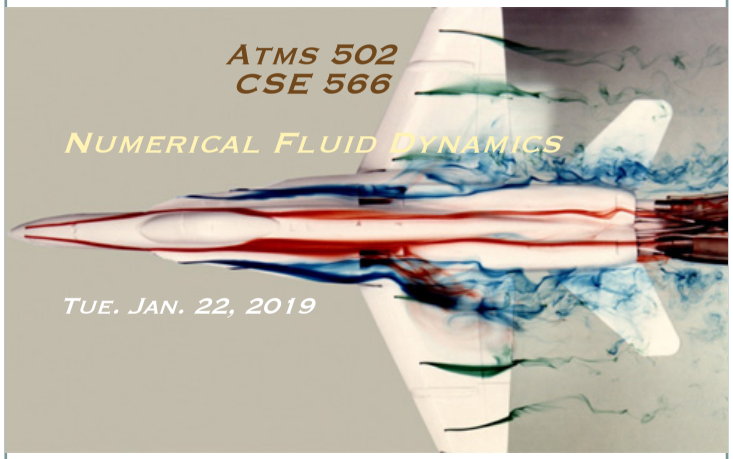
NASA/DRYDEN flow visualization facility



ATMS 502 - Spring 2019 1 1/22/2019

2

ATMS 502
CSE 566

Tuesday,
22 January 2019

Class #3

Plan for Today

- 1) FLUID FLOW EQUATIONS
  Full eqn. set vs. 1-D advection
  PDE linearity & order
- 2) METHODS:
  Lax-Wendroff: review
- 3) CODE/DATA:
  Web page update; Pgm1 work
- 4) INITIAL VALUE PROBLEM
  Predator/prey; resolution
- 5) Linearity: Nonlinear transition

ATMS 502 - Spring 2019 1/22/2019

Fluid flow equations:
1D advection

3

- 1-D transport ("advection")
- Linear vs. nonlinear problems

FOLLOW NOTES
FROM LAST CLASS
(CLASS 2 – JAN. 17)

References:
- A001 (fluid flow)
- A002 (advection)
- A003 (nonlinearity)
- A005 (1-way wave equation)

ATMS 502 - Spring 2019 1/22/2019

Review: Lax-Wendroff

4

1. Scheme used for Program 1

$$s_j^{n+1} = s_j^n - \frac{\nu}{2}\left(s_{j+1}^n - s_{j-1}^n\right) + \sigma\left(s_{j+1}^n - 2s_j^n + s_{j-1}^n\right)$$

This is the Lax-Wendroff method in 1-D.

2. We can summarize this numerical method as –
   - An approximation to the *1-way wave equation*
   - A *finite difference* method
   - An *explicit* method
   - A *2-time-level* method
   - Uses a *3-point stencil*

ATMS 502 - Spring 2019 C.001: Lax-Wendroff 1/22/2019

Review: Numerical method description

5

1. Lax-Wendroff is:
   - A *finite difference* method
     - contrast with: finite volume, semi-Lagrangian … other methods
     - we will discuss f.d. approximations today; derivations, later
   - An *explicit* method
     - "explicit" means: given current (time *n*) data, we can solve for the future (time *n+1*) state directly, one point at a time.
   - A *2-time-level* method
     - the method involves only two time levels (*n*, *n+1*).
   - Uses a *3-point stencil*
     - the method uses grid points (*j-1, j, j+1*) to find solution at *(j,n)*

Code/data: *Program #1*

6

WEB PAGE UPDATE
CODING / TESTING CYCLE
MAKING PLOTS

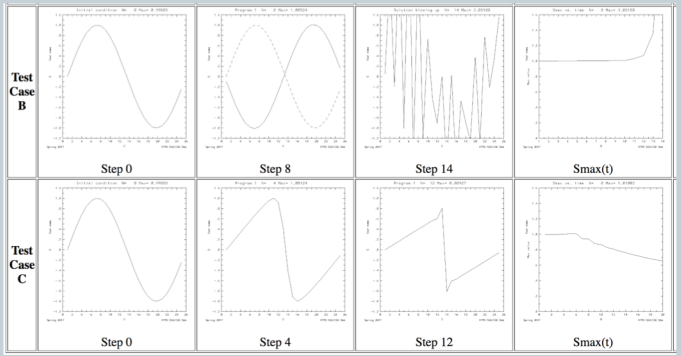
Code questions? Send me questions *plus your code:*

1. **make** archive
   - *On Stampede-2: This creates pgm1.tar*
2. **Mail** -a pgm1.tar bjewett@illinois.edu
   - *enter subject, hit return*
   - *type ^D (hold control, type d) to send email.*

Web page update

7

- Program 1 page now available



Working on Program #1

8

- How to do computing work:
  - *Run* the code on Stampede-2
    - *use idev* *(reserves a compute node for you)*
  - Editing code: choose either --
    - 1) transfer code to your PC, edit *locally*, transfer back to Stampede
      - local editors - on class page
      - file transfer tools - FileZilla, Xftp, etc - Stampede access page
    - 2) edit remotely - i.e. run editor ***on*** Stampede
      - e.g. nano, or Emacs with X-windows
  - Plotting
    - next page

Program 1: plotting

9

- Running your pgm1 code produces a *NCAR Graphics* plot file named *gmeta*.
  - "gmeta" is graphics metacode that can be used several ways...
- Converting *gmeta* to GIFs:

  ~tg457444/502/Tools/metagif gmeta -all -zip
  - This creates "gmeta.zip"; transfer it back to your PC; extract files from .zip file; put GIFs into a MS Word or Open Office document; print locally.
- Viewing alternatives.
  - *idt gmeta* on Stampede. X-windows must be running.
  - *Web viewer* – a bit later.

ATMS 502 - Spring 2019 1/22/2019

An initial value problem

10

"PREDATOR-PREY"

AKA LOTKA-VOLTERRA EQUATIONS (1925)

FOLLOW NOTES FROM LAST CLASS (CLASS 2 – JAN. 17)

Following Golub and Ortega, 1992

ATMS 502 - Spring 2019 C.090: Predator-Prey equations 1/22/2019

Fluid flow equations: Nonlinear transition

11

EVOLUTION DOESN'T HAVE TO BE EITHER/OR (ONLY LINEAR OR NONLINEAR)

References:
- A006 (nonlinear transition)
- A007 (Eady wave)

ATMS 502 - Spring 2019 1/22/2019

Nonlinear transition

12

- A numerical solution can also transition from a *linear to a nonlinear regime.*
  - a *small perturbation* (disturbance) might first grow in a *linear* mode - as expected from linear theory
    - Shape doesn't change – but amplitude does.
  - this perturbation might then grow large enough that nonlinear processes take over
    - Structure / evolution can change drastically, and quickly.

ATMS 502 - Spring 2019 A.006: Nonlinear transition 1/22/2019

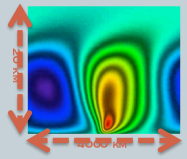
Nonlinear transition: Eady wave

13

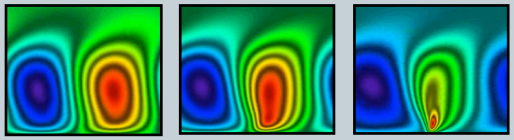
Example: Eady wave

(Atmospheric Sciences – growth of a baroclinic wave)

X-Z VERTICAL CROSS SECTION IS SHOWN



VERTICAL VELOCITY (UP IS RED)



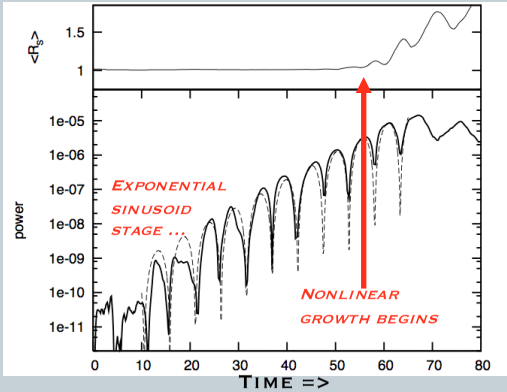
Linear growth | Transition | Nonlinear

Nonlinear transition: Supernovae behavior

14

Growth

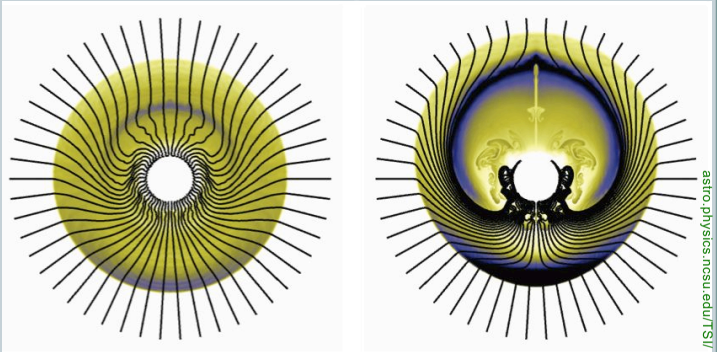
entropy field



Blondin, NCSU, http://arxiv.org/pdf/astro-ph/0507181.pdf

Nonlinear transition

15



astro.physics.ncsu.edu/TSI/

- A linear model of evolution may fit - or not - and the computational *demands* may change during the solution. *Will your* numerical method be adequate??