TASK TEAM FOR THE INTERCOMPARISON OF REANALYSES (TIRA)

Michael Bosilovich

(drawing on input from the TIRA telecons)

Main Objectives of TIRA

- The primary charge to the TIRA is to develop a reanalysis intercomparison project plan that will attain the following objectives.
  1) To foster understanding and estimation of uncertainties in reanalysis data by intercomparison and other means
  2) To communicate new developments and best practices among the reanalyses producing centers
  3) To enhance the understanding of data and assimilation issues and their impact on uncertainties, leading to improved reanalyses for climate assessment
  4) To communicate the strengths and weaknesses of reanalyses, their fitness for purpose, and best practices in the use of reanalysis datasets by the scientific community

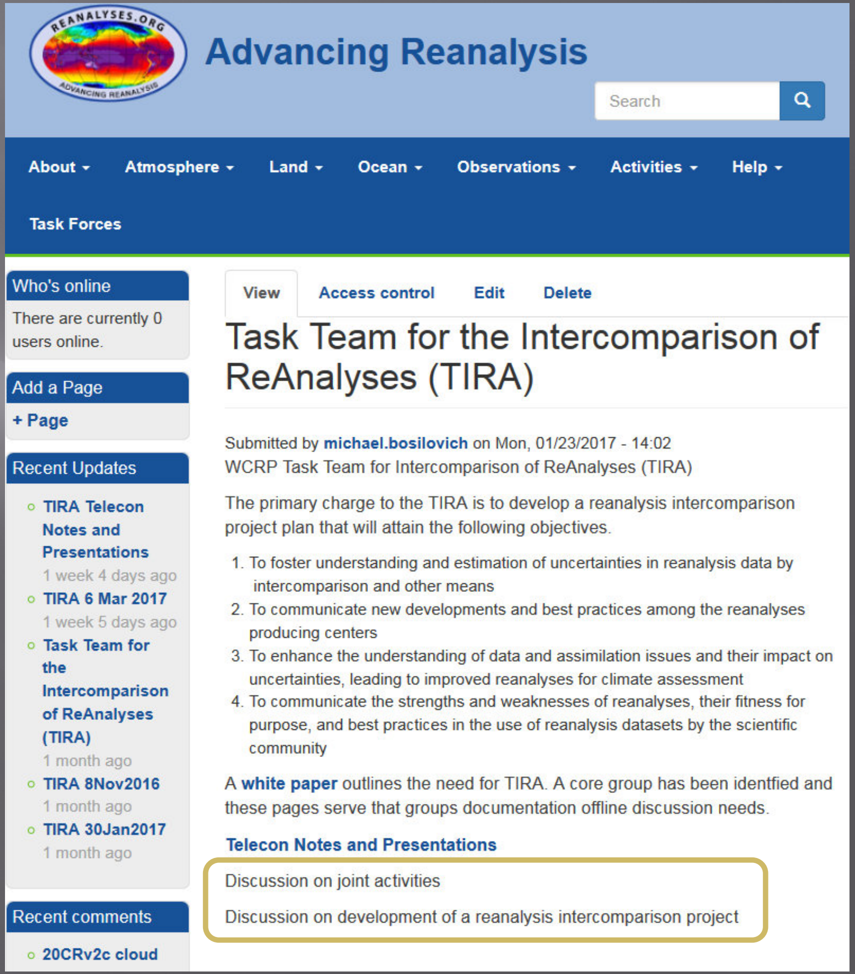
Task Team Members

- Magdelena Balmaseda (ECMWF/CLIVAR)
- Michael Bosilovich (NASA/GMAO/USA Co-Chair*)
- Gil Compo (CIRES/WRIT/USA)
- Chris Derksen (ECCC/CliC/Canada)
- Masatomo Fujiwara (JMA/SPARC/Japan/S-RIP)
- Hans Hersbach (ECMWF)
- Shinya Kobayashi (JMA)
- Suranjana Saha (NOAA/EMC/USA)
- Chenghu Sun (CMA/NMIC)
- Gerald Potter (NASA/CREATE/USA)
- Otis Brown (NCSU/USA/WDAC)
- Michel Rixen (WCRP)

*Looking for a co-chair

Telecons

- 8 Nov 16
  - Introductions/Status
  - Mission
- 21 Dec 2017
  - Intro cont.
  - AGU and ICR5
- 30 Jan 2017
  - Intercomparison Tools (WRIT/CREATE)
  - Reanalysis.org
- 6 Mar 2017
  - S-RIP and Ocean Reanalysis Workshop Reviews


REANALYSES.ORG ADVANCING REANALYSIS

Advancing Reanalysis

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Task Forces

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Task Team for the Intercomparison of ReAnalyses (TIRA)

Submitted by michael.bosilovich on Mon, 01/23/2017 - 14:02

WCRP Task Team for Intercomparison of ReAnalyses (TIRA)

The primary charge to the TIRA is to develop a reanalysis intercomparison project plan that will attain the following objectives.

1. To foster understanding and estimation of uncertainties in reanalysis data by intercomparison and other means
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4. To communicate the strengths and weaknesses of reanalyses, their fitness for purpose, and best practices in the use of reanalysis datasets by the scientific community

A white paper outlines the need for TIRA. A core group has been identfied and these pages serve that groups documentation offline discussion needs.

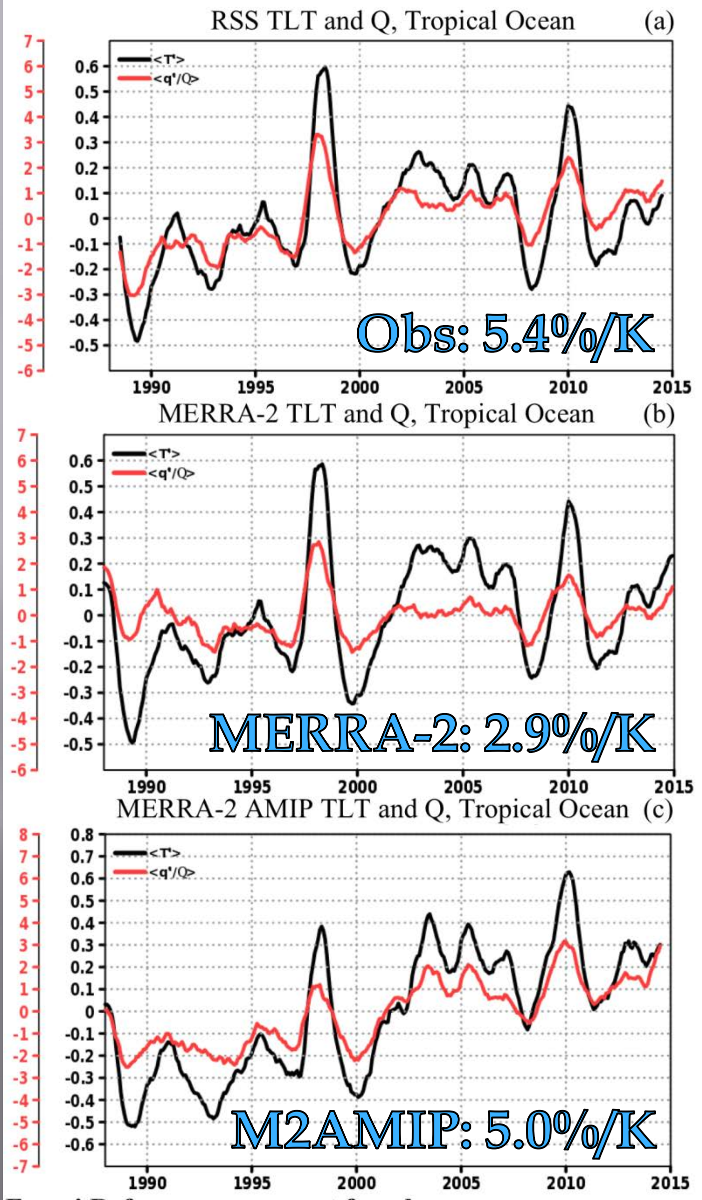
Telecon Notes and Presentations

Discussion on joint activities

Discussion on development of a reanalysis intercomparison project

Joint Activities

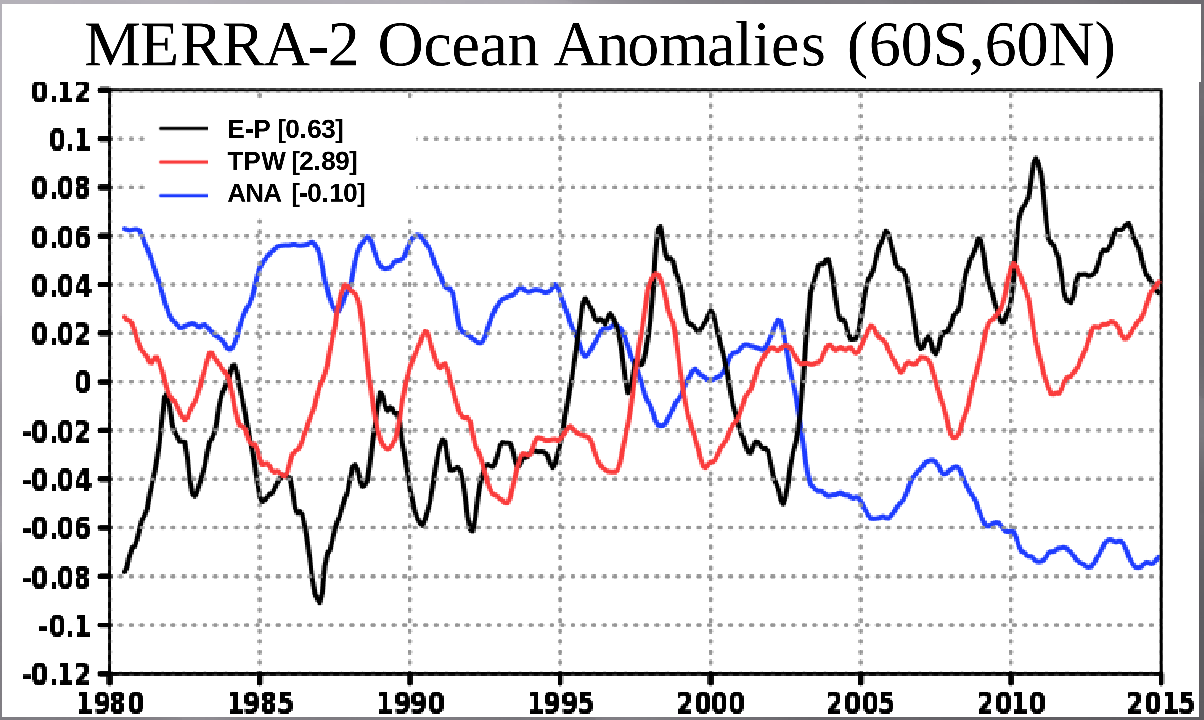
- Concept: Common issues can be present in more than one reanalysis, or new methods make help produce improved analysis
- Action: Determine which centers can participate. Develop an experimental plan including case studies and/or additional diagnostic output
- Cost: Developing centers incur computing and time to evaluate the experiments
- Benefit: Should provide more understanding of the reanalysis method than could be accomplished alone



Example: Clausius-Clapyeron

- Using TLT and TPW, MERRA-2 shows a weaker C-C relationship compared to RSS obs and AMIP simulation
- Analysis increment counters some local evaporative increases
- Other reanalyses also show a weak C-C relationship
- Bosilovich et al. (2016, JClim); Schröder et al. (2016, JAMC)

Ocean Anomalies: TPW, Evaporation and Analysis Increment



- TPW does respond to SST (e.g. apparent ENSO signal)
- E-P is increasing over the period, generally in response to SST, but also varies according to wind.
- Increment is always negative, and decreases in time – countering a model wet bias
- In MERRA-2, it appears the Analysis is damping C-C

Extension to Other Systems using T850 as a Proxy

System	T	Q	dT/dt	dQ/dt	%/K Detrend	%/K Trend	%/K S(Q)/S(T)	Corr(T,Q)
OBS	TLT	TPW	0.10	1.03	4.6	5.4	6.2	0.90
MERRA2	TLT	TPW	0.11	0.15	3.2	2.9	3.7	0.78
M2AMIP	TLT	TPW	0.28	1.53	4.5	5.0	7.1	0.97
MERRA2	T850	TPW	0.20	0.15	4.0	2.3	5.3	0.63
M2AMIP	T850	TPW	0.24	1.53	6.0	6.2	3.7	0.97
ERAI	T850	TPW	0.05	0.23	4.3	4.3	10.9	0.58
JRA55	T850	TPW	0.12	0.30	4.7	4.0	6.4	0.71
20CR	T850	TPW	0.13	0.84	6.8	6.7	6.4	0.95
ERA20C	T850	TPW	0.27	1.42	7.1	5.9	7.2	0.94
ERA20CM	T850	TPW	0.22	1.38	7.0	6.5	5.7	0.98

- Trends are K/dec and %/decade; MERRA and CFSR withheld

Next Steps

- Need further variables to test reanalyses (TLT, ANA) more completely
  - If not a result of analysis increment in other reanalyses, then what holds back the C-C relationship?
- Test satellite reanalyses removing water vapor assimilation (likely too expensive for most or all centers to consider)

Developing a Reanalysis Intercomparison Project

- Perhaps more of a coordinating body, than an actual project
- Could have membership that includes the disciplinary projects as well as developing centers
- Maintain and promote best practices and promotes communication of results
- Still needs discussion

Collaborative REAnalysis Technical Environment (CREATE)

- CREATE provides easy access to seven atmosphere reanalysis datasets
- Eight selected ocean reanalysis datasets, ensemble average and spread
- Distributed through the CREATE project space on the Earth System Grid Federation (ESGF) and the CREATE-V web interface
  - Also includes access to Obs4MIPs and CMIP/AMIP integrations
- This collection of data, services, and science collaborations will support future work in reanalysis intercomparison and interdisciplinary science.

7 Atmospheric Reanalyses

Atmosphere Reanalysis
NASA MERRA
NASA MERRA-2
ECMWF ERA-Interim
NOAA/NCEP CFSR
NOAA/ESRL 20CRv2c
JMA JRA-25
JMA JRA-55

6-hour variables

6-Hourly Variables
Total Cloud Fraction
Evaporation
Relative Humidity
Specific Humidity
Precipitation
Precipitable Water
Surface Pressure
Sea Level Pressure
Air Temperature
Surface Air Temperature
Ozone Mole Fraction
Eastward Wind
Near Surface Eastward Wind
Northward Wind
Near Surface Northward Wind
Geopotential Height

Variables published in CREATE on ESGF. Corresponding to CMIP5 format (CF compliant netCDF)

Variable (CF long name)	Reanalysis
Air Temperature	20CRv2c, CFSR, ERA-interim, MERRA, MERRA2, JMA-25, JMA-55
Condensed Water Path	ERA-interim
Air Pressure at Convective Cloud Base	CFSR
Air Pressure at Convective Cloud Top	CFSR
Condensed Water Path	ERA-interim
Convective Precipitation	ERA-Interim
Eastward Near-Surface Wind	20CRv2c, CFSR, ERA-interim, MERRA, MERRA2, JMA-25, JMA-55
Daily Maximum Near-Surface Air Temperature	20CRv2c, CFSR, JRA-25, MERRA2
Daily Minimum near-Surface Air Temperature	20CRv2c, CFSR, JRA-25, MERRA2
Downward Heat Flux at Sea Water Surface	CFSR
Eastward Near-Surface Wind	20CRv2c, CFSR, ERA-interim, MERRA, MERRA2, JMA-25, JMA-55
Eastward Wind	20CRv2c, CFSR, ERA-interim, MERRA, MERRA2, JMA-25, JMA-55
Evaporation	20CRv2c, CFSR, ERA-interim, MERRA, MERRA2, JMA-25, JMA-55
Evaporation from Canopy	CFSR
Geopotential Height	20CRv2c, CFSR, ERA-interim, MERRA, MERRA2, JMA-25, JMA-55
Ice Water Path	ERA-interim
Liquid water Content of Snow Layer	20CRv2c
Mole Fraction of Ozone	20CRv2c, CFSR, ERA-interim, MERRA, MERRA2, JMA-25, JMA-55
Moisture in Upper Portion of Soil Column	CFSR
Near-Surface Air Temperature	20CRv2c, CFSR, ERA-interim, MERRA, MERRA2, JMA-25, JMA-55
Near-Surface Relative Humidity	CFSR, JRA-25
Near-Surface Specific Humidity	20CRv2c, CFSR, MERRA2, JRA-25
Near-Surface Wind Speed	20CRv2c, CFSR, ERA-interim, MERRA, MERRA2, JMA-25, JMA-55
Northward Near-Surface Wind	20CRv2c, CFSR, ERA-interim, MERRA, MERRA2, JMA-25, JMA-55
Northward Wind	20CRv2c, CFSR, ERA-interim, MERRA, MERRA2, JMA-25, JMA-55
Precipitation	20CRv2c, CFSR, ERA-interim, MERRA, MERRA2, JMA-25, JMA-55
Relative Humidity	20CRv2c, CFSR, ERA-interim, MERRA, MERRA2, JMA-25, JMA-55
Sea Ice Thickness	20CRv2c, CFSR
Sea Ice Area Fraction	20CRv2c, CFSR
Sea Level Pressure	20CRv2c, CFSR, ERA-interim, MERRA, MERRA2, JMA-25, JMA-55
Sea Surface Height Above Geoid	CFSR
Sea Surface Temperature	CFSR
Snow Area Fraction	20CRv2c, CFSR
Snow Depth (on ice)	CFSR
Snow Depth (on land)	20CRv2c, CFSR
Snowfall Flux	ERA-interim

Specific Humidity	20CRv2c, CFSR, ERA-interim, MERRA, MERRA2, JMA-25, JMA-55
Surface Air Pressure	20CRv2c, CFSR, ERA-interim, MERRA, MERRA2, JMA-25, JMA-55
Surface Downward Eastward Wind Stress	20CRv2c, CFSR, ERA-interim, MERRA, MERRA2
Surface Downward Northward Wind Stress	20CRv2c, CFSR, ERA-interim, MERRA, MERRA2
Surface Downwelling Longwave Radiation	20CRv2c, CFSR, ERA-interim, MERRA, MERRA2, JMA-25, JMA-55
Surface Downwelling Clear-Sky Longwave Radiation	20CRv2c, CFSR, MERRA, MERRA2, JMA-25, JMA-55
Surface Downwelling Shortwave Radiation	20CRv2c, CFSR, ERA-interim, MERRA, MERRA2, JMA-25, JMA-55
Surface Runoff	CFSR
Surface Snow Amount	CFSR
Surface Snow and Ice Sublimation Flux	CFSR
Surface Temperature	20CRv2c, CFSR, ERA-interim, MERRA, MERRA2
Surface Upward Latent Heat Flux	20CRv2c, CFSR, ERA-interim, MERRA, MERRA2
Surface Upward Sensible Heat Flux	20CRv2c, CFSR, ERA-interim, MERRA, MERRA2, JMA-25
Surface Upwelling Longwave Radiation	20CRv2c, CFSR, ERA-interim, MERRA, MERRA2, JMA-25, JMA-55
Surface Upwelling Shortwave Radiation	20CRv2c, CFSR, ERA-interim, MERRA2, JMA-25, JMA-55
Surface Upwelling Clear-Sky Shortwave Radiation	CFSR, MERRA2, JMA-25, JMA-55
Temperature of Soil	CFSR
TOA Incident Shortwave Radiation	CFSR, ERA-interim, MERRA, MERRA2, JMA-25, JMA-55
TOA Outgoing Clear-Sky Longwave Radiation	CFSR, ERA-interim, MERRA, MERRA2, JMA-25, JMA-55
TOA Outgoing Clear-Sky Shortwave Radiation	CFSR, ERA-interim, MERRA, MERRA2, JMA-25, JMA-55
TOA Outgoing Longwave Radiation	20CRv2c, CFSR, ERA-interim, MERRA, MERRA2, JMA-25, JMA-55
TOA Outgoing Shortwave Radiation	20CRv2c, CFSR, ERA-interim, MERRA, MERRA2, JMA-25, JMA-55
Total Runoff	CFSR
Total Soil Moisture Content	CFSR
Total Cloud Fraction	20CRv2c, CFSR, ERA-interim, MERRA, MERRA2, JMA-25, JMA-55
Transpiration	CFSR
Water Content of Soil Layer	CFSR
Water Evaporation from Soil	CFSR
Water Vapor Path	20CRv2c, CFSR, ERA-interim, MERRA, MERRA2, JMA-25, JMA-55
omega (=dp/dt)	20CRv2c, CFSR, ERA-interim, MERRA, MERRA2

8 Ocean Reanalyses

Ocean Reanalysis
NOAA/NCEP CFSR
CMCC C-GLORSv5
NOAA/GFDL ECDAv31
Uni-Hamburg GECCO2
NOAA/NCEP GODAS
MOVE MRI.COM-G2i
ECMWF ORAS4
ECMWF ORAP5
ORA Ensemble

The NCCS has published monthly data from eight major ocean reanalysis projects (see table on left) from 1980 to 2010. Four state variables were processed:

- Potential Temperature
- Salinity
- U Velocity
- V Velocity

In addition to the native gridded data, the eight reanalyses were horizontally regridded and vertically interpolated to a common grid, and an ensemble and ensemble spread was generated.*

* at the request of the CLIVAR Global Synthesis and Observations Panel (GSOP)

Web-based Reanalysis Intercomparison Tools (WRIT)

Gilbert P. Compo, Catherine A. Smith, Don K. Hooper
CIRES/Univ. of Colorado at Boulder
PSD/Earth System Research Laboratory/NOAA

IN BOX
INSIGHTS and INNOVATIONS

Web-Based Reanalysis Intercomparison Tools (WRIT) for Analysis and Comparison of Reanalyses and Other Datasets

BY CATHERINE A. SMITH, GILBERT P. COMPO, AND DON K. HOOPER

MOTIVATION. Reanalysis (or retrospective analysis) is a scientific technique whereby observations taken over a long time period are combined objectively with a model forecast to form time series of fields representing the state of the system, "analyses." listing), with more becoming available soon. These reanalysis datasets have been used in an enormous number of studies, with more than 19,900 peer-reviewed publications relating to reanalysis available as of November 2013.

dx.doi.org/10.1175/BAMS-D-13-00192.1

https://reanalyses.org/atmosphere/writ

Web-based Reanalysis Intercomparison Tools (WRIT)

Submitted by Cathy.Smith@noaa.gov on Tue, 01/17/2012 - 14:11

Web-based Reanalysis Intercomparison Tools (WRIT) BAMS article:
http://journals.ametsoc.org/doi/abs/10.1175/BAMS-D-13-00192.1

A set of **web-based reanalysis intercomparison tools** (WRIT) is available from the NOAA ESRL **Physical Sciences Division** and University of Colorado **CIRES**.

WRIT Maps | WRIT Timeseries | WRIT Trajectories

The "WRIT" Maps tool allows users to examine **20CR**, **ERA-Interim**, **ERA-20C**, **JRA-55**, **MERRA**, **MERRA-2**, **NCEP R1**, **NCEP R2**, and **NCEP CFSR** reanalyses datasets. Pressure level data are available for most reanalyses, as well as 5 single level variables including sea level pressure, 2 m air temperature, 10 m winds, precipitation. Maps and pressure-level by longitude and pressure-level by latitude can be generated for monthly means, anomalies, and climatologies. Observational datasets have been made available that can be compared to 2m air temperature and precipitation. These quantities can be differenced between datasets.

Future enhancements include different time scales.

The "WRIT" Timeseries and correlation tool is also available from **WRIT**. It allows users to examine **20CR**, **ERA-Interim**, **ERA-20C**, **JRA-55**, **MERRA**, **MERRA-2**, **NCEP R1**, **NCEP R2**, and **NCEP-CFSR** as well as some observational dataset. Users can compare timeseries from different datasets, regions, variables and levels. Distributions, scatter plots, and auto-correlation are also available. Statistics for each timeseries including means, standaed deviations, slope and correlations are provided.

The "WRIT" Trajectory Tool is a new tool available from **WRIT**. It allows users to plot forward and backward trajectories from different reanalyses (currently **NCEP R1**, **NCEP R2**, and **20CR** with more planned). Users can plot the trajectories of one or more levels on a single plot. The output is plotted and is available as netCDF and as KMZ files suitable for Google Earth.

Web-based Reanalysis Intercomparison Tools allows a quick look comparison of many variables in user-selected regions

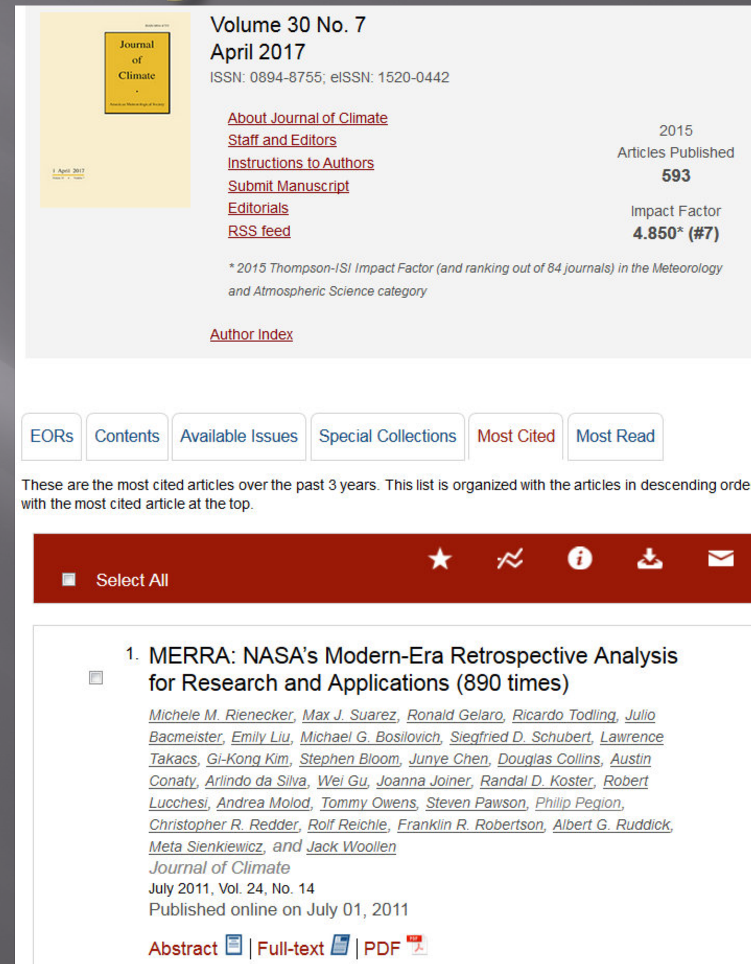
1. **Maps Tool**: Maps, Cross-Sections in Height by Latitude or Height by Longitude for pre-selected or user-defined map regions.
   a. Cylindrical equidistant
   b. Polar Stereographic
   c. Satellite-view – coming soon
2. **Time series Tool**: Time series averaged over all regions, Land, Ocean
3. **Trajectories**: NCEP-NCAR, NCEP-DOE, 20CRv2, 20CRv2c reanalyses only
4. Automatically regrids in vertical and horizontal for map and cross-section differences

Atmospheric Reanalysis Plans

- Subset from Shinya Kobayashi's report to AOPC
  - NASA GMAO
  - JMA
  - ERA
  - NCEP

NASA Reanalyses

- MERRA was discontinued in Feb 2016, but is still the most cited J. Clim paper over the last 3 years
- MERRA-2 Special Collection is being developed. The overview paper is reviewed and should be accepted soon
- Planning the next reanalysis is proceeding. More coupling to land and ocean. No firm timetable set



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Impact Factor
4.850* (#7)

** 2015 Thompson-ISI Impact Factor (and ranking out of 84 journals) in the Meteorology and Atmospheric Science category*

Author Index

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These are the most cited articles over the past 3 years. This list is organized with the articles in descending order with the most cited article at the top.

Select All

1. MERRA: NASA's Modern-Era Retrospective Analysis for Research and Applications (890 times)

Michele M. Rienecker, Max J. Suarez, Ronald Gelaro, Ricardo Todling, Julio Bacmeister, Emily Liu, Michael G. Bosilovich, Siegfried D. Schubert, Lawrence Takacs, Gi-Kong Kim, Stephen Bloom, Junye Chen, Douglas Collins, Austin Conaty, Arlindo da Silva, Wei Gu, Joanna Joiner, Randal D. Koster, Robert Lucchesi, Andrea Molod, Tommy Owens, Steven Pawson, Philip Pegion, Christopher R. Redder, Rolf Reichle, Franklin R. Robertson, Albert G. Ruddick, Meta Sienkiewicz, and Jack Woollen

Journal of Climate
July 2011, Vol. 24, No. 14
Published online on July 01, 2011

Abstract | Full-text | PDF

MERRA-2 Current and Near-Future Products

Data available from the NASA Goddard Earth Sciences (GES) Data Information Services Center (DISC)

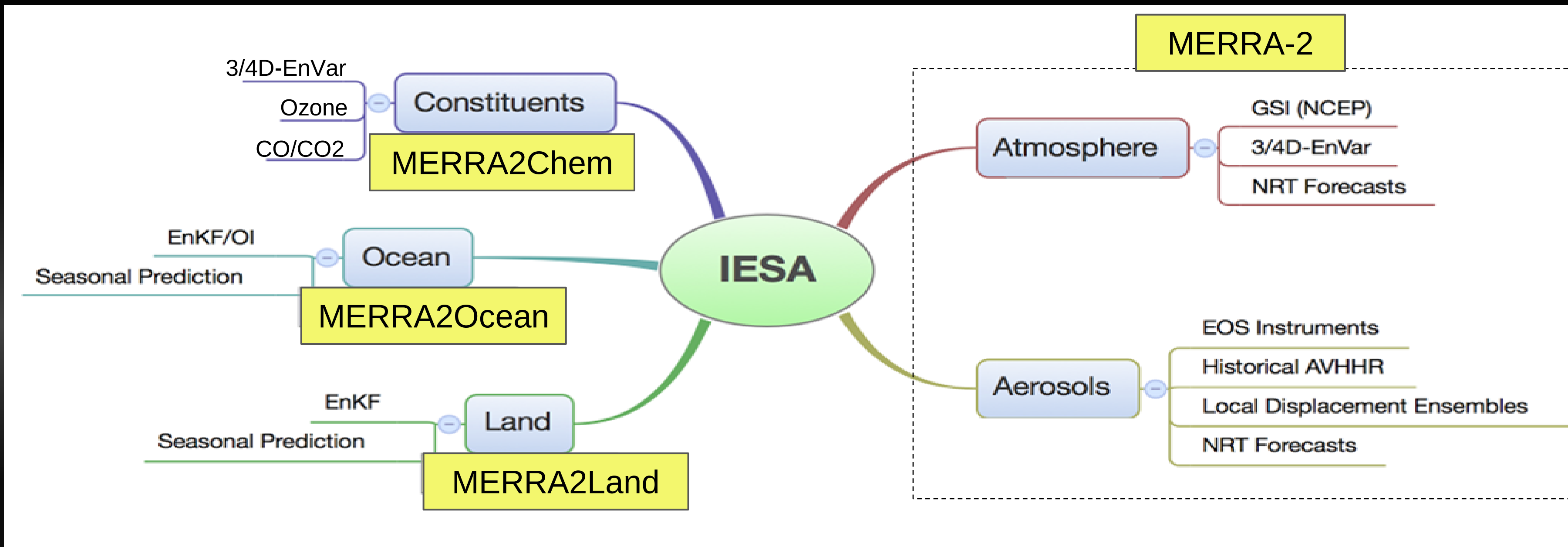
- 1-hourly surface/2D fields (COSP MODIS/ISCCP), 3- and 6-hourly 3D fields
- Daily Products ~25 GB/day (9.1 TB/yr)
- Monthly Products ~34 GB/mo (408 GB/yr)

Gridded Innovations and Observations (6 hourly conventional - monthly radiances O-F, O-A and BC, still under a QC review and documentation)

Ensemble of 10 AMIP integrations using MERRA-2 model configuration

MERRA-2-driven analyses of ocean state (physics and biogeochemistry), atmospheric chemistry (EOS period), and carbon cycle (~Summer 2017)

Toward NASA's Integrated Earth System Analysis

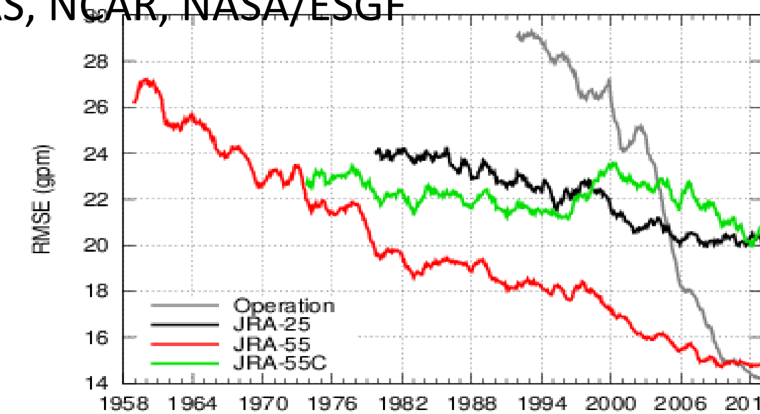


Coupled and MERRA2-driven component

reanalyses

JRA-55 family

- To facilitate investigations on the credibility of trends and low-frequency variability represented in JRA-55, different types of product have been produced with the common NWP system.
- JRA-55 (JMA)
  - Full observing system reanalysis
  - Available from JMA (http://jra.kishou.go.jp), DIAS, NCAR, NASA/ESGF
  - S. Kobayashi et al. (2015), Harada et al. (2016)
- JRA-55C (MRI/JMA)
  - Using conventional observations only
  - Available from DIAS, NCAR
  - C. Kobayashi et al. (2014)
- JRA-55AMIP (MRI/JMA)
  - AMIP type run
  - Available from DIAS, NCAR



RMS errors of 2-day forecasts of geopotential height (gpm) at 500hPa averaged over the northern hemisphere

Adapted and updated from C. Kobayashi (2014)

The next Japanese reanalysis

- **JRA-3Q** (pronounced as “Thank you!” in Japanese)
  - Japanese Reanalysis for Three Quarters of a Century
- Provisional specifications
  - Higher resolution: T_L319L60 -> T_L479L100
    - 40 km in horizontal, 100 layers up to 0.01 hPa in vertical
  - Extending the reanalysis period back in time
    - Atmospheric reanalysis from 1948 (planned) to present
  - New boundary conditions and forcing fields
    - COBE-SST2 (from the beginning to 1981)
    - MGDSST (satellite-based SST from 1982 onward)
  - New observations
    - Observations newly rescued and digitised by ERA-CLIM et al.
    - Improved satellite observations through reprocessing
    - JMA’s own tropical cyclone bogus

Data assimilation system

	JRA-55	JRA-3Q
Base system	JMA's operational system as of December 2009	JMA's operational system as of 2018 (planned)
Horizontal resolution	T_L319 (~55 km)	T_L479 (~40 km)
Vertical levels	60 levels up to 0.1 hPa	100 levels up to 0.01 hPa
Analysis scheme	4D-Var (with the T106 inner resolution)	4D-Var (with the T_L319 inner resolution)
Radiative transfer model for satellite radiances	RTTOV-9.3	RTTOV-10.2 (used in the current system) • Improved accuracy • Inclusion of the Zeeman effect • Inclusion of GHGs variations
GNSS-RO	Refractivity (up to 30 km)	Bending angle (up to 60 km)

Reanalyses Produced at ECMWF

New!

Atmosphere/land *including ocean waves*

- 1) 1979 - 1981 FGGE
- 2) 1994 - 1996 ERA-15
- **3) 2001** - 2003 ERA-40
- 4) 2006 - … ERA-Interim
- 5) 2016 - … ERA5

Ocean *including sea ice*

- 2006 ORAS3
- 2010 - … ORAS4
- 2016 - … ORAS5

Centennial

New!

- 2013 - 2015 ERA-20CM/20C
- 2016 CERA-20C

Enhanced land

- 2012 ERA-Int/Land
- 2014 ERA-20C/Land
- **2017 - …** ERA5L

Atmospheric composition

- 2008 - 2009 GEMS
- 2010 - 2011 MACC
- 2017 - … CAMS

Towards a coupled earth system

LAND	ATMOSPHERE	COMPOSITION
OCEAN	WAVE	ICE

What is new in ERA5?

	ERA-Interim	ERA5
Period	1979 - present	Initially 1979 – present, later addition 1950-1978
Start of production	August 2006	2016, 1979-NRT early 2018
Assimilation system	2006, 4D-Var	2016 ECMWF model cycle, 4D-Var
Model input (radiation and surface)	As in operations, *(inconsistent sea surface temperature)*	***Appropriate for climate***, e.g., evolution greenhouse gases, volcanic eruptions, sea surface temperature and sea ice
Spatial resolution	79 km globally 60 levels to 10 Pa	***31 km globally*** 137 levels to 1 Pa
Uncertainty estimate		Based on a 10-member ***4D-Var ensemble*** at 62 km
Land Component	79km	9km
Output frequency	6-hourly Analysis fields	***Hourly*** (three-hourly for the ensemble), ***Extended list of parameters ~ 5 Peta Byte***
Extra Observations	Mostly ERA-40, GTS	Various ***reprocessed CDRs***, ***latest instruments***
Variational Bias correction	Satellite radiances	Also ozone, aircraft, surface pressure

ERA5 Public Release Plan and future reanalyses

Recently a two-months ***test data set*** was made available

- Full resolution, 31km, hourly and 62km-ensemble 3-hourly
- Jan-Feb 2016
- https://climate.copernicus.eu/climate-reanalysis

Q2 2017: public release 2010 – 2016

- Includes observation feedback

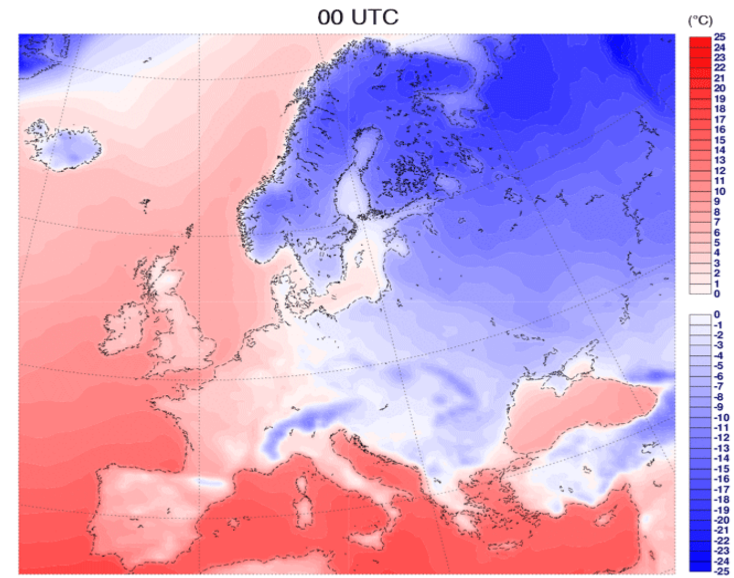
Q3 2017: 2016 – timely updates

- ERA5: Updates with about 2-months delay (final product)
- ERA5T: Updates with short delay (<1 week, preliminary product)

Begin 2018: Release 1979 – 2009:

- Continue ERA5 timely updates
- Continue ERA-Interim for another 6 months

2018: integration of ERA5 back-extension to 1950



CERA-SAT: A few-year long coupled CERA system at the ERA5 EDA resolution is currently being produced as a first step towards the preparation of **ERA6**

C3S is evaluating tendered proposals for European and Arctic Regional Reanalysis

Status of the CFSR and current CFSv2 operational suite

- The CFS version 2 was developed at the Environmental Modeling Center at NCEP. It is a fully coupled model representing the interaction between the Earth's atmosphere, oceans, land and seaice. It became operational at NCEP in March 2011.
- It also includes a real time weakly coupled data assimilation component which became an extension of the CFS Reanalysis at a higher atmospheric resolution of 28 Km (T574) and a real time coupled forecast model component that generates forecasts that are an extension of the retrospective forecasts generated by the same model.
- There are a total of 16 CFSv2 forecasts every day in real time, of which 4 runs go out to 9 months (required to calibrate the operational Climate Prediction Center (CPC) longer-term seasonal predictions of ENSO, etc.), 3 runs go out to 1 season (required to calibrate the operational CPC first season predictions for hydrological forecasts of precipitation, evaporation, runoff, streamflow, etc.) and 9 runs go out to 45 days (required for the operational CPC week3-week6 predictions of tropical circulations, such as MJO, PNA, etc.).
- All these forecasts are initiated from the CFSv2 real-time data assimilation system (CFSR-extension).
- The CFSv2 is primarily used to produce operational intra-seasonal to interannual forecasts of SST, surface temperature, and precipitation. These forecasts inform the operational prediction products at CPC.
- The skill of CFSv2 monthly and seasonal forecasts is competitive with similar models from other forecast centers and there is continuing development of its participation in real-time Multi-Model Ensemble (MME) forecast systems such as the North American MME (NMME) and the International MME (IMME) in order to inform seasonal prediction efforts at the CPC.

NCEP Unified Global Coupled System (UGCS) for Weather and Climate Prediction

- UGCS will include fully coupled components of the Earth system, namely Atmosphere, Land, Ocean, Sea-Ice, Waves and Aerosol, both for data assimilation and model forecasts.
- Use NEMS/ESMF software
- ***Atmosphere*** will comprise of a new FV3 dynamic core from GFDL, new physics, higher resolution in the horizontal and vertical, accompanied by an advanced 4D EnVAR data assimilation system
- ***Ocean*** component will be MOM6 and HYCOM model systems with updated physics and bio-geochemistry and an ensemble based coupled data assimilation system
- ***Land*** component will be the Noah Land model with upgrades to land surface physics and an upgraded ensemble based Land Information System that assimilates new data sources
- ***Sea-Ice*** component will be CICE5 and SIS2 model systems with an ensemble based coupled sea-ice data assimilation system for seaice cover and thickness
- ***Wave*** component will be Wavewatch III which will be fully coupled to the atmosphere and ocean, with a new ensemble based coupled data assimilation for assimilating significant wave height observations, etc.
- ***Aerosol*** component will be GOCART and will also have a ensemble based coupled data assimilation to incorporate AOD and other sources of data.
- Will unify the GFS, GEFS and CFS models under a single unified modeling system for:

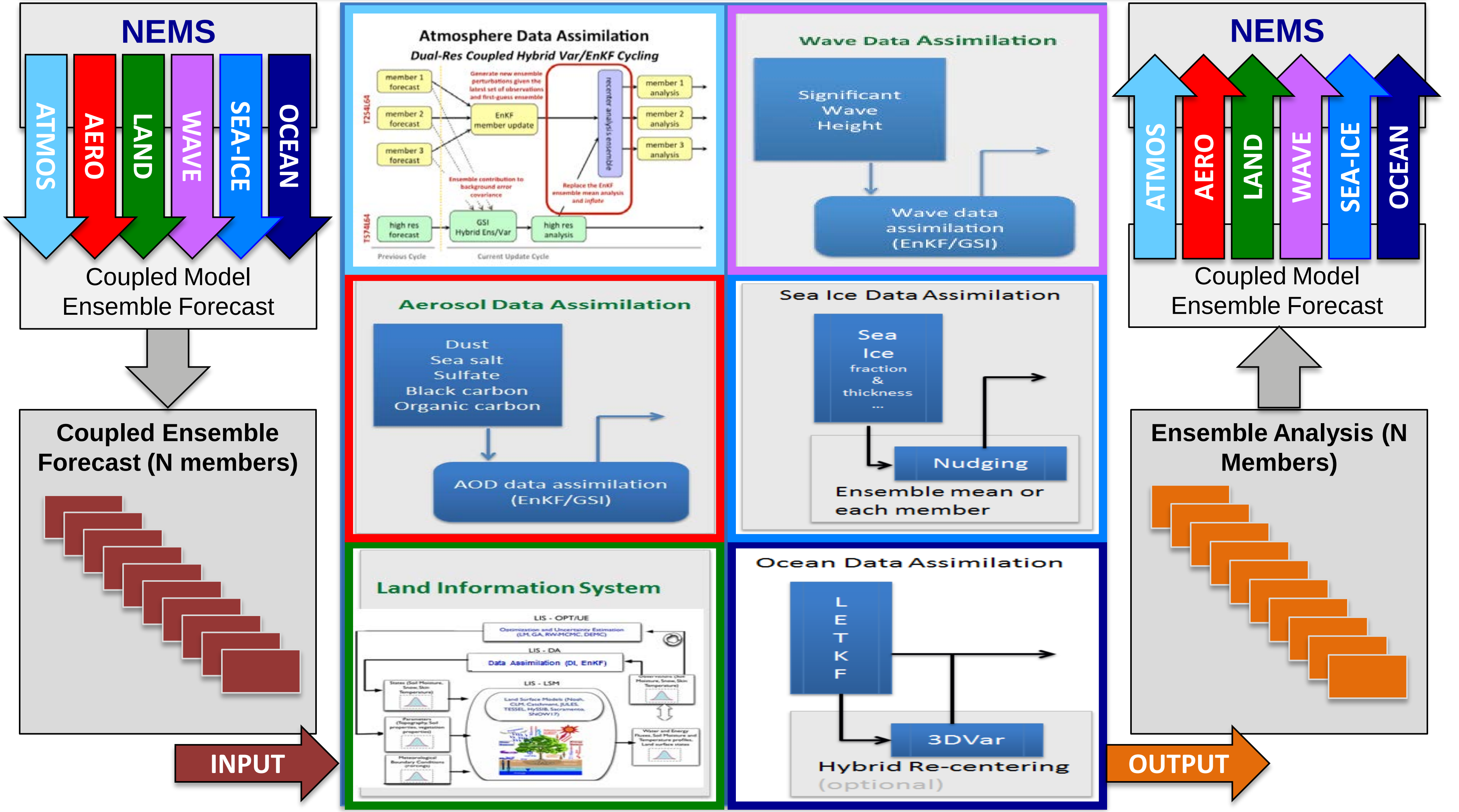
  Weather (GFS): ~10 days, 10 km, 128 levels, previous 3 year Reanalysis & hindcasts, implement every year

  Sub-seasonal (GEFS): ~45 days, 30km, 128 levels, 20+ year Reanalysis & hindcasts (1999-present), implement every 2 years

  Seasonal (CFS): ~12 months, 50km, 128 levels, 40+ year Reanalysis & hindcasts (1979-present), implement every 4years.

NCEP Coupled Hybrid Data Assimilation and Forecast System

Saha et al.

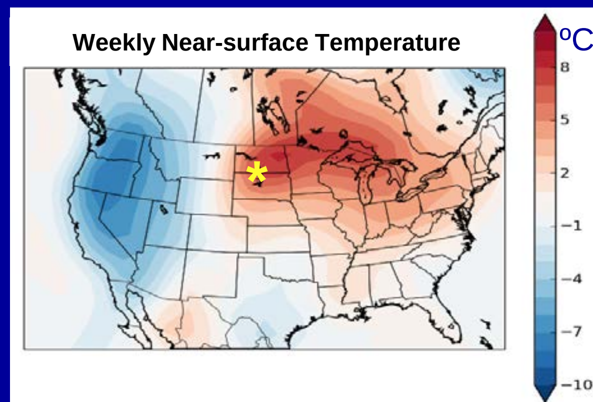


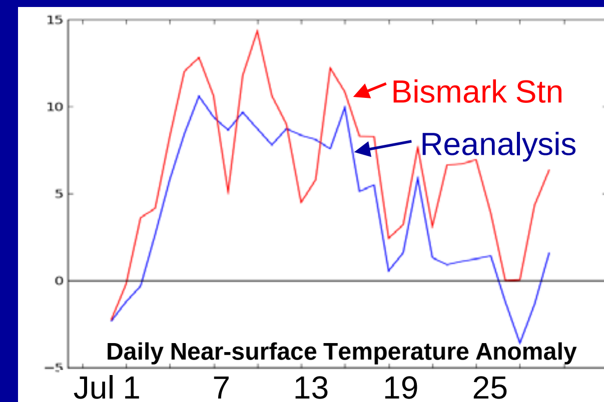
The 20th Century Reanalysis Project (1851-Present)

<u>Summary</u>: An international project led by NOAA and CIRES to produce *4-dimensional* reanalysis datasets for climate applications extending back to the 19th century using an Ensemble Kalman Filter and *only surface pressure observations.*

Weekly-averaged anomaly during July 1936 North American Heat Wave (> 2,000 dead during 10-day span)

Daily variations compare well with in-situ data.





The reanalyses provide:

-First-ever estimates of near-surface to tropopause 6-hourly fields extending to the beginning of the 20th century;

-Estimates of uncertainties in the basic reanalyses and derived quantities (e.g., storm tracks).

Examples of uses:

- Validating climate models.
- Determining storminess and storm track variations over the last 150 years.
- Understanding historical climate variations (e.g., 1930s Dust Bowl, 1920-1940s Arctic warming).
- Estimating risks of extreme events

Compo et al. 2011

Historical Reanalysis Status and Plans

20th Century Reanalysis Project http://go.usa.gov/XTd

- **Fall 2014**: 1871-2012 (includes time-varying CO2, volcanic aerosols, GFS from NCEP). **Ensemble mean and spread and individual member variables online now**.
  - http://www.esrl.noaa.gov/psd/data/gridded/data.20thC_ReanV2.html (NOAA ESRL)
  - http://dss.ucar.edu/datasets/ds131.1 (NCAR)
  - http://portal.nersc.gov/20C_Reanalysis **Every member** (US Dept of Energy, NERSC)
  - NERSC High Performance Storage System Tape Gateway **Every member**
  - Earth System Grid Federation ana4MIPS distribution and validation for IPCC AR5
  - British Atmospheric Data Center (BADC)

20CR v2c http://go.usa.gov/XTd

Ensemble mean and spread and 3D individual member variables online now.

Spring 2016: 1851-2012, 2013-2014 extension

Very similar system to 20CRv2. Fixed Sea ice using COBE-SST2 sea ice.
More observations, ensemble of SODAsi.2 SST (1851-2012), Reynolds et al. SST (2013-2014).
- distribution via: ESRL, NCAR, NERSC **Every member**

20CR version 3

Winter 2017: 1851-2015,additional tests for 1815-1850

Higher resolution, improved algorithm and observational quality control
Coordinate with ERA-CLIM2, SOUSEI, GFDL - Test possible BCs: HadISST2.1, COBE-SST2, SODAsi.3

Summary

- Reanalysis Data Development is still going strong - Centers have plans for Earth component coupling
- Tools are in place and growing to provide support for intercomparisons – users still need guidance on strengths and weaknesses
- TIRA is moving forward and will have a plan for the structure of a broad reanalysis intercomparison project