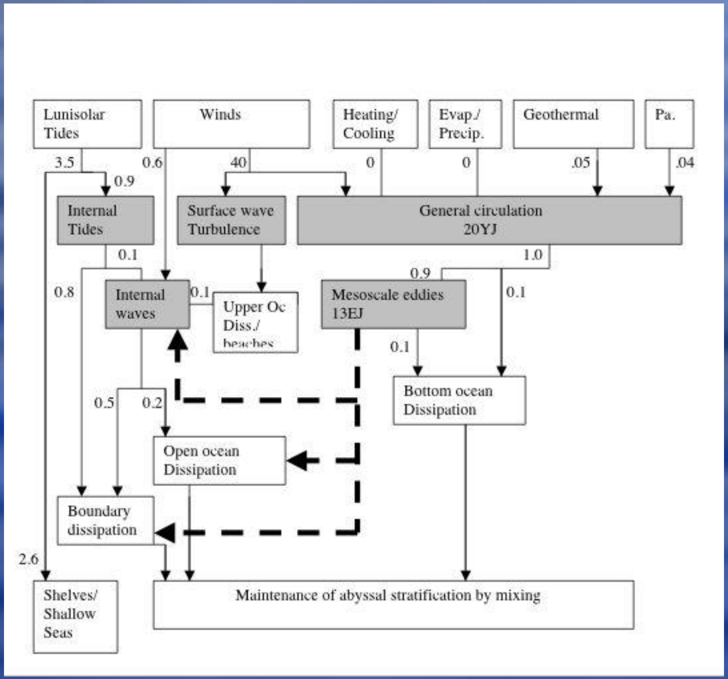
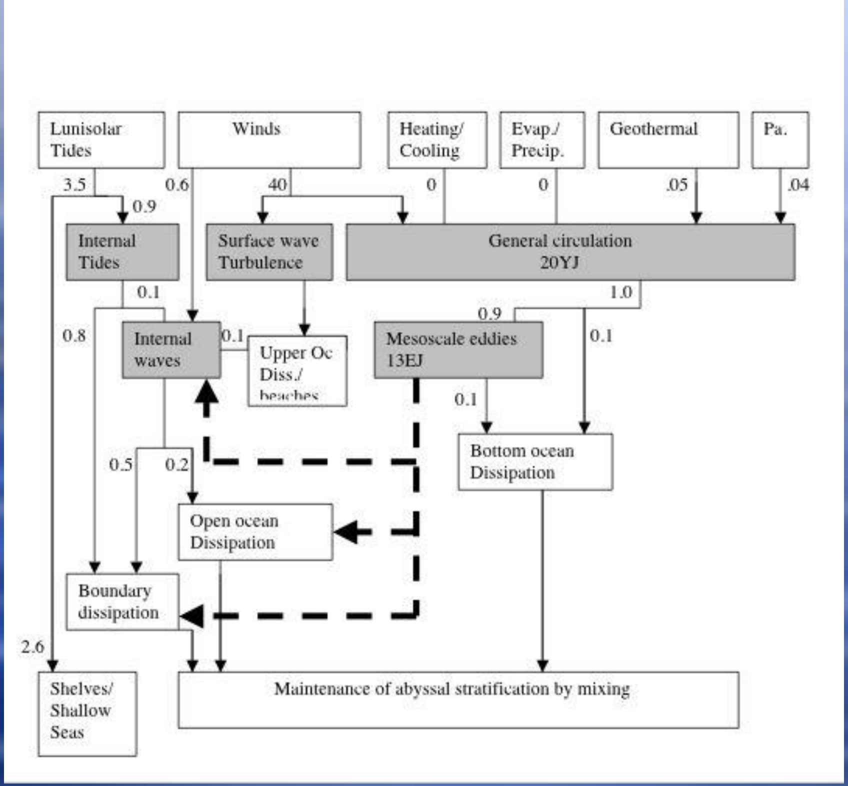
Inviscid Dissipation in Ocean Climate Models

FCI Seminar

March 24, 2011



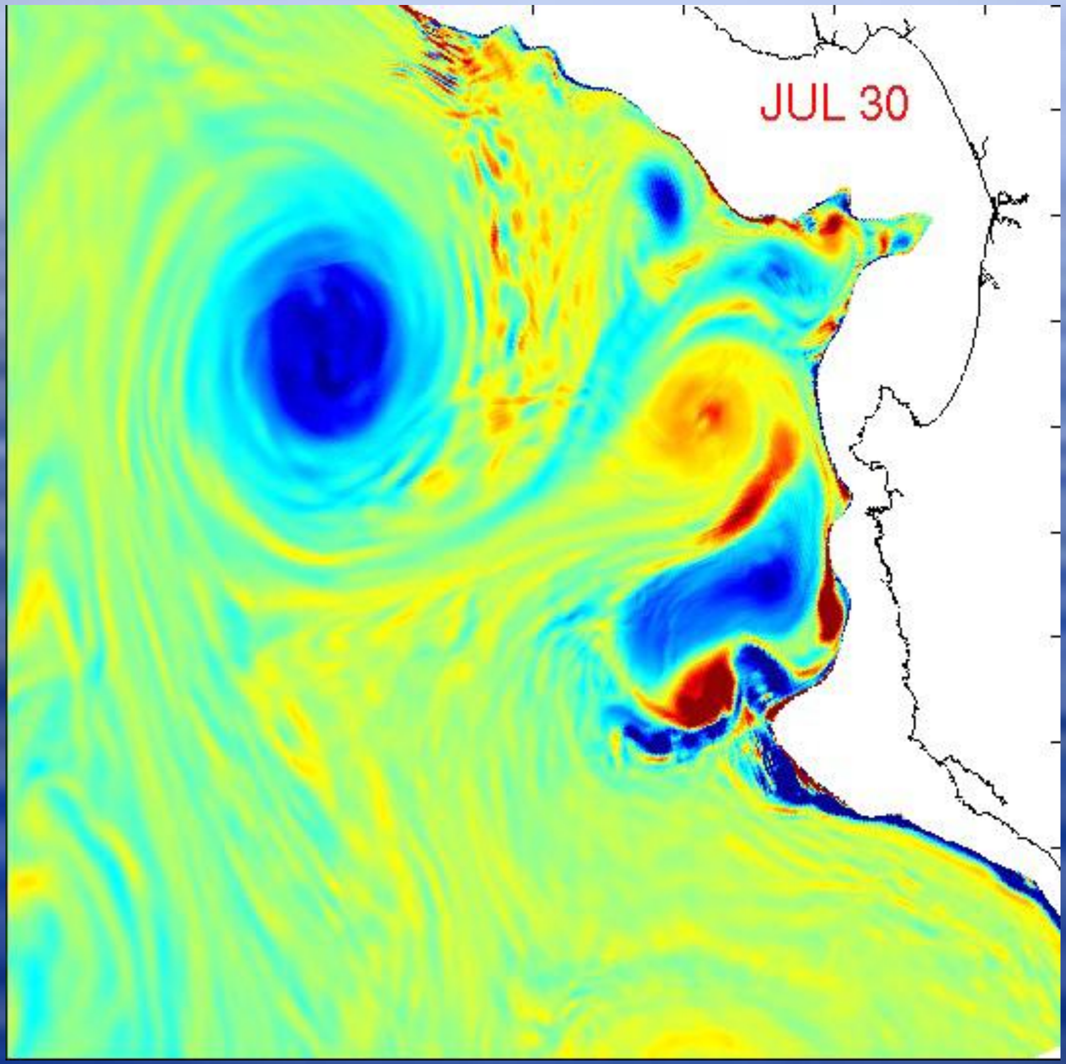
An analysis of ocean power, after Wunsch and Ferrari, 2004.

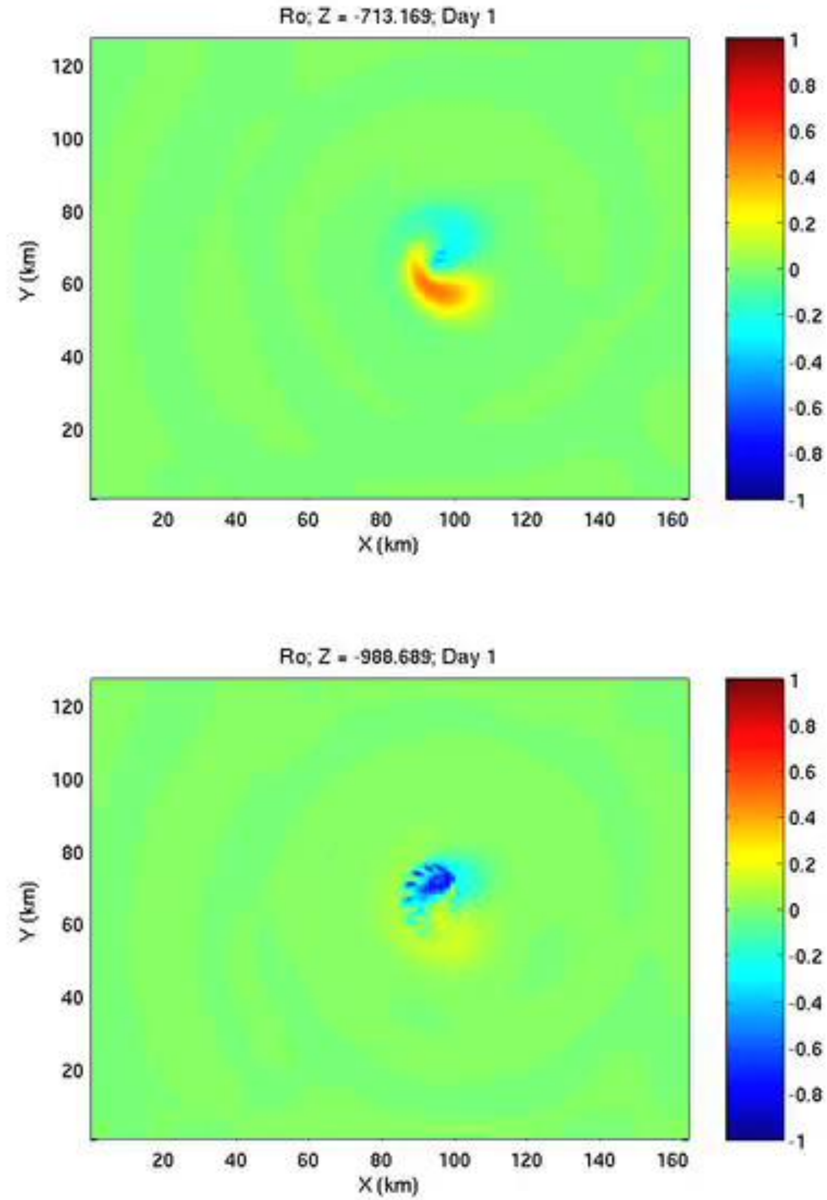


And there is a related potential vorticity budget question.

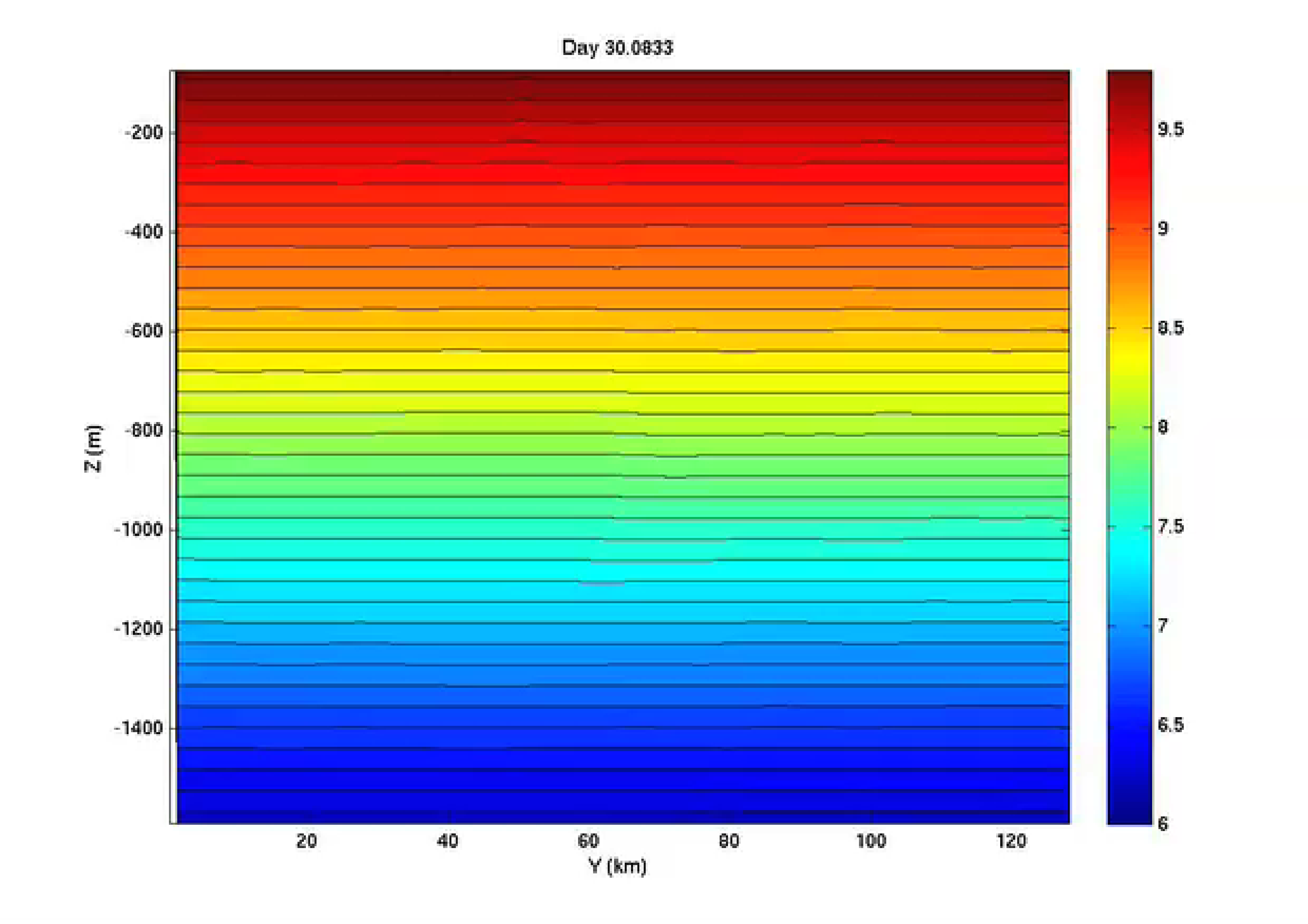
Numerical Evidence in Support

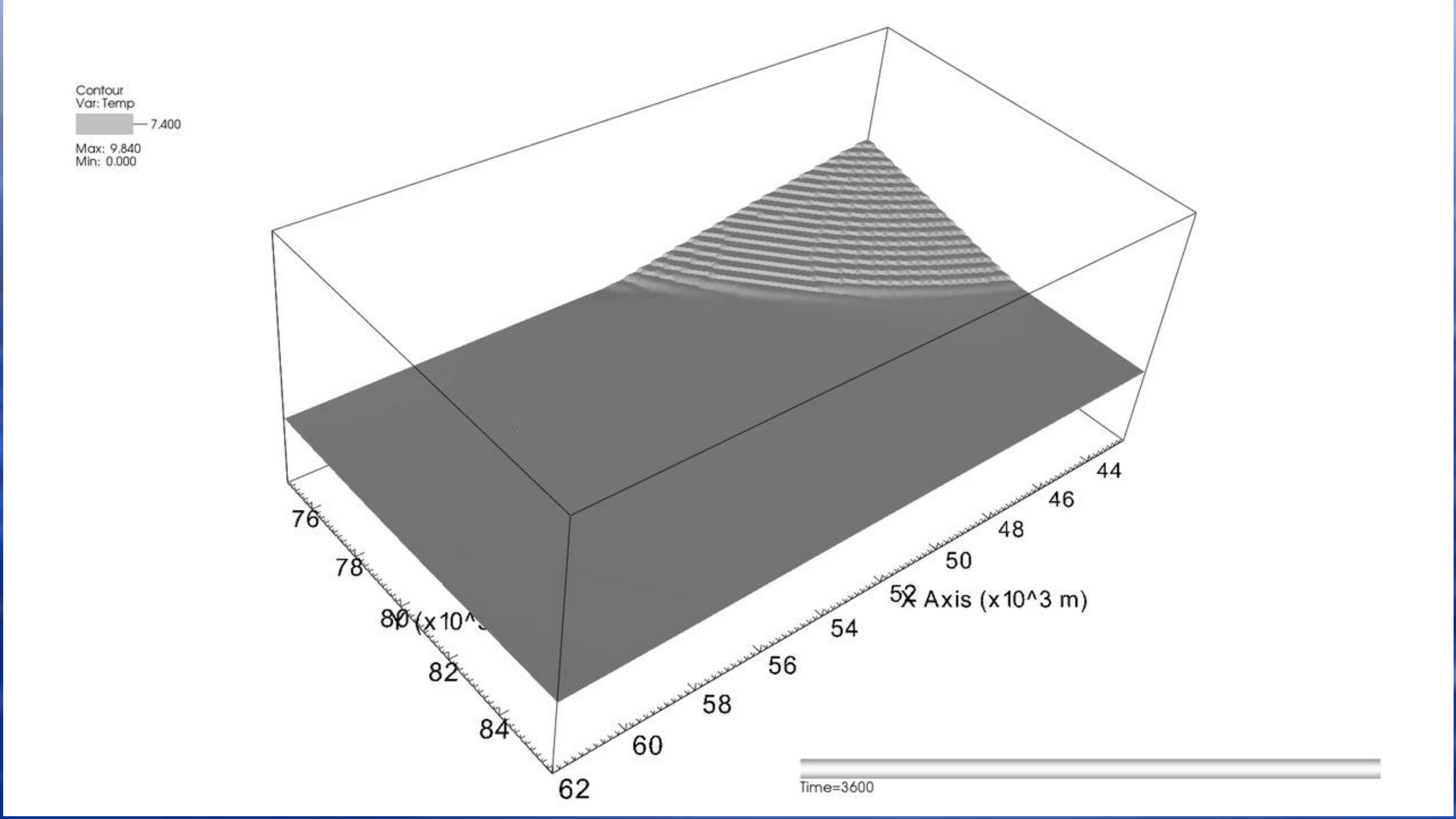
An ultra-fine embedded solution for Monterey Bay




Ro; Z = -713.169; Day 1
Y (km)
X (km)
120
100
80
60
40
20
20
40
60
80
100
120
140
160
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
Ro; Z = -988.689; Day 1
Y (km)
X (km)
120
100
80
60
40
20
20
40
60
80
100
120
140
160
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1

Temperature at western wall





Contour
Var: Temp
7.400
Max: 9.840
Min: 0.000
76
78
80
82
84
62
60
58
56
54
52
50
48
46
44
X Axis (x10^3 m)
Time=3600

Summary:

Something very interesting happens at topography when balanced flow interacts with it.

Question:

At the wall, normal flow vanishes and consider inviscid, adiabatic flow

$$\cancel{u_t} + u\cancel{u_x} + v\cancel{u_y} - fv = -M_x$$

$$v_t + \cancel{u}v_x + vv_y + f\cancel{u} = -M_y$$

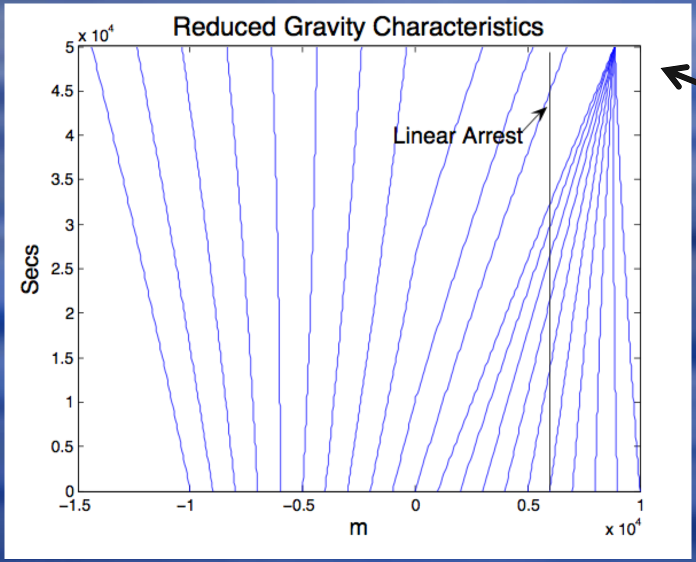
$$q_t + \cancel{u}q_x + vq_y = 0; \quad q = (f + v_x - \cancel{u_y})/z_\rho$$

$$M_{xx} - f^2 \frac{M_{\rho\rho}}{\overline{M}_{\rho\rho}} = 0$$

What does nonlinearity do?

$$v_t + \left(\frac{v^2}{2}\right)_y + (v_g v)_y + M_y = -v_{gt} - v_g v_{gy} - M_{gy}$$

Shock Formation (speed can be computed)



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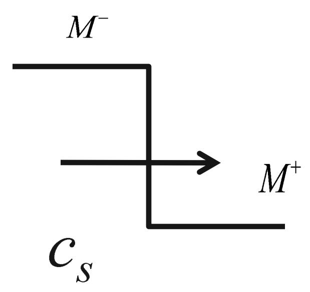
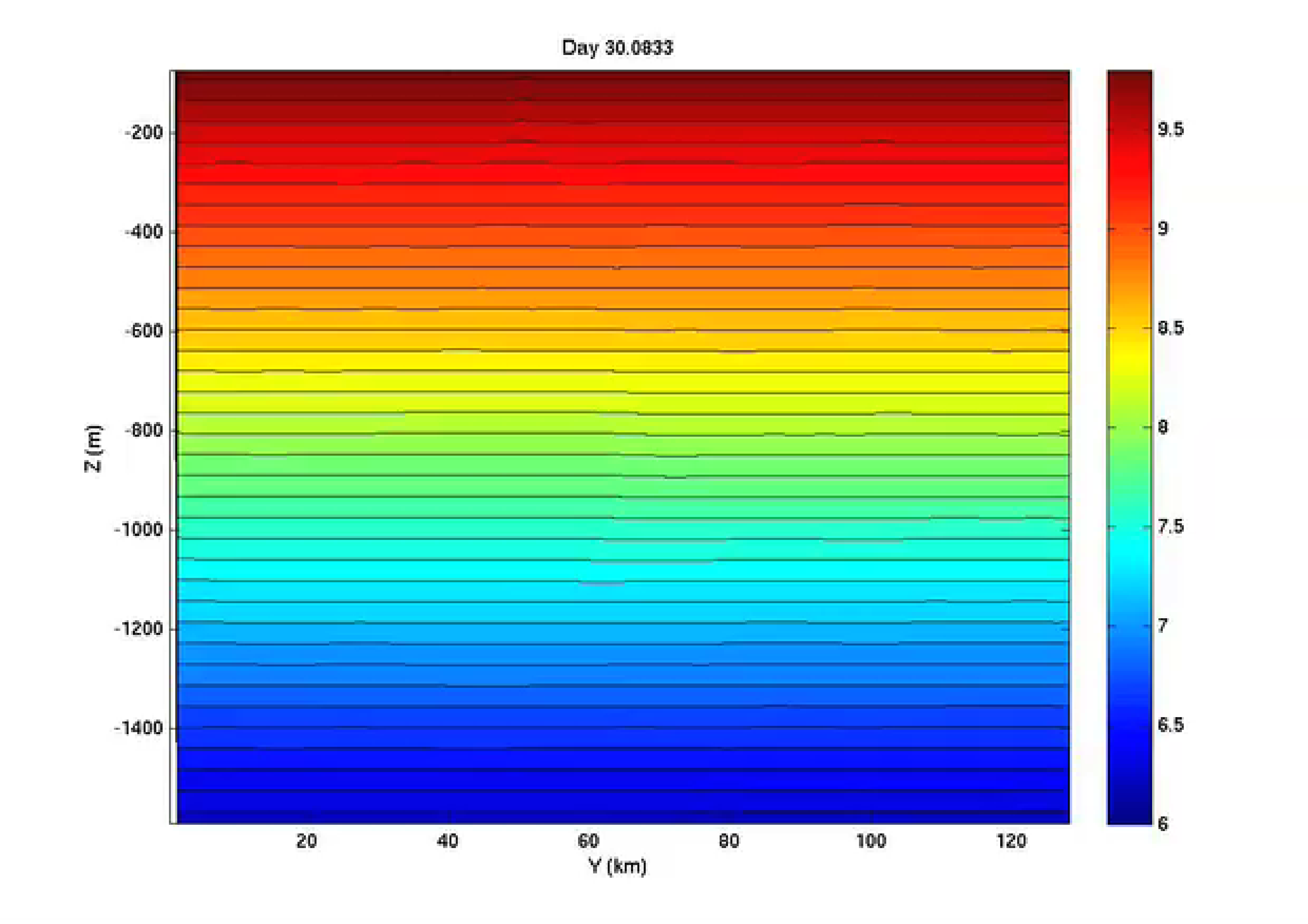
How fast does the shock go?

$$-c_s v_y + \left(\frac{v^2}{2}\right)_y + (v_g v)_y + M_y = (F(v_g))_y$$



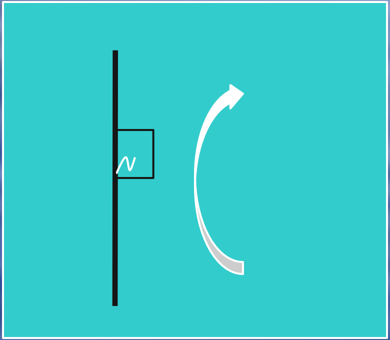
$$c_s = \frac{M^+ + M^-}{2\,fR} + v_g - c - fR$$

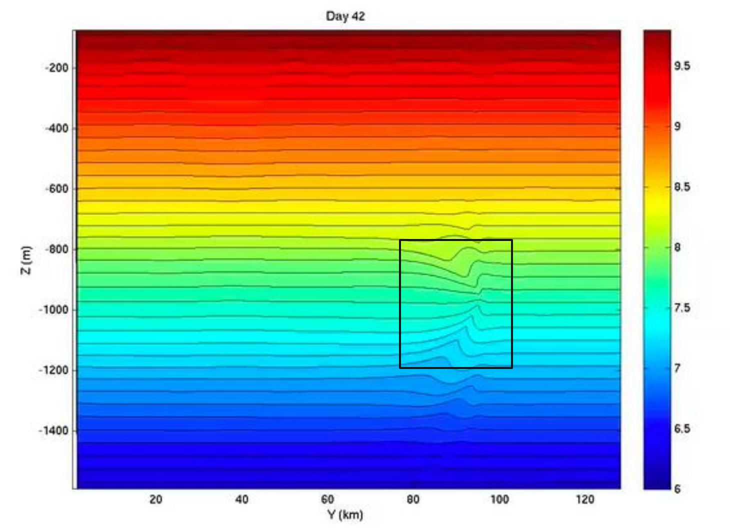
Temperature at western wall



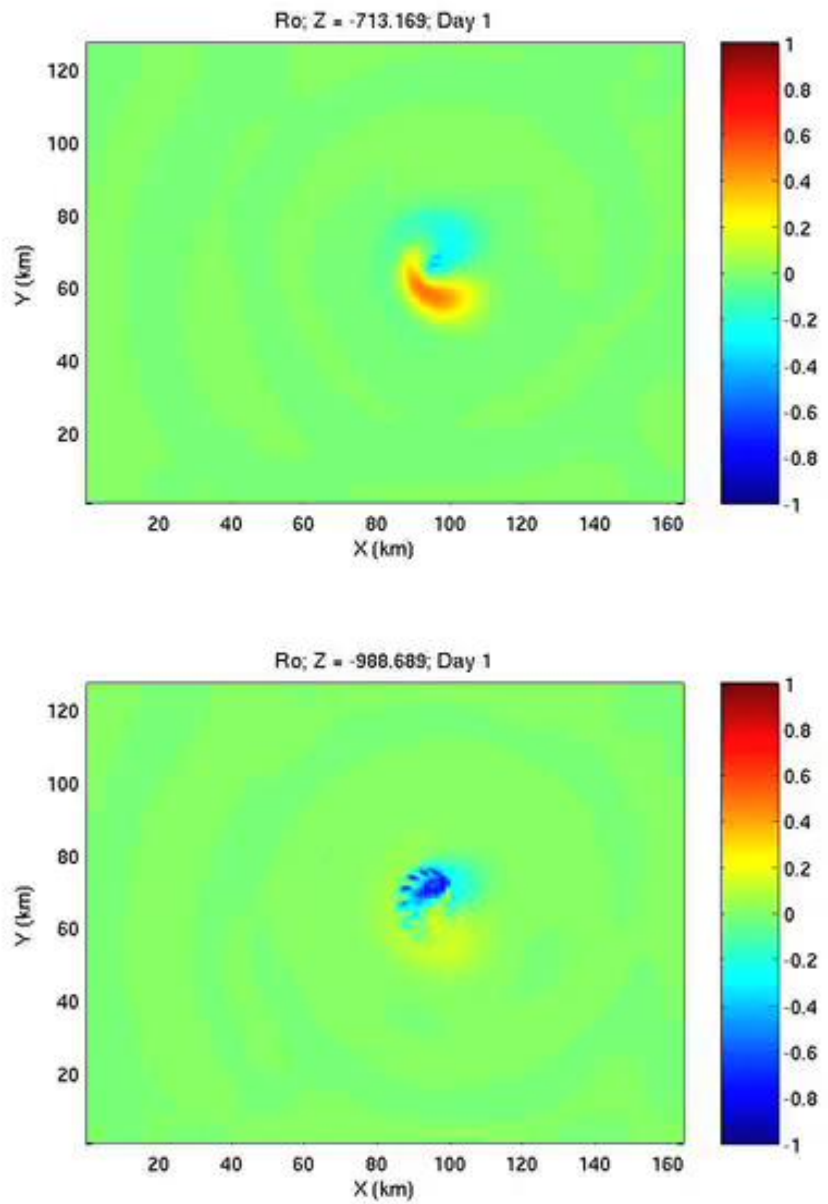
Non-hydrostatic dynamics arrest the shock

$$(z_\rho q)_t + (uqz_\rho)_x + \left(vqz_\rho\right)_y = (Y_x - X_y) + (u_\rho H)_y - (v_\rho H)_x$$





$$\iint uz_\rho q' \, dy \, d\rho = \iint \left[v_\rho H \right]_o dy \, d\rho = O(fR)^2$$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Y (km)
X (km)
Ro; Z = -988.689; Day 1
Y (km)
X (km)

Summary and to do list

Simple, surprisingly accurate local theory for wall interactions can be written

- steepening and breaking
- can be parameterized

Extend this to non-wall topography? (Yes)?

Introduce into models to control boundary dissipation