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Texas Winter Storm Patterns

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Introduction

- This presentation summarizes an article entitled, “A Synoptic Climatology of Texas Winter Storms,” written by Ted Ryan and Stacie Hanes, NWS Weather Forecast Office, Fort Worth, Texas and published in the *National Weather Digest*, Volume 33 - Number One August 2009

A SYNOPTIC CLIMATOLOGY OF TEXAS WINTER STORMS

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Abstract

Between the years of 1948 and 2005, 50 winter storms with snow and sleet accumulations of four inches or more affected the northern and central portions of the state of Texas. The upper level flow pattern of each storm case was examined and classified into one of six synoptic types. Additionally, geopotential height, moisture, and temperature anomalies associated with each case were studied in order to find quantitative similarities that may be used for operational forecasting. Results indicate that each synoptic regime possesses unique thermal and moisture profiles. Winter storms which exhibit characteristics similar to those presented here may be easier to forecast after one identifies the synoptic type. Characteristics of each synoptic pattern are discussed in detail to allow maximum application in the operational forecast setting.

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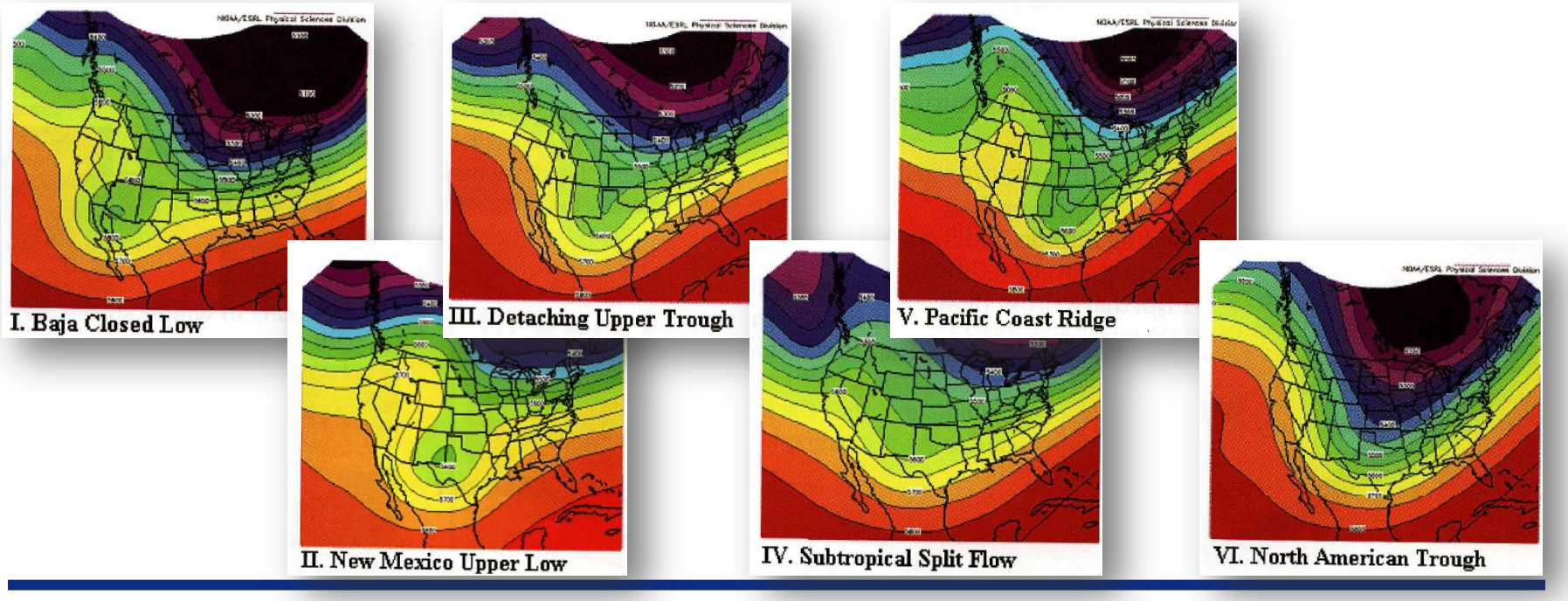
Introduction

- The authors identified 50 winter storms with snow and sleet accumulations of **four inches or more** that affected northern/central portions of Texas between 1948 and 2005
- Upper level flow pattern of each storm case was examined and classified into one of **six synoptic types**

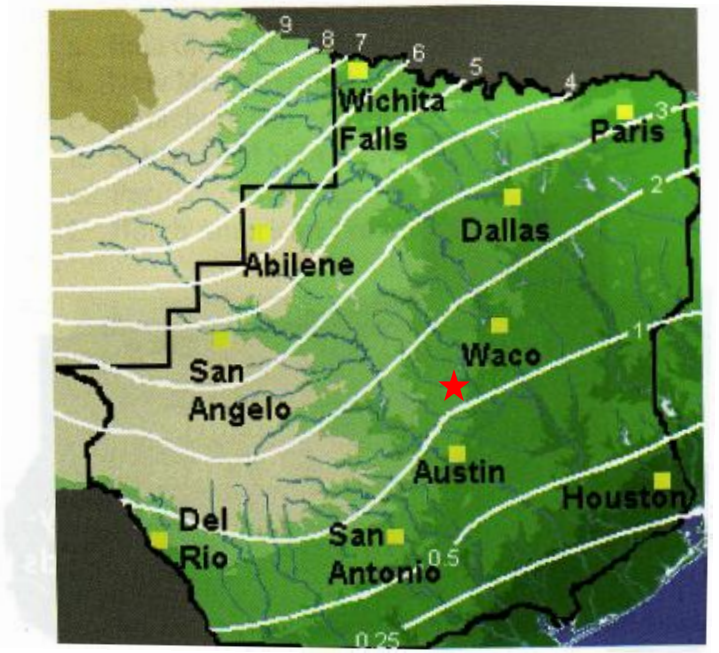


Introduction

- Purpose was to provide operational forecasters a climatological reference to compare against computer model guidance in order to acquire confidence (or doubt) in a particular forecast

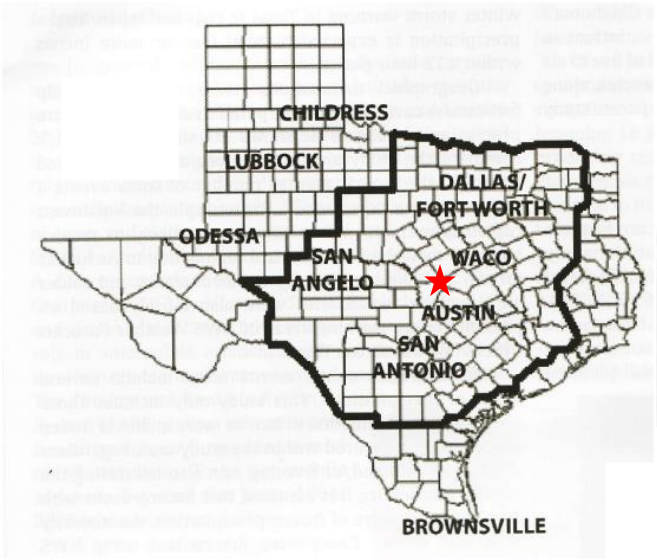
Background

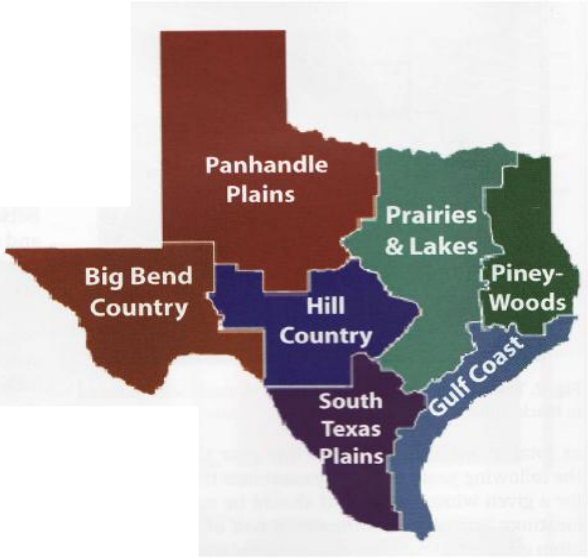
- Texas mean seasonal snowfall from NWS Local Climatological Data 1965-1995 (NCDC)
  - Study area outlined in black
  - Solid white lines are snowfall contours in inches
  - Fort Hood mean annual snowfall is **1.0** inches; maximum is 5.3 inches
  - Many locations across southeastern half of study area often go several years between accumulating snow events, **thus seasonal average snowfall can be misleading**

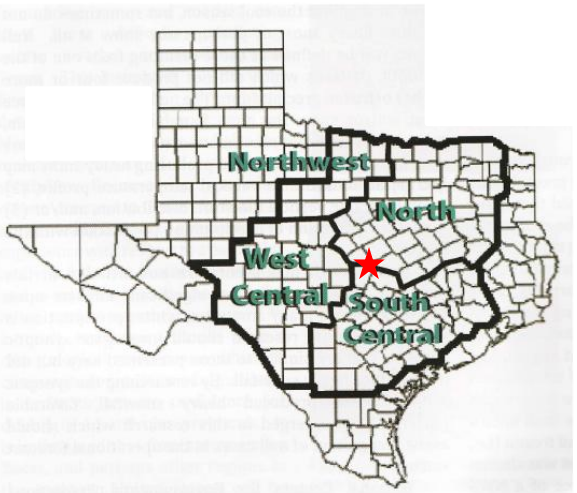


NOTE: Detailed snowfall records ceased after 1995 because of ASOSs

Background



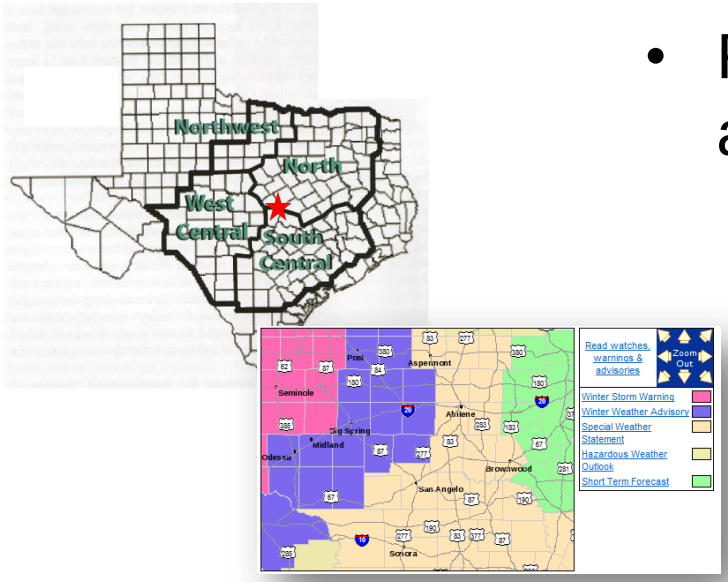




- Study area includes portions of all eight geographical regions
  - Area of interest limited to region with rare to very rare (approximately less than once a year to less than once a decade) occurrences of four or more inches of frozen precipitation (snow/sleet)

Background

- Four or more inches of frozen precipitation (snow/sleet) chosen as minimum value because issuance of a NWS winter storm warning in TX when frozen precipitation is expected to total four or more inches within 12-hour period
  - *Fort Hood warning criteria is:* ***≥ 2 inches within 12 hours***



- Regions defined based on annual average number of snow events
  - Northwest region more than four times likely to receive snowfall than South Central region, due to higher terrain and closer proximity to storm tracks and colder air

Background

- Synoptic pattern classification presented here occur throughout the cool season, but sometimes do not produce heavy snow *(4+ inches)* or perhaps any snow at all
- Limiting Factors:
  - Unfavorable vertical temperature profile
  - Unfavorable vertical moisture distribution
  - Inadequate duration of precipitation production with system
- General Rules:
  - Saturation of 850-mb layer required to produce significant snowfall
  - Sub-freezing 850-mb temperatures critical for occurrence of snowfall in every case

Synoptic Types

Synoptic Type	Average Max Snow Amount (inches)	# of Cases	Preferred Snow Band Orientation	Average Snow Area (miles^2)
I. Baja Closed Low	9.0	4	SW to NE	20,415
II. New Mexico Upper Low	7.2	7	W to E	2,823
III. Detaching Upper Trough	6.8	18	W to E	13,267
IV. Subtropical Split Flow	6.9	9	SW to NE	7,269
V. Pacific Coast Ridge	6.3	4	WSW to ENE	10,884
VI. North American Trough	5.6	8	W to E	4,718

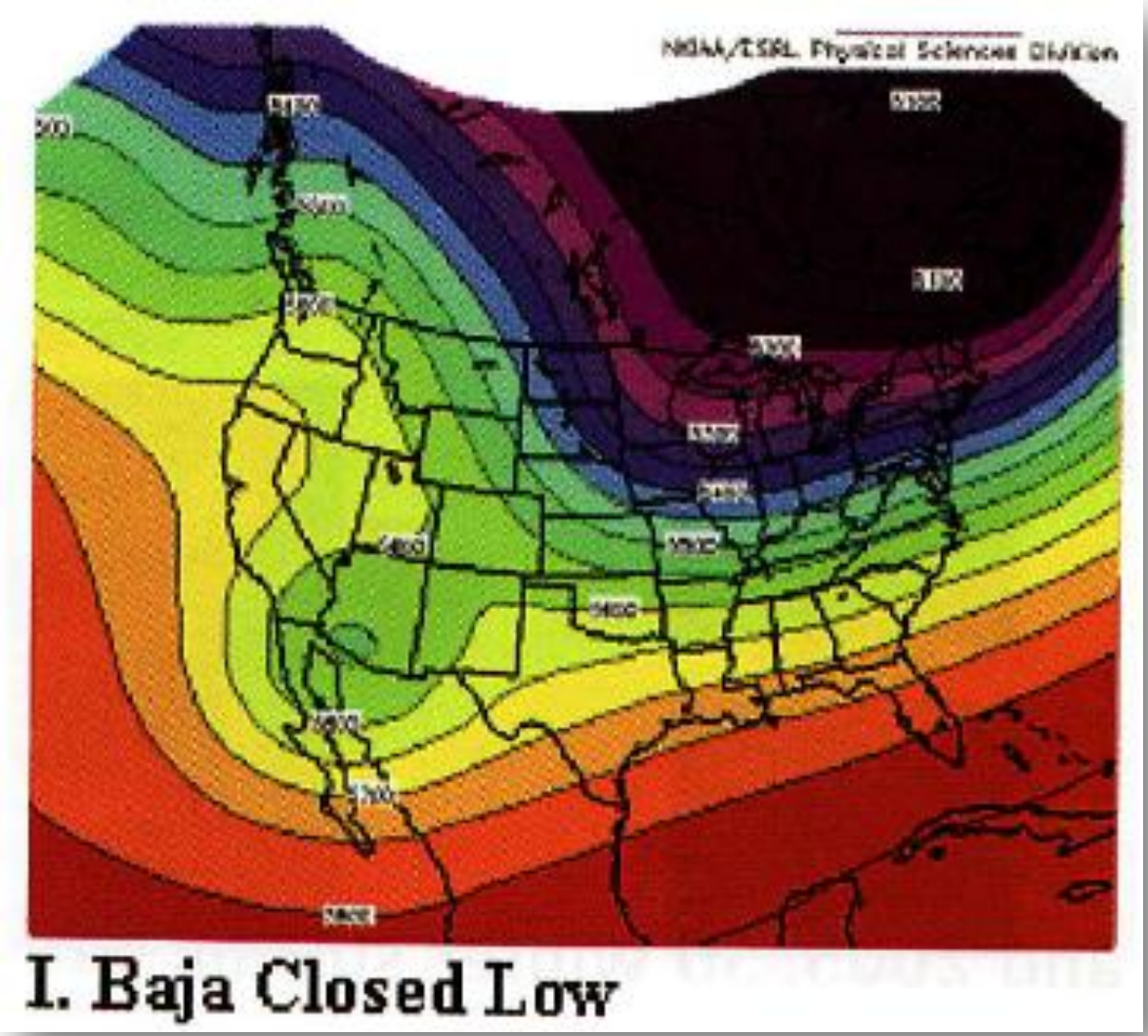
Key Upper-Air Parameters

Synoptic Type	500-mb				700-mb				850-mb
	T	T anom	q	q anom	T	T anom	q	q anom	T
I. Baja Closed Low	-23.8	-2.3	2.0	1.8	-2.8	-0.3	4.5	1.5	-2.3
II. New Mexico Upper Low	-24.9	-1.4	1.4	1.2	-6.1	-1.1	4.3	1.8	-1.9
III. Detaching Upper Trough	-24.9	-2.1	1.3	1.2	-6.8	-1.6	4.1	1.8	-3.2
IV. Subtropical Split Flow	-22.6	-1.2	1.3	1.3	-5.3	-1.0	3.8	1.2	-3.6
V. Pacific Coast Ridge	-27.3	-2.0	0.9	0.3	-9.0	-1.8	3.0	1.2	-4.3
VI. North American Trough	-26.1	-2.0	1.1	0.8	-11.3	-1.9	2.7	0.5	-6.8

T = Average temperature (^oC); T anom = Standardized temperature anomalies

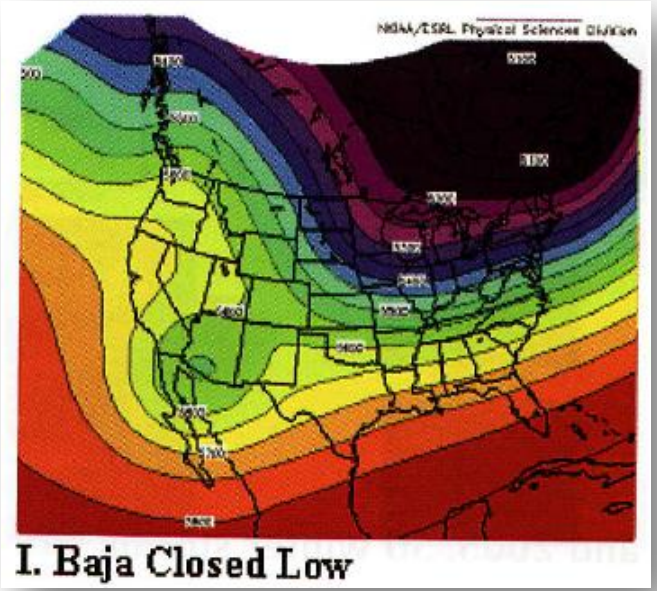
q = Mixing Ratio ($g\ kg^{-1}$); q anom = Standardized mixing ratio anomalies (mixing ratio is a measurement of the amount of water vapor (moisture) present in a given air sample)

I. Baja Closed Low



I. Baja Closed Low

- Upper-level low becomes cut-off from mean flow; drifts over northern Baja region of Mexico
  - Stationary or slow-moving; located well west when snow is falling across study region
- Events are long-lived
- Only four events were identified with this pattern, but it produced the highest average areal coverage of four inch-snowfall, and two events produced max totals up to 12 inches



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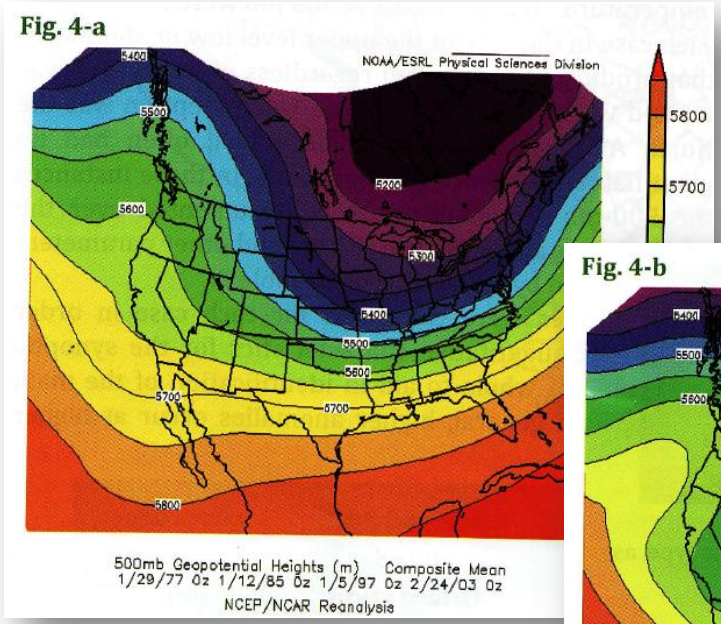
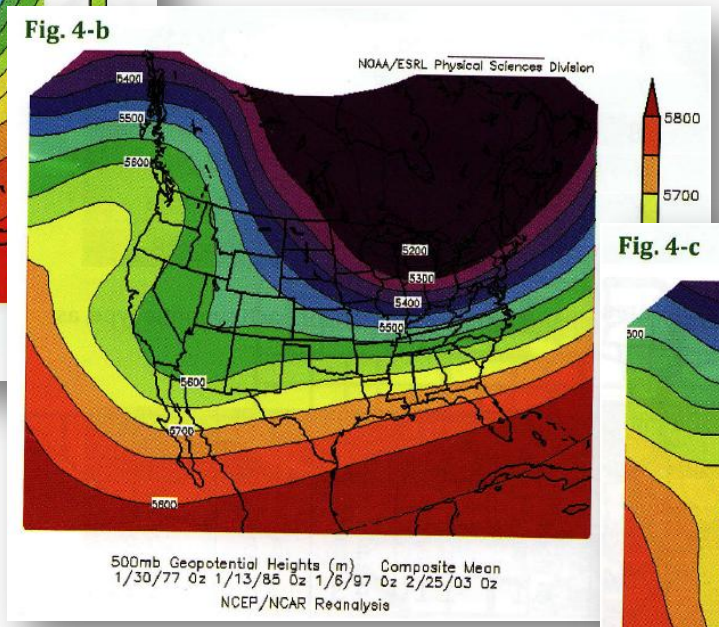
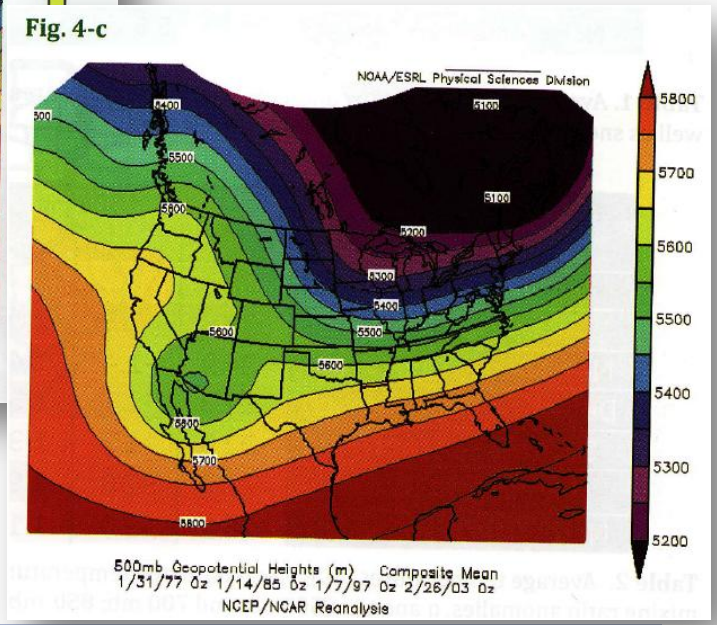
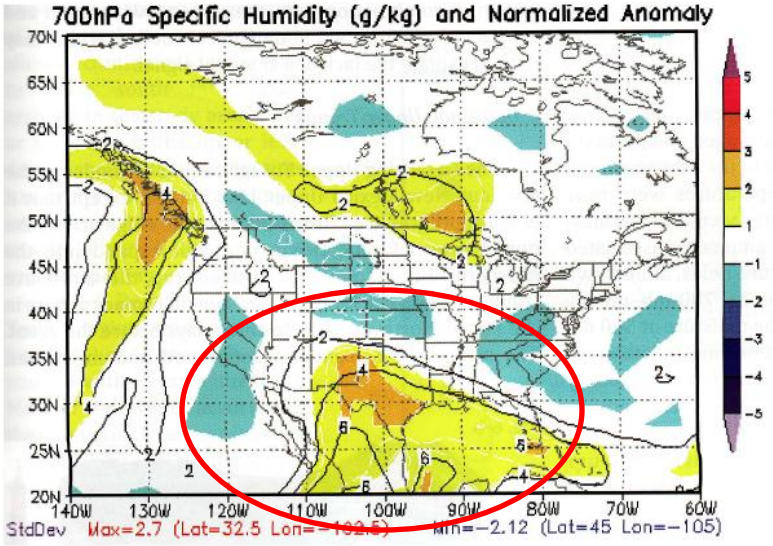


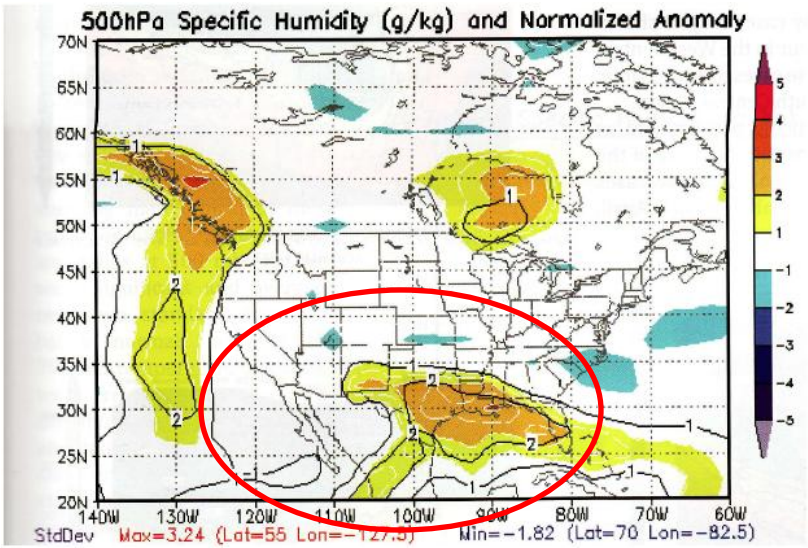




I. Baja Closed Low

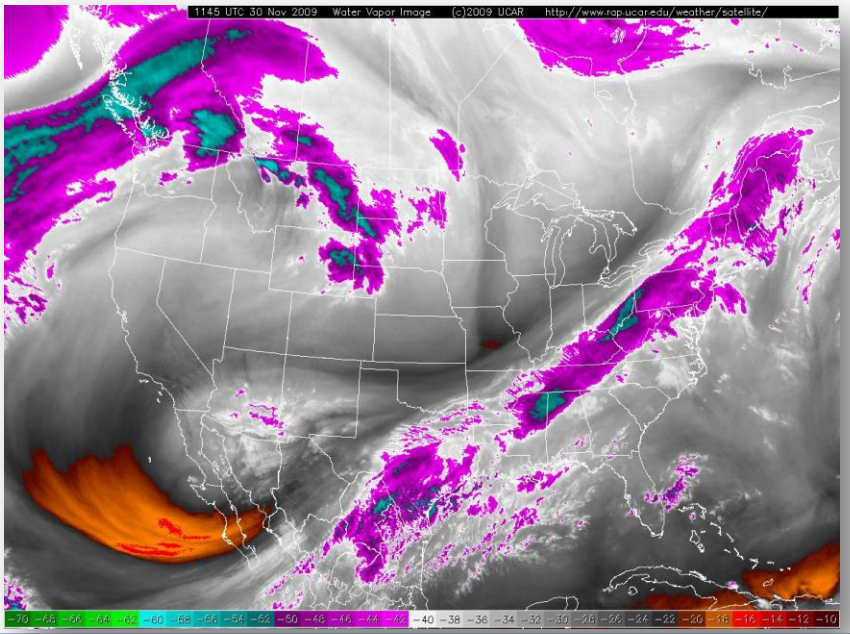
- Average 500-mb, 700-mb, and 850-mb temps were among the warmest of all six synoptic patterns
- Highest moisture content of all six synoptic patterns
  - Influx of subtropical moisture from Pacific Ocean

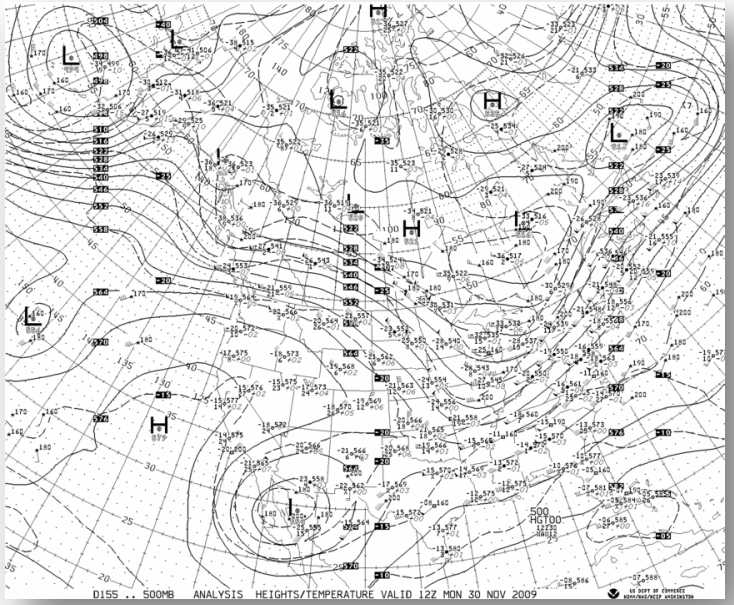




I. Baja Closed Low

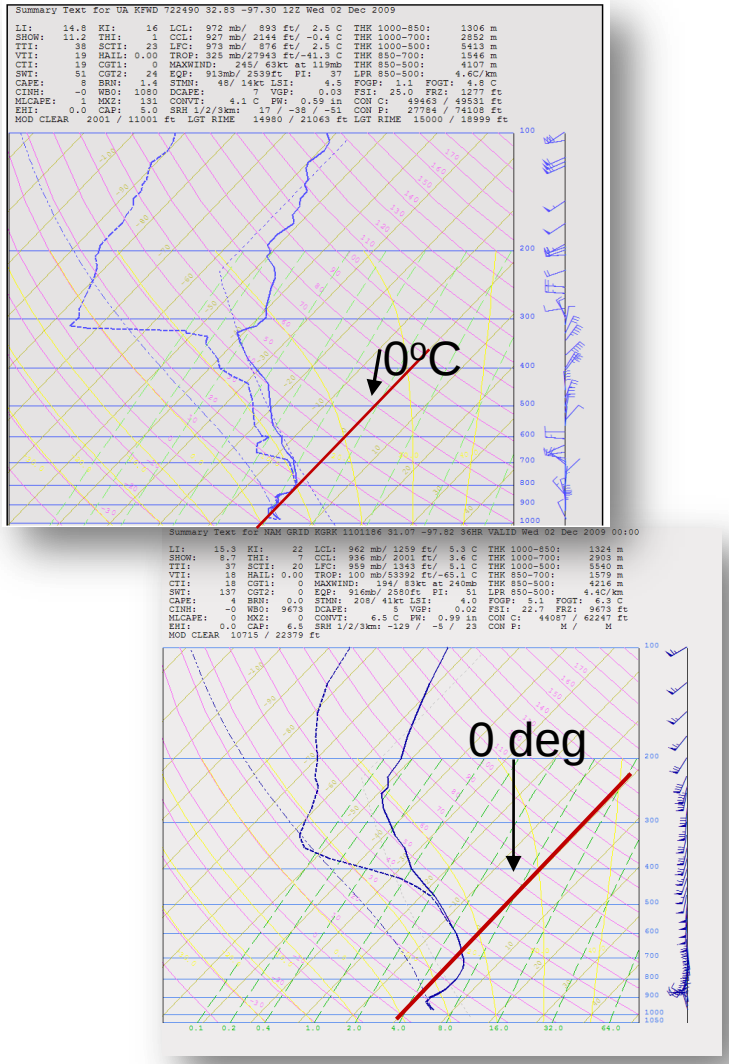
- Main <u>limiting factor</u> is a subfreezing column of air
  - Difficult to attain given inherent WAA associated with southwesterly flow aloft
- **This pattern only occurred within the climatological coldest time of the year—January or February**



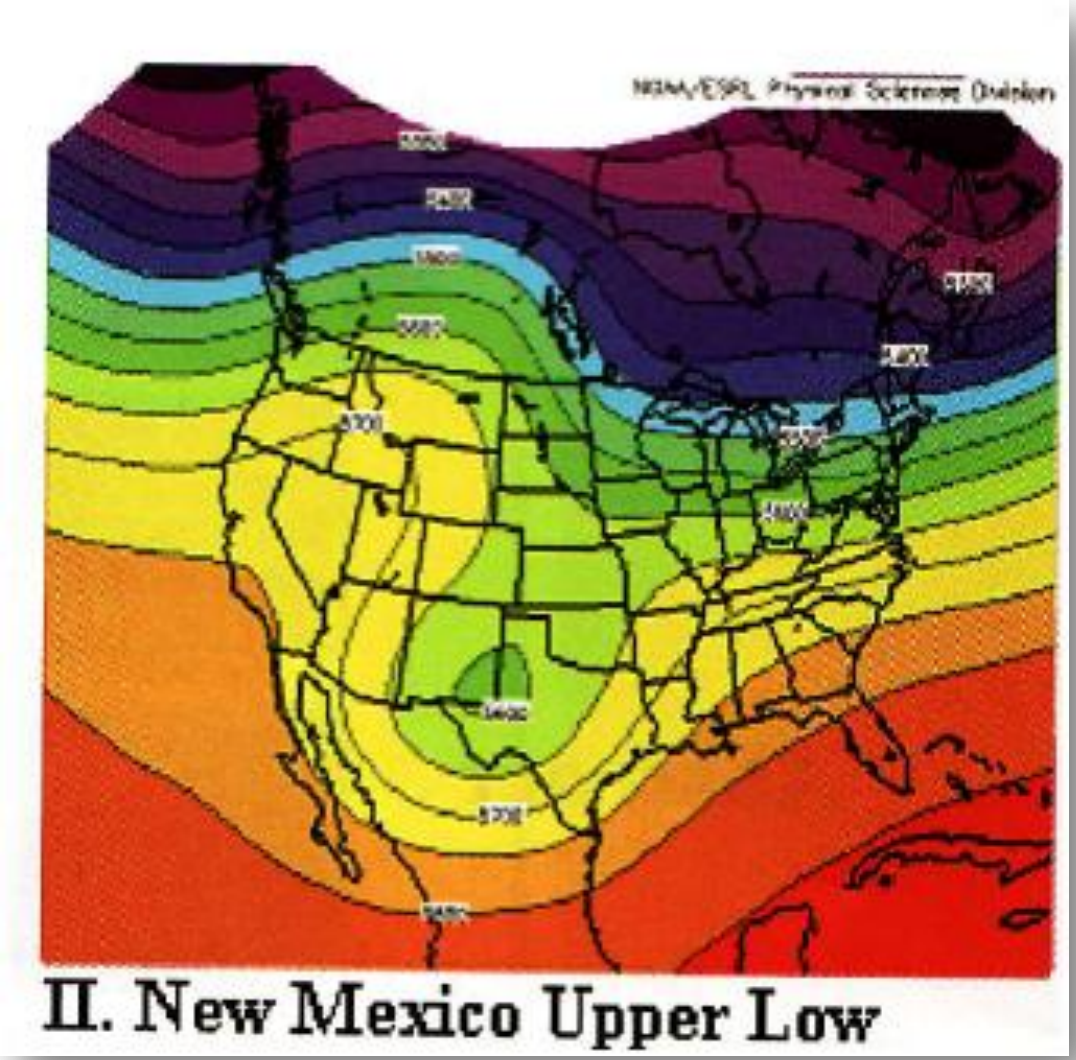


I. Baja Closed Low

- **Forecasting Tips:**
  - Closely monitor model/observed temperature profile forecasts
  - If profiles support snow, potential exists for snow amounts over four inches across a large area
  - Since cold air may be limiting factor for these systems to produce heavy snowfall, null cases would mostly be comprised of rain and or freezing rain events

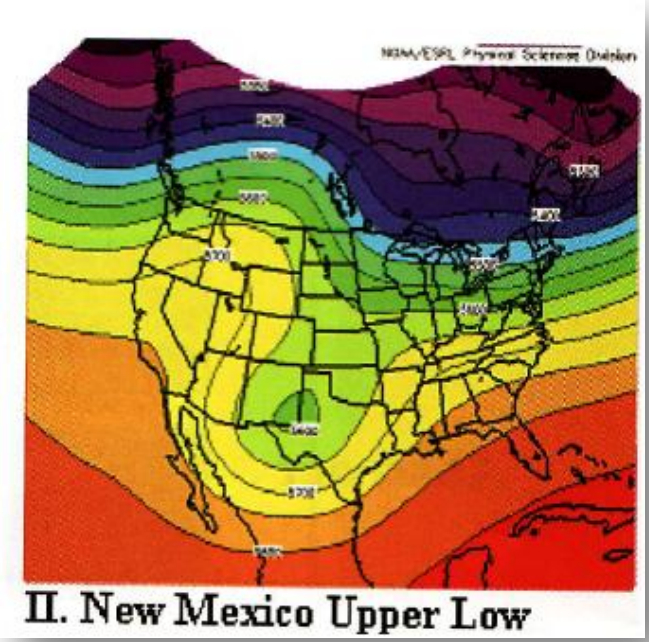


II. New Mexico Upper Low



II. New Mexico Upper Low

- Evolution of this pattern begins as an amplified upper ridge along Pacific coast and a weak/broad trough across the Rocky Mountains
  - Northeastward expansion of Pacific ridge into northern Rocky Mountains develops as ridge axis becomes oriented southwest to northeast
  - Southeast of upper-level ridge, at the base of the positively tilted trough, an upper-level low begins to close off over New Mexico



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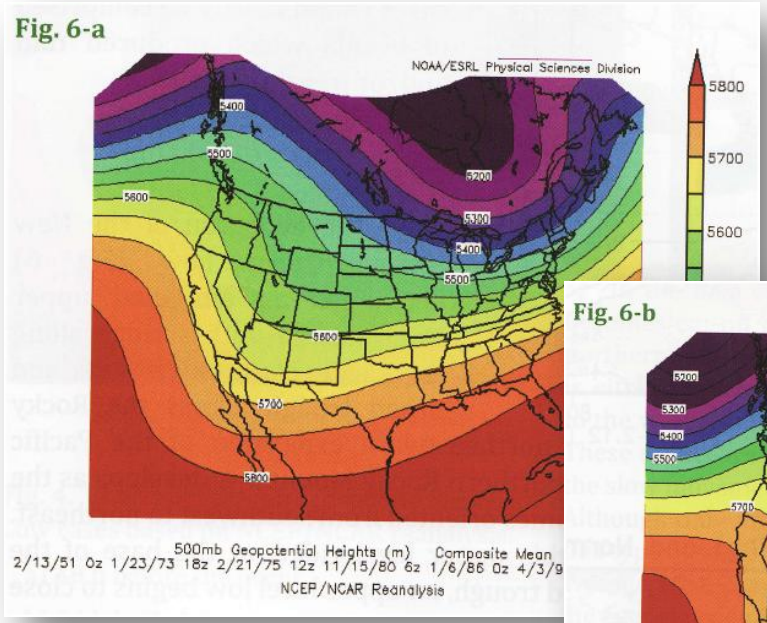
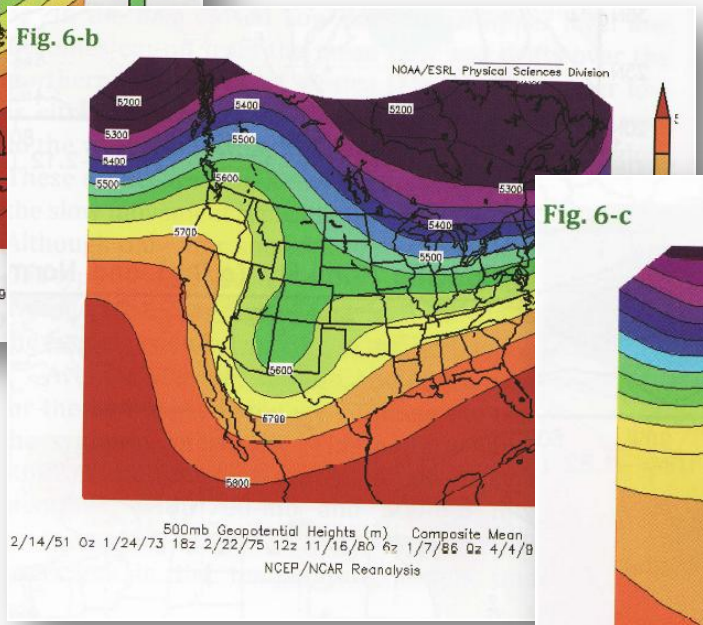
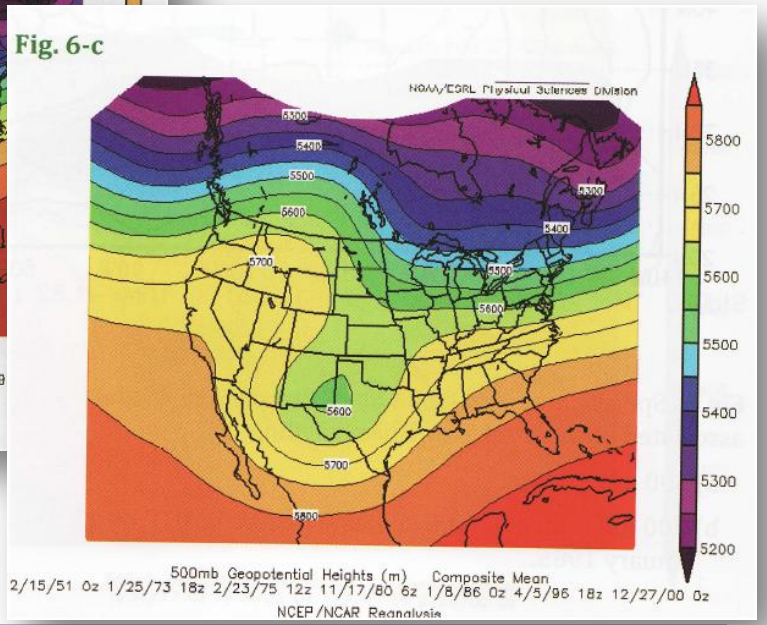






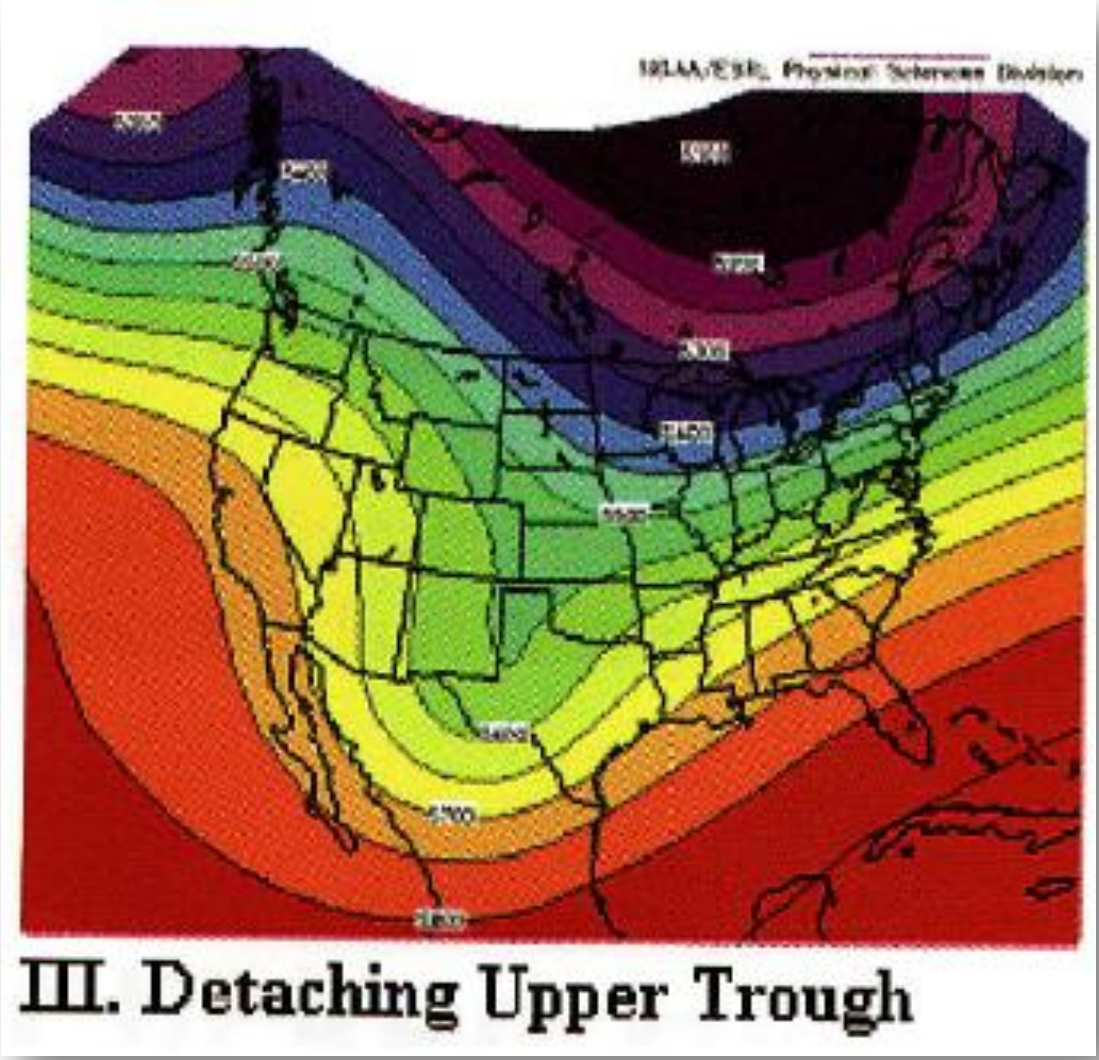
II. New Mexico Upper Low

- Texas is in the region where cold air is in place at the low-levels as upper-level low develops/intensifies over the Four Corners region and tracks eastward into Texas
  - 500-mb and 700-mb temperatures near median, but 850-mb temperatures among warmest of all synoptic patterns
  - Second highest moisture content of six synoptic patterns, primarily 700-mb and below
  - Null cases would likely result from an unfavorable vertical temperature profile, not a lack of moisture

II. New Mexico Upper Low

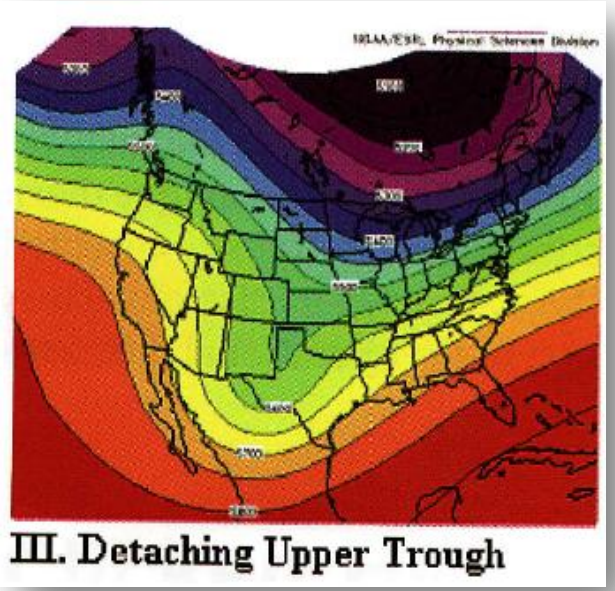
- Produced second highest maximum snowfall amount, but least areal coverage of all synoptic types
- Subfreezing air limited to small area just under upper low
  - Most events occurred in West Central region (Hill Country)
  - **No cases** produced 4+ inches of snow over South Central region
- Efficient snow-producing pattern—little correlation with respect to time of year—cases occurred **mid November to early April**

III. Detaching Upper Trough



III. Detaching Upper Trough

- Similar to New Mexico Upper Low pattern except more progressive
  - Ridge across northwestern Pacific Ocean does not expand into northern Rocky Mountains
  - Shortwave comes ashore in Pacific Northwest 2-3 days before event; digs southward and intensifies evolving into split flow regime
  - Faster eastward progression allows cP air to move south into Texas, arriving day or so ahead of upper-level system; by this time system has evolved into a closed upper low or pronounced shortwave trough



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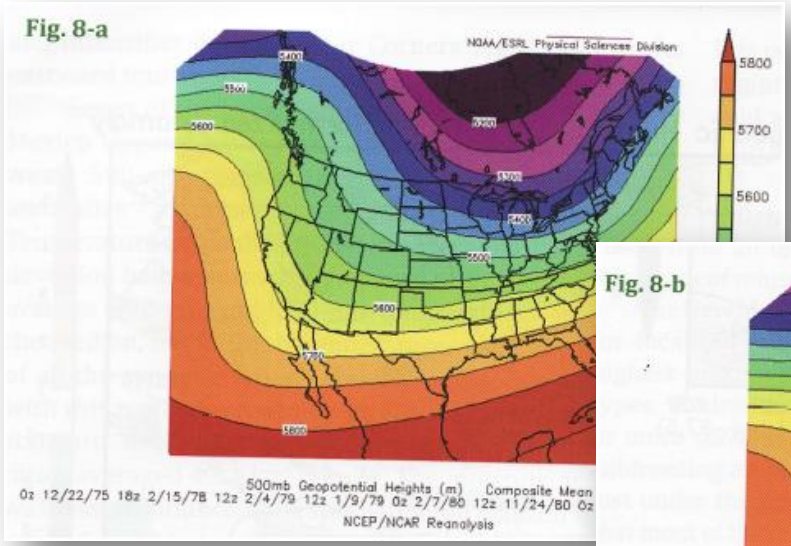
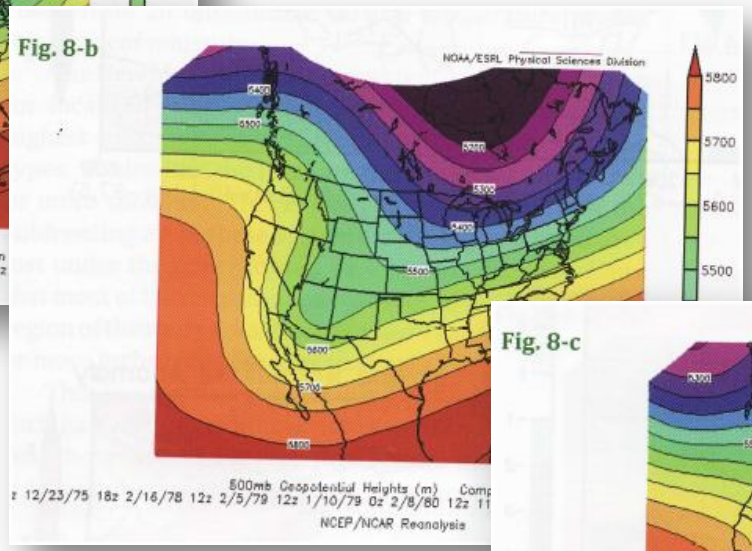
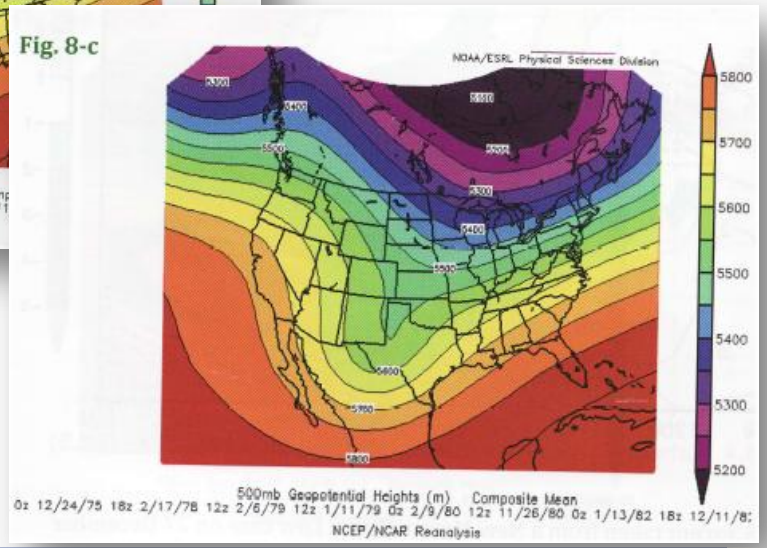




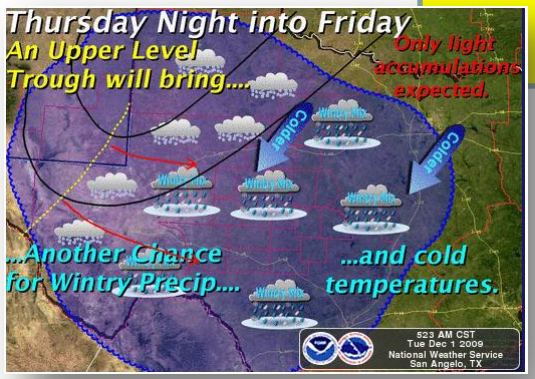


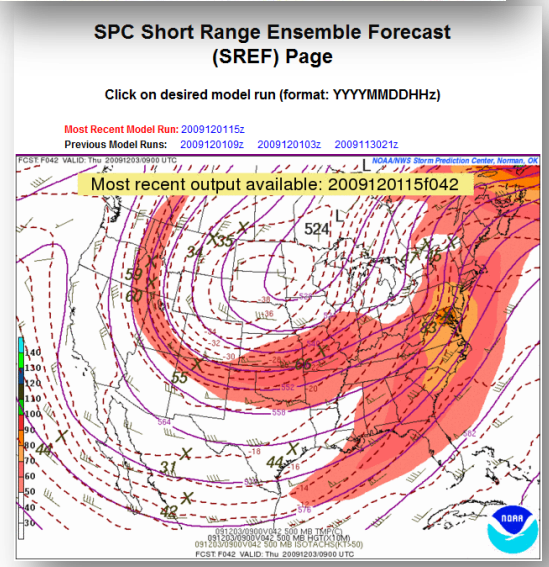
III. Detaching Upper Trough

- **Responsible for 40% of all snowfall events**
  - Most occurred in December, January, or February
  - Second highest areal coverage
  - Many cases showed long narrow band from west to east where the disturbance tracked across region
- Cold air aloft at 500-mb significant, but not at 700-mb
  - Suggests an environment with relatively steep mid-level lapse rates and mid-level instability
  - Combined with moisture could create conditions favorable for intense precipitation

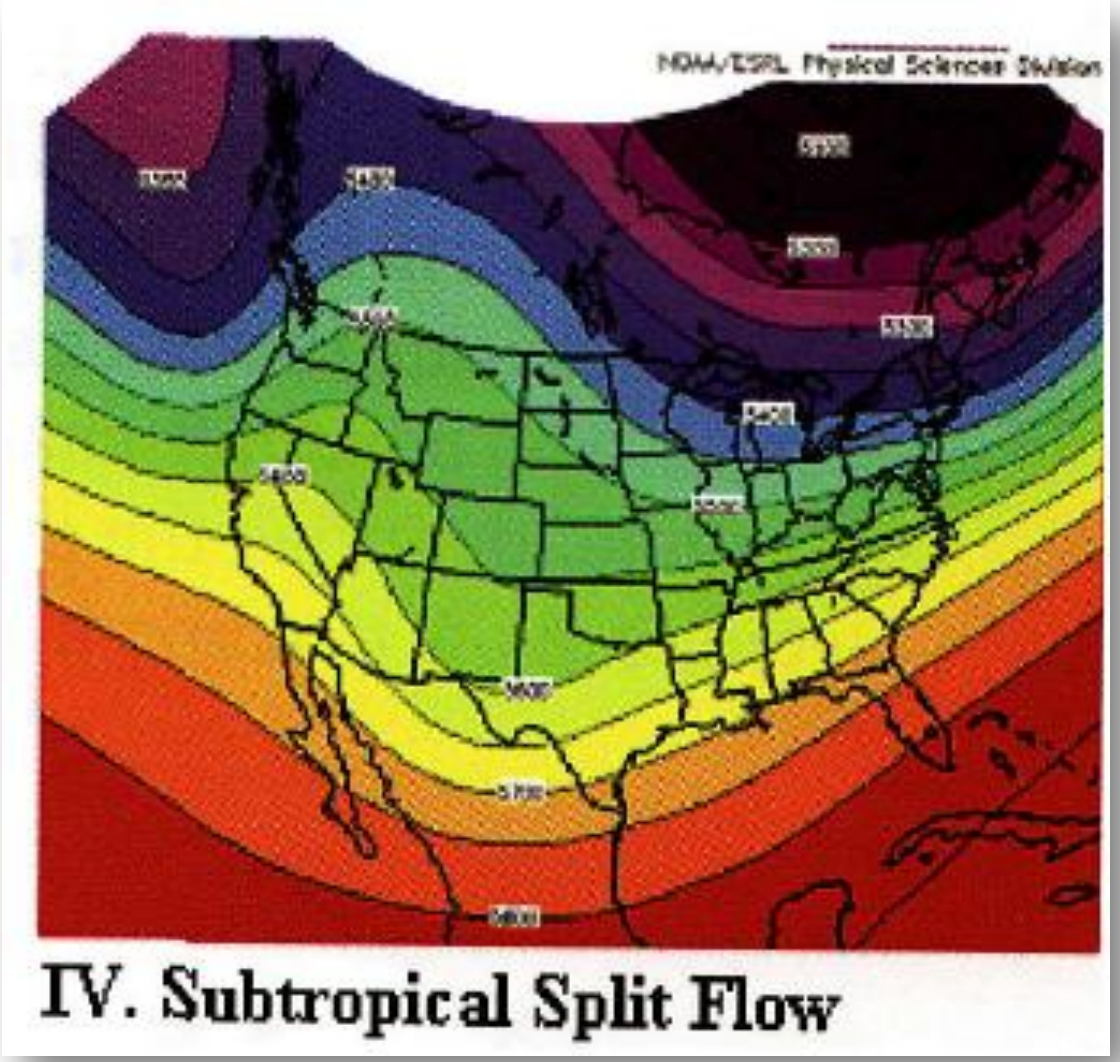
III. Detaching Upper Trough

- One of the most important synoptic patterns for forecasters to recognize
  - Synoptic setup brings cold air south first; then allows large amounts of moisture to be drawn north from Gulf of Mexico in mid-levels; then lifted ahead of upper-level low
  - Exact location where significant snowfall will occur is very hard to forecast due to narrow west to east swath
  - Critically dependent on track of disturbance, so forecasters may obtain better forecast accuracy using **ensemble products**



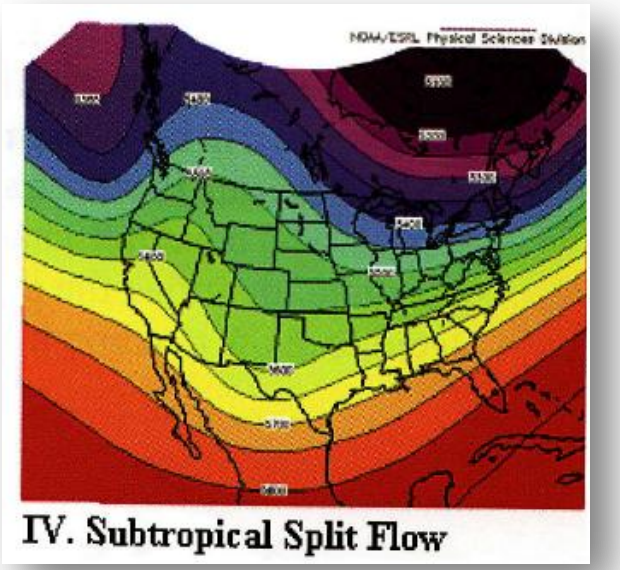


IV. Subtropical Split Flow



IV. Subtropical Split Flow

- Dominated by zonal split flow embedded within an active **subtropical branch of the jet stream**
- **Fast moving shortwave in southern branch is catalyst for these snow events**
- Split in flow is maximized 1 day before snow event begins
- Specific snowfall-producing synoptic features weak and subtle, similar to Baja Closed Low pattern



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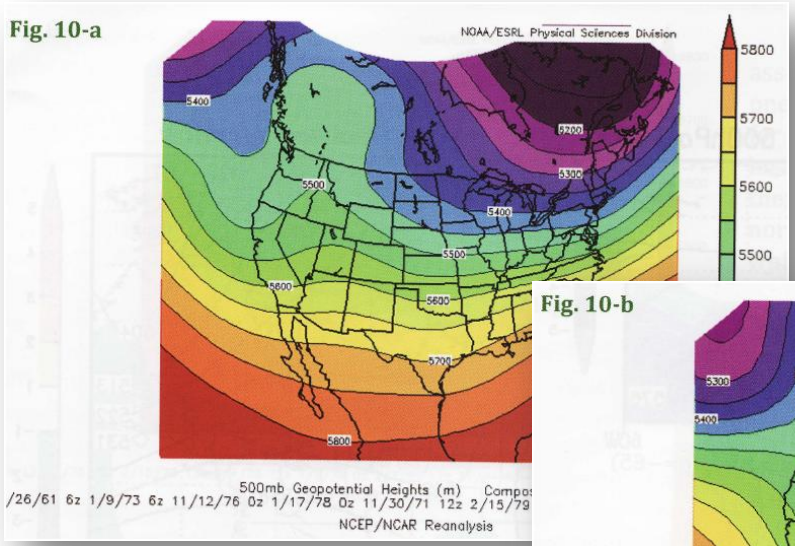
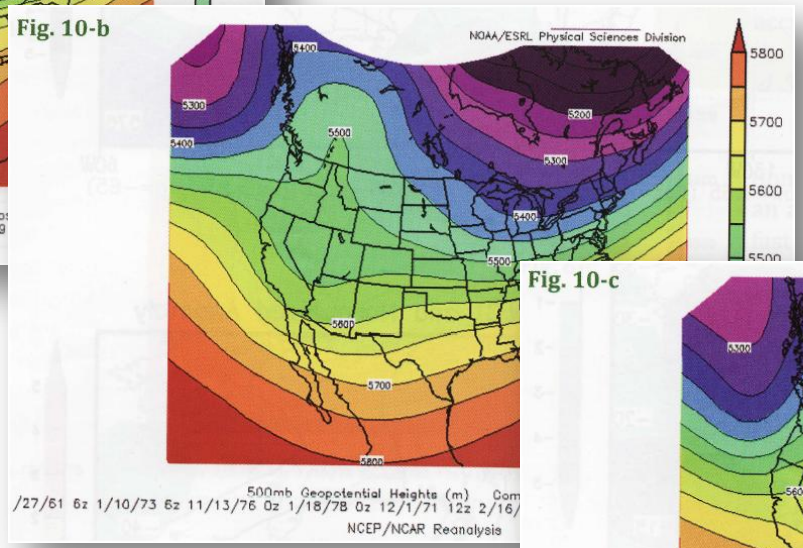
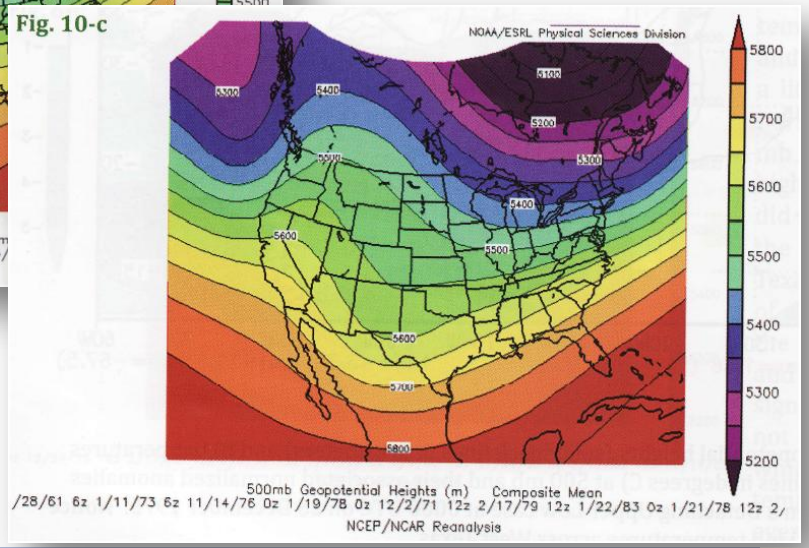


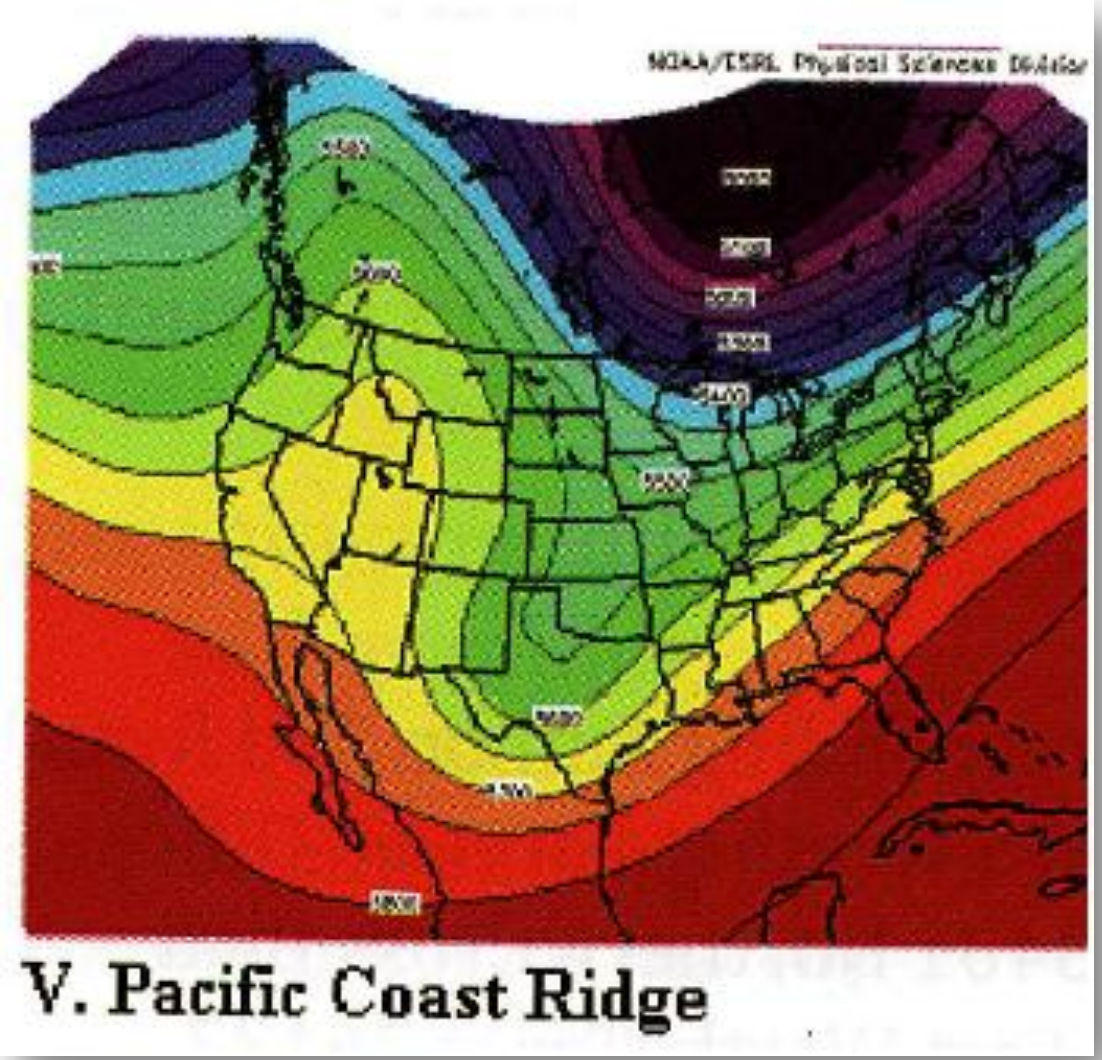




IV. Subtropical Split Flow

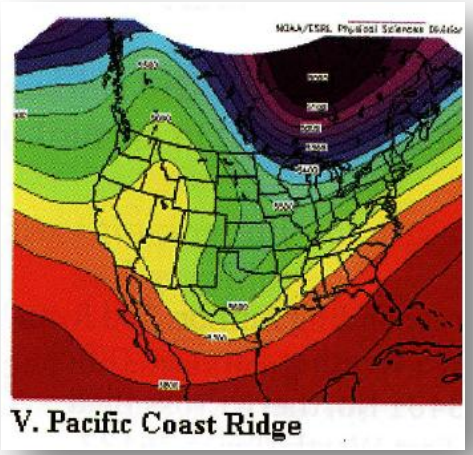
- Due to warm temps aloft (500-mb/700-mb), similar to Baja Closed Low pattern, cold air is main limiting factor in producing snow with this pattern; moisture usually not a factor due to Pacific Ocean subtropical connection
  - Deep cold air must be in place before southern stream energy moves across region
  - Null events would primarily occur due to unfavorable temperature profile
- Limited to coldest months (Late Dec thru Early Feb)
- Almost all cases of snowfall occurred either in North or Northwest regions; no heavy snow recorded in South Central Region

V. Pacific Coast Ridge



V. Pacific Coast Ridge

- Highly amplified pattern
  - Upper ridge along Pacific Coast with positively tilted trough along front range of Rocky Mountains
  - Resulting polar fetch allows cold air to plunge southward into Texas
- Temperatures aloft among coldest of all patterns
- Moisture low due to northwesterly flow
- Average maximum snowfall second lowest of all types with lowest number of cases
  - Lack of significant moisture could lead to null event where snowfall is less than four inches
  - Heaviest snows fell across North region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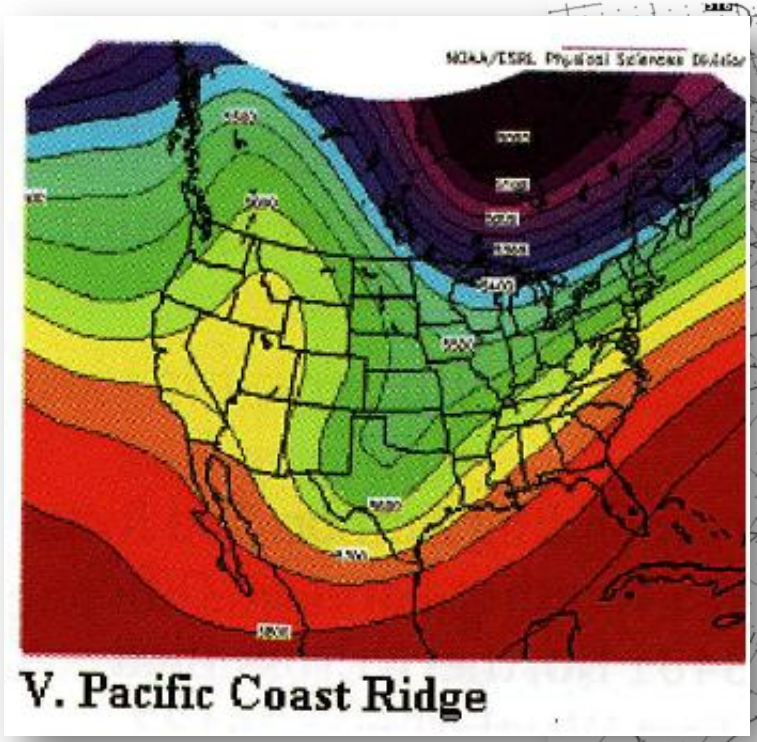
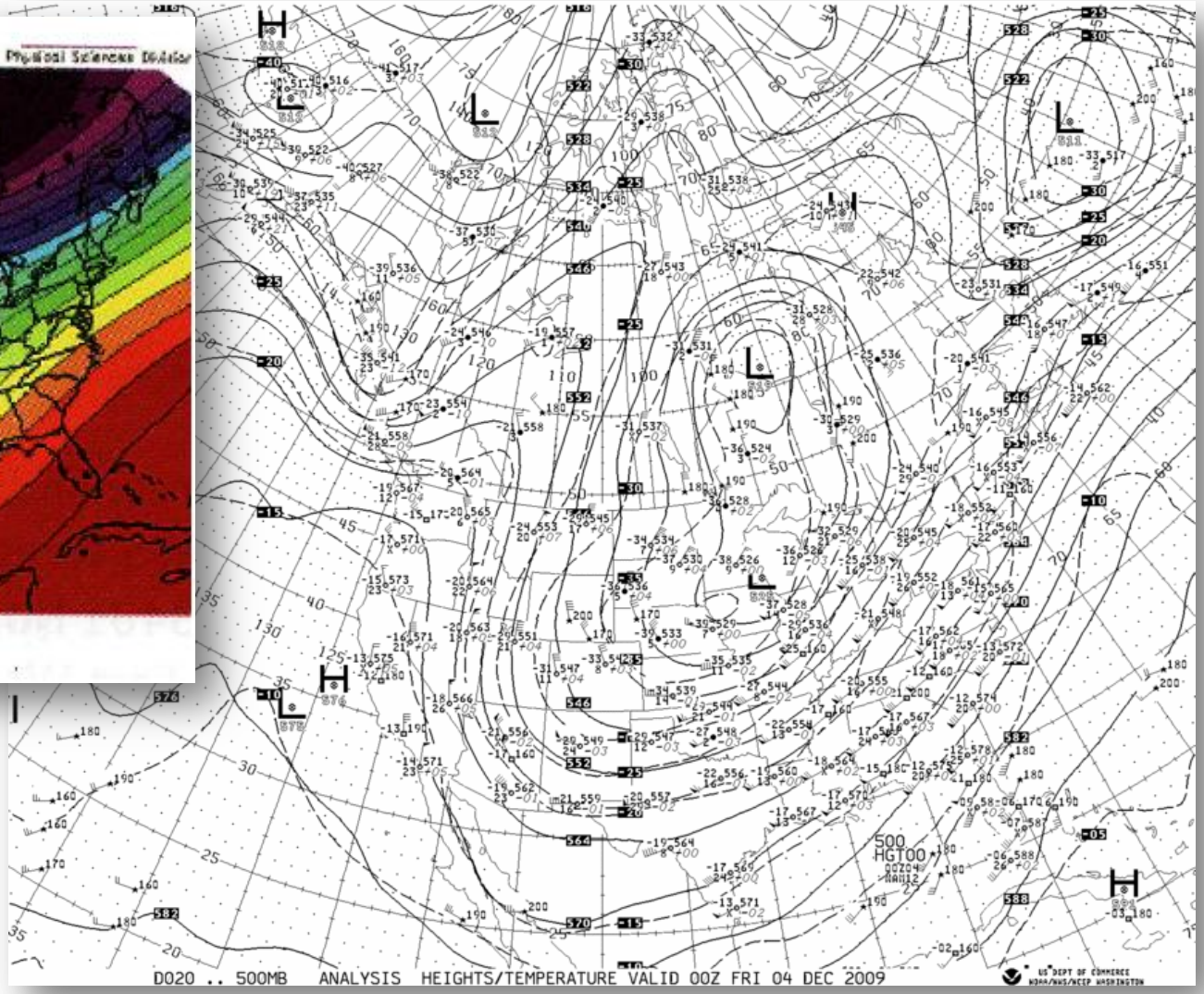
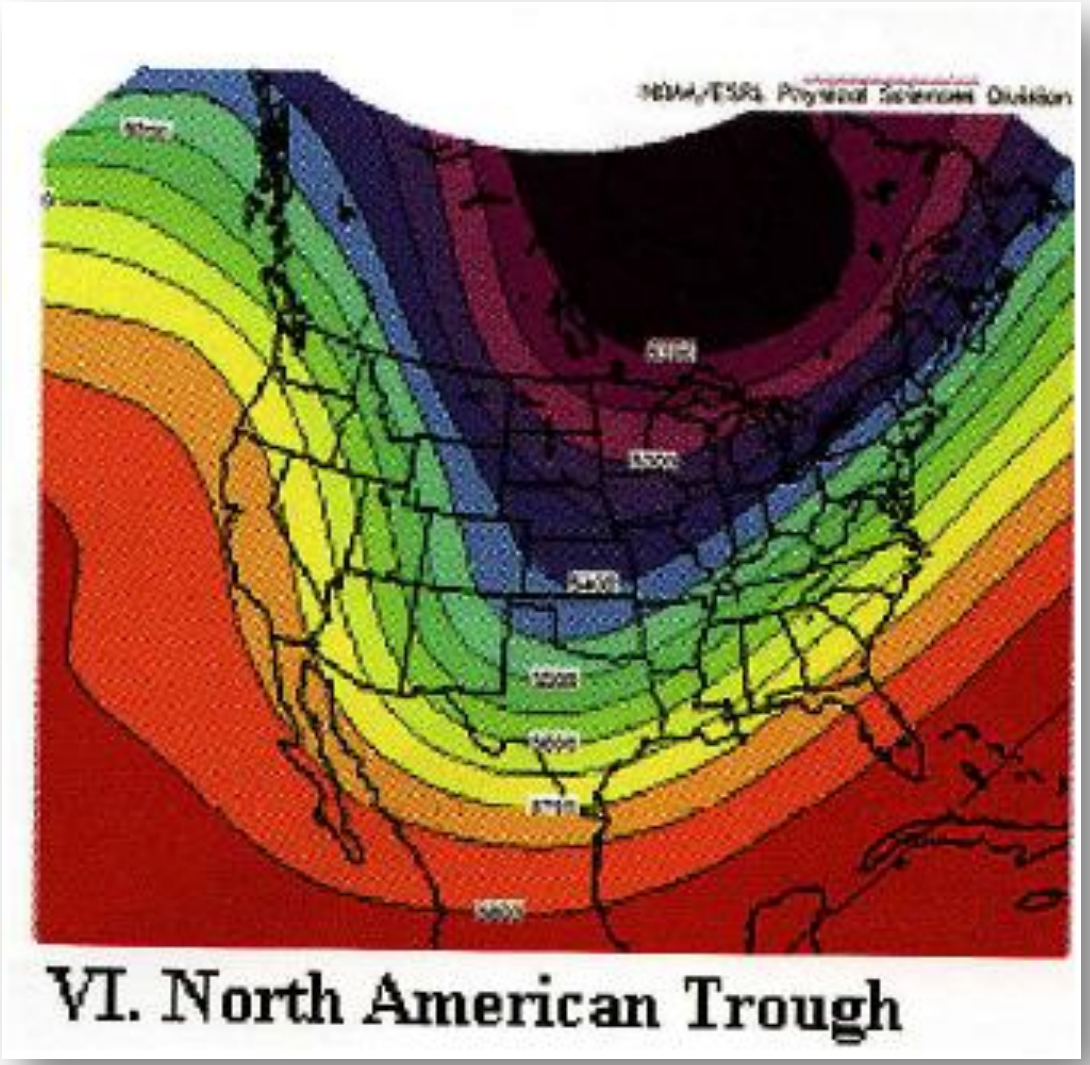


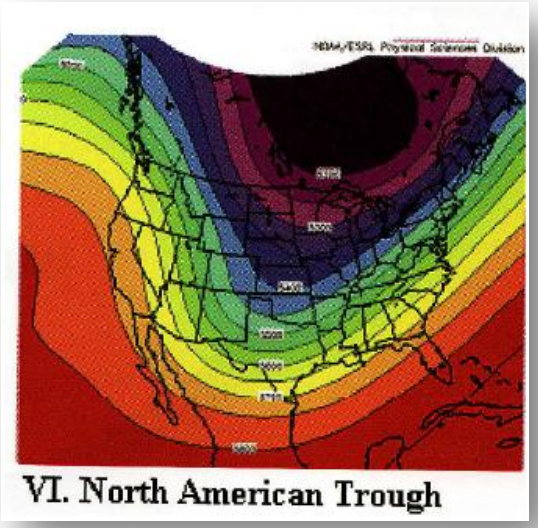


VI. North American Trough



VI. North American Trough

- Deep/potent upper trough across central North America
- Main synoptic feature was Hudson Bay polar low stationary across Northern Plains when snow was falling across study area
- Coldest of all synoptic patterns therefore low moisture
  - Lowest average maximum snowfall amount of all patterns
  - Flow is unable to bring moisture northward; however, deep cold air aloft allows snowfall production to be maximized in limited moisture environment resulting in low water-equivalent snowfalls


VI. North American Trough

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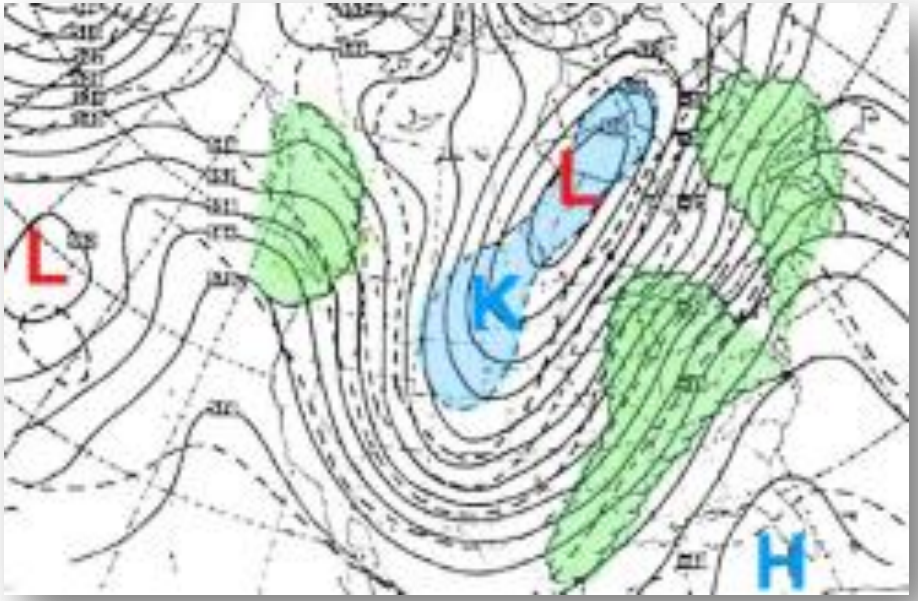
- Forecasters should watch long-wave troughs that are slow moving and very cold
- Null cases usually result in little or no precipitation due to lack of moisture

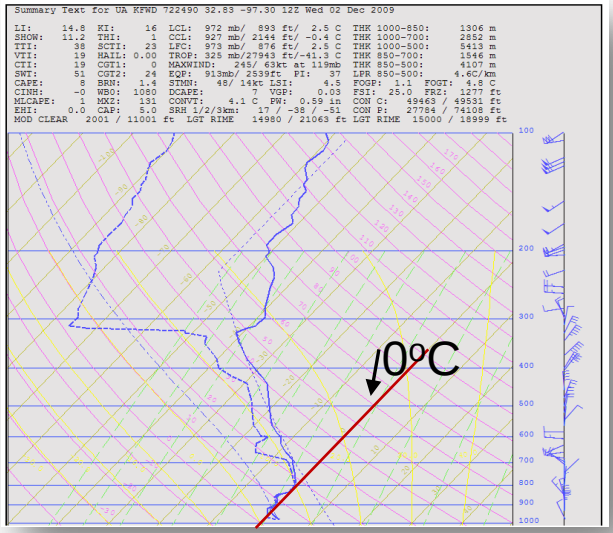


Conclusions…

- Pattern climatology integrated with model guidance in the forecast process can enhance accuracy and increase lead-times of snowfall events
- When a synoptic setup favorable for winter precipitation is forecast to develop, forecasters should first:
  - Classify regime as one of the six patterns
    - Comparison of key geopotential height, temperature, and moisture parameters between model forecasts and climatological averages for a particular synoptic type can aid in pattern recognition
- Is a pending snowfall event climatologically favorable or unfavorable?

Conclusions…

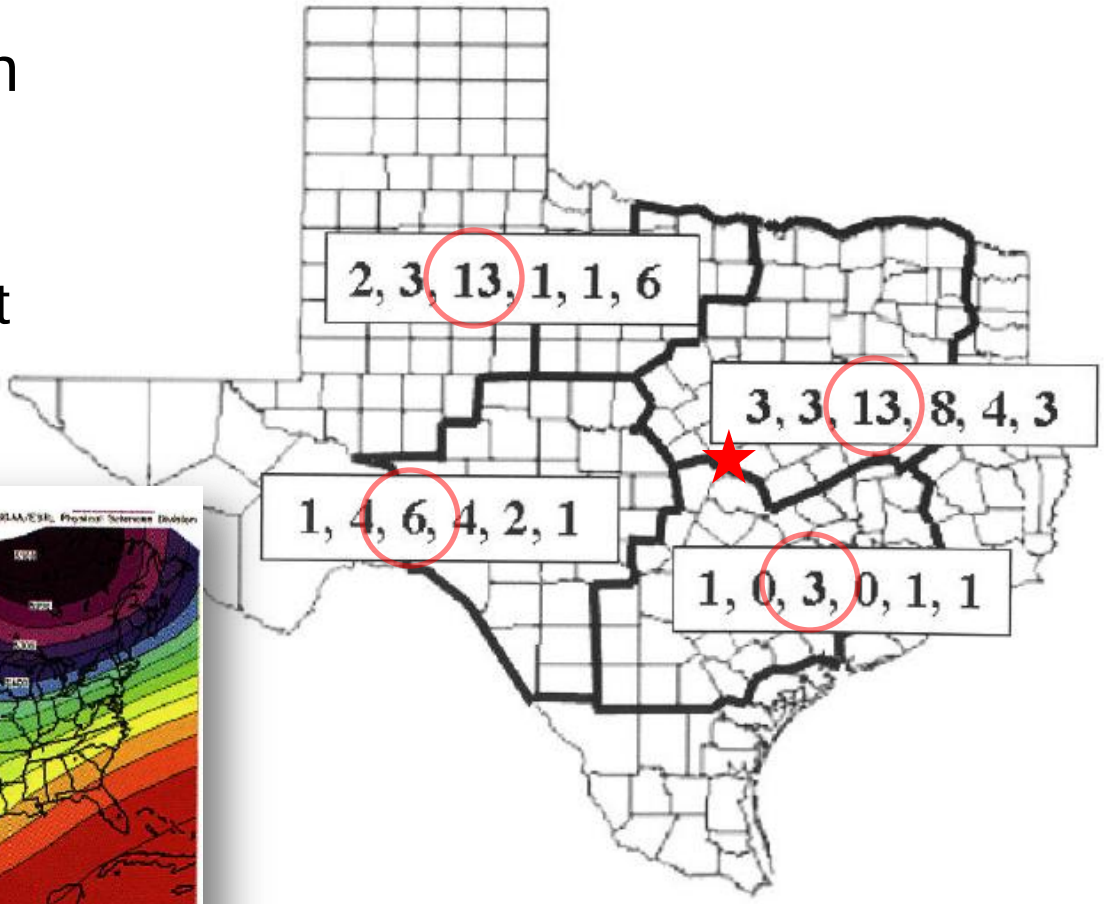
- If model forecasts climatologically unfavorable, forecasters will be able to key in on what parameter(s) must change in model forecasts or observed data in order to make conditions more favorable
- **Remember**—This study only investigated occurrences of 4 inches or more of snowfall, events might of occurred that produced a lesser amount that can still be <u>operationally significant</u> for Fort Hood ground/aviation operations

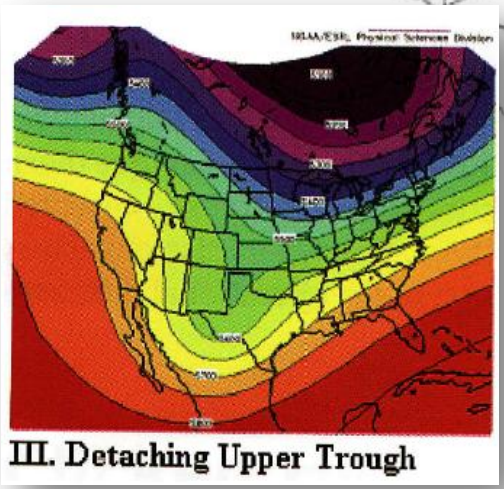


Is temperature or moisture profile more/less favorable?

Conclusions…

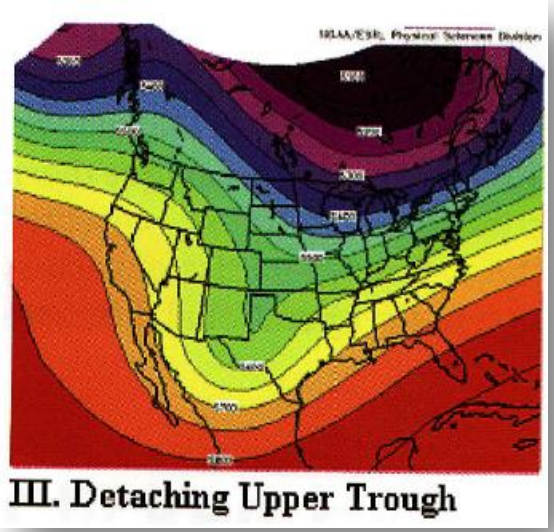
- Number of cases per synoptic type for each region
  - Detaching Upper Trough had greatest number of cases for all regions




III. Detaching Upper Trough

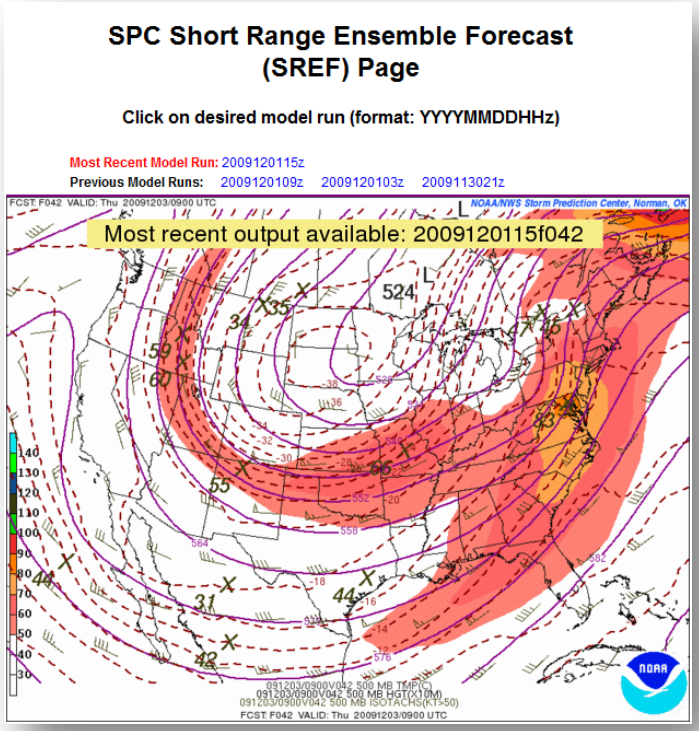
Summary
Detaching Upper Trough

- Normally occurred Dec, Jan, or Feb
- Second highest areal coverage
- Long narrow band from west to east where disturbance tracked across region
- Significant cold air aloft at 500-mb, but not at 700-mb
  - Suggests environment with relatively steep mid-level lapse rates and instability
  - Combined with moisture could create conditions favorable for intense precipitation


III. Detaching Upper Trough

Summary
Detaching Upper Trough

- Synoptic setup brings cold air south first; then allows large amounts of moisture to be drawn north from Gulf of Mexico in mid-levels; then lifted ahead of upper-level low
  - Exact location where significant snowfall will occur is very hard to forecast due to narrow west to east swath
  - Critically dependent on track of disturbance, so forecasters may obtain better forecast accuracy using **ensemble products**



Summary
Local Regimes

- The six synoptic types presented in this study can be matched or can be viewed as a variation of the local regimes listed in the Fort Hood FRN (26 OWS website)

Study Synoptic Type	**FRN Regime**
– Baja Closed Low	Southern Pacific Low
– New Mexico Low	Colorado Low
– Detaching Upper Trough	Colorado Low
– Pacific Coast Ridge	Texas Low
– Subtropical Split Flow	Southern Pacific Low
– North American Trough	Colorado Low


The End