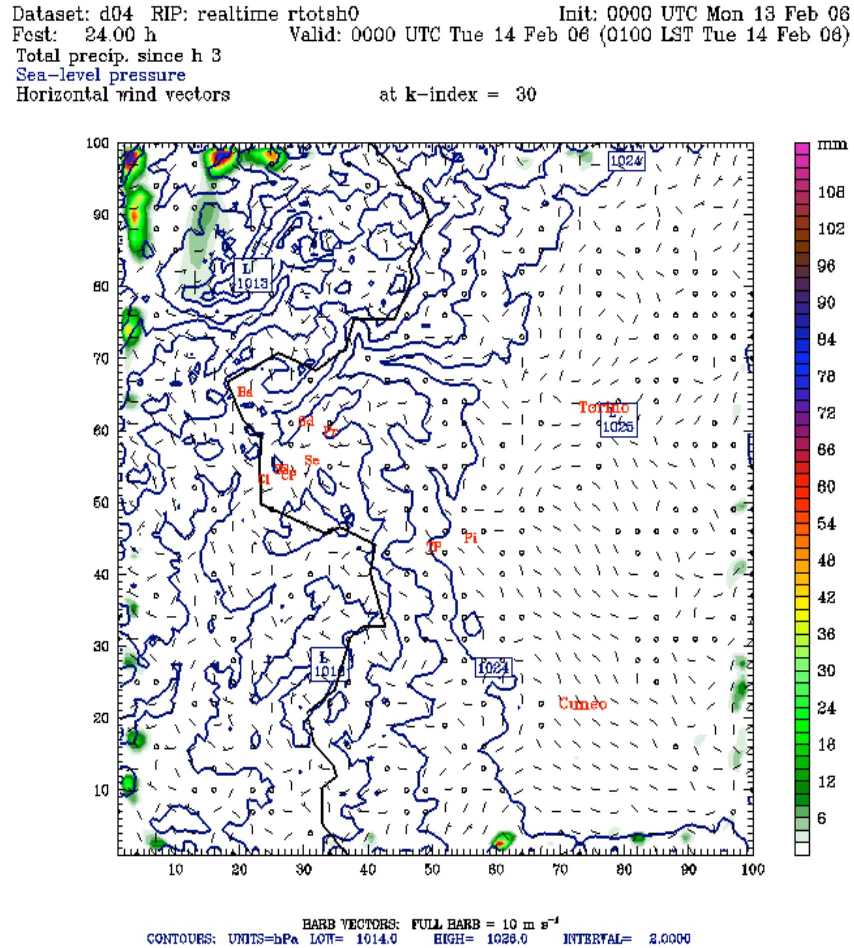
00UTC 13 Feb - 00UTC 14 Feb

Dry

MM5

WRF2.2





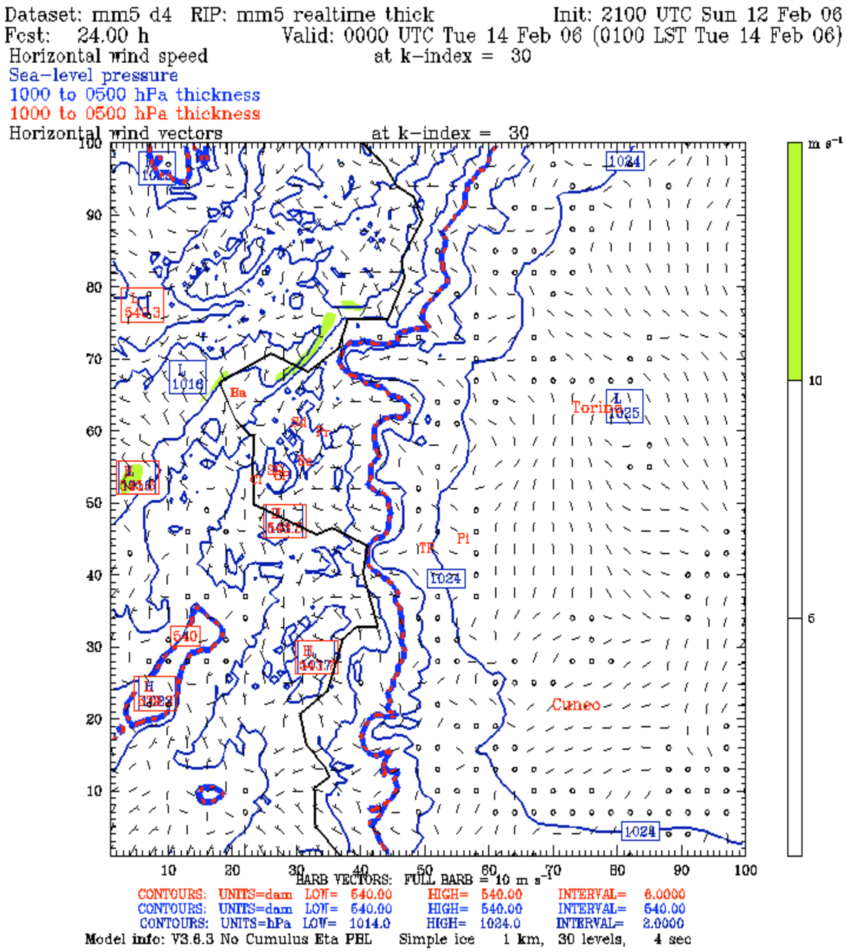
24-h Total Precip

Case 1

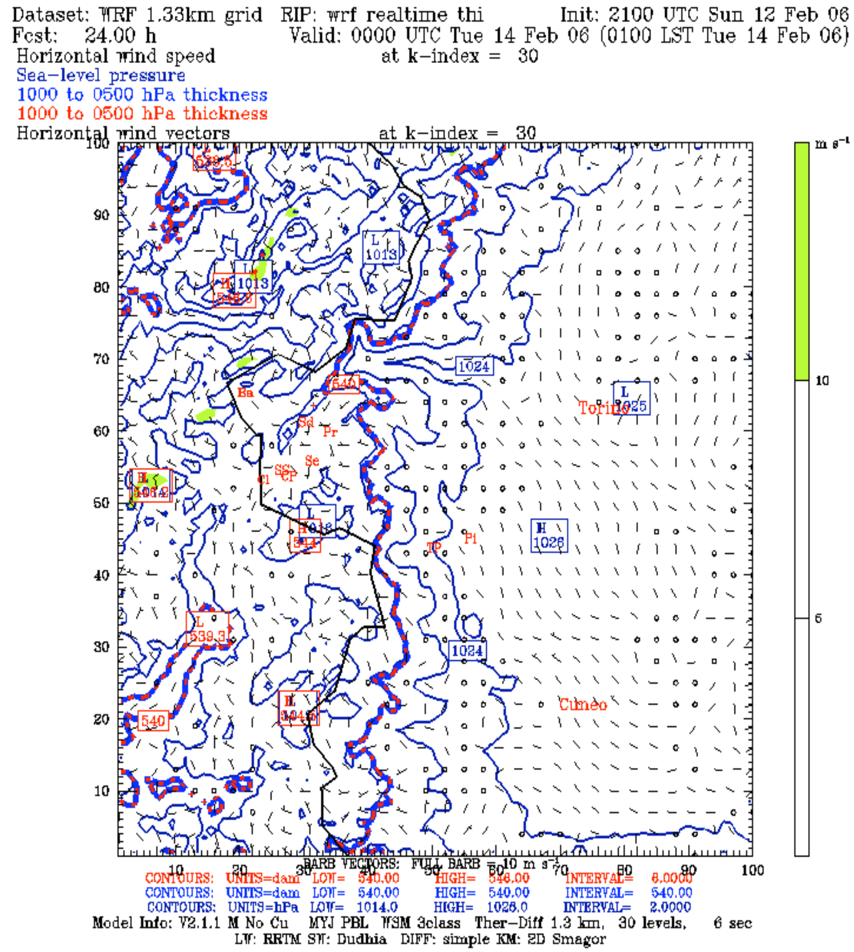
00UTC 13 Feb - 00UTC 14 Feb

Dry

MM5



WRF2.1



Wind Speed and 1000-500hPa Thickness

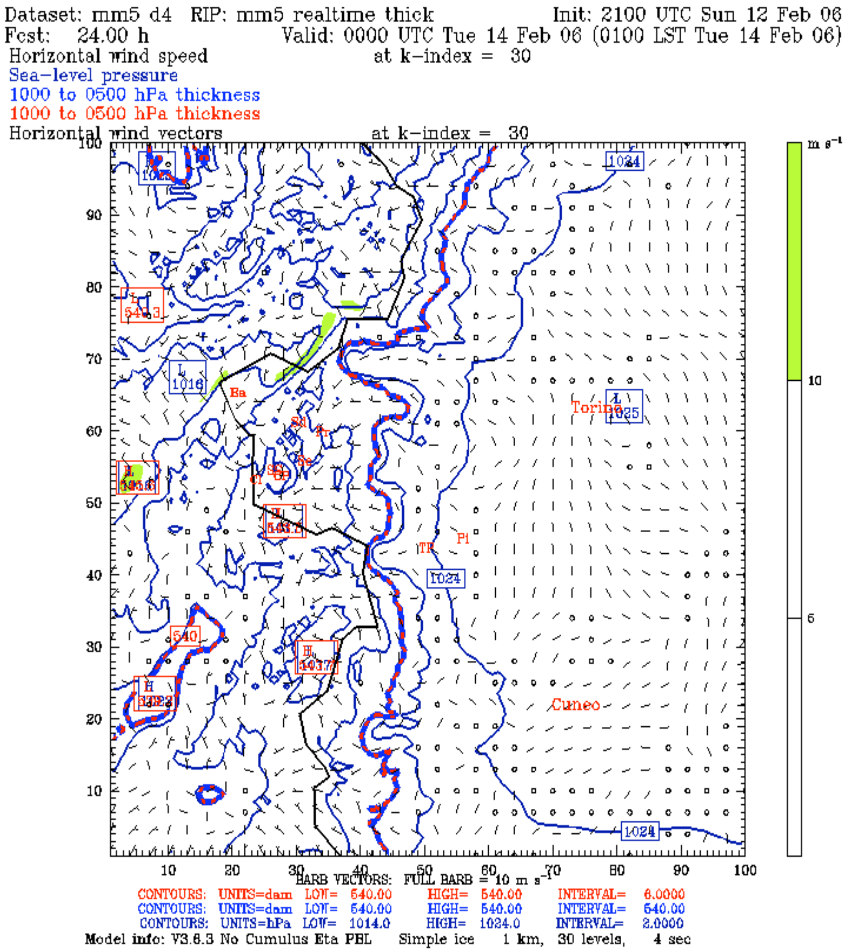
Case 1

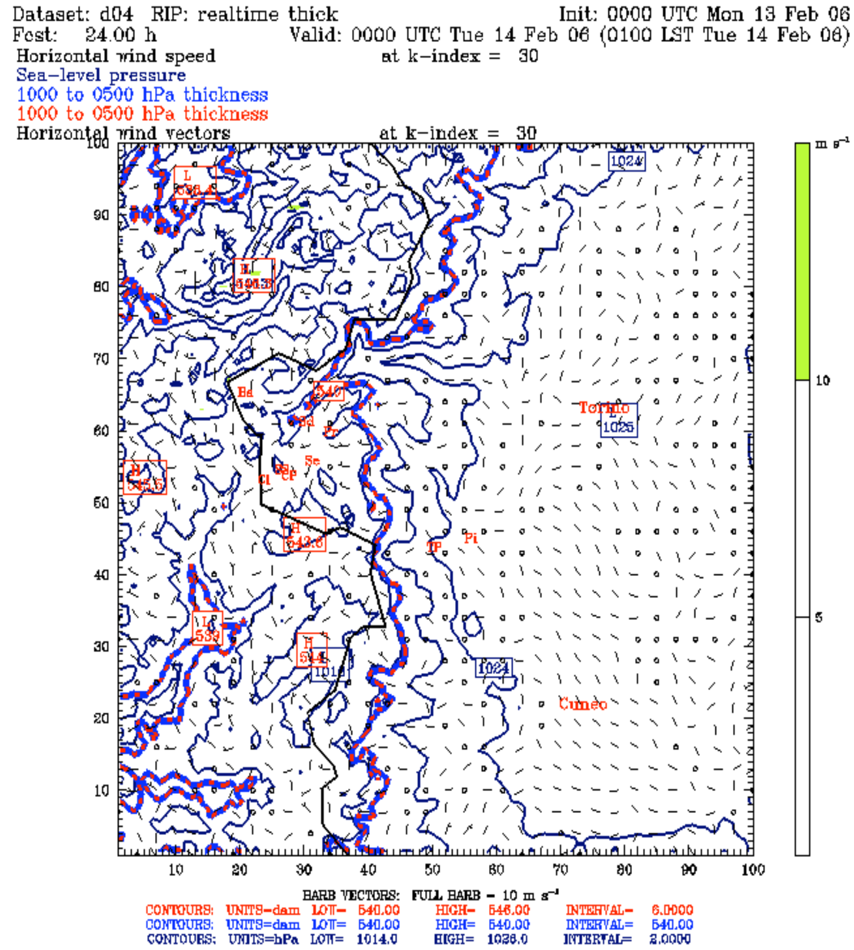
00UTC 13 Feb - 00UTC 14 Feb

Dry

MM5

WRF2.2





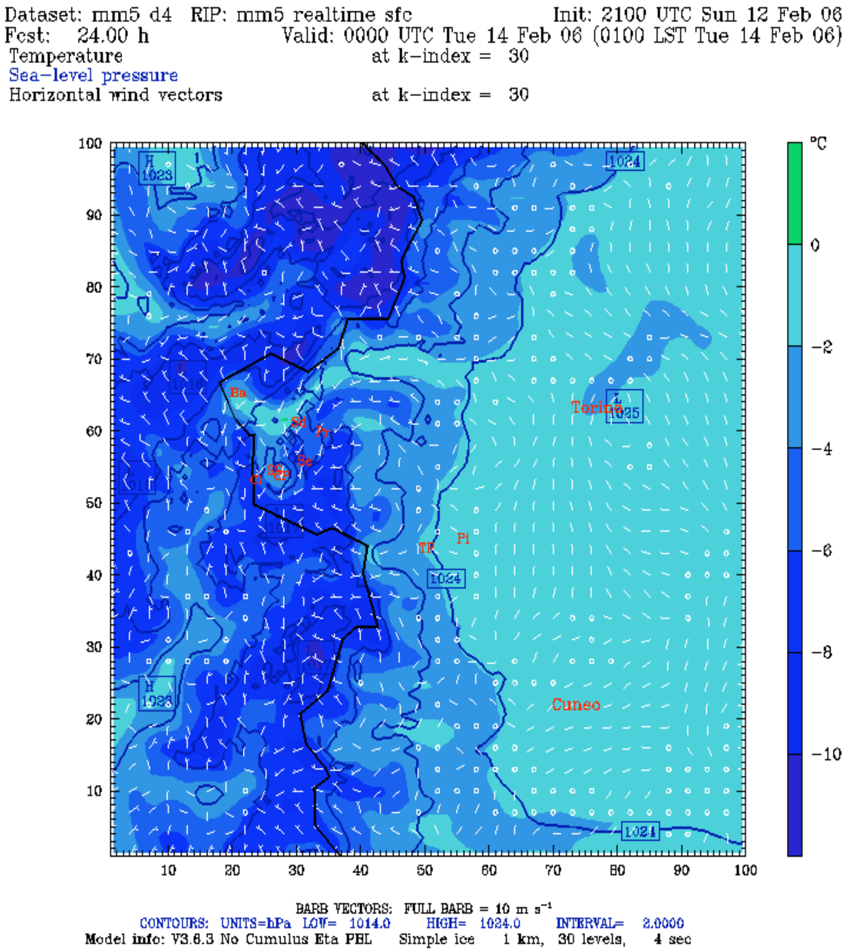
Wind Speed and 1000-500hPa Thickness

Case 1

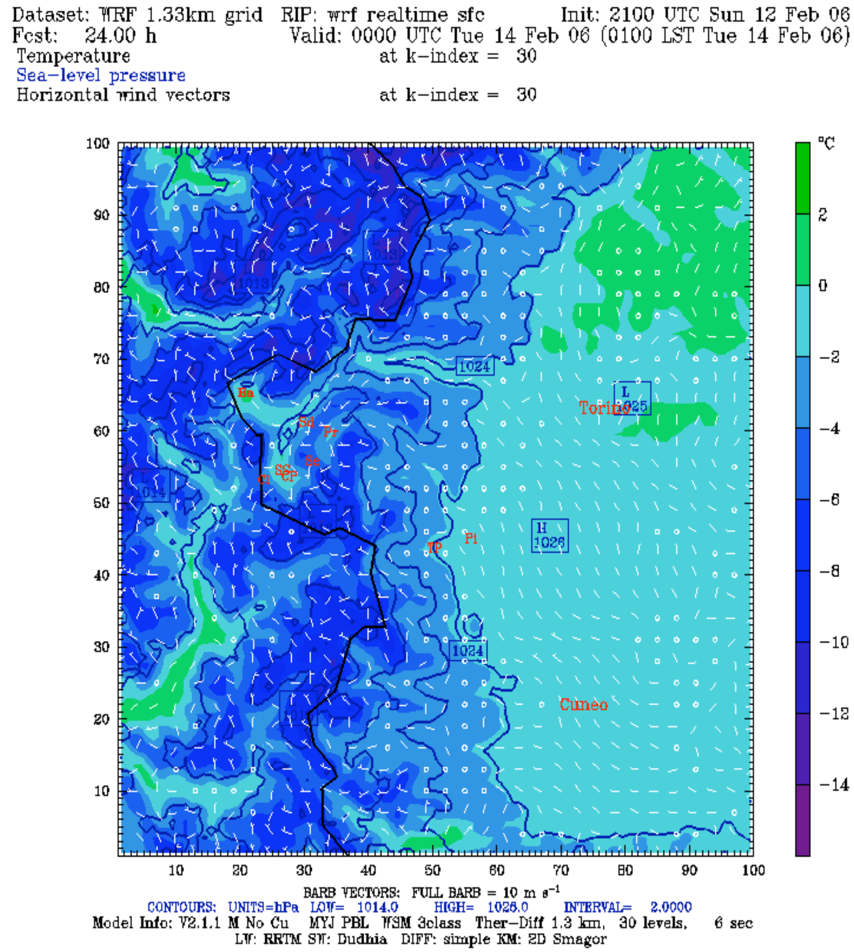
00UTC 13 Feb - 00UTC 14 Feb

Dry

MM5



WRF2.1



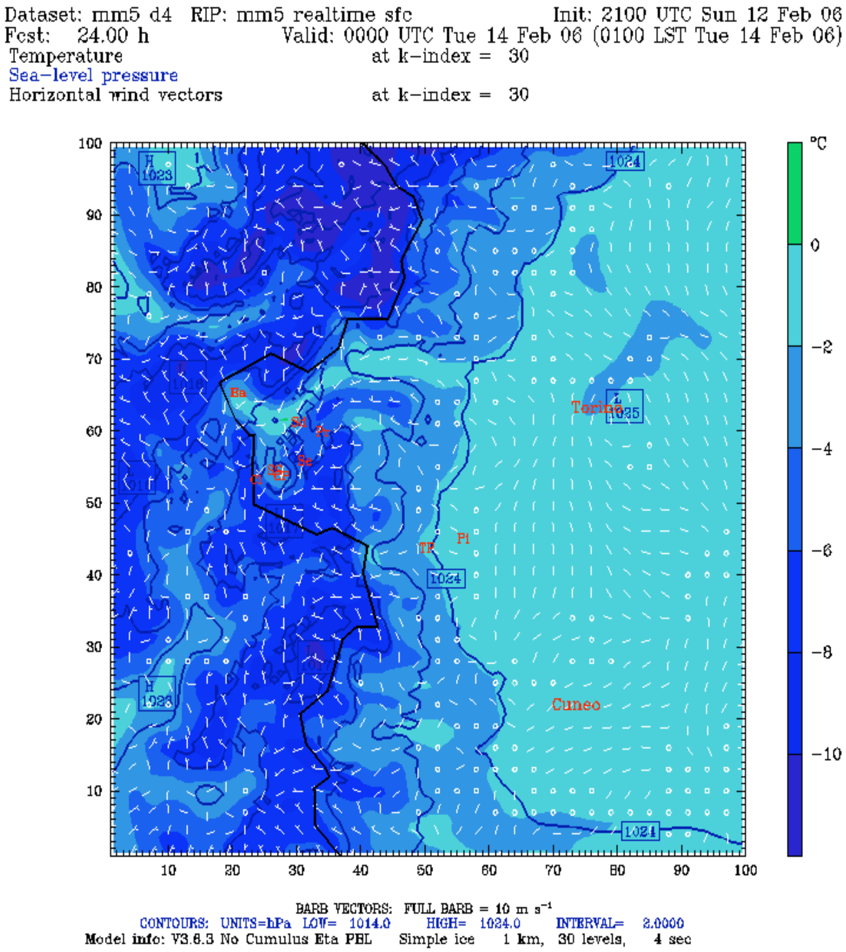
Surface Layer Temperature

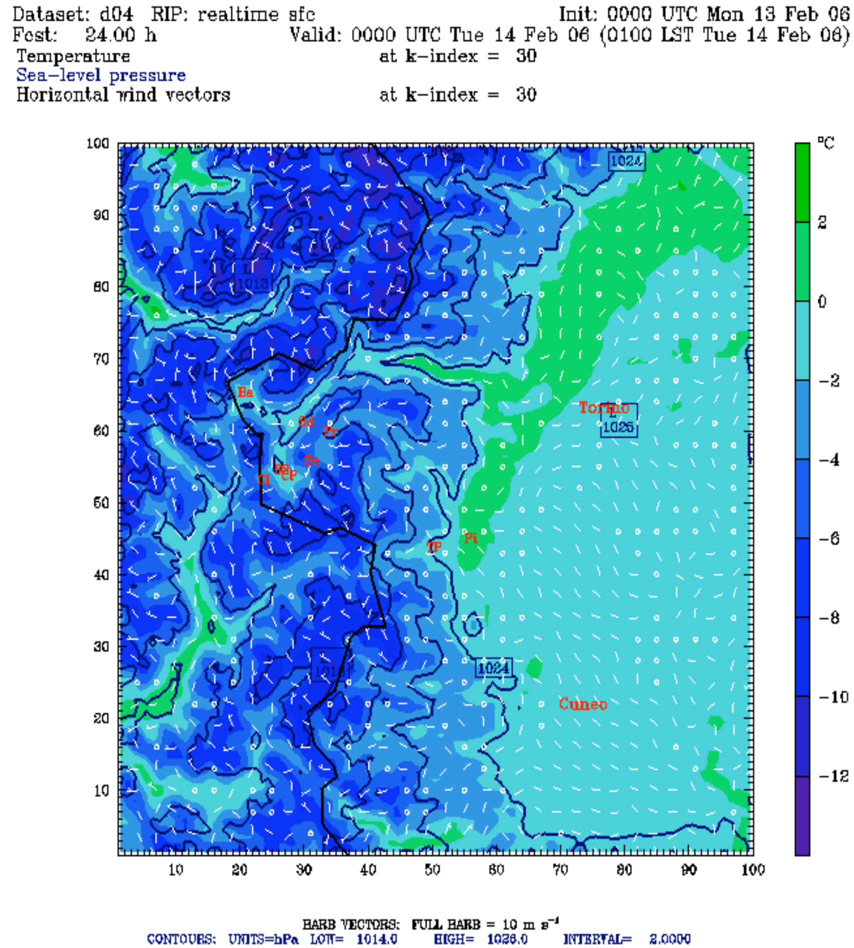
Case 1

00UTC 13 Feb - 00UTC 14 Feb

Dry

MM5 | WRF2.2





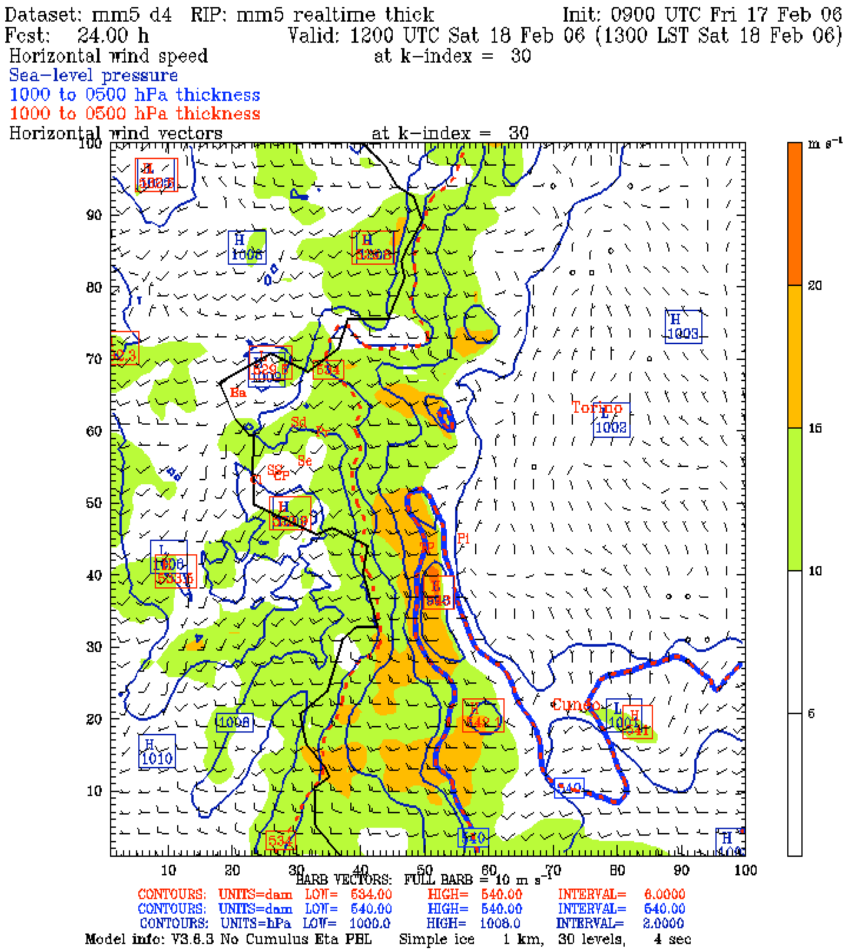
Surface Layer Temperature

Case 2

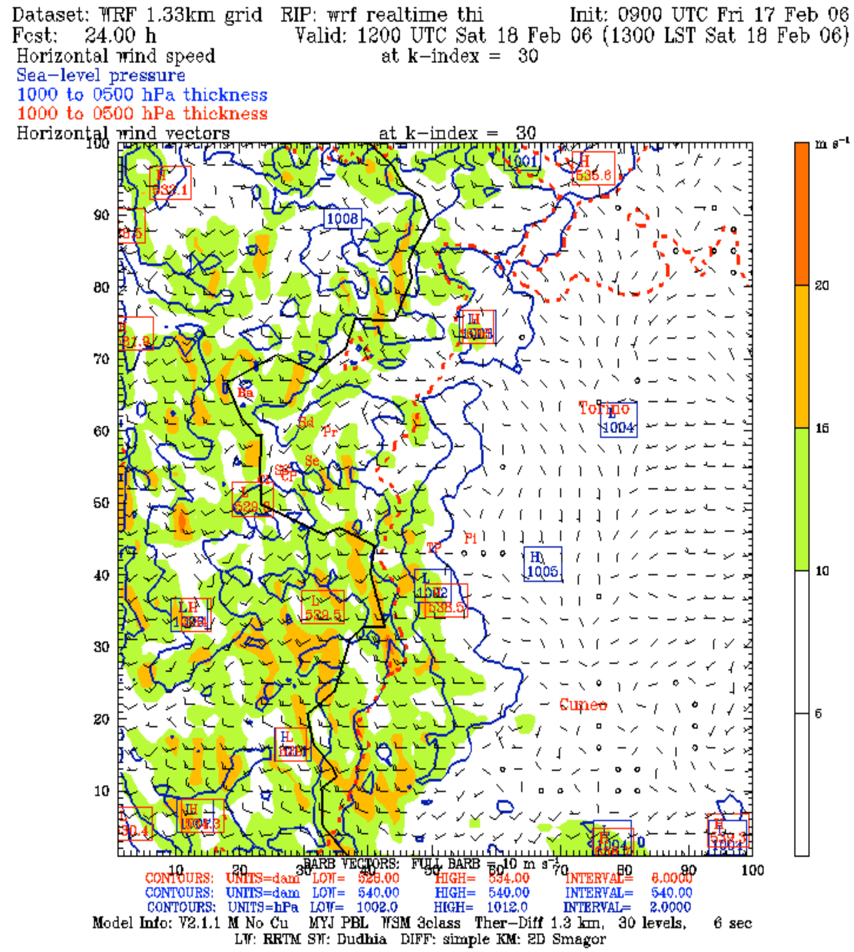
12UTC 17 Feb - 12UTC 18 Feb

Precip/Wind in Mountains

MM5



WRF2.1



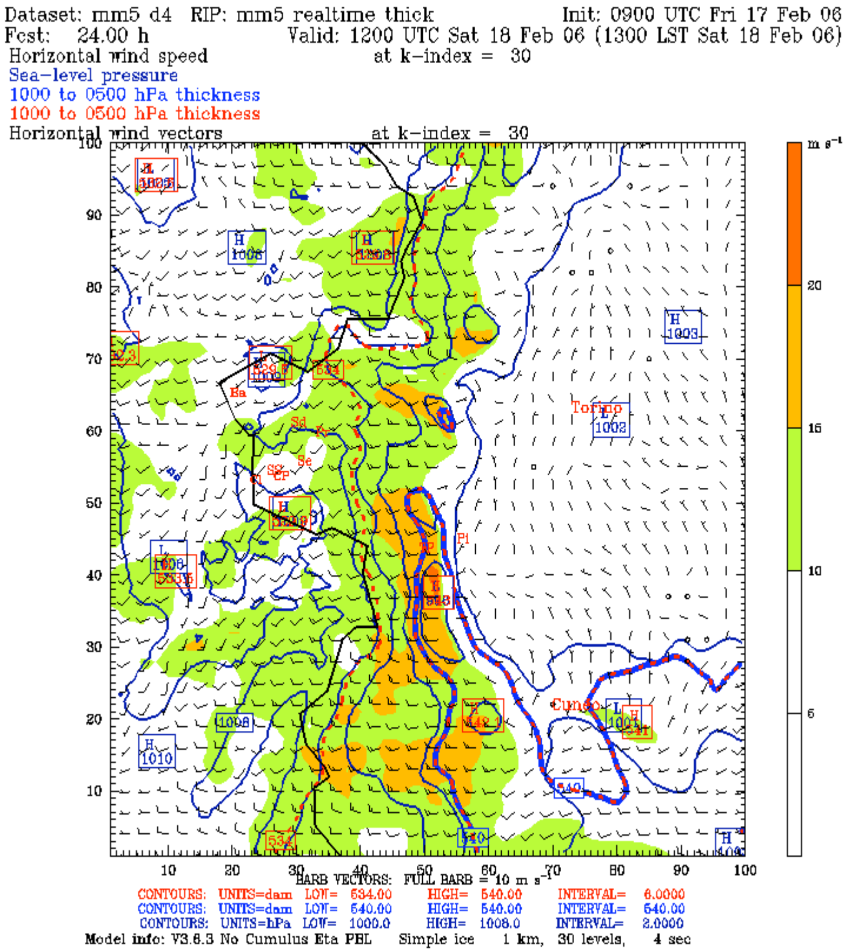
Wind Speed and 1000-500hPa Thickness

Case 2

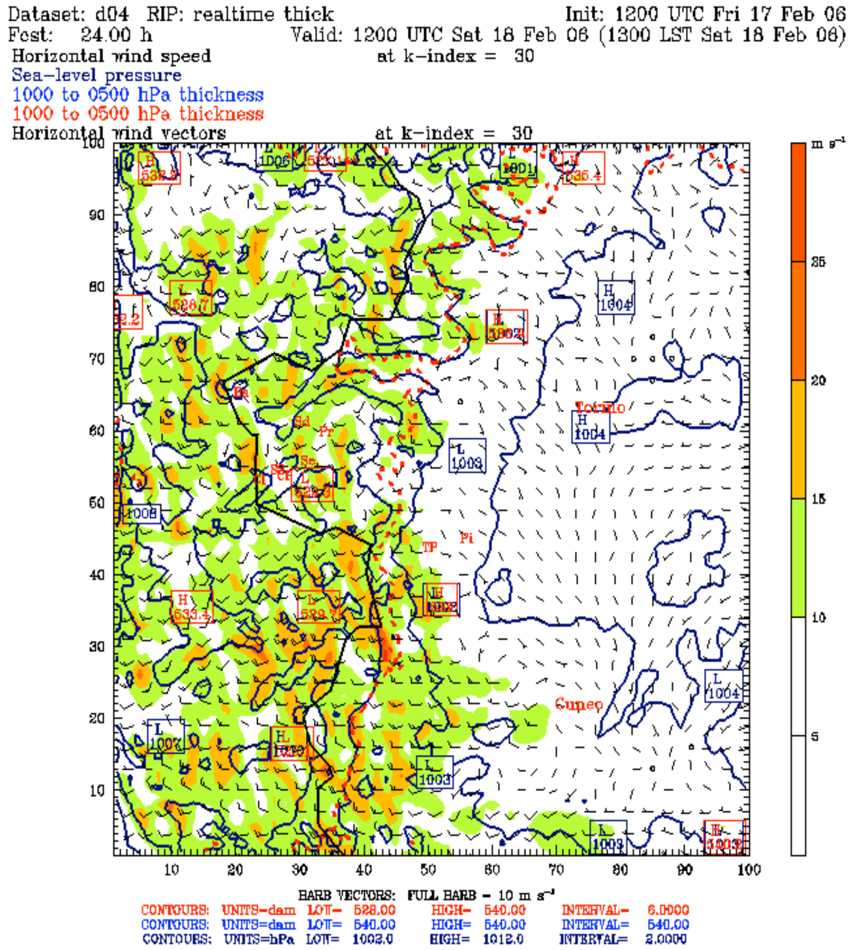
12UTC 17 Feb - 12UTC 18 Feb

Precip/Wind in Mountains

MM5



WRF2.2



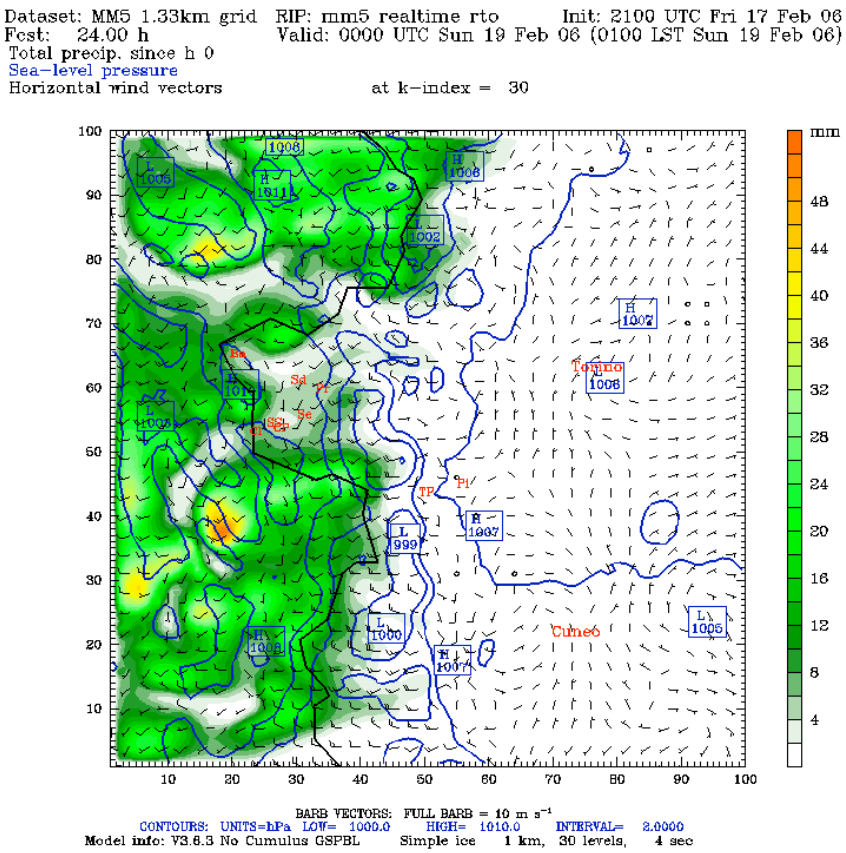
Wind Speed and 1000-500hPa Thickness

Case 3

00UTC 18 Feb - 00UTC 19 Feb

Precip in Mountains

Realtime MM5 | OBS



Weather data belong to Arpa Piemonte. Use allowed mentioning the source.

Data observed in the single venues: last update on 19/02/2006 at 00:00 local time

Venues	Sky	Temp.(°C)	Umidity (%)	Wind (m/s)	Total Precipitations (mm)	Last 24h new snow (cm)	Web Cam
Pinerolo palaghiaccio		3.6	92	W 1.40	-	-	
Cesana San Sicario		-1.8	67	WSW 2.00	-	7	
Sauze d'Oulx-Jovenceaux		0.5	67	S 1.60	-	11	
Pragelato		-2.2	66	SW 0.80	-	5	
Sestriere Borgata		-4.2	68	SW 1.70	-	6	
Sestriere Colle		-5.7	69	W 2.80	-	6	
Cesana Pariol		-2.1	79	WSW 2.00	-	5	
Torino esposizioni		3.4	93	ENE 0.70	-	-	
Bardonecchia		-2.9	79	E 0.70	-	12	
Pragelato Plan		-2.7	71	S 4.10	-	5	
San Sicario Fraiteve		-6.5	89	SW 3.90	-	12	

View of the Italian side from the French border

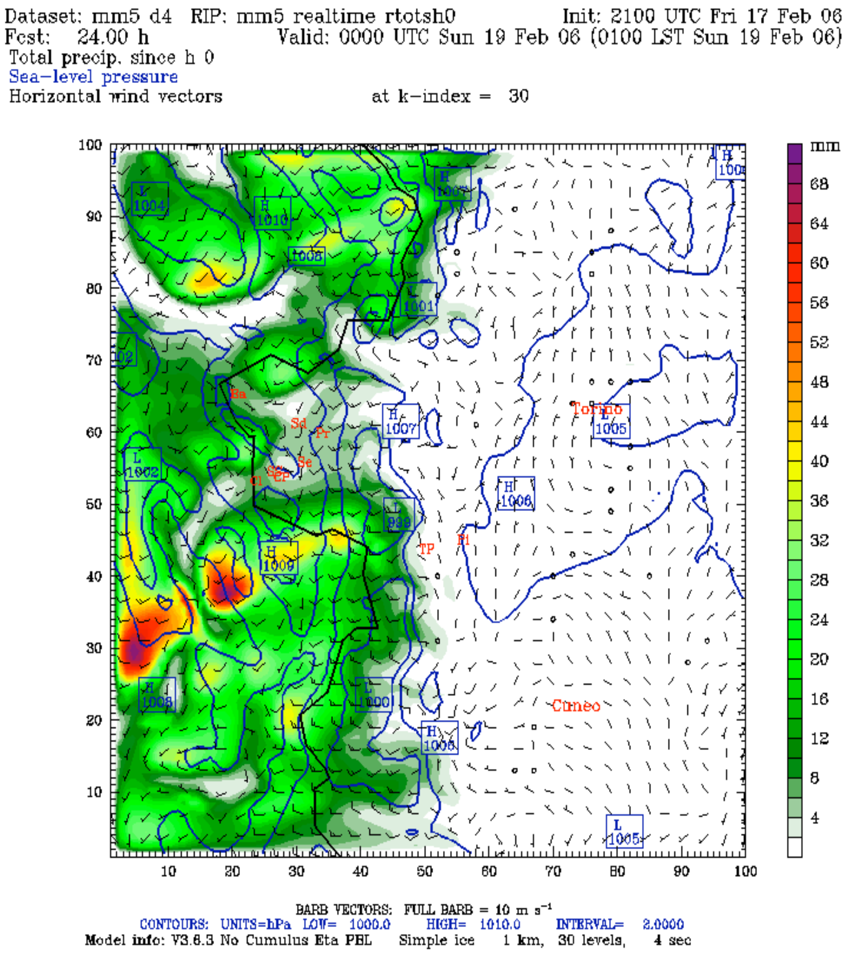
24-h Total Precip

Case 3

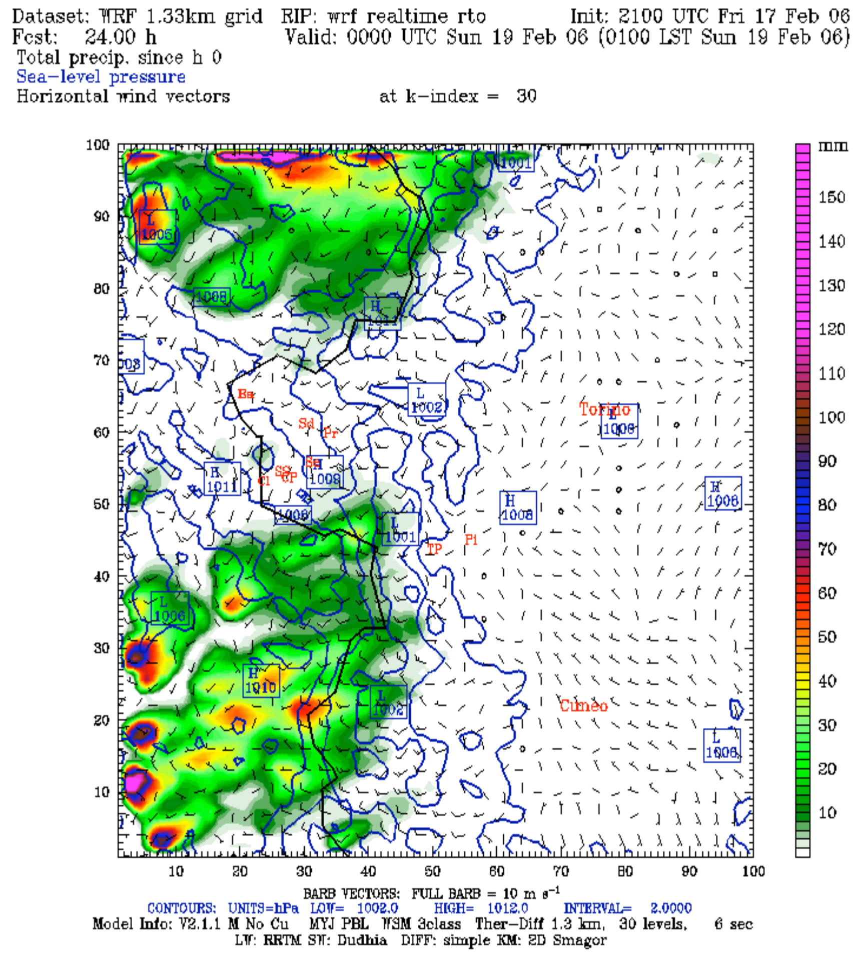
00UTC 18 Feb - 00UTC 19 Feb

Precip in Mountains

MM5



WRF2.1



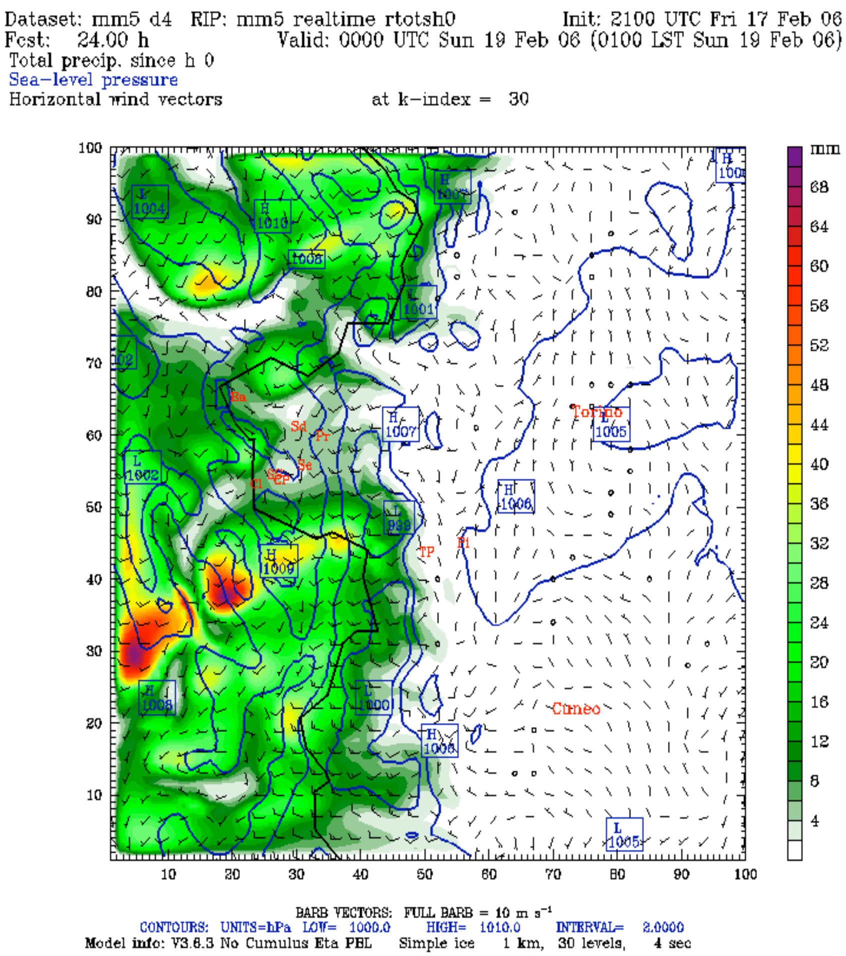
24-h Total Precip

Case 3

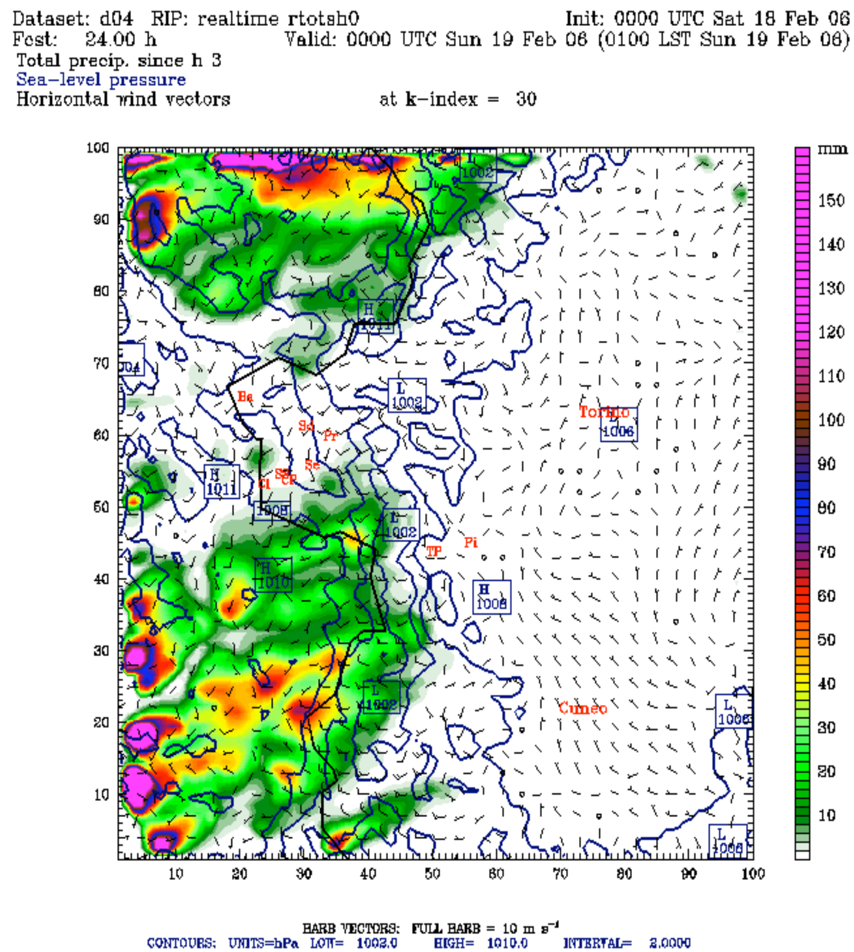
00UTC 18 Feb - 00UTC 19 Feb

Precip in Mountains

MM5



WRF2.2



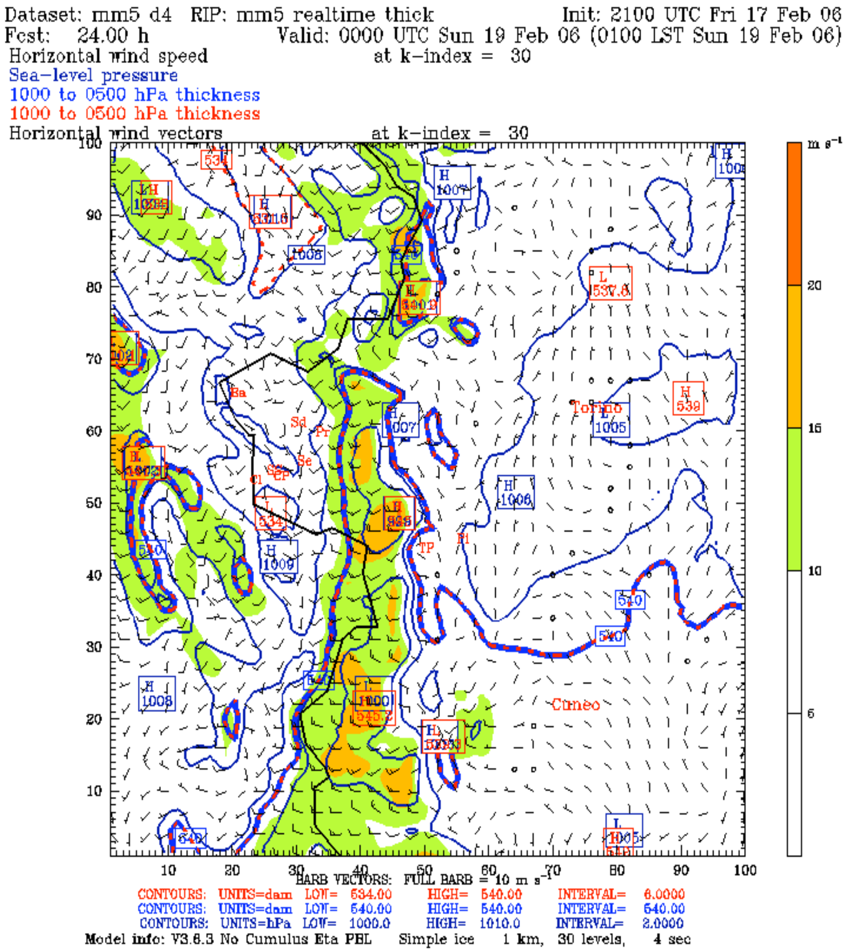
24-h Total Precip

Case 3

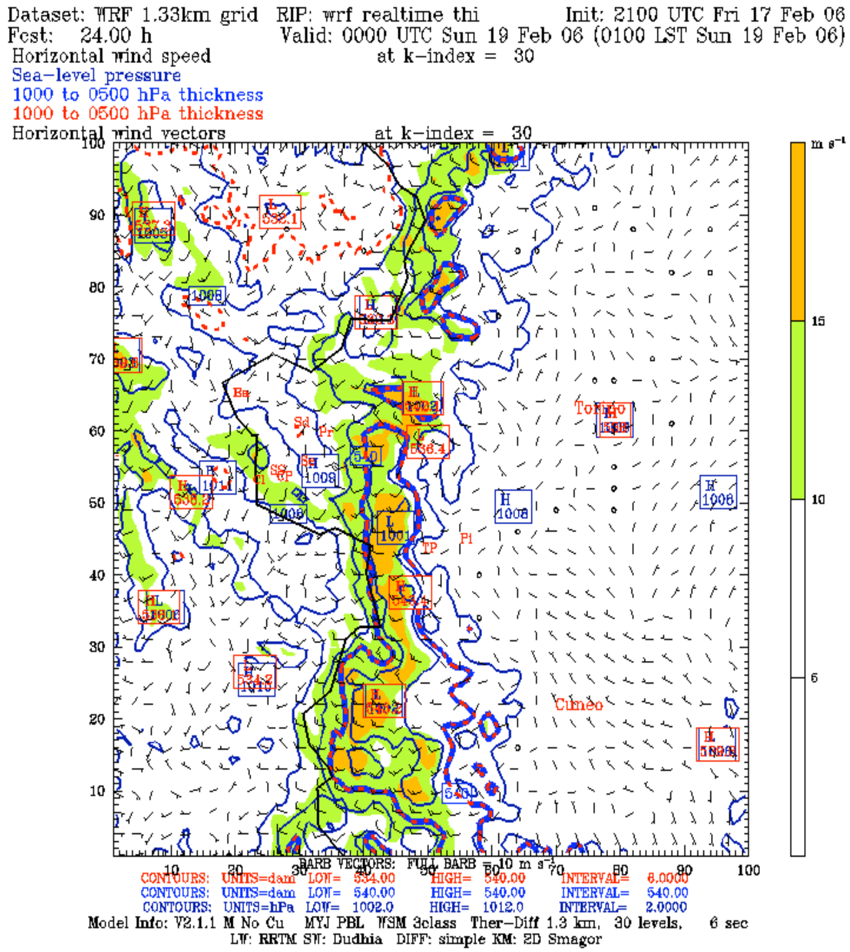
00UTC 18 Feb - 00UTC 19 Feb

Precip in Mountains

MM5



WRF2.1

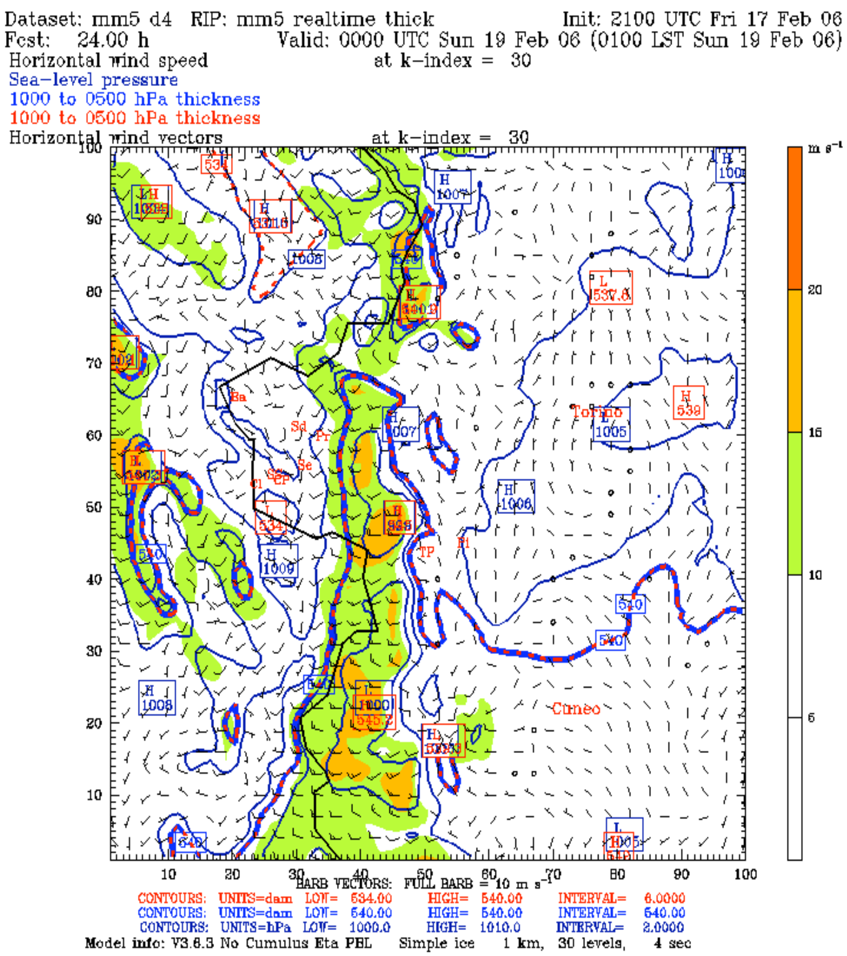


Wind Speed and 1000-500hPa Thickness

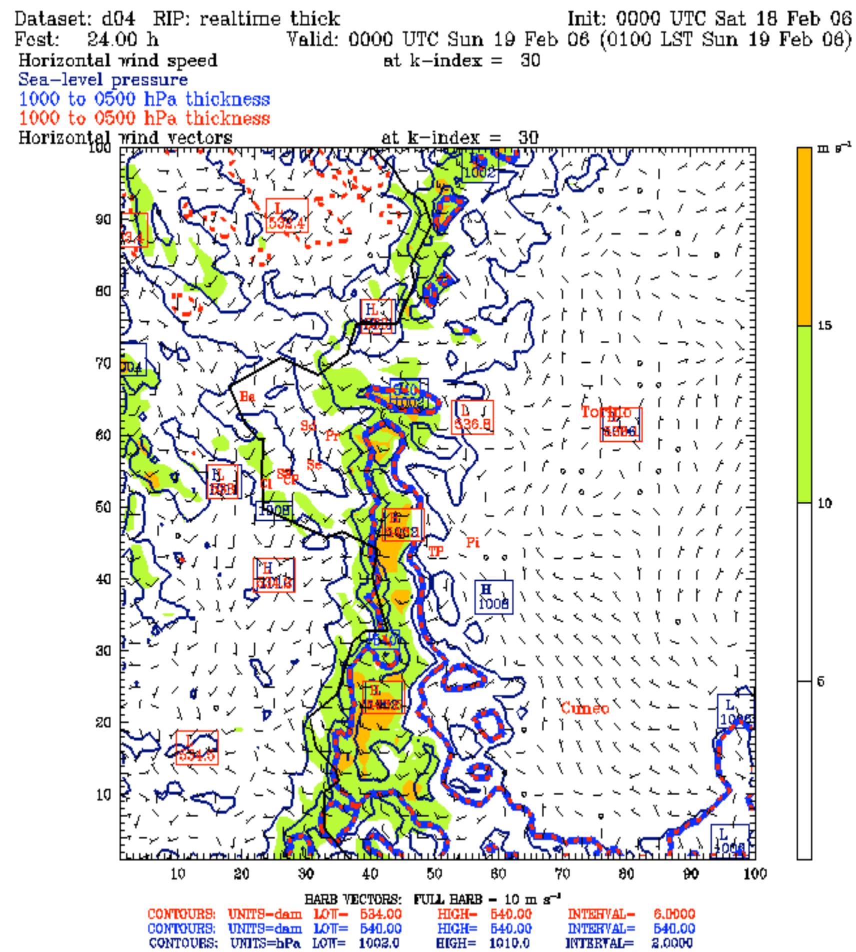
Case 3

00UTC 18 Feb - 00UTC 19 Feb
Precip in Mountains

MM5



WRF2.2



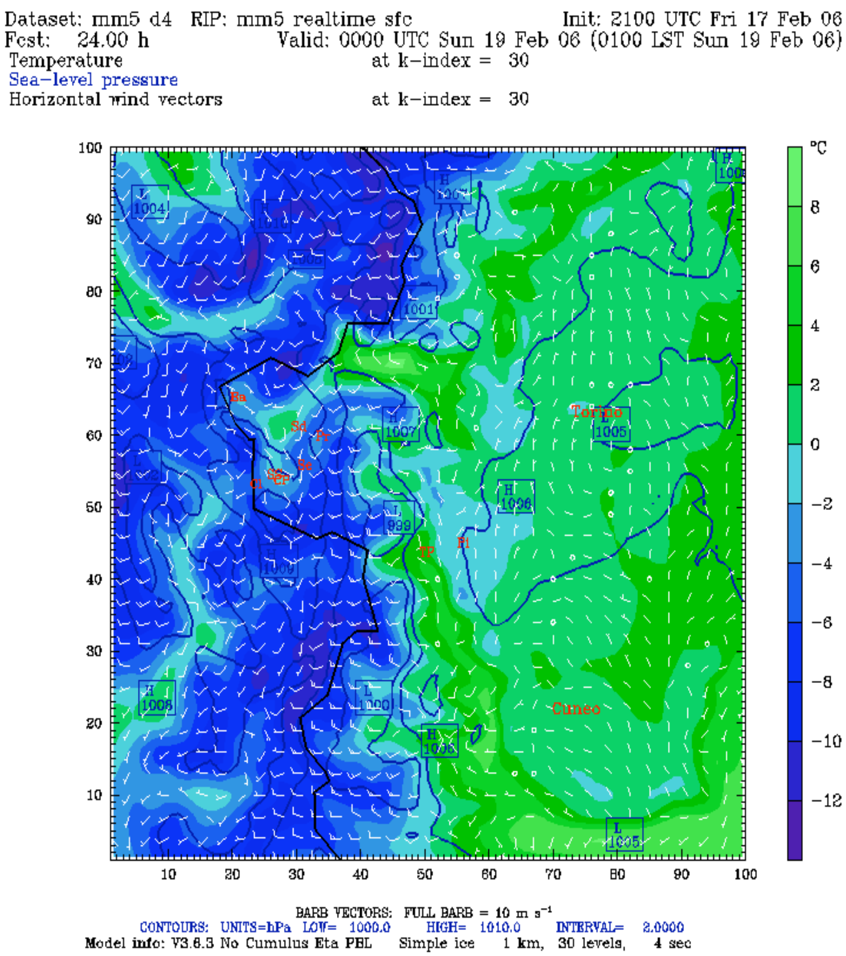
Wind Speed and 1000-500hPa Thickness

Case 3

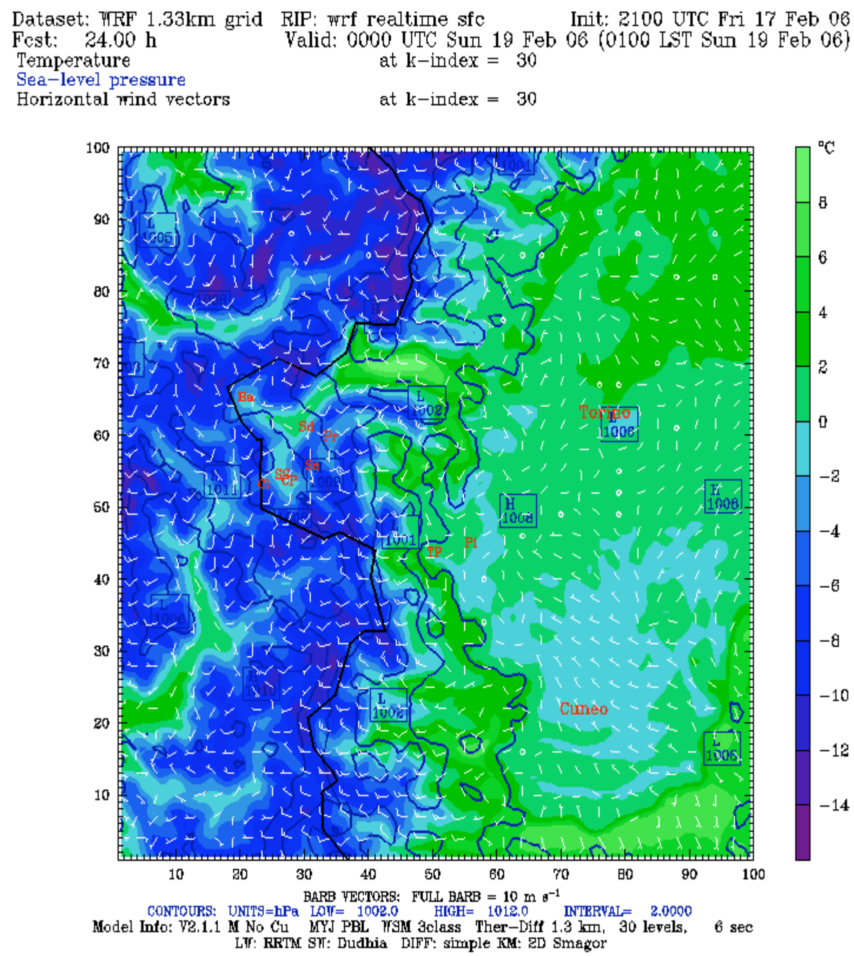
00UTC 18 Feb - 00UTC 19 Feb

Precip in Mountains

MM5



WRF2.1



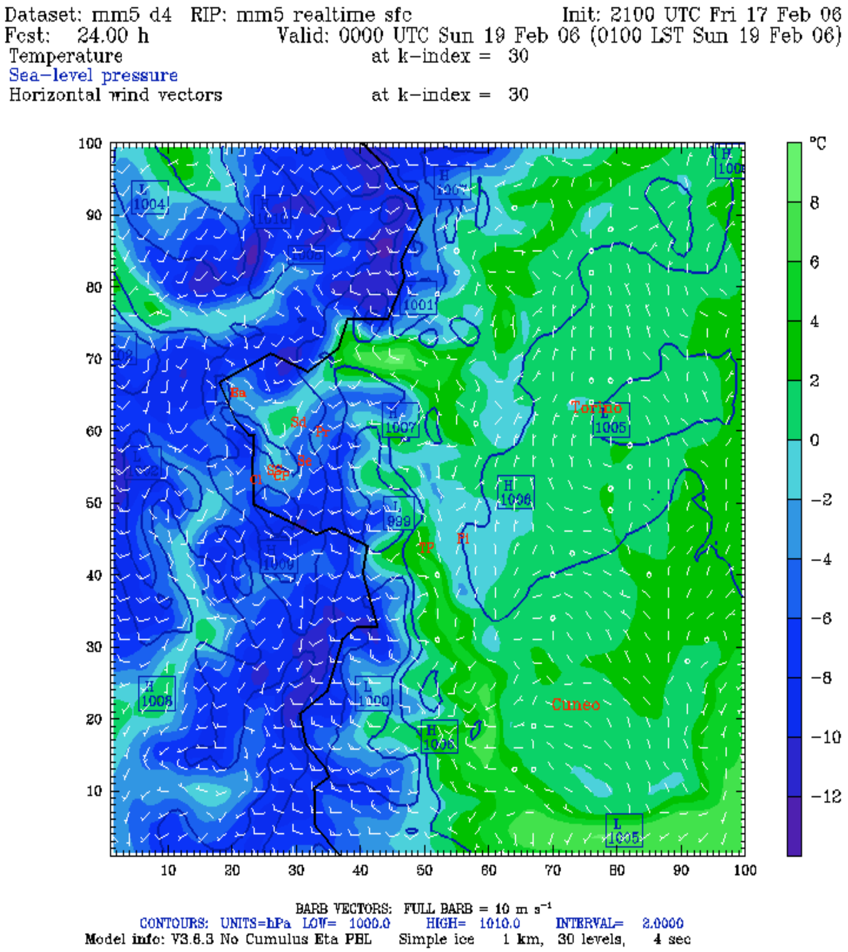
Surface Layer Temperature

Case 3

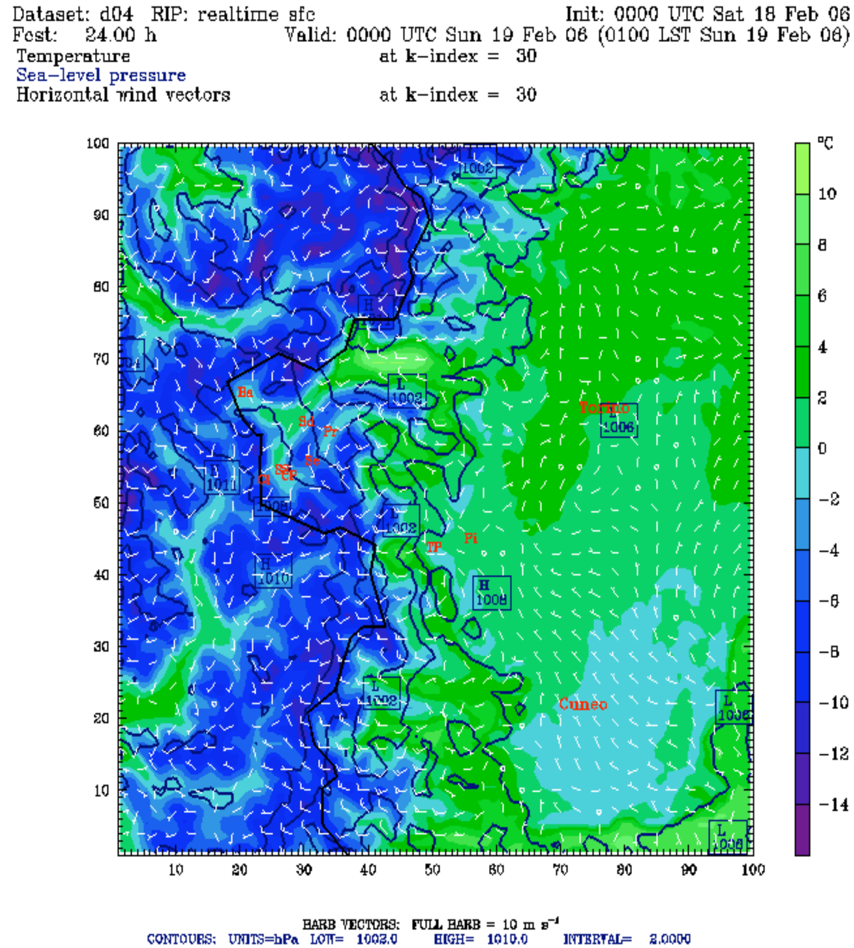
00UTC 18 Feb - 00UTC 19 Feb

Precip in Mountains

MM5



WRF2.2



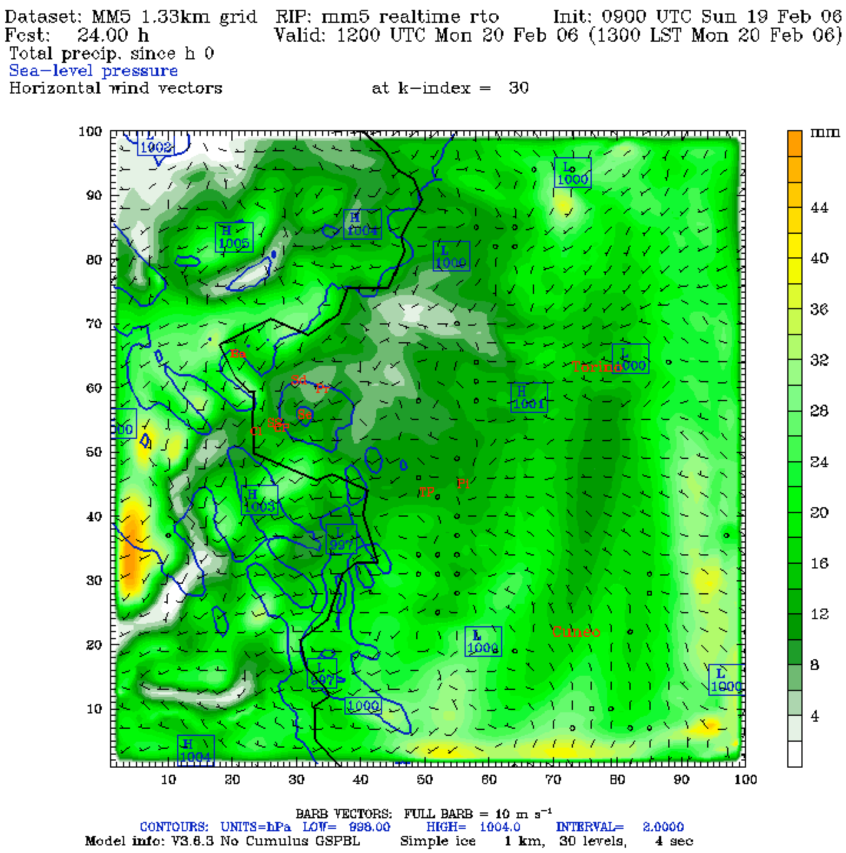
Surface Layer Temperature

Case 4

12UTC 19 Feb - 12UTC 20 Feb

Precip in Mountains and on Plains

Realtime MM5 OBS



ARPA Piemonte - The weather and snow service at the Games

Weather data belong to Arpa Piemonte. Use allowed mentioning the source.

Data observed in the single venues: last update on 20/02/2006 at 14:00 local time

Venues	Sky	Temp.(°C)	Umidity (%)	Wind (m/s)	Total Precipitations (mm)	Last 24h new snow (cm)	Web Cam
Pinerolo palaghiaccio		5.7	81	E 1.80	-	-	
Cesana San Sicario		0.5	60	N 1.00	-	25	
Sauze d'Oulx-Jovenceaux		4.7	62	N 1.00	-	16	
Pragelato		3.0	71	N 1.10	-	15	
Sestriere Borgata		1.3	52	SSW 1.40	-	18	
Sestriere Colle		-1.3	96	W 2.70	-	20	
Cesana Pariol		1.9	56	N 1.00	-	25	
Torino esposizioni		3.5	88	SSW 1.70	-	-	
Bardonecchia		1.8	65	W 1.20	-	18	
Pragelato Plan		3.9	48	SSE 1.30	-	15	
San Sicario Fraiteve		-0.2	59	WSW 3.90	-	25	

View of the Italian side from the French border

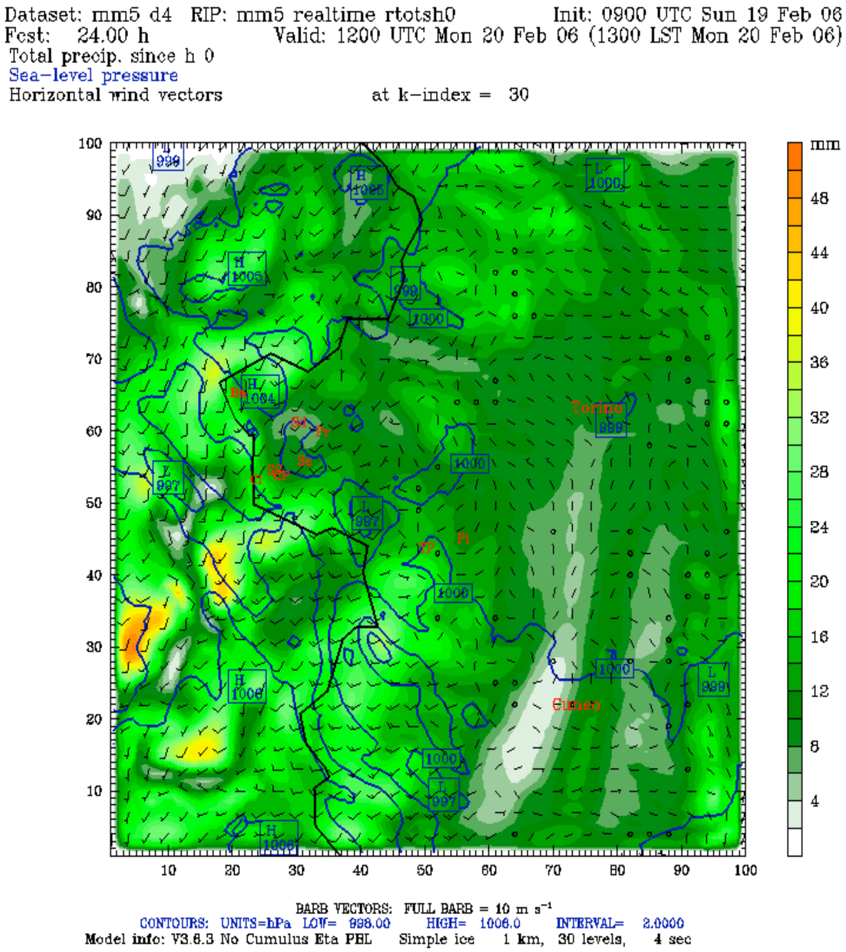
24-h Total Precip

Case 4

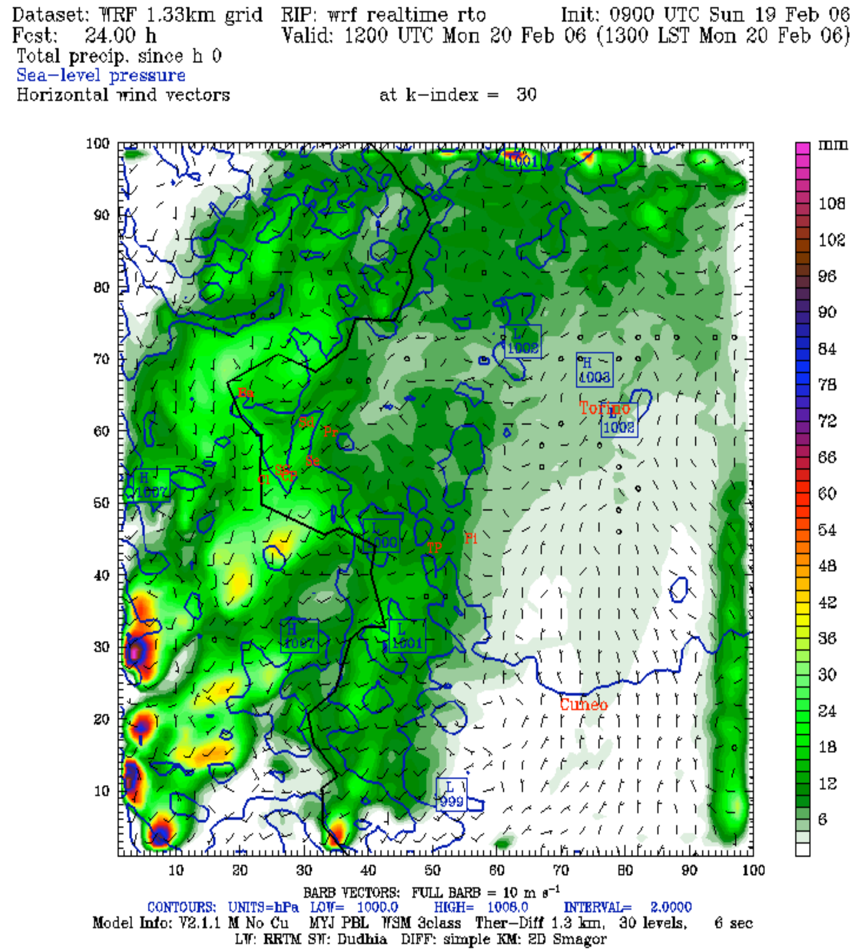
12UTC 19 Feb - 12UTC 20 Feb

Precip in Mountains and on Plains

MM5



WRF2.1



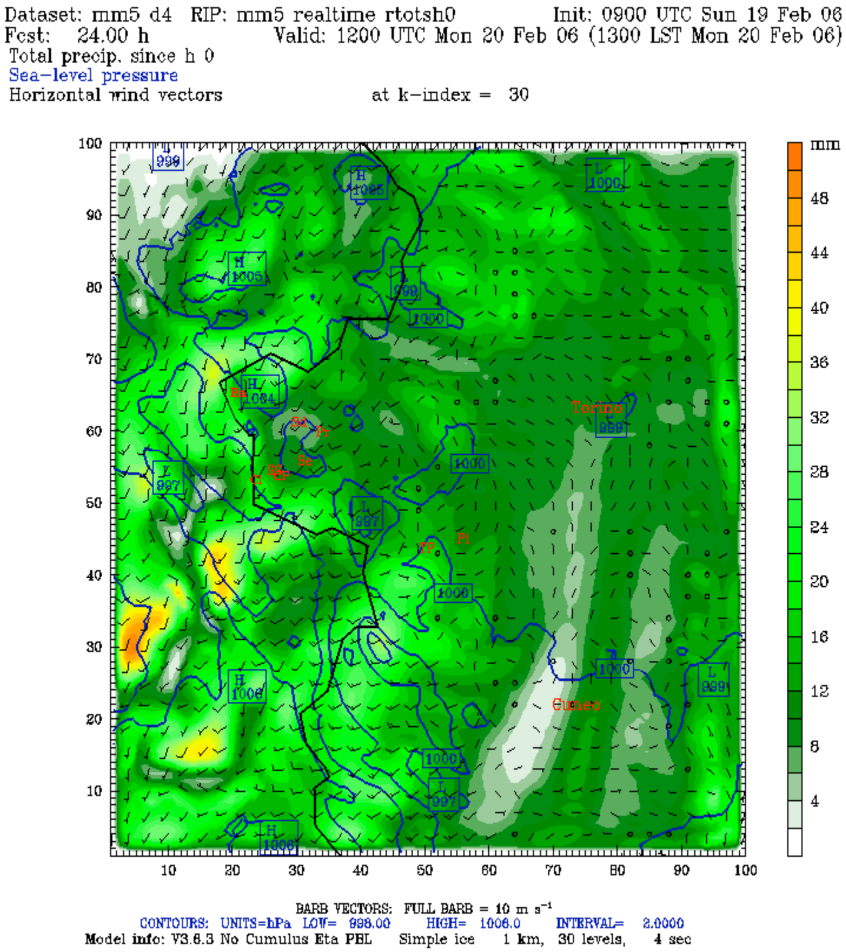
24-h Total Precip

Case 4

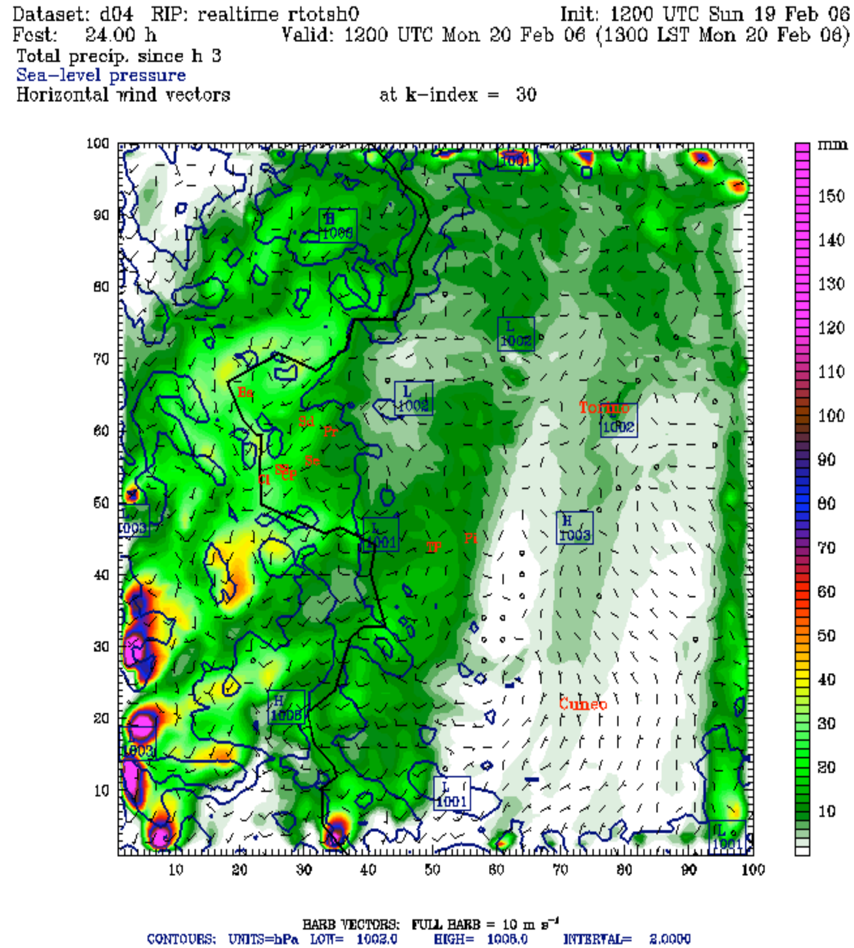
12UTC 19 Feb - 12UTC 20 Feb

Precip in Mountains and on Plains

MM5



WRF2.2



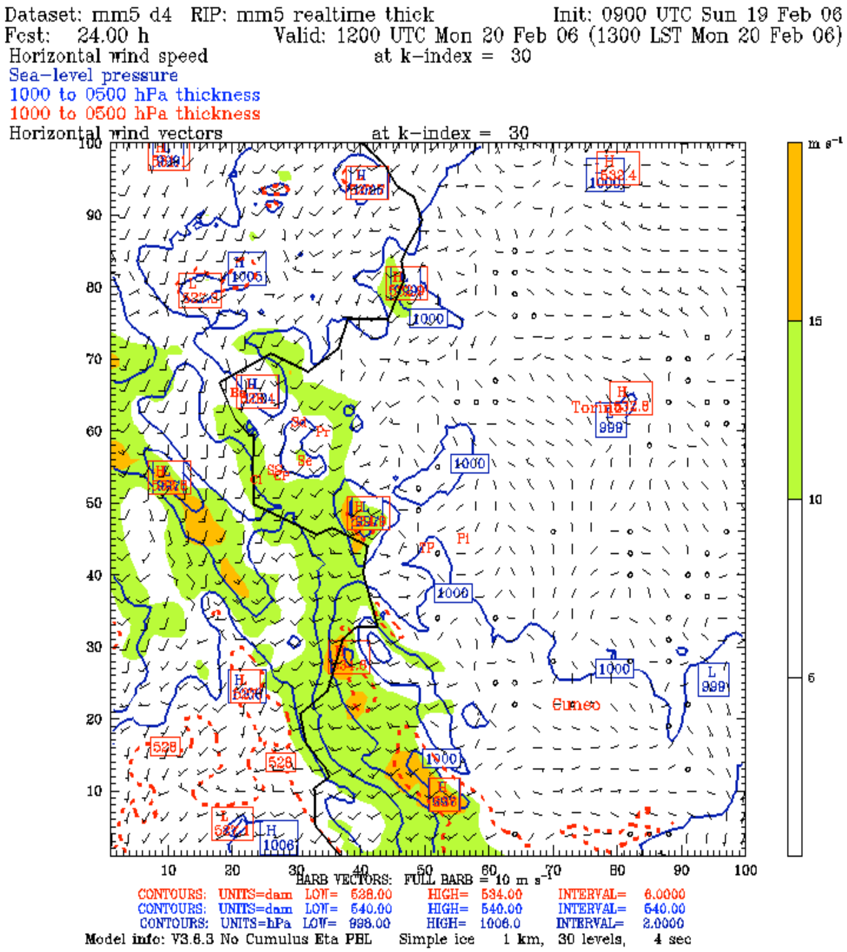
24-h Total Precip

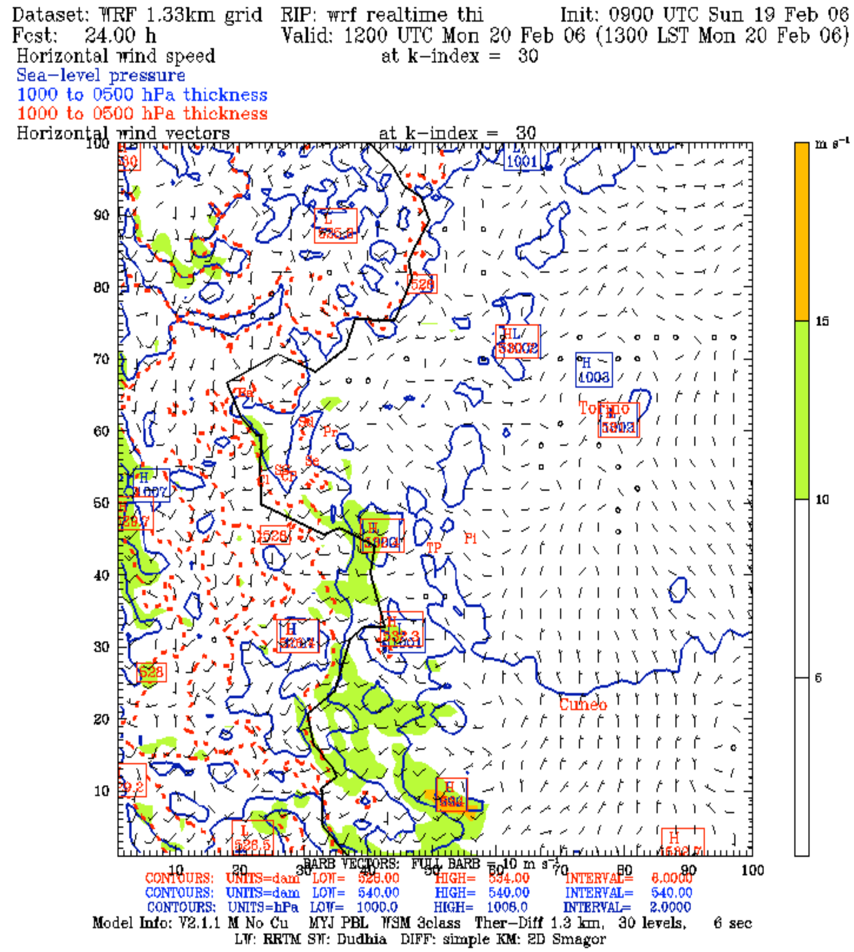
Case 4

12UTC 19 Feb - 12UTC 20 Feb

Precip in Mountains and on Plains

MM5 WRF2.1





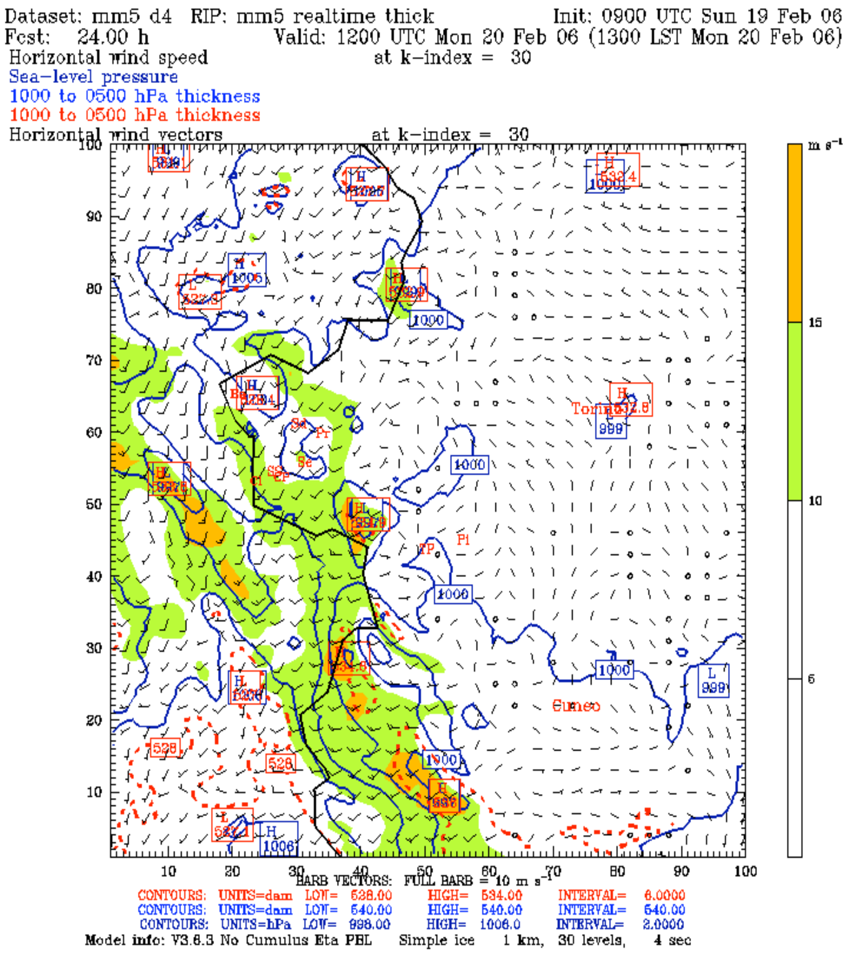
Wind Speed and 1000-500hPa Thickness

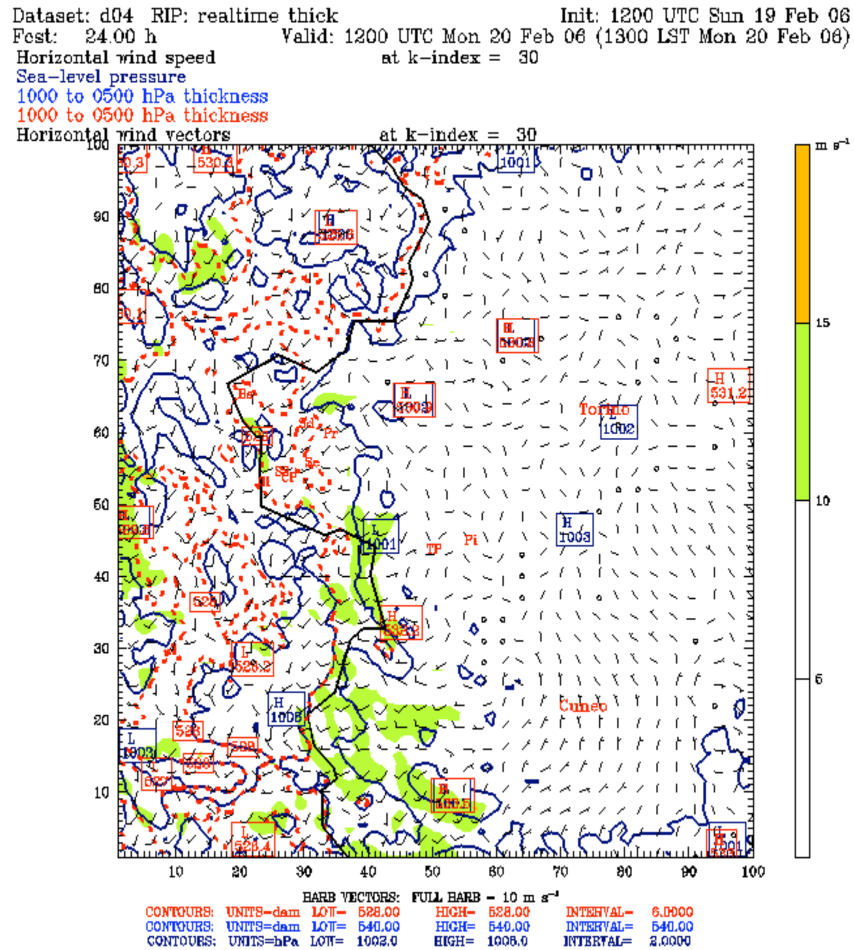
Case 4

12UTC 19 Feb - 12UTC 20 Feb

Precip in Mountains and on Plains

MM5	WRF2.2





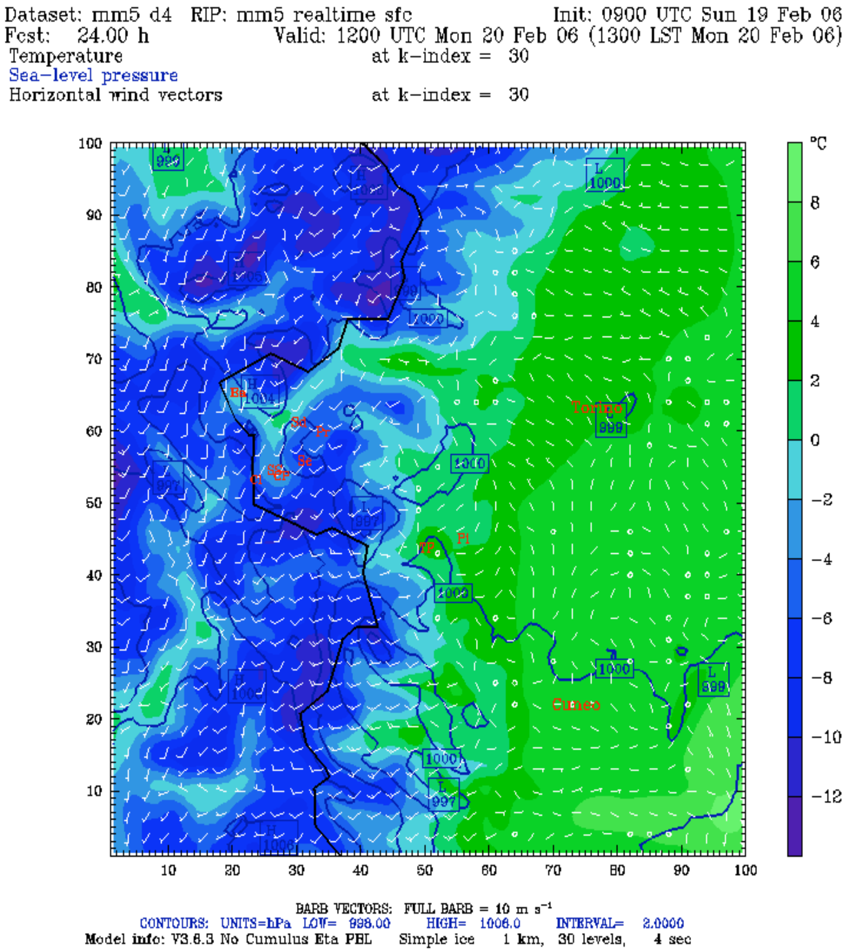
Wind Speed and 1000-500hPa Thickness

Case 4

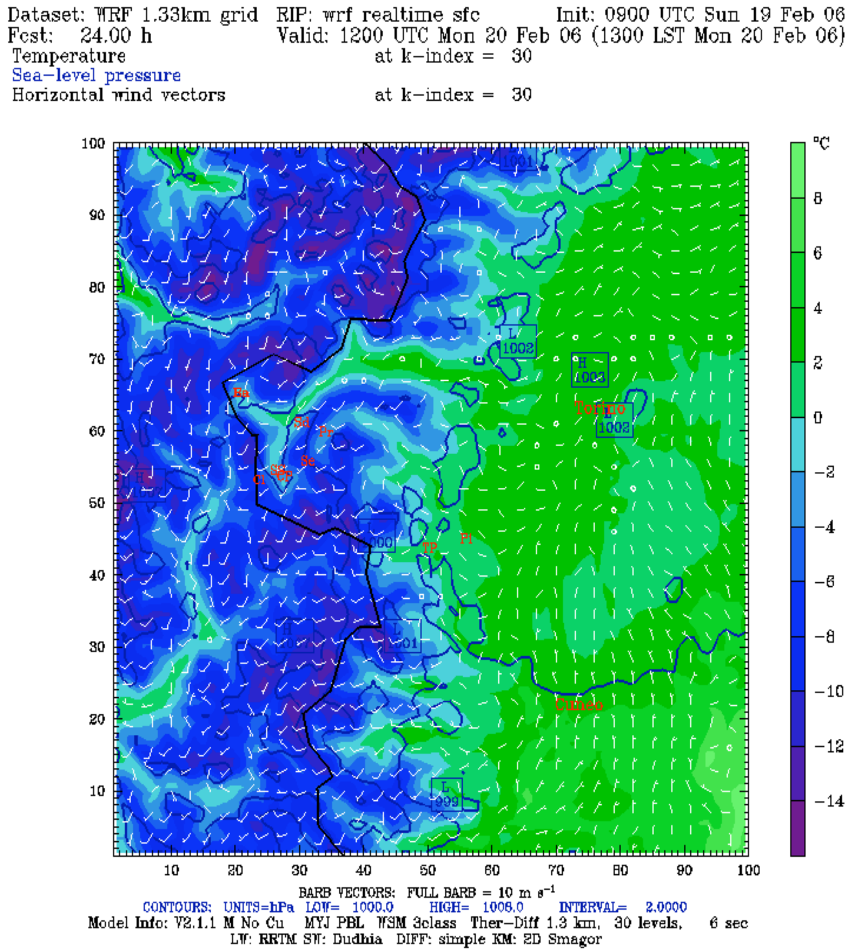
12UTC 19 Feb - 12UTC 20 Feb

Precip in Mountains and on Plains

MM5



WRF2.1



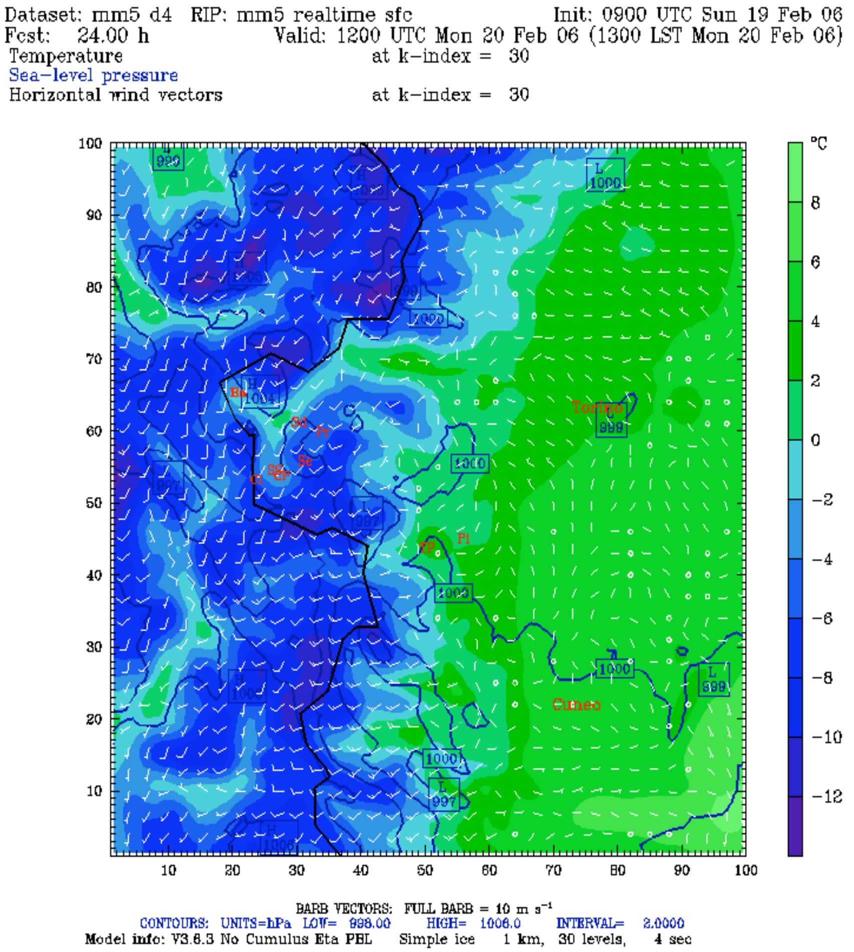
Surface Layer Temperature

Case 4

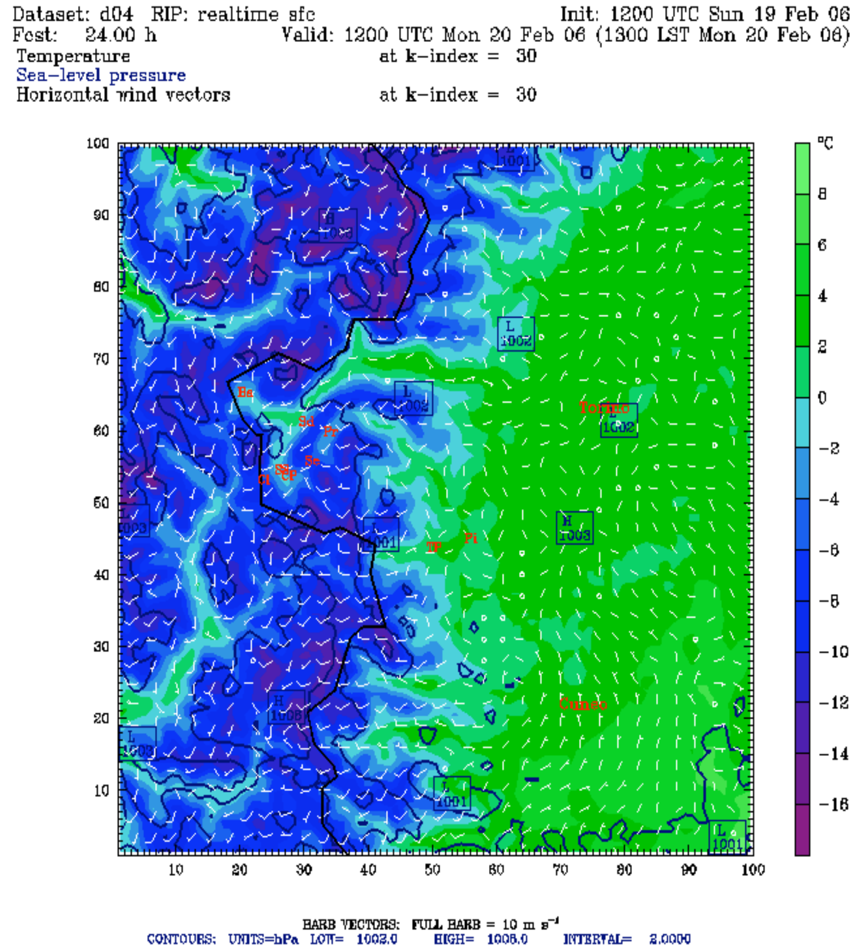
12UTC 19 Feb - 12UTC 20 Feb

Precip in Mountains and on Plains

MM5



WRF2.2



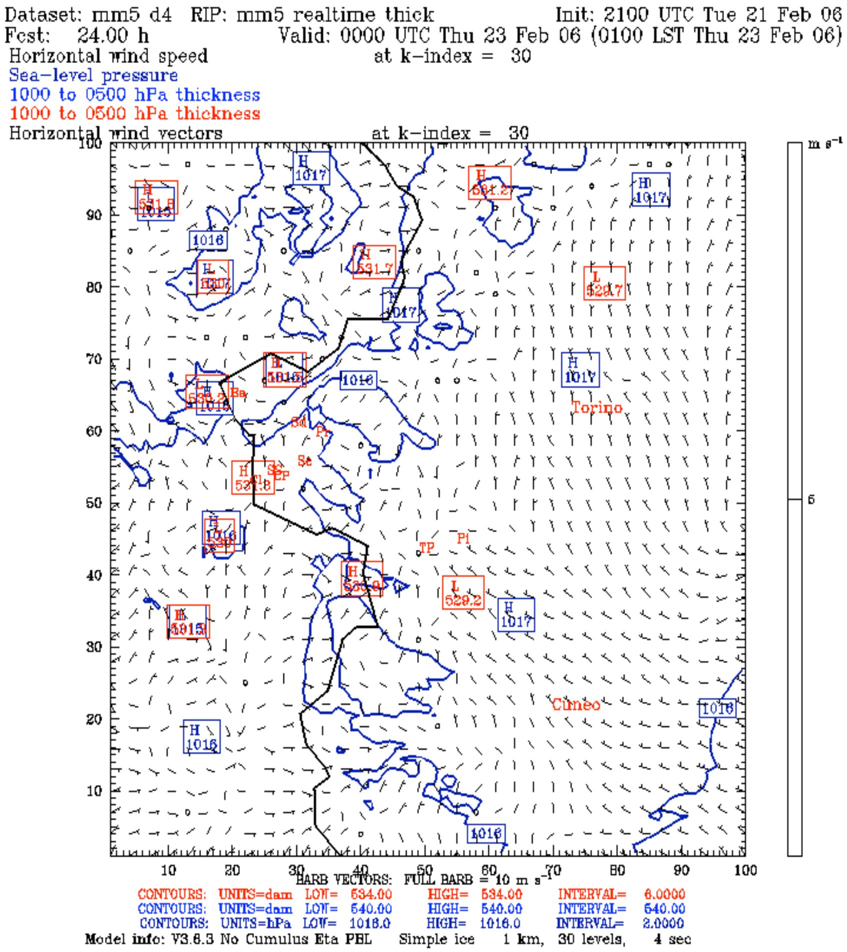
Surface Layer Temperature

Case 5

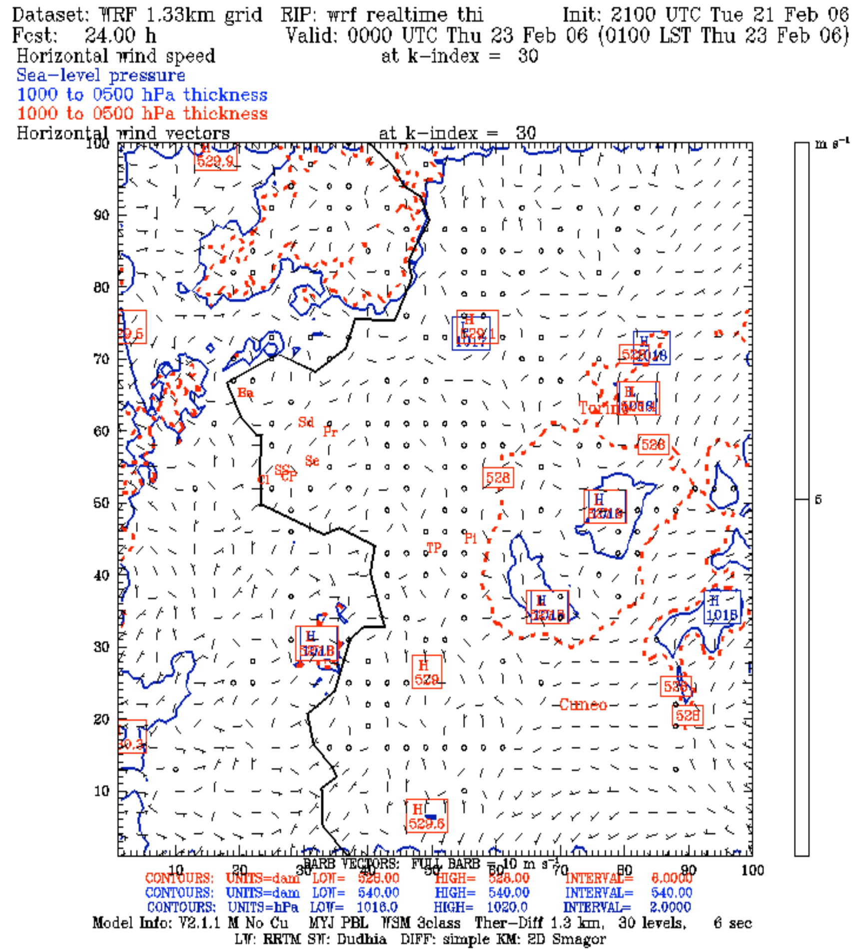
00UTC 22 Feb - 00UTC 23 Feb

Precip on Plains

MM5



WRF2.1



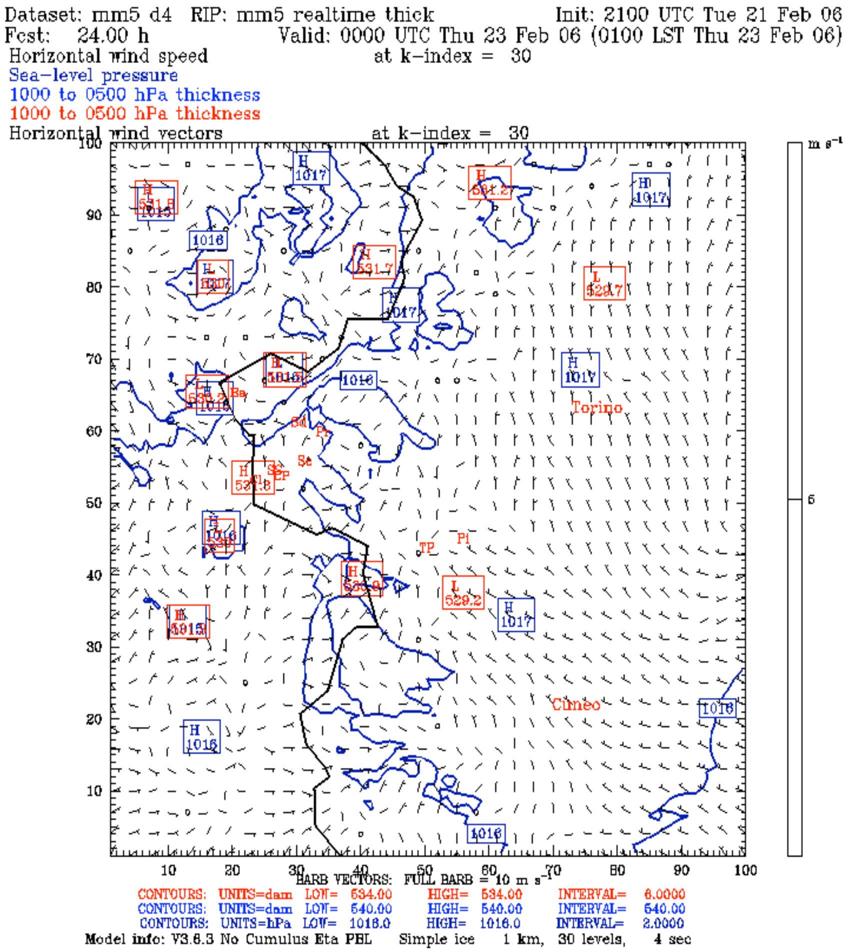
Wind Speed and 1000-500hPa Thickness

Case 5

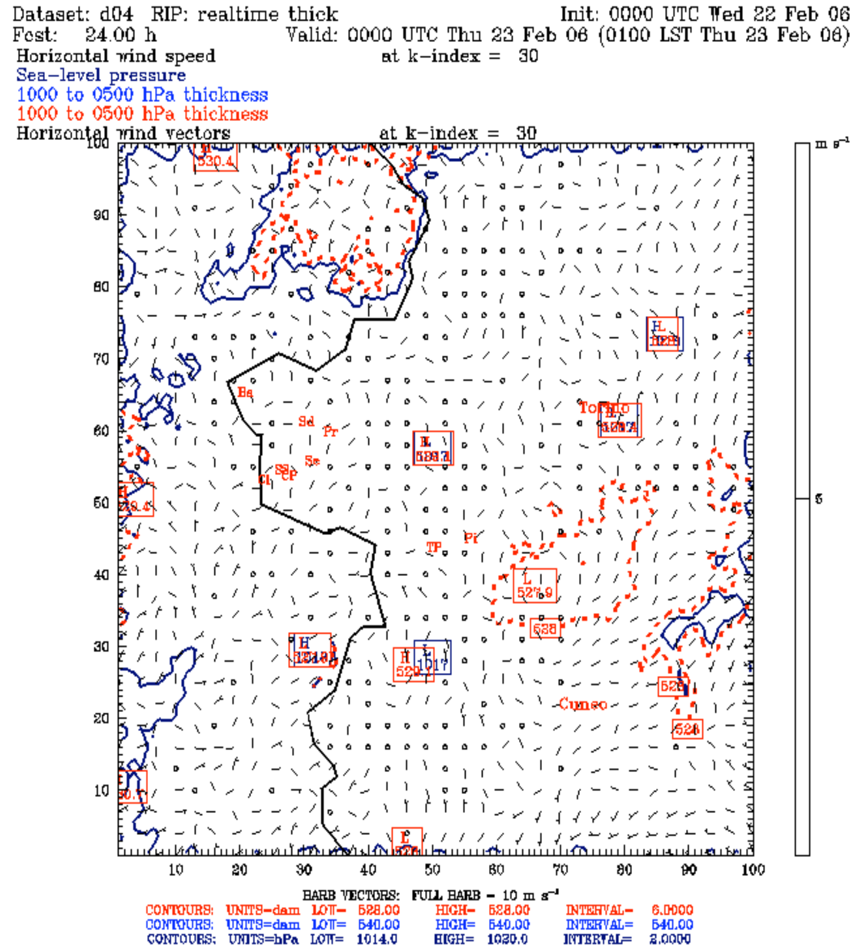
00UTC 22 Feb - 00UTC 23 Feb

Precip on Plains

MM5



WRF2.2



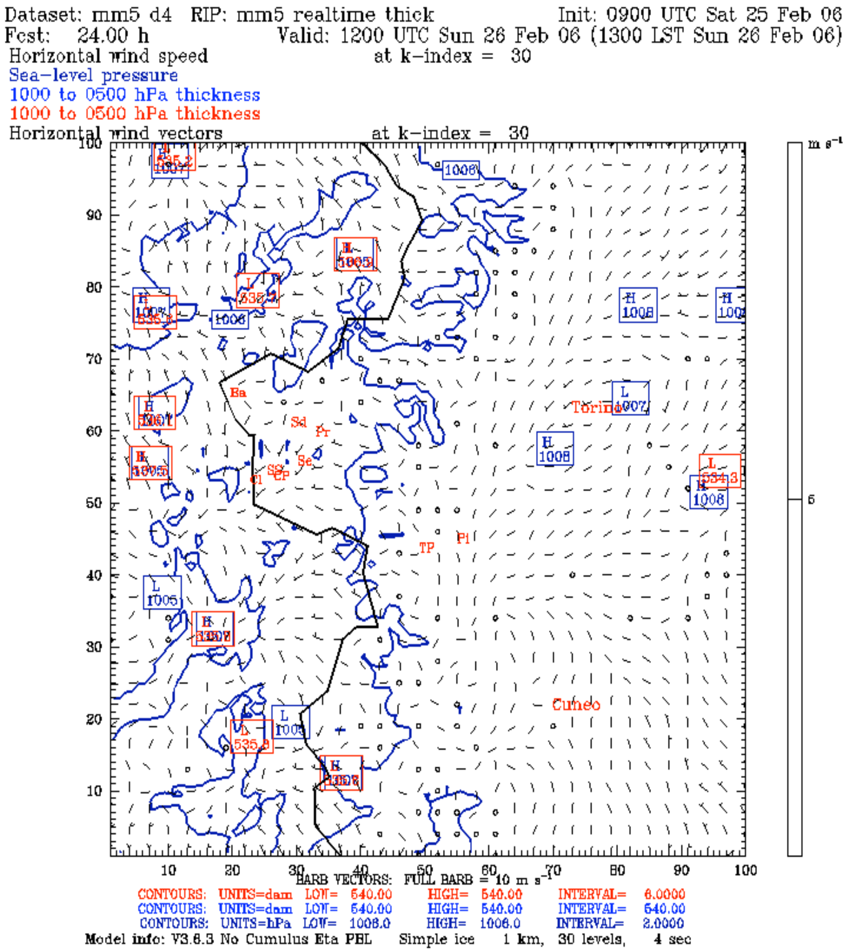
Wind Speed and 1000-500hPa Thickness

Case 6

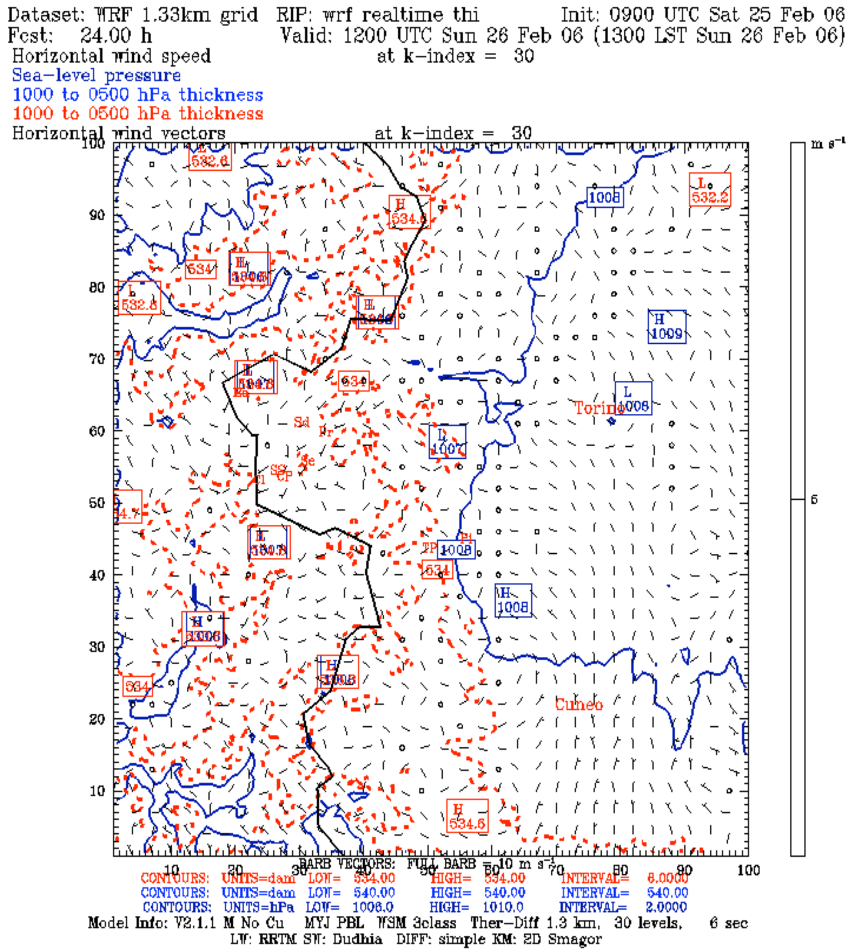
12UTC 25 Feb - 12UTC 26 Feb

Light Precip in Mountains and on Plains

MM5



WRF2.1



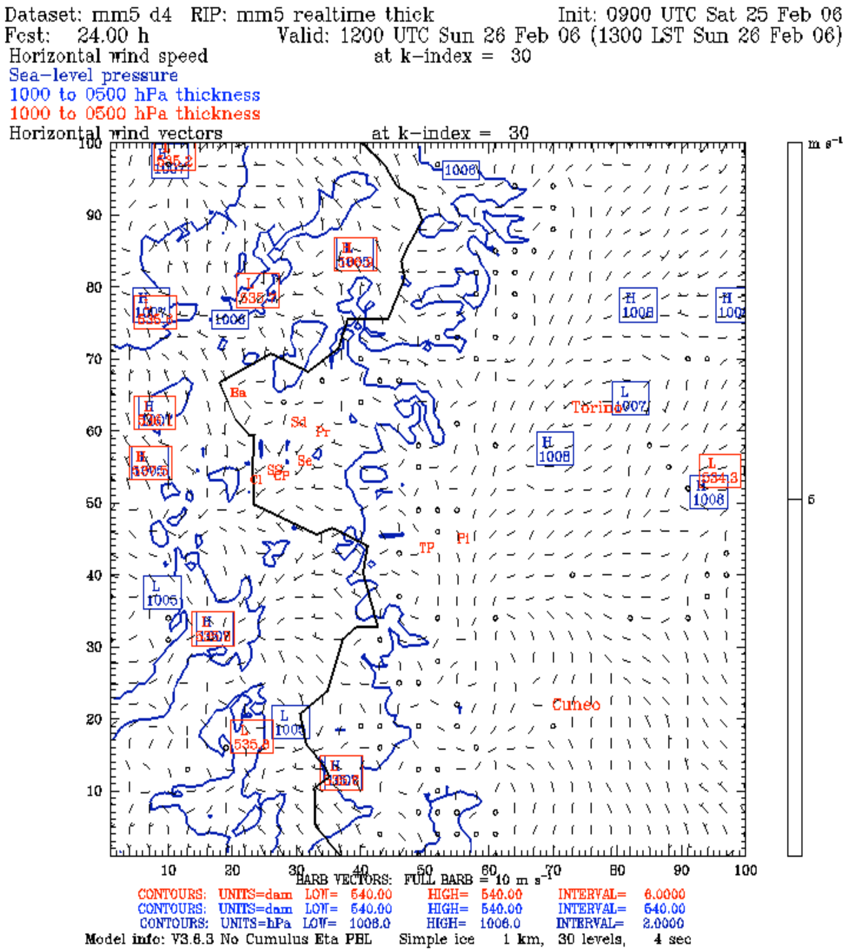
Wind Speed and 1000-500hPa Thickness

Case 6

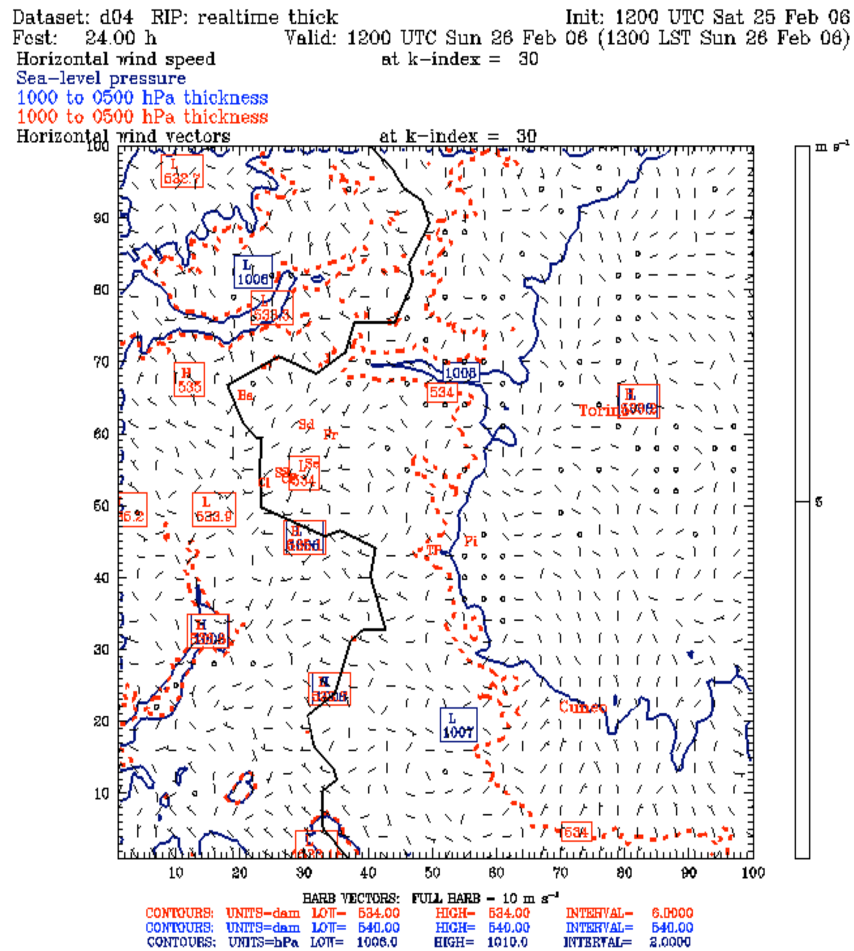
12UTC 25 Feb - 12UTC 26 Feb

Light Precip in Mountains and on Plains

MM5



WRF2.2



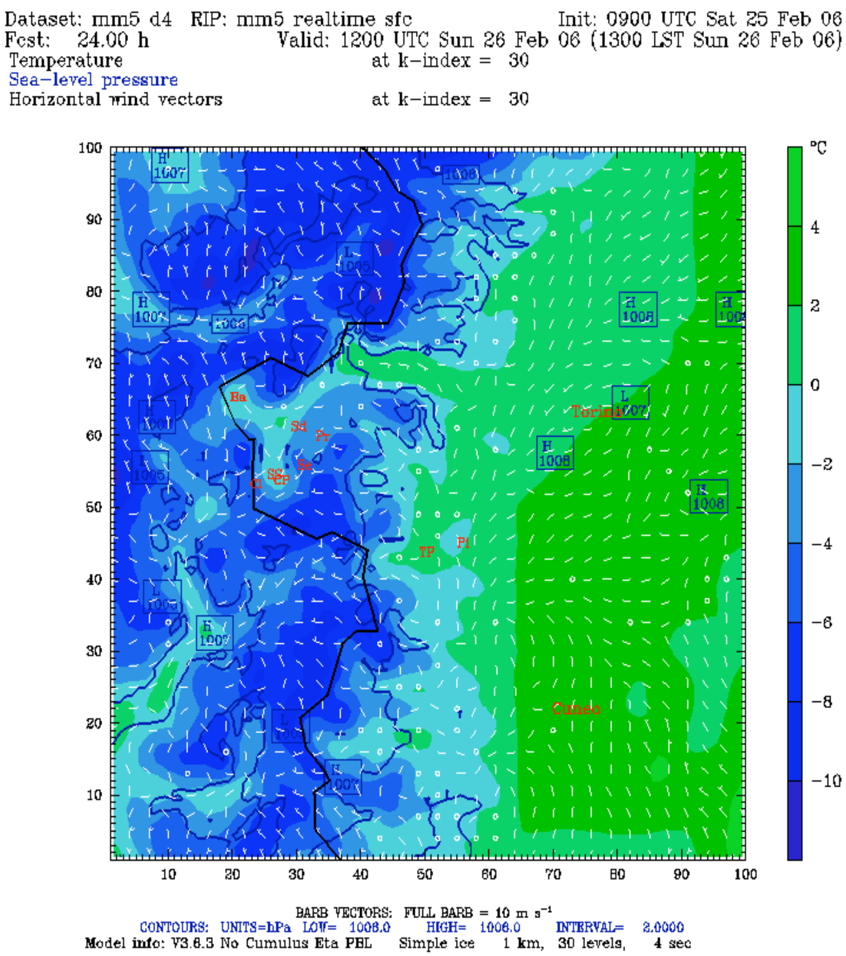
Wind Speed and 1000-500hPa Thickness

Case 6

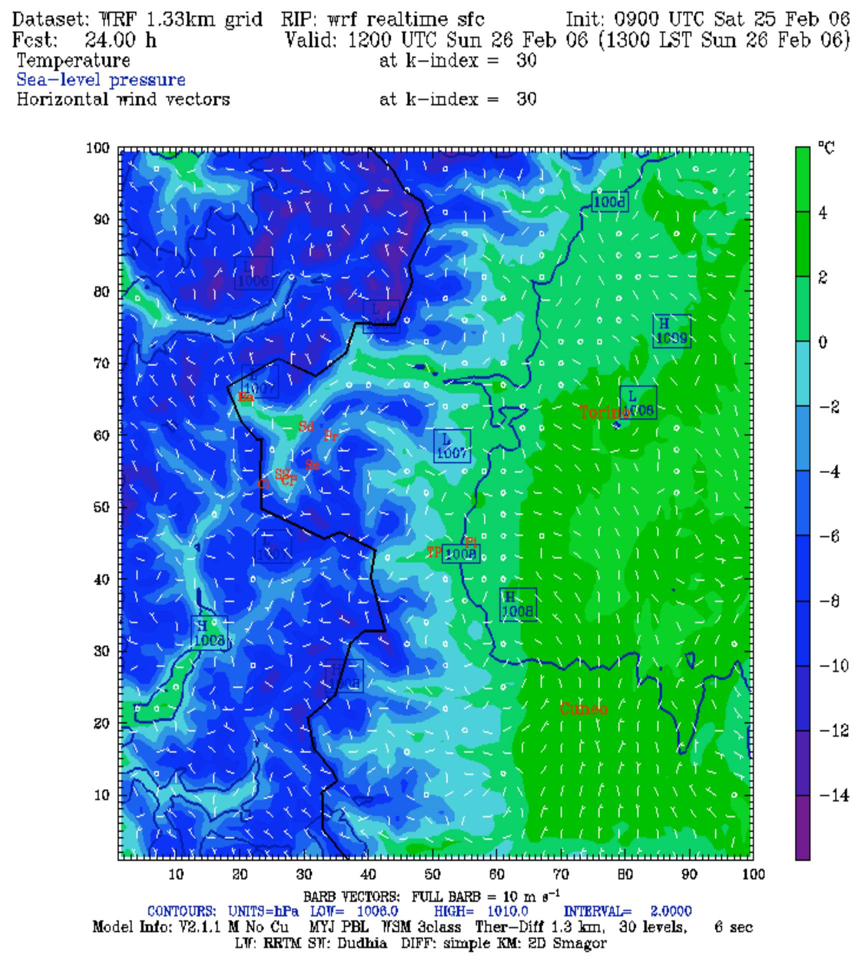
12UTC 25 Feb - 12UTC 26 Feb

Light Precip in Mountains and on Plains

MM5



WRF2.1



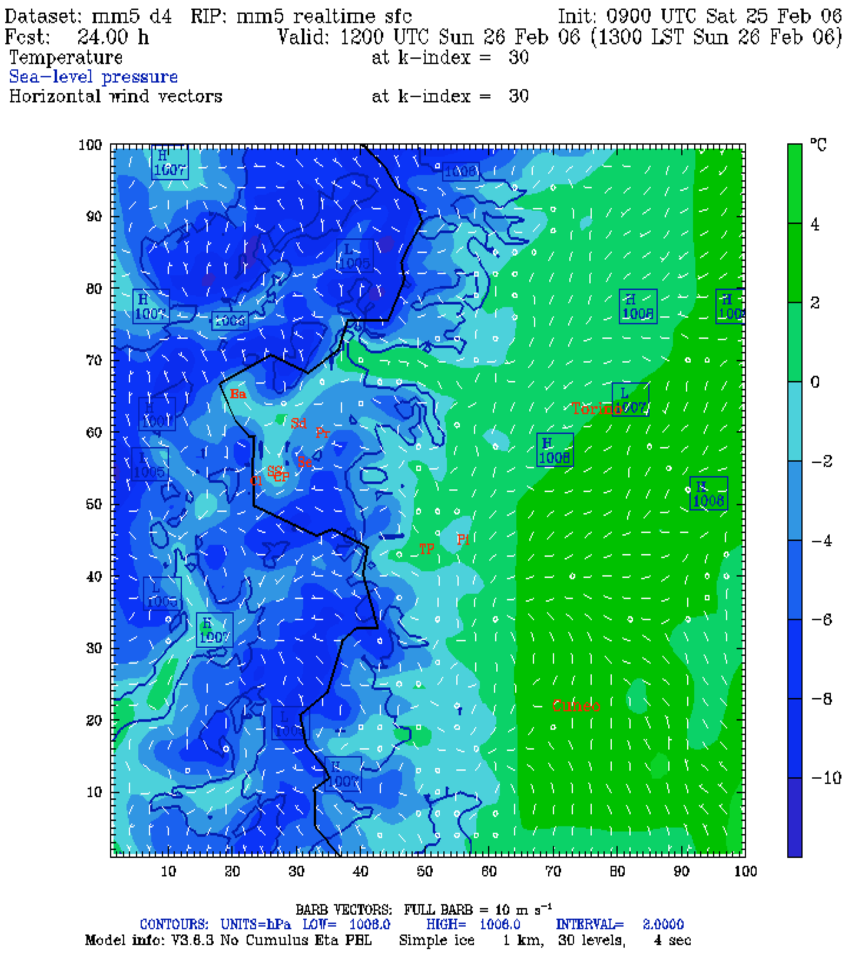
Surface Layer Temperature

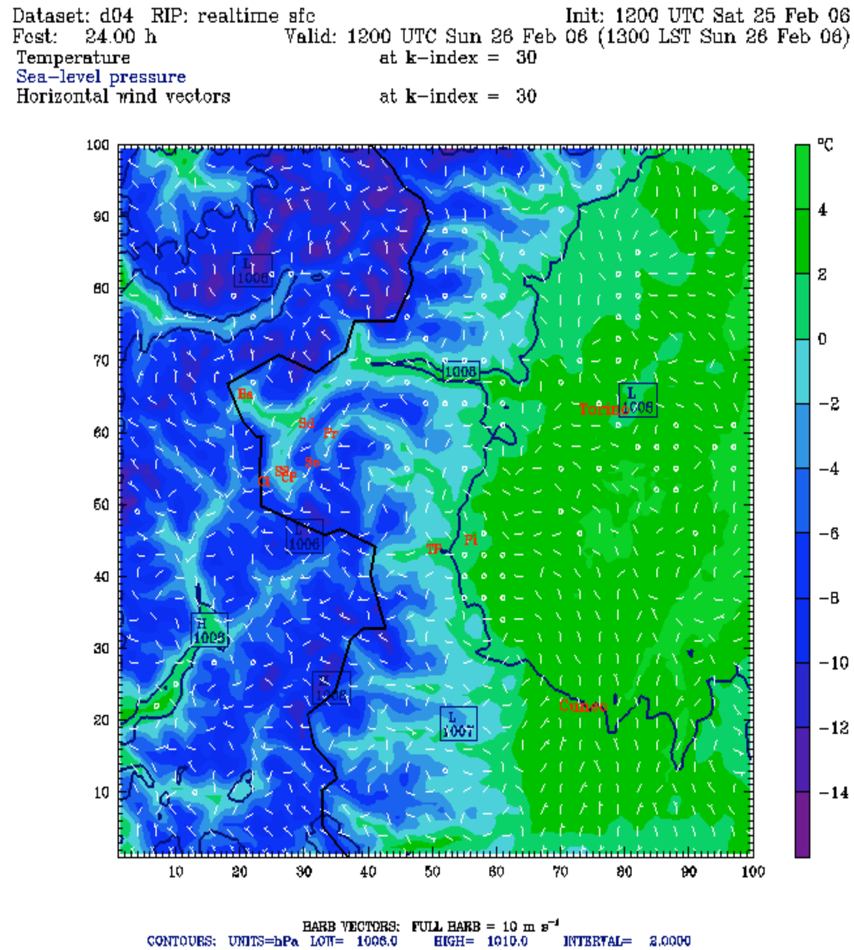
Case 6

12UTC 25 Feb - 12UTC 26 Feb

Light Precip in Mountains and on Plains

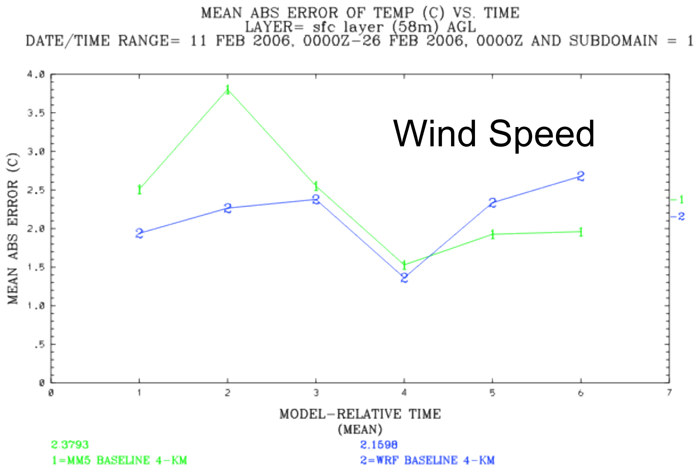
MM5 | WRF2.2

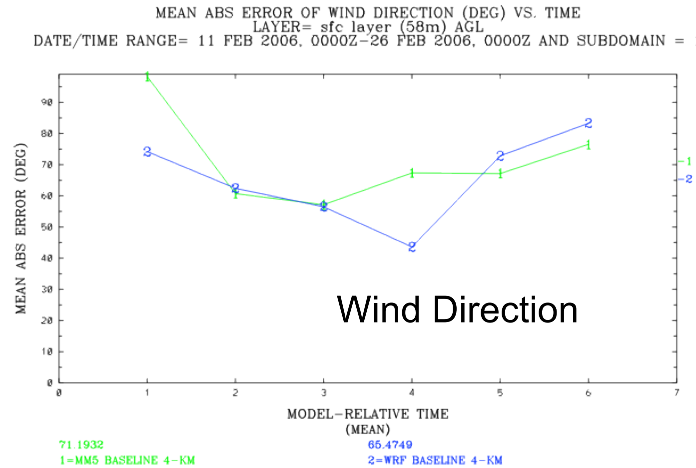


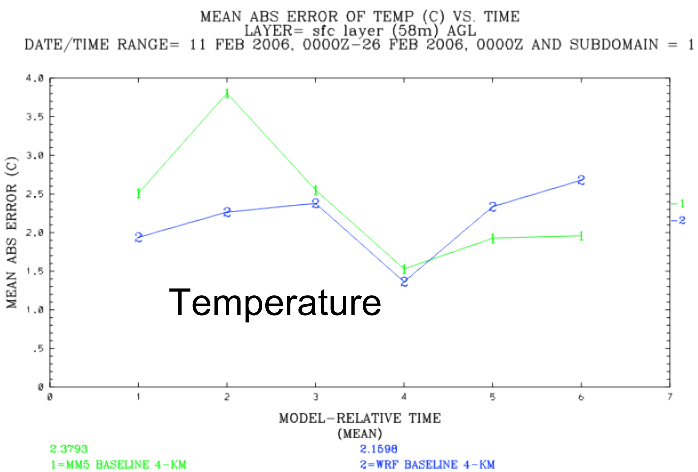


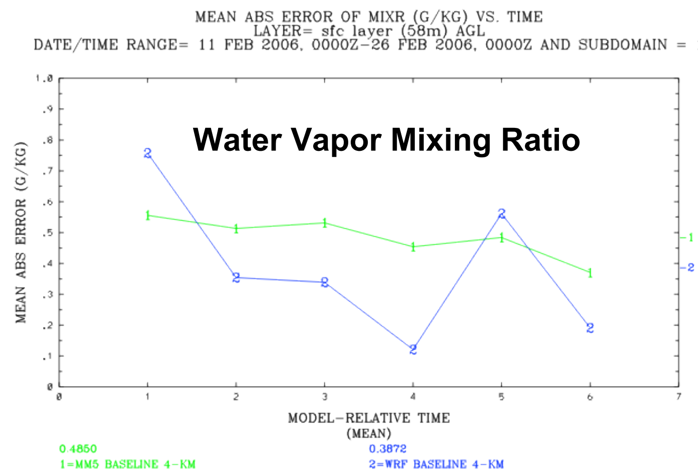
Surface Layer Temperature

4-km Grid Surface-Layer MAE

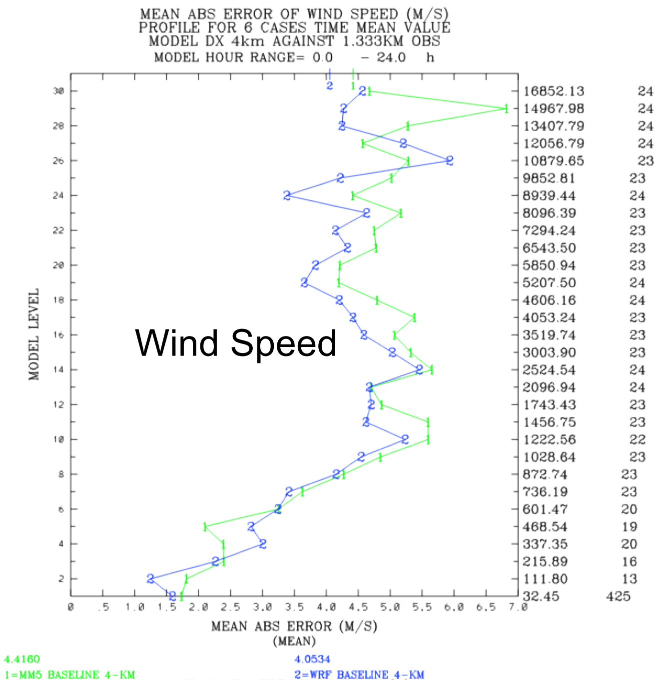




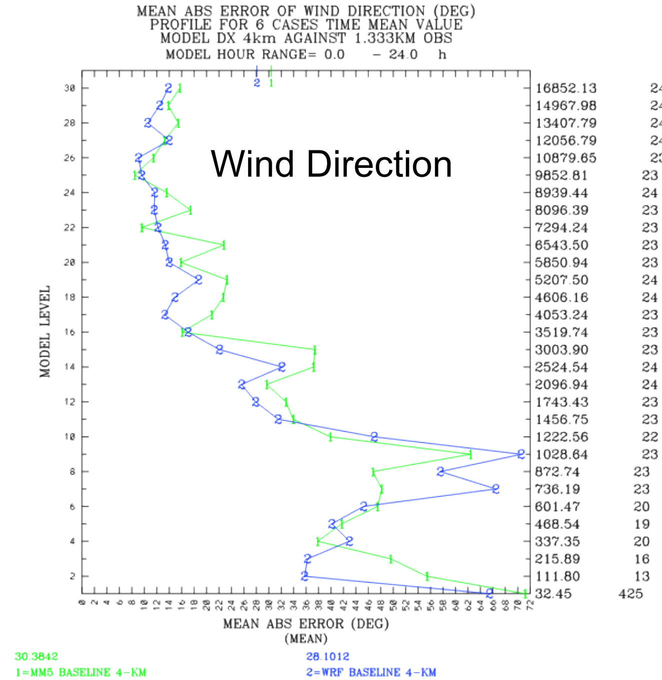




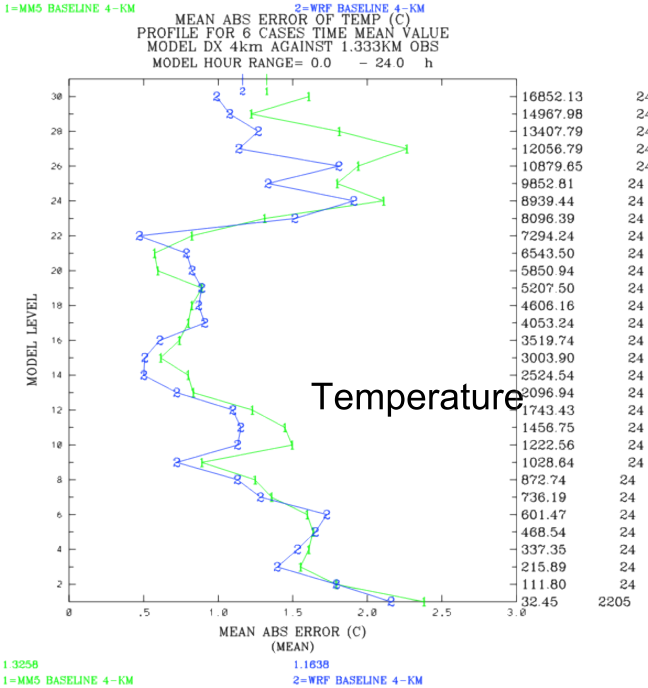
MAE 4-km



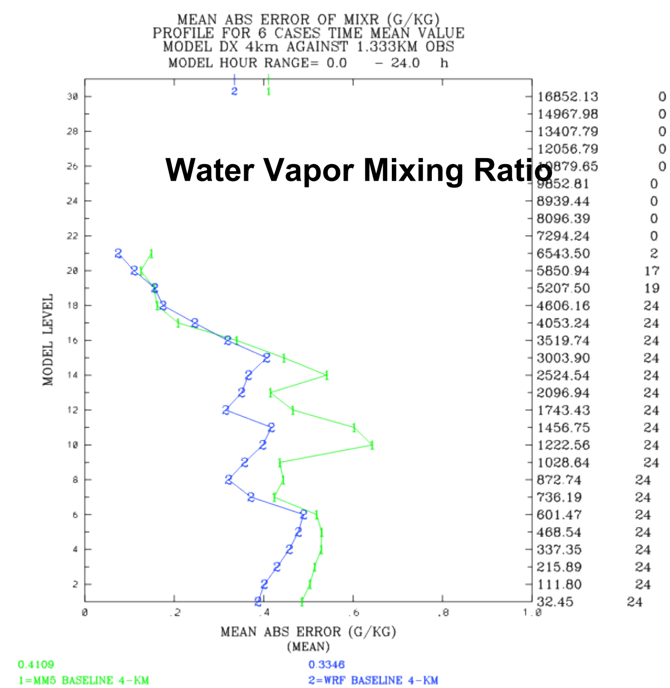
MEAN ABS ERROR OF WIND SPEED (M/S)
PROFILE FOR 6 CASES TIME MEAN VALUE
MODEL DX 4km AGAINST 1.333KM OBS
MODEL HOUR RANGE= 0.0 - 24.0 h
Wind Speed
MODEL LEVEL
MEAN ABS ERROR (M/S)
(MEAN)
4.4160
1=MM5 BASELINE 4-KM
4.0534
2=WRF BASELINE 4-KM



MEAN ABS ERROR OF WIND DIRECTION (DEG)
PROFILE FOR 6 CASES TIME MEAN VALUE
MODEL DX 4km AGAINST 1.333KM OBS
MODEL HOUR RANGE= 0.0 - 24.0 h
Wind Direction
MODEL LEVEL
MEAN ABS ERROR (DEG)
(MEAN)
30.3842
1=MM5 BASELINE 4-KM
28.1012
2=WRF BASELINE 4-KM



MEAN ABS ERROR OF TEMP (C)
PROFILE FOR 6 CASES TIME MEAN VALUE
MODEL DX 4km AGAINST 1.333KM OBS
MODEL HOUR RANGE= 0.0 - 24.0 h
Temperature
MODEL LEVEL
MEAN ABS ERROR (C)
(MEAN)
1.3258
1=MM5 BASELINE 4-KM
1.1638
2=WRF BASELINE 4-KM



MEAN ABS ERROR OF MIXR (G/KG)
PROFILE FOR 6 CASES TIME MEAN VALUE
MODEL DX 4km AGAINST 1.333KM OBS
MODEL HOUR RANGE= 0.0 - 24.0 h
Water Vapor Mixing Ratio
MODEL LEVEL
MEAN ABS ERROR (G/KG)
(MEAN)
0.4109
1=MM5 BASELINE 4-KM
0.3346
2=WRF BASELINE 4-KM