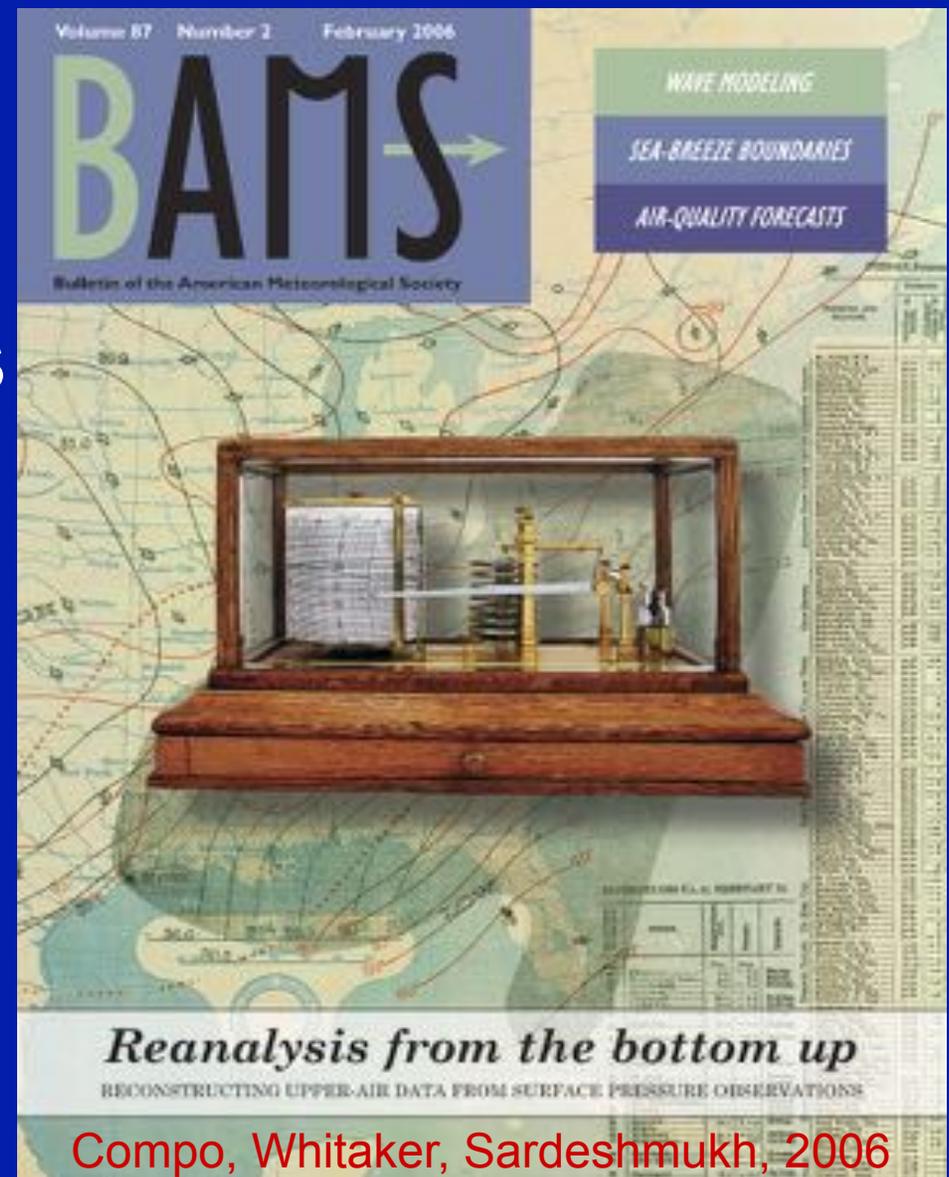


# Developing the Surface Input Reanalysis for Climate Applications (SIRCA) 1850-2012

Gilbert P. Compo,  
Jeffrey S. Whitaker, and  
Prashant D. Sardeshmukh

compo@colorado.edu  
Univ. of Colorado/CIRES  
Climate Diagnostics Center and  
NOAA Earth System Research  
Laboratory/PSD

Special thanks to **NCEP/EMC**



# The Twentieth Century Reanalysis Project

**Summary:** An international collaborative project led by NOAA and CIRES to produce high-quality tropospheric reanalyses for the last 100 years ***using only surface observations.***

The reanalyses will provide:

- First-ever estimates of near-surface and tropospheric 6-hourly fields extending back to the beginning of the 20<sup>th</sup> century;
- Estimates of biases and uncertainties in the basic reanalyses;
- Estimates of biases and uncertainties in derived quantities (storm tracks, etc.)

Initial product will have higher quality in the Northern Hemisphere than in the Southern Hemisphere.

**US Department of Energy INCITE computing award and NOAA Climate Program Office support to produce 1871-2008 by Spring 2010 (version 2).**

# Co-authors on 20th Century Reanalysis Project

- **Gilbert P. Compo**, co-Lead Twentieth Century Reanalysis Project, University of Colorado, CIRES, Climate Diagnostics Center & NOAA Earth System Research Laboratory, Physical Sciences Division
- **Jeffrey S. Whitaker**, co-Lead Twentieth Century Reanalysis Project, NOAA Earth System Research Laboratory, Physical Sciences Division
- **Prashant D. Sardeshmukh**, University of Colorado, CIRES, Climate Diagnostics Center & NOAA Earth System Research Laboratory, Physical Sciences Division
- **Nobuki Matsui**, University of Colorado, CIRES, Climate Diagnostics Center & NOAA Earth System Research Laboratory, Physical Sciences Division
- **Robert J. Allan**, ACRE Project Manager, Hadley Centre, Met Office, United Kingdom
- **Xungang Yin**, STG Inc., Asheville, NC
- **Byron E. Gleason, Jr.**, NOAA National Climatic Data Center
- **Russell S. Vose**, NOAA National Climatic Data Center
- **Glenn Rutledge**, NOAA National Climatic Data Center
- **Pierre Bessemoulin**, Meteo-France
- **Stefan Brönnimann**, ETH Zurich
- **Manola Brunet**, Centre on Climate Change (C3), Universitat Rovira i Virgili
- **Richard I. Crouthamel**, International Environmental Data Rescue Organization
- **Andrea N. Grant**, ETH Zurich
- **Pavel Y. Groisman**, University Corporation for Atmospheric Research & NOAA National Climatic Data Center
- **Philip D. Jones**, Climatic Research Unit, University of East Anglia
- **Michael Kruk**, STG Inc., Asheville, NC
- **Andries C. Kruger**, South African Weather Service
- **Gareth J. Marshall**, British Antarctic Survey
- **Maurizio Maugeri**, Dipartimento di Fisica, Università degli Studi di Milano
- **Hing Y. Mok**, Hong Kong Observatory
- **Øyvind Nordli**, Norwegian Meteorologisk Institutt
- **Thomas F. Ross**, NOAA Climate Database Modernization Program, National Climatic Data Center
- **Ricardo M. Trigo**, Centro de Geofísica da Universidade de Lisboa, IDL, University of Lisbon
- **Xiaolan L. Wang**, Environment Canada
- **Scott D. Woodruff**, NOAA Earth System Research Laboratory, Physical Sciences Division
- **Steven J. Worley**, National Center for Atmospheric Research

# Ensemble Filter Algorithm

Analysis  $x^a$  is a weighted average of the first guess  $x^b$  and observation  $y^o$

$$x^a = (I-KH)x^b + Ky^o$$

Algorithm uses an ensemble to produce the weight  $K$  that varies with the atmospheric flow and the observation network

$y^o$  is *only surface and sea level pressure observations*,

$Hx^b$  is guess surface pressure

$x$  is pressure, air temperature, winds, humidity, etc. at all levels and gridpoints.

## Using 56 member Ensemble

HadISST monthly boundary conditions (*Rayner et al. 2003*)

Version 1 (1908-1958): T62, 28 level NCEP CFS03 atmospheric model

Version 2 (1871-2008): T62, 28 level NCEP GFS08ex model

- time-varying CO<sub>2</sub>, solar and volcanic radiative forcing
- Note: sea ice concentration low near coasts

# International Surface Pressure Databank (ISPD) version 2

Subdaily observations assembled in partnership with

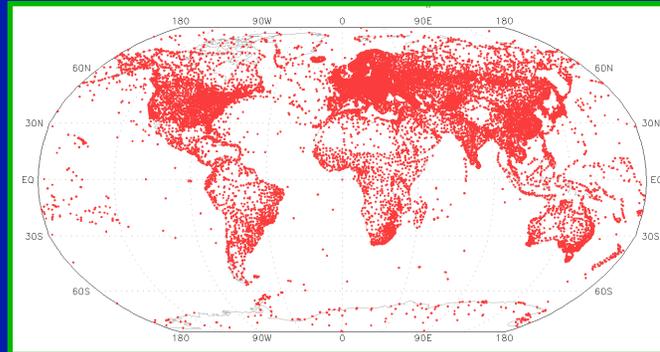
GCOS AOPC/OOPC Working Group on Surface Pressure

GCOS/WCRP Working Group on Observational Data Sets for Reanalysis

Atmospheric Circulation Reconstructions over the Earth (ACRE)

**Land data Component:** merged by NOAA NCDC, NOAA ESRL, and CU/CIRES

- 33 data sources
- 33,653 stations
- 1.7 billion obs
- 1768-2008

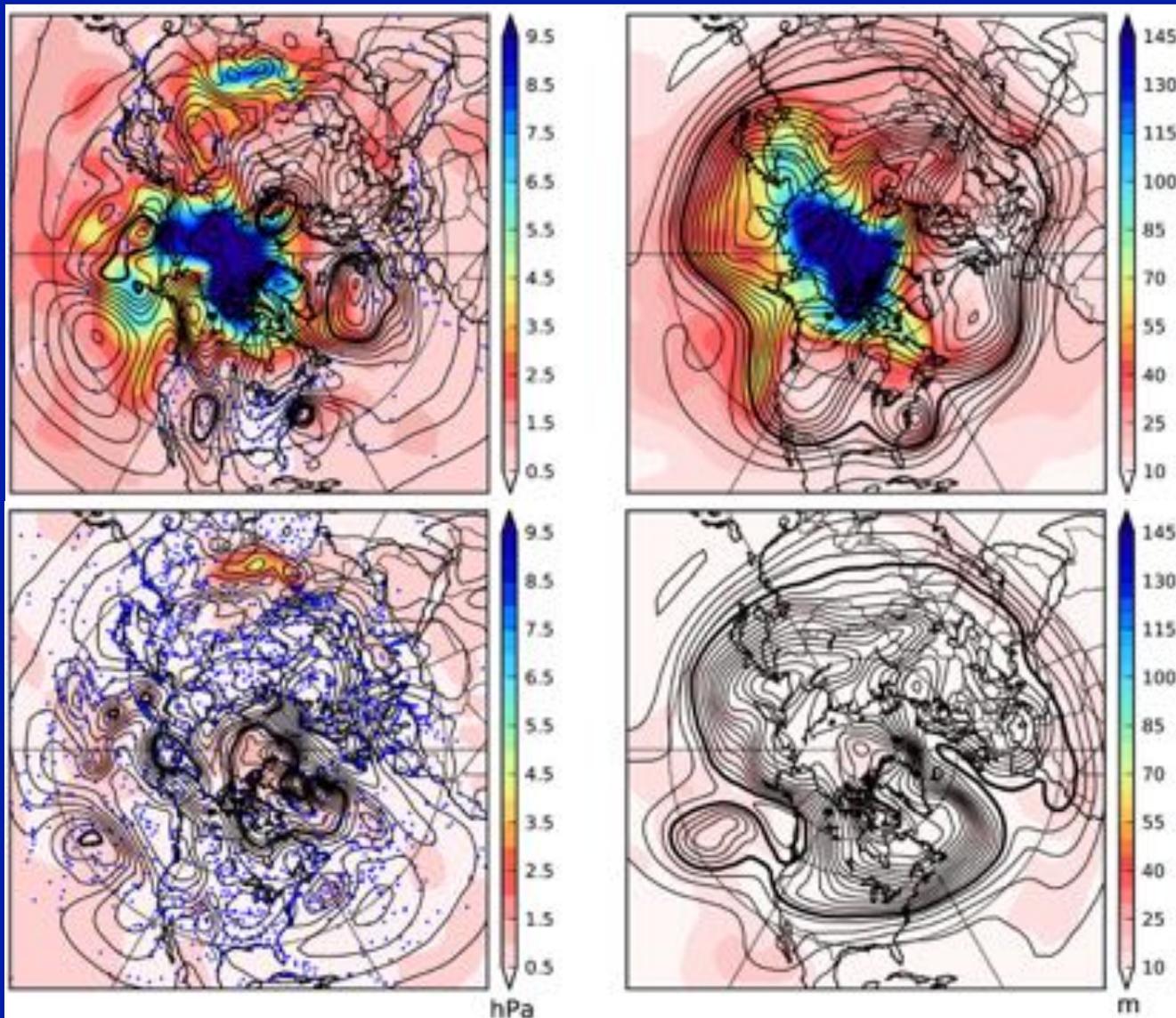


**Marine data component:** **ICOADS** merged by NOAA ESRL and NCAR NOAA

**Tropical Cyclone Best Track data component:** IBTrACS merged by NOAA NCDC

# Analyses for selected dates 29 January 1922 and 1972

1922

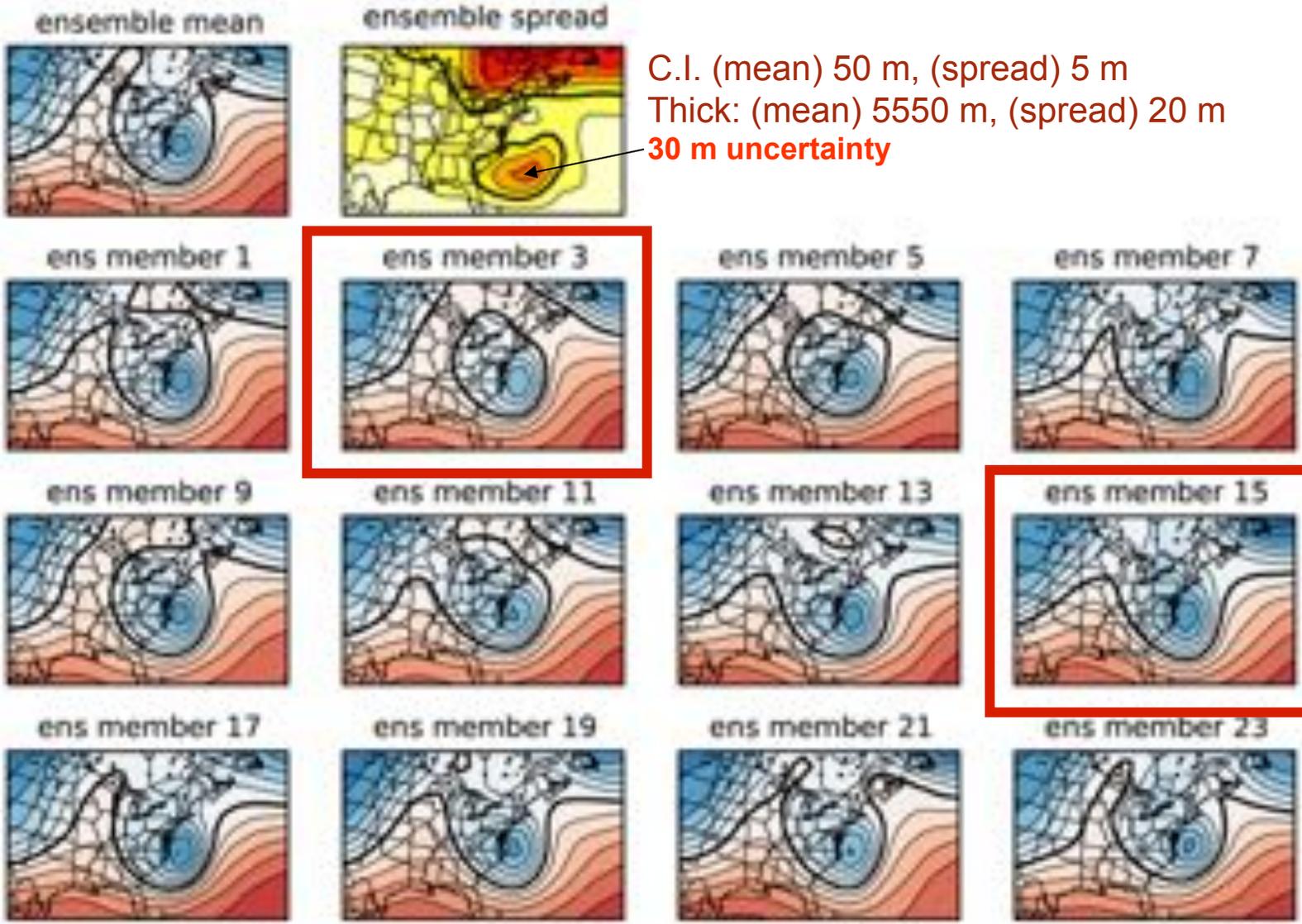


Contours-  
ensemble  
mean  
Shading-  
blue: more  
uncertain,  
white: more  
certain

Sea Level Pressure

500 hPa Geopotential Height

# Range of possibilities for 500 hPa Geopotential Height “Knickerbocker Storm” 29 January 1922 0Z using 12 (of 56) members



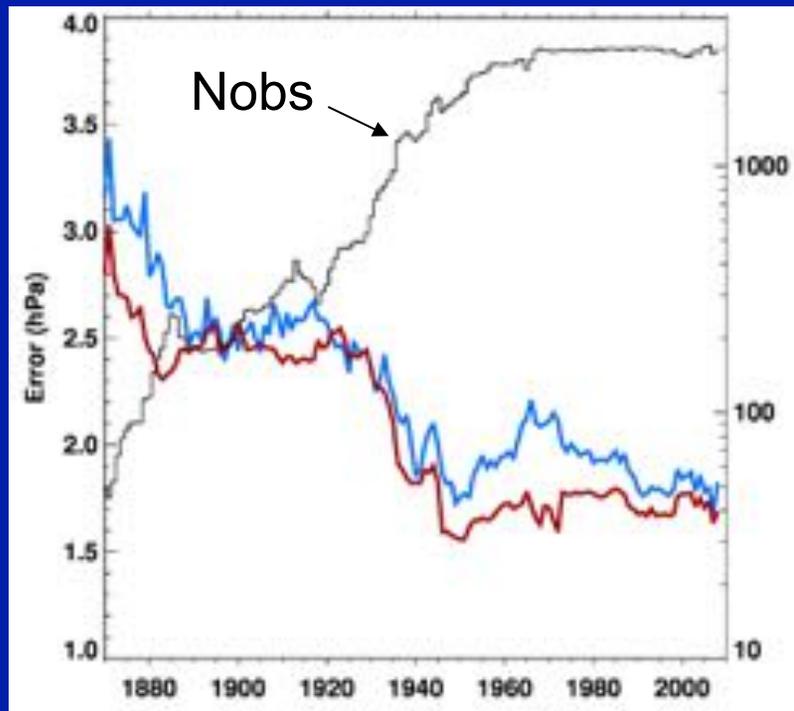
Ensemble of 56 possible realizations consistent with the observations

# Surface Pressure uncertainty estimate poleward of 20(S,N)

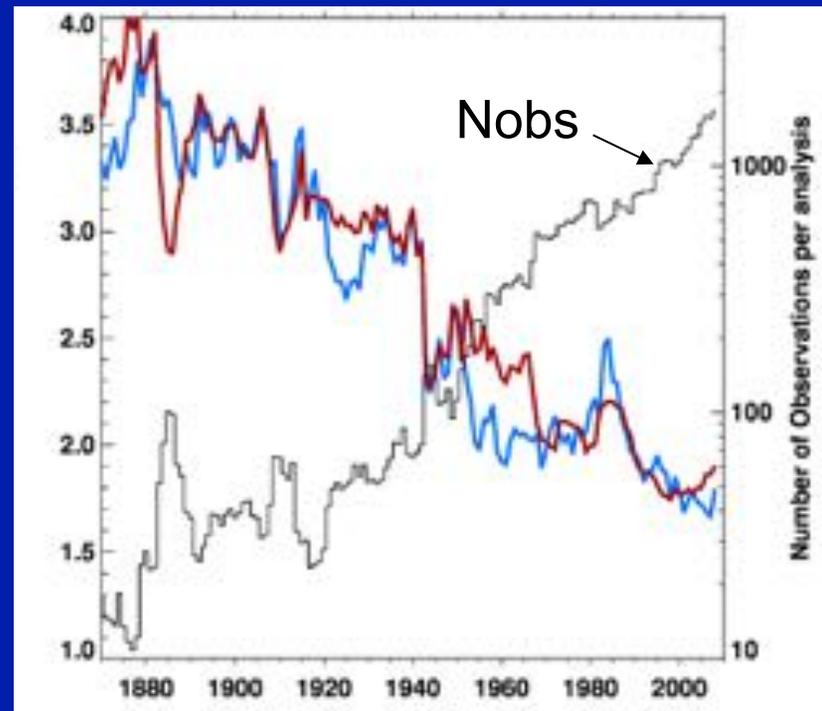
blue actual RMS difference

red expected RMS difference

## Northern Hemisphere



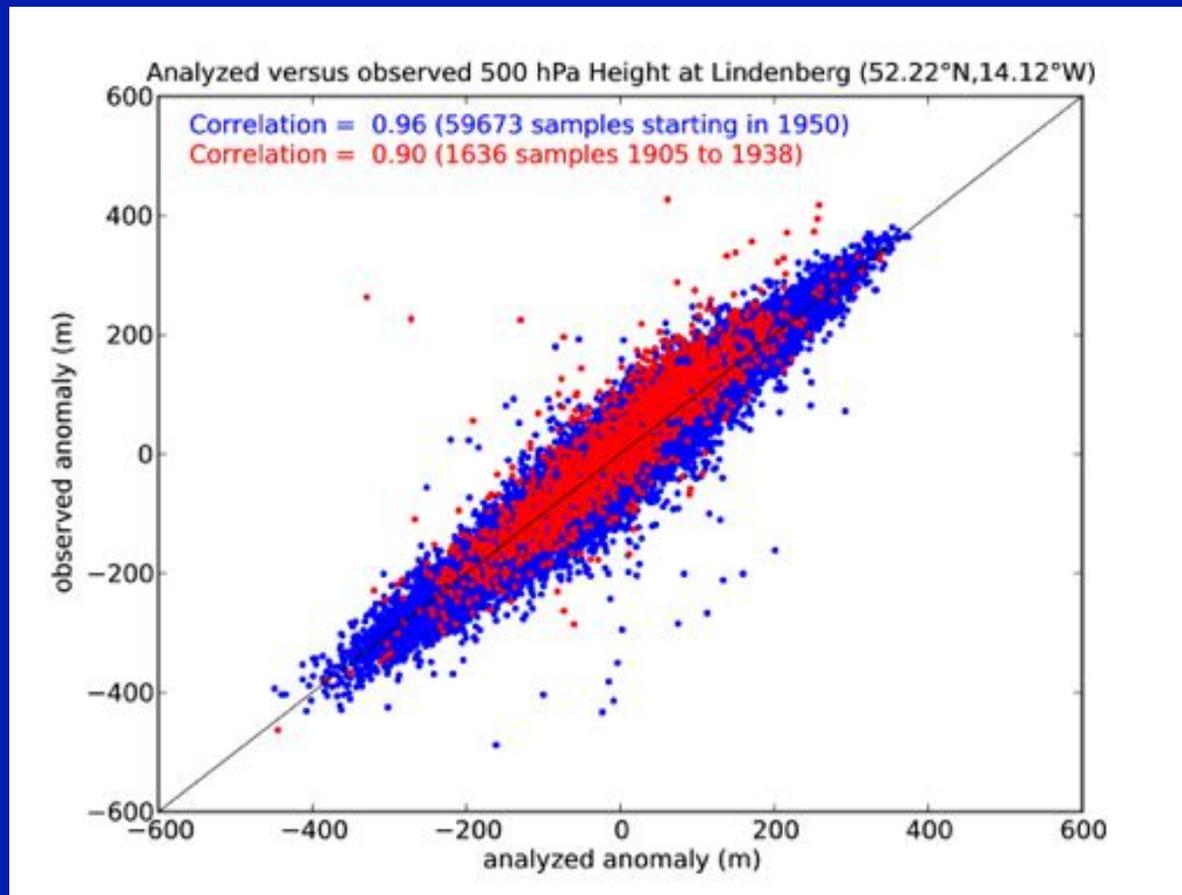
## Southern Hemisphere



Uncertainty estimates are consistent with actual differences between first guess and pressure observations even as the network changes over more than 100 years!

# Subdaily 500 hPa Geopotential Height anomalies from observations and 20th Century Reanalysis compare well.

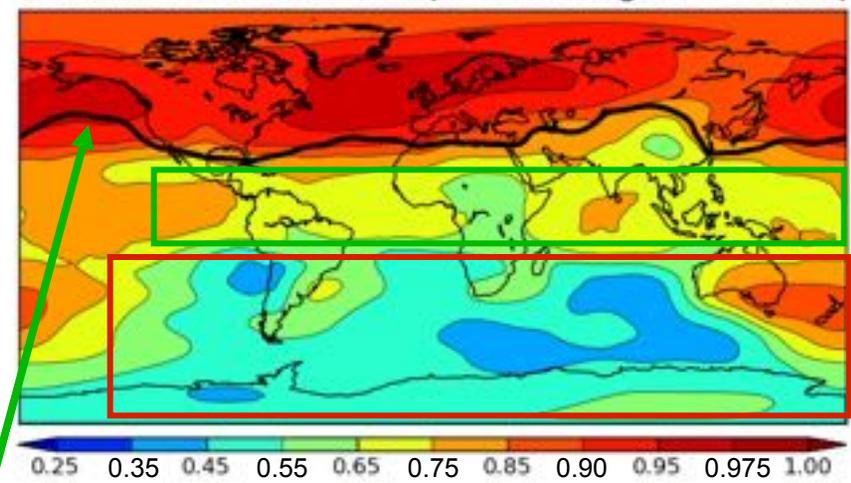
1905-2006  
Measurements  
from kites,  
aircraft,  
registering  
balloon, and  
radiosondes  
at Lindenberg,  
Germany



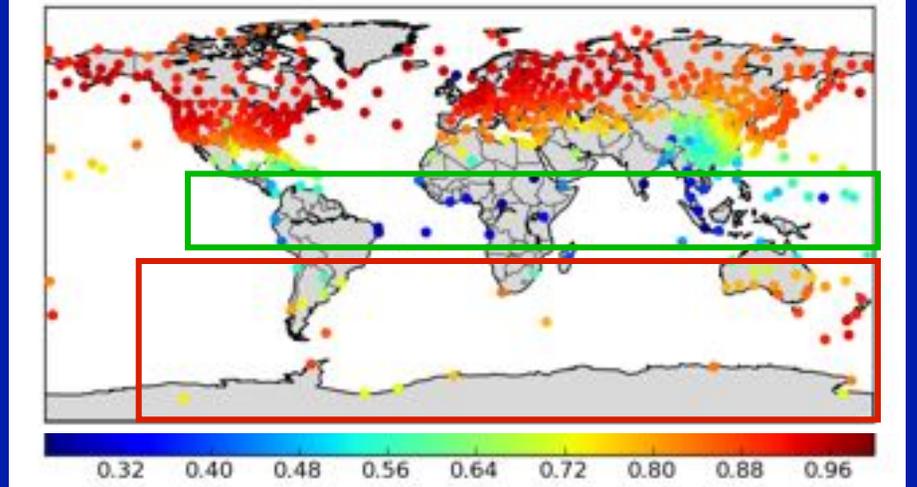
Observations from CHUAN dataset (*Stickler et al. 2010*)

# Local Anomaly Correlation of 20th Century Reanalysis (20CR), ERA40, and radiosonde 300 hPa geopotential height anomalies (1958 to 1978)

Correlation 20CR vs ERA40 (300 hPa Height 1958-1978)



Correlation of Analyses with Radiosondes (300 hPa Height 1958-1978)



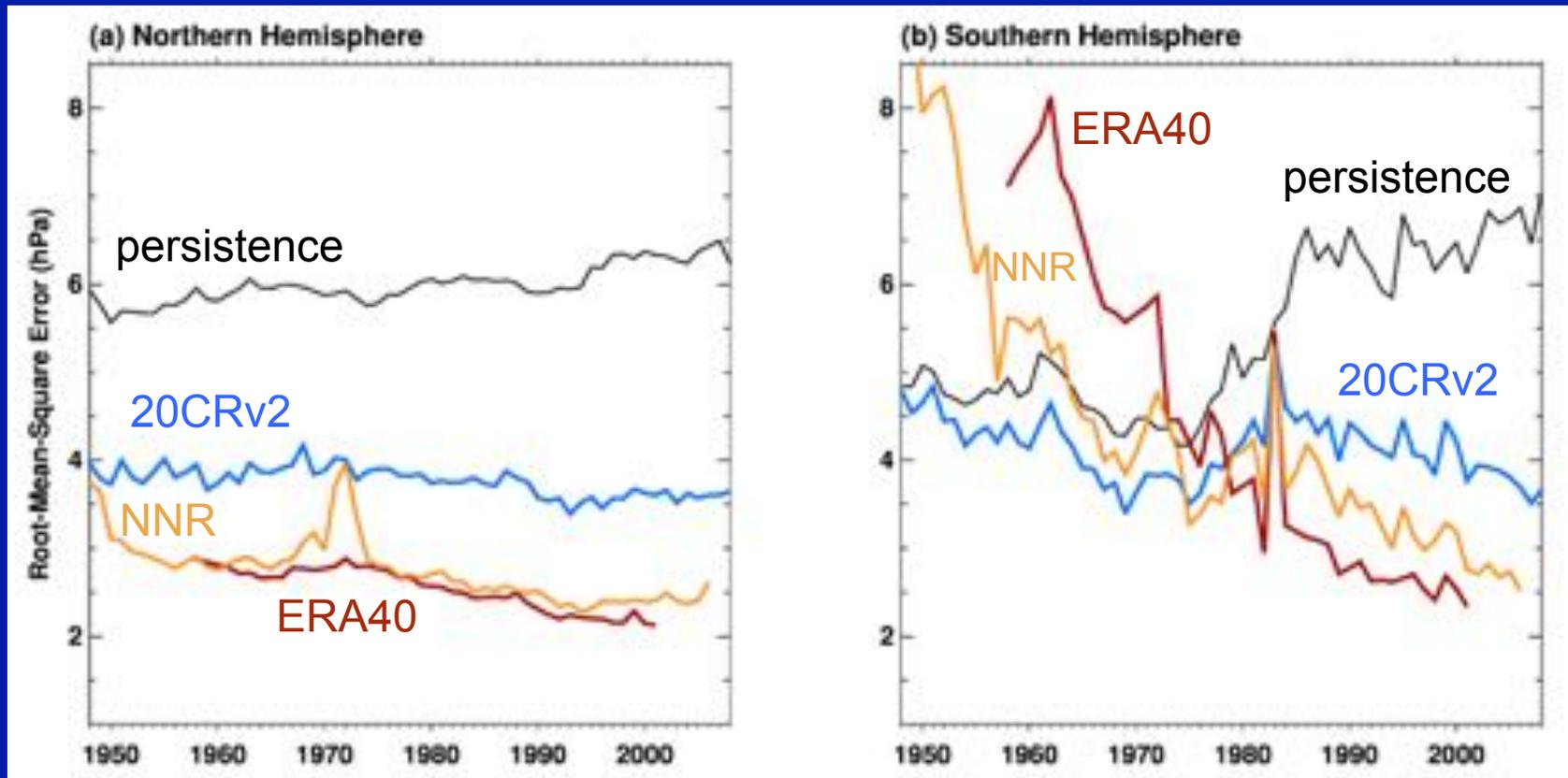
Black curve shows where NCEP-NCAR and ERA40 correlate > 0.975

Northern Hemisphere agreement is excellent where NNR and ERA40 agree.

Tropical agreement is moderate to poor with radiosondes but higher with ERA40.

Southern Hemisphere agreement is moderate to poor with ERA40 but higher with radiosondes.

## 24 hour Root Mean Square difference of Marine Pressure Observations and Forecasts from NCEP-NCAR Reanalysis, 20th Century Reanalysis v2, and ECMWF Reanalysis 40 (1948-2008)



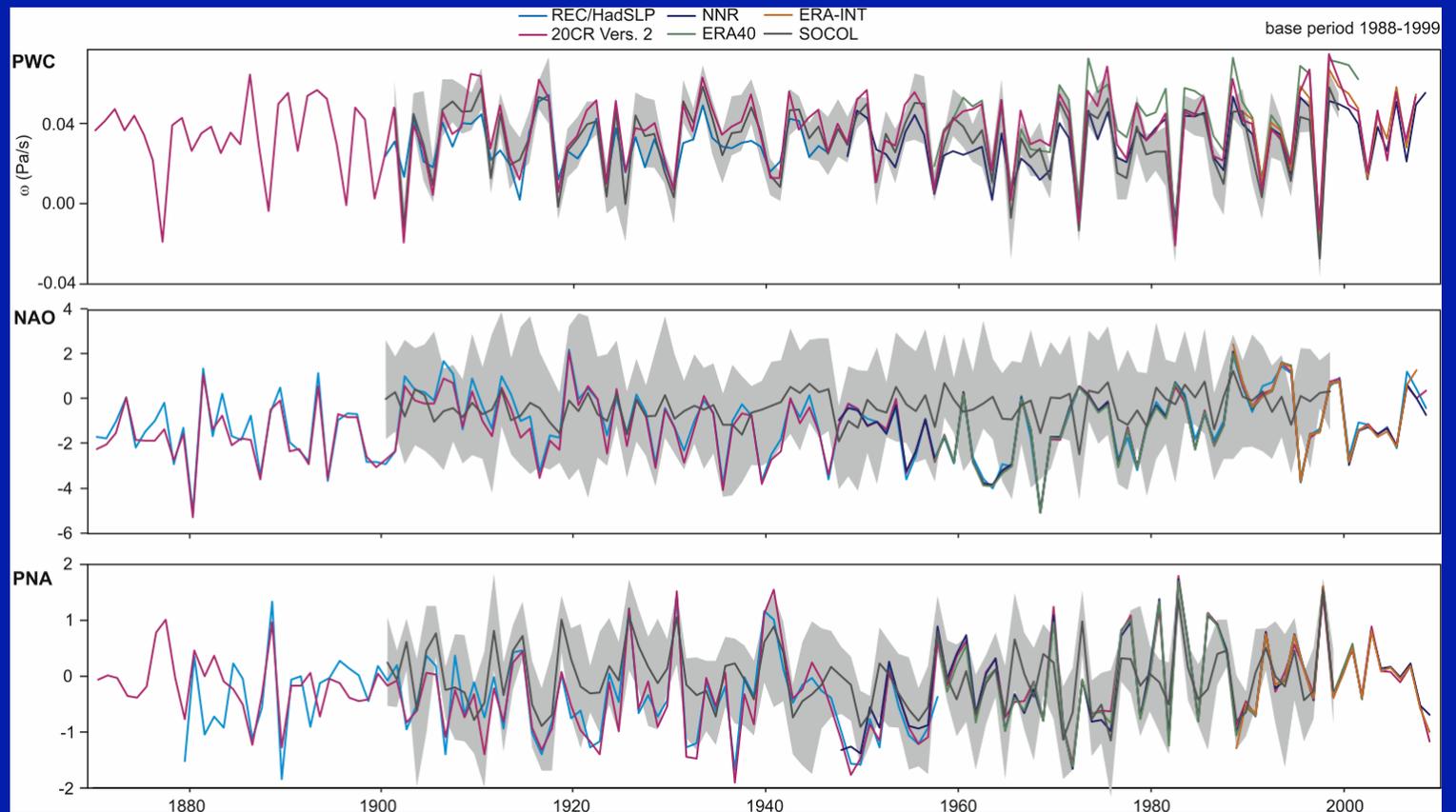
Before the satellite era (1970s), there is ***substantially better skill*** for 20CRv2 than for NCEP-NCAR Reanalysis or ERA40 in the Southern Hemisphere despite the lack of upper-air observations.

# Seasonal climate indices from Statistical Reconstructions, SST-forced GCM integrations, and 20<sup>th</sup> Century, ERA-40, NCEP-NCAR, ERA-Interim Reanalyses.

Pacific Walker  
Circulation  
(500 hPa  
vertical velocity,  
SONDJ)

North Atlantic  
Oscillation  
(Sea Level  
Pressure, DJF)

Pacific-North  
America  
Pattern Index  
(500 hPa  
geopotential  
height, DJF)



1870

2008

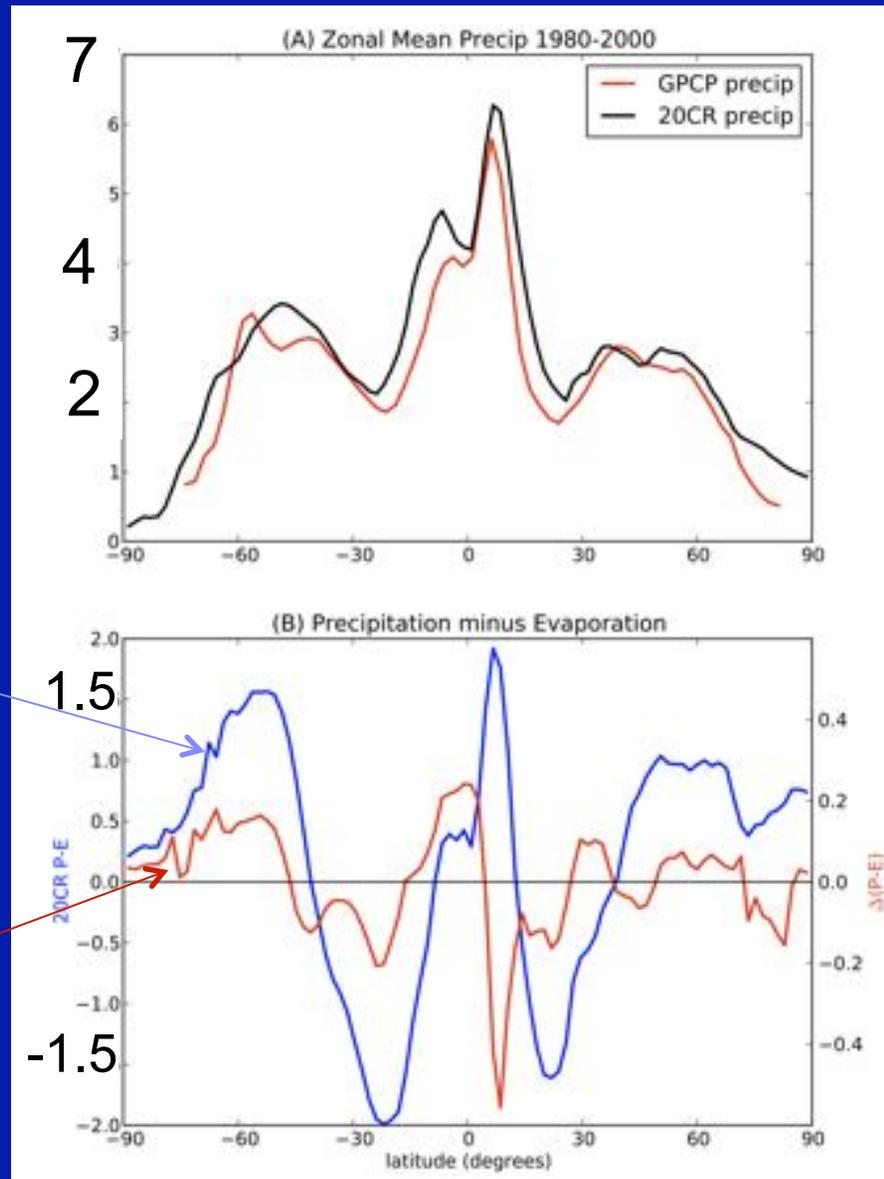
Agreement is high between observation-based estimates  
(correlations between ERA-40 and 20CRv2 > 0.95)

Courtesy S. Bronnimann

Zonally averaged  
Precipitation  $P$   
1980-2000

Precipitation  $P$  minus  
Evaporation  $E$   
1980-2000

Change  $\Delta(P-E)$   
1980-2000 minus  
1871-1891



mm/day

mm/day

20CR  $\Delta(P-E)$  does not resemble Mean  $P-E$ .  
Resemblance was expected from “robust” feature of climate models  
and simple arguments (Held and Soden, 2006).

# Historical Reanalysis Status and Plans

## **20th Century Reanalysis Project** [http://www.esrl.noaa.gov/psd/data/20thC\\_Rean](http://www.esrl.noaa.gov/psd/data/20thC_Rean)

- Data Access: Analyses and ISPD (with feedback) will be freely available from NCAR, NOAA/ESRL and NOAA/NCDC.
- **Spring 2009:** Version 1, 1908-1958 (complete)
  - [http://www.esrl.noaa.gov/psd/data/gridded/data.20thC\\_Rean.html](http://www.esrl.noaa.gov/psd/data/gridded/data.20thC_Rean.html) (NOAA ESRL)
  - <http://dss.ucar.edu/datasets/ds131.0> (NCAR)
- **Spring 2010:** Version 2, 1871-2008 (including time-varying CO<sub>2</sub>, aerosols, upgraded GFS from NCEP). **Ensemble mean and spread online now.**
  - [http://www.esrl.noaa.gov/psd/data/gridded/data.20thC\\_ReanV2.html](http://www.esrl.noaa.gov/psd/data/gridded/data.20thC_ReanV2.html) (NOAA ESRL)
  - <http://dss.ucar.edu/datasets/ds131.1> (NCAR)
  - <http://nomads.ncdc.noaa.gov> (NOAA NCDC, coming soon)
  - Coordinate with PCMDI CMIP5 distribution and validation for IPCC AR5

## **ECMWF Reanalysis Archive-Climate (ERA-CLIM)**

- Series of reanalyses, including Surface-observation based back to 1900 (ERA-P1).
- ERA-P1: T159 spectral (~125km grid spacing) 60 layers in the vertical, extending upward to 0.1 hPa (approximately 65km altitude)
- **ERA-P1: Available 2012** (Contingent on EU funding)

## Advances and Improvements towards

### ***Surface Input Reanalysis for Climate Applications (SIRCA)***

spanning 19th-21st centuries over the next 2-10 years

1. More land and marine observations back to early 19th century, especially Southern Hemisphere and Arctic.
2. User requirements for, and applications of, reanalyses
3. Higher resolution, improved methods, other surface variables (e.g., wind, T, Tropical Cyclone position)
4. Uncertainty in forcings (e.g, CO<sub>2</sub>, solar, SST)
5. Multi-model (e.g., NASA, NCAR, NCEP, GFDL, ESRL)

**Available 2014** – SIRCA (*1850-2013*)

**Available 2017** – include chemistry and coupling, CSIRCA (*1800-2016*)

Requires international cooperation, e.g.,

Atmospheric Circulation Reconstruction over the Earth initiative

<http://www.met-acre.org>

# Reanalyses.org: comparing Reanalyses with each other and with observations

Reanalyses.org Home Page | Reanalysis Intercomparison and Observations

Home Contact Us Login

## Reanalysis Intercomparison and Observations

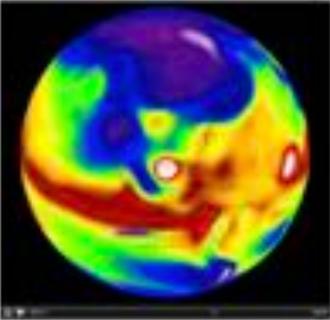
HOME ABOUT ATMOSPHERE OBSERVATIONS OCEAN

Search

### Welcome to the Reanalyses site.

Members will need to [login](#) to the site to see more information.

### Reanalyses.org Home Page



Reanalysis is a scientific method for developing a comprehensive record of how weather and climate are changing over time. In it, observations and a numerical model that simulates one or more aspects of the Earth system are combined objectively to generate a synthesized estimate of the state of the system. A reanalysis typically extends over several decades or longer, and covers the entire globe from the Earth's surface to well above the stratosphere. Reanalysis products are used extensively in climate research and services, including for monitoring and comparing current climate conditions with those of the past, identifying the causes of climate variations and change, and preparing climate predictions. Information derived from reanalyses is also being used increasingly in commercial and business applications in sectors such as energy, agriculture, water resources and insurance.

### Topics

- Overview of Current Atmospheric Reanalyses
- Atmospheric Reanalyses Comparison Table
- Reanalyses Plotting and Data Manipulation Tools

Partnership of ACRE,  
Working Groups of  
GCOS & WCRP  
Hosted by NOAA/ESRL

# Summary

- Demonstrated that surface-based reanalyses *throughout the troposphere* are feasible using advanced data assimilation and surface pressure observations.
- Effectively doubling the reanalysis record length from ~60 year to more than 120 years, allowing current atmospheric circulation patterns to be placed in a broader historical context. 😊
- Southern Hemisphere fields may be an improvement over first-generation upper-air based reanalyses before the satellite era.
- Challenges: Validating the dataset in regions of sparse observations and rapid change, e.g., the Arctic.
- Higher resolution and additional observations will further improve these reanalyses.
- For status updates, email
  - [jeffrey.s.whitaker@noaa.gov](mailto:jeffrey.s.whitaker@noaa.gov),
  - [compo@colorado.edu](mailto:compo@colorado.edu)

# *Thank you to organizations contributing observations to ISPD:*

All Union Research Institute of Hydrometeorological  
Information WDC  
Atmospheric Circulation  
Reconstructions over the Earth (ACRE)  
Australian Bureau of Meteorology  
British Antarctic Survey  
Danish Meteorological Institute  
Deutscher Wetterdienst  
EMULATE  
Environment Canada  
ETH-Zurich  
GCOS AOPC/OOPC WG on Surface Pressure  
Hong Kong Observatory  
IBTRACS  
ICOADS  
Instituto Geofisico da Universidade do Porto  
IEDRO  
Japanese Meteorological Agency  
Jersey Met Dept.  
KNMI  
MeteoFrance  
MeteoFrance – Division of Climate  
Meteorological and Hydrological Service, Croatia

National Center for Atmospheric Research  
Nicolaus Copernicus University  
NIWA  
NOAA Climate Database Modernization Program  
NOAA Earth System Research Laboratory  
NOAA National Climatic Data Center  
NOAA National Centers for Environmental Prediction  
NOAA Northeast Regional Climate Center at Cornell U.  
NOAA Midwest Regional Climate Center at UIUC  
Norwegian Meteorological Institute  
Ohio State U. – Byrd Polar Research Center  
Portuguese Meteorological Institute (IM)  
Proudman Oceanographic Laboratory  
SIGN - Signatures of environmental change in the  
observations of the Geophysical Institutes  
South African Weather Service  
UK Met Office Hadley Centre  
U. of Colorado-CIRES/Climate Diagnostics Center  
U. of East Anglia-Climatic Research Unit  
U. of Lisbon-Instituto Geofisico do Infante D. Luiz  
U. of Milan-Dept. of Physics  
U. Rovira i Virgili-CCRG  
ZAMG

[http://www.esrl.noaa.gov/psd/data/20thC\\_Rean/](http://www.esrl.noaa.gov/psd/data/20thC_Rean/)

Physical Sciences Division About Contact Research Data Products Outreach Intranet

We would greatly appreciate feedback on its use, in the classroom, for presentations or for research. Mail to psddata at (esrl.psd.data@noaa.gov).

**Help**

20thC at PSD  
20th dataset details

**Plot/Analysis**

Plot 20thC Monthly composites  
Plot 20thC Daily composites  
Plot 20thC Monthly composites:Google Earth Search and Plot all 20thC Data

**Background Information**

Referencing Plots

**Related Dataset Plotting and Analysis Pages**

Plot NCEP/NCAR Reanalysis | 6-hourly composites  
Plot NCEP/NCAR Reanalysis | daily composites  
Plot NCEP/NCAR Reanalysis | Monthly composites

### 20th Century Reanalysis

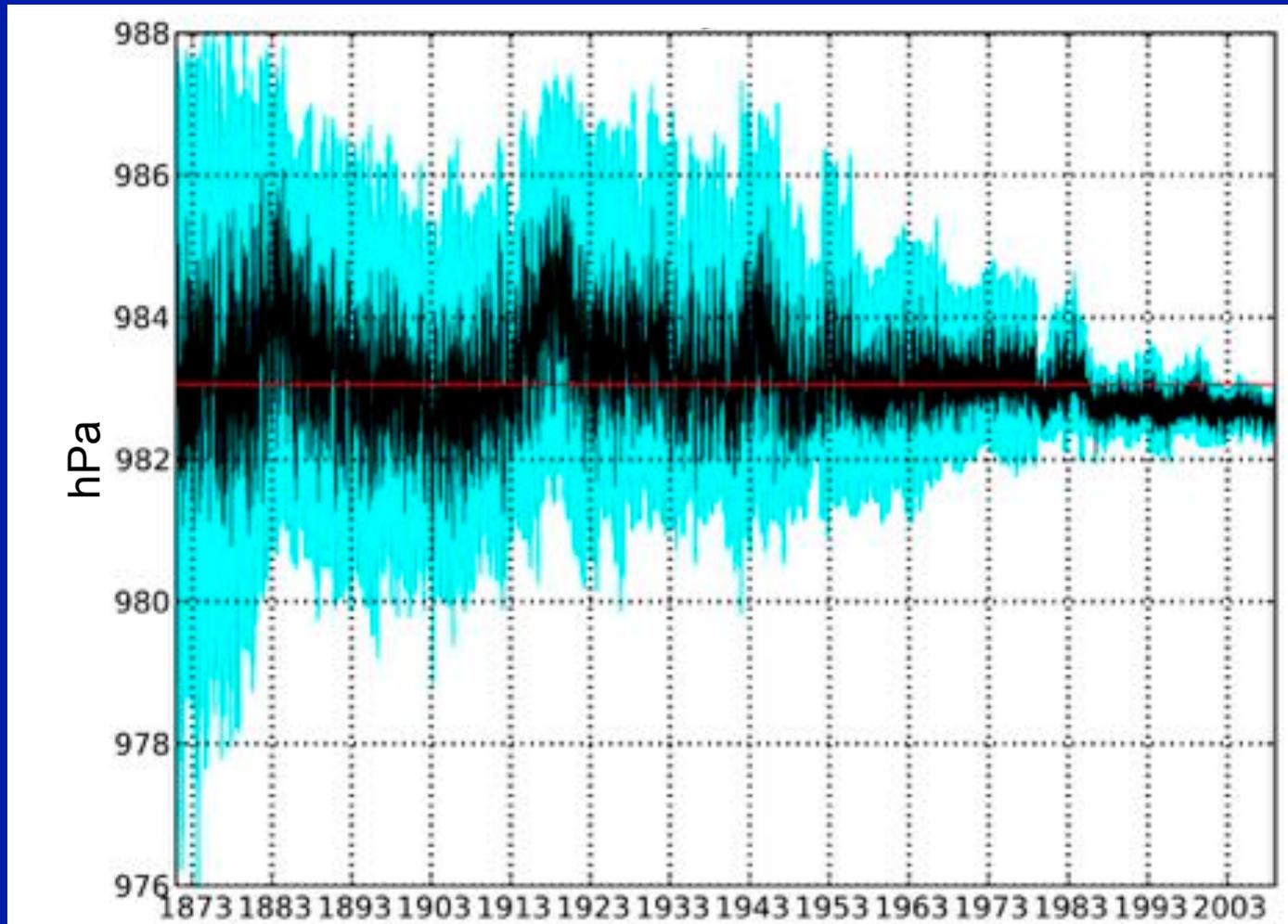
Dataset Information | Analysis and Plotting Pages | Related Links and Datasets | Feedback

**Using a state-of-the-art data assimilation system and surface pressure observations, the Twentieth Century Reanalysis Project is generating a six-hourly, four-dimensional global atmospheric dataset spanning 1871 to present to place current atmospheric circulation patterns into a historical perspective.**

**20th Century Reanalysis and PSD:** The NCEP-NCAR Reanalysis product starts from 1948, leaving many important climate events such as 1930's dust bowl droughts uncovered. To expand the coverage of global gridded reanalyses, the 20th Century Reanalysis Project is an effort led by PSD and the University of Colorado CIRES Climate Diagnostics Center to produce a reanalysis dataset spanning the entire twentieth century, assimilating only surface observations of synoptic pressure, monthly sea surface temperature and sea ice distribution. The observations have been assembled through international cooperation under the auspices of the Atmospheric Circulation Reconstructions over the Earth initiative), and working groups of GCOS and WCRP. The Project uses a recently-developed Ensemble Filter data assimilation method which directly yields each six-hourly analysis as the most likely state of the global atmosphere, and also the estimates the uncertainty in that analysis. This dataset will provide the first estimates of global tropospheric and stratospheric variability spanning 1871 to present at six-hourly resolution. The first version has global coverage spanning 1908-1958, and two degree longitude-latitude horizontal resolution.

# 20CRv2 Global Mean Dry Surface Pressure

Blue: Max/Min of 20CRv2 Ensemble



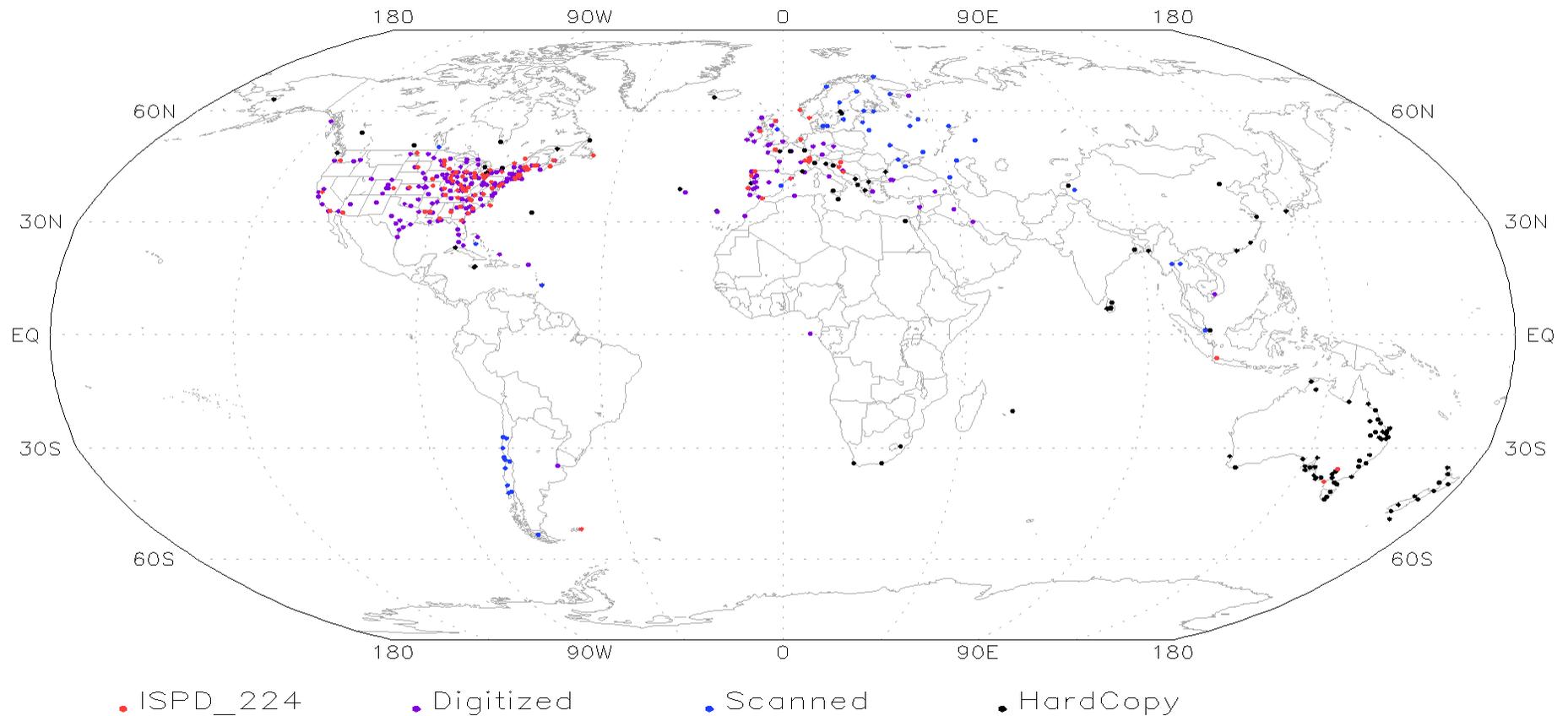
1979-2001  
ERA-40  
983.05  
983.02  
CFSR  
1979-2009  
(*van den Dool, 2010*)

Trenberth & Smith 2005; *van den Dool 2010*

# Current and future International Surface Pressure Databank station component (1670 to 2009)

<ftp://ftp.ncdc.noaa.gov/pub/data/ispd/add-station>

1873: Total # of ISPD stations = 93  
Total # of Additional stations = 401



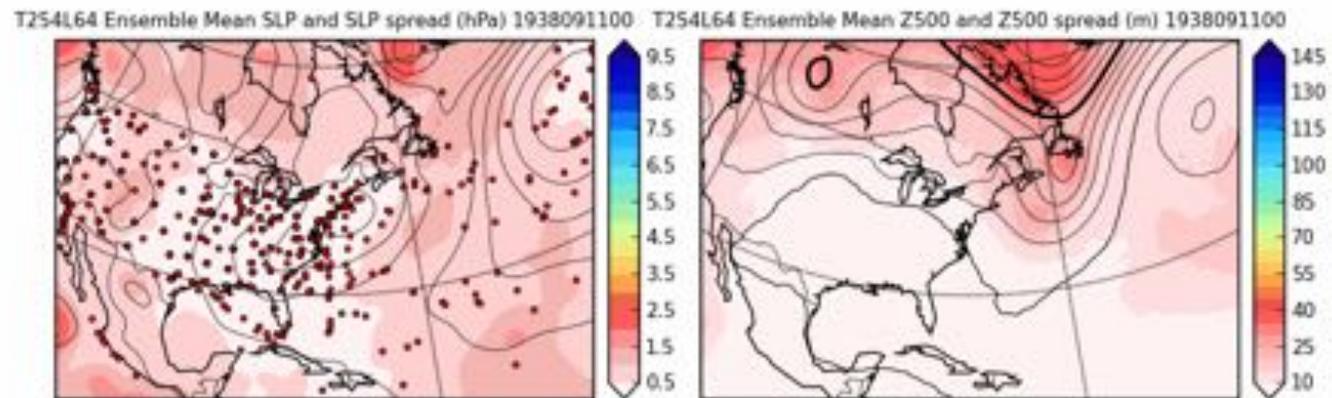
Courtesy X. Yin and R. Allan

# What does the climate community want/need from *long* reanalyses?

1. Climate model validation dataset for large-scale synoptic anomalies during extreme periods, such as droughts (30's, 50's).
2. Better understand events such as the 1920-1940's Arctic warming.
3. Determining storminess and storm track variations over last 100-150 years.
4. Developing new forecast products predicting changes in frequency and intensity of weather extremes, e.g., cold air outbreaks, severe storms.
5. Developing and improving forecasts of low-frequency (e.g., Pacific-North America pattern, North Atlantic Oscillation, ENSO) atmospheric and oceanic variations and their interannual to decadal variability.
6. Understanding changing atmospheric background state associated with interdecadal hurricane activity.
7. Homogenizing upper-air and other independent observations.
8. Estimating historical probability distributions for wind energy.
9. Estimating risks of extreme events for insurance and re-insurance.
- 10. Calibrating paleoclimate proxy reconstructions**

# Higher resolution example of Surface Input Reanalyses for Climate Applications (SIRCA)

# 2008 NCEP GFS at ~50km resolution September 1938 New England (movie)



T254L64 (~50 km)

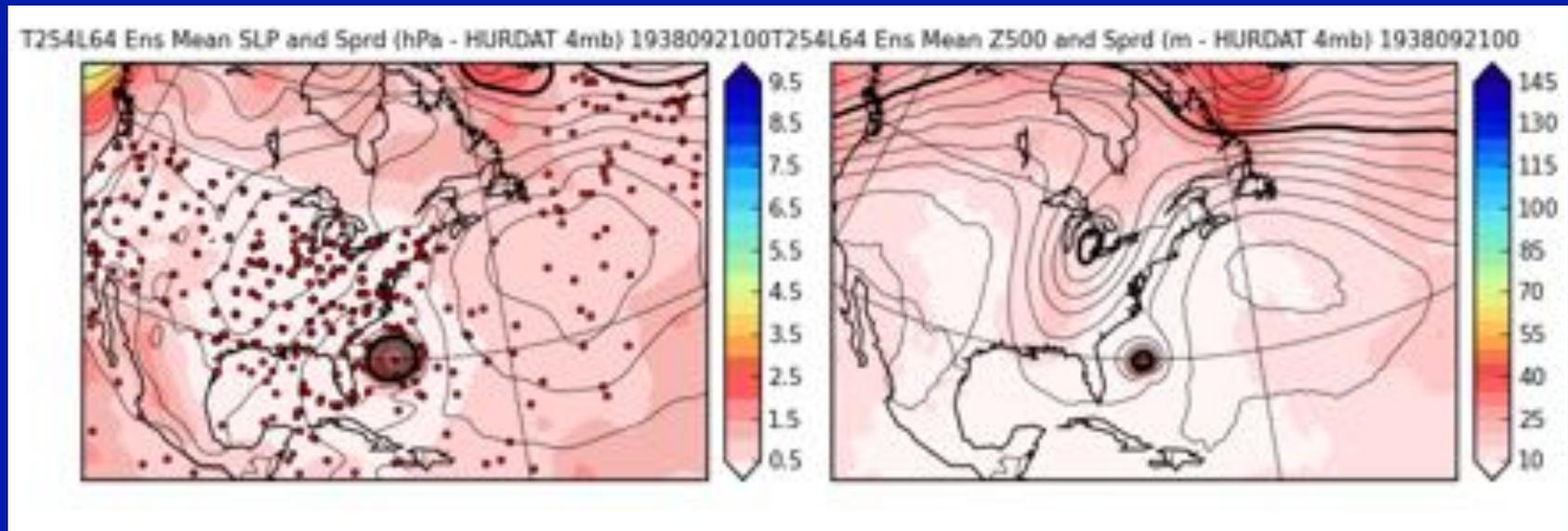
Is the extraordinary upper-level trough correct?

# 2008 NCEP GFS at ~50km resolution

## 21 September 1938 00 UTC

Sea Level Pressure

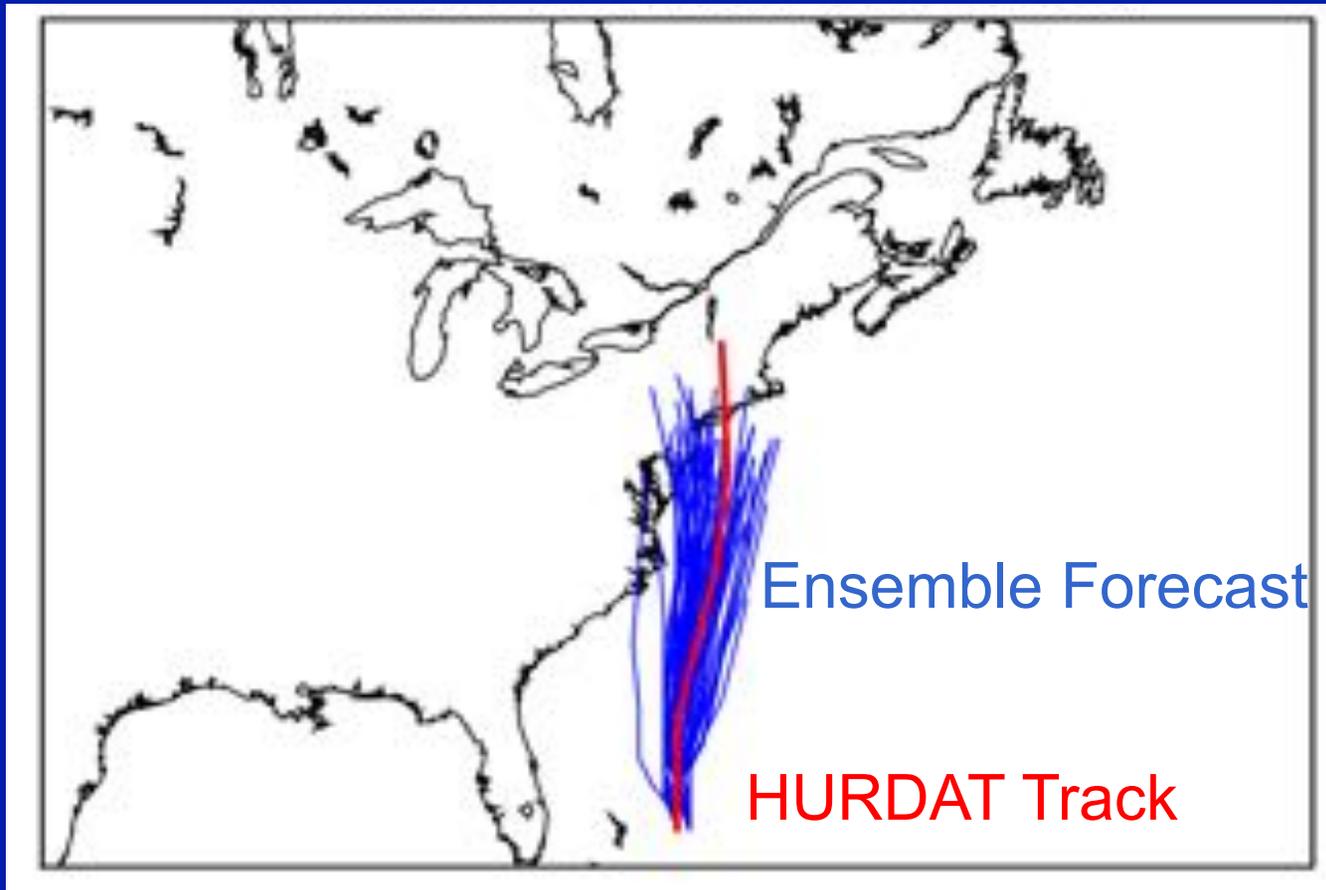
500 hPa geopotential height



Is the extraordinary upper-level trough correct?

# Any Skill Forecasting the Track?

36 hour forecast verifying 21 Sept 1938 18Z



using 56 ensemble members T254L64 (about 0.5 degree)

## US and International calls for historical reanalyses

Reanalysis datasets “spanning the instrumental record” (WCRP 3rd conference on reanalysis, Trenberth, EOS, 2008)

- Group on Earth Observations (GEO)/GCOS Task CL-06-01  
**Sustained Reprocessing and Reanalysis Efforts**
- U.S. GCRP Revised Strategic Plan (2008)  
Goal 3 Reduce uncertainty in projections of how the Earth’s climate and environmental systems may change in the future  
Key research topics: **Creating a Historical Reanalysis of the Atmosphere of the 20th Century**
- NOAA Strategic plan (2006-2011) to meet NOAA and GCRP goals calls for integrated observations and analysis with **“quantified uncertainties”**.
- Emphasis on reanalysis improvements for understanding multidecadal variability of **weather extremes** and variations (eg., CCSP, 2008, Weather and Climate Extremes SAP3.3)

# Challenges to meeting National and International goals for Historical Reanalyses

- Satellite network only back to 1970's, Upper-air network comprehensive only back to 1940's, scant to non-existent in 19th century
- 3-D Var data assimilation systems such as used in NCEP-NCAR, NCEP-DOE, ERA-40 reanalyses depends on upper-air data for high quality upper-level fields (*Bengtsson et al. 2004, Kanamitsu and Hwang 2005*).
- However, studies using advanced data assimilation methods (e.g., 4D-Var, Ensemble Filter) suggest surface network, especially surface pressure observations, could be used to generate high-quality upper-air fields (*Bengtsson 1980, Thepaut and Simmons 2003, Thepaut 2006, Whitaker et al. 2003, 2004, 2009, Anderson et al. 2005, Compo et al. 2006*).
- Surface Pressure observations are consistent and reliable throughout 20th Century and provide dynamical information about the full atmospheric column.

# Ensemble Filter Algorithm

$\mathbf{x}_j^b = \langle \mathbf{x} \rangle^b + \mathbf{x}'_j{}^b$  = first guess  $j$ th ensemble member ( $j=1, \dots, 64$ )

$y^o$  = single observation with error variance  $R$

First guess interpolated to observation location:  
 $\langle y \rangle^b = \mathbf{H} \langle \mathbf{x} \rangle^b$ ,  $y'_j{}^b = \mathbf{H} \mathbf{x}'_j{}^b$

Form analysis ensemble  $\mathbf{x}_j^a = \langle \mathbf{x} \rangle^a + \mathbf{x}'_j{}^a$  from

$$\langle \mathbf{x} \rangle^a = \langle \mathbf{x} \rangle^b + \mathbf{K} (y^o - \langle y \rangle^b)$$

$$\mathbf{x}'_j{}^a = \mathbf{x}'_j{}^b + \mathbf{K}^M (-y'_j{}^b) \text{ Note the different gain}$$

$$\mathbf{K} = \Sigma_j \mathbf{x}'_j{}^b y'_j{}^b (\Sigma_j y'_j{}^b y'_j{}^b + R)^{-1} \quad \text{Kalman Gain}$$

$$\mathbf{K}^M = (1 + \{R / (\Sigma_j y'_j{}^b y'_j{}^b + R)\}^{-1/2})^{-1} \mathbf{K} \text{ Modified Kalman Gain}$$

shrinks the ensemble

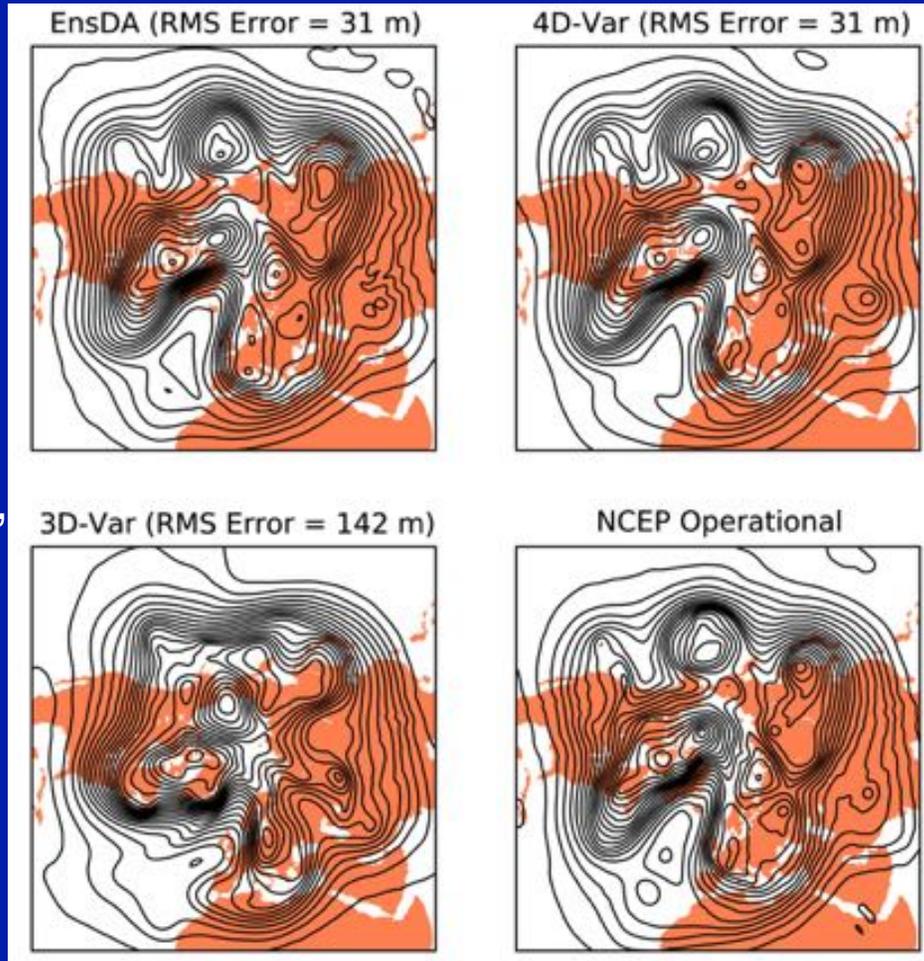
$(1/(n-1))$  is included in  $\Sigma_j$

Analysis ensemble becomes first guess ensemble for next observation.

Conduct Observing System Experiments using only surface pressure (e.g., Whitaker et al. 2009).

# 500 hPA Height Analyses for 20 Feb 2005 12Z

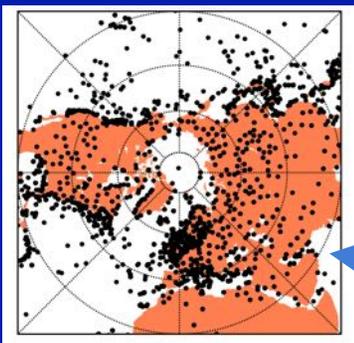
Ensemble Filter  
(~3800 surface  
pressure obs)  
RMS = 31 m



ECMWF “Surface”  
4D-Var  
(~3800 surface  
pressure obs)  
RMS = 31 m

ECMWF “Surface”  
3D-Var  
(~3800 surface  
pressure obs)  
RMS = 142 m

Full NCEP  
Operational  
(1,000,000+ obs)

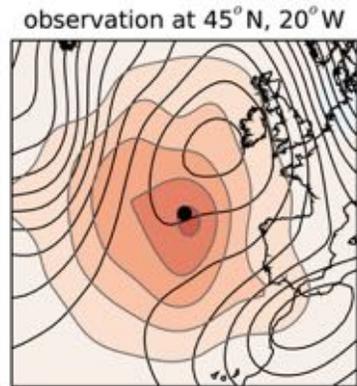


Surface pressure network  
reduced to ~1930's

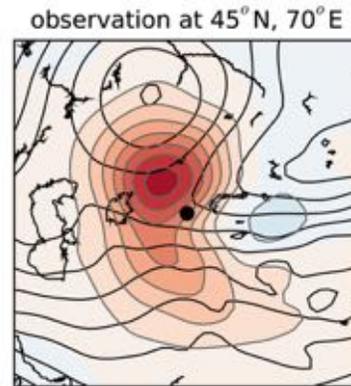
*Whitaker, Compo, Thepaut (2009)*

500 hPa Geopotential height first guess (line contours) and analysis minus first guess (shaded) for single pressure observation 1 hPa greater than first guess at selected locations along 45N

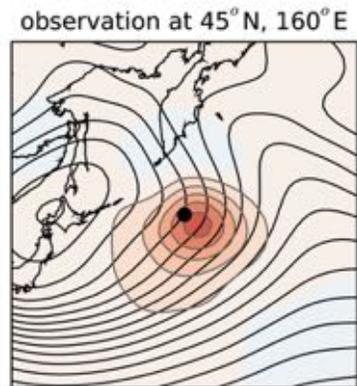
Eastern Atlantic



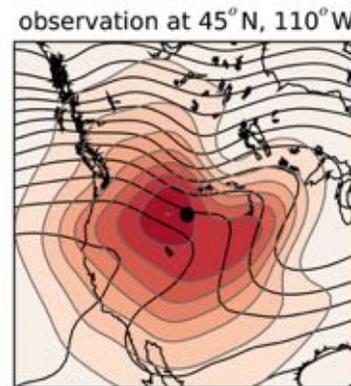
Central Asia



West Pacific



North America



Ensemble Filter can extract spatially-varying structures relative to the flow and the previous observational density.

In the 3D-Var used in NCEP-NCAR Reanalyses, all of these structures would be identical and centered on the observation location.

# Project Status and Plans (con't)

## Surface Input Reanalysis for Climate Applications (SIRCA)

SIRCA 1850-2011

- Higher resolution (T126 ~100km or higher)
- improved methods (e.g., Kalman Smoother)
- More input data (e.g., CDMP & ACRE, maybe winds and T, storm position)
- latest model from NCEP
- Include uncertainty in forcings (e.g., ensemble of SSTs and Sea Ice, CO2, solar)
- **Fall 2014**

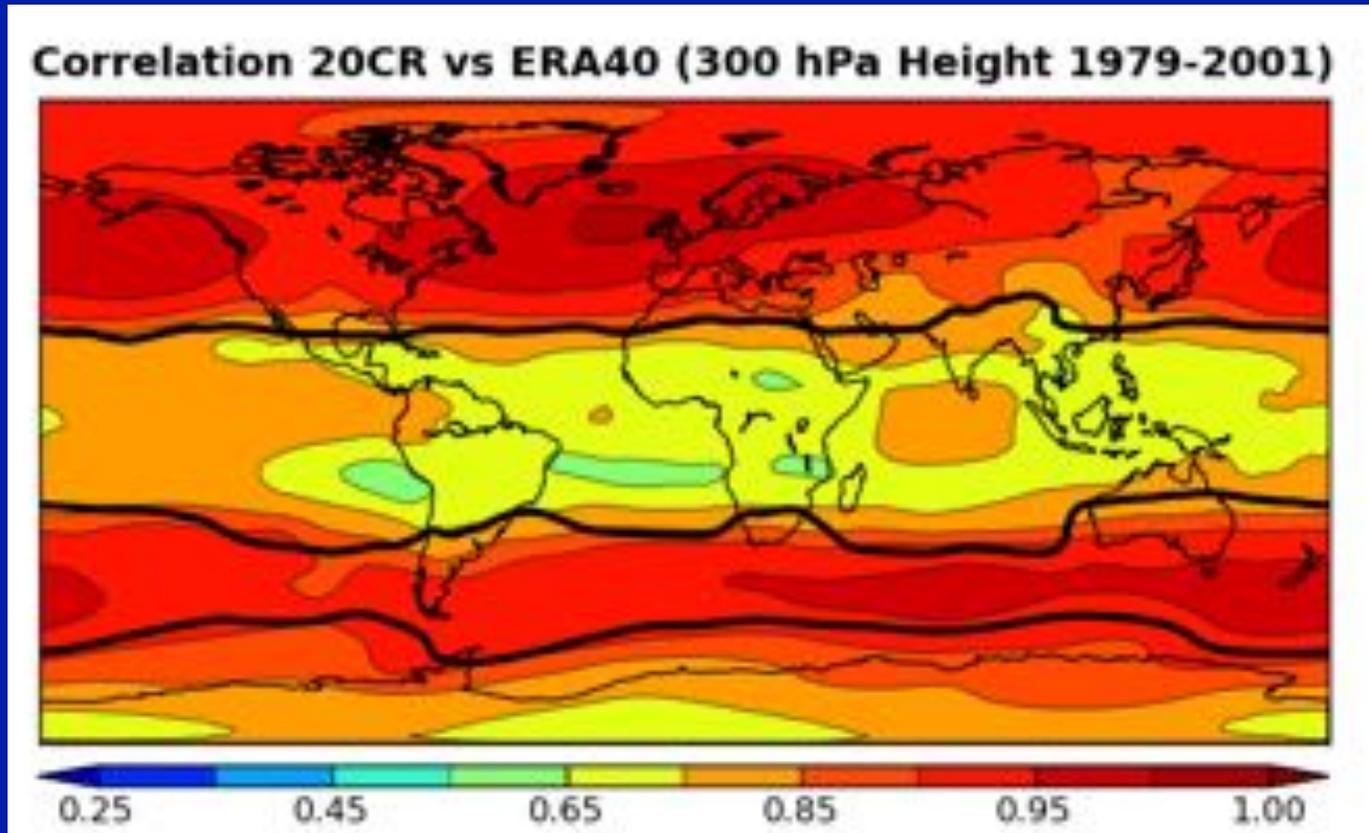
## Chemical and Surface Input Reanalysis for Climate Applications

CSIRCA 1800-2016

- Higher resolution (T382 or higher)
- improved methods (e.g., include coupled Cryosphere-Ocean-Land-Atmosphere-Chemistry system, link with NOAA CarbonTracker advances)
- More input data (e.g., ACRE-facilitated, maybe winds and T, storm position, trace gases)
- latest model from NCEP, multi-model with other models (e.g., NASA, GFDL, ESRL)
- **Fall 2017**

# Local Anomaly Correlation of 300 hPa geopotential height anomalies from 20th Century Reanalysis (20CRv2) and ERA40 (1979 to 2001)

Black curves show where NCEP-NCAR and ERA40 correlate > 0.975

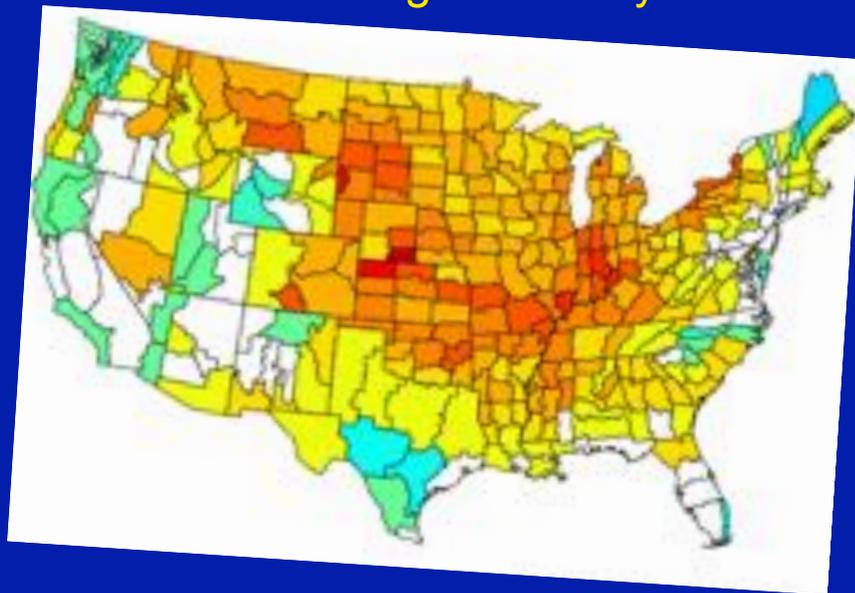


Northern and Southern Hemisphere agreement are excellent between 20CRv2 and ERA40 when ERA40 has satellite observations.

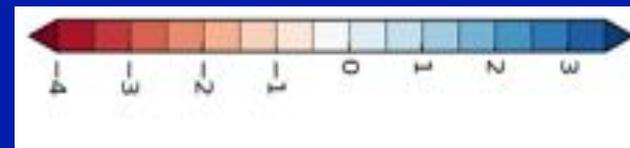
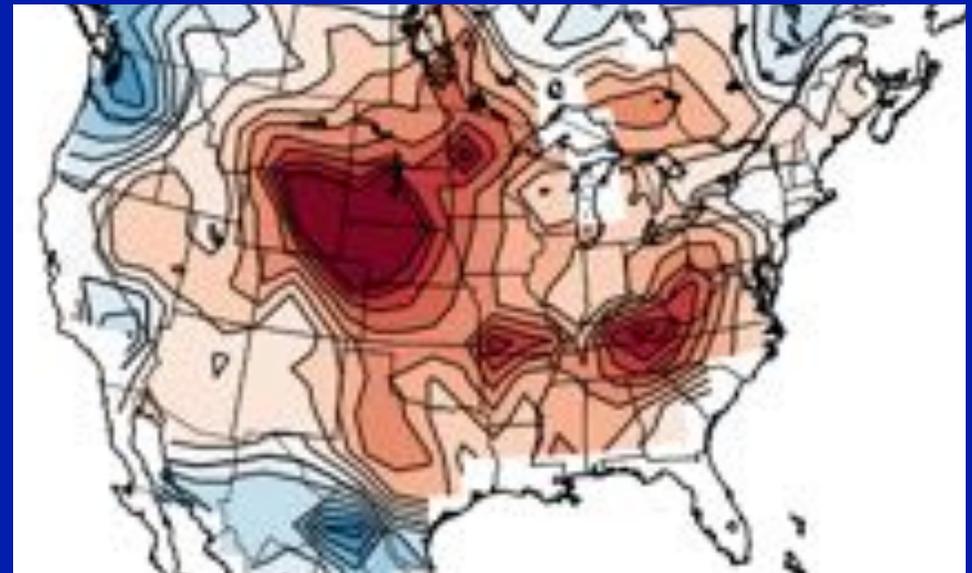
# U.S Dust Bowl (July 1936)

Standardized monthly anomalies relative to 1961-1990

US Climate Division  
Palmer Drought Severity Index



20CRv2 Soil Moisture 0-200 cm



Using only surface pressure, 20CR v2 appears to capture expected features even in derived quantities.

# Monthly mean composites (beta)

<http://www.cdc.noaa.gov/cgi-bin/data/composites/plot20thc.pl>

Plotting page courtesy Cathy Smith

(U. of Colorado CIRES and NOAA ESRL PSD)

U.S. Department of Commerce | National Oceanic & Atmospheric Administration | NOAA Research

**Earth System Research Laboratory**  
Physical Sciences Division

Search PSD:  Search  
Calendar | People | Publications

Physical Sciences Division    About    Contact    Research    Data    Products    Outreach    Intranet

**20th Century Reanalysis Monthly/Seasonal Composites**

Plot seasonal composites (averages) of the mean or anomalies (mean - total mean) of variables from the 20th Century Reanalysis reanalysis and other datasets. 20th century reanalysis data is available from **Jan 1908** to Dec 1958.

Which variable?     Level?

Beginning month of season:     Ending month:

Enter years for composites (from 1 to 16): e.g. 1972. For seasons that span a year (e.g. DJF), please enter year of the **LAST** month.

To subtract one set of years from another, use a minus sign (-) before the years that are to be subtracted

Help: In order to help ensure that this web analysis page remains available, we would greatly appreciate feedback on its use, particularly in the classroom, for presentations or for research. Mail to Cathy Smith at [cathy.smith@noaa.gov](mailto:cathy.smith@noaa.gov).

Complete Dataset Documentation

Help: Instructions, Datasets and variables, Index time-series info, Use your own time-series

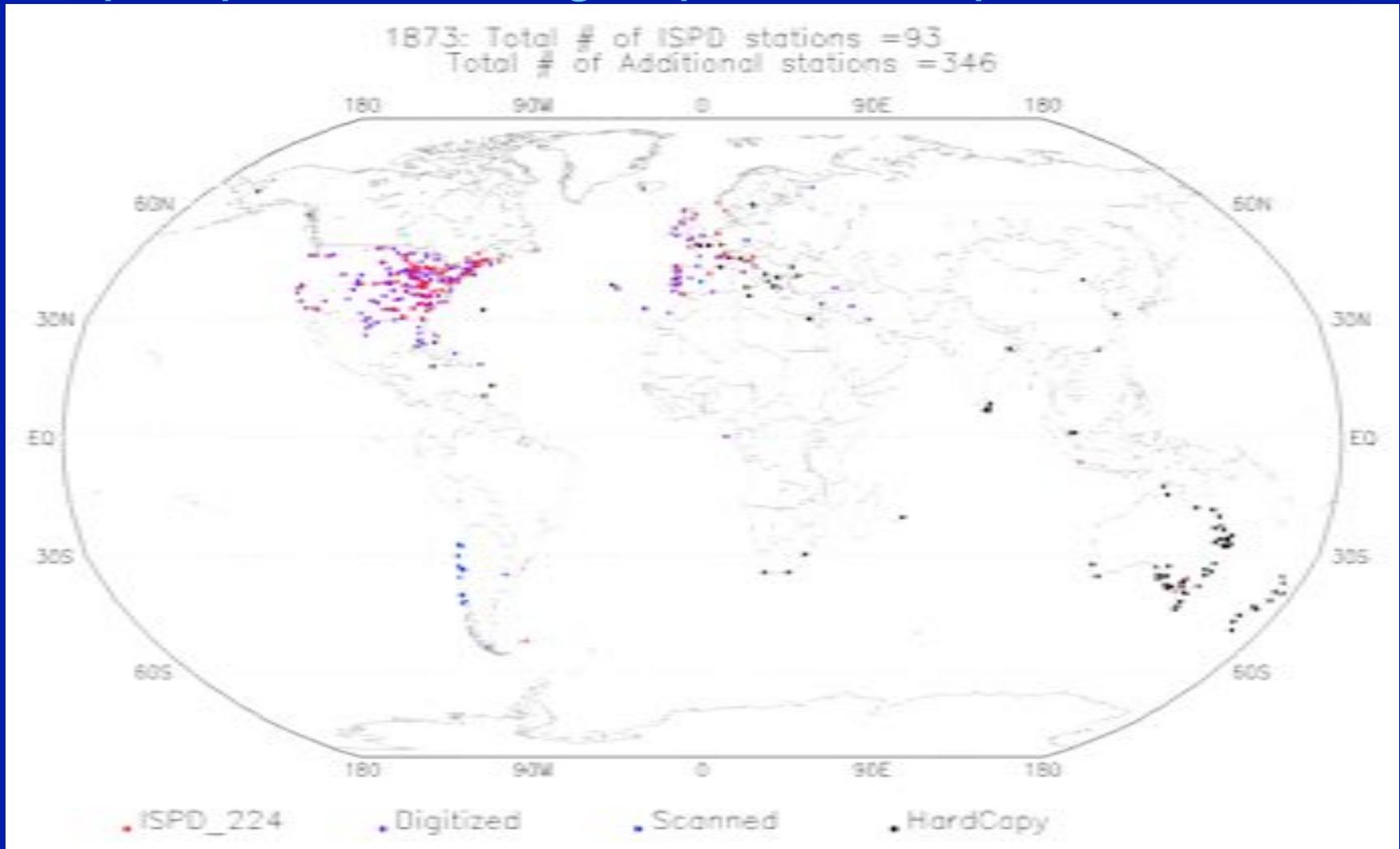
Background Information: Referencing Plots

Error on page.    Internet    100%

Daily means are also planned

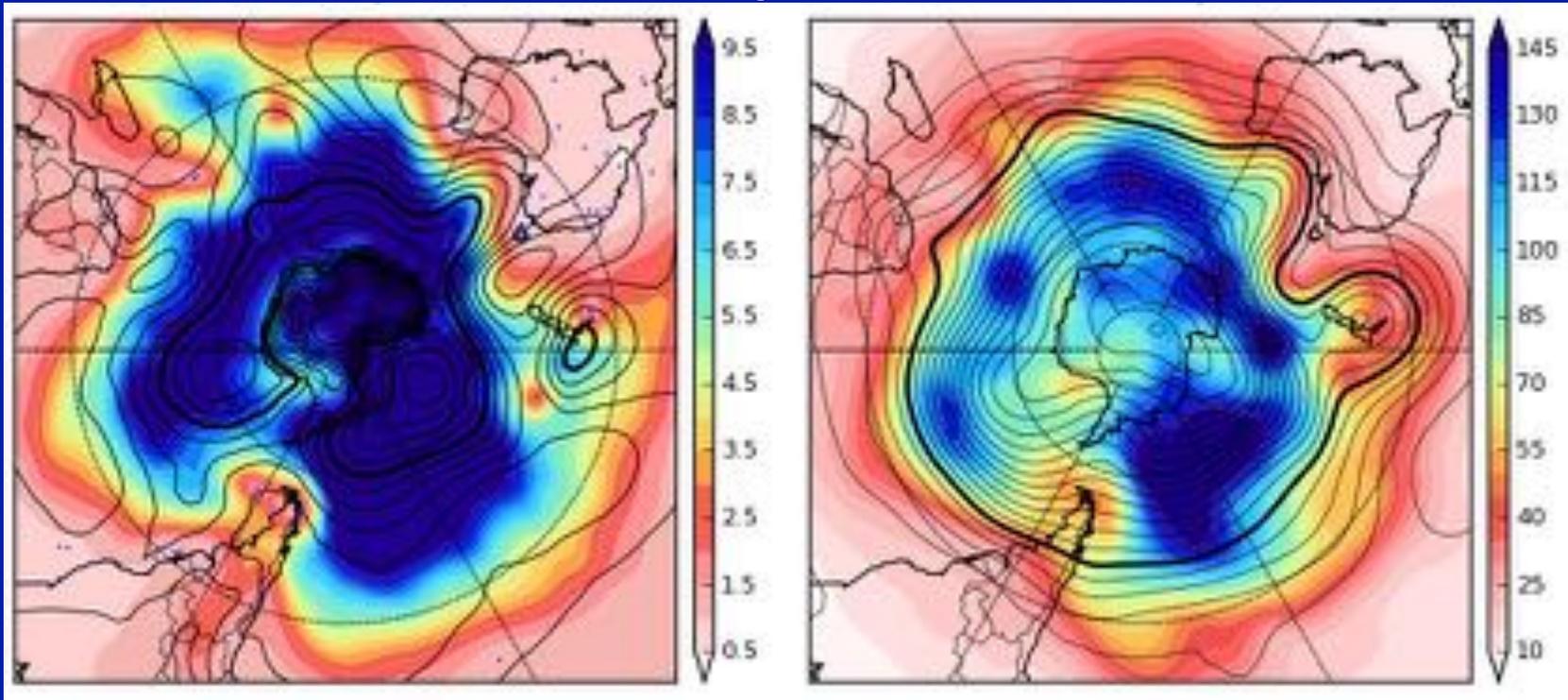
**Current** and future International Surface Pressure Databank  
station component  
(1670 to 2009)

<ftp://ftp.ncdc.noaa.gov/pub/data/ispd/add-station>



Courtesy X. Yin and R. Allan

# Analyses for selected dates 6 May 1923

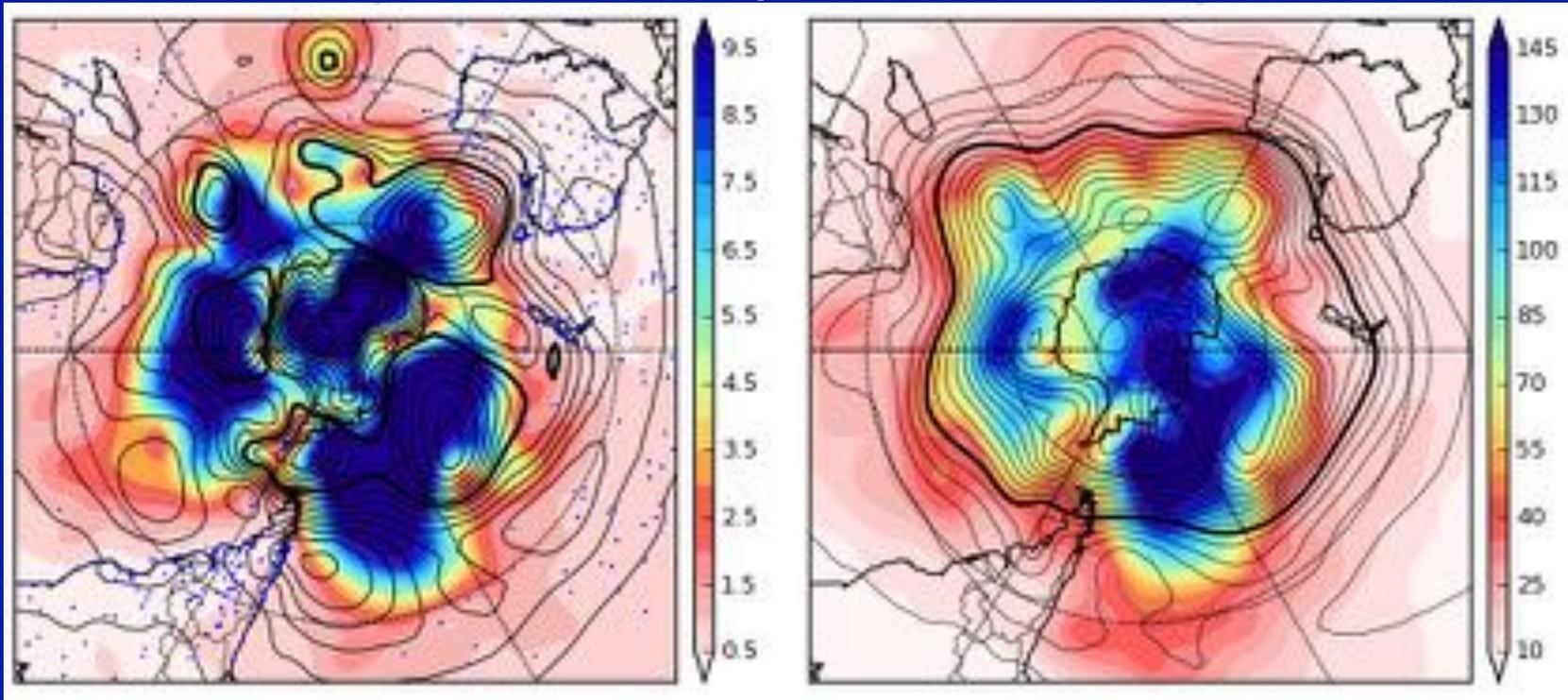


Sea Level Pressure (hPa)      500 hPa Geopotential Height (m)

Contours-  
Shading-

ensemble mean (*4 hPa, 50 m*)  
blue: more uncertain, white: more certain

# Analyses for selected dates 6 May 1973

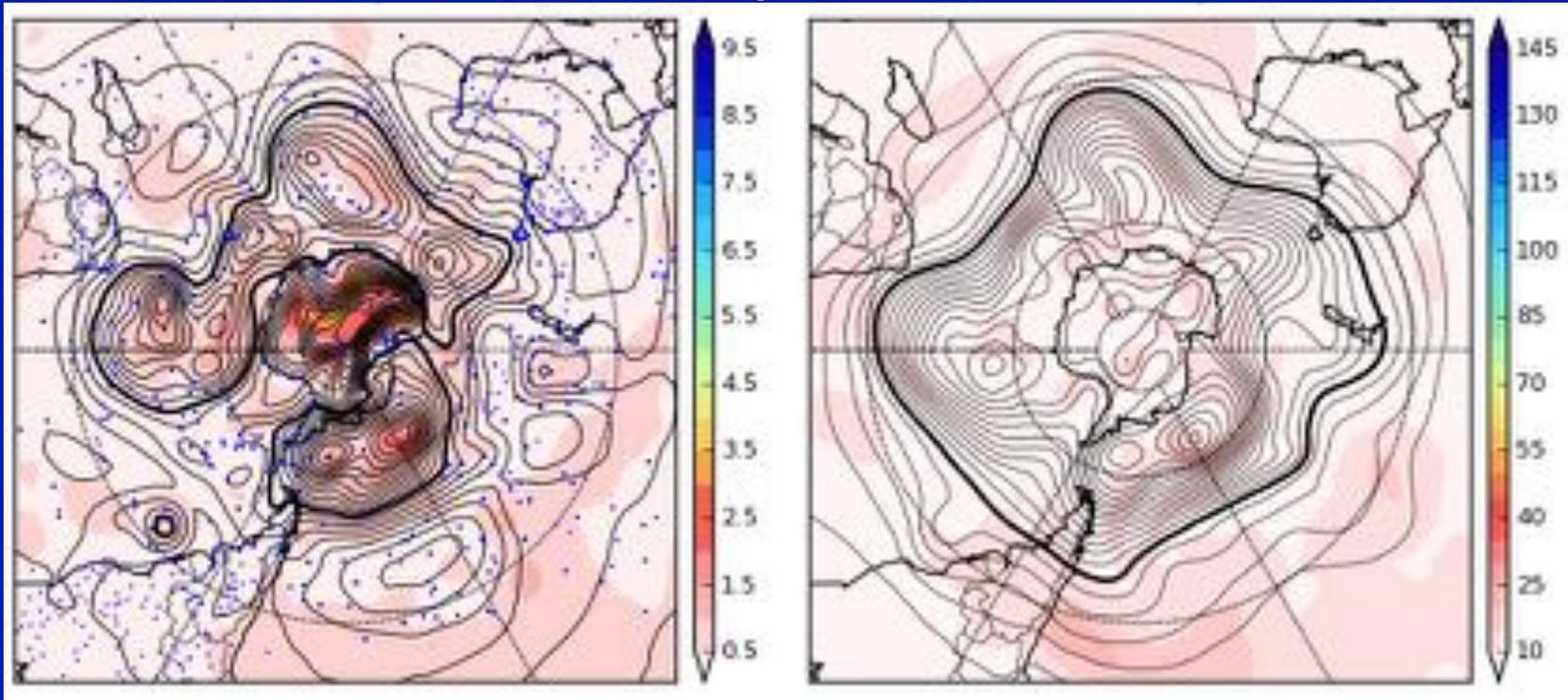


Sea Level Pressure (hPa)      500 hPa Geopotential Height (m)

Contours-  
Shading-

ensemble mean (4 hPa, 50 m)  
blue: more uncertain, white: more certain

# Analyses for selected dates 6 May 2008

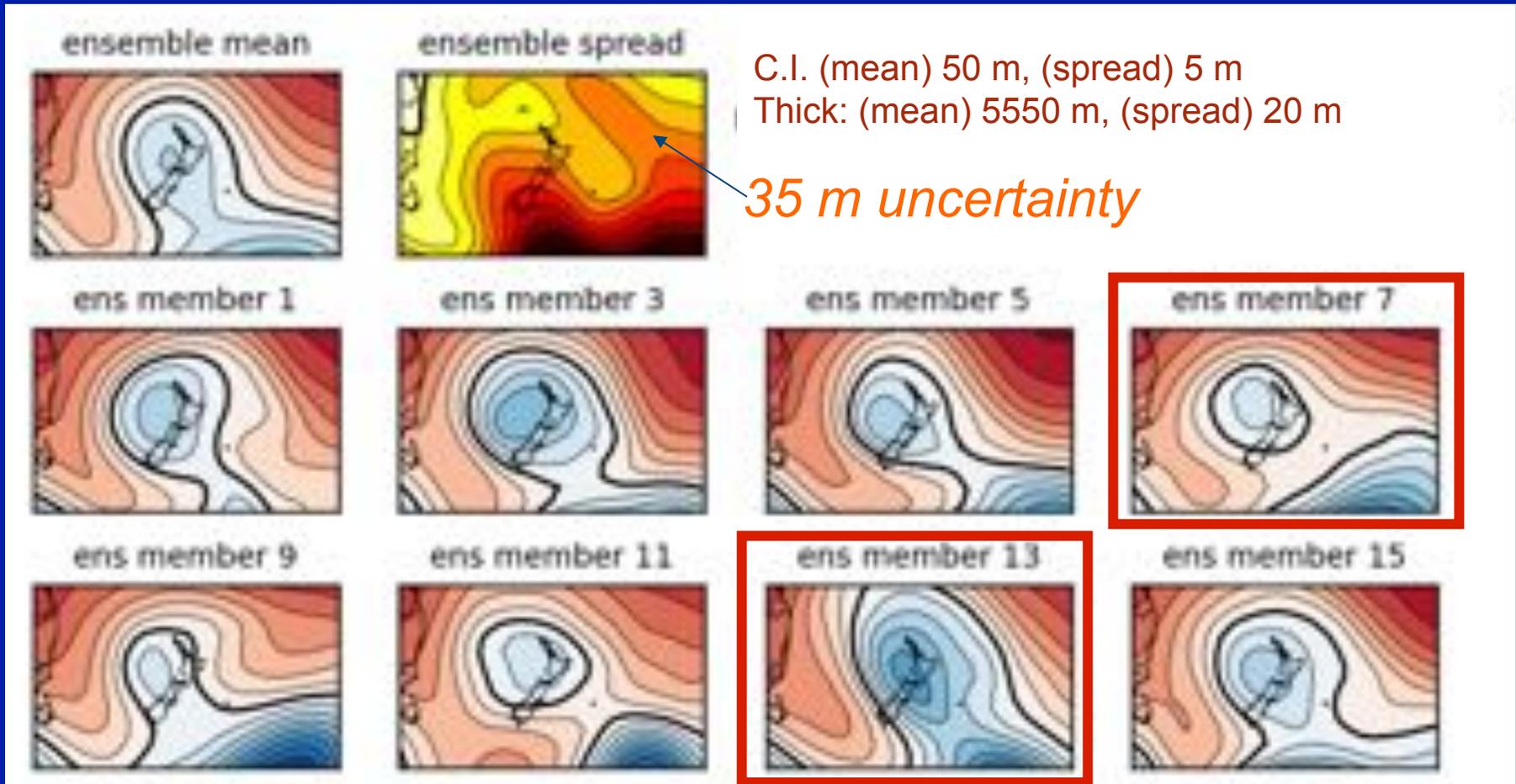


Sea Level Pressure (hPa)      500 hPa Geopotential Height (m)

Contours-  
Shading-

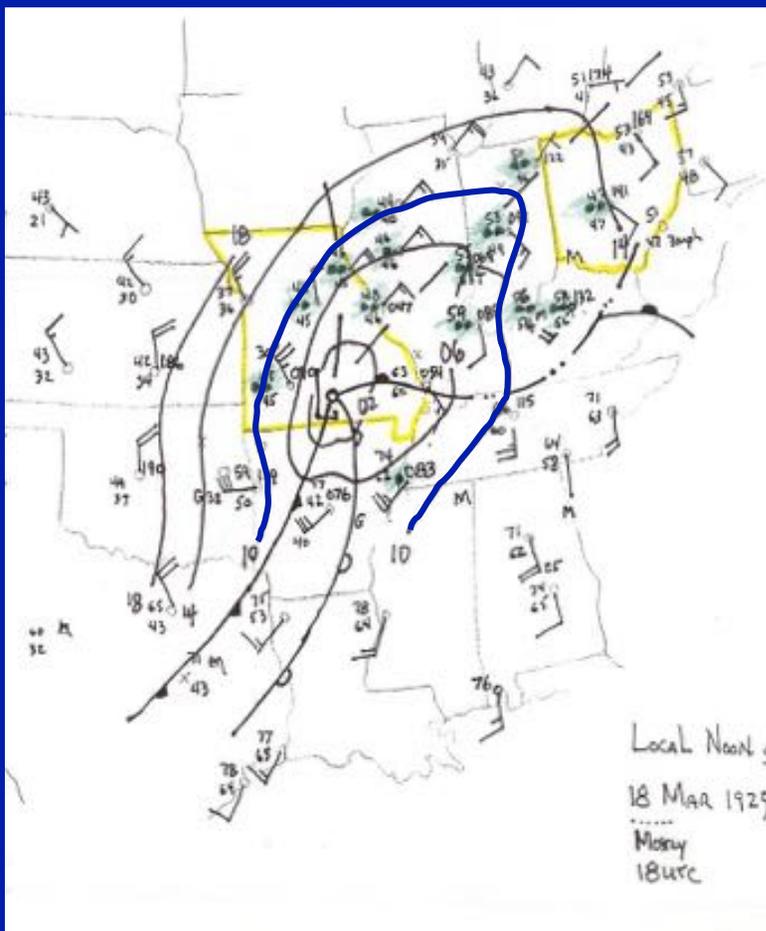
ensemble mean (*4 hPa, 50 m*)  
blue: more uncertain, white: more certain

# Range of possibilities for 500 hPa Geopotential Height During Severe Flooding Event 6 May 1923 0Z showing 12 (of 56) members

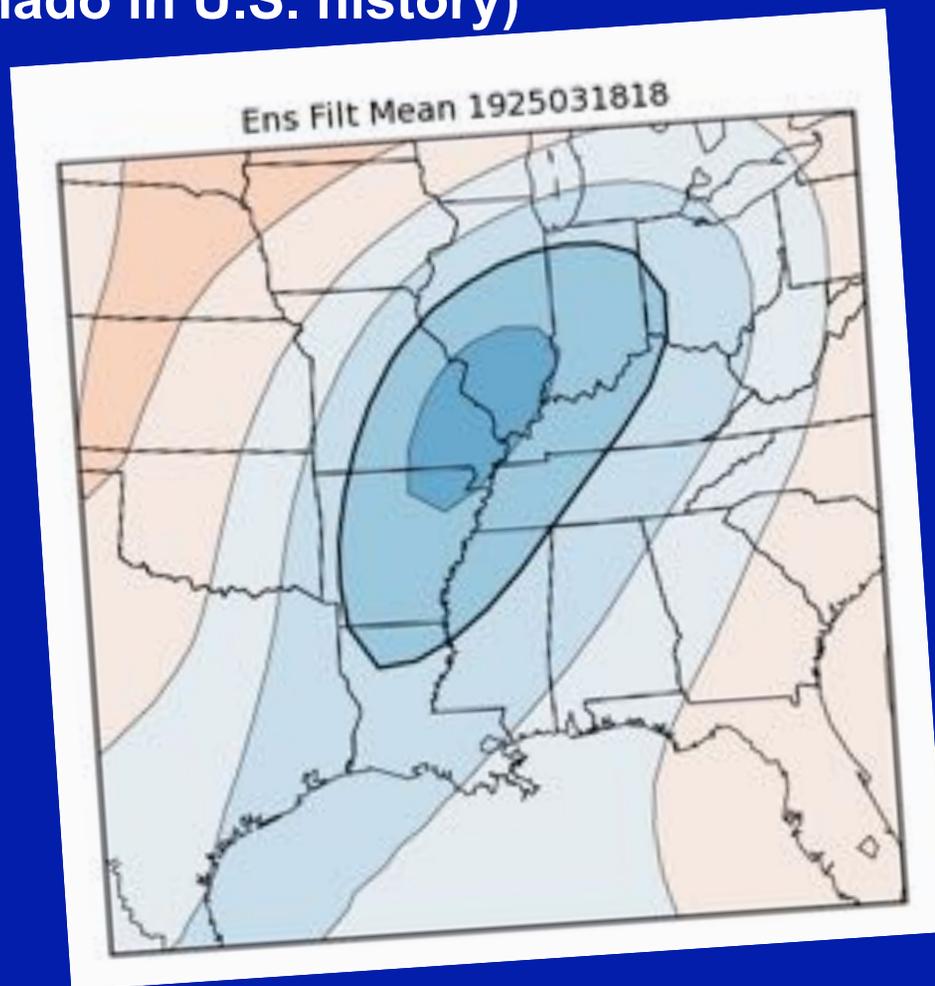


Ensemble of 56 possible realizations consistent with the observations

## Sea Level Pressure analyses for Tri-State Tornado Outbreak of 18 March 1925 (deadliest tornado in U.S. history)

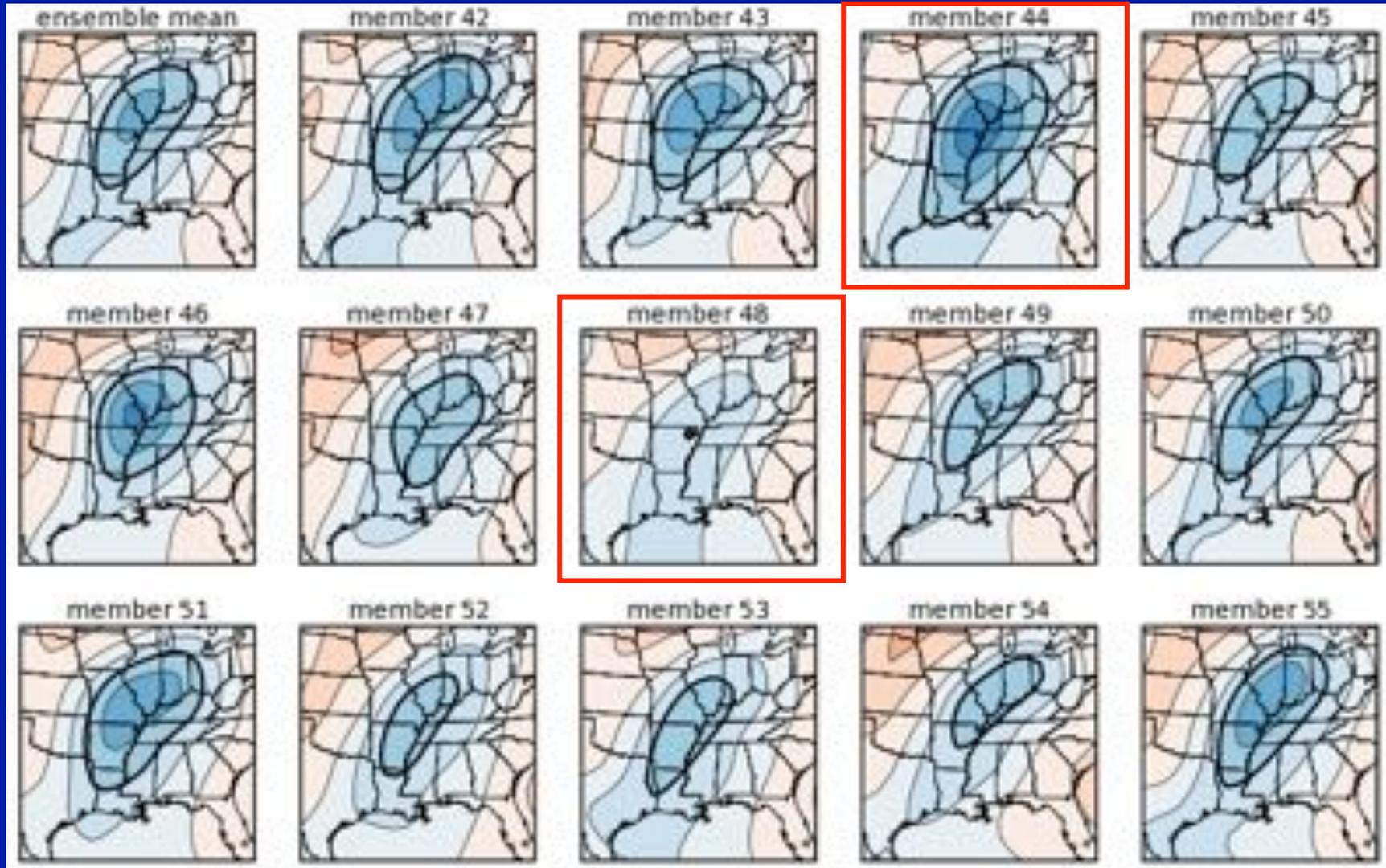


Manual Analysis, courtesy B. Maddox



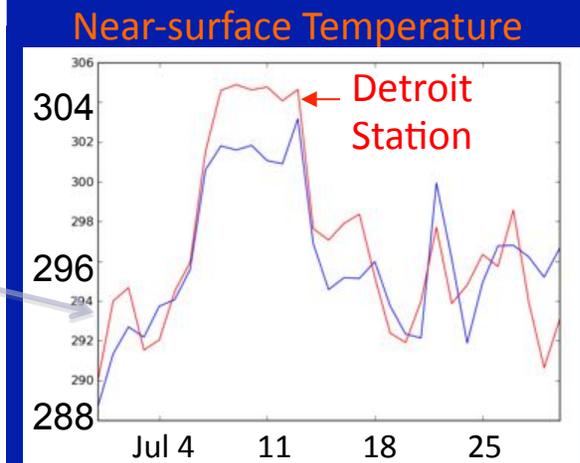
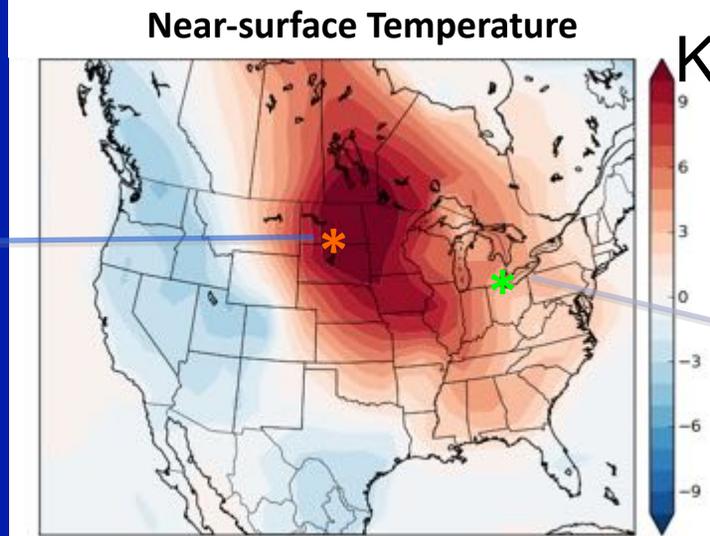
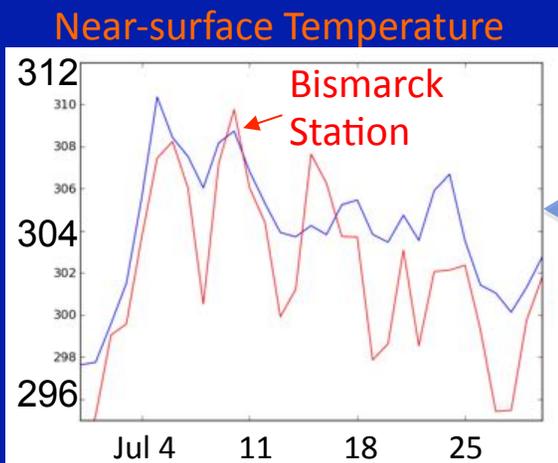
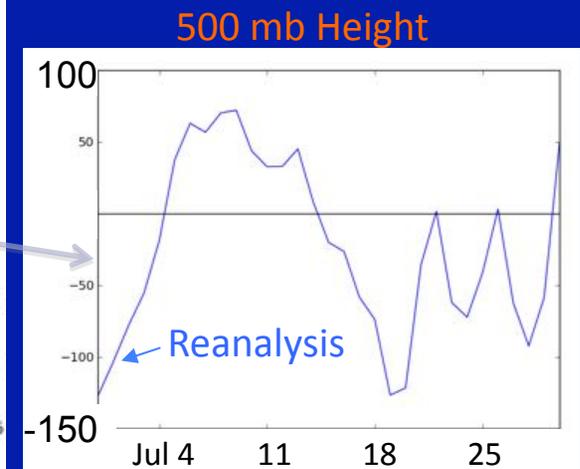
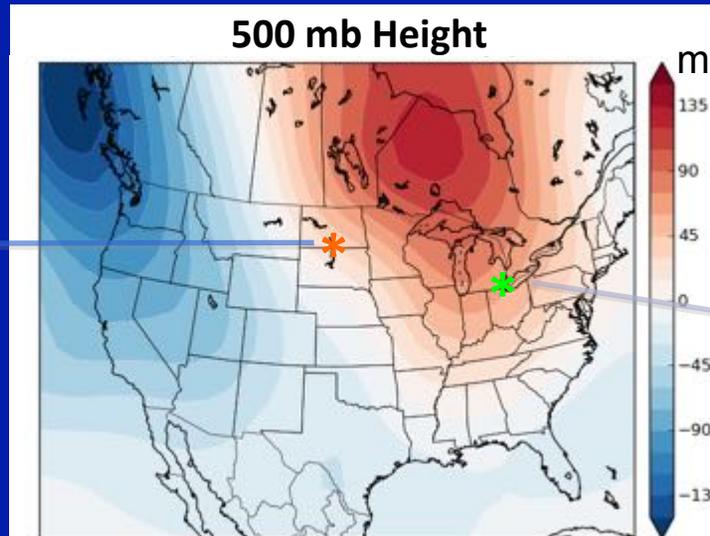
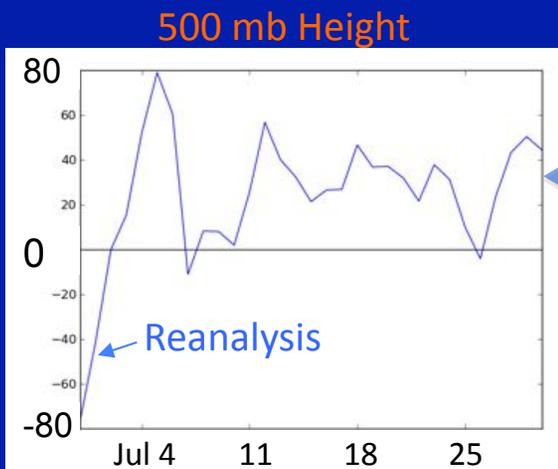
Ensemble mean from Ensemble Filter  
(4 hPa interval, 1010 hPa thick)  
**NOTE!!!** This analysis did not use ANY  
of the observations shown on the left.

# Range of possibilities for Sea Level Pressure 18 March 1925 18Z using 14 (of 56) members



Ensemble of 56 possible realizations consistent with the observations

# July 1936 North American Heat Wave (1,000+ US & 1,000+ Canadian deaths during 14-day span)

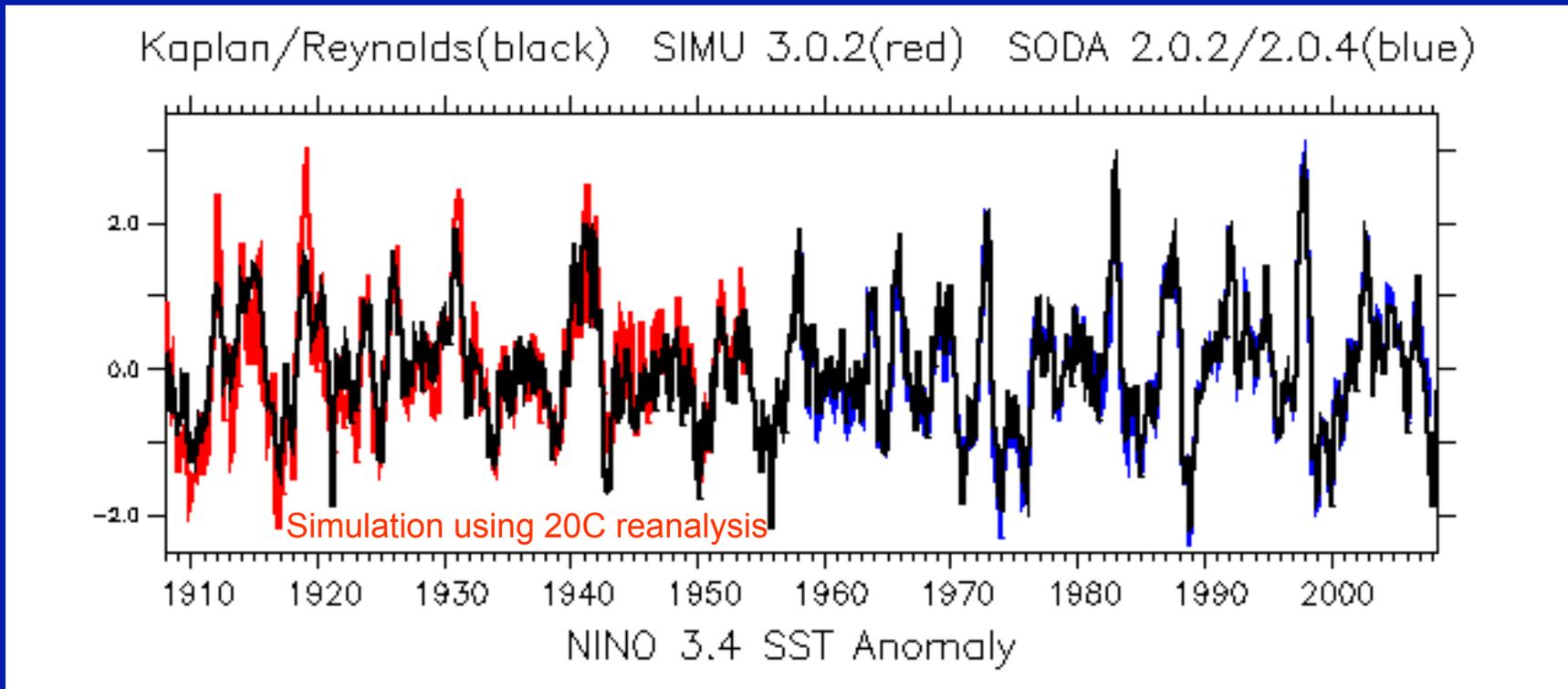


20<sup>th</sup> Century Reanalysis version 2  
Anomalies July 8 – 14 with respect to 1891-2007

# Tropical Validation

- Force global Parallel Ocean Program (POP) with daily 20th Century (1908-1956) reanalysis fields
  - 2m Air Temperature
  - 2m Specific Humidity
  - Downwelling Shortwave at Surface
  - Total cloud cover
  - 10 m Wind Speed
  - Precipitation
  - Zonal and Meridional Wind Stress  
(*Giese et al. BAMS 2009*)

# Nino3.4 Time series from Kaplan SST, POP Simulation, SODA Data Assimilation



- +20th Century reanalysis forcing fields **with no adjustment** generate realistic Nino3.4 variability in simulation
  - +Encouraging for Ocean and Coupled Data Assimilation.
- (Giese et al. BAMS 2010)

## Table of correlations of climate indices

PWC	20CR_V2	REC	NNR	ERA40	ERA-INT	SOCOL
20CR_V2	1	0.82	0.91	0.95	0.97	0.93
REC		1	na	na	na	0.83
NNR			1	0.96	0.991	0.89
ERA40				1	0.988	0.93
ERA-INT					1	0.97
SOCOL						1

PNA	20CR_V2	REC	NNR	ERA40	ERA-INT	SOCOL
20CR_V2	1	0.92	0.98	0.991	0.985	0.62
REC		1	na	na	na	0.62
NNR			1	0.987	0.98	0.70
ERA40				1	1.00	0.71
ERA-INT					1	0.90
SOCOL						1

NAO	20CR_V2	HADSLP	NNR	ERA40	ERA-INT	SOCOL
20CR_V2	1	0.98	0.995	0.994	0.997	0.26
HADSLP		1	na	na	na	0.22
NNR			1	0.997	0.998	0.25
ERA40				1	0.997	0.30
ERA-INT					1	0.11
SOCOL						1

# Uses of historical reanalyses

1. Effectively doubling the reanalysis record length 😊
2. Climate model validation dataset for large-scale synoptic anomalies during extreme periods, such as droughts (30's, 50's).
3. Better understand events such as the 1920-1940's Arctic warming.
4. Determining storminess and storm track variations over last 100-150 years.
5. Developing new forecast products predicting changes in frequency and intensity of weather extremes, e.g., cold air outbreaks, severe storms.
6. Developing and improving forecasts of low-frequency (e.g., Pacific-North America pattern, North Atlantic Oscillation) atmospheric variations and their interannual to decadal variability.
7. Understanding changing atmospheric background state associated with interdecadal hurricane activity.
8. Homogenizing upper-air and other independent observations.
9. Estimating historical probability distributions for wind energy.
10. Estimating risks of extreme events for insurance and re-insurance.
11. Calibrating paleoclimate proxy reconstructions