Total and Layered Precipitable Water Vapor Products – Applications for Forecasting Hazardous Precipitation Events – Part 1

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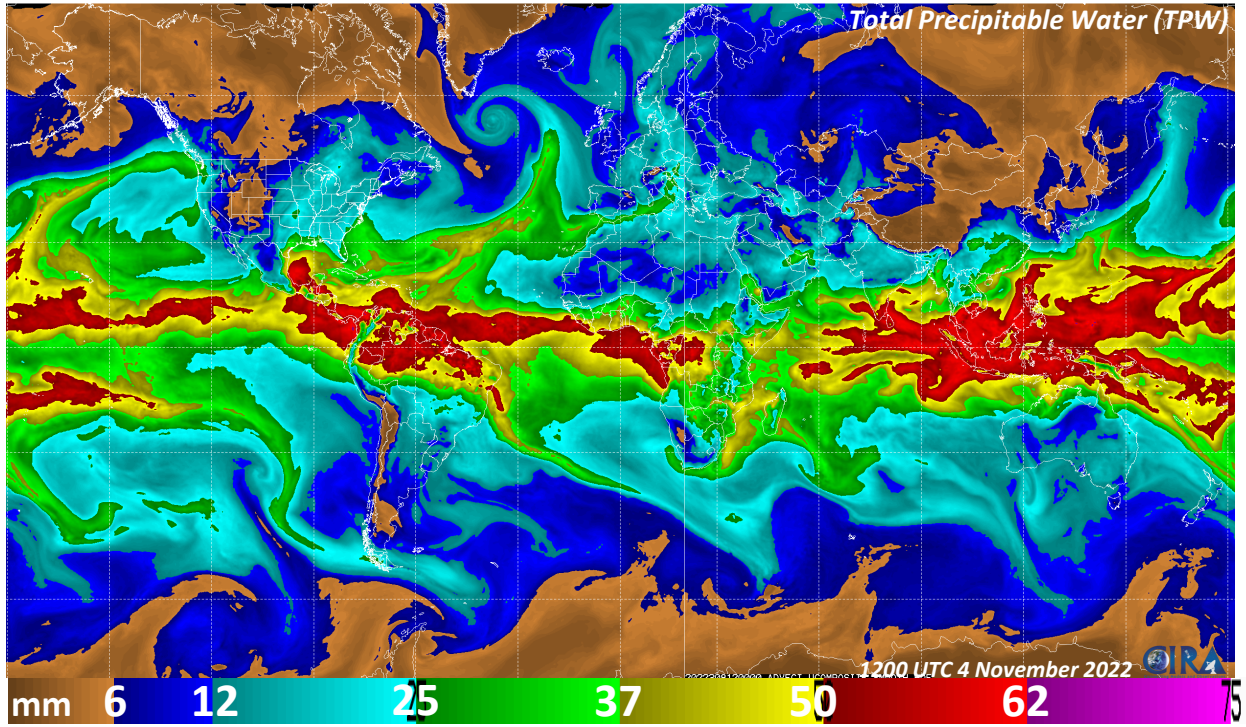
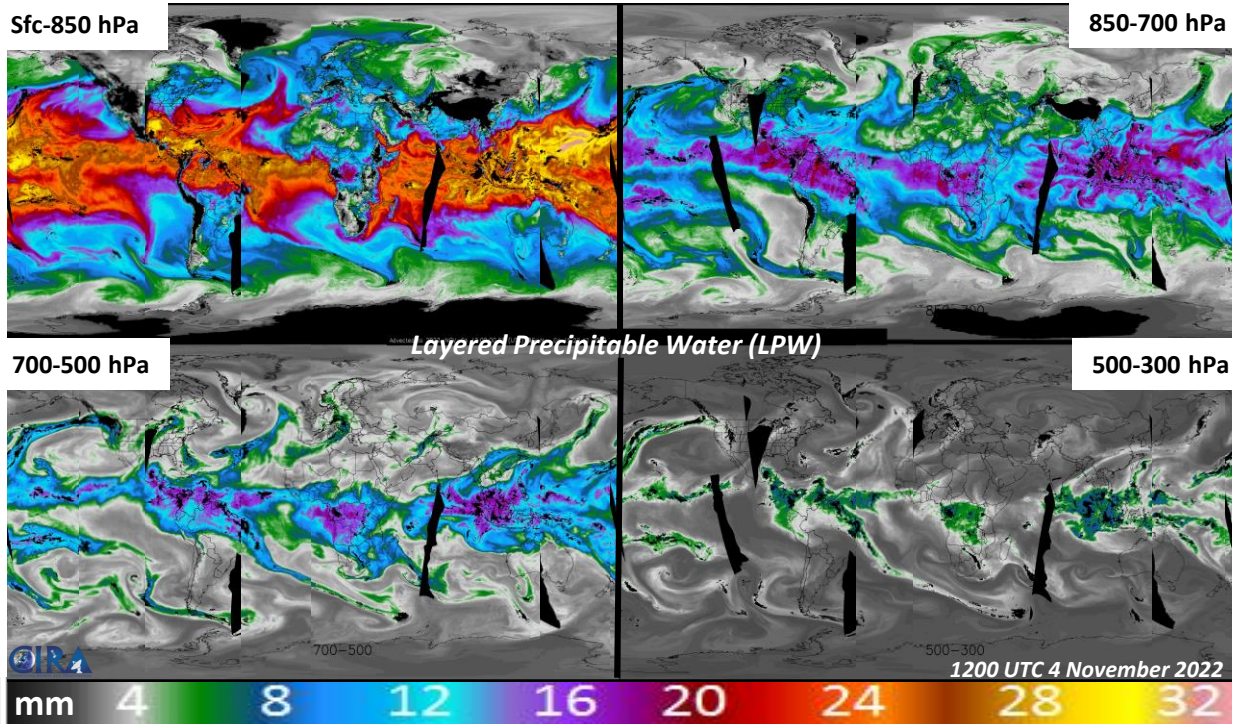
Retired NOAA/NESDIS

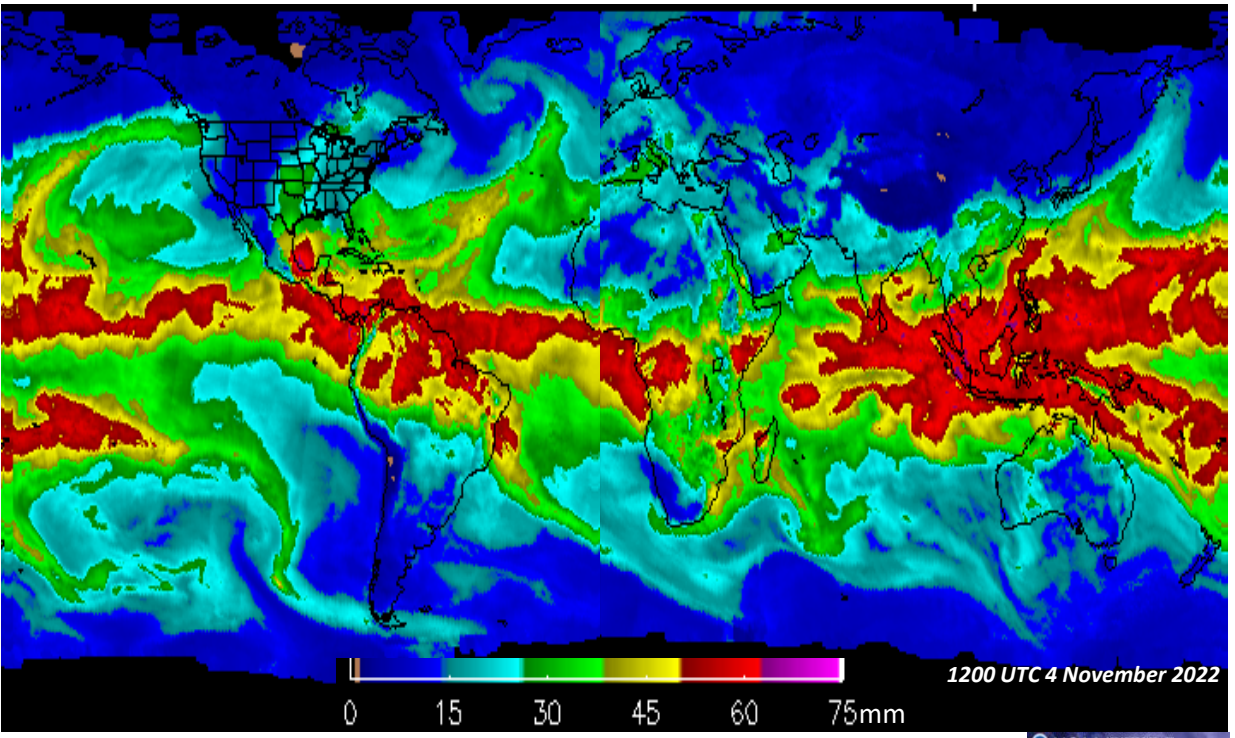
Contributions by John Forsythe, Stanley Kidder and Dan Bikos, CIRA/Colorado State University





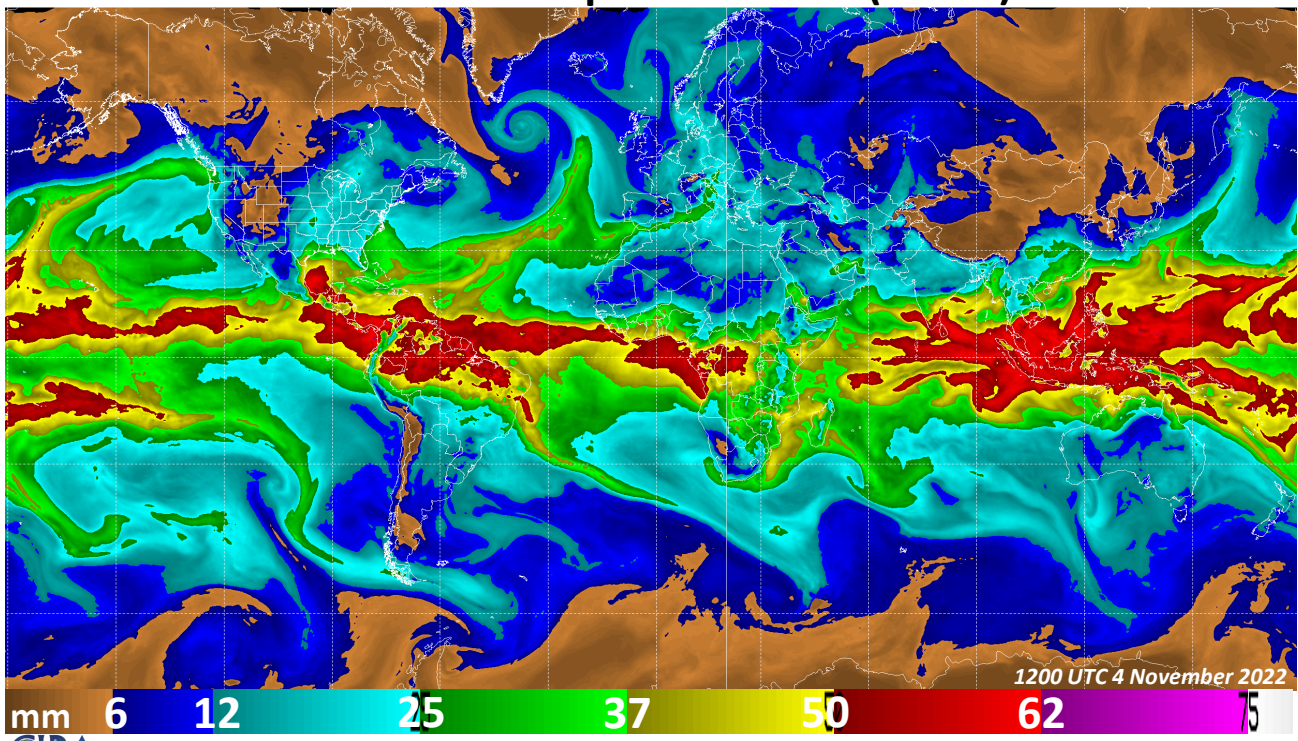
Blended Total Precipitable Water (bTPW) Being Upgraded to Advected Total Precipitable Water (aTPW) in 2023

Current NOAA/NESDIS Satellite Derived Operational Blended Total Precipitable Water (bTPW) Product



https://www.ospo.noaa.gov/Products/bTPW/

Upgraded CIRA Satellite Derived Experimental Advected Total Precipitable Water (aTPW) Product



http://cdat.cira.colostate.edu/CAT/aTPW/aTPW5.htm

Blended TPW (bTPW)

- New image passes replace old in composite, so not timely
- Operational for forecasters since 2009, so upgrade necessary
- Satellites used: N-19/20, S-NPP, Metop-B/C, GCOM-W, GPM GMI
- Over Continental US: Blend of MIRS TPW, GPS-MET, GOES ABI

Advected TPW (aTPW)

- New image passes advected to time of composite image; more timely
- Replacing bTPW for forecasters in 2023
- Satellites used: N-20/21, Metop-B/C, GCOM-W, GPM GMI
- Over Continental US: Blend of MIRS TPW, GPS-MET, GOES ABI

Special thanks to John Forsythe, CIRA, for the information

“Atmospheric Rivers” (AR) of Moisture that can Result in Heavy Amounts of Precipitation

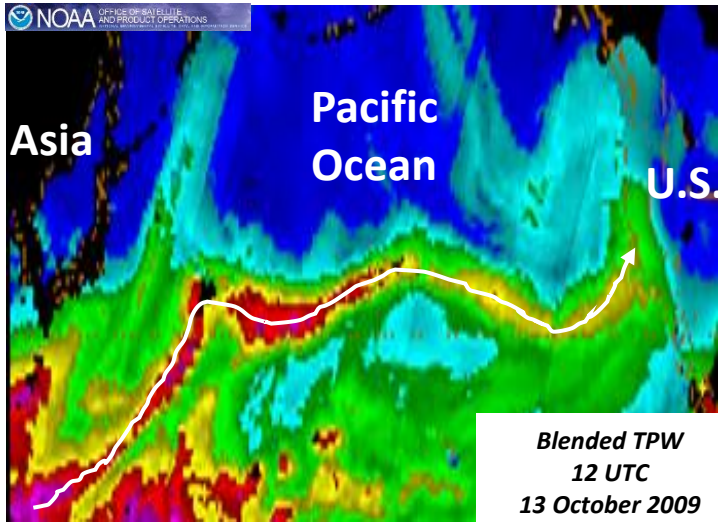
Early Season California Heavy Rain/Flooding

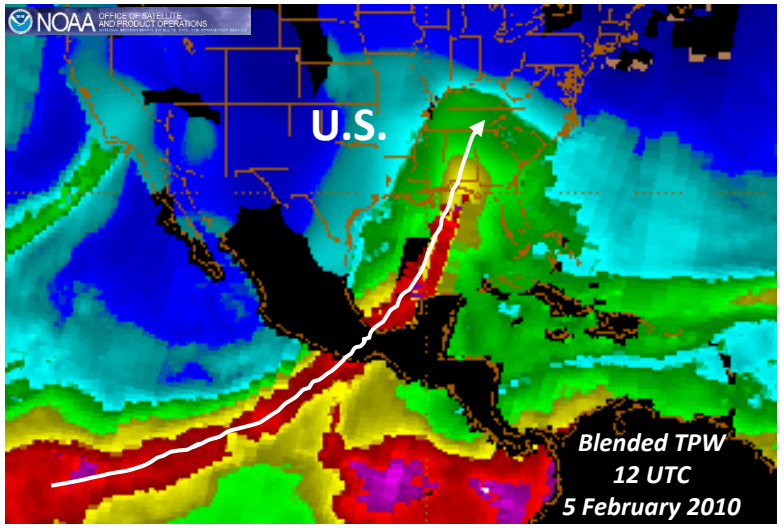
Washington DC Area 76+ cms of Snow

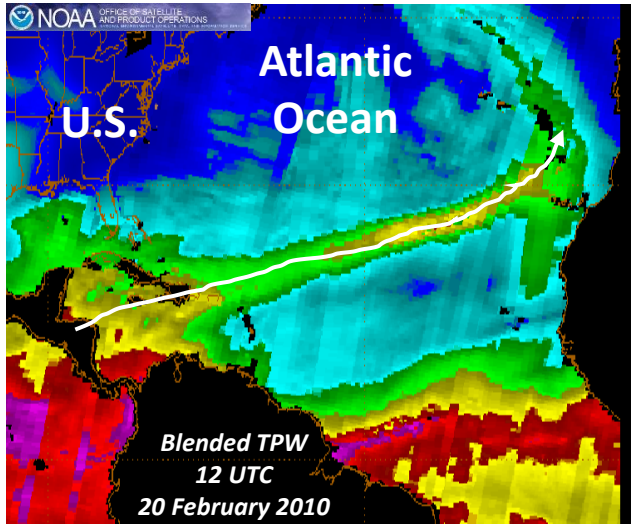
Dave Dildine/ WTOP

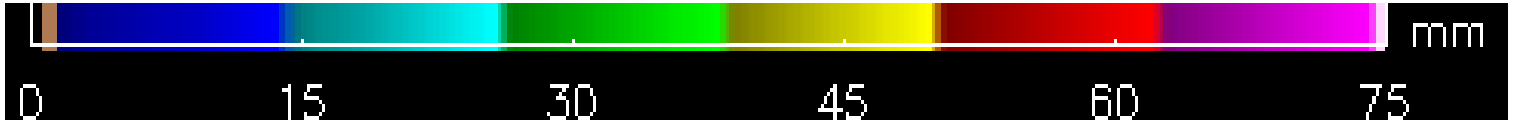
Madeira Floods and Mudslides

AP



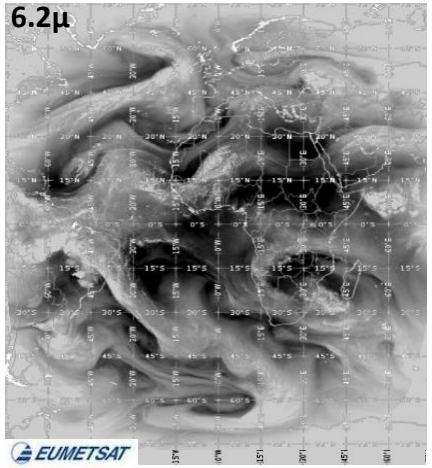




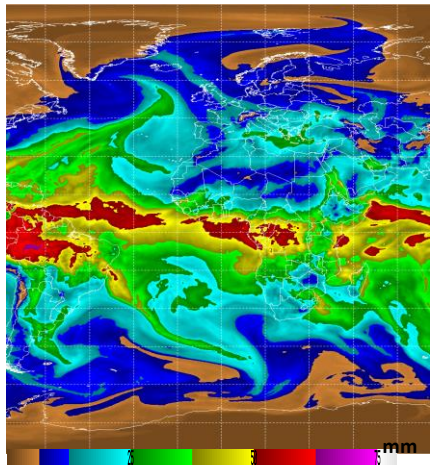


With Destructive Effects

Water Vapour Imagery

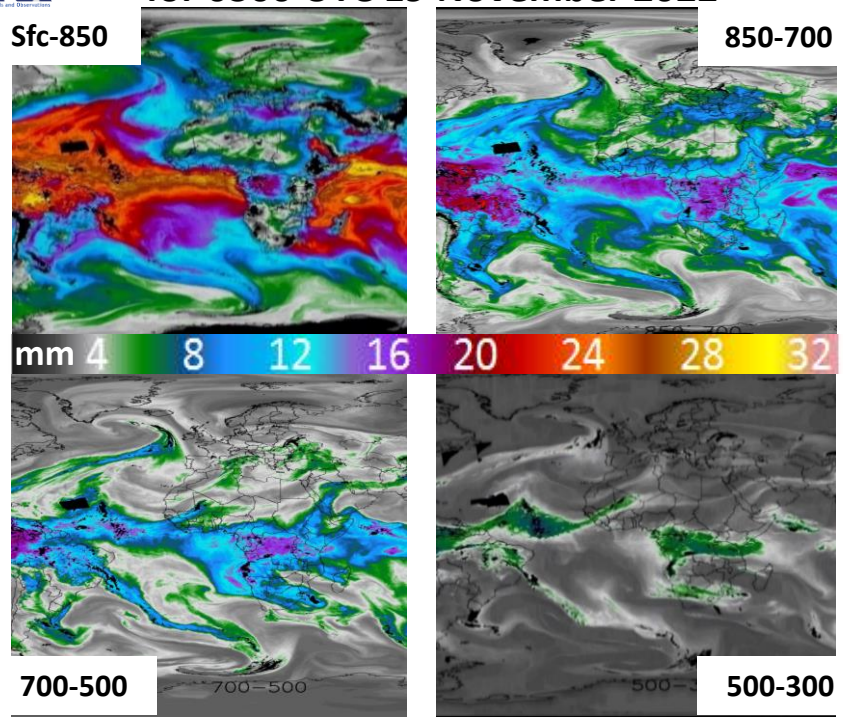


Advected TPW



0300 UTC 19 November 2022

CIRA Advected Layered Precipitable Water (ALPW) for 0300 UTC 19 November 2022



Blended total, layered water vapor products fill a void in observations

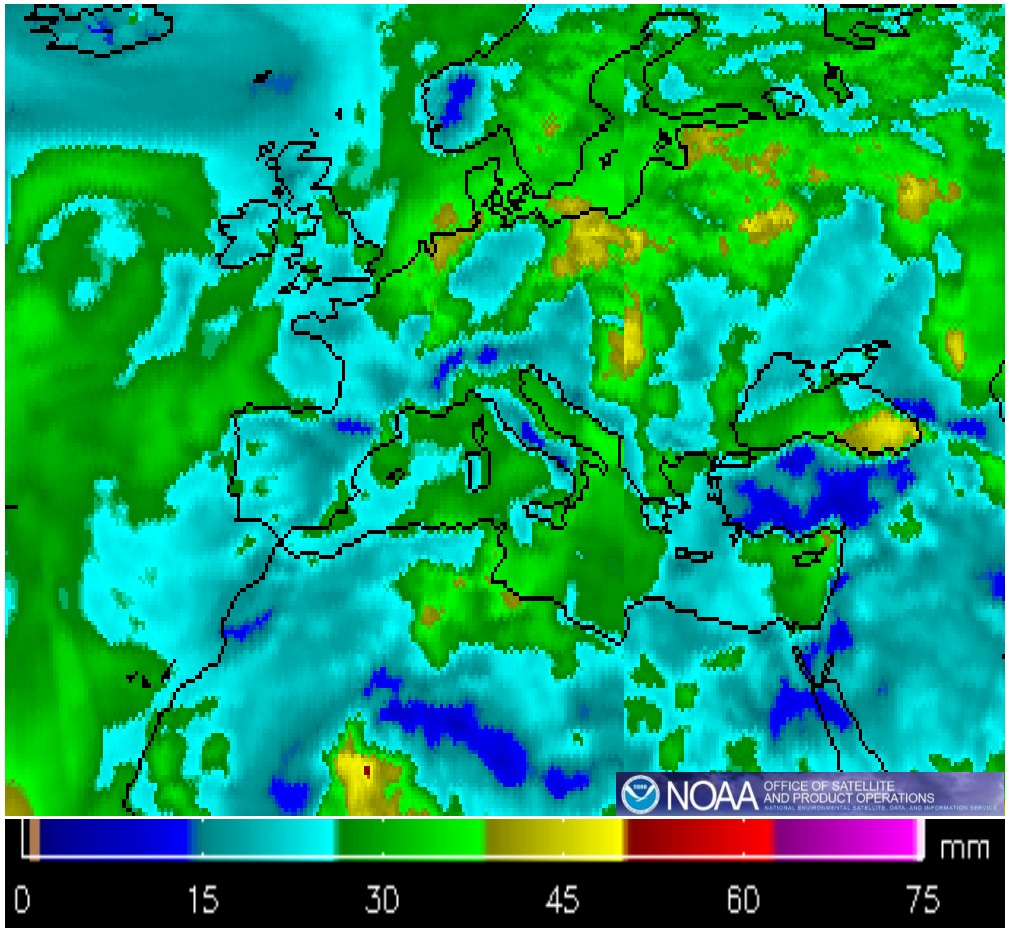
Moisture Product	Spatial Resolution and Coverage	Temporal Resolution	Strengths	Limitations
Radiosondes	~ 500 km over land None over ocean	12 hours	Trusted. High vertical resolution.	Spatial and temporal coverage
Water Vapor channel (6.3 and 7.3 µm) imagery	2 km, near-hemispheric coverage	15 minutes or less	Very high spatial & temporal resolution. Animations show flow.	Upper level moisture only. No vapor signal in clouds. Variable sensing depth
Advected TPW Advected Layered PW	16 km, global	1-3 hours (varies based on time of day), but advection improves latency	Retrievals in clouds Near-global coverage Multiple input types including *Metop-B* and Metop-C	No retrievals in heavy precipitation

For the future, interested in working with the Meteosat Third Generation (MTG) Hyperspectral Sounder to see how it compares, perhaps could be blended

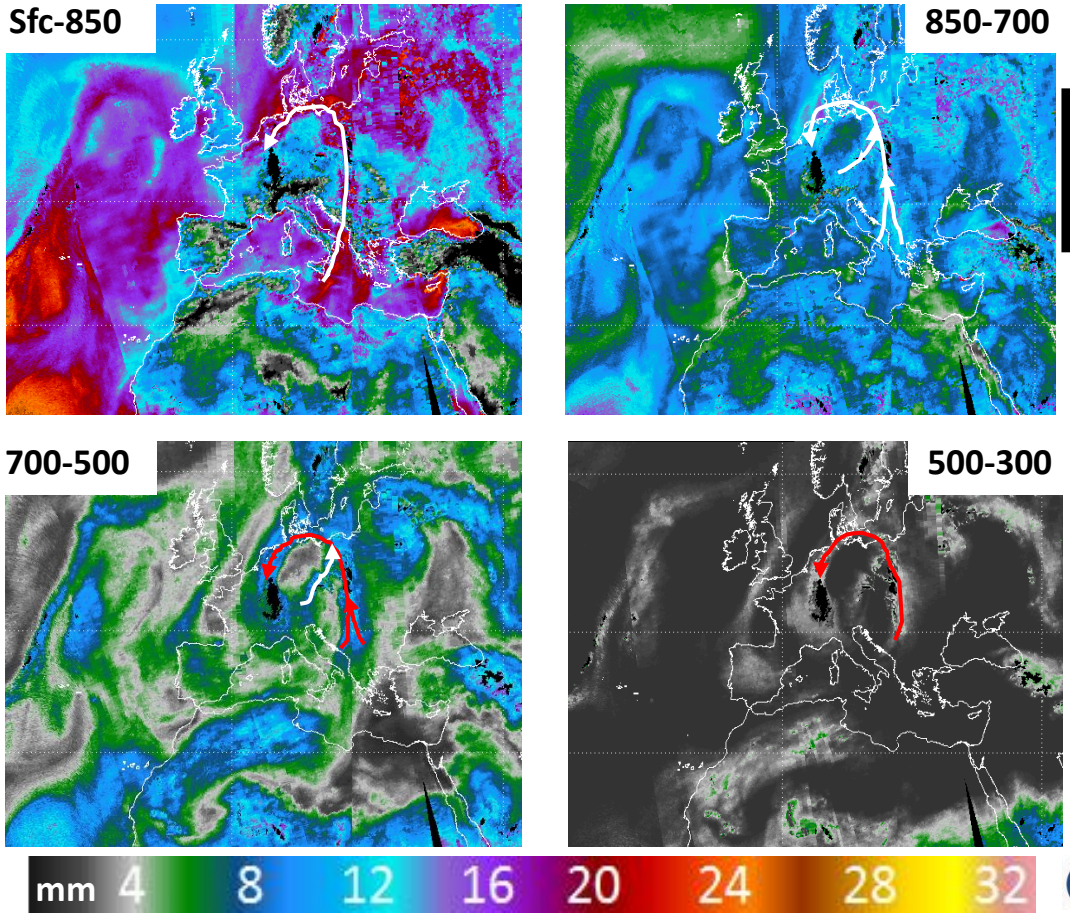
Prepared by Sheldon Kusselson, et.al

Sometimes Satellite Total Precipitable Water (TPW) and GEO Imagery Are Not Enough

Satellite Total Precipitable Water (TPW)
for 00 UTC 15 July 2021



CIRA Advected Layered Precipitable Water (ALPW)
for 00 UTC 15 July 2021

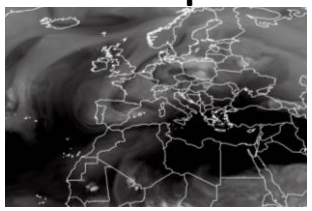


Average wind flow in layer below 700 hPa

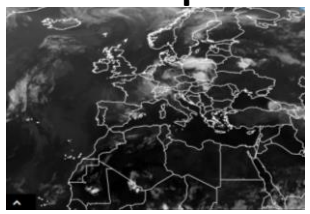
Layer Precipitable Water:
The condensed depth in some specified pressure layer

Average wind flow in layer above 700 hPa

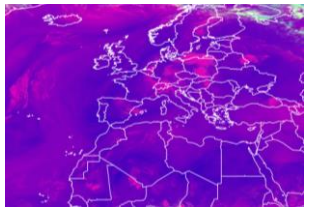
WV6.2µm



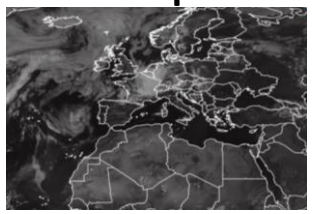
IR10.8µm



Conv RGB



VIS.6µm



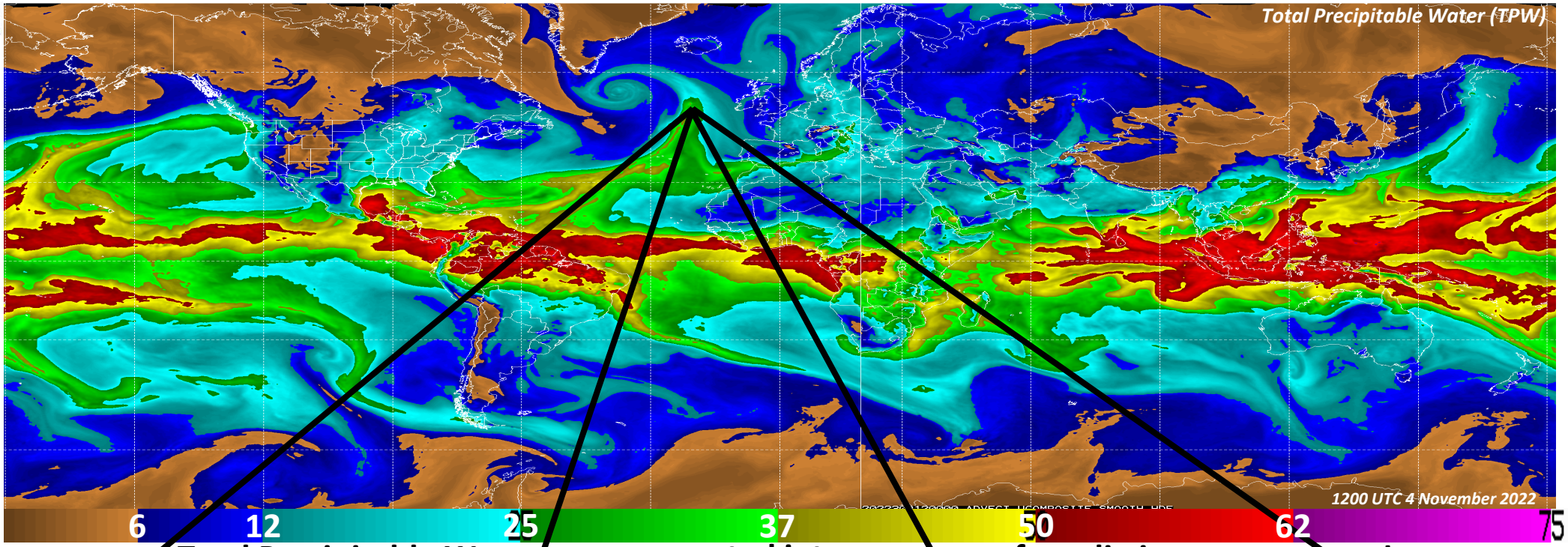
EUMETSAT

00 UTC 15 July WV & IR
00 UTC 15 July Conv RGB
14 UTC 14 July VIS

This is why the layered PW was an important addition to the TPW Product

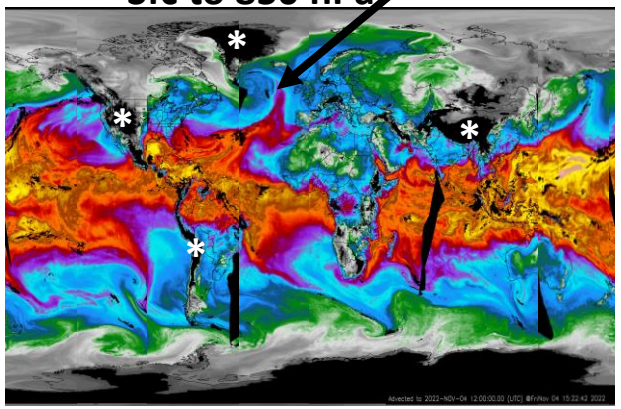
Prepared by Sheldon Kusselson

How the CIRA Experimental Advected Layered Precipitable Water (ALPW) is Made

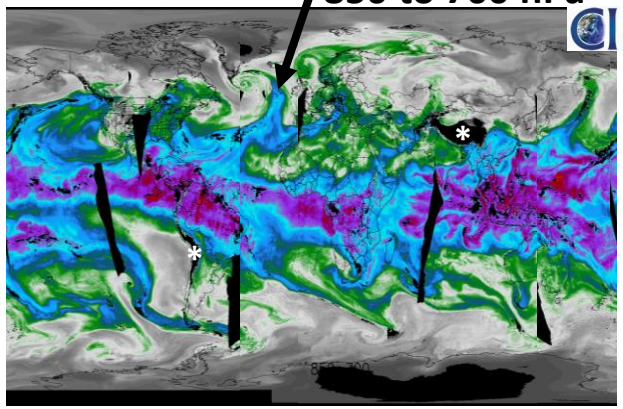


Total Precipitable Water separated into four distinct layers

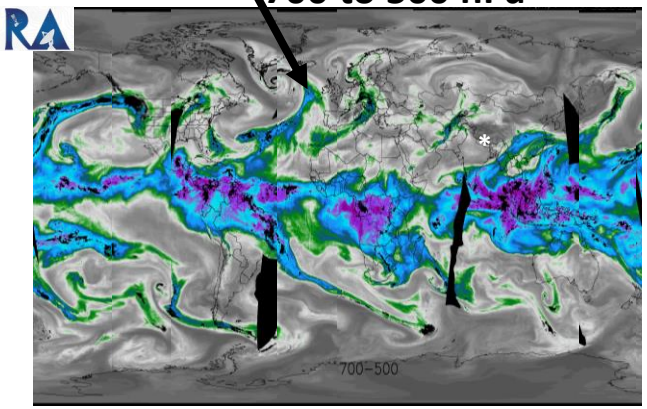
Sfc to 850 hPa



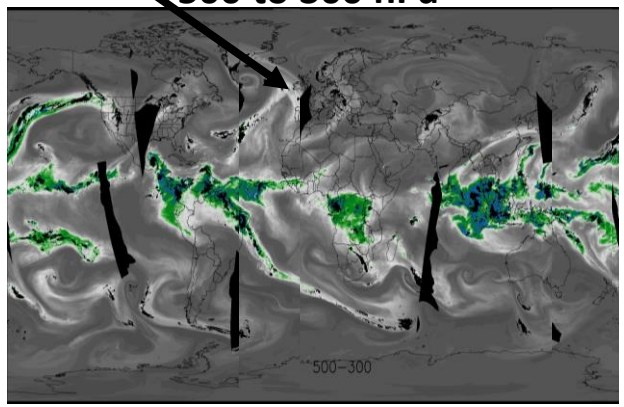
850 to 700 hPa



700 to 500 hPa



500 to 300 hPa



* **Note:** No PW data as layer below surface

mm 4 8 12 16 20 24 28 32

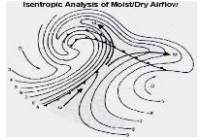
Note: GFS winds are only model used to produce product

Some Applications of the Advected Layered Precipitable Water (ALPW) for Various Cases

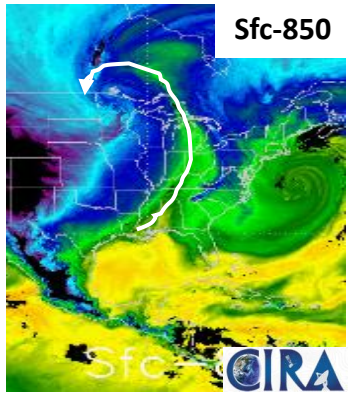
- Synoptic Conveyor Belt
- Developing/Deepening Coastal Winter Storm
- Severe Weather
- Out of Season, Hazardous Weather Events
- Remnant Tropical Storm Moisture

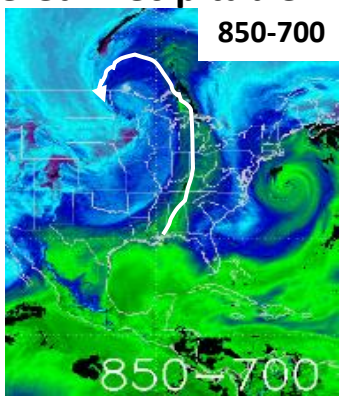
TROugh of Warm air ALoft (TROWAL) – Warm Moist Conveyor Belt into Cold Air

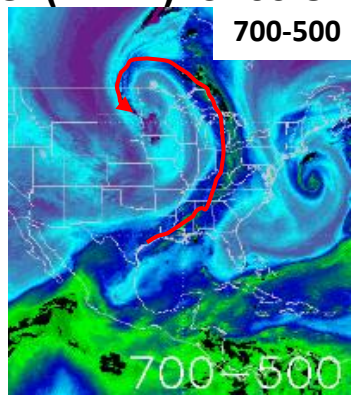
ALPW and TPW Comparisons over the U.S.

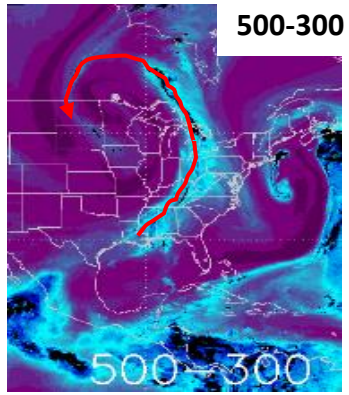


CIRA Advected Layered Precipitable Water (ALPW) for 00 UTC 12 October 2019

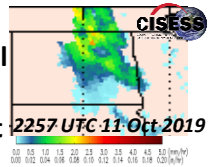








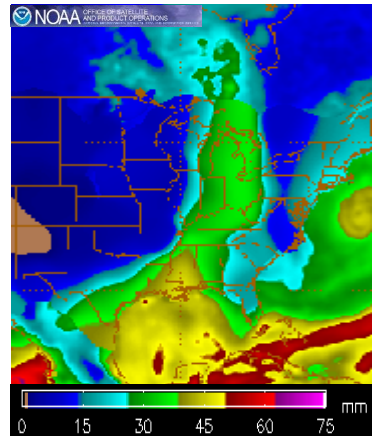
NESDIS Snowfall Rate Product



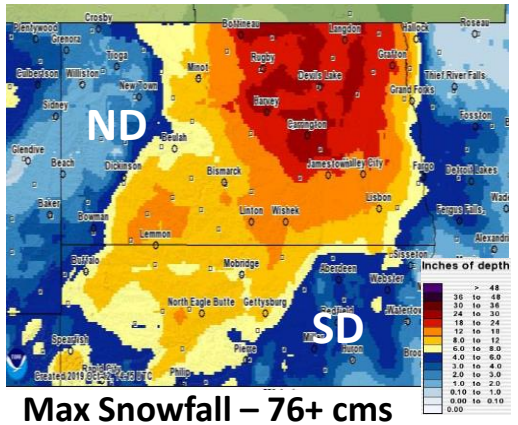
average wind flow in layer <u>below</u> 700 hPa for moisture advection

average wind flow in layer <u>above</u> 700 hPa for moisture advection

Total PW
00 UTC 12 Oct 2019

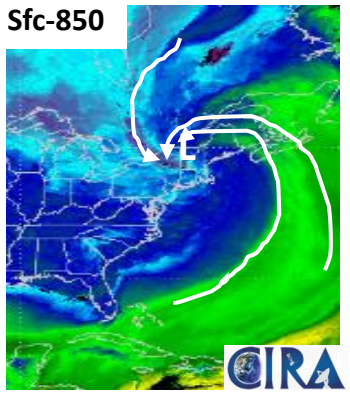


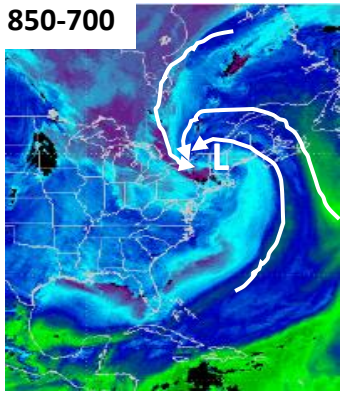
72-h Snowfall Through
12 UTC 12 October 2019

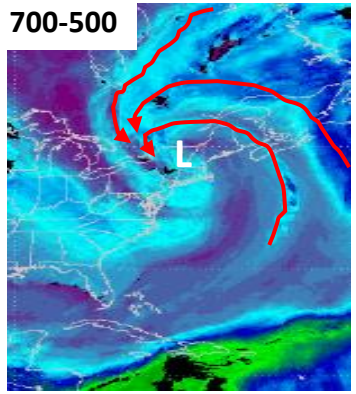


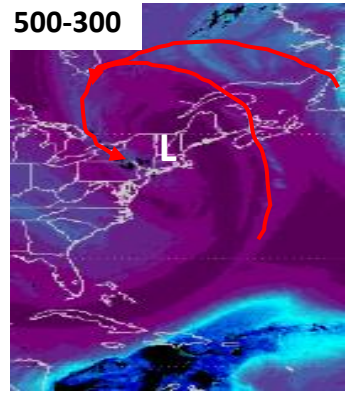
Max Snowfall – 76+ cms
North Dakota, USA

CIRA Advected Layered Precipitable Water (ALPW) for 21 UTC 20 November 2016

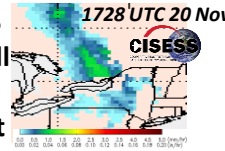




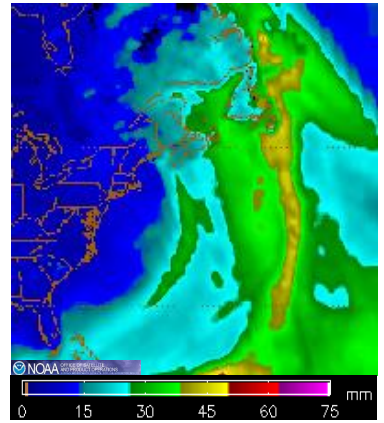




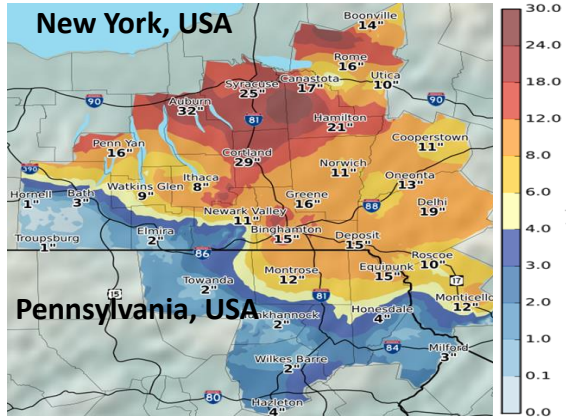
NESDIS Snowfall Rate Product



Total PW
21 UTC 20 Nov 2016



Snowfall Totals
19-22 Nov 2016

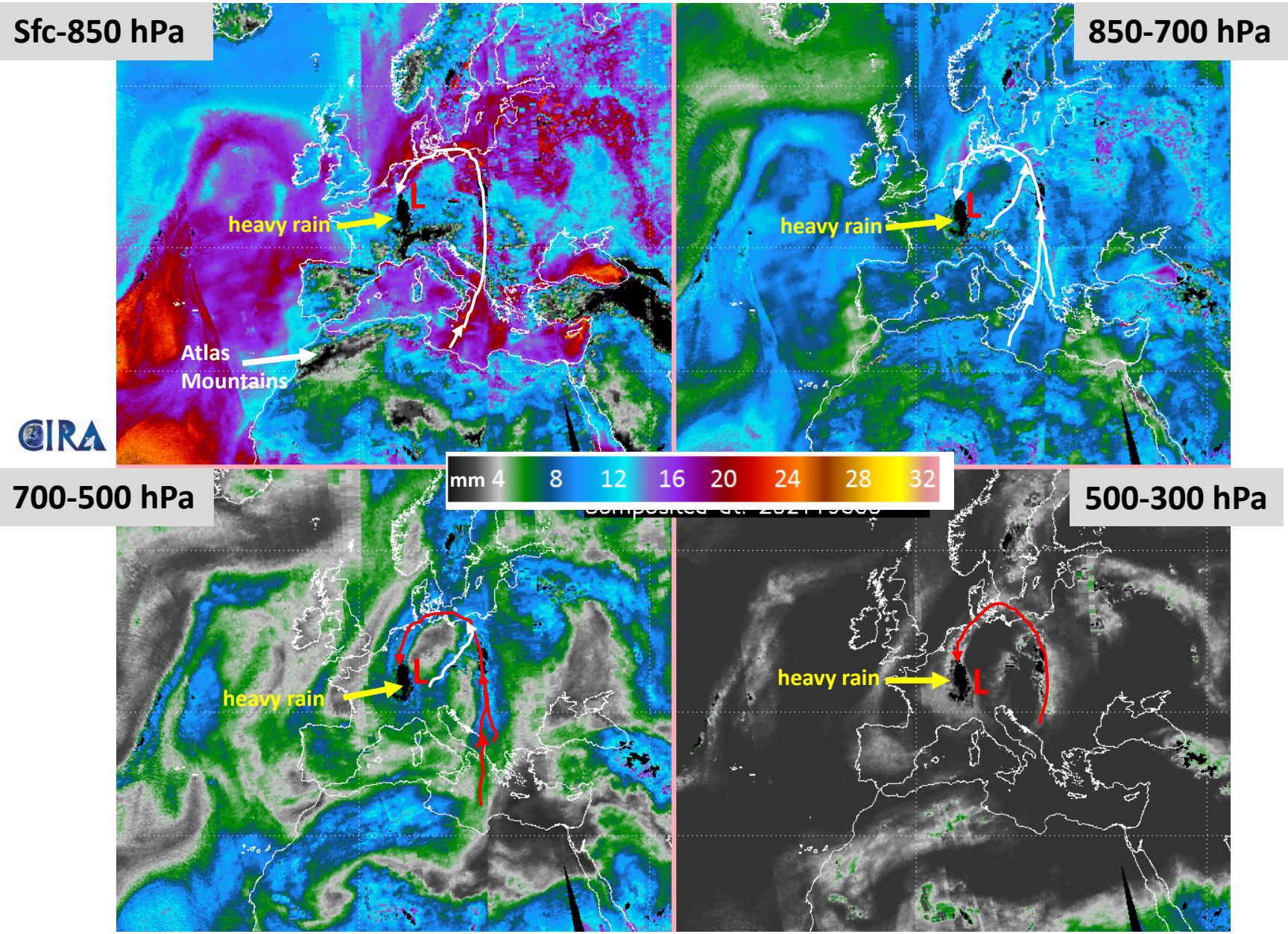


Max Snowfall – 76+ cms
New York, USA

moist conveyor belt shows better in each of the four distinct layers of ALPW

Prepared by Sheldon Kusselson

CIRA Advected Layered Precipitable Water (LPW) for 00 UTC 15 July 2021



layer average wind flow below 700 hPa for moisture transport

Layer average wind flow above 700 hPa for moisture transport

Bruno Fahy/AFP/ Getty Images

Sebastian Schmitt/dpa/AP

Some Notes on this Central Europe TROWAL/Flood Case:

- Sfc-850 hPa layer - “atmospheric river” of moisture not continuous because of terrain effects; still has the effect of a continuous moist long-fetch conveyor belt transport.
- Converging moisture at 850-700 and 700-500 hPa layers provides added depth to total column.
- “Atmospheric rivers” of moisture at three layers originating in Mediterranean and aligned with each other for deep moisture transport.
- Though 500-300 hPa layer moisture low, still helpful when aligned with other moisture layers
- Low provides instability to act on deep moisture to produce excessive rainfall

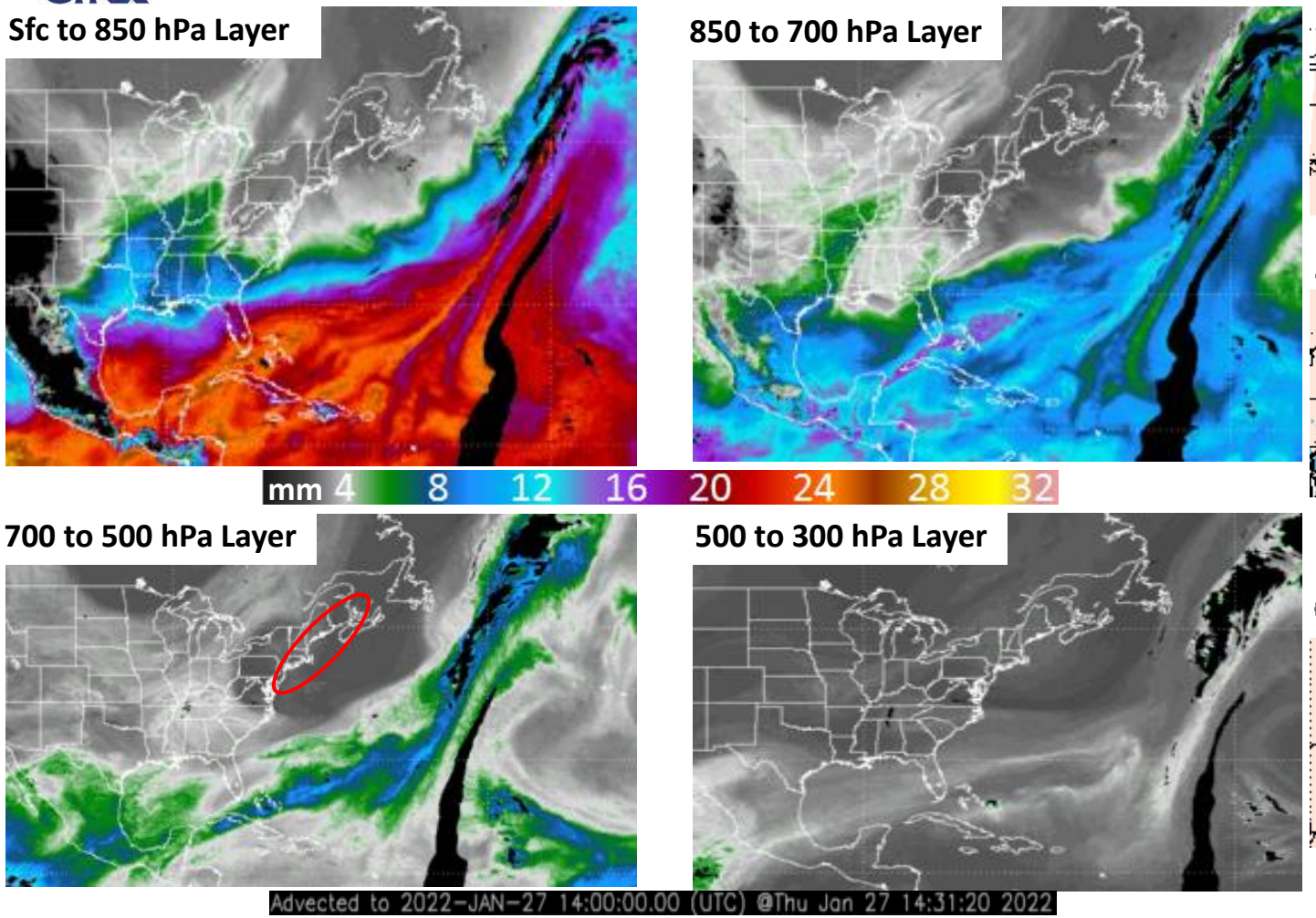
Analysis by Sheldon Kusselson

Application of Advected Layered Precipitable Water: Conveyor Belt

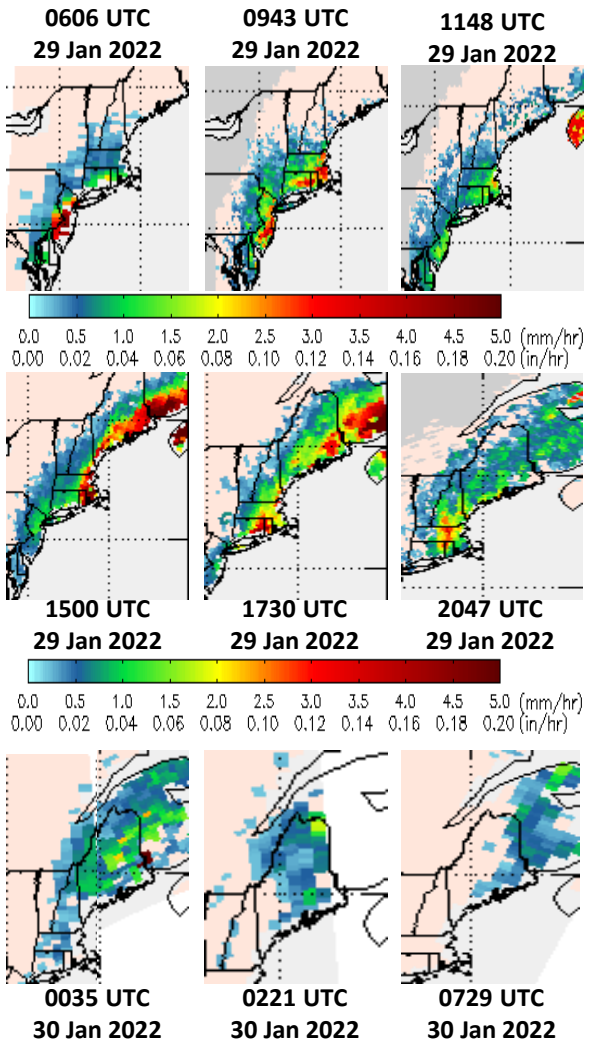
Finding the Best Dendritic Growth for Heavy Winter Snowfall – US East Coast Snow Storm of Jan 2022

Highest precipitable water values in the favored 700-500 hPa dendritic growth rate layer marks area of very heavy snow along the US East Coast.

CIRA Advected Layered Precipitable Water Loop for the Period 1400 UTC 27 January to 12 UTC 30 January 2022



Satellite Snowfall Results

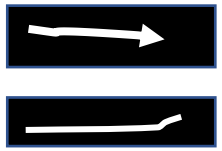


http://cics.umd.edu/sfr

Classic Severe Weather Signature in the Advected Layered Precipitable Water Product

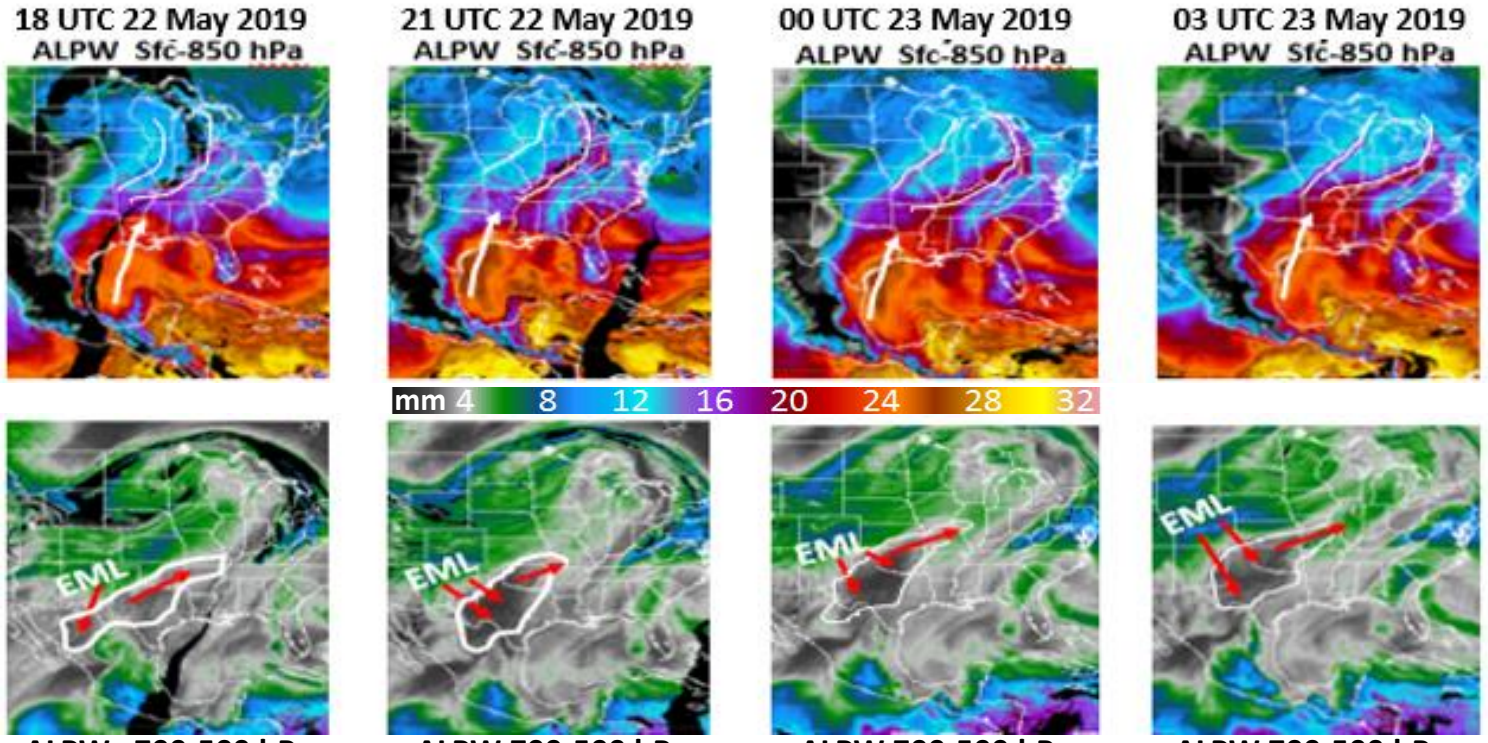
Middle of the U.S. Tornadoes and Damaging Winds

layer average wind flow <u>below</u> 700 hPa for moisture transport



Boundary or front

layer average wind flow <u>above</u> 700 hPa for moisture transport

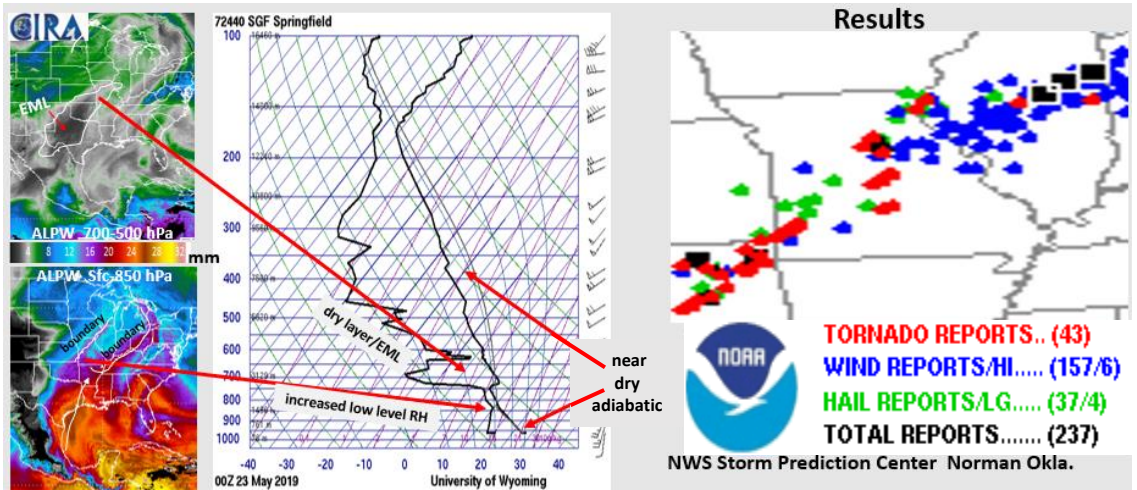


Key ALPW Points for this Severe Weather

- Persistent low-layer max amount moisture advection
- Dry air/EML middle-layer signature and advection
- EML origins C Mexico
- Boundary helpful to focus area for severe
- Confirmation with a RAOB sounding

<u>Elevated Mixed Layer (EML)</u>

is a layer of warm, dry air advected from a high terrain region to another location, characterized by a capping inversion and well mixed air above it.



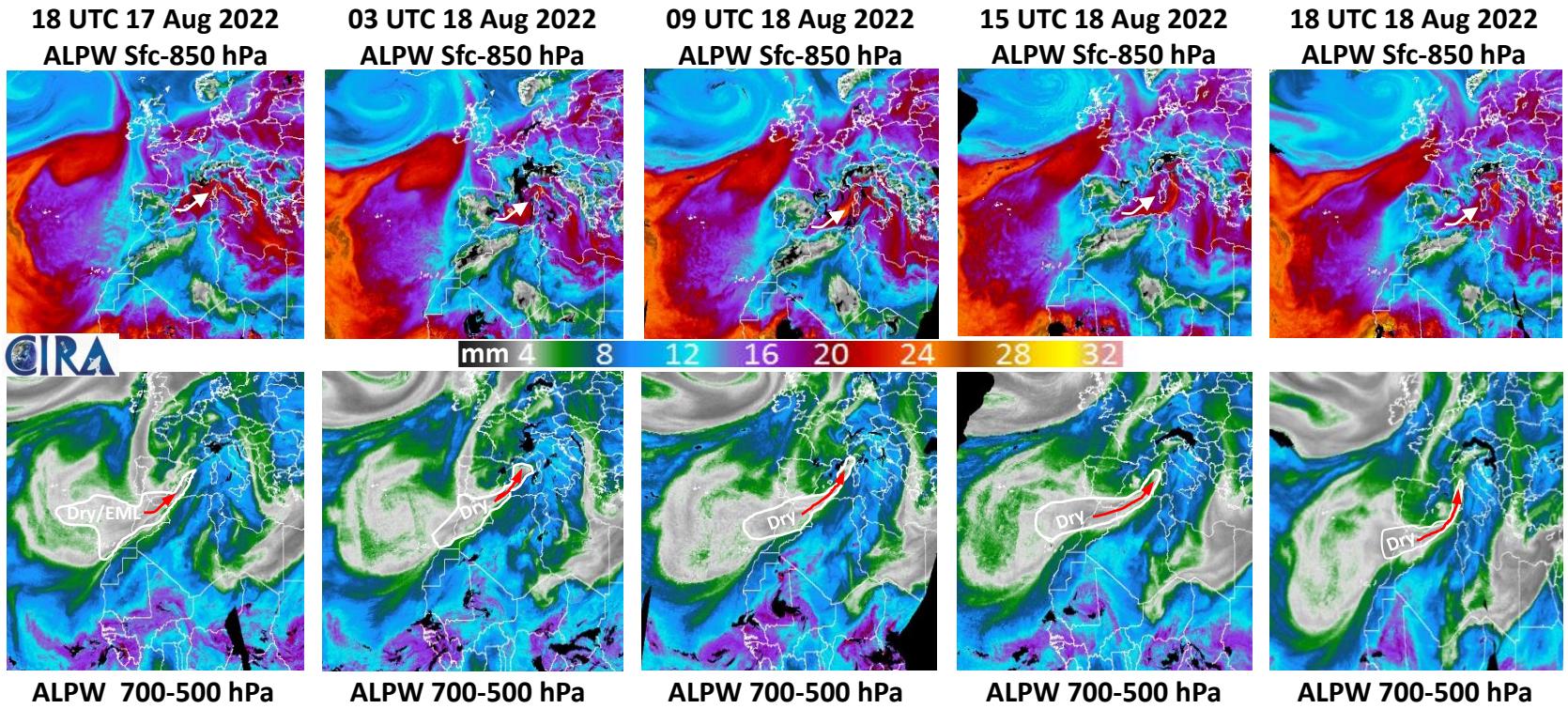
Classic Severe Weather Signature in the Advected Layered Precipitable Water Product

The Derecho Storms of 18 August 2022...what did the ALPW product show ?

layer average wind flow <u>below</u> 700 hPa for moisture transport

layer average wind flow <u>above</u> 700 hPa for moisture transport

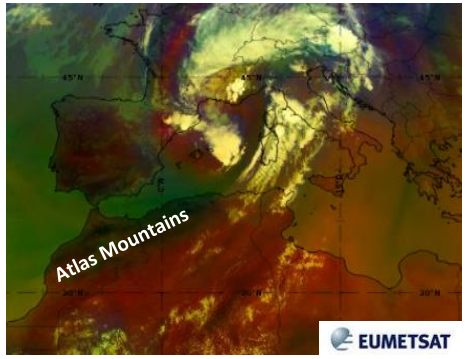
EML= Elevated Mixed Layer



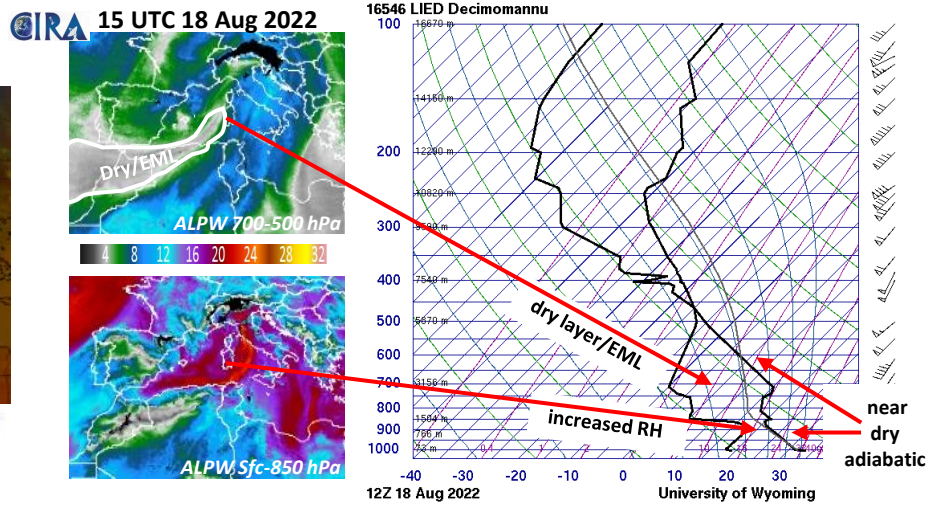
Key ALPW Points

- Small, but persistent low-layer max amount moisture advection
- Dry air/EML middle-layer signature and advection
- EML origins NW Africa/Atlas Mtns
- Confirmation with a RAOB sounding
- What about 700-500 moisture connection from Africa ahead of EML?

MSG Air Mass RGB



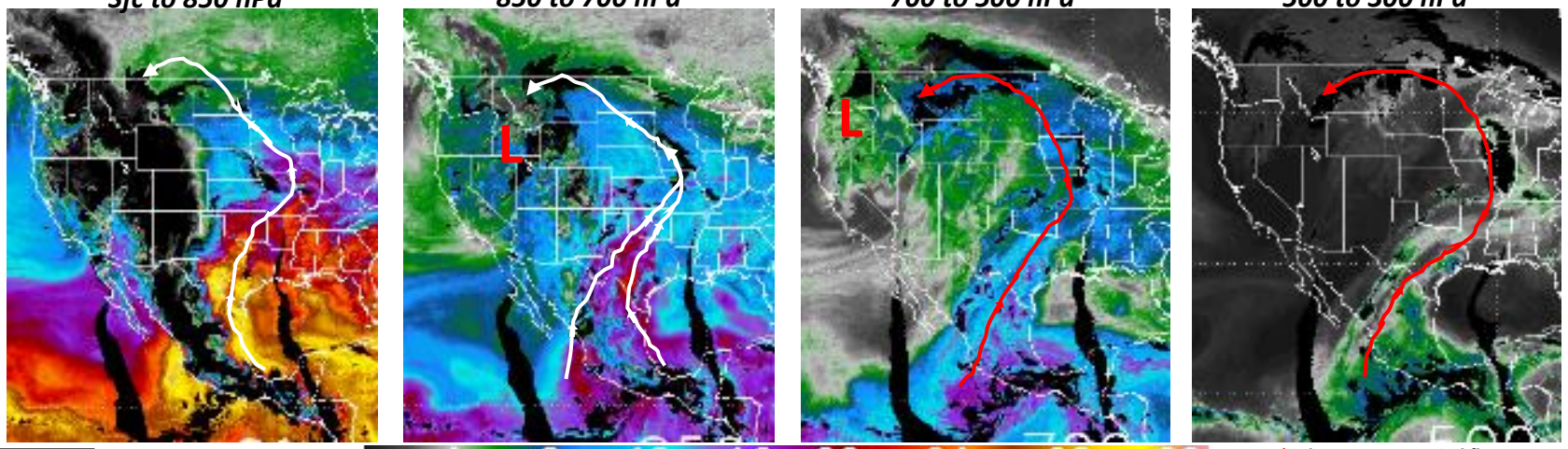
1500 UTC 18 Aug 2022



Results

Clash of Subtropical Moisture and Surface Cold to Help Produce Extraordinary Out-of-Season Weather

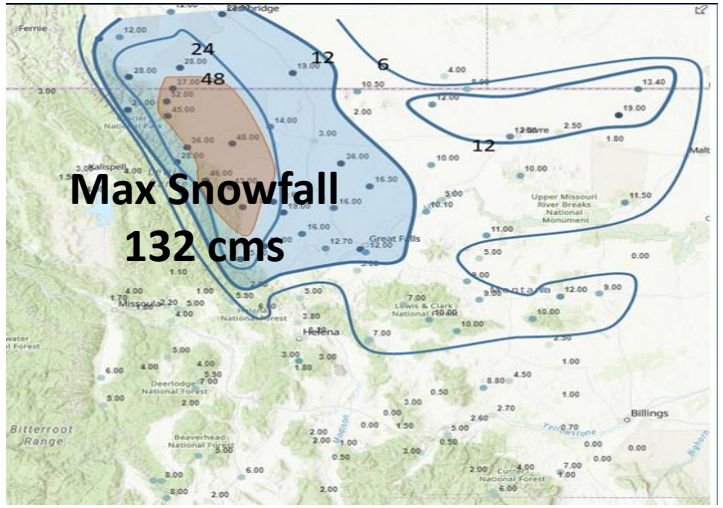
CIRA Advected Layered Precipitable Water for 06 UTC 29 Sep 2019



layer average wind flow below 700 hPa for moisture transport

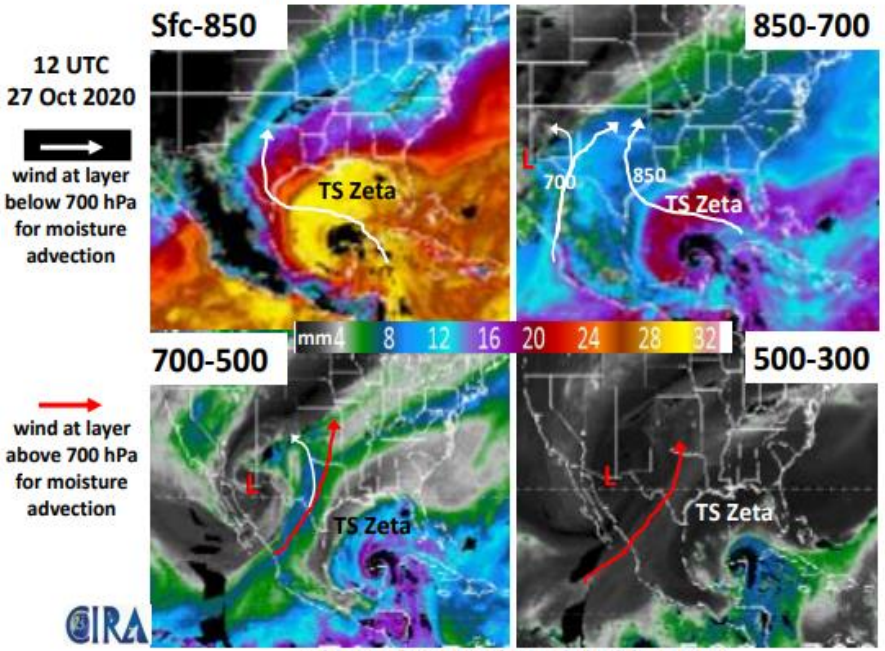
layer average wind flow above 700 hPa for moisture transport

Snow Reports, Sept. 28-30, 2019



Fox News

Oklahoma Ice Storm – 27 October 2020



Advected Layered Precipitable Water

Important Points Forecasters Need to Know

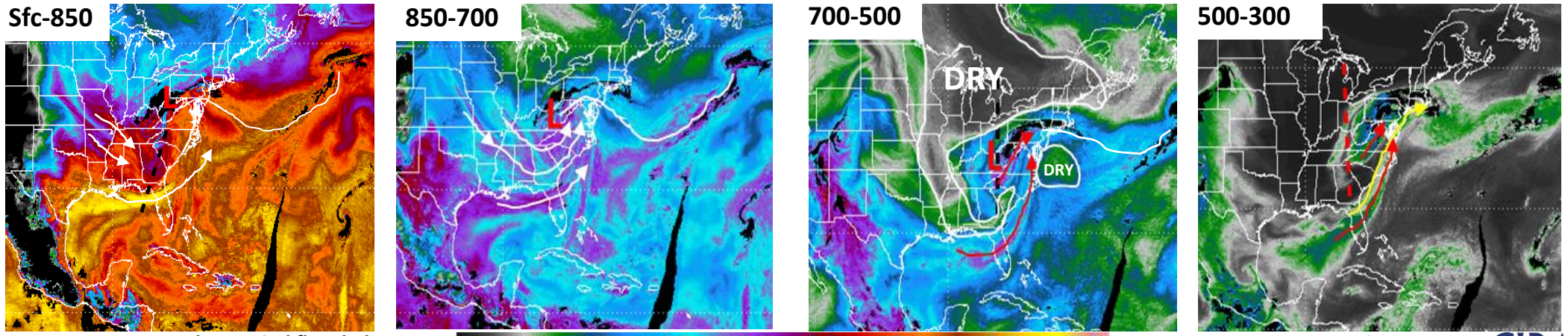
- At surface, cold air advecting in; above surface, milder air advecting over ice storm area
- High PW moisture from late season TS Zeta in Gulf of Mexico advecting into ice storm area
- Additional PW moisture above 700 hPa advecting from tropical East Pacific; helping to deepen moist column over below freezing surface of ice storm area
- Moist deformation/diffluence at 850-700 and 700-500 hPa layers helped increase precipitation rates and amounts over ice storm area leading to devastating results

Photo courtesy of Southeastern Electric Cooperative providing mutual aid assistance to Southwest Rural Electric Association in Tipton, Oklahoma.

Excessive Rainfall from the Remains of Tropical Storms – Analysis of the ALPW – Compare and Contrast

CIRA Advected Layered Precipitable Water for 1500 UTC 1 September 2021 (9 hours before excessive rain in NYC)

Sfc-850 | 850-700 | 700-500 | 500-300



mm 4 8 12 16 20 24 28 32

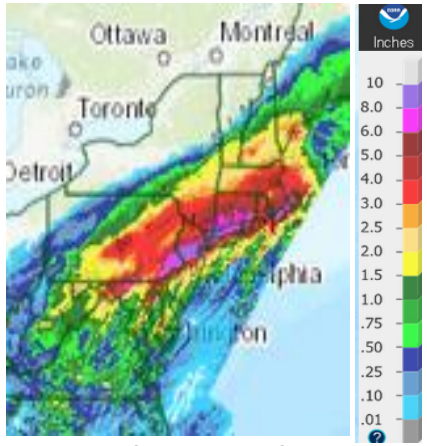
average layer wind flow below 700 hPa for moisture transport

boundary or front

average layer wind flow above 700 hPa for moisture transport

weak jet

Former Hurricane Ida Rainfall Results



24-hours ending 12 UTC 2 September 2021

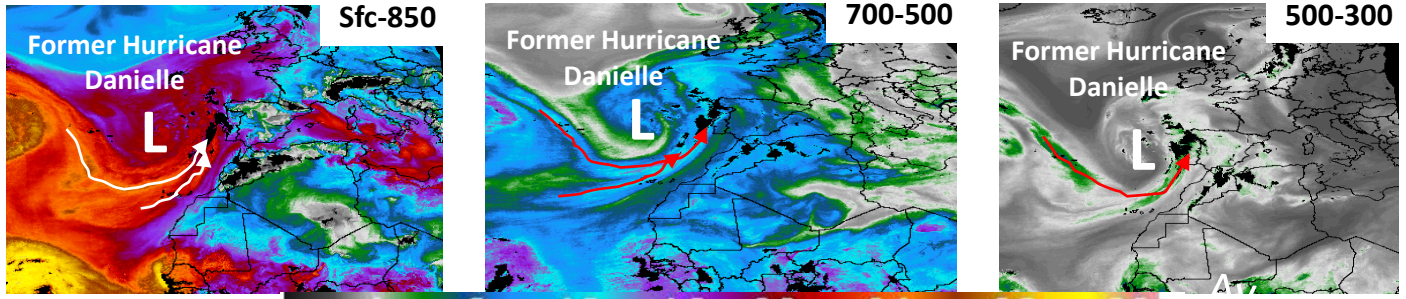
"Extratropical storm Danielle batters Portugal: floods, chaos and landslides"

What did the Advected Layered Precipitable Water product show?

METEORED

Results

CIRA Advected Layered Precipitable Water for 0300 UTC 12 September 2022



mm 4 8 12 16 20 24 28 32

average layer wind flow below 700 hPa for moisture transport

average layer wind flow above 700 hPa for moisture transport

Alignment of very high precipitable water

- multi-layer long fetch moisture
- multi-layer converging moisture

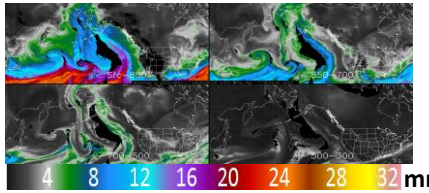
For deep moisture transport ahead of heavy rain/tragic floods

References for Layered Precipitable Water and TPW Products

Current Advected Layered Precipitable Water (ALPW) Sectors

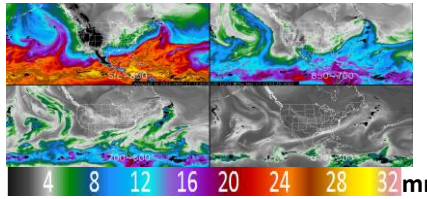
http://cat.cira.colostate.edu/SPoRT/Layered/Advected/LPW_Alaska.htm

Alaska and North Pacific

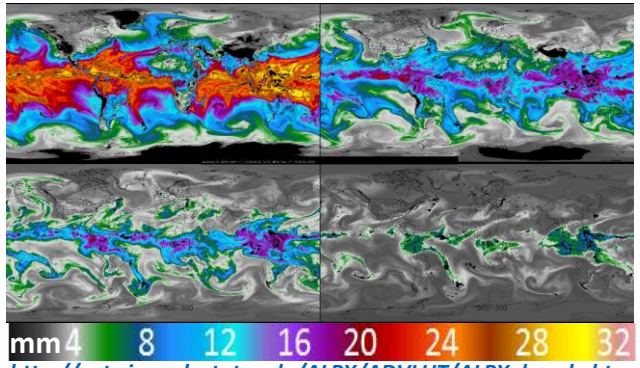


http://cat.cira.colostate.edu/SPoRT/Layered/Advected/ALPW_Hourly.htm

Western & Northern Hemisphere

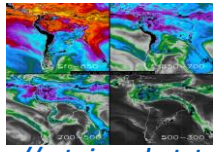


Global



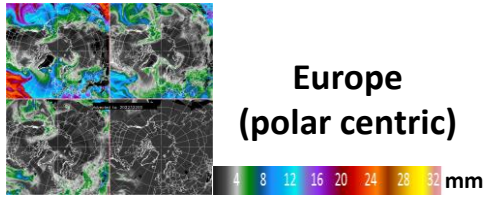
http://cat.cira.colostate.edu/ALPX/ADVLUT/ALPX_hourly.htm

South America



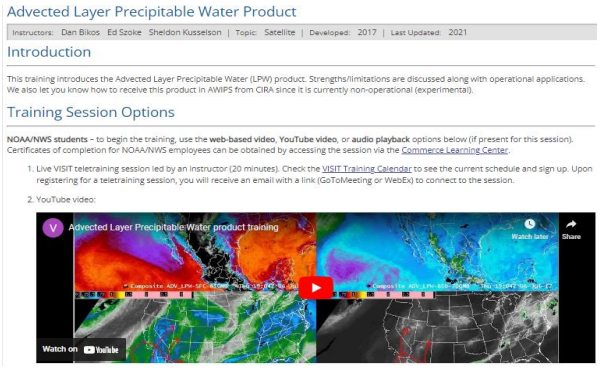
http://cat.cira.colostate.edu/SPoRT/Layered/Advected/ALPW_Hourly.htm

Europe (polar centric)



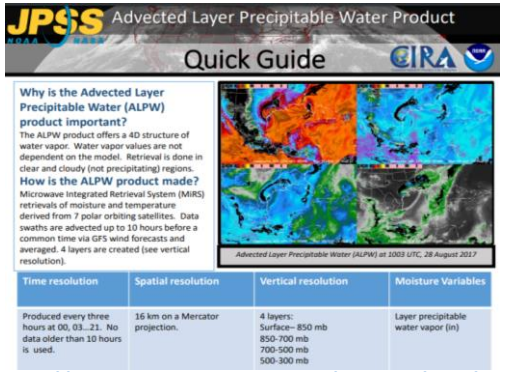
http://cat.cira.colostate.edu/ALPX/PS_NH/301.htm

Training for ALPW Product



https://rammb2.cira.colostate.edu/trainings/visit/training_sessions/advected_layer_precipitable_water_product/

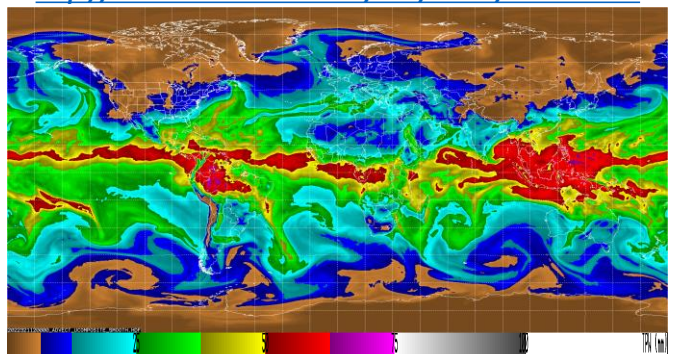
ALPW Product Quick Guide



https://rammb.cira.colostate.edu/training/visit/quick_guides/QuickGuide_LPW_Advected_20180223.pdf

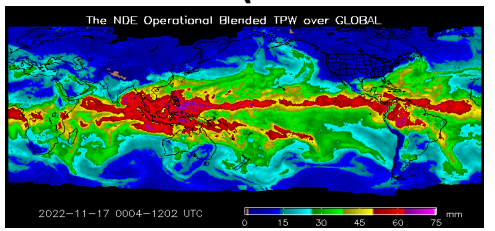
Global Advected Total Precipitable Water (ATPW)

http://cdat.cira.colostate.edu/CAT/aTPW/aTPW5.htm

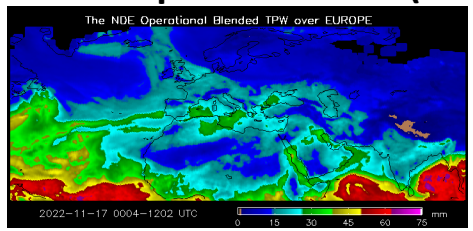


To be operational by mid 2023

Current Blended (non-advected) Total Precipitable Water (bTPW)



https://www.ospo.noaa.gov/Products/bTPW/TPW_Animation.html?product=GLOBAL_TPW

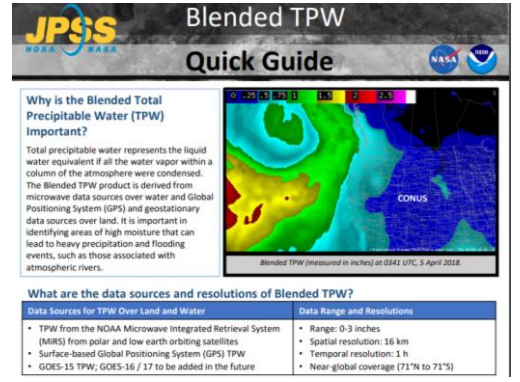


https://www.ospo.noaa.gov/Products/bTPW/TPW_Animation.html?product=EUROPE_TPW

ATPW Product Quick Guide Coming in Future

My email address: Sheldon.Kusselson@gmail.com

bTPW Product Quick Guide



https://rammb.cira.colostate.edu/training/visit/quick_guides/Blended_TPW_Quick_Guide_20180727.pdf

Reference Material for Satellite Derived Water Vapour Products

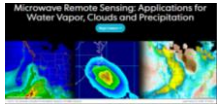
- Additional training, presentation sessions, plus case studies

https://rammb.cira.colostate.edu/training/visit/blog/ CIRA Search ALPW, TPW

https://www.meted.ucar.edu/index.php NCAR COMET

https://www.meted.ucar.edu/education_training/lesson/10139 Satellite Applications for Winter Weather: Mesoscale Snow Banding

https://www.meted.ucar.edu/satmet/microwave_topics/clouds_precip_wv_v2/navmenu.php?tab=1&page=2-5-0&type=flash
Microwave Remote Sensing: Applications for Water Vapor, Clouds and Precipitation



https://cimss.ssec.wisc.edu/satellite-blog/?s=Total+Precipitable+Water CIMSS Search Total Precipitable Water

https://www.youtube.com/watch?v=ddJHPWauPPM&list=PLJzZC8w9vPV3kIBVNmQYzZfHO6vGZeNhN&index=38&ab_channel=KashaudBowman-NOAAAffiliate
Satellite Book Club presentation, "Multisatellite Water Vapor Products for Forecasters – 24 February 2022

- Reference Papers

Gitro, C. M., and Coauthors, 2019: A demonstration of modern geostationary and polar-orbiting satellite products for the identification and tracking of elevated mixed layers. *J. Operational Meteor.*, Vol. 7, Issue 13, Dec. 2019, 180-192 .
https://objects-us-east-1.dream.io/nwafiles/jom/articles/2019/2019-JOM13/2019-JOM13.pdf

Gitro, C. M., and Coauthors, 2018: Using the multisensory advected layered precipitable water product in the operational forecast environment. *J. Operational Meteorology*, 6 (6), 59-73, doi: https://doi.org/10.15191/nwajom.2018.0606

Forsythe, J. M., S.Q.Kidder, K.K.Fuell, A.LeRoy, G.J.Jedlovec, and A.S.Jones, 2015: A multisensory, blended, layered water vapor product for weather analysis and forecasting. *Journal of Operational Meteorology*, 3, 41-58 .

Thanks for your attention!

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