An Overview of the Activities of the NASA Sea Level Change Team (N-SLCT)

Steve Nerem, University of Colorado
On behalf of the N-SLCT

NASA Sea Level Change Team (N-SLCT)

This program is intended to integrate research results, data sets, and model output to improve the accuracy and spatial resolution of sea level change estimates, and communicate these results in a simplified manner to the scientific community and general public. It is focused on the following four subelements, chosen because these areas are critical to improved understanding of sea level change, but lack adequate support:

- Proposals sought to address one or more of 4 elements:
  - Sea level rise and its regional variation
  - Improved knowledge of ice mass change
  - New sea level datasets
  - A NASA web portal for sea level change

Selected N-SLCT Investigations

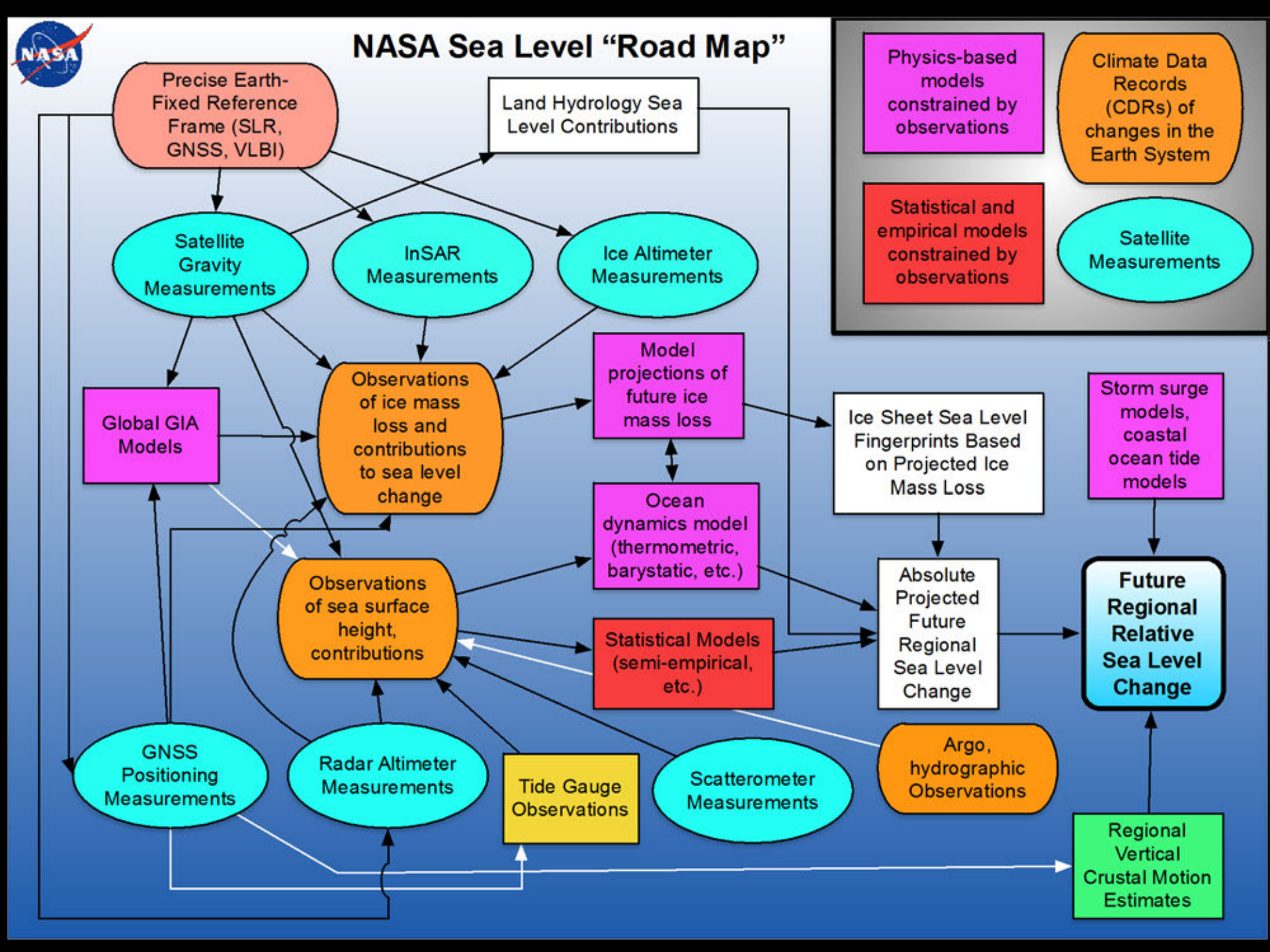
- Carmen Boening/Jet Propulsion Laboratory
  - "A NASA Web Portal for Sea Level Change"
- James Davis/Lamont-Doherty Earth Observatory
  - "Bayesian Integration of Multiple Geodetic Data Types for Investigation of the Coupled Impact of Climate Change on Earth Systems"
- James Famiglietti/University of California, Irvine
  - "Land Contributions to Regional and Global Mean Sea Level Rise"
- Patrick Heimbach/Massachusetts Institute of Technology
  - "Data and Forcing Integration for Improved Estimation of Spatial Sea Level Patterns and Their Uncertainties, With Extended Diagnostics for Closed Budget Analysis"
- Erik Ivins/Jet Propulsion Laboratory
  - "Ice Sheet Basal Conditions and Sea Level Rise"
- Steve Nerem/University Of Colorado, Boulder
  - "Observation-Driven Projections of Future Regional Sea Level Change"
- Richard Ray/Goddard Space Flight Center
  - "Past, Present, and Future Sea Level from Observations and Models"
- Eric Rignot/University of California, Irvine
  - "Mass Balance and Bed Topography Datasets of Ice Sheets for Sea Level Studies"

N-SLCT Team Members from Other Awards

- Anthony Arendt, University of Alaska, Fairbanks
  - GRACE, ICESAT, Icebridge
- Helen Fricker, Scripps Institution of Oceanography
  - ICESAT, ICESAT-2
- Ichiro Fukumori, Jet Propulsion Laboratory
  - Estimating mechanisms of the trend and decadal variability of sea level using an ocean general circulation model constrained by satellite altimeter observations
- Alex Gardner, Jet Propulsion Laboratory
  - Contributions of mountain glaciers to sea level change
- Ian Joughin, University of Washington
  - MEASURES PI, ice sheet velocities, cryospheric science
- Eric Larour, Jet Propulsion Laboratory
  - Ice sheet modeling

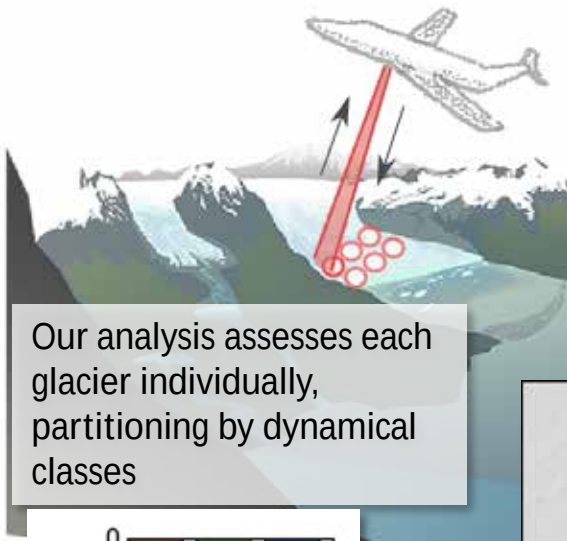
N-SLCT Team Members from Other Awards

- Bob Leben, University of Colorado
  - Sea level reconstructions
- Eric Leuliette, NOAA
  - NOAA climate and operational applications of satellite altimetry
- Scott Luthcke, NASA Goddard Space Flight Center
  - GRACE, ice mass contributions to sea level
- Sophie Nowicki, NASA Goddard Space Flight Center
  - Ice sheet modeling
- Ted Strub, Oregon State University
  - Processes connecting coastal to basin-scale ocean circulation
- Josh Willis, Jet Propulsion Laboratory
  - MEASURES PI, satellite altimetry, thermosteric sea level


NASA Sea Level "Road Map"
Precise Earth-Fixed Reference Frame (SLR, GNSS, VLBI)
Land Hydrology Sea Level Contributions
Satellite Gravity Measurements
InSAR Measurements
Ice Altimeter Measurements
Global GIA Models
Observations of ice mass loss and contributions to sea level change
Model projections of future ice mass loss
Ice Sheet Sea Level Fingerprints Based on Projected Ice Mass Loss
Storm surge models, coastal ocean tide models
Ocean dynamics model (thermometric, barystatic, etc.)
Observations of sea surface height, contributions
Statistical Models (semi-empirical, etc.)
Absolute Projected Future Regional Sea Level Change
Future Regional Relative Sea Level Change
GNSS Positioning Measurements
Radar Altimeter Measurements
Tide Gauge Observations
Scatterometer Measurements
Argo, hydrographic Observations
Regional Vertical Crustal Motion Estimates
Physics-based models constrained by observations
Climate Data Records (CDRs) of changes in the Earth System
Statistical and empirical models constrained by observations
Satellite Measurements

Surface melt dominates Alaska glaciers mass balance

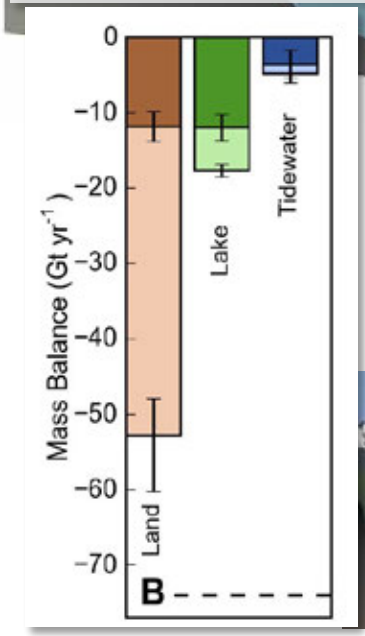
Larsen, Burgess, Arendt, O'Neel, Johnson, Kienholz (2015),
Geophysical Research Letters

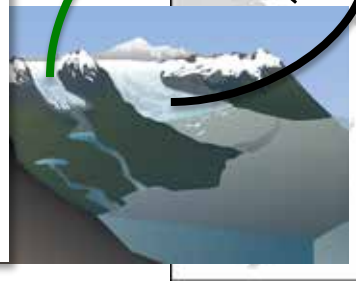


- Repeat glacier surface elevations measured using airborne laser altimetry supported by NASA's IceBridge program
- ~40% of regional ice cover directly measured
- Data extrapolated to all 87,000 km^2 of ice in Alaska/northern Canada

- Nearly all glaciers were thinning and losing mass (red colors) during the 20 year period

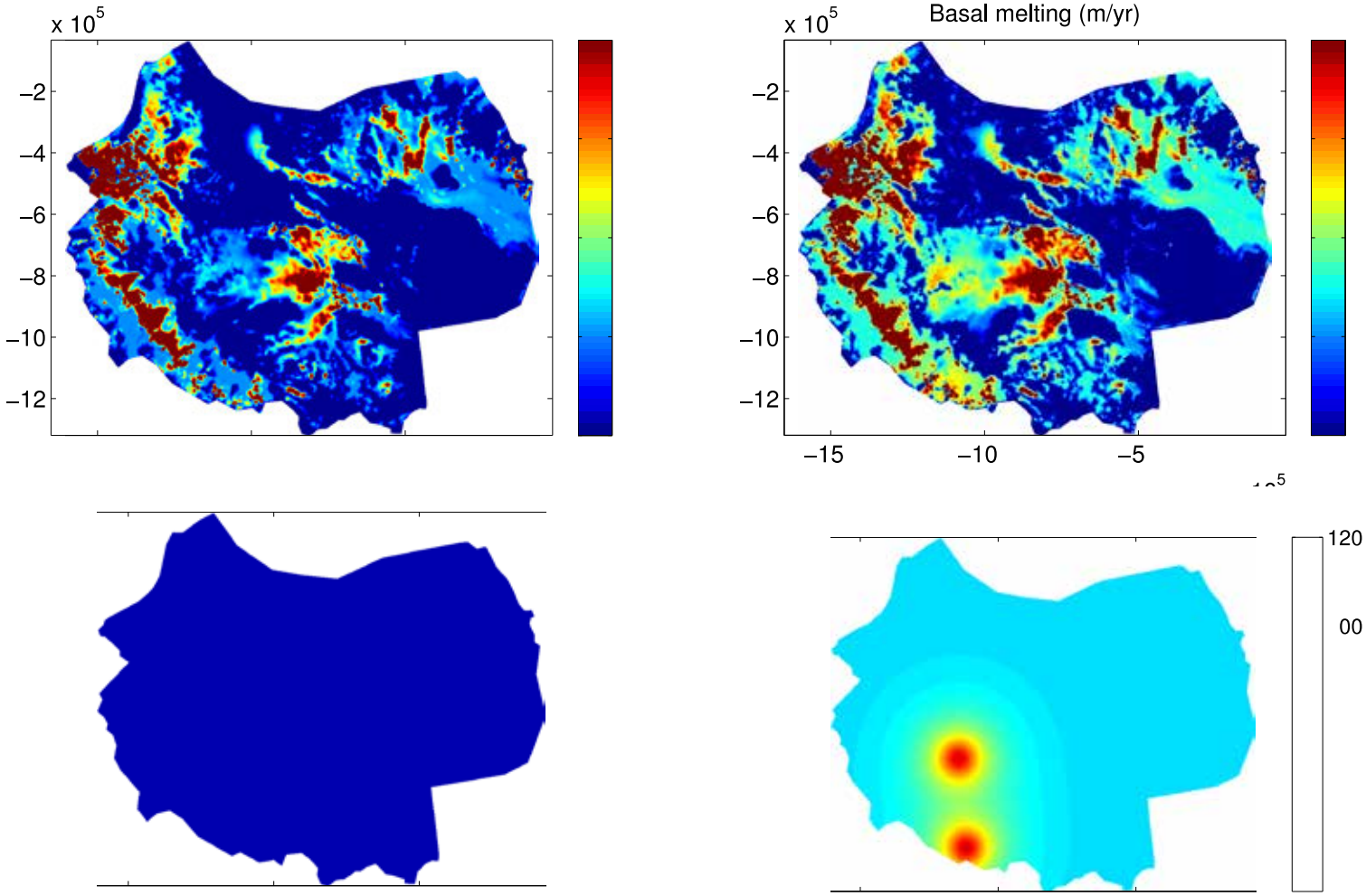
Our analysis assesses each glacier individually, partitioning by dynamical classes





Ice Sheet Basal Conditions and Sea Level Rise: Interface with Earth Structure Models and GIA

Erik Ivins, Helene Seroussi, Eric Larour

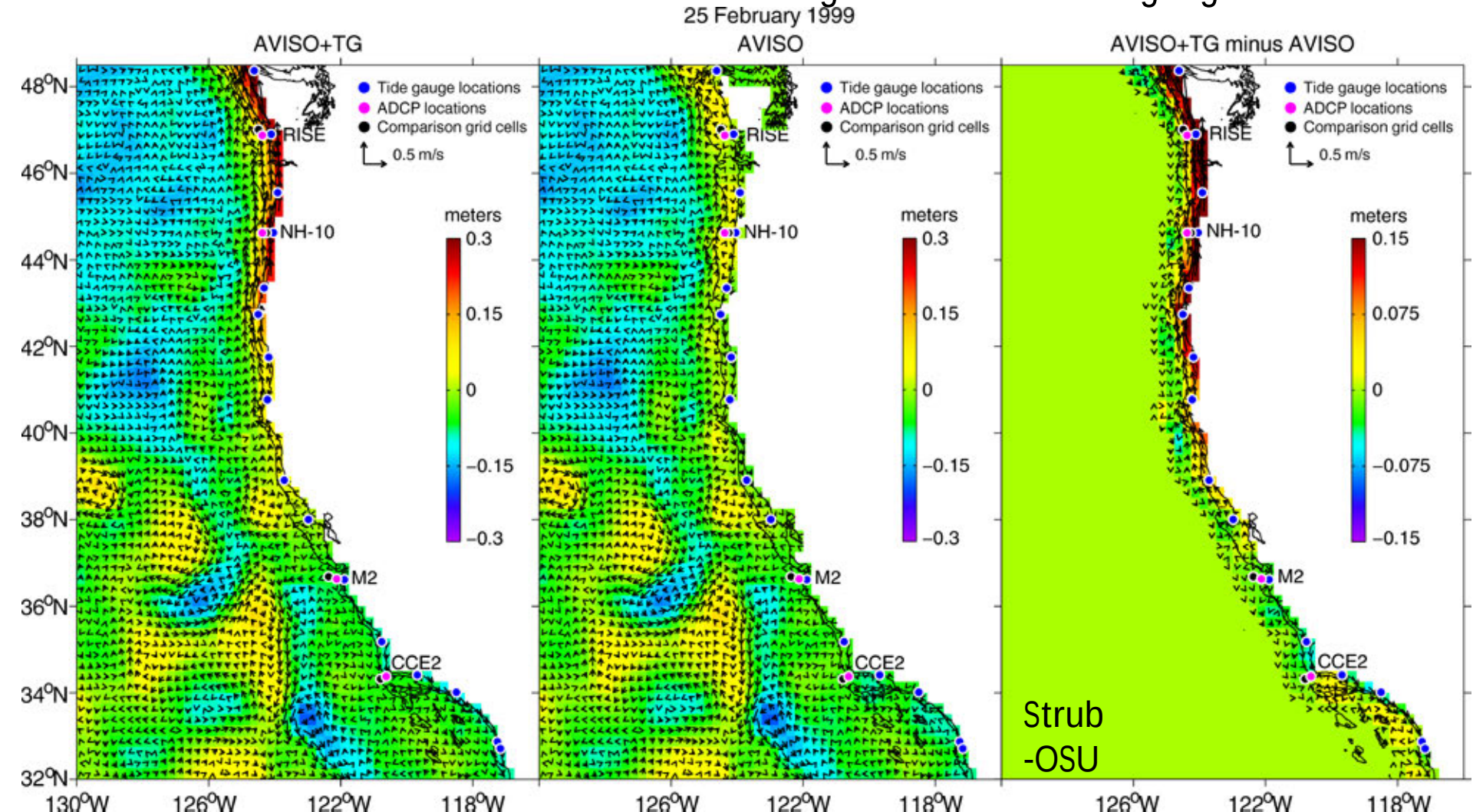


Next steps:

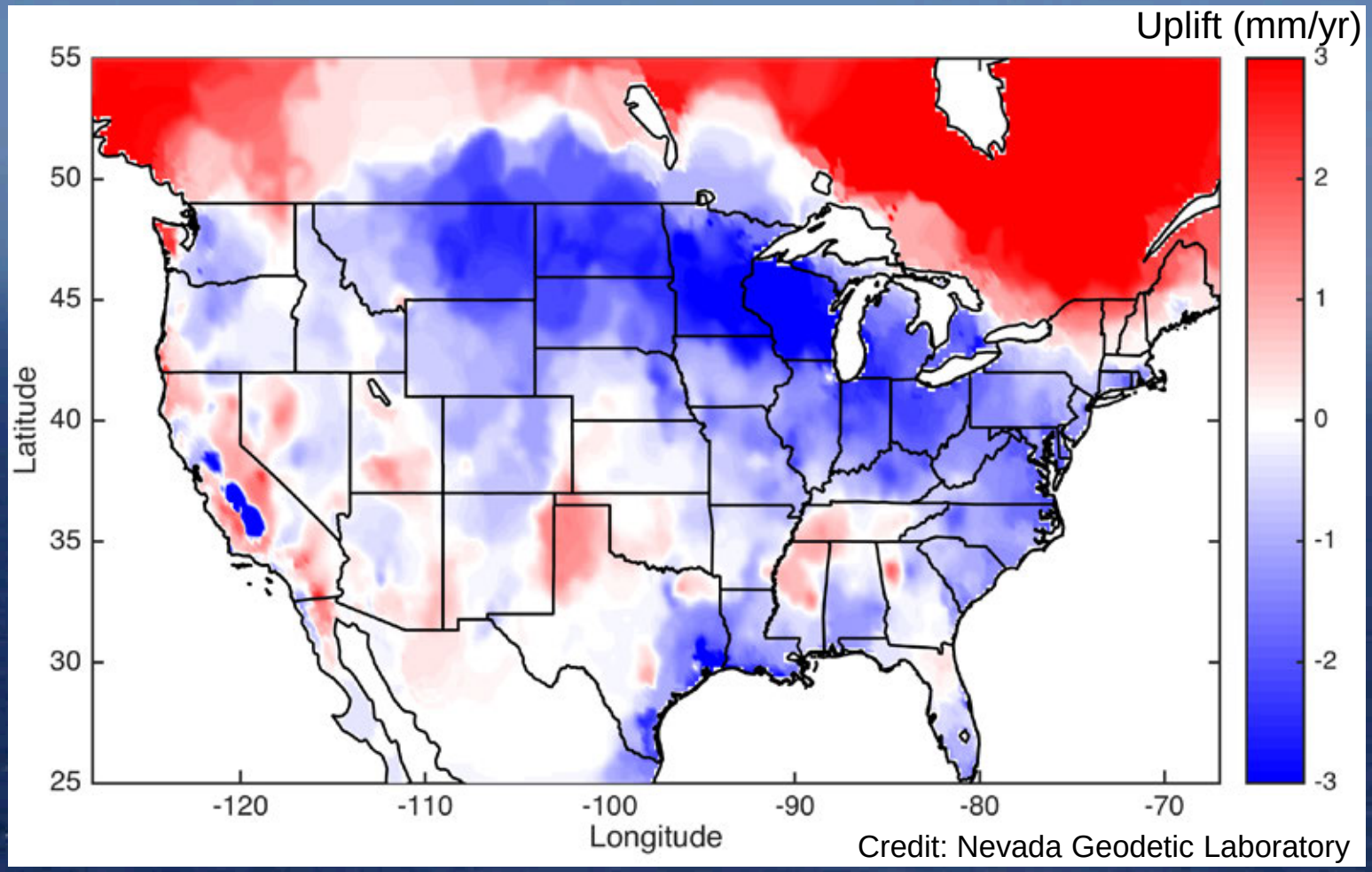
Define range of plume parameters and improve ice thermal model

Daily Merged Altimeter + Tide Gauge SLA: 1993-2014

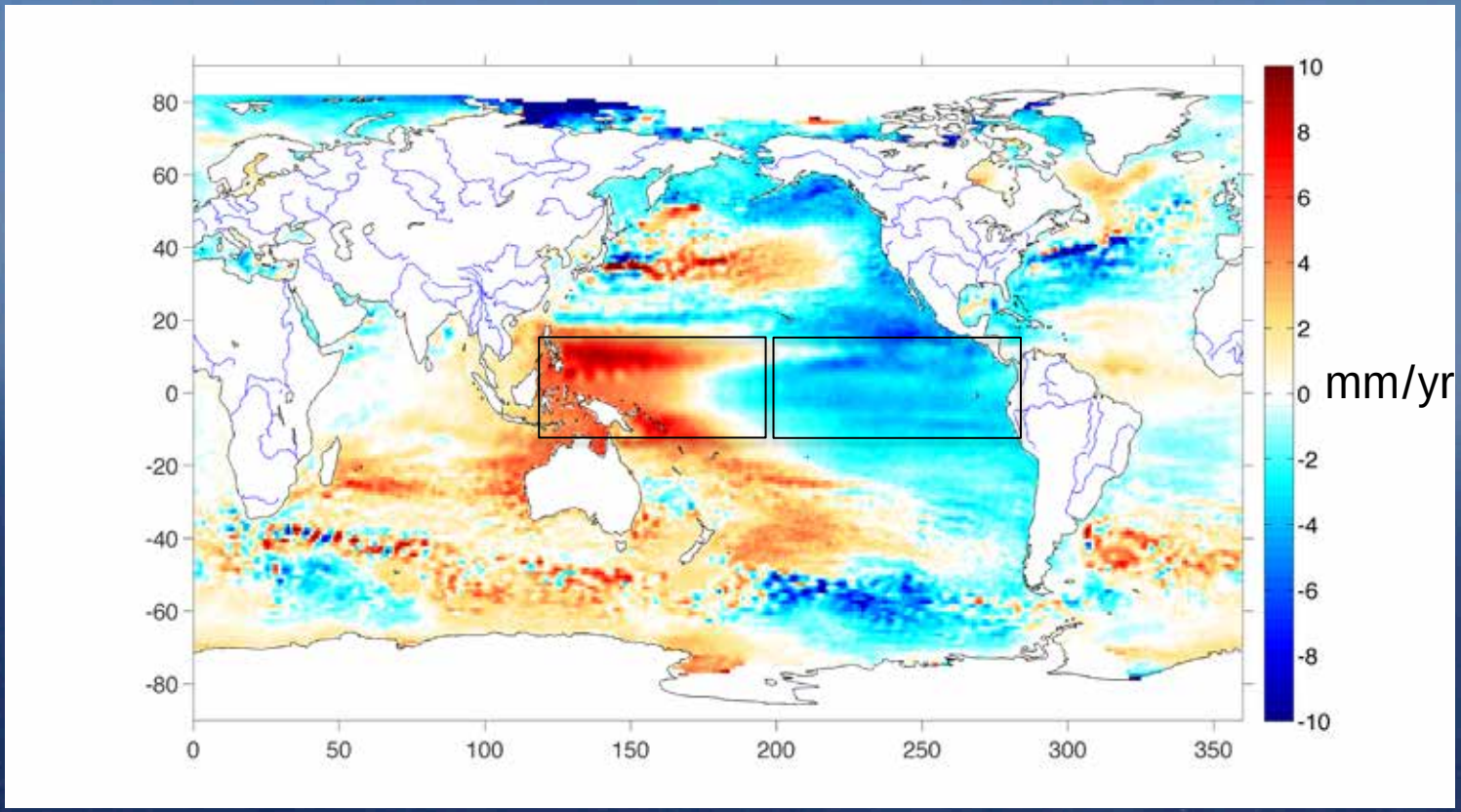
A daily SLA data set with enhanced coastal coverage is created by merging tide gauge data with AVISO daily ¼ ° gridded SLA fields. AVISO data within 70-100 km of the coast are replaced by interpolated TG data. In the right hand panel, the difference between the fields shows the changes due to the tide gauges.



GPS imaging of Vertical Land Motion: North America

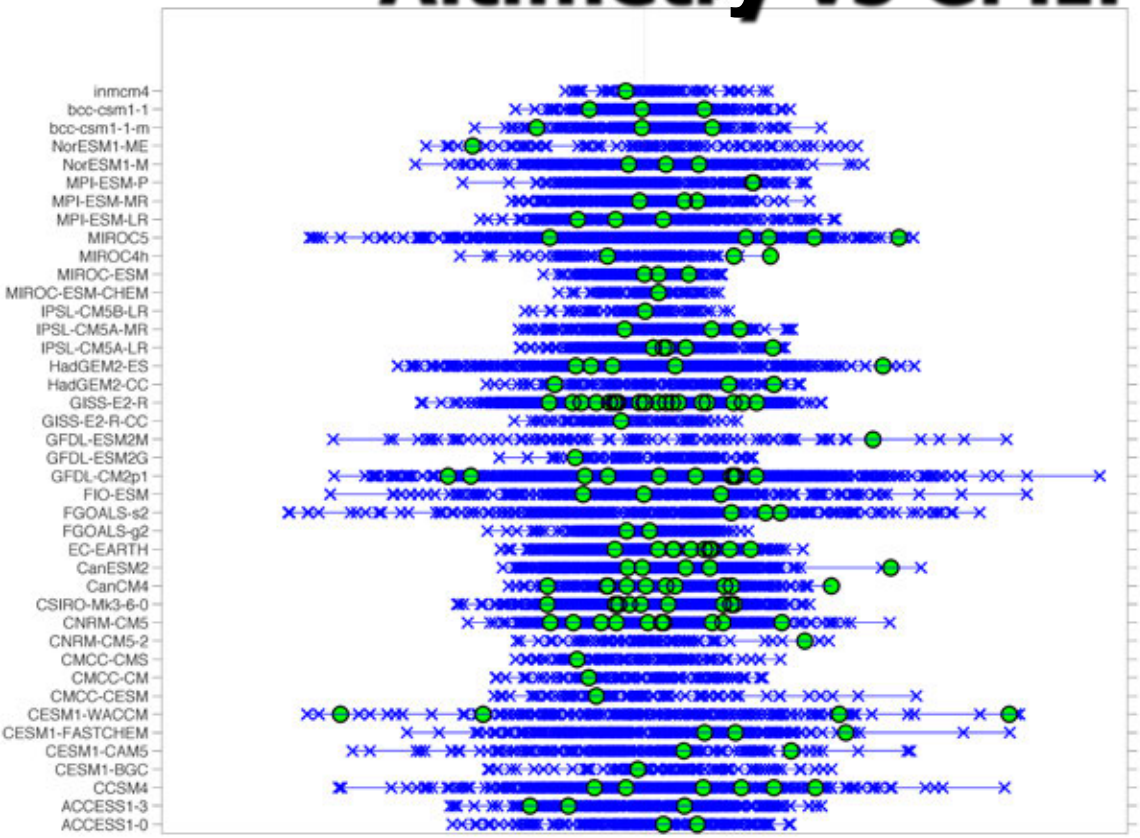


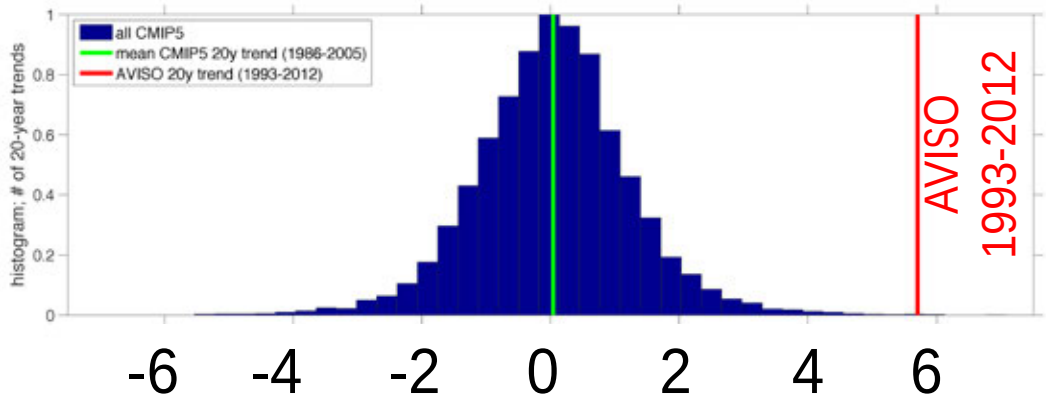
AVISO SSH trends (1993-2012)



- Pacific East-West dipole is the most prominent pattern over the last 20 years
- West minus East Pacific SSH 20-year trends:
  - CMIP5 *vs* observations?

Altimetry vs CMIP5 Models

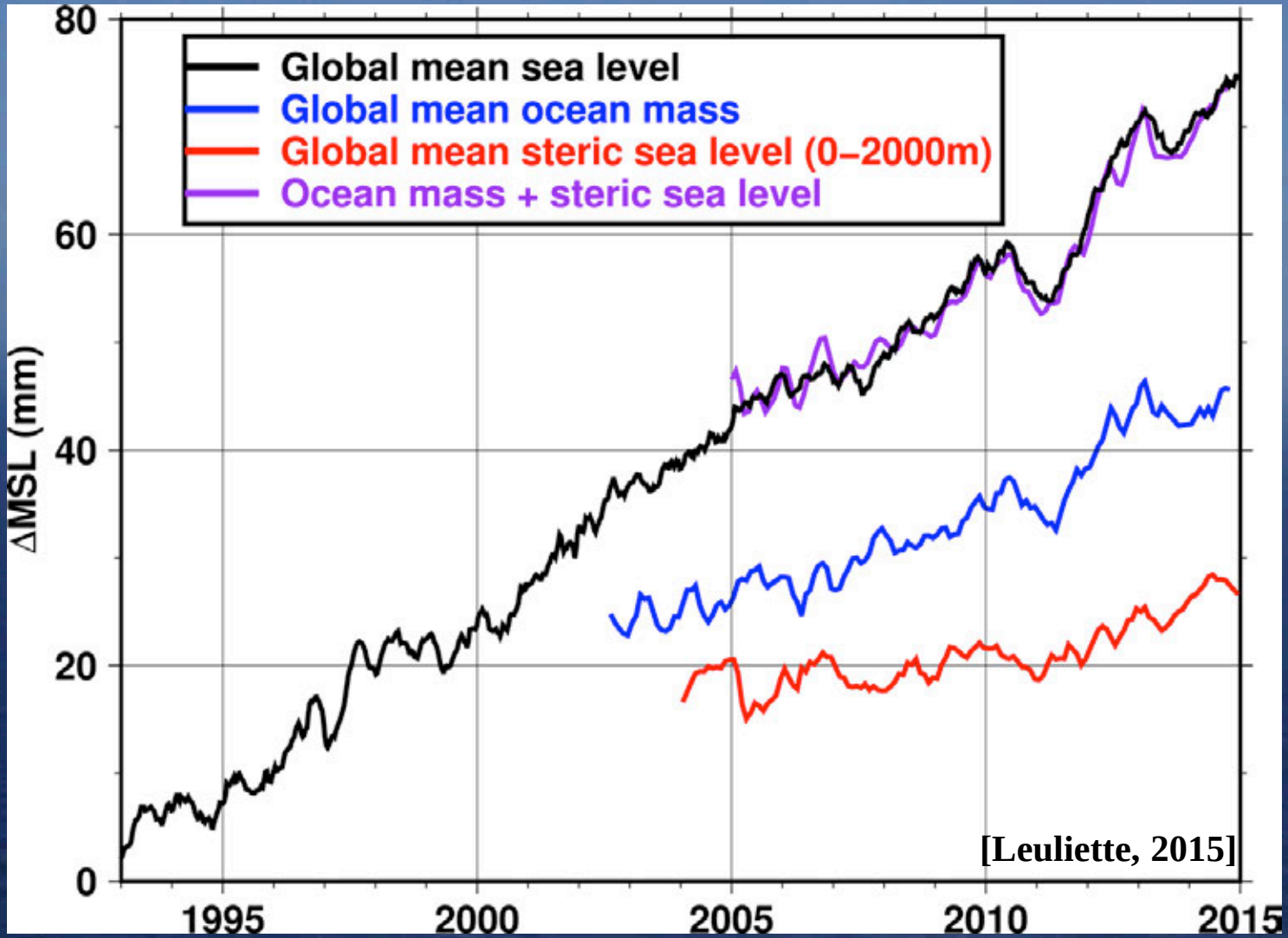




- Each **X** is a 20-year W-E Pacific trend value
- slide 20-year trend through 20C, increment by 1 year
- >13300 data points
- ● is the 1986-2005 20-year window

Landerer et al., 2015

Closing of the Sea Level Budget



Sea Level Change Web Portal
Portal Lead: Carmen Boening, JPL

- The Sea Level Change Portal will serve as ***central hub*** for enabling collaboration between the ***NASA Sea Level Change Team*** as well as distributing and communicating science results.
- The ultimate goal of the Sea Level Change Portal is to provide scientists and the general public with a ***"one-stop" source for current sea level change information and data***, including interactive tools for accessing, viewing, and analyzing regional data, and ongoing updates on sea level research that will help to facilitate ***interdisciplinary investigations*** and ***highlight NASA's sea level science***.

What's coming up for the N-SLCT?

- N-SLCT Fall Meeting November 10-12, 2015, "Towards understanding and projecting sea level change along the coast of the U.S."
- Initial release of web portal November/December 2015.
- AGU Town Hall Meeting December 17, 2015, 12:30-1:30 pm
- Recompetition of N-SLCT, 2016

COP21 OSTST Recommendation

"Observations of global sea level rise from space chart human caused climate change that is likely irreversible on time scales shorter than hundreds of years in a comprehensive and global way. As such the Ocean Surface Topography Science Team strongly recommends continued monitoring of sea level rise by precision satellite altimetry."

N-SLCT Questions?

- Eric Lindstrom, Steve Nerem, Richard Ray, Bob Leben, Josh Willis, Eric Leuliette, Ted Strub

21 years of global and regional sea level observations from the ESA-CCI Project

A.Cazenave[1,15], G.Larnicol[2],, M.Ablain[2], B.Meyssignac[1,15], J.F.Legeais[2], Y.Faugere[2], J.Benveniste[3], B.Manuel Lucas[3], S.Dinardo[3], J.Johannessen[4], D.Stammer[5], G.Timms[6], P.Knudsen[7], P.Cipollini[8], M.Roca[9], S.Rudenko[10], J.Fernandes[11], M.Balmaseda [12], G.Quartly[13], L.Fenoglio-Marc[14], T.Guinle[15].

1. LEGOS (France), 2. CLS (France) 3. ESA (Italy), 4.NERSC (Norway), 5. University of Hamburg (Germany), 6. CGI (UK), 7. DTU (Danemark), 8. NOC (UK), 9. isardSAT (Spain), 10. GFZ (Germany), 11. FCUP (Portugal), 12. ECMWF (UK), 13. PML (UK), 14. TUD (Germany), 15. CNES (France).

Context

GCOS
GLOBAL CLIMATE OBSERVING SYSTEM

esa
European Space Agency

CCI PROGRAM

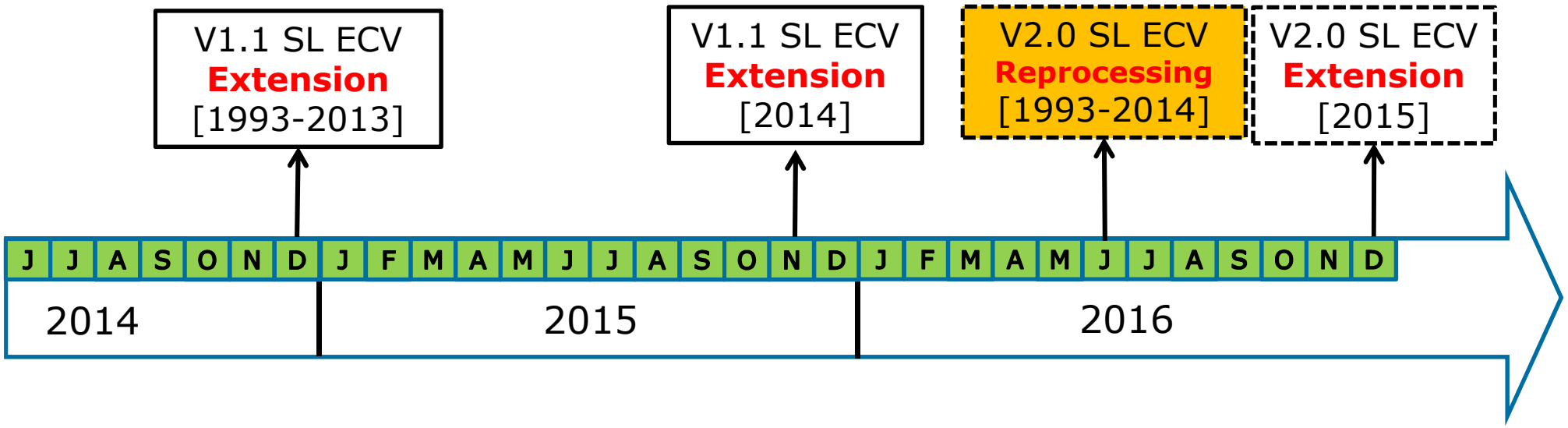
aerosol cci
ozone cci
ocean colour cci
cloud cci
sea ice cci
land cover cci
fire cci
cmug cci
sea level cci
sst cci
ghg cci
glaciers cci
soil moisture cci
ice sheets cci

Objective: To realise the best long term ECVs records the full potential of the long-term global Earth Observation archives from satellites (not just ESA but all sources via international collaboration) as a significant and timely contribution to the ECV databases required by UNFCCC and GCOS

What is in the CCI-sea level product?

Sea level multi-mission product based on satellite data from ESA, CNES, EUMETSAT, NASA, NOAA, US NAVY, ISRO…

- Current version with 7 missions (re)processed over 1993-2013 (T/P, Jason1/2, ERS-1/2, ENVISAT & GFO)
- same approach and data flow as for AVISO products but with uses improved standards developped for climate studies.
- A full reprocessing is planned in June 2016



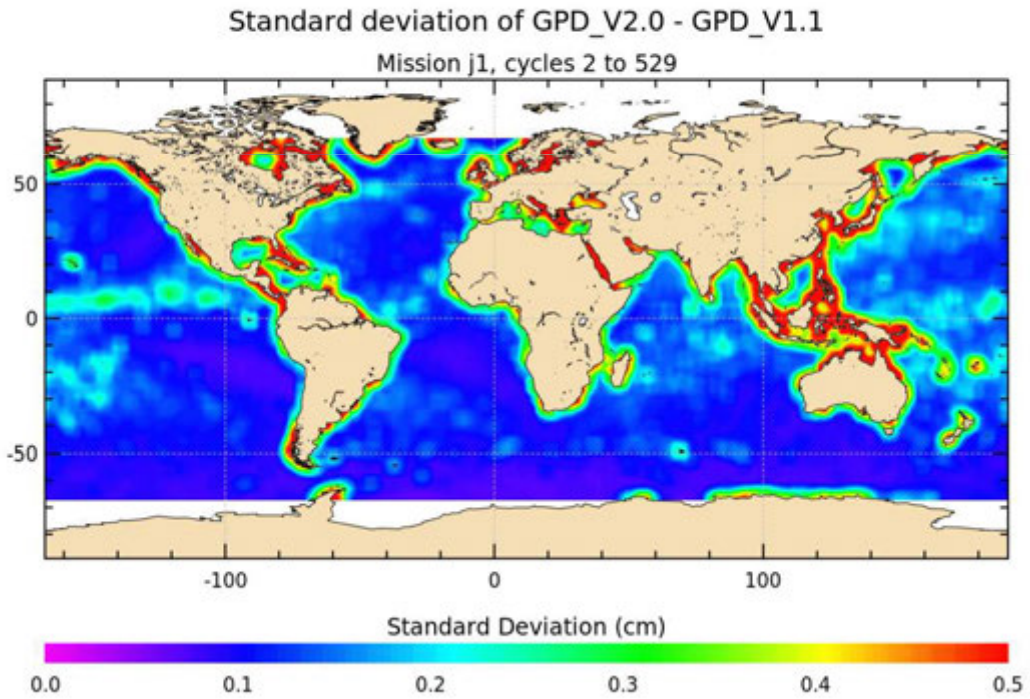
Improvements of the sea level record for climate studies

- The development of new algorithms/altimeter standards is finished
- The evaluation is on-going, and a selection meeting is planned to select the best algorithms for SL_cci V2.0

- **New tides (model) corrections:**
  - GOT4.10 and FES2014 was evaluated

- **New orbit solutions**
  - New GFZ and CNES orbit solutions

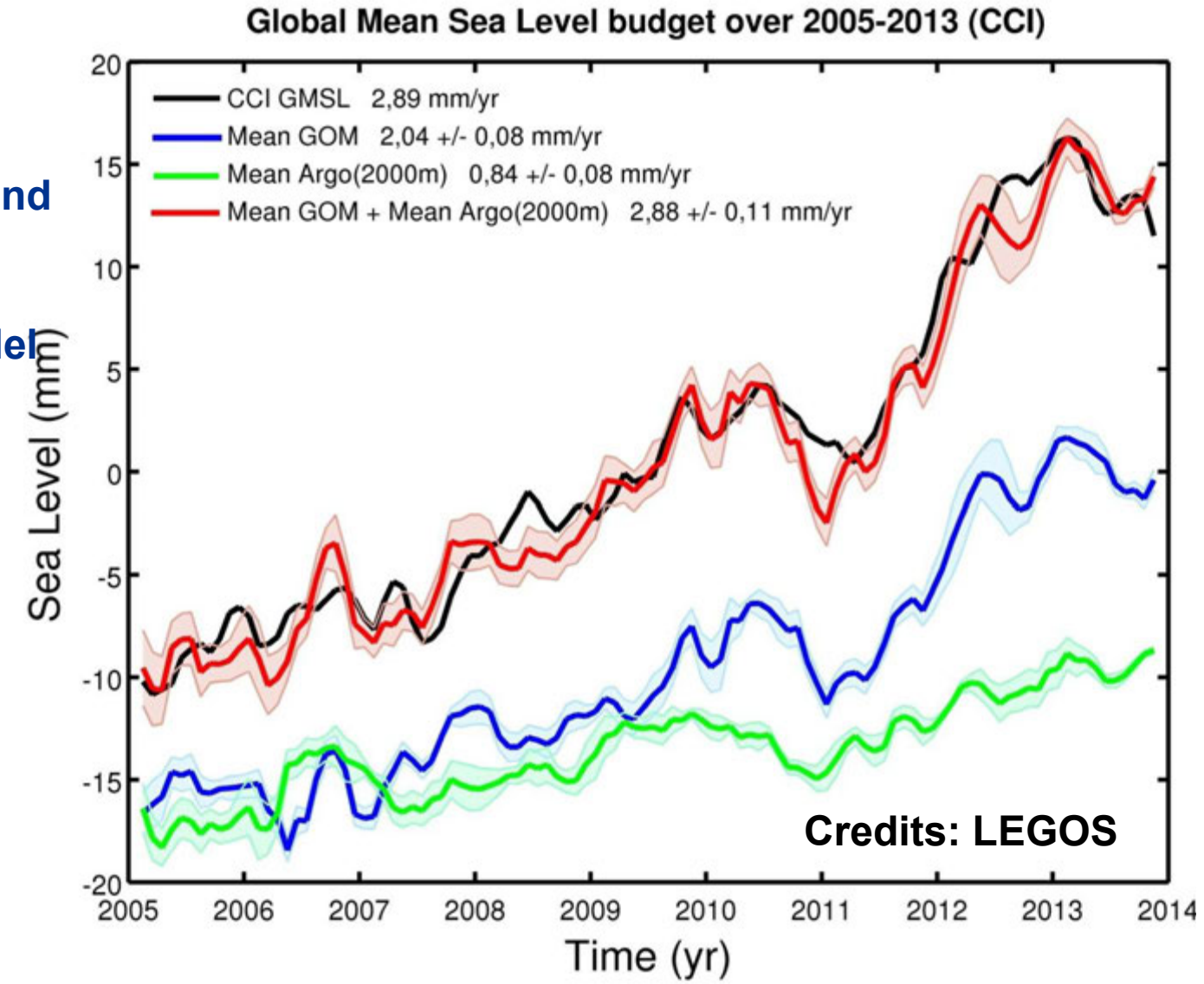
- **New atmospheric fields**
  - From ERA interim the Japanese reanalysis (JRA-55)
  - From radiometer correction (University of Porto)



Improvements of the sea level record for climate studies: Validation

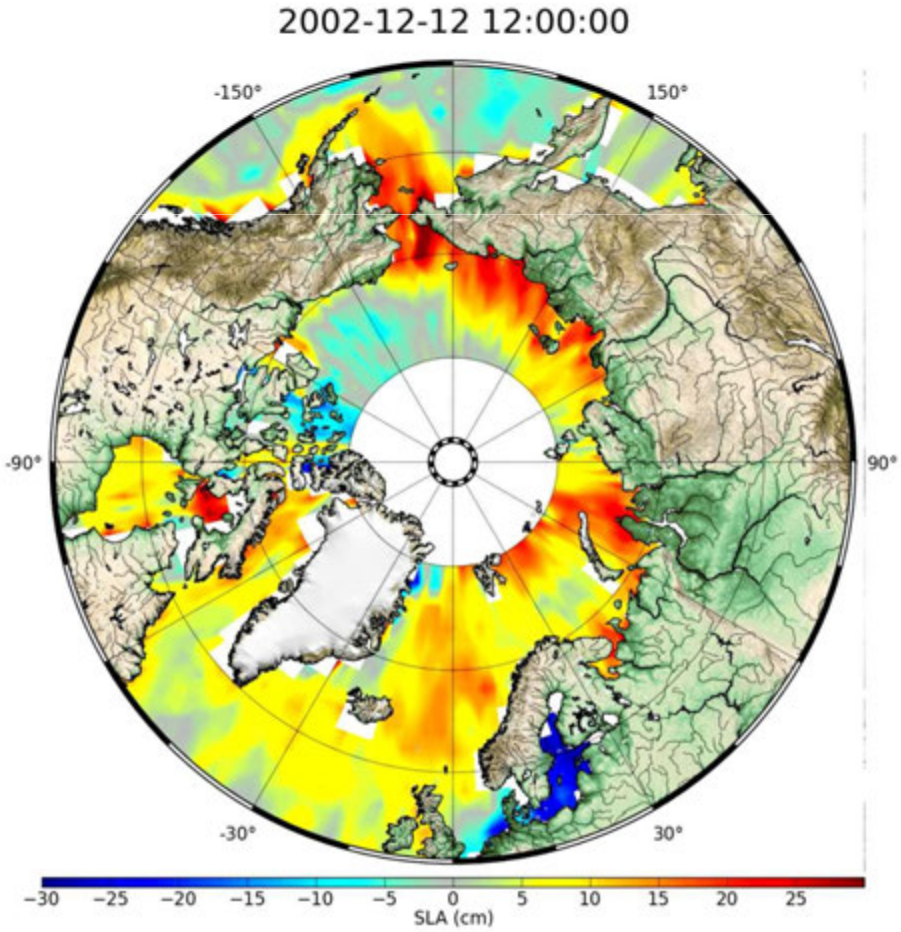
Assessment of SL_cci ECV products via:

- **Internal consistency check and comparison with in-situ data**
- **Comparison with ocean model assimilation experiments, by quantifying changes of the model performances.**
- **sea level budget studies at inter-annual scales**



Improvements of the sea level record for climate studies

- New Seal-Level Arctic products significantly improved over the frozen Arctic Ocean
  - Very good coverage over leads and SLA quality seems good
  - Continuity between open and ice covered ocean (thanks to new retracking)

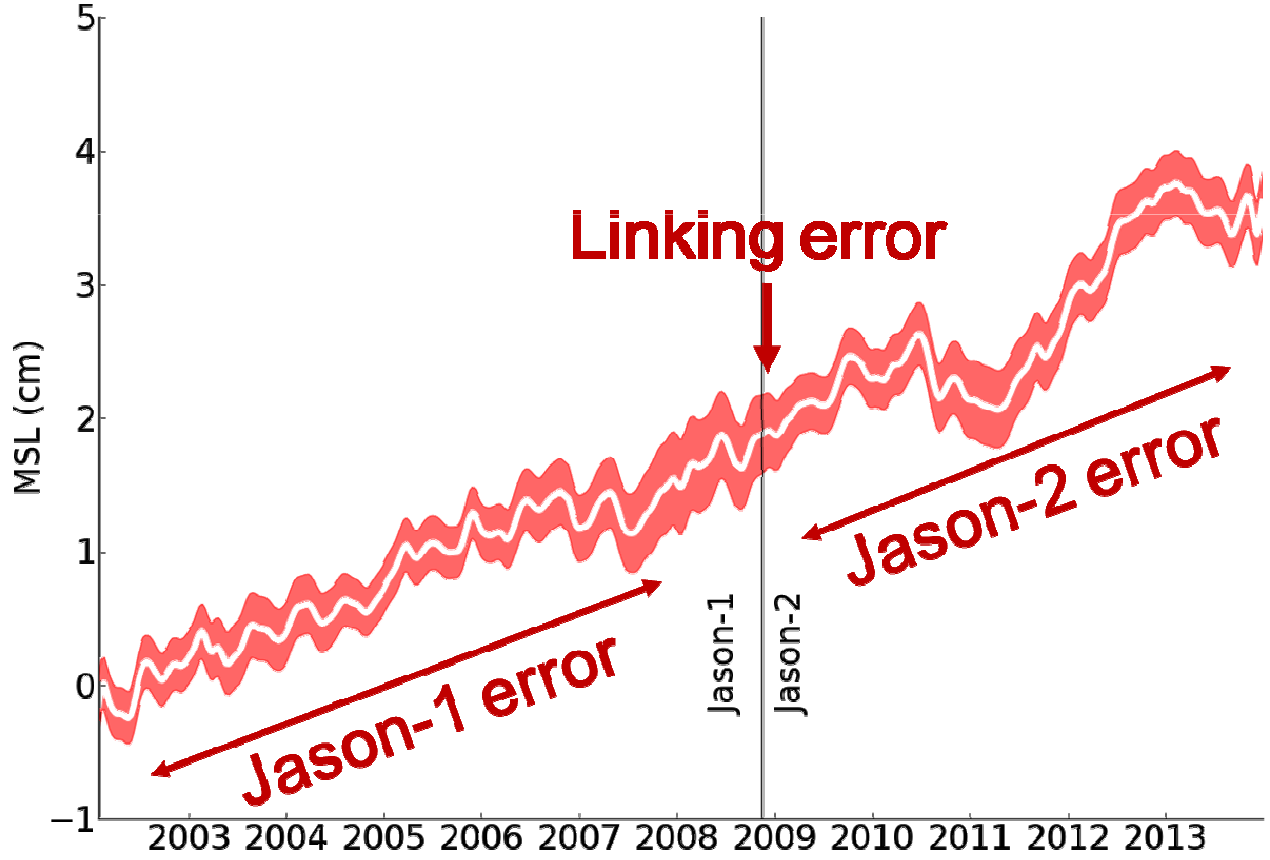


Envisat SLA from 20 Hz Envisat Data

Evaluation on- going

ESA CCI_Sea_Level: Uncertainties

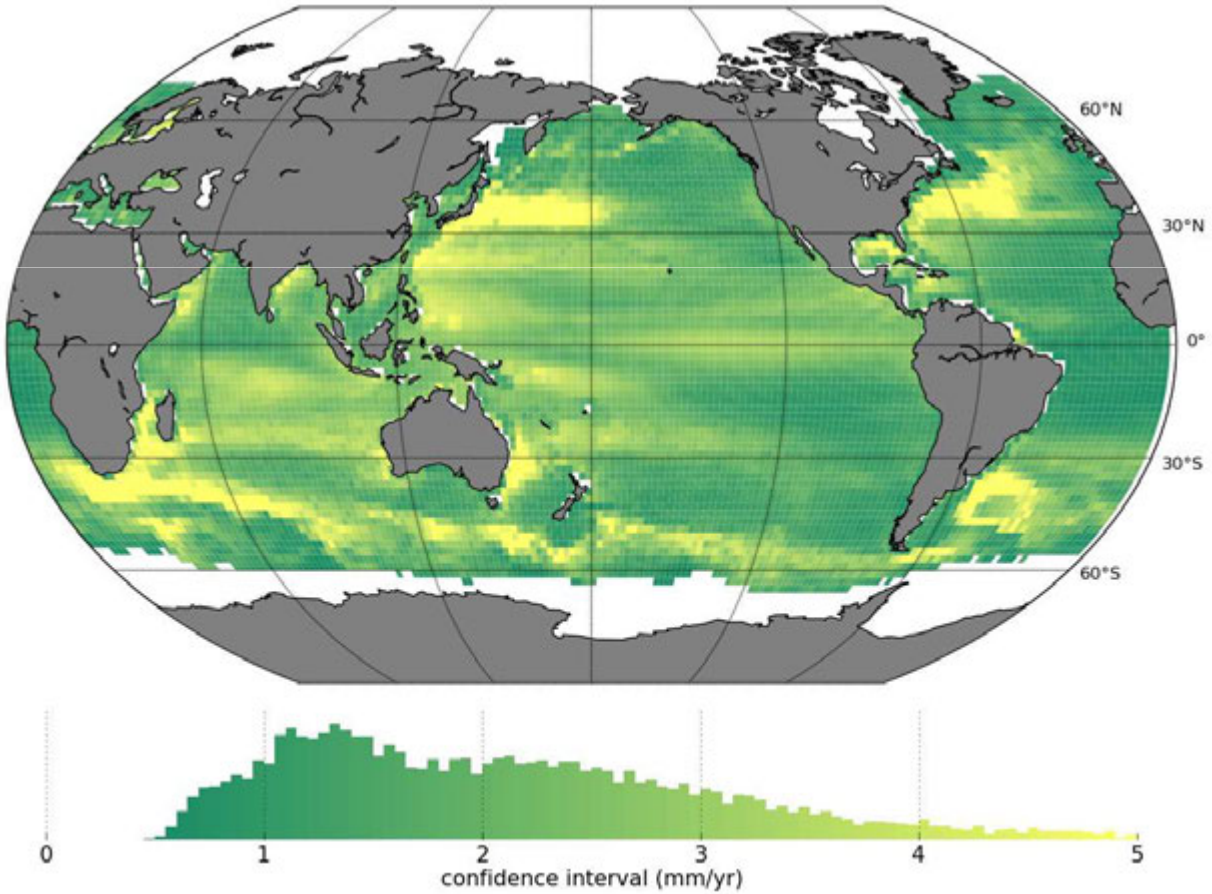
- **Uncertainty in GMSL trend:**
  ±0.5 mm/yr over 1993-2013 and ±0.36 mm/yr over 2000-2013
- **Uncertainty in GMSL variations (available in the next release): ~±2. mm**



See Zawadzki et al. presentation on Thursday 09:45, Grand Ballroom 1

ESA CCI_Sea_Level: Uncertainties

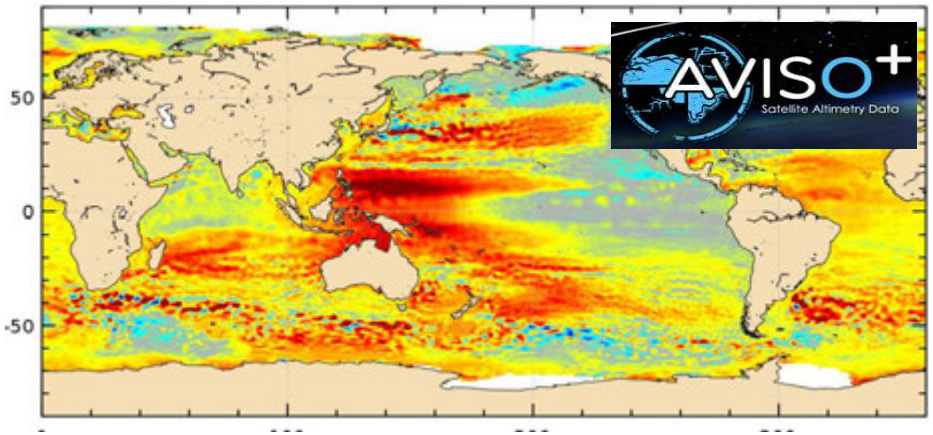
- **Uncertainty in regional sea level trend: from ±0.5 mm/yr to ±3 mm/yr over 1993-2013**



Work in progress

See Prandi et al. presentation on Thursday 10:15, Grand Ballroom 1

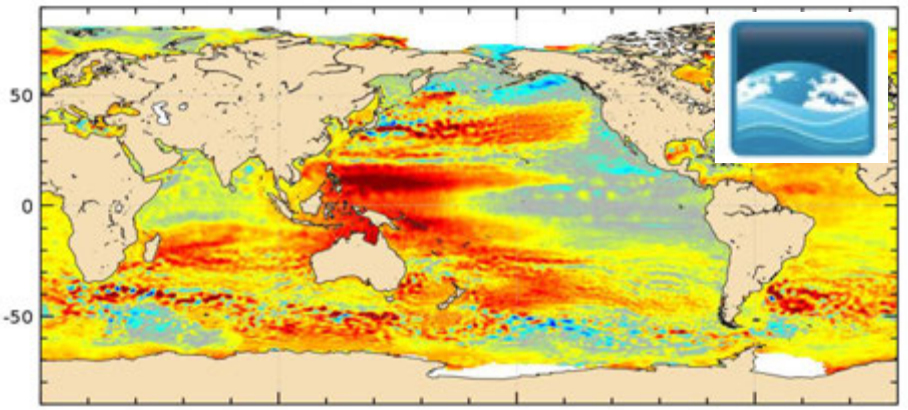
different products for different needs



Link: http://www.aviso.altimetry.fr

dataset: daily, along track or gridded (¼°x¼°)
Many products: mono and multi-mission near RT or delayed (with update ~5month)

objectives: optimised for mesoscale and ocean circulation. Provide frequently updated data and near RT products, high accuracy GMSL…
common applications: sea level studies at monthly to multi-decadal time scales, ocean circulation studies operationnal oceanography, assimilation in reanalysis(1993-2013).



Link: http://www.esa-sealevel-cci.org

dataset: monthly, gridded (¼°x¼°)

1 product: multi-mission, delayed (with update ~1yr, since Dec 2014)

objective: optimised for long term trends and decadal variability
common applications: sea level studies at interannual to multi-decadal time scales, trend studies, assimilation in long term reanalysis (1958-2013).

A.Cazenave[1,15], G.Larnicol[2],, M.Ablain[2], B.Meyssignac[1,15], J.F.Legeais[2], Y.Faugere[2], J.Benveniste[3], B.Manuel Lucas[3], S.Dinardo[3], J.Johannessen[4], D.Stammer[5], G.Timms[6], P.Knudsen[7], P.Cipollini[8], M.Roca[9], S.Rudenko[10], J.Fernandes[11], M.Balmaseda [12], G.Quartly[13], L.Fenoglio-Marc[14], T.Guinle[15].

1. LEGOS (France), 2. CLS (France) 3. ESA (Italy), 4.NERSC (Norway), 5. University of Hamburg (Germany), 6. CGI (UK), 7. DTU (Danemark), 8. NOC (UK), 9. isardSAT (Spain), 10. GFZ (Germany), 11. FCUP (Portugal), 12. ECMWF (UK), 13. PML (UK), 14. TUD (Germany), 15. CNES (France).