SALT LAKE CITY'S WINDSTORM EVENT

Salt Lake Oasis
Mar 10th 2024

Mani Rajagopal, Ph.D.

Credit: Francisco Kjolseth | The Salt Lake Tribune

OUTLINE

- Windstorm event on Sep 8th 2020 (one of COVID years)
  - Impacts
  - Observed windspeeds
  - Downslope windstorm: Conceptual model
  - What meteorological conditions lead to this event?

- Dust-storm event on Aug 24th 2020

Windstorm - Impacts

Windstorm - Impacts

Windstorm - Impacts

Windstorm - Impacts

Windstorm - Impacts

- **Hurricane force winds** (> 74 mph or 119 km/h)
- **One person was killed**
- **Power outages** in the Wasatch front affecting 140, 0000+
  - Not restored immediately but over next few days
  - No power and internet at my home to look at what's happening right away
- **Hundreds of uprooted trees**
  - Road cleared over next few days but took many months to be cleared from road side or medians

Windstorm - Observations

- **Hurricane force winds** (> 74 mph or 119 km/h)

Peak wind gusts

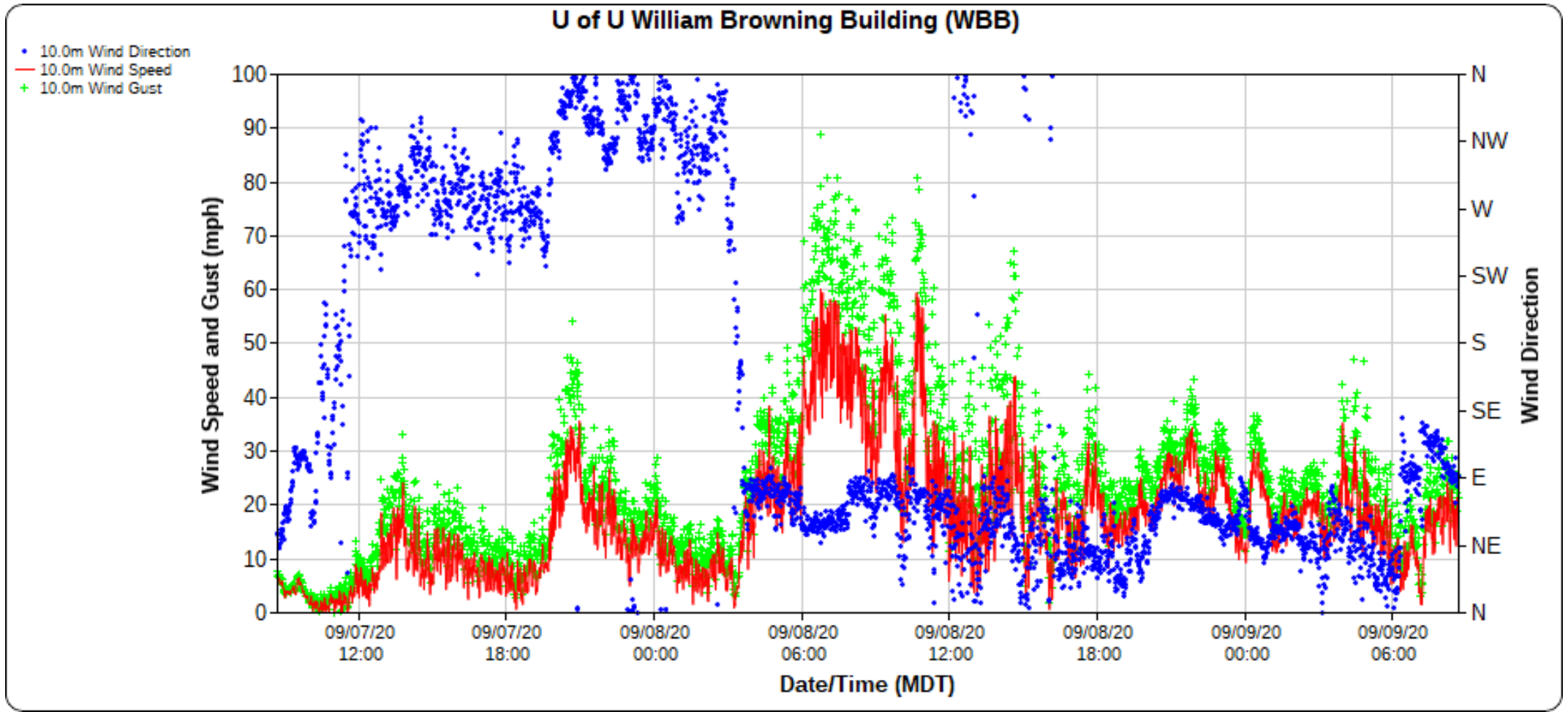
Shown are the peak wind gusts in Salt Lake City and northern Utah in the past 36 hours* reported by the National Weather Service.

Source: National Weather Service
*From 9:15 a.m., Sep. 9

GRAPHIC BY CHRISTOPHER CHERRINGTON | *The Salt Lake Tribune*

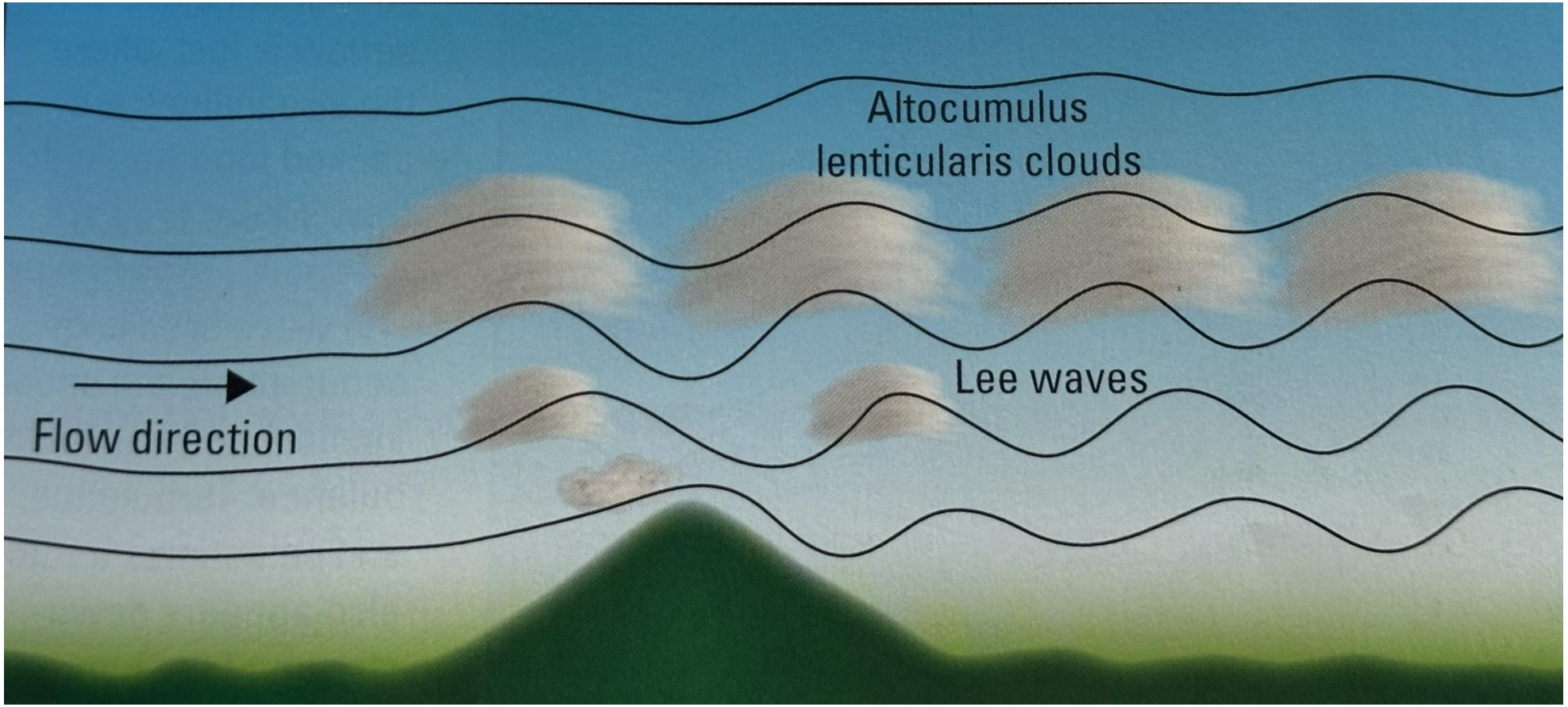
Windstorm - Observations

- Close to 6 am, winds speeds reached 89 mph



Windstorm – Conceptual model

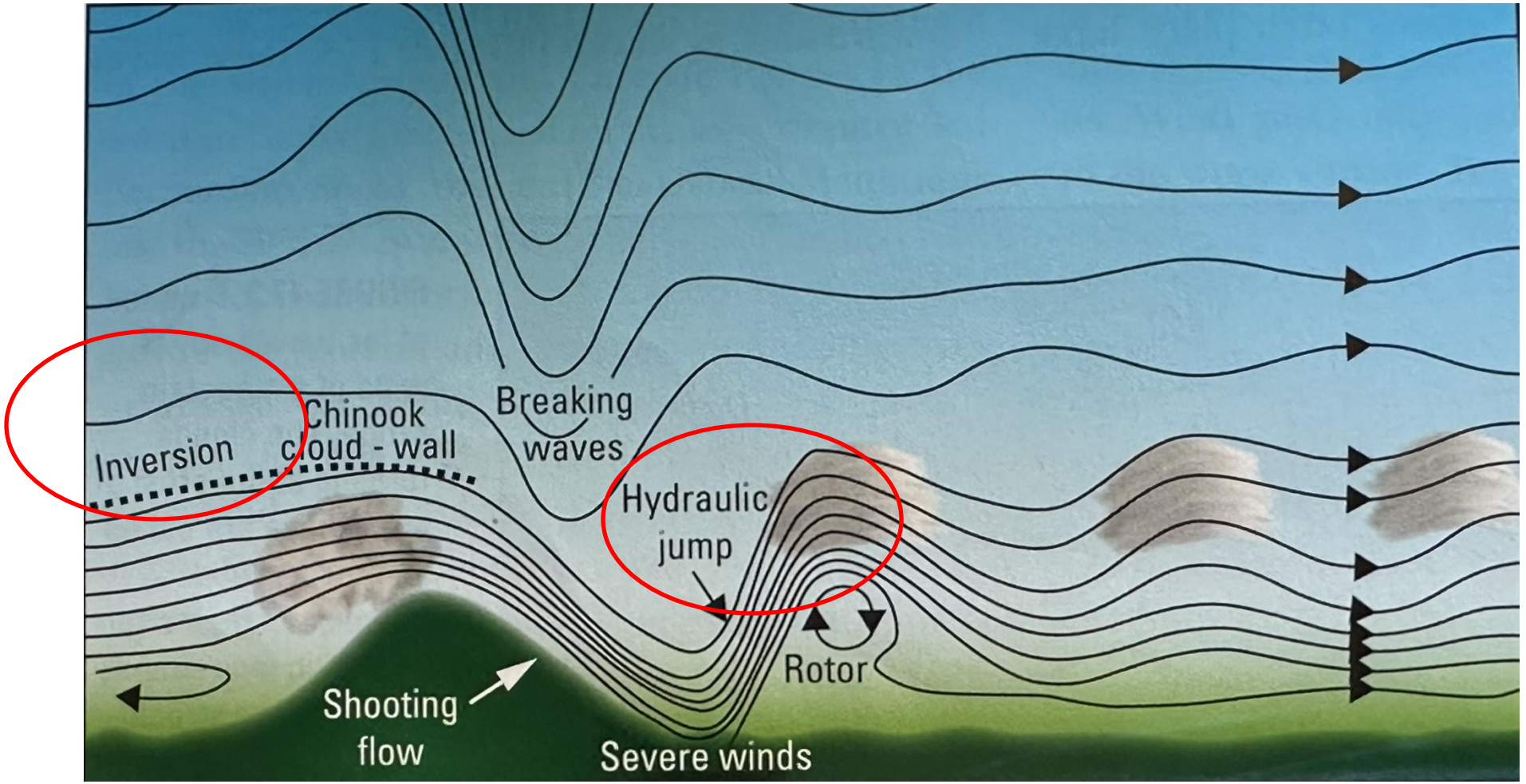
- Wind flow across the ridgeline with strong pressure gradient driving them



Credit: Rauber et al. (2012) text book

Windstorm – Conceptual model

- Wind flow across the ridgeline with strong pressure gradient driving them
- Inversion

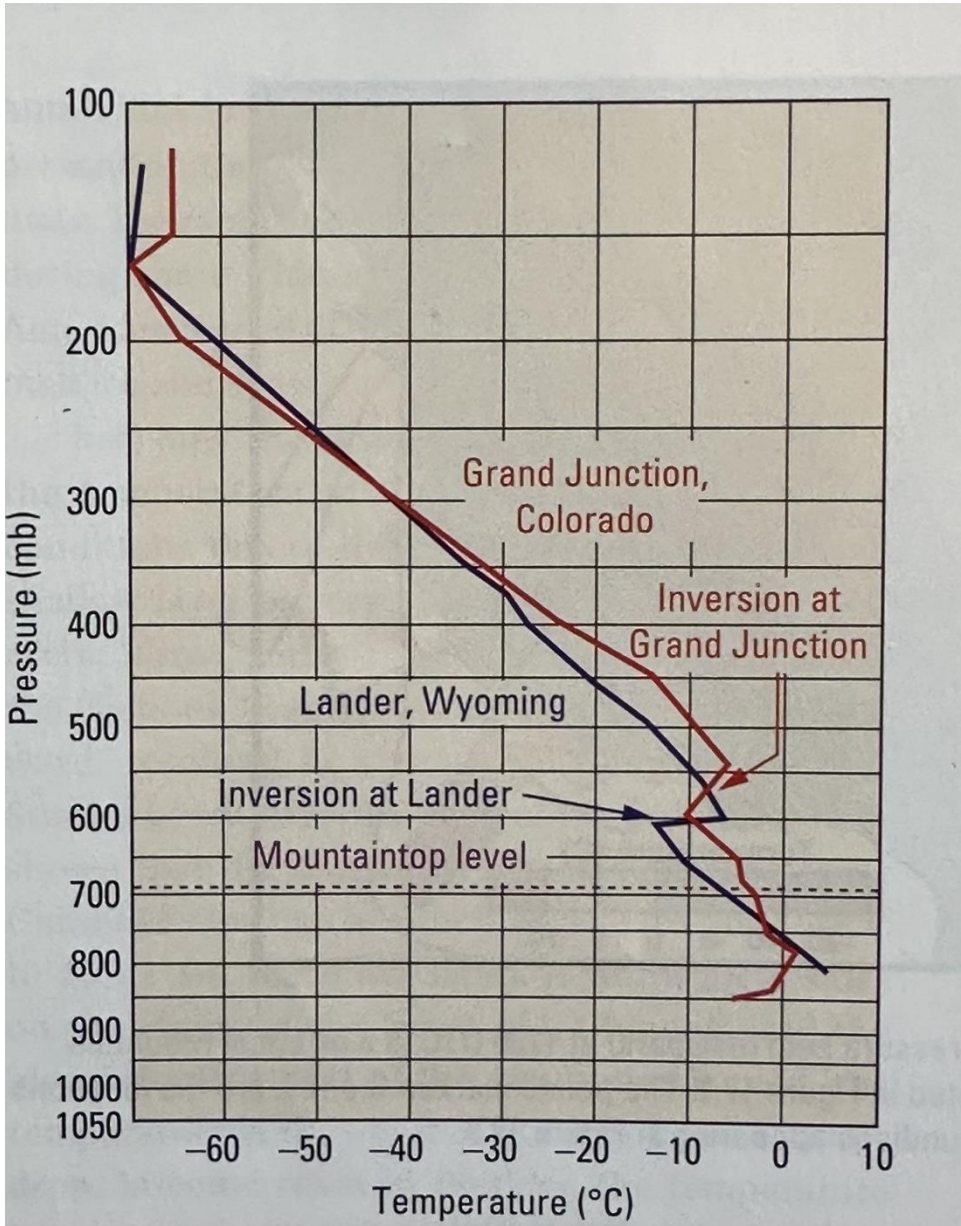


Credit: Rauber et al. (2012) text book

Windstorm – Conceptual model

- You need an inversion – Flexible lid
- Can happen at any height

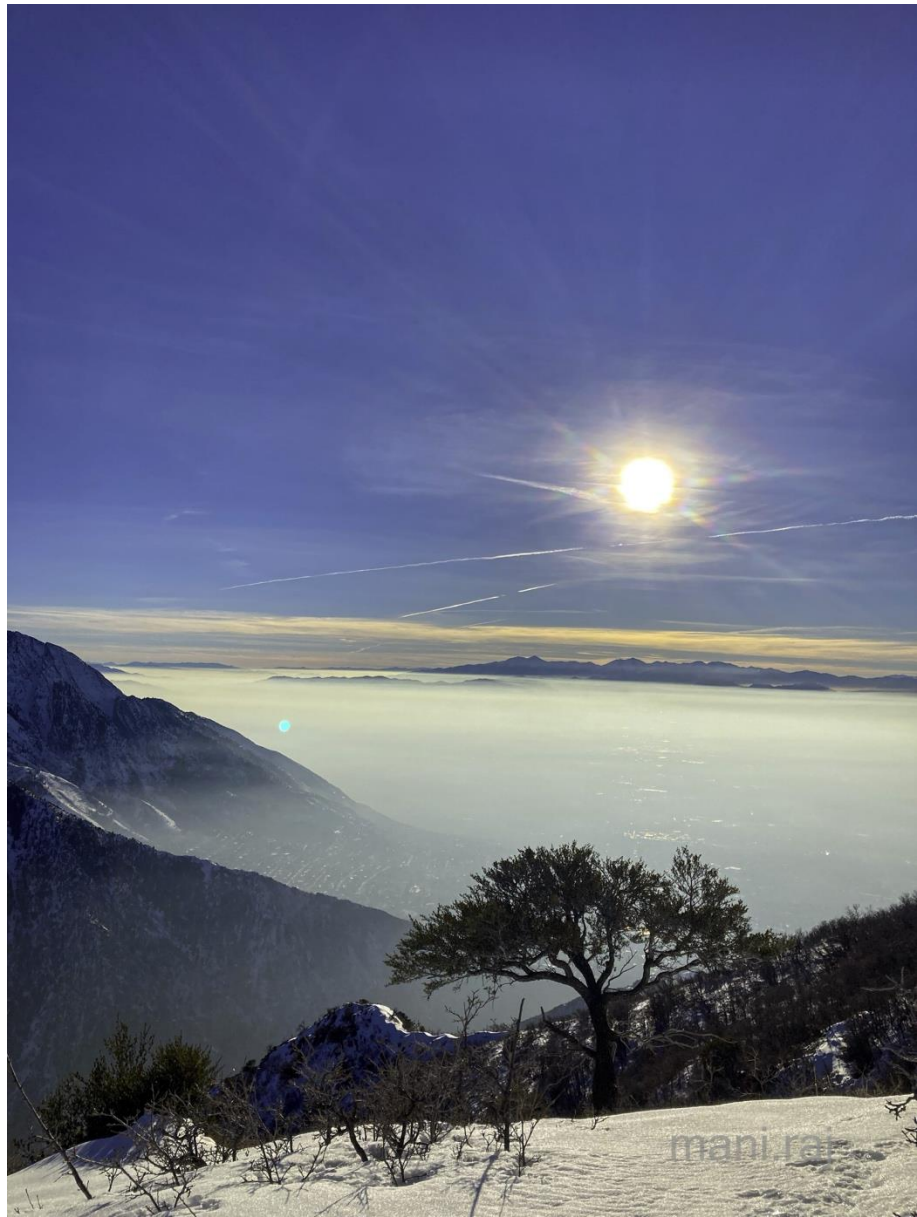
- **Winter inversion in the valley**
- **Inversion at the tropopause**
- **Inversion just above mountain top**



Credit: Rauber et al. (2012) text book

Windstorm – Conceptual model

- Valley inversion



Windstorm – Conceptual model

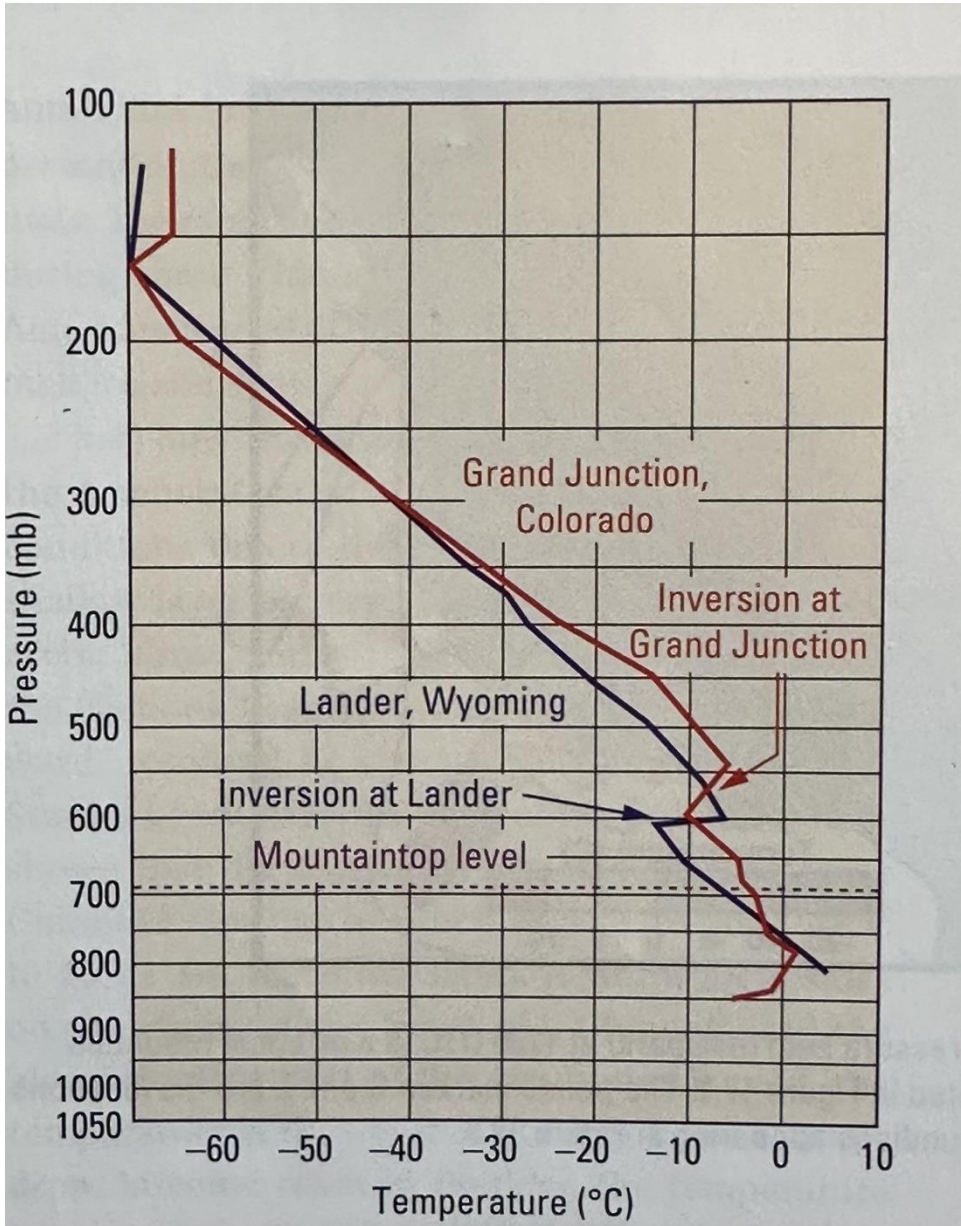
- Inversion near tropopause

Video showing the **“Tropopause”**

Windstorm – Conceptual model

- Inversion close to mountain top
- Air coming from a different direction or location

Video showing winds from different direction



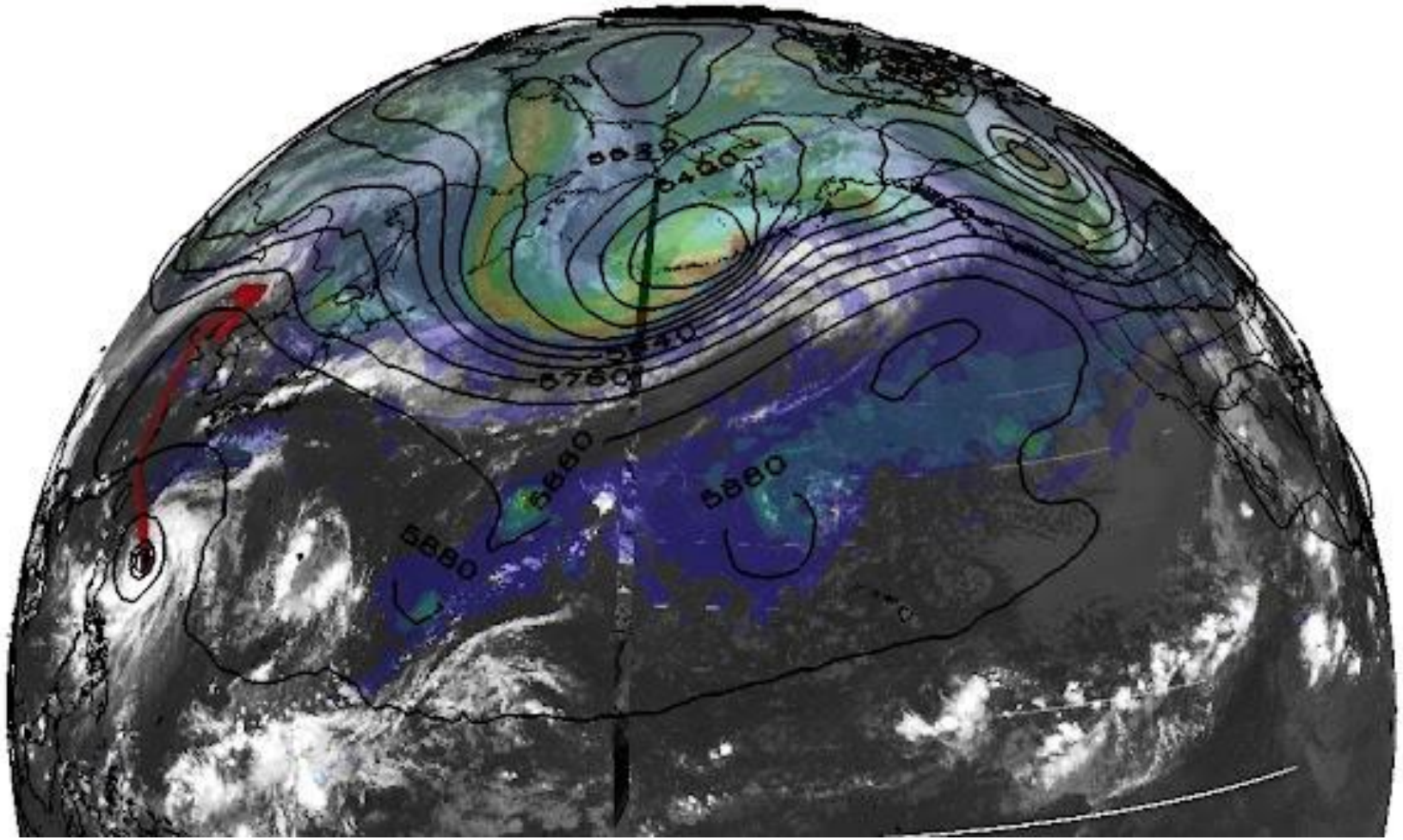
Credit: Rauber et al. (2012) text book

Windstorm – Conceptual model

Video showing tropopause

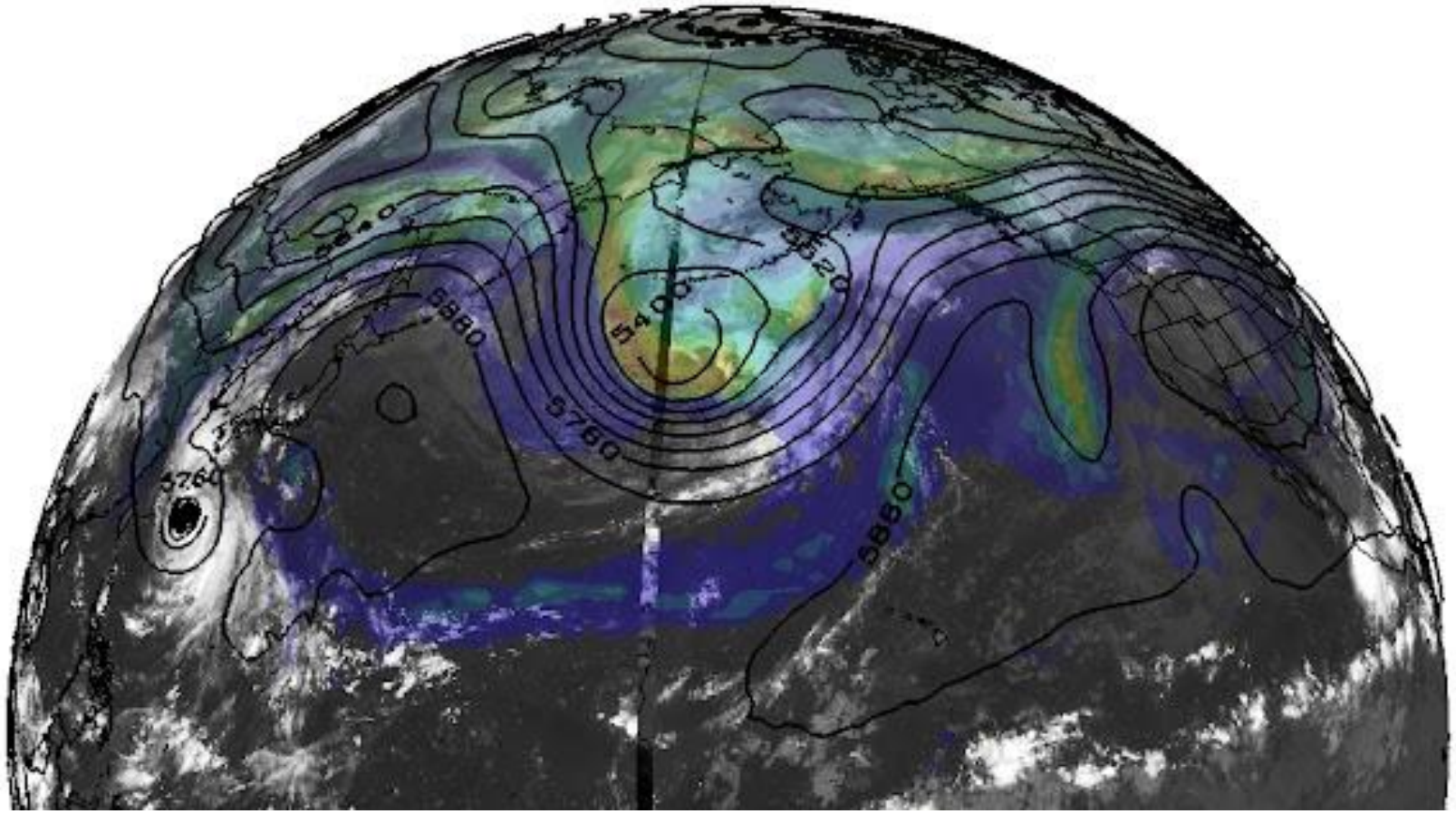
Windstorm – Conditions on Sep 8th 2020

Windstorm – Conditions on Sep 8th 2020



https://wasatchweatherweenies.blogspot.com/2020/09/

Windstorm – Conditions on Sep 8th 2020



https://wasatchweatherweenies.blogspot.com/2020/09/

Utah Climatology - Pressure patterns

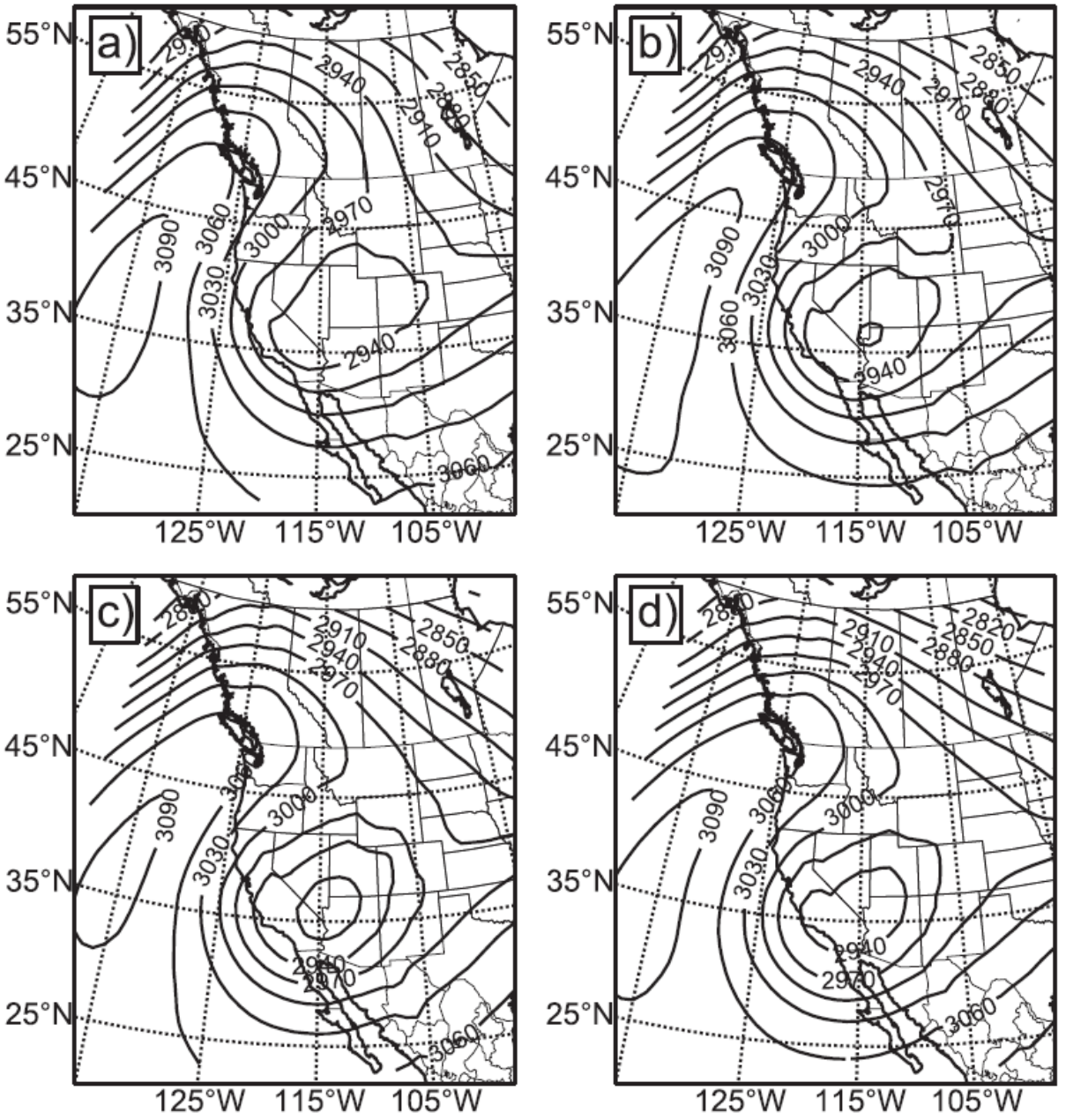
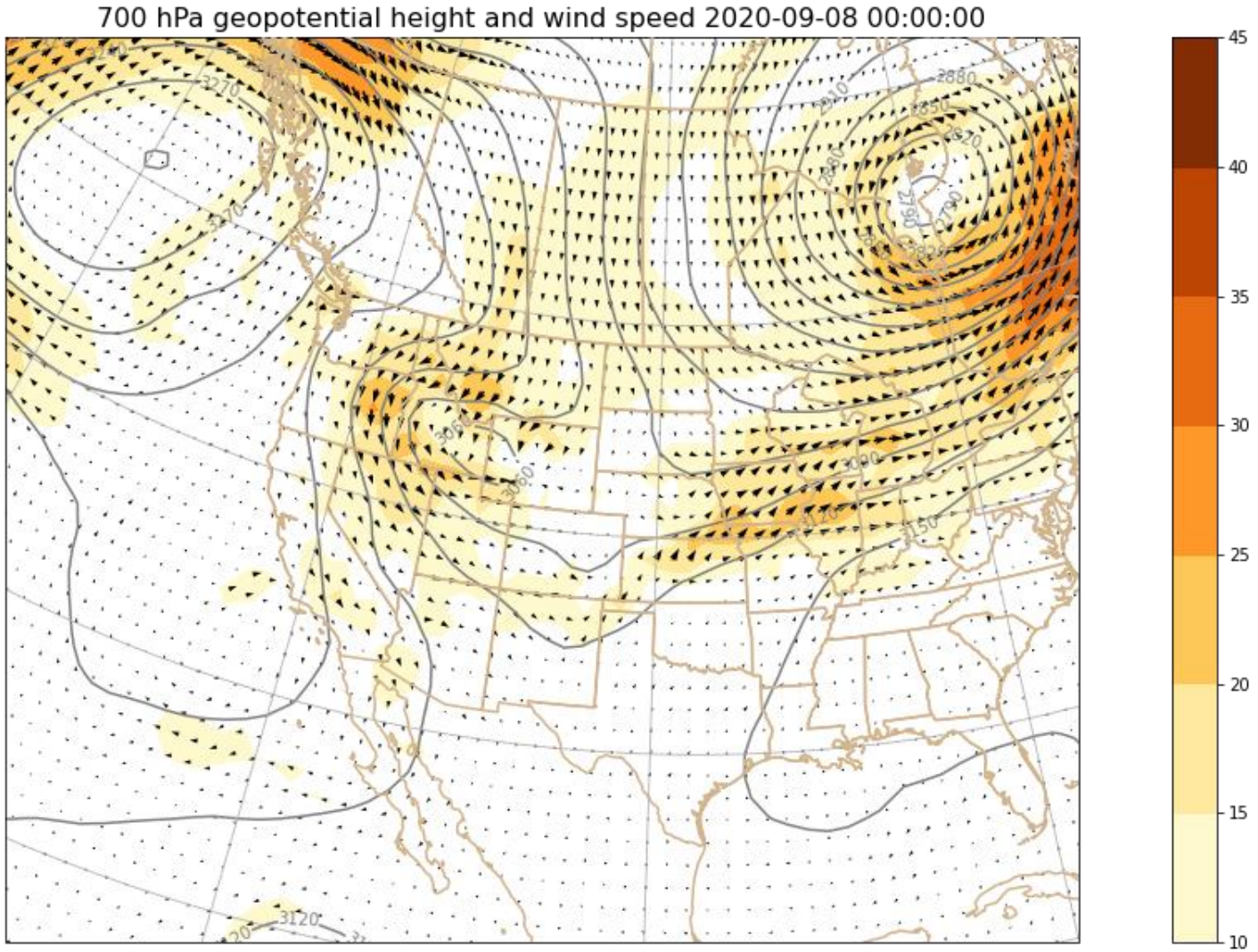


FIG. 5. Evolution of ERA-Interim 700-hPa geopotential height (contoured at 30-m intervals), composited over 13 downslope windstorm events at (a) 0000, (b) 0600, (c) 1200, and (d) 1800 UTC.

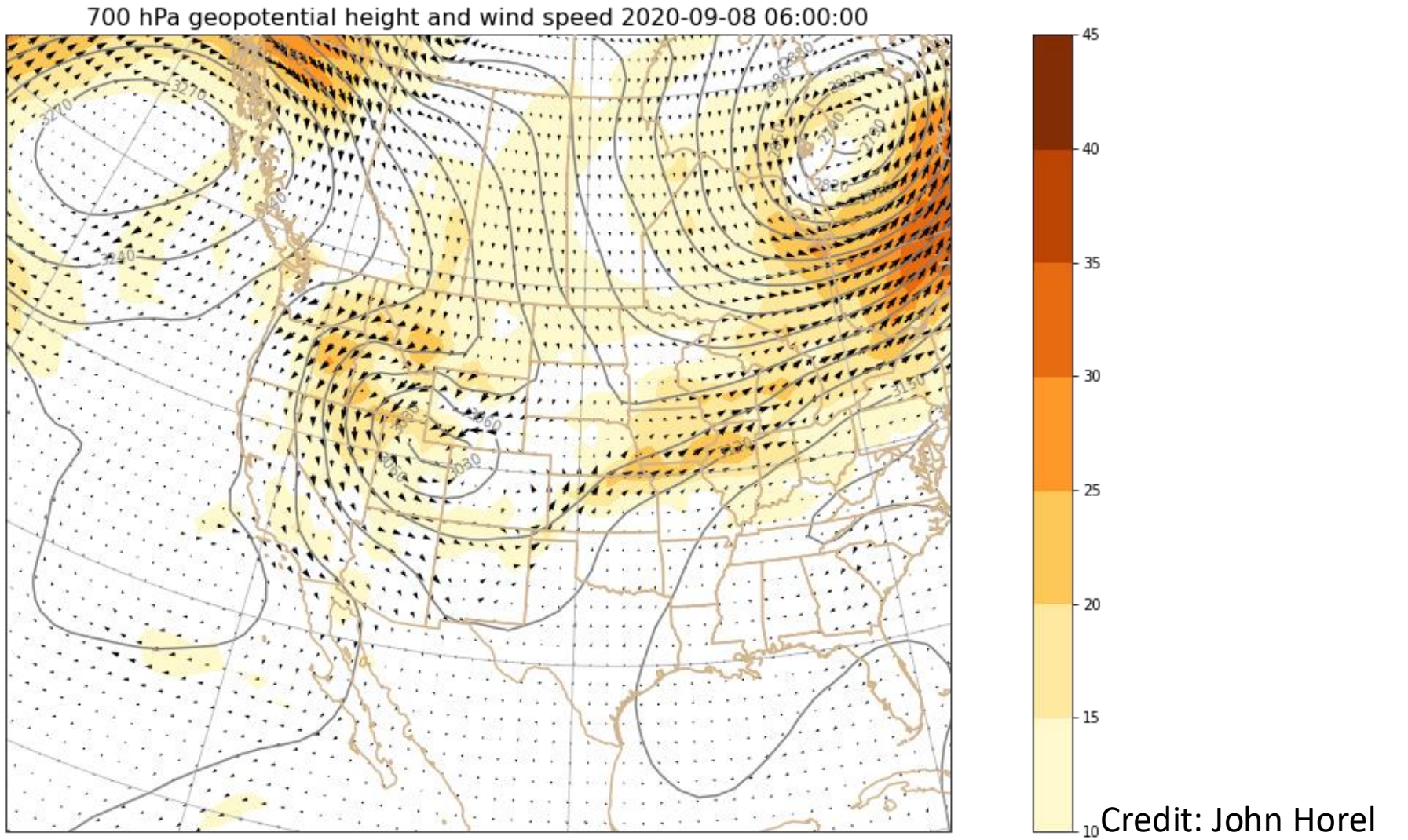
Lawson and Horel, (2015)

Windstorm – Conditions on Sep 8th 2020



Credit: John Horel

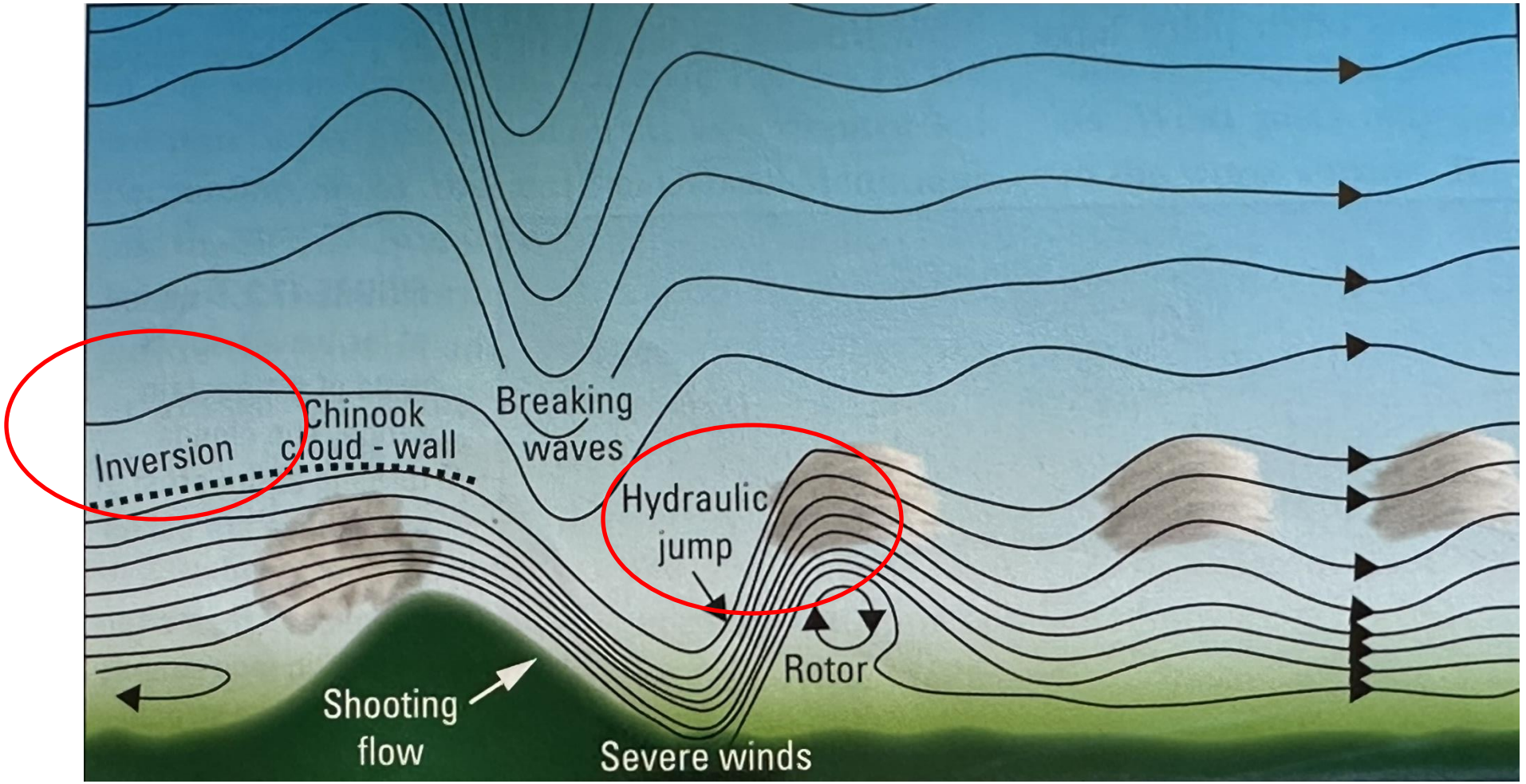
Windstorm – Conditions on Sep 8th 2020



Credit: John Horel

Windstorm – Conceptual model

- Wind flow across the ridgeline with strong pressure gradient driving them
- Inversion



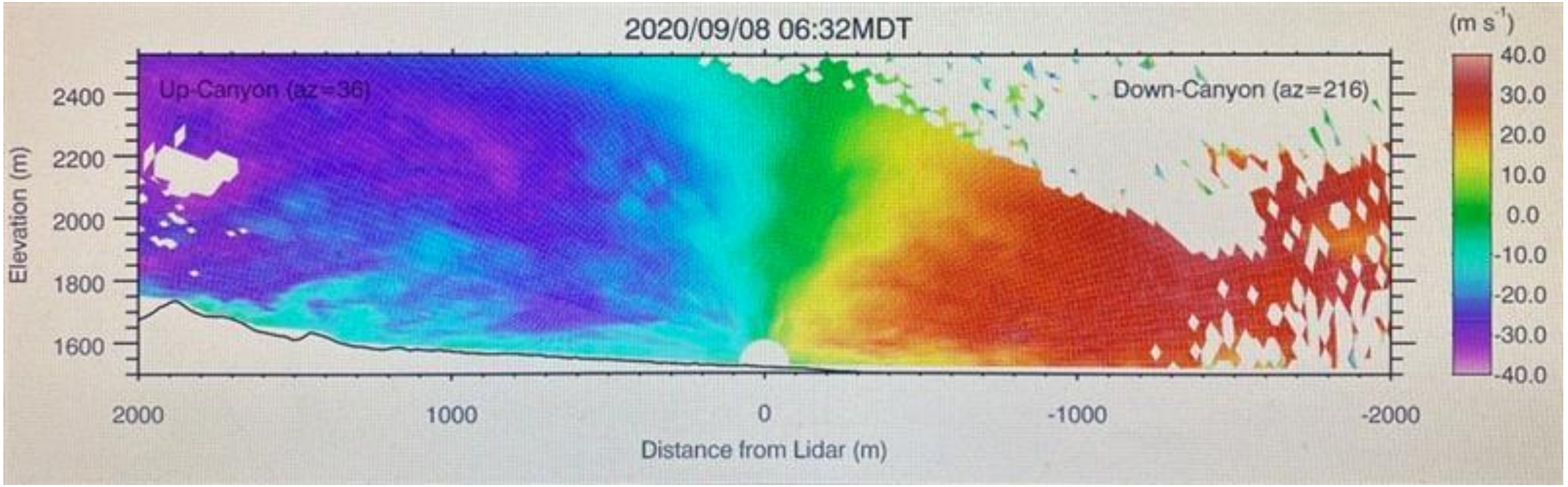
Credit: Rauber et al. (2012) text book

Windstorm – Conditions on Sep 8th 2020

Video showing hydraulic jump

Windstorm – Conditions on Sep 8th 2020

- Lidar instrument Near Red Butte Canyon
- > 40 m/s (88 mph)



Credit: Sebastian Hoch, University of Utah

Questions?

Extras

Windstorm

- Photos showing damages
- Data from John Horel's presentation
- Severe weather and hazardous weather book
- mesoscale meteorology book
- newspaper articles and images
- Read lit surveys

- Types of windstorm

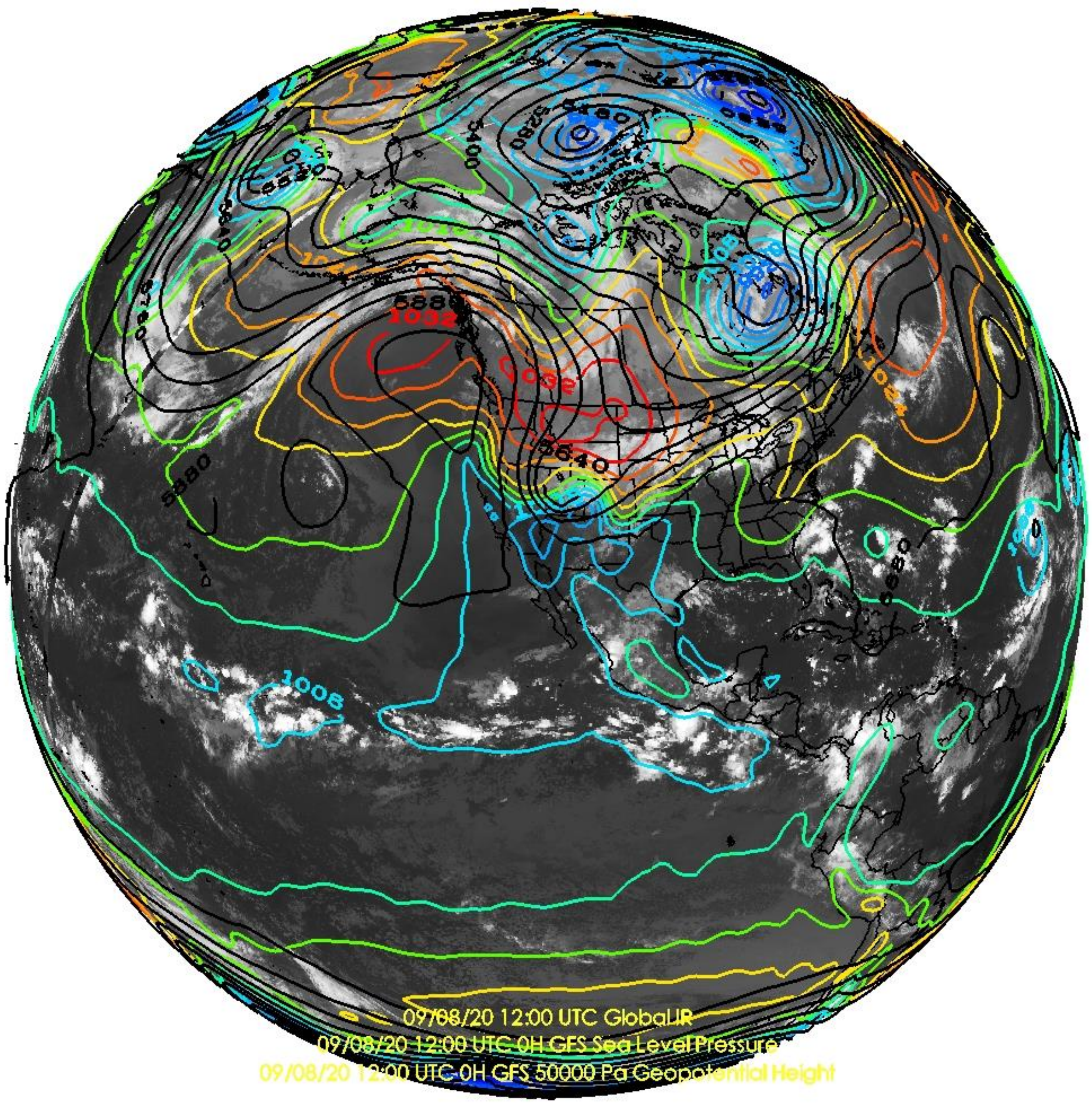
- Downslope windstorm
  - Science
  - Videos (hydraulic jump)
  - Science of it
    - Why the lid
    - Why less frequent here
    - Why in winter
    - Why is air warmer there
    - Does compressed cabin is warmer or cooler

AMS Glossary

- foehn—(Or föhn.) A warm, dry, downslope wind descending the lee side of the Alps as a result of synoptic-scale, cross-barrier flow over the mountain range.
- bora—A fall wind with a source so cold that, when the air reaches the lowlands or coast, the dynamic warming is insufficient to raise the air temperature to the normal level for the region; hence it appears as a cold wind
- downslope windstorm—A very strong, usually gusty, and occasionally violent wind that blows down the lee slope of a mountain range, often reaching its peak strength near the foot of the mountains and weakening rapidly farther away from the mountains

Two complementary theories for downslope wind storms

- focus on
  - presence of inversion/strong stable layer in flow over and upstream of crest
    - hydraulic jump falls in this camp
  - Presence of critical layer (reversal in direction of cross-barrier flow above crest)
    - Vertical propagation of internal gravity waves in continuously stratified atmosphere
    - In some cases, gravity wave breaking may “induce” critical layer
- Most strong cases are a mix of both (Mobbs et al. 2005)


09/08/20 12:00 UTC GlobalIR
09/08/20 12:00 UTC 0H GFS Sea Level Pressure
09/08/20 12:00 UTC 0H GFS 50000 Pa Geopotential Height

- Typhoon Julian and later Kristine, which on August 30th was near the Philippines but on track to move northward and interact

- At this point the door was open for further amplification of the upper-level flow and the push of an anticyclone (high pressure system) and cold air into the northern and Central Rockies. By 1200 UTC yesterday, cold air was surging down the east side of the Rockies, stimulating an upslope snowfall event along the front range, cold air was pushing across the Wasatch at the same time an upper-level trough was forming to drive strong northeasterly flow at crest level

- high pressure was centered over southern Montana, but a pronounced high-pressure ridge extended southward

- strong easterly flow originating over southwest Wyoming was directed across the northern Wasatch, driving downslope winds along the Wasatch Front.
- e, but the severity of the downslope wind storms along the Wasatch Front yesterday was probably also related to how the wind direction changed with height, which allowed for the trapping of mountain-wave energy at low levels.

Downslope Climatology

TABLE 2. Downslope windstorm events at KHIF as defined by this study.

Date	Time of max wind (UTC)	Speed of max wind [m s^{-1} (mi h^{-1})]	Gust of max wind [m s^{-1} (mi h^{-1})]
9 Oct 1979	1500	15 (34)	21 (48)
19 Jan 1980	1200	15 (34)	22 (49)
4 Apr 1983	1700	21 (46)	31 (70)
30 Mar 1984	1200	15 (34)	18 (41)
16 Jan 1987	1740	15 (34)	20 (44)
24 Dec 1987	0700	15 (34)	21 (46)
15 Dec 1988	1200	16 (36)	23 (51)
30 Jan 1993	1700	18 (41)	21 (48)
12 Jan 1997	1100	17 (38)	23 (52)
24 Feb 1997	1700	18 (40)	23 (51)
2 Apr 1997	1600	15 (34)	24 (53)
23 Apr 1999	1755	18 (40)	24 (53)
1 Dec 2011	1655	20 (45)	30 (67)

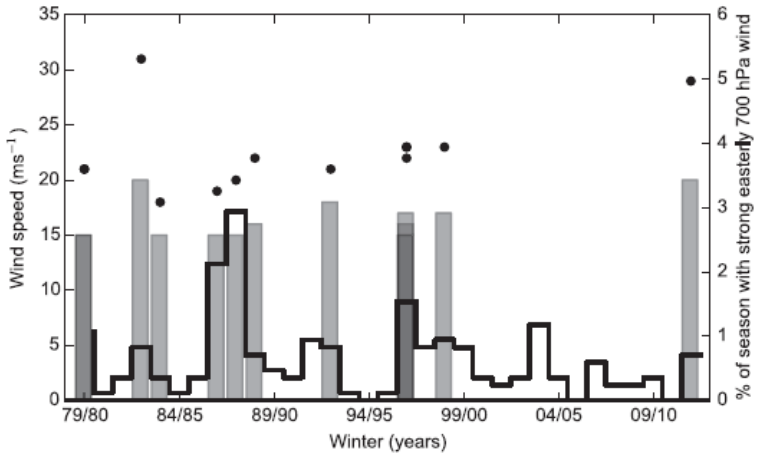
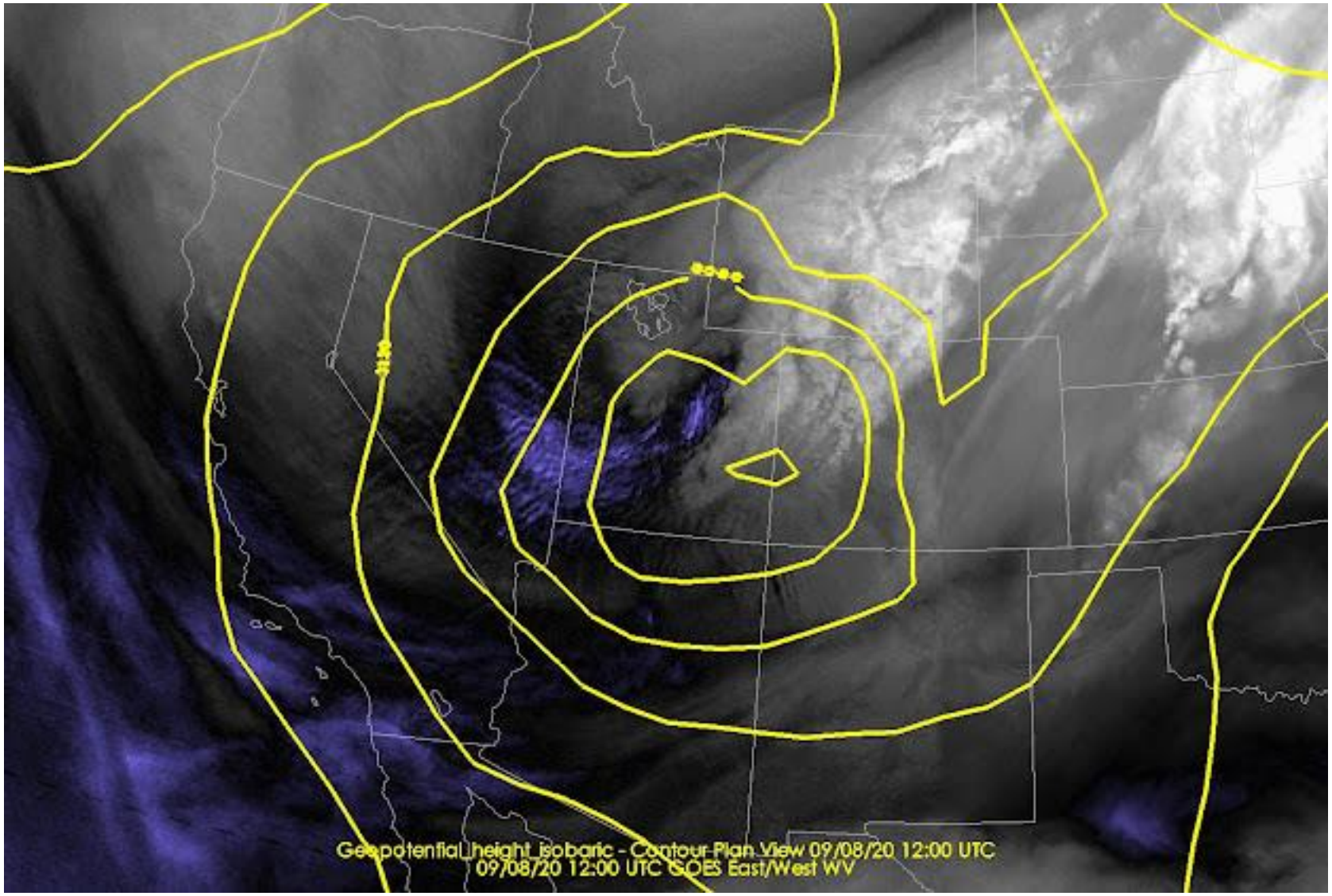


FIG. 4. Sustained wind (shaded bars) associated with downslope windstorms as a function of winter season at KHIF according to the scale on left. Filled circles indicate the max gust associated with each windstorm. Percent of season with strong (10 m s^{-1}) 700-hPa winds from the easterly direction in ERA-Interim data marked by black line according to the scale on the right. Two (three) events occur during the winter of 1979/80 (1996/97) and hence overlap on


Geopotential_height_isobaric - Contour Plan View 09/08/20 12:00 UTC
09/08/20 12:00 UTC GOES East/West WV

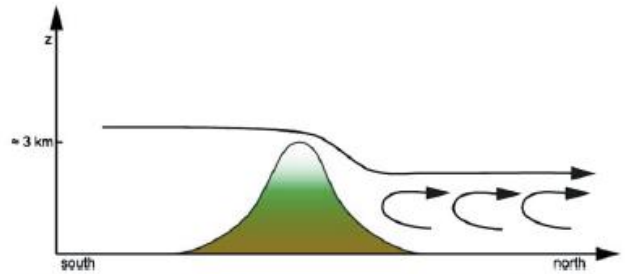


Fig. 4.11 Schematic representation of the *vertical aspiration theory* after Streiff-Becker (1933)

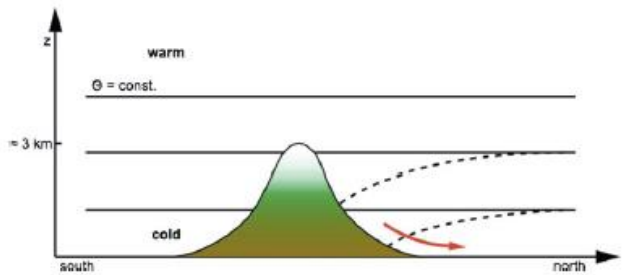


Fig. 4.12 Schematic representation of horizontal aspiration theory after Ficker (1931). *Solid lines* represent isentropes before, *dashed lines* isentropes after the aspiration by the low

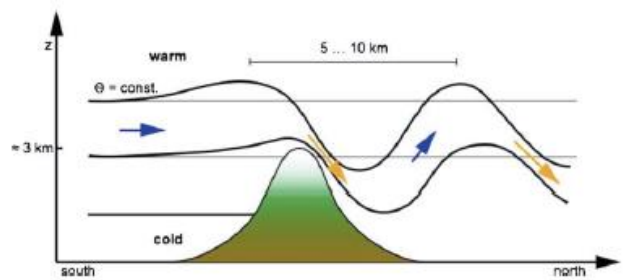


Fig. 4.13 Schematic representation of lee waves. *Solid lines* represent isentropes

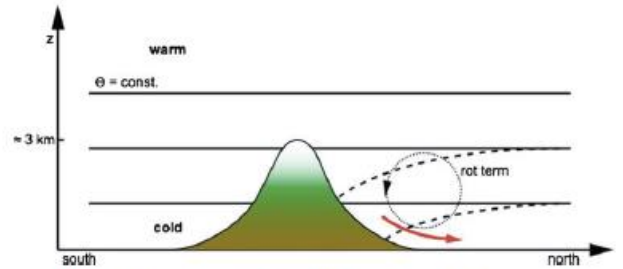


Fig. 4.14 Solenoid theory according to Frey (1944): effect of the rotational term due to the non-coincidence of temperature and pressure surfaces

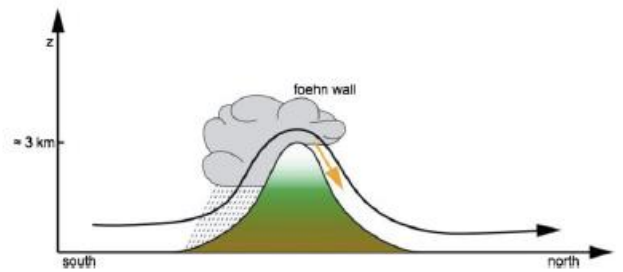


Fig. 4.15 Schematic representation of the waterfall theory according to Rossmann (1950)

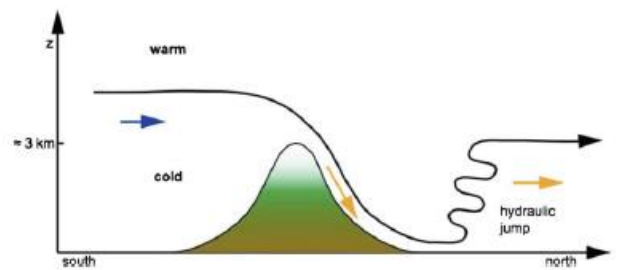


Fig. 4.16 Schematic depiction of the hydraulic jump theory according to Schweitzer (1953)

Dust-storm

- Dust source.
- Story

- Video
  - running
  - No rain
  - Dust that clears quickly

- Investigation

- Science - Cold pool
- Radar
- Temperature measurements