# Very High Resolution Arctic System Reanalysis for 2000-2011

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# Outline

- The Arctic System Reanalysis (ASR)
- ASR Components
- Atmospheric Data Assimilation
- Polar WRF
- Data for ASR
- ASR-Interim
- ASR-Interim Results
- Summary

# Arctic System Reanalysis Motivation

**1. Rapid change is happening in the Arctic climate system. A comprehensive picture of the interactions is needed.**

**2. The ASR is using the best available depiction of Arctic processes with improved temporal resolution and much higher spatial resolution than the global reanalyses.**

**3. A system-oriented approach provides community focus with the atmosphere, land surface and sea ice communities.**

**4. The ASR provides a convenient synthesis of Arctic field programs (SHEBA, LAII/ATLAS, ARM, ...).**

# ASR Outline

A physically-consistent integration of Arctic and other Northern Hemisphere data

High resolution in space (10 km) and time (3 hours)

Begin with years 2000-2010 (Earth Observing System)

## Participants:

Ohio State University - Byrd Polar Research Center (BPRC)
National Center Atmospheric Research (NCAR)
University of Colorado-Boulder
University of Illinois at Urbana-Champaign
Ohio Supercomputer Center (OSC)

# ASR Components

**The polar-optimized version of the Weather Research and Forecasting model (Polar WRF)** which includes an improved Noah land surface model and specifications for the following sea ice attributes: extent, concentration, thickness, albedo and snow cover (Bromwich et al. 2009, Hines et al. 2011, Hines and Bromwich 2008). (http://polarmet.osu.edu/PolarMet/pwrf.html)

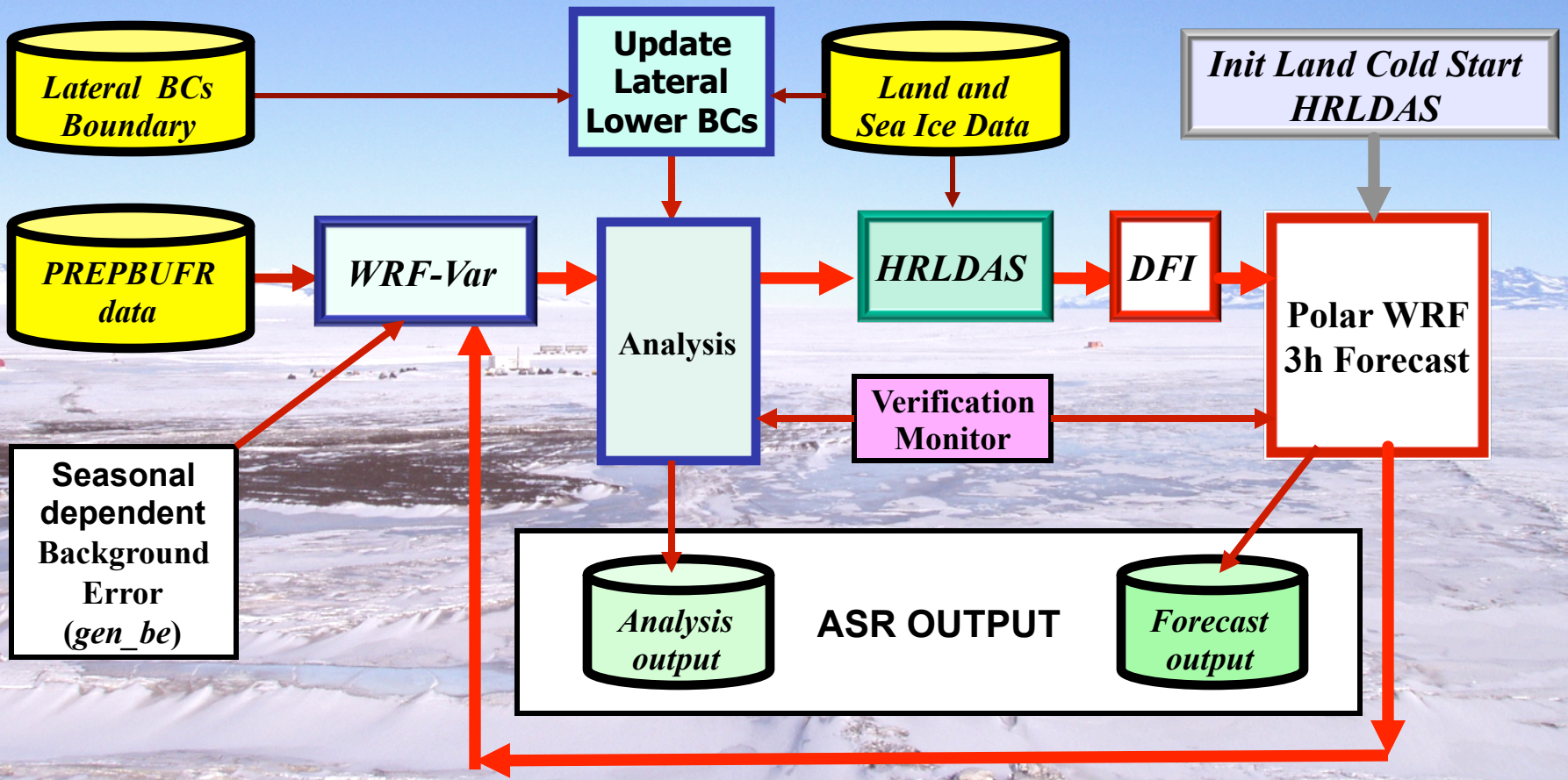
**WRF variational data assimilation (WRF-Var),** WRF-Var assimilates NCEP-PREPBUFR observation data (in-situ surface and upper air data, remotely sensed retrievals and satellite radiance data). (http://www.mmm.ucar.edu/wrf/users/wrfda/index.html)

**High Resolution Land Data Assimilation System (HRLDAS) (Chen et al. 2001),** HRLDAS is a vital component of ASR that assimilates snow cover and depth, observed vegetation fraction and albedo. The current HRLDAS uses NASA, NESDIS, and NOAA satellite observations to describe these surface properties.

# ASR Data Assimilation

## *WRF-3DVar HRLDAS POLAR-WRF*

## ASR performed in a 3-h interval



# Polar WRF
## (Version 3.3.1)

**Implementation of a fractional sea ice description in the Noah LSM + variable ice thickness and snow cover**
**Improved treatment of heat transfer for ice sheets and revised surface energy balance calculation in the Noah LSM**

**Model evaluations through Polar WRF simulations over Greenland, the Arctic Ocean (SHEBA site), Alaska, and Antarctica have been performed.**

**Polar WRF is used by ASR.**

# Numerical and Physics options
## for Polar WRF

Non hydrostatic dynamics;
5th order horizontal advection (upwind-based);
3rd order vertical advection;
Positive-definite advection for moisture;
6th-order horizontal hyper diffusion;
Grid nudging to ERA-Interim (top 20 levels);
Upper damping;
Morrison double-moment scheme;
New Grell sub-grid scale cumulus scheme;
RRTMG atmospheric radiation scheme;
RRTMG shortwave scheme;
MYNN planetary boundary layer scheme;
MYNN surface layer;
Noah land surface model;
Gravity wave drag;
Sea ice.

# Data for ASR

## ERA-Interim reanalysis model level data

The T255 (0.7 degrees) horizontal resolution ERA-Interim reanalysis surface and upper air model level data are used to provide the background initial, lateral boundary conditions and statistical background error for the ASR Interim.

## Atmospheric observation data (3-hour time window)

***PREPBUFR*** (including synop, metar, ship, buoy, qscat, sound, airep, profiler, pilot, satob, ssmi_retrieval_sea_surface_wind_speed, ssmi_retrieval_pw, gpspw)

***Radiances*** different sensors (amsua, amsub, mhs,hirs3, hirs4) in separate BUFR files

***GPS*** (GPSRO, GPSIPW)

***Obtained from Jack Woollen of NCEP***

## Sea ice data

Concentration, thickness, albedo and snow cover.

## Land data

Snow cover, depth and age, vegetation fraction and albedo from NASA, NESDIS, and NOAA satellite observations for High Resolution Land Data Assimilation System (HRLDAS).

# ASR-Interim 11 Year Data Assimilation

**Period: 2000~ 2010**

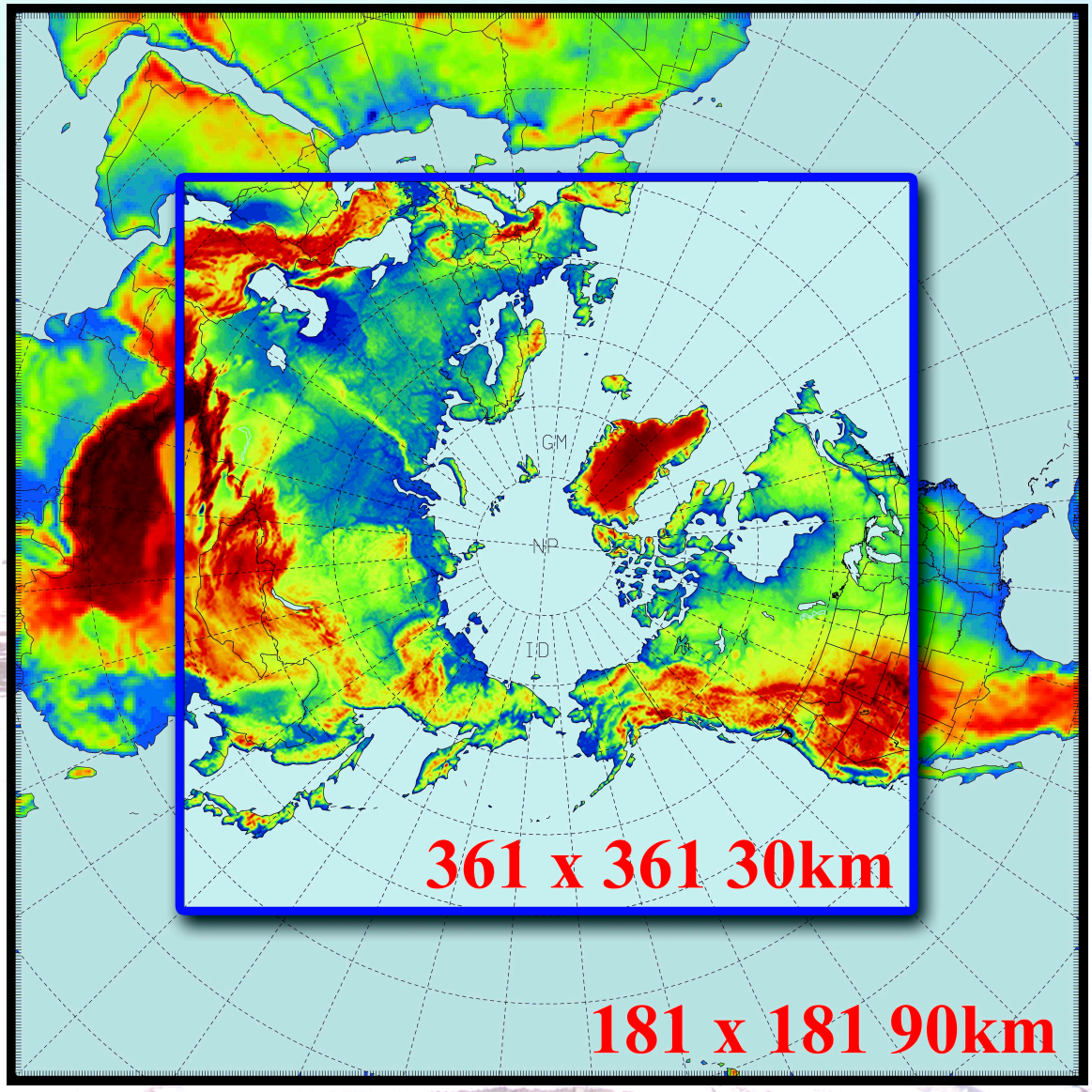
**Reduced Resolution: 30km-90km/71L, 10mb top**

**ERA-Interim reanalysis model level data as BC and LB**

**Full 3-hourly cycling run on OSC supercomputers**

**Polar WRF (V3.3.1), WRF-Var (V3.3.1) and HRLDAS are used for the data assimilations.**

# Domain for ASR-Interim



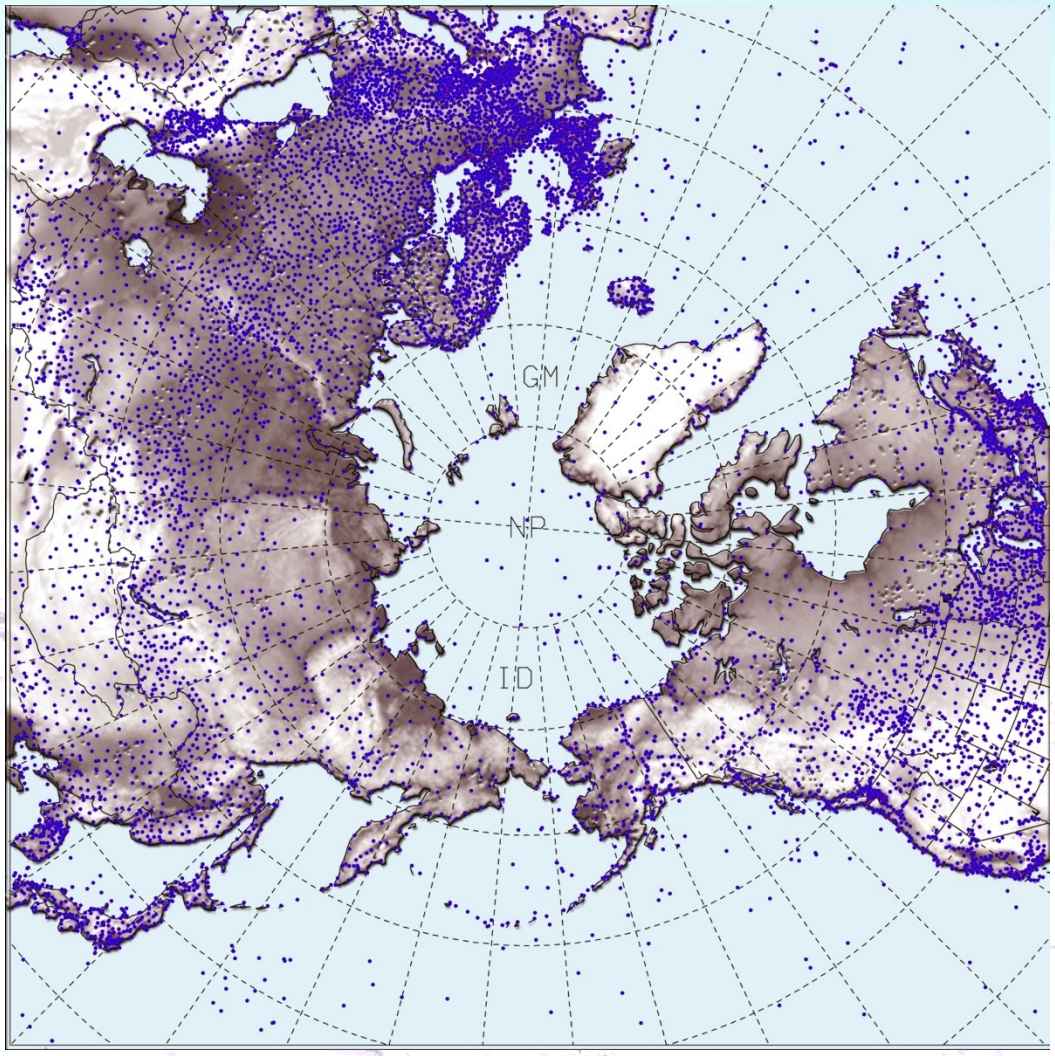
# Near Surface Variable Statistics

**The data used for the surface statistics:**

**ERA-Interim**

**Surface stations**

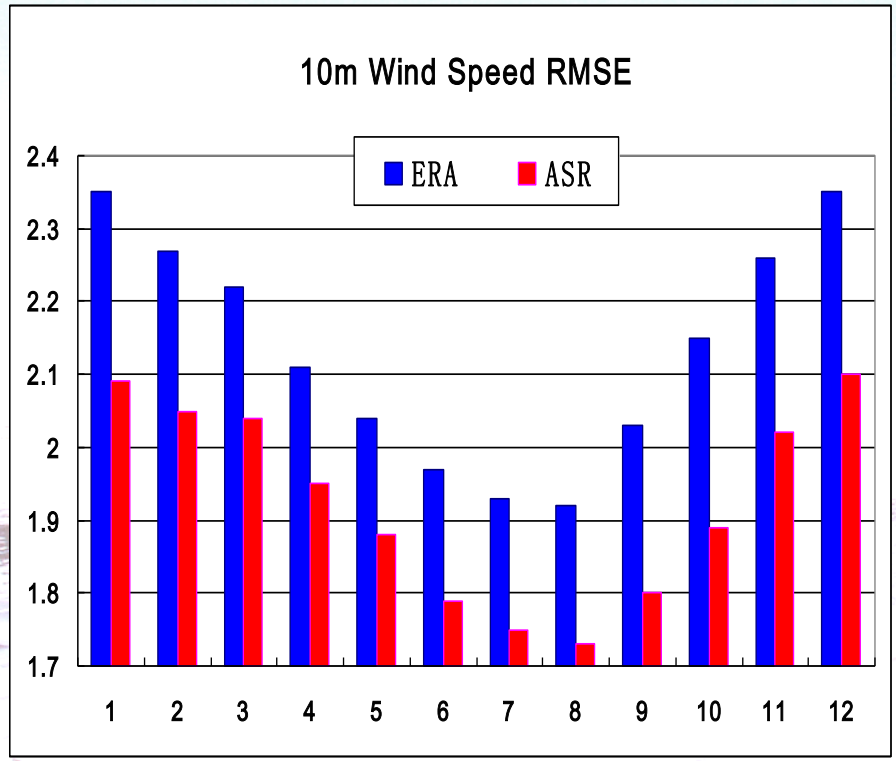
**(More than 5000 obtained from the National Climatic Data Center (NCDC) and Greenland Climate Network (GC-NET))**

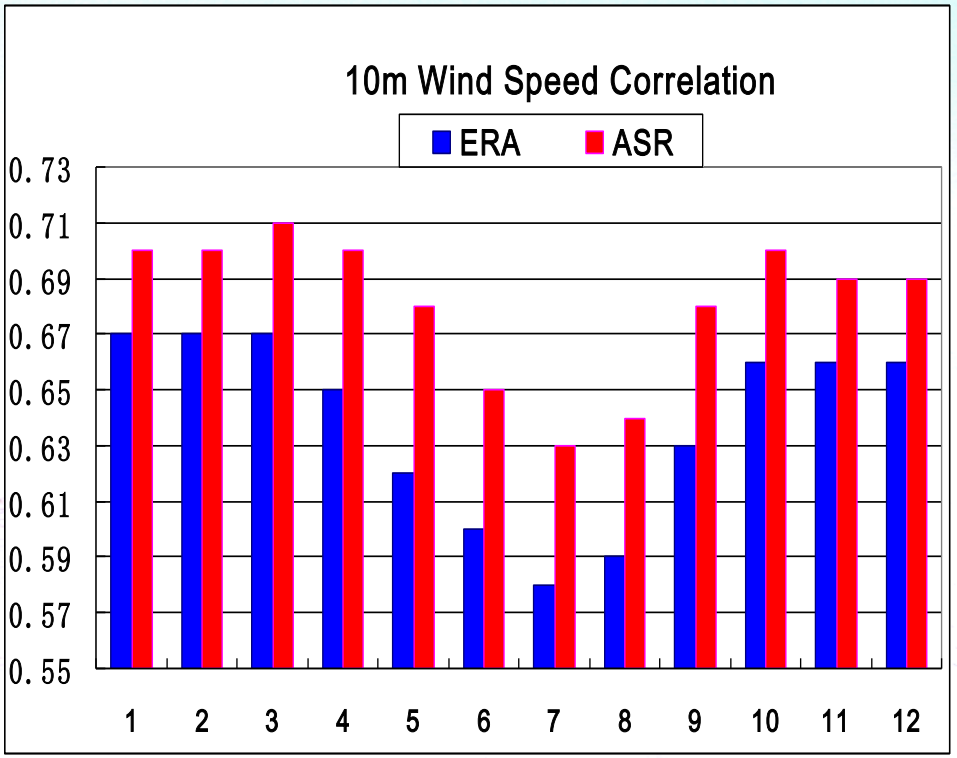


# Average statistics from comparing ASR-Interim and ERA-Interim with observations for 2000-2010

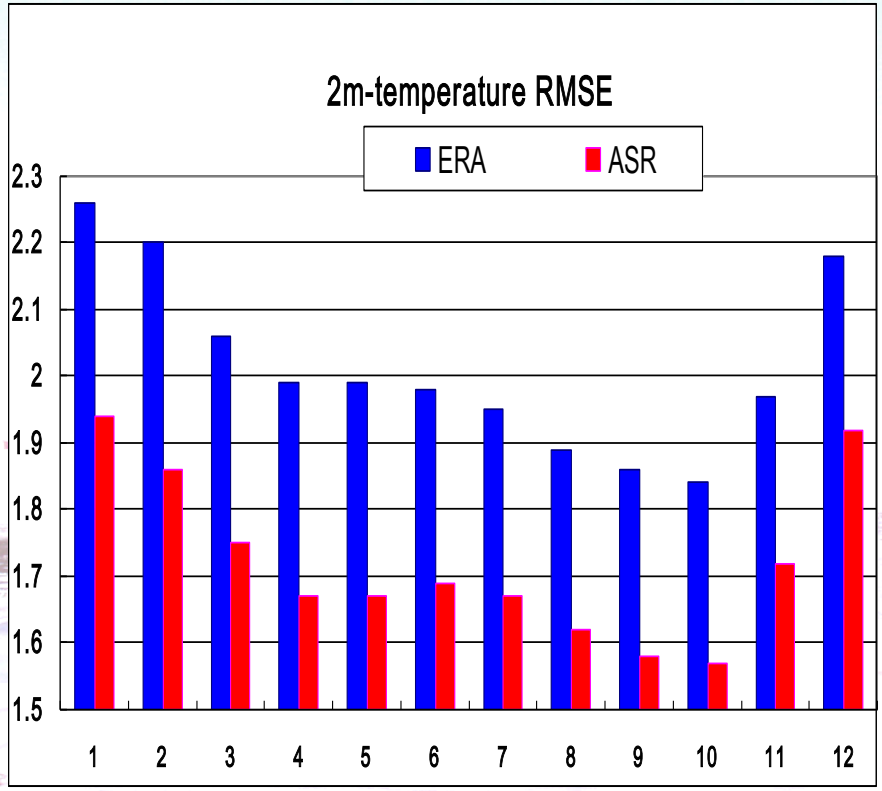
| Name | 10m Wind Speed | | | 2m-Temperature | | | 2m-Dew point | | | Surface pressure | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | bias | rmse | corr | bias | rmse | corr | bias | rmse | corr | bias | rmse | corr |
| ASR | 0.02 | 1.93 | 0.68 | -0.10 | 1.72 | 0.94 | -0.12 | 2.07 | 0.90 | 0.01 | 0.90 | 0.99 |
| ERA | 0.42 | 2.13 | 0.64 | 0.32 | 2.01 | 0.92 | 0.27 | 2.12 | 0.89 | 0.00 | 0.99 | 0.99 |

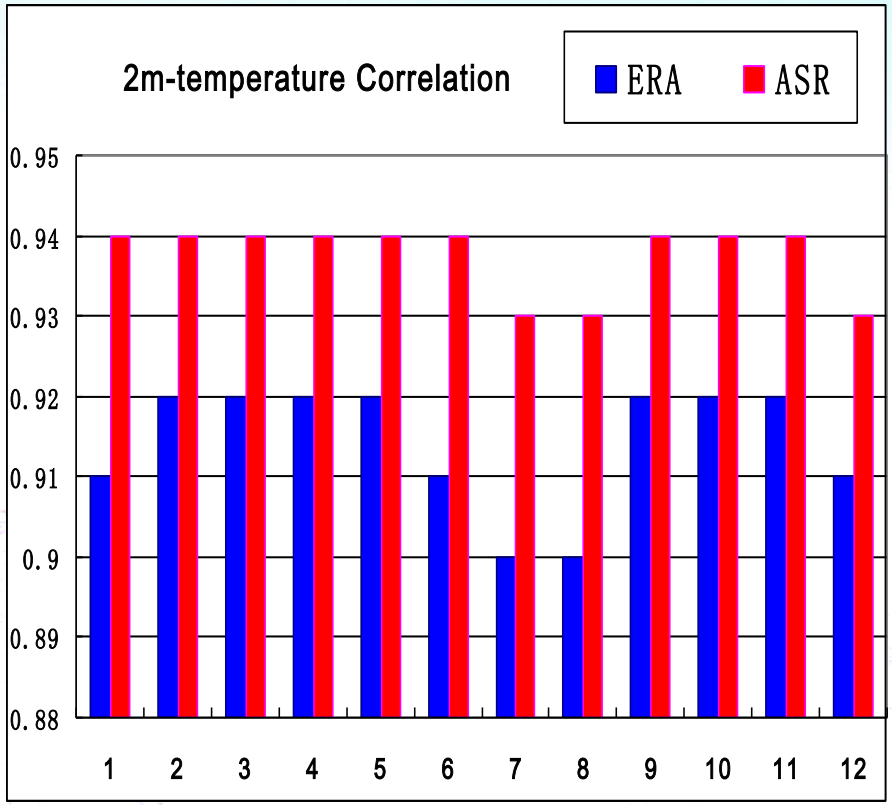
# Average statistics from comparing ERA-Interim (ERA) and ASR-Interim (ASR) with observations for 2000-2010



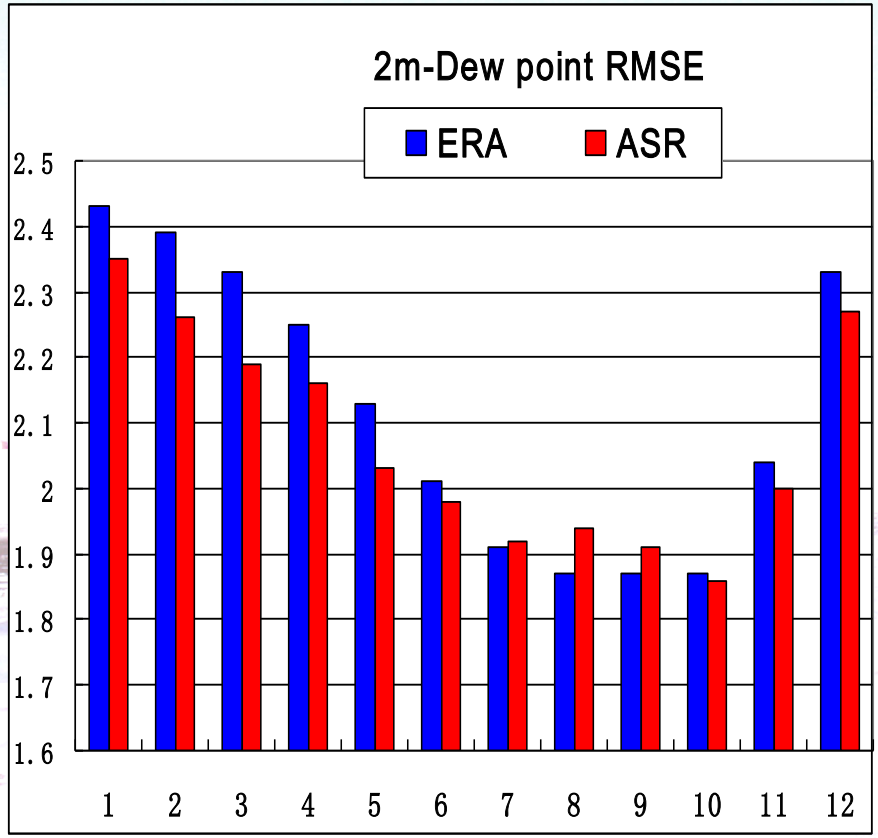



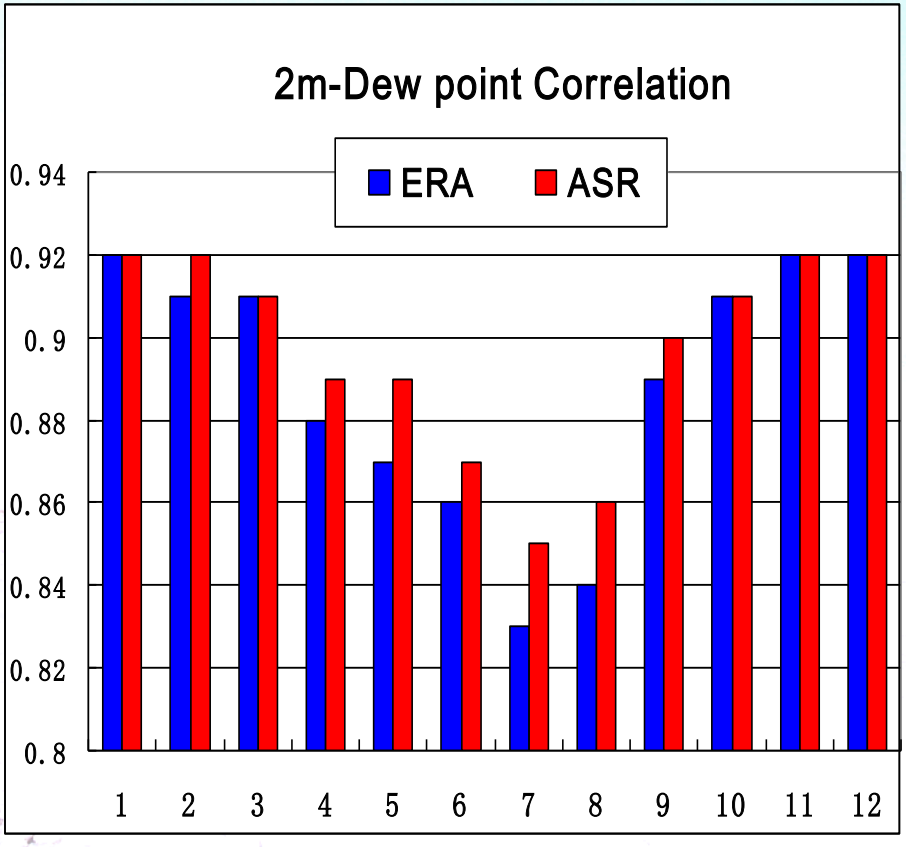
# Average statistics from comparing ERA-Interim (ERA) and ASR-Interim (ASR) with observations for 2000-2010



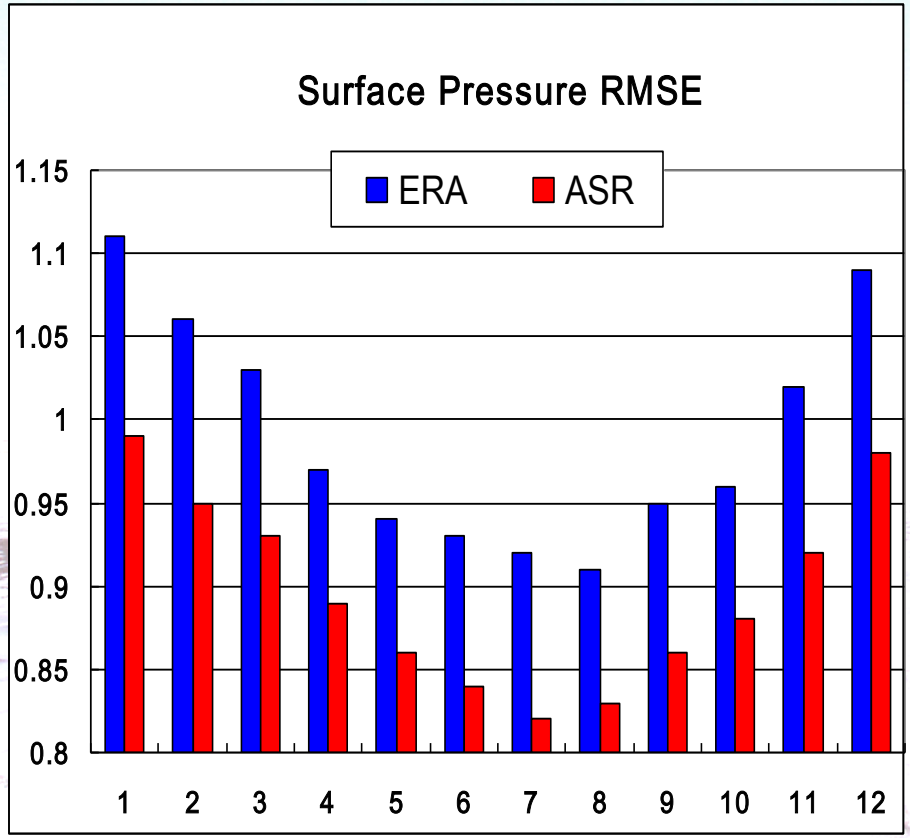



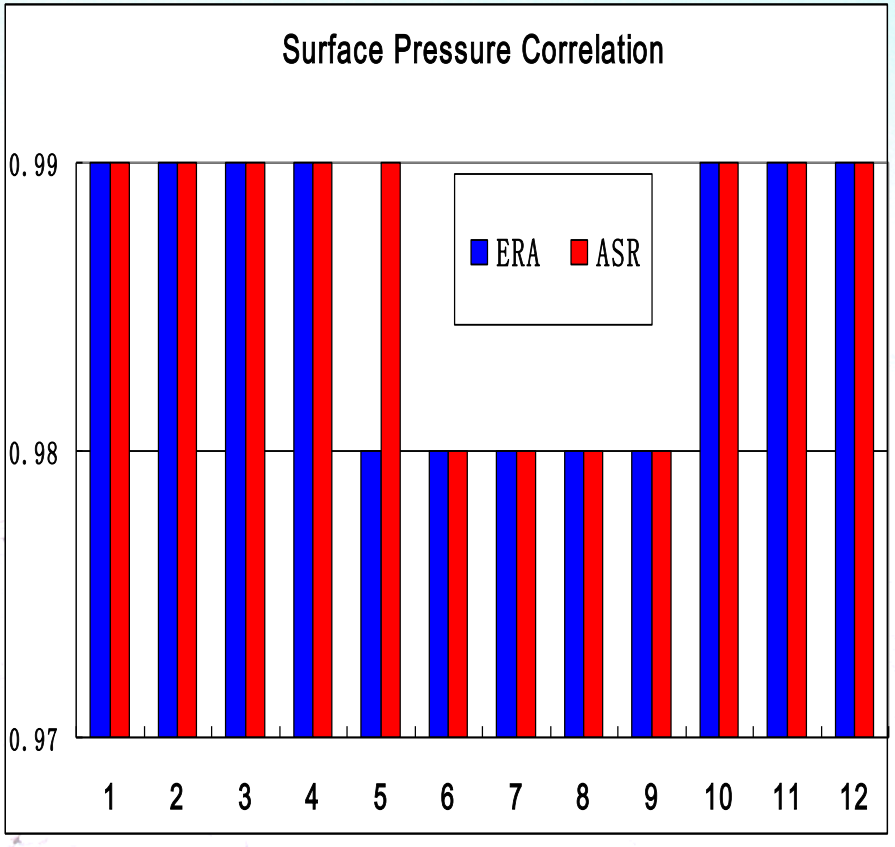
# Average statistics from comparing ERA-Interim (ERA) and ASR-Interim (ASR) with observations for 2000-2010



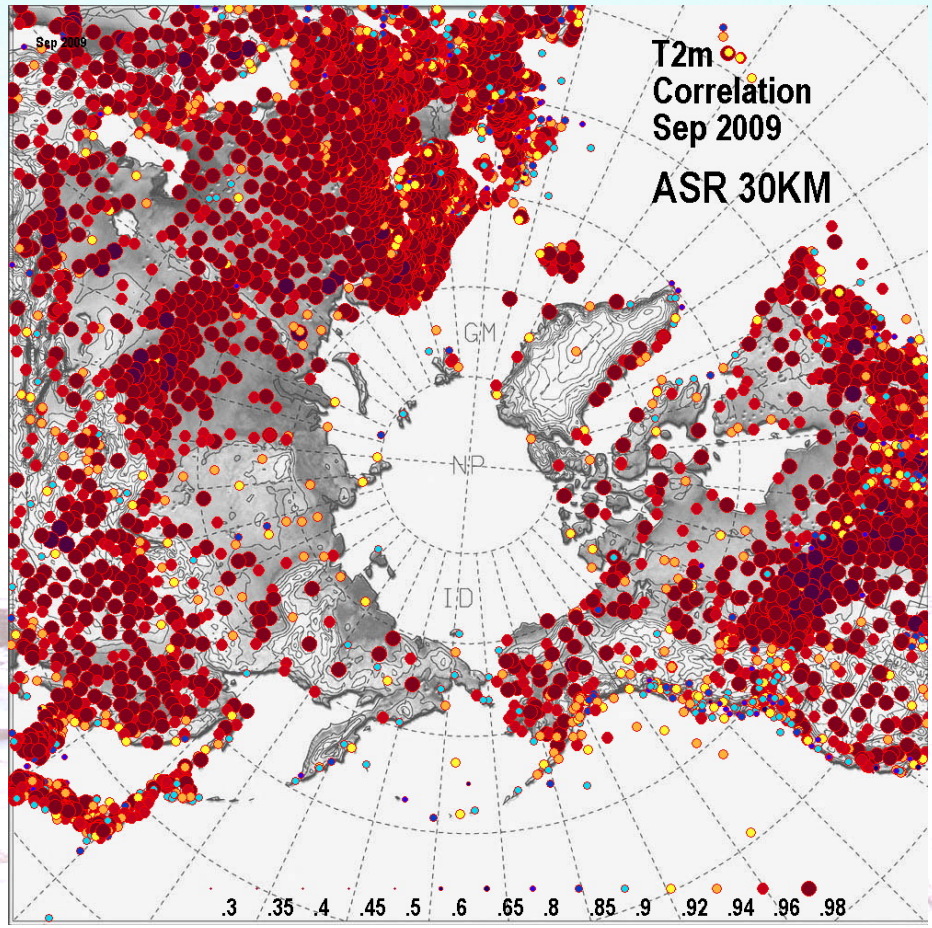
# Average statistics from comparing ERA-Interim (ERA) and ASR-Interim (ASR) with observations for 2000-2010

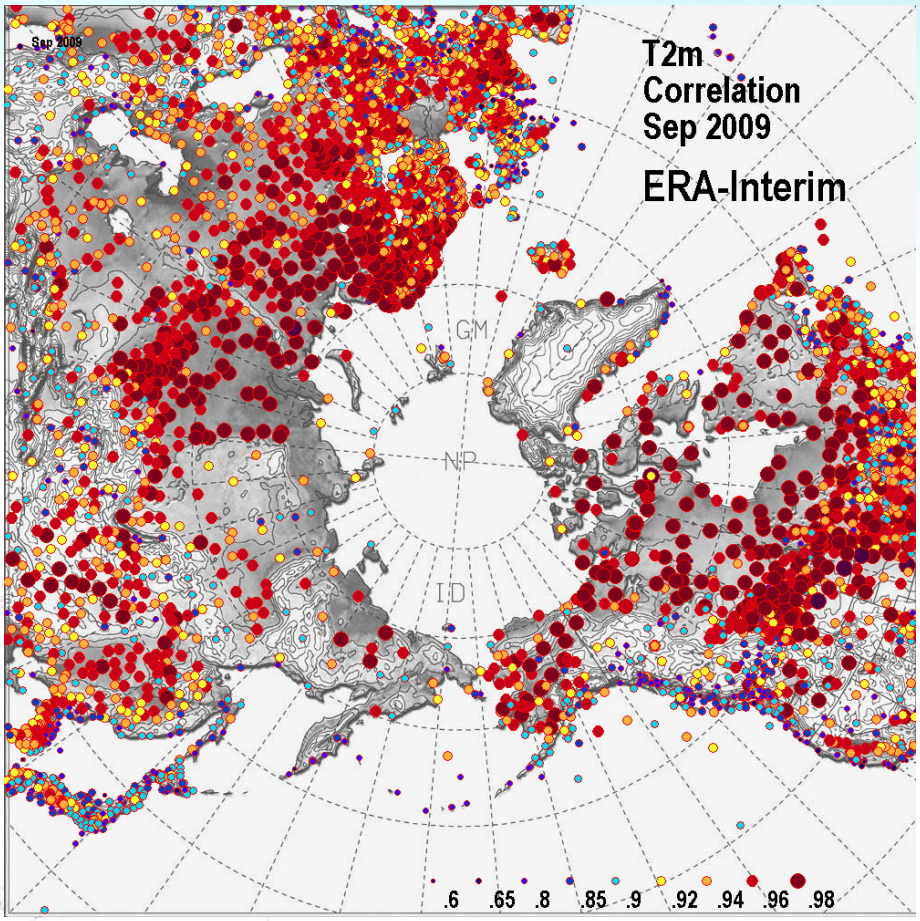


# *ASR Data Assimilation Result*

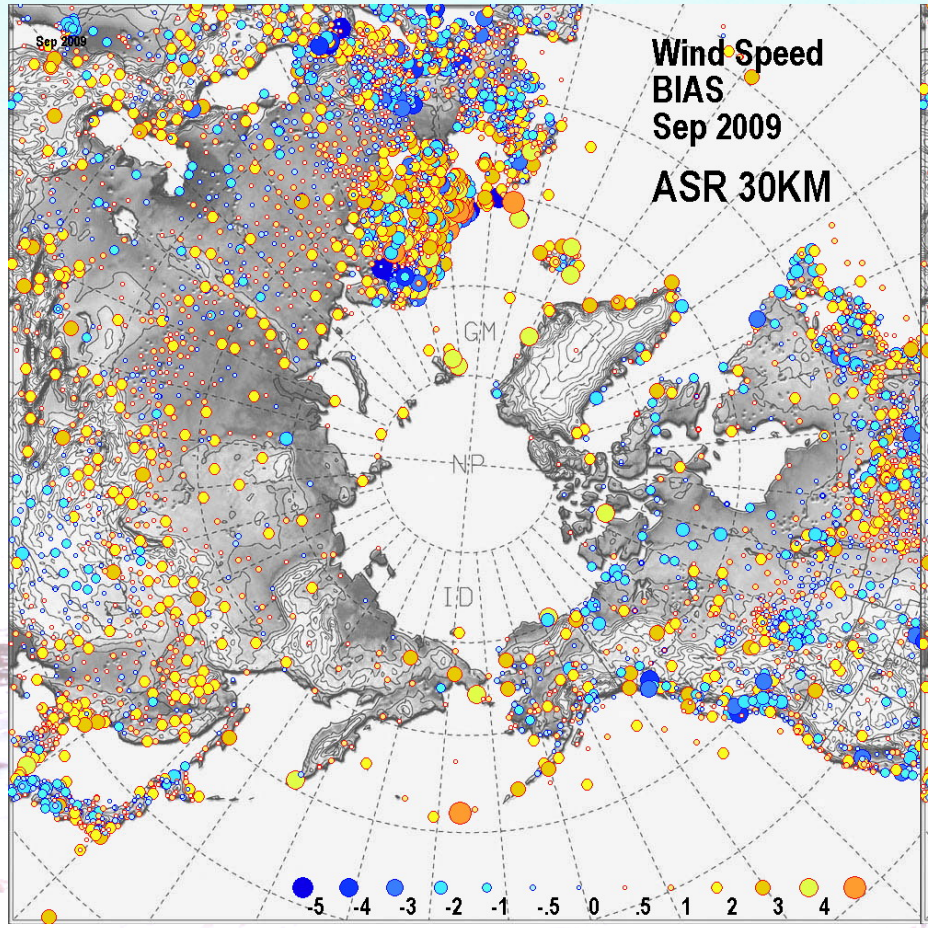
## between ASR-Interim (ERA-Interim) assimilation and observations

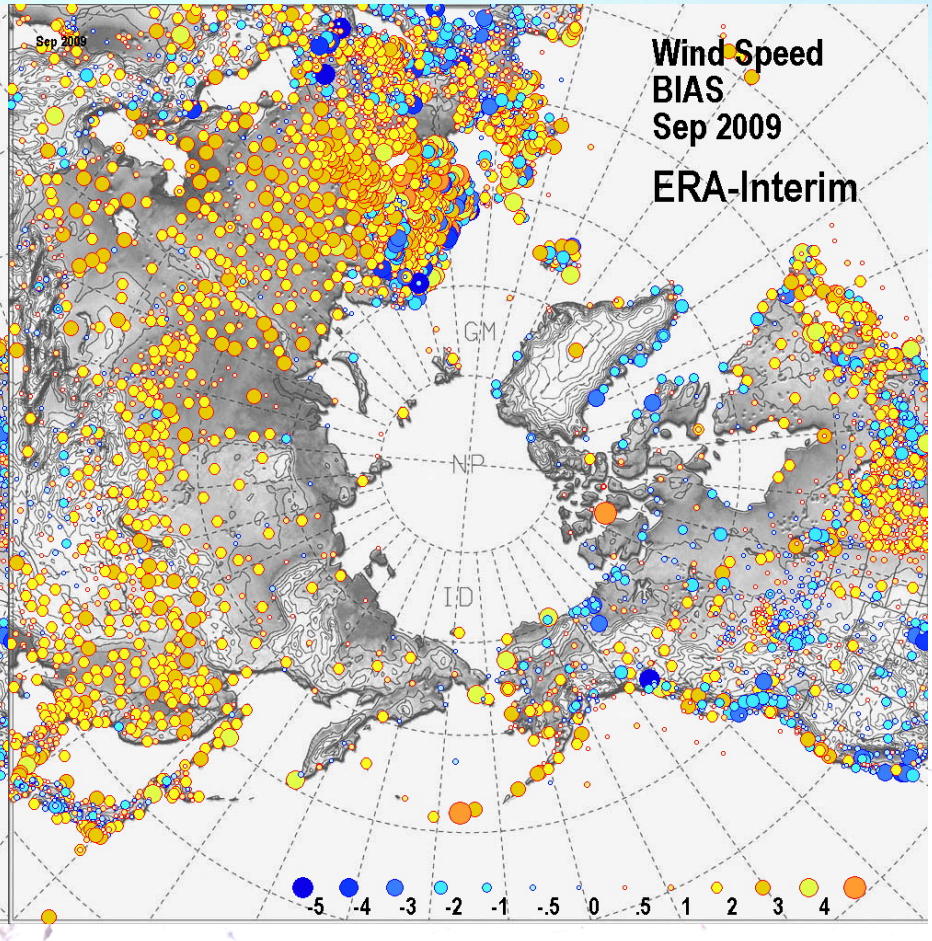


# *ASR Data Assimilation Result*

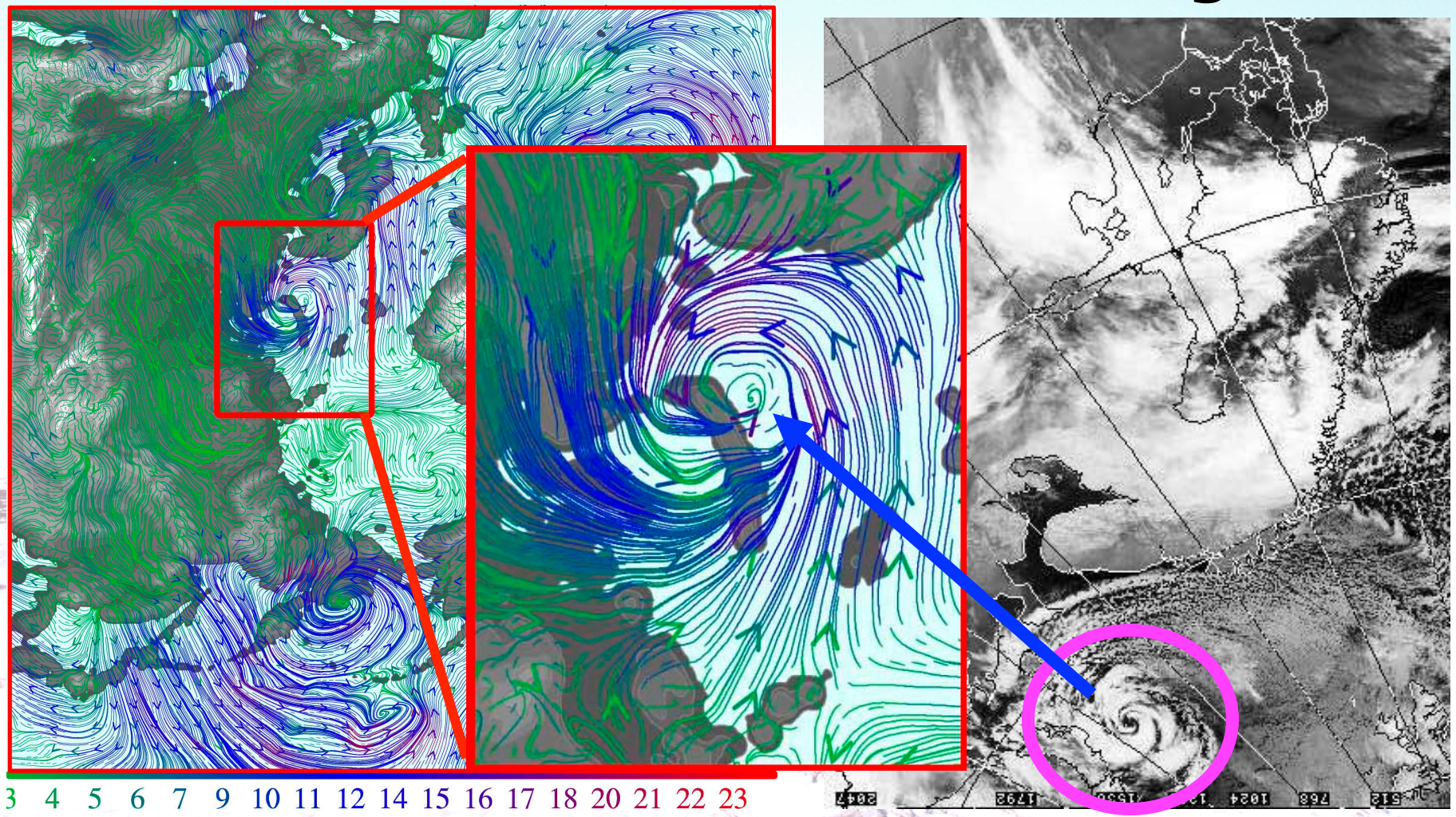
## between ASR-Interim (ERA-Interim) assimilation and observations



# ASR Data Assimilation Result: Polar Low

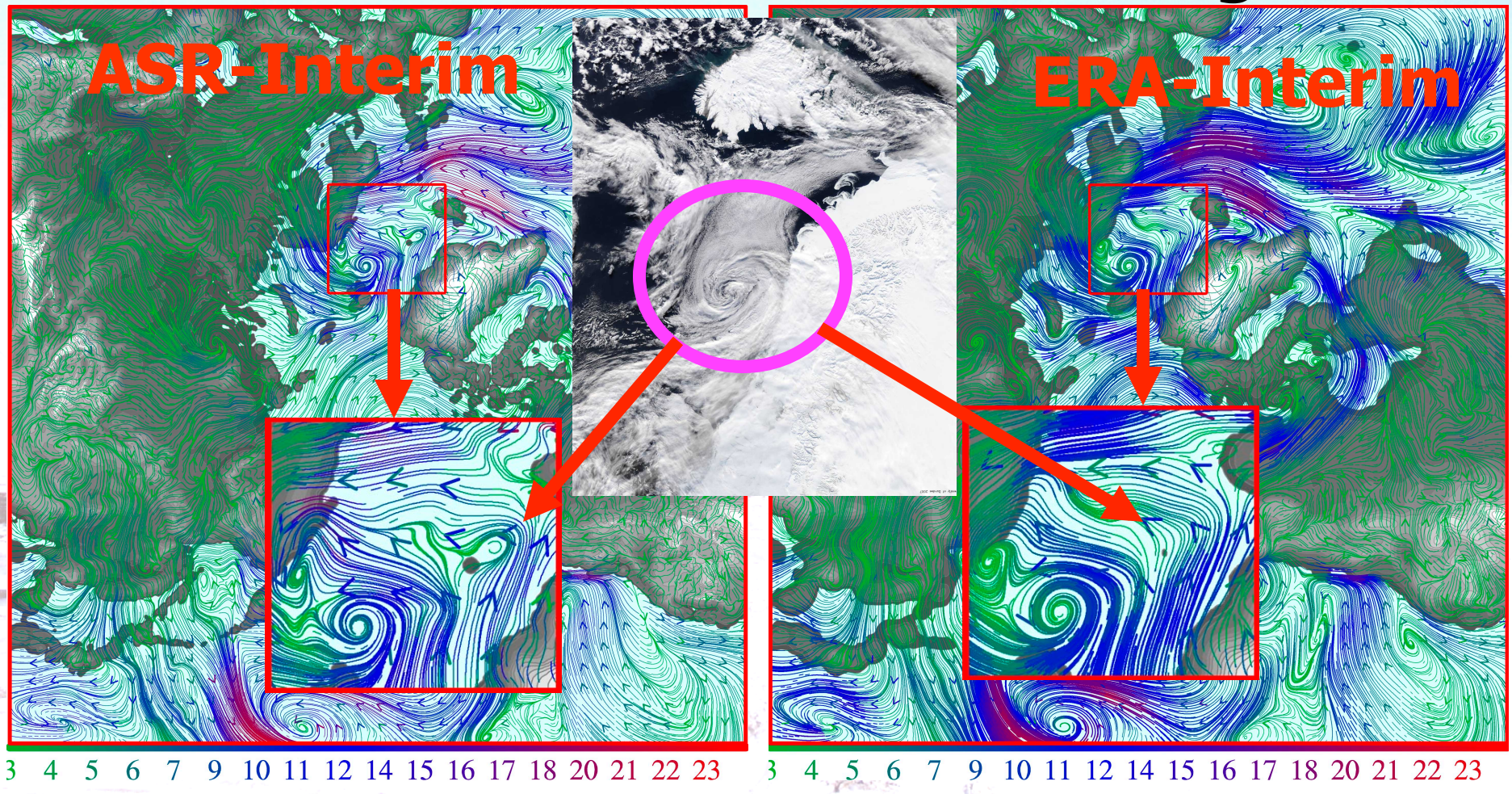
## 10 m Wind and Satellite Image




## 06 h DEC 20, 2007

# ASR Data Assimilation Result: Polar Low

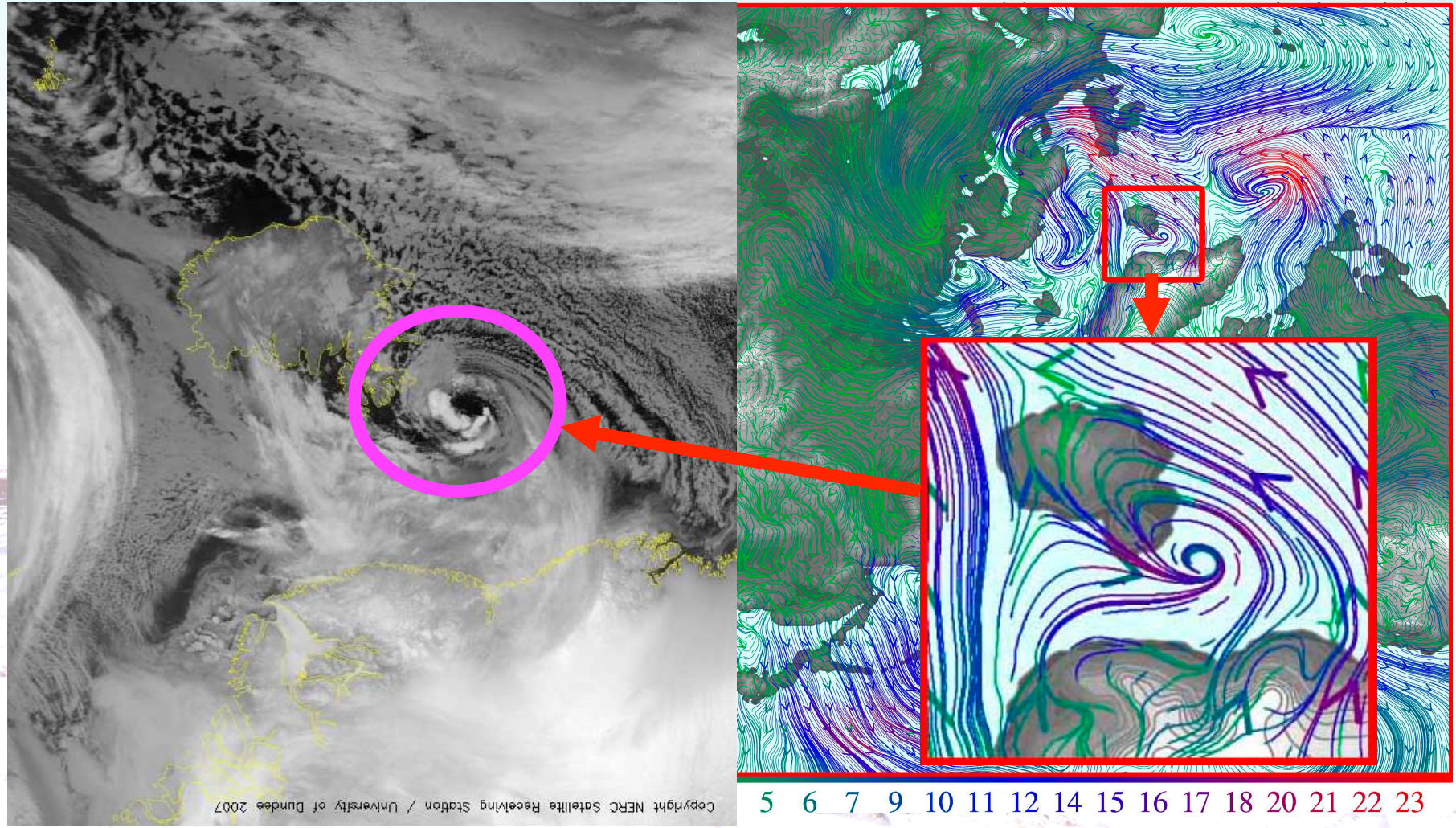
## 10 m Wind and Satellite Image




## 03h Mar 16, 2007

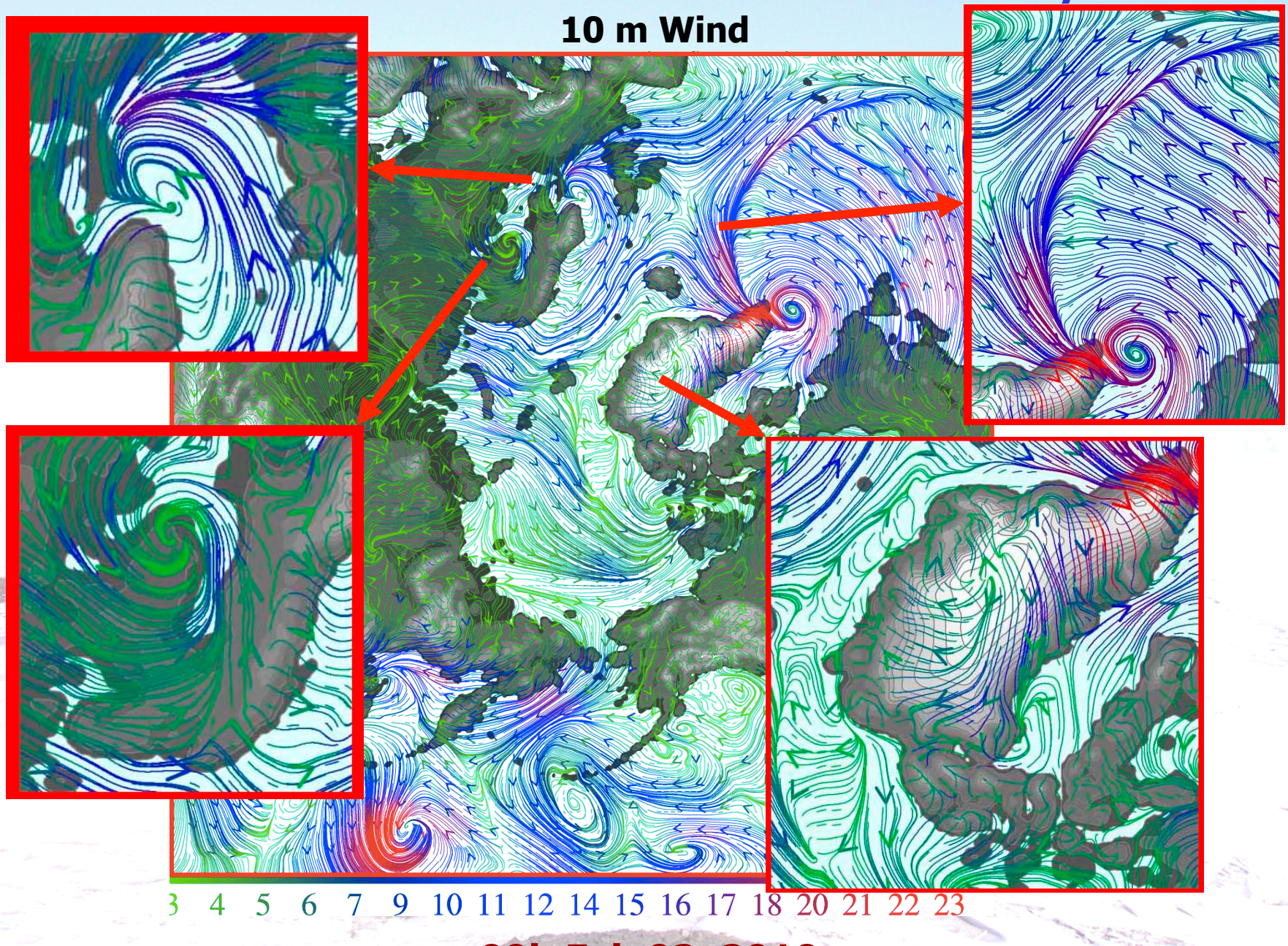
# ASR Data Assimilation Result: Polar Low

## 10 m Wind and Satellite Image



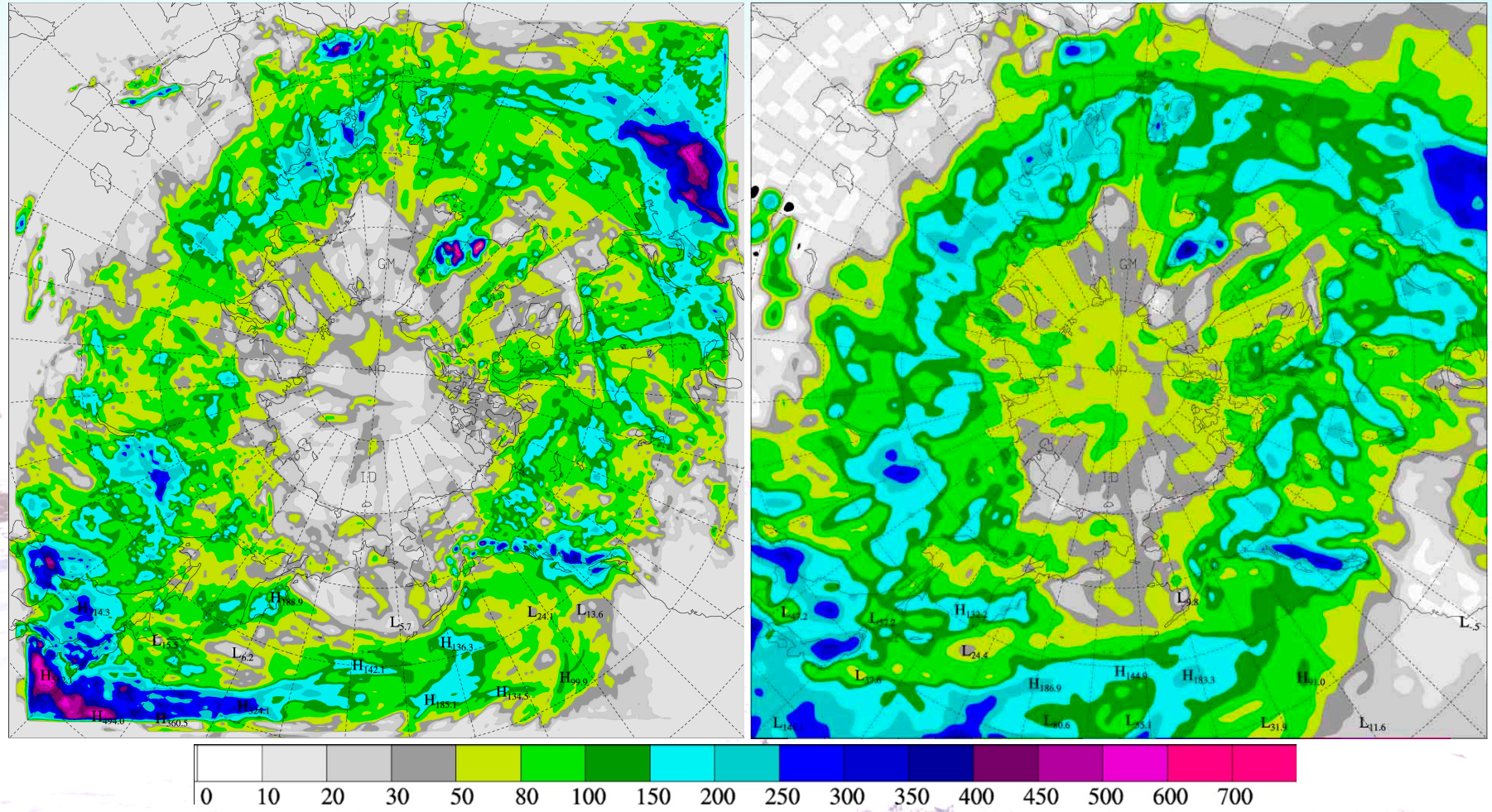

## 18h Jan 12, 2007

# ASR Data Assimilation Result: Arctic Weather System



# One-Month Cycling Run Results

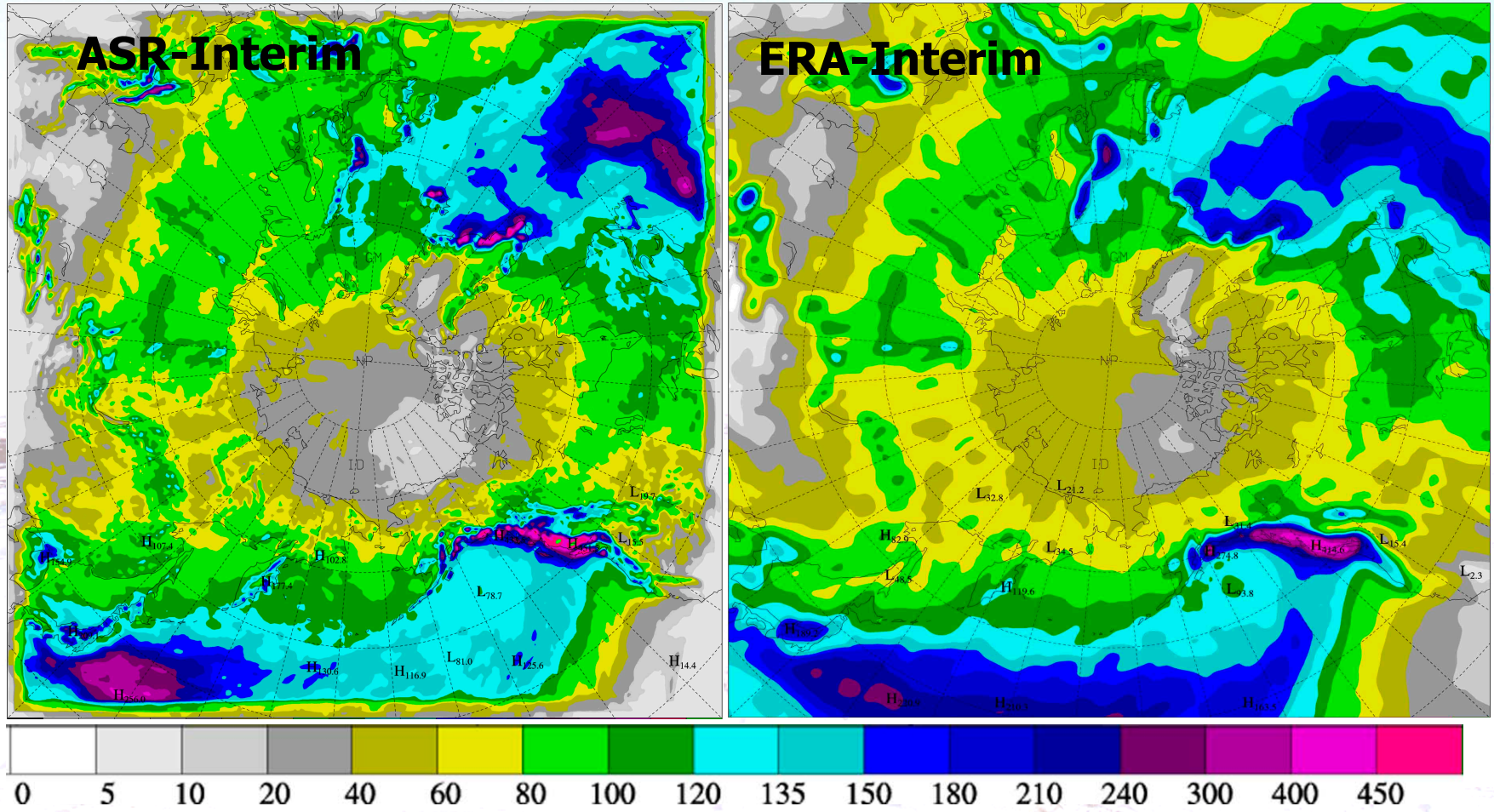
## *Precipitation* *(Monthly Total in August 2008, Unit: mm)*




**ASR-Interim** **ERA-Interim**

# ASR Data Assimilation Result

## Precipitation




**Yearly Total 2007, Unit: cm**

# Summary

**The ASR-Interim data assimilations with reduced resolution with nested grids (90 km outer domain; 30 km primary domain) have been performed from 2000 to 2010 at OSC. The results are very encouraging.**

**Polar WRF, WRF-3DVar and Noah Land Data Assimilation will be updated to correct the bias in $Q_{2m}$, $T_{2m}$, precipitation and to improve ASR performance, and used for the final run.**

**Based upon the ASR-Interim results and improvement of ASR system, the ASR team will perform 12 years (2000-2011) at 10 km resolution. The target date for completion is September 2012.**

**ASR data are distributed by NCAR's Research Data Archive and NOAA Earth System Research Laboratory (ESRL).**

# Average statistics from comparing ASR-Interim and ERA-Interim with observations for 2000-2010

| ASR Month | 10m Wind Speed | | | 2m-Temperature | | | 2m-Dew point | | | Surface pressure | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | bias | rmse | corr | bias | rmse | corr | bias | rmse | corr | bias | rmse | corr |
| 01 | 0.09 | 2.09 | 0.70 | 0.14 | 1.94 | 0.94 | 0.72 | 2.35 | 0.92 | 0.04 | 0.99 | 0.99 |
| 02 | 0.03 | 2.05 | 0.70 | -0.03 | 1.86 | 0.94 | 0.50 | 2.26 | 0.92 | 0.03 | 0.95 | 0.99 |
| 03 | -0.02 | 2.04 | 0.71 | -0.17 | 1.75 | 0.94 | 0.20 | 2.19 | 0.91 | 0.02 | 0.93 | 0.99 |
| 04 | -0.08 | 1.95 | 0.70 | -0.26 | 1.67 | 0.94 | 0.01 | 2.16 | 0.89 | -0.01 | 0.89 | 0.99 |
| 05 | -0.07 | 1.88 | 0.68 | -0.27 | 1.67 | 0.94 | -0.38 | 2.03 | 0.89 | -0.02 | 0.86 | 0.99 |
| 06 | -0.03 | 1.79 | 0.65 | -0.27 | 1.69 | 0.94 | -0.66 | 1.98 | 0.87 | -0.03 | 0.84 | 0.98 |
| 07 | -0.01 | 1.75 | 0.63 | -0.25 | 1.67 | 0.93 | -0.76 | 1.92 | 0.85 | -0.02 | 0.82 | 0.98 |
| 08 | 0.02 | 1.73 | 0.64 | -0.24 | 1.62 | 0.93 | -0.82 | 1.94 | 0.86 | -0.02 | 0.83 | 0.98 |
| 09 | 0.10 | 1.80 | 0.68 | -0.17 | 1.58 | 0.94 | -0.70 | 1.91 | 0.90 | -0.01 | 0.86 | 0.98 |
| 10 | 0.06 | 1.89 | 0.70 | -0.06 | 1.57 | 0.94 | -0.29 | 1.86 | 0.91 | 0.02 | 0.88 | 0.99 |
| 11 | 0.03 | 2.02 | 0.69 | 0.09 | 1.72 | 0.94 | 0.17 | 2.00 | 0.92 | 0.04 | 0.92 | 0.99 |
| 12 | 0.07 | 2.10 | 0.69 | 0.22 | 1.92 | 0.93 | 0.59 | 2.27 | 0.92 | 0.04 | 0.98 | 0.99 |
| **AVG** | **0.02** | **1.93** | **0.68** | **-0.10** | **1.72** | **0.94** | **-0.12** | **2.07** | **0.90** | **0.01** | **0.90** | **0.99** |

| ERAI Month | 10m Wind Speed | | | 2m-Temperature | | | 2m-Dew point | | | Surface pressure | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | bias | rmse | corr | bias | rmse | corr | bias | rmse | corr | bias | rmse | corr |
| 01 | 0.71 | 2.35 | 0.67 | 0.45 | 2.26 | 0.91 | 0.70 | 2.43 | 0.92 | 0.13 | 1.11 | 0.99 |
| 02 | 0.57 | 2.27 | 0.67 | 0.39 | 2.20 | 0.92 | 0.65 | 2.39 | 0.91 | 0.12 | 1.06 | 0.99 |
| 03 | 0.41 | 2.22 | 0.67 | 0.31 | 2.06 | 0.92 | 0.52 | 2.33 | 0.91 | 0.05 | 1.03 | 0.99 |
| 04 | 0.21 | 2.11 | 0.65 | 0.25 | 1.99 | 0.92 | 0.39 | 2.25 | 0.88 | -0.01 | 0.97 | 0.99 |
| 05 | 0.18 | 2.04 | 0.62 | 0.22 | 1.99 | 0.92 | 0.17 | 2.13 | 0.87 | -0.07 | 0.94 | 0.98 |
| 06 | 0.21 | 1.97 | 0.60 | 0.23 | 1.98 | 0.91 | -0.05 | 2.01 | 0.86 | -0.13 | 0.93 | 0.98 |
| 07 | 0.25 | 1.93 | 0.58 | 0.26 | 1.95 | 0.90 | -0.17 | 1.91 | 0.83 | -0.17 | 0.92 | 0.98 |
| 08 | 0.30 | 1.92 | 0.59 | 0.28 | 1.89 | 0.90 | -0.13 | 1.87 | 0.84 | -0.14 | 0.91 | 0.98 |
| 09 | 0.46 | 2.03 | 0.63 | 0.28 | 1.86 | 0.92 | 0.01 | 1.87 | 0.89 | -0.05 | 0.95 | 0.98 |
| 10 | 0.54 | 2.15 | 0.66 | 0.30 | 1.84 | 0.92 | 0.16 | 1.87 | 0.91 | 0.02 | 0.96 | 0.99 |
| 11 | 0.59 | 2.26 | 0.66 | 0.40 | 1.97 | 0.92 | 0.39 | 2.04 | 0.92 | 0.08 | 1.02 | 0.99 |
| 12 | 0.66 | 2.35 | 0.66 | 0.46 | 2.18 | 0.91 | 0.63 | 2.33 | 0.92 | 0.13 | 1.09 | 0.99 |
| **AVG** | **0.42** | **2.13** | **0.64** | **0.32** | **2.01** | **0.92** | **0.27** | **2.12** | **0.89** | **0.00** | **0.99** | **0.99** |