Synoptic Meteorology Lab 8
Due date: Wed 6 May 2015

Potential symmetric instability (PSI)

You are expected to be familiar with the Meted modules by Jim Moore on

- "frontogenetical circulations and stability" (http://www.meted.ucar.edu/norlat/frontal_stability/). T*his module nicely links static stability, frontogenetical ascent, and jet dynamics.*
- "heavy banded snow" (http://www.meted.ucar.edu/norlat/bandedsnow/). *This is a nice a survey of conveyor belts, trowal, and symmetric instability.*

We again use **gdcross**, as in Lab 7. The purpose is to find a cross section which contains a region with symmetric instability (SI). Dry SI does not happen in nature, at least not over a substantial depth, so we look at PSI, which can only be released if latent heat is released. A region where θ_e lines are steeper than M lines (in a 2D analysis), or where EPV<0 (in a 3D analysis) is potentially symmetrically unstable.

We will look for PSI for the same time as usual (the 20 December 2012 case study). Even though this is a mid-winter case, PSI and slantwise convection may be present.

Rather than being told which end points to use in CXSTNS in **gdcross**, you have to select it. Pick a cross section where you expect PSI to be present. You can simply argue "I think that this is a good cross section", but your guess will be more educated if you use some background knowledge, and you pre-examine your winter storm.

Background knowledge: as discussed in J. Moore's webcast, the keys are strong baroclinicity, a strong jet aloft, high humidity, and low stability (but no upright potential instability). J. Moore, in his module "heavy banded snow" (section 3 page 4), refers to a possible suitable location, i.e. near the trowal, as shown by Nicosia and Grumm (1999). More recent work by Rauber et al (2014, in JAS, titled "Stability and charging characteristics of the comma head region of continental winter cyclones") confirms this, in fact they find that the symmetric ascent sometimes leads to potential instability release. The Wyoming Cloud Radar captured this release in fine details, as you can read in Rauber et al. (2014) and in related papers (Rosenow et al. 2014 in JAS, Plummer et al. 2014, 2015 both in JAS). I do not know whether PSI was present in the 20 Dec 2012 storm, nor whether it is resolved in your WRF simulation, and I look forward to seeing your finding.

Pre-examination: examine some maps, either created for previous labs (same time, 12 Z on 20 Dec 2012) or specifically created for this assignment, using **gdplot2**, e.g. the following fields:

- **Map 1**: 300 mb height (contours) and wind speed (color fill): the expectation is that *PSI occurs on the anticyclonic side of the jet* (low inertial stability).
- **Map 2**: 500 mb height (solid contours) plus a potential stability index SUB(THTE@500,THTE@850) (dashed contours): the expectation is that *PSI occurs in a region with low potential stability* (but no instability, i.e. $\theta_{e,500}$ should be slightlylarger than $\theta_{e,850}$). Also show 700 mb RH, which you want to be >80% for PSI to be released. That is, color fill only where RH>80%. GFUNC = RELH (TEMP@700, DWPT@700)

Selecting your cross section: it should be normal to the jet, and long enough to capture the baroclinic zone and part of the more barotropic regions on both sides of it. The end points in CXSTNS can be LAT/LON values, or station identifiers. One way to map station locations is to go to http://www.rap.ucar.edu/weather/surface/java_metars/ , then unclick all real data (just leave "station ID" on), and then you can zoom and pan as needed. It shows all the metar station identifiers. Please add a K in front of the 3 letter ID, e.g. Laramie's ID is KLAR. In the past, some students have picked a cross section across the cold front, other transected the warm front. This is yours to decide. Please show the location of your cross section(s) on the 2 maps listed above.

Cross-sections to produce: please produce the following 4 cross sections using **gdcross,** all at 12 UTC on 20 Dec 2012**.** Make sure to save the gdcross commands as a *.nts file. In general, momentum (U, M…) lines are solid, and temperature (θ ,θ_e …) lines are dashed, but you can use a consistent pair of line colors if you prefer. Also, please limit the vertical extent, we do not need to see the stratosphere, e.g. YAXIS = 950,250,50.

Fig. A1: absolute vorticity AVOR(WND) (color fill or dashed contours) and NORM(WND) isotachs of wind component normal to X-section (>50 kts, 20 kts interval, solid contours)
Fig. A2: NORM(WND) isotachs (>50 kts, 20 kts interval, solid contours), θ lines (isentropes, 5K interval, dashed contours) and frontogenesis function (color fill, only where it is positive)
Fig. A3: lines of constant abs. momentum M (MSFC(WND), use 4 m/s interval, solid contours), θ_e lines (THTE, 5K interval, dashed contours), and equivalent potential vorticity (PVOR(THTE, WND), use color fill only where EPV≤ 0). Note: if you have empty θ_e areas, try GFUNC = thte(pres,tmpc,miss(dwpc,-50))
Fig. A4. RELH (only where RH>80%) and CIRC(WND, MUL(W,-0.1)) as arrows (true wind circulation in this cross section). Better still, remove the frontal motion from WND: VSUB(WND,(u_front,v_front)), where (u_front,v_front) is the frontal motion vector (constant). For instance, if you transect the cold front, and this front moves from the WNW at 18 m/s, use CIRC(VSUB(WND,VECR(17.7,-3.1)),MUL(W,-0.1)). This is similar to the removal of storm motion in Lab 7.

Generate these figures for a single cross section. Examine the results. Now you may want to reposition your cross section somewhat till you find a region of PSI (if any). Make sure to stay roughly normal to the jet.

<u>Questions</u>: (brief answers suffice)
α1. From Fig. A1 and A3 infer whether there is any inertial instability. If there is, highlight the region on the transects A1 and A3, and state the criterion you use. If not, you probably find <u>weak</u> inertial stability on the warm side of the jet. Why? (note: you can do the highlighting / contouring on paper, or else on computer using photoshop or word or powerpoint or adobe illustrator …)
α2. In Fig. A3, contour regions of PSI and PI, if any (PI=potential instability). Again state the criterion you use for both instabilities. Also manually draw in the front as a sloping surface, if there is any front.
α3. If PSI is present, does the model reveal a circulation that is consistent with slantwise convection (rising motion through the PSI region)?
α4. What is the relationship between frontogenesis and PSI in this case? Note that at this coarse resolution, the model output cannot distinguish between a frontogenetic and a slantwise-convective circulation.