

The influence of climate and weather on high-impact fires in Russia and resultant changes in ecosystems

Amber J. Soja, Brian Stocks, David J. Westberg, Nadezda Tchebakova, Elena Parfenova, Ji-Zhong Jin, Douglas J. McRae, Ludmila Buryak, Vladislav Konzai, Olga Kalenskaya, Elena Kukavskaya, Al Pankratz, Susan Conard, Galina Ivanova, Johann Goldammer, Paul W. Stackhouse Jr. and Anatoly I. Sukhinin



**Environment
Canada**

**Environnement
Canada**



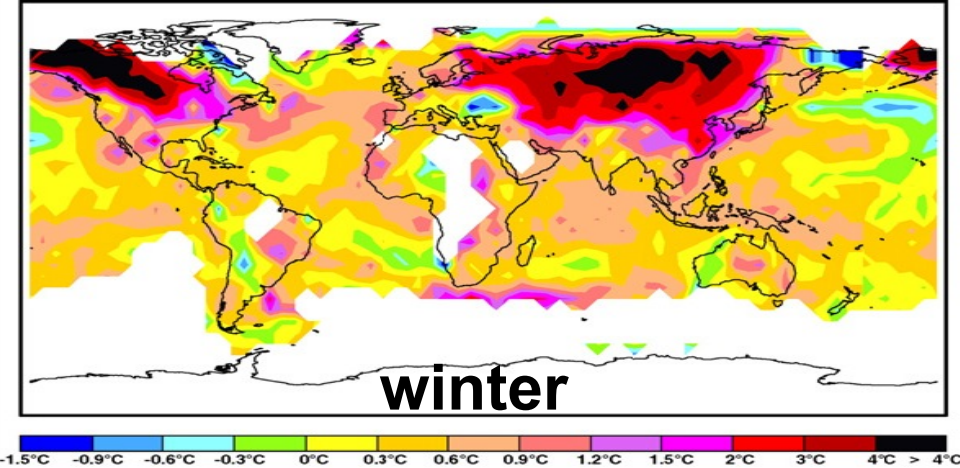


In Memory of the vibrant life and work of Anatoly Ivanovich Sukhinin

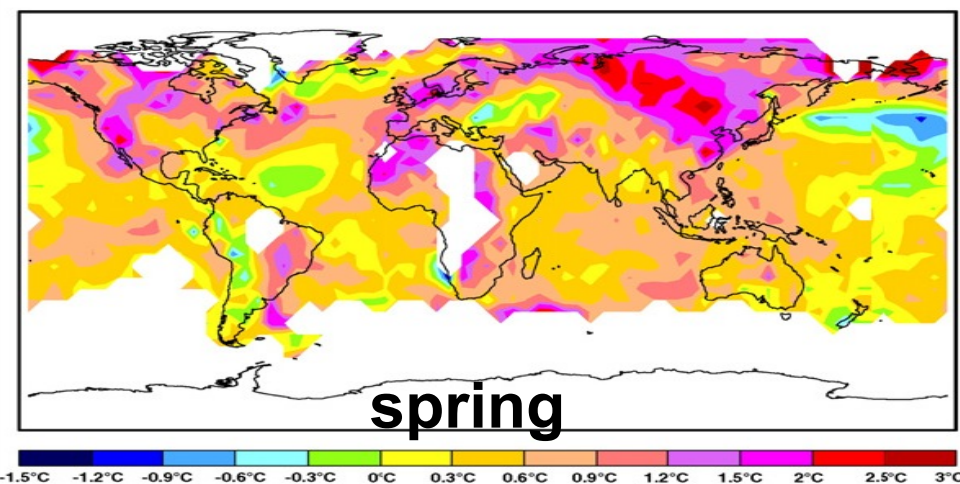
Anatoly argued that not only were catastrophic fires increasing but that catastrophic fires fed back to and influence local and synoptic-scale meteorology.

We invite you to leave a note of remembrance for yourself and Anatoly's friends and family at:

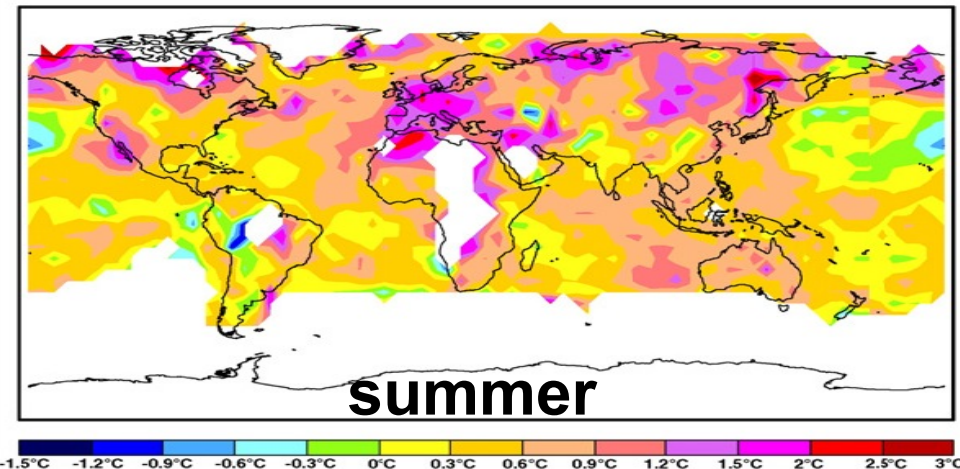
**[http://memorialwebsites.legacy.com/
AnatolyIvanovichSukhinin/homepage.aspx](http://memorialwebsites.legacy.com/AnatolyIvanovichSukhinin/homepage.aspx)**



Left - Mean seasonal temperature changes 1965 to 2004 [Groisman et al., 2007; Jones and Moberg, 2003, updated].

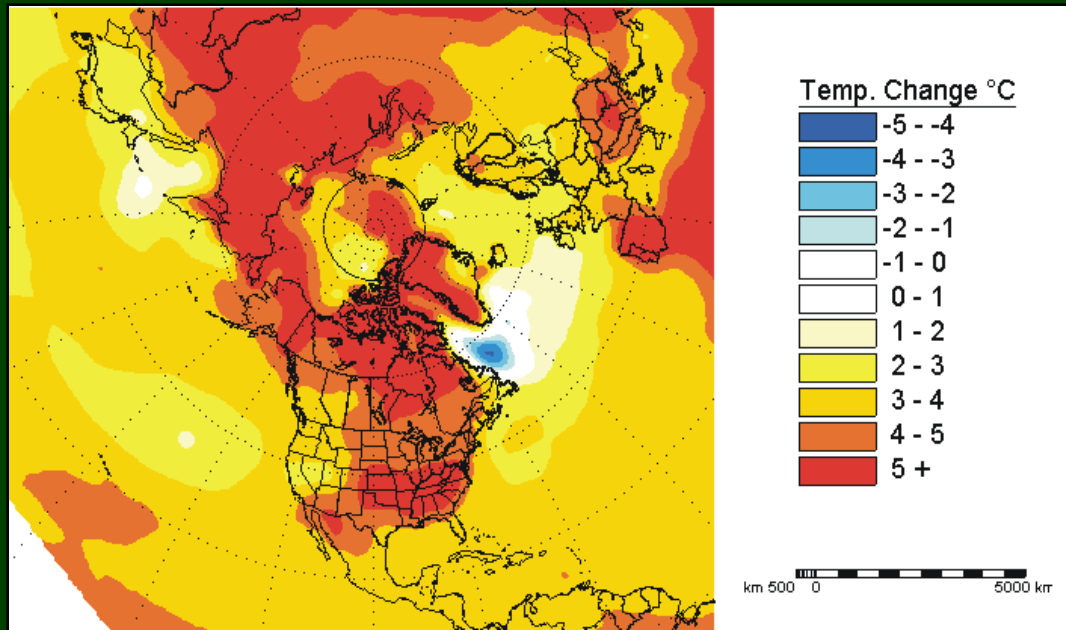


Mean global air temperature has increased by 0.74°C (range $0.56\text{--}0.92^{\circ}\text{C}$) from 1906 to 2005 (IPCC 2007).



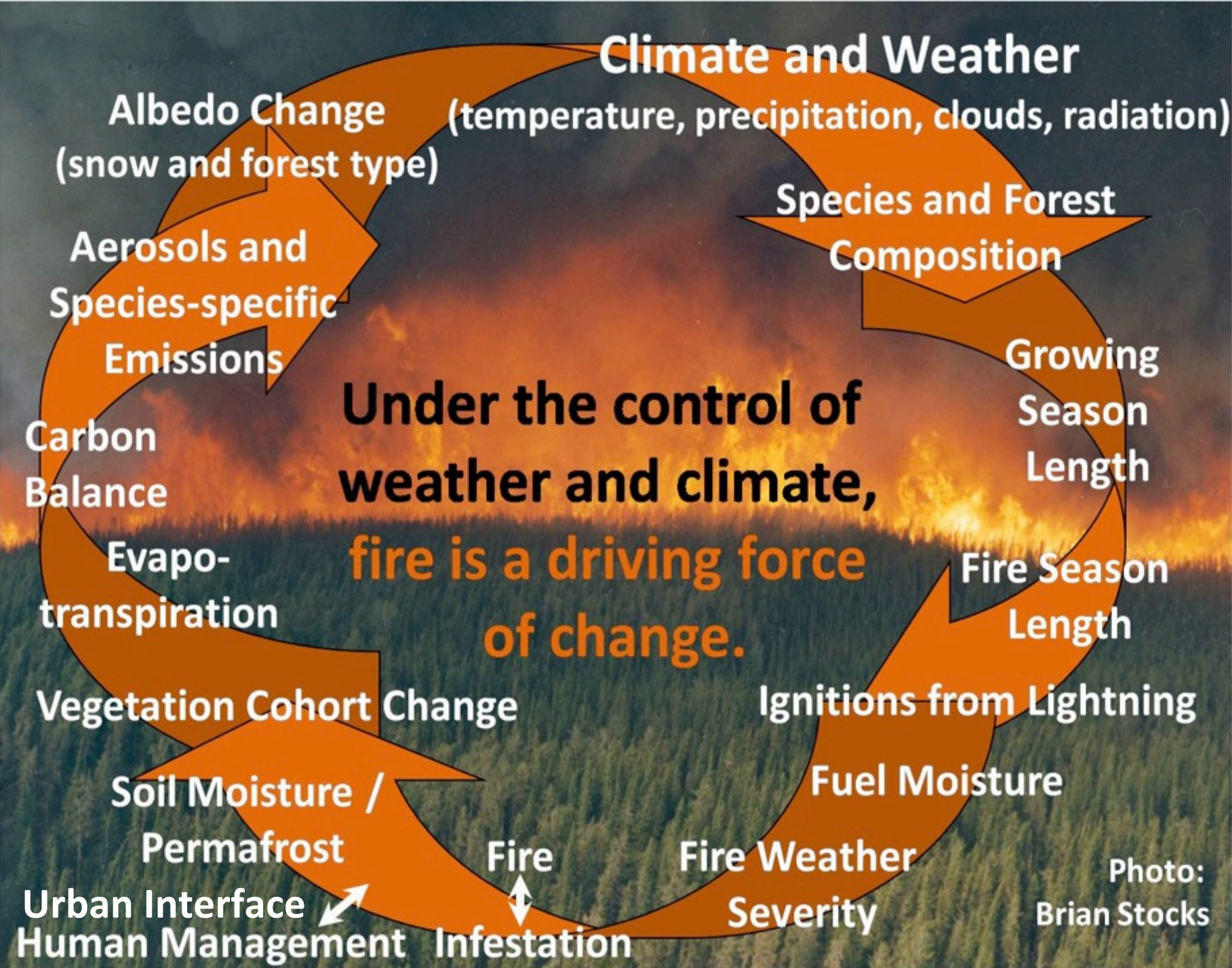
Temperatures are increasing, particularly in the Northern Hemisphere winter and spring, which leads to longer growing seasons, increased potential evapotranspiration and extreme fire weather.

Climate Change Realities and Projections

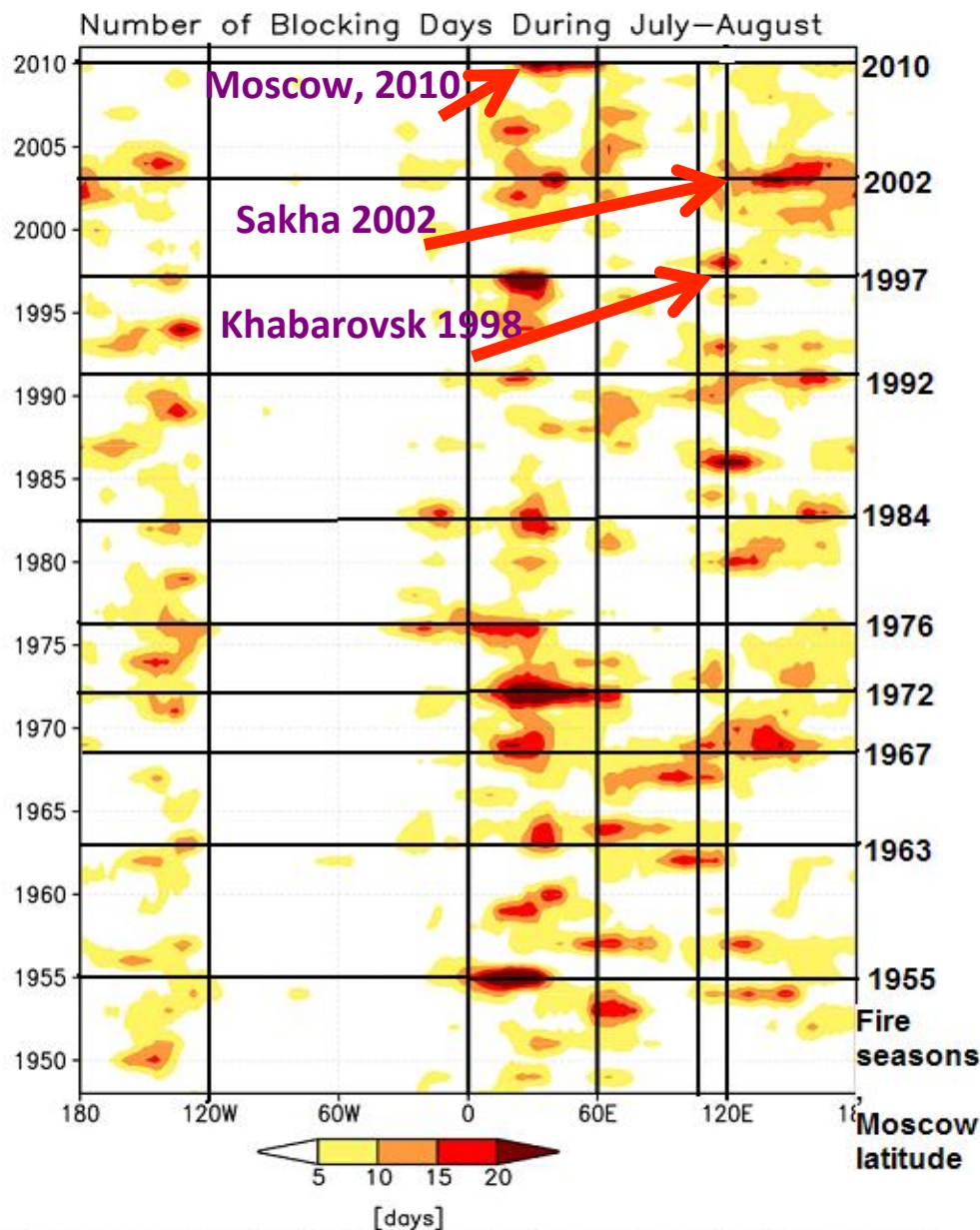


**Predicted
temperature
increase
2080-2100**

- Ocean General Circulation Models (AOGCM) project 1.8–4 °C (range 1.1–6.4 °C) increase in global mean temperature by 2100 (IPCC, 2007).
- Temperature increases are already evident in the Northern Hemisphere, particularly in the winter and spring and at high latitudes.
- Greatest increases will be at high latitudes, over land and in the winter/spring.
- Projected increases in extreme weather and extreme fire weather
- Precipitation projections are less certain



Number of Blocking Days: Regularities in CATASTROPIC fires



Krasnojarsk -1979, 1985, 1986, 1996, 2006

Khabarovsk – 1954, 1968, 1976, 1988, 1998

Evenkia – 1972, 1977, 1982, 1984, 1986, 1994, 1996, 2006

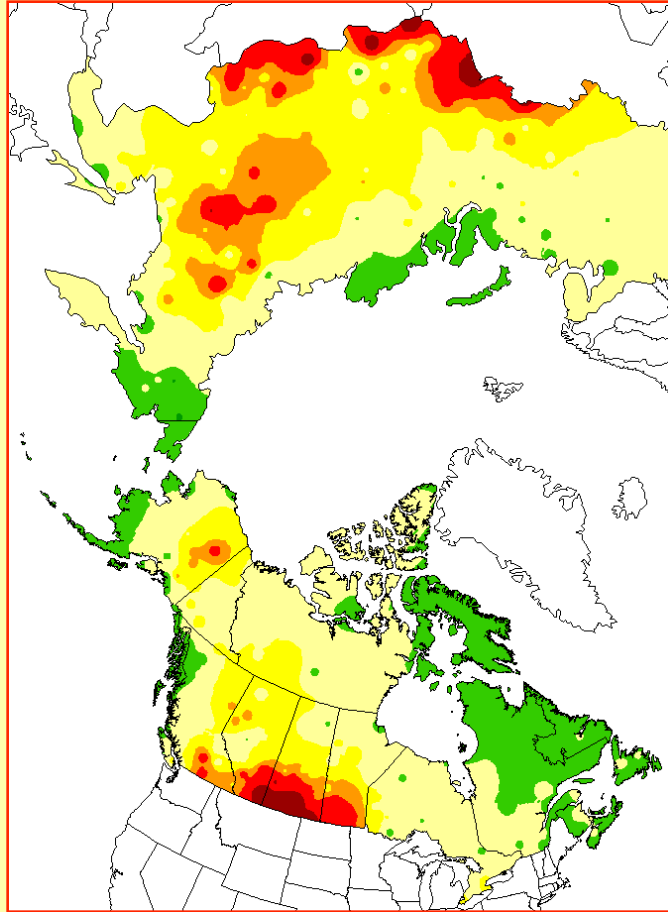
Sakha, formerly Yakutia – 2001, 2002, 2008, 2010

Transbaikalia (Irkutsk, Burjatia, Chita, Amurskaya) – 1987, 2003, 2007, 2008

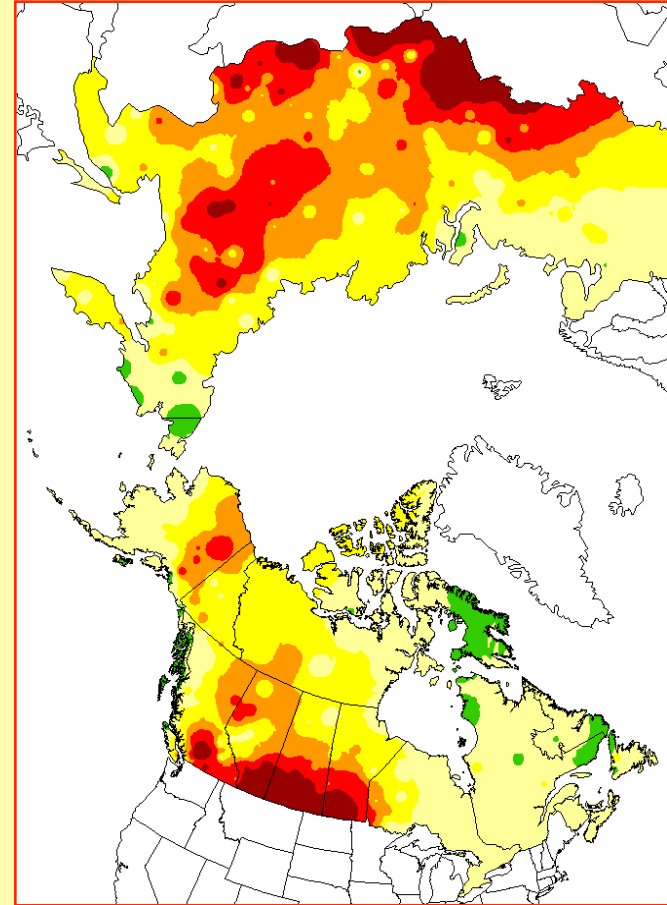
European Russia (Volga river basin) – 1921, 1936, 1946, 1955, 1963, 1967, 1972, 1976, 1984, 1992, 1996, 2002, 2010

(Modified from Anatoly Sukhinin based on Hoerling et al.)

Role of Future Climate Change



Historical Fire Weather



GCM: 2X CO₂

A close-up photograph of a tree trunk with a bird's nest made of twigs and moss.

**Relative to fire regimes, what is expected?
Under current climate change scenarios...**

**Increased fire season length (in boreal zones
up to 51 days, average 30 days)**

(Street 1989; Wotton and Flannigan 1993;
Stocks *et al.* 1998)

**Increased fire weather severity
(46% boreal average)**

(Street 1989; Flannigan and Van Wagner 1991,
Stocks *et al.* 1998)

**Boreal forest fire frequency and area burned
are expected to increase (25 – 50%)**

(Overpeck *et al.*, 1990; Flannigan and Van Wagner 1990, 1991;
Wotton and Flannigan 1993; Stocks *et al.* 1998, 2000;
Flannigan *et al.* 2001).

Increased ignition from lightning (20-40%)

(Fosberg *et al.* 1990, 1996; Price and Rind 1994)

Weather, Climate and Fire are Intimately Linked

Wildfire maintains age structure, species composition, and the floristic diversity of boreal forests by resolving the beginning and end of successional processes (Zackrisson 1977; Van Wagner 1978; Heinselman 1981; Antonovski et al. 1992).

Synoptic weather patterns are the major regional factor controlling the occurrence of fire. (Stocks and Street 1982; Pastor and Mladenoff 1992)

Boreal forest communities are particularly responsive to climate change. (Stocks and Street, 1982; Clark 1988; Payette and Gagnon 1985; Flannigan and Harrington 1988; Sirois, 1992)

Wildfire maintains stability and diversity in boreal forests in synchrony with the climate, or wildfire can be a mechanism by which forests move more rapidly towards a new equilibrium with the climate. (Soja et al. 2007; Tchebakova et al. 2011)

Two major forces are driving this potential altered state?

Humankind



Increasing human population and Wildland Urban-Fire Interface (WUI)

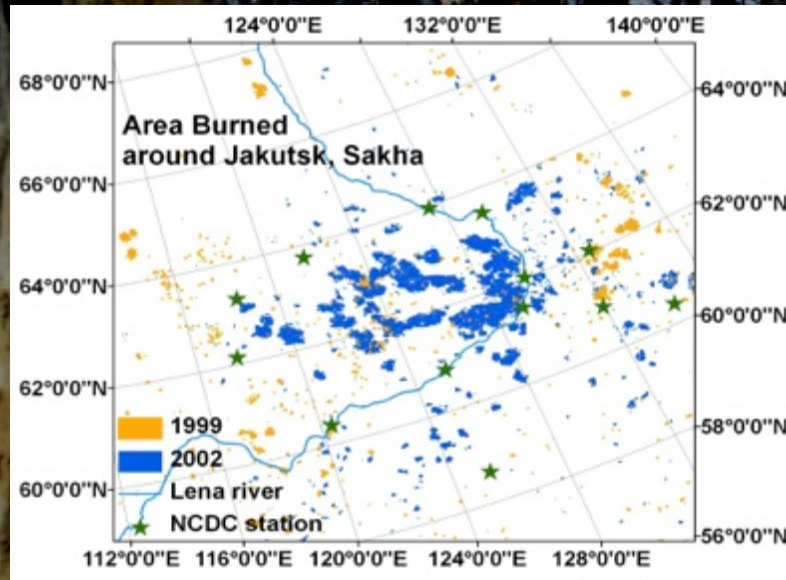
Increasing Risk



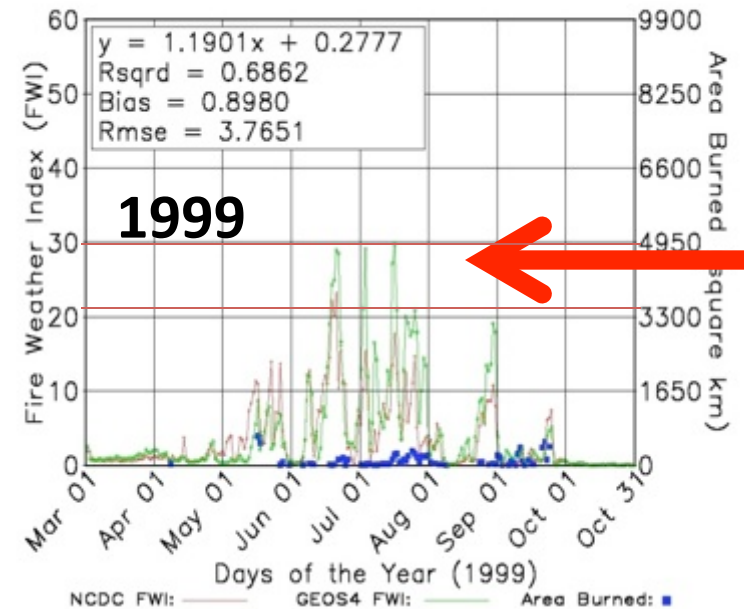
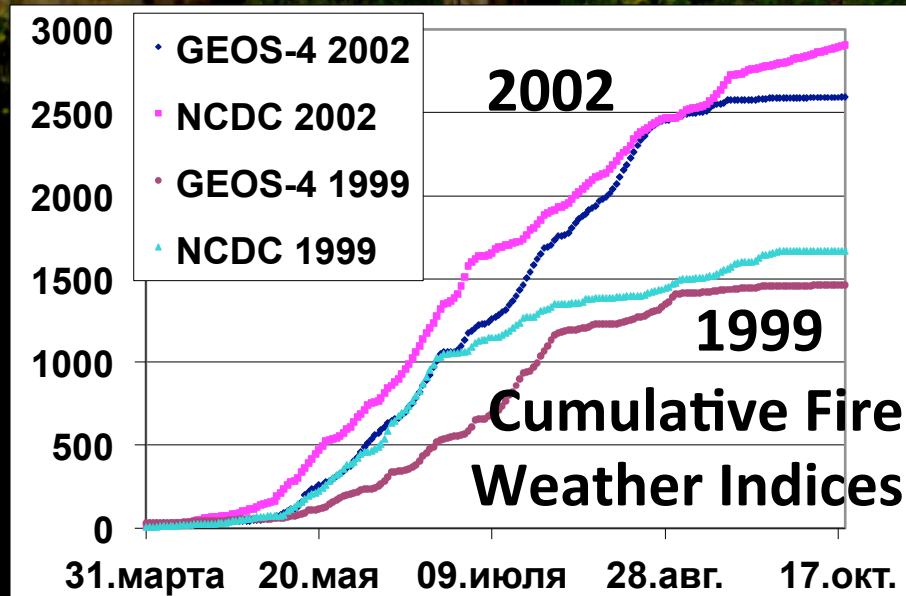
Increasing Fire Danger Conditions



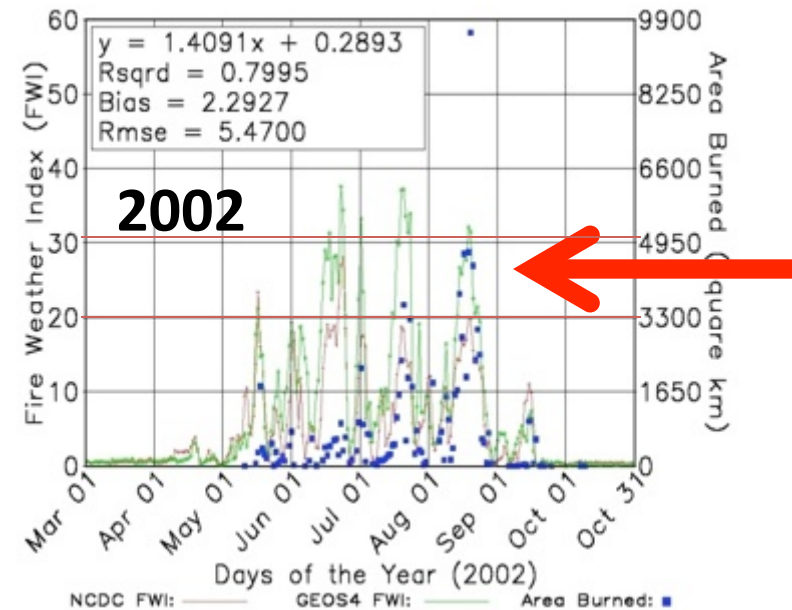
Comparison of normal fire year (1999) and an extreme fire year (2002).



**Yakutia
Sakha
Siberia
5 M ha
burned
in
2002**



Burned area is overlaid in blue

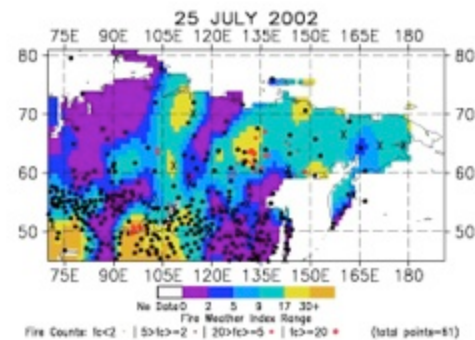
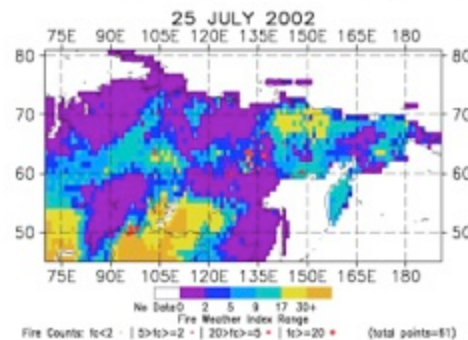
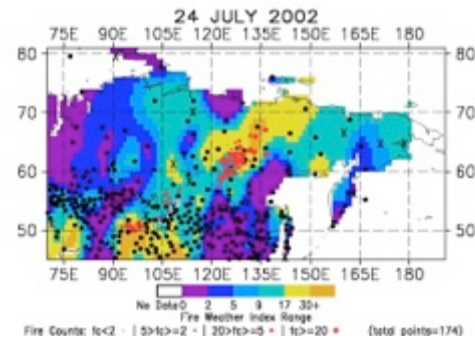
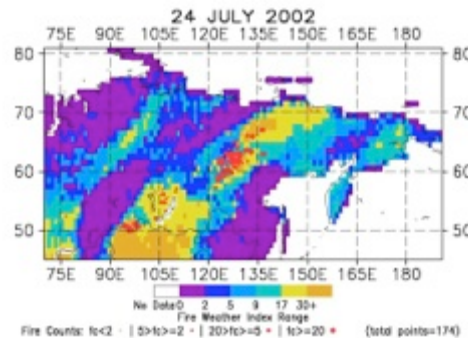
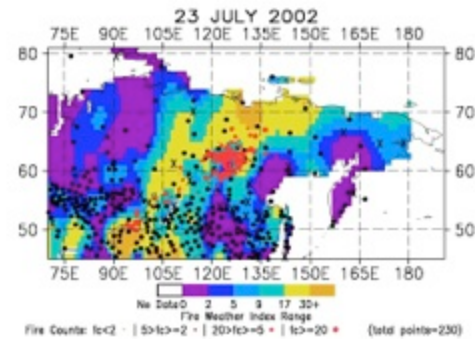
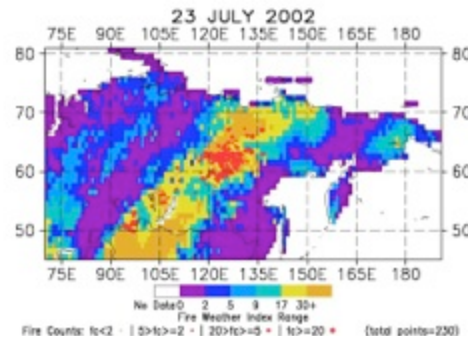
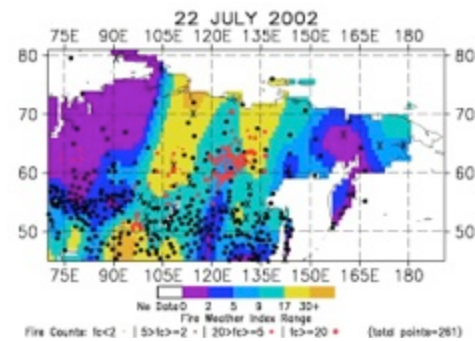
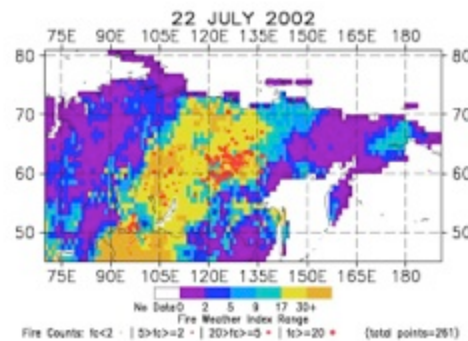


Comparison of large-scale GEOS-4-reanalysis and National Climate Data Center (NCDC) station-interpolated Fire Weather Indices (FWI).

Black dots - station locations; X
stations that did not meet the
minimum 75% (daily observations) /
60% (monthly observations) reporting
criteria. Fires are shown in red.

~ 74% of the cells contain 1
category FWI difference or less;
~ 18% - 2
cells diff.; ~ 7% 3 cells.

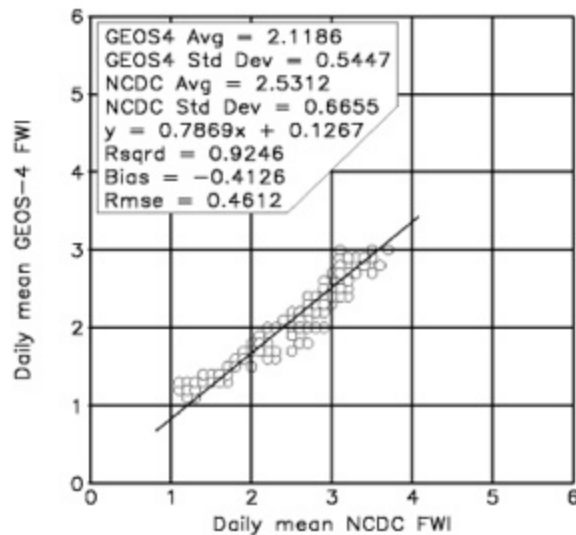
Disagreement- at edges,
southern boundaries & where
surface stations sparse.



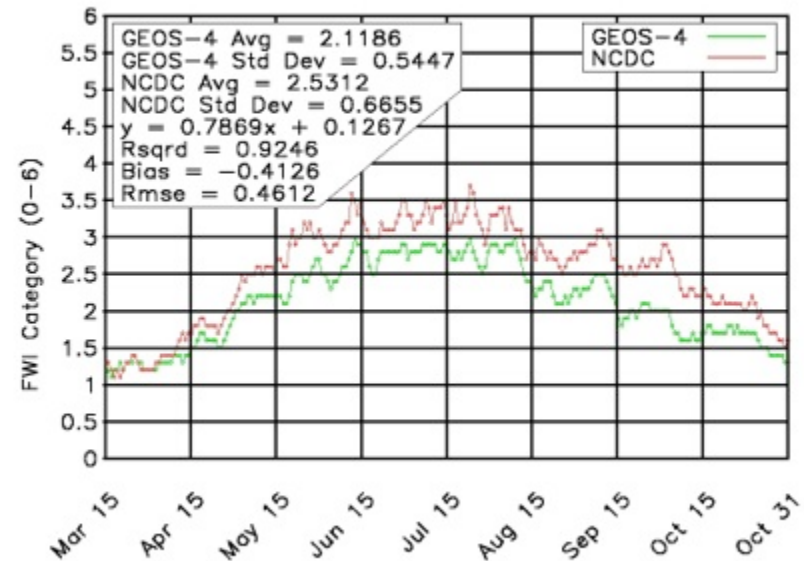
The GEOS-4 and NCDC FWI correlate well spatially and temporally at station, regional and continental scales(3 years of daily data analyzed).

Daily time series of the mean domain GEOS-4-reanalysis and NCDC-interpolated FWI for 1999.

The GEOS-4 and NCDC FWI correlate resulting in overall R^2 values of 0.93 in 1999, 0.90 in 2002 and 0.96 in 2004.



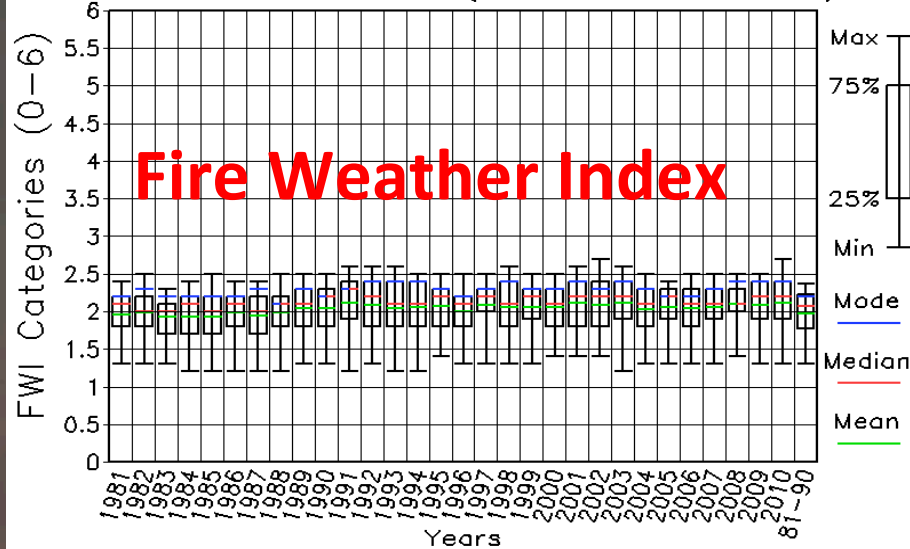
**Scatter
Plot
1999**



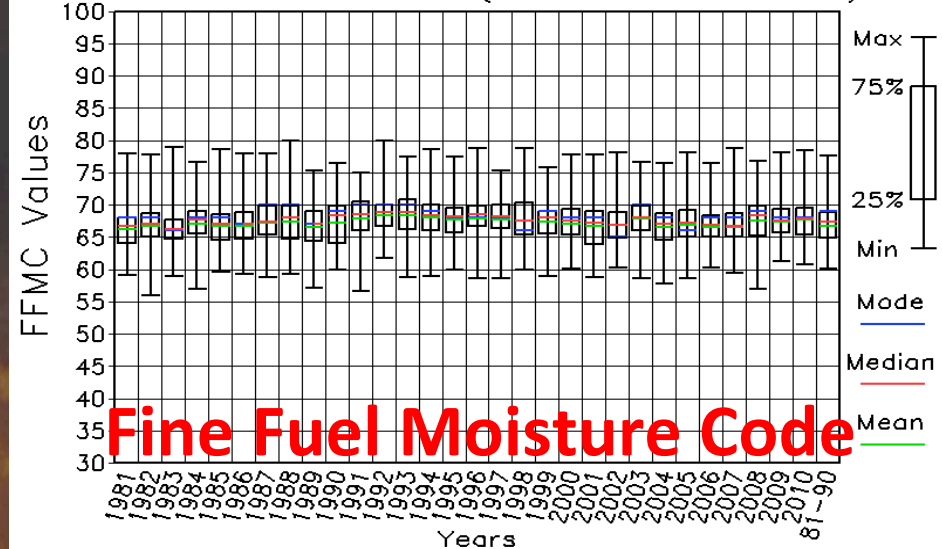
Even though the data correlate well, the NCDC mean domain data are consistently larger in 1999, 2002 and 2004, with rare exception.

Canadian Fire Danger System applied across Northern Eurasia

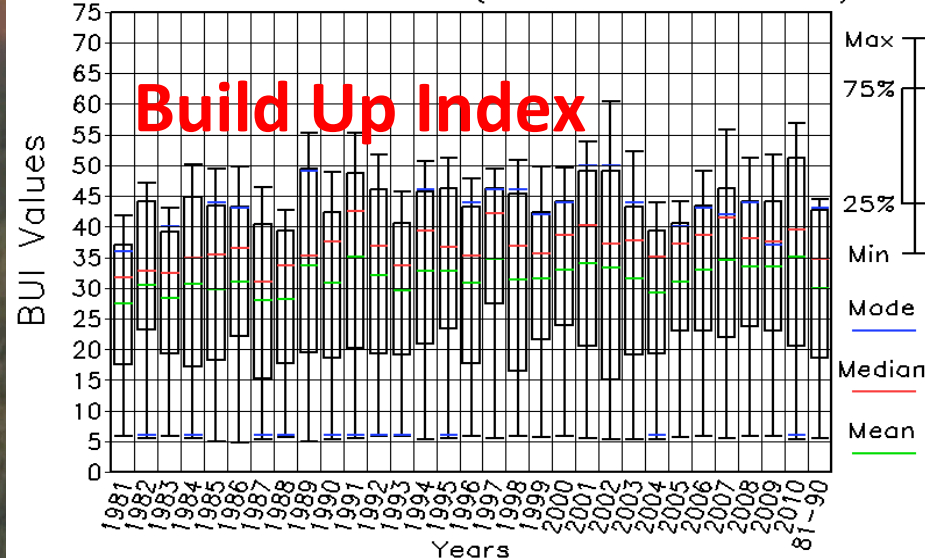
Average of Daily Domain (lat: 40–80 lon: 50–180)
FWI Values for the Period of March 01 to October 31
for Years 1981 to 2010 (water bodies unmasked)



Average of Daily Domain (lat: 40–80 lon: 50–180)
FFMC Values for the Period of March 01 to October 31
for Years 1981 to 2010 (water bodies unmasked)



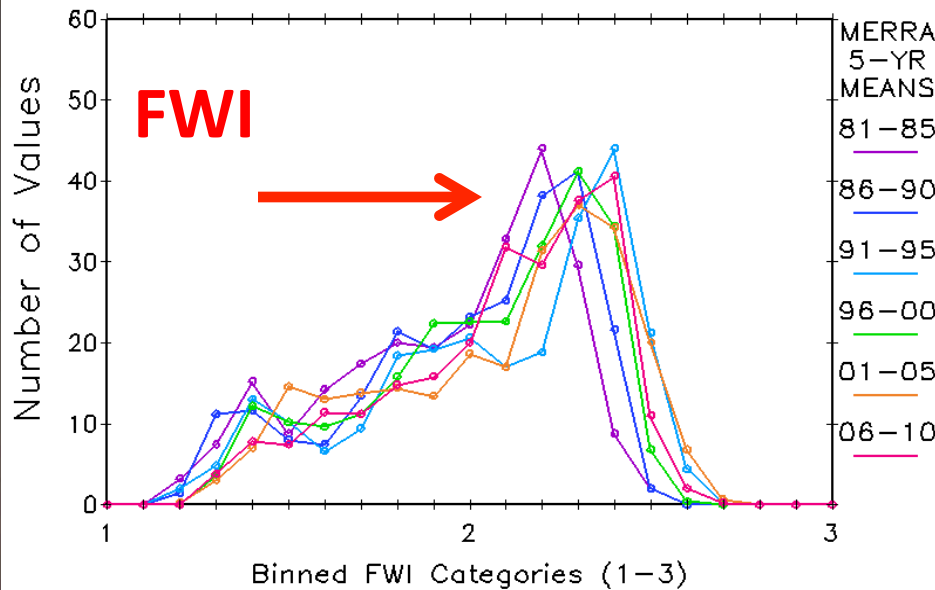
Average of Daily Domain (lat: 40–80 lon: 50–180)
BUI Values for the Period of March 01 to October 31
for Years 1981 to 2010 (water bodies unmasked)



Across Northern Eurasia, there is no notable change in the Fine Fuel Moisture Code (FFMC), Fire Weather Index (FWI), or Build Up Index (BUI) over the last 30 years using large-scale meteorological data [NASA Goddard Earth Observing System version 5 (GEOS-5)].

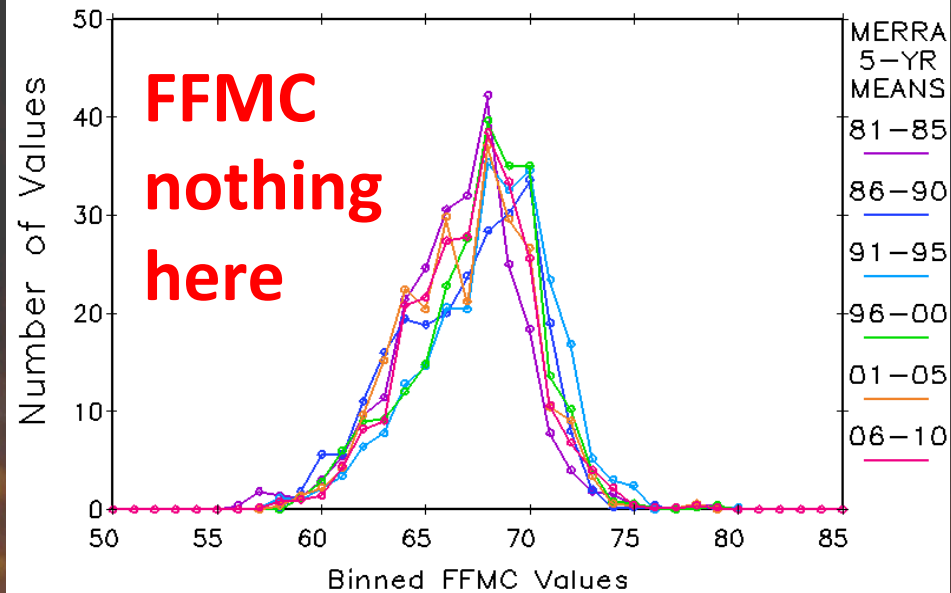
Daily Mean Fire Weather Index

(domain: lat: 40–80 lon: 50–180 from March 01 to October 31)



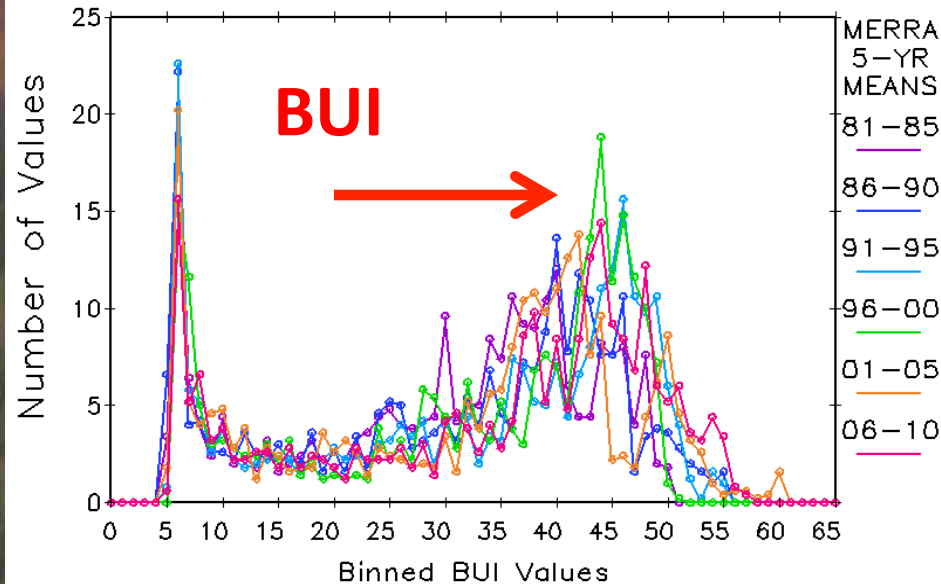
Daily Mean Fine Fuel Moisture Codes

(domain: lat: 40–80 lon: 50–180 from March 01 to October 31)



Daily Mean Build Up Index

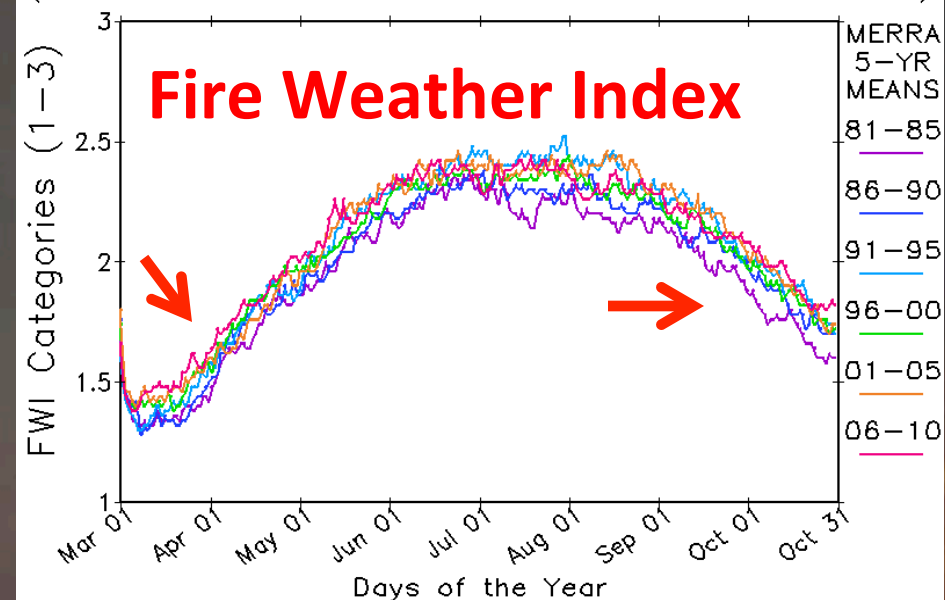
(domain: lat: 40–80 lon: 50–180 from March 01 to October 31)



Across Northern Eurasia, looking at 5-year means, there is a increase towards larger values of the Fire Weather Index (FWI) and Build Up Index (BUI) over the last 30 years using large-scale meteorological data [NASA Goddard Earth Observing System version 5 (GEOS-5)].

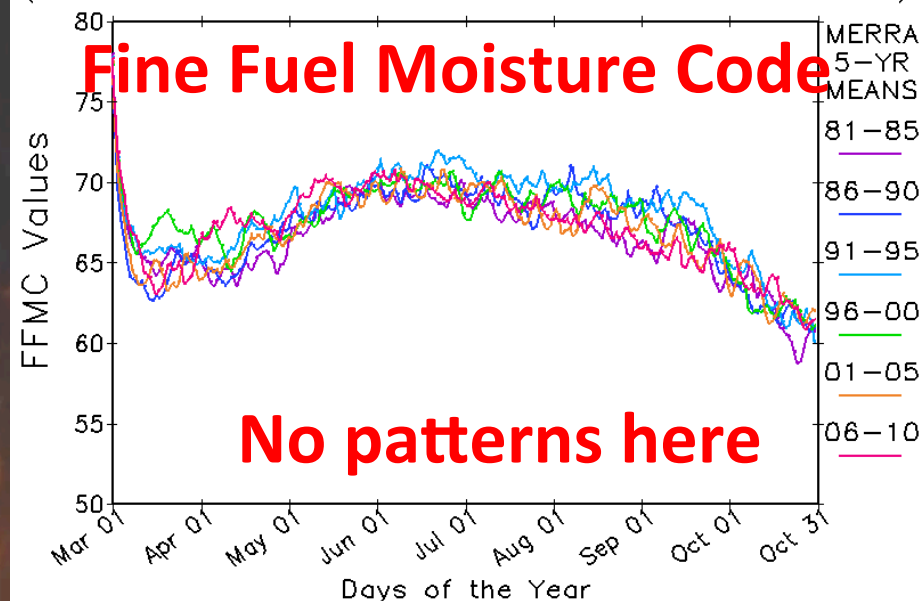
Daily Mean Fire Weather Index

(domain: lat: 40–80 lon: 50–180 from March 01 to October 31)



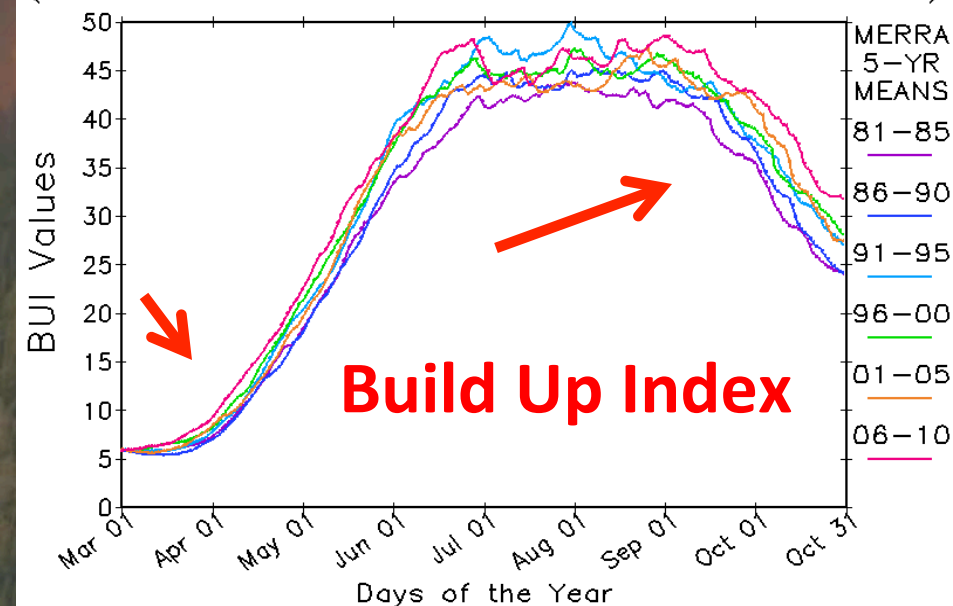
Daily Mean Fine Fuel Moisture Code

(domain: lat: 40–80 lon: 50–180 from March 01 to October 31)



Daily Mean Build Up Index

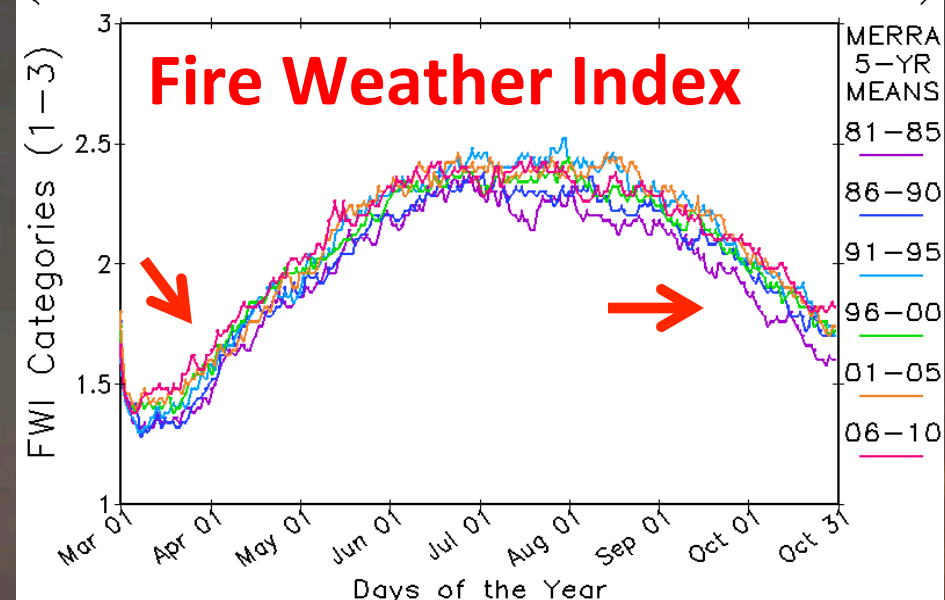
(domain: lat: 40–80 lon: 50–180 from March 01 to October 31)



Across Northern Eurasia, 5-year mean time series show increases in early and late season Fire Weather Index (FWI) and Build Up Index (BUI) over the last 30 years using large-scale meteorological data [NASA Goddard Earth Observing System version 5 (GEOS-5)].

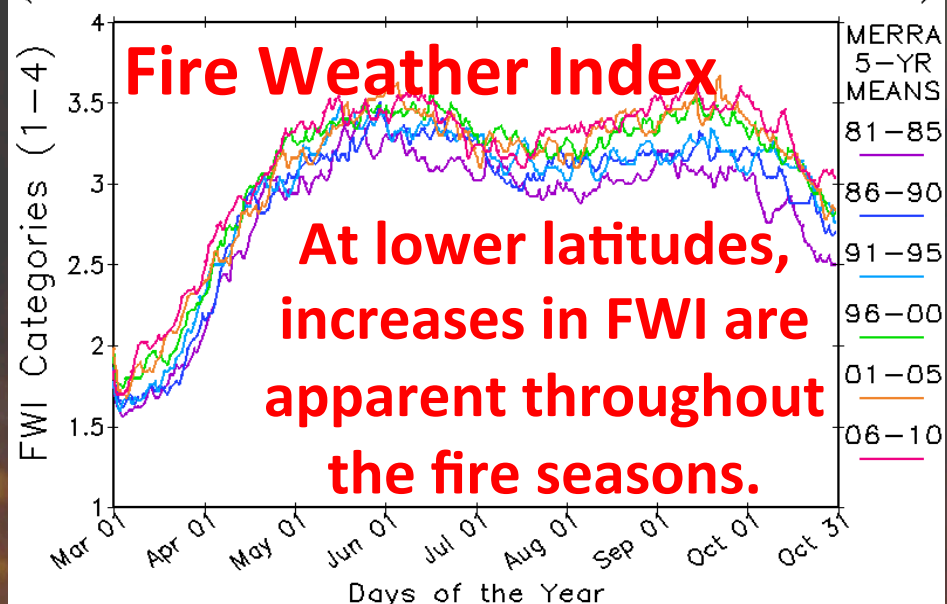
Daily Mean Fire Weather Index

(domain: lat: 40-80 lon: 50-180 from March 01 to October 31)



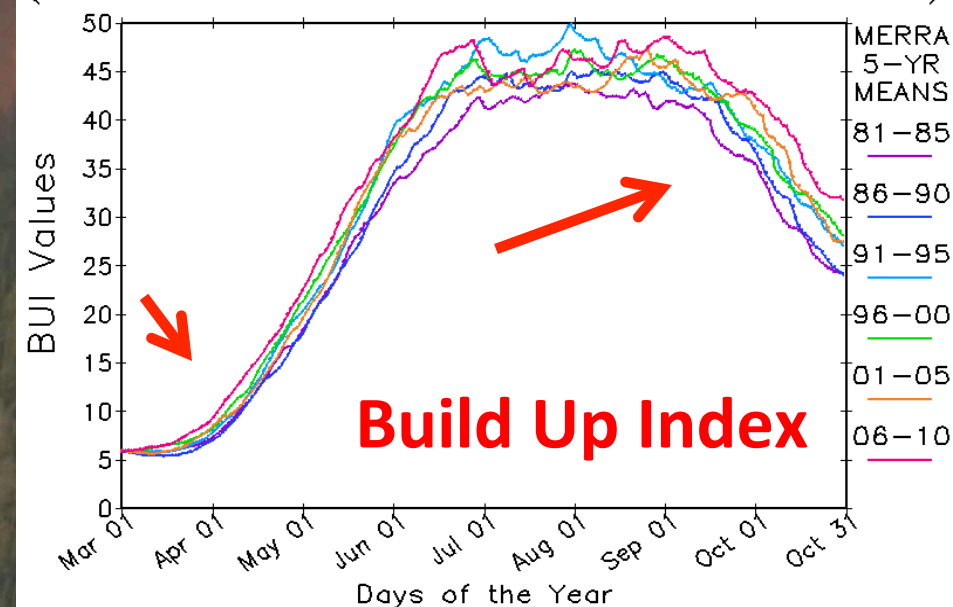
Daily Mean Fire Weather Index

(domain: lat: 40-55 lon: 50-180 from March 01 to October 31)



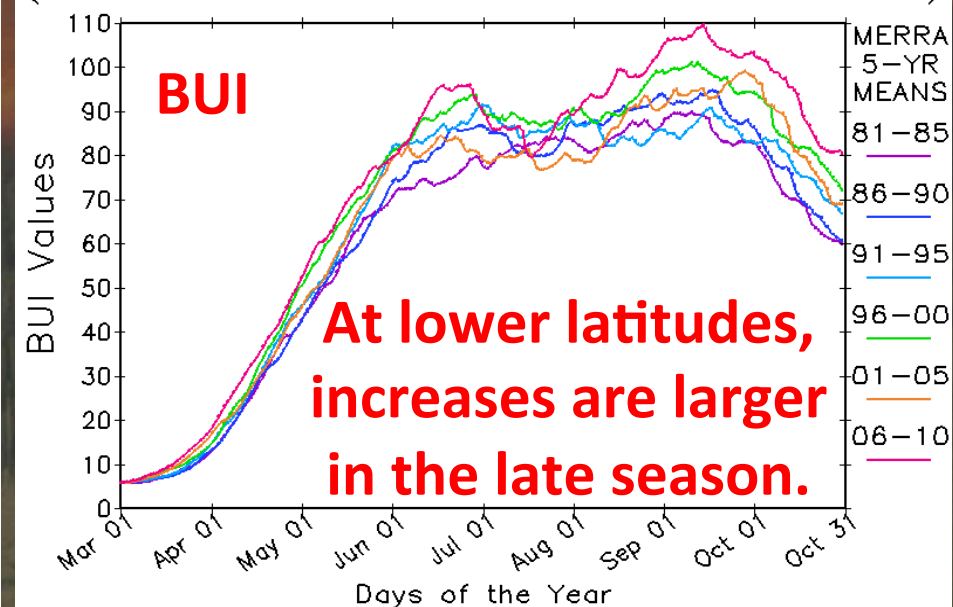
Daily Mean Build Up Index

(domain: lat: 40-80 lon: 50-180 from March 01 to October 31)



Daily Mean Build Up Index

(domain: lat: 40-55 lon: 50-180 from March 01 to October 31)



Highlights

Climate is predicted to drastically change at Northern Hemisphere upper latitudes, and there is already evidence of this change.

Large-scale reanalysis (meteorological) data are able to estimate Fire Danger at local, regional and continental scales.

2002 was an extreme fire year in the Republic of Sakha and fire danger could forecast this severity, as is also possible in a normal fire year (1999).

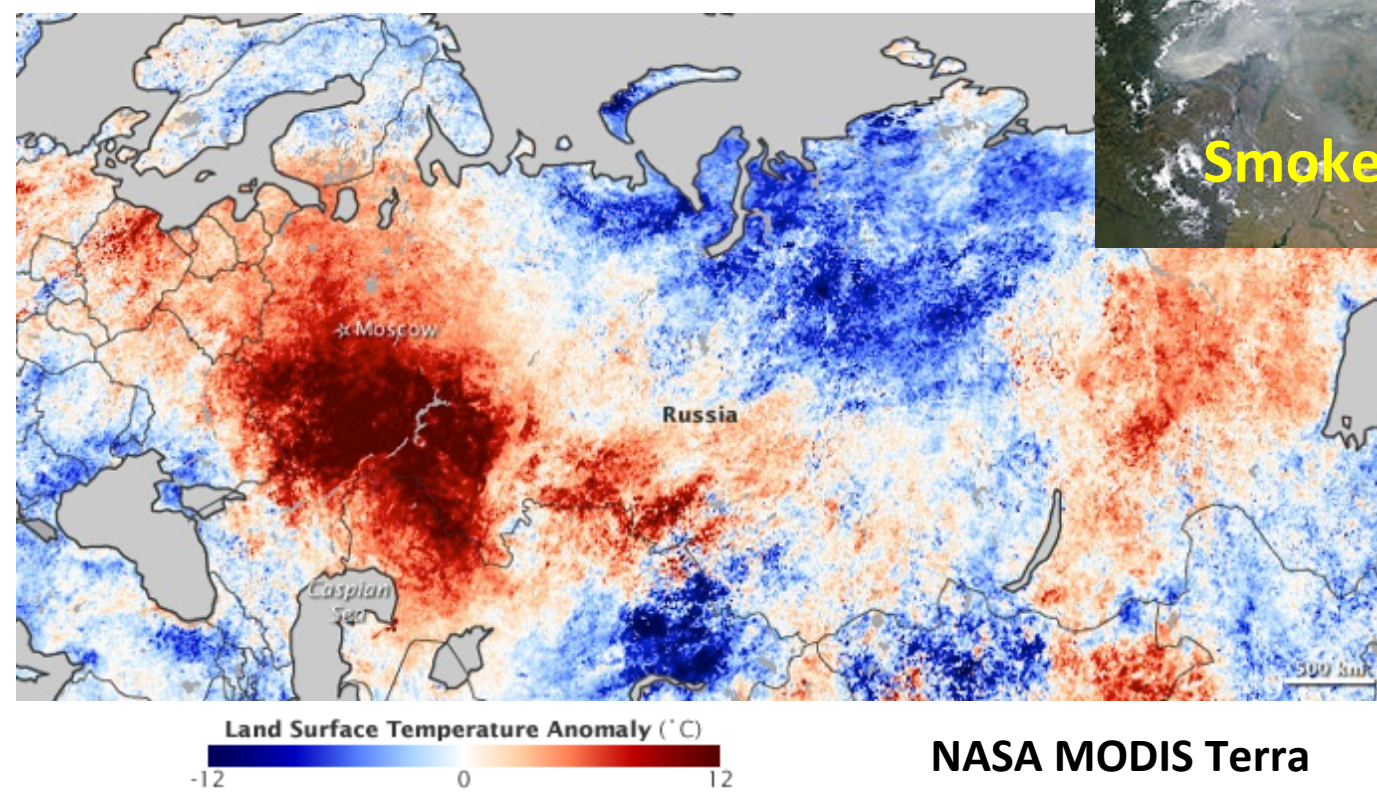
Even though, there is no general increases in Fire Danger across Northern Eurasia (40-80 N; 50- 180 W) using large-scale reanalysis data over the last 30 years,

- * there is an increase towards larger values (5-yr means) of FWI and BUI;

- * increases in early and late season FWI and BUI are apparent;

- * increases in FWI and BUI are greatest at lower latitudes throughout the fire seasons.

Temperature anomalies for the Russia from July 20–27, 2010, (2000 -2008)



- * Swamps and bogs surrounding Moscow had been drained in the 1960s for agricultural use and peat mining.

- * Cost roughly \$15 billion USD in damages.

- * Munich Re estimated 56,000 people died from the effects of the smog and heat wave (700/day; 2 times the average).

- * Record drought and hottest recorded summer in Russian history.

- * Fires burned from late July–Sept.

- * Temps reached 42°C (108°F)

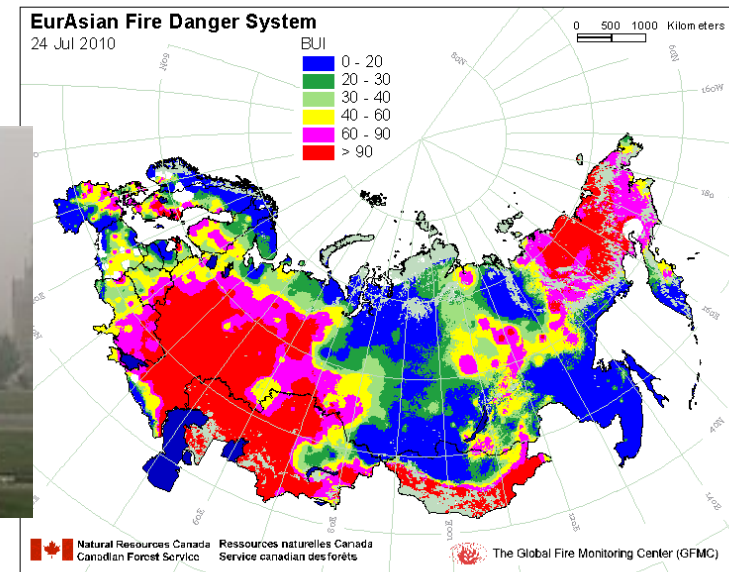
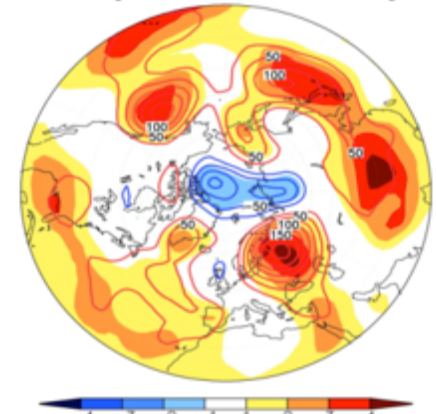
- * Area burned 736,000 ha (1.82 M acres; 7,360 km²) EC JRC 12 August.

Western Russia 2010

- Combine systemic problems with inevitable major fire event -creates a Perfect Storm situation
- Delayed recognition/ response of government
- Dozens of new human-caused fires daily in this region while crisis ongoing – speaks to lack of responsibility
- Systemic problems:
 - Downsizing of fire management capability
 - Lack of commitment to sustainability
 - General malaise in country and government viewed as corrupt
- Will Russian government learn?



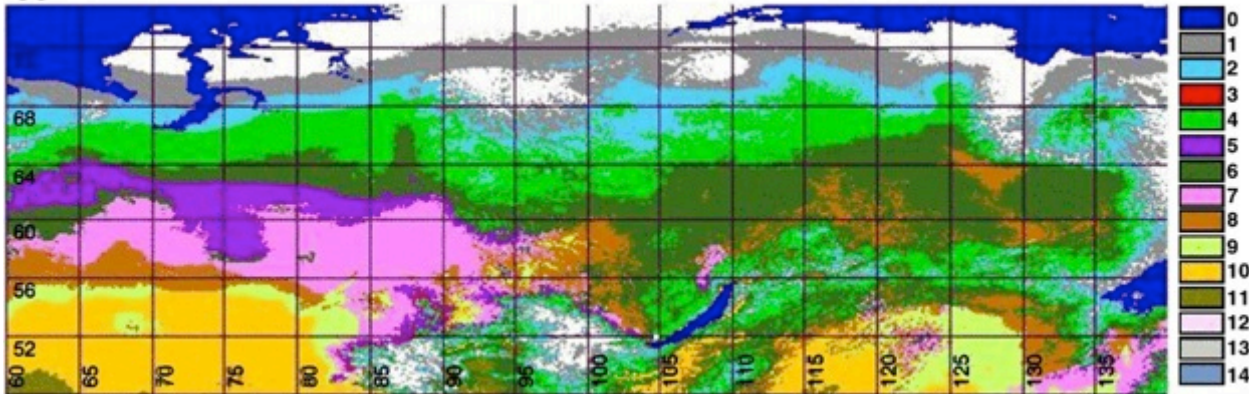
500 hPa Height Anomalies 10 Jul – 09 Aug 2010



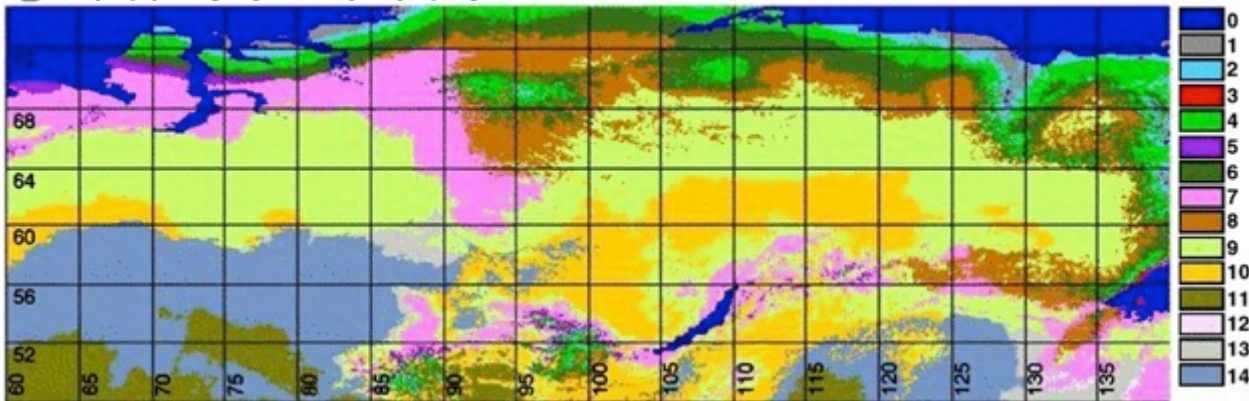
Siberia BioClimatic Model

It is predicted the taiga will largely be replaced by steppe and forest-steppe ecosystems in Siberia.

A Current simulation



B Future simulation



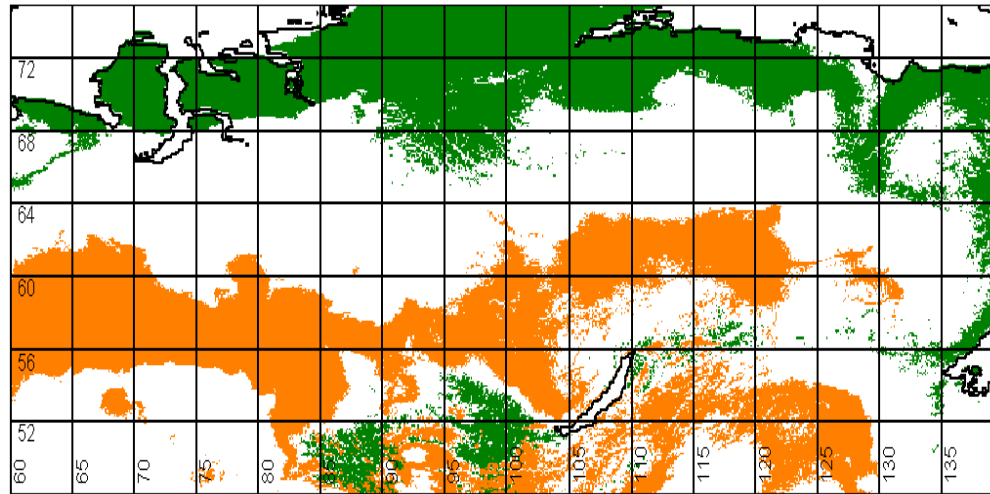
Vegetation distribution in Siberia: (A) current and (B) future (2100) based on a Hadley scenario (HadCM3GGal) (IPCC, 1996). Water (0), tundra (1), forest-tundra (2), northern dark taiga (3) and light taiga (4), middle dark taiga (5) and light taiga (6), southern dark taiga (7) and light taiga (8), forest-steppe (9), steppe (10), semidesert (11), broadleaved (12), temperate forest-steppe (13) and temperate steppe (14).

SiBCliM

Tchebakova and Parfenova

- There is already evidence of the migration of keystone ecosystems in the upland and lowland treeline of mountainous regions across southern Siberia (Soja et al., Global and Planetary change, 2007).

Siberian “Hot spots” of forest cover change by 2090



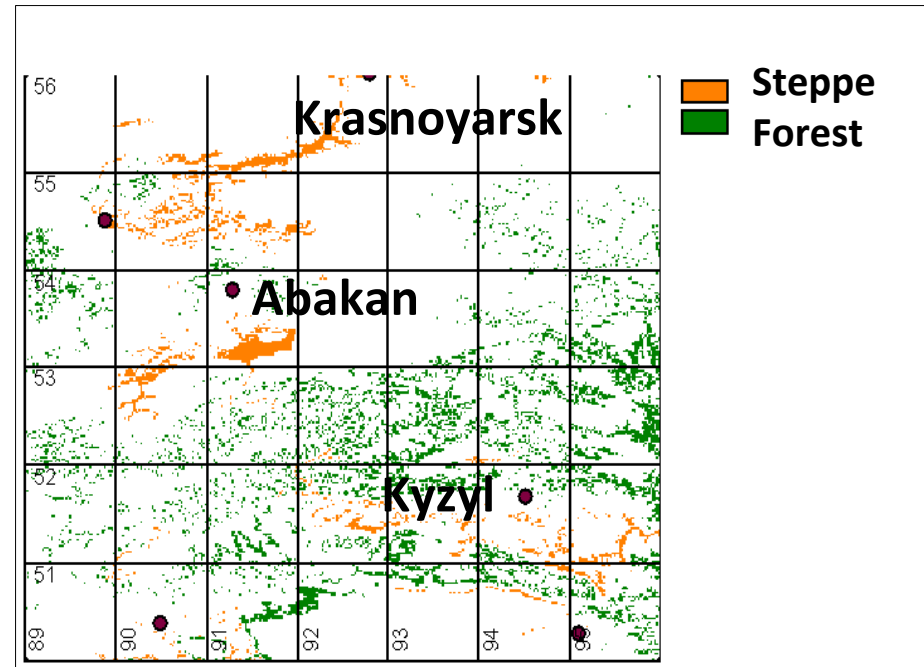
Steppe
Forest

Siberian Bioclimatic
Model (SiBCLiM)

Results

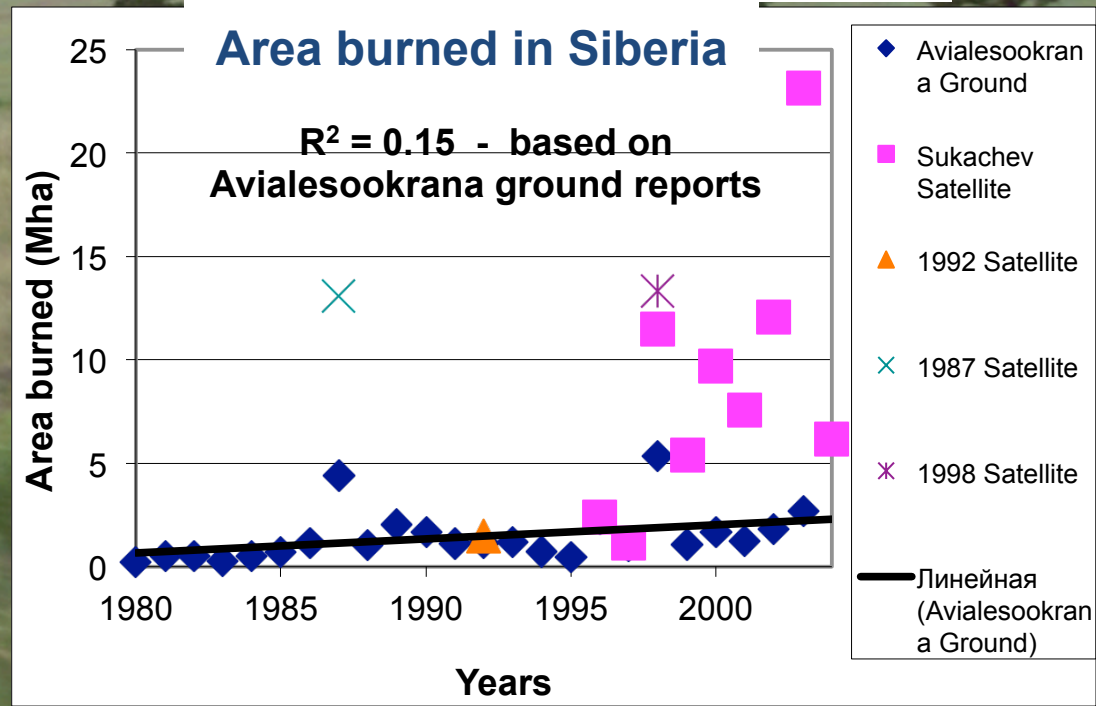
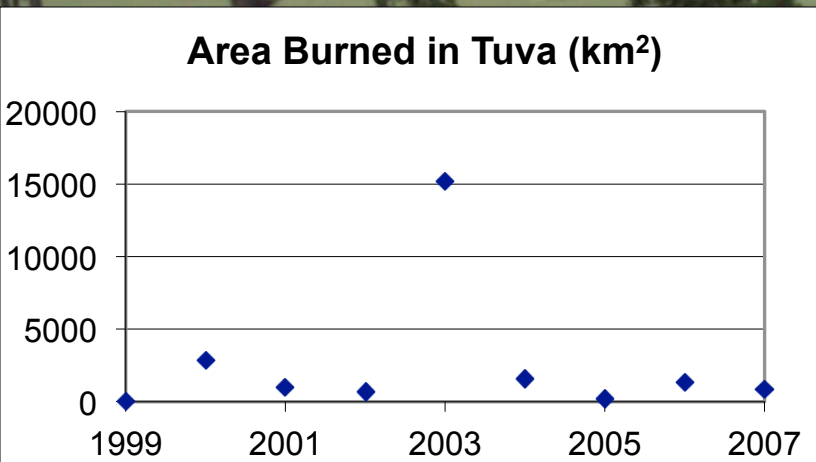
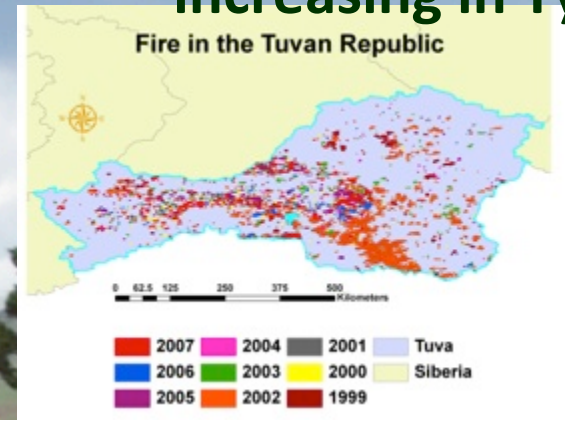
Tchebakova,
Parfenova, et al.
2006

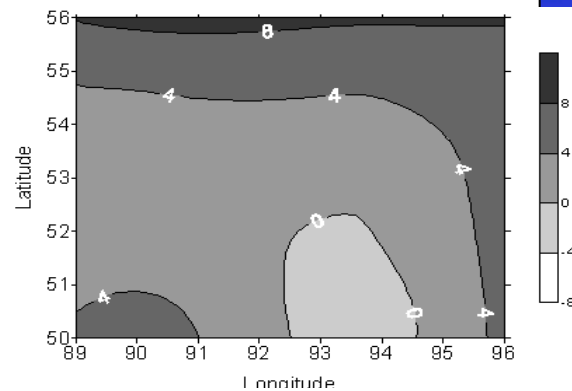
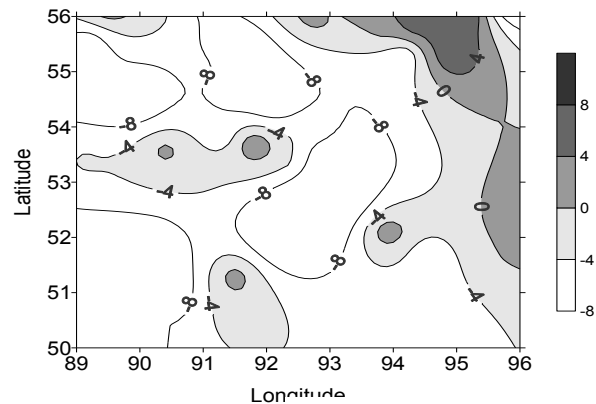
Republic of Tyva
“Hot spots” of change



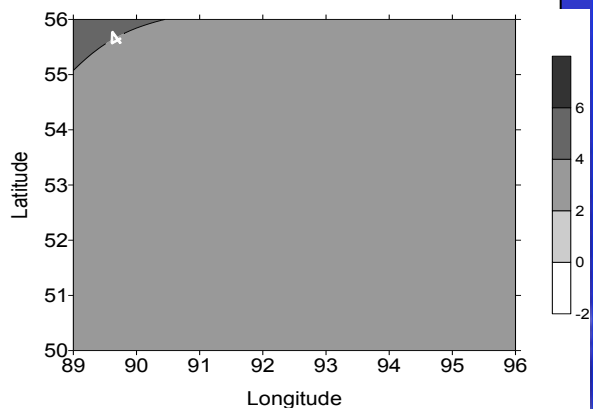
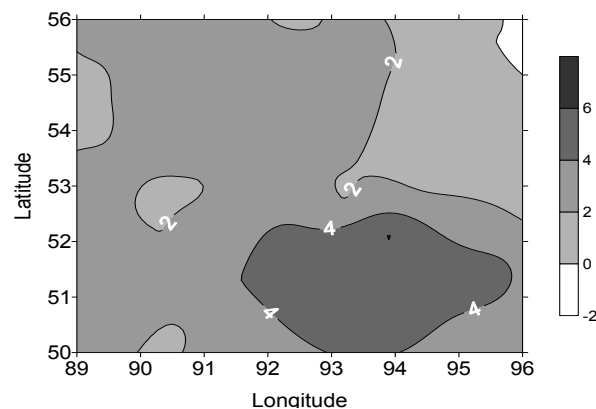
**Locals report the relic Pine forest is disappearing in Tyva.
Using satellite and local data, we do NOT find the
amount of area burned by fire is significantly
increasing in Tyva .**

**Even though it does
appear the number of
extreme fire years is
increasing across Russia.**

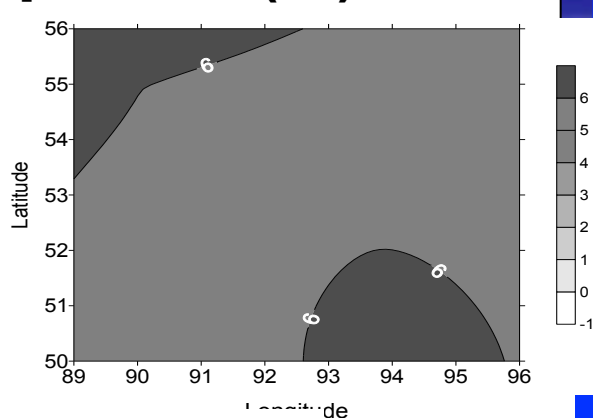
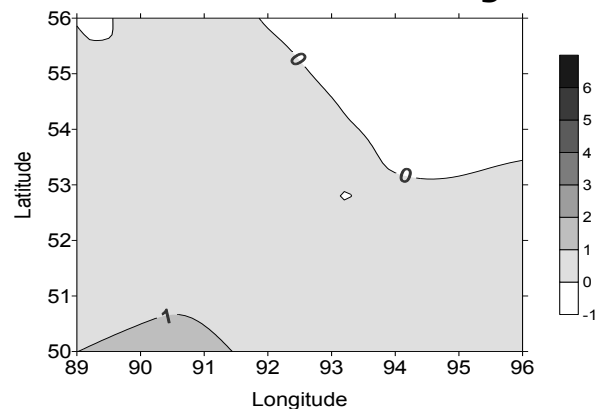




Annual precipitation (%)



January temperature (°C)



July temperature (°C)

Climate change in the Sayan Mountains: observations, 1980-2000 (left) and predicted (right) by a Hadley Centre scenario (HadCM3GGa1) for 2090.

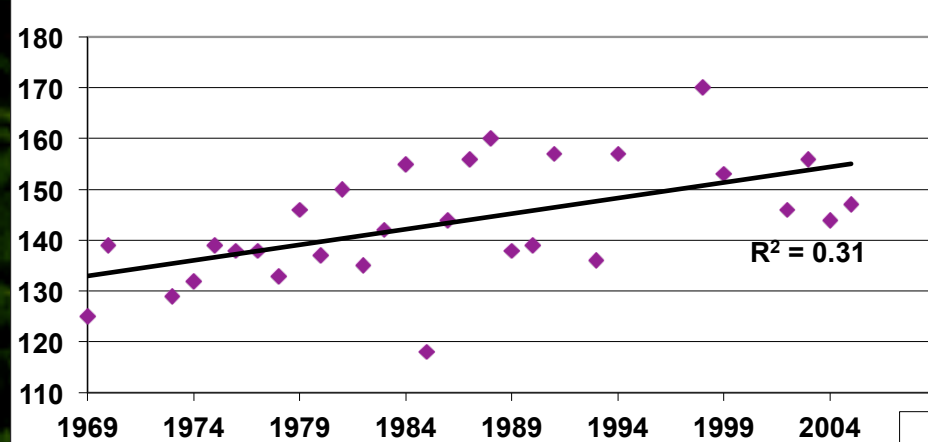
Winter temperatures have already exceeded 2090 model estimates, while summer temperatures have not. Patterns of precipitation are difficult to predict.

Soja, Tchebakova et al., 2007

Kyzyl, Tyva

National Climate Data Center (NCDC) station data (minimum 75% daily observations)

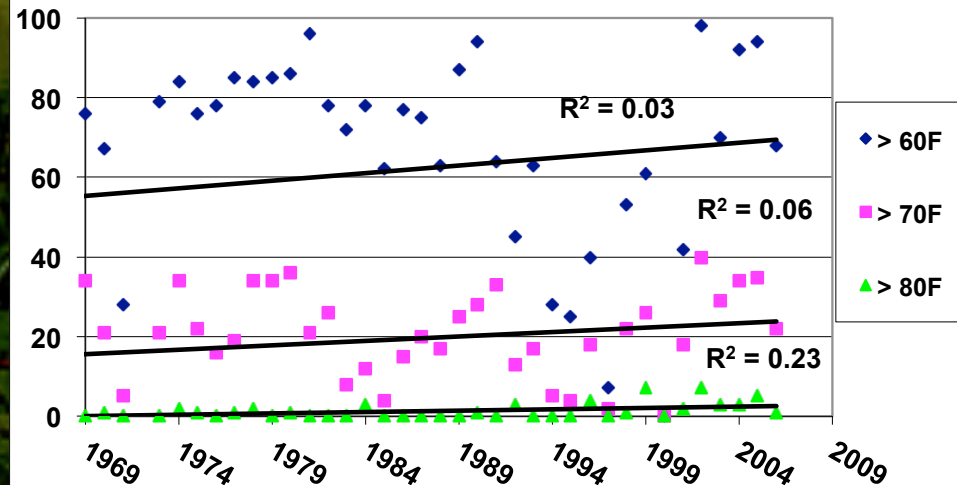
Increase in the Growing Season Length:
Contiguous Days > 40F



Increases in the
Growing Season Length;
the number of extremely
warm days in a year; and
the warmer the day,
the greater the increase

This leads to higher severity
fires, increased available
soil organic matter, deeper
burning to mineral soil.

Increases in Extreme Warm Temperature Days
Number of Days in a Year



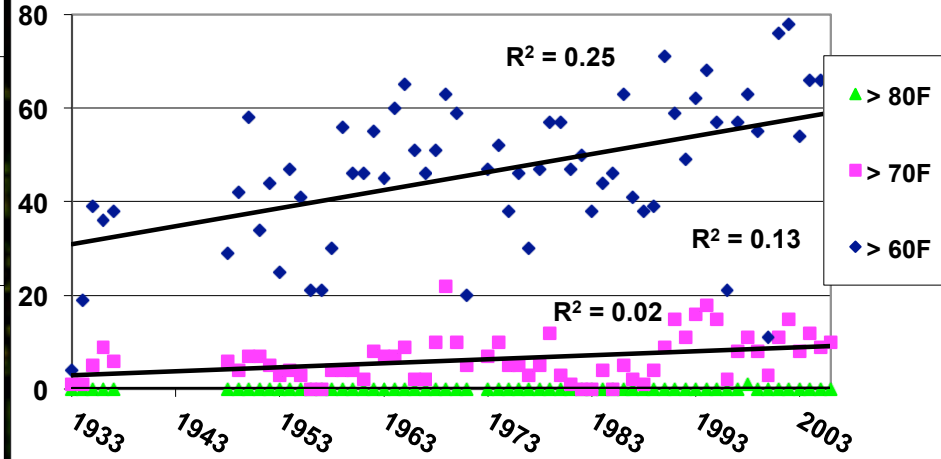
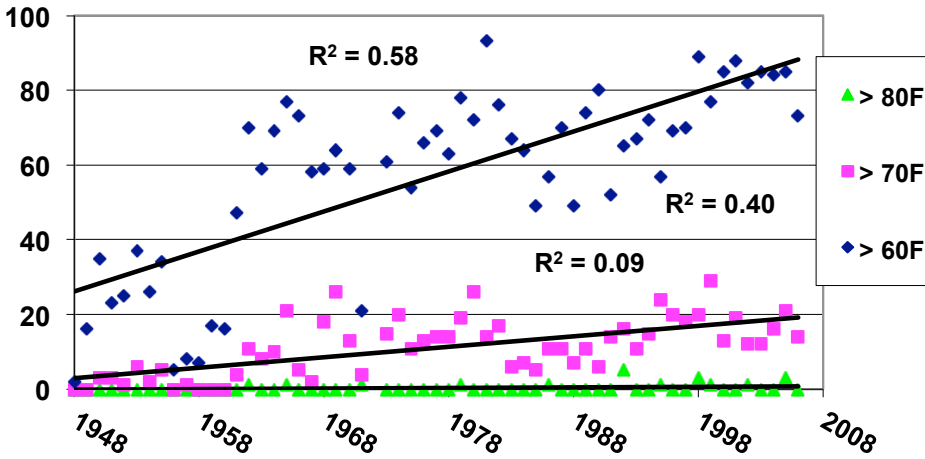
NW Tyva

Increases in Extremely Warm

NE Tyva

Increases in Extreme Warm Temperature Days
Number of Days in a Year

Increases in Extreme Warm Temperature Days
Number of Days in a Year

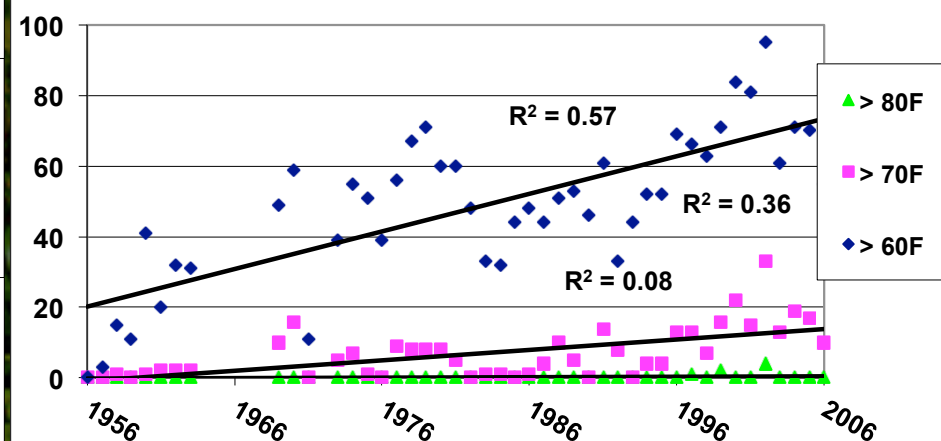
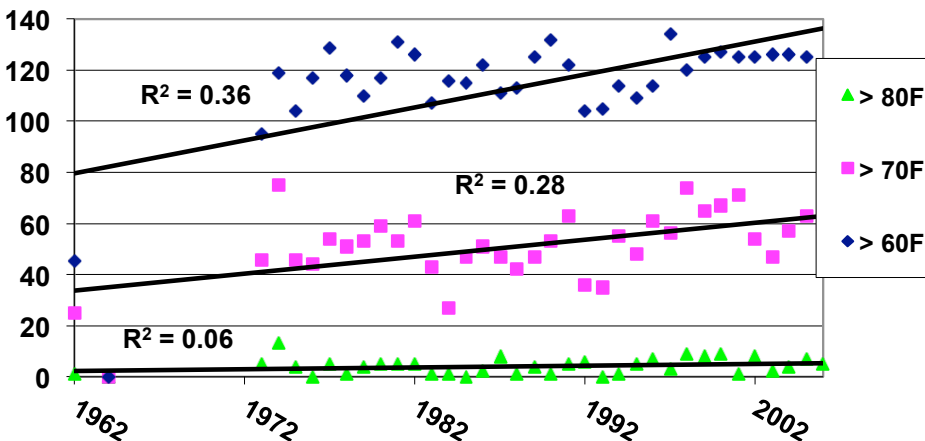


Southwest Tyva

Southeast Tyva

Increases in Extreme Warm Temperature Days
Number of Days in a Year

Increases in Extreme Warm Temperature Days
Number of Days in a Year





Healthy forest
Pinus sylvestris

**Just north of the
Tyvan Republic**

**Fire scars apparent; Moist forest floor
Recovery apparent;
Typical low-, medium-severity surface
Fire Return Interval 10 to 50 years;
Typical crown Fire Return Interval
50 -100 years**



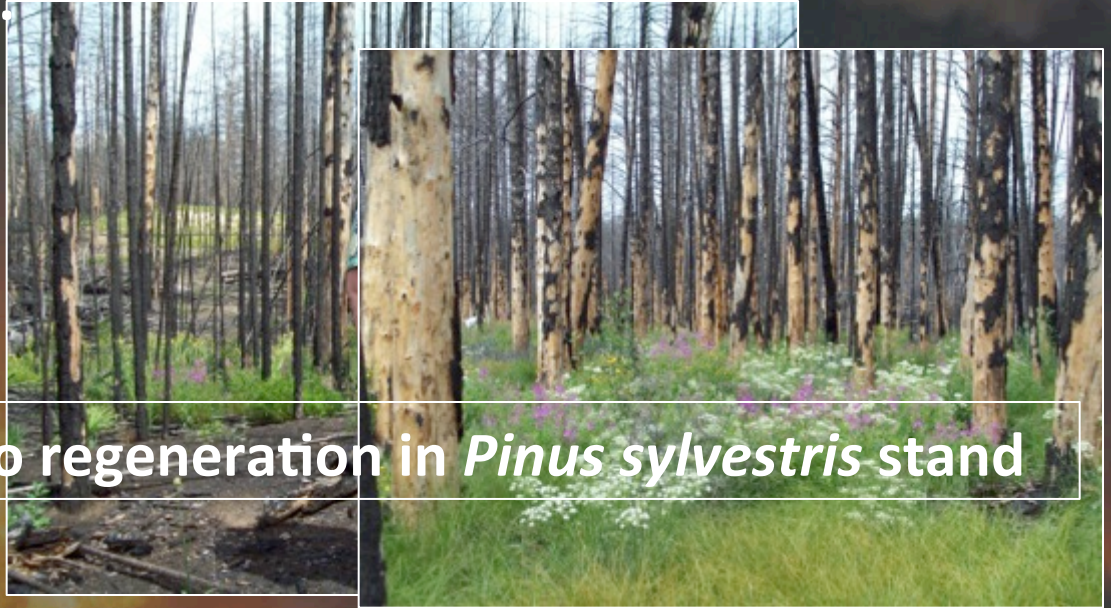


Republic of Tyva

**This *Pinus sylvestris* is not
and will not recover.**

**Burned to mineral soil, which
is currently too hot to sustain
seedlings.**

Of the 11 sites visited, only 3 showed signs of recovery (healthy and unhealthy seedlings), 2 had birch suckers and 6 sites showed NO signs of tree regeneration.



Site 3.1: Fire in 1996, no regeneration in *Pinus sylvestris* stand



Site 3.2: Fire in 1996 and 1998, suckers, minimal regeneration (almost none) in *Pinus sylvestris* stand (*Betula mix*).

The forest are getting a one-two punch: 1st the precipitant weather sets the conditions to burn to mineral soil and kills all the trees (soils hotter, dry and no shade results); and then the increasing growing season length and extreme temperatures inhibit seedling establishment.



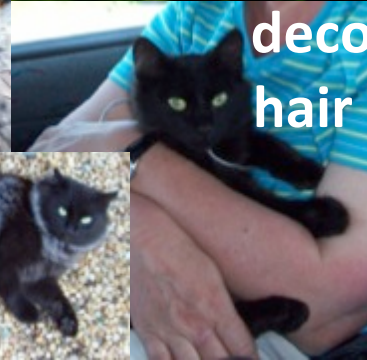
Site 7: Burned 2002 & 2007, no regeneration, some larch (minor birch) remaining.



Sites 4 & 5: Fire in 2003, no regeneration even near living trees, thick grass/sedge cover, some regeneration near roads in ditches (*Pinus sylvestris* stand)



Siberian cat from Tyvan steppe. Fur is 8cm thick on each side (not mane) decorative hair 10cm.





International Association of Wildland Fire

The International Association of Wildland Fire (IAWF) has received preliminary information concerning wildland firefighter fatalities in Russia.

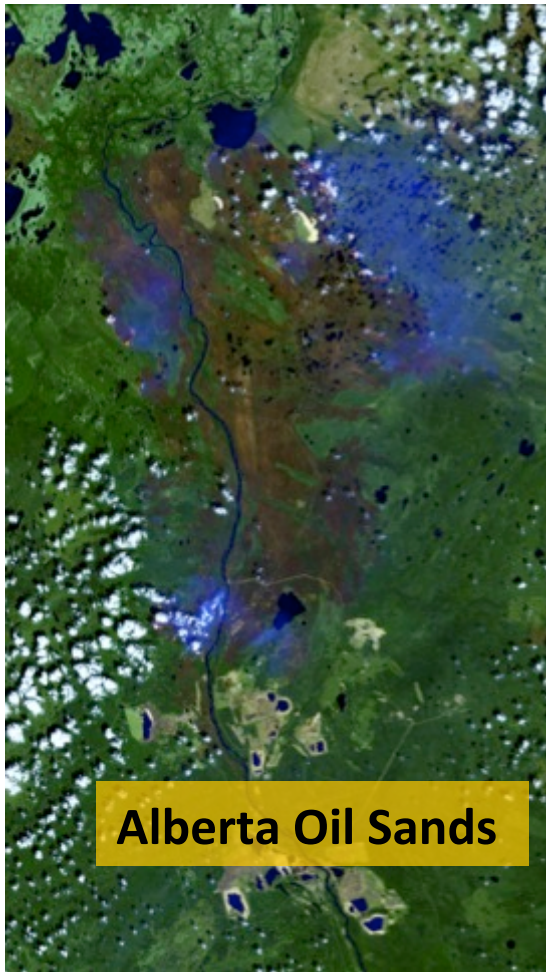
Our condolences go out to the families and co-workers.

Incident Description: Nine of a crew of thirteen firefighting parachutists (i.e. smoke jumpers) are reported to have died in a 500 hectare (1,236 acres) forest crown fire in the southern Siberia region of Russia in the remote republic of Tuva, Barun-Khemchiksky district, near the Mongolian border. The fire has been burning in mountainous terrain under the influence of strong winds. Original reports indicated eight deaths but a ninth is now being reported by Russian media company ITAR-TASS from a Rosleskhoz (Federal Forestry Agency) source. Four firefighters walked out of the fire area, one of which was an injured firefighter who has been transported by plane to a regional hospital. There are reported to be fourteen fires burning which began in the region on Wednesday local time and now cover an area of approximately 4,570 hectares (11,293 acres). Another 100 paratroop firefighters are being sent to the Tuva area. It has been said that the fires pose no threat to the Kara-Khol populated area which is about 30 kilometers (18.6 miles) away. An investigation has been launched to review the incident. Reportedly all had undergone training and had professional skills in fighting wildland fires.

Tale of two fires in Alberta, Canada: Both started on May 14th 2011

Richardson Fire (NE Alberta)

- * biggest Alberta wildfire since 1930s (1950 BC fire)**
- * Fire's southern edge near oilsands**
- * 707,648 hectares; 1,750,000 acres**
- * No loss of structures, * Minimum suppression (defensive)**



Slave Lake

4,700 hectares; 11,600 acres
400+ homes lost
2nd costliest in country's history
\$1.8 billion in total damages
Aggressive suppression



**2011 \$3.5M East Coast Peatlands
Great Dismal Swamp Lateral West, VA**

*** Burned Acres: 6377**

(2,580 ha, 25.8 km²)

*** Still burning (100% contained)!**

*** August 04 start – Park reopened
October 28th**

*** Average overall depth of 3-4 ft**

*** Burned organic matter -100s to
1000s of years old**

- 2008 South One Wildfire

- \$12 M; burned 121 days

- burned 4,884 acres

- Air quality health cost

- Recreation

- Outer Banks

**- Need specialized
equipment**

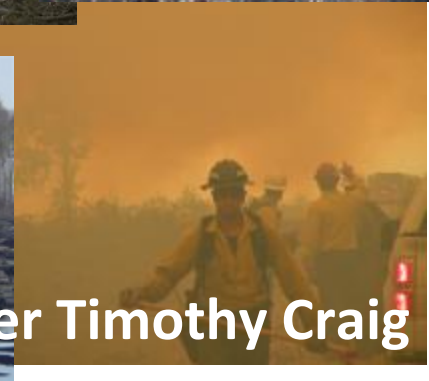


**Endangered
Canebrake**

**Habitat
Red-Cockaded
Woodpecker**



**Mom and baby
black bear**



Credits: Inciweb and Fire Manger Timothy Craig

2011 Pocosin Burning

Pains Bay Fire \$14 million

Alligator River National Wildlife Refuge

Burning since May 05th

45,294 acres (18,300 ha, 183 km²)

2008 \$20M suppression

Evans Road 40,704 acres

home to endangered red wolf

Popular recreation

area, photos,
hunting, fishing

100s migratory birds



Info. from Inciweb

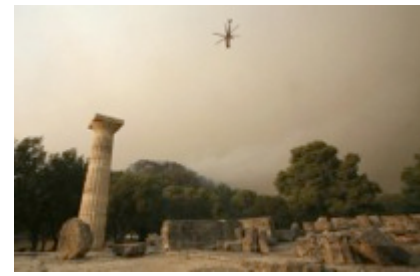


Peat can be
5-15 meters
in depth

Credit Vince Carver



Greece 2007



- No shortage of resources within Hellenic Fire Brigade:
14,000 employees and seasonal firefighters, 14 CL-215 and 10 CL-415 waterbombers, 20 additional aircraft, 5 owned and 16 contracted helicopters, 1500 fire trucks
- Heat waves in June and July each caused many large fires that overwhelmed resources, burning villages, killing citizens and firefighters.
- Third heat wave in mid August – extended drought, extreme fire danger conditions – devastating fires in southern Greece
- 2007 total: 84 deaths, >1000 homes, 270,000 ha (forest, farms, olive groves)
- Massive funds for centralized fire control (air operations, fire trucks, personnel) – little for forest management, biomass clearing, access, fire prevention, fire behavior and fire occurrence prediction
- Demographic changes have resulted in a population with less fire knowledge



Many authors have argued that the initial signs of climate-related change in fire regimes is currently evident across Northern Hemisphere upper latitudes

Anatoly Sukhinin – Increase in catastrophic fires in Siberia that sustain high pressure weather systems;

Stocks, Fosberg, Lynham, Mearns, Wotton, Yang, Zin, Lawrence, Hartley, Mason, McKenney (1998) - Canadian GCM predicts an earlier start to the fire season and significant increases in the area experiencing high to extreme fire danger in both Canada and Russia.

Gillette, Weaver, Zwiers, Flannigan (2004) - Human-induced climate change has had a detectable influence on the area burned by forest fire in Canada over recent decades;

Kasischke, Turetsky (2006) – Doubling of frequency of large fire across boreal NA;

Westerling, Hildalgo, Cayan, Swetnam (2006) – Historic large fires in the western US are largely under the control of weather and climate, not dominantly historic fire suppression.

Soja, Flannigan, Stocks, Chapin, Sukhinin (2007) – Initial signs of climate change are apparent (changes in species composition, increased extreme fire years across the circumboreal).

How would we recognize a Catastrophic, Extreme or Mega-fire?

Do Mega-fires have a physical, theoretical, statistical underpinning?

Or do we continue to define them arbitrarily and descriptively?

Physical basis for mega-fires

- Are megafires a legitimate phenomenon on their own with inherent/emergent properties?
- thermodynamics – can we envision numerous large fires in close proximity generating heat output similar to Dresden firestorm, or a mesoscale convective complex, capable of altering regional atmospheric circulation?

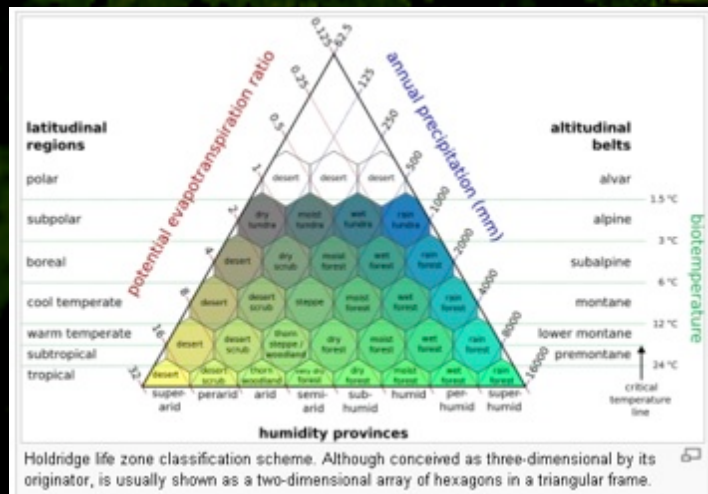
Possible statistical criteria for mega-fires

- Time spent in high or extreme categories e.g. drought code at a zone (lat-long). Cumulative statistic, similar to growing degree days;
- sudden ecozone change events, e.g. species shift, species endangered, extinct;
- 98th percentile of fuel loss;
- Cost of suppression and damages.

There are examples of classification schemes.

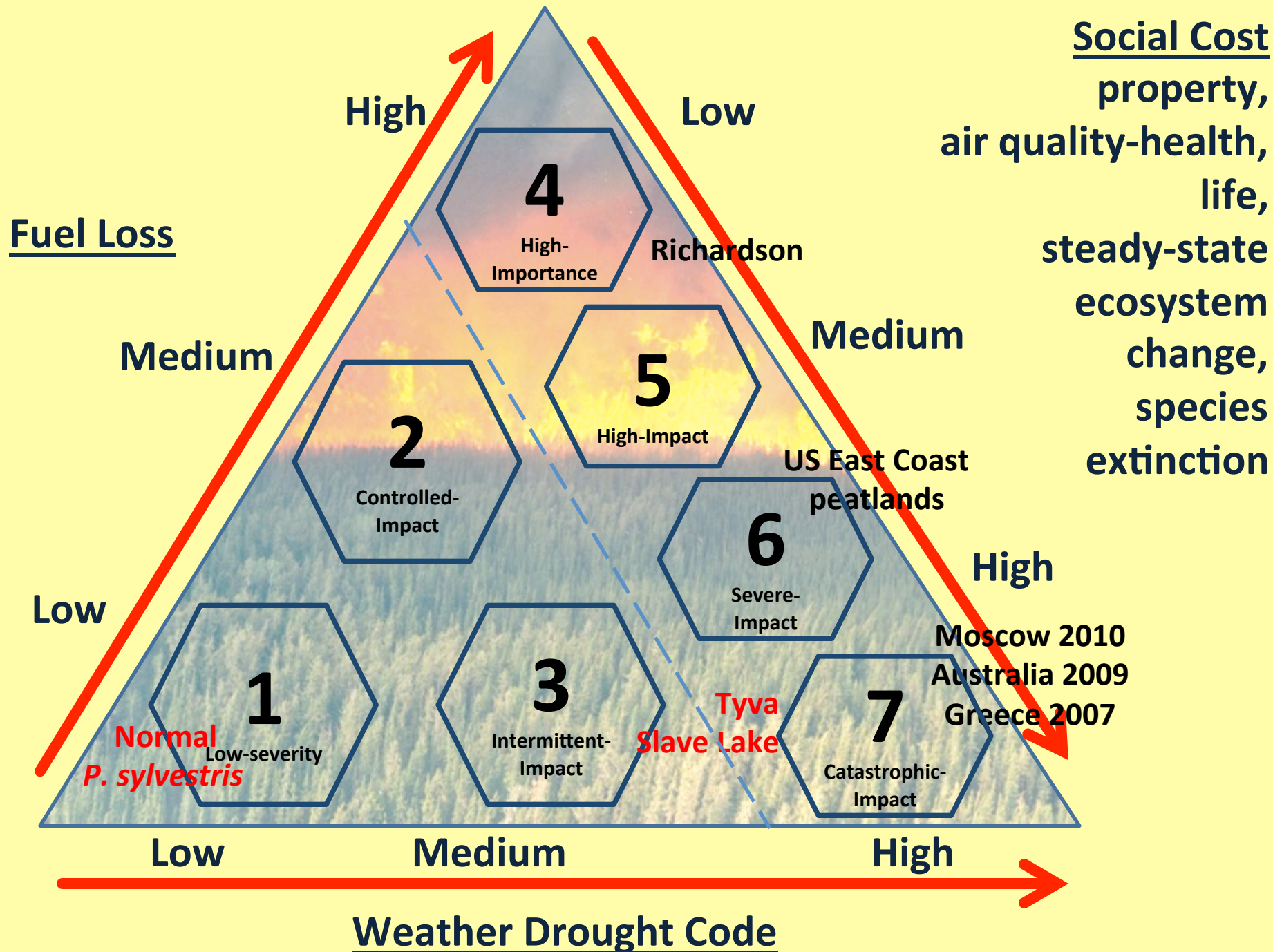
As a community, we need to define Mega-fires, so that we are better able to communicate with each other and the public. We are suggesting something similar to a Fujita scale for tornadoes, for wildfires that is based on overall strength of a fire event (fuel or area consumed; species loss or change in ecosystem steady state) and the type of damage done to values at risk (economy; infrastructure; life and health).

Holdridge-like zone to define scale?



Saffir-Simpson Hurricane scale detail
Category description that defines value

The Saffir-Simpson Hurricane Wind Scale Summary Table											
Climatology Names Wind Scale Extremes Models Breakpoints Hurricane Hunters											
PDF											
Category	Winds (1 min sustained winds in mph and km/hr)	Summary	People, Livestock, and Pets	Mobile Homes	Frame Homes	Apartments, Shopping Centers, and Industrial Buildings	High-Rise Windows and Glass	Signage, Fences, and Canopies	Trees	Power and Water	Example
1	74-95 mph 64-82 kt 119-153 km/hr	Very dangerous winds will produce some damage	People, livestock, and pets struck by flying or falling debris could be injured or killed.	Older (mainly pre-1994 construction) mobile homes could be destroyed, especially if they are not anchored properly as they tend to shift or roll off	Some poorly constructed frame homes can experience major damage, involving loss of the roof covering and damage to gable ends as	Some apartment building and shopping center roof coverings could be partially removed. Industrial buildings can lose roofing	Windows in high-rise buildings can be broken by flying debris. Falling and broken glass will pose a significant danger even after the storm.	There will be occasional damage to commercial signage, fences, and canopies.	Large branches of trees will snap and shallow rooted trees can be toppled.	Extensive damage to power lines and poles will likely result in power outages that could last a few to several days.	Hurricane Dolly (2008) is an example of a hurricane that brought Category 1 winds and impacts to South Padre Island, Texas.



**Information provided for this talk by the authors and
found on the following sites:**

inciweb

NASA imagery

USDA Forest Service

Canadian Forest Service

National Institute of Aerospace

**US federal, state and local Forest Service and Fire
Management Team photos**

Science Systems and Applications Incorporated

Aviallesookrana

Sukachev Institute of Forest

Fish and Wildlife Service

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Parfenova and Galina Ivanova**

Gita Ioannis and Eleni Dragozi

**Thank- you
all!**

Photo courtesy of Brian Stocks



In Memory of the vibrant life and work of Anatoly Ivanovich Sukhinin

Anatoly argued that not only were catastrophic fires increasing but that catastrophic fires fed back to and influence local and synoptic-scale meteorology.

We invite you to leave a note of remembrance for yourself and Anatoly's friends and family at:

**[http://memorialwebsites.legacy.com/
AnatolyIvanovichSukhinin/homepage.aspx](http://memorialwebsites.legacy.com/AnatolyIvanovichSukhinin/homepage.aspx)**