## Assignments

- Class Notes 2 review questions due today
- Additional assignment: due Feb. 8
- Read AMS draft policy statement on communicating science
- http://www.ametsoc.org/policy/draftstatements/comm unicating science draftstatement.pdf
- Summarize and critique the draft statement in a couple paragraphs
- Comment in a couple paragraphs on the role of appropriate use of statistics for communicating science


## 2010 Climate

- http://www.ncdc.noaa.gov/sotc


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* C ® http://www.ncdc.noaa.gov/sotc/service/global/significant-extremes/201013.gif $\quad$ -

Abstract: The climate of 2010 in hist... $\times \square$ 201013.gif (GIF Image, 2000x941... $\times$


Thir Arctic Sea Ice Extent 5
ret 2007 (lowest) and 2008 (second list During its a nual expansion, the Arctic reached its fiffhleast sea ice extent Finland had its c record on July 2 ? had its warmest since records began in 1979

Third driest' January since Winter 2009-2010 (December 2009-Februany 2010) was the records began in 1918 warmest and driest winter since national records began in 1948.

Canada also experienced its warmest spring (March-May) on record. Summer (June-August) 2010 was the third warmest on record for the nation, behind 1998 (warmest) and 2006 (second warmest). Autumn (September-November) 2010 was the second warmest, The U.K. and the Irish Republic expenienced their coolest winter (December-Febryary)

Eastern North Pacific Hurricane Season 3elow average activity: storms, 3 hurricanes. he number of named storms and urricanes was the lowest since reliable ecords began in 1971. 2010 had the hird lowest Accumulated Cyclone Energy (ACE) on record, behind 2007 ind 1977.

Hurricane Celia (Jun) Maximum winds $-260 \mathrm{~km} / \mathrm{hr}$ Second strongest June storm on record and second known Category 5 hurricane to develop during June. behind 1998 . Cyclonic Depression Xynthia Winter 2009-2010 (December 2009-February 2010) was the coolest winter since 1984-1985. Early in the year, a series of strong winter storms brought heavy snow and blizzard conditions to much of the U.S. Several seasonal records were broken.

Mexico
Hurricane Alex (Jun)
Maximum winds - $175 \mathrm{~km} / \mathrm{hr}$
July 2010 was the wettest July since 1941 and October 2010 was Alex was the first June hurricane in the Atlantic basin since 1995. Alexwas also the strongest June hurricane since 1966.


Caribbean
Several Caribbean countries were experiencing a record drought in late 2009 through early 2010.

Tropical Storm Agatha (May) Maximum winds - $75 \mathrm{~km} / \mathrm{hr}$ Agatha brought heavy rains to parts of Central America, triggering floods and landslides. Agatha was responsible for nearly 320 fatalities

EI Niño-Southern Oscillation (ENSO)
ENSO began 2010 in a warm phase (EI Niño), transitioning to a cold phase (La Niña) by July 2010.

periond since 1978-1979 and 1962-1963 respectively. Xynthia impacted parts of the coastal western Europe with hurricane force winds and heavy rain (Feb). This was the worst storm in the region since 1999


## Atlantic Hurricane

## Above average activity:

 19 storms, 12 hurricanes. The number of named storms and hurricanes was the highest since the record-setting 2005 season.


Storms brought heayy rain to southeastern France (Jun), mos leading to the worst floods sael of its worst drought in four decades. Rio Negro dropped to its lowest level of 44.7 feet ( 13.6 meters) since record keeping began in 1902. Peru

## Parts of western Africa were

 hard hit by heavy rainfall (Aug).Thousands of homes were
destroyed and nearly 200,000 peopte were affected. .


nanging climate, continual information about climate helps assess the incidence, hort-term and weather-scale tornado activity and tropical is to give the recent climate ctive based on 131 years of ts as well as paleoclimate tanding of the Earth's climate discussion of century-scale nperature and precipitation is f 2010 extreme events.
ort can be found online at: otc

## ANOMALIES IN 2010

or this manuscript is NOAA's rface Temperature (Smith et 380, making for a 131-year 2010 global (land and ocean e temperature anomaly was as the warmest calendar year global land temperature tied nest year on record, and the
month. This tied 2010 with 1998 as the calendar years with the most such "warmest months" on record, with three each. December 2010 was the coolest December since 2000.

| 2010 Annual <br> Temperature | Anomaly vs. 19012000 avg | 1880-2010 Rank (131 years) |  |
| :---: | :---: | :---: | :---: |
| Global |  |  |  |
| Land | $+0.96{ }^{\circ} \mathrm{C}$ | $2^{\text {nd }}$ warmest | tied 2005 |
| Ocean | $+0.49^{\circ} \mathrm{C}$ | $2^{\text {nd }}$ warmest | tied 2005 |
| Land \& Ocean | $+0.62^{\circ} \mathrm{C}$ | Warmest | tied 2005 |
| Northern Hemisphere |  |  |  |
| Land | $+1.08^{\circ} \mathrm{C}$ | $2^{\text {nd }}$ warmest |  |
| Ocean | $+0.51{ }^{\circ} \mathrm{C}$ | $3^{\text {rd }}$ warmest | tied 2003 |
| Land \& Ocean | $+0.73{ }^{\circ} \mathrm{C}$ | Warmest |  |
| Southern Hemisphere |  |  |  |
| Land | $+0.65^{\circ} \mathrm{C}$ | $5^{\text {th }}$ warmest | tied 2003 |
| Ocean | $+0.49^{\circ} \mathrm{C}$ | $5^{\text {th }}$ warmest |  |
| Land \& Ocean | $+0.51{ }^{\circ} \mathrm{C}$ | $6^{\text {th }}$ warmest |  |
| Table 1. 2010 surface temperature anomaly $\left({ }^{\circ} \mathrm{C}\right)$ and rank. Source: NOAA/NCDC. |  |  |  |

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NIT $\angle$ UUJ, putiolv 2010 temperature 00 base period, is anomalies occurred nd, and a large area specially north of the to South Asia. The quite warm. Cool and Mongolia, the eastern Pacific. The mperature ranks are
$y$ as 2009, the year te phases of ENSO st few months of the utumn, La Niña had gthened through the


Fig.1. Global surface temperature anomalies for 18802010. Source: NOAA/NCDC.


Fig. 6 Northern Hemisphere sea ice anomalies, September 1979-2010. Source: National Snow \& Ice Data Center.
counts ended 30 Ju 65 tropical storms, w average of 85.6. O alternatively, typhoo the long-term avera total of 35 . Tropical summarized in Table are preliminary.

Only the North A normal activity, cor during La Niña, whi shear conditions d named storms is the season, and tied wi the modern record seasons also occu storms reaching hu the modern era, extremely active Atla system made U.S. strength. This occ

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Fig. 7. Contiguous U.S. average annual temperatures, 1895-2010. Source: NOAA/NCDC.


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## ide Ranks

AA


Contiguous U.S., Precipitation, January-December


Fig. 10. Contiguous U.S. annual average precipitation, 1895-2010. Source: NOAA/NCDC.

## Changes in Climate Normals



Figure 1. The difference between the decade-averaged maximum temperatures in July

## Changes in Climate Normals

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Figure 2. Same as Figure 1, but for January minimum temperatures.


5DOmb Geopotential Height (m) Compoaite Anomaly (1968-19g6 Cli (m) Compoaite Anomaly
$12 / 1 / 10$ to $12 / 31 / 10$



5cOmb Geopotantial Height (m) Compoaite Anomaly (1968-1996 Climatology) $1 / 1 / 11$ to $1 / 29 / 11$
NCEP/NCAR Reanalysls



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850 HGT and Anomaly at 110203/0000V048



## Probability Definitions

- Event- possible uncertain outcomes
- Null event- can't happen
- Elementary event- can't be decomposed into other events
- Compound event- decomposable into 2 or more elementary events
- S- sample or event space- all possible elementary events
- Mutually exclusive- two events that can't occur at same time
- MECE- Mutually exclusive and collectively exhaustiveno more than 1 event can occur and at least one event will occur
$2 / 11$
lity of each event ation and location. aticians involved, oms", lemmas, etc. my event is
${ }_{1}$ English: an event or else it is not an
he compound event The probability will happen is 1 .
one or the other of two mutually exclusive events is the sum of their

|  |  |
| :---: | :---: |
| Temperature below <br> Precipitation below | Temperature above <br> Precipitation below |
| Temperature below <br> Precipitation above | Temperature above <br> Precipitation above |

Figure 4.2. MECE possibilities for seasonal forecasts temperature and precpitation anomalies for a specific location.

## More Definitions

- E- Event
- $\operatorname{Pr}\{E\}$ - probability of Event $E ; 0 \leq \operatorname{Pr}\{E\} \leq 1$
- $\operatorname{Pr}\{E\}=0$, event does not occur
- $\operatorname{Pr}\{E\}=1$ event occurs


## Storm Reports: Salt Lake County 1993-2005



Number of Opportunities: 2340 (180 days * 13 years)

## Two Statistical Frameworks:

 Frequency vs. Bayesian- Frequency- probability of an event is its relative frequency after many trials
- a- number of occurrences of E
- n- number of opportunities for $E$ to take place
- $a / n$ - relative frequency of $E$ occurring
- $\operatorname{Pr}\{E\} \rightarrow a / n$ as $n \rightarrow \infty$


## Two Statistical Frameworks: Frequency vs. Bayesian

- Bayesian- probability represents the degree of belief of an individual about an outcome of an uncertain event
- Some events occur so rarely that there is no long-term relevant probability
- Two individuals can have different probabilities for same outcome
- Bookies are Bayesian


## Live Lines



## More concepts

- $\{E\}^{c}$ - complement of $\{E\}$, event does not occur
- $\operatorname{Pr}\{E\}\}^{c}=1-\{E\}$
- $\operatorname{Pr}\left\{\mathrm{E}_{1} \cap \mathrm{E}_{2}\right\}$ - joint probability that $\mathrm{E}_{1} \& \mathrm{E}_{2}$ occur
- $\operatorname{Pr}\left\{E_{1} \cap E_{2}\right\}=0$ if $E_{1} \& E_{2}$ are mutually exclusive
- $\operatorname{Pr}\left\{E_{1} \cup E_{2}\right\}$ - probability that $E_{1}$ OR $E_{2}$ occur
- $\operatorname{Pr}\left\{\mathrm{E}_{1} \cup \mathrm{E}_{2}\right\}=\operatorname{Pr}\left\{\mathrm{E}_{1}\right\}+\operatorname{Pr}\left\{\mathrm{E}_{2}\right\}-\operatorname{Pr}\left\{\mathrm{E}_{1} \cap \mathrm{E}_{2}\right\}$


## Conditional Probability

- Conditional probability: probability of $\left\{\mathrm{E}_{2}\right\}$ given that $\left\{\mathrm{E}_{1}\right\}$ has occurred
- $\operatorname{Pr}\left\{\mathrm{E}_{2} \mid \mathrm{E}_{1}\right\}=\operatorname{Pr}\left\{\mathrm{E}_{1} \cap \mathrm{E}_{2}\right\} / \operatorname{Pr}\left\{\mathrm{E}_{1}\right\}$
- $\mathrm{E}_{1}$ is the conditioning event
- If $\mathrm{E}_{1}$ and $\mathrm{E}_{2}$ are independent of each other, then

$$
\operatorname{Pr}\left\{\mathrm{E}_{2} \mid \mathrm{E}_{1}\right\}=\operatorname{Pr}\left\{\mathrm{E}_{2}\right\} \text { and } \operatorname{Pr}\left\{\mathrm{E}_{1} \mid \mathrm{E}_{2}\right\}=\operatorname{Pr}\left\{\mathrm{E}_{1}\right\}
$$

- Fair coin- $\operatorname{Pr}\{$ heads $\}=0.5$
- chance of getting heads on second toss is independent of the first

Pr\{heads $\mid$ heads $\}=0.5$
Pr\{heads\} twice $=0.5^{*} 0.5=025$

## Bayes Theorem

- $\operatorname{Pr}\left\{\mathrm{E}_{2} \mid \mathrm{E}_{1}\right\}=\operatorname{Pr}\left\{\mathrm{E}_{1} \cap \mathrm{E}_{2}\right\} / \operatorname{Pr}\left\{\mathrm{E}_{1}\right\}$ or
- $\operatorname{Pr}\left\{E_{1} \cap E_{2}\right\}=\operatorname{Pr}\left\{E_{2} \mid E_{1}\right\}{ }^{*} \operatorname{Pr}\left\{E_{1}\right\}$
- $\operatorname{Pr}\left\{E_{1} \cap E_{2}\right\}=\operatorname{Pr}\left\{E_{1} \mid E_{2}\right\} * \operatorname{Pr}\left\{E_{2}\right\}$ then
- $\operatorname{Pr}\left\{\mathrm{E}_{1} \mid \mathrm{E}_{2}\right\}=\operatorname{Pr}\left\{\mathrm{E}_{2} \mid \mathrm{E}_{1}\right\} * \operatorname{Pr}\left\{\mathrm{E}_{1}\right\} / \operatorname{Pr}\left\{\mathrm{E}_{2}\right\}$
- What is the advantage? Probability of conditioning event $\mathrm{E}_{2}$ only computed once


## Bayesian Application: how a rational person responds to evidence

|  | Pos Test | Neg Test | TOTAL |
| :--- | :--- | :--- | :--- |
| DRUG USER | $0.495 \%$ | $0.005 \%$ | $0.5 \%$ |
| NOT DRUG <br> USER | $.995 \%$ | $98.505 \%$ | $99.5 \%$ |
| TOTAL | $1.49 \%$ | $98.51 \%$ | 1 |

What are odds of falsely accusing non drug user?
$\mathrm{E}_{1}$ - not drug user
$\mathrm{E}_{2}$ - positive test
$\operatorname{Pr}\left\{\mathrm{E}_{1}\right\}-99.5 \%$
$\operatorname{Pr}\left\{E_{2}\right\}-1.49 \%$
$\operatorname{Pr}\left\{\mathrm{E}_{2} \mid \mathrm{E}_{1}\right\}-.995 \%$
$\operatorname{Pr}\left\{\mathrm{E}_{1} \mid \mathrm{E}_{2}\right\}=\operatorname{Pr}\left\{\mathrm{E}_{2} \mid \mathrm{E}_{1}\right\} * \operatorname{Pr}\left\{\mathrm{E}_{1}\right\} / \operatorname{Pr}\left\{\mathrm{E}_{2}\right\}=$ $=0.995$ * $99.5 / 1.49=68 \%$

Conclusion: always ask for second opinion if clean and test positive

## Bayesian Application:

|  | COLD | WARM | TOTAL |
| :--- | :--- | :--- | :--- |
| DRY | 20 | 60 | 80 |
| WET | 20 | 0 | 20 |
| TOTAL | 40 | 60 | 100 |
| $E_{1}-$ cold |  |  |  |
| $\mathrm{E}_{2}-$ dry |  |  |  |
| $\operatorname{Pr}\left\{\mathrm{E}_{1}\right\}-0.4$ |  |  |  |
| $\operatorname{Pr}\left\{\mathrm{E}_{2}\right\}-0.8$ |  |  |  |
| $\operatorname{Pr}\left\{\mathrm{E}_{2} \mid \mathrm{E}_{1}\right\}-0.5$ |  |  |  |

We can't tell if it is cold or warm
But we know it is dry

$$
\begin{aligned}
\operatorname{Pr}\left\{\mathrm{E}_{1} \mid \mathrm{E}_{2}\right\} & =\operatorname{Pr}\left\{\mathrm{E}_{2} \mid \mathrm{E}_{1}\right\} * \operatorname{Pr}\left\{\mathrm{E}_{1}\right\} / \operatorname{Pr}\left\{\mathrm{E}_{2}\right\}= \\
& =0.5 * 0.4 / 0.8=0.25
\end{aligned}
$$

## NAME

$\qquad$
ATMOS 5040/6040 in Class Assignment
Number of opportunities: 2340
$\left\{\mathrm{E}_{3}\right\}=$ occurrence of winter storms ( $142+79=221$ )
$\left\{E_{3}\right\}=$ occurrence of convective storms (25+83=108)
$\left\{E_{2}\right\}=$ occurrence of property damage
$(79+113+25=217)$

| $\operatorname{Pr}\left[E_{1}\right]=$ | $\operatorname{Pr}\left[E_{3}\right]=$ | $\operatorname{Pr}\left[\mathrm{E}_{k}\right]=$ | $\operatorname{Pr}\left\{\mathrm{E}_{1} \cap \mathrm{E}_{3}\right\}=$ | $\operatorname{Pr}\left[E_{3} \cap E_{2}\right]=$ |
| :---: | :---: | :---: | :---: | :---: |
| $\operatorname{Pr}\left[\mathbf{E}_{1} \cup \mathrm{E}_{2}\right]=$ | $\operatorname{Pr}\left\{E_{2} \cup E_{2}\right\}=$ | $\operatorname{Pr}\left[\mathrm{E}_{1} \mathrm{UE}_{\mathrm{E}_{3}}\right]=$ | $\operatorname{Pr}\left\{\mathrm{E}_{3} \mid \mathrm{E}_{1}\right\}=$ | $\operatorname{Pr}\left\{\mathbf{E}_{3} \mid E_{3}\right\}=$ |

For astandard deck of 52 cards, desl out all cards in pairs. Pr\{sce $\}=\quad \operatorname{Pr}\{10-\mathrm{K}\}=\operatorname{Pr}\{2-9\}=$ What is the probsbility of getting a blsckjack for any pair of cards: $\operatorname{Pr}\{$ ace $\cap 10-\mathrm{K}\}=$ What is the probability of getting blackjack twice: $\operatorname{Pr}[$ ace $\cap 10-\mathrm{K}\}{ }^{*} \operatorname{Pr}\{$ ace $\cap 10-\mathrm{K}\}=$

Now, play at least 20 hands of blackjack with 3 other people Summarize in a table below your own relative frequencies ( $\mathrm{a} / \mathrm{n}$ ) of getting an ace, 10-K, 2-9, blackjack, and two blsckjacks. Who in your group was resily lucky?

|  | n | s | $\mathrm{s} / \mathrm{n}$ |
| :--- | :--- | :--- | :--- |
| ace |  |  |  |
| $10-\mathrm{K}$ |  |  |  |
| $2-9$ |  |  |  |
| blackjack |  |  |  |
| Two blackjocks |  |  |  |

