# *Tropical Pacific Observing System 2020 project and the connections to the Ocean Data Assimilation Community*

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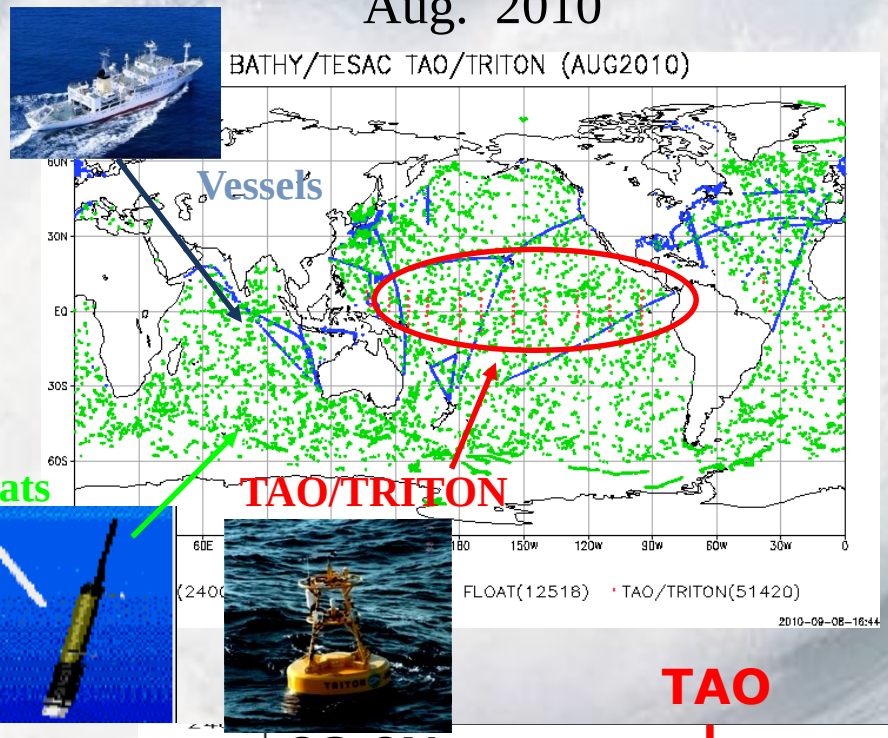
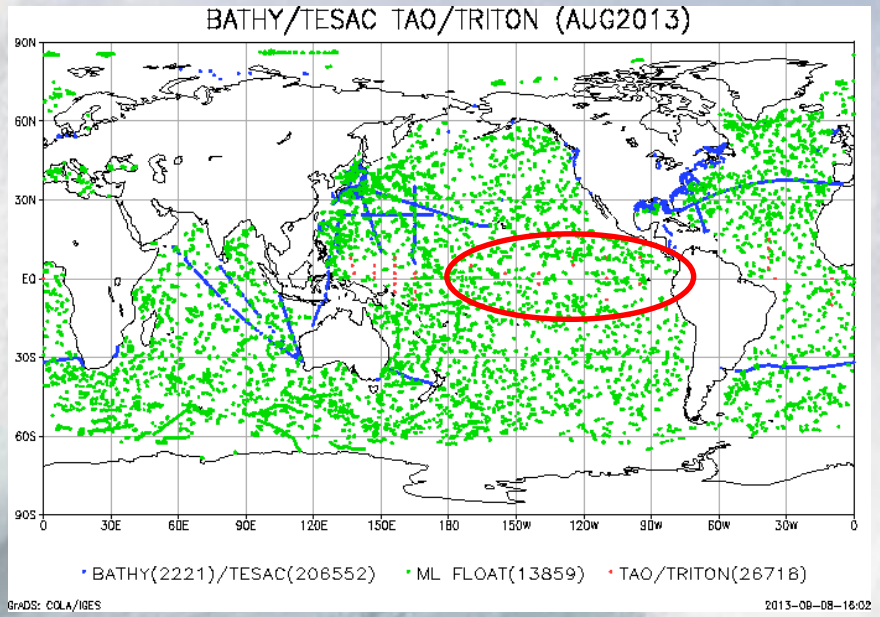
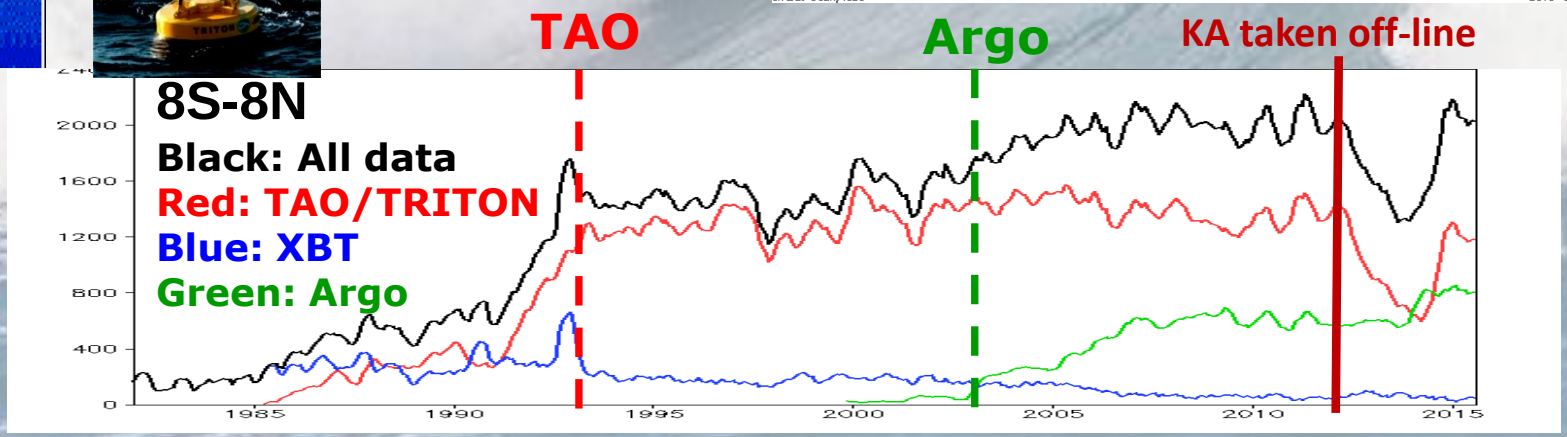
# ☆ TAO Array Crisis（2012-2014)

Aug. 2010




Aug. 2013




The number of observation data from TAO array severely reduced after the retirement of a NOAA's research vessel (KA).

# *NATURE NEWS gave warning on the crisis.*

*NATURE* | NEWS

## El Niño monitoring system in failure mode

**US budget woes cripple a key mooring array in the tropical Pacific Ocean.**

**Jeff Tollefson**

23 January 2014

Print

*NOAA*

Nearly half of the buoys in the Tropical Atmosphere Ocean array have failed because of delayed maintenance.

An ocean-monitoring system that extends across the tropical Pacific is collapsing, depriving scientists of data on a region that influences global weather and climate trends.

# ☆The La Jolla Workshop in Jan. 2014

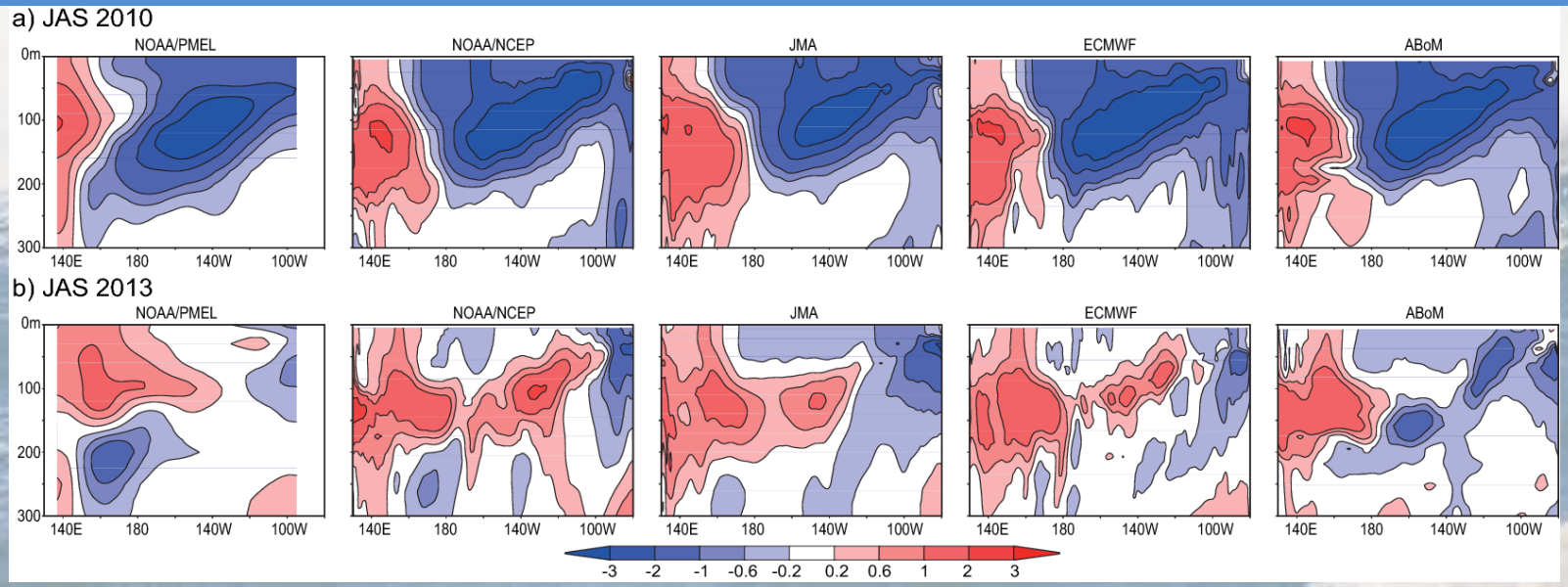
- The workshop was held in Jan. 2014 in response to this crisis.
- Evaluation of the impacts of Tropical Pacific Observing System (TPOS) on the ocean Data Assimilation systems (Fujii et al. 2015, QJRMS)
- Potential requirements of the TPOS for operational services and researches were summarized. (See white papers of the workshop)
- NOAA promised to recover TAO buoys to the level before the crisis and followed through. However this may just be a temporary solution.
- TPOS2020 project was proposed for reassessing TPOS and recommending design changes towards a more sustainable observing system

# ★ 2 difficulties we met in the La Jolla Meeting (1)

1. We had no systematic method to show promptly how the crisis influenced the performance of ocean DA and forecast systems and convey that information to relevant stakeholders (e.g., funding managers, society) .

- ✓ I managed to make the figure below in order to show the negative impacts of the TAO reduction.
- ✓ Large differences among systems in the summer of 2013 indicate that constraint of the analyzed ocean state was not enough due to lack of observations.
- ✓ This experience led us to the Real-Time MultiORA project.

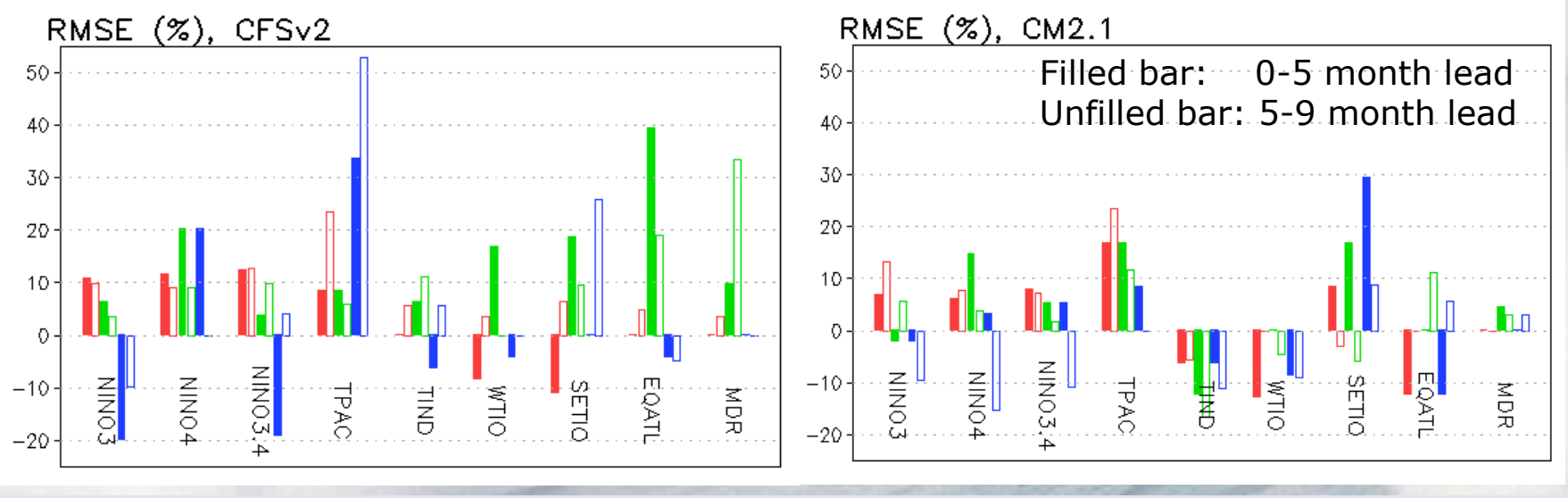
Comparison of the T anomaly in the equatorial Pacific (2˚S-2˚N) vertical (0-300m) section



# ★ 2 difficulties we met in the La Jolla Meeting (2)

1. A sentiment that model biases and model dependencies are too severe to evaluate the observing system through DA systems.

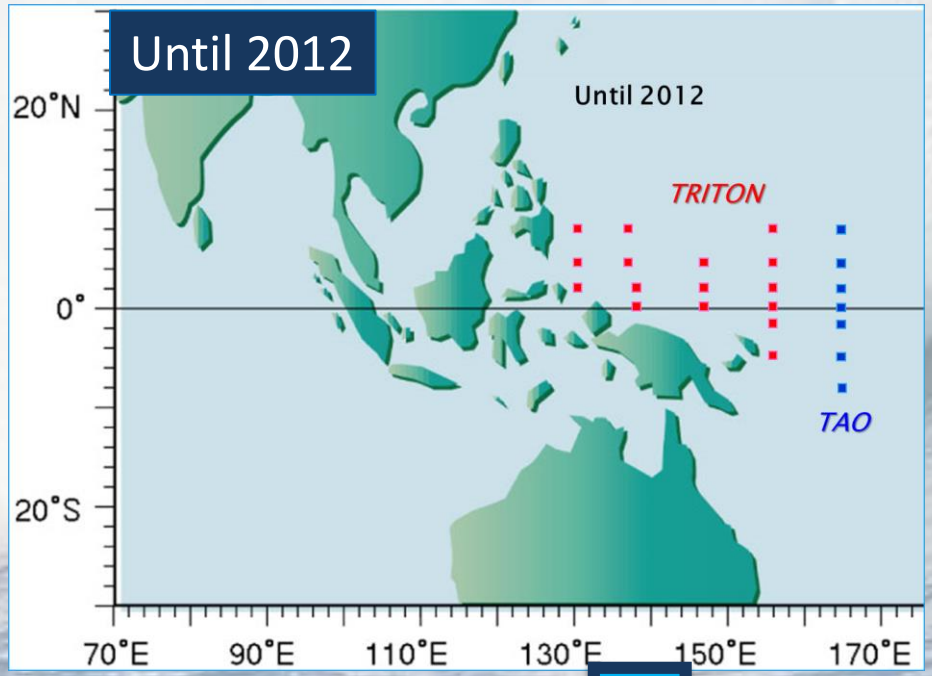
Impacts TAO, Argo, In-situ on RMSE skill for various SST indices

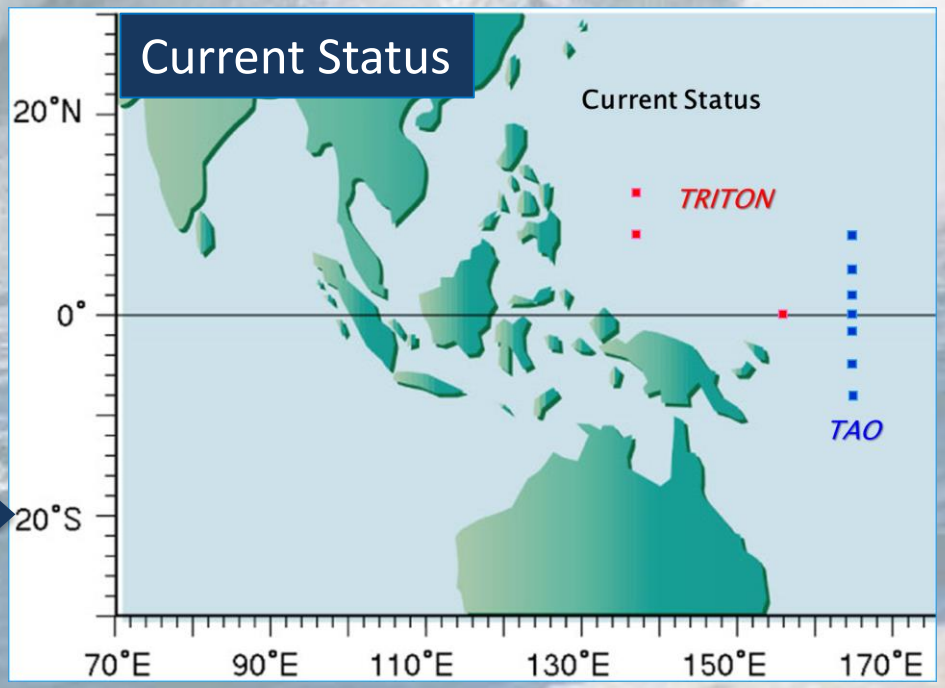



- TAO and Argo improves RMSE by 10-20 % for ENSO
- TAO, Argo, XBT together improved RMSE for ENSO, but not for short lead for NCEP and not for long lead for GFDL. The impact is often smaller than TAO or Argo alone.
- There is a large difference between the two systems
- indicating model systematic biases and model initialization shocks are obstacles in quantifying benefits of ocean observing systems

# ☆Further reduction of the TAO/TRITON array

Although efforts by NOAA recovered TAO array subsequent to La Jolla workshop, JAMSTEC reduced the number of TRITON buoys to 3



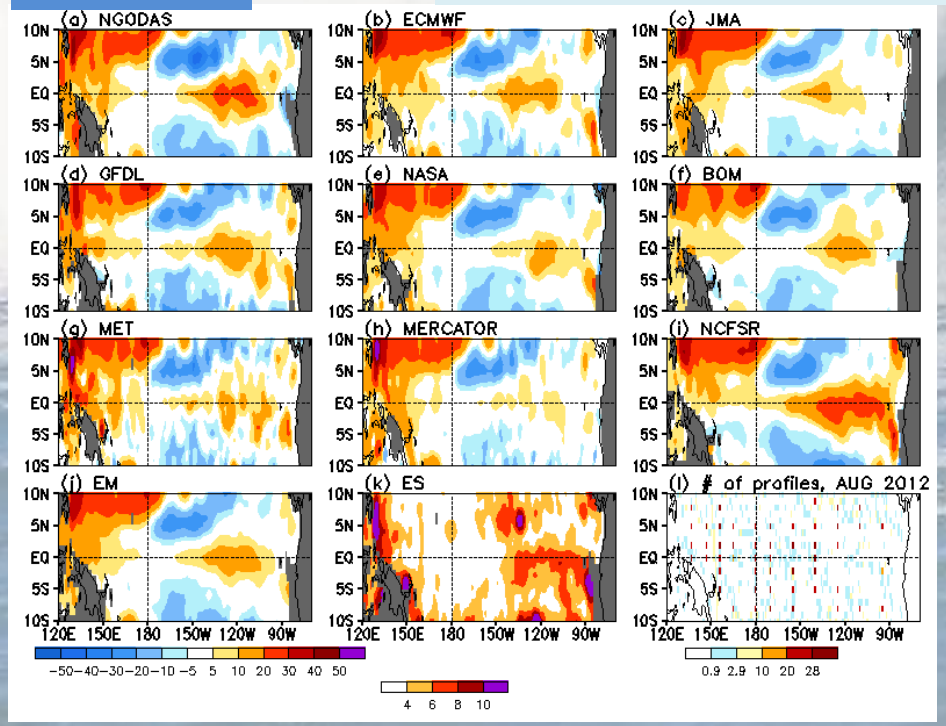
# ☆ Real-Time Multi-ORA Intercomparison

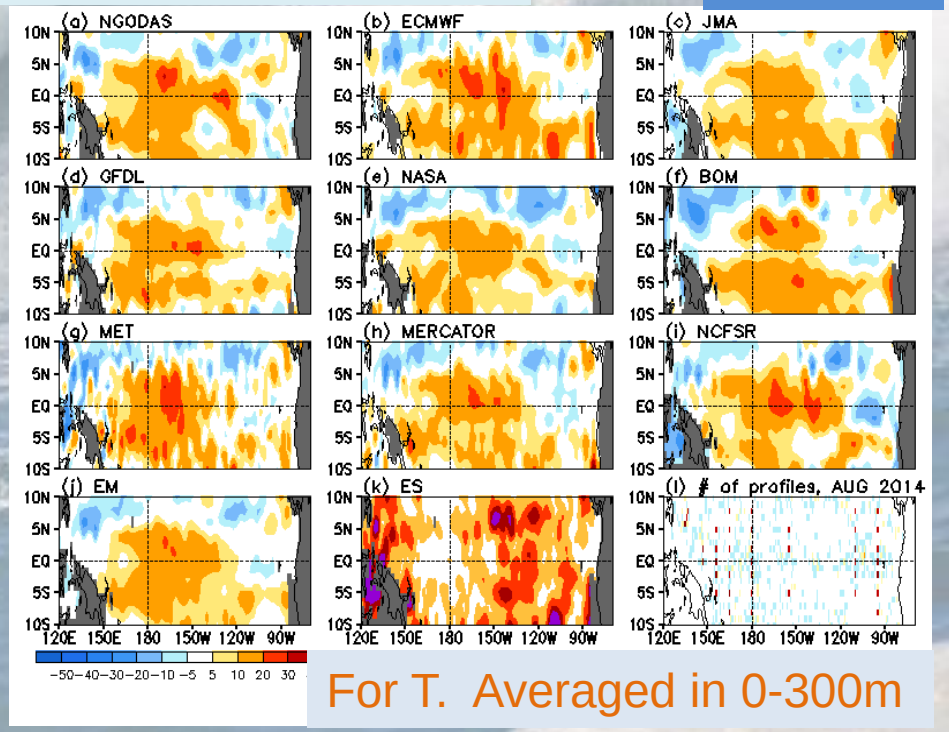
- ✓ Started 2014 according to the Proposal in La Jolla for real-time monitoring of impacts of TPOS
- ✓ Led by NCEP (temperature) and ABOM (salinity)
- ✓ Results of comparison are opened in near-real time via internet and NCEP Ocean Briefing. (Updated every month.)
- ✓ Temp.: http://www.cpc.ncep.noaa.gov/products/GODAS/multiora_body.html
- ✓ Sal.: http://poama.bom.gov.au/project/salt_19812010

Apr2012

An example figure on the web page

Apr2014

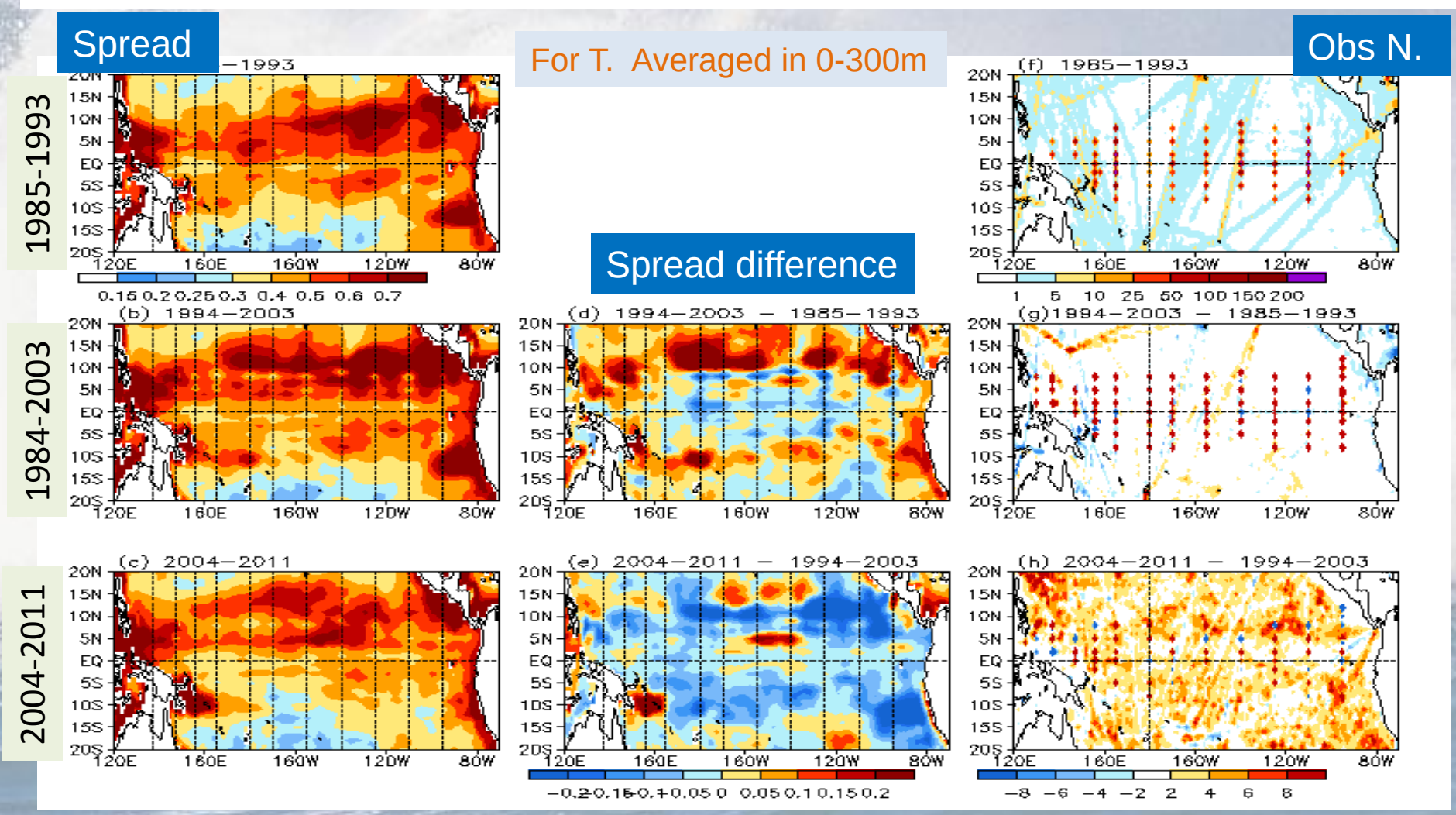



For T. Averaged in 0-300m

# ☆ Retrospective intercomparison of the Multi-ORA

➢ The results are summarized in Xue et al., 2017, Clim. Dyn. doi:10.1007/s00382-017-3535-y




✓ 1990s: Completion of TAO Array ⇒ The spread is reduced in the tropical Pacific

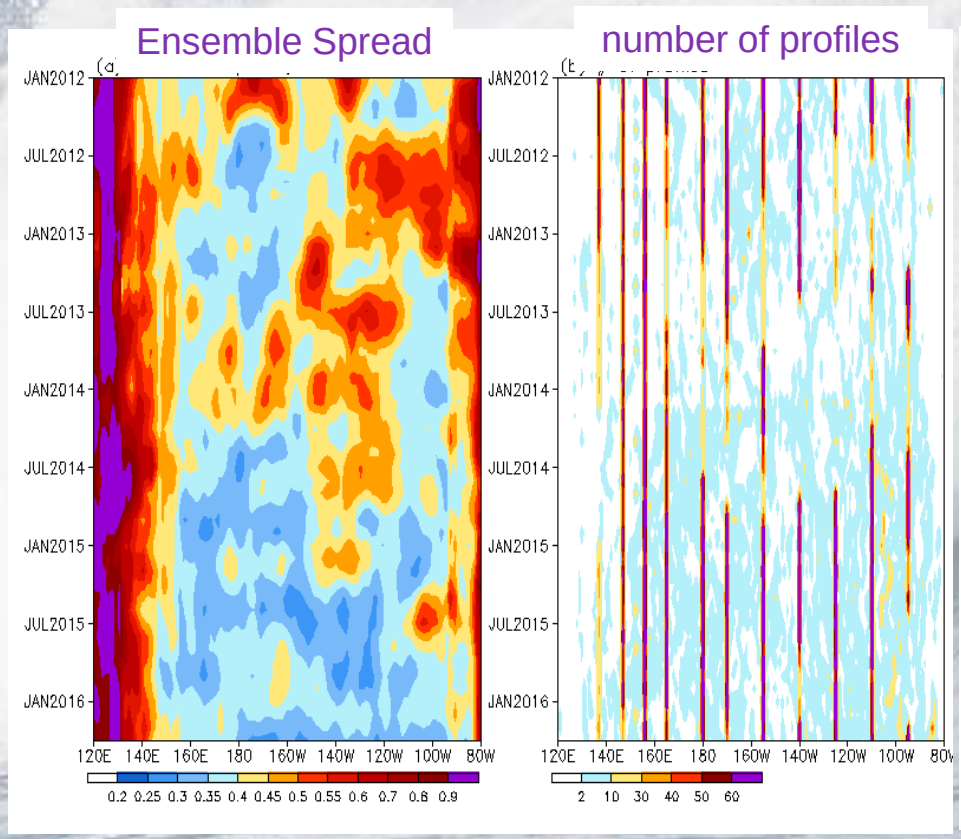
✓ 2000s: Increase of Argo ⇒ The spread is reduced in the entire region.

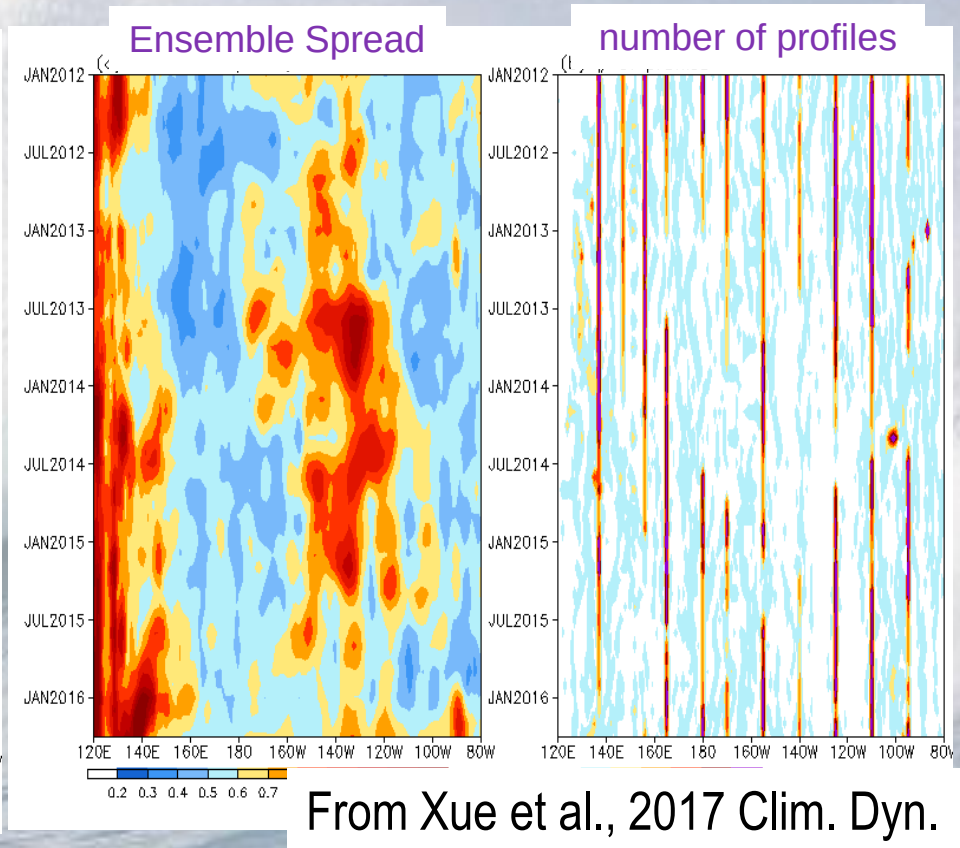
# ★ Correlated variation of the spread and obs number

➢ 2ºS-2ºN

➢ 3ºN-8ºN

For T. Averaged in 0-300m




From Xue et al., 2017 Clim. Dyn.

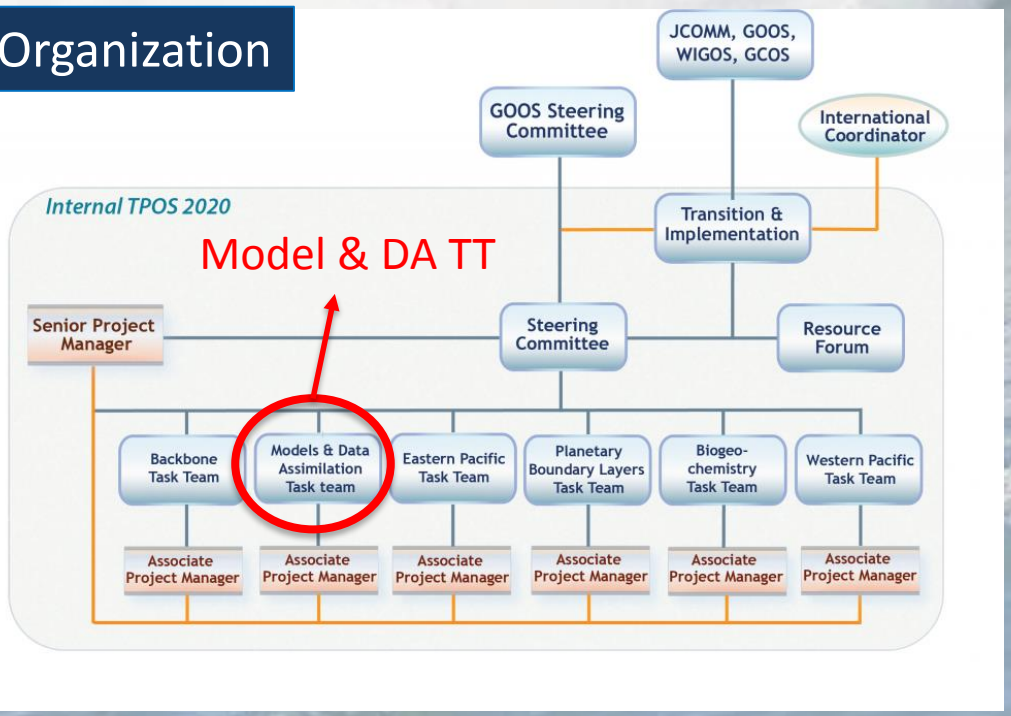
- ➢ The multi-system ensemble spread becomes larger where the number of profiles is small.
- ◆ Although real-time Multi-ORA is good initial effort, it is of limited utility in providing diagnostic information about the TPOS, e.g., what observations is being assimilated by ODA at different operational systems; no information is available about analysis increments, innovations, etc.

# TPOS 2020 Tropical Pacific Observing System

- Launched in 2015 according to the recommendation in La Jolla workshop.
- Purpose: Propose an efficient and sustainable design of TPOS for its reorganization
- Steering Committee:

  Co-chaired by William Kessler (NOAA/PMEL), Neville Smith (Austalaria)
- Having a resource forum (similar to Patron group in GOV) and 6 task teams
- http://tpos2020.org

## Organization




## Schedule

# ☆ First Report of TPOS2020

- Published
  - December 2016
  - Summary is translated and published (6 languages)
- 22 Recommendations
  - Many taking long-term view
- 15 Actions
- Available from the webpage

  http://tpos2020.org

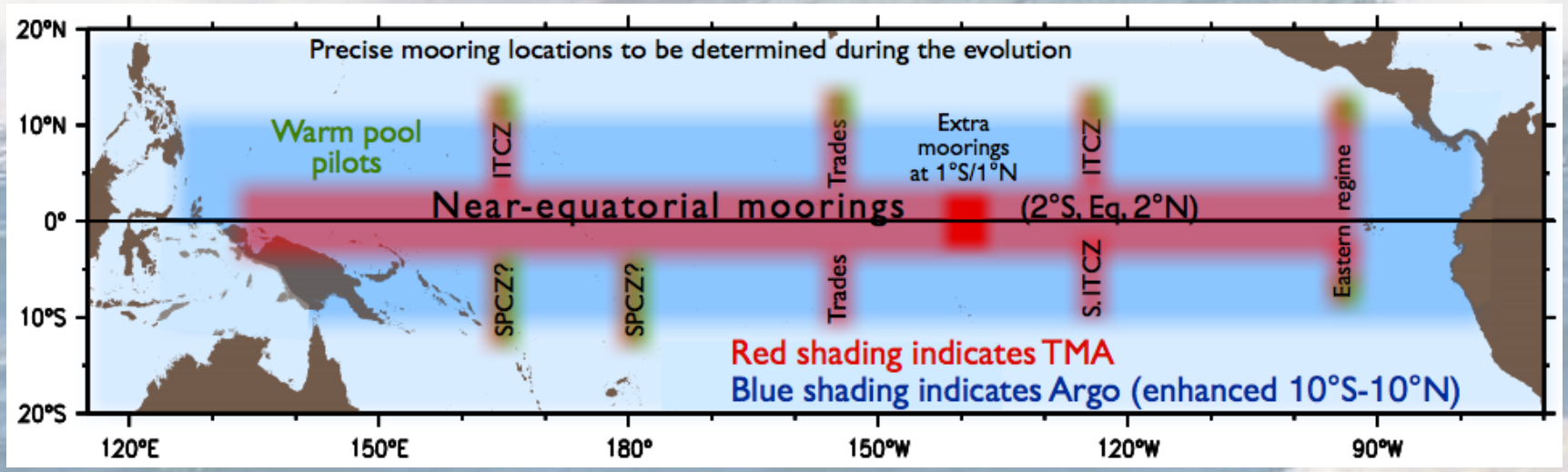
# ☆ Proposed design of TPOS in the first report

## Tropical Mooring Array (TMA)

- ✓ Retain all existing and historical near-equatorial sites at 2°S, 0°, 2°N across the basin
- ✓ Reduce priority for moorings away from the equator but several TMA extensions to cross the ITCZ and SPCZ regimes along historical lines
- ✓ Increase meridional mooring density near the equator (new sites at 1°S and 1°N at one or a few longitudes)
- ✓ Include more complete measurements of air-sea flux variables
- ✓ Enhance sampling of the rapidly-varying mixed layer
- ✓ Reduce temperature sampling below 300 m, except on the equator.

## Argo Floats

- ✓ Doubling of the number of Argo profiles in the 10°S-10°N band



# ⭐ Recommended Action for DA community (1)

## Extension of the current Real-Time Multi-ORA

- Extension to routine sharing of information on observational data and their influence, including data itself, QC flags, analysis increments, fit to observation etc. among operational centers.
- Extension to comparison of wind stress forcing data
- Support development of systems that enable us to monitor impacts of TPOS in data assimilation systems in near-real time through sophisticated techniques such as Degree of Freedom of System (DFS) and Forecast System Observation Impact (FSOI)
- Collaboration with GOV on this is recommended because intercomparison of analysis increments have been performed in GOV before.

# ⭐ Recommended Action for DA community (2)

## Assessment of recommended TPOS reconfiguration

- Assessment of the impact of the recommended TMA reconfiguration and the increase in Argo profile density while maintaining existing SSH and SST coverage.
- Use a combination of OSEs, OSSEs and alternative such as DFS and FSOI.
- Assessment for ENSO prediction (up to 2 years), subseasonal prediction (MJO, tropical cyclone, TIW), and ocean monitoring.
- Calibration of OSSEs using corresponding OSEs.
- Note strong dependency on the model, DA schemes, initialization procedures etc. To ensure robust conclusions it is essential that participation of three or more modeling groups with diversity of systems are involved in the joint assessment.
- To find suitable partner groups, TPOS 2020 should engage with GOV (primarily the OSEval and DA TTs), CLIVAR-GSOP and operational centers that maintain ENSO class forecast systems.

# ☆Toward the 2nd Report of TPSO2020

- TPOS 2020 has a clear recognition that to make effective use of observations, biases in the model need to be reduced. Providing recommendations on pathway as to how accomplish this will be one of the objectives of the 2nd TPOS report.

- The second report will put more focus on
  - Impacts in high-resolution ocean prediction systems.
  - Impacts of observation data in couple weather prediction system
  - requirements around Biogeochemistry and carbon cycle.

- Requirements and assessments associated with seasonal prediction systems are also likely to explored.

- The western tropical Pacific observing system is now changing drastically. Impacts of the change on DA and prediction systems should be carefully examined.

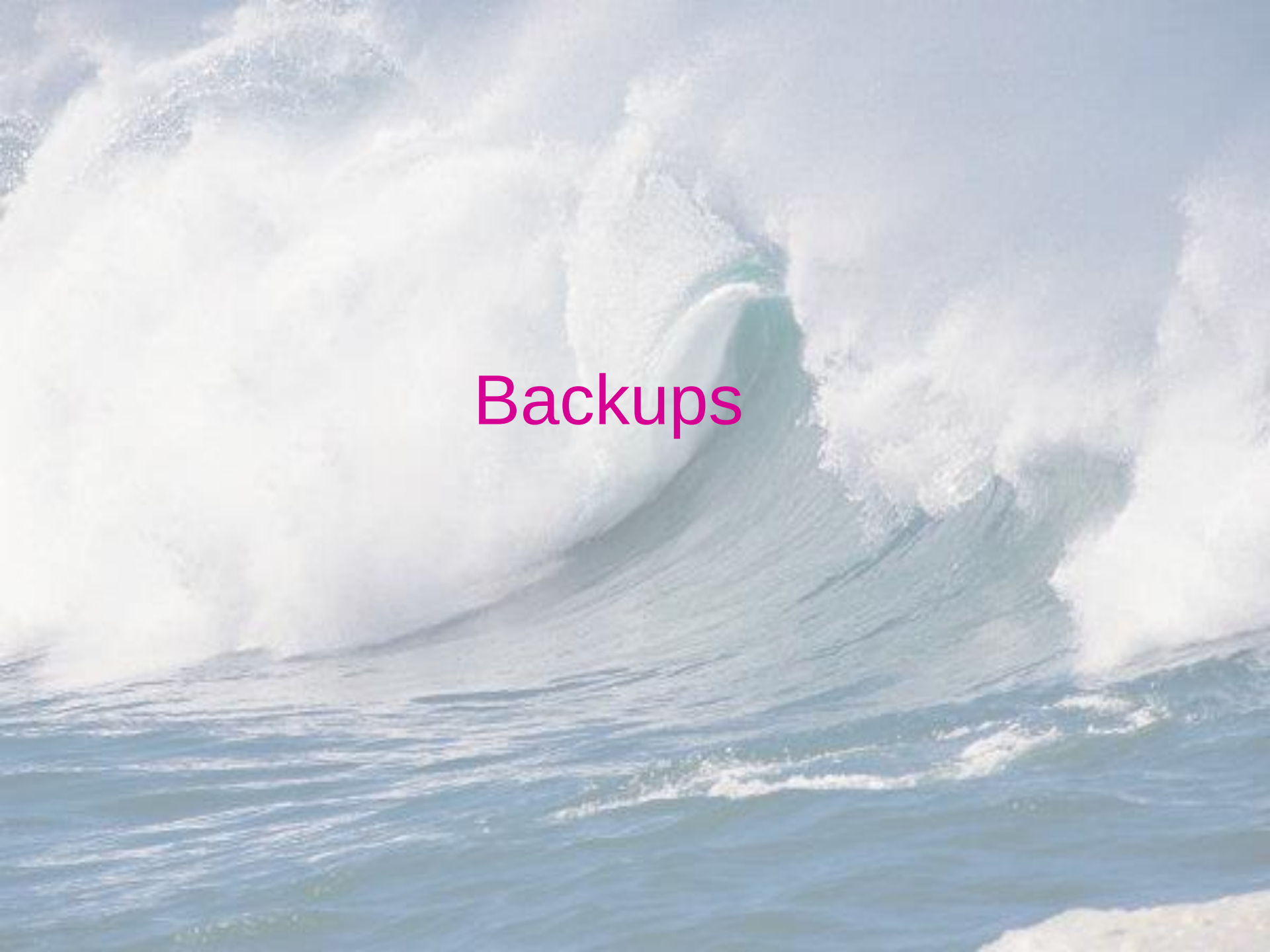
  (Maybe collaboration with TPOS2020 Western Pacific TT.)

# ☆Concluding Remarks

- TPOS2020 would like to have an assessment of the proposed TPOS reconfiguration
- Contribution of GOV community will be helpful for TPOS2020.
- Coordinated OSEval studies are favorable. However it is very difficult to execute and interpret.
- But OSEval studies by individual groups with their own ideas are still valuable.
- Considering severe dependency on systems, having several results of the assessment is very important to get a robust conclusion.
- Assessments of TPOS in any method with any condition is welcomed.
- It would be nice if you inform OSEval results (or efforts that may be of relevance for the assessment of observing system in the tropical Pacific) in your group to me or other people who are involved in TPOS2020.

- The collaboration for routine comparison and sharing of analysis results and relevant data is also valuable.

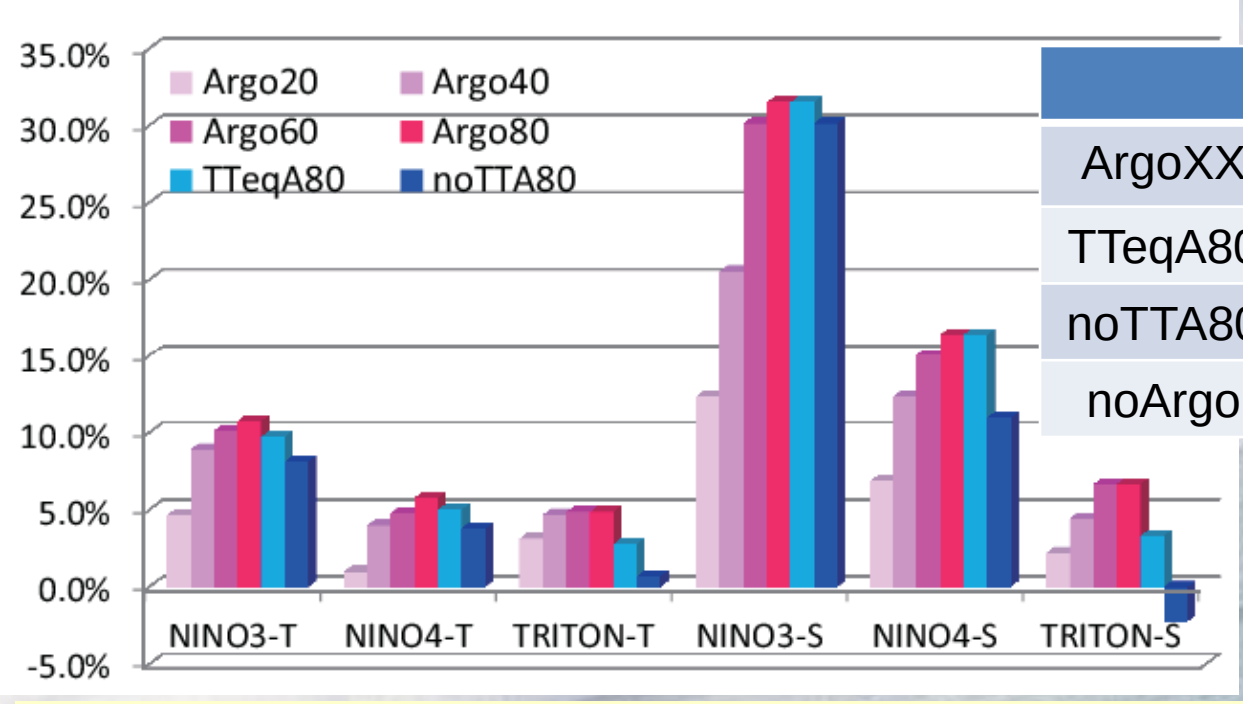
Thank you



# Backups

# NINO3・NINO4の解析精度に対するインパクト

解析値のRMSEの改善率（気象庁現行システム、対 noArgo）



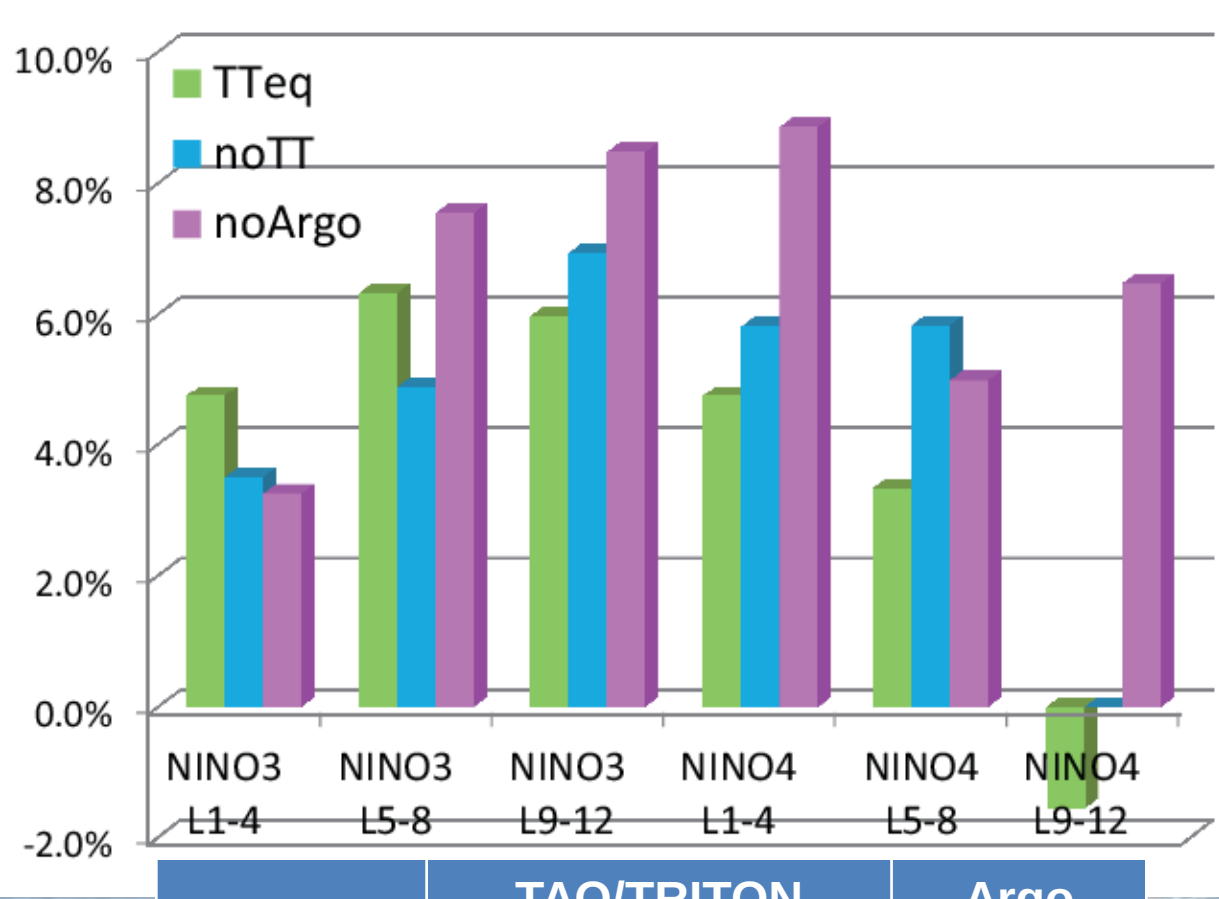

| | TAO/TRITON | Argo |
|---|---|---|
| ArgoXX | ALL | XX% |
| TTeqA80 | 2˚S-2˚N alone | 80% |
| noTTA80 | None | 80% |
| noArgo | ALL | None |

RMSEは20%の未同化アルゴデータに対して計算。

- ✓ 同化するアルゴフロートの数が大きいほど、インパクトも大きくなる。（ただし、数が多くなると、インパクトは頭打ちである。
- ✓ TRITON海域では、ブイのインパクト（Argo80とnoTTA80の差）が比較的大きく、水温についてはアルゴフロート80%と同程度で、塩分についてはそれより大きい。
- ✓ 現在進行しているTRITON観測数の減少による、熱帯太平洋西部の海洋解析の精度低下、及び、そのENSO予測への影響が懸念される。

# NINO3・NINO4の予測に対するインパクト

予報値のRMSEの改善率（気象庁現行システム）

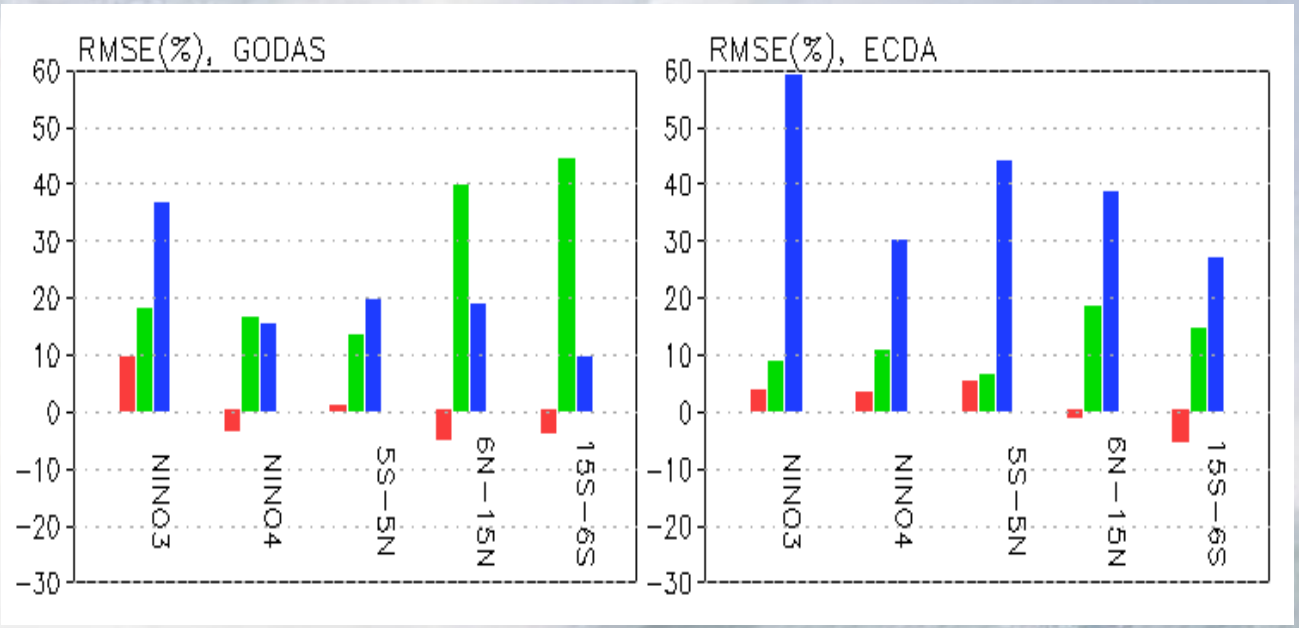



| | TAO/TRITON | Argo |
|---|---|---|
| TTeq | 2˚S-2˚N alone | ALL |
| noTT | None | ALL |
| noArgo | ALL | None |

- ✓ アルゴフロートのインパクトは、すべてのリードタイムに対して正である。
- ✓ TAO/TRITONのインパクトについても、NINO4の9－12ヶ月予報を除き、インパクトは正である。
- ✓ NINO3の1-4ヶ月予報やNINO4の5-8ヶ月予報では、TAO/TRITONのインパクトの方が大きいが、それ以外では、アルゴの方が大きい。
- ✓ 赤道近傍のブイの同化するより、すべてのブイを外した方が予報の精度が良い場合がある。（e.g., NINO3の1-4, 5-8ヶ月予報）

# ★ Impact on the sea surface height analysis

**NCEP**



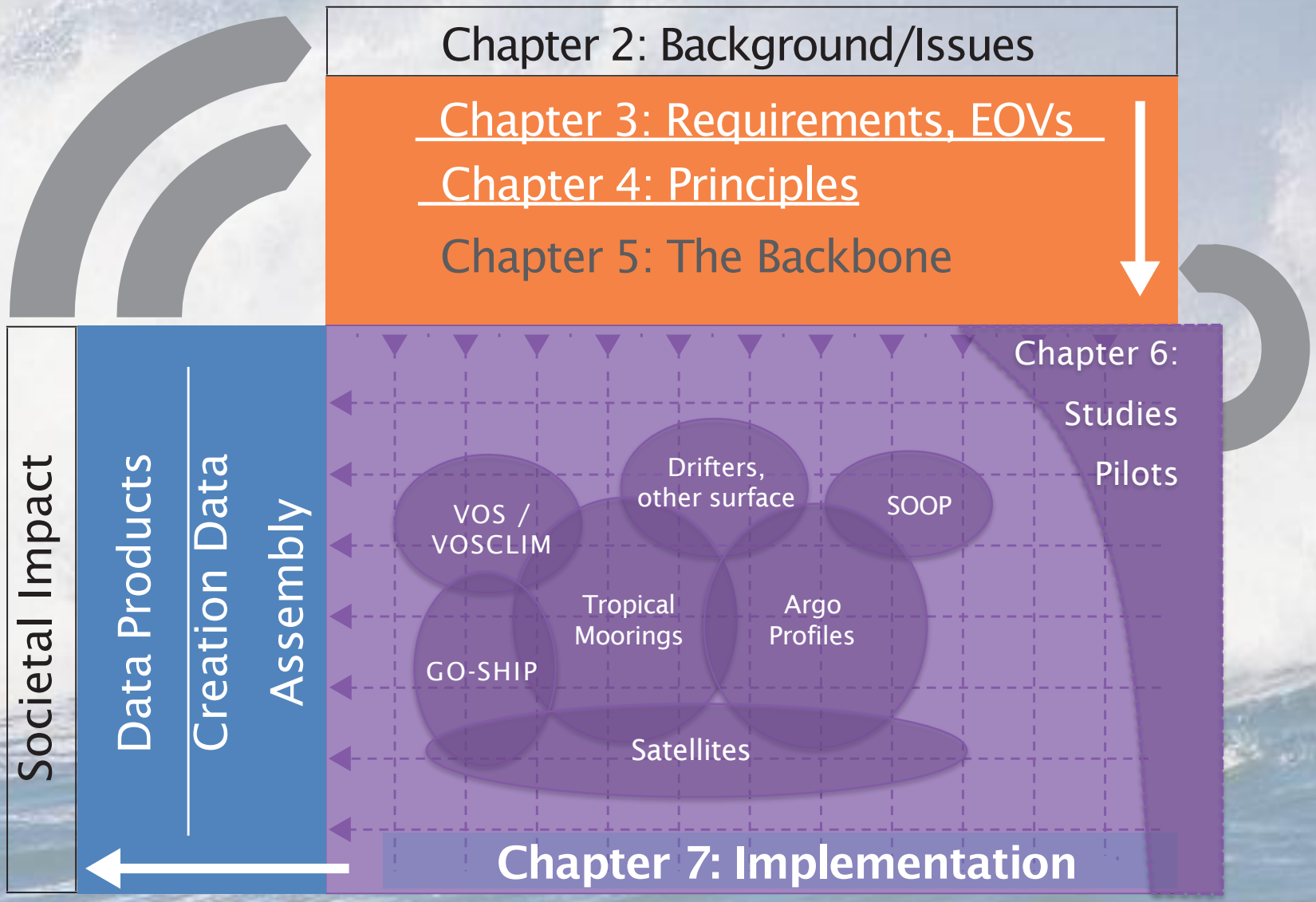

**GFDL**

- Validated against independent satellite SSH on interannual variability (monthly anomaly in 2004-2011)

- RMSE difference normalized by RMSE of ALL:
  - noMoor – ALL (red) --→ impacts of moorings
  - noArgo – ALL (green) ---> impacts of Argo
  - CTL – ALL (blue) --→ impacts of all in-situ profiles

- Inclusion of TAO improved RMSE by 5-10%
- Inclusion of Argo improved RMSE by 10-18% near Eq.
- Inclusion of TAO, Argo, XBT together improved RMSE by 8-50%

*Framework for Ocean Observing Process Diagram*



# ☆ 海洋解析データリアルタイム比較（精度の比較）

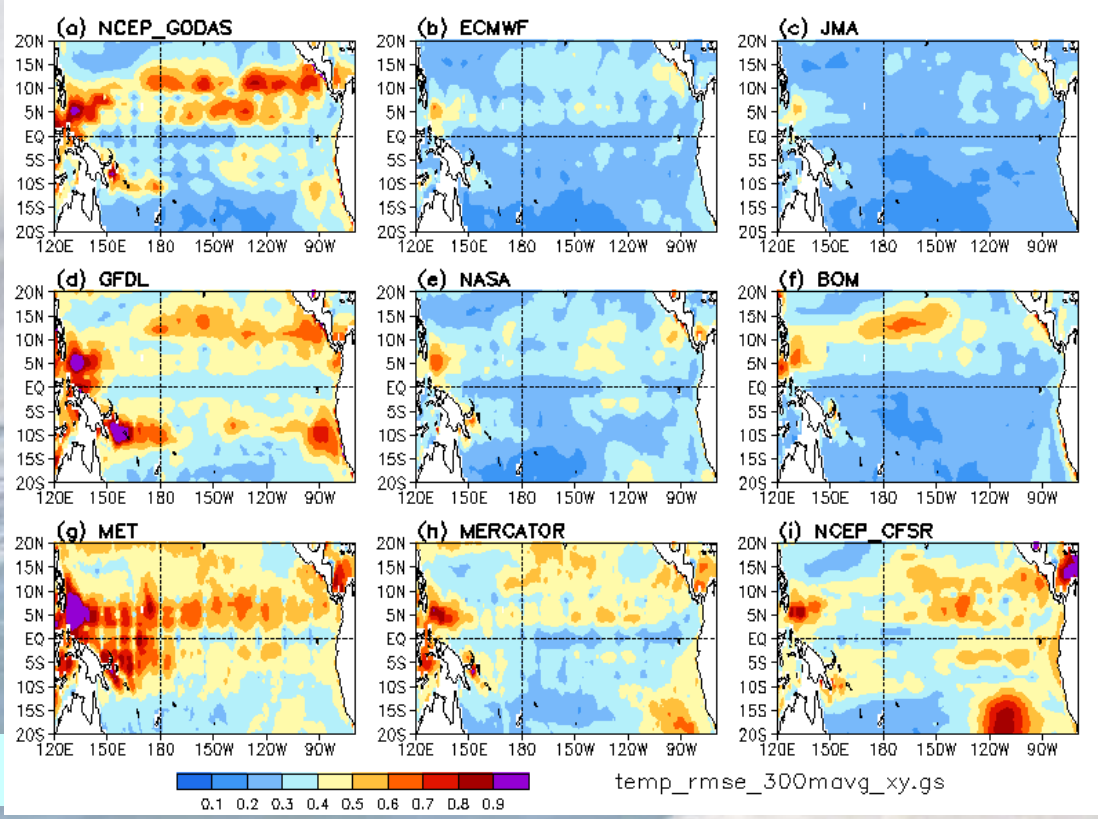
by Yan Xue

| | RMSD (°C) | NRMSD (%) | TAO/TRITON観測値とのRMSDを規格化した値(NRMSD)のアンサンブル平均との差。0-300m 平均(%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | EM | EM | NCEP GODAS | JMA | ECMWF | GFDL | NASA | BOM | MET | MERCATOR | NCEP CFSR |
| EEPac | 0.26 | 20.5 | 6.6 | 10. | 5.4 | 13.8 | 12.7 | 6.6 | -3.2 | 9.1 | 18.8 |
| WEPac | 0.25 | 23.8 | 7.7 | 10.9 | 4.2 | 18.6 | 9.5 | 7.9 | 0.6 | 14.2 | 16.8 |
| NEPac | 0.33 | 38.3 | 14.9 | 13.9 | 1.5 | 17.4 | 26.9 | 15.7 | -11.5 | 5.5 | 23.6 |
| NWPac | 0.29 | 26.5 | 7.2 | 10.8 | 0.1 | 20.1 | 12.9 | 18.5 | -4.3 | 9.7 | 20.0 |
| SPac | 0.21 | 24.3 | 3.0 | 7.3 | 3.0 | 27.0 | 11.7 | 9.5 | -2.2 | 10.6 | 23.1 |

規格化は、観測値の平均からの標準偏差で行う。

**EEPac:** 170W-90W, 2S/0/2N
**WEPac:** 120E-180W, 2S/0/2N
**NEPac:** 170W-90W, 5N/8N
**NWPac:** 120E-180W, 5N/8N
**Spac:** 120E-90W, 5S/8S

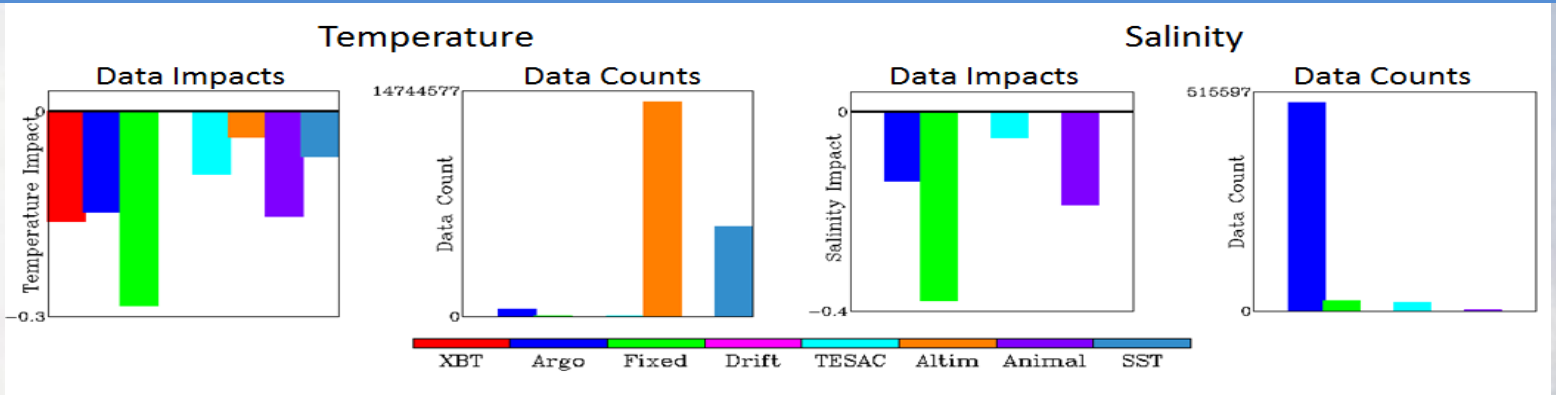
- ✓ 観測値との誤差が少ないから全体的な信頼度が、高いとは言えない。
- ✓ JMAの解析値(MOVE-G2)は、アンサンブル平均からの差が小さく、全体的に信頼度が高い。




アンサンブル平均からのRMSD

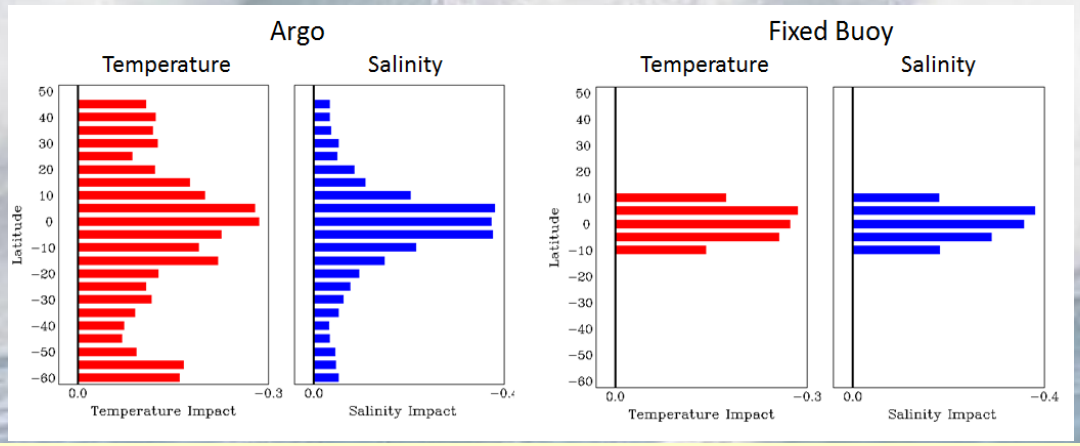
# ★ Evaluation of the forecast sensitivities (shown in La Jolla)

Per observation Impacts of T and S on reducing HYCOM 48-hour forecast error using adjoint method (Pacific Ocean, 16 Sep - 30 Nov 2012)



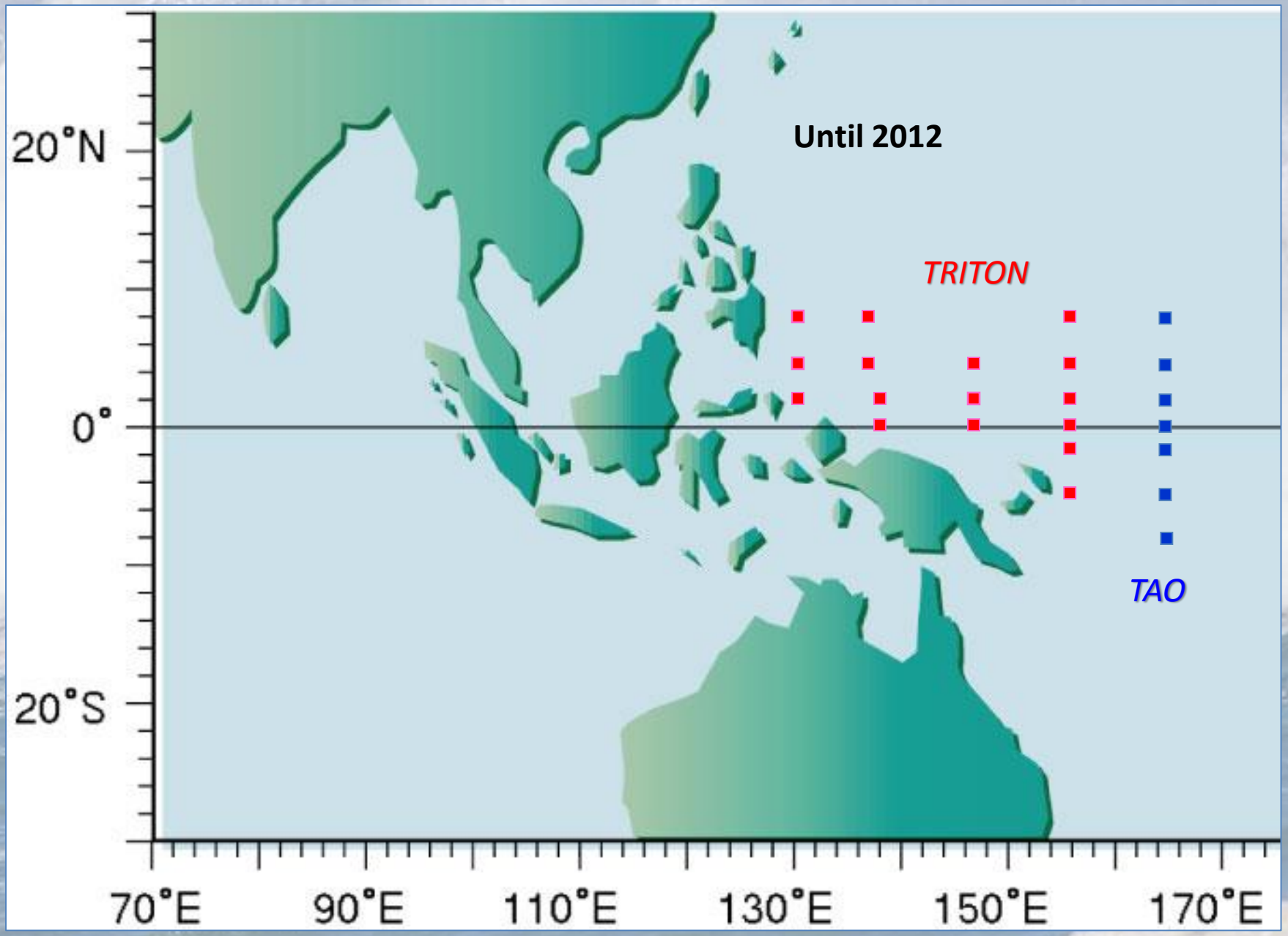

Per observation impacts of Argo and fixed buoy arrays for T and S partitioned by 5˚ latitude bands.

Fixed Buoy = TAO/TRITON array




- ✓ Impacts of temperature and salinity from all observing systems are beneficial.
- ✓ Most effective data type on a per observation basis are TAO/TRITON array.
- ✓ The impact of Argo is comparable to the impact of the moorings in the tropics.
- ✓ This result severely depends on the ocean model used for the evaluation.

# Development and decay plan of TRITON buoy array



# Development and decay plan of TRITON buoy array