ifo GAME Database of Natural Hazards

Prof. Gabriel Felbermayr, PhD Dr. Jasmin Gröschl Thomas Steinwachs

Ifo Institute – Leibniz Institute for Economic Research at the University of Munich

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ifo Institute
Leibniz Institute for Economic Research
at the University of Munich

Motivation

Understanding the economic impact of natural hazards is important

- Climate change implies increase in disaster frequency and scale (IPCC, 2012; World Bank, 2012; Stern, 2006)
- 243 Mio people per year affected by natural disasters (Oxfam, 2009)
- Nexus between climate change and growth has not yet been understood

Most existing economic studies use outcome based disaster data

- Reporting issues in EM-DAT and NatCatServ (Gall et al., 2008; Strobl, 2012)
  - reporting probability depends on income → **selection bias**
  - losses unequally distributed across disaster types → **hazard bias**
  - less reporting in earlier years → **temporal bias**
  - small and chronicle events underrepresented → **threshold bias**
- Monetary disaster intensity measures correlate with income per capita (Kahn, 2005; Toya and Skidmore, 2007)
  → **endogeneity of damage**, even if reporting were exogenous
- Data aggregated at country level, discarding geographic scope of an event
  → **aggregation/attennuation bias**, especially for large countries

Idea

An emerging literature uses exogenous data on physical intensities

- Usually restricted in geographic scope and/or to a single hazard-type
  - floods in Mumbai (Hallegatte et al., 2010)
  - hurricanes in the US (Strobl, 2010; Murphy and Strobl 2010)

Research Goal

- Build a new database of **g**eological **a**nd **m**eteorological **e**vents *(Ifo GAME)*
  - combining physical intensities for various kinds of hazards
  - collected from primary sources
  - covering the entire world
  - at country, region and grid cell level

  $\Rightarrow$ Felbermayr and Gröschl (2014)
- Analyze potential mechanisms at the hazard/growth nexus:
  - international trade
  - international migration
  - international financial flows

  $\Rightarrow$ Improve understanding of the economic impacts of natural hazards

  $\Rightarrow$ Contribute to the development of adaptation strategies

Mechanisms at the Hazard/Growth Nexus

Standard neoclassical production function

$$Y = A \cdot F(B, K, hL)$$

- e.g., droughts negatively affect total factor productivity A, earthquakes and storms destroy K,...
- some factors can be accumulated, others (like arable land B) cannot
- K reflects trade and financial flows
- L reflects migration and death-toll
- institutional capacities play an important roll
  - $\Rightarrow$ e.g., Hallegatte et al. (2007) show with a reduced-form model that GDP impact of natural disasters can be close to zero if reconstruction capacity is large, or very high if reconstruction capacity is low

Overview of Empirical Literature

Natural Hazards and Economic Growth

- Event studies on economic impact of natural disasters show output-drop (Charveriat, 2000; Auffret, 2003)
- Studies on long-run growth find negative or neutral effect for geophysical and positive effect for climatic events (Skidmore & Toya, 2002)
- Short-run results depend on size, type, and measure used; they range from
  - positive or neutral (Albala-Bertrand, 1993),
  - to neutral or ambiguous (Noy, 2009; Fomby et al., 2013; Cavallo et al., 2013; Loayza et al., 2012; Felbermayr & Gröschl, 2013),
  - to clear negative disaster effects (Rasmussen, 2004; Noy & Nualsri, 2007; Raddatz, 2007, 2009; Hochrainer, 2009)

Mitigating Factors

- Democracies experience lower death counts (Kahn, 2005)
- Advanced economies and those with better institutions cope better (Toya & Skidmore, 2007; Noy, 2009; Escaleras et al., 2007; Raschky; 2008)
- Others find insignificant effects of democracy, political rights, civil liberties (Strömberg, 2007; Skidmore & Toya, 2013)

Overview of Empirical Literature

Natural Hazards and International Trade

- CGE framework to analyze impact of climate change on economic activity, trade, migration, growth, welfare (Desmet and Rossi-Hansberg; 2013)
- Gravity studies find that international trade allows countries to smooth the effects of temporary output shocks (Gassebner et al., 2010; Oh and Reuveny, 2010)
- Large disasters boost imports and hamper exports; magnitudes depend on financial integration (Felbermayr and Gröschl, 2013)

Natural Hazards and International Migration

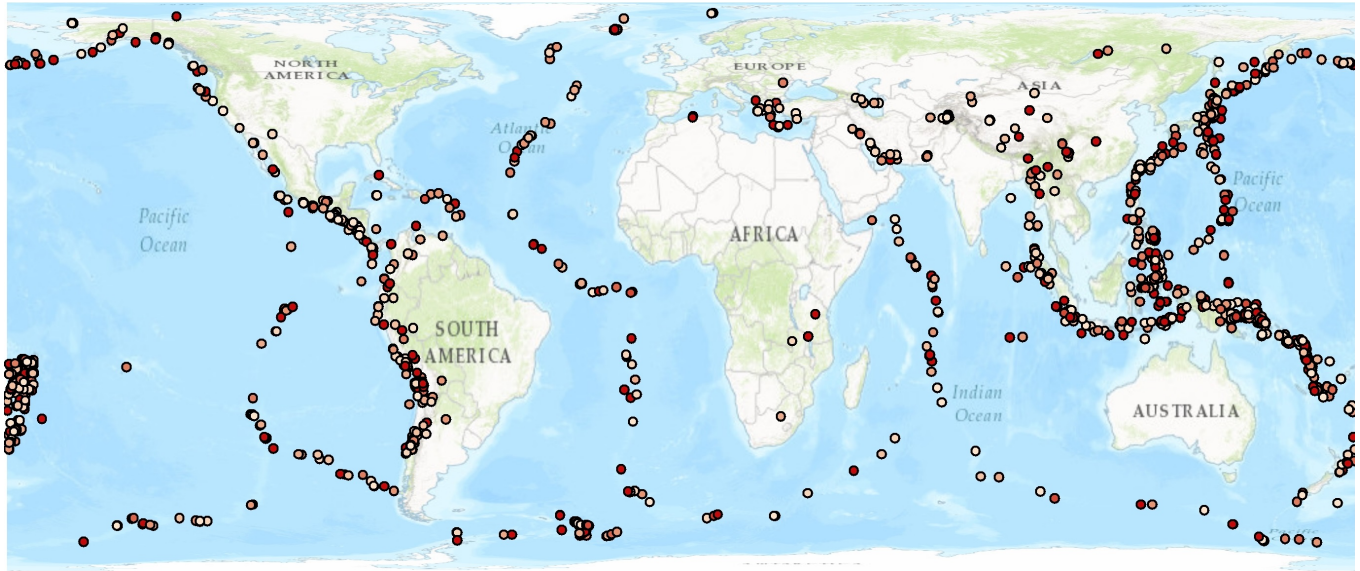
- Disasters cause relocation *within* countries (Barrios, Bertinelli and Strobl, 2006)
- Disasters in Sub-Saharan Africa or development countries cause international outmigration (Naudé, 2010; Drabo and Mbaye, 2011)
- No push effect of disasters found in gravity study using bilateral migration Data (Beine and Parsons, 2015)

Earthquakes

Incorporated Research Institutions for Seismology (IRIS)

- Richter Scale magnitudes [0,10)
- Exact locations of earthquake epicenters
- Coverage used: 1979-2014

Spatial distribution of Earthquakes with magnitude 5 or higher in 2014



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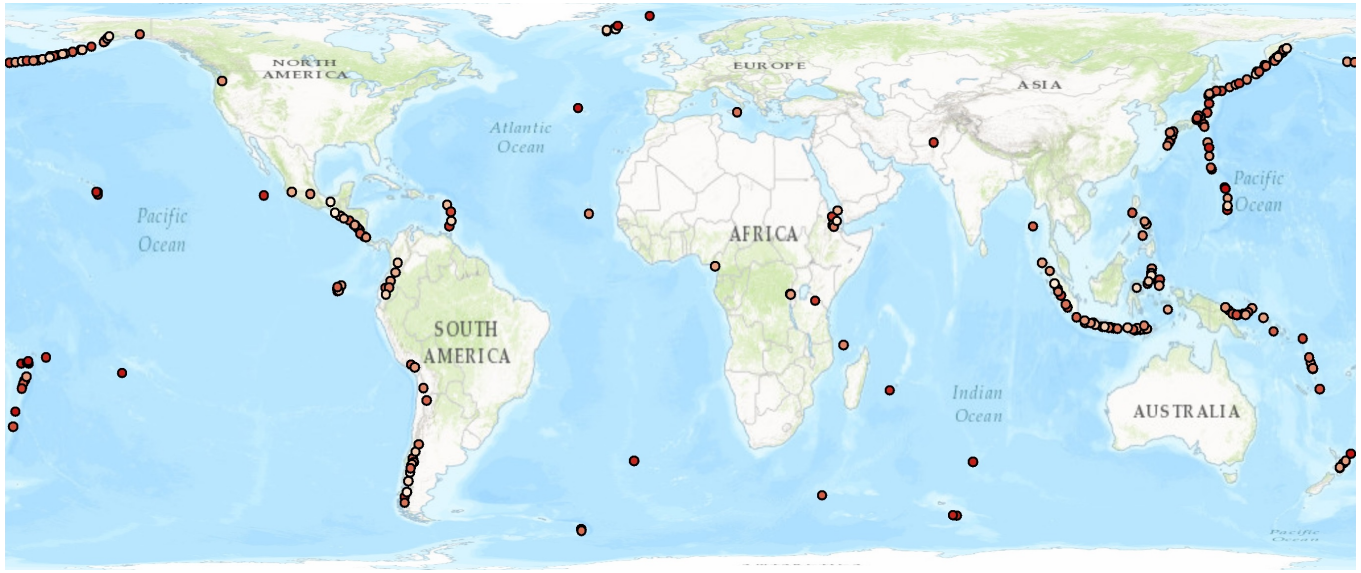
Volcanic Explosions

Smithsonian Global Volcanism Program

- Volcanic Explosivity Index (VEI), discrete [0,8]
- Exact locations of volcanoes
- Coverage used: 1979-2014

Spatial distribution of Volcanoes erupting between 1979 and 2014



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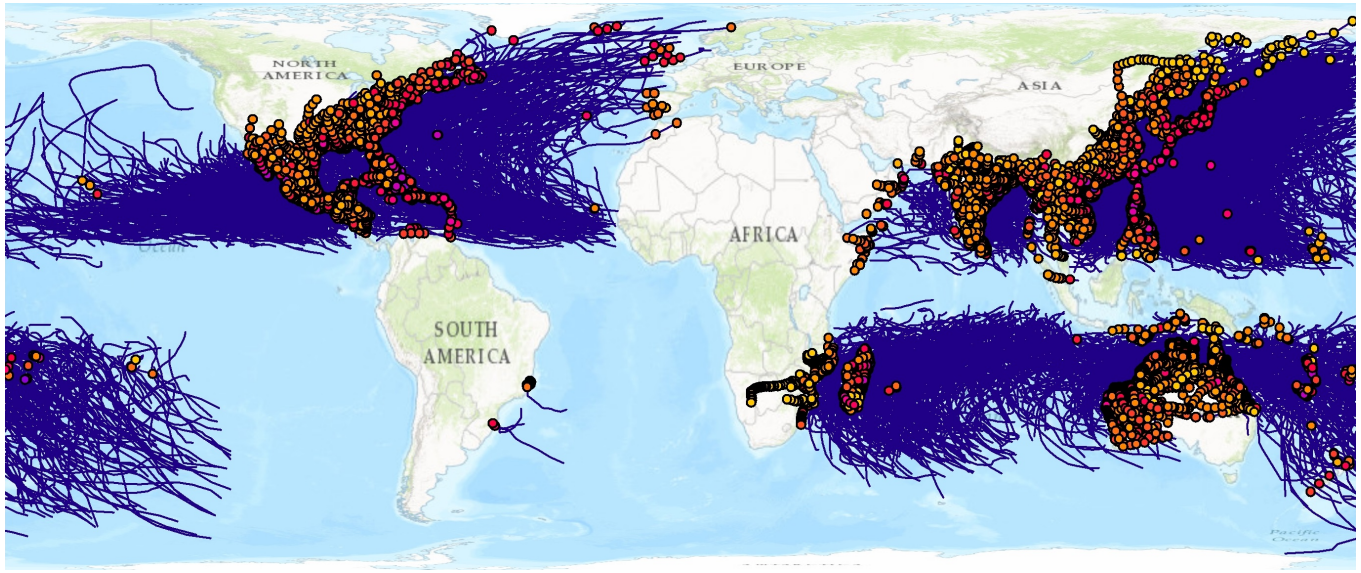
Hurricanes

International Best Track Archive for Climate Stewardship (IBTrACS)

- Wind speeds in knots
- Exact locations / paths of hurricane centers
- Coverage used: 1979-2014

Spatial distribution of Hurricanes from 1979 to 2014



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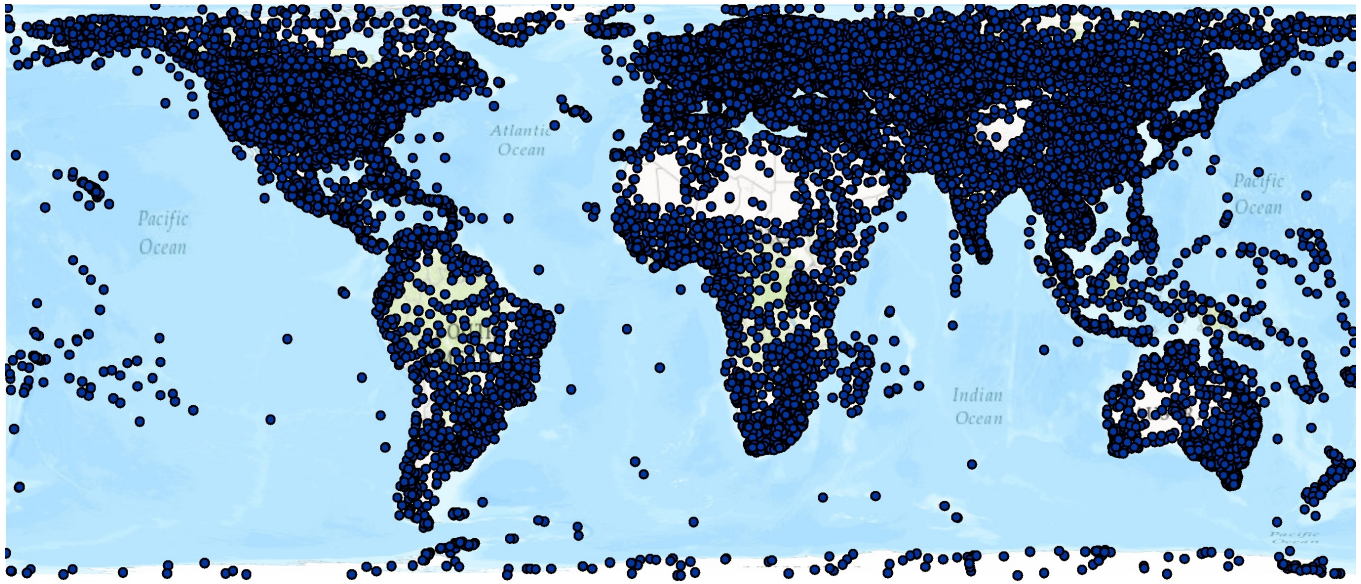
Storms

Global Summary of the Day (GSOD)

- Used as a complement to IBTrACS, to identify smaller storms and gusts
- Exact locations of 23,749 weather stations; wind speeds in knots
- Coverage used: 1979-2014

Spatial distribution of Weather Stations



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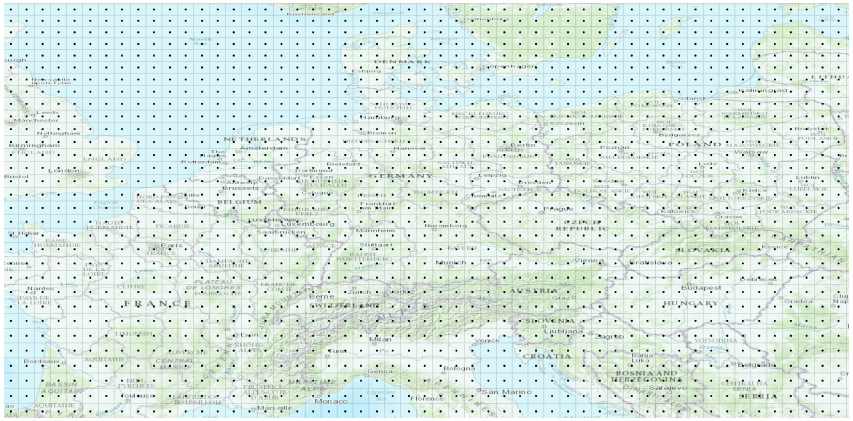
Temperature

GHCN_CAMS Gridded 2m Temperature (Land)

- Interpolated combination of two weather station datasets:
  - Global Historical Climatology Network version 2 (GHCN)
  - Climate Anomaly Monitoring System (CAMS)
- Monthly means of global land surface temperatures in degrees Celsius
- High resolution gridded data (0.5°x 0.5°)
- Coverage used: 1979-2014

0.5° gridded data



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Precipitation

NASA Global Monthly Merged Precipitation Analyses of GPCP

- GPCP Version 2.2 Satellite-Gauge Combined Precipitation Data Set:
  - Combines Satellite and Weather Station (Gauge) Data
  - Data from different Satellites and Stations are harmonized
- Monthly precipitation in millimeters
- Intermediate resolution gridded data (2.5°x 2.5°)
- Coverage used: 1979-2014

International Research Institute for Climate and Society (IRI), Earth Institute, Columbia University: IRI Analyses SPI

- Standardized Precipitation Index (SPI) analyzes of CAMS_OPI Data:
  - Takes "normal rainfall amount" at given locations into account
  - Specifically designed to identify droughts
- Standardized precipitation measures $\sim$ [-3,3]
- Intermediate resolution gridded data (2.5°x 2.5°)
- Coverage used: 1979-2014

Aggregation of GAME Data to the Country Level

Aggregation of gridded data

- By country-year-month:
  - arithmetic mean
  - standard deviation
  - maximum
  - minimum
- By country-month:
  - long run arithmetic mean over all 36 years

Caveat 1: Measuring points are located at the grid cells' centers

- Small countries (e.g. Austria) may not have any measuring points within their geographic boundaries
- For larger countries, measuring points in border regions may concern only a relatively small aerial fraction of a country

Caveat 2: Fixed-Degree grid cells have varying metric area along latitudes

- Measuring points more remote from equator affect smaller land area

Aggregation of GAME Data to the Country Level

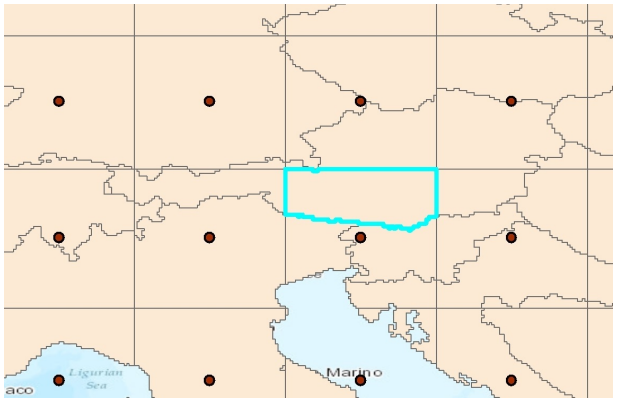
Technique addressing both caveats:

Step 1: Split each country i into fractions *frac* by grid cells

Step 2: Calculate geodesic land area a in km^2 for each fraction in a cell

Step 3: At any point in time t, add values of each measuring point to all fractions within its respective cell

Step 4: Calculate fraction-area-weighted means $\bar{x}^{*^{i,t}}$ and standard deviations $sd(x)^{*^{i,t}}$ by country-year(-month)



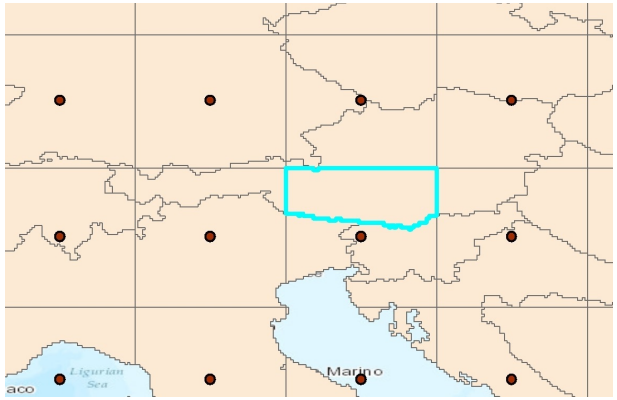
$$\bar{x}^{*^{i,t}} = \frac{\sum_{frac \in i} a^i_{frac} \cdot x^{i,t}_{frac}}{\sum_{frac \in i} a^i_{frac}}$$

$$sd(x)^{*^{i,t}} = \sqrt{\frac{\sum_{frac \in i} a^i_{frac} \cdot (x^{i,t}_{frac} - \bar{x}^{*^{i,t}})}{\frac{M-1}{M} \sum_{frac \in i} a^i_{frac}}}$$

Aggregation of GAME Data to the Country Level

How about country max and min?

- Weighting problematic, as truly extreme events might be veiled
- Instead: Use absolute max and min across all fractions with a "non-minor" role for a given country
- Selection rule:



$$x_{max}^{i,t} = max\left(x_{frac\in i}^{i,t} \middle| minor_{frac} \neq 1\right) \quad \forall \quad i,t$$
$$x_{min}^{i,t} = min\left(x_{frac\in i}^{i,t} \middle| minor_{frac} \neq 1\right) \quad \forall \quad i,t \quad ,$$

where

$$minor_{frac} = \begin{cases} 1, & \text{if } \left(\sum_{frac\in i} a_{frac}^{i} \geq a_{cell}\right) \wedge \left(a_{frac}^{i} < \frac{1}{5}\cdot a_{cell}\right) \\ 1, & \text{if } \left(\sum_{frac\in i} a_{frac}^{i} < a_{cell}\right) \wedge \left(a_{frac}^{i} < \frac{1}{5}\cdot \sum_{frac\in i} a_{frac}^{i}\right) \\ 0, & \text{otherwise} \end{cases}$$

Aggregation of GAME Data to the Country Level

Aggregation of non-gridded hazards

- Direct mapping of *monthly maximum* to all countries within a radial buffer around the exact hazard location
- Geodesic buffer sizes:
  - Volcanoes: 50 km
  - Hurricanes: 100 km
  - Earthquakes: 150 km

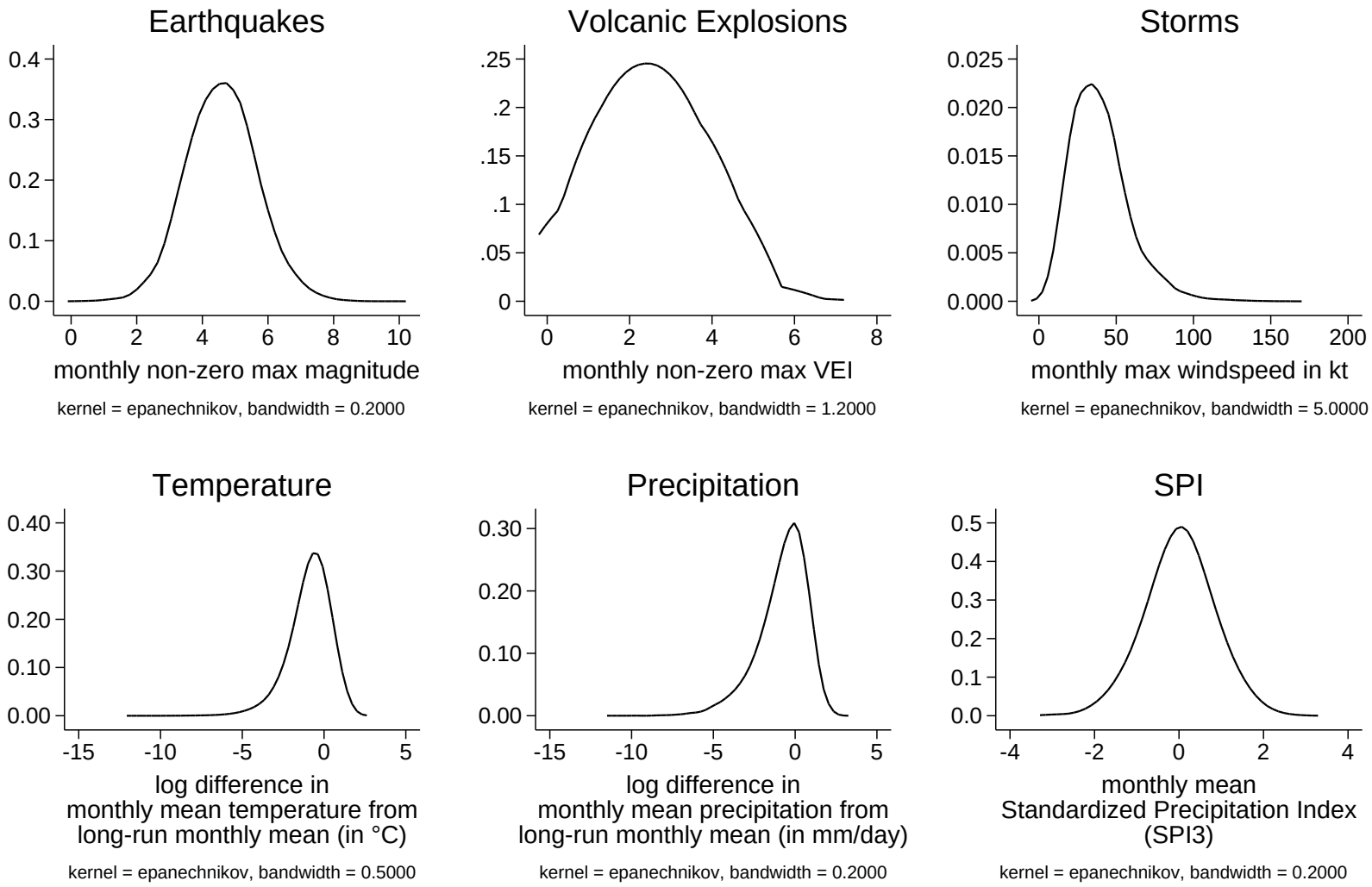
Potential issues of non-gridded hazards

- Volcanoes are very local events, but gas plumes can have extensive impact
- True geographic extent of earthquakes very hard to predict given only their magnitude and depth of epicenter

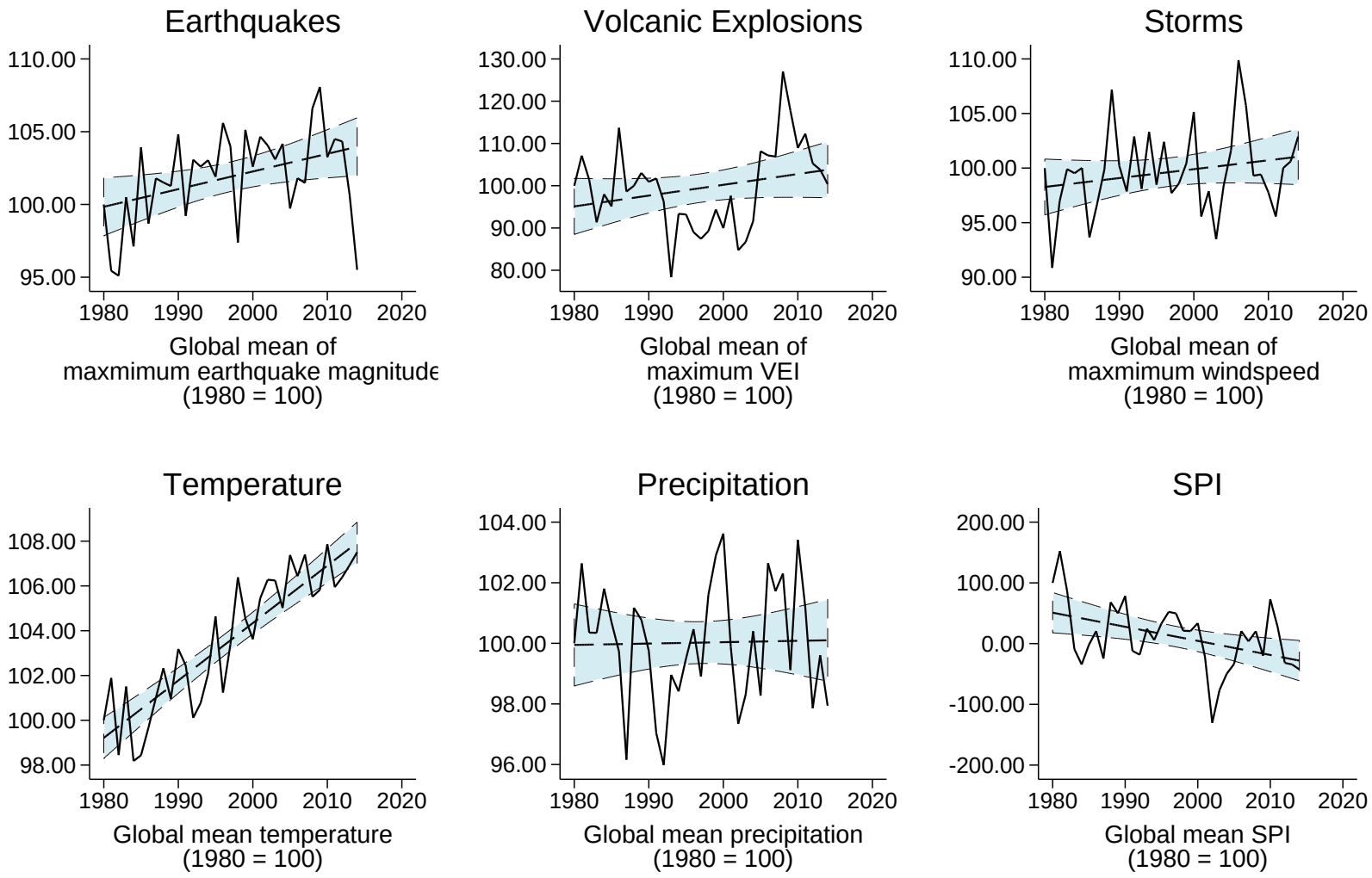
  $\Rightarrow$ too many local geological and earth surface characteristics matter
- Wind field simulation for hurricanes preferable to assuming a fixed radius

  $\Rightarrow$ potential outcome in cooperation with PIK

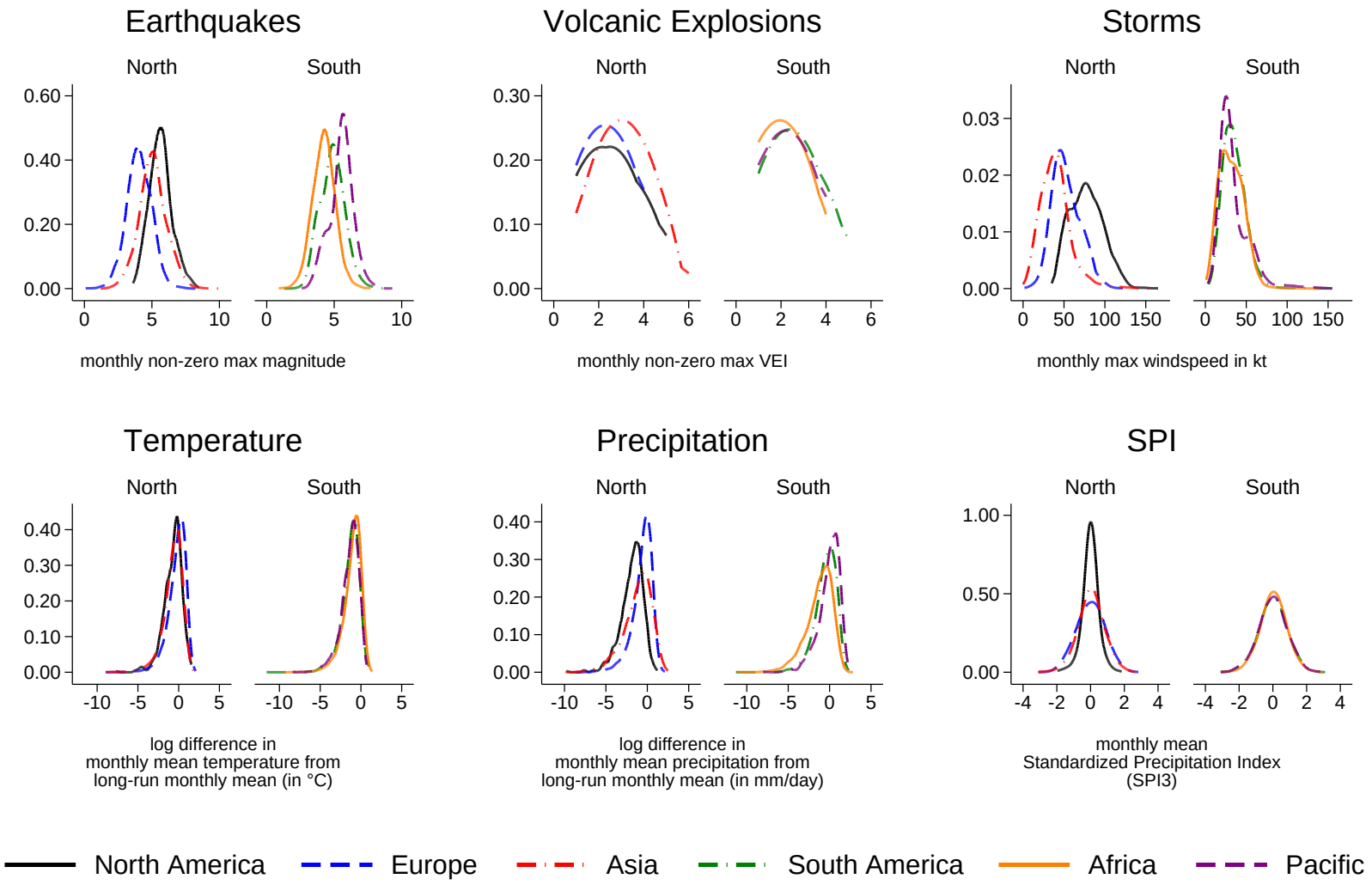
Summary


Earthquakes
0.4
0.3
0.2
0.1
0.0
0 2 4 6 8 10
monthly non-zero max magnitude
kernel = epanechnikov, bandwidth = 0.2000
Volcanic Explosions
.25
.2
.15
.1
.05
0
0 2 4 6 8
monthly non-zero max VEI
kernel = epanechnikov, bandwidth = 1.2000
Storms
0.025
0.020
0.015
0.010
0.005
0.000
0 50 100 150 200
monthly max windspeed in kt
kernel = epanechnikov, bandwidth = 5.0000
Temperature
0.40
0.30
0.20
0.10
0.00
-15 -10 -5 0 5
log difference in
monthly mean temperature from
long-run monthly mean (in °C)
kernel = epanechnikov, bandwidth = 0.5000
Precipitation
0.30
0.20
0.10
0.00
-15 -10 -5 0 5
log difference in
monthly mean precipitation from
long-run monthly mean (in mm/day)
kernel = epanechnikov, bandwidth = 0.2000
SPI
0.5
0.4
0.3
0.2
0.1
0.0
-4 -2 0 2 4
monthly mean
Standardized Precipitation Index
(SPI3)
kernel = epanechnikov, bandwidth = 0.2000

Evolution Across Time



Distribution Across Space



Next Steps

Data Work

- Aggregate non-gridded location-based hazard data to grid cells
  - Earthquakes
  - Volcanoes
  - Storms
- Process and spatially match covariates
  - night time lights emissions
  - gridded population of the world data
  - gridded GDP
- Refine hazard indicators
  - use RX5 for precipitation-induced floods
  - improve hurricane data by adding wind-field information (coop. with PIK)

Further analyses

- Apply theory-consistent state-of-the-art gravity estimation techniques to trade and migration analyses (Head and Mayer, 2014)
- Analyze effects of natural hazards on financial flows and growth
- Develop estimation framework at grid cell level

Definition of hazard count variables

Count Indicator	Intensity Measure	Bound	Minimum Event Type
Earthquakes	maximum magnitude	≥ 4	felt shaking of the earth with light damage caused to buildings and structures
Storms	maximum sustained wind speed	≥ 64 knots	some damage to buildings and trees, extensive damage to to power lines and poles (Cat. 1 on Saffir-Simpson Hurricane Scale)
Volcanoes	maximum Volcanic Explosivity Index (VEI)	≥ 1	light eruption with ejecta volume $> 10{,}000\ m^3$
Droughts	mean Standardized Precipitation Index (SPI)	≤ 0	mild drought according to SPI classes by McKee et al. (1993)
Floods	positive difference of monthly mean precipitation over monthly long-run mean	≥ 0.387	light excess-rain anomaly following classes in Felbermayr and Gröschl (2014), Table B-I
Temperatures	absolute difference of monthly mean temperature over monthly long-run mean	≥ 0.011	light temperature anomaly following classes in Felbermayr and Gröschl (2014), Table B-I

Summary Statistics Hazards and Trade

Variable	N	Mean	Std. Dev.	Max	Min
Imports$_{ij,t}$	27200	0.02	0.29	13.41	0.00
ln Supply$_{i,t}$	27200	13.07	1.82	17.11	8.78
ln Demand$_{j,t}$	27200	12.35	1.82	16.57	8.28
RTA$_{ij,t}$	27200	0.50	0.50	1.00	0.00
WTO$_{ij,t}$	27200	0.88	0.33	1.00	0.00
Hazard count$_{i,t}$	27200	29.30	9.05	58.00	10.00
Earthquake count$_{i,t}$	27200	6.53	4.40	12.00	0.00
Storm count$_{i,t}$	27200	3.46	4.13	12.00	0.00
Temperature count$_{i,t}$	27200	10.23	1.99	12.00	0.00
Pos. precipitation count$_{i,t}$	27200	1.77	1.53	8.00	0.00
Drought count$_{i,t}$	27200	5.77	4.07	12.00	0.00
Hazard index$_{i,t}$	27200	75.44	15.83	118.12	16.33
Geo hazard index$_{i,t}$	27200	5.78	1.97	13.00	0.00
Climate hazard index$_{i,t}$	27200	69.66	14.80	108.92	11.33
Earthquakes$_{i,t}$	27200	5.44	1.34	10.00	0.00
Volcanoes$_{i,t}$	27200	0.35	0.92	4.00	0.00
Storms$_{i,t}$	27200	56.21	14.70	98.91	0.00
Pos. precipitation anomalies$_{i,t}$	27200	0.71	0.46	4.03	0.00
Droughts$_{i,t}$	27200	0.78	0.60	2.97	0.00
Absolute Temperature$_{i,t}$	27200	11.97	6.03	26.10	1.53
Hazard count$_{i,t}$, land area	27200	2.41	0.66	4.69	0.63
Earthquake count$_{i,t}$, land area	27200	0.51	0.33	1.20	0.00
Storm count$_{i,t}$, land area	27200	0.26	0.31	1.06	0.00
Temperature count$_{i,t}$, land area	27200	0.87	0.26	2.08	0.00
Pos. precipitation count$_{i,t}$, land area	27200	0.16	0.15	1.04	0.00
Drought count$_{i,t}$, land area	27200	0.49	0.37	2.08	0.00
Hazard index$_{i,t}$, land area	27200	6.24	1.34	12.28	1.41
Geo hazard index$_{i,t}$, land area	27200	0.47	0.14	1.03	0.00
Climate hazard index$_{i,t}$, land area	27200	5.77	1.28	11.36	0.98
Earthquakes$_{i,t}$, land area	27200	0.45	0.11	1.03	0.00
Volcanoes$_{i,t}$, land area	27200	0.02	0.07	0.28	0.00
Storms$_{i,t}$, land area	27200	4.62	1.04	7.28	0.00
Pos. precipitation anomalies$_{i,t}$, land area	27200	0.06	0.05	0.38	0.00
Droughts$_{i,t}$, land area	27200	0.07	0.06	0.44	0.00
Absolute Temperature$_{i,t}$, land area	27200	1.02	0.60	3.57	0.11
MR contig$_{ij,t}$	27200	0.00	0.00	0.02	-0.00
MR ln dist$_{ij,t}$	27200	0.42	0.01	0.47	0.40
MR RTA$_{ij,t}$	27200	0.01	0.01	0.04	-0.00
MR WTO$_{ij,t}$	27200	0.05	0.01	0.05	-0.00