NWP and new conceptual models

Meteorology 411 – Iowa State University – Week 13

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Overview of NWP

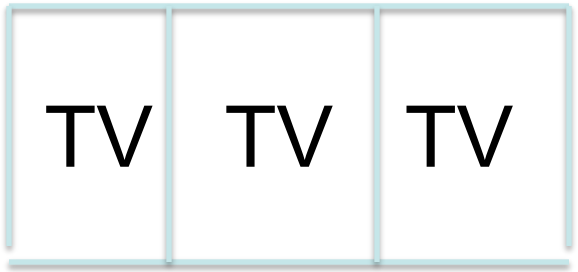
- Laws of physics (like F=ma) can be coded to predict future weather (some approximations are required to represent the laws)

Important considerations for any model

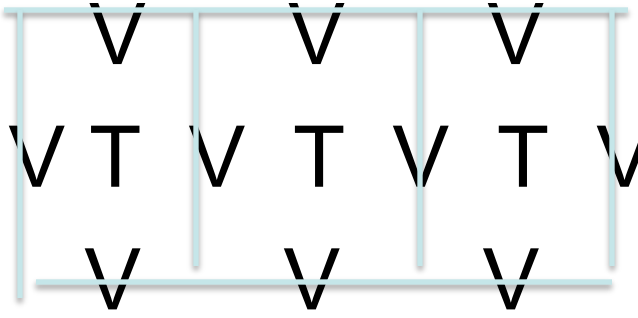
- Grid layout (staggering) and size (both horizontal & vertical) plus domain
- Discretization of equations – how to treat, e.g., dA/dt = -udA/dx (how to solve it?)
- Parameterization of small-scale processes (like convection, microphysics, radiation, land-sfc interaction, turbulence)
- Data assimilation and initialization

Grids

- A systematic layout of grid points is usually needed so that you can solve the equations



or



These are 2 among at least 5 common choices. Any ideas on reasons for these?

Grid spacing/Domain size

- What happens if you only run the model over a piece of the Earth?

-- good thing is it takes less computer power than running over the whole planet

-- bad thing is what do you do on the edges since most equations have terms involving things like dA/dx or dA/dy?

Trade-off

- Global models (like GFS, ECMWF) run over the whole planet and thus are able to predict what will happen over the whole planet. But, this means they must use coarser (bigger) grid boxes, like 23 km for GFS and 13 km for ECMWF

Trade-off

- Regional models only do a piece of the earth and can use finer grid spacing (NAM is 12 km, HRRR is 3 km), but they need to "steal" predictions at the edge of their domains, and thus their forecasts can be influenced by the "other" model (NAM uses GFS), and they likely do not do as well as time goes beyond 2-3 days.

Discretization

- If you have dA/dt = -uDT/dx, how do you solve it in a model?
- There are multiple options, such as centered finite differences, or one-sided differences. A mixture of these are often used.
- E.g., $A(t=2) = A(t=1) - \Delta t[u(t=1)\{T(t=1,x=i+1) - T(t=1,x=i-1)\}/2\Delta x]$

Parameterizations

- These are really “Black Boxes” and many different ones exist for the same atmospheric process
- Which ones work best or are needed at all depend on the grid spacing
- If $\Delta x < 8$ km or so, no need for a convective parameterization, but otherwise yes, and this makes a huge impact on the precipitation forecast

Parameterizations

- Most of the weather the public cares about happens near the ground, and unfortunately that means parameters like wind, temperature and dew point are very sensitive to the land-surface and boundary layer parameterizations
- Because it is very hard to get these processes right, MOS (which uses statistics to correct model problems) is usually much better than using model data raw

Most commonly used American models

- RAP – very short range (0-18 h), updated hourly, 13km grid, 50 levels, see rapidrefresh.noaa.gov
- HRRR – super high resolution (0-15 h), updated hourly, 3 km grid.
- NAM – short range (0-84 h), updated every 6 h, 12 km grid, see http://www.emc.ncep.noaa.gov/index.php?branch=NAM
- GFS – long range (0-384 h), updated every 6 h, 23 km grid (soon 13 km), 64 levels, see http://www.emc.ncep.noaa.gov/index.php?branch=GFS

Ensembles

- Research has proven there is no single best way to design a model, so that it always makes the best forecast
- Thus, an ensemble (a collection of many different model runs) tends to work best at predicting things, especially farther out in time, but it won't help you to tell the public ONE EXACT scenario. Instead, it will give you probability information and confidence information

Ensemble designs

- Perturbed Initial and Boundary Conditions – most common type of ensemble used operationally. You basically run X versions of the same model but with X slightly different starting scenarios. Each member should be equally likely to happen, and probability information should be very good. If 70 of 100 member predictions show rain in Ames, forecast a 70% chance.

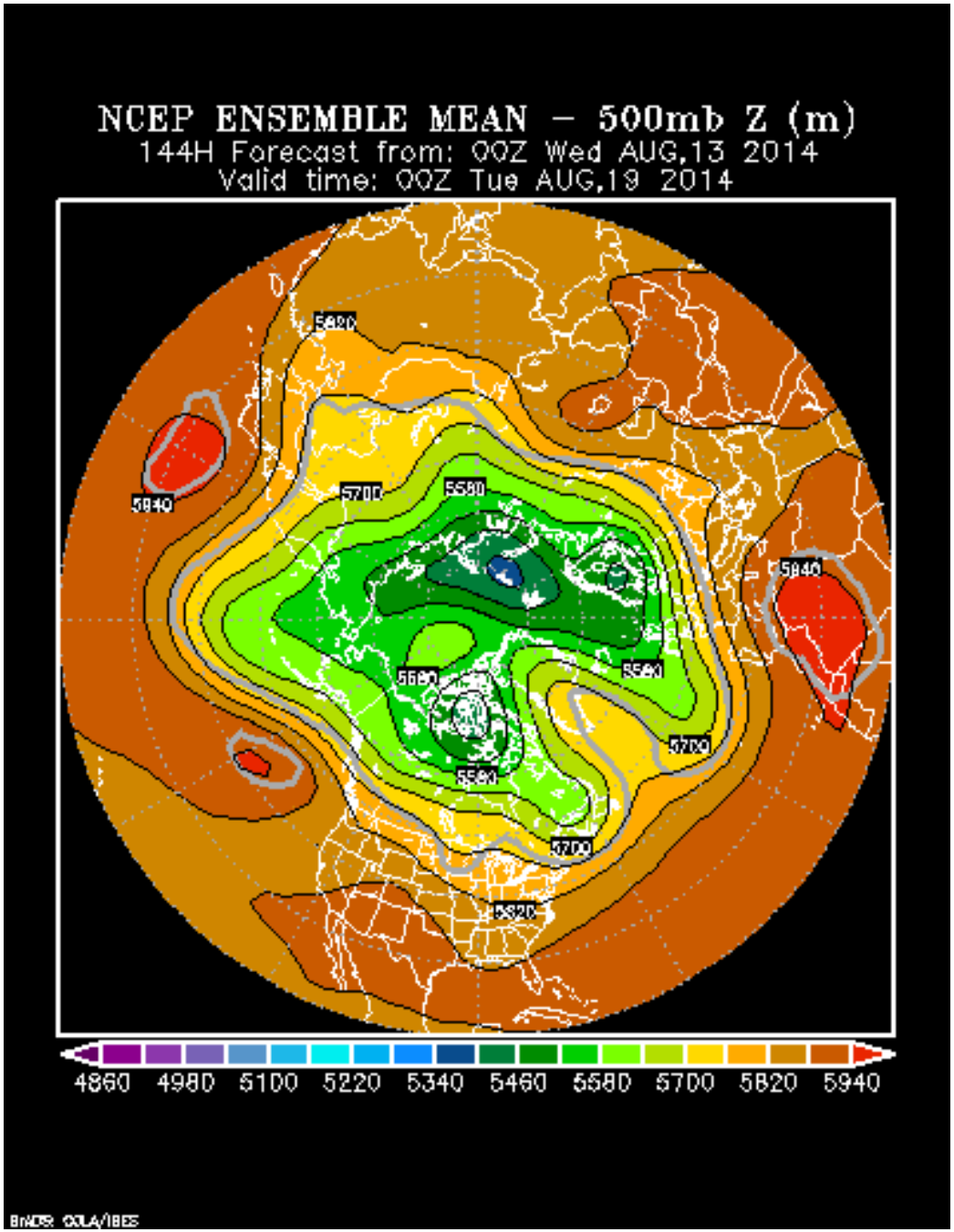
- Can also create an ensemble using different models or different parameterizations. These are sometimes called “a poor man’s ensemble”. Since it is likely some parameterizations or models are more accurate than others, this may not give the best probability information, but often it gives more variety (spread) than the other method, and thus what really happens is more likely to fall within that range of ensemble members.

NCEP Operational Ensembles

- SREF (short-range), 16 km grid (about to be 12 km), out 84 hours (21 members)
- GEFS (long range), 55 km grid (soon 35 km), out 384 hours (21 members)

Ways to convey ensemble forecast information

- Mean
- Probability charts
- Spaghetti charts
- Spread measures (variance)
- Postage stamps (see each member)


NCEP ENSEMBLE MEAN - 500mb Z (m)
144H Forecast from: 00Z Wed AUG,13 2014
Valid time: 00Z Tue AUG,19 2014
5820
5940
5700
5580
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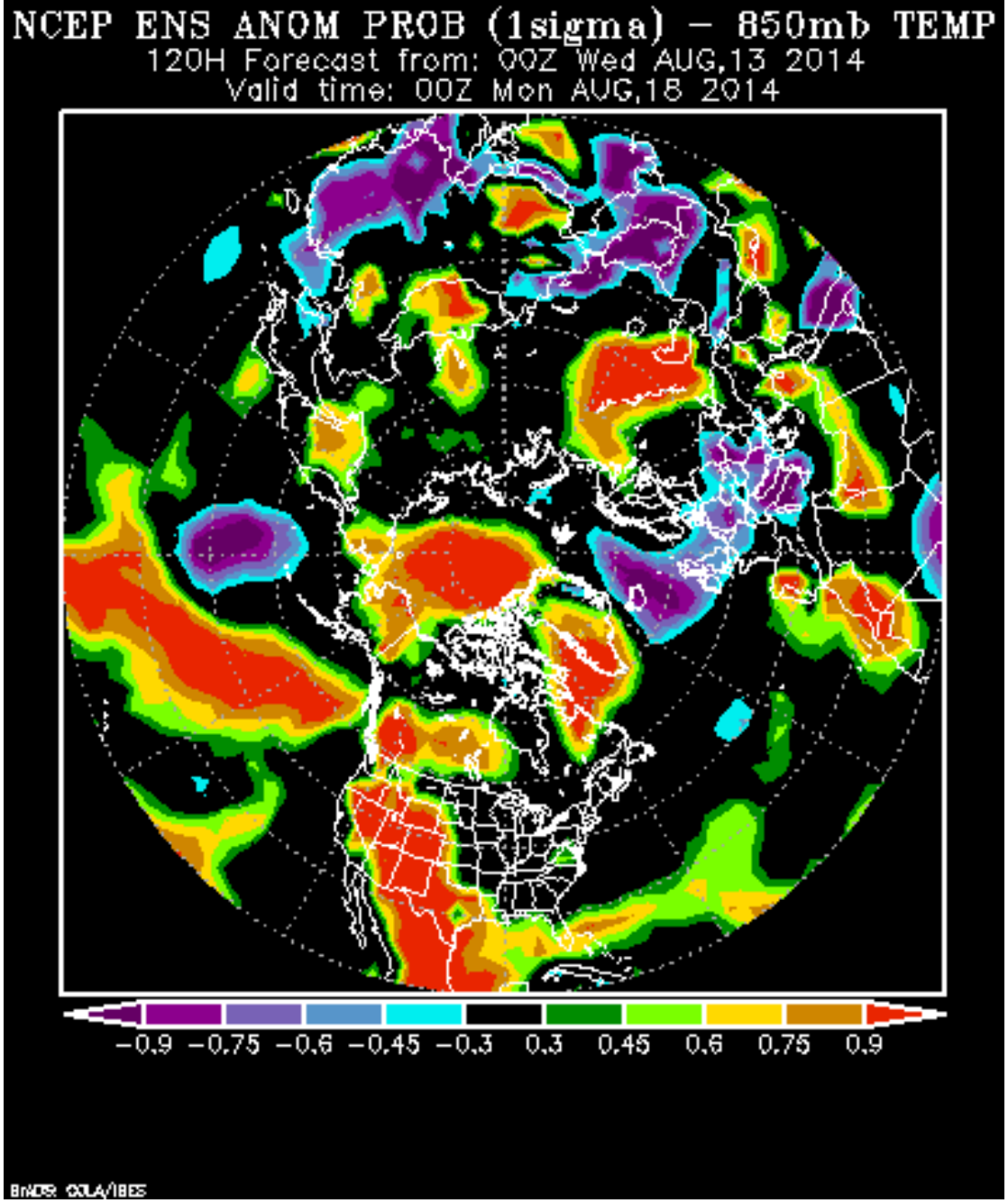
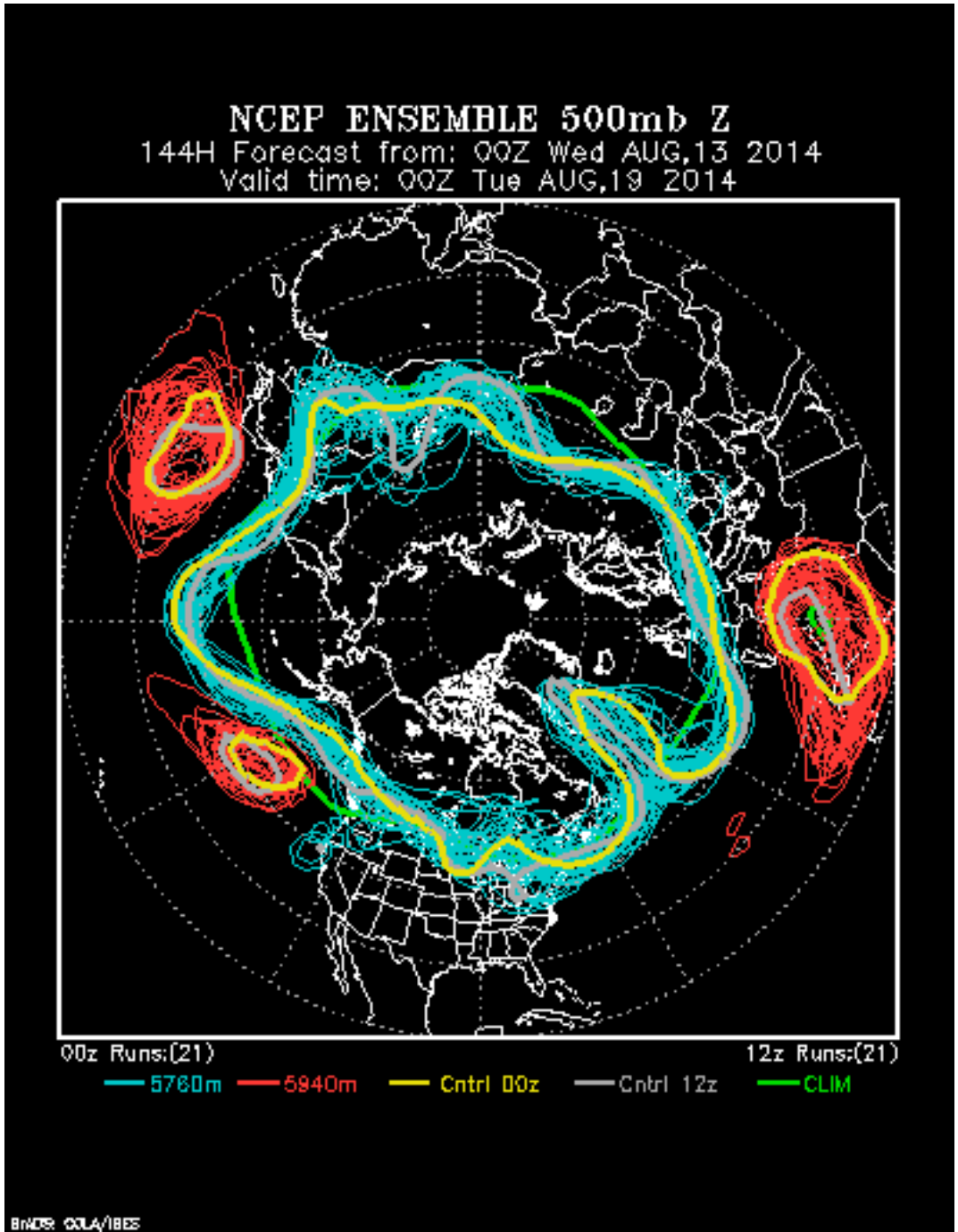
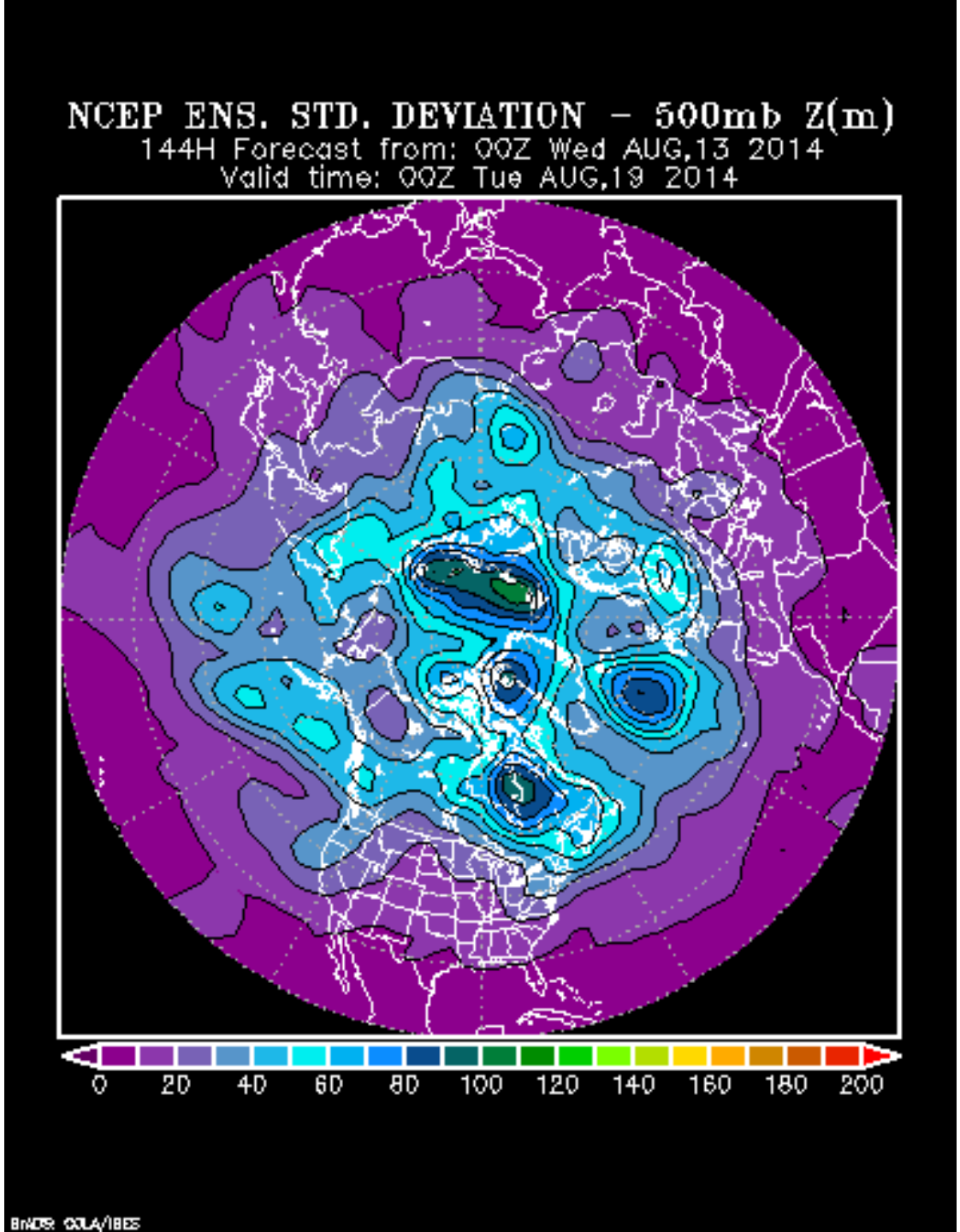
BrNOS: COLA/IBES


NCEP ENS ANOM PROB (1sigma) - 850mb TEMP
120H Forecast from: 00Z Wed AUG,13 2014
Valid time: 00Z Mon AUG,18 2014
-0.9 -0.75 -0.6 -0.45 -0.3 0.3 0.45 0.6 0.75 0.9
BNOS: GOLA/IBES


NCEP ENSEMBLE 500mb Z
144H Forecast from: 00Z Wed AUG,13 2014
Valid time: 00Z Tue AUG,19 2014
00z Runs:(21)
12z Runs:(21)
5760m
5940m
Cntrl 00z
Cntrl 12z
CLIM
BASED ON ECMWF/IBES


NCEP ENS. STD. DEVIATION - 500mb Z(m)
144H Forecast from: 00Z Wed AUG,13 2014
Valid time: 00Z Tue AUG,19 2014
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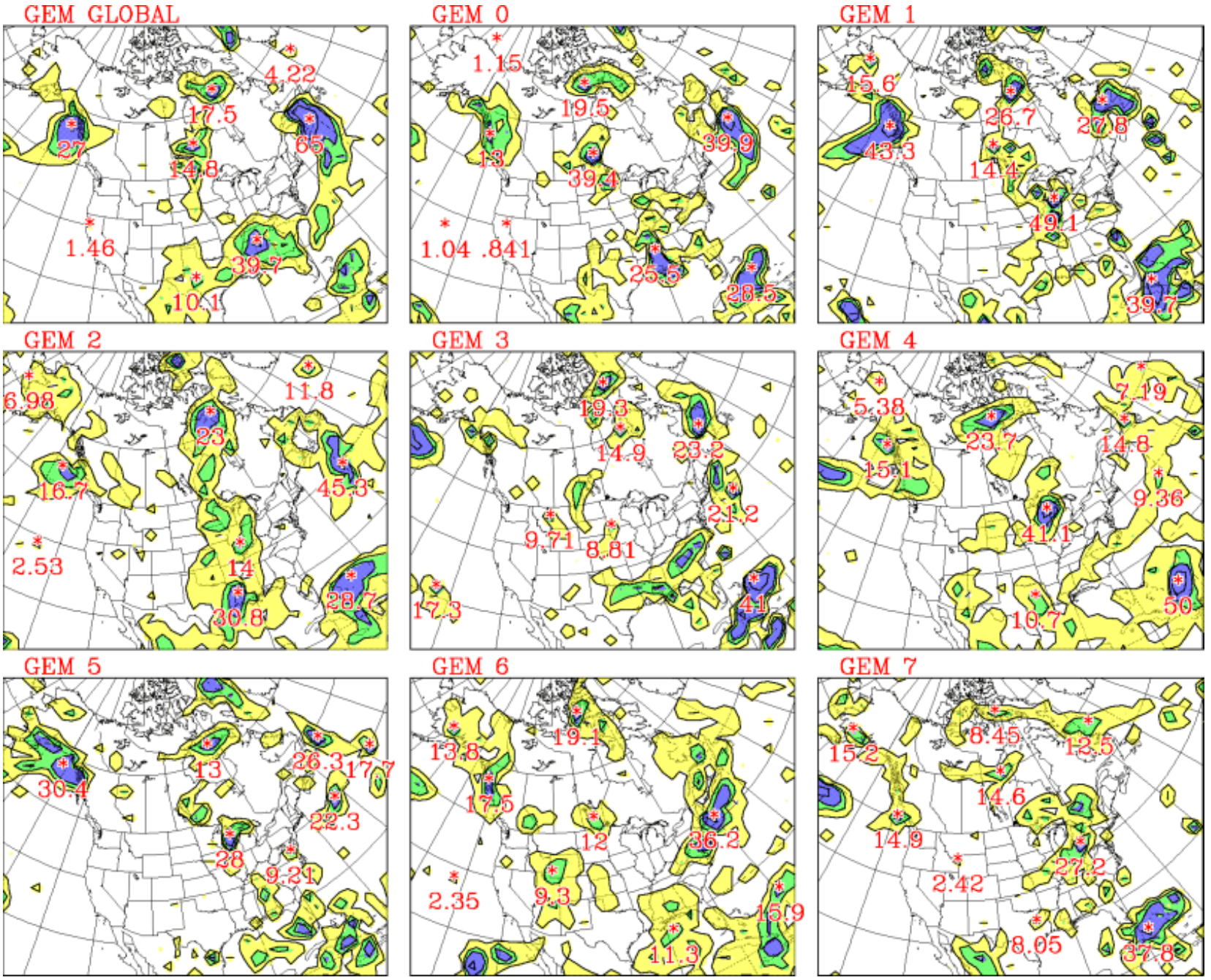
160
180
200
BNDS: COLA/IBES

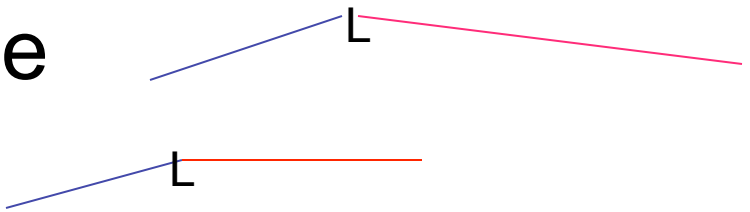

GEM GLOBAL
4.22
17.5
27
65
14.8
1.46
39.7
10.1
GEM 0
1.15
19.5
39.9
13
39.4
1.04
.841
25.5
28.5
GEM 1
15.6
26.7
27.8
43.3
14.4
49.1
39.7
GEM 2
6.98
11.8
23
16.7
45.3
2.53
14
28.7
30.8
GEM 3
19.3
14.9
23.2
21.2
9.71
8.81
17.3
41
GEM 4
5.38
7.19
23.7
14.8
15.1
9.36
41.1
10.7
50
GEM 5
26.3
17.7
13
30.4
22.3
28
9.21
GEM 6
19.1
13.8
17.5
12
36.2
2.35
9.3
15.9
11.3
GEM 7
8.45
12.5
15.2
14.6
14.9
27.2
2.42
8.05
37.8

New conceptual models: T-bone model

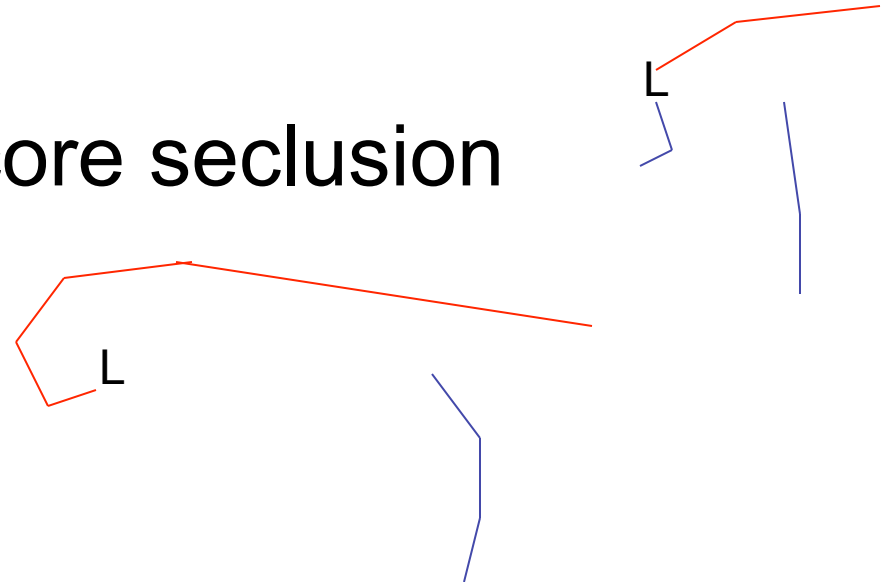
- Developed from special data collection project (GALE) off east coast, and may be most appropriate for big Nor'Easters
- Consists of 4 stages that have been observed in sfc data, suggested in satellite data, and even found in models

T-Bone model

- 1) Incipient frontal cyclone
- 2) Frontal Fracture



- 3) frontal T-bone and bent-back warm front
- 4) warm core seclusion

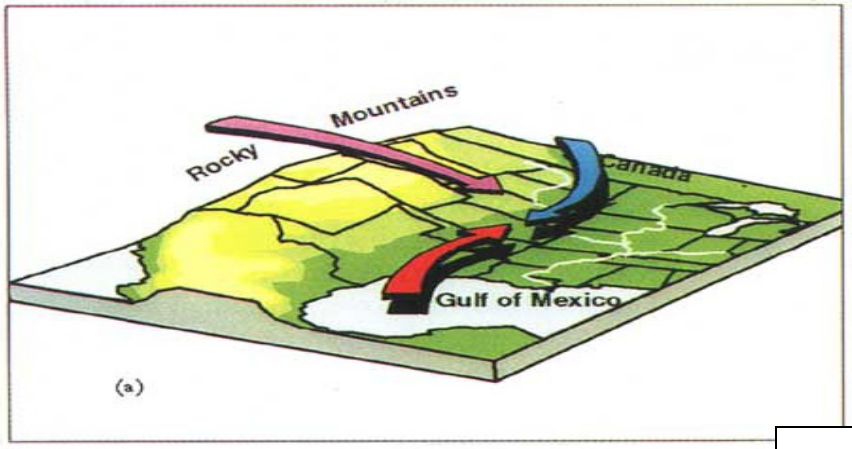


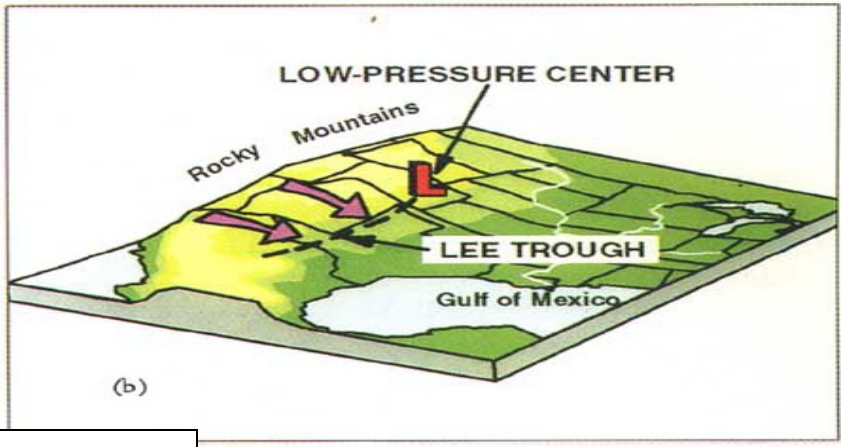
Warm Core Seclusion

- Seclusion was found to contain warm air surrounding low – kind of like a warm core, or tropical low.
- This air is warm not because of latent heat release but because the cold air that swirled around low pretty much missed this region, so it still contains warm air present before storm system really developed
- Sometimes, an eye-like feature is found in satellite images near this seclusion, but that seems to be more a coincidence and not related to any dynamics in the low

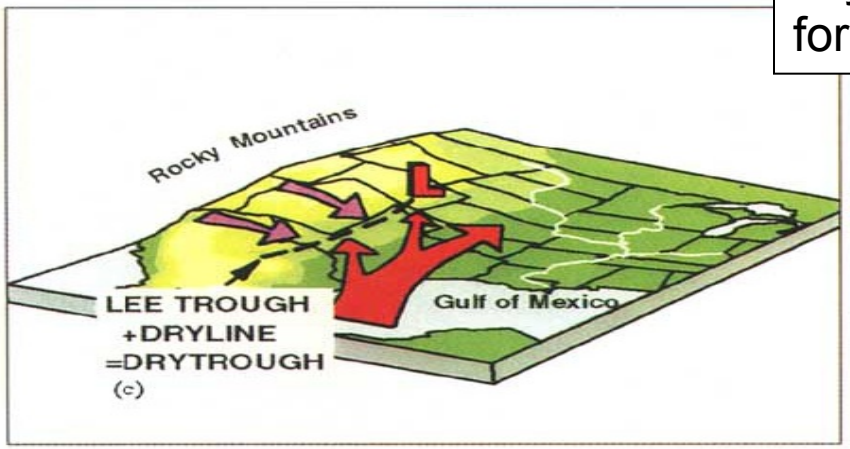
New Model for central US: Dry Trof/Cold Front Aloft

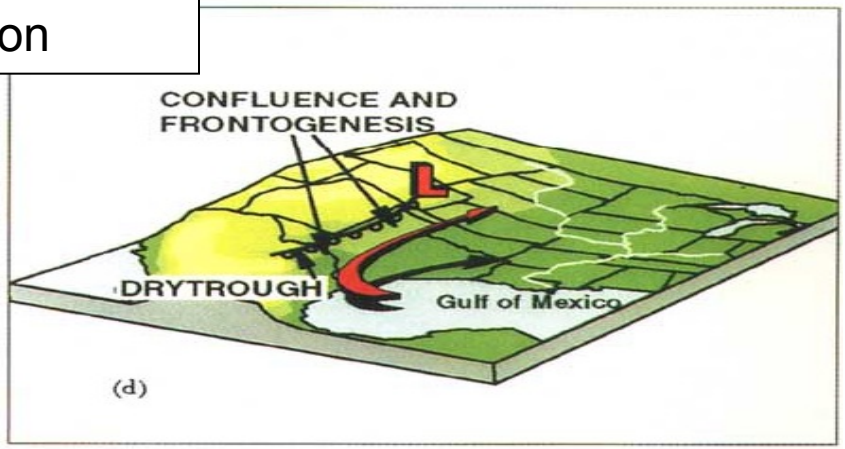
- 1) Short wave leads to dry trof
- 2) Acts like a warm front with overrunning of dry air above moist air which creates potential instability. Saturation is first reached at leading edge where lift has been greatest, and this forms pre-dry-trof rainband
- 3) Little precipitation is ahead of Arctic front due to lack of moisture
- 4) Cold Front Aloft advances out and produces rainband.

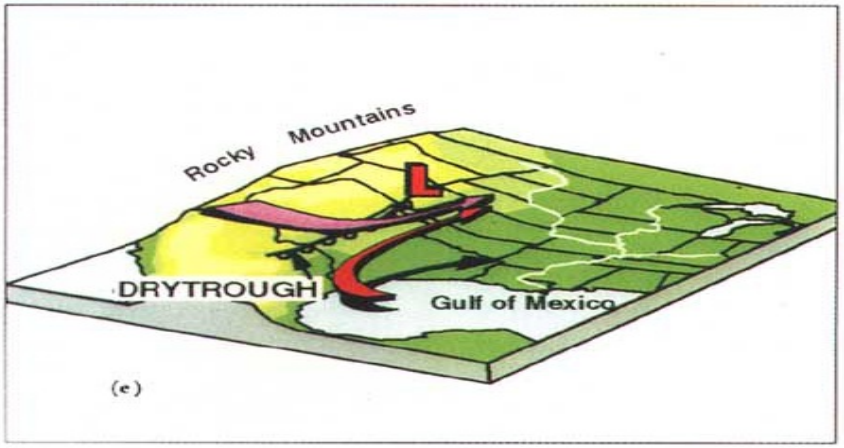


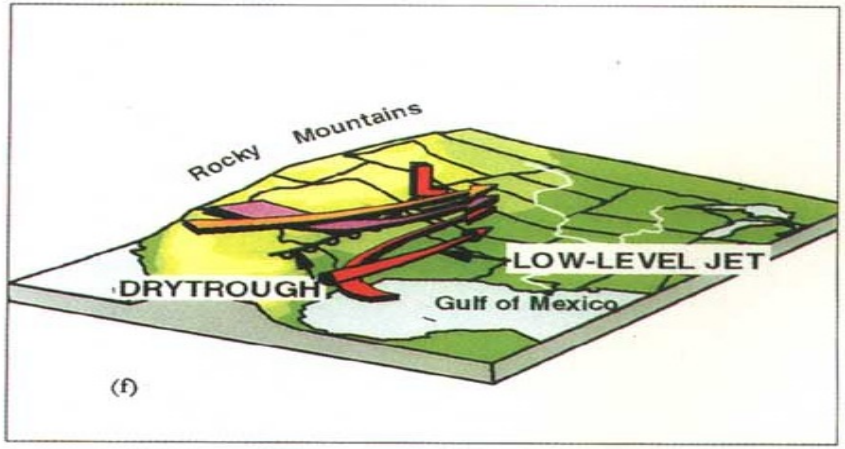


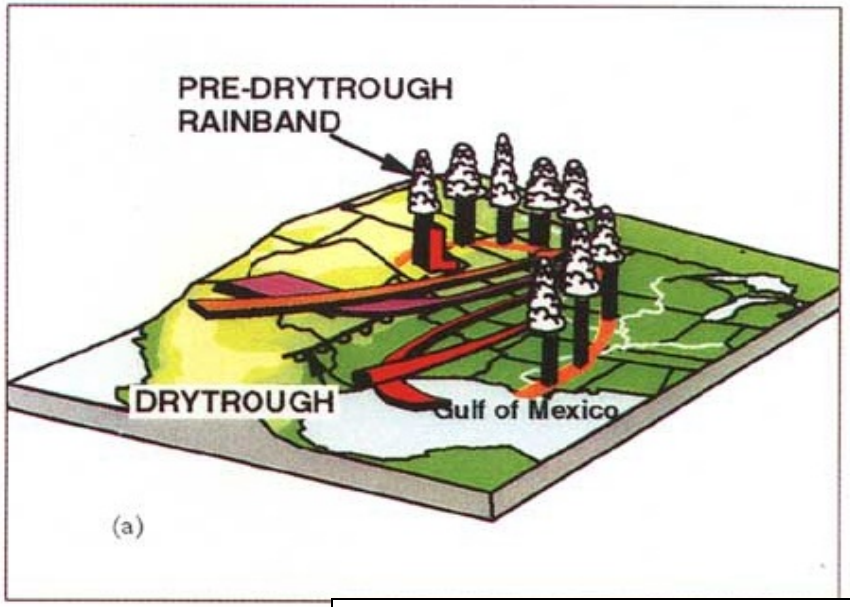
Dry Trof formation

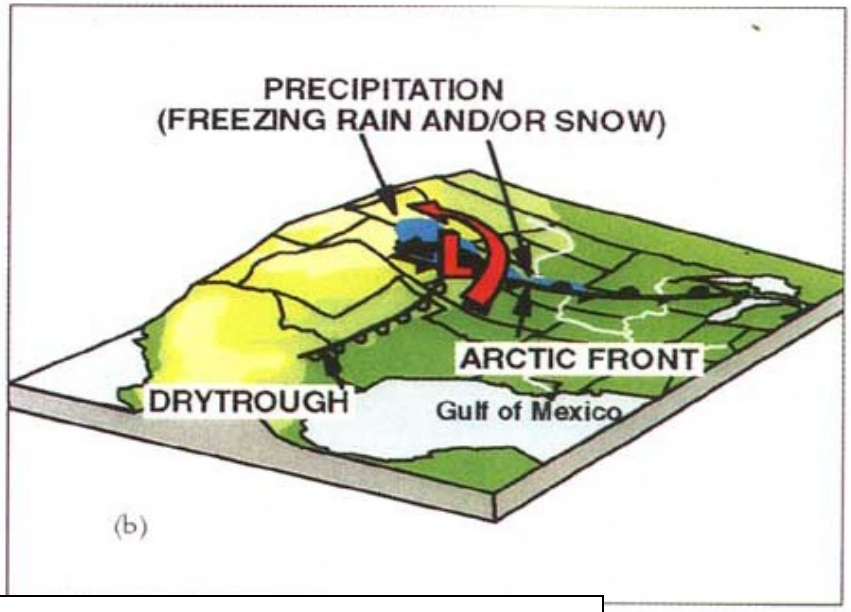




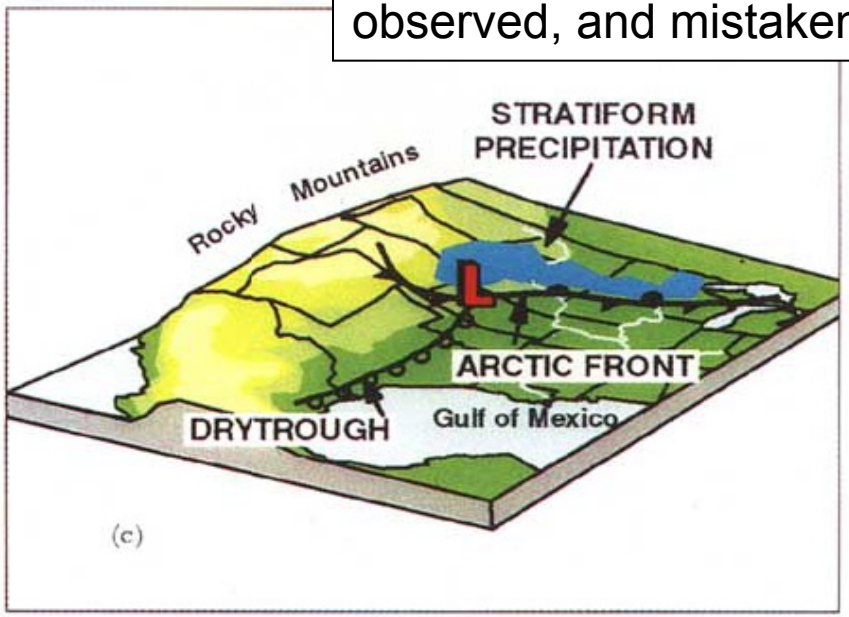


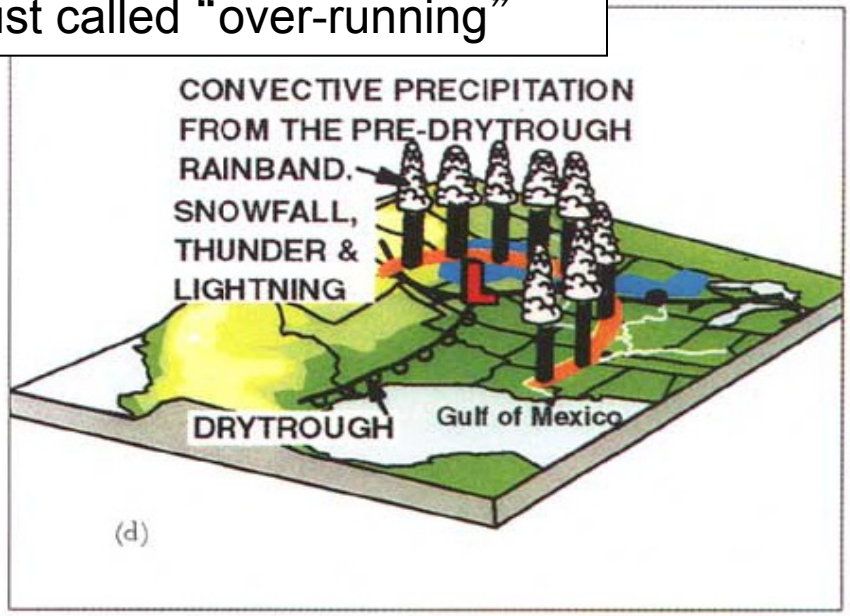




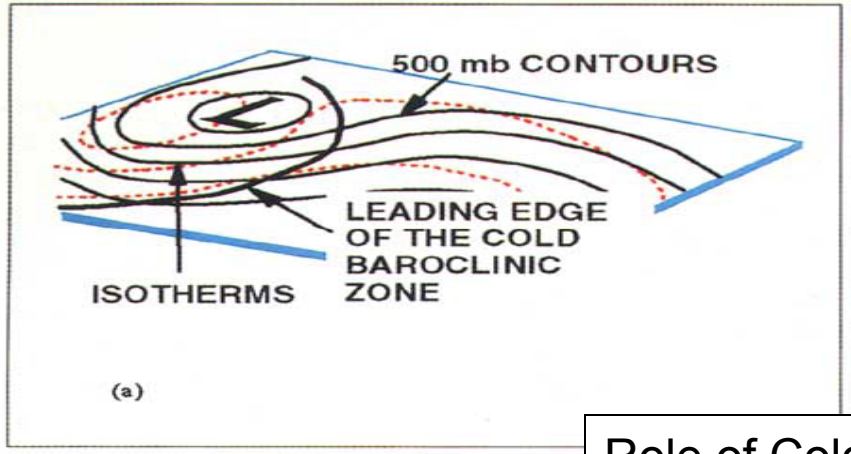


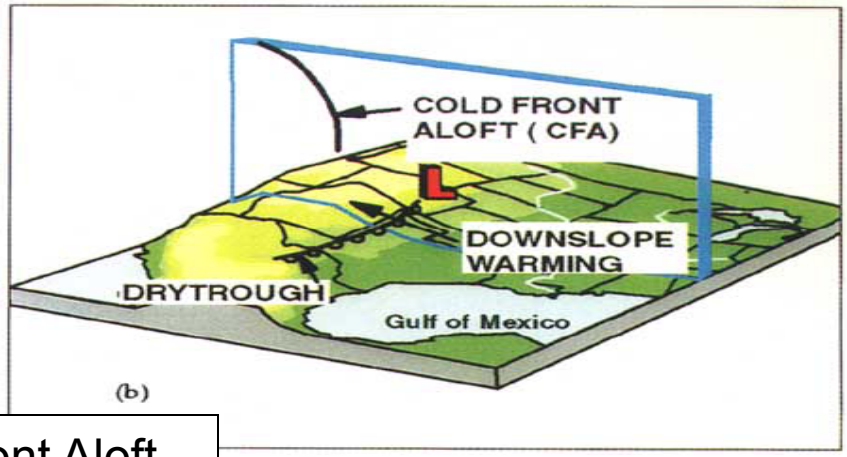
Role of Dry Trof in creating band of precip often observed, and mistakenly just called “over-running”

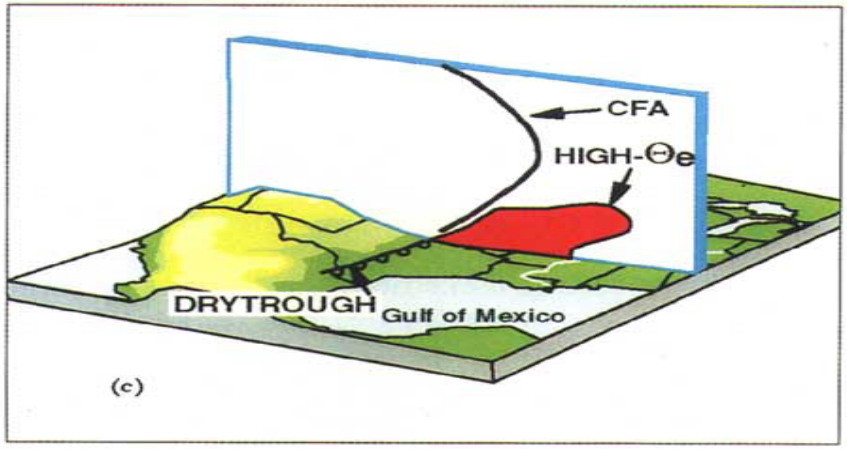


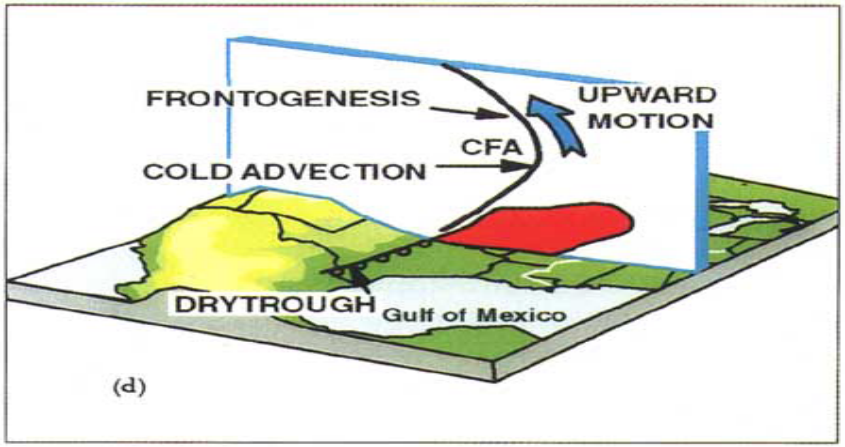


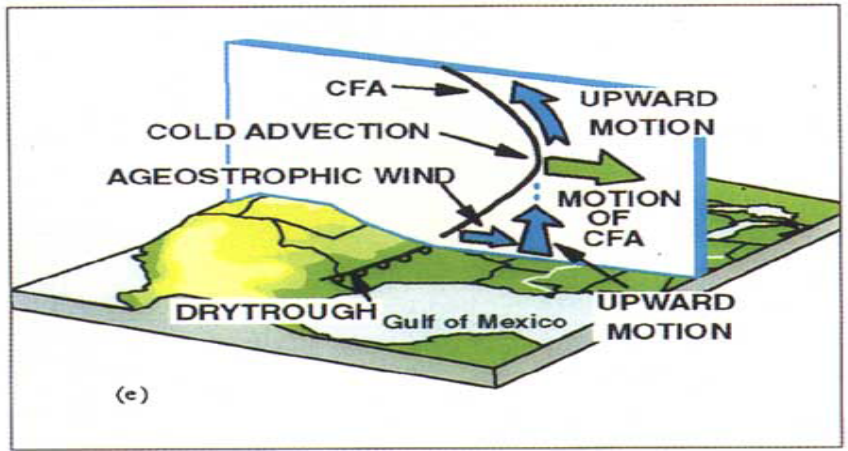
Role of Cold Front Aloft

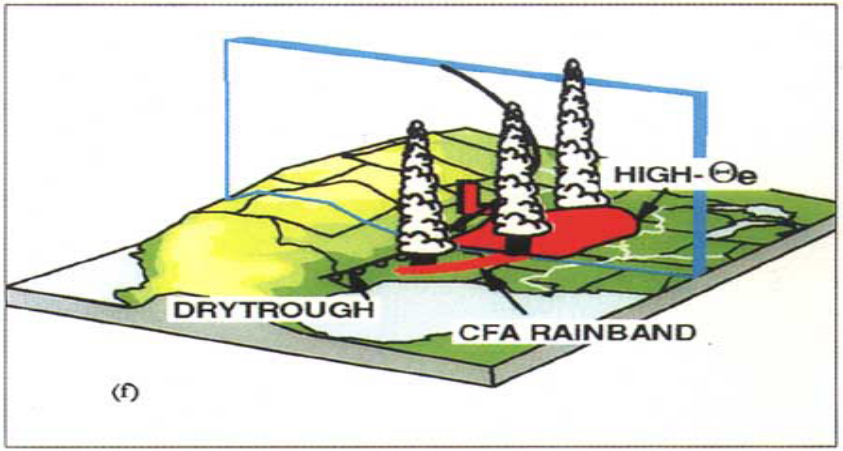




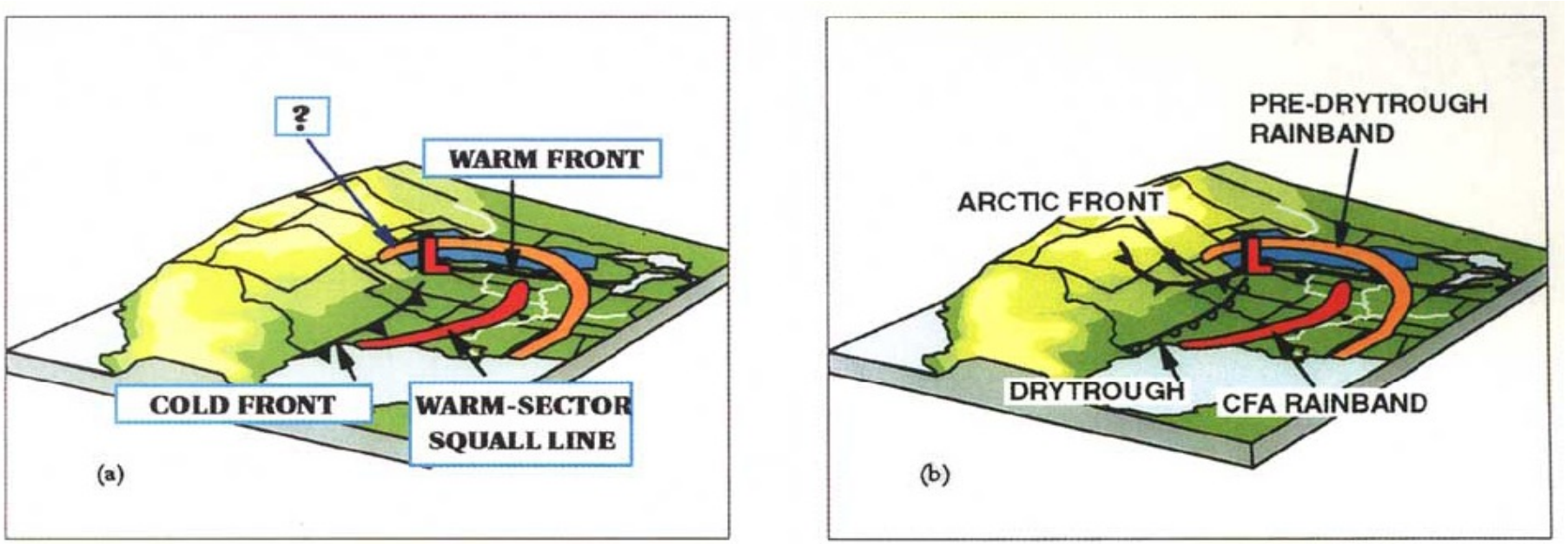








Contrast of Norwegian Cyclone model interpretation (e.g., some precip is just from overrunning of warm front, while squall line is just the remains of precip that formed along the cold front and then raced out ahead faster than the front) with….



New model approach which explains precip as being due to pre-drytrof rainband and the cold front aloft position. Note the old NCM forced us to call the thing in Texas a cold front even though temps really didn't differ across it. We now see it is a dry trof, and show the arctic front back where the real temperature gradient is.