

# Atmospheric Circulation Reconstructions over the Earth: The 20<sup>th</sup> Century Reanalysis Project and longer historical reanalyses

**Rob Allan<sup>1</sup>, Gilbert P Compo<sup>2,3</sup>, Jeffrey S Whitaker<sup>3</sup>, Prashant D Sardeshmukh<sup>2,3</sup>**

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**QCCCE**



# What is ACRE?

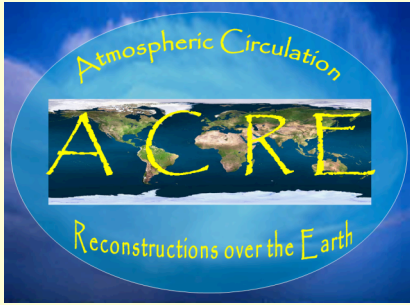
## Atmospheric Circulation Reconstructions over the Earth

**This initiative spans from**

- 1. The recovery of historical global weather observations underpinning climate reanalyses**

**To**

- 2. The development of tailored and downscaled products from the reanalysis 3D weather variables for**
  - climate applications, e.g., agricultural and biophysical models**
  - climate impacts, e.g., risk of high impact phenomena**



## Three surface input only historical reanalyses generating 6-hourly 3D atmospheric weather variables

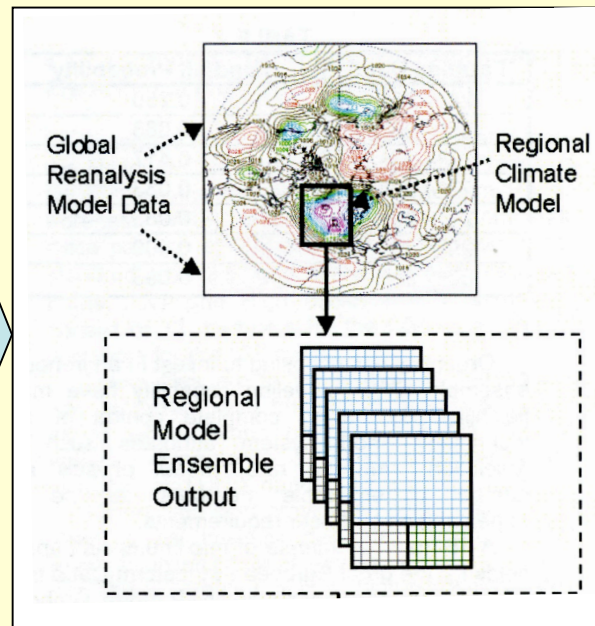
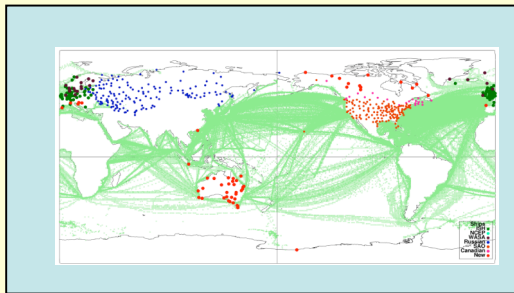
20th Century Reanalysis Project: 1892 to present  
(supported in US by NOAA & DoE)

Early to mid-19th Century: 1830s to present

North Atlantic-European Region:  
1750/1800 to present

## Climate applications & biophysical models

Global historical surface  
daily to sub-daily  
weather observations



and downscaling

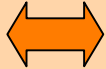
- Ecological
- Phenological
- Health & Disease
- Reinsurance
- Climate Monitoring
- Model Validation
- Environmental Assessments
- Extremes, Impacts & Risks
- Water resources
- Agricultural
- Forestry
- Energy
- Marine operations
- Cultural landscapes & built heritage



# **Daily to Sub-Daily Data**



**DATA RESCUE**  
(MEDARE  
MedCLIVAR  
IEDRO  
SIGN)



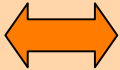
## ATMOSPHERIC CIRCULATION RECONSTRUCTIONS OVER THE EARTH





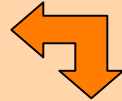
**NATIONAL METEOROLOGICAL SERVICES**  
(ECSN, ETCCDI, VACS, CMA, MeteoFrance)

**GLOBE**



**TERRESTRIAL DATA**

**MARINE DATA**



**RECLAIM**

**NCDC**



**CDMP**

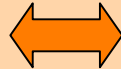




### GCOS AOPC/OOPC

**Working Group on Surface Pressure**  
**International Surface Pressure Databank**





**ICOADS**  
International COADS



**HISTORICAL CLIMATE QUALITY REANALYSES**

# International Surface Pressure Databank

Sub-daily observations assembled under

GCOS AOPC/OOPC Working Group on Surface Pressure

GCOS/WCRP Working Group on Observational Data Sets for Reanalysis

NOAA NCDC and NOAA ESRL: merging station data

NOAA ESRL and NCAR (ICOADS): merging marine data

**Thank you to partners contributing observations:**

All Union Research Institute of Hydrometeorological  
Information WDC

Atmospheric Reconstructions over the Earth

Australian Bureau of Meteorology

British Antarctic Survey

Danish Meteorological Institute

Deutscher Wetterdienst

EMULATE

Environment Canada

ETH-Zurich

GCOS AOPC/OOPC Working Group on Surface  
Pressure

Hong Kong Observatory

ICOADS

Instituto Geofisico da Universidade do Porto

Japanese Meteorological Agency

Jersey Met Dept.

KNMI

MeteoFrance

Meteorological and Hydrological Service, Croatia

National Center for Atmospheric Research

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

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

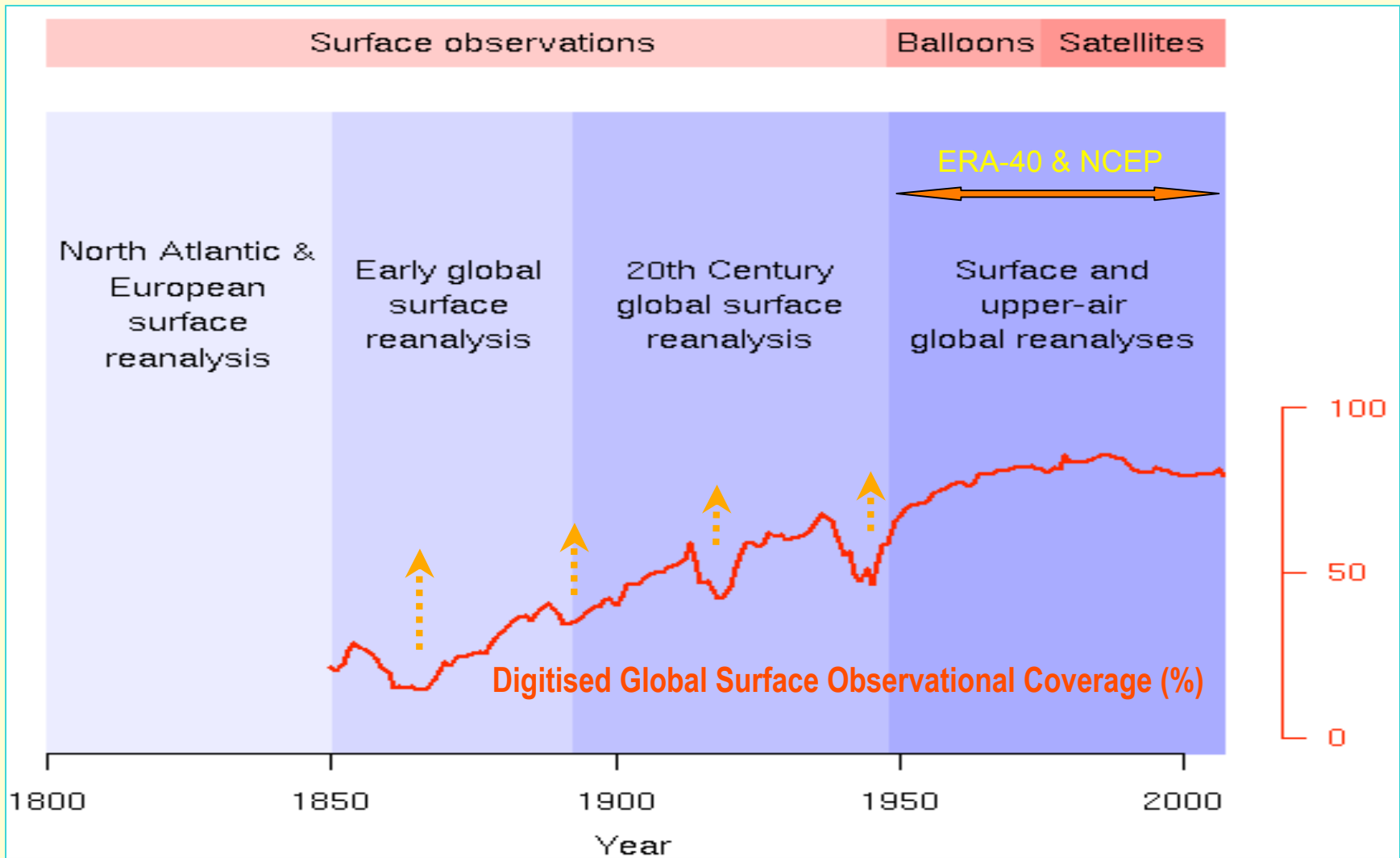
U. of Lisbon- Instituto de Meteorologia

U. of Milan-IFGA

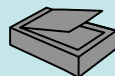
U. Rovira i Virgili-CCRG

# ACRE Historical Reanalyses of 3D weather conditions

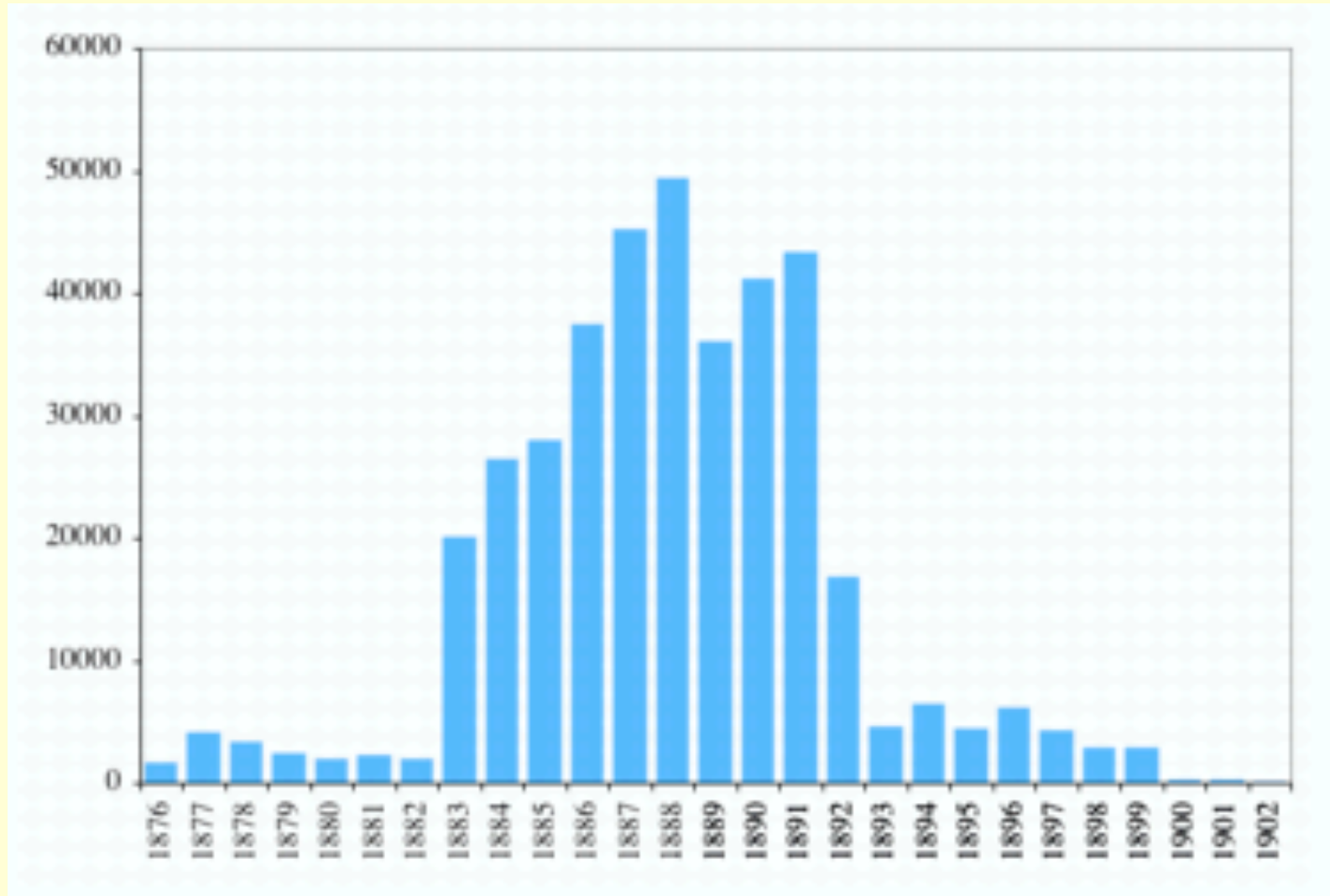
(globally every 6 hours at 2° x 2° latitude x longitude)



## Improve Digital Holdings of Surface Observations



# New DWD Merchant Marine Data



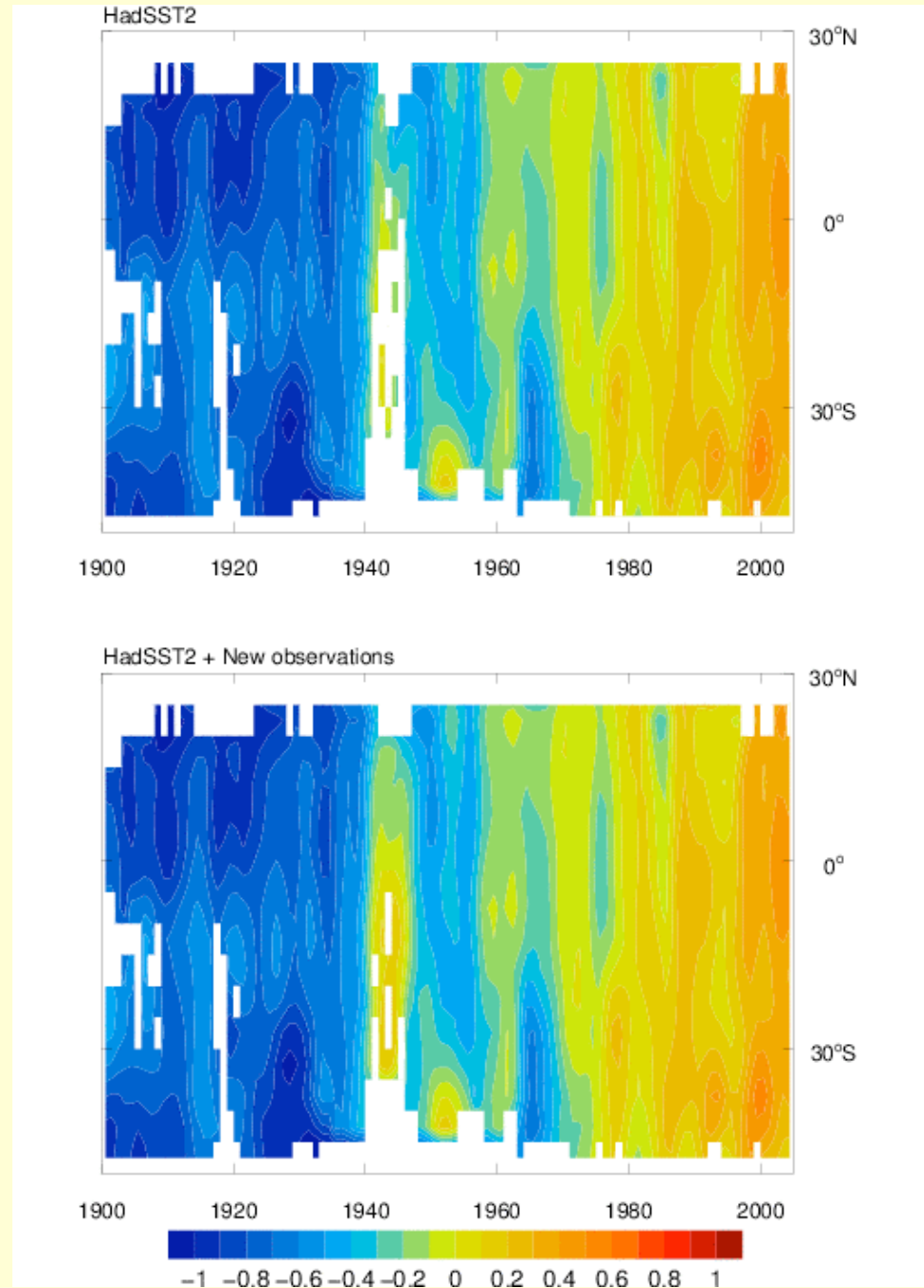
# World War 2 ship log book imaging and digitisation

**Latitude time sections of zonal-mean Indian Ocean SST anomalies (C) for 1900 to 2005, relative to the 1961-90 mean (after figure 3.5 from the IPCC 4th Assessment Report).**

**Upper panel: HadSST2.**

**Lower panel: HadSST2 with the newly digitised World War 2 observations.**

Source (Brohan *et al.*, 2008)



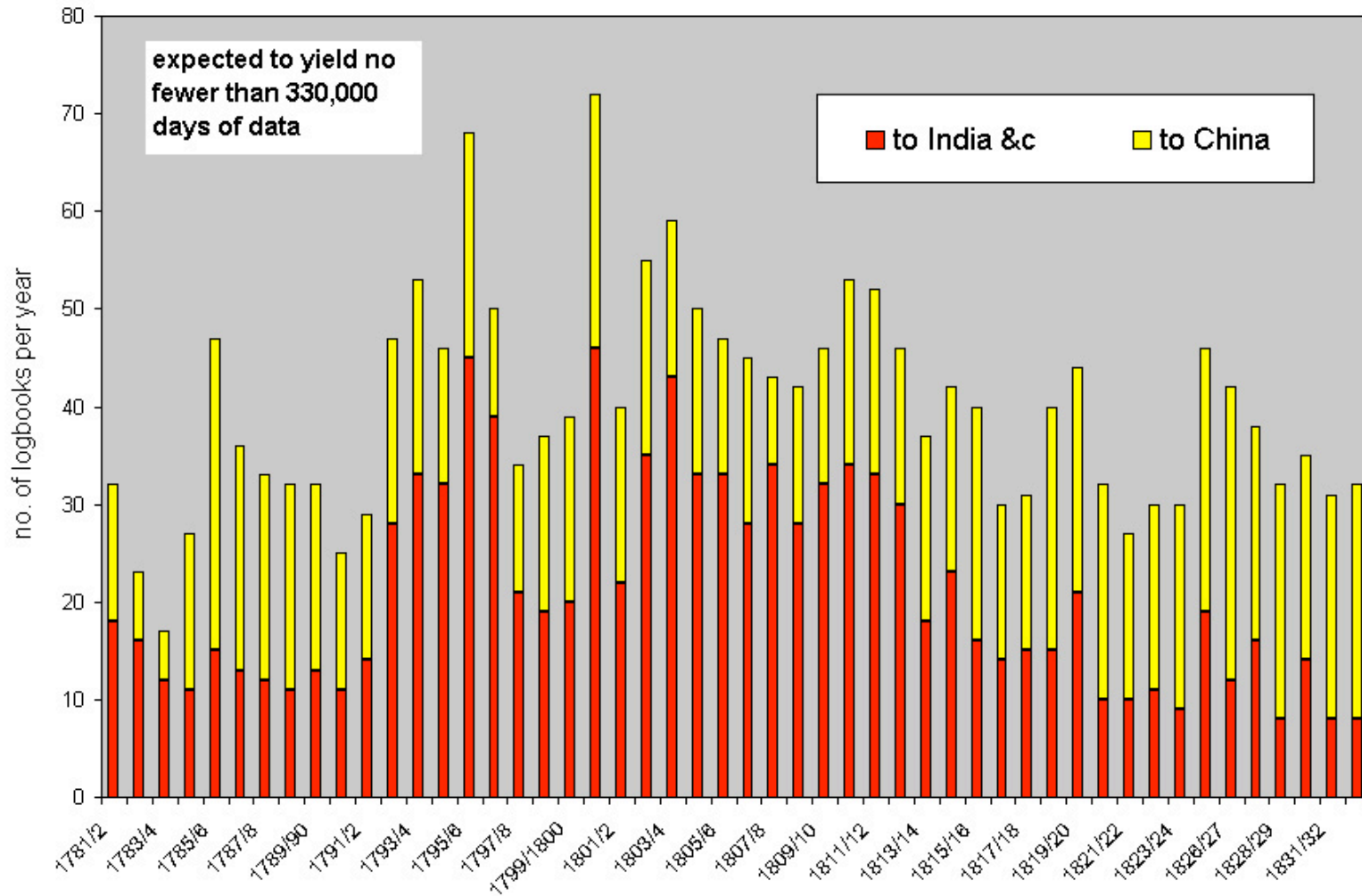
## Activities in recovering, imaging and digitising historical ship logbook & remarks books observations

- **2007/2008:** British East India Company (EIC) logbooks (1780s-1830s) – held in the British Library (imaging by British Library, digitised by CDMP in US) **1,000** of the 2,000 logs have instrumental data [200K images]

£400K split over two years - £200K in 2007/8 & £200K in 2008/9, from the climate research subcontract budget within the Defra/MoD funded Integrated Climate Programme



# Graphical summary of logbook availability for the period 1780 to 1833



Source: Dennis Wheeler

# Sample EIC Ship Log Book



*N. C. S. Castle Huntly, towards Bengal.*

H	Course	K	F	Winds, &c	LEE WAY.															
1	NbW	7	6	No fresh breeze		Sunday April 15 <sup>th</sup> 1780														
2	Drift	7	6	South breeze fresh																
3																				
4																				
5	NbW	9	8	Squally fresh thro' the Main		First part a strong fall from N. with rain and sharp squalls, amidst heavy squalls to the N. with rain, latter a strong breeze from the West with fine weather.														
6																				
7																				
8																				
9																				
10	Drift	7	6	South breeze fresh		The necessary duty of the Ship prevents the performance of a more business.														
11																				
12																				
1																				
2																				
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				
11																				
12																				
Dist. 179 Miles																				
<table border="1"> <tr> <td>Course &amp; Dist. NbW 179</td> <td>X Lat { ob. 16 ac. 23</td> <td>X Lon { ac. 20 chr. 29</td> <td>Lat { ob. 27 52 1/2 ac. 29 56 1/2</td> <td>Lon { mde 2 25 in 60 7 1/2</td> <td>CO 12 24 chr 12 25</td> <td>Var { pm. 2 1/2 am.</td> </tr> <tr> <td>Depart. 1780</td> <td>P of Acc. 11</td> <td>S of Acc. 11</td> <td>Bar. 29 50 1/2</td> <td>Ther. 60</td> <td colspan="2">Cause by the N. 179 miles</td> </tr> </table>							Course & Dist. NbW 179	X Lat { ob. 16 ac. 23	X Lon { ac. 20 chr. 29	Lat { ob. 27 52 1/2 ac. 29 56 1/2	Lon { mde 2 25 in 60 7 1/2	CO 12 24 chr 12 25	Var { pm. 2 1/2 am.	Depart. 1780	P of Acc. 11	S of Acc. 11	Bar. 29 50 1/2	Ther. 60	Cause by the N. 179 miles	
Course & Dist. NbW 179	X Lat { ob. 16 ac. 23	X Lon { ac. 20 chr. 29	Lat { ob. 27 52 1/2 ac. 29 56 1/2	Lon { mde 2 25 in 60 7 1/2	CO 12 24 chr 12 25	Var { pm. 2 1/2 am.														
Depart. 1780	P of Acc. 11	S of Acc. 11	Bar. 29 50 1/2	Ther. 60	Cause by the N. 179 miles															
1	Drift	8	4	West fresh breeze		Monday April 17 <sup>th</sup> 1780														
2																				
3																				
4																				
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11																				
12																				
Dist. 177 Miles																				
<table border="1"> <tr> <td>Course &amp; Dist. NbW 177</td> <td>X Lat { ob. 17 ac. 11</td> <td>X Lon { ac. 26 chr. 22</td> <td>Lat { ob. 24 33 1/2 ac. 24 20</td> <td>Lon { mde 2 26 1/2 in 60 7 1/2</td> <td>CO 11 24 chr 11 25</td> <td>Var { pm. 2 1/2 am.</td> </tr> <tr> <td>Depart. 1780</td> <td>P of Acc. 5</td> <td>S of Acc. 11</td> <td>Bar. 29 97</td> <td>Ther. 55</td> <td colspan="2">Cause by the N. 177 miles</td> </tr> </table>							Course & Dist. NbW 177	X Lat { ob. 17 ac. 11	X Lon { ac. 26 chr. 22	Lat { ob. 24 33 1/2 ac. 24 20	Lon { mde 2 26 1/2 in 60 7 1/2	CO 11 24 chr 11 25	Var { pm. 2 1/2 am.	Depart. 1780	P of Acc. 5	S of Acc. 11	Bar. 29 97	Ther. 55	Cause by the N. 177 miles	
Course & Dist. NbW 177	X Lat { ob. 17 ac. 11	X Lon { ac. 26 chr. 22	Lat { ob. 24 33 1/2 ac. 24 20	Lon { mde 2 26 1/2 in 60 7 1/2	CO 11 24 chr 11 25	Var { pm. 2 1/2 am.														
Depart. 1780	P of Acc. 5	S of Acc. 11	Bar. 29 97	Ther. 55	Cause by the N. 177 miles															





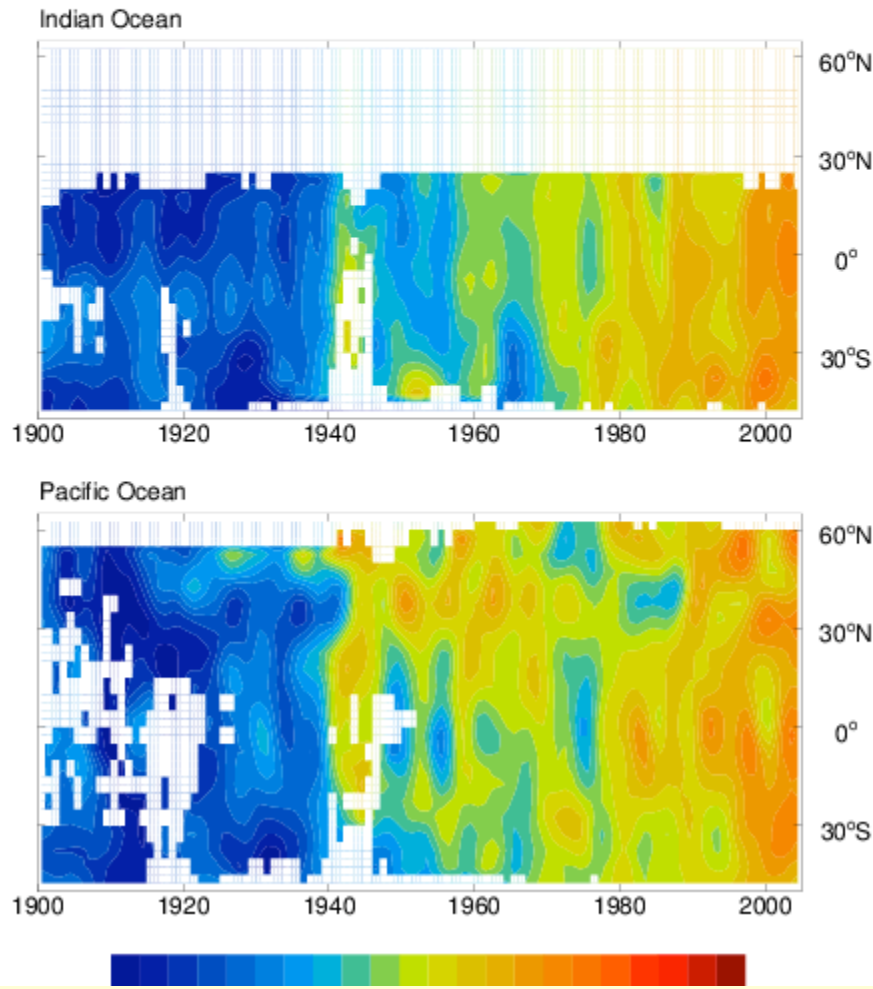
## Activities in recovering, imaging and digitising historical ship logbook & remarks books observations

- **2008/2009:** Extended World War 1 period logbooks (1914-1923) - held in the UK National Archives (imaging by UK National Archives) at least **8,000** logs [300K+ images]

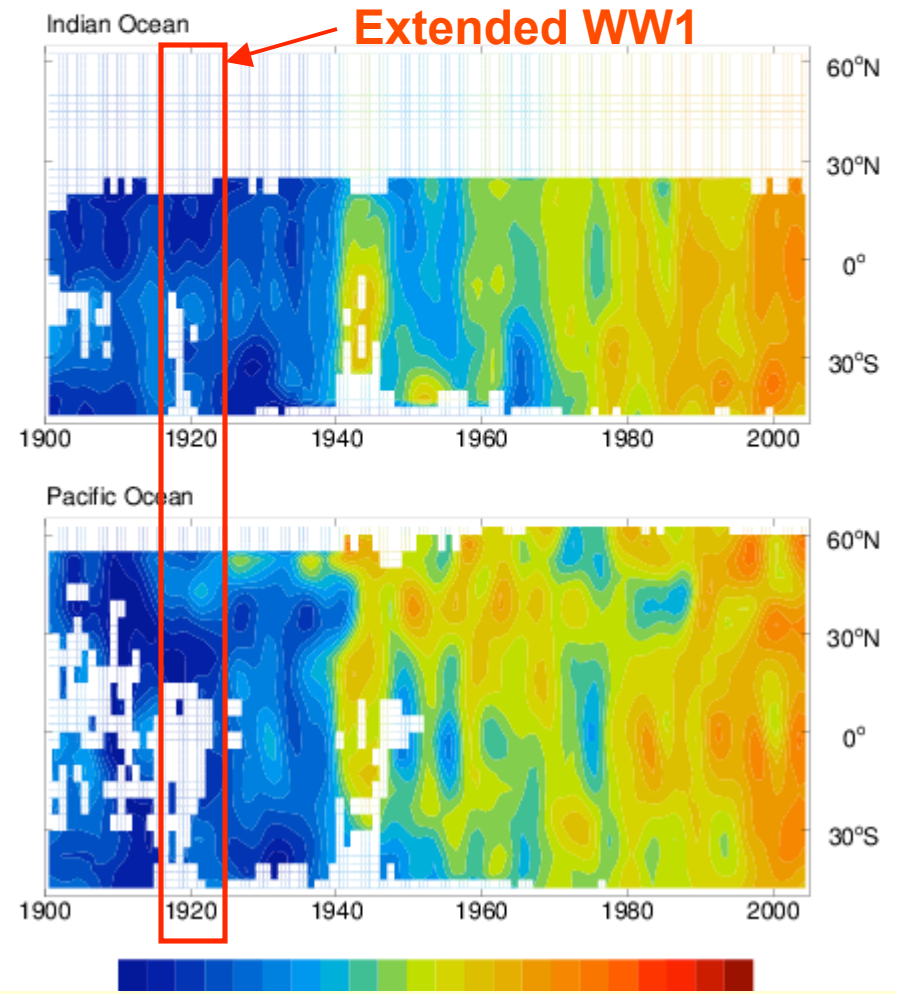
£400K split over two years - £200K in 2007/8 & £200K in 2008/9, from the climate research subcontract budget within the Defra/MoD funded Integrated Climate Programme

# Latitude time sections of zonal-mean Indian Ocean and Pacific Ocean SST anomalies (C) for 1900 to 2005, relative to the 1961-90 mean

## HadSST2



## HadSST2 with the newly digitised World War 2 observations



## Activities in recovering, imaging and digitising historical ship logbook & remarks books observations

- **2007/2008:** Printed/published logbooks of late 19<sup>th</sup>-early 20<sup>th</sup> Century Antarctic expeditions plus ships of exploration – online plus held in the Met Office Library & Archives (imaging & digitisation)

£400K split over two years - £200K in 2007/8 & £200K in 2008/9, from the climate research subcontract budget within the Defra/MoD funded Integrated Climate Programme



## Digitised printed late 19th- early 20th Century Antarctic expeditions

### Ship logs

1897-1899 Belgian Antarctic Expedition,  
*Belgica* – Antarctic Peninsula

1898-1900 British Antarctic Expedition,  
*Southern Cross* – Ross Sea

1901-1904 British National Expedition, *Discovery* - Ross Sea

1907-1909 British Antarctic Expedition,  
*Nimrod* – New Zealand to McMurdo Sound

1908-1910 Fourth French Antarctic Expedition,  
*Pourquoi-Pas IV* – Bellingshausen/Amundsen Seas

1910-1913 British Antarctic Expedition,  
*Terra Nova* – Ross Sea

1911-1914 Australasian Antarctic Expedition,  
*Aurora* – Antarctic coast south of Australia

1929-1931 British Australian & New Zealand Expedition,  
*Discovery* - Australian Antarctic Territory

1939-1941 US Antarctic Service Expedition,  
*North Star & Bear* - Palmer Pen, Stonnington Is

1940-1941 US Antarctic Service Expedition,  
*North Star & Bear* – Ross Sea

### Base stations

Cape Adare

Cape Royds

Petermann Island

Cape Evans

Cape Dennison, The Grottoes,  
Macquarie Island

East Base

Little America III



## Activities in recovering, imaging and digitising historical ship logbook & remarks books observations

- **2008:** British hydrographic and survey vessel remarks books (1834-1909) – held at the UK Hydrographic Office (inventory of holdings in the archives of the UK Hydrographic Office) about **6,000** remarks books

£400K split over two years - £200K in 2007/8 & £200K in 2008/9, from the climate research subcontract budget within the Defra/MoD funded Integrated Climate Programme

# UKHO Ships' Remarks Books

From 1759, Masters of HM Ships were required by the Admiralty to keep Remarks Books detailing coasts and ports they visited, and often observations of currents and tides.

When Francis Beaufort was in charge of the Hydrographic Office (1829-1853), he issued his Captains undertaking surveying missions with specific meteorological forms to enter their observations into.

As a result the **UKHO Archives have some 6,000 Remarks Books covering the period 1834-1909**, the bulk of which contain daily to sub-daily instrumental meteorological observations made during marine surveys all over the world.

The UKHO Archives also have some holdings which contain essentially Remarks Books with detailed daily to sub-daily instrumental meteorological observations in the early decades of the 19<sup>th</sup> Century.

# **Surface Input Reanalyses**

## **ACRE-facilitated global climate-quality reanalyses plus ISPD and ICOADS databases**

**ACRE** will support and facilitate the surface observational (terrestrial and marine) requirements for a series of climate-quality reanalyses led by NOAA and CIRES in the US:

- **20th Century Reanalysis Project: global 1892 to present** (supported in US by NOAA and DoE)
- **Early to mid-19th Century Reanalysis: global 1830s to present**
- **Mid18th-early 19th Century Reanalysis: North Atlantic-European Region 1750/1800 to present**

▪ **The observations will be held in the**

- **International Surface Pressure Data bank (ISPD)**
- **International Comprehensive Ocean-Atmosphere Data set (ICOADS).**

▪ **ACRE** coordinates closely with GCOS AOPC/OOPC WG-Surface Pressure and GCOS/WCRP WG on Observational Data Sets for Reanalyses.

▪ **The ISPD and ICOADS observations and the various reanalysis products will be made available to the international scientific community.**

# Global Historical Reanalyses Products

Each of the **ACRE**-facilitated global historical reanalyses will produce a 56\* member ensemble of some 68 3D weather variables every 6 hours at 2° latitude x 2° longitude spatial resolution over the entire globe. The ensemble mean is taken as the best analysis.

Some major 3D weather variables produced by the reanalyses

Geopotential Height

Temperature

u wind

v wind

Pressure vertical velocity

Specific humidity

Relative humidity

At 19 Levels: (1000 hPa–100 hPa every 50 hpa)

Others at specific levels (eg, sigma) or over the depth of the atmospheric column include:

Surface pressure, Tropopause height, Precipitable water, Convective Avail. Pot. Energy, Convective inhibition, Potential temp. Total ozone, Cloud water, Sensible heat flux, Latent heat flux, Volumetric soil moisture, Accum. Snow, Downward long wave flux, Upward long wave flux, Upward short wave flux, Downward short wave flux, Precipitation rate, Convective precip. Rate, Ground heat flux, Land cover, Ice concentration, Water runoff, Potential evaporation rate, Planetary boundary layer height, Albedo, Total cloud cover, Zonal momentum flux, Meridional momentum flux.

\* started in November of year before, 56 random initial conditions produced from integrations of the T62 28 sigma level model forced by SSTs

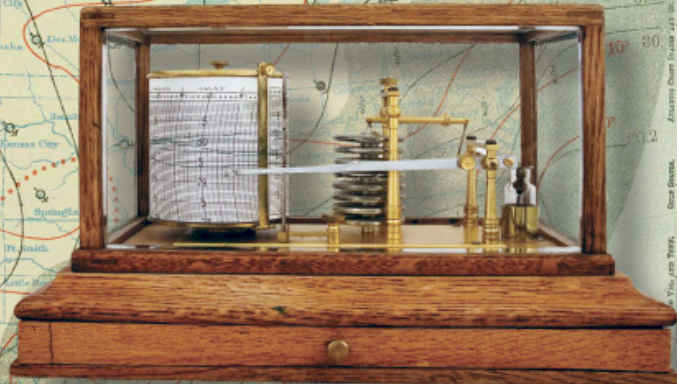
# Preliminary results from the 20<sup>th</sup> Century Reanalysis Project

Volume 87 Number 2 February 2006

# BAMS

Bulletin of the American Meteorological Society

WAVE MODELING  
SEA-BREEZE BOUNDARIES  
AIR-QUALITY FORECASTS



*Reanalysis from the bottom up*  
RECONSTRUCTING UPPER-AIR DATA FROM SURFACE PRESSURE OBSERVATIONS

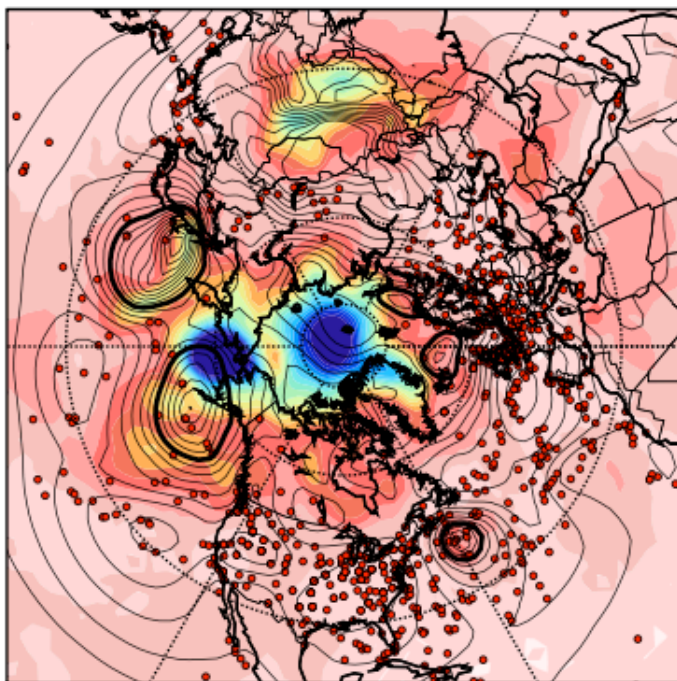
	NOAA	CHINA	INDONESIA
10	30.6	30.5	30.2
15	30.7	30.4	30.1
20	30.8	30.3	30.0
25	30.9	30.2	29.9
30	31.0	30.1	29.8
35	31.1	30.0	29.7
40	31.2	29.9	29.6
45	31.3	29.8	29.5
50	31.4	29.7	29.4
55	31.5	29.6	29.3
60	31.6	29.5	29.2
65	31.7	29.4	29.1
70	31.8	29.3	29.0
75	31.9	29.2	28.9
80	32.0	29.1	28.8
85	32.1	29.0	28.7
90	32.2	28.9	28.6
95	32.3	28.8	28.5
100	32.4	28.7	28.4



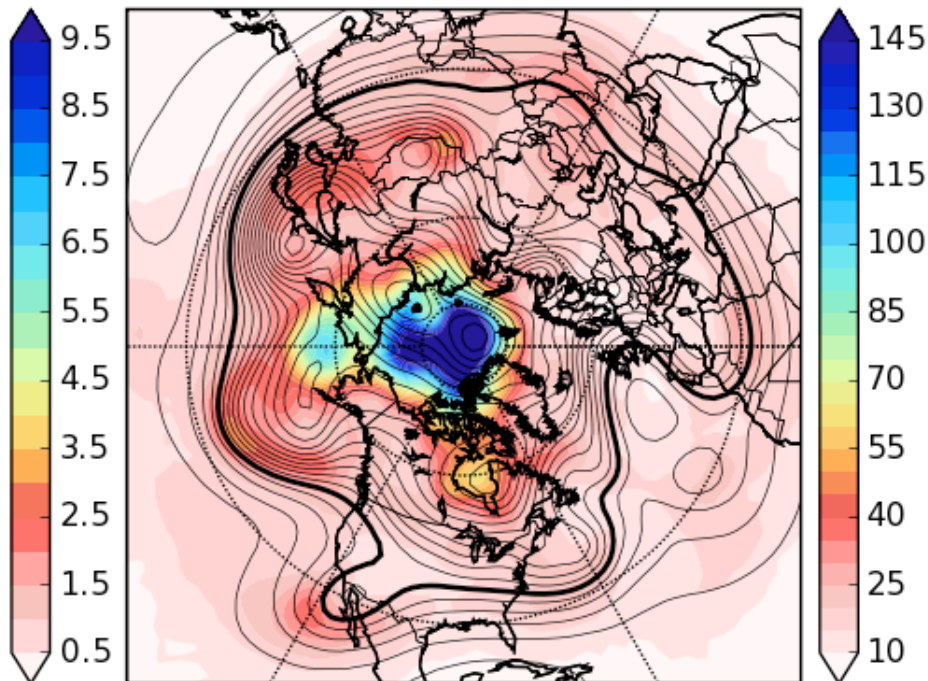
# Northern Hemisphere

1931

Ensemble Mean SLP and SLP spread (hPa) 1931011012



Ensemble Mean Z500 and Z500 spread (m) 1931011012



**MSLP**

**500 hPa GEOPOTENTIAL HEIGHT**

Contours-  
Shading-

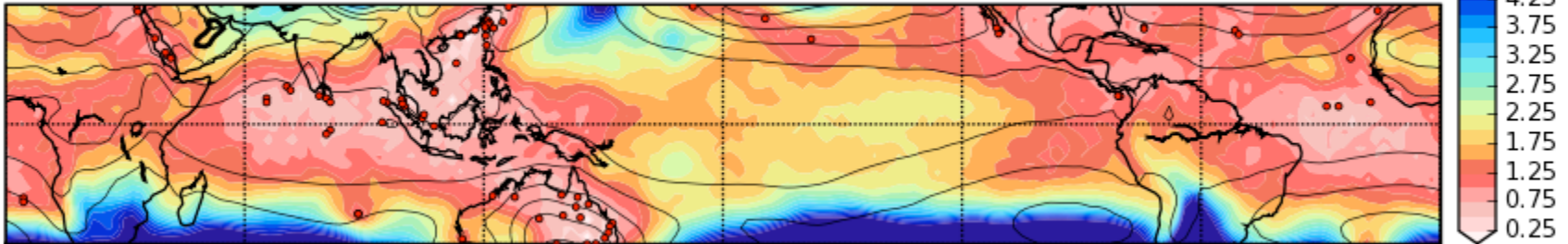
ensemble mean  
blue: more uncertain, white: more certain



# Tropics

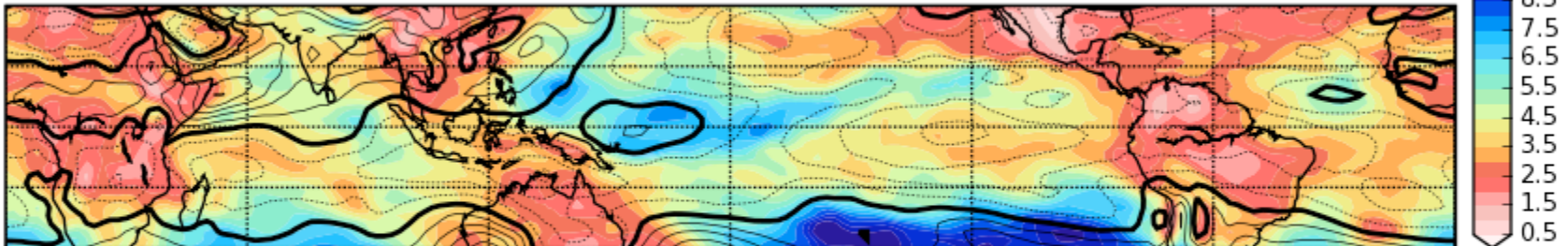
1919

Ensemble Mean SLP and SLP spread (hPa) 1919071518



**MSLP**

Ensemble Mean U850 and U850 spread (mps) 1919071518



**850 hPa Zonal Wind**

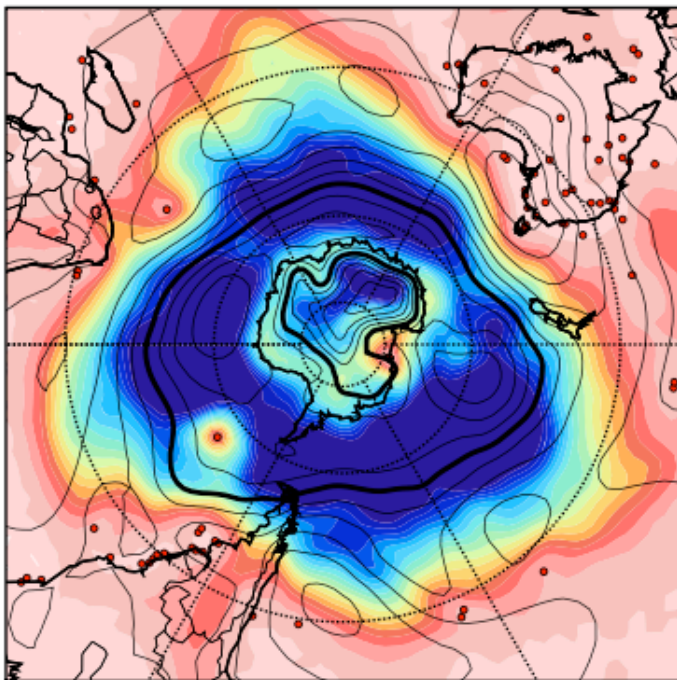
Contours-  
Shading-

ensemble mean  
blue: more uncertain, white: more certain

# Southern Hemisphere

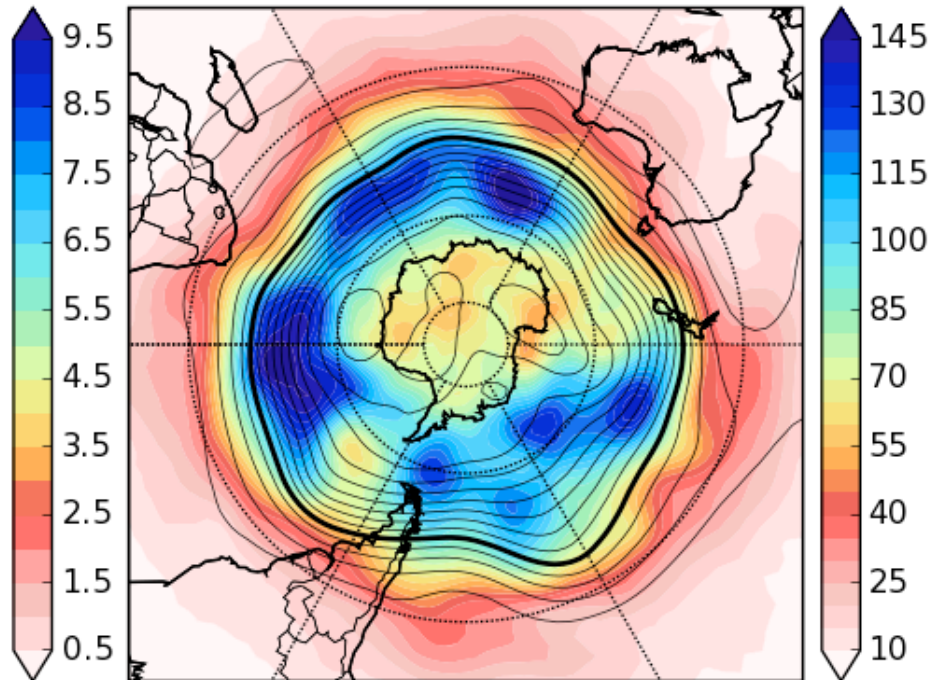
1929

Ensemble Mean SLP and SLP spread (hPa) 1929012018



**MSLP**

Ensemble Mean Z500 and Z500 spread (m) 1929012018



**500 hPa GEOPOTENTIAL HEIGHT**

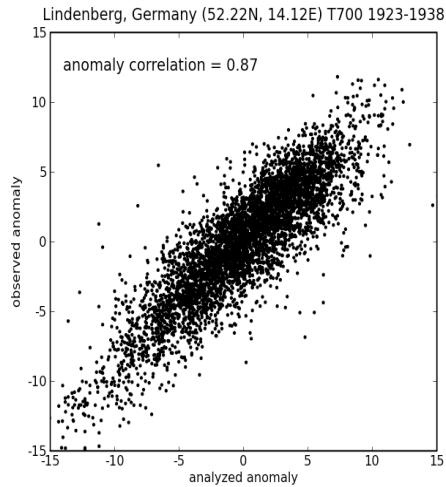
Contours-  
Shading-

ensemble mean  
blue: more uncertain, white: more certain

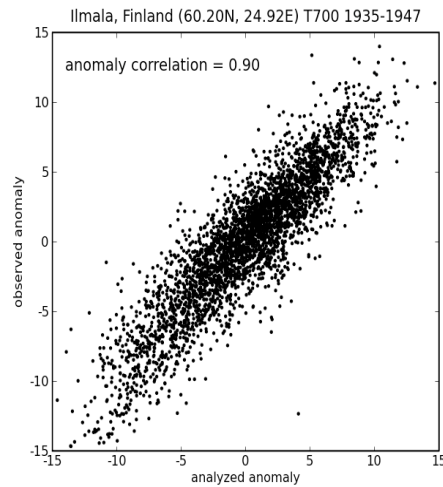
# Verifications of preliminary reanalysis products against independent radiosonde data from Europe

(courtesy of Stefan Bronniman and Andrea Grant, ETH, Switzerland)

## Temperature 700 hPa

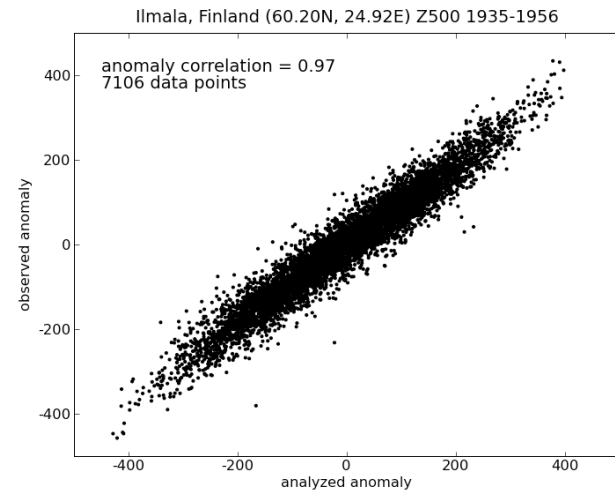


**Anom Corr = 0.87**



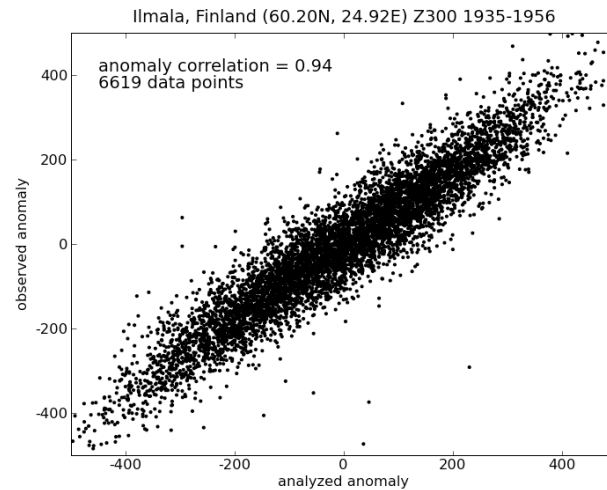
**Anom Corr = 0.90**

## Geopotential Height 500 hPa



**Anom Corr = 0.97**

## Geopotential Height 300 hPa



**Anom Corr = 0.94**

# PROJECTED/POTENTIAL TIMELINE

**2008-Spring 2009:** The 20th Century Reanalysis Project: 1892 to present

*Version 1: 1908-1958 coming soon*

*Version 2: 1892-2008 available Spring 2009*

**Mid-2009:** British East India Company (EIC) logbooks (1780s-1830s) Imaged & Digitised

**2009-2010:** Final version of HadISST2

**2010-2011:** Extended World War 1 period logbooks (1914-1923) Imaged & Digitised

**2009-2011:** Early to mid-19th Century Reanalysis  
(with DoE and NOAA support)

*Version 3: mid-19<sup>th</sup> – 21<sup>st</sup> century*

*would need all data by August 2010*

*improved version of NCEP model at higher resolution*

*=> hurricanes, high impact phenomena?*

*potentially available in 2012*

**201?:** British hydrographic and survey vessel remarks books (1834-1909)  
Imaging & Digitisation

**201?:** North Atlantic-European Region mid18th-early 19th Century Reanalysis:  
1750/1800 to present

# ACRE Project Manager

**Dr Rob Allan**

**Climate Monitoring and Attribution Group,**

**Met Office Hadley Centre**

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**International phone: +44 1392 886552**

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