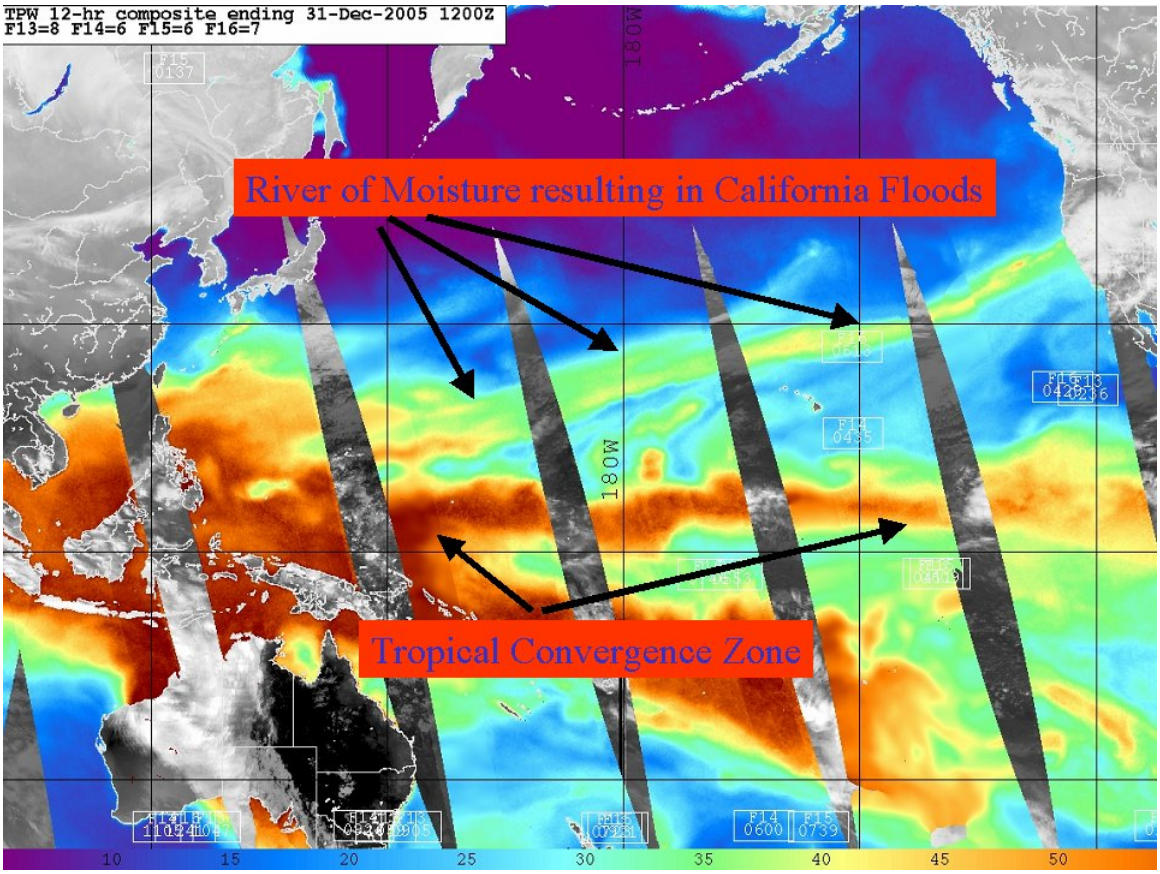
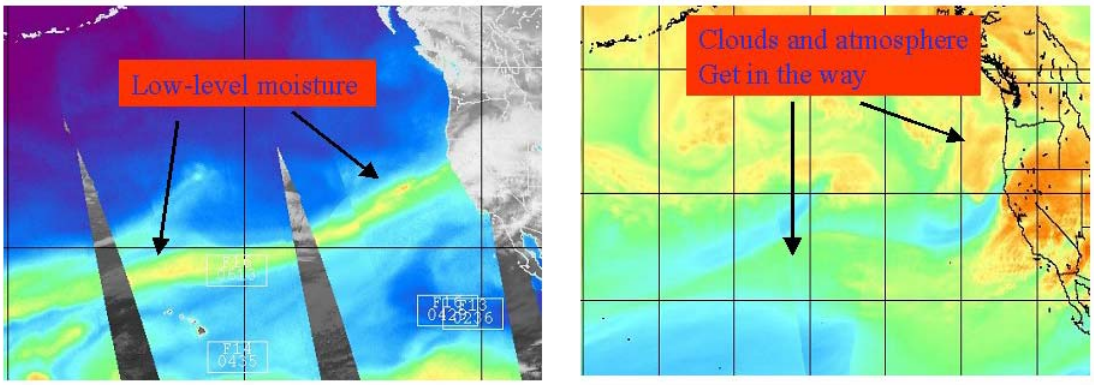
Heavy Precipitation Forecasting using Microwave Total Precipitable Water



Above: The Total Precipitable Water (TPW) product reveals long belts of moisture concentrated in the lowest few kilometers of the atmosphere. TPW is the integrated quantity of water vapor from the surface of earth to the top of the atmosphere. It is the most easily quantifiable measure of water vapor that satellite measurements can provide. Look for example at the plume, or atmospheric "river", which originates near the Philippines and extends all the way to the west coast of the United States. Torrential rains and floods in California resulted after the river flowed for several days. The product is based on passive microwave data from the Special Sensor Microwave Imager (SSM/I) sensor aboard the DMSP polar orbiting satellites. The microwave energies used by this satellite are capable of penetrating most clouds, enabling us to see water vapor hidden from the view of other satellite sensors.

Below: We compare the same TPW product from above with an infrared "water vapor" product from the GOES geostationary satellite at the same time and over the same place. The TPW product (left) shows us the river of moist low-level air moving over the west coast. But the GOES product (right) is based on an infrared channel sensitive to water vapor and clouds in the middle and upper troposphere. Thus, its view of the lower atmosphere is blocked, and it can't reveal plumes of low-level moisture. Furthermore, it cannot see through clouds. The GOES water vapor product is effective, however, at observing the middle troposphere and monitoring the jet stream. Use of polar orbiting microwave TPW and geostationary 6.7 micron water vapor are used to compliment and supplement each other for improved analyses and forecasts of precipitation.



Total Precipitable Water (TPW) Geostationary Water Vapor

The NESDIS Satellite Applications branch (SAB) sent this message to forecast offices based on the imagery available at the time of the example above: "MICROWAVE ANALYSIS SHOWS PW PLUME HAS REMAINED A FAIRLY NARROW RIBBON OF HIGH VALUES THAT CONTS TO EXTEND BACK INTO THE TROPICS W OF THE DATELINE. MAX PW/S AS PER SSMI ARE 1.3-1.4" INSIDE 140W …"

Why We're Interested…

Forecasters use these products to nowcast the likelihood of heavy precipitation in coastal areas. TPW products serve as a useful check on precipitation guidance from numerical models, which are sometimes not well initialized in the subtropics or midlatitudes. TPW products also give

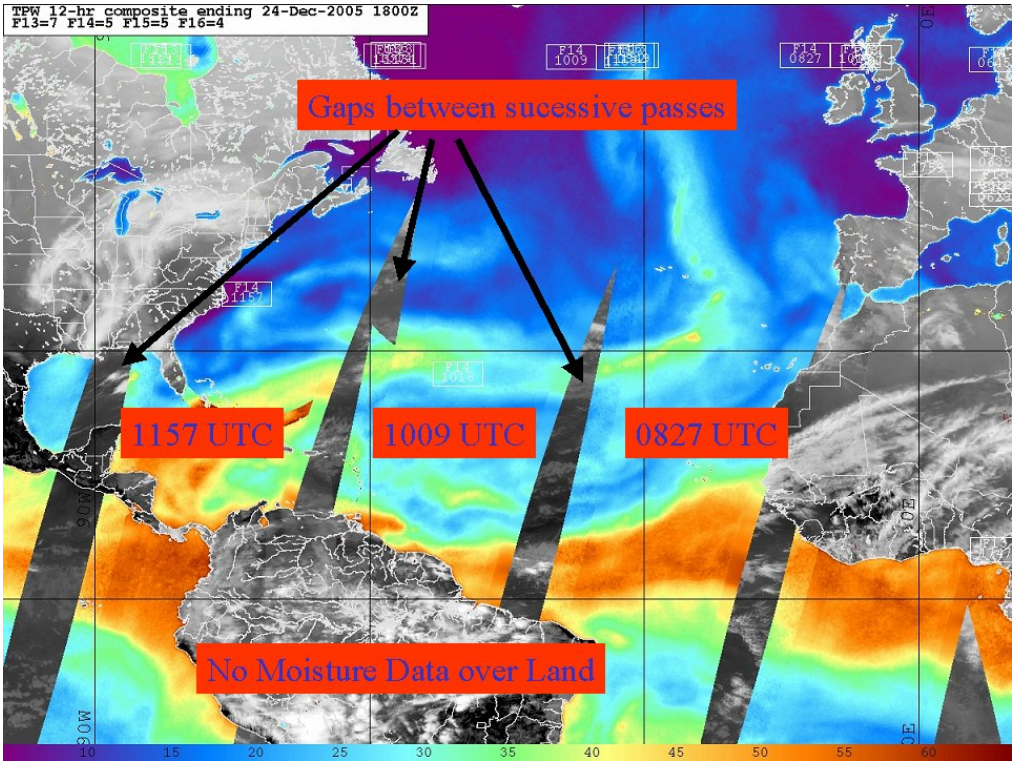
forecasters a heads up on moisture surges headed toward coastal areas before the actual precipitation comes within radar range.

How This Product is Created…

Microwave satellite instruments utilize a set of channels which sense the atmosphere at various frequencies, measured in Gigahertz (or GHz), for example 22 GHz. These channels are combined in computer processing to arrive at TPW, the amount of water vapor integrated from the surface of the ocean to the top of the atmosphere. The units are kilogram per meter squared (kg/m2), meaning the total mass of water vapor above a square meter of the ocean. It usually ranges over 0 to 70 kg/m2. It has an equivalent range in mm, from 0 to 70 mm. In U.S. National Weather Service forecast discussions, TPW products are often discussed with units in inches. To convert to inches from units in kg/m2 or mm, multiply by .04. For example, a TPW amount of 25 mm is equivalent to 1 inch.

Microwave passes from satellite are narrow, from about 1000 to 2000 km wide. Compositing consecutive microwave passes from a particular satellite creates the microwave TPW product over an ocean basin. The data in the composite are not all valid at the same time. Each pass is separated in time from the adjacent one by about 100 minutes, the time needed for the satellite to orbit the earth. Thus, on the image below notice that the UTC valid times for the DMSP F-14 passes increase as you move from east to west across the Atlantic. On the products the times are marked in white often near the top of the product. You can see gaps between the orbits where two successive orbits do not overlap. In the gaps infrared imagery from geostationary satellites are substituted to give a sense of continuity (see image below). Furthermore, microwave algorithms do not work over land, creating further gaps.

Notice the color bar at the bottom. By matching the color on the product with the color on the bar you can find out the magnitude of the TPW at any spot. For example, off France and the northern coast of Spain the color purple corresponds to about 10 kg/m2 or 10 mm on the color bar.



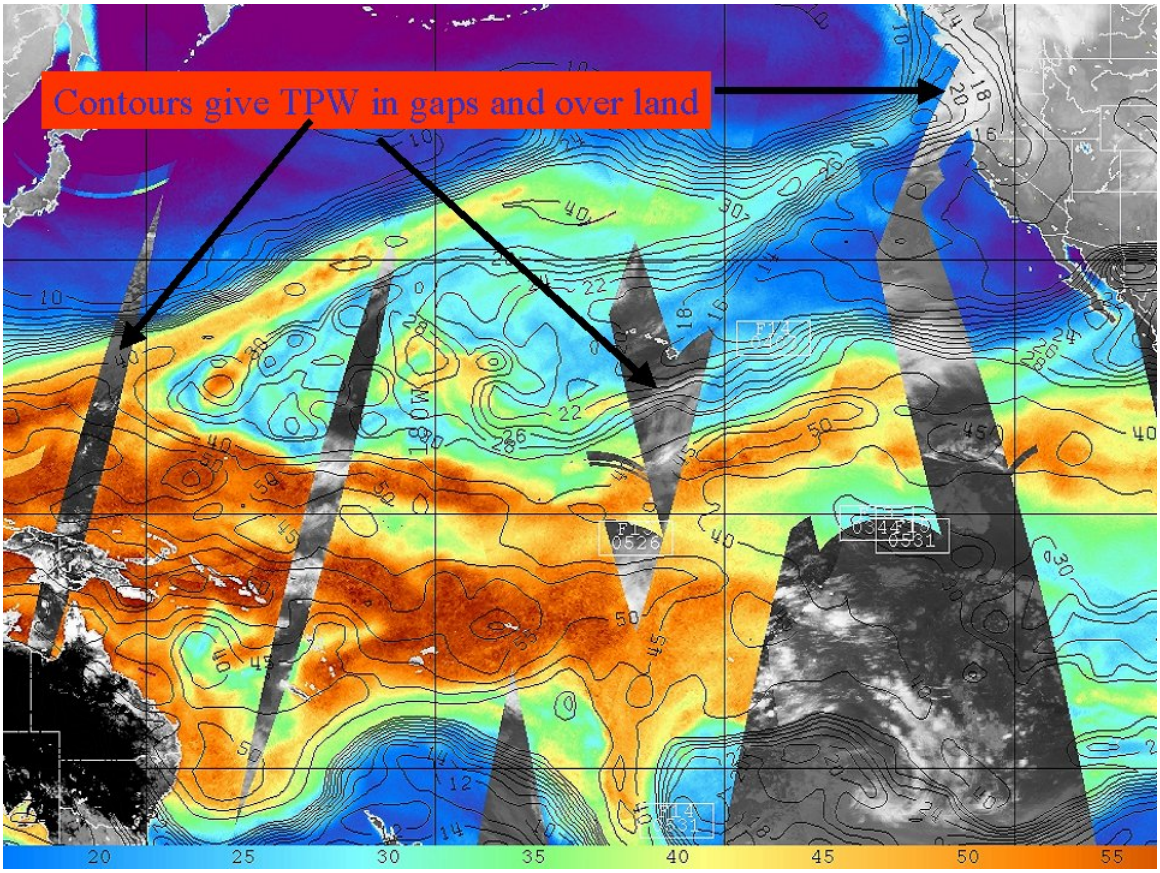
Construction of a TPW Product illustrating successive passes and data gaps

How to Interpret…

Although this product gives total vapor amount from the surface of the ocean to the top of the atmosphere, in practice it serves as a guide to low-level moisture in the lowest 1 or 2 km of the atmosphere. This is because the warm lower atmosphere contains much more vapor than the atmospheric layers above. This product is therefore quite different in its application than geostationary water vapor products that show moisture conditions in the mid-troposphere. The geostationary water vapor product can help trace upper tropospheric jet streams, while the microwave water vapor products are useful to follow low-level rivers of atmospheric moisture.

One Naval Research Laboratory (NRL) version (link below) of the TPW product includes overlays of TPW based on the U.S. Navy NOGAPS numerical model. The purpose of the overlays is to provide TPW information in gaps, either between orbits or over land. The NOGAPS overlays, sometimes based on short-term forecasts, are not quite as reliable as the observed satellite data from the actual passes, but are still useful. In the example below we can see a plume of vapor extending across the Pacific into

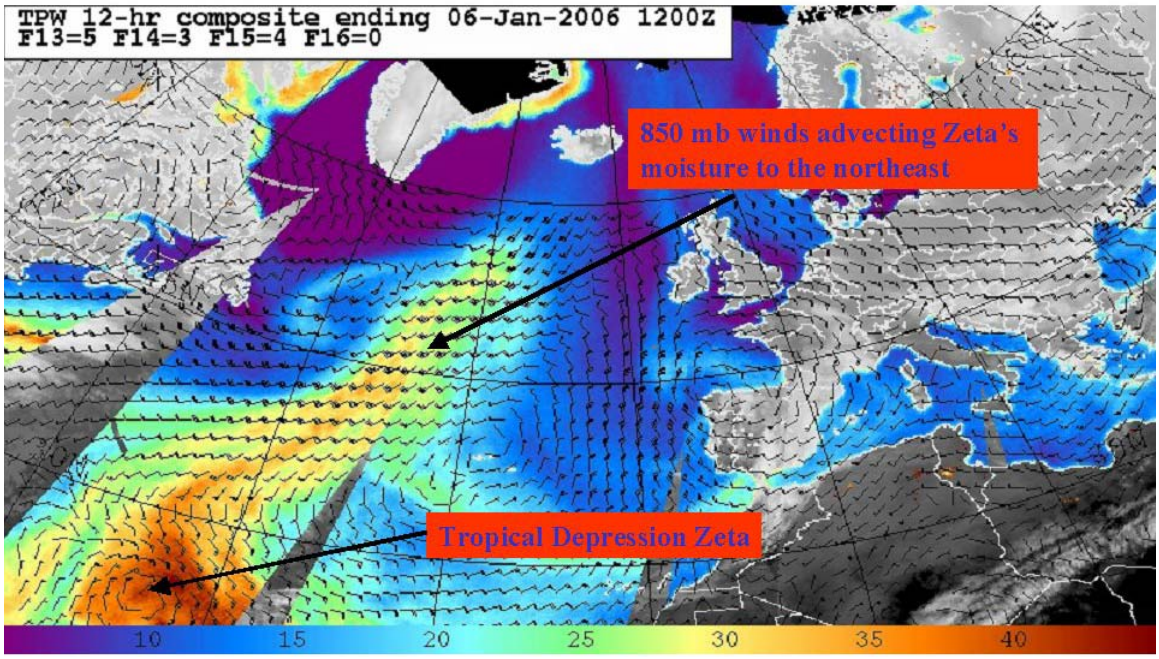
the Pacific Northwest. At the coast there is a data gap from missing satellite data, and over land the SSM/I retrievals are unavailable. Advantageously, the contours appear over the inland areas, extending the usefulness of the information.



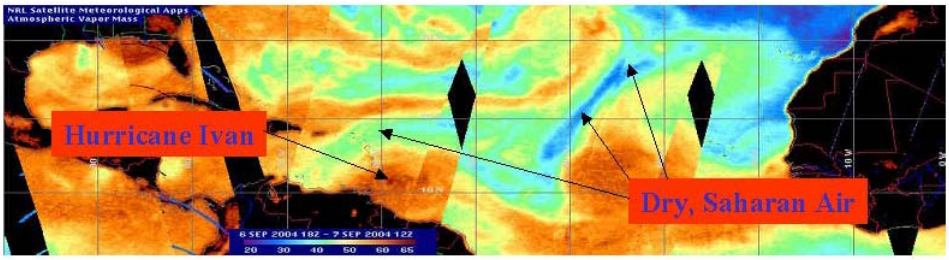
What to Look For:

Look for elongated plumes of elevated values that appear aimed toward land areas. This could be trouble, and floods could result! Of course, weather forecasters already have models to predict heavy rains and floods, but sometimes the models are not well initialized with the correct moisture and can produce underestimates (or overestimates) of expected precipitation. By viewing the TPW products, forecasters can double check the model forecasts and adjust them accordingly. Since TPW products have become available, National Weather Service forecasters use them assiduously when heavy rain threatens coastal areas. Consider using the product with 850 mb wind vectors overlain (below). The winds at this level (around 1500m) trace

the general flow of the moisture plumes, in this case from Tropical Depression Zeta.

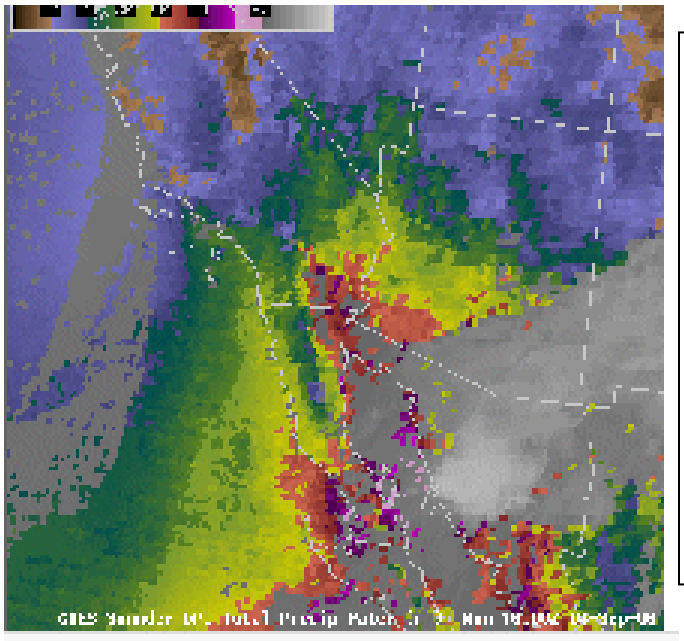


Often it is helpful to look for plumes of dry (not moist) air, for example, in the vicinity of tropical cyclones. A dry plume may interact with such a storm and weaken it, for example, in the vicinity of Hurricane Ivan in 2004. Dry air from the Sahara (blues and greens) moved around the north side of the hurricane. The storm weakened under the influence of the dry air before strengthening a few days later as it moved into a moister environment.



Additional Sources of TPW over the Continental US (CONUS)

The GOES sounder provides TPW over the continental United States and in offshore regions. Its two advantages over microwave products are that (1) it is frequently refreshed over the large regions covered by the sounder; (2) it can retrieve values over land as well as ocean. Its two disadvantages are: (1) its TPW values are less accurate than from polar orbiting satellites; (2) it is contaminated by clouds. Below is a GOES Sounder TPW image of the moisture from Hurricane John affecting southern California, and the discussion from the Severe Storms Prediction Center.



MESOSCALE DISCUSSION 1931 NWS STORM PREDICTION CENTER NORMAN OK 0214 PM CDT MON SEP 04 2006 AREAS AFFECTED...SRN CA CONCERNING
...HEAVY RAINFALL VALID 041914Z - 042115Z

GOES SATL SOUNDER SUGGESTS THAT 1.50-1.75 INCH PWAT VALUES WERE ESTABLISHED OVER THE LOWER DESERTS OF SWRN AZ INTO SRN CA THIS AFTN. STRONG HEATING HAS DESTABILIZED THE BOUNDARY LAYER WITH SBCAPES IN THE 1500-2000 J/KG RANGE. NASCENT CB/S WERE OBSERVED ALONG THE CREST OF THE SRN CA MOUNTAINS FROM SRN SAN BERNARDINO COUNTY SWD TO ERN SAN DIEGO COUNTY AND ARE COINCIDENT WITH GENTLE ELY UPSLOPE FLOW. TSTMS SHOULD GRADUALLY DEVELOP AND MOVE SWWD INTO THE INLAND VLYS OF SRN CA THROUGH LATE AFTN. THE HIGH PWATS IN PLACE AND RELATIVELY WEAK TROPOSPHERIC FLOW WILL FAVOR HEAVY RAINFALL...PARTICULARLY WHERE STORMS TRAIN/DEVELOP VCNTY MESOSCALE BOUNDARIES/CONVERGENCE ZONES. RELATIVELY DRY SUB-CLOUD LAYER WILL ALSO BE CONDUCIVE FOR PSBL ISOLD DAMAGING WIND GUSTS

Looking Toward the NPOESS Era…

In the NPOESS era there will be two instruments capable of producing TPW. One is called the Advanced Technology Microwave Sounder (ATMS), which will also fly on the NPOESS Preparatory Project (NPP), the precursor to the NPOESS satellites. The other will be a conical scanner like the SSM/I featured here. NPOESS data will come in much faster than currently, and TPW products therefore will be that much more useful.

Upcoming NWS Field Operational Capabilities

As of this writing (AWIPS Operational Build 6), NWS field offices have access to the GOES Sounder and SSM/I. However, the SSM/I data is plotted in point format instead of image format. For most offices there is no capability with any of the polar orbiters to superimpose consecutive overpasses that would facilitate the detection of the low level "rivers of moisture". In AWIPS Operational Build 7.2 (2007) SSM/I and AMSU TPW composites will become available in all NWS field forecast offices.

Want to Learn More?

Detailed training is available from the COMET module on Clouds, Vapor and Precipitation.

CIRA's AMSU Website has TPW products which, until recently, combined TPW data from GPS stations over the continental U.S. with AMSU TPW over the oceans. The GPS data have become temporarily unavailable (November 1 2006), but may be re-incorporated into the products if an alternative data feed can be found.

For more information about AMSU and SSM/I products see the NOAA NESDIS site for microwave products, or the NOAA NESDIS GOES Sounder site. Another site with GOES Sounder information is the CIMMS realtime satellite page.

NOAA NESDIS has regional pages for the Eastern Pacific and Atlantic which contain microwave TPW as well as complimentary products.

For TPW on the NRL's site go to NexSat, Tropics, or Tropical Cyclones Pages.

Funding for U.S. GPS TPW has been curtailed, but Suominet has a useful product over the continental United States:

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