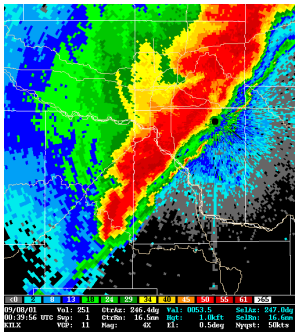
Precipitation Measurements



Dr. Christopher M. Godfrey
University of North Carolina at Asheville

1

Raindrops…

…are shaped liked hamburger buns!

(Smaller drops are more spherical)

2

Methods of Precipitation Measurement

- Point Measurements
  - Accumulation
    - Mass
      - Measure the weight (m × g) of accumulated precipitation
    - Volume
      - Let water accumulate in a unit volume
      - Measure number of unit volumes filled
  - Optical
    - Precipitation passes through a beam of light
  - Depth (for snow)
    - Ruler or acoustic transmitter-receiver
- Remote sensing
  - Radar or satellite

3

Precipitation Rate

- Precipitation rate is the depth to which a flat horizontal surface would have been covered by rain or snow per unit time, assuming…
  - No evaporation
  - No runoff
  - No percolation
- Time unit
  - Per minute, per hour, per day, per year, per storm, etc.

4

Precipitation Rate

- Definition
  - Volume flow rate of liquid or solid water across a horizontal plane per unit time

5

6

Accumulation Gauges

- Collection cross section of known area
- Collect precipitation until emptied manually or automatically

7

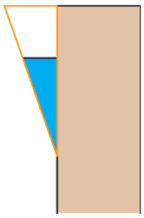
Accumulation Gauges

- Simplest design is an open container (like a backyard rain gauge)
  - Measurand: Rainfall rate, R
  - Output: Depth of water, h
  - h is the sum of all rainfall rates throughout an event:

8

Accumulation Gauges

- We can enhance the resolution of h by:
  1) Giving the gauge a triangular cross-section

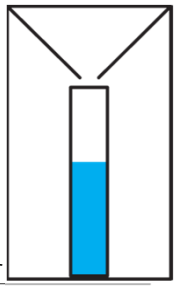


  - Variable amplification of height
  - High sensitivity for small amounts, but large capacity

9

Accumulation Gauges

- We can enhance the resolution of h by:
  2) Catching precipitation with a large catch area A_C and draining it into a smaller-diameter inner tube with measurement area A_m.



  - Constant amplification of height
    - $h_{amplified} = A_c h / A_m$
    - Overflow contained in larger cylinder

10

National Weather Service Standard Gauge

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Weighing Gauges

- Measure precipitation accumulated in a bucket using a weighing scale
  - Weight of water measured by springs, strain gauges, or vibrating wires
  - Can be automated
  - Must empty the bucket
  - Subject to evaporation
  - Some have siphons or pumps to empty bucket automatically

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Weighing Gauges

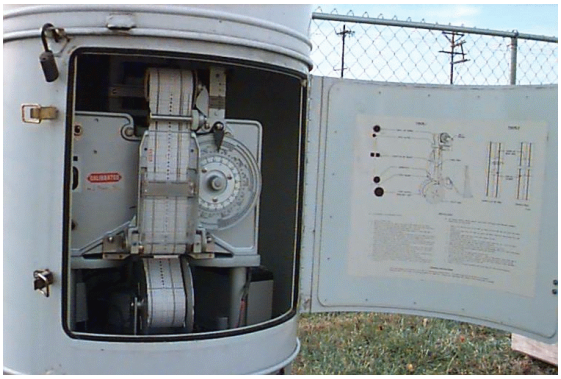
- Rainfall rate is given by the time rate of change of the weight in the bucket:

13

Fischer-Porter Weighing Gauge

14

Fischer-Porter Internal View



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Belfort Universal Precipitation Gauge

Sources: http://www.belfortinstrument.com/content/precipitation_s5780_5915.cfm
http://www.crh.noaa.gov/dmx/coop-equip.php

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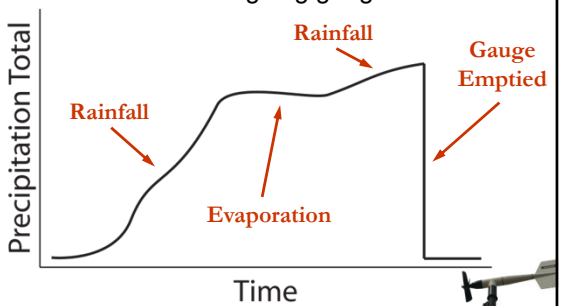
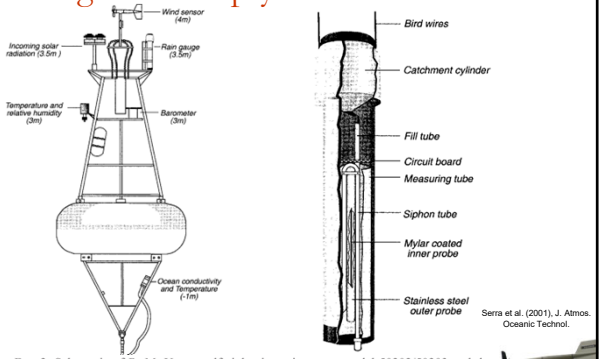
Weighing Gauges

- Consider a typical time evolution of rainfall accumulation in a weighing gauge:



17

Gauges can empty themselves!



Serra et al. (2001), J. Atmos. Oceanic Technol.

FIG. 2. Schematic of R. M. Young self-siphoning rain gauge model 50202/50203 and the ATLAS buoy with surface instrumentation noted.

18

Siphon Gauges

- Volume of water determined by capacitance
- Mylar-coated stainless steal capacitive probe in center of collection tube
- Capacitance measured between steal probe and water; mylar is the dielectric
- As water rises, surface area in contact with mylar increases, increasing capacitance
- Cylinder emptied by siphon tube

Photo source: http://oceanworld.tamu.edu/resources/oceanography-book/observingthepacific.htm

Pressure Gauges

- Pressure sensor indicates that gauge is full and turns on pump

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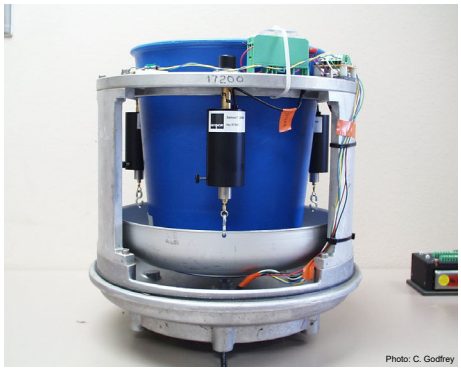
Geonor Vibrating Wire Gauge



20

Geonor Vibrating Wire Gauge

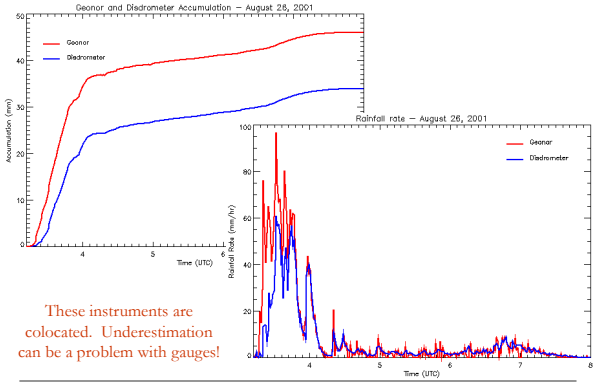
- Vibrating wire is driven by transducer
- Wire vibrates at resonant frequency
- Vibrations are picked up and frequency is recorded by data logger

21

Geonor Vibrating Wire Gauge

22

Rainfall Rate vs. Accumulation



These instruments are colocated. Underestimation can be a problem with gauges!

23

Tipping Bucket Rain Gauges

- Fully automatic
- Precipitation funneled into a bucket
- When bucket is full, it tips; other bucket fills
- Each tip represents a specific depth of rain
- Datalogger records tips

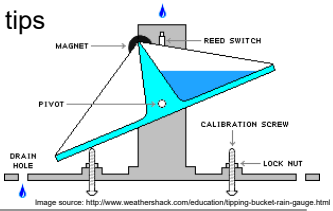


Image source: http://www.weathershack.com/education/tipping-bucket-rain-gauge.html

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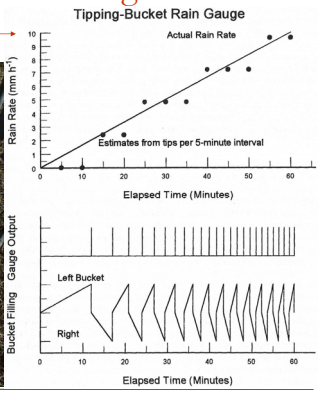
Tipping Bucket Rain Gauges

A tipping bucket rain gauge showing increasing rainfall rate



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Tipping Bucket Example

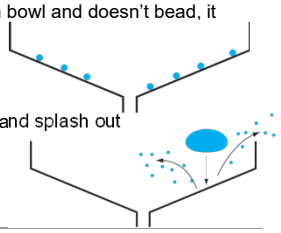
26

27

28

Problems With Precipitation Sensors

- Evaporation
  - Not enough rain for a tip; leftover water evaporates and never gets measured
  - Negative accumulation in bucket over time
- Wetting of the bowl
  - If water stays in the collection bowl and doesn't bead, it never gets measured
- Splashes
  - Raindrops hit collection area and splash out



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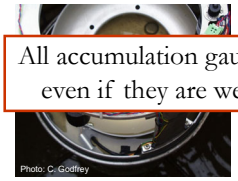
Problems With Precipitation Sensors

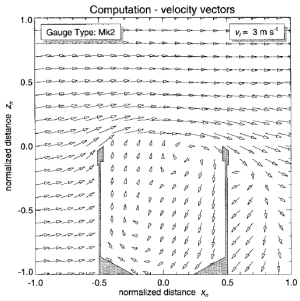
- Debris in the funnel or blocking components
- Need frequent calibration
- Bucket or support failure
- Siphon problems
- Wind effects



All accumulation gauges underestimate the catch, even if they are well-designed and calibrated.

30

Mitigating Wind Effects–Alter Shield



Nespor and Sevruk (1999), J. Atmos. Oceanic Technol.

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Mitigating Wind Effects–Other Shields

Ott Gauge with Tretyakov Shield

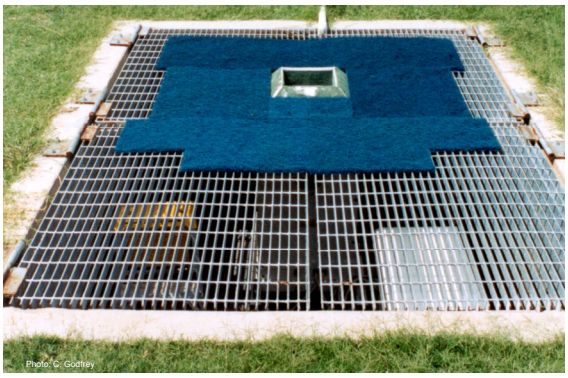
Nipher Shield

Wyoming Shield

For more examples, visit http://www.rap.ucar.edu/projects/marshall/Wind_Shields.html

32

Mitigating Wind Effects–The Pit



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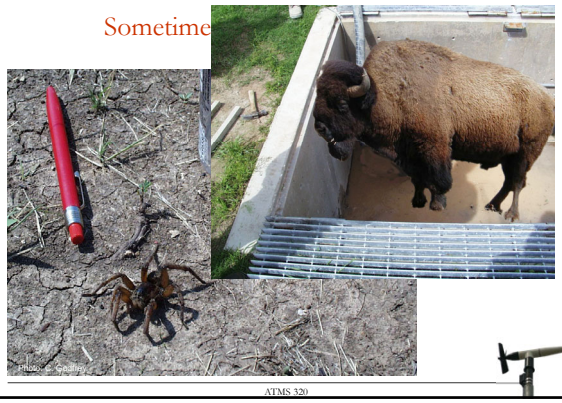
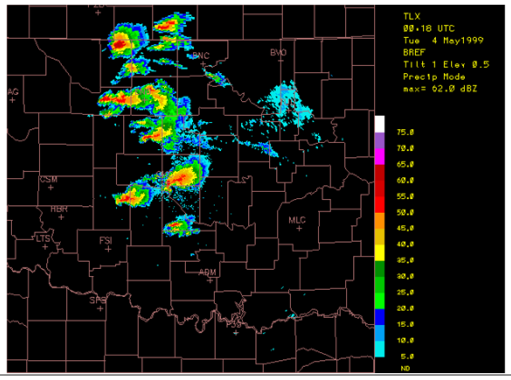
Mitigating Wind Effects–The Pit

Sometime



34

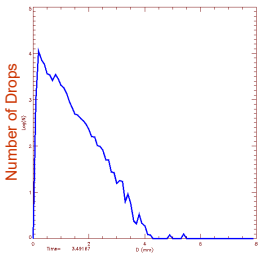
Sampling error can also be a problem



35

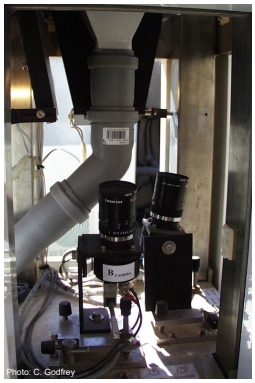
Optical Gauges: 2-D Video Disdrometer

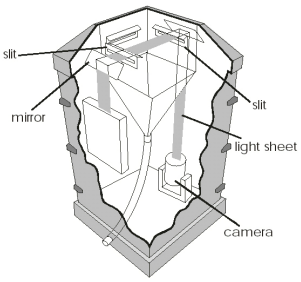
Disdrometers measure the entire drop-size distribution



36

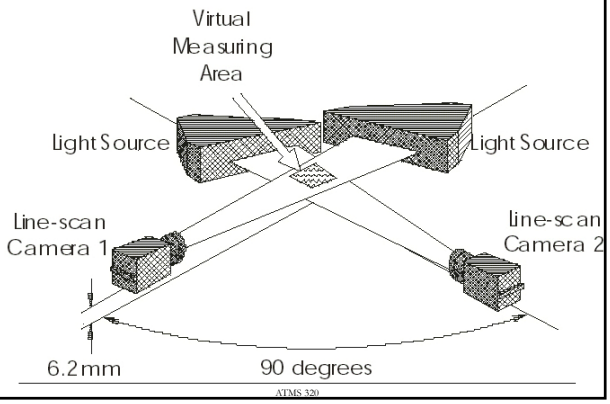
Optical Gauges: 2-D Video Disdrometer





37

Optical Gauges: 2-D Video Disdrometer



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Optical Gauges: 2-D Video Disdrometer

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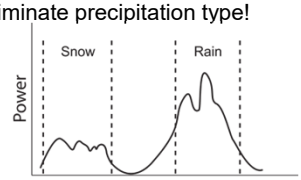
Other optical gauges

- As raindrops fall through a light beam, scintillations occur in the received beam
- The frequency power spectrum of the scintillations depends upon the size and terminal velocity of the particles
- The signal strength is proportional to rainfall rate
- Can discriminate precipitation type!

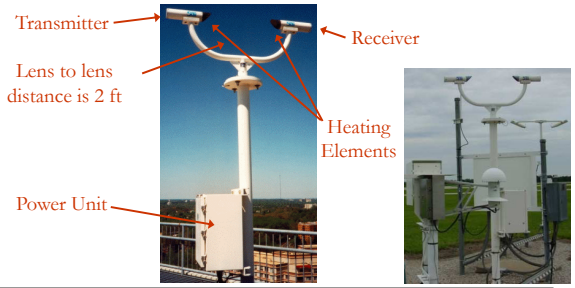


40

Other optical gauges–LEDWI

Light Emitting Diode Weather Identifier *or* Precipitation Identification sensor (PI)

- Used in ASOS
- Usually reports unknown precipitation (UP) for mixed rain and snow



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Frozen Precipitation

- There are many ways to measure frozen precipitation and freezing rain:
  - Antifreeze
  - Heaters
  - Snow stakes/rulers
  - Snow pillow
  - Acoustic sounding
  - Optical sensors

Image source: http://www.panoramamtn.com/stats.htm

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Frozen Precipitation–Freezing Rain Sensor

- Used in ASOS
- Small, cylindrical probe vibrates at resonant frequency
- When ice freezes on the probe, the vibration frequency decreases

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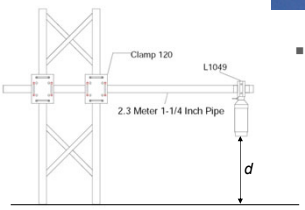
Frozen Precipitation–Acoustical Sounder

- Sound pulse transmitted to ground
- Measure time for pulse to reflect from surface back to sensor



- Measures snow or water depth, *d*:

$$d = \frac{ct}{2}$$

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Snow Pillow

- Bladder contains antifreeze solution
- As snow accumulates on pillow, weight of snow pushes an equal weight of antifreeze solution up a standpipe in the instrument house
- Snow water equivalent (SWE) measured by height of antifreeze

Image source: http://www.meted.ucar.edu/hydro/precip_est/part1_measurement/print.htm

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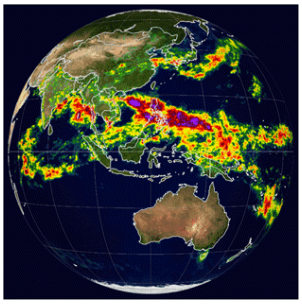
We can measure precipitation from satellite



For more information on the Global Precipitation Measurement program, visit
http://www.meted.ucar.edu/hydro/precip_est/part1_measurement/print.htm

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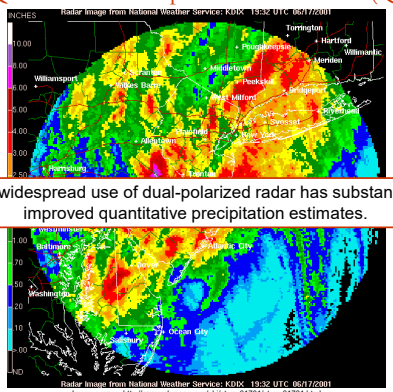
Radar Quantitative Precipitation Estimation (QPE)



The widespread use of dual-polarized radar has substantially improved quantitative precipitation estimates.

Image source: http://www.erh.noaa.gov/phi/storm61701/storm61701.html

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Water also goes up!

This is an evaporation pan

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