Lecture 1 ASEN 5090
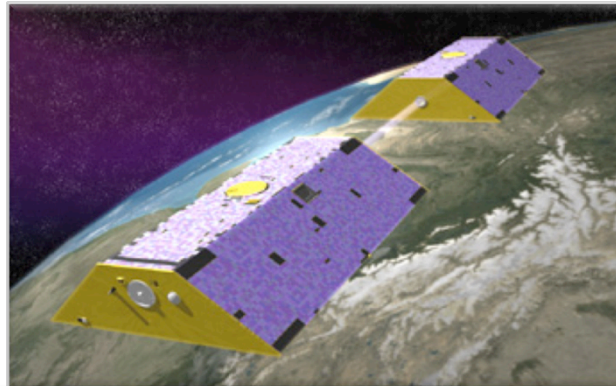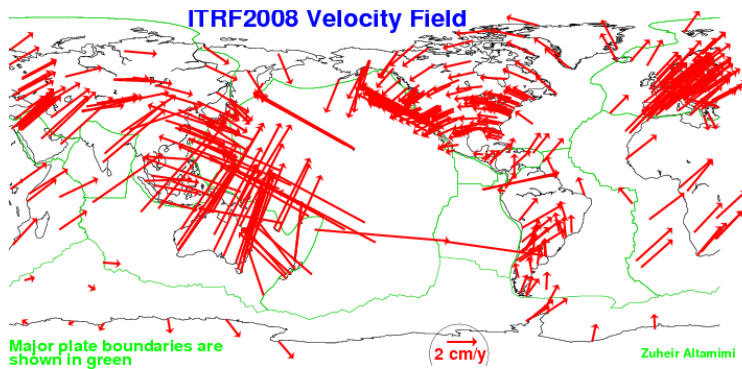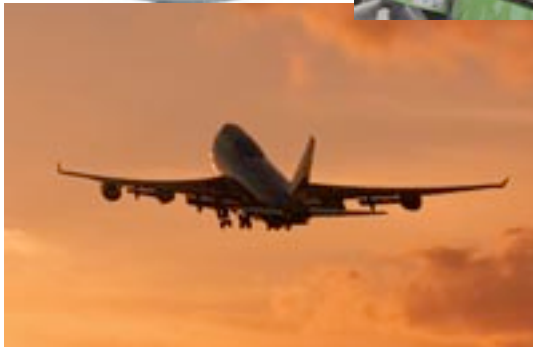# Introduction to GNSS

University of Colorado Boulder

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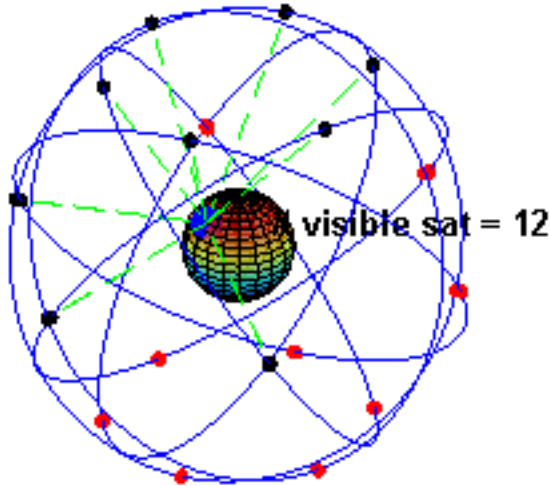
GNSS = Global Navigation Satellite Systems

The Global Positioning System is just one of these systems.

My goal for this lecture:

Let you know enough about the class that you can decide whether you would like to take it.

My goal for this class:

By the end of the semester, you will essentially know how a hand-held GPS receiver works.

GNSS in the news

- LightSquared will not be allowed to harm GPS: FCC
  - WASHINGTON | Tue Aug 9, 2011 7:41pm EDT, Reuters
- Supreme Court Decision in : United States v. Jones (2012)
- Drone Spoofing
- Most recent GPS satellite launch, May 2013, PRN 27.
- June 2013, GPS can be used to detect volcanic plumes.
- July 22, 2013 three Russian GNSS satellites blow up on launch (three were also lost in a 2010 launch).
- July 2013, U.S. House of Representatives cuts all of GPS out of the White House proposed budget.
- Next generation GPS to launch in 2015?

ASEN 5090 INTRODUCTION TO GNSS

MWF 10-10:50, ECCS 1B12

Everything will be on D2L (fingers crossed)

All homework will be submitted to D2L.

All questions about D2L should go to our TA, Siamak Hesar (see syllabus)

Instructor
> Kristine M. Larson
> kristinem.larson@gmail.com (I also read CU email, but not as often)
> 303-492-6583 (but not a good way to reach me)
> ECAE 177 (first floor, aero wing, my office faces Colorado Ave.)

Office Hours
> TBD (I will likely take MW and Siamak will take TTh)

Tentative Schedule is online

COURSE DESCRIPTION

- Core AES course for the Astrodynamics and Satellite Navigation Focus Area
- Overview of the principles of operation of satellite navigation systems with primary emphasis on the U.S. Global Positioning System.
- Fundamentals of GNSS hardware and algorithms/software
- ASEN 5090 is a prerequisite for the two advanced AES courses, one on GNSS receivers (6091) and the other on applications/software (6090). These are typically which offered in alternating spring semesters.
- A new advanced GNSS class (6092?) is scheduled to be taught next fall – GNSS environmental sensing.

PREREQUISITES & ELIGIBILITY

- Open to graduate students in Engineering, Physics, Applied Math, Geological Sciences, Geography, and related fields.
- Undergraduates must get instructor permission.
- Students are expected to have:
  - good problem solving skills
  - vector and matrix math, linear algebra
  - computer programming (MATLAB)
  - experience planning and conducting experiments
  - positive attitude about learning how to use software, lab equipment, etc

TEXTBOOKS

- **Required Text** - *Global Positioning System – Signals, Measurements, and Performance*, Pratap Misra and Per Enge, 2nd Edition. ISBN 0-9709544-1-7
  - You can order it directly from their distributor NavtechGPS:
  - http://www.navtechgps.com/supply/2500.asp
  - Two copies are on reserve at the library.

- *Understanding GPS - Principles and Applications*, E.D. Kaplan and C.J. Hegarty, Eds., 2nd Edition. ISBN 1-58053-894-0
- *GNSS Applications and Methods,* S. Gleason and D. Gebre-Egziabher, Eds., ISBN 978-1-59693-329-3
- *GPS Satellite Surveying*, A. Leick, 3rd Edition. ISBN 0-471-05930-7
- *Global Positioning System, Theory & Practice,* 5th Edition, Hofmann-Wellenhof, Lichtenegger, Collins, ISBN 3-211-83534-2
- *A Software-Defined GPS & Galileo Receiver,* K. Borre et al., ISBN 0-8176-4390-7

MAGAZINES & JOURNALS

- *GPS World*
- *Inside GNSS*
- *GPS Solutions*
- *Navigation*, Journal of the Institute of Navigation, and Proceedings of ION Conferences
- *IEEE Transactions on Aerospace and Electronics*

- Applications of GNSS appear in various aerospace and science journals

WEB RESOURCES

from www.gps.gov

- http://pnt.gov/

- http://www.gps.gov/

- http://www.navcen.uscg.gov/gps/ – U.S. Coast Guard Navigation Information Center, status, and navigation data downloads

- FAA GPS Site – Information on LAAS, WAAS, certification of GPS, and other GPS aviation issues

- GPS Resource Library

- GPS Joint Program Office

- GPS Modernization - Information and presentations on GPS Modernization and the new signals

- I find myself using the GPS wikipedia page an awful lot!

SUBJECT OUTLINE

We'll do a high level overview first, then circle back around and get into the details.

- GNSS Basics
- Measurements and Errors
- Position Solutions
- GPS Signals and Receivers
- Applications

- Midterm Exam: Oct 11, 2013
- Final Exam: Dec 16, 2013

ASSIGNMENTS

- Homework - problems from the book

- Projects – software use and development

- Labs – *class size may preclude a lab*

- Partners – on campus students will be assigned partners for some of the assignments. CAETE students can work individually or with other if the logistics work out.

- Collaboration is permitted on these assignments. This means you may discuss the means and methods for solving problems and even compare answers, but you are not free to copy solutions from classmates or from internet resources. All figures copied from other sources must include an appropriate citation.

CLASS & UNIVERSITY POLICIES

Disabilities

- If you qualify for accommodations because of a disability, please submit to me a letter from Disability Services in a timely manner so that your needs may be addressed. Disability Services determines accommodations based on documented disabilities. Contact: 303-492-8671, Willard 322, and www.Colorado.EDU/disabilityservices.

Religious obligations

- Campus policy regarding religious observances requires that faculty make every effort to reasonably and fairly deal with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. Please review the assignment calendar for this class and notify the instructor by email within the first 2 weeks of class if you have such a conflict. See full details at http://www.colorado.edu/policies/fac_relig.html

Classroom behavior

- Students are required to be familiar with the policies governing classroom behavior provided here:

- http://www.colorado.edu/policies/classbehavior.html   and at http://www.colorado.edu/studentaffairs/judicialaffairs/code.html#student_code

CLASS & UNIVERSITY POLICIES (continued)

Discrimination and Sexual Harassment

The University of Colorado at Boulder policy on Discrimination and Harassment http://www.colorado.edu/policies/discrimination.html - The University of Colorado policy on Sexual Harassment and the University of Colorado policy on Amorous Relationships applies to all students, staff and faculty. Any student, staff or faculty member who believes s/he has been the subject of discrimination or harassment based upon race, color, national origin, sex, age, disability, religion, sexual orientation, or veteran status should contact the Office of Discrimination and Harassment (ODH) at 303-492-2127 or the Office of Judicial Affairs at 303-492-5550. Information about the ODH and the campus resources available to assist individuals regarding discrimination or harassment can be obtained at http://www.colorado.edu/odh.

Honor code

- All students of the University of Colorado at Boulder are responsible for knowing and adhering to the academic integrity policy of this institution. Violations of this policy may include: cheating, plagiarism, aid of academic dishonesty, fabrication, lying, bribery, and threatening behavior. All incidents of academic misconduct shall be reported to the Honor Code Council (honor@colorado.edu; 303-725-2273). Students who are found to be in violation of the academic integrity policy will be subject to both academic sanctions from the faculty member and non-academic sanctions (including but not limited to university probation, suspension, or expulsion). Other information on the Honor Code can be found at http://www.colorado.edu/policies/honor.html and at http://www.colorado.edu/academics/honorcode/.

- Students are required to read, sign, and submit the honor code agreement.

TECHNICAL WRITING

- Order of presentation
- Third person
- No slang, contractions, informal usage
- Figures
- Tables (significant figures)

Homework 0:

Please e-mail me (kristinem.larson@gmail.com) about yourself and your GNSS interests/questions

- Name
- Department & Year
- MATLAB Experience
- GPS/GNSS Experience
- Do you own a GPS receiver or GPS-enabled smart phone? What make/model?
- Questions about GPS that have been bugging you?
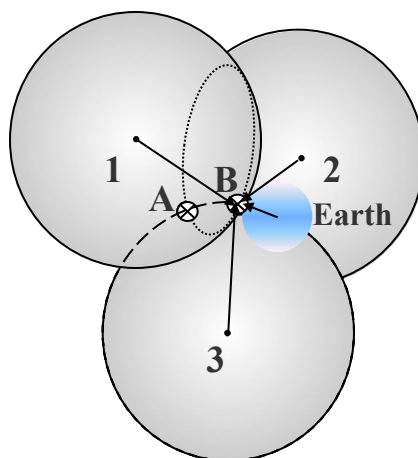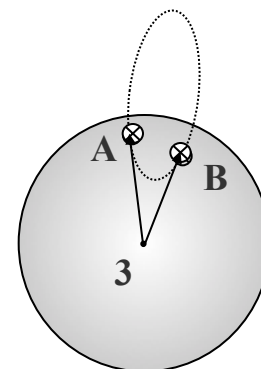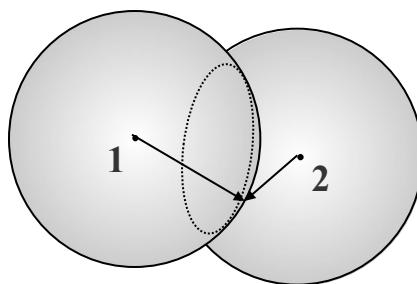- What GNSS applications would you be most interested in hearing about?
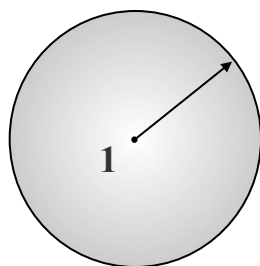
GLOBAL NAVIGATION SATELLITE SYSTEMS (GNSS)

- US Global Positioning System

- Russian GLONASS

- European Galileo

- Chinese Beidou COMPASS

- Constellation of satellites that transmit continuously to allow 1-way ranging by passive users
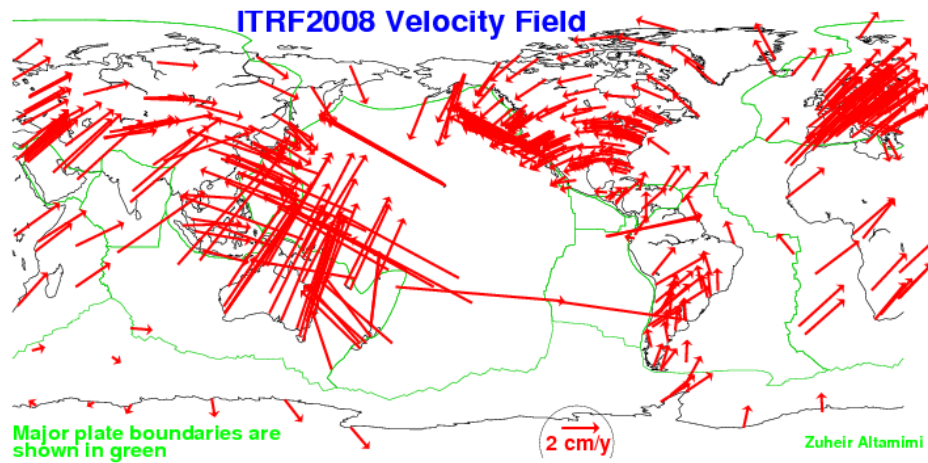
TRILATERATION

KEY REQUIREMENTS

- High accuracy, precision
- 24/7 operation, all weather, day & night
- Dual use – both military and civil users

"The United States Government shall... Provide on a continuous, worldwide basis civil space-based positioning, navigation, and timing services free of direct user fees for civil, commercial, and scientific uses and for homeland security through the Global Positioning System and its augmentations, and provide open, free access to information necessary to develop and build equipment to use these services."
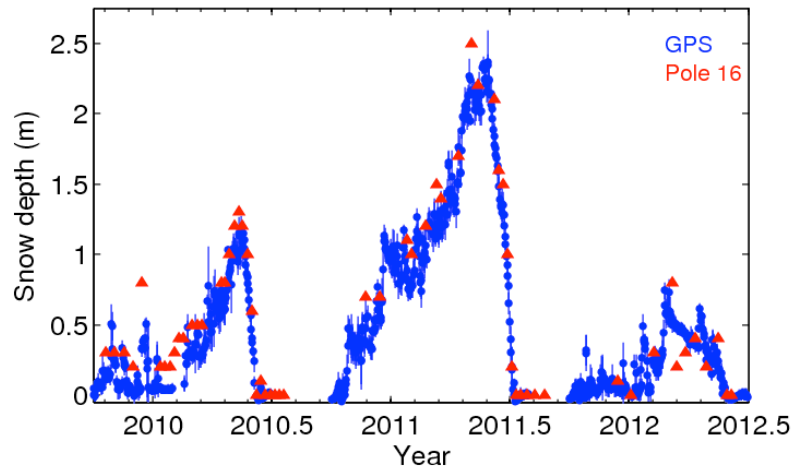
President George W. Bush, U.S. National Space-Based Positioning, Navigation, and Timing Policy, December 2004
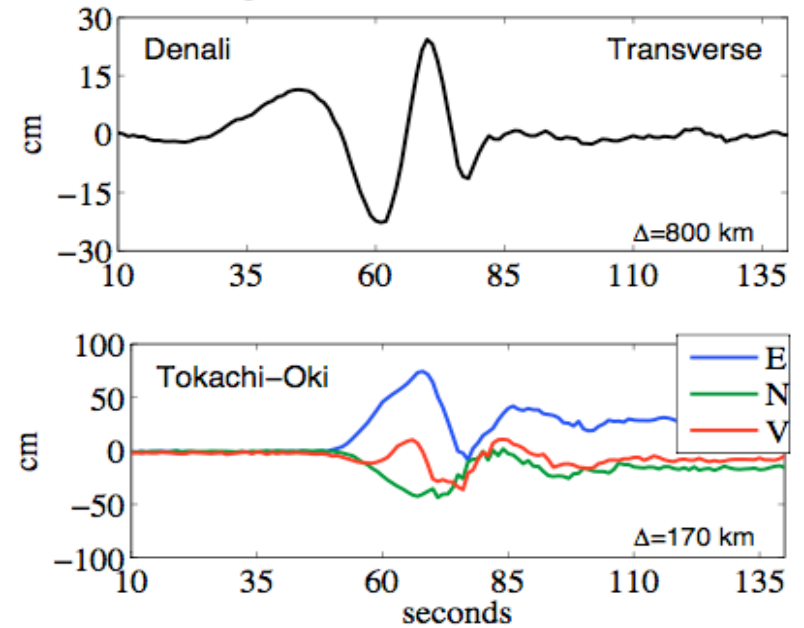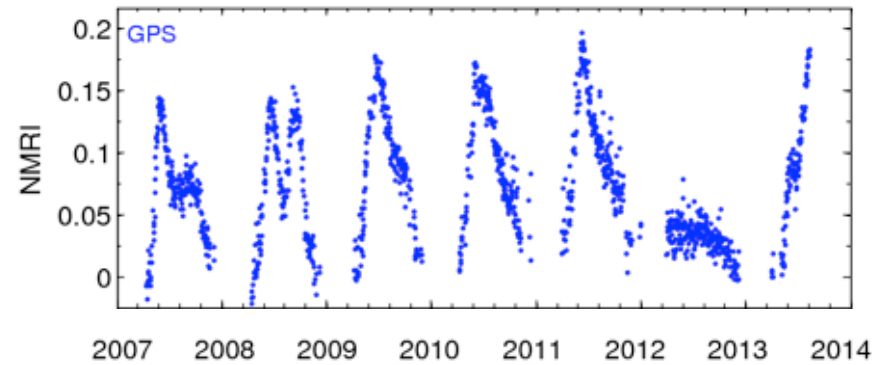
WHAT I DO

ITRF2008 Velocity Field

Major plate boundaries are shown in green

2 cm/y

Zuheir Altamimi

High-Rate GPS Position Estimates

Denali   Transverse

Δ=800 km

Tokachi-Oki

E
N
V

Δ=170 km

seconds

nwot

Snow depth (m)

GPS
Pole 16

Year

p042

GPS

NMRI

DISCIPLINES IN GNSS

- Ranging Signals:

- Satellites:

- Environment

- Users

- Politics

DISCIPLINES IN GNSS

- Ranging Signals:
  - Electromagnetics, signal processing, coding, antennas, jamming & interference
- Satellites:
  - Orbits, relativity, perturbations, attitude control, launch/maintenance, atomic clocks
- Environment
  - Ionosphere, troposphere, antenna installation
- Users
  - Platform dynamics, challenging environments (antenna shading), computational capability, size, estimation methods, accuracy requirements (aiding or stand-alone)
- Politics
  - Spectrum usage, privacy, fees, security, national pride…

APPLICATIONS OF GNSS?