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Suess effect on biomarkers used to determine sediment provenance from land-use changes

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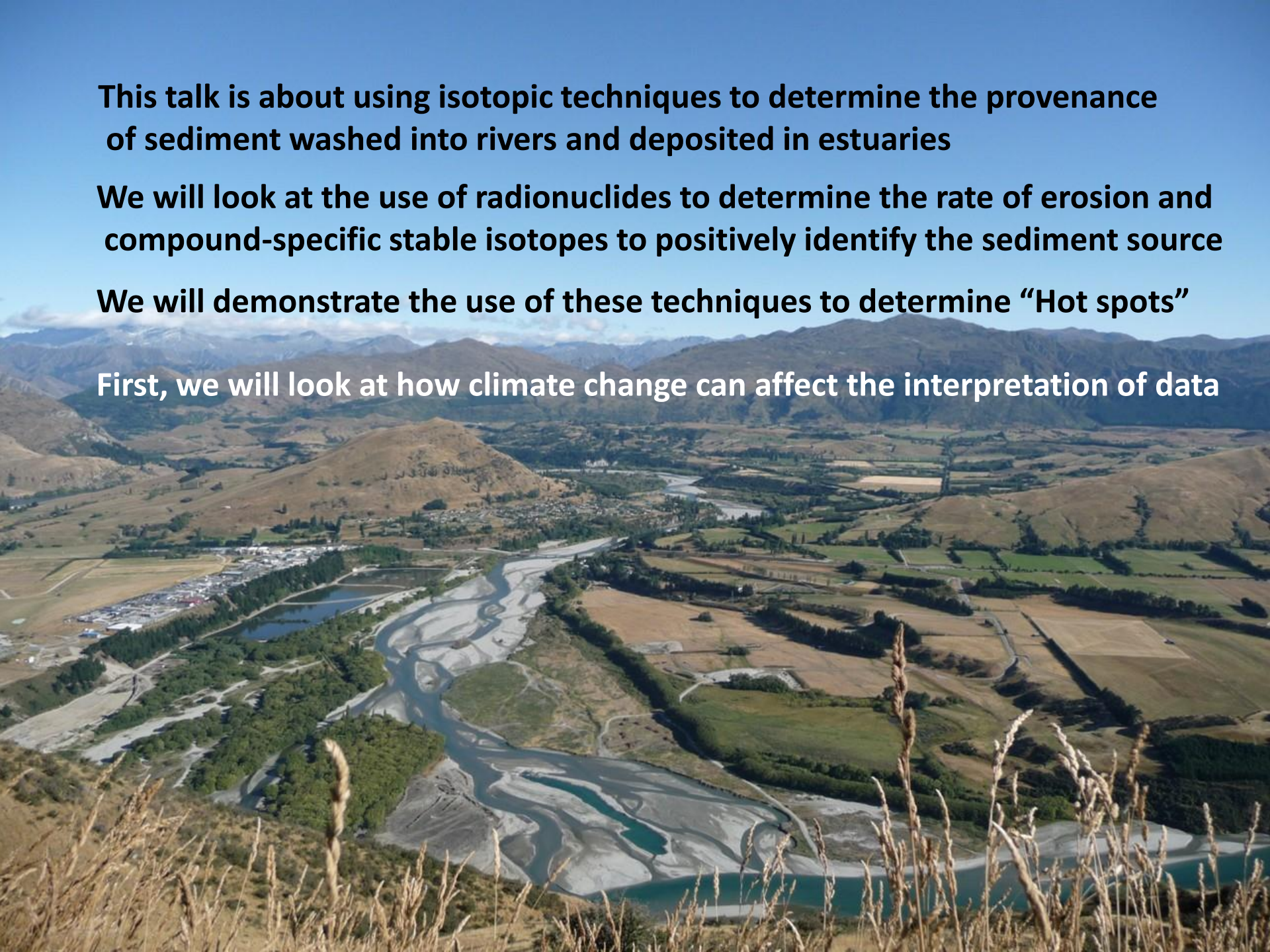
NIWA
Taihoro Nukurangi

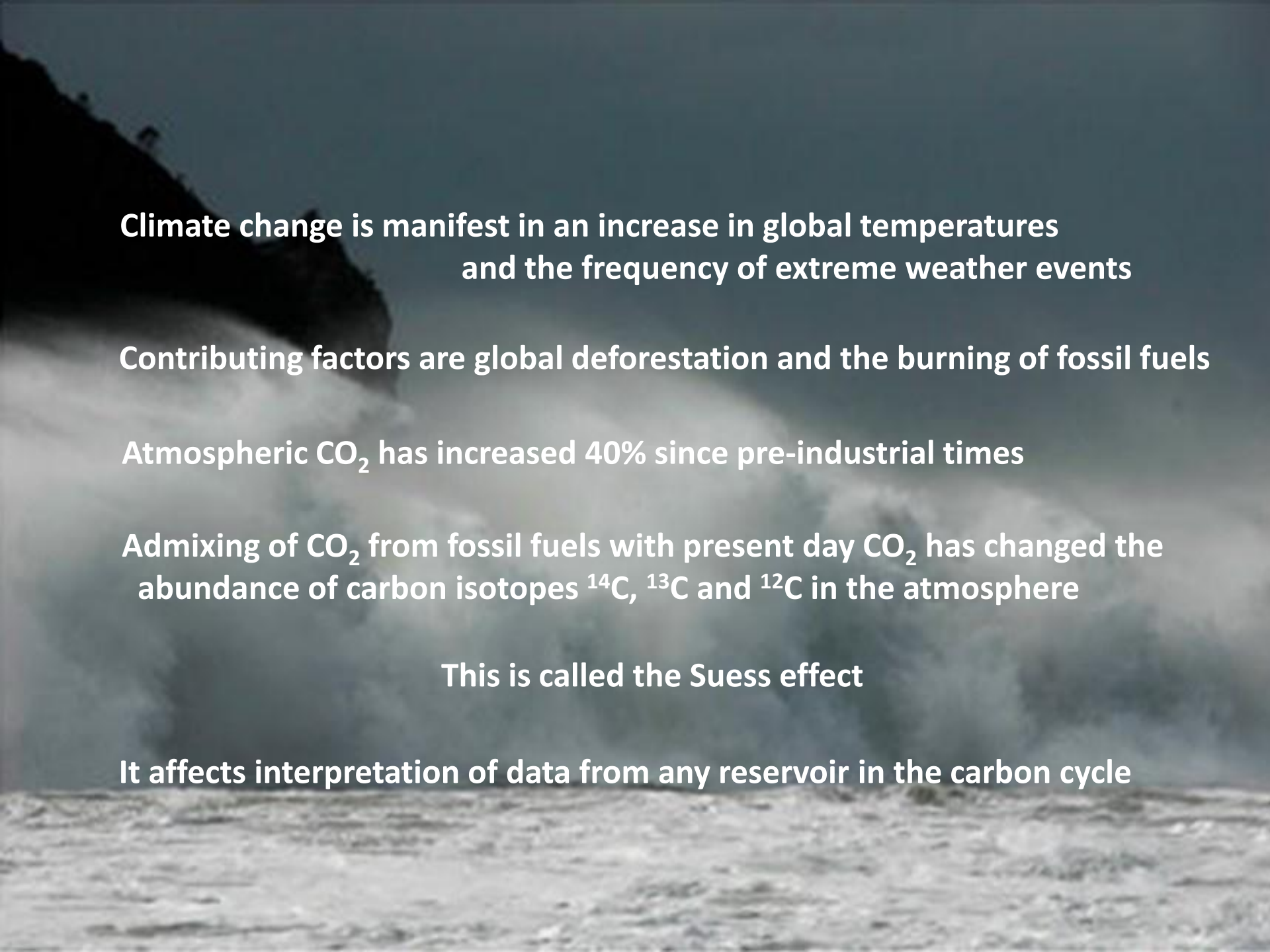


This talk is about using isotopic techniques to determine the provenance of sediment washed into rivers and deposited in estuaries

We will look at the use of radionuclides to determine the rate of erosion and compound-specific stable isotopes to positively identify the sediment source

We will demonstrate the use of these techniques to determine “Hot spots”

First, we will look at how climate change can affect the interpretation of data



Climate change is manifest in an increase in global temperatures and the frequency of extreme weather events

Contributing factors are global deforestation and the burning of fossil fuels

Atmospheric CO_2 has increased 40% since pre-industrial times

Admixing of CO_2 from fossil fuels with present day CO_2 has changed the abundance of carbon isotopes ^{14}C, ^{13}C and ^{12}C in the atmosphere

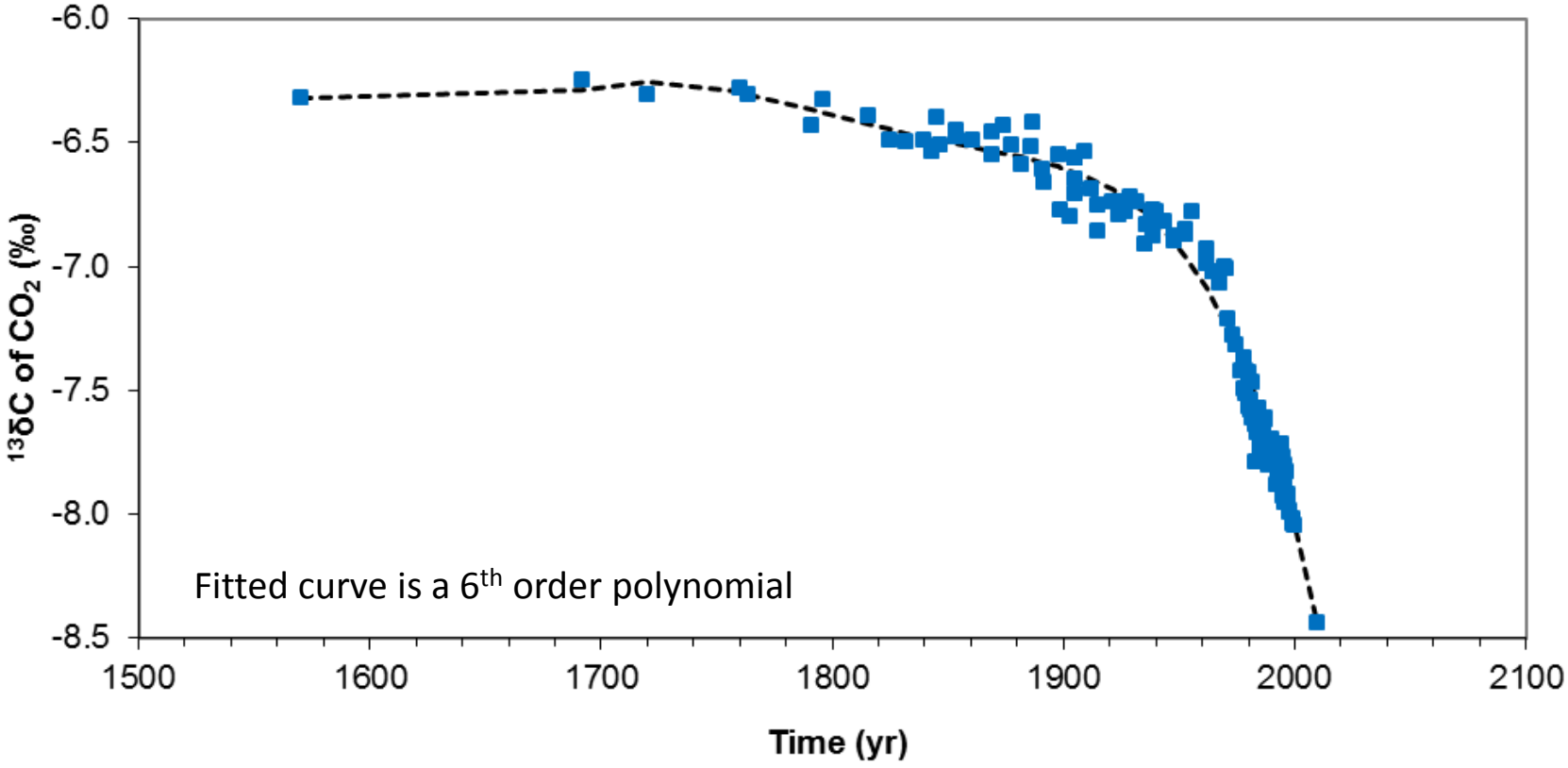
This is called the Suess effect

It affects interpretation of data from any reservoir in the carbon cycle

The Suess effect can measured and modelled

Because the carbon in fossil fuels is isotopically depleted by around 18‰, the CO_2 released when that fuel is burnt is isotopically depleted

This depleted CO_2 results in isotopic depletion of the CO_2 in the air

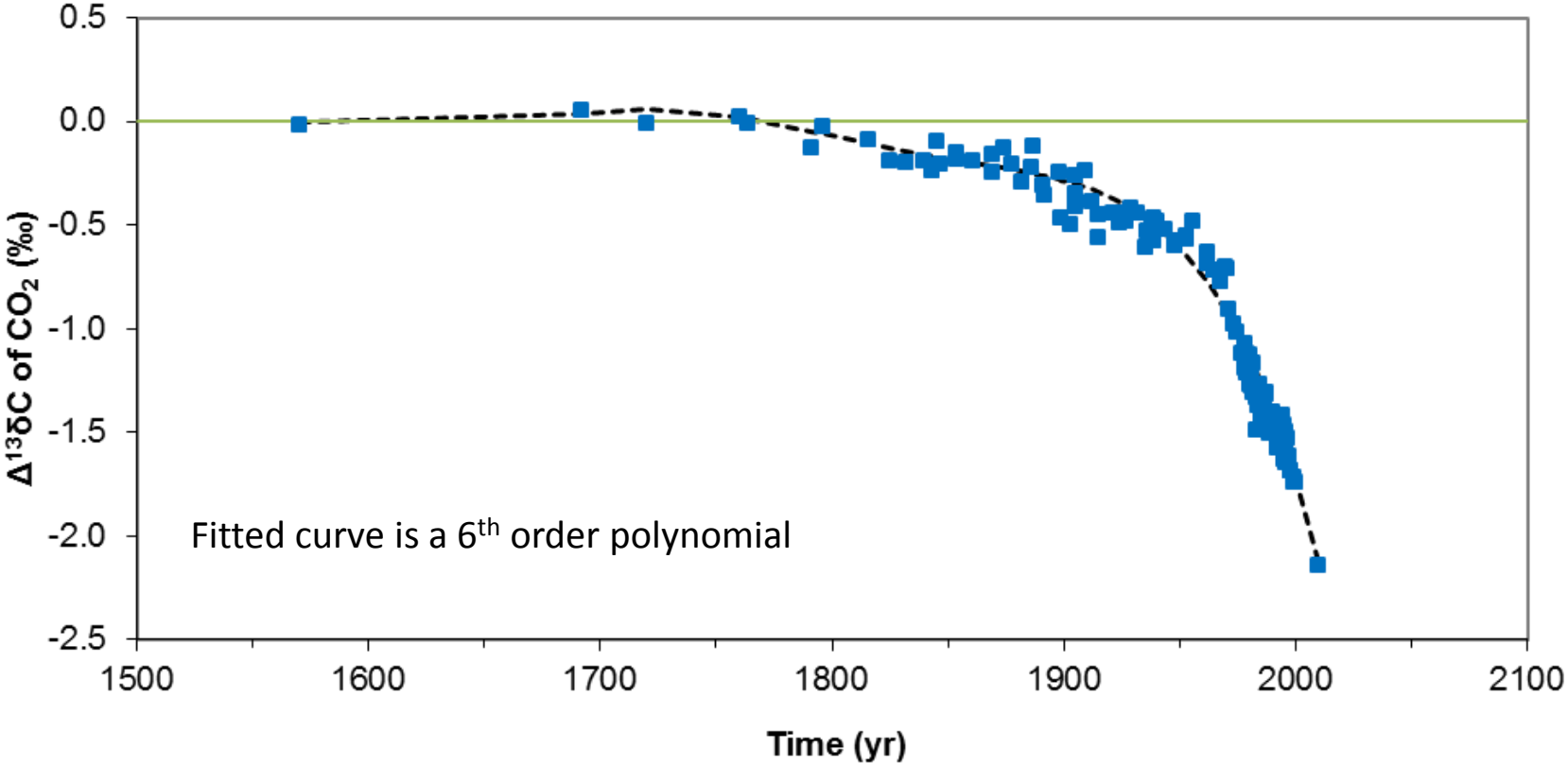


From Verburg 2007: Journal of Paleolimnology 37:591–602

Isotopically, "You are what you eat, plus a bit"

Plants assimilating atmospheric CO_2 today will have carbon isotopically depleted by 0.7‰ relative to the same plants growing just 20 years ago

Studies looking back in time need to correct for the Suess effect



Compound-specific stable isotope (CSSI) forensic technique*

The CSSI technique was developed to positively identify the provenance of soil sources in contemporary estuarine sediments

Conceptually, plants growing on land define the land-use

Fatty acids biomarkers from the plants label the source soils

Identification of the soil source relies on different plants producing the same biomarkers but with different isotopic signatures

Fatty acids biomarkers are extracted and analysed isotopically

A mixing model is used to determine the proportional contribution of each source soil contributing the sediment at the sample location

*** Gibbs 2008: Estuaries and Coasts 31: 344-359**

Spatial mapping

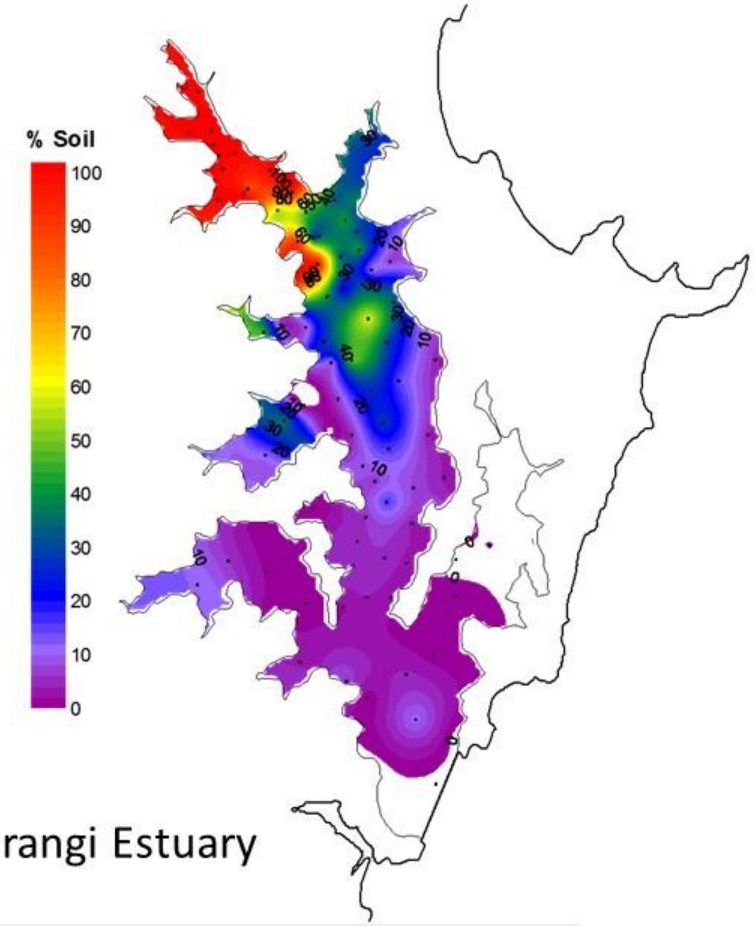
The soil proportions determined from the CSSI technique can be used to evaluate a single site or combined in a spatial map

Data interpretation for this application of the CSSI technique does not require a Suess effect correction

– all the sources and sinks are contemporary

Spatial mapping of CSSI technique results

Total Soil contribution and distribution

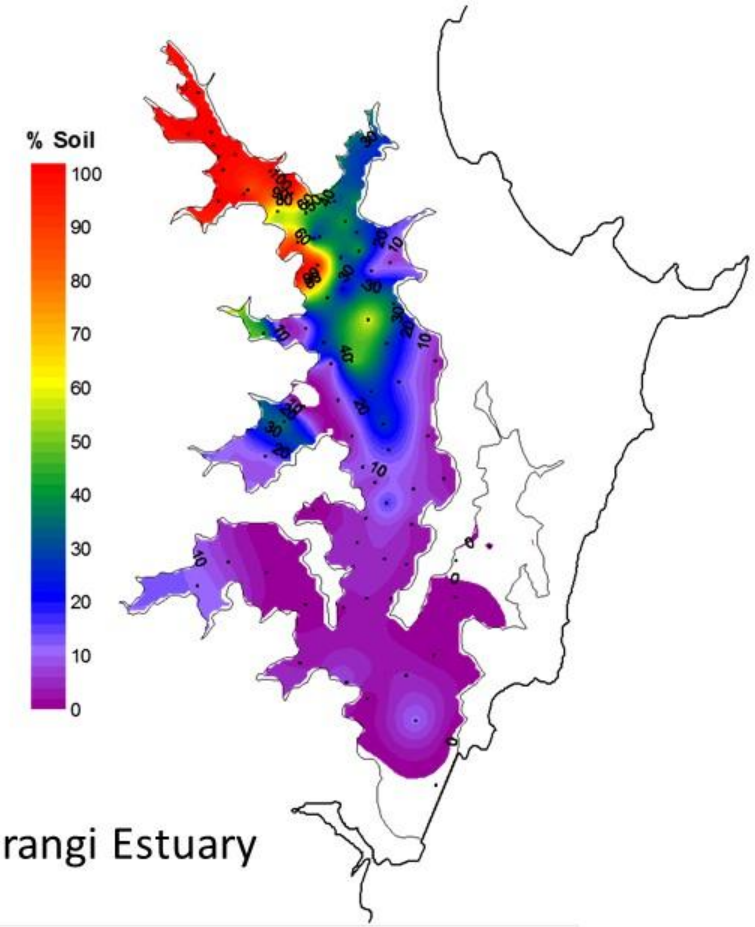


Mahurangi Estuary

Mean % soil contribution proportions
Uncertainty <±5%

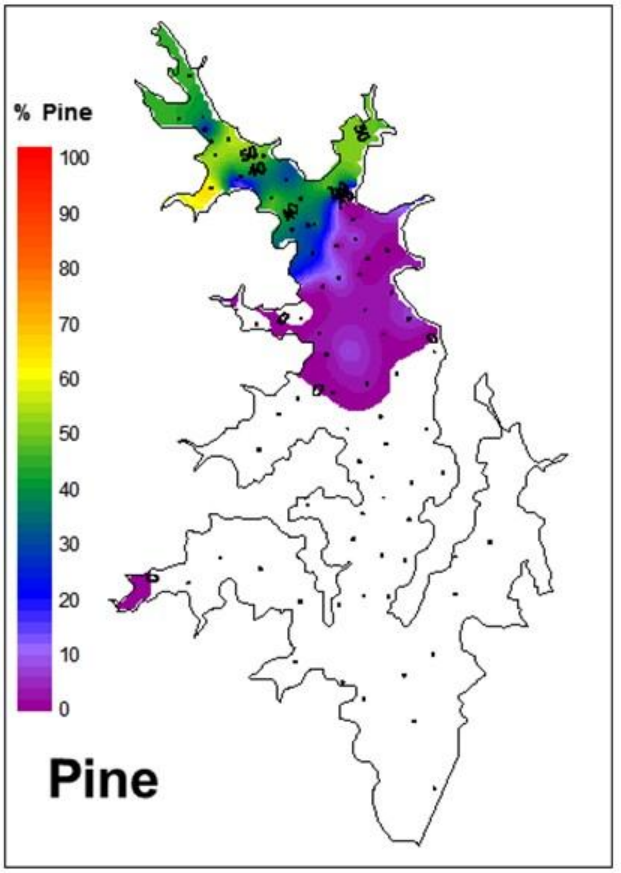
Spatial mapping of CSSI technique results

Total Soil contribution and distribution



Mean % soil contribution proportions
Uncertainty <±5%

Pine forest component



Mean % Pine contribution proportions
Uncertainty <±5%


Erosion “hot spot”

Correction for the Suess effect is needed where the isotopic records from sediment cores are being use to reconstruct the past using present day soil source stable isotope data

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Sediment cores collected in the Bay of Islands were analysed to unlock the historical record of land-use practices that caused sediment erosion

The sediment cores were dated using ^{7}Be, ^{137}Cs and $^{210}Pb_{ex}$

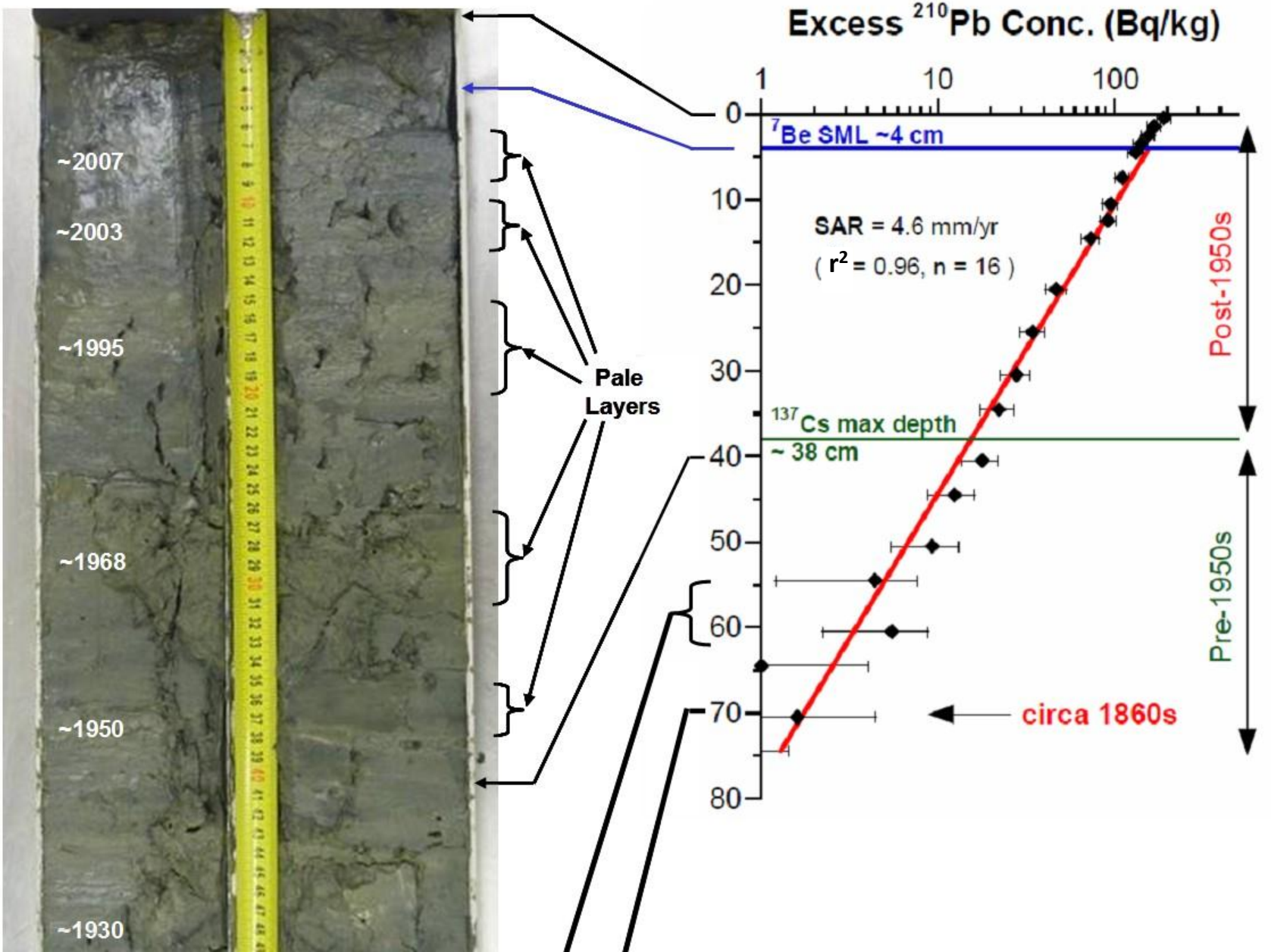
^{7}Be provides an estimate of the mixed depth

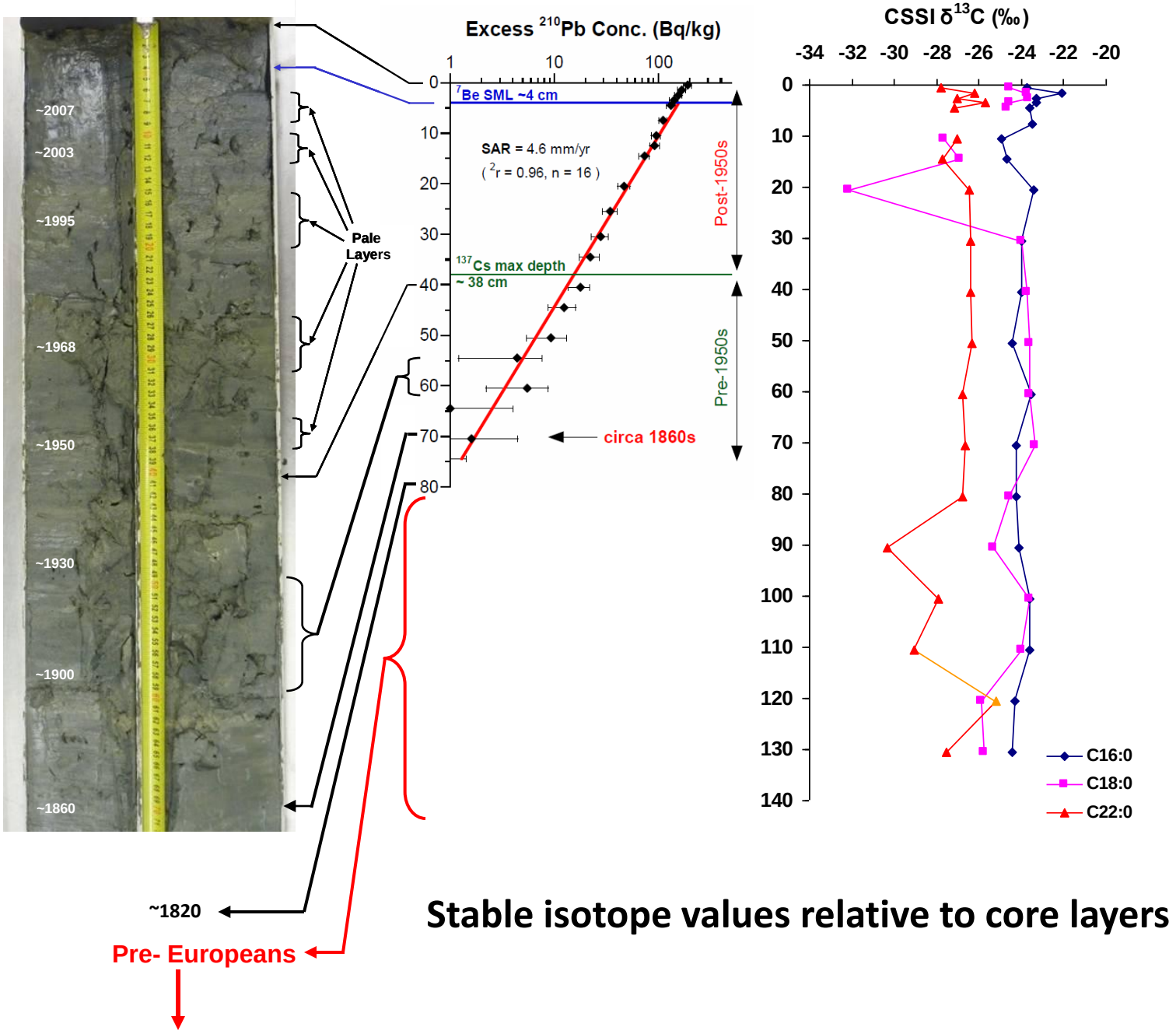
^{137}Cs is a time marker for the date 1954

$^{210}Pb_{ex}$ provides the dating timeline for the core

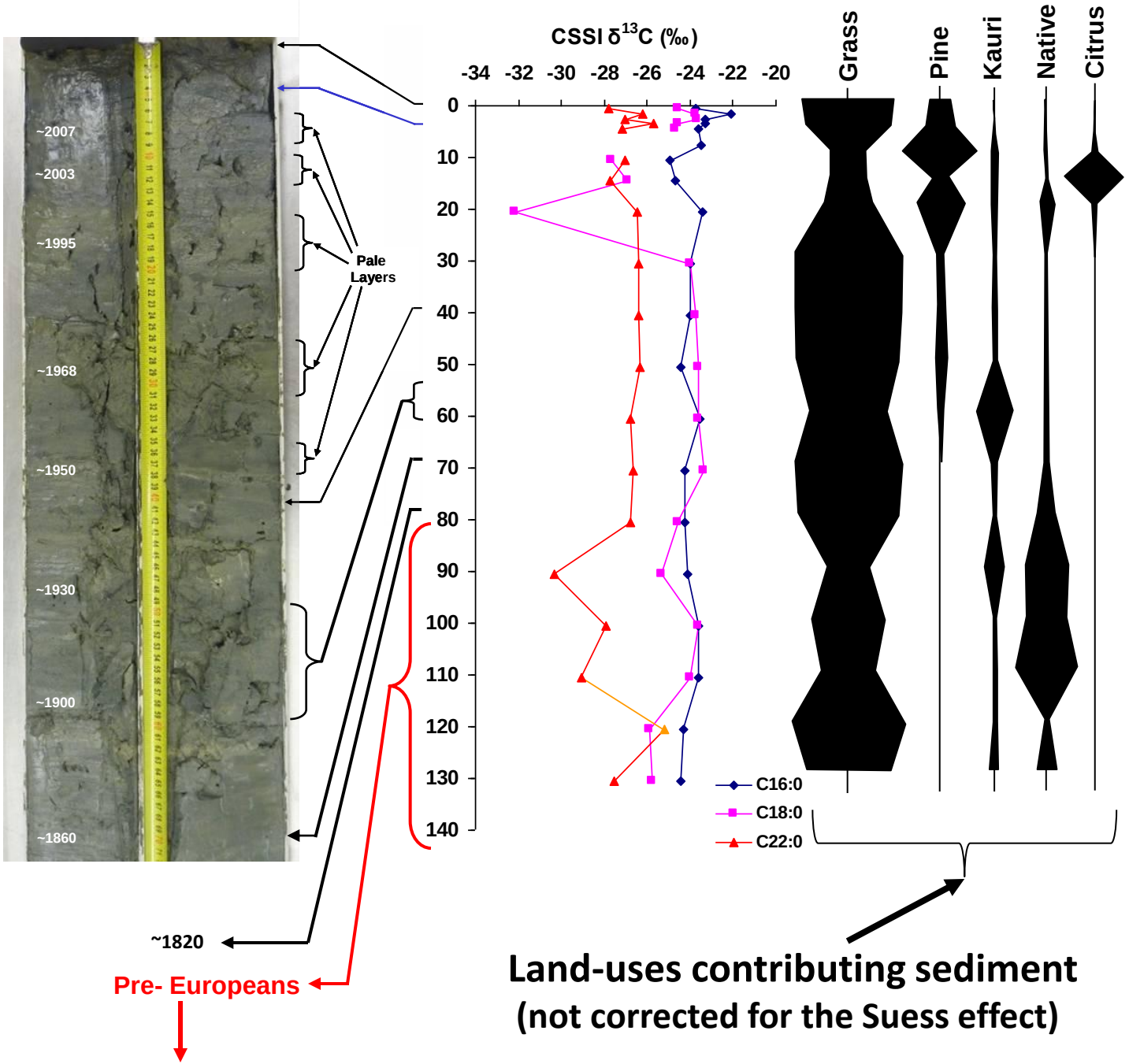
The $^{210}Pb_{ex}$ was used to estimate sediment accumulation rates (SAR)

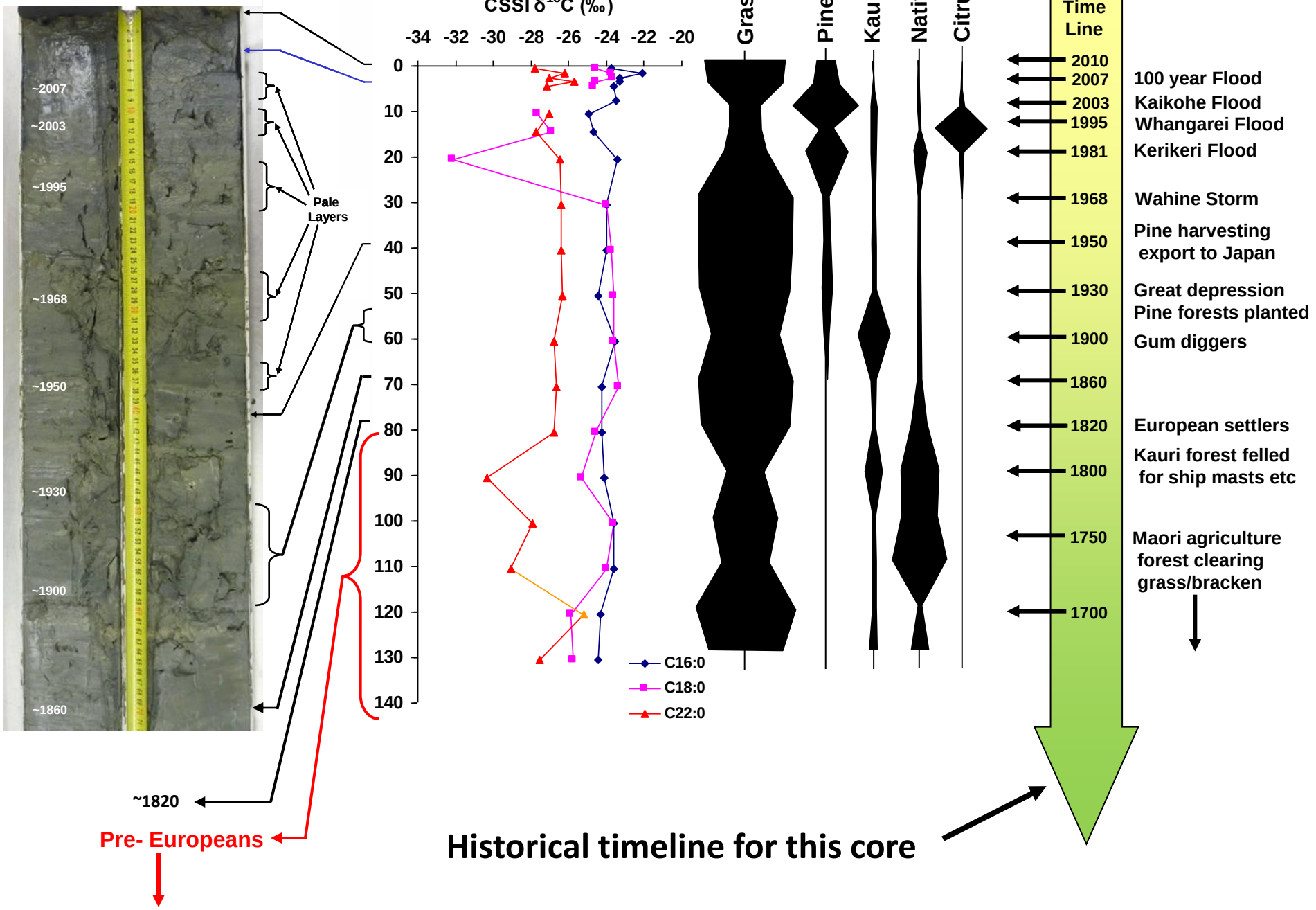
$^{210}Pb_{ex}$ dating relative to sediment core layers





Stable isotope values relative to core layers


~2007
~2003
~1995
~1968
~1950
~1930
~1900
~1860
Pale Layers
CSSI δ13C (‰)
-34 -32 -30 -28 -26 -24 -22 -20
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140
Grass
Pine
Kauri
Native
Citrus
C16:0
C18:0
C22:0
~1820
Pre- Europeans
Land-uses contributing sediment
(not corrected for the Suess effect)


~2007
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Pale Layers
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-34 -32 -30 -28 -26 -24 -22 -20
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140
C16:0
C18:0
C22:0
Grass
Pine
Kauri
Native
Citrus
Time Line
2010
2007
2003
1995
1981
1968
1950
1930
1900
1860
1820
1800
1750
1700
100 year Flood
Kaikohe Flood
Whangarei Flood
Kerikeri Flood
Wahine Storm
Pine harvesting export to Japan
Great depression
Pine forests planted
Gum diggers
European settlers
Kauri forest felled for ship masts etc
Maori agriculture forest clearing grass/bracken
~1820
Pre- Europeans
Historical timeline for this core

The data from this core was remodelled after correcting the CSSI values for the Suess effect by age

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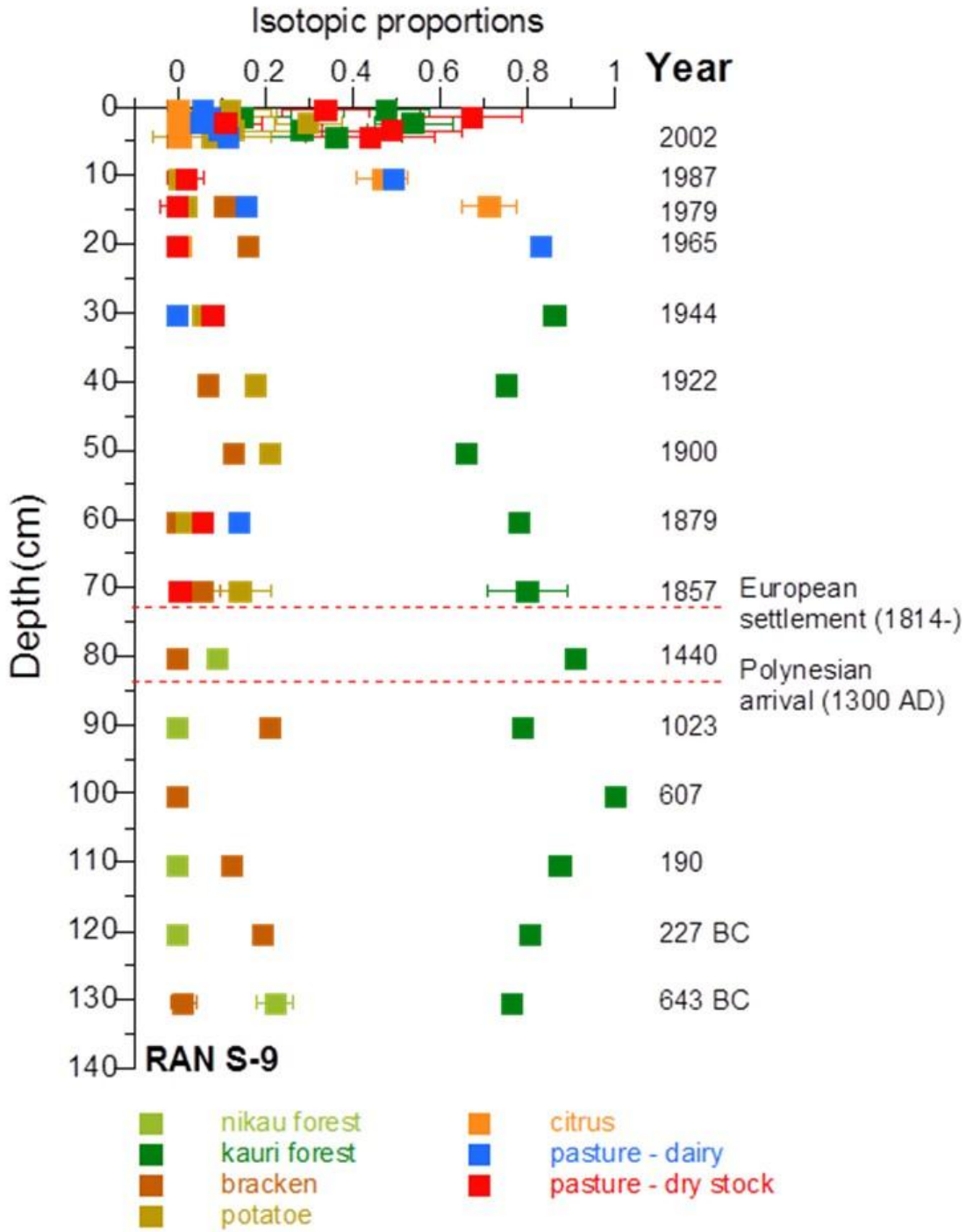
The core dating using the $^{210}Pb_{ex}$ technique was augmented using ^{14}C radio isotopic dating of shell fragments from the core at different depths

This allowed the core timeline to be extended back more than 2500 years

The CSSI values before 1700 were all given the maximum correction of 2.2 ‰

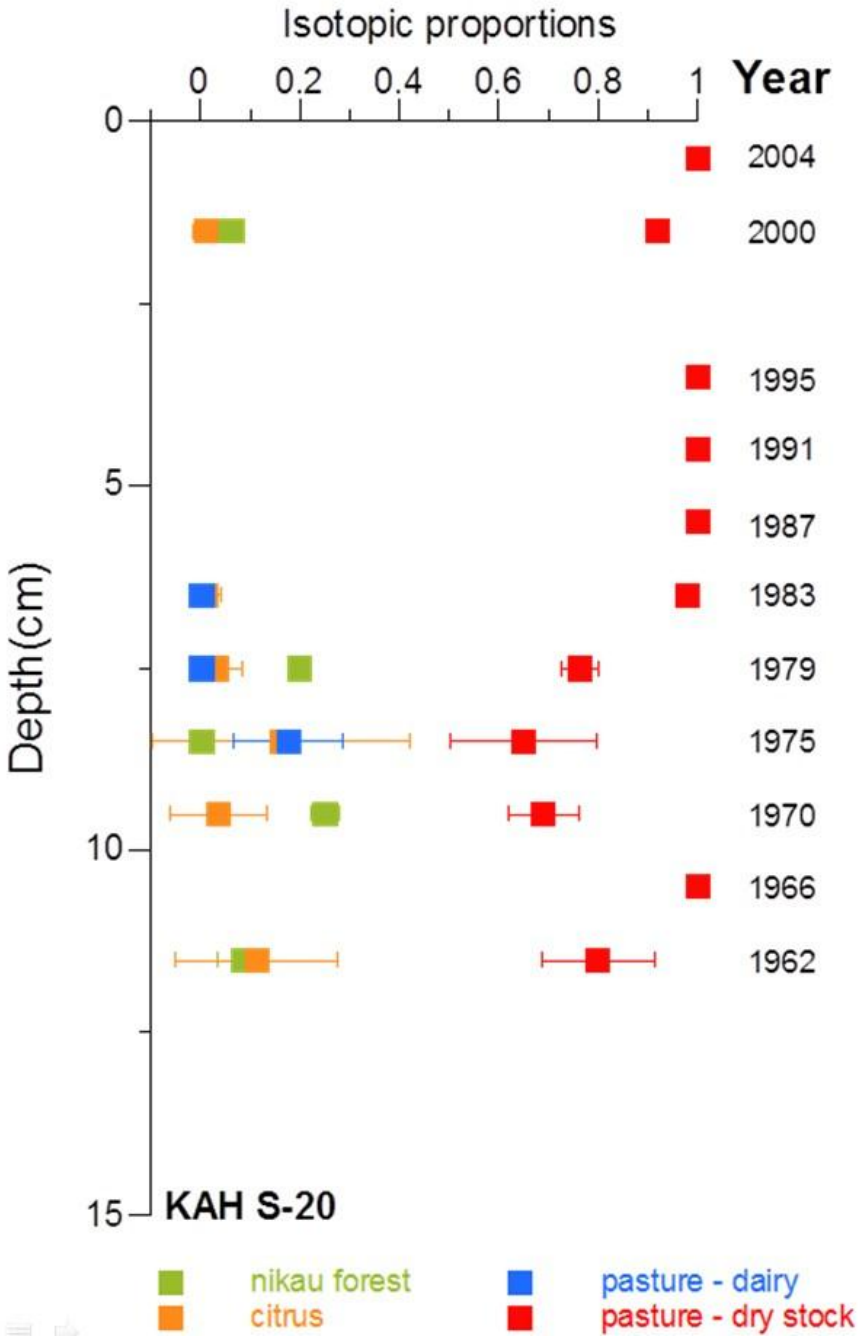

Isotopic proportions
0
0.2
0.4
0.6
0.8
1
Year
Depth(cm)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
2002
1987
1979
1965
1944
1922
1900
1879
1857
European settlement (1814-)
1440
Polynesian arrival (1300 AD)
1023
607
190
227 BC
643 BC
RAN S-9
nikau forest
kauri forest
bracken
potatoe
citrus
pasture - dairy
pasture - dry stock

“Hot spots” or “hot land-use practices” of erosion

Earlier we showed that >50% of the soil in local estuarine sediment came from a single location - a “hot spot”

“Hot land-use practices” are “hot spots” that persist over time

Another sediment core from the Bay of Islands identified a “hot land-use practice” in a catchment as “pasture dry-stock”

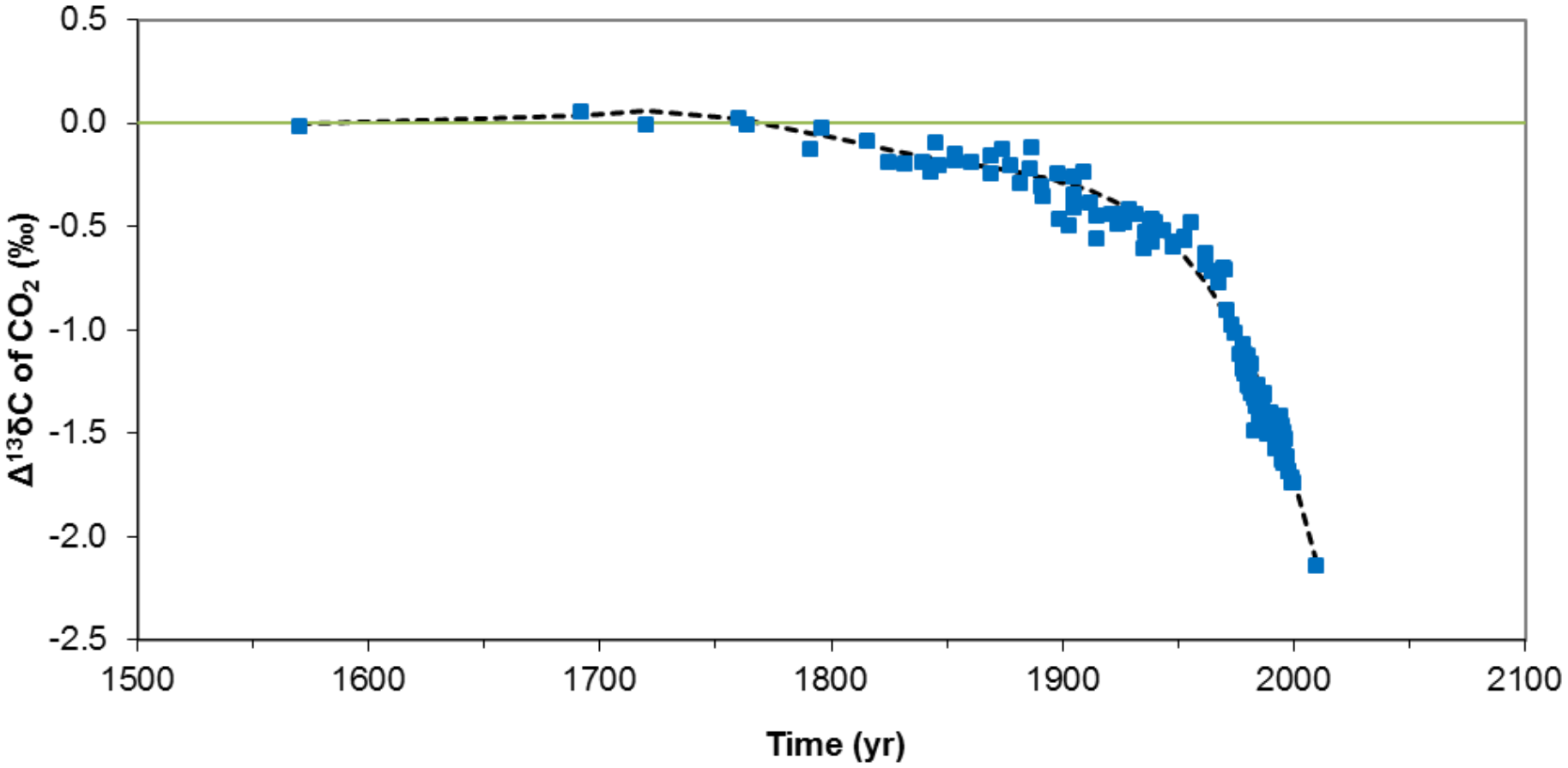

Isotopic proportions
0
0.2
0.4
0.6
0.8
1
Year
0
5
10
15
Depth(cm)
2004
2000
1995
1991
1987
1983
1979
1975
1970
1966
1962
KAH S-20
nikau forest
citrus
pasture - dairy
pasture - dry stock

Not an obvious “Hot Spot”

Bay of Islands, New Zealand

Look closer to see the “Hot land-use practice”

Farms like this have been losing their productive land for at least 40 years through poor land-use practices which are simple to remedy - Just close the gate



Remember to correct for the Suess effect

Thank you

NIWA
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