4.10 An Operational Coastal Mesoscale Forecast System.

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1. INTRODUCTION

WeatherFlow provides operational coastal weather and wind forecasts for a variety of clients, including windsurfers, kitesurfers, and sailors. This unique client base demands high resolution meso- and microscale wind forecasting that generic boat and beach forecasts cannot provide. In response to this need, WeatherFlow has developed an exclusive, coastal mesoscale forecast system.

Essentially, this forecast system is the culmination of high-quality coastal mesonet data, a mesoscale numeric model, knowledge-based post processing, and a team of experienced meteorologists specifically focused on high resolution wind forecasting. Short term forecasts are provided three times daily and extended forecasts twice daily. Forecast regions include Southern California, the San Francisco Bay area, the Columbia River Gorge, and much of the East Coast from the Outer Banks northward through Massachusetts.

2.1 RAMS FORECAST MODEL

WeatherFlow operates its own version of RAMS (Regional Atmospheric Modeling System) over several domains that cover much of the coastal United States. RAMS is a state-of-the-art, multipurpose numerical prediction model designed to simulate atmospheric circulations spanning in size from hemispheric scales down to large eddy simulations (LES) of the planetary boundary layer (Tremback and Walko). RAMS spatial resolution of up to 2 kilometers lends itself well to the high resolution needs of WeatherFlow's operational forecast system.

Operational use began in the spring of 2004 with two large domains, one for the east coast at 36km and one for the west coast at 32km. Model runs are generated twice daily at 00 and 12 UTC out to 36 hours. Nested, higher resolution grids are run within the two main domains for San Francisco Bay, Chesapeake Bay, and Cape Cod (See Figures' 1 through 3). [1]

Figure 1. New England/Cape Cod-4km

Figure 2. Chesapeake Bay-4km

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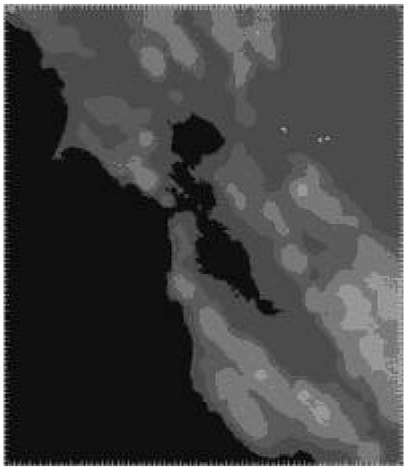

Figure 3. San Francisco Bay-2km

2.2 WEATHERFLOW MESONET

The key to the WeatherFlow forecast system is the interaction between RAMS and the company's national coastal mesonet. The network is continually expanding, with 240 sites as of November 2004 in 21 states including Hawaii and three providences in Canada (see Figure 4).

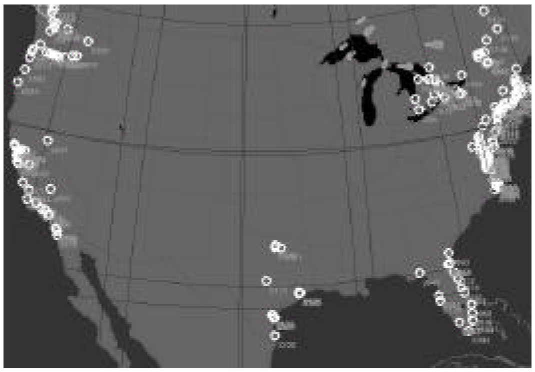

Figure 4. National Coastal Mesonet

The unique aspect of the WeatherFlow mesonet is that sites are installed in locations as a function meteorological need. That is, locations are currently not well represented as a function of the closest existing data collection source representative of the climate at the proposed site. Several factors are taken into account to determine the exact placement of mesonet sensors, from topography to climatology to existing data sources. WeatherFlow's engineering staff matches the sensor suite, temporal resolution, and means of communication to each specific installation.

At the root of WeatherFlow's network lies a proprietary NextGen data logger and integrated network capability. The NextGen station is specifically engineered to minimize data collection costs and to adapt to variable applications. Administrative control of each data logger can be adjusted on the fly without requiring changes to field software.

3. MODEL/MESONET SYSTEM

The mesonet/model relationship is tightly integrated and be broken into 4 components: assimilation, knowledge-based post processing, statistical nudging, and verification.

3. 1 ASSIMILATION – The full suite of from each mesonet location data are added to surface fields. Air temperature and barometric pressure information at and over the land/sea interface important can prove quite instrumental in contributing to many mesoscale features such as the potential onset of sea and land breezes. Although of lesser contribution of the entire duration of a model run, wind data itself has been shown improve forecast output in the short-term (i.e., first few hours of a forecast output cycle).

3.2 AUTOMATED KNOWLEDGE-BASED POST-PROCESSING

WeatherFlow's proprietary Expert System is a set of post-processing tests performed on model data. The system capitalizes over 10 year's worth of the forecast team's experience. That is, intimate, learned knowledge of meso- and microscale processes and how they affect coastal winds. In this way, mesoscale patterns from numeric models are further refined and adjusted into a microscale forecast based on small scale factors such as coastal orientation and seabreezes. All tests are computed automatically and are at the forecaster's disposal to provide yet another tool to aid in preparing forecasts. Among the separate modules currently the overall post-processing scheme include: sea breeze, mechanical mixing, dissimilar grid cell correction for on versus offshore winds, dissimilar grid cell roughness correction, precipitation-altering, and tidal sea breeze enhancement.

3.3 REAL-TIME STATISTICAL NUDGING

After the model cycle is complete, and the post-processing scheme is applied. The resultant forecast output are saved for verification purposes, and pushed to a final staging area where wind values are compared to current observations. If the comparisons are "different" a final nudging algorithm is applied to continually adjust forecasted values closer to observed values. The simple scheme is as follows:

Adjusted fx = w * observed + (1-w) * forecast,

For 10 time steps within 2 hour period

w=.1+0.9*(120-timediff)/110; 10<=timediff<=120

Obs	Obs Time	FX	"nudge"	FX time
8.69	4:25PM	10	+0	6:00
6.95	4:56PM	10	-0	6:00
8.69	5:16PM	10	+0	6:00
4.34	5:27PM	10	-4	6:00

This insures that the adjustment factor is more heavily weighted towards the forecast value when the observation time is close to the valid time of the forecast. As time progresses beyond the valid forecast time, the adjustment factor is weighed more heavily towards the observation so that the forecast is nudged closer to the observation (See figure 5). The thin line represents the “nudged” forecast, adding some more variability to the forecast value. The forecast values rise to 18 knots and holds steady, whereas the observations show much more variation (darkest line). This automatic adjustment, albeit simplistic, is advantageous for point forecasts. Initial attempts are now being evaluated to use an area of influence approach to use point observations to nudge gridded forecasts too.

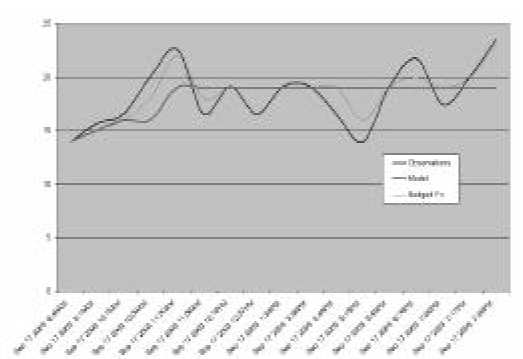

Figure 5. Forecast Nudging

3.4 VERIFICATION

As a final step in WeatherFlow’s forecast system, keeps a large numerical database of forecasted values and observations. The following table exhibits how well the NCEP ETA model (12 km horizontal resolution) compares to the Weatherflow RAMS (4km resolution) when compared to observations from a weatherflow site on the northern Chesapeake Bay. The error statistics are the wind vector difference, which sums the squares of the difference in the observed versus modeled U and V wind vectors. On this comparison, the 4 km model provides the superior output on 11 of the 13 days compared. More the a straight determination of model superiority, the ability to perform quick calculations of model performance provides WeatherFlow staff with the needed information to determine when a particular model may be the choice for a given weather event, or when and where a model may need tuning.

date		Observations			NOAA	WxFlow	
	site	samples	avg dir	avg speed	ETA 12km	4 km	Error Diff
10/13/2004	Duxbury (76)	4	N	5	10.7	12.2	-1.5
10/14/2004	Duxbury (76)	7	ENE	5.6	16.5	12.8	3.8
10/15/2004	Duxbury (76)	8	NE	6.9	10.7	20.7	[illegible]
10/16/2004	Duxbury (76)	8	WSW	11.6	28.4	20.6	7.8
10/17/2004	Duxbury (76)	8	WSW	18.9	31.9	21.4	10.5
10/18/2004	Duxbury (76)	8	WNW	9.8	24.8	23.5	1.3
10/19/2004	Duxbury (76)	8	ENE	7.6	24.5	19.9	4.6
10/20/2004	Duxbury (76)	8	E	22.1	36.6	28.8	7.8
10/21/2004	Duxbury (76)	8	E	18.7	43.1	37.8	5.3
10/22/2004	Duxbury (76)	8	ENE	23.4	53.7	46.3	7.5
10/23/2004	Duxbury (76)	8	ENE	26.4	55.4	44.8	[illegible]
10/24/2004	Duxbury (76)	8	ENE	23.6	53	34.6	[illegible]
10/25/2004	Duxbury (76)	3	ENE	28	26.3	15.1	11.2

4. CONCLUSIONS

The WeatherFlow forecast system has grown out of a unique demand for high resolution coastal wind data and forecasts not available from existing meteorological sources. The National Weather Service, whose mission states “working together to save lives” provides a valuable service to the marine community with its operational marine forecasts, but does not routinely produce the high temporal and spatial meso/micro scale forecasts that the sailing community demands to meet its recreational and racing needs. The system continues to mature with new assimilation schemes and improved learned behavior techniques, so the future should continue to yield more accurate forecasts. More information on the WeatherFlow system and its commercial products can be found at www.weatherflow.com.

5. REFERENCES

Walko R.L. and Tremback C.J. (1991), RAMS - The Regional Atmospheric Modelling System Version 2C: User's Guide. Published by ASTeR, Inc., PO Box 466, Fort Collins, Colorado, 86.