

An Ocean Climate Reanalysis for the 20th Century

An Ocean Climate Reanalysis for the 20th Century

Department of Oceanography

Supercomputing

Benjamin Giese

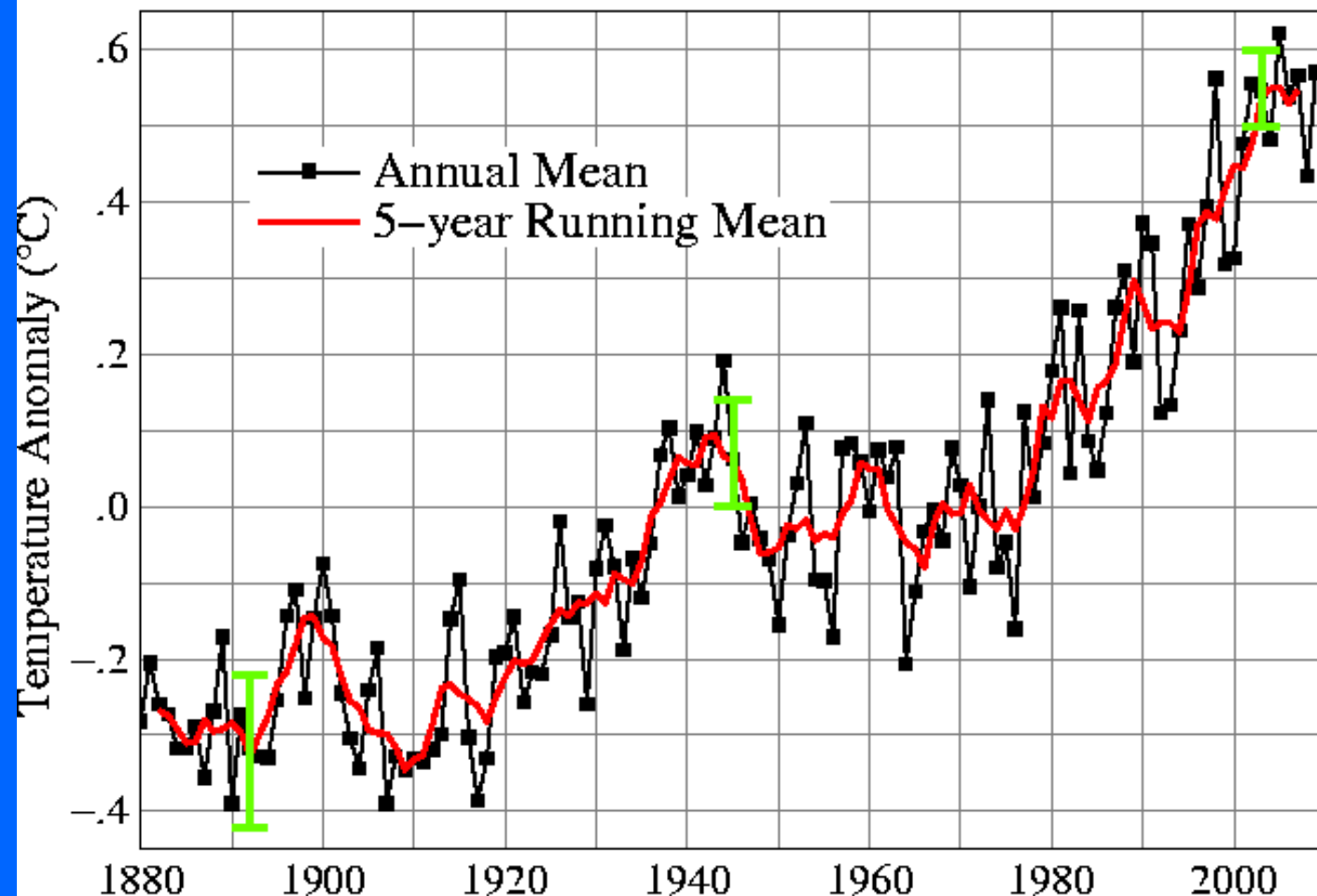
Ping Luo

Hank Seidel

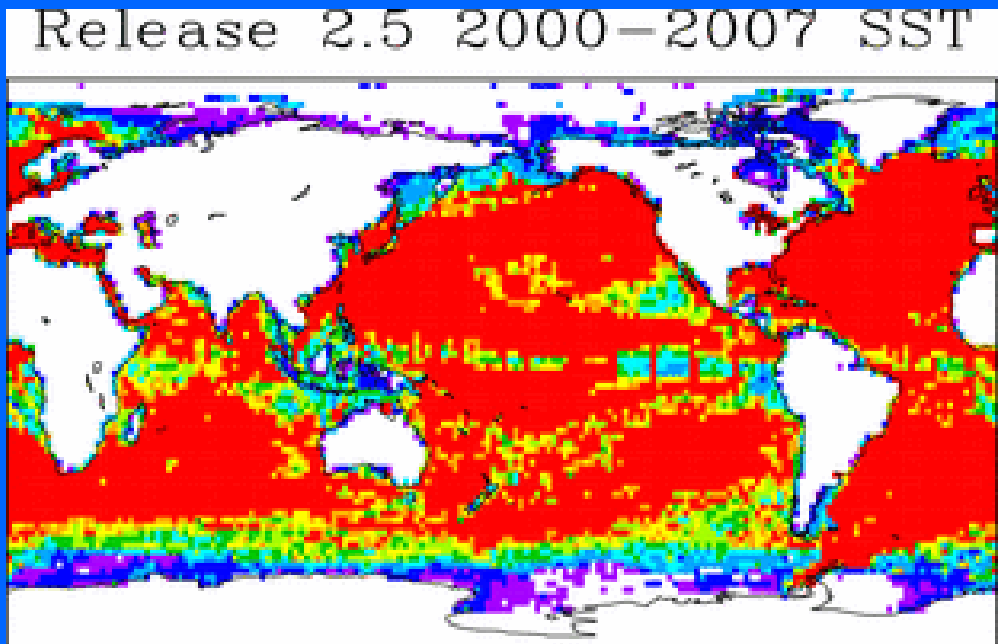
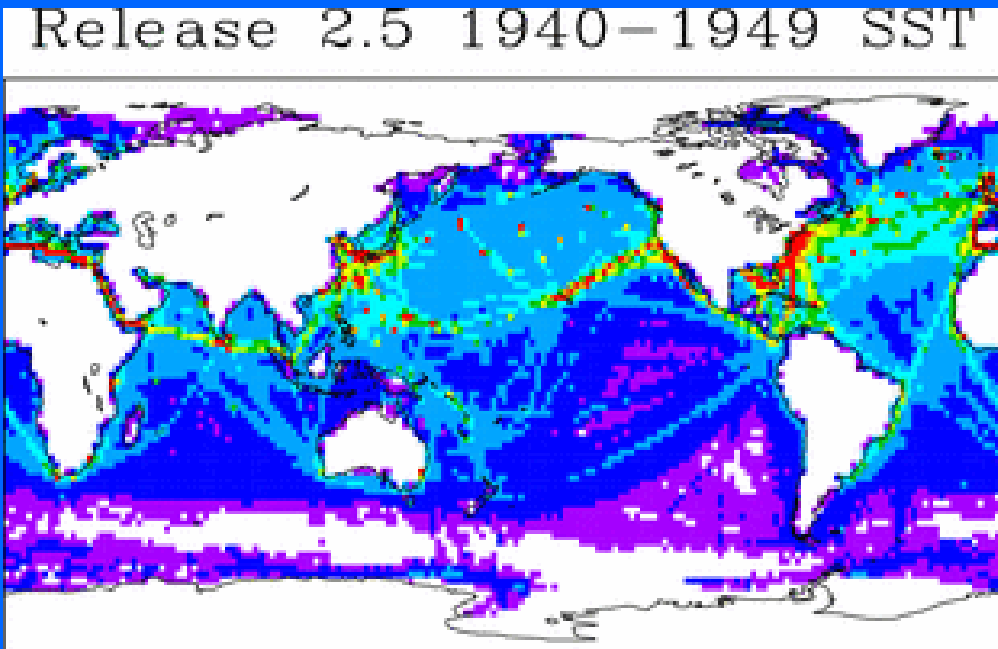
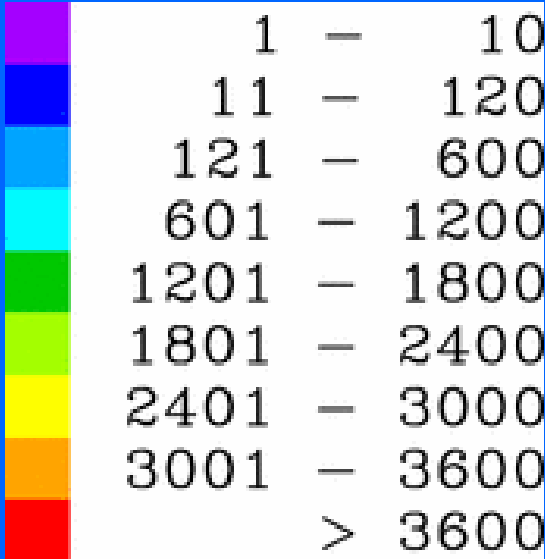
Sulagna Ray

Chunxue Yang

Global Land–Ocean Temperature Index



ICOADS # of Observations Per Decade



SODA: Simple Ocean Data Assimilation

Carton and Giese, MWR, 2008

A Synthesis of:

Global Ocean Observing Systems
Fine resolution Global Ocean Model

Uses:

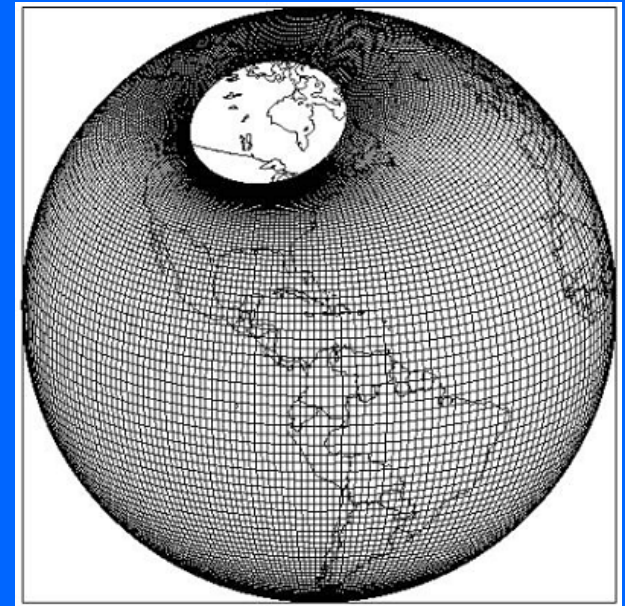
- State estimation for the global oceans
- Boundary conditions for regional models
- Analysis of climate variability

20th Century Atmospheric Reanalysis 1871 - 2008

- Uses a consistent set of observations
- Surface pressure and reconstructed SST
- Provides winds and atmospheric variables needed for the ocean model bulk formulae

SODA 2.2.4

- **Numerics**
 - Parallel Ocean Program
- **Domain**
 - Global (including Arctic)
- **Resolution**
 - 0.4×0.25 on eq. ($\sim 25\text{km} \times 25\text{km}$ midlat) horizontal
 - 40 levels: 10m near surface to 450m in deep ocean
- **Winds**
 - 20C_r daily stress 1871 – 2008
- **Heat and Salt fluxes**
 - Bulk formulae using 20C_r daily variables
- **SODA Data Assimilation**
 - WOD09 Hydrographic and ICOADS SST data

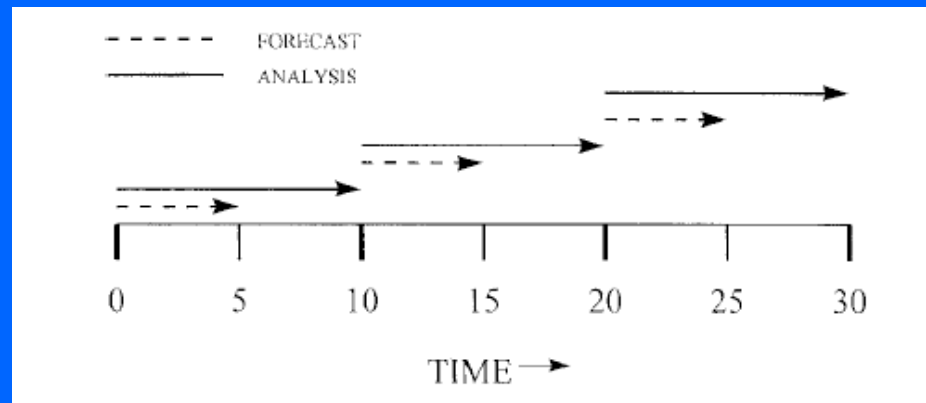


Assimilation details

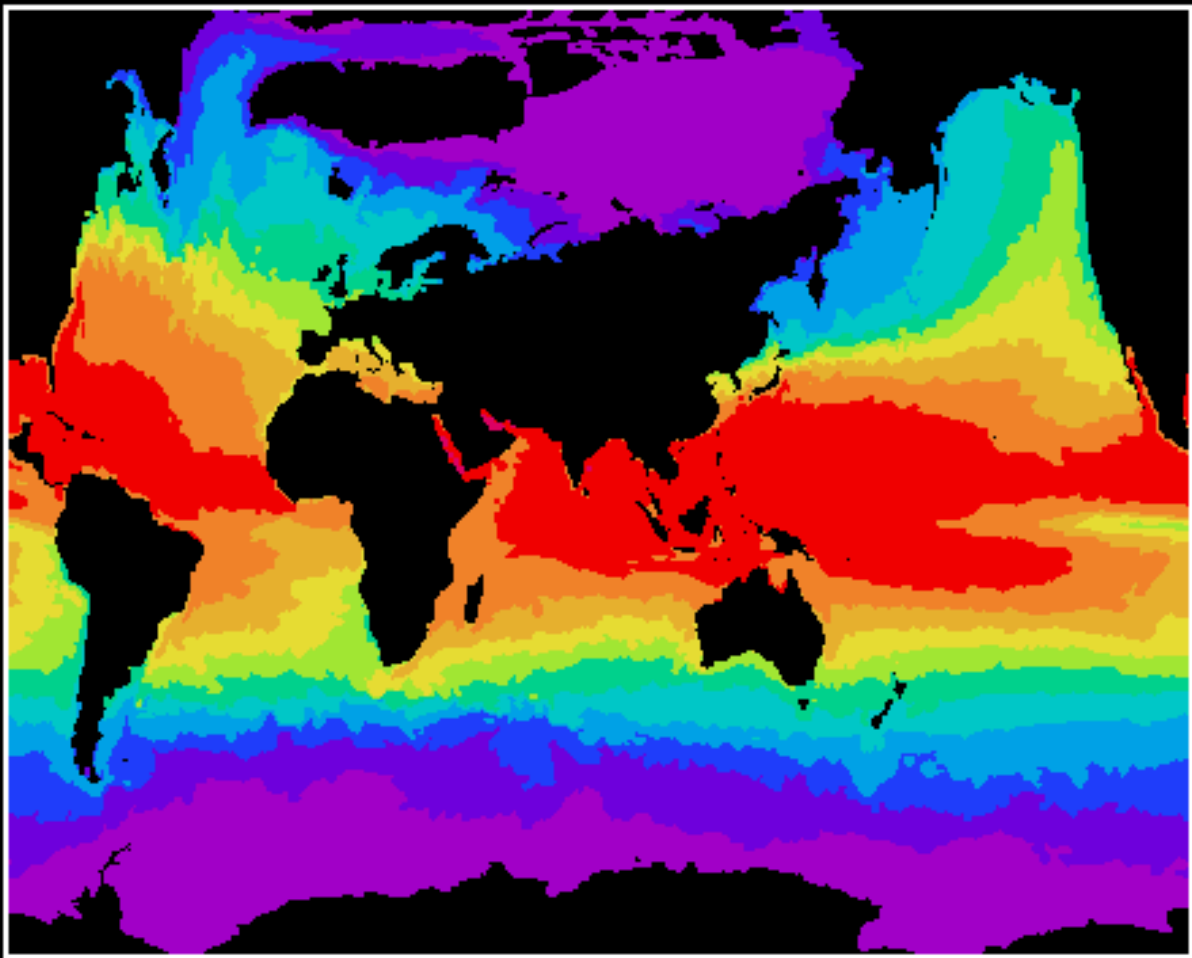
- Sequential Estimation - like OI but.....
- Error covariances:
 - Flow-dependent, anisotropic, latitude/depth-dependent
- Updating Equations
 - Analysis = Forecast - L(Obs-H(Model Forecast))
 - 10-day Incremental Updating
- Data
 - WOD09
 - Hydrography (MBTs, XBTs, CTDs, floats, moored thermistor chains, Argo, etc.)

The SODA Cycle

1. A 5-day forecast is made with the ocean-only model
2. An analysis of the forecast - observations is done
3. The analysis is used to construct “innovations” which are added to an integration for 10 days
4. Repeat



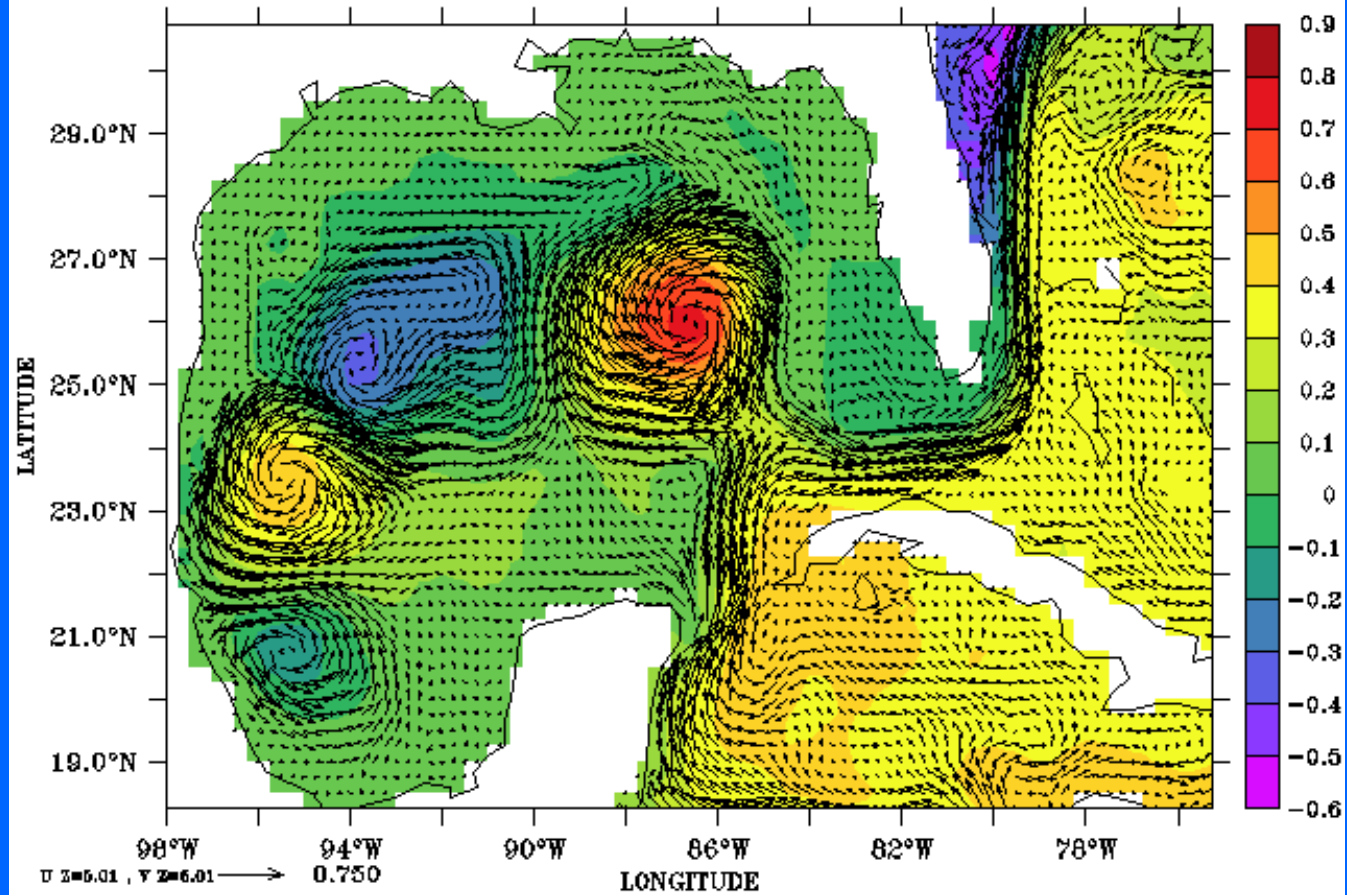
- 120 processors on Hydra
- Still took 3 months to complete
- Or...30 years on a single processor machine



TIME : 09-DEC-2001 12:00

DATA SET: N_ATLANTIC₂001.mnc

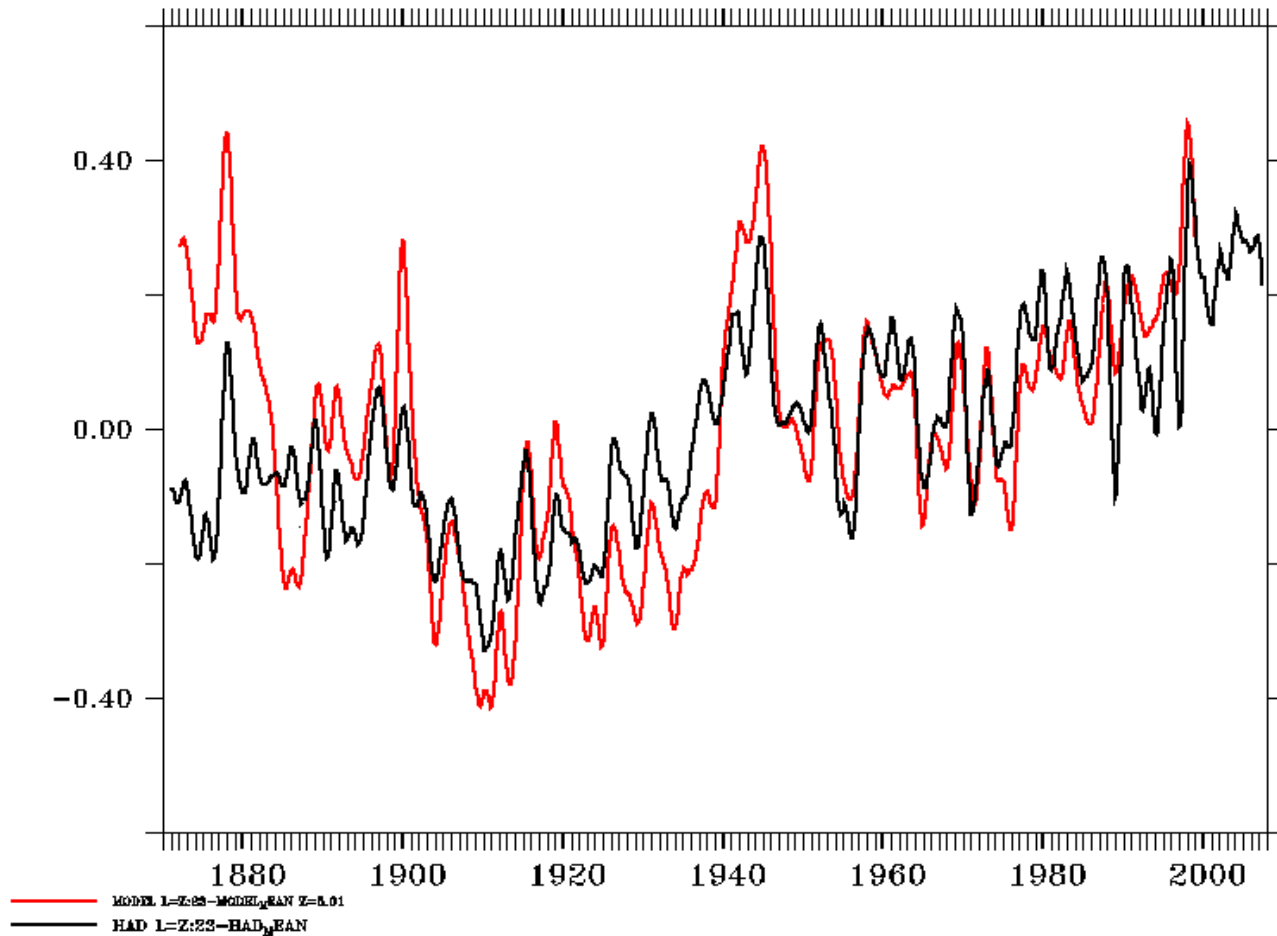
SODA - POP Assimilation Run ERA40



SEA LEVEL HEIGHT (m)

Global (60s-60n) SST

RED – SODA_2.2.4 BLACK - HADISST



The 1918/1919 El Niño

The 1918/1919 El Niño

A collaboration between TAMU, the University
Of Colorado, and the University of Maryland

Published in: the Bulletin of the American
Meteorological Society, 2010

"All the News That's Fit to Print."

The New York Times.

THE WEATHER
For the City and Vicinity
Forecast for Nov. 11, 1918
Partly cloudy with light rain
Temperature 45 to 55

NEW YORK, MONDAY, NOVEMBER 11, 1918. TWENTY-FOUR PAGES. TWO CENTS PER COPY.

ARMISTICE SIGNED, END OF THE WAR! BERLIN SEIZED BY REVOLUTIONARIES; NEW CHANCELLOR BEGS FOR ORDER; OUSTED KAISER FLEES TO HOLLAND

SON FLEES WITH EX-KAISER

Hindenburg Also Believed to be Among Those in His Party.

ALL ARE HEREBY ARMED

Autonomous Bricks with Rifles as Fighting Arms at Berlin Front.

ON THEIR WAY TO BE STUNG

Explosives Told to Them, "Are You the First Way to Paris?"

LONDON, Nov. 11.—Such is the German Government's attitude toward the revolution in Berlin, that it has ordered the German army to be ready to march into the city at any moment. The German Government has also ordered the German army to be ready to march into the city at any moment.

Princes may be killed in the city, according to the German Government. The German Government has also ordered the German army to be ready to march into the city at any moment.

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Kaiser Fought Hindenburg's Call for Abolition; Failed to Get Army's Support in Keeping Throne

By GEORGE BROWN. LONDON, Nov. 11.—The Kaiser's attitude toward the revolution in Berlin is a subject of interest to all who follow the progress of the war. The Kaiser's attitude toward the revolution in Berlin is a subject of interest to all who follow the progress of the war.

Kaiser Shamed as His Squad Advances

LONDON, Nov. 11.—The Kaiser's attitude toward the revolution in Berlin is a subject of interest to all who follow the progress of the war. The Kaiser's attitude toward the revolution in Berlin is a subject of interest to all who follow the progress of the war.

GERMAN DYNASTIES BEING WIPED OUT

King of Wurtemberg Addresses—Governor of Saxony to Follow Suit.

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BERLIN TROOPS JOIN REVOLT

Reds Seize Building in Which Officers Vainly Resist.

THROUGH DEMANDS PUBLIC

Revolutionary Flag on Roof Palace—Queen's Palace Also Seized.

GENERAL STRIKE IS BEGUN

Regiment and Police Regiments' Offices Now in the Hands of the Revolutionaries.

LONDON, Nov. 11.—

The revolution in Berlin has spread to the city of Berlin. The revolution in Berlin has spread to the city of Berlin. The revolution in Berlin has spread to the city of Berlin.

THE WAR MINISTRY HAS COLLAPSED

When the revolutionaries seized the War Ministry, the War Ministry collapsed. The War Ministry collapsed when the revolutionaries seized the War Ministry.

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Socialist Chancellor Appeals to All Germans To Help Him Save Fatherland from Anarchy

BERLIN, Nov. 11.—The Socialist Chancellor, Friedrich Ebert, has appealed to all Germans to help him save the fatherland from anarchy. The Socialist Chancellor, Friedrich Ebert, has appealed to all Germans to help him save the fatherland from anarchy.

CONGRESSMAN HAS BEEN KILLED

By a bullet from the German Government. The German Government has also ordered the German army to be ready to march into the city at any moment.

THE REVOLUTIONARY GOVERNMENT HAS BEEN FORMED

The revolutionary government has been formed in Berlin. The revolutionary government has been formed in Berlin. The revolutionary government has been formed in Berlin.

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WAR ENDS AT 6 O'CLOCK THIS MORNING

The State Department in Washington Made the Announcement at 2:45 o'Clock.

ARMISTICE WAS SIGNED IN FRANCE AT MIDNIGHT

Terms include Withdrawal from Alsace-Lorraine, Disarming and Demobilization of Army and Navy, and Occupation of Strategic Naval and Military Points.

By Dr. Leonard P. Wick

WASHINGTON, Monday, Nov. 11, 2:45 A. M.—The armistice between Germany, on the one hand, and the allied Governments and the United States, on the other, has been signed.

The State Department announced at 2:45 o'clock this morning that Germany had signed. The State Department announced at 2:45 o'clock this morning that Germany had signed.

THE DEPARTMENT'S ANNOUNCEMENT SIMPLY SAID: "THE ARMISTICE HAS BEEN SIGNED."

The world war will end this morning at 6 o'clock, Washington time, 11 o'clock Paris time. The armistice was signed by the German representatives at midnight.

This announcement was made by the State Department at 2:50 o'clock this morning. The announcement was made verbally by an official of the State Department in the form:

"The armistice has been signed. It was signed at 5 o'clock A. M. Paris time, [midnight, New York time,] and hostilities will cease at 11 o'clock this morning, Paris time, [6 o'clock, New York time.]"

The terms of the armistice, it was announced, will not be made public until later. Military men here, however, regard it as certain that they include:

Immediate retirement of the German military forces from France, Belgium, and Alsace-Lorraine.

Disarming and demobilization of the German armies.

Occupation by the allied and American forces of such strategic points in Germany as will make impossible a renewal of hostilities.

Delivery of part of the German High Seas Fleet and a certain number of submarines to the allied and American naval forces.

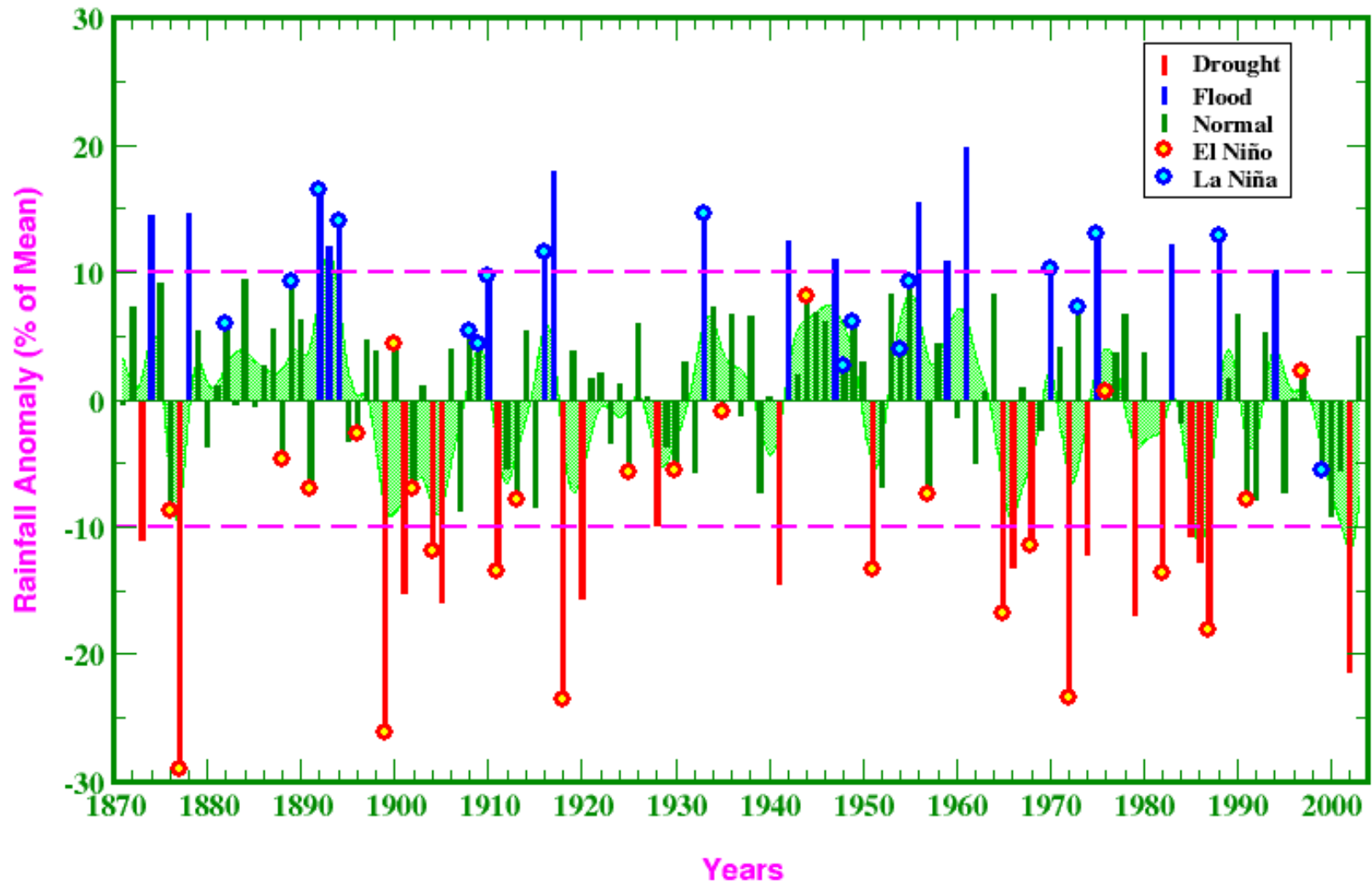
Disarmament of all other German warships.

Camp Funston, Kansas 1918



All-India Summer Monsoon Rainfall, 1871-2003

(Based on IITM Homogeneous Indian Monthly Rainfall Data Set)



BLIZZARD PARALYZES OHIO AND NATION

CONGRESS SET ON REVAMPING WAR BUREAU

Bills to be introduced in House and Senate as result of probes into Military Affairs.

BAKER, WILSON OPPOSE

Investigating Committee in Senate Secretary Durr-states Facts.

BY NEW T. ALLEN
From Signal Bureau, Washington, Jan. 12.

Legislation to bring about a more complete reorganization of the war department will be introduced in both House and Senate as a result of the reorganization of the war department by the Senate investigating committee.

That of the several bills already introduced providing for the reorganization of the war department.

Members of War Board today on the extreme west declared the reorganization in the presence of a Department. In proposing the reorganization, which has already been introduced in the House.

The investigating committee in the House today proposed a more complete reorganization of the war department.



AMERICANS IN BOMBING RAIDS TELL EXPLOITS

Aviators Describe How They Blow Up For's Arms Depots.

ONLY GERMAN RICH STAVE OFF HUNGER

Hoflander Tells of Conditions in Berlin During Recent

BRITISH WARSHIP WRECKED; ENTIRE CREW IS LOST

Destroyer Recoon Found Off Ireland; Find 22 Bodies.

SUICIDE MAY SIFT MURDERS IN CAMP

Army Captain Shoots Himself, Leaves Bloody Town

ALL TRAIN SERVICE IS SUSPENDED; DEATHS AND SUFFERING IN STATE; CLEVELAND FIGHTS FUEL SHORTAGE

Perry and Other Big Roads Abandon Western Schedules; Scores Die; 27 Below is Lowest.

CITIES FACE FUEL CRISIS

Chicago, Hard Hit, Struggles Under Deluge of Snow; Trade Paralyzed.

Created from Associated Press Dispatches

The entire nation is in the grip of record breaking cold that is causing deaths by the score, completely paralyzing all train service, including some of the biggest cities in the country and forcing many other cities to grapple with a fuel problem that has never seemed unmanageable.

From the Atlantic to the Pacific and from Canada to the Gulf of Mexico the record breaking cold is a deadly and relentless foe.

The temperature in Cleveland today is 27 below zero.

Thousands in Cleveland Wage Battle to Heat Homes as Gas and Coal Supplies Run Low.

COLD FIGURES

City	Temperature
Cleveland	27
Chicago	25
St. Louis	20
Philadelphia	15
New York	10
San Francisco	5
Los Angeles	0
Houston	-5
Portland	-10
Seattle	-15
Denver	-20
Minneapolis	-25
St. Paul	-28
Chicago	-30
St. Louis	-32
Philadelphia	-35
New York	-38
San Francisco	-40
Los Angeles	-45
Houston	-50
Portland	-55
Seattle	-60
Denver	-65
Minneapolis	-70
St. Paul	-75
Chicago	-80
St. Louis	-85
Philadelphia	-90
New York	-95
San Francisco	-100
Los Angeles	-105
Houston	-110
Portland	-115
Seattle	-120
Denver	-125
Minneapolis	-130
St. Paul	-135
Chicago	-140
St. Louis	-145
Philadelphia	-150
New York	-155
San Francisco	-160
Los Angeles	-165
Houston	-170
Portland	-175
Seattle	-180
Denver	-185
Minneapolis	-190
St. Paul	-195
Chicago	-200
St. Louis	-205
Philadelphia	-210
New York	-215
San Francisco	-220
Los Angeles	-225
Houston	-230
Portland	-235
Seattle	-240
Denver	-245
Minneapolis	-250
St. Paul	-255
Chicago	-260
St. Louis	-265
Philadelphia	-270
New York	-275
San Francisco	-280
Los Angeles	-285
Houston	-290
Portland	-295
Seattle	-300
Denver	-305
Minneapolis	-310
St. Paul	-315
Chicago	-320
St. Louis	-325
Philadelphia	-330
New York	-335
San Francisco	-340
Los Angeles	-345
Houston	-350
Portland	-355
Seattle	-360
Denver	-365
Minneapolis	-370
St. Paul	-375
Chicago	-380
St. Louis	-385
Philadelphia	-390
New York	-395
San Francisco	-400
Los Angeles	-405
Houston	-410
Portland	-415
Seattle	-420
Denver	-425
Minneapolis	-430
St. Paul	-435
Chicago	-440
St. Louis	-445
Philadelphia	-450
New York	-455
San Francisco	-460
Los Angeles	-465
Houston	-470
Portland	-475
Seattle	-480
Denver	-485
Minneapolis	-490
St. Paul	-495
Chicago	-500
St. Louis	-505
Philadelphia	-510
New York	-515
San Francisco	-520
Los Angeles	-525
Houston	-530
Portland	-535
Seattle	-540
Denver	-545
Minneapolis	-550
St. Paul	-555
Chicago	-560
St. Louis	-565
Philadelphia	-570
New York	-575
San Francisco	-580
Los Angeles	-585
Houston	-590
Portland	-595
Seattle	-600
Denver	-605
Minneapolis	-610
St. Paul	-615
Chicago	-620
St. Louis	-625
Philadelphia	-630
New York	-635
San Francisco	-640
Los Angeles	-645
Houston	-650
Portland	-655
Seattle	-660
Denver	-665
Minneapolis	-670
St. Paul	-675
Chicago	-680
St. Louis	-685
Philadelphia	-690
New York	-695
San Francisco	-700
Los Angeles	-705
Houston	-710
Portland	-715
Seattle	-720
Denver	-725
Minneapolis	-730
St. Paul	-735
Chicago	-740
St. Louis	-745
Philadelphia	-750
New York	-755
San Francisco	-760
Los Angeles	-765
Houston	-770
Portland	-775
Seattle	-780
Denver	-785
Minneapolis	-790
St. Paul	-795
Chicago	-800
St. Louis	-805
Philadelphia	-810
New York	-815
San Francisco	-820
Los Angeles	-825
Houston	-830
Portland	-835
Seattle	-840
Denver	-845
Minneapolis	-850
St. Paul	-855
Chicago	-860
St. Louis	-865
Philadelphia	-870
New York	-875
San Francisco	-880
Los Angeles	-885
Houston	-890
Portland	-895
Seattle	-900
Denver	-905
Minneapolis	-910
St. Paul	-915
Chicago	-920
St. Louis	-925
Philadelphia	-930
New York	-935
San Francisco	-940
Los Angeles	-945
Houston	-950
Portland	-955
Seattle	-960
Denver	-965
Minneapolis	-970
St. Paul	-975
Chicago	-980
St. Louis	-985
Philadelphia	-990
New York	-995
San Francisco	-1000

12 BELOW ZERO IS FORECAST FOR CITY TODAY BY BUREAU

Thousands in Cleveland Wage Battle to Heat Homes as Gas and Coal Supplies Run Low.

Cleveland, Monday, January 13, 1918. The forecast for today is 12 below zero.

Many Ohio Trains Stalled in Snowdrifts; Temperatures Run From 6 to 26 Degrees Below.

FACTORIES, STORES SHUT

Cold Wave Made Worse in Some Quarters by Fuel Shortage.

From Signal Bureau, Washington, Jan. 12.

Ohio temperatures tonight are expected to drop to 26 below zero.

At the same time the snow will reach the maximum depth in some places.

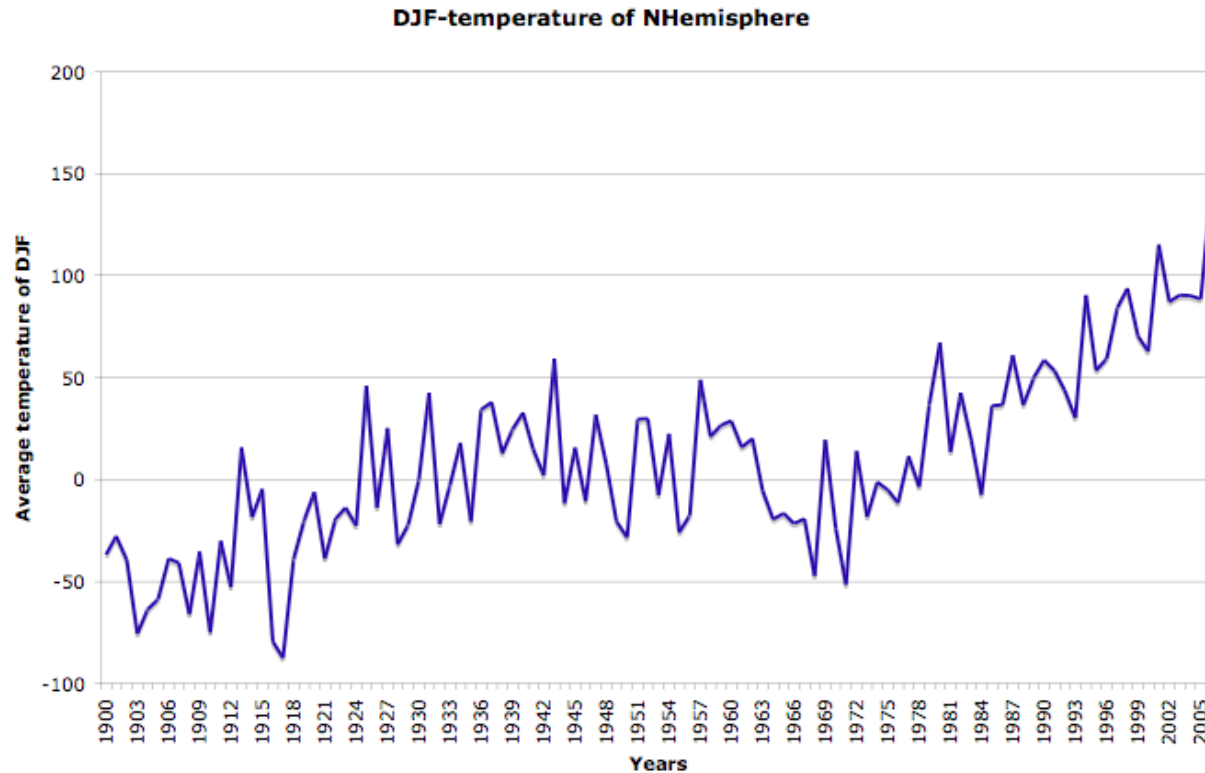
Many of the trains are stalled in snowdrifts.

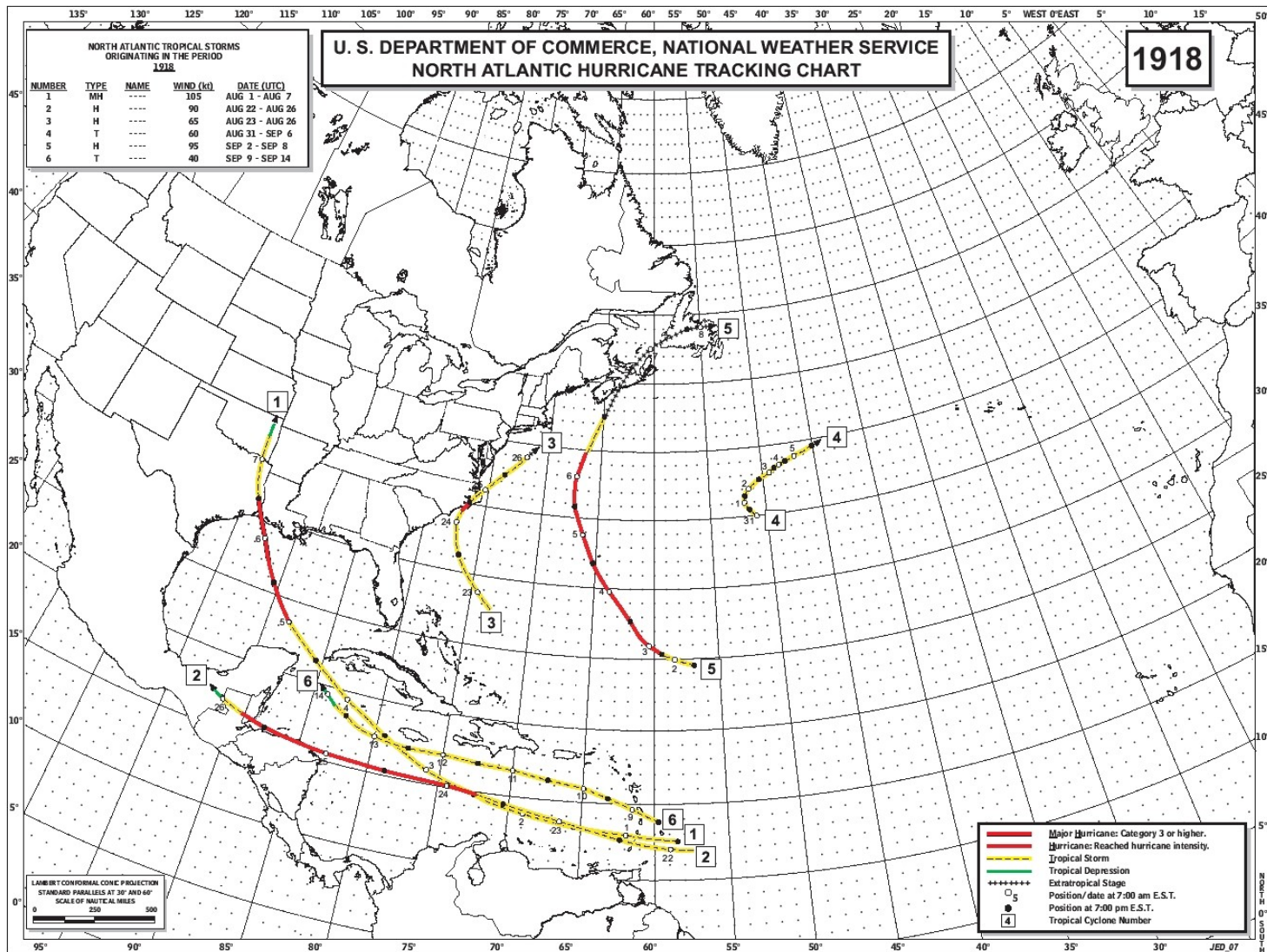
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Cleveland, Monday, January 13, 1918. The forecast for today is 12 below zero.

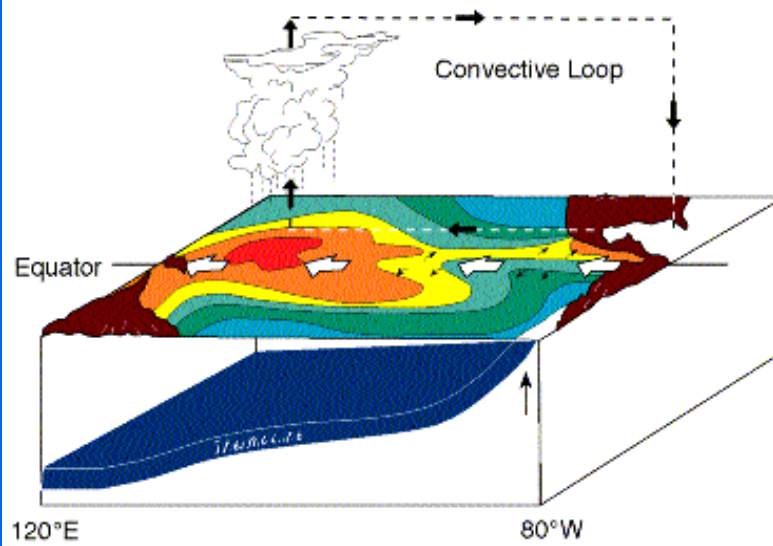
Cleveland Plain Dealer, January 13, 1918

GISS N. Hem. DJF Surface Temperature X 100

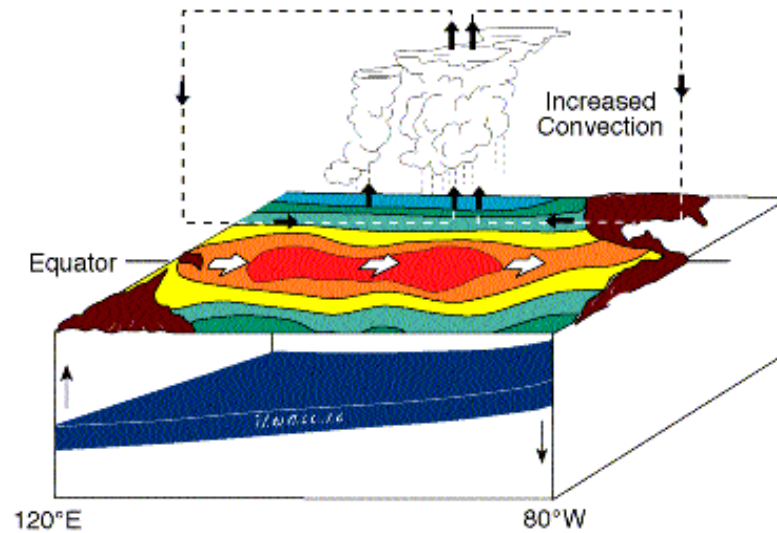




Normal Conditions



El Niño Conditions



December 1997 SST Anomaly

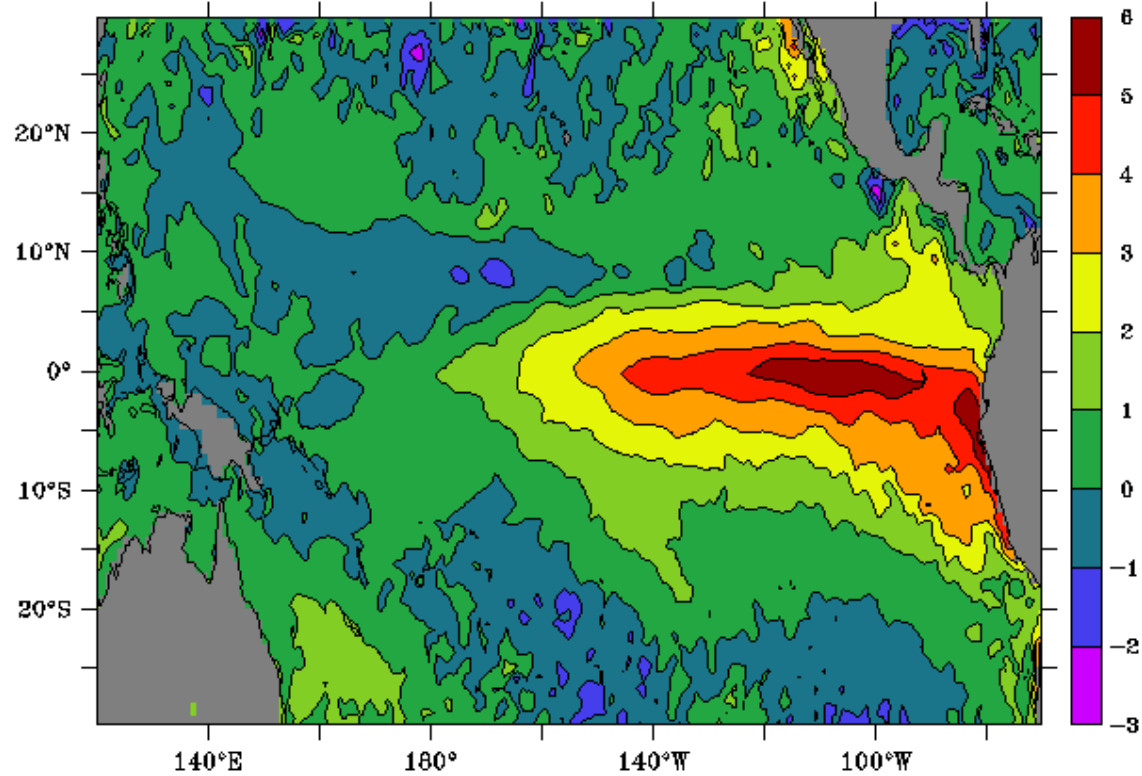
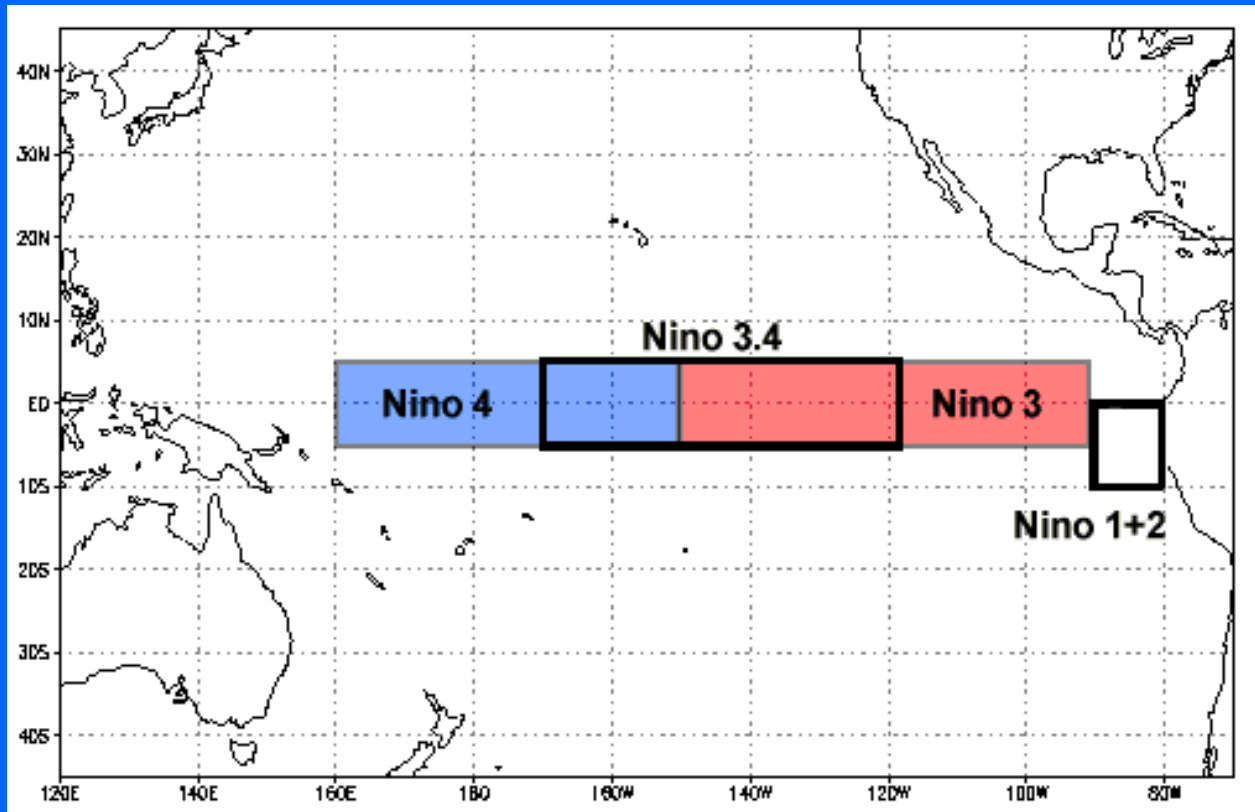


TABLE 2. El Niño Events of Moderate and Near-Moderate Intensities, Their Confidence Ratings, and Information Sources

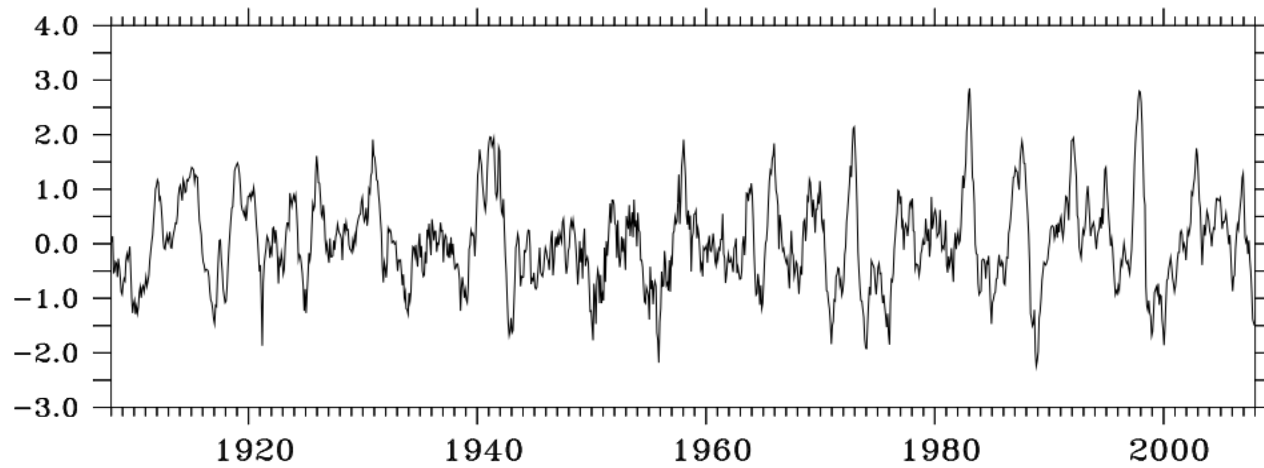
El Niño Event	Event Strength	Confidence Rating	Information Sources
1806–1807	M	3	<i>Stevenson</i> [1829], <i>Remy</i> [1931], and <i>Unanue</i> [1815]
1812	M	4	<i>Palma</i> [1894] and <i>Gonzalez</i> [1913]
1817	M+	5	<i>Eguiguren</i> [1894], <i>Labarthe</i> [1914], <i>Portocarrero</i> [1926], and <i>Taulis</i> [1934]
1819	M+	4	<i>Eguiguren</i> [1894] and <i>Taulis</i> [1934]
1821	M	5	<i>Eguiguren</i> [1894], <i>Fuchs</i> [1925], <i>Remy</i> [1931], and <i>Taulis</i> [1934]
1824	M	5	<i>Spruce</i> [1864], <i>Basadre</i> [1884], and <i>Eguiguren</i> [1894]
1832	M	5	<i>Spruce</i> [1864], and <i>Eguiguren</i> [1894]
1837	M	5	<i>Eguiguren</i> [1894], <i>Labarthe</i> [1914], <i>Portocarrero</i> [1926], and <i>Taulis</i> [1934]
1850	M	5	<i>Eguiguren</i> [1894], <i>Fuchs</i> [1925], and <i>Taulis</i> [1934]
1854	W/M	4	<i>Spruce</i> [1864], <i>Eguiguren</i> [1894], and <i>Taulis</i> [1934]
1857–1858	M+	5	<i>Eguiguren</i> [1894], <i>Labarthe</i> [1914], <i>Portocarrero</i> [1926], <i>Gaudron</i> [1925], <i>Zegarra</i> [1926], and <i>Taulis</i> [1934]
1860	M	4	<i>Labarthe</i> [1914], <i>Portocarrero</i> [1926], and <i>Taulis</i> [1934]
1866	M	4	<i>Eguiguren</i> [1894], <i>Labarthe</i> [1914], <i>Bachmann</i> [1921], and <i>Portocarrero</i> [1926]
1867–1868	M	4	<i>El Comercio</i> (January 10, 1872), <i>Raimondi</i> [1897], <i>Taulis</i> [1934], and <i>Eguiguren</i> [1894]
1874	M	4	<i>Bravo</i> [1903], <i>La Patria</i> (February 9, 1874), and <i>Bachmann</i> [1921]
1880	M	4	<i>Eguiguren</i> [1894], <i>Puls</i> [1895], and <i>Taulis</i> [1934]
1887–1889	W/M	5	<i>Eguiguren</i> [1894], <i>Labarthe</i> [1914], <i>Portocarrero</i> [1926], and <i>Taulis</i> [1934]
1896–1897	M+	4	<i>Bravo</i> [1903], <i>El Comercio</i> (February 3, 1897, and February 22, 1897), and <i>Bachmann</i> [1921]
1902	M+	4	<i>El Comercio</i> (February 17, 1902), <i>Bachmann</i> [1921], and <i>Taulis</i> [1934]
1905	W/M	4	<i>Bachmann</i> [1921], and <i>Taulis</i> [1934]
1907	M	3	<i>Remy</i> [1931], and <i>Paz Soldan</i> [1908]
1914	M+	5	<i>Labarthe</i> [1914], <i>Portocarrero</i> [1926], <i>Petersen</i> [1935], <i>Taulis</i> [1934], and <i>Schweigger</i> [1961]
1918–1919	W/M	5	<i>Murphy</i> [1923], <i>Portocarrero</i> [1926], <i>Vogt</i> [1940], <i>Hutchinson</i> [1950], and <i>Taulis</i> [1934]
1923	M	5	<i>Lavalle y Garcia</i> [1924], <i>Balen</i> [1925], <i>Zegarra</i> [1926], <i>Gunther</i> [1936], <i>Hutchinson</i> [1950], and <i>Schweigger</i> [1961]
1930–1931	W/M	5	<i>Petersen</i> [1935], <i>Hutchinson</i> [1950], <i>Schweigger</i> [1961], <i>Miller and Laurs</i> [1975], and <i>Woodman</i> [1984]
1939	M+	5	<i>Vogt</i> [1940], <i>Schweigger</i> [1940], <i>Mears</i> [1944], <i>Hutchinson</i> [1950], <i>Sears</i> [1954], <i>Mugica</i> [1983], and <i>Woodman</i> [1984]
1943	M+	5	<i>Schweigger</i> [1961], <i>Miller and Laurs</i> [1975], <i>Caviedes</i> [1975], <i>Mugica</i> [1983], and <i>Woodman</i> [1984]
1951	W/M	5	<i>Garcia Mendez</i> [1953], <i>Schweigger</i> [1961], <i>Wooster and Guillen</i> [1974], and <i>Miller and Laurs</i> [1975]
1953	M+	5	<i>Rudolph</i> [1953], <i>Sears</i> [1954], <i>Wooster and Jennings</i> [1955], <i>Merriman</i> [1955], <i>Avila</i> [1961], <i>Hutchinson</i> [1950], <i>Schweigger</i> [1961], <i>Petersen</i> [1935], <i>Hutchinson</i> [1950], <i>Schweigger</i> [1961], <i>Miller and Laurs</i> [1975], and <i>Woodman</i> [1984]

Official NOAA El Niño Definition

A positive sea surface temperature departure from normal in the Niño 3.4 region greater than or equal in magnitude to 0.5°C averaged over three consecutive months.



Nino 3.4 SST Anomaly - Kaplan et al. (1998)

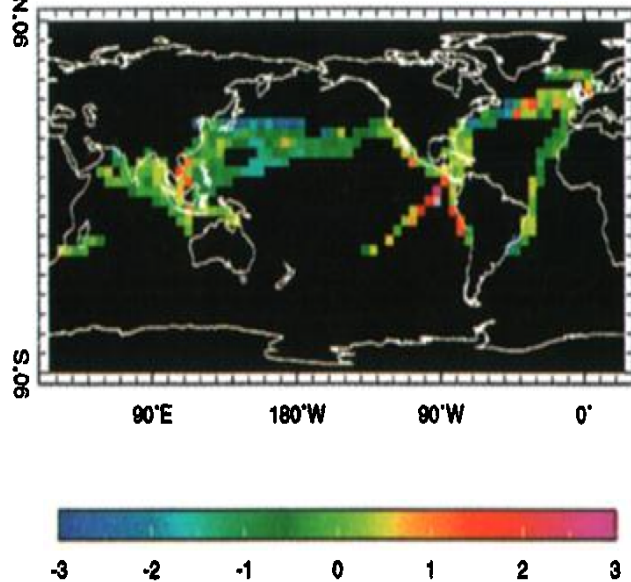


SST reconstructions

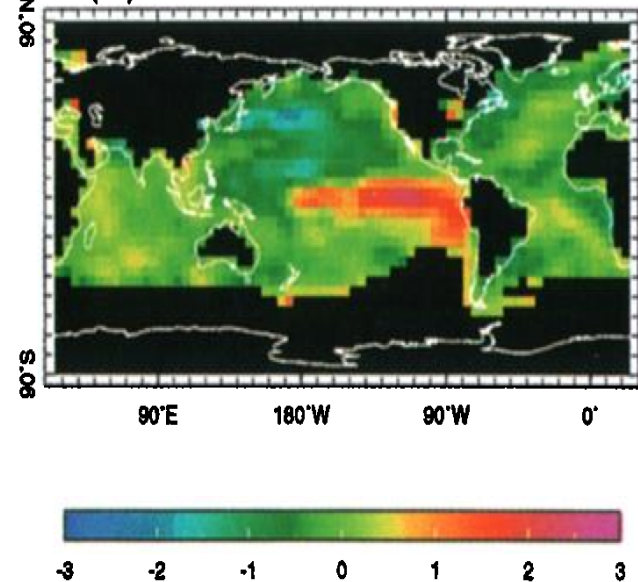
18,578

KAPLAN ET AL.: ANALYSES OF GLOBAL SST 1856-1991

(a) GOSTA observations: Dec 1918



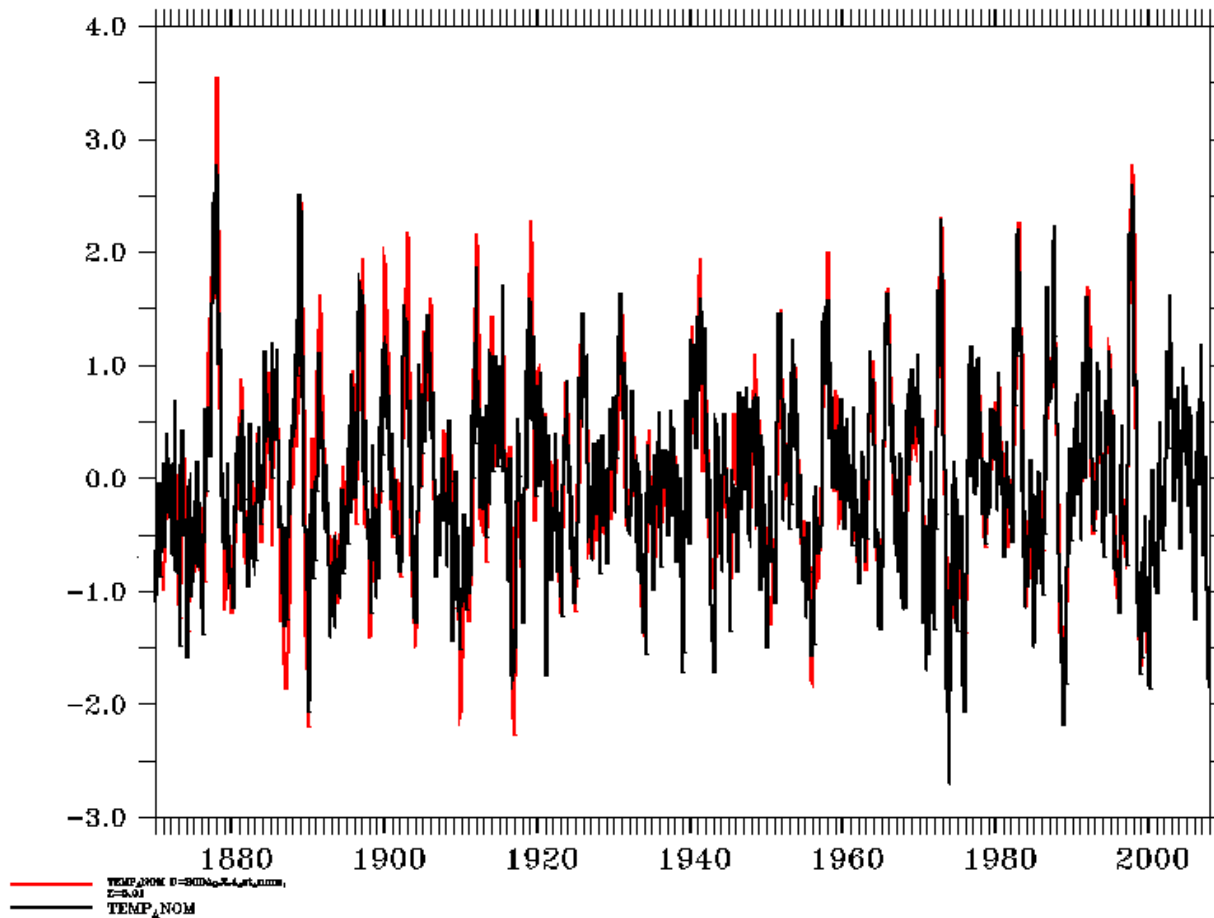
(b) Full OS: Dec 1918



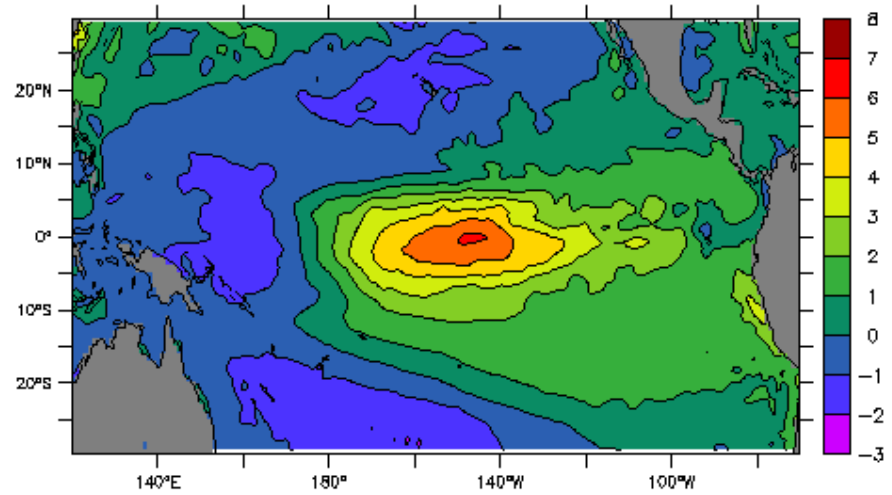
Looks like the 1997 El Nino
– except weaker!

Nino 3.4 SST Anomaly

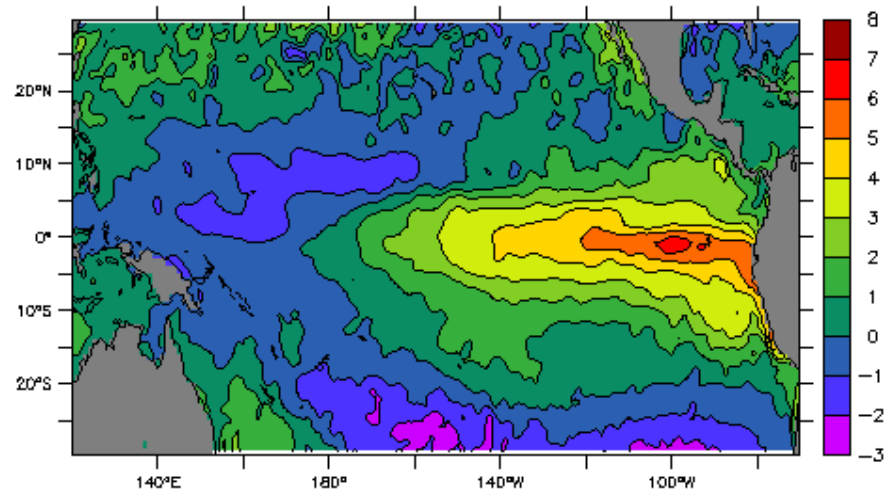
RED – SODA 2.2.4 BLACK - HADISST



DJF 1918/1919
- DJF 1917/1918

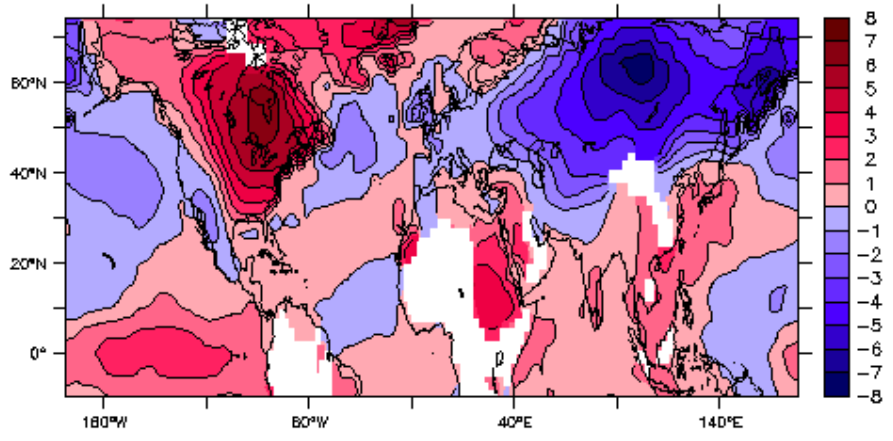


DJF 1997/1998
- DJF 1996/1997

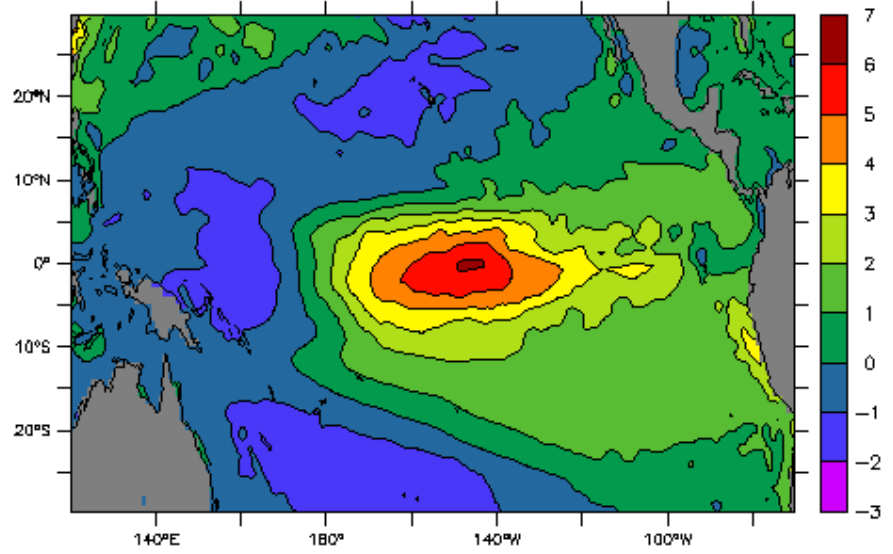


DJF 1918/1919
- DJF 1917/1918

Surface Air Temp



SST



Conclusions

- We used Hydra to complete a reanalysis of the global Oceans that spans the 20th Century
- The reanalysis is being used to explore global warming and climate variability in the 20th Century
- The 1918/1919 El Niño may have been much stronger than previously believed