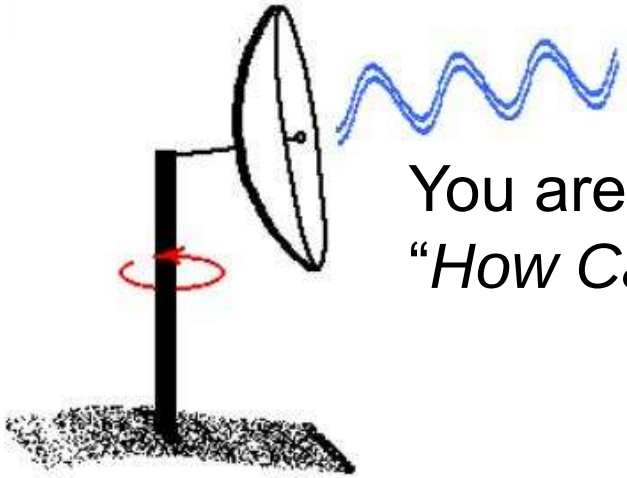

Doppler radar? God only knows what it means! We will all know after we take the MSC Radar Course though.


For God's sake, we had to wait 25 years for Doppler… I pray it won't be that long to get Dual Polarized!

Cold Fronts - Outline

- Cold Front Basics
- Conceptual Models
- Conventional Radar Signatures
- Doppler Signatures
- Conveyor Belt Conceptual Model (CBCM)
- Summary



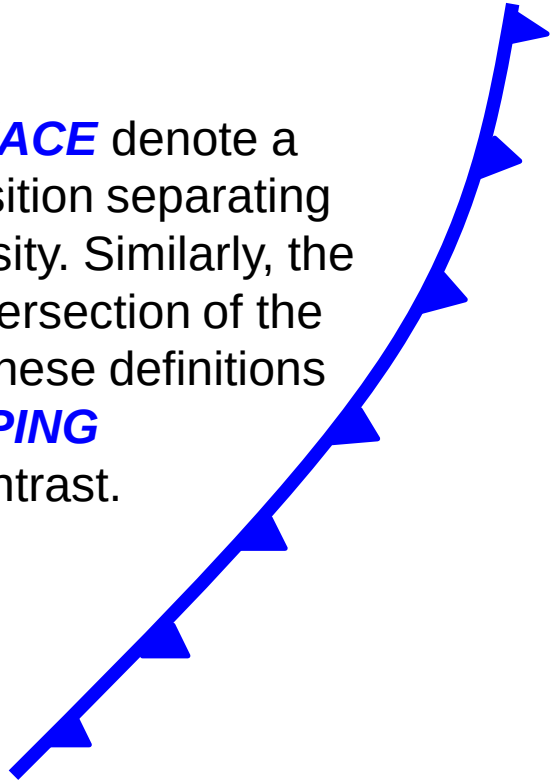
You are wondering…

"*How Can I phil an hour with radar cold fronts?*"

The Classic Cold Front

S. Petterssen's 1956 text: *Weather Analysis and Forecasting, Vol. 1, Motion and Motion Systems*, pp. 189

...let the term ***FRONTAL SURFACE*** denote a sloping surface or zone of transition separating two air masses of different density. Similarly, the term ***FRONT*** will denote the intersection of the frontal surface with a chart. In these definitions the emphasis is upon the ***SLOPING*** arrangement of a ***DENSITY*** contrast.

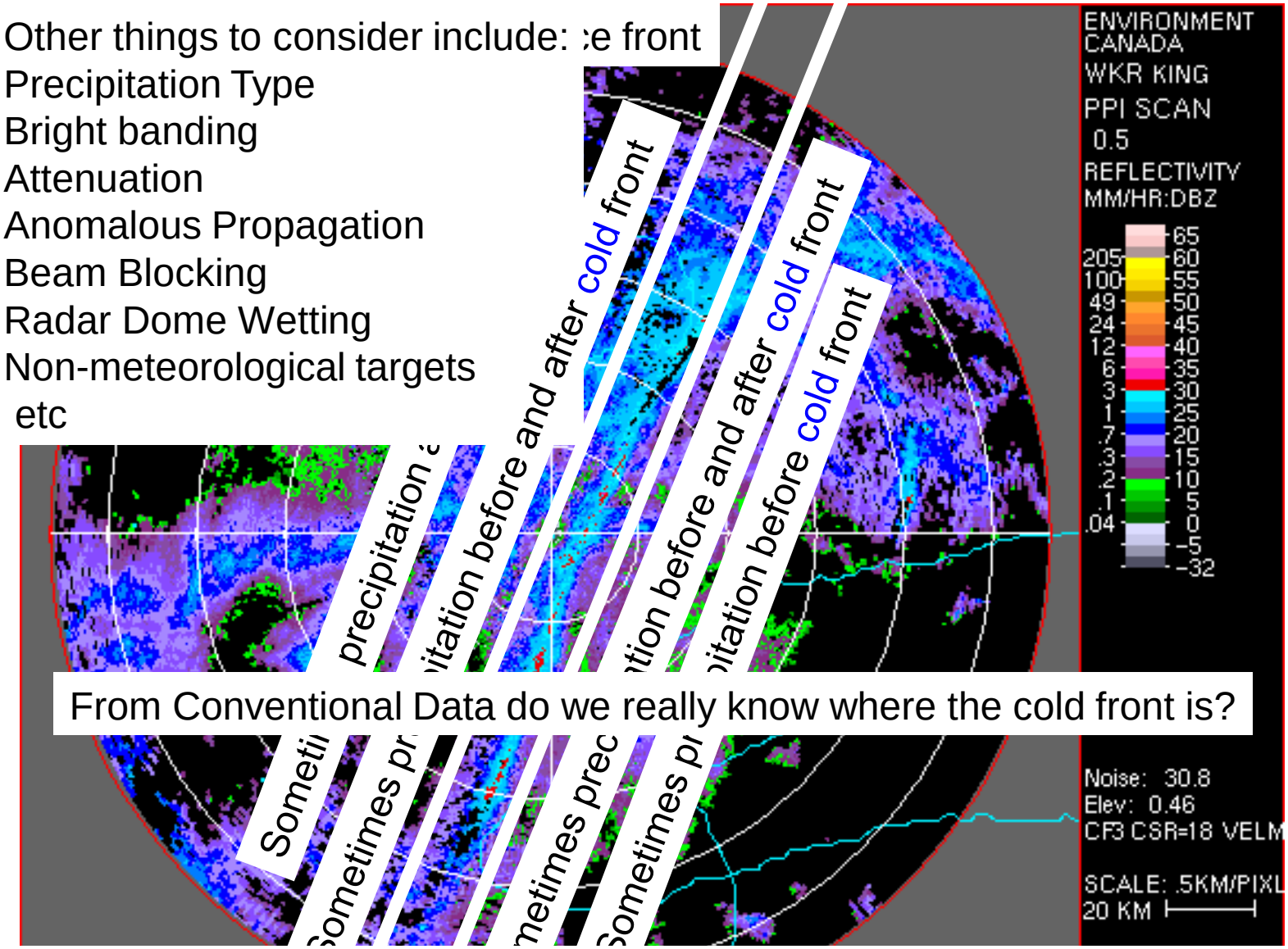


The ***mixing zone*** is behind the surface ***front*** and under the ***frontal surface***

The Classic Cold Front – Conventional Radar

Typic Other things to consider include: e front
- Precipitation Type
- Bright banding
- Attenuation
- Anomalous Propagation
- Beam Blocking
- Radar Dome Wetting
- Non-meteorological targets

etc

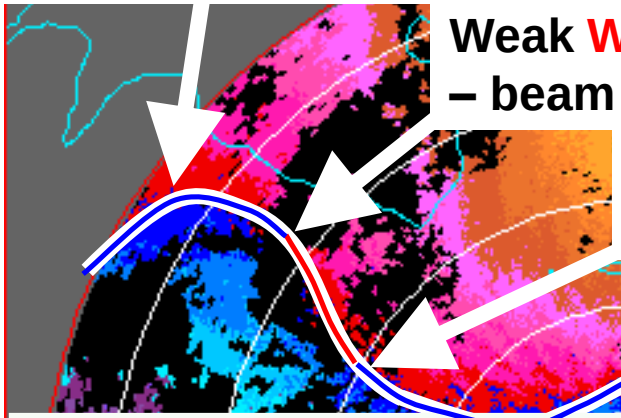


Take Home Message (THM):

Conventional radar for precipitation distribution, character, phase & more

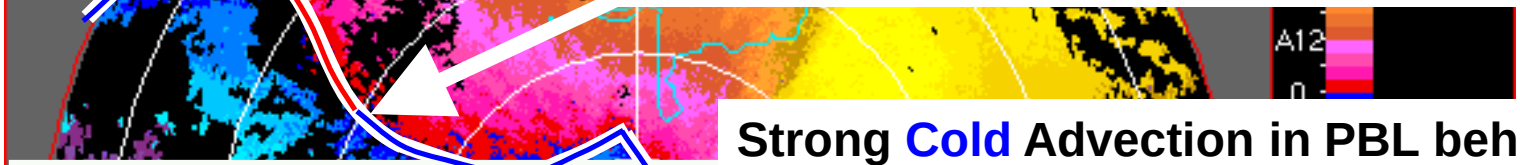
The Classic Cold Front – Doppler Radar

Strong Cold Advection
– beam above ANA front

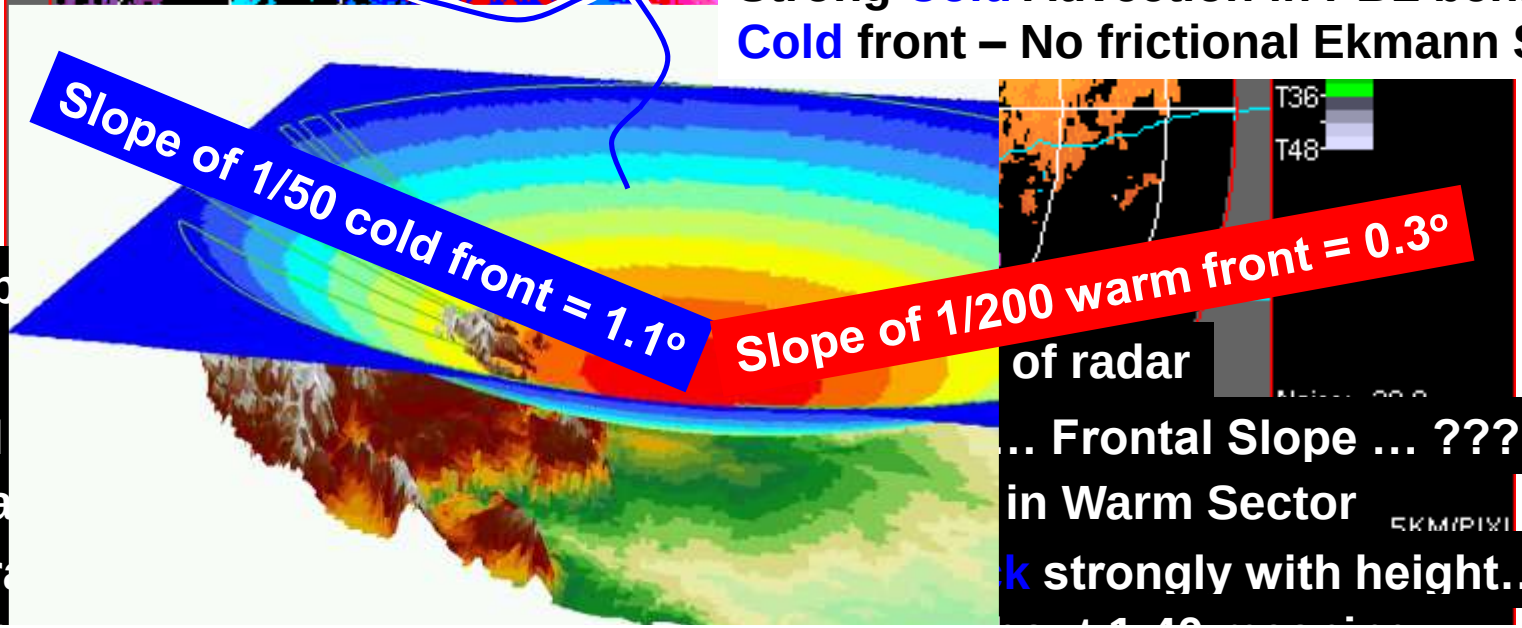


Weak Warm Advection
– beam in mixing zone or above frontal surface to here

Strong Cold Advection
– beam likely under frontal surface to here



Strong Cold Advection in PBL behind
Cold front – No frictional Ekmann Spiral



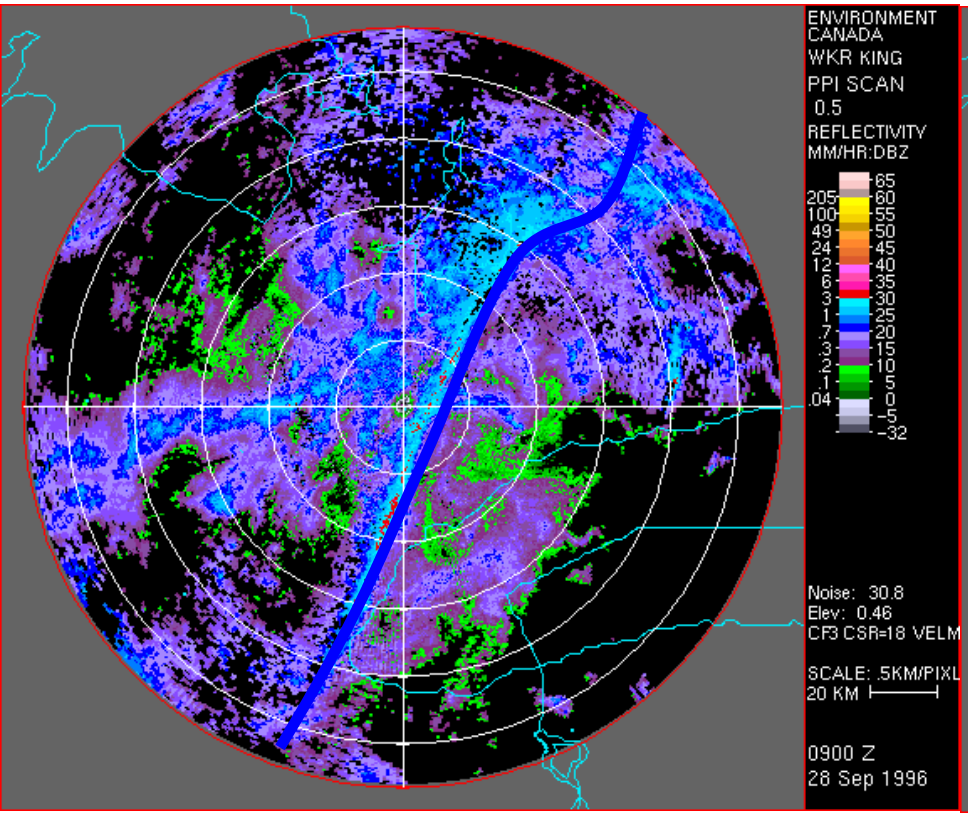
Winds b
Vertical
Vertical
SE of ra
NW of r

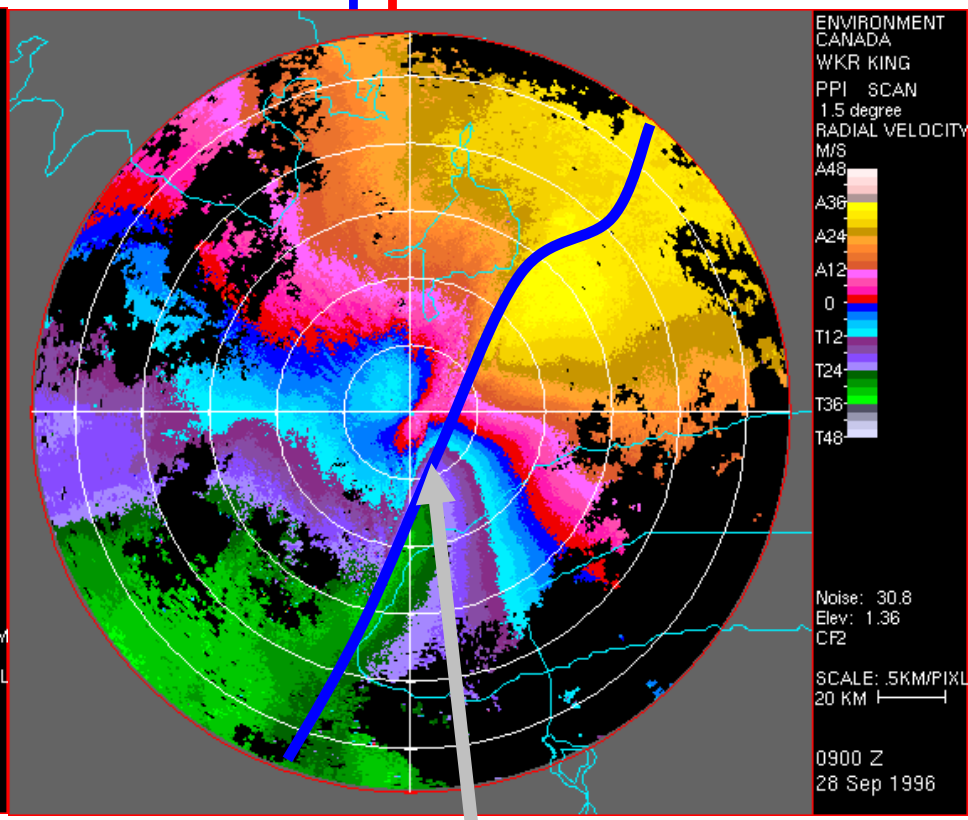
of radar
… Frontal Slope … ???????
in Warm Sector
k strongly with height…

Take Home Message (THM): Doppler radar for winds, VWS, front location, slope, advections, stability… do you know where your beam is ?.. complicated

The Classic Cold Front

Conventional and Doppler Radar





Surface front ahead of elevated front

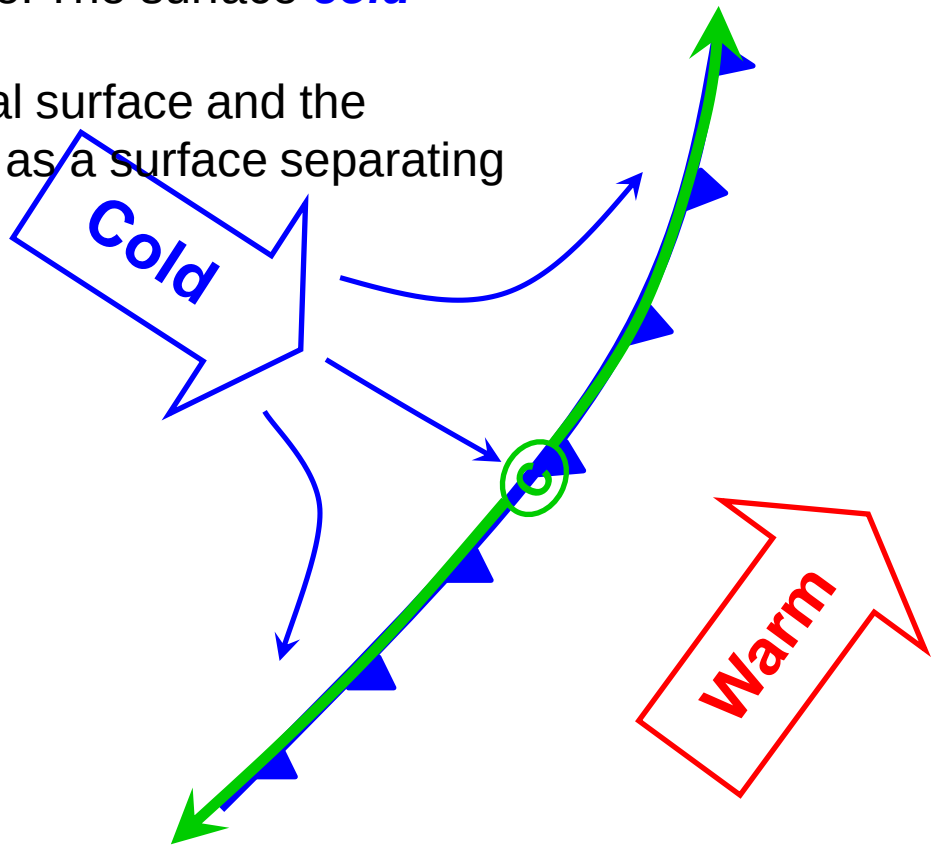
They are very different …

They both have valuable information…

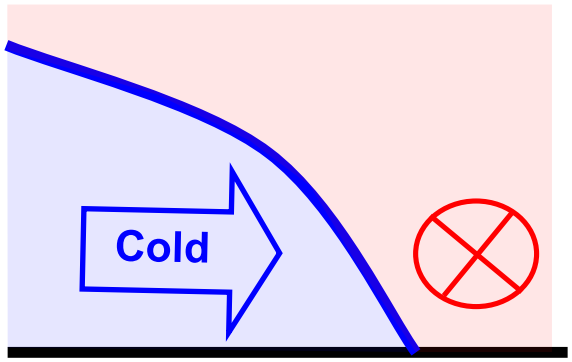
Take Home Message (THM):
Conventional and Doppler radar allow analysis and diagnosis of real WX

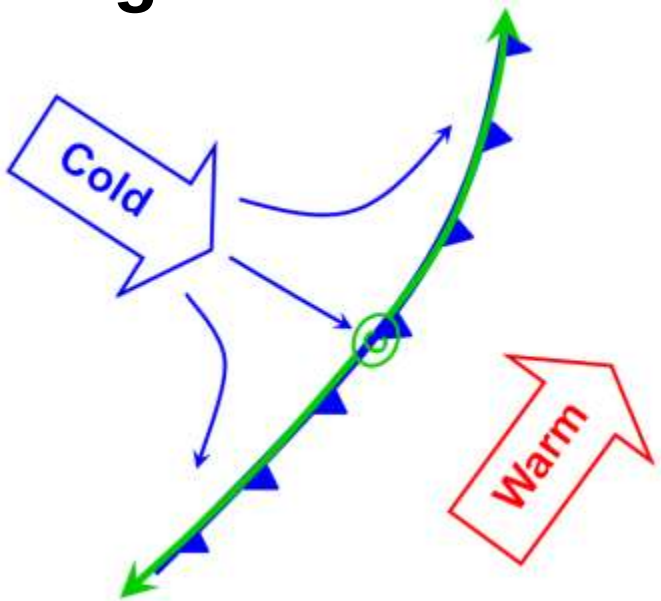
The Classic Cold Front

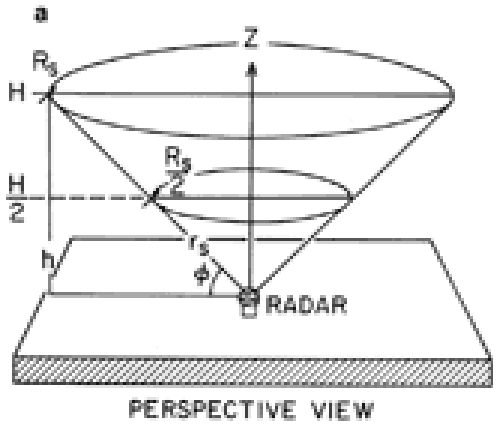
Circulation and deformation occur at every level in the atmosphere. The surface ***cold*** front is ***JUST One***.
Think of the cold frontal surface and the deformation zone/skin as a surface separating air masses.

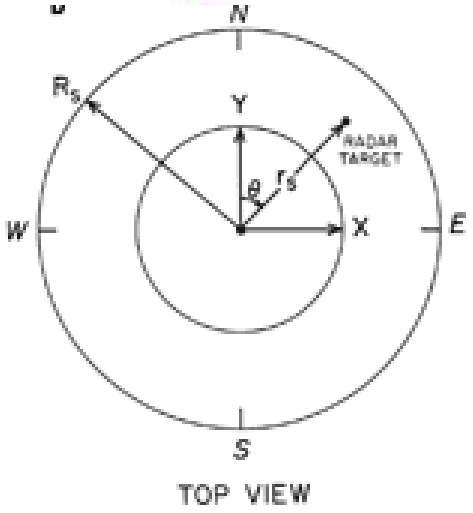


Radar Viewing









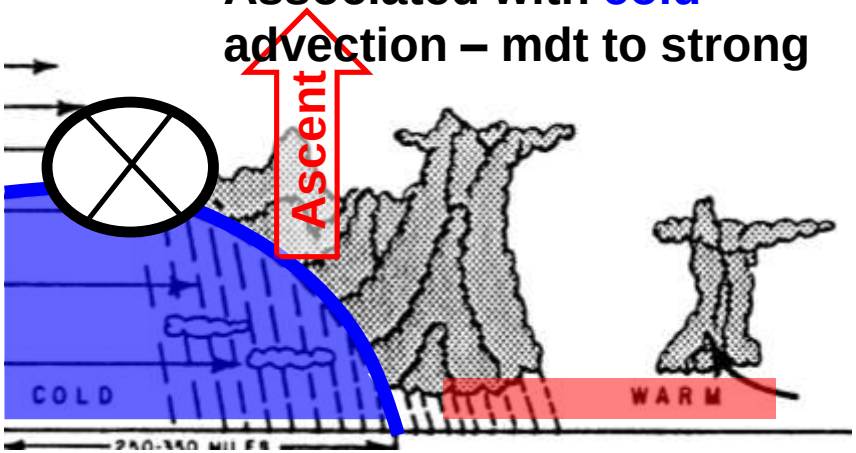
Radar Interpretation of the Cold Frontal Discontinuity is Complex 3D of Radar Measurement *and* 3D of the Cold Frontal Surface

Anabatic and Katabatic Cold Fronts

Green for "GO"

Frontogenesis *Ana* Active

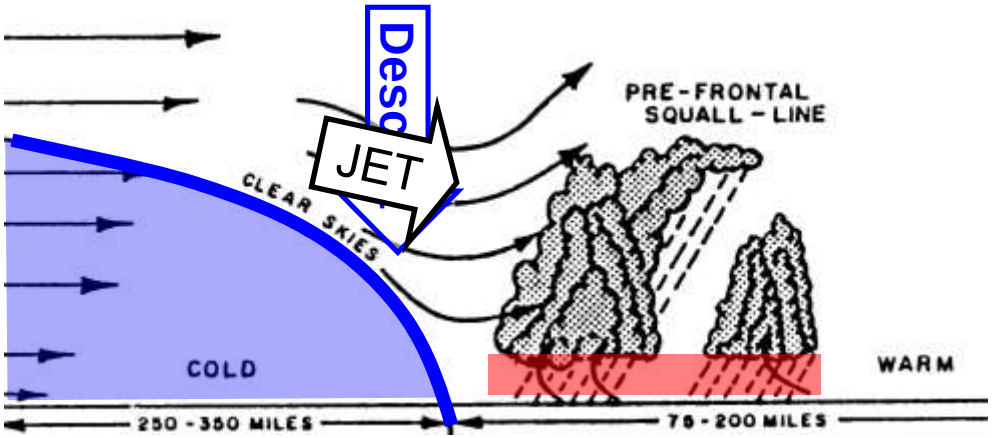
- Jet axis & dry intrusion parallel the frontal cloud band to form a sharp rear cloud edge
- Zero vorticity line parallels/near sharp back cloud edge
- Clouds and precipitation:
  - along and behind the cold front
  - Associated with cold advection – mdt to strong



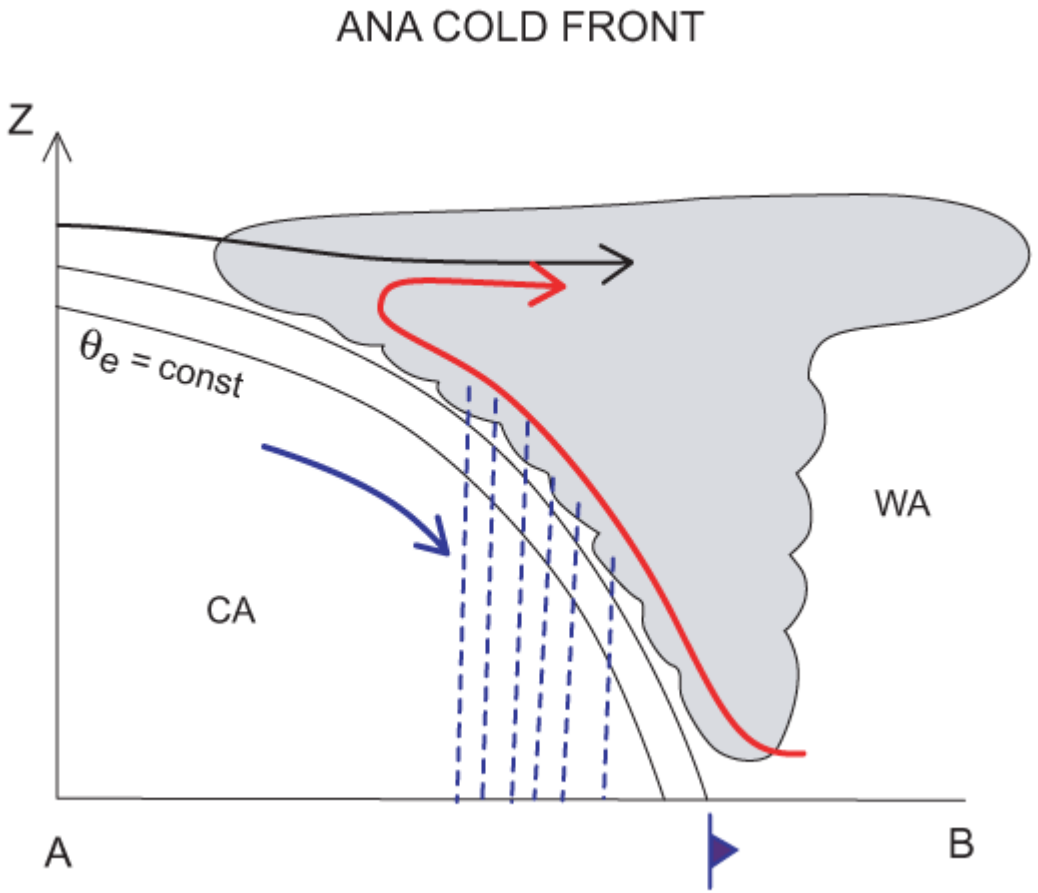
Red for "Stop"

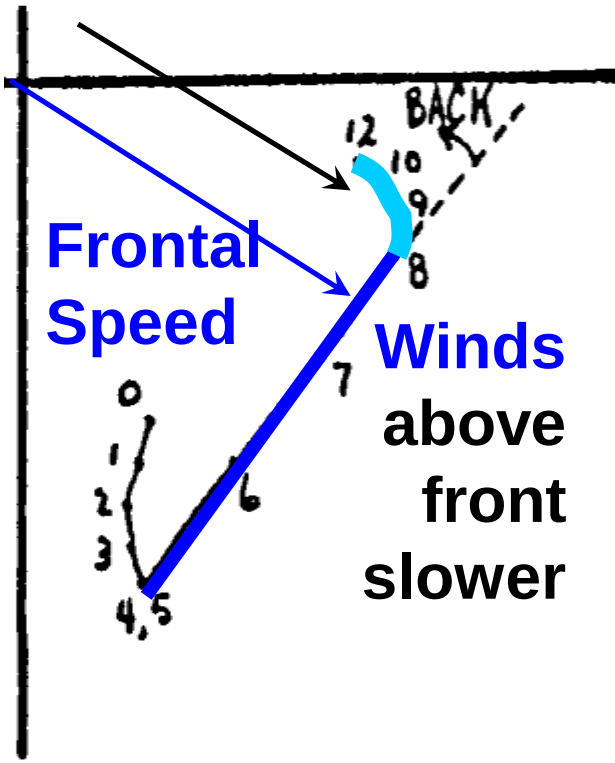
Frontolysis *Kata* Knot active

- Jet axis crosses frontal cloud band
- Zero vorticity line crosses front - higher cloud poleward & lower clouds equatorward
- Clouds and precipitation:
  - ahead of cold front
  - Associated with warm advection – or weakening cold advection



Active or Anabatic Cold front

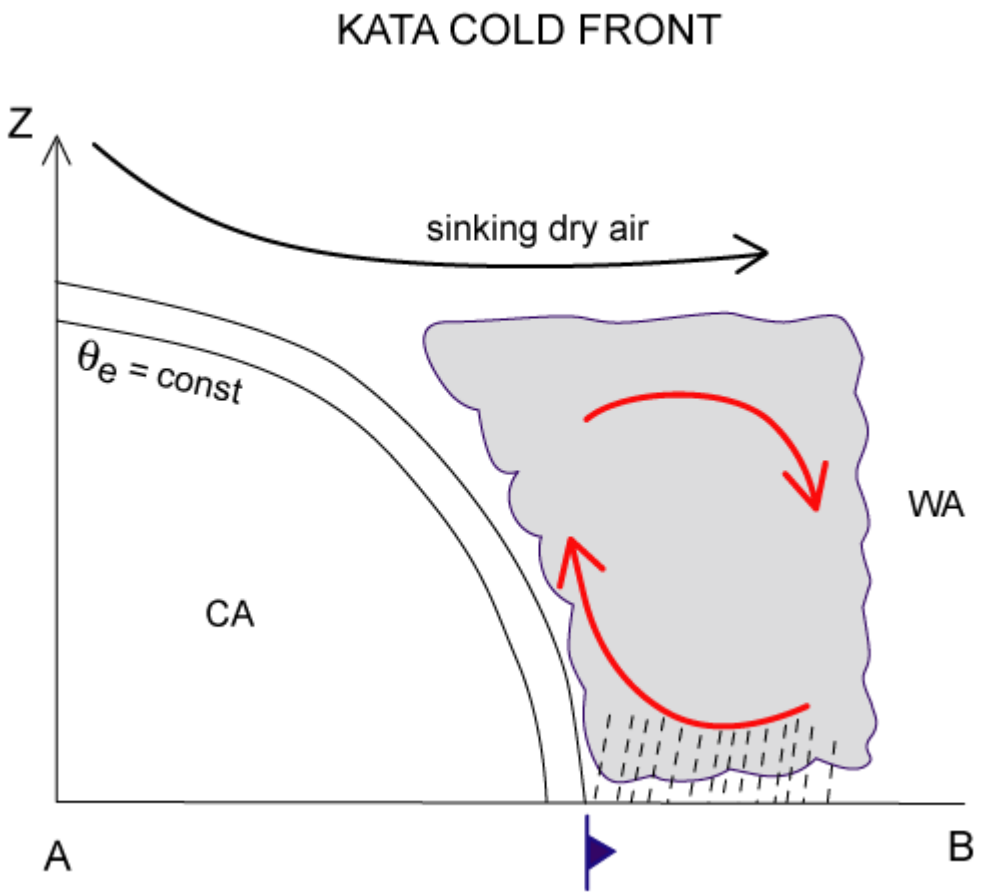


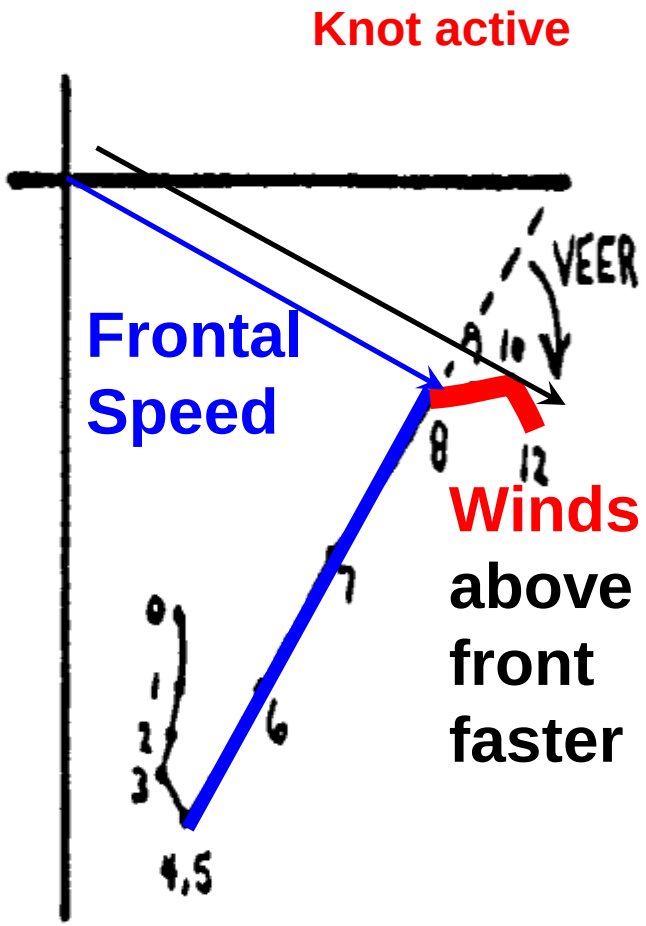


Winds *back* with height above the cold front to the left of the COL

Backing winds mean ***unstable*** - ***Active*** Green for ***"Go"***

Inactive or Katabatic Cold Front





Winds *veer* with height above the cold front to the right of the COL

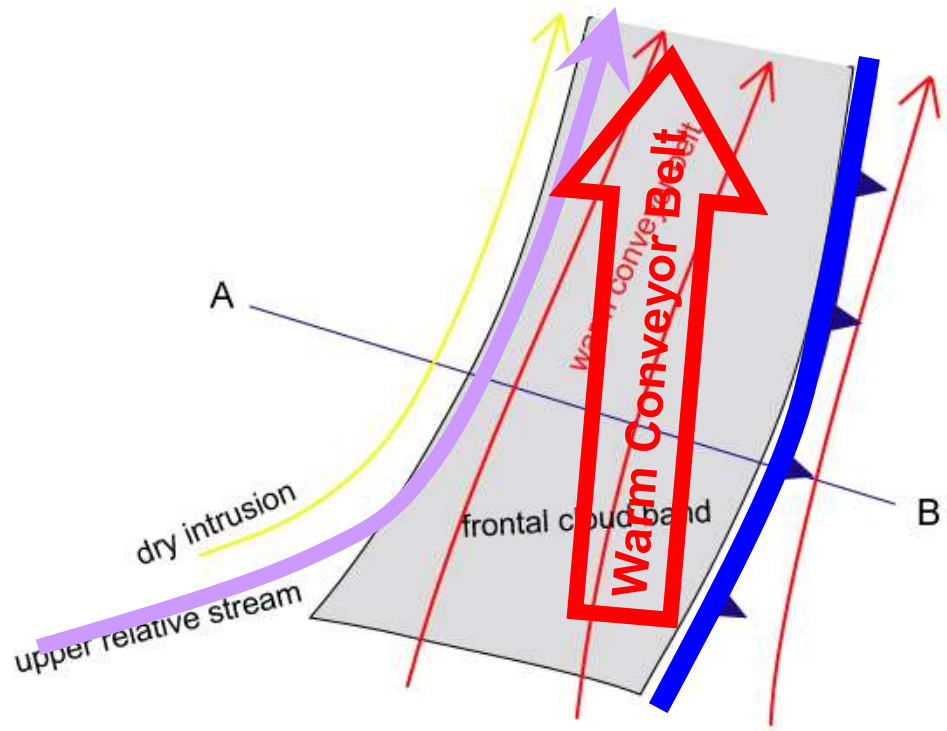
Veering winds mean ***stable*** - ***Knot active*** Red for ***"Stop"***

Anabatic and Katabatic Cold Fronts

Active

WX After

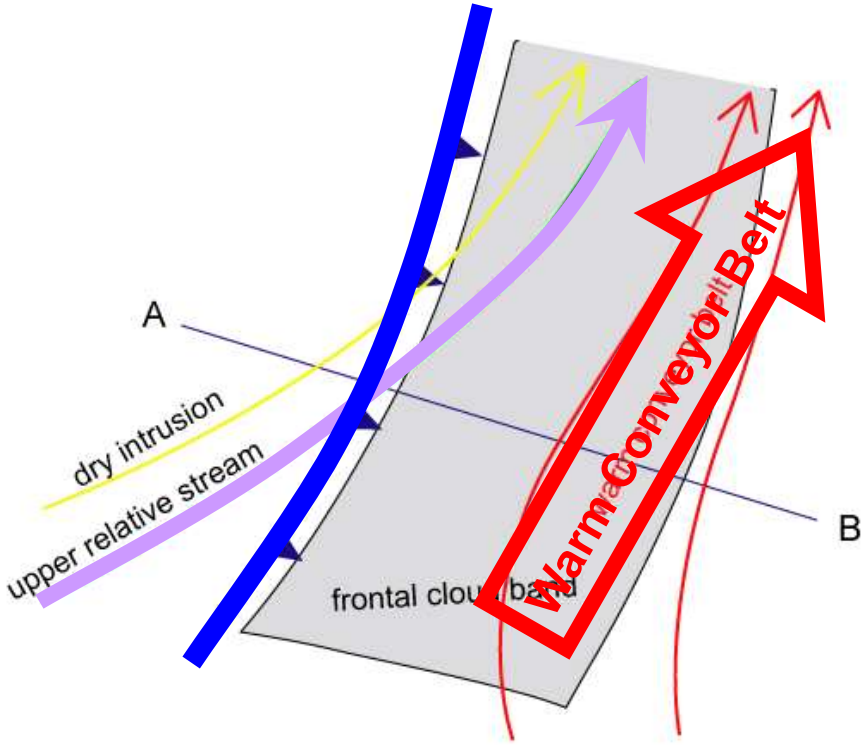
ANA COLD FRONT



Knot active

WX Before

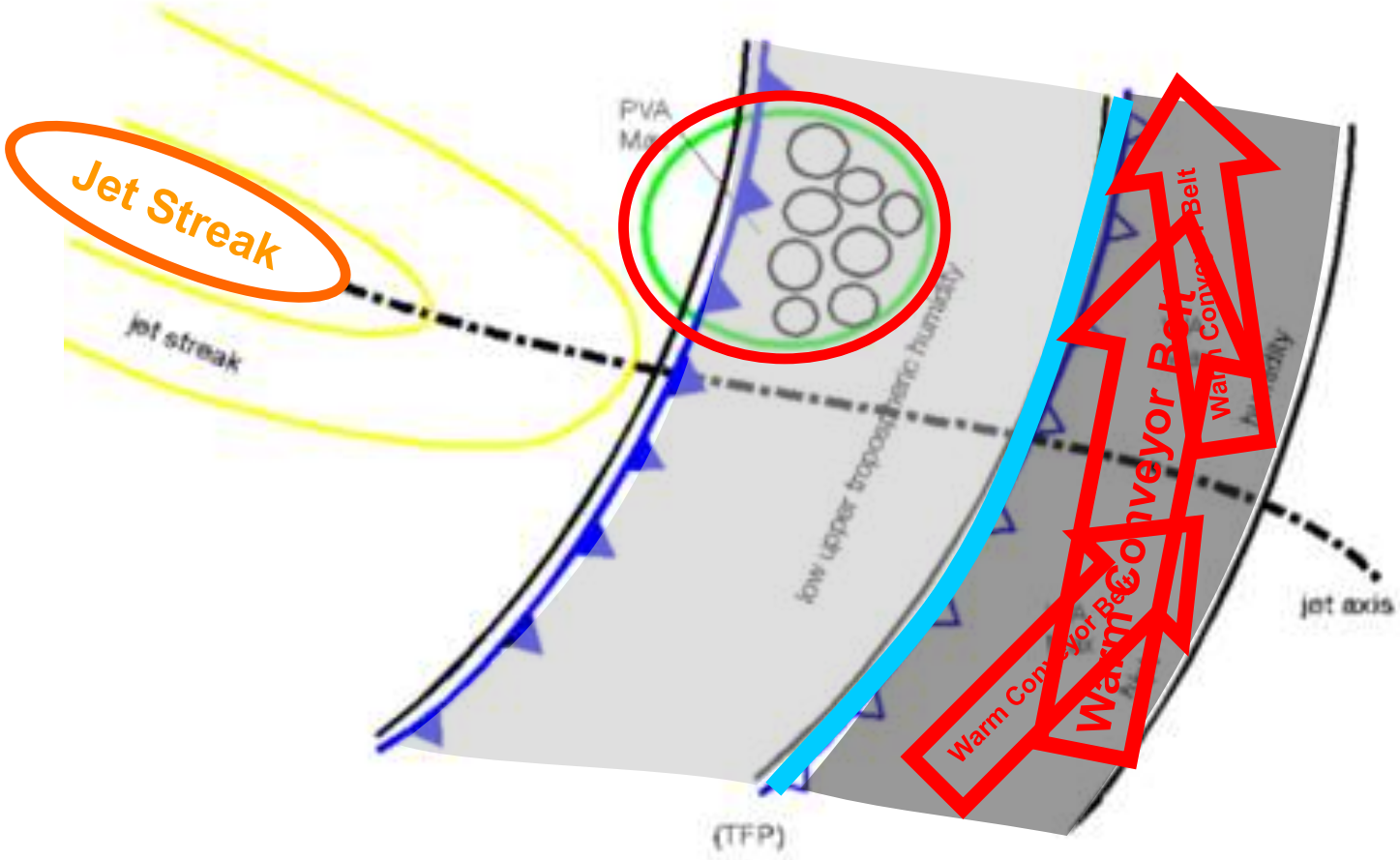
KATA COLD FRONT



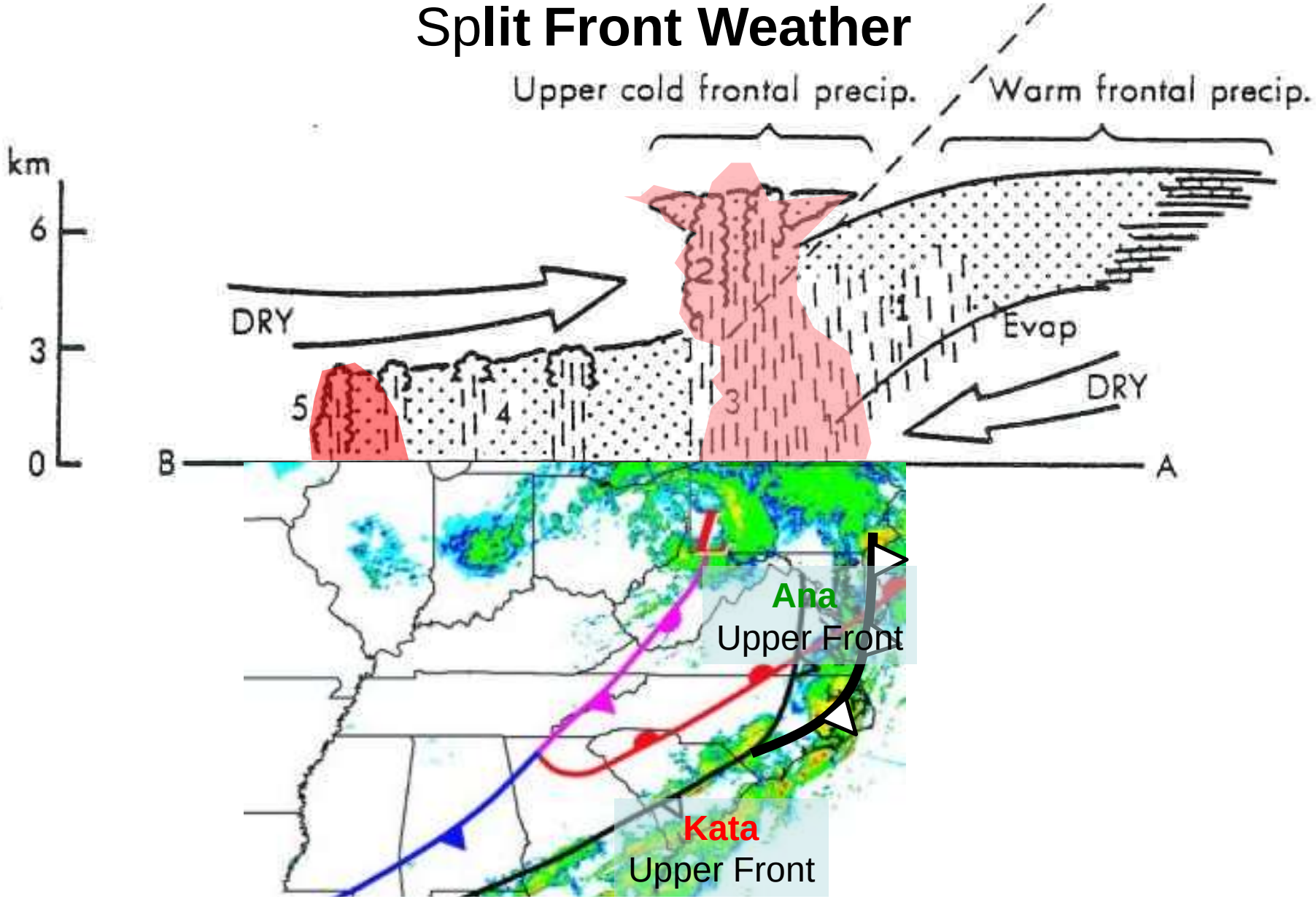
From my Buddies at ZAMG

Split Cold Front Conceptual Model

- WCB (Warm Conveyor Belt)
- Jet streak and positive vorticity advection (PVA) at a large acute angle
- Dry above the low level cloud band and a strong gradient between the two cloud bands at different heights.
- Left of jet fronts tend to be **ANA** in character.
- Right of jet fronts tend to be **KATA** in character



Split Front Weather

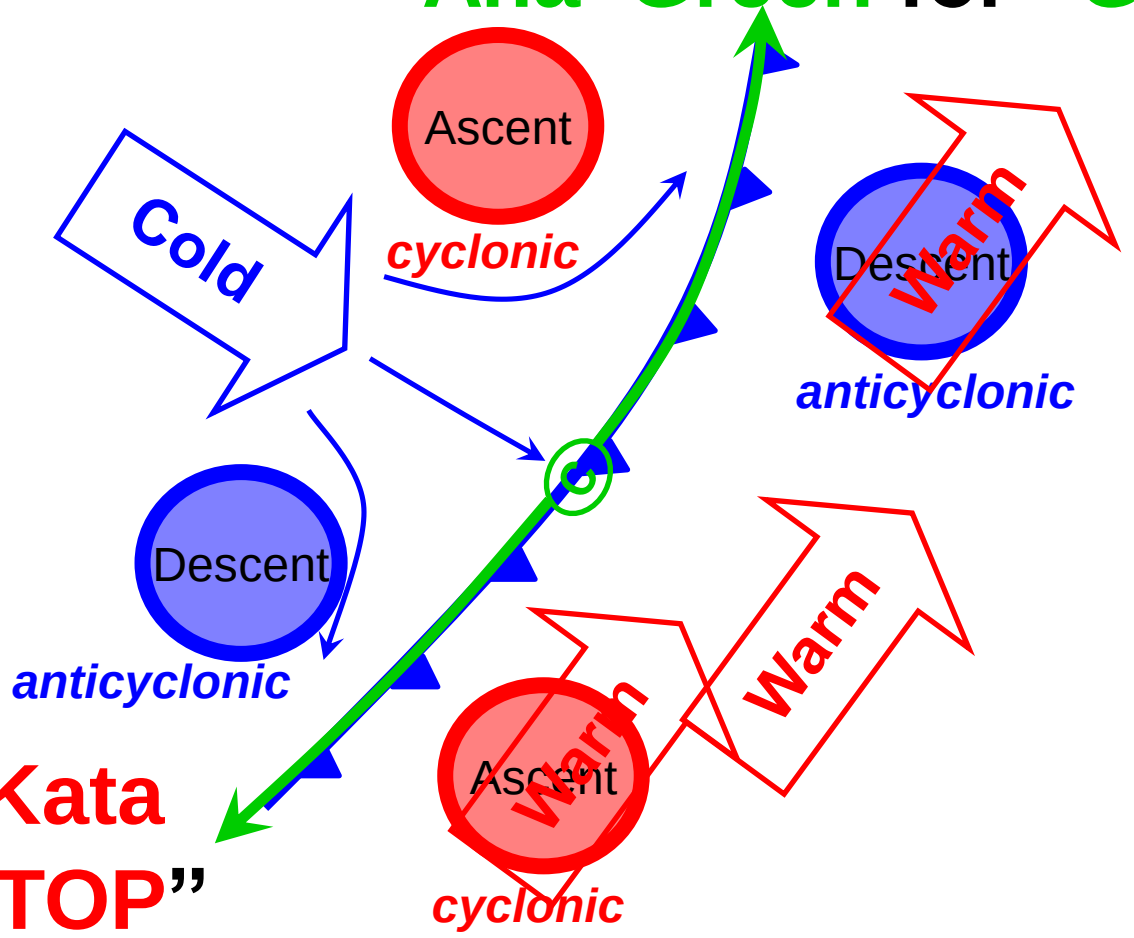


Take Home Message (THM): With split front most WX with upper cold front – still apply ANA, KATA ideas.

Transitional Cold Fronts

Applying the *Deformation Zone* Conceptual Model

Ana Green for "GO"

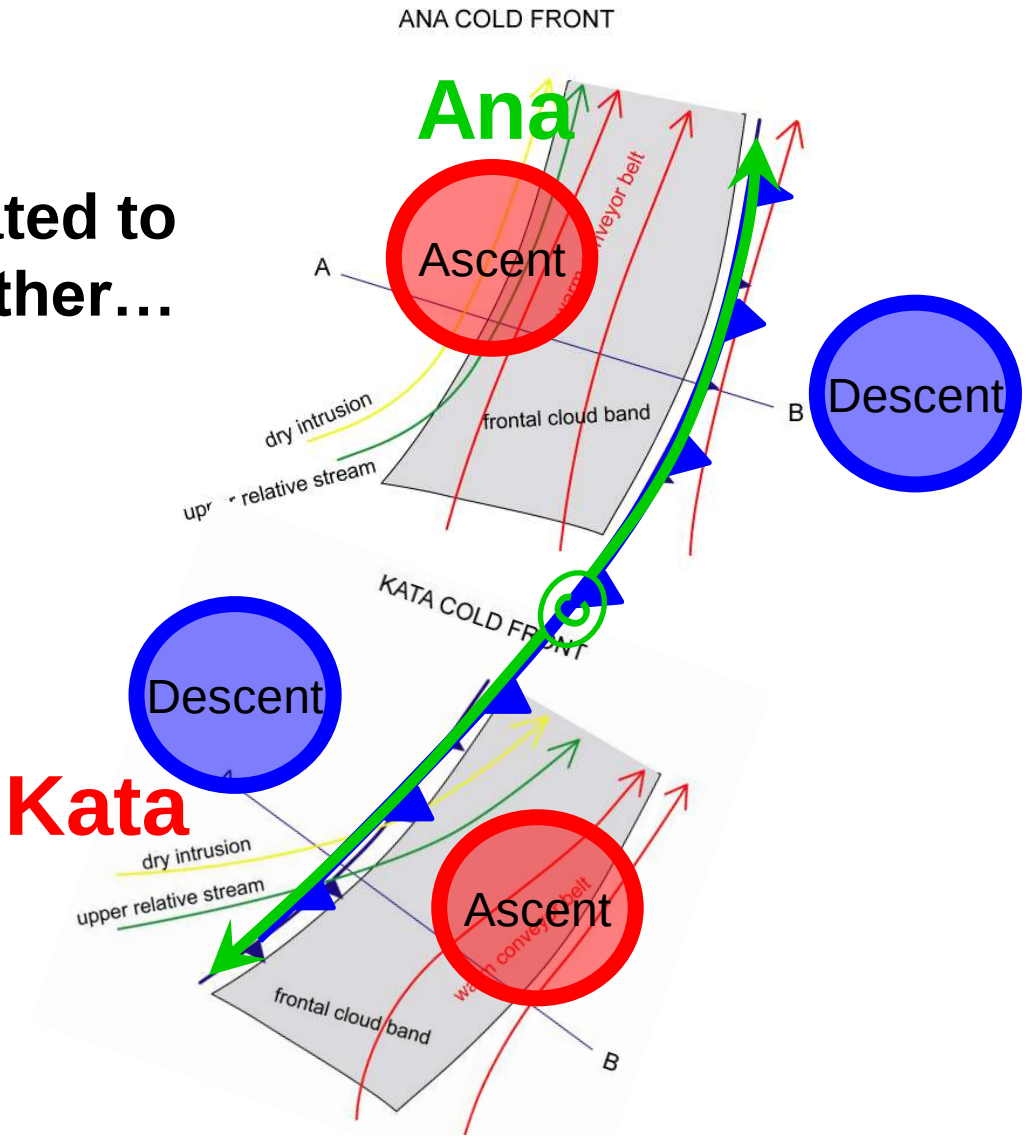


Kata

Red for "STOP"

Transitional Cold Fronts

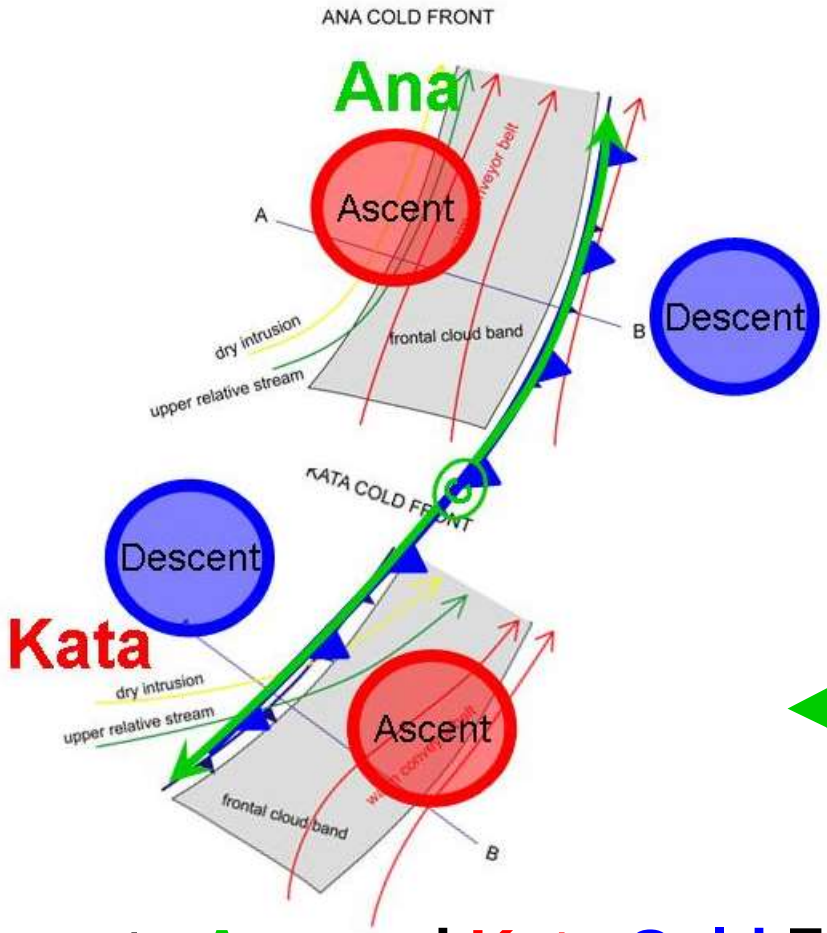
Related to weather…

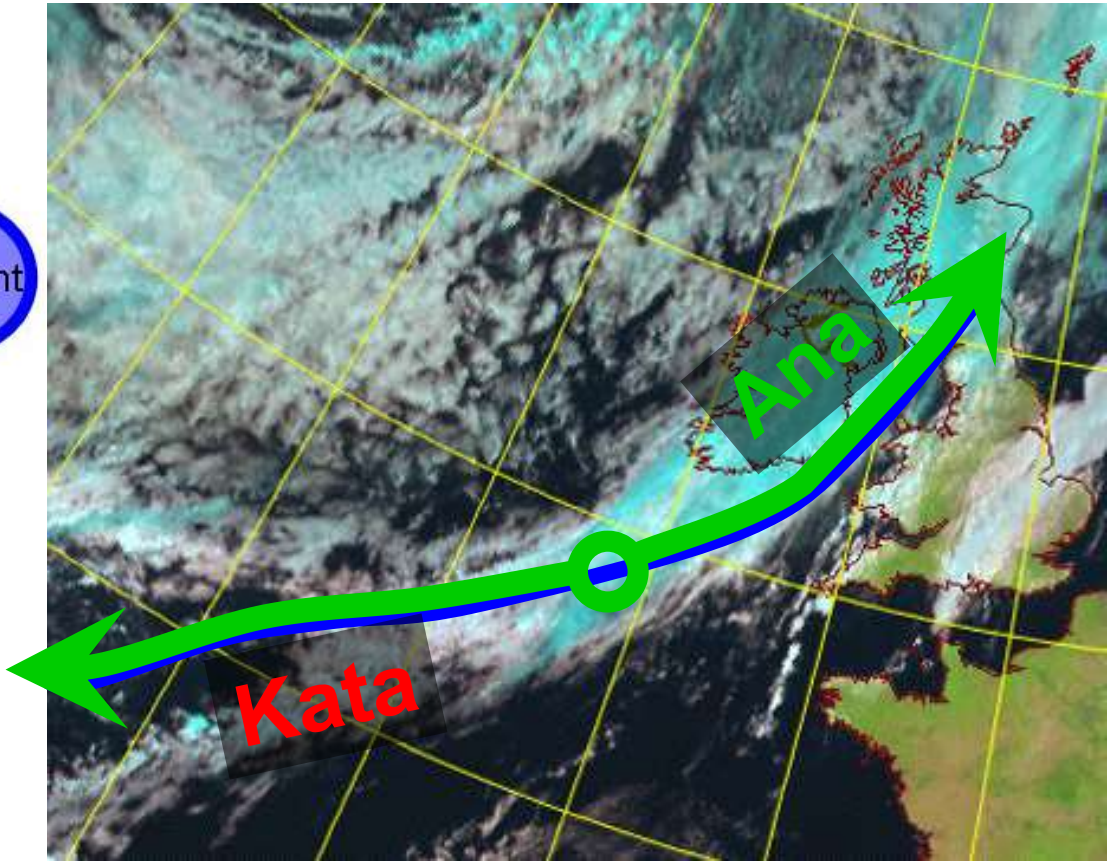


Take Home Message (THM):
Deformation Zone Conceptual Model consistent with Ana and Kata CM's

Transitional Cold Fronts

Applying the Deformation Zone Conceptual Model

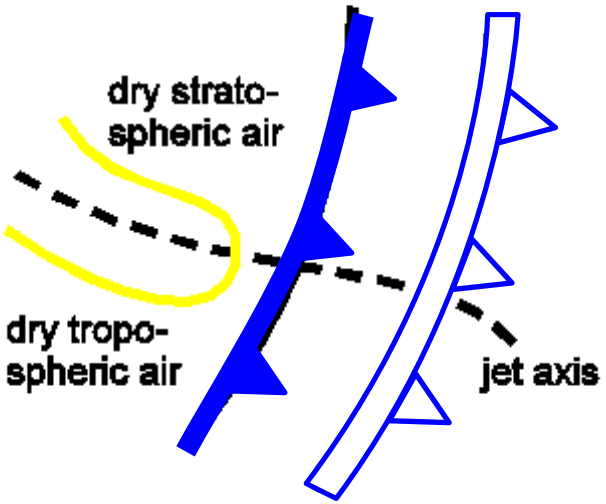


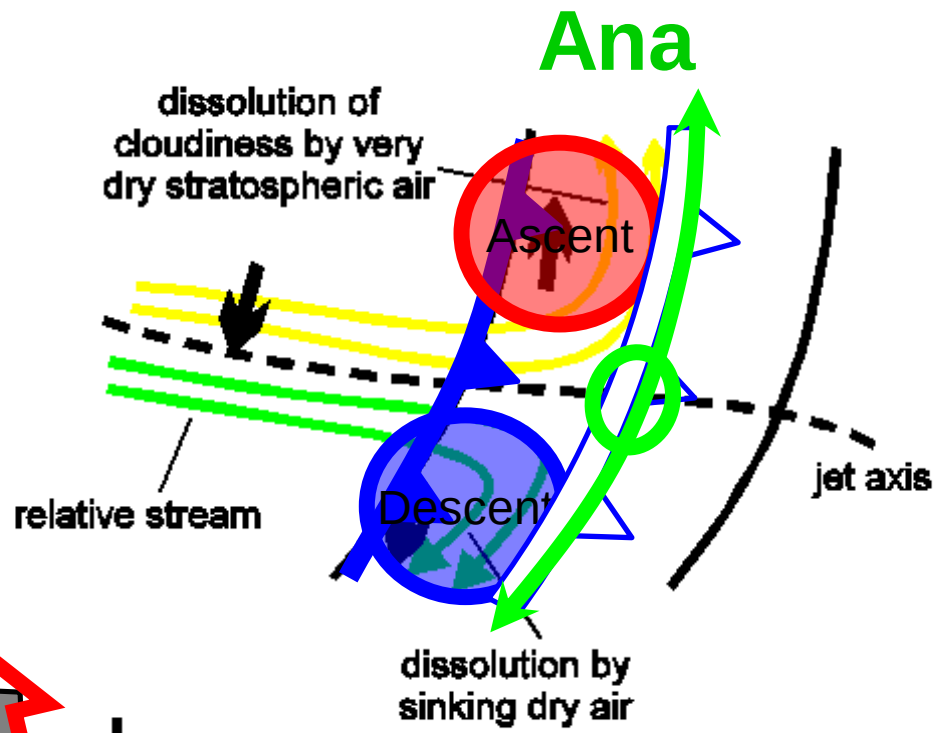


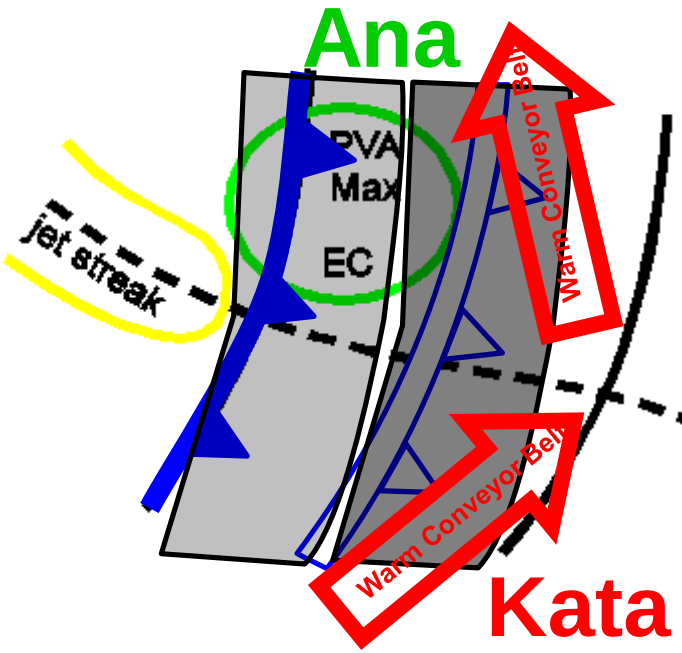
to Ana and Kata Cold Fronts CM's. Highly Idealized but…

a useful Conceptual Model that can assist…

Split Front and the Upper Deformation Zone



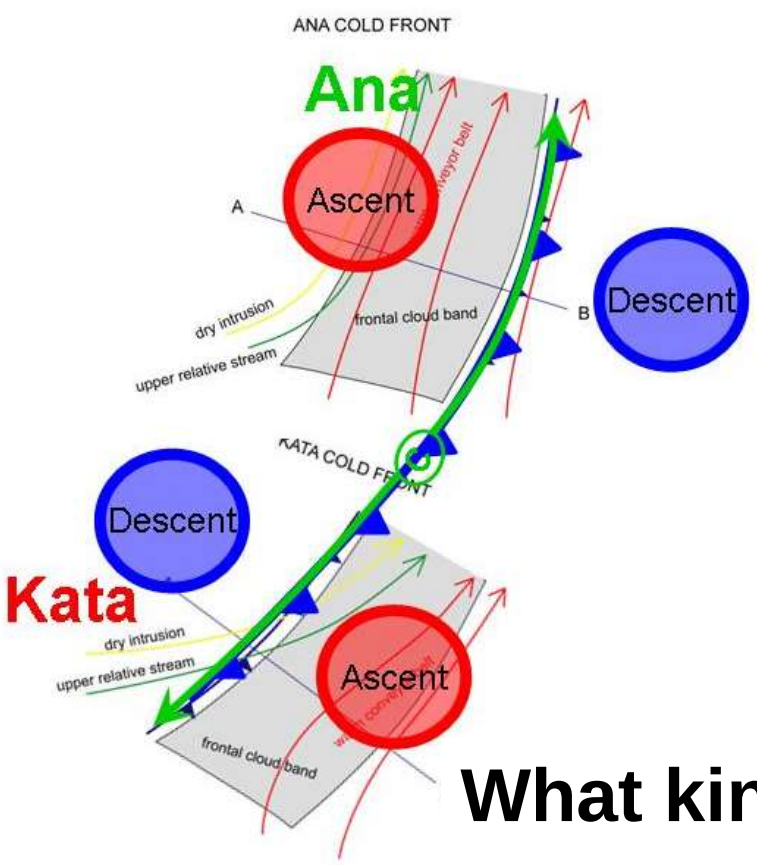


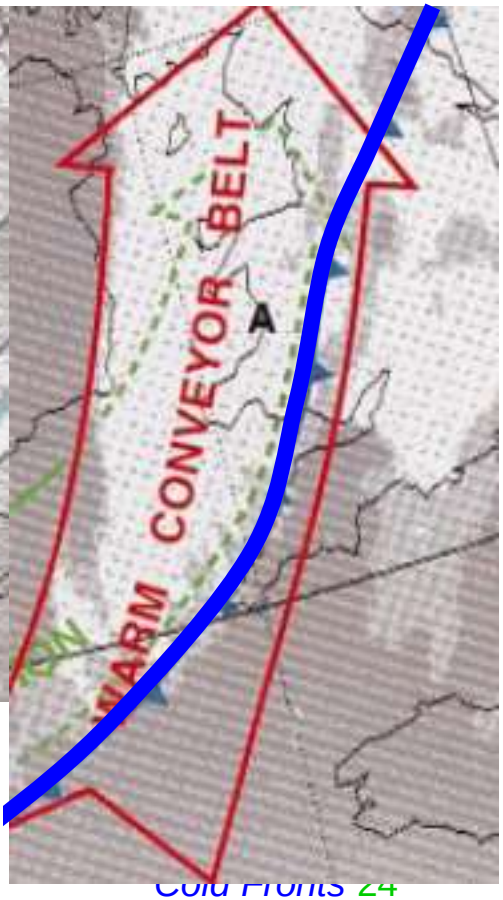


Apply to both ***surface*** and ***upper*** cold fronts

Conventional Radar

- **Anabatic - Ana Front - Active - WX After Front**
- **Katabatic - Kata Front - Knot Active - WX Before Front**
- **Placement of clouds and weather relative to cold front**

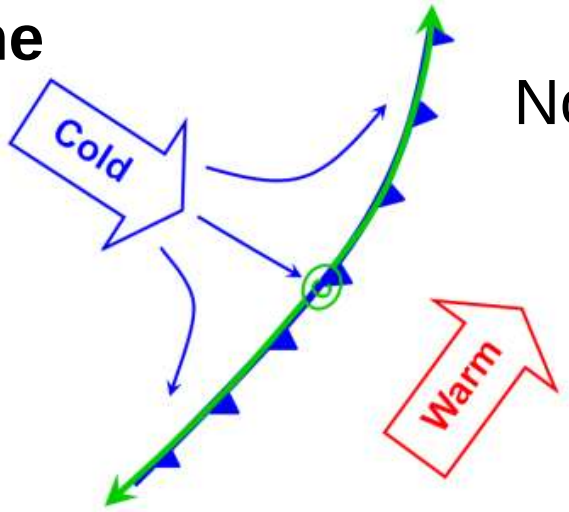




What kind of cold front?

Doppler Radar

- Anabatic - Ana Front - Active - WX After Front
- Katabatic - Kata Front - Knot Active - WX Before Front
- Placement of clouds and weather relative to cold front
- Wind direction – depends on viewing perspective
- Usually sharp change in wind direction
- Usually sharp change in radial wind component
- Discontinuity on Doppler
- Discontinuity along a range ring or radial ?
- Discontinuity = line

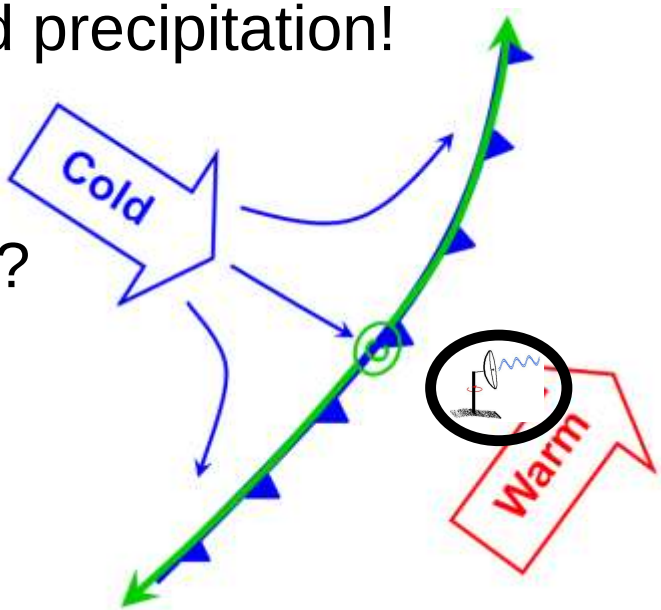


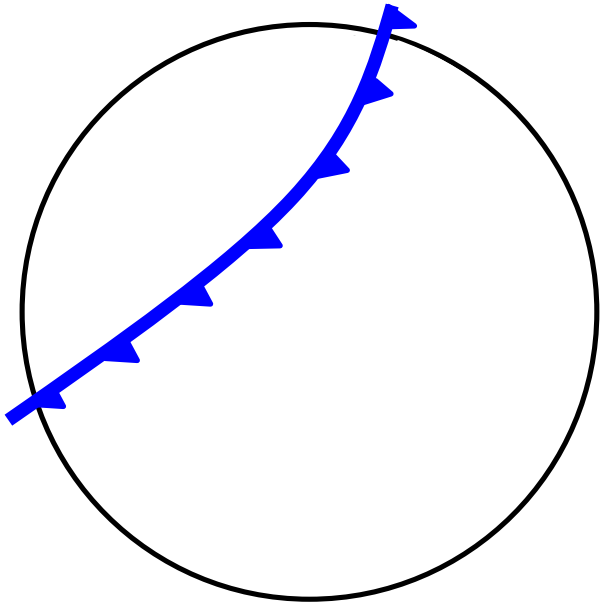
Not along a range ring

Doppler – Cold Front Approaching Radar

- Assuming there is widespread precipitation!

What Doppler Sectors?
What Doppler Colours? Where?





Anabatic Precipitation Distribution?

Ana - main zone of cloudiness and precipitation after the surface front.

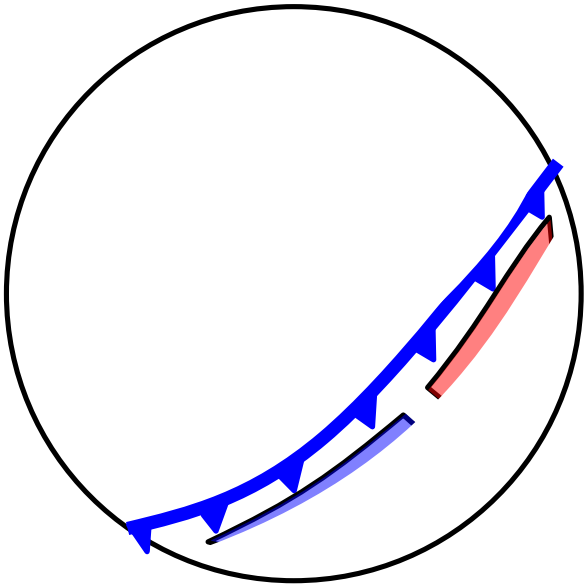
Katabatic Precipitation Distribution?

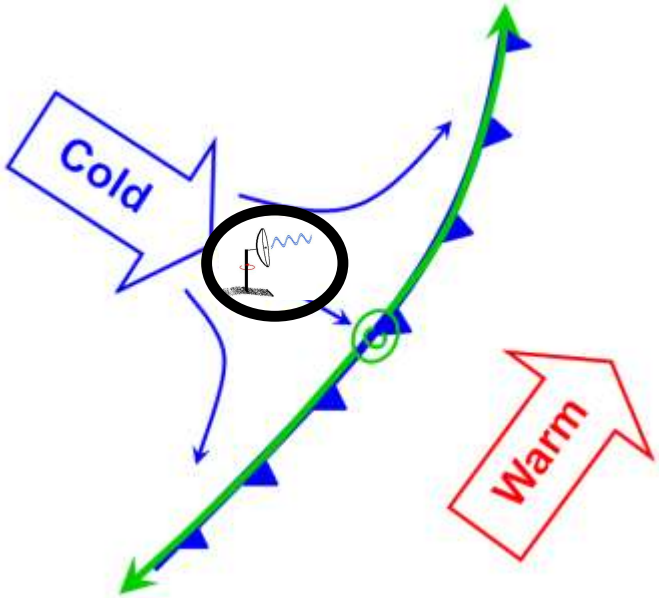
Kata - main zones of cloudiness and precipitation before the surface front.

Doppler – Cold Front Past Radar

- Assuming there is widespread precipitation!

What Doppler Sectors?
What Doppler Colours? Where?





Anabatic Precipitation Distribution?

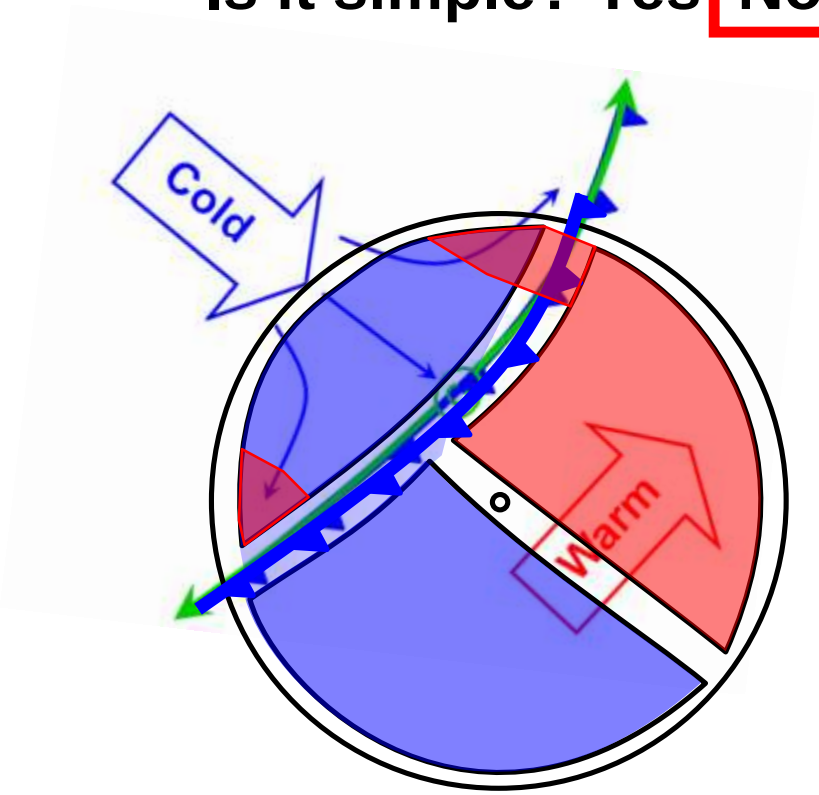
Ana - main zone of cloudiness and precipitation after the surface front.

Katabatic Precipitation Distribution?

Kata - main zones of cloudiness and precipitation before the surface front.

Doppler – Cold Front Approaching Radar

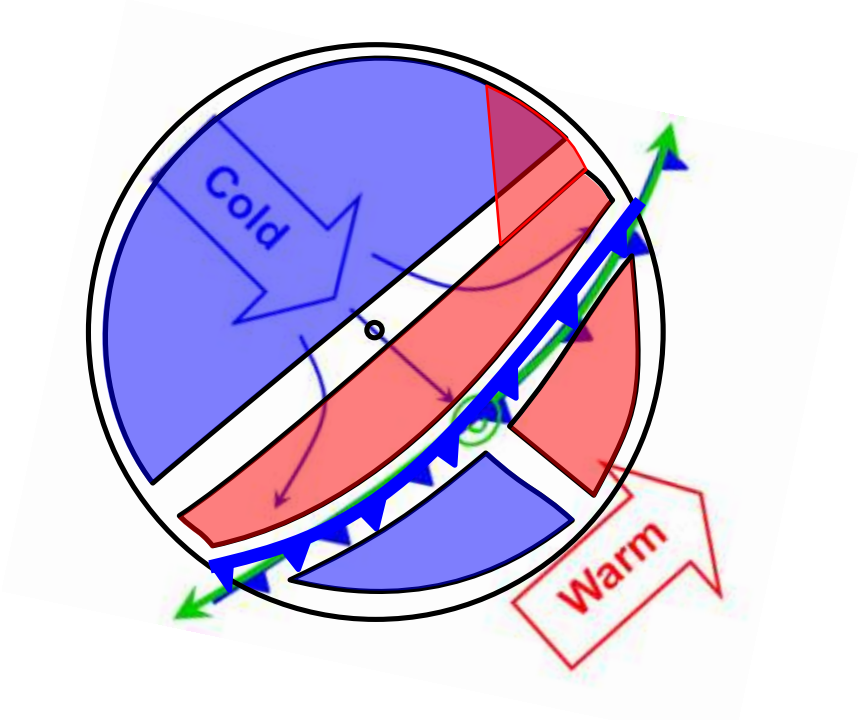
Is it simple? Yes No



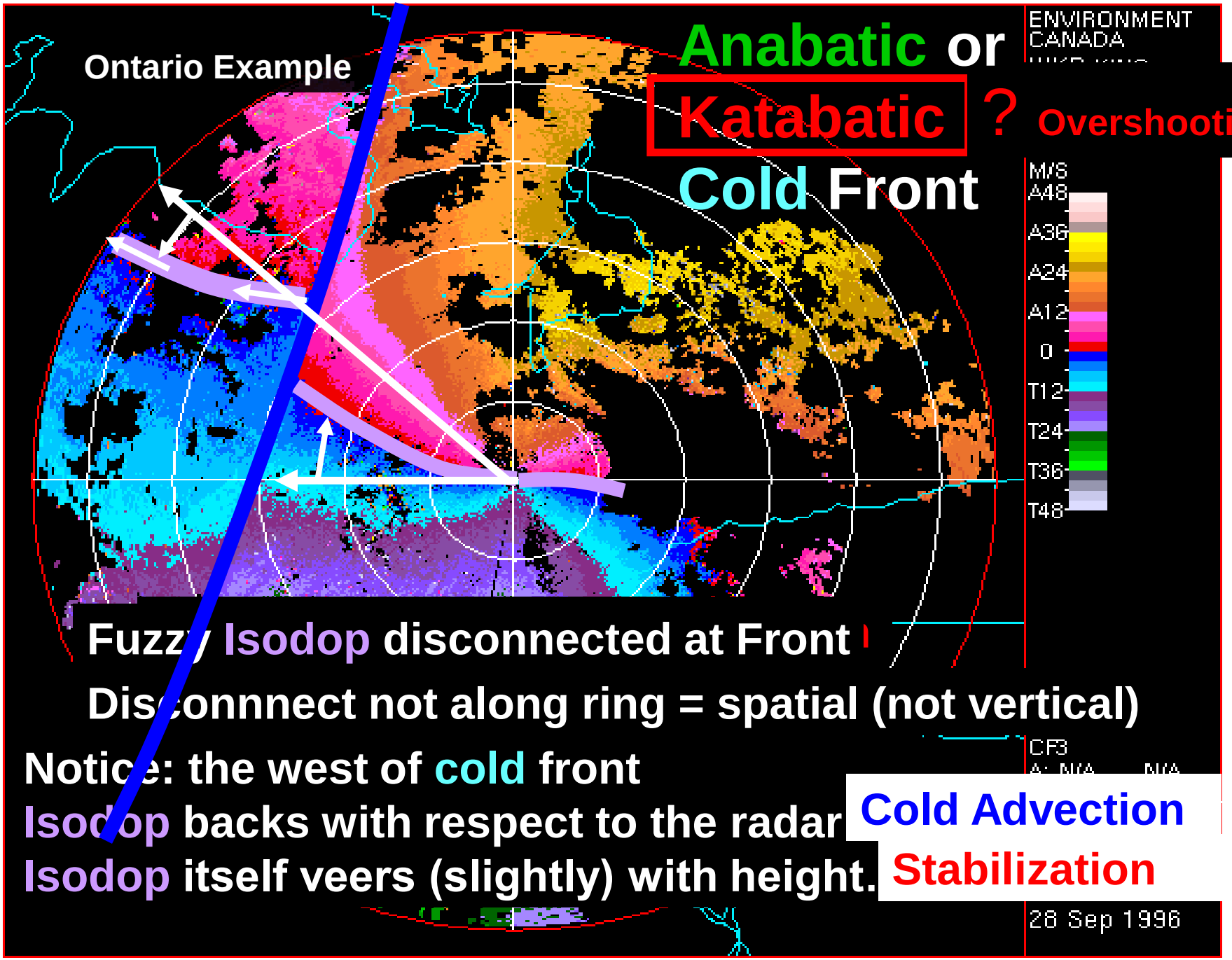
Depends where the Doppler Radar is…
Relative to the pattern…

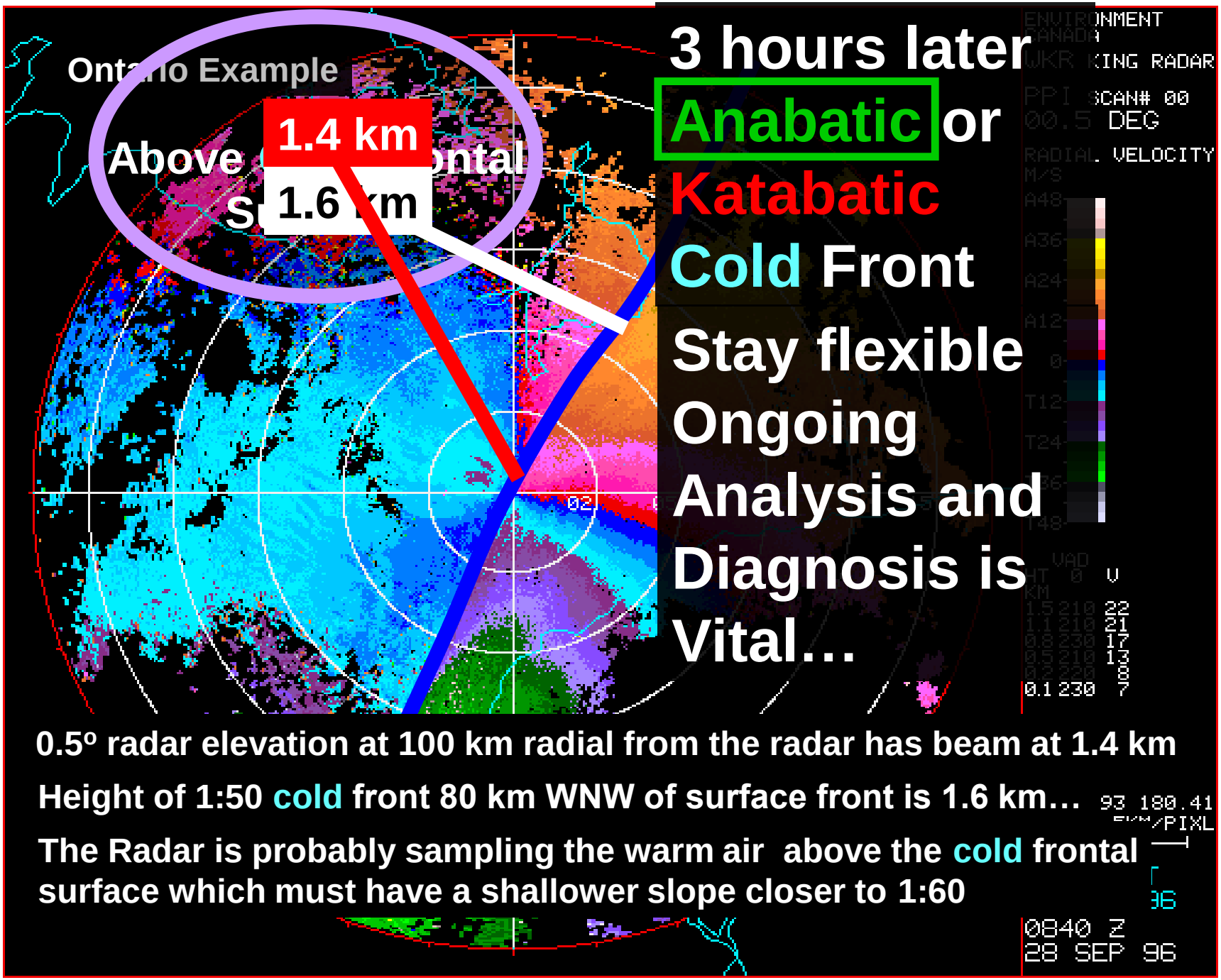
Doppler – Cold Front Past Radar

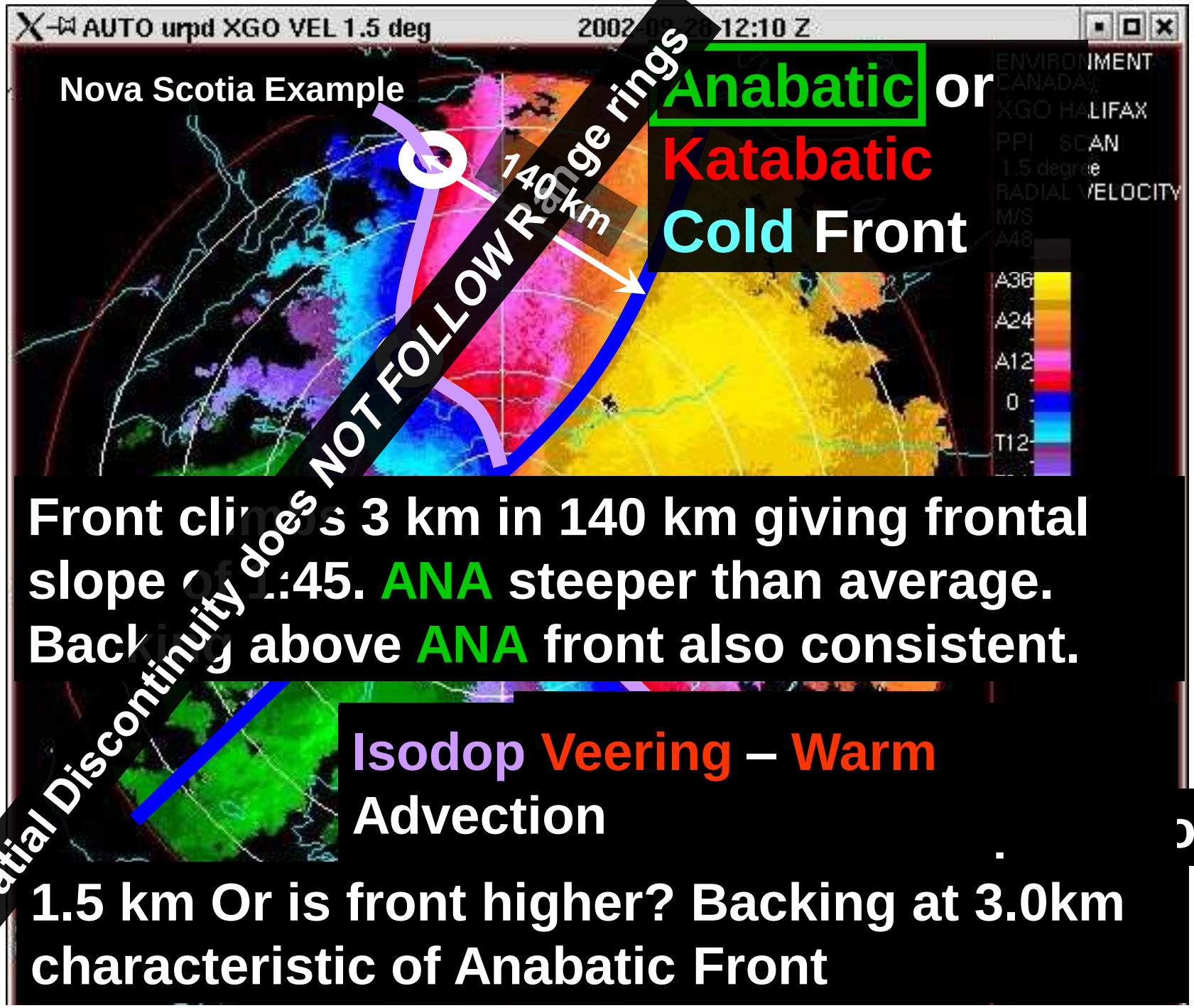
Is it simple? Yes No

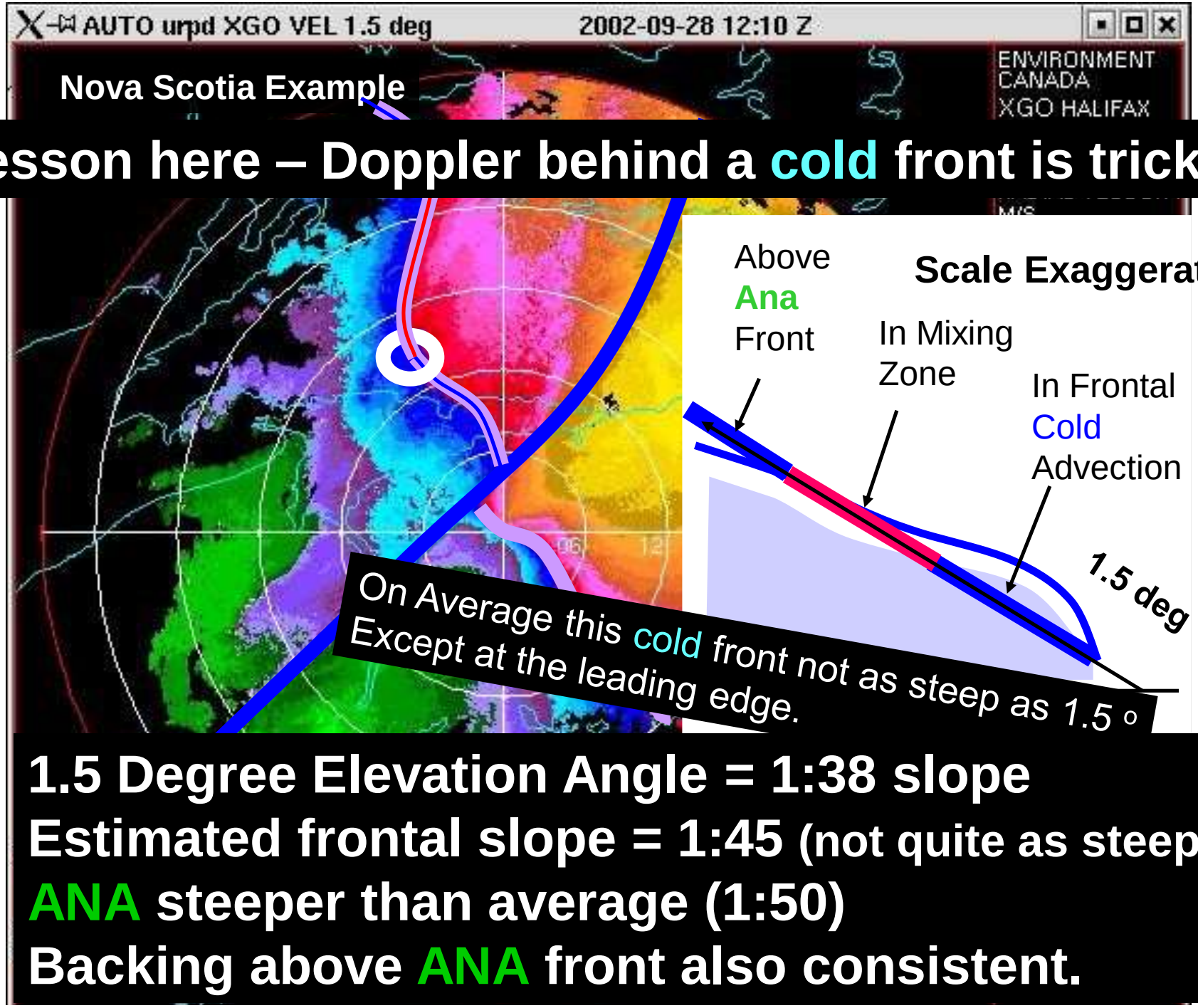


Depends where the Doppler Radar is…
Relative to the pattern…


Ontario Example
Anabatic or
Katabatic ?
Overshooting
Cold Front
ENVIRONMENT
CANADA
M/S
A48
A36
A24
A12
0
T12
T24
T36
T48
Fuzzy Isodop disconnected at Front
Disconnnect not along ring = spatial (not vertical)
Notice: the west of cold front
Isodop backs with respect to the radar
Isodop itself veers (slightly) with height.
Cold Advection
Stabilization
CF3
28 Sep 1996


Ontario Example
Above
1.4 km
1.6 km
3 hours later
Anabatic or
Katabatic
Cold Front
Stay flexible
Ongoing
Analysis and
Diagnosis is
Vital…
ENVIRONMENT CANADA
KING RADAR
PPI SCAN# 00
00.5 DEG
RADIAL VELOCITY M/S
VAD
0840 Z
28 SEP 96
0.5° radar elevation at 100 km radial from the radar has beam at 1.4 km
Height of 1:50 cold front 80 km WNW of surface front is 1.6 km…
The Radar is probably sampling the warm air above the cold frontal surface which must have a shallower slope closer to 1:60


AUTO urpd XGO VEL 1.5 deg
2002 12:10 Z
Nova Scotia Example
Anabatic or
Katabatic
Cold Front
140 km
Range rings
NOT FOLLOW
Spatial Discontinuity does
A36
A24
A12
0
T12
Front cli s 3 km in 140 km giving frontal
slope of 1:45. ANA steeper than average.
Back g above ANA front also consistent.
Isodop Veering – Warm
Advection
oft?
1.5 km Or is front higher? Backing at 3.0km
characteristic of Anabatic Front


AUTO urpd XGO VEL 1.5 deg
2002-09-28 12:10 Z
ENVIRONMENT CANADA
XGO HALIFAX
Nova Scotia Example
Lesson here – Doppler behind a cold front is tricky!
Above Ana Front
In Mixing Zone
In Frontal Cold Advection
Scale Exaggerated
1.5 deg
On Average this cold front not as steep as 1.5 o
Except at the leading edge.
1.5 Degree Elevation Angle = 1:38 slope
Estimated frontal slope = 1:45 (not quite as steep)
ANA steeper than average (1:50)
Backing above ANA front also consistent.

Anabatic or Katabatic Cold Front

Another Cold front

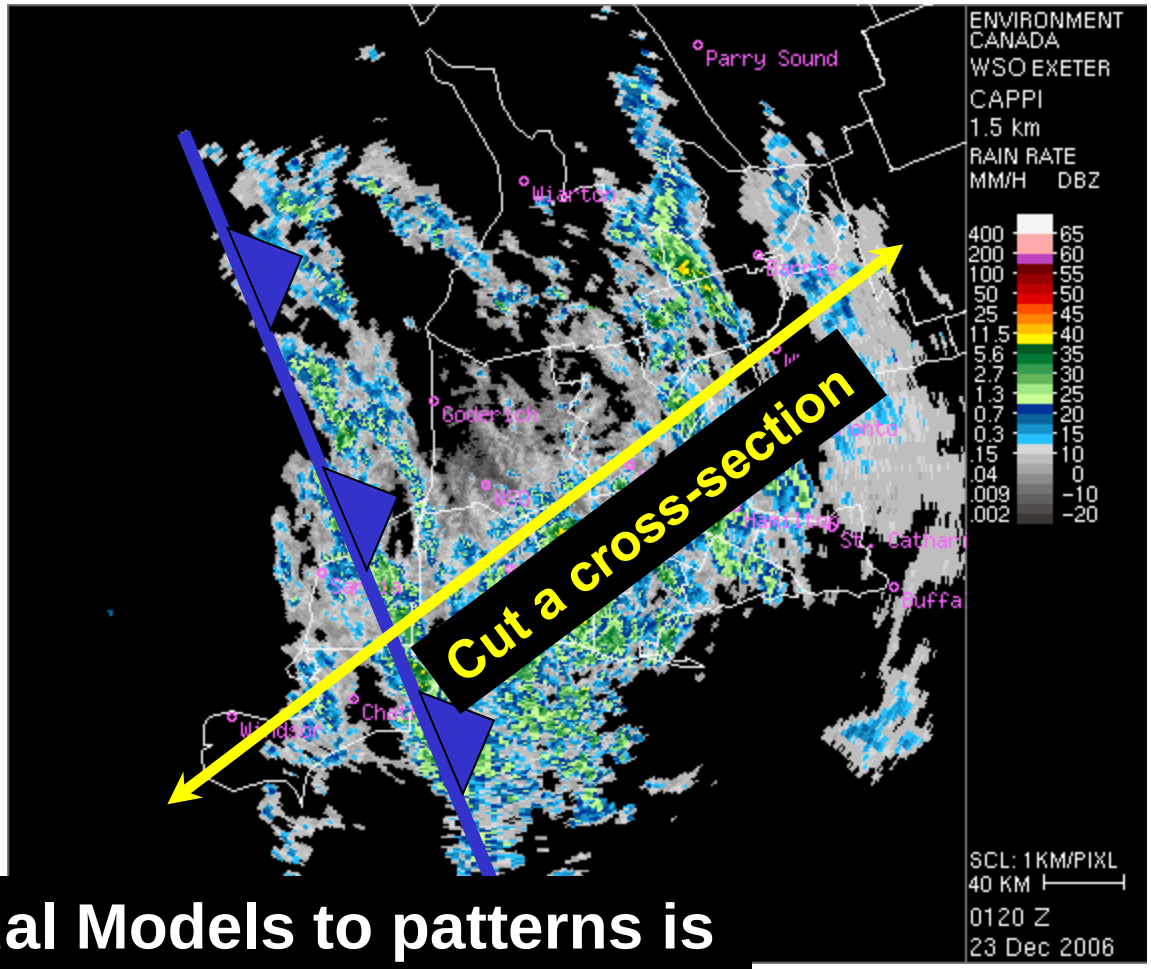
WSO

Southwestern Ontario

0120Z Dec 23, 2006

CAPPI 1.5 km

Rain rate



Applying Conceptual Models to patterns is fundamental to operational meteorology.

Katabatic

The same Cold front

You can almost see the subsidence…

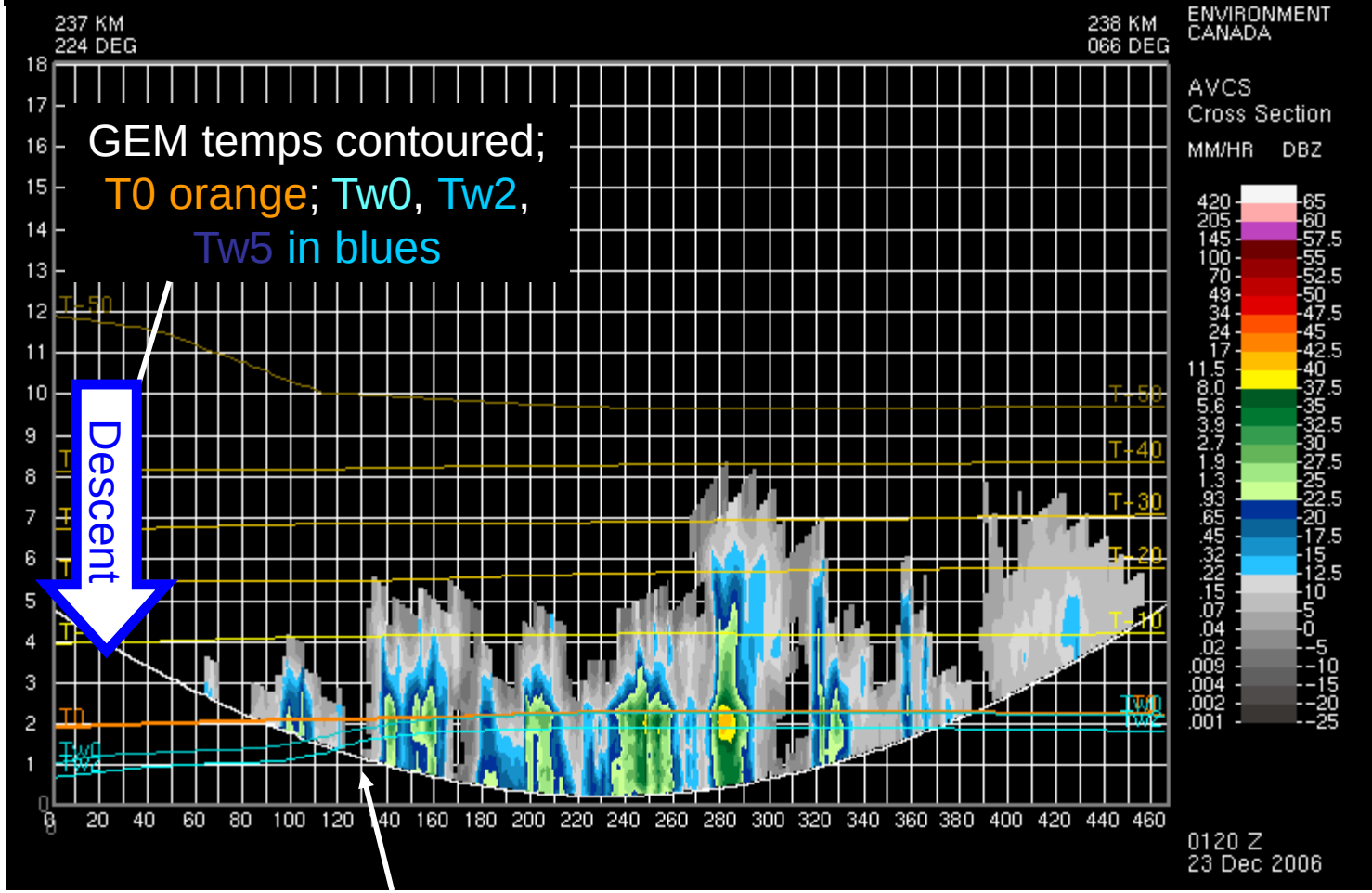
Vertical Cross-Section

WSO

Southwest Ontario

0120Z Dec 23, 2006

Rain rate



SW

GEM cold front

NE

The same Cold front

Cold sector Isodop almost backs… counter clockwise

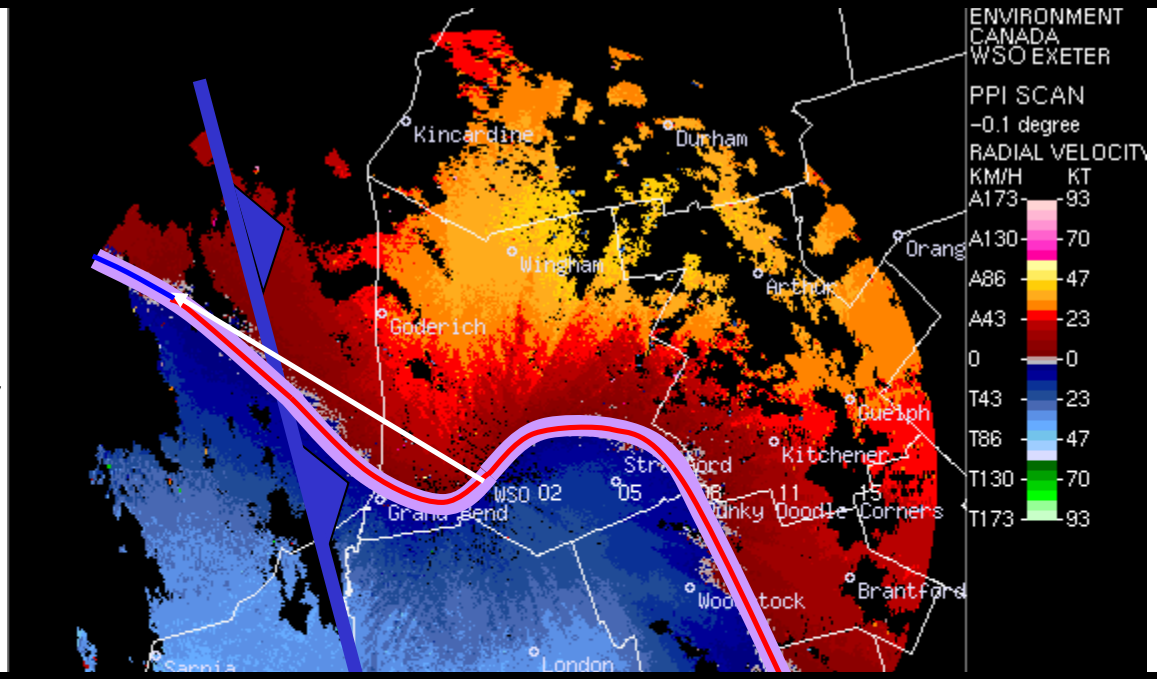
Warm sector Isodop veers… clockwise

WSO

Southwestern Ontario

0120Z Dec 23, 2006

-0.09° Radial Velocity



Cold Advection over Warm Advection ?

Destabilization – Isodop backs with range/height ?

Is it real?

Yes, it is real – but SO weak & where relative to frontal surface?

The same Cold front 2 hours later

Not much of a COLD front

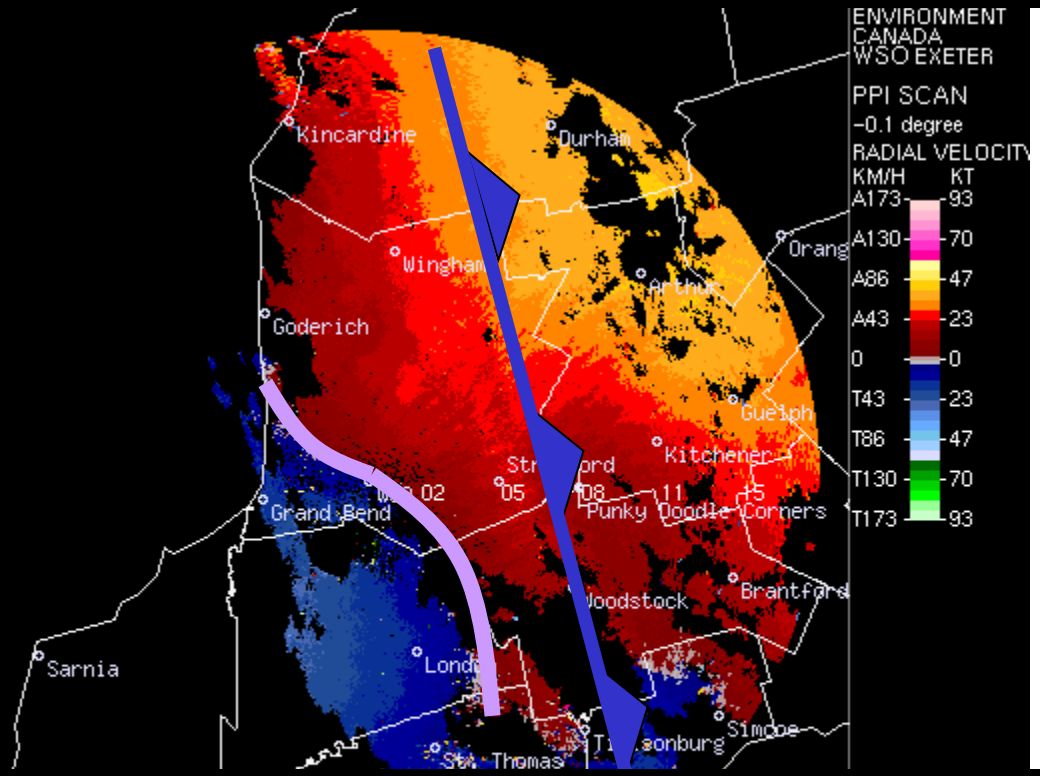
Cold sector Isodop veers… clockwise ???

WSO

Southwestern Ontario

0320Z Dec 23, 2006

-0.09˚ Radial Velocity



But wait… this makes no sense…

-0.09º = near surface= frictional Ekmann Spiral

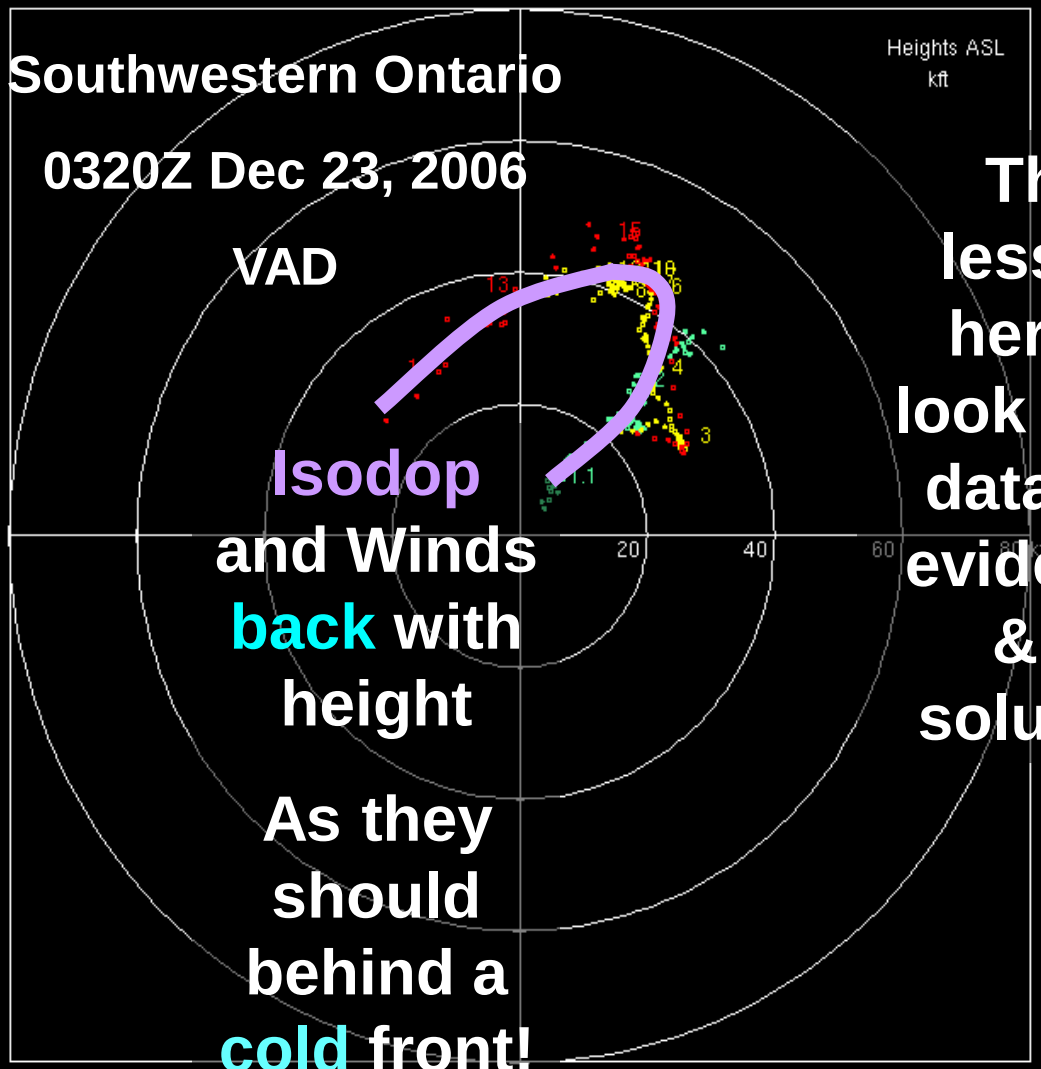
Cold front

WSO

Southwestern Ontario

0320Z Dec 23, 2006

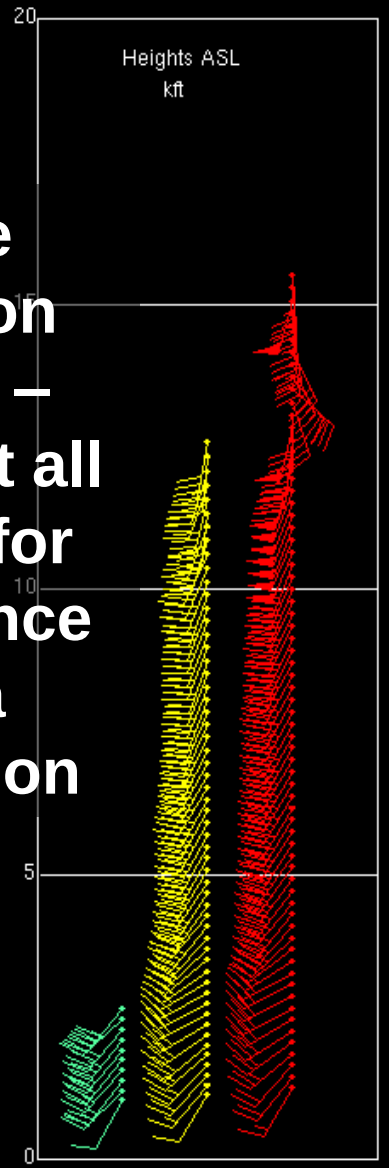
VAD

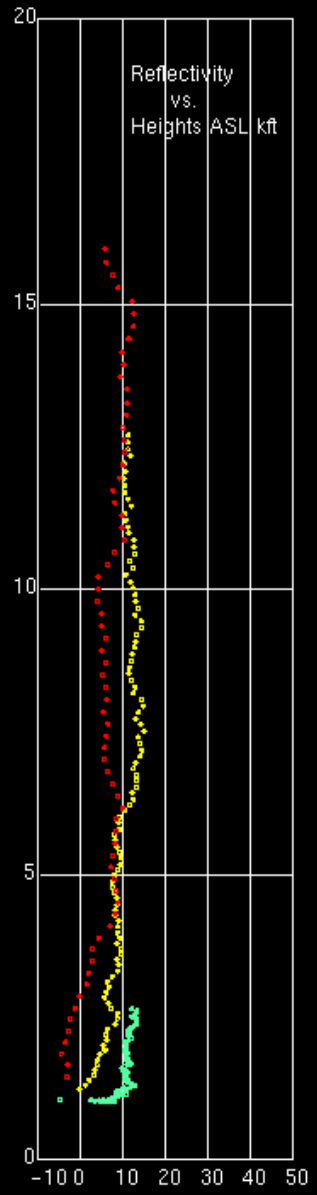


Isodop and Winds back with height

As they should behind a cold front!

The lesson here – look at all data for evidence & a solution





The same Cold front 2 hours later

Anabatic or

Katabatic

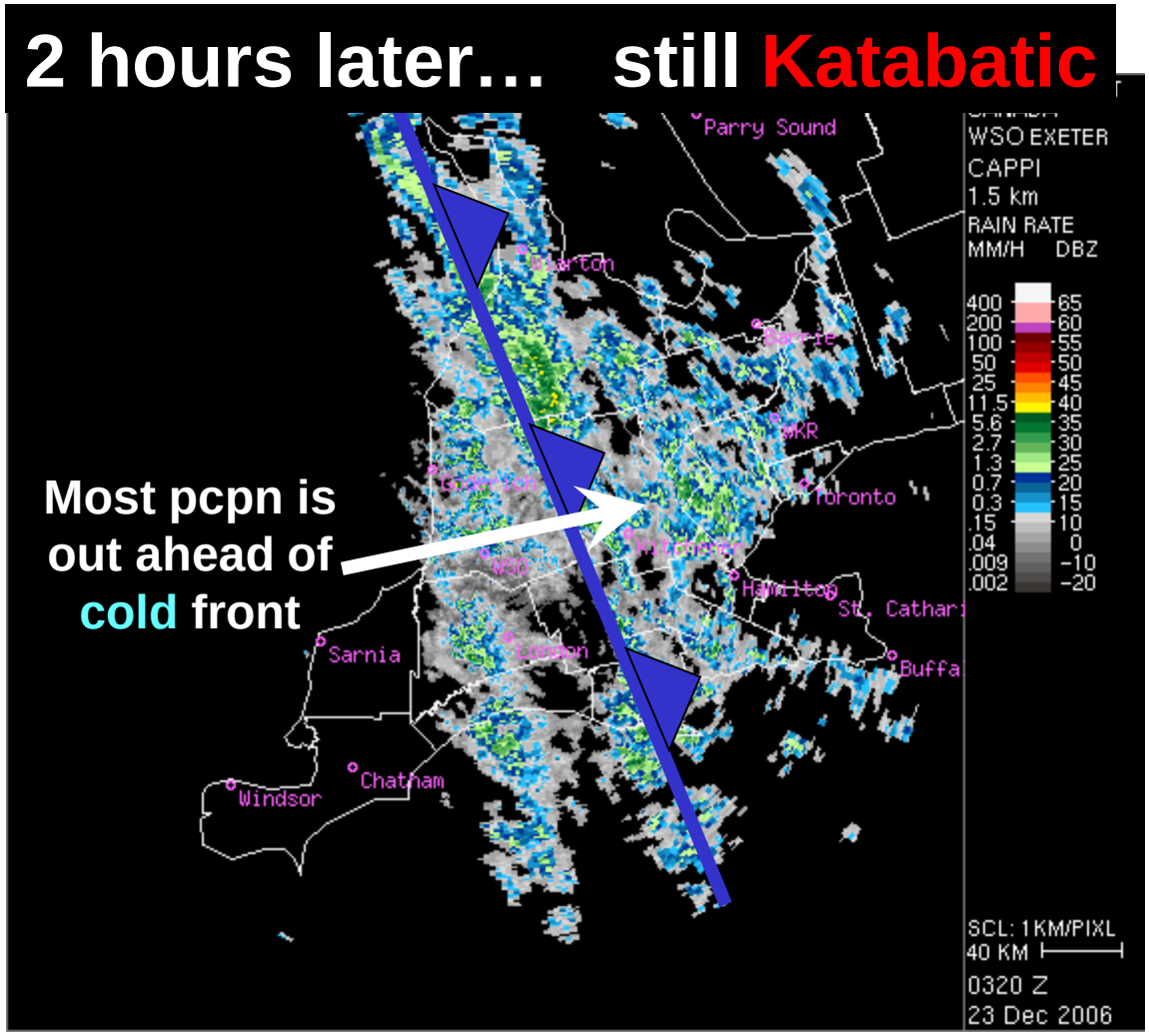
Cold Front

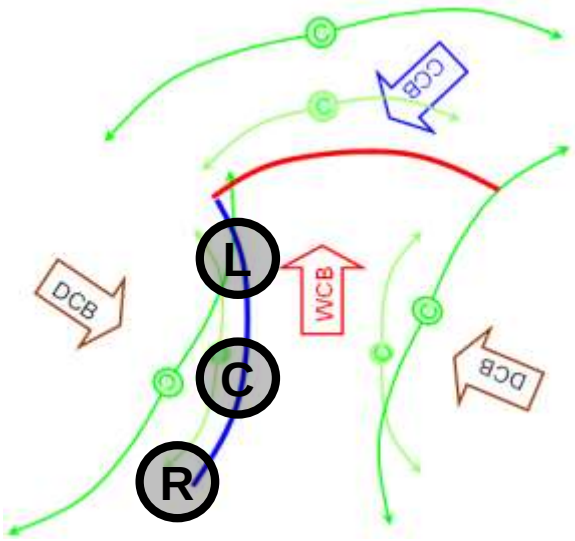
WSO

Southwestern Ontario

0320Z Dec 23, 2006

CAPPI 1.5 km Rain rate





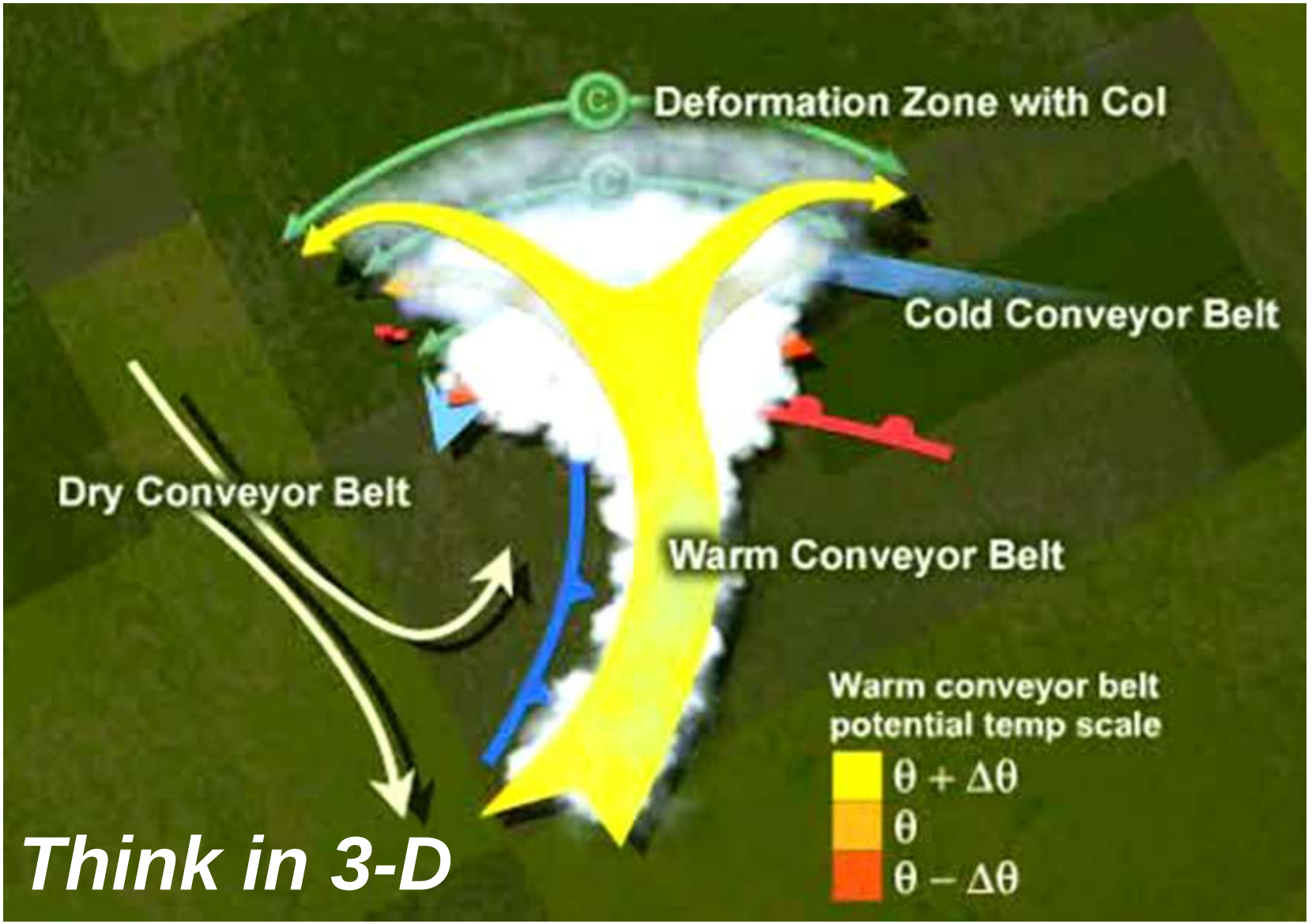
The Conveyor Belt Conceptual Model

Cold Front Conceptual Models

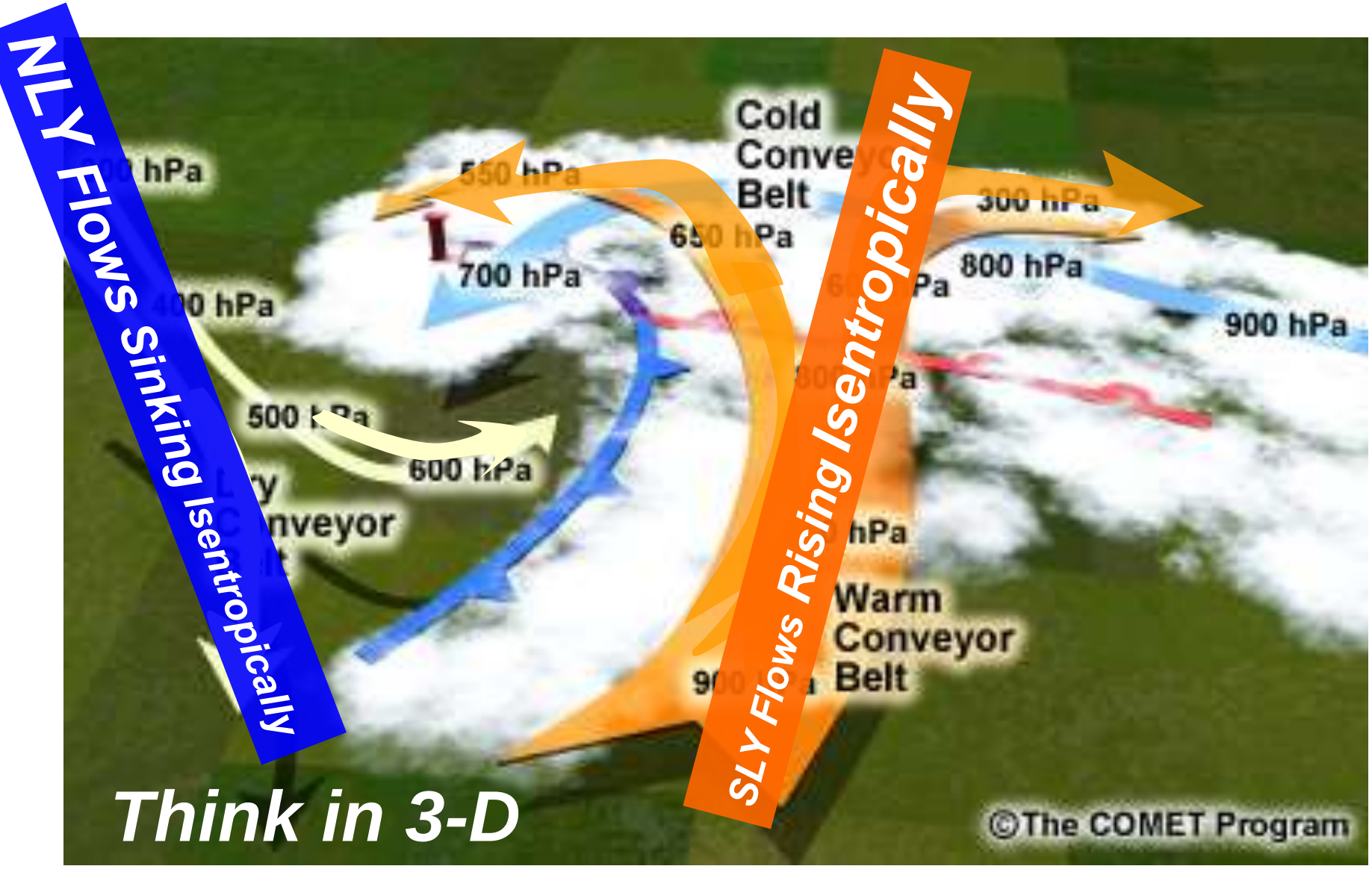
With a Radar Emphasis

R = Right of the Col
C = Centered on the Col
L = Left of the Col

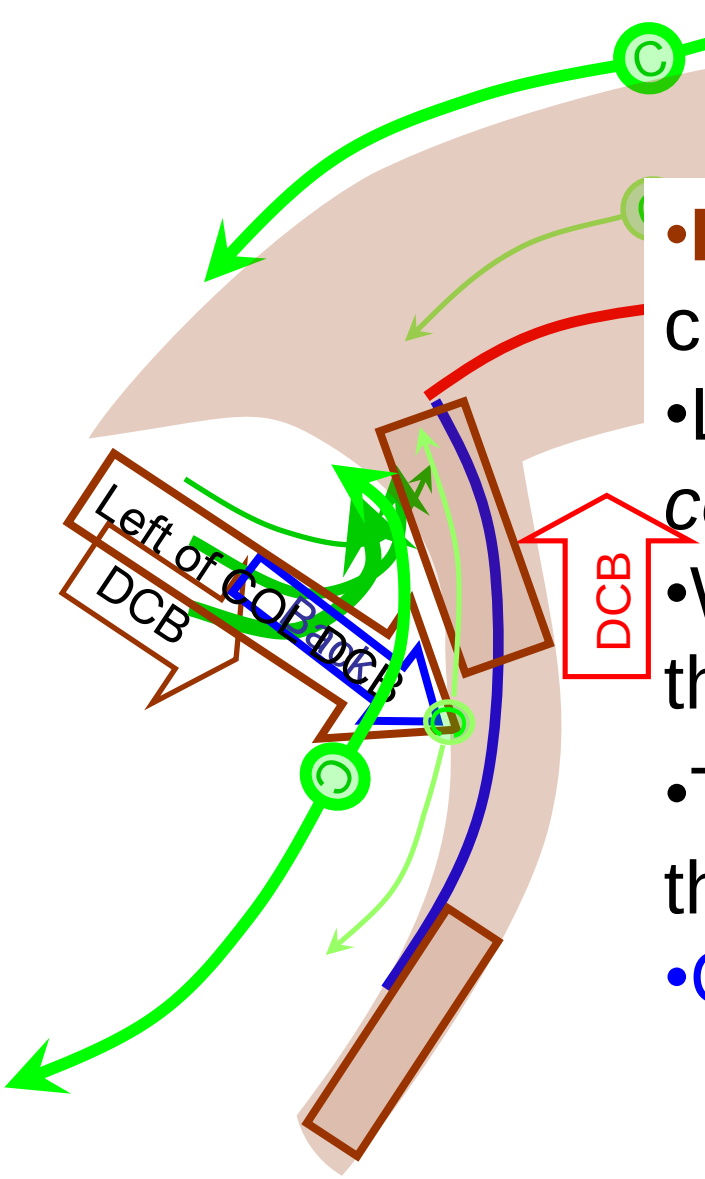
The Conveyor Belt Conceptual Model



Radar Signatures Relative to the Conveyor Belts

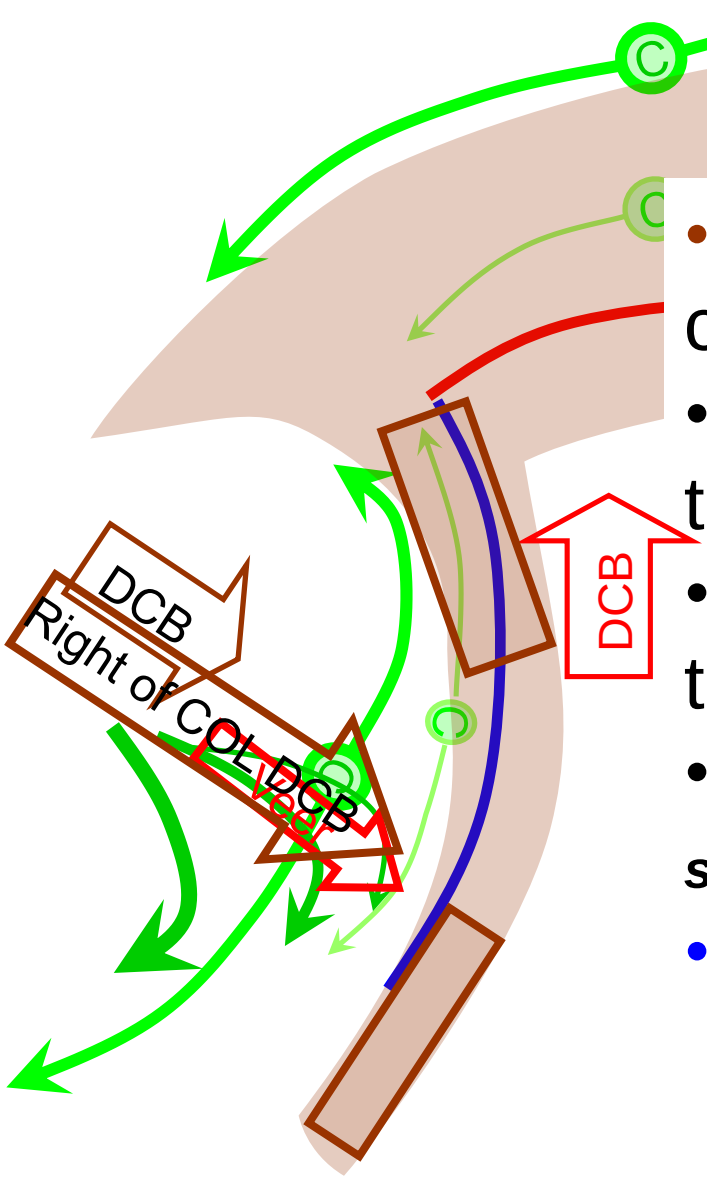


Vertical Deformation Zone Distribution and the CBCM Summary Left of the Col



- **DCB** rises *isentropically* as it curls ***cyclonically*** northward
- Located in the dry slot of the *comma head*
- Winds back with height above the cold frontal surface
- The cold frontal slope is ***steeper*** than the average 1:50
- Cold front is likely **Anabatic**

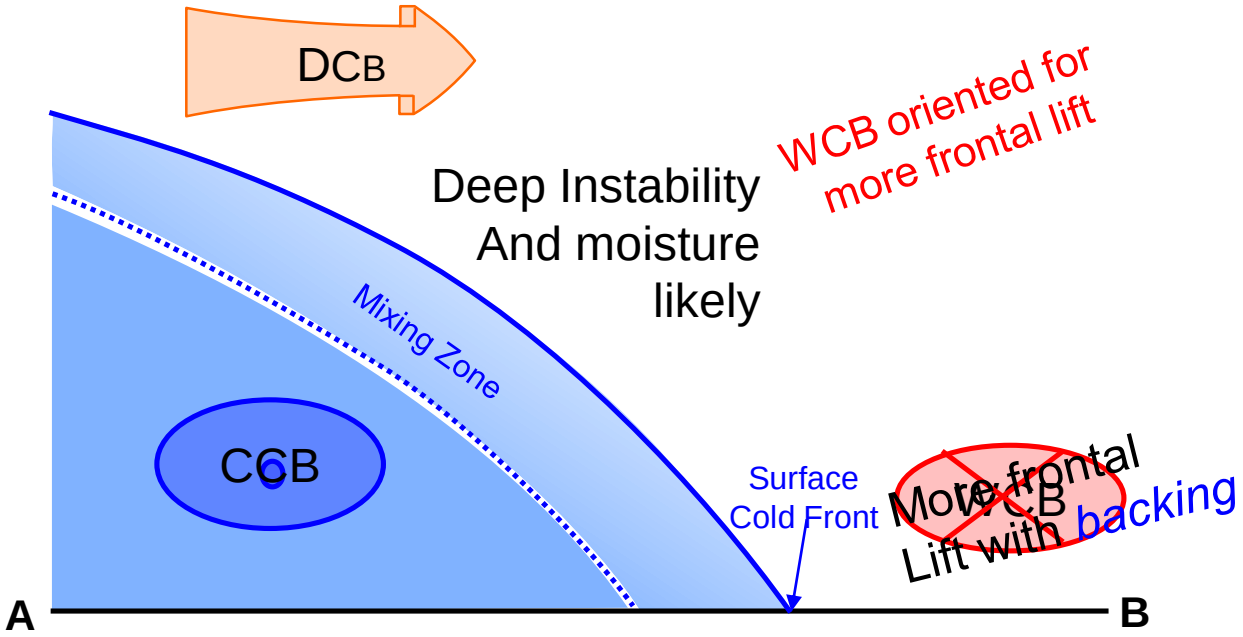
Vertical Deformation Zone Distribution and the CBM Summary Right of the Col

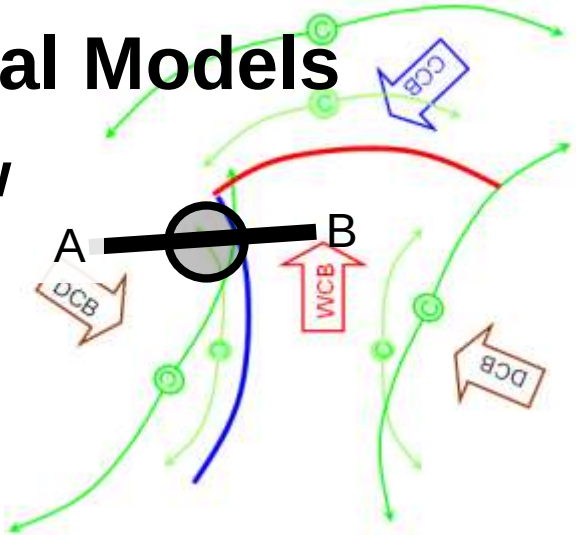


- **DCB** sinks *isentropically* as it curls ***anticyclonically*** southward
- Located along the equatorward tip of the *comma tail*
- Winds veer with height above the cold frontal surface
- The cold frontal slope is more ***shallow*** than the average 1:50
- Cold front is likely **Katabatic**

Behind the Cold Front Conceptual Models

Left of the Col looking across the flow





Cold air in Cold Conveyor Belt (CCB) deep & moist.

Precipitation will be extensive for acceptable radar depiction of the features

Warm Conveyor Belt (WCB) very deep, warm, moist and rising isentropically

CCB approximately horizontal or rising slightly and moving southeastward

CCB backs with strong cold advection

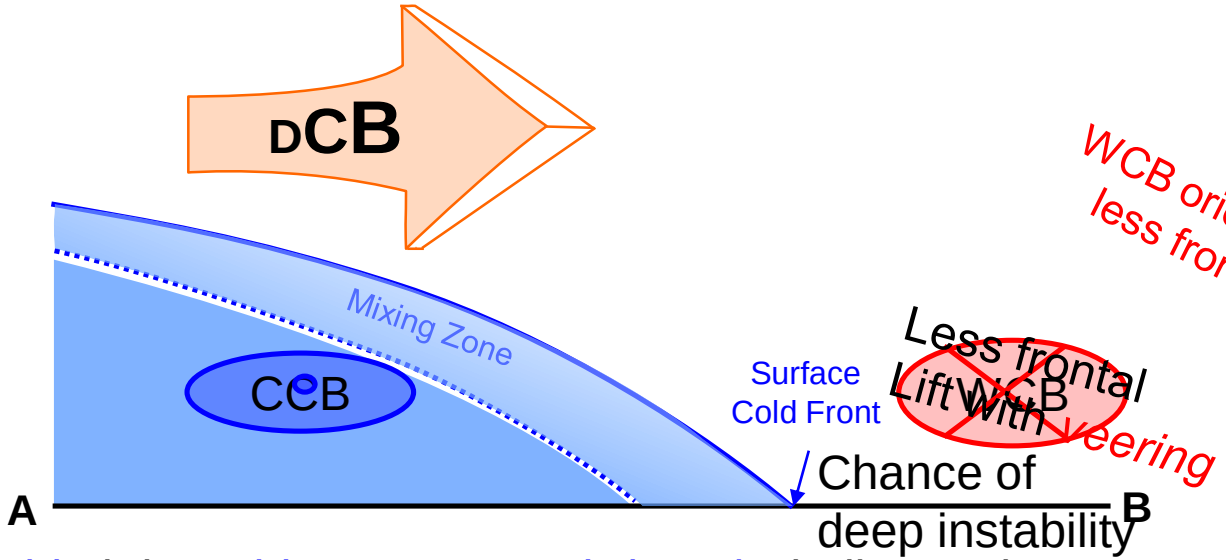
WCB just ahead of cold front backs with significant VWS

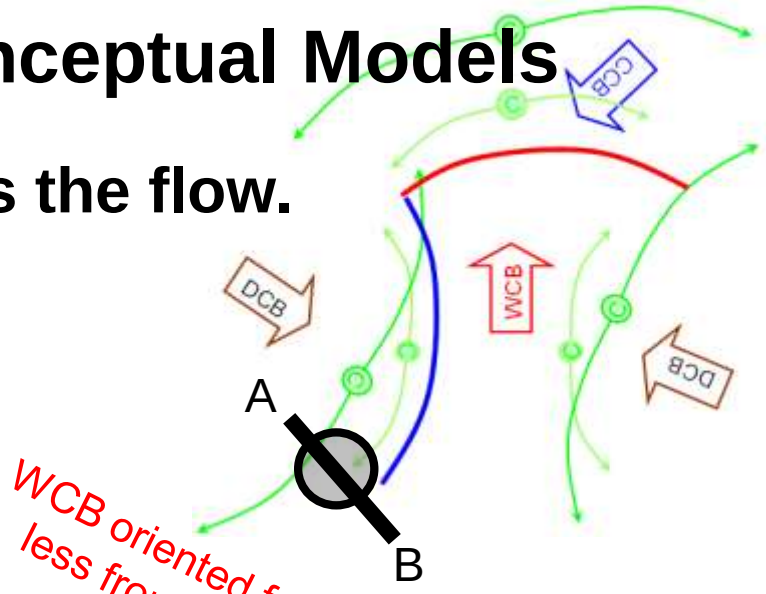
Frontal slope is steeper than the typical 1:50

Significant backing above the frontal zone – **anabatic** cold front

Behind the Cold Front Conceptual Models

Right of the Col looking across the flow.





Cold air in Cold Conveyor Belt (CCB) shallow & dry.

Precipitation will be lacking for radar depiction of the features

Warm Conveyor Belt (WCB) is shallow, warm, moderately moist and rising isentropically

CCB sinks isentropically southwestward

CCB veers with height consistent with weakening cold advection ~ warm advection

WCB just ahead of cold front also typically veers with height

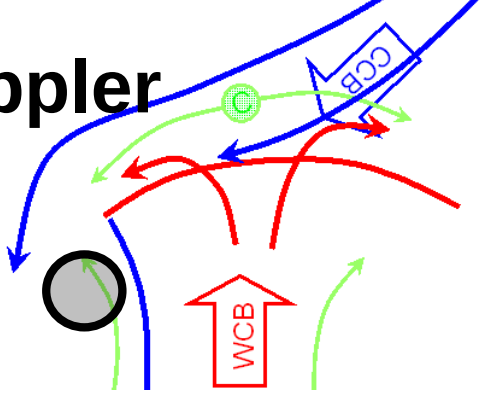
Frontal slope is more shallow than the typical 1:50

Veering winds above the frontal zone indicative of **katabatic** cold front *Cold Fronts* 49 ***End***

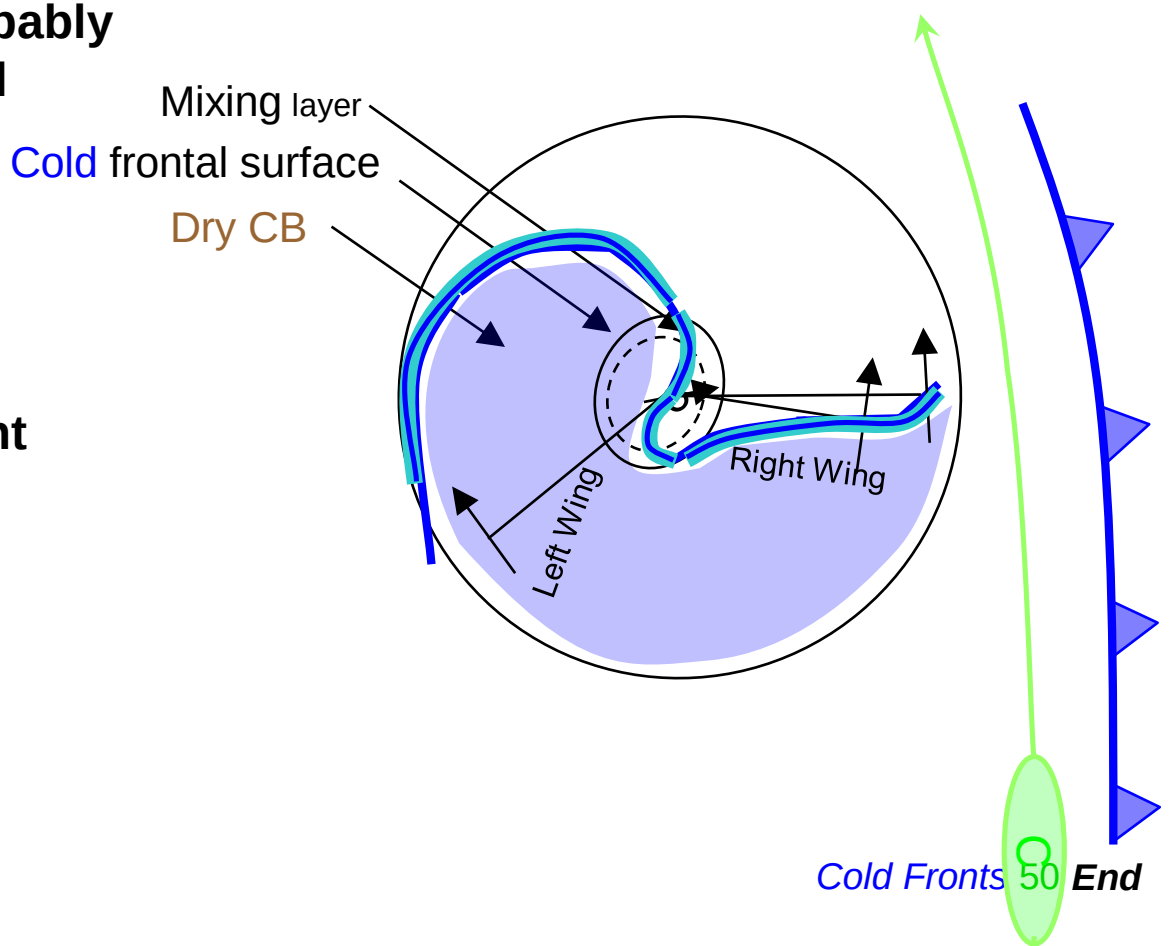
DCB to the Left of the Col - Doppler

The Cold Left Wing Climb Conceptual Model

- DCB in dry slot is typically ascending and backing
- Steeper frontal slope will be evident.



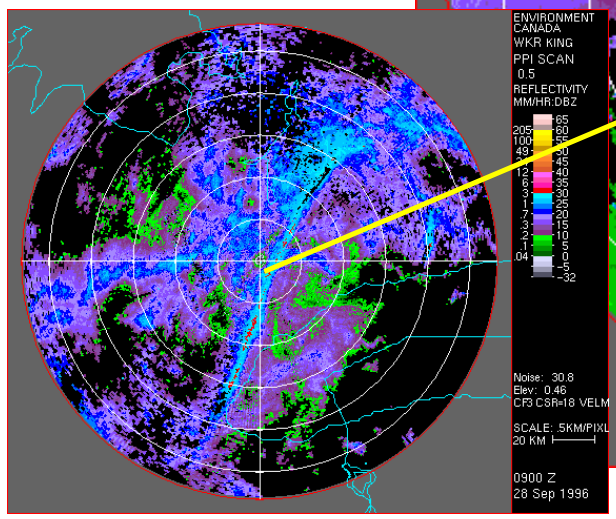
Within the CCB – Cold Advection:
•Cold advection backing probably overpowers the Ekman spiral veering. Beaked eagle.

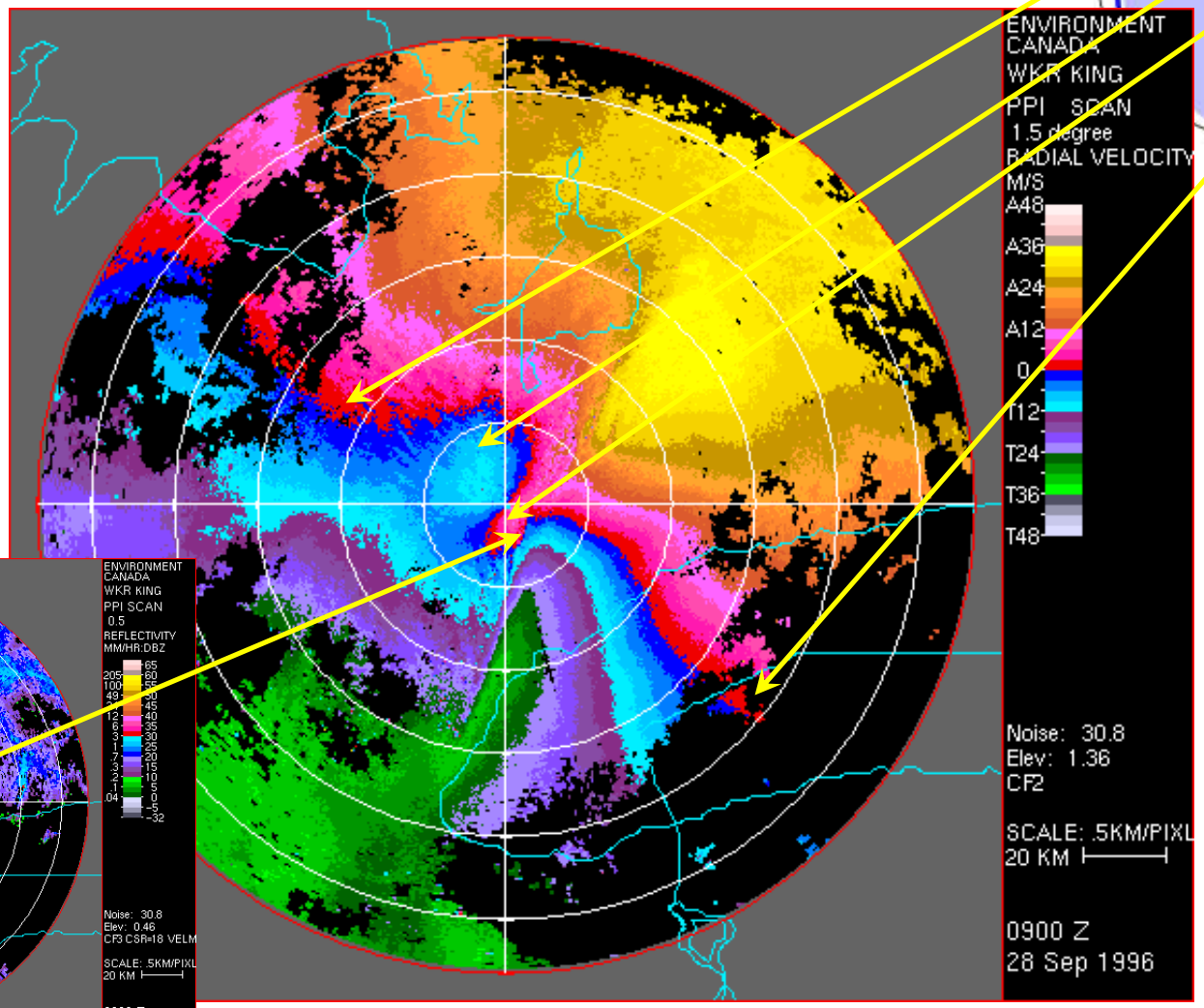


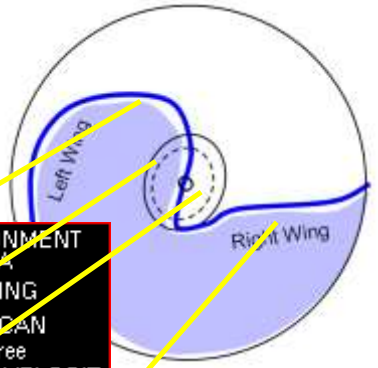
Within the DCB:
•West of radar backing, cold advection, Anabatic cold front
•East of radar nil VWS or possibly weaker backing

The Cold Left Wing Climb CM

This cold front is oriented NNE-SSW. **Anabatic !**

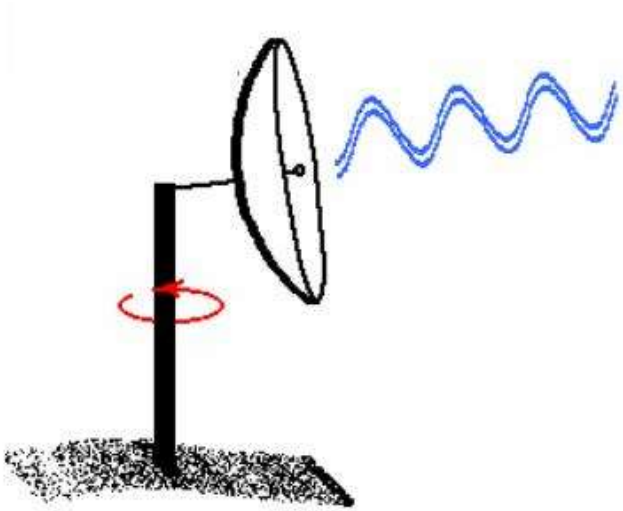






Cold Fronts - Outline

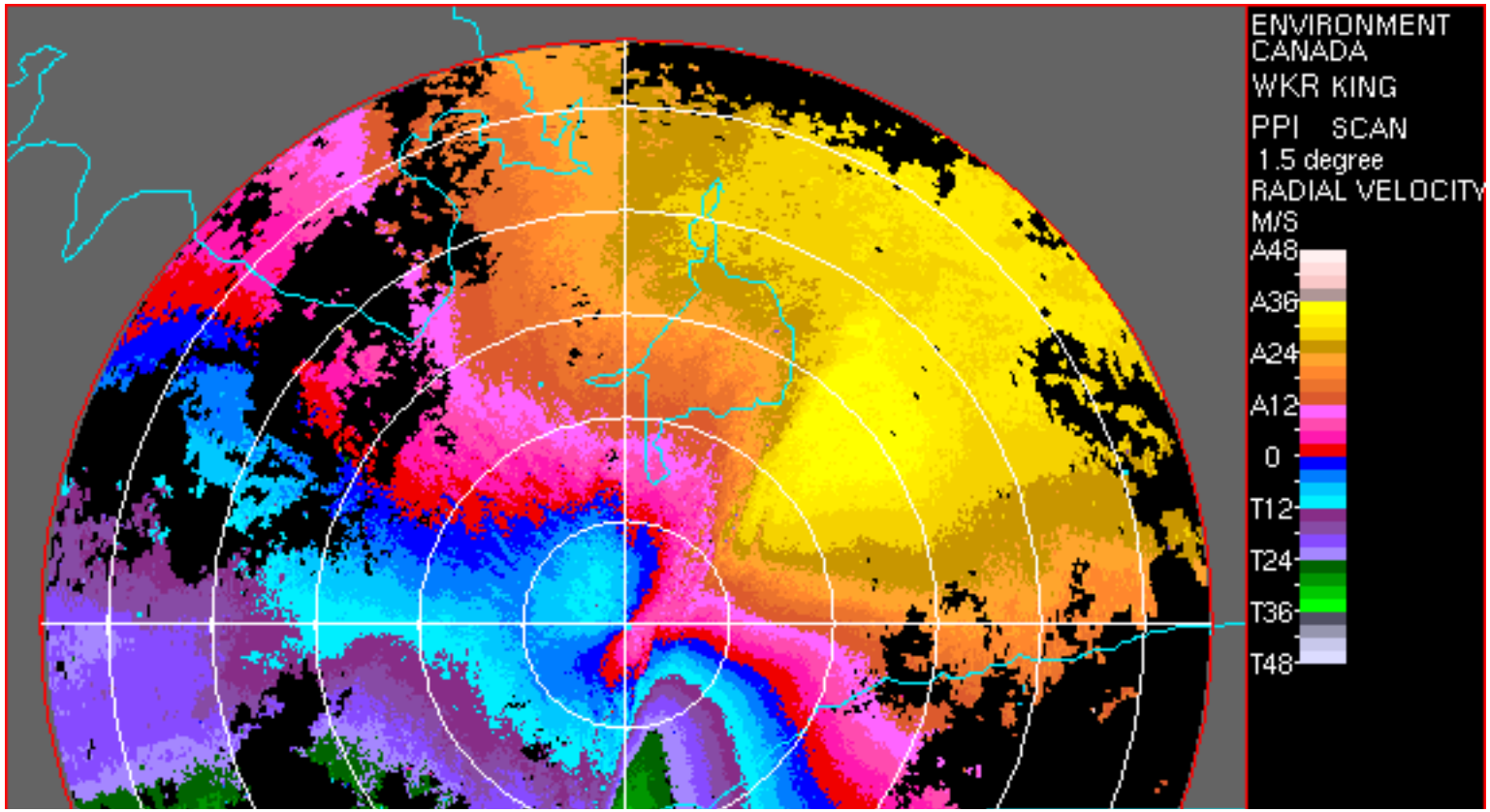
- Cold Front Basics
- Conceptual Models
- Conventional Radar Signatures
- Doppler Signatures
- Conveyor Belt Conceptual Model (CBCM)
- Summary



Thank you for your attention!
Remote sensing is your Friend!

Take Home Message (THM):
Radar is useful to analyze and diagnosis cold fronts … *Doppler* is tricky!

Radar Analysis and Diagnosis of Cold Fronts



One Final Take Home Message (THM):

Expect any **cyclonic**, **backing** flow to be **anabatic**.

Expect any **anticyclonic**, **veering** flow to be **katabatic**.

Southerly flows typically rise isentropically.

Northerly flows typically sink isentropically.