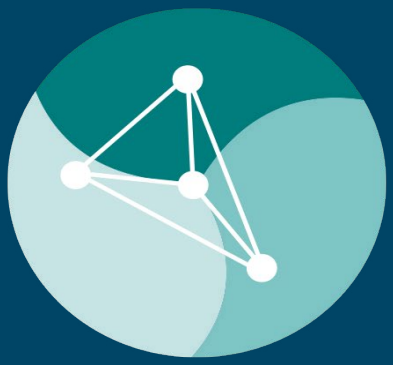

SETS
CONVERGENCE

SETS CONVERGENCE RESEARCH

MAY 2021

GRANT NUMBER 1934933

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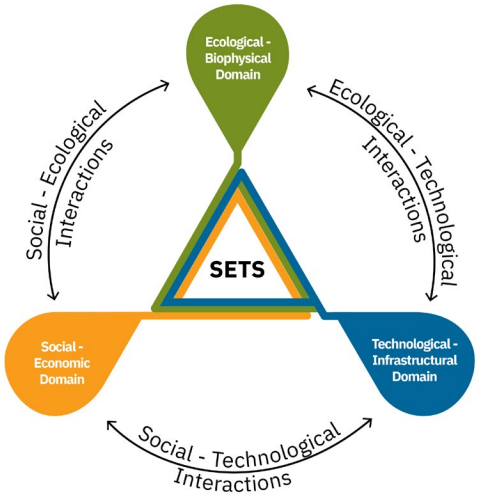
I. SCIENTIFIC PROGRESS

Our *Growing Convergence Research* project aims to equip cities with a process for integrating social, ecological, and infrastructural (technological) (SETS) resilience approaches to extreme events, using a cohesive framework that advances the capabilities of cities to respond to the increasing complexity associated with climate-driven extreme events. In this project, we ask: how do SETS domains interact to generate vulnerability or resilience to climate-related extreme events, and how can urban SETS dynamics be guided along more resilient, equitable, and sustainable trajectories? We advance a convergent urban system science by bringing together a fundamentally transdisciplinary team to develop transformative capacities for resilience to extreme events. The network bridges researchers, practitioners, and community members in a co-design process for envisioning resilient urban futures and articulating needs for implementation of convergent systems-oriented interventions. Domain-specific and interdisciplinary work, in Phase I of the project, has established the foundation for Phase II convergence activities with inter- and transdisciplinary teams across four cities in Atlanta, GA, New York, NY, Phoenix, AZ, and San Juan, Puerto Rico. Core theories, processes, models, and datasets have been developed in Phase I.

Advancing SETS Theory: We have significantly developed and advanced the SETS resilience theory, providing a more critical perspective on how to navigate each domain's capabilities towards appropriate adaptation in cities. Prior to our project, SETS theory was nascent, and our team has embraced the perspective as essential for helping cities adapt. Resilience theory to date remains highly domain-specific, with some cross domain efforts. The social-ecological systems (SES), science technology studies (STS), and infrastructure engineering communities have separately evolved their resilience framings, and there remains a significant disconnect between them. The social resilience model emphasizes a community's ability to cope, the ecological model emphasizes adaptation and transformation, and the infrastructure engineering model emphasizes robustness (i.e., strengthening). Through Convergence Capacity Building meetings, team charrettes, and place-based research projects, we are developing and putting into practice SETS resilience theory — not as a singular definition but as a series of concepts to help communities adapt in increasingly complex environments (greater interconnectivity of systems, path dependencies, polarized stakeholder views, etc.). The SETS theory emphasizes interventions instead of solutions, leveraging the capabilities across domains, breaking lock-in of decision-making, and consensus building.



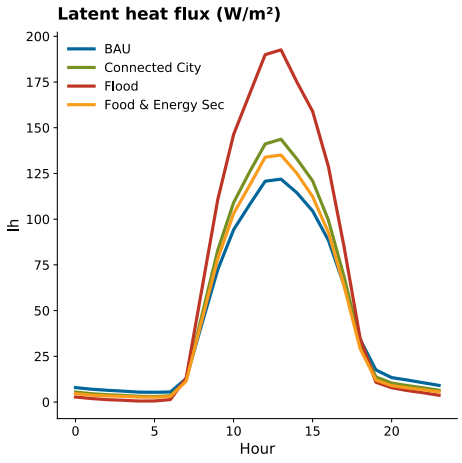
To engage the SETS resilience framing in research and practice, our team has worked within and across multiple **SETS Convergence Working Groups (WG)**:

Governance and Institutions WG: The team has advanced a framework for transformative governance informed by the literature on sustainability transformations. The framework is being used as both a diagnostic tool to evaluate existing governance capacities and inform the development of Assessment and Transitions Labs to build needed capacities. Some of the capacities to be examined through Assessment and Transition Labs include: SETS awareness; recognition of path dependencies and systemic inequities; foresight about future un/desirable pathways; collective vision for radical sustainability changes; new partnership and collaborative networks; multilevel/polycentric governance; diverse knowledge system and co-production; leadership and institutional navigation. Through surveys, content analysis of governance documents, and virtual engagement with stakeholders in Atlanta, Phoenix, New York, and San Juan, we have taken stock of existing governance and knowledge networks around climate resilience, leadership and other governance roles, and the main climate resilience activities and strategies preferred by multiple governance sectors.

Urban Ecological Infrastructure (UEI) and Ecosystem Services WG: This working group has advanced knowledge of diverse types of UEI as opportunities for discovering/implementing nature-based solutions for climate resilience. We have developed a conceptual and methodological basis for a species trait-based approach to ecological resilience assessment. We have developed classifications of UEI types as a basis for collecting new UEI data and creating a UEI geodatabase for GCR cities using publicly available data. With this database, we will conduct comparative spatial analyses and build models to prioritize and site UEI interventions. The database provides insight into how cities are currently planning, typologizing, and evaluating UEI. Next, we will create a UEI data governance index to describe how UEI spatial data can be shared and analyzed across systems. This project creates actionable knowledge, which supports SETS convergence capacity in our group by characterizing UEI across SETS geographic and administrative spatial scales.

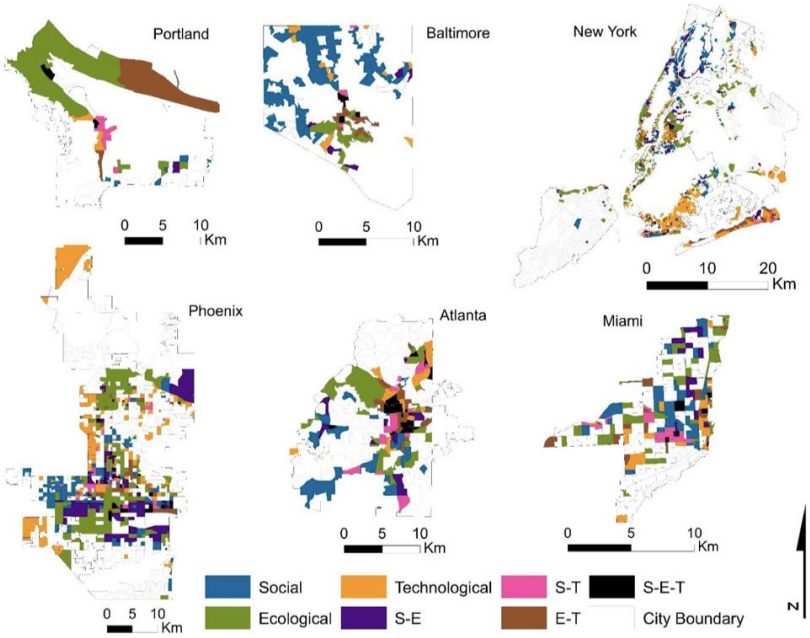
Infrastructure Resilience WG: The working group has advanced how we understand and position infrastructure (T) within the broader urban SETS resilience framework. Meetings early in the project supported i) the development of the synthetic infrastructure models, including elucidating infrastructure interdependencies, defining extreme event scenarios, and merging socio-economic information, and ii) describing infrastructure dynamics with S and E systems. Recently, the focus has shifted to T in SETS theory framing. The team has advanced resilience strategies for our four cities that consider Robust Decision Making (Decision-making Under Deep Uncertainty) that balances infrastructure decisions with loss of service and human impact, post-disaster recovery planning, including knowledge co-generation activities to support shifting of infrastructure designs towards SETS resilience, and re-imagining design storm criteria in infrastructure planning.

Integrated Land Use, Flood and Heat Risk WG: In order to allow for SETS Convergence analysis of how social, ecological, and infrastructural changes in the future (e.g., based on co-developed future scenarios developed in Phase I & II) will differentially impact potential future climate risks, this working group has developed and prototyped a method for integrated modeling of heat and flood risk assessment at high resolution. The model uses co-developed qualitative future scenario inputs into our data-driven, machine-learning, cellular automata (CA)-based land-cover modeling environment to deliver future land-change outputs. These outputs then serve as inputs into heat and flood risk models to assess how stakeholder visions influence future climate risks at 30m or similar spatial scales. Additionally, this team has created a new custom CA model for New York, which will be replicated in other cities in Phase II, that incorporates



LIDAR and orthoimagery data to increase the resolution to 4m and also adds population and social-demographic modeled scenarios. The figure above compares future heat in San Juan under four scenarios.

SETS Vulnerability WG: We developed and applied a SETS framework to assess the spatial distribution of vulnerability to flooding in six US cities (Chang et al. 2021). We chose eighteen metrics for exposure, sensitivity, and adaptive capacity in the three (S, E, T) domains and mapped SETS vulnerability as exposure x sensitivity / adaptive capacity. Findings showed that a focus on just one or two domains will fail to give a complete picture of SETS vulnerability. Further, areas where there was significant overlap might be good targets for interventions that can build resilience. The figure to the right shows areas of highest vulnerability (top quartile) for S, E, and T domains and their overlaps. Note areas of S-T and E-T overlap on the Rockaways Peninsula in New York City (NYC), S-E overlap in south-central Phoenix, and S-E-T overlap in central Atlanta.



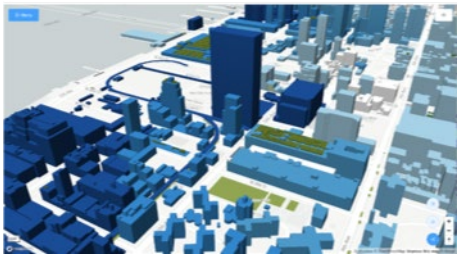
SETS Interdependence WG: A student-led team is using the SETS framework to understand and explore dynamic, interconnected, and interdependent relationships within cities to support integrated urban flood management. With a lens on flooding in our cities, the team is assessing S, E, and T relationships; identifying feedback loops, pathways of disruption, and cascading failures; generating insights into the SETS dynamics that amplify or attenuate extreme events; and suggesting new ways to protect critical infrastructure services from extreme events from an interdisciplinary perspective. For example, protecting a city's critical services against flooding requires consideration of four key urban hydrological processes. The relationships between the gray and ecological systems are governed by processes, codes, and rules that in turn affect a city's ability to institute resilience strategies. Working through these described dynamics is paramount. The interdependencies identified in this work will be used in semi-structured interviews with local flood managers to identify opportunities for coordination in the SETS Futures WG.

Co-Development of SETS Futures WG: The participatory process of developing future SETS scenarios is an integrative approach for opening up the problem space and envisioning alternative long-term resilient futures with a multiplicity of perspectives and knowledge (Iwaniec et al. 2020). The co-developed futures are the basis for integrated modeling, assessments, and transition labs in Phase II. We developed three novel scenario co-development processes: 1) Strategic Scenarios to explore potential outcomes of cities' existing planning goals; 2) Adaptive Scenarios to co-develop scenarios that address climate resilience challenges; and 3) Transformative Scenarios to articulate visions of radical social-ecological-technological change in the pursuit of resilience, sustainability, and equity. We also developed business-as-usual (BAU) scenarios for comparative baseline analysis. We are conducting this scenario research in all four cities. In San Juan and Phoenix, we have co-produced the suite of strategic, adaptive, and transformative scenarios and have

initiated Phase II assessment and transitions labs. In Atlanta and NYC, we have conducted several participatory meetings (virtual) focusing on scoping and framing for scenario co-development and convergence capacity building, and have produced strategic scenarios in NYC.

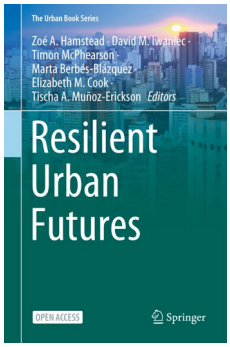
Co-production Assessment and Transition Labs (Phase II): We developed an approach for analysis and integrative assessment to evaluate SETS domains, resilience, equity, and sustainability of future scenario visions. We have analyzed San Juan and Phoenix scenarios and used the results with San Juan stakeholders to plan transitions towards flood resiliency with the Alianza por la Cuenca del Río Piedras. In addition, we have developed virtual, participatory approaches for developing transformative capacities and an inventory of digital tools and activities for designing participatory workshops, assessment labs, and transition labs.

SETS Data Visualization Platform: In parallel with ongoing infrastructure analysis and modeling, our team continues to update and enhance the project's Data Visualization Platform, an interactive web application to advance SETS understanding of each GCR city. We now show map layers to delineate NYC's water and power infrastructure; digital elevation models and buildings across all cities to provide location context for SETS indicators and the ability to compare and contrast across map layers. The next phase will include synthesizing cities' past, current, and future land-use changes and impacts on future flood and heat projections for viewing and interacting on the web platform.



Key outputs that illustrate progress: Since submitting our annual report in September 2020, the project has published two new books, increased our journal article output to 36 research publications and Op-Eds (with five more under review), given over 20 interviews and media mentions, and produced an exciting variety of new products. In addition to traditional academic outputs like databases, protocols, and survey materials, we have developed numerous public-facing outputs: interactive StoryMaps, podcasts, a cooperative board game, and a climate equity XR app (described on p. 9). We have also presented on SETS framing at leading conferences across the three domains and through keynotes, as well as contributed to United Nations Regional Centres of Expertise: Greater Atlanta, San Juan ULTRA, Ecological Society of America, and other symposium sessions and stakeholder engagement events in our site cities. As a project, we have also taken on the education, training, and mentorship of ten graduate students and seven postdoctoral scholars, a rewarding endeavor likely to have the greatest impact on urban resilience and SETS thinking long-term of anything we do.

SETS Convergence researchers have collaborated on two books on future cities. *Resilient Urban Futures* (by Co-PI's Iwaniec, McPhearson, Cook, and Muñoz-Erickson) addresses how cities can develop anticipatory and long-range planning capacities for more resilient futures, earnest collaboration across disciplines, and radical reconfigurations of the power regimes that have institutionalized the disenfranchisement of minority groups. Urban Infrastructure: Reflections for 2100 (by PI Chester and with contributions from GCR Co-PIs) includes 40 visions of resilient infrastructure at end-of-century described through essays, songs, artwork, and games.



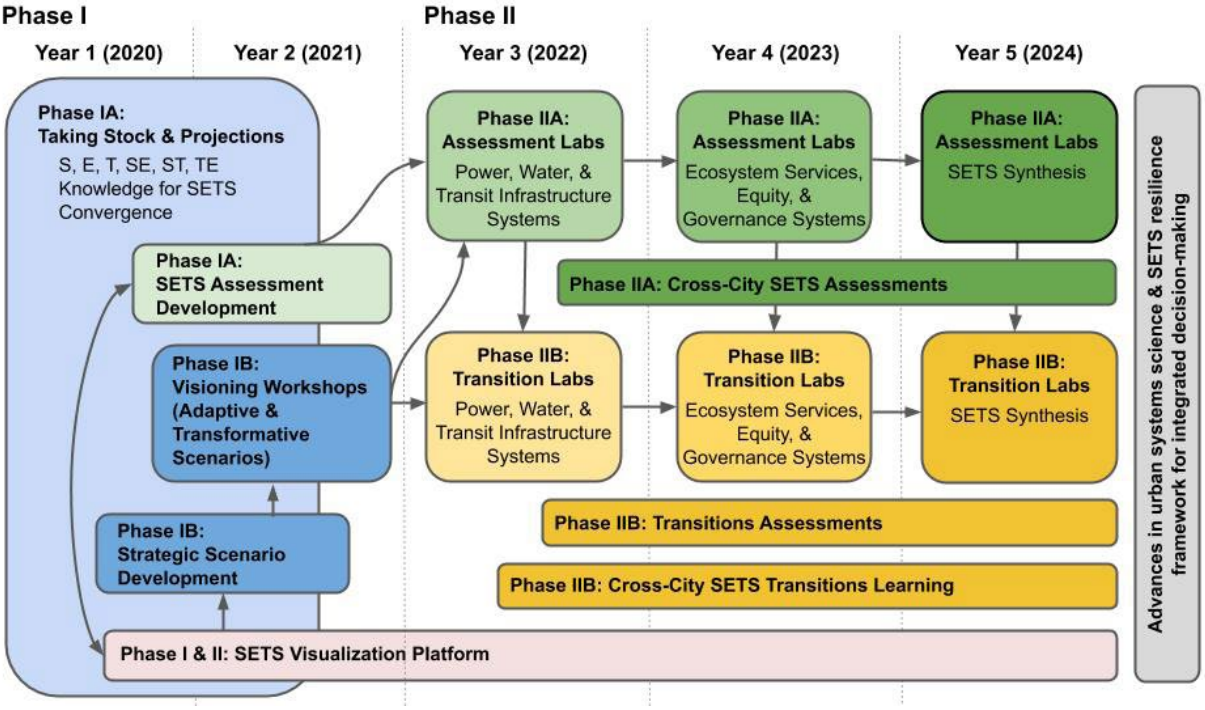
The team is compiling and developing tools to explore urban futures and transition pathways. We built a web-based Transitions Toolkit that serves as a platform for city stakeholders to access a diversity of resources and tools to support local planning and implementation initiatives, including examples from other cities, collaboration activities to support transition planning, and interactive data visualizations. We continue to test approaches and tools to support virtual, participatory settings for engagement in the following year.

II. EVOLUTION OF PROJECT

The core goal of the project is to advance deep convergence around urban resilience to extreme events. A central pillar of the work to achieve this goal is the transdisciplinary integration of knowledge and perspectives across our four cities. The academic research teams (composed of social scientists, ecologists, and engineers) work across all four cities, creating capabilities for transferring insights from one city to another (e.g., how can precipitation-based flooding strategies in Phoenix translate to Atlanta, and how can cities leverage place-based SETS capabilities?). In each city, we collaborate with a diversity of practitioners in co-generation activities to open up solution spaces and share knowledge. We've created an environment of inclusiveness in virtual connections (due to COVID-19), where researchers interested in urban resilience for climate adaptation have embedded themselves in our project network.

Convergence Capacity-Building: A central mechanism for convergence among our team members has been our Convergence Capacity Building meetings where our team members discuss various topics to advance SETS resilience theory and address conceptual and methodological challenges and opportunities of convergence research. Convergence Capacity Building meetings have also been used for team building, including development of strategies for improving diversity, equity, and inclusion in the GCR network. We've held 22 meetings since December of 2019 with 25-35 attendees and often guest speakers. We also held 12 Infrastructure Resilience Discussions open to the network.

Responding to Challenges: In light of COVID-19, our work with each city has been flexible in order to support shifting city timelines, local politics, and priorities for our collaborative work. In some cases, such as in San Juan, shifting priorities and new coalitions have allowed us to move faster with more frequent dialogues and charrettes to respond to stakeholder needs and emerging issues, while in other cases, such as Atlanta, we have shifted our timeline to reflect the need to develop and establish rapport and connections through smaller virtual engagements prior to the planned participatory scenario workshop in Phase I. With respect to project management and stakeholder engagement, we have shifted as much as possible to virtual formats for the numerous city practitioner stakeholder meetings in our four cities. In addition, we have conducted virtual workshops and larger stakeholder engagements in San Juan and Atlanta and are planning near-term workshops to test new protocols in NYC. While it



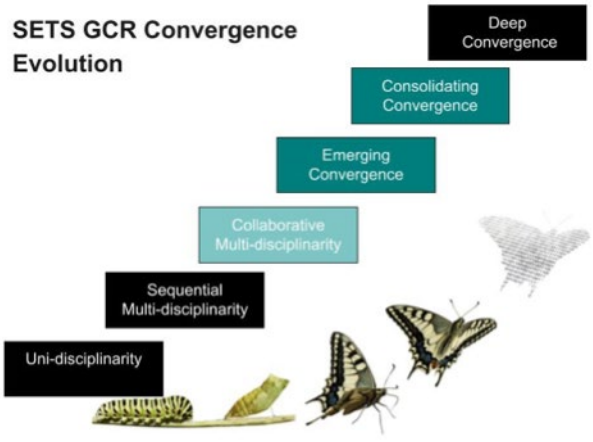
is a challenge to reimagine and rework engagement techniques (and timeline) in a virtual environment, we have also found several benefits, including more regular engagement opportunities in each city, better opportunities for inclusive engagement (e.g., use of online tools), and less travel required of the SETS GCR team.

Shifting to respond to opportunities: Members of the infrastructure resilience working group led a study at the onset of the COVID-19 crisis to describe how the pandemic is in many ways a harbinger of the change and uncertainty associated with climate change and other Anthropocene challenges (Carvalhaes et al. 2020). Members of the UEI working group led studies at the onset of the pandemic to explore how well-being and inequities are impacted by access to greenspace during lockdown in NYC and nationally (McPhearson et al. 2021; Spotswood et al. in review; Maurer et al. in review). Findings highlight the disproportionate impacts of COVID-19, the importance of urban greenspace as a mechanism to ensure community resilience, and the importance of infrastructure transformation for future resilience.

Plan for Phase II: At the end of our Phase I work, despite challenges from COVID, we have met or exceeded our goals of establishing SETS theory, developing foundational datasets and computational capabilities for exploring adaptation pathways in our cities, and building a network of researchers and practitioners that will drive our Phase II activities. In Phase II, our research goals will shift towards assessment labs (evaluating adaptation pathways and capacities for change) and transition labs (fostering pathways and building capacities to implement interventions and overcome barriers). This work will first occur in each city, as a knowledge co-generation activity among practitioners and researchers, informed by the underlying science, theory, models, and visualization tools developed (Phase I), and then include cross-city SETS assessments and transitions learning. The cross-city efforts will focus on identifying the tensions and leverage points for S, E, and T capabilities and how similar hazards (e.g., heat in NYC versus Phoenix) may necessitate different SETS adaptation strategies.

III. PROGRESS TOWARDS CONVERGENCE

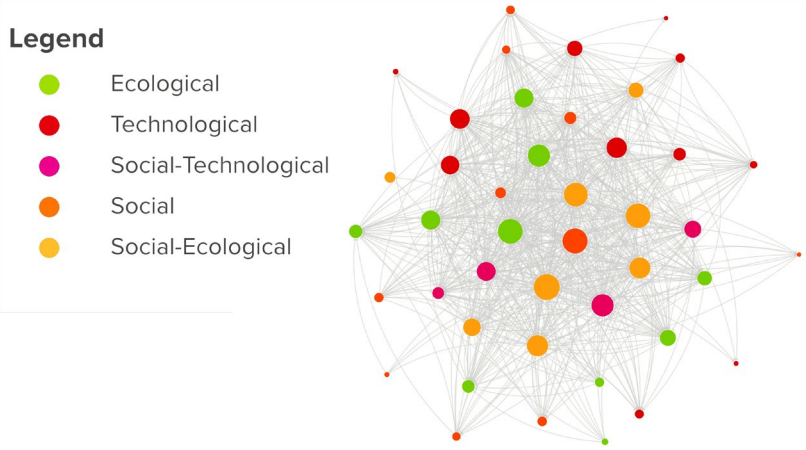
Since project inception, the team has been meeting regularly to review the status of resilience theory in various literatures: ecology, social-ecological systems, social science (i.e., transitions, risk, and vulnerability), engineering, sustainable engineering, and sustainability science. We have identified commonalities and distinctions across these different theories and considered how and why they converge or diverge. Discussions in our Convergence Capacity Building meetings with key authors in these various areas (e.g., Carl Folke (Stockholm Resilience Center), David Woods (The Ohio State University), Niki Frantzeskaki (Swinburne University of Technology, Australia), Constantine Samaras (Carnegie Mellon University), Mary Uhl-Bien (Texas Christian University)) have helped to sharpen our perspective on how the framing of SETS resilience can meet challenges of the Anthropocene. We are preparing a manuscript invited for PNAS that outlines advances in resilience theory as applied to SETS.



Our research team is steadily moving up the Convergence Evolution Ramp (framework provided by Toolbox Dialogue Initiative at first PI meeting) from a stage of Emerging Convergence at the beginning of Phase I, building on earlier progress in the UREx SRN, to Consolidating Convergence in Phase II. Our progress towards productive, convergent teams and the establishment of an identity as convergence scholars is evident from multiple products and tools we are using

and developing. We used the same survey instrument developed by the Toolbox Dialogue Initiative to assess our team members' perceptions towards essential conceptual, management, and methodological elements of research, as well as the role of values in scientific research. Twenty-six of our researchers, staff members, students, and postdocs (60%) responded to the survey, and we found many areas of consensus, notably the view that "each discipline involved in our team's project is equally important to the project's success" (88% strongly agreed) and that "attention to the process of convergence research is just as important as attention to research outcomes."

We also assess our progress by examining how we are interacting with other team members and SETS domains (Figure right). We used social network analysis to examine and visualize the connections of team members in the network and found a high level of connectivity across all team members (researcher-researcher, researcher-students, students-postdocs, etc.) and across all SETS domains (S-E, S-T, E-T, S-T, S-E-T). The high level of connectivity and collaboration is to be expected given the team and domain integration we have encouraged over Phase I of the project through Working Groups, Convergence Capacity Building Meetings, city engagement activities, and other informal (but equally important spaces) in which our team members interact. We will repeat the data collection and analysis each year of Phase II to monitor our progress towards SETS convergence. Finally, we examined how well our outputs reflect this convergence by analyzing our team's publications to date from the perspective of SETS and found that 70% of our publications resulted from the collaboration of researchers from more than one domain, and 30% of all publications are written by convergent teams that include all SETS domains.



Mechanisms for Convergence: We are also building convergence in our four cities through various co-production approaches. Drawing on extensive research on sustainability transitions and innovation, we are designing various assessments and transition labs with partners in our cities to test and evaluate SETS strategies and interventions in building transformative capacities. In some of our cities, convergence is evolving from Sequential to Collaborative Multidisciplinarity (Atlanta) and from Collaborative Multidisciplinarity towards Emerging Convergence (NYC, San Juan, and Phoenix) as we move into Phase II of the project. Publications resulting from this work highlight convergence advancements through a novel scenario co-development framework and SETS-based assessments of future scenarios for city-specific and cross-city comparisons of urban resilience (Iwaniec et al. 2020a, b; Hamstead et al 2021). The work has also advanced the field's conceptualization of transformative change and lays out key criteria for conducting sustainability transformation research (Iwaniec et al. 2019).

- **Atlanta**: Our research team has been engaging with a diverse network of climate resilience actors in Atlanta. Our focus has been on fomenting a community of practice and through activities for taking stock of the existing knowledge system, leadership and governance roles in the network, and scoping and framing the climate resilience agenda. Our team has been engaging with the City of Atlanta to develop their Urban Ecology Framework and Central Atlanta Progress to develop the City of Atlanta Sustainability Plan. Both activities are incorporating SET Convergence Phase I research (e.g., knowledge systems, governance network, urban ecological infrastructure, and scenario research).

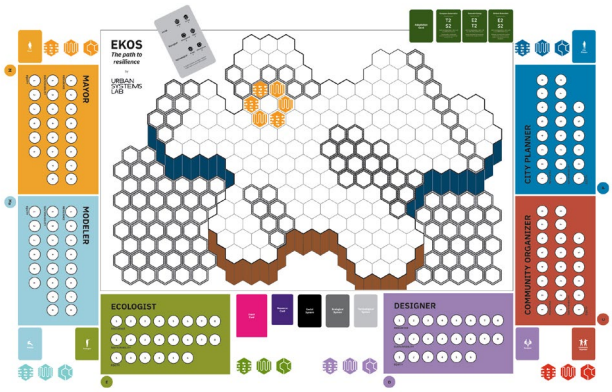
- **New York**: The NYC team is working with the Mayor's Office of Climate Resiliency (MOCR) to develop long-term future visions, bringing together multiple agencies and stakeholders that represent S-E-T perspectives. The process, including the goals and outcomes, has been co-developed with the MOCR team and builds on ongoing NYC climate resilience initiatives. The MOCR plans to integrate the co-produced visions into their upcoming Climate Adaptation Roadmap, which will be presented as guidance to the incoming Mayoral administration. Additionally, members of the Convergence team are collaborating with the NYC Panel on Climate Change (NPCC) to assist in the next phase of their climate risk modeling and the Environmental Justice Advisory Board to integrate environmental justice into NPCC. We are also co-led the science behind the first (2021) NYC Stormwater Resiliency Plan.
- **Phoenix**: The City of Phoenix, for instance, is developing a Climate Action Plan for net-zero emissions by 2045. In collaboration with the City of Phoenix, our team is developing a database of locally relevant climate mitigation strategies that are inspired by the future scenarios co-produced with Phoenix stakeholders. The team is also examining the GHG reduction potential of each scenario, using the Delphi method to examine the plausibility of implementing the strategies, and co-develop a new "Just and Equitable Net-Zero Carbon" scenario as a compilation of existing scenarios to inform the Climate Action Plan. The city is also now working with other regional cities in Maricopa County (most of the Phoenix metropolitan area) and our Phoenix team to develop plans for transitions to a "Resilient and Thriving Maricopa 2030."
- **San Juan**: The San Juan team is working with the Alianza por la Cuenca del Río Piedras, a coalition of agencies, NGOs, scientists, and residents, to integrate the flood resilience visions co-produced during the scenario workshops into various transition spaces towards integrated flood management. We have conducted a number of Assessment Labs to bring different actors and knowledges to understand the city's flood problem from a SETS perspective, including monthly and bi-monthly speaker seminars, community dialogues with city residents, and design charrettes with local landscape architects.

Demonstration of Progress and Broader Impacts: The success of our project is partly based on the applicability of our SETS convergence theory and work in communities. We have seen our research directly embedded into the cities and communities where we work and experienced our SETS theory being increasingly used by the broader academic community. For example, in San Juan the scenario outputs are being used by the Alianza por la Cuenca del Río Piedras as inspiration to develop flood resilience visions and strategies. In NYC, our work is being positioned to support the Climate Adaptation Roadmap, the most significant climate plan since their 2012 Special Initiative for Rebuilding and Resiliency report. Our research represents a long-term futures approach for resilience and sustainability, and our team engages in regular dialogues, capacity building, and collaboration with communities and city practitioners to advance resilience planning initiatives.

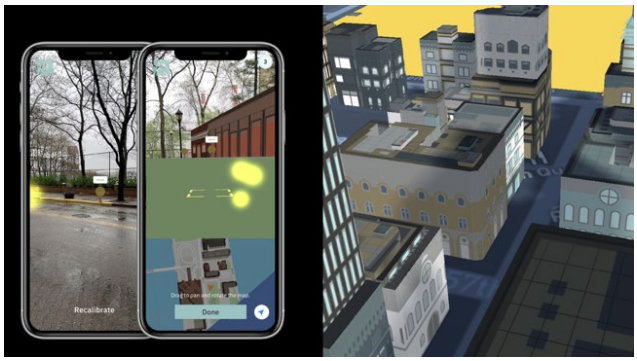
SETS framing is proving central to reconceptualizing convergent science and urban sustainability and resilience science. As we've engaged with international scholars during our capacity-building meetings, we've received feedback that our evolving SETS framework is increasingly being used to frame our city partner's resilience activities. In addition, our work will lead to improved anticipatory capacities and action in the face of future urban resilience challenges. Furthermore, network analysis of the climate resilience community of practice over time will be a key contribution to understanding how transdisciplinary networks function and provide recommendations to foster collective action.

The SETS Convergence Network also has developed several innovative, non-traditional broader impact products, including: an urban resilience cooperative board game (Ekos described below); Future Cities Podcast series on "Infrastructure and the Anthropocene" and "Positive Future Scenarios"; interactive StoryMaps to disseminate co-produced long-term urban futures in San Juan (Visiones de Ciudad - San Juan 2080); interactive climate equity and risk mapping (Climate Equity XR app described below); and two published books for academic and non-academic audiences. Our activities

result in training of early career scholars (described below), focus on Justice, Equity, Diversity, and Inclusion, and an exchange of knowledge and information with network participants, including cross-referencing and disseminating publications and presentations.



Ekos: The Path to Resilience is a multiplayer board game that challenges a group of six community members — a Mayor, City Planner, Community Organizer, Ecologist, Designer, and Modeler — to come together and envision a more equitable and sustainable Ekos in the face of climate change and other challenges. During the game of Ekos, players alternate between building SETS and responding to moderate and extreme events. Working cooperatively to challenges earns you Sustainability, Equity, and Resilience points. Ekos was developed with the goal of creating a playful platform for individuals and communities to discuss and learn about issues of urban resilience, climate governance, and community-based codesign.



Climate Equity XR: The Climate Equity XR app provides interactive geospatial maps and 3D visualizations of heat, flood risk, and other climate risk indicators in NYC. It experiments with augmented reality layers that allow you to project interactive maps onto a physical surface and explore your urban environment from a mobile-first data-driven SETS risk and resilience environment from wherever you are in the city.

Justice, Equity, Diversity, and Inclusion (JEDI) & Training for Early Career Scholars: Our JEDI task force has organized virtual Convergence Capacity Building discussions on JEDI within the network, brought core JEDI principles into our work with stakeholders, and JEDI has been a core research topic of SETS Convergence demonstrated through our publications, courses, and lectures. We developed and supported transdisciplinary research training and collaboration opportunities (funded and not) for postdoctoral fellows and graduate students to interact with, learn from, and build working relationships with practitioners and researchers from other disciplines. Training opportunities include new approaches to governance and network analysis, LULC and climate modeling, spatial analysis, and deployment of key assets through the Data Visualization Platform and social network visualization platform (KUMU). Graduate and postdoctoral fellows have taken leadership roles for core project research such as governance document analysis, the climate resilience survey, network analysis, urban ecological infrastructure mapping, integrated water systems framework, future scenarios modeling, and heat/flood risk analysis, and have an opportunity to present on their research in a variety of collaborative settings, including various disciplinary and interdisciplinary conferences and bi-monthly meetings with Convergence network members.

IV. OUTPUTS

A comprehensive list of all products available at: convergence.urexsrn.net/products/

Journal Articles, Books and Book Chapters

Carvalhaes T, et al. (2020). COVID-19 as a Harbinger of Transforming Infrastructure Resilience. *Front. Built Environ.* 6:148.

Chang, H., et al. (2021). Assessment of urban flood vulnerability using the social-ecological- technological systems framework in six US cities. *Sustainable Cities and Society*, 68.

Chester, M., et al. (2020). Keeping infrastructure reliable under climate uncertainty. *Nature Climate Change*, 10(6): 488-490.

Chester, M., et al. (2021). Infrastructure resilience to navigate increasingly uncertain and complex conditions in the Anthropocene. *npj Urban Sustain* 1, 4.

Childers, D., et al. (2019). Urban Ecological Infrastructure: An inclusive concept for the non-built urban environment. *Elementa: Science of the Anthropocene*, 7(1): 46.

Derrible, S., & Chester, M. (Eds). (2020). *Urban infrastructure: Reflections for 2100*. Self-published.

Elmqvist, T, et al. (2021). Urbanization in and for the Anthropocene. *npj Urban Sustain* 1:6.

Fraser, A., et al. (2020). Wildfire risk, post-fire debris flows, and transportation infrastructure vulnerability. *Sustainable and Resilient Infrastructure*.

Grimm, N. B. (2020). Urban ecology: What is it and why do we need it? In P. Barbosa (Ed.), *Urban ecology: its nature and challenges* (pp. 1–14). CABI.

Hamstead, Z., et al. (Eds.). (2021). *Resilient Urban Futures*. Nature-Springer Publishing.

Helmrich, A. & Chester, M. (2020). Reconciling complexity and deep uncertainty in infrastructure design for climate adaptation. *Sustainable and Resilient Infrastructure*.

Helmrich, A., et al.. (2020). Using biomimicry to support resilient infrastructure design. *Earth's Future* 8.

Iwaniec, D., et al. (2020). The co-production of sustainable future scenarios. *Landscape and Urban Planning*, 197, 103744. DOI: 10.1016/j.landurbplan.2020.103744

Maurer, M., et al. Understanding Multiple Dimensions of Greenspace Access and their Effect on Subjective Well-being During a Global Pandemic. (in review). *Frontiers in Sustainable Cities*.

McPhearson, T., et al. (2021). Pandemic Injustice: Spatial and Social Distributions of COVID-19 in the US Epicenter. Journal of Extreme Events, 2150007.

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Meerow, S., et al. (2021). How do heat and flood risk drive residential green infrastructure implementation in Phoenix, Arizona? *Urban Ecosystems*.

Spotswood et al. (2021). Who has nature during the pandemic? COVID-19 cases track widespread inequity in nature access across the United States.(in revision) *Nature Sustainability.*

Conference Presentations

Growing Convergence Research – PI Meeting (January 13 – 15, 2020) at the Westin Old Town Alexandria, VA (co-PIs).

Intergovernmental Panel on Climate Change AR6 Third Lead Author Meeting, Faro, Portugal, Jan - Feb. 2020 (McPhearson).

Plenary. The Future of Synthesis in Ecology. Title: Merging concepts of resilience to meet challenges of the Anthropocene. Virtual, National Center for Ecological Analysis and Synthesis, February 2021 (Grimm).

Symposium. A Social-Ecological-Technological systems (SETS) Approach to Advancing Urban Systems Science, Ecological Society of America Conference (August 2020) (Chester, Cook, Grimm, McPhearson)

Margalef Plenary Lecture. Limnología 2020. Title: The need for positive thinking in times of crisis: co-producing sustainable future scenarios and nature-based solutions for cities. Virtual Conference, October 2020 (Grimm).

Webinar Presentation, National Academy of Sciences Sustainability Roundtable Webinar Series. Title: Urban sustainability: resilience to extreme events in social-ecological- technological systems (SETS). Virtual, November 2020. (Grimm)

Story Maps

Seguridad Alimentaria y Energética

Ciudad Justa y Habitable (Just and Livable City)

Municipio Conectado (Connected Municipality)

Inundaciones Urbanas (Urban Flooding)

Inundaciones Costeras (Coastal Flooding)

Inundaciones Ribereñas (River Flooding)

Other Products

Ekos SETS Convergence Game

eRAMS Convergence Database

Future Cities Podcast episodes 49-52, 53

Climate Resilience Dialogues - Convergence

Institutional Analysis - Atlanta Stormwater

Network Maps of Climate Resilience Governance Actors and Roles (Decision Support Tool)