Optical remote sensing of wetlands and lakes

Hybrid approaches

Thomas Gumbricht

Hybrid approach

The pantropical wetland/peatland map published earlier this year used a hybrid approach:

- Hydrology and topography to derive topographic wetness, and separating the sources of surface wetness
- Time-series of optical multispectral satellite images at medium resolution (MODIS) to allow phenological analysis of surface wetness
- Geomorphological conditions related to hydrology in general and wetlands in particular (”hydromorphology”) to distinguish idiosyncratic settings

Hybrid approach

The hybrid approach developed for the pantropical wetland mapping is more of an expert system, and not dependent on local reference data:

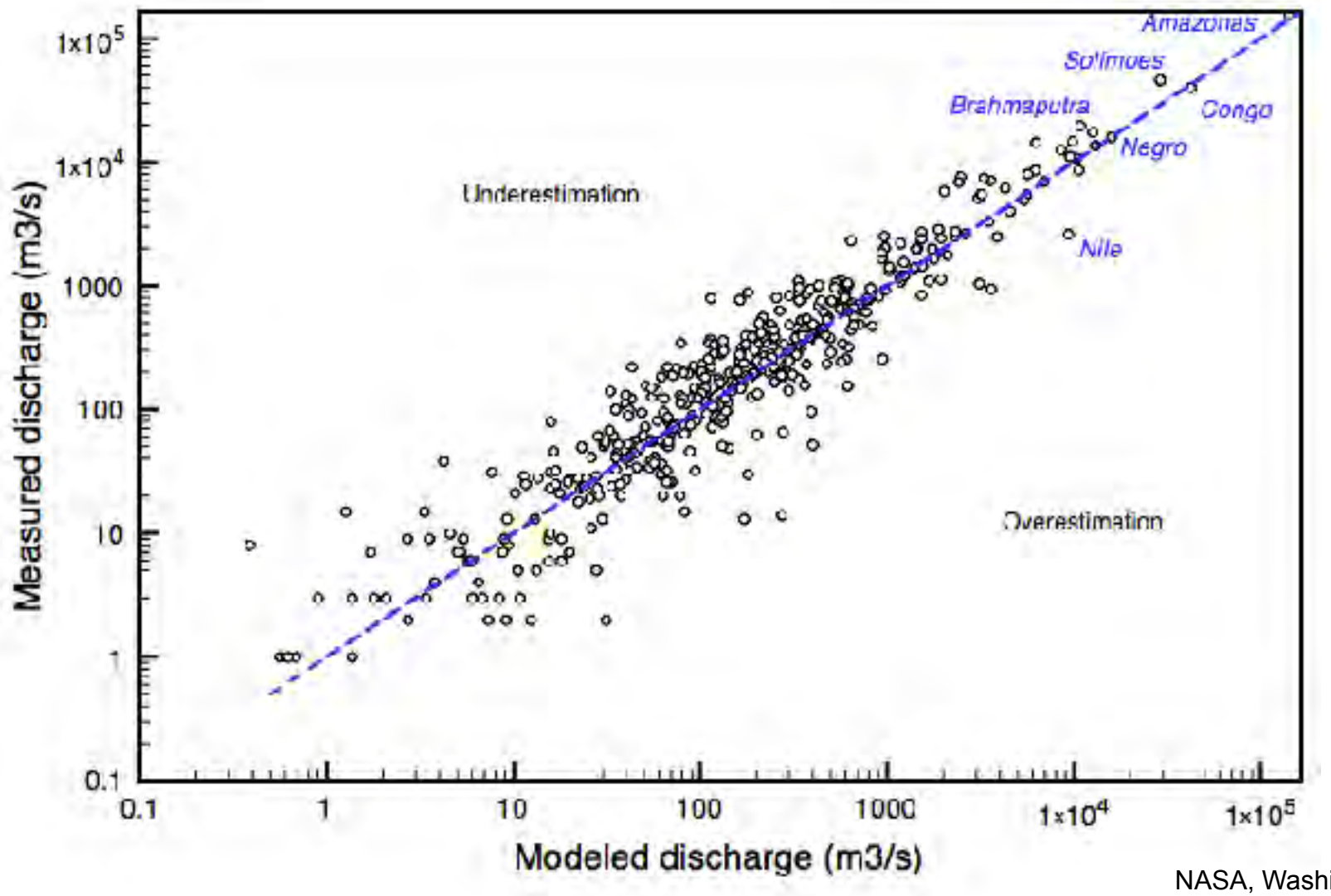
- All derived data used in the classification is intelligible,
- Most input layers are of ratio or ordinal scale, and can be used for calibrating the wetland map in different regions, or as input in other classification schemes,
- Hydromorphological (nominal) information is used as boolean data for identifying potential wetland areas, and for distinguishing different wetland classes

Hybrid approach

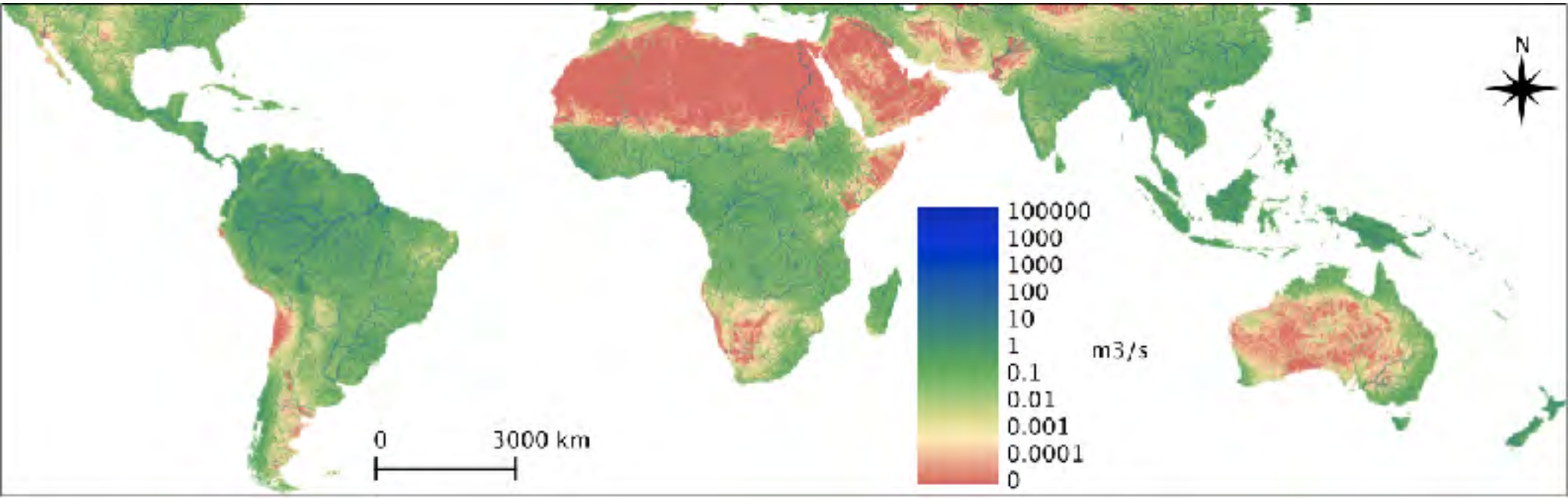
Hydrology and topography to derive surface wetness and its local source

- Development of a global high spatial resolution rainfall-runoff model,
- Including estimates of flooding and floodout volumes
- Definition of thematic wetland topographic convergence indexes (wTCI) for describing surface wetness using selected components of the water cycle (e.g. rainfall, surface flow, groundwater flow).

- Global rainfall-runoff model at 250 m spatial resolution and annual time step - results



- Global average runoff (m3/s)



Hybrid mapping global tropical wetlands

Wetland Topographic Convergence Index

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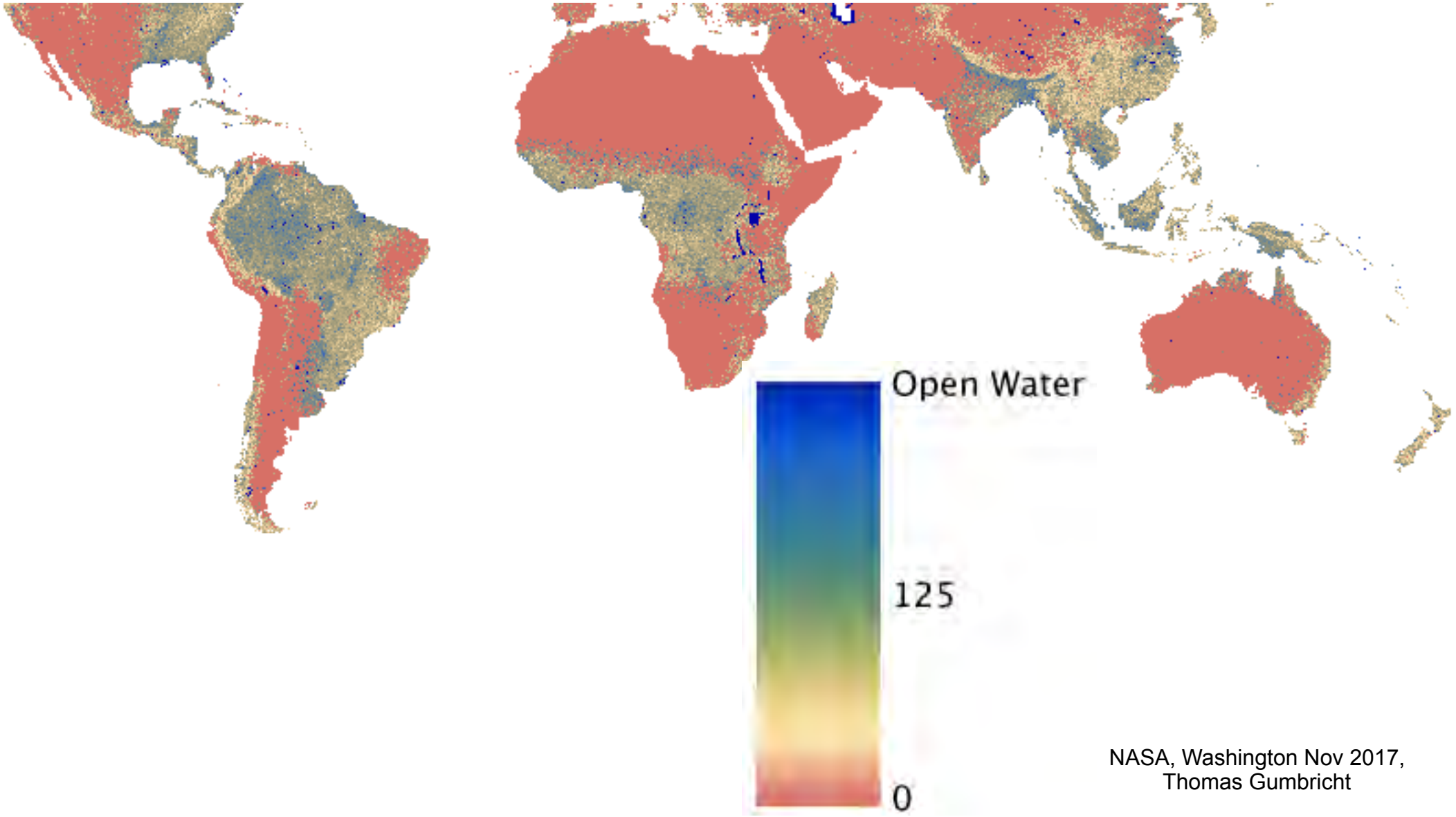
Hybrid mapping global tropical wetlands

Wetland Topographic Convergence Index

General Wetlands



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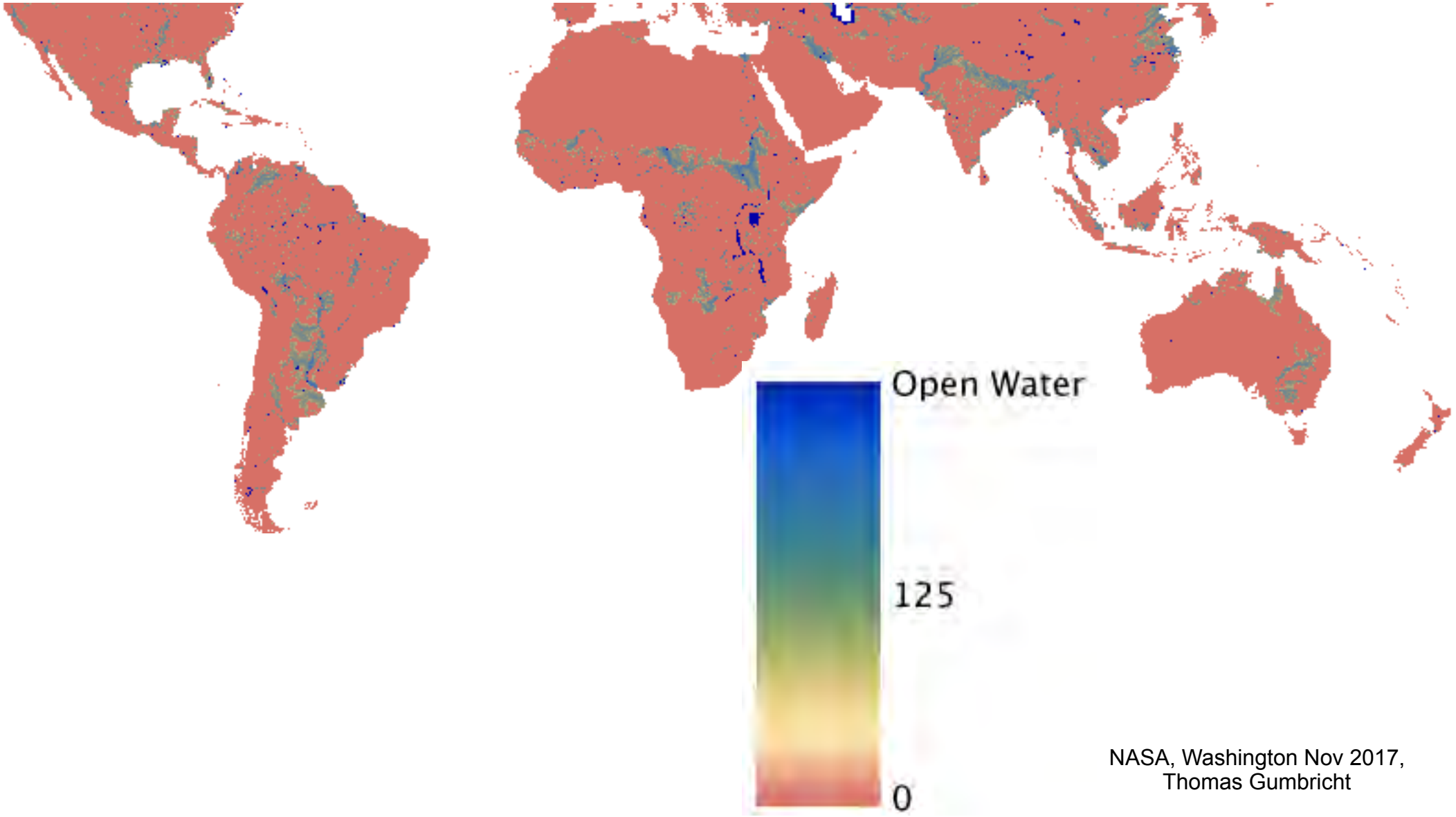
Hybrid mapping global tropical wetlands

Wetland Topographic Convergence Index

Floodout Wetlands



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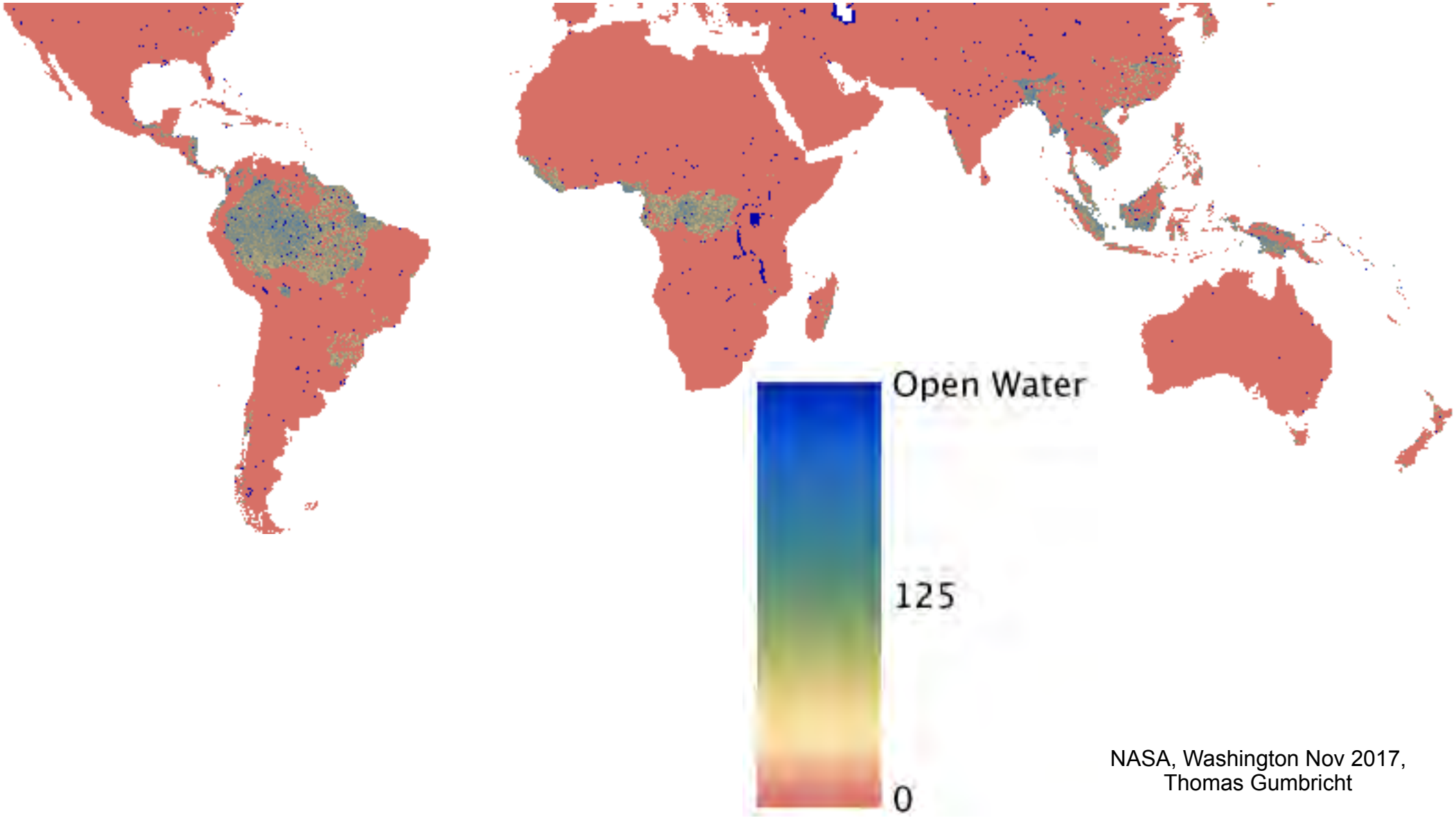
Hybrid mapping global tropical wetlands

Wetland Topographic Convergence Index

Ombrotrophic bogs



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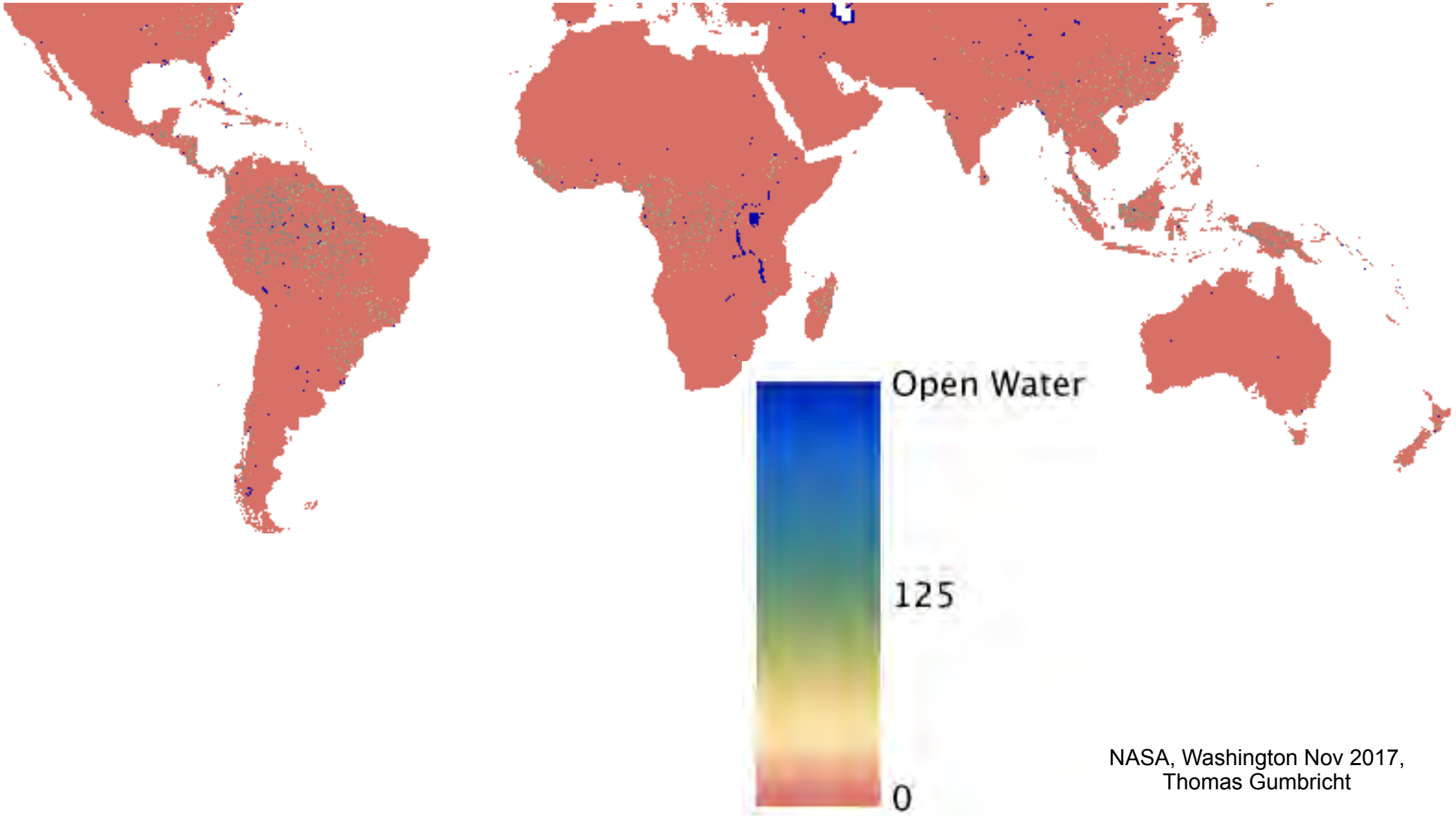
Wetland Topographic Convergence Index

Minerotrophic fens



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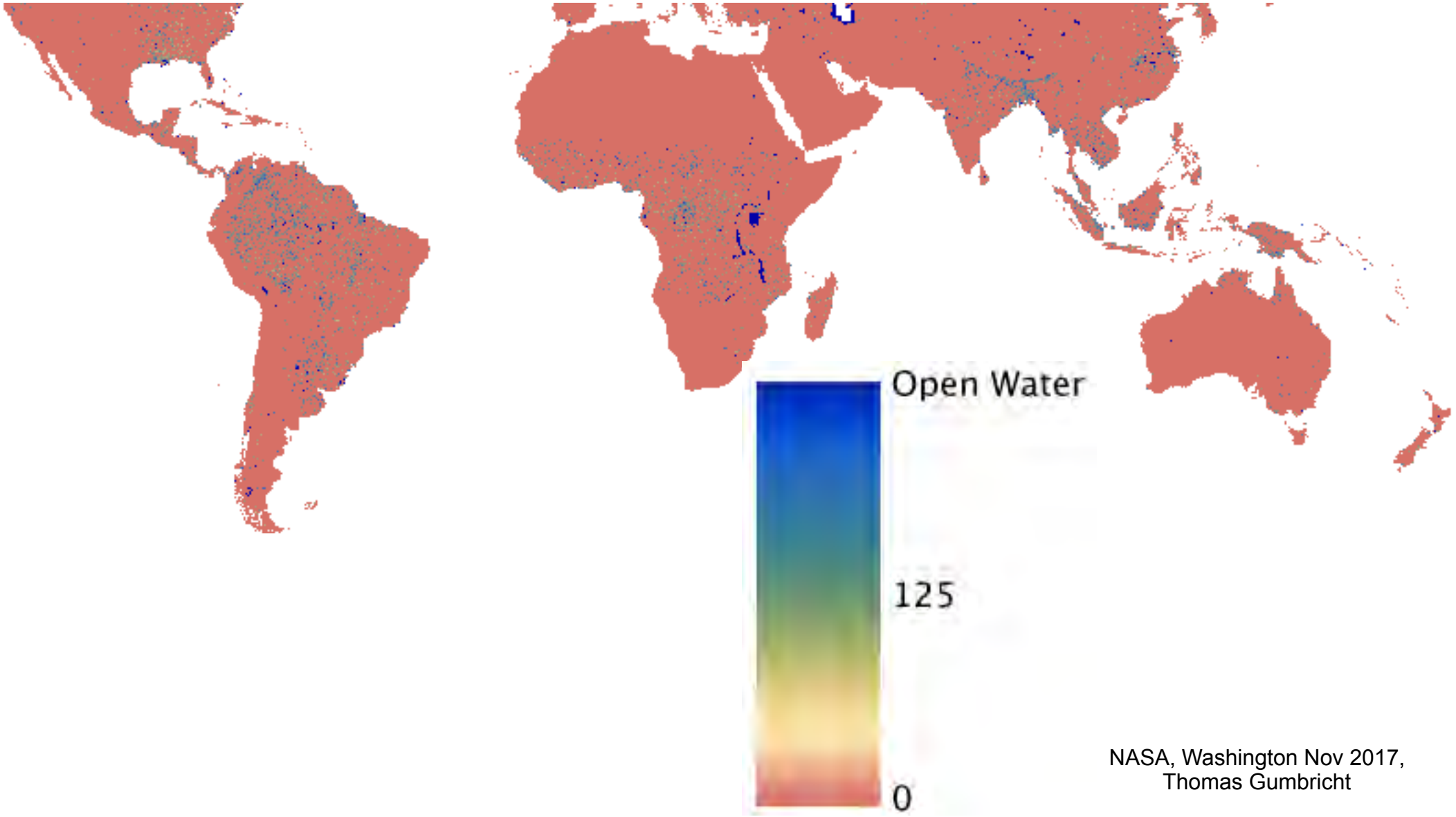
Hybrid mapping global tropical wetlands

Wetland Topographic Convergence Index

Riverine Wetlands



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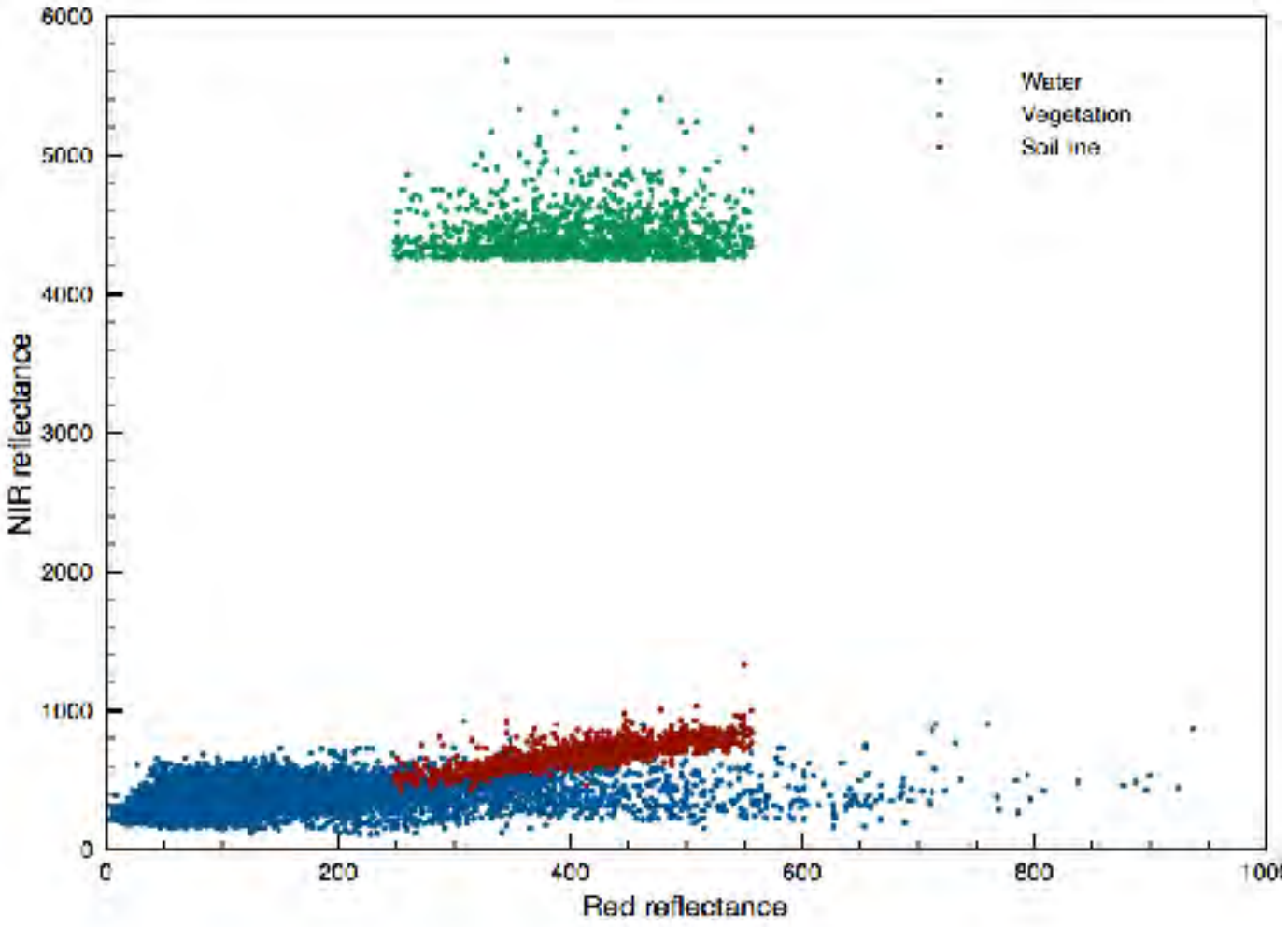
Hybrid approach

- Optical multispectral satellite images for deriving a surface wetness index

  - Definition of global tropical spectral end-members
  - Optimized eigen-vector transformation for converting band reflectance to soil and surface wetness features (Sometimes called Tasseled Cap in image processing)
  - Definition of the Transformed Wetness Index (TWI), an optimized normalized difference algorithm using the soil and wetness features to capture surface wetness

- Optical multispectral satellite images for deriving a surface wetness index



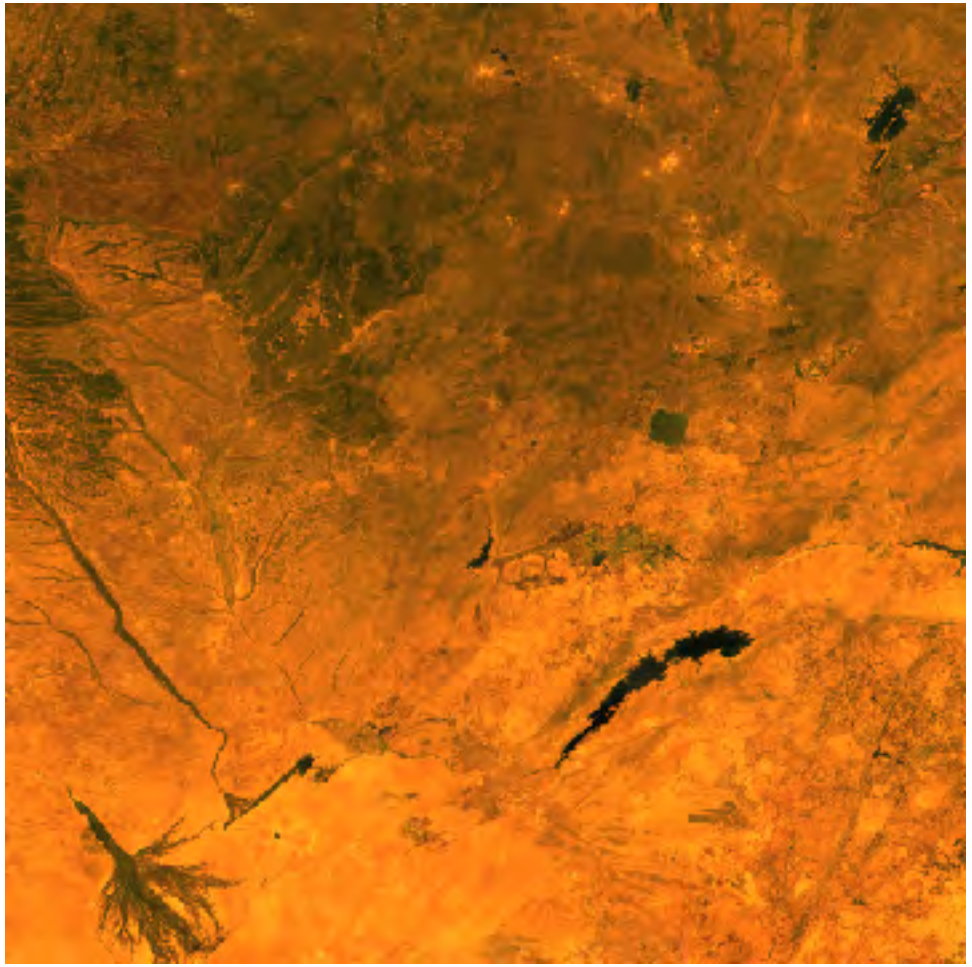
Spectral end-members for parts of Indonesia and Malaysia

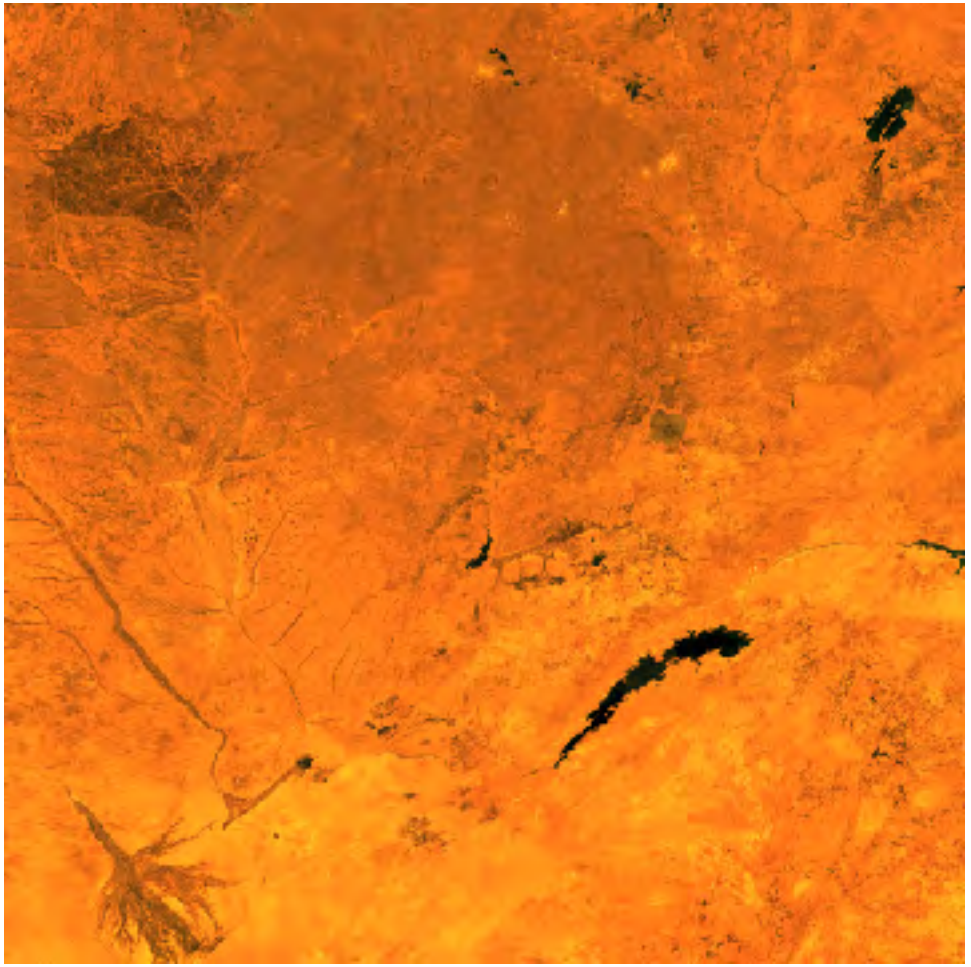
- Optical multispectral satellite images for deriving a surface wetness index

Material	R	NIR	B	G	MIRa	MIRb	MIRc
Dark soil (offset)	0.0563	0.1008	0.0147	0.0507	0.1531	0.1836	0.1699
Brightness	0.314812	0.320970	0.359456	0.336364	0.249772	0.657334	0.247078
PV	-0.193666	0.798701	-0.140345	-0.094762	0.390175	-0.199024	-0.322562
NPV	0.482520	0.134057	-0.025535	0.347607	0.071952	-0.653813	0.441669
Wetness	0.188177	0.038364	0.493917	0.350060	-0.358132	-0.173122	-0.662112

Optimized eigen vectors for surface wetness mapping

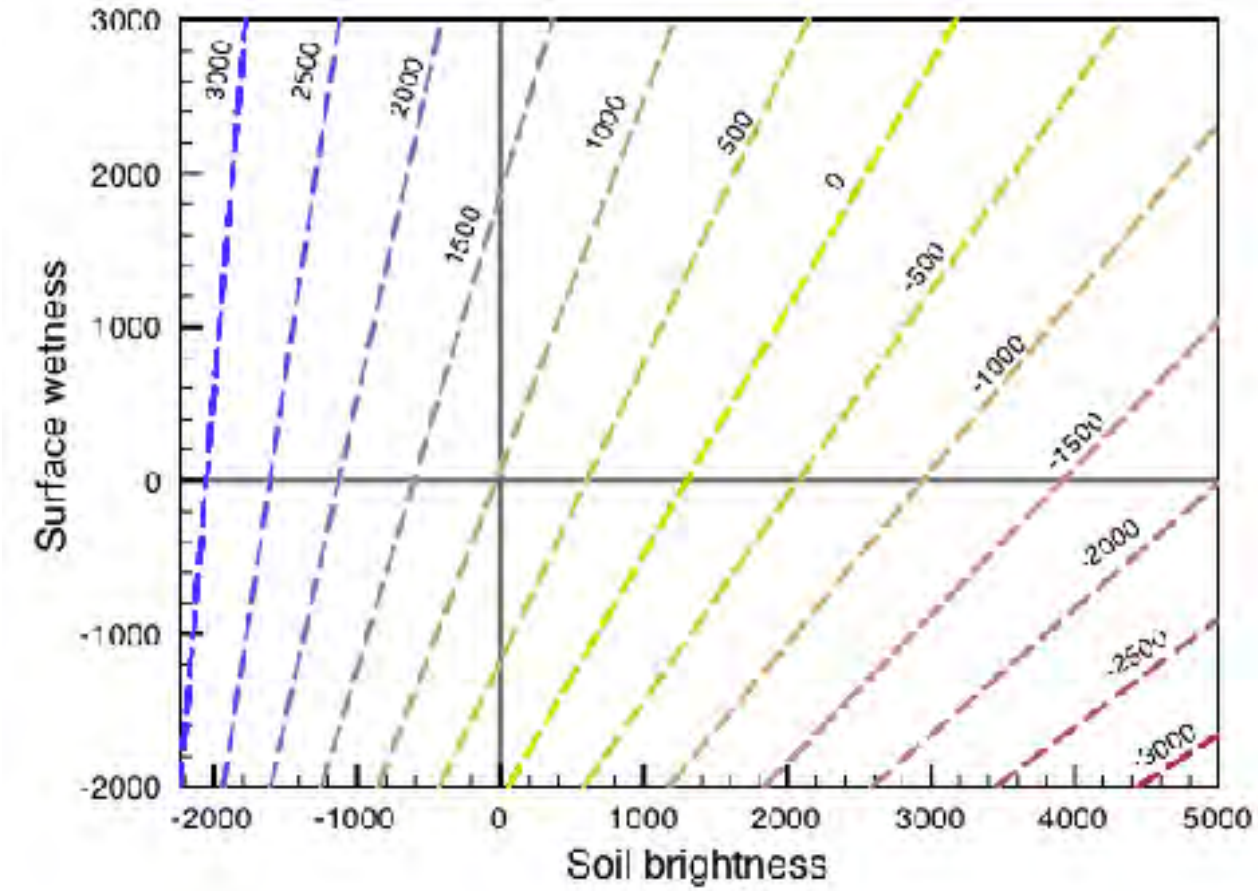
- Optical multispectral satellite images for deriving a surface wetness index





The adoption of Orthogonal vectors can be regarded as a kind of pixel-unmixing, where the vegetation parts of the optical VIS/NIR reflectance is removed. The soil wetness index is based on the image to the right (recomposed from the PCs, excluding vegetation components).

- Optical multispectral satellite images for deriving a surface wetness index



Isolines of soil wetness as defined by soil brightness (PC1) and surface wetness (PC4)

- Optical multispectral satellite images for deriving a surface wetness index

	All probes						Cosmic-ray probes (COSMOS)					
Sensor	**bias**	**r^2**	**rmse**	**E**	**Stn**	**n**	**bias**	**r^2**	**rmse**	**E**	**Stn**	**n**
Global models (global normalization)												
Θ_{TWI}	4.5	0.05	10.8	-0.54	800	13825	4.3	0.16	10.5	-0.21	55	841
$\Theta_{AMSR\text{-}E}$	-6.8	0.11	10.4	-0.33	770	121327	-4.9	0.06	11.0	-0.52	48	5276
Θ_{SMOS}	-6.4	0.24	9.9	-0.03	731	60338	-7.8	0.23	10.3	-0.05	52	4640
Local models (aggregated local normalizations)												
Θ_{TWI}	-0.2	0.52	7.7	0.44	750	13694	-0.1	0.80	5.1	0.79	54	839
Θ_{AMSR}	0.0	0.65	6.5	0.62	763	121303	0.0	0.84	4.5	0.84	47	5271
Θ_{SMOS}	0.0	0.76	5.6	0.74	669	60198	0.0	0.91	3.4	0.91	49	4634

- Optical multispectral satellite images for deriving a surface wetness index

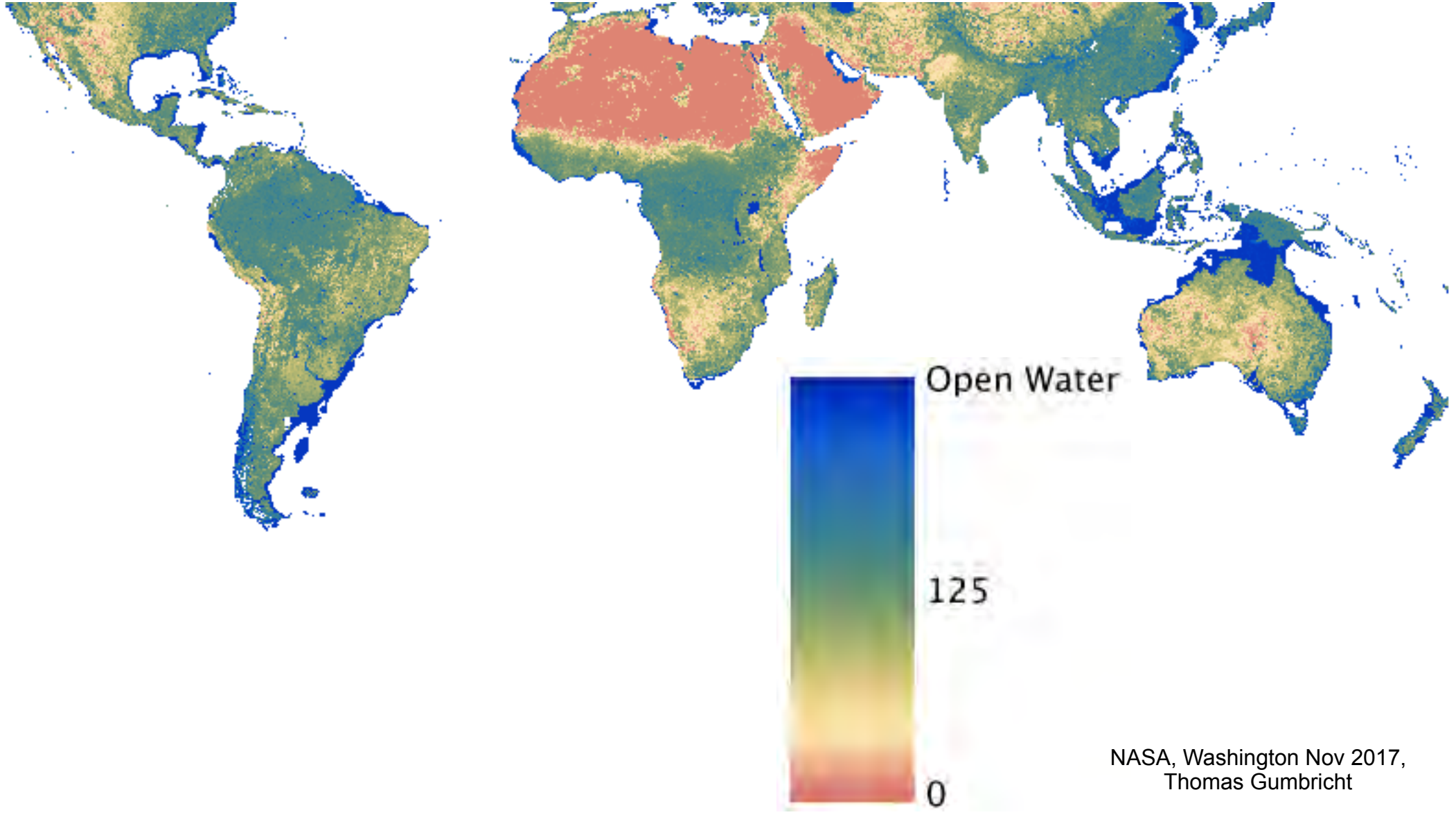
	Tropical					
Model	**bias**	**r^2**	**rmse**	**E**	**stn**	**n**
Regional models (regional normalization)						
Θ_{TWI}	2.0	0.42	11.0	0.30	20	425
Θ_{AMSR-E}	-10.5	0.00	13.6	-1.0	15	2309
Θ_{SMOS}	-2.1	0.27	12.2	0.04	20	2692
Local models (aggregated local normalizations)						
Θ_{TWI}	-0.3	0.79	6.5	0.78	19	421
Θ_{AMSR-E}	0.0	0.75	6.8	0.73	15	2309
Θ_{SMOS}	0.0	0.80	6.4	0.79	20	2692

Transformed Wetness Index (TWI)

Hybrid mapping global tropical wetlands

Transformed Wetness Index (TWI)

Mean TWI 2011



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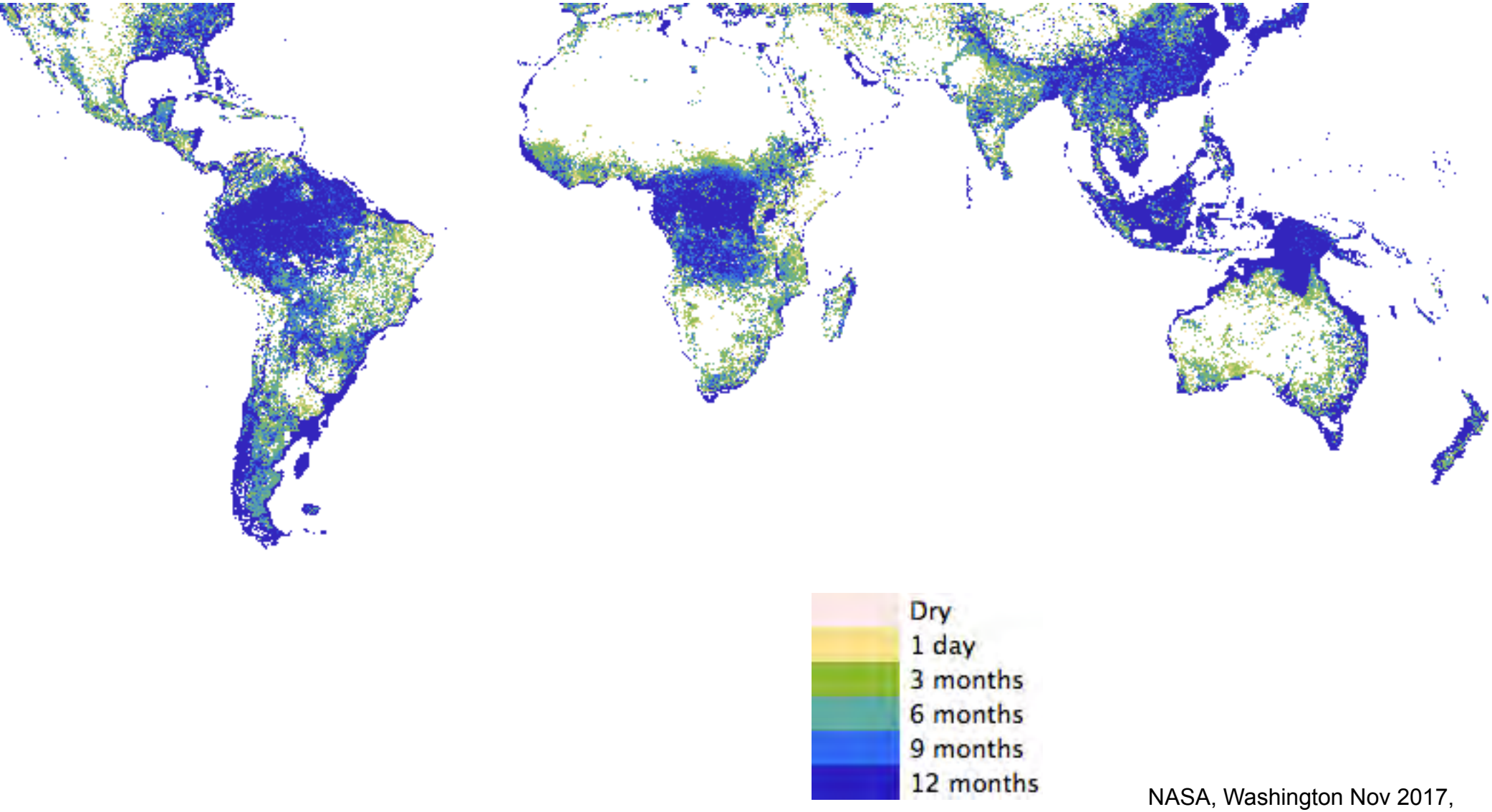
Transformed Wetness Index (TWI)

Length Wet Season (Soil moisture > 25 %) 2011



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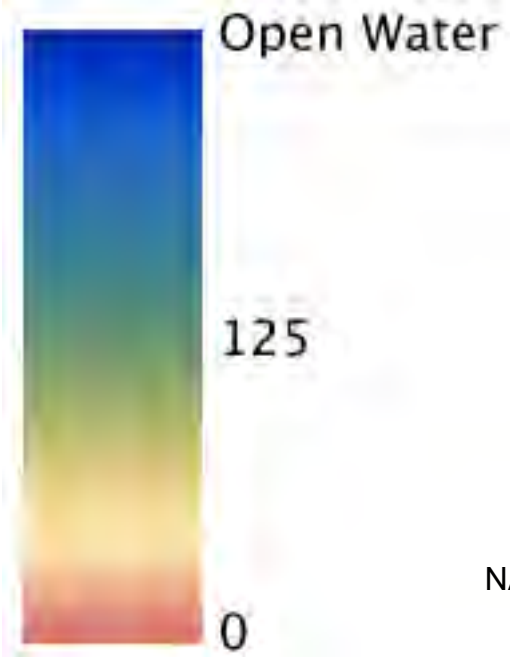
compounded Transformed Wetness Index (cTWI)



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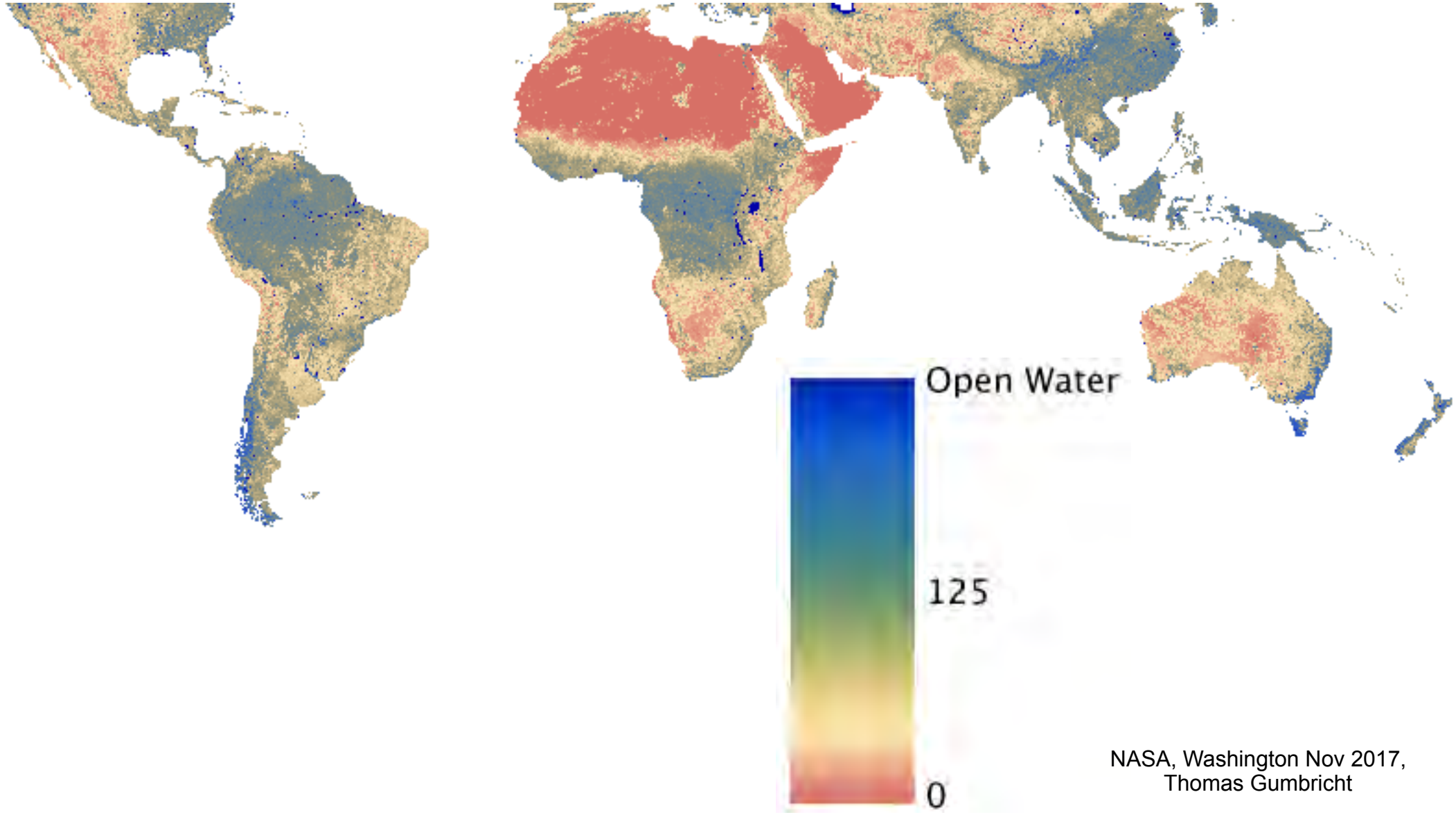
Hybrid mapping global tropical wetlands

compounded Transformed Wetness Index (cTWI)

General Wetlands



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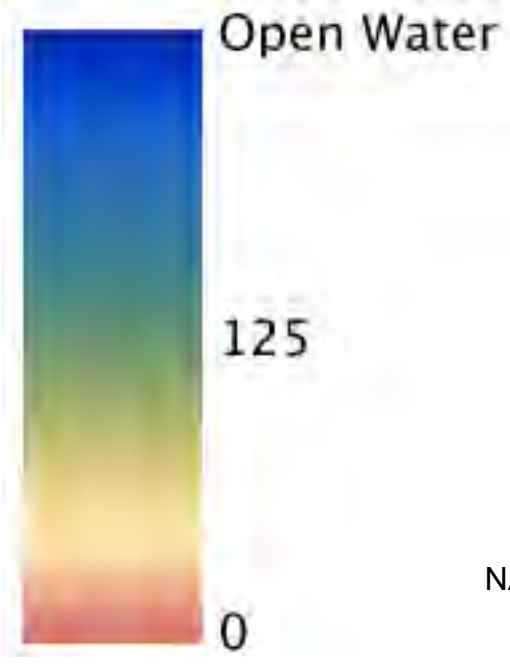
compounded Transformed Wetness Index (cTWI)



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Hybrid approach

- Hydromorphological maps

- Hydraulic terrain relief
- Channel valleys
- Small and Large valleys (with or without flowing channels)
- General geomorphology
- Plain and valley geomorphology

Hydromorphology

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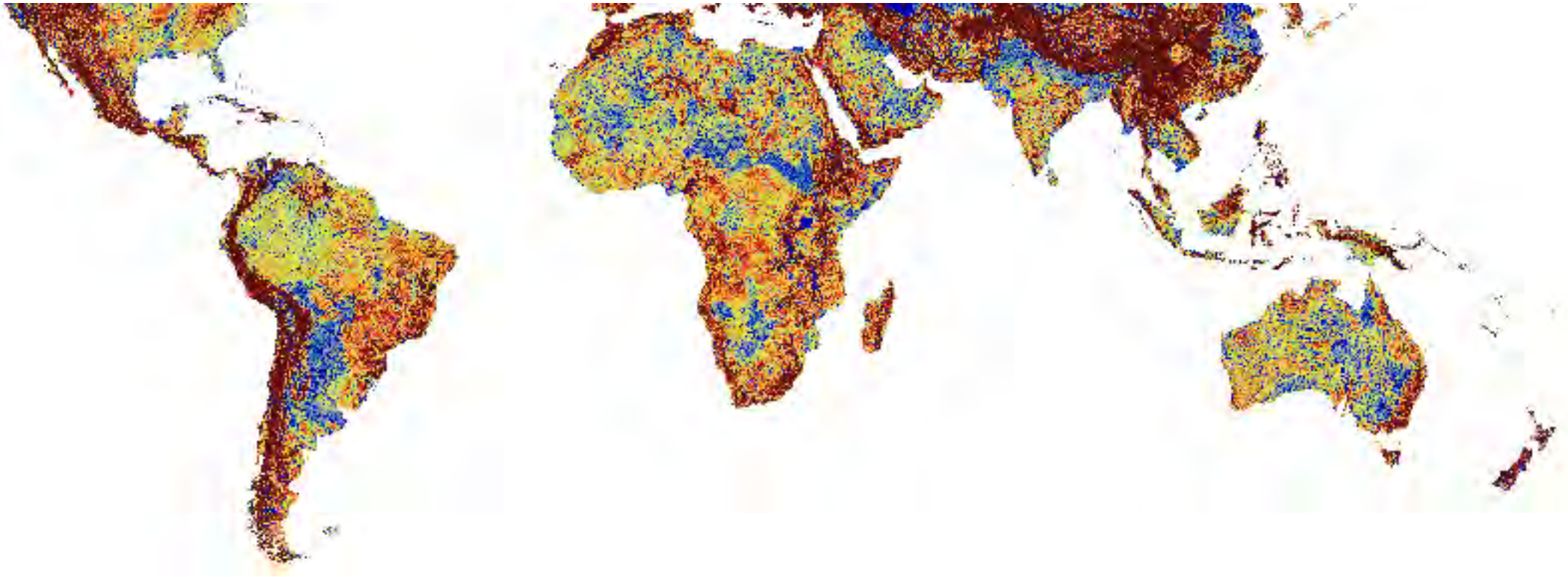
Hydromorphology

Hydraulic terrain relief (floodouts and floodplains)



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Hydromorphology

Geomorphology

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Hydromorphology

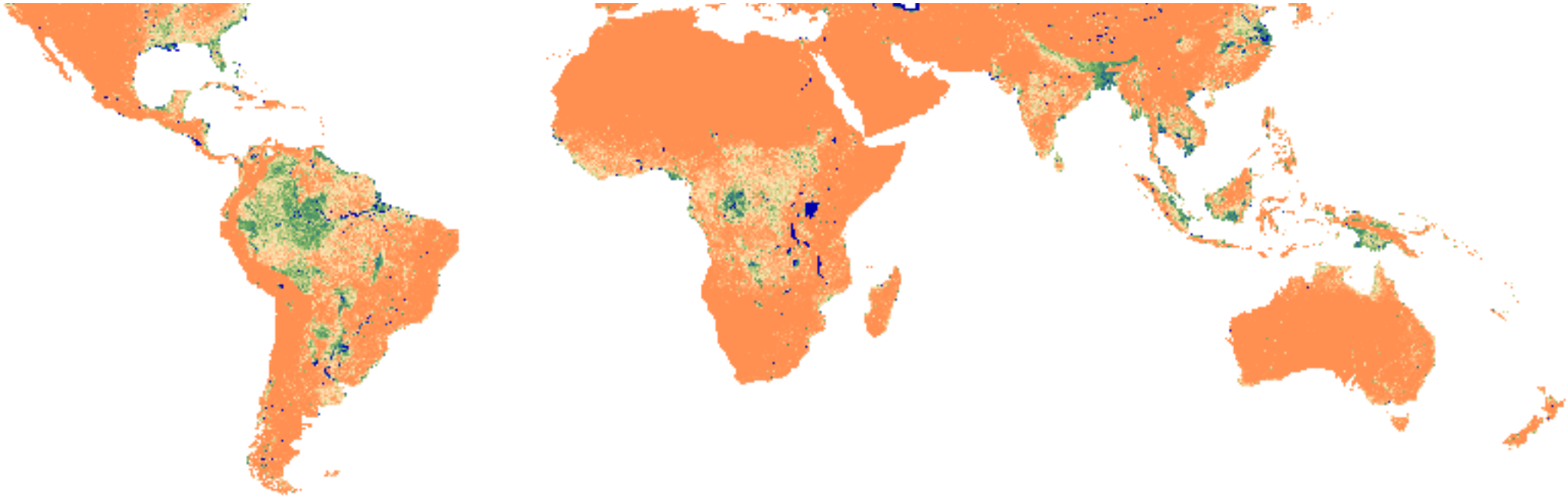
Hybrid approach

- Hybrid mapping, combine
  - Thematic or generic WTCI, and
  - Thematic or generic cTWI, with
  - Hydromorphological constraints.
  - Set a threshold for defining (thematic) wetlands or peatlands

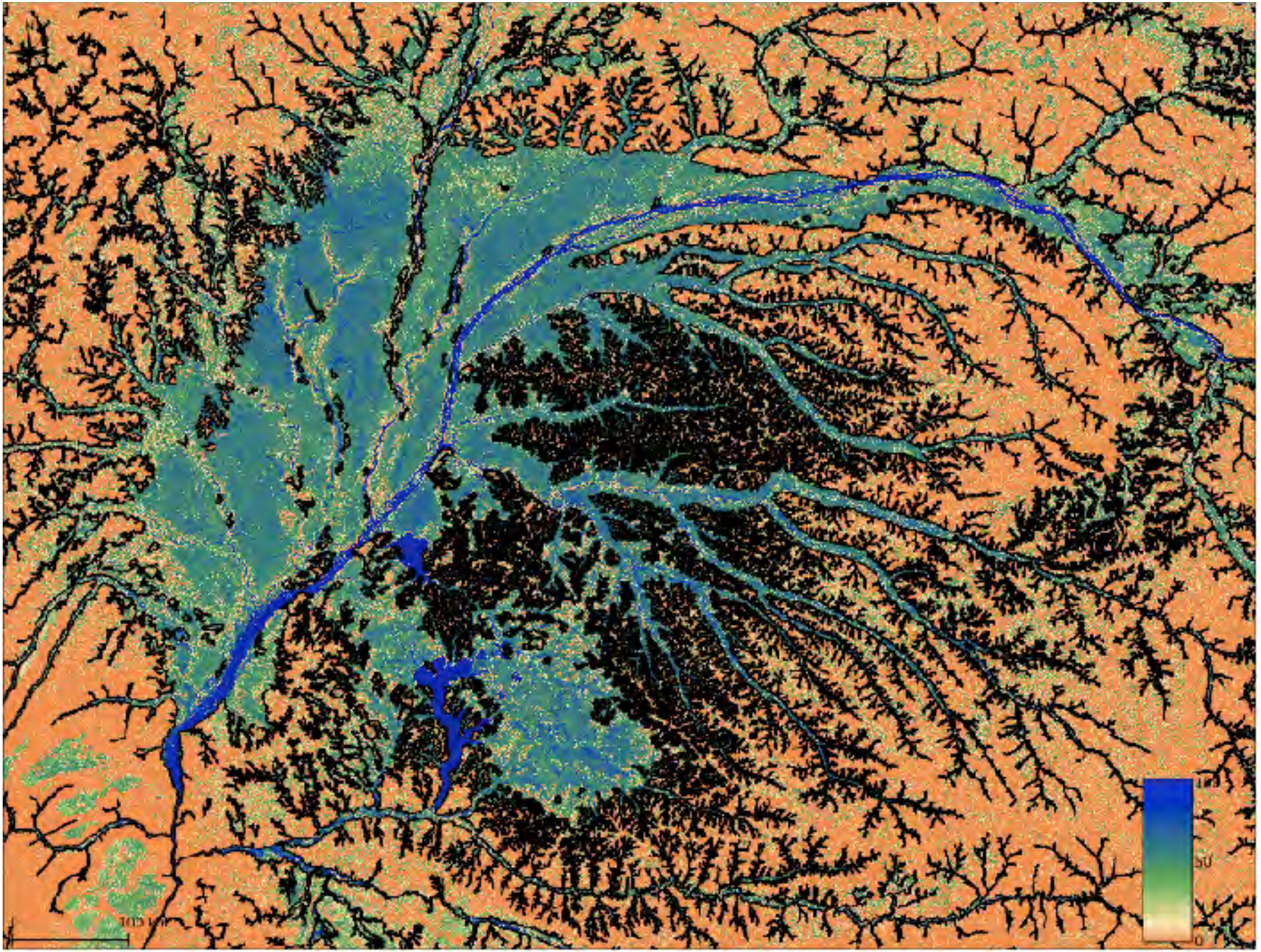
e.g. ”Find all areas where WTCI from precipitation alone is > 150 and the period of annual inundation is longer than 60 days, and that is either a plain or dome-shaped. Classify index values above 50 as ombrotrophic bogs”

Hybrid approach

Hybrid approach

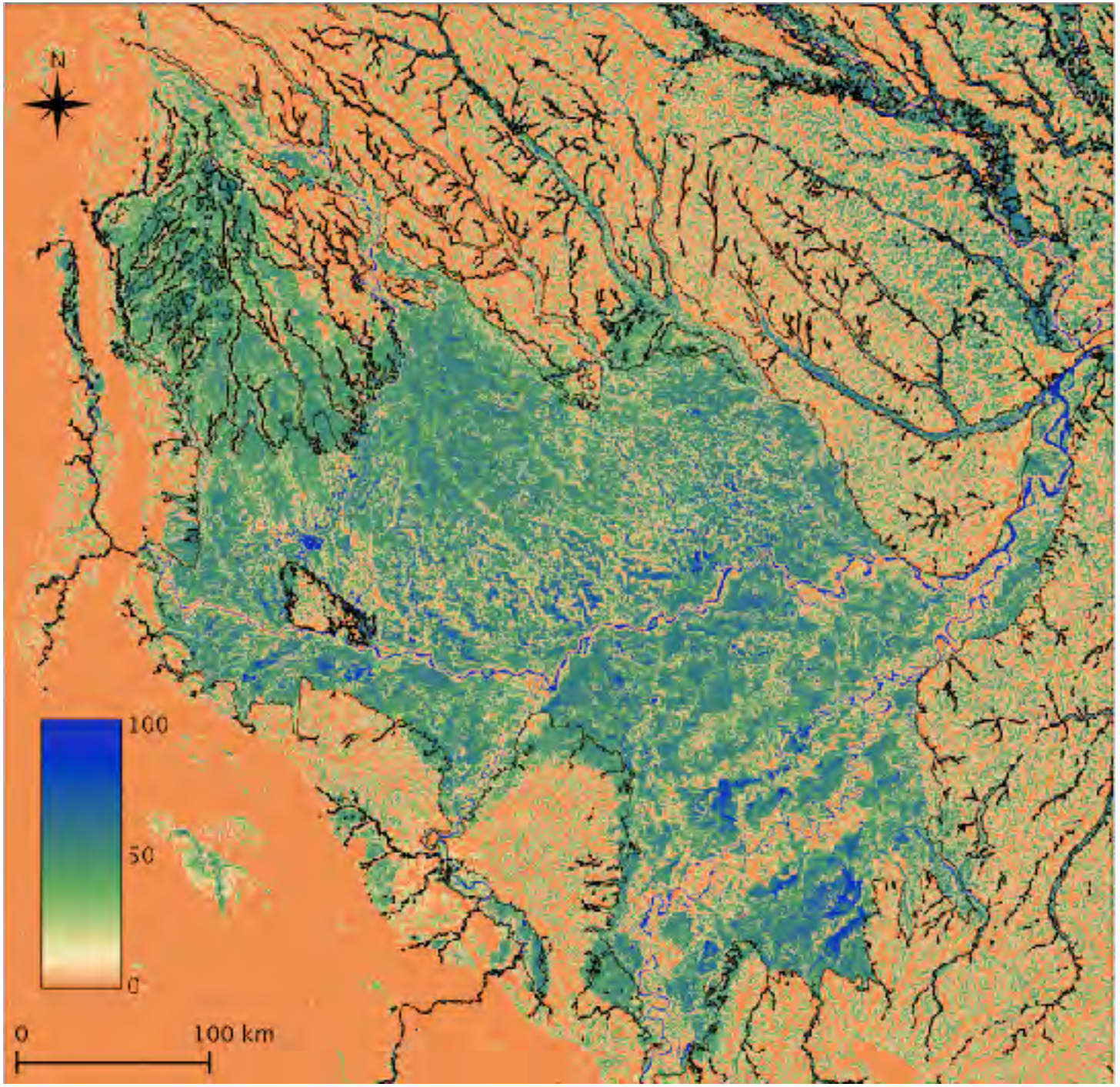


Hybrid mapping global tropical wetlands



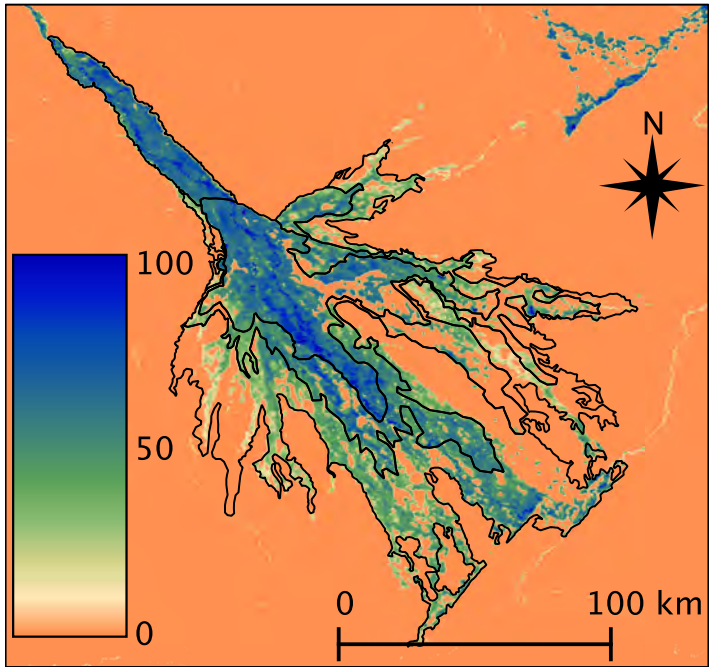
Wetland map from Bwangoy et al (2010) over the central Congo basin (black).

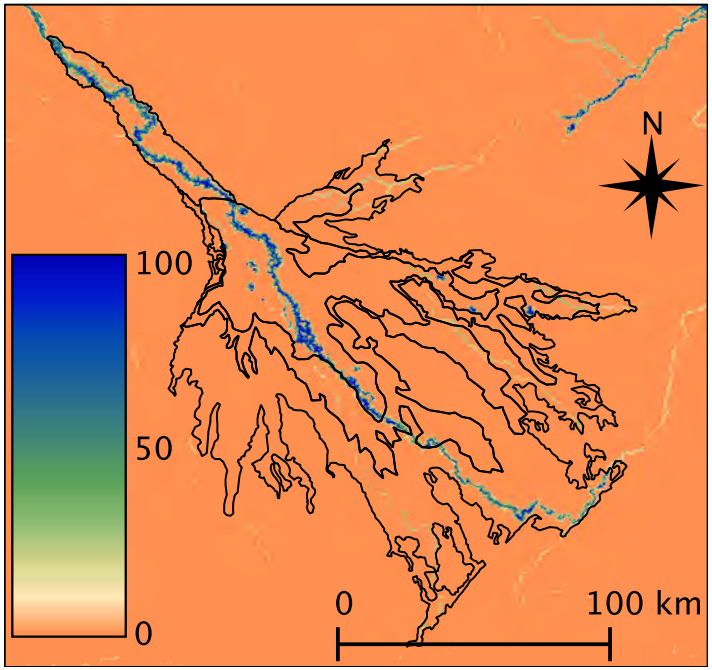
Hybrid mapping global tropical wetlands



Wetland map from Hess et al (2012) over the Peruvian Amazon (black).

Hybrid mapping global tropical wetlands





Wetland map from McCarthy et al (2002) over the Okavango (black).
Left map calculated using **river floodout;**
Right map calculated using **channel flooding**

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Estimates of tropical wetlands and peatlands (bounded by 20^{o} latitude)

	Total area	Volumetric area*	Total volume
	km^2	km^2	km^3
Open Water	540,000	--	--
Wetlands	4,100,000	2,700,000	10,000
Peatlands	2,100,000	1,500,000	7,100

*The volumetric area excludes all cells with a recorded wetland or peatland depth equal to zero.

The GIEMS dataset estimate of wetlands bounded by 30 deg latitude varies between 3.8 and 6.0 million km2 (compared to 4.1 to the tropics bounded by 20 deg latitude in here).