The Dynamics of Atmospheric Bores

Dale Durran[1] and Kevin Haghi[2]

[1]University of Washington Seattle Campus
[2]Amazon

November 26, 2022

Abstract

Atmospheric bores are disturbances whose passage is accompanied by a pressure rise and a semi-permanent upward displacement of the isentropic surfaces. A series of waves often trails behind the bore's leading edge, and in contrast to density currents, the near-surface temperature remains relatively unchanged, or even warms, after the bore passes. One of the most spectacular and well-studied examples of an atmospheric bore is the "Morning Glory", which occurs in the Gulf of Carpentaria region of northeastern Australia. Atmospheric bores also occur frequently in the nocturnal environment over the Great Plains of the United States, where they are often initiated by gust fronts and density currents in thunderstorm outflows. In favorable conditions, these nocturnal bores can propagate hundreds of kilometers and trigger new convection through low-level lifting that can grow upscale into large organized convective systems. The dynamics of a prototypical atmospheric bore are investigated through a series of two-dimensional numerical simulations and linear theory. These simulations demonstrate that the bore dynamics are inherently finite amplitude. Although the environment supports linear trapped waves, the supported waves propagate in roughly the opposite direction to that of the bore. Qualitative analysis of the Scorer parameter can therefore give misleading indications of the potential for wave trapping, and linear internal gravity wave dynamics do not govern the behavior of the bore. The presence of a layer of enhanced static stability below a deep layer of lower stability, as would be created by a nocturnal inversion, was not necessary for the development of a bore. The key environmental factor allowing bore propagation was the presence of a low-level jet directed opposite to the movement of the bore. Significant turbulence developed in the layer between the jet maximum and the surface, which reduced the low-level static stability behind the bore. Given the essential role of jets and thereby strong environmental wind shear, and given that idealized bores may persist in environments in which the static stability is constant with height, shallow-water dynamics do not appear to be quantitatively applicable to atmospheric bores propagating against low-level jets, although there are qualitative analogies.

The Dynamics of Atmospheric Bores

Dale Durran* and Kevin Haghi^

*Department of Atmospheric Sciences, University of Washington and ^Amazon

Introduction

Atmospheric bores are disturbances whose passage is accompanied by a pressure rise and a semi-permanent upward displacement of the isentropic surfaces.

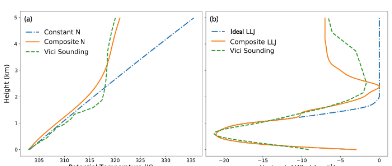
- A series of waves often trails behind the bore's leading edge
- In contrast to density currents, the near-surface temperature remains relatively unchanged, or even warms, after the bore passes.
- In the US Great Plains nocturnal bores can propagate hundreds of kilometers and trigger new convection through low-level lifting.

Bore dynanmics have modeled using

- Shallow-water theory
- Linear trapped internal gravity waves

Methodology

We test these theories using two-dimensional numerical simulations and a prototypical bore sounding composited from observations collected on 0900 UTC 4 June 2002 during the IHOP experiment.



Enivronmental θ(z), U(z) profiles. LLJ opposes the bore's motion: audio caption.

OPEN

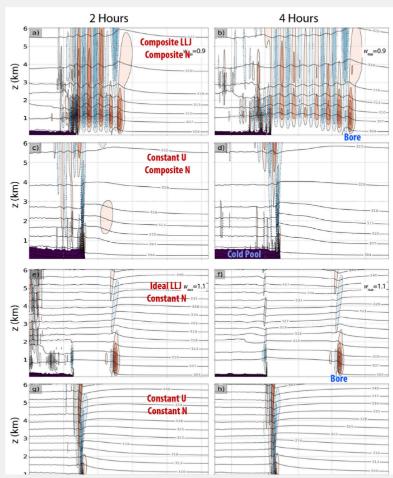
Sensitivity to N(z) and U(z)

Four Environments

Disturbances are triggered by an expanding cold pool (black densely packed isentropes at lower left in each plot).

Bore develops well ahead of the cold pool in cases with low-level jet, even when *N(z)* is constant

No bores develop in the cases where *U(z)* is a constant 10 m/s, even in the case with a layer of high *N* at the surface.



OPEN

Inherently Finite-Amplitude

Bore is not a trapped internal wave

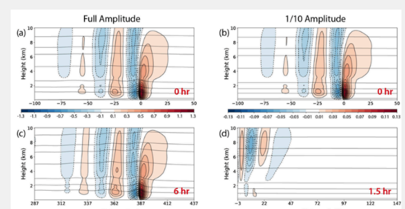
There are no eigenvalue-eigenfunction solutions to the vertical structure equation

$$\hat{w}_{zz} + \left(\frac{N^2}{(U-c)^2} - \frac{U_{zz}}{U-c} - k^2\right)\hat{w} = 0$$

corresponding to linear trapped waves moving at a speed *c* even roughly similar to the speed of the bore.

Testing sensitivity to amplitude

- The isolated full-amplitude bore propagates with almost constant form for 6 hrs.
- The reduced-amplitude isolated bore dissipates within 1.5 hrs



Evolution of full- and 1/10-amplitude isolated bores: audio caption

OPEN

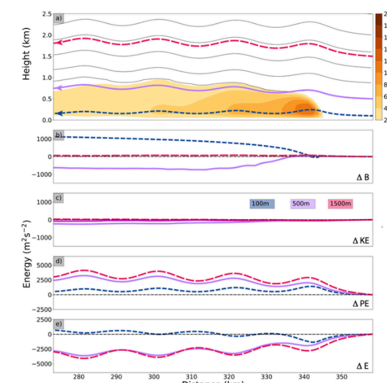
Air-mass transformation

Bore-relative Bernoulli function analysis

$$B = c_p T + gz + \frac{1}{2}\left[(u-c)^2 + w^2\right]$$

Perturbations satisfy

$$\Delta \mathrm{B} = \Delta \mathrm{E} + \Delta \mathrm{PE} + \Delta \mathrm{KE}$$



Changes in ΔB and its components along bore-relative streamlines: audio caption

0:00 / 1:32

OPEN

VIDEO SESSION | AUTHOR INFORMATION | ABSTRACT | REFERENCES | CONTACT AUTHOR | GET POSTER