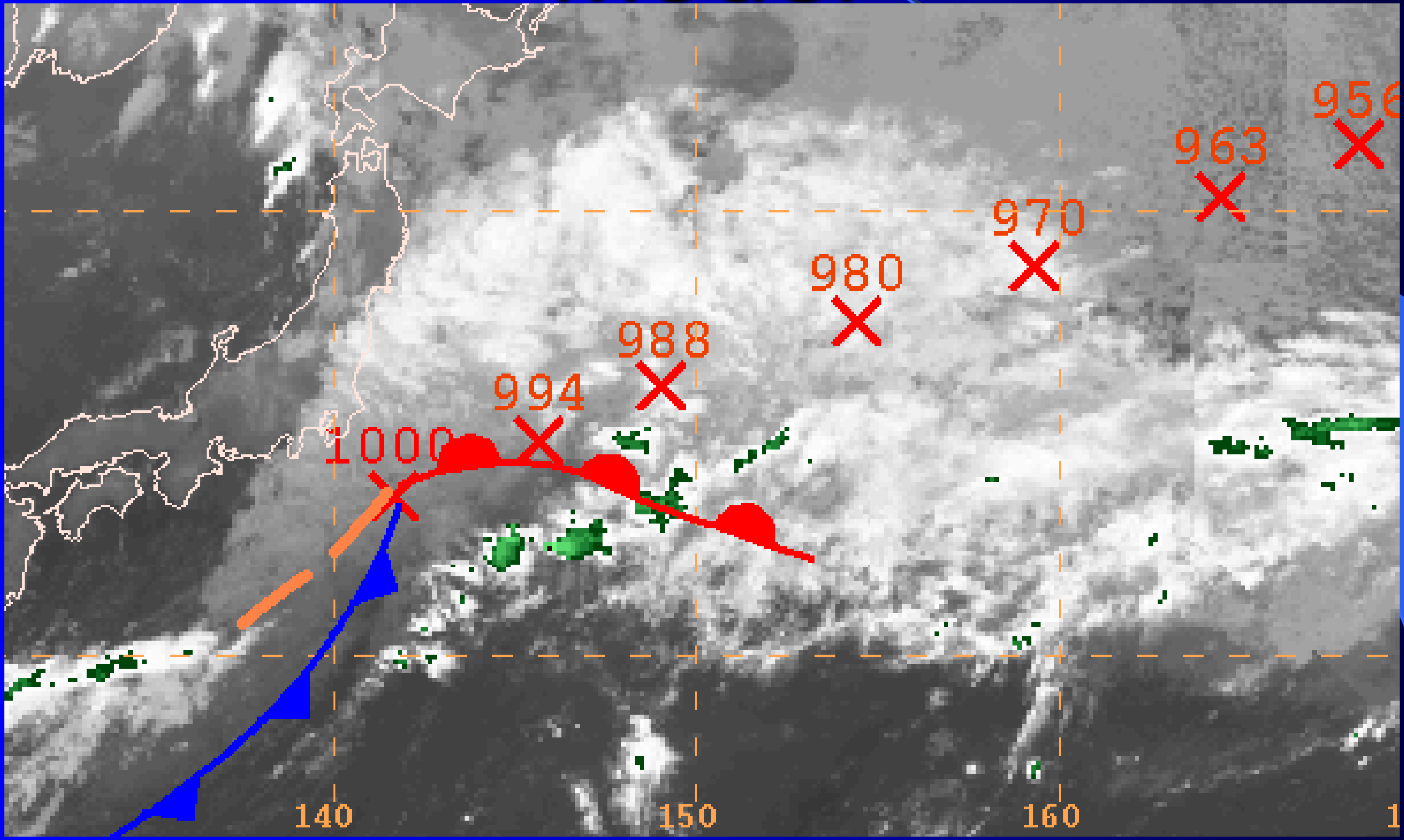
Shapiro Keyser Cyclone Model



Shapiro – Keyser Cyclone Model

Palmen Memorial Volume 1991
Ch. 10 – Fronts, Jet Streams and the Tropopause

What is a front?

According to the Glossary of Meteorology – The interface or transition zone between two air masses of different density is a front.

Key words…Zone – implies a three dimensional zone of large horizontal (density) temperature gradient

Density difference – Since temperature is the most important regulator of atmospheric density…a front, therefore, separates air masses of different temperature

A front is Characterized by: Temperature (density) gradient, a pressure trough, a change in wind direction

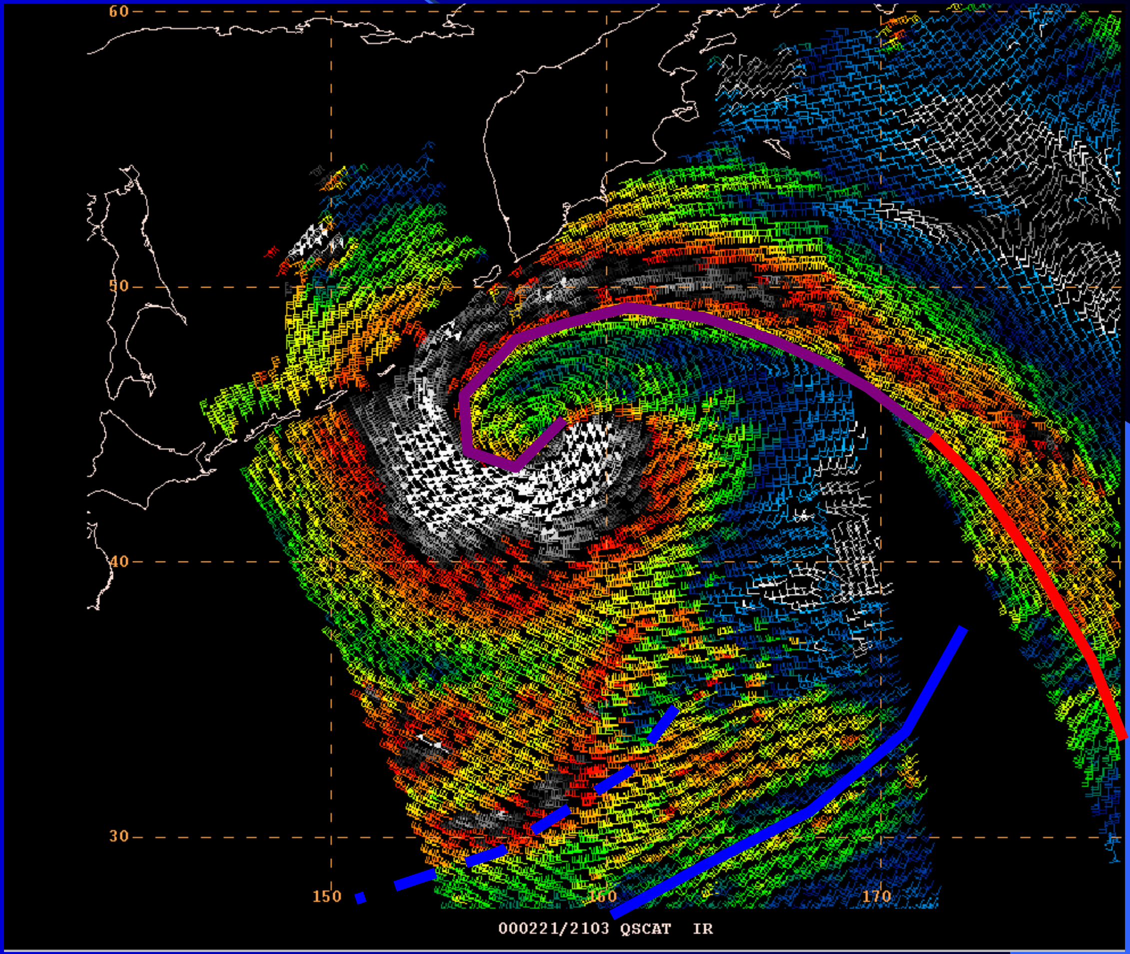
As practiced in operational meteorology, defining fronts has become subjective. I believe the definition as presented in the Glossary of Meteorology is adequate with clarification. The definition of ZONE helps bolster what I think should be the MPC working definition of a front….not necessarily the boundary between two air masses but a zone of large horizontal temperature gradient. This somewhat restricts the overuse of designating fronts…it also allows for breaking fronts.

Cyclone frontal structure – Why is it important?

The horizontal and vertical gradients of density (frontal structure) are directly related to the sea level pressure distribution, therefore the pressure gradient and more importantly the wind field. In short, the frontal structure and wind field of a cyclone are directly related.

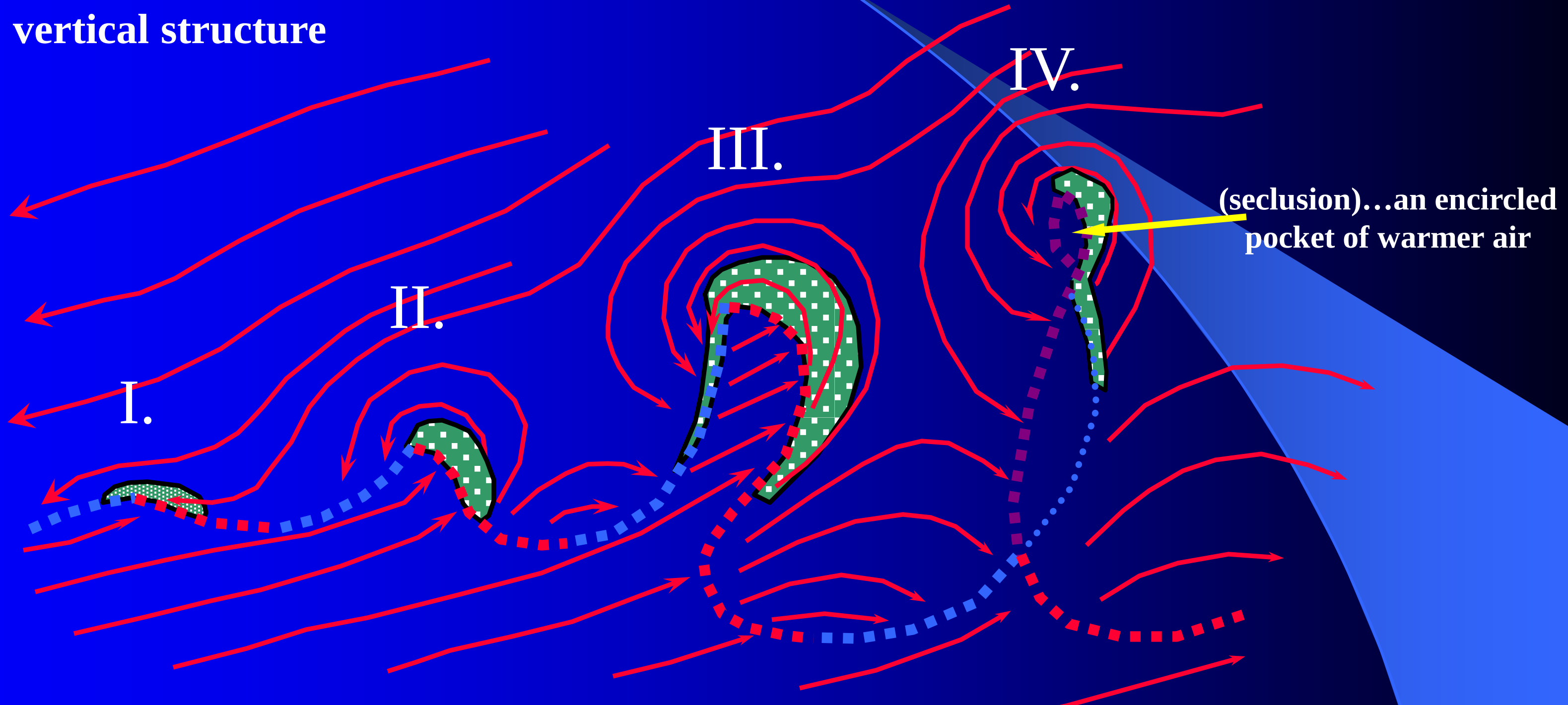
Can you pick out the fronts
In this QuikSCAT image?

Where is the cold front?



Norwegian Cyclone Model

- World War I era (limited surface observations)
- Eastern North Atlantic and Western European Cyclones
-Kite and meteograph obs, along with observing vertical wind shear (watching the clouds) to determine vertical structure

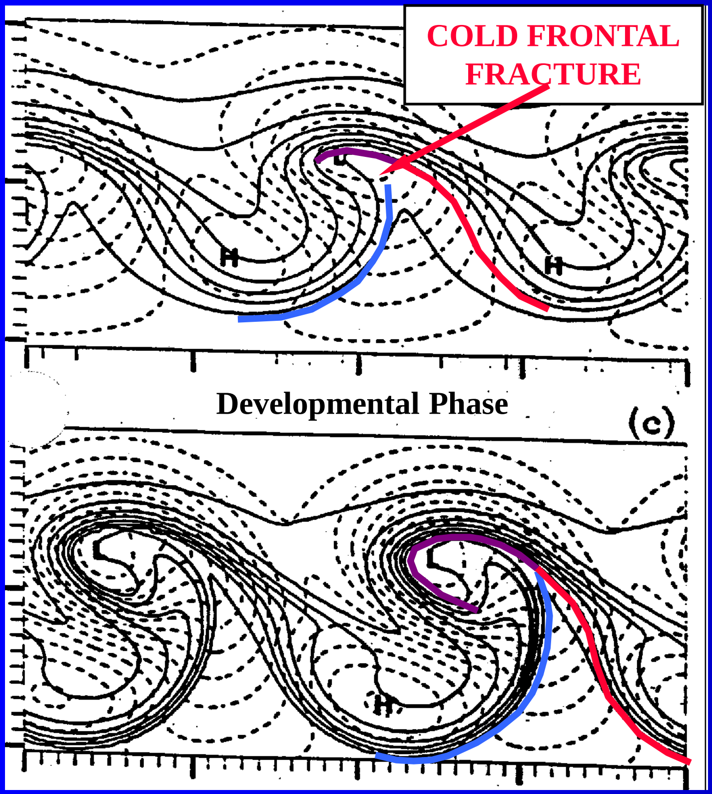


Evolution of cyclone from incipient phase (I.) to occlusion (IV.), Showing airflow, frontal structure, and precipitation.

(Bjerknes and Solberg 1922)

Numerical Simulations of cyclones from the 1980's

Computer model simulations of both idealized extratropical cyclones and actual explosive marine cyclones in the 1980's showed some characteristics different from the Norwegian model of the 1920's.



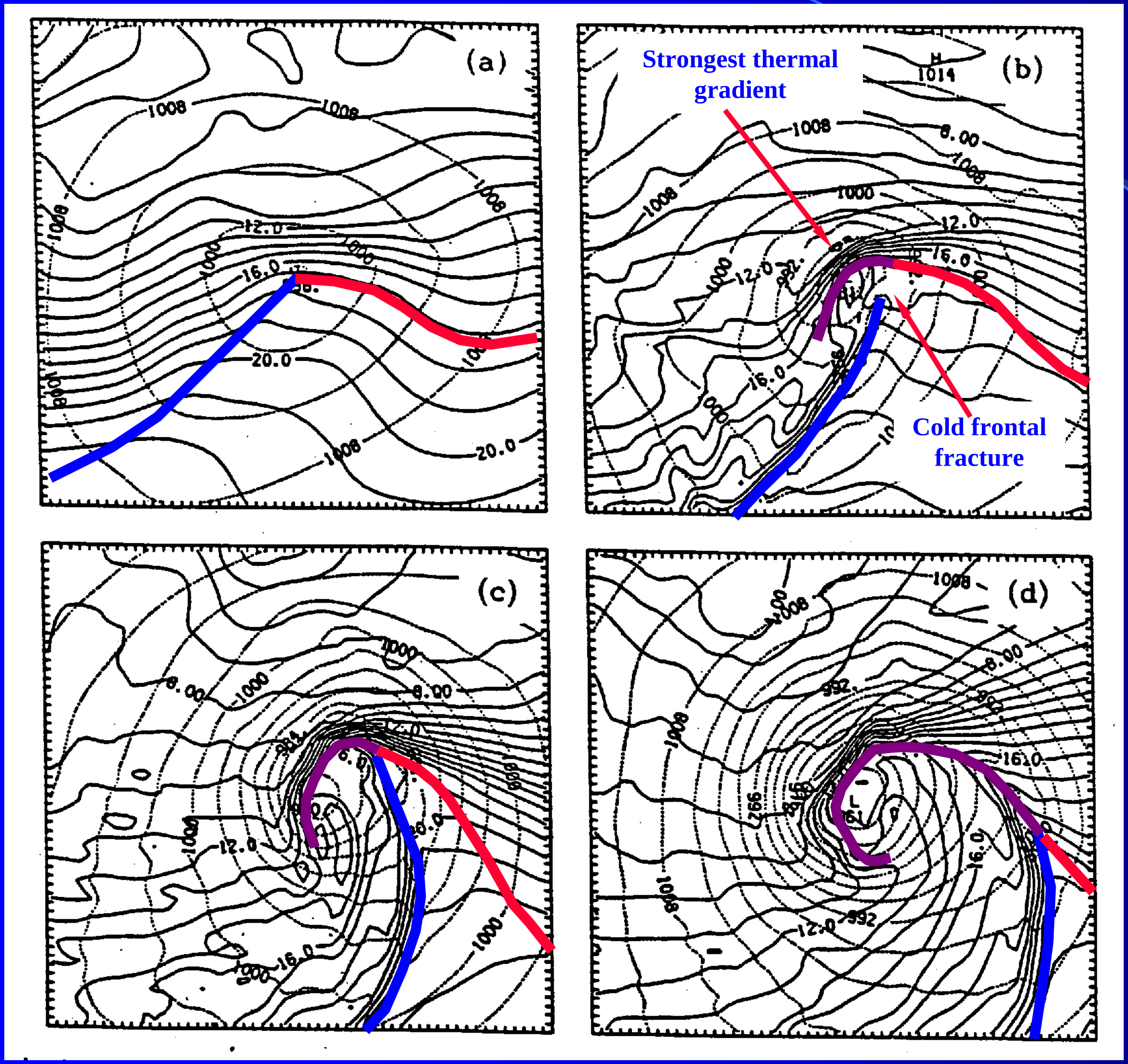
Idealized cyclone

In the developmental phase the temperature gradient (solid lines) contracts and bridges across the cyclone center. In essence the "occluded front" is a westward extension of the warm front.

The cold frontal thermal gradient also has contracted from the incipient phase with the tightest thermal gradient well removed from the "triple" point. Isobars barely curve through the region south of the triple point also suggesting a weak density (temperature) gradient. Does the cold front really extend into the triple point? Following from the definition of the front one could argue that there indeed is not enough temp gradient to continue the cold front here and instead "FRACTURE" the front.

In the mature phase, the occlusion has encircled the cyclone center. Also, the temperature gradient associated with the cold front has tightened south of the triple point, there no longer is a fracture. Notice that the strongest temp gradient is immediately adjacent to the occluded front.

The QE2 Storm of 1978



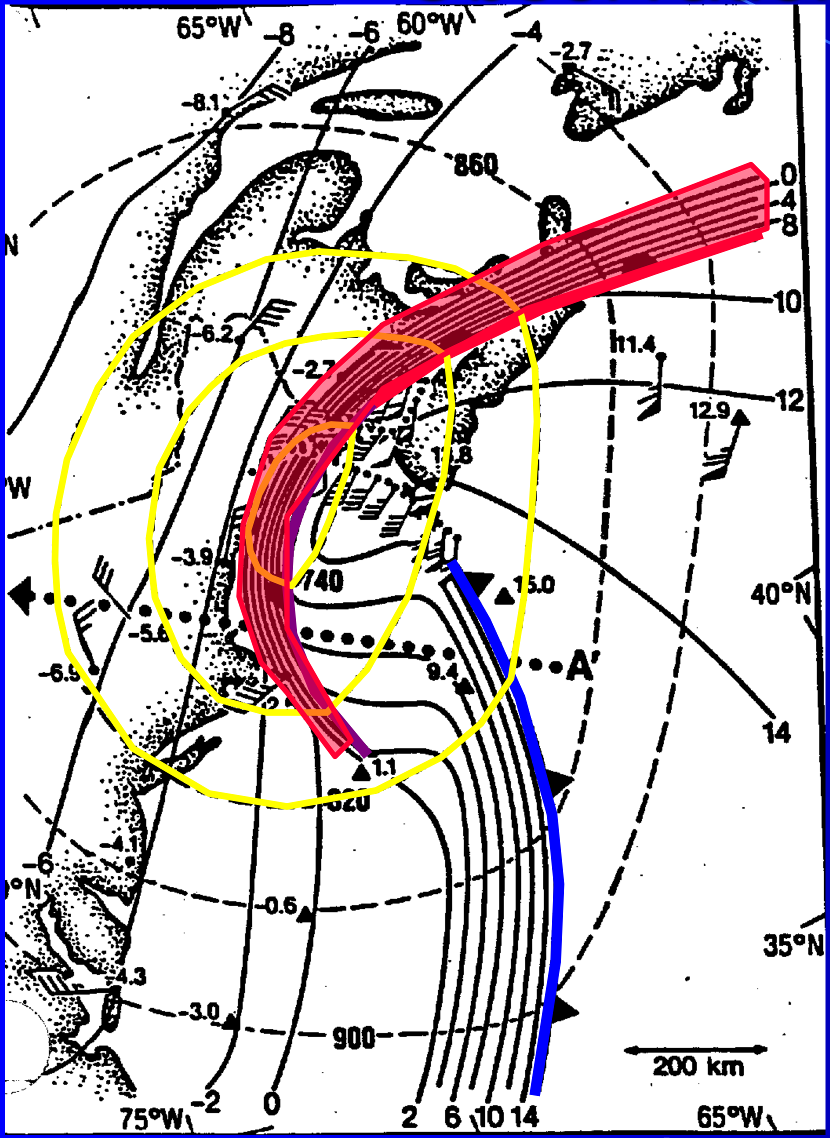
Similar to the idealized simulation on the last slide, the frontal evolution does not really look like the Norwegian model.

In (b), there is a weakness south of the triple point along the cold frontal thermal gradient…another fracture. Also, look where the strongest temp gradient is…with the occluded front.

In c, the thermal gradient with the occluded front has strengthened SSW of the center. The south portion of the front has begun to swing east. Also, the fractured cold front has filled in as the temp gradient has strengthened south of the triple point.

(d) The nearly mature cyclone, a warm pocket has developed over the center (seclusion) and the occluded front has continued to wrap eastward south of the center.

Observational Evidence



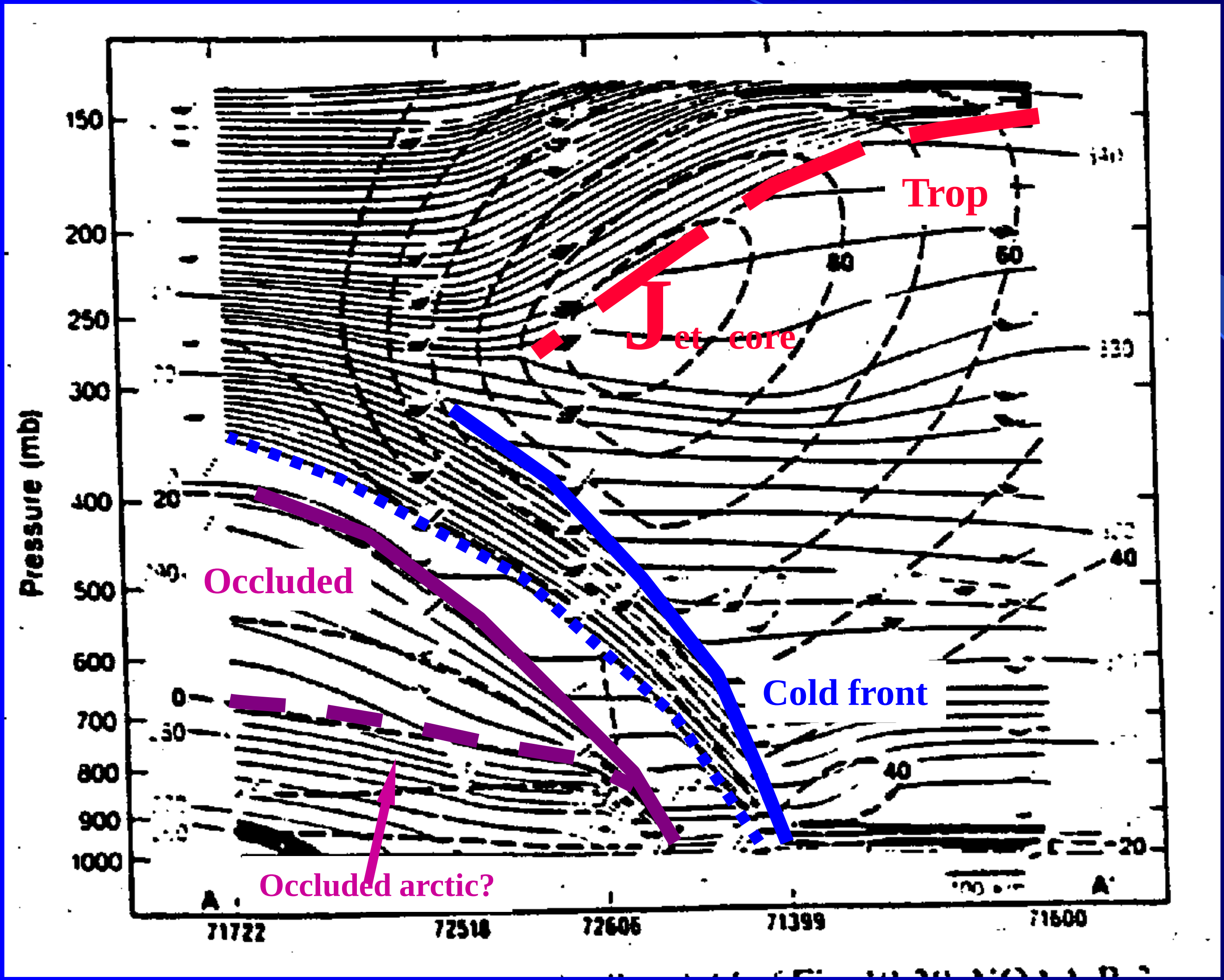
The 920 mb temp (solid lines) and geopotential height field for a January 1987 cyclone. (Hit return key) The continuous boundary from warm front to occluded front is quite evident with again the strongest thermal gradient in the entire storm system there. The cold front is indeed fractured with a gradual thermal gradient in this region.

Hit the return key to bring up a height contour in yellow. The first contour looks similar to what the surface isobars should look like. Notice that the maximum turning or change in direction occurs at the frontal boundaries.

Hit the return key again… The next height contour does not turn as sharply in the vicinity of the frontal fracture…since the contour is straight (just like an isobar) it suggests there is very little thermal contrast in this region SW of Cape Sable, Nova Scotia. Also, look at the turning of the height contour through the large temp contrast with both the warm front and the occluded front. Since the surface or low level pressure field is heavily weighted by the density of the air immediately above it…it makes sense that the isobars (or height contours) would curl or curve in areas of large temp gradients. **(NO TURNING OF ISOBARS – NO TEMP GRADIENT – NO FRONT)**

Hit the return key again. The last height contour illustrates the point I just made. Isobars (or height contours) turn in areas of large temperature contrast.

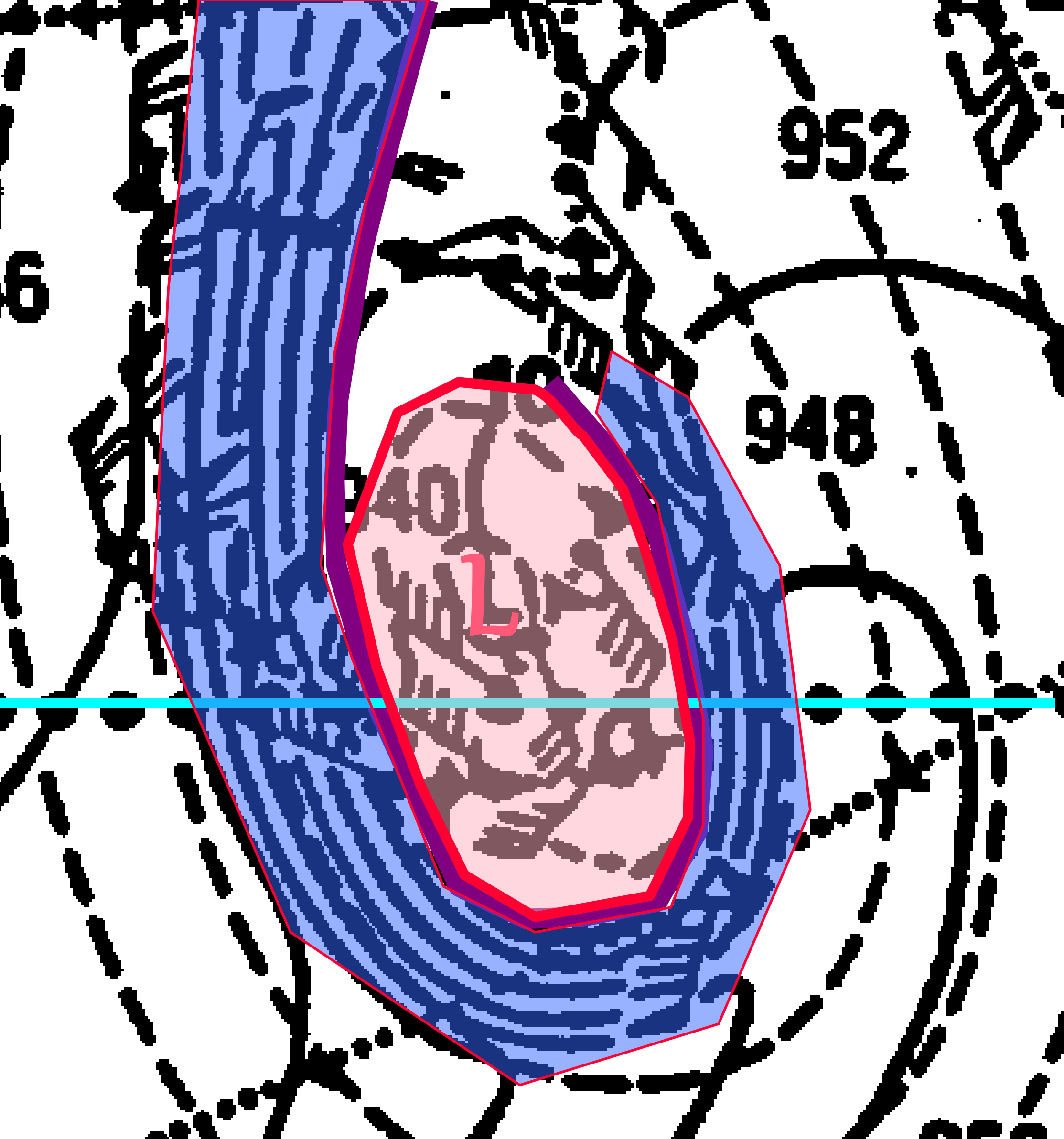
Potential Temperature cross-section through the occluded and cold fronts



This just shows you the vertical structure through the previous cyclone along the line A-A'.

Both the occluded and cold fronts look similar with the cold front not as shallow. The cold front is fairly sharp and a classic ana-type cold front

The occluded front seems to have a double structure with a shallow strong thermal gradient and deeper weaker gradient. It looks like a shallow arctic air mass has contributed to the occluded boundary.



The Seclusion

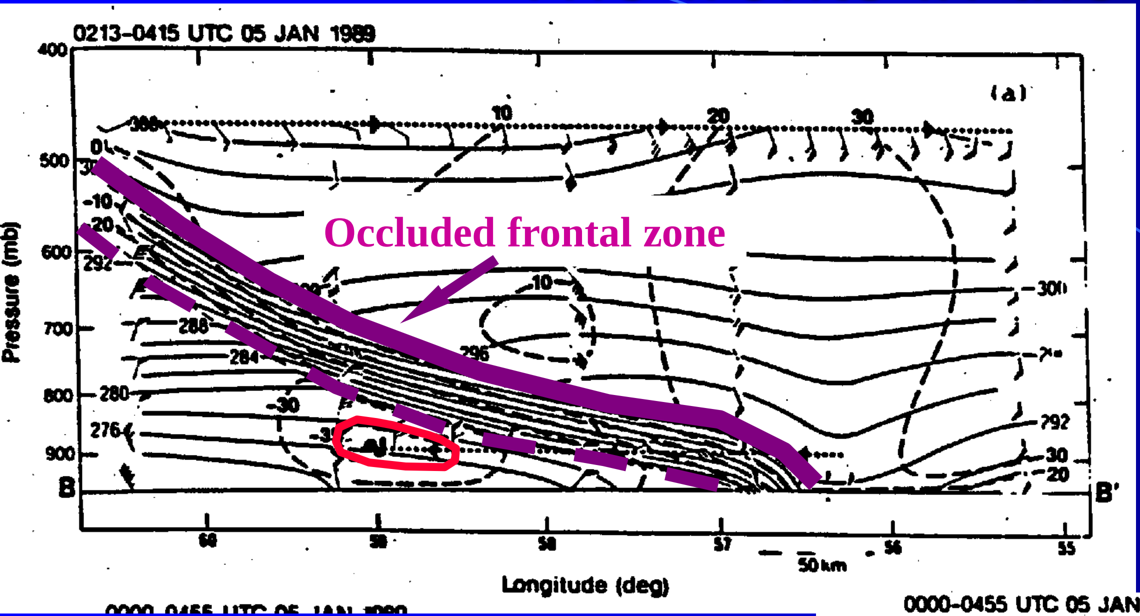
This horizontal analysis from aircraft and sonde data shows in detail the thermal structure (isotherms as solid lines) of a full blown **935 mb** **hurricane force** Storm!! Hit the return key 4 times.

The storm center is marked by an L. The purple line is the occluded front…nearly encircling the center. The shaded blue zone is the frontal zone. The shaded red area is the warm pocket of secluded warm air. The solid lines are isotherms with cold air outside the occlusion and a warm pocket over the low center.

At flight level SE of the center the occluded front separated 85 kt of wind (outside the occlusion) with 35 kt on the inside. The front is not only an extremely sharp thermal boundary but a very strong wind boundary.

Using IR satellite imagery you would place the occluded front on the very back edge of the low to mid cloud encircling the low center.

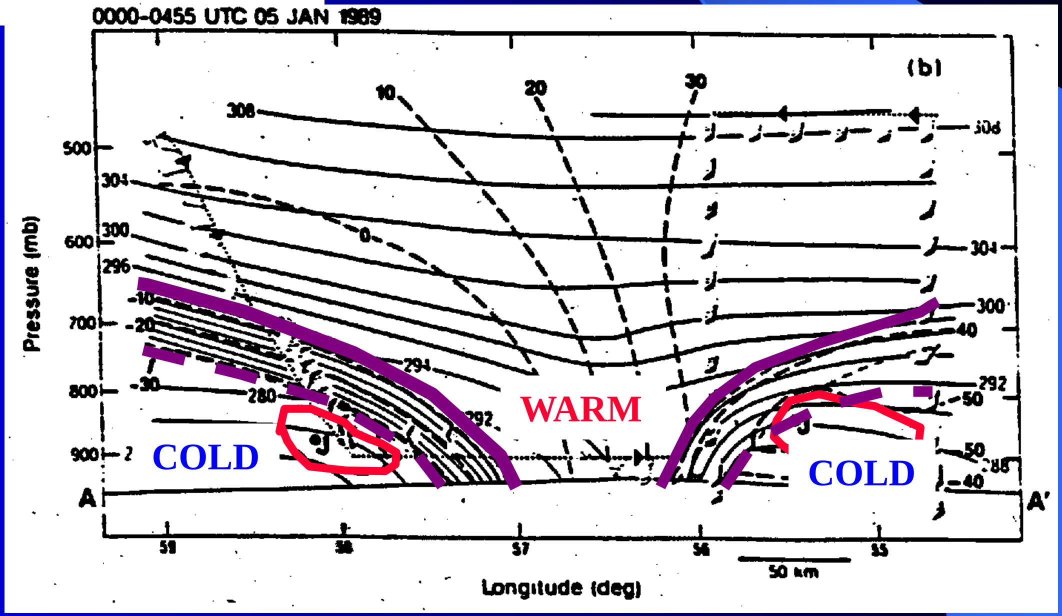
The fronts in the vertical



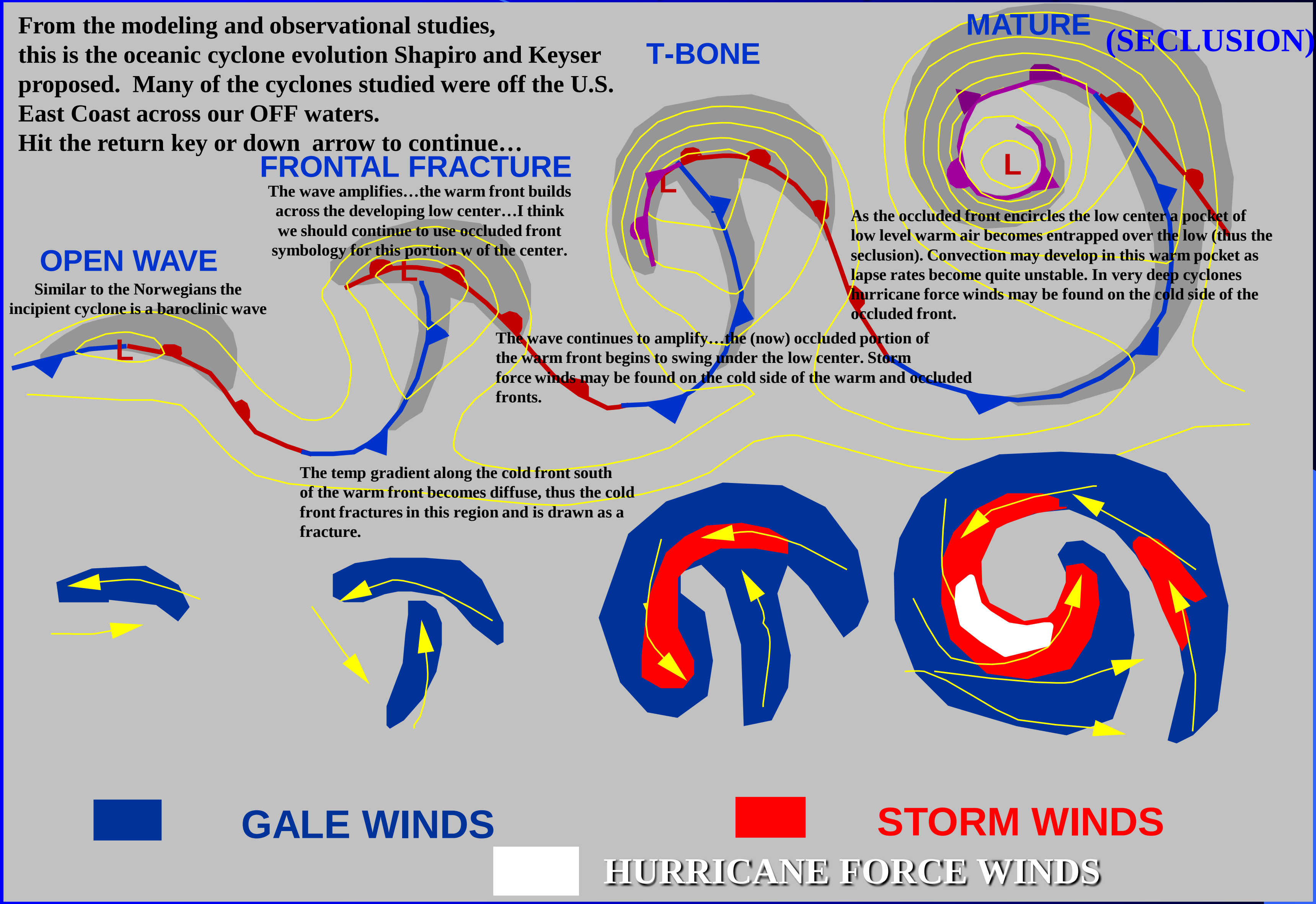
From the previous page…On the left is the potential temperature cross section of the occluded front N of the storm center. By its slope it looks just like a warm front…it should, it is the extension of the warm front. The red contour shows the location of a low level wind max in the cold air…notice it is removed from The immediate frontal boundary (solid purple line).

This cross section cuts right through both sides of the occluded front. The red contours are wind maxima… No surprise that they are removed from the immediate frontal boundary. Also notice that the "occluded" front has a steeper front here as opposed to the more warm frontal slope above.

The stronger front is to the W of the center…however the portion to the E is respectable. Over the low is a a relatively shallow warm core….the seclusion.



The evolution – Shapiro Keyser Cyclone



That's the Shapiro-Keyser Cyclone Model in a nutshell

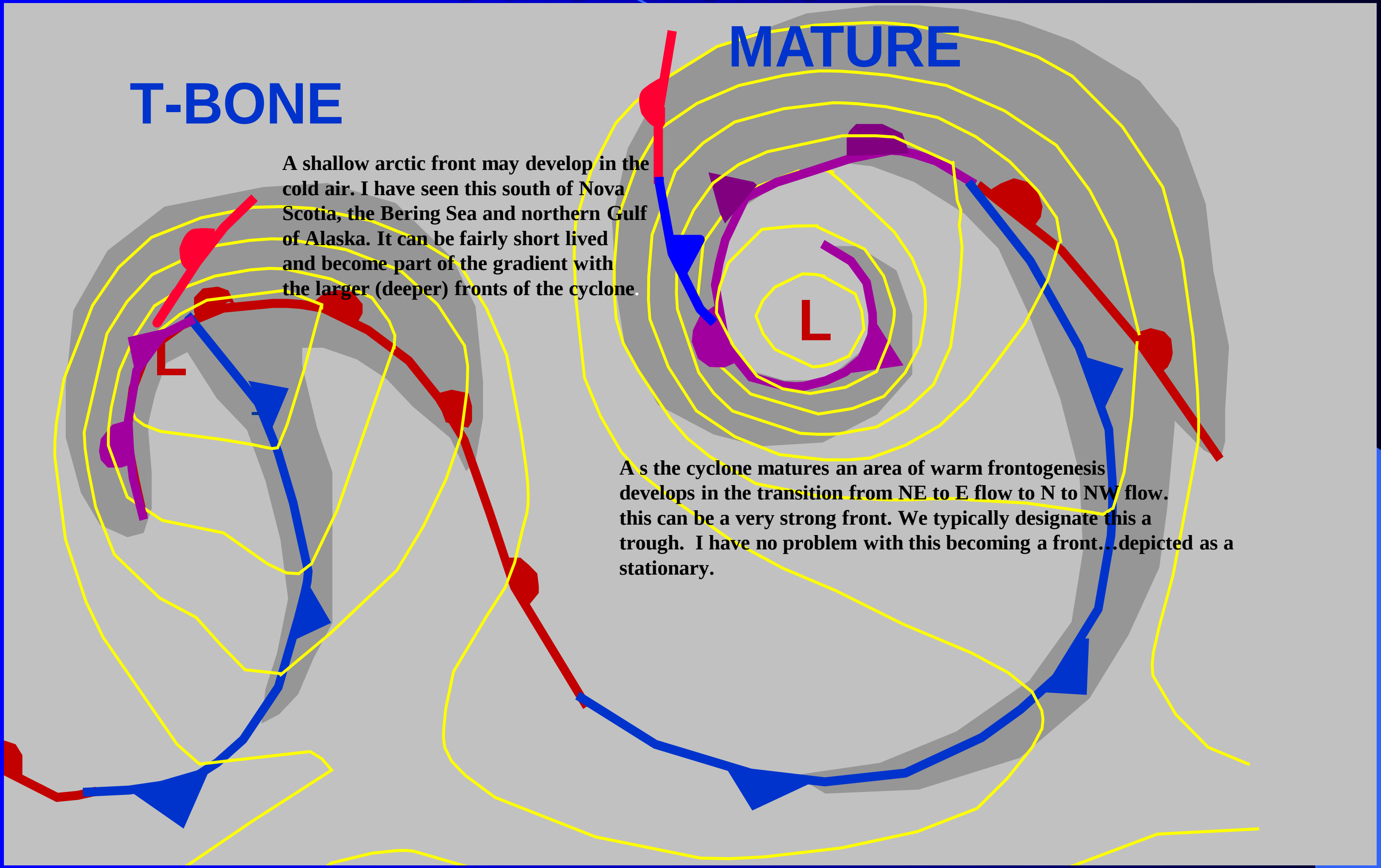
-The occluded front is an extension of the warm front (S-K refer to it as a bent back warm front…I do not think this terminology is appropriate and only leads to confusion. Thinking here is we continue to use the occluded front symbology.

-The occlusion process does not occur as the Norwegians describe. (Cold front catching up to a warm front). In my discussion with colleagues and professors, it appears that over the oceans only warm occlusions occur and that cold occlusions may not even exist.

-Is this the only evolution that takes place over the oceans…NO!!! And that is the subject for the next paper!

- Are these the only fronts in ocean cyclones…there is some debate on that. Here are some observations.

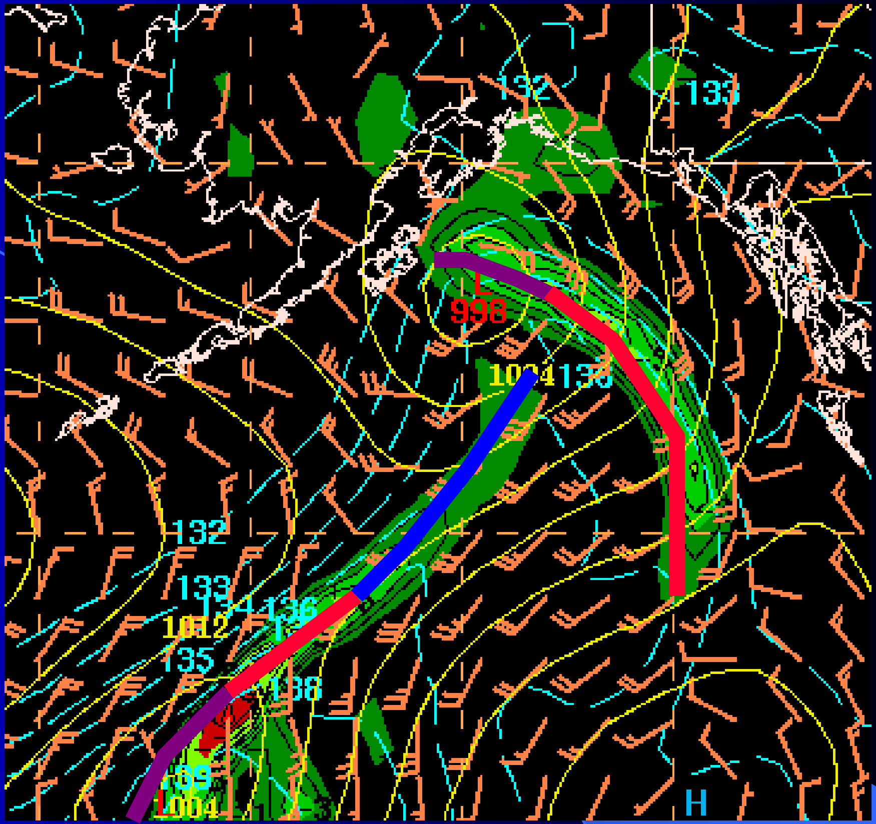
Other fronts



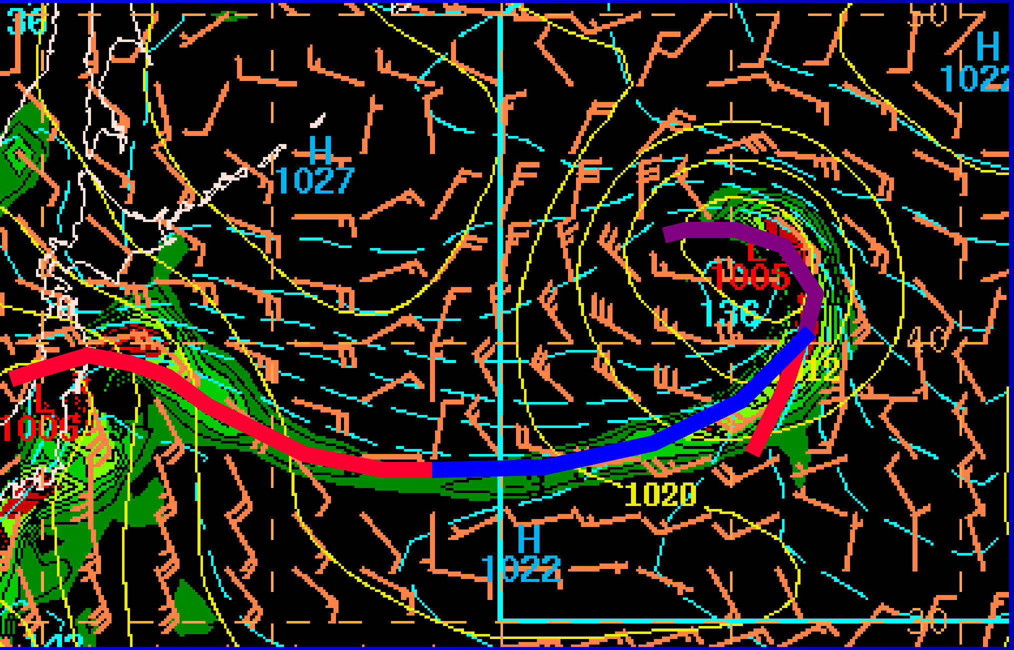
Tools we can use

Under avn / exp marine / MARINE FRONTS are the PBL moisture convergence and 1000-850 mb thickness. These are excellent tools to get an idea where the model thinks the fronts are. It also can give you some insight as to where to look for frontal features in the analysis precess.

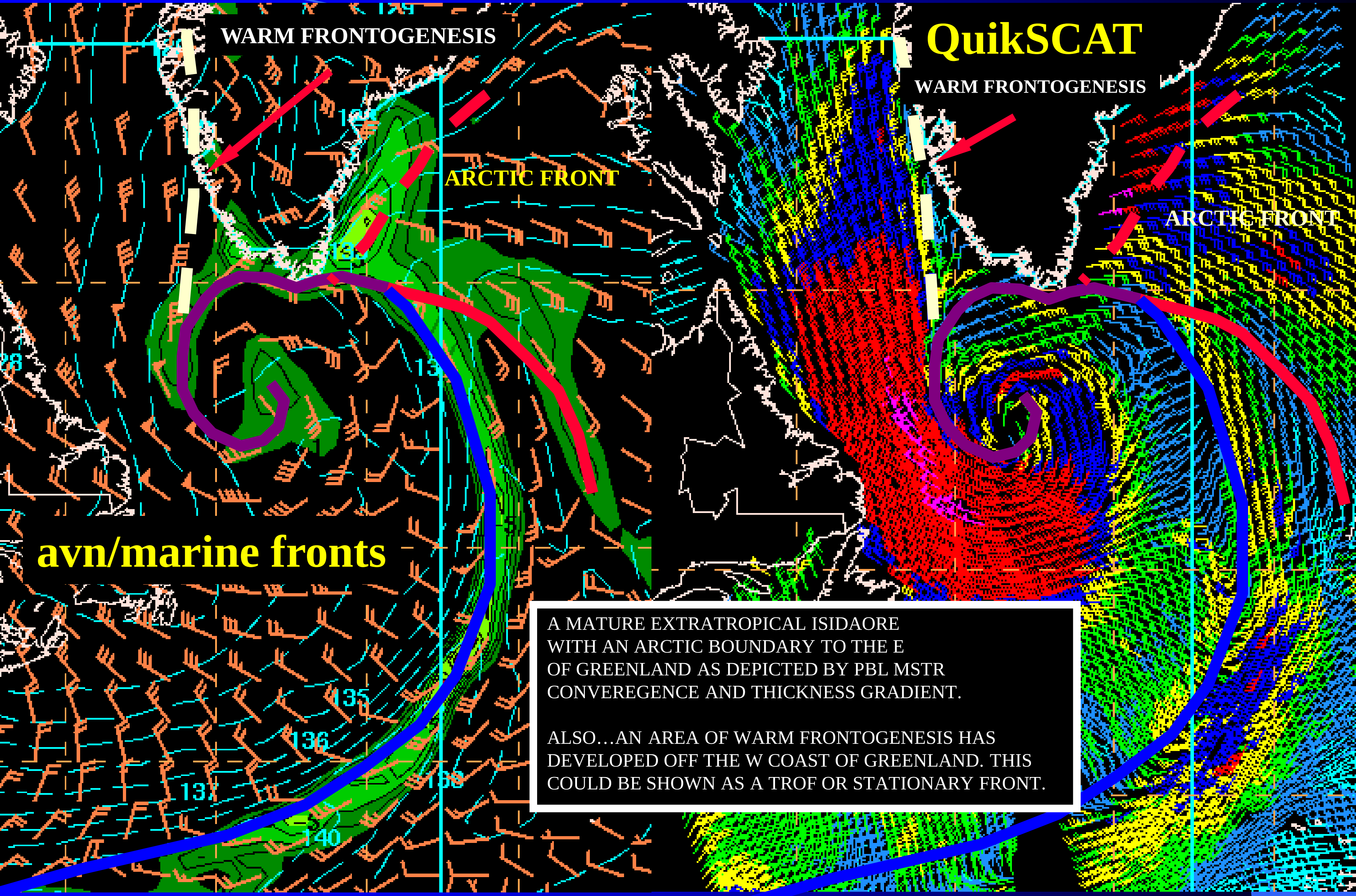
QuikSCAT is also useful for trying to determine where fronts may be.



Example 2. WPAC…Not much of a warm front with the lead system east of Japan. Occluded front is more of an extension of the cold front with at best a short stubby warm front. To the west is a strong warm frontal boundary.



Example 1. Gulf of Alaska…A possible frontal fracture of the cold front SW of the triple point. A weakness in moisture convergence and thickness gradient suggesting a fracture. Also, a strong T-bone structure with continuous warm frontal to occluded frontal boundary.


WARM FRONTOGENESIS
ARCTIC FRONT
avn/marine fronts
QuikSCAT
WARM FRONTOGENESIS
ARCTIC FRONT
A MATURE EXTRATROPICAL ISIDAORE
WITH AN ARCTIC BOUNDARY TO THE E
OF GREENLAND AS DEPICTED BY PBL MSTR
CONVEREGENCE AND THICKNESS GRADIENT.
ALSO…AN AREA OF WARM FRONTOGENESIS HAS
DEVELOPED OFF THE W COAST OF GREENLAND. THIS
COULD BE SHOWN AS A TROF OR STATIONARY FRONT.

The End

Why an emphasis on fronts…that's where the wind is!!

Next month…
When to Shapiro Keyser and when not to!!!