Tidal Surge
Flood Forecasting and Warning

Guy Cooper
Flood Resilience

46 Flood Alert areas

(15 tidal, 28 fluvial, 3 Broads)

Norfolk = 17 (5 tidal, 3 Broads, 10 fluvial)

Suffolk = 12 (4 tidal, 8 fluvial)

Essex = 14 (6 tidal, 10 fluvial)

137 Flood Warning areas

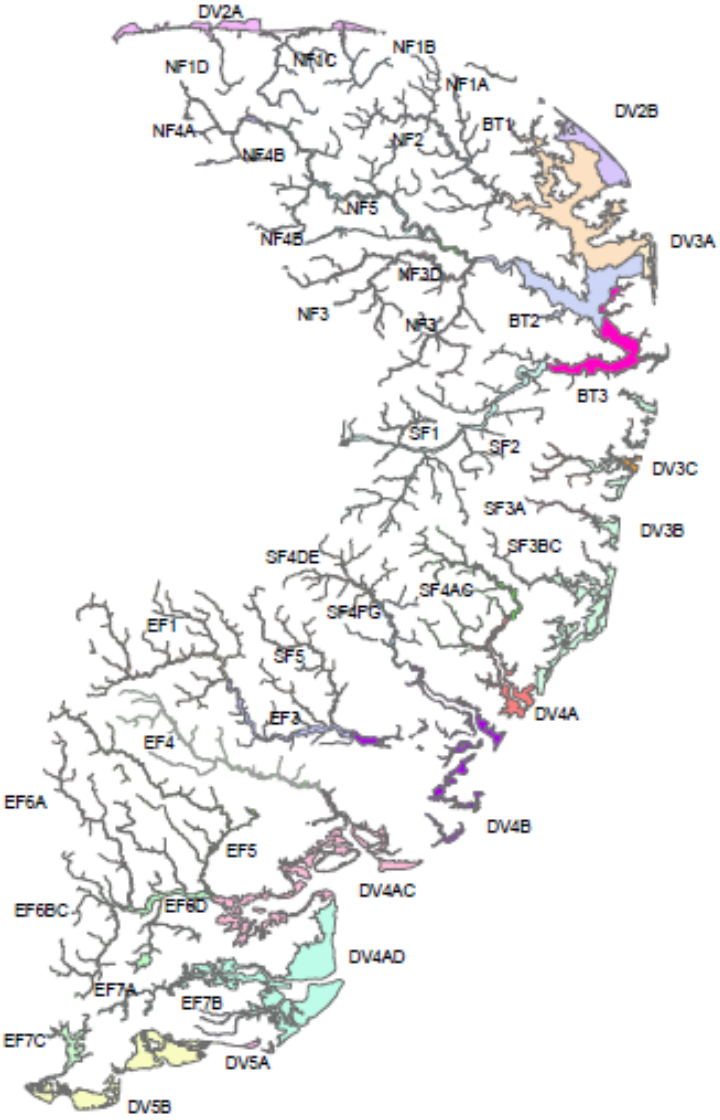
(78 tidal, 51 fluvial, 8 Broads)

Norfolk = 45 (22 tidal, 16 fluvial, 8 broads)

Suffolk = 40 (23 tidal, 17 fluvial)

Essex = 52 (34 tidal, 18 fluvial)

We also take into account Wind force and direction and wave height



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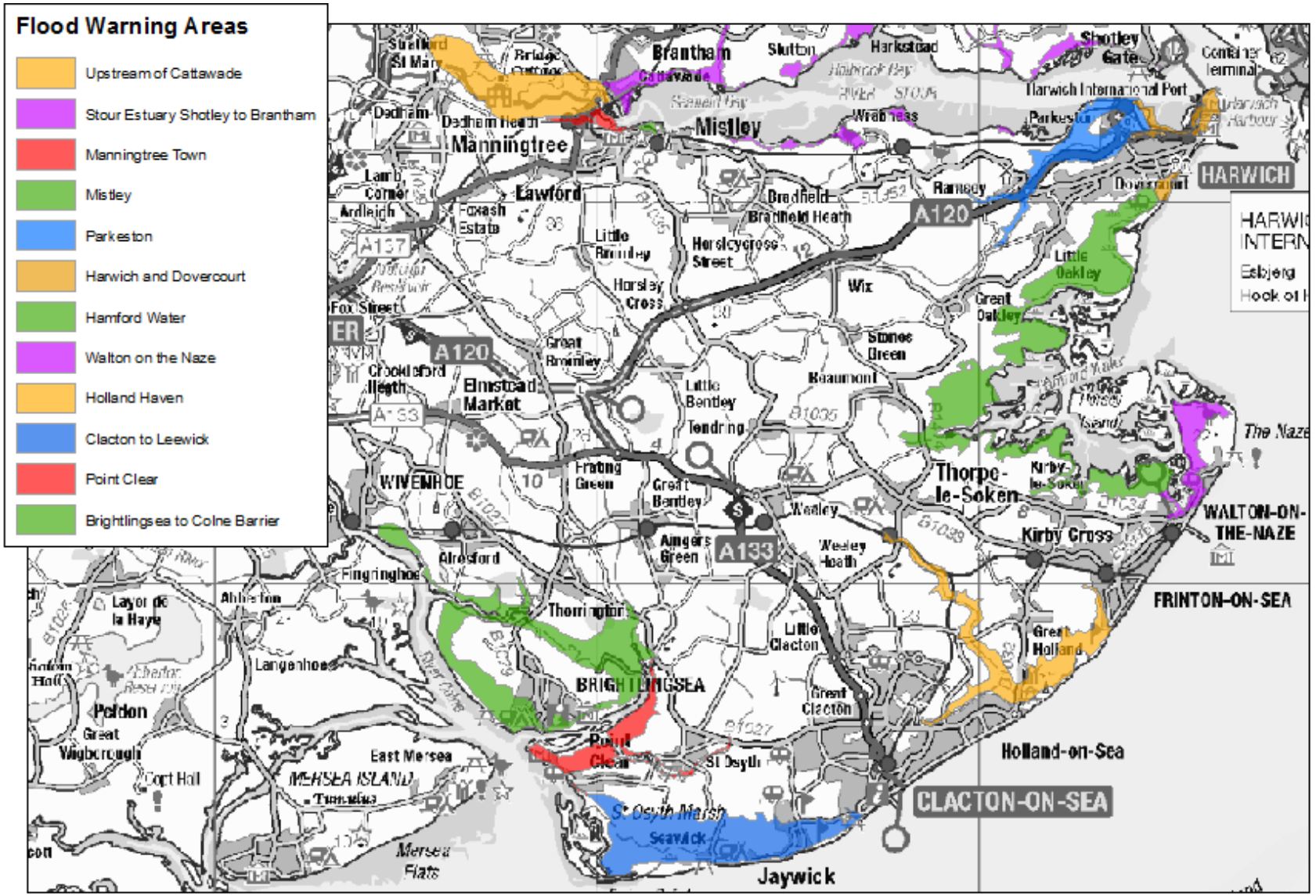
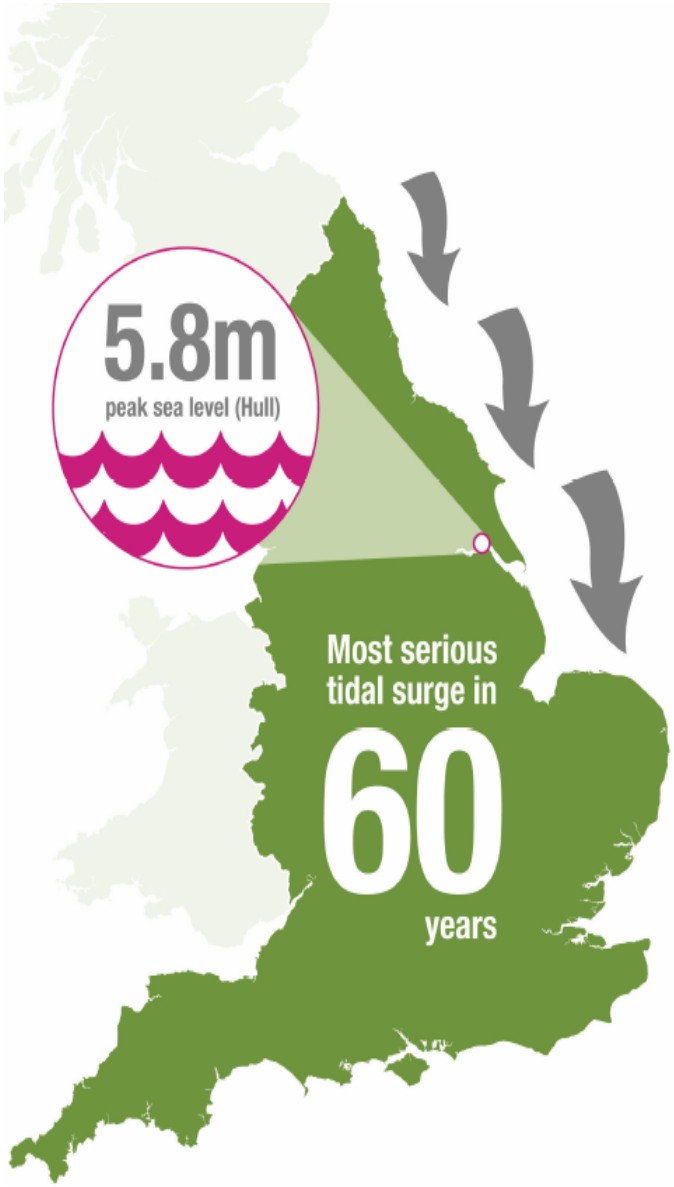


Environment Agency



Tidal surge
December 2013

Environment Agency

5 December saw the most serious tidal surge in over 60 years, here's a look at some of the facts surrounding the event:

160,000
warnings sent to homes and businesses

18,000
people evacuated

London
saw highest tide since the Thames Barrier opened in 1984

800,000
properties protected by Environment Agency flood defences

2,800
kilometres of flood defences put to the test along the coast

64 severe flood warnings
in place across the UK at the peak

"Our thoughts remain with those people who have been affected by flooding"
- Paul Leinster, Chief Executive, Environment Agency

County	Commercial	Residential	Total
Norfolk	46	193	239
Suffolk	117	114	231
Essex	33	5	38
TOTALS	196	312	508

Environment Agency

Essex			
Mistley and Manningtree	11	1	12
Harwich	1	0	1
Landermere Wharf/Quay	2	0	2
Kirby le Soken	0	2	2
Brightlingsea	13	0	13
Great Bentley	1	0	1
West Mersea	2	2	4
Burnham on Crouch	3	0	3
Total	33	5	38

Environment Agency

Place	Highest initial Peak forecast level (m)	Actual Peak level (m)	Return period (approx years)	When it last reached or exceeded this level	Highest recorded level (m)	Level recorded 1953 (m)
Wells next the sea	4.98	**5.215**	1:500	Before records began	5.22 (2013)	5.13
Cromer*	4.38	**3.756**	n/a	n/a	3.76 (2013)	n/a
Great Yarmouth	3.17	**3.318**	1:175	Before records began	3.32 (2013)	3.28
Lowestoft	3.17	**3.29**	1:200	1953	3.35 (1953)	3.35

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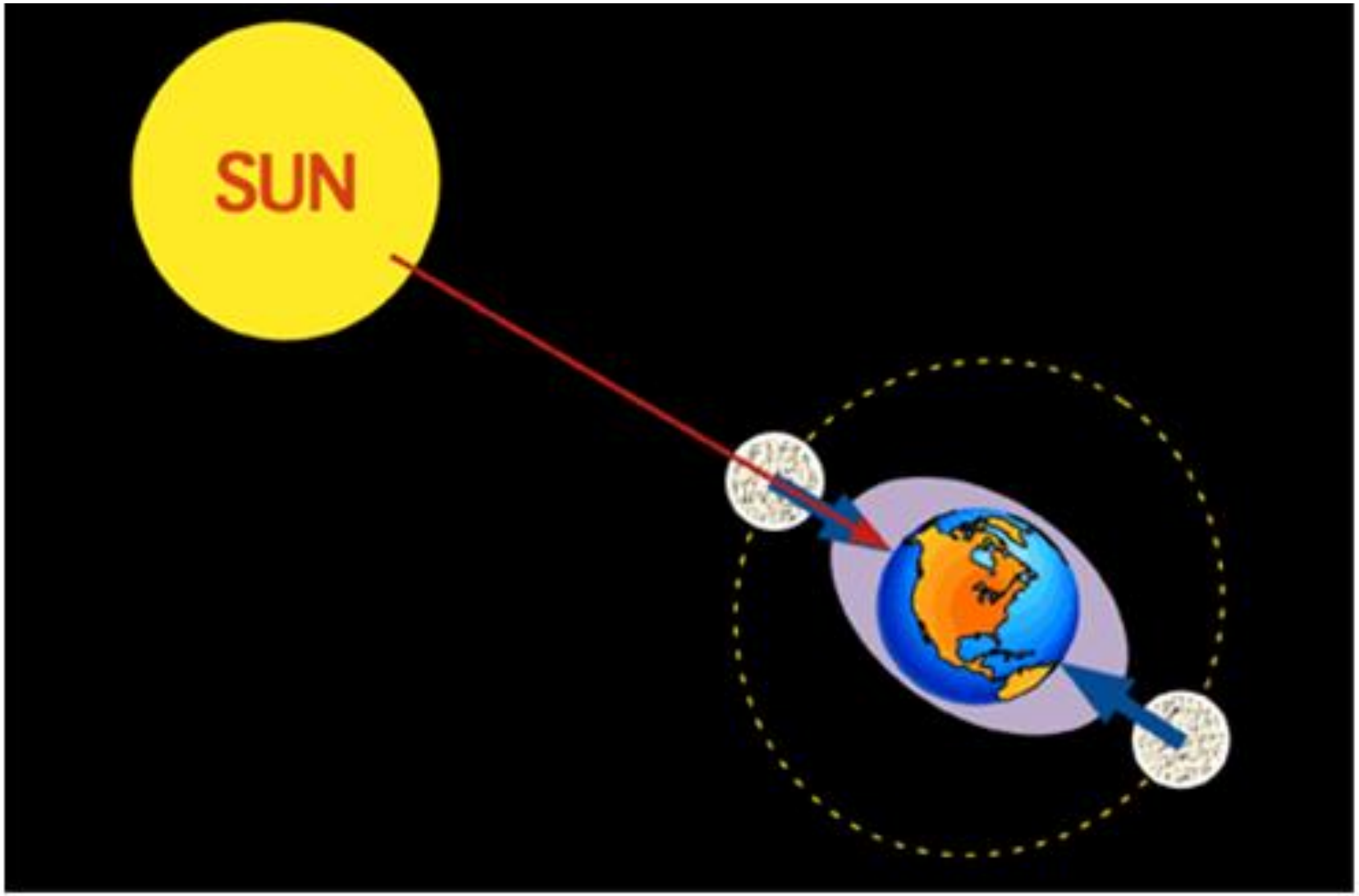
Astronomical Tides!!!!

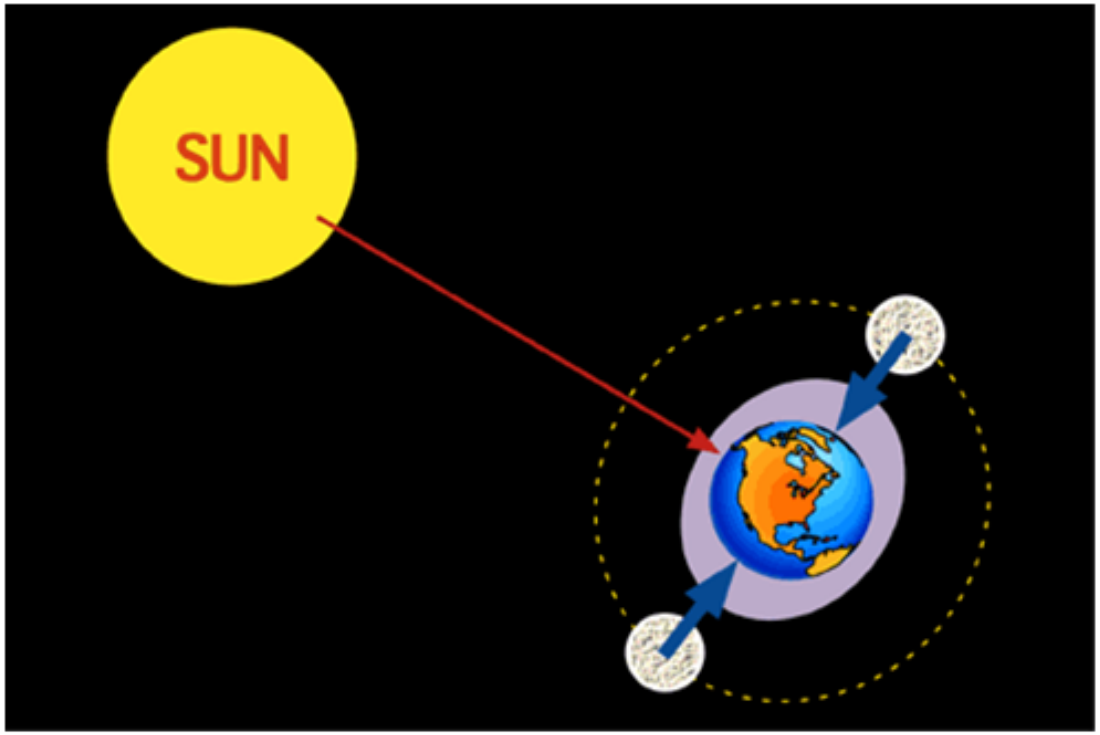
Spring tides

Syzygy of the Earth, Moon and Sun

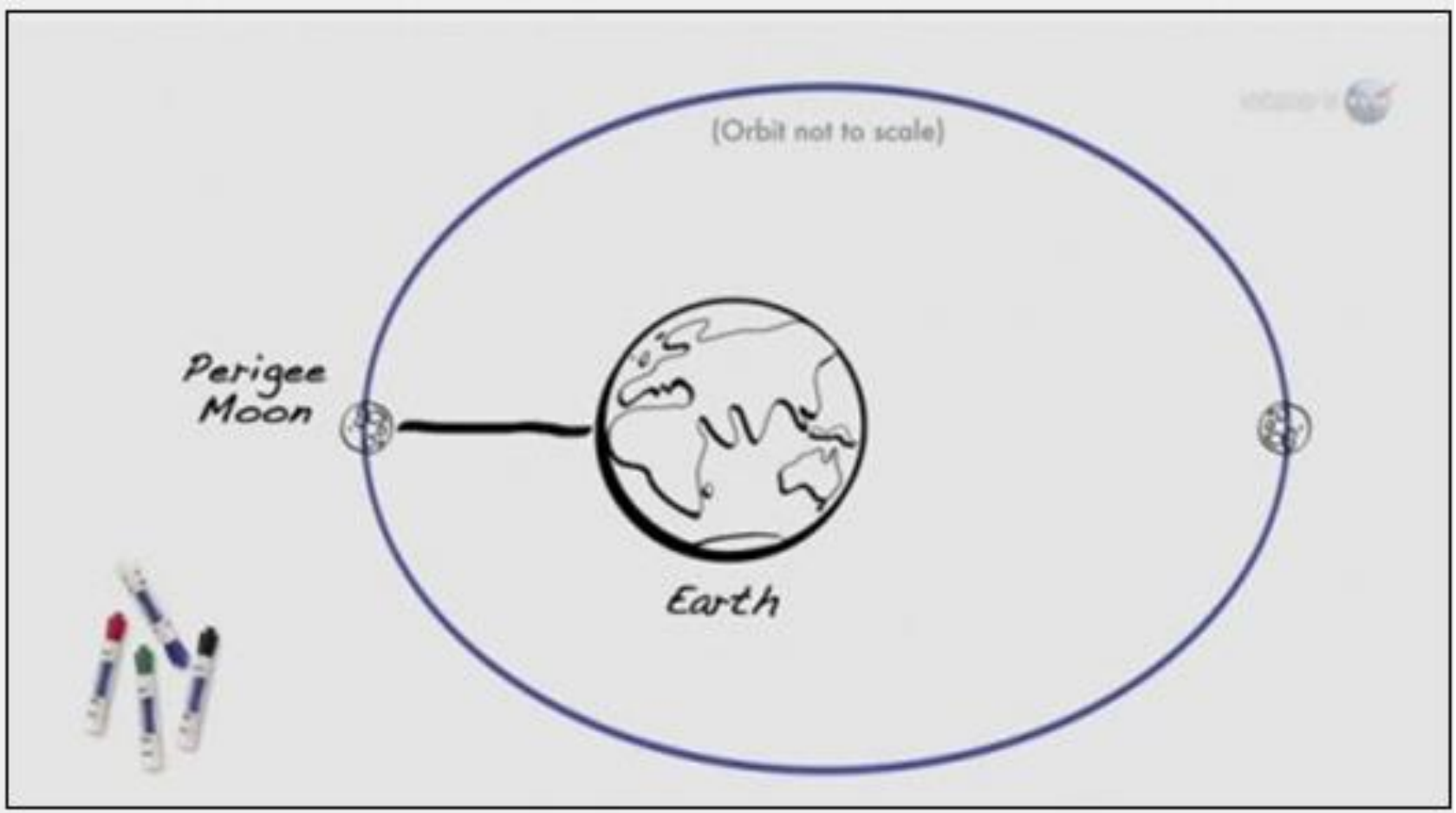


Neap Tides

When the gravitational pull of the moon and Sun are at right angles to each other, the daily tidal variations on the Earth are at their least. These events are called neap tides and they occur during the first and last quarter of the moon. (See Below)



Perigee

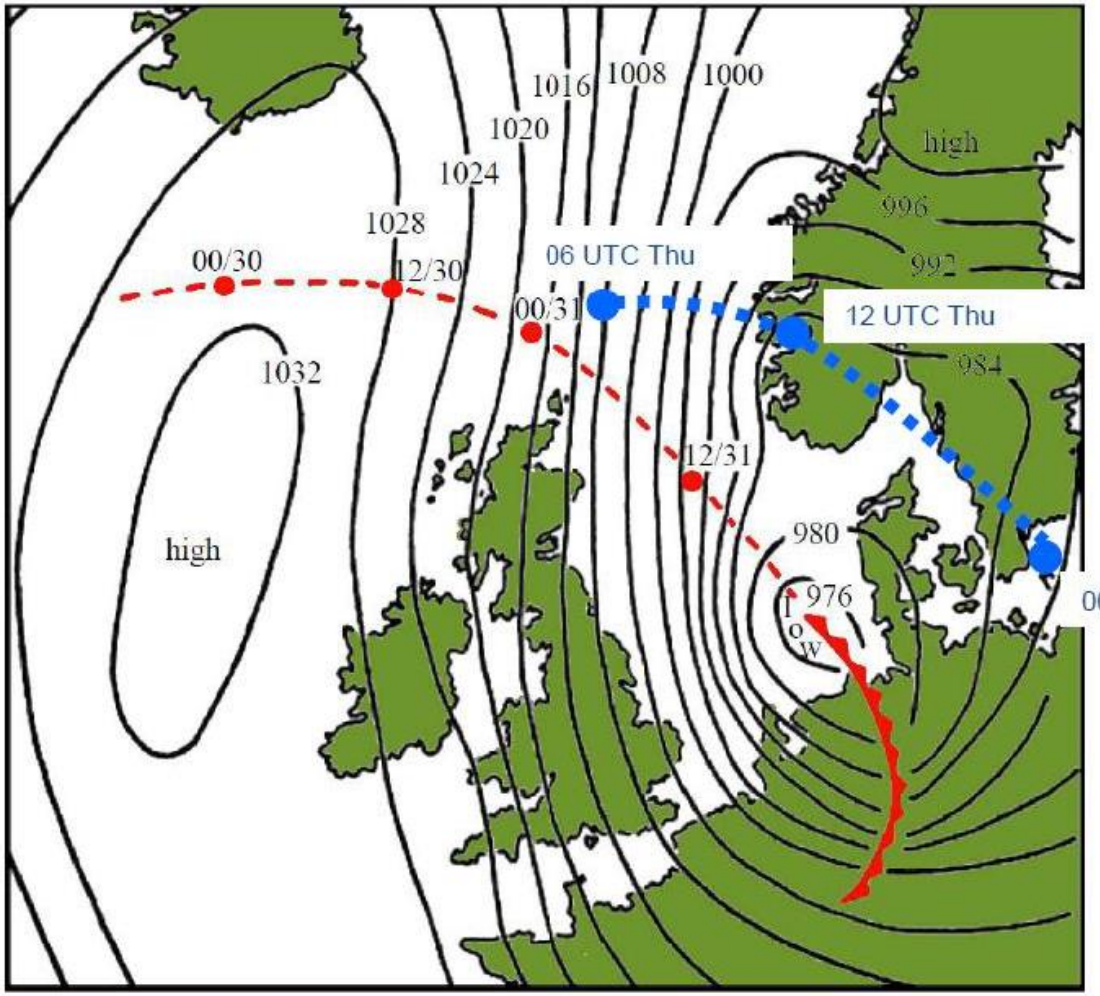


Perigee is the point in the Moon's elliptical orbit closest to Earth. Diagram #1.

Perigee, Apogee

Surge!!!!

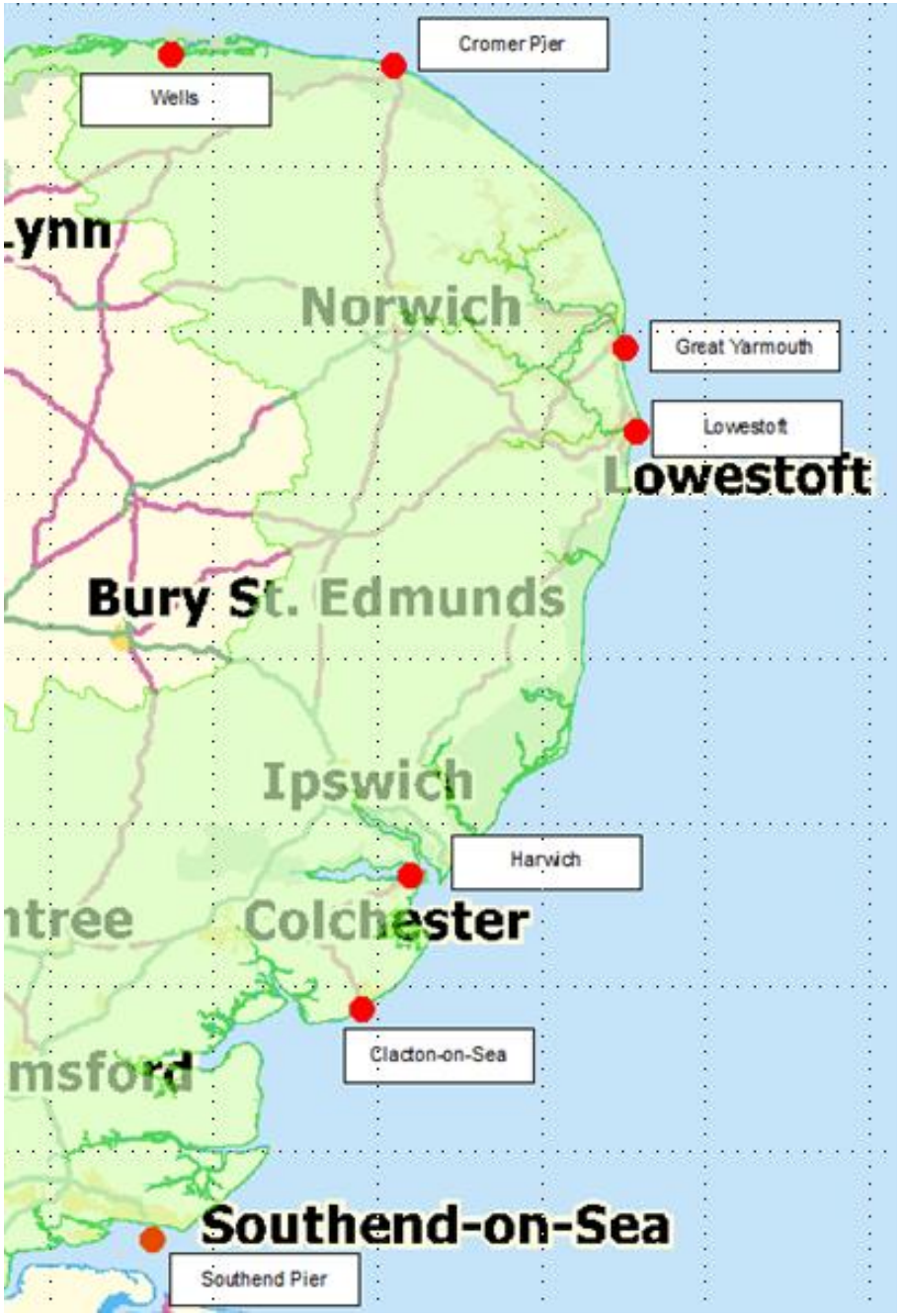
5/6th December 2013 Event



Red line track & low pressure pattern of 1953 storm

Blue dashed line is low pressure centre track 5-6 Dec 2013

Forecasting



Tidal Gauges

- We receive forecasts for these points in our Area

Tides on our Coast

- We have a high tide every 12 hours and 24 minutes

- Two week cycle of Springs and Neaps

- Tides are affected by Coriolis Affect and interference from sea bed and bays to form Amphidromic Systems

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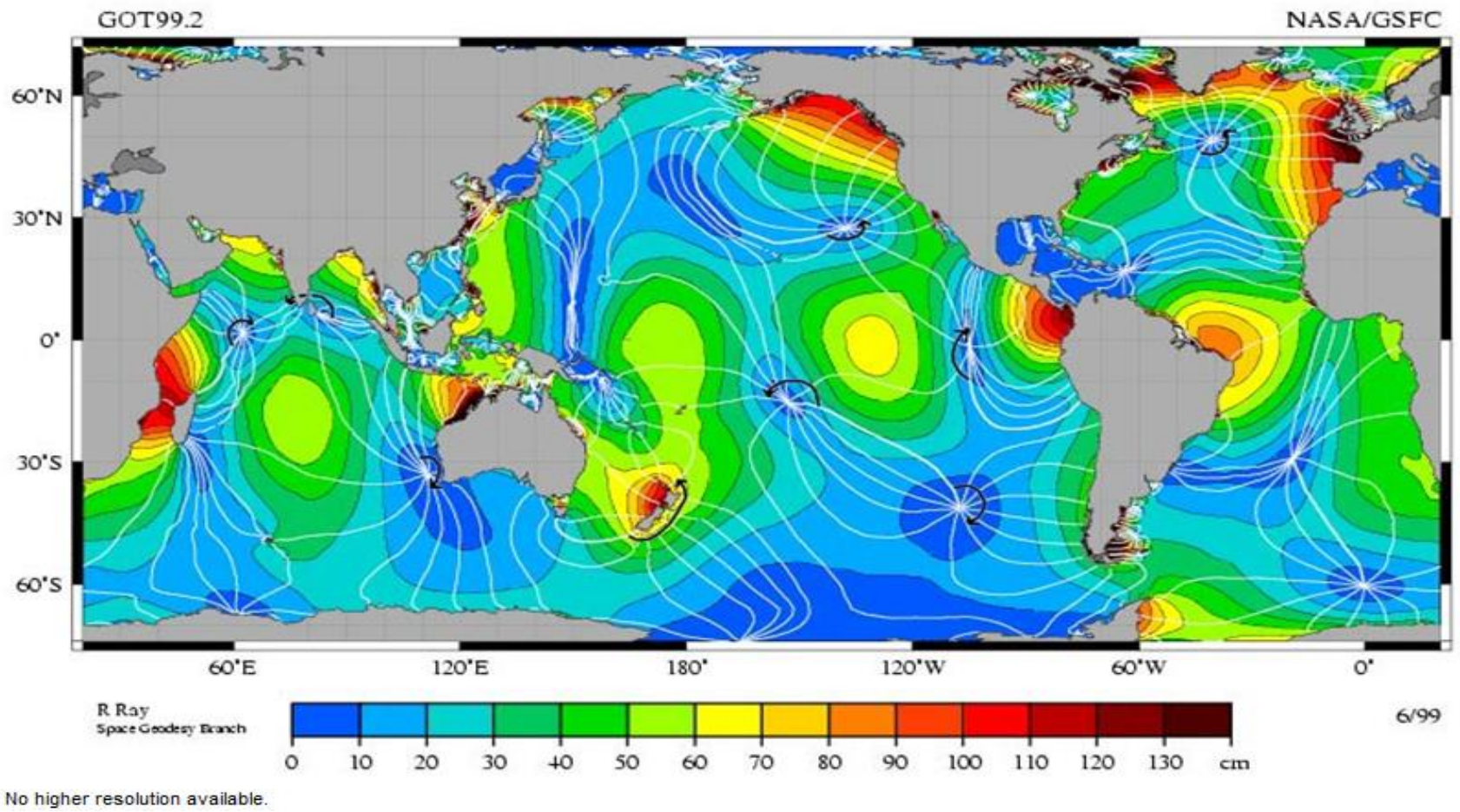
Tides move around Amphidromes



No higher resolution available.

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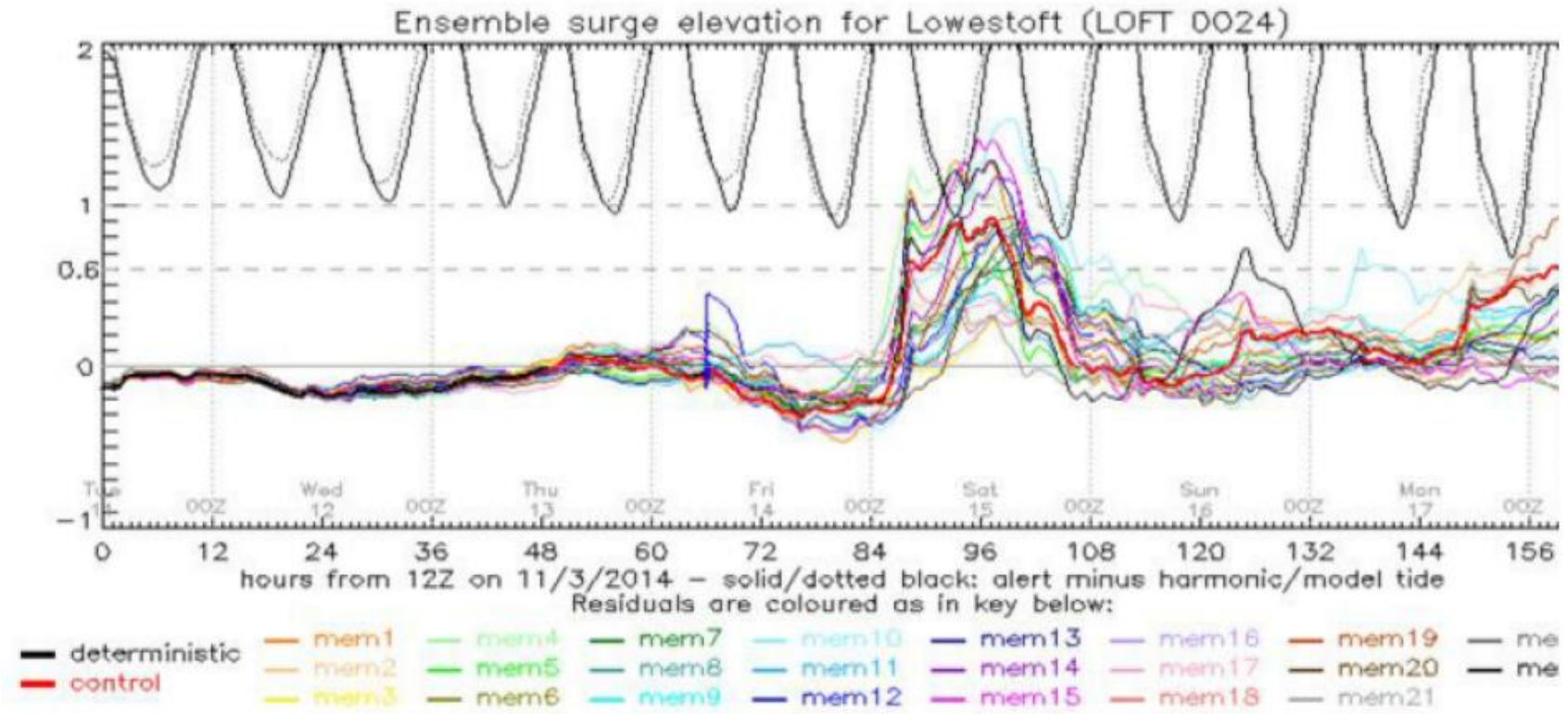
Forecast Types

- Probabilistic – ensemble
- Deterministic – one single number

- Modelling techniques are constantly improving

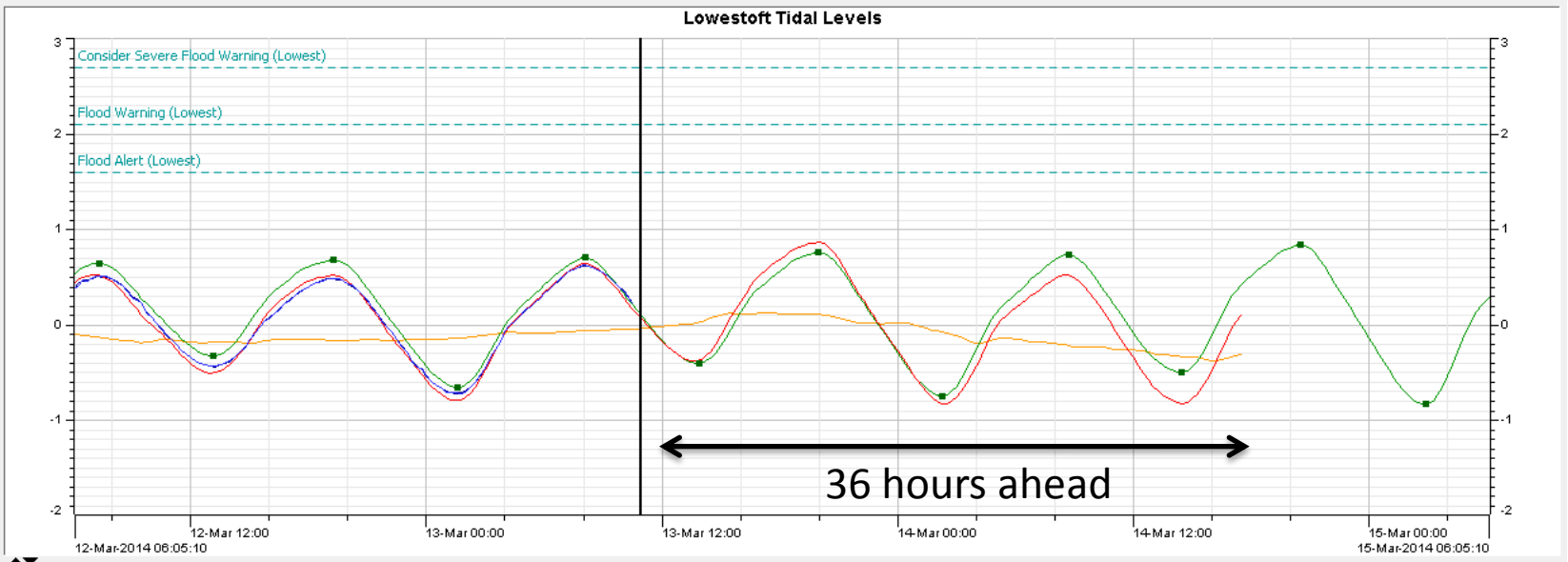
- Models taking account of the all of the variables I have listed to try to give:
  1. A value for high water
  2. A time for when that high water will occur

Example Probabilistic Forecast



- 5 Day tidal forecast (run twice a day at 02:00 and 14:00)
- Probabilistic not deterministic
- 24 model members modelling slightly different parameters
- Our dedicated forecasters monitor this and calculate:
  minimum, maximum, ‘most likely’ and ‘worse credible’ forecasts

Example Deterministic Forecast



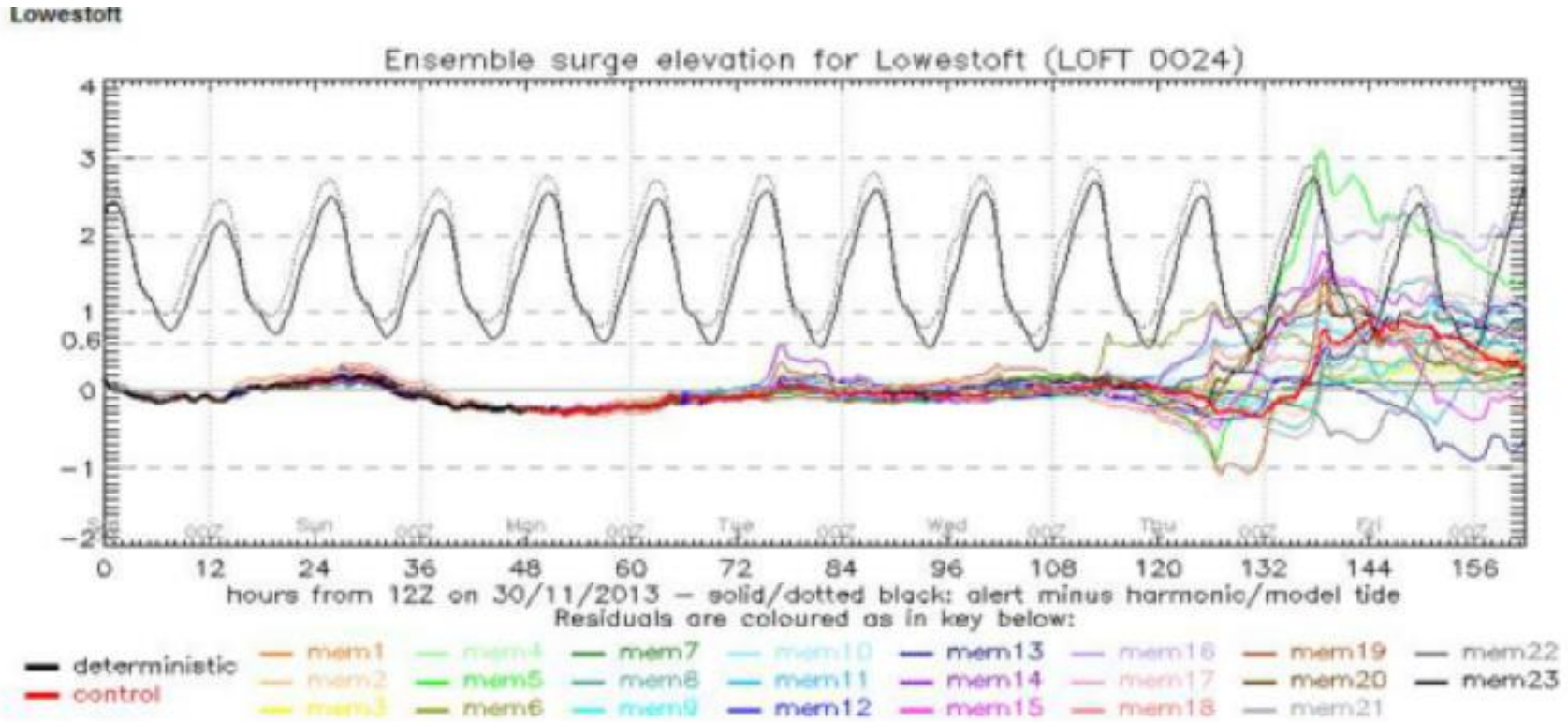
Trend	Tag Name	Address	Intersect Time	Intersect	Max	Min	Mean	Stream	Server	Data Type	Style
	AFFS SURGE DATA LOWESTOFT - WAS E5071 TO 02102007	E5686			0.127	-0.375	-0.1114242	AN_SCOPE E_VALUE	an_oracle	Raw Data	Line
	ASTROP TIDE LOWESTOFT FORECAST	E5046			0.84	-0.83	0.1125207	AN_SCOPE E_VALUE	an_oracle	Raw Data	Line
	AFFS LOWESTOFT TIDAL FORECAST	E5699			0.871	-0.824	0.009135565	AN_SCOPE E_VALUE	an_oracle	Raw Data	Line
	ASTROP HIGH LOW TIDE LOWESTOFT FORECAST	E5134			0.84	-0.83	0.0775	AN_SCOPE E_VALUE	an_oracle	Raw Data	Point
	AFFS CLASS A LOWESTOFT - INTERFACE - AFFS DATA IMPORT	E5758			0	0	0	AN_SCOPE E_VALUE	an_oracle	Raw Data	Line
	LOWESX TIDE LEVEL TRANSFER	E70019			0.631	-0.7179999	0.06484288	AN_SCOPE E_VALUE	an_oracle	Raw Data	Line
	LOWESX TIDE LEVEL TRANSFER AVERAGE MAOD	E70039			0.6230011	-0.7170029	0.06562742	AN_SCOPE E_VALUE	an_oracle	Raw Data	Line

- 36 hours ahead (up to three tides)
- Deterministic forecast – one number for each tide
- UKCMF model – 4 runs a day (approx 06:00, 12:00, 18:00, 00:00)
- Our Forecasters may add “adjustments”
- Confidence levels in forecast

December 2013 Tidal Surge

Environment Agency

Sunday 1st December



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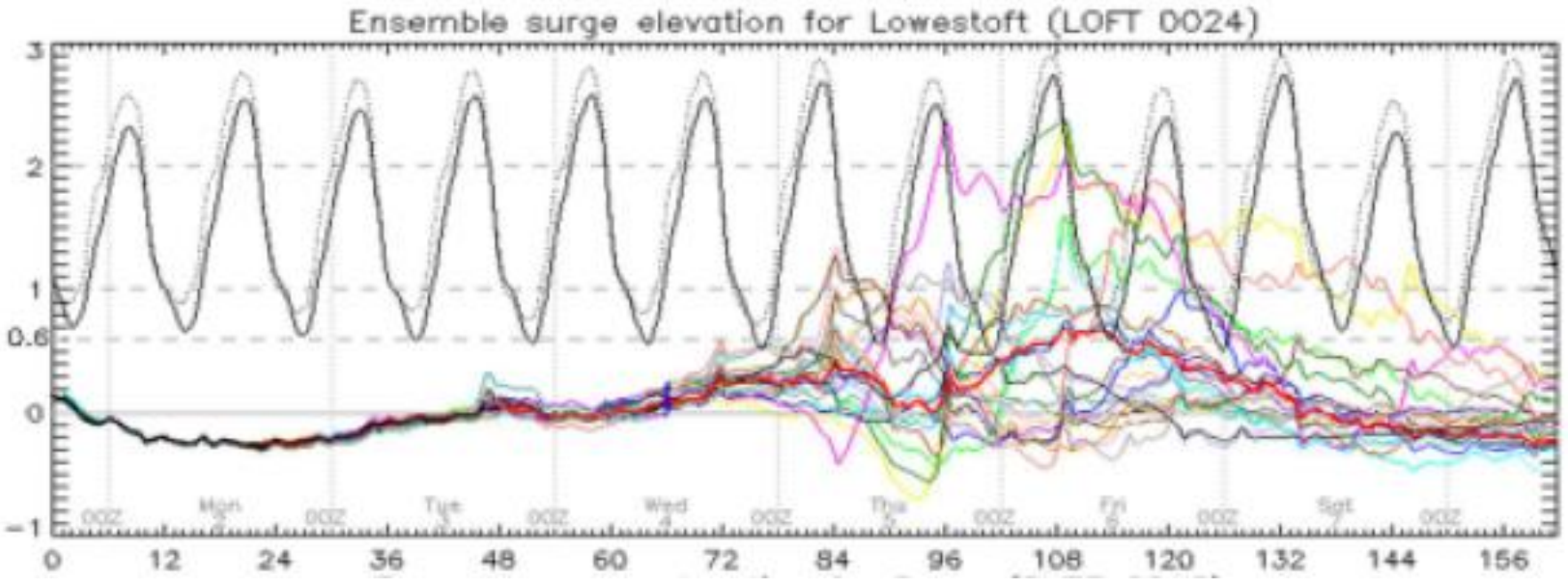
Monday 2nd December



Flood Guidance Statement – Monday

10:30 - 23:59hrs
Monday
02 December 2013

Tuesday
03 December 2013

Wednesday
04 December 2013

Thursday
05 December 2013

Friday
06 December 2013

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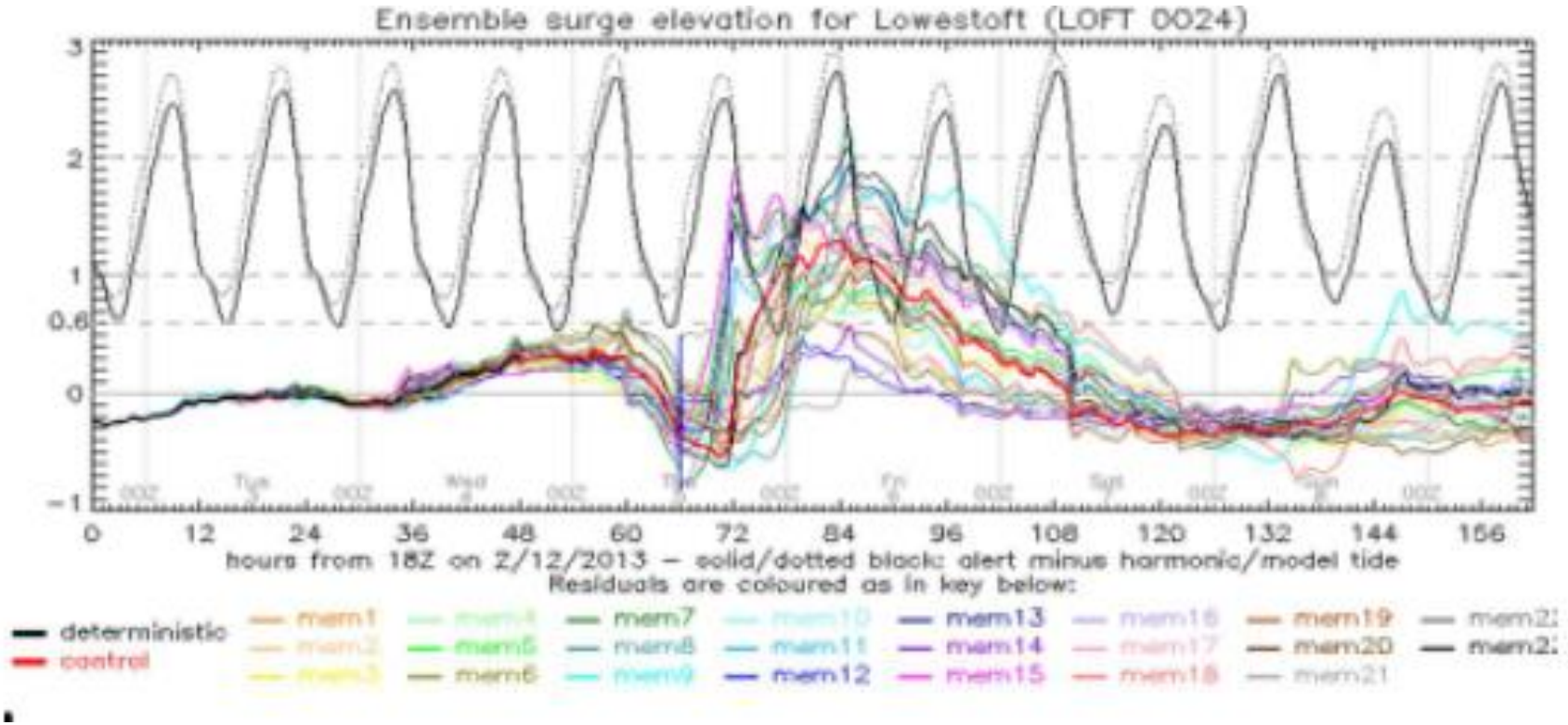
Tuesday 3rd December



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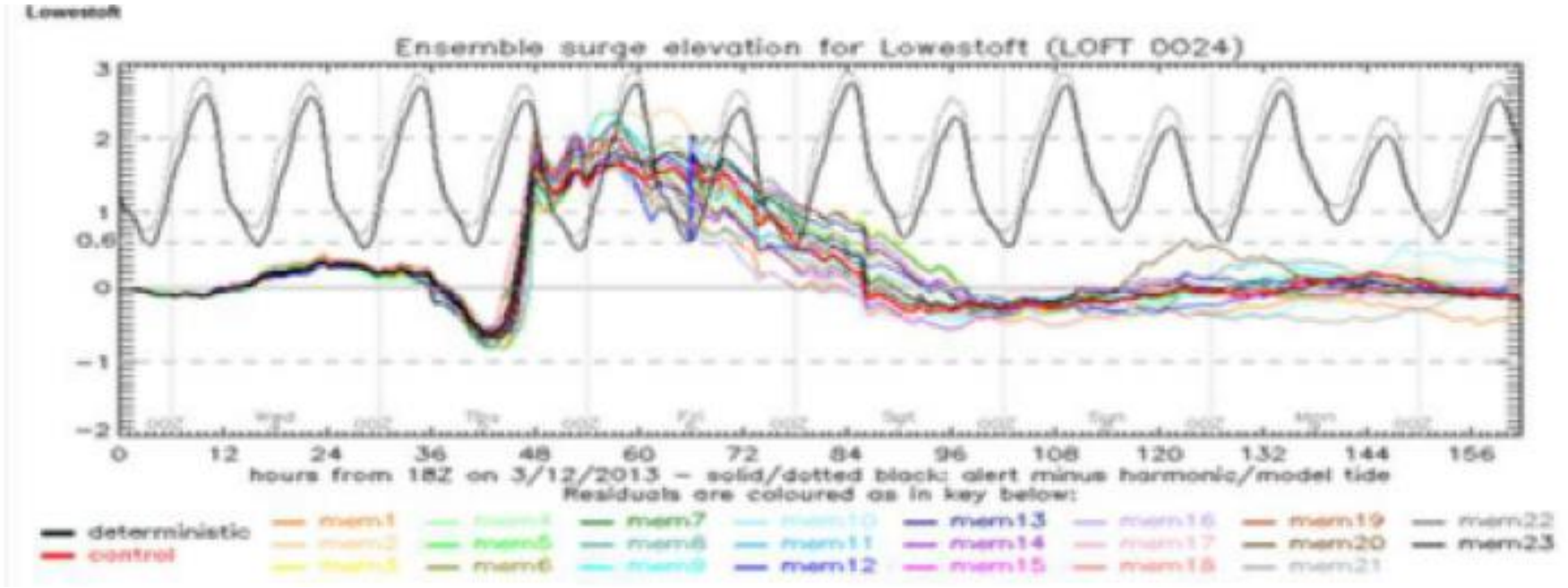
Wednesday 4th December



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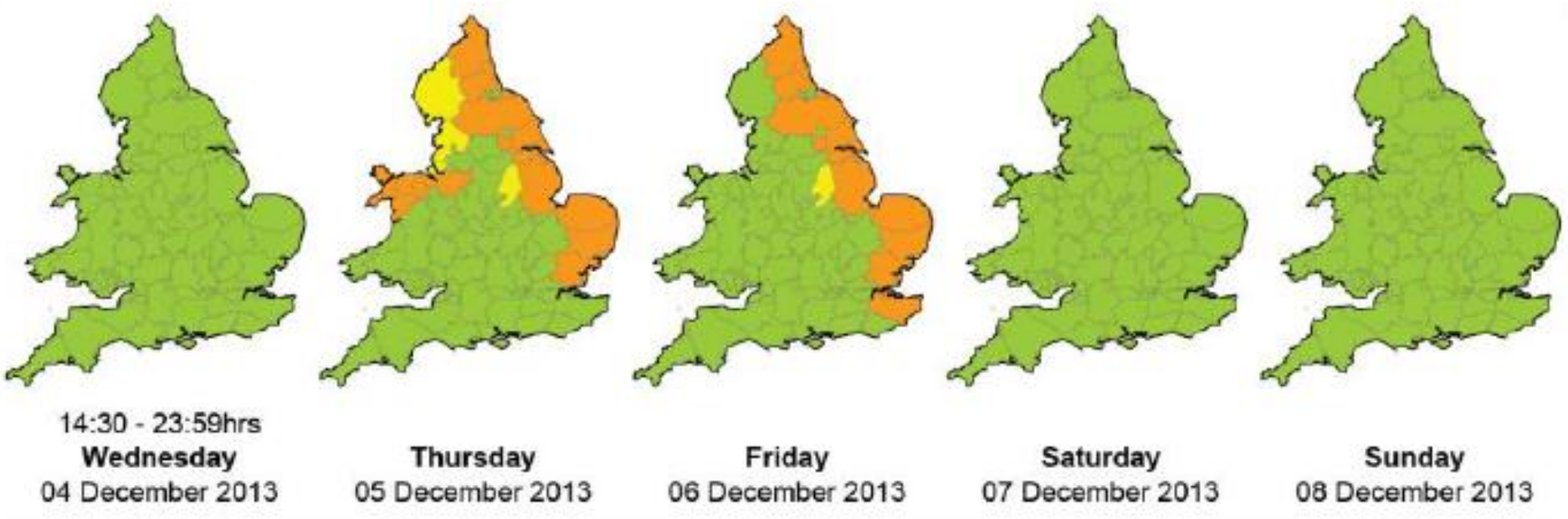
FGS - Wednesday



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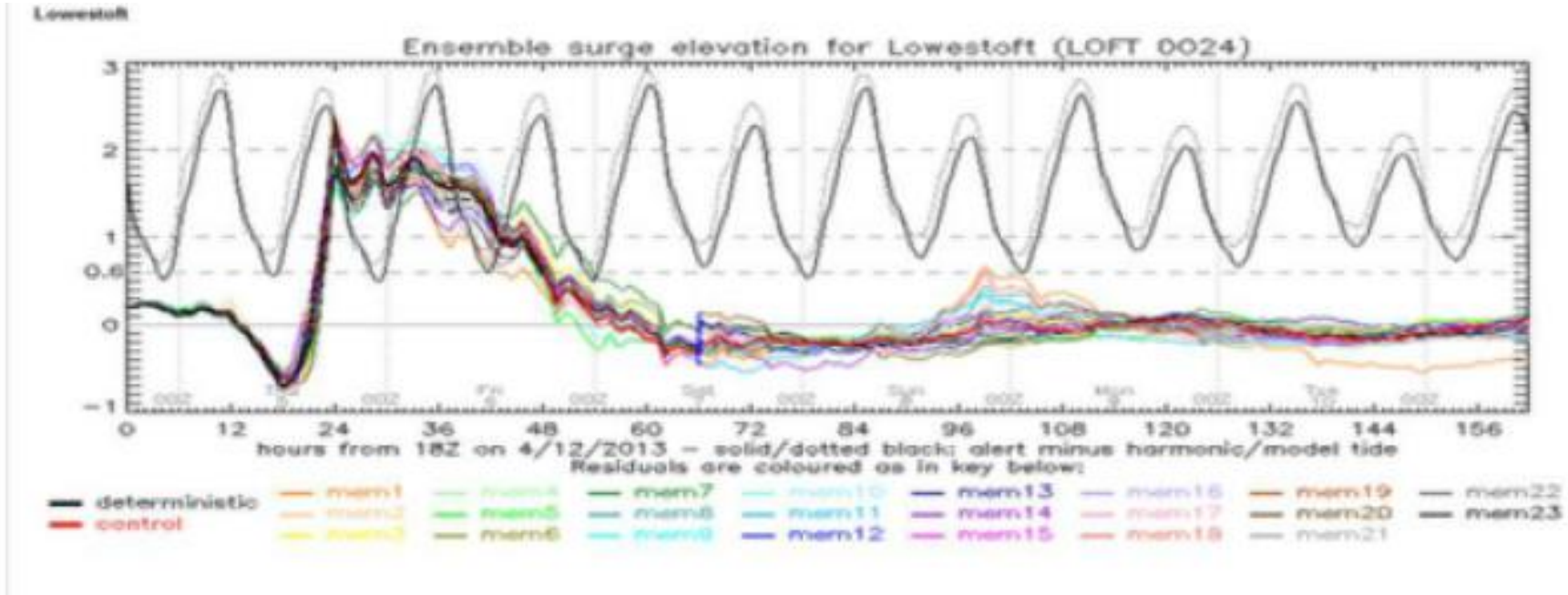
Thursday 5th December



FGS – Thursday

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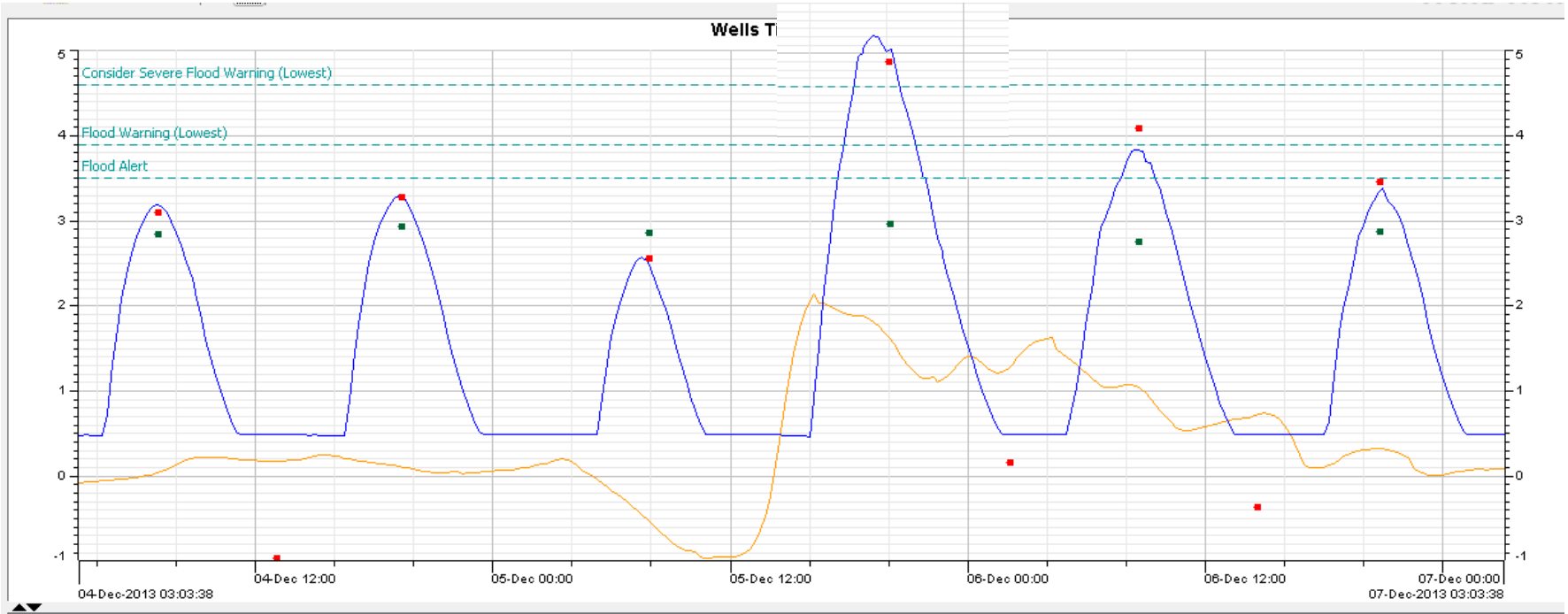
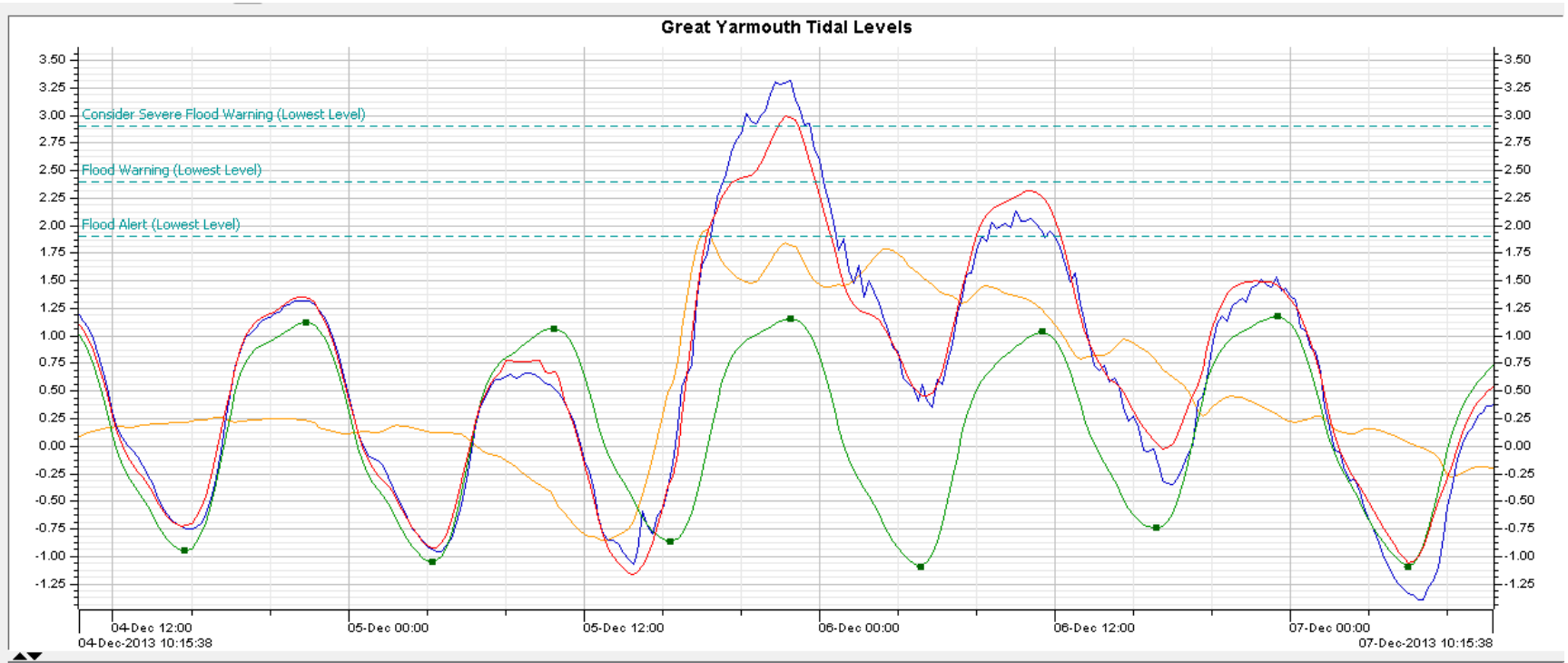
Forecaster Advice

Gauge	Tues Most likely	Tues worse credible	Weds morning forecast	Thursday morning forecast, last we could act on
Wells	3.90	3.90	4.83	4.98
Cromer	3.20	3.50	4.15	4.38
Great Yarmouth	1.90	2.40	2.83	3.13
Lowestoft	1.82	2.45	2.87	3.13
Harwich	2.90	3.40	3.41	3.66
Clacton	3.17	3.70	3.60	3.81
Southend	3.87	4.14	4.09	4.11

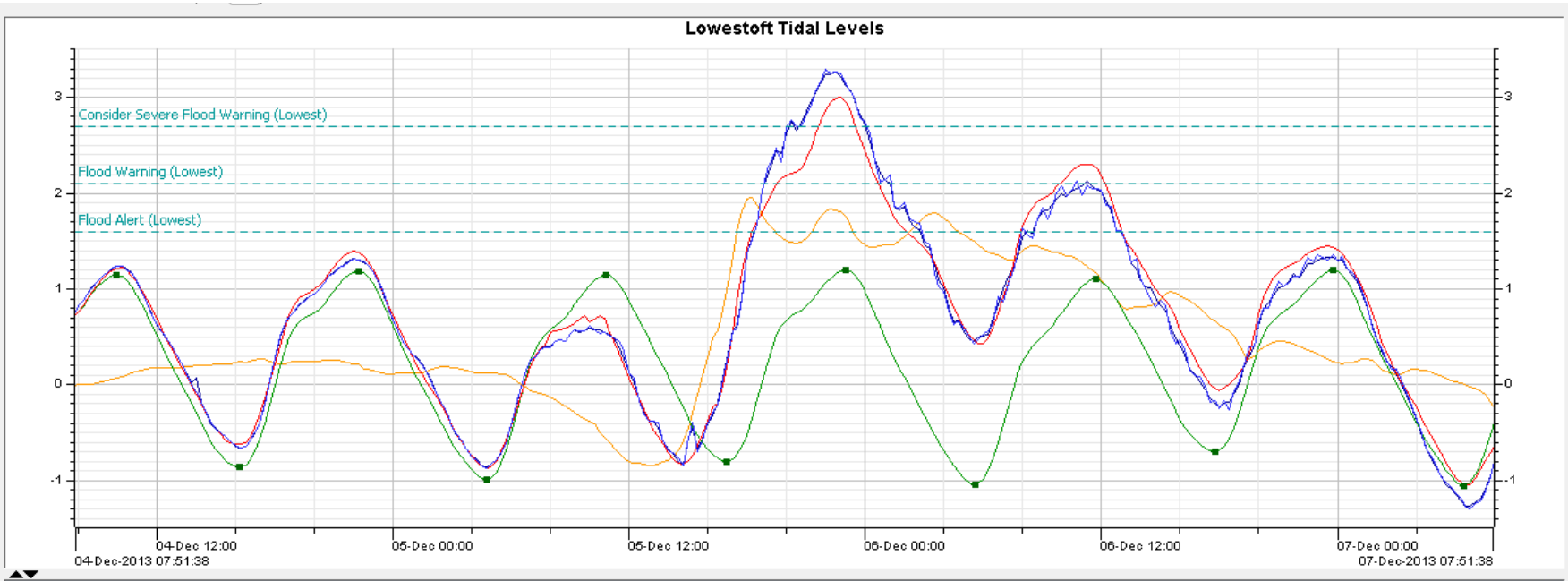
	Flood Alerts	Flood Warnings	Severe Flood Warnings	Comment
Tuesday Forecast Most Likely	11	6	0	
Tuesday Forecast Worse Credible	11	37	1	Indicating tides worse from Lowestoft South
Wednesday Morning Forecast Deterministic	11	44	8	
Thursday Morning Forecast Deterministic	11	36	23	Indicating tides worse down to Lowestoft.



Trend	Tag Name	Address	Intersect Time	Intersect	Max	Min	Mean	Server	Style	Stream	Time Axis	Data Type
	AFFS SURGE DATA WELLS - WAS E5069 TO 02102007	E5688			2.141	-0.957	0.4206533	an_oracle	Line	AN_SCOPE E_VALUE	Bottom	Raw Data
	ASTROP HIGH LOW TIDE WELLS FORECAST	E5137			2.96	2.75	2.871667	an_oracle	Point	AN_SCOPE E_VALUE	Bottom	Raw Data
	AFFS WELLS TIDAL FORECAST HILO	E5708			4.897	-1.691	1.36725	an_oracle	Point	AN_SCOPE E_VALUE	Bottom	Raw Data
	WELLST PTX TIDE LEVEL ARCHIVE SCALED 0.5 TO 6.9...	E23327			5.215	0.465	1.634568	an_oracle	Line	AN_SCOPE E_VALUE	Bottom	Raw Data



Trend	Tag Name	Address	Intersect Time	Intersect	Max	Min	Mean	Stream	Data Type	Server	S
	AFFS SURGE DATA LOWESTOFT - WAS E5071 TO 02102007	E5686			1.957	-0.85	0.5106589	AN_SCOPE E_VALUE	Raw Data	an_oracle	L
	ASTROP TIDE GREAT YARMOUTH FORECAST	E5052			1.17	-1.09	0.129273	AN_SCOPE E_VALUE	Raw Data	an_oracle	L
	ASTROP HIGH LOW TIDE GREAT YARMOUTH FORECAST	E5138			1.18	-1.09	-0.01909091	AN_SCOPE E_VALUE	Raw Data	an_oracle	P
	AFFS GREAT YARMOUTH TIDAL FORECAST	E5702			2.992	-1.162	0.6433801	AN_SCOPE E_VALUE	Raw Data	an_oracle	L
	GYARMT TIDE LEVEL PRIMARY 15MIN AVERAGE	E41137			3.318	-1.388	0.6157075	AN_SCOPE E_VALUE	Raw Data	an_oracle	L



Trend	Tag Name	Address	Intersect Time	Intersect	Max	Min	Mean	Stream	Server	Data Type	Style
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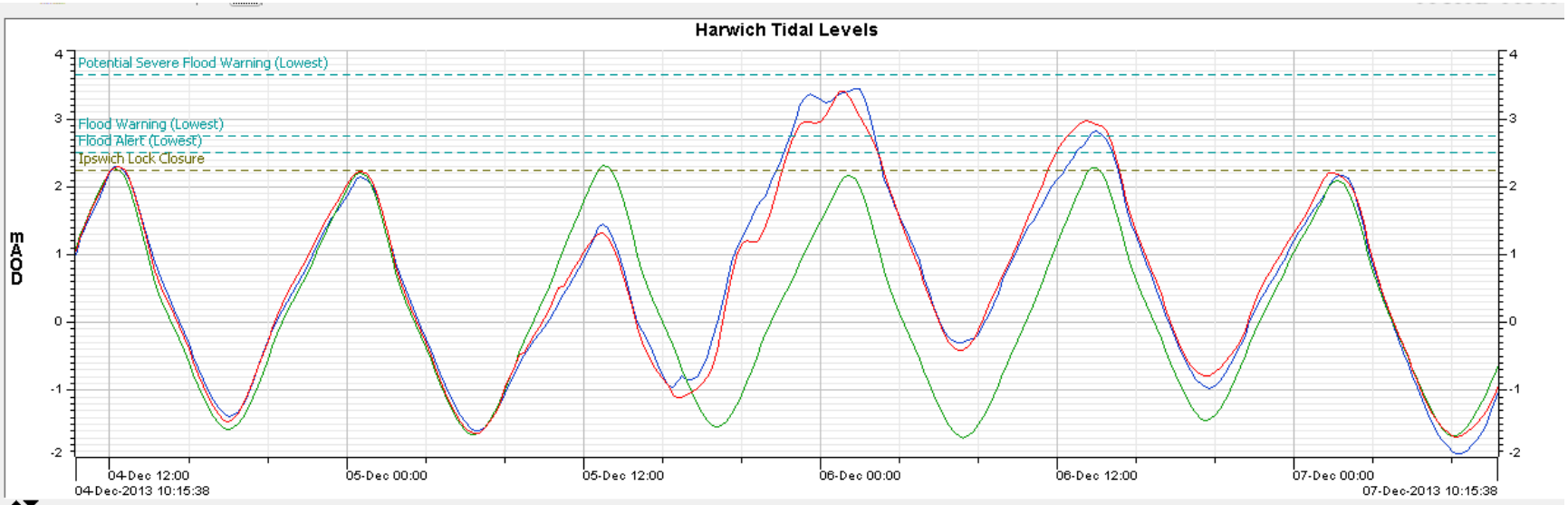
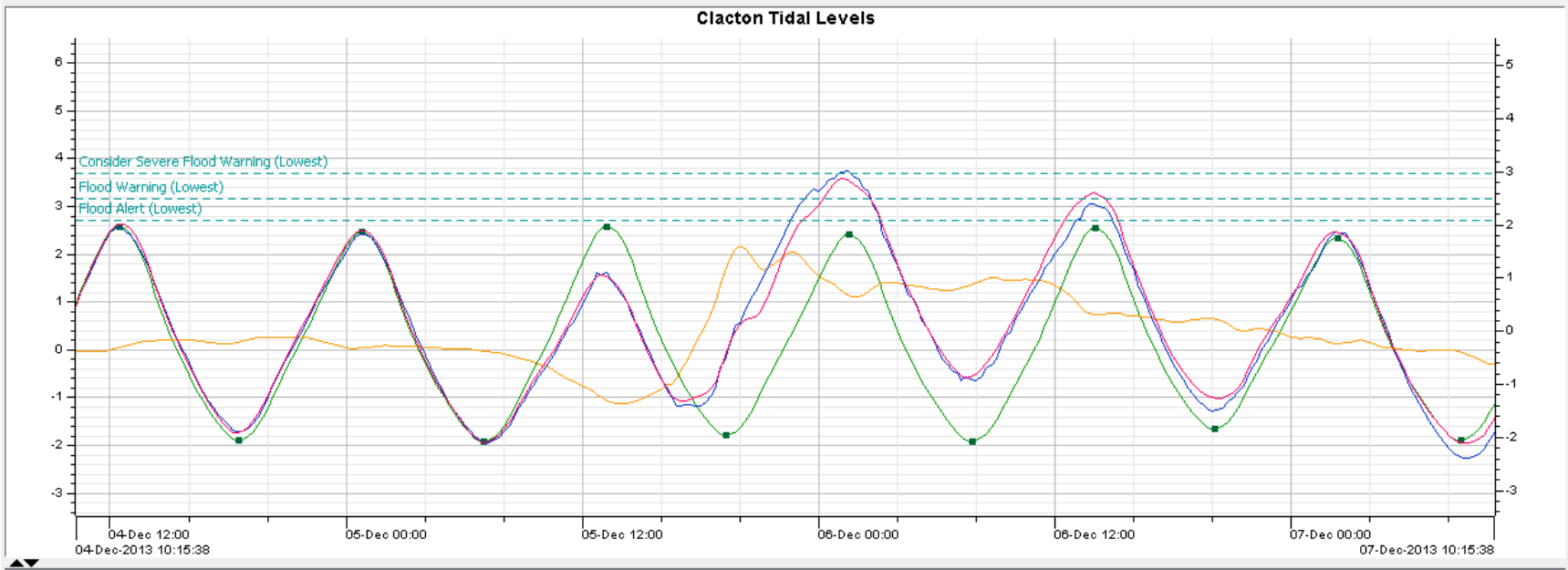
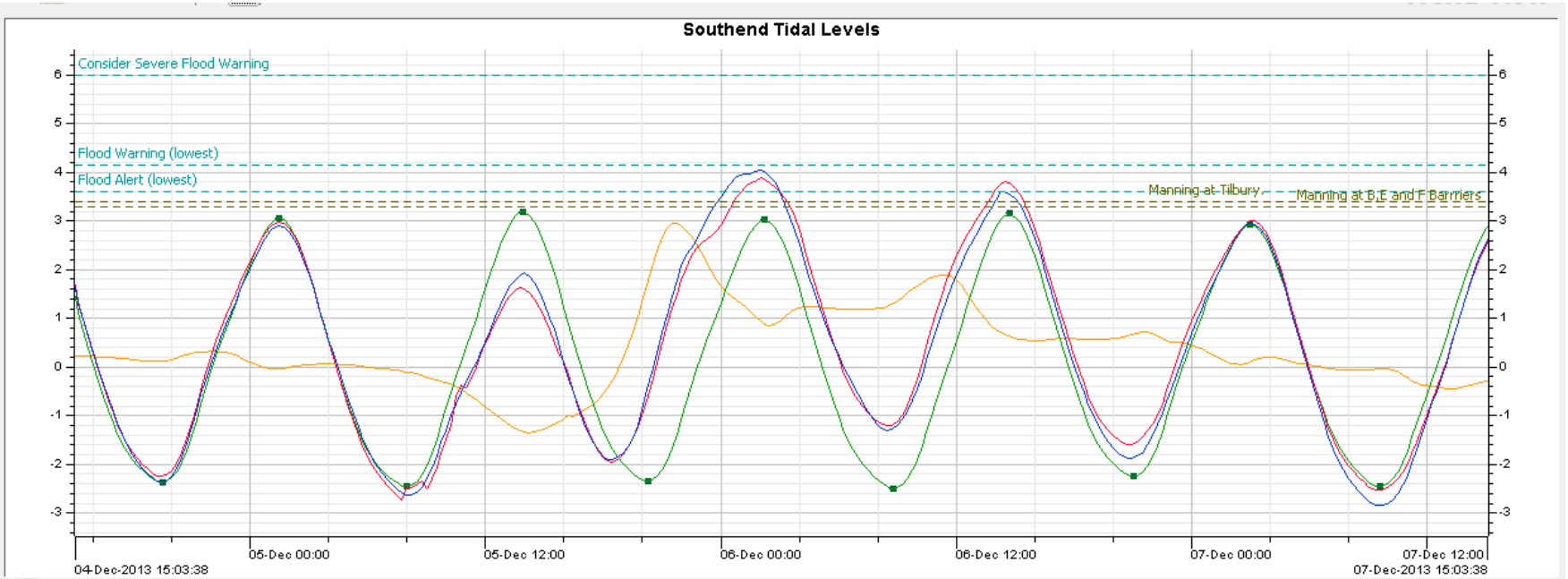
	ASTROP TIDE LOWESTOFT FORECAST	E5046			1.2	-1.05	0.1948375	AN_SCOPE E_VALUE	an_oracle	Raw Data	Line
	AFFS LOWESTOFT TIDAL FORECAST	E5699			3.001	-1.048	0.7173005	AN_SCOPE E_VALUE	an_oracle	Raw Data	Line
	ASTROP HIGH LOW TIDE LOWESTOFT FORECAST	E5134			1.2	-1.05	0.1266667	AN_SCOPE E_VALUE	an_oracle	Raw Data	Point
	AFFS CLASS A LOWESTOFT - INTERFACE - AFFS DATA IMPORT	E5758			0	0	0	AN_SCOPE E_VALUE	an_oracle	Raw Data	Line
	LOWESX TIDE LEVEL TRANSFER	E70019			3.291	-1.301	0.6995908	AN_SCOPE E_VALUE	an_oracle	Raw Data	Line
	LOWESX TIDE LEVEL TRANSFER AVERAGE MAOD	E70039			3.264	-1.274002	0.6960726	AN_SCOPE E_VALUE	an_oracle	Raw Data	Line



Trend	Tag Name	Address	Intersect Time	Intersect	Max	Min	Mean	Data Type	Server	Stream	Style	Tim
	AFFS SURGE DATA FELIXSTOWE - WAS E5072 TO 02102007	E5683			0	0	0	Raw Data	an_oracle	AN_SCOPE E_VALUE	Line	Bc
	ASTROP TIDE HARWICH FORECAST	E5042			2.31	-1.7	0.1934288	Raw Data	an_oracle	AN_SCOPE E_VALUE	Line	Bc
	AFFS HARWICH TIDAL FORECAST	E5764			3.414	-1.683	0.6230511	Raw Data	an_oracle	AN_SCOPE E_VALUE	Line	Bc
	HARWIX TIDE LEVEL TRANSFER AVERAGE MAOD	E71439			3.447006	-1.935997	0.6094226	Raw Data	an_oracle	AN_SCOPE E_VALUE	Line	Bc



Trend	Tag Name	Address	Intersect Time	Intersect	Max	Min	Mean	Server	Stream	Data Type	Style	Time Axis	Value Ax
	ASTROP TIDE CLACTON FORECAST	E5054			2.59	-1.92	0.1624419	an_oracle	AN_SCOPE E_VALUE	Raw Data	Line	Bottom	Left
	ASTROP HIGH LOW TIDE CLACTON FORECAST	E5147			2.59	-1.92	0.3216667	an_oracle	AN_SCOPE E_VALUE	Raw Data	Point	Bottom	Left
	AFFS CLACTON SURGE DATA	E5754			2.168	-1.129	0.4294	an_oracle	AN_SCOPE E_VALUE	Raw Data	Line	Bottom	Left
	AFFS CLACTON TIDAL FORECAST	E5810			3.582	-1.955	0.5901593	an_oracle	AN_SCOPE E_VALUE	Raw Data	Line	Bottom	Left
	CLACTT HYDRORANGER ULTRASONIC TIDE L...	E24861			3.756	-2.275	0.5389096	an_oracle	AN_SCOPE E_VALUE	Raw Data	Line	Bottom	Left



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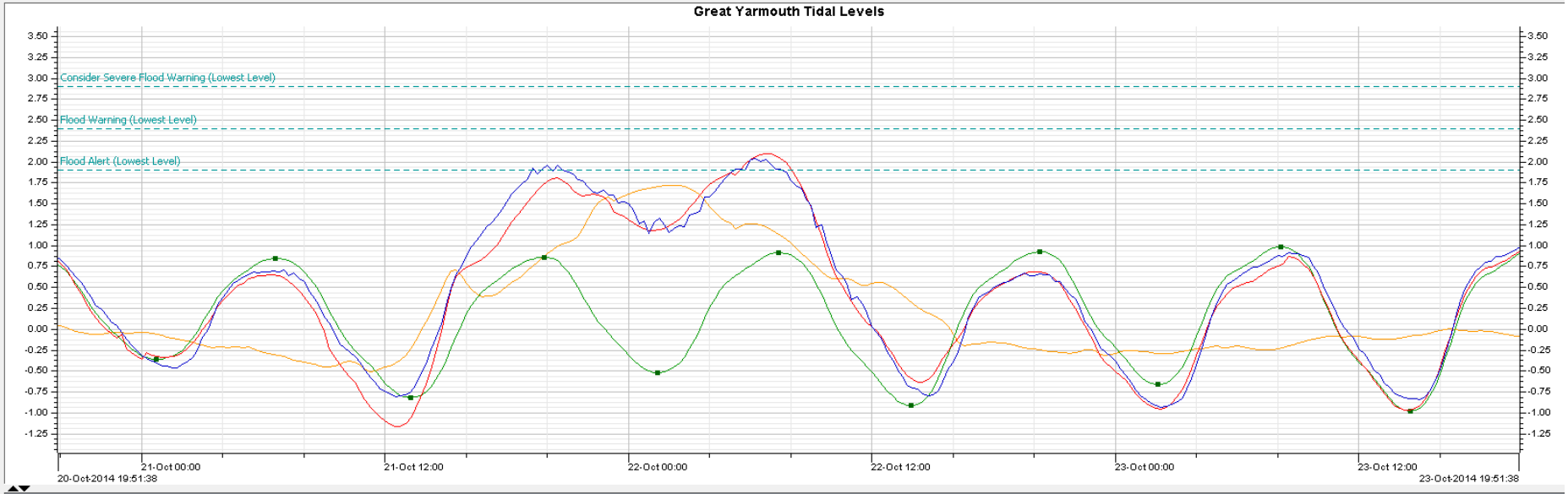
	AFFS SURGE DATA SHEERNESS - WAS E5074 TO 02102007	E5687			2.947	-1.354	0.3804083	AN_SCOPE E_VALUE	an_oracle	Raw Data	Line	E
	ASTROP TIDE SOUTHEND FORECAST	E5049			3.18	-2.49	0.08283402	AN_SCOPE E_VALUE	an_oracle	Raw Data	Line	E
	ASTROP HIGH LOW TIDE SOUTHEND FORECAST	E5135			3.19	-2.5	0.09	AN_SCOPE E_VALUE	an_oracle	Raw Data	Point	E
	AFFS SOUTHEND TIDAL FORECAST	E5700			3.895	-2.725	0.4122148	AN_SCOPE E_VALUE	an_oracle	Raw Data	Line	E
	SOUTHT SDI12 OTT PLS PRESSURE PROBE TIDE LEVEL SCALE...	E22941			4.036	-2.849	0.363043	AN_SCOPE E_VALUE	an_oracle	Raw Data	Line	E
	AFFS CLASS A SHEERNESS - INTERFACE - AFFS DATA IMPORT	E5761			0	0	0	AN_SCOPE E_VALUE	an_oracle	Raw Data	Line	E

Great Yarmouth Gauge October 2014



Trend	Tag Name	Address	Intersect Time	Intersect	Max	Min	Mean	Stream	Data Type	Server	Style	Time Axis	Value Axis	Displayed	Markers	Values	Limits
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	ASTROP TIDE GREAT YARMOUTH FORECAST	E5052			0.99	-0.98	0.1327739	AN_SCOPE E_VALUE	Raw Data	an_oracle	Line	Bottom	Left	Yes	No	No	
	ASTROP HIGH LOW TIDE GREAT YARMOUTH FORECAST	E5138			0.99	-0.98	0.02727273	AN_SCOPE E_VALUE	Raw Data	an_oracle	Point	Bottom	Left	Yes	Yes	No	
	AFFS GREAT YARMOUTH TIDAL FORECAST	E5702			2.103	-1.163	0.3731951	AN_SCOPE E_VALUE	Raw Data	an_oracle	Line	Bottom	Left	Yes	No	No	
	GYARMT TIDE LEVEL PRIMARY 15MIN AVERAGE	E41137			2.045	-0.929	0.4425452	AN_SCOPE E_VALUE	Raw Data	an_oracle	Line	Bottom	Left	Yes	No	No	

How do we translate the forecast into a warning?

Tidal Flood Warnings

Predictive rather than reactive

- We issue warnings for coastal flood warning areas based on the forecast
- Thresholds set with defences and impacts in mind: Target 10 to 12 hours
- We cover all low lying coastal areas, we extrapolate from the gauges available
- Timing is key to avoid confusion with preceding tide and the next tide.
- Timing of any surges, positive or negative is key

Environment Agency

How the service works

Online flood forecast

FLOOD ALERT

FLOODING IS POSSIBLE. BE PREPARED.

FLOOD WARNING

FLOODING IS EXPECTED. IMMEDIATE ACTION REQUIRED.

SEVERE FLOOD WARNING

SEVERE FLOODING. DANGER TO LIFE.

Warning no longer in force

FLOOD ALERT

FLOODING IS POSSIBLE. BE PREPARED.

Flood Alert

Triggers:

- Forecasts of high tides, surges
- Recorded, or forecast water levels that will cause flooding

Impact on the ground:

- Flooding of minor roads, farmland, car parks, recreation land
- Fast flowing, or bank-full rivers
- Surface water flooding
- Wave / spray overtopping on coasts

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Colne Point
NATURE RESERVE

Flood Alert advice

Flooding is possible. Be prepared. Prepare a flood kit.

- Ring Floodline on 0345 988 11 88 for up-to-date information
- Keep a watch on the weather and water levels
- Tune in to weather and travel bulletins
- Drive carefully – roads may be flooded. Review travel plans.
- Be aware the situation could worsen into further flooding.
- Store valuable / sentimental items upstairs
- Tell your family, friends and neighbours
- Check livestock and pets.
- Prepare a flood kit …

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FLOOD WARNING

FLOODING IS EXPECTED. IMMEDIATE ACTION REQUIRED.

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Flood Warning

Triggers:

- Forecasts of high tides, and surges
- Observed rising river levels (outstation triggers)

Impact on the ground:

- Flooding of homes or businesses, major roads / rail
- Significant flood plain inundation (high risk to campsites)
- Flooding of major tourist / recreational attractions
- Significant wave / spray overtopping on the coast
- Damage to flood defences

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FLOOD WARNING

FLOODING IS EXPECTED. IMMEDIATE ACTION REQUIRED.

Environment Agency

Flood Warning advice

Flooding is expected. Immediate action required.
Act now to protect your property.

The same as for a Flood Alert plus:

- **Act Now!** - Do as much as you can in daylight
- Try to keep warm and dry and safe!
- Check you have adequate water and food supplies
- Avoid contact with flood water
- Be ready to turn off gas and electricity supplies
- Protect items inside and outside your property
- Reduce floodwater getting into your home
- Don't drive, cycle or walk through flood water
- Move your car if necessary, and possible

Environment Agency

SEVERE FLOOD WARNING

SEVERE FLOODING. DANGER TO LIFE.

Environment Agency

Severe Flood Warning

Triggers – as per Flood Warning plus:

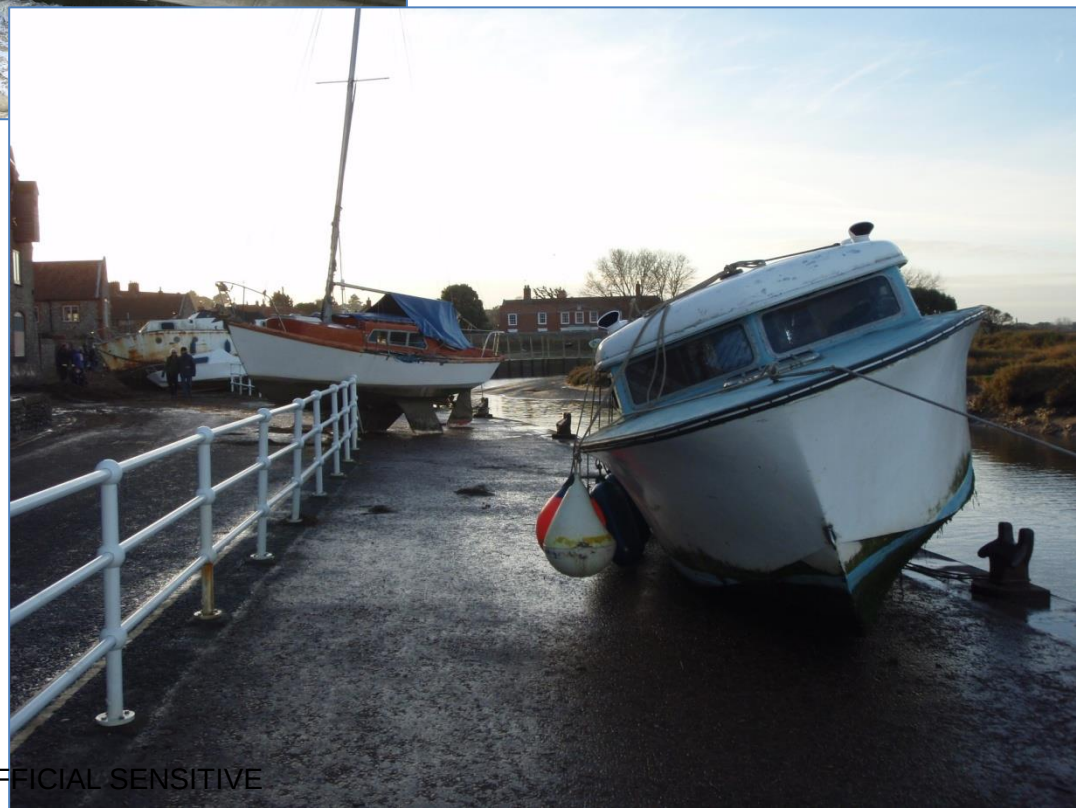
- Significant risk to life, or severe disruption to communities
- Predictions of major tidal surges
- Issued only after a consultation process

Impact on the ground:

- Significant risk to life
- Large numbers of homes / businesses expected to flood
- Severe adverse impact on local infrastructure
- Communities left without essential services
- Flood defence failures

Environment Agency

SEVERE FLOOD WARNING



Severe Flood Warning advice

Severe Flooding. Danger to life.

The same as for a Flood Warning plus:

- Protect yourself, your family, pets and valuables – floods can kill
- Co-operate with emergency services and local authorities
- Be ready should you need to be evacuated to rest centres
- Be ready for power cuts and loss of utilities: water, gas, electricity and phone services
- Avoid contact with floodwater
- Call 999 if you are in immediate danger

Environment Agency

How we issue a SFW

- Receive weather warnings from the Met Office
- Monitor river and tide levels
- Early assessment of potential risk to life
- Chair local Flood Advisory Service teleconference
  - Presents an early opportunity to discuss and consider issuing a Severe Flood Warning
- Continue consultation with partners
  - SCG / TCG / operational teams
- Use the checklist
- Obtain internal approval and issue SFW's

Environment Agency

Severe Flood Warning Criteria

Significant Risk to Life

- Deep fast flowing water
- Debris in water that could cause death or injury
- Potential / observed collapse of buildings / structures
- The vulnerability of the population or their surroundings

Significant disruption to communities

- Town / City isolated by floodwaters with no obvious means of escape
- Critical resources / infrastructure for communities disabled
- Emergency services and authorities unable to cope with large volumes of evacuees and rest centres at full capacity
- Mutual aid / military support necessary or called upon

Environment Agency

How are the warnings issued?

Floodline Warnings Direct

Environment Agency

Floodline

- 24 hour year round call centre with up to the minute flooding information and advice.
- Telephone numbers
  - **0345 988 1188**
- Members of the public can register for flood warnings via this number also.

Environment Agency

Websites

- www.gov.uk/environment-agency
- Shoothill working with the EA has created the following sites.
- www.gaugemap.co.uk
- http://www.shoothill.com/floodmap/
- http://www.checkmyfloodrisk.co.uk/

Environment Agency

Social Media

- Twitter:
  - @envagency
  - @mattbutcherEA
  - @trevbondEA
  - @andrewraineEA
  - @cbeardallEA
- Facebook
  - www.facebook.com/environmentagency

Environment Agency

Chart Datum and mAODN

Time and Tide

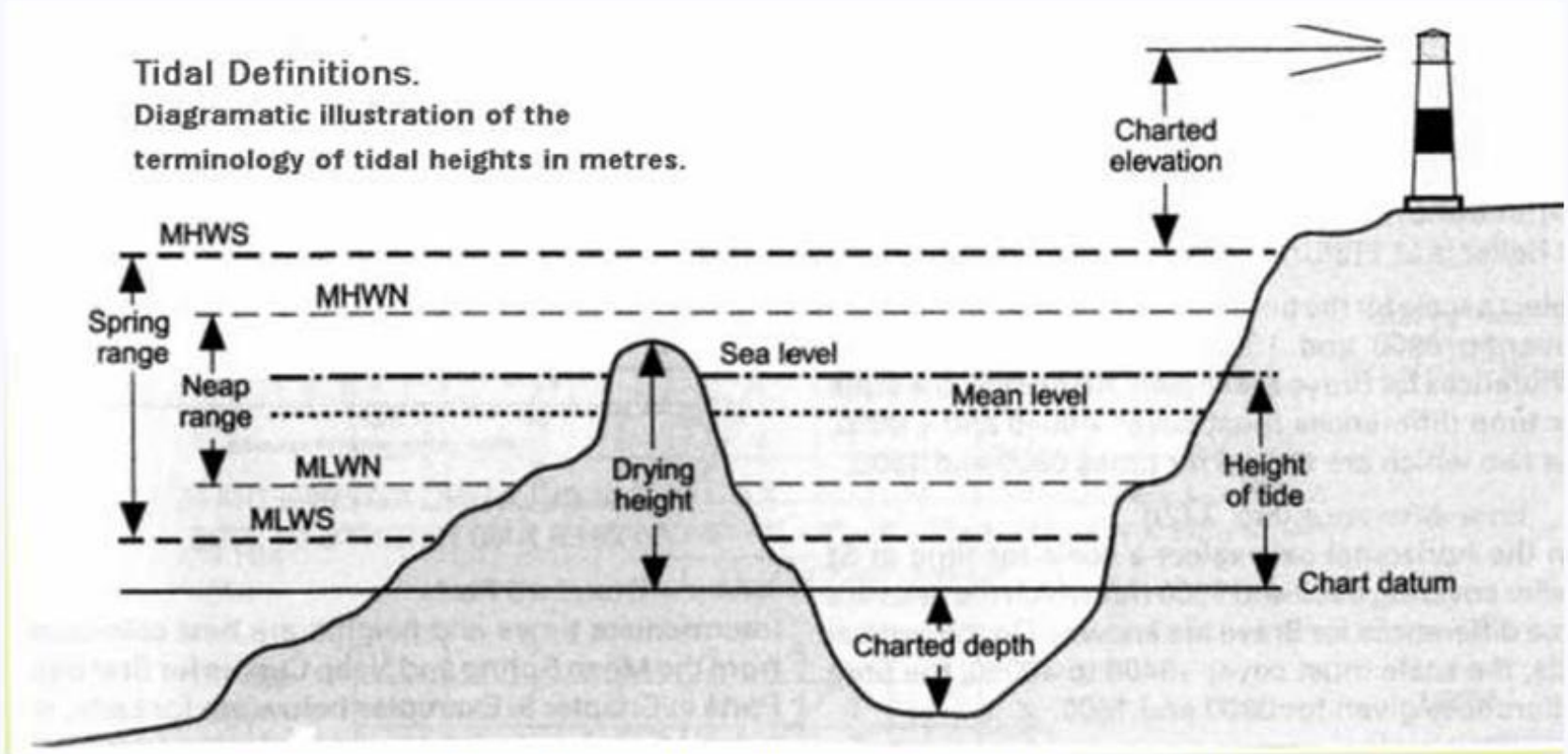


Chart datum is the reference level above which heights of tide are predicted and below which charted depths are measured. The datum used for most British ports is the lowest sea level predicted under average meteorological conditions for that port unlike the land mapping datum for the ordinance survey which is fixed for the whole U.K. and is based on **mean** sea level.