Argo Operational & Coverage Status AST#17

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Content

References 3

Design & Definitions 3

Operational status 7

Coverage Status 10

Conclusion 19

References

AST #14 http://www.argo.ucsd.edu/Argo_Enhancements.pdf
AST #15 http://www.argo.ucsd.edu/Argo_Indicators_AIC.xlsx
AST #16 http://argo.jcommops.org/FTPRoot/Doc/Meetings/AST/16/Indicators.xslx

Design & Definitions

To define Argo targets and build performance indicators we prepared a 3°x3° base, taking into account bathymetry, ice extent, deployment practices, and regional requirements.
Such grid is slightly reviewed once a year before AST, according to new requirements.

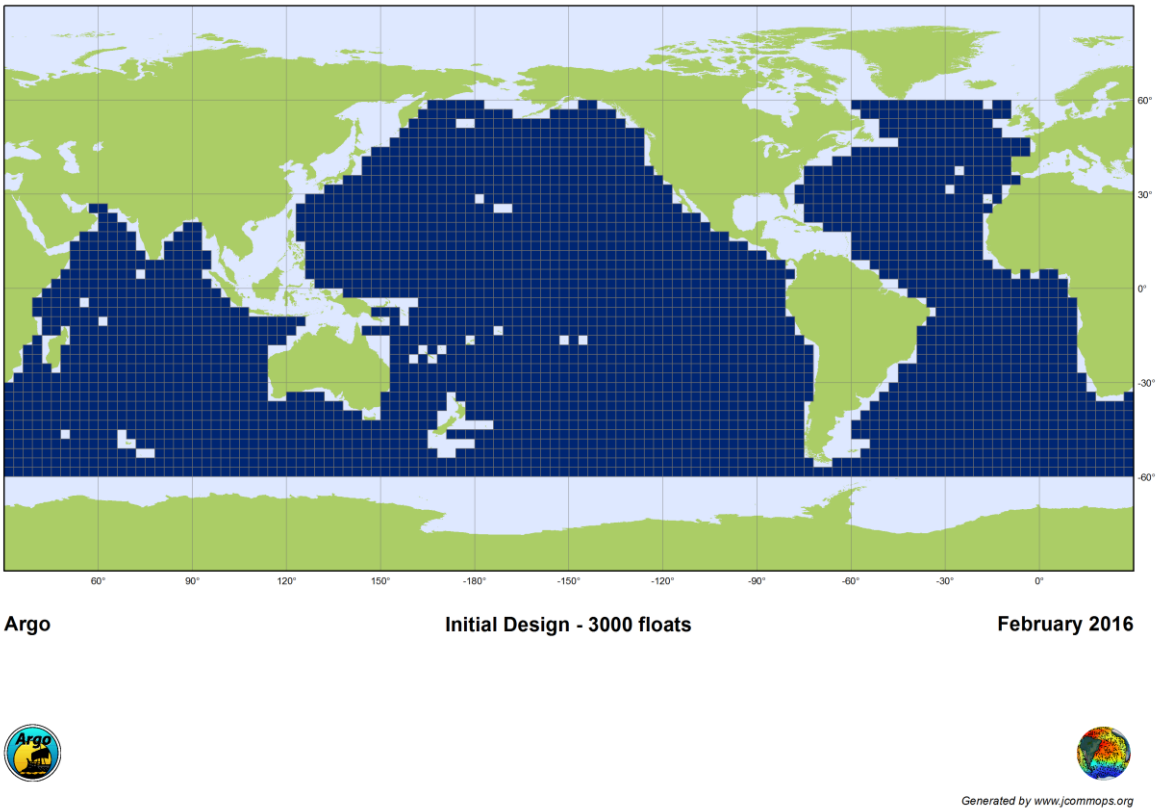


Fig. 1 Initial Design with 3076 grid elements.

The same grid is used to define the design and targets for Argo's expansions including; global, deep and bio.
These sketch designs have emerged from community requirements since OceanObs'09. They are not yet fully supported by AST, and national funding agencies have not yet all bought into these expansions. However, some programmes (e.g. EuroArgo) have started to use them to dimension their requirements and raise appropriate funds, and some others have started to implement them (eq. Pacific, NW Pacific WBC).

The global Argo design includes 4 expansions areas (Polar, WBC, Equatorial and Marginal Seas) of different target densities.

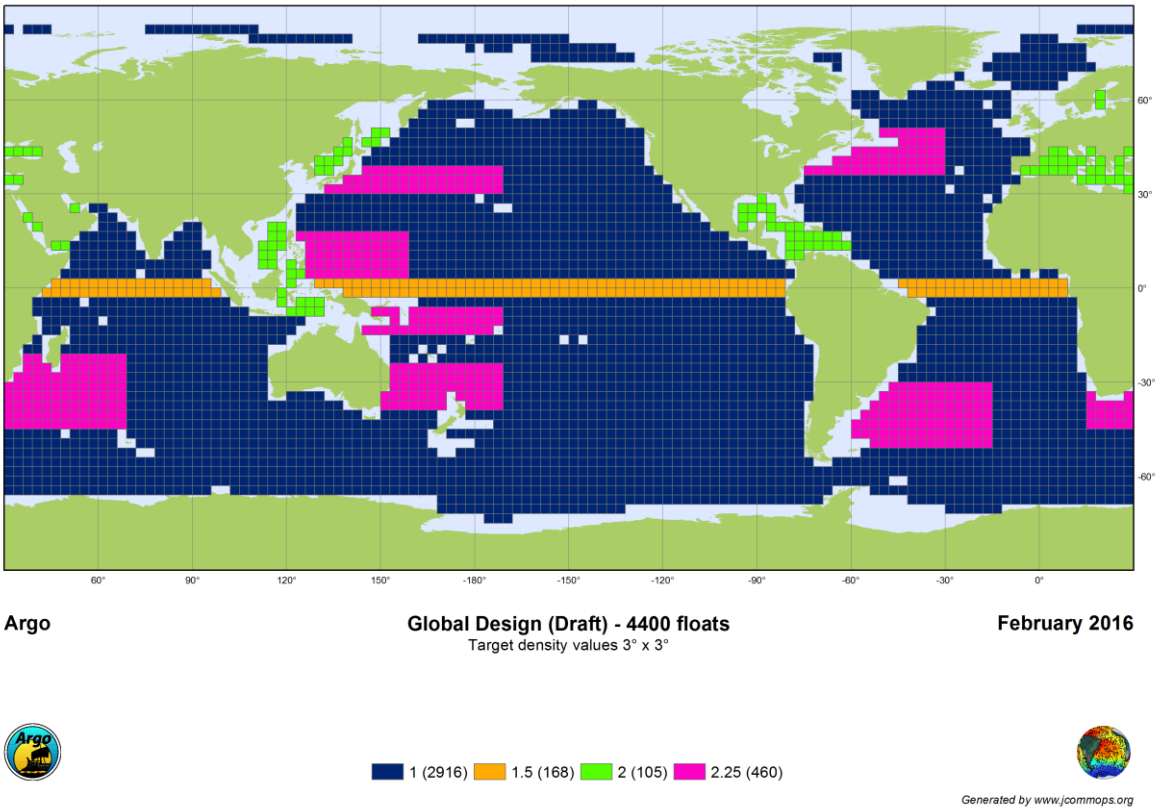


Fig. 2 Global Design with 3649 grid elements, for a total target of 4413 floats.

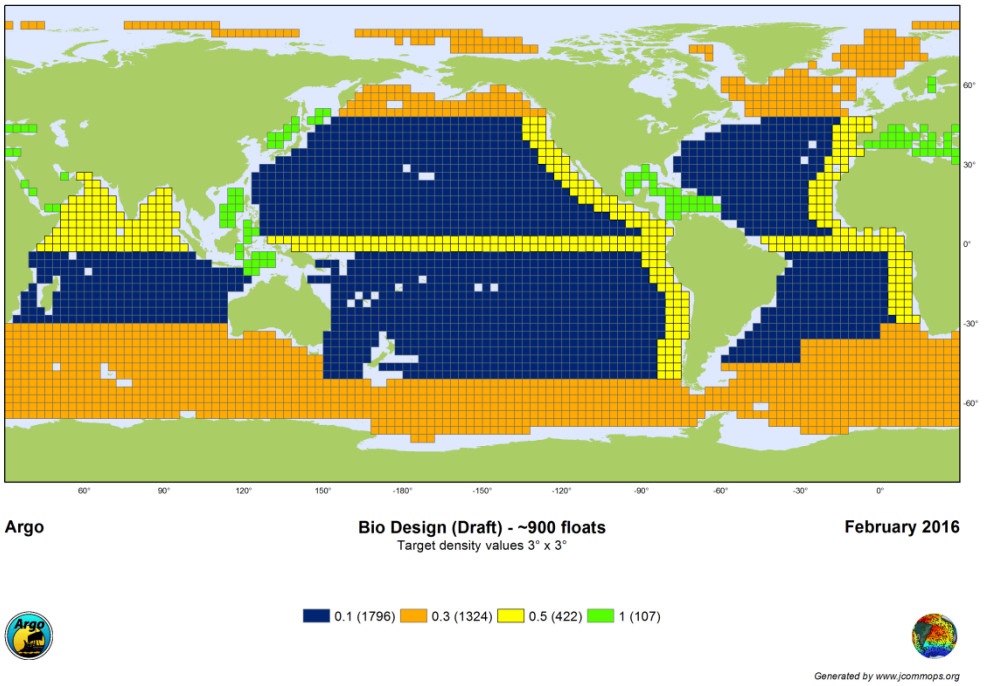


Fig. 3 First draft of BioArgo Design for a total of 895 floats

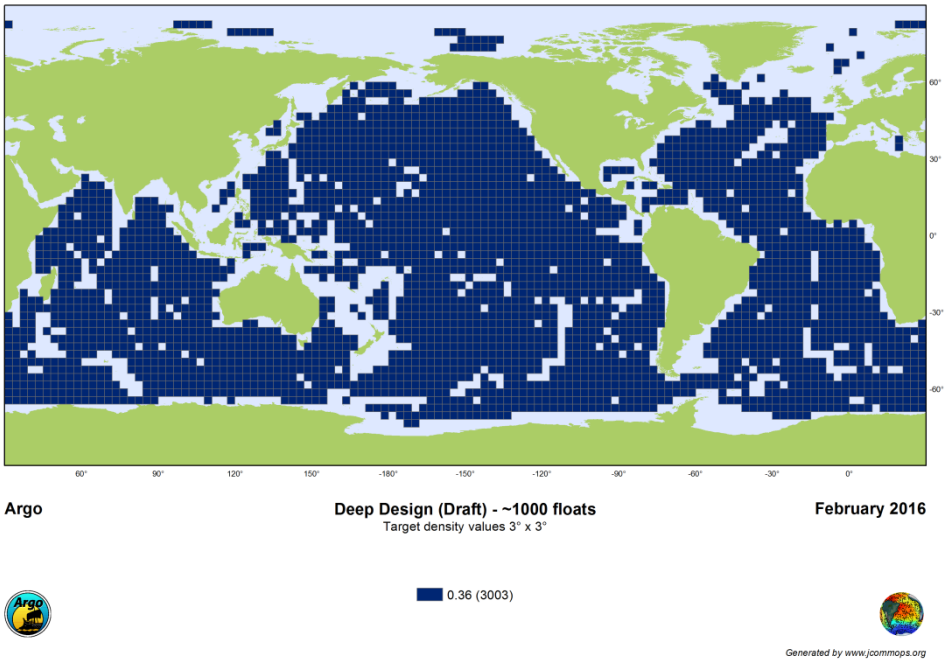


Fig. 4 First draft of DeepArgo Design for a total of 1081 floats. Note that community requirements for DeepArgo have concluded on a 1228 floats target. Grid needs to be refined to approach the recommended number as far as possible.

This study will focus anyway on the initial and global designs.
3 indicators will be covered, and developed over each design, ocean and expansion regions:

Operationality: how many units are sending data vs requirements

Intensity: how many units have been deployed vs requirements. A 4.1 years float lifetime is considered.

Coverage: how many grid elements are well sampled.

Such coverage calculation is made on observations (source: Argo GDACs) between the period 2010-2015. For each year, we calculate the average of monthly observations in each grid elements. Different filtering and normalizations allow building a short time series for each case.
A well sampled grid element is an element that had at least 3 obs/months in average over the year.

All calculations have been made using GIS software, and spatial database tools. Coverage maps are available on the new website in the interactive and static map sections, and can be “animated” in time.

To check the network status in real-time several additional layers are proposed on the new website on a 6°x6° grid, normalized on the initial and global designs, either simple, or including float probability to survive a year, or including deployment plans.

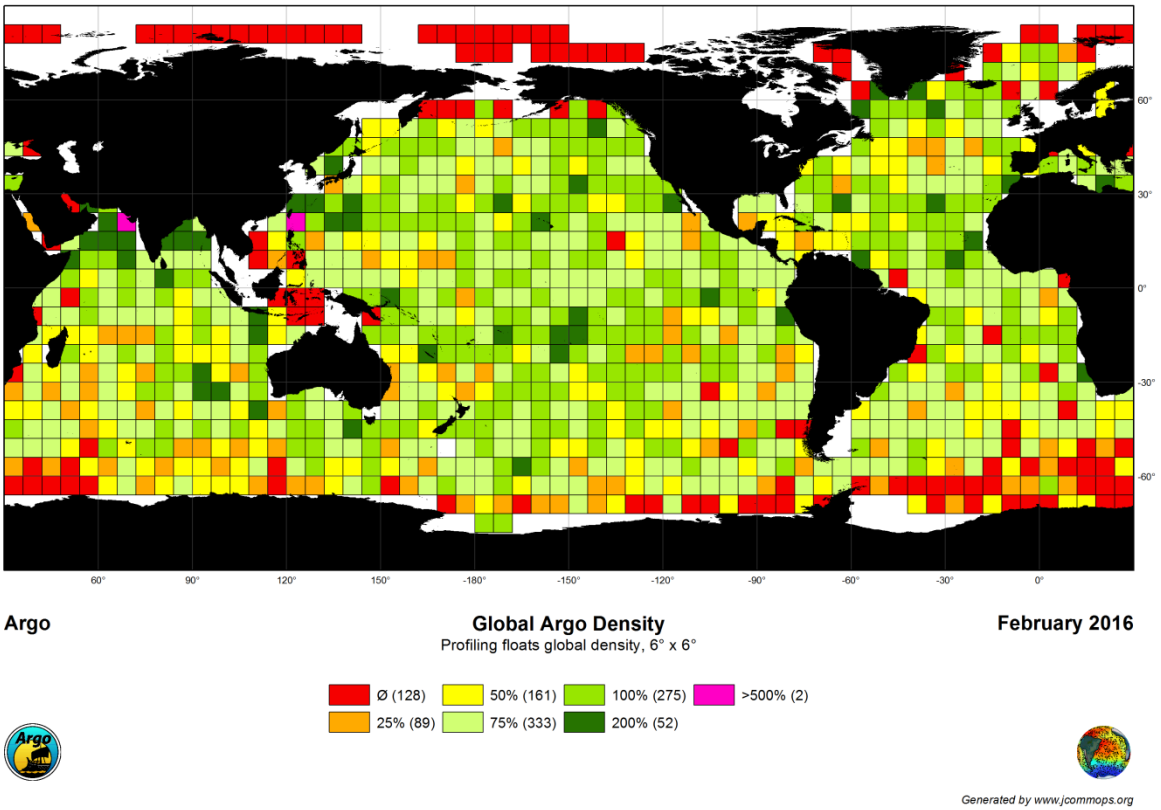


Fig. 5 Latest monthly Density Map normalized on the Global Design.

Operational status

Ocean basins are defined as following, with color codes to ease table/charts reading:

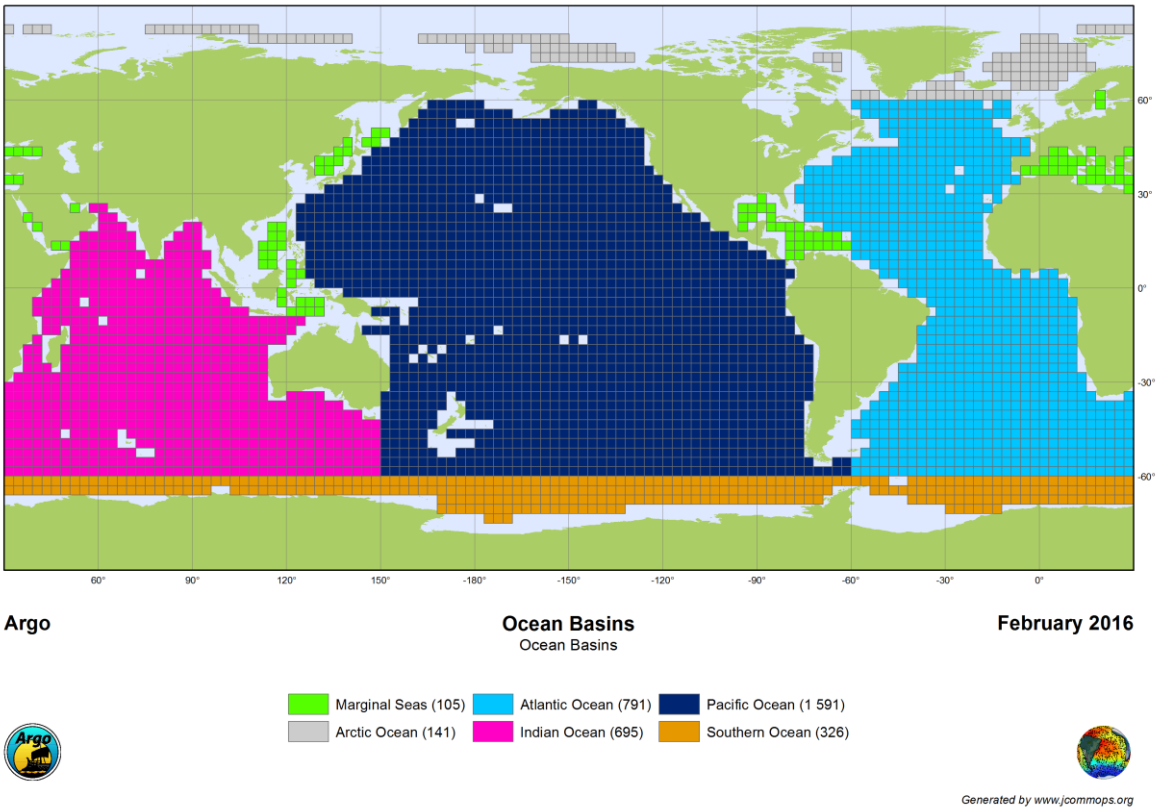


Fig. 6 Basin boundaries for performance Indicators

	2015 STATUS NB		TARGETS NB		OPERATIONALITY %		INTENSITY %	
OCEAN BASINS	**OPERATIONAL**	**DEP 2015**	**INITIAL**	**GLOBAL**	**INITIAL**	**GLOBAL**	**INITIAL**	**GLOBAL**
Arctic Ocean	53	21	0	141		37.6		61.2
Atlantic Ocean	792	234	791	1007.25	100.1	78.6	121.6	95.5
Baltic Sea	2	2	0	4		50.0		205.5
Banda Sea	0	0	0	12		0.0		0.0
Black Sea	4	3	0	10		40.0		123.3
Caribbean Sea	12	8	0	38		31.6		86.5
Celebes Sea	2	0	0	6		33.3		0.0
Flores Sea	0	0	0	2		0.0		0.0
Gulf of Aden	1	5	0	4		25.0		513.8
Gulf of Mexico	11	6	0	20		55.0		123.3
Gulf of Oman	0	0	0	2		0.0		0.0
Indian Ocean	689	136	695	833	99.1	82.7	80.4	67.1
Japan Sea	22	15	0	16		137.5		385.3
Makassar Strait	0	0	0	4		0.0		0.0
Mediterranean Sea	60	46	0	56		107.1		337.6
Pacific Ocean	1837	394	1590	1895.75	115.5	96.9	101.8	85.4
Red Sea	1	1	0	4		25.0		102.8
Sea of Okhotsk	0	0	0	8		0.0		0.0
South China Sea	7	3	0	22		31.8		56.0
Southern Ocean	139	89	0	326		42.6		112.2
Sulu Sea	0	0	0	2		0.0		0.0
TOTAL	**3632**	**963**	**3076**	**4413**	**118.1**	**82.3**	**128.7**	**89.7**
EXPANSIONS								
POLAR	192	110		467		41.1		96.8
WBC	573	120	459	1035	124.8	55.4	107.5	47.7
EQUATORIAL	239	42	168	252	142.3	94.8	102.8	68.5
MARGINAL SEAS	122	89		210		58.1		174.2

Table 1 2015 status and targets for "Operationality" and Intensity indicators

Initial Design:

With regard to operational floats required, the total shows 118%. Enough float are operating to properly cover the initial Argo design. Main ocean basins are all above 100%. This is similar to 2014 with a 10% loss of floats for the Indian Ocean (IO).

AO and PO show a stable intensity of deployments (respectively of 120 and 100%) while IO shows a strong drop from 229 units to 136 or (140% to 80%).

IO is short of 20% (or about 35 floats) to maintain the initial design.

In general, we have a reserve of 30% extras deployments to maintain the initial design.

Global Design:

The number of operational floats required to maintain the global design is short of 18%. Except for the PO, almost complete, AO and IO need an extra 20% to meet the global design quantitative requirements.

10% more deployments per year and the global design would be achievable.

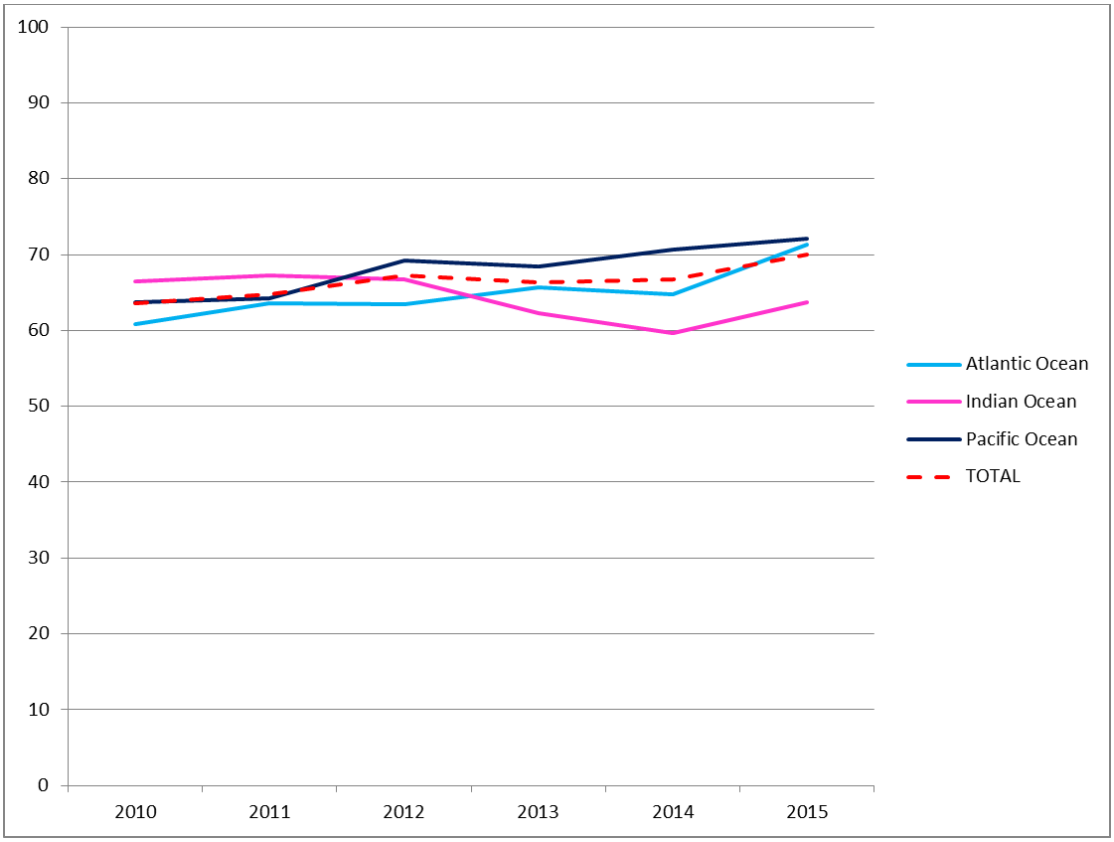
The Southern Ocean (here below 60°S), is half implemented and had a strong intensity boost compared to 2014. But it remains more or less at the level of 2014 with regard to operational floats. 2015 has probably covered the lack of 2014 deployments.
Marginal seas such as Med Sea or Japan Sea show an intensity of 300%. The design may be reviewed in these areas. A lower lifetime (to be demonstrated) in Marginal Seas or Southern Ocean should also be considered to refine intensity targets. Some floats (Bio Argo) are as well retrieved and redeployed which inflates artificially the intensity indicator.

Expansion areas for the global design are half implemented, except the Equatorial almost fully implemented. Intensity for Marginal seas is still very high. It seems appropriate for polar regions and too low for the equatorial (but last year had a boost at 200%). WBC numbers do not move vs 2014.

Coverage Status

Once we know quantitatively if we have enough units to meet our goals, we can take a closer look to the qualitative aspects and check how floats are distributed.
The initial design is well implemented, even if a few small gaps remain.
Over the last 6 years, the initial design coverage has improved from 60% to 70%.
AO and PO have followed this general trend. The IO however has not progressed that much and is 10% behind.

For the global design, this is the same conclusion. Gradual progress up to 55% in general; No progress in IO. Polar and WBC expansions have a lot of margin to progress.
The 10% decrease for Marginal Seas raise some questions, while intensity of deployment is very high.
The small marginal seas status weights probably too much on statistics.



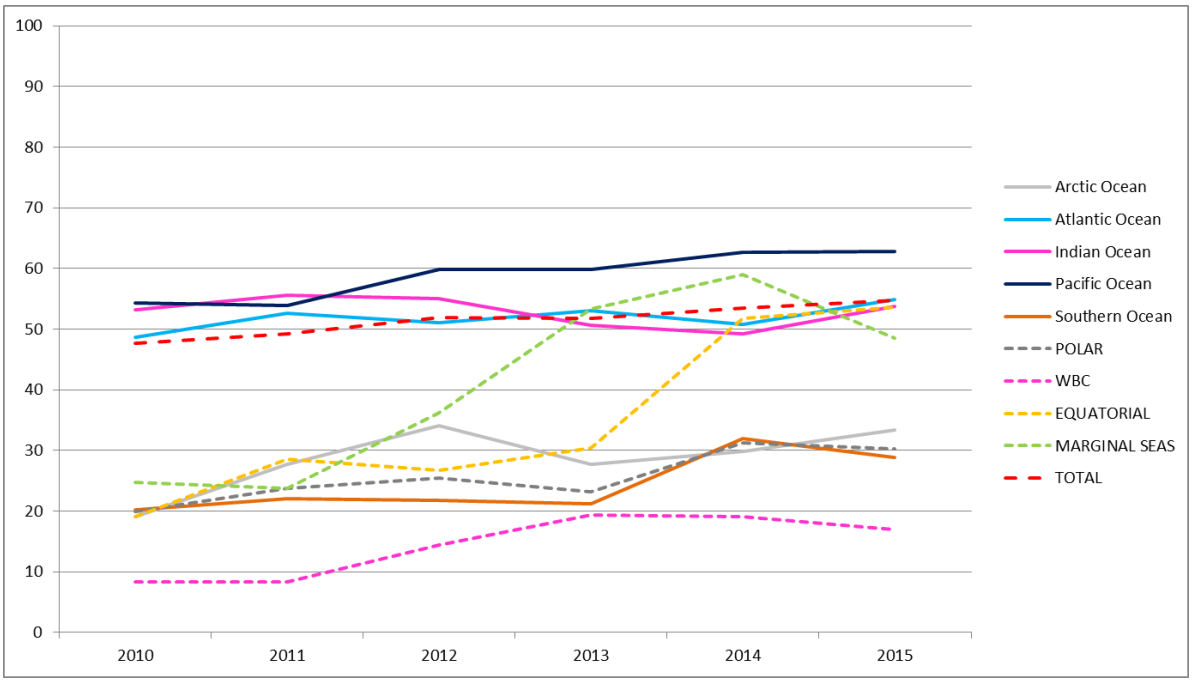
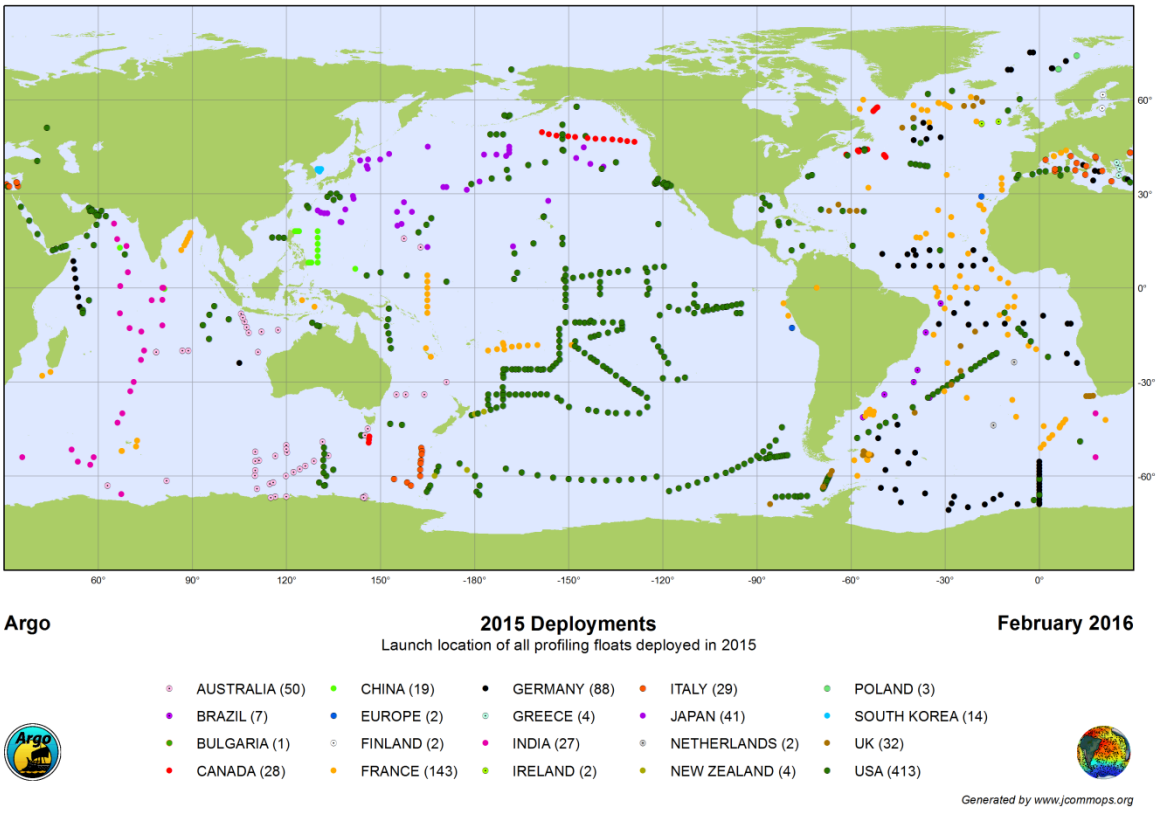


Fig. 7, 8 proportion of the network that is well sampled (averaged over a year)for initial/global designs and main expansions areas.

	COVERAGE vs INITIAL						COVERAGE vs GLOBAL					
OCEAN	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Arctic Ocean							19.1	27.7	34	27.7	29.8	33.3
Atlantic Ocean	60.8	63.6	63.5	65.6	64.7	71.3	48.7	52.6	51.1	53.1	50.8	54.9
Baltic Sea							0	0	50	100	50	50
Banda Sea							0	0	0	0	0	0
Black Sea							20	60	80	80	100	80
Caribbean Sea							0	0	5.26	26.3	26.3	15.8
Celebes Sea							0	0	33.3	0	66.7	33.3
Flores Sea							0	0	0	0	0	0
Gulf of Aden							0	50	100	50	100	50
Gulf of Mexico							40	20	10	50	70	30
Gulf of Oman							0	0	0	0	0	0
Indian Ocean	66.5	67.2	66.8	62.3	59.7	63.7	53.2	55.5	55	50.6	49.2	53.8
Japan Sea							100	100	75	100	87.5	75
Makassar Strait							0	0	0	0	0	0
Mediterranean Sea							25	25	50	75	85.7	96.4
Pacific Ocean	63.7	64.3	69.2	68.4	70.7	72.1	54.3	53.9	59.8	59.8	62.7	62.8
Red Sea							0	0	0	0	0	50
Sea of Okhotsk							0	0	0	0	0	0
South China Sea							54.5	36.4	72.7	72.7	63.6	36.4
Southern Ocean							20.2	22.1	21.8	21.2	31.9	28.8
Sulu Sea							0	0	0	100	100	0
TOTAL	**63.6**	**64.8**	**67.2**	**66.3**	**66.7**	**70.0**	**47.6**	**49.2**	**51.9**	**51.7**	**53.4**	**54.8**

EXPANSIONS												
POLAR							19.9	23.8	25.5	23.1	31.3	30.2
WBC	66.2	67.1	73.2	76	76	80.6	8.26	8.26	14.3	19.3	19.1	17
EQUATORIAL	61.3	65.5	62.5	63.7	81	85.7	19	28.6	26.8	30.4	51.8	53.6
MARGINAL SEAS							24.8	23.8	36.2	53.3	59	48.6

Table 2 numbers for Fig 10,11



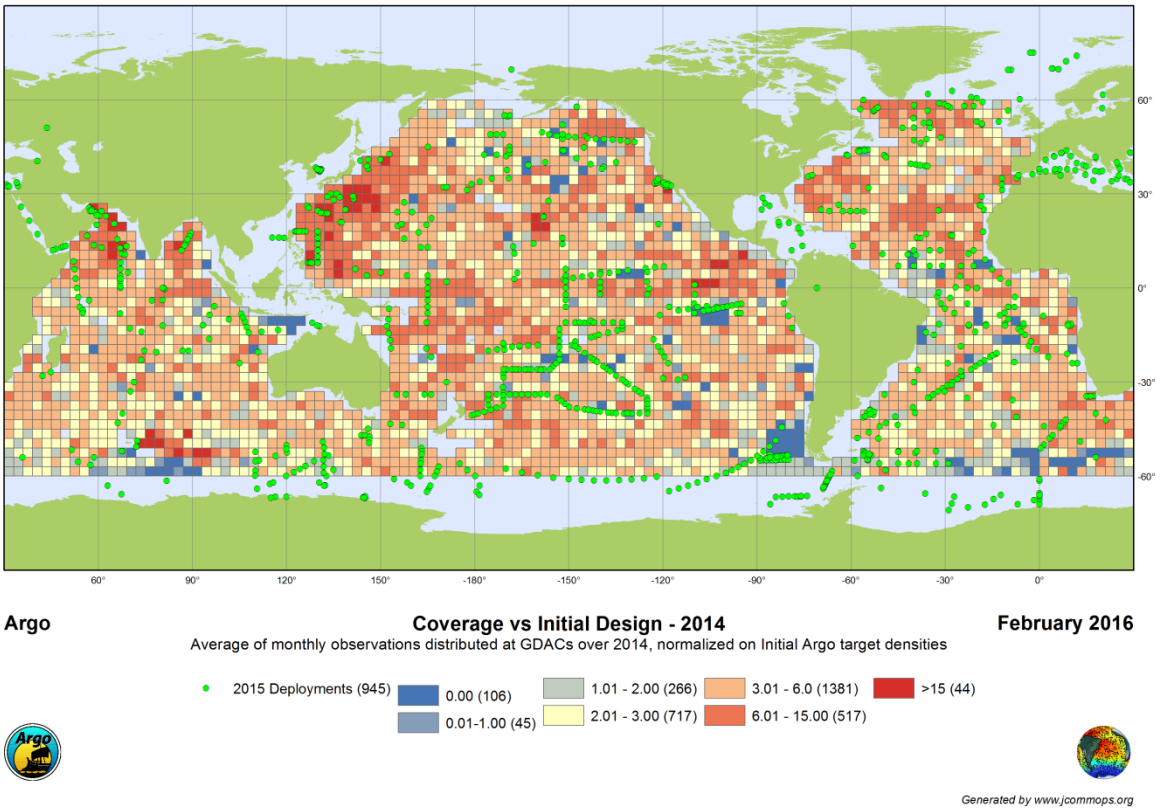


Fig. 9,10 2015 deployments by country vs 2014 coverage status

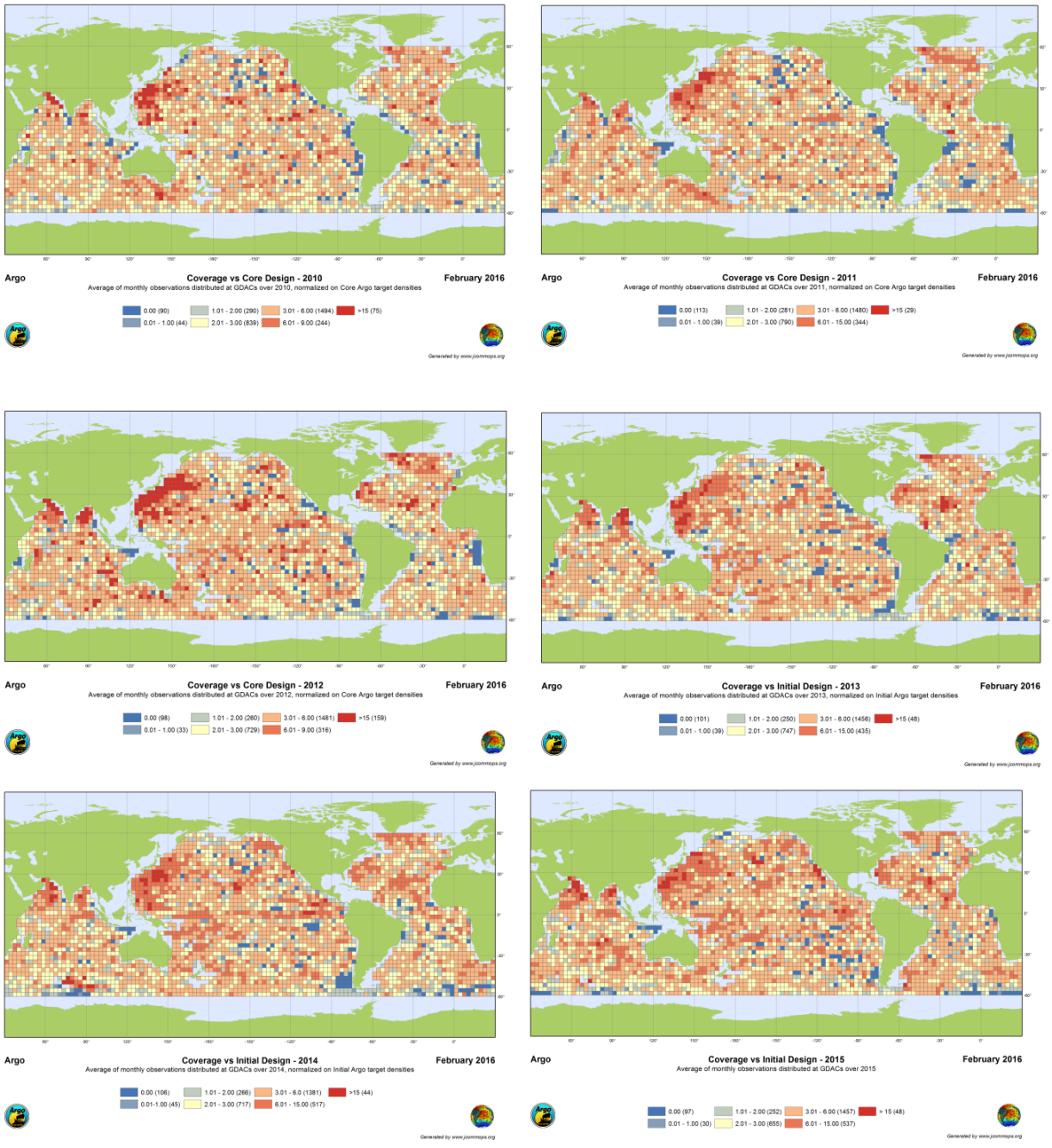
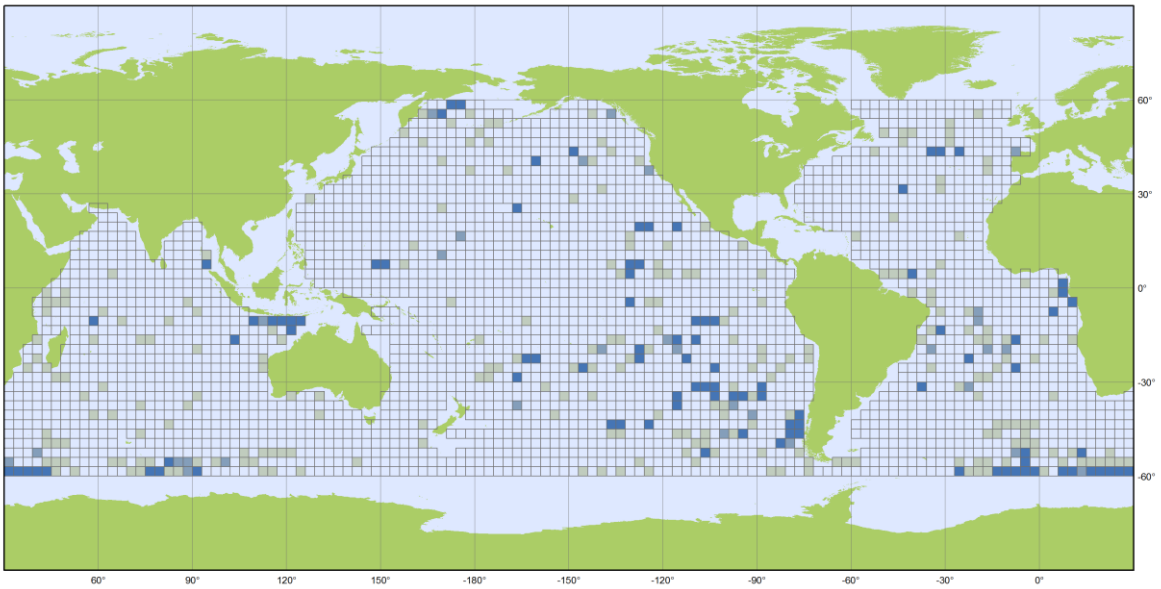


Fig 11-16 Coverage initial design, 2010-2015 evolution.



Argo **Coverage vs Initial Design - 2015** **February 2016**

Average of monthly observations distributed at GDACs over 2015

0.00 (97) | 0.01 - 1.00 (30) | 1.01 - 2.00 (252) | 2.01 - 3.00 (655) | 3.01 - 6.00 (1457) | 6.01 - 15.00 (537) | > 15 (48)

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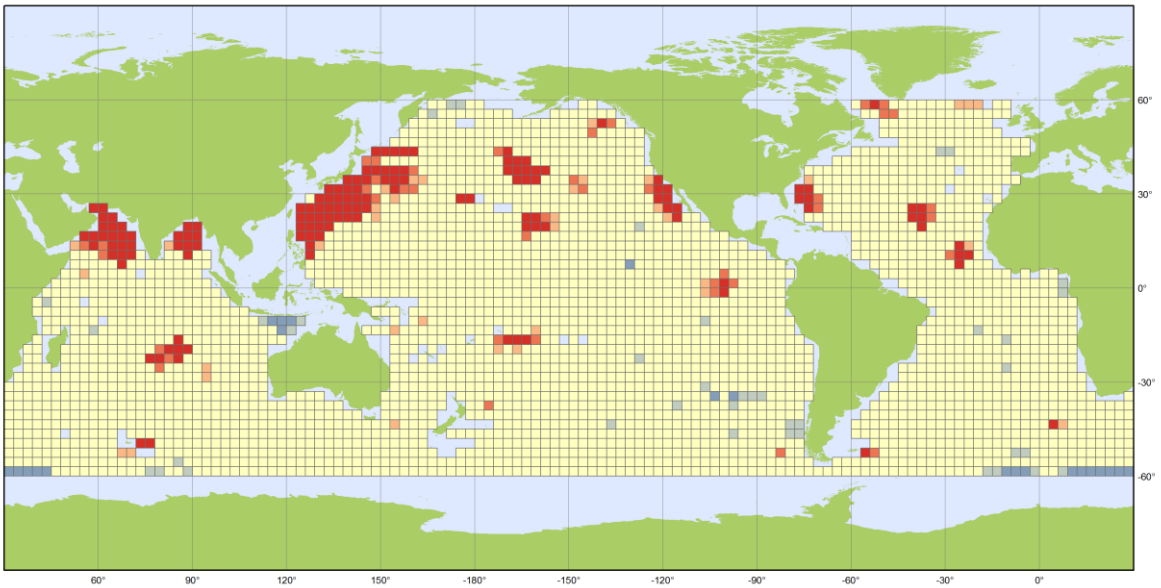

Argo **Coverage vs Initial Design - 2015 - Hot Spot Analysis** **February 2016**

For each float a spatial weight on age is calculated according to neighbours to identify spatial clusters of hot/cold spots.
To be statistically significant, the hot/cold spot will have a high/low value and be surrounded by other features with high/low values. (Getis-Ord Method)

Cold Spot - 99% Confidence | Cold Spot - 95% Confidence | Cold Spot - 90% Confidence | Not Significant | Hot Spot - 90% Confidence | Hot Spot - 95% Confidence | Hot Spot - 99% Confidence

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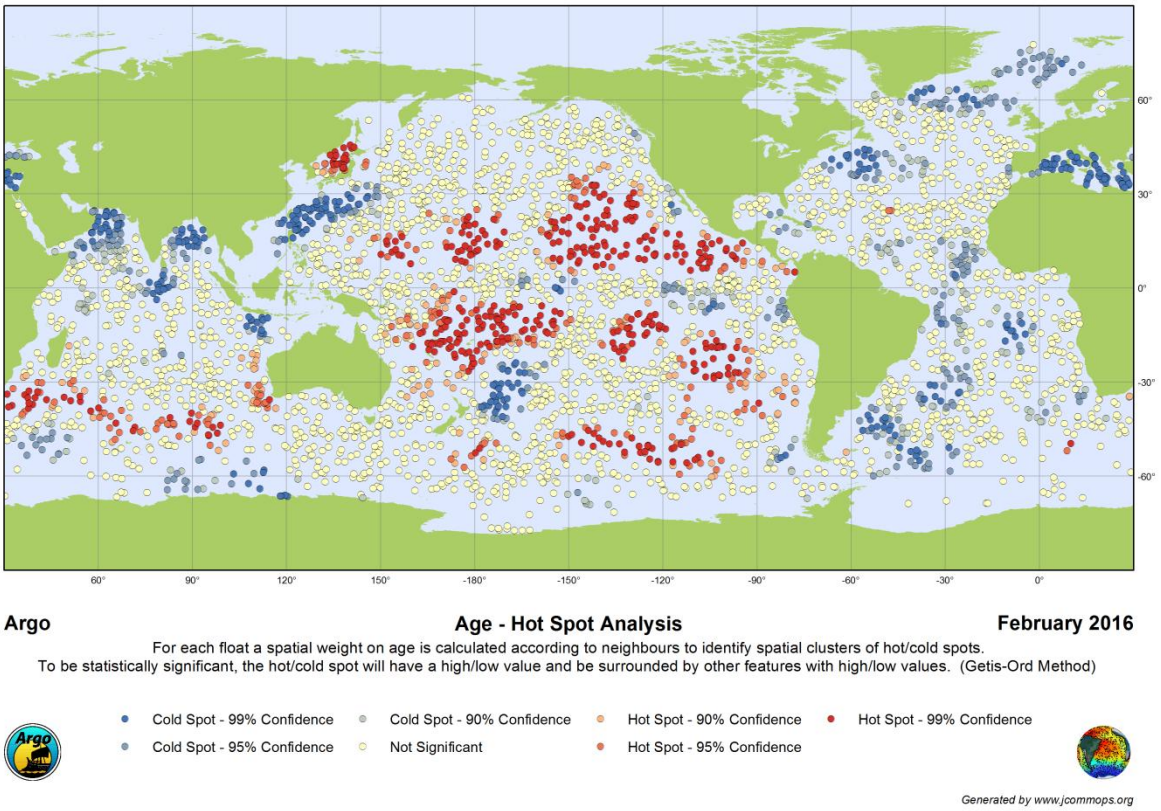


Fig. 17,18,19 2015 coverage for initial design with gaps highlighted and network age to guide 2016 implementation plan

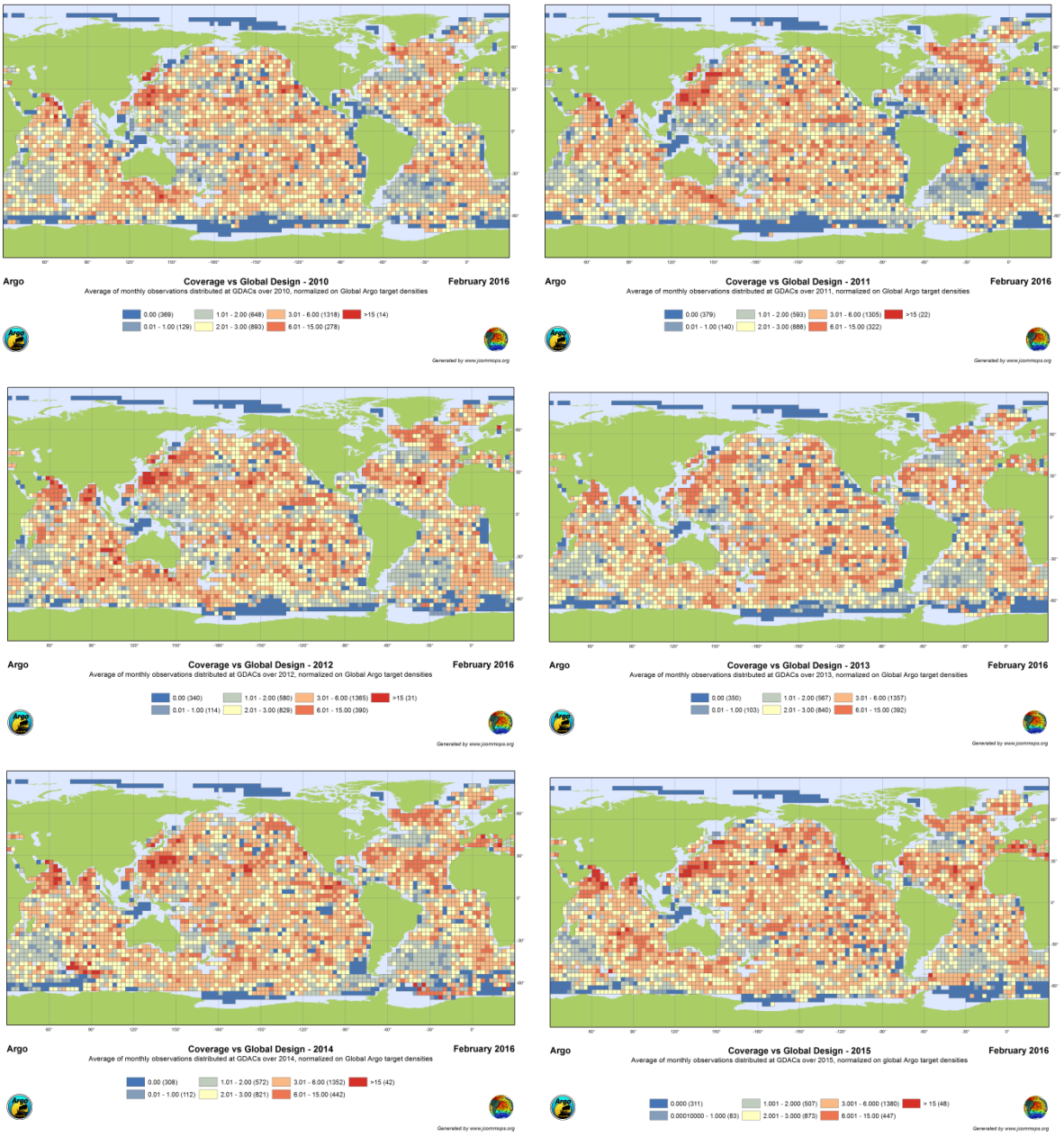
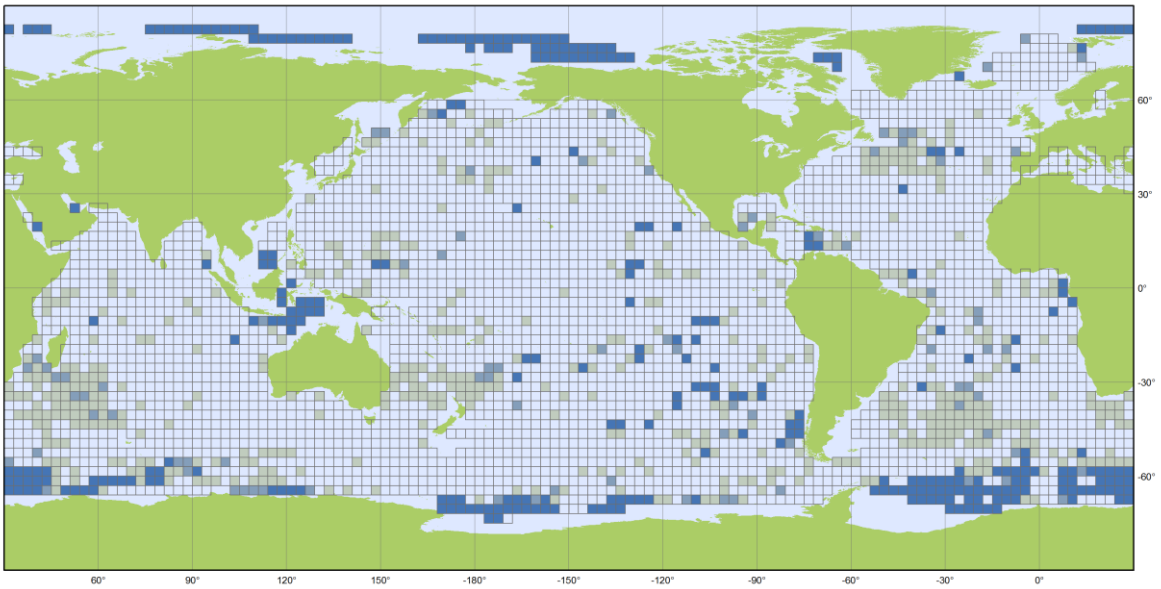


Fig 20-25 Coverage global design, 2010-2015 evolution.



Argo **Coverage vs Global Design - 2015** **February 2016**

Average of monthly observations distributed at GDACs over 2015, normalized on global Argo target densities

0.000 (311)	1.001 - 2.000 (507)	3.001 - 6.000 (1380)	> 15 (48)
0.00010000 - 1.000 (83)	2.001 - 3.000 (873)	6.001 - 15.00 (447)	

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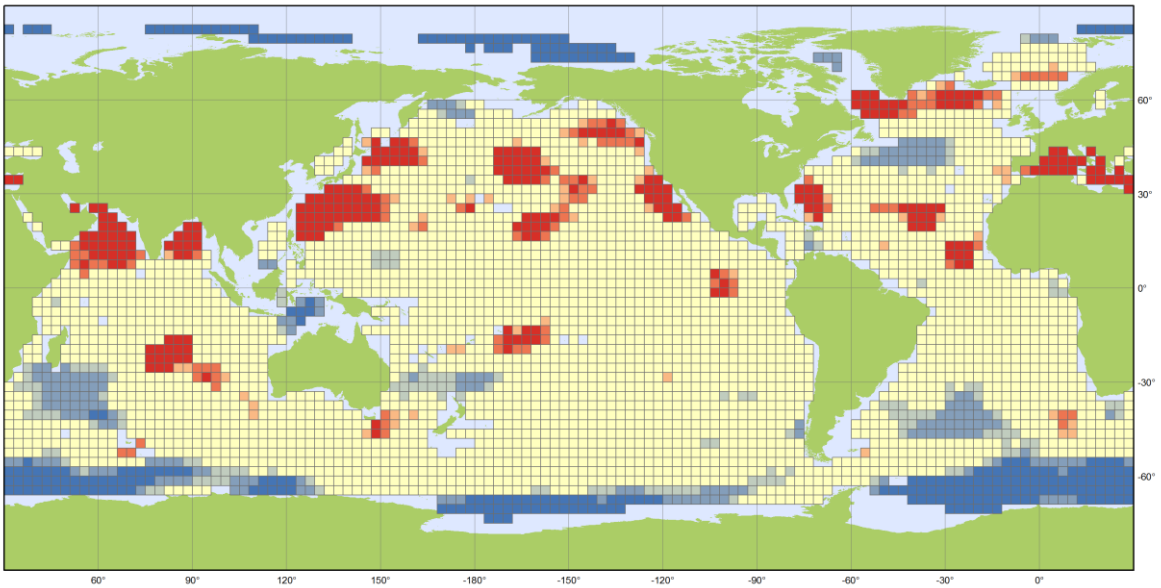

Argo **Coverage vs Global Design - 2015 - Hot Spot Analysis** **February 2016**

For each float a spatial weight on age is calculated according to neighbours to identify spatial clusters of hot/cold spots.
To be statistically significant, the hot/cold spot will have a high/low value and be surrounded by other features with high/low values. (Getis-Ord Method)

Cold Spot - 99% Confidence (278)	Cold Spot - 90% Confidence (145)	Hot Spot - 90% Confidence (60)
Cold Spot - 95% Confidence (184)	Not Significant (2639)	Hot Spot - 95% Confidence (92)
		Hot Spot - 99% Confidence (251)

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Fig. 26,27 Coverage Map for 2015, normalized on the Global Design, and Hot Spots analysis

Conclusion

Very little efforts are required to complete the initial design. A cruise along 54-60°S from mid-Atlantic to mid-Indian would be mostly welcome. Another in the South East Pacific ocean might fill gaps and anticipate old floats decay. Small regional requirements remain, probably made difficult by EEZ access and could only be implemented through strong regional cooperation. But they have all been implemented in the past at some point.
Intensity of deployments should be increased in Indian Ocean to cover 2015 deficit and anticipate float decay along 45°S. Design and targets for the Indian Ocean could be reviewed as we note a clear over sampling in Arabian Sea and Bay of Bengal. Ideally, 200 units should be deployed in the IO in 2016.
Overall, coverage of the initial design keeps progressing and should be even better when Indian Ocean issue will be addressed.

Global design implementation has definitely started. An increase of 10% of deployments per year would allow covering these enhancements, quantitatively (more in the Indian).
Efforts in the Southern ocean should be sustained to avoid decay in a region where float lifetime might be lower than expected.
Med. Sea is close to perfect implementation, at the cost of a very high intensity of deployments.
Black sea is in good shape. South China Sea and Japan Sea have a decreasing coverage which could be accelerated next year given float age in Japan Sea.
Equatorial band has progressed.
WBC (except in NW Pacific) implementation has not really started.

Overall, Argo is doing very good and keeps improving its coverage year after year. There is still some margin for improvement in the Indian Ocean in particular.

For further information please see the report on deployment opportunities, based on these requirements, and on-line. Display at the same time on the interactive map, density or coverage maps, and cruise plans, deployment plans.