Strategies of Monitoring, Reporting and Verification

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26th of July 2013

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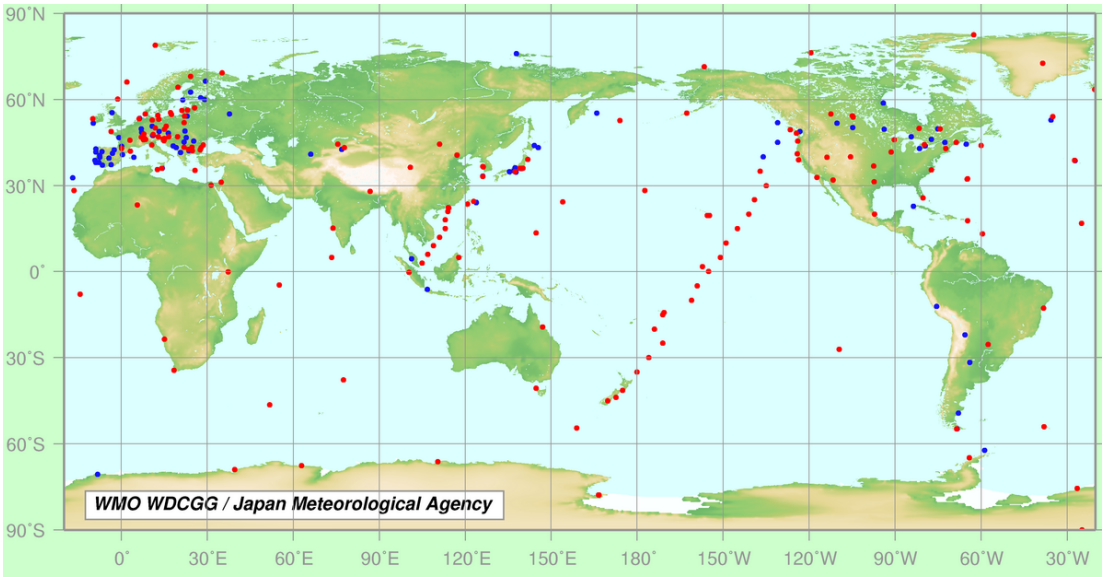
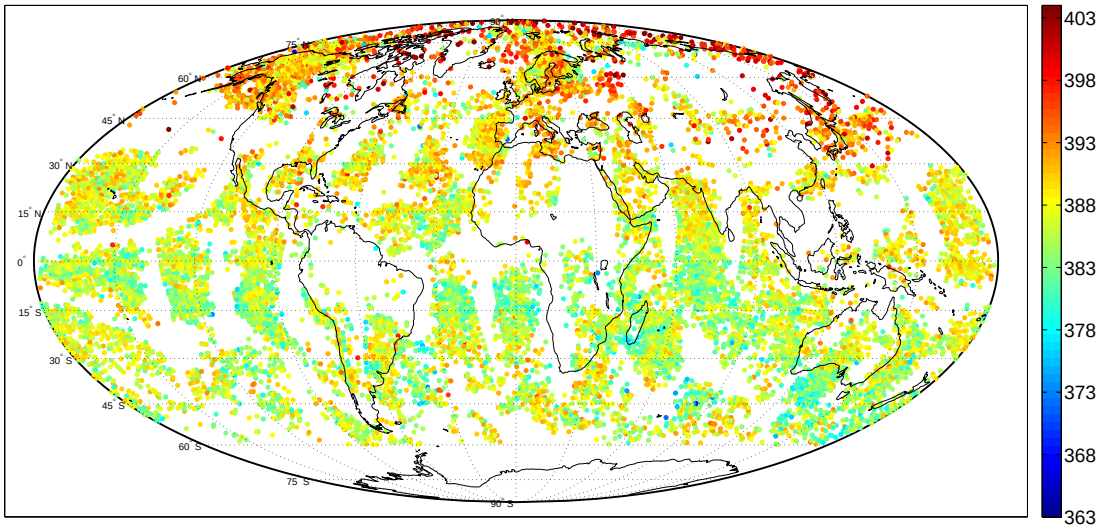
Netzwerk aus Bodenmessstationen



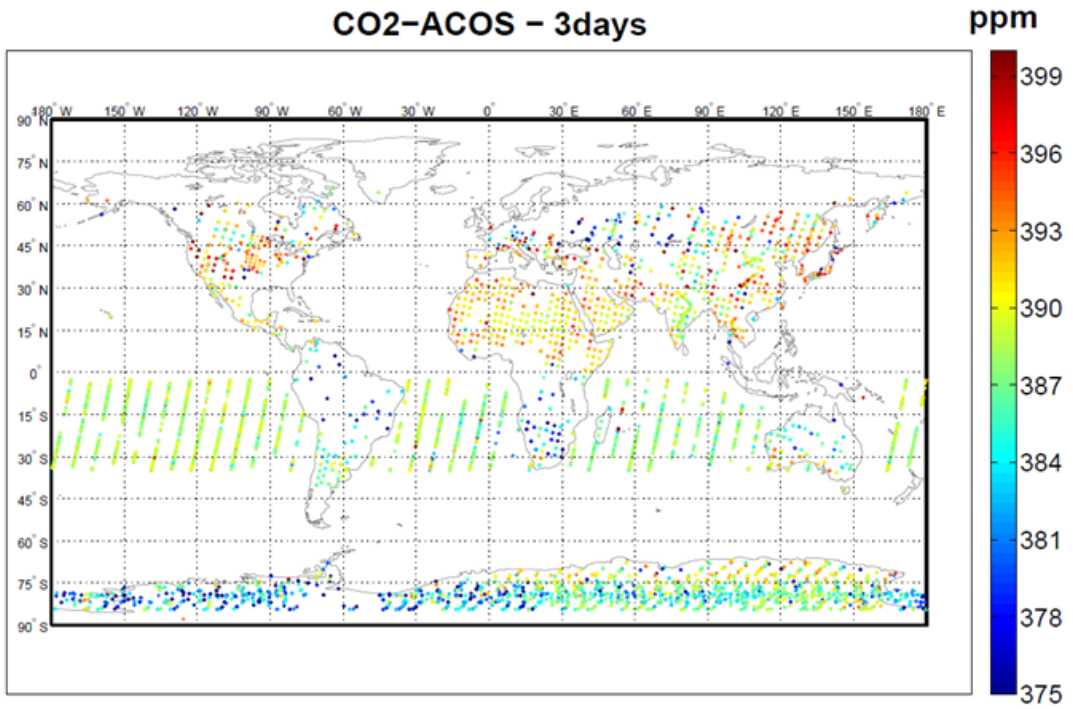
- Internationales Netzwerk aus Bodenmessstationen
- Vorteile:
  - Messung in Bodennähe
  - Lange Zeitreihen
- Nachteil: Räumliche Abdeckung mangelhaft
  (209 Stationen / 156 davon aktiv)

NASA Satellit “Aqua“



- Vorteile:
  - $\sim$ 12000 Messpunkte am Tag - Zeitreihe von 10 Jahren
  - sehr gute globale Abdeckung
- Nachteile:
  - Durchschnittliche CO_2 Konzentration in der mittlere Troposphäre (5-9km Höhe)
  - Starke Vermischung - Troposphäre = Wetterschicht

Greenhouse gases Observing Satellite Mission of Japan



- Durchschnittliche CO_2 Konzentration zwischen 0-9km Höhe
- Bodenzug vorhanden
- verrauscht durch Vermischung in der Troposphäre

Modellierung von Umweltprozessen

Deterministisch	*Stochastisch*
• $Y_t(\mathbf{s}) = f(\mathbf{s}, t, \mathbf{X})$	• $Y_t(\mathbf{s}) = \delta_t(\mathbf{s}) + \epsilon_t(\mathbf{s})$
• bekannte deterministische Zusammenhänge	• $f(\mathbf{s}, t, \mathbf{X})$ nicht bekannt
• Theorien, Hypothesen	• Aber: räumliche Verteilung und zeitliche Entwicklung von $Y_t(\mathbf{s})$, verursacht durch $f(\mathbf{s}, t, \mathbf{X})$, beobachtbar
	• räumlich und zeitliche Auto-Korrelation
	• $\boldsymbol{\delta}_t = \mathbf{H}\boldsymbol{\delta}_{t-1} + \boldsymbol{\gamma}_t$
	• $\boldsymbol{\delta}_t \vert \boldsymbol{\delta}_{t-1} \sim N_n(\mathbf{0}, \boldsymbol{\Sigma}_t(\boldsymbol{\theta}))$

Linear Mixed-Effects Models

$$
\begin{aligned}
Y_t(\mathbf{s}) &= \mathbf{x}_t(\mathbf{s})'\boldsymbol{\beta} + \delta_t(\mathbf{s}) + \epsilon_t(\mathbf{s}) \\
\boldsymbol{\delta}_t &= \mathbf{H}\boldsymbol{\delta}_{t-1} + \boldsymbol{\gamma}_t \\
\boldsymbol{\delta}_t|\boldsymbol{\delta}_{t-1} &\sim N_n(\mathbf{0}, \boldsymbol{\Sigma}_t(\boldsymbol{\theta}))
\end{aligned}
$$

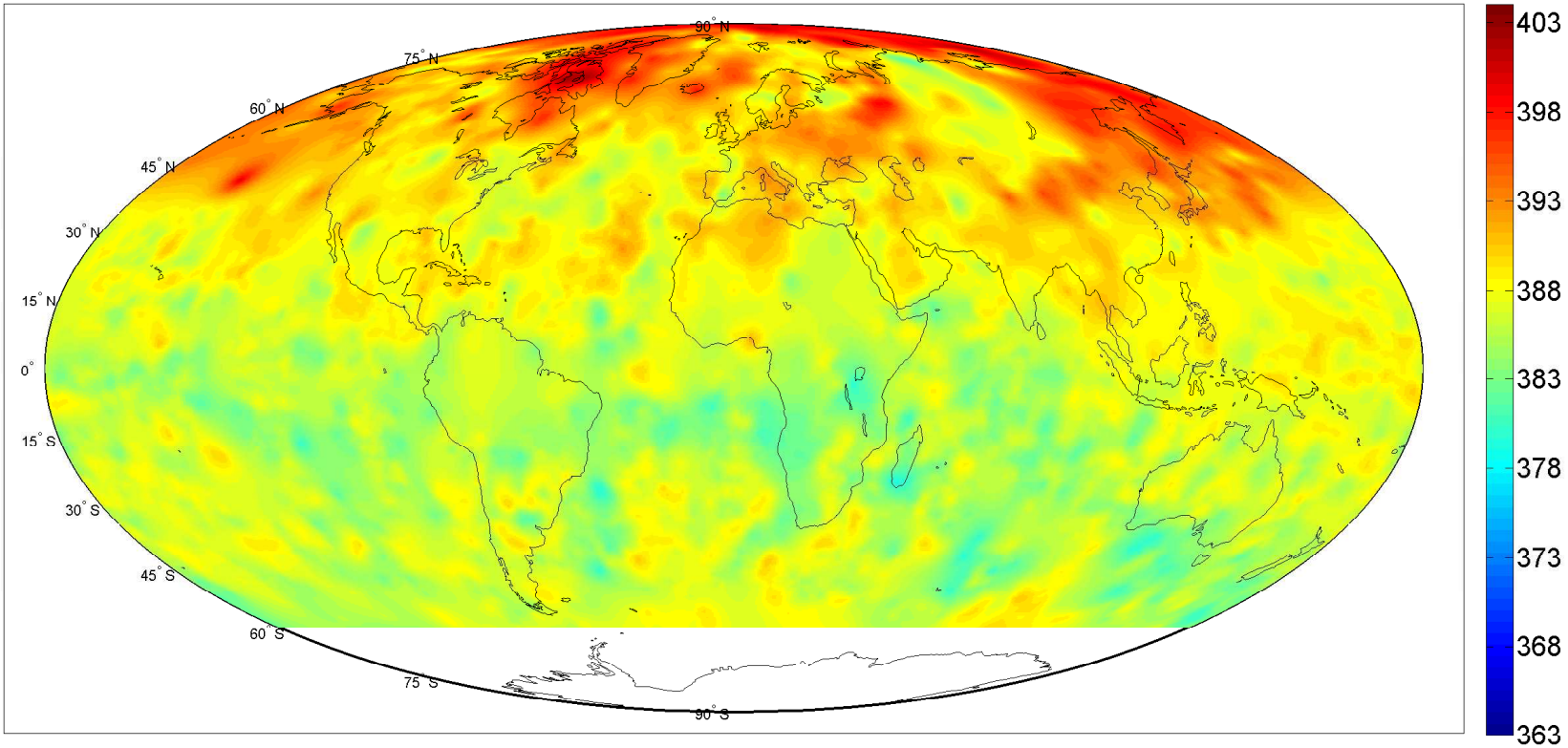
Räumlicher Prozess

$$\begin{aligned} Y(\mathbf{s}) &= \mu(\mathbf{s}) + \delta(\mathbf{s}) + \epsilon(\mathbf{s}) \\ \boldsymbol{\delta} &\sim N_n(\mathbf{0}, \boldsymbol{\Sigma}) \end{aligned}$$

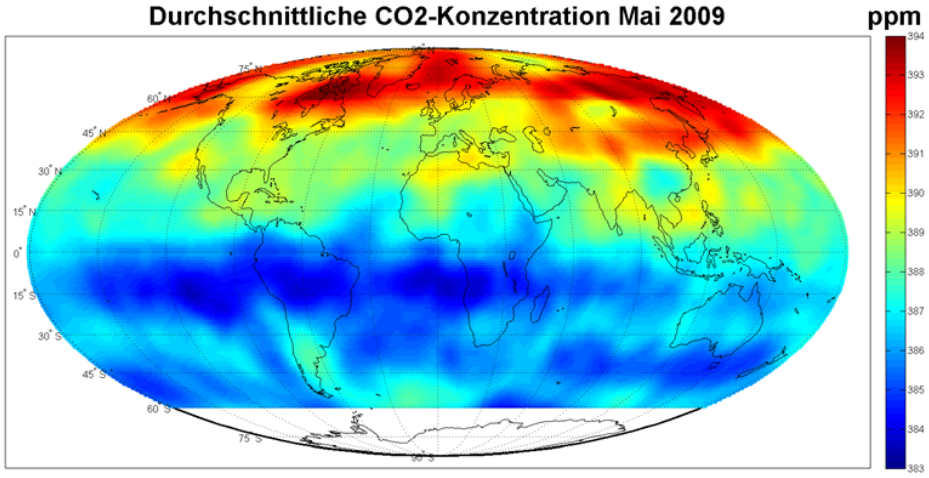
Problemstellung

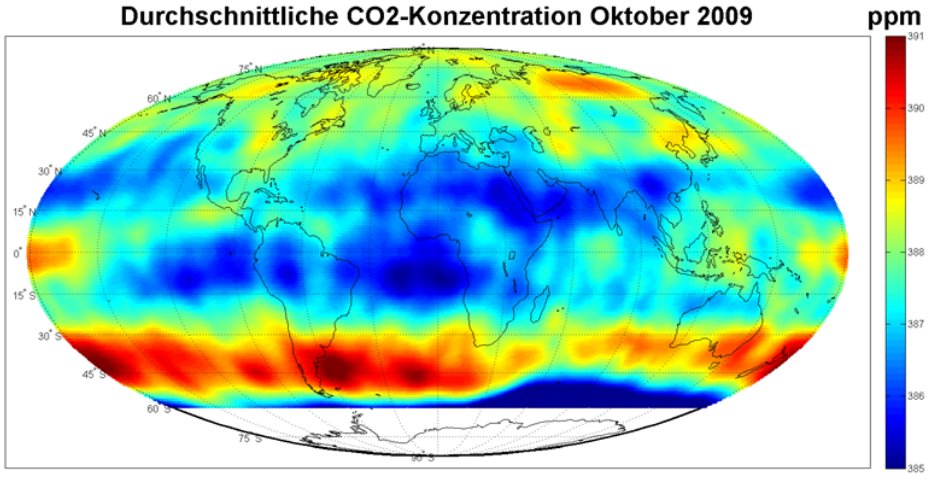
- Modellschätzung und Vorhersage benötigt Invertierung von $\boldsymbol{\Sigma}$
- mit zunehmender Datensatzgröße technisch nicht mehr möglich
- approximative Methoden entwickelt

Räumlicher Prozess

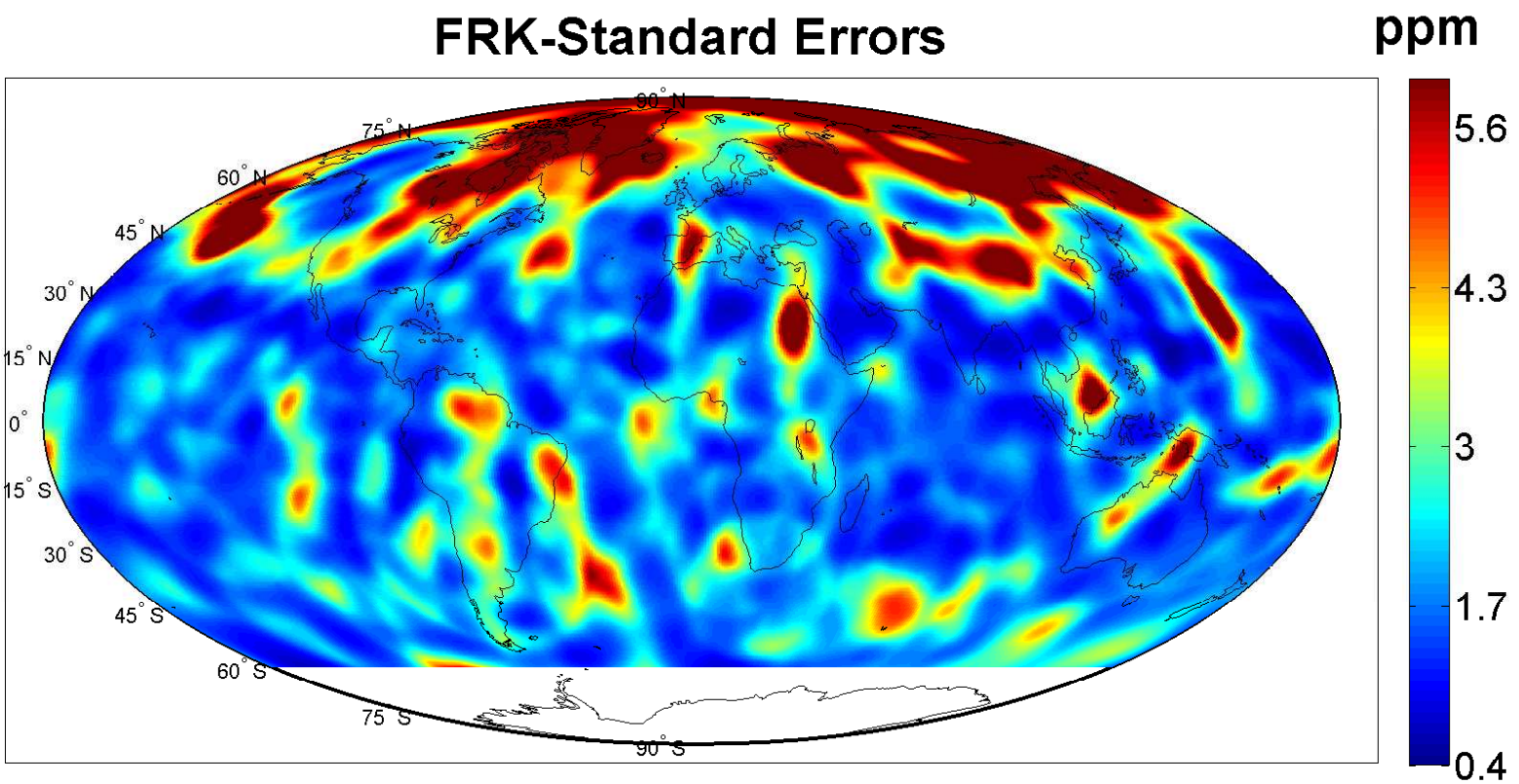


Räumlicher Prozess





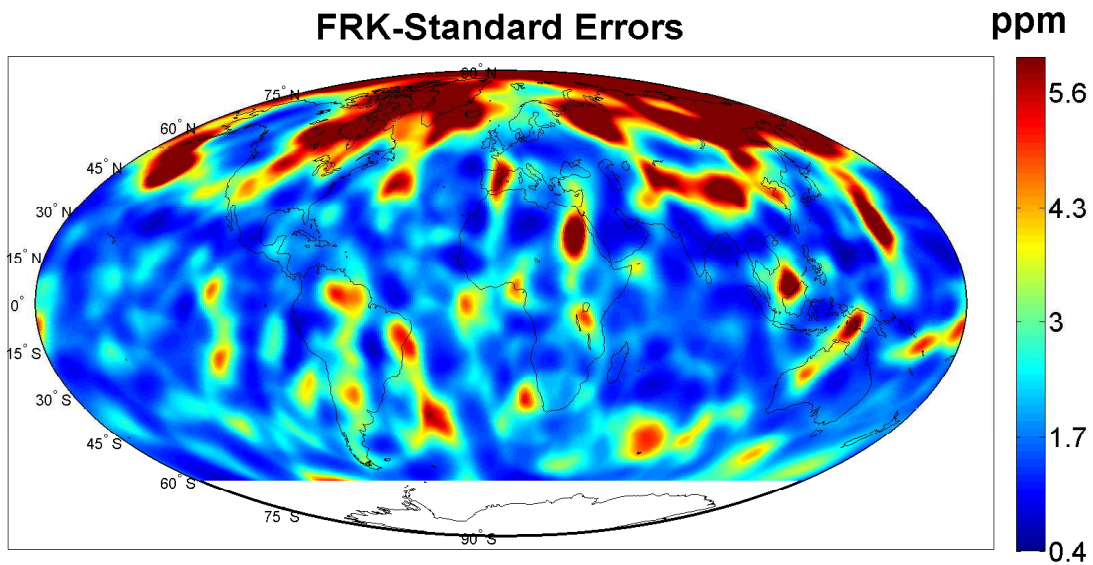
Räumlicher Prozess

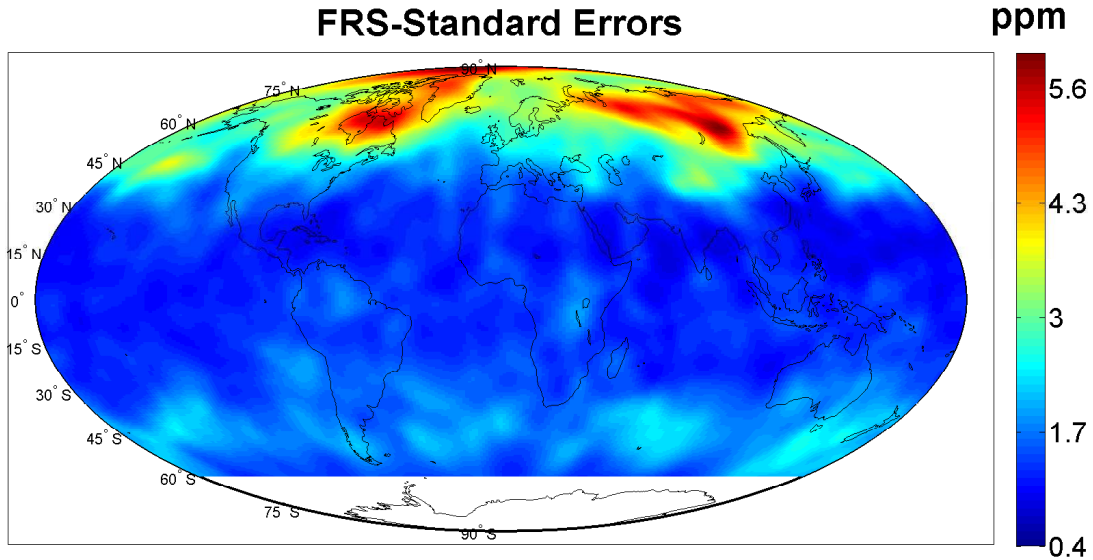


Dynamischer Räumliche Prozess

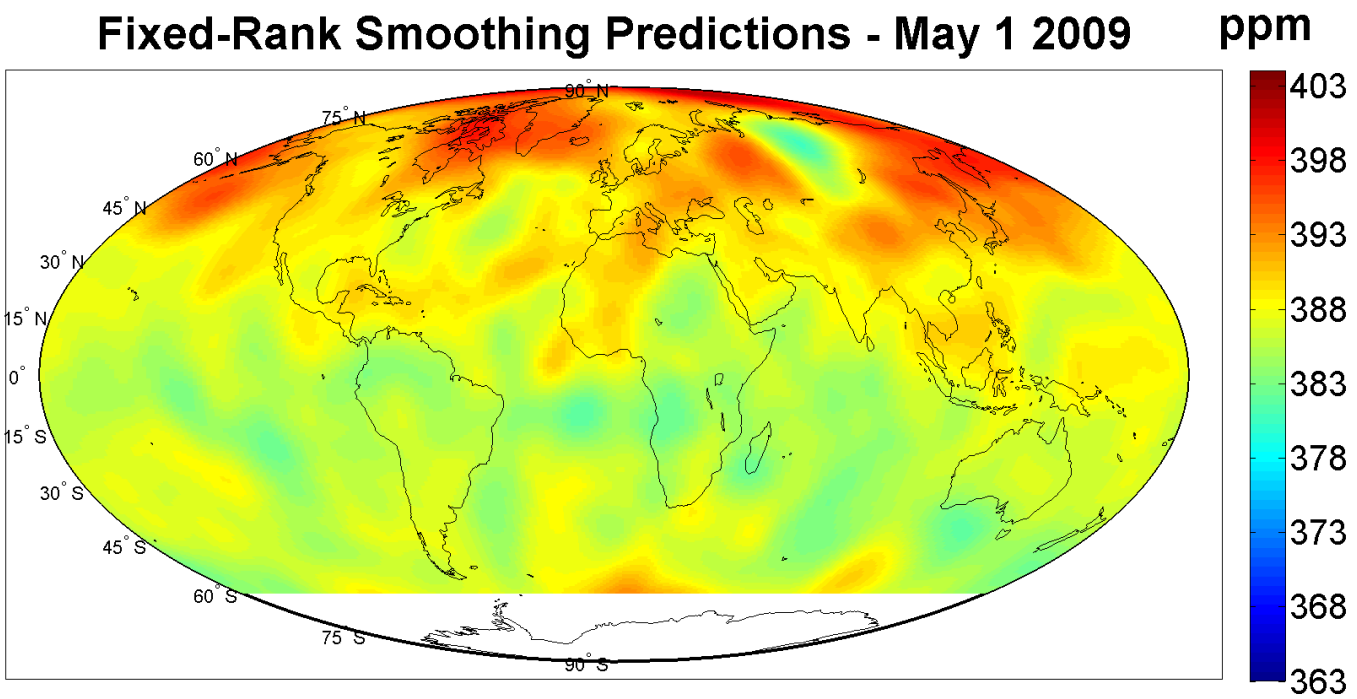
$$
\begin{aligned}
Y_t(\mathbf{s}) &= \mu(\mathbf{s}) + \delta_t(\mathbf{s}) + \epsilon_t(\mathbf{s}) \\
\boldsymbol{\delta}_t &= \mathbf{H}\boldsymbol{\delta}_{t-1} + \boldsymbol{\gamma}_t \\
\boldsymbol{\delta}_t | \boldsymbol{\delta}_{t-1} &\sim N_n(\mathbf{0}, \boldsymbol{\Sigma}_t(\boldsymbol{\theta}))
\end{aligned}
$$

Räumlicher Prozess





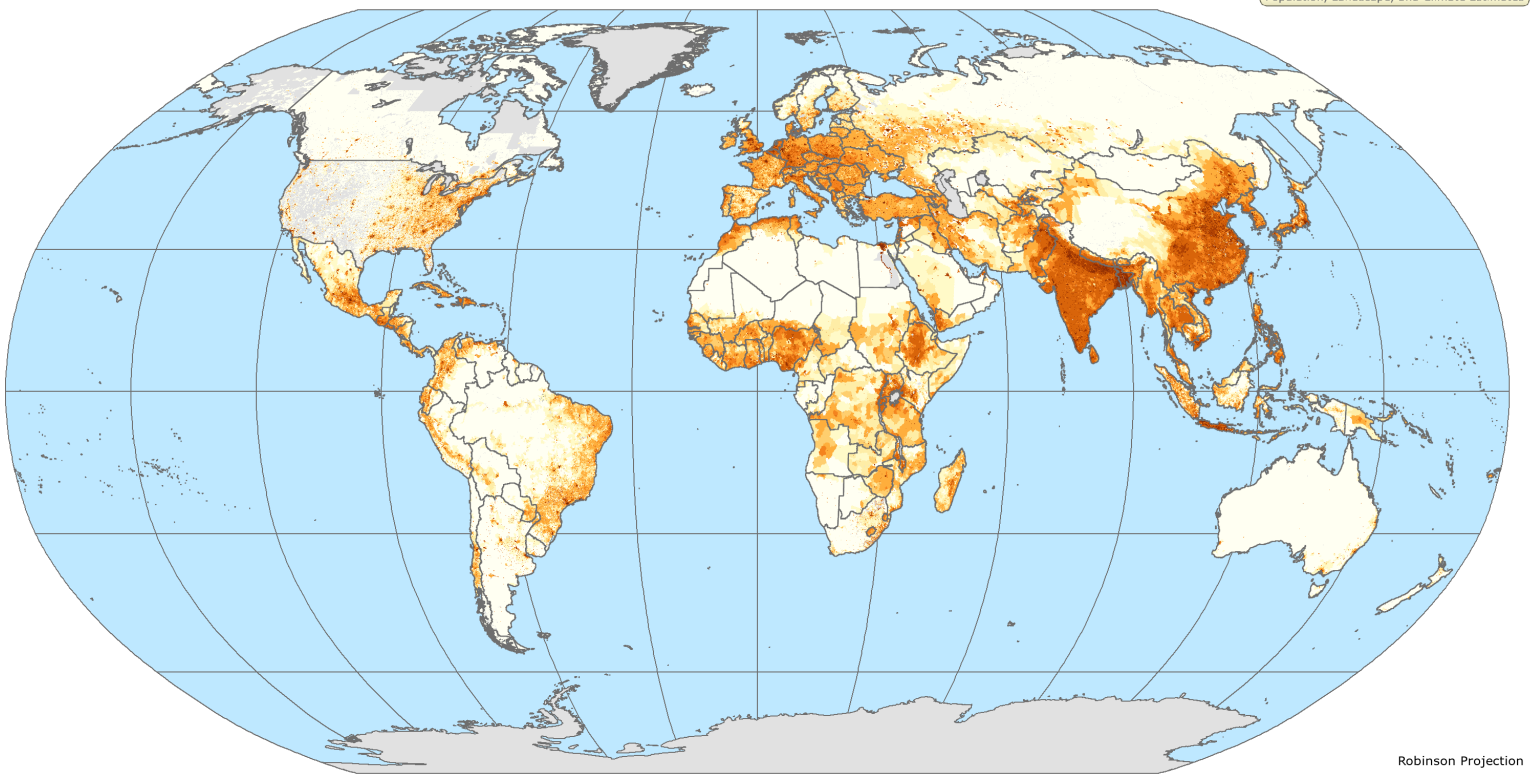
Animation of CO_2 Concentrations in May 2009



Population, Landscape, and Climate Estimates, v3: Population Density 2000, Global

National Aggregates of Geospatial Data Collection

PLACE III
Population, Landscape, and Climate Estimates



Robinson Projection

The data in this map represents 2000. These Population Density layers, for 1990, 2000, and 2010 were were developed for the Global Rural-Urban Mapping Project, Version1 (GRUMPv1). They were created by dividing the 1990, 2000, and 2010 UN-adjusted population (POP) count grids by the land area (LA) grid. The pixel values for the resulting grid layers, one each for 1990, 2000 and 2010, were then aggregated to form the 12 population density classes. Source information: http://sedac.ciesin.columbia.edu/gpw/.

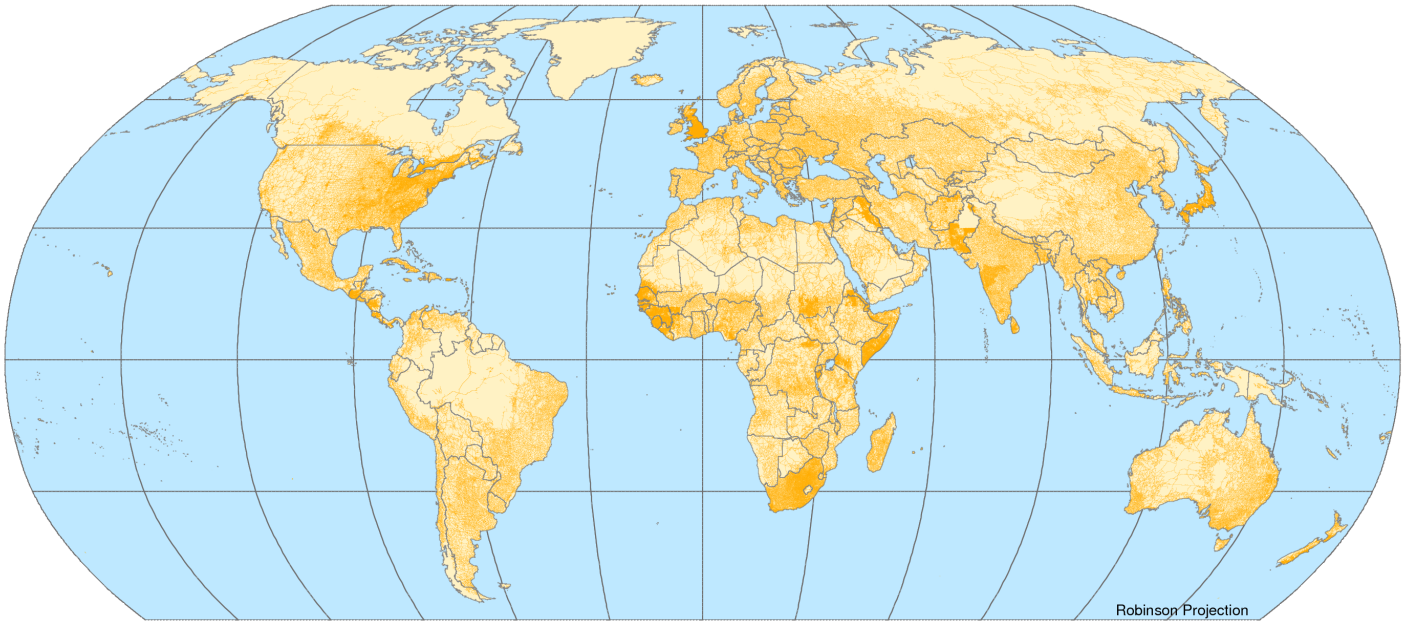
People per square kilometer:

Center for International Earth Science Information Network
Earth Institute | Columbia University

Publication Date:
May 2012

Global Roads Open Access Data Set, Version 1 (gROADSv1)

Global Roads



Map Credit: CIESIN Columbia University, March 2013.

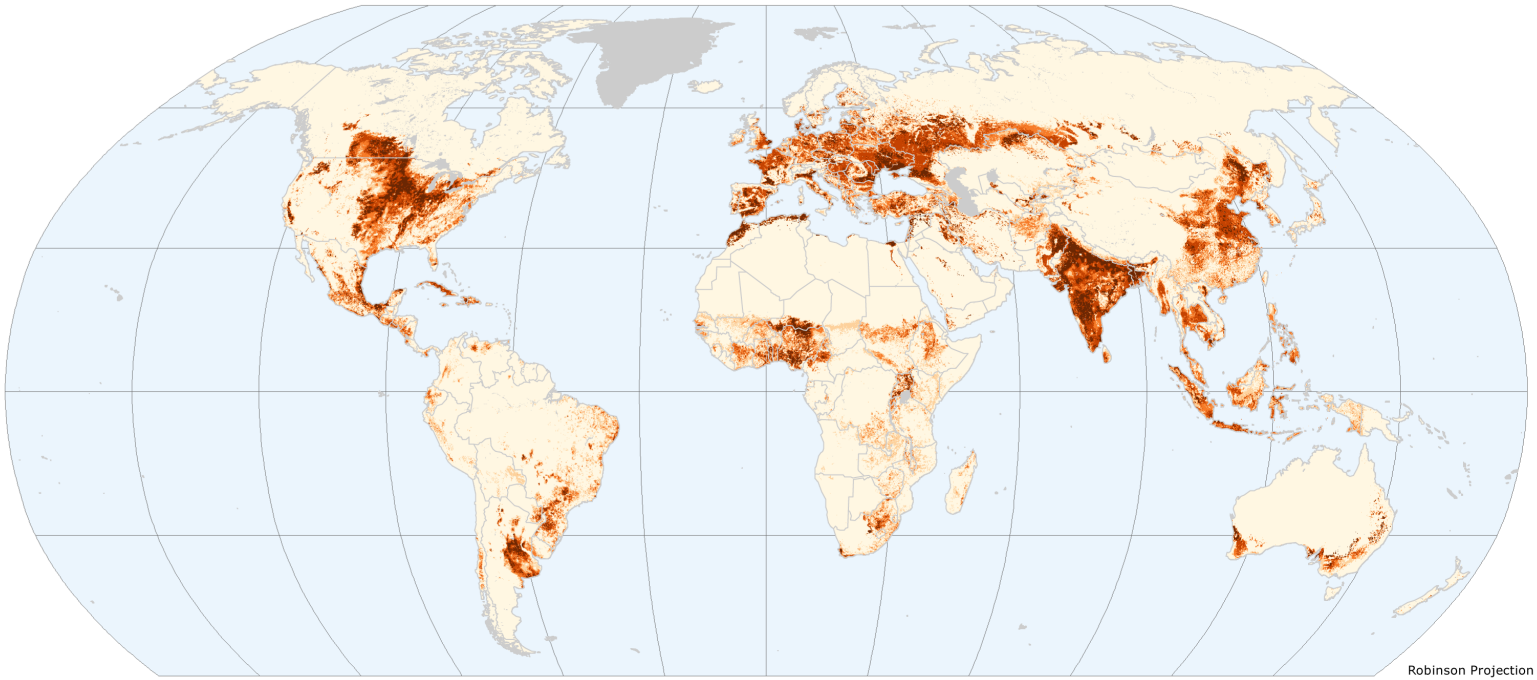
The Global Roads Open Access Data Set, Version 1 (gROADSv1) was developed under the auspices of the CODATA Global Roads The Global Roads Open Access Data Set, Version 1 (gROADSv1) was developed under the auspices of the CODATA Global Roads Data Development Task Group. The data set combines the best available roads data by country into a global roads coverage, using the UN Spatial Data Infrastructure Transport (UNSDI-T) version 2 as a common data model. Because the data are compiled from multiple sources, the dates for road network representations range from the 1980s to 2010, depending on the country, and spatial accuracy varies. National borders are provided for reference purposes only, and CIESIN and its sponsors do not take a position with regards to the representation of boundaries.

Center for International Earth Science Information Network
Earth Institute | Columbia University

Data source: Center for International Earth Science Information Network (CIESIN)/Columbia University, and Information Technology Outreach Services (ITOS)/University of Georgia. 2013. Global Roads Open Access Data Set, Version 1 (gROADSv1). Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). http://sedac.ciesin.columbia.edu/data/set/groads-global-roads-open-access-v1

Croplands, 2000: Global

Global Agricultural Lands



Global Croplands in 2000 map the proportion of each 5 minute (10km) grid cell land area that is under cropland. Dark shaded areas denote higher proportion of area under cropland. Data from Moderate Imaging Spectroradiometer (MODIS) land cover product and Satellite Pour l'Observation de la Terre (SPOT) VEGETATION's Global Land Cover 2000 product were combined with UN Food and Agriculture (FAO) agricultural statistics to generate the data set.

Percent grid cell area under cropland

- Less than 10%
- 10.01% - 25%
- 25.01% - 50%
- 50.01% - 75%
- 75.01% - 100%

Center for International Earth Science Information Network
Earth Institute | Columbia University

Data Source: Ramankutty, N., A.T. Evan, C. Monfreda, and J.A. Foley. 2010. Global Agricultural Lands: Croplands, 2000. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). http://sedac.ciesin.columbia.edu/data/set/aglands-croplands-2000.

Publication Date: 3/2012

Figure: Lights at Night

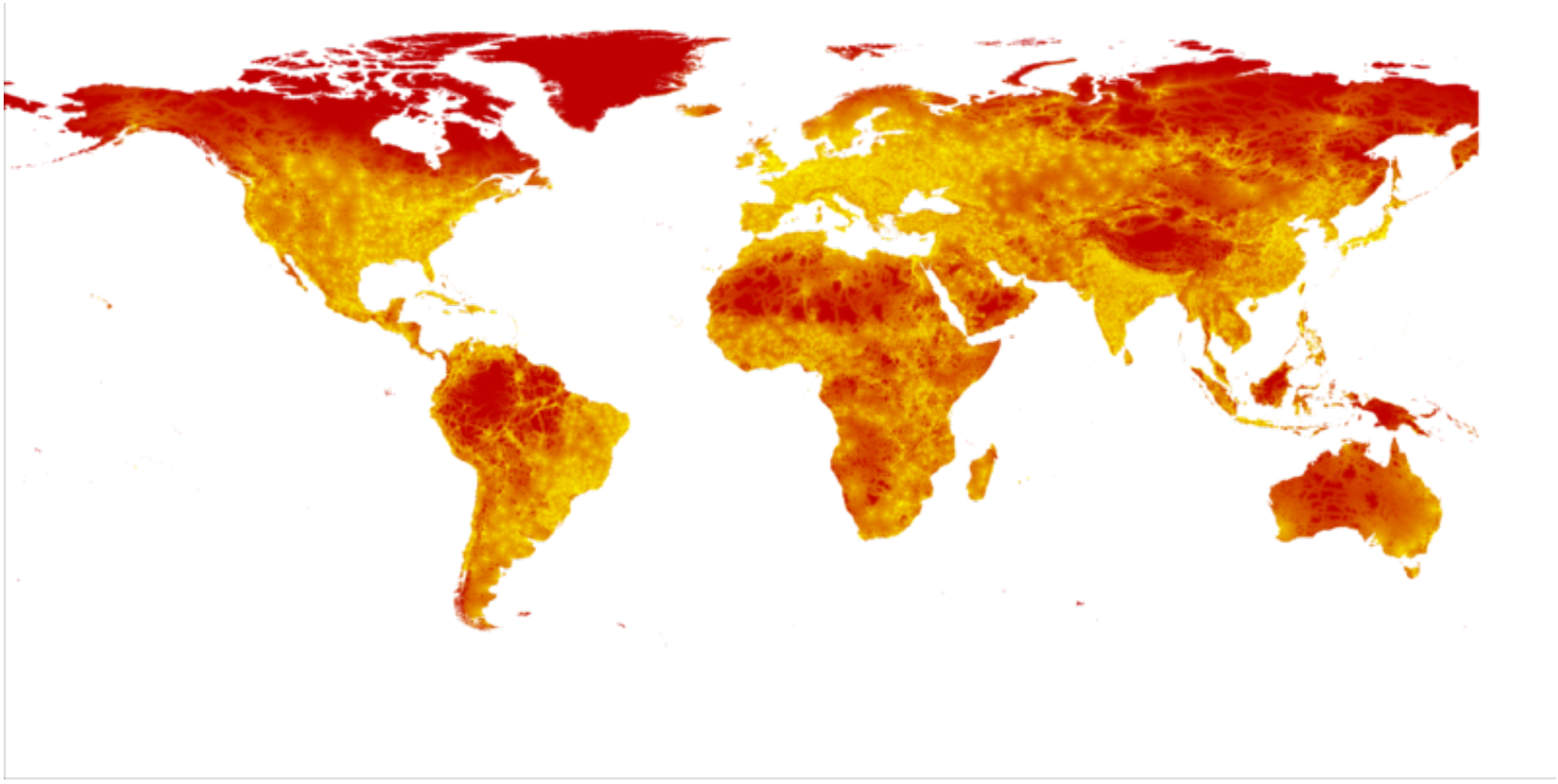


Figure: Average Travel Time to Major Cities

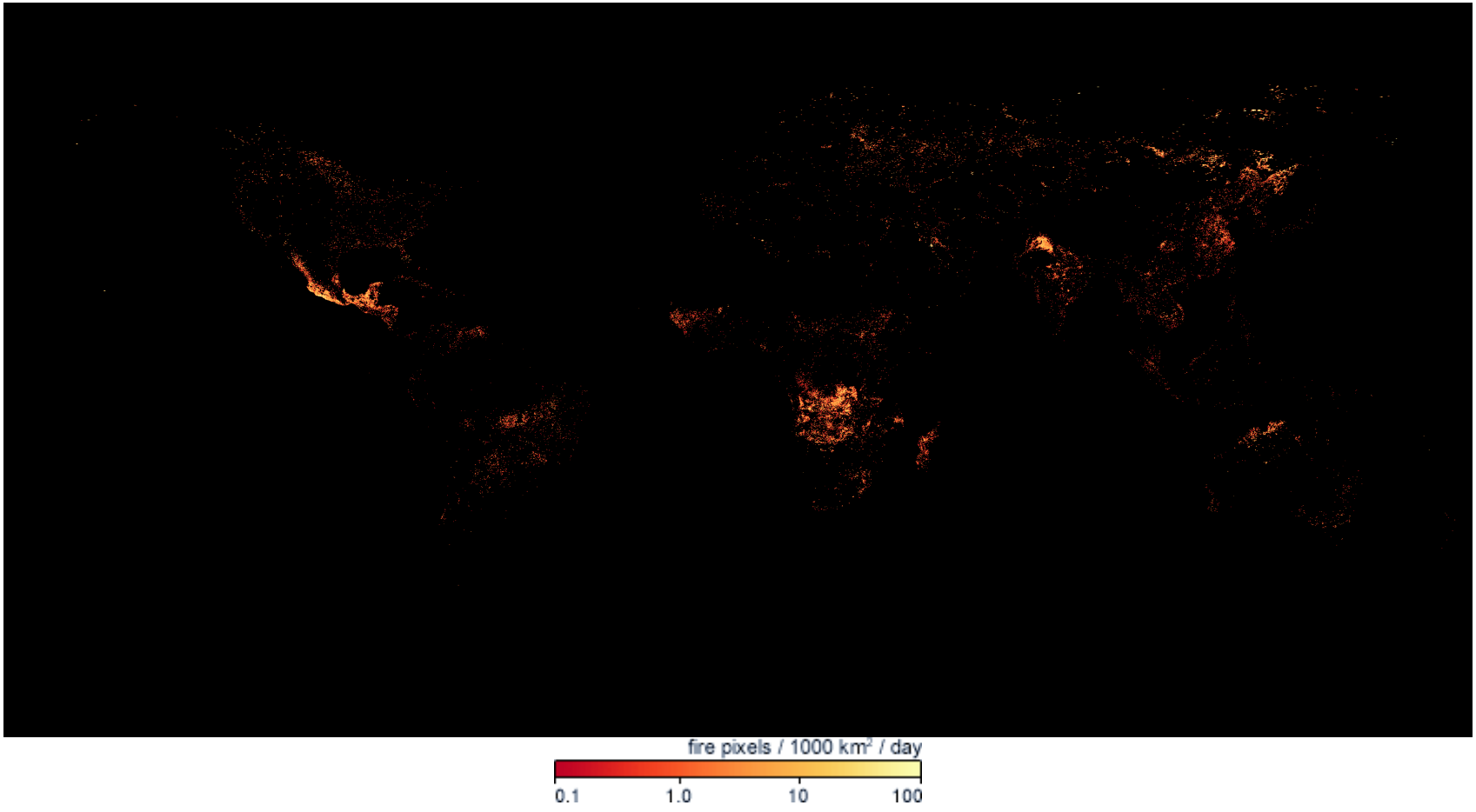


Figure: Active Fires

Regressoren

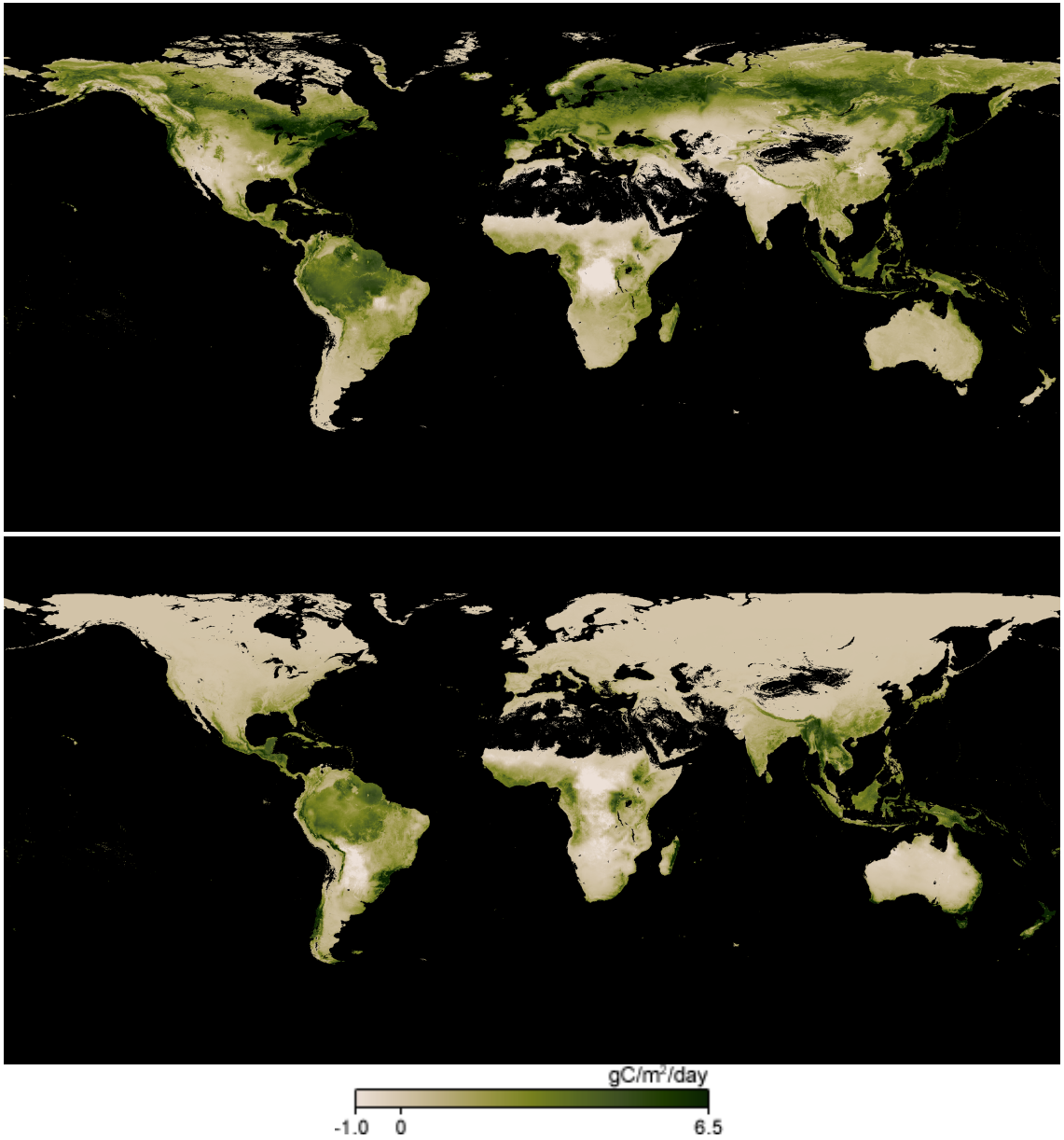


Figure: Netto-CO_2 Aufnahme von Pflanzen

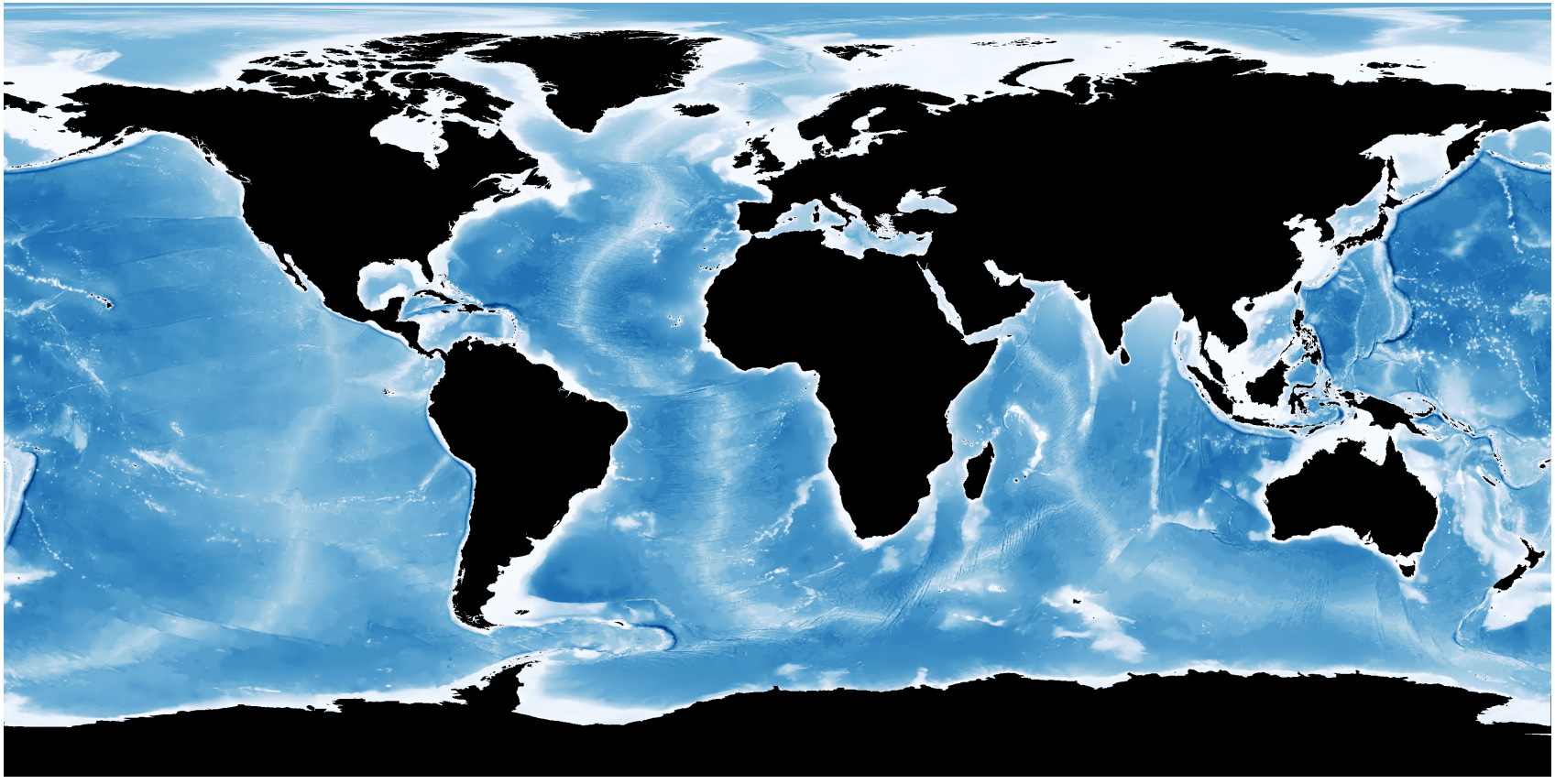


Figure: Water Depth

Regressoren

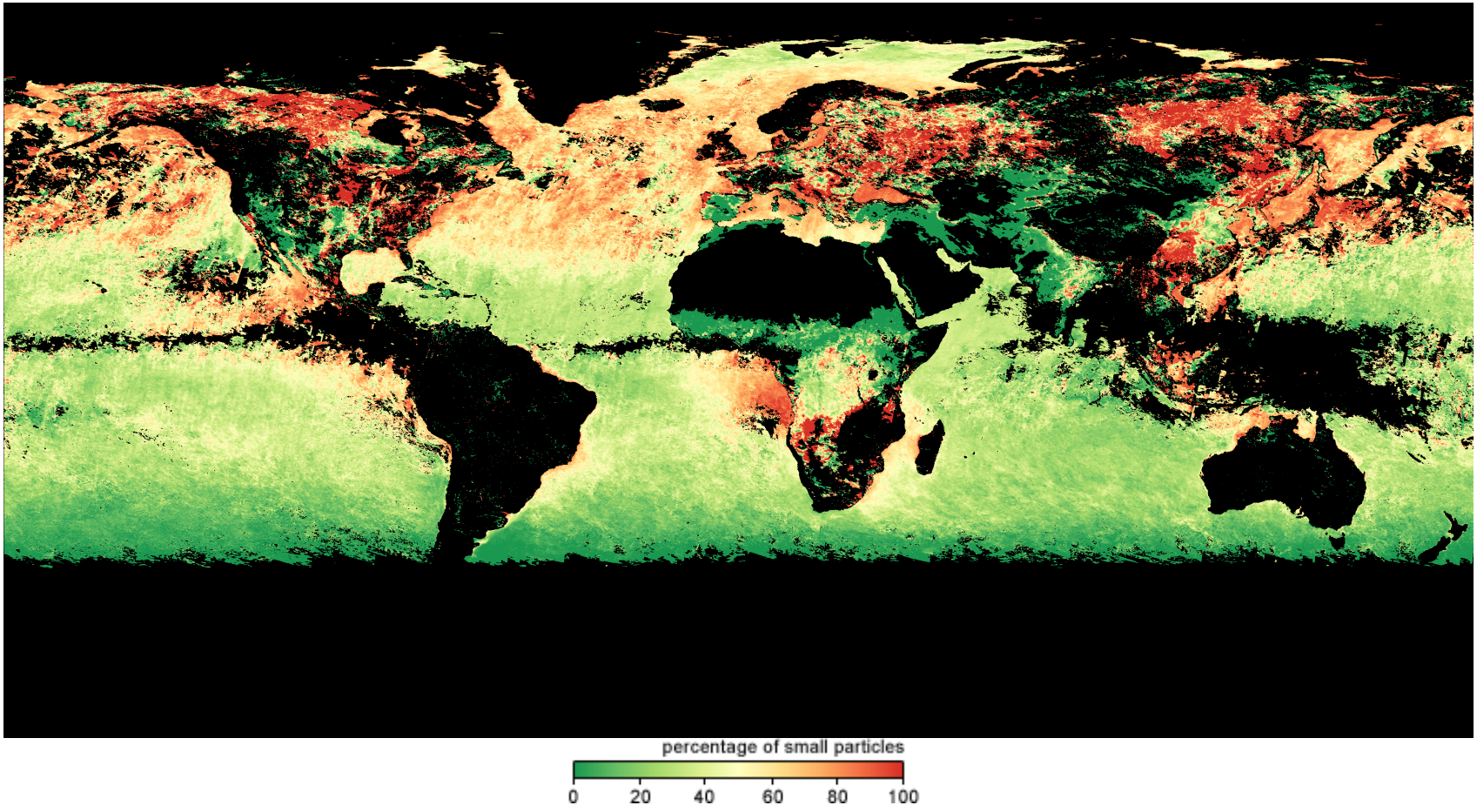


Figure: Aerosol Particle Radius - Smaller Particles anthropogenic source

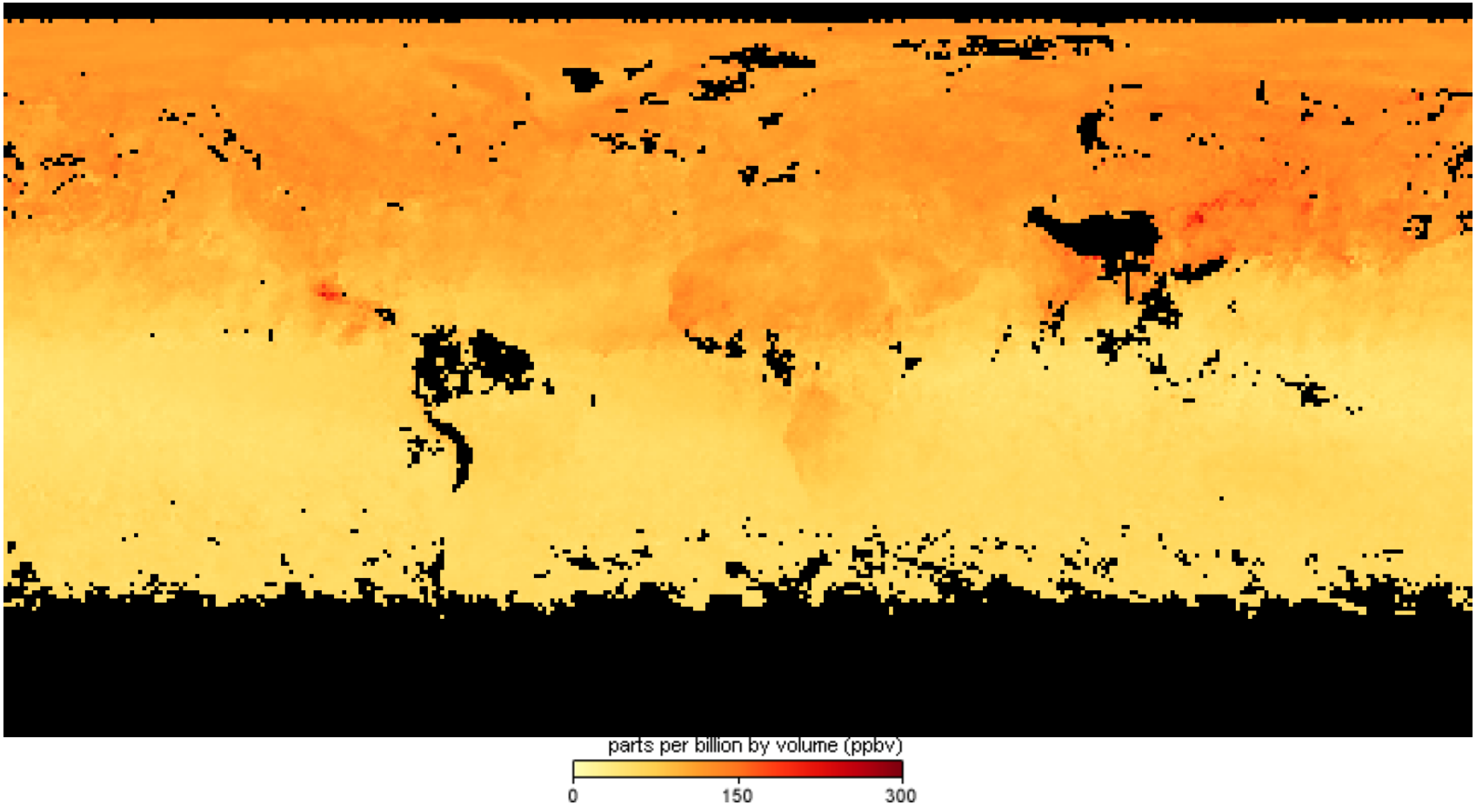


Figure: Carbon Monoxide

Multivariater Stochastischer Raum-Zeit Prozess

$$
\begin{aligned}
\mathbf{Y}(\mathbf{s},t) &= (\mathbf{y}_{Boden}(\mathbf{s},t), \mathbf{y}_{NASA}(\mathbf{s},t), \mathbf{y}_{GOSAT}(\mathbf{s},t))' \\
\mathbf{Y}(\mathbf{s},t) &= \mathbf{X}_t(\mathbf{s})\boldsymbol{\beta} + \sum_{i=1}^{c} \alpha_i \odot \mathbf{x}_{i,t}(\mathbf{s}) \odot \boldsymbol{\delta}_{Reg,i,t}(\mathbf{s}) \\
&\quad + \sum_{j=1}^{c} \mathbf{x}_{t,j}(\mathbf{s})\mathbf{z}_{Reg,j}(t) + \boldsymbol{\delta}_t(\mathbf{s}) + \mathbf{z}(t) + \boldsymbol{\epsilon}_t(\mathbf{s}) \\
\mathbf{z}_t &= \mathbf{H}\mathbf{z}_{t-1} + \boldsymbol{\eta}_t \\
\boldsymbol{\delta}_t(\mathbf{s}) &\sim N_3(\mathbf{0}, \boldsymbol{\Gamma}_t) \\
\boldsymbol{\Gamma}_t &= \begin{pmatrix} \rho_{B,t}(\mathbf{s},\mathbf{s}') & \rho_{B,N,t}(\mathbf{s},\mathbf{s}') & \rho_{B,G,t}(\mathbf{s},\mathbf{s}') \\ \rho_{N,B,t}(\mathbf{s},\mathbf{s}') & \rho_{N,t}(\mathbf{s},\mathbf{s}') & \rho_{N,G,t}(\mathbf{s},\mathbf{s}') \\ \rho_{G,B,t}(\mathbf{s},\mathbf{s}') & \rho_{G,N,t}(\mathbf{s},\mathbf{s}') & \rho_{G,t}(\mathbf{s},\mathbf{s}') \end{pmatrix}
\end{aligned}
$$