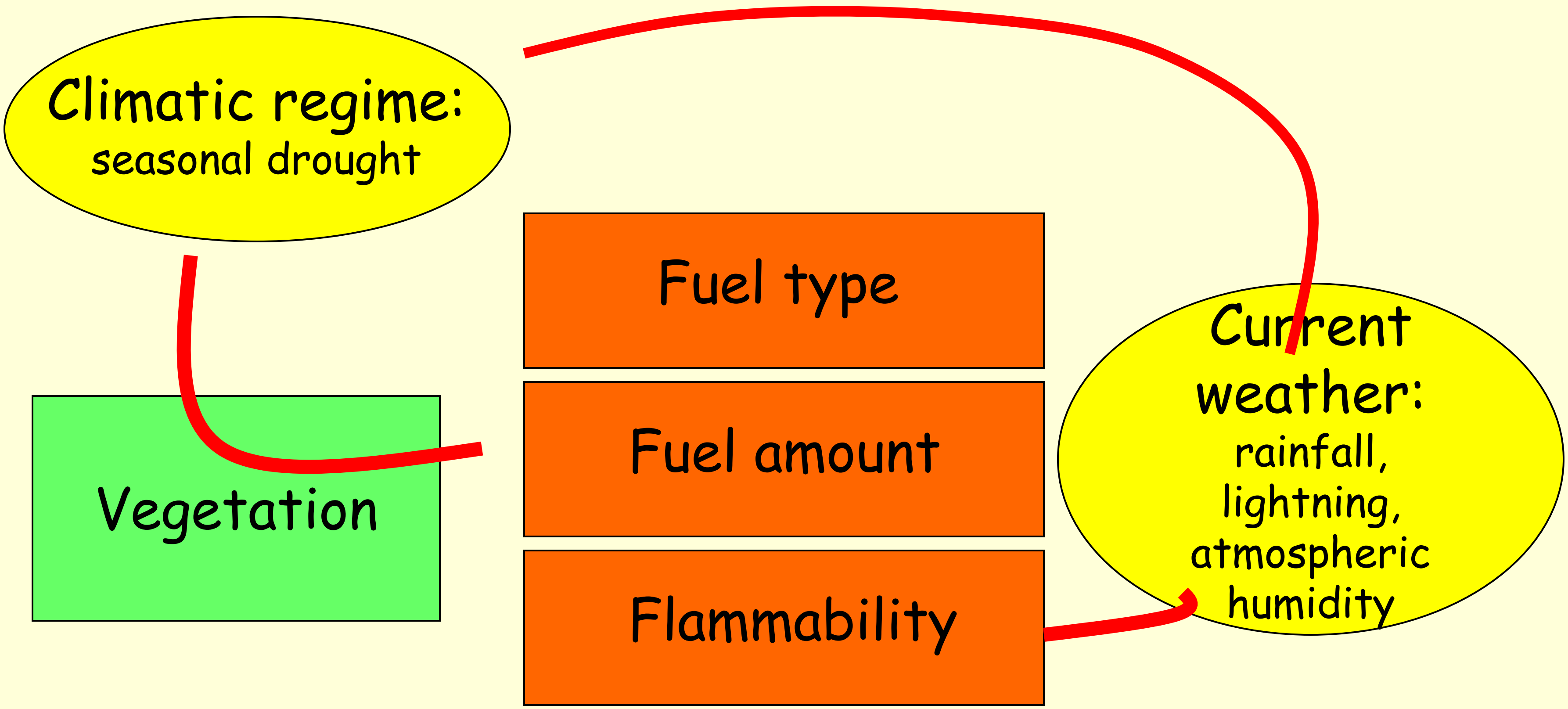
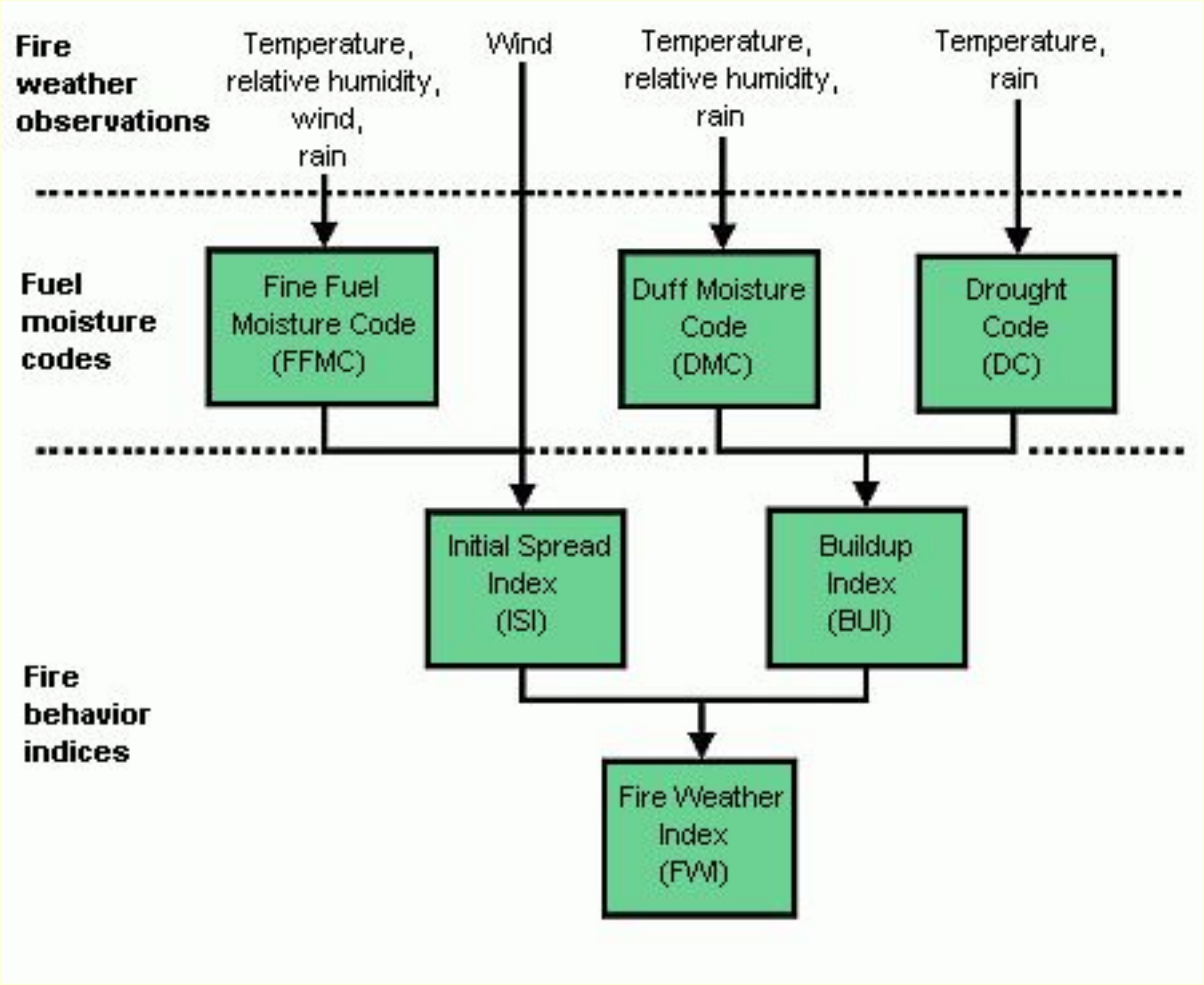
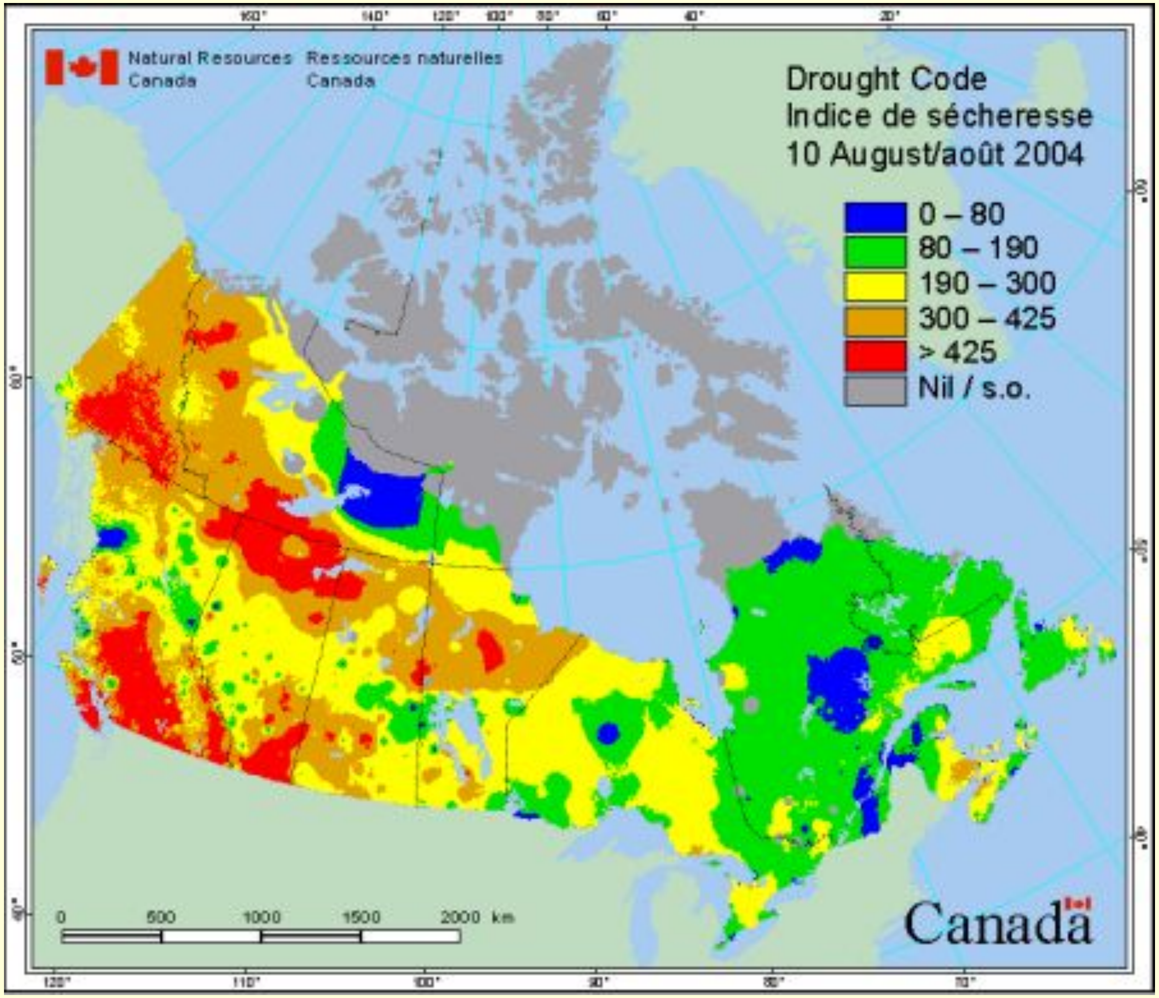
Wildfire hazard



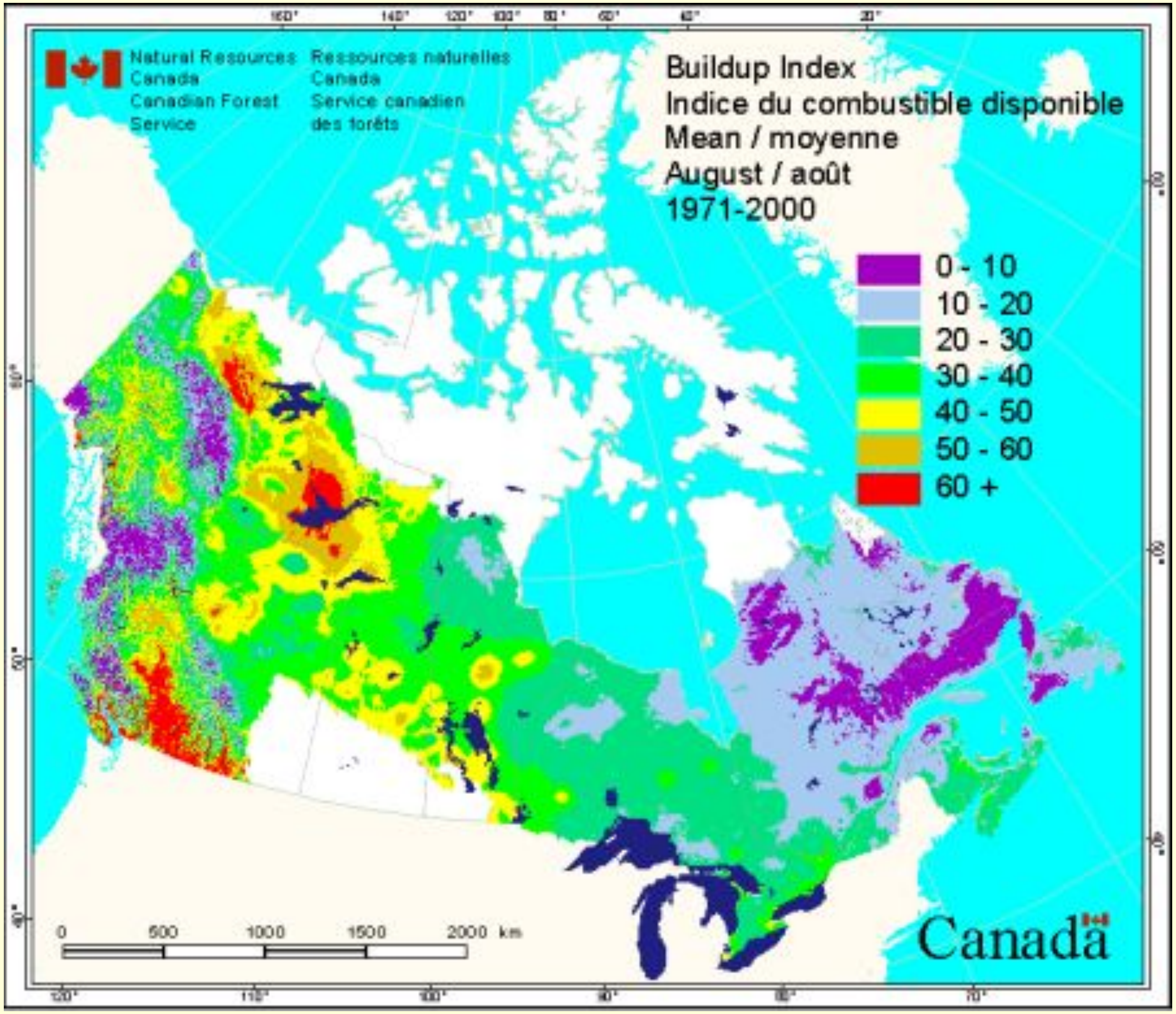
Assessing the wildfire hazard in Canada



Drought Code (fuel flamma-bility)

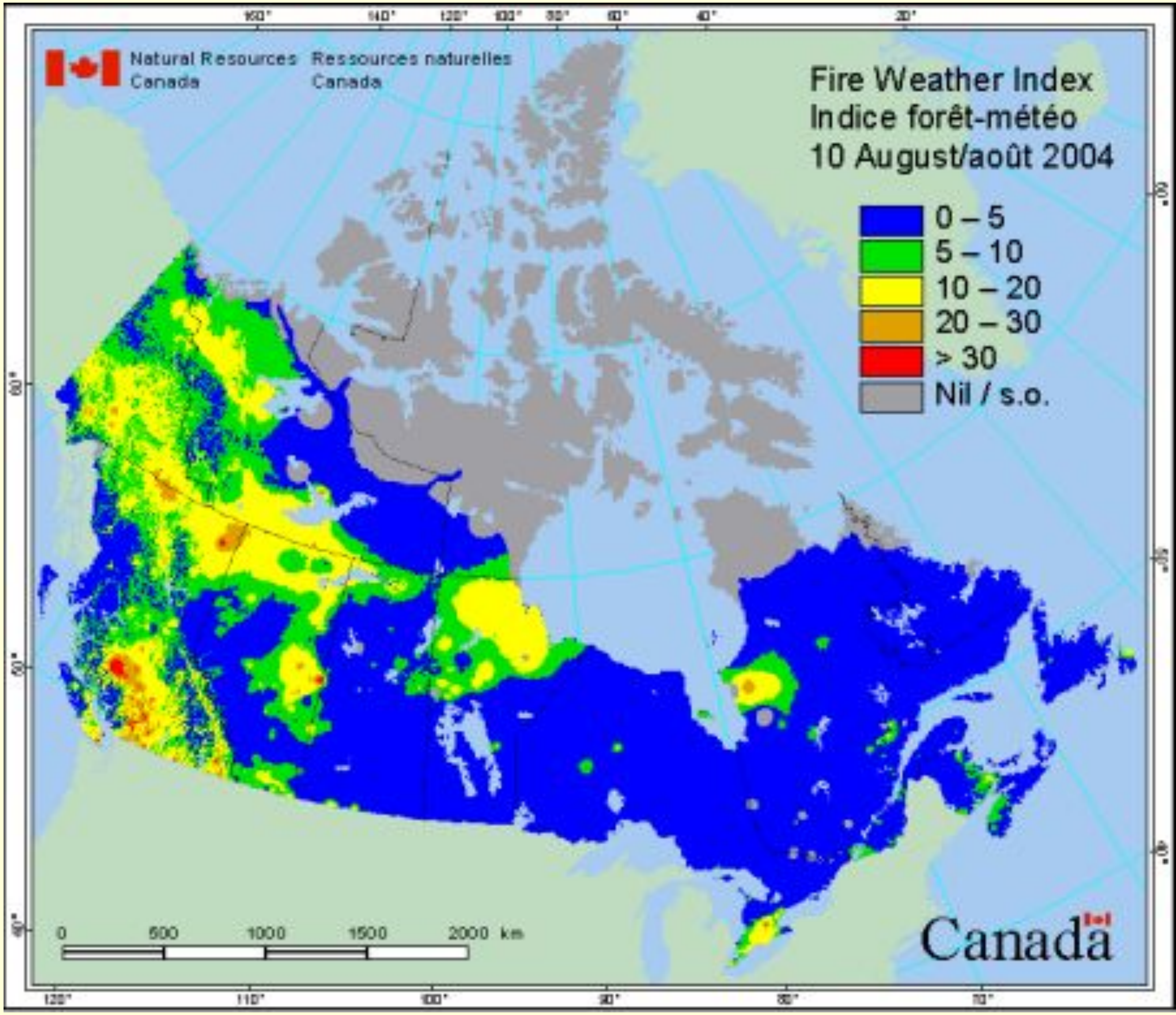


Buildup Index = Fuel availability

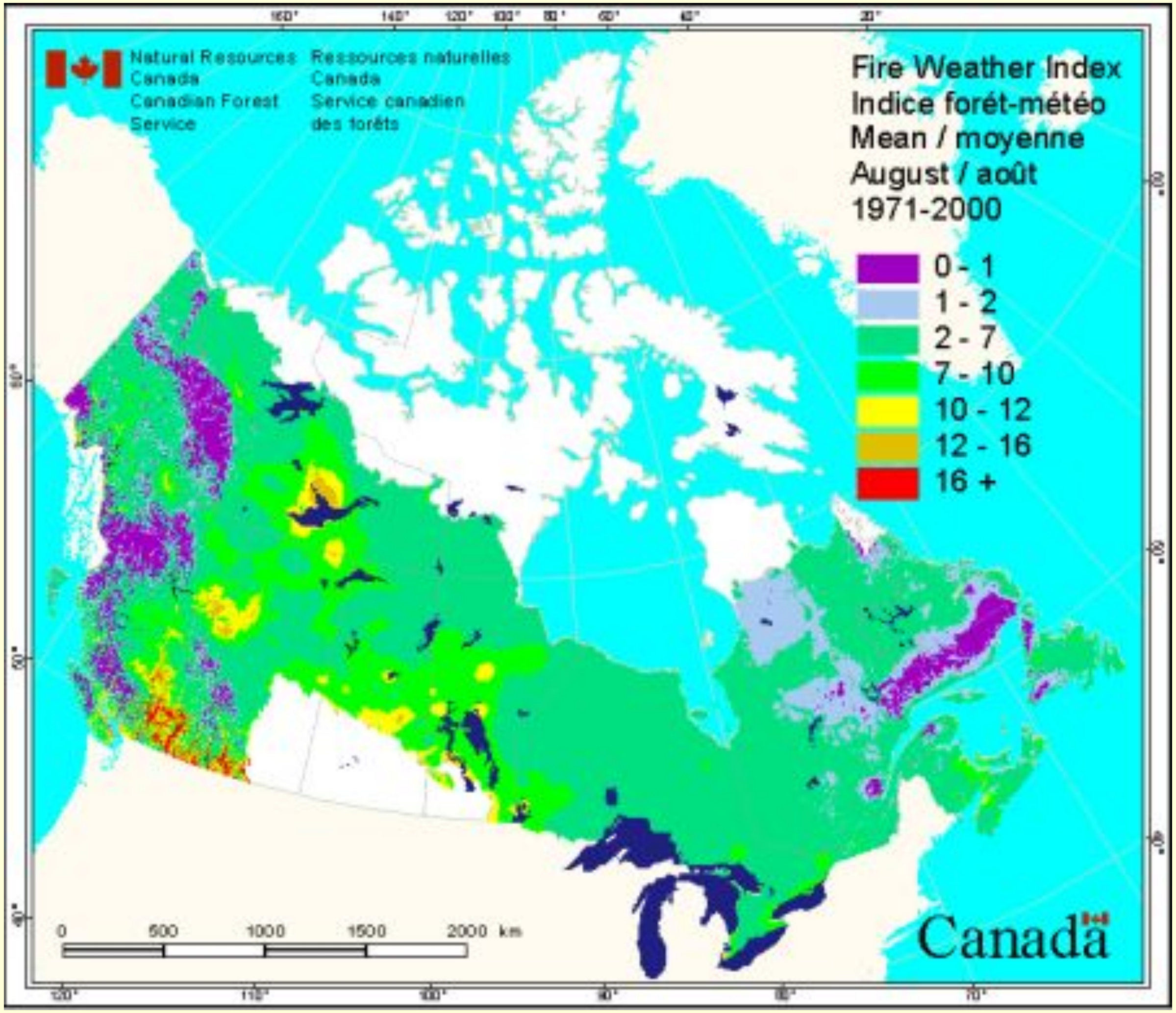


August normals

Fire Weather Index

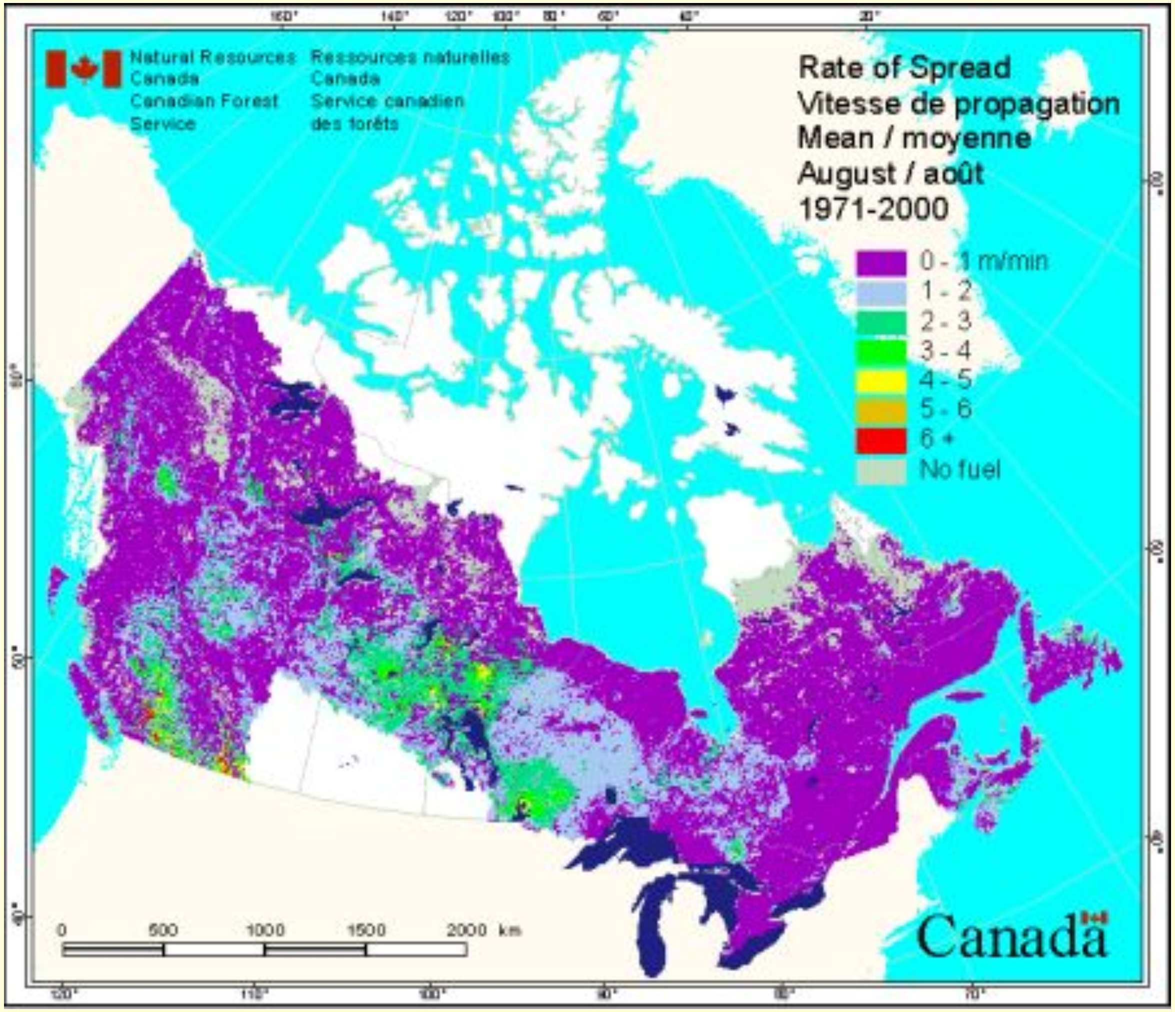


Fire Weather Index



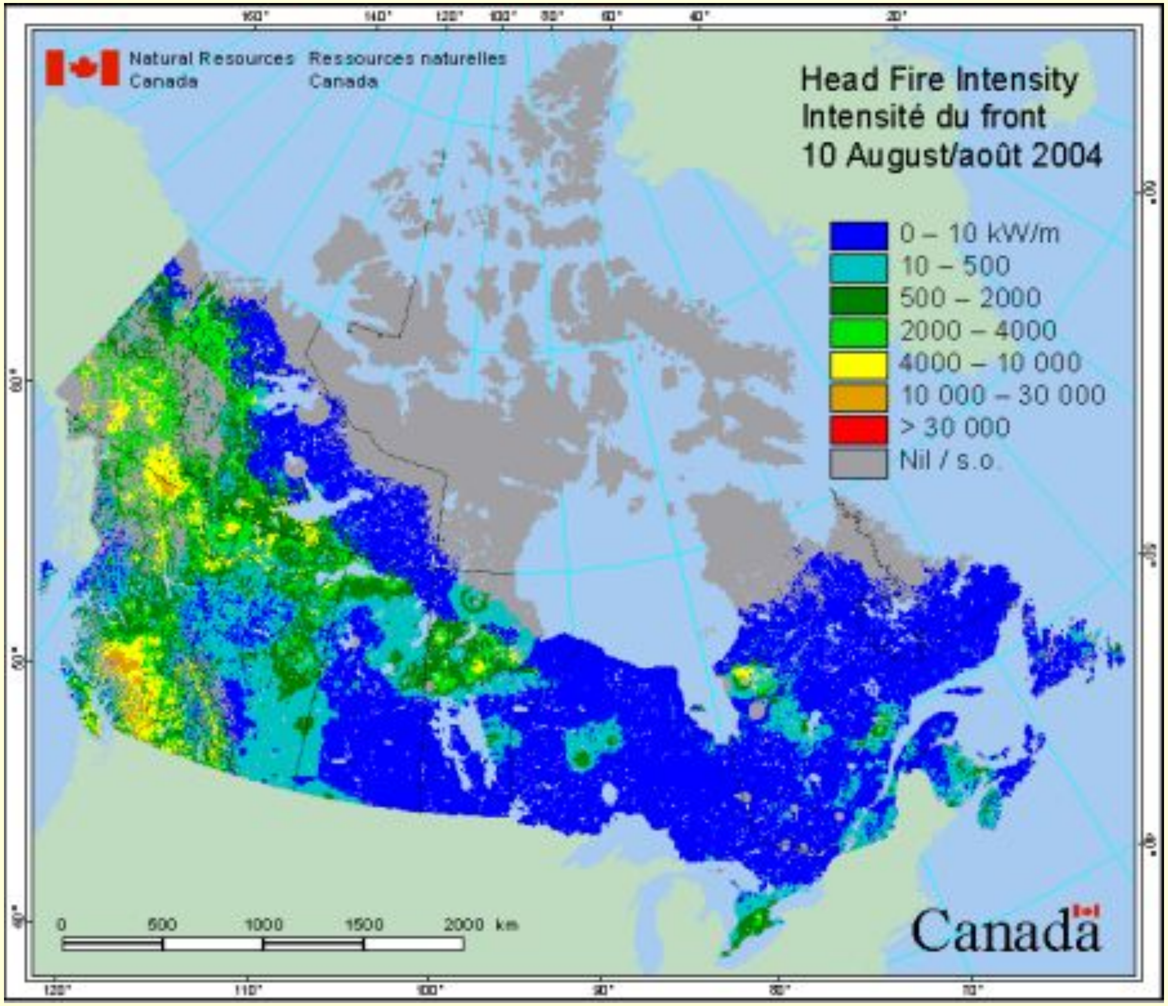
August normals

Rate of spread (fuel, wind, topo-graphy)



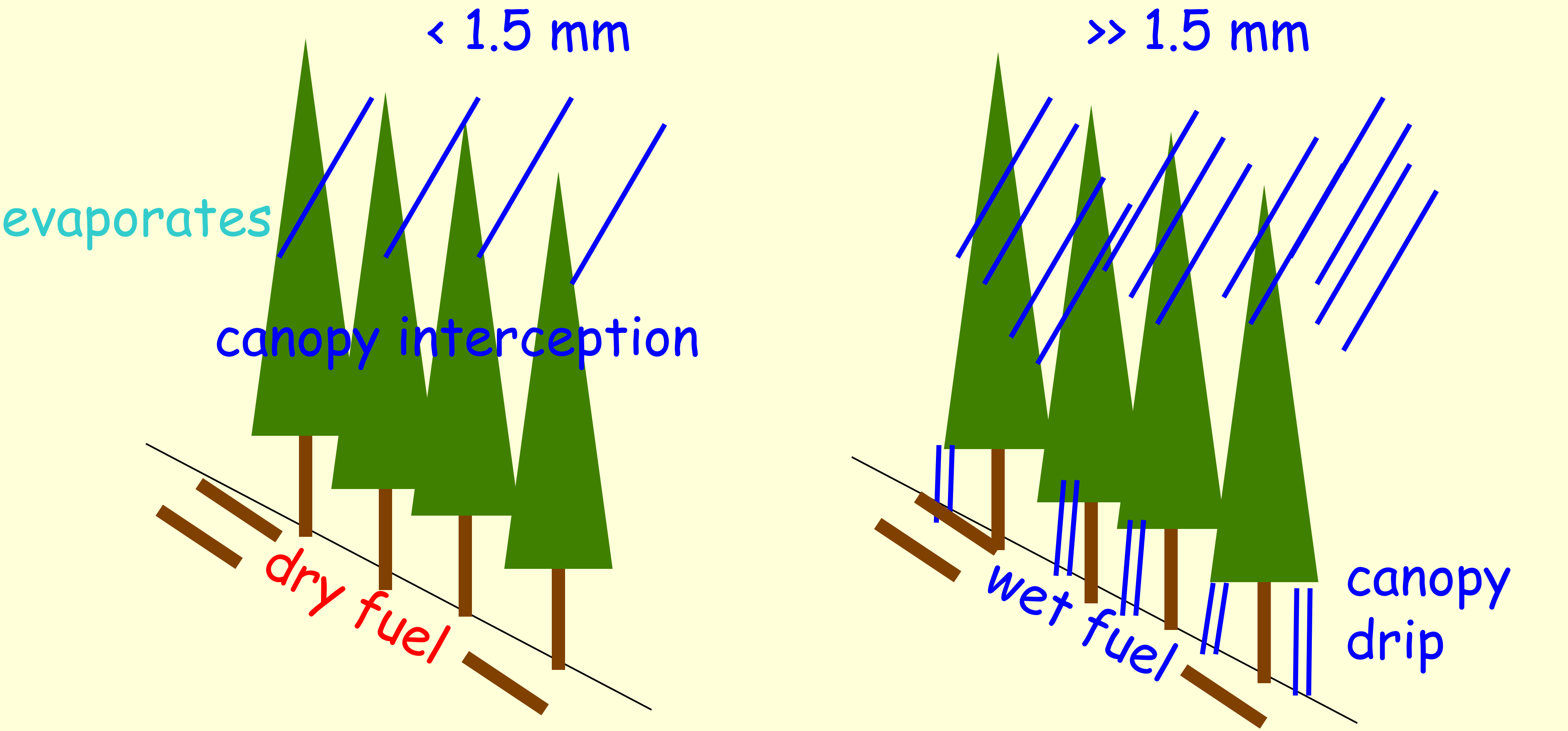
August normals

Head Fire Intensity = energy output (how hard is it to suppress?)

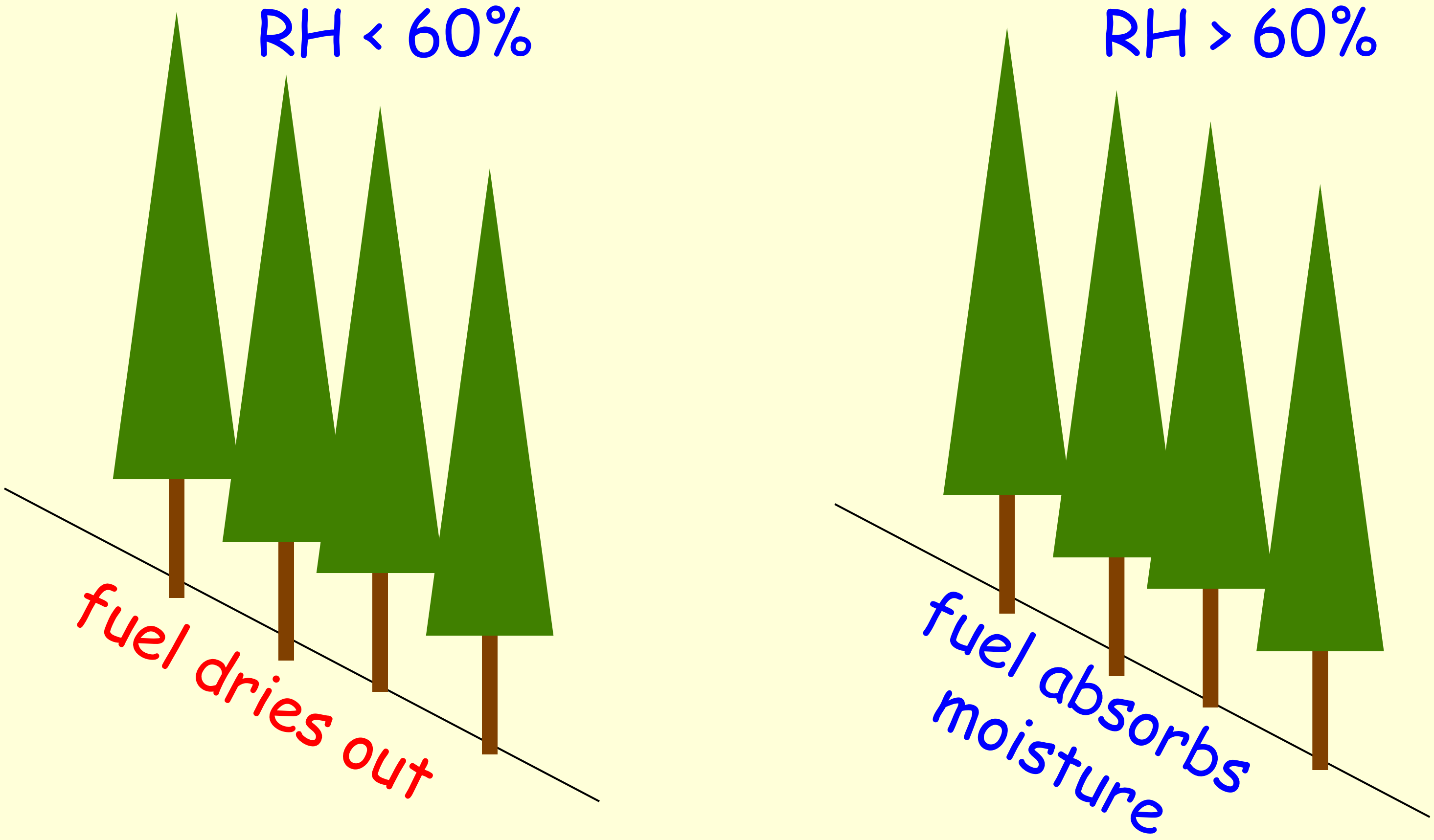


Critical factors in wildfire hazard in coniferous forests:

1. antecedent precipitation



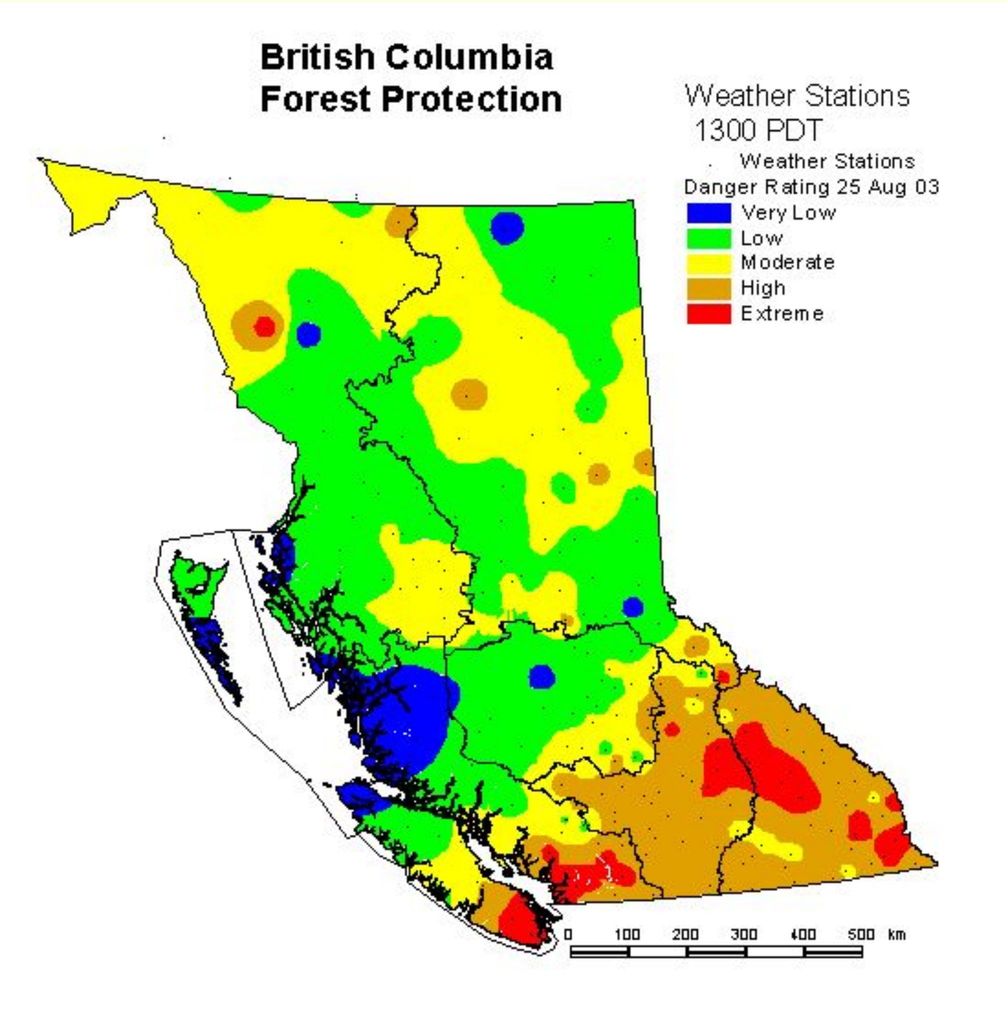
Critical factors in wildfire hazard in coniferous forests:
2. humidity of atmosphere

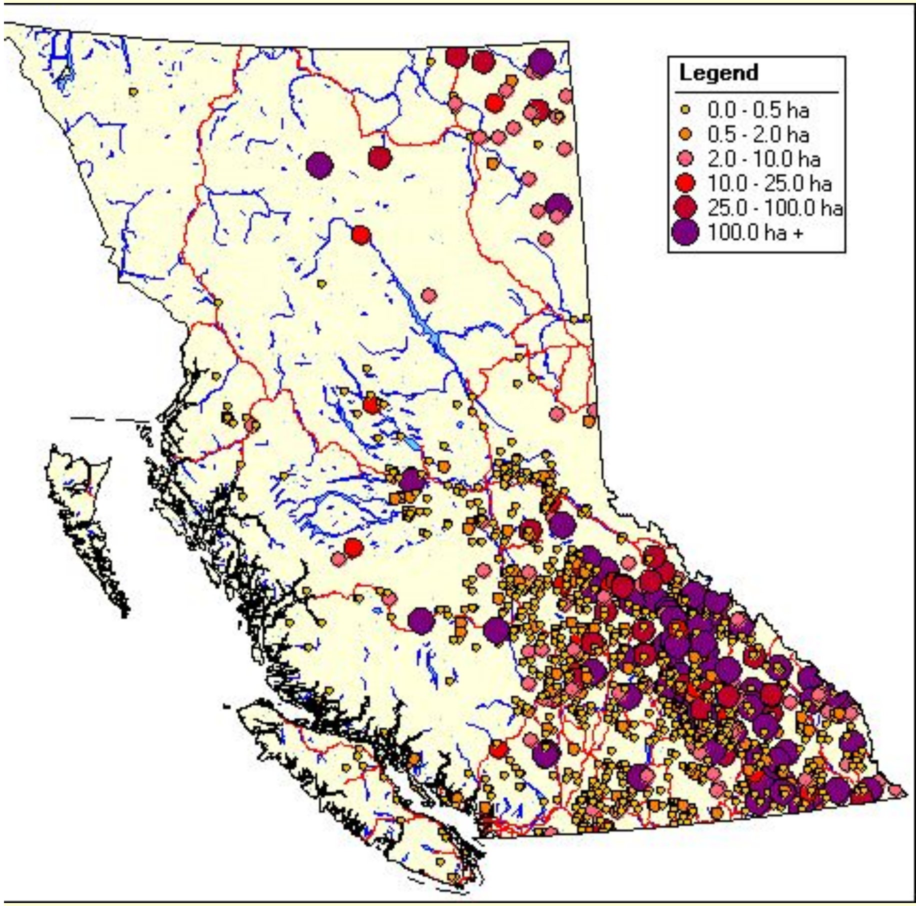


BC fire history (1996-2006)

Data: http://www.bcwildfire.ca/History/average.htm

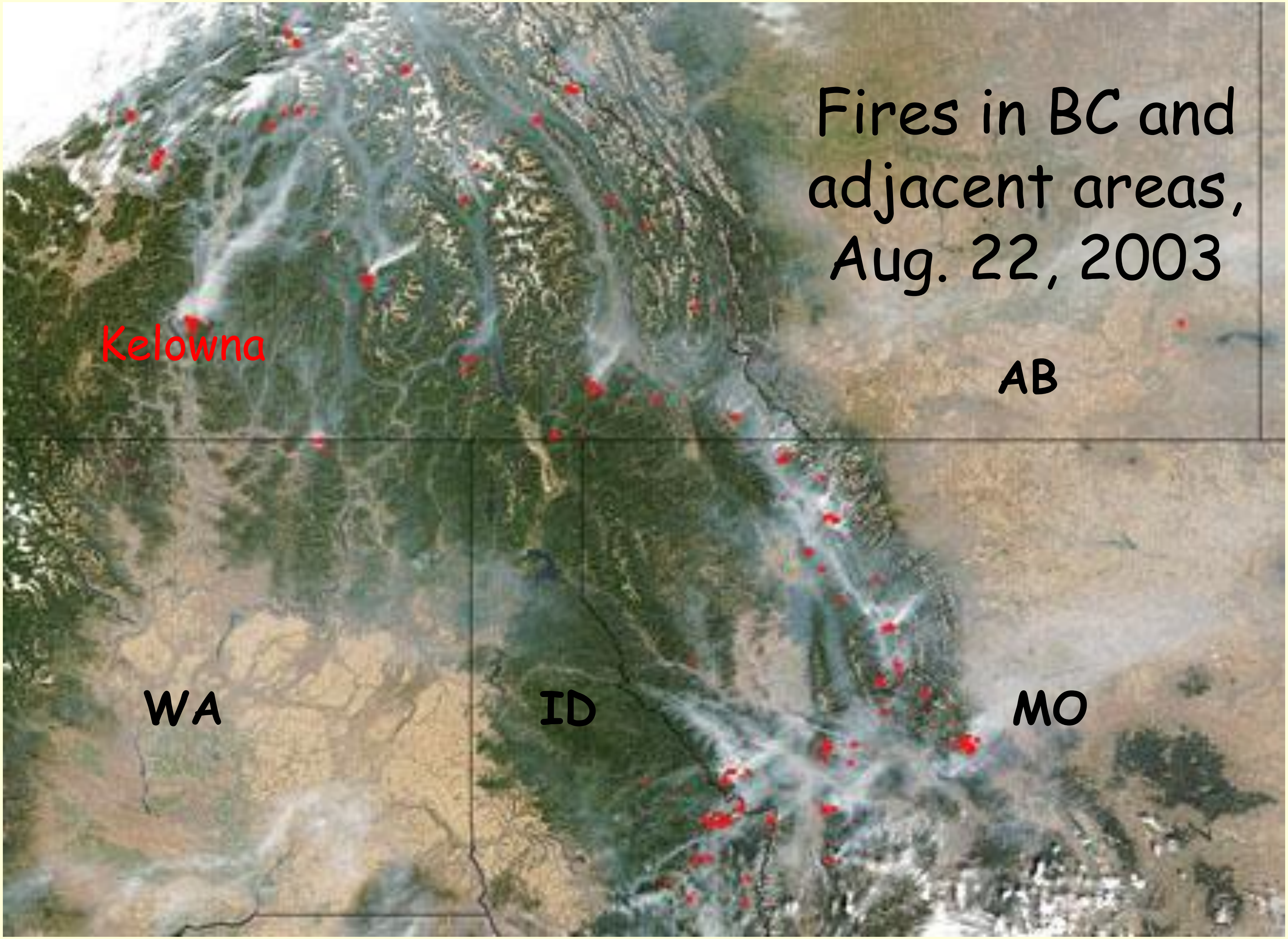
British Columbia: 2003 fire season





Fire Danger: 25 Aug. 2003

Lightning fires 2003


Fires in BC and adjacent areas, Aug. 22, 2003
Kelowna
AB
WA
ID
MO

OK Mountain Park Fire

Discovered: August 16
August 25: 19,400 hectares
Notes: The fire was started by lightning and, as of August 24, was being attacked by 330 fire fighters, 150 military personnel, 17 helicopters, 140 pieces of heavy equipment as well as air tankers. As of August 24, the fire had destroyed an estimated $100 million in real estate including 244 homes in Kelowna. Dry winds, steep terrain and heavy smoke are hindering attempts to contain the fire. At one point 26,000 people were evacuated from Kelowna.

Direct damage: homes ablaze in Kelowna suburbs

Indirect damage: particulates and human health

Smoke in Okanagan valley, Aug. 2003

Recent major fires in BC

Lonesome Lake fire (S. Tweedsmuir Park) (2004):
20,900 ha burned

Salmon Arm fire (1998):
6000 ha burned; 7000 people evacuated; 40 buildings destroyed; $10M to extinguish

Penticton fire (1994):
5500 ha burned; 3500 people evacuated; 18 buildings destroyed

Eg fire (1982):
Near Liard R., Alaska Highway - 180,000 ha burned

Fire management in BC

Risk assessment:
>200 weather stations reporting on fire hazard;
Entire province covered by automatic lightning locator systems - lightning strikes reported to the Penticton Forest Protection office within 60 milliseconds.

Prevention:
e.g. education, thinning, prescribed fires

Control:
e.g. rap-attack crews; air tankers; fire retardants

Budget: $55M (exceeded in 2003 by mid-August)

Fire bombers: water vs. retardant

Southern California wildfires (October, 2003)

Causes:

1. Persistent drought
2. Santa Ana winds
3. Volative native and exotic vegetation

Damages:

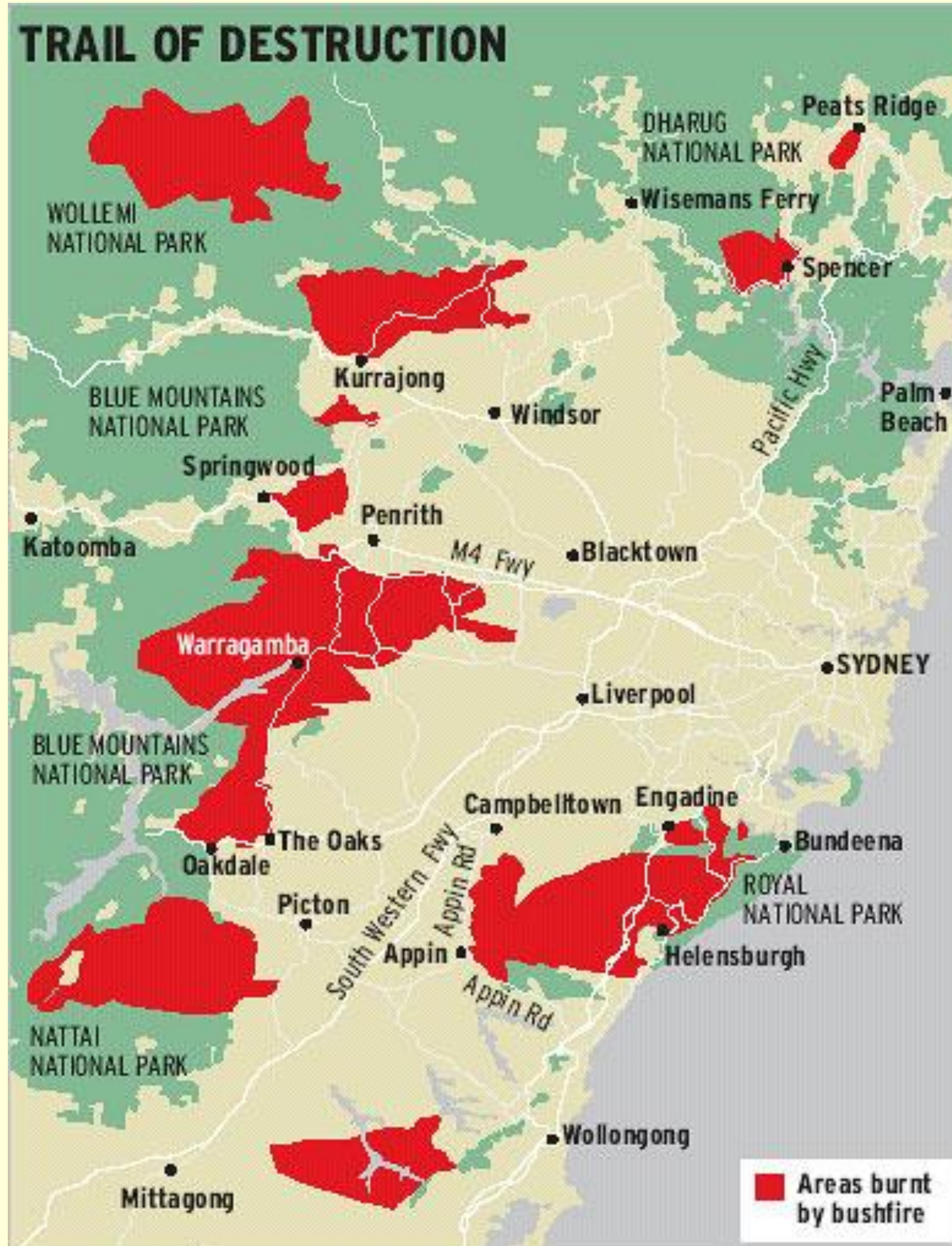
1. ~300 000 ha. burnt
2. 22 deaths
3. 3570 homes destroyed

Wildfire hazards:

Sydney, December 2001

0 25

km



Wildfire hazards

(all photos taken from Sydney Morning Herald, Dec. 2001)

Homes in fire-prone areas

There is increasing residential sprawl into the "wildland-urban interface" and federal, provincial and state forest services in affected areas are reconsidering forest fire-fighting tactics in these WUI areas.

Homeowners in these areas are urged to adopt "firesmart" practices. These include:

- building a fire-resistant home, and
- developing "defensible space" around the house

A defensible site

Slope: Flames traveling up a 30% slope are commonly twice as high, and travel 150% faster than flames on a flat area.

Aspect: S and SW-facing slopes are drier, and therefore more fire-prone than N and NE slopes (in N. hemisphere).

Forest type: Tall forest with dense underbrush and thick fuel accumulations on the forest floor are more hazardous than open forest with grassland.

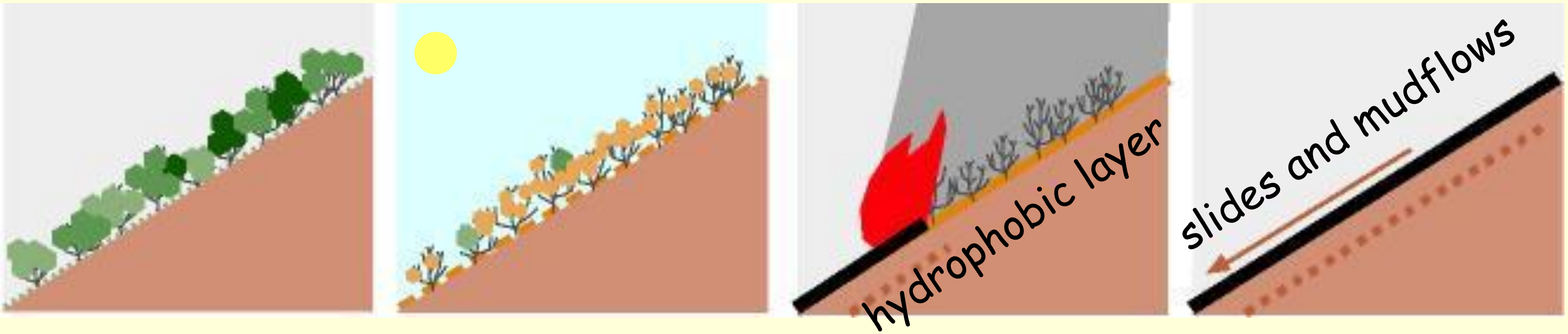
Ease of access and egress: roads and fire-proof bridges.

A defensible house

- Roofs may be ignited by firebrands; use fire-resistant materials and remove debris from gutters.
- Walls may be ignited by heat from flames; use fire-resistant siding and deck supports; keep windows and vents small, and block in event of forest fire.
- Clear trees and shrubs from 10m zone around house. Create a fire break by irrigating this area.
- Build pond for emergency water supply.

Fire and slope stability

S. California



* in the summer of 1999 x2 average acreage burned in S. California

What would be the pattern in the eucalypt forests of New South Wales?

Other weather-related hazards

- Frost hollows
- Fog
- Hail
- Cold spells
- Blizzards
- Freezing rain

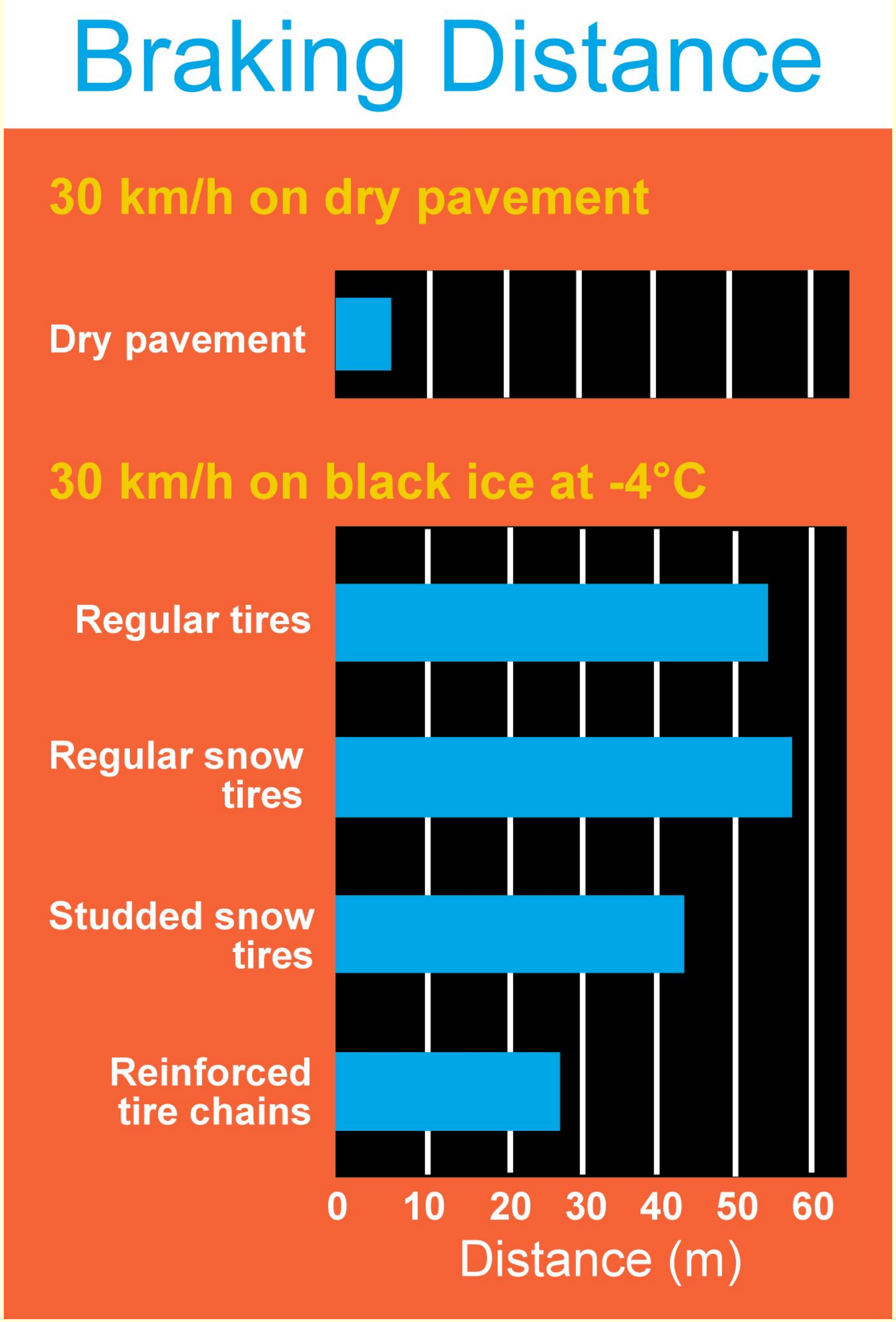
Frost and fog hollows

Frost hollows as crop hazards: Okanogan County, WA.

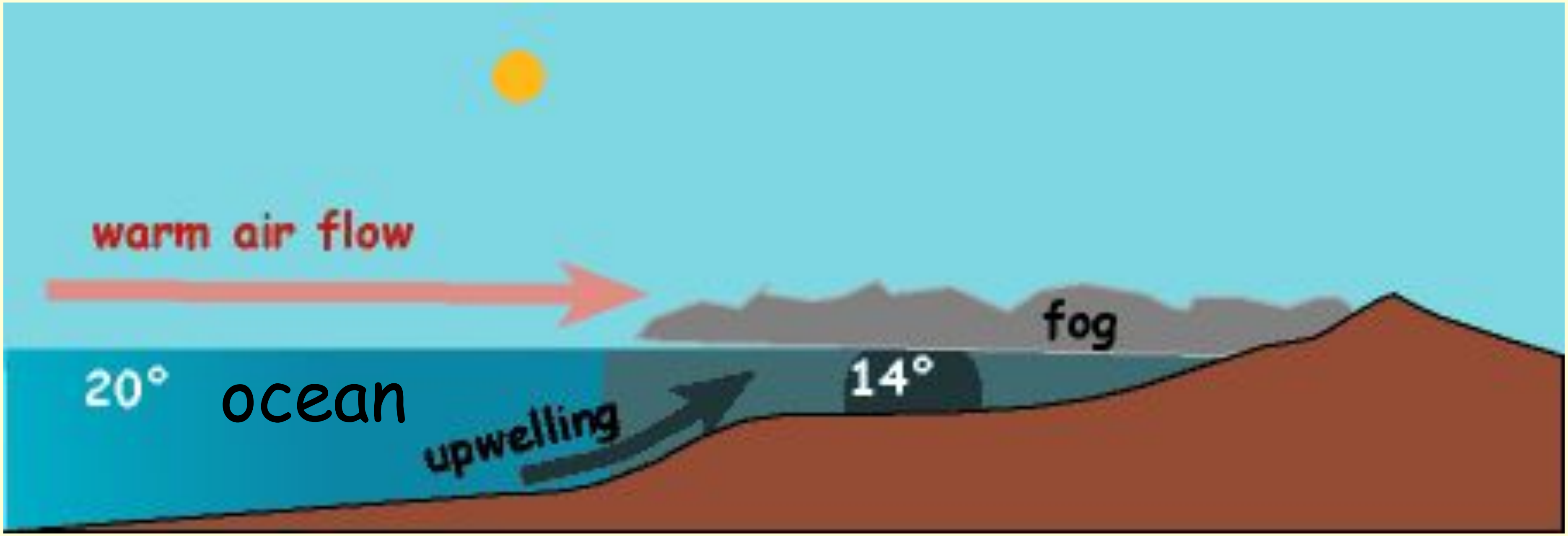
Frost hollows as traffic hazards

Braking distances increase by a factor of ~10 on black (glare) ice

data from California Highway Patrol website

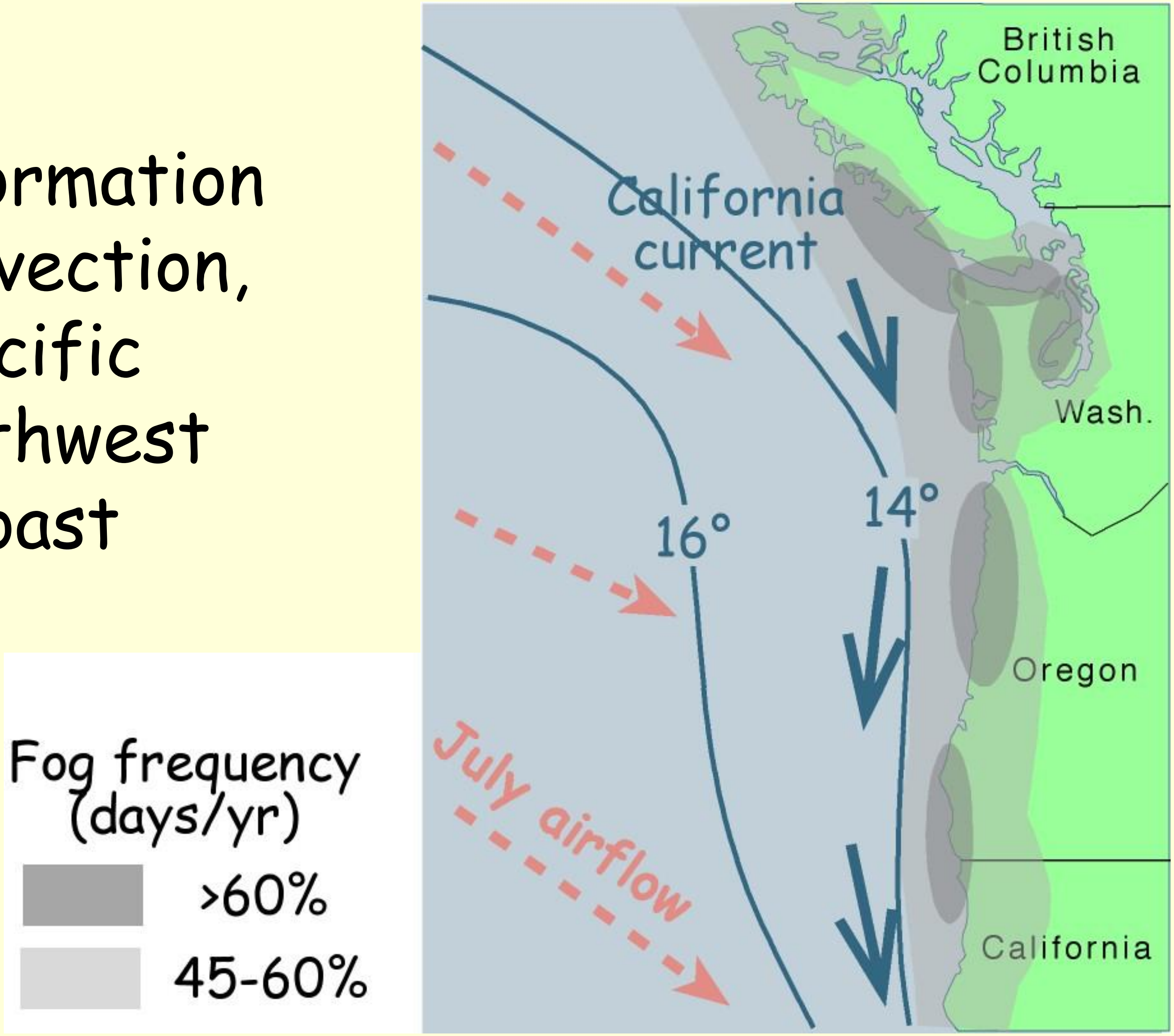


Advection fog



Advection fog bank, southern Oregon

Fog formation by advection, Pacific Northwest coast

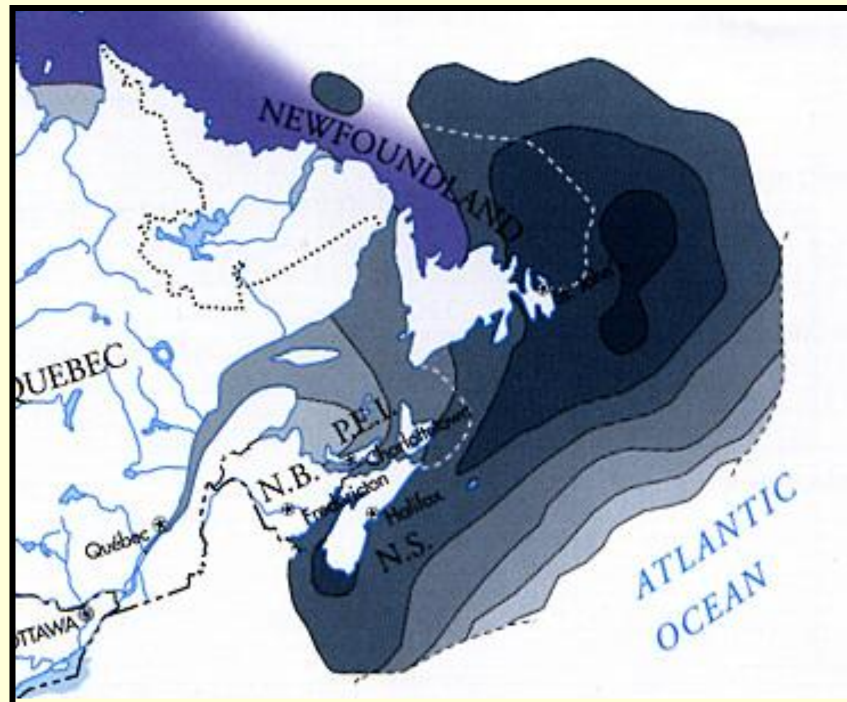


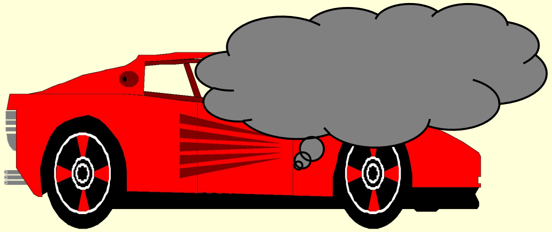
Fog incidence

Areas prone to fog

visibility less than half a nautical mile in July, measured in percentage frequency

- less than 5
- 5 to 9.9
- 10 to 19.9
- 20 to 29.9
- 30 to 40
- greater than 40





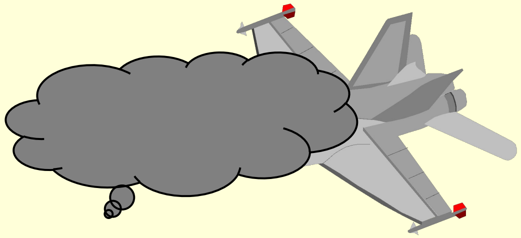
Fog and road accidents

Feb. 12, 1996: 12 killed, 100 injured in a 300-vehicle pile-up in dense fog on freeway near Padua.

Feb. 12, 1998: 4 killed, “dozens injured” in a 250-vehicle crash in dense fog on freeway near Padua.

Oceanside, California

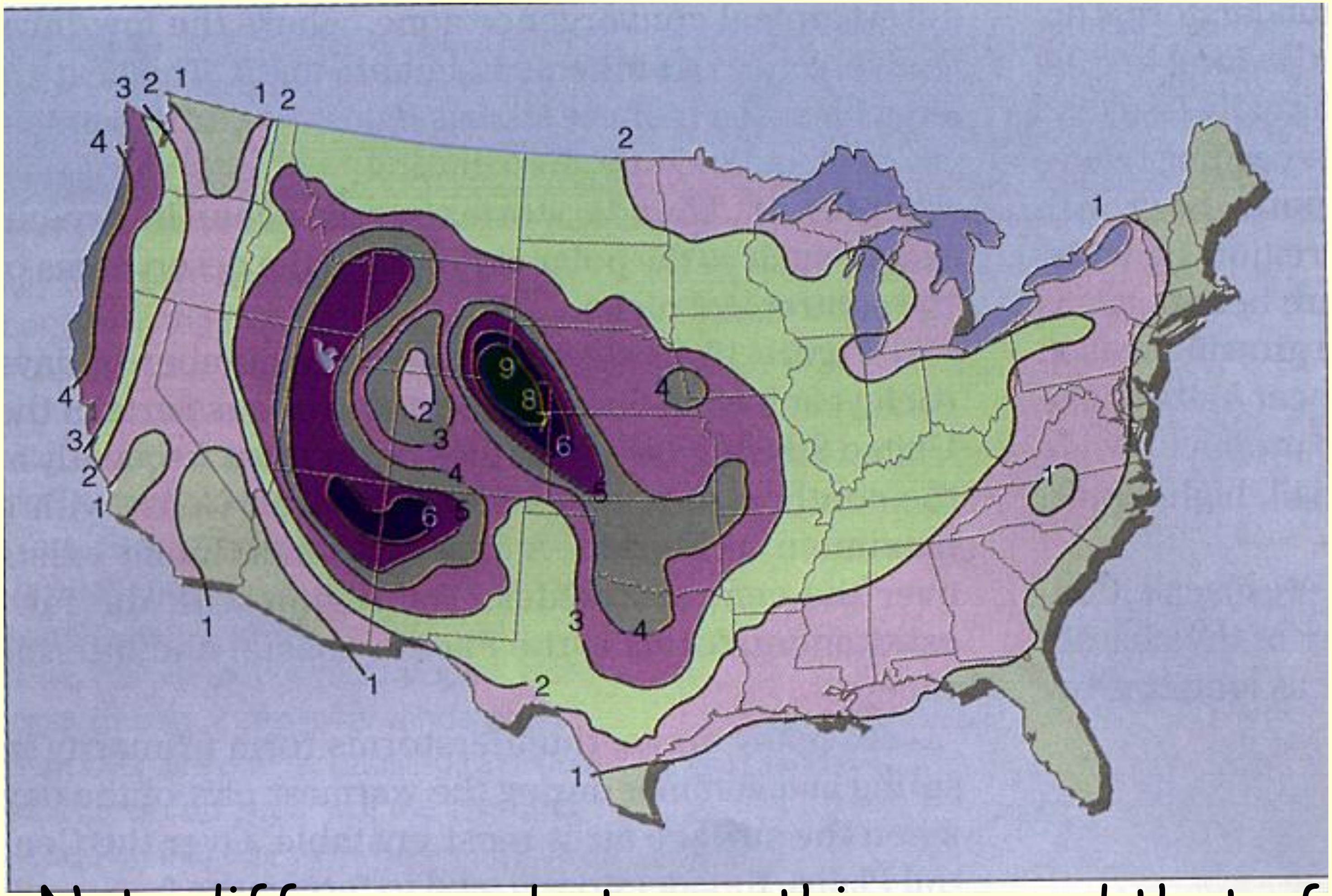
Nov. 25, 1995: 1 killed, “dozens injured” in two pile-ups involving 130 vehicles in dense fog on I-5 freeway near San Diego.
Visibility <10m.



Fog and aircraft safety

- Fog can cause flight delays, cancellations, and accidents.
- Some airports (e.g. SFO) and airlines (e.g. Alaska) especially hard-hit. Latter used to lose US $5M/yr as a result of fog-caused problems.
- New technology (“Fog Buster”) allows pilots to takeoff in <100m visibility, and land in <200m visibility.

Hail incidence (days/year)

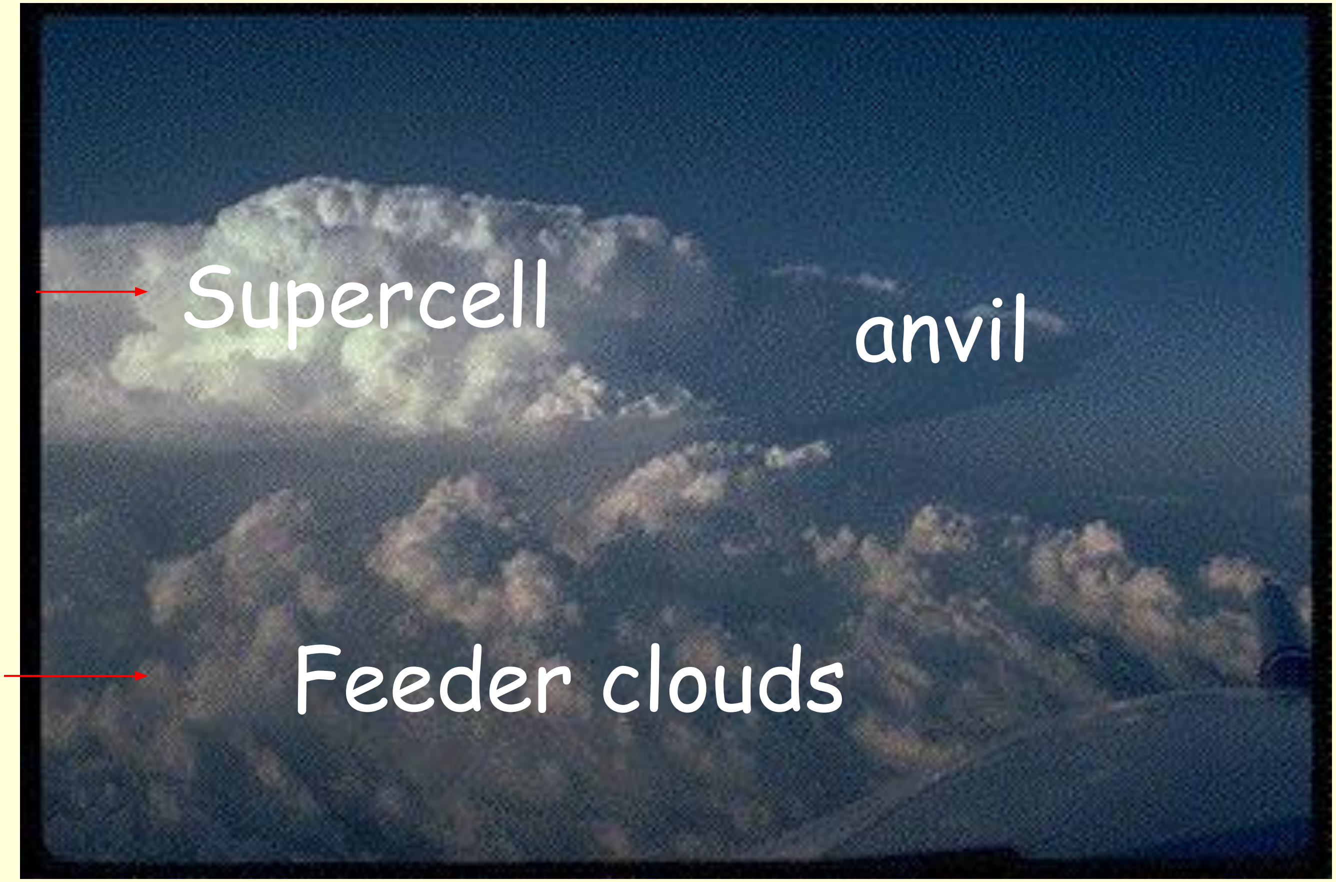


Note differences between this map and that of thunderstorm distribution (severe storms lecture)

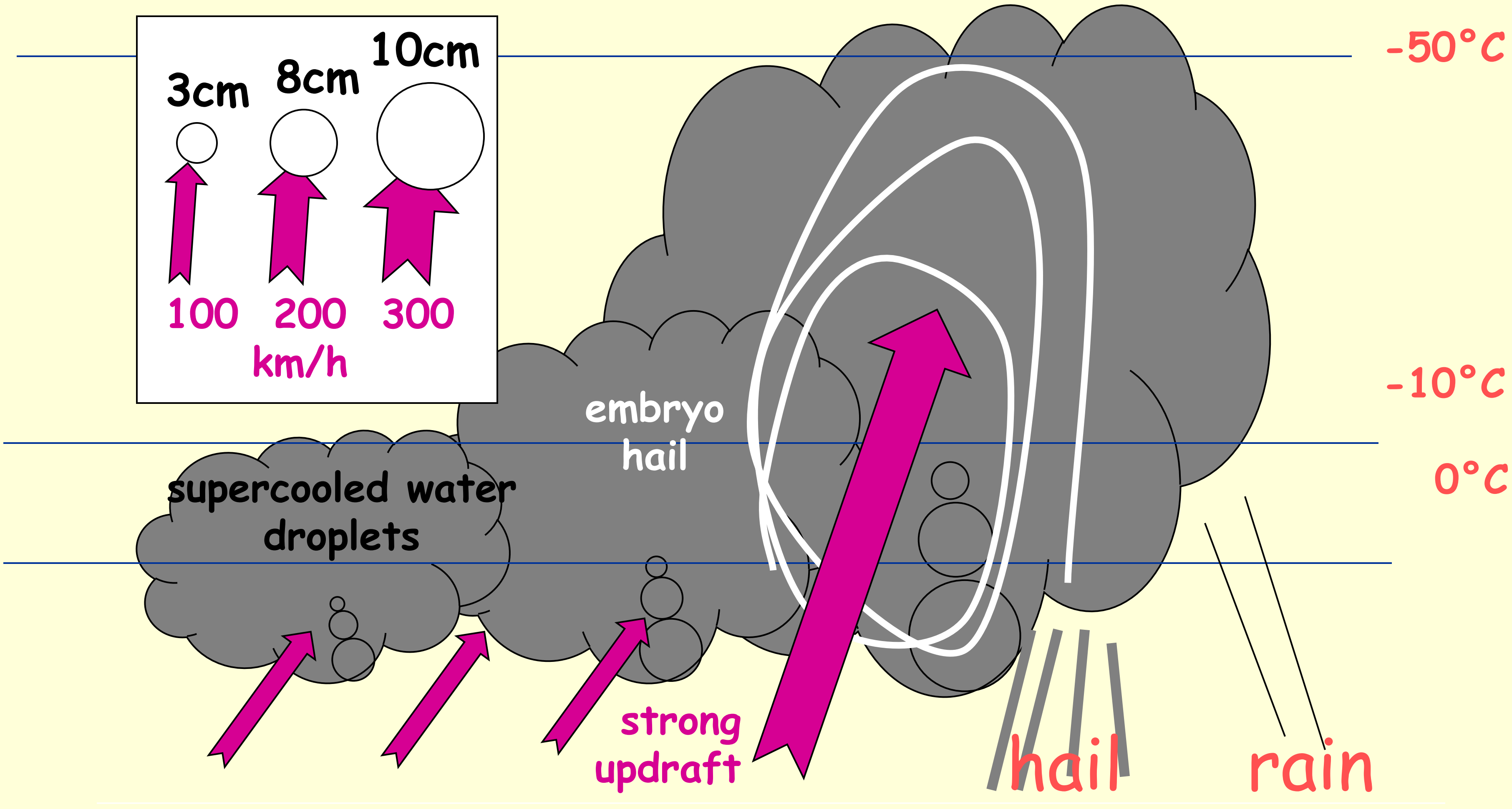
Hail formation

-50°C
all droplets
are solid ice

-10°C
embryo
ice pellets
form



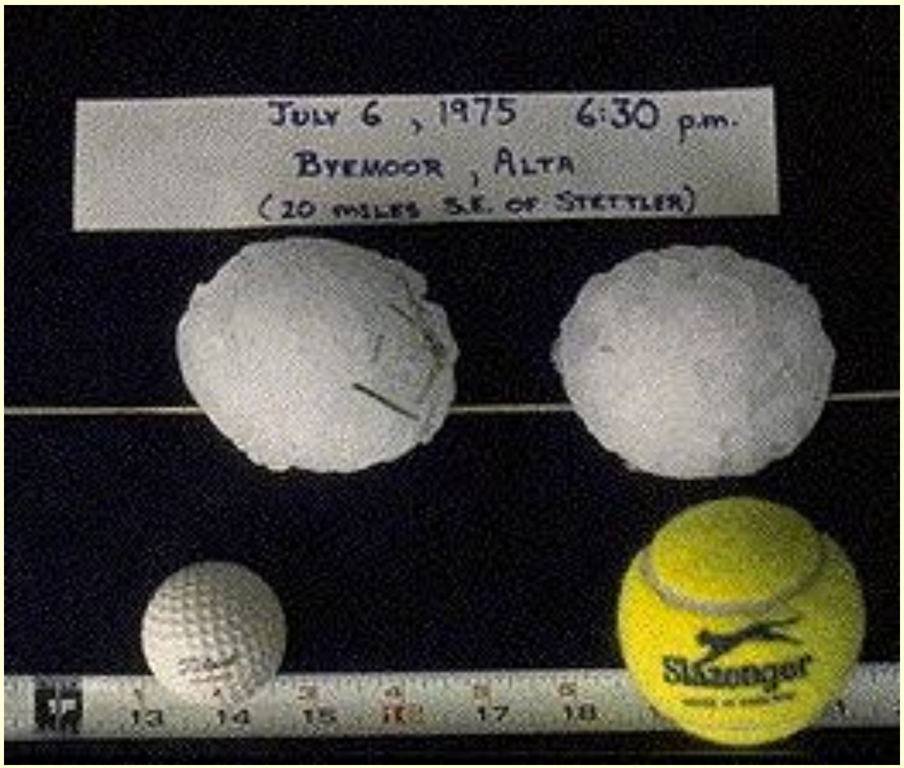
Hail formation: feeder clouds and double-vortex thunderstorm



Hailstorms, west Texas

Flooding as a result of hailstorms
e.g. “Isaac’s Storm”

Hailstones and hail damage



Hail damage

Severe incidents

- Denver, COL -- US$625M insurance costs for damage from large hail (July 11, 1990)
- Calgary, AL --US$400M (Sept., 7, 1991)

Annual costs of hail damage (mainly to crops) in Alberta in early 1980's ~US$100M. Urban damage now commonly exceeds agricultural damage.

Hail suppression

Based on the concept that there are insufficient ice nuclei in a cloud producing large hail. Seeding the cloud with artificial nuclei (AgI) produces competition for the supercooled water in the cloud, so the hailstones that are produced will be smaller and therefore produce less damage. If enough nuclei are introduced into the growth region, then the hailstones may be small enough to melt before reaching the ground.

Hail suppression logistics

Seeding locations -- in vicinity of strongest updrafts; either at surface, in base, or at top of cloud [depending on storm structure (visible and radar clues)]. Aim to produce >1300 ice crystals per litre of air.

Results of hail suppression

N. Dakota: 45% reduction in hail insurance claims (1976-88) compared to a control area in eastern Montana.

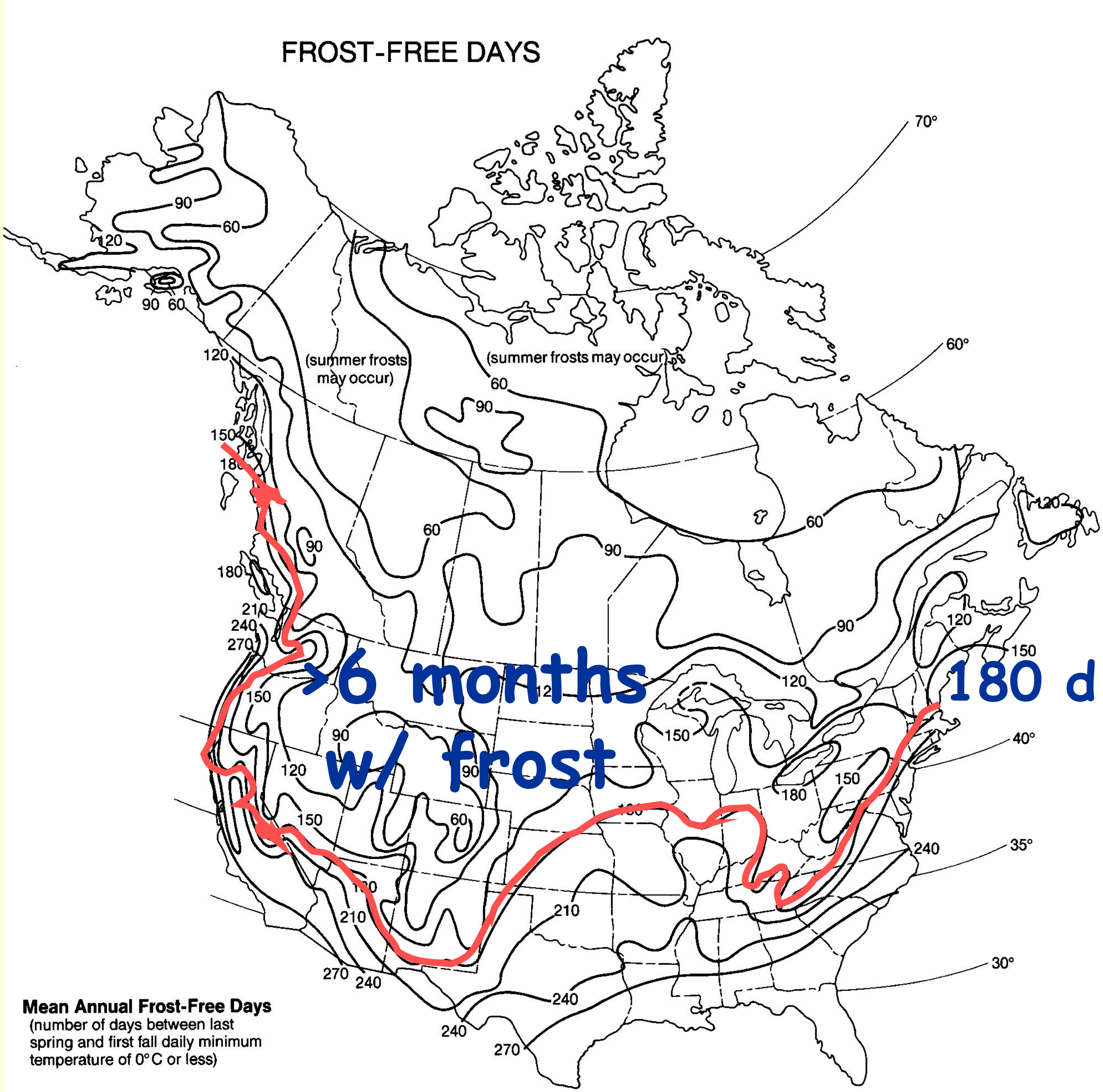
Alberta (1980-85): 20% reduction in crop losses - some of the reduction due to climate change? Program cancelled, but new project now underway (1999-2004).

Greece (1984-88): 52% reduction in number of hailstones, 34% reduction in maximum hail size, and 74% reduction in hail impact energy. Insurance losses in suppression area declined by 18-59%.

Winter hazards

- **Thermal:**
  human discomfort and disease
  heating costs (10% of Swedish GNP!)
  damage to crops, buildings, roads, etc.
- **Precipitation:**
  blizzards, freezing rain

Frost hazards



Hypothermia

- Cold exposure results in vascorestriction of blood vessels, restricting flow of blood to skin.
- When deep body temperature falls below **35°C** thermal control is lost. Death occurs when deep body temperature falls below **26°C**

Wind chill factor

Until 2001, the Siple-Passel formula was used in North America to calculate wind chill:

$H = (SQRT\ [100V] + 10.45 - V) \times (33 - T_a)$

where H is the rate of heat loss ($W/m^2/min$); V is the wind speed in m/s, and T_a is the air temperature.

H ranges from 50-2500.

H>1400 → frostbite on exposed skin surfaces.

H>2300 → frostbite within 30 seconds.

New wind chill equation

In 2001 Environment Canada and the US National Weather Service adopted a new wind chill index. The 'Celsius' version of the wind chill equation is:

$$W = 13.12 + 0.6215 \times T - 11.37 \times V^{0.16} + 0.3956T \times V^{0.16}$$

where

W is the wind chill index (intended to represent temperature *sensation*, not a 'real' temperature);

T is the air temperature in degrees Celsius (°C), and

V is the wind speed at 10 metres (standard anemometer height), in kilometres per hour (km/h).

Wind Chill Calculation Chart

/T air (°C)	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50
V_{10} (km/h)												
5	4	-2	-7	-13	-19	-24	-30	-36	-41	-47	-53	-58
10	3	-3	-9	-15	-21	-27	-33	-39	-45	-51	-57	-63
15	2	-4	-11	-17	-23	-29	-35	-41	-48	-54	-60	-66
20	1	-5	-12	-18	-24	-31	-37	-43	-49	-56	-62	-68
25	1	-6	-12	-19	-25	-32	-38	-45	-51	-57	-64	-70
30	0	-7	-13	-20	-26	-33	-39	-46	-52	-59	-65	-72
35	0	-7	-14	-20	-27	-33	-40	-47	-53	-60	-66	-73
40	-1	-7	-14	-21	-27	-34	-41	-48	-54	-61	-68	-74
45	-1	-8	-15	-21	-28	-35	-42	-48	-55	-62	-69	-75
50	-1	-8	-15	-22	-29	-35	-42	-49	-56	-63	-70	-76
55	-2	-9	-15	-22	-29	-36	-43	-50	-57	-63	-70	-77
60	-2	-9	-16	-23	-30	-37	-43	-50	-57	-64	-71	-78
65	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79
70	-2	-9	-16	-23	-30	-37	-44	-51	-59	-66	-73	-80
75	-3	-10	-17	-24	-31	-38	-45	-52	-59	-66	-73	-80
80	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81

where Tair = Actual air temperature in °C

V_{10} = Wind speed at 10 metres in km/h (as reported in weather observations)

Approximate Thresholds:

Risk of frostbite in prolonged exposure: windchill below	-25	
Frostbite possible in 10 minutes at	-35	Warm skin, suddenly exposed. Shorter time if skin is cool at the start.
Frostbite possible in less than 2 minutes at	-60	Warm skin, suddenly exposed. Shorter time if skin is cool at the start.

Wind chill - Minutes to Frostbite

Minutes to frostbite for the 5% most susceptible segment of the population

Temperature(°C) Wind (km/h)	-15	-20	-25	-30	-35	-40	-45	-50
10	*	*	22	15	11	8	7	6
20	*	*	14	10	7	6	**5**	**4**
30	*	18	11	8	6	**4**	**4**	**3**
40	42	14	9	6	**5**	**4**	**3**	**2**
50	27	12	8	**5**	**4**	**3**	**2**	**2**
60	22	10	7	**5**	**3**	**3**	**2**	**2**
70	18	9	6	**4**	**3**	**2**	**2**	**2**
80	16	8	**5**	**4**	**3**	**2**	**2**	**1**

* = Frostbite unlikely

Frostbite possible in 2 minutes or less

Frostbite possible in 3 to 5 minutes

Frostbite possible in 6 to 10 minutes

The wind speed, in km/h, is at the standard anemometer height of 10 metres (as reported in weather observations).

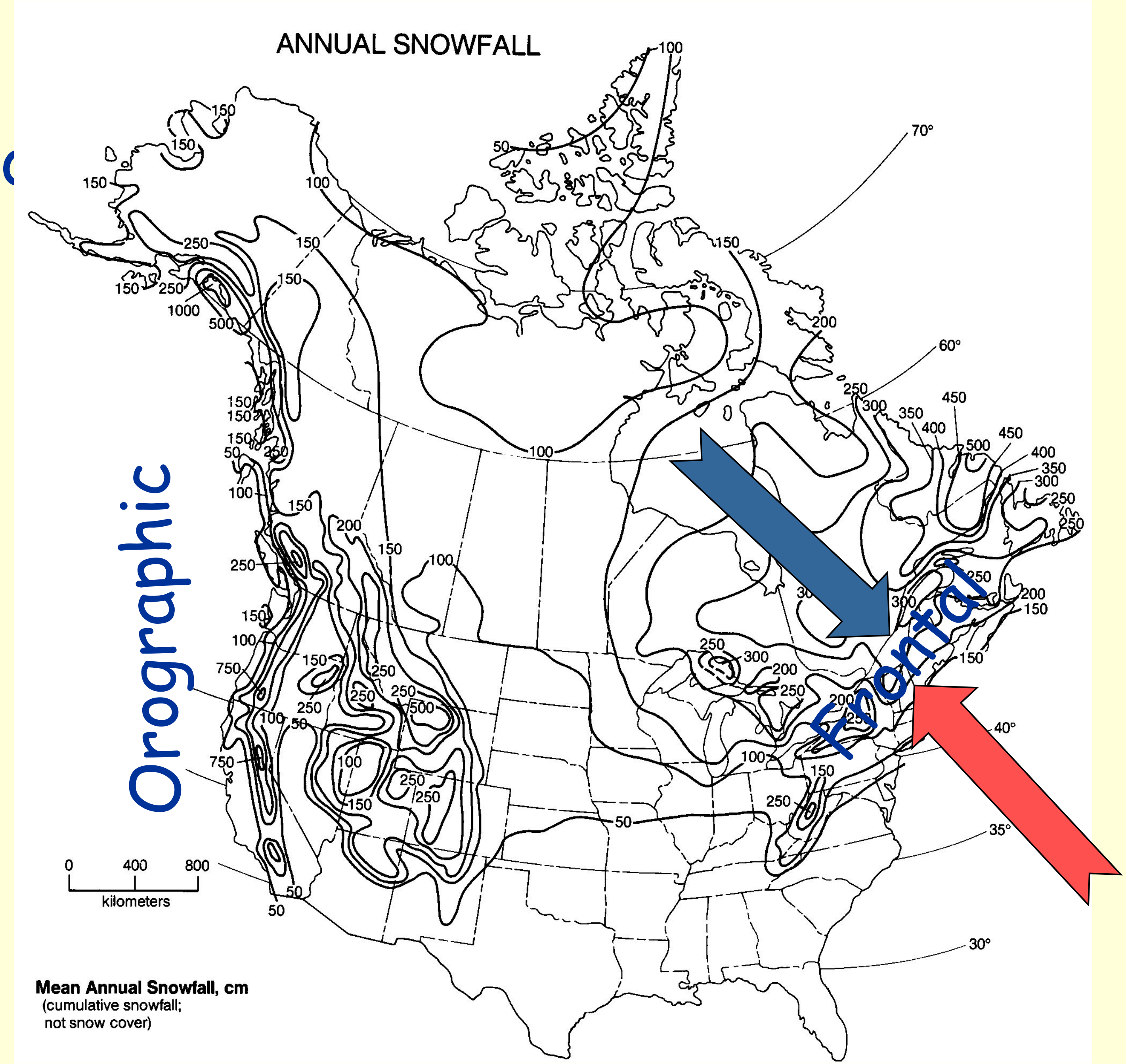
Winter hazards: property damage

- Freeze-thaw damage to roads, bridges, buildings*, etc.

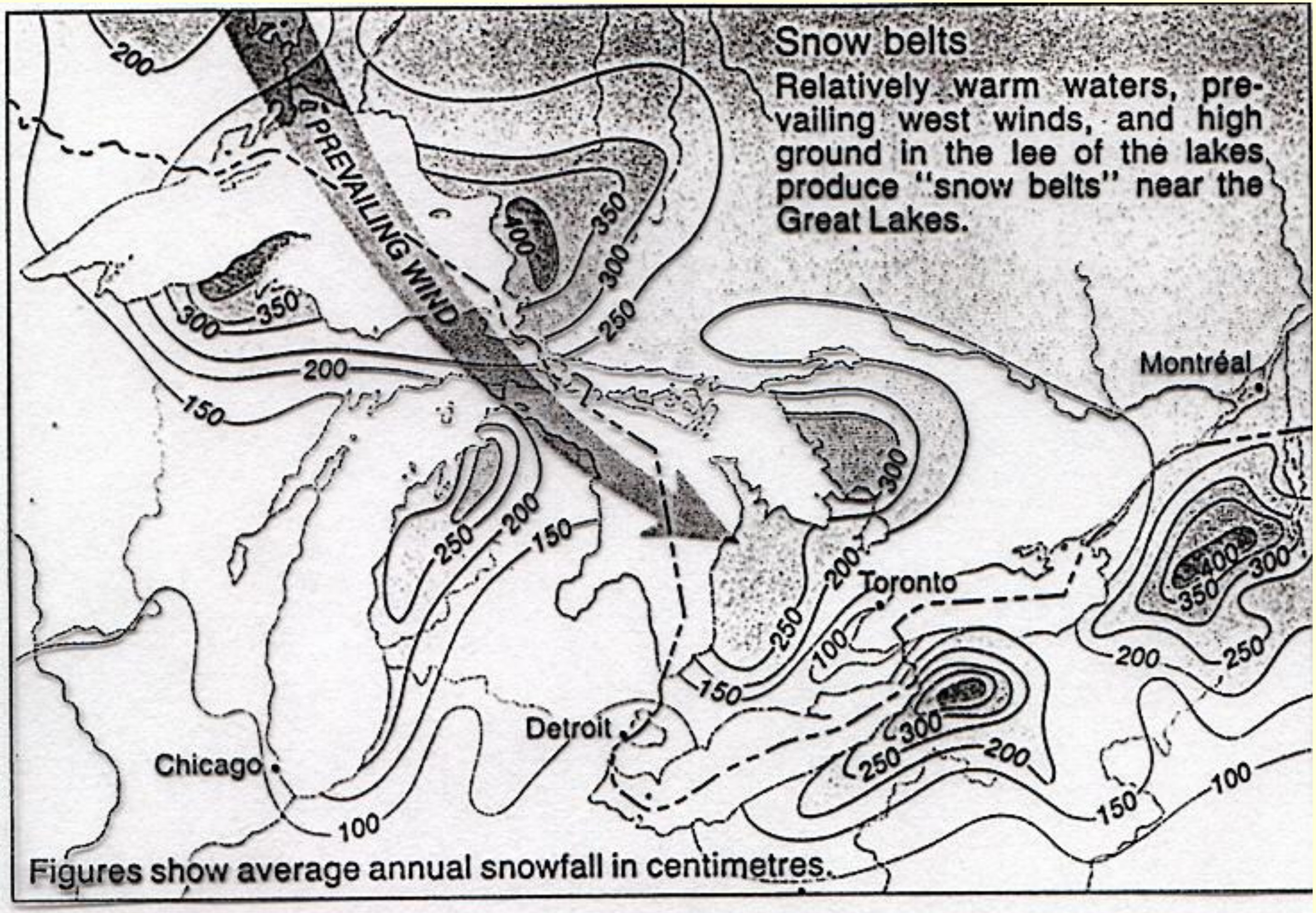
  e.g. State Farm Insurance paid out $4M in house freeze-up claims for week of January 16-23, 1994 in Ontario.

- Salt damage to vehicles/ environment

Or


ANNUAL SNOWFALL
Orographic
Frontal
0 400 800
kilometers
Mean Annual Snowfall, cm
(cumulative snowfall;
not snow cover)

"Snow belts"



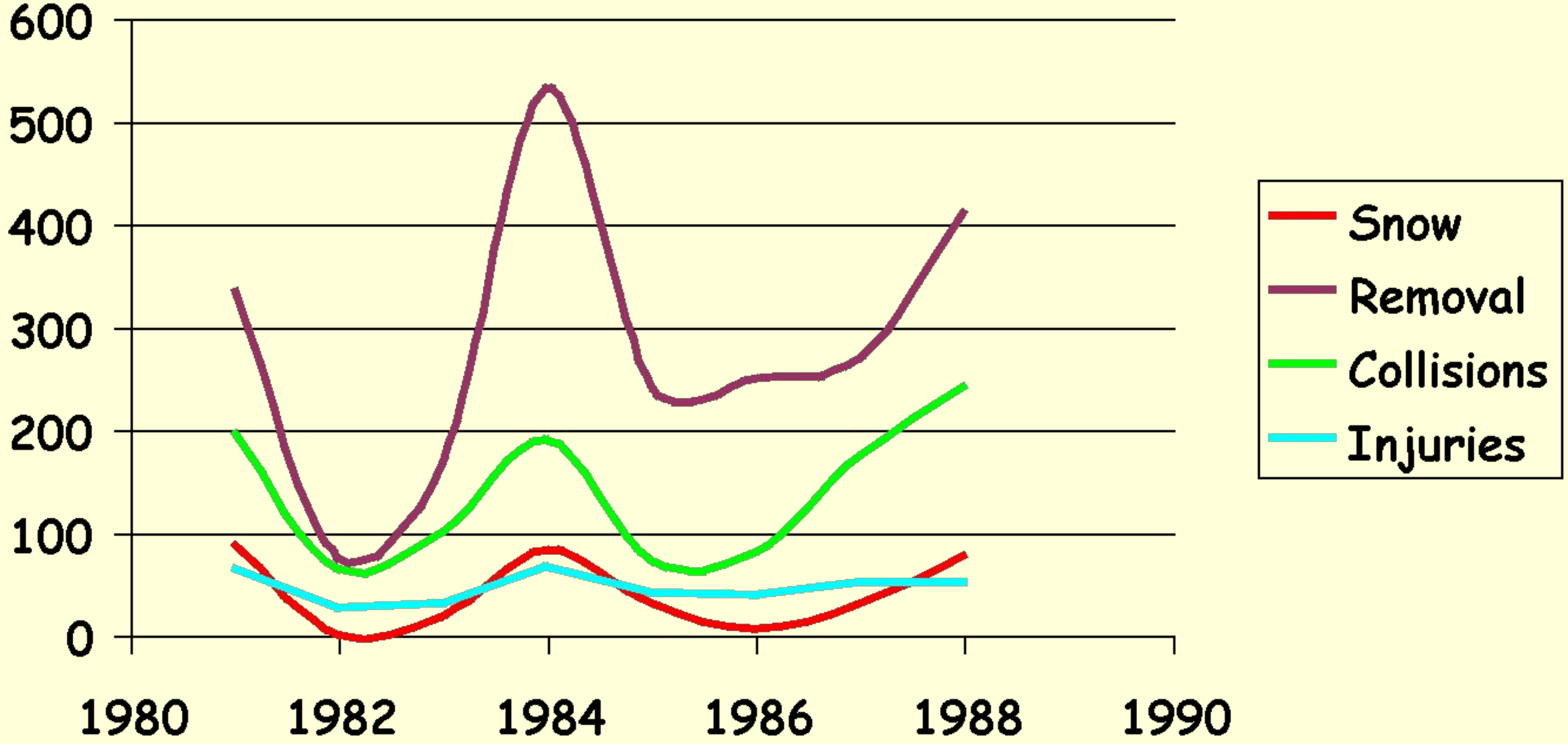
Snow belts
Relatively warm waters, prevailing west winds, and high ground in the lee of the lakes produce "snow belts" near the Great Lakes.
PREVAILING WIND
Montréal
Toronto
Detroit
Chicago
200
400
350
300
250
150
100
Figures show average annual snowfall in centimetres.

Blizzard hazards

- e.g. 1997 blizzard in southern BC (~60 cm of snow in 24 h in Victoria; drifts 10 m high in eastern Fraser Valley)
- Traffic accidents
- Road closures
- Airport closures
- Power blackouts
- Lost productivity

Maclean's (January 13, 1997)

Costs of snow - Surrey, BC



Snow-clearing costs I

City	Snowfall (cm)	Roads (km)	Sidewalks (km)	Cost ($M) 1993
Vancouver	10	-	-	0.2
Edmonton	130	4000	-	14
Montreal	215	2000	3250	58*
Ottawa	220	-	-	10
Moncton	350	-	-	2

*costs $300K/cm of snow!

Snow-clearing costs II

- Montreal has 72 ploughs, 47 loaders. 68 blowers (@$250K each), 100 sanding trucks, 123 sidewalk bombardiers, and 3000 workers on call.
- Winnipeg (like all Canadian cities) has a snow-clearing strategy to reduce costs:
  ≤3 cm - clear major roads only;
  ~5 cm - city core cleared;
  ≥15 cm - residential streets cleared

Insurance costs

In January 1993, a relatively snow-free month, 5200 auto insurance claims cost the insurance companies in Ontario $11M.

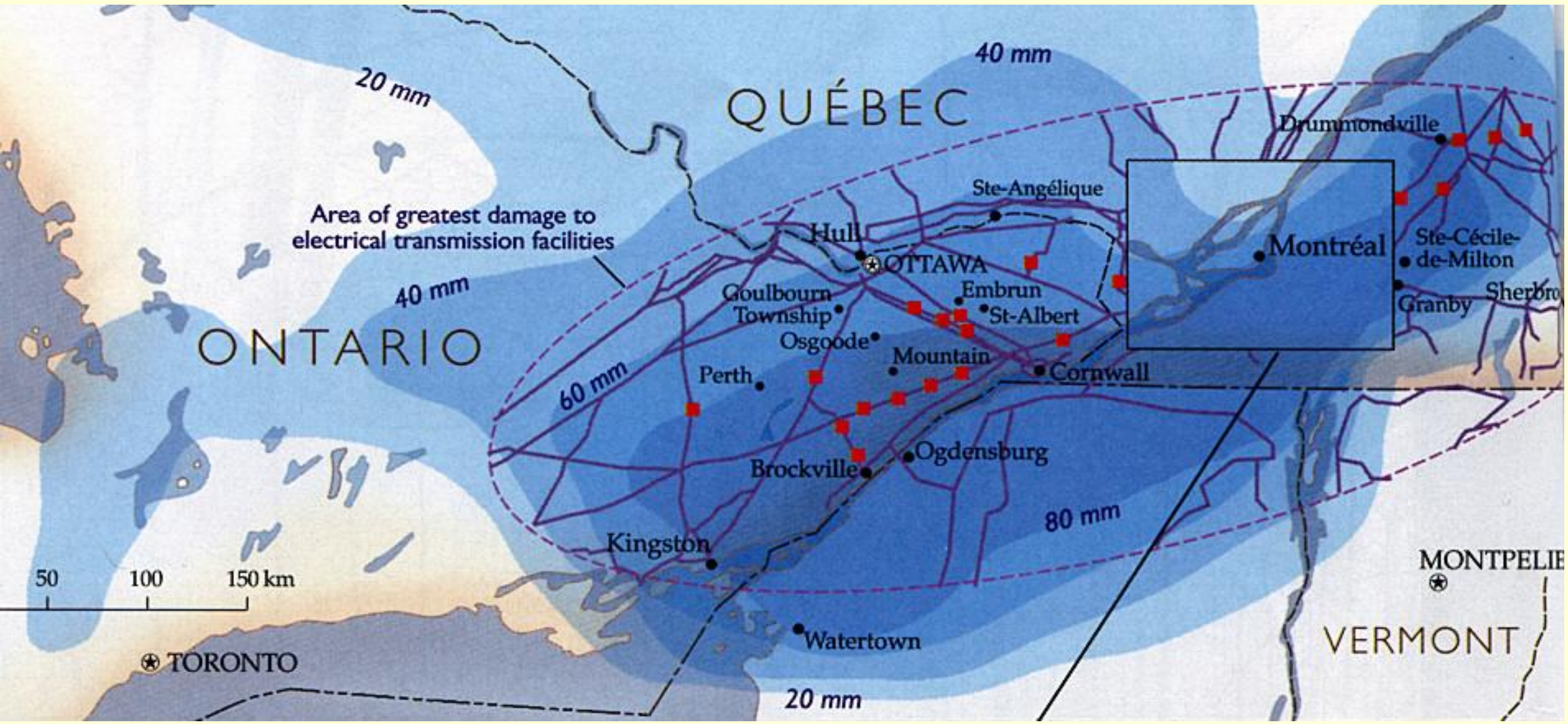
In January 1994, heavy snowfalls resulted in 7600 claims and payouts of $19M.

Freezing rain

Major ice storms in recent Canadian history:

Montréal (1942) -- 39 mm in 2 days
Montréal (1961) -- 30 mm in 2 days
St. John's, Nfld (1984) -- 150 mm in four days
Ottawa (1986) -- 30 mm in 2 days
Montréal (1998) -- 80 mm in 6 days
Newfoundland (2002) -- 12 mm in 1 day

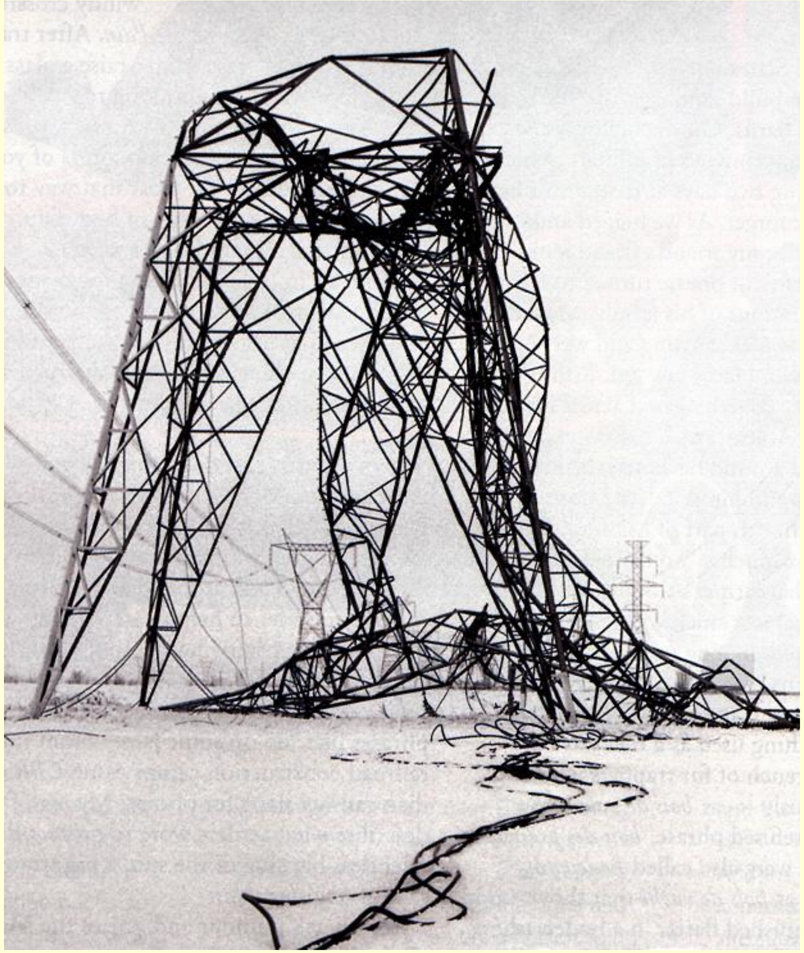
The geography of the 1998 ice storm



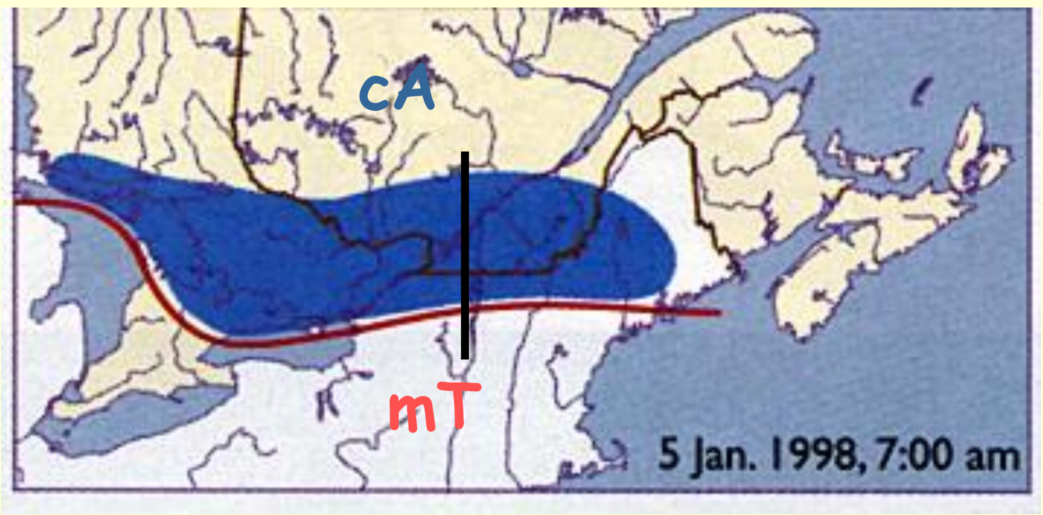
Up to 40mm in Maritimes

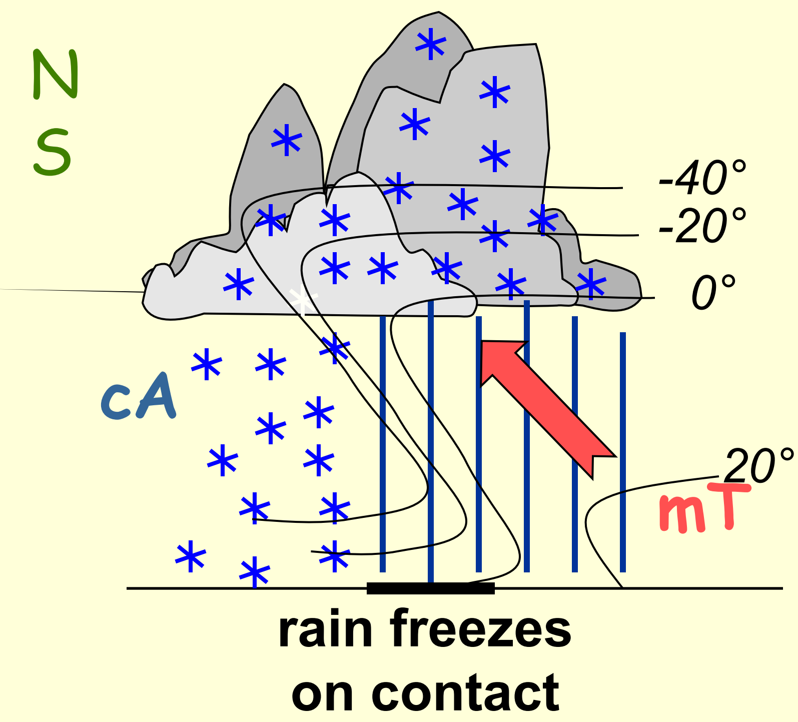
The 1998 ice storm:

>1300 hydro towers and 40,000 hydro poles damaged



Ice storm climatology





The 1998 ice storm
of customers without power

- CANADA

Qué: 1.4M

Ont: 230K

New Bruns: 28K

Nova Scotia: 20K

- USA

Maine: 315K

New Hamp: 68K

New York: 130K

Vermont: 33K

Grand total = 2.22M;

Many people in Québec without power for >4 weeks

Ice storm tally (Canada only)

- Insurance claims - $500M
- Repair and construction:
  Hydro-Québec - $500M
  Ontario Hydro - $120M
  Residents, etc. - $1.4B
- Lost economic output - $1.6B
- 16,000 Canadian troops mobilized; 440 shelters opened
- Deaths: 25