## National Weather Service Operations During 1997 Floods

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Good afternoon. I guess the hardest thing I'm going to have to do this afternoon is try to remember all of the things Bill Mork said I was going to talk about. I'm sure Bill will throw something at me and kind of remind me.

I'm going to do sort of like Bill, sort of a two-part show here since with all the interest in El Niño I'm going to do my first half about the flood of 1997, and then talk a little bit about all the things Bill said I should talk about.

A lot of this information has been touched on already. As we went into the Christmas break we had the very heavy precip and snow in the Sierra. Then we had the forecast of a big ridge on through the holidays. Like Bill has done, we put out special weather statements about all the dense fog, everyone drive carefully etc. Didn't mention a word or anything about rain.

On Christmas Day we started seeing the models beginning to flip flop and, as we heard from Maury Roos, sort of the classic-type of recipe for flooding events - had a recent very heavy amount of snow down to real low level. So you bring all this warm rain in on top of it.

What we started doing at the National Weather Service at that time. We put out the first statement, it looked like something big was going to happen. That went public on the 27th of December. At that time we also started doing daily briefings with the State Office of Emergency Services, as well as Offices of Emergency Services in the San Francisco Bay Area. I should explain our office has a dual function. We're the San Francisco Bay Area office going from about Santa Rosa down to San Luis Obispo, most of the coastal and the first tier of counties inland. And then we act as the overall office for all of northern-central California, sort of as a coordinating office doing a lot of the trying to put everything together so the offices are putting out a consistent package.

I should also point out that we also do not operate in a vacuum, there's a lot of interplay amongst forecasters in our offices, talking to Owen Rhea at River Forecast Center, Ekern at Water Resources, talking to Bill Mork at DWR, Dr. John Monteverdi at San Francisco State. There was a lot of E-mail floating around during these major storms because we find ourselves looking at this vast amount of information that's available to us. I have something like 12 different computer models that I can look at on any single day. And there's different fields for each model. I obviously can't look at all that. But with lots of eyes looking at it we can start picking our some of the key types of features.

What I'm going to show you coming up here will be the sort of the problems we were looking at, and then sort of some of the tools that we use for looking at those. Some of the toys, if you will, that we've had access to during this past year.

We saw going into this storm there were going to be three separate problems. One was going to be the potential flooding. That was combined with the problems from the snow melt in the foothill areas, and then on down into the valley. Then winds; we'd had a major wind storm earlier in December, we were very sensitive to that. The winds from this were not as strong as that one and/or as strong as were forecast. But these were the initial types of problems that we were looking at.

In a weather forecast office, a lot of the problems get to be with just trying to get everything together. Here are some of the logistical types of problems that we had to deal with. We were going into a major holiday period, a lot of people on vacation, not only in our agency, but in almost all the state and county agencies people were going to be out of town. That was one of the things that prompted us to start the calls as early as the 27th, the official calls. There was actually some talk on the 26th with some of these agencies. So they could people in town, bring people in, and we did the same thing with the staffing in our office. By the time all was said and done, we had done over 200+ interviews with the media and that was just basically the Bay Area media that called us. That wouldn't include calls that came to the Flood Information Center, those that came to the Sacramento office of the Weather Service, Eureka, Fresno, Medford offices that we also coordinate with.

Our office alone generated about 150 hours of comp time or overtime for people. Again, this is during a holiday period when normally they would have been off. Now here they are working extra days. Then dealing with all those offices, a vast amount of work goes into coordination so that if we're talking about flooding from our office and adjacent offices, or everyone is sort of on the same page, as far as putting out the same types of forecasts.

What are the different types of resources that we had to use? The one that has been historically used by the Weather Service is called AFOS and that's been around so long that most people don't even remember what is stands for. It's Automated Field Operations System, or something close to that. They took maps that are generated by the National Meteorological Center in Washington. Those maps are sent out to the field. That is being replaced very rapidly in the weather service community and a lot of other agencies where just the gridded data is sent out and then it's processed in-house, so we are usually doing this on HP workstations for most of it. A couple different applications were running are called NTRANS, GARP, and again I don't even remember the whole alphabet soup that goes with those.

Probably for a flooding event and what I heard Bill talking about a lot was forecasting the amount of rainfall - QPF, quantitative precipitation forecasting. In a flood, that's sort of the name of the game. If we can forecast the right amount of rain, it's going to help the people in the River Forecast Center and the other agencies know how much is going to be going down the streams and/or flooding.

This is off a model that's called the "meso-eta." It has a 10 kilometer difference between grid points which is a very fine model as far as the resolution. The regular eta model has grid points that are about 50 miles between grid points, so this is a much finer resolution. It's a lot slower to run on the computers and all, but this chart is from January 2nd at 4 o'clock in the morning for the next 33 hours, and the total precipitation - you can see just for that period, we're showing the same areas that Bill and Maury talked about and the Four Trees area, Buck's Lake, in the Feather River drainage. And we're looking at a forecast amount of about 10 inches.

Now I'll show you one of the problems for forecasters. (FIGURE 1) These are, you'll see in the bottom right is the meso-eta model and you can see the same 10.02 amount of rainfall. If you look up here. This is our NGM, nested grid model; our aviation model; our eta model. On all of these the grid spacing is much higher. They're not as accurate, and you can see - if you remember the verification data that Bill showed, the concentrations and the mountains. Where if you look at this you can see this big broad area they have under

rain with these models. And the reason for that is if we look at the same - look at the topography that goes into these various models. You can see up here it shows basically zero at the coast with a gradual gradient on up to the Sierra, sort of a big flat plateau over the Great Basin. So it doesn't even recognize that there is a Central Valley here. It's not until we get down into the 29 kilometer meso-eta and this 10 kilometer meso-eta that you can start seeing that there is a Central Valley. And so you have effects both from the Coast Range and from the Sierra Nevada. It's as we get down into this finer type of resolution that we are seeing much better performance out of the computer models.

To that end, this is a special product that we began using this past year which is becoming the standard at least throughout the western United States. Mountain Mapper is going nationwide, or just west? (FIGURE 2) (FIGURE 3)

This allows the forecasters to look at graphically what the rainfall amounts that's he forecasting for points is going to look like over a spatial area. For example, if I were to forecast, or point up here around Santa Rosa, the one here in the South Bay area and there's one down in Chew's Ridge down here. Mountain Mapper will draw the rest of this data in there. What we found though, the data that is going into this has at this point been untouched by human hands. This is coming right out of Owen Rhea's model. I'll show you some verification statistics that lead us to believe that as a first guess that's better than us tampering with it.

We were able to take this product, make a gif image out of it, post it on the Internet so that Emergency Service Agencies, like state OES could see; rather than a list of tables of amounts for just points, they can look at anyplace in the state and see the amounts of rainfall that we were forecasting. This was, we sort of did it almost as a lark. Let's see if we can post it on the Web page, find out if there's any interest in it. We were overwhelmed, as a matter of fact, when we got into the storms later on in the month, around the 20th of January. Myself and the other persons that had done this before, we were both off so it didn't get done and we were blasted by going - well, where's that new graphic that showed what was going on. So, I'm not sure what the future of this is going to be.

We tried another experiment this year, and again it will probably proceed in the future depending on our staffing. We had a meteorologist at Coastal Region Office of Emergency Services during the 29th, 30th and 31st who was able to take the information from all the various offices, package it together, write a little summary of it rather than - these people who are trying to get trucks up to the Russian River and to evacuate people and order National Guard helicopters, having to wade through these reams and reams of paper that weather services are real good at generating. This was able to be put down in a very concise manner for them. Again, that is a luxury; whether that is something we'll be able to continue in the future is unknown. It's very similar to what they do from Sacramento office with Cindy Matthews going from the Weather Service and going into the Flood Information Center and providing briefings as a coordination on process in between agencies.

It's one thing for the Weather Service to have this information but we need to be able to get it out to all the users. And that trickles down to the state OES, the county OES, individual cities, and even down to some cities that are divided into different flood districts. So there would calls from individual flood districts. You know, I've looked at the big picture; what's going to happen for my particular area.

This is similar to some stuff that Bill showed. (FIGURE 4) This is an analysis, this center line, this December 27th, the second low, shorter period than Bill's. What shows 20 inches in the upper part of the Sierra Nevada like we've talked about. Some other fairly interesting amounts is this 20-inch area pushing into the Russian River basin. If you remember, they got up to, like, 48 feet or so, which is only 16 above flood stage there. That wasn't as big as 1986, but people certainly were aware that it had rained.

I also have this 16-inch area down here in the Coast Range south of Monterey, and the Shasta basin has some huge amounts which, again, go down into the Sacramento drainage.

This is looking at the amount that was observed minus the amount that was forecast. The zero line, if you - and this is from the 48 kilometer eta model - this is sort of the coarse grid model. And you can see in some places it was off by about 25 inches. This is at Four Trees. It had forecast, and I think this was for the whole period, it had way underforecast the amount. A similar graph that we put together, looking at how the different models performed. A lot of these various along the bottom - this is Blue Canyon - and the key over here, this is from the MM5 which is another meso-scale model which we did not have operational at the time - we've gone back and plugged in the numbers just to look at the relative performance of these different models for storm. Basically, what you want to look at is the shorter the line is better, the closer to the zero line the better job it did forecasting.

Look at this orangish color. That's Owen Ray's model and most of that is by far the shortest line. The second area is the yellow. Those are the QPF forecasts put out by the Operational Forecasters at Monterey. I think we determined the MM5 was the next best, 29 kilometers, then the 20 kilometer, in succession. It looks like the big improvement we can make over just taking the output from the orographic model would be just timing for it. If it falls - our forecasts are for discreet six-hour periods. So it looks like a storm's a little faster if we could move it more into one six-hour period and out of the other. Just to shift the amounts around. You can certainly see the vast variation in quality of the models for a number of points.

This is a on-going part of going back and looking at this storm and some of the verification. On our Web page, which I promise to give at the end, in our Projects and Research section there is a site that was just posted by a grad student we have working with us who goes back and is beginning to analyze all this. That will be a growing and ongoing site.

I'd mentioned something called NTRANS and that gives us something neat we can do. We can take a cross section - for those of you not familiar with this type of graphic, what we're looking at, this is Omega, which is just the amount of vertical velocity in the atmosphere. (FIGURE 5) The more vertical motion you have the higher the clouds are going to get, the more rain you're going to get. Usually we're seeing with storms, we're seeing colors like this, not even light blue, more like this darkish color in here. Oh, figure minus two, minus three, minus five we say, "Hey, that's going to be a pretty good rain." This is elevation into the atmosphere here, this starts up off the coast of Washington at 48 degrees north 130 west and goes a slight, almost right down the California coast. This point in here is about where it comes ashore, about Cape Mendocino, this is the northern Coast Range, San Francisco would be about here, Monterey's about here. This on down the Coast Range. This cross section, you're looking at a slice that starts up here, comes down over Cape Mendocino, down over the Coast Range, the Bay Area, and then down off the coast south of Point Conception.

This is from a January storm in 1995, and I brought if first to show the similarities to what we saw this year. This is the sort of thing we see when we start thinking, rather than tenths of inches of rain, we're thinking in whole inches or multiples of five inches at a time in the orographic Coast Range area. It's a real attention getter for our forecasters.

This is another tool. This is off the new series of satellites and what the satellite is able to look down and look at the amount of scattering and determine what the winds are. So we can see where the winds are changing here, we're able to see where the strongest winds are, strongest winds associated with where the front it. This correlates very well to the areas, where the heaviest precipitation is.

We can also look at the SSMI determined rainfall rates and you can see in the blue area (the scale's not quite on there, this is in millimeters per hour) - when we start seeing these enhanced areas, we're looking at something on the order of seven or eight millimeters per hour. This is out over the ocean before there's any orographic enhancement to it. Again, this is another type of tools we were able to use for looking at the intensity of some of these systems as they were coming in.

That's sort of the storm of 1997 portion. You want to take any quick questions about that before I go on?

As I'm sure all of you have heard, on about the 16th of June there was a press conference in Washington and they said there is going to be an El Niño this year. On the 17th there was a headline in the *San Jose Mercury News* that said "storms of 1982 to return." Yes, something is going to happen this year. I guarantee something will happen. That's about it as far as the forecasting part. As you will see looking at some of this data, some of the things that Bill had said, some of the other people here who have looked at this data can affirm, we haven't seen this animal before. It's strong, kind of like '82 was but it's earlier in the season. We don't know, maybe it's going to start early and end early. It's one of these things, this is all uncharted territory for us, every answer we have there's about five more questions.

I want to look some of the pass types of El Niño events and how they have related to the rainfall in California.

First I need to talk about this. This is basically the same graphic that Bill showed. (FIGURE 6) This is from just about a week and a half ago showing, here's Ecuador and this warm plume of water, the classic sort of El Niño type of signature. It's fairly strong, extending on out across the equatorial Pacific. You can also see this area of pretty warm water off the California coast. I agree, I think it's some totally different, I think it's unrelated. In the past when we seen ENSO we have seen later on into the ENSO episode warmer waters off of our coast. I think this is a different de-coupled type of animal.

This is a brief look at the evolution of how rapidly this has grown. Niños 3 and 4 refer to this area of the equatorial Pacific, for the key area they look at. Then they also look at this Niño 1 + 2 area which is right off the coast of Ecuador. So you see we went along fat, dumb and happy, colder than normal here until about February and then boom, it has exploded. You can see a little bit more lag on out into the central as the warmer water worked itself on out to the west. This rate of growth is just, it's off the charts. It's nothing we seen before. The increase in 1982-83 was much more gradual than this.

We didn't know about it at the time. The sorts of instruments we have out there now, we're able to monitor this stuff on a daily basis. There are sensors out there bouncing data off the satellites and we can see this daily warming. We're probably about the same point in the power curve as 1982-83. We have just gotten there a little bit differently.

This shows the same sort of areas going back to the 1978. You see, here's our huge event in 1982-83. It's pretty easy to pick out. Here's what we're starting to do now. We're already past where we went to in the 1991-92 event along the South American coast, and we're rapidly approaching that, I think the next time this chart is updated we're going to see it's going to pass everything but 1982-83. Certainly the slope of this would indicate that that might be the direction that we're headed.

I like this because it's a very pretty graphic actually. This shows the amount of warming off of our coast and it's in Fahrenheit, for all of you people who still like a number you don't have to think about. You can see down here, about the latitude of San Diego we have almost $70^{o}$ water which is pretty darned warm. Even along the central California coast where we should be seeing some upwelling this time of year, we're seeing

some upwelling but it's still warmer than it normally would be. This graphic is also available off the Web page.

What about forecasts? This is what Climate Prediction Center is forecasting for the El Niño event to do June through August. This is March on out across the eastern Pacific. And looking at the last SST it almost looks like we're almost out to now where we would at the end of this. I believe this is an average over the whole period but still makes me think that we're going faster than even this model was showing. You can see we're starting to get this even warmer water on out into the Pacific and lost some of the real hot, hot stuff in here but if you look at this shade of red it is considerably farther out, continuing on out to nearer the Date Line.

Bill had said I'd talk about types of El Niños. There was a paper from Schoener and Nicholson about 1986 which used some work from Fu and Diaz where they looked at the different types of events and by very warm they're basically talking about temperature anomalies greater that 2° Celsius above normal. (FIGURE 7) These are the El Niño years that correspond to this sort of event. These are the big, or the strong type of El Niño eventsThose are important ones to remember. The figures I'll show seem to point that those have the strongest signature as far as rainfall in California. With the Type II events like we saw in 1953, 1963 and 1967 again it was 0 to +2 above normal - I mean SST anomalies almost all the way across the Pacific. So a much broader stretch of warm water but it doesn't have the strength. (FIGURE 8)

I should point out you'll see in a lot of the different literature about El Niño and different groups use different ways to begin the dates. For rainfall seasons in California we usually do July 1 to June 30. Hydrologists use a Water Year which is October 1 through September 30. Some people use calendar years. You need to look at as 1991-92, you sort of have to use a little bit of deductive reasoning to figure out which event we're talking about. If you get figures out of different journals and texts you'll see dates that have slipped one year or the other and it's just their numbering scheme, if you will.

This was our sole Type III. (FIGURE 9) A little bit of warm water, just in the eastern Pacific. This corresponds to our drought years, but whether there's an analog there or no it hard to say. You know, with a sample size of one it's a little hard to tell. It's nice for doing a talk or an interview because when you talk you can say, okay, we'll have a flood or drought. You pretty much have it nailed down.

The impact of El Niños in California. We're looking here at a total of 13 samples. I don't know if we can say anything very definitive and none of them are the same. What else is going into the atmosphere? You know, we can't think of El Niño as de-coupling from what happened last year or any other year. There are years that don't have La Niñas or El Niños and we need to keep that in mind. There does seem to be a strong wet signature in Southern California. In Northern California sort of a mixed signal and sort of a dry, warm type of signature in the Pacific Northwest. The farther south you go in Central California, the stronger wet signal that there is.

Here a quick legend of what I'm going to run by real quickly. (FIGURE 10) Nine different graphs from across the state. Heres' what I've done. I've normalized the rainfall where you just take the average and you divide it by the normal. If you have a normal year it's going to be on the zero line. The ones that go above or above normal years, this line is one standard deviation above the normal, one standard deviation below the normal. These are rainfall seasons on July 1st to July 30th. The year is the year that it begins.

I looked at the data set I had the easiest access to, these are nine National Weather Service offices in California, Eureka in the north, all the way down to San Diego on the wall. Okay, here we go for Eureka. (FIGURE 11) Marked "red" are the years that there were Type I only from El Niño events. If you start throwing in the other ones it's a real muddy signal. I wanted to show something that's going to show

something. You can see, there are eight Type I events, four above normal and four of them are below normal. That's what I meant by a mixed signal.

Redding up in the north, little bit more of a stronger signal toward wet. What are the influences going on there? I don't know. Moving down here to Sacramento, still what I would call in the mixed signal category. The ones that are above, we only have a couple that get very much above a standard deviation. This is, of course, is 1982-83. San Francisco six above, two below. (FIGURE 12) A few more that are above a standard deviation. Fresno seven above, one below. Four of those seven are above a standard deviation and two of those are above two standard deviations. Bakersfield looks a lot like Fresno. If you've ever been there you sort of know that already.

If we're looking at Santa Maria, you see we only have this one event that was below. One, two, three, four, five are much above normal a standard deviation. Again, two of those are two standard deviations.

Los Angeles. Anybody here from L.A.? Out of eight Type I events, all eight are above normal. (FIGURE 13) You have three events that are close to two standard deviations above normal, maybe four. This tells me, if I lived in Southern California with a Type I event, I'd be thinking rain this year. In San Diego, as you can probably guess from this progression we've been doing, all the wet, pretty strong (and we even had a couple that were a standard deviation below normal).

Now looking at the same sort of thing on a larger scale. I keep putting something like this up that I don't have the reference on. I got this off the Web last night and I apologize, especially if it's somebody here who I've stolen it from. This is going to be a little hard to see, we'll chop off the top ones to get the legend at first. This is looking at individual El Niño years, going across, going from $20^{o}$ north up to $60^{o}$ north. So this is our latitude in here and the blue, basically I think of those as wet years and the red are dry years. So you see, look at this dry signature here for Washington and Oregon. It really stands out. Less so as we go on down into California. Again, you'll see this in a lot of the literature about El Niño, the warm, dry signature for the Pacific Northwest. This certainly, I think, shows that.

Our web site is http://nws.bay.net. That will take you to National Weather Service home page, and then there's a separate El Niño page on there, and also probably of interest to you are the research and projects page that's there. Finally, if all else fails there's my E-mail that's also on the home page if you have any questions that I don't answer now.

Thank you very much.