Data Science and AI: The Next Frontier for Evidence-Based Policy-Making

Evidence-Based Health and Environmental Policies and the Potential Mismatch with Citizens' Perceptions: *A Data Science Perspective*

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FrackMap | HARVARD T.H. CHAN SCHOOL OF PUBLIC HEALTH Department of Environmental Health | CIRANO Knowledge into action Center for Interuniversity Research and Analysis on Organizations | POLYTECHNIQUE MONTRÉAL

INTRODUCTION:
DATA SCIENCE AND EVIDENCE-BASED PUBLIC POLICY

- **Integrating large quantities of data from multiple, disparate sources** can create new opportunities to understand complex questions.

- Currently, efforts are under way to develop methods to **reliably integrate data from sources :**

  - that are **not traditionally used** such as electronic medical files, data used in peer-reviewed publications and crowd-based sources

  - with **location information** such as geospatial datasets and geolocalized tweets.

INTRODUCTION :
DATA SCIENCE AND VISUAL COMMUNICATION OF DATA

- **Visualizations** of **geospatial datasets** and **crowd-based sources (geolocalized tweets, etc)** could help to **inform** a specific decision and help **communicate** the results of an analysis

INTRODUCTION :
DATA SCIENCE AND EVIDENCE-BASED PUBLIC POLICY

The purpose of 1) data integration and 2) data visualization for environmental health research and decision-making is to improve public health by monitoring environmental exposures and health outcomes.

Source : National Academies of Sciences, Engineering, and Medicine 2018. Informing Environmental Health Decisions Through Data Integration: Proceedings of a Workshop in Brief. Washington, DC: The National Academies Press https://doi.org/10.17226/25139.

CASE STUDY : [FrackMap Project]
Natural Gas and Shale Gas Extraction in the US
A data science perspective

- Natural gas and shale gas extraction operations creates **several social, environmental and economic challenges** for local communities.

- Energy-based companies highlight the **economic opportunity** of such operations (local, regional, state, and national level) and scientific studies point out a vast array of potential and proven **risks: ecological, seismic, public health, occupational health**, etc.

1) Integrating data

2) Visualizing data

CASE STUDY :
Natural Gas and Shale Gas Extraction in the US
A data science perspective

1) Integrating data

Integrating large quantities of data from multiple, disparate sources can create new opportunities to understand complex environmental health questions.

- **Natural gas and shale gas extraction operations data**
- **Peer-reviewed publications on potential and real impacts** of hydraulic fracturing on health and environment
- **Tweets about #shalegas and #fracking (public perception)**

CASE STUDY :
Natural Gas and Shale Gas Extraction in the US
A data science perspective

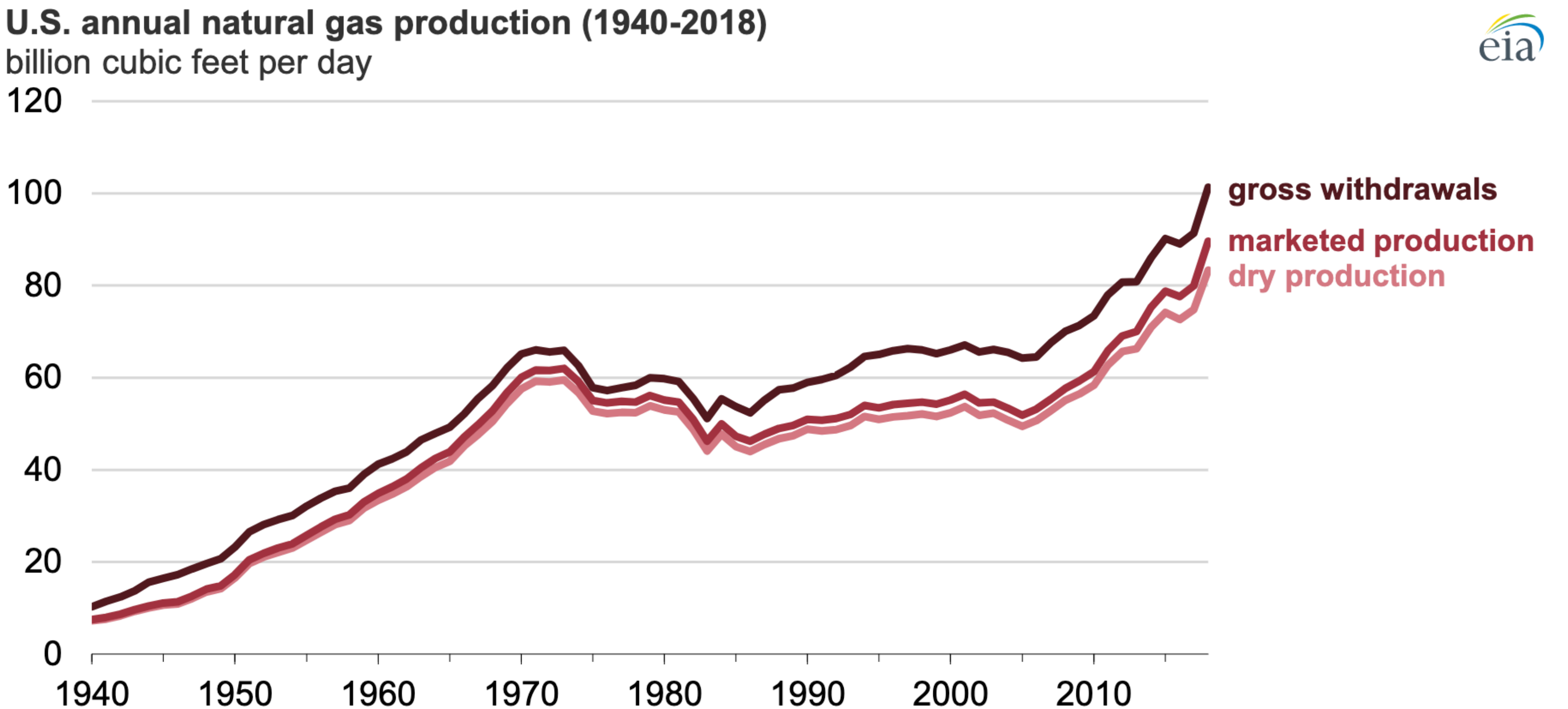
1) Integrating data

Natural gas and shale gas extraction operations data* :

- shale formations' locations
- wells' locations
- horizontal legs' locations
- production by state
- permits by state and by wells
- reports of specific chemical used by wells
- regulations by state, etc.

*** Publicly available data**

U.S. natural gas production hit a new record high in 2018



Source: U.S. Energy Information Administration, *Monthly Crude Oil, Lease Condensate, and Natural Gas Production Report*, *Natural Gas Monthly*

https://www.eia.gov/todayinenergy/detail.php?id=42337

U.S shale gas production by state

Independent Statistics & Analysis
U.S. Energy Information Administration

Sources & Uses | Topics | Geography | Tools | Learn About Energy | News | A-Z Index

NATURAL GAS

OVERVIEW | DATA | ANALYSIS & PROJECTIONS | GLOSSARY › | FAQS ›

Shale Gas Production

(Billion Cubic Feet)

Period: Annual

Download Series History | Definitions, Sources & Notes

	2013	2014	2015	2016	2017	2018	View History
U.S.	11,415	13,447	15,213	17,032	18,589	22,054	2007-2018
Alabama						0	2007-2018
Alaska	0	0	0	0	0	0	2007-2018
Arkansas	1,026	1,038	923	733	618	521	2007-2018
California	89	3	2	6	6	4	2011-2018
Colorado	18	236	325	164	97	126	2007-2018
Kansas	3	1	1	0	0	0	2012-2018
Kentucky	4	2	1	0	W	0	2007-2018
Louisiana	1,510	1,191	1,153	1,111	1,450	2,044	2007-2018
North	1,509	1,169	1,129	1,085	1,414	2,044	2007-2018
South Onshore	1	22	24	26	36	0	2011-2018
Michigan	101	96	65	84	63	77	2007-2018
Mississippi	5	2	3	2	2	0	2012-2018
Montana	19	42	39	19	18	18	2007-2018
New Mexico	16	28	46	497	592	785	2007-2018
East	13	25	44	491	W	785	2007-2018
West	3	3	2	6	W	0	2007-2018
North Dakota	268	426	545	582	664	840	2007-2018
Ohio	101	441	959	1,386	1,747	2,337	2007-2018
Oklahoma	698	869	993	1,082	1,290	1,325	2007-2018
Pennsylvania	3,076	4,009	4,597	5,049	5,365	6,079	2007-2018
Texas	3,876	4,156	4,353	5,029	5,171	6,392	2007-2018
RRC District 1	630	822	892	690	652	693	2007-2018
RRC District 2 Onshore	474	649	793	642	584	654	2010-2018
RRC District 3 Onshore	2	10	17	23	23	21	2007-2018
RRC District 4 Onshore	316	381	500	706	677	689	2007-2018
RRC District 5	1,128	1,022	903	827	730	680	2007-2018
RRC District 6	409	270	238	339	333	515	2007-2018
RRC District 7B	218	165	143	116	110	118	2007-2018
RRC District 7C	13	111	140	451	494	597	2010-2018
RRC District 8	62	78	109	730	1,115	1,960	2007-2018
RRC District 8A	0	1	3	0	1	6	2012-2018
RRC District 9	619	639	608	505	452	459	2007-2018
RRC District 10	5	8	7	0	0	0	2007-2018
Virginia	3	3	3	4	4	0	2012-2018
West Virginia	498	869	1,163	1,270	1,486	1,504	2007-2018
Wyoming	102	29	36	5	6	0	2007-2018
Eastern States* (IL, IN, OH, PA, WV)							2007-2008
Western States (AR, KS, LA, MT, OK)							2007-2008

Click on the source key icon to learn how to download series into Excel, or to embed a chart or map on your website.

- = No Data Reported; -- = Not Applicable; **NA** = Not Available; **W** = Withheld to avoid disclosure of individual company data.

Notes: Shale Gas production data collected in conjunction with proved reserves data on Form EIA-23 are unofficial. Official Shale Gas production data from Form EIA-895 can be found in Natural Gas Gross Withdrawals and Production. See Definitions, Sources, and Notes link above for more information on this table.

Release Date: 12/12/2019
Next Release Date: 11/20/2020

Note : Fracking was disallowed in three states – New York, Vermont, and Maryland – due to the risk of contaminated drinking water (Boersma & Johnson, 2012).

https://www.eia.gov/dnav/ng/ng_prod_shalegas_s1_a.htm

CASE STUDY :
Natural Gas and Shale Gas Extraction in the US
A data science perspective

1) Integrating data

More than 1000 peer-reviewed publications with datasets* on potential impacts about :

- water quality,
- air quality,
- induced seisms,
- publich health,
- etc

*** with specific information about the location**

METHODOLOGY (peer-reviewed articles database)

- **Peer-reviewed publications from January 2005 to Novembre 2019** about environmental and health impacts in the US
- **Systematically searched and screened**
- **Databases** : PubMed, MEDLINE, ScienceDirect, Scopus, Web of science, Proquest, Google Scholar, etc
- **Key research terms** : water impacts (water usage, wastewater, water quality (ground water), Air pollution, Climate change (greenhouse gases, large scale impacts), Ecological impacts (forestry, fauna and flora), Health (public health and occupational exposure), Seismicity, etc.
- **Data location** (in the title, abstract, keywords) : State, County, City, Shale Play, River, Lake,…

1000-ish peer-reviewed publications with geographical data

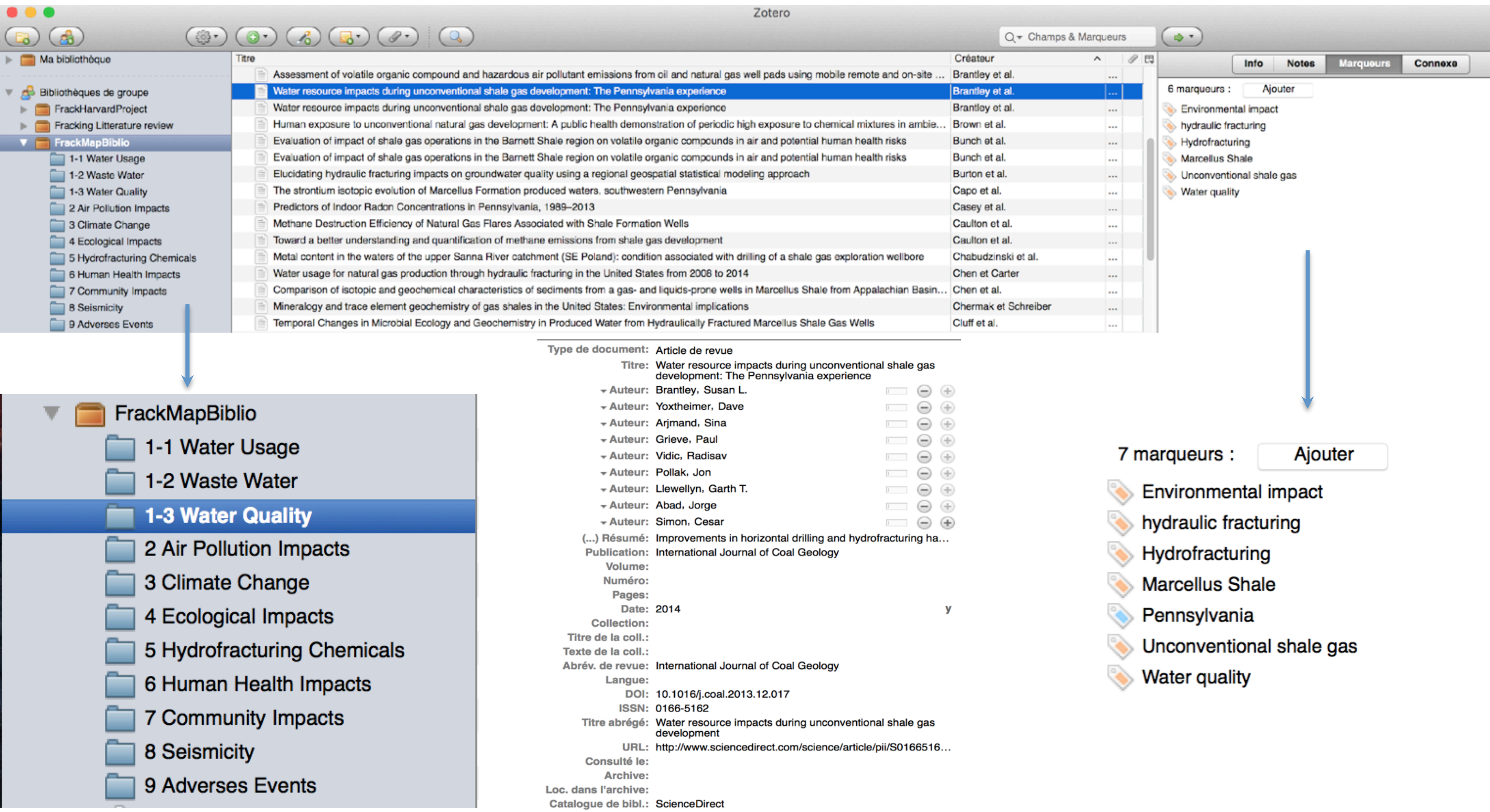
William L. Ellsworth,
Injection-Induced Earthquakes
Science 12 Jul 2013:
Vol. 341, Issue 6142, 1225942
DOI: 10.1126/science.1225942

Microearthquakes (that is, those with magnitudes below 2) are routinely produced as part of the hydraulic fracturing (or “fracking”) process used to stimulate the production of oil, but the process as currently practiced appears to pose a low risk of inducing destructive earthquakes. More than 100,000 wells have been subjected to fracking in recent years, and the largest induced earthquake was magnitude 3.6, which is too small to pose a serious risk. Yet, wastewater disposal by injection into deep wells poses a higher risk, because this practice can induce larger earthquakes. For example, several of the largest earthquakes in the **U.S. midcontinent** in 2011 and 2012 may have been triggered by nearby disposal wells. The largest of these was a magnitude 5.6 event in **central Oklahoma** that destroyed 14 homes and injured two people. The mechanism responsible for inducing these events appears to be the well-understood process of weakening a preexisting fault by elevating the fluid pressure. However, only a small fraction of the more than 30,000 wastewater disposal wells appears to be problematic—typically those that dispose of very large volumes of water and/or communicate pressure perturbations directly into basement faults.

https://science.sciencemag.org/content/341/6142/1225942.abstract

Peer-reviewed articles database

zotero



CASE STUDY :
Natural Gas and Shale Gas Extraction in the US
A data science perspective

1) Integrating data

- **More than 65 000 geolocalized tweets about #shalegas and #fracking (public perception)**

Twitter and Fracking

- The domain of public opinion, political agenda, and the controversy of fracking is nowadays a well-studied phenomenon, where **public attitudes were massively influenced online in social medias in addition to the traditional news medi**a (Hopke & Simis, 2015).

- The hashtag **#fracking** can be used capture the viral messages related to anti-fracking sentiments sent by prominent actors or opinion leaders The support groups for fracking use other hashtags such as natural gas **(#natural-gas**) or shale **oil (#shale-oil**) (Sharag-Eldin, Ye, & Spitzberg, 2018).

- Social medias such as Twitter allow **new forms of activism**, for instance the organization and promotion of an environmental movement centered on a transnational day of action calling for a ban on hydraulic fracturing: the Global Frackdown (Hopke, 2015).

METHODOLOGY (geolocalized tweets dataset)

1 Tweet = 140 characters maximum, including keywords-hashtags (#) (+ image or video or text, etc) (from 2018 = 280 characters)

A tweet contains more than **40 elements in its metadata**:

- the name of the user that sent the message,
- its geolocation (if activated),
- the time the message was sent,
- the content of the message,
- how many times the message has been liked, etc.

Moreover, metrics such as the sentiment associated with a message or how many times it has been retweeted provide additional information.

METHODOLOGY (geolocalized tweets dataset)

Using hashtags of the keywords used for Biblio

- #Fracking #FrackingWasteWater #FrackQuake #EarthQuake
- #ShaleOil #ShaleGas
- #Marcellusshale #Uticashale #BarnettShale #BakkenShale #EagleFordshale

Data from Harvard Center Geographic Analysis : « One Billion Tweets Project » (2012-2015)

- Harvard CGA Geolocated Archive / Geotagged Tweets
- List of # and keywords

Use of the **Nuance-R technological Platform** (PI: Warin, T. 2015)

We access the Twitter REST API with the streameR R package [Barbera, 2018] and selected #

➢ **65 000 tweets**

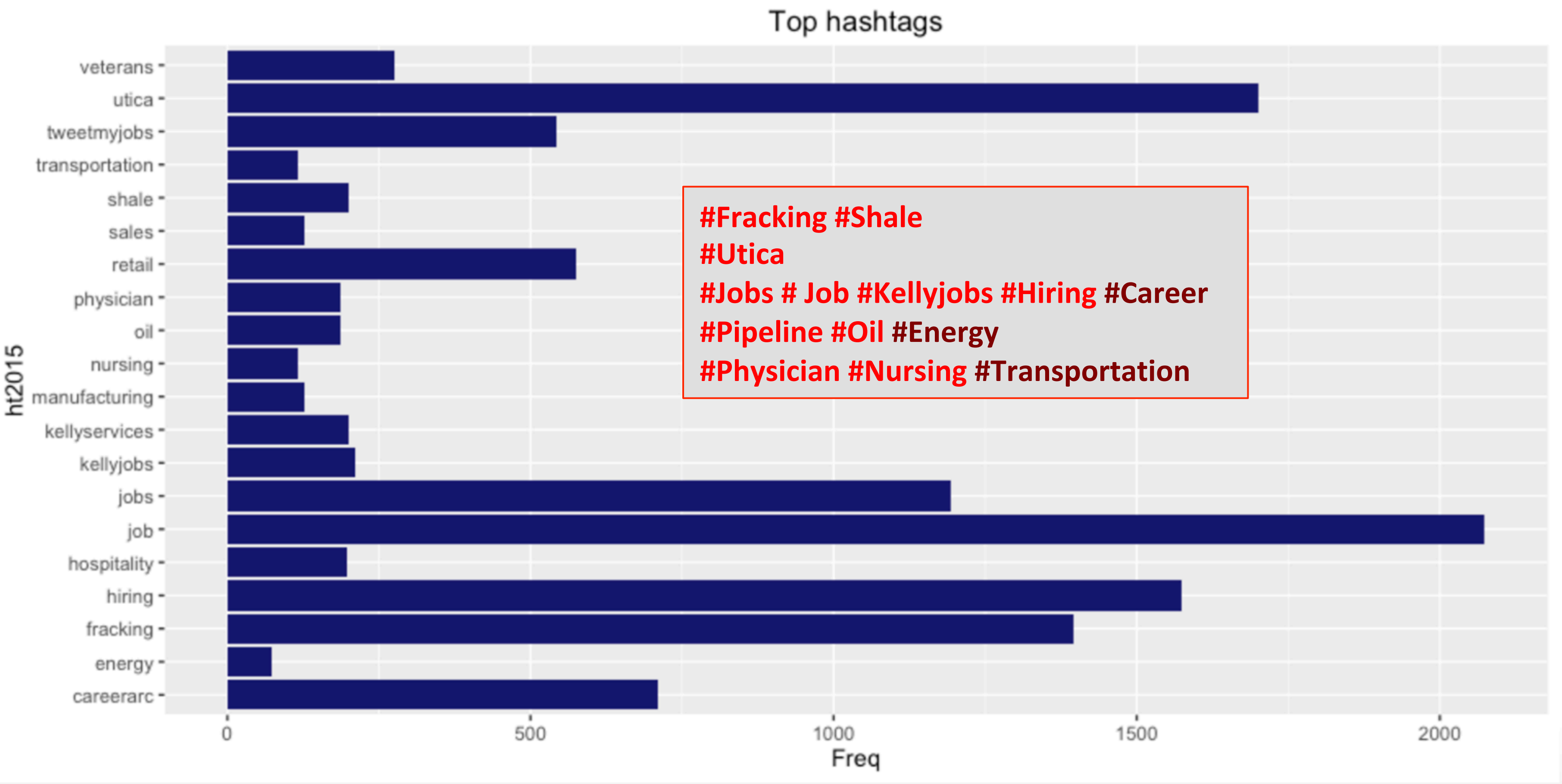
METHODOLOGY (geolocalized tweets dataset)
Content and Sentiment Analysis :

The first step of the analytical analysis is **to tidy our dataset** following Hadley Wickham's description [Wickham, 2014] : "each variable is a column, each observation is a row, each type of observational unit is a table".

In order **to associate a sentiment score to each twee**t we manipulate our dataset in order to remove all links from the messages, then tokenize each message and finally we remove all stopwords following Silge and Robinson (2017) approach.

We compare the results of the sentiment analysis of the messages associated to each # with the lexicon [Hu et Liu, 2004].

Opinion Formation: Most used # hashtags

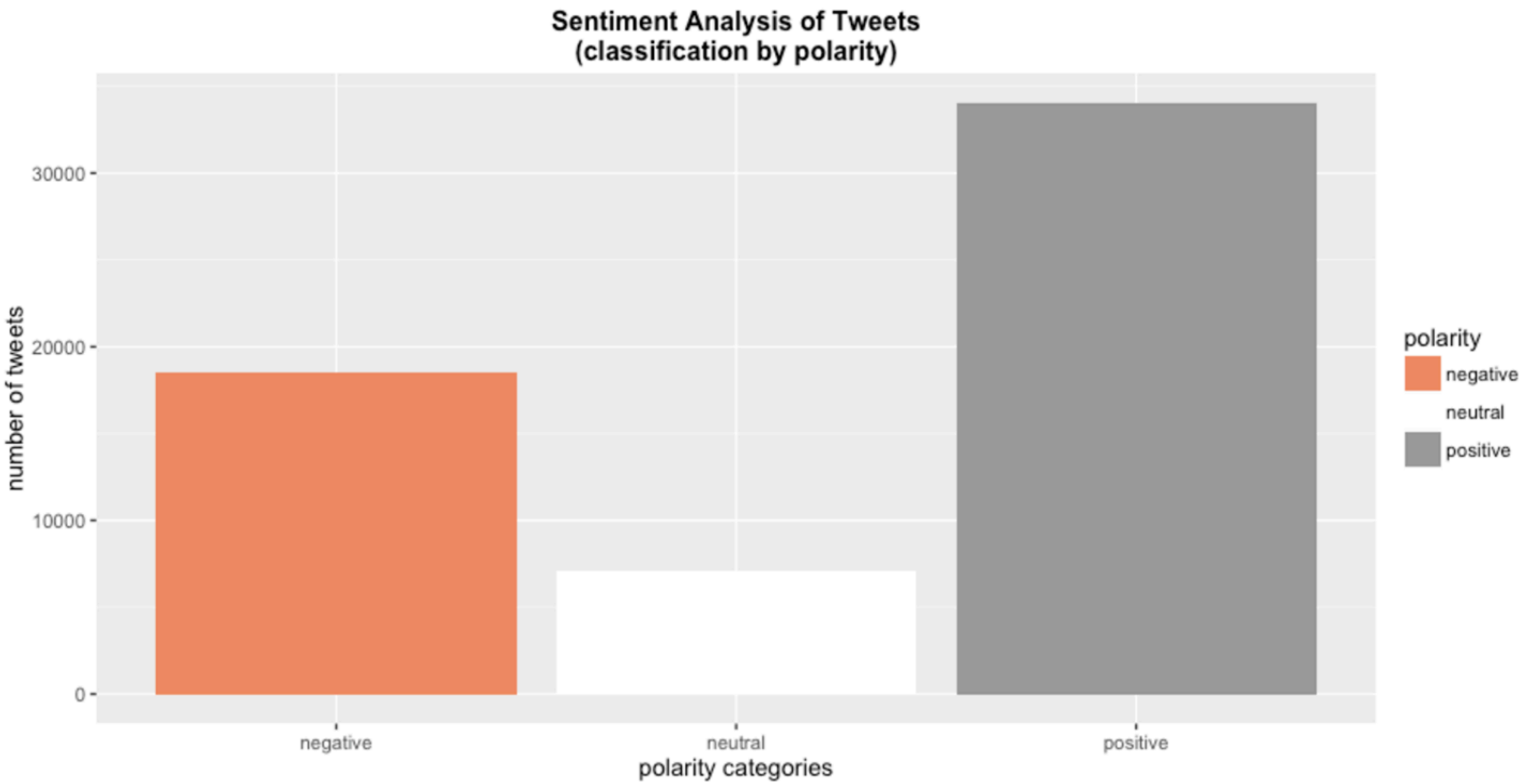


Opinion Formation: "Relevant" words by count

2012 to 2015

2015

Sentiment Analysis: Classification by Polarity



CASE STUDY :
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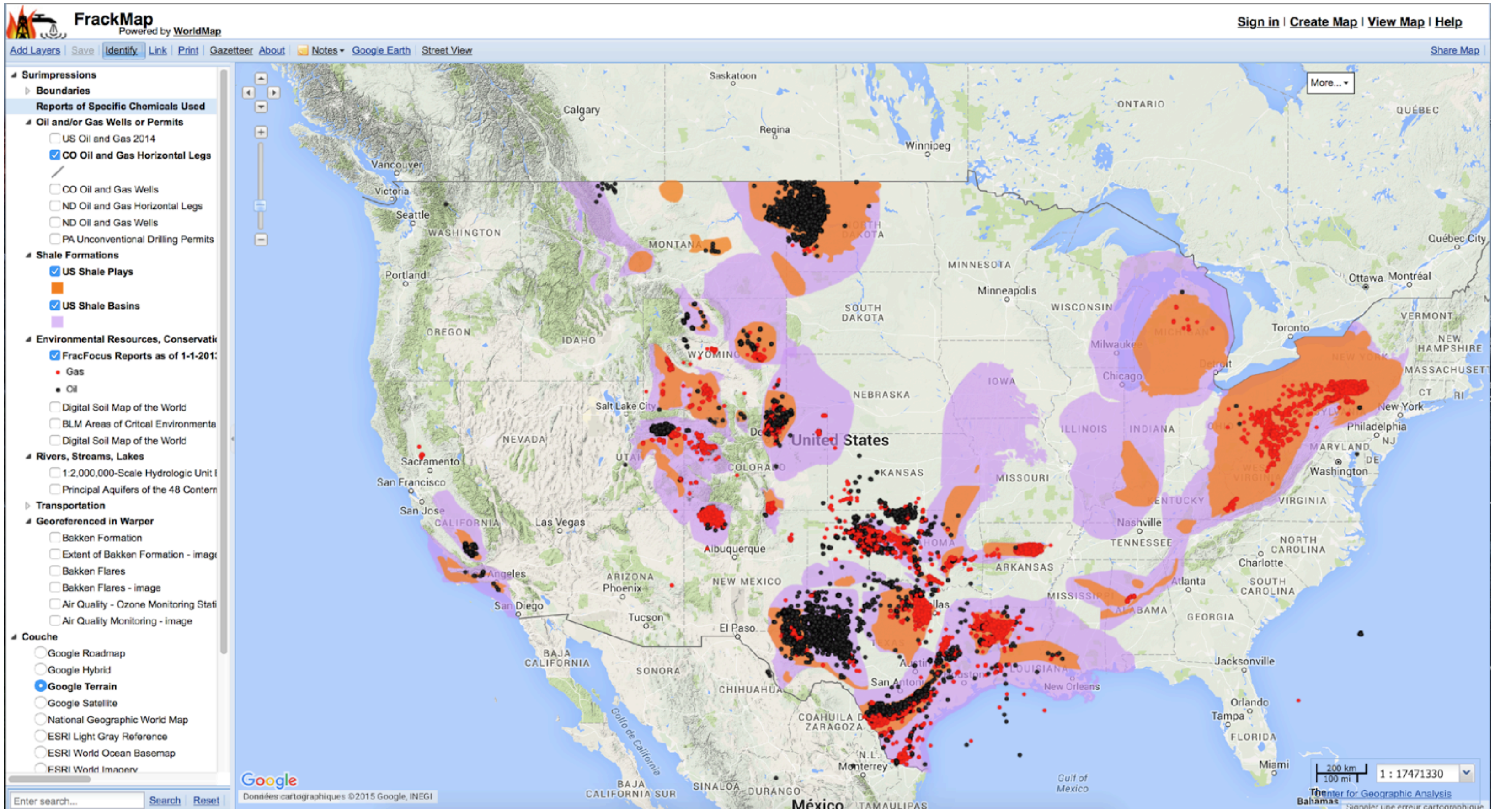
2) Visualising data

Visual communication of data from multiple, disparate sources can create new opportunities to understand complex environmental health questions.

- **Natural gas and shale gas extraction operations data : wells locations, etc.**
- **More than 1000 peer-reviewed publications on potential and real impacts** of hydraulic fracturing on health and environment with **data locations**
- **More than 65 000 geolocalized tweets about #shalegas and #fracking (public perception)**

The FrackMap brings together a range of fracking related datasets



Data: oil and gas permits, shale formations, horizontal legs, etc.

Harvard WorldMap a public domain collaborative mapping platform
http://worldmap.harvard.edu/maps/FrackMap

Algorithms to gather geographical data within articles

Article mentions state

Does the article mention shale?

Yes:

Get a map of the state with shale plays information. Does the state only have one shale within its borders?

- **Yes:** Pinpoint the center of the Shale. Association of that shale to all such state missing a shale in the database.

  E.g.: Fayetteville (AR); Monterey (CA); Antrim (MI).

- **No:** Pinpoint the center of the portion of the shale within that state.

  E.g.: Bakken (MT, ND); Niobrara (CO, NE, WY); Marcellus (NY, OH, PA, WV).

No:

Get a map of the state with shale plays information. Does the state only have one shale within its borders?

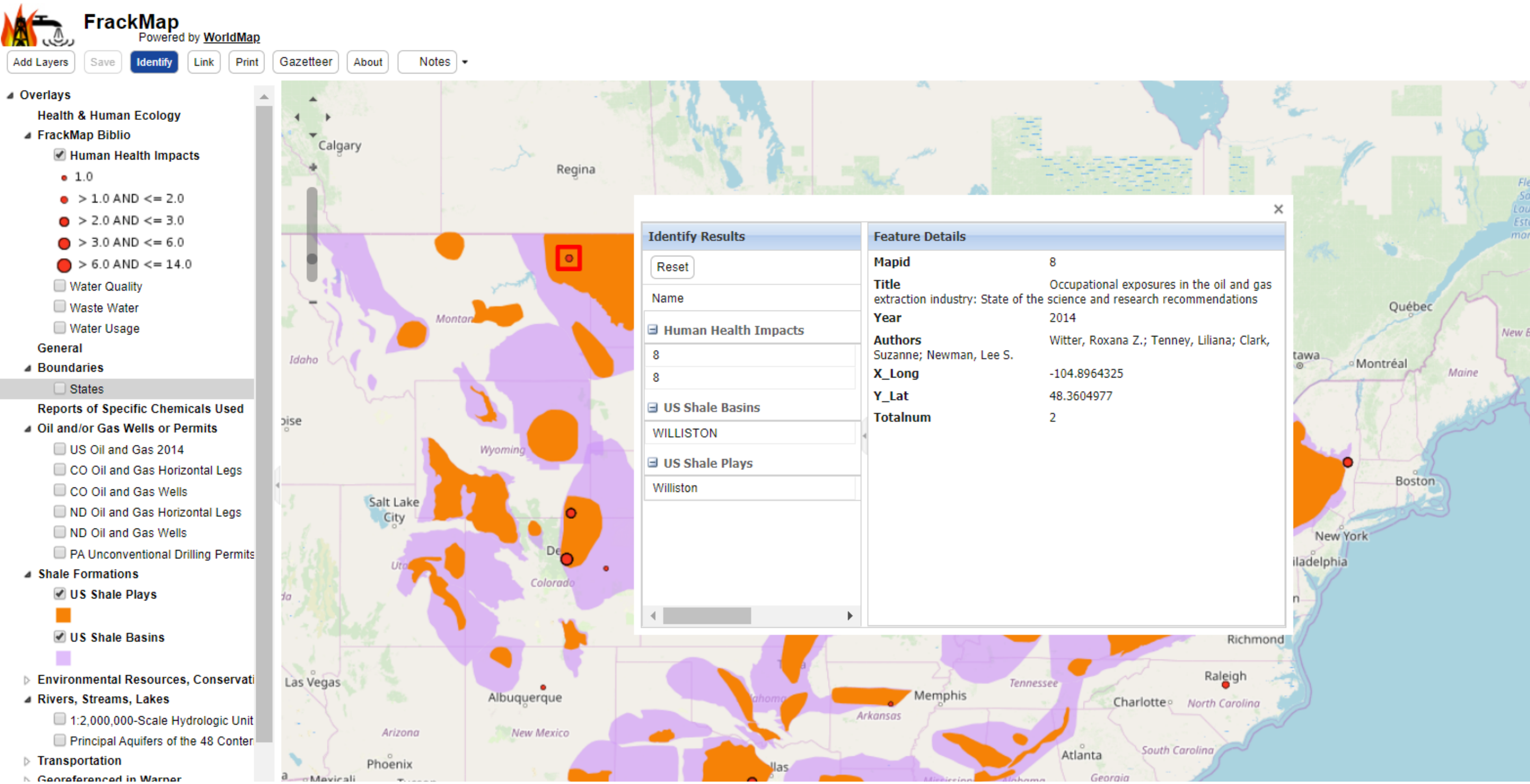
- **Yes:** Pinpoint the center of the shale. Association of that shale to all such state missing a shale in the database.

  E.g.: Fayetteville (AR); Monterey (CA); Antrim (MI).

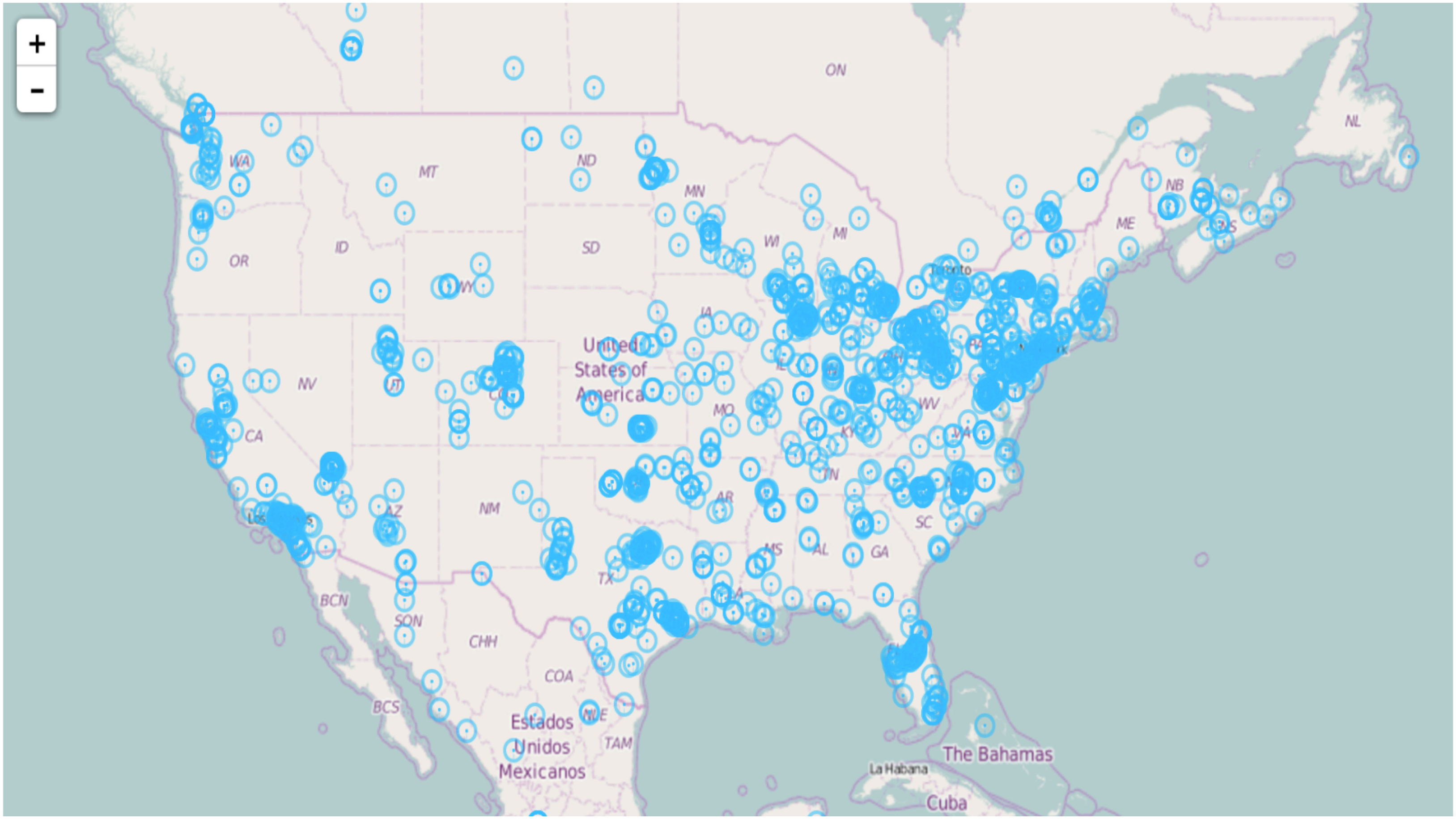
- **No:** Pinpoint the state capital.

  E.g.: Texas (Barnett, Eagle Ford, Haynesville, Permian) is pinpointed on Austin. Colorado (Wattenberg, Piceance, Niobrara) on Denver.

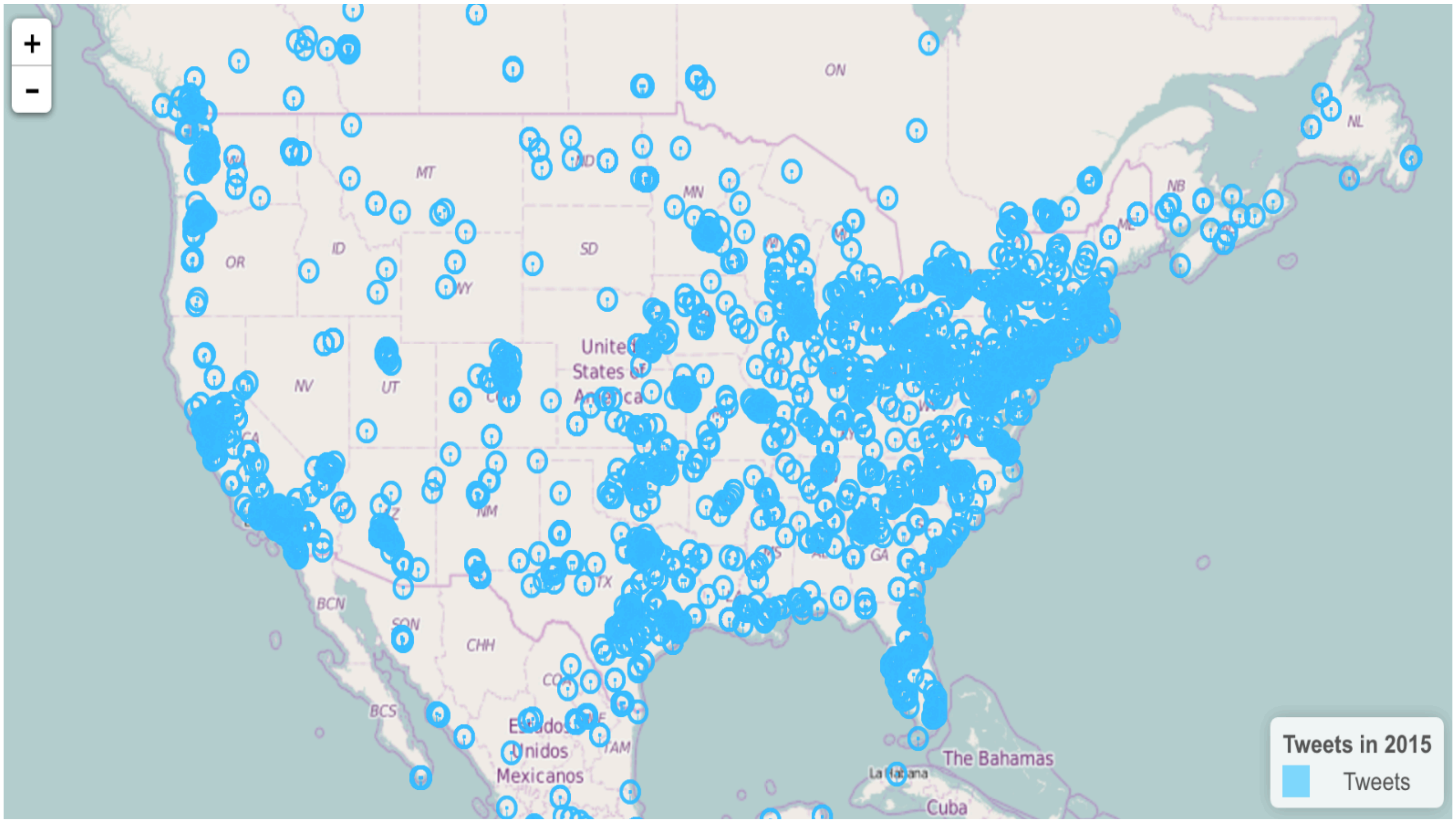
Map, by state, peer-reviewed literature about potential environmental and health issues and impacts associated with U.S. shale gas plays



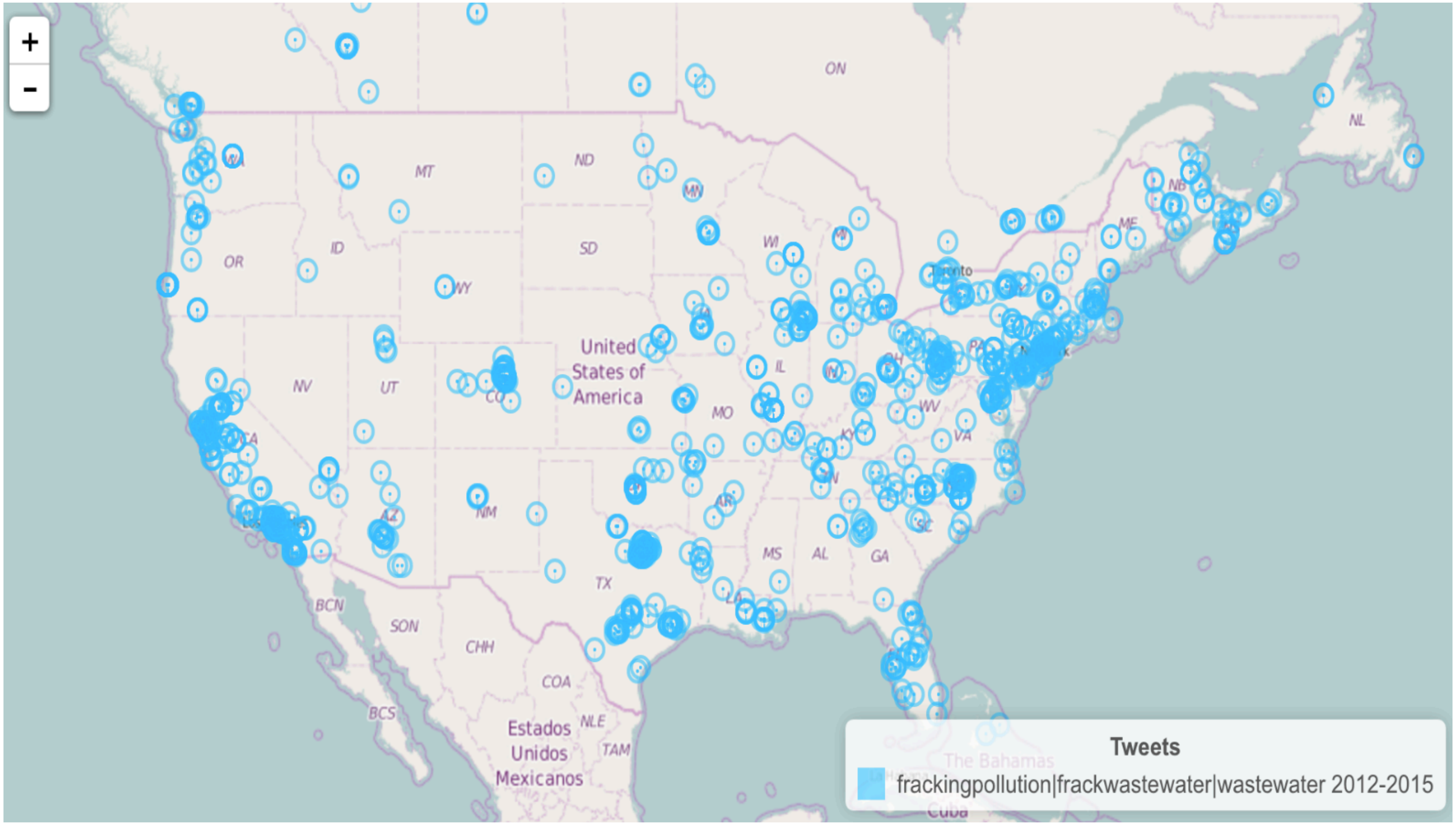
Mapping the tweets, 2012



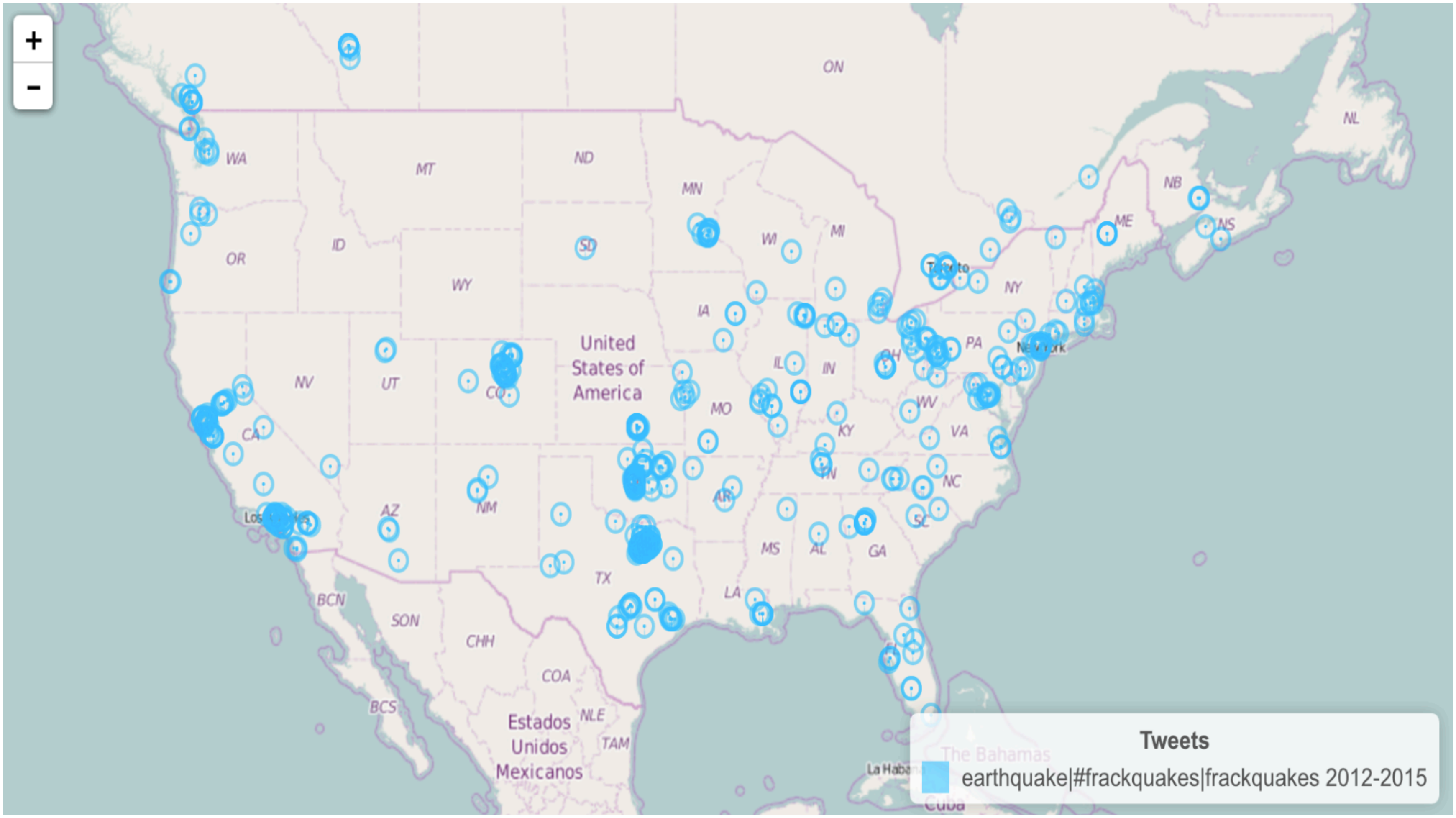
Mapping the tweets, 2015



Mapping the tweets, water impacts



Mapping the tweets, earthquake + frackquake



Conclusion

Integrating and visualizing glarge quantities of data from multiple sources can create new opportunities to understand complex questions and could help **communicate.**

FrackProject is an innovative tool to integrate data and communicate through maps and interactive data visualization

FrackProject could help regulators and industry to implement best risk management practices and invent safer practices.

- Twitter is an interesting platform :
  - to study opinion formation and the nature and pace of the spread of an information through Twitter conversations
  - The conversation is more about **#jobs, #jobs, #jobs…** which contradicts the evidence.