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5 **The Long Arm of Climate Change: Societal Teleconnections and the Future of**
6 **Climate Change Impacts Studies**

7
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10
11 **Abstract**

12 “Societal teleconnections” – analogous to physical teleconnections such as El Niño – are
13 human-created linkages that link activities, trends, and disruptions across large distances,
14 such that locations spatially separated from the locus of an event can experience a variety
15 of impacts from it nevertheless. In the climate change context, such societal
16 teleconnections add a layer of risk that is currently neither fully appreciated in most
17 impacts or vulnerability assessments nor in on-the-ground adaptation planning.
18 Conceptually, societal teleconnections arise from the interactions among *actors*, and the
19 *institutions* that guide their actions, affecting the movement of various *substances*
20 through different *structures* and *processes*. Empirically, they arise out of societal
21 interactions, including globalization, to create, amplify, and sometimes attenuate climate
22 change vulnerabilities and impacts in regions far from those where a climatic extreme or
23 change occurs. This paper introduces a simple but systematic way to conceptualize
24 societal teleconnections and then highlights and explores eight unique but interrelated
25 types of societal teleconnections with selected examples: (1) trade and economic
26 exchange, (2) insurance and reinsurance, (3) energy systems, (4) food systems; (5) human
27 health, (6) population migration, (7) communication, and (8) strategic alliances and
28 military interactions. The paper encourages further research to better understand the
29 causal chains behind socially teleconnected impacts, and to identify ways to routinely
30 integrate their consideration in impacts/vulnerability assessment and adaptation planning
31 to limit the risk of costly impacts.
32

33 **1 Teleconnections – An Introduction**

34
35 Teleconnections are a widely recognized phenomenon in the physical sciences, made
36 most famous by the El Niño-Southern Oscillation (ENSO).³ The most globally significant

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37 physical teleconnections are generally those that originate in the ocean or atmosphere
38 (e.g., ENSO). However, teleconnections can occur between and across land, ocean,
39 freshwater and atmosphere. Beyond the direct physical impacts, sometimes extensive and
40 expensive environmental and societal impacts also ensue in their wake. For instance, an
41 El Niño event can have a devastating impact on the Peruvian fisheries. In the western
42 U.S., there is strong evidence that winter and spring snow cover extent over North
43 America impacts monsoonal variables in the desert southwest, such as the total amount
44 and frequency of precipitation, hail, wind and severe weather (Hawkins et al. 2002, see
45 also Supplementary Material #1 for a more extensive discussion on societal impacts from
46 physical teleconnections).

47
48 But teleconnections are in no way constrained to the physical world alone. The phrase
49 "teleconnections" has been adopted by some social scientists to help convey the idea that
50 vulnerabilities and climate change impacts do not just originate and unfold in one place
51 but can also result from long-distance relationships (Adger, Eakin and Winkels 2009).
52 The idea of "societal teleconnections" thus is analogous to that of physical
53 teleconnections, but is focused on the human-created linkages via people, structures,
54 institutions and processes.

55
56 For instance, floods in Thailand in 2011 (driven by the strongest monsoon in 50 years)
57 killed more than 800 people locally, disrupted local agriculture, and forced some 10,000
58 computer supply and electronic car and camera part manufacturing factories to close and
59 lay off 350,000 employees (Garside 2012). In addition to the economic impact locally, it
60 also had rebounding impacts globally. Before the floods, one facility owned by Western
61 Digital (a Silicon Valley-based corporation) produced 60% of the company's hard-drive
62 production and 25% of the world's supply of "sliders," a prime component of hard-disk
63 drives. Post-floods the cost of hard drives doubled (Acclimatise 2014). The event not
64 only caused about \$45 billion in damages to the Thai economy, and weakened the
65 economic recovery throughout Asia, it also had far-reaching – and expensive – impacts
66 on a leading economic sector in California, USA. This example is now widely cited by
67 the private sector and has spurred several Fortune 500 firms to begin to assess supply
68 chain vulnerability—one possible societal teleconnection—through the lens of climate
69 change (Gledhill et al. 2013).

70
71 This example of an economic teleconnection illustrates how local climate vulnerabilities
72 can and do originate in far-away places. This adds a layer of risk that is currently not
73 fully appreciated in most climate change impacts assessments and on-the-ground
74 adaptation planning. Yet being unprepared for these additional risks can cost millions of
75 dollars and, sometimes, lives. In short, teleconnections point to a risky gap in both
76 research, policy and planning.

³ Remarkably, however, the recognition of physical teleconnections is not at all new: the Southern Oscillation – the atmospheric component of ENSO – was first characterized by the British mathematician and meteorologist, Sir Gilbert Walker. In 1924 he wrote: "By the Southern Oscillation is implied the tendency of pressure at stations in the Pacific ... to increase, while pressure in the region of the Indian Ocean ... decreases." A few years later, Angstrom (1935) was the first to use the term "teleconnections" in reference to the north-south dipole atmospheric anomaly pattern now referred to as the North Atlantic Oscillation.

77 This paper proposes a systematic, but pragmatic and simple conceptual framework that
78 helps researchers and practitioners identify how what happens afar can affect them. It
79 then highlights and conceptually explores a range of societal teleconnections that have
80 arisen out of societal interactions and the globalization of our world and which create,
81 amplify, and sometimes attenuate climate change vulnerabilities and impacts in regions
82 far from those where a climatic extreme or change occurs. Our goal is to encourage
83 further research to better understand the causal chains behind socially teleconnected
84 impacts, and to identify ways to routinely integrate their consideration in impacts
85 research and adaptation planning. To achieve the latter, the inclusion of long-distance
86 relationships in locally-focused assessments must remain a manageable task for
87 adaptation practitioners in the private and public sectors who neither have easy access to
88 nor the capacity for complex systems modeling, but whose assets are nonetheless at
89 stake.

91 **2 Societal Teleconnections**

92 **2.1 Societal Teleconnections: A Simple but Systematic Framework**

94 The notion of societal teleconnections applies the idea of long-distance interactions and
95 connectivity to the social realm. While the basic idea of spatial interactions in the
96 physical/natural environment or in societal activities is as old as the discipline of
97 geography, and therefore has a rich theoretical and empirical basis in that field, the idea
98 of societal teleconnections was first explicitly discussed by Adger, Eakin and Winkels
99 (2009). Societal teleconnections link activities, trends, and disruptions across large
100 distances, such that locations spatially separated from the locus of an event can
101 experience a variety of impacts from it nevertheless. The concept of teleconnections
102 broadens place-based discussions of climate change impacts to also include the dynamic,
103 process-based implications of long-distance connections across the globe (Seto et al.
104 2012, Liu et al. 2013).

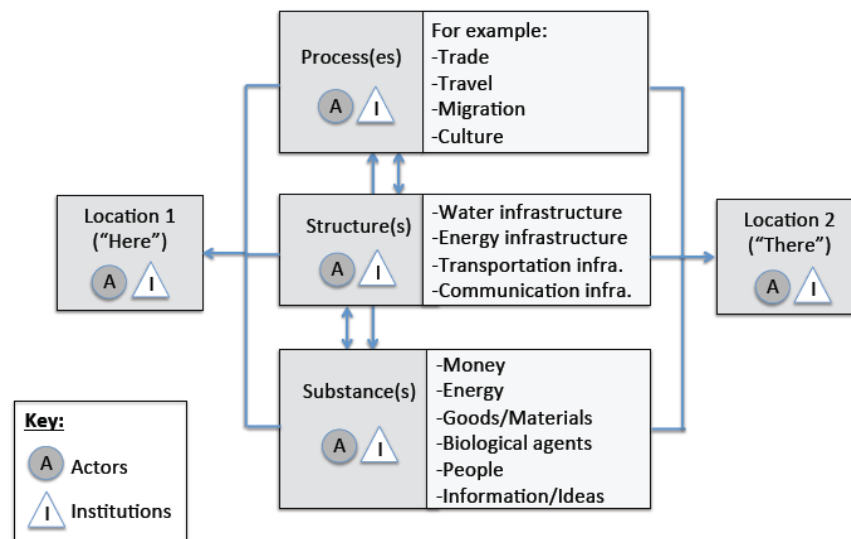
106 There is a broad body of literature on the impacts of globalization and related activities
107 on social, economic, and coupled human-natural systems (e.g., Young et al. 2006,
108 Leichenko and O'Brien 2008). To pick just one example, several studies have examined
109 the impacts of deforestation – due primarily to global demands for increased cropland
110 and local slash and burn agriculture – on communities located near the sites of
111 deforestation (Aide and Grau 2004, Lambin and Meyfroidt 2010). Such studies clearly
112 bring into focus the interconnectivity across space, but these connections have not been
113 fully accounted for to date in climate impacts and vulnerability studies. Moreover, while
114 globalization is one of the main *processes* creating and perpetuating societal
115 teleconnections, it is by far not the only important way in which locations and events get
116 connected across long distances.

118 Others have developed the related but broader notion of "tele-coupling" as an overarching
119 conceptual framework to link complex, coupled human-environment systems across
120 spatial distances (e.g., Liu et al. 2014; Eakin et al. 2014; Liu et al. 2013). While
121 teleconnections as conceptualized here (and more commonly used in the climate change
122 literature) focuses on the structural and functional connection itself, tele-coupling extends

123 the integrative systems research (particularly in land use and land change science) that
 124 emerged over the past two decades on coupled natural-human systems to account for
 125 long-distances influences on the functioning of these systems. The influence of biofuels
 126 production, such as ethanol from corn, on land clearing and thus carbon emissions is a
 127 good example (e.g., Melillo et al. 2009; Youngs and Somerville 2014). Our framework
 128 resembles that of tele-coupling, but aims to keep it as simple as possible, yet as complex
 129 as necessary, to uncover distal vulnerabilities via a distinct focus on the connection itself.
 130

131 Societal teleconnections require at minimum three basic components in order to occur. If
 132 one or more are missing, the teleconnection is interrupted (Figure 1):

- 133 • A natural system or human-built construct that forms the conveying or
 134 transmitting physical *structure* (metaphorically, one may think of this as the
 135 “hardware”). It does not itself move but stays in place as a teleconnection is made.
 136 The finite set of types of physical structures include water, energy, transportation
 137 and communication-related infrastructure⁴ such as roads, ports, pipes,
 138 transmission lines, wires, or satellites.
- 139 • The *process* explains the reason, manner or cause for the teleconnection (the
 140 “software”). It establishes a functional exchange or relationship between distant
 141 entities. Examples of an almost infinitely large set of social processes include the
 142 market, travel or migration, human needs and desires, or social and cultural ties.
 143 This process is enacted by *actors*, who in turn are enabled and constrained in their
 144 actions by applicable *institutions*, i.e., the social norms, cultural customs, laws,
 145 rules and regulations that govern the interaction.
- 146 • A material *substance* or immaterial element that is moved from one location to
 147 another in the course of a teleconnection. It is the only part in a teleconnection
 148 that physically moves (the “data”). Again, the finite set of substance types include
 149 money, energy, goods or materials, biological agents, people, and information or
 150 ideas.



⁴ In emergency management these four fundamental types of physical infrastructure are known as “life lines” and are familiar terms to emergency, land use, and adaptation/resilience planners.

151 **Figure 1: Key Components of a Societal Teleconnection between Two Locations**
152 **(explanation in text)**

153
154 The combination of *structure*, *process* and *substance* result in connection and movement
155 over long distances, often in complex ways and through combinations of mechanisms.
156 Importantly, there is a finite number of physical structures and of types of substances, but
157 a large number of types of processes, and with them come a wide variety of actors and
158 institutions. The latter are involved in establishing, maintaining and sometimes disrupting
159 the physical structure of a teleconnection. They also enact important services as agents of
160 change and as guardians of the causal interconnectivity (and thus as producers,
161 consumers or movers of the substance being conveyed). Actors are also crucial as those
162 who can increase or decrease a community's vulnerability or resilience in the face of
163 disruption originating elsewhere. This basic way of organizing and thinking of
164 teleconnections helps explain how each component exerts its effects, and how climatic
165 changes and climate-driven disruptions can impact communities and sectors across long
166 distances. In essence, climate change and its impacts can:

- 167 • interrupt, modify, reroute or create structural connections;
- 168 • alter, establish, disrupt or eliminate (with the help of actors and/or changed
169 institutional arrangements) the causal processes; and
- 170 • transport at lower or greater quantity, different quality, or speed certain
171 substances or elements (both familiar, new or unknown).

172
173 The resulting wide range of long-distance relationships and interactions can either
174 attenuate or amplify the impacts of far-away events on local circumstances (Pidgeon,
175 Kasperson, and Slovic 2003; Renn 2011). Thus, societal teleconnections should not be
176 understood as inherently good or bad (although the same teleconnection can lead to
177 impacts perceived as positive at one scale, and as negative at another): how exactly they
178 play out will depend on a number of factors, including some that have nothing to do with
179 the teleconnection itself, but with the ability of local communities, sectors, and actors to
180 deal with variable circumstances in their specific context (i.e., preparedness, robustness,
181 and resilience). Of greatest importance, however, may be those far-away events that can
182 exert economic, social, public health or political harm in local contexts.

183
184 **2.2 Some Important Societal Teleconnections**

185 Using the systematic conceptualization of teleconnections introduced above, we have
186 delineated a few crucial teleconnections (Table 1). Several of these connections and how
187 climate change impacts will “use” them to cause far-reaching impacts (i.e., the “long arm
188 of climate change”) are discussed below with their main causal relationships as well as
189 key agents and institutions involved.

190
191 The sample of teleconnections listed in Table 1 is incomplete, several are interrelated and
192 some can be nested within or may result in other teleconnections mentioned. We would
193 argue nonetheless that the ones listed are teleconnections that fundamentally affect the
194 resilience of local communities or even larger regions as many current examples of crises
195 attest (weather-related disasters, the Ebola epidemic, social and military unrest in the
196 Middle East). Below, we discuss some of these societal teleconnections through the lens

197 of our conceptual framework and discuss what communities might consider to begin
198 planning for these teleconnections.

199

200 **[Table 1 is inserted at the end of this document]**

201

202 *Economic Teleconnections: Trade and Insurance*

203 One of the most important long-distance relationships in society results from global
204 economic relationships. A quick look at the labels in clothing or the stickers on food
205 indicates the origin of what we consume locally. While perceived as necessities, these
206 economic ties in a globalized economy make consumers, and intermediaries involved
207 anywhere along the trade chain vulnerable to impacts occurring far from a product's
208 origin. Teleconnections can derive from disruptions to the production process, supply
209 chain, or critical transportation routes and communication channels. Impacts on the
210 perceived desirability of sites or shifts in the labor market due to climate related impacts
211 can ultimately increase production costs and consumer prices.

212

213 In the example of the 2011 Thai floods, examining the impacts to one sector specifically,
214 e.g., hard drives sold by a company such as Western Digital, the *structure* that allowed
215 this teleconnection to occur were the transportation routes and communication channels
216 that established the manufacturing linkage between the Silicon Valley and Thailand. The
217 *process* that drives the teleconnection is the desire for cheap labor and the globalization
218 of manufacturing. The *substances* that should have been transported were hard drive
219 components and subsequent financial transactions based on a completed work flow. The
220 key *actors* directly involved include regulators in Thailand allowing the hard drive
221 producing subsidiary to locate in the floodplain and those at Western Digital (and/or their
222 intermediaries) deciding from where – and where alone – to purchase key equipment for
223 their Silicon Valley firm. Land use plans and regulations, building standards, and disaster
224 preparedness policies and measures are the *institutions* most directly affecting the Thai
225 location, but the "law of supply and demand", shareholder agreements, the drive to ever
226 larger profit margins, indirect economic drivers, and organizational policies and norms
227 (or lack thereof) to downplay safety and disaster preparedness across the trade system in
228 question also contributed to the ultimate impact.

229

230 The Thai Floods resulted in \$15-20 billion in insurance claims (Garside 2012), thus
231 bringing in yet another set of actors, and rippling through the insurance industry with its
232 own set of institutional arrangements. The example highlights the interconnection of
233 trade and economic interests with insurance interests, which is why we integrate them
234 here.

235

236 Importantly, this example of supply chain teleconnections should not be confined to the
237 private sector. Local governments also have their own supply chains, both for their
238 normal operations (e.g., materials and equipment needed in water treatment, fire safety,
239 local infrastructure maintenance) and even more so in the case of emergencies (e.g., food
240 and water, health services, building materials).

241

242

243 *Energy Systems and Markets*

244 Another subset of economic activity, singled out because of its importance in all societal
245 and economic activities, is energy production, transmission and use. Pathways are both
246 direct and indirect, and disruptions can have local, regional, national, and sometimes even
247 international ripple effects. Energy production in one location can be disrupted by climate
248 change impacts and thus directly (through immediate interruptions of supply through
249 brown- or black-outs) or indirectly (through increased energy prices for energy purchased
250 from elsewhere) affect consumers in faraway places. The spatial extent depends on the
251 area served by the affected utilities and on supply redundancies in the system. Climate
252 change impacts on supply may result from extreme heat (e.g., affecting nuclear power
253 plant operations), inland or coastal flooding as sea level increases (power plant
254 operations), or drought (availability of and competition among various users for scarce
255 water resources for hydropower generation, nuclear power, fracking, etc.). Similarly,
256 energy transmission can be disrupted by climate change-related extremes (wildfire, heat,
257 storms, ice). Again, the spatial extent depends on the area served by the affected utilities
258 and on supply redundancies in the system.

259

260 In September 2011, a transmission line tripped due to high heat in Yuma, Arizona, USA
261 – notably a location already adapted to high heat – which led to a chain of approximately
262 20 additional events over an 11-minute period culminating in the shutdown of the San
263 Onofre nuclear power plant in California. The power loss impacted Arizona, California
264 and Mexico and resulted not only in long-distant impacts along the interconnected energy
265 system, but also cascading impacts on other sectors, such as sewage spills and water
266 distribution disruptions in the City of San Diego, USA, impacting more than seven
267 million people (Wilbanks et al. 2012b).

268

269 Using our teleconnection conceptualization described above, the *structures* that initiated
270 this teleconnected event are the transmission lines, transmitters and power stations that
271 connect power generation and use, in this instance, across multiple states. The *processes*
272 underlying the linkage involved the energy market, driven on one level by supply and
273 demand, yet more directly by the decisions of energy producers and traders, and the
274 energy policies and market regulations that affect utilities' decisions. The primary
275 *substance* moved (or rather: no longer moved) was electricity, but as the event unfolded
276 also sewage. As the cascade of events proceeded, different *actors* come to be involved,
277 such as water treatment plant operators, emergency responders and, of course, the
278 affected consumers and businesses.

279

280 With reduced redundancies in the supply system, due to higher electricity demands
281 during heat waves, the most immediate impacts of such a disruption may be only regional
282 or maybe statewide, but energy markets often go beyond state boundaries, thus
283 potentially having far-reaching ripple effects through direct losses and increases in
284 energy pricing (Sathaye et al. 2013). The role of cascading impacts due to
285 interdependencies and a better understanding of the behavioral, ecological, and
286 technological coupling and feedbacks were identified as critical gaps in knowledge in a
287 recent report informing the Third U.S. National Climate Assessment (Wilbanks et al.
288 2012a). In the case of energy transmission and distribution, feedbacks and impacts will

289 be exacerbated in urban environments due to the higher population and increased number
290 of infrastructural interdependencies; what is necessary for efficiency in large urban
291 centers may in turn contribute to a greater risk of cascading impacts (Wilbanks et al.
292 2012b).

293

294 *Population Migration*

295 Migration of people is among the more widely recognized societal teleconnections.
296 Migration always has multiple reasons. People tend to not wish to migrate away from
297 their ancestral or cultural home unless faced with complex and extreme conditions
298 affecting their ability to maintain their security (O'Brien and Barnett 2013; Birkmann et
299 al. 2013; Black, Adger and Arnell 2013). Climate change in this context has been
300 conceptualized as a "threat multiplier" (CNA 2006) that may aggravate already
301 challenging circumstances to the point where people will consider leaving home. Such
302 aggravated threats may come from climate change impacts such as reduced water
303 availability with negative impact on the ability to sustain minimal subsistence
304 requirements or grow food for external markets; sea-level rise and related repeated
305 coastal flooding, progressive coastal erosion, permanent inundation, and saltwater
306 intrusion undermining public safety and the ability to maintain land, communities,
307 economic activities or agriculture in place; or any number of other direct and indirect
308 impacts of a climate-altered environment. Migration in the context of climate change is
309 considered a transformative adaptation (Kates, Travis and Wilbanks 2011).

310

311 A 2009 report by the International Organization for Migration (IOM) noted the
312 distinction between migrations due to sudden, extreme events versus slow-onset
313 environmental impacts (Laczko and Aghazarm 2009). For instance, after Hurricanes
314 Katrina and Rita, a large proportion of the city of New Orleans was evacuated and
315 200,000 homes were either destroyed or severely damaged, resulting in several hundred
316 thousand city residents without a place to return to. By October 2006, ~65% of evacuees
317 had returned to their pre-hurricane addresses and 73% had returned to the counties in
318 which they lived prior to the hurricanes (Groen and Polivka 2008). In contrast to sudden
319 events, migration from slow environmental degradation, which is expected to increase in
320 the future, may have larger and longer lasting impacts and affects more people. Between
321 1978 and 2008, 78 million people were affected by storms compared to 1.6 billion people
322 affected by gradual environmental changes (EM-DAT 2009).

323

324 The *structures* through which the teleconnection is established are the legal or illegal
325 transportation routes, and the *substance* being moved are people, but the reasons for
326 migrating, the causal *processes*, and thus the actors and institutions involved, can vary
327 significantly. In the case of an extreme event, the causal *process* may be the need for
328 temporary safety and shelter, involving evacuees, first responders, and those providing
329 temporary refuge, while people migrating permanently away from an environmentally
330 degraded home region may need relocation/housing assistance, help with finding new
331 permanent work, assistance with socio-cultural integration and so on. Such help can take
332 many forms, and can both help or hinder in maintaining community functioning and
333 ecological integrity, which in turn increase local resilience in the face of other future
334 stresses. For instance, Hecht and Saatchi (2007) describe how in El Salvadore,

335 outmigration remittances allowed relatives who stayed behind to be able to buy food,
336 rather than utilize slash and burn agricultural practices to grow their own food, thus
337 contributing to forest resurgence instead of further deforestation. In both instances of
338 short-term and permanent relocation, migration has immediate and lasting impacts on the
339 affected regions as well as permanent demographic, economic, health, and socio-cultural
340 impacts on the source and destination regions (McIntosh 2008; Hori and Bowman 2008).

341

342 Considering the teleconnection of people via migration in local adaptation planning
343 requires that a local jurisdiction develop a better understanding of their community's
344 demographics and socioeconomic conditions to assess who may be mobile, immobile and
345 most at risk of being dislocated (e.g., Black et al. 2013) and their community's capacity to
346 absorb temporary or permanent new residents. For instance, sea-level rise – in
347 combination with other complex, non-environmental processes – is expected to cause
348 outmigration over time from low-elevation island nations (e.g., Pigué 2012; Marino
349 2012; McLeman and Hunter 2010). Migrants may seek new homes in the U.S., Australia
350 or New Zealand, where there are already established migration pathways, kin or cultural
351 communities. For communities that already have sizable populations of former island
352 residents residing there, it is reasonable to expect additional influx as sea level continues
353 to rise (e.g., Perch-Nielsen et al. 2008). Anticipating this increase in immigration allows
354 the jurisdiction to identify municipal and community needs and resources to adequately
355 prepare. A slow-onset impact, such as sea-level rise, also illustrates that some
356 teleconnections can play out in advance of the actual climate change impact manifesting,
357 i.e., people may decide to abandon a location due to the anticipated impact prior to it
358 actually becoming uninhabitable (Kiribati's "Migration with Dignity" plan, aimed at
359 establishing expatriate communities off-island for i-Kiribati people to join on their own
360 terms instead of waiting for a refuge problem later is one example [Wyett 2013]).

361

362 *Human Health*

363 Our final example focuses on health. Human health and well-being are the result of
364 complex interactions of social, economic, occupational, lifestyle, psychological, cultural
365 and genetic factors. This is a clear case of individual to global interconnectivity.
366 McMichael (2013) discusses the correlation of climate change and globalization in
367 human health. Among those discussed, climate change can have impacts on human health
368 through the spread of disease vectors; further spread of vectors due to migratory
369 displacement; impacts on fresh- and coastal water quality; impacts on air quality; impacts
370 on food production (Luber et al. 2014).

371

372 The SARS epidemic of 2003 highlights how a virus originating in one corner of the
373 world (in this instance, the Guangdong Province in China) can quickly spread globally
374 (with cases reported in Canada), due to international trade and travel (Adger, Eakin and
375 Winkels 2009). In this instance, the *structures* leading to the linkage were the existing
376 ground and international air transportation infrastructure, and – importantly – the global
377 communication infrastructure that carried both the threat and warnings ahead of the threat
378 around the world. The causal *processes* driving the teleconnection were related to trade
379 and travel and the *substance* transported was the SARS virus (and secondarily warnings
380 and information about the health threat). The *actors* involved included those affected by

381 the disease, health care providers and local, national and international health system
382 observers (WHO and national centers for disease control) under the international and
383 intra-national agreements and guides for public health emergency response.

384
385 The communication of these sorts of teleconnected, global pandemics is expected to
386 increase with climate change. However, the enhanced flow of information also allows the
387 world to respond quickly to potential outbreaks, epidemics and disasters and there is
388 increased coordination in vaccination programs and systems to respond to infectious
389 disease (McMichael 2013). Thus, human health provides an excellent example of how
390 teleconnections connect the local to the global and can both attenuate and amplify
391 different situations.

392

393 **3 Identifying and Prioritizing Possible Research Questions**

394 The types of teleconnections introduced above are easily exemplified, but have not yet
395 been assessed systematically, neither globally nor nationally nor locally. While a range of
396 studies have used the broader tele-coupling framework on questions of land use,
397 ecosystem services, and sustainability more broadly (e.g., Challies et al. 2014; Liu et al.
398 2013; Güneralp et al. 2013; Seto et al. 2012), few studies have attempted to do so in the
399 context of climate change (e.g., Perdinan and Winkler 2013; Adger, Eakin and Winkels
400 2009). These global connections have been largely neglected in U.S., and other national
401 and global climate assessments to date. The importance of formally assessing such long-
402 distance linkages, however, has been recognized in the Third U.S. National Climate
403 Assessment (NCA) and in Working Group II of the IPCC's Fifth Assessment (e.g.,
404 Oppenheimer et al. 2014; Correll et al. 2014; Wilbanks et al. 2012a) and is an important
405 area for further improvement in future assessments. Below we highlight some key areas
406 ripe for further investigation.

407

408 *Quantification of Teleconnected Impacts*

409 Quantifying the impacts of teleconnections is actually quite complex. The case of the
410 2011 Thai floods may be rare in that there was a fairly direct link between economic
411 losses and companies whose manufacturing plants were flooded and ensuing cascading
412 impacts. In many instances, however, societal teleconnections are more difficult to trace
413 and/or are deeply interwoven, thus making analyses difficult. Quantification of these
414 interconnections requires a systems modeling approach that can work at both the local
415 and globally-integrated scale in order to catch the nuance of place-based repercussions of
416 global linkages (Wilbanks et al. 2012b, Perdinan and Winkler 2013). Moreover, when
417 dealing with impacts to trade, it can be difficult to get information since data typically are
418 proprietary or considered trade secrets.

419

420 *Attributing Impacts to Climate Change Versus Other Driving Forces*

421 For many societal teleconnections, it will be difficult to point to a clear or singular cause
422 and effect. For instance, the Arab Spring cannot be solely attributed to wheat shortages in
423 China or Russia (Sternberg 2013, Werrell and Femia 2013). Similarly, it may never be
424 possible to pin a violent conflict singularly on climate change impacts, yet multiple,
425 complex teleconnections between the threat multiplier of climate change and national
426 security, regional stability and violent conflict are of growing concern to the military

427 (e.g., CNA 2006). In-depth studies of cases such as these can help sort out and better
428 understand the significance of different societal teleconnections, informing the
429 development of systematic assessment models.

430

431 *Identification of Most Important Linkages*

432 The linkages between and among different societal teleconnections are complex, but
433 ubiquitous. It is therefore critical to identify "the most important" linkages for different
434 types of climate change impacts. Some may dominate regardless of context whereas
435 others may play out differently depending on context. Under what circumstances do
436 which of these linkages matter the most? This may not be a simple question to answer in
437 light of the various components of vulnerability: exposure, sensitivity and adaptive
438 capacity all affect how severely a climatic change or extreme event manifests locally, and
439 each of these components of vulnerability is affected differently by societal
440 teleconnections (e.g., global economic forces, cultural teleconnections via education and
441 knowledge flows co-determine local adaptive capacity; legal and governance structures
442 shape capacities and barriers to adaptation). The answer to these questions, however, will
443 be of critical value to adaptation planners in public offices as well as in private firms who
444 may otherwise be overwhelmed by the universe of potential teleconnections.

445

446 *Impact of Increased Urbanization*

447 With an increasing number of people choosing, or having no choice but, to live in urban
448 areas, the impacts of societal teleconnections have the potential to be compounded. As in
449 the example of the San Onofre power plant shutdown in 2011, seven million people were
450 impacted by that 11-minute series of events. Identification of urban interdependencies
451 and redundancies, and how those could be impacted with increasing population, is critical
452 for effective disaster preparedness and adaptation.

453

454 *Impact on Resilience*

455 How is local resilience enhanced or diminished through societal teleconnections and how
456 can communities use this understanding in their efforts to prepare and plan for the long
457 arm of climate change? In the 2011 Thai floods, for instance, production and sales for
458 Silicon Valley companies (and elsewhere) were temporarily crippled because there was
459 no redundancy in their supply chains. Building diversity into business operations may
460 reduce economic efficiency in the short-term but buffer against major disruptions and
461 economic losses over the medium to longer term. How can such diversification strategies
462 be applied to local communities? How do legal, communication, social and cultural
463 teleconnections simplify or complicate adaptation options?

464

465 **4 Conclusion**

466 In summary, societal teleconnections are important considerations for locally-based
467 climate change vulnerability assessments and adaptation planning in the public and
468 private sector. While not necessarily understood in technical terms ("teleconnections"),
469 the high-profile flooding in Thailand has had a major awareness-raising impact on private
470 firms, which now increasingly assess the impacts of climate change on their supply
471 chains. By contrast, societal teleconnections are not yet included in local vulnerability
472 assessments or adaptation planning, largely because they are not recognized or, if they

473 are, they are considered too complex to assess or manage. Work to date on tele-coupling
474 has highlighted the complex natural-human systems interactions, yet most communities
475 do not have resources or capacity to conduct such computationally-demanding studies.
476 We have therefore proposed a simple and pragmatic but systematic framework for better
477 identifying, understanding, and thus planning for, societal teleconnections. In our
478 examples, we also focused on teleconnections that are crucial to basic community
479 functioning and thus relate most easily to land use planning and resource management,
480 basic service provisions, and emergency preparedness, which is where most adaptation
481 planning currently resides.

482
483 The research questions we have identified certainly do not exhaust the research agenda
484 on societal teleconnections, but they delineate key elements of further examination that
485 would significantly improve our understanding of local vulnerabilities to climate change
486 in a deeply interconnected world. Answers to these types of research questions would
487 also support a needed addition in focus to adaptation planning in urban, business or
488 resource management contexts that expands the perspective from the local to the relevant
489 global. Building our understanding of societal teleconnections, in this way, would help
490 counteract some persistent but misleading slogans about vulnerability and adaptation:
491 neither the context of vulnerability nor all adaptation is ever just local. It is glocal.

492 493 494 **Acknowledgments**

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497 reviewers and the participants in a session on supply chain risk at the California
498 Adaptation Forum in August 2014. We have appreciated all their inputs, but take full
499 responsibility for the views expressed here.

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Table 1. List of eight crucial teleconnections, their structures, and causal processes (including the involved actors and institutions) that convey an element or substance.

Teleconnection	Structure/Conveyor	Cause/Process	Element/Substance
Trade and economic exchange	Transportation routes, communication channels	Market exchange, business activity, globalization	Goods, services, raw materials
Insurance & Reinsurance	Insurance Policy	Legal requirements, risk tolerance	Money
Energy Systems	Transmission lines connecting power generation (power plants) and consumption	Supply & demand markets	Electricity, oil, natural gas, etc.
Human Health	Air transportation, trains, roads, ocean- or river-based ship transportation	Trade, human travel (for business or tourism)	Disease carriers (vectors)
Population migration	Legal or illegal migration routes (by land, sea, air)	Seasonal migration, permanent, resettlement, urbanization, conflict etc.	People
Communication systems	Satellite-based, underground, or underwater transmission lines, routers, computers	Exchange via mainstream or social media	(Digital) information, data, knowledge, imagery
Legal obligations	Nations, states, business entities, tribes, etc.	Treaties, laws, regulations, statutory rights	Regulated exchange of goods, raw materials, services, money, information
Strategic & military interests	Nations, ethnic entities, tribes (via communication, population, economic, and transportation routes)	Political, ethnic or religious relationships, tensions or conflicts	People, military personnel, money, military logistical equipment
Cultural ties	Nations, ethnic groups, subgroups (via communication, population, economic, and transportation routes)	Deeply rooted, evolved, inherited or adopted practices, maintenance of identity, sense of belonging	Ideas, habits, ideals, rites, customs, and activities

688 **The Long Arm of Climate Change: Societal Teleconnections and the Future of**
689 **Climate Change Impacts Studies: Supplementary Material**

690
691 **Susanne C. Moser**
692 **Juliette Finzi Hart**
693

694 **Background**

695 To provide more context to the concept of *societal* teleconnections, we offer a brief
696 overview on the more commonly understood, discussed and studied physical
697 teleconnections and their corresponding societal impacts. In the atmospheric sciences, a
698 teleconnection is defined as “a linkage between weather changes occurring in widely
699 separated regions of the globe...the name refers to the fact that such correlations suggest
700 that information is propagating between the distant points through the atmosphere.” Jet
701 streams and oceanic currents act as “bridges” and “tunnels,” respectively, that carry
702 changes in atmospheric, oceanic, or land patterns along the length of the teleconnection,
703 leading to impacts thousands of miles away (Alexander et al. 2002, Liu and Alexander
704 2007).

705
706 The most globally significant physical teleconnections are generally those that originate
707 in the ocean or atmosphere (e.g., ENSO). Beyond the direct physical impacts, sometimes
708 extensive and expensive environmental and societal impacts can ensue in their wake. The
709 negative impacts of El Niño events on the Peruvian fisheries and on coastal regions of the
710 U.S. West Coast illustrate the point: During an El Niño-event, the southwest of the U.S.
711 experiences cooler and wetter winters, higher sea levels along the West coast, and – as a
712 result of both – typically witnesses severe coastal storms and flooding. El Niño events in
713 the winters of 1982-1983 and 1997 were particularly damaging for Southern California,
714 during which major infrastructure and coastal communities were badly damaged from
715 flooding, increased storm surge, and major coastal erosion (Lajoie and Mathieson 1997;
716 Griggs 1994). Compounding these negative impacts, the increased precipitation across
717 the Southwest during such years can lead to high plant growth and accumulation of fuel
718 that makes forests more vulnerable to fire during subsequent La Niña events (Kitzberger
719 et al. 2001). Moreover, a number of recent studies in Southern California have examined
720 the theoretical connection between El Niño events and the spread of West Nile Virus due
721 to the potentially expanded habitat of the mosquito that carries the disease (Heft and
722 Walton 2008, Cheng2009). Thus, an El-Niño event can have broad implications for local
723 economies, infrastructure extreme events and related disaster management, and for
724 human health.

725
726 Beyond oceanic teleconnections, freshwater/atmospheric teleconnections also occur. For
727 instance, it was found that due to hydroclimatological teleconnections, North American
728 river flows in September correlate significantly with Northern European river flows in
729 October (Kingston et al. 2006). In the western U.S., there is strong evidence that winter
730 and spring snow cover extent over North America affects monsoonal variables in the
731 desert Southwest of the U.S., such as the total amount and frequency of precipitation,
732 hail, wind and severe weather (Hawkins et al. 2002).
733

734 **Land Use and Environmental Teleconnections**

735 Teleconnections can occur across smaller regions and between the atmosphere and land
736 and, in some instances, land cover changes can alter atmospheric circulation. Several
737 studies have shown a correlation between deforestation in the tropics and precipitation in
738 mid- and high-latitudes winters (Gedney and Valdes 2000; Roni and Werth 2005). This
739 occurs due to reductions in large-scale circulation, which impacts the transfer of moisture
740 throughout the atmosphere. Similarly, irrigated farmlands in the U.S. plains were found
741 to impact the weather for the high Rocky Mountains due to changes in relative humidity
742 in the atmosphere (Chase et al. 1999) and to increase summer precipitation (Moore and
743 Rojstaczer 2002). Similar changes have been observed at the scale of micro-climates
744 (e.g., urban land use changes affecting temperature and wind fields).

745
746 Beyond climatic teleconnections, the natural environment features many other long-
747 distance connections. Dispersal of dust, volcanic ash and other particles on the wind,
748 flows of surface or ground water (and associated material flows), and species migration
749 and dispersal are the most important other teleconnection mechanisms (e.g. Bauer and
750 Hove 2014). For example, rivers transport sediments and nutrients from the source to the
751 end point (generally the sea). While this is a natural process, overloading of nutrients
752 along the flow can lead to detrimental environmental impacts at the river terminus or
753 along the way. For the U.S., the most well-known example of this is agricultural run-off
754 along the Mississippi River, which discharges into the Gulf of Mexico and is a key
755 contributor to the biological dead zone (Turner et al. 2008). Runoff of nutrients and
756 pollutants from streams and rivers into enclosed bays or estuaries is of particular concern
757 (Moser, Williams and Boesch 2012). As another example, in the animal kingdom, animal
758 migrations have exceedingly complex cascading trophic, energetic, and ecological
759 impacts that can even range to global in scale (Bauer and Hove 2014). For instance, many
760 species of old-world songbirds, which breed in northern Europe and then return to sub-
761 Saharan Africa, harbor parasites from both their breeding and wintering ranges and thus
762 potentially transmit these parasites from one to the other locale (Bauer and Hove 2014).
763 The Northern fulmar breeds along the Arctic coastlines and migrates to more southerly
764 regions outside of breeding season; the fulmars accordingly fertilize nutrient-poor
765 terrestrial systems in the Arctic with nutrient-rich excrement derived from their southern
766 habitats.

767

768 **Relevance to Management**

769 Physical teleconnections, whether global in scale such as ENSO or more localized such
770 as snow cover extent in the U.S. Rocky Mountains, have direct environmental and
771 societal impacts. Understanding this relationship has already lead to better forecasting,
772 which, in turn, supports better preparation for and management of these impacts.
773 NOAA's Climate Prediction Center routinely monitors several atmospheric/oceanic
774 teleconnections to predict climate and weather patterns for the U.S. and North America.
775 Better understanding the link between snow cover extent and monsoon season, for
776 example, could allow for seasonal forecasting of start and duration of monsoon seasons,
777 allowing managers in the southwestern U.S. to better plan for either intense and
778 damaging flash flooding or drought conditions.

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839 **Supplementary Literature**

840 In the course of our research, we found interesting and relevant articles that we were not
841 able to include in the published text. We include them here for those interested in further
842 reading.
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