Spurious Reflection of Atmospheric Waves by Model Tops: A Real Problem?

Curt Covey, PCMDI / LLNL

Work performed at the Lawrence Livermore National Laboratory under auspices of the Office of Science, US Department of Energy, under Contract DE-AC52-07NA27344 (LLNL-PRES-681900).

MONTHLY WEATHER REVIEW
VOLUME 96, NUMBER 3
MARCH 1968

OSCILLATIONS IN ATMOSPHERES WITH TOPS

R. S. LINDZEN*
National Center for Atmospheric Research, Boulder, Colo.
E. S. BATTEN
The RAND Corporation, Santa Monica, Calif.
J.-W. KIM
University of California, l

ABSTRA

Free and forced oscillations are compared for infinite
layer bounded atmospheres are considered. It is found tha
of the infinite atmosphere with accuracy that depends on t
oscillations. In studying forced oscillations, the spurious o
resonances. In general, bounded atmospheres do not prope

1. INTRODUCTION

It is common practice to use simplified calculations in order to elucidate the nature of various more complicated atmospheric problems. As pointed out by Lindzen [3], a variety of such problems is included in the consideration of linearized perturbations on a static basic state (or one with a "constant" zonal flow). Such a study gives a remarkably good description of Rossby-Haurwitz waves, atmospheric tides, and other features. It is clear that various multilevel numerical models do not correspond precisely to the real atmosphere—especially as concerns vertical resolution and the upper boundary. If the above mentioned simplified calculations had been carried out for prototypes of the model atmospheres rather than of the real atmosphere, what would have resulted? In this paper we will consider the behavior of free and thermally forced linear perturbations on a static isothermal atmosphere for three different models:

1. An infinite atmosphere where disturbances are required to remain bounded as z (i.e., altitude) $\rightarrow \infty$. If the disturbances propagate vertically, a radiation condition is imposed at great altitudes.
2. A bounded atmosphere where $dp/dt=0$ at some upper boundary height.
3. A bounded atmosphere wherein the continuous

Quart. J. R. Met. Soc. (1986), **112**, pp. 1195–1218 551.509.313:551.513.1

Toward atmospheres without tops: Absorbing upper boundary conditions for numerical models

By PHILIP J. RASCH
Na
(I

The appropriatc
atmospheric physics i
on the UBC formulat
new technique for co
solutions to simplifica
radiation UBCs (ofte
and space. Approxin
exact radiation UBC:
UBC is tested for cc
damped nonlinear qu

The appropı
has been of conc
the atmosphere i
modelling purpo:
the differential s
atmospheric moc
aims:
(i) A review of

The Surface-Pressure Signature of Atmospheric Tides in Modern Climate Models

CURT COVEY
Program for Climate Model Diagnosis and Intercomparison, Lawrence Livermore National Laboratory, Livermore, California

AIGUO DAI AND DAN MARSH
National Center for Atmospheric Research, Boulder, Colorado*

RICHARD S. LINDZEN
Massachusetts Institute of Technology, Cambridge, Massachusetts

Unforced atmospheric waves on a sphere: Classical equations of motion . . .*

"Primitive Equations"

↓ Linearize around an <u>isothermal</u> background state: constant scale height *H*, longitude wavenumber *s*.

PDE in pertubation geopotential height (a function of latitude φ and altitude z)

↓ Separate variables:

$$\Phi'(\varphi, z) = \Theta(\varphi)\ G(z)\ e^{z/2H}$$

Laplace Tidal Equation for $\Theta(\varphi)$ [solve later]

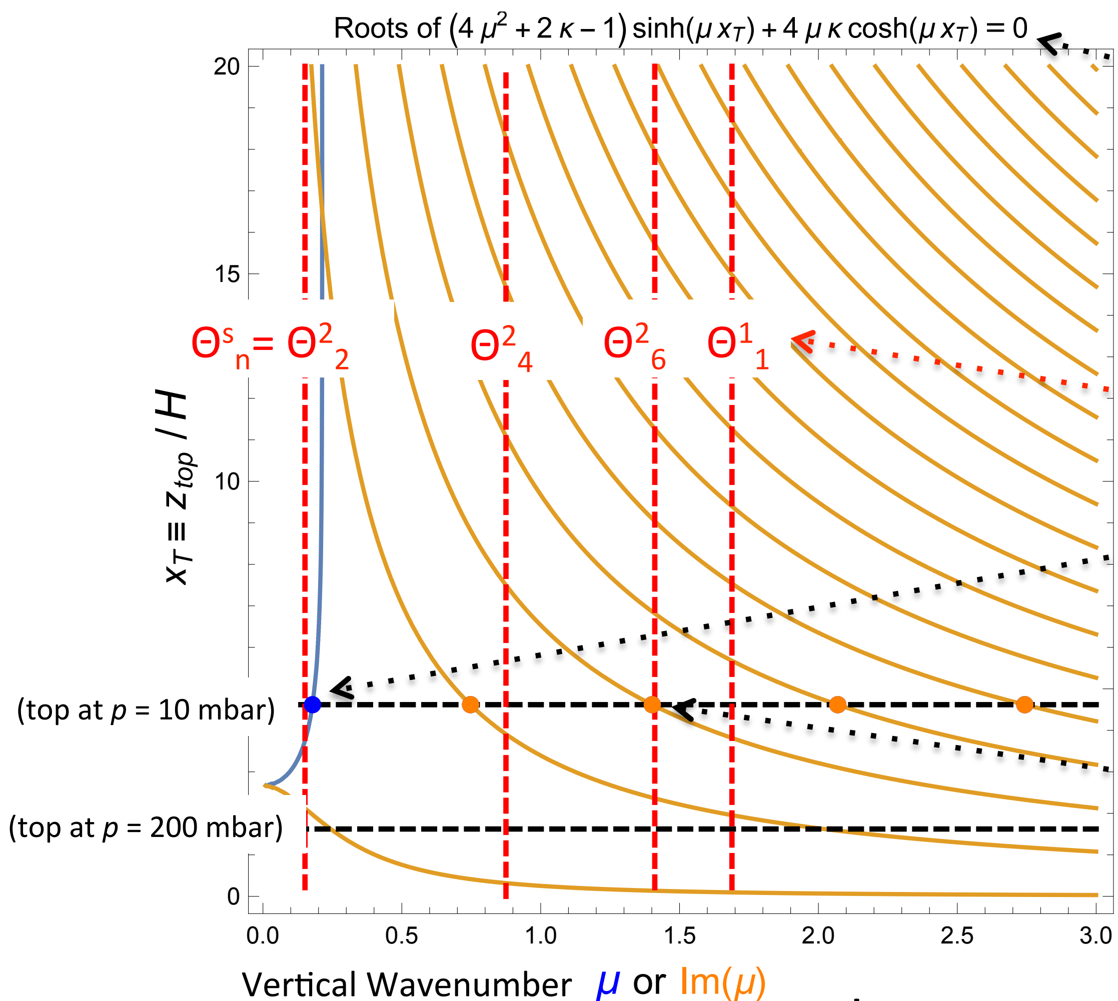
Vertical Structure Equation:

$$\frac{d^2 G}{d z^2} = \left(\frac{\mu}{H}\right)^2 G$$

* See Chapman & Lindzen (1970) *Atmospheric Tides: Thermal and Gravitational*, or Forbes (1995) "Tides and Planetary Waves" in *The Upper Mesosphere and Lower Thermosphere: A Review of Experiment and Theory*, etc.

. . . with a non-classical boundary condition*

- At the surface $w = 0$ as usual, but now the model has a top at $z = x_T H$ where $dp/dt = 0$.
- Eigenvalue problem has one realistic solution + an infinite number of unrealistic solutions



Transcendental equation relates vertical wavenumber μ to x_T:

- Real μ → evanescent waves
- Imaginary μ → standing waves

Solar heating forces tidal modes.

Resonant amplification of semidiurnal tide seemed plausible . . . until the real temperature profile of the middle atmosphere was discovered.

Spurious resonances of tides can occur in numerical models (Lindzen et al., *Monthly Weather Review* 1968).

* See Covey (2015) LLNL Technical Report #678645: https://e-reports-ext.llnl.gov/pdf/802140.pdf

Upper b.c.'s in modern GCMs not well documented

Lawrence Livermore Nation... | ES-DOC-Comparator | Information Management (IM)

compare.es-doc.org

Most Visited

es-doc v0.9.3.1
Earth System Documentation

Project CMIP5 | Comparator Model Component Properties | **Open** | **Support**

Step 2 : View report table | **Help** | **CSV** | **Back**

??? = Incomplete documentation. N/A = Not applicable (model did not realize component). **Models = 39, Components = 1, Properties = 2.**

Component	Atmosphere > Dynamical Core	Atmosphere > Dynamical Core
Property	**Scientific Properties > Top Boundary Condition**	**Scientific Properties > Wind Treatment At Top**
ACCESS1.0	Radiation boundary condition	???
ACCESS1.3	Radiation boundary condition	???
BCC-CSM1.1	???	Calculated
CFSV2-2011	Sponge layer	[illegible]
CMCC-CESM	Sponge layer	[illegible]
CMCC-CM	Sponge layer	[illegible]
CMCC-CMS	Sponge layer	[illegible]
CNRM-CM5	Radiation boundary condition	???
CSIRO-MK3.6.0	Radiation boundary condition	0
EC-EARTH	???	???
GFDL-CM2P1	Sponge layer	Damp zonal mean winds to zero
GFDL-CM3	Sponge layer	???
GFDL-ESM2G	Sponge layer	Damp zonal mean winds to zero
GFDL-ESM2M	Sponge layer	Damp zonal mean winds to zero
GFDL-HIRAM-C180	Sponge layer	[illegible]
GFDL-HIRAM-C360	Sponge layer	[illegible]
GISS-E2-H	Radiation boundary condition	[illegible]
GISS-E2-H-CC	Radiation boundary condition	[illegible]
GISS-E2-R	Radiation boundary condition	[illegible]
GISS-E2-R-CC	Radiation boundary condition	[illegible]
GISS-E2CS-H	Radiation boundary condition	[illegible]
GISS-E2CS-R	Radiation boundary condition	[illegible]
HADCM3	???	???

"Sponge layer" means adding strong diffusion to the equations of motion. It's not a boundary condition!

"Radiation condition" means choosing the sign of $\exp(\pm i \omega t)$ to impose upward energy propagation– nonlocal in time and very difficult to apply in a GCM dynamical core. Do these entries actually refer to <u>sub-gridscale</u> gravity waves?