National Weather Service

Volume 4, Issue 3 August 10, 2014

ZSE Weather Watch

A newsletter from the Seattle ARTCC Center Weather Service Unit

Convective Turbulence *by James Vasilj*

IN THIS ISSUE

Thunderstorms develop where there is a source of rising air (lift). This lift can be the result of unstable air, where relatively warm air is below cooler air (summertime daytime heating, for example); where there is a mechanical lift, such as air blowing toward mountain ranges; and near frontal boundaries where warmer air overruns cooler air. These situations lead to up and down drafts, and thus turbulent air. When combined with other favorable environmental conditions, this can lead to thunderstorm development. Some known regions for convectively induced turbulence around thunderstorms (**Figure 1**) include areas near or just downwind of the overshooting top (A), the anvil (B), and downwind of the middle of the storm (C). Strong up and down drafts are associated with these areas.

The FAA advises that pilots should avoid all thunderstorms, not attempt to fly below a thunderstorm, and stay a minimum of 5 miles away with 20 or more miles being recommended. If a pilot inadvertently penetrates a thunderstorm, he should reduce air speed to the manufacturer's recommendation for turbulent air penetration for the aircraft's specific gross weight, and maintain a straight and level altitude that will take the aircraft out of the storm in the minimum amount of time.

Although thunderstorms are more common east of the Rocky Mountains, convection still occurs over the Pacific Northwest (**Figure 2**). And thunderstorms can rise beyond 50,000 feet, which is above the maximum height most aircraft fly.

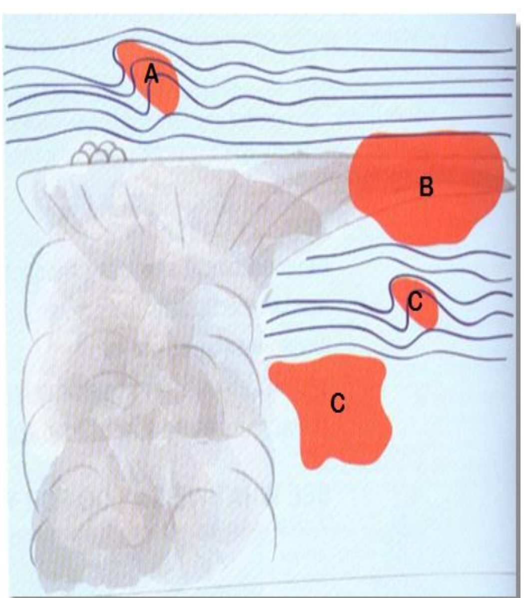

***Figure 1** – Shaded red areas are known regions of turbulence around thunderstorms (from Aviation Weather Center).*

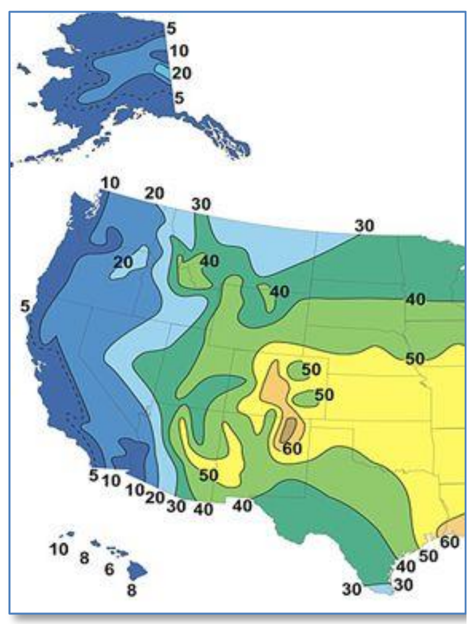

***Figure 2** – Average number of thunderstorm days per year (from National Weather Service Southern Region).*

Forecasting Marine Stratus Burn Off *by John Werth*

One of the most challenging forecasts for meteorologists at the FAA's Seattle Air Route Traffic Control Center in Auburn, WA is determining when early morning, marine stratus will burn off over the Puget Sound lowlands in Washington and the Willamette Valley in Oregon (**Figure 3**). Predicting the burn off is critical to operations at both SeaTac (**SEA**) and Portland (**PDX**) since low clouds affect who can fly into the airports, what runways will be used, aircraft spacing on final approach, and the number of arrivals and departures per hour at each airport. Extended departure and/or arrival can be costly for airlines and passengers.

What determines where low clouds develop and whether or not they burn off? Clinton Rockey (NWS Aviation Forecaster from Portland, OR) wrote an excellent article titled "Marine Stratus Surges" in the June 2013 issue of ***ZSE Weather Watch*.** In it, he discussed the areal extent and strength of marine pushes (low clouds and fog) into Western Washington and Western Oregon. But what determines whether or not they burn off later in the day? Computer models – even the latest, high resolution, rapid refresh models - oftentimes do a poor job predicting when or if marine stratus will dissipate over the interior lowlands. They oftentimes lack the vertical and/or horizontal resolution required to properly simulate the development and dissipation of shallow low clouds. And the boundary layer schemes used to simulate the lowest layers of the atmosphere, often fail when the atmosphere is stable (colder air near the earth's surface with warmer above). Because of this, the models tend to over forecast the amount of mixing (vertical and horizontal), causing the low clouds to dissipate too quickly.

The following items are some of the factors that determine when and if marine stratus will burn off.

(1) ***Sun angle and time of year*.** Mixing or overturning of the lower atmosphere is enhanced when sun angles are high and the days are long. Mixing destroys (evaporates) low clouds. During times of the year when the sun angle is low and daylight hours are shorter, less solar radiation reaches the earth's surface to burn off the clouds.

(2) ***Depth of the marine layer*.** The deeper the layer of marine clouds, the harder it will be for them to burn off during the day. Shallow stratus will oftentimes only be 1,500 to 2,500 feet thick; whereas a deep layer of marine stratus can be 5,000 to 6,000 feet thick and extend from the coast to the crest of the Cascades.

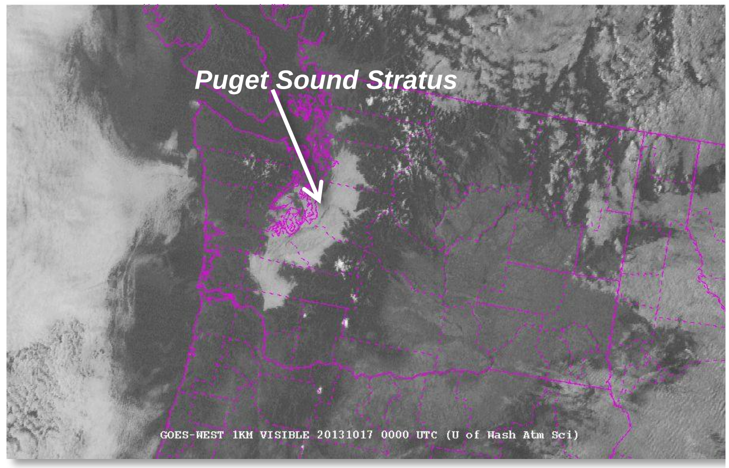

Figure 3 *– Visible satellite image showing marine stratus over the interior lowlands of Western Washington*

(3) ***Strength of low level flow*.** Low level winds blowing from the coast to the interior (onshore flow), can reinforce low clouds over the interior, resulting in a later burn off. However, when low level winds blow from the interior to the coast (offshore flow), the air warms and dries as it flows down the western slopes of the Cascades. The warm, descending air will dissipate low clouds over the interior, if it can reach the lowlands.

(4) ***Strength of the inversion capping the layer of cool, moist, marine air*.** Inversions suppress vertical motion in the atmosphere, making it harder for low level moisture and clouds to mix with warmer, drier air aloft.

(5***) Location of the upper level ridge over the eastern Pacific.*** When the upper level ridge is centered off the coast, low level winds tend to be onshore, promoting low clouds. When the upper level ridge is centered inland from the coast, low level winds will typically be offshore, which limits the amount of low clouds over the interior.

There are times when forecast models struggle to simulate the real atmosphere; however, there are times when the newer, high-resolution models are incredibly accurate at forecasting marine stratus. **Figure 4** shows output from NOAA's High Resolution Rapid Refresh (HRRR) model valid 12Z Tuesday, 29 July 2014. Areas shaded red and pink indicate low clouds or fog with IFR to LIFR flight conditions**. Figure 5** is the visible satellite image for the same day valid 1530Z, showing widespread low clouds and/or fog (areas in white) along the coast, over the offshore waters, in the Strait of Juan de Fuca, with fingers of low clouds extending inland up the lower Chehalis and Columbia River valleys...very similar to what the model forecast. Skies were clear over the Puget Sound lowlands and the Willamette Valley. **Figure 6** is the HRRR forecast valid for

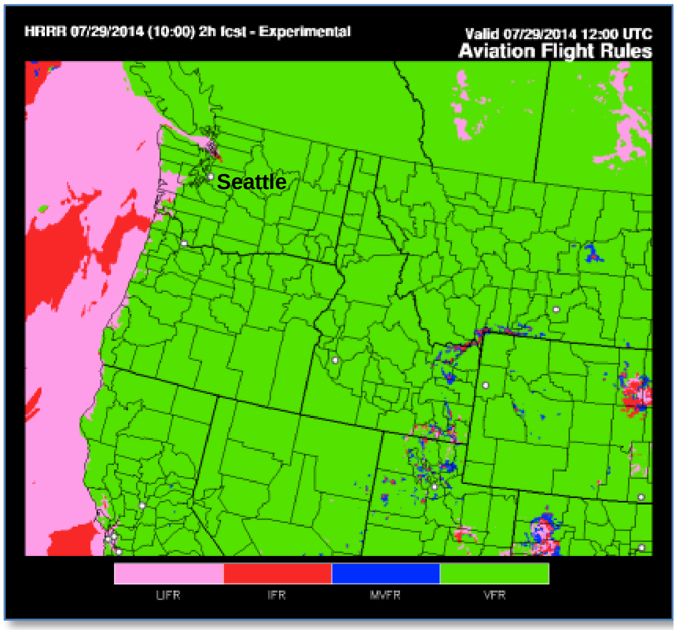

Figure 4 – *HRRR forecast valid 12Z (5am PDT) Tuesday 29 July 2014. Areas shaded pink and red indicate IFR to LIFR ceilings.*

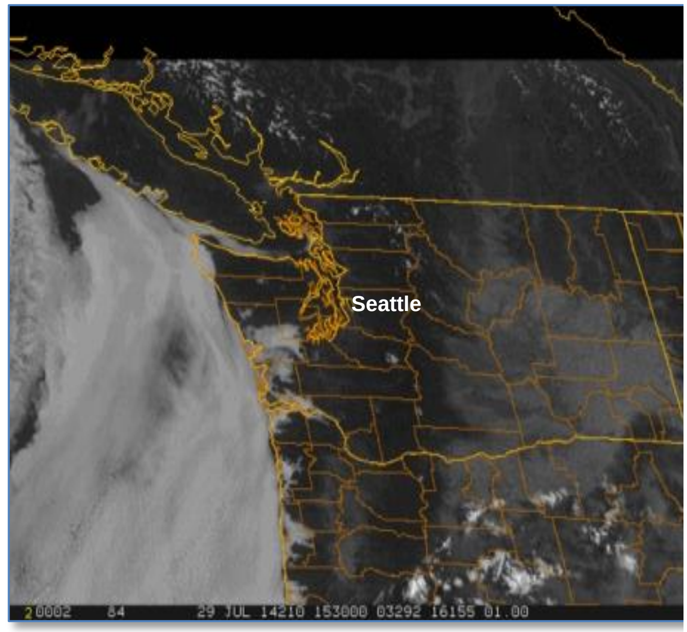

Figure 5 – *Visible satellite image valid 1530Z 29 July 2014 showing the low clouds extending inland through the Strait of Juan de Fuca, the Chehalis gap, and the lower reaches of the Columbia River.*

18Z, showing low clouds (IFR to LIFR flight conditions) confined to the immediate coast, the offshore waters, and the western entrance to the Strait of Juan de Fuca. Low clouds over inland portions of Western Washington and Western Oregon were forecast to burn off by this time. **Figure 7** is the visible satellite image valid for 1715Z showing low clouds mainly along the immediate coast and over the offshore waters. However…stratus continued in the Strait of Juan de Fuca and didn't burn off until late that afternoon. Fortunately, forecasters are aware of the model weaknesses and try to compensate for them subjectively!

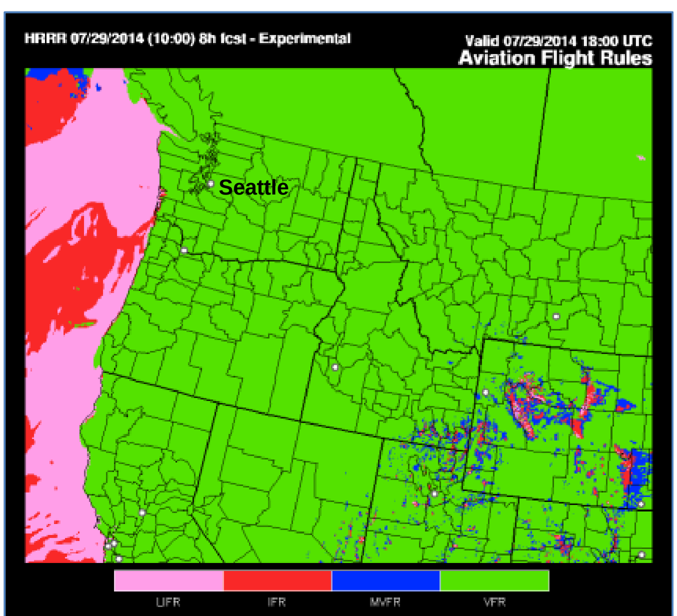

Figure 6 *– HRRR forecast valid 18Z (11 am PDT) Tuesday 29 July 2014. Areas shaded pink and red indicate IFR to LIFR ceilings.*

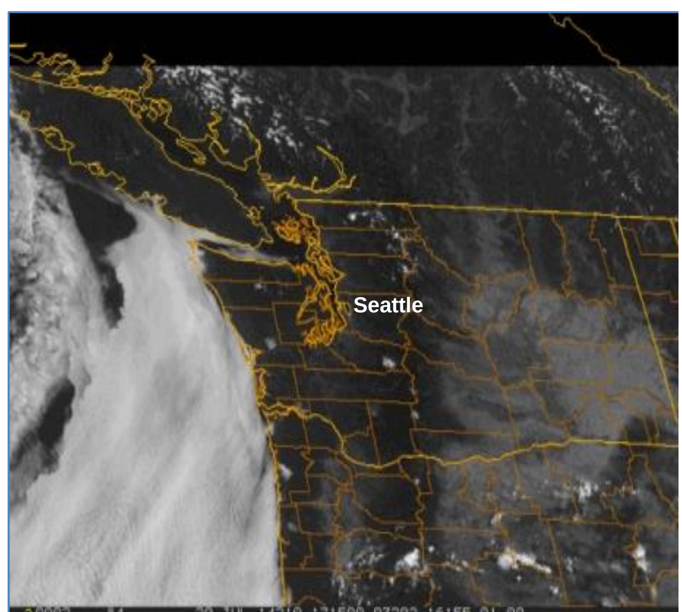

Figure 7 – *Visible satellite image valid 1715Z 29 July 2014 showing low clouds in the Strait of Juan de Fuca and along the coast.*

Active Mid-Summer Weather Day for ZSE *by Steve Adams*

An unseasonably vigorous weather system moved through the ZSE airspace on July 23, 2014. This system produced many strong to severe thunderstorms over northern portions of the airspace and heavy rainfall which broke long-standing daily records over western Washington and northwest Oregon.

A slow-moving frontal boundary and associated upper trough **(Fig. 8)** approached the Pacific Northwest coast early that morning causing rain and scattered thunderstorms to develop over western Washington and northwest Oregon.

The air mass became increasingly unstable as the upper trough feature moved east **(Fig. 9)**, causing thunderstorms to develop over eastern Washington and the Idaho Panhandle by mid-afternoon.

Thunderstorms over eastern Washington were in many cases severe with multiple weather spotter reports of large hail and damaging winds See **Figures 10** and **11**.

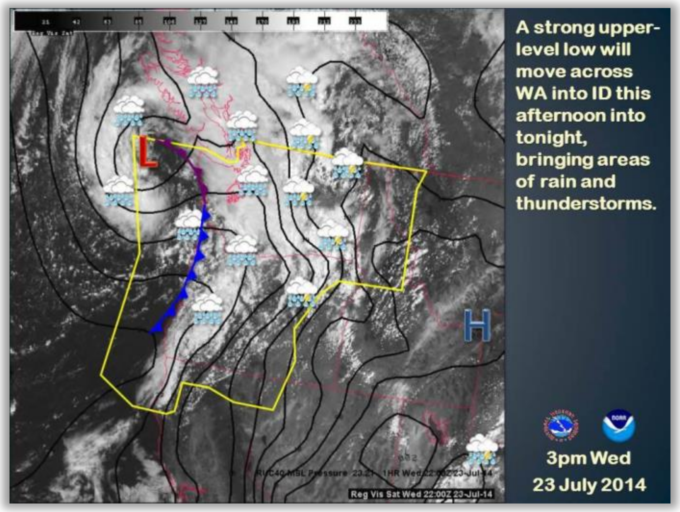

Figure 9 - *Satellite Image with weather annotations at 3pm PDT*

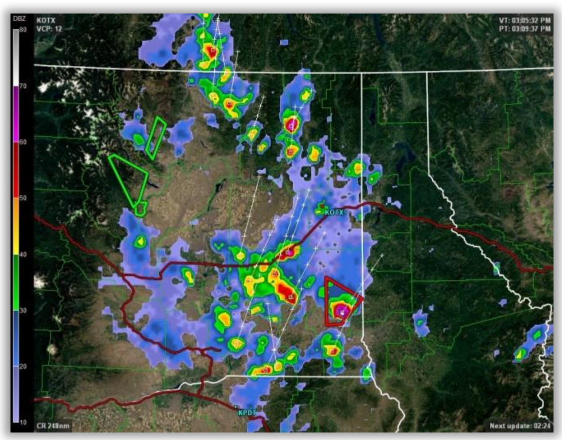

Figure 10 - *Spokane WSR 88-D radar image 3:10 PM PDT*

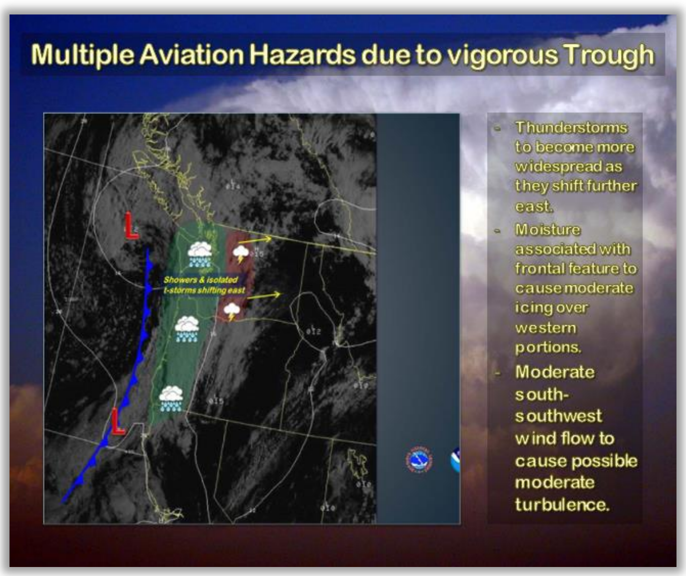

Figure 8 - *ZSE Weather Story Graphic issued at 8am PDT*

Though widespread rain gradually became scattered over western portion of the airspace, localized heavier showers persisted into the evening (**Fig. 12**). Rainfall totals for July 23rd set long-standing daily records at many locales over western Washington and northwest Oregon. (**Table 1.**)

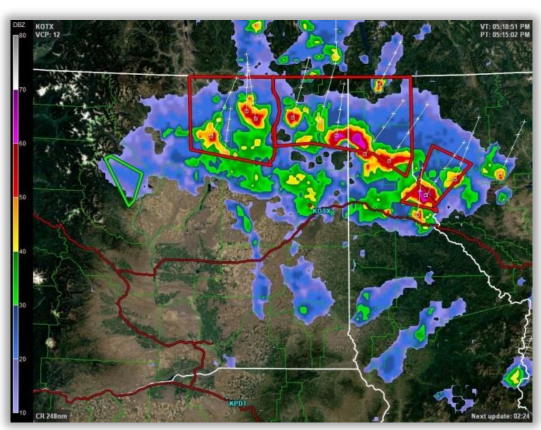

Figure 11 - *Spokane WSR 88-D radar image 5:15 PM PDT*

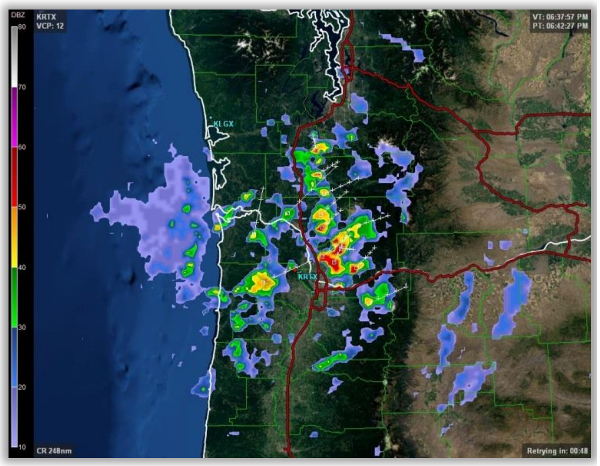

Figure 12 *- Portland WSR 88-D radar image 6:45 PM PDT.*

Location	New Record	Old Record	Record Year
Sea-Tac	0.76	0.54	1949
Bellingham	0.72	0.22	1949
Hoquiam	0.63	0.04	1995
Olympia	0.27	0.25	1949
Astoria	0.82	0.42	1952
Portland	0.62	0.06	1959
Eugene	0.21	0.17	1918

Table 1 - *Daily Record Rainfall Totals for July 23, 2014*

Northern California Summer Thunderstorms *by Alexander Dodd*

Thunderstorms are a part of familiar summertime weather across Northern California, especially over the higher mountainous terrain surrounding the Central Valley. The northern Sierra are the most susceptible, with the highest mountains helping to enhance upward motion in the atmosphere under several different weather regimes. The Sierra is also closest in proximity to monsoonal moisture, which is the main contributing source of moist air necessary for thunderstorm development in the summer across the Western United States.

Thunderstorm activity is a little harder to come by for areas from the Plumas National Forest across to Mount Shasta, and over to the Trinity Alps and Yolla Bolly Mountains on the west side of the Central Valley. These areas are not only typically farther away from the source of monsoonal moisture, but also are closer to the Pacific Ocean, which is a source of cooler and more stable air. A semi-permanent area of high pressure sets up shop over the cold waters of the Eastern Pacific in the late spring and summer. This couples with thermally-induced low pressure that develops over the interior of California during hot summer weather, and produces onshore flow in the lower part of the atmosphere. Low stratus clouds and fog which develop over the cold stable ocean waters are pushed onshore, usually not making it much past the coastal ranges, but the marine air can penetrate farther inland. However, as we head through summer, high pressure over the Pacific tends to be weaker aloft, while high pressure over the Rockies strengthens. The clockwise flow around that high **(Fig. 13)** will allow stronger surges of monsoonal moisture to travel farther northward. If the mid- and upper–level pattern is such that the flow of moisture from the south has an easterly component, monsoonal moisture is able to travel farther north and westward toward the coastal ranges of Northern California and southern Oregon.

That is not to say that thunderstorms cannot develop over northern California in other ways. When the Jetstream is farther south, usually closer to Spring, mid- and upper level-disturbances passing through in generally a west to east fashion, will help trigger convection across interior Northern California. Typically this will be more dependent on daytime heating, which is greater later in the spring and summer, to provide enough instability to allow cumulus clouds to grow into cumulonimbus. This atmospheric flow regime typically has westerly or southwesterly winds aloft though, which will favor thunderstorm development on the east side of the southern Cascades, from around Mount Shasta and the horn of Trinity County across to the northern Sierra.

Thunderstorms play a major role in wildfire season, as most fire starts are due to lightning. Lightning is a more efficient fire starter when the fuel for fires is drier, and when the thunderstorms produce less rainfall. Dry thunderstorms are more common earlier in the summer season on the periphery of the Monsoon **(Fig. 13)**, as atmospheric moisture is more confined to a relatively thin layer above dry, low-level air. Often these thunderstorms will carry gusty winds with them as well, as rain falling from the clouds evaporates as it falls into the drier air, cooling and gaining momentum as it surges toward the ground. Virga (rain shafts which do not reach the ground) and dust being kicked up are common signature of dry thunderstorms that produce gusty outflow winds. As these storms become more frequent and the monsoonal moisture spreads farther north and westward later in the summer, the lower atmosphere becomes cooler and moister, and thunderstorms will bring more wetting rain.

From a specifically aviation standpoint, although dry thunderstorms will have relatively high cloud bases with little visibility reductions in the lowest several thousand feet, they can be particularly dangerous. These gusty outflow winds can occasionally be very strong, blowing 40-50 mph or more, and may be erratic in direction, while resulting in low-level wind shear.

As September approaches and summer begins to come to an end, the Jetstream begins to move farther south, and high pressure over the Rockies begins to weaken. This not only results in less monsoonal moisture surges, but those that do occur are shifted to the east of northern California by westerly pushes of more stable air, as cold fronts begin to track farther south across the Pacific Northwest. Daytime heating decreases with the decreasing sun angle, and instability for thunderstorms lessens as well.

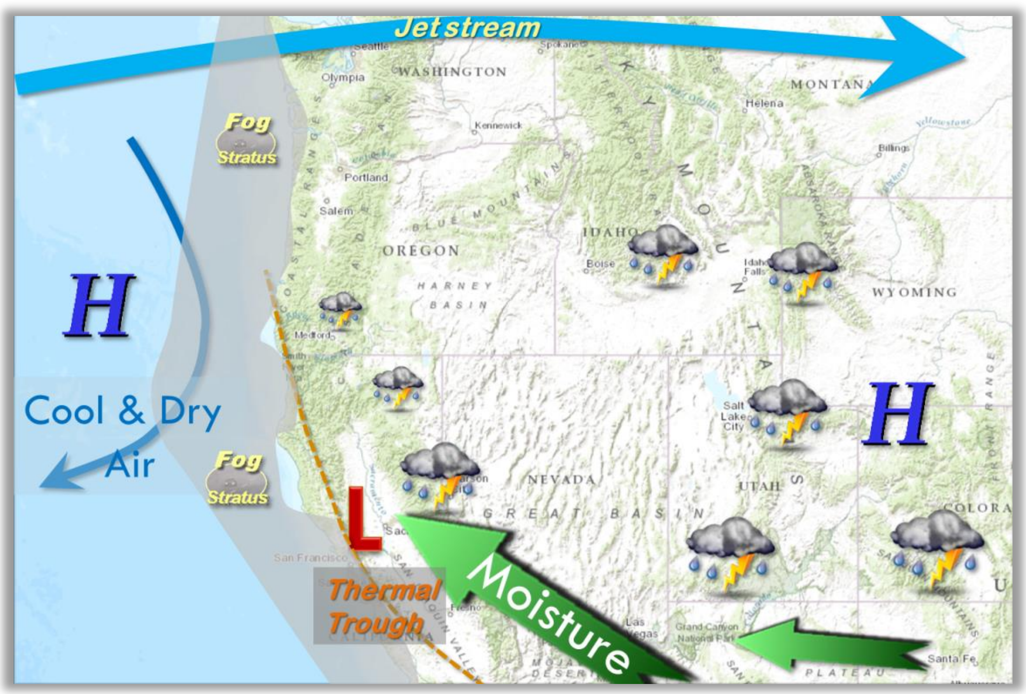

Figure 13 – *Typical summertime pressure pattern and weather across the Western U.S.*

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