



# GRID<sup>3</sup>

GEO-REFERENCED INFRASTRUCTURE AND  
DEMOGRAPHIC DATA FOR DEVELOPMENT

## COVID-19: Supporting the Government of Sierra Leone with mobility data

Flowminder Foundation

BILL & MELINDA  
GATES foundation



Center for International Earth  
Science Information Network  
EARTH INSTITUTE | COLUMBIA UNIVERSITY



world  
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africell



MITGOV/LAB

CIVIC DESIGN  
DATA LAB

# Authors

**The Directorate of Science, Technology and Innovation (DSTI)** uses science, technology and innovation to support the Government of Sierra Leone to deliver on its national development plan effectively and efficiently; and to help transform Sierra Leone into an innovation and entrepreneurship hub. DSTI sits in the Office of the President and executes its functions through the Office of the Chief Minister. The Chief Innovation Officer (CIO) serves as an Advisor to the President and Chief Minister of Sierra Leone. [dsti.gov.sl](http://dsti.gov.sl)

**Flowminder Foundation** is a non-profit foundation specialising in the analysis of anonymous mobile phone data, satellite imagery and household survey data for humanitarian and development purposes. Flowminder provides insight and strengthen the capacity of governments, mobile network operators, national and international agencies and researchers to use big data for humanitarian and development purposes. Flowminder is one of the implementing partners of the GRID3 programme, currently operational in Sierra Leone. [www.flowminder.org](http://www.flowminder.org) | [covid19.flowminder.org](http://covid19.flowminder.org) | [grid3.org](http://grid3.org)

**Africell Sierra Leone**, with more than 70% of the market share, serves almost five million active subscribers in Sierra Leone. Africell Sierra Leone has made it a responsibility to honor corporate social responsibility by actively seeking ways to alleviate poverty by promoting education, supporting entertainment and giving back to less privileged communities. Africell is pride of being the people's choice. For over fifteen years, Africell has consistently been the leading voice in telecommunications; making innovation, affordability and social responsibilities our priority.

**MIT GovLab** collaborates with civil society, funders, and governments on research that builds and tests theories about how innovative programs and interventions affect political behavior and make governments more accountable to citizens. [mitgovlab.org](http://mitgovlab.org)

**MIT Civic Data Design Lab** works with data to understand it for public good. It seeks to develop alternative practices which can make the work we do with data and images richer, smarter, more relevant, and more responsive to the needs and interests of citizens traditionally on the margins of policy development. In this practice, it experiments with and develop data visualization and collection tools that allow it to highlight urban phenomena. Its methods borrow from the traditions of science and design by using spatial analytics to expose patterns and communicating those results, through design, to new audiences. [civicdatadesignlab.mit.edu](http://civicdatadesignlab.mit.edu)





- Introduction
  - About GRID3
  - About Flowminder
  - Mobile operator data & mobility
  - The value of mobility data for decision-making
- Findings
  - Key takeaways
  - Period of analysis & data coverage
  - Number of chiefdoms visited
  - Flows and travelled distance
  - Presence
- Annexes
  - Data considerations
  - Additional results

## Report 1 | Contents



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# About GRID3





**Our Vision** Mapping a path to sustainable development for everyone.

**Our Mission** To build spatial data solutions that make development goals achievable.





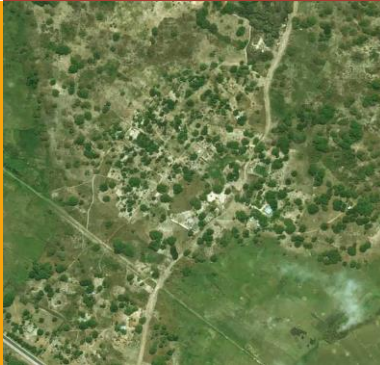
Housing census &  
hybrid method  
support



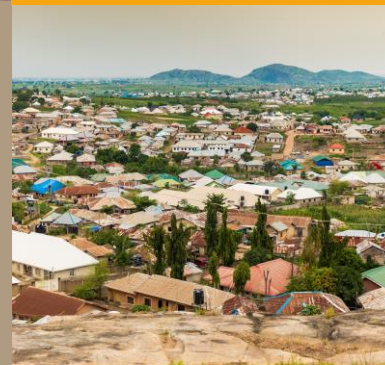
High-resolution  
population estimates



Capacity  
Strengthening



Subnational  
boundaries



Comprehensive  
settlement locations

Locating critical  
infrastructure



Mobility  
analysis







# About Flowminder



# About Flowminder

**Flowminder's mission:** Enabling decision makers to access the data they need to transform the lives of vulnerable people at scale

- Non-profit organisation
- Supporting governments and mobile operators to use insights from mobile operator data to improve government decision-making
- Pioneered of the analysis of mobile network data to support responses to infectious disease outbreaks and natural disasters





# Privacy & data governance

- Flowminder releases aggregated and anonymised statistics
- No individual level data leaves the country
- No individual level data leaves the control of the mobile network operator
- GDPR compliant
- Open code to allow peer review and build trust

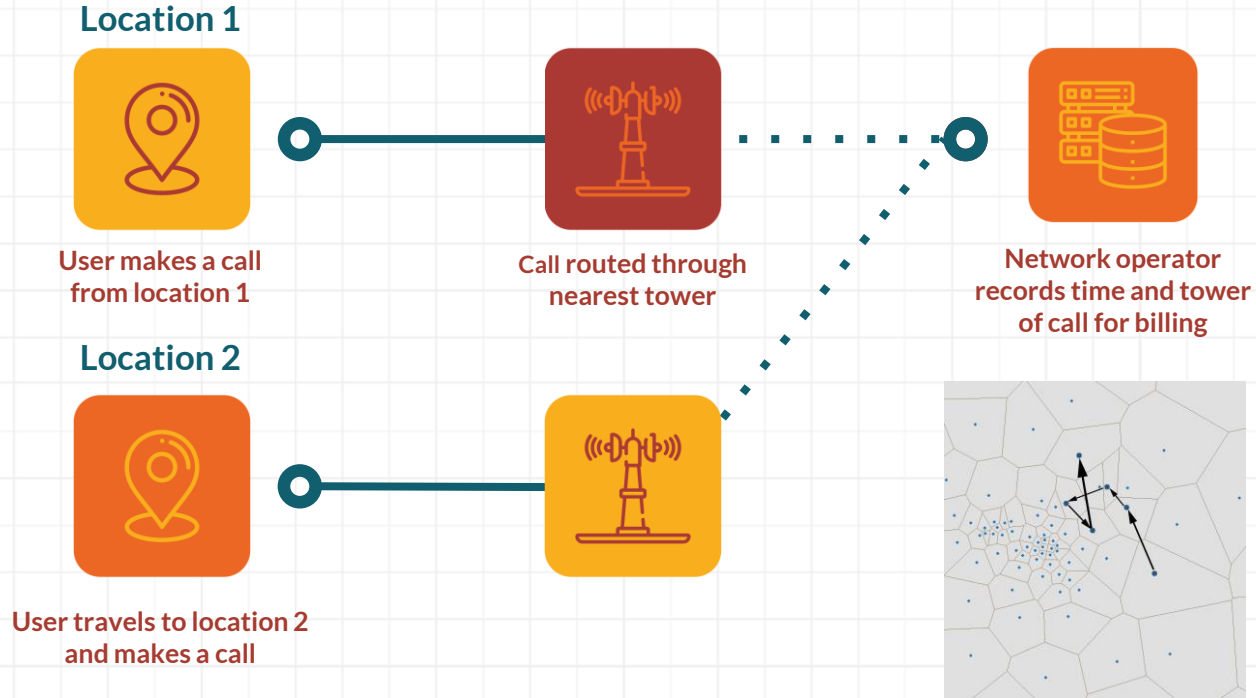


# Mobile operator data & mobility



# Call Detail Records (CDR data)

- Base stations/towers with multiple cells
- Mobile Network Operators maintain a database of CDRs for billing purposes
- Generated each time a mobile phone subscriber makes or receives a call, sends or receives a SMS, or uses mobile data.
- See annex 1 for main caveats of CDR data





# The value of mobility data for decision-making





# Using mobility data for the COVID-19 response



Knowledge of  
existing mobility  
patterns & their  
changes



Knowledge of  
population  
redistributions



Informed epidemic  
scenario planning  
and modeling



Identification and  
monitoring of  
areas with high  
population mixing



Post the COVID-  
19 response: core  
building blocks for  
an improved  
outbreak and  
disaster response



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# Report 1

# Key takeaways



## Reduction in overall mobility in spring:

- Average number of chiefdoms visited per day and subscriber on working days was reduced by 8% following the introduction of inter-district travel restrictions (9 April until 30 June). This is equivalent to double the mobility decrease observed on a normal Sunday.
- During the two lockdown periods, the number of chiefdoms visited per subscriber reduced by circa 25%, which is 4-5 times lower than a normal Sunday.

## Reduced flows to cities during inter-district travel restrictions (11 April until 24 June):

- Freetown saw a median 24% reduction in in-out flow, compared to a 16% median reduction on a normal Sunday.
- Bo Town in-out flow reduced by 25%, i.e. a reduction 25 times greater than the reduction observed on normal Sunday (1%).



## Increases in mobility following announcements of restrictions:

- Large increases in movements between Freetown and some chiefdoms between the announcement and implementation of first lockdown. Similar patterns observed for Bo Town, Kenema, and Port Loko.

## Mixed signals for a return to normal from July:

- Most mobility indicators remain below normal, but they may be affected by a reduction in calling frequency (see *Caveats* below).
- Travelled distance, the indicator the most robust to the change in the calling frequency, bounces back to normal once the inter-district travel restrictions are lifted end of June.

**Caveats:** *The reduction in movements is matched by a reduction in the number of calls per day. This makes it challenging to state with confidence that the mobility reduction observed for is not an artifact of reduced call frequency.*



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Report 1 | Key takeaways (2/2)





# Analysis Period of analysis & data coverage

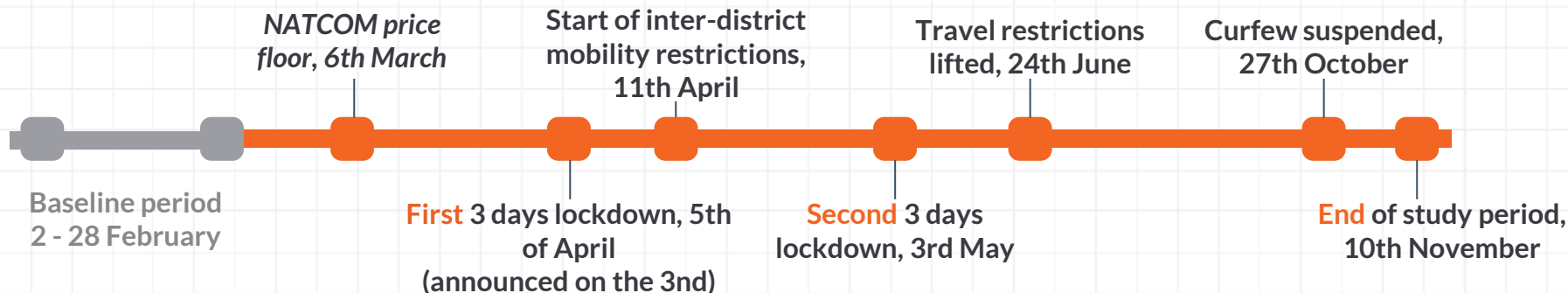


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### Key dates:

- **Baseline period:** 2 February - 28 February
- **Comparison period:** 3 April-10 November

**Reading the graphs:** Most results are expressed as percentage changes from the baseline period preceding the announcement of the first lockdown (3 April), i.e. compared to normal conditions. The timeline below summarises the period of analysis.



**Data sources:** Africell provided Call Detail Records (CDR) of their subscribers to DSTI, MIT aggregated it following a methodology proposed by Flowminder (see [here](#) and [here](#)). Flowminder then derived the mobility indicators presented in this report (see [here](#) for the method).

**Caveats:** NATCOM, the telecoms regulator enforced a 'price floor' on 6 March which significantly reduced calling by Africell subscribers. Because of this, some results may exaggerate decrease in mobility relative to the baseline period.



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## Report 1 | Study period and data sources



# Aggregates Coverage

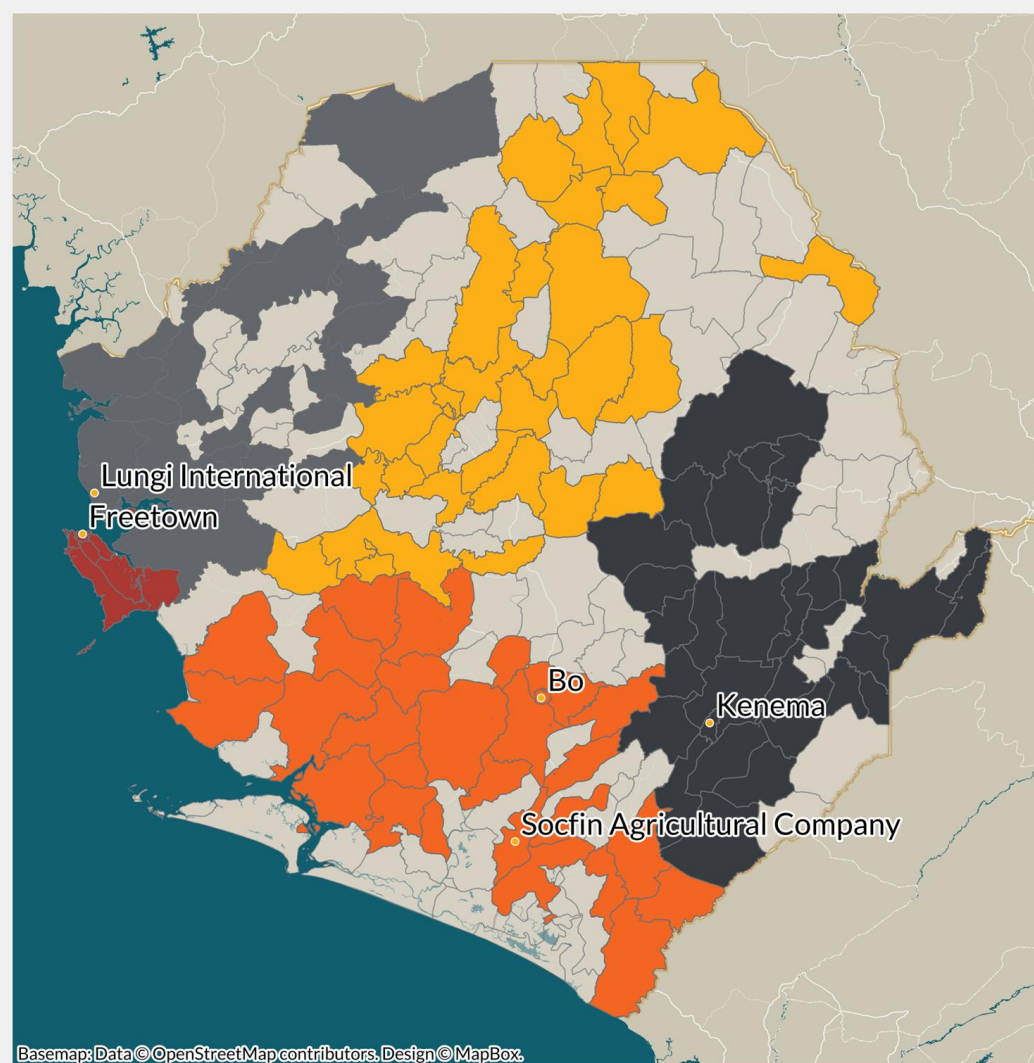
Coverage by aggregates in each province

- Yellow: **Northern**
- Off black: **Eastern**
- Orange: **Southern**
- Red: **Western**
- Dark grey: **North Western**

*Light grey areas: no data*



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# Analysis Number of chiefdoms visited

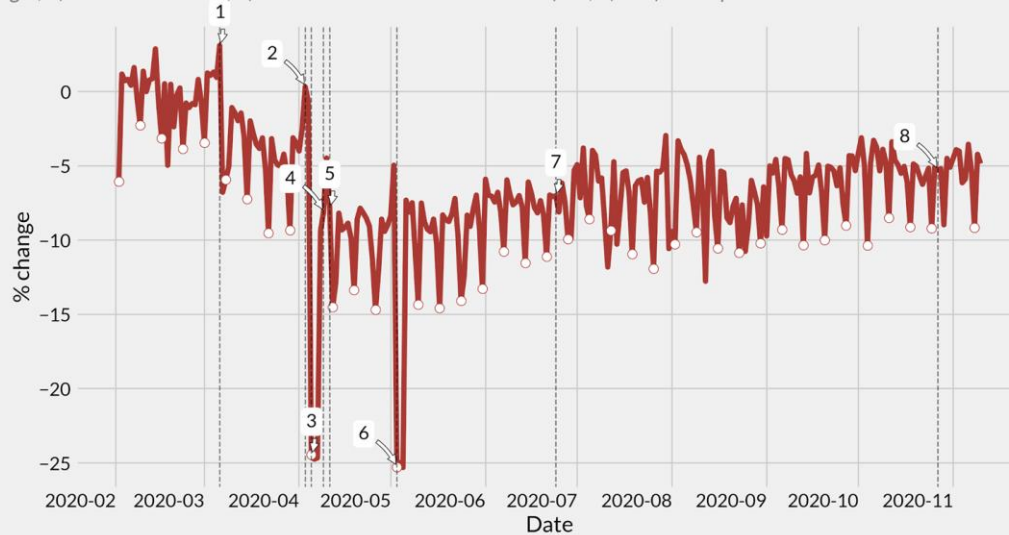


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# Number of chiefdoms visited

Key events: 1) NATCOM price floor introduced, 2) First lockdown announced, 3) First lockdown, 4) Inter-district travel restrictions and curfew announced, 5) Inter-district travel restrictions and curfew begin, 6) Second lockdown, 7) Inter-district travel restrictions lifted, 8) Curfew suspended



**Definition:** The line shows the change in average number of chiefdoms visited per subscriber relative to the baseline period.



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**Overview of the graph** The average number of chiefdoms visited shows a classic work-week pattern (white dots are Sundays). There are important drops (circa -25%) during the two lockdowns (dotted lines 3 and 6). Both are preceded by a spike on the day of their announcements (circa 3% increase on the day before in both cases). Following the inter-district travel restrictions (dotted line 5), weekday mobility drops by 8% (circa twice the reduction of a normal Sunday in the baseline period). After restrictions were lifted (dotted line 7), mobility stays below normal (-5%).

**Interpretation** The reduction in mobility is very large during the two lockdowns: six times more than the reduction on a normal Sunday. During the inter-district travel restriction (between dotted line 5 and 7), the reduction is less severe as mobility within districts was not restricted. Nevertheless, it may have helped slowing the spread of the virus. Mobility stabilised somewhat below baseline levels from July onwards, with a slight downward trend through August which recovered to 5% below baseline levels from September onwards.

**Caveat** The reduction in movements is matched by a reduction in the number of calls per day (see Annex 2). This makes it challenging to state with confidence that the mobility reduction observed for is not an artifact of reduced call frequency. These results are also largely driven by urban areas and influenced by the varying size and shape of chiefdoms.

# Results Flows

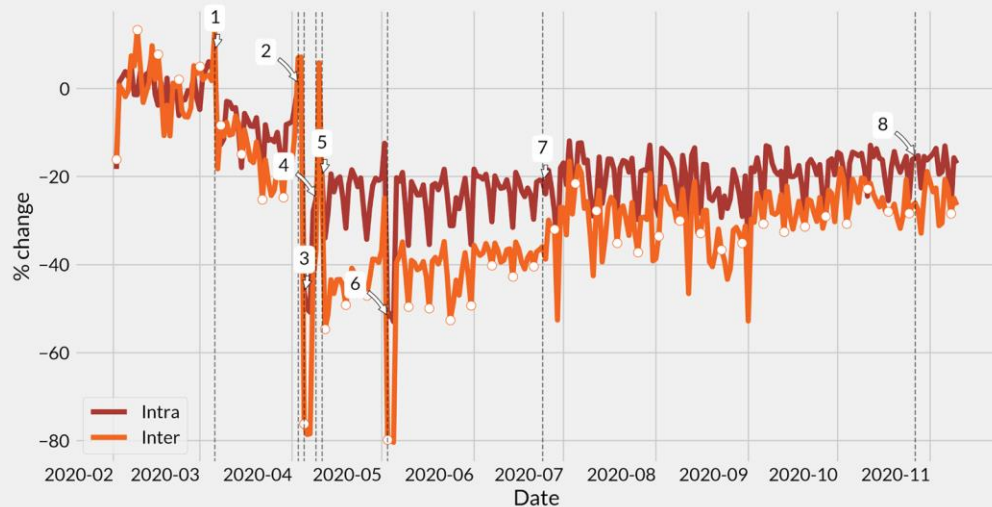


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# District level flow

Key events: 1) NATCOM price floor introduced, 2) First lockdown announced, 3) First lockdown, 4) Inter-district travel restrictions and curfew announced, 5) Inter-district travel restrictions and curfew begin, 6) Second lockdown, 7) Inter-district travel restrictions lifted, 8) Curfew suspended



**Definition:** The red and orange lines show change relative to baseline of total flux within and between districts, respectively and circles denote Sundays. Flux is measured as the number of *active* subscribers seen in two different chiefdoms on the same day (see Annex 1 for more details).



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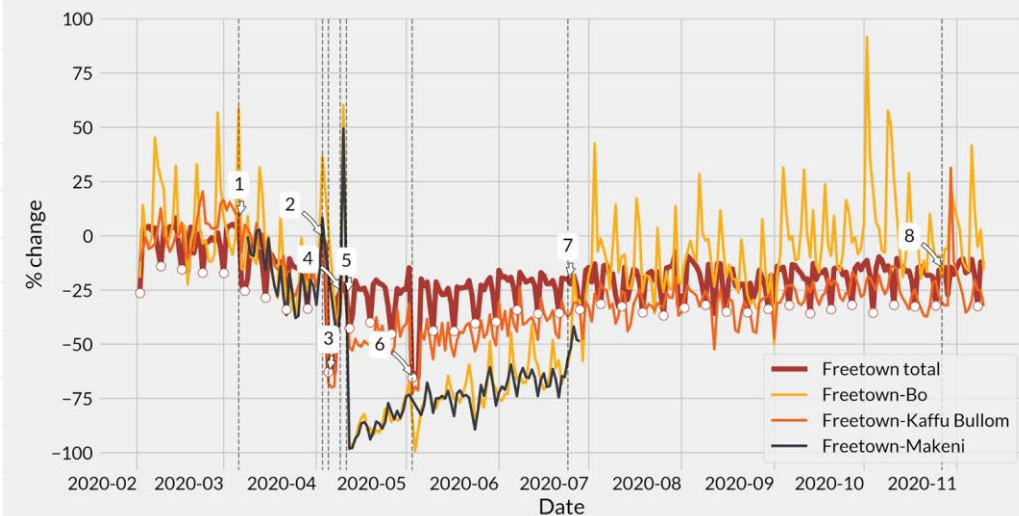
**Overview of the graph.** During the the two lockdowns (dotted line 3 and 6), movement within and between districts dropped by circa 50% and 80% respectively (compared to circa 1% and 12% on a normal Sunday in the baseline, or 6% and 20% following the price-floor). After the start of the inter-district travel restrictions (dotted line 5), weekday movement within and between districts are reduced by median 18% and 39% respectively. Flows did not recover to normal after the end of the restrictions (dotted line 7), although inter-district flows were less reduced compared to the baseline (weekday median of -28% compared to -38% between lifting of lockdown and lifting of travel restrictions). Flows between districts remain more reduced compared to the baseline than flows within district.

**Interpretation.** The continuation of the work-week pattern in the flows between districts (orange line) after the start of the travel restrictions suggests that commuting between districts was not eliminated. This may be the result of limited enforcement of the travel restrictions combined with the exemption categories. The decrease in movements *within* districts may be partly explained by the reduction in subscribers crossing districts as well as the impact of the rainy season on the ability to travel across the country, but may also reflect the reduction in calling following the price floor.

**Caveat:** As on previous slide, the reduction in movements is matched by a reduction in the number of calls per day (see Annex 2).

# Flow to and from Freetown

Key events: 1) NATCOM price floor introduced, 2) First lockdown announced, 3) First lockdown, 4) Inter-district travel restrictions and curfew announced, 5) Inter-district travel restrictions and curfew begin, 6) Second lockdown, 7) Inter-district travel restrictions lifted, 8) Curfew suspended



**Definition:** The lines show change relative to baseline of the sum of in and out flows to Freetown (details in *District level flow* slide). Circles denote Sundays.



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**Caveat:** Reduced call frequency (see Caveats on previous slides)

**Overview of the graph** Total flow to and from Freetown was reduced by more than 60% during the two lockdowns (compared to 16% on a normal Sunday). After travel restrictions started (dotted line 5), they stabilised during weekdays at circa 24% below baseline and remained ~20% at the end of June.

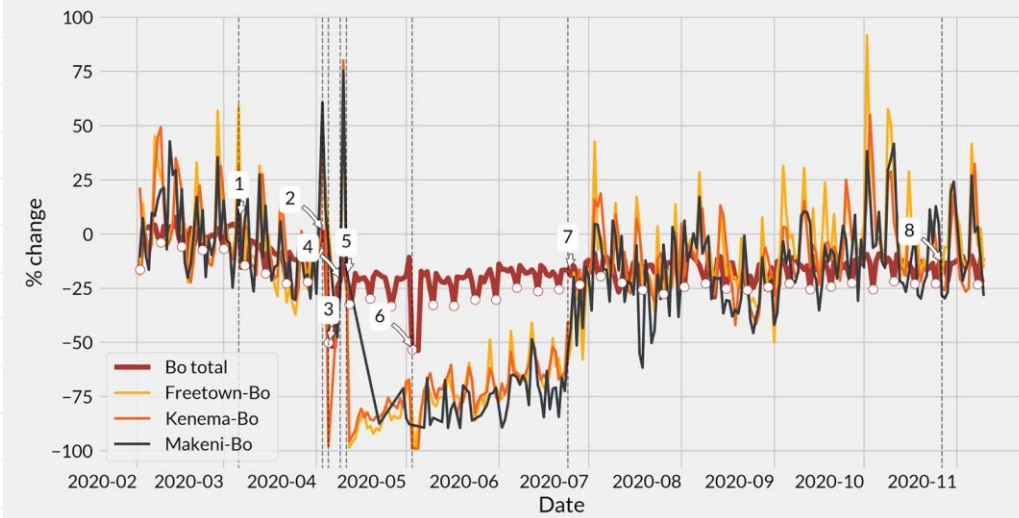
Flow with Bo and Makeni reduced massively (-95%) following the inter-district restriction and then increased gradually, returning to close to baseline levels from september. Flows with Kaffu Bullom (the chiefdom on the opposite side of the Tagrin Bay of Freetown) also reduced importantly (well below a normal Sunday). Large spikes in flows are observed at the announcements of measures (dotted lines 2 and 4).

**Interpretation** Total flows continue to show a work-week pattern after travel restrictions, suggesting that Freetown workers were able to commute over spring and summer. The spike between the announcements and starts of measures may reflect movements of subscribers seeking to relocate before being trapped in a given location. These sudden moves may have helped spread the virus. The larger fall in flow with Bo and Makeni may have had a significant economic impact.



# Flow to and from Bo Town

Key events: 1) NATCOM price floor introduced, 2) First lockdown announced, 3) First lockdown, 4) Inter-district travel restrictions and curfew announced, 5) Inter-district travel restrictions and curfew begin, 6) Second lockdown, 7) Inter-district travel restrictions lifted, 8) Curfew suspended



**Definition:** The lines show change relative to baseline of the sum of in and out flows to Bo Town (details in *District level flow* slide). Circles denote Sundays.



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**Overview of the graph** Total flow to and from Bo Town reduced by more than 50% during the two lockdowns.

There were large spikes at the announcements of the measures (dotted lines 2 and 4). Flows during week days decreased to a level ~ 5 times lower than the median Sunday during the baseline (circa -25% vs circa -5%) after the interdistrict travel restriction started (dotted line 4).

Flows between Bo Town and major urban centres (Free Town, Kanema, Makeni) decreased sharply before picking-up toward the end of June but appear to have stabilised below baseline.

**Interpretation** As for Freetown, the workweek pattern during spring suggests that workers were able to commute during this period. The large reduction of flows with Freetown, Kenema and Makeni may have helped limit the spread of the virus, but may have had an important economic cost. By contrast, the large spikes between the announcements and starts of measures may have helped spread the virus.

**Caveat** As in previous slides: reduced call frequency may impact our ability to estimate mobility.

# Flow between chiefdoms in different districts during travel restrictions

**Definition:** The map shows for each chiefdom the median sum of all in and out flows with chiefdoms located in another district, expressed as absolute change from the baseline.

## Overview of the map

Total in and out flows from each chiefdom to chiefdoms located in another district are reduced during the inter district restriction period, with larger decreases in urban areas. There are minor increases in the chiefdoms of Bagruwa, Barri, Tambakha Yobangie, Wara Wara Bafodia, and Kamadu Yiraia (likely not significant as the number of subscribers there is low).

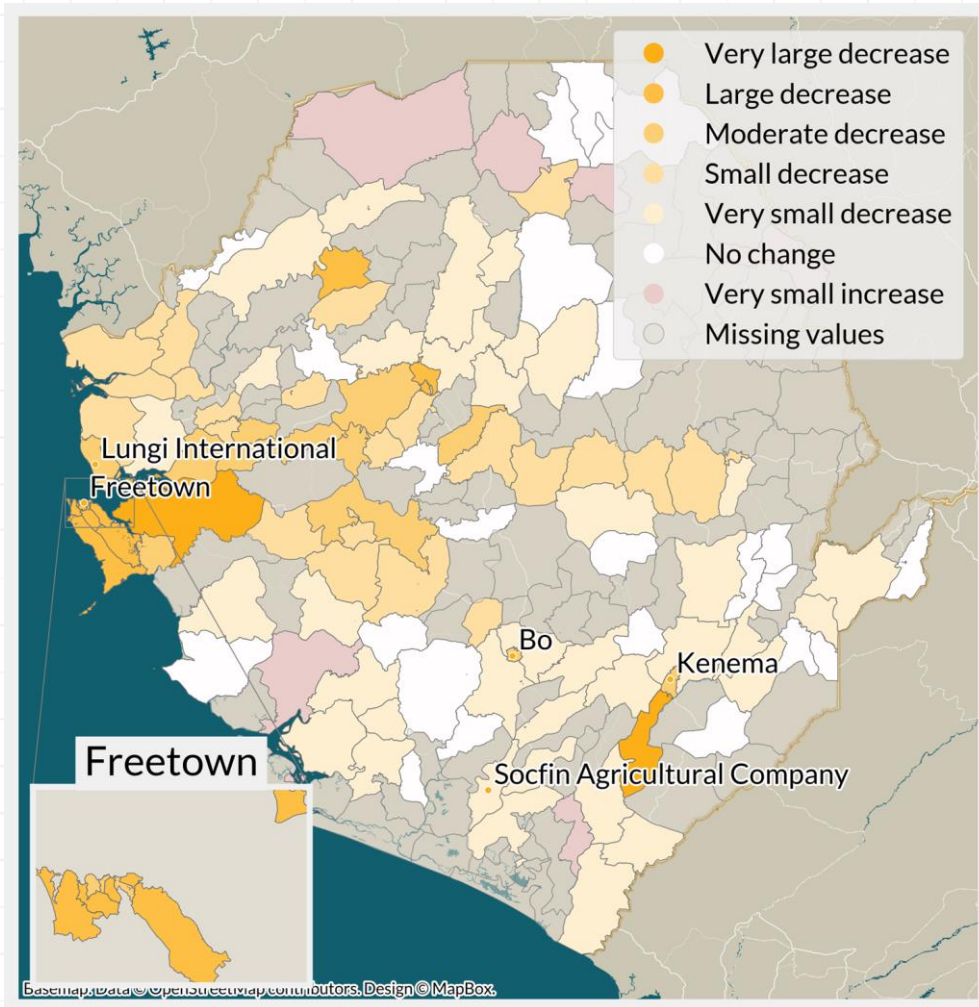
## Interpretation

Travel restrictions appear to have been *moderately* effective, particularly in urban areas. This may have helped slow down the spread of the virus.

**Caveat** Lower call volumes (see previous slide)



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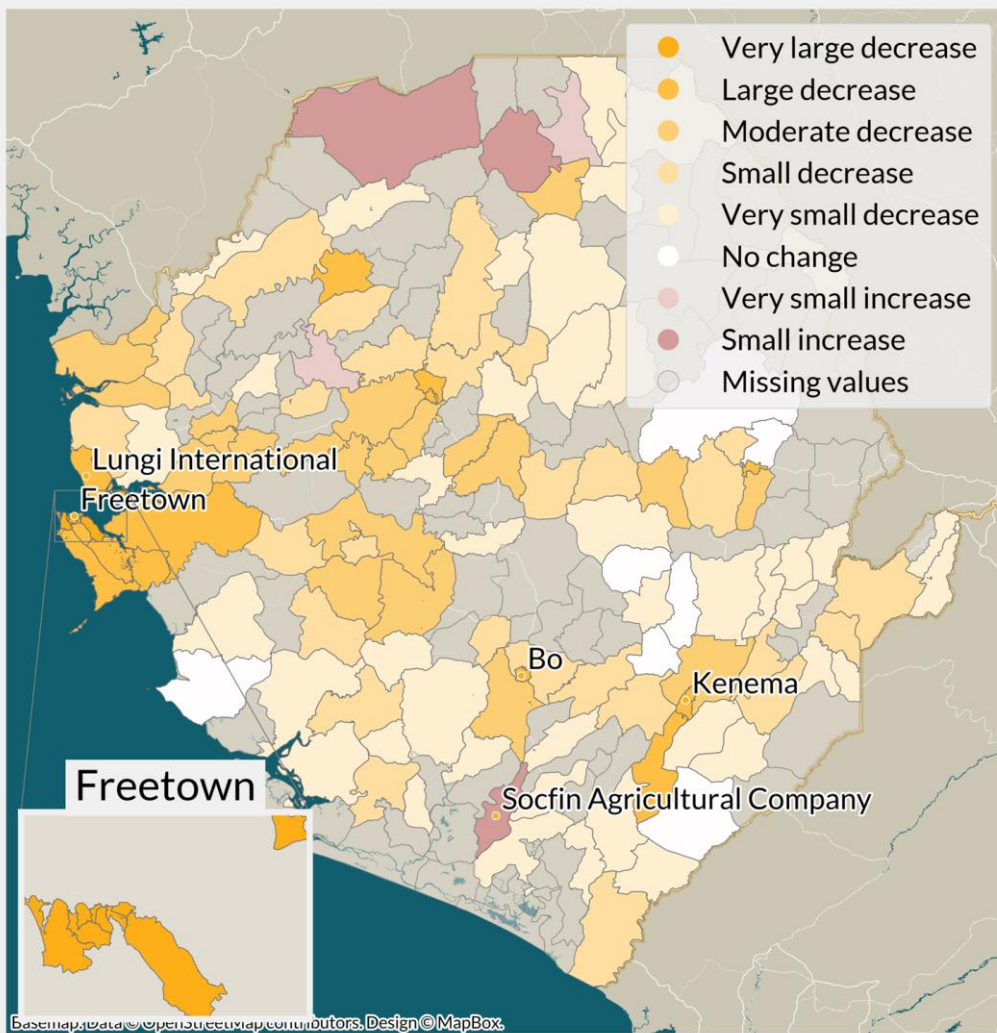


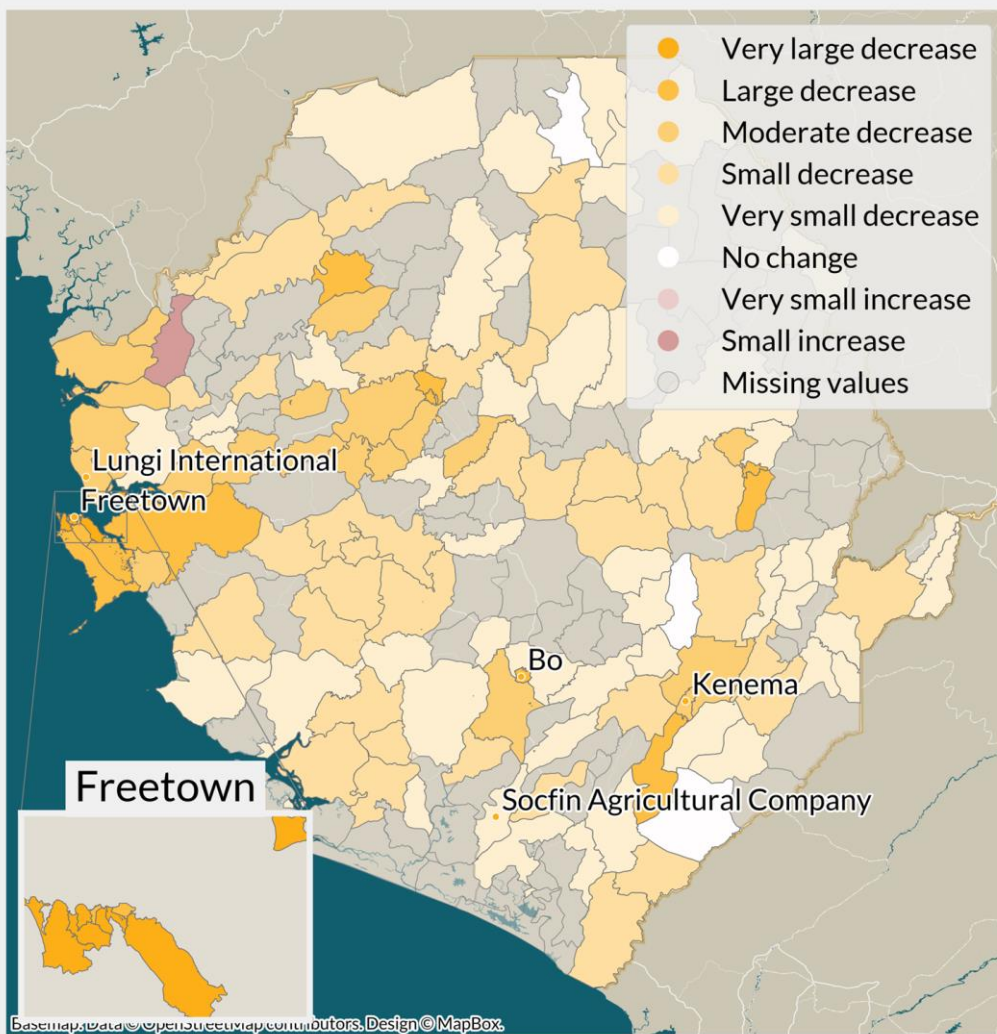
# Flow between any chiefdoms during travel restrictions

**Definition:** The map shows for each chiefdom the median sum of in and out flow with any chiefdom (in and out the district), expressed as absolute change from the baseline.

**Overview of the map** In most chiefdoms, flows have decreased, particularly in urban areas, although increases are observed in in Malen in the Southern province. There is also a modest increase in the North (Wara Wara Bafodia, Tambakha Yobangie, and Dembelia chiefdoms).

**Interpretation** The increase in flow in Malen may reflect traffic around the Socfin Agricultural Company related to agricultural activities. The increase in flow in the North/Northwest may be a result of the informal border crossings with Guinea found in this area, which may indicate increased smuggling activity, although results may not be significant because of the low number of subscribers.





# Flow between any chiefdoms after travel restrictions

**Definition:** The map shows for each chiefdom the median sum of in and out flow with any chiefdom (in and out the district), expressed as absolute change from the baseline.

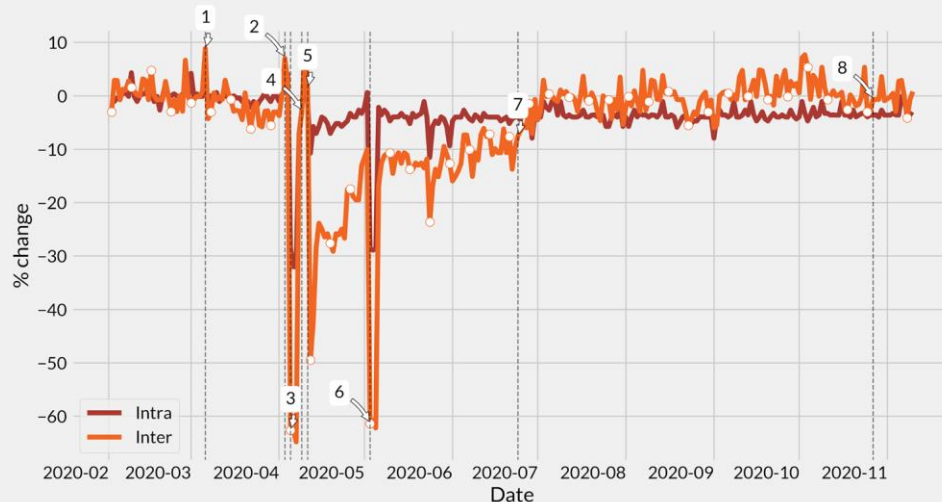
**Overview of the map** In most chiefdoms, flows remain decreased, but to a much lesser extent than while restrictions were in force. There is a small increase in flows to and from Magbema chiefdom.

**Interpretation** Overall, most districts have returned to close to normal levels of flux. We would expect this to appear slightly below the baseline, even with 'normal' movements, because of the impact on calling frequency of the price floor. As seen in the time series, this seems to have had a lasting impact on calling behaviours. The increased flux with Magbema is likely due to the reopening of the border and resumption of the formal trade route to Conakry.



# Median travelled distance

Key events: 1) NATCOM price floor introduced, 2) First lockdown announced, 3) First lockdown, 4) Inter-district travel restrictions and curfew announced, 5) Inter-district travel restrictions and curfew begin, 6) Second lockdown, 7) Inter-district travel restrictions lifted, 8) Curfew suspended



**Definition:** The red and orange lines show change relative to baseline of median travelled distance within and between districts, respectively. Circles denote Sundays. Travelled distance is measured as the distance between the geographic center of the two chiefdoms in which a subscriber has been active.

**Overview of the graph.** During the the two lockdowns (dotted line 3 and 6), travelled distance within and between districts dropped by circa 30% and 60%. There are minor spikes before the announcement of each measure. After the start of the inter-district travel restrictions (dotted line 5), travelled distance between districts decreased massively (50%) before growing back gradually to normal until the end of June when the restrictions were lifted. By contrast, travelled distance within districts did not change much. From July, travelled distance between districts is back to normal level while travelled distance within districts is slightly below normal.

**Interpretation.** The decrease in median travelled distance between districts suggest that the inter-district travel restriction did have an impact on how far subscribers were travelling. This may have helped to limit the spread of the virus.

**Caveats** This metric is somewhat **more robust** to the issue of call frequency highlighted on previous slide as it is based on median value of non-zero trips rather than on the count of subscribers seen at two locations on the same day. Nevertheless, the same caveats apply.



# Analysis Presence

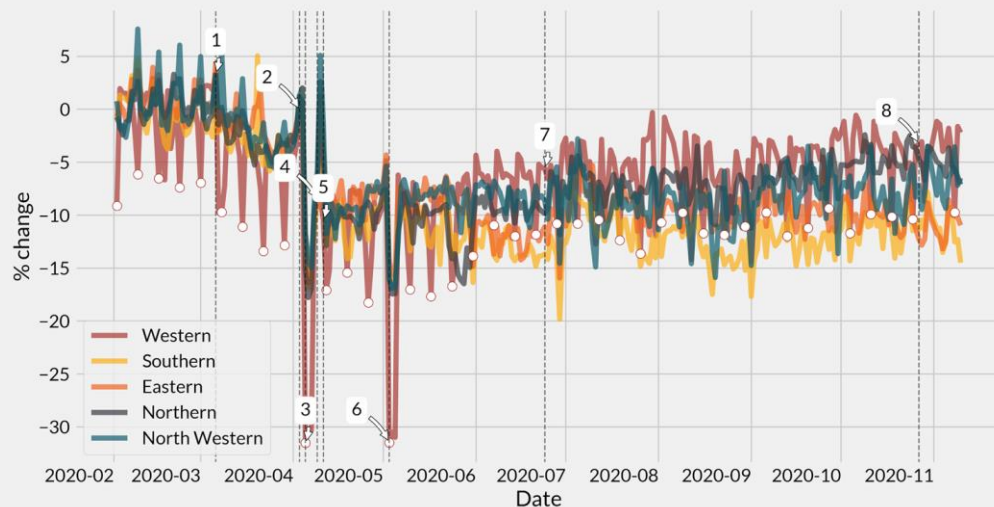


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# Provinces

Key events: 1) NATCOM price floor introduced, 2) First lockdown announced, 3) First lockdown, 4) Inter-district travel restrictions and curfew announced, 5) Inter-district travel restrictions and curfew begin, 6) Second lockdown, 7) Inter-district travel restrictions lifted, 8) Curfew suspended



**Definition:** The lines show change in median unique subscribers per chiefdom relative to baseline in each province. Circles denote Sundays.

**Overview of the graph** The median number of unique subscribers per chiefdom dropped in all provinces during the two lockdowns, particularly in the Western Province where Freetown is located (>30%). It also declined following the introduction of inter-district travel restrictions and stabilised until the end of May. All provinces remain below normal, with a greater decrease in the Southern and Eastern areas.

**Interpretation** Because of reduced flows between districts following the imposition of the inter-district travel restrictions, fewer subscribers were present in the same chiefdom on a particular day. This may have helped reduce the circulation of the virus.

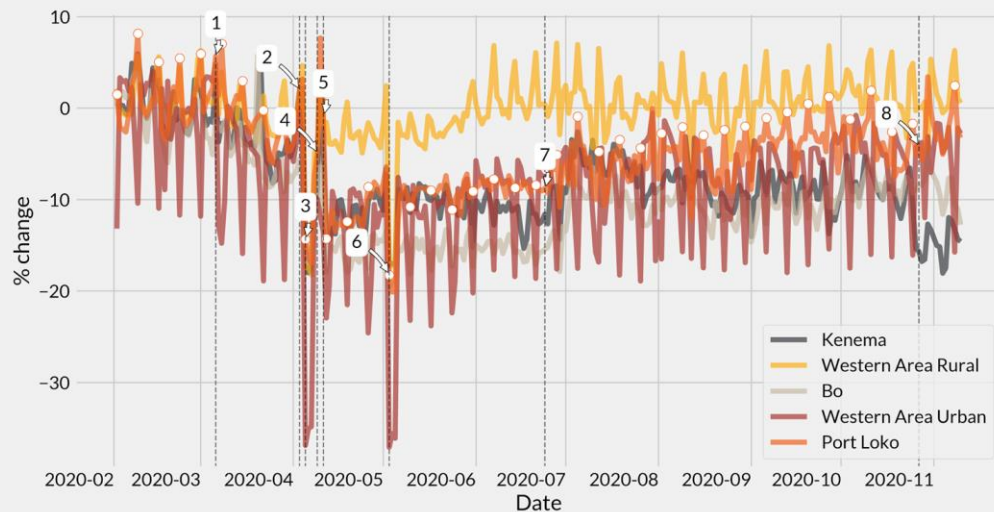
**Caveats** The results for each province are largely affected by urban chiefdoms where the reduction in visits have been the most important. The reduction in presence is matched by a reduction in the number of calls per day (see Annex). This makes it challenging to state with confidence that the mobility reduction observed for is not an artifact of reduced call frequency.



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# Focus districts

Key events: 1) NATCOM price floor introduced, 2) First lockdown announced, 3) First lockdown, 4) Inter-district travel restrictions and curfew announced, 5) Inter-district travel restrictions and curfew begin, 6) Second lockdown, 7) Inter-district travel restrictions lifted, 8) Curfew suspended



**Definition:** The lines show change in median unique subscribers per chiefdom relative to baseline in each focus district. Circles denote Sundays.



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**Overview of the graph** There is a large drop in presence in all focus district during the two lockdowns, particularly in Western Area Urban (-35%), where Freetown is located. Visits in Western Area Rural was slightly higher than baseline throughout June (preceding relaxation of restrictions) and thereafter.

**Interpretation** The largest sustained drop in presence is observed in the most urban districts, with the longest lived effects in Bo and Kenema. This decrease in presence may have helped to limit the spread of the virus within these urban areas. It may also have had a significant impact on businesses relying on the presence of customers or for individuals whose livelihood depends on their presence in these urban areas.

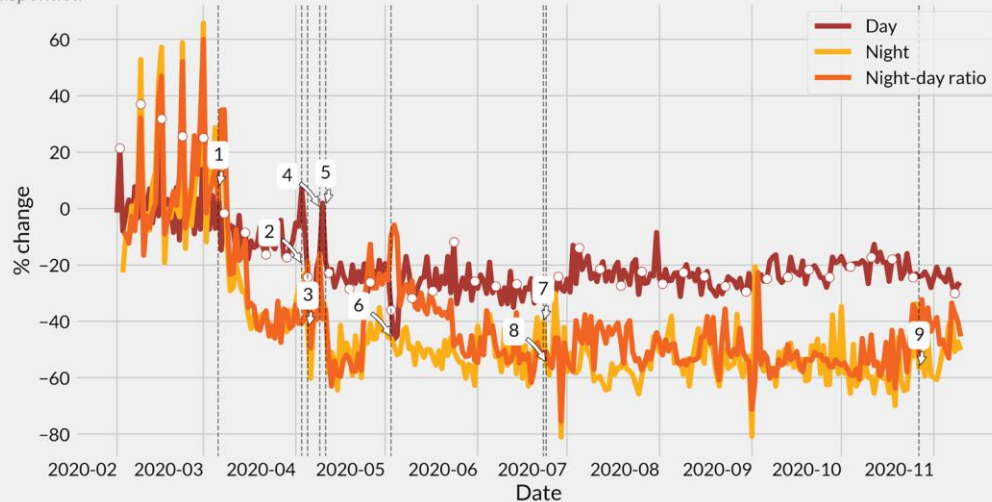
The positive trend for Western Area Rural area since June may reflect the seasonal factors such as the maize or cassava harvest season.

**Caveats:** Change in call frequency as on previous slides.



# Curfew

Key events: 1) NATCOM price floor introduced, 2) First lockdown announced, 3) First lockdown, 4) Inter-district travel restrictions and curfew announced, 5) Inter-district travel restrictions and curfew begin, 6) Second lockdown, 7) Curfew relaxed, 8) Inter-district travel restrictions lifted, 9) Curfew suspended



**Definition:** The lines show the percentage change from baseline of median day and night hourly subscriber counts, and the median day-night ratio. Circles denote Sundays.

**Overview of the graph** Median numbers of both night (8PM-5AM) and day (5AM-8PM) subscribers across all chiefdoms fell after the baseline, with a previously regular weekly pattern of increased night-time subscriber numbers being disrupted by the introduction of the price floor.

After the price floor, night-time subscriber counts fell by a median of 36%, which increased to 50% after combined restrictions. Following the relaxation of the curfew, this fell further (-55%), with a small recovery after the curfew was suspended (-50%).

**Interpretation** The curfew appears to have been effective at reducing night-time activity, which may have helped reduce activities with a higher risk of spreading the virus. The sustained reduction and modest recovery in response to relaxation and removal of the curfew restrictions suggest that there may have been a serious and sustained impact on the night-time economy.

**Caveats:** Change in call frequency as on previous slides.

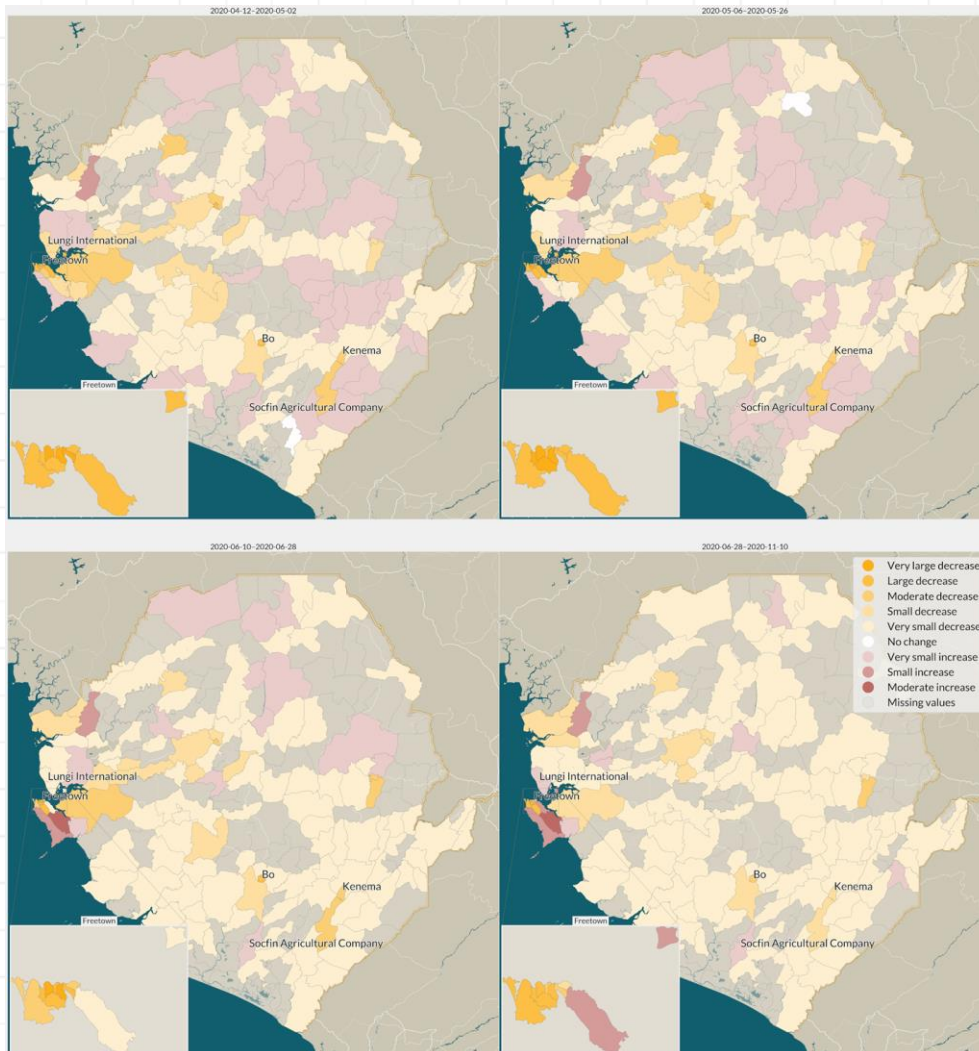


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# Stable periods

**Definition:** Maps show the median absolute change from baseline in unique subscribers visit during four *stable* periods

**Overview of the maps.** Presence is reduced relative to baseline in urban areas across all provinces in all four periods, with some signs of recovery around Freetown and reduced presence in rural areas in the June period.





# Annexes



The background of the slide is a photograph of a woman in traditional African attire, including a patterned headwrap and a floral-patterned wrap. She is holding a young child who is sleeping peacefully. The image has a warm, golden-brown color cast. A white grid pattern is overlaid on the right side of the image.

# Annex 1 Data considerations

# Data quality

## System or processing issues

Data missing for some time period

Corrupted records

Errors in location e.g. location is outside  
country borders

## Analysis issues

Spatial resolution

Temporal resolution

Representativeness of the data

*Not everyone uses a mobile phone*

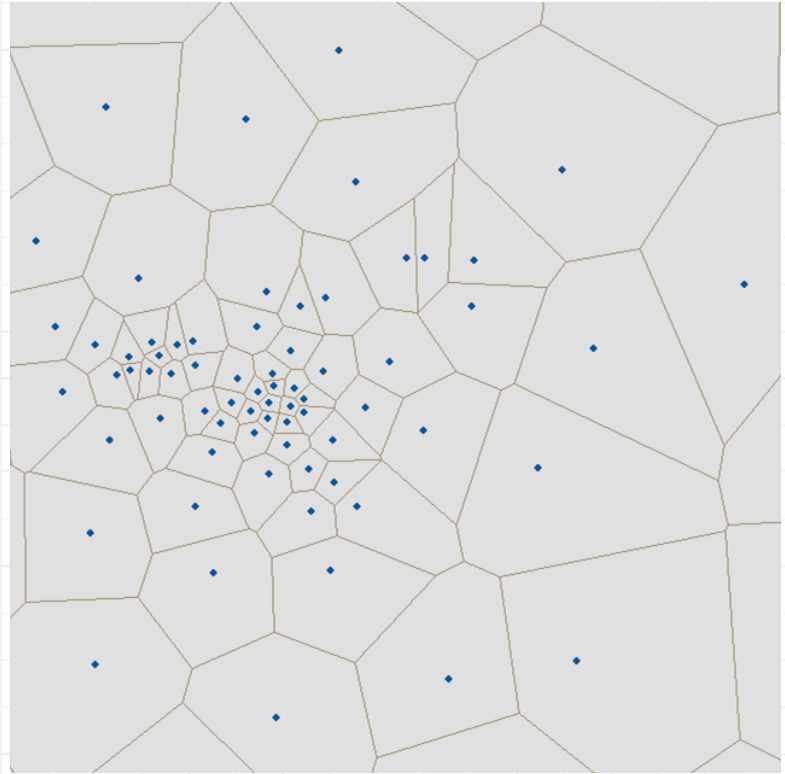
*We only have data from one MNO*

*One SIM doesn't always correspond to one person*



# Spatial resolution

The density of cell towers affects the precision of our location estimates. Furthermore, the location of the cell tower is often the only available information about its potential coverage.

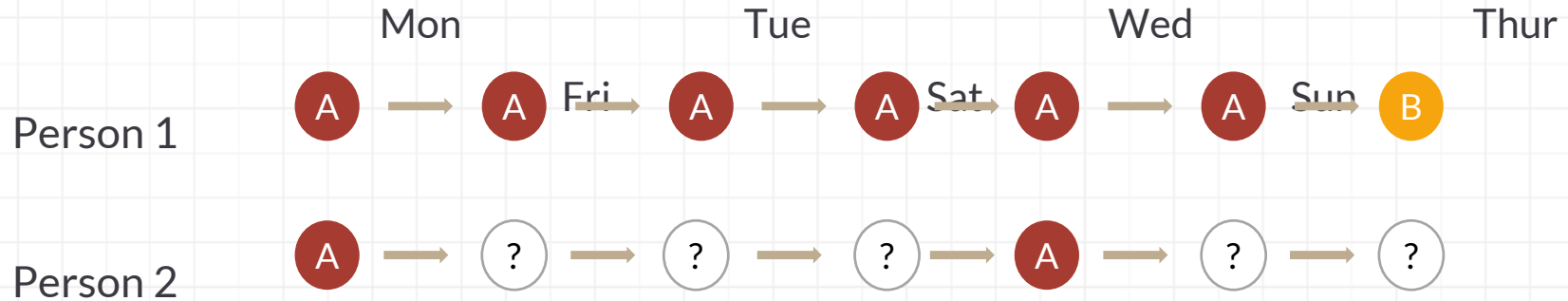




# Temporal resolution

We only 'see' a subscriber when they use their phone.

If they don't use their phone on a particular day, we can't confidently say where they are on that day.

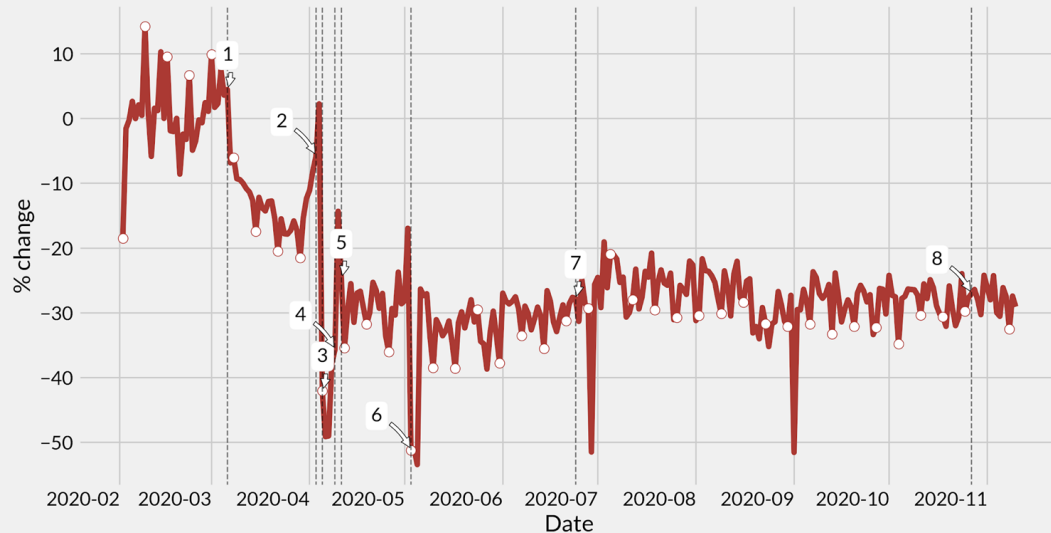




# Annex 2 Additional results

# Total events

Key events: 1) NATCOM price floor introduced, 2) First lockdown announced, 3) First lockdown, 4) Inter-district travel restrictions and curfew announced, 5) Inter-district travel restrictions and curfew begin, 6) Second lockdown, 7) Inter-district travel restrictions lifted, 8) Curfew suspended



**Definition:** The line shows change in total daily events relative to the baseline period

**Overview of the graph** One notable feature of the Africell data is that there are significant changes in the total number of events across the study period. Following the introduction of a price floor by the regulator on the 6th of March (dotted line 1), call volumes dropped by circa 20%. Call volumes also dropped during the two lockdowns by circa 50%.

Furthermore, the level of call frequency is 30% below the baseline period from April onwards.

**Interpretation** This makes it challenging to identify whether changes in presence and movement patterns are a result of lower call volumes, or whether both are reflecting similar underlying causes. All things being equal, lower call frequency will tend to reduce measured mobility.



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# GRID<sup>3</sup>

GEO-REFERENCED INFRASTRUCTURE AND  
DEMOGRAPHIC DATA FOR DEVELOPMENT

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For project updates and announcements, visit us online at:



**@GRID3Global**



**www.grid3.org**

Or follow our partners on Twitter at @Flowminder, @WorldPopProject, @PopDevUNFPA, and @CIESIN