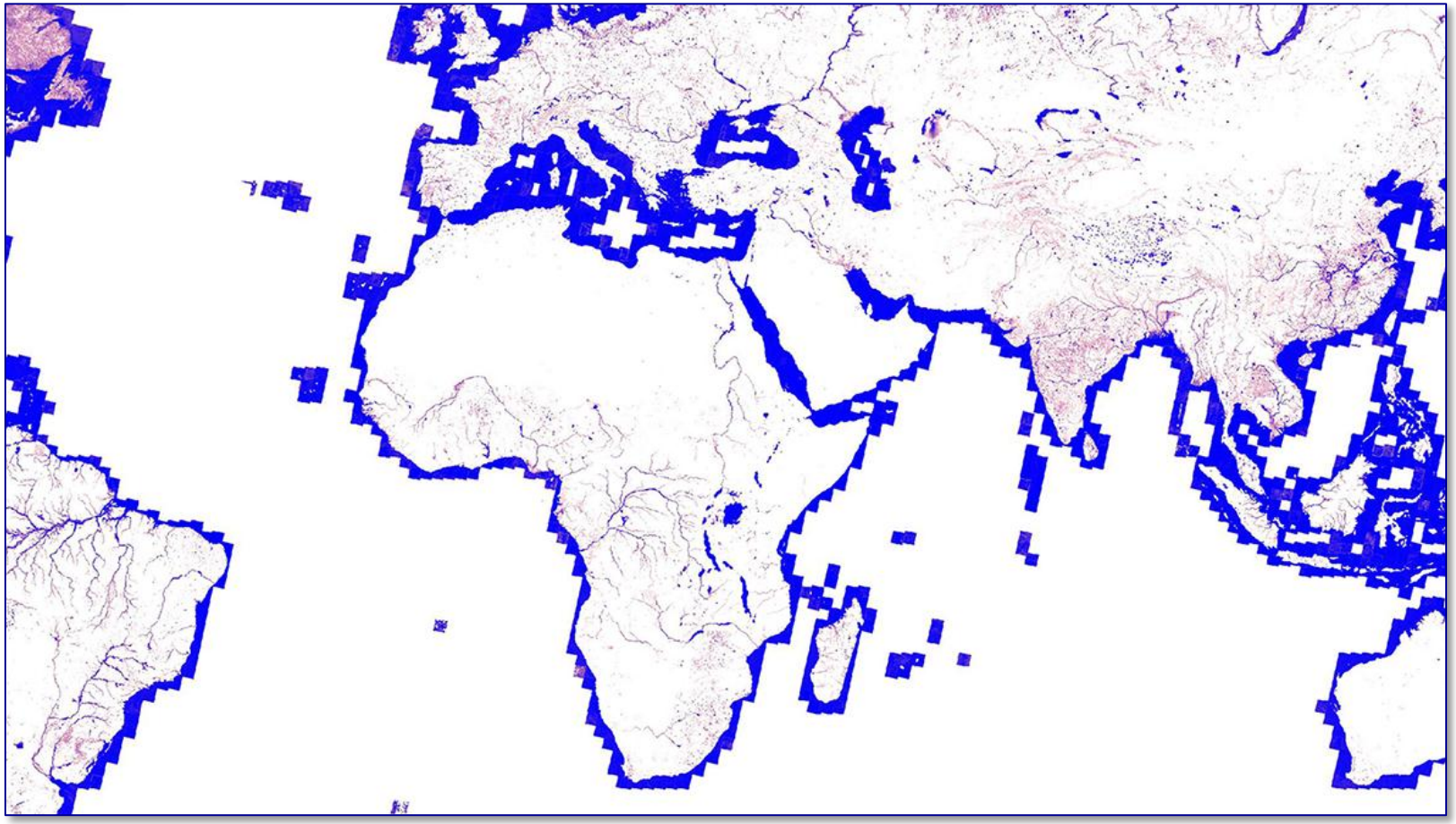


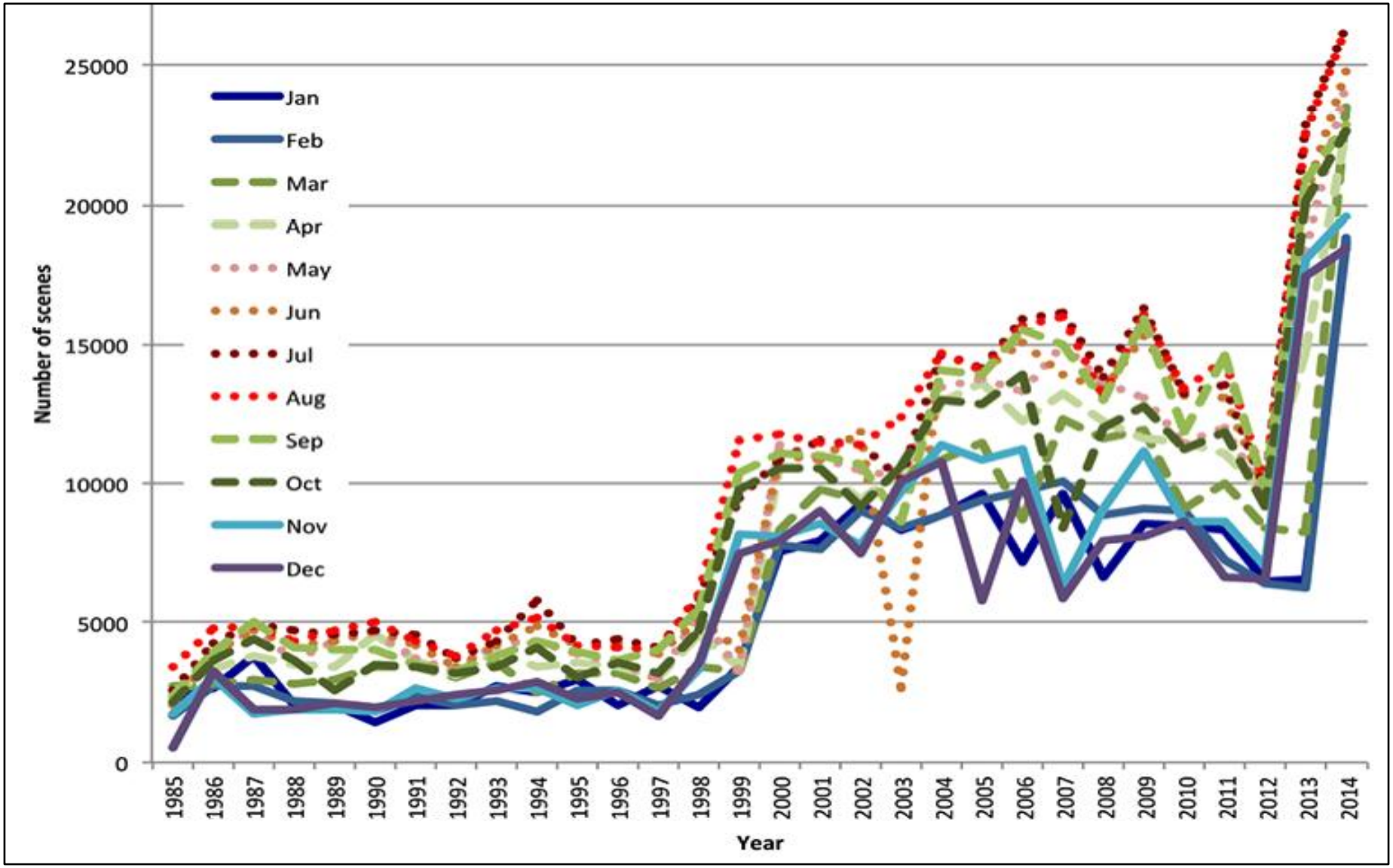
Mapping 3 decades of Global Surface Water Occurrence and Seasonality

Jean-Francois Pekel, Andrew Cottam, Noel Gorelick* and Alan Belward
EC Joint Research Centre, Ispra
***Google Earth Outreach**

Source LtoR: A. Anlicker, M.O.Stevens, A.S. Belward, Ptijue, A.S. Belward, A. Jones, J & K. Hollingsworth, JohnnyOneSpeed, H. Varlan

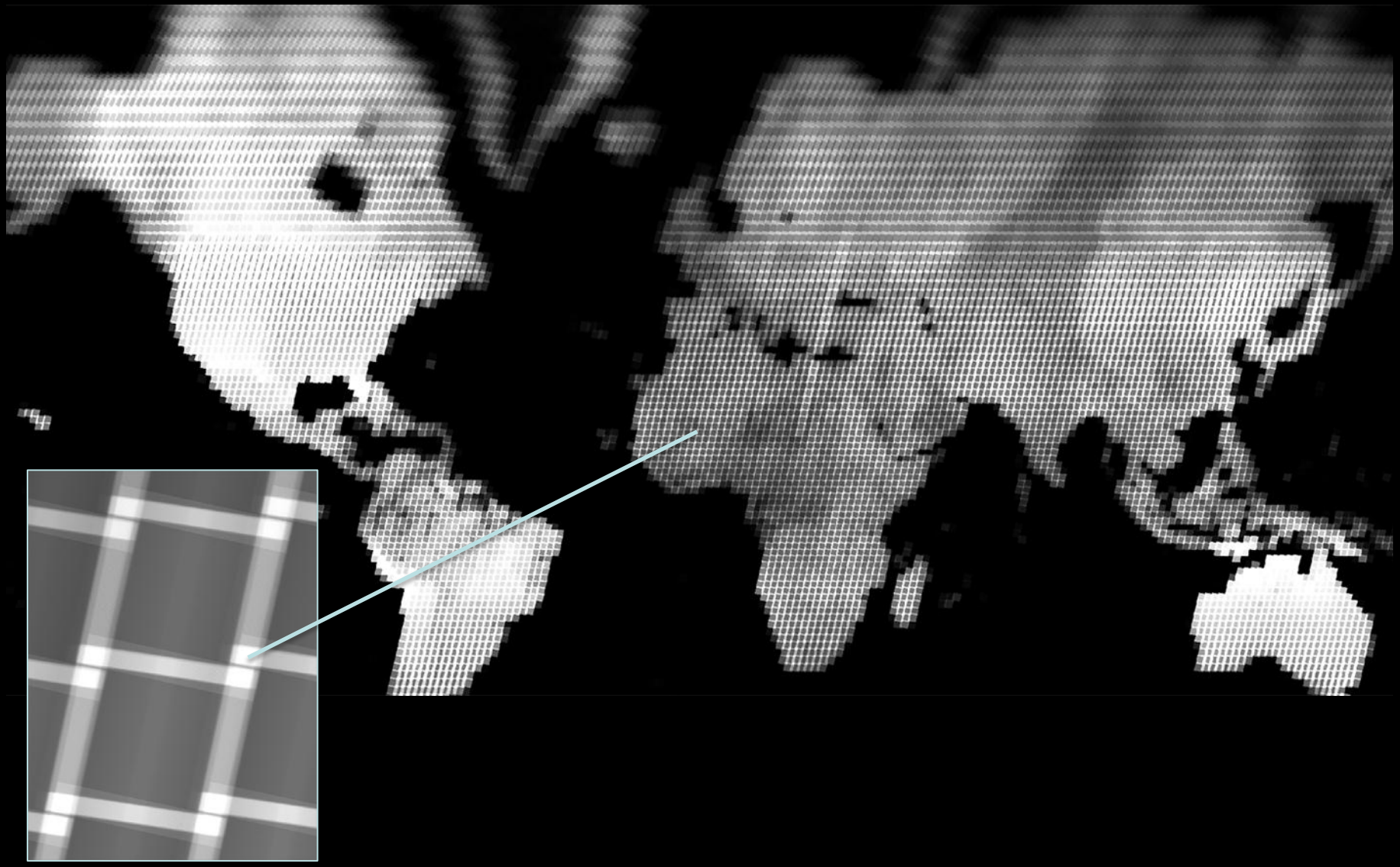
Source LtoR: T.J. Keegan, Vegafish, Ibdodane, skatebiker, US FishandWildlife, Unknownbutpublic

2,804,590* Landsat L1T scenes distributed over 30 years
1st March 1985 – 10th March 2015 (L5, 7, 8)

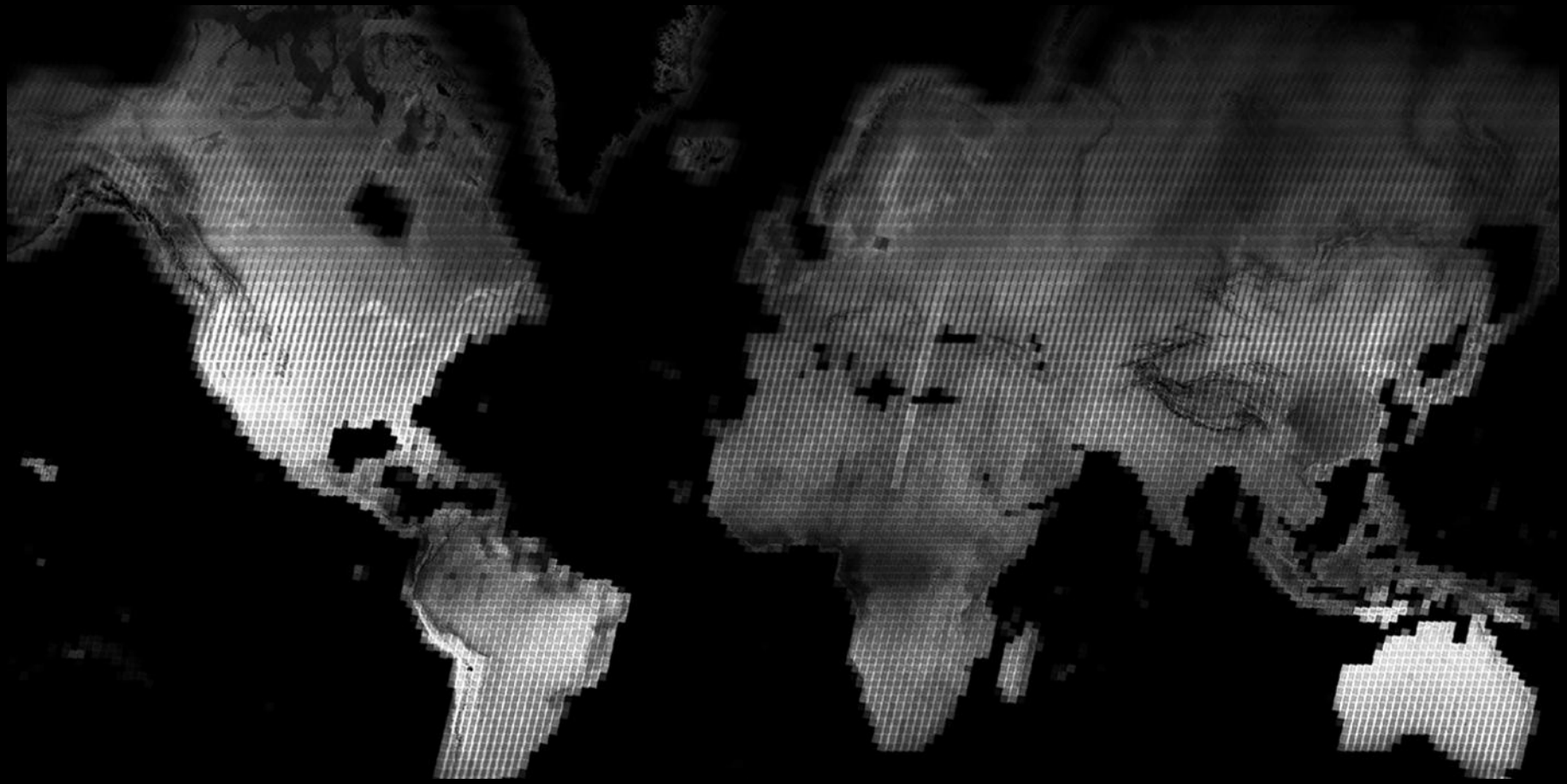


* out of 4,222,194 i.e., 34% not yet orthorectified

1st March 1985 – 10th March 2015 L5,7, 8
(Black = 0, White = 2287, mean 389 median 327 includes corner counts)



Valid observations for water mapping – cloud, shadow, snow and ‘bad’ pixels excluded (Black = 0, White = 1237 mean 215 median 187)

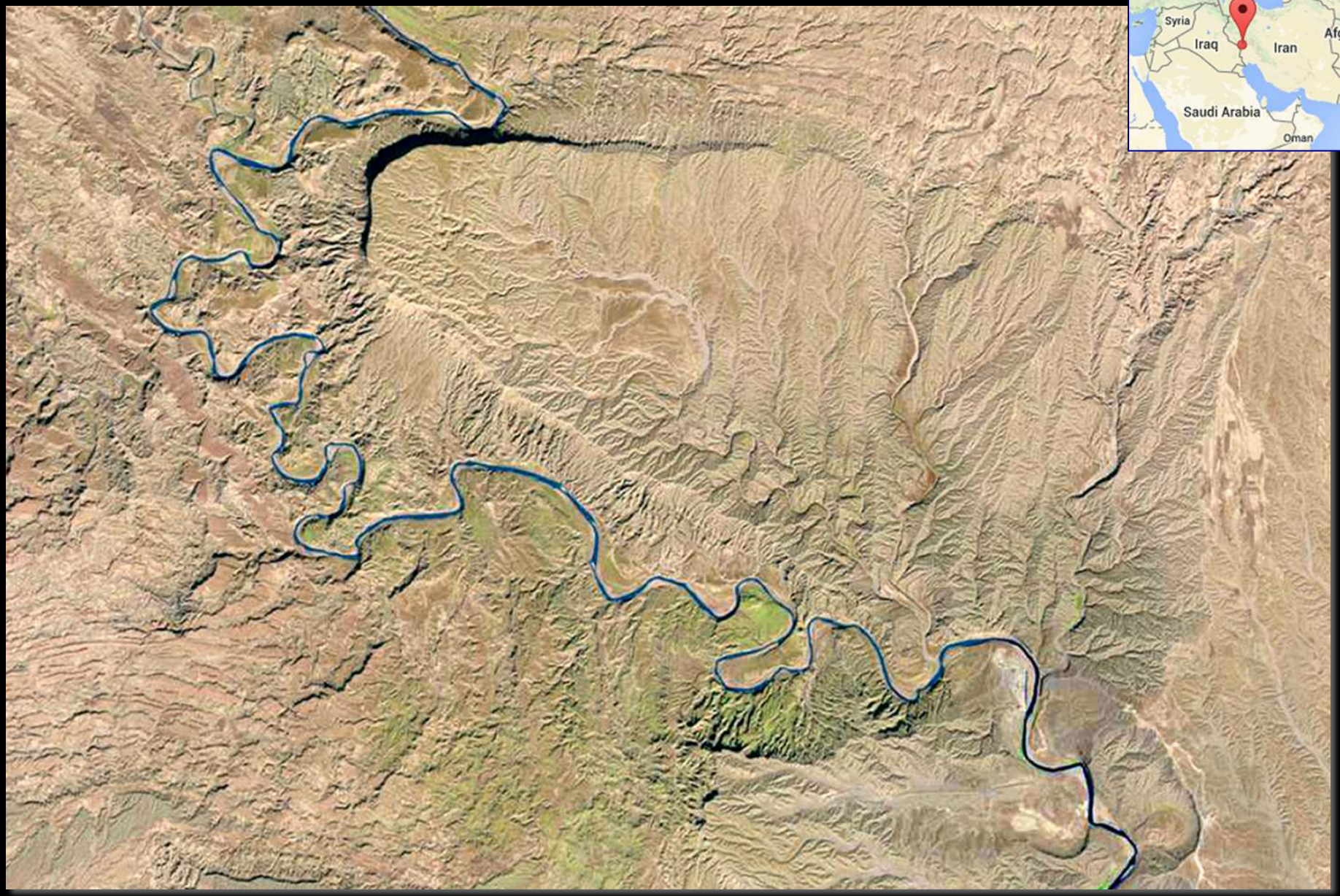


81,371 km2 with zero obs (<0.05% landmass)

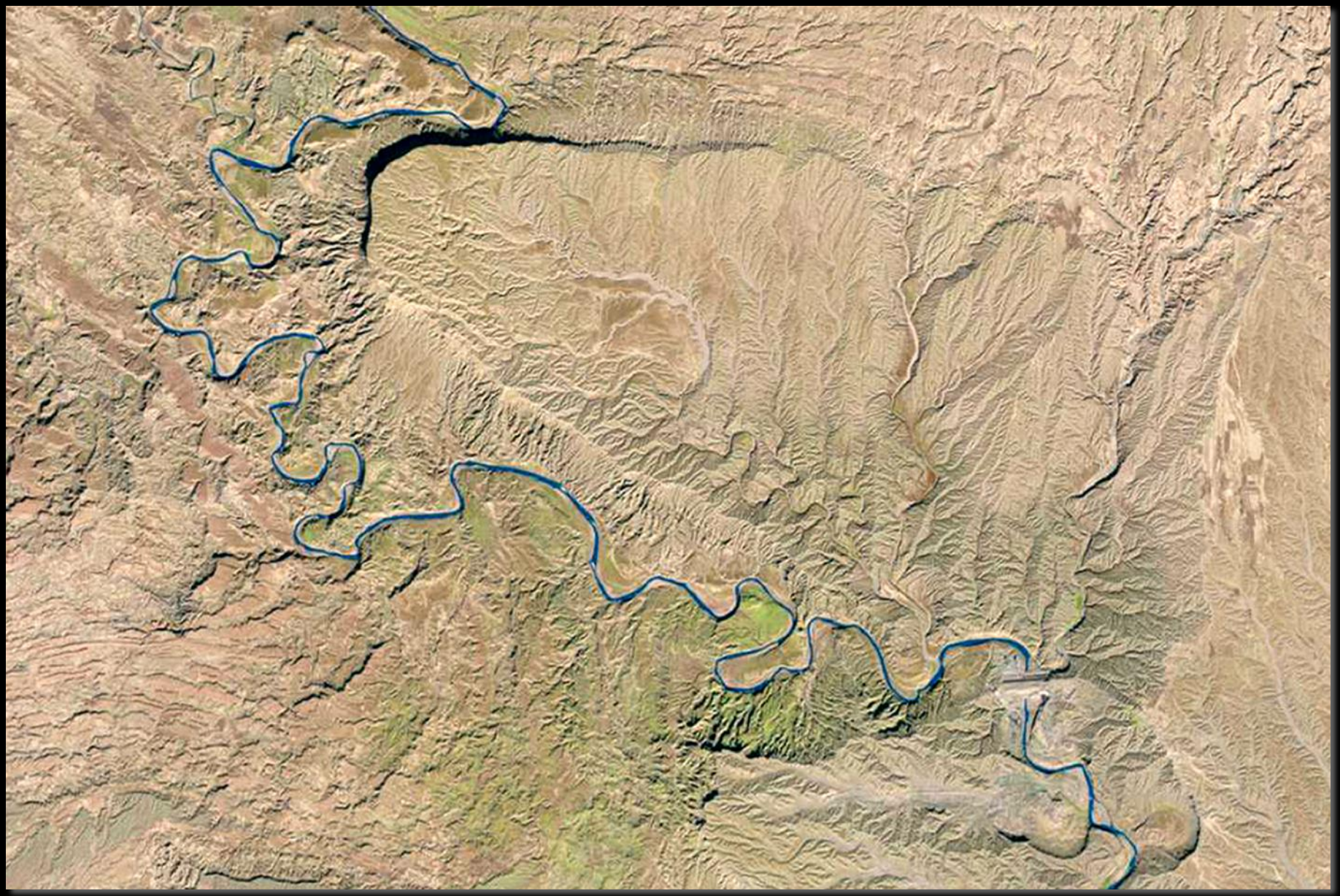
Global Surface Water Occurrence

A research product by
EC's Joint Research Centre
& Google Earth Engine

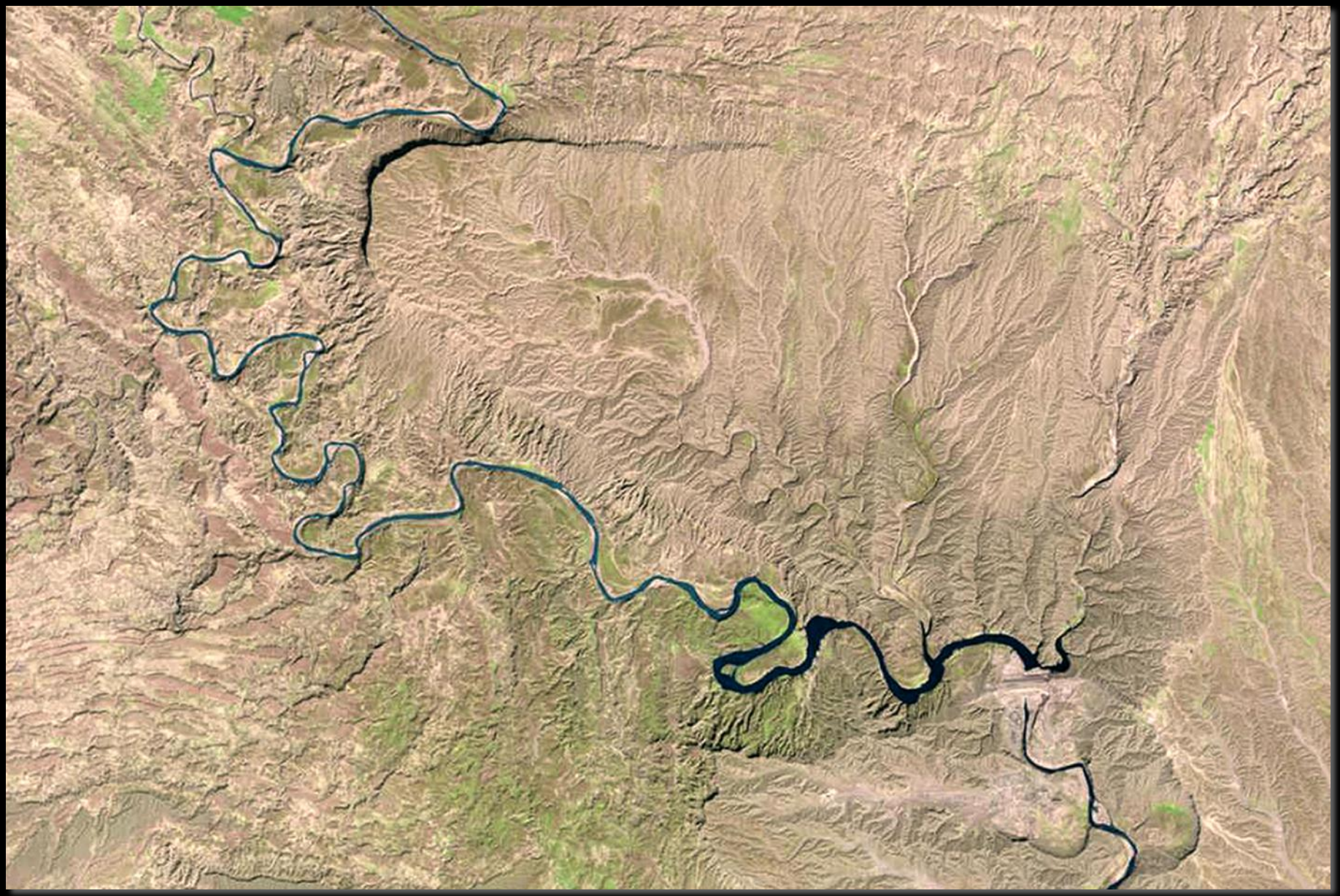
30m resolution, 30 year 1985 - 2015 (% observation-record water)



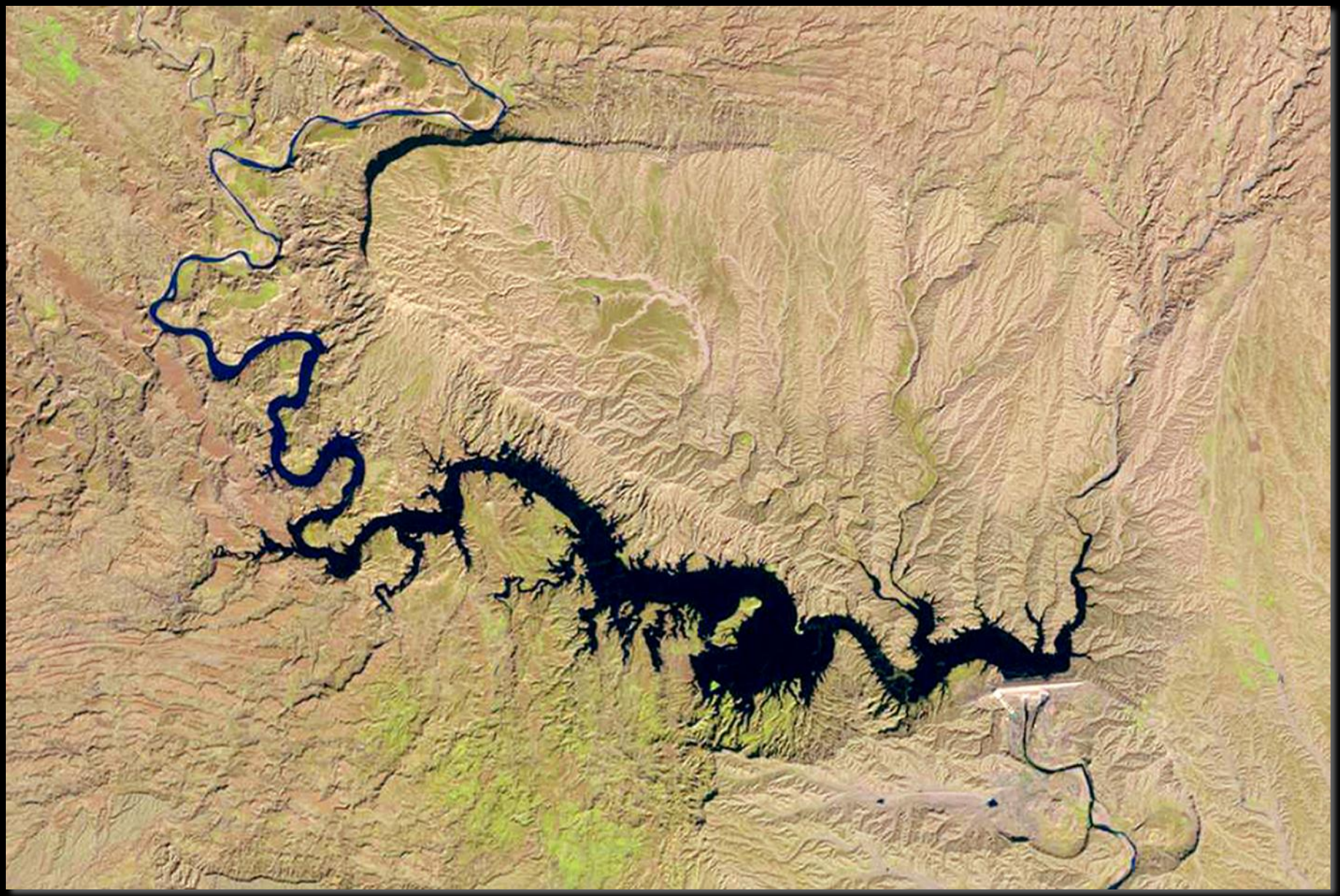
Karkheh River, Iran 21st July 1993 merged into 21st December 1999 Landsat courtesy USGS / NASA



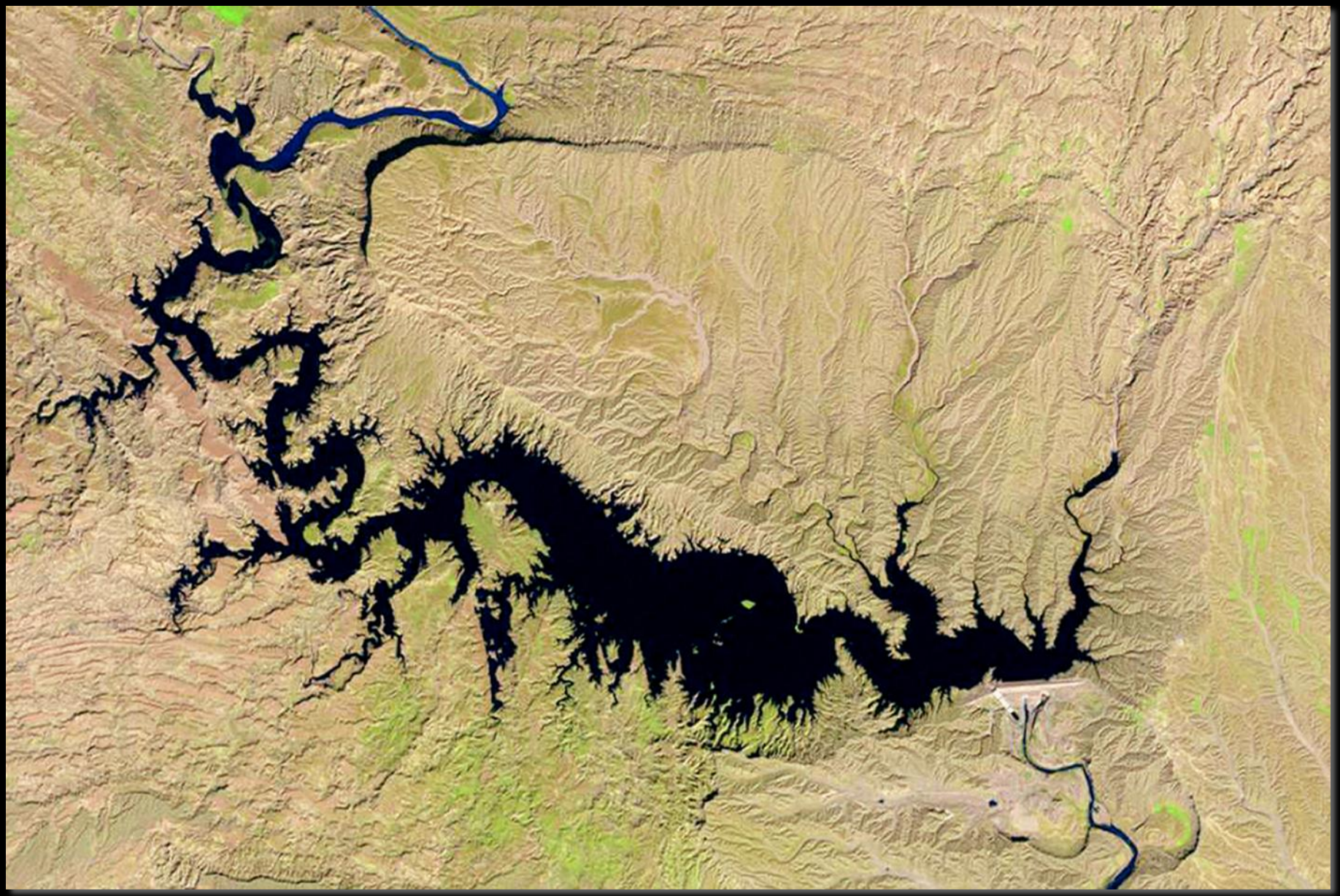
Karkheh River, Iran 21st December 1999 Landsat courtesy USGS / NASA



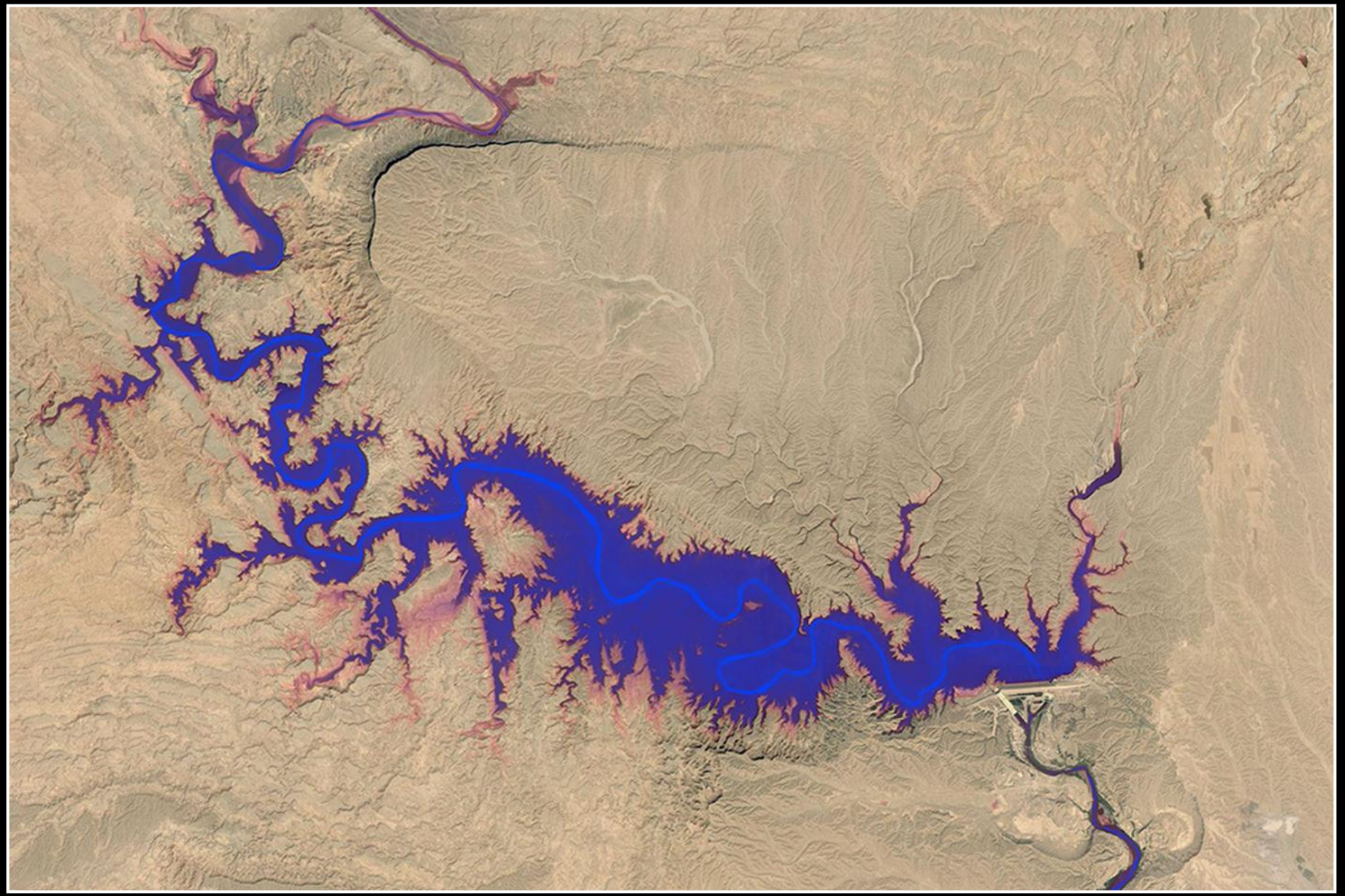
Karkheh River, Iran 23rd February 2000 Landsat courtesy USGS / NASA



Karkheh River, Iran 24th January 2001 Landsat courtesy USGS / NASA



Karkheh River, Iran 27th January 2002 Landsat courtesy USGS / NASA



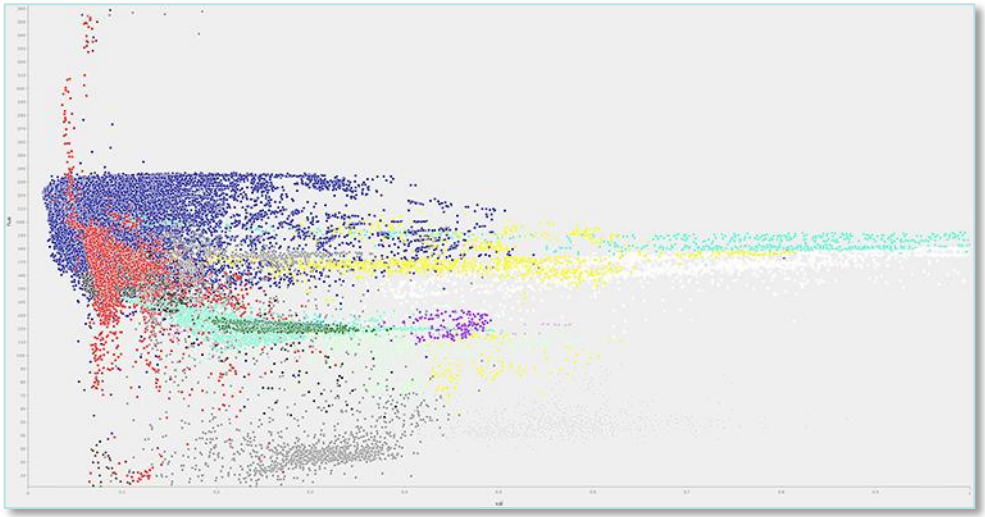
Karkheh River, Iran Global Water Occurrence 1984 – 2014 Source JRC and GEE

Surface water detection method

1. **Based on Hue/Saturation/Value colour model**
2. **Sensor neutral** – used on L5, L7, L8 and MODIS
3. **Uses Google Earth Engine for processing**
4. **Uses tools built on top of GEE -** for spectral library development, classification and validation
5. **Uses dynamic masks:**

Cloud
Snow and Ice
Shadow
Bare rock

Spectral library of 50,000 control points (water and non-water)



HV 7, 5, 4

Source: J-F Pekel, A. Cottam, JRC

epoch

1985 → 1999

2000 → 2015

epoch

January

Sum by month by epoch...

and over three decades

- w is a pixel classified as water
- Σw is the sum of all water detections per month
- vo is the number of valid observations after masks and cleaning
- Σvo is the sum of all valid observations per month
- (Σw/Σvo)*100 = water occurrence by month

December

12 month average by epoch

and over three decades

and an annual average for 2014

Global Surface Water Occurrence maps

epoch

1985 → 1999

2000 → 2015

epoch

January

Calculate water month by epoch...

and over three decades

- If water occurrence by month < 50% then non-water month pixel
- If water occurrence by month ≥ 50% then water month pixel (wm)
- n is number of months with valid observations (pixel)
- If Σwm = n then permanent water
- If 0 < Σwm ≤ (n-1) then seasonal water
- If Σwm = 0 then never water

12 month analysis by epoch

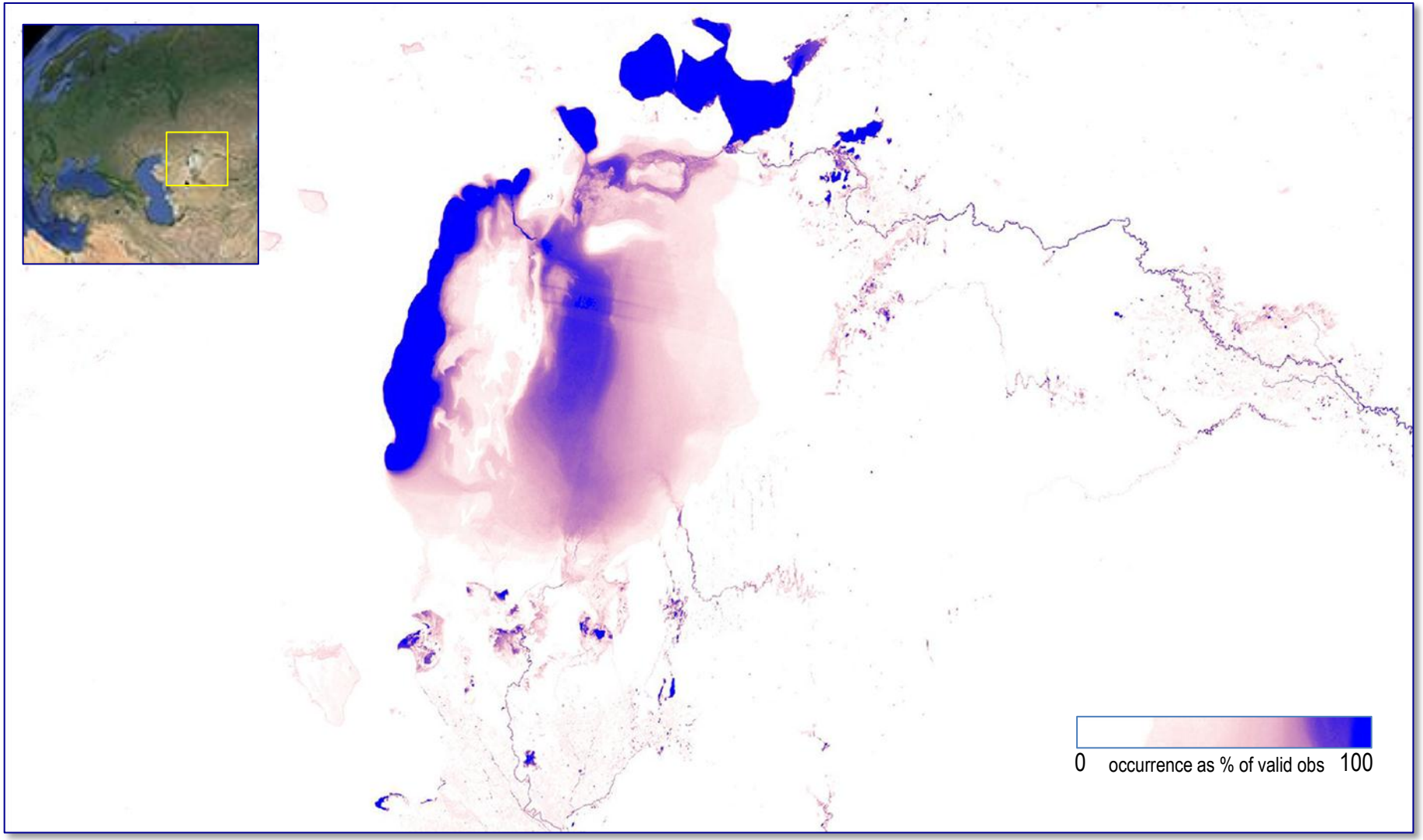
and over three decades

December

Global Surface Water Seasonality maps

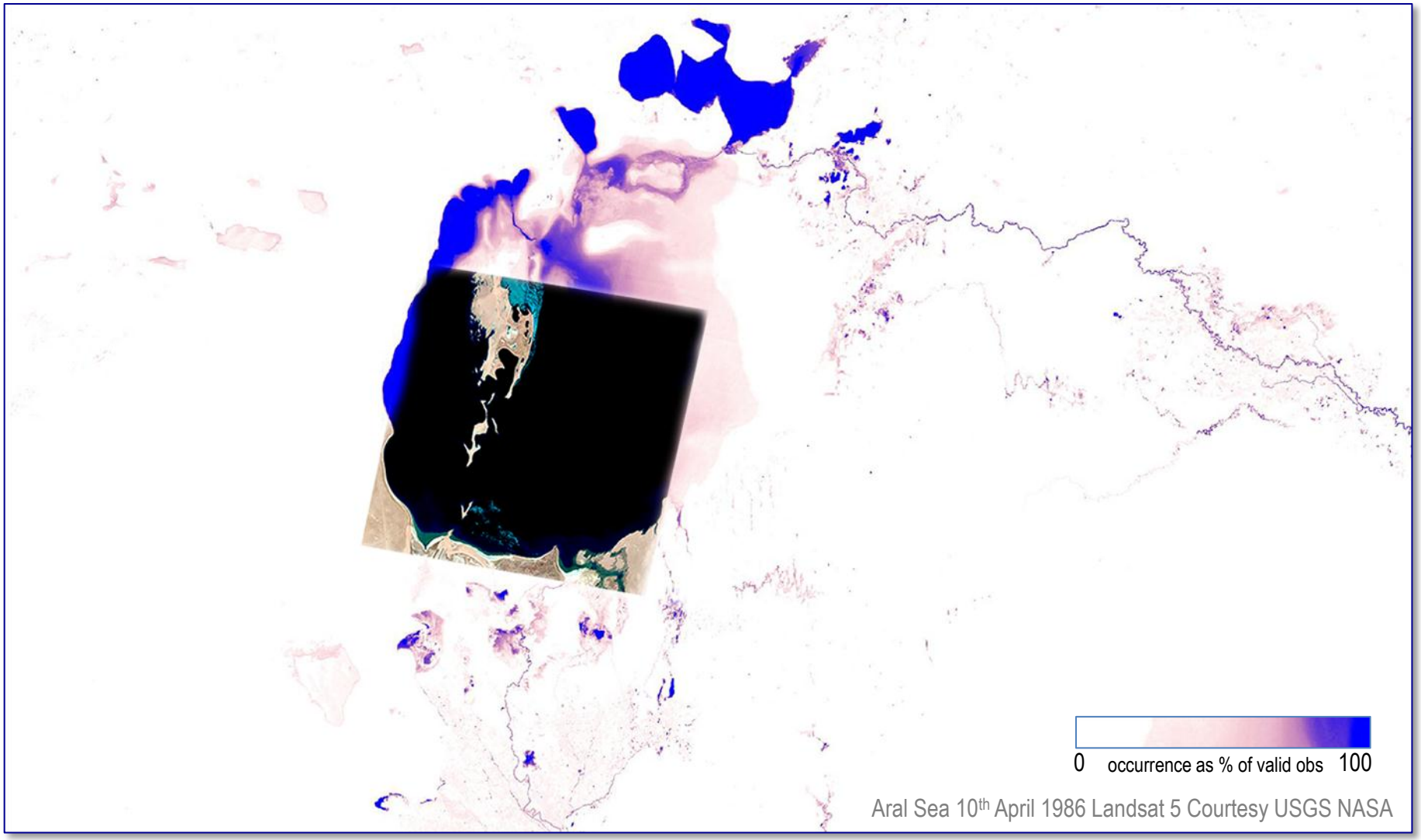
Source JRC GEE

30 year Global Surface Water Occurrence



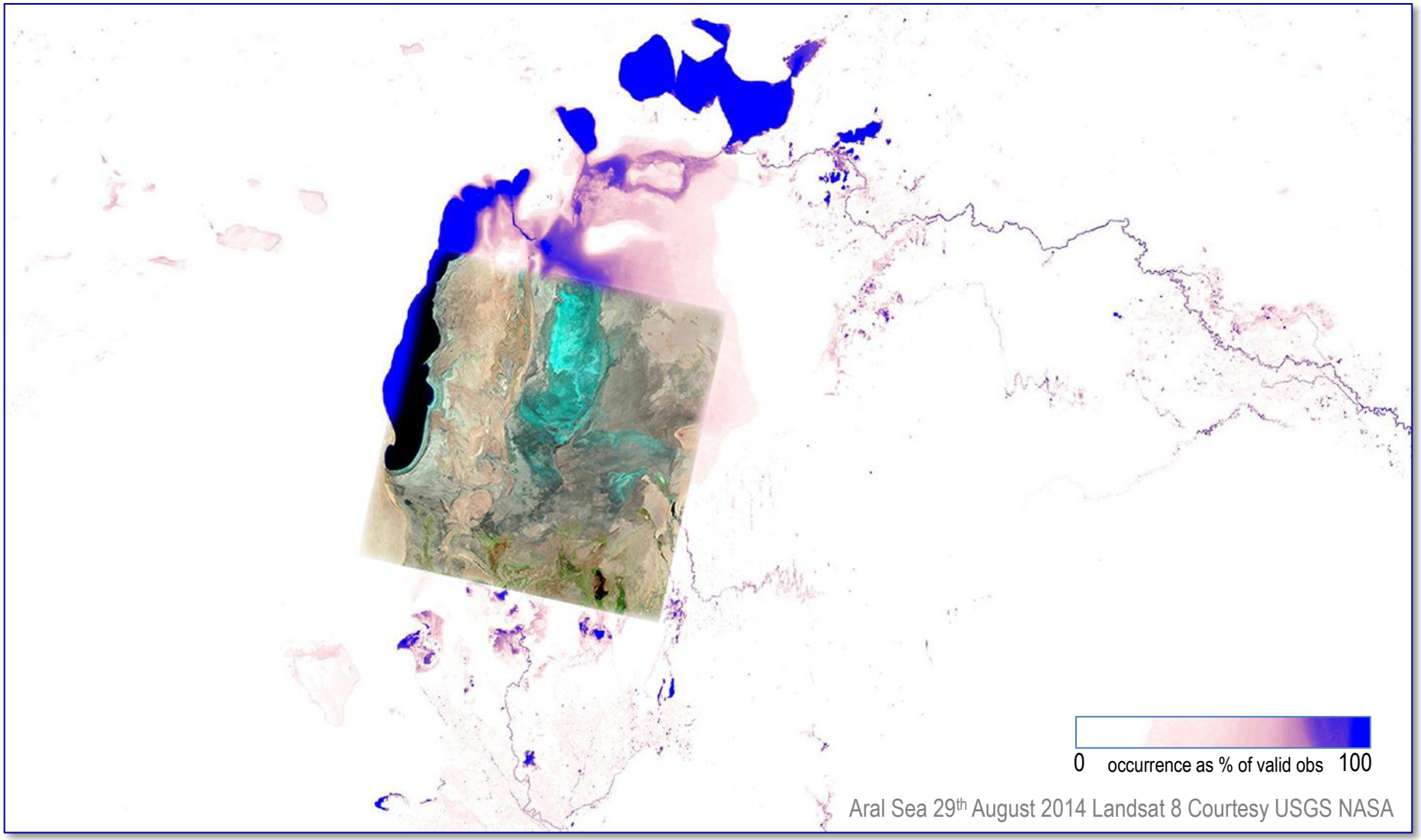
Source JRC GEE

30 year Global Surface Water Occurrence



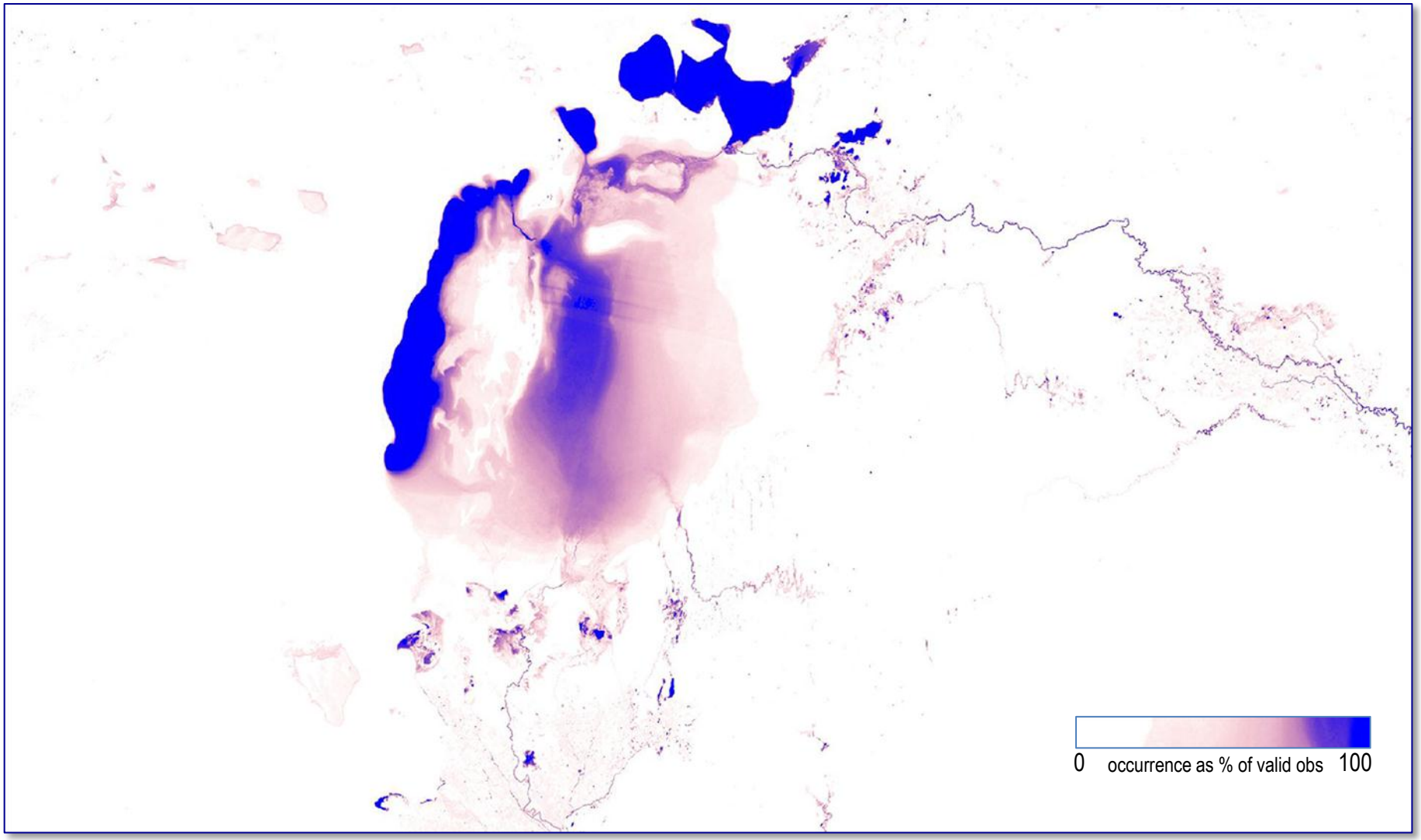
Source JRC GEE

30 year Global Surface Water Occurrence



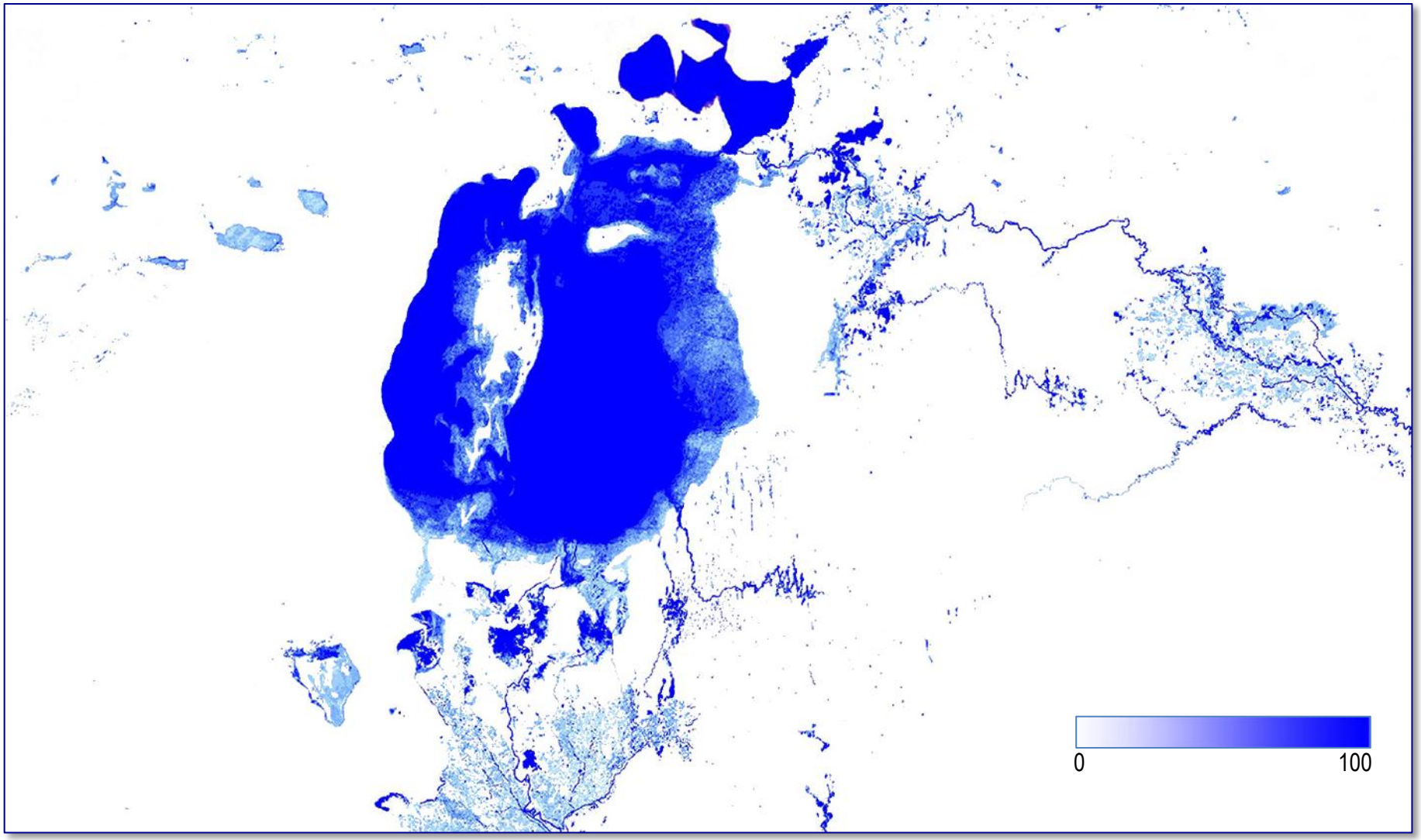
Source JRC GEE

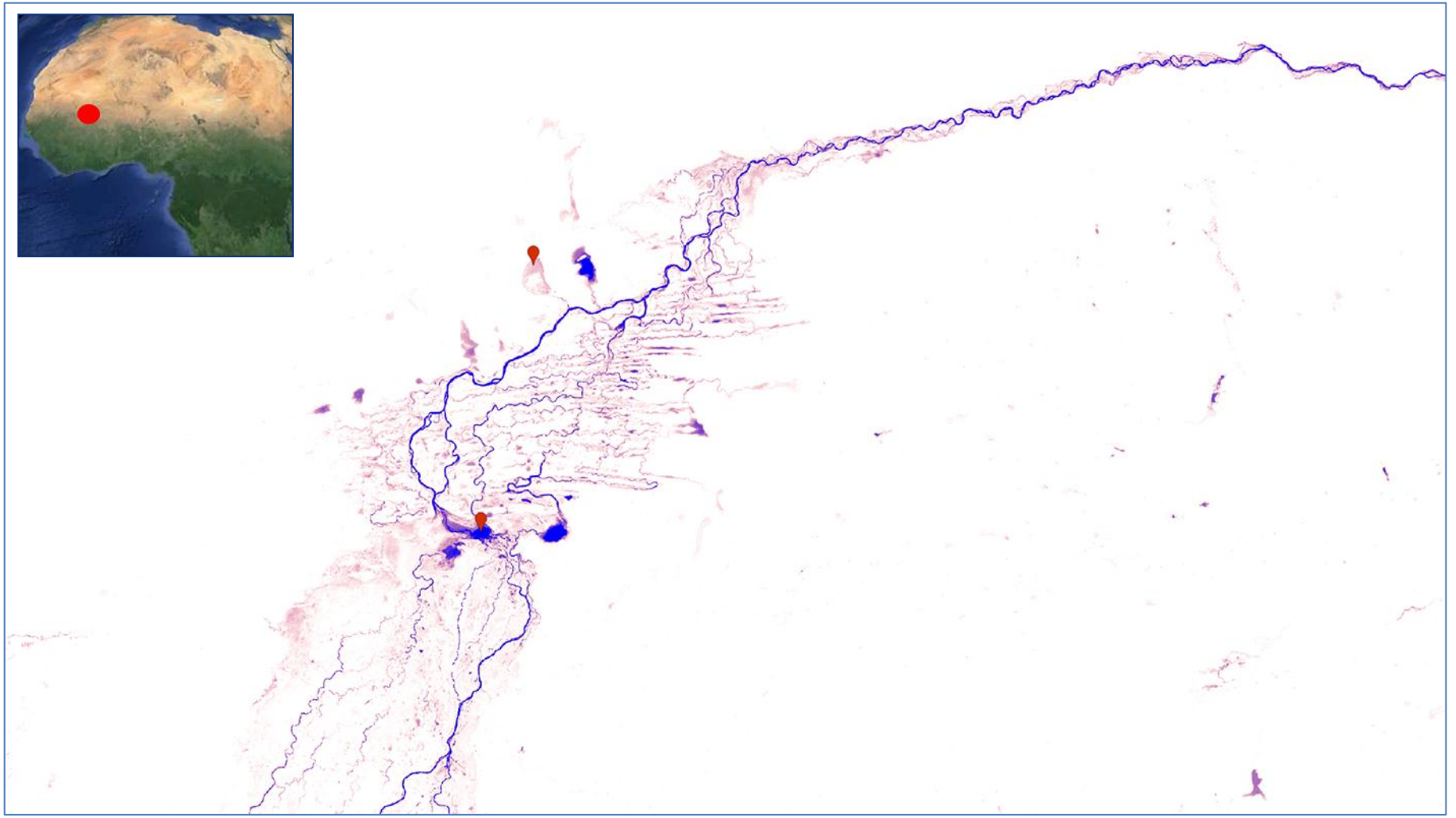
30 year Global Surface Water Occurrence



Source JRC GEE

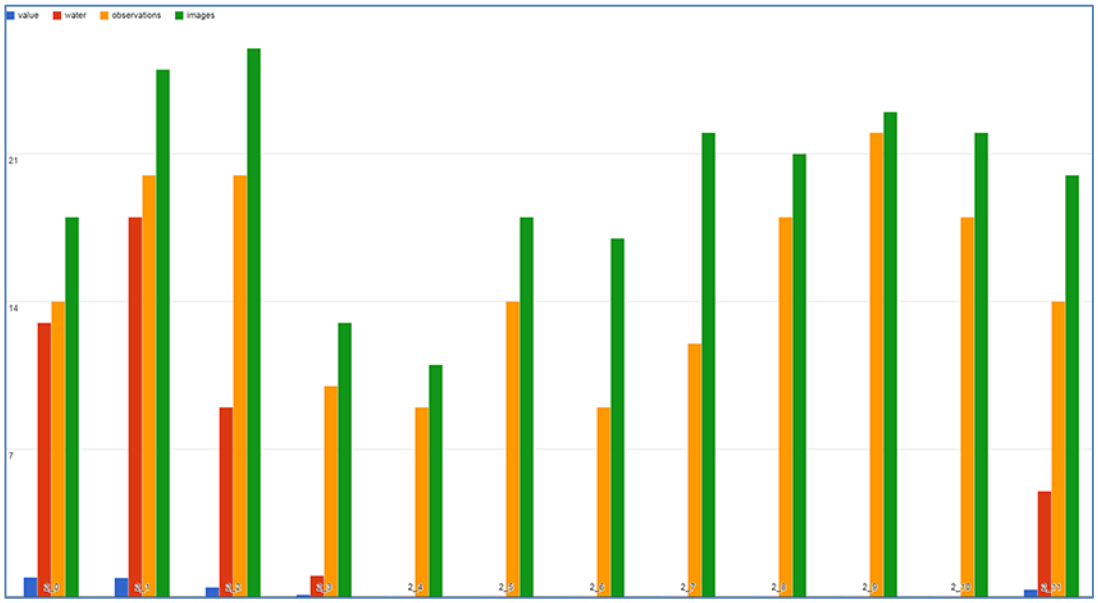
30 year Global Surface Water Seasonality





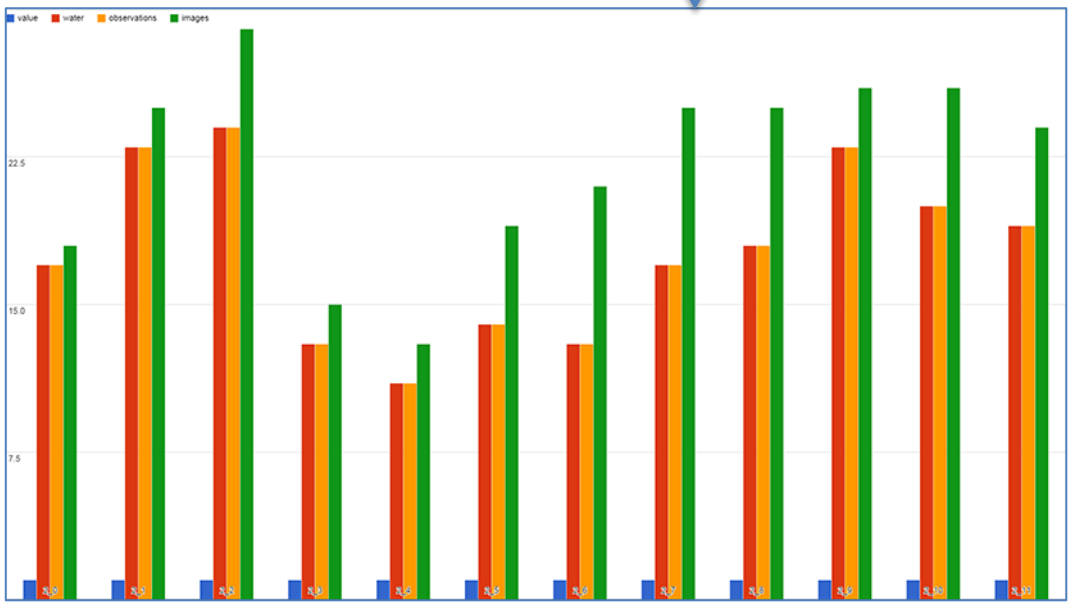
The Niger delta

Source: Global surface water occurrence, JRC/GEE



Jan

Dec



Jan

Dec

Number of unique views (scenes)

Number of valid observations

Number of vo classified as water

30 year monthly occurrence

Landsat Courtesy USGS NASA

Yingkou, China, 13th July 1985

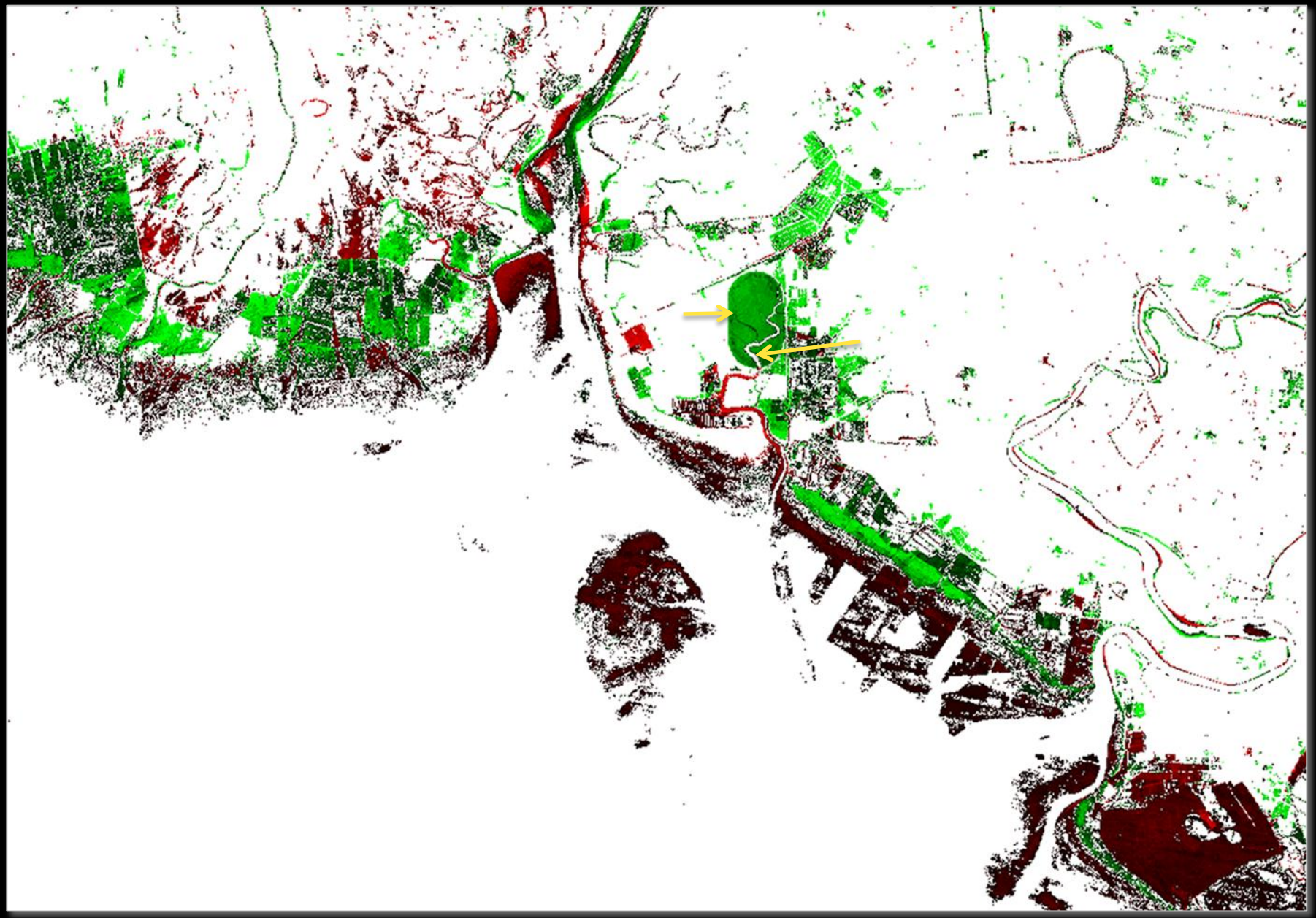
10 km

Landsat Courtesy USGS NASA

Yingkou, China, 13th July 2014

10 km

Landsat Courtesy USGS NASA

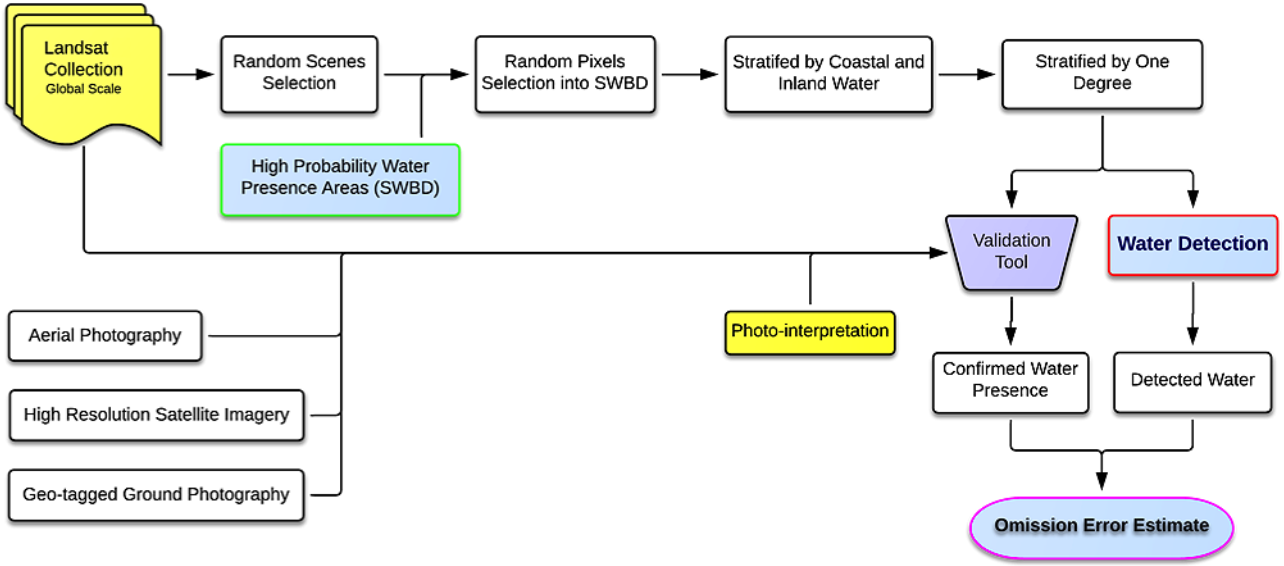


Yingkou, China, 10%-100% change in water occurrence 1985 – 2015

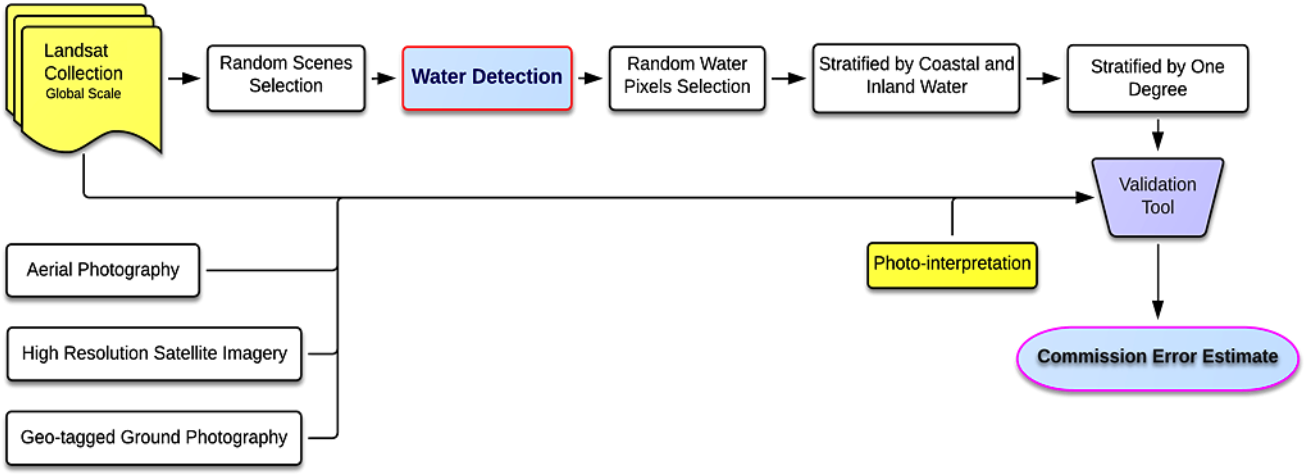
Red was water (1985-1999) Green new water (2000-2015)

10 km

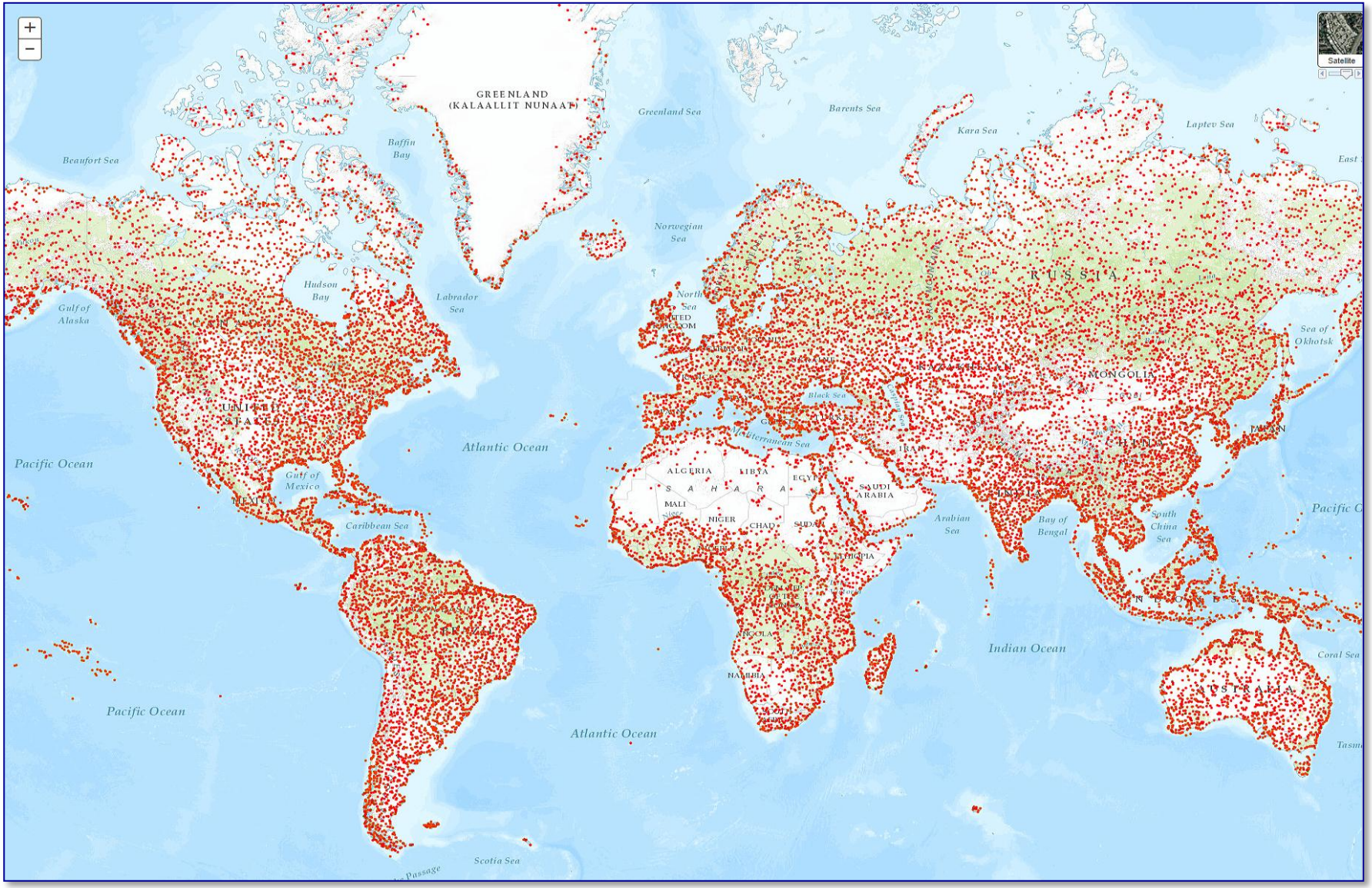
Validation protocols

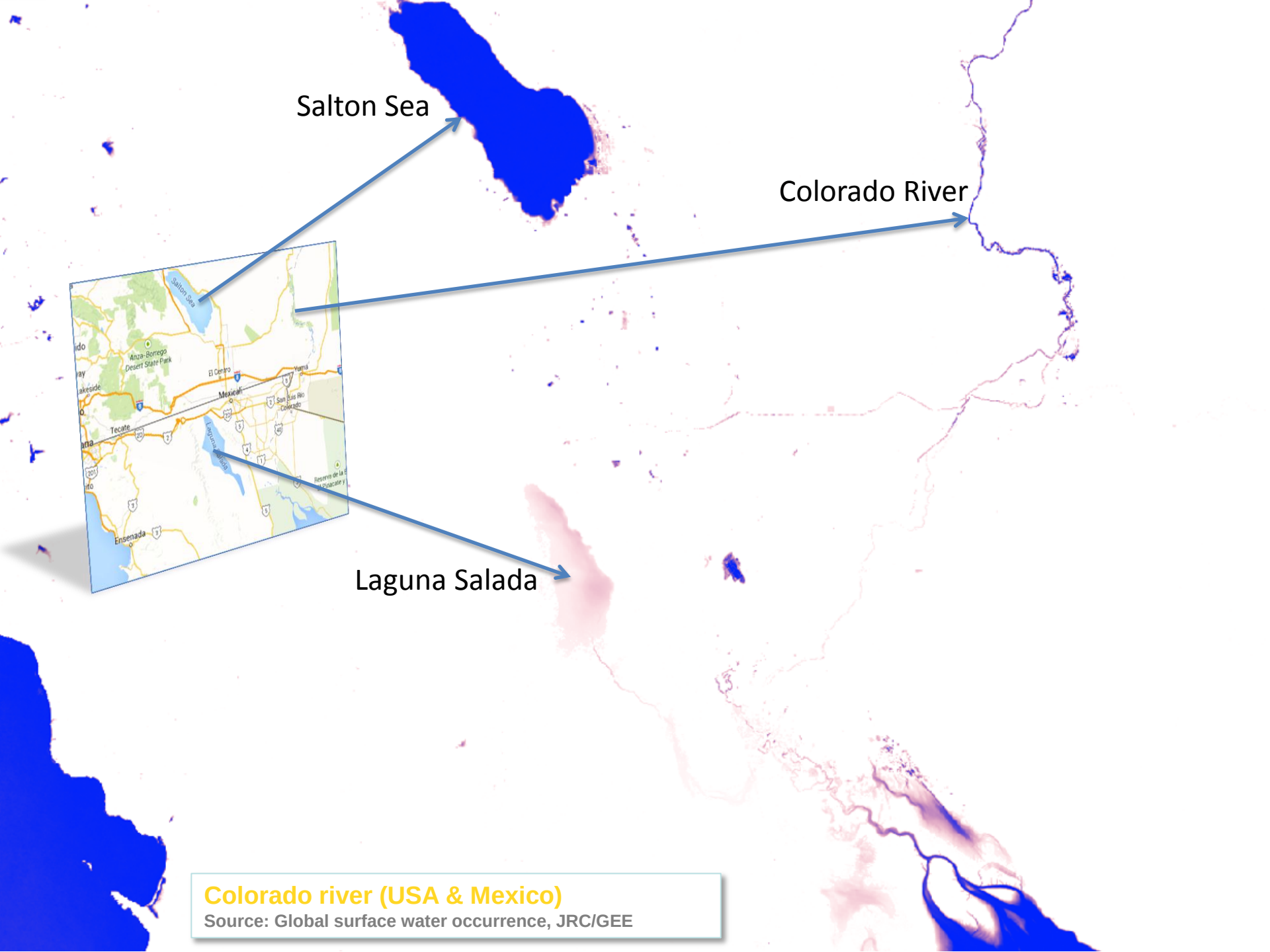


20,000 control points



Control points for L8 example





Colorado river (USA & Mexico)

Source: Global surface water occurrence, JRC/GEE

the ridge forming were three times higher in the presence of modern greenhouse-gas concentrations than those found just before the industrial revolution.

Barton Thompson of the Stanford Woods Institute for the Environment says he worries more about California warming. Since the 1980s average temperatures in the state have been higher than they were in the 50 years before; 2014 was the hottest year on record. A changing climate sees warm and dry periods more often occur together in California, according to another Stanford study. This makes the severity of droughts worse. Extra heat means that moisture evaporates from the soil faster, so plants need more watering. And less snow falls: the water content of the Sierra Nevada mountains' snowpack, which acts as a natural water-storage system until the spring thaw, was just 5% of its April 1st average last month. "Droughts will be more frequent in years to come and they will be worse," reckons Mr Thompson.

As surface sources of water have dried up, farmers and others have turned to groundwater to replace their missing supplies. As much as 65% of the water used in the state last year may have been pumped to the surface—up from 40% during average years—according to the California Water Foundation, an environmental group. It replaced about three-quarters of lost surface sources. "The pumping cannot go on as it has for the past four years," believes Ryan Jacobsen, a farmer in Fresno who also runs his county's Farm Bureau.

Well-raiding has led to subsidence and damage to underground layers of sand and clay that might otherwise have held more water in the future. It also means salt water can enter aquifers on the coast. Yet California was the last Western s
to embrace laws for mana
ter use; legislation was pa
ber 2014. And its effects
quickly. New managemer
derground sources have u
come environmentally sus

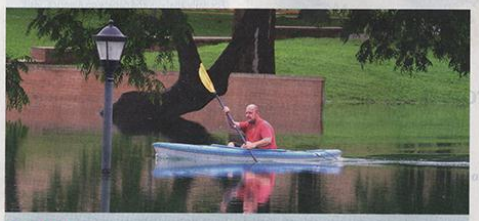
Going nuts

Meanwhile, guzzling grou
good business sense for
California is the nation's la
with sales of farm product
lion in 2012. It grows more
America's vegetables and
fruit and nuts. Health fads
diets, perhaps inspired b
state's own film stars, mak
tonne of money," accordin
Irrigating orchards of thirst
pistachios used 3.8m acre-
2010, 54% more than a dec
the value of the nuts was
year, meaning farmers tur
for every acre-foot of water
Alfalfa, a crop that slurpe
feet of water—more than a
cows, not celebrities.

Abandoning thirsty crops could solve many of California's water woes. Agriculture contributes just 2% of the state's economic output and employs 3% of its workers. Nevertheless, Mr Jacobsen asks where Americans would get their fruit and vegetables without the bounty of the Central Valley. "Farmers are just borrowers of water. The consumers of their products are the ultimate beneficiaries," he says, "and the scale on which we do things here means that middle-class people can afford to buy them." It is precisely the area's desert-like natural conditions that boost yields thanks to the long, dry growing season. Few consumers think about how much water has been used to grow the food they buy.

What else can be done? California's cities provide some lessons. The amount of water used by residents of Los Angeles and San Francisco is lower than it was in 1980—despite surging populations. But cities can have their fruit and eat it too. Rich urban areas can afford to buy extra water when needed. They can also pay for costly desalination plants (as Santa Barbara has done). Tiered pricing, under which consumers pay more above certain usage levels, can discourage water waste too—but their legality was successfully challenged in a state appeals court in April.

Some urge setting up more water-trading markets, to help the flexibility of supplies. Others want to turn Cent
lands into a solar-energy hub



Texas floods

Pray for a proper policy

SAN ANTONIO

The Lone Star State would do well to plan for floods

IN 2011 Rick Perry, then Texas's governor, and now a presumed Republican presidential candidate, devised a policy to help tackle a severe drought. "Under the authority vested in me by the Constitution and Statutes of the State of Texas," he formally did "hereby proclaim the three-day period from Friday, April 22, 2011, to Sunday, April 24, 2011, as Days of Prayer for Rain in the State of Texas."

It is not clear whether Mr Perry's successor, Greg Abbott, will now call for prayer for the end of rain. But given the weather the state has endured Texans might think him justified. Between May 23rd and 26th, a holiday weekend, parts of Texas and Oklahoma were deluged with as much as 11 inches (28cm) of rain. Large chunks of Houston and Austin were flooded, as were tens of smaller cities. At least 19 people were killed across the two states; thousands of homes were flooded and hundreds of cars left abandoned, piled up in a foot or so of murky water on the motorway.

The flooding is the worst in central Texas in over a decade—possibly the worst since 1981, when a flood, also on the Memorial Day holiday weekend, killed 11 people in Austin. Since then, however, Texas's population has surged from less than 15m to almost 27m. Newcomers have filled up hastily built subdivisions across central Texas. Not all are well prepared for extreme weather.

Texas has no centralised flood-control programme: it leaves that responsibility to cities and counties. But cities which are strapped for cash do not always build infrastructure. In 2012, of 27 Army Corps of Engineers flood-reduction projects in the state, only 12 received federal funding—largely because of a lack of money from local sponsors. It does not help that most of Texas's major rivers and floodplains are not well mapped.

Over the next three decades, Texas's population is expected roughly to double again. Without planning, prayer might be the best option available.

Ms Hanak sees better data as a priority. "For the centre of the world's technology economy," she says, "we have a pitiful information system at the state level about water."

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tem at the state level about water."

Ellen Hanak
director of the Water Policy Center
Public Policy Institute of California

The Economist, All the leaves are brown, 30th May 2015

① Landsat is providing better water data – not just at the state level or nationally, but globally

② A reliable global DEM is needed

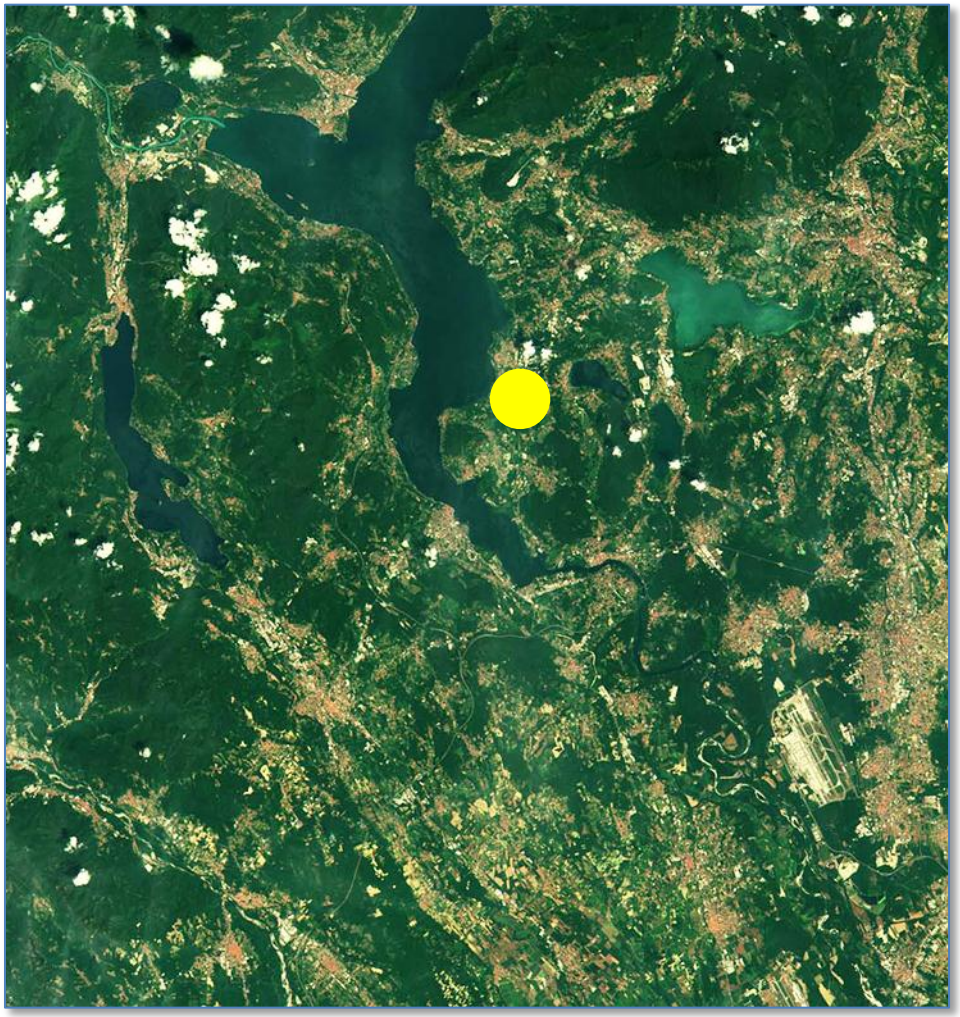
③ TIRS is an important element

④ L1T production of the remaining 36% of the L5,7,8 archives is urgently needed

⑤ Analysis must include L4 TM

⑥ Repatriation of international archives should continue

⑦ SPOT/DMC/CBERS/S1/S2 data merge should be examined



Sentinel 2a 27th June 2015 – Italian Lakes