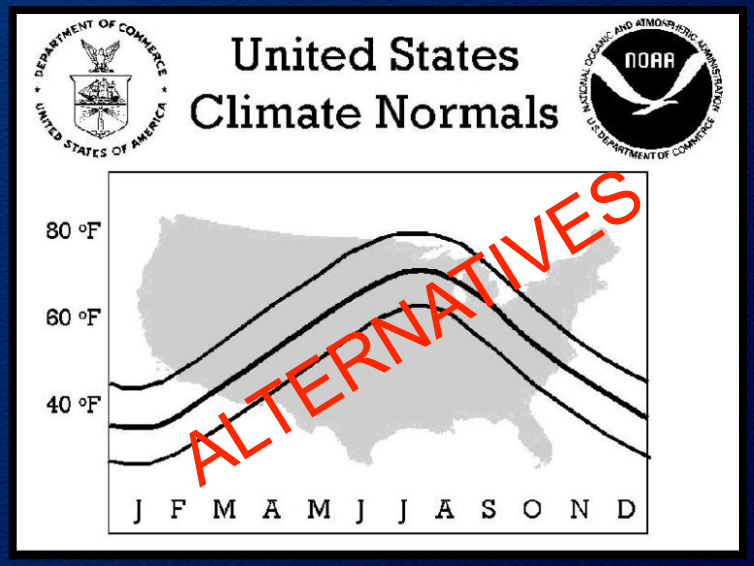
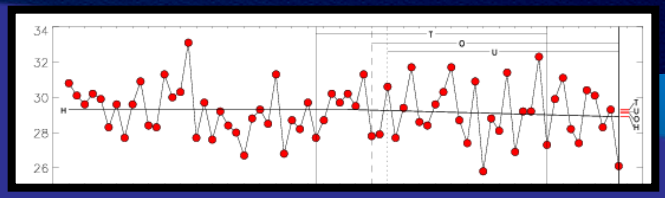
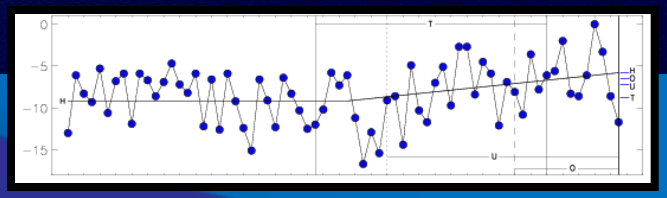


Alternative Climate Normals: A Philosophical View

Anthony Argüez

NOAA's National Climatic Data Center





Key Takeaway Messages

- Traditional Normals don't account for climate change

- Alternative Normals can be derived by changing the generalized formula we use to calculate Normals

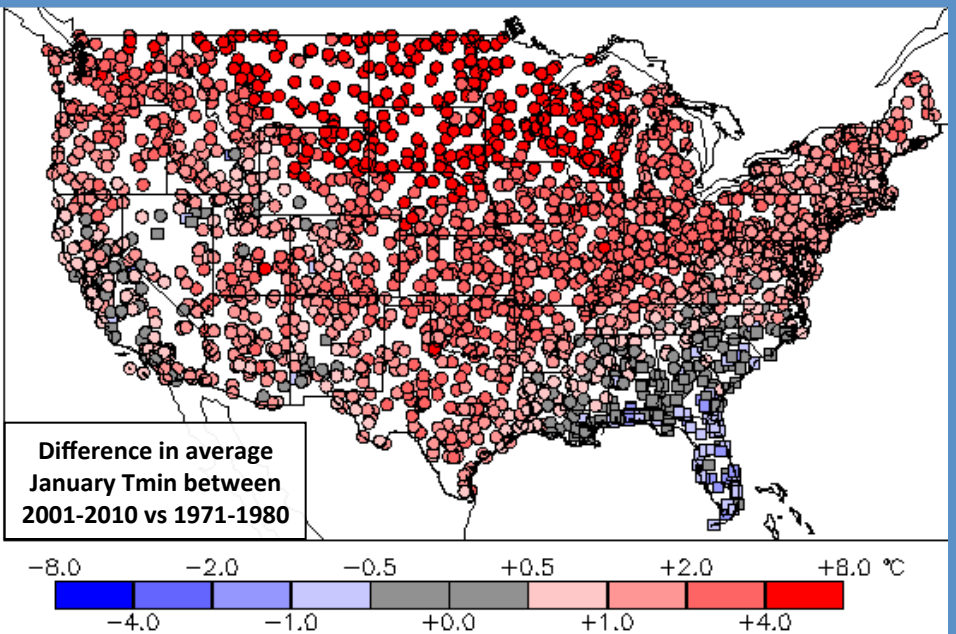
- Energy Industry is a natural partner for these efforts

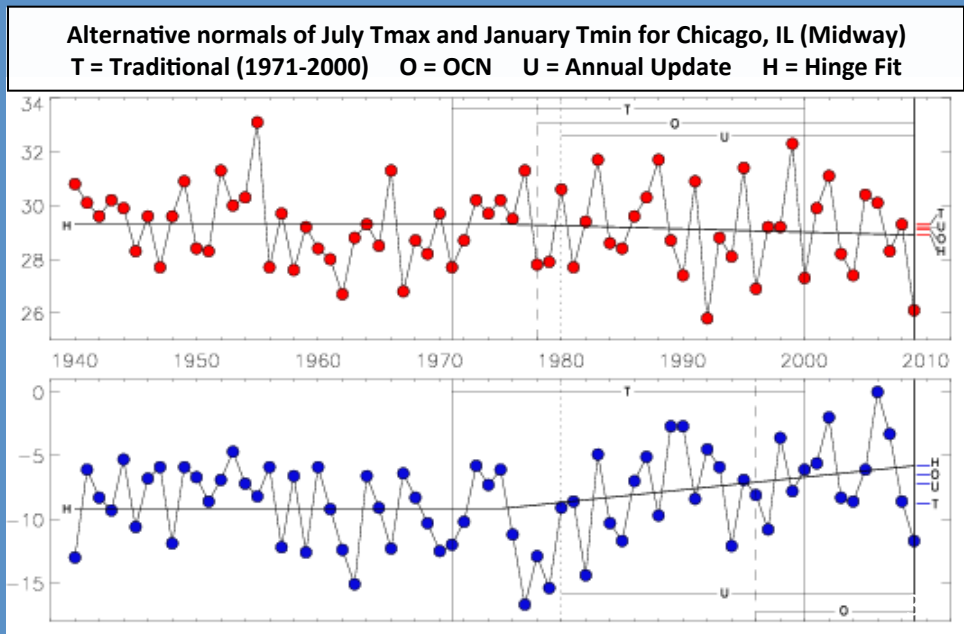
1981-2010 Normals

- Official (legacy) product
- Designed for stationary climates
- 30-Year Averages
- Large suite of variables
- Produced every ten years

Alternative Normals

- *Experimental products*
- ***Accounts for climate change***
- *N-Year Averages, Linear Fits, etc.*
- *Monthly temperatures (currently)*
- *Uses most recent data available*





Timeline

RENEWED INTEREST IN ALTERNATIVES AT NCDC

- 2005: Preliminary discussions on "Dynamic Normals"
- 2006: a. Letter from Cascade Natural Gas
  b. Bob Livezey research (became Livezey et al. 2007)
- 2007: a. May Telecon on "Optimal Normals"
  b. September Webcast on "Optimal Normals"
- 2008: Continued Engagement: load forecasters, PUC/PSCs
- 2009: "Alternative Normals" release with webcast
- 2009-2012: AMS Energy Committee
- 2010-2011: Focus on Traditional Normals, Hourly Normals
- 2011: Argüez and Vose appears in BAMS

Philosophical Issues

- *Climate Normals are calculated retrospectively, but are utilized prospectively*
- *The best predictor of future behavior is past behavior*
- Is the climate stubborn?
- But can we really assume the climate is stationary?
- If not, climate normals are not representative of the current state of the climate, much less future climate conditions

Philosophical Issues, Continued

- Dual purpose of Normals:
  - A point of reference (i.e., for monitoring)
  - As a predictive tool (e.g., for planning)
- For a stationary climate, traditional normals work for both purposes
- Little reason to update them frequently IF AT ALL
- Moving the goal posts…
  - Fixed normals: An observation of 83°F will always be 2°F above a 81°F Normal
  - Updated normals: 83°F can be above normal one year and below normal the next year if the normal is updated

Philosophical Issues, Continued

- Dual purpose of Normals:
  - A point of reference (i.e., for monitoring)
  - As a predictive tool (e.g., for planning)
- For a non-stationary climate, traditional normals still work as points of reference, but the predictive ability is compromised
- Climate change renders the traditional climate normal inadequate as a predictive tool, necessitating the development of alternative climate normals

A Generalized Normals Equation

$$y(t_0 + k\Delta t) = \sum_{t_0 + k\Delta t - N + 1}^{t_0 + k\Delta t} w(i)x(i)$$

INGREDIENTS

y: climate normal

w: weighting function

x: annual climate time series

Δt: update frequency

t_o*:* reference year

k: any integer

N: number of years averaged

The Traditional Normals Equation

$$y(t_0 + k\Delta t) = \sum_{t_0 + k\Delta t - N + 1}^{t_0 + k\Delta t} w(i)x(i)$$

$$y(t_0 + 10k) = \frac{1}{30} \sum_{i=t_0 + 10k - 29}^{t_0 + 10k} x(i)$$

Just One Recipe

The 1981-2010 Normals Equation

$$y(t_0 + k\Delta t) = \sum_{t_0 + k\Delta t - N + 1}^{t_0 + k\Delta t} w(i)x(i)$$

$$y(t_0 + 10k) = \frac{1}{30} \sum_{i=t_0 + 10k - 29}^{t_0 + 10k} x(i)$$

$$y(2010) = \frac{1}{30} \sum_{i=1981}^{2010} x(i)$$

Just One Batch

Five Key Attributes of Normals Definition

- temporal average
- the average is unweighted
- the averaging period is thirty consecutive years
- a causal filter (using past and current values only)
- updated once per decade

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Five Key Attributes of Normals Definition

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  $w = {}^{1}/_{30}$
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$$y(t_o + 10k) = \frac{1}{30} \sum_{i=t_o+10k-29}^{t_o+10k} x(t)$$

$$y(2010) = \frac{1}{30} \sum_{i=1981}^{2010} x(t)$$

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$$y(2010) = \frac{1}{30} \sum_{i=1981}^{2010} x(t)$$

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$$y(t_o + 10k) = \frac{1}{30} \sum_{i=t_o+10k-29}^{t_o+10k} x(t)$$

$$y(2019) = \frac{1}{30} \sum_{i=1981}^{2010} x(t)$$

$$y(2010) = \frac{1}{30} \sum_{i=1981}^{2010} x(t)$$

Five Key Attributes of Normals Definition

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  $\Delta t = 10$ years

Temporal Average

- the defining characteristic of climate normals
- essentially a running average, climate normals smooth out year-to-year variability to try and capture the 'background state'

ALTERNATIVES

- Median
- Linear or 'Hinge' Fits (time-dependent)
- Empirical Mode Decomposition (time-dependent)

Unweighted Average

- Every year in the averaging period carries the same level of influence
- Works best when there is no trend, autocorrelation
- Why not give more weight to more recent years?

ALTERNATIVES: weighted averages

- Weights determined theoretically
- Weights determined empirically

N = 30 years

- 30 is the "rule of thumb" minimum for samples
- Changing N is most common approach for alternative normals
- For stationary time series, N should be large
- For non-stationary time series, N should be small

ALTERNATIVES: N-year averages

- Arbitrarily select 10, 15, 20 year averages
- Optimal Climate Normals (OCN): fixed at N=10 for temperature and N=15 for precipitation
- Livezey et al. (2007): analytical OCN, not fixed

Causal Filter

- Only consider past and present values
- No forecasting & Not centered averages
- Are the 1981-2010 normals representative of climatic conditions in 1995/1996?
- In 2010, the 1971-2000 normals were still the official version of normals – 1985/1986?

ALTERNATIVES: using projections (of future values)

- Statistical forecasting (e.g., ARMA model)
- Downscaled climate model projections
- Can also lead to estimates of "future normal"

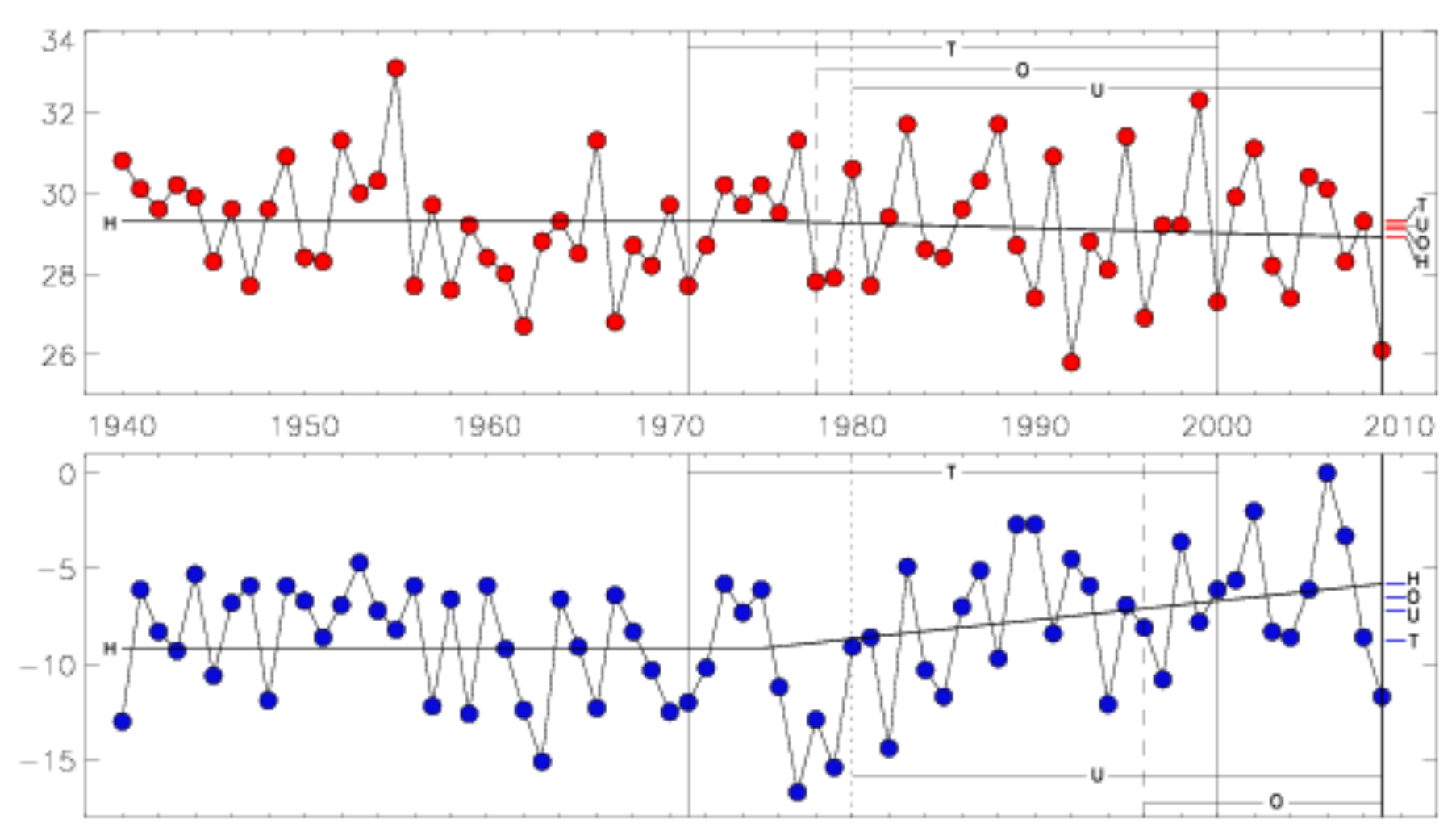
Decadal Update

- WMO recommendation (mandate is every 30 years)
- Updating normals is not as critical for stationary climate series
- For non-stationary climate series, updates should be as frequent as possible (for predictability)
- Otherwise, the normals become increasingly obsolete as we progress through the decade

ALTERNATIVE:

- Update climate normals every year

Alternative normals of July Tmax and January Tmin for Chicago, IL (Midway)
T = Traditional (1971-2000) O = OCN U = Annual Update H = Hinge Fit



CPC Perspective

- NOAA's Climate Prediction Center (part of NWS)
- CPC has used Optimal Climate Normals as a forecast tool since 1995
- CPC forecasts are relative to 1981-2010 normals computed "in house." This approach has many advantages, including freedom to use different OCN for temperature & precipitation, etc.
- CPC does not recommend OCN to be the alternative normal. It is argued that OCN is not aggressive enough is following temperature trends. This can be examined quantitatively . . . .

Energy Industry's Unique Role

- AMS Energy Committee support
- Support from folks in the room
- Impacts:
  - load forecasting
  - rate cases (both utilities and regulators)
  - building design standards
  - T&D equipment – very capital intensive industry
- Climate change impacting operations
- Adaptation
- Can Alternative Climate Normals help?

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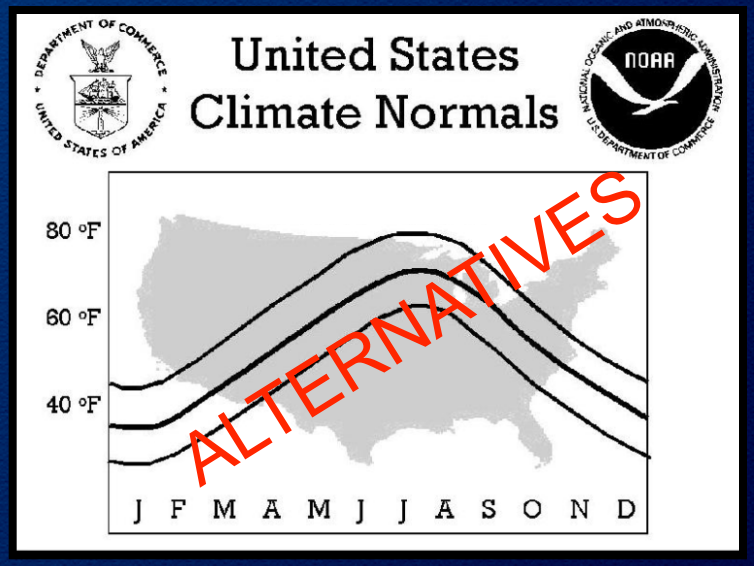

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