Special Bureau of the Atmosphere Status, and review of Atmospheric Analyses and Models, with Application to Geodetic Uses

David Salstein
Atmospheric and Environmental Research
Lexington, MA

GGFC Workshop
Vienna, Austria
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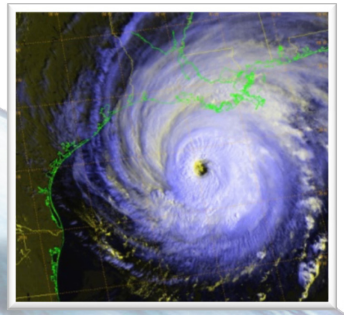


Outline

Special Bureau for the Atmosphere of the IERS:

- --History
- --Current holdings
- --Membership and collaboration
- Global atmospheric data sets
- --Analyses
- --Models
- Atmospheric model results/data use in geodesy
- Special analyses, models
  - -- Climate of the twentieth century reanalyses
  - -- Coupled Model Intercomparison Project (3,5)
- Torques, regional distribution of the AAM, pressure and zonal winds

History of Special Bureau for the Atmosphere

- Starr (1948) noted the partition of angular momentum between solid Earth and atmosphere

- Calculations of AAM by Rosen and Salstein as part of the NASA LAGEOS and Crustal Dynamics Projects (1970s-80s)

- Meetings at NASA, and ECMWF and AGU in late 1970s for routine calculations of angular momentum (Hide, Smith, Miller, Rosen, Salstein, Hollingsworth, Dickey)

History, continued

- Hide et al. (1980); Barnes et al. (1983), Rosen and Salstein (1983)
- Special Study Groups of the IAG (Dickey et al., JPL)
- 1989: IERS Sub-Bureau for Atmospheric Angular Momentum (SBAAM) established at AER in partnership with NOAA (Salstein et al., 1993, BAMS paper) --Cooperation with Paris Observatory (Central Bureau)
- 2000: During introduction of GGFC, SBAAM merged into the Special Bureau for the Atmosphere recognizing: (a) the atmosphere was only one of the fluid impacting Earth rotation and (b) AAM was only one of the atmospheric elements for use by geodesy
- Zhou et al. (2006) updates Barnes et al. for SBA ; new formulation, constants, excitation versus angular momentum

Current holdings of the SBA

- **At AER**

Operational:

Analyses from US NCEP; Japan Meteorological Agency, UK Meteorological Office, European Center for Medium Range Weather Forecasts (older)

Reanalysis:

- US NCEP, NCEP2, ERA40

At NOAA

Operational analyses and forecasts (NCEP, JMA,UKMO)

Membership and collaboration

Membership

- AER – D. Salstein, K. Quinn
- Shanghai Astronomical Observatory – Y. Zhou
- US NOAA (Natl. Oceanic and Atmospheric Administration) – C. Long

Products from Associates: AAM, gravity, loading, atmospheric delays, torques

Associated linked institutions:

- Vienna University of Tech. – GGOS-Atmos project
- GFZ Potsdam – Earth system modeling
- U. Luxembourg –Atmospheric loading
- Recent applicants answering call
- Cooperation with forecasting: USNO and Paris Obs. link to SBA
- Interest in atmospheric regional excitation: Space Research Center of PAS, Warsaw

- ---European partners important in obtaining ECMWF –based information

Global atmospheric models

-- structure can be grid point or spherical harmonic

-- can use real initial conditions or be “spun up”, and boundary conditions

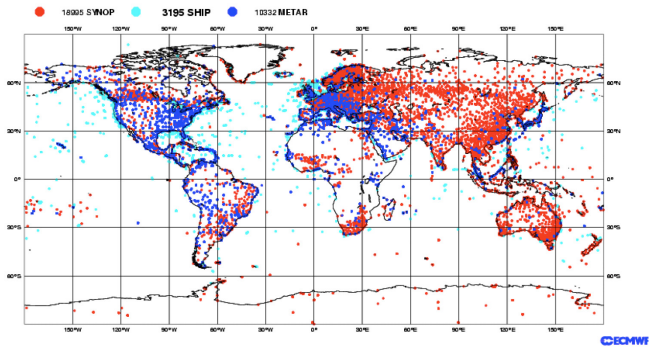
-- solves laws physics of the atmosphere

-- makes forecast by advancing equations of motion (dynamics), energy (thermodynamics) and variable mass quantities (esp. moisture)

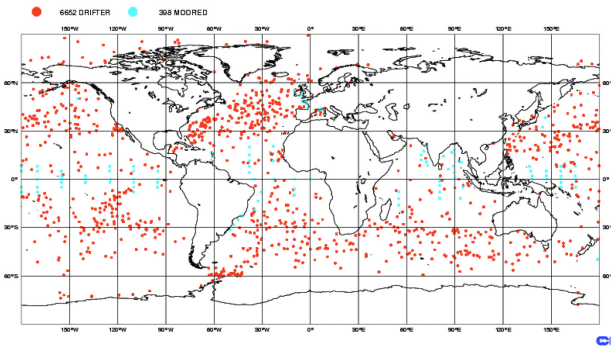
-- may be part of a system, e.g. coupled atmosphere-ocean models; used for testing climate hypotheses

Raw meteorological data (e.g. 00.18.04.12)

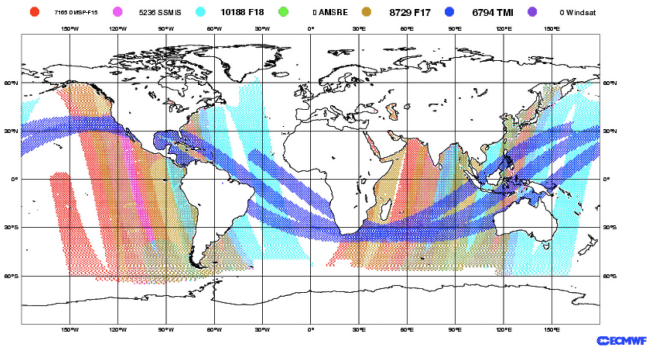
RAOBS, SURFACE



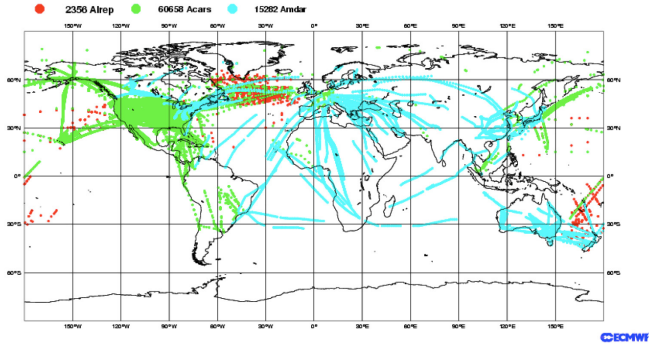
BUOYS



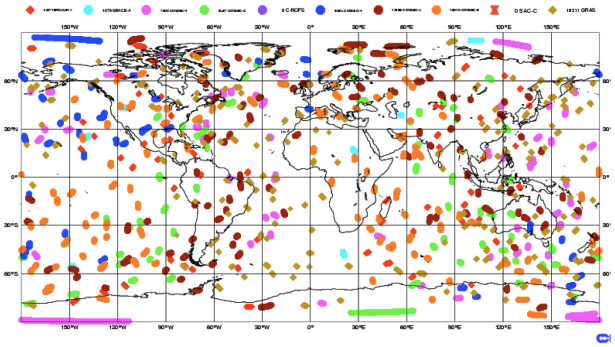
Microwave, (PO+OO)



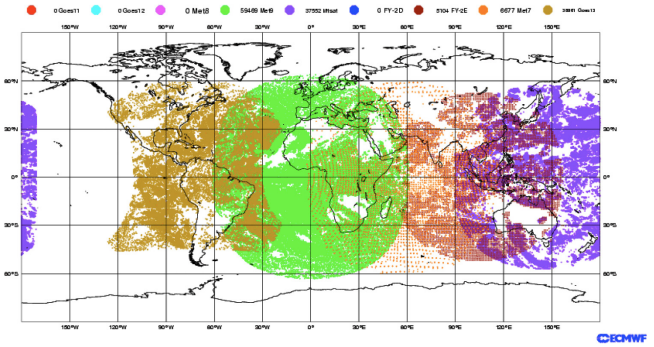
AIRCRAFT



GPS



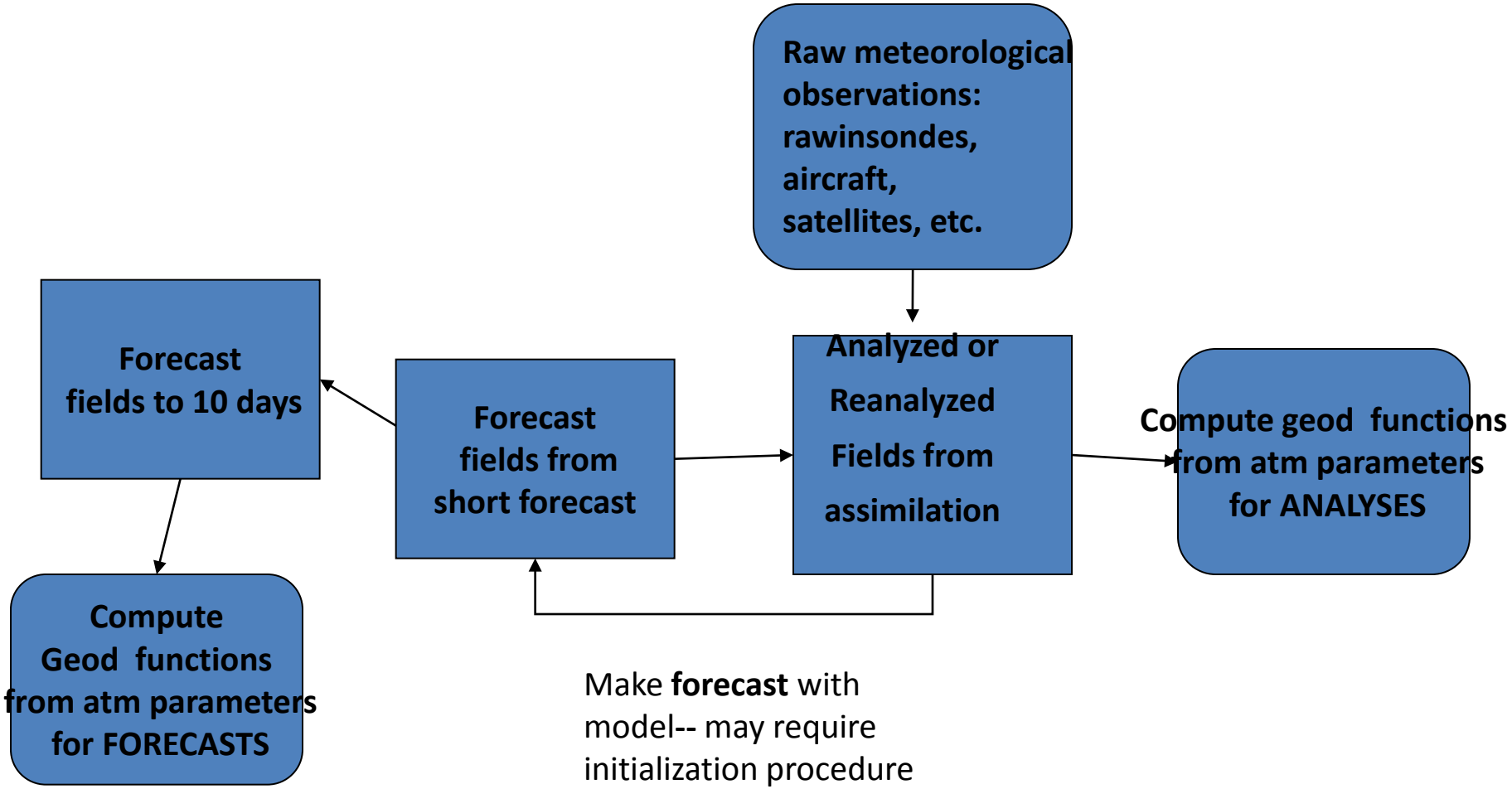
IR (Geostationary)



Global atmospheric analyses

- Uses sets of observations (in combinations with model forecasts) to produce fields of quantities (Very different characteristics,)
- May use 4-D data assimilation
- Operational analyses: change with time (including discontinuities)
- Reanalyses: consistent model to assimilate historical data
- Specialized reanalyses: e.g. Twentieth century; High-resolution (may be limited area)

METEOROLOGICAL DATA ASSIMILATION and FORECAST SYSTEM



AAM: excitation (χ) vector for Earth rotation: polar motion (1,2) and rotation rate (3)

Polar motion (1,2)

Earth rotation: Length-of-Day (3)

mass

$$\chi^{\mathbf{P}} = \chi_1^P + i\chi_2^P = \frac{-1.098R^4}{(C-A)g}\iint p_s \sin\phi\cos^2\phi e^{i\lambda} d\lambda d\phi$$

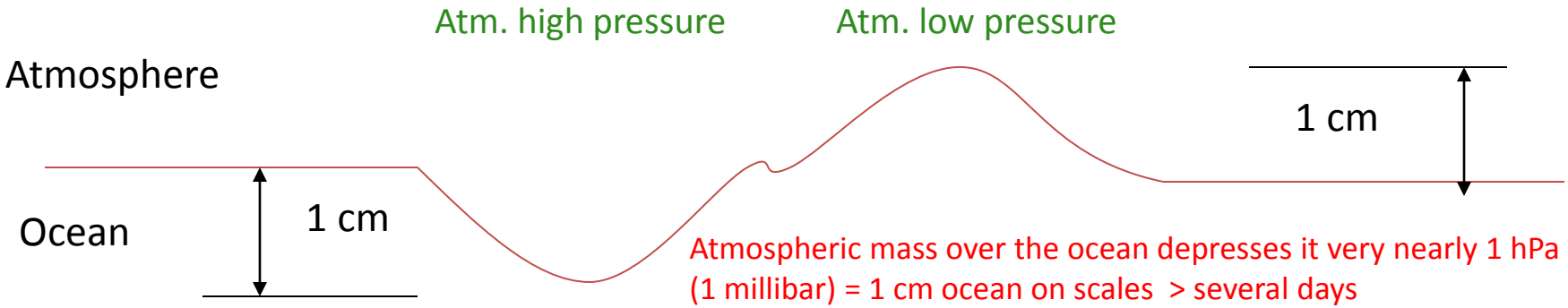
$$\chi_3^P = \frac{0.753R^4}{C_m g}\iint p_s \cos^3\phi d\lambda d\phi$$

motion

$$\chi^{\mathbf{W}} = \chi_1^W + i\chi_2^W = \frac{-1.5913R^3}{\Omega(C-A)g}\iiint (u\sin\phi + iv)\cos\phi e^{i\lambda}\mathrm{dpd}\lambda\mathrm{d}\phi$$

$$\chi_3^W = \frac{0.998R^3}{C_m\Omega g}\iiint u\cos^2\phi\mathrm{dpd}\lambda\mathrm{d}\phi$$

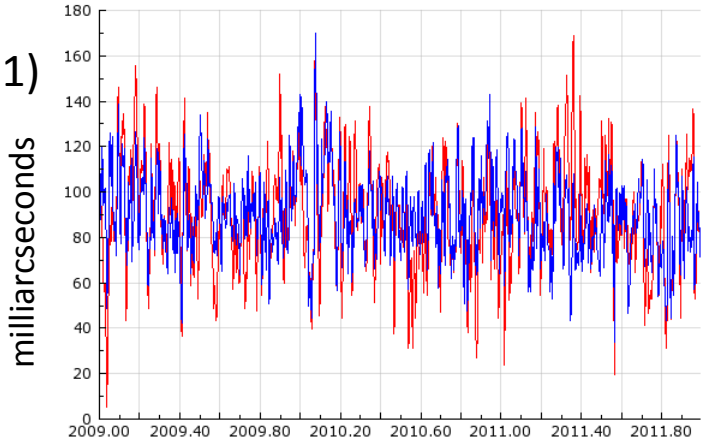
Zhou, Salstein, Chen, (2006), updates Barnes et al. (1983)



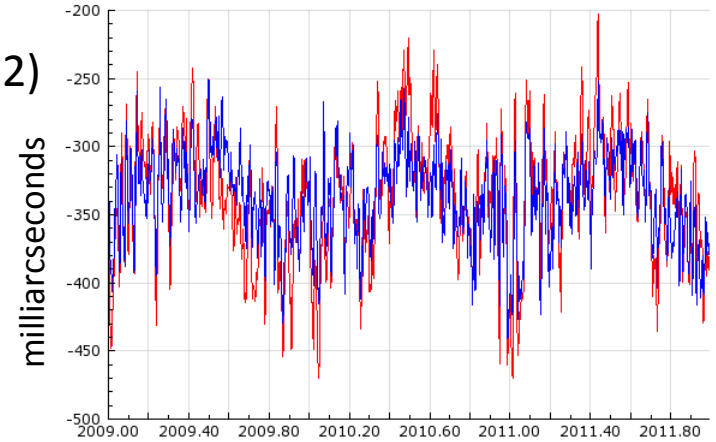
Atmospheric mass over the ocean depresses it very nearly 1 hPa (1 millibar) = 1 cm ocean on scales > several days

AAM (NCEP-NCAR Reanalyses) and Earth Rotation Parameters (01/2009 – 12/2011)

(1)

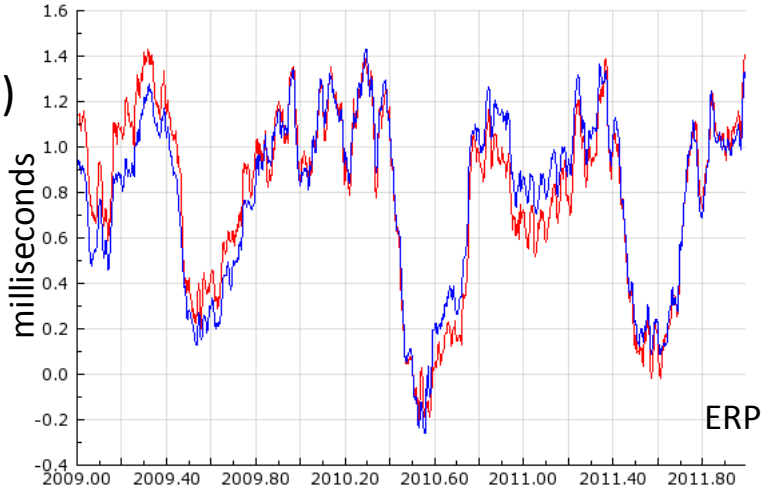


(2)



Polar motion

(3)



Length-of-day

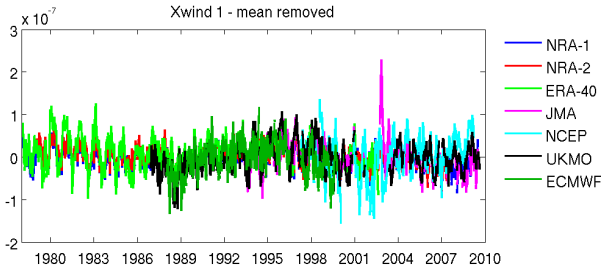
AAM

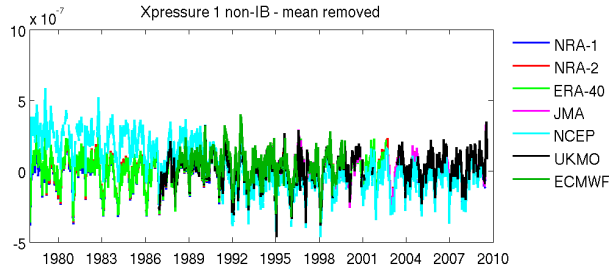
ERP (geodetic)

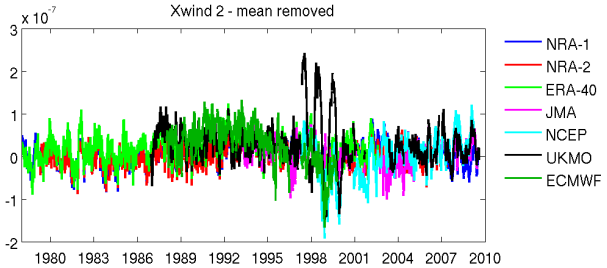
ERP data and software: Paris Observatory

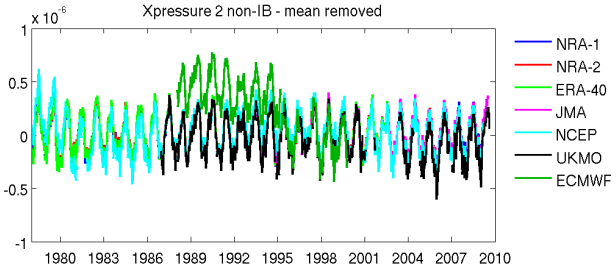
Atmospheric and Environmental Research

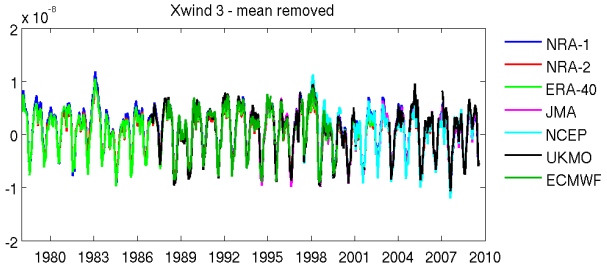
Excitation (AAM) series from the SBAtmosphere (30 day mean removed)

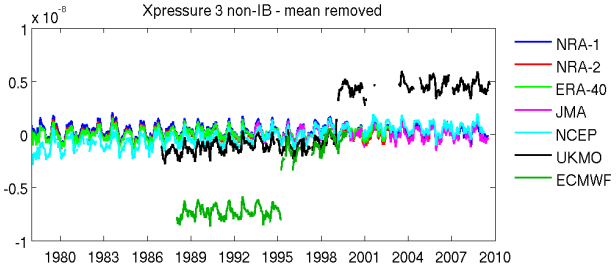






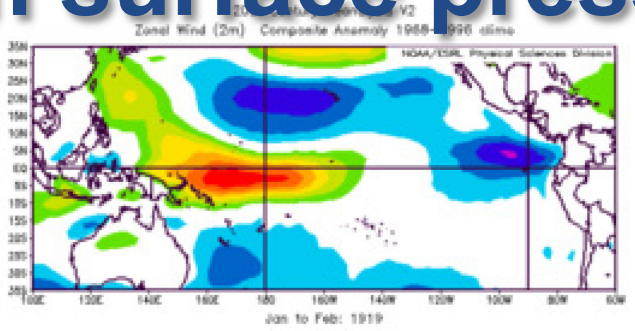




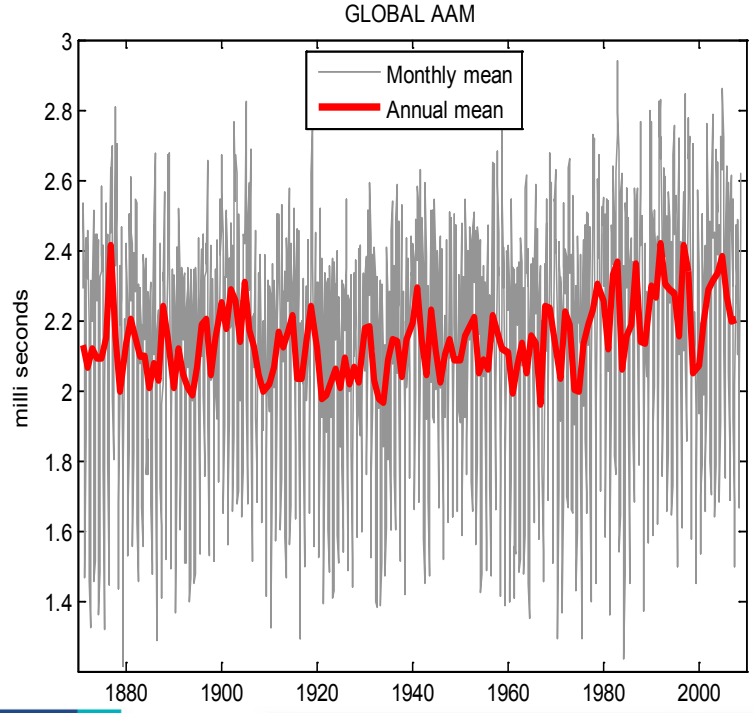


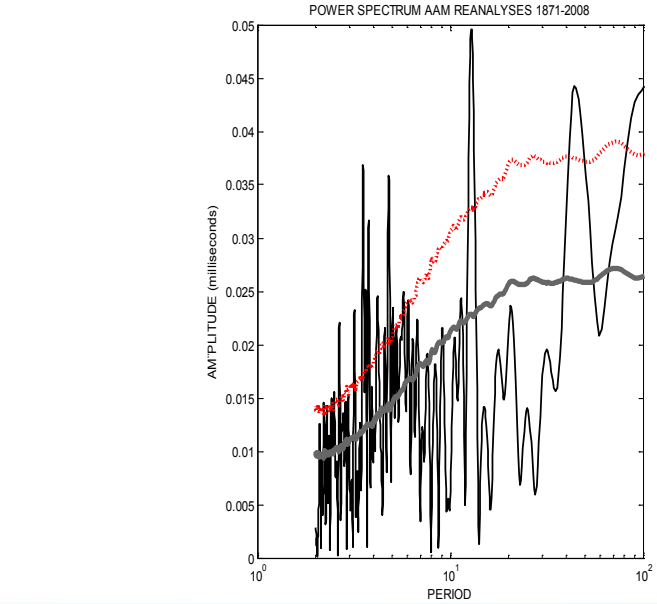
Special Reanalysis: Climate of the 20th Century, based on surface pressure

El Nino of 1919, wind anomaly →



Compo, G.P., et al, 2011:The Twentieth Century Reanalysis Project. Quarterly J. Roy. Meteorol. Soc., 137, 1-28. DOI: 10.1002/qj.776.





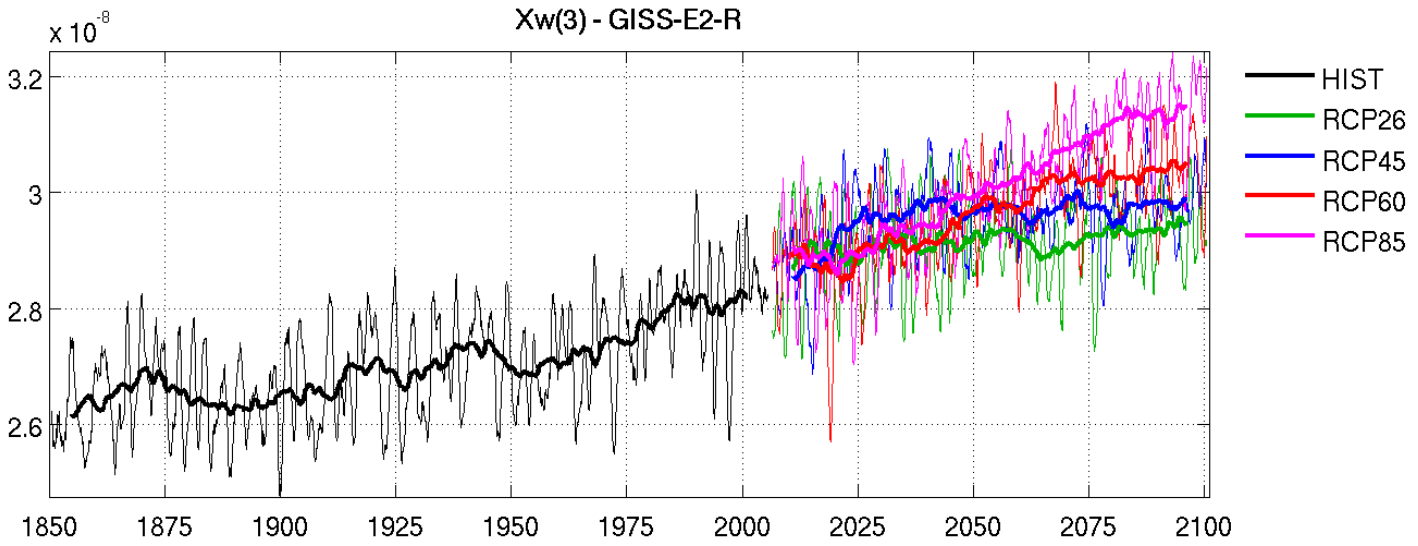
Abarca del Rio and Salstein, 2011

Atmosphere component, coupled model

Uses climate models with Greenhouse gas and other forcing: basis of the assessment reports of climate change by the Intergovernmental Panel on Climate Change.

CMIP 5

Updated IPCC scenarios have quantitative RCP's (Representative Concentration Pathways) that span the climate space of radiative forcing

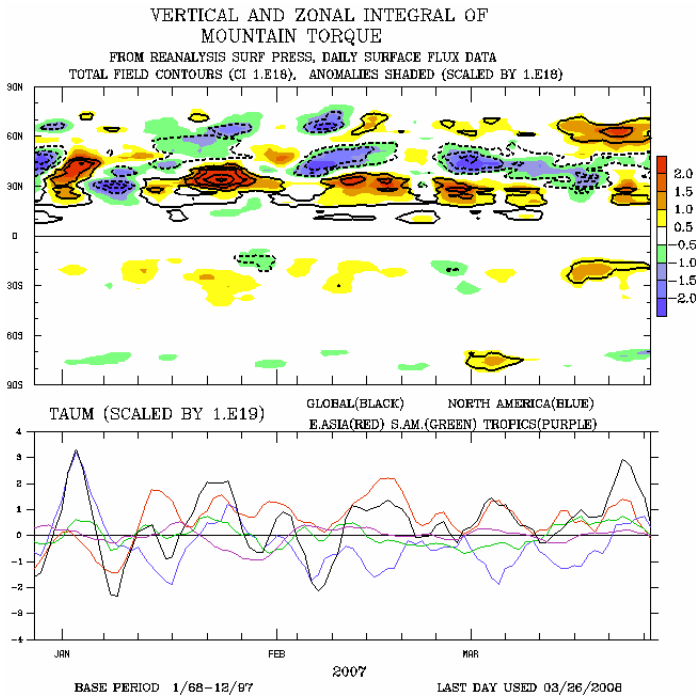


Torques (NOAA)

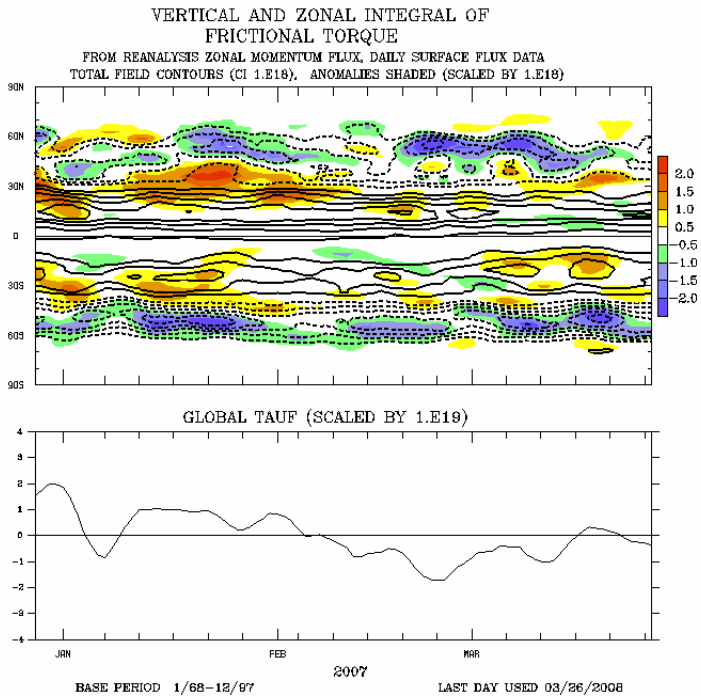
$$T_{mountain} = -R^2 \int\int p_s \frac{\partial Z}{\partial \lambda} \cos\phi d\phi d\lambda$$

$$T_{friction} = R^3 \int\int \tau \cos^2\phi d\phi d\lambda$$

Mountain



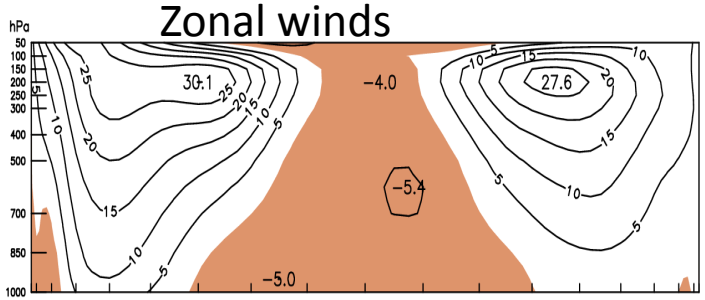
Friction



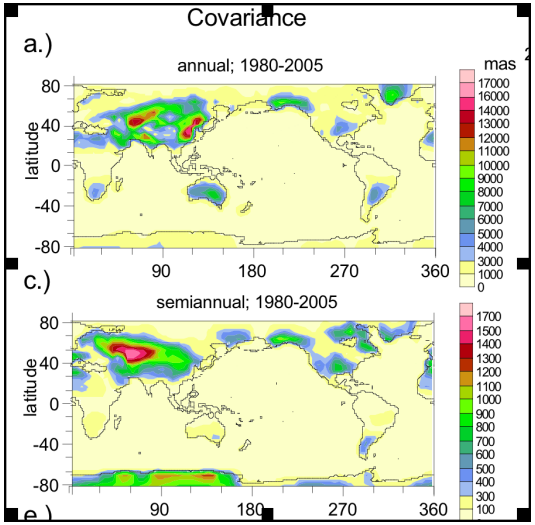
Different continental areas

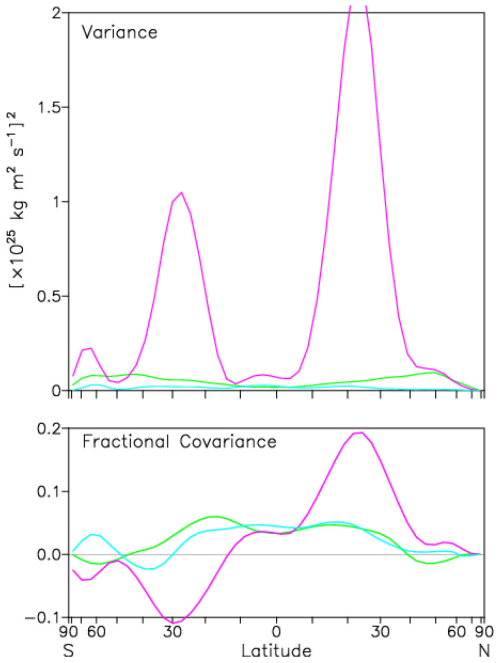
Where are changes coming from in the atmosphere?

Zonal winds



Pressure (polar motion)





Variance and fractional covariance by latitude

Conclusions

- The SBA is an effort, with data collected at AER and NOAA and links from many other groups
- SBA started as SBAAM, broadened its mission, when joined GGFC
- Different models and data assimilation (analyses) important
- Analyses show historical info; forecasts can be made; models projections into future
- Values are important themselves as atmospheric diagnostics and climate variables

Acknowledgment

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