Dry Slots and Large Wildfire Growth in the United States

Dry slots are responsible for rapid surface drying and increased gusty winds causing increased fire behavior

A Case for better utilization of satellite water vapor imagery

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Abstract:

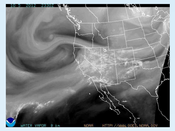
DRY SLOTS INFLUENCING LARGE WILDFIRE GROWTH IN THE UNITED STATES

Dry slots are responsible for rapid surface drying and increased gusty winds causing increased fire behavior

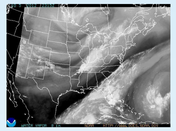
Operational fire weather meteorology can be improved utilizing satellite water vapor imagery for identifying dry slots, which are responsible for rapid surface drying and increased gusty winds causing increased wildland fire behavior in the United States (U.S.). There is a plethora of research papers dealing with fire weather and wildland fires in the U.S. However, few of them discuss the influence of dry slots. A re-examination and re-evaluation of the relevant literature on the subject of wildfires specifically influenced by dry slots is approached from the point-of-view of utilizing more water vapor satellite imagery for operational wildland fire weather meteorology in the future. Wildland fire weather forecasting in the U.S. is an important facet of mesoscale and synoptic meteorology. Indeed, the very first Standard Firefighting Order deals precisely with weather - Keep informed on fire weather conditions and forecasts. Moreover, two of the 18 Watch Out Situations deal specifically with dryness and winds. It is well documented in the available literature that surfacing mid- to upper-tropospheric weather is responsible for dry air intrusions. Most times, these dry intrusions manifest themselves as clearly visible dark bands in the satellite water vapor imagery, referred to as dry slots. These dry slots usually result in abrupt surface drying and strong, gusty winds often radically influencing wildland fire behavior and hence fire growth. These phenomena can be significant safety issues for fire managers, especially for those fireline supervisors and firefighters on or near the active firelines. This will also apply to active prescribed and/or controlled burns. Therefore, accurate and timely dry slot recognition and warnings clearly address the rules in the Standard Firefighting Orders and would allow for better recognition and mitigation of the 18 Watch Out Situations. Dry slots are particularly well documented for Australian wildfires thanks to the work of Dr. Graham Mills and others. Due in large part to their research and efforts, the Australian Bureau of Meteorology utilizes dry slot forecasting and nowcasting on a regular basis during their bushfire seasons. In fact, they even utilize a 'dry slot poster' to better educate and inform their fire managers to 'beware the dry slot.' However, little is known or documented for such dry slot occurrences in the U.S. In the cases examined, taken from the existing literature, it will be shown that several wildland fires in the U.S. have in fact been influenced by these dry slots resulting in extreme and unusual fire behavior and large fire growth. One of the issues addressed by the author is the fact that the 'dry slot' term is not very well utilized in the U.S. and there as many as thirty synonymous expressions used in the relevant literature. Positive research excerpts from the literature regarding the benefits of utilizing water vapor imagery in nowcasting and forecasting will be addressed. A case will be made for more consistent utilization of water vapor imagery and dry slot nowcasting and forecasting in the U.S. resulting in more accurate operational fire weather meteorology.

WATER VAPOR IMAGERY
DRY SLOTS - DRY AIR INTRUSIONS
October 5, 2012 - 2330 Z
Courtesy NOAA, GOES, NESDIS

Western Sector US WVI



Eastern Sector US WVI



Dry Slots

- Identifying **dry slots** can provide the fire weather forecasters with beneficial nowcasting and forecasting verifications that are especially helpful in making accurate confident fire weather predictions.
- Ideally, this presentation will galvanize you to look into the subject further and spread the word about your **dry slot** knowledge, a new fire weather indicator.

Causes - Contributing Factors Precursors - Indicators -

- ***Appear as dark bands or dark holes in WVI between 4km and 6 km***
- ***Cannot be seen by the naked eye, WVI only; not well predicted by computer modeling***
- ***Originate in dry mid-tropospheric and/or lower stratospheric regions***
- ***At high altitude, hot air mixing with cooler air***
- ***Pulls down the drier, faster-moving air, rapidly to the surface; only those that reach Earth's surface affect drying and winds***
- ***Most likely occur in mid-afternoon, especially on hot days***
- ***75% occur with troughs, dry cold front passage, cool changes, co-located with jet streams***
- ***Different types of problem dry slots associated by Critical Fire Weather Patterns (e.g. post-frontal, pre-frontal, breakdown of the upper level ridge, foehn wind, low-level jet entrance circulations, advance of tropical storms)***
- ***Dry intrusions and dry slots often evident in WVI almost a full day before seen in IR or VIS. Tropospheric jet stream induced gravity waves; topographic rather than coastal influenced***
- ***Mountain-wave breaking – Lee trough circulations***
- ***Dry slots ALWAYS reflect comparatively dry middle and upper troposphere***
- ***The darker the dry slot, the lower the humidity***
- ***Satellite imagery will reveal structures not detected by conventional data***
- ***Surfacing dry slots almost always result in Haines 5 or 6!***
- ***Surface RH drop caused by surfacing dry slots - almost always lower than the forecast RH....surprisingly low!***
- ***Abrupt decrease in relative humidity, dew points, and ultimately fuel moistures***
- ***Strong, gusty winds***
- ***Rapid, sustained increased fire behavior***

Fighting Fire By The Rules

- On the fireline - as strictly as possible - follow the TEN STANDARD FIRE ORDERS and heed the 18 WATCH OUT SITUATIONS.
- As fireline supervisors, we all use clouds as weather indicators to predict fire weather, especially winds.
- I will be presenting a new, REAL-TIME fire weather indicator and fire weather forecasting tool, adopted from the Australians, viewed only through satellite WVI
- Regarding fire weather forecasting, several of the STANDARD FIRE ORDERS and WATCH OUT SITUATIONS directly apply to fire weather conditions and forecasting:
  - TEN STANDARD FIRE ORDERS
  - 18 WATCH OUT SITUATIONS
  - WVI and **DRY SLOTS** -- Real-Time Fire Weather Indicator and Operational Meteorology Tool (15-30 minutes NOAA)
- We base our strategy and tactics on accurate fire weather forecasting. Accurate fire weather forecasting allows us to more safely accomplish our tactical wildland firefighting and supervision responsibilities.
- It's the *PREDICTED* fire behavior that is often underestimated and/or unheeded, many times resulting in tragedy.
- According to lessons learned and investigation reports, it's the unpredicted fire behavior generally catching firefighters off guard, usually resulting in burns, burn-overs, or fatalities.
- Accurate real-time **dry slot** identification and forecasting would better address the predicted fire behavior realm, thus hopefully preventing injury and other dire consequences.

Fire Weather Forecasting

- Several well-respected North American fire weather forecasters, meteorologists, and researchers have identified, researched, and written about the "*dry slot*" phenomenon as it exists in North America, even though not specifically referring to them as such.
- Currently, utilized somewhat in weather forecasting in AZ, NM, CO, Northeast regions, and fairly extensively in the South and Southeast.
- These are often times referred to as dark bands and/or filaments and/or ribbons of dry air in the literature.
- Well-educated, trained meteorologists are readily able to *see* these "**dry slots**" with precision using WVI - accurate and timely fire weather nowcasts and predictions is the desired outcome.
- With some exceptions, fireline supervisors have a very basic knowledge of subsidence, dry air intrusions, and **dry slots**, but generally not a working knowledge.
- On the fireline, the best we can do is view WVI from a laptop on the hood of a truck. Forecasting these events and broadcasting them to us while on the fireline would be much safer if accomplished by meteorologists.
- This would give us time to more "safely" and "aggressively" practice wildland fire fighting, anticipating the "expected fire behavior" on a real time basis, so we could disengage and/or change tactics and/or escape and move to safety if need be. Better situational awareness.
- Goal? North American fire weather predictions – utilize the Australian Bureau of Meteorology "**dry slot**" fire weather nowcasting and forecasting on a regular basis, as they occur.
- Would allow for more accurate REAL TIME fire weather predictions of abrupt surface drying, associated wind events affecting fire weather, resulting in erratic fire behavior.
- Conventional fire weather forecasting, modeling. Very good job thus far – merely want to add another tool to meteorologists' toolboxes, i.e. WVI **dry slot** nowcasting and forecasting.
- Standardized terminology. North America and Australia.

United States Wildfires Affected by Dry Slots

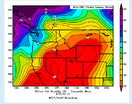
- Without exception, the discussed North American wildland fires were influenced by **very dry upper level air**, i.e. dry air intrusions and/or dry slots.
- In every case, this **dry air** appeared (or would have appeared) as **dark bands** on WVI satellites. These **dark bands** are commonly referred to as **dry slots**.
- These intrusions of cold, **dry air** are rapidly and sharply transported downwards to the earth's surface from the mid- to upper-troposphere and/or lower-stratosphere.
- **Subsidence** brings down **very dry air** from upper levels to the surface. The dryness enhances through adiabatic compression, and warming, leading to air with very low relative humidities and dew points. It often results in strong gusty winds as well. Sometimes the drying occurs horizontally via advection.
- In every case, a dry air intrusion and/or **dry slot** passed over the fire area causing very low RH's, dew points, and strong winds, to align resulting in unusual, often extreme, and/or erratic fire behavior.

Limited North American Dry Slot Research

- Mann Gulch Fire of 5 August 1949; Helena N.F. in Montana
- Mack Lake Fire of 5 May1980, in Northern Michigan, Huron N.F.
- Willis Gulch Fire of 26-27 July, 1988; Boise N.F. in Idaho.
- Lowman Fire of 29 July1989; Boise N.F. in Idaho.
- Awbrey Hall Fire of 4 August 1990 near Bend in Central Oregon.
- Double Trouble State Park Fire (DTSP) in East-Central New Jersey on 2 June 2002.
- Texas and Oklahoma wildfires on 1 January 2006.
- Lower North Fork Prescribed Burn escape, 26 March 2012.

Mann Gulch Fire
Helena N.F. Montana
August 5, 1949

"RH pattern of the western US indicated a "tongue of very dry air extending from the Great Basin into the Northern Rockies." Estimated RH 10% - 15%. Courtesy of NOAA/ESRL - Physical Science Division - 20th Century Reanalysis Project



850 mb RH at 0Z (1800 MDT)

Mann Gulch Fire – Helena N.F. Near Helena, Montana August 5, 1949

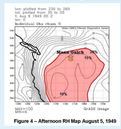


Figure 4 – Afternoon RH Map August 5, 1949

Low RH at Mann Gulch fire due to the '**tongue of very dry air**' in Montana. Surface RH's ranged on the fire to About 15% - shaded area.

This more than likely would have been seen as a **dry intrusion** and/or a **dry slot** on WVI.

Courtesy of NOAA-CIRES/ Climate Diagnostics Center and Paul Werth

Mann Gulch Fire – Helena N.F. Near Helena, Montana August 5, 1949

- Record-setting heat wave over Western U.S. early August 1949, including Montana.
- Maximum temps in Helena in 90's; RH dropped from 40% in the AM, to 24% by noon; winds in Helena 5-8 m/h in the AM, increasing to 15 m/h at noon; likely similar on fire site; unstable air mass over area.
- Mann Gulch is 20 miles north, northeast of Helena
- Helena reported winds of 30+ m/h in PM, downdrafts calculated at 40 – 50 m/h (modeling and interviews).
- Fuels – grass, Ponderosa Pine, Douglas Fir
- "Tongue of very dry air" (**dry slot** and/or **dry intrusion**) extending from the Great Basin to Northern Rockies.
- Within this area, surface relative humidity ranged from 10-20 percent. The Mann Gulch area was located near the 15 percent RH contour line within this area (shaded area).
- August 1949, temp and RH graph (not shown) indicate temp of 97 and RH of 16%.
- "Calculated high altitude Haines Index … solid 5 and a borderline 6".
- "… at about the time of the Mann Gulch Fire blowup, and the resulting entrapment of the smokejumpers, the weather pattern at the fire site was dominated by: an upper level ridge of high pressure; a surface heat low (or thermal trough), and very dry air near the surface." p. 3, Werth (2007)
- Increased fire behavior > fire whirls > spotting > crowning > blow-up > entrapment > fatalities

Lowman Fire

BOISE NF 29 July, 1989
GOES-7 IR, July 29, 1989, 2101 UTC

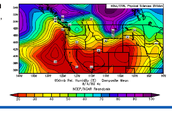
- WVI indicates a dry intrusion extending from southern California, through Nevada, and into Idaho and Montana over fire area at 1500 UTC. This is just before the inversion broke at 1700 UTC and prior to erratic fire behavior at 1900 UTC. Fire behavior finally diminished at 0100 UTC on July 30.
- Fuels – pines, grass, and brush with pockets of logging slash.
- RH values 8% to 14%. Temperature 90° F to 95° F. Haines 6 in Idaho.
- Erratic fire behavior due to alignment of dry air intrusion radically lowering RH, a high Haines Index coinciding with dry slot passage.
- Very heavy fuel loading of dead and down trees result of April 1986 thunderstorm downburst. Persistent drought since 1987. Palmer drought index severe.
- Experienced a fire behavior blow-up described as a "fire storm" on July 29th with fire moving at 1500 meters per hour.

Surface thermal trough extending from southern Nevada to western Idaho border

Awbrey Hall Fire Central Oregon near Bend August 4, 1990

Courtesy of NOAA – CIRES, Earth Systems Research Laboratory, Climate Diagnostics Center, Reanalysis Program

Note **dry intrusion** through Southwest, UT, CA, NV, NW, ID. RH estimated 10% to 20%



Mack Lake Fire - 1980

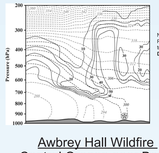
- Result of an escaped RX burn near Mio, Michigan - northeast portion of the lower peninsula of Michigan, on the Huron N.F.
- Purpose was to prepare for replanting Jack Pine in the area, part of a wildlife project for the Kirtland's Warbler, an endangered bird.
- Fuels – Jack Pine, Red Pine, Pin Oak, Black Oak, Red Oak, and understory vegetation
- "Very High" fire danger; ignited at 1426 on 5 May 1980; 1615 spotted across Michigan State Highway 33; declared a wildfire. First three and one-half hours, fire advanced 7.5 miles. Within six hours it took one life, destroyed 44 homes and buildings and within 30 hours burned 21,000 acres. *They intended to burn only 28 acres.*
- Major fire run between 1230 and 1600 hours on May 5th. Between 1700 and 1800, the fire advanced at 6 to 8 miles ph.
- RH fell to 21% during the day.
- Leading edge of cold front arrived 5 May 1980 at 1800 UTC

Mack Lake Fire - 1980

- "The Mack Lake fire was characterized by a developing upper-level front embedded within a shortwave trough in the vicinity of the fire. …. The **subsidence** ushered **dry air** from the **middle and upper-troposphere downward** along sloping isentropes **adiabatically warming and drying** it along the way. A well-developed **dry air intrusion** … [supplied] the fire environment with **dry air that originated in the upper-troposphere/lower stratosphere**. The organized **subsidence** was also responsible for **downwind advection of high momentum air** from within the frontal zone into the fire environment …. We conclude that upper-frontal processes, characteristic of northwesterly synoptic-scale flow, are likely a contributing factor to the prevalence of wildfire spread under such synoptic-scale conditions." Zimet at 131
- A **dry slot** may be **inferred** on the following image. Note the very low humidities in the upper reaches of the atmosphere.

Mack Lake Fire – 1980

Vertical cross-section, **RH solid black lines** in %, contoured at 10% valid at 1800 UTC, 5 May 1980. *Courtesy of Zimet, et al (2007).*



Note the low RH's in the troposphere. **Dry slot** inferred.

Awbrey Hall Wildfire Central Oregon near Bend August 4, 1990

- Unusual, extreme fire occurrence and peak fire intensity 2100-2400 hours – plume dominated fire behavior
- Fuels – second growth ponderosa pine with nearly continuous bitterbrush undergrowth and grass
- Temperature 95° F; Humidity 15% Winds 20-45 knots Haines of 5 and 6
- WVI indicates **dry intrusion** over fire area at 0301 UTC (3-6 hours after erratic and unusual fire behavior)
- Erratic and unusual fire behavior due to very low RH, high temperature, wind, moderate to high Haines Index in alignment as **dry intrusion** passes over fire area

Awbrey Hall Fire August 4, 1990

Courtesy of Saltenberger and Barker

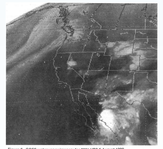


Figure 8. GOES water vapor imagery for 0301 UTC 5 August 1990

Double Trouble Fire Dry Slot

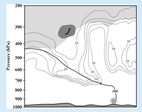
WVI 0015 UTC 3 June 2002

Double Trouble Wildfire - 2002

- Quite clearly, GOES imagery indicates a dark band - "**a ribbon**" or "**narrow filament" of dry air** - advancing south-eastward toward the fire. This is a **dry slot.**
- Surface winds begin light, then increase from less than 10 m/h to 70+ m/h and shift from west-southwest to west-northwest. Result of frontal passage.
- A narrow, dark filament [**dry slot**] is visible on GOES satellite WVI coinciding with rapidly lowering RH values and strong winds on the surface, appearing about 1600 and lasting throughout the fire's maximum intensities.
- Theory (at the time) - source of the dry, high-momentum air originated in the middle troposphere.
- Conclusion – fire's outbreak and rapid growth resulted from the **downward transport of a narrow filament of low relative humidity air** linked to a reservoir of dry air in the middle troposphere. This was indeed a **dry slot**.

Mack Lake Fire - 1980

The bold solid line is the 300 isentrope. The **light gray lines are contours of RH** valid at 1800 UTC, 5 May 1980. Light gray shading indicates air with potential vorticity with greater than 1.5 PVU. **The dark shading with the 'J' inscribed is the 32.5 ms -1 isotach indicating the upper tropospheric jet**. Asterisk within a circle is approximate location of the Mack Lake fire. This also would very likely have shown up as a **dry slot** on WVI. Courtesy of Zimet, et al.

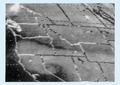


Note the low RH's in the atmosphere

Dry slot inferred through RH contours

Willis Gulch Fire Boise NF - July 26, 1988

Water vapor satellite imagery and Haines Index for 1200 UTC 26 July 1988. Courtesy of Werth and Ochoa.



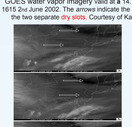
Water vapor satellite imagery 1200 UTC 26 July 1988

Willis Gulch Fire Boise NF, Idaho July 1988

- Temps 95° to 102° F, **RH 10% to 15%.**
- Fuels - pines, grass, and brush, scattered aspens.
- **26 July major fire run coincided with dry slot passage over fire area influenced by thermal trough and weak cold front.**
- Haines focus. Observe "**dark band**" on WVI. **Concede dry slot low-level dry air.** Continue Haines focus. Conclude Haines and very low RH key factors. **ACTUAL - Haines 5, dry slot passing over fire area severely reducing RH - alignment - causing erratic fire behavior.**
- *Werth, Paul and Richard Ochoa (1993) The Evaluation of Idaho Wildfire Growth Using the Haines Index, Amer. Meteor. Soc. 8, 223-234.*

Double Trouble Fire

GOES water vapor imagery valid at a 14.15 UTC, b 15.15, c 1615 2nd June 2002. The arrows indicate the changing location of the two separate dry slots. Courtesy of Kaplan, et al, 2008.



1415 UTC

1515 UTC

1615 UTC
Note the darkest dry slot with distinct boundaries prior to active fire behavior

Double Trouble Fire - 2002 Fire Weather

Weather conditions on June 2, 2002 (erratic fire behavior):

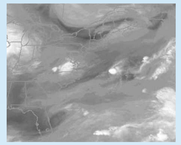
- 1415 – temperature 75° F, relative humidity 62%.
- 1700 – temperature approximately 82° F.
- 1800 – RH at its lowest value, less than 10% - A remarkable drop of 50%+ humidity drop in 4 hours!
- 1700 to 2200 – temperature hovers around 80° F.
- Winds have shifted from northwest to west-northwest. Strengthening and gusty.
- Lowest dew points, relative humidities, and highest winds align at 1800, coinciding with high temperatures and increased fire behavior as visible **dry slot** passes over the fire area.

Double Trouble Fire - 2002 Fire Weather

- Fuels – Pine Barrens fuel type with Pitch Pine, Shortleaf Pine, Scrub Pine, various oaks, with brush and scrub understory.
- "Geostationary Operational Environmental Satellite (GOES) water vapor imagery for [the afternoon and evening of] 2 and 3 June 2002 … delineates a **ribbon of dry air** advancing south-eastward during this time period. This **ribbon of dry** air coincides closely with the axis of the jet streak at 1200 UTC 2 June 2002 and 0000 3 June 2002 … The GOES imagery suggest that **dry air in the middle-to-upper troposphere** moves over southern New England … in the previous days." Charney at 431
- The obvious "**dry slot**" is referred to as a "**ribbon of dry air**."

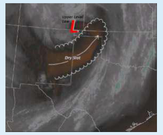
Double Trouble Fire Dry Slot

WVI 1215 UTC 2 June 2002



WVI Dry slot – Texas – January 1, 2006

GOES-East water vapor channel satellite image from approximately 1600 UTC, 1 January 2006 showing a midlevel cyclone centered over far southeast Colorado with a pronounced **dry slot** across eastern New Mexico into the Texas and Oklahoma Panhandles. Courtesy of Lindley, et al.

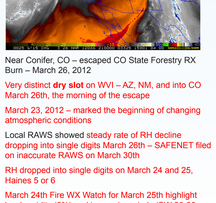


Texas and Oklahoma January 1, 2006

- Very poor weather forecast modeling drastically and unfortunately underestimated RH values and winds and completely missed an approaching cold front, radically increasing fire behavior on several wildfires with varying consequences
- 143 fires, 303,570 acres burned, 115 structures destroyed
- KBDI of 600 to 800 (extreme) - Extreme drought for several years
- Very heavy grass fuel loadings due to vigorous spring and summer growth
- Recurrent dry cold front passages throughout fire season
- **Dry slot** passing over eastern New Mexico and northwest Texas results in very low RH's and dew points, critically low fuel moistures, and winds aligning regularly resulting in very erratic fire behavior

North Fork Escaped RX Burn CO March 26, 2012

16-KM WVI at 2100 Z (0900 MDT) on Monday, March 26, 2012 just west of the burn unit. **Mid-level dry air** indicated by Dark and Orange enhancement. Courtesy of CO State Univ. Co-op Institute for Res. in the Atmosphere (CIRA)



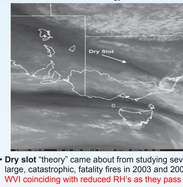
- Near Conifer, CO – escaped CO State Forestry RX Burn – March 26, 2012
- Very distinct **dry slot** on WVI – AZ, NM, and into CO March 26th, the morning of the escape
- March 23, 2012 – marked the beginning of changing atmospheric conditions
- Local RAWS showed steady rate of RH decline dropping into single digits March 26th – SAFENET filed on inaccurate RAWS on March 30th
- RH dropped into single digits on March 24 and 25, Haines 5 or 6
- March 24th Fire WX Watch for March 25th highlight low humidity (6%) and increasing winds (SW 20-30 mi/h gusting to 45 mi/h)
- Fire WX Watch upgraded to Red Flag, March 26th – high winds with increasing winds up to 80 mi/h, "very low RH"
- WVI revealed **mid-level dry air** extending NE from the Desert SW into western CO at 0900 MDT, MANUALLY CALCULATED Haines 6, record warm and dry March 2012
- Corresponding WVI also showed significant **mid-level dryness** over the Lower North Fork at the same time. RH decreases from **17% to 5%** at Polhemus RAWS (approx 13.25 miles) and **12% to 6%** at Bailey (approx. 7.25 miles).
- Fuels – open Ponderosa Pine with light grass understory and denser PP/DF stands with timber litter understory
- Ember showers began 1240, spot fires showing at 1340

Positive Dry Slots Commentary in the Literature

- "One of the least ambiguous interpretation scenarios occurs when the middle and upper troposphere are very dry. … The dark areas **always** reflect a comparatively dry middle and upper troposphere." (emphasis added), pp 705-706, Muller and Fuelberg (1990).
- "…. Satellites can reveal structures not detected by conventional data …." (emphasis added), p. 711, Muller and Fuelberg (1990).
- "Thus, a **dry band** cannot only denote convective instability if it moves over low level moisture, but it also can be associated with the upper level disturbance that may 'trigger' the instability." p. 721 Muller and Fuelberg (1990).
- The literature indicates that numerous wildland fire, government departments and agencies, the public, Indian tribes, scientists and researchers, non-governmental executive and leadership and other councils, strategists, numerous other stakeholders, legal, fire weather meteorology, and predictive services' documents and organizations have advocated for, among other things, "better fire weather prediction."
- "**…. the dry intrusion is often evident in the [WVI] ALMOST A DAY BEFORE** it can be found in the IR [infrared] and VIS [visible]." (emphasis added), p. 318, Browning (1997); also at p. 205, Lagouvardos and Kotroni (2000); also at p. 318, Smigielski and Ellrod. (1985).
- "The extremely close agreement between the surface reports of damaging winds and the satellite signature of the southern fork of the dry intrusion is a major finding of this paper." (emphasis added) p. 38, Iaccopelli and Knox (2001).
- "It is interesting to note the strongest wind gusts were confined to the region of the dry slot." p. 4, Grum, DeVoir, and Villani (2004).
- "… The known association between mid-tropospheric dry slots and reduced atmospheric humidity may make the [WVI] a useful guide to areas where atmospheric instability over an active fire may be reduced, in addition [to] their effects on lower-atmosphere drying." p. 22, Mills (2005).
- Satellite data provides a significant benefit over complex terrain for the mountain meteorologist. …. [WVI] is an excellent tool for diagnosing mountain wave signatures. (emphasis added) P. 21, Meyers (2010). (mountain waves often indicate extreme upper air turbulence)
- Thus, if the air immediately above the mixed layer should dry abruptly, then this change could be realised at the surface in time-scales less than an hour, …." (emphasis added), p. 302, Mills, 2008.
- "…. the potential for using WVI to monitor the movement of mid-tropospheric dry air towards the fire site should be investigated as an aid in this process …." p. 308, Mills, 2008.
- "Water vapor imagery has proved to be a valuable tool for observing the ridge developments, particularly the role of the upstream ridge where clouds are absent." p. 111, Weldon and Holmes, 1991.
- "Improved prediction and understanding of weather ….", p.31, Cohesive Stategy.
- "…. Water vapor imagery … could be very useful at a later stage of the decision making process … to refine forecasts … atmospheric behavior can be compared to model output. Forecasts can then be confirmed, modified, or significantly changed." p. 60, Weldon and Holmes.

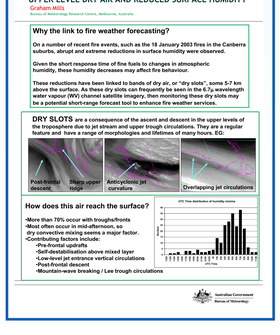
Australian Dry slots

Dry slot extending across New South Wales – WVI -18 January 2003 Courtesy of Japan Meteorological Agency and Bureau of Meteorology, 0430 18 UTC



- **Dry slot** "theory" came about from studying several of Australia's large, catastrophic, fatality fires in 2003 and 2005. **Dark bands** in WVI coinciding with reduced RH's as they pass over the fire area.
- The Australians are in the vanguard of **dry slot** research utilizing **dry slot** nowcasting as a regular course of business in their fire weather broadcasts. No longer a theory. They are very confident with **dry slot** forecasting
- For years, Australia has used research from the "HighFire Risk Project" to study and better understand **dry slots**, among other things.
- In his paper 'Dry Slots Fan the Flames,' Dr. Graham Mills, a **dry slot** researcher says: "If there is a going fire, then the **dry slot** is potentially one of the triggers to set the fire going uncontrollably. Suddenly, the fuel is drying out more quickly, the wind is stronger and gustier, and the fire can take off explosively." Mills (2006)

Dry Slot Poster



Model Forecasting Limitations

- "often difficult to interpret a single water vapor image. Best is sequence or time-lapse motion." (emphasis added) p. 77, Weldon and Holmes (1991).
- "At various points in the chain of events, the forecasts made for weather …by **computer models** or human intuition did **not accurately predict actual conditions**." (emphasis added), p. 63, Bass, William, et al CO RX Burn (2012).
- Inexperienced forecasters tend to rely too much on computer models and tend to be reactive with forecasts. p. 16, Meyers (2010).
- Quoting Bosart (2003) in his article "Whither the weather analysis and Forecasting Process" in *Weather Forecasting* **18** , 'Forecasters who grow accustomed to letting Model Output Statistics and the models do their thinking for them on a regular basis … at high risk of 'going down in flames' when the atmosphere is in an outlier [atypical, infrequent] mode.' p. 23, Meyers (2010).
- Dangerously significant shortcomings of January 1, 2006 TX and OK wildland fire wx computer forecasting guidance per numerous TX NWS meteorologists. pages 1-10, Lindley et al (2006).

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Conclusions

- "**Atmospheric conditions aloft** are becoming increasingly recognized as important factors in producing more accurate fire weather and fire behavior predictions, particularly for **periods of extreme and erratic fire behavior**. The atmospheric structures that contribute to these conditions are, in many cases, ***predictable hours or even days in advance of the event***." Charney, 18 (207). (emphasis added).
- "The task is to develop and implement indices and diagnostics into the operational fire weather and fire behavior forecasting that sense these conditions and communicate to the forecasters and the operational users of fire weather prediction when and where the potential exists for extreme fire behavior." Charney, 18-19 (2007)
- Remember to use your knowledge of this new indicator – **dry slots**. Be on the lookout for **dry slots** appearing on satellite WVI, as well as the causes, contributing factors, precursors, and indicators you've learned about.
- Remember, these "**dry slots**" indicate ***super-dry air aloft***. In addition, ***gusty winds*** are often associated. Altogether, this combination makes for risky adverse fire weather and increased fire behavior. Beware the **dry slot**.
- You are now at a tipping and leverage point. Spread the word. Make a difference by utilizing your new knowledge! Ask about and include **dry slots** in briefings. Push for utilizing **dry slot** nowcasting and forecasting.

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